MAN B&W S50ME-B9.3-TII

Project Guide

Electronically Controlled
Two-stroke Engines
with Camshaft Controlled Exhaust Valves

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
This Project Guide book and the 'Extent of Delivery' forms are available on the Internet at: www.marine.man.eu → 'Two-Stroke', where they can be downloaded.

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Chapter		Section	

Engine Design

1

The Fuel Optimised ME-B Tier II Engine

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 to match the prevailing operating conditions.

A system with electronically controlled hydraulic activation provides the required flexibility, this system form the core of the ME-B ‘Engine Control System’, described later in detail in Chapter 16.

Concept of the ME-B engine

The ME-B engine concept consists of a hydraulic-mechanical system for activation of the fuel injection. The actuator is 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 activated by a light camshaft, driven by a chain drive placed in the aft end of the engine. The closing timing of the exhaust valve is electronically controlled for lower fuel consumption at low load.

To have common spare parts, the exhaust valve used for the ME-B is the same as the one used for the MC-C. The exhaust valve is of the DuraSpindle type with a W-seat bottom piece.

In the hydraulic system, the normal lube oil is used as the medium. It is filtered and pressurised by an electrically driven Hydraulic Power Supply unit mounted on the engine.

The starting valves are opened pneumatically by the mechanically activated starting air distributor.

By electronic control of the above valve 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 NO_x emission limitation.

The market is always moving, and requirements for more competitive engines, i.e. the lowest possible propeller speed, lower fuel consumption, lower lube oil consumption and more flexibility regarding emission and easy adjustment of the engine parameters, call for a re-evaluation of the design parameters, engine control and layout.

Engine design and IMO regulation compliance

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

The potential derating and part load SFOC figures for the Tier II engines have also been updated.

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_x regulations place a limit on the SFOC on two-stroke engines. In general, NO_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_x limit and, therefore, NO_x emissions may not be further increased.

The IMO NO_x limit is given as a weighted average of the NO_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_x limit.

Optimisation of SFOC in the part-load (50-85%) or low-load (25-70%) range requires selection of a tuning method:

- ECT: Engine Control Tuning
- VT: Variable Turbine Area
- EGB: Exhaust Gas Bypass
- HPT: High Pressure Tuning (only for ME-C)

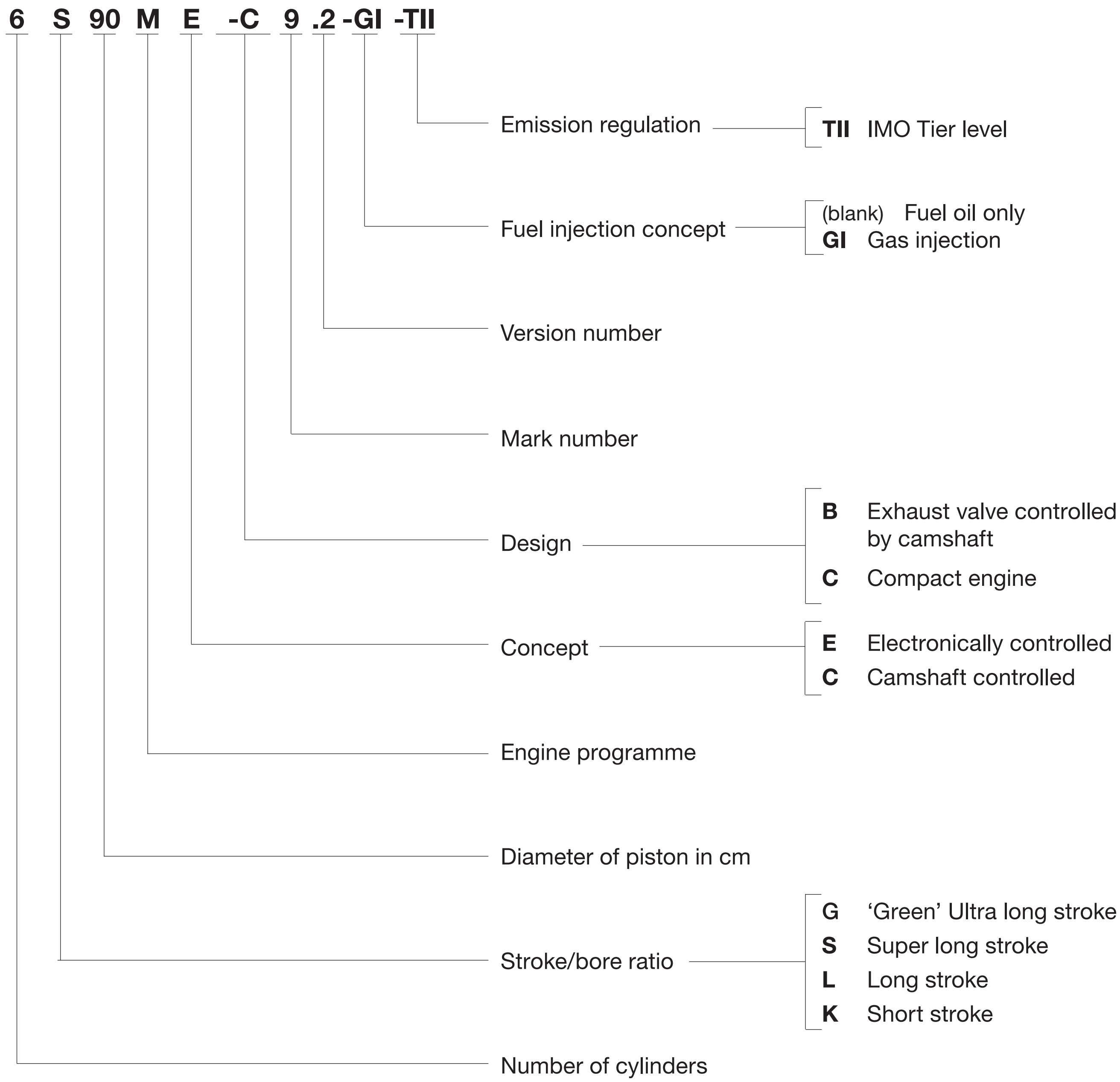
Each tuning method makes it possible to optimise the fuel consumption when normally operating at low loads, while maintaining the possibility of operating at high load when needed.

The tuning methods are available for all SMCR in the specific engine layout diagram but they cannot be combined. The specific SFOC reduction potential of each tuning method together with full rated (L_1/L_3) and maximum derated (L_2/L_4) is shown in Section 1.03.

For engine types 40 and smaller, as well as for larger types with conventional turbochargers, only high-load optimisation is applicable.

In general, data in this project guide is based on high-load optimisation unless explicitly noted. For part- and low-load optimisation, calculations can be made in the CEAS application described in Section 20.02.

Engine Type Designation

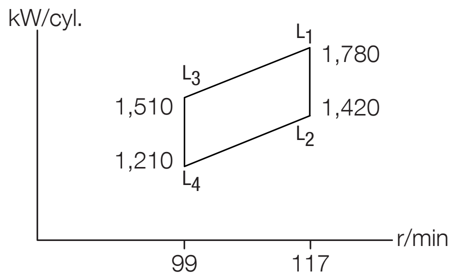


Power, Speed and Fuel Oil

MAN B&W S50ME-B9.3-TII

Cyl.	L_1 kW
5	8,900
6	10,680
7	12,460
8	14,240
9	16,020

Stroke: 2,214 mm



SFOC for engines with layout on L_1 - L_3 line [g/kWh] — **L_1/L_3 MEP:** 21.0 bar

SFOC optimised load range	Tuning	50%	75%	100%
High load (85%-100%)	-	167.5	165.0	168.0
Part load (50%-85%)	ECT	166.5	164.0	171.0
	VT	164.5	163.5	168.5
	EGB	164.5	163.5	169.5
Low load (25%-70%)	ECT	165.0	164.5	169.5
	VT	162.5	164.5	168.5
	EGB	162.5	164.5	169.5

SFOC for engines with layout on L_2 - L_4 line [g/kWh] — **L_2/L_4 MEP:** 16.8 bar

SFOC optimised load range	Tuning	50%	75%	100%
High load (85%-100%)	-	163.5	159.5	162.0
Part load (50%-85%)	ECT	162.5	158.5	165.0
	VT	160.5	158.0	162.5
	EGB	160.5	158.0	163.5
Low load (25%-70%)	ECT	161.0	159.0	163.5
	VT	158.5	159.0	162.5
	EGB	158.5	159.0	163.5

The SFOC excludes 1 g/kWh for the consumption of the electric HPS

Fig 1.03.01: Power, speed and fuel oil

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 L_1, L_2, L_3 and L_4.

Discrepancies between kW and metric horsepower (1 BHP = 75 kpm/s = 0.7355 kW) are a consequence of the rounding off of the BHP values.

L_1 designates nominal maximum continuous rating (nominal MCR), at 100% engine power and 100% engine speed.

L_2, L_3 and L_4 designate layout points at the other three corners of the layout area, chosen for easy reference.

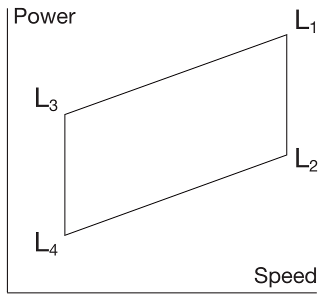


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Fig. 1.04.01: Layout diagram for engine power and speed

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%

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% (at 100% SMCR) 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

Although the engine will develop the power specified up to tropical ambient conditions, specific fuel oil consumption varies with ambient conditions and fuel oil lower calorific value. For calculation of these changes, see Chapter 2.

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 of up to 1.5 times the stated values should be used.

Performance Curves

Updated engine and capacities data is available from the CEAS program on www.marine.man.eu → 'Two-Stroke' → 'CEAS Engine Calculations'.

ME-B Mark 9 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 is of the welded design and the normally cast part for the main bearing girders is made from either rolled steel plates or cast steel.

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 normally vertical and are provided with gratings.

Horizontal outlets at both ends can be arranged for some cylinder numbers, however this must be confirmed by the engine builder.

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 framebox is of the well-proven triangular guide-plane design with twin staybolts giving excellent support for the guide shoe forces.

Cylinder Frame and Stuffing Box

For the cylinder frame, two possibilities are available.

- Nodular cast iron
- Welded design with integrated scavenge air receiver.

The cylinder frame is 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 with a low-situated flange. The top of the cylinder liner is fitted with a cooling jacket. The cylinder liner has scavenge ports and drilled holes for cylinder lubrication.

The Piston Cleaning ring (PC-ring) is installed between the liner and the cylinder cover, scraping off excessive ash and carbon formations from the piston topland.

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, a starting valve and an indicator valve.

The cylinder cover is attached to the cylinder frame with studs and nuts tightened with hydraulic jacks.

Crankshaft

The crankshaft is of the semi-built design, in one piece, and made from forged steel.

At the aft end, the crankshaft is provided with the collar for the thrust bearing, 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. The thrust shaft is an integrated part of the crankshaft and it is lubricated by the engine's lubricating oil system.

As the propeller thrust is increasing due to the higher engine power, a flexible thrust cam has been introduced to obtain a more even force distribution on the pads.

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.

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 journal, and the housing is fixed to the main bearing support.

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 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 and has four ring grooves which are hard-chrome plated on both the upper and lower surfaces of the grooves.

The piston is bore-cooled and with a high topland.

The piston ring pack is No. 1 piston ring, high CPR (Controlled Pressure Relief), Nos. 2 to 4, piston rings with angle cut. All rings are with Alu-coat on the running surface for safe running-in of the piston ring.

The uppermost piston ring is higher than the others. The piston skirt is of cast iron with a bronze band.

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 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.

Scavenge Air Cooler

For each turbocharger is fitted a scavenge air cooler of the mono-block type designed for seawater cooling at up to 2.0 - 2.5 bar working pressure, alternatively, a central cooling system can be chosen with freshwater of maximum 4.5 bar working pressure.

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. 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.

The auxiliary blower design is of the integrated type.

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 further on 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

Three turbocharger makes are available for the ME-B engines, i.e. MAN, ABB and MHI. As an option, MAN TCA turbochargers can be delivered with variable nozzle area technology that reduce 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.

Camshaft and Cams

The camshaft is made in one piece with exhaust cams.

The exhaust cams are made of steel, with a hardened roller race, and are shrunk onto the shaft. They can be adjusted and dismantled hydraulically.

The camshaft bearings consist of one lower half-shell fitted in a bearing support. The camshaft is lubricated by the main lubricating oil system.

Chain Drive

The camshaft is driven from the crankshaft by a chain drive, which is kept running tight by a manually adjusted chain tightener. The long free lengths of chain are supported by rubber-clad guidebars and the chain is lubricated through oil spray pipes fitted at the chain wheels and guidebars.

2nd Order Moment Compensators

The 2nd order moment compensators are relevant only for 5 or 6-cylinder engines, and can be mounted either on the aft end or on both fore and aft end. The aft-end compensator consists of balance weights built into the camshaft chain drive.

The fore-end compensator consists of balance weights driven from the fore end of the crankshaft. The 2nd order moment compensators as well as the basic design and options are described in Section 17.02.

Hydraulic Cylinder Unit

The hydraulic cylinder unit (HCU) consists of a base plate on which a distributor block is mounted. The distributor block is fitted with one accumulator to ensure that the necessary hydraulic oil peak flow is available for the Electronic Fuel Injection.

The distributor block serves as a mechanical support for the hydraulically activated fuel pressure booster.

There is one Hydraulic Cylinder Unit per two cylinders. The HCU is equipped with two pressure boosters, two ELFI valves and two Alpha Lubricators. Thereby, one HCU is operating two cylinders.

The Hydraulic Power Supply

The Hydraulic Power Supply (HPS) is installed in the front end of the engine. The HPS is electrically driven and consists of two electric motors each driving a hydraulic pump.

The pressure for the hydraulic oil is 300 bar. Each of the pumps has a capacity corresponding to min. 55% of the engine power. In case of malfunction of one of the pumps, it is still possible to operate the engine with 55% engine power, enabling around 80% ship speed.

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.

Fuel injection is activated by a proportional valve, which is electronically controlled by the Cylinder Control Unit.

The fuel oil high-pressure pipes are double-walled and insulated but not heated.

Further information is given in Section 7.01.

Fuel Valves and Starting Air Valve

Each cylinder cover is equipped with two fuel valves, starting valve, and 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.

An automatic vent slide allows circulation of fuel oil through the valve and 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.

The mechanically driven starting air distributor is the same as the one used on the MC-C engines.

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

Engine Control System

The ME-B Engine Control System (ECS) controls the hydraulic fuel booster system, the fuel injection, governor function and cylinder lubrication.

The ECS consists of a number of computer-based control units, operating panels and auxiliary equipment located in the engine room and the engine control room.

The ME-B Engine Control System is described in Chapter 16.

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 of the W-seat design.

The exhaust valve spindle is a DuraSpindle, a spindle made of Nimonic is available as an option. The housing is provided with a spindle guide in any case.

The exhaust valve is tightened to the cylinder cover with studs and nuts. It is opened hydraulically and closed by means of air pressure. The hydraulic system consists of a piston actuator placed on the roller guide housing, a high-pressure pipe, and a working cylinder on the exhaust valve.

The piston actuator is activated by a cam on the camshaft, a built-in timing piston and a control valve enables control of the closing time of the exhaust valve.

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.

Reversing

On reversible engines (with Fixed Pitch Propellers mainly), reversing of the engine is performed in the Engine Control System by letting the starting air distributor supply air to the cylinders in order of the desired direction of rotation and by timing the fuel injection accordingly.

The exhaust valve gear is not to be reversed.

Indicator Cock

The engine is fitted with an indicator cock to which the PMI pressure transducer is connected. The PMI system, a pressure analyser system, is described in Section 18.02.

MAN B&W Alpha Cylinder Lubrication

The electronically controlled MAN B&W Alpha cylinder lubrication system is applied to the ME-B engines.

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.

Manoeuvring System

The engine is provided with a pneumatic/electric manoeuvring system. The system transmits orders from the Engine Control System to the engine.

The manoeuvring system makes it possible to start, stop, reverse the engine and control the engine speed.

The engine is provided with an engine side console and instrument panel.

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.

Piping Arrangements

The engine is delivered with piping arrangements for:

- Fuel oil
- Heating of fuel oil pipes
- Lubricating oil, piston cooling oil and hydraulic oil pipes
- 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
- 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.

Engine Cross Section of S50ME-B9

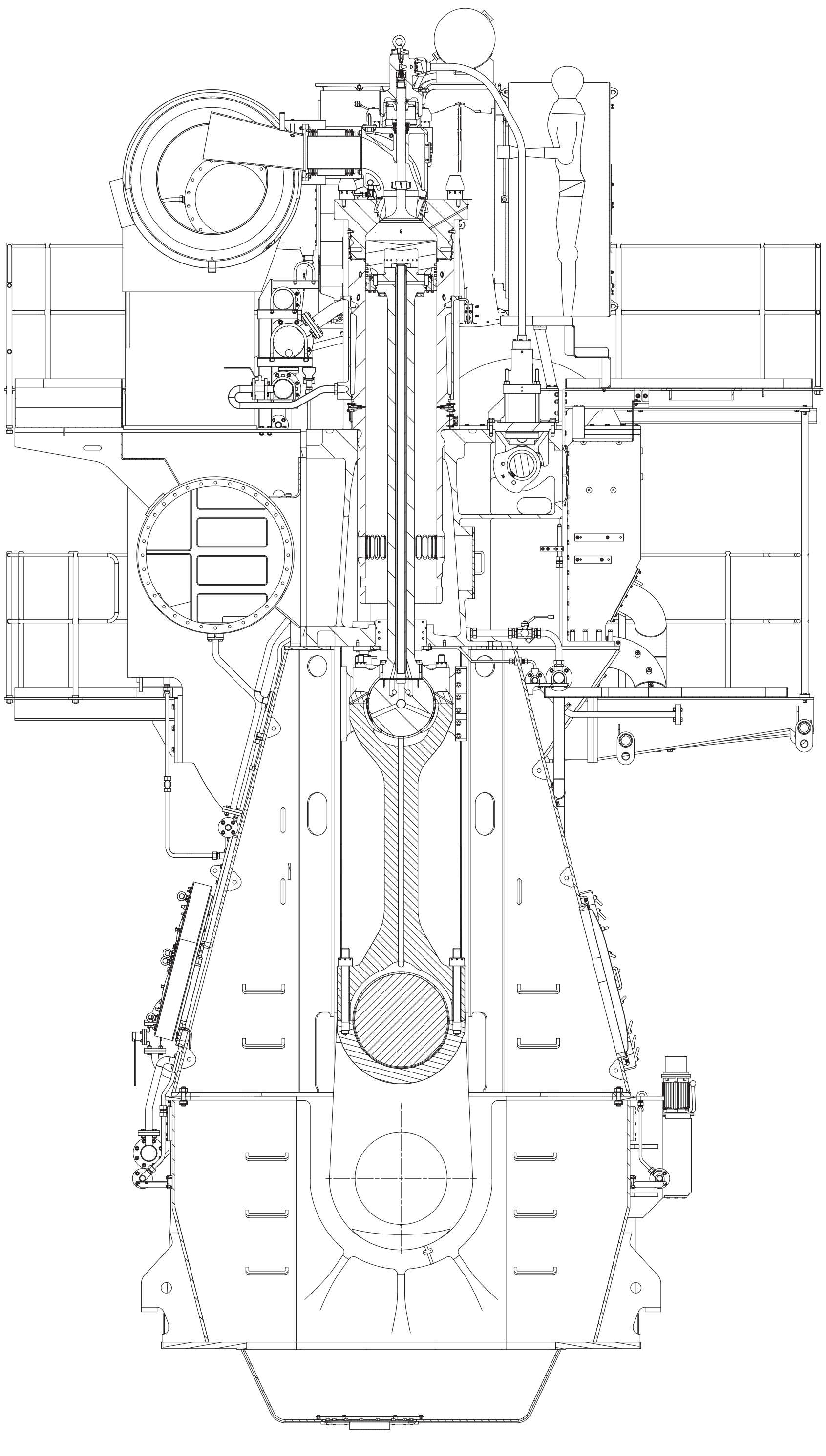

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Fig.: 1.07.01: Engine cross section

Engine Layout and Load Diagrams, SFOC

2

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:

$$P = c \times pe \times n$$

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

$$P = c \times n^1 \text{ (for constant mep)}$$

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

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

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:

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

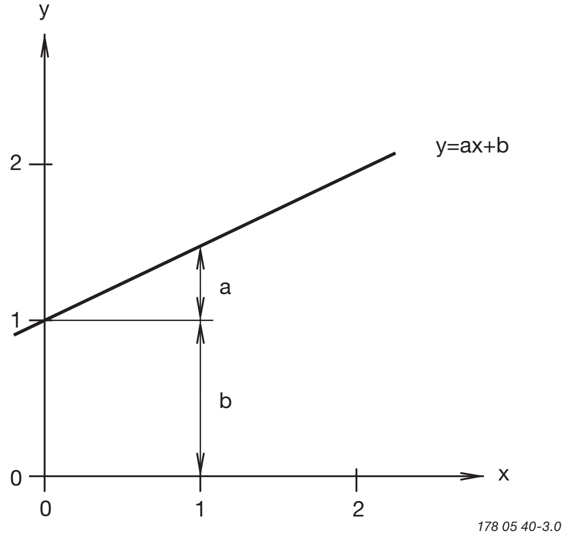


Fig. 2.01.01: Straight lines in linear scales

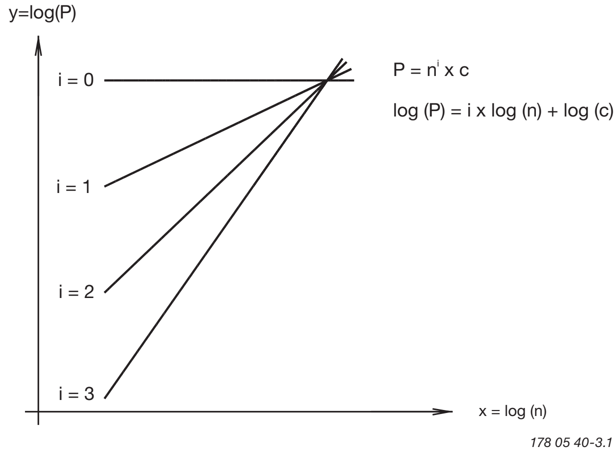


Fig. 2.01.02: Power function curves in logarithmic scales

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

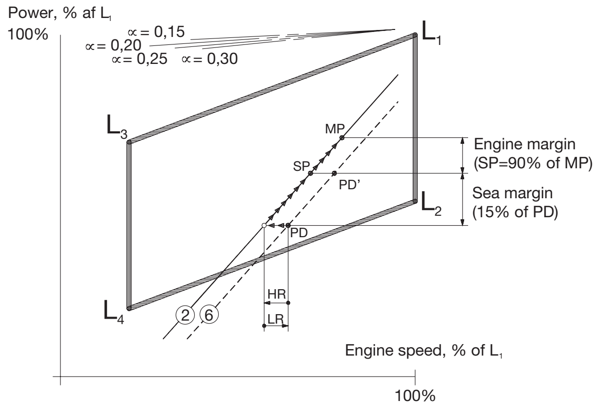
The relation between power and propeller speed for a fixed pitch propeller is as mentioned above described by means of the propeller law, i.e. the third power curve:

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

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), 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.



Line 2	Propulsion curve, fouled hull and heavy weather (heavy running), recommended for engine layout
Line 6	Propulsion curve, clean hull and calm weather (light running), for propeller layout
MP	Specified MCR for propulsion
SP	Continuous service rating for propulsion
PD	Propeller design point
HR	Heavy running
LR	Light running

178 05 41-5.3

Fig. 2.01.03: Ship propulsion running points and engine layout

Fouled hull

When the ship has sailed for some time, the hull and propeller become fouled and the hull's resistance will increase. Consequently, the ship's speed will be reduced unless the engine delivers more power to the propeller, i.e. the propeller will be further loaded and will be heavy running (HR).

As modern vessels with a relatively high service speed are prepared with very smooth propeller and hull surfaces, the gradual fouling after sea trial will increase the hull's resistance and make the propeller heavier running.

Sea margin and heavy weather

If, at the same time the weather is bad, with head winds, the ship's resistance may increase compared to operating in calm weather conditions. When determining the necessary engine power, it is normal practice to add an extra power margin, 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 ∝, 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 ∝ 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.

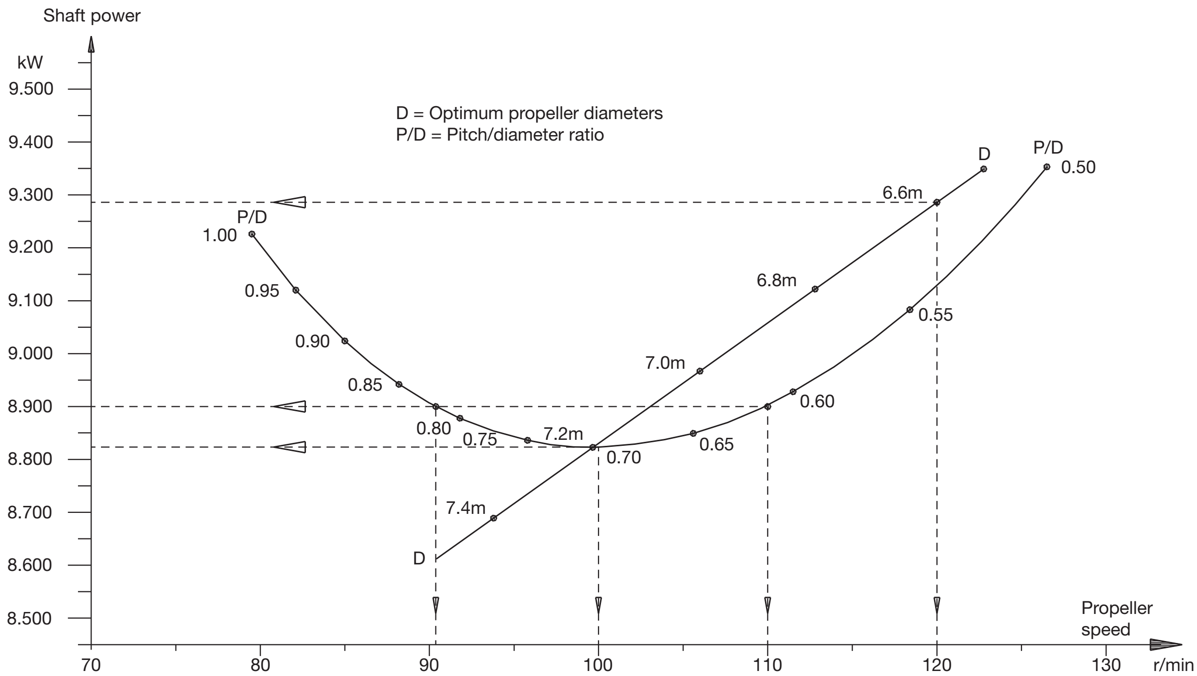
When the optimum propeller diameter D is increased from 6.6 m to 7.2. m, the power demand is reduced from about 9,290 kW to 8,820 kW, and the optimum propeller speed is reduced from 120 r/min to 100 r/min, corresponding to the constant ship speed coefficient $\propto$ = 0.28 (see definition of $\propto$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



178 47 03-2.0

Fig. 2.02.01: Influence of diameter and pitch on propeller design

Constant ship speed lines

The constant ship speed lines ∝, 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:

$P_2 = P_1 \times (n_2/n_1)^{\propto}$

where:
P = Propulsion power
n = Propeller speed, and
∝= 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 'MP_1', selected in the layout area and parallel to one of the ∝-lines, another specified propulsion MCR point 'MP_2' upon this line can be chosen to give the ship the same speed for the new combination of engine power and speed.

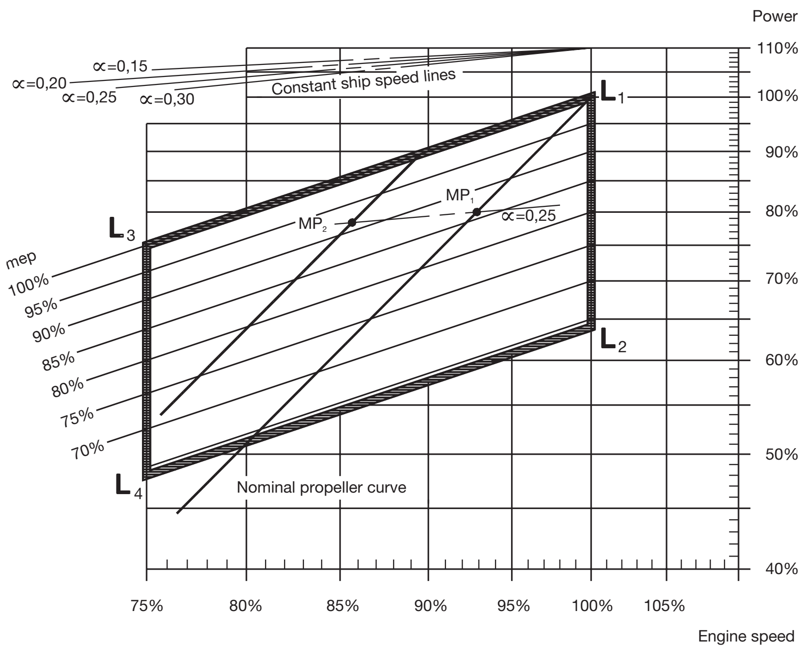
Fig. 2.02.02 shows an example of the required power speed point MP_1, through which a constant ship speed curve ∝= 0.25 is drawn, obtaining point MP_2 with a lower engine power and a lower engine speed but achieving the same ship speed.

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
∝= 0.25 -0.30

and for reefers and container vessels
∝= 0.15 -0.25

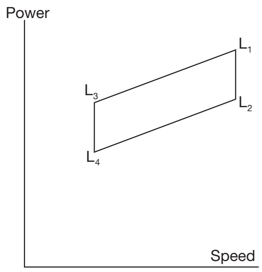
When changing the propeller speed by changing the pitch diameter ratio, the ∝ constant will be different, see above.



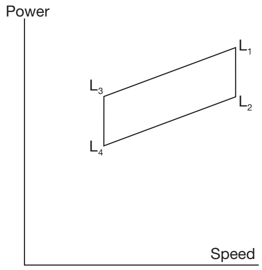
178 05 66-7.0

Fig. 2.02.02: Layout diagram and constant ship speed lines

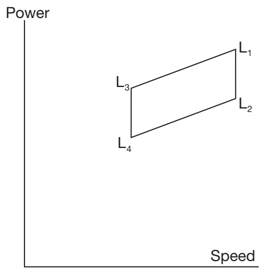
Layout Diagram Sizes



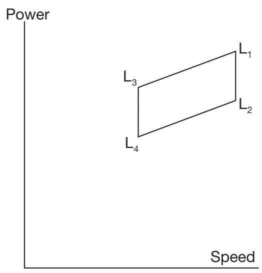
100 - 80% power and
100 - 79% speed range
valid for the types:
G70ME-C9.2
G60ME-C9.2



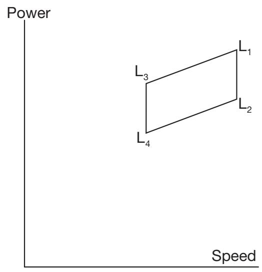
100 - 80% power and
100 - 81% speed range
valid for the types:
G80ME-C9.2-Extended



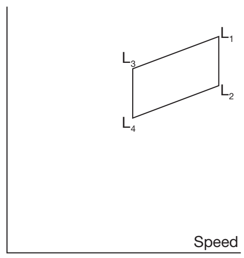
100 - 80% power and
100 - 84% speed range
valid for the types:
L70MC-C/ME-C8.2



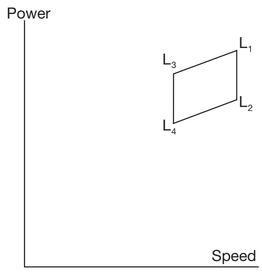
100 - 80% power and
100 - 85% speed range
valid for the types:
G80ME-C9.2-Basic
S70/65MC-C/ME-C8.2
S60MC-C/ME-C/ME-B8.3
L60MC-C/ME-C8.2
G/S50ME-B9.3
S50MC-C/ME-C8.2/ME-B8.3
S46MC-C/ME-B8.3
G45ME-B9.3
G/S40ME-B9.3, S40MC-C
S35MC-C/ME-B9.3
S30ME-B9.3



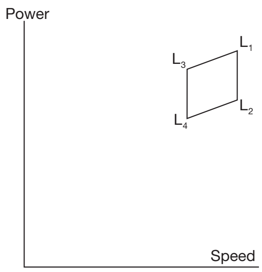
100 - 80% power and
100 - 85.7% speed range
valid for the types:
S90ME-C10.2
S90ME-C9.2
S80ME-C8.2



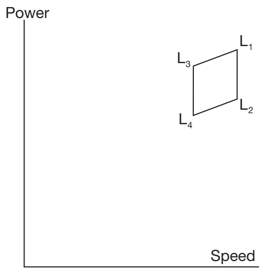
100 - 80% power and
100 - 87.5% speed range
valid for the types:
G95ME-C9.2



100 - 80% power and
100 - 90% speed range
valid for the types:
K80ME-C9.2



100 - 80% power and
100 - 92% speed range
valid for the types:
S80ME-C9.2/4
S90ME-C8.2



100 - 80% power and
100 - 93% speed range
valid for the types:
K98ME/ME-C7.1

See also Section 2.05 for actual project.

178 62 22-5.3

Fig. 2.03.01 Layout diagram sizes

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 $L_2 – L_4$, and by two constant engine speed lines $L_1 – L_2$ and $L_3 – L_4$. 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 optained 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.

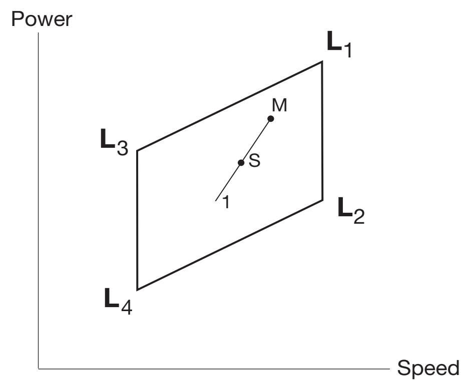


Fig. 2.04.01: Engine layout diagram

Engine Load Diagram

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.

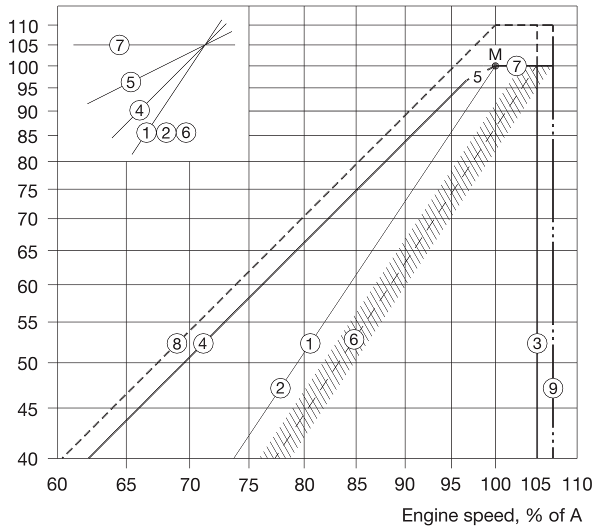
Line 2:
Propeller curve, fouled hull and heavy weather – heavy running.

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 L_1 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 L_1, provided that torsional vibration conditions permit.



Regarding 'i' in the power function $P = c \times n^i$, see page 2.01.

M	Specified MCR point
Line 1	Propeller curve through point M (i = 3) (engine layout curve)
Line 2	Propeller curve, fouled hull and heavy weather – heavy running (i = 3)
Line 3	Speed limit
Line 4	Torque/speed limit (i = 2)
Line 5	Mean effective pressure limit (i = 1)
Line 6	Propeller curve, clean hull and calm weather – light running (i = 3), for propeller layout
Line 7	Power limit for continuous running (i = 0)
Line 8	Overload limit
Line 9	Speed limit at sea trial

178 05 42-7.6

Fig. 2.04.02: Standard engine load diagram

Running at low load above 100% of the nominal L_1 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.

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 L_1 speed, whereas for MC/MC-C engines it is around 20-25% (electronic governor).

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.

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.

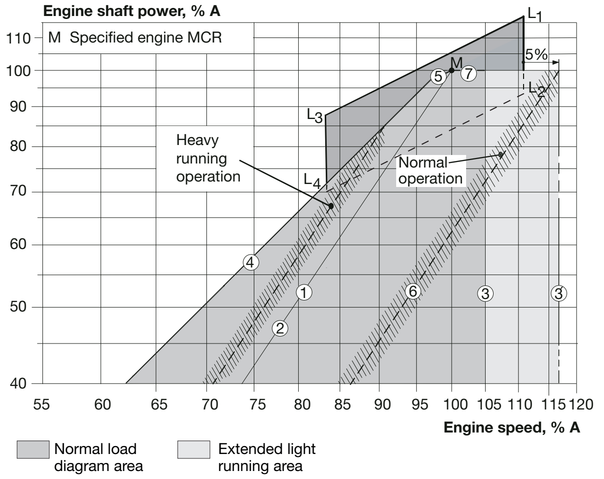
Extended load diagram for speed derated engines with increased light running

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.



Line 1: Propeller curve through SMCR point (M)
- layout curve for engine
Line 2: Heavy propeller curve
- fouled hull and heavy seas
Line 3: Speed limit
Line 3': Extended speed limit, provided torsional vibration conditions permit
Line 4: Torque/speed limit
Line 5: Mean effective pressure limit
Line 6: Increased light running propeller curve
- clean hull and calm weather
- layout curve for propeller
Line 7: Power limit for continuous running

178 60 79-9.1

Fig. 2.04.03: Extended load diagram for speed derated engine with increased light running

Examples of the use of the Load Diagram

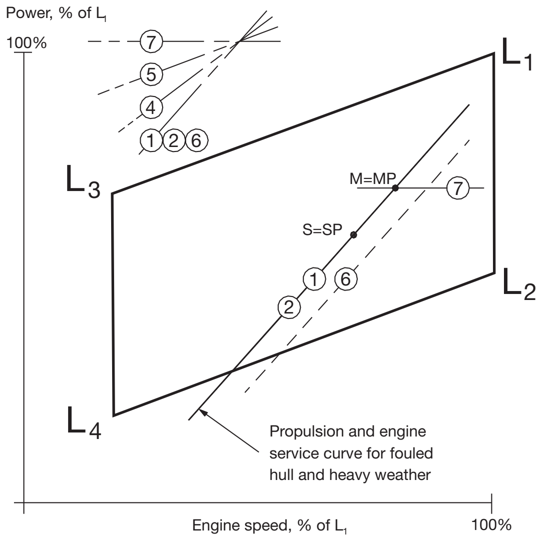
In the following are some examples illustrating the flexibility of the layout and load diagrams.

- 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.

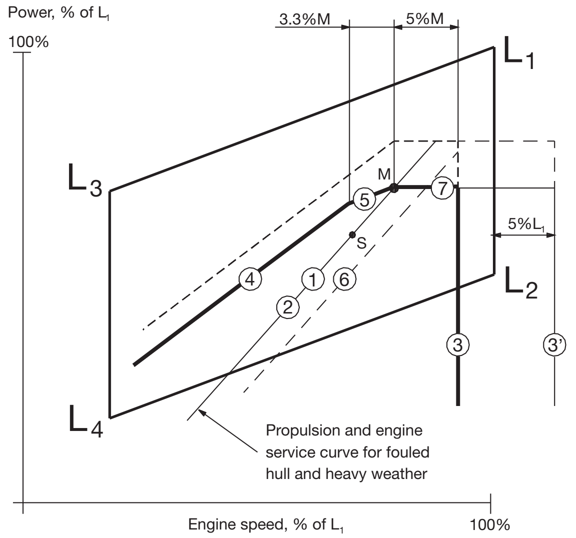
For a specific project, the layout diagram for actual project shown later in this chapter may be used for construction of the actual load diagram.

Example 1: Normal running conditions.
Engine coupled to fixed pitch propeller (FPP) and without shaft generator

Layout diagram



Load diagram



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.

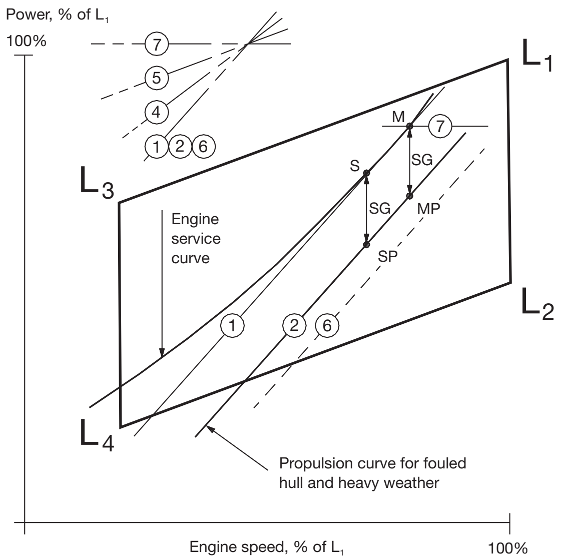
Once point M has been selected in the layout diagram, the load diagram can be drawn, as shown in the figure, and hence the actual load limitation lines of the diesel engine may be found by using the inclinations from the construction lines and the %-figures stated.

178 05 44-0.9

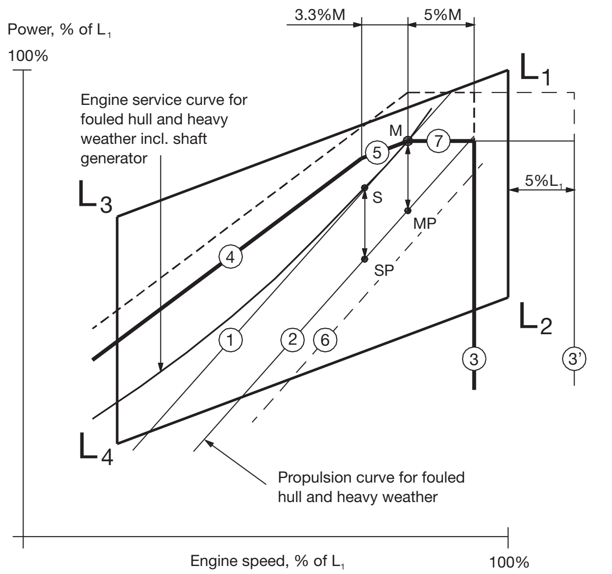
Fig. 2.04.04: Normal running conditions. Engine coupled to a fixed pitch propeller (FPP) and without a shaft generator

Example 2: Normal running conditions.
Engine coupled to fixed pitch propeller (FPP) and with shaft generator

Layout diagram



Load 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 power

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.

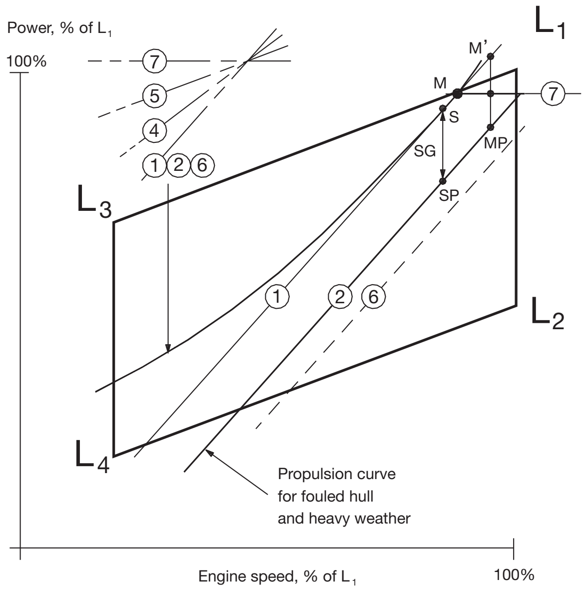
The specified MCR M will then be chosen and the load diagram can be drawn as shown in the figure.

178 05 48-8.9

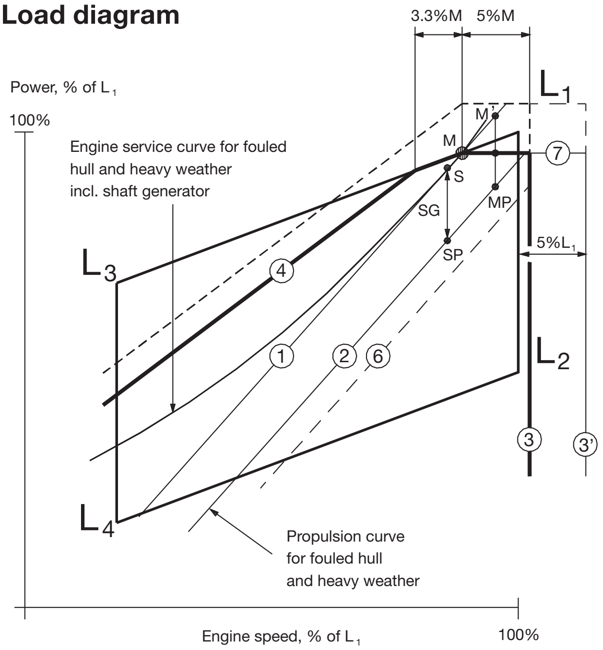
Fig. 2.04.06: Normal running conditions. Engine coupled to a fixed pitch propeller (FPP) and with a shaft generator

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

Layout diagram



Load 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

Point M of the load diagram is found:

Line 1	Propeller curve through point S
Point M	Intersection between line 1 and line $L_1 - L_3$

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.

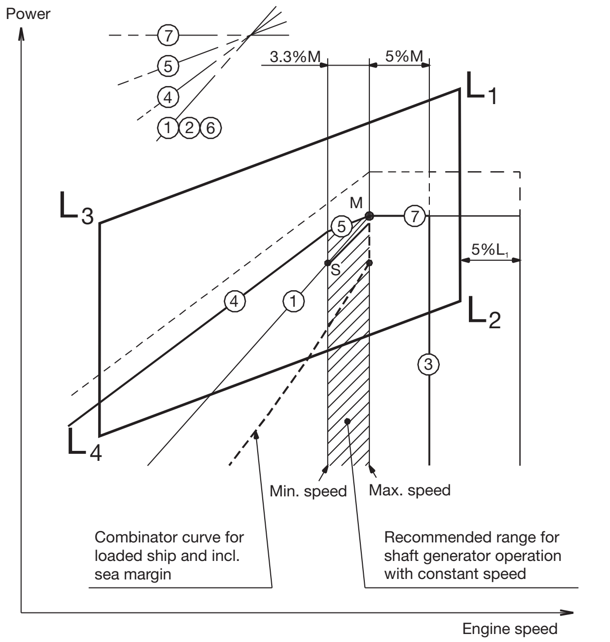
However, such a situation will seldom occur, as ships are rather infrequently running in the upper propulsion power range.

Point M, having the highest possible power, is then found at the intersection of line $L_1 - L_3$ with line 1 and the corresponding load diagram is drawn.

178 06 35-1.9

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



M Specified MCR of engine
S Continous service rating of engine

178 39 31-4.5

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

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.

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.

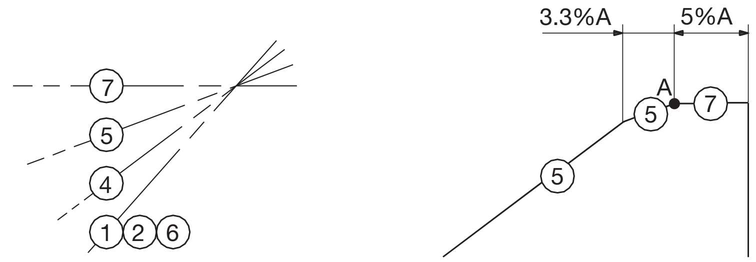
The procedure shown in examples 2 and 3 for engines with FPP can also be applied here for engines with CPP running with a combinator curve.

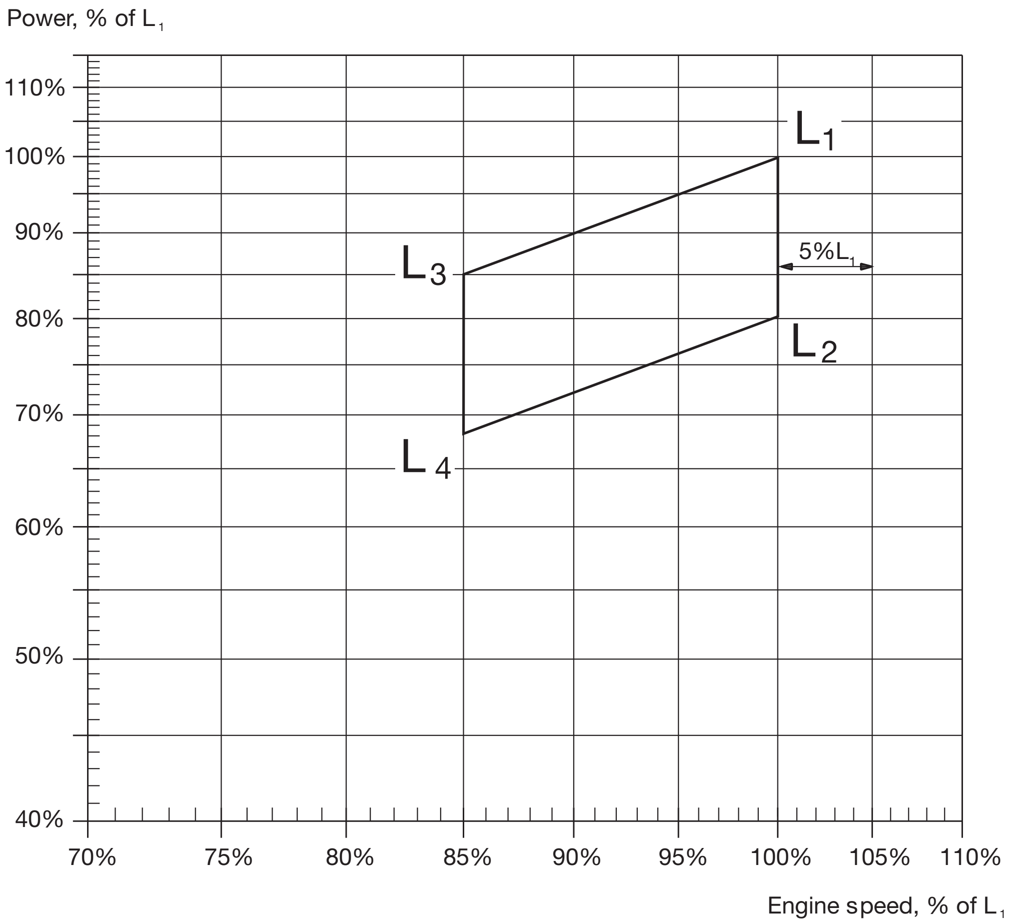
Load diagram
Therefore, when the engine's specified MCR point (M) has been chosen including engine margin, sea margin and the power for a shaft generator, if installed, point M may be used in the load diagram, which can then be drawn.

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.

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.





178 62 34-5.0

Fig. 2.05.01: Construction of layout diagram

Specific Fuel Oil Consumption, ME versus MC engines

As previously mentioned the main feature of the ME/ME-C engine is that the fuel injection and the exhaust valve timing are optimised automatically over the entire power range, and with a minimum speed down to around 15-20% of the L_1 speed, but around 20-25% for MC/MC-C.

Comparing the specific fuel oil comsumption (SFOC) of the ME and the MC engines, it can be seen from the figure below that the great advantage of the ME engine is a lower SFOC at part loads.

It is also noted that the lowest SFOC for the ME/ME-C engine is at 70% of M, whereas it is at 80% of M for the MC/MC-C/ME-B engine.

For the ME engine only the turbocharger matching and the compression ratio (shims under the piston rod) remain as variables to be determined by the engine maker / MAN Diesel & Turbo.

The calculation of the expected specific fuel oil consumption (SFOC) valid for standard high load optimised engines can be carried out by means of the following figures for fixed pitch propeller and for controllable pitch propeller, constant speed. Throughout the whole load area the SFOC of the engine depends on where the specified MCR point (M) is chosen.

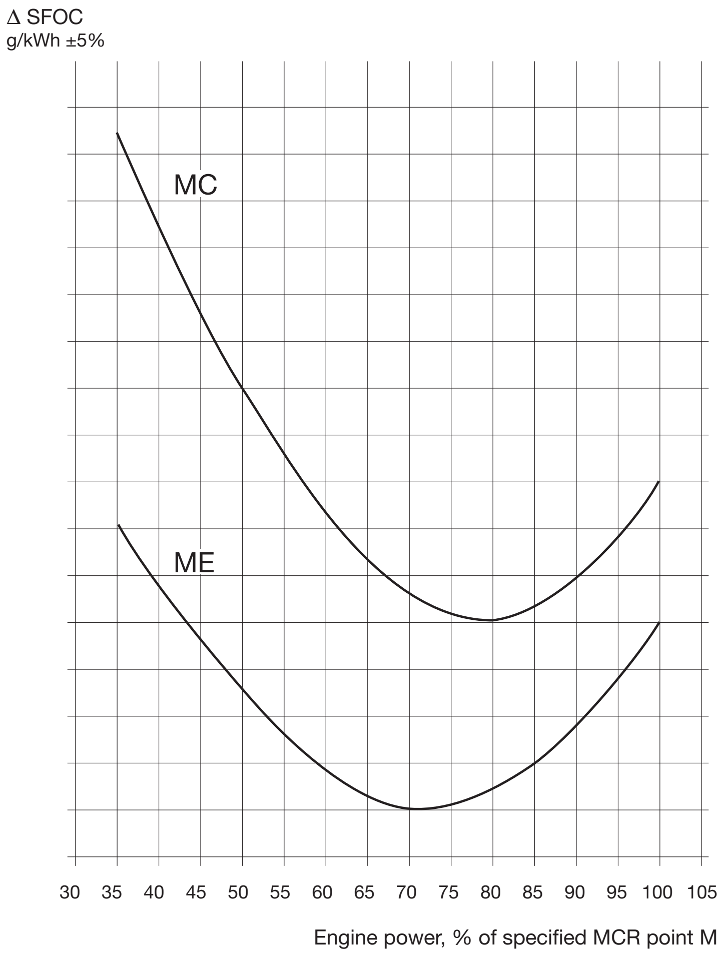


Fig. 2.06.01: Example of part load SFOC curves for ME and MC with fixed pitch propeller

SFOC for High Efficiency Turbochargers

All engines are as standard fitted with high efficiency turbochargers, option: 4 59 104.

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

For standard high load optimised ME-B engines the lowest SFOC may be obtained at 80% of the specified MCR.

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

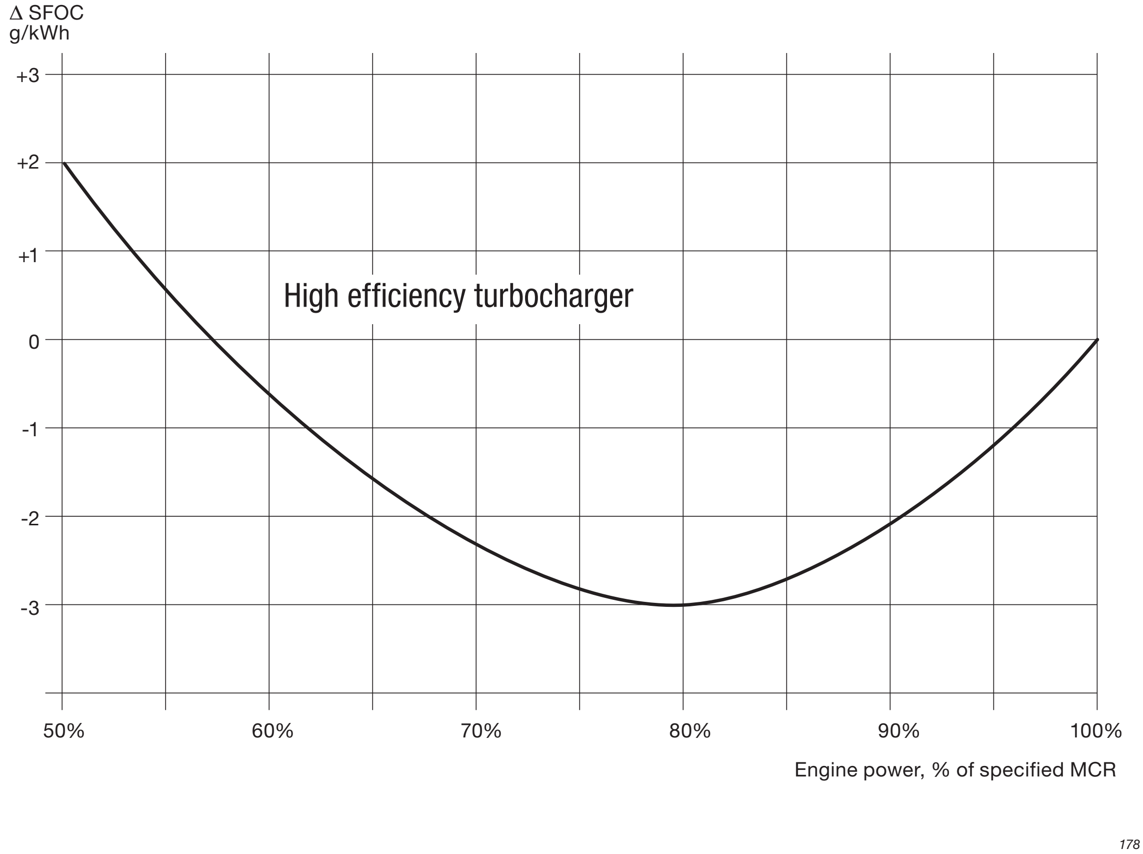


Fig. 2.07.01: Example of part load SFOC curves for high efficiency turbochargers

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/BHPh 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.

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

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_{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 SFOC

The examples shown in Fig. 2.09 and 2.10 are valid for a standard high-load optimised engine.

The following Diagrams a, b and c, valid for fixed pitch propeller (b) and constant speed (c), respectively, show the reduction of SFOC in g/kWh, relative to the SFOC for the nominal MCR L_1 rating.

The solid lines are valid at 100%, 80% and 50% of SMCR point M.

Point M is drawn into the above-mentioned Diagrams b or c. A straight line along the constant mep curves (parallel to L_1-L_3) is drawn through point M. The intersections of this line and the curves indicate the reduction in specific fuel oil consumption at 100, 80 and 50% of the SMCR point M, related to the SFOC stated for the nominal MCR L_1 rating.

An example of the calculated SFOC curves are shown in Diagram a, and is valid for an engine with fixed pitch propeller, see Fig. 2.10.01.

For examples based on part-load and low-load optimised engines, please refer to our publication:

SFOC Optimisation Methods
For MAN B&W Two-stroke IMO Tier II Engines

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

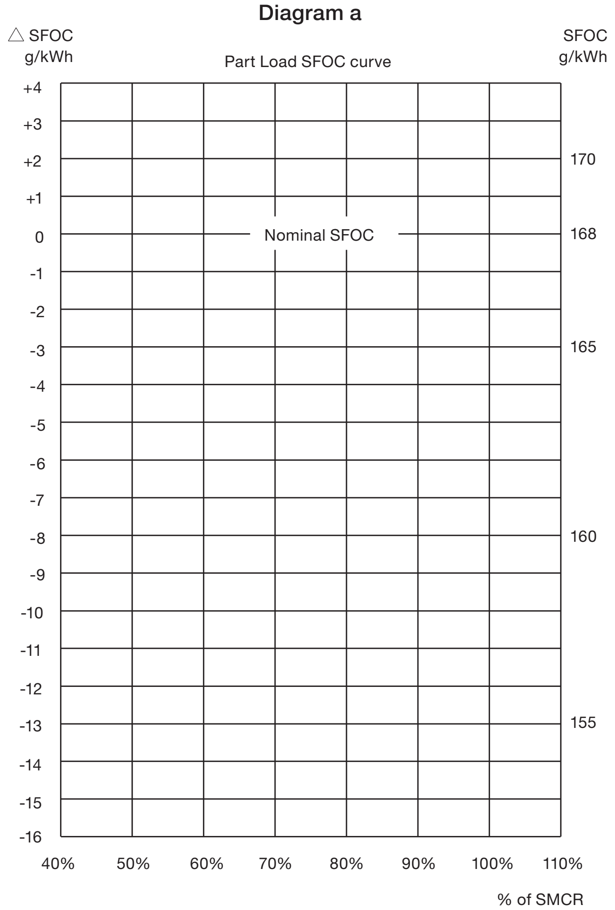
SFOC calculations can be made in the CEAS application, see Section 20.02.

SFOC Calculations for S50ME-B9.3

Data at nominel MCR (L_1)			SFOC at nominal MCR (L_1)
			High efficiency TC
Engine	**kW**	**r/min**	**g/kWh**
5 S50ME-B9.3	8,900	117	168
6 S50ME-B9.3	10,680		
7 S50ME-B9.3	12,460		
8 S50ME-B9.3	14,240		
9 S50ME-B9.3	16,020		

Data SMCR point (M):	
	cyl. No.
Power: 100% of (M)	kW
Speed: 100% of (M)	r/min
SFOC found:	g/kWh

Diagram a



178 61 40-9.1

Fig. 2.09.01

SFOC for S50ME-B9.3 with fixed pitch propeller

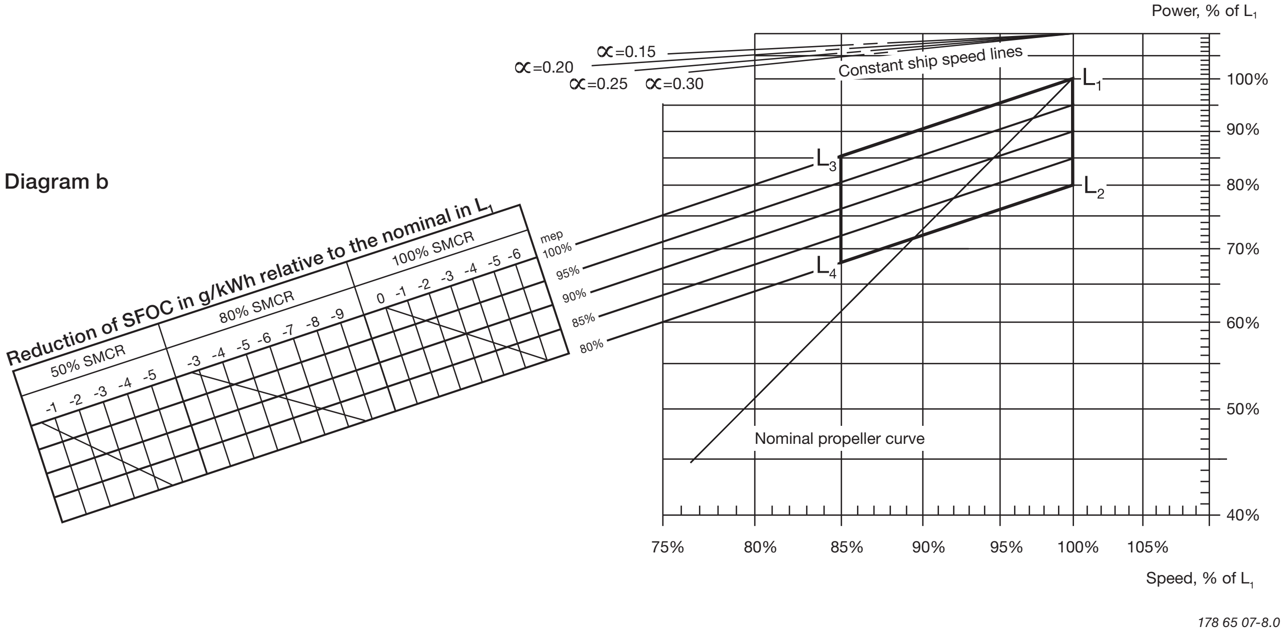


Fig. 2.09.02

SFOC for S50ME-B9.3 with constant speed

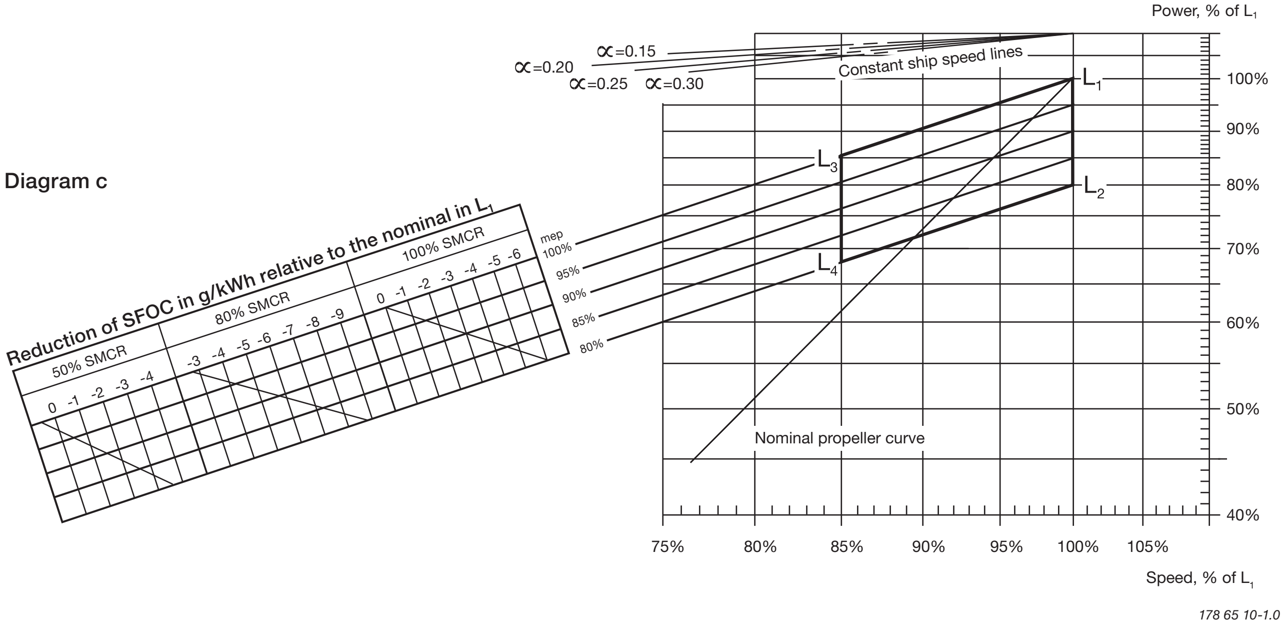


Fig. 2.09.03

SFOC calculations, example

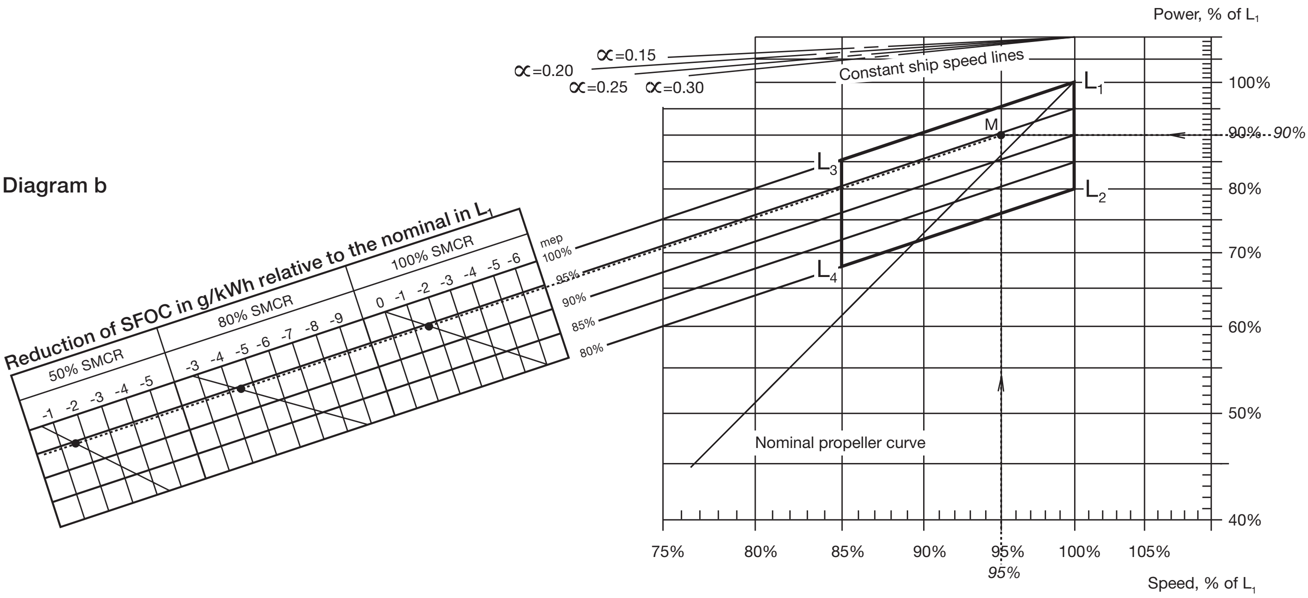
Valid for standard high-load optimised engine	
Data at nominal MCR (L_1): 6S50ME-B9.3	
Power 100%	10,680 kW
Speed 100%	117 r/min
Nominal SFOC:	
• High efficiency turbocharger	168 g/kWh

Example of specified MCR = M	
Power	9,612 kW (90% L_1)
Speed	111.2 r/min (95% L_1)
Turbocharger type	High efficiency
SFOC found in M	166.4 g/kWh

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

M = 90% L_1 power and 95% L_1 speed

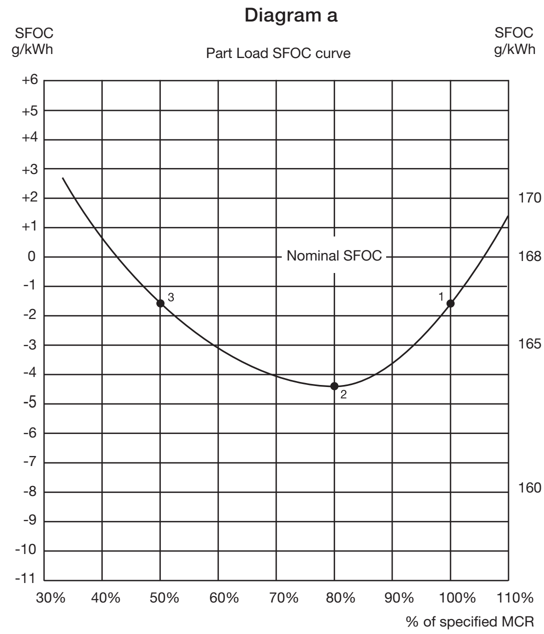
Diagram b



178 65 00-5.0

The reductions, see diagram b, in g/kWh compared to SFOC in L_1:

Part load points		SFOC g/kWh	SFOC g/kWh
1	100% M	-1.6	166.4
2	80% M	-4.4	163.6
3	50% M	-1.6	166.4



178 65 03-0.0

Fig. 2.10.01: Example of SFOC for derated 6S50ME-B9.3 with fixed pitch propeller and high efficiency turbocharger

Fuel Consumption at an Arbitrary Load

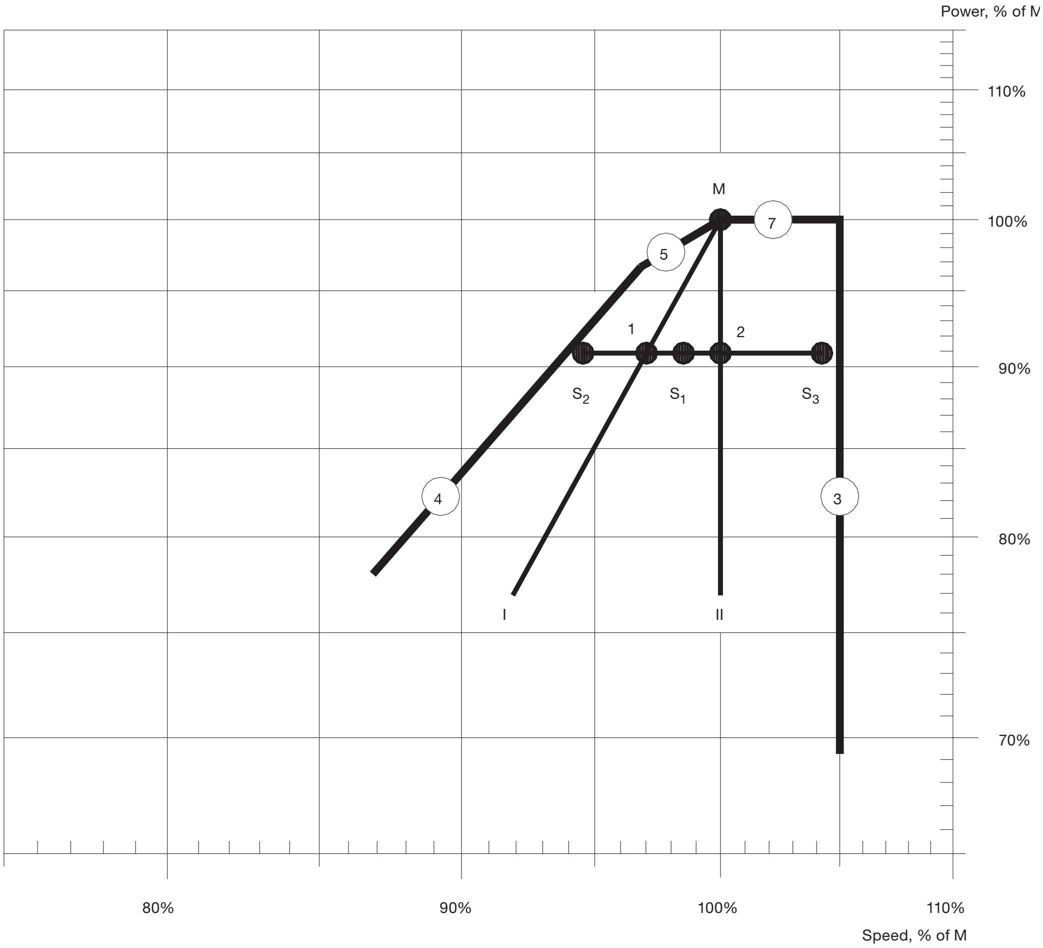
Once the specified MCR (M) of the engine has been chosen, the specific fuel oil consumption at an arbitrary point S_1, S_2 or S_3 can be estimated based on the SFOC at point '1' and '2'.

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 S_1 can be calculated as an interpolation between the SFOC in points '1' and '2', and for point S_3 as an extrapolation.

The SFOC curve through points S_2, 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.



198 95 96-2.2

Fig. 2.11.01: SFOC at an arbitrary load

Turbocharger Selection & Exhaust Gas By-pass

3

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.

High efficiency turbochargers for the MAN B&W S50ME-B9.3 engines - L_1 output			
Cyl.	**MAN (TCA)**	**ABB (A-L)**	**MHI (MET)**
5	1 x TCA55	1 x A265-L	1 x MET53MB
6	1 x TCA66	1 x A170-L	1 x MET60MB
7	1 x TCA66	1 x A270-L	1 x MET60MB
8	1 x TCA66	1 x A175-L	1 x MET66MB
9	1 x TCA77	1 x A175-L	1 x MET66MB

Table 3.01.01: High efficiency turbochargers

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 scavenge 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.

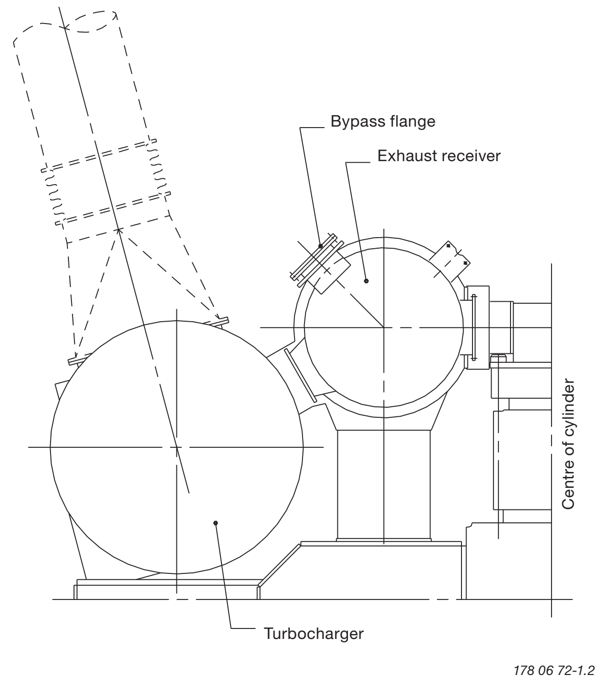


Fig. 3.02.01: Total bypass of exhaust for emergency running

Emission Control

IMO Tier II NO_x emission limits

All ME, ME-B and ME-C/-GI engines are, as standard, fulfilling the IMO Tier II NO_x emission requirements, a speed dependent NO_x 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.

NO_x reduction methods for IMO Tier III

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

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

Details of MAN Diesel & Turbo's NO_x 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

4

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 parrallel:

- 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:

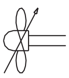
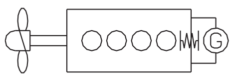
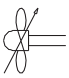
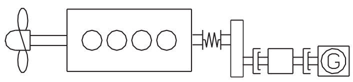
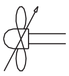
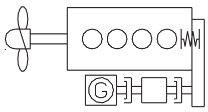
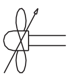
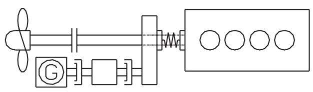
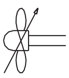
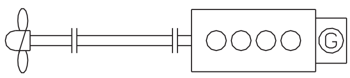
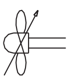
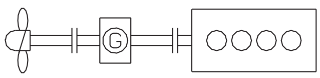
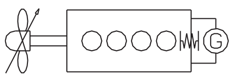
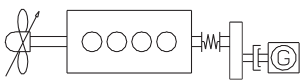
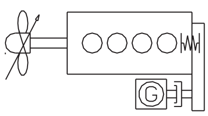
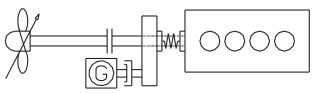
- PTO/RCF
  (Power Take Off/Renk Constant Frequency):
  Generator giving constant frequency, based on mechanical-hydraulical speed control.
- PTO/CFE
  (Power Take Off/Constant Frequency Electrical):
  Generator giving constant frequency, based on electrical frequency control.
- PTO/GCR
  (Power Take 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	Design	Seating	Total efficiency (%)
PTO/RCF	1a  1b 	BW I/RCF	On engine (vertical generator)	88-91
	2a  2b 	BW II/RCF	On tank top	88-91
	3a  3b 	BW III/RCF	On engine	88-91
	4a  4b 	BW IV/RCF	On tank top	88-91
PTO/CFE	5a  5b 	DMG/CFE	On engine	84-88
	6a  6b 	SMG/CFE	On tank top	89-91
PTO/GCR	7 	BW I/GCR	On engine (vertical generator)	92
	8 	BW II/GCR	On tank top	92
	9 	BW III/GCR	On engine	92
	10 	BW IV/GCR	On tank top	92

178 63 68-7.0

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

178 39 55-6.0

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.

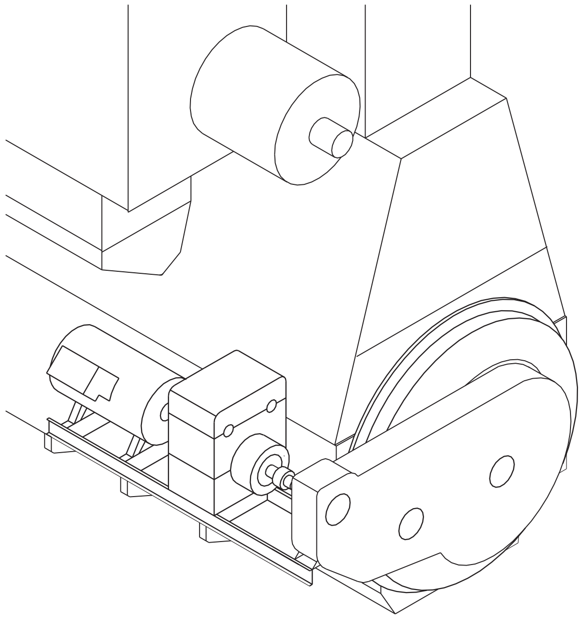


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Fig. 4.01.03: Side mounted BW III/RCF

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.

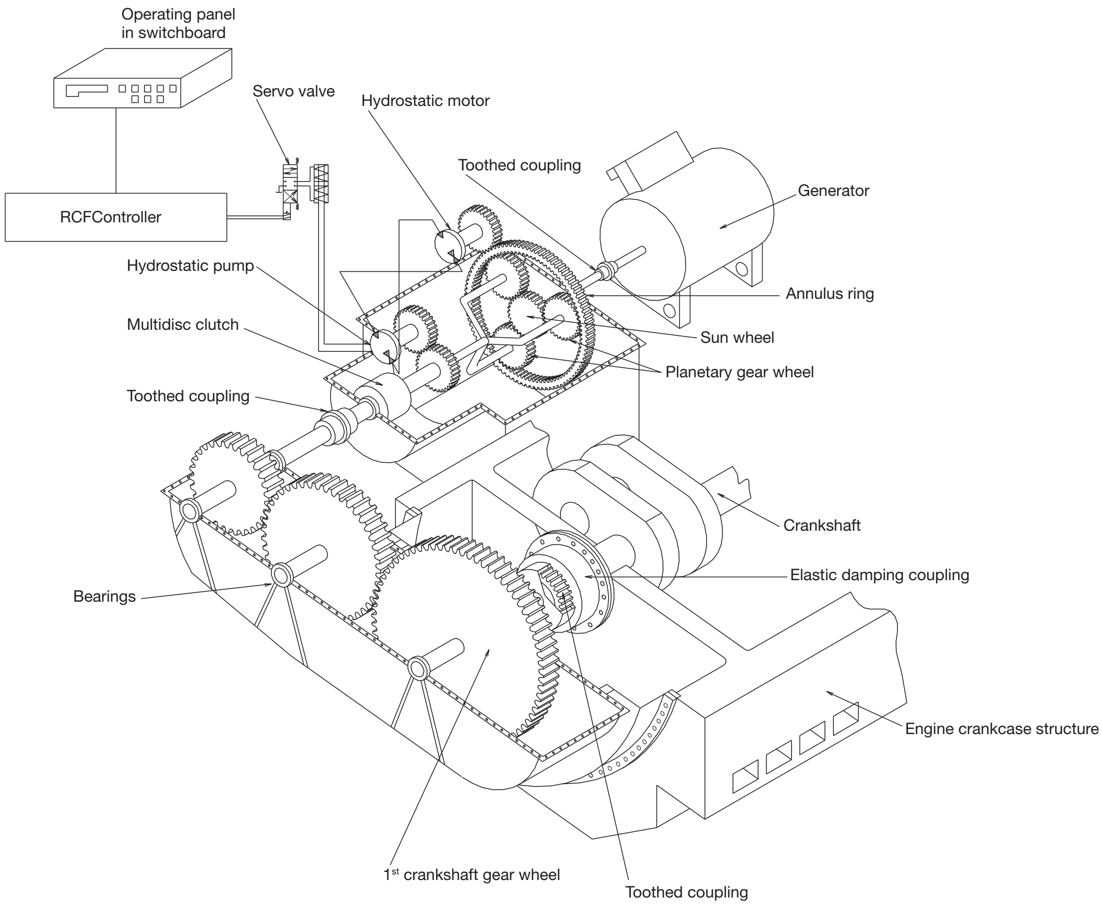

Fig. 4.01.04: Power take off with RENK constant frequency gear: BW III/RCF, option: 4 85 253

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:

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

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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.

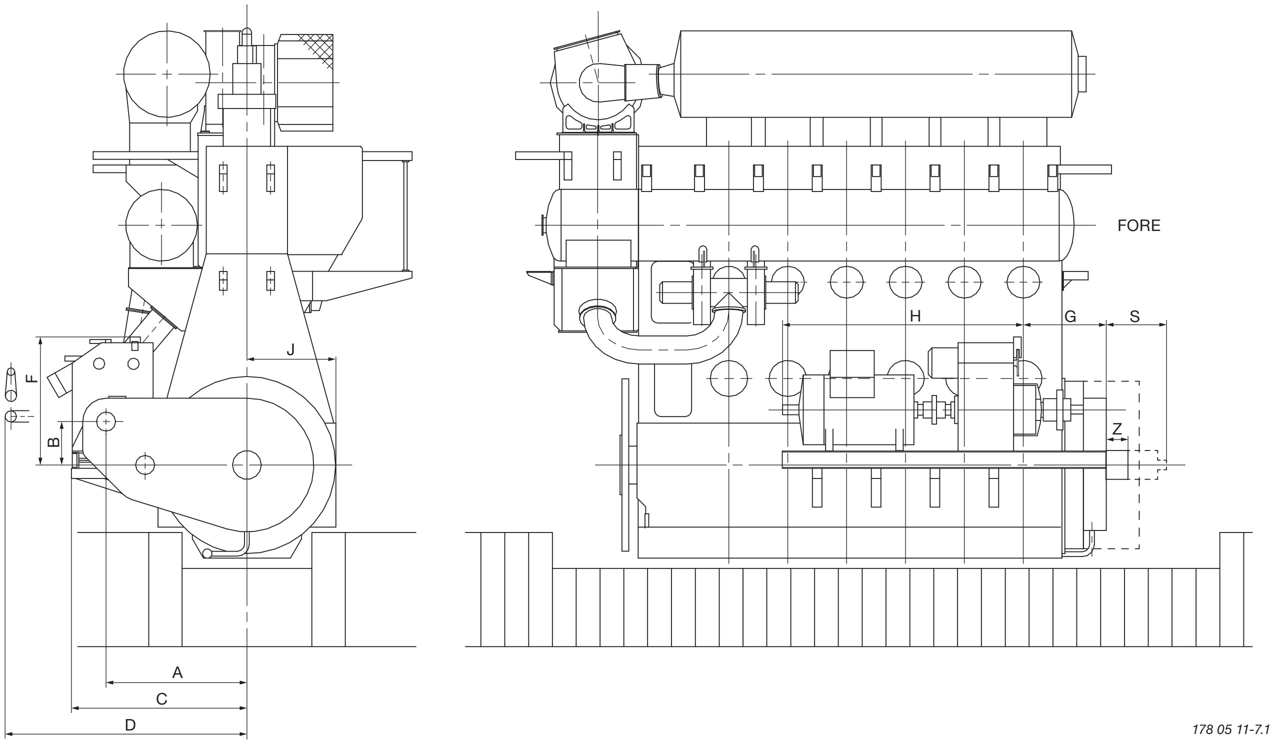
3. Wiring between the generator and the operator control panel in the switchboard.

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.



	kW generator			
	700 kW	**1,200 kW**	**1,800 kW**	**2,600 kW**
A	2,550	2,550	2,690	2,690
B	870	870	870	870
C	3,250	3,250	3,500	3,200
D	3,550	3,550	3,800	3,800
F	1,850	1,950	2,100	2,200
G	2,250	2,250	2,550	2,550
H	2,300	2,800	3,200	4,550
J	1,645	1,645	1,645	1,645
S	1,000	1,000	1,000	1,000
Z	500	500	500	500
	System mass (kg) with generator:			
	22,750	26,500	37,100	48,550
	System mass (kg) without generator:			
	20,750	23,850	32,800	43,350

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 on plants with turbocharger on the exhaust side.

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 S50-C/RCF

Engine preparations for PTO

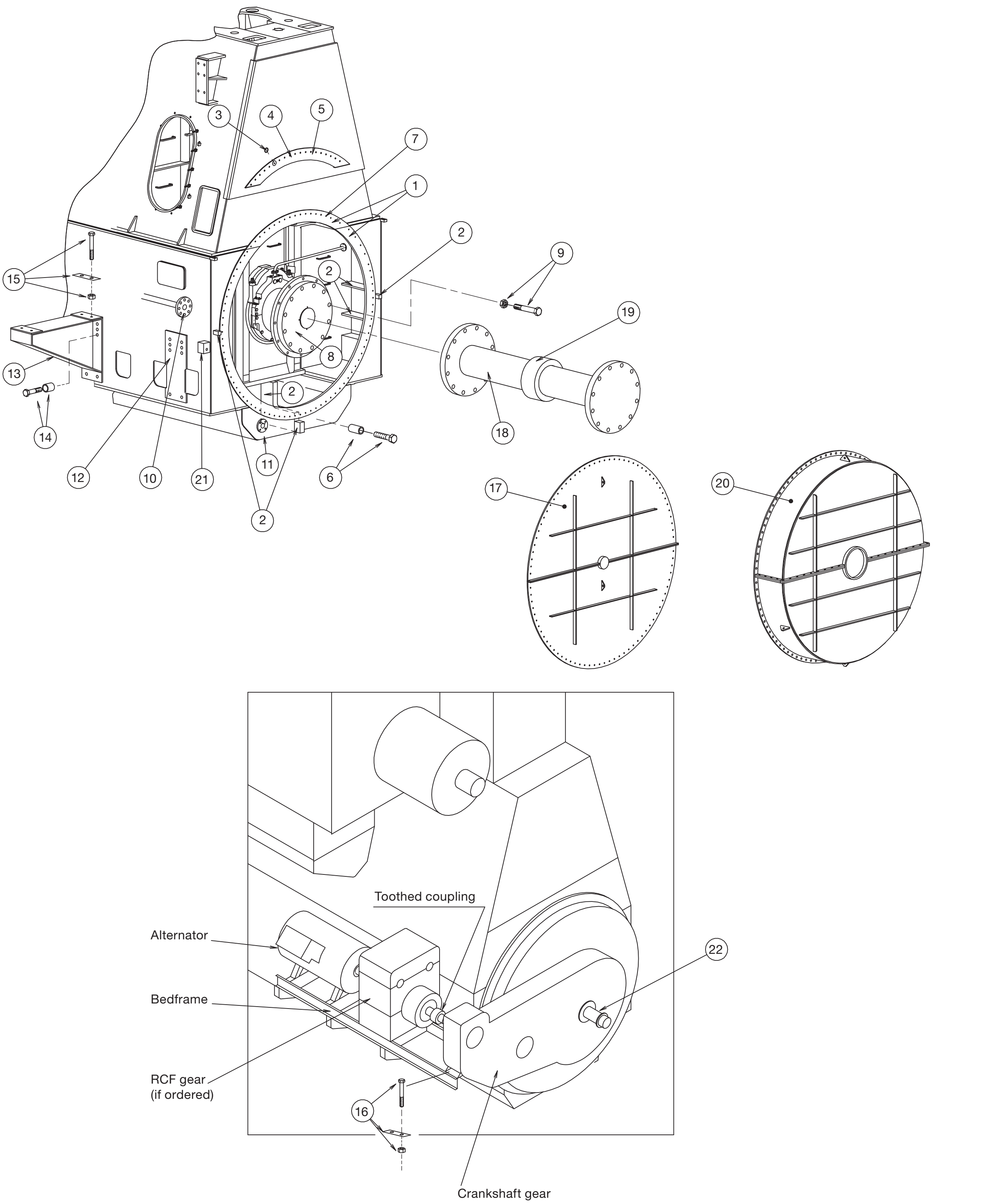


Fig. 4.03.01a: Engine preparations for PTO, BWIII/RCF system 178 57 15-7.1

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	
BWIII/CFE	A	A	A	A		B		A	B	A	A	A	A	A	B	B	A				A	A	
BWII/RCF								A	A									A	A	A	A		A
BWII/CFE								A	A									A	A	A	A		A
BWI/RCF	A	A	A	A		B		A	B								A				A		A
BWI/CFE	A	A	A	A		B		A	B	A	A						A				A		A
DMG/CFE	A	A			A	B	C	A	B								A				A		A

A: Preparations to be carried out by engine builder

B: Parts supplied by PTO maker

C: See text of pos. no.

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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:

Nominal output of generator	kW	700	1,200	1,800	2,600
Lubricating oil flow	m^3/h	4.1	4.1	4.9	6.2
Heat dissipation	kW	12.1	20.8	31.1	45.0

RCF gear with separate lubricating oil system:

Nominal output of generator	kW	700	1,200	1,800	2,600
Cooling water quantity	m^3/h	14.1	22.1	30.0	39.0
Heat dissipation	kW	55	92	134	180
El. power for oil pump	kW	11.0	15.0	18.0	21.0
Dosage tank capacity	m^3	0.40	0.51	0.69	0.95
El. power for Renk controller		24V DC ± 10%, 8 amp			

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

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

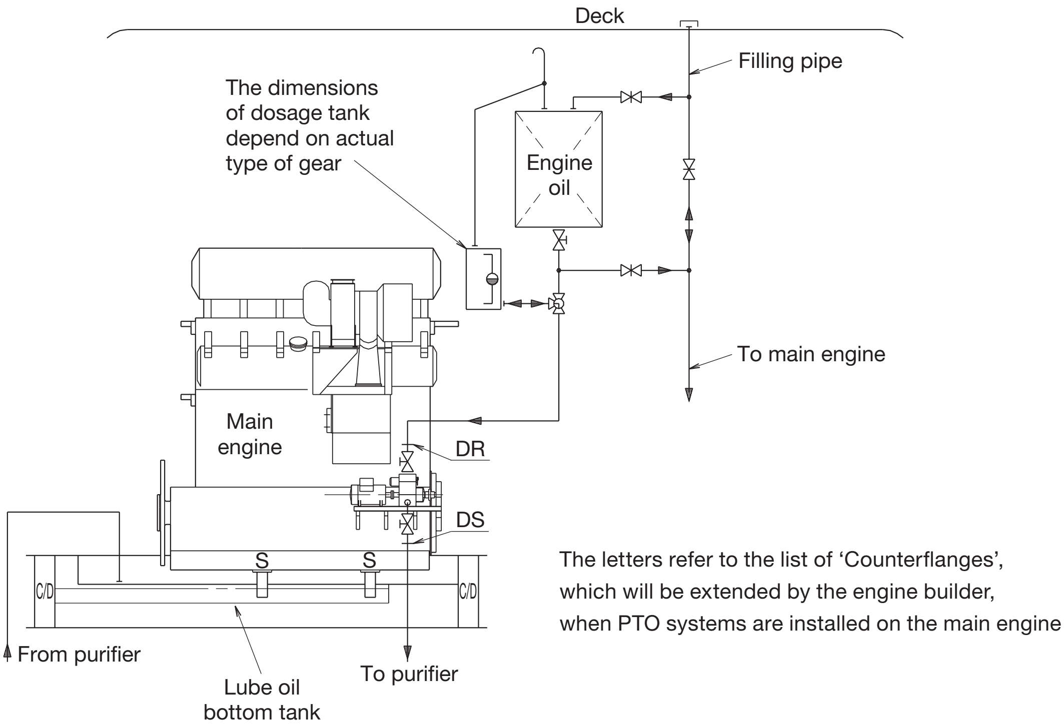

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Fig. 4.03.03: Lubricating oil system for RCF gear

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.

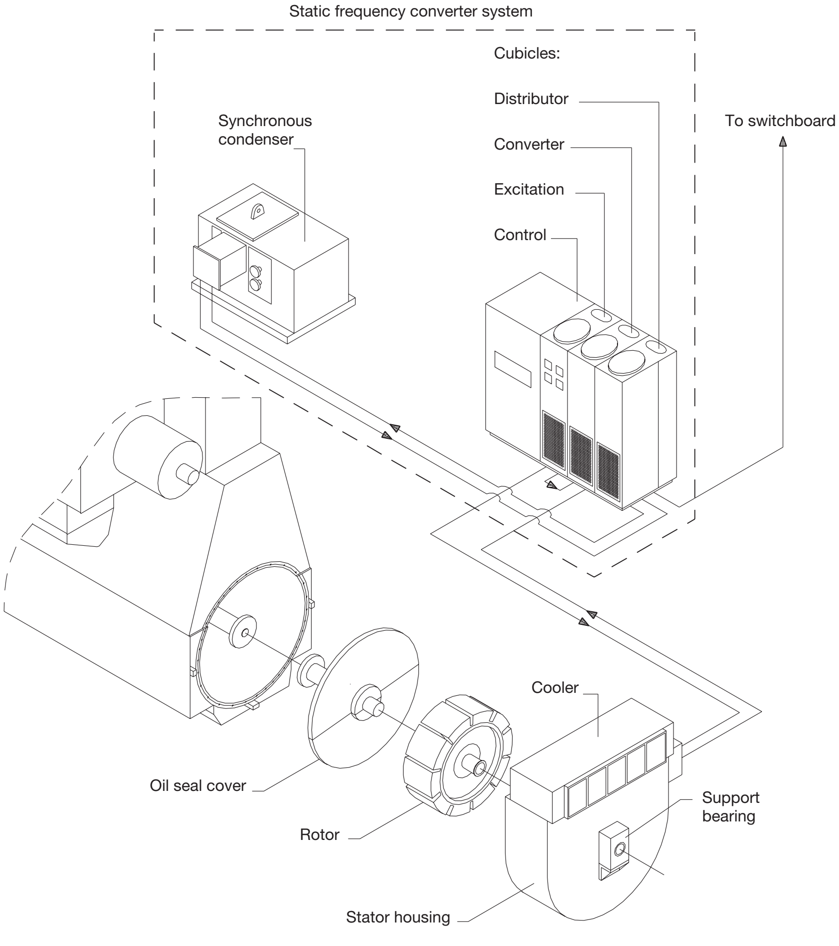

Fig. 4.03.04: Standard engine, with direct mounted generator (DMG/CFE)

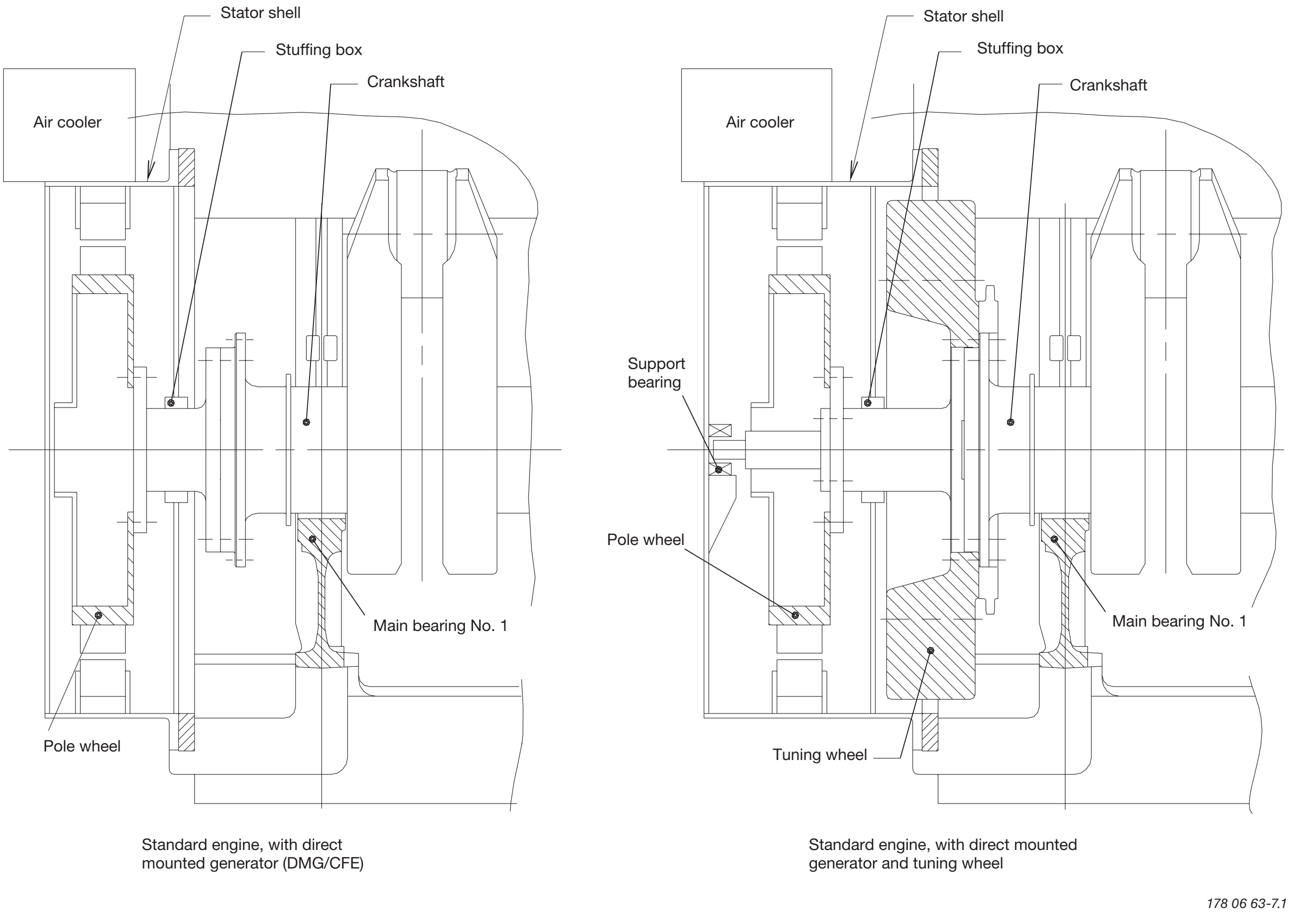

Fig. 4.03.05: Standard engine, with direct mounted generator and tuning wheel

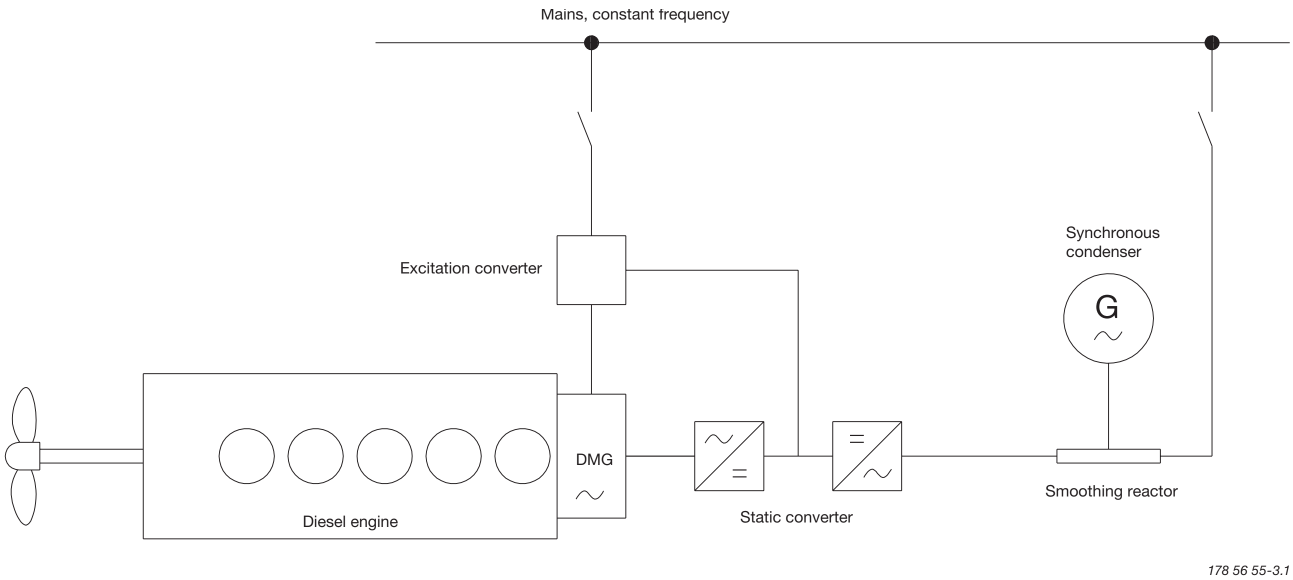

Fig. 4.03.06: Diagram of DMG/CFE with static converter

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

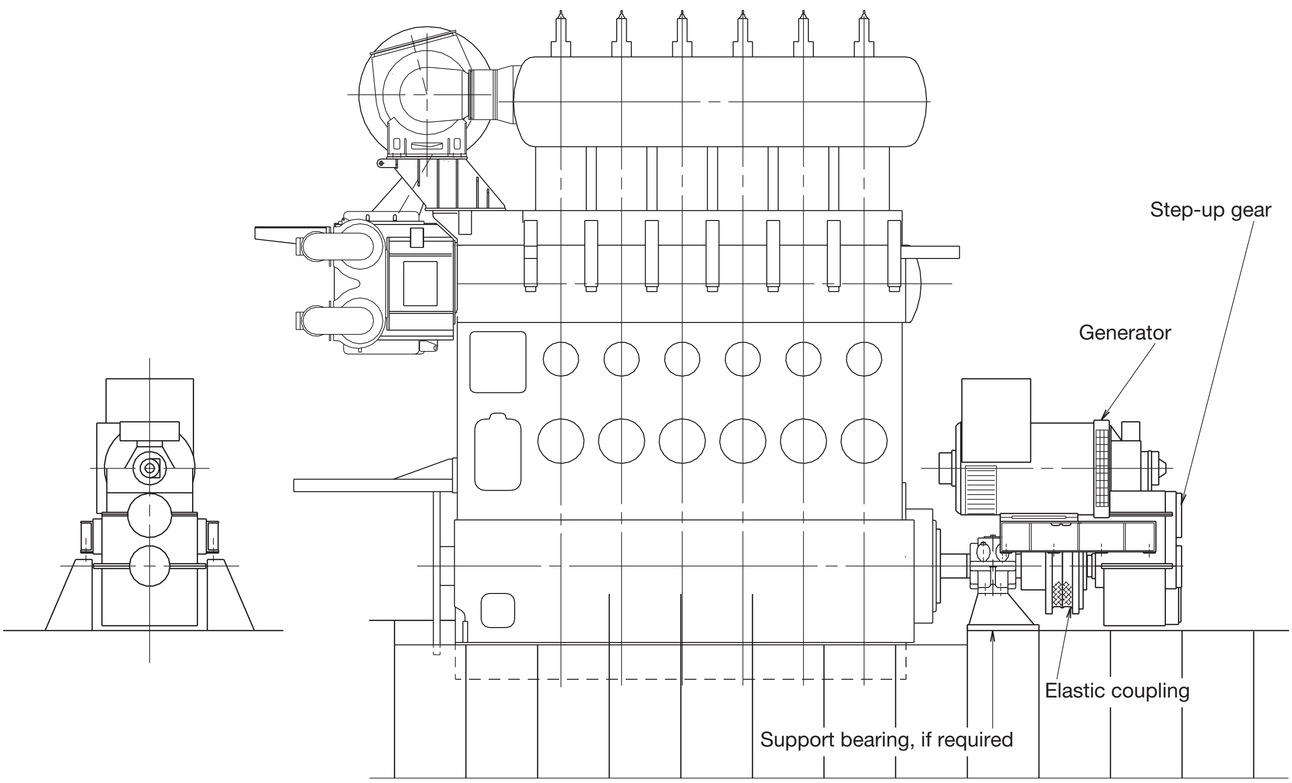

Fig. 4.04.01: Generic outline of Power Take Off (PTO) BW II/GCR

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.

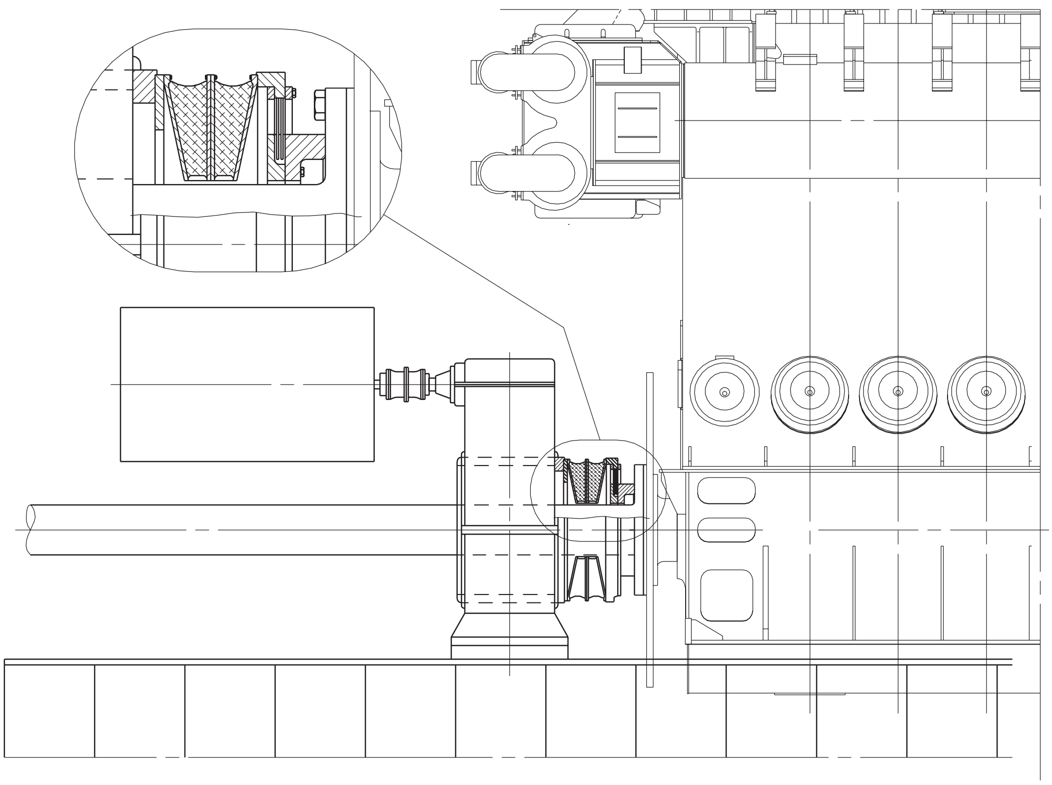

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Fig. 4.04.02: Generic outline of BW IV/GCR, tunnel gear

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.

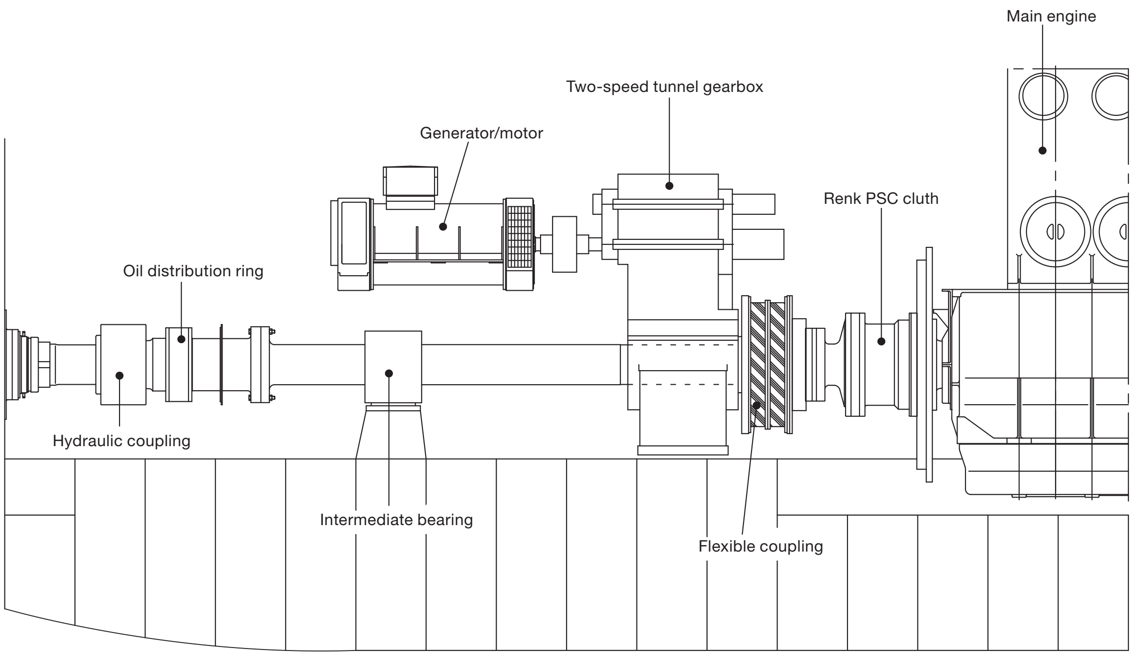

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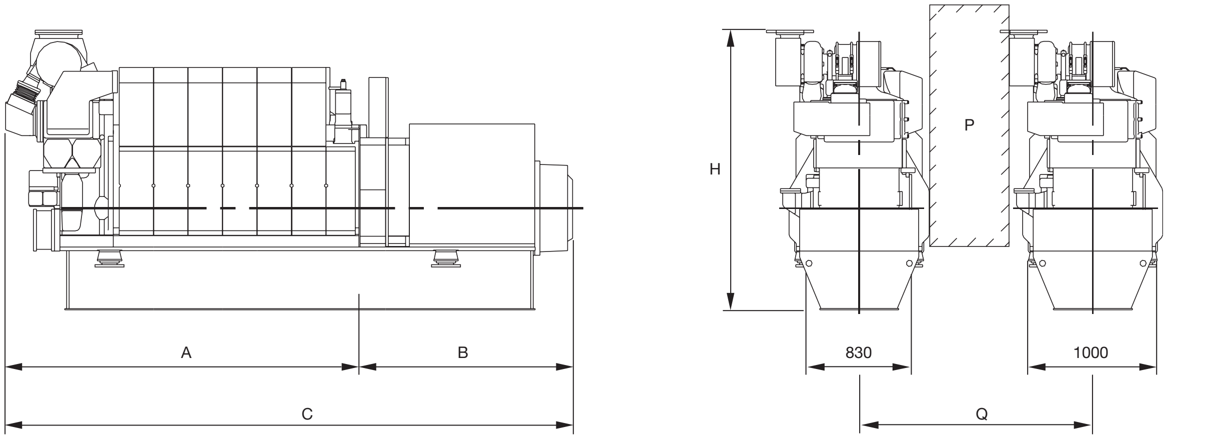
Fig. 4.04.03: Auxiliary propulsion system

Waste Heat Recovery Systems (WHRS)

This section is not applicable

L16/24-TII GenSet Data

Bore: 160 mm				Stroke: 240 mm
	Power layout			
	1,200 r/min	60 Hz	1,000 r/min	50 Hz
	Eng. kW	Gen. kW	Eng. kW	Gen. kW
5L16/24	500	475	450	430
6L16/24	660	625	570	542
7L16/24	770	730	665	632
8L16/24	880	835	760	722
9L16/24	990	940	855	812



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

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.

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Fig. 4.06.01: Power and outline of L16/24, IMO Tier II

L16/24-TII GenSet Data

5L:90 kW/cyl., 6L-9L: 95 kW/Cyl. at 1,000 rpm						
Reference Condition: Tropic						
Air temperature	°C			45		
LT-water temperature inlet engine (from system)	°C			38		
Air pressure	bar			1		
Relative humidity	%			50		
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)				
Number of Cylinders	-	**5**	**6**	**7**	**8**	**9**
Engine output	kW	450	570	665	760	855
Speed	rpm			1,000		
Heat to be dissipated [3]						
Cooling water (C.W.) Cylinder	kW	107	135	158	181	203
Charge air cooler; cooling water HT	kW	138	169	192	213	234
Charge air cooler; cooling water LT	kW	56	69	80	91	102
Lube oil (L.O.) cooler	kW	98	124	145	166	187
Heat radiation engine	kW	15	19	23	26	29
Flow rates [4]						
Internal (inside engine)						
HT circuit (cylinder + charge air cooler HT stage)	m^3/h	10.9	12.7	14.5	16.3	18.1
LT circuit (lube oil + charge air cooler LT stage)	m^3/h	15.7	18.9	22	25.1	28.3
Lube oil	m^3/h	18	18	30	30	30
External (from engine to system)						
HT water flow (at 40°C inlet)	m^3/h	5.2	6.4	7.4	8.3	9.2
LT water flow (at 38°C inlet)	m^3/h	15.7	18.9	22	25.1	28.3
Air data						
Temperature of charge air at charge air cooler outlet	°C	49	51	52	54	55
Air flow rate	m^3/h [5]	2,721	3,446	4,021	4,595	5,169
	kg/kWh	6.62	6.62	6.62	6.62	6.62
Charge air pressure	bar			4.13		
Air required to dissipate heat radiation (engine)(t_2-t_1=10°C)	m^3/h	4,860	6,157	7,453	8,425	9,397
Exhaust gas data [6]						
Volume flow (temperature turbocharger outlet) Mass flow	m^3/h [7]	5,710	7,233	8,438	9,644	10,849
Temperature at turbine outlet	t/h	3.1	3.9	4.5	5.2	5.8
Heat content (190°C)	°C	375	375	375	375	375
Permissible exhaust back pressure	kW	170	216	252	288	324
	mbar			< 30		
Pumps						
a) Engine driven pumps						
HT circuit cooling water (2.5 bar)	m^3/h	10.9	12.7	14.5	16.3	18.1
LT circuit cooling water (2.5 bar)	m^3/h	15.7	18.9	22	25.1	28.3
Lube oil (4.5 bar)	m^3/h	18	18	30	30	30
b) External pumps [8]						
Diesel oil pump (5 bar at fuel oil inlet A1)	m^3/h	0.32	0.40	0.47	0.54	0.60
Fuel oil supply pump (4 bar discharge pressure)	m^3/h	0.15	0.19	0.23	0.26	0.29
Fuel oil circulating pump (8 bar at fuel oil inlet A1)	m^3/h	0.32	0.40	0.47	0.54	0.60
Starting air data						
Air consumption per start, incl. air for jet assist (IR/TDI)	Nm^3	0.47	0.56	0.65	0.75	0.84
Air consumption per start, incl. air for jet assist (Gali)	Nm^3	0.80	0.96	1.12	1.28	1.44

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

L16/24-TII GenSet Data

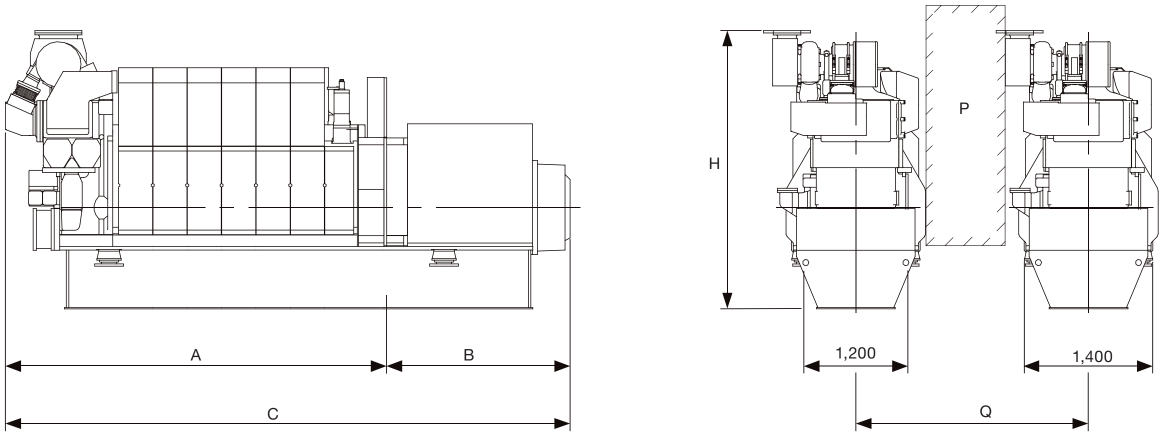
5L:100 kW/cyl., 6L-9L: 110 kW/Cyl. at 1,200 rpm						
Reference Condition: Tropic						
Air temperature	°C			45		
LT-water temperature inlet engine (from system)	°C			38		
Air pressure	bar			1		
Relative humidity	%			50		
Temperature basis						
Setpoint HT cooling water engine outlet [1]	°C	79 nominal (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)				
Number of Cylinders	**-**	**5**	**6**	**7**	**8**	**9**
Engine output	kW	500	660	770	880	990
Speed	rpm			1,200		
Heat to be dissipated [3]						
Cooling water (C.W.) Cylinder	kW	100	132	154	177	199
Charge air cooler; cooling water HT	kW	149	187	211	234	255
Charge air cooler; cooling water LT	kW	66	83	96	109	122
Lube oil (L.O.) cooler	kW	113	149	174	199	224
Heat radiation engine	kW	17	23	26	30	34
Flow rates [4]						
Internal (inside engine)						
HT circuit (cylinder + charge air cooler HT stage)	m^3/h	13.1	15.2	17.4	19.5	21.6
LT circuit (lube oil + charge air cooler LT stage)	m^3/h	19.3	20.7	24.2	27.7	31.1
Lube oil	m^3/h	21	21	35	35	35
External (from engine to system)						
HT water flow (at 40°C inlet)	m^3/h	5.7	7.3	8.4	9.4	10.4
LT water flow (at 38°C inlet)	m^3/h	19.1	20.7	24.2	27.7	31.1
Air data						
Temperature of charge air at charge air cooler outlet	°C	51	53	55	56	57
Air flow rate	m^3/h [5]	3,169	4,183	4,880	5,578	6,275
	kg/kWh	6.94	6.94	6.94	6.94	6.94
Charge air pressure	bar			3.92		
Air required to dissipate heat radiation (engine) (t_2-t_1= 10°C)	m^3/h	5,509	7,453	8,425	9,721	11,017
Exhaust gas data [6]						
Volume flow (temperature turbocharger outlet)	m^3/h [7])	6,448	8,511	9,929	11,348	12,766
Mass flow	t/h	3.6	4.7	5.5	6.3	7.1
Temperature at turbine outlet	°C	356	356	356	356	356
Heat content (190°C)	kW	178	235	274	313	352
Permissible exhaust back pressure	mbar			< 30		
Pumps						
a) Engine driven pumps						
HT circuit cooling water (2.5 bar)	m^3/h	13.1	15.2	17.4	19.5	21.6
LT circuit cooling water (2.5 bar)	m^3/h	19.3	20.7	24.2	27.7	31.1
Lube oil (4.5 bar)	m^3/h	21	21	35	35	35
b) External pumps [8]						
Diesel oil pump (5 bar at fuel oil inlet A1)	m^3/h	0.35	0.47	0.54	0.62	0.70
Fuel oil supply pump (4 bar discharge pressure)	m^3/h	0.17	0.22	0.26	0.30	0.34
Fuel oil circulating pump (8 bar at fuel oil inlet A1)	m^3/h	0.35	0.47	0.54	0.62	0.70
Starting air data						
Air consumption per start, incl. air for jet assist (IR/TDI)	Nm^3	0.47	0.56	0.65	0.75	0.84
Air consumption per start, incl. air for jet assist (Gali)	Nm^3	0.80	0.96	1.12	1.28	1.44

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
	Power layout			
	900 r/min	60 Hz	1,000 r/min	50 Hz
	Eng. kW	Gen. kW	Eng. kW	Gen. kW
5L21/31	1,000	950	1,000	950
6L21/31	1,320	1,254	1,320	1,254
7L21/31	1,540	1,463	1,540	1,463
8L21/31	1,760	1,672	1,760	1,672
9L21/31	1,980	1,881	1,980	1,881



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Cyl. no	A (mm)	* B (mm)	* C (mm)	H (mm)	**Dry weight GenSet (t)
5 (900 rpm)	3,959	1,870	5,829	3,183	21.5
5 (1000 rpm)	3,959	1,870	5,829	3,183	21.5
6 (900 rpm)	4,314	2,000	6,314	3,183	23.7
6 (1000 rpm)	4,314	2,000	6,314	3,183	23.7
7 (900 rpm)	4,669	1,970	6,639	3,289	25.9
7 (1000 rpm)	4,669	1,970	6,639	3,289	25.9
8 (900 rpm)	5,024	2,250	7,274	3,289	28.5
8 (1000 rpm)	5,024	2,250	7,274	3,289	28.5
9 (900 rpm)	5,379	2,400	7,779	3,289	30.9
9 (1000 rpm)	5,379	2,400	7,779	3,289	30.9

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 galley)
* 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						
Air temperature	°C			45		
LT-water temperature inlet engine (from system)	°C			38		
Air pressure	bar			1		
Relative humidity	%			50		
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)				
Number of Cylinders	**-**	**5**	**6**	**7**	**8**	**9**
Engine output	kW	1,000	1,320	1,540	1,760	1,980
Speed	rpm			1,000		
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]						
Internal (inside engine)						
HT circuit (cylinder + charge air cooler HT stage)	m^3/h	61	61	61	61	61
LT circuit (lube oil + charge air cooler LT stage)	m^3/h	61	61	61	61	61
Lube oil	m^3/h	34	34	46	46	46
External (from engine to system)						
HT water flow (at 40°C inlet)	m^3/h	10.7	13.5	15.4	17.1	18.8
LT water flow (at 38°C inlet)	m^3/h	61	61	61	61	61
Air data						
Temperature of charge air at charge air cooler outlet	°C	49	52	54	55	56
Air flow rate	m^3/h [5]	6,548	8,644	10,084	11,525	12,965
	kg/kWh	7.17	7.17	7.17	7.17	7.17
Charge air pressure	bar		4.13			
Air required to dissipate heat radiation (engine) (t_2-t_1=10°C)	m^3/h	17,980	23,800	27,600	31,500	35,300
Exhaust gas data [6]						
Volume flow (temperature turbocharger outlet)	m^3/h [7]	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)	m^3/h	61	61	61	61	61
LT circuit cooling water (2.5 bar)	m^3/h	61	61	61	61	61
Lube oil (4.5 bar)	m^3/h	34	34	46	46	46
b) External pumps [8]						
Fuel oil feed pump (4 bar)	m^3/h	0.30	0.39	0.46	0.52	0.59
Fuel booster pump (8 bar)	m^3/h	0.89	1.18	1.37	1.57	1.76
Starting air data						
Air consumption per start, incl. air for jet assist (TDI)	Nm^3	1.0	1.2	1.4	1.6	1.8

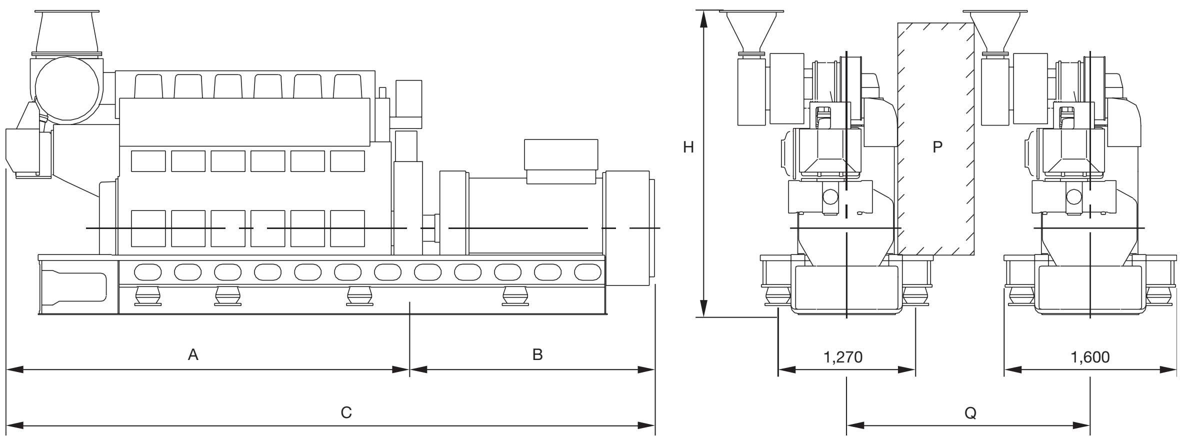
1) LT cooling water flow first through LT stage charge air cooler, then through lube oil cooler, water temperature outlet engine regulated by mechanical thermostat
2) HT cooling water flow irst through water jacket and cylinder head, then trough HT stage charge air cooler, water temperature outlet engine 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 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. 4.07.02a: List of capacities for L21/31, 900 rpm, IMO Tier II

L23/30H-TII GenSet Data

Bore: 225 mm Stroke: 300 mm

	Power layout					
	720 r/min Eng. kW	60 Hz Gen. kW	750 r/min Eng. kW	50 Hz Gen. kW	900 r/min Eng. kW	60 Hz Gen. kW
5L23/30H	650	620	675	640		
6L23/30H	780	740	810	770	960	910
7L23/30H	910	865	945	900	1,120	1,065
8L23/30H	1,040	990	1,080	1,025	1,280	1,215



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

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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 kWCyl., 750 rpm					
Reference Condition : Tropic					
Air temperature	°C	45			
LT-water temperature inlet engine (from system)	°C	36			
Air pressure	bar	1			
Relative humidity	%	50			
Temperature basis					
Setpoint HT cooling water engine outlet	°C	82°C (engine equipped with HT thermostatic valve)			
Setpoint Lube oil inlet engine	°C	60°C (SAE30), 66°C (SAE40)			
Number of Cylinders	-	**5**	**6**	**7**	**8**
Engine output	kW	650 / 675	780 / 810	910 / 945	1,040 / 1,080
Speed	rpm	720 / 750			
Heat to be dissipated [1]					
Cooling water (C.W.) Cylinder	kW	182	219	257	294
Charge air cooler; cooling water HT	kW	1 stage cooler: no HT-stage			
Charge air cooler; cooling water LT	kW	251	299	348	395
Lube oil (L.O.) cooler	kW	69	84	98	112
Heat radiation engine	kW	27	33	38	44
Air data					
Temperature of charge air at charge air cooler outlet, max.	°C	55	55	55	55
Air flow rate	m^3/h [4]	4,556	5,467	6,378	7,289
	kg/kWh	7.39	7.39	7.39	7.39
Charge air pressure	bar	3.08			
Air required to dissipate heat radiation (engine) (t_2-t_1=10°C)	m^3/h	8,749	10,693	12,313	14,257
Exhaust gas data [5]					
Volume flow (temperature turbocharger outlet)	m^3/h [6]	9,047	10,856	12,666	14,475
Mass flow	t/h	5.1	6.1	7.2	8.2
Temperature at turbine outlet	°C	342	342	342	342
Heat content (190°C)	kW	234	280	327	374
Permissible exhaust back pressure	mbar	< 30			
Pumps					
a) Engine driven pumps					
Fuel oil feed pump (5.5-7.5 bar)	m^3/h	1.0			
HT cooling water pump (1-2.5 bar)	m^3/h	36			
LT cooling water pump (1-2.5 bar)	m^3/h	55			
Lube oil (3-5 bar)	m^3/h	16	16	20	20
b) External pumps [7]					
Diesel oil pump (4 bar at fuel oil inlet A1)	m^3/h	0.48	0.57	0.67	0.76
Fuel oil supply pump [8] (4 bar discharge pressur)	m^3/h	0.23	0.28	0.32	0.37
Fuel oil circulating pump (8 bar at fuel oil inlet A1)	m^3/h	0.48	0.57	0.67	0.76
Cooling water pumps for for "Internal Cooling Water System 1"					
+ LT cooling water pump (1-2.5 bar)	m^3/h	35	42	48	55
Cooling water pumps for for "Internal Cooling Water System 2"					
HT cooling water pump (1-2.5 bar)	m^3/h	20	24	28	32
+ LT cooling water pump (1-2.5 bar)	m^3/h	35	42	48	55
Lube oil pump (3-5 bar)	m^3/h	14	15	16	17
Starting air system					
Air consuption per start	Nm^3	2.0	2.0	2.0	2.0
Nozzle cooling data					
Nozzle cooling data	m^3/h	0.66			

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

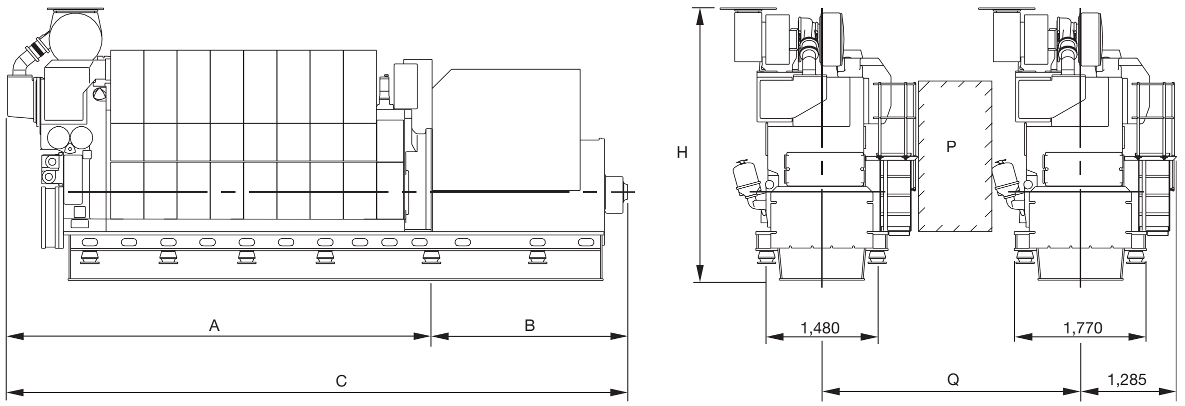
6-8L23/30H: 160 kW/Cyl., 900 rpm				
Reference Condition: Tropic				
Air temperature	°C		45	
LT-water temperature inlet engine (from system)	°C		36	
Air pressure	bar		1	
Relative humidity	%		50	
Temperature basis				
Setpoint HT cooling water engine outlet	°C		82°C (engine equipped with HT thermostatic valve)	
Setpoint Lube oil inlet engine	°C		60°C (SAE30), 66°C (SAE40)	
Number of Cylinders	-	**6**	**7**	**8**
Engine output	kW	960	1,120	1,280
Speed	rpm		900	
Heat to be dissipated 1)				
Cooling water (C.W.) Cylinder	kW	244	285	326
Charge air cooler; cooling water HT	kW		- 1 stage cooler: no HT-stage -	
Charge air cooler; cooling water LT	kW	369	428	487
Lube oil (L.O.) cooler	kW	117	137	158
Heat radiation engine	kW	32	37	43
Air data				
Temperature of charge air at charge air cooler outlet, max.	°C	55	55	55
Air flow rate	m^3/h 4)	6,725	7,845	8,966
	kg/kWh	7,67	7,67	7,67
Charge air pressure	bar		3.1	
Air required to dissipate heat radiation (engine) (t_2-t_1=10°C)	m^3/h	10,369	11,989	13,933
Exhaust gas data 5)				
Volume flow (temperature turbocharger outlet)	m^3/h 6)	13,970	16,299	18,627
Mass flow	t/h	7.6	8.8	10.1
Temperature at turbine outlet	°C	371	371	371
Heat content (190°C)	kW	410	479	547
Permissible exhaust back pressure	mbar		< 30	
Pumps				
a) Engine driven pumps				
Fuel oil feed pump (5.5-7.5 bar)	m^3/h		1.3	
HT cooling water pump (1-2.5 bar)	m^3/h		45	
LT cooling water pump (1-2.5 bar)	m^3/h		69	
Lube oil (3-5 bar)	m^3/h	20	20	20
b) External pumps 7)				
Diesel oil pump (4 bar at fuel oil inlet A1)	m^3/h	0.68	0.79	0.90
Fuel oil supply pump (4 bar discharge pressur)	m^3/h	0.33	0.38	0.44
Fuel oil circulating pump (8 bar at fuel oil inlet A1)	m^3/h	0.68	0.79	0.90
Cooling water pumps for for "Internal Cooling Water System 1"				
+ LT cooling water pump (1-2.5 bar)	m^3/h	52	61	70
Cooling water pumps for for "Internal Cooling Water System 2"				
HT cooling water pump (1-2.5 bar)	m^3/h	30	35	40
+ LT cooling water pump (1-2.5 bar)	m^3/h	52	61	70
Lube oil pump (3-5 bar)	m^3/h	17	18	19
Starting air system				
Air consuption per start	Nm^3	2.0	2.0	2.0
Nozzle cooling data				
Nozzle cooling data	m^3/h		0.66	

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
	Power layout					
	720 r/min Eng. kW	60 Hz Gen. kW	750 r/min Eng. kW	50 Hz Gen. kW	720/750 r/min (MGO/MDO) Eng. kW	60/50 Hz (MGO/MDO) Gen. kW
5L27/38	1,500	1,440	1,600	1,536	-	-
6L27/38	1,980	1,900	1,980	1,900	2,100	2,016
7L27/38	2,310	2,218	2,310	2,218	2,450	2,352
8L27/38	2,640	2,534	2,640	2,534	2,800	2,688
9L27/38	2,970	2,851	2,970	2,851	3,150	3,024



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

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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

6-9L27/38: 350 kW/cyl., 720 rpm, MGO

Reference Condition: Tropic					
Air temperature	°C	45			
LT-water temperature inlet engine (from system)	°C	38			
Air pressure	bar	1			
Relative humidity	%	50			
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)			
Number of Cylinders	-	6	7	8	9
Engine output	kW	2,100	2,450	2,800	3,150
Speed	rpm	720			
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)					
Internal (inside engine)					
HT circuit (cylinder + charge air cooler HT stage)	m^3/h	58	58	58	58
LT circuit (lube oil + charge air cooler LT stage)	m^3/h	58	58	58	58
Lube oil	m^3/h	64	92	92	92
External (from engine to system)					
HT water flow (at 40°C inlet)	m^3/h	21.5	24.8	28.1	31.4
LT water flow (at 38°C inlet)	m^3/h	58	58	58	58
Air data					
Temperature of charge air at charge air cooler outlet	°C	50	53	55	56
Air flow rate	m^3/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) (t_2-t_1= 10°C)	m^3/h	22,682	26,247	30,135	33,699
Exhaust gas data 6)					
Volume flow (temperature turbocharger outlet)	m^3/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					
a) Engine driven pumps					
HT circuit cooling water (2.5 bar)	m^3/h	58	58	58	58
LT circuit cooling water (2.5 bar)	m^3/h	58	58	58	58
Lube oil (4.5 bar)	m^3/h	64	92	92	92
b) External pumps 8)					
Diesel oil pump (5 bar at fuel oil inlet A1)	m^3/h	1.48	1.73	1.98	2.23
Fuel oil supply pump (4 bar discharge pressure)	m^3/h	0.71	0.83	0.95	1.07
Fuel oil circulating pump (8 bar at fuel oil inlet A1)	m^3/h	1.48	1.73	1.98	2.23
Starting air data					
Air consumption per start, incl. air for jet assist (IR/TDI)	Nm^3	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

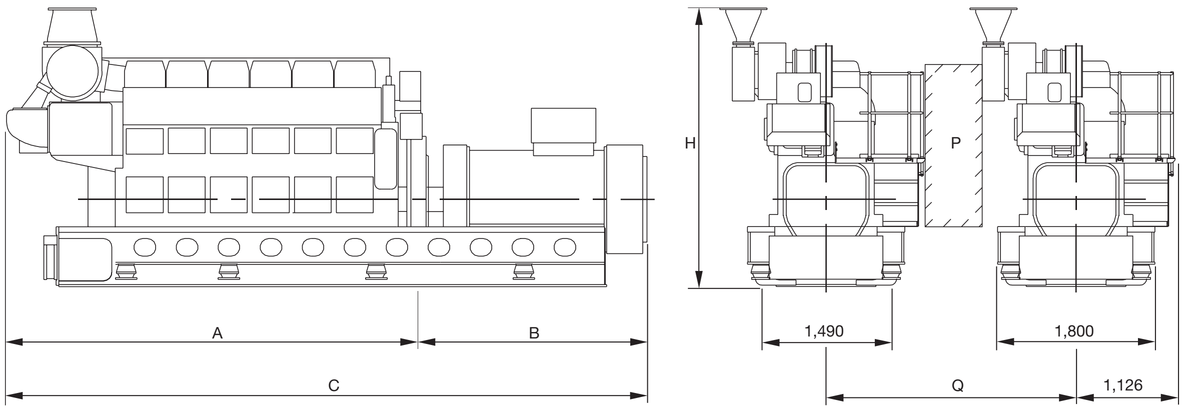
Reference Condition : Tropic					
Air temperature	°C		45		
LT-water temperature inlet engine (from system)	°C		38		
Air pressure	bar		1		
Relative humidity	%		50		
Temperature basis					
Setpoint HT cooling water engine outlet [1]	°C	79 nominal (Range of mechanical thermostatic element 77 to 85)			
Setpoint 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)			
Number of Cylinders	**-**	**6**	**7**	**8**	**9**
Engine output	kW	2,100	2,450	2,800	3,150
Speed	rpm		750		
Heat to be dissipated [3]					
Cooling water (C.W.) Cylinder	kW	315	368	421	473
Charge air cooler; cooling water HT	kW	679	797	916	1037
Charge air cooler; cooling water LT	kW	181	208	234	258
Lube oil (L.O.) cooler	kW	282	329	376	423
Heat radiation engine	kW	70	81	93	104
Flow rates [4]					
Internal (inside engine)					
HT circuit (cylinder + charge air cooler HT stage)	m³/h	69	69	69	69
LT circuit (lube oil + charge air cooler LT stage)	m³/h	69	69	69	69
Lube oil	m³/h	66	96	96	96
External (from engine to system)					
HT water flow (at 40°C inlet)	m³/h	21.9	25.4	28.9	32.2
LT water flow (at 38°C inlet)	m³/h	69	69	69	69
Air data					
Temperature of charge air at charge air cooler outlet	°C	55	55	55	55
Air flow rate	m³/h [5])	13,003	15,170	17,338	19,505
	kg/kWh	6.78	6.78	6.78	6.78
Charge air pressure	bar		4.09		
Air required to dissipate heat radiation (engine) (t_2-t_1=10°C)	m³/h	22,682	26,247	30,135	33,699
Exhaust gas data [6]					
Volume flow (temperature turbocharger outlet)	m³/h [7])	27,567	32,161	36,756	41,350
Mass flow	t/h	14.7	17.1	19.5	22.0
Temperature at turbine outlet	°C	382	382	382	382
Heat content (190°C)	kW	844	985	1,126	1,266
Permissible exhaust back pressure	mbar		< 30		
Pumps					
a) Engine driven pumps					
HT circuit cooling water (2.5 bar)	m³/h	69	69	69	69
LT circuit cooling water (2.5 bar)	m³/h	69	69	69	69
Lube oil (4.5 bar)	m³/h	66	96	96	96
b) External pumps [8]					
Diesel oil pump (5 bar at fuel oil inlet A1)	m³/h	1.48	1.73	1.98	2.23
Fuel oil supply pump (4 bar discharge pressure)	m³/h	0.71	0.83	0.95	1.07
Fuel oil circulating pump (8 bar at fuel oil inlet A1)	m³/h	1.48	1.73	1.98	2.23
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. 4.09.02b: List of capacities for L27/38, 750 rpm, IMO Tier II

L28/32H-TII GenSet Data

Bore: 280 mm				Stroke: 320 mm
	Power layout			
	720 r/min Eng. kW	60 Hz Gen. kW	750 r/min Eng. kW	50 Hz Gen. kW
5L28/32H	1,050	1,000	1,100	1,045
6L28/32H	1,260	1,200	1,320	1,255
7L28/32H	1,470	1,400	1,540	1,465
8L28/32H	1,680	1,600	1,760	1,670
9L28/32H	1,890	1,800	1,980	1,880



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

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.

178 33 92-1.3

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

L28/32H-TII GenSet Data

5L-9L: 220 kW/Cyl. at 750 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	1,100	1,320	1,540	1,760	1,980
Speed	rpm	750				
Heat to be dissipated [1]						
Cooling water (C.W.) Cylinder	kW	245	294	343	392	442
Charge air cooler; cooling water HT	kW			0 (Single stage charge air cooler)		
Charge air cooler; cooling water LT	kW	387	435	545	587	648
Lube oil (L.O.) cooler	kW	201	241	281	321	361
Heat radiation engine	kW	27	33	38	44	49
Flow rates [2]						
Internal (inside engine)						
HT cooling water cylinder	m^3/h	37	45	50	55	60
LT cooling water lube oil cooler *	m^3/h	7.8	9.4	11	12.7	14.4
LT cooling water lube oil cooler **	m^3/h	28	28	40	40	40
LT cooling water charge air cooler	m^3/h	37	45	55	65	75
Air data						
Temperature of charge air at charge air cooler outlet	°C	52	54	52	52	55
Air flow rate	m^3/h [3]	7,826	9,391	10,956	12,521	14,087
	kg/kWh	7.79	7.79	7.79	7.79	7.79
Charge air pressure	bar			3.07		
Air required to dissipate heat radiation (engine) (t_2-t_1=10°C)	m^3/h	8,749	10,693	12,313	14,257	15,878
Exhaust gas data [4]						
Volume flow (temperature turbocharger outlet)	m^3/h [5]	15,520	18,624	21,728	24,832	27,936
Mass flow	t/h	8.8	10.5	12.3	14.1	15.8
Temperature at turbine outlet	°C	342	342	342	342	342
Heat content (190°C)	kW	401	481	561	641	721
Permissible exhaust back pressure	mbar			< 30		
Pumps						
a) Engine driven pumps						
Fuel oil feed pump (5,5-7,5 bar)	m^3/h	1.4	1.4	1.4	1.4	1.4
HT circuit cooling water (1,0-2,5 bar)	m^3/h	45	45	60	60	60
LT circuit cooling water (1,0-2,5 bar)	m^3/h	45	60	75	75	75
Lube oil (3,0-5,0 bar)	m^3/h	24	24	34	34	34
b) External pumps [6]						
Diesel oil pump (4 bar at fuel oil inlet A1)	m^3/h	0.78	0.93	1.09	1.24	1.40
Fuel oil supply pump (4 bar discharge pressure)	m^3/h	0.37	0.45	0.52	0.60	0.67
Fuel oil circulating pump (8 bar at fuel oil inlet A1)	m^3/h	0.78	0.93	1.09	1.24	1.40
HT circuit cooling water (1,0-2,5 bar)	m^3/h	37	45	50	55	60
LT circuit cooling water (1,0-2,5 bar) *	m^3/h	45	54	65	77	89
LT circuit cooling water (1,0-2,5 bar) **	m^3/h	65	73	95	105	115
Lube oil (3,0-5,0 bar)	m^3/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. 4.10.02a: List of capacities for L28/32H, 750 rpm, IMO Tier II

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 [1]						
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 [2]						
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 [3]	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			2.97		
Air required to dissipate heat radiation (engine) (t_2-t_1=10°C)	m³/h	8,425	10,045	11,665	13,609	15,230
Exhaust gas data [4]						
Volume flow (temperature turbocharger outlet)	m³/h [5]	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						
a) 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
b) External pumps [6]						
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

5

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 (L_1).

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.

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.

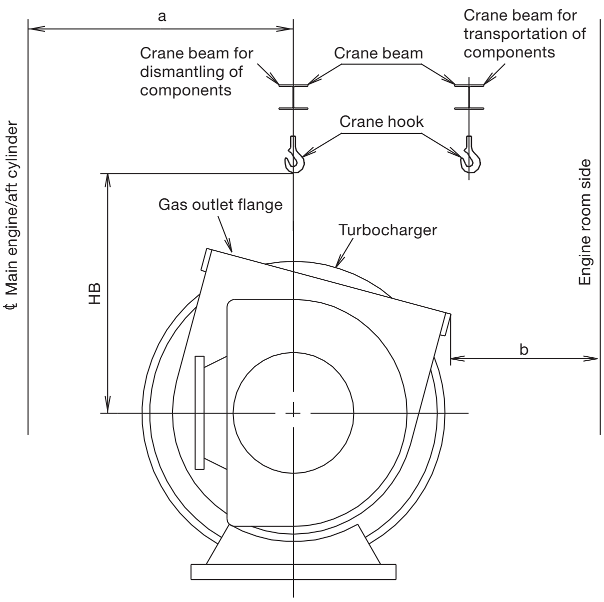
Two trolleys are to be available at the compressor end and one trolley is needed at the gas inlet end.

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 figures 'a' are stated on the 'Engine and Gallery Outline' drawing, Section 5.06.

Fig. 5.03.01a: Required height and distance

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.

MAN B&W						
	Units	**TCA44**	**TCA55**	**TCA55**	**TCA66**	**TCA77**
W	kg	1,000	1,000	1,000	1,200	2,000
HB	mm	1,200	1,400	1,400	1,600	1,800
b	m	500	600	600	700	800

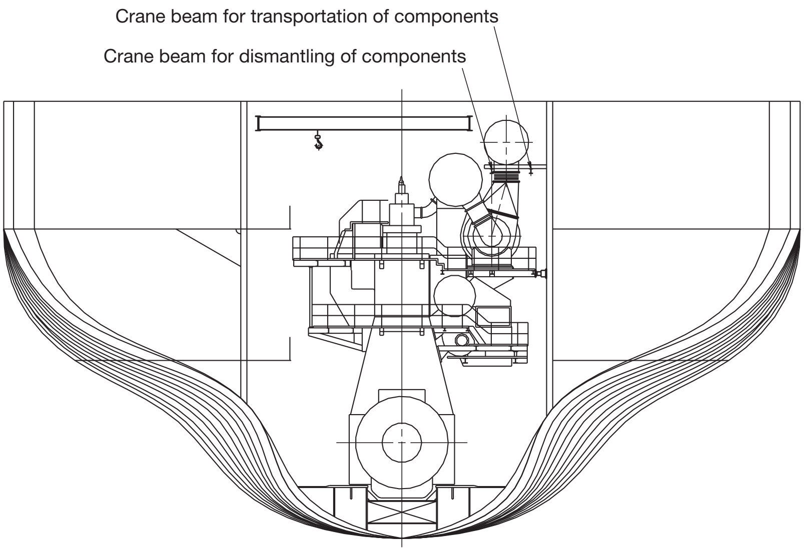
ABB						
	Units	**A170**	**A175**	**A180**	**A265**	**A270**
W	kg			*)		
HB	mm	1,450	1,725	1,975	1,400	1,650
b	m	500	500	600	500	500

Mitsubishi						
	Units	**MET42**	**MET53**	**MET60**	**MET66**	**MET71**
W	kg	1,000	1,000	1,000	1,500	1,800
HB	mm	1,500	1,500	1,600	1,800	1,800
b	m	600	700	700	800	800

*) Available on request. Data on Mitsubishi MET48 is available on request.

Fig. 5.03.01b: Required height and distance and weight

Crane beam for turbochargers



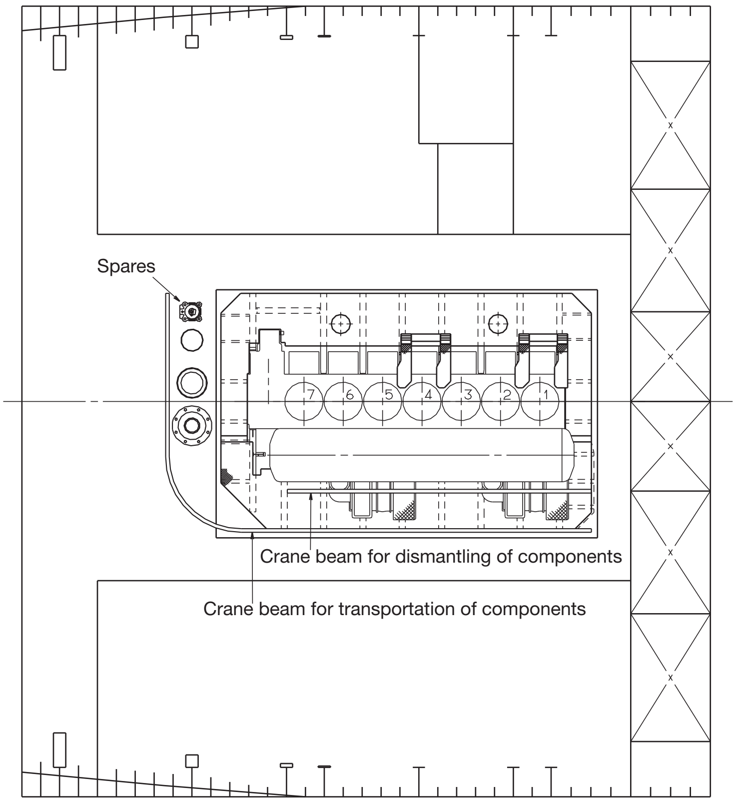


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Fig. 5.03.02: Crane beam for turbocharger

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.

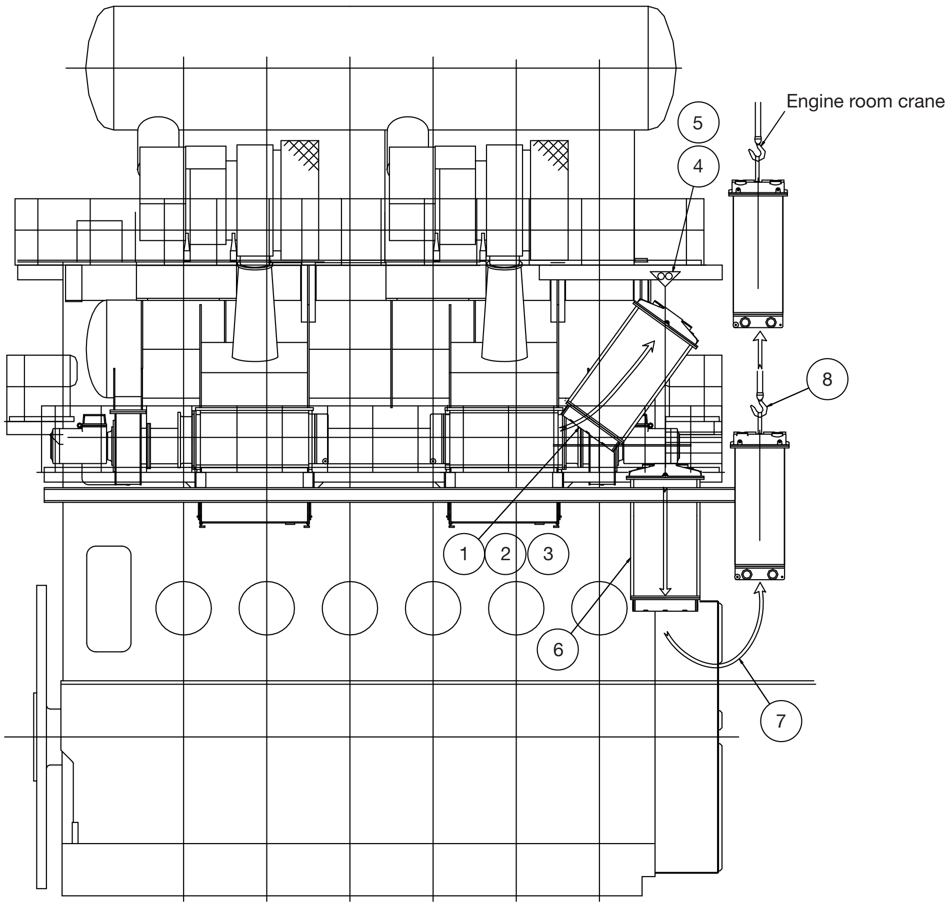

Fig.: 5.03.03: Crane beam for overhaul of air cooler, turbochargers located on exhaust side of the engine

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Crane beam for overhaul of air cooler

Overhaul/exchange of scavenge air cooler.

The text and figures are for guidance only.

Valid for all engines with aft mounted Turbocharger.

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. By using the engine room crane the air cooler insert can be lifted out of the engine room.

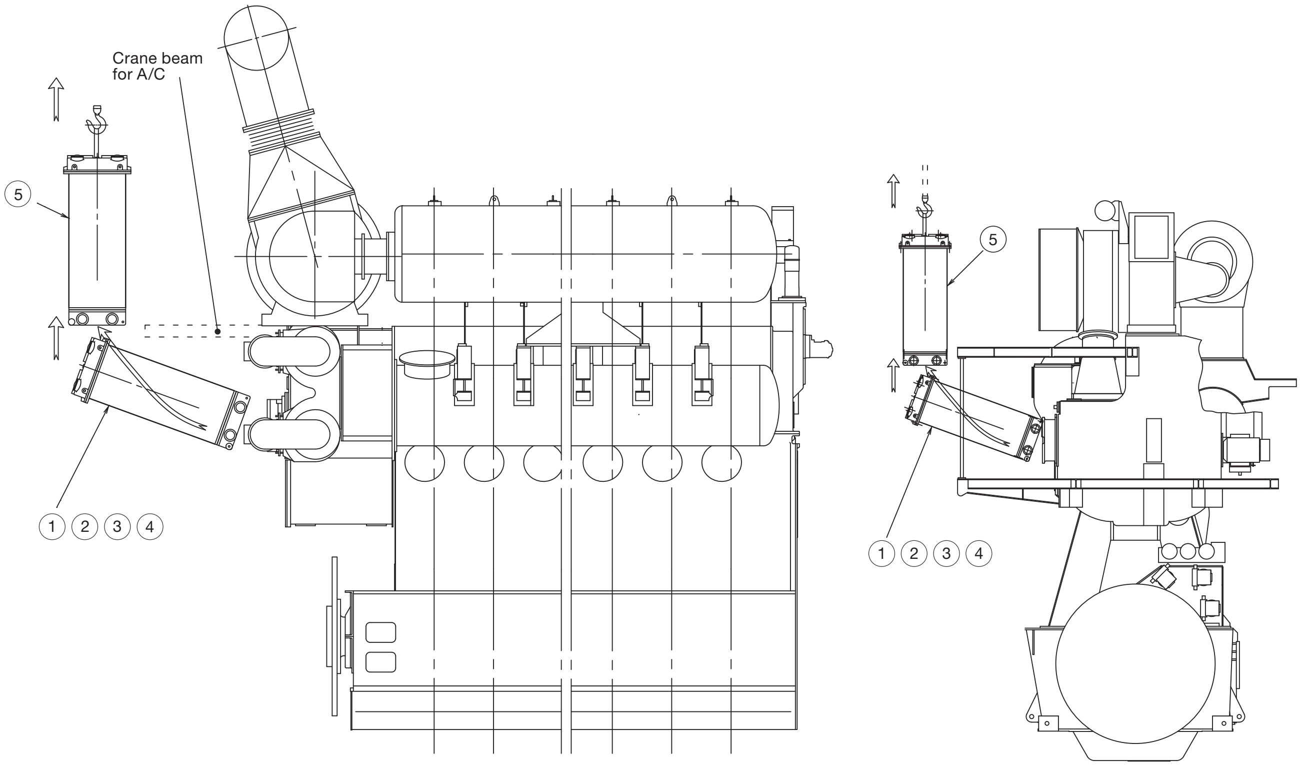

Fig.: 5.03.04: Crane beam for overhaul of air cooler, turbocharger located on aft end of the engine

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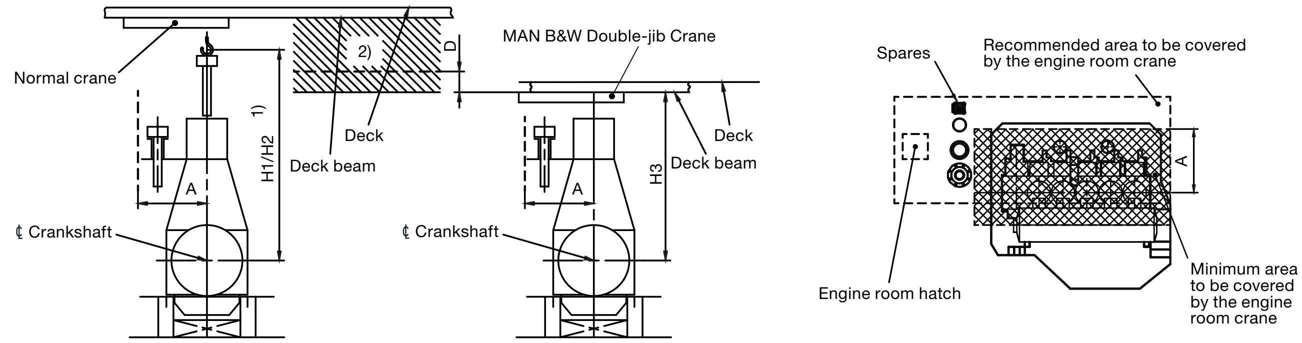
Engine room crane

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 can 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.



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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 H).

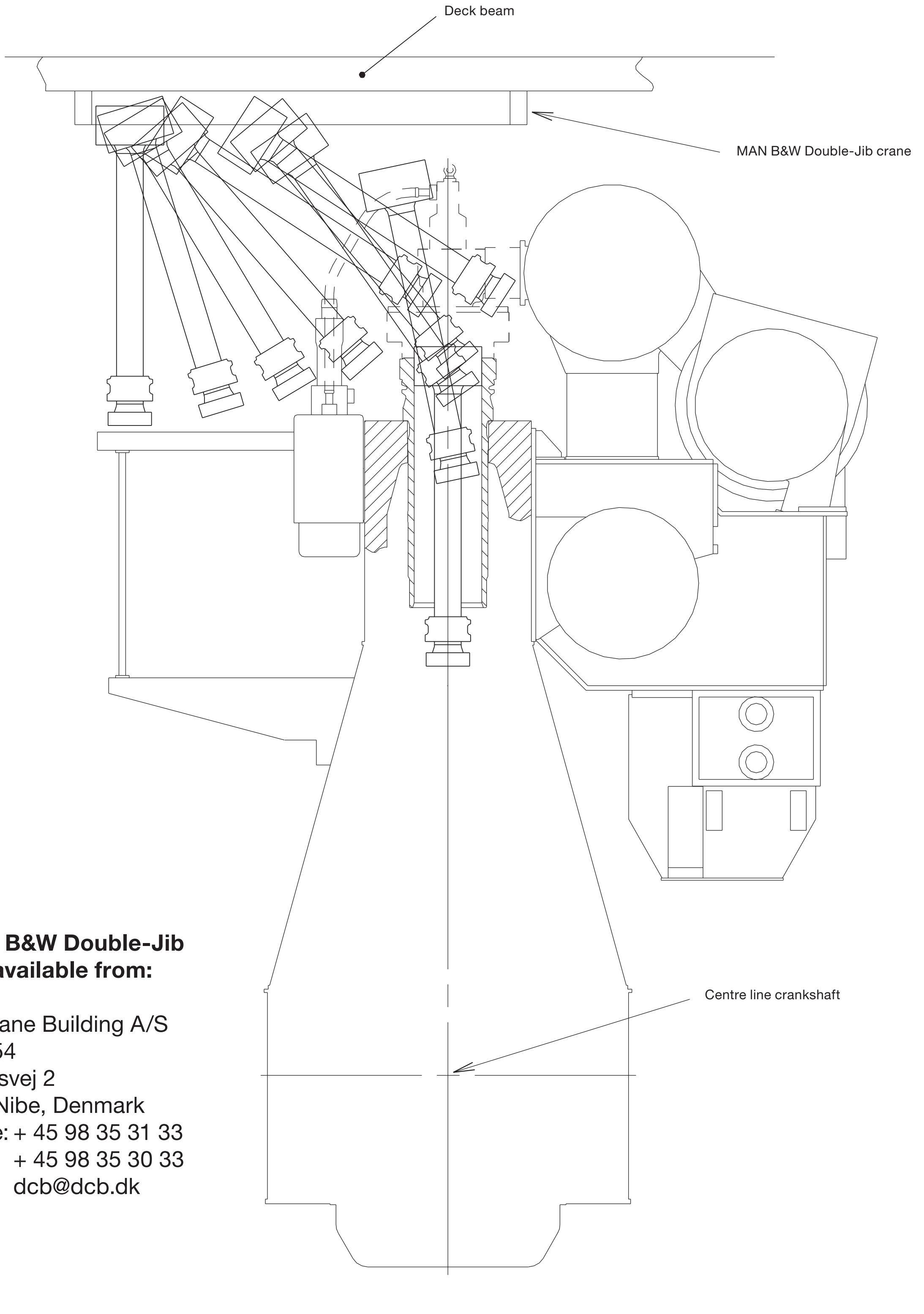
2) The hatched area shows the height where an MAN B&W Double-Jib Crane has to be used.

Mass in kg including lifting tools			**Crane capacity in tons selected in accordance with DIN and JIS standard capacities**		**Crane operating width in mm**	**Normal Crane Height to crane hook in mm for:**		**MAN B&W Double-Jib Crane**	
						Normal lifting procedure	**Reduced height lifting procedure involving tilting of main components (option)**	**Building-in height in mm**	
Cylinder cover complete with exhaust valve	Cylinder liner with cooling jacket	Piston with rod and stuffing box	Normal crane	MAN B&W Double-Jib Crane	A Minimum distance	H1 Minimum height from centre line crankshaft to centre line crane hook	H2 Minimum height from centre line crankshaft to centre line crane hook	H3 Minimum height from centre line crankshaft to underside deck beam	D Additional height required for removal of exhaust valve complete without removing any exhaust stud
Available on request						9,775	9,125	8,900	Available on request

Fig. 5.04.01: Engine room crane

078 74 58-9.2.0

Overhaul with MAN B&W Double-Jib Crane



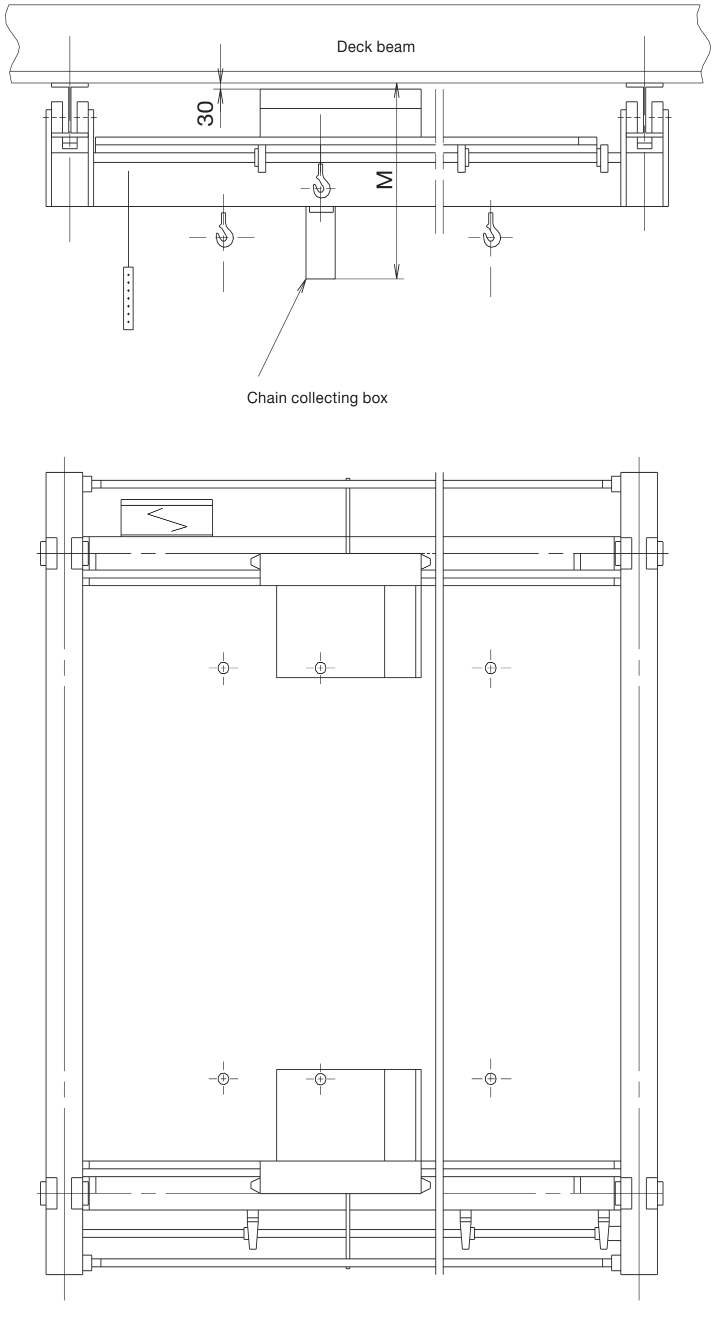
The MAN B&W Double-Jib crane is available from:

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

178 24 86-3.2

Fig. 5.04.02: Overhaul with Double-Jib crane

MAN B&W Double-Jib Crane



178 37 30-1.1

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

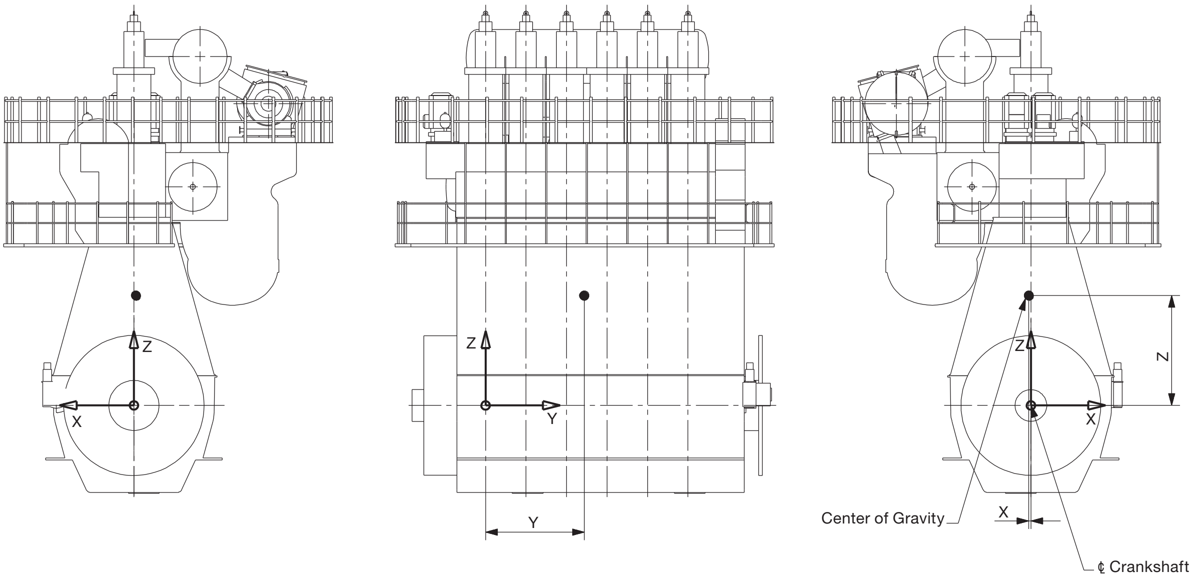
Section 5.06 show the gallery outline for engines rated at nominal MCR (L1).

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



178 68 08-6.0

For engines with two turbochargers*					
No. of cylinders	**5**	**6**	**7**	**8**	**9**
Distance X mm	5	10	15	25	Available on re-quest
Distance Y mm	1,925	2,425	2,875	3,325	
Distance Z mm	2,275	2,325	2,350	2,375	

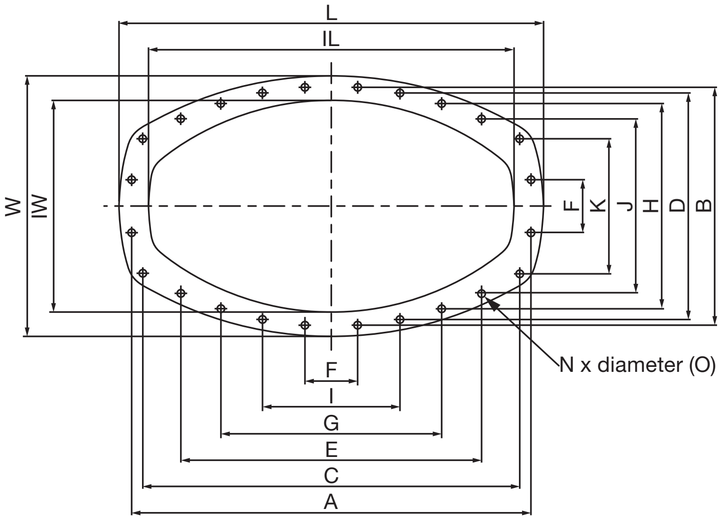
All values stated are approximate
* Data for engines with a different number of turbochargers is available on request.
** Dry mass tonnes

525 79 29-3.0.0

Fig. 5.07: Centre of gravity, turbocharger located on exhaust side of engine

Counterflanges, Connection D

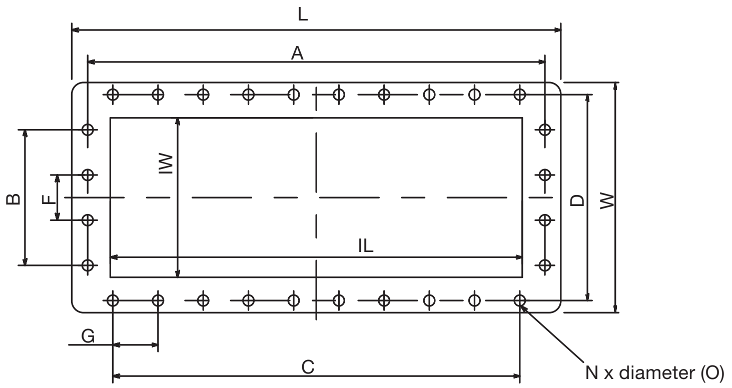
MAN Type TCA33



178 63 96-2.0

Type TCA series																
TC	L	W	IL	IW	A	B	C	D	E	F	G	H	I	J	K	N	O
TCA33	802	492	690	400	755	448	712	427	568	100	417	387	260	329	254	24	ø13,5

MAN Type TCA44-99

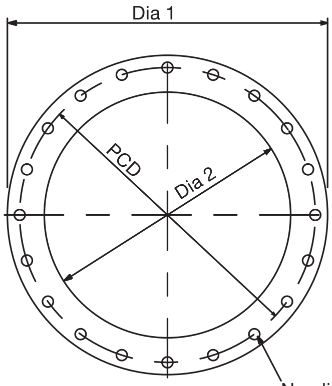


501 29 91-0.13.0a

Type TCA series – Rectangular type													
TC	L	W	IL	IW	A	B	C	D	E	F	G	N	O
TCA44	1,054	444	949	340	1,001	312	826	408	1,012	104	118	24	ø13.5
TCA55	1,206	516	1,080	390	1,143	360	1,000	472	1,155	120	125	26	ø17.5
TCA66	1,433	613	1,283	463	1,358	420	1,200	560	1,373	140	150	26	ø17.5
TCA77	1,694	720	1,524	550	1,612	480	1,440	664	1,628	160	160	28	ø22
TCA88	2,012	855	1,810	653	1,914	570	1,710	788	1,934	190	190	28	ø22
TCA99	2,207	938	1,985	717	2,100	624	1,872	866	2,120	208	208	28	ø22

Counterflanges, Connection D

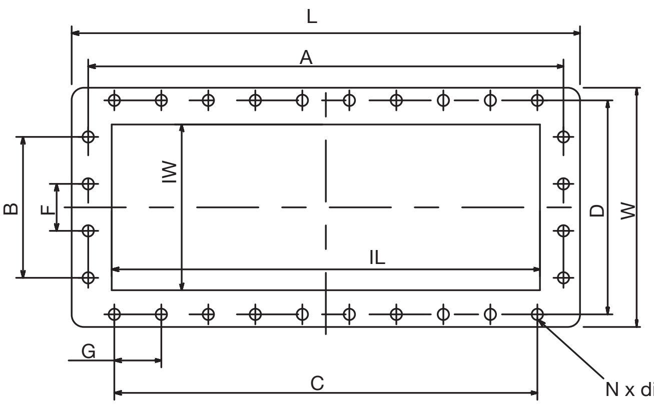
MAN Type TCR



Type TCR series – Round type					
TC	**Dia 1**	**Dia 2**	**PCD**	**N**	**O**
TCR18	425	310	395	12	ø22
TCR20	540	373	495	15	ø22
TCR22	595	434	550	16	ø22

501 29 91-0.13.0a

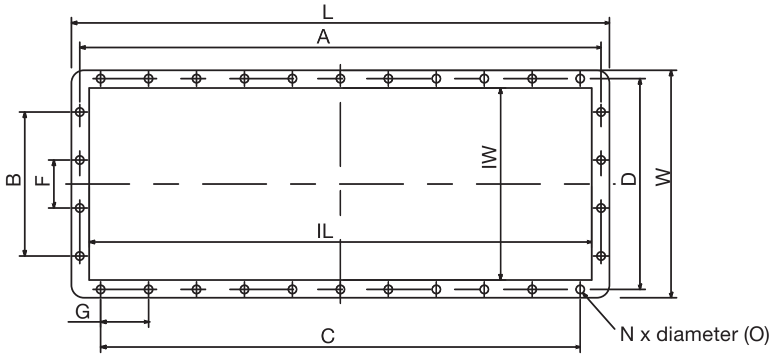
ABB Type A100/A200-L



Type A100/A200-L series – Rectangular type												
TC	**L**	**W**	**IL**	**IW**	**A**	**B**	**C**	**D**	**F**	**G**	**N**	**O**
A165/A265-L	1,114	562	950	404	1,050	430	900	511	86	100	32	ø22
A170/A270-L	1,280	625	1,095	466	1,210	450	1,080	568	90	120	32	ø22
A175/A275-L	1,723	770	1,319	562	1,446	510	1,260	710	170	140	28	ø30
A180/A280-L	1,743	856	1,491	634	1,650	630	1,485	786	150	135	36	ø30
A185/A285-L	1,955	958	1,663	707	1,860	725	1,595	886	145	145	36	ø30
A190/A290-L	2,100	1,050	1,834	781	2,000	750	1,760	970	150	160	36	ø30

501 29 91-0.13.0b

MHI Type MET



Type MET – Rectangular type												
TC	**L**	**W**	**IL**	**IW**	**A**	**B**	**C**	**D**	**F**	**G**	**N**	**O**
Series MB												
MET42	1,094	381	1,004	291	1,061	261	950	351	87	95	30	ø15
MET53	1,389	485	1,273	369	1,340	330	1,200	440	110	120	30	ø20
MET60	1,528	522	1,418	410	1,488	330	1,320	482	110	110	34	ø20
MET66	1,713	585	1,587	459	1,663	372	1,536	535	124	128	34	ø20
MET71	1,837	617	1,717	497	1,792	480	1,584	572	120	132	36	ø20
MET83	2,163	731	2,009	581	2,103	480	1,920	671	160	160	34	ø24
MET90	2,378	801	2,218	641	2,312	525	2,100	741	175	175	34	ø24
Series MA												
MET33	700	310	605	222	670	0	550	280	130	110	18	ø15
MET42	883	365	793	275	850	240	630	335	80	90	24	ø15
MET53	1,122	465	1,006	349	1,073	300	945	420	100	105	28	ø20
MET60	1,230	500	1,120	388	1,190	315	1,050	460	105	105	30	ø20
MET66	1,380	560	1,254	434	1,330	345	1,200	510	115	120	30	ø20
MET71	1,520	600	1,400	480	1,475	345	1,265	555	115	115	34	ø20
MET83	1,740	700	1,586	550	1,680	450	1,500	640	150	150	30	ø24
MET90	1,910	755	1,750	595	1,850	480	1,650	695	160	165	30	ø24

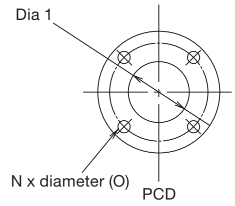
501 29 91-0.13.0d

Fig. 5.10.02: Turbocharger, exhaust outlet

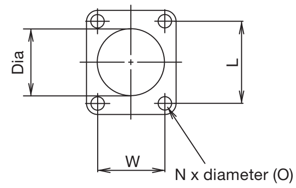
Counterflanges, Connection E

MAN Type TCA

TC	Dia/ISO	Dia/JIS	PCD	N	O	Thickness of flanges
TCA44	61	77	90	4	14	14



TC	Dia/ISO	Dia/JIS	L	W	N	O	Thickness of flanges
TCA55	61	77	86	76	4	14	16
TCA66	90	90	110	90	4	18	16



TC	Dia/ISO	Dia/JIS	L	W	N	O	Thickness of flanges
TCA77	115	103	126	72	4	18	18
TCA88	141	141	150	86	4	18	18
TCA99	141	141	164	94	4	22	24

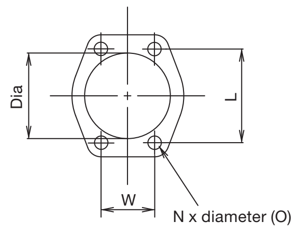
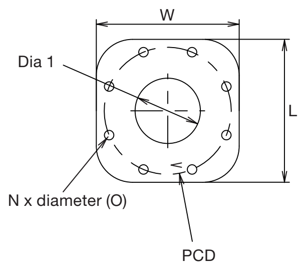


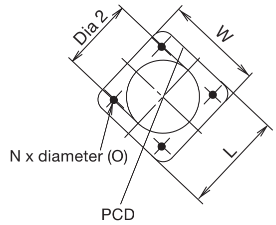
ABB Type A100/A200-L

TC	Dia 1	PCD	L + W	N	O	Thickness of flanges
A165/A265-L	77	100	106	8	8,5	18
A170/A270-L	43	100	115	8	11	18
A175/A275-L	77	126	140	8	11	18
A180/A280-L	90	142	158	8	13	18
A185/A285-L	115	157	178	8	13	18
A190/A290-L	115	175	197	8	13	18

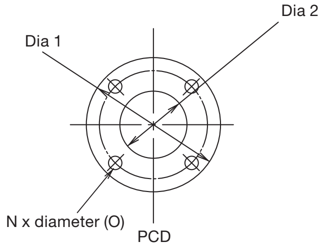


MHI Type MET MB
Air vent

TC	L+W	Dia 2	PCD	N	O	Thickness of flanges (A)
MET42MB	105	61	105	4	14	14
MET53MB	125	77	130	4	14	14
MET60MB	140	90	145	4	18	14
MET66MB	140	90	145	4	18	14

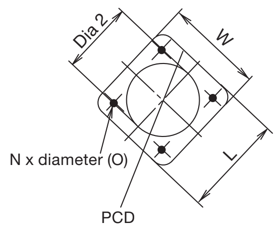


TC	Dia 1	Dia 2	PCD	N	O	Thickness of flanges (A)
MET71MB	180	90	145	4	18	14
MET83MB	200	115	165	4	18	16
MET90MB	200	115	165	4	18	16



MHI Type MET MB
Cooling air

TC	L+W	Dia 2	PCD	N	O	Thickness of flanges (A)
MET53MB	95	49	95	4	14	12
MET90MB	125	77	130	4	14	14



TC	Dia 1	Dia 2	PCD	N	O	Thickness of flanges (A)
MET42MB	95	43	75	4	12	10
MET60MB	120	49	95	4	14	12
MET66MB	120	49	95	4	14	12
MET71MB	120	49	95	4	14	12
MET83MB	120	49	95	4	14	12

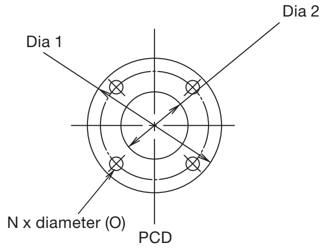
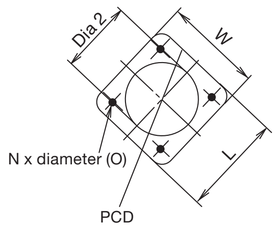


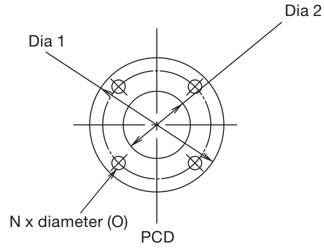
Fig. 5.10.03: Venting of lubricating oil discharge pipe for turbochargers

MHI Type MET MB

TC	L+W	Dia 2	PCD	N	O	Thickness of flanges (A)
MET42MB	105	61	105	4	14	14
MET53MB	125	77	130	4	14	14
MET60MB	140	90	145	4	18	14
MET66MB	140	90	145	4	18	14
MET71MB	140	90	145	4	18	14
MET90MB	155	115	155	4	18	14

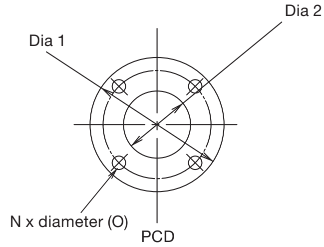


TC	Dia 1	Dia 2	PCD	N	O	Thickness of flanges (A)
MET83MB	180	90	145	4	18	14

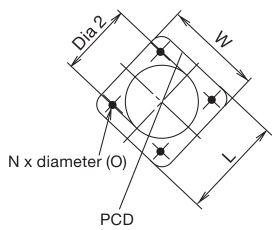


Connection EB

TC	Dia 1	Dia 2	PCD	N	O	Thickness of flanges (A)
MET42MB	95	43	75	4	12	10
MET60MB	120	49	95	4	14	12
MET66MB	120	49	95	4	14	12
MET71MB	120	49	95	4	14	12
MET83MB	120	49	95	4	14	12



TC	L+W	Dia 2	PCD	N	O	Thickness of flanges (A)
MET53MB	95	49	95	4	14	12
MET90MB	125	77	130	4	14	14



501 29 91-0.13.0c

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

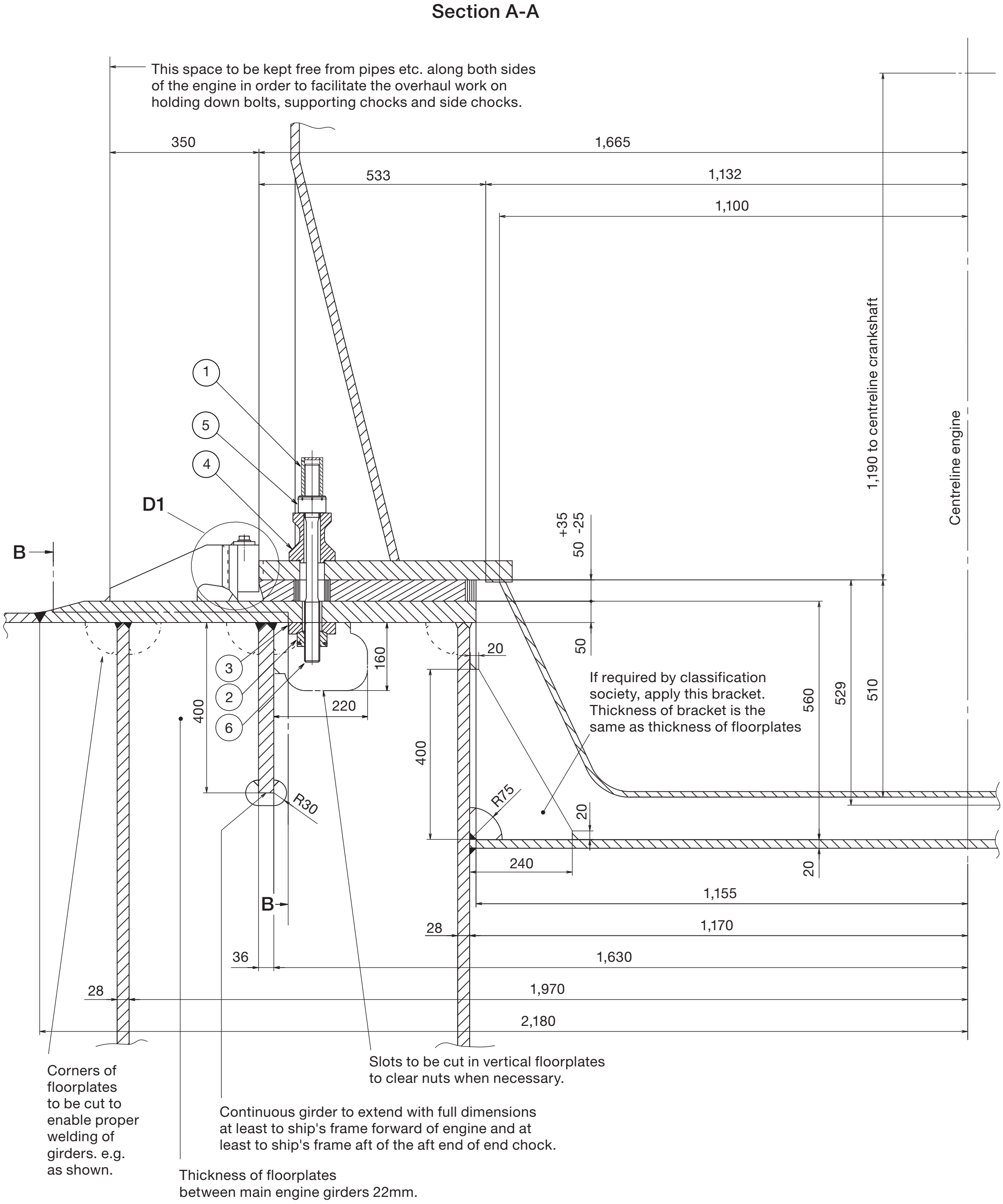
The dimensions of the seating stated in Figs. 5.12.01 and 5.12.02 are for guidance only.

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

Engine Seating Profile



Holding down bolts, option: 4 82 602 include:

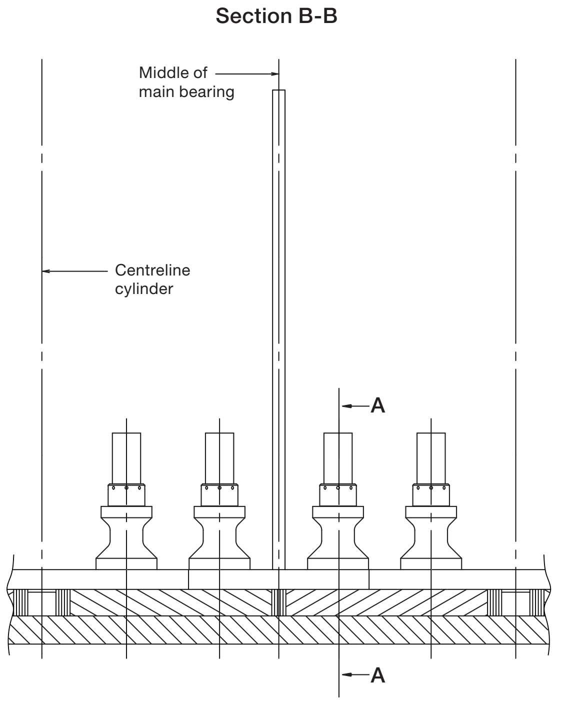
1. Protecting cap
2. Spherical nut
3. Spherical washer
4. Distance pipe
5. Round nut
6. Holding down bolt

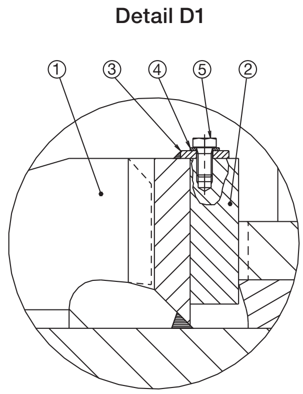
Fig. 5.12.02a : Profile of engine seating

079 40 88-6.2.0a

Side chock brackets, option: 4 82 622 includes:
1. Side chock brackets

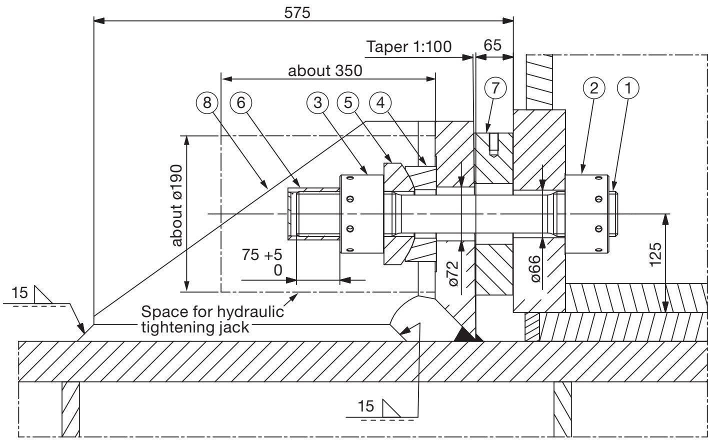
Side chock liners, option: 4 82 620 includes:
2. Liner for side chock
3. Lock plate
4. Washer
5. Hexagon socket set screw





079 40 88-6.2.0b

Fig. 5.12.02b: Profile of engine seating, end chocks, option: 4 82 620



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

Fig. 5.12.02c: Profile of engine seating, end chocks, option: 4 82 610

079 29 22-7.2.0

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.

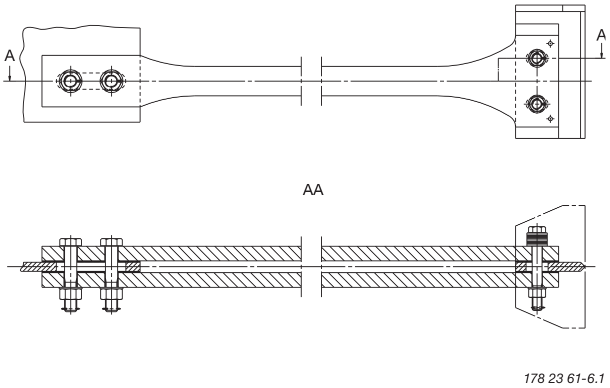


Fig. 5.13.01: Mechanical top bracing stiffener. Option: 4 83 112

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.

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.

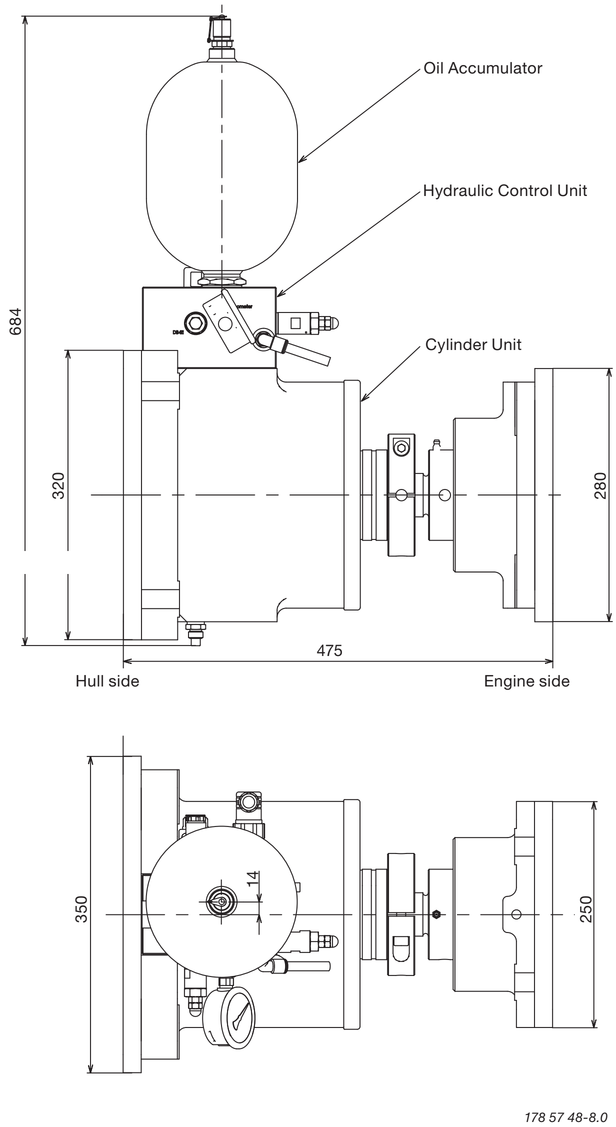
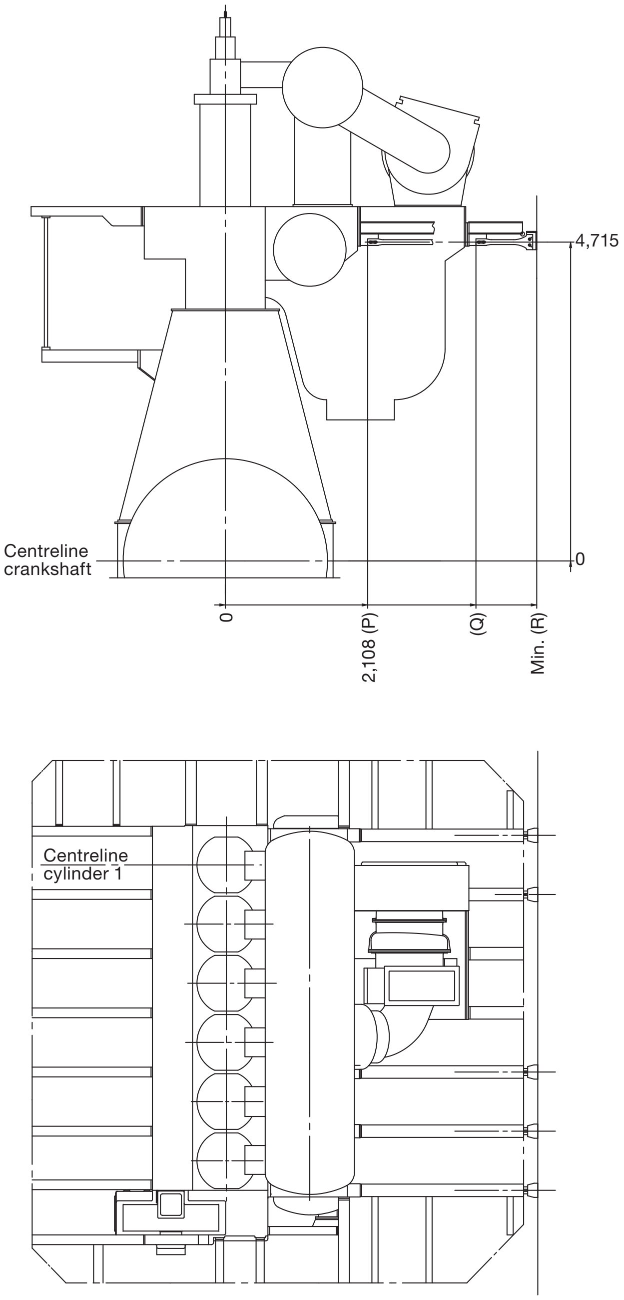
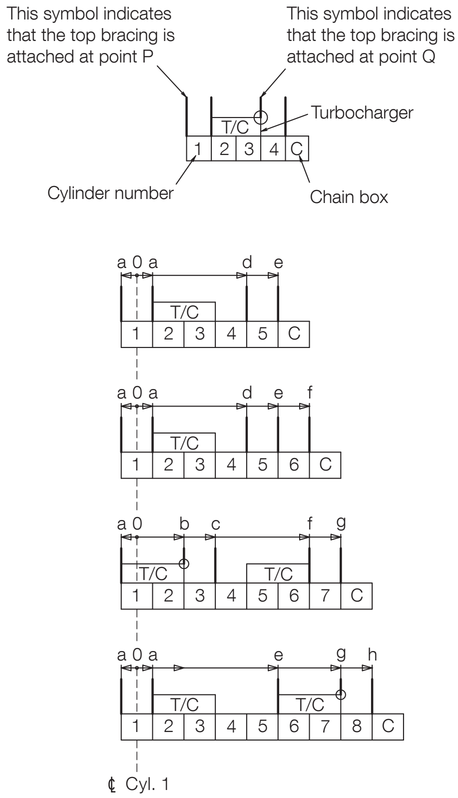


Fig. 5.13.02: Outline of a hydraulic top bracing unit. The unit is installed with the oil accumulator pointing either up or down. Option: 4 83 123

Mechanical Top Bracing





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Horizontal distance between top bracing fix point and ℄ cyl. 1

a	=	4 37	f	=	4,812
b	=	2,187	k	=	9,187
d	=	3,062	l	=	10,062
e	=	3,937	m	=	10,937

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.

Turbocharger	Q	R
TCA66	3,710	4,610

For other turbochargers applicable, the measures Q and R are available on request.

Fig. 5.14: Mechanical top bracing arrangement

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):

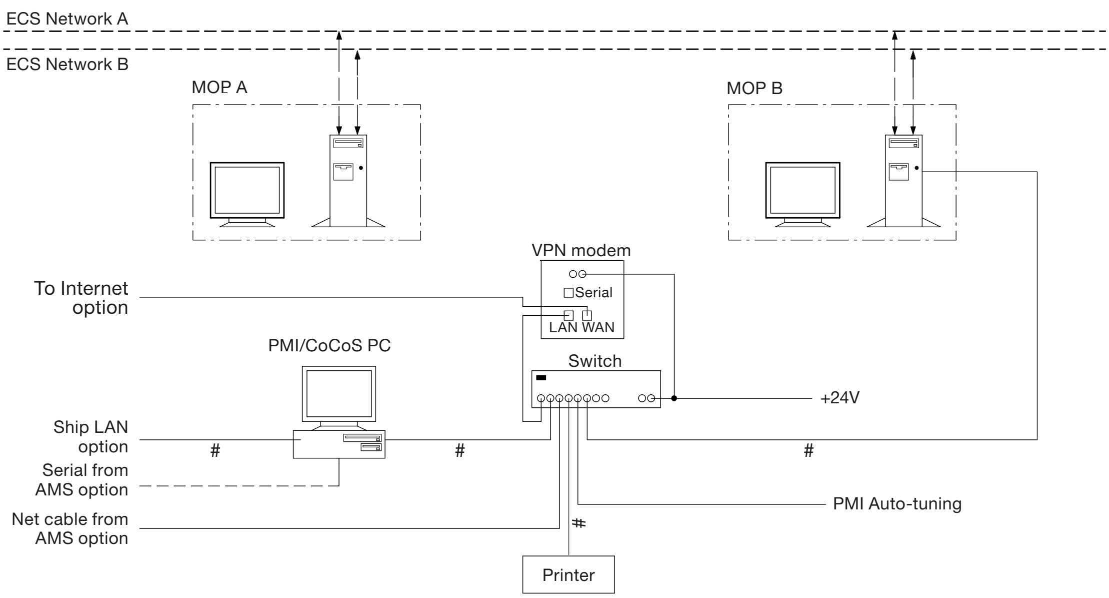
- 2 pcs EICU (Engine Interface Control Unit)
  (1 pcs only for ME-B engines)
- 1 pcs MOP A (Main Operating Panel)
  EC-MOP with touch display, 15”
  or
  Touch display, 15”
  PC unit with pointing device for MOP
- 1 pcs MOP B
  EC-MOP with touch display, 15”
  or
  Touch display, 15”
  PC unit with keyboard 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.



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Abbreviation:

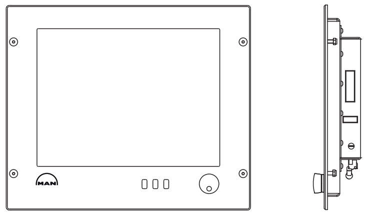
PDB:	Power Distribution Box
UPS:	Uninterruptible Power Supply
PMI:	Pressure Indicator
CoCos-EDS:	Computer Controlled Surveillance-Engine Diagnostics System
AMS:	Alarm Monitoring Systems

Yard Supply

Ethernet, supply with switch, cable length 10 metres
Type: RJ45, STP (Shielded TwistedPair), CAT 5
In case that 10 metre cable is not enough, this becomes Yard supply.

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



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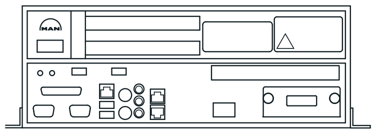
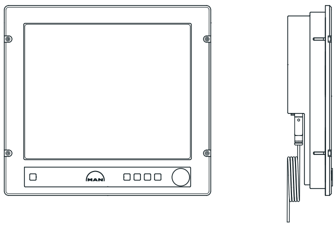
MOP PC
- MOP control unit
- Without display



188 18 66-0.2.0

Main operating panel (Display)
- LCD (TFT) monitor 15” with touch display (calibrated)
  - Direct dimming control (0-100%)
  - USB connection at front
  - IP54 resistant front



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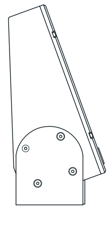

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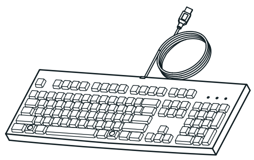
Pointing device
- Keyboard model
  - UK version, 104 keys
  - USB connection
- Trackball mouse
  - USB connection



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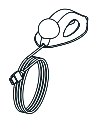

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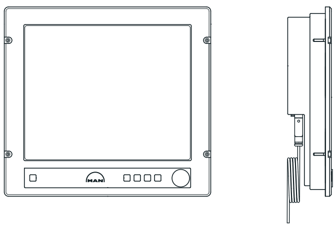
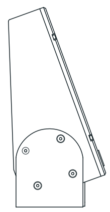
PMI/CoCos Display
- LCD (TFT) monitor 19”
  - Active matrix
  - Resolution 1,280x1,024, auto scaling
  - Direct dimming control (0-100%)
  - IP65 resistant front



188 15 30-4.2.0



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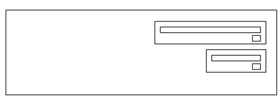
PMI/CoCos PC
- Standard industry PC with MS Windows operating system, UK version



178 62 31-3.0

Router
- Ethernet switch and VPN router with firewall

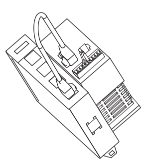


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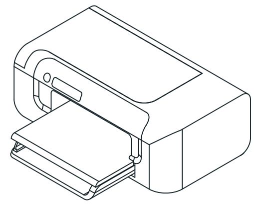
Fig. 5.16.02 MOP PC equipment for the ME/ME-B Engine Control System

Printer

- Network printer, ink colour printer



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EICU Cabinet

- Engine interface control cabinet for ME-ECS for installation in ECR (recommended) or ER

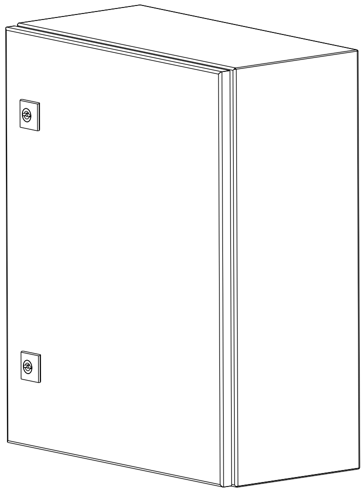

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Fig. 5.16.03 The EICU cabinet unit for the ME-B Engine Control System

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.

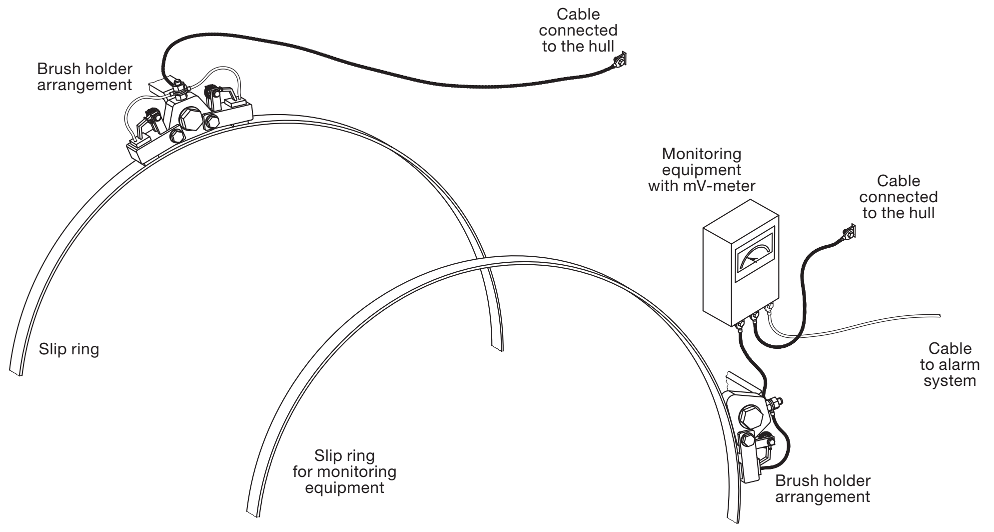


Fig. 5.17.01: Connection of cables for the shaftline earthing device

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

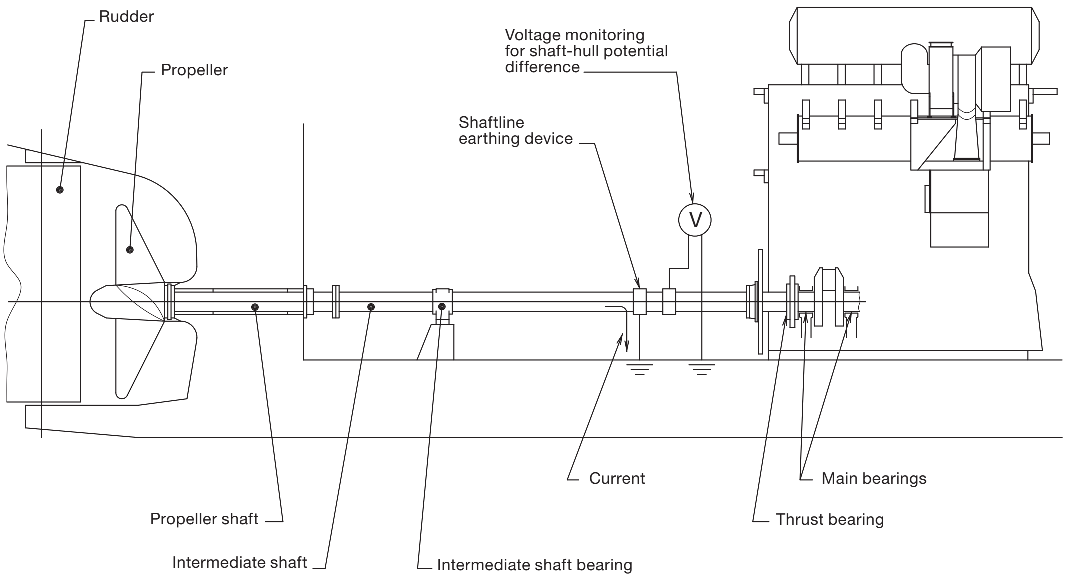


Fig. 5.17.02: Installation of shaftline earthing device in an engine plant without shaft-mounted generator

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

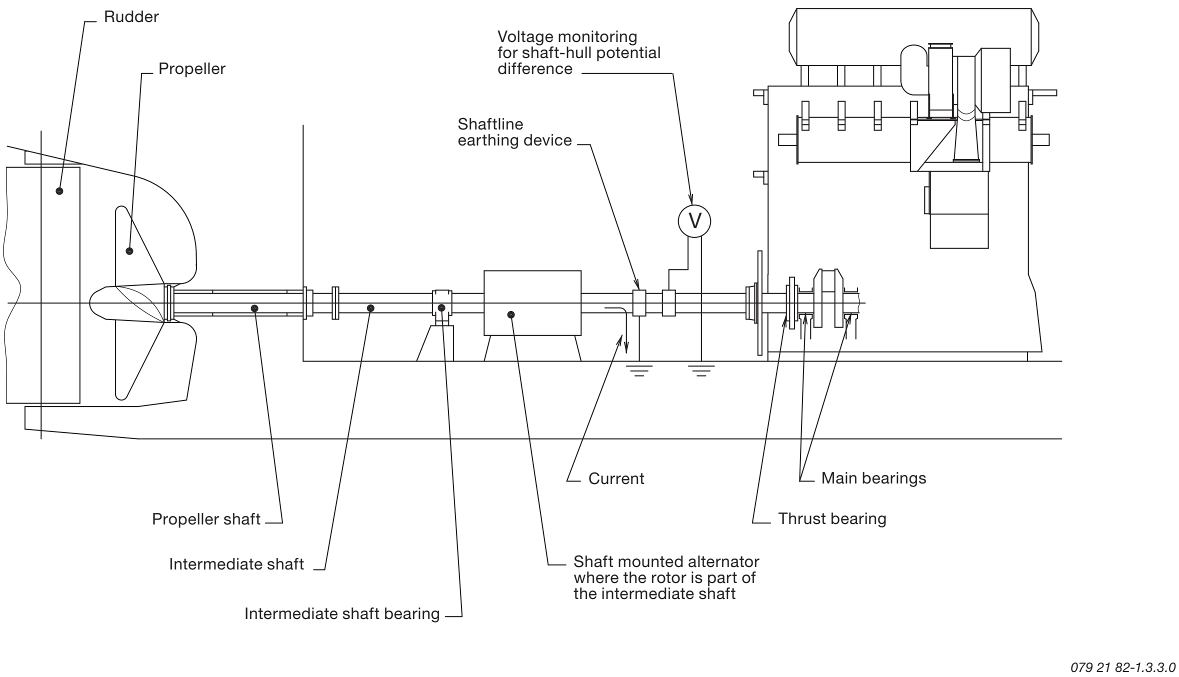


Fig. 5.17.03: Installation of shaftline earthing device in an engine plant with shaft-mounted generator

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.

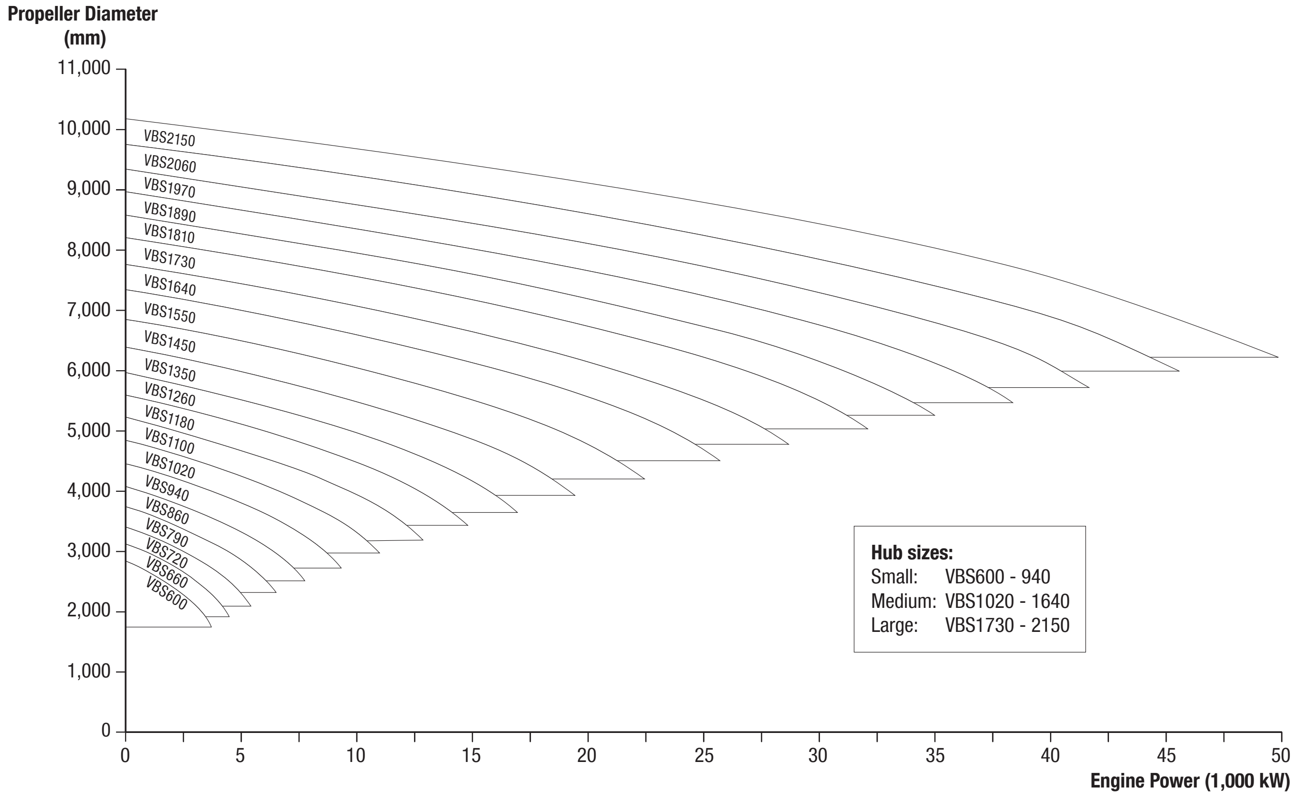


Fig. 5.18.01: MAN Alpha type VBS Mk 5 Controllable Pitch (CP) propeller range. As standard the VBS Mk 5 versions are 4-bladed; 5-bladed versions are available on request

Data Sheet for Propeller

Identification: ______________________________

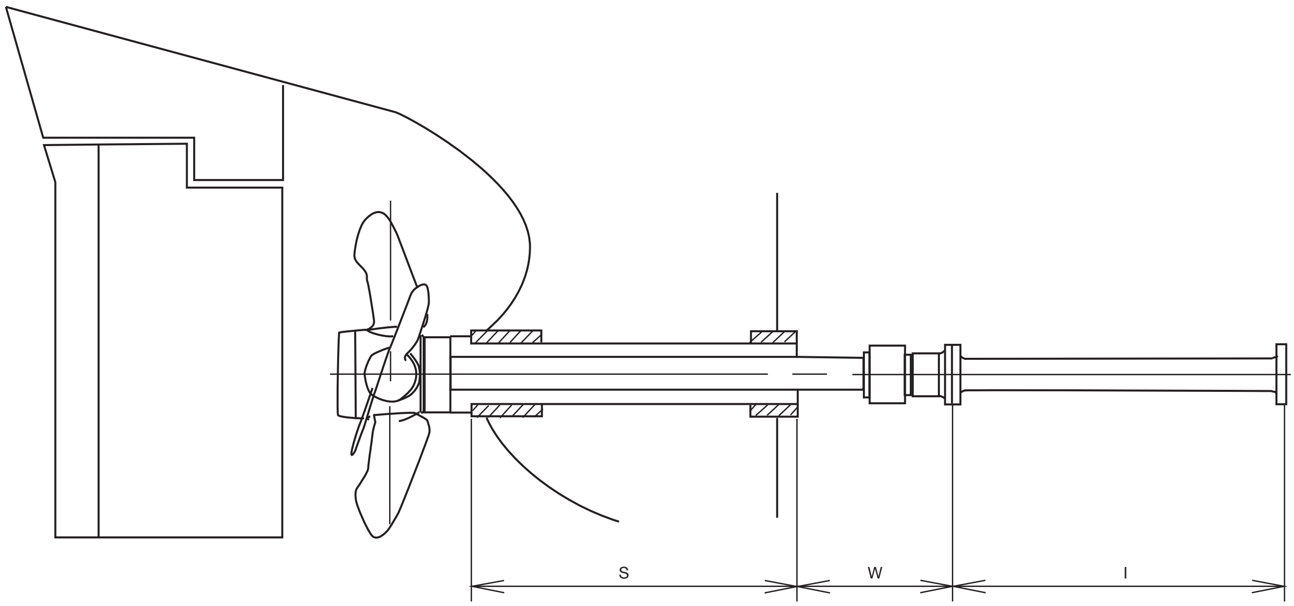


Fig. 5.18.02a: Dimension sketch for propeller design purposes

Type of vessel: ______________________________

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

	Symbol	Unit	Ballast	Loaded
Length between perpendiculars	LPP	m		
Length of load water line	LWL	m		
Breadth	B	m		
Draft at forward perpendicular	TF	m		
Draft at aft perpendicular	TA	m		
Displacement	o	m3		
Block coefficient (LPP)	CB	-		
Midship coefficient	CM	-		
Waterplane area coefficient	CWL	-		
Wetted surface with appendages	S	m2		
Centre of buoyancy forward of LPP/2	LCB	m		
Propeller centre height above baseline	H	m		
Bulb section area at forward perpendicular	AB	m2		

178 22 97-0.0

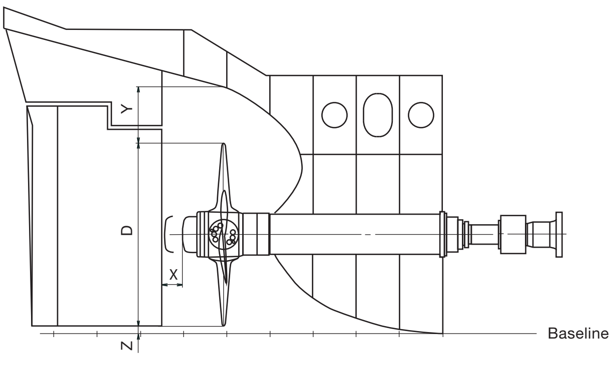
Table 5.18.03: Data sheet for propeller design purposes, in case model test is not available this table should be filled in

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.



178 22 37-2.0

Fig. 5.18.04: Propeller clearance

Hub	Dismant-ling of cap X mm	High-skew propeller Y mm	Non-skew propeller Y mm	Baseline clearance Z mm
VBS 600	120	15-20% of D	20-25% of D	Min. 50-100
VBS 660	130			
VBS 720	140			
VBS 790	155			
VBS 860	170			
VBS 940	185			
VBS 1020	200			
VBS 1100	215			
VBS 1180	230			
VBS 1260	245			
VBS 1350	265			
VBS 1460	280			
VBS 1550	300			
VBS 1640	320			
VBS 1730	340			
VBS 1810	355			
VBS 1890	370			
VBS 1970	385			
VBS 2060	405			
VBS 2150	425			

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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.

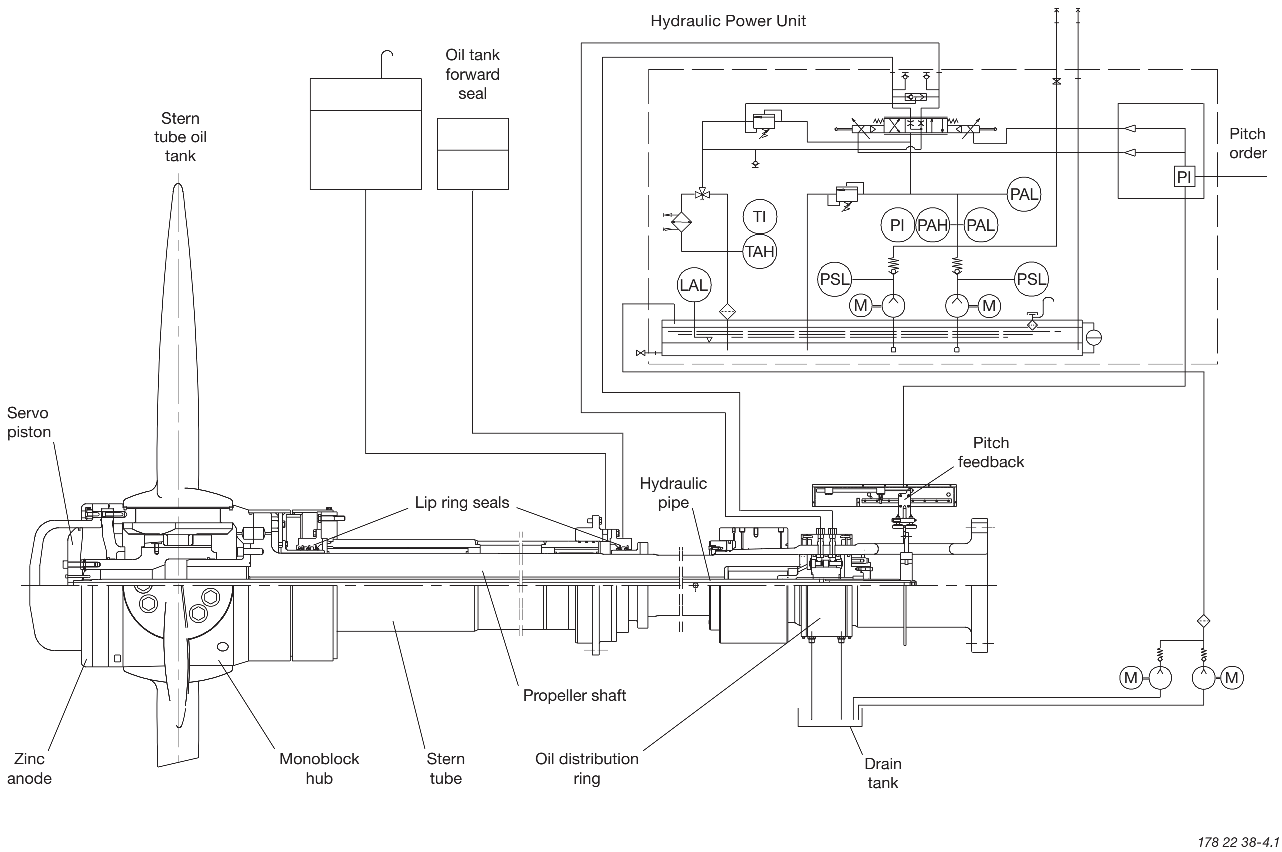

Fig. 5.18.05: Servo oil system for MAN Alpha VBS type CP propeller

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.

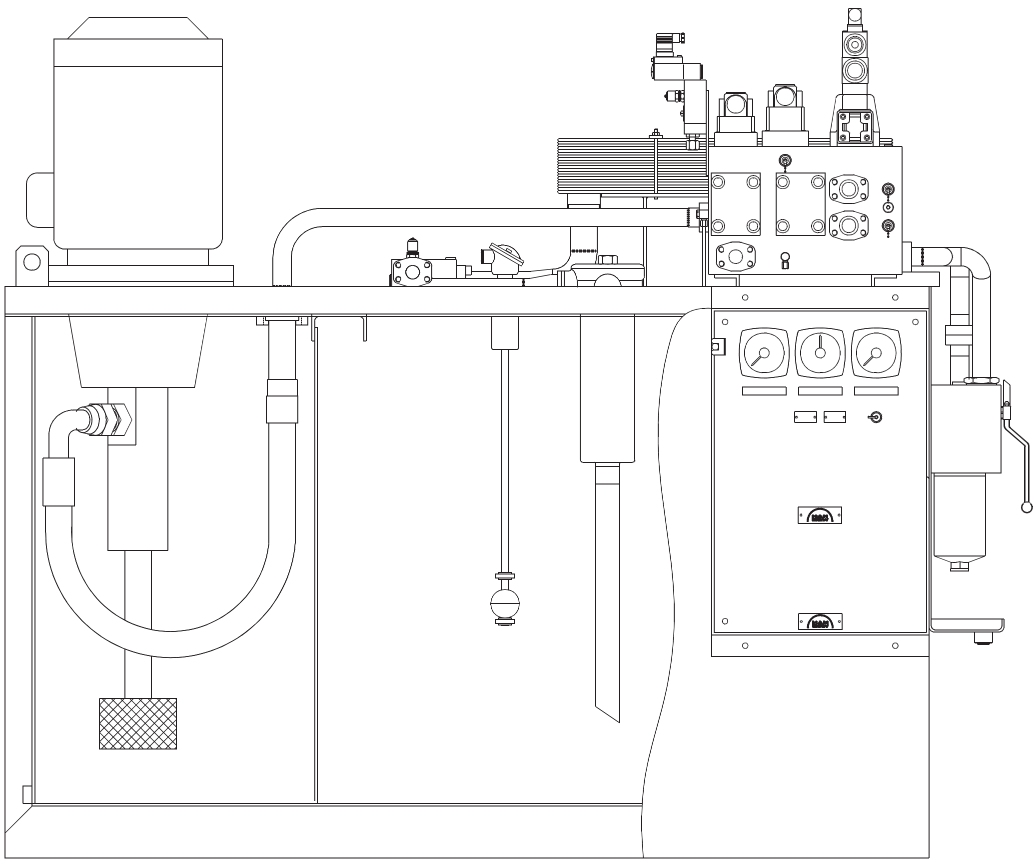

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Fig. 5.18.06: Hydraulic Power Unit for MAN Alpha CP propeller, the servo oil tank unit

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.

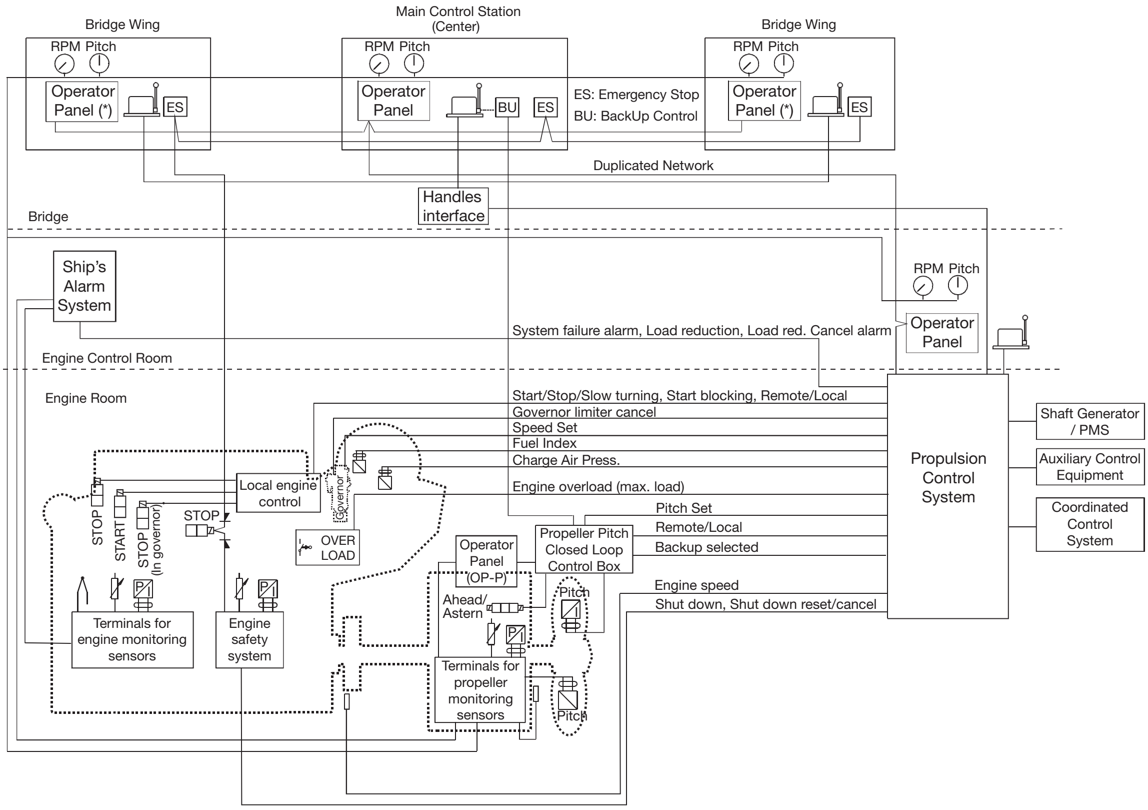


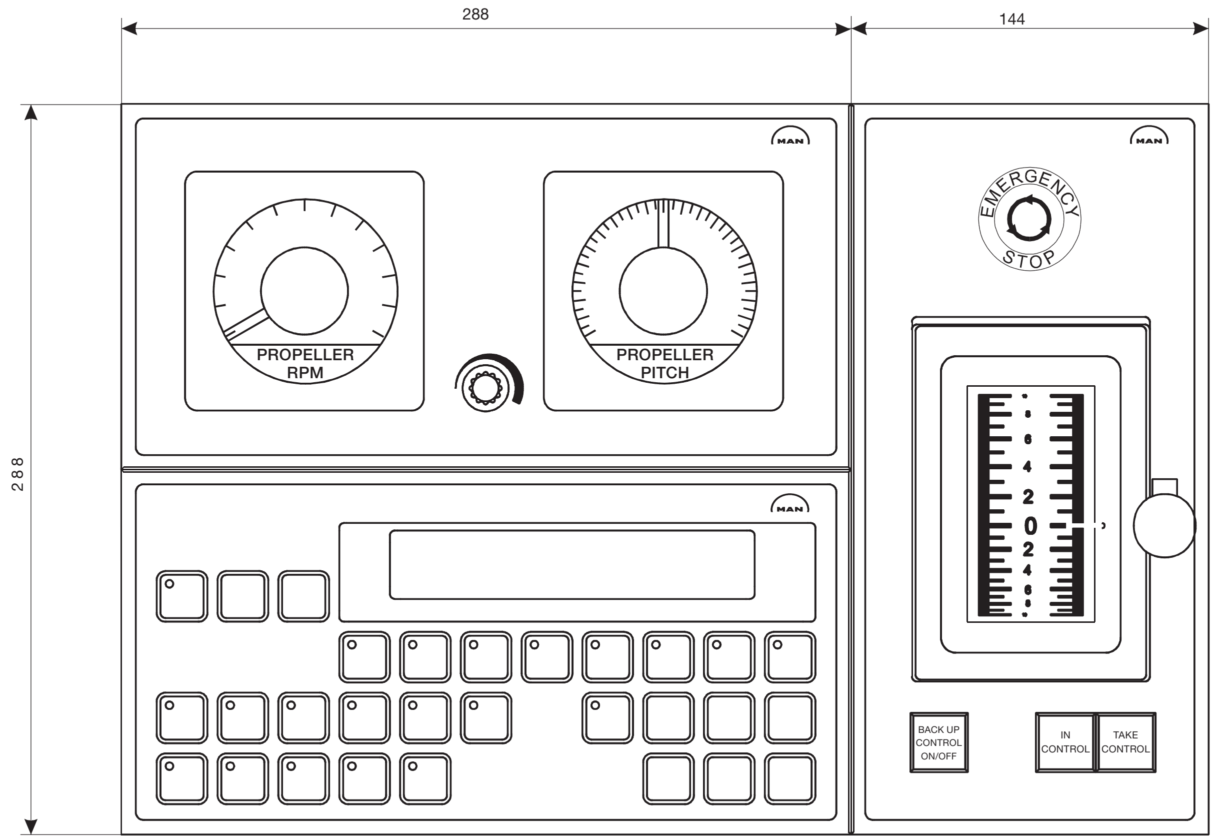
Fig. 5.18.07: MAN Alphatronic 2000 Propulsion Control System

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.



178 22 41-8.1

Fig. 5.18.08: Main bridge station standard layout

Renk PSC Clutch for auxilliary propulsion systems

The Renk PSC Clutch is a shaftline de-clutching device for auxilliary 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

6

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:

Engine ratings	Point / Index	Power	Speed
Nominal MCR point	L_1	P_{L1}	n_{L1}
Specified MCR point	M	P_M	n_M
Service point	S	P_S	n_S

Fig. 6.01.01: Nomenclature of basic engine ratings

Parameters			Cooler index		Flow index	
Q	=	Heat dissipation	air	scavenge air cooler	sw	seawater flow
V	=	Volume flow	lub	lube oil cooler	cw	cooling/central water flow
M	=	Mass flow	jw	jacket water cooler	exh	exhaust gas
T	=	Temperature	cent	central cooler	fw	freshwater

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 NO_x 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 (L_1) 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 L_1).

The air consumption is approximately 98.2% of the calculated exhaust gas amount, ie. $M_{air} = M_{exh} \times 0.982$.

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.

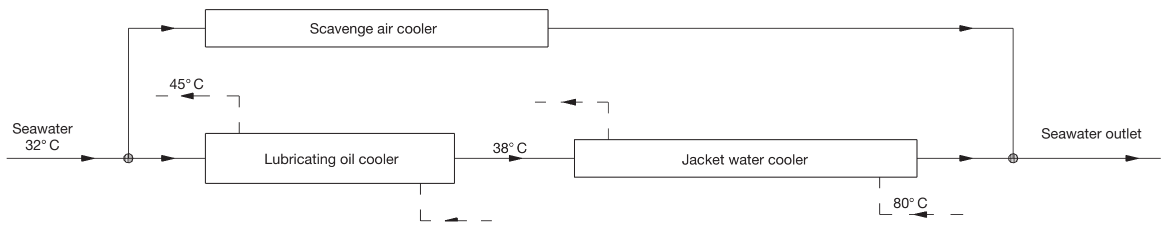


Fig. 6.02.01: Diagram for seawater cooling system

178 11 26-4.1

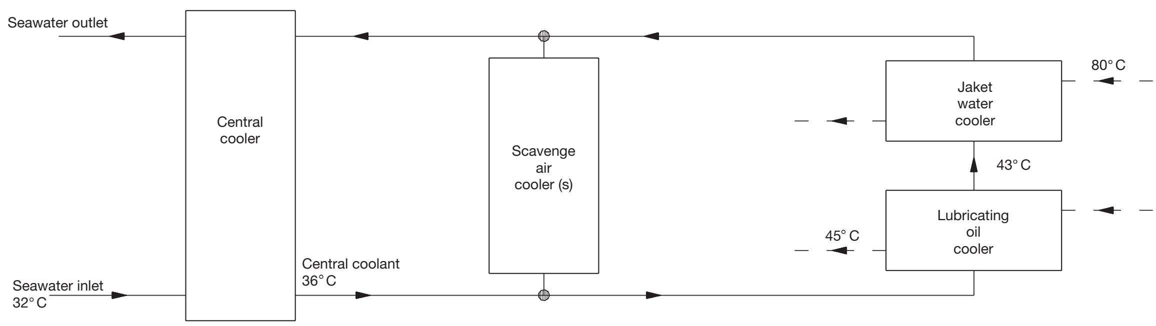


Fig. 6.02.02: Diagram for central cooling water system

178 11 27-6.1

List of Capacities for 5S50ME-B9.3-TII at NMCR

		Seawater cooling						Central cooling					
		Conventional TC			High eff. TC			Conventional TC			High eff. TC		
		1 x TCA55-24	1 x A165-L37	1 x MET53MB	1 x TCA55-24	1 x A265-L	1 x MET53MB	1 x TCA55-24	1 x A165-L37	1 x MET53MB	1 x TCA55-24	1 x A265-L	1 x MET53MB
Pumps													
Fuel oil circulation	m³/h	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Fuel oil supply	m³/h	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Jacket cooling	m³/h	80	80	80	80	80	80	80	80	80	80	80	80
Seawater cooling *	m³/h	272	273	276	277	278	281	267	267	268	272	272	273
Main lubrication oil *	m³/h	190	190	190	190	190	190	190	190	190	190	190	190
Central cooling *	m³/h	-	-	-	-	-	-	210	212	214	214	215	218
Scavenge air cooler(s)													
Heat diss. app.	kW	3,310	3,310	3,310	3,420	3,420	3,420	3,290	3,290	3,290	3,400	3,400	3,400
Central water flow	m³/h	-	-	-	-	-	-	118	118	118	121	121	121
Seawater flow	m³/h	162	162	162	167	167	167	-	-	-	-	-	-
Lubricating oil cooler													
Heat diss. app. *	kW	750	760	780	750	760	780	750	760	780	750	760	780
Lube oil flow *	m³/h	190	188	189	190	188	189	190	188	189	190	188	189
Central water flow	m³/h	-	-	-	-	-	-	92	93	96	92	93	96
Seawater flow	m³/h	110	111	114	110	111	114	-	-	-	-	-	-
Jacket water cooler													
Heat diss. app.	kW	1,410	1,410	1,410	1,410	1,410	1,410	1,410	1,410	1,410	1,410	1,410	1,410
Jacket water flow	m³/h	85	85	85	85	85	85	81	81	81	81	81	81
Central water flow	m³/h	-	-	-	-	-	-	92	93	96	92	93	96
Seawater flow	m³/h	110	111	114	110	111	114	-	-	-	-	-	-
Central cooler													
Heat diss. app. *	kW	-	-	-	-	-	-	5,450	5,460	5,480	5,560	5,570	5,590
Central water flow	m³/h	-	-	-	-	-	-	210	212	214	214	215	218
Seawater flow	m³/h	-	-	-	-	-	-	267	267	268	272	272	273
Starting air system, 30.0 bar g, 12 starts. Fixed pitch propeller - reversible engine													
Receiver volume	m³	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0
Compressor cap.	m³	300	300	300	300	300	300	300	300	300	300	300	300
Starting air system, 30.0 bar g, 6 starts. Controllable pitch propeller - non-reversible engine													
Receiver volume	m³	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5
Compressor cap.	m³	150	150	150	150	150	150	150	150	150	150	150	150
Other values													
Fuel oil heater	kW	70	70	70	70	70	70	70	70	70	70	70	70
Exh. gas temp. **	°C	255	255	255	235	235	235	255	255	255	235	235	235
Exh. gas amount **	kg/h	63,804	63,804	63,804	67,355	67,355	67,355	63,804	63,804	63,804	67,355	67,355	67,355
Air consumption **	kg/s	17.3	17.3	17.3	18.3	18.3	18.3	17.3	17.3	17.3	18.3	18.3	18.3

* 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/ceas/index.htm

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 6S50ME-B9.3-TII at NMCR

		Seawater cooling						Central cooling					
		Conventional TC			High eff. TC			Conventional TC			High eff. TC		
		1 x TCA55-26	1 x A170-L37	1 x MET53MB	1 x TCA66-24	1 x A170-L37	1 x MET60MB	1 x TCA55-26	1 x A170-L37	1 x MET53MB	1 x TCA66-24	1 x A170-L37	1 x MET60MB
Pumps													
Fuel oil circulation	m^3/h	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Fuel oil supply	m^3/h	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Jacket cooling	m^3/h	97	97	97	97	97	97	97	97	97	97	97	97
Seawater cooling *	m^3/h	323	327	328	332	333	337	319	320	320	326	327	328
Main lubrication oil *	m^3/h	220	220	220	220	220	220	220	220	220	220	220	220
Central cooling *	m^3/h	-	-	-	-	-	-	250	253	254	257	258	261
Scavenge air cooler(s)													
Heat diss. app.	kW	3,970	3,970	3,970	4,100	4,100	4,100	3,950	3,950	3,950	4,080	4,080	4,080
Central water flow	m^3/h	-	-	-	-	-	-	141	141	141	146	146	146
Seawater flow	m^3/h	194	194	194	200	200	200	-	-	-	-	-	-
Lubricating oil cooler													
Heat diss. app. *	kW	880	910	910	900	910	930	880	910	910	900	910	930
Lube oil flow *	m^3/h	218	217	217	220	217	218	218	217	217	220	217	218
Central water flow	m^3/h	-	-	-	-	-	-	109	112	112	110	112	114
Seawater flow	m^3/h	129	133	134	131	133	136	-	-	-	-	-	-
Jacket water cooler													
Heat diss. app.	kW	1,690	1,690	1,690	1,690	1,690	1,690	1,690	1,690	1,690	1,690	1,690	1,690
Jacket water flow	m^3/h	102	102	102	102	102	102	97	97	97	97	97	97
Central water flow	m^3/h	-	-	-	-	-	-	109	112	112	110	112	114
Seawater flow	m^3/h	129	133	134	131	133	136	-	-	-	-	-	-
Central cooler													
Heat diss. app. *	kW	-	-	-	-	-	-	6,520	6,550	6,550	6,670	6,680	6,700
Central water flow	m^3/h	-	-	-	-	-	-	250	253	254	257	258	261
Seawater flow	m^3/h	-	-	-	-	-	-	319	320	320	326	327	328
Starting air system, 30.0 bar g, 12 starts. Fixed pitch propeller - reversible engine													
Receiver volume	m^3	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0
Compressor cap.	m^3	300	300	300	300	300	300	300	300	300	300	300	300
Starting air system, 30.0 bar g, 6 starts. Controllable pitch propeller - non-reversible engine													
Receiver volume	m^3	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5
Compressor cap.	m^3	150	150	150	150	150	150	150	150	150	150	150	150
Other values													
Fuel oil heater	kW	84	84	84	84	84	84	84	84	84	84	84	84
Exh. gas temp. **	°C	255	255	255	235	235	235	255	255	255	235	235	235
Exh. gas amount **	kg/h	76,565	76,565	76,565	80,826	80,826	80,826	76,565	76,565	76,565	80,826	80,826	80,826
Air consumption **	kg/s	20.8	20.8	20.8	22.0	22.0	22.0	20.8	20.8	20.8	22.0	22.0	22.0

* 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/ceas/index.htm

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 7S50ME-B9.3-TII at NMCR

		Seawater cooling						Central cooling					
		Conventional TC			High eff. TC			Conventional TC			High eff. TC		
		1 x TCA66-24	1 x A270-L	1 x MET60MB	1 x TCA66-24	1 x A270-L	1 x MET60MB	1 x TCA66-24	1 x A270-L	1 x MET60MB	1 x TCA66-24	1 x A270-L	1 x MET60MB
Pumps													
Fuel oil circulation	m³/h	5.9	5.9	5.9	5.8	5.8	5.8	5.9	5.9	5.9	5.9	5.9	5.9
Fuel oil supply	m³/h	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Jacket cooling	m³/h	112	112	112	112	112	112	112	112	112	112	112	112
Seawater cooling *	m³/h	379	380	383	386	388	391	372	373	374	380	380	381
Main lubrication oil *	m³/h	250	250	250	250	250	250	250	250	250	250	250	250
Central cooling *	m³/h	-	-	-	-	-	-	293	295	297	299	300	303
Scavenge air cooler(s)													
Heat diss. app.	kW	4,630	4,630	4,630	4,790	4,790	4,790	4,610	4,610	4,610	4,760	4,760	4,760
Central water flow	m³/h	-	-	-	-	-	-	165	165	165	170	170	170
Seawater flow	m³/h	226	226	226	234	234	234	-	-	-	-	-	-
Lubricating oil cooler													
Heat diss. app. *	kW	1,040	1,050	1,070	1,040	1,050	1,070	1,040	1,050	1,070	1,040	1,050	1,070
Lube oil flow *	m³/h	250	247	248	250	247	248	250	247	248	250	247	248
Central water flow	m³/h	-	-	-	-	-	-	128	129	132	128	129	132
Seawater flow	m³/h	152	154	157	152	154	157	-	-	-	-	-	-
Jacket water cooler													
Heat diss. app.	kW	1,960	1,960	1,960	1,960	1,960	1,960	1,970	1,970	1,970	1,970	1,970	1,970
Jacket water flow	m³/h	118	118	118	118	118	118	113	113	113	113	113	113
Central water flow	m³/h	-	-	-	-	-	-	128	129	132	128	129	132
Seawater flow	m³/h	152	154	157	152	154	157	-	-	-	-	-	-
Central cooler													
Heat diss. app. *	kW	-	-	-	-	-	-	7,620	7,630	7,650	7,770	7,780	7,800
Central water flow	m³/h	-	-	-	-	-	-	293	295	297	299	300	303
Seawater flow	m³/h	-	-	-	-	-	-	372	373	374	380	380	381
Starting air system, 30.0 bar g, 12 starts. Fixed pitch propeller - reversible engine													
Receiver volume	m³	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0
Compressor cap.	m³	300	300	300	300	300	300	300	300	300	300	300	300
Starting air system, 30.0 bar g, 6 starts. Controllable pitch propeller - non-reversible engine													
Receiver volume	m³	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5
Compressor cap.	m³	150	150	150	150	150	150	150	150	150	150	150	150
Other values													
Fuel oil heater	kW	98	98	98	98	98	98	98	98	98	98	98	98
Exh. gas temp. **	°C	255	255	255	235	235	235	255	255	255	235	235	235
Exh. gas amount **	kg/h	89,326	89,326	89,326	94,297	94,297	94,297	89,326	89,326	89,326	94,297	94,297	94,297
Air consumption **	kg/s	24.2	24.2	24.2	25.6	25.6	25.6	24.2	24.2	24.2	25.6	25.6	25.6

* 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/ceas/index.htm

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 8S50ME-B9.3-TII at NMCR

		Seawater cooling						Central cooling					
		Conventional TC			High eff. TC			Conventional TC			High eff. TC		
		1 x TCA66-26	1 x A175-L35	1 x MET66MB	1 x TCA66-26	1 x A175-L37	1 x MET66MB	1 x TCA66-26	1 x A175-L35	1 x MET66MB	1 x TCA66-26	1 x A175-L37	1 x MET66MB
Pumps													
Fuel oil circulation	m³/h	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7
Fuel oil supply	m³/h	3.9	3.9	3.9	3.8	3.8	3.8	3.9	3.9	3.9	3.8	3.8	3.8
Jacket cooling	m³/h	129	129	129	129	129	129	129	129	129	129	129	129
Seawater cooling *	m³/h	432	437	440	441	446	449	425	427	428	434	436	436
Main lubrication oil *	m³/h	280	270	280	280	270	280	280	270	280	280	270	280
Central cooling *	m³/h	-	-	-	-	-	-	335	339	342	341	346	348
Scavenge air cooler(s)													
Heat diss. app.	kW	5,290	5,290	5,290	5,470	5,470	5,470	5,270	5,270	5,270	5,440	5,440	5,440
Central water flow	m³/h	-	-	-	-	-	-	188	188	188	194	194	194
Seawater flow	m³/h	259	259	259	267	267	267	-	-	-	-	-	-
Lubricating oil cooler													
Heat diss. app. *	kW	1,180	1,220	1,240	1,180	1,220	1,240	1,180	1,220	1,240	1,180	1,220	1,240
Lube oil flow *	m³/h	275	273	275	275	273	275	275	273	275	275	273	275
Central water flow	m³/h	-	-	-	-	-	-	146	150	152	146	150	152
Seawater flow	m³/h	173	179	182	173	179	182	-	-	-	-	-	-
Jacket water cooler													
Heat diss. app.	kW	2,240	2,240	2,240	2,240	2,240	2,240	2,250	2,250	2,250	2,250	2,250	2,250
Jacket water flow	m³/h	135	135	135	135	135	135	129	129	129	129	129	129
Central water flow	m³/h	-	-	-	-	-	-	146	150	152	146	150	152
Seawater flow	m³/h	173	179	182	173	179	182	-	-	-	-	-	-
Central cooler													
Heat diss. app. *	kW	-	-	-	-	-	-	8,700	8,740	8,760	8,870	8,910	8,930
Central water flow	m³/h	-	-	-	-	-	-	335	339	342	341	346	348
Seawater flow	m³/h	-	-	-	-	-	-	425	427	428	434	436	436
Starting air system, 30.0 bar g, 12 starts. Fixed pitch propeller - reversible engine													
Receiver volume	m³	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0
Compressor cap.	m³	300	300	300	300	300	300	300	300	300	300	300	300
Starting air system, 30.0 bar g, 6 starts. Controllable pitch propeller - non-reversible engine													
Receiver volume	m³	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0
Compressor cap.	m³	180	180	180	180	180	180	180	180	180	180	180	180
Other values													
Fuel oil heater	kW	112	112	112	112	112	112	112	112	112	112	112	112
Exh. gas temp. **	°C	255	255	255	235	235	235	255	255	255	235	235	235
Exh. gas amount **	kg/h	102,087	102,087	102,087	107,768	107,768	107,768	102,087	102,087	102,087	107,768	107,768	107,768
Air consumption **	kg/s	27.7	27.7	27.7	29.3	29.3	29.3	27.7	27.7	27.7	29.3	29.3	29.3

* 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

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Table 6.03.01h: Capacities for seawater and central systems as well as conventional and high efficiency turbochargers stated at NMCR

List of Capacities for 9S50ME-B9.3-TII at NMCR

		Seawater cooling						Central cooling					
		Conventional TC			High eff. TC			Conventional TC			High eff. TC		
		1 x TCA66-26	1 x A175-L37	1 x MET66MB	1 x TCA77-24	1 x A175-L37	1 x MET66MB	1 x TCA66-26	1 x A175-L37	1 x MET66MB	1 x TCA77-24	1 x A175-L37	1 x MET66MB
Pumps													
Fuel oil circulation	m³/h	7.5	7.5	7.5	7.5	7.5	7.5	7.6	7.6	7.6	7.5	7.5	7.5
Fuel oil supply	m³/h	4.3	4.3	4.3	4.3	4.3	4.3	4.4	4.4	4.4	4.3	4.3	4.3
Jacket cooling	m³/h	145	145	145	145	145	145	145	145	145	145	145	145
Seawater cooling *	m³/h	485	491	493	498	501	503	478	480	481	489	490	490
Main lubrication oil *	m³/h	300	300	300	300	300	300	300	300	300	300	300	300
Central cooling *	m³/h	-	-	-	-	-	-	376	381	383	385	388	390
Scavenge air cooler(s)													
Heat diss. app.	kW	5,950	5,950	5,950	6,150	6,150	6,150	5,930	5,930	5,930	6,120	6,120	6,120
Central water flow	m³/h	-	-	-	-	-	-	212	212	212	219	219	219
Seawater flow	m³/h	291	291	291	301	301	301	-	-	-	-	-	-
Lubricating oil cooler													
Heat diss. app. *	kW	1,330	1,360	1,380	1,340	1,360	1,380	1,330	1,370	1,380	1,350	1,370	1,380
Lube oil flow *	m³/h	301	299	301	305	299	301	301	299	301	305	299	301
Central water flow	m³/h	-	-	-	-	-	-	163	168	170	166	168	170
Seawater flow	m³/h	194	200	202	197	200	202	-	-	-	-	-	-
Jacket water cooler													
Heat diss. app.	kW	2,530	2,530	2,530	2,530	2,530	2,530	2,530	2,530	2,530	2,530	2,530	2,530
Jacket water flow	m³/h	152	152	152	152	152	152	145	145	145	145	145	145
Central water flow	m³/h	-	-	-	-	-	-	163	168	170	166	168	170
Seawater flow	m³/h	194	200	202	197	200	202	-	-	-	-	-	-
Central cooler													
Heat diss. app. *	kW	-	-	-	-	-	-	9,790	9,830	9,840	10,000	10,020	10,030
Central water flow	m³/h	-	-	-	-	-	-	376	381	383	385	388	390
Seawater flow	m³/h	-	-	-	-	-	-	478	480	481	489	490	490
Starting air system, 30.0 bar g, 12 starts. Fixed pitch propeller - reversible engine													
Receiver volume	m³	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0
Compressor cap.	m³	300	300	300	300	300	300	300	300	300	300	300	300
Starting air system, 30.0 bar g, 6 starts. Controllable pitch propeller - non-reversible engine													
Receiver volume	m³	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0
Compressor cap.	m³	180	180	180	180	180	180	180	180	180	180	180	180
Other values													
Fuel oil heater	kW	126	126	126	126	126	126	127	127	127	126	126	126
Exh. gas temp. **	°C	255	255	255	235	235	235	255	255	255	235	235	235
Exh. gas amount **	kg/h	114,847	114,847	114,847	121,239	121,239	121,239	114,847	114,847	114,847	121,239	121,239	121,239
Air consumption **	kg/s	31.2	31.2	31.2	32.9	32.9	32.9	31.2	31.2	31.2	32.9	32.9	32.9

* 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/ceas/index.htm

Table 6.03.01i: Capacities for seawater and central systems as well as conventional and high efficiency turbochargers stated at NMCR

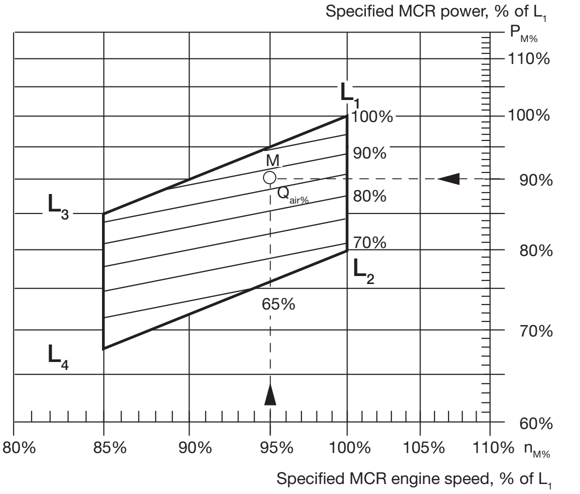
Auxiliary Machinery Capacities

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 (L_1), 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 (L_1).

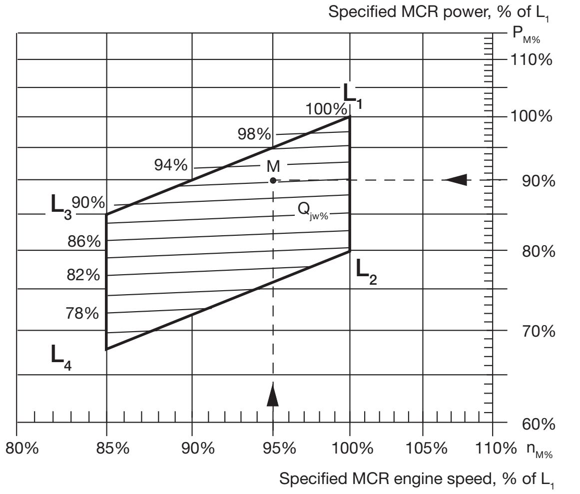


178 63 63-8.0

$Q_{air\%} = 100 \times (P_M/P_{L1})^{1.68} \times (n_M/n_{L1})^{-0.83} = 1$

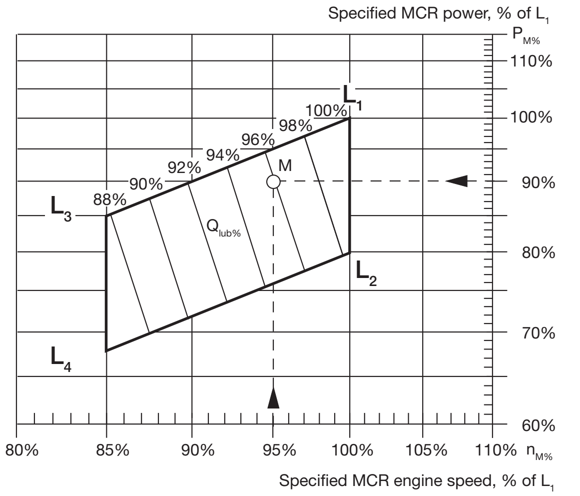
Fig. 6.04.01: Scavenge air cooler, heat dissipation $Q_{air\%}$ in point M, in % of the L_1 value $Q_{air,\ L1}$

The percentage power ($P_{M\%}$) and speed ($n_{M\%}$) of L_1 ie: $P_{M\%} = P_M/P_{L1} \times 100\%$
$n_{M\%} = n_M/n_{L1} \times 100\%$
for specified MCR (M) of the derated engine is used as input in the above-mentioned diagrams, giving the % heat dissipation figures relative to those in the 'List of Capacities'.



$Q_{jw\%} = e^{(-0.0811 \times \ln(n_{M\%}) + 0.8072 \times \ln(P_{M\%}) + 1.2614)}$ 178 63 62-6.1

Fig. 6.04.02: Jacket water cooler, heat dissipation $Q_{jw\%}$ in point M, in % of the L_1 value $Q_{jw,\ L1}$



178 63 65-1.1

$Q_{lub\%} = 67.3009 \times \ln(n_{M\%}) + 7.6304 \times \ln(P_{M\%}) - 245.0714$

Fig. 6.04.03: Lubricating oil cooler, heat dissipation $Q_{lub\%}$ in point M, in % of the L_1 value $Q_{lub,\ L1}$

The derated cooler capacities may then be found by means of following equations:

$Q_{air, M} = Q_{air, L1} \times (Q_{air\%} / 100)$
$Q_{jw, M} = Q_{jw, L1} \times (Q_{jw\%} / 100)$
$Q_{lub, M} = Q_{lub, L1} \times (Q_{lub\%} / 100)$

and for a central cooling water system the central cooler heat dissipation is:

$Q_{cent,M} = Q_{air,M} + Q_{jw,M} + Q_{lub,M}$

Pump capacities

The pump capacities given in the 'List of Capacities' refer to engines rated at nominal MCR (L_1). 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:

$V_{sw,air,M} = V_{sw,air,L1} \times (Q_{air\%} / 100)$
$V_{sw,lub,M} = V_{sw,lub.L1} \times Q_{lub\%} / 100)$
$V_{sw,jw,M} = V_{sw,lub,M}$

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:

$V_{cw,air,M} = V_{cw,air,L1} \times (Q_{air\%} / 100)$
$V_{cw,lub,M} = V_{cw,lub,L1} \times (Q_{lub\%} / 100)$
$V_{cw,jw,M} = V_{cw,lub,M}$
$V_{cw,cent,M} = V_{cw,air,M} + V_{cw,lub,M}$
$V_{sw,cent,M} = V_{sw,cent,L1} \times Q_{cent,M} / Q_{cent,L1}$

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:

	Pump head bar	Max. working temp. °C
Fuel oil supply pump	4	100
Fuel oil circulating pump	6	150
Lubricating oil pump	4.2	70
Seawater pump	2.5	50
Central cooling water pump	2.5	80
Jacket water pump	3.0	100

Flow velocities

For external pipe connections, we prescribe the following maximum velocities:

Marine diesel oil .... 1.0 m/s
Heavy fuel oil .... 0.6 m/s
Lubricating oil .... 1.8 m/s
Cooling water .... 3.0 m/s

Calculation of List of Capacities for Derated Engine

Example 1:

Pump and cooler capacities for a *derated 6S50ME-B9.3-TII with 1 high efficiency MAN TCA55-26 turbocharger, high load, fixed pitch propeller and central cooling water system.*

Nominal MCR, (L_1) P_{L1}: 10,680 kW (100.0%) and 117.0 r/min (100.0%)

Specified MCR, (M) P_M: 9,612 kW (90.0%) and 111.2 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.:

$$Q_{air,M} = Q_{air,L1} \times Q_{air\%} / 100$$

$$Q_{air,M} = 4{,}080 \times 0.874 = 3{,}566 \text{ kW}$$

Heat dissipation of jacket water cooler
Fig. 6.04.02 indicates a $Q_{jw\%}$ = 92.2% heat dissipation; i.e.:

$$Q_{jw,M} = Q_{jw,L1} \times Q_{jw\%} / 100$$

$$Q_{jw,M} = 1{,}690 \times 0.922 = 1{,}558 \text{ kW}$$

Heat dissipation of lube oil cooler
Fig. 6.04.03 indicates a $Q_{lub\%}$ = 95.8% heat dissipation; i.e.:

$$Q_{lub,M} = Q_{lub,\,L1} \times Q_{lub\%} / 100$$

$$Q_{lub,M} = 900 \times 0.958 = 862 \text{ kW}$$

Heat dissipation of central water cooler

$$Q_{cent,M} = Q_{air,M} + Q_{jw,M} + Q_{lub,\,M}$$

$$Q_{cent,M} = 3{,}566 + 1{,}558 + 862 = 5{,}986 \text{ kW}$$

Total cooling water flow through scavenge air coolers

$$V_{cw,air,M} = V_{cw,air,L1} \times Q_{air\%} / 100$$

$$V_{cw,air,M} = 146 \times 0.874 = 128 \text{ m}^3\text{/h}$$

Cooling water flow through lubricating oil cooler

$$V_{cw,lub,M} = V_{cw,lub,L1} \times Q_{lub\%} / 100$$

$$V_{cw,lub,M} = 110 \times 0.958 = 105 \text{ m}^3\text{/h}$$

Cooling water flow through central cooler (Central cooling water pump)

$$V_{cw,cent,M} = V_{cw,air,M} + V_{cw,lub,M}$$

$$V_{cw,cent,M} = 128 + 105 = 233 \text{ m}^3\text{/h}$$

Cooling water flow through jacket water cooler (as for lube oil cooler)

$$V_{cw,jw,M} = V_{cw,lub,M}$$

$$V_{cw,jw,M} = 105 \text{ m}^3\text{/h}$$

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 326 m^3/h and 6,670 kW the derated seawater pump flow equals:

Seawater pump:

$$V_{sw,cent,M} = V_{sw,cent,L1} \times Q_{cent,M} / Q_{cent,L1}$$

$$= 326 \times 5{,}986 / 6{,}670 = 293 \text{ m}^3\text{/h}$$

		Nominal rated engine (L_1) high efficiency 1 x MAN TCA66-24	Specified MCR (M) high efficiency 1 x MAN TCA55-26
Shaft power at MCR	kW	10,680	9,612
Engine speed at MCR	r/min	117.0	111.2
Pumps:			
Fuel oil circulating	m^3/h	5.0	4.7
Fuel oil supply	m^3/h	2.9	2.6
Jacket cooling water	m^3/h	97	97
Central cooling water	m^3/h	256	233
Seawater	m^3/h	326	293
Lubricating oil	m^3/h	220	220
Coolers:			
Scavenge air cooler			
Heat dissipation	kW	4,080	3,566
Central cooling water flow	m^3/h	146	128
Lub. oil cooler			
Heat dissipation	kW	900	862
Lubricating oil flow	m^3/h	220	220
Central cooling water flow	m^3/h	110	105
Jacket water cooler			
Heat dissipation	kW	1,690	1,558
Jacket cooling water flow	m^3/h	97	97
Central cooling water flow	m^3/h	110	105
Central cooler			
Heat dissipation	kW	6,670	5,986
Central cooling water flow	m^3/h	256	233
Seawater flow	m^3/h	326	293
Fuel oil heater:	kW	84	75
Gases at ISO ambient conditions*			
Exhaust gas amount	kg/h	80,800	72,600
Exhaust gas temperature	°C	235	231
Air consumption	kg/s	21.0	19.8
Starting air system: 30 bar (gauge)			
Reversible engine			
Receiver volume (12 starts)	m^3	2 x 5.0	2 x 5.0
Compressor capacity, total	m^3/h	300	300
Non-reversible engine			
Receiver volume (6 starts)	m^3	2 x 2.5	2 x 2.5
Compressor capacity, total	m^3/h	150	150
Exhaust gas tolerances: temperature ±5 °C and amount ±15%			

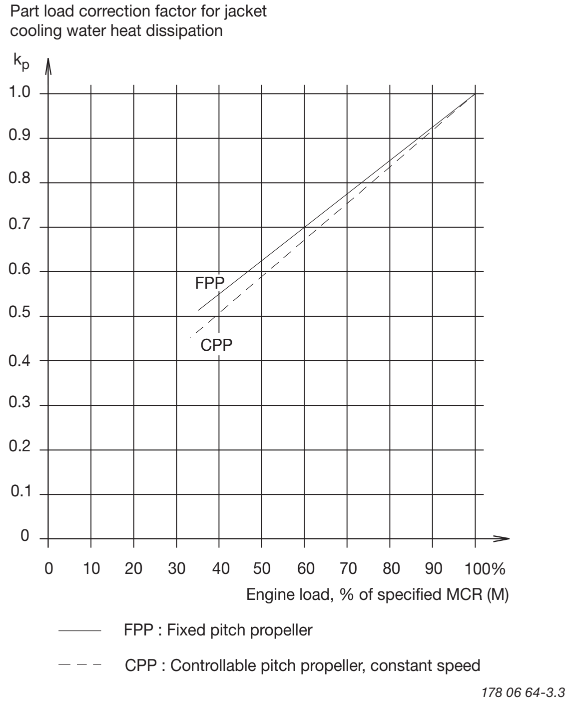
The air consumption and exhaust gas figures are expected and refer to 100% specified MCR, ISO ambient reference conditions and the exhaust gas back pressure 300 mm WC
The exhaust gas temperatures refer to after turbocharger
* Calculated in example 3, in this chapter

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 (L_1) 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 L_1, the relative jacket water heat dissipation for point M may be found, as previously described, by means of Fig. 6.04.02.



$$\text{FPP} : k_p = 0.742 \times \frac{P_S}{P_M} + 0.258$$

$$\text{CPP} : k_p = 0.822 \times \frac{P_S}{P_M} + 0.178$$

Fig. 6.04.04: Correction factor 'kp' for jacket cooling water heat dissipation at part load, relative to heat dissipation at specified MCR power

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:

   $$Q_{jw,M} = Q_{jw,L1} \times \frac{Q_{jw\%}}{100} \times 0.9 \ (0.88) \qquad [1]$$

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

   $$Q_{jw} = Q_{jw,M} \times k_p \ \text{-15\%/0\%} \qquad [2]$$

where

Q_{jw} = jacket water heat dissipation
$Q_{jw,L1}$ = jacket water heat dissipation at nominal MCR (L_1)
$Q_{jw\%}$ = 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 Qjw - may, for guidance, be estimated as 0.03 t/24h per 1 kW heat, i.e.:

M_{fw} = 0.03 x Qjw t/24h -15%/0% [3]

where

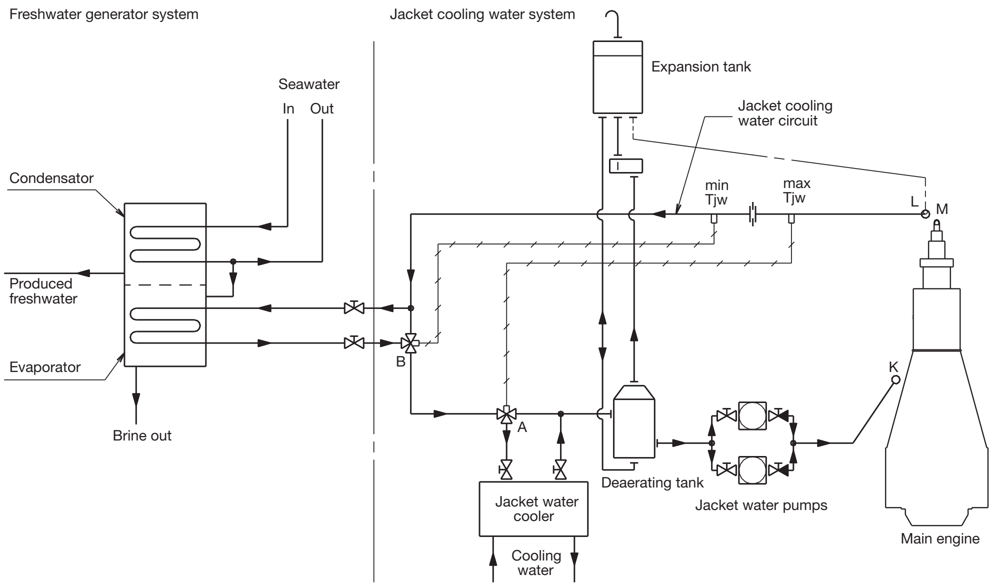
M_{fw} is the freshwater production in tons per 24 hours

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} < 80° C
Valve B: ensures that T_{jw} > 80 – 5° C = 75° 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

178 23 70-0.0

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 6S50ME-B9.3-TII with 1 high efficiency MAN TCA55-26 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_l) P_{L1}: 10,680 kW (100.0%) and 117.0 r/min (100.0%)

Specified MCR, (M) P_M: 9,612 kW (90.0%) and 111.2 r/min (95.0%)

Service rating, (S) P_S: 7,689 kW and 103.2 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 Δp_M .... 300 mm WC

The expected available jacket cooling water heat at service rating is found as follows:

$Q_{jw,L1}$ = 1,690 kW from List of Capacities
$Q_{jw\%}$ = 92.2% 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:

$$Q_{jw,M} = Q_{jw,L1} \times \frac{Q_{jw\%}}{100} \times 0.885$$

$$= 1{,}690 \times \frac{92.2}{100} \times 0.885 = 1{,}379 \text{ kW}$$

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 using 80.0% in Fig. 6.04.04
Q_{jw} = $Q_{jw,M} \times k_p$ = 1,379 x 0.852 = 1,175 kW -15%/0%

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 x Q_{jw} = 0.03 x 1,175 = 35.3 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 : power in kW at specified MCR point
n_M : speed in r/min at specified MCR point

b) The ambient conditions, and exhaust gas back-pressure:

T_{air} : actual ambient air temperature, in °C
p_{bar} : actual barometric pressure, in mbar
T_{CW} : actual scavenge air coolant temperature, in °C
Δp_M : 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 : 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} : exhaust gas amount in kg/h, to be found
T_{exh} : exhaust gas temperature in °C, to be found

$$M_{exh} = M_{L1} \times \frac{P_M}{P_{L1}} \times \left\{1 + \frac{\Delta m_{M\%}}{100}\right\} \times \left\{1 + \frac{\Delta M_{amb\%}}{100}\right\} \times \left\{1 + \frac{\Delta m_{s\%}}{100}\right\} \times \frac{P_{S\%}}{100} \quad \text{kg/h} \quad +/-5\% \quad [4]$$

$$T_{exh} = T_{L1} + \Delta T_M + \Delta T_{amb} + \Delta T_S \quad °C \quad -/+15\ °C \quad [5]$$

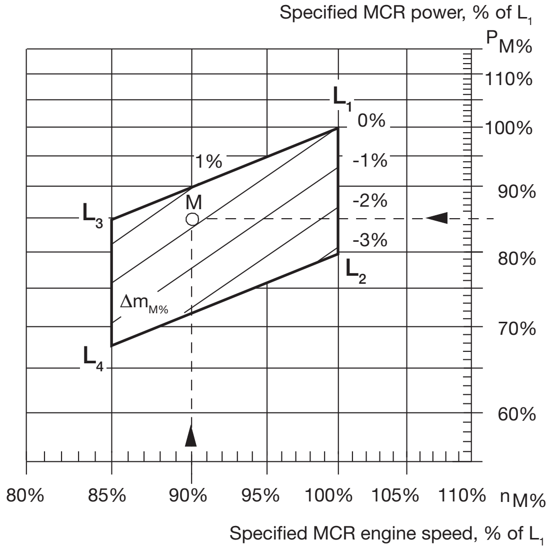
where, according to 'List of capacities', i.e. referring to ISO ambient conditions and 300 mm WC back-pressure and specified in L_1:
M_{L1}: exhaust gas amount in kg/h at nominal MCR (L_1)
T_{L1}: exhaust gas temperature after turbocharger in °C at nominal MCR (L_1)

Fig. 6.04.06: Summarising equations for exhaust gas amounts and temperatures

The partial calculations based on the influencing factors are described in the following:

a) *Correction for choice of specified MCR point*

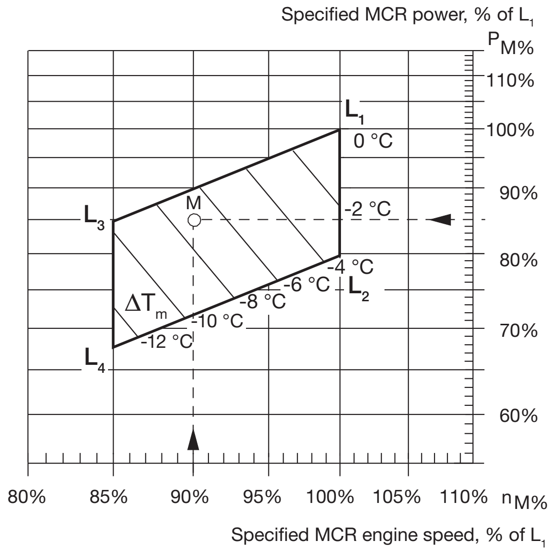
When choosing a specified MCR point 'M' other than the nominal MCR point 'L_1', the resulting changes in specific exhaust gas amount and temperature are found by using as input in diagrams the corresponding percentage values (of L_1) for specified MCR power $P_{M\%}$ and speed $n_{M\%}$:
$P_{M\%} = P_M/P_{L1} \times 100\%$
$n_{M\%} = n_M/n_{L1} \times 100\%$



$\Delta m_{M\%} = 14 \times \ln (P_M/P_{L1}) - 24 \times \ln (n_M/n_{L1})$

178 51 11-7.2

Fig. 6.04.07: Change of specific exhaust gas amount, $\Delta m_{M\%}$ in % of L_1 value



$\Delta T_M = 15 \times \ln (P_M/P_{L1}) + 45 \times \ln (n_M/n_{L1})$

178 51 13-0.2

Fig. 6.04.08: Change of exhaust gas temperature, ΔT_M in point M, in °C after turbocharger relative to L_1 value

$\Delta m_{M\%}$: change of specific exhaust gas amount, in % of specific gas amount at nominal MCR (L_1), see Fig. 6.04.07.

ΔT_M : change in exhaust gas temperature after turbocharger relative to the L1 value, in °C, see Fig. 6.04.08. ($P_O = P_M$)

b) Correction for actual ambient conditions and back-pressure

For ambient conditions other than ISO 3046-1:2002 (E) and 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.

Parameter	**Change**	**Change of exhaust gas temperature**	**Change of exhaust gas amount**
Blower inlet temperature	+ 10° C	+ 16.0° C	- 4.1 %
Blower inlet pressure (barometric pressure)	+ 10 mbar	- 0.1° C	+ 0.3 %
Charge air coolant temperature (seawater temperature)	+ 10° C	+ 1.0° C	+ 1.9 %
Exhaust gas back pressure at the specified MCR point	+ 100 mm WC	+ 5.0° C	-1.1 %

Fig. 6.04.09: Correction of exhaust gas data for ambient conditions and exhaust gas back pressure

$\Delta M_{amb\%}$ = - 0.41 x (T_{air} - 25) + 0.03 x (p_{bar} - 1000) + 0.19 x (T_{CW} - 25) - 0.011 x (Δp_M - 300) % [7]

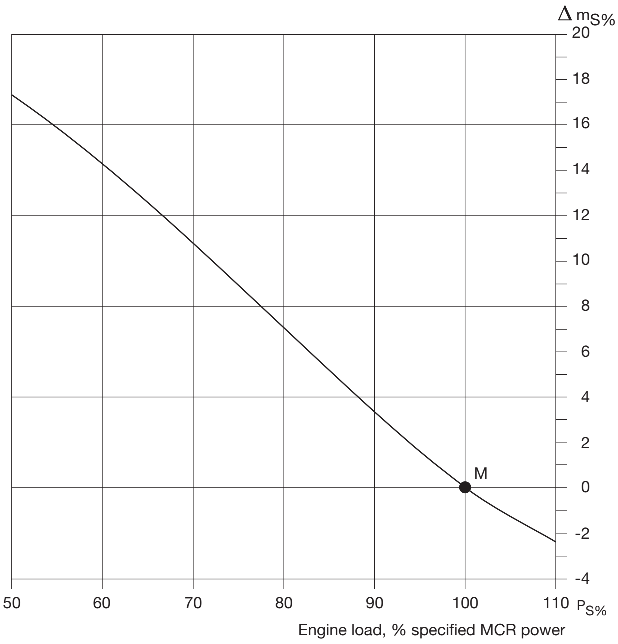
ΔT_{amb} = 1.6 x (T_{air} - 25) - 0.01 x (p_{bar} - 1000) +0.1 x (T_{CW} - 25) + 0.05 x (Δp_M - 300) °C [8]

where the following nomenclature is used:

$\Delta M_{amb\%}$: change in exhaust gas amount, in % of amount at ISO conditions

ΔT_{amb} : change in exhaust gas temperature, in °C compared with temperatures at ISO conditions

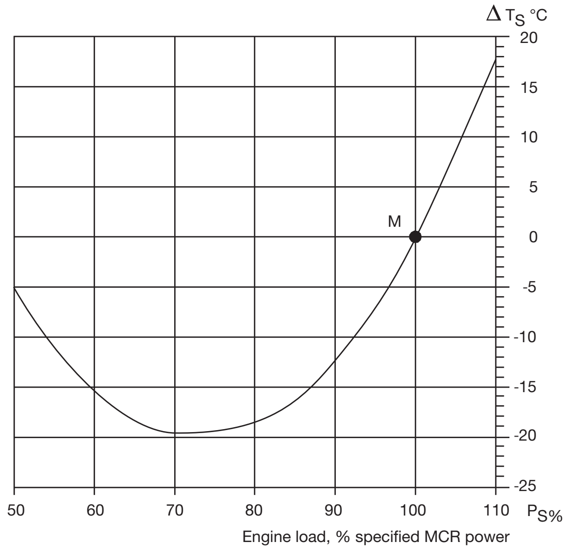
Fig. 6.04.10: Exhaust gas correction formula for ambient conditions and exhaust gas back pressure



$P_{S\%}$ = (P_S/P_M) x 100%

$\Delta m_{S\%}$= 37 x $(P_S/P_M)^3$ - 87 x $(P_S/P_M)^2$ + 31 x (P_S/P_M) + 19

Fig. 6.04.11: Change of specific exhaust gas amount, $\Delta m_{s\%}$ in % at part load, and valid for FPP and CPP



$P_{S\%}$ = (P_S/P_M) x 100%

ΔT_S = 280 x $(P_S/P_M)^2$ - 410 x (P_S/P_M) + 130

Fig. 6.04.12: Change of exhaust gas temperature, ΔT_S in °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 $P_{S\%}$ = (P_S/P_M) x 100%:

$\Delta m_{s\%}$: change in specific exhaust gas amount, in % of specific amount at specified MCR point, see Fig. 6.04.11.

ΔT_s : change in exhaust gas temperature, in °C, see Fig. 6.04.12.

Calculation of Exhaust Data for Derated Engine

Example 3:

Expected exhaust gas data for a *derated 6S50ME-B9.3-TII with 1 high efficiency MAN TCA55-26 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, (L_1) P_{L1}: 10,680 kW (100.0%) and 117.0 r/min (100.0%)

Specified MCR, (M) P_M: 9,612 kW (90.0%) and 111.2 r/min (95.0%)

Service rating, (S) P_S: 7,689 kW and 103.2 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 Δp_M .... 300 mm WC

a) Correction for choice of specified MCR point M:

$$P_{M\%} = \frac{9,612}{10,680} \times 100 = 90.0\%$$

$$n_{M\%} = \frac{111.2}{117.0} \times 100 = 95.0\%$$

By means of Figs. 6.04.07 and 6.04.08:

$\Delta m_{M\%}$ = -0.25%
ΔT_M = -3.9 °C

b) Correction for ambient conditions and back-pressure:

By means of equations [7] and [8]:

$$\Delta M_{amb\%} = -0.41 \times (20 - 25) + 0.03 \times (1,013 - 1,000) + 0.19 \times (18 - 25) - 0.011 \times (300 - 300)\%$$

$$\Delta M_{amb\%} = +1.11\%$$

$$\Delta T_{amb} = 1.6 \times (20 - 25) - 0.01 \times (1,013 - 1,000) + 0.1 \times (18 - 25) + 0.05 \times (300 - 300)\ °C$$

$$\Delta T_{amb} = -8.8\ °C$$

c) Correction for the engine load:

Service rating = 80% of specified MCR power
By means of Figs. 6.04.11 and 6.04.12:

$\Delta m_{S\%}$ = + 7.1%

ΔT_S = - 18.8 °C

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} = 80,800 kg/h

$$M_{exh} = 80,800 \times \frac{9,612}{10,680} \times (1 + \frac{-0.25}{100}) \times$$

$$(1 + \frac{1.11}{100}) \times (1 + \frac{7.1}{100}) \times \frac{80}{100} = 62,841 \text{ kg/h}$$

M_{exh} = 62,800 kg/h ±15%

The exhaust gas temperature

T_{L1} = 235 °C

T_{exh} = 235 - 3.9 - 8.8 - 18.8 = 203.5 °C

T_{exh} = 203.5 °C ±5 °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 $P_{S\%}$ = 100, $\Delta m_{s\%}$ = 0.0 and ΔT_s = 0.0.

For ISO ambient reference conditions where $\Delta M_{amb\%}$ = 0.0 and ΔT_{amb} = 0.0, the corresponding calculations will be as follows:

$$M_{exh,M} = 80,800 \times \frac{9,612}{10,680} \times (1 + \frac{-0.25}{100}) \times (1 + \frac{0.0}{100})$$

$$\times (1 + \frac{0.0}{100}) \times \frac{100.0}{100} = 72,558 \text{ kg/h}$$

$M_{exh,M}$ = 72,600 kg/h ±15%

$T_{exh,M}$ = 235 - 3.9 + 0 + 0 = 231.1 °C

$T_{exh,M}$ = 231.1 °C ±5 °C

The air consumption will be:

72,558 x 0.982 kg/h = 71,252 kg/h <=>
71,252 / 3,600 kg/s = 19.8 kg/s

Fuel

7

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 sulpher content in fuel oil due to exhaust gas emission control.

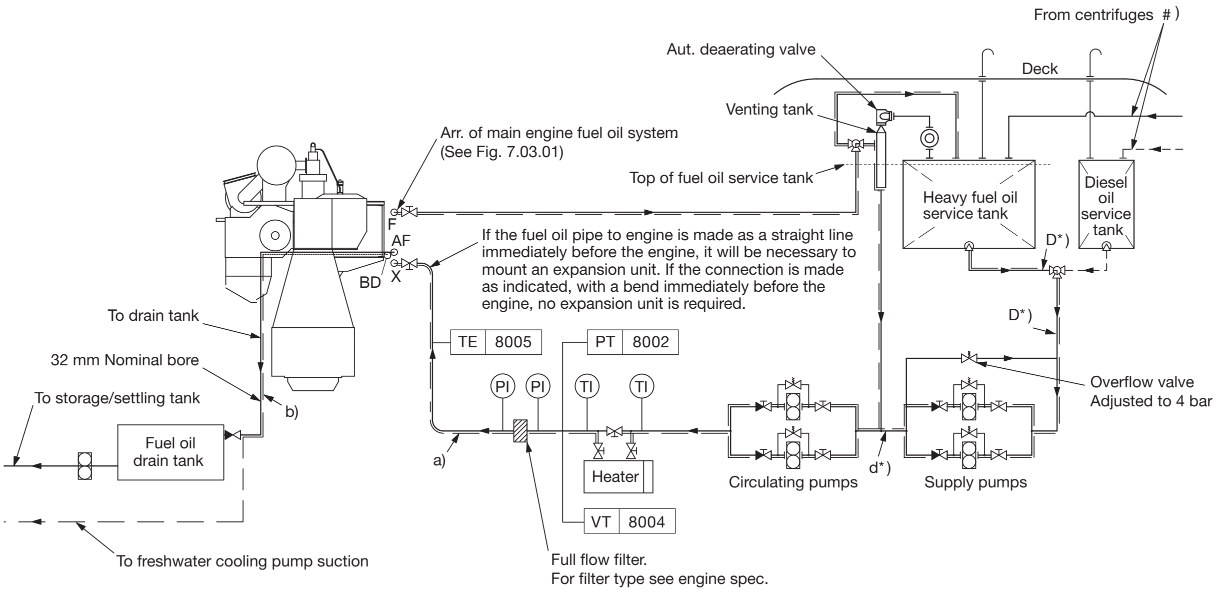
In special circumstances a change-over to diesel oil may become necessary – and this can be performed at any time, even when the engine is not running. Such a change-over may become necessary if, for instance, the vessel is expected to be inactive for a prolonged period with cold engine e.g. due to:

- 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



#) Approximately the following quantity of fuel oil should be treated in the centrifuges: 0.23 l/kwh as explained in Section 7.05. The capacity of the centrifuges to be according to manufacturer's recommendation.

*) D to have min. 50% larger passage area than d.

078 70 06-1.1.0a

- - - - - - 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 'AF' to the fuel oil drain tank.

The flow rate in litres is approximately as listed in Table 7.01.02.

Engine	Flow rate, litres/cyl. h. HFO 12 cSt
S50ME-C, G/S50ME-B	0.25
S46/40/35/30ME-B	0.25
G40ME-B	0.25

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 'AF' is to collect pure fuel oil from the fuel pumps as well as the unintentional leakage from the high pressure pipes. From the drain tank, the drained fuel oil is led to a storage 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.

Drain 'AF' is 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 NO_x 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.

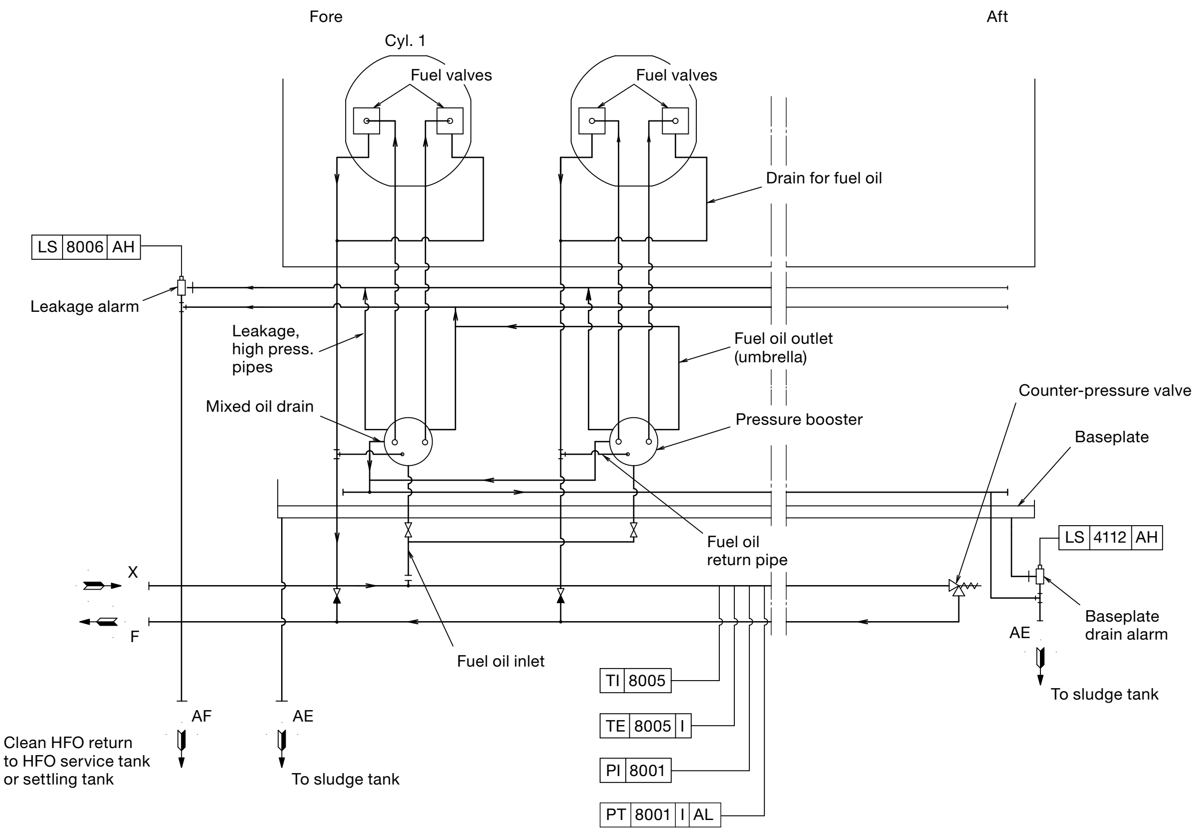
Heavy fuel oils limited by this specification have, to the extent of the commercial availability, been used with satisfactory results on MAN B&W two-stroke low speed diesel engines.

The data refers to the fuel as supplied i.e. before any on-board cleaning.

Guiding specification (maximum values)		
Density at 15 °C	kg/m³	≤ 1.010*
Kinematic viscosity		
at 100 °C	cSt	≤ 55
at 50 °C	cSt	≤ 700
Flash point	°C	≥ 60
Pour point	°C	≤ 30
Carbon residue	% (m/m)	≤ 20
Ash	% (m/m)	≤0.15
Total sediment potential	% (m/m)	≤0.10
Water	% (v/v)	≤ 0.5
Sulphur	% (m/m)	≤ 4.5
Vanadium	mg/kg	≤ 450
Aluminum + Silicon	mg/kg	≤60
Equal to ISO 8217:2010 - RMK 700 / CIMAC recommendation No. 21 - K700		
* 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'

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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/m^3 and covered with glass cloth of minimum 400 g/m^2.

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/m^3 covered with glass cloth of minimum 400 g/m^2.

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/m^2, containing mineral wool stuffed to minimum 150 kg/m^3.

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.

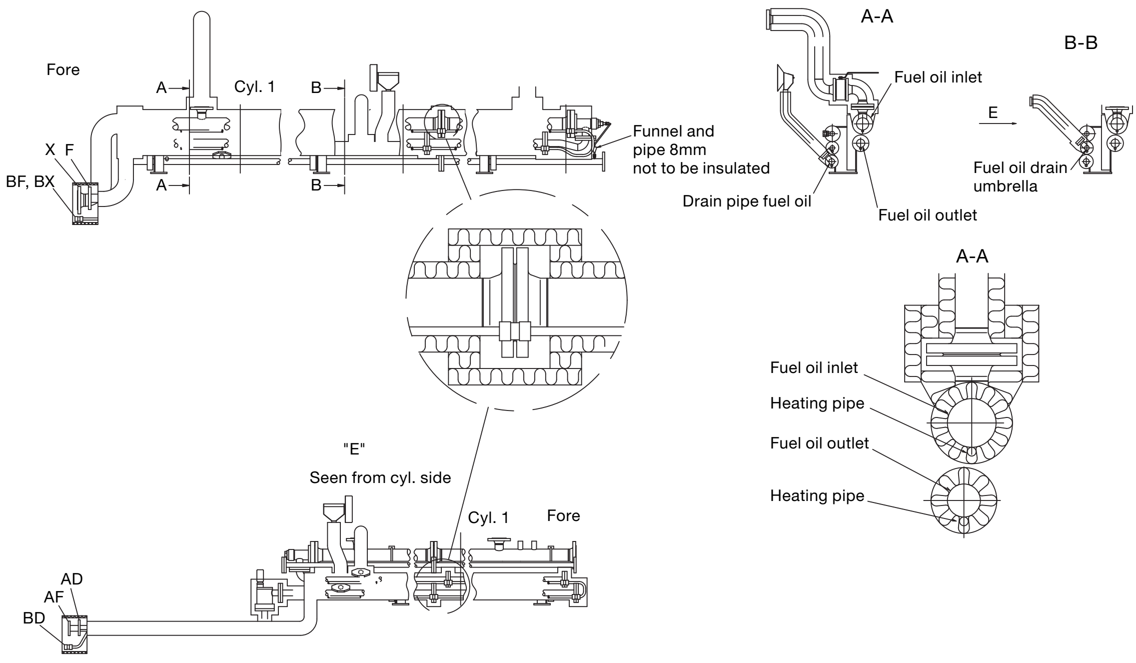

Fig. 7.04.01: Details of fuel oil pipes insulation, option: 4 35 121. Example from 98-50 MC engine

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Heat Loss in Piping

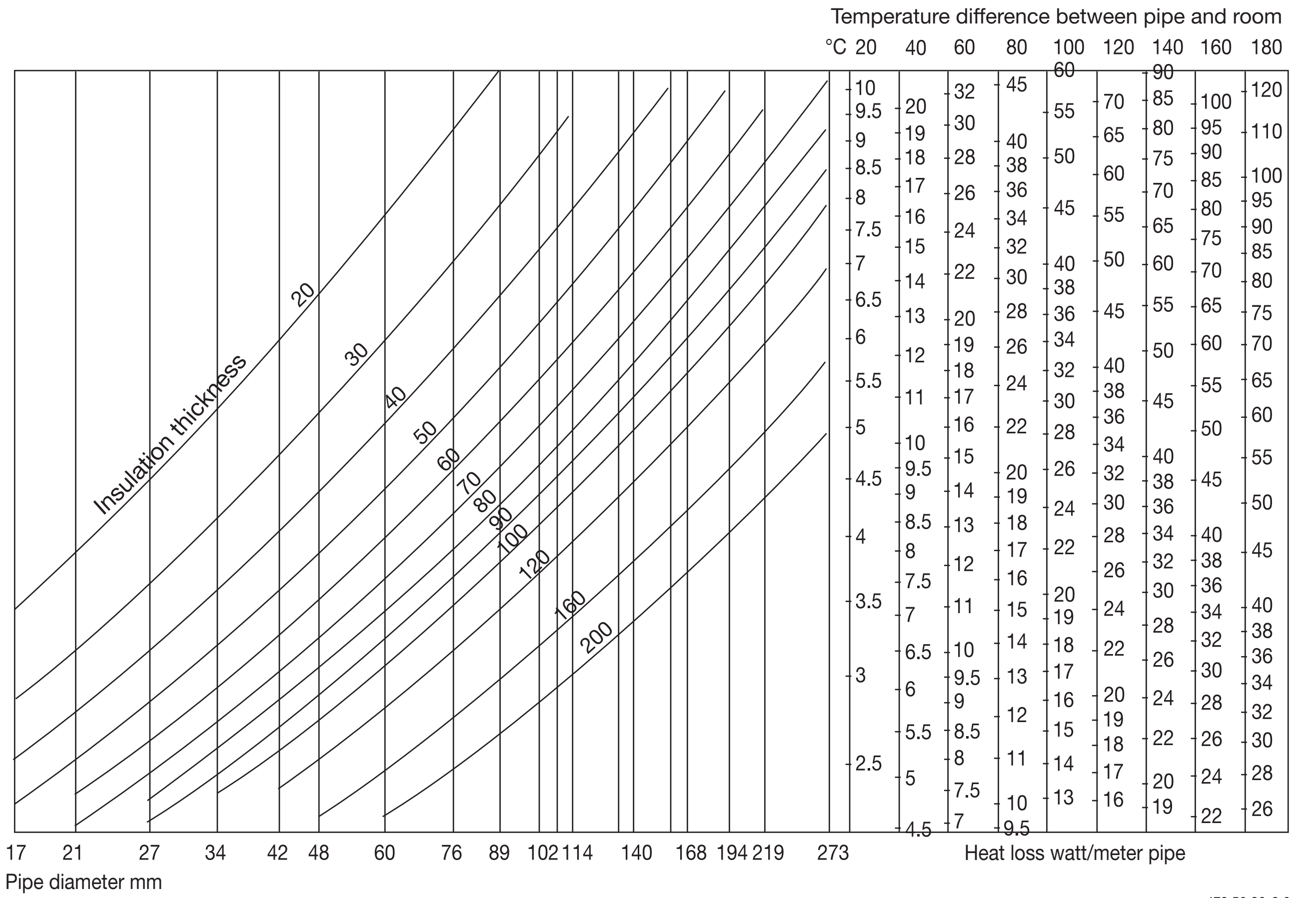


Fig. 7.04.02: Heat loss/Pipe cover

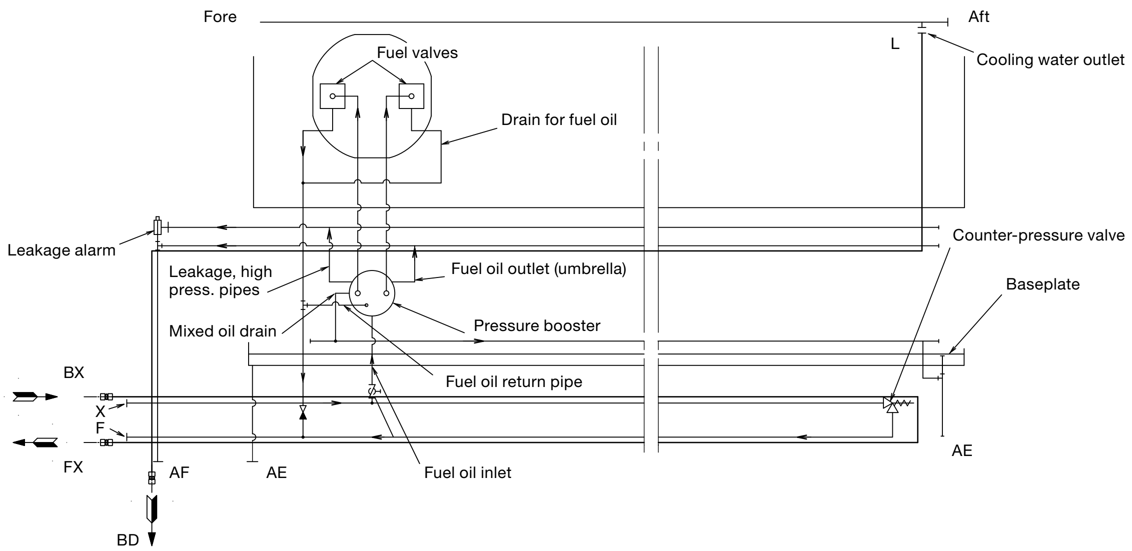
Fuel Oil Pipe Heat Tracing

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 °C.

   To heat the pipe to pumping level we recommend to use 100 watt leaking/meter pipe.



The letters refer to list of 'Counterflanges'

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Fig. 7.04.03: Fuel oil pipe heat tracing

Fuel Oil and Lubricating Oil Pipe Spray Shields

In order to fulfil IMO regulations, fuel oil and lubricating oil pipe assemblies are to be enclosed by spray shields 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.

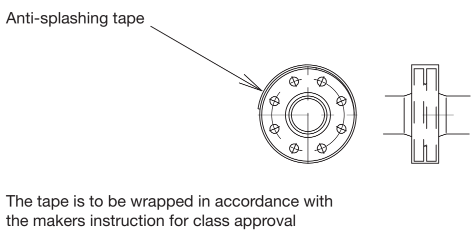

Fig. 7.04.04a: Spray Shields by anti-splashing tape

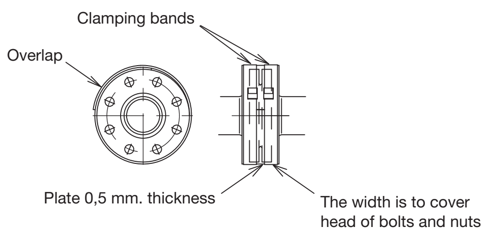

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Fig. 7.04.04b: Spray Shields by clamping bands

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 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: ÷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: ÷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.

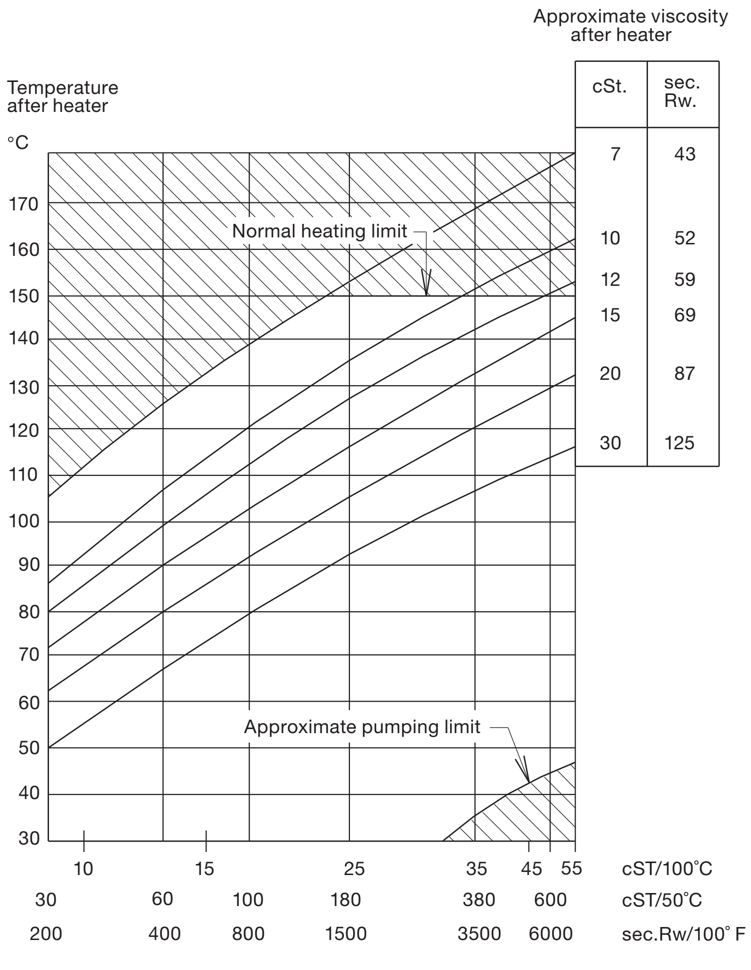


Fig. 7.05.01: Fuel oil heating chart

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.

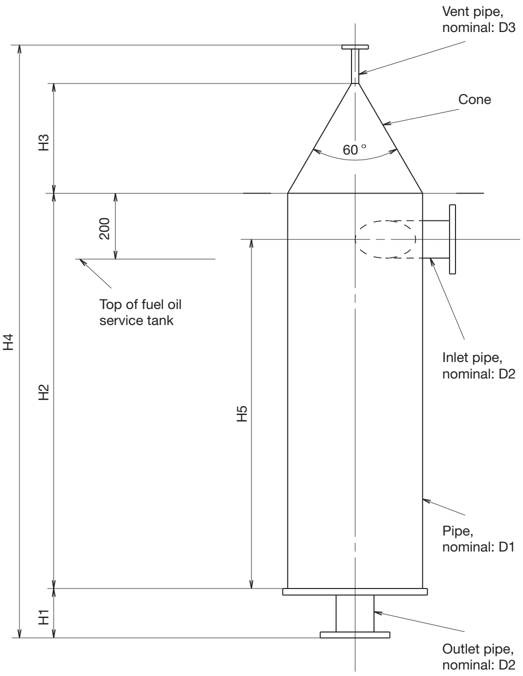
Fuel oil flow .... see 'List of capacities'
Working pressure .... 10 bar
Test pressure...................... according to class rule
Absolute fineness.. 50 μm
Working temperature .... maximum 150 °C
Oil viscosity at working temperature .... 15 cSt
Pressure drop at clean filter........ maximum 0.3 bar
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.



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Flow m³/h	Dimensions in mm							
Q (max.)*	D1	D2	D3	H1	H2	H3	H4	H5
1.3	150	32	15	100	600	171.3	1,000	550
2.1	150	40	15	100	600	171.3	1,000	550
5.0	200	65	15	100	600	171.3	1,000	550
8.4	400	80	15	150	1,200	333.5	1,800	1,100
11.5	400	90	15	150	1,200	333.5	1,800	1,100
19.5	400	125	15	150	1,200	333.5	1,800	1,100
29.4	500	150	15	150	1,500	402.4	2,150	1,350
43.0	500	200	15	150	1,500	402.4	2,150	1,350

* The maximum flow of the fuel oil circulation pump

Fig. 07.05.02: Fuel oil venting box

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

The emulsification of water into the fuel oil reduces the NO_x 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 NO_x emission, the exhaust gas temperature will decrease due to the reduced air / exhaust gas ratio and the increased specific heat of the exhaust gas.

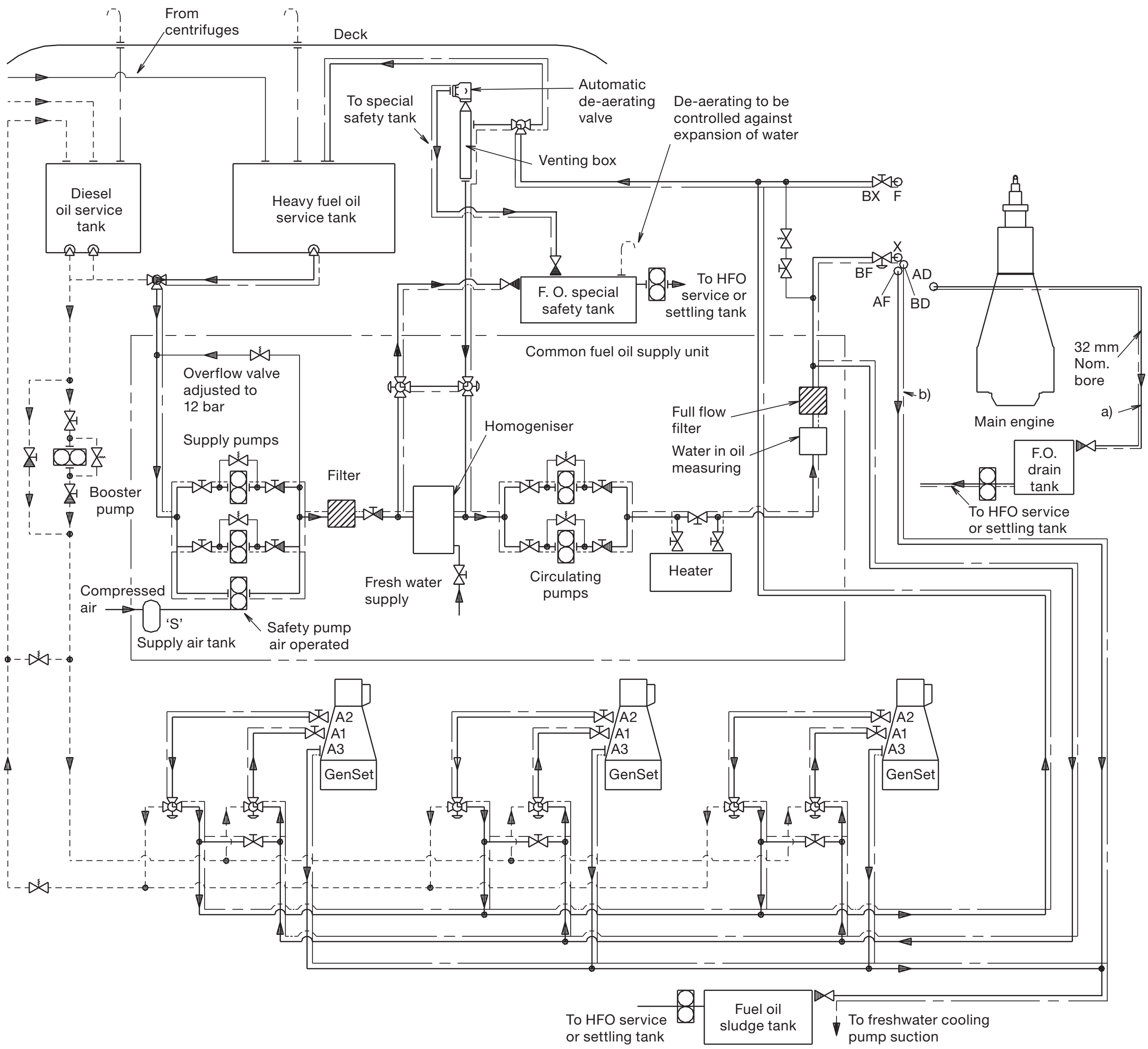
Depending on the water content, this will have an impact on the calculation and design of the following items:

- 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'



Diesel oil
Heavy fuel oil
Heated pipe with insulation

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

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'.

198 99 01-8.3

Fig. 7.06.01: System for emulsification of water into the fuel common to the main engine and MAN GenSets

Lubricating Oil

8

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 the 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.

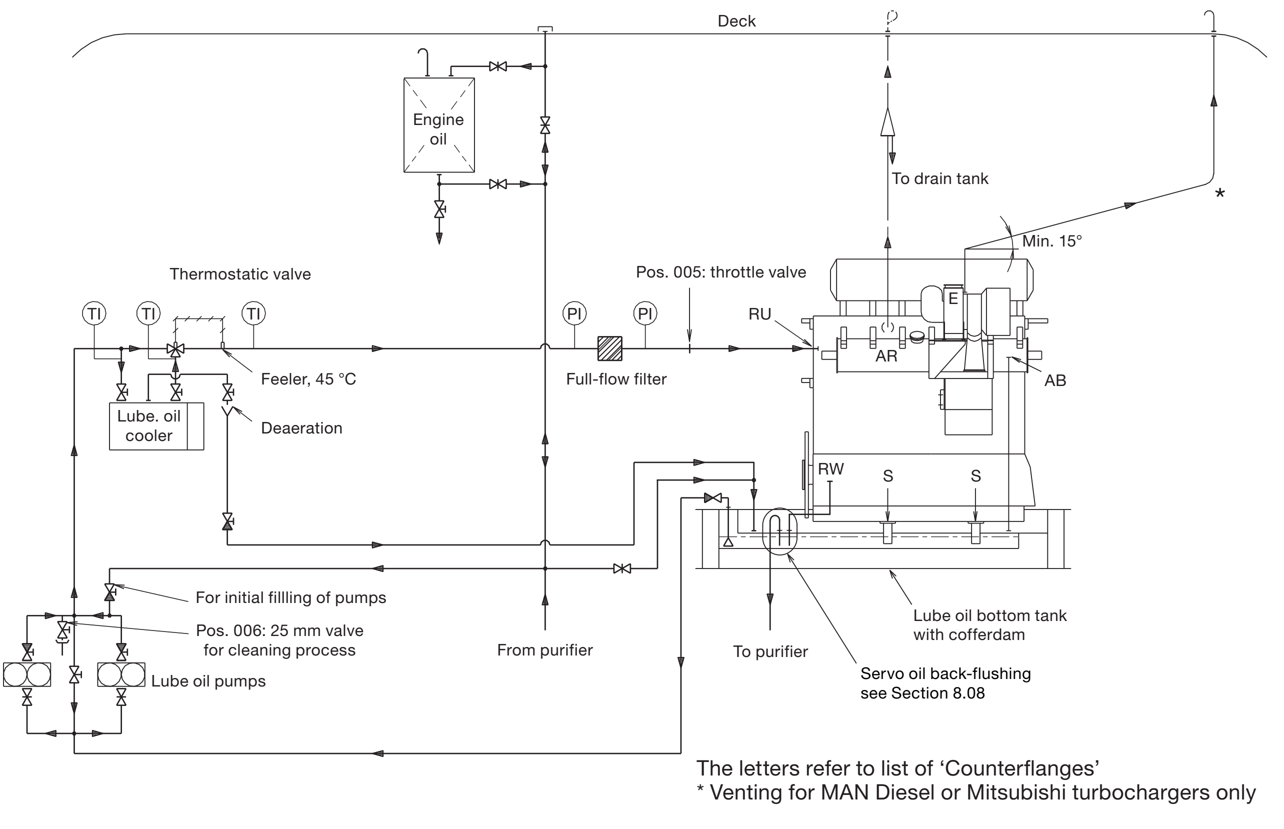


Fig. 8.01.01 Lubricating and cooling oil system

Hydraulic Power Supply Unit

Internally on the engine, the system oil inlet RU is connected to the Hydraulic Power Supply unit (HPS) which supplies the hydraulic oil to the Hydraulic Cylinder Units (HCUs). The HPS unit is mounted onto the engine and is electrically driven.

The hydraulic power supply unit shown in Fig. 8.02.01, consists of:

- an automatic main filter with a redundancy filter, in parallel
- two electrically driven pumps
- a safety and accumulator block

RW is the oil outlet from the automatic backflushing filter.

The HPS in service

The max. operating pressure for the hydraulic oil to the HCUs is 300 bar.

At start and in service both pumps are activated. Each of the pumps has a capacity sufficient to operate the engine with 55% engine power enabling around 80% ship speed, should one pump fail.

The hydraulic oil is supplied to the Hydraulic Cylinder Units (HCU), where it is supplied to the electronic Fuel Injection system, which perform the fuel injection.

The electronic signals to the proportional Electronic Fuel Injection control (ELFI) valves are given by the Engine Control System, see Chapter 16, Engine Control System (ECS).

Hydraulic Power Supply Unit and Lubricating Oil Pipes

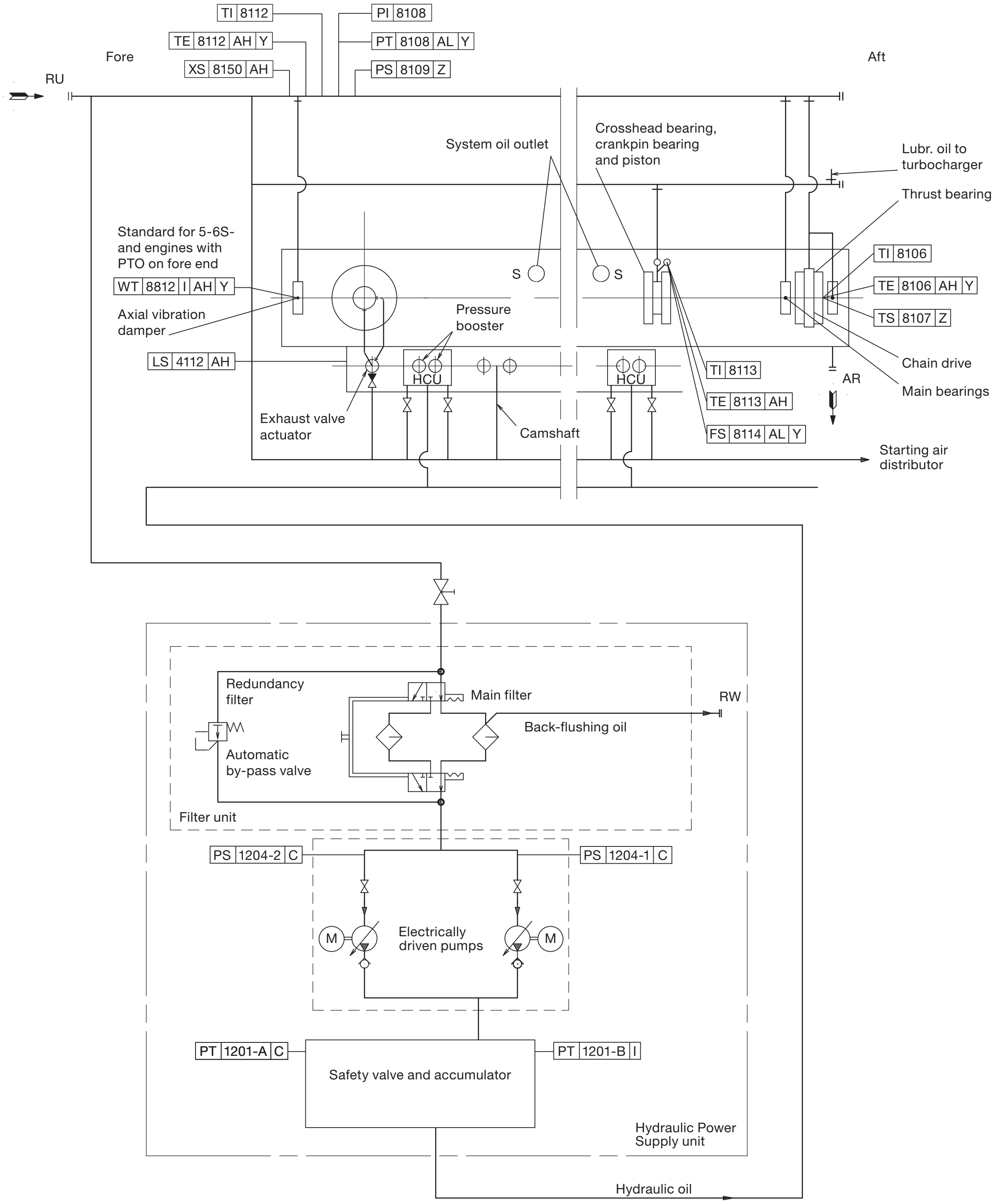


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Fig. 8.02.01: Hydraulic Power Supply Unit and lubricating oil pipes

Lubricating Oil Pipes for Turbochargers

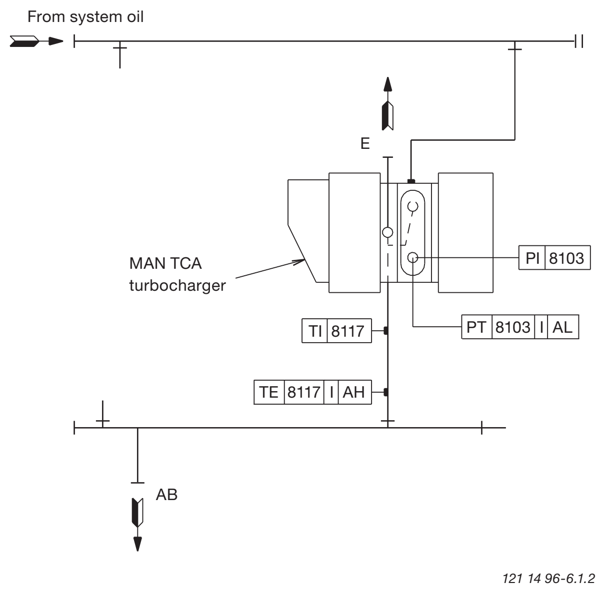

Fig. 8.03.01: MAN turbocharger type TCA

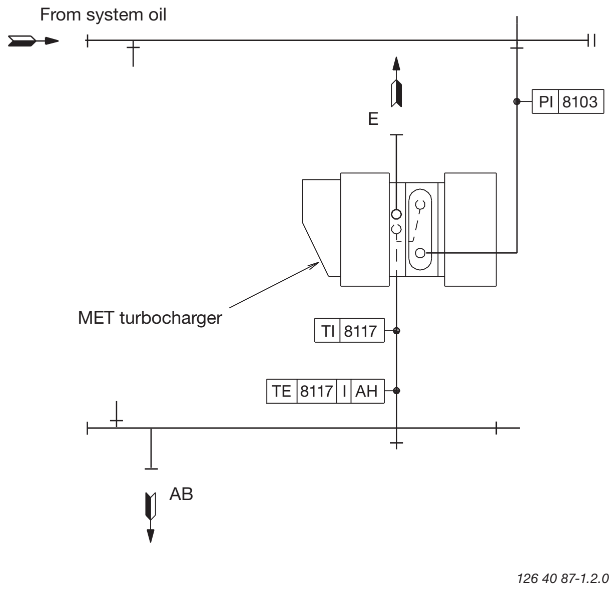

Fig. 8.03.03: Mitsubishi turbocharger type MET

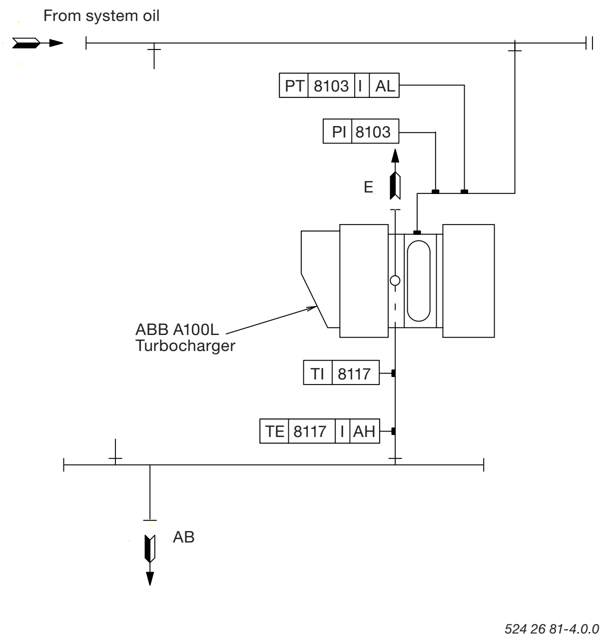

Fig. 8.03.03: ABB turbocharger type A100L

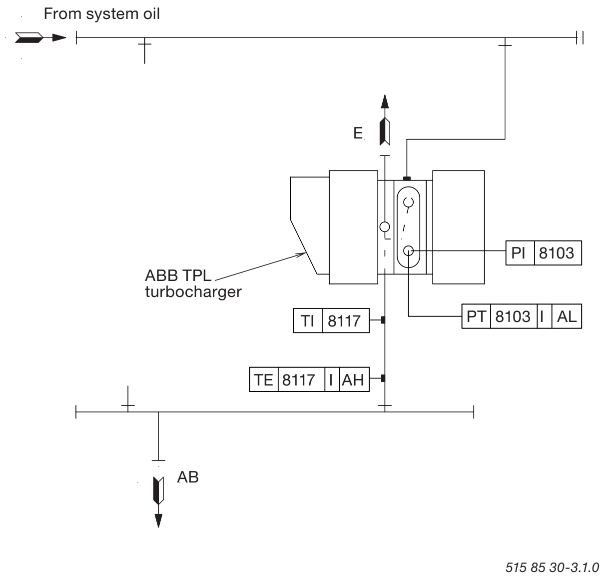

Fig. 8.03.02: ABB turbocharger type TPL85B14-16 / TPL 91B12

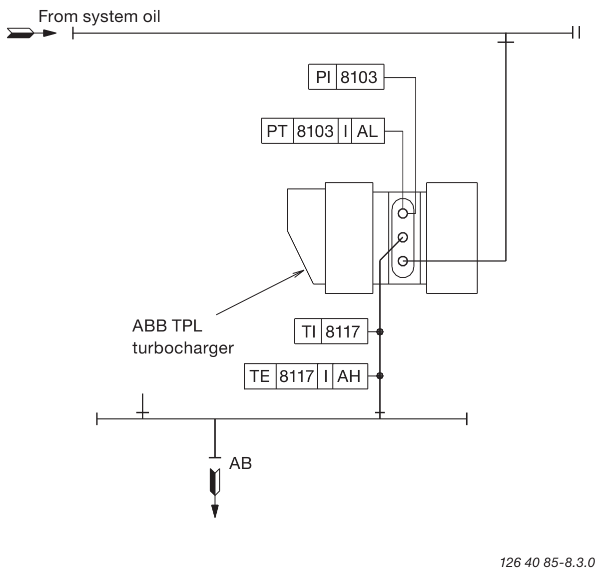

Fig. 8.03.02: ABB turbocharger type TPL65B12 - TPL85B12

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 detergengy 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).

Company	Circulating oil SAE 30, BN 5-10
Aegean	Alfasys 305
BP	OE-HT 30
Castrol	CDX 30
Chevron	Veritas 800 Marine 30
ExxonMobil	Mobilgard 300
Gulf Oil Marine	GulfSea Superbear 3006
Lukoil	Navigo 6 SO
JX	Marine S30
Shell	Melina S 30
Sinopec	System Oil 3005
Total	Atlanta Marine D3005

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.......................................4.2 bar
Delivery pressure ....4.2 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........................4.2 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 ....4.2 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.

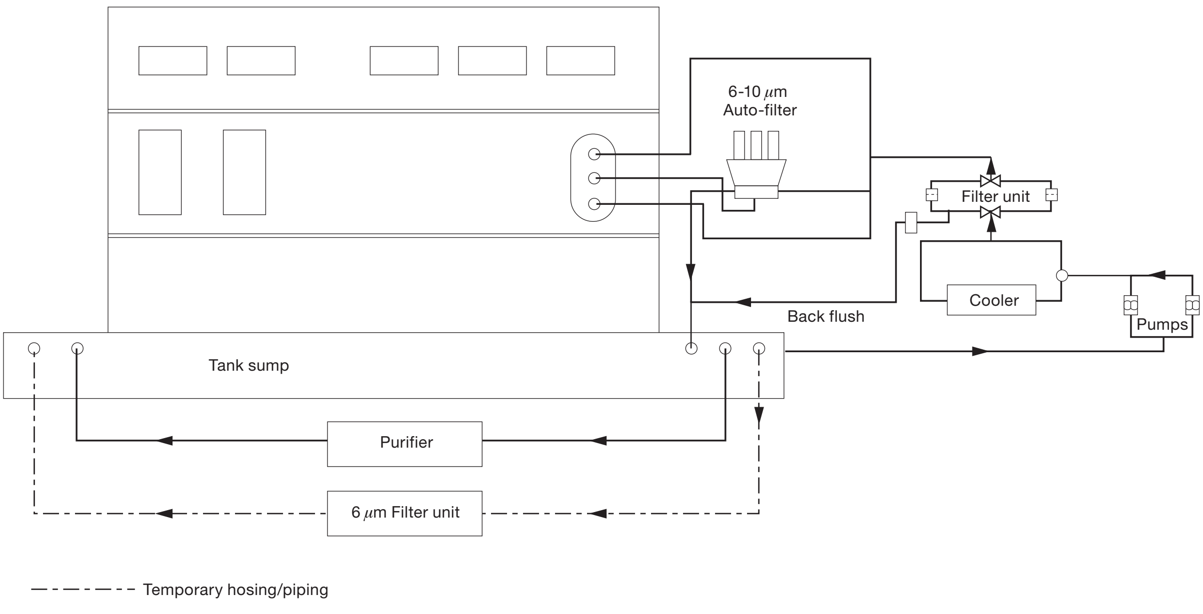

Fig. 8.05.01: Lubricating oil system with temporary hosing/piping for flushing at the shipyard

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.

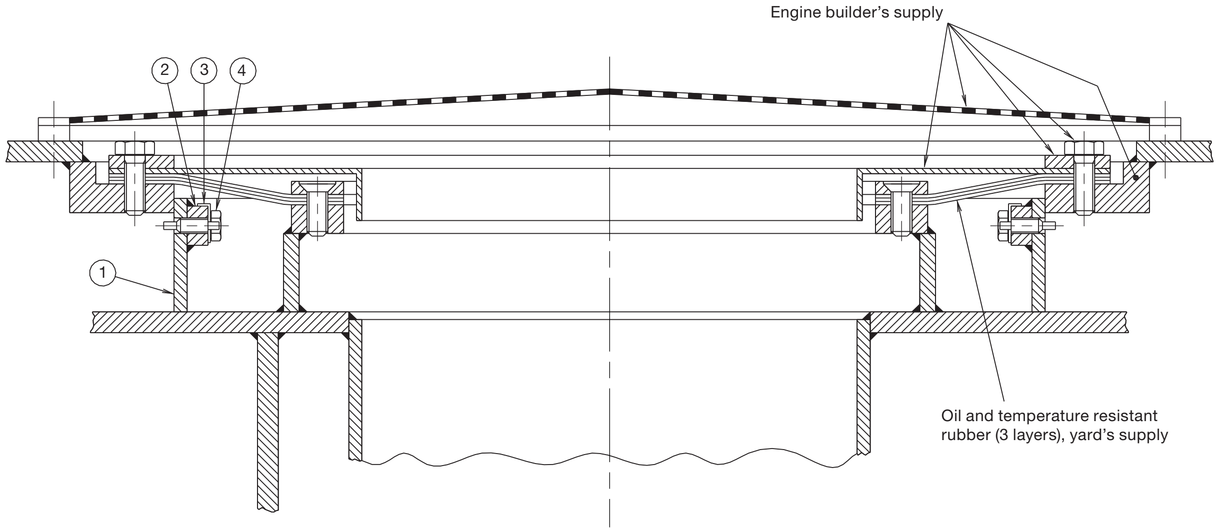

Fig. 8.05.02: Lubricating oil outlet

Crankcase Venting and Bedplate Drain Pipes

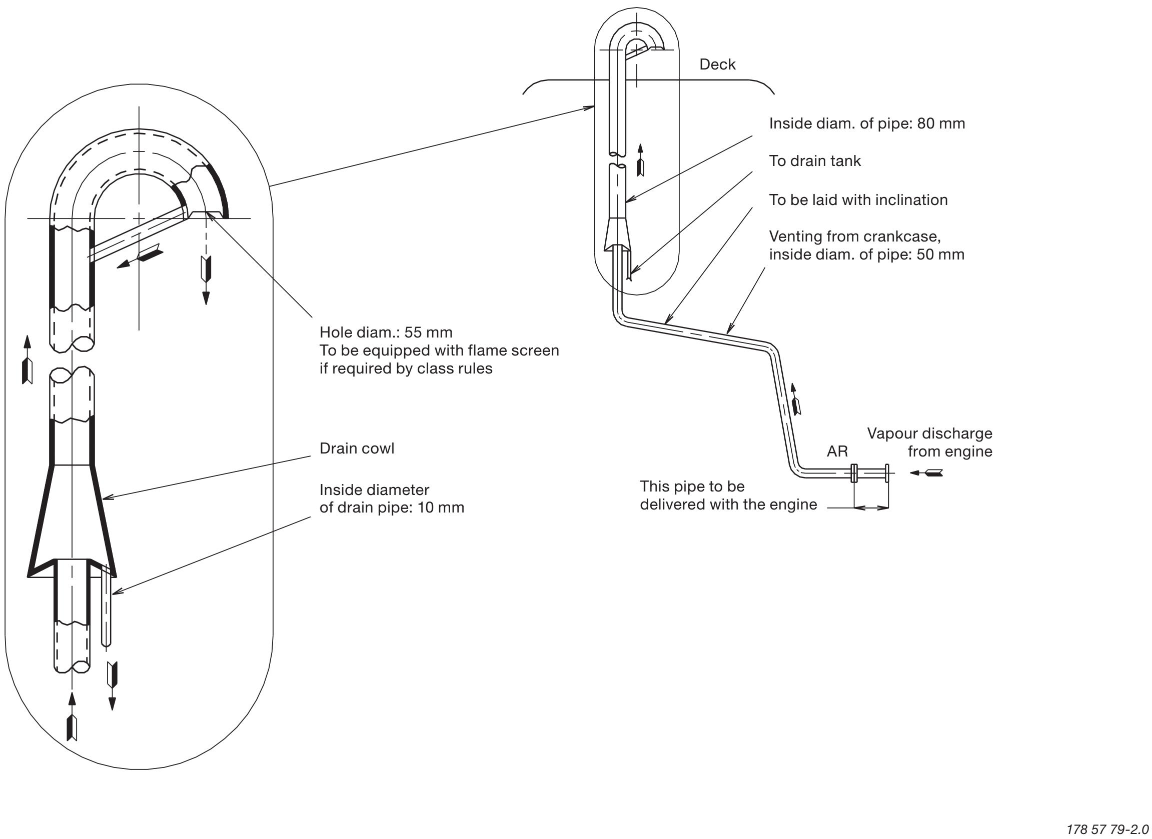

Fig. 8.07.01: Crankcase venting

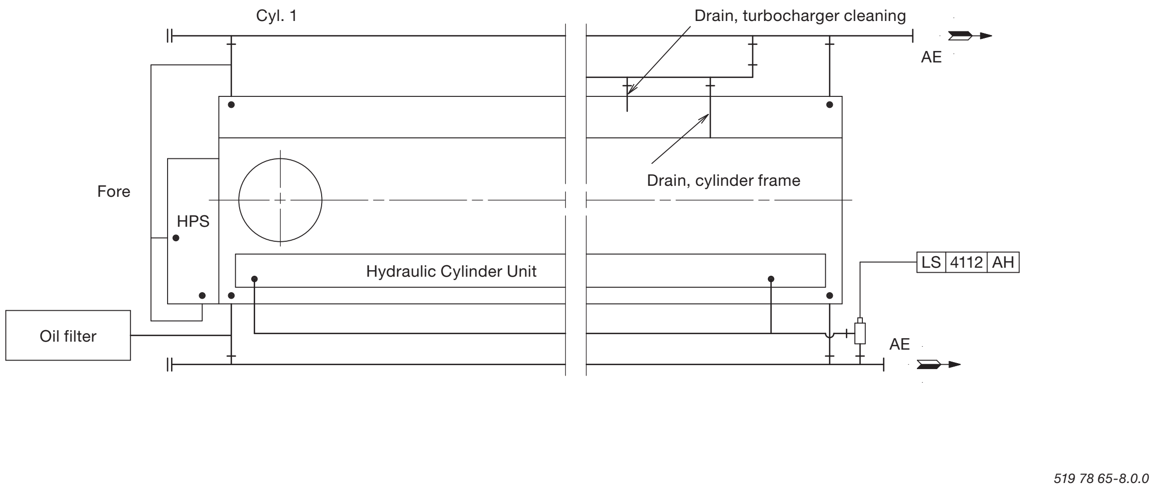

Fig. 8.07.02: Bedplate drain pipes

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.

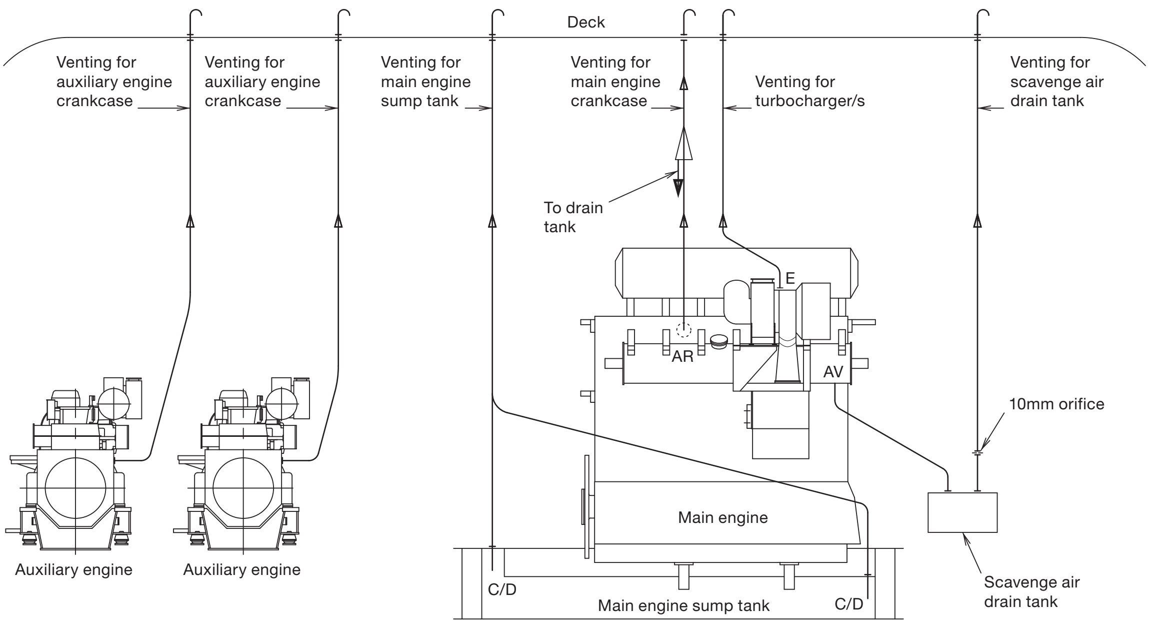

Fig. 8.07.03a: Separate venting of all systems directly to outside air above deck

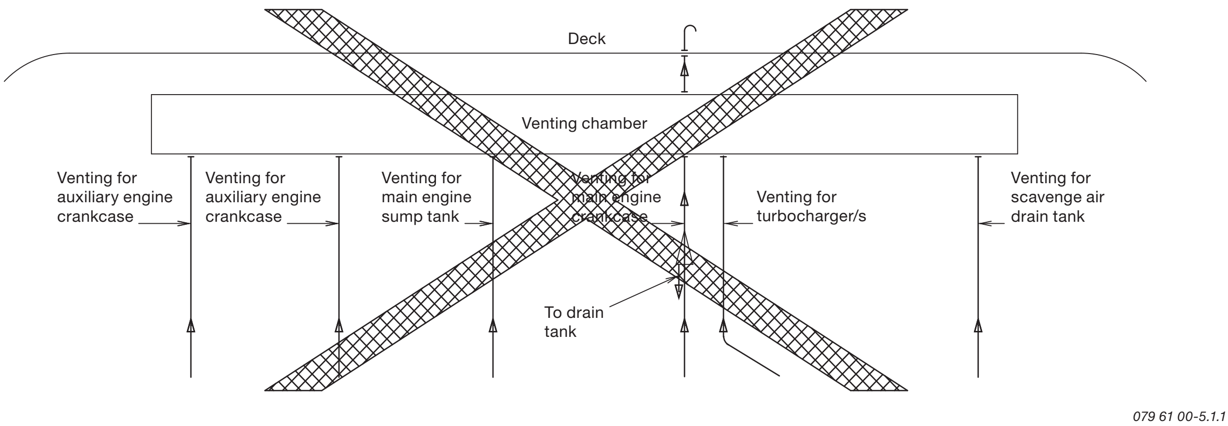

*Fig. 8.07.03b: Venting through a common venting chamber is **not recommended***

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.

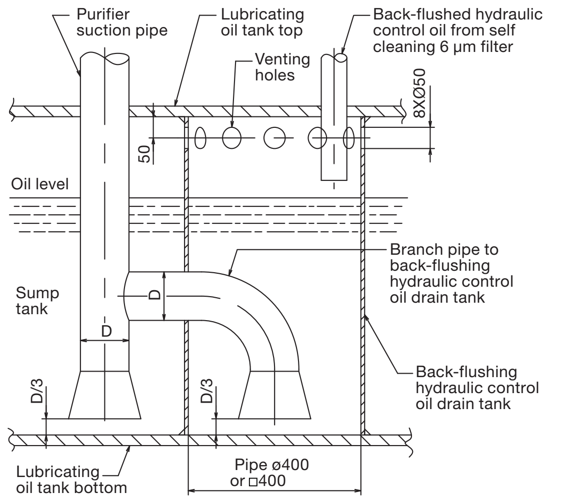

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Fig. 8.08.01: Back-flushing servo oil drain tank

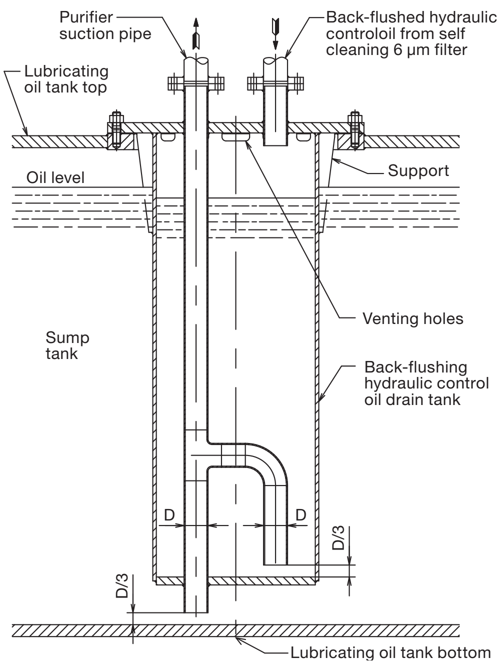

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Fig. 8.08.02: Alternative design for the back-flushing servo oil drain tank

Separate System for Hydraulic Control Unit

This section is not applicable

Cylinder Lubrication

9

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

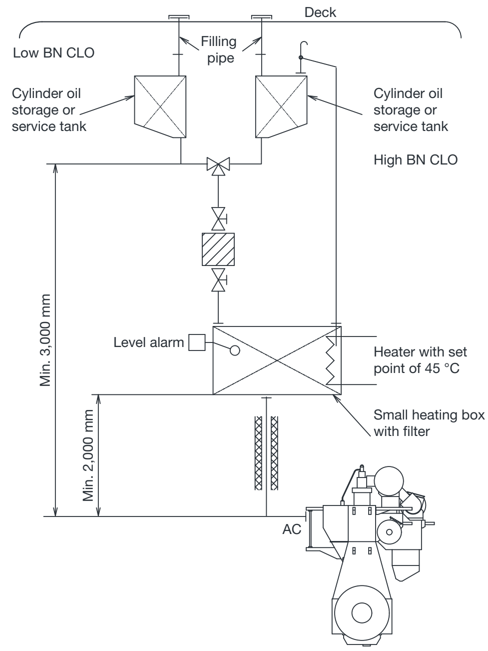
In short, MAN Diesel and Turbo recommends the use of cylinder oils with the following main properties:

- 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.



The letters refer to list of ‘Counterflanges’

178 52 37-6.3

Fig. 9.01.01: Cylinder lubricating oil system

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).

Company	Cylinder oil name, SAE 50	BN level
Aegean	Alfacylo 540 LS	40
	Alfacylo 100 HS	100
BP	CL-DX 405	40
	Energol CL 100 ACC	100
Castrol	Cyltech 40SX	40
	Cyltech CL 100 ACC	100
Chevron	Taro Special HT LS 40	40
	Taro Special HT 100	100
ExxonMobil	Mobilgard L540	40
	Mobilgard 5100	100
Gulf Oil Marine	GulfSea Cylcare DCA 5040H	40
	GulfSea Cylcare 50100	100
JX Nippon Oil & Energy	Marine C405	40
	MC-1005-8 *(internal code)*	100
Lukoil	Navigo 40 MCL	40
	Navigo 100 MCL	100
Shell	Alexia S6	100
Sinopec	Marine Cylinder Oil 5040	40
Total	Talusia LS 40	40
	Talusia Universal 100	100

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, plese 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.

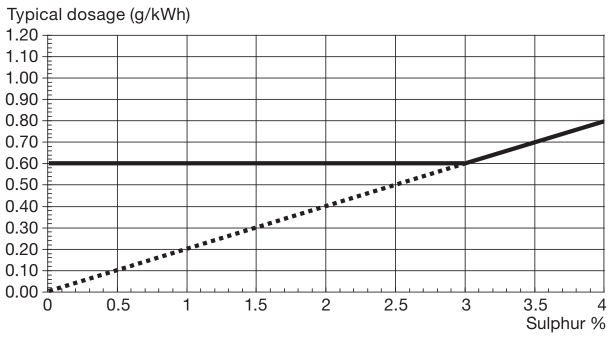


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Fig. 9.02.01a: ACC = 0.20 g/kWh × S% and BN100 cylinder oil – average consumption less than 0.65 g/kWh

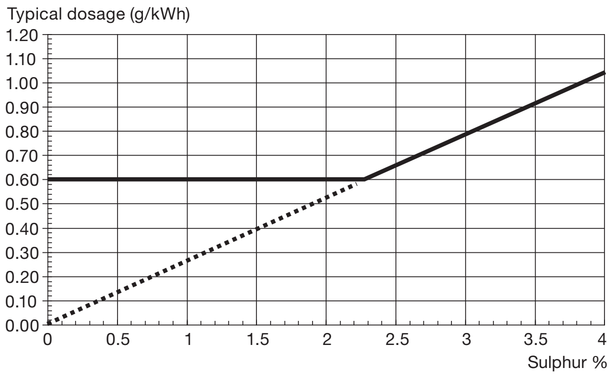

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Fig. 9.02.01b: ACC = 0.26 g/kWh × S% and BN100 cylinder oil – average consumption less than 0.7 g/kWh

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 electricallly 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 juntion box on the engine. See Figs. 9.02.02a and 9.02.02b.

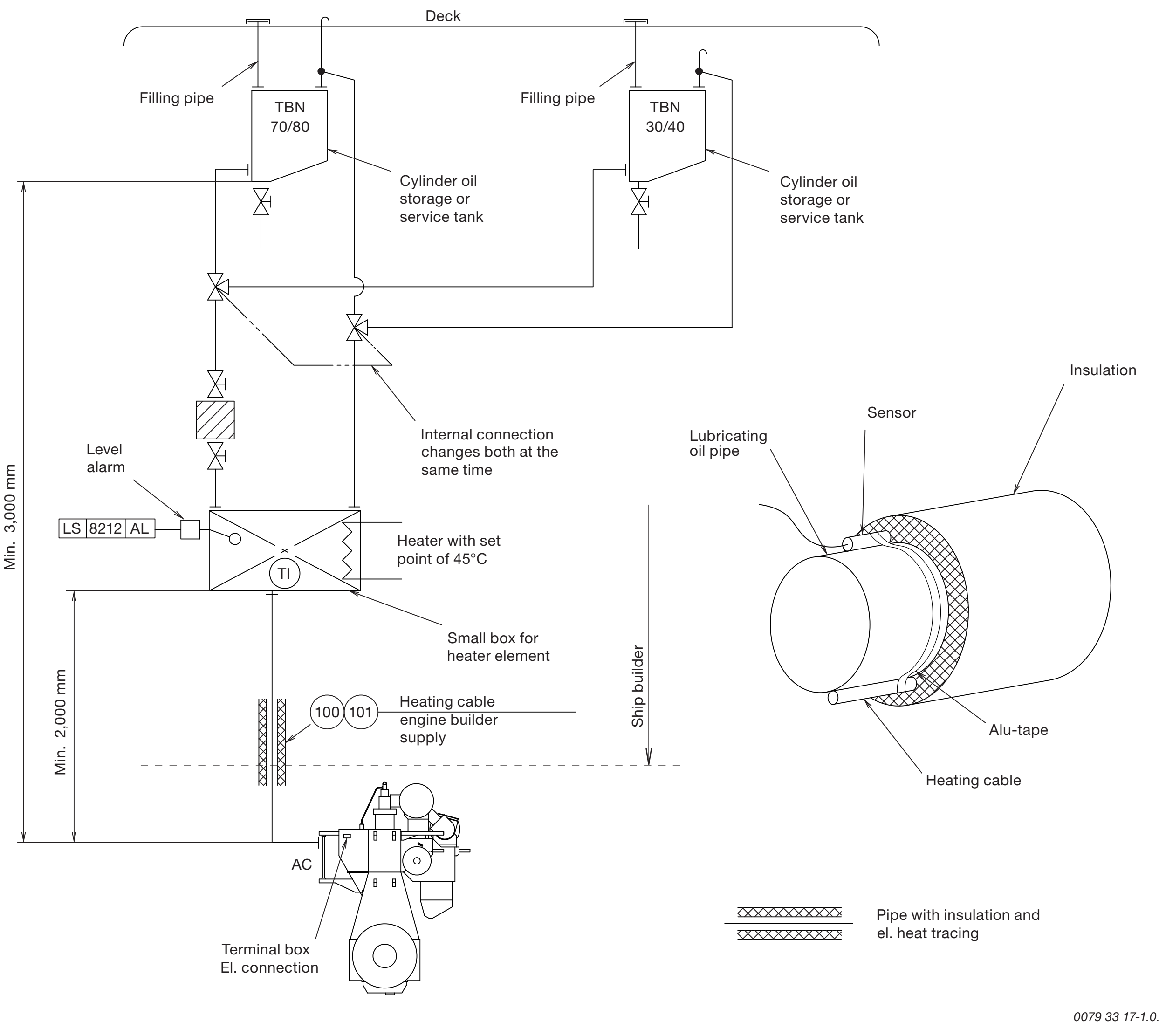

Fig. 9.02.02a: Cylinder lubricating oil system with dual service tanks for two different TBN cylinder oils

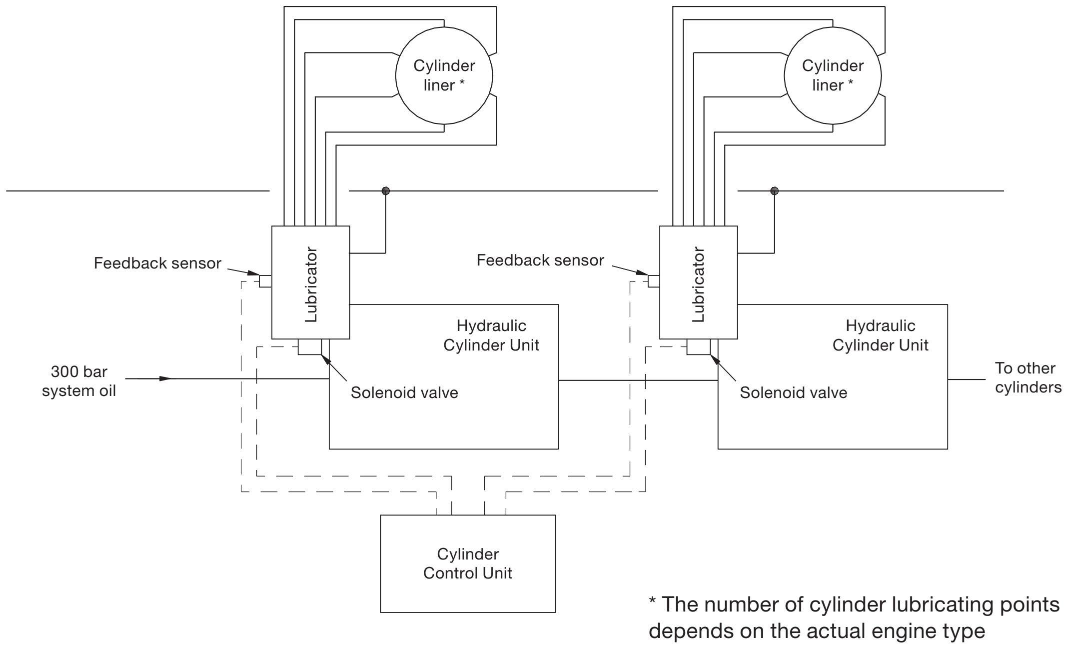

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Fig. 9.02.02b: Cylinder lubricating oil system. Example from S60/50ME-B

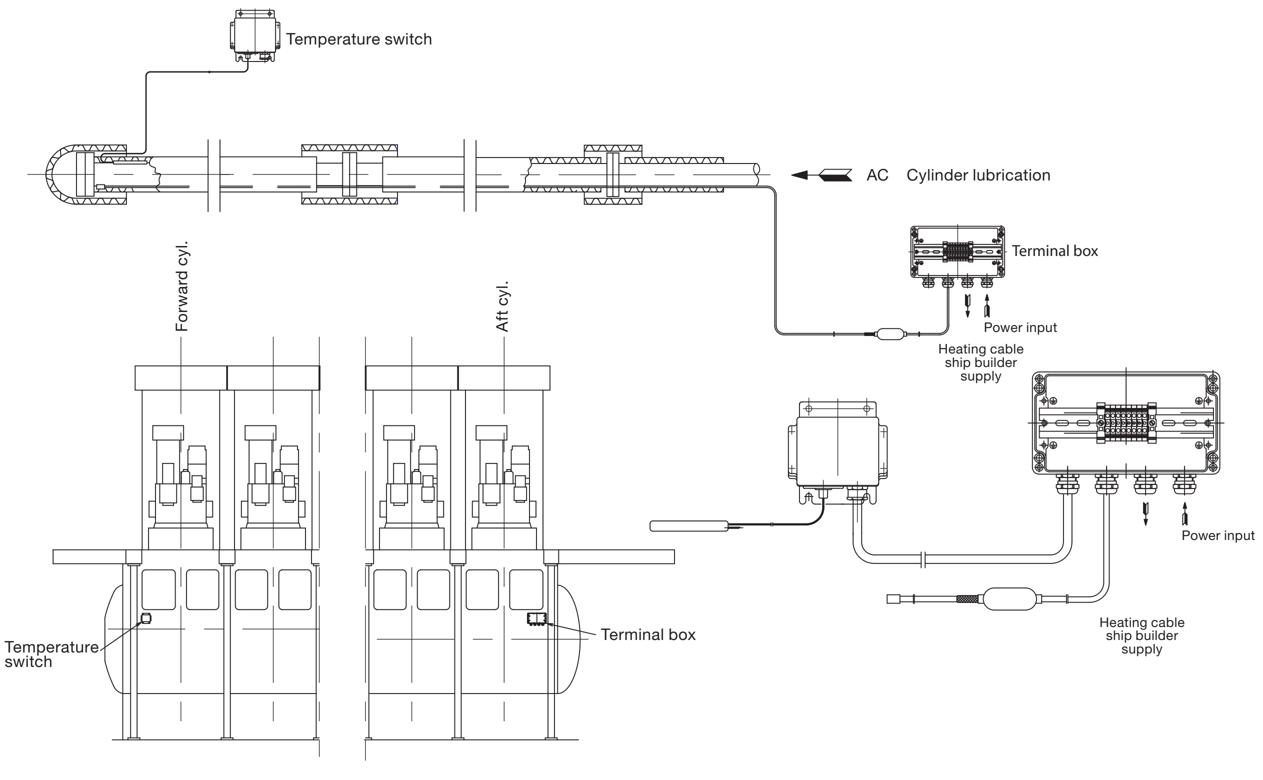

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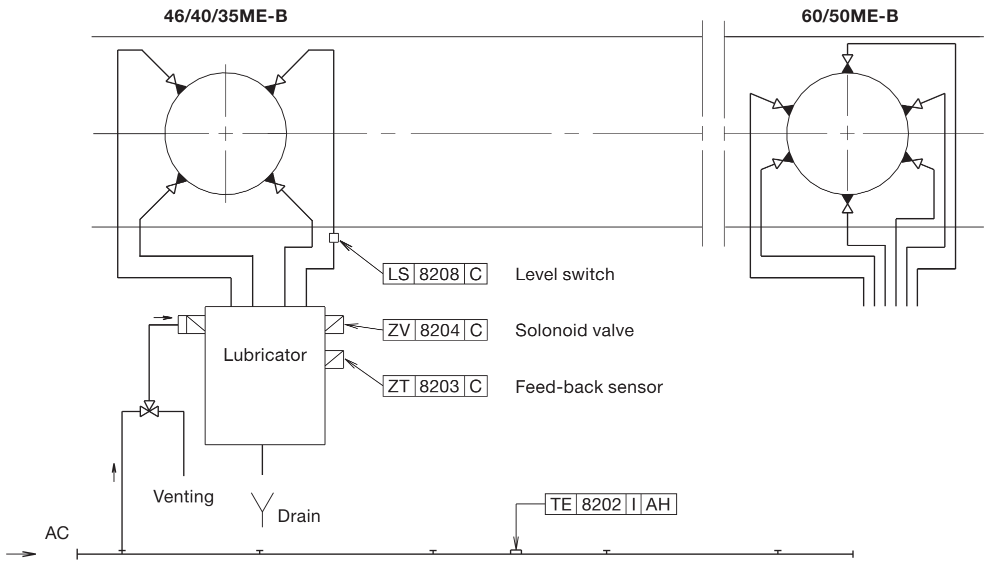
Fig. 9.02.03: Electric heating of cylinder oil pipes



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The letters refer to list of 'Counterflanges'

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Fig. 9.02.04: Cylinder lubricating oil pipes

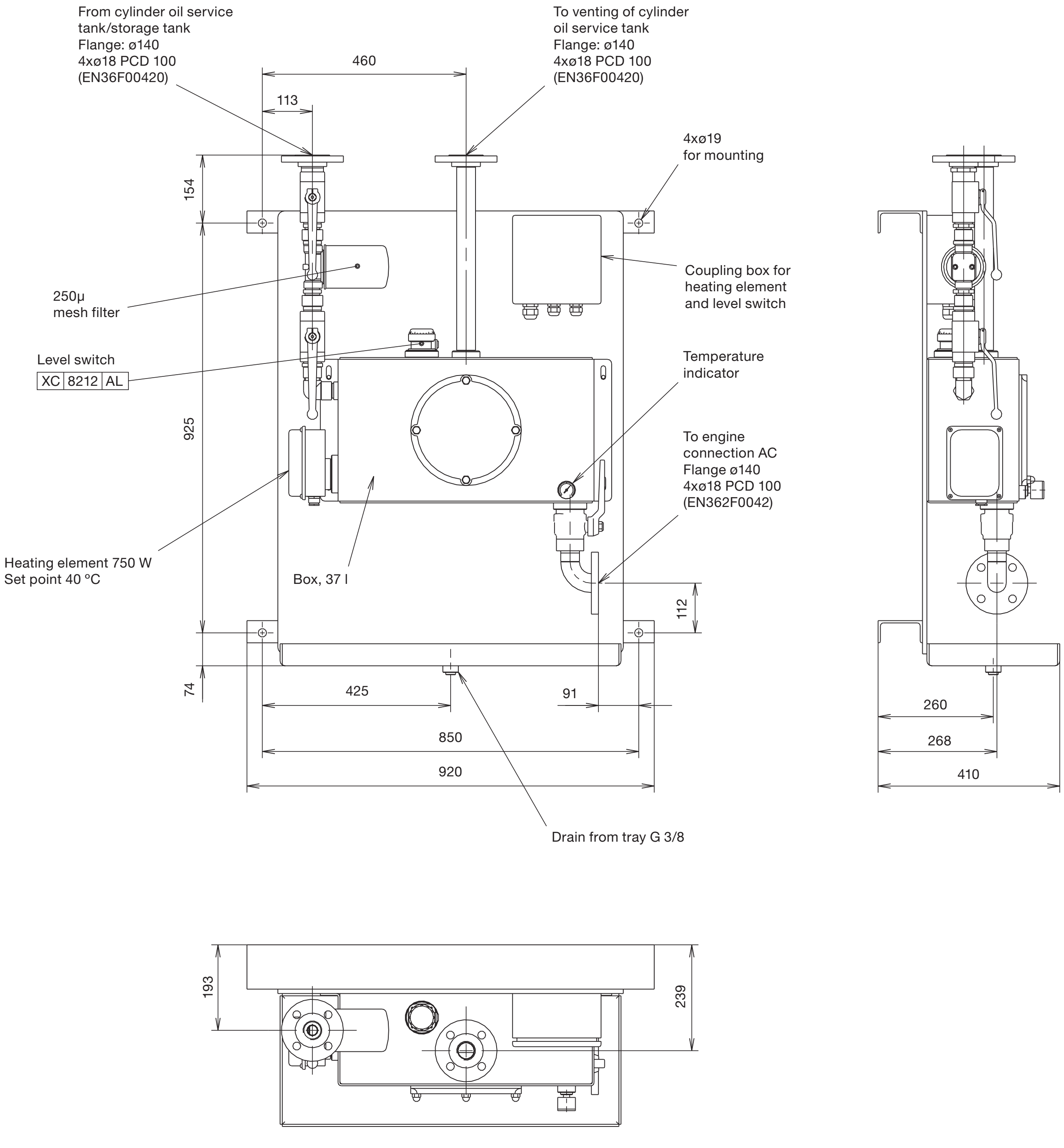

Fig. 9.02.05: Suggestion for small heating box with filter

Piston Rod Stuffing Box Drain Oil

10

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, HFO settling tank or is burnt in the incinerator, Fig. 10.01.01. (Yard's supply).

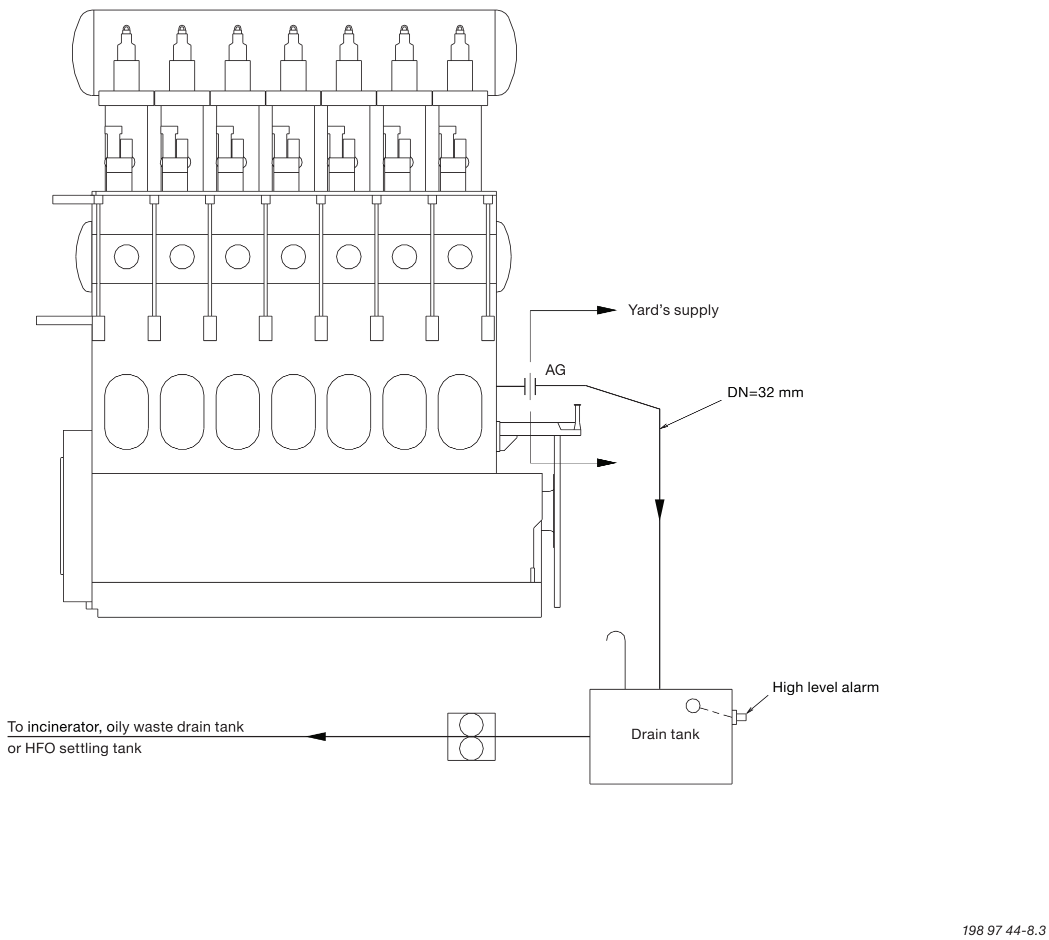

Fig. 10.01.01: Stuffing box drain oil system

Central Cooling Water System

11

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

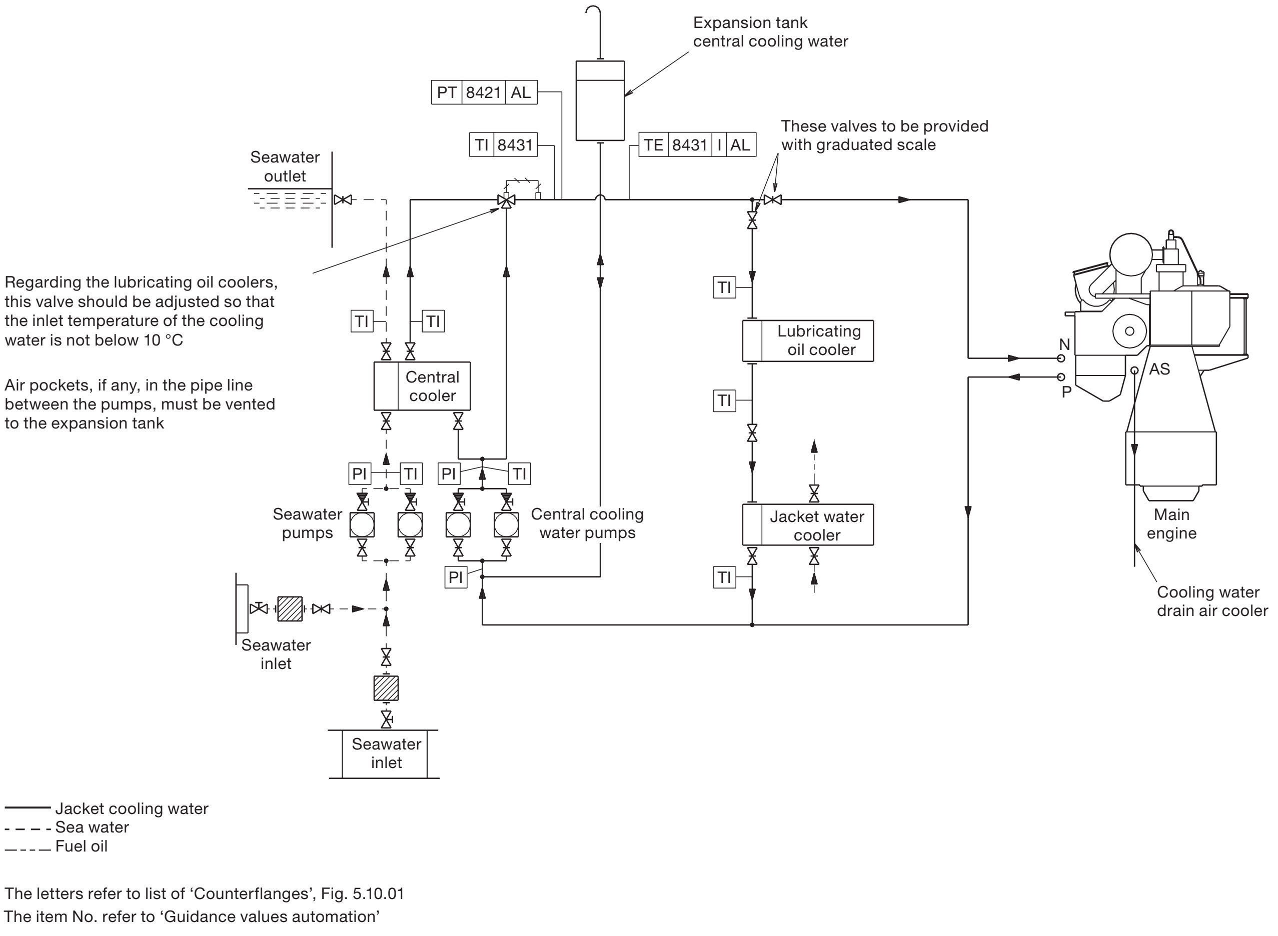

Fig. 11.02.01: Central cooling water system

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 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 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 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 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

12

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.

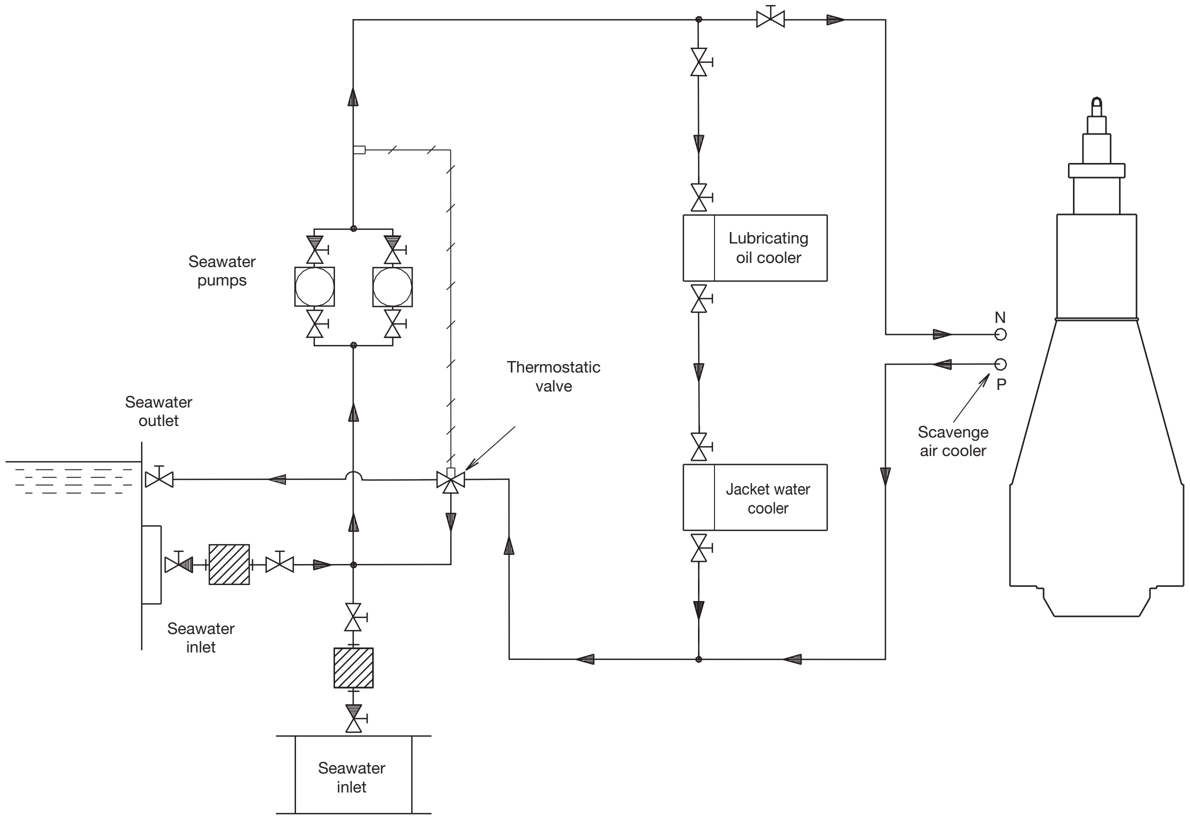

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Fig. 12.02.01: Seawater cooling system

Cooling Water Pipes

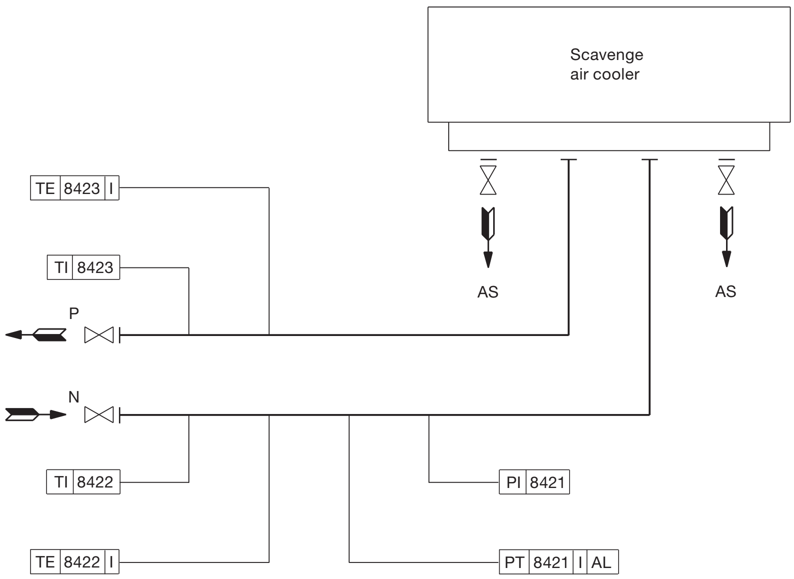

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Fig. 12.03.01: Cooling water pipes for engines with one turbocharger

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.

Lubricating oil cooler

See Chapter 8 'Lubricating Oil'.

Jacket water 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'
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.

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.

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

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.

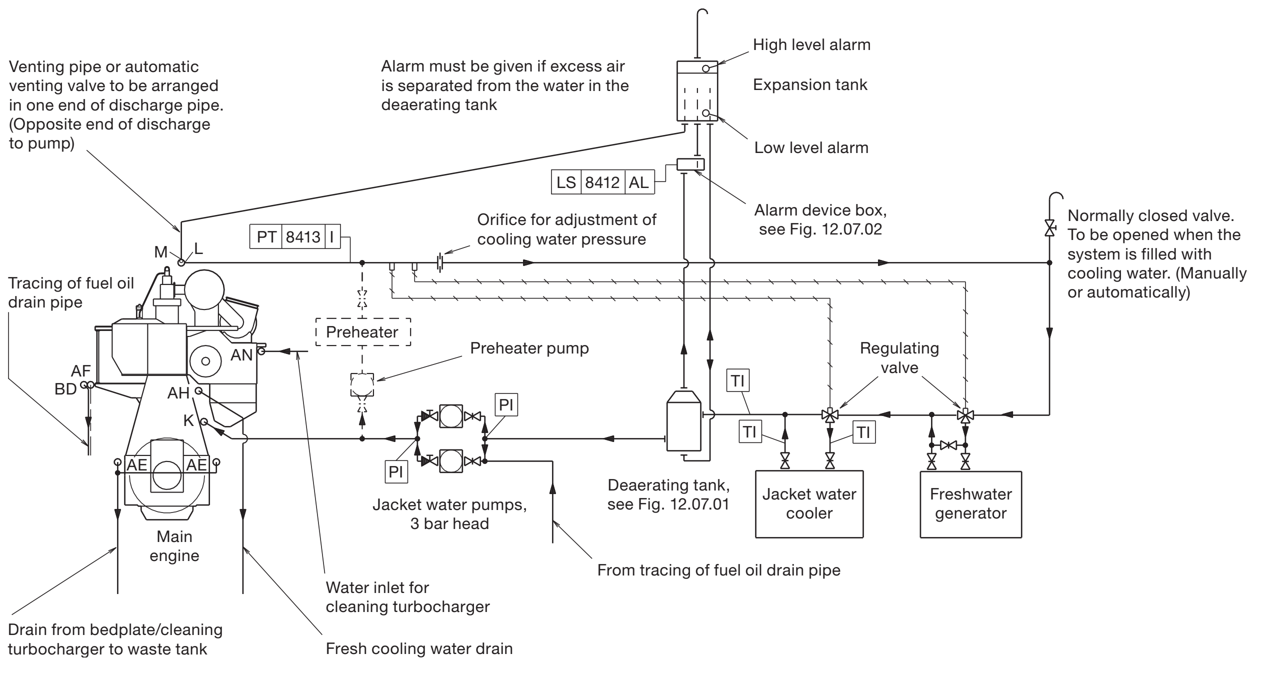
The venting pipe in the expansion tank should end just below the lowest water level, and the expansion tank must be located at least 15 m above the top of the exhaust valves.

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'

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Fig. 12.05.01: Jacket cooling water system

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 production 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 stated in Chapter 6 ‘List of Capacities‘.

For illustration of installation of fresh water generator 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 temperature 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 approximate 10% of the total jacket cooling water amount in the system.

Fresh water treatment

MAN Diesel & Turbo’s recommendations for treatment of the jacket water/freshwater are available on request.

Deaerating tank

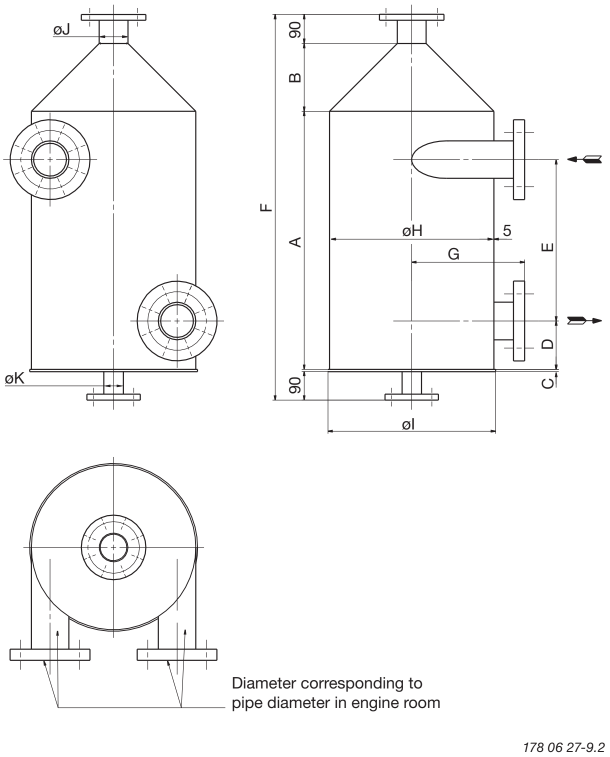

Fig. 12.07.01: Deaerating tank, option: 4 46 640

Deaerating tank dimensions		
Tank size	0.05 m³	0.16 m³
Max. jacket water capacity	120 m³/h	300 m³/h
	Dimensions in mm	
Max. nominal diameter	125	200
A	600	800
B	125	210
C	5	5
D	150	150
E	300	500
F	910	1,195
G	250	350
øH	300	500
øI	320	520
øJ	ND 50	ND 80
øK	ND 32	ND 50

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.

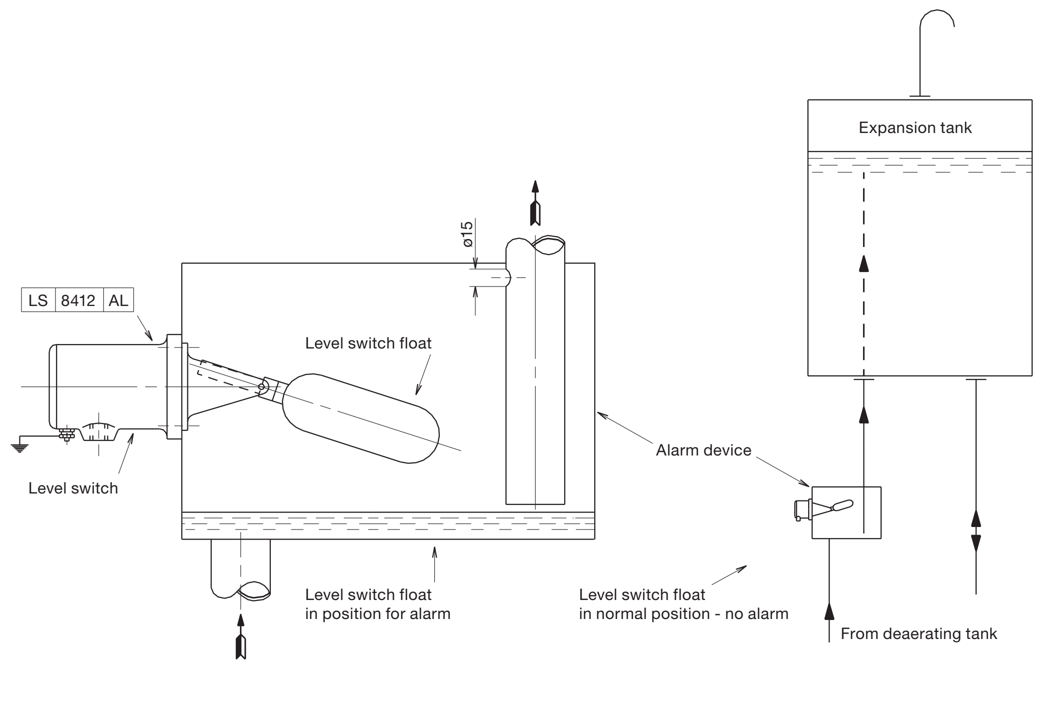

Fig. 12.07.02: Deaerating tank, alarm device, option: 4 46 645

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.

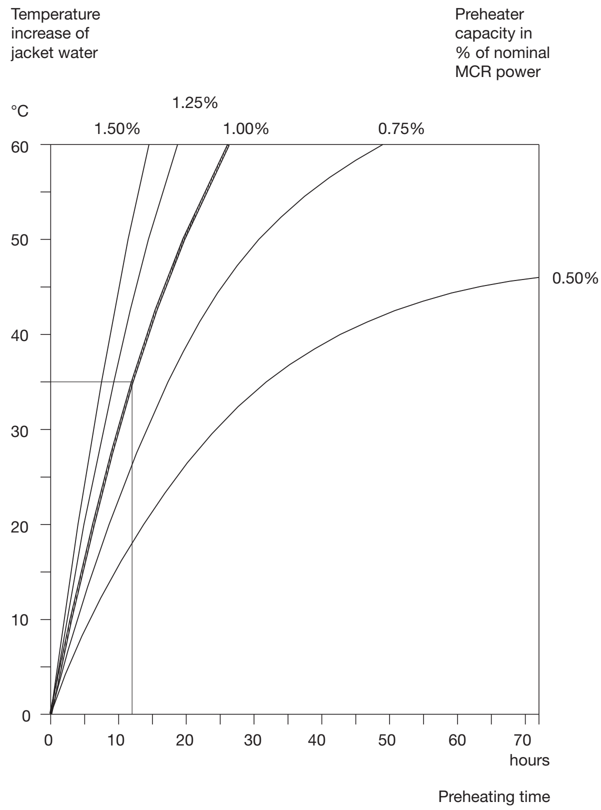

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Fig. 12.08.01: Jacket water preheater, example

Starting and Control Air

13

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.

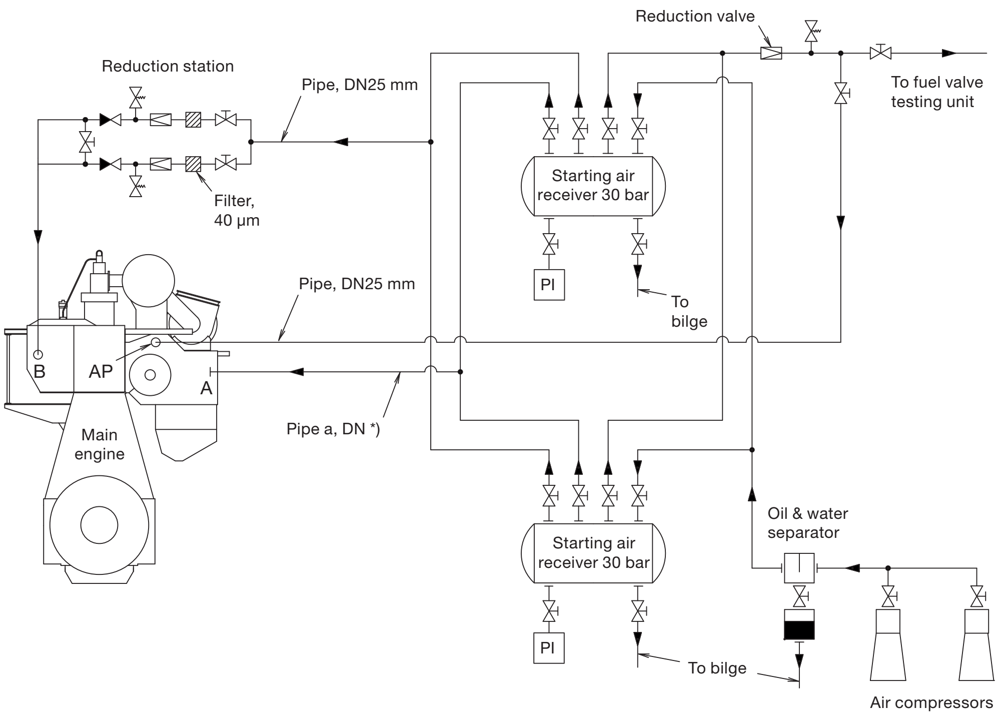
Please note that the air consumption for control air, safety air, turbocharger cleaning, sealing air for exhaust valve and for fuel valve testing unit are momentary requirements of the consumers.

The components of the starting and control air systems are further desribed in Section 13.02.

For information about a common starting air system for main engines and MAN Diesel 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'.



The letters refer to list of 'Counterflanges'
*) Pipe a nominal dimension: DN100 mm

078 83 76-7.3.0

Fig. 13.01.01: Starting and control air systems

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 m^3/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 m^3/s

The consumption of compressed air for control air, exhaust valve air springs and safety air as well as air for turbocharger cleaning and fuel valve testing 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.

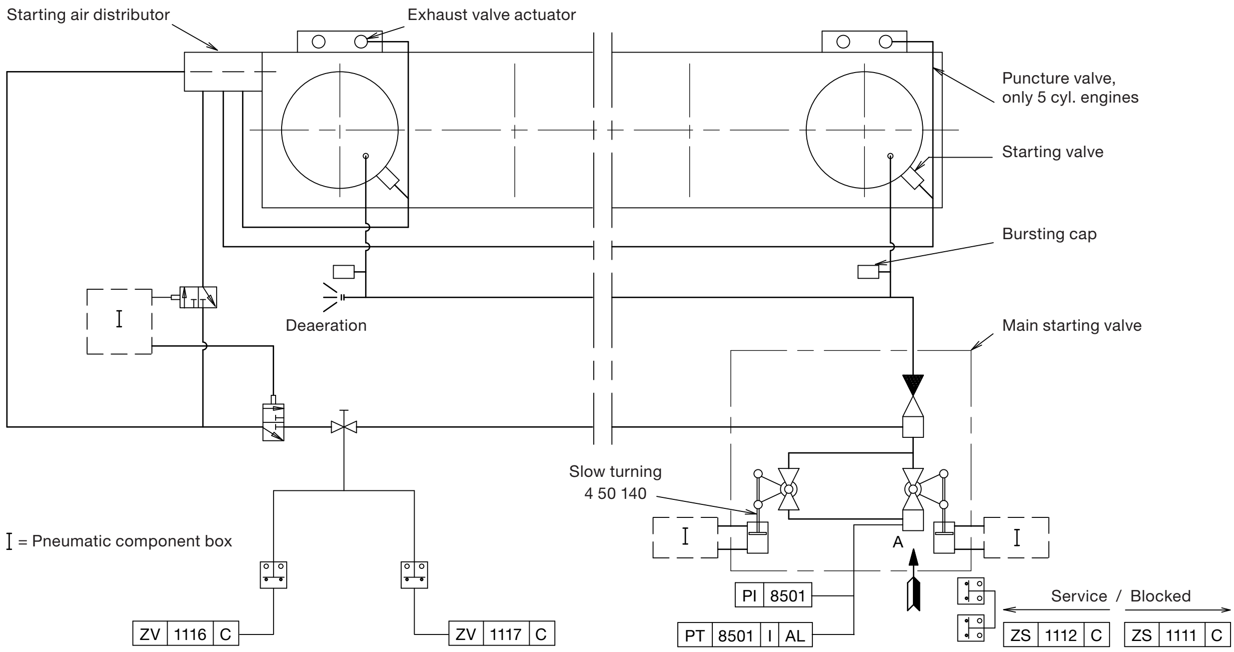
The Engine Control System regulates the supply of control air to the starting valves in accordance with the correct firing sequence and the timing.

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:

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'.



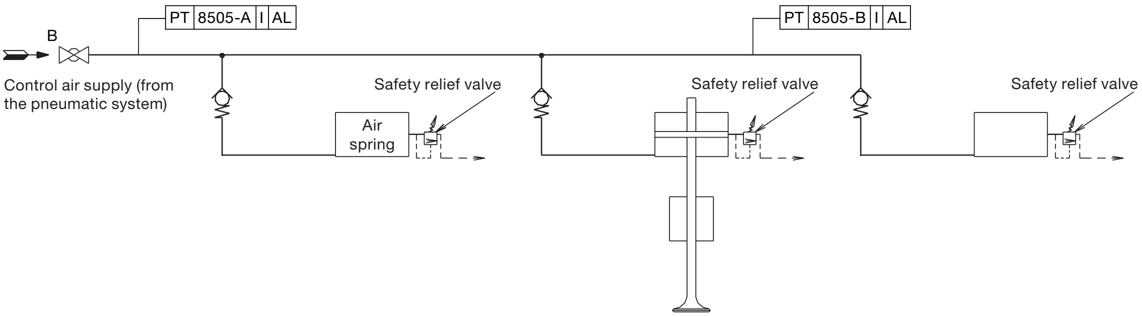
The letters refer to list of 'Counterflanges'
The item Nos. refer to 'Guidance values automation'
The piping is delivered with and fitted onto the engine

317 18 20-5.0.0

Fig. 13.03.01: Starting and control air pipes

Exhaust Valve Air Spring Pipes

The exhaust valve is opened hydraulically and the closing force is provided by an ‘air spring’ which leaves the valve spindle free to rotate, see Fig. 13.03.02.



The item Nos. refer to ‘Guidance values automation’
The piping is delivered with and fitted onto the engine

121 36 87-1.1.1c

Fig. 13.03.02: Air spring pipes for exhaust valves

Scavenge Air

14

Scavenge Air System

Scavenge air is supplied to the engine by one or two turbochargers located on the exhaust side of the engine, option: 4 59 123, or from one turbocharger located on the aft end of the engine, option: 4 59 121.

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. The scavenge air cooler is provided with a water mist catcher, which prevents condensated 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.

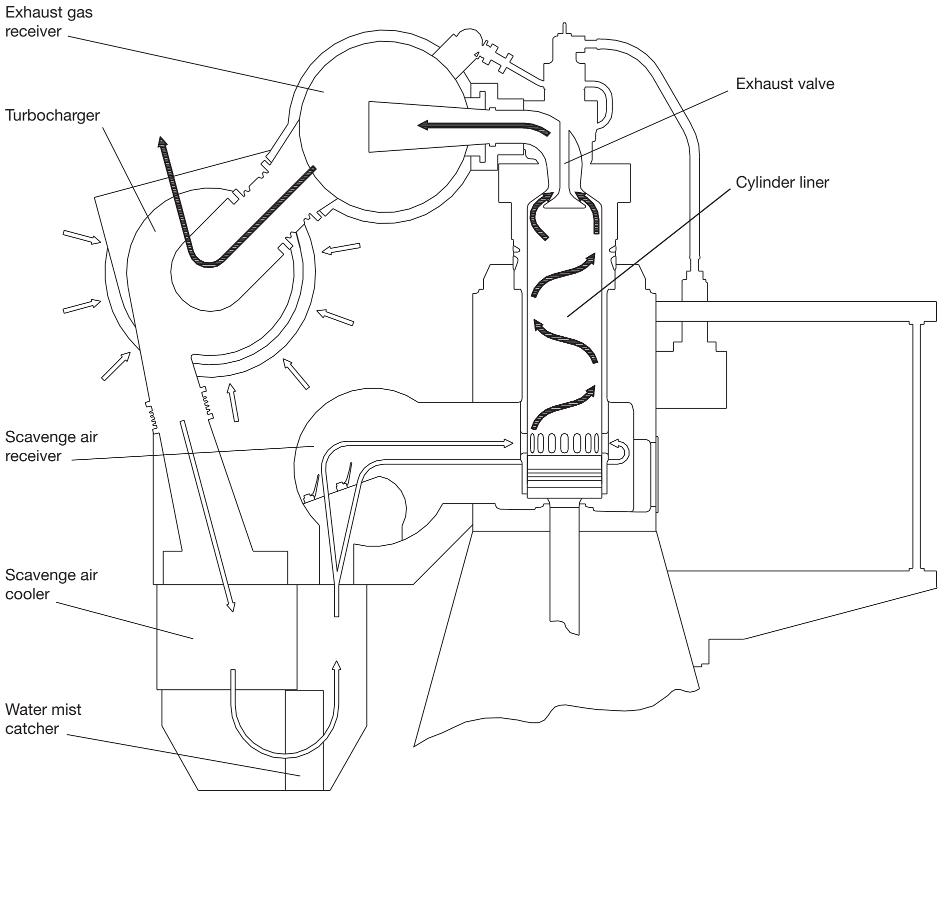


Fig. 14.01.01: Scavenge Air System

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. 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.

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.

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:

Influence of Ambient Temperature Conditions

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

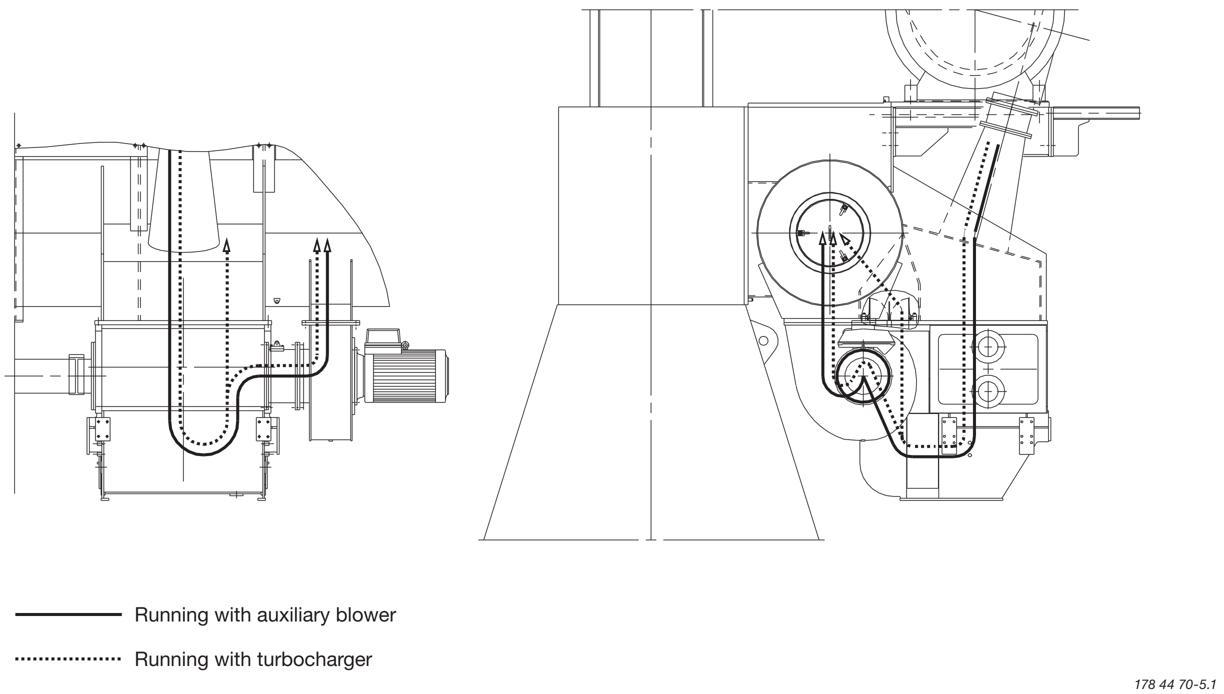


Fig. 14.02.01: Auxiliary blowers for scavenge air system

Control of the Auxiliary Blowers

The auxiliary blowers are fitted onto the main engine and controlled by a system comprising:

1 pc Control Panel
1 pc Starter Panel per Auxiliary Blower
2 pc Pressure Switches

Referring to the diagram of the auxiliary blower control system, Fig. 14.02.02:

- The Control Panel controls the run/stop signals to all Auxiliary Blower Starter Panels. The Control Panel consists of an operation panel and a terminal row interconnected by a 1,200 mm long wire harness.

- The Auxiliary Blower Starter Panels control and protect the Auxiliary Blower motors, one panel with starter per blower.

- The pressure switch 'P' controls the run/stop signals, while pressure switch 'B' is part of the auxiliary blower alarm circuit.

The control panel is yard's supply. It can be ordered as an option: 4 55 650.

The starter panels with starters for the auxiliary blower motors are not included, they can be ordered as an option: 4 55 653. (The starter panel design and function is according to MAN Diesel'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: 4 55 155.

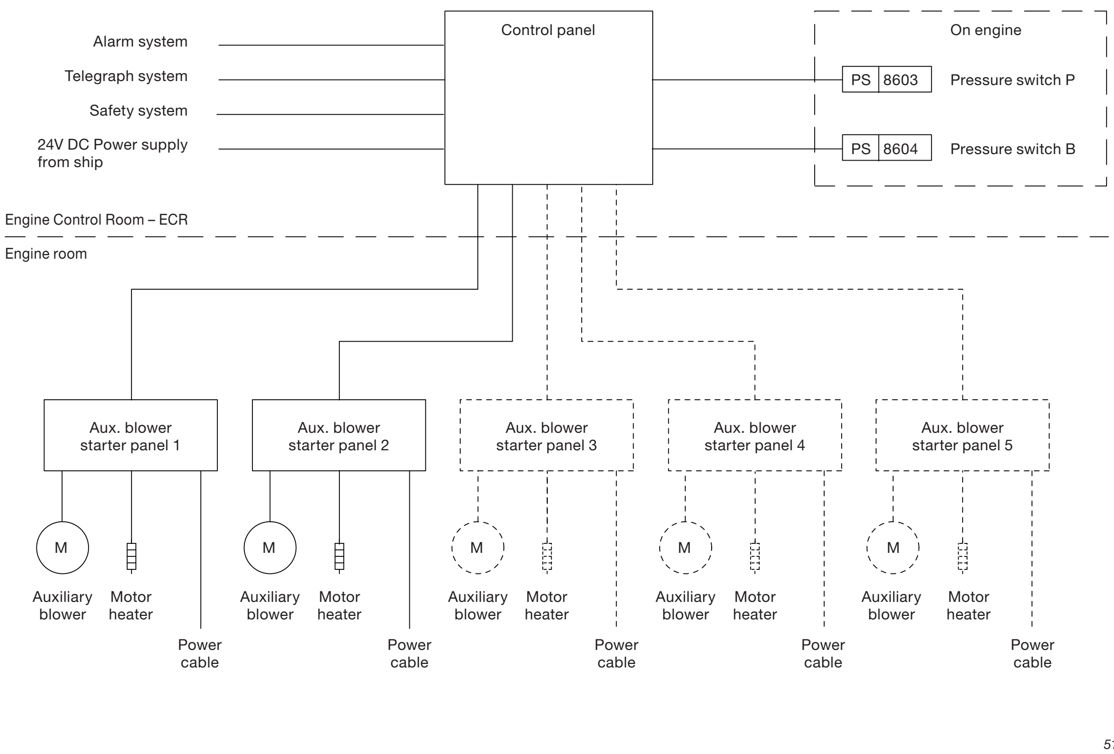


Fig. 14.02.02: Diagram of auxiliary blower control system

Operation Panel for the Auxiliary Blowers

On the operation panel, three control modes are available to run/stop the blowers:

- AUTO – Run/stop is automatically controlled by scavenge air pressure
- MANUAL – Start of all blowers in sequence at intervals of 6 sec
- OFF – The auxiliary blowers are stopped after a set period of time, 30 sec for instance.

The operation panel and terminal row have to be mounted in the Engine Control Room Manoeuvring Console, see Section 16.01.

The control panel for the auxiliary blowers including the operation panel, wiring harness and terminal row is shown in Fig. 14.02.03.

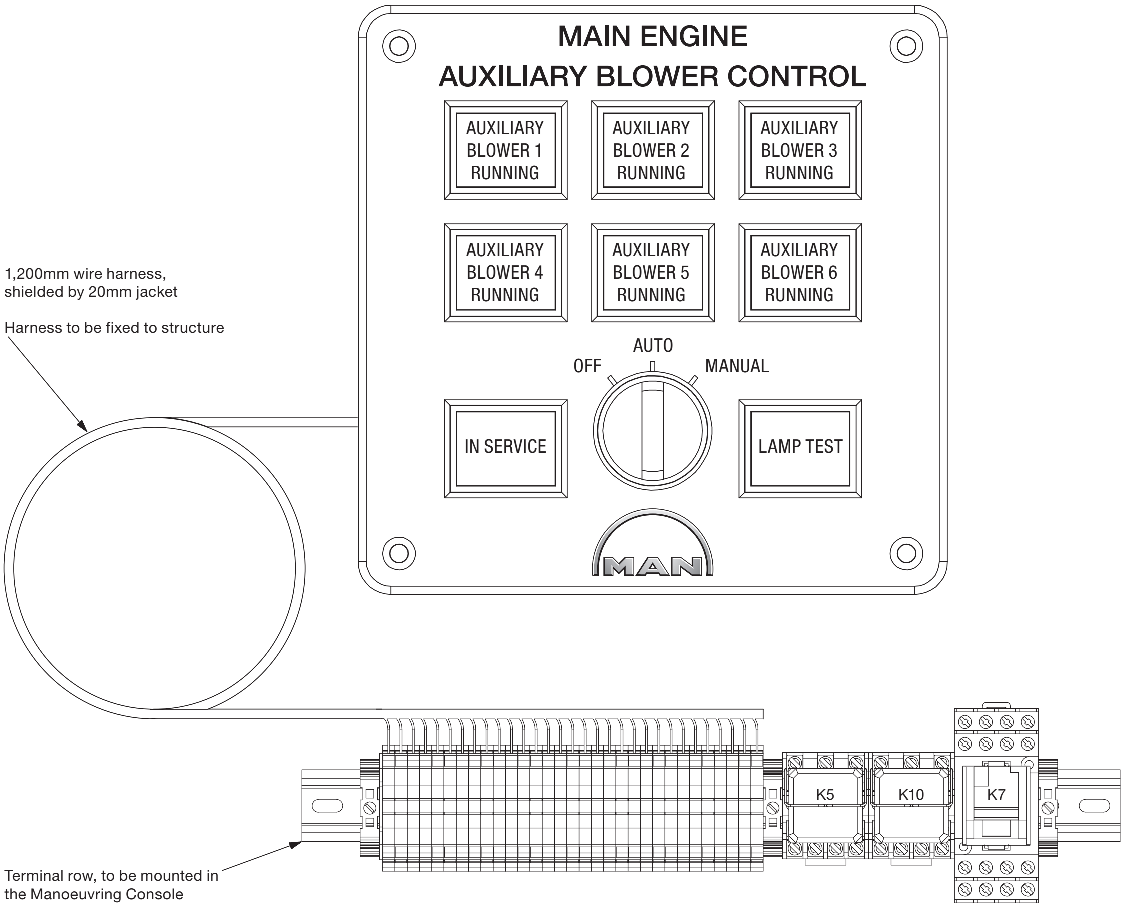


Fig. 14.02.03: Control panel including operation panel, wiring harness and terminal row, option: 4 55 650

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.

Motor start method and size

Direct Online Start (DOL) is required for all auxiliary blower electric motors to ensure proper operation under all conditions.

For typical engine configurations, the installed size of the electric motors for auxiliary blowers are listed in Table 14.04.01.

Special operating conditions

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.

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.

Number of cylinders	Number of auxiliary blowers	Required power/blower kW	Installed power/blower kW
5		33	35
6		39	43
7	2	46	53
8		52	54
9		59	65

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, engine with turbocharger located on aft end or exhaust side

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.

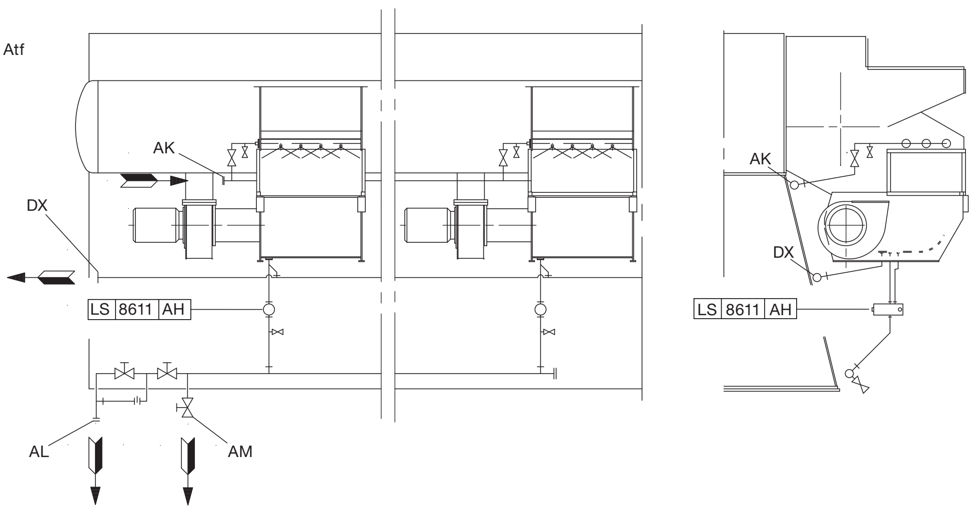
The system is equipped with a drain box with a level switch, indicating any excessive water level.

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
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The item no refer to 'Guidance values automation'

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Fig. 14.05.01: Air cooler cleaning pipes

Auto Pump Overboard System

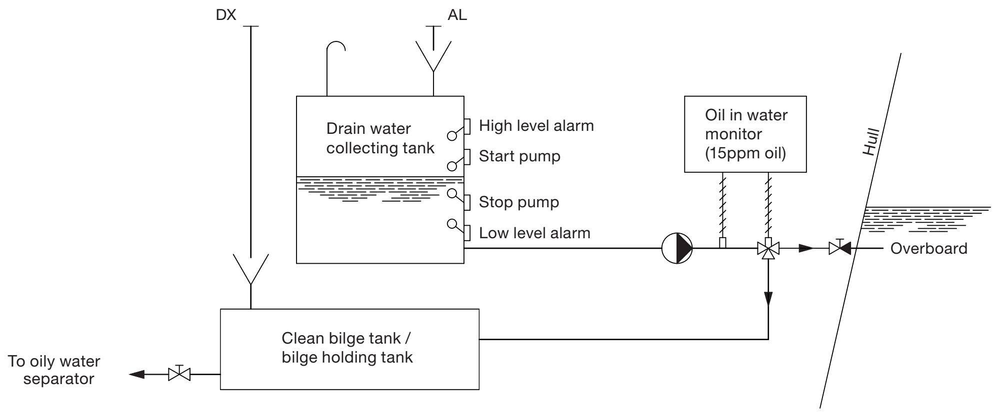
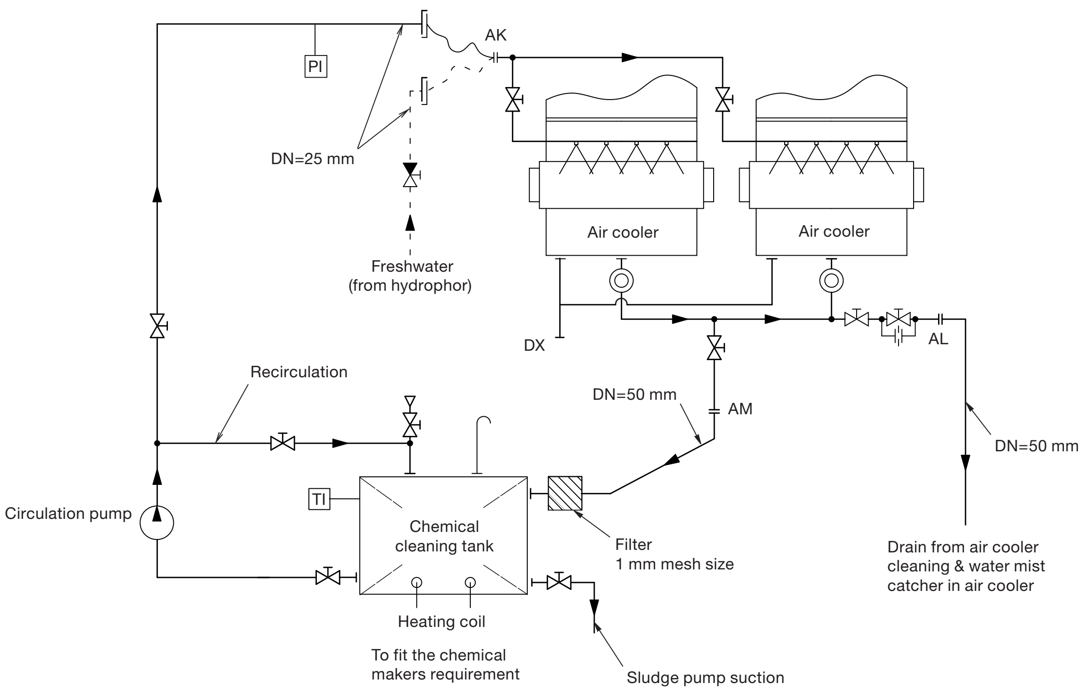


Fig. 14.05.02: Suggested automatic disposal of drain water, if required by owner (not a demand from MAN Diesel & Turbo)

Air Cooler Cleaning Unit



The letters refer to list of 'Counterflanges'

	No. of cylinders	
	5-8	9
Chemical tank capacity, m^3	0.3	0.6
Circulation pump capacity at 3 bar, m^3/h	1	2

079 21 94-1.0.1a

Fig. 14.05.03: Air cooler cleaning system with Air Cooler Cleaning Unit, option: 4 55 665

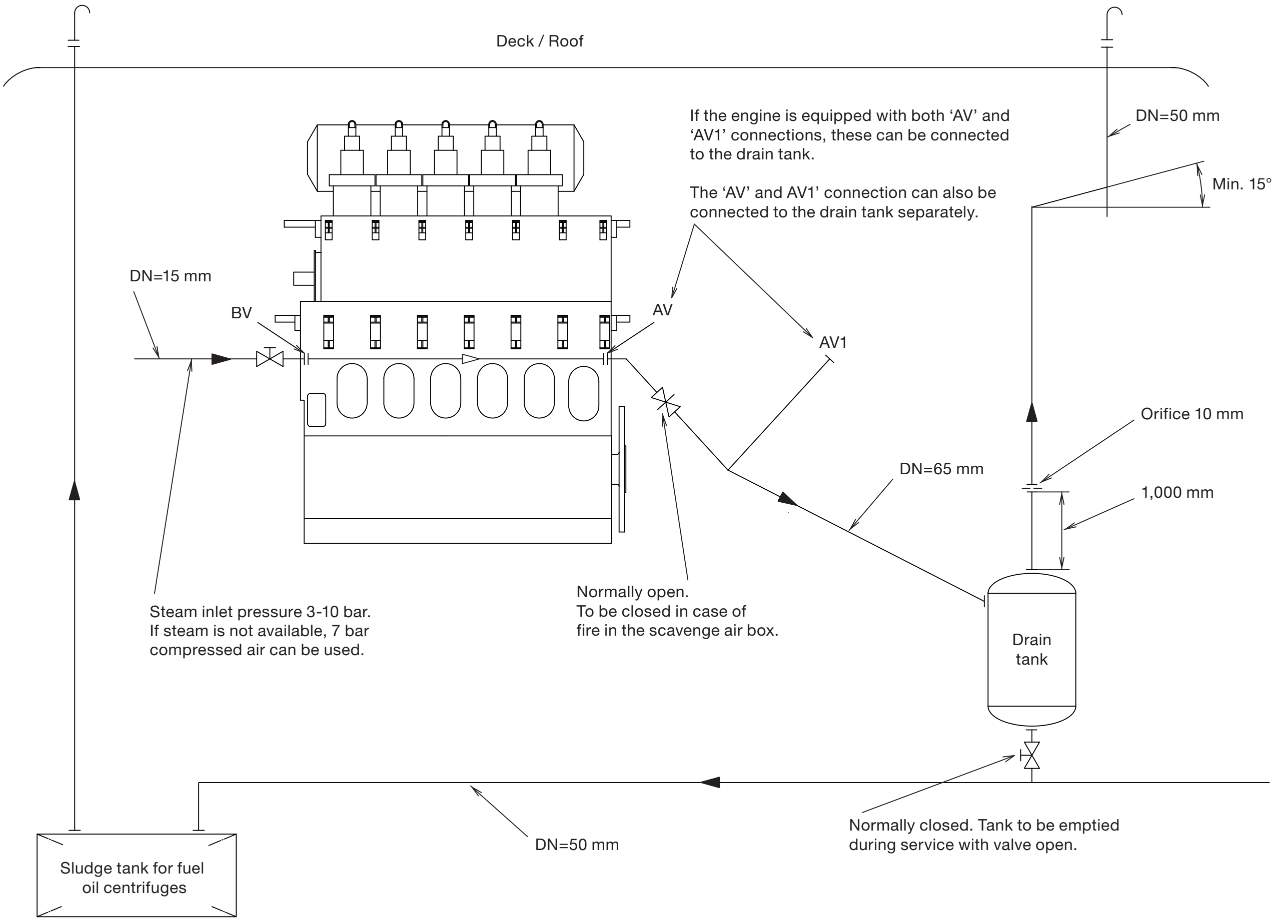
Scavenge Air Box Drain System

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. 14.03.02 Scavenge air space, drain pipes.



The letters refer to list of 'Counterflanges'

No. of cylinders:	5-6	7-9
Drain tank capacity, m^3	0.3	0.4

079 61 03-0.4.1

Fig. 14.06.01: Scavenge air box drain system

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 CO_2.

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:

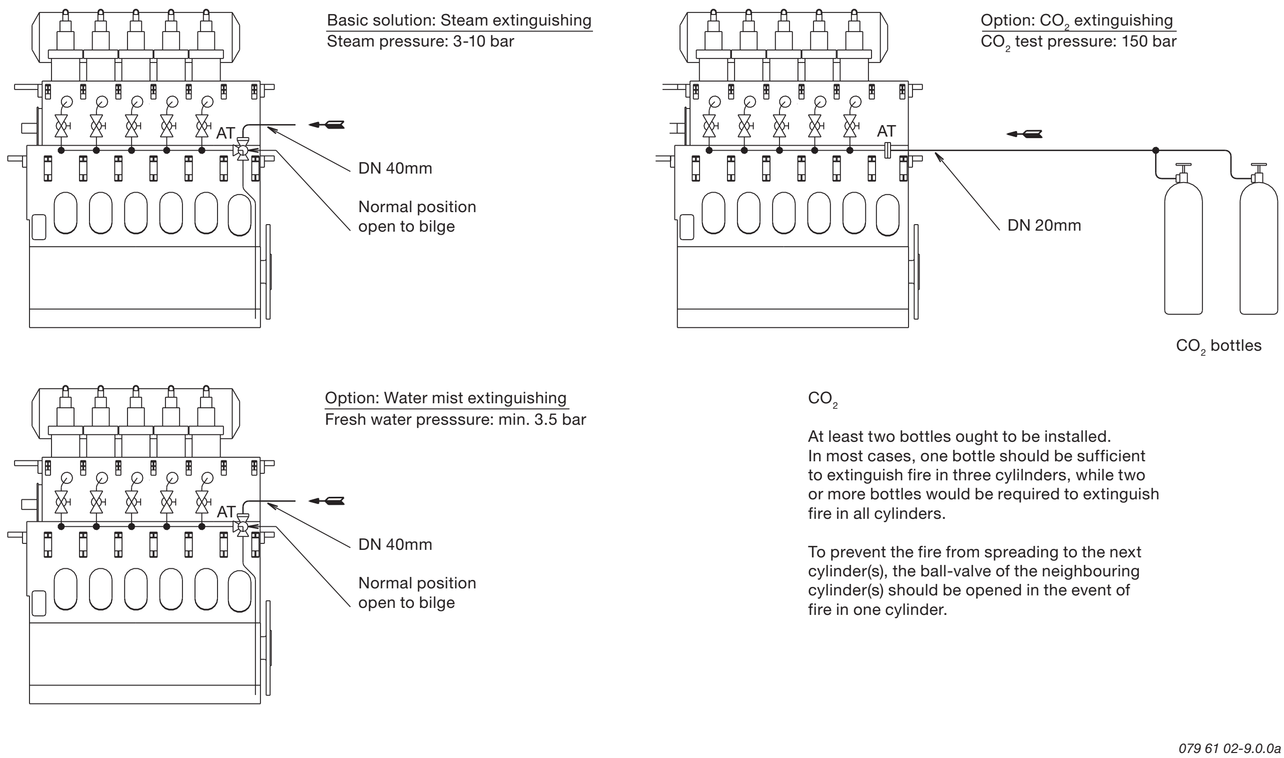
- basic solution: 4 55 140 Steam
- option: 4 55 142 Water mist
- option: 4 55 143 CO_2

The key specifications of the fire extinguishing agents are:

Steam fire extinguishing for scavenge air space
Steam pressure: 3-10 bar
Steam quantity, approx.: 2.2 kg/cyl.

Water mist fire extinguishing for scavenge air space
Freshwater pressure: min. 3.5 bar
Freshwater quantity, approx.: 1.7 kg/cyl.

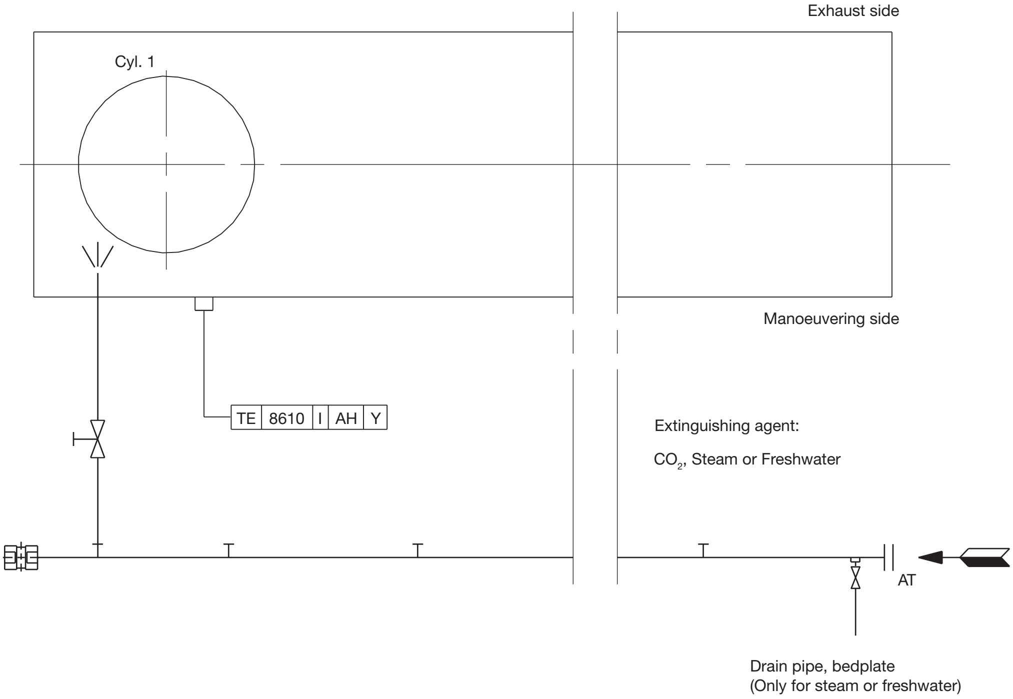
CO_2 fire extinguishing for scavenge air space
CO_2 test pressure: 150 bar
CO_2 quantity, approx.: 4.3 kg/cyl.



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



126 40 81-0.6.0a

The letters refer to list of ‘Counterflanges’

Fig. 14.07.02: Fire extinguishing pipes in scavenge air space

Exhaust Gas

15

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 turbocharger can either be located on the aft end of the engine, option: 4 59 121, or on the exhaust side of the engine, option: 4 59 123. However, if the engine is fitted with two turbochargers, they are always located on the exhaust side.

The engine is designed for the installation of the MAN turbocharger types TCA (4 59 101), ABB turbocharger type A-L (4 59 102), or MHI turbocharger type MET (4 59 103).

All makes of turbochargers are fitted with an arrangement for soft blast cleaning of the turbine side, and optionally water washing of the compressor side, option: 4 59 145, see Figs. 15.02.02 and 15.02.03. Washing of the turbine side is only applicable by special request to TC manufacturer on MAN turbochargers.

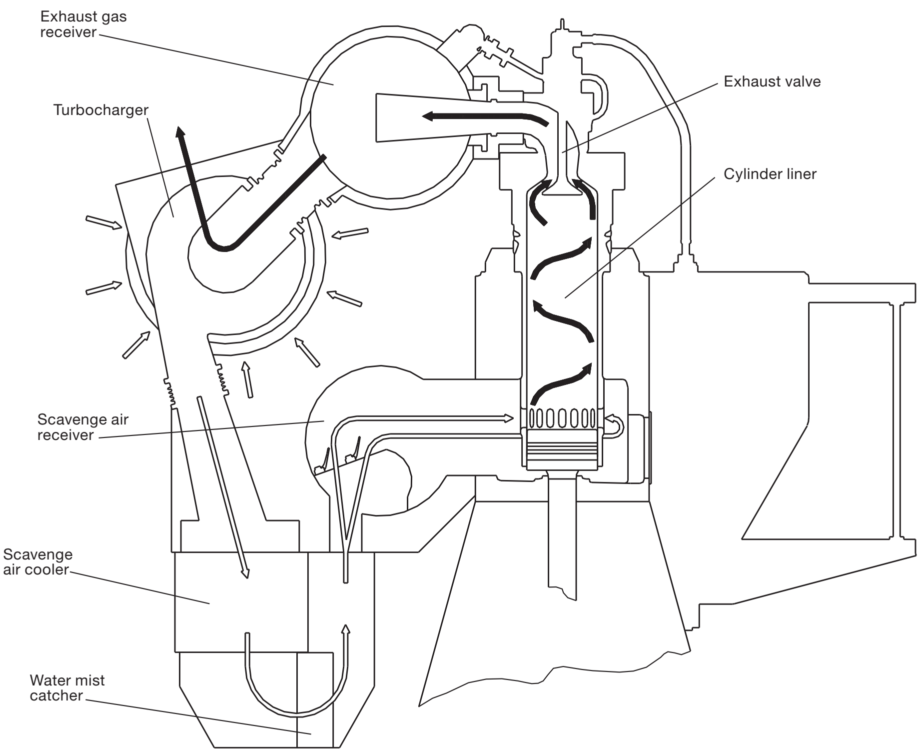


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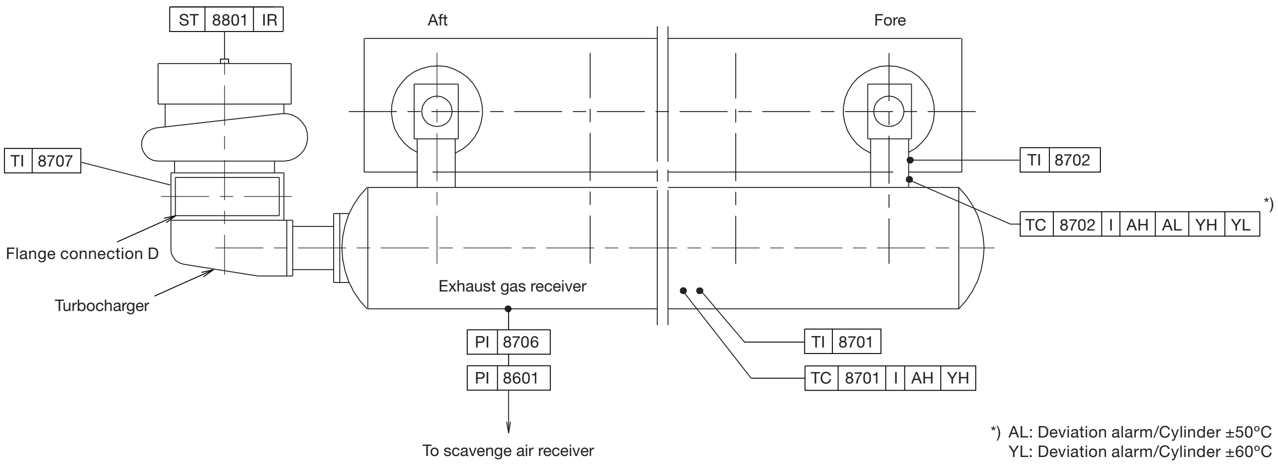
Fig. 15.01.01: Exhaust gas system on engine

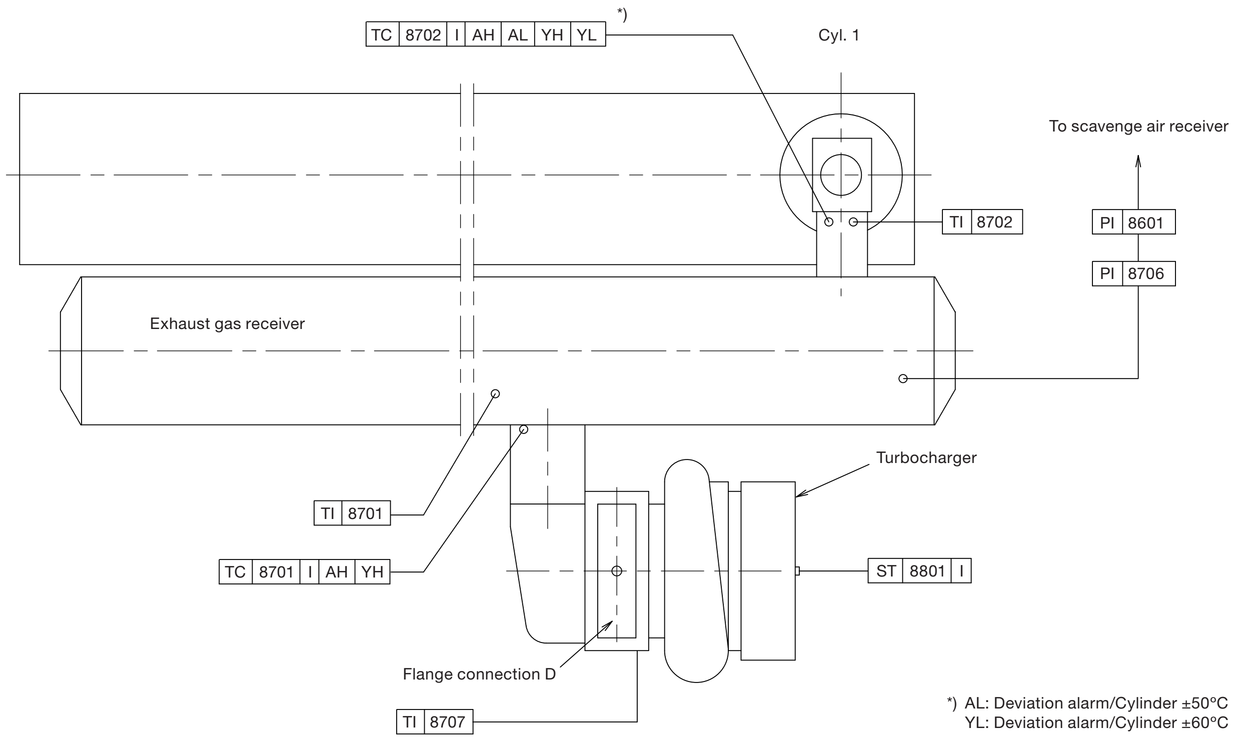
Exhaust Gas Pipes



The letters refer to 'List of flanges'
The position numbers refer to 'List of instruments'
The piping is delivered with and fitted onto the engine

178 38 69-2.2

Fig.15.02.01a: Exhaust gas pipes, with turbocharger located on aft end of engine, option 4 59 121



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The item no. refer to 'Guidance Values Automation'

121 15 27-9.2.0

Fig. 15.02.01b: Exhaust gas pipes, with turbocharger located on exhaust side of engine, option 4 59 123

Cleaning Systems

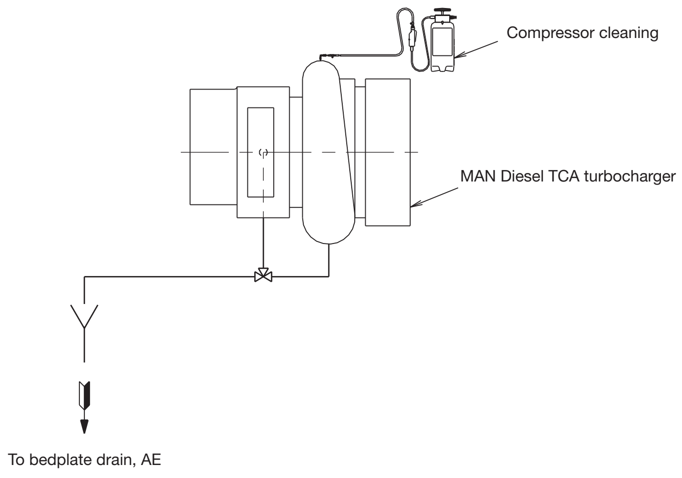


Fig. 15.02.02: MAN TCA turbocharger, water washing of compressor side, option: 4 59 145

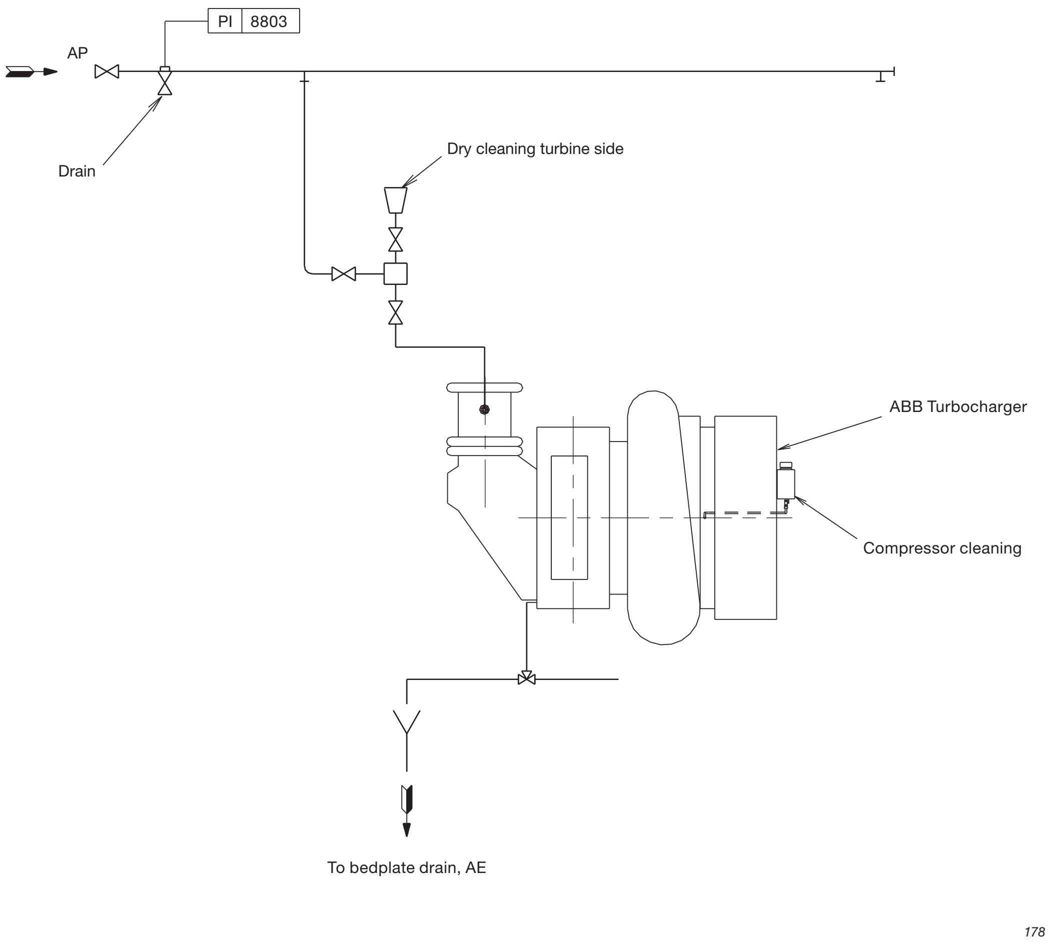


Fig. 15.02.03: Soft blast cleaning of turbine side and water washing of compressor side for ABB turbochargers

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.

The exhaust system for the main engine comprises:

- Exhaust gas pipes
- Exhaust gas boiler
- Silencer
- Spark arrester (if needed)
- Expansion joints (compensators)
- Pipe bracings.

In connection with dimensioning the exhaust gas piping system, the following parameters must be observed:

- Exhaust gas flow rate
- Exhaust gas temperature at turbocharger outlet
- Maximum pressure drop through exhaust gas system
- Maximum noise level at gas outlet to atmosphere
- Maximum force from exhaust piping on turbocharger(s)
- Sufficient axial and lateral elongation ability of expansion joints
- Utilisation of the heat energy of the exhaust gas.

Items that are to be calculated or read from tables are:

- Exhaust gas mass flow rate, temperature and maximum back pressure at turbocharger gas outlet
- Diameter of exhaust gas pipes
- Utilisation of the exhaust gas energy
- Attenuation of noise from the exhaust pipe outlet
- Pressure drop across the exhaust gas system
- Expansion joints.

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.

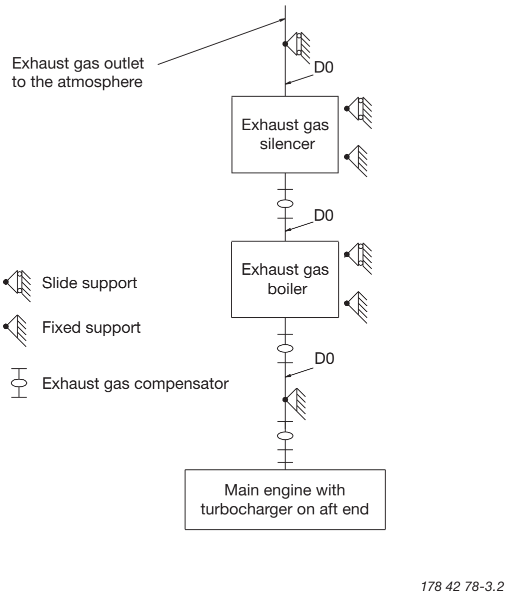


Fig. 15.04.01a: Exhaust gas system, one turbocharger

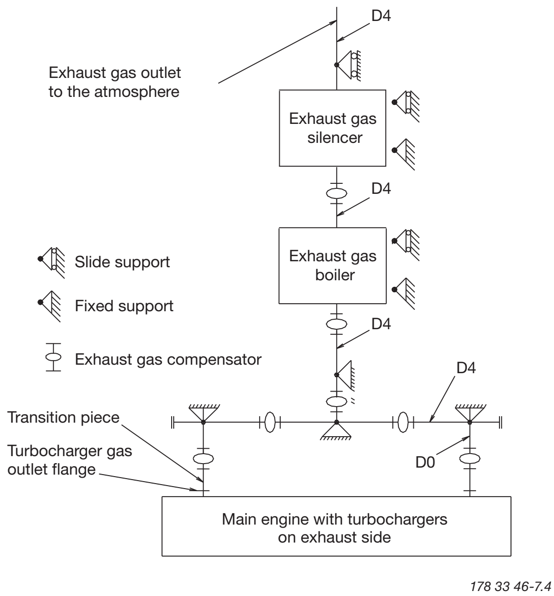


Fig. 15.04.01b: Exhaust gas system, two or more TCs

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.

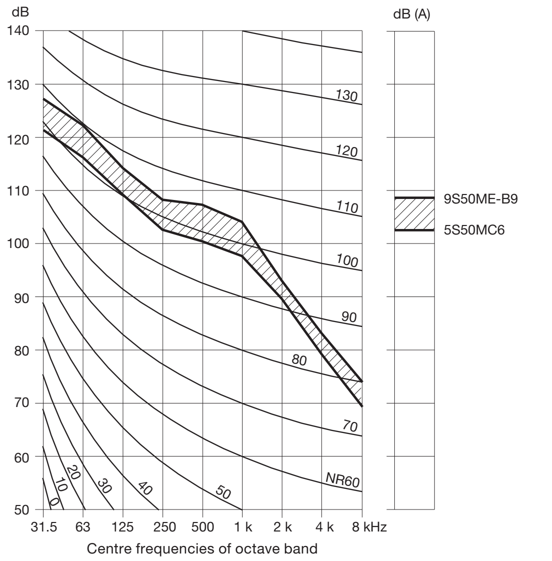
For each doubling of the distance, the noise level will be reduced by about 6 dB (far-field law).

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.



178 59 42-1.0

Fig. 15.04.02: ISO's NR curves and typical sound pressure levels from the engine's exhaust gas system. The noise levels at nominal MCR and a distance of 1 metre from the edge of the exhaust gas pipe opening at an angle of 30 degrees to the gas flow and valid for an exhaust gas system – without boiler and silencer, etc. Data for a specific engine and cylinder no. is available on request.

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)

$$\rho \cong 1.293 \times \frac{273}{273 + T} \times 1.015 \text{ in kg/m}^3$$

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:

$$v = \frac{M}{\rho} \times \frac{4}{\pi \times D^2} \text{ in m/s}$$

Pressure losses in pipes (Δp)

For a pipe element, like a bend etc., with the resistance coefficient ζ, the corresponding pressure loss is:

$$\Delta p = \zeta \times ½ \rho v^2 \times \frac{1}{9.81} \text{ in mm WC}$$

where the expression after ζ 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 (Δp_M)

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:

Δp_M 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

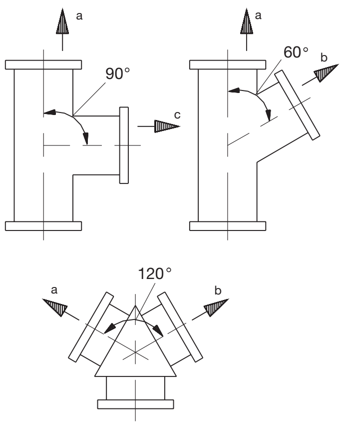
At any given position in the exhaust gas system, the total pressure of the flow can be divided into dynamic pressure (referring to the gas velocity) and static pressure (referring to the wall pressure, where the gas velocity is zero).

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



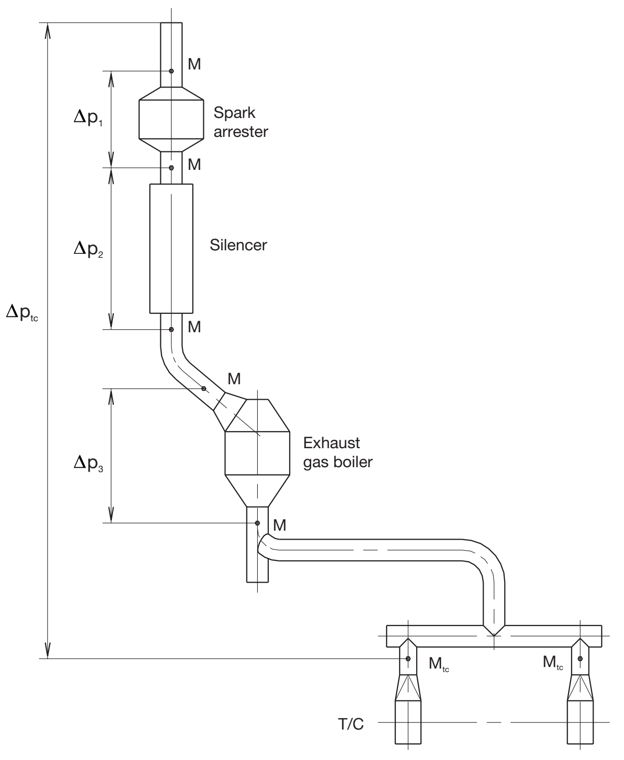
Change-over valves

Change-over valve of type with constant cross section

ζa = 0.6 to 1.2
ζb = 1.0 to 1.5
ζc = 1.5 to 2.0

Change-over valve of type with volume

ζa = ζb = about 2.0



M: Measuring points

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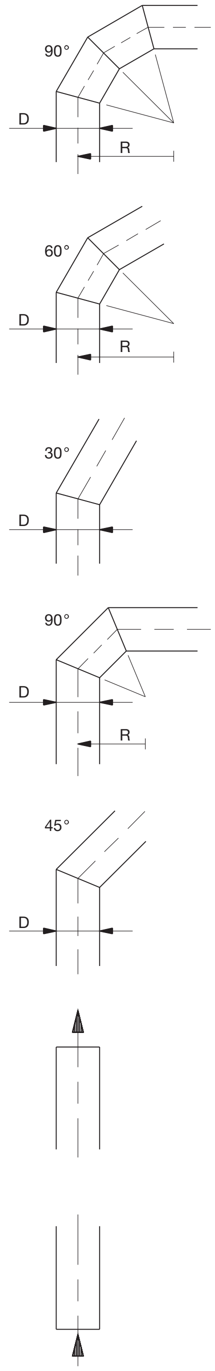


90° bend:
R = D ζ = 0.28
R = 1.5D ζ = 0.20
R = 2D ζ = 0.17

60° bend:
R = D ζ = 0.16
R = 1.5D ζ = 0.12
R = 2D ζ = 0.11

30° bend: ζ = 0.05

90° bend:
R = D ζ = 0.45
R = 1.5D ζ = 0.35
R = 2D ζ = 0.30

45° bend: ζ = 0.14

Outlet from top of exhaust gas uptake ζ = 1.00

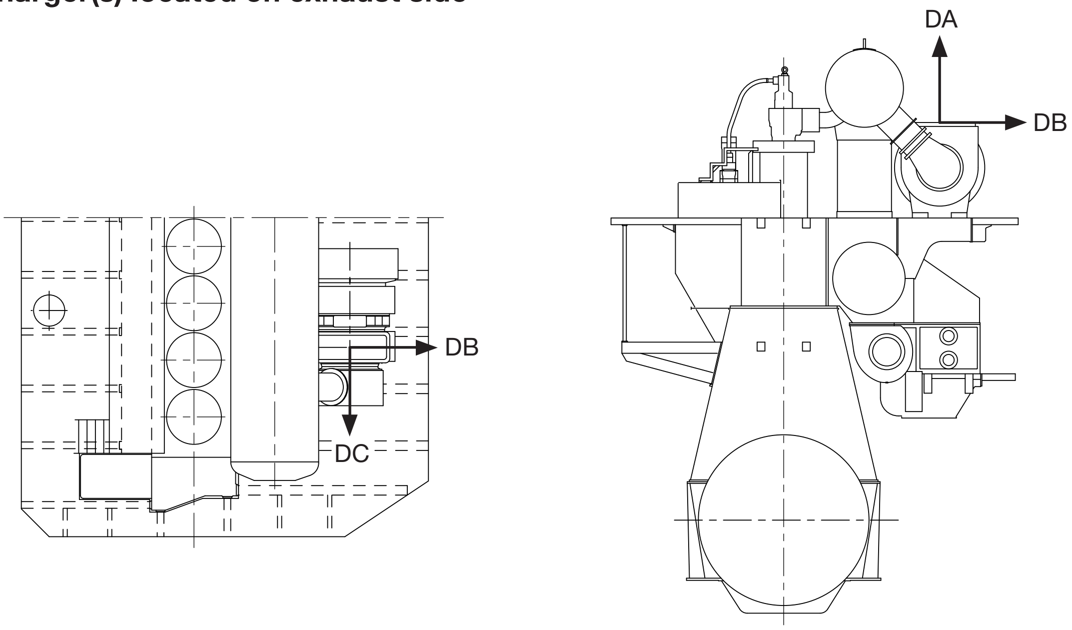
Inlet (from turbocharger) ζ = – 1.00

178 06 85-3.0

Fig. 15.05.01: Pressure losses and coefficients of resistance in exhaust pipes

Forces and Moments at Turbocharger

Turbocharger(s) located on exhaust side



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

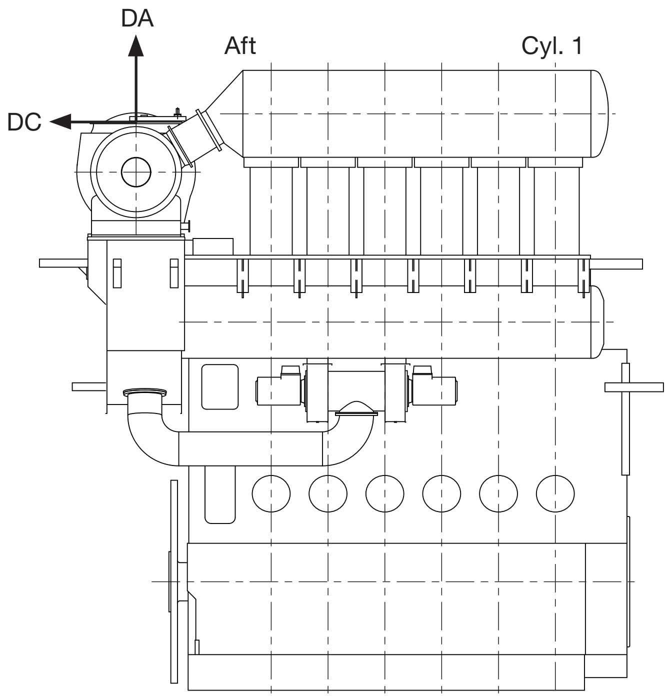
078 87 11-1.0.0b

Fig. 15.06.01a: Vectors of thermal expansion at the turbocharger exhaust gas outlet flange, TC on exhaust side

No. of cylinders		**5-9**		**5**	**6**	**7**	**8**	**9**
Turbocharger Make	**Type**	**DA mm**	**DB mm**	**DC mm**	**DC mm**	**DC mm**	**DC mm**	**DC mm**
MAN	TCA44							
	TCA55							
	TCA66							
	TCA77							
ABB	A265							
	A170 / A270							
	A175 / A275	Available on request						
	A180							
MHI	MET42							
	MET48							
	MET53							
	MET60							
	MET66							
	MET71							

Table 15.06.02a: Max. expected movements of the exhaust gas flange resulting from thermal expansion, TC on exhaust side

One turbocharger located on aft end



DA: Max. movement of the turbocharger flange in the vertical direction
DC: Max. movement of the turbocharger flange in the longitudinal direction

078 87 11-1.0.0a

Fig. 15.06.01b: Vectors of thermal expansion at the turbocharger exhaust gas outlet flange, TC on aft end

No. of cylinders		5-9	5	6	7	8	9
Turbocharger Make	Type	DA mm	DC mm	DC mm	DC mm	DC mm	DC mm
MAN	TCA44	Available on request					
	TCA55						
	TCA66						
	TCA77						
ABB	A265						
	A170 / A270						
	A175 / A275						
	A180						
MHI	MET42						
	MET48						
	MET53						
	MET60						
	MET66						
	MET71						

Table 15.06.02b: Max. expected movements of the exhaust gas flange resulting from thermal expansion, TC on aft end

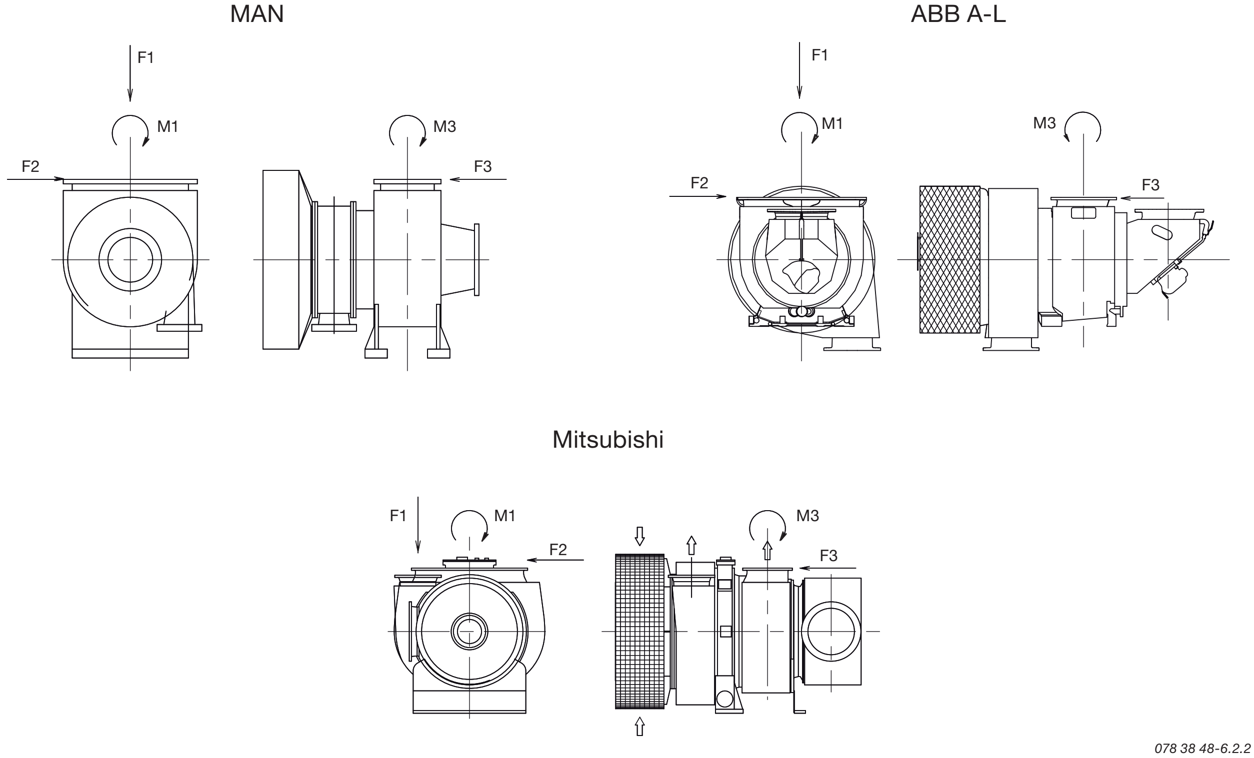


Fig. 15.06.03: Forces and moments on the turbochargers' exhaust gas outlet flange

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.

Turbocharger Make	**Type**	**M1 Nm**	**M3 Nm**	**F1 N**	**F2 N**	**F3 N**
MAN	TCA44	3,200	6,400	8,500	8,500	4,200
	TCA55	3,400	6,900	9,100	9,100	4,500
	TCA66	3,700	7,500	9,900	9,900	4,900
	TCA77	4,100	8,200	10,900	10,900	5,400
ABB	A265	1,200	1,200	2,800	1,800	1,800
	A170 / A270	1,900	1,900	3,600	2,400	2,400
	A175 / A275	3,300	3,300	5,400	3,500	3,500
	A180	4,600	4,600	6,800	4,400	4,400
MHI	MET42	3,400	1,700	5,800	2,000	1,800
	MET48	Available on request				
	MET53	4,900	2,500	7,300	2,600	2,300
	MET60	6,000	3,000	8,300	2,900	3,000
	MET66	6,800	3,400	9,300	3,200	3,000
	MET71	7,000	3,500	9,600	3,300	3,100

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.

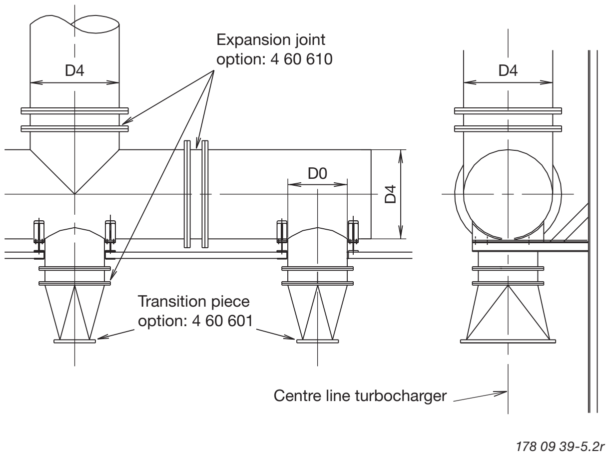


Fig. 15.07.01a: Exhaust pipe system, with turbocharger located on exhaust side of engine, option: 4 59 123

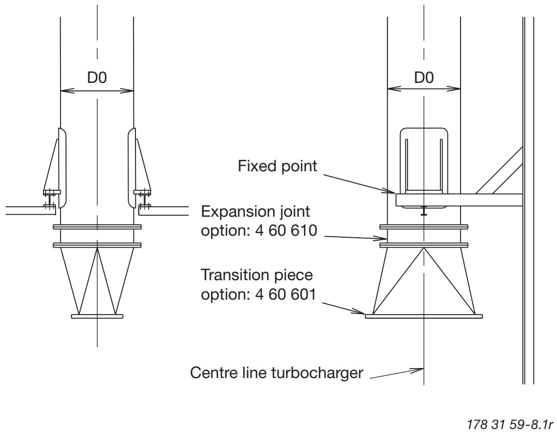


Fig. 15.07.01b: Exhaust pipe system, with single turbocharger located on aft end of engine, option: 4 59 121

Gas velocity				Exhaust gas pipe diameters			
35 m/s	40 m/s	45 m/s	50 m/s	D0			D4
Gas mass flow				1 T/C	2 T/C	3 T/C	
kg/s	kg/s	kg/s	kg/s	[DN]	[DN]	[DN]	[DN]
15.0	17.2	19.3	21.5	900	650	500	900
16.7	19.1	21.5	23.9	950	650	550	950
18.6	21.2	23.9	26.5	1,000	700	600	1,000
20.5	23.4	26.3	29.2	1,050	750	600	1,050
22.4	25.7	28.9	32.1	1,100	800	650	1,100
24.5	28.0	31.5	35.1	1,150	800	650	1,150
26.7	30.5	34.3	38.2	1,200	850	700	1,200
31.4	35.8	40.3	44.8	1,300	900	750	1,300
36.4	41.6	46.8	51.9	1,400	1,000	800	1,400
41.7	47.7	53.7	59.6	1,500	1,050	850	1,500
47.5	54.3	61.1	67.8	1,600	1,150	900	1,600

Table 15.07.02: Exhaust gas pipe diameters and exhaust gas mass flow at various velocities

Engine Control System

16

Engine Control System ME-B

The Engine Control System for the ME-B engine is prepared for conventional remote control, having an interface to the Bridge Control system and the Engine Side Console (ESC).

The layout of the Engine Control System is shown in Fig. 16.01.01, the mechanical-hydraulic system is shown in Fig. 16.01.02, and the pneumatic system, shown in Fig. 16.01.03.

Main Operating Panel (MOP)

In the engine control room a MOP screen is located, which is a Personal Computer with a touch screen as well as a trackball from where the engineer can carry out engine commands, adjust the engine parameters, select the running modes, and observe the status of the control system.

A conventional marine approved PC is also located in the engine control room serving as a back-up unit for the MOP.

Engine Interface Control Unit (EICU)

The EICU installed in the engine control room perform such tasks as interface with the surrounding control systems, See Fig. 16.01.01.

Cylinder Control Unit (CCU)

The control system includes one CCU per one or two cylinders. The CCU controls the electronic fuel Valve Activitation (ELFI), in accordance with the commands received from the ECS.

All the CCUs are identical, and in the event of a failure of a CCU for two cylinders only these cylinders will automatically be put out of operation.

It should be noted that any electronic part could be replaced without stopping the engine, which will revert to normal operation immediately after the replacement of the defective 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 (EEC) is available as an option in order to optimise the steam production versus SFOC, option: 4 65 342.

Engine Side Console (ESC)

In normal operating the engine can be controlled from either the bridge or from the engine control room.

Alternatively, the Engine Side Console can be activated.

The layout of the Engine Side Console includes the components indicated in the manoeuvring diagram, shown in Figs. 16.01.04a and 16.01.04b. The console and an electronic speed setting device is located on the camshaft side of the engine.

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.

Power supply A	
System	IT (Floating), DC system w. individually isolated outputs
Voltage	Input 100-240V AC, 45-65 Hz, output 24V DC
Protection	Input over current, output over current, output high/low voltage
Alarms as potential free contacts	AC power, UPS battery mode, Batteries not available (fuse fail)

Power supply B	
System	IT (Floating), DC system w. individually isolated outputs
Voltage	Input 110-240 VAC, output 24V DC
Protection	Input over current, output over current, output high/low voltage
Alarms as potential free contacts	AC power, UPS battery mode, Batteries not available (fuse fail)

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.

Hydraulic Power Supply (HPS)

The purpose of the 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.

As hydraulic medium, normal lubricating oil is used, and it is in the standard execution taken from the main lubricating oil system of the engine.

Hydraulic power is supplied by two electrically driven pumps. The pumps are of the variable displacement type and are the same size. The displacement of the pumps is hydraulically controlled to meet the pressure set point from the ECS.

The sizes and capacities of the HPS unit depend on the engine type. Further details about the lubricating oil/hydraulic oil system can be found in Chapter 8.

Engine Control System Layout

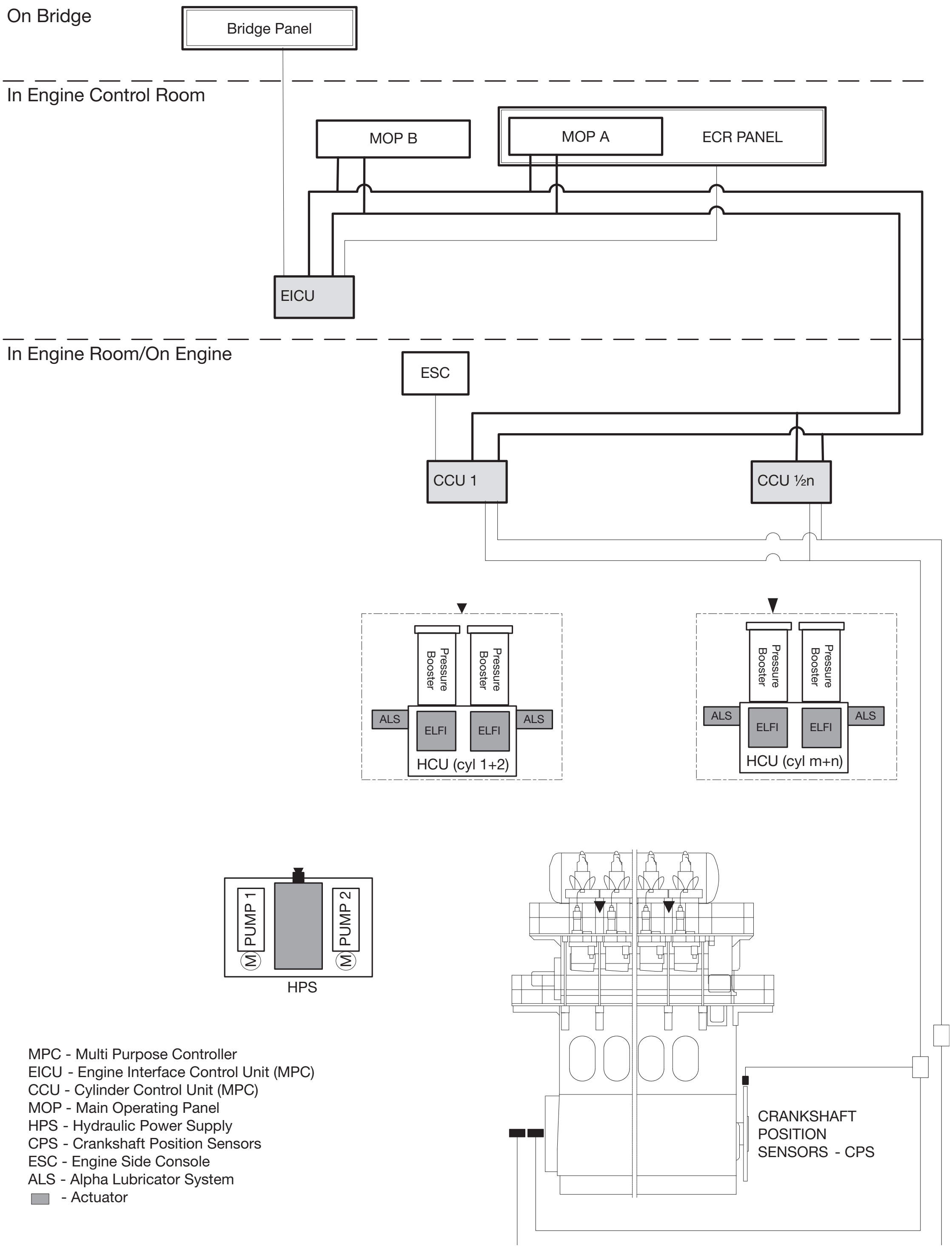


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Fig. 16.01.01: Engine Control System Layout

Mechanical-hydraulic System with Hydraulic Power Supply Unit on Engine

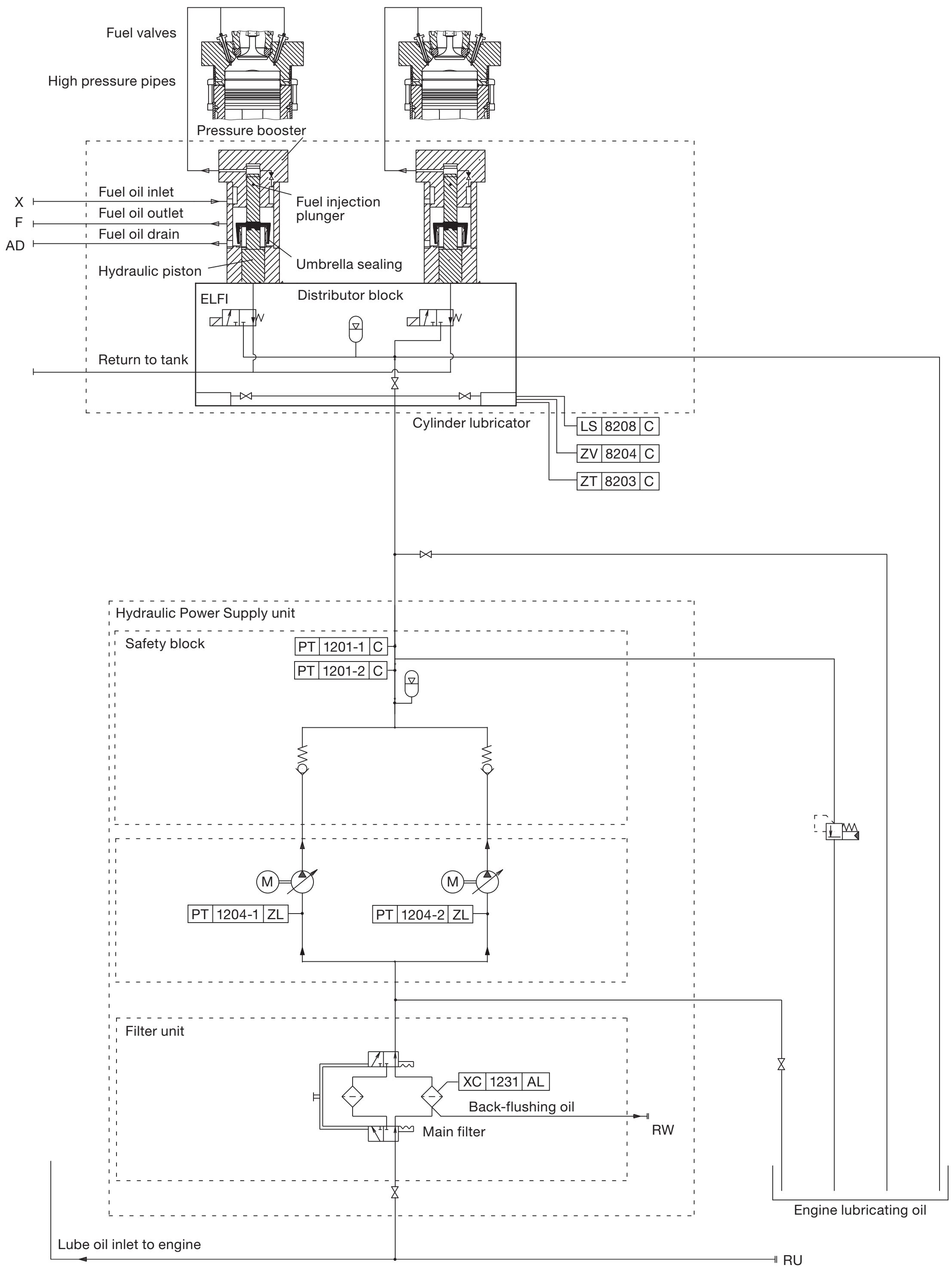

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Fig. 16.01.02: Mechanical-hydraulic System with Hydraulic Power Supply Unit on Engine

Engine Control System Interface to Surrounding Systems

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

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.

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.

The safety system is included in the basic extent of delivery.

Telegraph system

The telegraph system is an independent 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 Engine Side Console (ESC).

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 an approved supplier.

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 based on the status for:

- fuel oil system
- lube oil system
- cooling water systems

and partly from the ECS

- 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

Instrumentation

Chapter 18 in the Project Guide for the specific engine type includes lists of instrumentation for:

The class requirements and MAN Diesel & Turbo's requirements for alarms, slow down and shut down for Unattended Machinery Spaces.

Pneumatic Manoeuvring Diagram, FPP

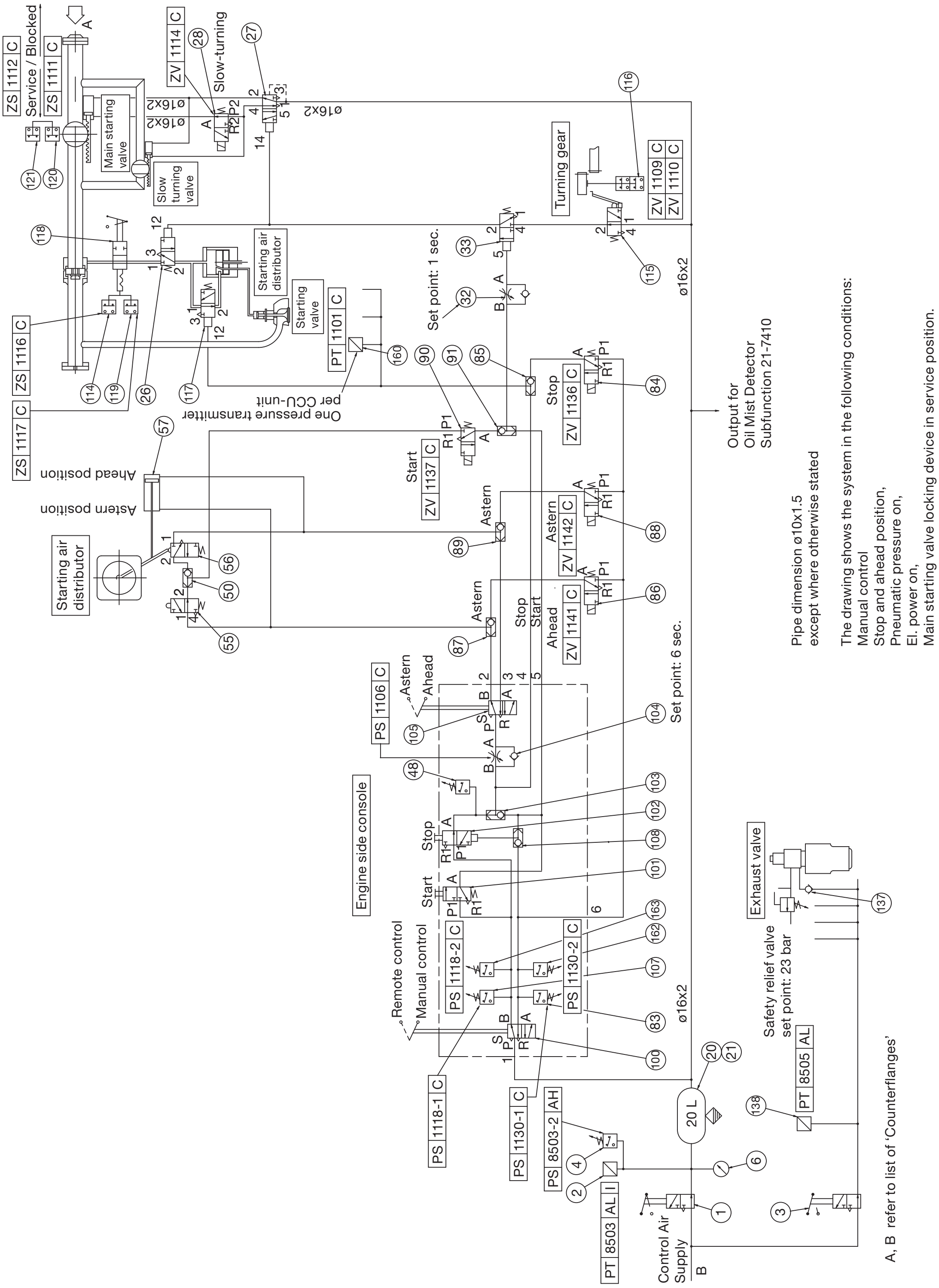

Fig. 16.01.04a: Pneumatic Manoeuvring Diagram , Fixed Pitch Propeller (FPP)

Pneumatic Manoeuvring Diagram, CPP

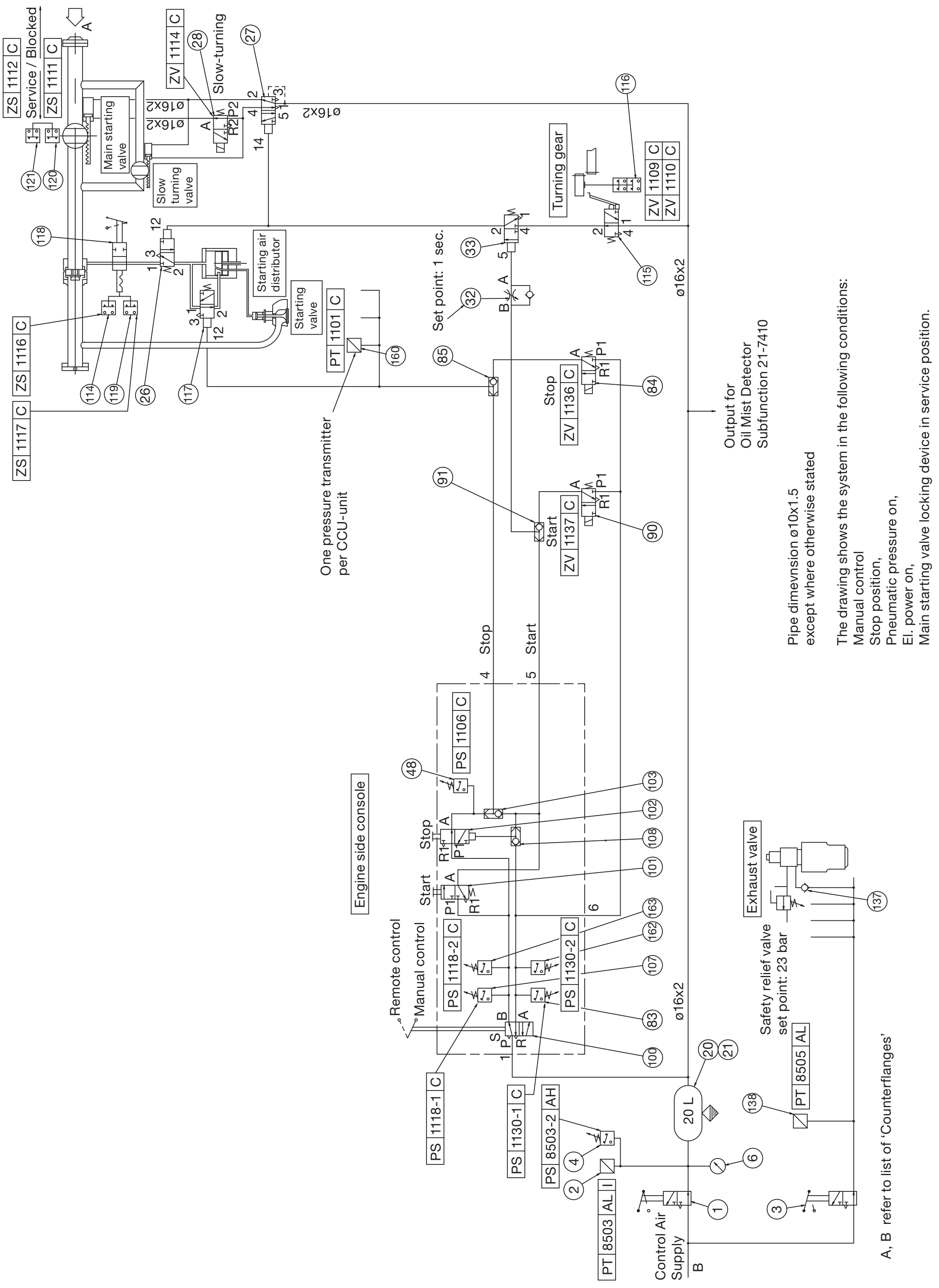

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Fig. 16.01.04b: Pneumatic Manoeuvring Diagram, Controllabe Pitch Propeller (CPP)

Vibration Aspects

17

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.

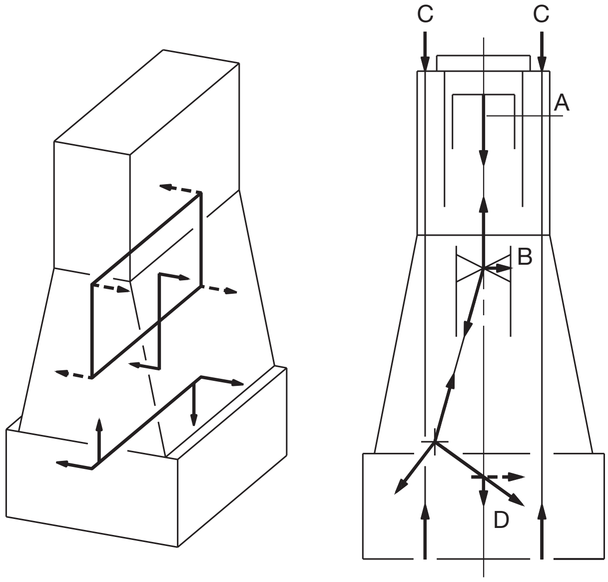
In the following, a brief description is given of their origin and of the proper countermeasures needed to render them harmless.

External unbalanced moments

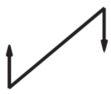
The inertia forces originating from the unbalanced rotating and reciprocating masses of the engine create unbalanced external moments although the external forces are zero.

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.

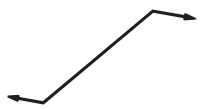
Countermeasures have to be taken if hull resonance occurs in the operating speed range, and if the vibration level leads to higher accelerations and/or velocities than the guidance values given by international standards or recommendations (for instance related to special agreement between shipowner 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.



A – Combustion pressure
B – Guide force
C – Staybolt force
D – Main bearing force

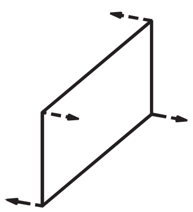


1st order moment vertical 1 cycle/rev.
2nd order moment, vertical 2 cycle/rev.



1st order moment, horizontal
1 cycle/rev.

Guide force moment,
H transverse Z cycles/rev.
Z is 1 or 2 times number of cylinder



Guide force moment,
X transverse Z cycles/rev.
Z = 1, 2, 3 ... 11, 12, 14

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Fig. 17.01.01: External unbalanced moments and guide force moments

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.

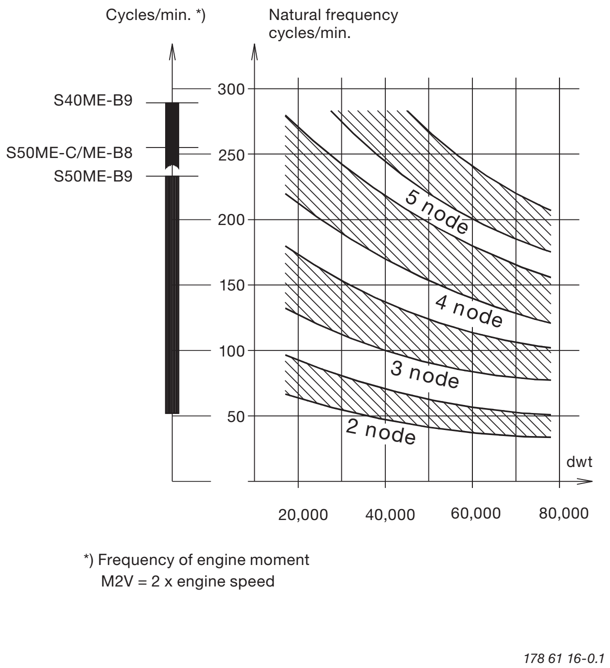

Fig. 17.02.01: Statistics of vertical hull vibrations, an example from tankers and bulk carriers

Compensator solutions

On engines where engine-driven moment compensators cannot be installed aft nor fore, two solutions remain to cope with the 2nd order moment as shown in Fig. 17.03.02:

1) No compensators, if considered unnecessary on the basis of natural frequency, nodal point and size of the 2nd order moment.

2) An electrically driven moment compensator placed in the steering gear room, as explained in Section 17.03, option: 4 31 253 or 255.

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. Due to its position in the steering gear room, solution 2) is not particularly sensitive to the position of the node.

Determine the need

A decision regarding the vibrational aspects and the possible use of compensators should preferably 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 this.

If the compensator is initially omitted, measurements taken during the sea trial, or later in service and with fully loaded ship, will be able to show if a compensator has to be fitted at all.

Preparation for compensators

If no calculations are available at the contract stage, we advise to make preparations for the fitting of an electrically driven moment compensator in the steering compartment, see Section 17.03.

Basic design regarding compensators

Experience with our two-stroke slow speed engines has shown that propulsion plants with small bore engines (engines smaller than 46 types) are less sensitive regarding hull vibrations exited by 2nd order moments than the larger bore engines. Therefore, engines type 40 and 35 do not have engine driven 2nd order moment compensators specified as standard.

For 5 and 6-cylinder engines type 50, the basic design regarding 2nd order moment compensators is:

- With MAN B&W external electrically driven moment compensator, RotComp, EoD: 4 31 255

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.

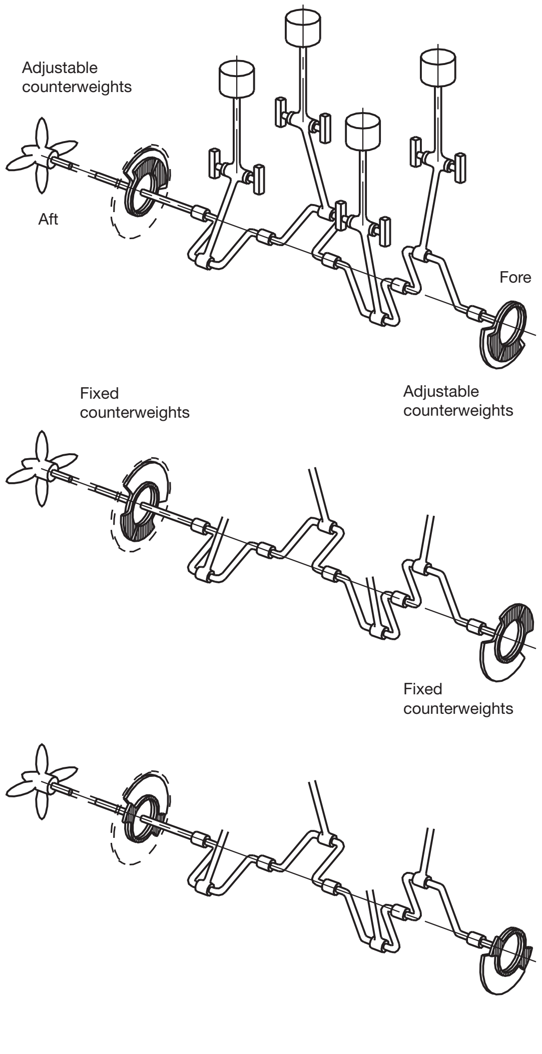

Fig. 17.02.02: Examples of counterweights

Electrically Driven Moment Compensator

If 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 and it offers several advantages over the engine mounted solutions:

- When placed in the steering gear room, the compensator is not particularly sensitive to the positioning of the node.

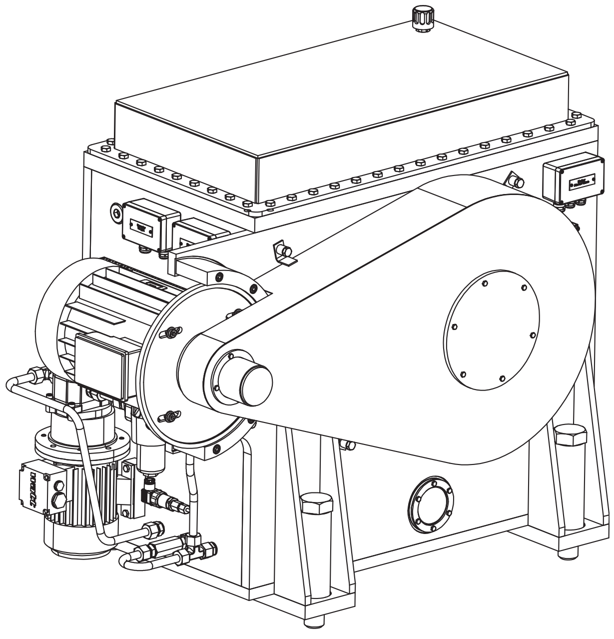

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Fig. 17.03.01: MAN B&W external electrically driven moment compensator, RotComp, option: 4 31 255

- 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.

- 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 re-used on another ship.

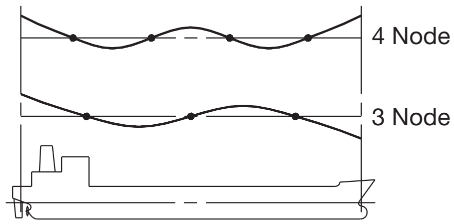
It is a condition for the application of the rotating force moment compensator that no annoying longitudinal hull girder vibration modes are excited. Based on our present knowledge, and confirmed by actual vibration measurements onboard a ship, we do not expect such problems.

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.

Nodes and Compensators

3 and 4-node vertical hull girder mode



Electrically driven moment compensator

Compensating moment
F_D × Lnode
outbalances M2V

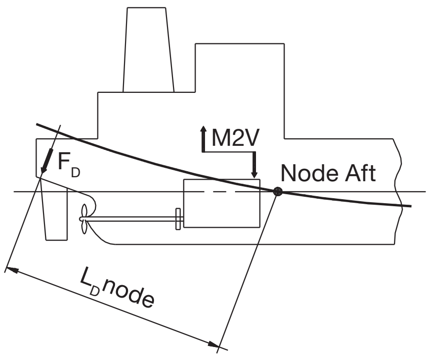


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Fig. 17.03.02: Compensation of 2nd order vertical external moments

Power Related Unbalance

To evaluate if there is a risk that 1st and 2nd order external moments will excite disturbing hull vibrations, the concept Power Related Unbalance (PRU) can be used as a guidance, see Table 17.04.01 below.

$$PRU = \frac{\text{External moment}}{\text{Engine power}} \text{ Nm/kW}$$

With the PRU-value, stating the external moment relative to the engine power, it is possible to give an estimate of the risk of hull vibrations for a specific engine.

Based on service experience from a great number of large ships with engines of different types and cylinder numbers, the PRU-values have been classified in four groups as follows:

PRU Nm/kW	Need for compensator
0 - 60	Not relevant
60 - 120	Unlikely
120 - 220	Likely
220 -	Most likely

S50ME-B9 – 1,780 kW/cyl at 117 r/min

	5 cyl.	6 cyl.	7 cyl.	8 cyl.	9 cyl.	10 cyl.	11 cyl.	12 cyl.	14 cyl.
PRU acc. to 1st order, Nm/kW	11.5	0.0	4.9	14.3	13.0	N.a.	N.a.	N.a.	N.a.
PRU acc. to 2nd order, Nm/kW	135.9	78.8	19.6	0.0	17.2	N.a.	N.a.	N.a.	N.a.

Based on external moments in layout point L_1
N.a. Not applicable

Table 17.04.01: Power Related Unbalance (PRU) values in Nm/kW

Calculation of External Moments

In the table at the end of this chapter, the external moments (M_1) are stated at the speed (n_1) and MCR rating in point L_1 of the layout diagram. For other speeds (n_A), the corresponding external moments (M_A) are calculated by means of the formula:

$$M_A = M_1 \times \left\{\frac{n_A}{n_1}\right\}^2 \text{ kNm}$$

(The tolerance on the calculated values is 2.5%).

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 (L_1) 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 (M_H)

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.

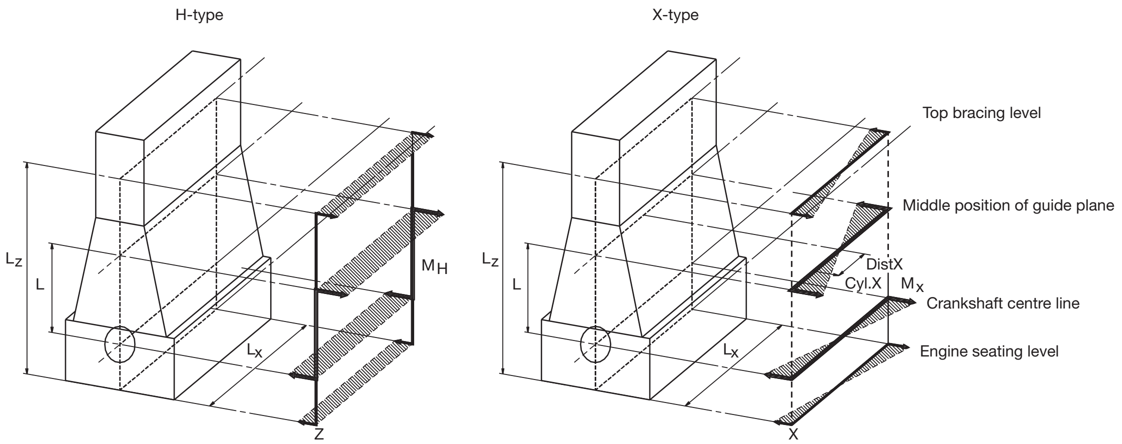

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Fig. 17.05.01: H-type and X-type guide force moments

As the deflection shape for the H-type is equal for each cylinder, the N[th] 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:

Force = M_H/L [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:

$\text{Force}_Z = M_H/L_Z$ [kN]

Any other vertical distance may be applied so as to accomodate 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.

$\text{Force}_{Z,\text{ one point}} = \text{Force}_{Z,\text{ total}}/N_{\text{top bracing, total}}$ [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):

'Bi-moment' = Σ [force-couple(cyl.X) × distX] in kNm^2

The X-type guide force moment is then defined as:

M_X = 'Bi-Moment'/L kNm

For modelling purpose, the size of the four (4) forces can be calculated:

Force = M_X/L_X [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:

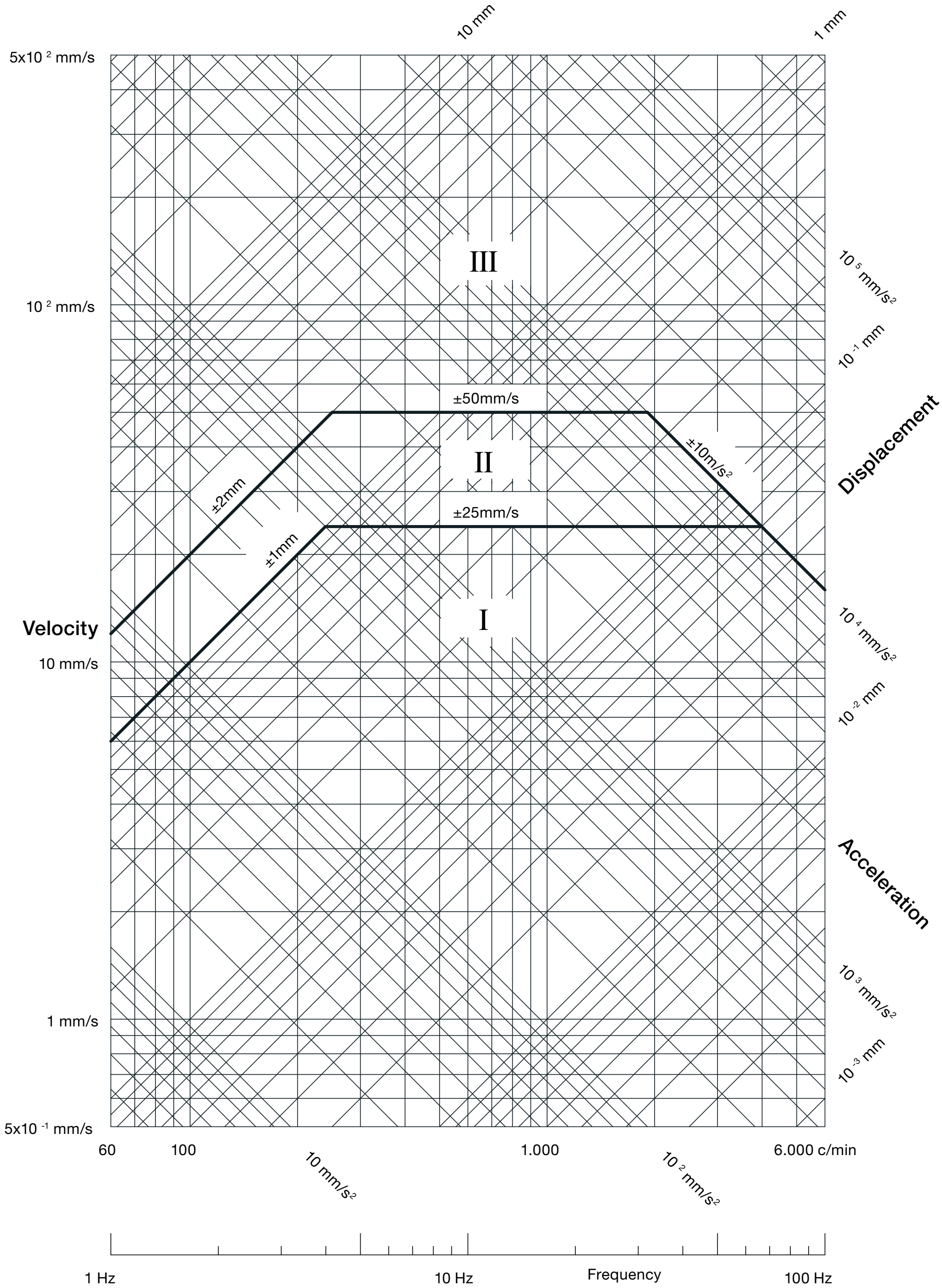
$\text{Force}_{Z,\text{ one point}} = \frac{M_x \times L}{L_x \times L_x}$ [kN]

In order to calculate the forces, it is necessary to know the lengths of the connecting rods = L, which are:

Engine Type	L in mm
S60ME-B8	2,540
G50ME-B9	2,500
S50ME-B9	2,214
S50ME-B8	2,050
S46ME-B8	1,980
S40ME-B9	1,770
S35ME-B9	1,550

*) Available on request

Vibration Limits Valid for Single Order Harmonics



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

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Fig.17.05.02: Vibration limits

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 consideraed.

An axial damper is fitted as standard on all engines, minimising the effects of the axial vibrations, EoD: 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'.

External Forces and Moments, S50ME-B9.3 Layout point L_1

No of cylinder :	5	6	7	8	9
Firing type :	1-4-3-2-5	1-5-3-4-2-6	1-7-2-5-4-3-6	1-8-3-4-7-2-5-6	1-6-7-3-5-8-2-4-9
External forces [kN] :					
1. Order : Horizontal	0	0	0	0	0
1. Order : Vertical	0	0	0	0	0
2. Order : Vertical	0	0	0	0	0
4. Order : Vertical	0	0	0	0	0
6. Order : Vertical	0	10	0	0	0
External moments [kNm] :					
1. Order : Horizontal a)	102	0	61	203	209
1. Order : Vertical a)	102	0	61	203	209
2. Order : Vertical	1,210	842	244	0	275
4. Order : Vertical	8	60	172	70	87
6. Order : Vertical	1	0	0	0	22
Guide force H-moments in [kNm] :					
1 x No. of cyl.	952	758	594	442	302
2 x No. of cyl.	103	30	11	17	27
3 x No. of cyl.	-	-	-	-	-
Guide force X-moments in [kNm] :					
1. Order :	85	0	50	169	174
2. Order :	216	150	44	0	49
3. Order :	176	318	348	446	551
4. Order :	37	284	806	328	408
5. Order :	0	0	76	950	375
6. Order :	22	0	13	0	778
7. Order :	167	0	0	30	38
8. Order :	109	76	6	0	20
9. Order :	6	119	13	12	0
10. Order :	0	28	80	0	8
11. Order :	2	0	43	56	5
12. Order :	10	0	2	8	31
13. Order :	4	0	0	11	4
14. Order :	0	2	0	0	3
15. Order :	0	7	0	1	12
16. Order :	0	3	1	0	1

a) 1st order moments are, as standard, balanced so as to obtain equal values for horizontal and vertical moments for all cylinder numbers.

Table 17.07.01

Monitoring Systems and Instrumentation

18

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(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.

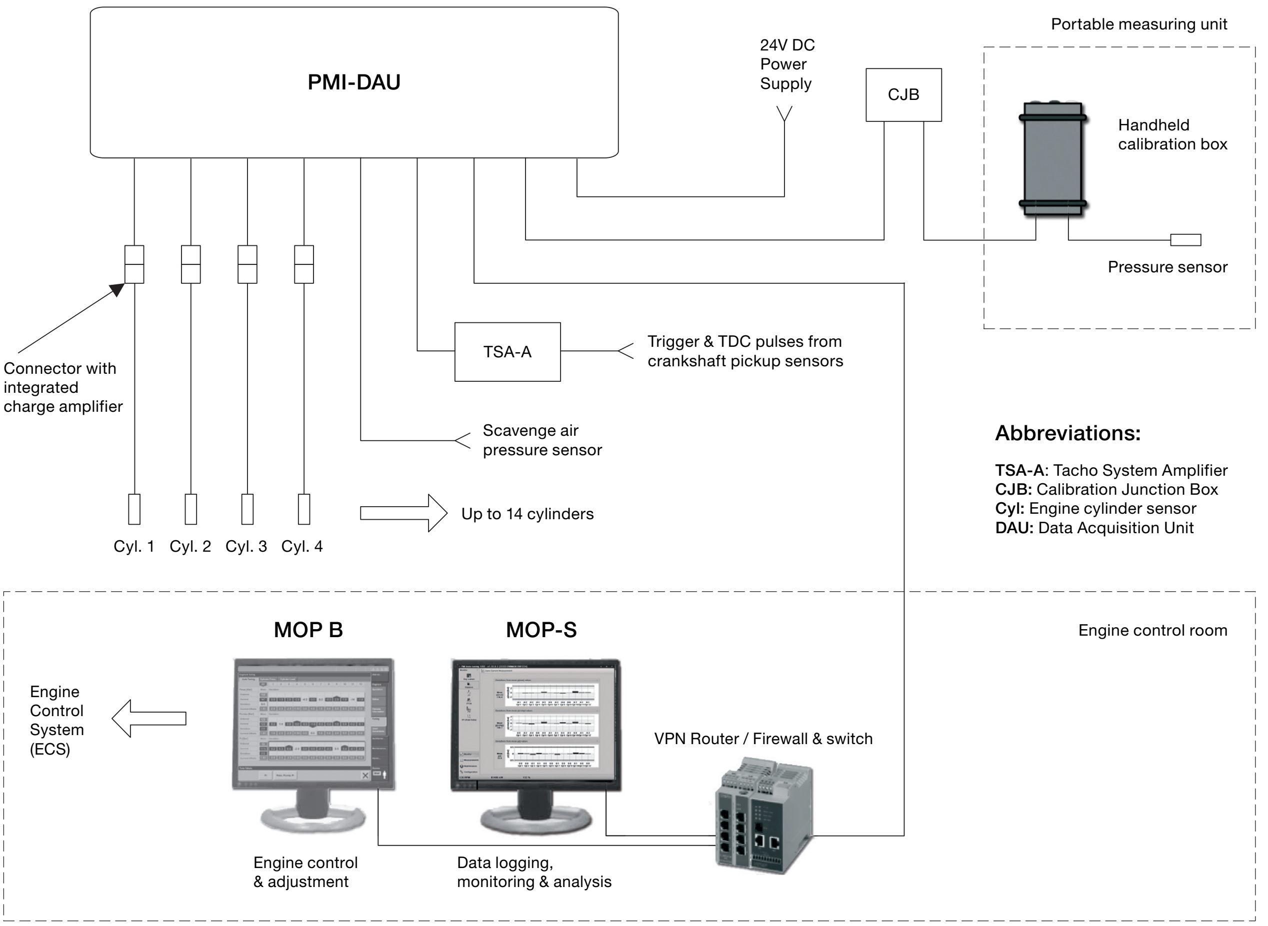

Fig. 18.02.01: PMI Auto-tuning system, EoD: 4 75 216

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’.

Sensor	Parameter name	No. of sensors	Recommended range	Resolution 3)	Remark
	Fuel oil system data				
PT 8001	Inlet pressure	1	0 - 10 bar	0.1 bar	
TE 8005	Inlet temperature	1	0 - 200 °C	0.1 °C	
	Cooling water system				
PT 8421	Pressure air cooler inlet	A/C	0 - 4 bar	0.1 bar	
TE 8422	Temperature air cooler inlet	1	0 - 100 °C	0.1 °C	
TE 8423	Temperature air cooler outlet	A/C	0 - 100 °C	0.1 °C	
PDT 8424	dP cooling water across air cooler	A/C	0 - 800 mbar	0.1 mbar	
	Scavenging air system				
PT 8601	Scavenge air receiver pressure	Rec.	0 - 4 bar	1 mbar	1)
TE 8605	Scavenge air cooler air inlet temperature	A/C	0 - 200 °C	0.1 °C	
PDT 8606	dP air across scavenge air cooler	A/C	0 - 100 mbar	0.1 mbar	
TE 8608	Scavenge air cooler air outlet temperature	A/C	0 - 100 °C	0.1 °C	Optional if one T/C
TE 8609	Scavenge air receiver temperature	Rec.	0 - 100 °C	0.1 °C	
TE 8612	T/C air intake temperature	T/C	0 - 100 °C	0.1 °C	
	Exhaust gas system				
TC 8701	Exhaust gas temperature at turbine inlet	T/C	0 - 600 °C	0.1 °C	
TC 8702	Exhaust gas temperature after exhaust valve	Cyl.	0 - 600 °C	0.1 °C	
PT 8706	Exhaust gas receiver pressure	Rec.	0 - 4 bar	0.01 bar	
TC 8707	Exhaust gas temperature at turbine outlet	T/C	0 - 600 °C	0.1 °C	
PT 8708	Turbine back presssure	T/C	0 - 100 mbar	0.1 mbar	
	General data				
ZT 8801	Turbocharger speed	T/C	rpm	1 rpm	
PT 8802	Ambient pressure	1	900 - 1,100 mbar	1 mbar	Absolute!
ZT 4020	Engine speed	1	rpm	0.1 rpm	1)
XC 8810	Governor index (relative)	1	%	0.1 %	1)
–	Power take off/in from main engine shaft (PTO/PTI)	1	kW	1 kW	With option installed
	Pressure measurement				
XC1401	Mean Indicated Pressure, MIP	Cyl.	bar	0.01 bar	2)
XC1402	Maximum Pressure, Pmax	Cyl.	bar	0.1 bar	2)
XC1403	Compression Pressure, Pcomp	Cyl.	bar	0.1 bar	2)
–	PMI online engine speed	Cyl.	rpm	0.1 rpm	2)

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.

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 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.

Alarm, slow down and remote indication sensors

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.

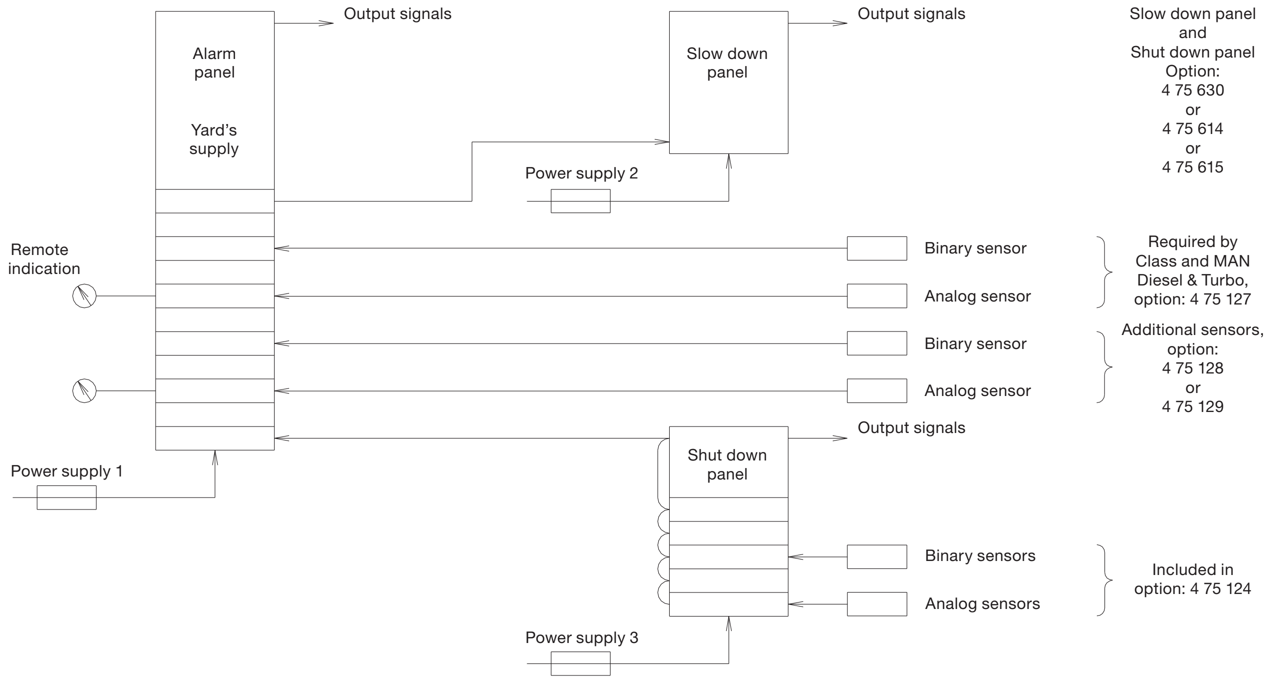

Fig. 18.04.01: Panels and sensors for alarm and safety systems

Alarms for UMS – Class and MAN Diesel & Turbo requirements

ABS	BV	CCS	DNV	GL	KR	LR	NK	RINA	RS	IACS	MAN Diesel	Sensor and function	Point of location
													Fuel oil
1	1	1	1	1	1	1	1	1	1	1	1	PT 8001 AL	Fuel oil, inlet engine
1	1	1	1	1	1	1	1	1	1	1	1	LS 8006 AH	Leakage from high pressure pipes
													Lubricating oil
1	1	1	1	1	1	1	1	1	1	1	1	TE 8106 AH	Thrust bearing segment
1	1	1	1	1	1	1	1	1	1	1	1	PT 8108 AL	Lubricating oil inlet to main engine
1	1	1	1	1	1	1	1	1	1	1	1	TE 8112 AH	Lubricating oil inlet to main engine
1	1	1	1	1	1		1	1	1	1	1	TE 8113 AH	Piston cooling oil outlet/cylinder
1	1	1	1	1	1		1	1	1	1	1	FS 8114 AL	Piston cooling oil outlet/cylinder
1	1	1		1	1	1		1	1	1	1	TE 8117 AH	Turbocharger lubricating oil outlet from turbocharger/turbocharger
											1	TE 8123 AH	Main bearing oil outlet temperature/main bearing (S40/35ME-B9 only)
											1	XC 8126 AH	Bearing wear (All types except S40/35ME-B9); sensor common to XC 8126/27
											1	XS 8127 A	Bearing wear detector failure (All types except S40/35ME-B)
		1		1		1	1				1	PDS 8140 AH	Lubricating oil differential pressure – cross filter
											1	XS 8150 AH	Water in lubricating oil; sensor common to XS 8150/51/52
											1	XS 8151 AH	Water in lubricating oil – too high
											1	XS 8152 A	Water in lubricating oil sensor not ready
													MAN B&W Alpha Lubrication
											1	LS 8212 AL	Small box for heating element, low level

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

ABS	BV	CCS	DNV	GL	KR	LR	NK	RINA	RS	IACS	MAN Diesel	Sensor and function	Point of location
													Hydraulic Power Supply
											1	XC 1231 A	Automatic main lube oil filter, failure (Boll & Kirch)
				1							1	TE 1310 AH	Lubrication oil inlet (Only for ME/-GI with separate oil system to HPS installed)
													Cooling water
1	1	1	1	1	1	1	1	1	1	1	1	PT 8401 AL	Jacket cooling water inlet
											1	PDT 8403 AL	Jacket cooling water across engine; to be calculated in alarm system from sensor no. 8402 and 8413 3)
											1	PDT 8404 AL	Jacket cooling water across cylinder liners 2)
											1	PDT 8405 AL	Jacket cooling water across cylinder covers and exhaust valves 2)
				1							1	TE 8407 AL	Jacket cooling water inlet
1	1	1	1	1	1	1	1	1	1	1	1	TE 8408 AH	Jacket cooling water outlet, cylinder
											1	TT 8410	Cylinder cover cooling water outlet, cylinder 2)
											1	PT 8413 I	Jacket cooling water outlet, common pipe
1	1	1		1	1	1	1	1	1	1	1	PT 8421 AL	Cooling water inlet air cooler
				1							1	TE 8422 AH	Cooling water inlet air cooler/air cooler
													Compressed air
1	1	1		1	1	1	1	1	1	1	1	PT 8501 AL	Starting air inlet to main starting valve
1	1	1	1	1	1	1	1	1+	1	1	1	PT 8503 AL	Control air inlet and finished with engine
			1								1	PT 8505 AL	Air inlet to air cylinder for exhaust valve
													Scavenge air
				1					1		1	PS 8604 AL	Scavenge air, auxiliary blower, failure (Only ME-B)
	1	1		1			1÷				1	TE 8609 AH	Scavenge air receiver
1	1	1	1	1	1	1	1	1	1	1	1	TE 8610 AH	Scavenge air box – fire alarm, cylinder/cylinder
1	1	1		1	1	1	1	1	1	1	1	LS 8611 AH	Water mist catcher – water level

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 wirh 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

ABS	BV	CCS	DNV	GL	KR	LR	NK	RINA	RS	IACS	MAN Diesel	Sensor and function	Point of location
													Exhaust gas
1	1	1	1	1	1	(1)	1	1	1	1	1	TC 8701 AH	Exhaust gas before turbocharger/turbocharger
1	1		1		1	1	1	1	1	1	1	TC 8702 AH	Exhaust gas after exhaust valve, cylinder/cylinder
1	1	1	1	1	1	1	1	1	1	1		TC 8707 AH	Exhaust gas outlet turbocharger/turbocharger (Yard's supply)
													Miscellaneous
											1	WT 8812 AH	Axial vibration monitor 2)
1	1	▢	1	1	1	1	1	1	1	1	1	XS 8813 AH	Oil mist in crankcase/cylinder; sensor common to XS 8813/14
	1										1	XS 8814 AL	Oil mist detector failure
											1	XC 8816 I	Shaftline earthing device
											1	TE 8820 AH	Cylinder liner monitoring/cylinder 3)
													Engine Control System
1	1	1	1	1	1	1	1	1	1	1	1	XC 2201 A	Power failure
1	1		1	1		1	1	1	1	1	1	XC 2202 A	ME common failure
											1	XC 2202-A A	ME common failure (ME-GI only)
											1	XC 2213 A	Double-pipe HC alarm (ME-GI only)
													Power Supply Units to Alarm System
											1	XC 2901 A	Low voltage ME power supply A
											1	XC 2902 A	Low voltage ME power supply B
											1	XC 2903 A	Earth failure ME power supply

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.

3) Required for: K98ME/ME-C, S90ME-C, K90ME-C and K80ME-C9 engines incl. ME-GI variants.

▢ Alarm for overheating of main, crank and crosshead bearings, option: 4 75 134.

Table 18.04.02c: Alarm functions for UMS

Slow down for UMS – Class and MAN Diesel & Turbo requirements

ABS	BV	CCS	DNV	GL	KR	LR	NK	RINA	RS	IACS	MAN Diesel	Sensor and function	Point of location
1	1	1	1	1	1	1	1	1	1	1	1	TE 8106 YH	Thrust bearing segment
1	1	1	1*	1	1	1	1	1	1	1	1	PT 8108 YL	Lubricating oil inlet to main engine
				1		1						TE 8112 YH	Lubricating oil inlet to main engine
1	1	1	1	1	1		1	1	1	1	1	TE 8113 YH	Piston cooling oil outlet/cylinder
1	1	1	1	1	1		1	1	1	1	1	FS 8114 YL	Piston cooling oil outlet/cylinder
											1	TE 8123 YH	Main bearing oil outlet temperature/main bearing (S40/35ME-B9 only)
											1	XC 8126 YH	Bearing wear (All except S40/35ME-B9)
1	△1	△1	1		1	△1	1	1	1	1	1	PT 8401 YL	Jacket cooling water inlet
											1	PDT 8403 YL	Jacket cooling water across engine (Not for LDCL)
											1	PDT 8404 YL	Jacket cooling water across cylinder liners (Only for LDCL)
											1	PDT 8405 YL	Jacket cooling water across cylinder covers and exhaust valves (Only for LDCL)
1	1	1	1	1	1	1	1	1	1	1	1	TE 8408 YH	Jacket cooling water outlet, cylinder/cylinder
	1	[1					[1					TE 8609 YH	Scavenge air receiver
1	1	[1	1	1	1	1	[1	1	1	1	1	TE 8610 YH	Scavenge air box fire-alarm, cylinder/cylinder
		1	1						1			TC 8701 YH	Exhaust gas before turbocharger/turbocharger
1	1		1	[1	1	1	1	1	1	1	1	TC 8702 YH	Exhaust gas after exhaust valve, cylinder/cylinder
			1	[1								TC 8702 YH	Exhaust gas after exhaust valve, cylinder/cylinder, deviation from average
											1	WT 8812 YH	Axial vibration monitor 2)
(1)	(1)	( )	(1*)		(1)	(1)	(1)	(1)	(1)	(1)	1	XS 8813 YH	Oil mist in crankcase/cylinder
											1	XS/XT 8817 Y	Turbocharger overspeed (Only in case of VT TC, Waste Heat Recovery, Exhaust Gas Bypass, TC Cut-out)
				1							1	TE 1310 YH	Lubrication oil inlet (Only for ME/-GI with separate oil system to HPS installed)

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 shut down

( ) 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

ABS	BV	CCS	DNV	GL	KR	LR	NK	RINA	RS	IACS	MAN Diesel	Sensor and function	Point of location
1	1	1	1*	1	1	1	1	1	1	1	1	PS/PT 8109 Z	Lubricating oil inlet to main engine and thrust bearing
1	1	1	1*	1	1	1	1	1	1	1	1	ZT 4020 Z	Engine overspeed
1	1	1			1			1	1	1	1	TE/TS 8107 Z	Thrust bearing segment
				1								PS/PT 8402 Z	Jacket cooling water inlet
			[*]	[1]								XS 8813 Z	Oil mist in crankcase/cylinder

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.

Local instruments	Remote sensors	Point of location
Thermometer, stem type	**Temperature element/switch**	
		Hydraulic power supply
	TE 1270	HPS bearing temperature (Only ME/ME-C with HPS in centre position)
		Fuel oil
TI 8005	TE 8005	Fuel oil, inlet engine
		Lubricating oil
TI 8106	TE 8106	Thrust bearing segment
	TE/TS 8107	Thrust bearing segment
TI 8112	TE 8112	Lubricating oil inlet to main engine
TI 8113	TE 8113	Piston cooling oil outlet/cylinder
TI 8117	TE 8117	Lubricating oil outlet from turbocharger/turbocharger (depends on turbocharger design)
	TE 8123	Main bearing oil outlet temperature/main bearing (S40/35ME-B9 only)
		Cylinder lubricating oil
	TE 8202	Cylinder lubricating oil inlet
	TS 8213	Cylinder lubricating heating
		High temperature cooling water, jacket cooling water
TI 8407	TE 8407	Jacket cooling water inlet
TI 8408	TE 8408	Jacket cooling water outlet, cylinder/cylinder
TI 8409	TE 8409	Jacket cooling water outlet/turbocharger
TI 8410	TT 8410	Cylinder cover cooling water outlet, cylinder (Only for LDCL)
		Low temperature cooling water, seawater or freshwater for central cooling
TI 8422	TE 8422	Cooling water inlet, air cooler
TI 8423	TE 8423	Cooling water outlet, air cooler/air cooler
		Scavenge air
TI 8605	TE 8605	Scavenge air before air cooler/air cooler
TI 8608	TE 8608	Scavenge air after air cooler/air cooler
TI 8609	TE 8609	Scavenge air receiver
	TE 8610	Scavenge air box – fire alarm, cylinder/cylinder
Thermometer, dial type	**Thermo couple**	
		Exhaust gas
TI 8701	TC 8701	Exhaust gas before turbocharger/turbocharger
	TI/TC 8702	Exhaust gas after exhaust valve, cylinder/cylinder
	TC 8704	Exhaust gas inlet exhaust gas receiver
TI 8707	TC 8707	Exhaust gas outlet turbocharger

Table 18.05.01a: Local thermometers on engine, options 4 70 119, and remote indication sensors, option: 4 75 127

Local instruments	Remote sensors	Point of location
Pressure gauge (manometer)	**Pressure transmitter/switch**	
		Fuel oil
PI 8001	PT 8001	Fuel oil, inlet engine
		Lubricating oil
PI 8103	PT 8103	Lubricating oil inlet to turbocharger/turbocharger
PI 8108	PT 8108	Lubricating oil inlet to main engine
	PS/PT 8109	Lubricating oil inlet to main engine and thrust bearing
	PDS 8140	Lubricating oil differential pressure – cross filter
		High temperature jacket cooling water, jacket cooling water
PI 8401	PT 8401	Jacket cooling water inlet
	PS/PT 8402	Jacket cooling water inlet (Only Germanischer Lloyd)
	PDT 8403	Jacket cooling water across engine (or PT 8401 and PT 8413) (Not for LDCL)
	PDT 8404	Jacket cooling water across cylinder liners (Only for LDCL)
	PDT 8405	Jacket cooling water across cylinder covers and exhaust valves (Only for LDCL)
	PT 8413	Jacket cooling water outlet, common pipe
		Low temperature cooling water, seawater or freshwater for central cooling
PI 8421	PT 8421	Cooling water inlet, air cooler
		Compressed air
PI 8501	PT 8501	Starting air inlet to main starting valve
PI 8503	PT 8503	Control air inlet
	PT 8505	Air inlet to air cylinder for exhaust valve (Only ME-B)
		Scavenge air
PI 8601	PT 8601	Scavenge air receiver (PI 8601 instrument same as PI 8706)
PDI 8606	PDT 8606	Pressure drop of air across cooler/air cooler
	PDT 8607	Pressure drop across blower filter of turbocharger (ABB turbochargers only)
		Exhaust gas
PI 8706		Exhaust gas receiver/Exhaust gas outlet turbocharger
		Miscellaneous functions
PI 8803		Air inlet for dry cleaning of turbocharger
PI 8804		Water inlet for cleaning of turbocharger (Not applicable for MHI turbochargers)

Table 18.05.01b: Local pressure gauges on engine, options: 4 70 119, and remote indication sensors, option: 4 75 127

Local instruments	Remote sensors	Point of location
Other indicators	**Other transmitters/ switches**	
		Hydraulic power supply
	XC 1231	Automatic main lube oil filter, failure (Boll & Kirch)
	LS 1235	Leakage oil from hydraulic system
	LS 1236	Leakage oil from hydraulic system
		Engine cylinder components
	LS 4112	Leakage from hydraulic cylinder unit
		Fuel oil
	LS 8006	Leakage from high pressure pipes
		Lubricating oil
	FS 8114	Piston cooling oil outlet/cylinder
	XC 8126	Bearing wear (All types except S40/35ME-B9)
	XS 8127	Bearing wear detector failure (All types except S40-35ME-B9)
	XS 8150	Water in lubricating oil
	XS 8151	Water in lubricating oil – too high
	XS 8152	Water in lubricating oil sensor not ready
		Cylinder lube oil
	LS 8208	Level switch
	LS 8212	Small box for heating element, low level
		Scavenge air
	LS 8611	Water mist catcher – water level
		Miscellaneous functions
	ZT 8801 I	Turbocharger speed/turbocharger
WI 8812	WT 8812	Axial vibration monitor (For certain engines only, see note in Table 18.04.04)
		(WI 8812 instrument is part of the transmitter WT 8812)
	XS 8813	Oil mist in crankcase/cylinder
	XS 8814	Oil mist detector failure
	XC 8816	Shaftline earthing device
	XS/XT 8817	Turbocharger overspeed (Only in case of VT TC, Waste Heat Recovery, Exhaust Gas Bypass, TC Cut-out)

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:

4 75 162	Oil mist detector Graviner MK7. Make: Kidde Fire Protection
4 75 161	Oil mist detector Graviner MK6. Make: Kidde Fire Protection
4 75 163	Oil mist detector Visatron VN 215/93. Make: Schaller Automation
4 75 165	Oil mist detector QMI. Make: Quality Monitoring Instruments Ltd.
4 75 166	Oil mist detector MD-SX. Make: Daihatsu Diesel Mfg. Co., Ltd.
4 75 167	Oil mist detector Vision III C. Make: Specs Corporation
4 75 168	Oil mist detector GDMS-OMDN09. Make: MSS GmbH
4 75 271	Oil mist detector Triton. Make: Heinzmann

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.

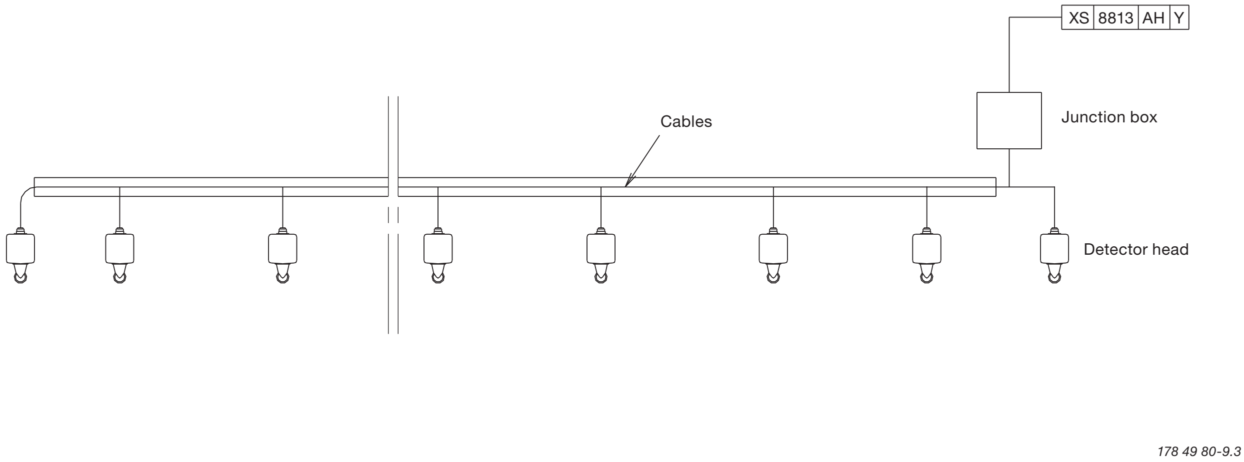

Fig. 18.06.01a: Oil mist detector wiring on engine, example based on type Graviner MK6 from Kidde Fire Protection, option: 4 75 161

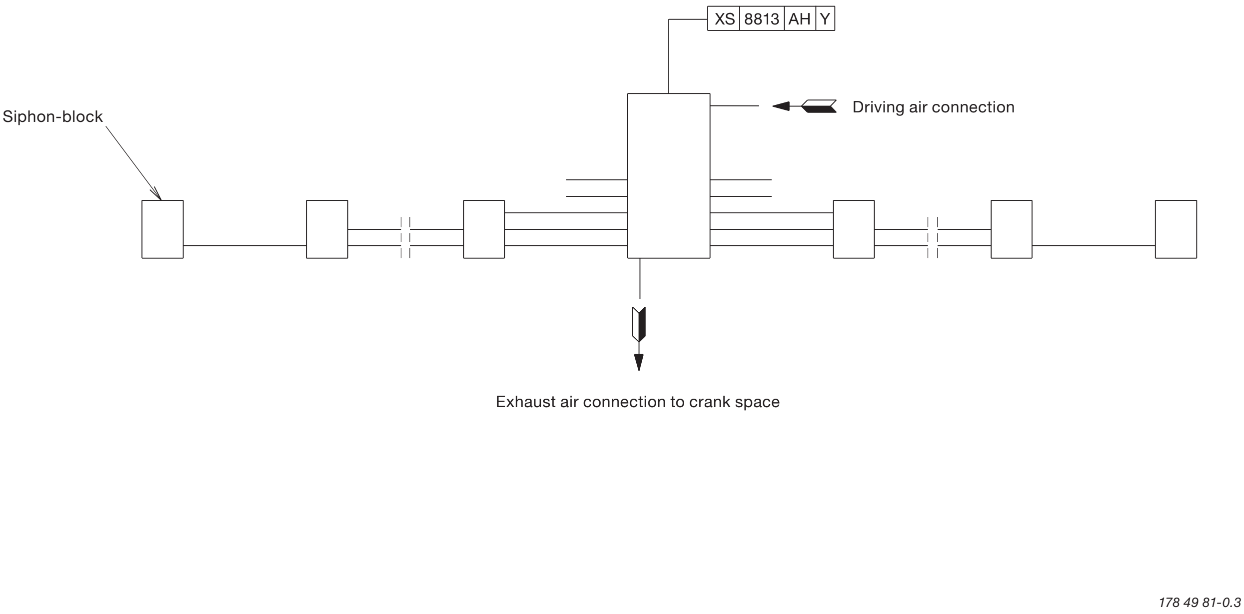

Fig. 18.06.01b: Oil mist detector pipes on engine, type Visatron VN215/93 from Schaller Automation, option: 4 75 163

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:

4 75 261	Bearing Wear Monitoring System XTS-W. Make: AMOT
4 75 262	Bearing Wear Monitoring System BDMS. Make: Dr. E. Horn
4 75 263	Bearing Wear Monitoring System PS-10. Make: Kongsberg Maritime
4 75 264	Bearing Wear Monitoring System OPEN-predictor. Make: Rovsing Dynamics

Types 60, 50, 46 and 45 ME-B 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:

4 75 133	Temperature sensors fitted to main bearings
4 75 134	Temperature sensors fitted to main bearings, crankpin bearings, crosshead bearings and for moment compensator, if any
4 75 135	Temperature sensors fitted to main bearings, crankpin bearings and crosshead bearings

S40ME-B9 and S35ME-B9 engines are as standard specified with option 4 75 133.

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:

Engine condition	Water activity, aw
High alarm level	0.5
High High alarm level	0.9

The aw = 0.5 alarm level gives sufficient margin to the satuartion 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.

In the Extent of Delivery, the Liner Wall Monitoring system is available as option: 4 75 136.

LDCL Cooling Water Monitoring System

With the Load Dependent Cylinder Liner (LDCL) cooling water system, the cooling water outlet temperature from the cylinder liner is controlled relative to the engine load, independent of the cooling water outlet from the cylinder cover.

The interval for the liner outlet may be wide, for instance from 70 to 130 degrees Celsius. The cooling water outlet temperature is measured by one sensor for each cylinder liner of the engine.

For monitoring the LDCL cooling water system the following alarm and slow down functionality must be fulfilled:

The Alarm system must be able, from one common analog sensor, to detect two alarm limits and two slow down limits as follows:

- Upper slow down limit
- Upper alarm limit
- Load dependent slow down limit
- Load dependent alarm limit.

An example of the limits is shown in Fig. 18.06.02. The load dependent limits must include at least one break point to allow cut-in/-out of the lower limits. The upper limits are fixed limits without breakpoints.

The values of the load dependent limits are defined as a temperature difference (ΔT) to actual cooling water temperature (which vary relative to the engine load).

The cooling water temperature is plant dependent and consequently, the actual values of both upper limits and load dependent limits are defined during commissioning of the engine.

All 95-50ME-C10/9/-GI dot 2 and higher as well as G50ME-B9.5/.3 and S50ME-B9.5 are as standard specified with LDCL Cooling Water Monitoring System while S50ME-B9.3 and G45ME-C9.5/-GI are prepared for the installation of it.

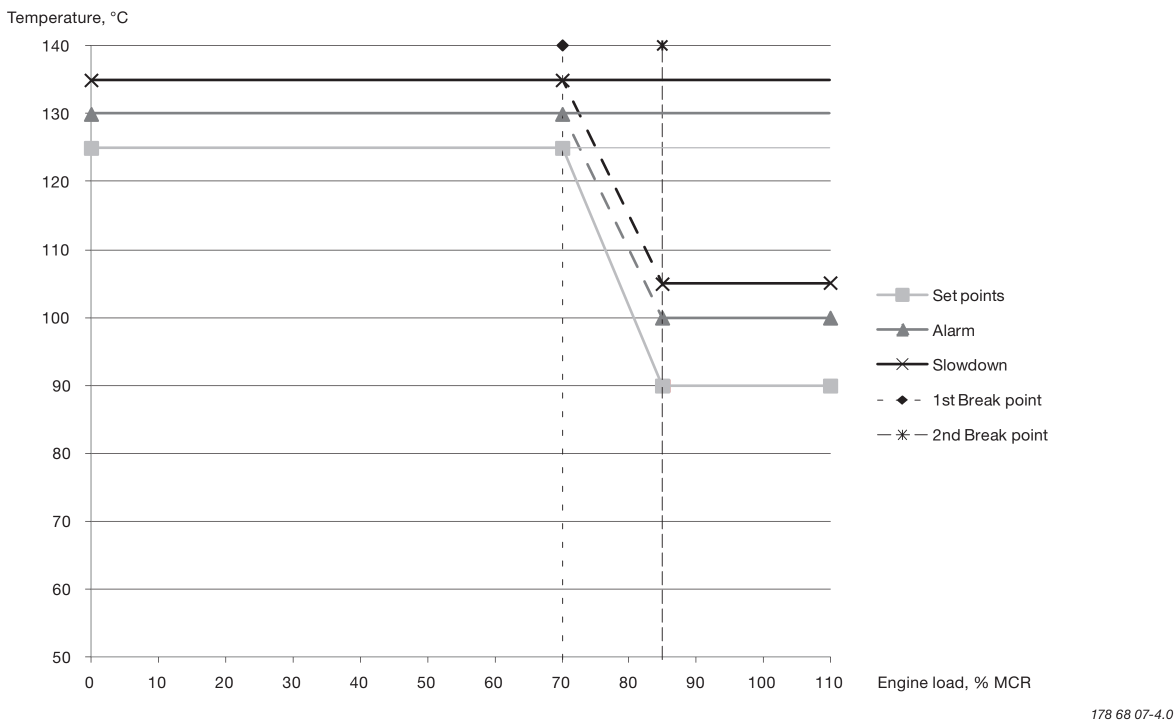

Fig. 18.06.02: Example of set points versus slow down and alarm limits for LDCL cooling water system

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 18.06.03 below. The sensor identification codes are listed in Table 18.07.01.

Sensor	Point of location
	Manoeuvring system
ZS 1109-A/B C	Turning gear – disengaged
ZS 1110-A/B C	Turning gear – engaged
ZS 1111-A/B C	Main starting valve – blocked
ZS 1112-A/B C	Main starting valve – in service
ZV 1114 C	Slow turning valve
ZS 1116-A/B C	Start air distribution system – in service
ZS 1117-A/B C	Start air distribution system – blocked
ZV 1120 C	Activate pilot press air to starting valves
ZS 1121-A/B C	Activate main starting valves - open
E 1180	Electric motor, auxiliary blower
E 1181	Electric motor, turning gear
E 1185 C	LOP, Local Operator Panel
	Hydraulic power supply
PT 1201-1/2/3 C	Hydraulic oil pressure, after non-return valve
ZV 1202-A/B C	Force-driven pump bypass
PS/PT 1204-1/2/3 C	Lubricating oil pressure after filter, suction side
	Tacho/crankshaft position
ZT 4020	Tacho for safety
	Engine cylinder components
XC 4108 C	ELVA NC valve
ZT 4111 C	Exhaust valve position
ZT 4114 C	Fuel plunger, position 1
	Fuel oil
ZV 8020 Z	Fuel oil cut-off at engine inlet (shut down), Germanischer Lloyd only
	Cylinder lubricating oil
ZT 8203 C	Confirm cylinder lubricator piston movement, cyl/cyl
ZV 8204 C	Activate cylinder lubricator, cyl/cyl
	Scavenge air
PS 8603 C	Scavenge air receiver, auxiliary blower control
	ME-GI alarm system (ME-GI only)
XC 2212	External gas shut down (request)
	ME-GI safety system (ME-GI only)
XC 2001	Engine shut down (command)
XC 6360	Gas plant shut down (command)

Table 18.06.03: 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

TI 8005 indicates a local temperature indication (thermometer) in the fuel oil system.

ZS 1112-A C and 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.

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.

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Table 18.07.01b: Identification of instruments

Dispatch Pattern, Testing, Spares and Tools

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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

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
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 alkyd primer, weather resistant.	1 - 2 layer(s) Total NDTF 80 µm	Free
	Oil and acid resistant alkyd paint. Temperature resistant to minimum 80 °C.	1 layer Total NDTF 40 µm – – – – – Total NDTF 120 µm	White: RAL 9010 DIN N:0:0.5 MUNSELL N-9.5
2. Components, outside engine			
Engine body, pipes, gallery, brackets, etc. Delivery standard is in a primed and finished-painted condition, unless otherwise stated in the contract.	In accordance with corrosivity categories C2 Medium ISO 12944-5		
	Engine alkyd primer, weather resistant.	1 - 2 layer(s) Total NDTF 80 µm	Free
	Final alkyd paint resistant to salt water and oil, option: 4 81 103.	1 layer Total NDTF 40 µm – – – – – Total NDTF 120 µm	Light green: RAL 6019 DIN 23:2:2 MUNSELL 10GY 8/4
3. Gas pipe (ME-GI/ME-LGI only)			
Chain pipes, supply pipe.	In accordance with corrosivity categories C2 Medium ISO 12944-5		
	Engine alkyd primer, weather resistant.	1 - 2 layer(s) Total NDTF 80 µm	Free
	Final alkyd paint resistant to salt water and oil, option: 4 81 103.	1 layer Total NDTF 40 µm – – – – – Total NDTF 120 µm	Yellow: RAL 1021 MUNSELL 2.5 Y 8114
	ME-LGI only: additional marking tape on pipes acc. to ISO 14726:2008.		Violet: RAL 4001 MUNSELL 2.5P 4/11
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), (Non water cooled housing only).	In accordance with corrosivity categories C3 Medium ISO 12944-5		
	Ethyl silicate based zinc-rich paint, heat resistant to minimum 300 °C.	1 layer – – – – – Total NDTF 80 µm	

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 NDTF 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 NDTF 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. Note: Duplex/Stainless steel is not to be painted.	Total NDTF 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. Purchased equipment painted in maker's colour is acceptable, unless otherwise stated in the contract/drawing.	Electro(-) galvanised.	See specifications from product data sheet.	
Tool panels	Oil resistant paint.	1 - 2 layer(s) – – – – – Total NDTF 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.

074 33 57-9.11.1

Fig. 19.02.01: Painting of main engine, option: 4 81 101, 4 81 102 or 4 81 103

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 oil test

Before leaving the factory, the engine is to be carefully tested on diesel oil in the presence of representatives of Yard, Shipowner, Classification Society, and MAN Diesel & Turbo.

At each load change, all temperature and pressure levels etc. should stabilise before taking new engine load readings.

Fuel oil analysis is to be presented.

All tests are to be carried out on diesel or gas oil.

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 NO_x 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 NO_x 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 NO_x 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

or

- 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.

Cylinder cover, plate 2272-0300

1 Cylinder cover with fuel, exhaust and starting valves, indicator valve and sealing rings (disassembled).
½ set Studs for 1 cylinder cover

Piston, plate 2272-0400

1 Piston complete (with cooling pipe), piston rod, piston rings and stuffing box, studs and nuts
1 set Piston rings for 1 cyl.

Cylinder liner, plate 2272-0600

1 Cylinder liner inclusive of sealing rings and gaskets. For all except GL

Cylinder lubricating oil system, plate 3072-0600 [1])

1 set Spares for lubricating oil system for 1 cyl.
2 Lubricator backup cable

Connecting rod, and crosshead bearing, plate 1472-0300, 2572-0200

1 Telescopic pipe with bushing for 1 cyl.
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 bearing, plate 2572-0600

1 set Thrust pads for 'ahead'.
For NK also 1 set 'astern' if different from 'ahead'

Hydraulic power supply, HPS, plate 4572-1000, 1465-0401, 4572-0900 and others [1 and 2])

1 Proportional valve for hydraulic pumps
1 Claw coupling
1 Accumulator
6 Chain links. Only for ABS, LR, and NK
1 High-pressure pipe kit
1 set Flex pipes, one of each size. Only for S60ME-B
1 Electric motor

Engine control system, plate 4765-1901, 7072-1250, 7065-1100, 7072-1100, 4772-1550 [1 and 2])

1 Multi Purpose Controller MPC
1 Multi Purpose Controller MPC-10, if applied
1 Trigger sensor for tacho system (if trigger ring is specified)
1 Marker sensor for tacho system
1 Tacho signal amplifier
1 ID-key
1 Encoder
1 Fuse kit

Starting valve, plate 3472-0200

1 Starting valve, complete

Hydraulic cylinder unit, plate 4572-0500 and others [1 and 2])

1 Fuel booster barrel, complete with plunger
1 ELFI valve complete
1 Suction valve complete
1 Packing kit

Exhaust valve, plate 2272-0200, 2272-0240

2 Exhaust valves complete
(The 2nd exhaust valve is mounted in the Cylinder cover complete)
1 Exhaust valve complete. Only for GL
1 High-pressure pipe from actuator to exhaust valve

Fuel valve, plate 4272-0200, 4272-0100

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

Turbocharger, plate 5472-0700

1 set Maker's standard spare parts

Fig. 19.06.01a: List of spare parts, unrestricted service, option: 4 87 601

Bearings and bedplate, plate 2572-0400, 1072-0400

1		Main bearing shell in 2/2 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.

Please note: Plate numbers refer to Instruction Book, Vol. II/III containing plates with spare parts

Fig. 19.06.01b: List of spare parts, unrestricted service, option: 4 87 601

Additional Spares

Beyond class requirements or recommendation, for easier maintenance and increased security in operation.

Cylinder cover, plate 2272-0300
- 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, plate 7670-0100, 2270-0315
- 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
- 1 box Locking wire, L=63 m
- 5 Piston rings of each kind
- 2 D-rings for piston skirt
- 2 D-rings for piston rod

Piston rod stuffing box, plate 2272-0500
- 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
- ½ set Studs for cylinder cover for one cylinder
- 1 Bushing

Cylinder liner and cooling jacket, plate 2272-0600
- 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
- 1 set Spares for MAN B&W Alpha lubricating oil system for one cylinder
- 1 Lubricator
- 2 Feedback sensor (inductive), complete
- 1 Complete sets of O-rings for lubricator (depending on no. of lubricating nozzles per cylinder)

Connecting rod and crosshead, plate 1472-0300, 2572-0200
- 1 Telescopic pipe
- 2 Thrust piece

Hydaulic power supply, HPS, plate 4572-1000 and others
- 1 Delivery pump including electric motor
- 1 Pressure relief valve

Engine control system, plate 4772-1550, 7072-1250
- 1 set Fuses for MPC, TSA, CNR
- 1 Segment for trigger ring (if trigger ring is specified)

Hydraulic cylinder unit, HCU, plate 4572-0500
- 1 set Packings

Main starting valve, plate 3472-0300
- 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
- 2 Locking plates
- 2 Piston
- 2 Spring
- 2 Bushing
- 1 set O-rings
- 1 Valve spindle

Fig. 19.07.01a: Additional spare parts beyond class requirements or recommendation, option: 4 87 603

Exhaust valve, plate 2272-0200 and others
- 1 Exhaust valve spindle
- 1 Exhaust valve seat
- ½ set O-ring exhaust valve/cylinder cover
- 4 Piston rings
- ½ set Guide 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 cool. water conn.
- 1 Conical ring in 2/2
- 1 set O-rings for spindle/air piston
- 1 set Non-return valve

Exhaust valve, plate 2272-0200
- 1 Sealing oil control unit

Exhaust valve actuator, plate 4572-0100
- 1 Hydraulic exhaust valve actuator complete for one cylinder

Cooling water outlet, plate 5072-0100
- 2 Ball valve
- 1 Butterfly valve
- 1 Compensator
- 1 set Gaskets for butterfly valve and compensator

Fuel injection system, plate 4272-0500
- 1 Fuel oil pressure booster complete, for one cylinder
- 1 Hydraulic cylinder unit
- 1 set Gaskets and sealings
- 1 Electronic fuel injection control valve

Fuel valve, plate 4272-0200
- 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
- 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

By-pass valve, plate 4272-0030
- 1 By-pass valve, complete
- 1 O-rings of each kind

Scavenge air receiver, plate 5472-0600
- 2 Non-return valves complete
- 1 Compensator

Exhaust pipes and receiver, plate 5472-0900
- 1 Compensator between TC and receiver
- 2 Compensator between exhaust valve and receiver
- 1 set Gaskets for each compensator

Auxiliary blower, plate 5472-0500
- 1 set Bearings for electric motor
- 1 set Shaft sealings
- 1 set Bearings/belt/sealings for gearbox (only for belt-driven blowers)

Turbocharger, plate 5472-0700
- 1 Spare rotor for one turbocharger, complete with bearing
- 1 set Spare parts for one turbocharger

Arrangement of safety cap, plate 3472-0900
- 1 set Bursting disc

Engine lubricating oil system, plate 4572-0800
- 1 set 6μ filter

Note:
Plate numbers refer to Instruction Book, Vol. II/III containing plates with spare parts

Fig. 19.07.01b: 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.

Service hours	8,000	12,000	16,000	20,000	24,000	32,000	36,000	40,000	48,000	56,000	60,000	64,000	72,000	80,000	84,000	88,000	96,000
Description	**Replace parts**																
Piston																	
▪ Soft iron gasket (1 set per cylinder)			x			x			x			x		x			x
▪ Piston crown (1 pc per cylinder)												x					
▪ O-rings for piston (1 set per cylinder)												x					
▪ Piston rings (1 set per cylinder)			x			x			x			x		x			x
▪ Piston cleaning ring (1 pc per cylinder)												x					
Stuffing box																	
▪ Lamellas (1 set per cylinder)						x						x					x
▪ Top scraper ring (1 pc per cylinder)						x						x					x
▪ O-rings (1 set per cylinder)			x			x			x			x		x			x
Cylinder liner												x					
▪ O-rings for cylinder liner (1 set per cylinder)												x					
▪ O-rings for cooling water jacket (1 set per cylinder)												x					
▪ O-rings for cooling water connections (1 set per cyl.)												x					
Exhaust valve																	
▪ DuraSpindle (1 pc per cylinder)									x								x
▪ Nimonic spindle (1 pc per cylinder)																	x
▪ Bottom piece (1 pc per cylinder)									x								x
▪ Piston rings for exhaust valve & oil piston (1 set per cyl.)									x								x
▪ O-rings for bottom piece (1 set per cylinder)	x		x			x			x			x		x			x
Fuel valves																	
▪ Valve nozzle (2 sets per cylinder)			x			x			x			x		x			x
▪ Spindle guide (2 sets per cylinder)			x			x			x			x		x			x
▪ O-ring (2 sets per cylinder)	x		x		x	x		x	x	x		x	x	x		x	x
▪ Spring housings (1 set per cylinder)																	x
Bearings																	
▪ Crosshead bearing (1 set per cylinder)												x					
▪ Crankpin bearing (1 set per cylinder)																	x
▪ Main bearing (1 set per cylinder)																	x
▪ Thrust bearing (1 set per engine)																	x
Cylinder cover (1 pc per cylinder)																	x
▪ O-rings for cooling water jacket (1 set per cylinder)			x			x			x			x		x			x
▪ O-ring for starting valve (1 pc per cylinder)		x			x		x		x		x		x		x		x

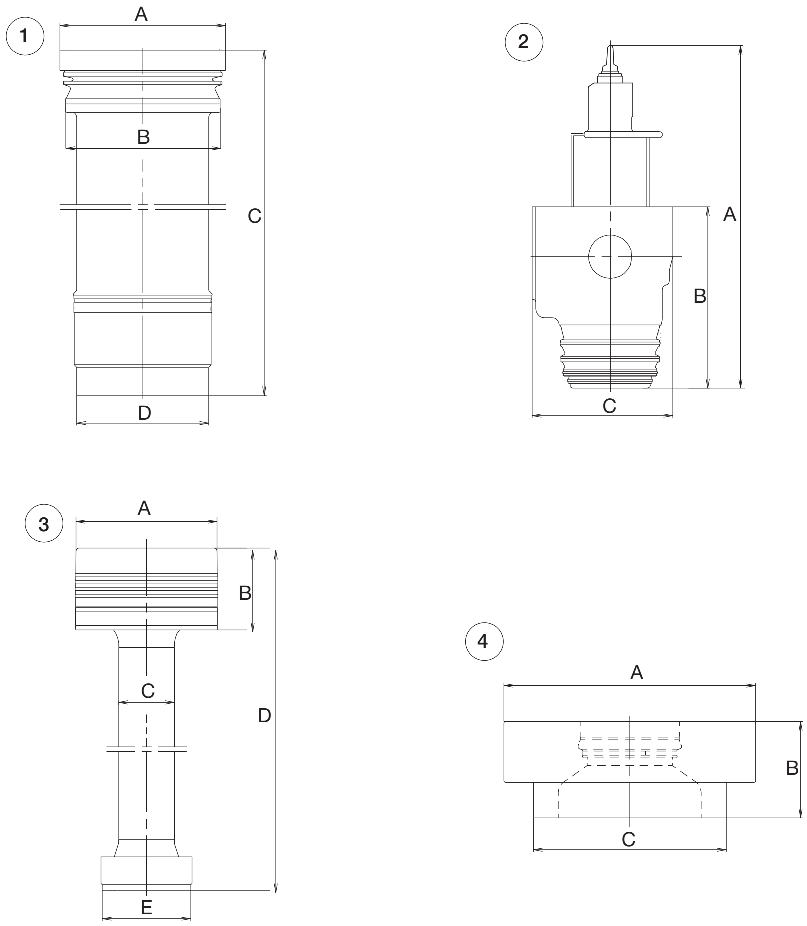
Table 19.08.01a: Wearing parts according to Service Letter SL-509

Service hours	8,000	12,000	16,000	20,000	24,000	32,000	36,000	40,000	48,000	56,000	60,000	64,000	72,000	80,000	84,000	88,000	96,000
Description	**Replace parts**																
Air cooler(s) (1 pc per turbocharger)									x								x
Chains (1 set per engine)																	x
Turbocharger(s) *)																	
Alpha Lubricator																	
▪ Solenoid valve (1 pc per pump)					x				x				x				x
▪ Non-return valve (1 pc per pump piston)					x				x				x				x
▪ O-rings (1 set per lubricator)					x				x				x				x
Mechanical cylinder lubricator *)																	
ME-B Parts																	
▪ Hydraulic hoses (1 set per engine)						x						x					x
▪ ELFI valve (1 pc per cylinder)												x					
▪ Fuel oil pressure booster (1 pc per cylinder)												x					
▪ Angle encoder (2 pcs per engine)												x					
▪ MPC (1 pc per 2 cylinders + 1 pc)												x					
▪ MOP A (1 pc per engine)												x					
▪ MOP B (1 pc per engine)												x					
▪ Proportional valve for main hydraulic pump				x				x			x			x			
▪ Hydrostatic bearings for main hydraulic pump						x						x					x
▪ Sealings for pressure relief valve for main hydr. pump								x						x			
▪ Static sealing rings for exh. valve actuator (1 pc per cyl.)						x						x					x
▪ Membranes for accumulators on HPS						x						x					x
▪ Membranes for accumulators on HCU						x						x					x
▪ Marker sensor (1 per engine)												x					
▪ Cables (1 set per engine)																	x
ME-GI Parts																	
▪ Gas nozzles (1 set per cylinder) **)			x			x			x			x		x			x
▪ Sealings rings and gaskets for gas nozzles (1 set per engine) **)	x		x		x	x		x	x	x		x	x	x		x	x

*) 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



178 51 59-7.3

Pos	Sec. Description	Mass	Dimensions (mm)				
		(kg)	A	B	C	D	E
1	Cylinder liner, incl. cooling jacket	2,076	740	2,413	555		
2	Exhaust valve	440	1,310	665	494		
3	Piston complete, with piston rod	342	ø500	349	188	3,064	300
4	Cylinder cover, incl. valves	1,100	938	419			

Fig. 19.09.01: Large spare parts, dimensions and masses

Rotor for turbocharger

MAN

Type	Max Mass	Dimensions (mm)		
	kg.	A (ø)	B	C (ø)
TCA44	90	480	880	460
TCA55	140	570	990	515
TCA66	230	670	1,200	670
TCA77	390	800	1,380	730
TCA88	760	940	1,640	980
TCR18	22	280	469	
TCR20	39	337	566	
TCR21	87	440	739	
TCR22	87	440	739	

561 70 21-6.0.0

ABB

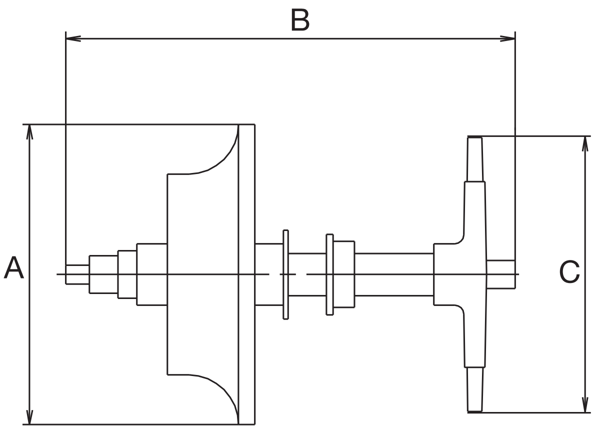
Type	Max Mass	Dimensions (mm)		
	kg.	A (ø)	B	C (ø)
A165-L	90	500	940	395
A170-L	130	580	1,080	455
A175-L	220	700	1,300	550
A180-L	330	790	1,470	620
A185-L	460	880	1,640	690
A190-L	610	970	1,810	760
A265-L	100	500	930	395
A270-L	140	580	1,090	455
A275-L	240	700	1,320	550
A280-L	350	790	1,490	620
A285-L	490	880	1,660	690

561 66 78-9.0.0

MHI

Type	Max Mass	Dimensions (mm)		
	kg.	A (ø)	B	C (ø)
MET33MA	45	373	662	364
MET33MB	55	373	692	364
MET42MA	68.5	462	807	451
MET42MB	85	462	847	451
MET48MB	155	524	954	511
MET53MA	190	586	1,035	571
MET53MB	210	586	1,068	571
MET60MA	240	652	1,188	636
MET60MB	270	652	1,185	636
MET66MA	330	730	1,271	712
MET66MB	370	730	1,327	712
MET71MA	400	790	1,318	771
MET71MB	480	790	1,410	771
MET83MA	600	924	1,555	902
MET83MB	750	924	1,608	902
MET90MA	850	1,020	1,723	996
MET90MB	950	1,020	1,794	996

561 68 37-2.1.0



178 68 17-0.0

Fig. 19.09.02: Large spare parts, dimensions and masses

Project Support and Documentation

20

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 ll Engine
EoD 46-35 MC-C Tier ll Engines
EoD 98-50 ME/ME-C/ME-C-GI Tier ll Engines
EoD 60-30 ME-B Tier ll 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

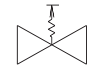
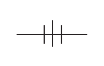
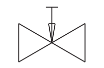
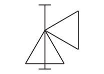
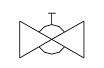
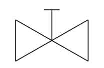
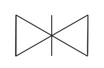
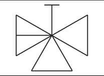
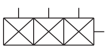
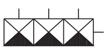
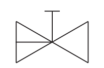
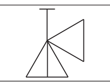
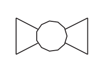
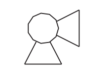
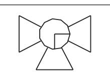
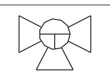
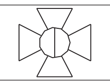
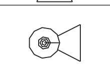
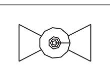
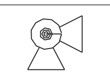
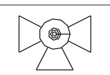
Ordered auxiliary equipment

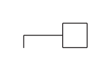
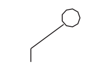
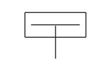
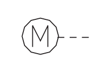
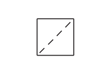
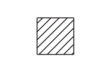
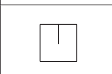
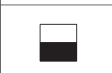
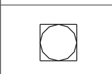
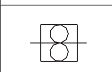
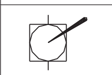
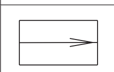
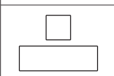
Appendix

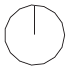
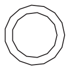
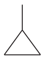
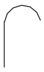
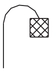
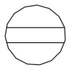
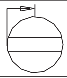
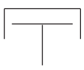
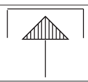
A

Symbols for Piping

No.	Symbol	Symbol designation	No.	Symbol	Symbol designation
1	**General conventional symbols**		2.14		Spectacle flange
1.1		Pipe	2.15		Bulkhead fitting water tight, flange
1.2		Pipe with indication of direction of flow	2.16		Bulkhead crossing, non-watertight
1.3		Valves, gate valves, cocks and flaps	2.17		Pipe going upwards
1.4		Appliances	2.18		Pipe going downwards
1.5		Indicating and measuring instruments	2.19		Orifice
2	**Pipes and pipe joints**		**3**	**Valves, gate valves, cocks and flaps**	
2.1		Crossing pipes, not connected	3.1		Valve, straight through
2.2		Crossing pipes, connected	3.2		Valves, angle
2.3		Tee pipe	3.3		Valves, three way
2.4		Flexible pipe	3.4		Non-return valve (flap), straight
2.5		Expansion pipe (corrugated) general	3.5		Non-return valve (flap), angle
2.6		Joint, screwed	3.6		Non-return valve (flap), straight, screw down
2.7		Joint, flanged	3.7		Non-return valve (flap), angle, screw down
2.8		Joint, sleeve	3.8		Flap, straight through
2.9		Joint, quick-releasing	3.9		Flap, angle
2.10		Expansion joint with gland	3.10		Reduction valve
2.11		Expansion pipe	3.11		Safety valve
2.12		Cap nut	3.12		Angle safety valve
2.13		Blank flange	3.13		Self-closing valve

No.	Symbol	Symbol designation
3.14		Quick-opening valve
3.15		Quick-closing valve
3.16		Regulating valve
3.17		Kingston valve
3.18		Ballvalve (cock)
3.19		Butterfly valve
3.20		Gate valve
3.21		Double-seated changeover valve
3.22		Suction valve chest
3.23		Suction valve chest with non-return valves
3.24		Double-seated changeover valve, straight
3.25		Double-seated changeover valve, angle
3.26		Cock, straight through
3.27		Cock, angle
3.28		Cock, three-way, L-port in plug
3.29		Cock, three-way, T-port in plug
3.30		Cock, four-way, straight through in plug
3.31		Cock with bottom connection
3.32		Cock, straight through, with bottom conn.
3.33		Cock, angle, with bottom connection
3.34		Cock, three-way, with bottom connection

No.	Symbol	Symbol designation
4	**Control and regulation parts**	
4.1		Hand-operated
4.2		Remote control
4.3		Spring
4.4		Mass
4.5		Float
4.6		Piston
4.7		Membrane
4.8		Electric motor
4.9		Electro-magnetic
5	**Appliances**	
5.1		Mudbox
5.2		Filter or strainer
5.3		Magnetic filter
5.4		Separator
5.5		Steam trap
5.6		Centrifugal pump
5.7		Gear or screw pump
5.8		Hand pump (bucket)
5.9		Ejector
5.10		Various accessories (text to be added)

No.	Symbol	Symbol designation	No.	Symbol	Symbol designation
5.11		Piston pump	**7**	**Indicating instruments with ordinary symbol designations**	
6	**Fittings**		7.1		Sight flow indicator
6.1		Funnel	7.2		Observation glass
6.2		Bell-mounted pipe end	7.3		Level indicator
6.3		Air pipe	7.4		Distance level indicator
6.4		Air pipe with net	7.5		Counter (indicate function)
6.5		Air pipe with cover	7.6		Recorder
6.6		Air pipe with cover and net			
6.7		Air pipe with pressure vacuum valve			
6.8		Air pipe with pressure vacuum valve with net			
6.9		Deck fittings for sounding or filling pipe			
6.10		Short sounding pipe with selfclosing cock			
6.11		Stop for sounding rod			

The symbols used are in accordance with ISO/R 538-1967, except symbol No. 2.19

178 30 61-4.1

Fig. A.01.01: Symbols for piping