MAN B&W G60ME-C9.5-TII

Project Guide

Electronically Controlled
Two-stroke Engines

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-es.com → '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-es.com → 'Two-Stroke', where they can be downloaded.

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Chapter		Section	

Engine Design

1

The Fuel Optimised ME 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 and exhaust valve activation, which are the two most important factors in adjusting the engine to match the prevailing operating conditions.

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

Concept of the ME engine

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

MAN Energy Solutions has specifically developed both the hardware and the software in-house, in order to obtain an integrated solution for the engine control system.

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

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

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

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

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

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

Engine design and IMO regulation compliance

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

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

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

Tier II fuel optimisation

NO_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 cannot 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:

- EGB: Exhaust Gas Bypass
- HPT: High Pressure Tuning (on request and 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 potentials of the EGB tuning method in part- and low-load are 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

6 G 95 M E -C 9 .5 -GI -TII

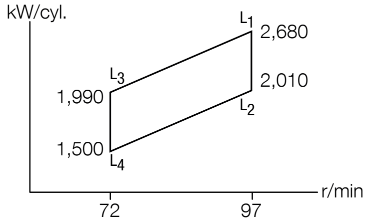
- **-TII** – Emission regulation
  - **TII** IMO Tier level
- **-GI** – Fuel injection concept
  - (blank) Fuel oil only
  - **GI** Gas injection
  - **LGI** Liquid Gas Injection
- **.5** – Version number
- **9** – Mark number
- **-C** – Design
  - **B** Exhaust valve controlled by camshaft
  - **C** Compact engine
- **E** – Concept
  - **E** Electronically controlled
  - **C** Camshaft controlled
- **M** – Engine programme
- **95** – Diameter of piston in cm
- **G** – Stroke/bore ratio
  - **G** 'Green' Ultra long stroke
  - **S** Super long stroke
  - **L** Long stroke
  - **K** Short stroke
- **6** – Number of cylinders

Power, Speed and Fuel Oil

MAN B&W G60ME-C9.5-TII

Cyl.	L_1 kW
5	13,400
6	16,080
7	18,760
8	21,440

Stroke: 2,790 mm/L_1 **MEP:** 21.0 bar



Fuel Oil

MAN B&W G60ME-C9.5

L_1 SFOC [g/kWh]

Opt. load range	50%	75%	100%
High load	165.5	163.0	167.0
Part load EGB	162.5	161.5	168.5
Low load EGB	160.5	162.5	168.5

SFOC for derated engines can be calculated in the CEAS application at www.marine.man-es.com → 'Two-Stroke' → 'CEAS Engine Calculations'.

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.

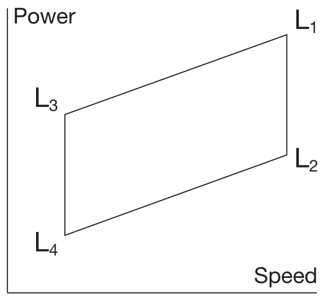


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Fig. 1.04.01: Layout diagram for engine power and speed

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-es.com → ’Two-Stroke’ → ’CEAS Engine Calculations’.

ME Engine Description

Please note that engines built by our licensees are in accordance with MAN Energy Solutions drawings and standards but, in certain cases, some local standards may be applied; however, all spare parts are interchangeable with MAN Energy Solutions de-signed parts.

Some components may differ from MAN Energy Solutions' design because of local production facili-ties or the application of local standard compo-nents.

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

Bedplate and Main Bearing

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

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

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

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

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

Frame Box

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

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

Cylinder Frame and Stuffing Box

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

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

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

Cylinder Liner

The cylinder liner is made of alloyed cast iron and is suspended in the cylinder frame 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.

On engines type 95-80, the basic design includes cylinder liners prepared for installation of temperature sensors. On all other engines, this type of liner is available as an option.

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

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

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

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

Thrust Bearing

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

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

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

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

Step-up Gear

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

Turning Gear and Turning Wheel

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

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

The control device for the turning gear, consisting of starter and manual control box, is included in the basic design.

Axial Vibration Damper

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

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

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

An axial vibration monitor with indication for condition check of the axial vibration damper and terminals for alarm and slow down is required for engines Mk 9 and higher.

Tuning Wheel / Torsional Vibration Damper

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

Connecting Rod

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

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

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

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

Piston

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

The piston has three or four ring grooves which are hard-chrome plated on both the upper and lower surfaces of the grooves. Three or four piston rings are fitted depending on the engine type.

The uppermost piston ring is of the CPR type (Controlled Pressure Relief), whereas the other two or three piston rings are of the CPR type or have an oblique cut. Depending on the engine type, the uppermost piston ring is higher than the others. All rings are alu-coated on the outer surface for running-in.

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

Piston Rod

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

Crosshead

The crosshead is of forged steel and is provided with cast steel guide shoes with white metal on the running surface.

The guide shoe is of the low friction type and crosshead bearings of the wide pad design.

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

Scavenge Air System

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

Scavenge Air Cooler

For each turbocharger a scavenge air cooler of the mono-block type is fitted.

The scavenge air cooler is most commonly cooled by freshwater from a central cooling system. Alternatively, it can be cooled by seawater from either a seawater cooling system or a combined cooling system with separate seawater and freshwater pumps. The working pressure is up to 4.5 bar.

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

Auxiliary Blower

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

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

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

Further information is given in Chapter 14.

Exhaust Gas System

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

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

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

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

Exhaust Turbocharger

The engines can be fitted with either MAN, ABB or MHI turbochargers.

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

Reversing

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

2nd Order Moment Compensators

The 2nd order moment compensators are in general relevant only for 5 or 6-cylinder engines, and can be mounted either on the aft end or on both fore and aft end of the engine.

The aft-end compensator consists of balance weights driven by chain. 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.

The Hydraulic Power Supply

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

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

A combined HPS, mechanically driven with electrically driven start-up/back-up pumps with back-up capacity, is available as an option.

Hydraulic Cylinder Unit

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

The distributor block serves as a mechanical support for the hydraulically activated fuel pressure booster and the hydraulically activated exhaust valve actuator. Single-wall piping has been introduced with the 300 bar hydraulic systems.

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 multi-way valve (ELFI or FIVA), which is electronically controlled by the Cylinder Control Unit (CCU) of the engine control system.

The fuel oil high-pressure pipes are of the double-wall type with built-in conical support. The pipes are insulated but not heated. On engines type 95-90 and G80ME-C9, a ‘fuel oil leakage’ system for each cylinder detects fuel oil leakages and immediately stops the injection on the actual cylinder.

Further information is given in Section 7.01.

Fuel Valves and Starting Air Valve

The cylinder cover is equipped with two or three fuel valves, starting air 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.

Supply of starting air is provided by one solenoid valve per cylinder, controlled by the CCUs of the engine control system.

The starting valve is opened by control air, timed by the engine control system, and is closed by a spring.

Slow turning before starting is a program incorporated in the basic engine control system.

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

Exhaust Valve

The exhaust valve consists of the valve housing and the valve spindle. The valve housing is of the un-cooled Millenium type and made of cast iron. The housing is provided with a water cooled bottom piece of steel with a flame hardened seat of the Wide-seat design.

The exhaust valve spindle is a DuraSpindle, the housing provided with a spindle guide.

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

The exhaust valve is of the low-force design and the operation of the exhaust valve controlled by a multi-way valve (ELVA or FIVA).

In operation, the valve spindle slowly rotates, driven by the exhaust gas acting on a vane wheel fixed to the spindle.

Sealing of the exhaust valve spindle guide is provided by means of Controlled Oil Level (COL), an oil bath in the bottom of the air cylinder, above the sealing ring. This oil bath lubricates the exhaust valve spindle guide and sealing ring as well.

Indicator Cock

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

MAN B&W Alpha Cylinder Lubrication

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

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

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

The ME/Alpha Lubricator is replaced by the Alpha Lubricator Mk 2 on some engines.

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

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
- Lubricating oil, piston cooling oil, hydraulic oil
- Cylinder lubricating oil
- Cooling water to scavenge air cooler
- Jacket and turbocharger cooling water
- Cleaning of turbocharger
- Fire extinguishing in scavenge air space
- Starting air
- Control air
- Oil mist detector (required only for Visatron VN 215/93, make Schaller Automation)
- Various drain pipes.

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

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

Engine Cross section

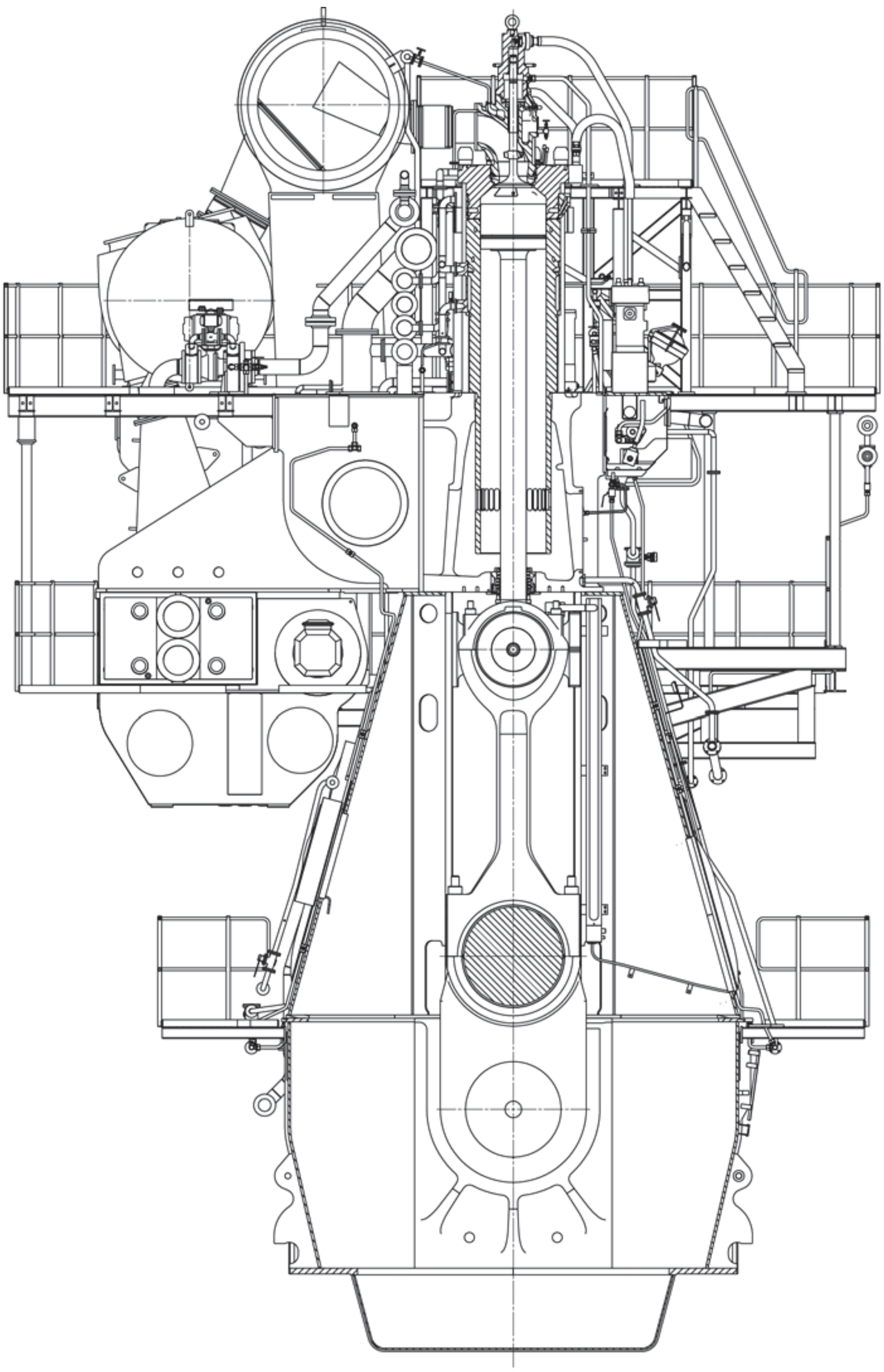
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Fig. 1.07.01: Engine cross section, turbocharger(s) mounted on the exhaust side.

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 (mep) 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.

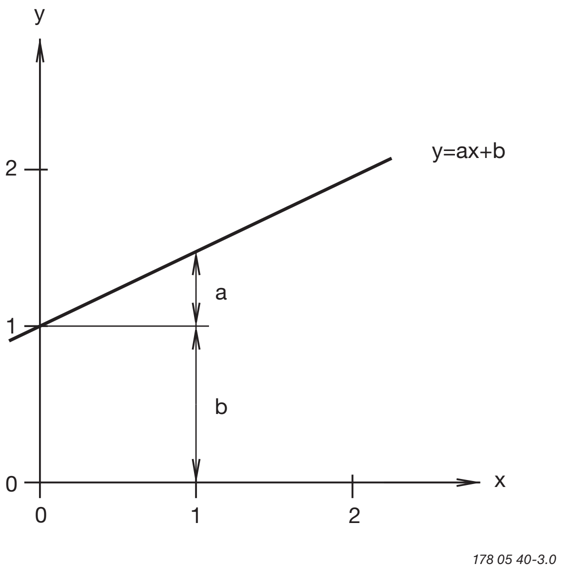


Fig. 2.01.01: Straight lines in linear scales

The power functions $P = c \times n^i$ will be linear functions when using logarithmic scales as shown in Fig. 2.01.02:

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

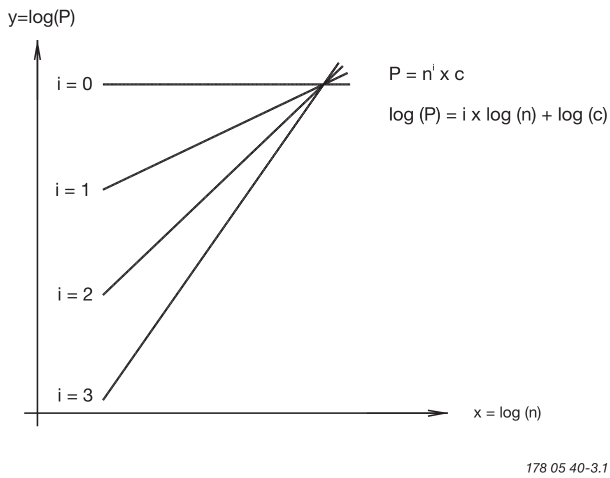


Fig. 2.01.02: Power function curves in logarithmic scales

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 often used, giving simple diagrams with straight lines.

Propulsion and Engine Running Points

Propeller curve

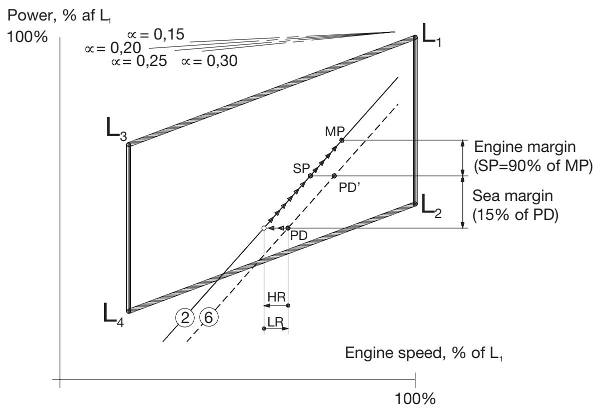
The relation between power and propeller speed for a fixed pitch propeller is as mentioned above described by means of the propeller law, i.e. the third power curve:

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

P = engine power for propulsion
n = propeller speed
c = constant

The exponent i=3 is valid for frictional resistance. For vessels having sufficient engine power to sail fast enough to experience significant wave-making resistance, the exponent may be higher in the high load range.

Propeller design point



Line 2 Propulsion curve, fouled hull and heavy weather (heavy running), engine layout curve
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
PD' Propeller design point incorporating sea margin
HR Heavy running
LR Light running

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Fig. 2.01.03: Propulsion running points and engine layout

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 Fig. 2.01.03.

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.

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).

Sea margin and heavy weather

If the weather is bad with headwind, 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, so that the design speed can be maintained in average conditions at sea. The sea margin is traditionally about 15% of the power required to achieve design speed with a clean hull in calm weather (PD).

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.

We recommend using a light running margin (LRM) of normally **4.0-7.0%**, however for special cases up to **10%**, that is, for a given engine power, the light running propeller RPM is 4.0 to 10.0% higher than the RPM on the engine layout curve.

The recommendation is applicable to all draughts at which the ship is intended to operate, whether ballast, design or scantling draught. The recommendation is applicable to engine loads from 50 to 100%. If an average of the measured (and possibly corrected) values between 50 and 100% load is used for verification this will smoothen out the effect of measurement uncertainty and other variations.

The high end of the range, 7 to 10%, is primarily intended for vessels where it is important to be able to develop as much of the full engine power as possible in adverse conditions with a heavy running propeller. For example for vessels that are operating in ice.

Vessels with shaft generators may in some cases also benefit from a light running margin in the high range. It is then possible to keep the shaft generator in operation for a larger proportion of the time spent at sea.

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.

With engine margin, the engine will operate at less than 100% power when sailing at design speed with a vessel resistance corresponding to the selected sea margin, for example 90% engine load if the engine margin is 10%.

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

Constant ship speed lines

The constant ship speed lines $\propto$, are shown at the very top of Fig. 2.01.03. They indicate the power required at various propeller speeds in order to keep the same ship speed. It is assumed that, for each ship speed, the optimum propeller diameter is used, taking into consideration the total propulsion efficiency. See definition of $\propto$ in Section 2.02.

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

Propeller diameter and pitch, influence on the optimum propeller speed

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

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

The example shown in the Fig. 2.02.01 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 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 a 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 0.9%, and the corresponding 'equal speed curves' are $\propto$ = +0.1 and $\propto$ = -0.1, respectively, so there is a certain interval of propeller speeds in which the 'power penalty' is very limited.

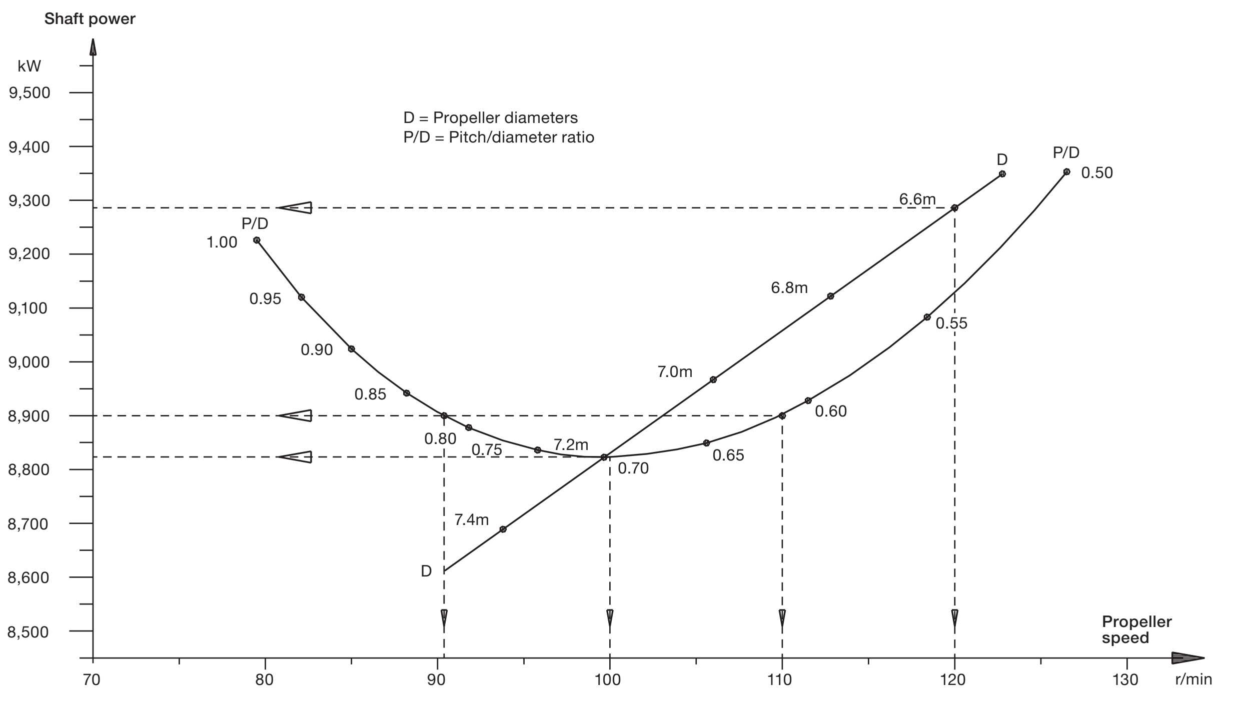


Fig. 2.02.01: Influence of diameter and pitch on propeller design

Constant ship speed lines

The constant ship speed lines ∝, 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 an optimum pitch diameter ratio is used at any given speed, taking into consideration the total propulsion efficiency.

Normally, if propellers with optimum pitch are used, 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
∝ = 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 is used for a given propeller diameter the following data applies when changing the propeller diameter:

for general cargo, bulk carriers and tankers
∝ = 0.20 - 0.30

and for reefers and container vessels
∝ = 0.15 - 0.25

When changing the propeller speed by changing the pitch, the ∝ constant will be different, see Fig. 2.02.01.

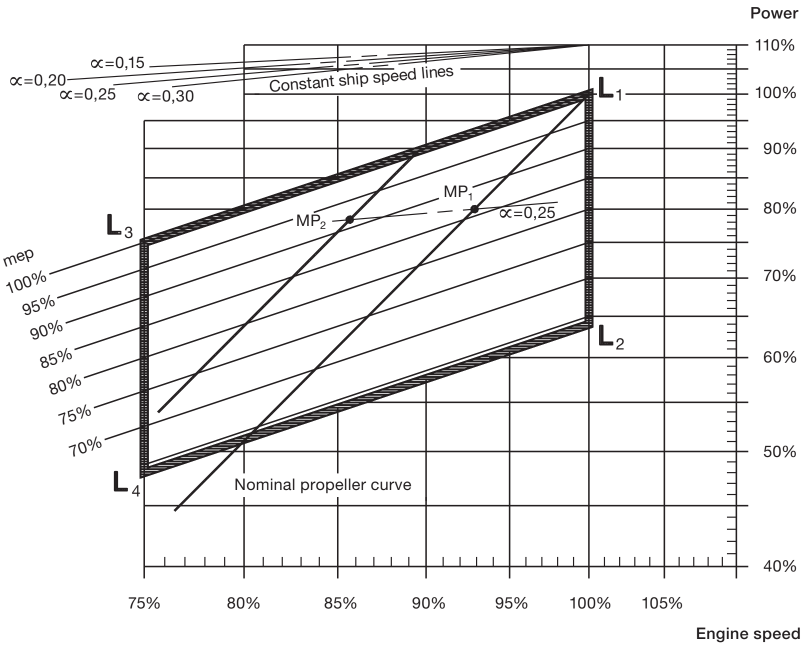


Fig. 2.02.02: Layout diagram and constant ship speed lines

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 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.

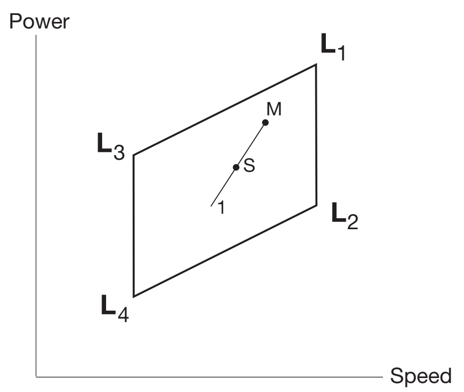


Fig. 2.04.01: Engine layout diagram

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 a power-speed diagram like in Fig. 2.04.01. 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 mechanical design of the engine, for example the turbocharger(s), the piston shims, the liners and the fuel valve nozzles.

Once the specified MCR has been chosen, the engine design and the capacities of the auxiliary equipment will be adapted to the specified MCR.

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

It is therefore important to consider, already at the project stage, if the specification should be prepared for a later change of SMCR. This should be indicated in the Extent of Delivery.

For **ME and ME-C/-GI/-LGI** 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/-GI/-LGI** 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).

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.

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 corresponds to 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

The 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, and overload limits 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.

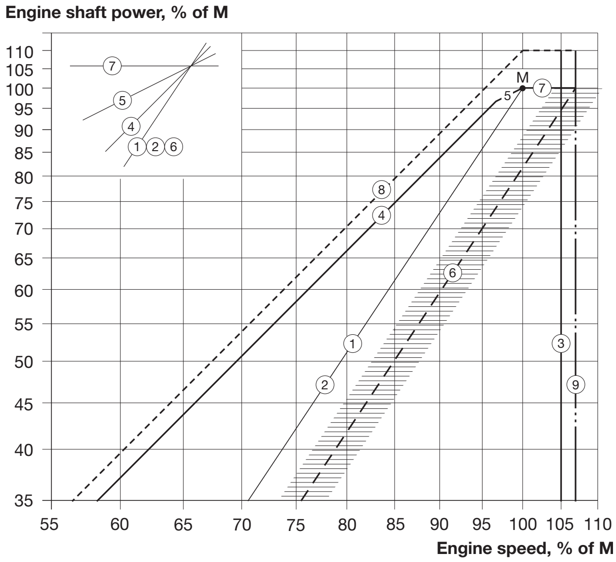
Line 3 and line 9:
Maximum engine speed limits. In Fig. 2.04.02 they are shown for an engine with a layout point M selected on the L_1/L_2 line, that is, for an engine which is not speed derated.

The speed limit for normal operation (line 3) is:

Maximum 110% of M, but no more than 105% of L_1/L_2 speed, provided that torsional vibrations permit. If M is sufficiently speed derated, more than 110% speed is possible by choosing 'Extended load diagram' which is described later in this chapter.

The speed limit for sea trial (line 9) is:

Maximum 110% of M, but no more than 107% of L_1/L_2 speed, provided that torsional vibrations permit. If M is sufficiently speed derated, more



Regarding 'i' in the power function $P = c \times n^i$, see Section 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. The hatched area indicates the full recommended range for LRM (4.0-10.0%)
Line 7 Power limit for continuous running (i = 0)
Line 8 Overload limit
Line 9 Speed limit at sea trial

178 05 42-7.9

Fig. 2.04.02: Engine load diagram for an engine specified with MCR on the L_1/L_2 line of the layout diagram (maximum MCR speed).

than 110% speed is possible by choosing 'Extended load diagram' which is described later in this chapter.

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.

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. Bearing loads may also become too high.

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, often used for propeller layout/design.

Line 7:
Represents the maximum power for continuous operation.

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).

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 for operation

The area between lines 1, 3 and 7 is available for continuous operation without limitation.

The area between lines 1, 4 and 5 is available for operation in shallow waters, in heavy weather and during acceleration, i.e. for non-steady operation without any strict time limitation.

The area between lines 4, 5, 7 and 8 is available for overload operation for 1 out of every 12 hours.

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 polishing the propeller.

If the engine and shaft line has a barred speed range (BSR) it is usually a class requirement to be able to pass the BSR quickly. The quickest way to pass the BSR is the following:

1. Set the rpm setting to a value just below the BSR.

2. Wait while the vessel accelerates to a vessel speed corresponding to the rpm setting.

3. Increase the rpm setting to a value above the BSR.

When passing the BSR as described above it will usually happen quickly.

Layout considerations

In some cases, for example in certain manoeuvring situations inside a harbour or at sea in adverse conditions, it may not be possible to follow the procedure for passing the BSR outlined above. Either because there is no time to wait for the vessel speed to build up or because high vessel resistance makes it impossible to achieve a vessel speed corresponding to the engine rpm setting. In such cases it can be necessary to pass the BSR at a low ship speed.

For 5- and 6-cylinder engines with short shaft lines, such as on many bulkers and tankers, the BSR may extend quite high up in the rpm range. If all of the BSR is placed below 60% of specified MCR rpm and the propeller light running margin is within the recommendation, it is normally possible to achieve sufficiently quick passage of the BSR in relevant conditions. If the BSR extends further up than 60% of specified MCR rpm it may require additional studies to ensure that passage of the BSR will be sufficiently quick.

For support regarding layout of BSR and PTO/PTI, please contact MAN Energy Solutions, Copenhagen at LEE5@man-es.com.

Extended load diagram

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.

For some 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.

This could be relevant in the following cases, especially when more than one of the listed cases are applicable to the vessel:

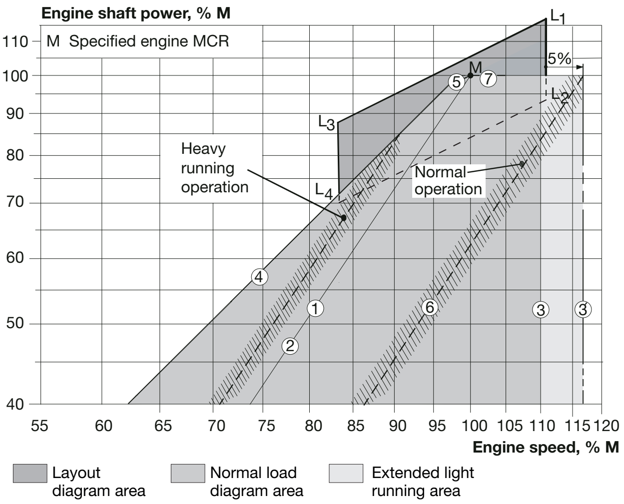
- ships sailing in areas with very heavy weather
- ships sailing for long periods in shallow or otherwise restricted waters
- ships with a high ice class
- ships with two fixed pitch propellers/two main engines, where one propeller/one engine is stopped/declutched for one or the other reason
- ships with large shaft generators (>10% of SMCR power)

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

Example of extended load diagram for speed derated engines with increased light running margin

For speed derated engines it is possible to extend the maximum speed limit to maximum 105% of the engine's L_1/L_2 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 selected extended maximum speed limit.

When choosing an increased light running margin, 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.



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 79-9.3

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

Examples of the use of the Load Diagram

In the following some examples illustrating the flexibility of the layout and load diagrams are presented, see Figs. 2.04.04-06.

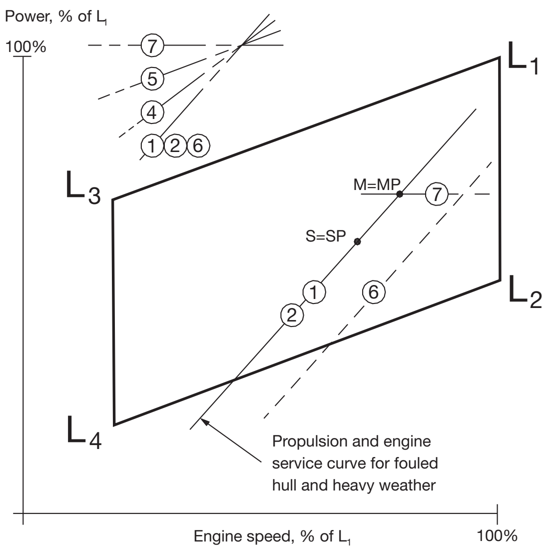
- Example 1 shows how to place the load diagram for an engine without shaft generator coupled to a fixed pitch propeller.
- Example 2 shows the same layout for an engine with fixed pitch propeller (example 1), but with a shaft generator.
- Example 3 is a special case of example 2, where the specified 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.

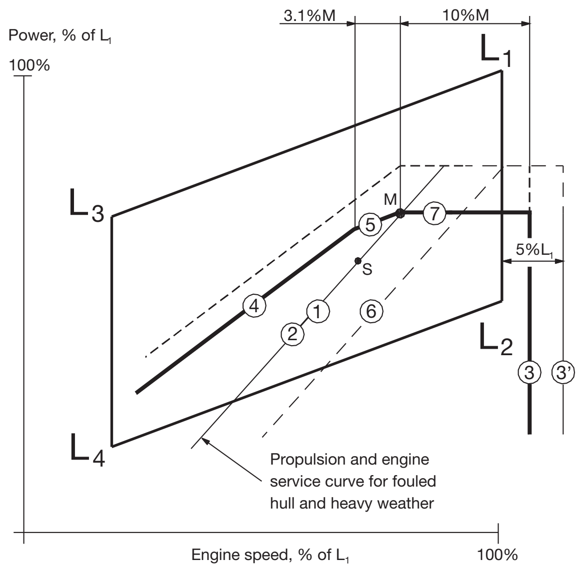
For a specific project, the layout diagram for actual project shown later in this chapter may be used for construction of the actual load diagram.

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) will normally be selected on the engine service curve 2.

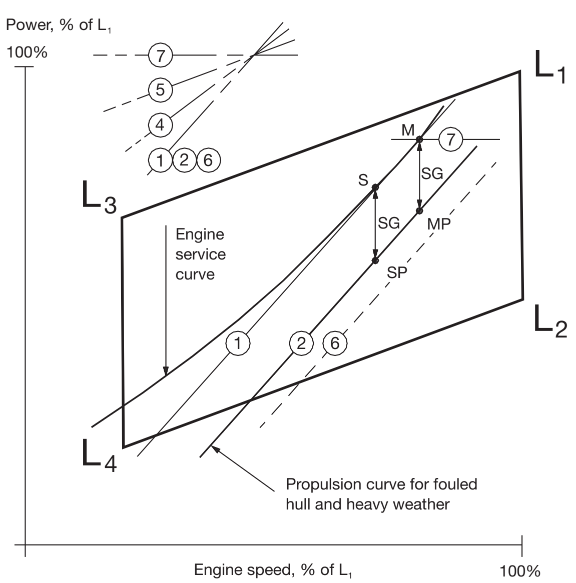
Once point M has been selected in the layout diagram, the load diagram can be drawn, as shown in the figure, and hence the actual load limitation lines of the diesel engine may be found by using the inclinations from the construction lines and the %-figures stated.

178 05 44-0.11a

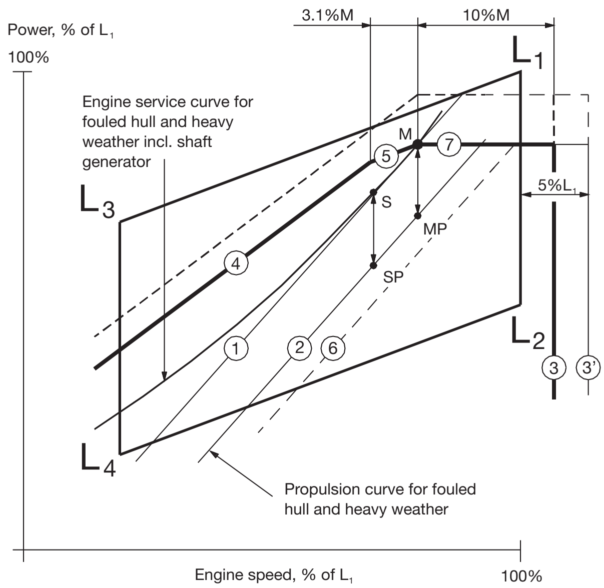
Fig. 2.04.04: Normal running conditions. Engine coupled to a fixed pitch propeller (FPP) and without a shaft generator

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.

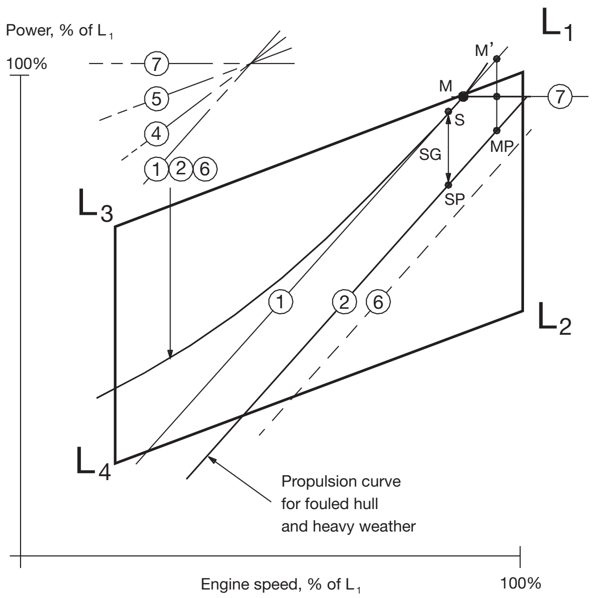
The specified MCR M will then be chosen and the load diagram can be drawn as shown in the figure.

178 05 48-8.11

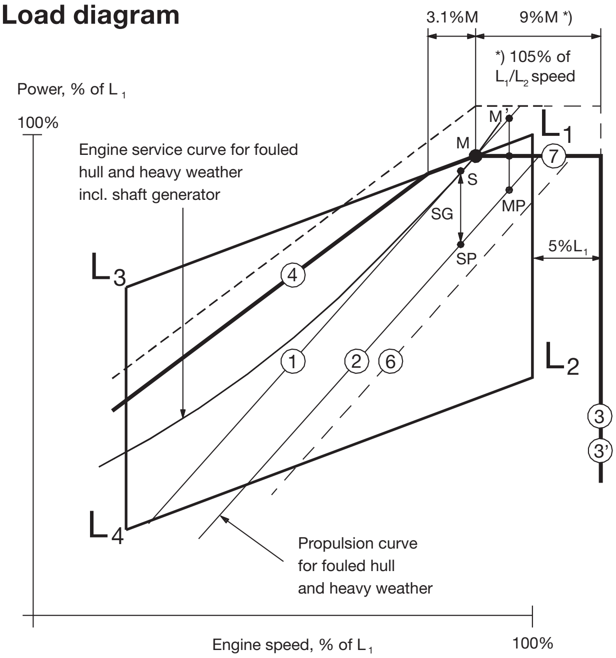
Fig. 2.04.05: Normal running conditions. Engine coupled to a fixed pitch propeller (FPP) and with a shaft generator

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.

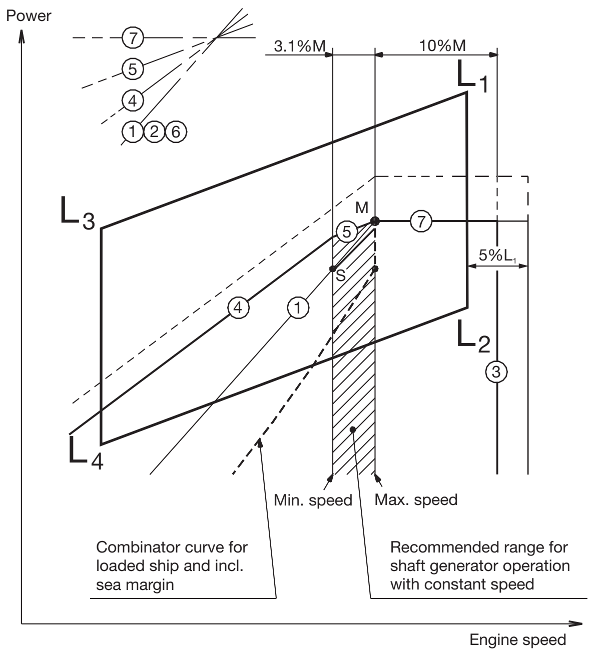
In choosing the latter solution, the required specified MCR power can be reduced from point M' to point M as shown. Therefore, when running in the upper propulsion power range, a diesel generator has to take over all or part of the electrical power production.

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 35-1.11

Fig. 2.04.06: 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 31-4.7

Fig. 2.04.07: Engine with Controllable Pitch Propeller (CPP), with or without a shaft generator

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 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 in Fig. 2.04.07.

With shaft generator

The hatched area in Fig. 2.04.07 shows the recommended speed range between 100% and 96.9% 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 as the basis for drawing the engine load diagram.

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 in Fig. 2.04.07.

For support regarding CPP propeller curves, please contact MAN Energy Solutions, Copenhagen at LEE5@man-es.com.

Diagram for actual project

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

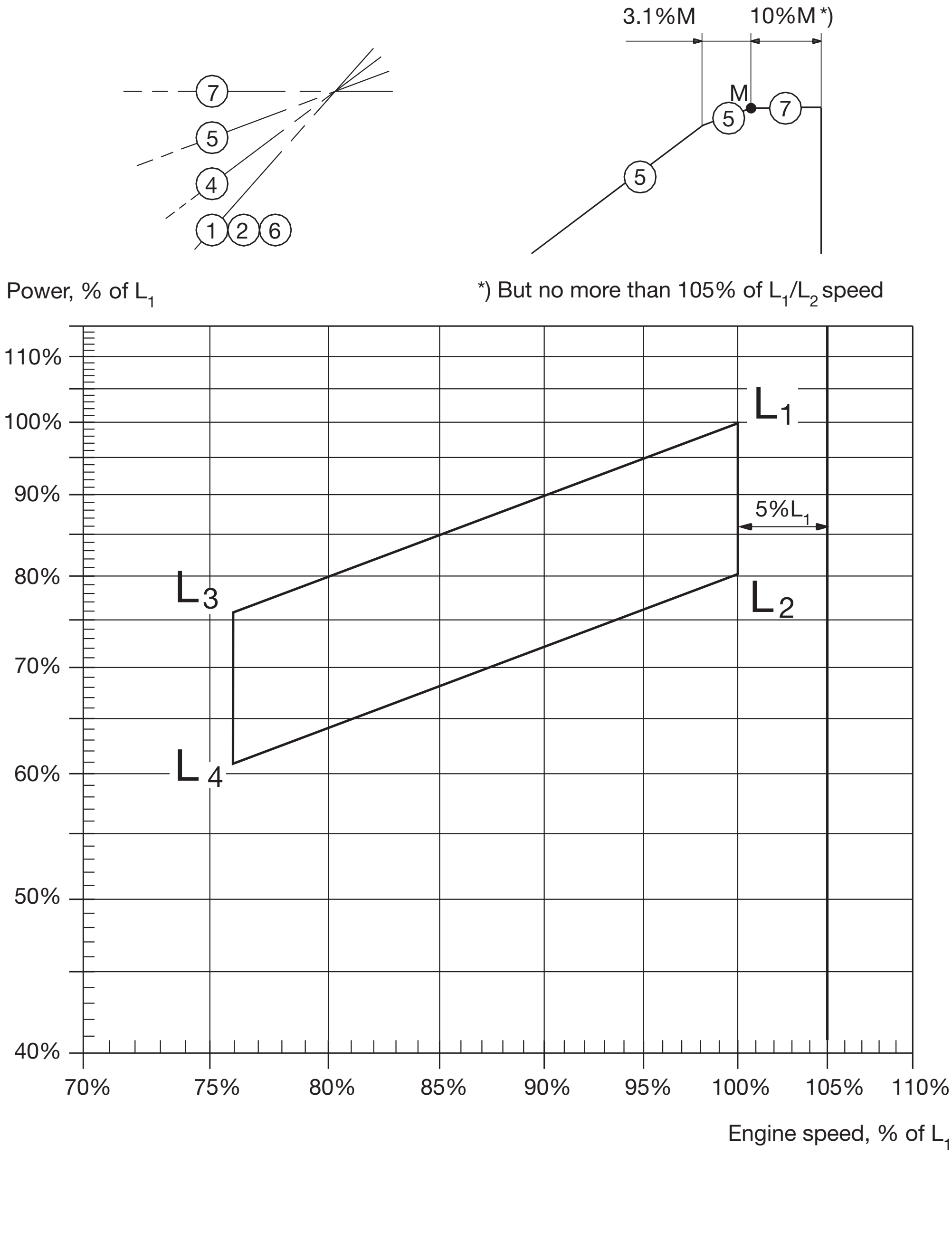


Fig. 2.04.01: Construction of a load diagram

Specific Fuel Oil Consumption (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 fuels with lower calorific values (LCV) as specified in Table 2.05.01.

Fuel type (Engine type)	LCV, kJ/kg
Diesel	42,700
Methane (GI)	50,000
Ethane (GIE)	47,500
Methanol (LGIM)	19,900
LPG (LGIP)	46,000

178 69 17-6.0

Table 2.05.01: Lower calorific values of fuels

For ambient conditions that are different from the ISO reference conditions, the SFOC will be adjusted according to the conversion factors in Table 2.05.02.

		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, lower calorific value	per 1 %	–1.00%	–1.00%

178 69 18-8.0

Table 2.05.02: Specific fuel oil consumption conversion factors

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 SFOC guarantee refers to the above ISO reference conditions and lower calorific values and is valid for one running point only.

The Energy Efficiency Design Index (EEDI) has increased the focus on partload 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, the SFOC guarantee is dependent on the selected guarantee point and given with a tolerance of:

Engine load (% of SMCR)	SFOC tolerance
100 - 85%	5%
<85 - 65%	6%
<65 - 50%	7%

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

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.

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.

With a lower cooling water temperature, the air cooler and water mist catcher will remove more water from the compressed scavenge air. This has a positive effect on the cylinder condition as the humidity level in the combustion gasses is lowered, and the tendency to condensation of acids on the cylinder liner is thereby reduced.

Derating for lower Specific Fuel Oil Consumption

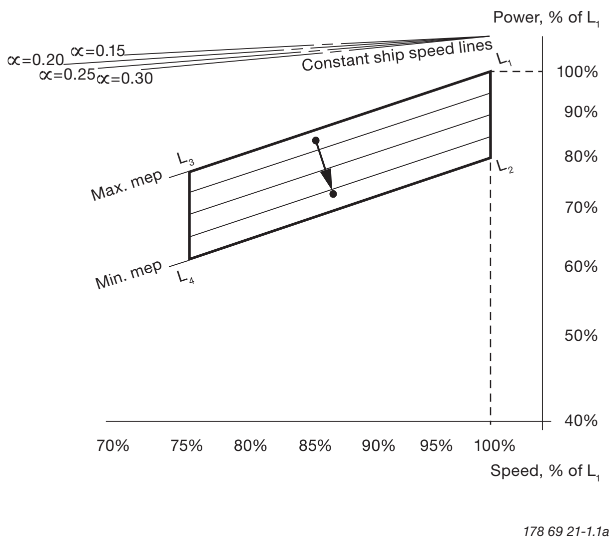


Fig. 2.05.03a: Layout diagram. MEP derating, SFOC is reduced

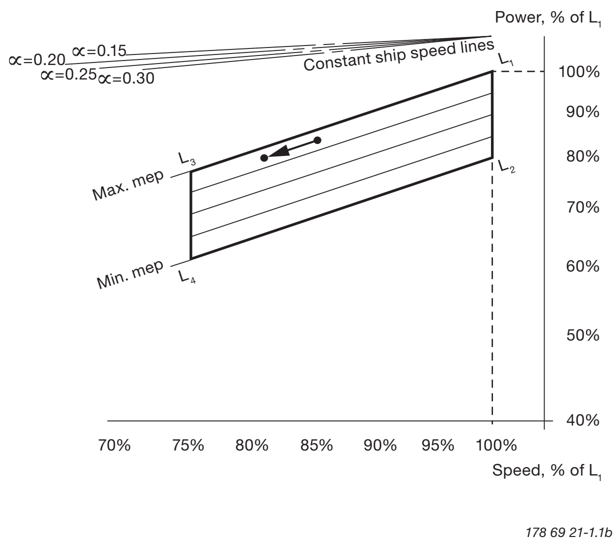


Fig. 2.05.03b: Layout diagram. Power and speed derating but no MEP derating, SFOC is unchanged

The ratio between the maximum firing pressure (P_{max}) and the mean effective pressure (MEP) is influencing the efficiency of a combustion engine. If the Pmax/MEP ratio is increased the SFOC will be reduced.

The engine is designed to withstand a certain P_{max} and this P_{max} is utilised by the engine control system when other constraints do not apply.

The maximum MEP can be chosen between a range of values defined by the layout diagram of the engine and it is therefore possible to specify a reduced MEP to achieve a reduced SFOC. This concept is known as MEP derating or simply derating, see Fig. 2.05.03a.

If the layout point is moved parallel to the constant MEP lines, SFOC is not reduced, see Fig. 2.05.03b.

Engine choices when derating

Due to requirements of ship speed and possibly shaft generator power output, derating is often not achieved by reducing MCR power. Instead a larger engine is applied in order to be able to choose a lower MEP rating, for example an engine of the same type but with an extra cylinder.

Derating reduces the overall SFOC level. The actual SFOC for a project will also depend on other parameters such as:

- Engine tuning method
- Engine running mode (Tier II, Tier III)
- Operating curve (fixed pitch propeller, controllable pitch propeller)
- Actual engine load
- Ambient conditions.

The actual SFOC for an engine can be found using the CEAS application available at www.marine.man-es.com → ’Two-Stroke’ → ’CEAS Engine Calcula-tions’.

It is possible to use CEAS to see the effect of derating for a particular engine by running CEAS for different engine ratings, for example the L_1 rating (not MEP derated) and the L_2 rating (fully MEP derated). This information can be used in the initial design work where the basic layout of the propulsion plant is decided.

Example of SFOC curves

Fig. 2.05.04 shows example SFOC curves for high-load tuning as well as part-load (EGB-PL) and low-load (EGB-LL) exhaust gas bypass tuning for an engine operating with a fixed pitch propeller.

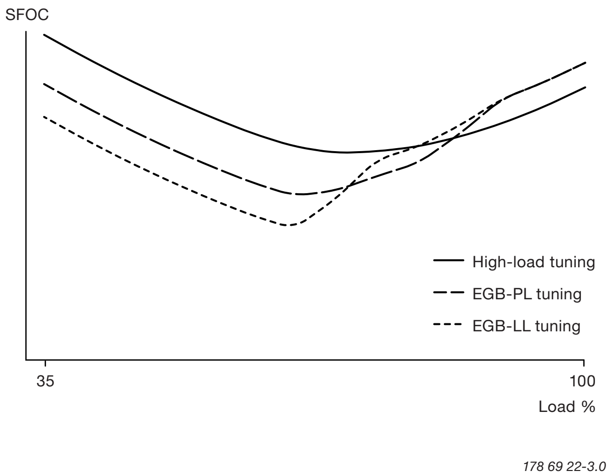


Fig. 2.05.04: Influence on SFOC from engine tuning method and actual engine load

The figure illustrates the relative changes in SFOC due to engine tuning method and engine load. The figure is an example only. CEAS should be used to get actual project values.

Fuel Consumption at an Arbitrary Operating Point

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', Fig. 2.06.01.

These SFOC values at point '1' and '2' can be found by using our CEAS application, see Section 20.02, 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. This is a service which is available to our customers on request. Please contact MAN Energy Solutions, Copenhagen at LEE5@man-es.com.

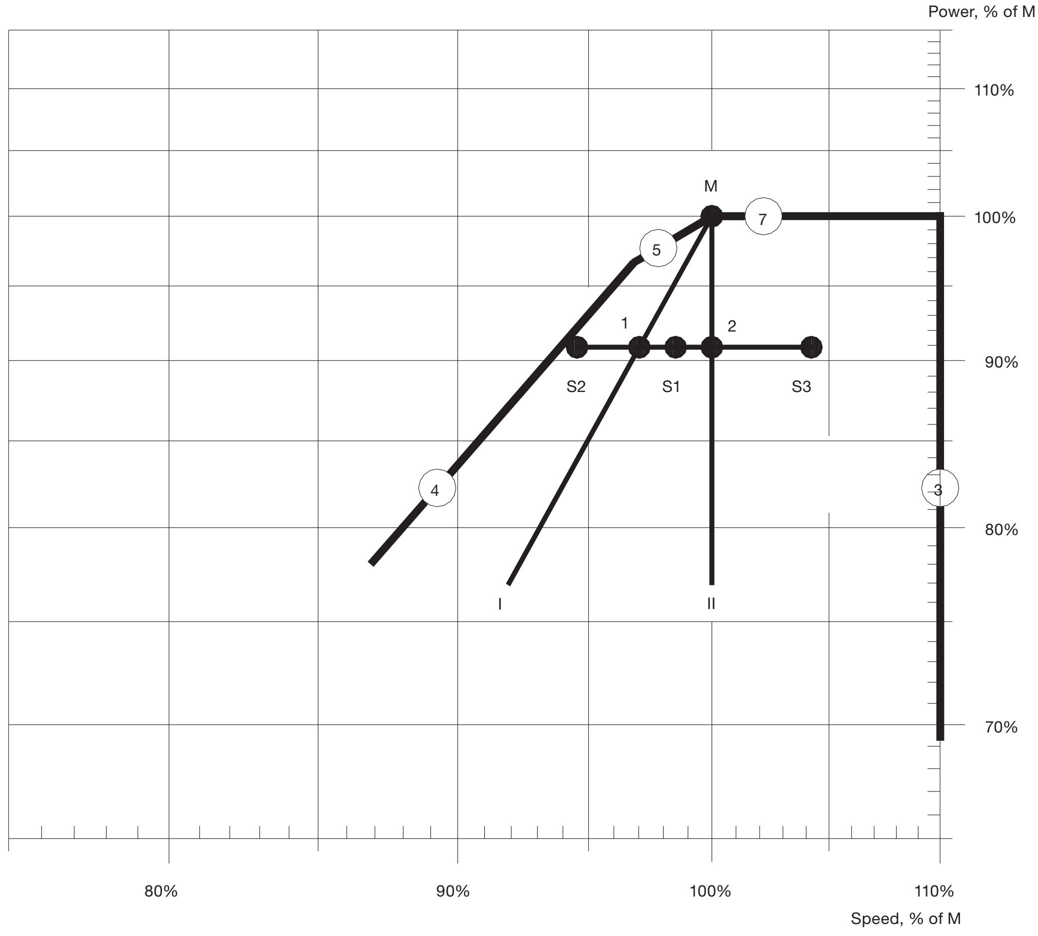


Fig. 2.06.01: SFOC at an arbitrary load

Turbocharger Selection & Exhaust 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-es.com → 'Two-Stroke' → 'Turbocharger Selection'.

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

The MAN B&W 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 G60ME-C9.5 engines - L_1 output			
Cyl.	**MAN**	**ABB**	**MHI**
5	1 x TCA66	1 x A175-L	1 x MET66MB
6	1 x TCA77	1 x A275-L	1 x MET71MB
7	1 x TCA77	1 x A180-L	1 x MET83MB
8	1 x TCA88	1 x A280-L	1 x MET83MB

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-es.com → '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.

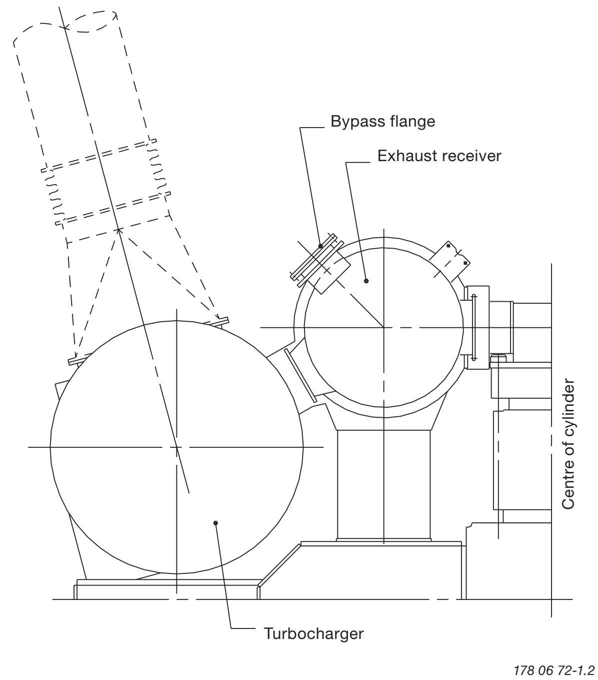


Fig. 3.02.01: Total bypass of exhaust for emergency running

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 Energy Solutions' 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-es.com →' 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
- 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 Energy Solutions.

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/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.

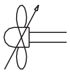
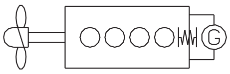
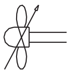
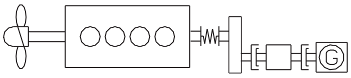
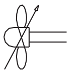
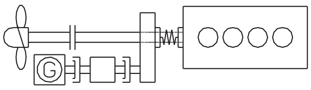
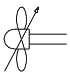
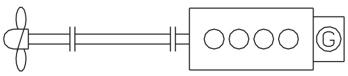
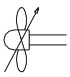
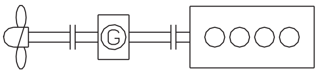
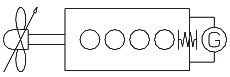
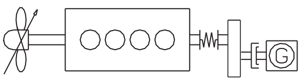
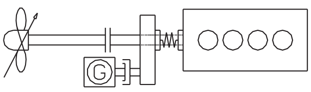
Within each PTO system, several designs are available, depending on the positioning of the gear:

- 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 IV:
  A free-standing step-up gear connected to the intermediate propeller shaft, with a horizontal generator.

BW III, the RENK PTO system with side-mounted generator, has been discontinued as of January 2017.

	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 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 IV/GCR	On tank top	92

178 63 68-7.1

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-es.com → ’Two-Stroke’ → ’Technical Papers’.

Power take off

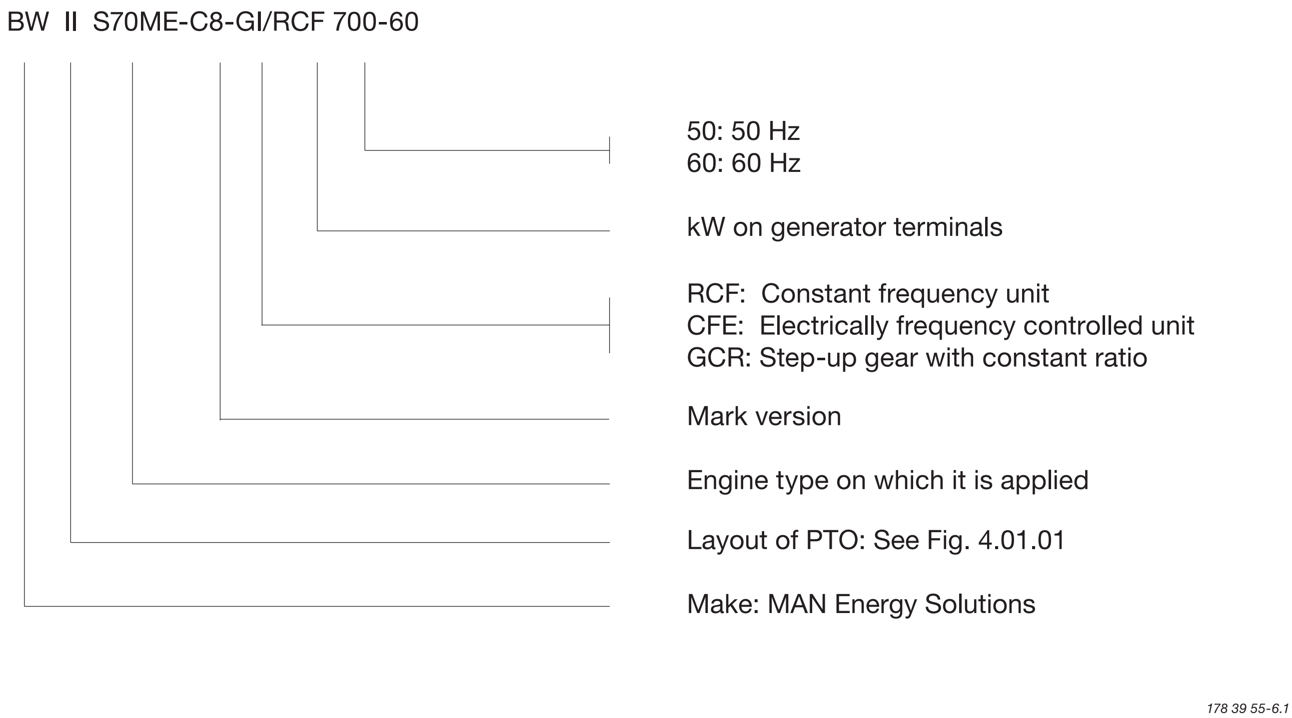


Fig. 4.01.02: Example of designation of PTO

Space Requirement for Side-Mounted Generator

This section is not applicable

Engine preparations for PTO

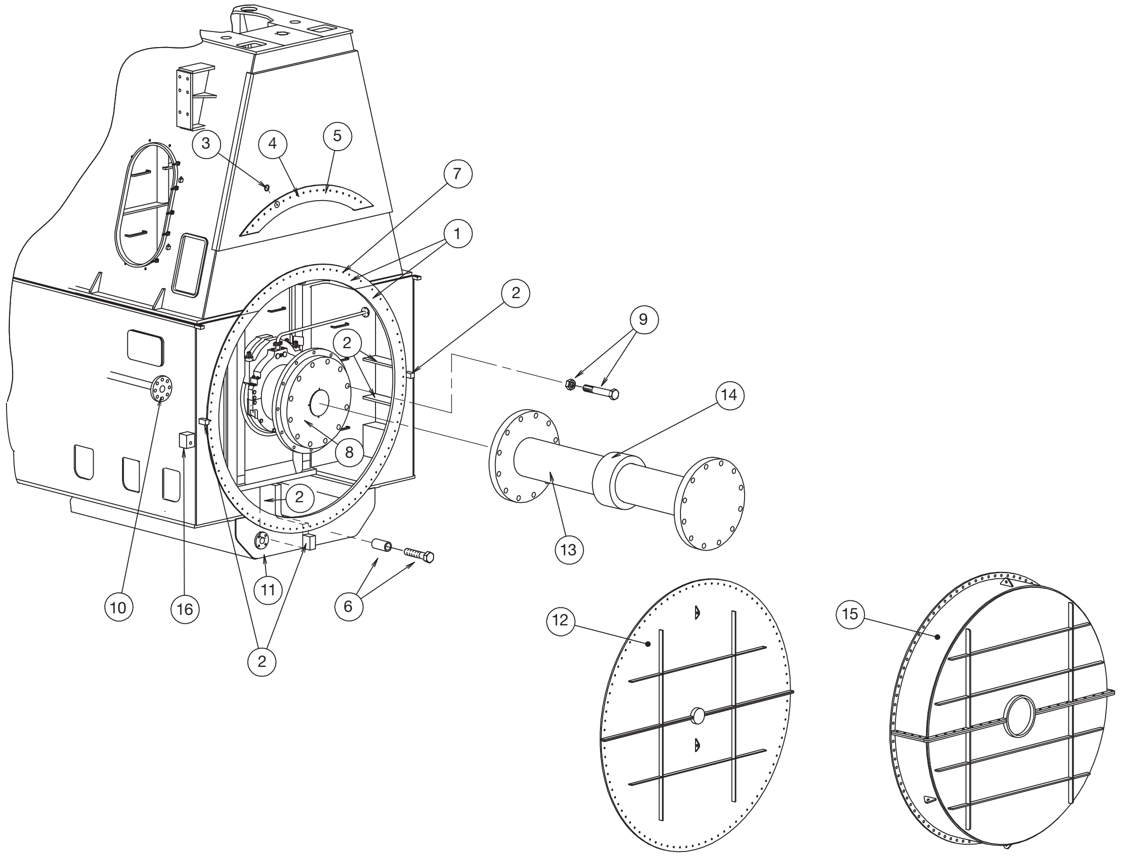


Fig. 4.03.01a: Engine preparations for PTO

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 Engine cover with connecting bolts to bedplate/frame box to be used for shop test without PTO
13 Intermediate shaft between crankshaft and PTO
14 Oil sealing for intermediate shaft
15 Engine cover with hole for intermediate shaft and connecting bolts to bedplate/frame box
16 Plug box for electronic measuring instrument for checking condition of axial vibration damper
– Tacho trigger ring on turning wheel (aft) for ME control system. Only for PTO BW II on engines type 50 and smaller

Pos. no:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	–
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.

178 89 34-2.2

Table 4.03.01b: Engine preparations for PTO

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 co-operation 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.

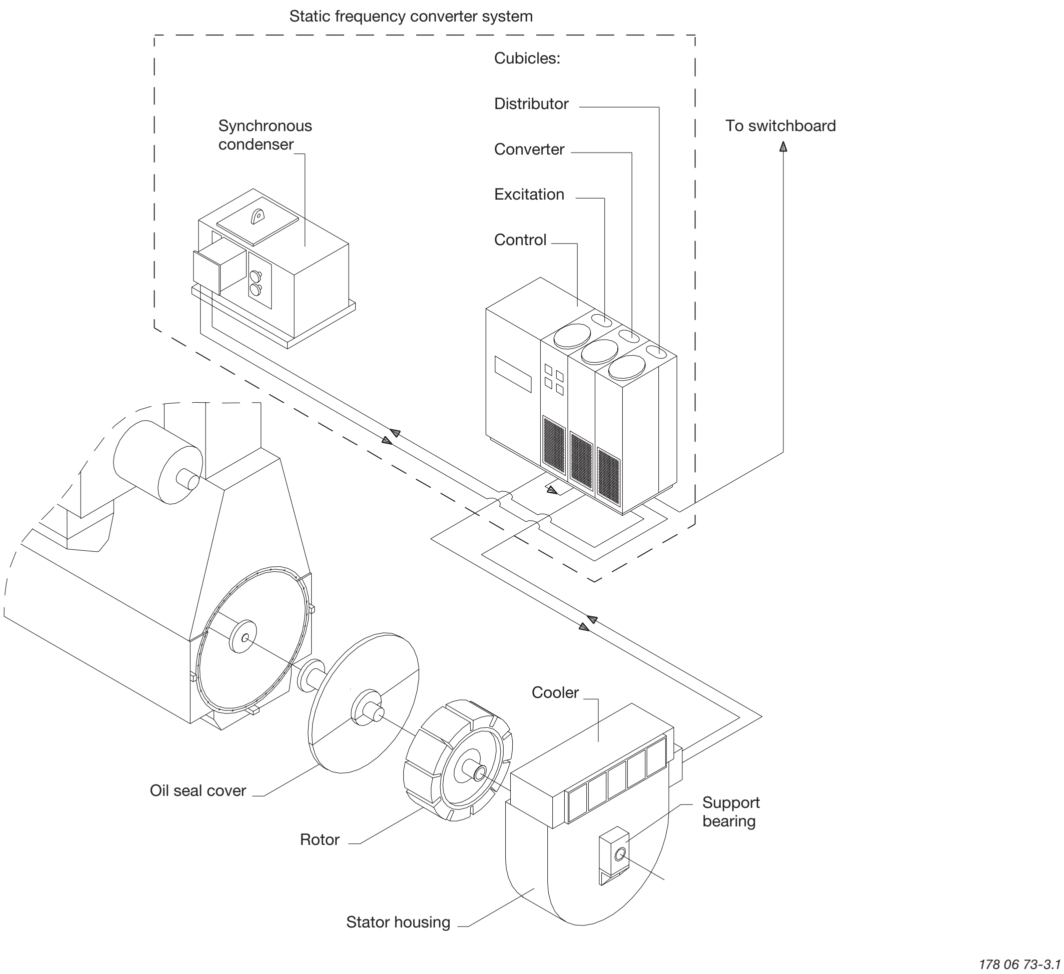


Fig. 4.03.04: Standard engine, with direct mounted generator (DMG/CFE)

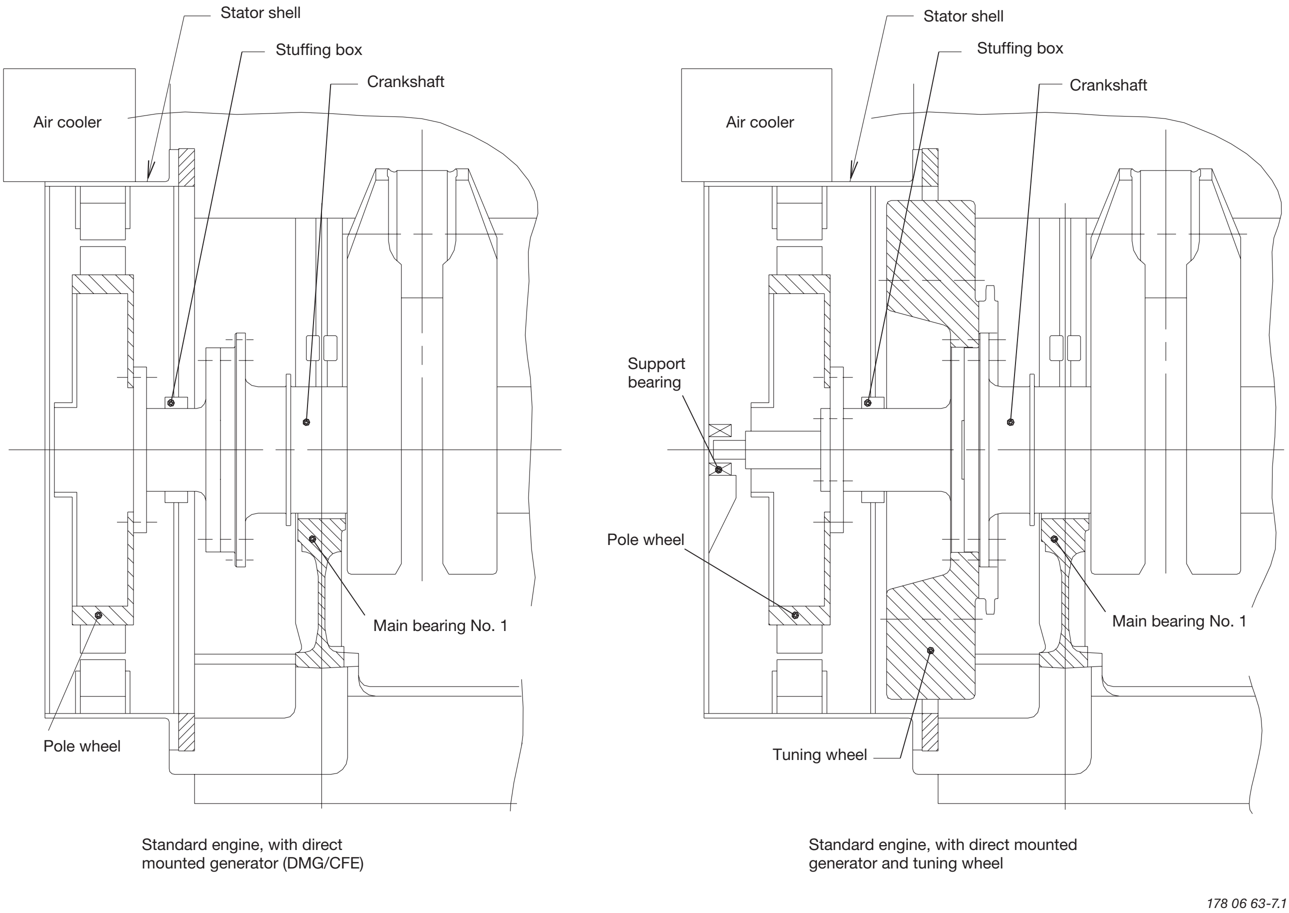


Fig. 4.03.05: Standard engine, with direct mounted generator and tuning wheel

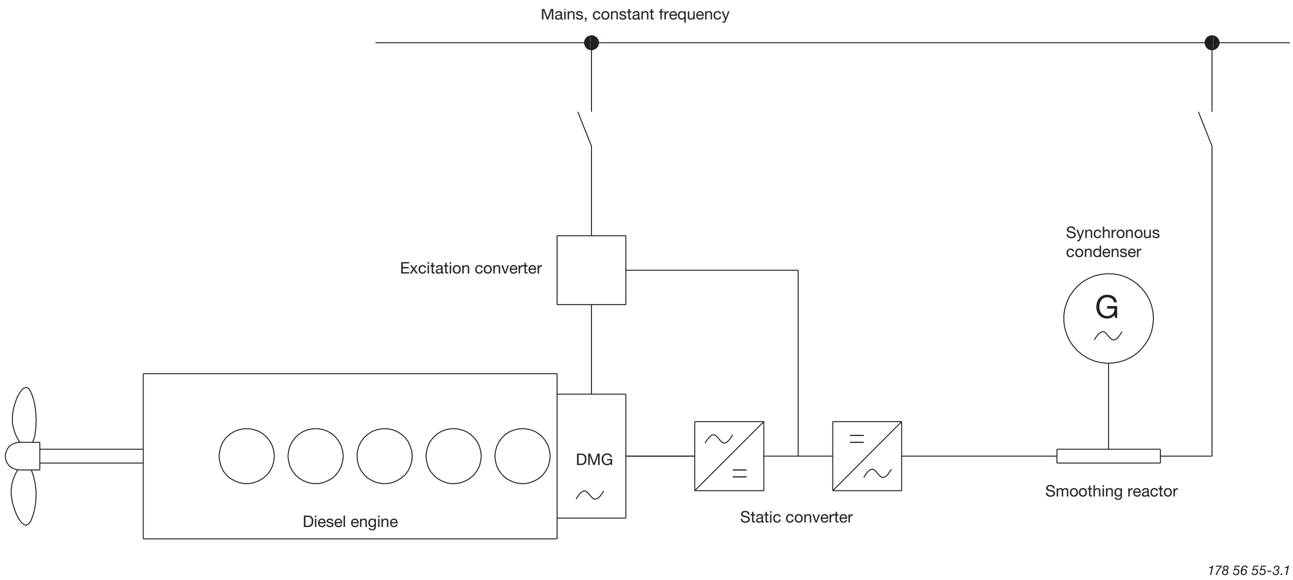


Fig. 4.03.06: Diagram of DMG/CFE with static converter

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

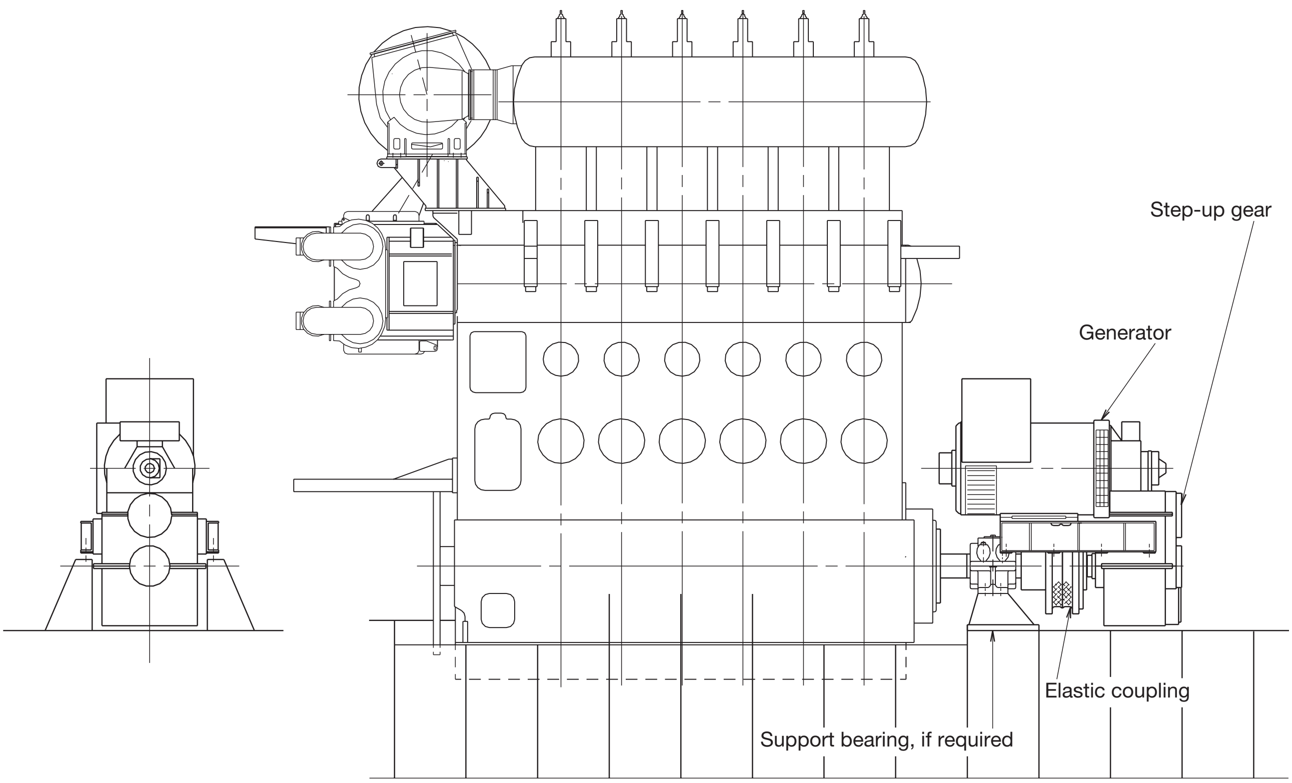


Fig. 4.04.01: Generic outline of Power Take Off (PTO) BW II/GCR

combinator mode. This will, however, require an additional 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.

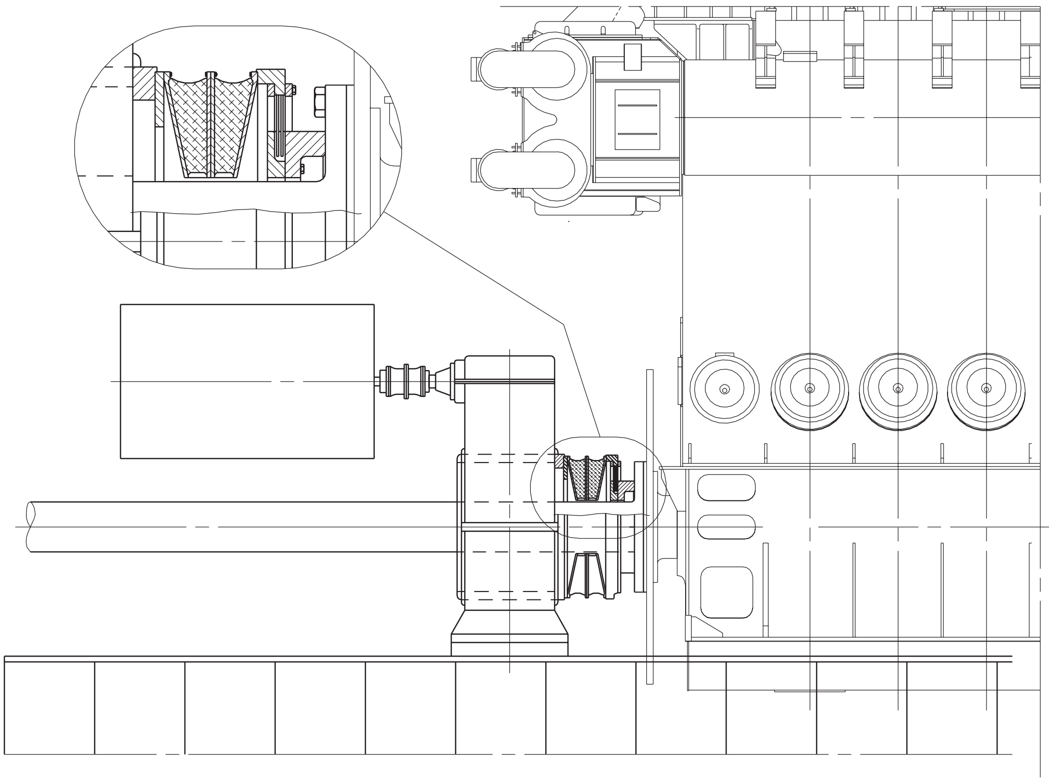
Generator step-up gear and flexible coupling integrated in the shaft line

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.



178 18 25-0.1

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 Energy Solutions 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.

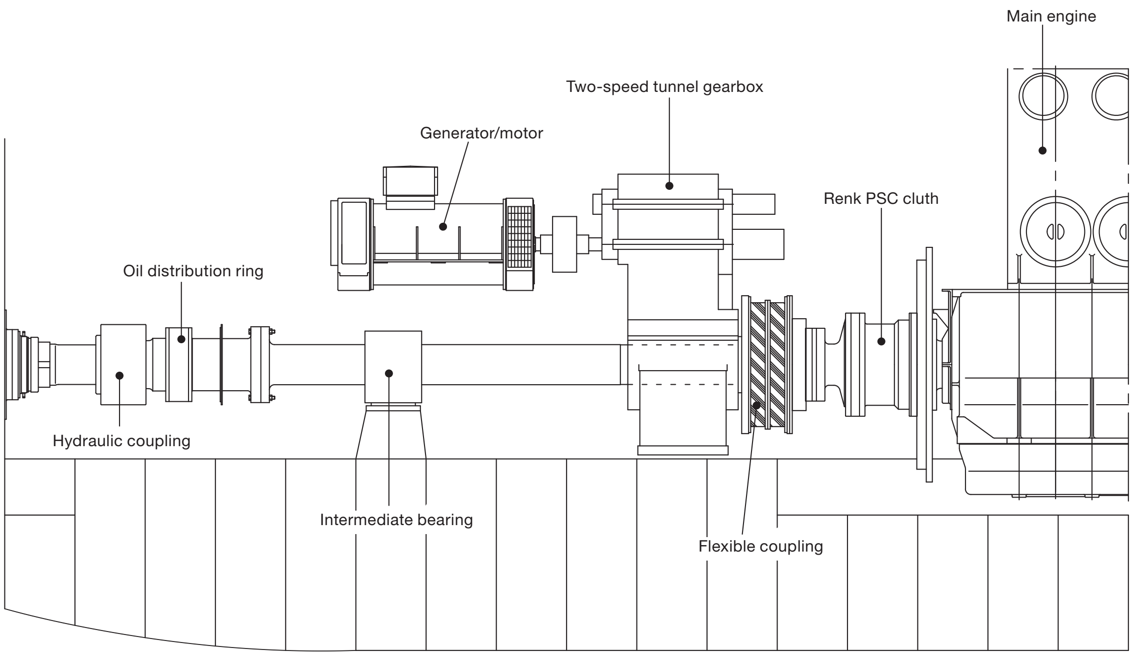


Fig. 4.04.03: Auxiliary propulsion system

Waste Heat Recovery Systems (WHRS)

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

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

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

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

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

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

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

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

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

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

Power Turbine Generator (PTG)

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

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

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

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

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

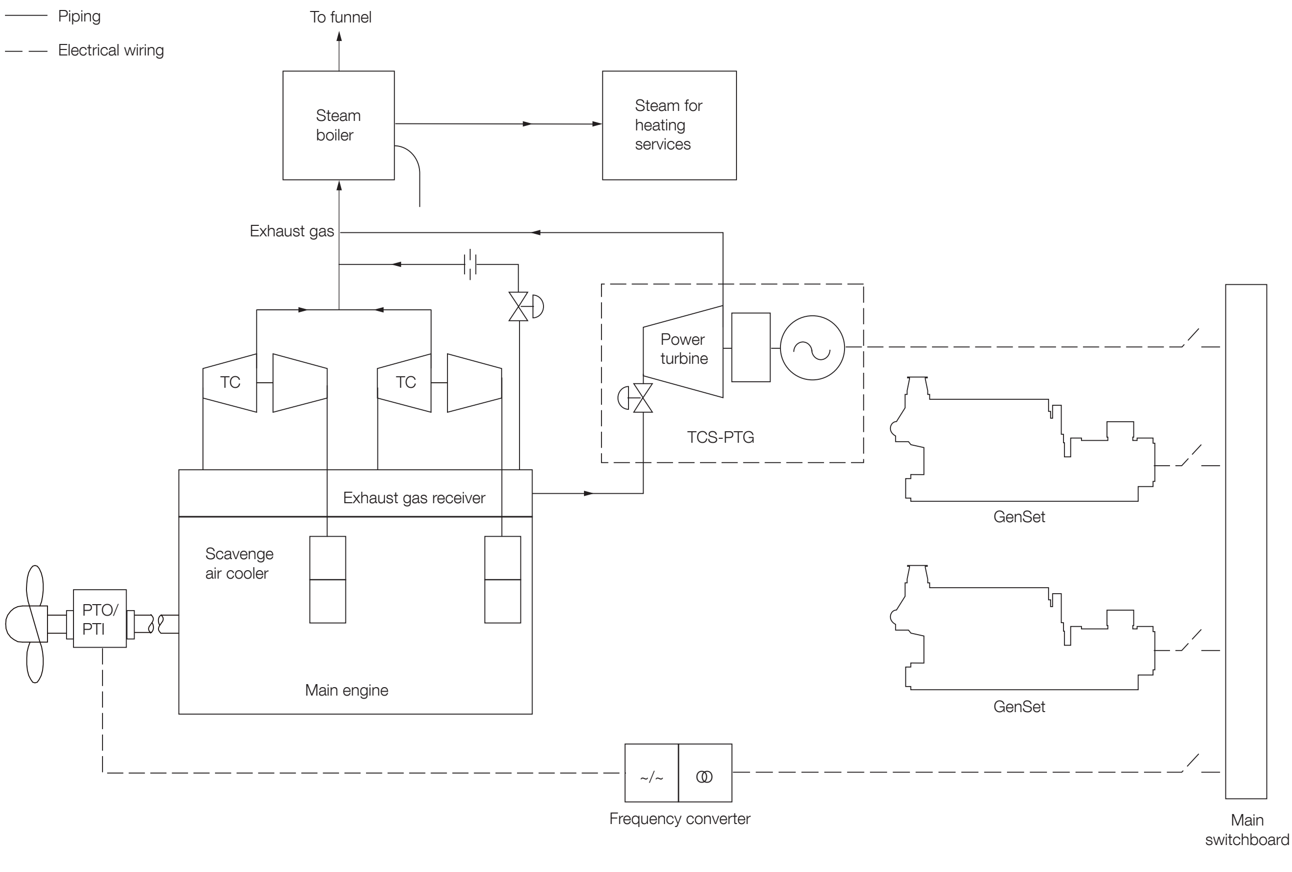


Fig. 4.05.01: PTG diagram

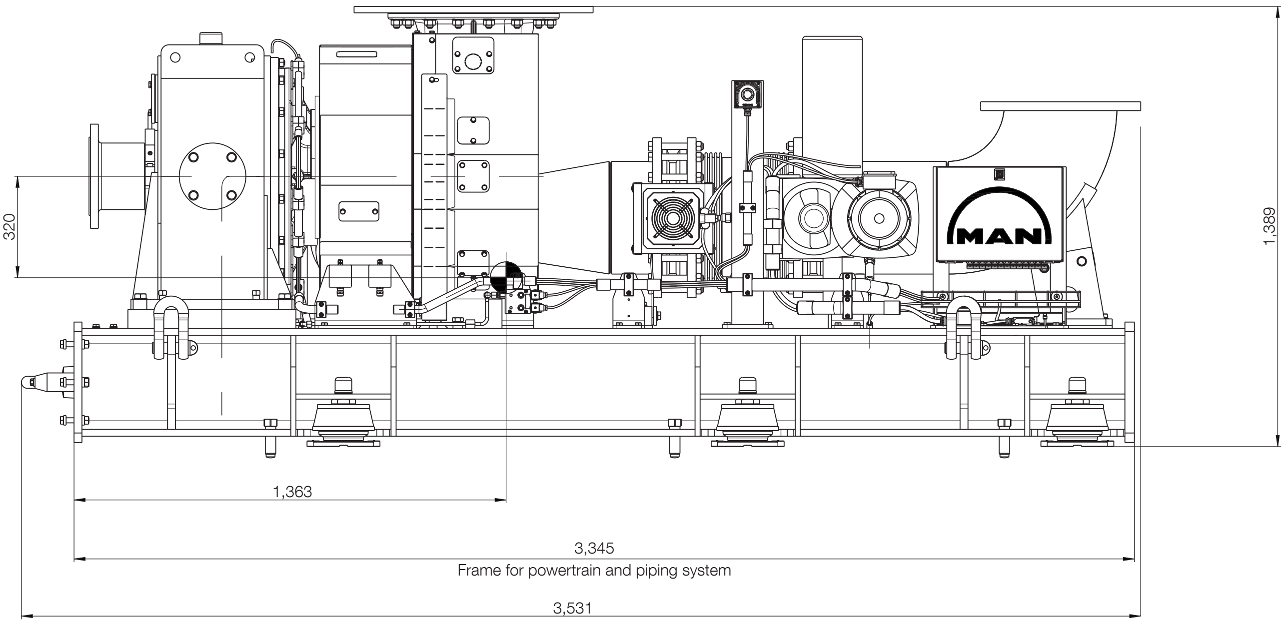


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Fig. 4.05.02: MAN Energy Solutions 1,500 kW TCS-PTG solution

Steam Turbine Generator (STG)

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

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

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

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

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

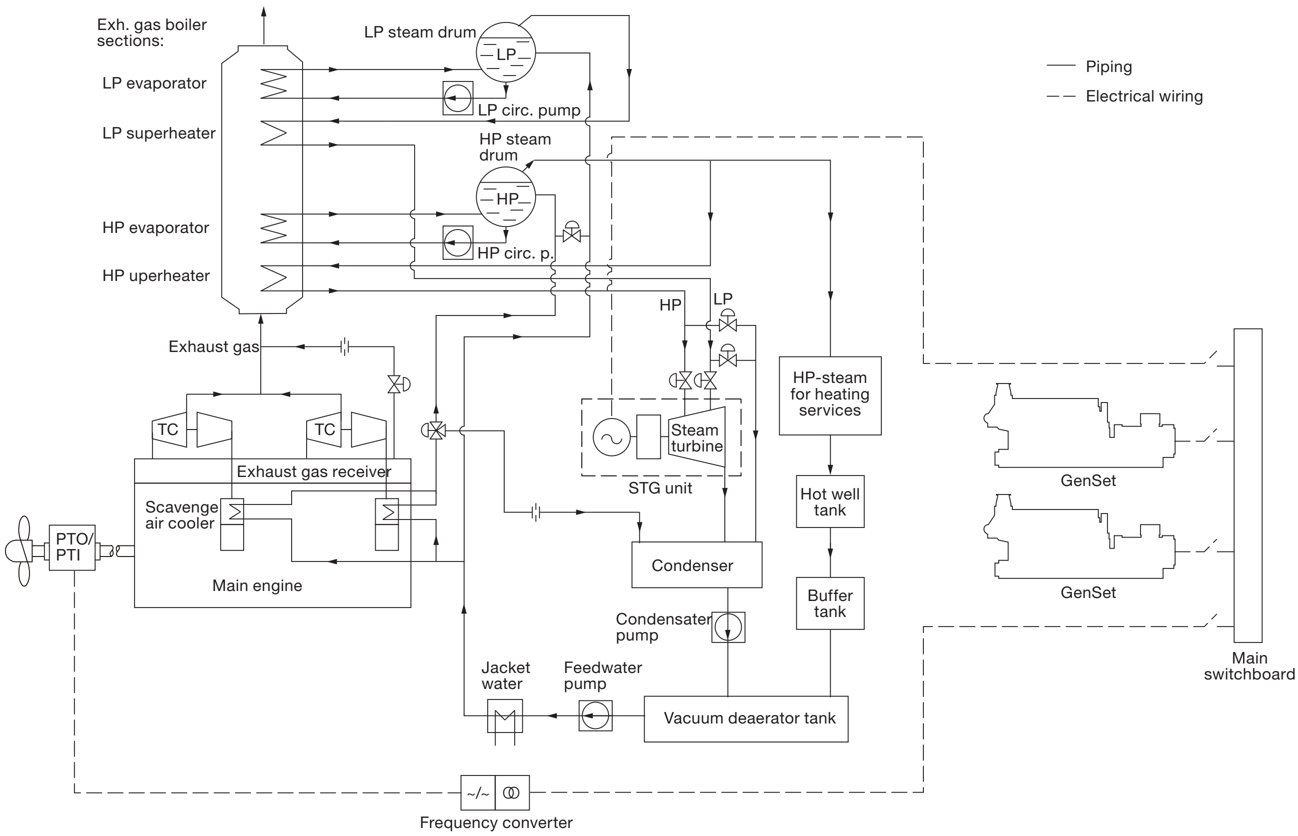
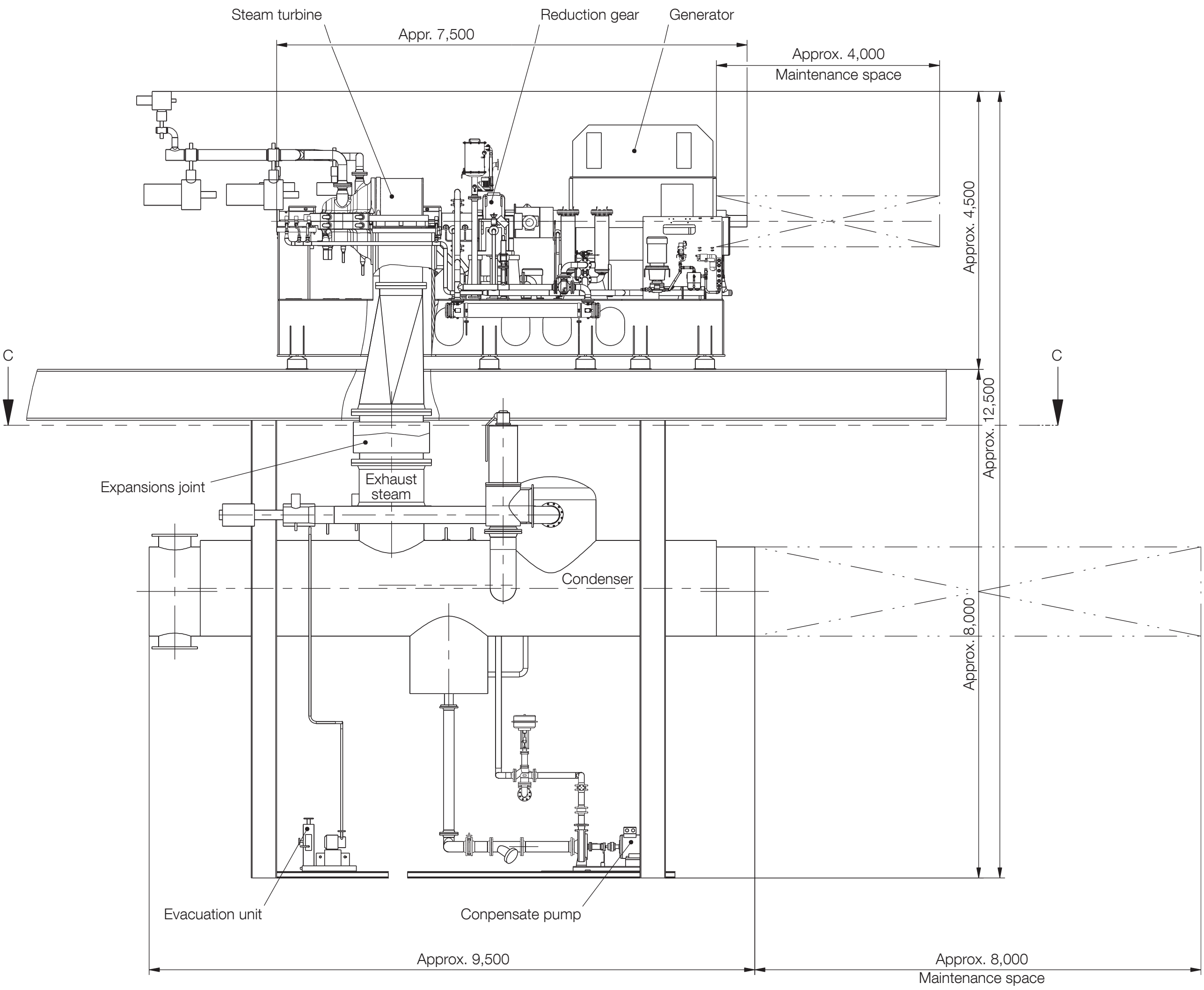


Fig. 4.05.03: STG system diagram



178 63 83-0.1

Fig. 4.05.04: STG steam turbine generator arrangement with condenser - typical arrangement

Full WHRS Steam and Power Turbines Combined

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

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

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

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

As mentioned, the systems with steam turbines require a larger boiler to be installed. The size of the boiler system will be considerably bigger than the size of an ordinary boiler system, and the actual boiler size has to be calculated from case to case. Casing space for the exhaust boiler must be reserved in the initial planning of the ship's machinery spaces.

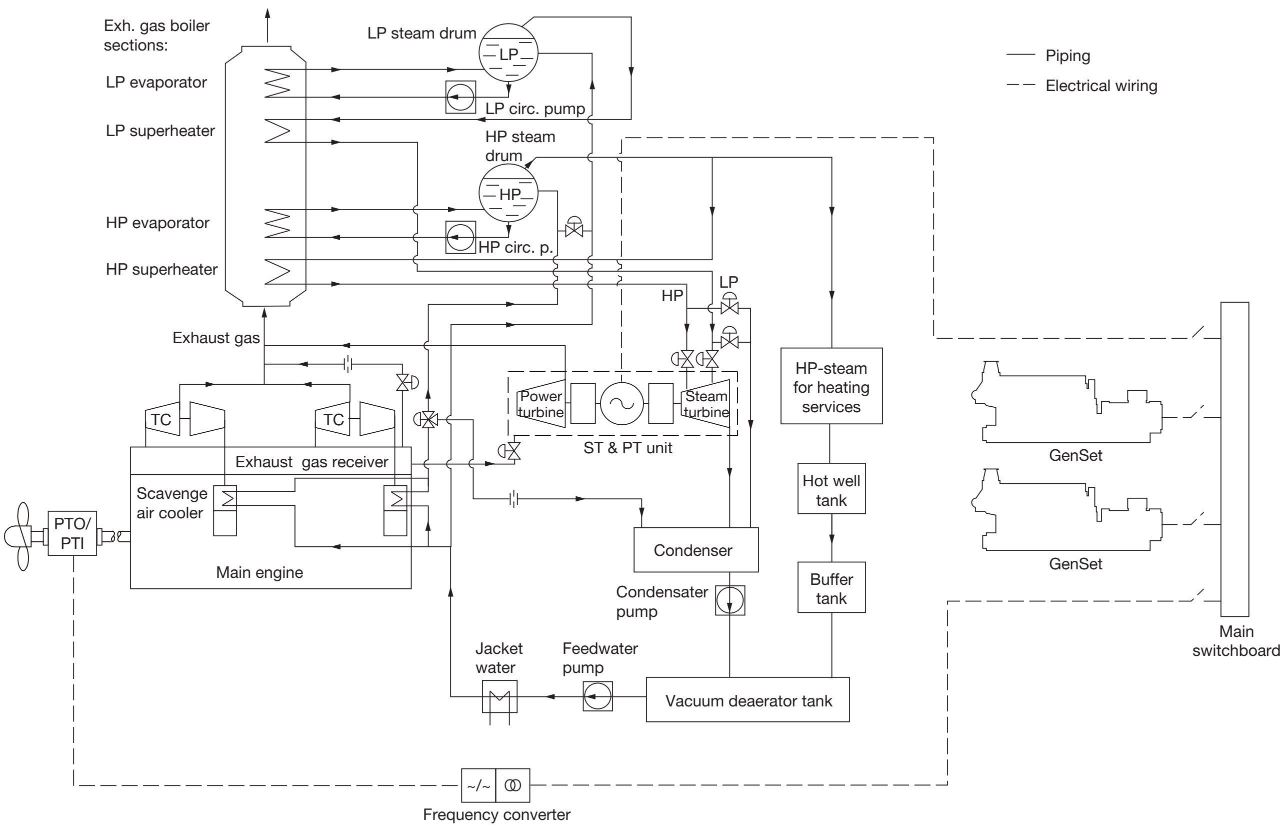


Fig. 4.05.05: Full WHRS with both steam and power turbines

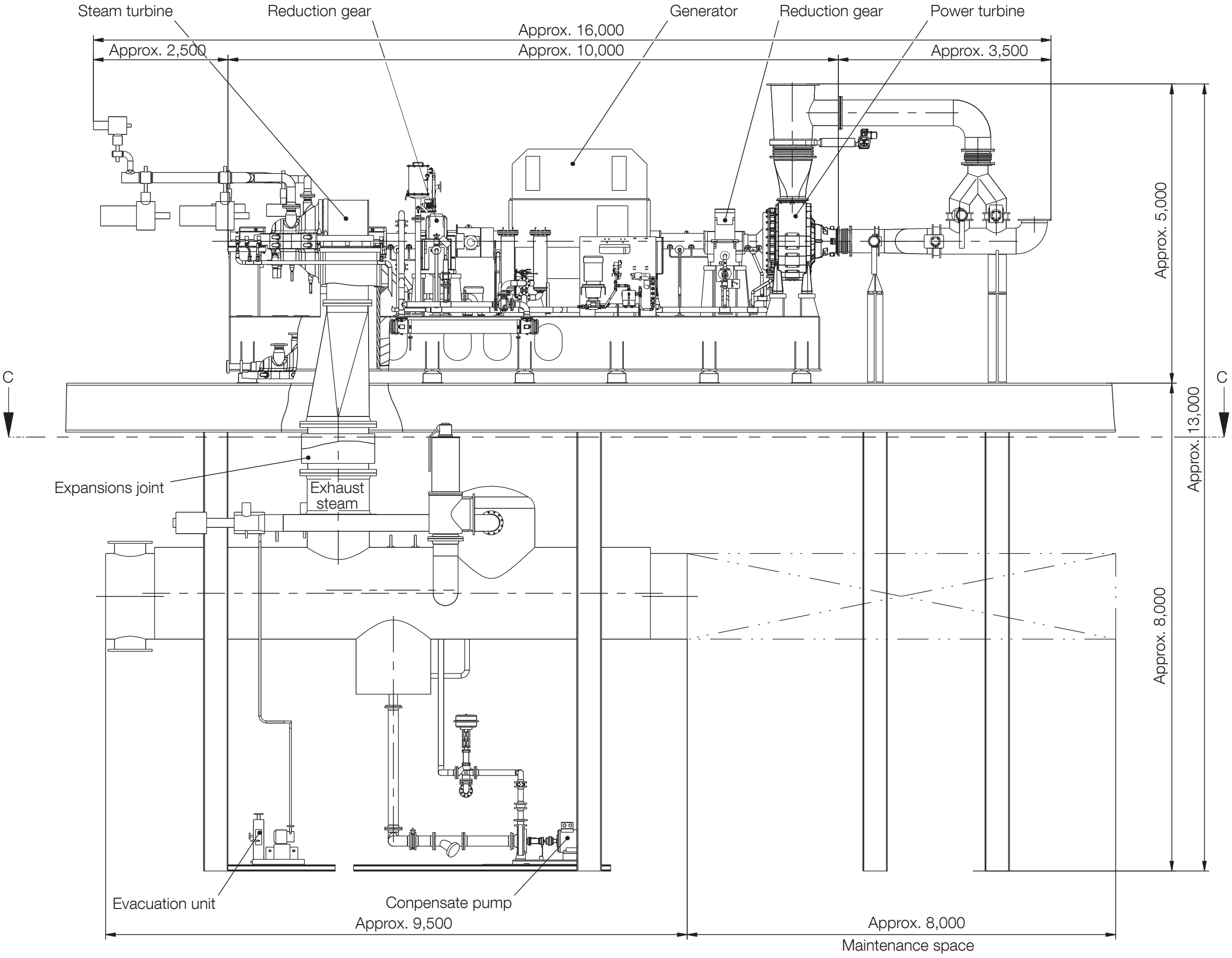


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Fig. 4.05.06: Full ST & PT full waste heat recovery unit arrangement with condenser - typical arrangement

WHRS generator output

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

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

WHRS output at a rating lower than L_1

As engines are seldom rated in L_1, it is recommended to contact MAN Energy Solutions Copen-hagen, department Marine Project Engineering, e-mail: lee5@man-es.com for specific WHRS generator output.

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

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

Waste Heat Recovery System (WHRS)

The publication is available at www.marine.man-es.com → 'Two-Stroke' → 'Technical Papers/Brochures'.

Guidance output of WHR for G60ME-C8.2/-GI-TII engine rated in L_1 at ISO conditions					
Cyl.	Engine power		PTG	STG	Full WHRS with combined turbines
	% SMCR	kW	kWe	kWe	kWe
5	100	13,400	485	670	1,101
	75	10,050	308	504	733
6	100	16,080	585	859	1,328
	75	12,060	376	611	886
7	100	18,760	687	1,009	1,557
	75	14,070	446	720	1,041
8	100	21,440	789	1,162	1,788
	75	16,080	519	832	1,198

Note 1: The above given preliminary WHRS generator outputs is based on HP service steam consumption of 0.3 ton/h and LP service steam consumption of 0.7 ton/h for the ship at ISO condition.
Note 2: 75% SMCR is selected due to the EEDI focus on the engine load.

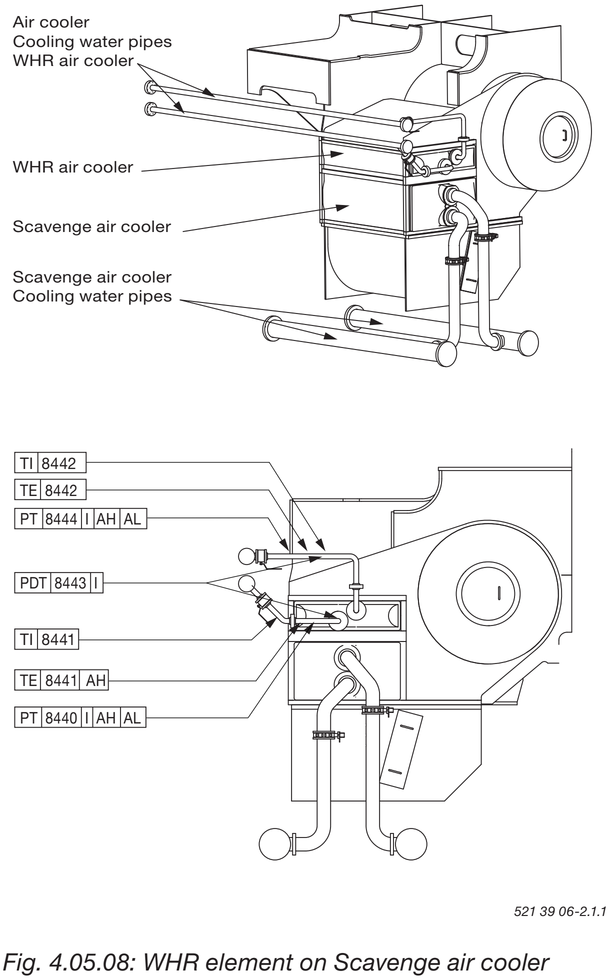
Table 4.05.07: Theoretically calculated outputs

Waste Heat Recovery Element and Safety Valve

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

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

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



521 39 06-2.1.1

Fig. 4.05.08: WHR element on Scavenge air cooler

Safety valve and blow-off

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

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

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

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

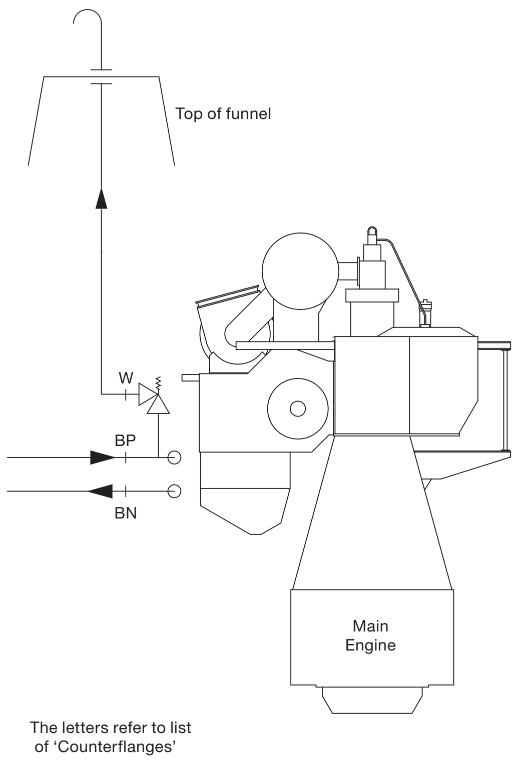


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Fig. 4.05.09: WHR safety valve blow-off through connection 'W' to the funnel

L16/24 GenSet Data

Engine ratings

Engine type No of cylinders	1000 rpm		1200 rpm	
	1000 rpm	Available turning direction	1200 rpm	Available turning direction
	kW	CW [1]	kW	CW [1]
5L16/24	450	Yes	500	Yes
6L16/24	570	Yes	660	Yes
7L16/24	665	Yes	770	Yes
8L16/24	760	Yes	880	Yes
9L16/24	855	Yes	990	Yes

[1] CW clockwise

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General

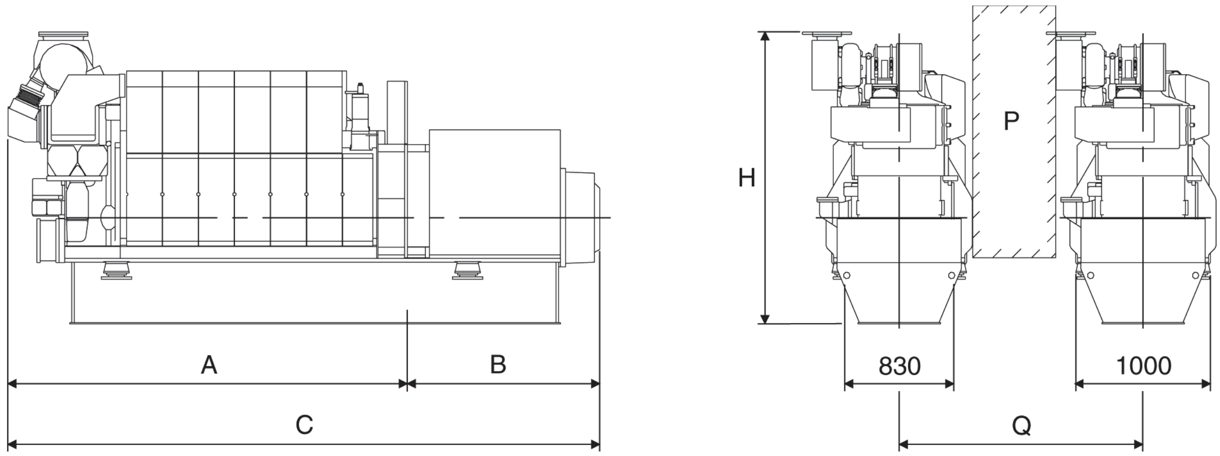

Fig. 4.06.01:

Cyl. no	A (mm)	* B (mm)	* C (mm)	H (mm)	** Dry weight GenSet (t)
5 (1000 rpm)	2807	1400	4207	2337	9.5
5 (1200 rpm)	2807	1400	4207	2337	9.5
6 (1000 rpm)	3082	1490	4572	2337	10.5
6 (1200 rpm)	3082	1490	4572	2337	10.5
7 (1000 rpm)	3557	1585	5142	2337	11.4
7 (1200 rpm)	3557	1585	5142	2415	11.4
8 (1000 rpm)	3832	1680	5512	2415	12.4
8 (1200 rpm)	3832	1680	5512	2415	12.4
9 (1000 rpm)	4107	1680	5787	2415	13.1
9 (1200 rpm)	4107	1680	5787	2415	13.1

P Free passage between the engines, width 600 mm and height 2000 mm.
Q Min. distance between engines: 1800 mm.

* Depending on alternator
** Weight included a standard alternator

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

Capacities

5L:90 kW/cyl., 6L-9L: 95 kW/Cyl. at 1000 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°C nominal *(Range of mech. thermostatic element 77-85°C)*					
Setpoint LT cooling water engine outlet [2]		°C	35°C nominal *(Range of mech. thermostatic element 29°-41°C)*					
Setpoint Lube oil inlet engine		°C	66°C nominal *(Range of mech. thermostatic element 63-72°C)*					
Number of cylinders			5	6	7	8	9
Engine output		kW	450	570	665	760	855
Speed		rpm	1000				
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)		m3/h	10.9	12.7	14.5	16.3	18.1
LT circuit (lube oil + charge air cooler LT stage)		m3/h	15.7	18.9	22	25.1	28.3
Lube oil		m3/h	18	18	30	30	30
External (from engine to system)							
HT water flow (at 40°C inlet)		m3/h	5.2	6.4	7.4	8.3	9.2
LT water flow (at 38°C inlet)		m3/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]	2721	3446	4021	4595	5169
		kg/kWh	6.62	6.62	6.62	6.62	6.62
Charge air pressure		bar	4.13	4.13	4.13	4.13	4.13
Air required to dissipate heat radiation (eng.)(t_2-t_1= 10°C)		m^3/h	4860	6157	7453	8425	9397
Exhaust gas data [6]							
Volume flow (temperature turbocharger outlet)		m^3/h [7]	5710	7233	8438	9644	10849
Mass flow		t/h	3.1	3.9	4.5	5.2	5.8
Temperature at turbine outlet		°C	375	375	375	375	375
Heat content (190°C)		kW	170	216	252	288	324
Permissible exhaust back pressure		mbar	< 30	< 30	< 30	< 30	< 30
Pumps							
External pumps [8]							
Diesel oil pump	(5 bar at fuel oil inlet A1)	m3/h	0.32	0.40	0.47	0.54	0.60
Fuel oil supply pump	(4 bar discharge pressure)	m3/h	0.15	0.19	0.23	0.26	0.29
Fuel oil circulating pump	(8 bar at fuel oil inlet A1)	m3/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

Capacities

5L:100 kW/cyl., 6L-9L: 110 kW/Cyl. at 1200 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°C nominal *(Range of mech. thermostatic element 77-85°C)*				
Setpoint LT cooling water engine outlet [2)]		°C	35°C nominal *(Range of mech. thermostatic element 29-41°C)*				
Setpoint Lube oil inlet engine		°C	66°C nominal *(Range of mech. thermostatic element 63-72°C)*				
Number of cylinders			5	6	7	8	9
Engine output		kW	500	660	770	880	990
Speed		rpm	1200				
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)		m3/h	13.1	15.2	17.4	19.5	21.6
LT circuit (lube oil + charge air cooler LT stage)		m3/h	19.3	20.7	24.2	27.7	31.1
Lube oil		m3/h	21	21	35	35	35
External (from engine to system)							
HT water flow (at 40°C inlet)		m3/h	5.7	7.3	8.4	9.4	10.4
LT water flow (at 38°C inlet)		m3/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)]	3169	4183	4880	5578	6275
		kg/kWh	6.94	6.94	6.94	6.94	6.94
Charge air pressure		bar	3.92	3.92	3.92	3.92	3.92
Air required to dissipate heat radiation (eng.)(t_2-t_1= 10°C)		m^3/h	5509	7453	8425	9721	11017
Exhaust gas data [6)]							
Volume flow (temperature turbocharger outlet)		m^3/h [7)]	6448	8511	9929	11348	12766
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	< 30	< 30	< 30	< 30
Pumps							
External pumps [8)]							
Diesel oil pump	(5 bar at fuel oil inlet A1)	m3/h	0.35	0.47	0.54	0.62	0.70
Fuel oil supply pump	(4 bar discharge pressure)	m3/h	0.17	0.22	0.26	0.30	0.34
Fuel oil circulating pump	(8 bar at fuel oil inlet A1)	m3/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

Remarks to capacities

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

D10050_3700002-9.2 & D10050_3700003-0.3

L21/31 GenSet Data

Engine ratings

Engine type No of cylinders	900 rpm		1000 rpm	
	900 rpm	Available turning direction	1000 rpm	Available turning direction
	kW	CW [1]	kW	CW [1]
5L21/31	1000	Yes	1000	Yes
6L21/31	1320	Yes	1320	Yes
7L21/31	1540	Yes	1540	Yes
8L21/31	1760	Yes	1760	Yes
9L21/31	1980	Yes	1980	Yes

[1] CW clockwise

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General

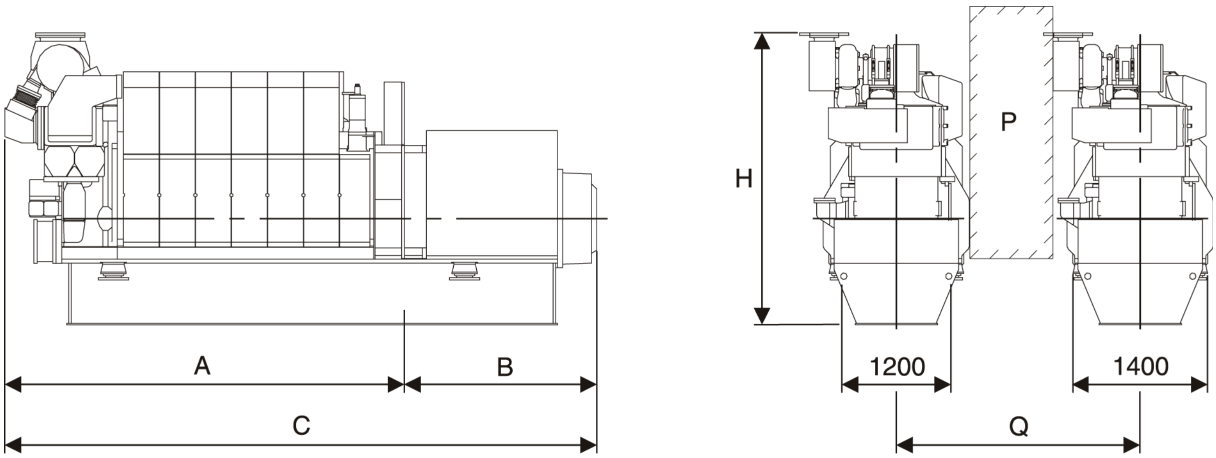

Fig. 4.07.01:

1 bearing

Cyl. no	A (mm)	* B (mm)	* C (mm)	H (mm)	** Dry WEight GenSet (t)
5 (900 rpm) 5 (1000 rpm)	3959 3959	1820 1870	5779 5829	3183 3183	22.5 22.5
6 (900 rpm) 6 (1000 rpm)	4314 4314	1870 2000	6184 6314	3183 3183	26.0 26.0
7 (900/1000 rpm)	4669	1970	6639	3289	29.5

2 bearings

Cyl. no	A (mm)	* B (mm)	* C (mm)	H (mm)	** Dry weight GenSet (t)
5 (900/1000 rpm)	4507	2100	6607	3183	22.5
6 (900/1000 rpm)	4862	2100	6962	3183	26.0
7 (900/1000 rpm)	5217	2110	7327	3289	29.5
8 (900/1000 rpm)	5572	2110	7682	3289	33.0
9 (900/1000 rpm)	5927	2135	8062	3289	36.5

P Free passage between the engines, width 600 mm and height 2000 mm.
Q Min. distance between engines: 2400 mm (without gallery) and 2600 mm (with gallery)

* Depending on alternator
** Weight included a standard alternator

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

Capacities

5L: 200 kW/cyl., 6L-9L: 220kW/Cyl. at 900 rpm, 1-String						
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°C nominal *(Range of mech. thermostatic element 77-85°C)*				
Setpoint LT cooling water engine outlet 2)	°C	35°C nominal *(Range of mech. thermostatic element 29°-41°C)*				
Setpoint Lube oil inlet engine	°C	66°C nominal *(Range of mech. thermostatic element 63-72°C)*				
External (from engine to system)						
1-string cooling water (mix)	°C	52.4	56.4	59.1	61.6	64.2
Number of cylinders		5	6	7	8	9
Engine output	kW	1000	1320	1540	1760	1980
Speed	rpm	900				
Heat to be dissipated 3)						
Cooling water (C.W.) Cylinder	kW	208	289	347	405	464
Charge air cooler; cooling water HT	kW	346	435	490	542	590
Charge air cooler; cooling water LT	kW	198	244	274	303	332
Lube oil (L.O.) cooler	kW	176	238	281	324	368
Heat radiation engine	kW	49	65	76	87	98
Flow rates 4)						
Internal (inside engine)						
HT circuit (cylinder + charge air cooler HT stage)	m3/h	55	55	55	55	55
LT circuit (lube oil + charge air cooler LT stage)	m3/h	55	55	55	55	55
Lube oil	m3/h	31	31	41	41	41
External (from engine to system)						
HT water flow (at 40°C inlet)	m3/h	11.1	14.1	16.0	17.8	19.5
LT water flow (at 38°C inlet)	m3/h	55	55	55	55	55
Air data						
Temperature of charge air at charge air cooler outlet	°C	52	56	58	60	62
Air flow rate	m^3/h 5)	6656	8786	10250	11714	13178
	kg/kWh	7.28	7.28	7.28	7.28	7.28
Charge air pressure	bar	4.58	4.61	4.63	4.64	4.66
Air required to dissipate heat radiation (eng.)(t_2-t_1= 10°C)	m^3/h	17980	23800	27600	31500	35300
Exhaust gas data 6)						
Volume flow (temperature turbocharger outlet)	m^3/h 7)	13484	17918	20981	24055	27130
Mass flow	t/h	7.5	9.9	11.5	13.2	14.8
Temperature at turbine outlet	°C	353	357	360	362	363
Heat content (190°C)	kW	366	496	587	679	771
Permissible exhaust back pressure	mbar	< 30	< 30	< 30	< 30	< 30
Pumps						
External pumps 8)						
Diesel oil pump (5 bar at fuel oil inlet A1)	m3/h	0.89	1.18	1.37	1.57	1.76
Fuel oil supply pump (4 bar discharge pressure)	m3/h	0.30	0.39	0.46	0.52	0.59
Fuel oil circulating pump (8 bar at fuel oil inlet A1)	m3/h	0.89	1.18	1.37	1.57	1.76

5L: 200 kW/cyl., 6L-9L: 220kW/Cyl. at 900 rpm, 1-String						
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
Air consumption per start, incl. air for jet assist (Gali)	Nm^3	1.8	2.1	2.4	2.7	3.0

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

D10050_1689479-1.5

Capacities

5L:200 kW/cyl., 6L-9L: 220 kW/Cyl. at 1000 rpm, 1-String						
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°C nominal *(Range of mech. thermostatic element 77-85°C)*				
Setpoint LT cooling water engine outlet [2]	°C	35°C nominal *(Range of mech. thermostatic element 29°-41°C)*				
Setpoint Lube oil inlet engine	°C	66°C nominal *(Range of mech. thermostatic element 63-72°C)*				
External (from engine to system)						
1-String coding water (mix)	°C	50.6	54.1	56.4	58.6	60.8
Number of cylinders		5	6	7	8	9
Engine output	kW	1000	1320	1540	1760	1980
Speed	rpm	1000				
Heat to be dissipated [3]						
Cooling water (C.W.) Cylinder	kW	206	285	342	399	456
Charge air cooler; cooling water HT	kW	321	404	455	503	548
Charge air cooler; cooling water LT	kW	192	238	266	294	321
Lube oil (L.O.) cooler	kW	175	236	279	322	365
Heat radiation engine	kW	49	65	76	87	98

5L:200 kW/cyl., 6L-9L: 220 kW/Cyl. at 1000 rpm, 1-String						
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	51	55	57	59	60
Air flow rate	m^3/h [5]	6647	8774	10237	11699	13161
	kg/kWh	7.27	7.27	7.27	7.27	7.27
Charge air pressure	bar	4.25	4.28	4.29	4.30	4.31
Air required to dissipate heat radiation (eng.)(t_2-t_1= 10°C)	m^3/h	17980	23800	27600	31500	35300
Exhaust gas data [6]						
Volume flow (temperature turbocharger outlet)	m^3/h [7]	13730	18235	21348	24468	27594
Mass flow	t/h	7.5	9.9	11.5	13.2	14.8
Temperature at turbine outlet	°C	365	369	372	373	375
Heat content (190°C)	kW	394	532	628	725	823
Permissible exhaust back pressure	mbar	< 30	< 30	< 30	< 30	< 30
Pumps						
External pumps [8]						
Diesel oil pump (5 bar at fuel oil inlet A1)	m^3/h	0.89	1.18	1.37	1.57	1.76
Fuel oil supply pump (4 bar)	m^3/h	0.30	0.39	0.46	0.52	0.59
Fuel oil circulating 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
Air consumption per start, incl. air for jet assist (Gali)	Nm^3	1.8	2.1	2.4	2.7	3.0

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

D10050_1689499-4.5

L23/30H Mk2 GenSet Data

Engine ratings

Engine type No of cylinders	720 rpm		750 rpm		900 rpm	
	720 rpm	Available turning direction	750 rpm	Available turning direction	900 rpm	Available turning direction
	kW	CW [1]	kW	CW [1]	kW	CW [1]
5L23/30H Mk2	650/710	Yes	675/740	Yes	–	–
6L23/30H Mk2	852	Yes	888	Yes	1050	Yes
7L23/30H Mk2	994	Yes	1036	Yes	1225	Yes
8L23/30H Mk2	1136	Yes	1184	Yes	1400	Yes
[1] CW clockwise						

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General

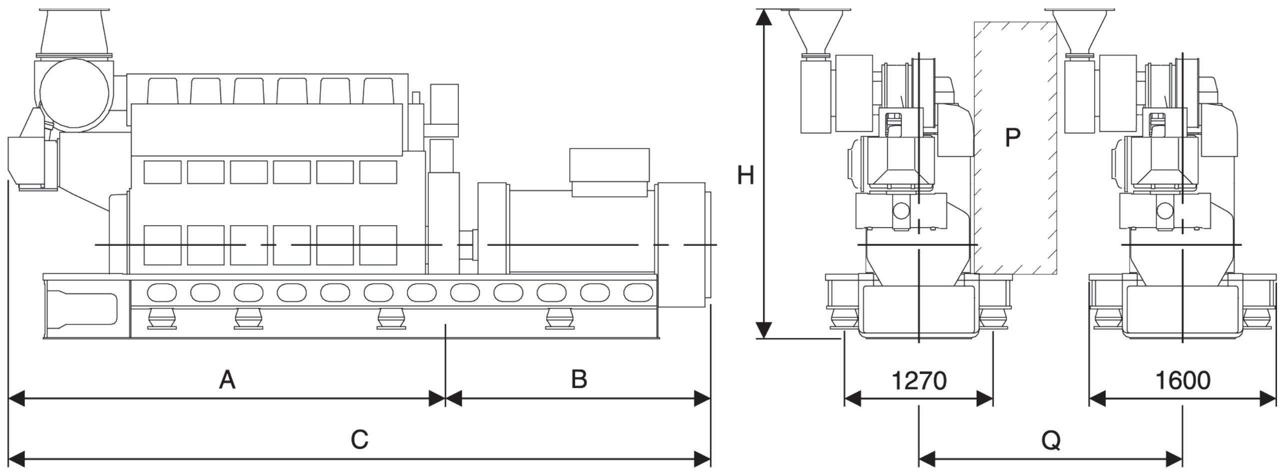

Fig. 4.08.01:

Cyl. no	A (mm)	* B (mm)	* C (mm)	H (mm)	** Dry weight GenSet (t)
5 (720 rpm)	3369	2155	5524	2402	18.0
5 (750 rpm)	3369	2155	5524	2402	17.6
6 (720 rpm)	3738	2265	6004	2402	19.7
6 (750 rpm)	3738	2265	6004	2402	19.7
6 (900 rpm)	3738	2265	6004	2466	21.0
7 (720 rpm)	4109	2395	6504	2466	21.4
7 (750 rpm)	4109	2395	6504	2466	21.4
7 (900 rpm)	4109	2395	6504	2466	22.8
8 (720 rpm)	4475	2480	6959	2466	23.5
8 (750 rpm)	4475	2480	6959	2466	22.9
8 (900 rpm)	4475	2340	6815	2466	24.5

P Free passage between the engines, width 600 mm and height 2000 mm.
Q Min. distance between engines: 2250 mm

* Depending on alternator
** Weight included a standard alternator

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

Capacities

5-8L23/30H Mk 2: 142 kW/Cyl., 720 rpm or 148 kW/Cyl., 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 [2)]					
Setpoint HT cooling water engibe 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	710/740	852/888	994/1036	1136/1184
Speed	rpm	720/750	720/750	720/750	720/750
Heat to be dissipated [1)]					
Cooling water (CW) cylinder	kW	190/195	230/235	270/276	310/317
Charge air cooler; cooling water HT (1 stage cooler: no HT-stage)	kW	-	-	-	-
Charge air cooler; cooling water LT	kW	299/327	356/390	413/452	470/514
Lube oil (LO) cooler	kW	71/72	86/86	101/102	116/117
Heat radiation engine	kW	30	36	42	48
Air data					
Charge air temp. at charge air cooler outlet, max.	°C	55	55	55	55
Air flow rate	m^3/h [4)]	4792/4994	5750/5993	6708/6992	7667/7991
	kg/kWh	7.39	7.39	7.39	7.39
Charge air pressure	bar	3.08	3.08	3.08	3.08
Air required to dissipate heat radiation (eng.) ($t_2-t_1=10°C$)	m^3/h	9756	11708	13659	15610
Exhaust gas data [5)]					
Volume flow (temperature turbocharger outlet)	m^3/h [6)]	9516/9918	11419/11902	13323/13885	15226/15869
Mass flow	t/h	5.4/5.6	6.5/6.7	7.5/7.9	8.6/9.0
Temperature at turbine outlet	°C	342	342	342	342
Heat content (190°C)	kW	244/254	293/305	341/356	390/407
Permissible exhaust back pressure	mbar	< 30	< 30	< 30	< 30
Pumps [3)]					
Engine driven pumps					
HT cooling water pump (1-2.5 bar)	m^3/h	36	36	36	36
LT cooling water pump (1-2.5 bar)	m^3/h	55	55	55	55
Lube oil (3-5 bar)	m^3/h	16	16	20	20
External pumps [7)]					
Diesel oil pump (4 bar at fuel oil inlet A1)	m^3/h	0.52	0.62	0.73	0.83
Fuel oil supply pump [8)] (4 bar discharge pressure)	m^3/h	0.25	0.31	0.36	0.41
Fuel oil circulating pump (8 bar at fuel oil inlet A1)	m^3/h	0.53	0.63	0.74	0.84
Cooling water pumps 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 "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 consumption per start	Nm^3	2.0	2.0	2.0	2.0

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

D10050_3700220-9.0

Capacities

6-8L23/30H Mk 2: 175 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 2)				
Setpoint HT cooling water engine outlet	°C	82°C (engine equipped with HT thermostatic valve)		
Setpoint lube oil inlet engine	°C	60° (SAE30), 66°C (SAE40)		
Number of cylinders		6	7	8
Engine output	kW	1050	1225	1400
Speed	rpm	900	900	900
Heat to be dissipated 1)				
Cooling water (CW) Cylinder	kW	265	311	357
Charge air cooler; cooling water HT				
1 stage cooler: no HT-stage	kW	-	-	-
Charge air cooler; cooling water LT	kW	441	512	581
Lube oil (LO) cooler	kW	126	148	170
Heat radiation engine	kW	35	41	47
Air data				
Temp. of charge air at charge air cooler outlet, max.	°C	55	55	55
Air flow rate	m^3/h 4)	7355	8581	9806
	kg/kWh	7.67	7.67	7.67
Charge air pressure	bar	3.1	3.1	3.1
Air required to dissipate heat radiation (eng.) (t_2-t_1=10°C)	m^3/h	11383	13334	15285
Exhaust gas data 5)				
Volume flow (temperature turbocharger outlet)	m^3/h 6)	15280	17826	20373
Mass flow	t/h	8.3	9.6	11.0
Temperature at turbine outlet	°C	371	371	371
Heat content (190°C)	kW	447	521	595
Permissible exhaust back pressure	mbar	< 30	< 30	< 30

6-8L23/30H Mk 2: 175 kW/Cyl., 900 rpm				
Pumps [3]				
Engine driven pumps				
HT cooling water pump (1-2.5 bar)	m^3/h	45	45	45
LT cooling water pump (1-2.5 bar)	m^3/h	69	69	69
Lube oil (3-5 bar)	m^3/h	20	20	20
External pumps [7]				
Diesel oil pump (4 bar at fuel oil inlet A1)	m^3/h	0.74	0.87	0.99
Fuel oil supply pump [8] (4 bar discharge pressure)	m^3/h	0.36	0.43	0.49
Fuel oil circulating pump (8 bar at fuel oil inlet A1)	m^3/h	0.75	0.88	1.01
Cooling water pumps for "Internal cooling water system 1"				
LT cooling water pump (1-2.5 bar)	m^3/h	52	61	70
Cooling water pumps 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 consumption per start	Nm^3	2.0	2.0	2.0

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

D10050_3700221-0.0

L27/38 GenSet Data

Engine ratings

Engine type No of cylinders	720 rpm		750 rpm		720/750 MGO	
	720 rpm	Available turning direction	750 rpm	Available turning direction	720/750 rpm	Available turning direction
	kW	CW [1]	kW	CW [1]	kW	CW [1]
5L27/38	1500	Yes	1600	Yes	–	–
6L27/38	1980	Yes	1980	Yes	2100	Yes
7L27/38	2310	Yes	2310	Yes	2450	Yes
8L27/38	2640	Yes	2640	Yes	2800	Yes
9L27/38	2970	Yes	2970	Yes	3150	Yes

[1] CW clockwise

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General

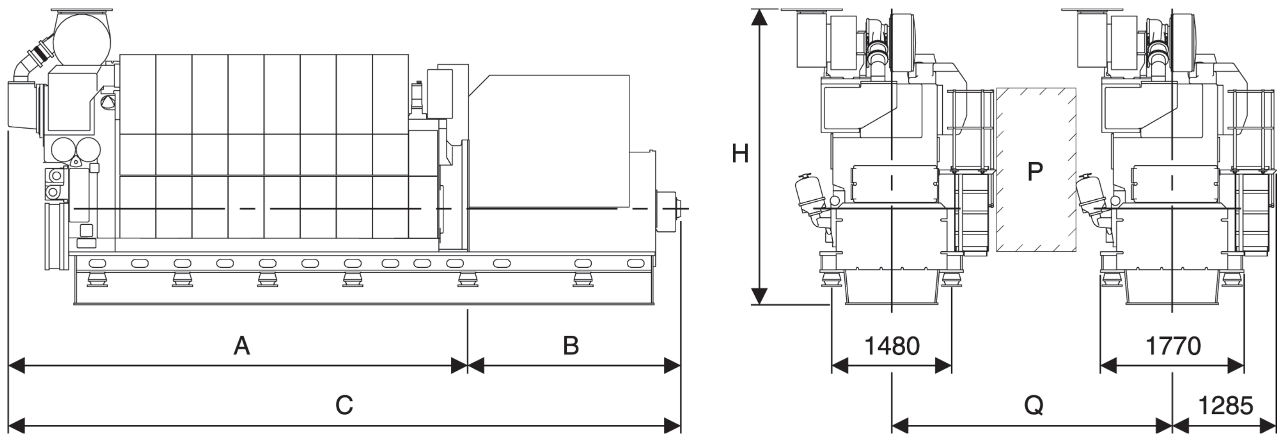

Fig. 4.09.01:

Cyl. no	A (mm)	* B (mm)	* C (mm)	H (mm)	** Dry weight GenSet (t)
5 (720 mm)	4346	2486	6832	3712	40.0
5 (750 mm)	4346	2486	6832	3712	40.0
6 (720 mm)	4791	2766	7557	3712	44.5
6 (750 mm)	4791	2766	7557	3712	44.5
7 (720 mm)	5236	2766	8002	3899	50.4
7 (750 mm)	5236	2766	8002	3899	50.4
8 (720 mm)	5681	2986	8667	3899	58.2
8 (750 mm)	5681	2986	8667	3899	58.2
9 (720 mm)	6126	2986	9112	3899	64.7
9 (750 mm)	6126	2986	9112	3899	64.7

P Free passage between the enginges, width 600 mm and height 2000 mm.
Q Min. distance between engines: 2900 mm (without gallery) and 3100 mm (with gallery)

* Depending on alternator
** Weight included a standard alternator

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

Capacities

5L27/38: 300 kW/cyl., 720 rpm, 6-9L27/38: 330 kW/cyl., 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				
Temperature basis:						
Setpoint HT cooling water engine outlet [1]	°C	79°C nominal *(Range of mech. thermostatic element 77-85°C)*				
Setpoint LT cooling water engine outlet [2]	°C	35°C nominal *(Range of mech. thermostatic element 29°-41°C)*				
Setpoint Lube oil inlet engine	°C	66°C nominal *(Range of mech. thermostatic element 63-72°C)*				
Number of cylinders		5	6	7	8	9
Engine output	kW	1500	1980	2310	2640	2970
Speed	rpm	720				
Heat to be dissipated [3]						
Cooling water (C.W.) Cylinder	kW	256	330	385	440	495
Charge air cooler; cooling water HT	kW	466	594	675	750	820
Charge air cooler; cooling water LT	kW	178	216	242	268	297
Lube oil (L.O.) cooler	kW	224	279	325	372	418
Heat radiation engine	kW	63	83	97	111	125
Flow rates [4]						
Internal (inside engine)						
HT circuit (cylinder + charge air cooler HT stage)	m3/h	58	58	58	58	58
LT circuit (lube oil + charge air cooler LT stage)	m3/h	58	58	58	58	58
Lube oil	m3/h	64	64	92	92	92
External (from engine to system)						
HT water flow (at 40°C inlet)	m3/h	16	20.2	23	25.5	28
LT water flow (at 38°C inlet)	m3/h	58	58	58	58	58
Air data						
Temperature of charge air at charge air cooler outlet	°C	50	53	55	56	57
Air flow rate	m^3/h [5]	9137	12061	14071	16082	18092
	kg/kWh	6.67	6.67	6.67	6.67	6.67
Charge air pressure	bar	4.01	4.01	4.01	4.01	4.01
Air required to dissipate heat radiation (eng.)(t_2-t_1= 10°C)	m^3/h	20414	26895	31431	35968	40504
Exhaust gas data [6]						
Volume flow (temperature turbocharger outlet)	m^3/h [7]	19203	25348	29572	33797	38021
Mass flow	t/h	10.3	13.6	15.9	18.1	20.4
Temperature at turbine outlet	°C	376	376	376	376	376
Heat content (190°C)	kW	575	759	886	1012	1139
Permissible exhaust back pressure	mbar	< 30	< 30	< 30	< 30	< 30
Pumps						
External pumps [8]						
Diesel oil pump (5 bar at fuel oil inlet A1)	m3/h	1.06	1.40	1.63	1.87	2.10
Fuel oil supply pump (4 bar discharge pressure)	m3/h	0.51	0.67	0.79	0.90	1.01
Fuel oil circulating pump (8 bar at fuel oil inlet A1)	m3/h	1.06	1.40	1.63	1.87	2.10
Starting air data						
Air consumption per start, incl. air for jet assist (IR/TDI)	Nm^3	2.5	2.9	3.3	3.8	4.3

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

D10050_1689471-7.3

Capacities

5L27/38: 320 kW/cyl., 750 rpm, 6-9L27/38: 330 kW/cyl., 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				
Temperature basis:						
Setpoint HT cooling water engine outlet [1]	°C	79°C nominal *(Range of mech. thermostatic element 77-85°C)*				
Setpoint LT cooling water engine outlet [2]	°C	35°C nominal *(Range of mech. thermostatic element 29°-41°C)*				
Setpoint Lube oil inlet engine	°C	66°C nominal *(Range of mech. thermostatic element 63-72°C)*				
Number of cylinders		5	6	7	8	9
Engine output	kW	1600	1980	2310	2640	2970
Speed	rpm	750				
Heat to be dissipated [3]						
Cooling water (C.W.) Cylinder	kW	263	330	385	440	495
Charge air cooler; cooling water HT	kW	488	587	666	741	811
Charge air cooler; cooling water LT	kW	194	225	252	280	307
Lube oil (L.O.) cooler	kW	230	279	325	372	418
Heat radiation engine	kW	67	83	97	111	125
Flow rates [4]						
Internal (inside engine)						
HT circuit (cylinder + charge air cooler HT stage)	m3/h	69	69	69	69	69
LT circuit (lube oil + charge air cooler LT stage)	m3/h	69	69	69	69	69
Lube oil	m3/h	66	66	96	96	96
External (from engine to system)						
HT water flow (at 40°C inlet)	m3/h	16.8	20.3	23	25.7	28.2
LT water flow (at 38°C inlet)	m3/h	69	69	69	69	69

5L27/38: 320 kW/cyl., 750 rpm, 6-9L27/38: 330 kW/cyl., 750 rpm							
Air data							
Temperature of charge air at charge air cooler outlet		°C	51	53	55	56	57
Air flow rate		m^3/h 5)	9951	12314	14367	16419	18472
		kg/kWh	6.81	6.81	6.81	6.81	6.81
Charge air pressure		bar	4.04	4.04	4.04	4.04	4.04
Air required to dissipate heat radiation (eng.)(t_2-t_1= 10°C)		m^3/h	21710	26895	31431	35968	40504
Exhaust gas data 6)							
Volume flow (temperature turbocharger outlet)		m^3/h 7)	20546	25426	29664	33901	38139
Mass flow		t/h	11.2	13.9	16.2	18.5	20.8
Temperature at turbine outlet		°C	365	365	365	365	365
Heat content (190°C)		kW	589	729	850	972	1093
Permissible exhaust back pressure		mbar	< 30	< 30	< 30	< 30	< 30
Pumps							
External pumps 8)							
Diesel oil pump	(5 bar at fuel oil inlet A1)	m3/h	1.13	1.40	1.63	1.87	2.10
Fuel oil supply pump	(4 bar discharge pressure)	m3/h	0.54	0.67	0.79	0.90	1.01
Fuel oil circulating pump	(8 bar at fuel oil inlet A1)	m3/h	1.13	1.40	1.63	1.87	2.10
Starting air data							
Air consumption per start, incl. air for jet assist (IR/TDI)		Nm^3	2.5	2.9	3.3	3.8	4.3

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

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L28/32H GenSet Data

Engine ratings

Engine type No of cylinders	720 rpm		750 rpm	
	720 rpm	Available turning direction	750 rpm	Available turning direction
	kW	CW [1]	kW	CW [1]
5L28/32H	1050	Yes	1100	Yes
6L28/32H	1260	Yes	1320	Yes
7L28/32H	1470	Yes	1540	Yes
8L28/32H	1680	Yes	1760	Yes
9L28/32H	1890	Yes	1980	Yes
[1] CW clockwise				

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General

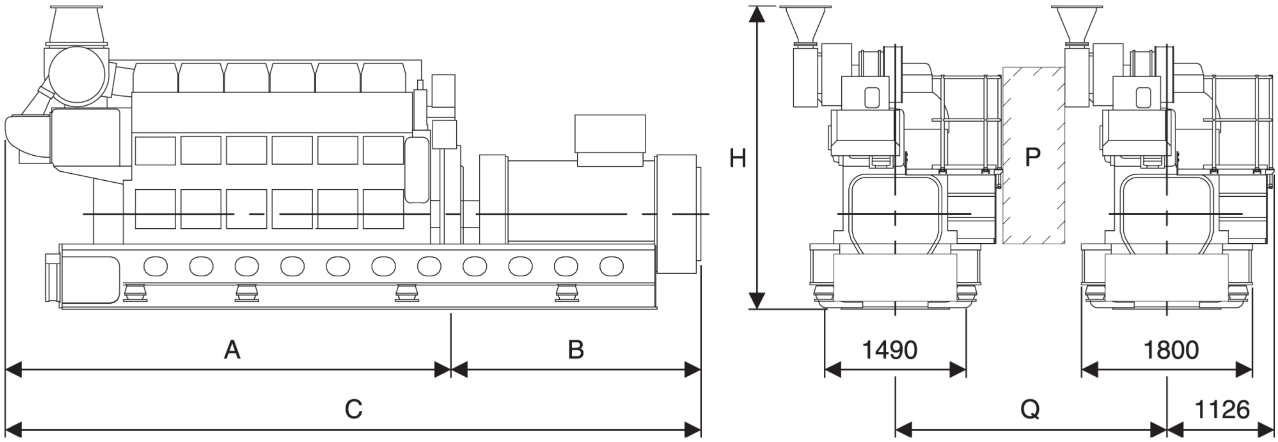

Fig. 4.10.01:

Cyl. no	A (mm)	* B (mm)	* C (mm)	H (mm)	** Dry weight GenSet (t)
5 (720 rpm)	4279	2400	6679	3184	32.6
5 (750 rpm)	4279	2400	6679	3184	32.3
6 (720 rpm)	4759	2510	7269	3184	36.3
6 (750 rpm)	4759	2510	7269	3184	36.3
7 (720 rpm)	5499	2680	8179	3374	39.4
7 (750 rpm)	5499	2680	8179	3374	39.4
8 (720 rpm)	5979	2770	8749	3374	40.7
8 (750 rpm)	5979	2770	8749	3374	40.6
9 (720 rpm)	6199	2690	8889	3534	47.1
9 (750 rpm)	6199	2690	8889	3534	47.1

P Free passage between the engines, width 600 mm and height 2000 mm.
Q Min. distance between engines: 2655 mm (without gallery) and 2850 mm (with gallery).

* Depending on alternator
** Weight included a standard alternator

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

Capacities

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	1050	1260	1470	1680	1890
Speed	rpm	720	720	720	720	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	0	0	0	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	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	51	52	51	52	53
Air flow rate	m^3/h 3)	7355	8826	10297	11768	13239
	kg/kWh	7.67	7.67	7.67	7.67	7.67
Charge air pressure	bar	2.97	2.97	2.97	2.97	2.97
Air required to dissipate heat radiation (engine) (t_2-t_1= 10°C)	m^3/h	8425	10045	11665	13609	15230
Exhaust gas data 4)						
Volume flow (temperature turbocharger outlet)	m^3/h 5)	14711	17653	20595	23537	26479
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	< 30	< 30	< 30	< 30
Starting air system						
Air consumption per start	Nm^3	2.5	2.5	2.5	2.5	2.5
Pumps						
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
External pumps 6)						
Diesel oil pump (4 bar at fuel oil inlet A1)	m^3/h	0.74	0.89	1.04	1.19	1.34
Fuel oil supply pump (4 bar discharge pressure)	m^3/h	0.36	0.43	0.50	0.57	0.64
Fuel oil circulating pump (8 bar at fuel oil inlet A1)	m^3/h	0.74	0.89	1.04	1.19	1.34
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

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Capacities

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	1100	1320	1540	1760	1980
Speed	rpm	750	750	750	750	750
Heat to be dissipated [1]						
Cooling water (C.W.) Cylinder	kW	245	294	343	392	442
Charge air cooler; cooling water HT (Single stage charge air cooler)	kW	0	0	0	0	0
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]	7826	9391	10956	12521	14087
	kg/kWh	7.79	7.79	7.79	7.79	7.79
Charge air pressure	bar	3.07	3.07	3.07	3.07	3.07
Air required to dissipate heat radiation (engine) (t_2-t_1= 10°C)	m^3/h	8749	10693	12313	14257	15878
Exhaust gas data [4]						
Volume flow (temperature turbocharger outlet)	m^3/h [5]	15520	18624	21728	24832	27936
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	< 30	< 30	< 30	< 30
Starting air system						
Air consumption per start	Nm^3	2.5	2.5	2.5	2.5	2.5

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

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Installation Aspects

5

Space Requirements and Overhaul Heights

The latest version of the Installation Drawings of this section is available for download at www.marine.man-es.com → 'Two-Stroke' → 'Installation Drawings'. Specify engine and accept the 'Conditions for use' before clicking on 'Download Drawings'.

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.

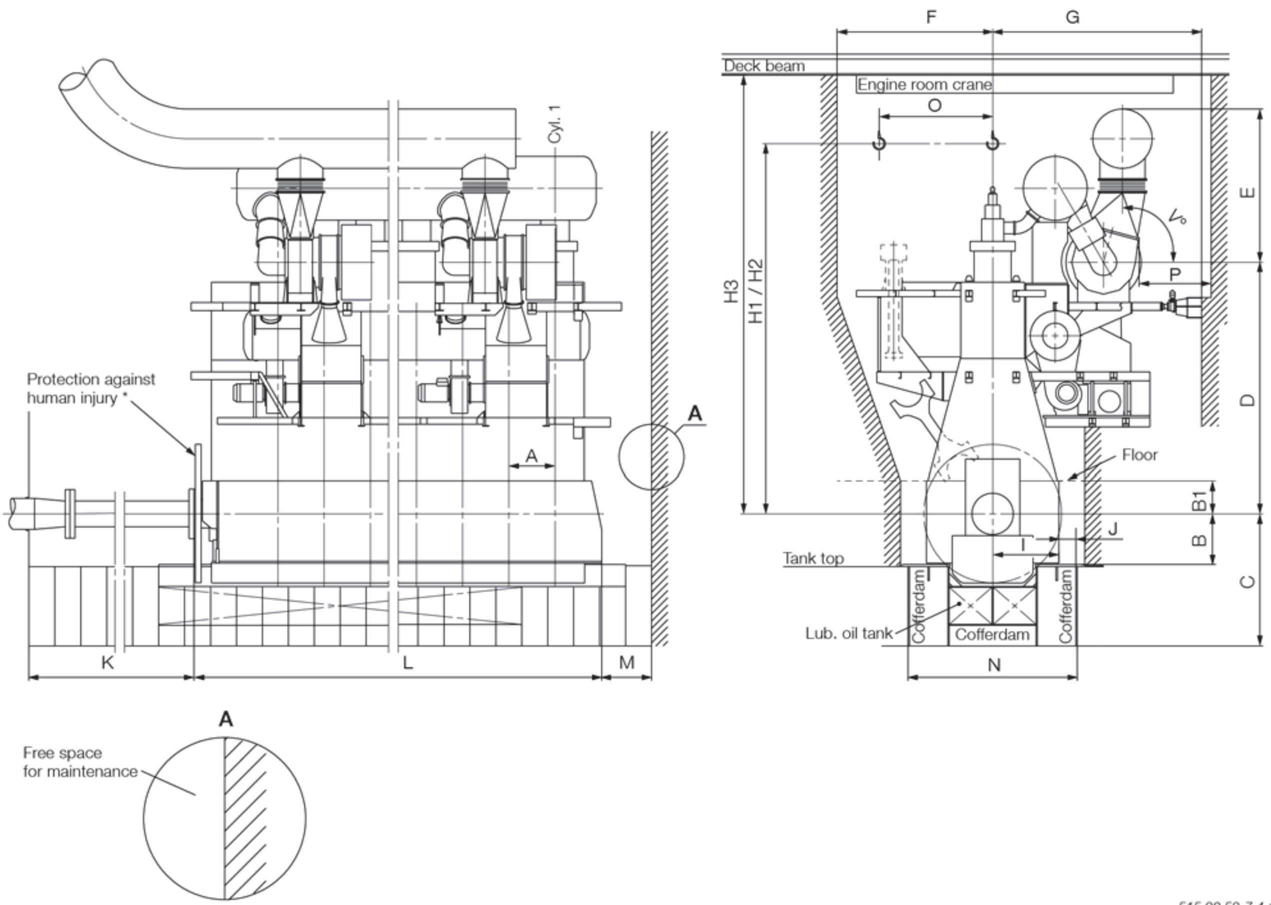
Please note that the distance 'E' in Fig. 5.02.01, given for a double-jib crane is from the centre of the crankshaft to the lower edge of the deck beam.

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.

Space Requirement



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

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

* To avoid human injury from rotating turning wheel, the turning wheel has to be shielded or access protected (Yard supply).

Fig. 5.02.01: Space requirement for the engine, turbochargers mounted on exhaust side, 4 59 122

<table>
<tr><td>Cyl. No.</td><td>5</td><td>6</td><td>7</td><td>8</td><td colspan="2"></td></tr>
<tr><td>A</td><td colspan="4">1,080</td><td colspan="2">Cylinder distance</td></tr>
<tr><td>B</td><td colspan="4">1,550</td><td colspan="2">Distance from crankshaft centre line to foundation</td></tr>
<tr><td>C</td><td>3,710</td><td>3,775</td><td>3,815</td><td>3,880</td><td colspan="2">The dimension includes a cofferdam of 600 mm and must fulfil minimum height to tank top according to classification rules</td></tr>
<tr><td rowspan="3">D *)</td><td>7,395</td><td>7,745</td><td>7,745</td><td>7,745</td><td>MAN TCA</td><td rowspan="3">Dimensions according to turbocharger choice at nominal MCR</td></tr>
<tr><td>7,330</td><td>7,330</td><td>-</td><td>-</td><td>ABB A-L</td></tr>
<tr><td>7,460</td><td>7,460</td><td>-</td><td>-</td><td>Mitsubishi MET</td></tr>
<tr><td rowspan="3">E *)</td><td>3,742</td><td>4,292</td><td>4,392</td><td>4,766</td><td>MAN TCA</td><td rowspan="3">Dimensions according to turbocharger choice at nominal MCR</td></tr>
<tr><td>3,817</td><td>4,222</td><td>4,433</td><td>4,633</td><td>ABB A-L</td></tr>
<tr><td>3,646</td><td>4,176</td><td>4,334</td><td>4,534</td><td>Mitsubishi MET</td></tr>
<tr><td>F</td><td colspan="4">See text</td><td colspan="2">See drawing: ‘Engine Top Bracing’, if top bracing fitted on camshaft side</td></tr>
<tr><td rowspan="3">G</td><td>5,075</td><td>5,275</td><td>5,275</td><td>-</td><td>MAN TCA</td><td rowspan="3">The required space to the engine room casing includes mechanical top bracing</td></tr>
<tr><td>5,275</td><td>5,275</td><td>-</td><td>-</td><td>ABB A-L</td></tr>
<tr><td>5,475</td><td>5,475</td><td>-</td><td>-</td><td>Mitsubishi MET</td></tr>
<tr><td>H1 *)</td><td colspan="4">12,175</td><td colspan="2">Minimum overhaul height, normal lifting procedure</td></tr>
<tr><td>H2 *)</td><td colspan="4">11,400</td><td colspan="2">Minimum overhaul height, reduced height lifting procedure</td></tr>
<tr><td>H3 *)</td><td colspan="4">11,075</td><td colspan="2">The minimum distance from crankshaft centre line to lower edge of deck beam, when using MAN B&W Double Jib Crane</td></tr>
<tr><td>I</td><td colspan="4">2,045</td><td colspan="2">Length from crankshaft centre line to outer side bedplate</td></tr>
<tr><td>J</td><td colspan="4">490</td><td colspan="2">Space for tightening control of holding down bolts</td></tr>
<tr><td>K</td><td colspan="4">See text</td><td colspan="2">K must be equal to or larger than the propeller shaft, if the propeller shaft is to be drawn into the engine room</td></tr>
</table>

Cyl. No.	5	6	7	8	
L *)	7,940	9,020	10,240	11,320	Minimum length of a basic engine, without 2nd order moment compensators.
M	≈ 800				Free space in front of engine
N	5,022				Distance between outer foundation girders
O	2,450				Minimum crane operation area
P	See text				See drawing: 'Crane beam for Turbocharger' for overhaul of turbocharger
V	0°, 15°, 30°, 45°, 60°, 75°, 90°				Maximum 30° when engine room has minimum headroom above the turbocharger

*) The min. engine room crane height is ie. dependent on the choice of crane, see the actual heights 'H1', 'H2' or 'H3'.

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

Max. length of engine see the engine outline drawing.

Length of engine with PTO see corresponding space requirement.

568 56 45-5.1.0

Table. 5.02.01: Space requirement for the engine

Crane beam for overhaul of turbocharger

If the travelling area of the engine room crane covers the recommended area in the Engine Room Crane drawing, Fig. 5.04.01, crane beams can be omitted for the overhaul of turbocharger. If not, a crane beam with trolleys is required at each end of the turbocharger(s).

Crane beam and trolleys

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

as indicated in Figs. 5.03.01a and 5.03.02.

Lifting capacity

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

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

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

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

The lifting capacity of the crane beam for the heaviest component 'W', is indicated in Fig. 5.03.01b for the various turbocharger makes and types.

The crane beam shall be dimensioned for lifting the weight 'W' with a deflection of some 5 mm only.

Relative position of the crane hook

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: 4 59 122, the letter 'a' indicates the distance between vertical centrelines of the engine and the turbocharger.

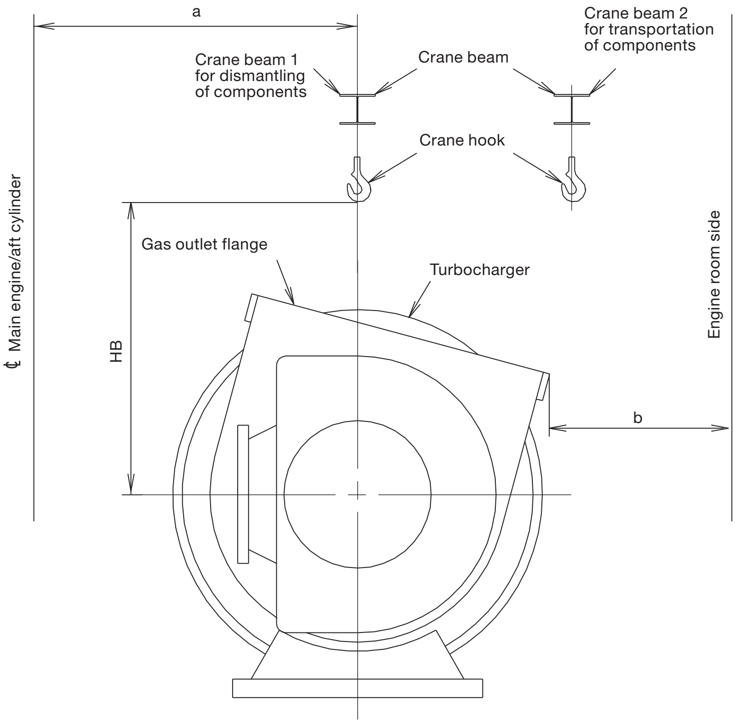

Fig. 5.03.01a: Required height and distance

MAN									
	Units	**TCR18**	**TCR20**	**TCR22**	**TCA44**	**TCA55**	**TCA66**	**TCA77**	**TCA88**
W	kg	1,500	1,500	1,500	1,000	1,000	1,200	2,000	3,080
HB	mm	760	1,000	1,200	1,200	1,384	1,608	1,700	2,040
b	m	500	500	500	500	600	700	800	1,000

ABB												
	Units	**A160-L**	**A165-L**	**A170-L**	**A175-L**	**A180-L**	**A185-L**	**A265-L**	**A270-L**	**A275-L**	**A280-L**	**A285-L**
W	kg	1,000	1,000	1,000	1,250	1,750	2,350	1,000	1,000	1,250	1,750	2,350
HB	mm	1,000	1,250	1,450	1,730	1,990	2,190	1,480	1,790	1,990	2,180	2,420
b	m	500	500	500	500	600	600	500	500	500	600	600

Mitsubishi (MHI)											
	Units	**MET33**	**MET37**	**MET42**	**MET48**	**MET53**	**MET60**	**MET66**	**MET71**	**MET83**	**MET90**
W	kg	1,000	1,000	1,000	1,000	1,000	1,000	1,500	1,800	2,700	3,500
HB	mm	1,500	1,500	1,500	1,500	1,500	1,600	1,800	1,800	2,000	2,200
b	m	600	600	600	700	700	700	800	800	1,000	1,000

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

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Fig. 5.03.01b: Required height, distance and weight

Crane beam for turbochargers

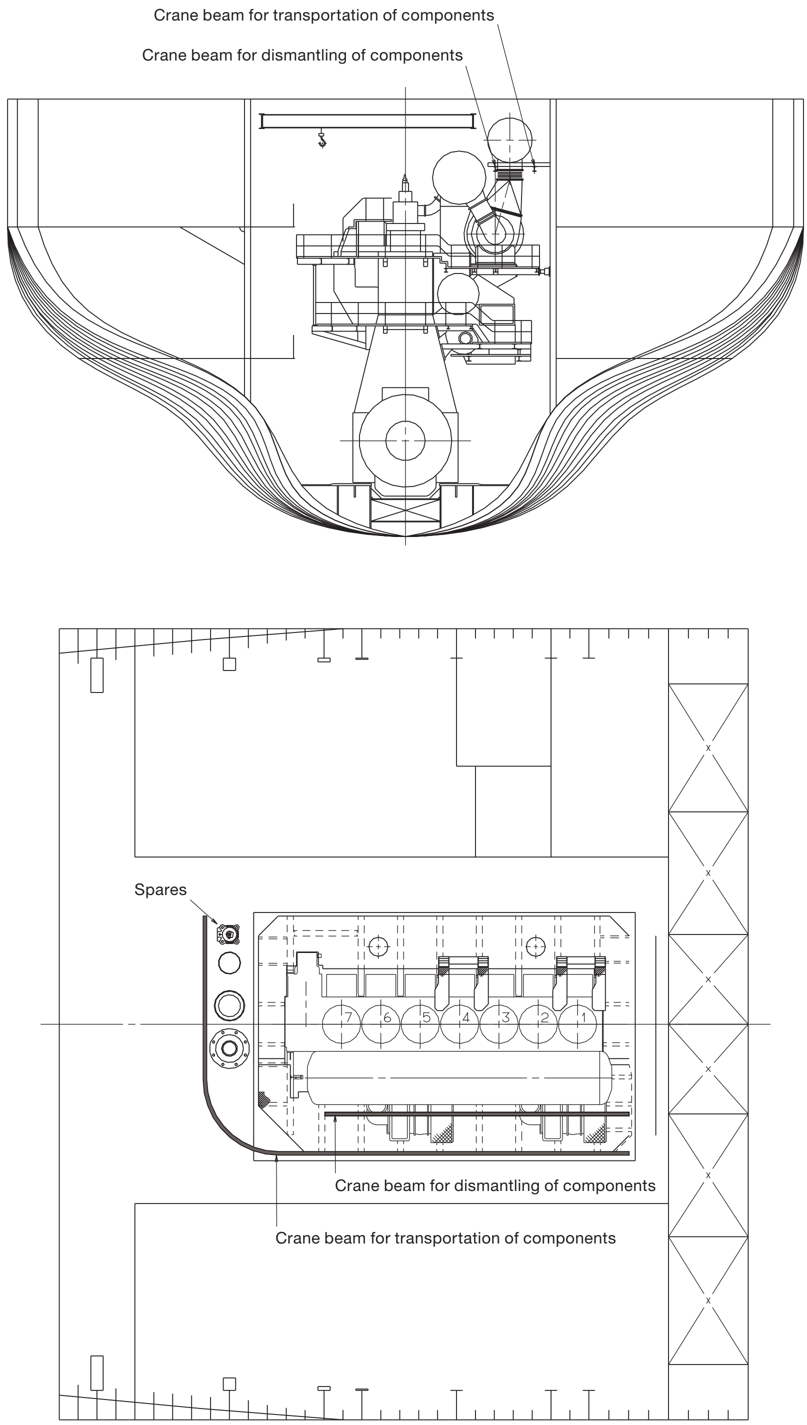

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Fig. 5.03.02: Crane beam for turbocharger

Crane beam for overhaul of air cooler, turbocharger on exhaust side

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.

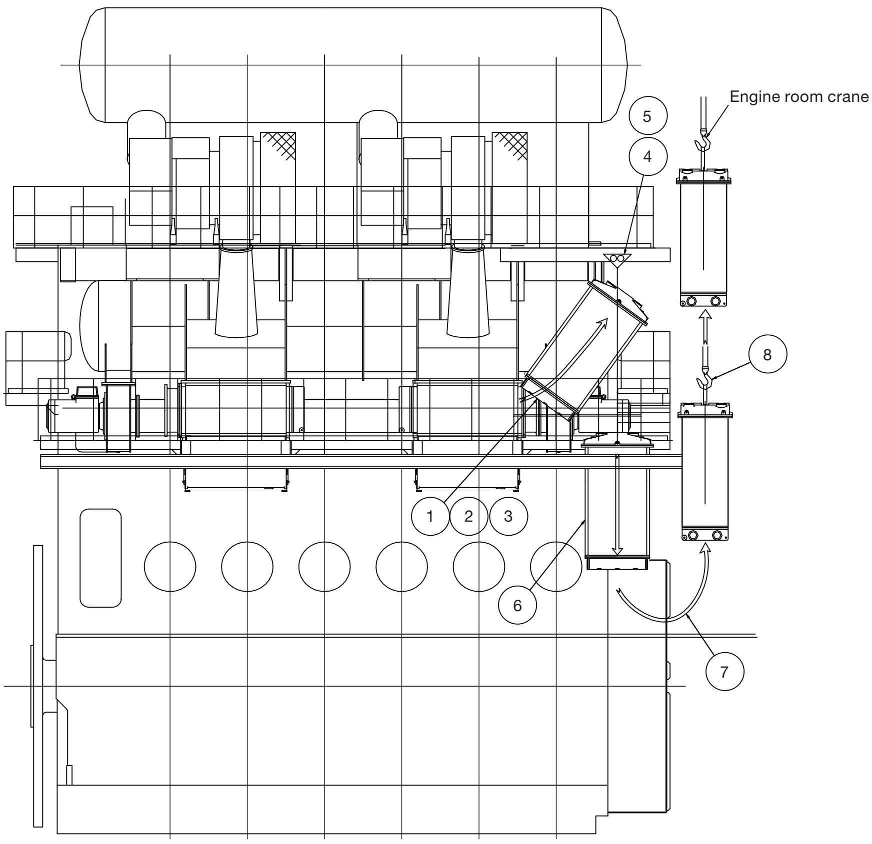

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Fig. 5.03.03: Crane beam for overhaul of air cooler, turbochargers located on exhaust side of the engine

Crane beam for overhaul of air cooler, turbocharger on aft end

This section is not applicable

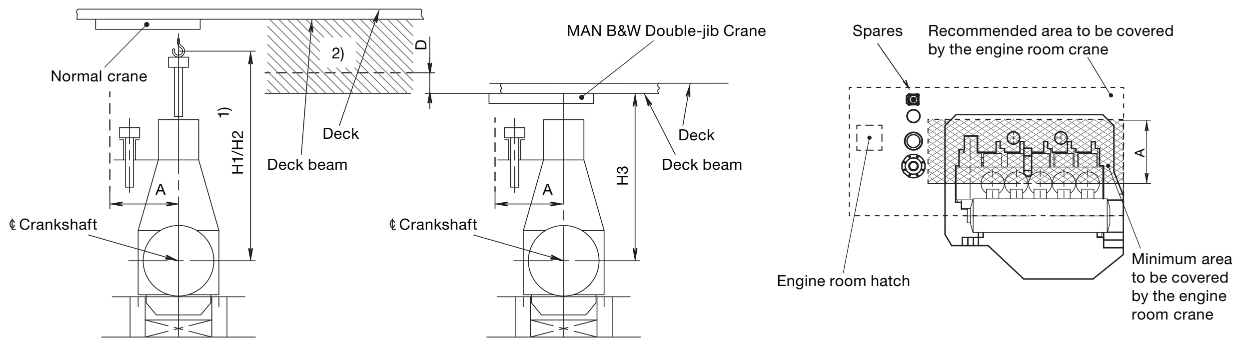
Engine room crane

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

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

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

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



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

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

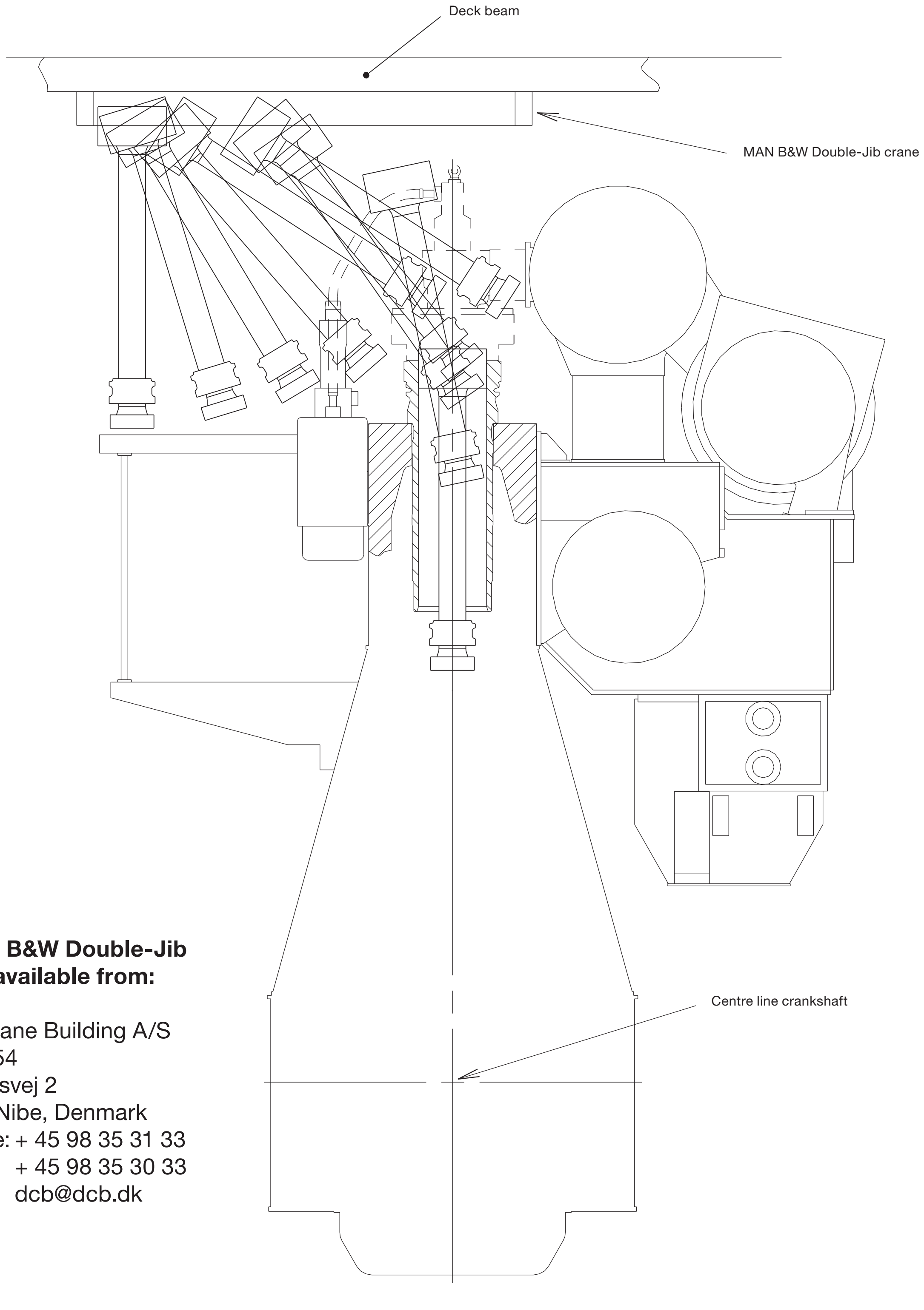
519 46 28-0.0.1

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
2,260	3,900	1,850	4.0	2x2.0	2,450	12,175	11,400	11,075	175

Fig. 5.04.01: Engine room crane

527 09 39-5.4.0

Overhaul with MAN B&W Double-Jib Crane



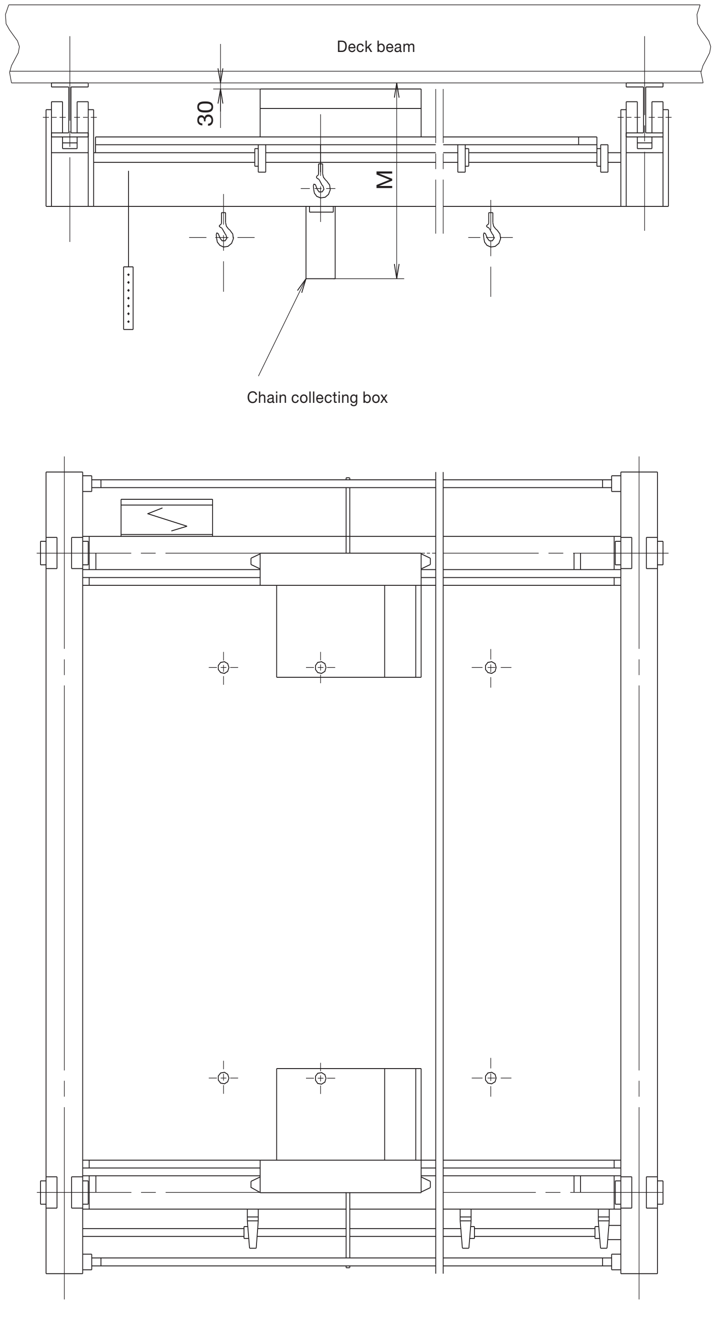
The MAN B&W Double-Jib crane is available from:

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.

Engine and Gallery Outline

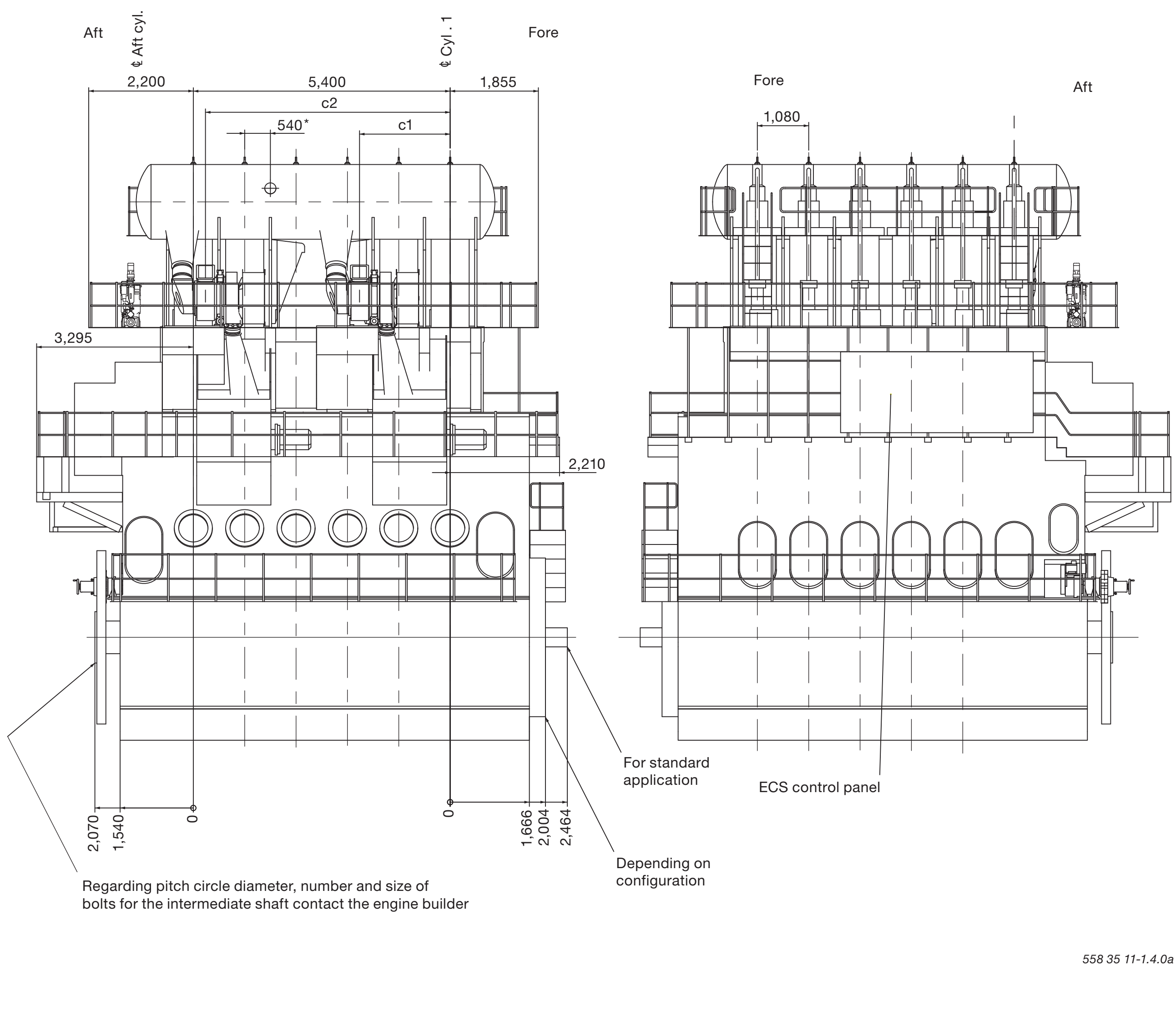
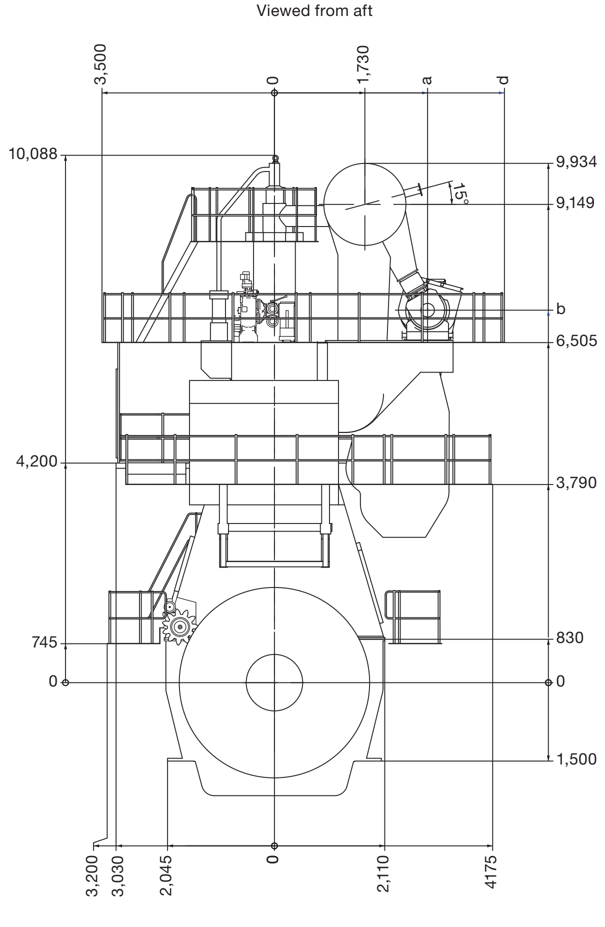


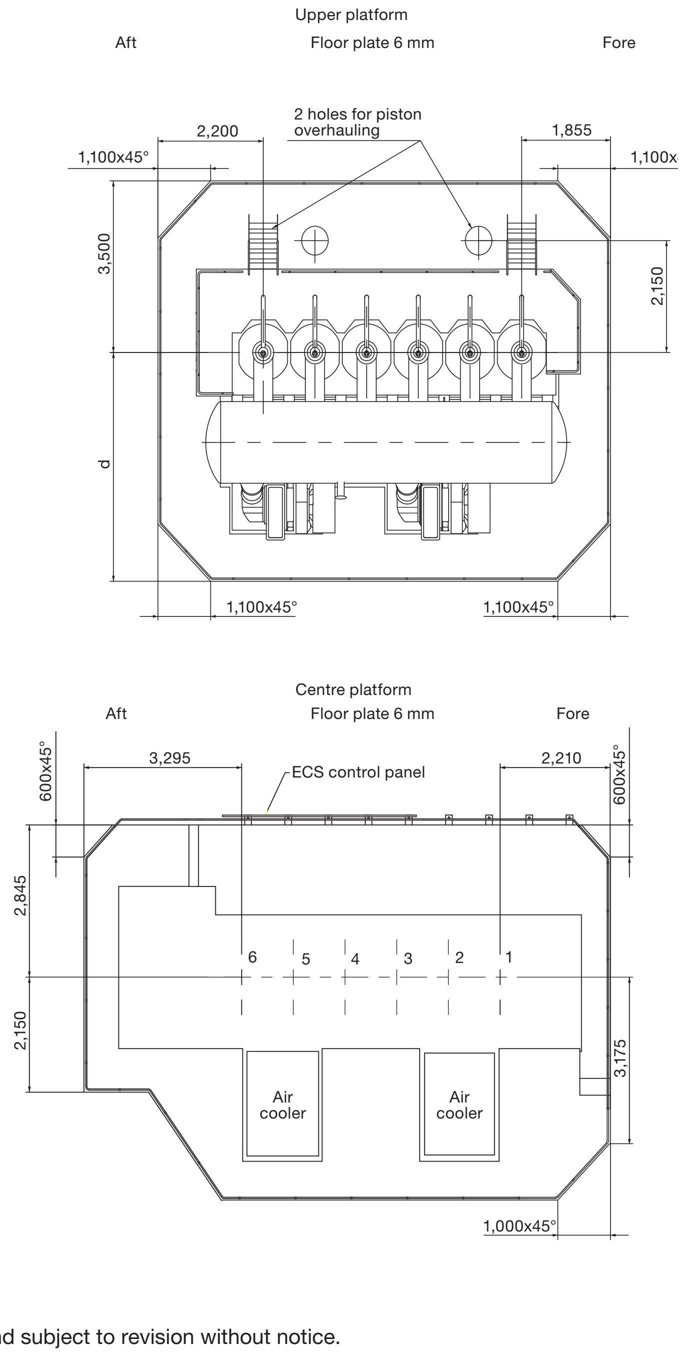
Fig. 5.06.01a: Gallery outline example: 6G60ME-C9 with two MET42MB turbochargers on exhaust side



TC type		a	b	c1	c2	d
MHI	MET42MB	2,930	7,125	1,905	5,145	4,400
	MET48MB	2,950	7,205	1,931	5,171	4,600

558 35 11-1.4.0b

Fig. 5.06.01b: Gallery outline example: 6G60ME-C9 with two MET42MB turbochargers on exhaust side



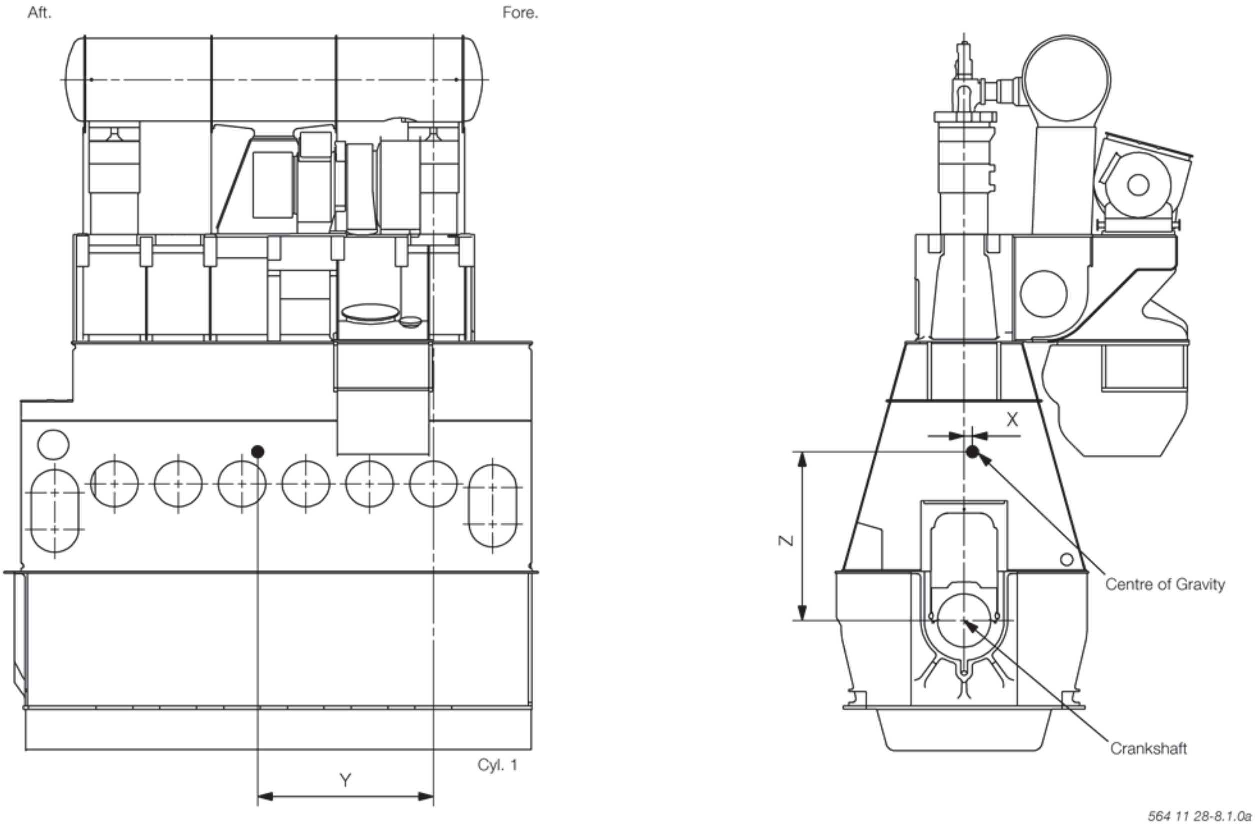
558 35 11-1.4.0c

The dimensions are in mm and subject to revision without notice.

Please note that the latest version of the dimensioned dr awing is available for download at www.marine.man-es.com → 'Two-Stroke' → 'Installation Drawings'. First choose engine series, then engine type and select 'Outline drawing' for the actual number of cylinders and type of turbocharger installation in the list of drawings available for download.

Fig. 5.06.01c: Gallery outline example: 6G60ME-C9 with two MET42MB turbochargers on exhaust side

Centre of Gravity



For engines with one turbocharger*						
No. of cylinders***	5		6		7	
	W	W/O	W	W/O	W	W/O
Distance X mm	155	Available on request	141	Available on request		
Distance Y mm	2,381		2,975			
Distance Z mm	2,850		2,857			
DMT**	393		446			

W With moment comensator fore end.

W/O Without moment comensator fore end.

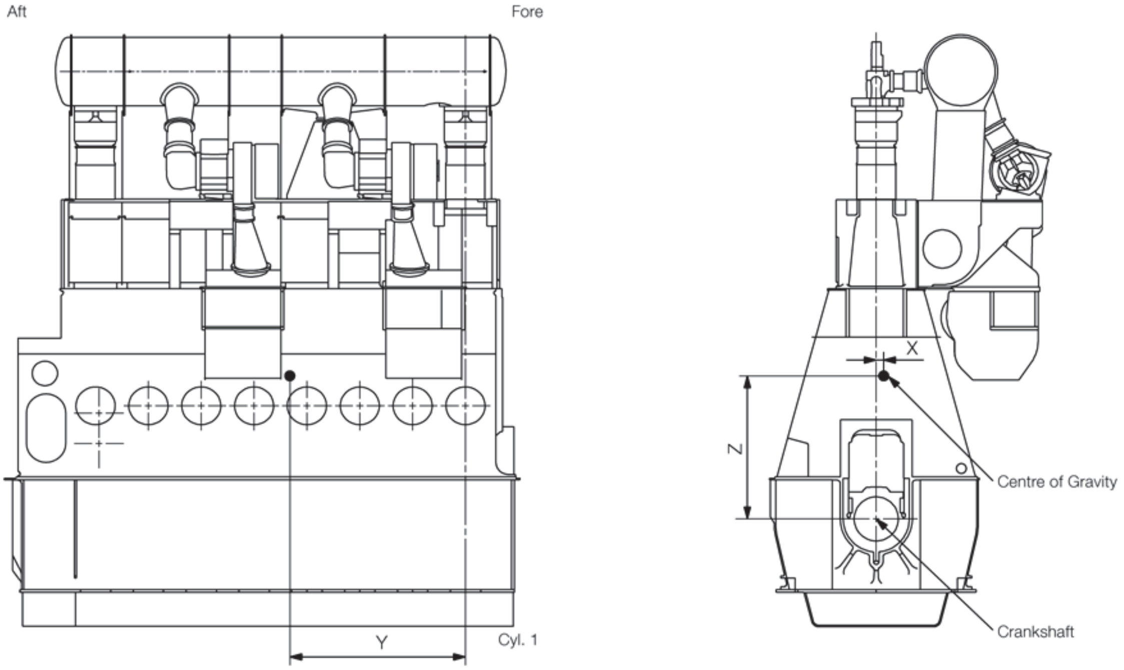
All values stated are approximate. For engine dry weights, see Dispatch pattern, Section 19.04.

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

** Dry Mass Tonnes

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

Fig. 5.07.01: Centre of gravity, G60ME-C9.5 with one turbocharger located on exhaust side



564 11 28-8.1.0b

For engines with two turbochargers*						
No. of cylinders***	6		7		8	
	W	W/O	W	W/O	W	W/O
Distance X mm	163	Available on request		152	Available on request	–140
Distance Y mm	3,033			3,590		4,105
Distance Z mm	2,879			2,925		2,940
DMT**	452			499		554

W With moment comensator fore end.
W/O Without moment comensator fore end.

All values stated are approximate. For engine dry weights, see Dispatch pattern, Section 19.04.

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

** Dry Mass Tonnes

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

Fig. 5.07.02: Centre of gravity, G60ME-C9.5 with two turbochargers located on exhaust side

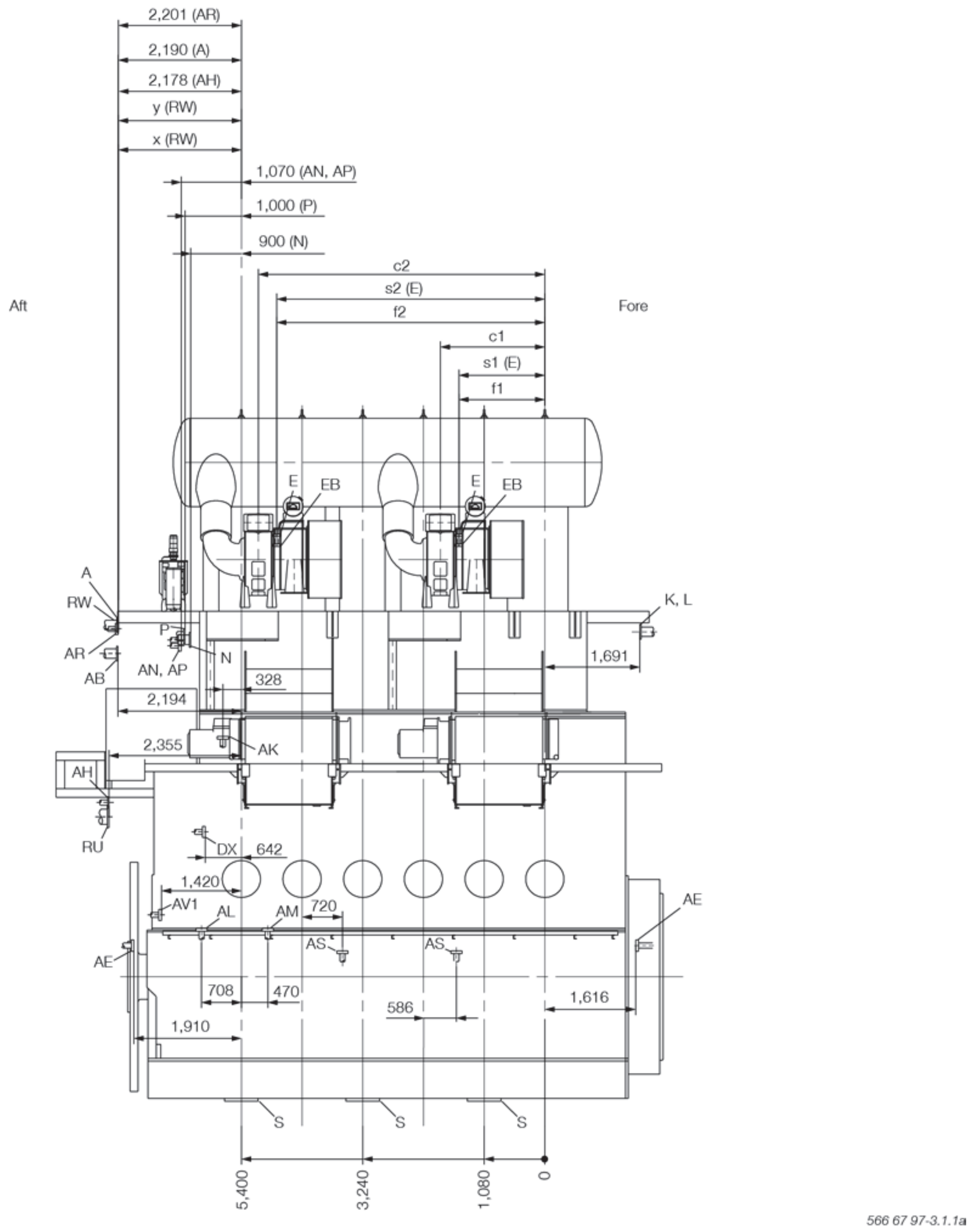
Mass of Water and Oil

No. of cylinders	Mass of water and oil in engine in service						
	Mass of water			Mass of oil			
	Jacket cooling water kg	Scavenge air cooling water kg	Total kg	Engine system kg	Oil pan kg	Hydraulic system kg	Total kg
5	1,003	458	1,461	968	732	845	2,545
6	1,249	470	1,719	1,157	878	1,015	3,050
7	1,421	482	1,903	1,346	1,024	1,184	3,554
8	1,594	494	2,088	1,535	1,171	1,353	4,059

568 20 84-2.0.0

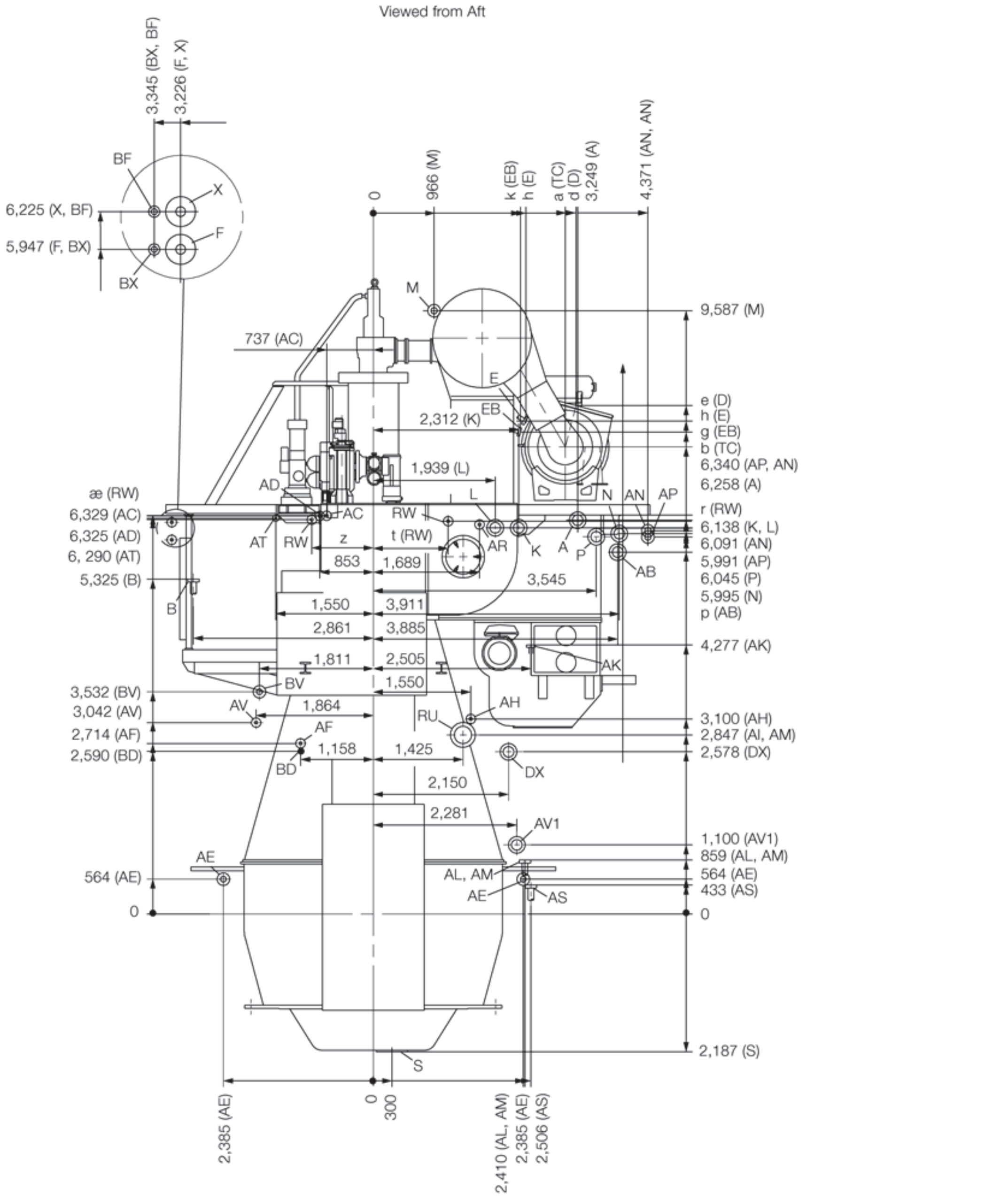
Fig. 5.08.01: Water and oil in engine

Engine Pipe Connections



The letters refer to list of 'Counterflanges', Fig. 5.10.01.

Fig. 5.09.01a: Engine Pipe Connections, 6G60ME-C9.5 with two turbochargers mounted on the exhaust side, connections K, L fore end



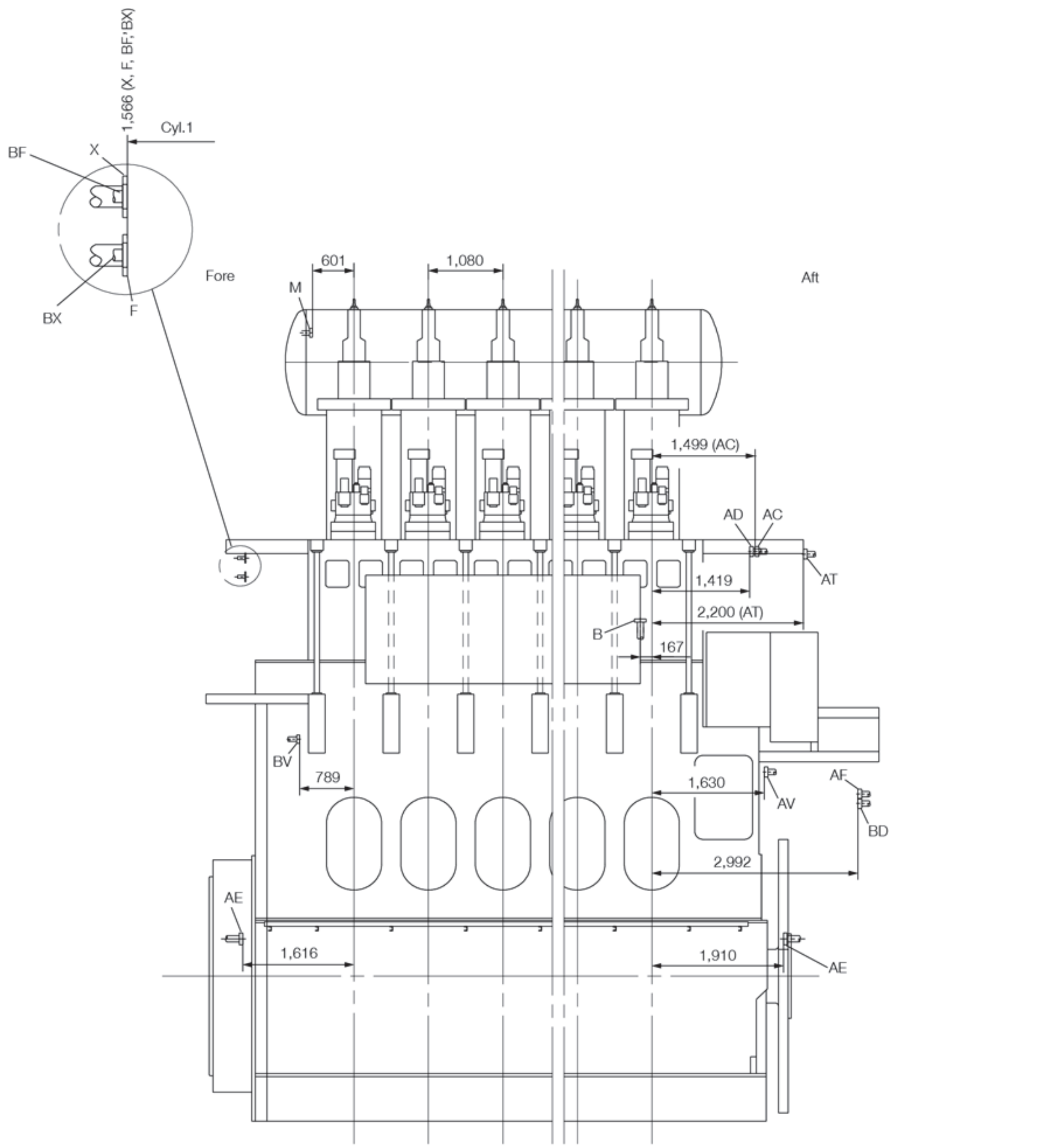
The letters refer to list of ‘Counterflanges’, Fig. 5.10.01.

Fig. 5.09.01b: Engine Pipe Connections, 6G60ME-C9.5 with two turbochargers mounted on the exhaust side, connections K, L fore end

TC Type	a	b	c1	c2	d	e	s1	s2	h	n	k	g	f1	f2
MAN														
TCA55	2,900	7,395	1,868	5,108	3,076	8,071	1,515	4,755	7,535	2,378	Not applicable			
TCA66	Available on request													
TCA77														
TCA88														
ABB														
Available on request														
MHI														
MET42MB	2,930	7,125	1,905	5,145	3,079	7,580	1,597	4,837	7,507	2,548	2,408	7,265	1,593	4,833
MET48MB	2,950	7,205	1,931	5,171	3,123	7,852	1,597	5,437	7,615	2,540	2,438	7,342	1,605	4,845
MET53	Available on request													
MET60														
MET66														
MET71 MET83														

Filter	r	t	x	œ	z	y
Boll & Kirch	6,242	4,270	2,185			
Kanagawa				6,267	978	2,012

Table 5.09.01: Engine Pipe Connections, 6G60ME-C9.5 with two turbochargers mounted on the exhaust side, connections K, L fore end



The letters refer to list of 'Counterflanges', Fig. 5.10.01. Some of the pipes can be connected fore or aft as shown and the engine builder has to be informed which end to be used.

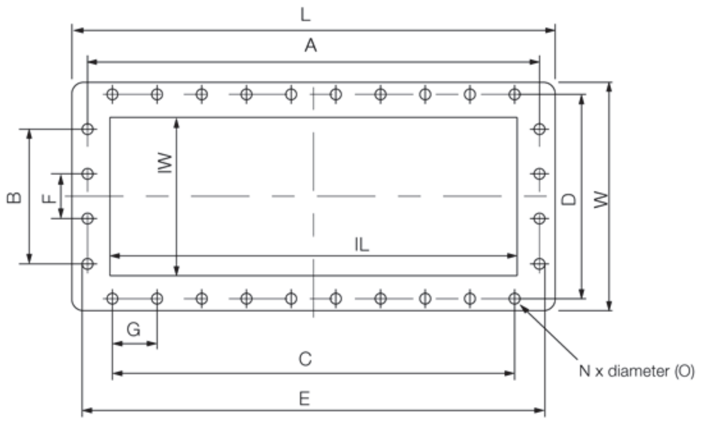
Please note that the latest version of the dimensioned drawing is available for download at www.marine.man-es.com→ 'Two-Stroke' → 'Installation Drawings'. First choose engine series, then engine type and select 'Outline drawing' for the actual number of cylinders and type of turbocharger installation in the list of drawings available for download.

For platform dimensions, see 'Gallery Outline'.

Fig. 5.09.01c: Engine Pipe Connections, 6G60ME-C9.5 with two turbochargers mounted on exhaust side, connection K, L fore end

Counterflanges, Connection D

MAN Type TCA44-88



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	2100	624	1,872	866	2,120	208	208	28	ø22

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	16	ø22
TCR22	703	487	650	20	ø22

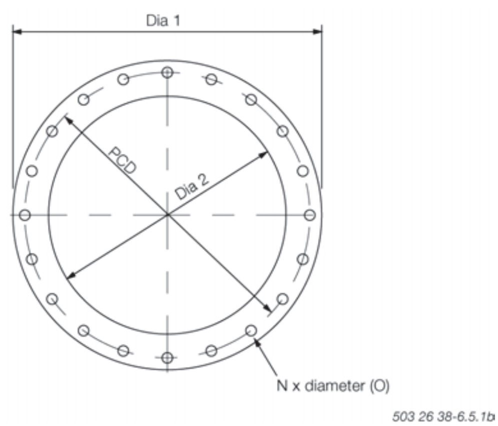
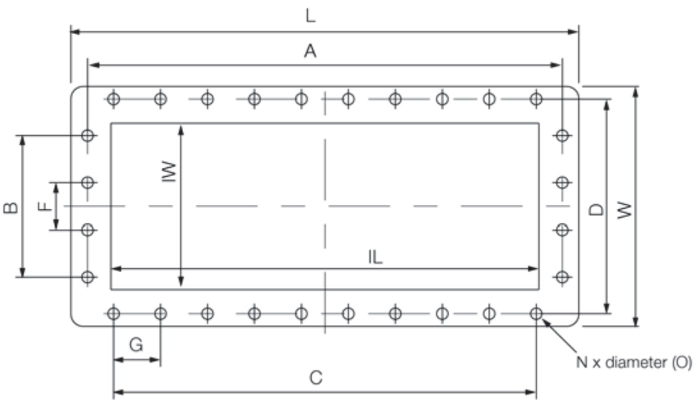


Fig. 5.10.01a and b: Turbocharger MAN TCA and TCR, exhaust outlet, connection D

ABB Type A100/A200-L

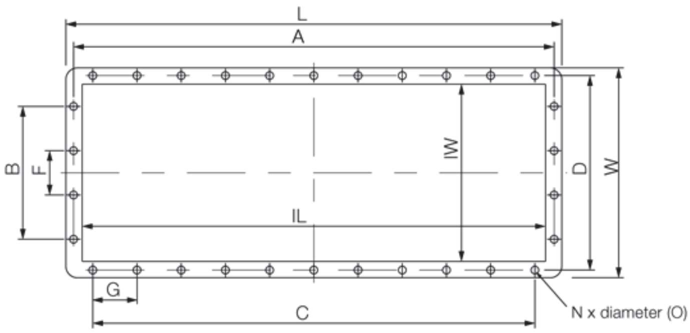


501 29 91-0.18.0b

Type A100/200-L series – Rectangular type												
TC	L	W	IL	IW	A	B	C	D	F	G	N	O
A160/A260-L	Available on request											
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	1,523	770	1,320	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

Fig. 5.10.01c: Turbocharger ABB A100/200-L, exhaust outlet, connection D

MHI Type MET



501 29 91-0.18.0a

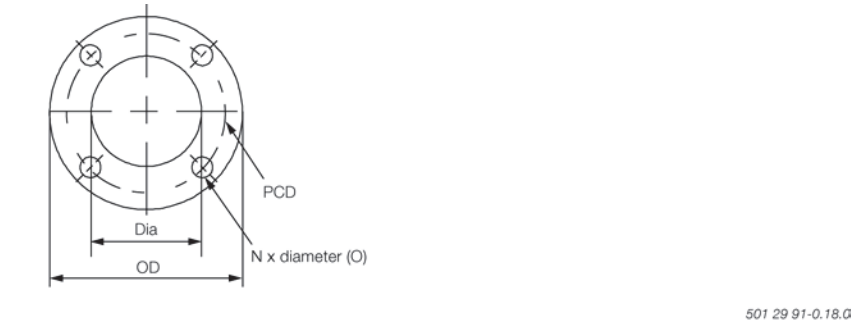
503 26 38-6.5.1a

Type MET – Rectangular type												
TC	L	W	IL	IW	A	B	C	D	F	G	N	O
Series MB												
MET33	Available on request											
MET42	1,094	381	1,004	291	1,061	261	950	351	87	95	30	ø15
MET48	1,240	430	1,140	330	1,206	300	1,070	396	100	107	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	2,318	525	2,100	741	175	175	34	ø24
Series MA												
MET33	700	310	605	222	670	180	550	280	90	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

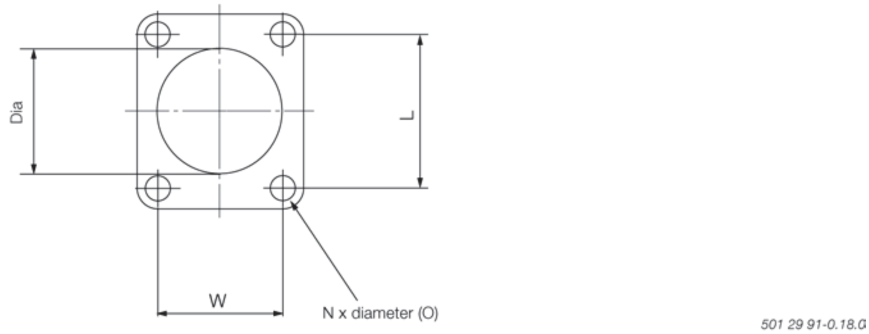
Fig. 5.10.01d: Turbocharger MHI MET MB and MA, exhaust outlet, connection D

Counterflanges, Connection E

MAN Type TCA

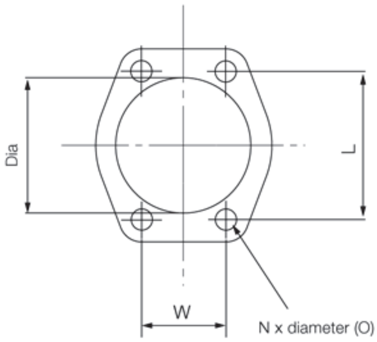


TC	Dia/ISO	Dia/JIS	OD	PCD	N	O	Thickness of flanges
TCA44	61	61	120	90	4	ø14	14



TC	Dia/ISO	Dia/JIS	L	W	N	O	Thickness of flanges
TCA55	61	61	86	76	4	ø14	16
TCA66	90	90	110	90	4	ø18	16

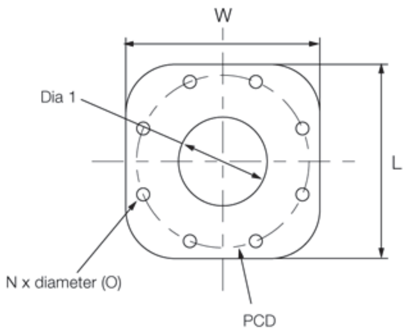
Fig. 5.10.01e and f: Turbocharger MAN TCA, venting of lube oil discharge pipe, connection E



TC	Dia/ISO	Dia/JIS	L	W	N	O	Thickness of flanges
TCA77	115	115	126	72	4	ø18	18
TCA88	141	141	150	86	4	ø18	18
TCA99	141	141	164	94	4	ø22	24

Fig. 5.10.01g: Turbocharger MAN TCA, venting of lube oil discharge pipe, connection E

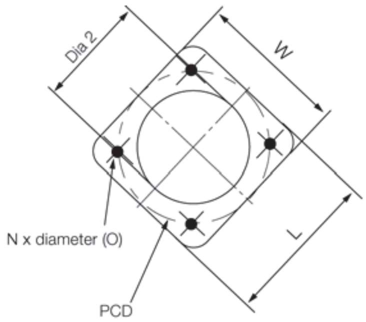
ABB Type A100/A200-L



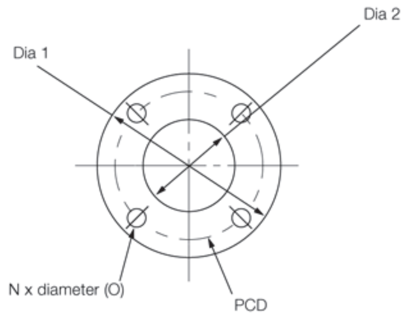
TC	Dia 1	PCD	L = W	N	O	Thickness of flanges
A160/A260-L	Available on request					
A165/A265-L	43	100	106	8	ø8.5	18
A170/A270-L	77	100	115	8	ø11	18
A175/A275-L	77	126	140	8	ø11	18
A180/A280-L	90	142	158	8	ø13	18
A185/A285-L	115	157	178	8	ø13	18
A190/A290-L	115	175	197	8	ø13	18

Fig. 5.10.01h: Turbocharger ABB A100/200-L, venting of lube oil discharge pipe, connection E

MHI Type MET MB



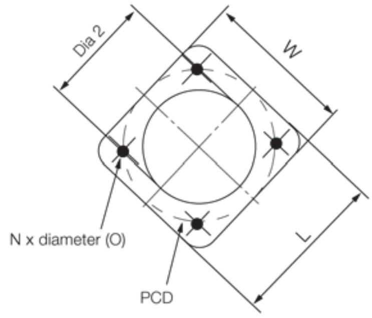
TC	L = W	Dia 2	PCD	N	O	Thickness of flanges (A)
MET33MB	Available on request					
MET42MB	105	61	105	4	ø14	14
MET48MB	125	77	130	4	ø14	14
MET53MB	125	77	130	4	ø14	14
MET60MB	140	90	145	4	ø18	14
MET66MB	140	90	145	4	ø18	14



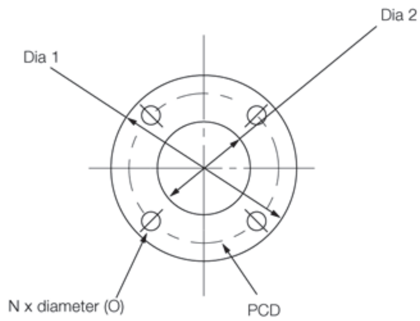
TC	Dia 1	Dia 2	PCD	N	O	Thickness of flanges (A)
MET71MB	180	90	145	4	ø18	14
MET83MB	200	115	165	4	ø18	16
MET90MB	200	115	165	4	ø18	16

Fig. 5.10.01i and j: Turbocharger MHI MET MB, venting of lube oil discharge pipe, connection E

MHI Type MET MA



TC	L = W	Dia 2	PCD	N	O	Thickness of flanges (A)
MET33MA	Available on request					
MET42MA	105	61	105	4	ø14	14
MET53MA	125	77	130	4	ø14	14
MET60MA	140	90	145	4	ø18	14
MET66MA	140	90	145	4	ø18	14
MET71MA	140	90	145	4	ø18	14
MET90MA	155	115	155	4	ø18	14

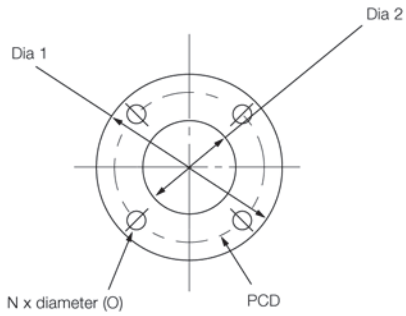


TC	Dia 1	Dia 2	PCD	N	O	Thickness of flanges (A)
MET83MA	180	90	145	4	ø18	148

Fig. 5.10.01k and l: Turbocharger MHI MET MA, venting of lube oil discharge pipe, connection E

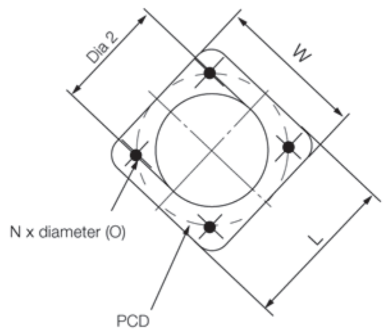
Counterflanges, connection EB

MHI Type MET MB



501 29 91-0.18.0

TC	Dia1	Dia 2	PCD	N	O	Thickness of flanges (A)
MET42MB	95	43	75	4	ø12	10
MET60MB	120	49	95	4	ø14	12
MET66MB	120	49	95	4	ø14	12
MET71MB	120	49	95	4	ø14	12
MET83MB	120	49	95	4	ø14	12



501 29 91-0.18.0

TC	L = W	Dia 2	PCD	N	O	Thickness of flanges (A)
MET48MB	95	49	95	4	ø14	12
MET53MB	95	49	95	4	ø14	12
MET90MB	125	77	130	4	ø14	14

501 29 91-0.18.0c

198 70 27-3.5

Fig. 5.10.01m and n: Turbocharger MHI MB, cooling air, connection EB

Engine Seating and Holding Down Bolts

The latest version of the Installation Drawings of this section is available for download at www.marine.man-es.com→'Two-Stroke' →Installation Drawings'. Specify engine and accept the 'Conditions for use' before clicking on 'Download Drawings'.

Engine seating and arrangement of holding down bolts

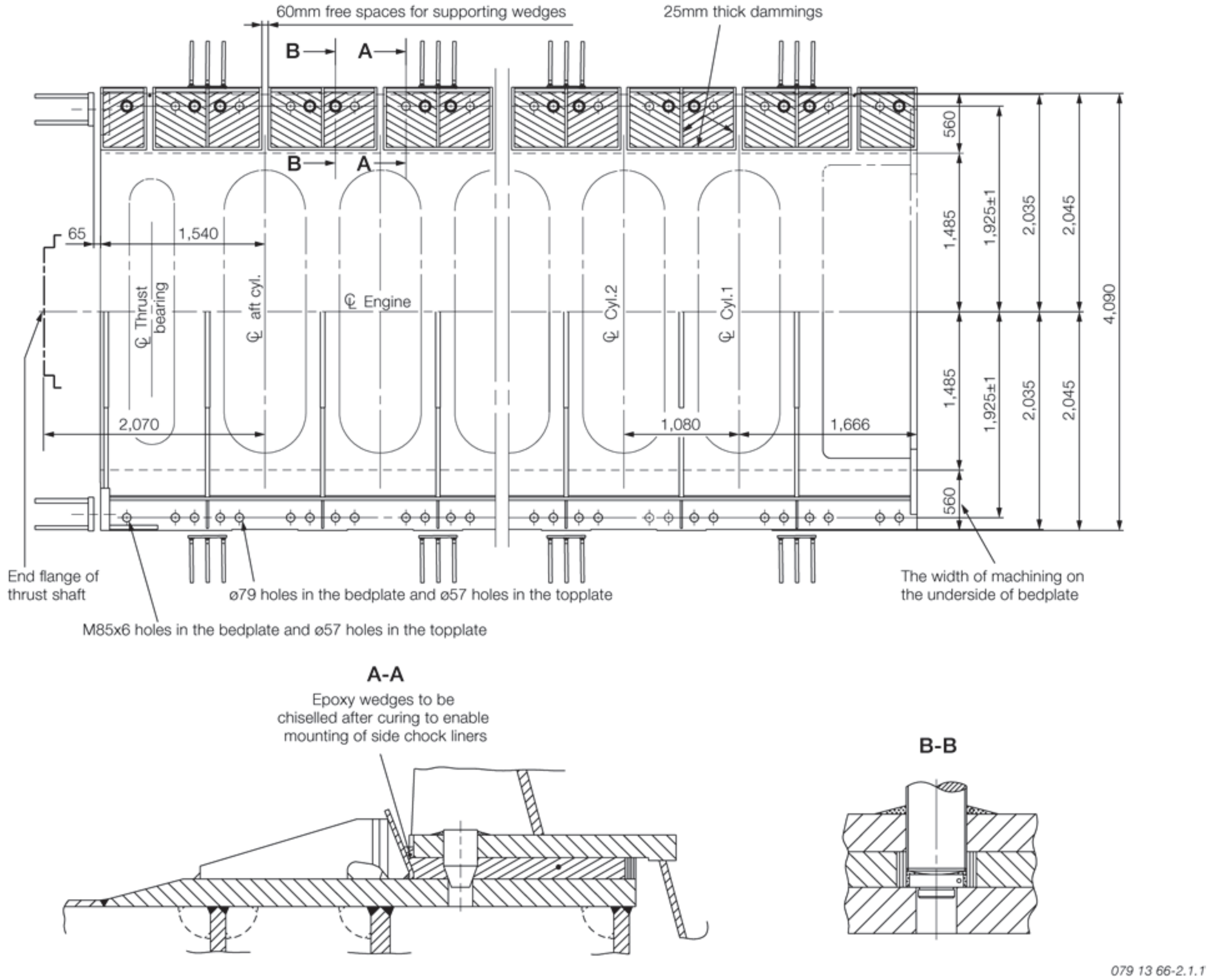
The dimensions of the seating stated in Figs. 5.12.01 and 5.12.02 are for guidance only.

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 Energy Solutions are:

- 'Chockfast Orange PR 610 TCF' and 'Epocast 36' from ITW Philadelphia Resins Corporation, USA.
- 'Durasin' from Daemmstoff Industrie Korea Ltd.
- 'EPY' from Marine Service Jaroszewicz S.C., Poland.
- 'Loctite Fixmaster Marine Chocking', Henkel.
- 'CMP Liner Blue' from Chugoku Marine Paints Ltd, Japan.

Epoxy Chocks Arrangement



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

Preparing holes for holding down bolts

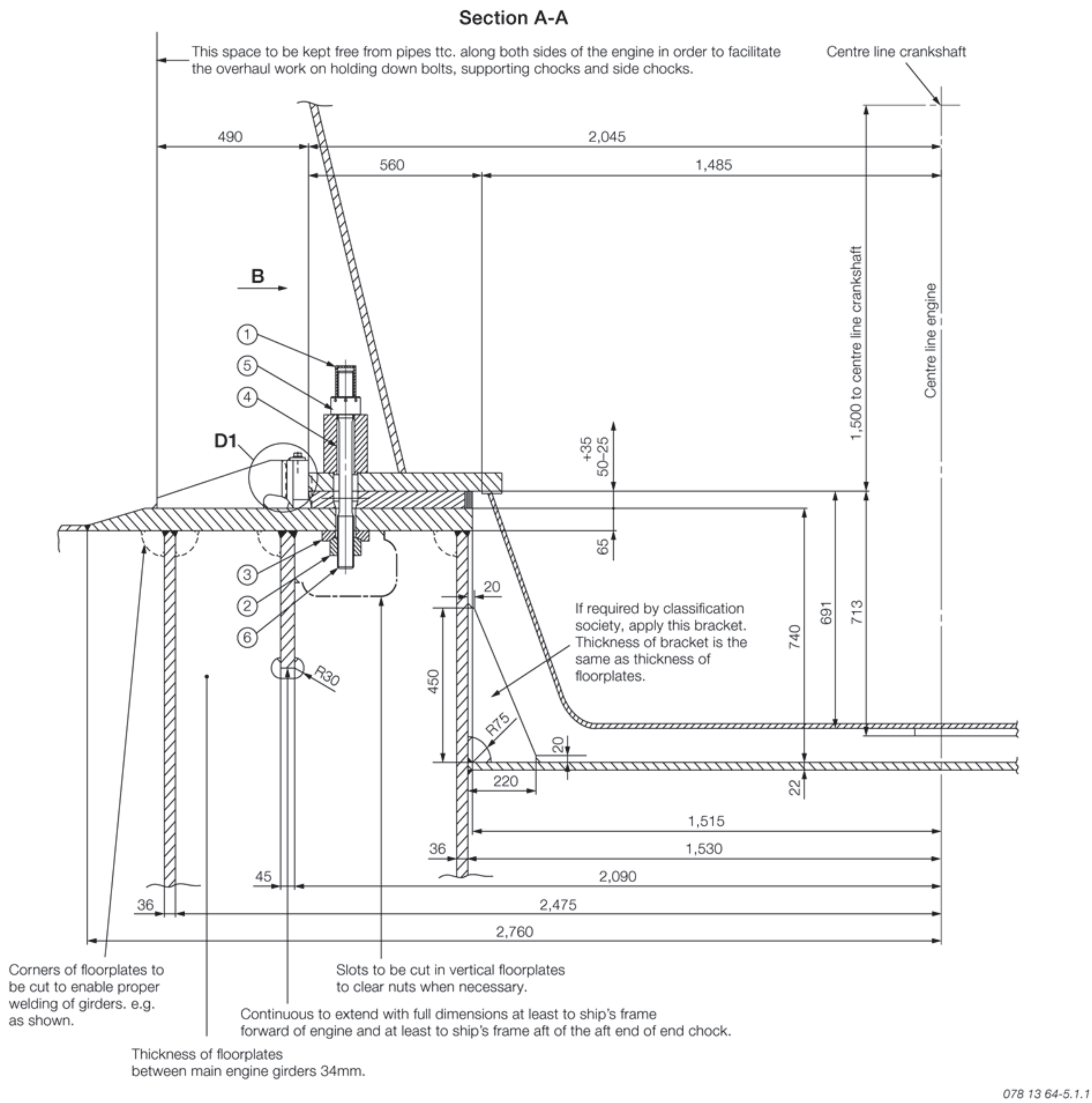
1) The engine builder drills the holes for holding down bolts in the bedplate while observing the toleranced locations indicated on MAN Energy Solutions' drawings for machining the bedplate

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

3) The holding down bolts must be made in accordance with MAN Energy Solutions' drawings of these bolts.

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

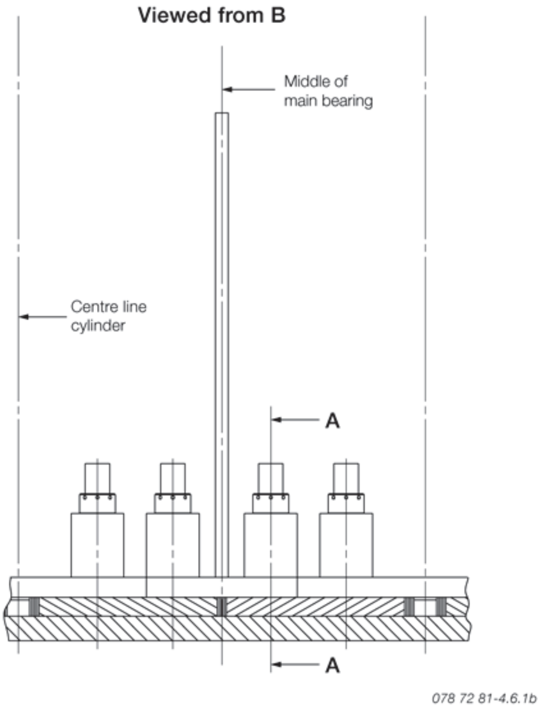
Engine Seating Profile



Holding down bolts, option: 4 82 602 include:

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

Fig.5.12.02a: Profile of engine seating



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

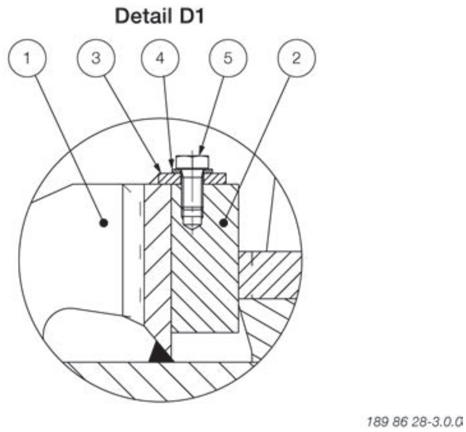
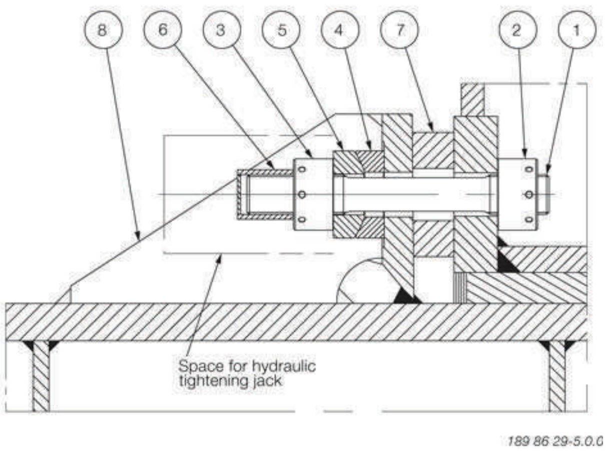


Fig. 5.12.02b: Profile of engine seating, side view, side chocks, option: 4 82 620



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

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 Energy Solutions 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 system is installed either as a mechanical top bracing (typically on smaller engine types) or a hydraulic top bracing (typically on larger engine types). Both systems are described below.

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

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 Energy Solutions instructions.

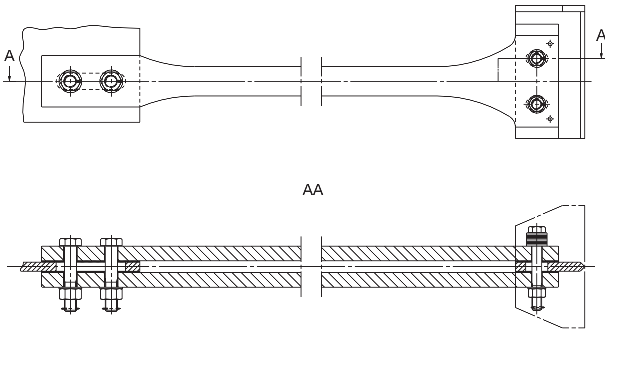


Fig. 5.13.01: Mechanical top bracing stiffener. Option: 4 83 112

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.

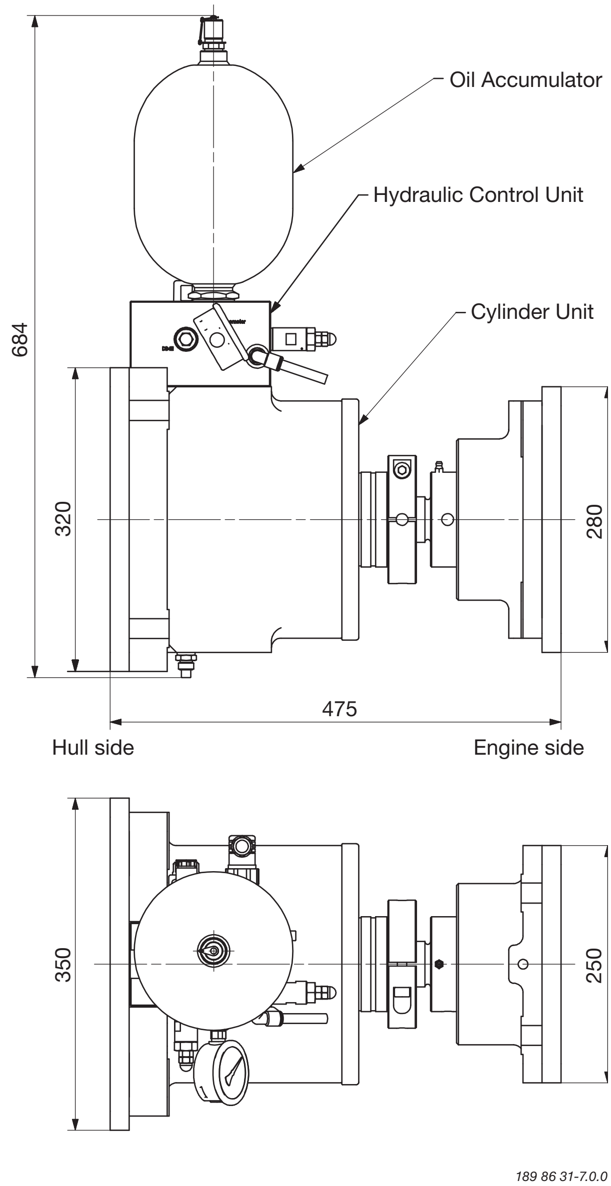
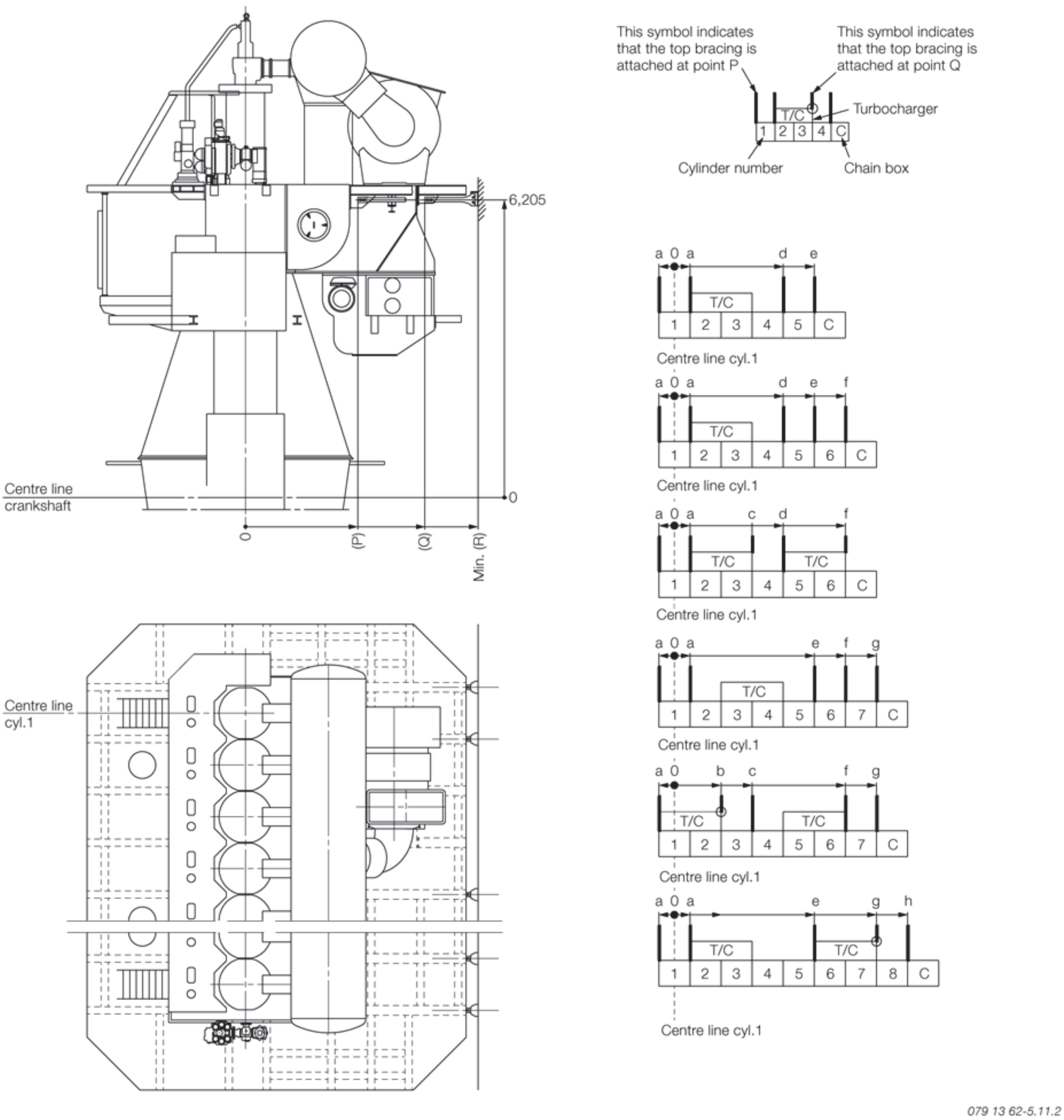


Fig. 5.13.02: Outline of a hydraulic top bracing unit. The unit is installed with the oil accumulator pointing either up or down. Option: 4 83 123

Mechanical Top Bracing



Horisontal distance (mm) between top bracing fix point and centre line cyl. 1:

a =	540	e =	4,860
b =	1,620	f =	5,940
c =	2,700	g =	7,020
d =	3,780	h =	8,100

Fig. 5.14.01: Mechanical top bracing arrangement with turbocharger(s) mounted on the exhaust side

Turbocharger		P	Q	R
MAN	TCA55	2,343	3,739	4,650
	TCA66	2,343	3,739	4,850
	TCA77	2,343	3,939	5,050
ABB	A165-L	2,343	3,579	4,650
	A170-L	2,343	3,739	4,850
	A175-L	2,343	3,939	5,050
	A270-L	2,343	3,769	4,850
MHI	MET42	2,343	3,579	5,050
	MET48	2,343	3,679	4,850
	MET60	2,343	3,769	4,850
	MET66	2,343	4,086	5,250

Table 5.14.01: Mechanical top bracing arrangement with turbocharger(s) mounted on the exhaust side

Horisontal vibrations on the upper part of the 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 the X-moment is the major excitation source.

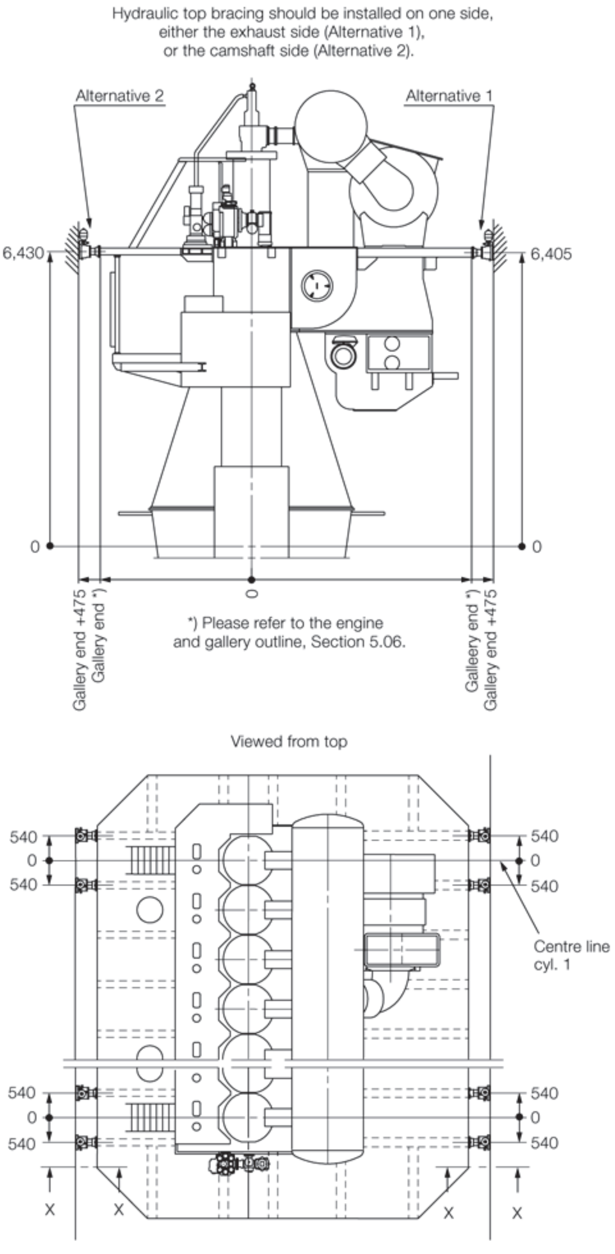
For engines with vibrations excited by the X-moment, bracings at the centre of the engine are of only minor importance..

Top bracings should only be installed on one side, either the exhaust side or the manoeuvring side. If the top bracing has to be installed on the manoeuvring side, please contact MAN Energy Solutions.

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

The complete arrangement to be delivered by the shipyard.

Hydraulic Top Bracing Arrangement



Note: All dimensions are in mm

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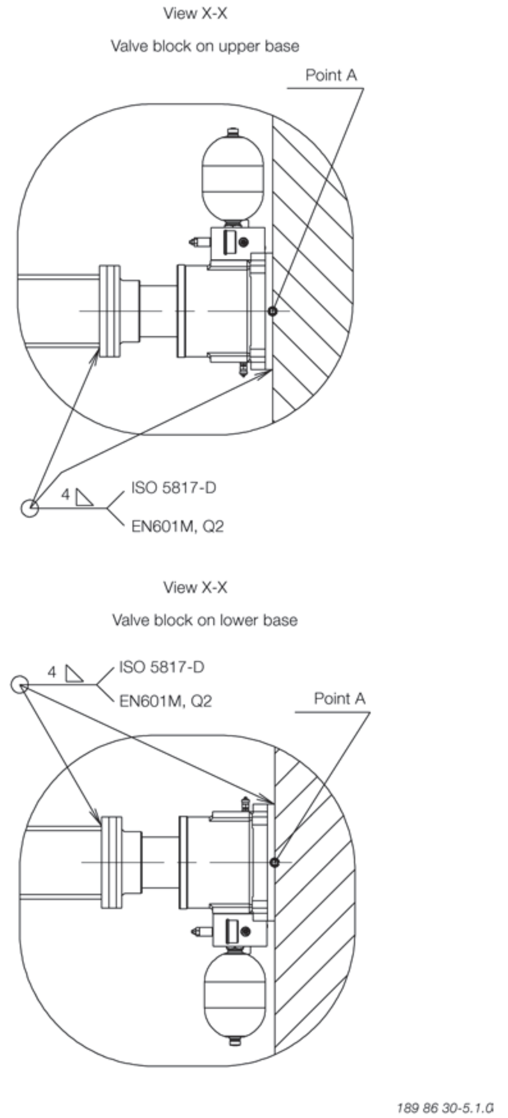
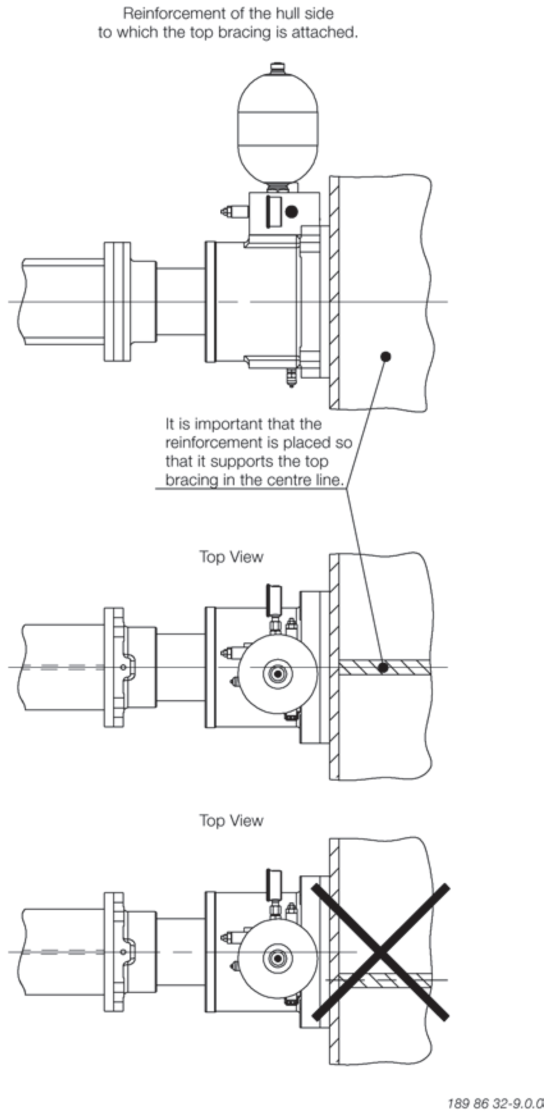
Fig. 5.15.01: Hydraulic top bracing data, turbocharger(s) mounted on the exhaust side





As the rigidity of the casing structure to which the top bracing is attached is most important, it is recommended that the top bracing is attached directly into a deck.

Required rigidity of the casing side point A:

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

Max. corresponding deflection
of casing side: 0.51 mm

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

Max. corresponding deflection
of casing side: 2.00 mm

Fig. 5.15.02: Hydraulic top bracing data

Components for Engine Control System

Installation of ECS in the Engine Control Room

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

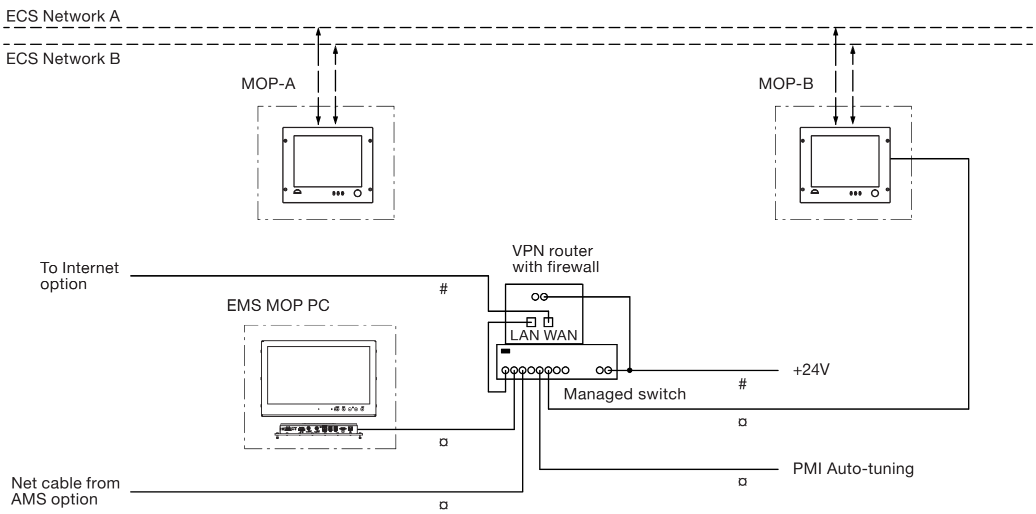
- 2 pcs EICU (Engine Interface Control Unit)
  (1 pcs only for ME-B engines)
- 1 pcs ECS MOP-A (Main Operating Panel)
  EC-MOP with touch display, 15”
- 1 pcs ECS MOP-B
  EC-MOP with touch display, 15”
- 1 pcs EMS MOP with system software
  Display, 24” marine monitor
  PC unit
- 1 pcs Managed switch 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 EMS MOP PC, the operator can view the status and operating history of both the ECS and the engine, EMS is decribed in Section 18.01.

The PMI Auto-tuning application is run on the EMS MOP PC. PMI Auto-tuning is used to optimize the combustion process with minimal operator attendance and improve the efficiency of the engine. See Section 18.01.

CoCoS-EDS ME Basic is included as an application in the Engine Management Services as part of the standard software package installed on the EMS MOP PC. See Section 18.01.



Abbreviations:
AMS: Alarm Monitoring Systems
EICU: Engine Interface Control Unit
EMS: Engine Management Services
MOP: Main Operating Panel

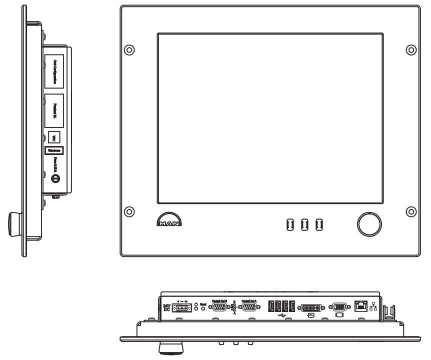
Yard Supply

¤ Ethernet, 10 m patch cable supplied with switch. Type: RJ45, STP (Shielded Twisted Pair), CAT 5.
In case 10 m cable is not enough, this becomes Yard supply.

078 74 78-1.5.3b

Fig. 5.16.01 Network and PC components for the ME/ME-B Engine Control System

EC-MOP
- Integrated PC unit and touch display, 15”
  - Direct dimming control (0-100%)
  - USB connections at front
  - IP20 resistant front
  - Dual Arcnet



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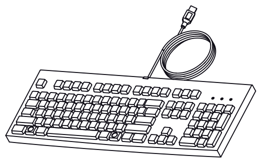
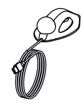
Pointing device
- Keyboard model
  - UK version, 104 keys
  - USB connection
- Trackball mouse
  - USB connection





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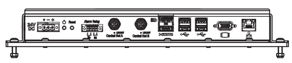
EMS MOP PC
- Standard industry PC with MS Windows operating system, UK version



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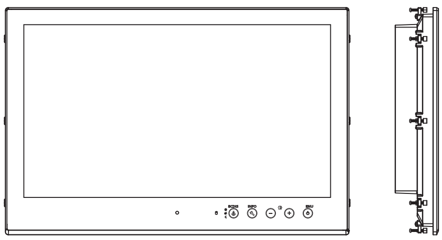
Marine monitor for EMS MOP PC
- LCD (MVA) monitor 24”
  - Projected capacitive touch
  - Resolution 1,920x1,080, WSXGA+
  - Direct dimming control (0-100%)
  - IP54 resistant front
  - For mounting in panel
- Bracket for optional mounting on desktop, with hinges (5° tilt, adjustable 95°) or without hinges (10° tilt, not adjustable)



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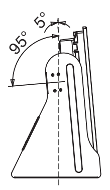

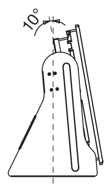

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Network components
- Managed switch and VPN router with firewall

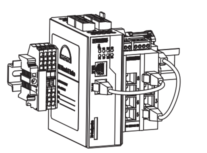

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Fig. 5.16.02 MOP PC equipment for the ME/ME-B Engine Control System

EICU Cabinet

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

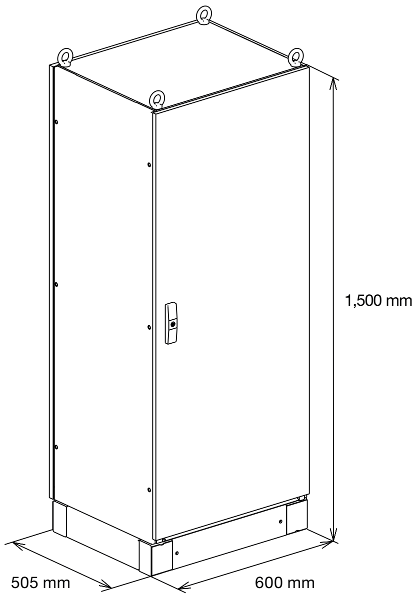

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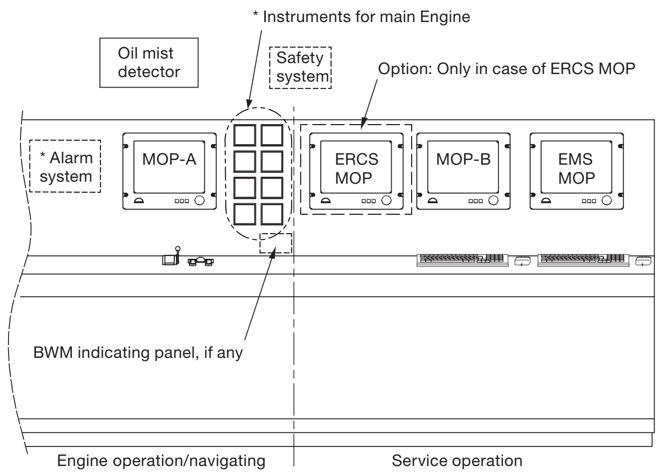
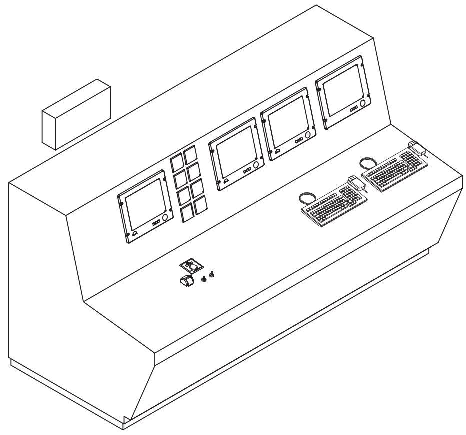
Fig. 5.16.03: The network printer and EICU cabinet unit for the ME Engine Control System

Engine control room console

- Recommended outline of Engine Control Room console with ME equipment





*Yard supply

Oil mist detector equipment depending on supplier/maker
BWM: Bearing Wear Monitoring

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Fig. 5.16.04: Example of Engine Control Room console

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 mm^2. 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.

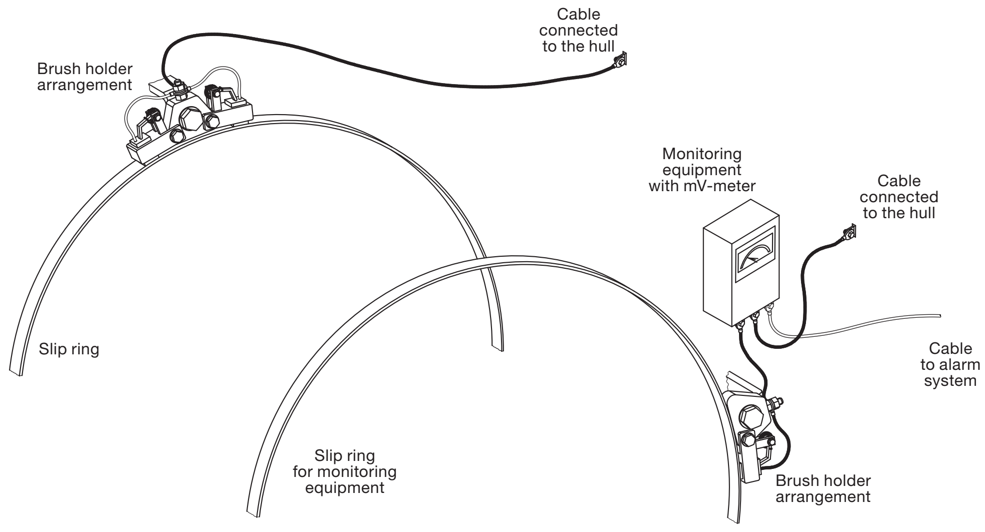

Fig. 5.17.01: Connection of cables for the shaftline earthing device

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

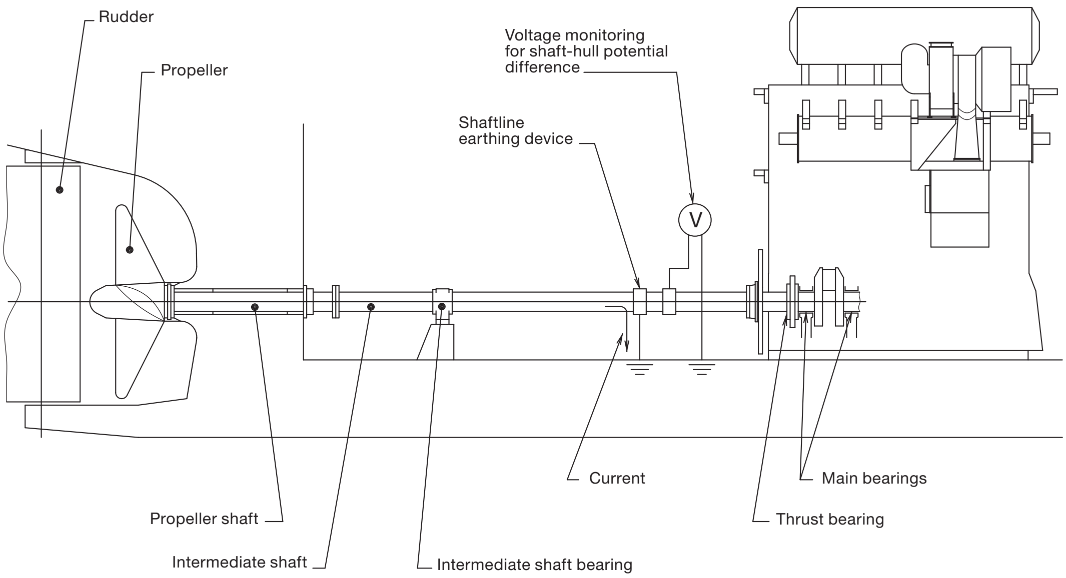

Fig. 5.17.02: Installation of shaftline earthing device in an engine plant without shaft-mounted generator

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

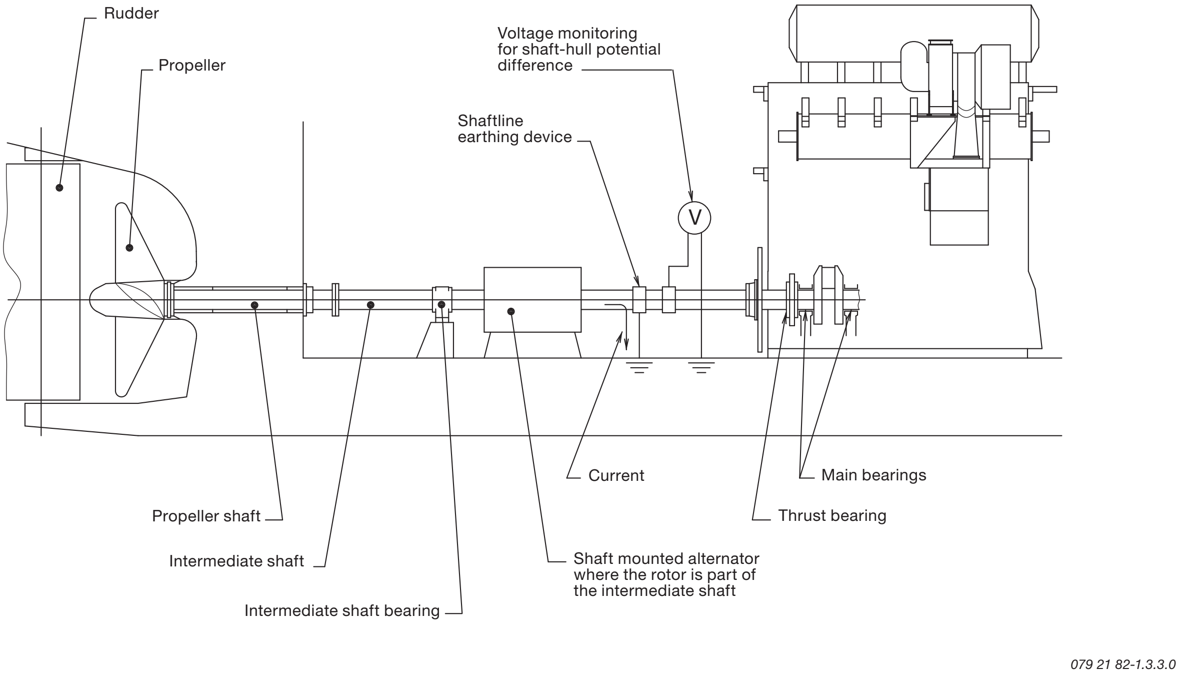

Fig. 5.17.03: Installation of shaftline earthing device in an engine plant with shaft-mounted generator

MAN Alpha Controllable Pitch Propeller and Alphatronic Propulsion Control

MAN Energy Solutions' MAN Alpha Controllable Pitch propeller

On MAN Energy Solutions' 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.

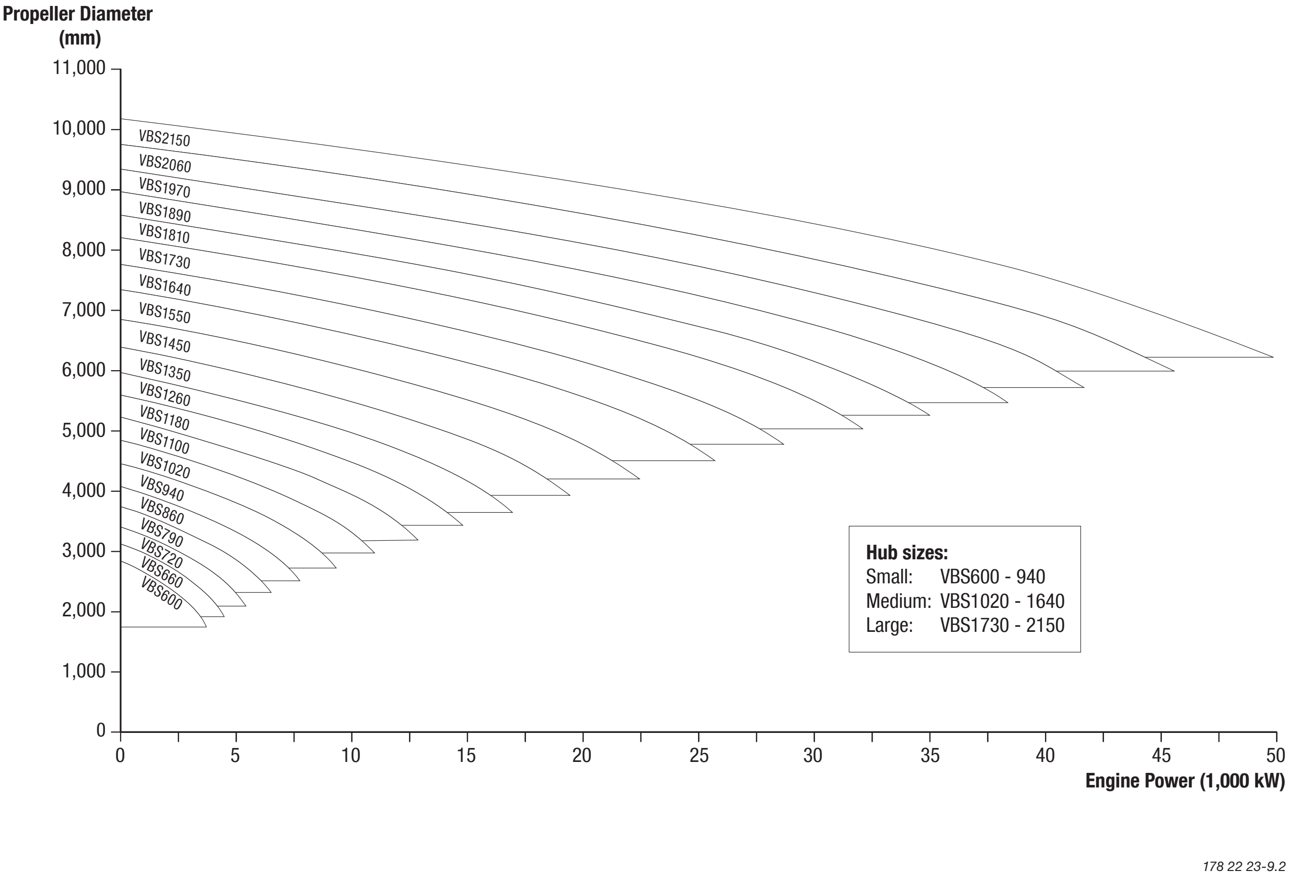

Fig. 5.18.01: MAN Alpha type VBS Mk 5 Controllable Pitch (CP) propeller range. As standard the VBS Mk 5 versions are 4-bladed; 5-bladed versions are available on request

Data Sheet for Propeller

Identification: ______________________________

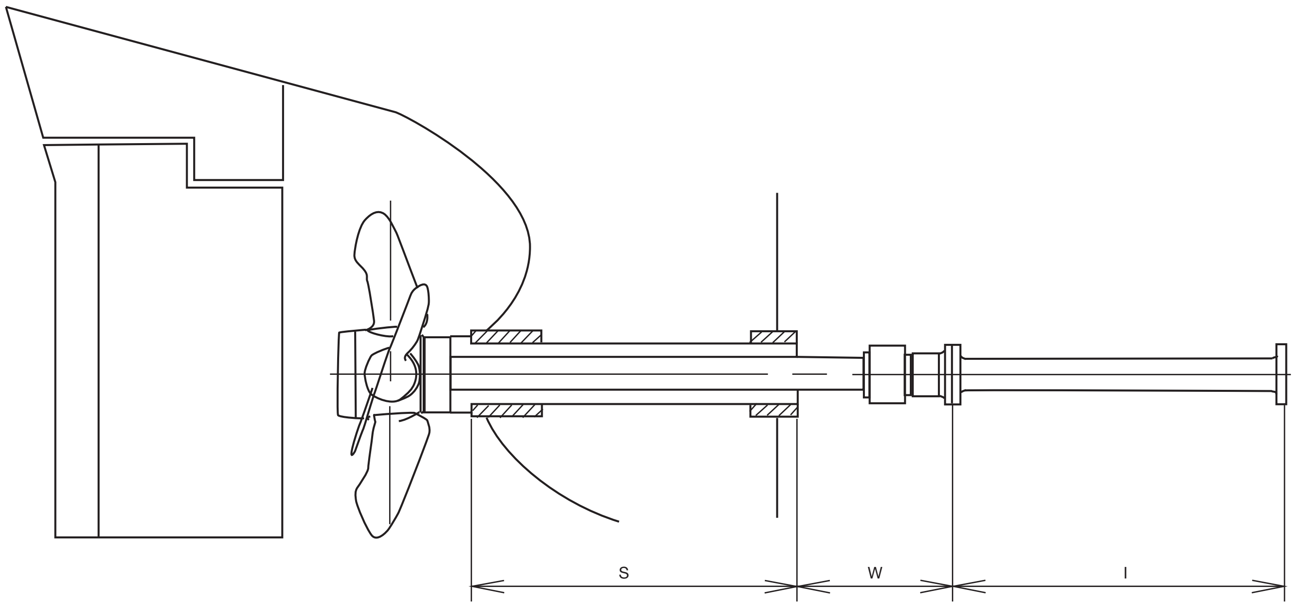

Fig. 5.18.02a: Dimension sketch for propeller design purposes

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 Energy Solutions 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.

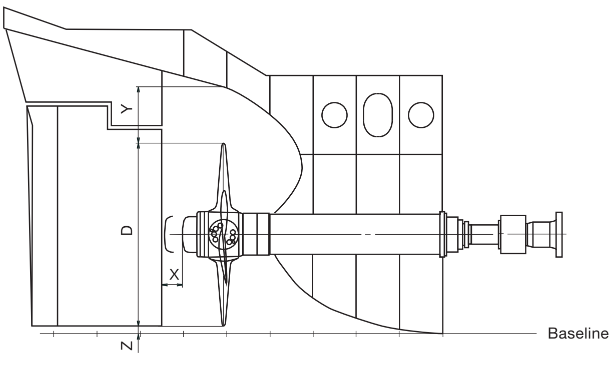

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Fig. 5.18.04: Propeller clearance

Hub	Dismantling 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 Energy Solutions 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.

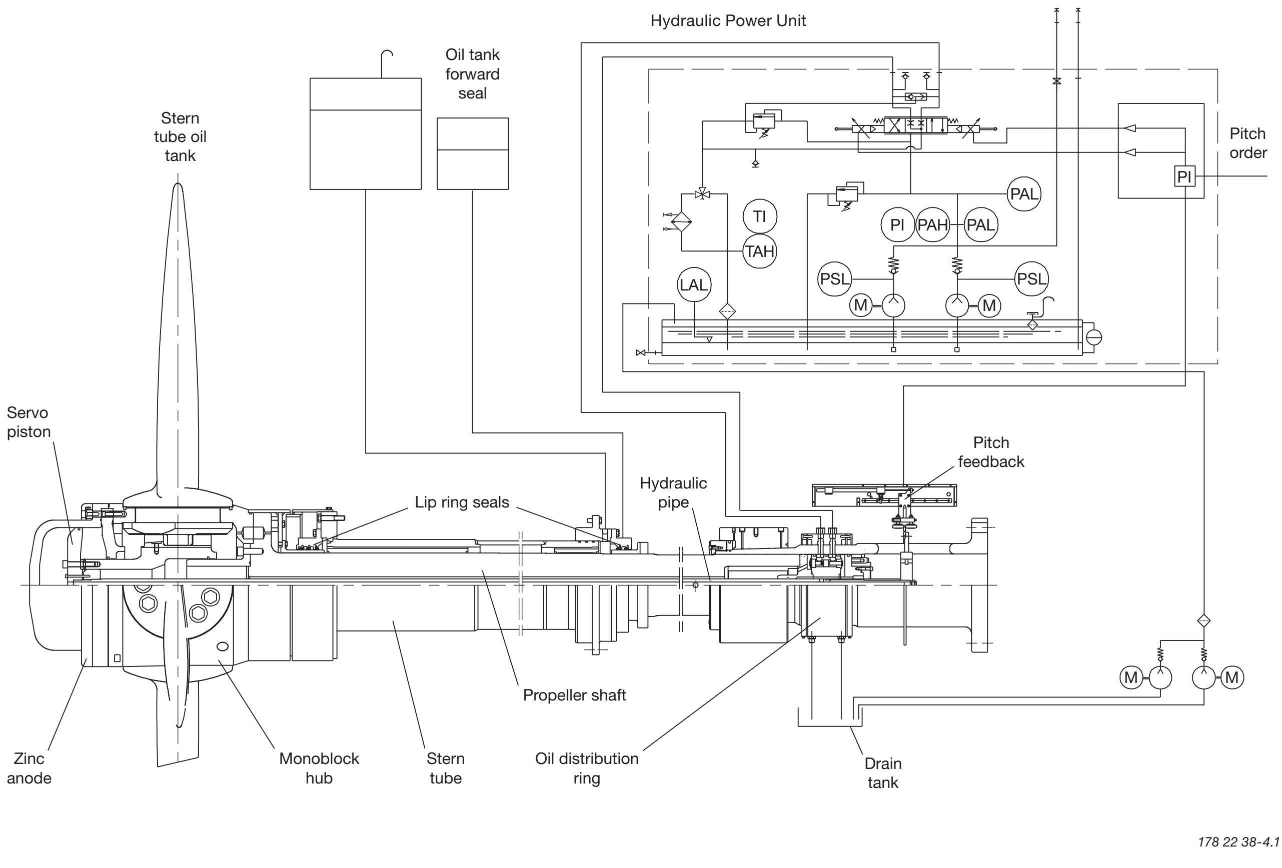

Fig. 5.18.05: Servo oil system for MAN Alpha VBS type CP propeller

Hydraulic Power Unit for MAN Alpha CP propeller

The servo oil tank unit, the Hydraulic Power Unit for MAN Energy Solutions' MAN Alpha CP propeller shown in Fig. 5.18.06, consists of an oil tank with all other components top mounted to facilitate instal-lation 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.

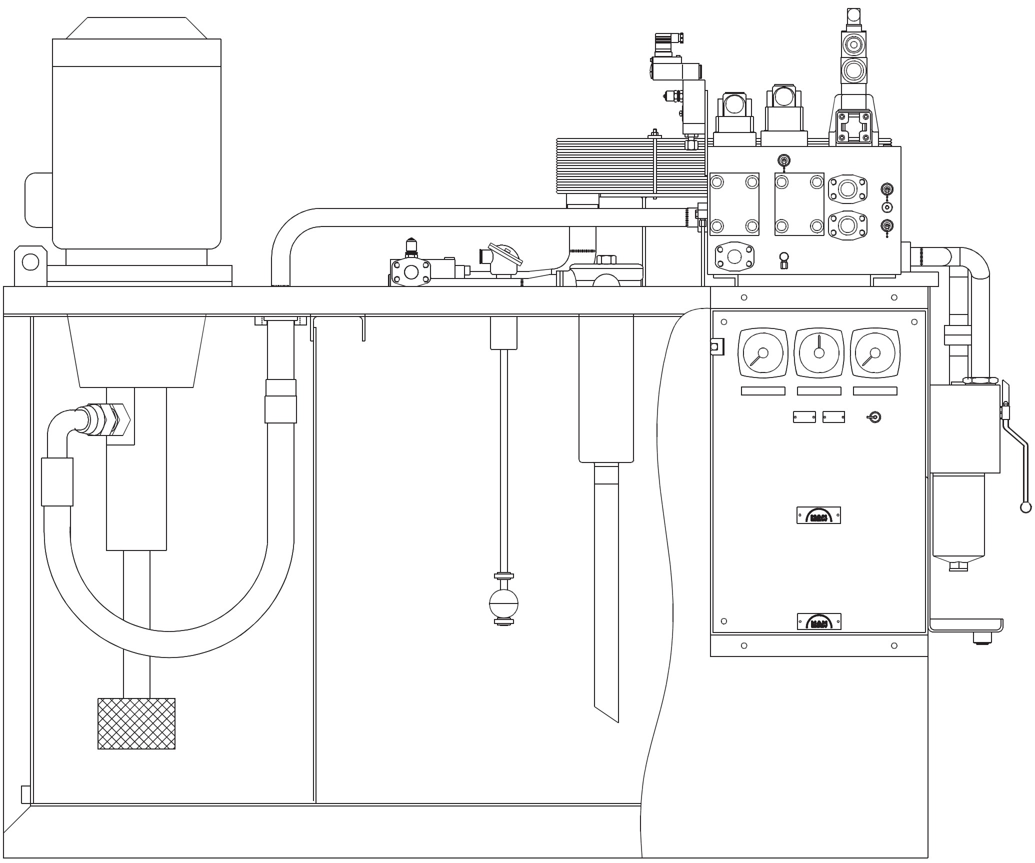

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Fig. 5.18.06: Hydraulic Power Unit for MAN Alpha CP propeller, the servo oil tank unit

MAN Alphatronic 2000 Propulsion Control System

MAN Energy Solutions' MAN Alphatronic 2000 Pro-pulsion Control System (PCS) is designed for con-trol of propulsion plants based on diesel engines with CP propellers. The plant could for instance include tunnel gear with PTO/PTI, PTO gear, mul-tiple 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.

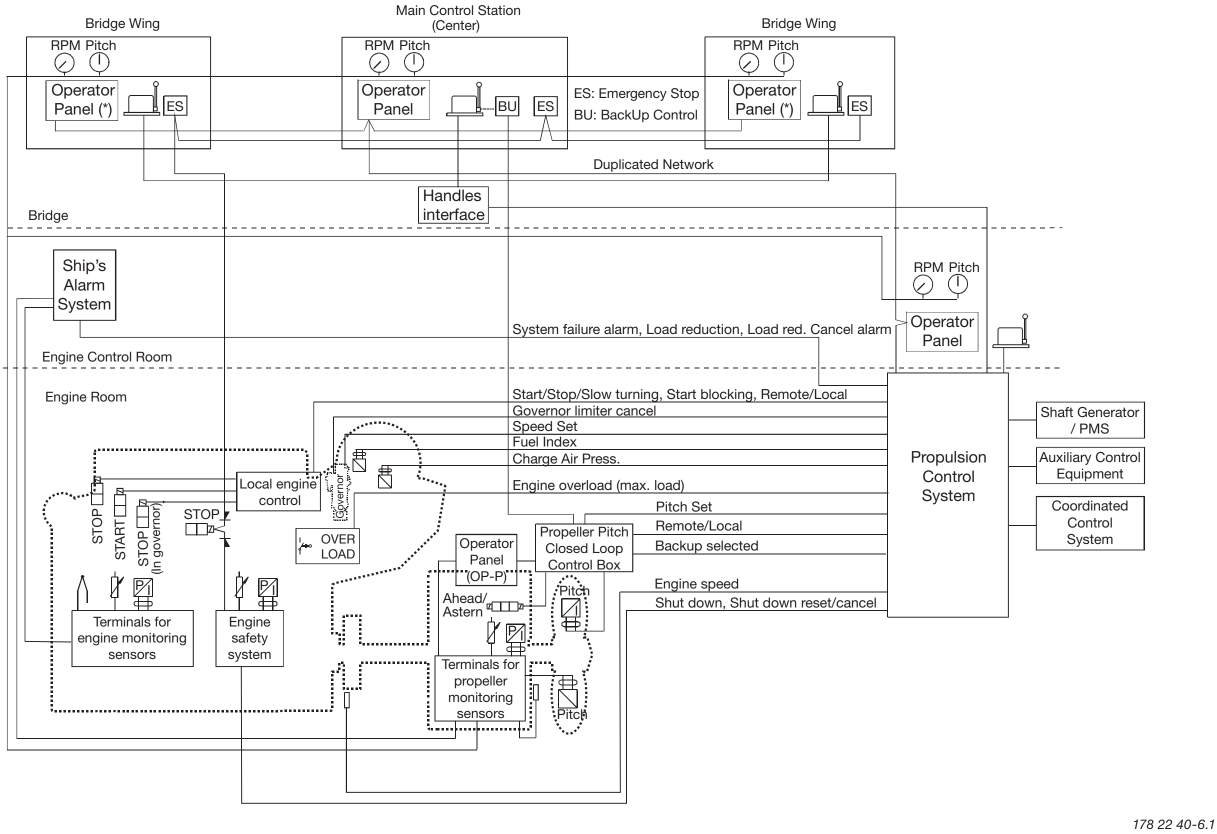

Fig. 5.18.07: MAN Alphatronic 2000 Propulsion Control System

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.

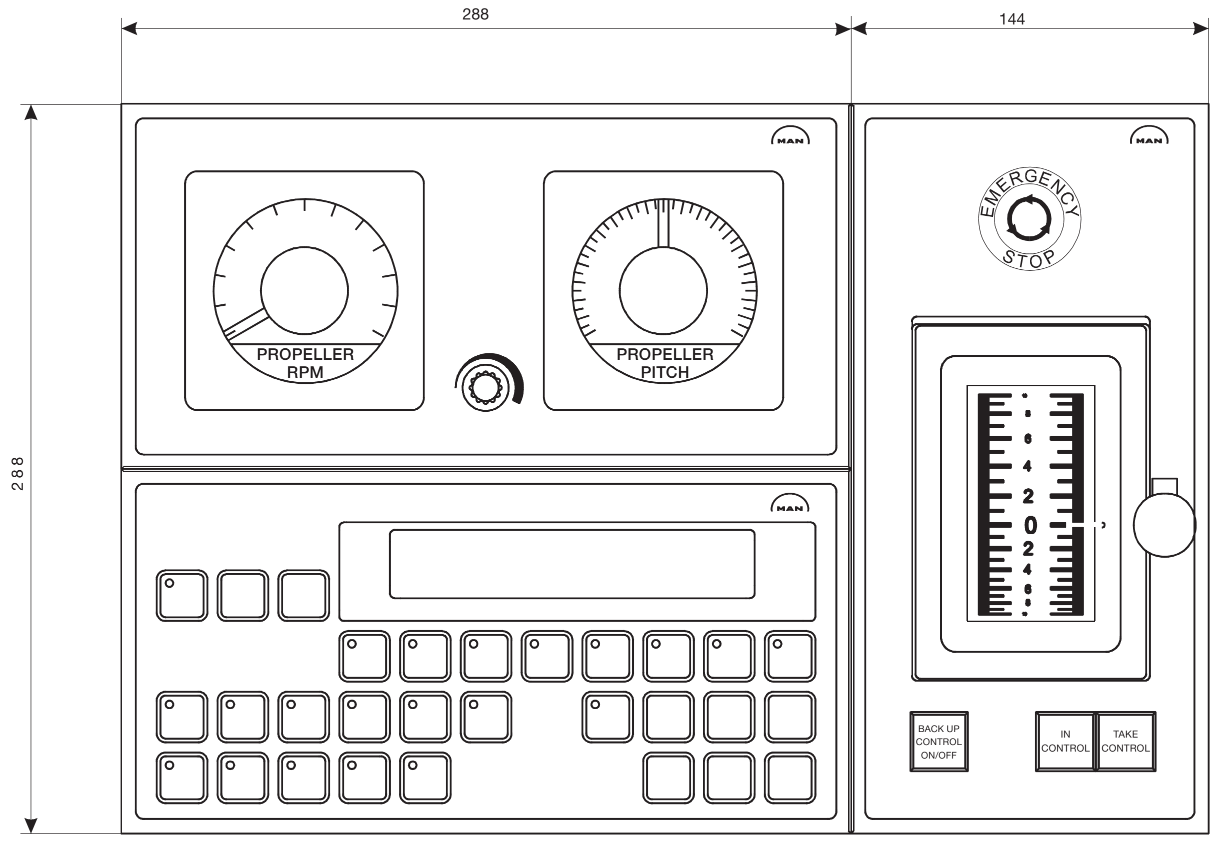

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Fig. 5.18.08: Main bridge station standard layout

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 Energy Solutions' 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-es.com → ’Propeller & Aft Ship’.

List of Capacities: Pumps, Coolers & Exhaust Gas

6

Calculation of List of Capacities

Updated engine and capacities data is available from the CEAS application at www.marine.man-es.com→ '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 a 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.

For a derated engine, calculations of:

- Derated capacities
- Available heat rate, for example for freshwater production
- Exhaust gas amounts and temperatures

can be made in the CEAS application available at the above link.

Nomenclature

In the following description and examples of the auxiliary machinery capacities in Section 6.02, the below nomenclatures are used:

Engine ratings	Point / Index	Power	Speed
Nominal maximum continuous rating (NMCR)	L_1	P_{L1}	n_{L1}
Specified maximum continuous rating (SMCR)	M	P_M	n_M
Normal continuous rating (NCR)	S	P_S	n_S

Fig. 6.01.01: Nomenclature of basic engine ratings

Parameters	Cooler index	Flow index
M = Mass flow	air scavenge air cooler	exh exhaust gas

Fig. 6.01.02: Nomenclature of coolers and volume flows, etc.

Engine configurations related to SFOC

The engine type is available in the following versions with respect to the efficiency of the turbocharger(s) alone:

High efficiency turbocharger, the basic engine design (EoD: 4 59 104)

Conventional turbocharger, (option: 4 59 107)

for both of 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 NMCR. 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 NMCR 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

The radiation and convection heat losses to the engine room is around 1% of the engine power at NMCR.

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 'Counterflanges'; both can be found in Chapter 5.

The diagrams use the 'Basic symbols for piping', the symbols for instrumentation are according to 'ISO 1219-1' / 'ISO 1219-2' and the instrumentation list both found in Appendix A.

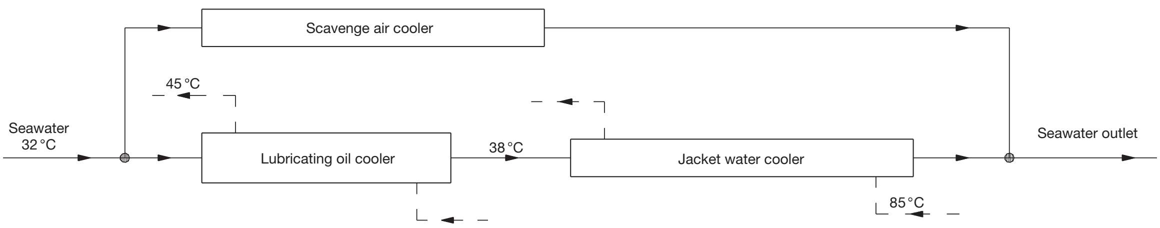


Fig. 6.02.01: Diagram for seawater cooling system

178 11 26-4.2b

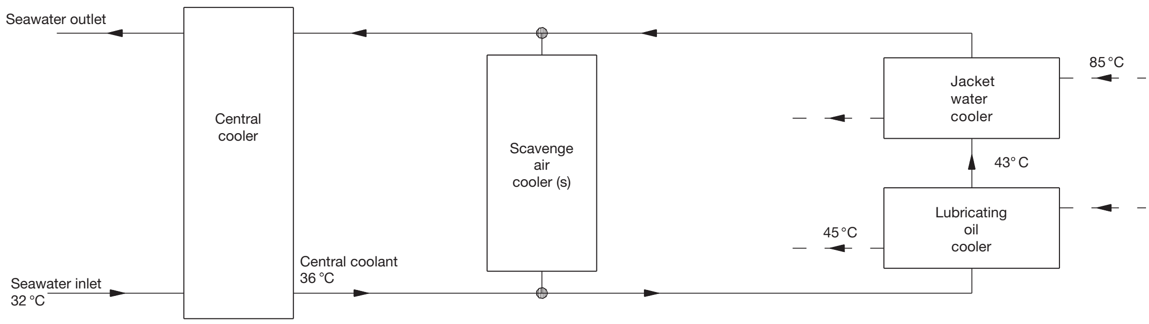


Fig. 6.02.02: Diagram for central cooling water system

178 11 27-6.2b

List of Capacities for 5G60ME-C9.5-TII at NMCR

		Seawater cooling						Central cooling					
		Conventional TC			High eff. TC			Conventional TC			High eff. TC		
		1 x TCA66-21	1 x A270-L	1 x MET66-MB	1 x TCA66-26	1 x A175-L37	1 x MET66-MB	1 x TCA66-21	1 x A270-L	1 x MET66-MB	1 x TCA66-26	1 x A175-L37	1 x MET66-MB
Pumps													
Fuel oil circulation	m³/h	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
Fuel oil supply	m³/h	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Jacket cooling	m³/h	95	95	95	95	95	95	95	95	95	95	95	95
Seawater cooling *	m³/h	390	400	400	400	410	410	380	380	380	390	390	390
Main lubrication oil *	m³/h	270	260	270	270	260	270	270	260	270	270	260	270
Central cooling *	m³/h	-	-	-	-	-	-	300	300	310	310	310	320
Scavenge air cooler(s)													
Heat diss. app.	kW	4,830	4,830	4,830	5,050	5,050	5,050	4,820	4,820	4,820	5,030	5,030	5,030
Central water flow	m³/h	-	-	-	-	-	-	170	170	170	180	180	180
Seawater flow	m³/h	240	240	240	250	250	250	-	-	-	-	-	-
Lubricating oil cooler													
Heat diss. app. *	kW	1,050	1,060	1,110	1,050	1,090	1,110	1,050	1,060	1,110	1,050	1,090	1,110
Lube oil flow *	m³/h	270	260	270	270	260	270	270	260	270	270	260	270
Central water flow	m³/h	-	-	-	-	-	-	130	130	140	130	130	140
Seawater flow	m³/h	150	160	160	150	160	160	-	-	-	-	-	-
Jacket water cooler													
Heat diss. app.	kW	1,800	1,800	1,800	1,790	1,790	1,790	1,810	1,810	1,810	1,800	1,800	1,800
Jacket water flow	m³/h	95	95	95	95	95	95	95	95	95	95	95	95
Central water flow	m³/h	-	-	-	-	-	-	130	130	140	130	130	140
Seawater flow	m³/h	150	160	160	150	160	160	-	-	-	-	-	-
Central cooler													
Heat diss. app. *	kW	-	-	-	-	-	-	7,680	7,690	7,740	7,880	7,920	7,940
Central water flow	m³/h	-	-	-	-	-	-	300	300	310	310	310	320
Seawater flow	m³/h	-	-	-	-	-	-	380	380	380	390	390	390
Starting air system, 30.0 bar g, 12 starts. Fixed pitch propeller - reversible engine													
Receiver volume	m³	2 x 5.5	2 x 5.5	2 x 5.5	2 x 5.5	2 x 5.5	2 x 5.5	2 x 5.5	2 x 5.5	2 x 5.5	2 x 5.5	2 x 5.5	2 x 5.5
Compressor cap.	m³	330	330	330	330	330	330	330	330	330	330	330	330
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	105	105	105	104	104	104	105	105	105	105	105	105
Exh. gas temp. **	°C	255	255	255	235	235	235	255	255	255	235	235	235
Exh. gas amount **	kg/h	100,070	100,070	100,070	106,760	106,760	106,760	100,070	100,070	100,070	106,760	106,760	106,760
Air consumption **	kg/s	24.8	24.8	24.8	26.5	26.5	26.5	25.0	25.0	25.0	26.7	26.7	26.7

* For main engine arrangements with built-on power take-off (PTO) of a MAN Energy Solutions 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.man-es.com/ceas/LOC *Table 6.03.01e: Capacities for seawater and central systems as well as conventional and high efficiency turbochargers stated at NMCR*

List of Capacities for 6G60ME-C9.5-TII at NMCR

		Seawater cooling						Central cooling					
		Conventional TC			High eff. TC			Conventional TC			High eff. TC		
		1 x TCA77-21	1 x A175-L37	1 x MET66-MB	1 x TCA77-21	1 x A275-L	1 x MET71-MB	1 x TCA77-21	1 x A175-L37	1 x MET66-MB	1 x TCA77-21	1 x A275-L	1 x MET71-MB
Pumps													
Fuel oil circulation	m³/h	7.6	7.6	7.6	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	4.3	4.3	4.3	4.3	4.3	4.3
Jacket cooling	m³/h	110	110	110	110	110	110	110	110	110	110	110	110
Seawater cooling *	m³/h	470	470	470	490	490	500	450	450	450	460	460	470
Main lubrication oil *	m³/h	320	310	320	320	310	320	320	310	320	320	310	320
Central cooling *	m³/h	-	-	-	-	-	-	370	370	370	380	380	380
Scavenge air cooler(s)													
Heat diss. app.	kW	5,800	5,800	5,800	6,050	6,050	6,050	5,780	5,780	5,780	6,040	6,040	6,040
Central water flow	m³/h	-	-	-	-	-	-	210	210	210	220	220	220
Seawater flow	m³/h	280	280	280	300	300	300	-	-	-	-	-	-
Lubricating oil cooler													
Heat diss. app. *	kW	1,270	1,290	1,300	1,270	1,290	1,340	1,270	1,290	1,310	1,270	1,290	1,340
Lube oil flow *	m³/h	320	310	320	320	310	320	320	310	320	320	310	320
Central water flow	m³/h	-	-	-	-	-	-	160	160	160	160	160	160
Seawater flow	m³/h	190	190	190	190	190	200	-	-	-	-	-	-
Jacket water cooler													
Heat diss. app.	kW	2,160	2,160	2,160	2,150	2,150	2,150	2,170	2,170	2,170	2,160	2,160	2,160
Jacket water flow	m³/h	110	110	110	110	110	110	110	110	110	110	110	110
Central water flow	m³/h	-	-	-	-	-	-	160	160	160	160	160	160
Seawater flow	m³/h	190	190	190	190	190	200	-	-	-	-	-	-
Central cooler													
Heat diss. app. *	kW	-	-	-	-	-	-	9,220	9,240	9,260	9,470	9,490	9,540
Central water flow	m³/h	-	-	-	-	-	-	370	370	370	380	380	380
Seawater flow	m³/h	-	-	-	-	-	-	450	450	450	460	460	470
Starting air system, 30.0 bar g, 12 starts. Fixed pitch propeller - reversible engine													
Receiver volume	m³	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0
Compressor cap.	m³	360	360	360	360	360	360	360	360	360	360	360	360
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	125	125	125	126	126	126	126	126	126
Exh. gas temp. **	°C	255	255	255	235	235	235	255	255	255	235	235	235
Exh. gas amount **	kg/h	120,090	120,090	120,090	128,110	128,110	128,110	120,090	120,090	120,090	128,110	128,110	128,110
Air consumption **	kg/s	29.7	29.7	29.7	31.8	31.8	31.8	30.0	30.0	30.0	32.1	32.1	32.1

* For main engine arrangements with built-on power take-off (PTO) of a MAN Energy Solutions 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.man-es.com/ceas/LOC *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 7G60ME-C9.5-TII at NMCR

		Seawater cooling						Central cooling					
		Conventional TC			High eff. TC			Conventional TC			High eff. TC		
		1 x TCA77-21	1 x A275-L	1 x MET71-MB	1 x TCA77-26	1 x A180-L37	1 x MET83-MB	1 x TCA77-21	1 x A275-L	1 x MET71-MB	1 x TCA77-26	1 x A180-L37	1 x MET83-MB
Pumps													
Fuel oil circulation	m^3/h	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8
Fuel oil supply	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
Jacket cooling	m^3/h	130	130	130	130	130	130	130	130	130	130	130	130
Seawater cooling *	m^3/h	540	550	550	560	570	580	530	530	530	540	540	540
Main lubrication oil *	m^3/h	370	360	370	370	370	370	370	360	370	370	370	370
Central cooling *	m^3/h	-	-	-	-	-	-	420	420	430	430	440	440
Scavenge air cooler(s)													
Heat diss. app.	kW	6,760	6,760	6,760	7,060	7,060	7,060	6,750	6,750	6,750	7,040	7,040	7,040
Central water flow	m^3/h	-	-	-	-	-	-	240	240	240	250	250	250
Seawater flow	m^3/h	330	330	330	350	350	350	-	-	-	-	-	-
Lubricating oil cooler													
Heat diss. app. *	kW	1,460	1,480	1,530	1,460	1,510	1,570	1,470	1,490	1,540	1,470	1,510	1,570
Lube oil flow *	m^3/h	370	360	370	370	370	370	370	360	370	370	370	370
Central water flow	m^3/h	-	-	-	-	-	-	180	180	190	180	190	190
Seawater flow	m^3/h	210	220	220	210	220	230	-	-	-	-	-	-
Jacket water cooler													
Heat diss. app.	kW	2,520	2,520	2,520	2,510	2,510	2,510	2,530	2,530	2,530	2,520	2,520	2,520
Jacket water flow	m^3/h	130	130	130	130	130	130	130	130	130	130	130	130
Central water flow	m^3/h	-	-	-	-	-	-	180	180	190	180	190	190
Seawater flow	m^3/h	210	220	220	210	220	230	-	-	-	-	-	-
Central cooler													
Heat diss. app. *	kW	-	-	-	-	-	-	10,750	10,770	10,820	11,030	11,070	11,130
Central water flow	m^3/h	-	-	-	-	-	-	420	420	430	430	440	440
Seawater flow	m^3/h	-	-	-	-	-	-	530	530	530	540	540	540
Starting air system, 30.0 bar g, 12 starts. Fixed pitch propeller - reversible engine													
Receiver volume	m^3	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0
Compressor cap.	m^3	360	360	360	360	360	360	360	360	360	360	360	360
Starting air system, 30.0 bar g, 6 starts. Controllable pitch propeller - non-reversible engine													
Receiver volume	m^3	2 x 3.5	2 x 3.5	2 x 3.5	2 x 3.5	2 x 3.5	2 x 3.5	2 x 3.5	2 x 3.5	2 x 3.5	2 x 3.5	2 x 3.5	2 x 3.5
Compressor cap.	m^3	210	210	210	210	210	210	210	210	210	210	210	210
Other values													
Fuel oil heater	kW	147	147	147	146	146	146	148	148	148	147	147	147
Exh. gas temp. **	°C	255	255	255	235	235	235	255	255	255	235	235	235
Exh. gas amount **	kg/h	140,100	140,100	140,100	149,460	149,460	149,460	140,100	140,100	140,100	149,460	149,460	149,460
Air consumption **	kg/s	34.7	34.7	34.7	37.1	37.1	37.1	35.0	35.0	35.0	37.4	37.4	37.4

* For main engine arrangements with built-on power take-off (PTO) of a MAN Energy Solutions 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.man-es.com/ceas/LOC *Table 6.03.01g: Capacities for seawater and central systems as well as conventional and high efficiency turbochargers stated at NMCR*

List of Capacities for 8G60ME-C9.5-TII at NMCR

		Seawater cooling						Central cooling					
		Conventional TC			High eff. TC			Conventional TC			High eff. TC		
		1 x TCA77-26	1 x A280-L	1 x MET83-MB	1 x TCA88-21	1 x A280-L	1 x MET83-MB	1 x TCA77-26	1 x A280-L	1 x MET83-MB	1 x TCA88-21	1 x A280-L	1 x MET83-MB
Pumps													
Fuel oil circulation	m^3/h	10.1	10.1	10.1	10.0	10.0	10.0	10.1	10.1	10.1	10.1	10.1	10.1
Fuel oil supply	m^3/h	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
Jacket cooling	m^3/h	150	150	150	150	150	150	150	150	150	150	150	150
Seawater cooling *	m^3/h	620	630	640	640	640	650	600	600	600	620	620	620
Main lubrication oil *	m^3/h	420	420	430	430	420	430	420	420	430	430	420	430
Central cooling *	m^3/h	-	-	-	-	-	-	480	490	500	500	500	510
Scavenge air cooler(s)													
Heat diss. app.	kW	7,730	7,730	7,730	8,070	8,070	8,070	7,710	7,710	7,710	8,050	8,050	8,050
Central water flow	m^3/h	-	-	-	-	-	-	280	280	280	290	290	290
Seawater flow	m^3/h	380	380	380	390	390	390	-	-	-	-	-	-
Lubricating oil cooler													
Heat diss. app. *	kW	1,660	1,700	1,770	1,680	1,700	1,770	1,660	1,710	1,770	1,690	1,710	1,770
Lube oil flow *	m^3/h	420	420	430	430	420	430	420	420	430	430	420	430
Central water flow	m^3/h	-	-	-	-	-	-	200	210	220	210	210	220
Seawater flow	m^3/h	240	250	260	250	250	260	-	-	-	-	-	-
Jacket water cooler													
Heat diss. app.	kW	2,890	2,890	2,890	2,870	2,870	2,870	2,890	2,890	2,890	2,880	2,880	2,880
Jacket water flow	m^3/h	150	150	150	150	150	150	150	150	150	150	150	150
Central water flow	m^3/h	-	-	-	-	-	-	200	210	220	210	210	220
Seawater flow	m^3/h	240	250	260	250	250	260	-	-	-	-	-	-
Central cooler													
Heat diss. app. *	kW	-	-	-	-	-	-	12,260	12,310	12,370	12,620	12,640	12,700
Central water flow	m^3/h	-	-	-	-	-	-	480	490	500	500	500	510
Seawater flow	m^3/h	-	-	-	-	-	-	600	600	600	620	620	620
Starting air system, 30.0 bar g, 12 starts. Fixed pitch propeller - reversible engine													
Receiver volume	m^3	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0	2 x 6.0
Compressor cap.	m^3	360	360	360	360	360	360	360	360	360	360	360	360
Starting air system, 30.0 bar g, 6 starts. Controllable pitch propeller - non-reversible engine													
Receiver volume	m^3	2 x 3.5	2 x 3.5	2 x 3.5	2 x 3.5	2 x 3.5	2 x 3.5	2 x 3.5	2 x 3.5	2 x 3.5	2 x 3.5	2 x 3.5	2 x 3.5
Compressor cap.	m^3	210	210	210	210	210	210	210	210	210	210	210	210
Other values													
Fuel oil heater	kW	168	168	168	167	167	167	169	169	169	168	168	168
Exh. gas temp. **	°C	255	255	255	235	235	235	255	255	255	235	235	235
Exh. gas amount **	kg/h	160,110	160,110	160,110	170,810	170,810	170,810	160,110	160,110	160,110	170,810	170,810	170,810
Air consumption **	kg/s	39.7	39.7	39.7	42.4	42.4	42.4	40.0	40.0	40.0	42.8	42.8	42.8

* For main engine arrangements with built-on power take-off (PTO) of a MAN Energy Solutions 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.man-es.com/ceas/LOC *Table 6.03.01h: Capacities for seawater and central systems as well as conventional and high efficiency turbochargers stated at NMCR*

Auxiliary Machinery Capacities

Further to the auxiliary machinery capacities for a nominally rated engine shown in Section 6.03, the dimensioning of heat exchangers (coolers) and pumps for derated engines as well as calculating the:

- List of capacities for derated engine
- Available heat to be removed, for example for freshwater production
- Exhaust gas amounts and temperatures

can be made in the CEAS application descibed in Section 20.02.

The CEAS application is available at www.marine.man-es.com → 'Two-Stroke' → 'CEAS Engine Calcula-tions'.

Pump pressures and temperatures

The pump heads stated in the table below are for guidance only and depend on the actual pressure drop across coolers, filters, etc. in the systems.

	Pump head, bar	Max. working temp. °C
Fuel oil supply pump	4	100
Fuel oil circulating pump	6	150
Lubricating oil pump	4.5	70
Seawater pump, for seawater cooling system	2.5	50
Seawater pump, for central cooling water system	2.0	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

Centrifugal pump selection

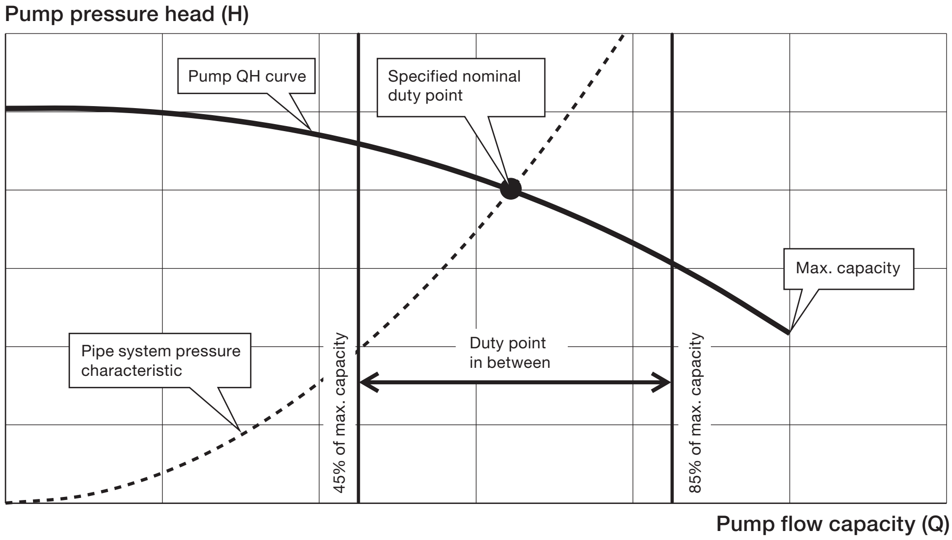


Fig. 6.04.01: Location of the specified nominal duty point (SNDP) on the pump QH curve

When selecting a centrifugal pump, it is recommended to carefully evaluate the pump QH (capacity/head) curve in order for the pump to work properly both in normal operation and under changed conditions. But also for ensuring that the maximum pipe design pressure is not exceeded.

The following has to be evaluated:

- Location of the specified nominal duty point (SNDP) on the pump QH curve
- Pump QH curve slope
- Maximum available delivery pressure from the pump.

Location of the duty point on the pump QH curve

Particularly important is the location of the specified nominal duty point (SNDP) on the pump QH curve: the SNDP is equal to the intersection of the pump QH curve and the pipe system pressure characteristic, which is defined at the design stage.

The SNDP must be located in the range of 45 to 85% of the pump's maximum capacity, see Fig. 6.04.01.

Thus, the pump will be able to operate with slightly lower or higher pipe system pressure characteristic than specified at the design stage, without the risk of cavitation or too big variations in flow.

Pump QH curve slope

At the location of the SNDP, the pump capacity should not decrease by more than 10% when the pressure is increased by 5%, see Fig. 6.04.02.

This way, the flow stays acceptable even if the pipe system pressure is higher than expected and the flow does not change too much, for example when a thermostatic valve changes position.

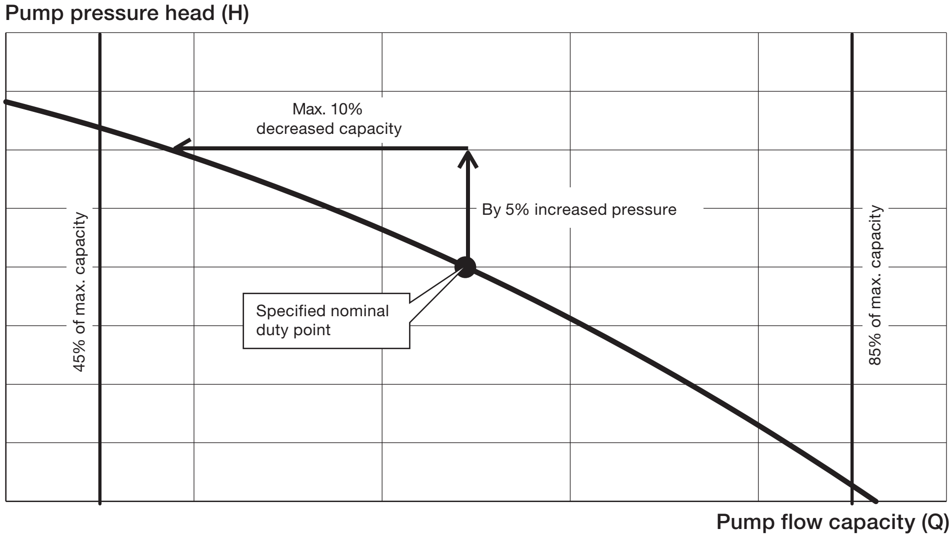


Fig. 6.04.02: Pump QH curve slope

Maximum available pump delivery pressure

It is important to evaluate, if the maximum available delivery pressure from the pump contributes to exceeding the maximum allowable design pressure in the pipe system.

The maximum available delivery pressure from the pump will occur e.g. when a valve in the system is closed, see Fig. 6.04.03.

The maximum allowable pipe system design pressure must be known in order to make the pressure rate sizing for equipment and other pipe components correctly.

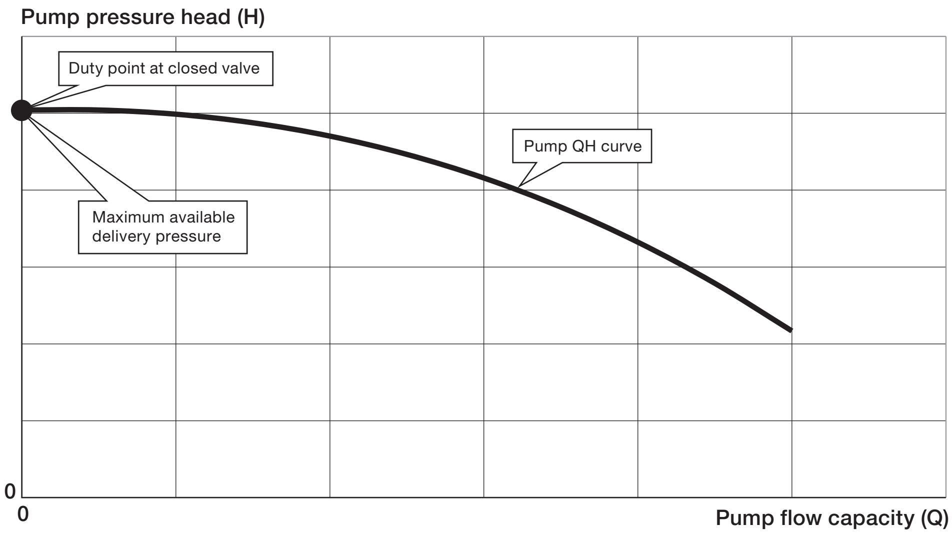


Fig. 6.04.03: Maximum available pump delivery pressure

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.

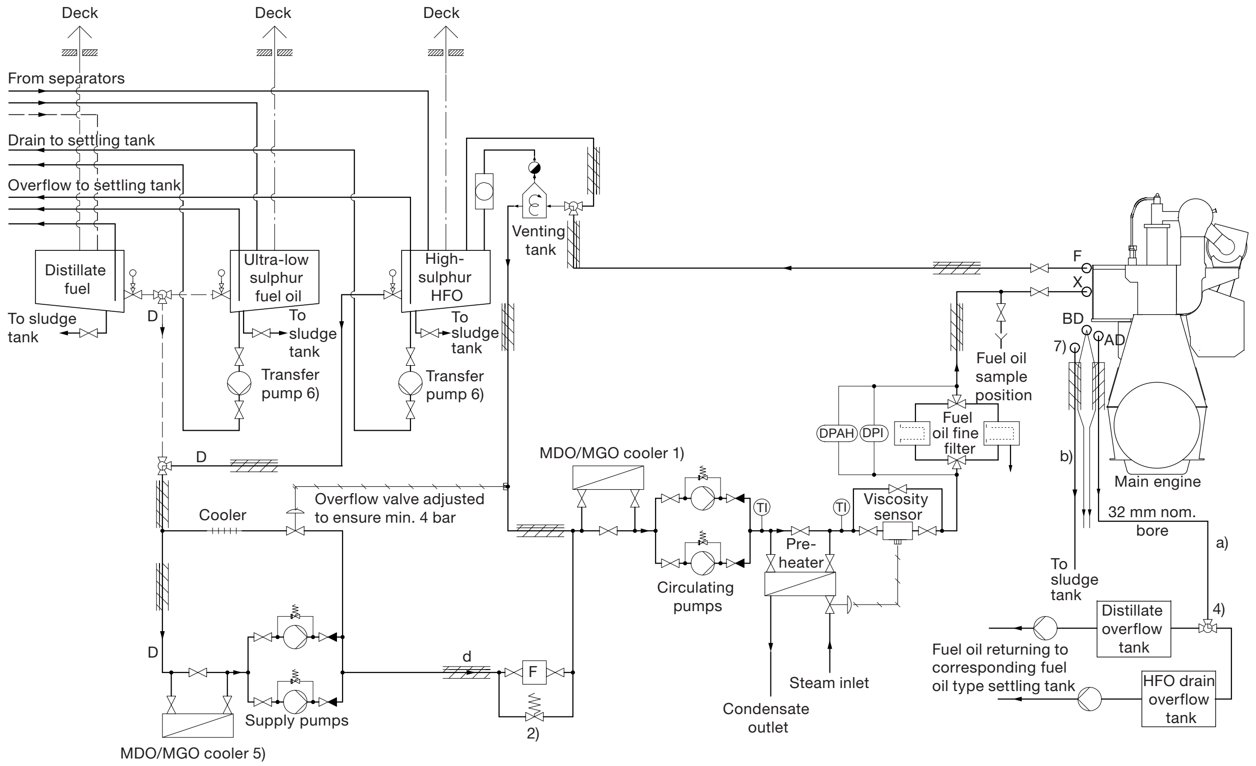
In special circumstances a change-over to diesel oil may become necessary – and this can be performed at any time, even when the engine is not running. Such a change-over may become necessary if, for instance, the vessel is expected to be inactive for a prolonged period with cold engine e.g. due to:

- 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



1) MDO/MGO Cooler
For low-viscosity distillate fuels like marine gas oil (MGO), it is necessary to have a cooler to ensure that the viscosity at engine inlet is above 2 cSt.

Location of cooler: As shown or, alternatively, anywhere before inlet to engine.

2) Fuel oil flowmeter (Optional)
Flow rate: See 'List of Capacities' (same as fuel supply pump).
Type: In case a damaged flow meter can block the fuel supply, a safety bypass valve is to be placed across the flowmeter.

3) 0.23 litre/kWh in relation to cerfitied Flow Rate (CFR); the engine SMCR can be used to determine the capacity. The separators should be capable of removing cat fines (Al+Si) from 80 ppm to a maximum level of 15 ppm Al+Si but preferably lower.
Inlet temperature: Min. 98 °C.

4) Valve in engine drain pipe
Valve in engine drain pipe is not acceptable. If the drain is blocked, the pressure booster top cover seal will be damaged.
In case a valve between the engine connection AD and the drain tank is required, the valve should be locked in open position and marked with a text, indicating that the valve must only be closed in case of no fuel oil pressure to the engine. In case of non-return valve, the opening pressure for the valve has to be below 0.2 bar.

5) MDO/MGO Cooler (Optional)
For protection of supply pumps against too warm oil and thus too low viscosity.

6) Transfer pump (Optional)
The transfer pump has to be able to return part of the content of the service tank to the settling tank to minimize the risk of supplying fuel to the engine with a high content of settled particles, e.g. cat fines, if the service tank has not been used for a while.

7) Name of flange connection
AF for engines with a bore of 60 cm and above
AE for engines with a bore of 50 cm and below

a) Tracing, fuel oil lines: By jacket coolon water

b) Tracing, drain lines: By jacket cooling water
– only for engines with bore of 60 cm and above

*) Optional installation

The letters refer to the list of 'Counterflanges'

Heavy fuel oil
Distillate fuel or ultra-low sulphur fuel oil
Heated pipe with insulation

079 95 01-2.3.1

Fig. 7.01.01: Fuel oil system

Heavy fuel oil tank

This type of tank should be used for any residual fuel usage. (It can also be used for distillate fuel). The tank must be designed as high as possible and equipped with a sloping bottom in order to collect the solid particles settling from the fuel oil.

The tank outlet to the supply pumps must be placed above the slope to prevent solid particles to be drawn into the heavy fuel oil supply pumps. An overflow pipe must be installed inside the tank below the pump outlet pipe to ensure that only ‘contaminated’ fuel is pumped back to settling tank.

A possibility of returning the day tank content to the settling tank must be installed for cases where the day tank content have not been used for some time.

Drain of clean fuel oil from HCU, pumps, pipes

The HCU Fuel Oil Pressure Booster has a leakage drain of clean fuel oil from the umbrella sealing through ‘AD’ to the fuel oil drain tank.

The drain amount in litres per cylinder per hour is approximately as listed in Table 7.01.02.

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.

Engine bore, ME/ME-C, ME-B (incl. -GI & -LGI versions)	**Flow rate, litres/cyl./hr.**
98	On request
95, 90	1.7
80	2.1
70, 65	1.5
60	1.2

Table 7.01.02: Drain amount from fuel oil pump umbrella seal, figures for guidance

Leakage oil amount dependencies

Due to tolerances in the fuel pumps, the table figures may vary and are therefore for guidance only. In fact, the leakage amount relates to the clearance between plunger and barrel in the third power. Thus, within the drawing tolerances alone, the table figures can vary quite a lot.

The engine load, however, has little influence on the drain amount because the leakage does not originate from the high-pressure side of the fuel pump. For the same reason, the varying leakage amount does not influence the injection itself.

The figures in Table 7.01.02 are based on fuel oil with 12 cSt viscosity. In case of distillate fuel oil, the figures can be up to 6 times higher due to the lower viscosity.

Fuel oil drains in service and for overhaul

The main purpose of the drain ‘AD’ is to collect fuel oil from the fuel pumps.

The drain oil is led to an overflow tank and can be pumped to the heavy fuel oil (HFO) tank or to the settling tank. In case of ultra low sulphur (ULSFO) or distillate fuel oil, the piping should allow the fuel oil to be pumped to the ultra low sulphur or distillate fuel oil tank.

As a safety measure for the crew during maintenance, an overhaul drain from the umbrella leads clean fuel oil from the umbrella directly to drain ‘AF’ and further to the sludge tank. Also washing water from the cylinder cover and the baseplate is led to drain ‘AF’.

The ‘AF’ drain is provided with a box for giving alarm in case of leakage in a high pressure pipe.

The size of the sludge tank is determined on the basis of the draining intervals, the classification society rules, and on whether it may be vented directly to the engine room.

Drains ‘AD’, ‘AF’ and the drain for overhaul are shown in Fig. 7.03.01.

Drain of contaminated fuel etc.

Leakage oil, in shape of fuel and lubricating oil contaminated with water, dirt etc. and collected by the HCU Base Plate top plate (ME only), as well as turbocharger cleaning water etc. 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’. (Flange BD and the tracing line are not applicable on MC/MC-C engines type 42 and smaller).

Fuel oil flow velocity and viscosity

For external pipe connections, we prescribe the following maximum flow velcities:

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.

Cat fines

Cat fines is a by-product from the catalytic cracking used in fuel distillation. Cat fines is an extremely hard material, very abrasive and damaging to the engine and fuel equipment. It is recommended always to purchase fuel with as low cat fines content as possible.

Cat fines can to some extent be removed from the fuel by means of a good and flexible tank design and by having optimum conditions for the separator in terms of flow and high temperature.

Further information about fuel oil specifications and other fuel considerations is available in our publications:

Guidelines for Fuels and Lubes Purchasing

Guidelines for Operation on Fuels with less than 0.1% Sulphur

The publications are available at www.marine.man-es.com → ’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.

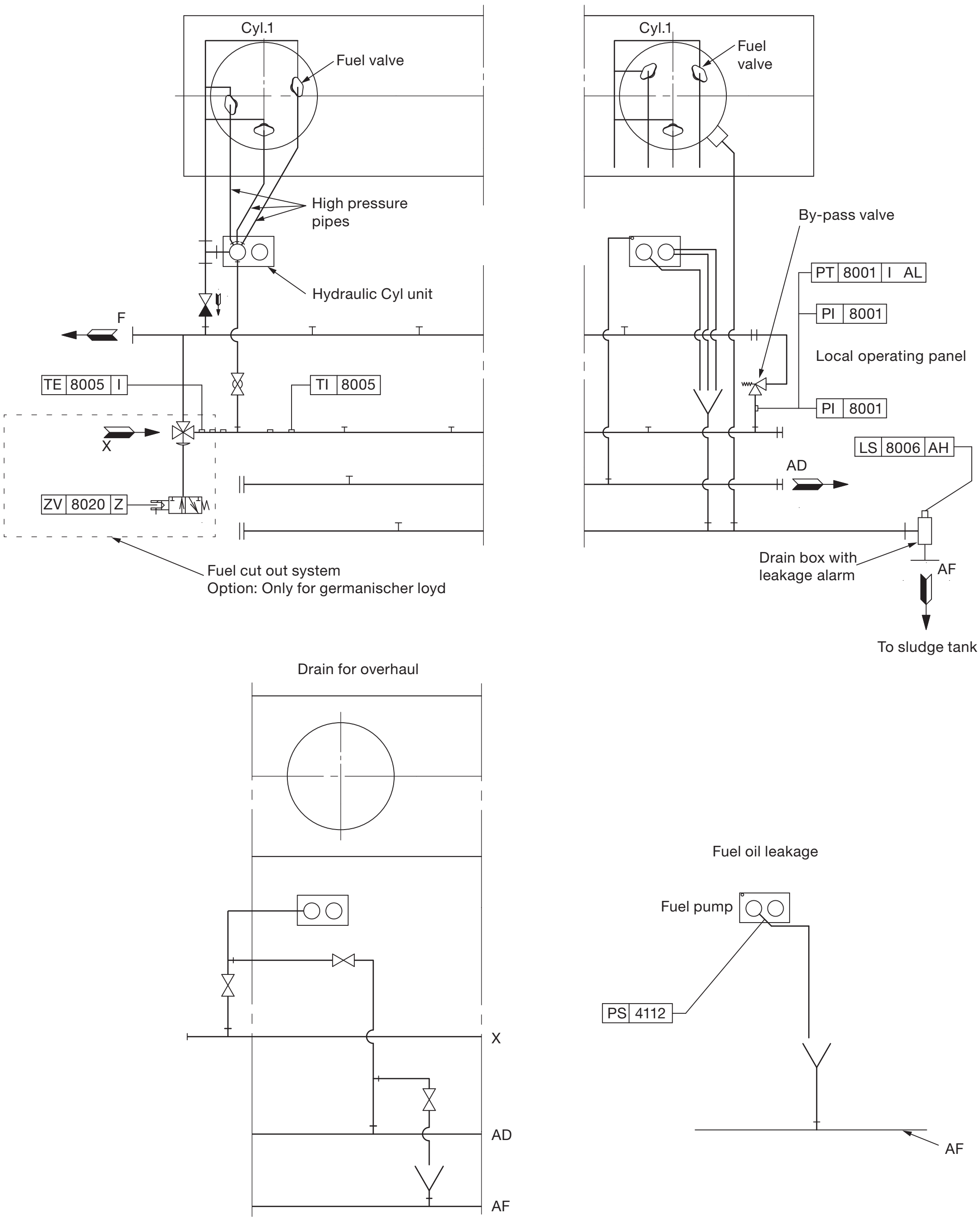
Heavy fuel oils limited by this specification have, to the extent of the commercial availability, been used with satisfactory results on MAN B&W two-stroke low speed diesel engines.

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 nos. refer to 'Guidance values automation'

546 95 16-8.3.0

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.

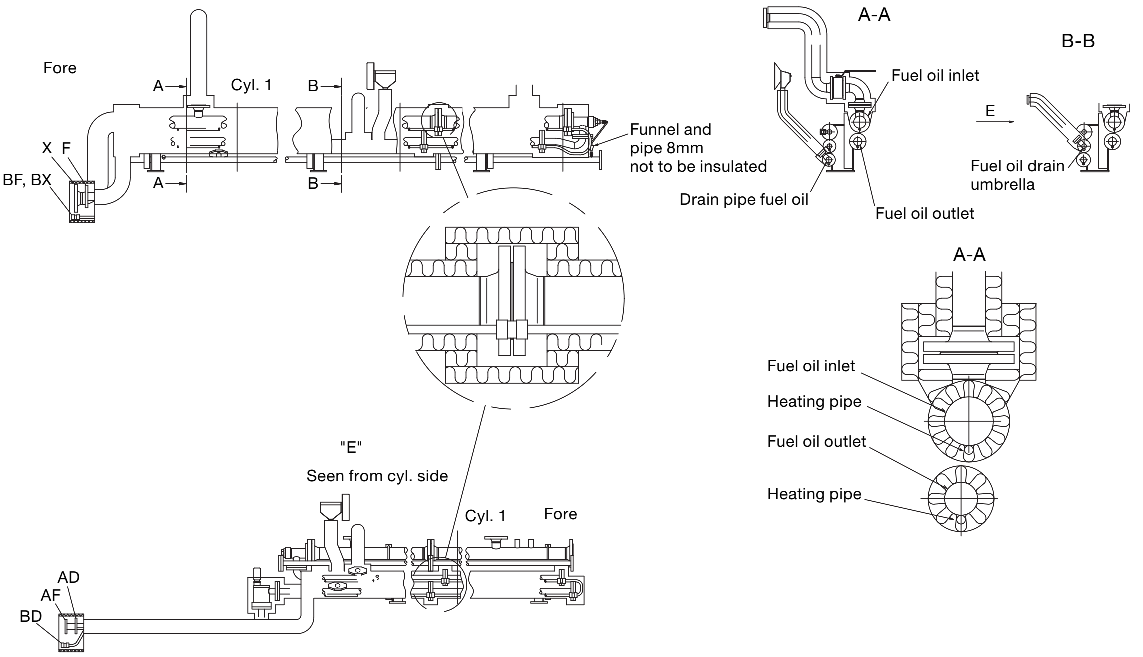
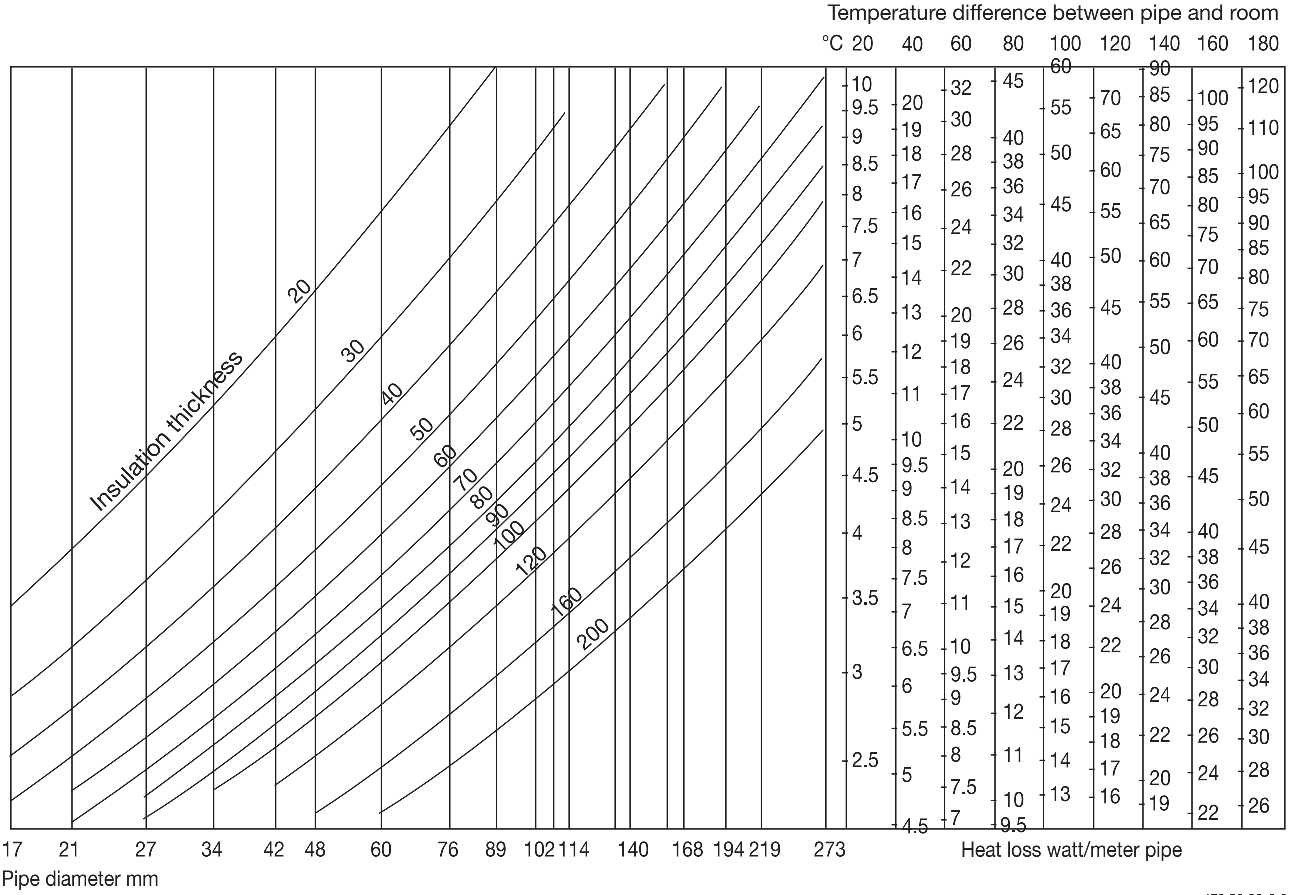


Fig. 7.04.01: Details of fuel oil pipes insulation, option: 4 35 121. Example from 98-50 MC engine

178 50 65 -0.2

Heat Loss in Piping



178 50 60-2.0

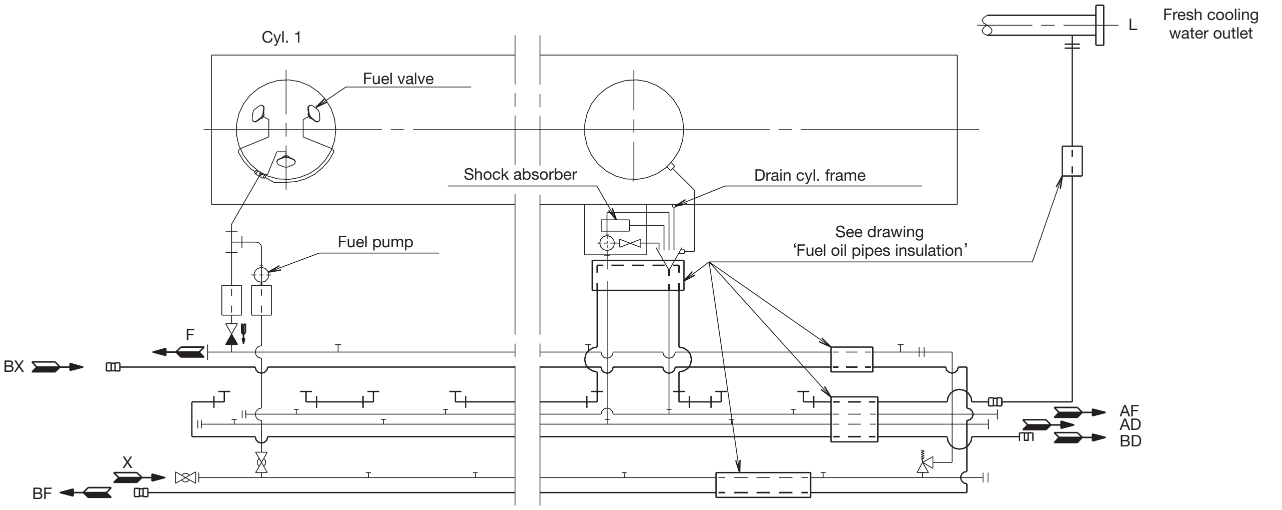
Fig. 7.04.02: Heat loss/Pipe cover

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'

178 50 62-5.0

Fig. 7.04.03: Fuel oil pipe heat tracing

Fuel Oil and Lubricating Oil Pipe Spray Shields

To fulfill IMO regulations, fuel and oil pipe assemblies are to be secured by spray shields.

The shields can be made either by a metal flange cover according to IMO MSC/Circ.647 or anti-splashing tape wrapped according to makers instruction for Class approval, see examples shown in Fig. 7.04.04a and b.

To ensure tightness, the spray shields are to be applied after pressure test of the pipe system.

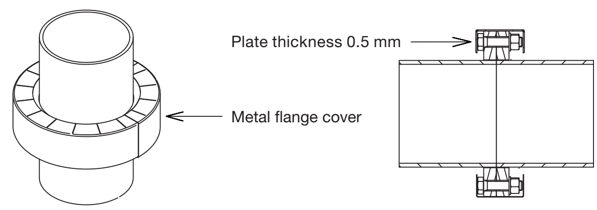


Fig. 7.04.04a: Metal flange cover and clamping band

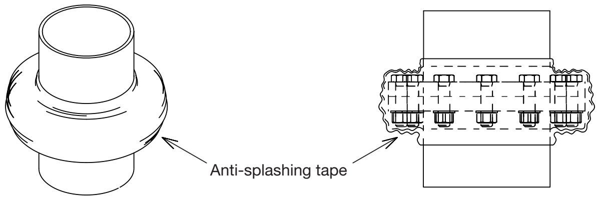


Fig. 7.04.04b: Anti-splashing tape (FN tape)

176 94 23-4.4.2

Components for Fuel Oil System

Fuel oil separator

The manual cleaning type of separators are not to be recommended. Separators 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: RMA-RMD grades and British Standard 6843 from RMA to RMH, and CIMAC from A to H-grades)
- Specific gravities > 0.991 (corresponding to ISO 8217: RME-RMK grades and CIMAC K-grades).

For the latter specific gravities, the manufacturers have developed special types of separators, e.g.:

Alfa Laval..Alcap
Westfalia... Unitrol
Mitsubishi .... E-Hidens II

MAN Energy Solutions also recommends using high-temperature separators, which will increase the efficiency.

The separator should be able to treat approximately the following quantity of oil:

0.23 litres/kWh in relation to CFR (certified flow rate)

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 Specified MCR can be used to determine the capacity. The separator capacity must always be higher than the calculated capacity.

Inlet temperature to separator, minimum.......98 °C

CFR according to CEN, CWA 15375

The size of the separator has to be chosen according to the supplier's table valid for the selected viscosity of the Heavy Fuel Oil and in compliance with CFR or similar. Normally, two separators are installed for Heavy Fuel Oil (HFO), each with adequate capacity to comply with the above recommendation.

A separator for Marine Diesel Oil (MDO) is not a must. However, MAN Energy Solutions recommends that at least one of the HFO separators 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 separator of the same size as that for HFO.

It is recommended to follow the CIMAC Recommendation 25:

Recommendations concerning the design of heavy fuel treatment plants for diesel engines.

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 .... 700 cSt
Fuel oil viscosity, minimum .... 2 cSt
Pump head..4 bar
Fuel oil flow .... see 'List of Capacities'
Delivery pressure ....4 bar
Working temperature, maximum .... 110 °C *)

*) If a high temperature separator is used, higher working temperature related to the separator must be specified.

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 .... 700 cSt
Fuel oil viscosity, minimum .... 2 cSt
Fuel oil flow .... see ‘List of Capacities’
Pump head...6 bar
Delivery pressure ....10 bar
Working temperature ....150 °C

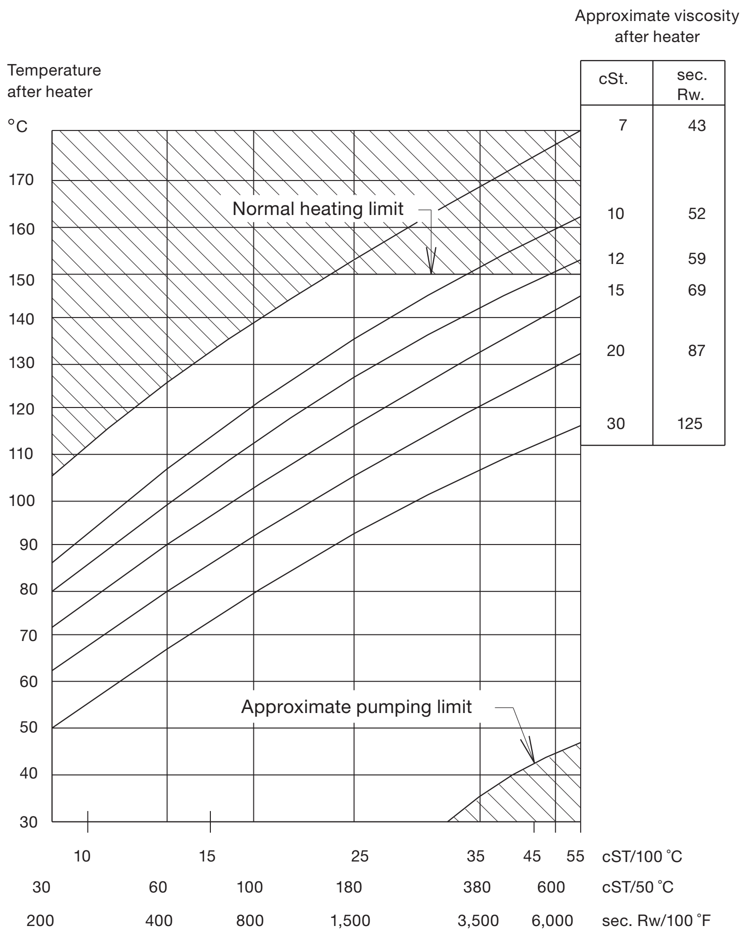
The capacity stated in ‘List of Capacities’ is to be fulfilled with a tolerance of: –0% to +15% and shall also be able to cover the back-flushing, see ‘Fuel oil filter’.

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.



178 06 28-0.1

Fig. 7.05.01: Fuel oil heating chart

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 20 cSt at 150 °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 at 15 cSt
Working pressure ....10 bar
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.

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.

Alternatively positioned in the supply circuit after the supply pumps, the filter has the same flow rate as the fuel oil supply pump. In this case, a duplex safety filter has to be placed in the circulation circuit before the engine. The absolute fineness of the safety filter is recommended to be maximum 60 µm and the flow rate the same as for the circulation oil pump.

The fuel oil filter should be based on heavy fuel oil of: 130 cSt at 80 °C = 700 cSt at 50 °C = 7,000 sec Redwood I/100 °F.

Fuel oil flow ....see 'Capacity of fuel oil circulating pump'
Working pressure ....10 bar
Test pressure.................... according to Class rule
Absolute fineness, maximum........................10 µm
Working temperature, maximum .... 150 °C
Oil viscosity at working temperature,
maximum ....20 cSt
Pressure drop at clean filter,
maximum ....0.3 bar
Filter to be cleaned at a pressure
drop of ....0.5 bar

Note:
Some filter makers refer the fineness of the filters to be 'nominal fineness'. Thus figures will be approximately 40% lower than the 'absolute fineness' (6 µm nominal).

The filter housing shall be fitted with a steam jacket for heat tracing.

Further information about cleaning heavy fuel oil and other fuel oil types is available in MAN Energy Solutions' most current Service Letters on this subject.

The Service Letters are available at www.marine.man-es.com → 'Two-Stroke' → 'Service Letters'.

Fuel oil filter (option)

Located as shown in drawing or alternatively in the supply circuit after the supply pumps. In this case, a duplex safety filter has to be placed in the circulation circuit before the engine, with an absolute fineness of maximum 60 µm.

Pipe diameter ‘D’ & ‘d’

The pipe (D) between the service tank and the supply pump is to have minimum 50% larger passage area than the pipe (d) between the supply pump and in the circulating pump. This ensures the best suction conditions for the supply pump (small pressure drop in the suction pipe).

Overflow Valve

See ‘List of Capacities’ (fuel oil supply oil pump).

Flushing of the fuel oil system

Before starting the engine for the first time, the system on board has to be flushed in accordance with MAN Energy Solutions recommendations:

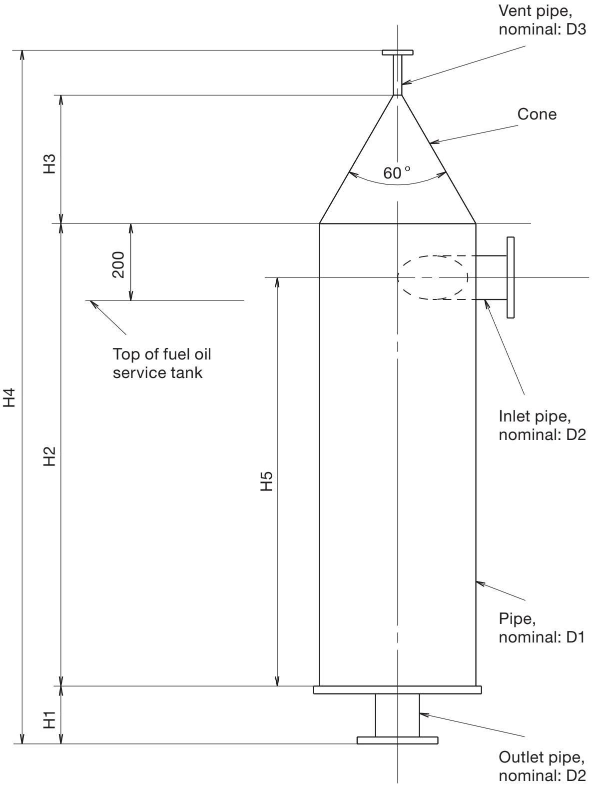
Flushing of Fuel Oil System

which is available from MAN Energy Solutions, Co-penhagen.

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.

The venting tank has to be placed at the top service tank. If the venting tank is placed below the top of the service tank, the drain pipe from the automatic venting valve has to be led to a tank placed lower than the venting valve. The lower tank can be a ‘Fuel oil over flow tank’, if this tank has venting to deck.



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

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Fig. 07.05.02: Fuel oil venting box

Cooling of Distillate Fuels

The external fuel systems (supply and circulating systems) have a varying effect on the heating of the fuel and, thereby, the viscosity of the fuel when it reaches the engine inlet.

Today, external fuel systems on-board are often designed to have an optimum operation on HFO, which means that the temperature is kept high.

For low-viscosity distillate fuels like marine diesel oil (MDO) and marine gas oil (MGO), however, the temperature must be kept as low as possible in order to ensure a suitable viscosity at engine inlet.

Fuel oil viscosity at engine inlet

The recommended fuel viscosity range for MAN B&W two-stroke engines at engine inlet is listed in Table 7.05.03.

The lower fuel viscosity limit is 2 cSt

However, 3 cSt or higher is preferable as this will minimise the risk of having problems caused by wear for instance.

For low-viscosity fuel grades, care must be taken not to heat the fuel too much and thereby reduce the viscosity.

Range	Fuel viscosity at engine inlet, cSt
Minimum	2
Normal, distillate	3 or higher
Normal, HFO	10-15
Maximum	20

Table 7.05.03: Recommended fuel viscosity at engine inlet

Information about temperature – viscosity relationship of marine fuels is available in our publication:

Guidelines for Operation on Fuels with less than 0.1% Sulphur, SL2014-593

The publication is available at www.marine.man-es.com → 'Two-Stroke' → 'Service Letters'.

Impact of fuel viscosity on engine operation

Many factors influence the actually required minimum viscosity tolerance during start-up and low-load operation:

- engine condition and maintenance
- fuel pump wear
- engine adjustment (mainly starting index)
- actual fuel temperature in the fuel system.

Although achievable, it is difficult to optimise all of these factors at the same time. This situation complicates operation on fuels in the lowest end of the viscosity range.

Fuel oil cooler

To build in some margin for safe and reliable operation and to maintain the required viscosity at engine inlet, installation of a cooler will be necessary as shown in Fig. 7.01.01.

Viscosity requirements of fuel pumps etc.

The fuel viscosity does not only affect the engine. In fact, most pumps in the external system (supply pumps, circulating pumps, transfer pumps and feed pumps for the separator) also need viscosities above 2 cSt to function properly.

MAN Energy Solutions recommends contacting the actual pump maker for advice.

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, moment compensator, torsional vibration damper, exhaust valve and Hydraulic Cylinder Unit.

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 various turbocharger makes.

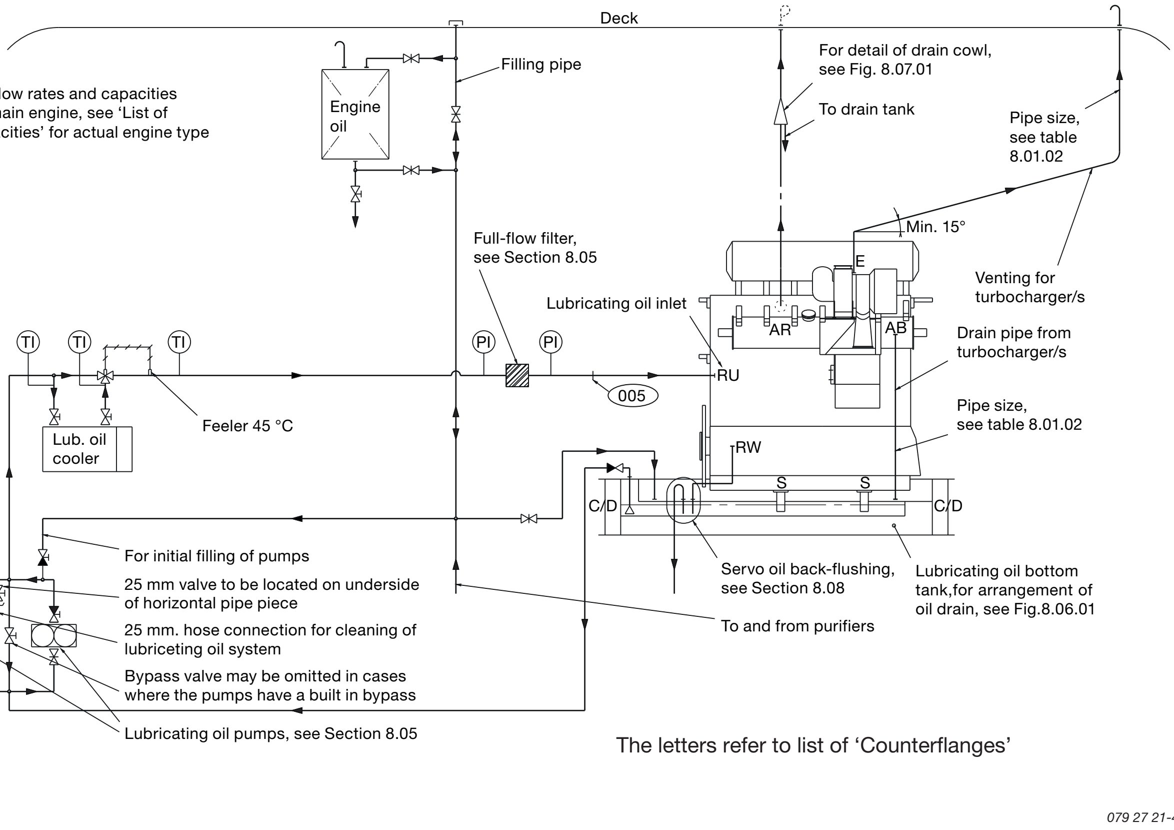

Fig. 8.01.01 Lubricating and cooling oil system

Turbocharger venting and drain pipes

MAN

Type	No. of TC	Venting pipeDrain		
		Each TC DN	Collect TC DN	Pipe from TC DN
TCR22	1	50	50	65
TCA44	1	65	65	65
	2	65	100	100
TCA55	1	65	65	65
	2	65	100	100
TCA66	1	80	80	80
	2	80	125	125
TCA77	1	100	100	100
	2	100	125	125
TCA88	1	125	125	125
	2	125	150	150
	3	125	200	200
	4	125	250	250

ABB

Type	No. of TC	Venting pipeDrain		
		Each TC DN	Collect TC DN	Pipe from TC DN
A165-L A265-L	1	60	65	65
	2	60	80	80
A170-L A270-L	1	65	65	65
	2	65	90	90
A175-L A275-L	1	65	65	65
	2	65	100	100
	3	65	125	125
A180-L A280-L	1	80	80	80
	2	80	100	100
	3	80	125	125
A185-L A285-L	1	80	80	80
	2	80	125	125
	3	80	150	150
	4	80	150	150
A190-L A290-L	1	80	80	80
	2	80	125	125
	3	80	150	150
	4	80	175	175
A195-L A295-L *)	1	80	90	90
	2	80	125	125
	3	80	150	150
	4	80	175	175

Table. 8.01.02: Turbocharger venting and drain pipes

Mitsubishi (MHI)

Type	No. of TC	Venting pipeDrain		
		Each TC DN	Collect TC DN	Pipe from TC DN
MET33	1	40	40	65
	2	40	80	90
MET42	1	50	50	80
	2	50	65	125
MET53	1	65	65	90
	2	65	80	125
	3	65	100	150
MET66	1	80	80	100
	2	80	100	150
	3	80	125	175
	4	80	150	225
MET71	1	80	80	125
	2	80	100	175
	3	80	125	225
	4	80	150	300
MET83	1	100	100	125
	2	100	125	175
	3	100	150	225
	4	100	175	300
MET90	1	100	100	125
	2	100	125	175
	3	100	150	225
	4	100	175	300

For size of turbocharger inlet pipe see ‘List of capacities’

**) Preliminary*

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Hydraulic Power Supply Unit

Hydraulic power for the ME hydraulic-mechanical system for activation of the fuel injection and the exhaust valve is supplied by the Hydraulic Power Supply (HPS) unit.

As hydraulic medium, normal lubricating oil is used, as standard taken from the engine's main lubricating oil system and filtered in the HPS unit.

HPS connection to lubrication oil system

Internally on the engine, the system oil inlet RU is connected to the HPS unit which supplies the hydraulic oil to the Hydraulic Cylinder Units (HCUs). See Figs. 16.01.02a and 16.01.02b.

RW is the oil outlet from the automatic backflushing filter.

The hydraulic oil is supplied to the Hydraulic Cylinder Units (HCU) located at each cylinder. From here the hydraulic oil is diverted to the multi-way valves, which perform the fuel injection and open the exhaust valve respectively: Electronic Fuel Injection (ELFI or FIVA) and Electronic exhaust Valve Actuation (ELVA/PEVA or FIVA). The exhaust valve is closed by the conventional 'air spring'.

The electronic signals to the multi-way valves are given by the Engine Control System, see Chapter 16, Engine Control System (ECS).

HPS configurations

The HPS pumps are driven either mechanically by the engine (via a step-up gear from the crankshaft) or electrically.

The HPS unit is mounted on the engine no matter how its pumps are driven.

With mechanically driven pumps, the HPS unit consists of:

- an automatic and a redundant filter
- three to five engine driven main pumps
- two electrically driven start-up pumps
- a safety and accumulator block

as shown in Fig. 8.02.01.

With electrically driven pumps, the HPS unit differs in having a total of three pumps which serve as combined main and start-up pumps.

Motor start method

Direct Online Start (DOL) is required for all the electric motors for the pumps for the Hydraulic Power Supply (HPS) to ensure proper operation under all conditions, including the start up against maximum pressure in the system.

HPS unit types

Altogether, three HPS configurations are available:

- STANDARD mechanically driven HPS, EoD: 4 40 160, with mechanically driven main pumps and start-up pumps with capacity sufficient to deliver the start-up pressure only. The engine cannot run with all engine driven main pumps out of operation, whereas 66% engine load is available in case one main pump is out

- COMBINED mechanically driven HPS unit, EoD: 4 40 167 with electrically driven start-up pumps with back-up capacity. In this case, at least 15% engine power is available as back-up power if all engine driven pumps are out

- electrically driven HPS, EoD: 4 40 161, with 66% engine load available in case one pump is out.

The electric power consumption of the electrically driven pumps should be taken into consideration in the specification of the auxilliary machinery capacity.

Hydraulic Power Supply Unit, Engine Driven, and Lubricating Oil Pipes

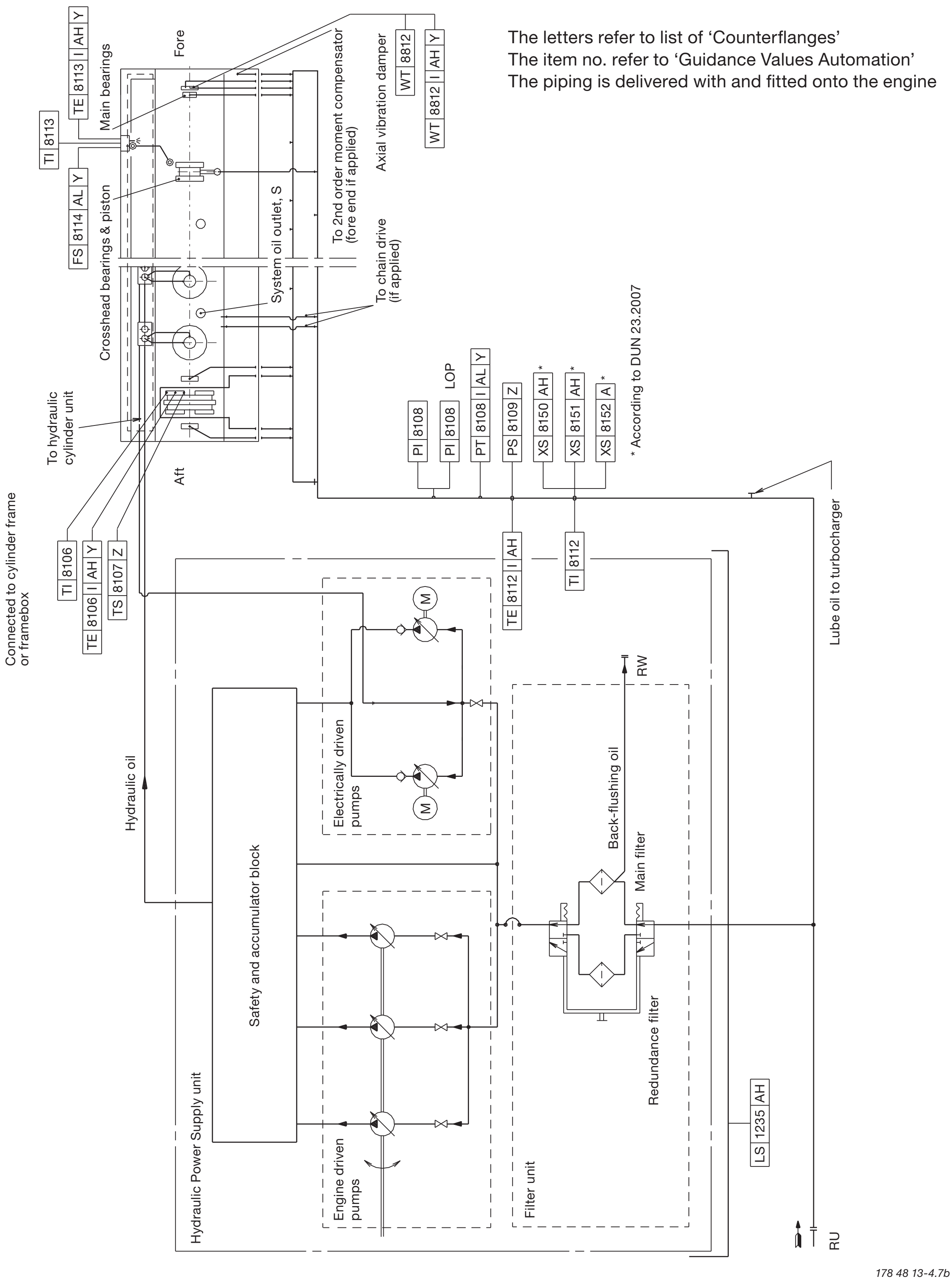

Fig. 8.02.01: Engine driven hydraulic power supply unit and lubricating oil pipes

Lubricating Oil Pipes for Turbochargers

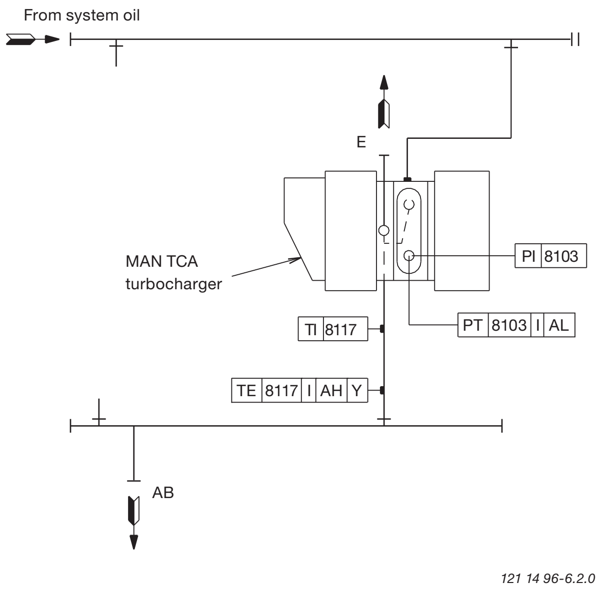

Fig. 8.03.01: MAN turbocharger type TCA

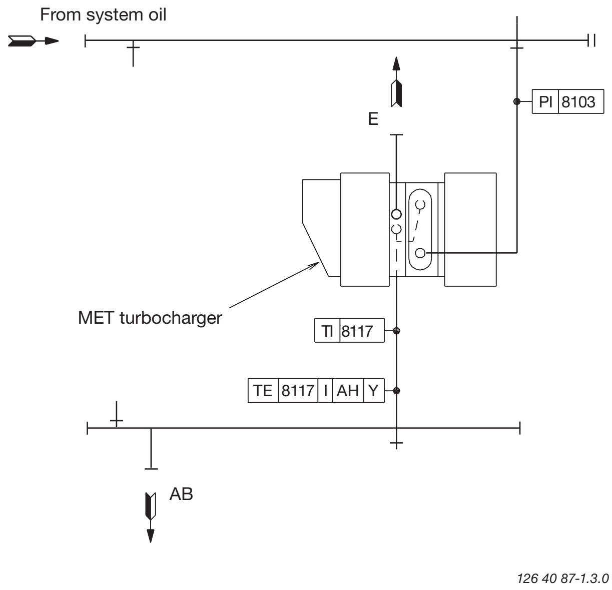

Fig. 8.03.02: Mitsubishi turbocharger type MET

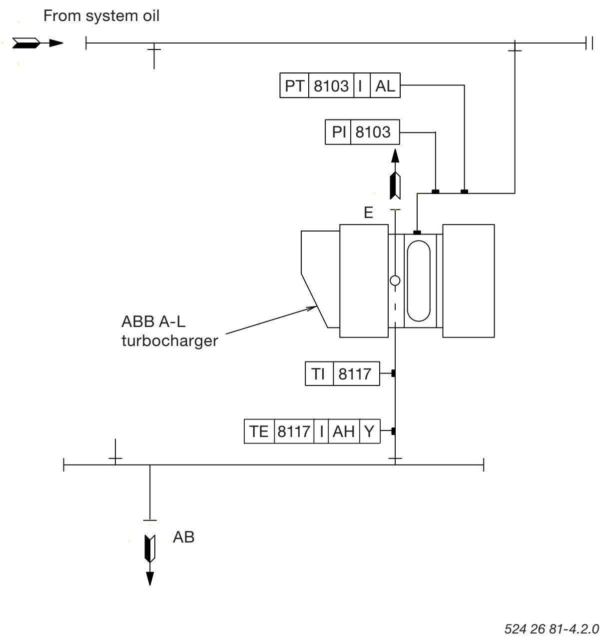

Fig. 8.03.03: ABB turbocharger type A-L

Lubricating Oil Consumption, Centrifuges and List of Lubricating Oils

Lubricating oil consumption

The system oil consumption from the ship's system oil plant depends on factors like back flushing from the purifiers and drain from stuffing boxes.

Furthermore, the consumption varies for different engine sizes as well as operational and maintenance patterns.

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-es.com → 'Two-Stroke' → 'Technical Papers'.

Recommendations regarding engine lubrication is available in MAN Energy Solutions' most current Service Letters on this subject.

The Service Letters are available at www.marine.man.es.com → 'Two-Stroke' → 'Service Letters'.

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 Energy Solutions 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.

Company	**Circulating oil SAE 30, BN 5 - 10**
Aegean	Alfasys 305
Castrol	CDX 30
Chevron	Veritas 800 Marine 30
ExxonMobil	Mobilgard 300
Gulf Oil Marine	GulfSea Superbear 3006
Indian Oil Corp.	Servo Marine 0530
JX Nippon Oil & Energy	Marine S30
Lukoil	Navigo 6 SO
Shell	Melina S 30
Sinopec	System Oil 3005
Total	Atlanta Marine D3005

Do not consider the list complete, as oils from other companies can be equally suitable. Further information can be obtained from the engine builder or MAN Energy Solutions, 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 ....4.5 bar
Delivery pressure ....4.5 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........................4.5 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 ....4.5 bar
Test pressure.....................according to class rules
Absolute fineness...50 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 35 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 Energy Solutions 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 by-pass the main engine oil system. Through tem-porary piping and/or hosing, the oil is circulated through the vessel's system and directly back to the main engine oil sump tank.

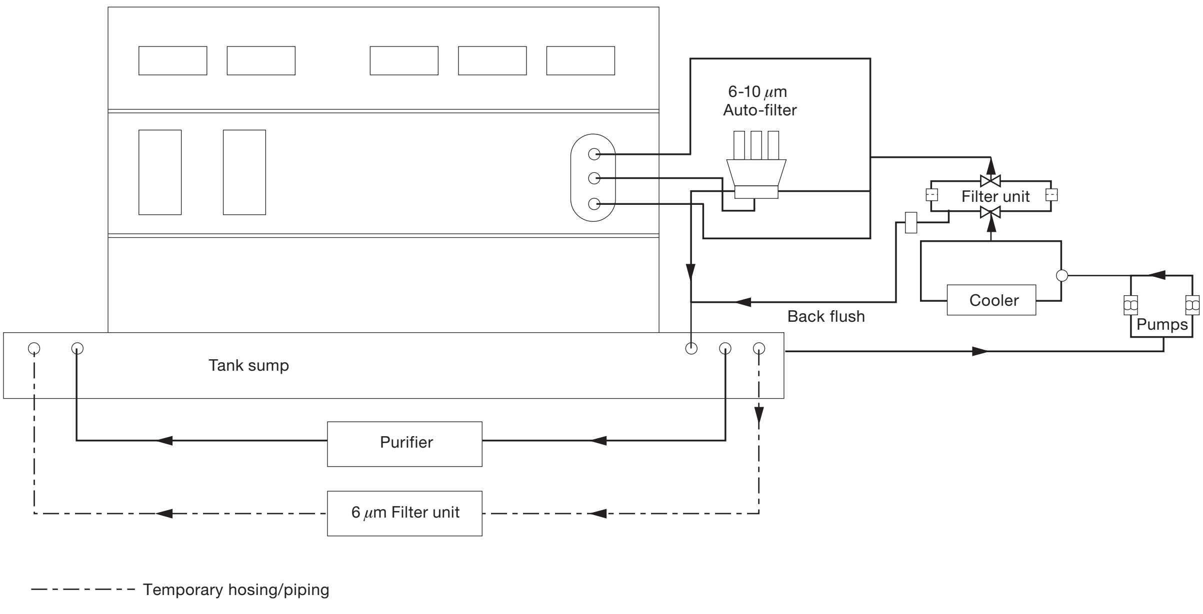

Fig. 8.05.01: Lubricating oil system with temporary hosing/piping for flushing at the shipyard

If the system has been out of operation, un-used 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 dur-ing 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 f lushing log**
  MAN Energy Solutions 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 Energy Solutions. 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 Energy Solutions 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 Energy Solutions.

- **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 Energy Solutions.

Lubricating oil outlet

A protecting ring position 1-4 is to be installed if required, by class rules, and is placed loose on the tanktop and guided by the hole in the flange.

In the vertical direction it is secured by means of screw position 4, in order to prevent wear of the rubber plate.

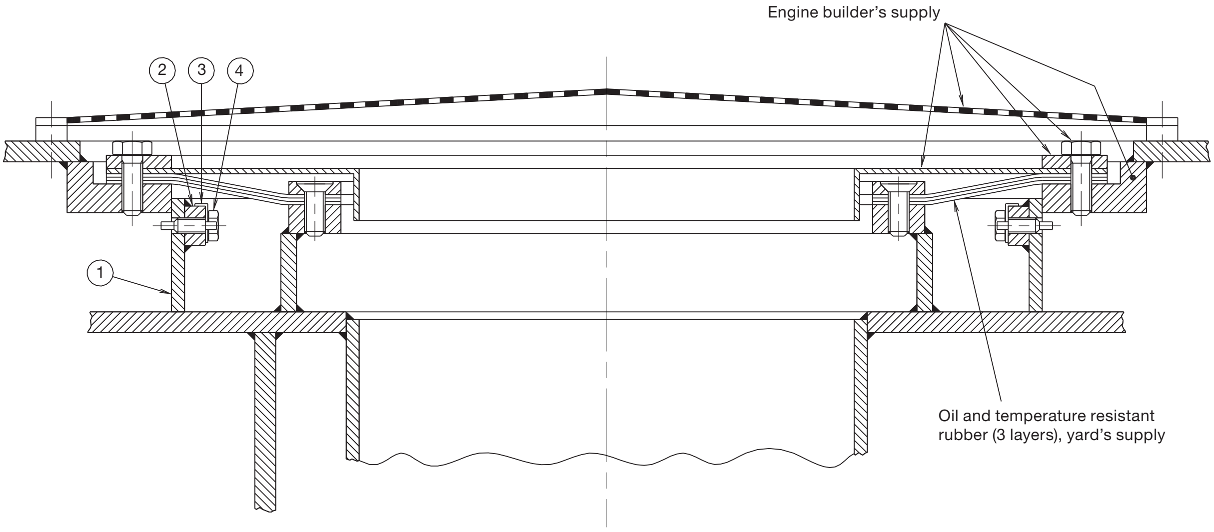

Fig. 8.05.02: Lubricating oil outlet

Lubricating Oil Tank

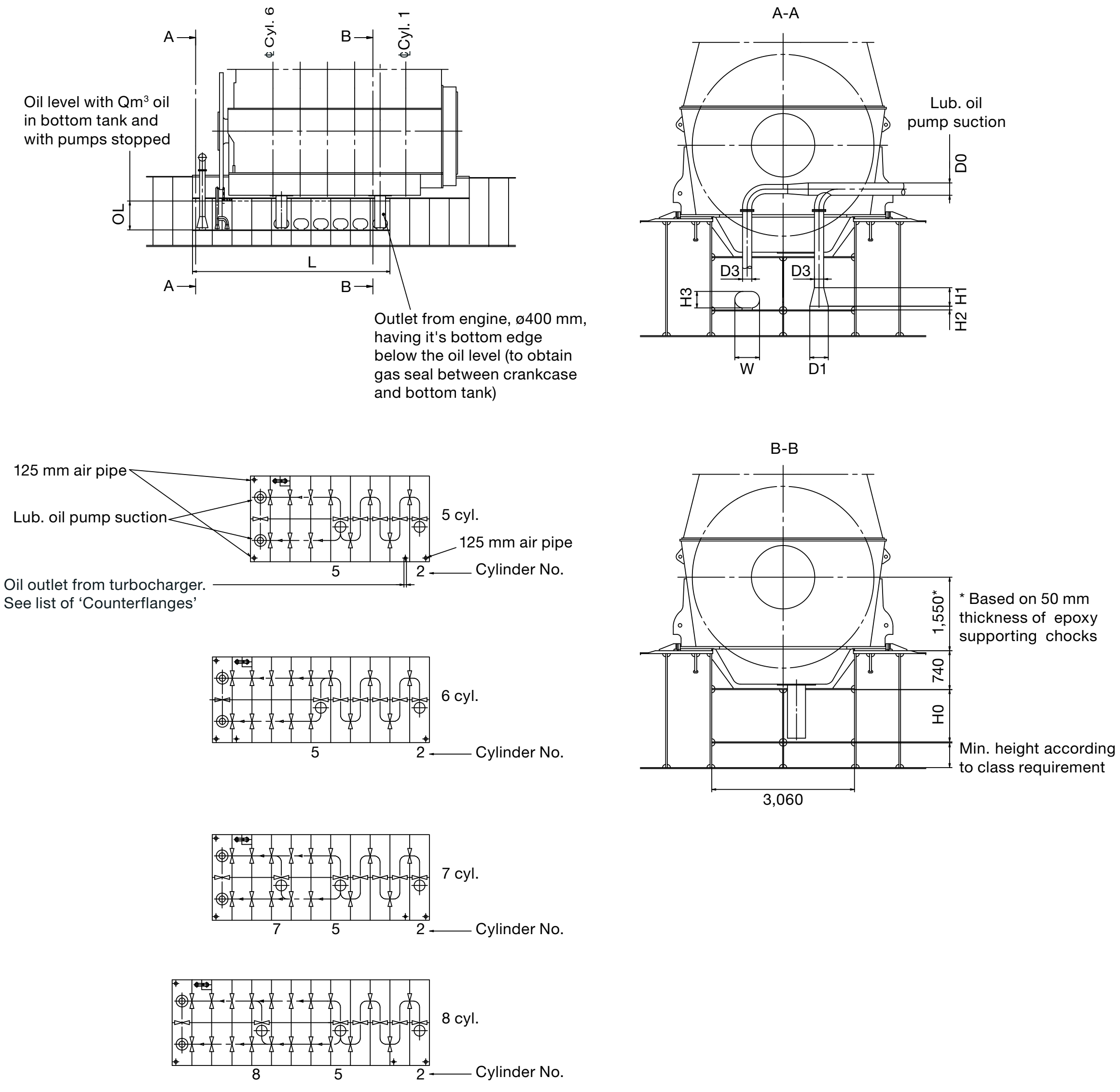

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Fig. 8.06.01a: Lubricating oil tank, with cofferdam

Note:
When calculating the tank heights, allowance has not been made for the possibility that a quantity of oil in the lubricating oil system outside the engine may be returned to the bottom tank, when the pumps are stopped.

If the system outside the engine is so designed that an amount of the lubricating oil is drained back to the tank, when the pumps are stopped, the height of the bottom tank indicated in Table 8.06.01b has to be increased to include this quantity.

Cylinder No.	Drain at cyl. No.	D0	D1	D3	H0	H1	H2	H3	W	L	OL	Qm^3
5	2-5	250	2×375	2×175	950	375	75	400	500	7,200	850	18.7
6	2-5	275	2×425	2×200	1,015	425	85	400	500	8,000	915	22.4
7	2-5-7	275	2×425	2×200	1,050	425	85	400	500	8,800	950	25.6
8	2-5-8	300	2×450	2×225	1,120	450	90	400	600	10,400	1,020	32.5

Table 8.06.01b: Lubricating oil tank, with cofferdam

If space is limited, however, other solutions are possible. Minimum lubricating oil bottom tank volume (m^3) is:

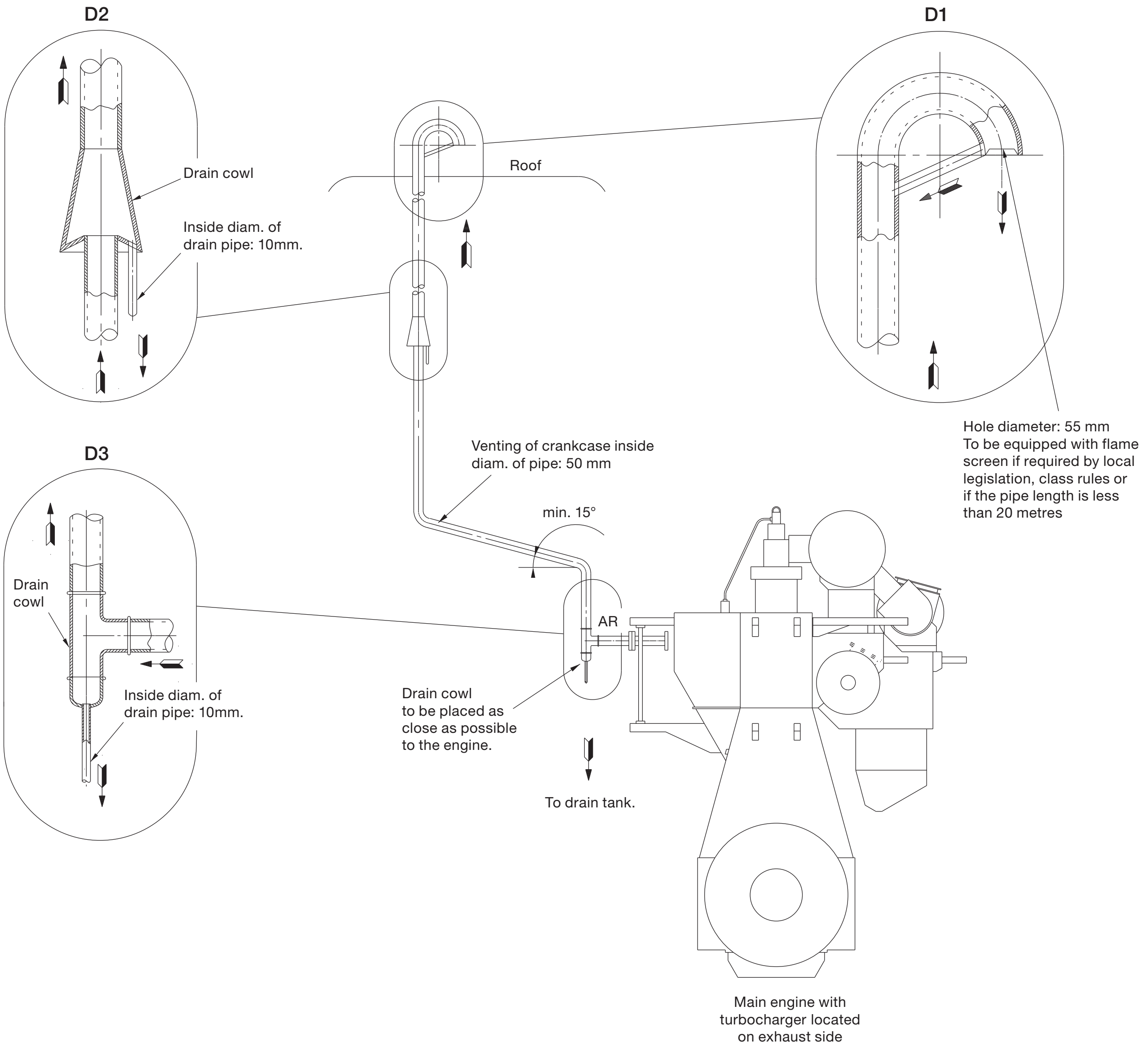
5 cyl.	6 cyl.	7 cyl.	8 cyl.
14.7	17.7	20.5	23.8

Lubricating oil tank operating conditions

The lubricating oil bottom tank complies with the rules of the classification societies by operation under the following conditions:

Angle of inclination, degrees			
Athwartships		Fore and aft	
Static	Dynamic	Static	Dynamic
15	22.5	5	7.5

Crankcase Venting



The venting pipe has to be equipped with a drain cowl as shown in detail D2 and D3.
Note that only one of the above solutions should be chosen.

Fig. 8.07.01: Crankcase venting

Bedplate Drain Pipes

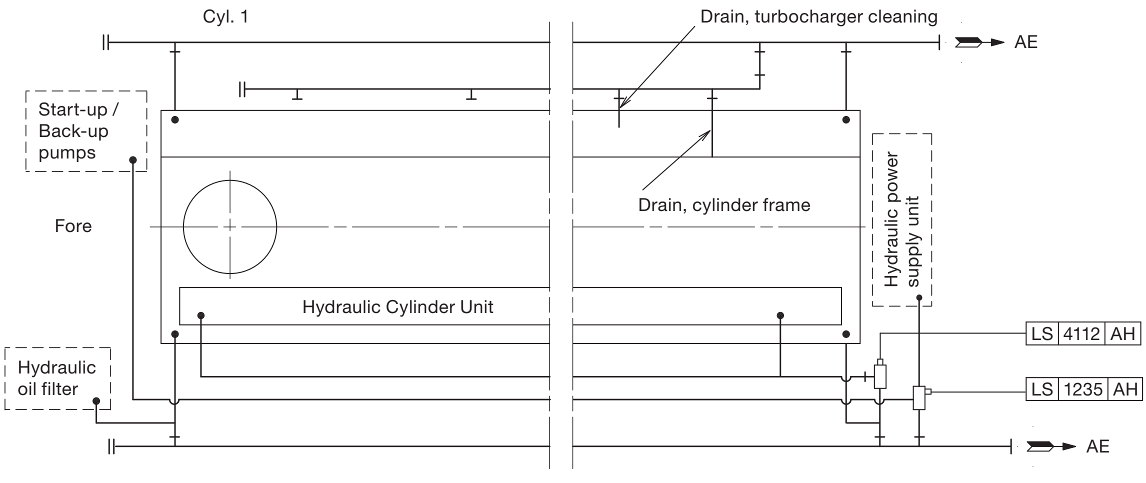


Fig. 8.07.02: Bedplate drain pipes, aft-mounted HPS

Engine and Tank Venting to the Outside Air

Venting of engine plant equipment separately

The various tanks, engine crankcases and turbochargers should be provided with sufficient venting to the outside air.

MAN Energy Solutions 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 Energy Solutions, Copenhagen.

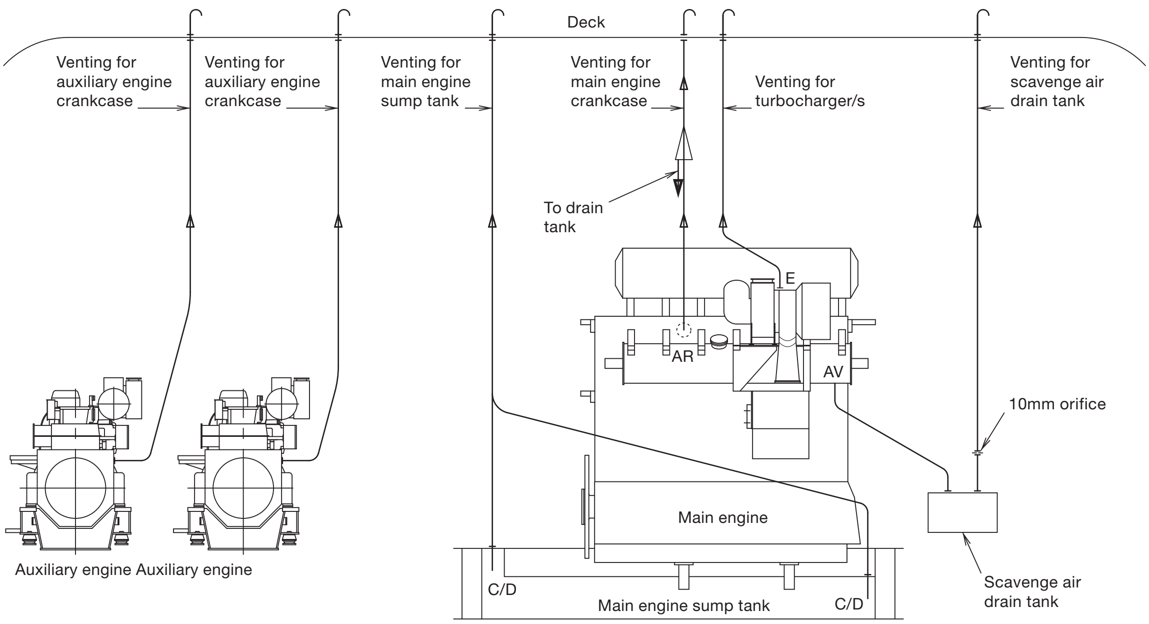


Fig. 8.07.03a: Separate venting of all systems directly to outside air above deck

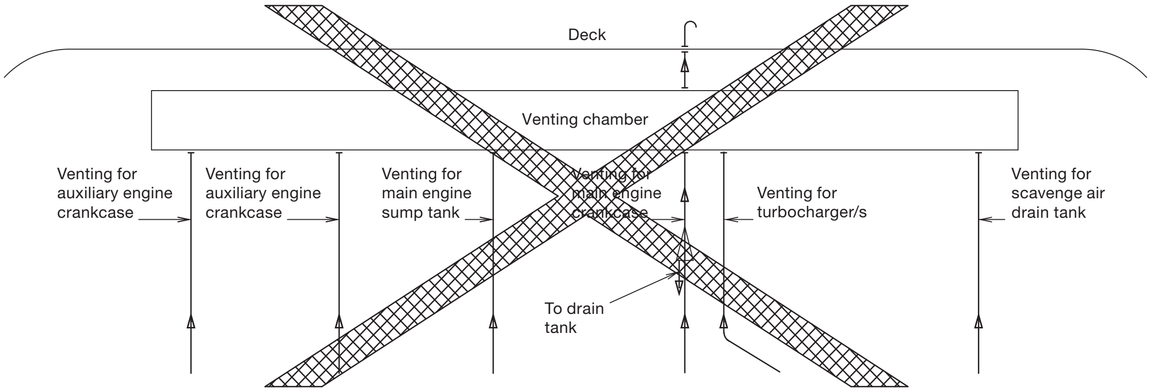


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*Fig. 8.07.03b: Venting through a common venting chamber is **not recommended***

Hydraulic Oil Back-flushing

The special suction arrangement for purifier suction in connection with the ME engine (Integrated system).

The back-flushing oil from the self cleaning 6 µm hydraulic control oil filter unit built onto the engine is contaminated and it is therefore not expedient to lead it directly into the lubricating oil sump tank.

The amount of back-flushed oil is large, and it is considered to be too expensive to discard it. Therefore, we suggest that the lubricating oil sump tank is modified for the ME engines in order not to have this contaminated lubricating hydraulic control oil mixed up in the total amount of lubricating oil. The lubricating oil sump tank is designed with a small 'back-flushing hydraulic control oil drain tank' to which the back-flushed hydraulic control oil is led and from which the lubricating oil purifier can also suck.

This is explained in detail below and the principle is shown in Fig. 8.08.01. Three suggestions for the arrangement of the drain tank in the sump tank are shown in Fig. 8.08.02 illustrates another suggestion for a back-flushing oil drain tank.

The special suction arrangement for the purifier is consisting of two connected tanks (lubricating oil sump tank and back-flushing oil drain tank) and of this reason the oil level will be the same in both tanks, as explained in detail below.

The oil level in the two tanks will be equalizing through the 'branch pipe to back-flushing oil drain tank', see Fig. 8.08.01. As the pipes have the same diameters but a different length, the resistance is larger in the 'branch pipe to back-flushing oil drain tank', and therefore the purifier will suck primarily from the sump tank.

The oil level in the sump tank and the back-flushing oil drain tank will remain to be about equal because the tanks are interconnected at the top.

When hydraulic control oil is back-flushed from the filter, it will give a higher oil level in the back-flushing hydraulic control oil drain tank and the purifier will suck from this tank until the oil level is the same in both tanks. After that, the purifier will suck from the sump tank, as mentioned above.

This special arrangement for purifier suction will ensure that a good cleaning effect on the lubrication oil is obtained.

If found profitable the back-flushed lubricating oil from the main lubricating oil filter (normally a 50 or 40 µm filter) can also be returned into the special back-flushing oil drain tank.

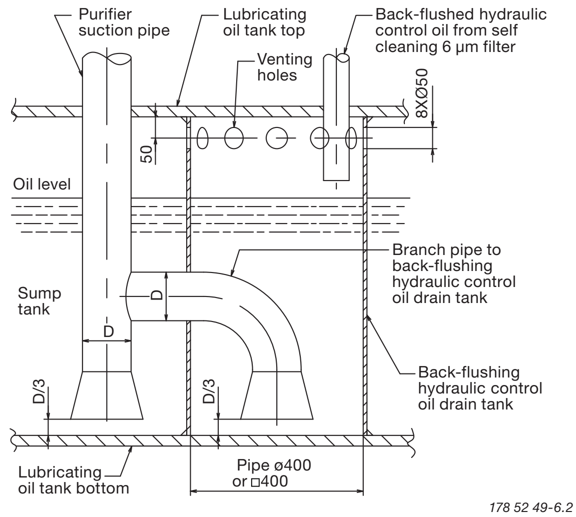


Fig. 8.08.01: Back-flushing servo oil drain tank

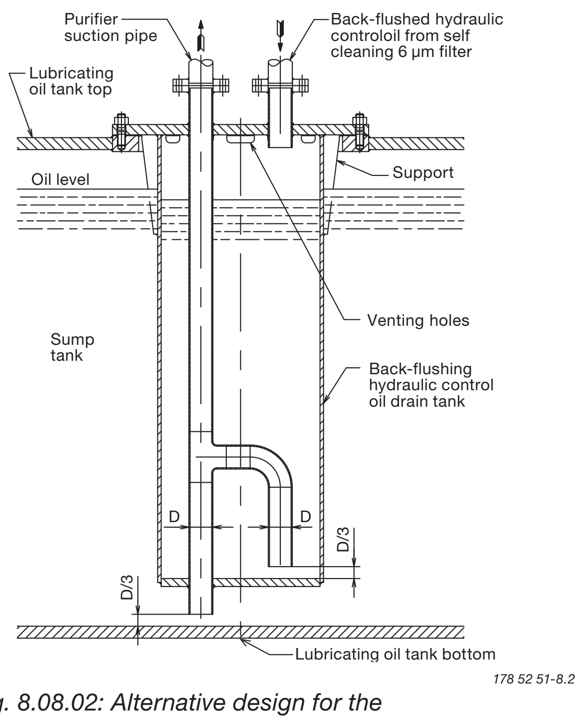


Fig. 8.08.02: Alternative design for the back-flushing servo oil drain tank

Separate System for Hydraulic Control Unit

As an option, the engine can be prepared for the use of a separate hydraulic control oil system Fig. 8.09.01.

The separate hydraulic control oil system can be built as a unit, or be built streamlined in the engine room with the various components placed and fastened to the steel structure of the engine room.

The design and the dimensioning of the various components are based on the aim of having a reliable system that is able to supply low-pressure oil to the inlet of the engine-mounted high-pressure hydraulic control oil pumps at a constant pressure, both at engine stand-by and at various engine loads.

Cleanliness of the hydraulic control oil

The hydraulic control oil must fulfil the same cleanliness level as for our standard integrated lube/cooling/hydraulic-control oil system, i.e. ISO 4406 XX/16/13 equivalent to NAS 1638 Class 7.

Information and recommendations regarding flushing, the specified cleanliness level and how to measure it, and how to use the NAS 1638 oil cleanliness code as an alternative to ISO 4406, are available fromMAN Energy Solutions.

Control oil system components

The hydraulic control oil system comprises:
1 Hydraulic control oil tank
2 Hydraulic control oil pumps (one for stand-by)
1 Pressure control valve
1 Hydraulic control oil cooler, water-cooled by the low temperature cooling water
1 Three-way valve, temperature controlled
1 Hydraulic control oil filter, duplex type or automatic self-cleaning type
1 Hydraulic control oil fine filter with pump
1 Temperature indicator
1 Pressure indicator
2 Level alarms
Valves and cocks
Piping.

Hydraulic control oil tank

The tank can be made of mild steel plate or be a part of the ship structure.

The tank is to be equipped with flange connections and the items listed below:
1 Oil filling pipe
1 Outlet pipe for pump suctions
1 Return pipe from engine
1 Drain pipe
1 Vent pipe.

The hydraulic control oil tank is to be placed at least 1 m below the hydraulic oil outlet flange, RZ.

Hydraulic control oil pump

The pump must be of the displacement type (e.g. gear wheel or screw wheel pump).

The following data is specified in Table 8.09.02:
- Pump capacity
- Pump head
- Delivery pressure
- Working temperature
- Oil viscosity range.

Pressure control valve

The valve is to be of the self-operating flow controlling type, which bases the flow on the pre-defined pressure set point. The valve must be able to react quickly from the fully-closed to the fully-open position (t_{max}= 4 sec), and the capacity must be the same as for the hydraulic control oil low-pressure pumps. The set point of the valve has to be within the adjustable range specified in a separate drawing.

The following data is specified in Table 8.09.02:
- Flow rate
- Adjustable differential pressure range across the valve
- Oil viscosity range.

Hydraulic control oil cooler

The cooler must be of the plate heat exchanger or shell and tube type.

The following data is specified in Table 8.09.02:
- Heat dissipation
- Oil flow rate
- Oil outlet temperature
- Maximum oil pressure drop across the cooler
- Cooling water flow rate
- Water inlet temperature
- Maximum water pressure drop across the cooler.

Temperature controlled three-way valve

The valve must act as a control valve, with an external sensor.

The following data is specified in Table 8.09.02:
- Capacity
- Adjustable temperature range
- Maximum pressure drop across the valve.

Hydraulic control oil filter

The filter is to be of the duplex full flow type with manual change over and manual cleaning or of the automatic self cleaning type.

A differential pressure gauge is fitted onto the filter.

The following data is specified in Table 8.09.02:
- Filter capacity
- Maximum pressure drop across the filter
- Filter mesh size (absolute)
- Oil viscosity
- Design temperature.

Off-line hydraulic control oil fine filter / purifier

Shown in Fig. 8.09.01, the off-line fine filter unit or purifier must be able to treat 15-20% of the total oil volume per hour.

The fine filter is an off-line filter and removes metallic and non-metallic particles larger than 0,8 μm as well as water and oxidation **residues**. The filter has a pertaining pump and is to be fitted on the top of the hydraulic control oil tank.

A suitable fine filter unit is:
Make: CJC, C.C. Jensen A/S, Svendborg, Denmark - www.cjc.dk.

For oil volume <10,000 litres:
HDU 27/-MZ-Z with a pump flow of 15-20% of the total oil volume per hour.

For oil volume >10,000 litres:
HDU 27/-GP-DZ with a pump flow of 15-20% of the total oil volume per hour.

Temperature indicator

The temperature indicator is to be of the liquid straight type.

Pressure indicator

The pressure indicator is to be of the dial type.

Level alarm

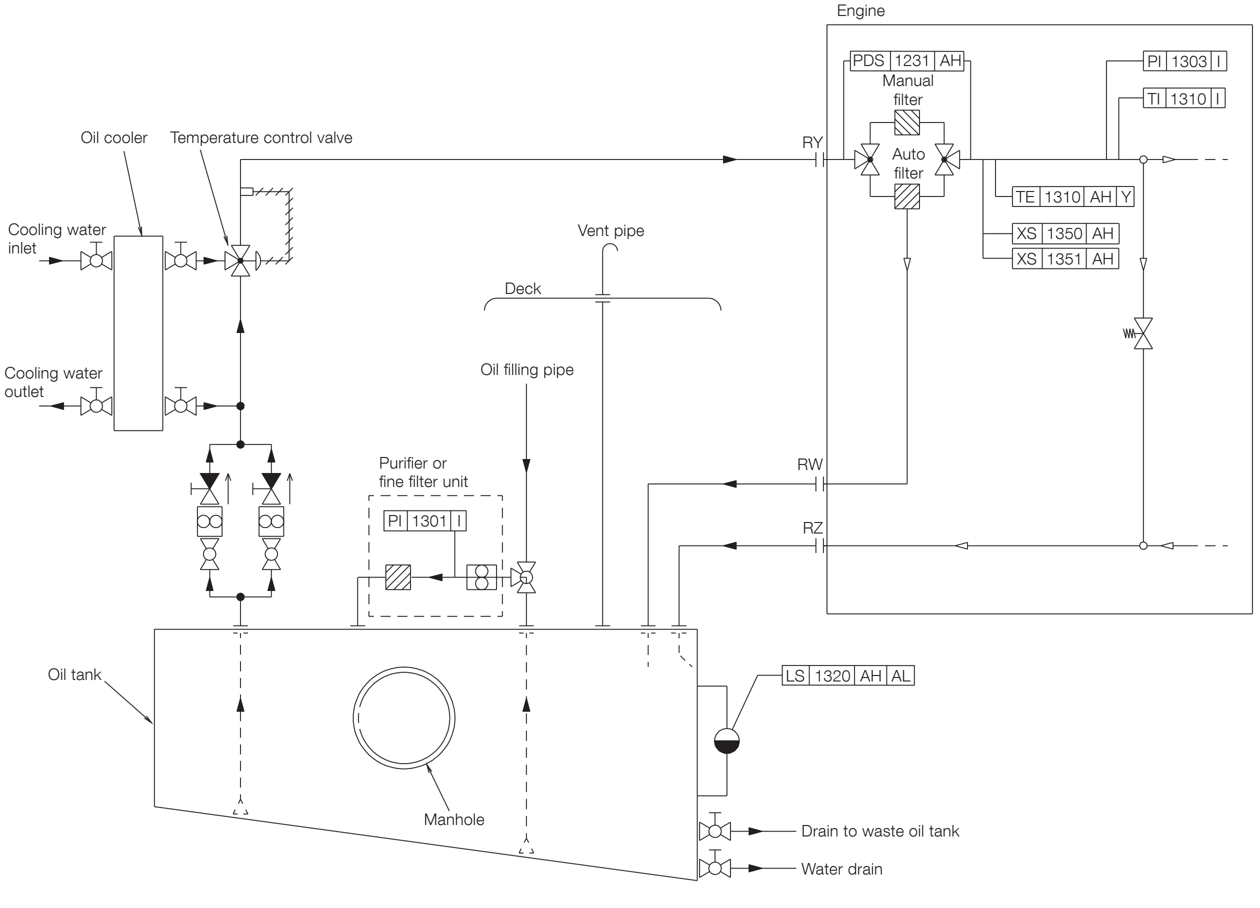
The hydraulic control oil tank has to have level alarms for high and low oil level.

Piping

The pipes can be made of mild steel.

The design oil pressure is to be 10 bar.

The return pipes are to be placed vertical or laid with a downwards inclination of minimum 15°.



The letters refer to list of 'Counterflanges'

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Fig. 8.09.01: Hydraulic control oil system, manual filter

Hydraulic Control Oil System Capacities, G60ME-C9

Cylinder no.		**5**	**6**	**7**	**8**
	r/min	97	97	97	97
	kW	13,400	16,080	18,760	21,440
Hydraulic Control Oil tank:					
Volumen, approx.	m³	1.5	2.0	2.0	2.5
Hydraulic Control Oil Pump					
Pump capacity	m³/h	20	25	25	30
Pump head	bar	4	4	4	4
Delivery pressure	bar	4	4	4	4
Design temperature	°C	70	70	70	70
Oil viscosity range	cSt	15 - 90	15 - 90	15 - 90	15 - 90
Pressure control valve					
Lubricating oil flow	m³/h	20	25	25	30
Adjustable pressure	bar	2 - 4	2 - 4	2 - 4	2 - 4
Design temperature	°C	55	55	55	55
Oil viscosity range	cSt	15 - 90	15 - 90	15 - 90	15 - 90
Hydraulic Control Oil Cooler					
Heat dissipation	kW	85	100	120	135
Lubricating oil flow	m³/h	20	25	25	30
Oil outlet temperature	°C	45	45	45	45
Oil pressure drop, max	bar	0.5	0.5	0.5	0.5
Cooling water flow	m³/h	13	15	18	20
S.W. inlet temperature	°C	32	32	32	32
F.W. inlet temperature	°C	36	36	36	36
Water pressure drop, max	bar	0.2	0.2	0.2	0.2
Temperature Controlled Three-way Valve					
Lubricating oil flow	m³/h	20	25	25	30
Adjustable temp. range	°C	2 - 4	2 - 4	2 - 4	2 - 4
Design temperature	°C	70	70	70	70
Oil pressure drop, max	bar	0.3	0.3	0.3	0.3
Hydraulic Control Oil Filter					
Lubricating oil flow	m³/h	20	25	25	30
Absolute fineness	μm	6	6	6	6
Design temperature	°C	55	55	55	55
Design pressure	bar	4	4	4	4
Oil pressure drop, max	bar	0.3	0.3	0.3	0.3

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Fig. 8.09.02: Hydraulic control oil system capacities

Cylinder Lubrication

9

Cylinder Lubricating Oil System

The cylinder oil lubricates the cylinder and piston. The oil is used in order to reduce friction, introduce wear protection and inhibit corrosion. It cleans the engine parts and keep combustion products in suspension.

Cylinder lubricators

Each cylinder liner has a number of lubricating quills, through which oil is introduced from the MAN B&W Alpha Cylinder Lubricators, see Section 9.02.

The oil is pumped into the cylinder (via non-return valves) when the piston rings pass the lubricating orifices during the upward stroke.

The control of the lubricators is integrated in the ECS system. An overview of the cylinder lubricating oil control system is shown in Fig. 9.02.02b.

Cylinder lubrication strategy

The general lubrication strategy is to match the cylinder oil with the fuel. Tabel 9.01.01 gives a general overview of cylinder oils When operating on liquid natural gas (LNG), ethane or methanol, the same cylinder oil is used as for ULSFO to LFSO operation. For specific lubrication guidelines, please refer to the most recent lubrication guideline for your specific engine type, e.g. service letters and circular letters. Service letters are publicly available . Circular letters are only distributed to customers that have the specific engine type/s dealt with in the specific letter.

MAN Energy Solutions recommends using cylinder lubricating oils characterised primarily by their Base Number (BN) and SAE viscosity and to use a feed rate according to the cylinder oil's BN and the fuel's sulphur content.

The BN is a measure of the neutralization capacity of the oil. What BN level to use depends on the sulphur content of the fuel.

In short, MAN Energy Solution recommends the use of cylinder oils with the following main properties:

- Kinematic viscosity: min. 18.5 cSt at 100° C
  max. 21.9 cSt at 100° C
- BN 100 - 140 high sulphur heavy fuel oil over 1%
- BN 15 - 40 for ultra to low-sulphur fuel (< 1% S)
- BN 15 - 40 when operating on LNG, LPG, ethane and methanol.

BN 15 - 40 are low-BN cylinder lubricating oils, currently available to the market in the BN levels 16, 25 and 40. However, development continues and in the future there could be oils with other BN levels. Good performance of the low-BN oil is the most important factor for deciding.

Engine type		Two-stroke		
Engine design		≤ Mark 7		≥ Mark 8
Optimised for improved fuel consumption: Part- load optimised and derated engines		No	Yes	Base design
Cylinder oil	Ultra- to low-S fuel	15-40 BN	15-40 BN	15-40 BN
	High-S fuel	70 BN	70-100 BN	100-140 BN

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Tabel 9.01.01: General overview of cylinder oils

Two-tank cylinder oil supply system

Supporting the cylinder lubrication strategy for MAN B&W engines to use two different BN cylinder oils according to the applied fuel sulphur content, storage and settling tanks should be arranged for the two cylinder oils separately.

A traditional cylinder lubricating oil supply system with separate storage and service tanks for high- and low-BN cylinder oils is shown in Fig. 9.02.02a. The alternative layout for the automated cylinder oil mixing (ACOM) system described below is shown in Fig. 9.02.02b.

Cylinder oil feed rate (dosage)

The minimum feed rate is 0.6 g/kWh and this is the amount of oil that is needed to lubricate all the parts sufficiently. Continuously monitoring of the cylinder condition and analysing drain oil samples are good ways to optimise the cylinder oil feed rate and consumption and to safeguard the engine against wear.

Adjustment of the cylinder oil dosage to the sulphur content in the fuel being burnt is explained in Section 9.02.

Further information about cylinder lubrication is available in MAN Energy Solutions' most current Service Letters on this subject.

The Service Letters are available at www.marine.man-es.com → 'Two-Stroke' → 'Service Letters'.

Adaptation of cylinder BN to the sulphur level

Matching the actual sulphur content to the right lube oil according to the engine type and operating pattern is a key factor in achieving efficient lubrication. Furthermore, the increasing use of ultra-low-sulphur oils in both fuel oil and gas engines makes it recommendable to faster adapt the cylinder oil BN (base number) to the sulphur level actually used.

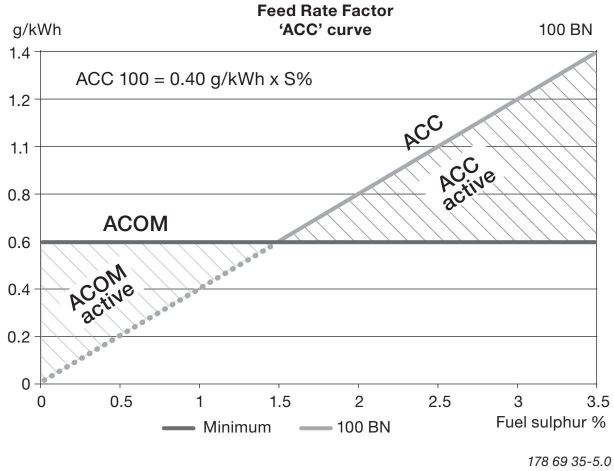

Fig. 9.01.01: Mixing principle, ACOM

Automated cylinder oil mixing system (ACOM)

The automated cyloinder oil mixing (ACOM) is a cylinder oil delivery system which automatically mixes to two fully formulated cylinder oils to the optimum BN depending on the sulphur in the fuel. Serveral lube oil suppliers are testing and have finished the tsting of their oil in the ACOM system. Table 9.01.02 lists the companies that have finished the testing.

Company	Cylinder oil name, SAE 50	BN level
Castrol	Cyltech ACT	16
	Cyltech 140	140
Shell	Alexia S3	25
	Alexia 140	140
Chevron	Taro special HT LF	25
	Taro special HT 100	100
	Taro special HT ultra	140
Gulf Oil Marine	Gulfsea Cylcare ECA 50	17
	Gulfsea Cylcare 50100X	100
	Gulfsea Cylcare 50140X	140
Total	Talusia LS 25	25
	Talusia HR 140	140

Table 9.01.02

MAN Energy Solutions' ACOM (Automated Cylinder Oil Mixing) system mixes commercially available cylinder oils to the required BN value needed. The resulting BN in the cylinder oil supplied to the liners is in the range of the BN values of the two cylinder oils stored on board.

The basic principle is to mix an optimal cylinder lubricating oil (optimal BN), as illustrated in Fig. 9.01.01. At a certain sulphur content level, the engine needs to run on the high-BN cylinder oil as usual.

The ACOM working principle

The mixing is based on input of the sulphur content in the fuel that the engine is running on and the ME-ECS then controls the ACOM accordingly.

In gas operation mode, the sulphur content of the resulting fuel depends on the:

- engine load
- amount of pilot oil in the resulting fuel
- sulphur content in the pilot fuel.

The sulphur content in the resulting fuel is called the Sulphur Equivalent, S_e.

ACOM automatically calculates the S_e and the BN. The system is implemented in the engine control system of the ME-C/-GI/-LGI and ME-B-GI/-LGI and input on the sulphur content of the pilot fuel must be entered on the MOP by the crew.

On the ME-B, the ACOM is a stand-alone installation. It is controlled from the ACOM operating panel separate to the ME-B ECS and with alarms handled by the ship's alarm system.

Mixing volumes are kept small enabling a fast changeover from one BN to another.

Two-tank cylinder lubrication system with ACOM

The ACOM design makes it possible to measure the daily consumption of cylinder lubricating oil which eliminates the need for the two cylinder oil service / day tanks. Compared to the traditional two-tank cylinder lubrication system, Fig. 9.02.02a, the ACOM system also eliminates the two small tanks with heater element as shown in Fig. 9.02.02b.

The cylinder lubricating oil is fed from the storage tanks to the ACOM by gravity. The ACOM is located in the engine room near to and above the cylinder lubricating oil inlet flange, AC, in a vertical distance of minimum 2m. The layout of the ACOM is shown in Fig. 9.01.02.

ME-C-GI and ME-B-GI engines running in specified dual fuel (SDF) mode (i.e. all LNG tankers) and quoted after 2017-01-01 are as standard specified with ACOM, EoD: 4 42 171. For all other engines, ACOM is available as an option.

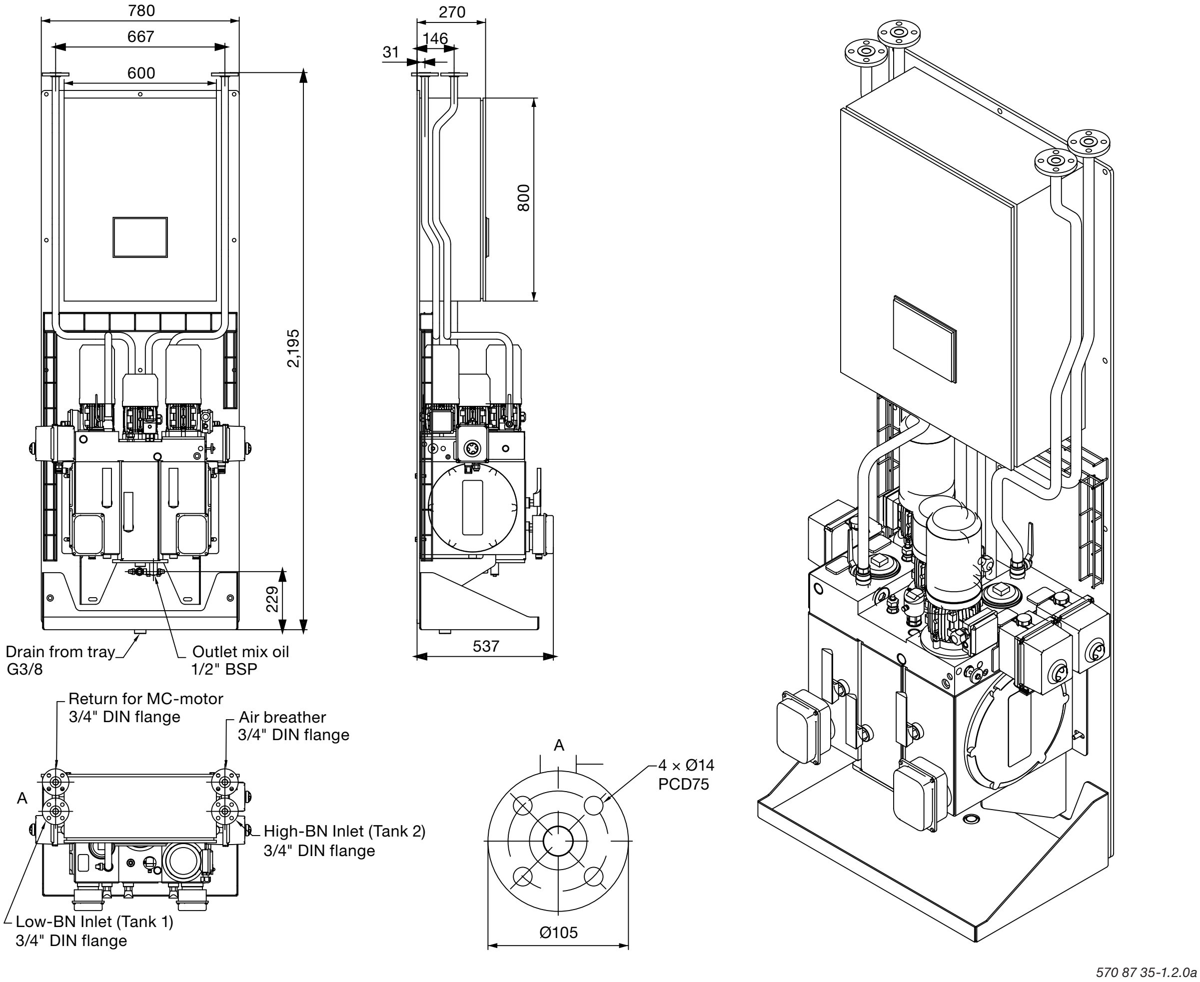

Fig. 9.01.02: Automated cylinder oil mixing system (ACOM) in single-rack version for installation in engine room

List of cylinder oils

The major international cylinder oil brands listed below have been tested in service with acceptable results.

Company	Cylinder oil name, SAE 50	BN level
Aegean	Alfacylo 525 DF	25
	Alfacylo 540 LS	40
	Alfacylo 100 HS	100
Castrol	Cyltech 40SX	40
	Cyltech 100	100
Chevron	Taro Special HT LF	25
	Taro Special HT LS 40	40
	Taro Special HT 100	100
ExxonMobil	Mobilgard 525	25
	Mobilgard 5100	100
Gulf Oil Marine	GulfSea Cylcare ECA 50	17
	GulfSea Cylcare DCA 5040H	40
	GulfSea Cylcare 50100	100
Indian Oil Corp.	Servo Marine LB 1750	17
JX Nippon Oil & Energy	Marine C255	25
	Marine C405	40
	Marine C1005	100
Lukoil	Navigo 40 MCL	40
	Navigo 100 MCL	100
Shell	Alexia S3	25
	Alexia S6	100
Sinopec	Marine Cylinder Oil 5025	25
	Marine Cylinder Oil 5040	40
	Marine Cylinder Oil 50100	100
Total	Talusia LS 25	25
	Talusia LS 40	40
	Talusia Universal 100	100

Do not consider the list complete, as oils from other companies can be equally suitable. Further information can be obtained from the engine builder or MAN Energy Solutions, Copenhagen.

MAN B&W Alpha Cylinder Lubrication System

The MAN B&W Alpha cylinder lubrication system, see Figs. 9.02.02a, 02b and 02c, is designed to supply cylinder oil intermittently, for instance every 2, 4 or 8 engine revolutions with electronically controlled timing and dosage at a defined position.

Traditional two-tank cylinder lubrication system

Separate storage and service tanks are installed for each of the different Base Number (BN) cylinder oils used onboard ships operating on both high- and low-sulphur fuels, see Fig. 9.02.02a.

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 about one week's cylinder lubricating oil consumption.

Oil feed to the Alpha cylinder lubrication system

Cylinder lubricating oil is fed to the Alpha cylinder lubrication system by gravity from the service tank or ACOM.

The oil fed to the injectors is pressurised by the Alpha Lubricator which is placed on the hydraulic cylinder unit (HCU) and equipped with small multi-piston pumps.

The oil pipes fitted on the engine are shown in Fig. 9.02.04.

The whole system is controlled by the Cylinder Control Unit (CCU) which controls the injection frequency based on 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 (Adaptable 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.

Regarding the filter and the small tank for heater, please see Fig. 9.02.05.

Alpha Lubricator variants

Since the Alpha Lubricator on ME and ME-B engines are controlled by the engine control system, it is also referred to as the ME lubricator on those engines.

A more advanced version with improved injection flexibility, the Alpha Lubricator Mk 2, is being introduced on the G95/50/45/40ME-C9 and S50ME-C9 including their GI dual fuel variants.

Further information about the Alpha Lubricator Mk 2 is available in our publication:

Service Experience MAN B&W Two-stroke Engines

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

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, cylinder condition and BN of the cylinder oil.

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 - 0.40 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. The ACC factor is also referred to as the Feed Rate Factor (FRF).

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.

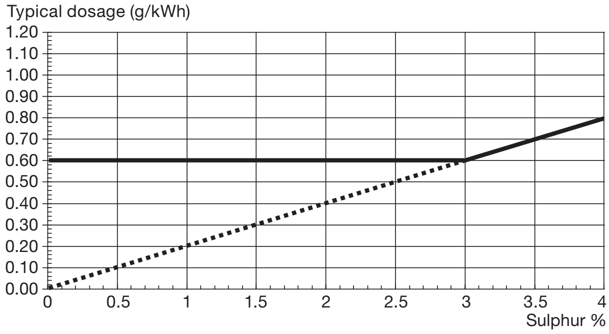

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Fig. 9.02.01a: FRF = 0.20 g/kWh × S% and BN 100 cylinder oil – average consumption less than 0.65 g/kWh

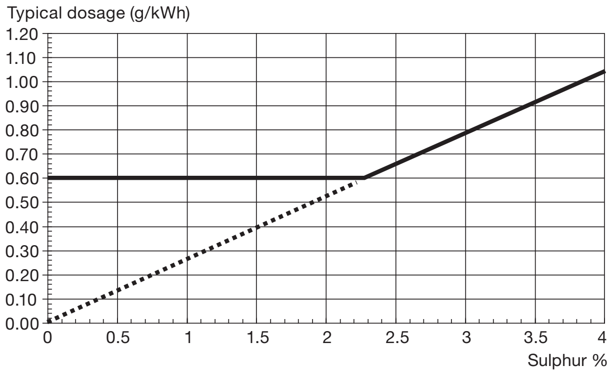

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Fig. 9.02.01b: FRF = 0.26 g/kWh × S% and BN 100 cylinder oil – average consumption less than 0.7 g/kWh

Further information about cylinder oil dosage is available in MAN Energy Solutions' most current Service Letters on this subject available at www.marine.man-es.com → 'Two-Stroke' → 'Service Letters'.

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 for heater element in the vessel, Fig. 9.02.02a, or from the ACOM, Fig. 9.02.02b, and the main cylinder oil pipe on the engine is insulated and electricallly heated.

The engine builder is to make the insulation and heating of the main cylinder oil pipe on the engine. Moreover, the engine builder is to mount the terminal 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 is to be mounted from the small tank for heater element or the ACOM to the terminal box on the engine, see Figs. 9.02.02a and 02b.

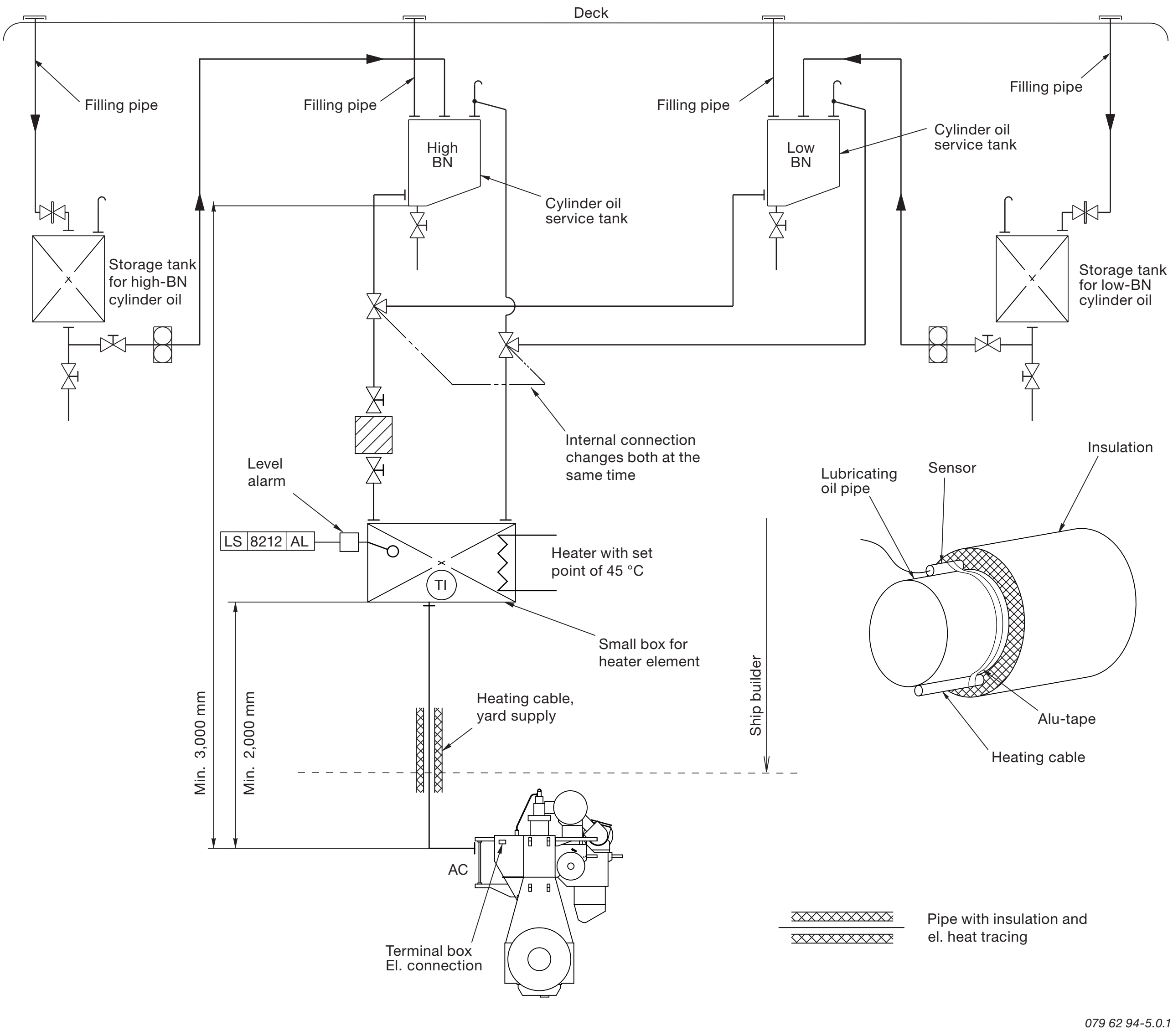


Fig. 9.02.02a: Cylinder lubricating oil system with dual storage and service tanks

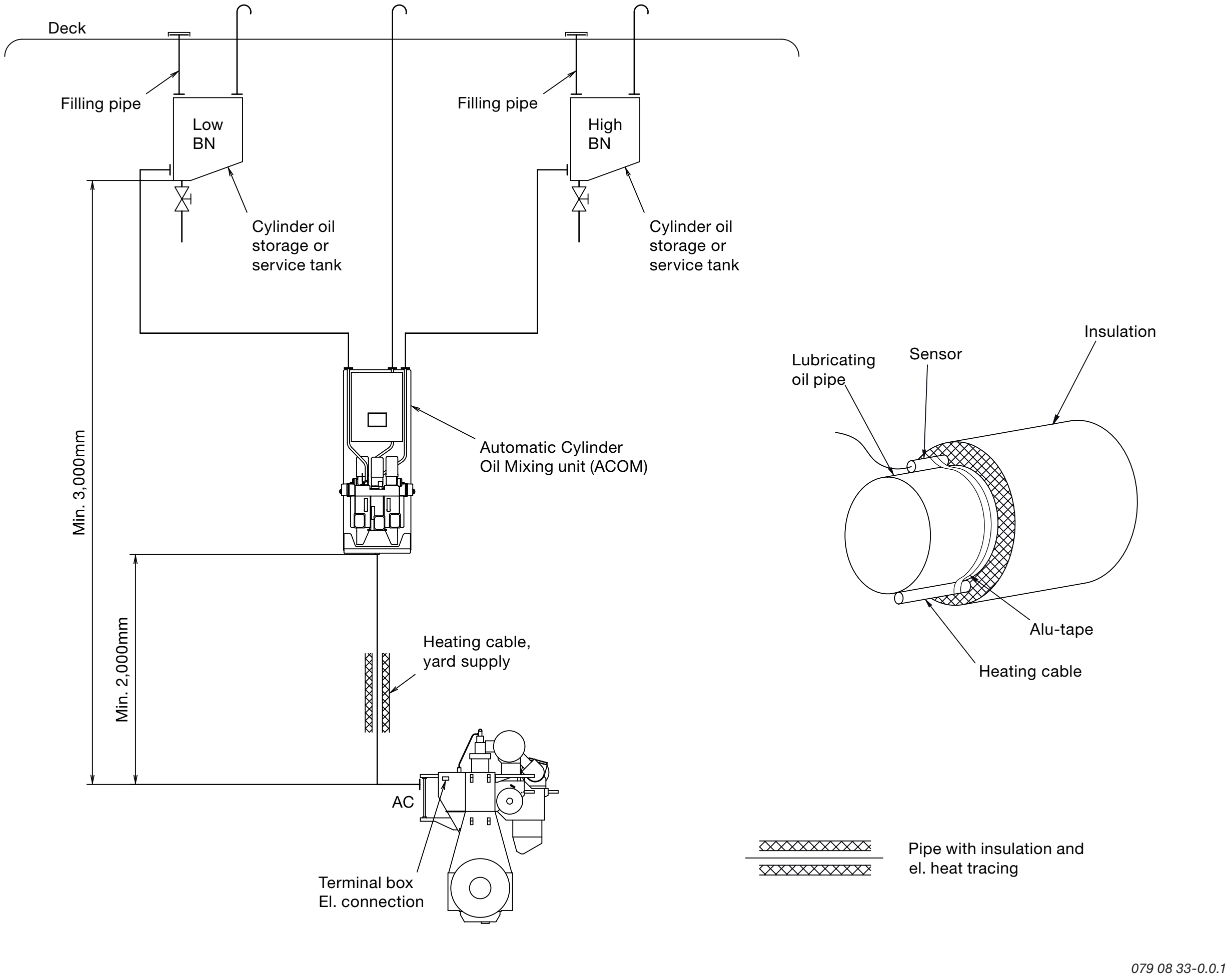


Fig. 9.02.02b: Cylinder lubricating oil system with dual storage or service tanks and ACOM

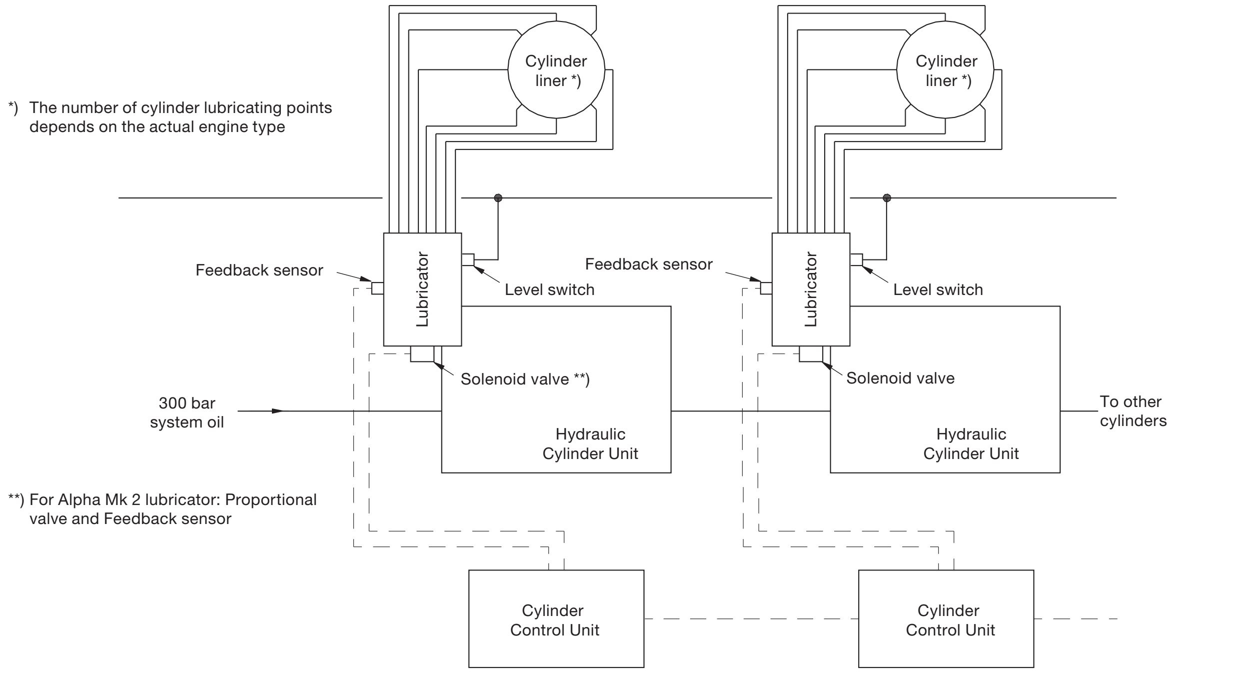


Fig. 9.02.02c: Cylinder lubricating oil system. Example from 80/70/65ME-C/-GI/-LGI engines

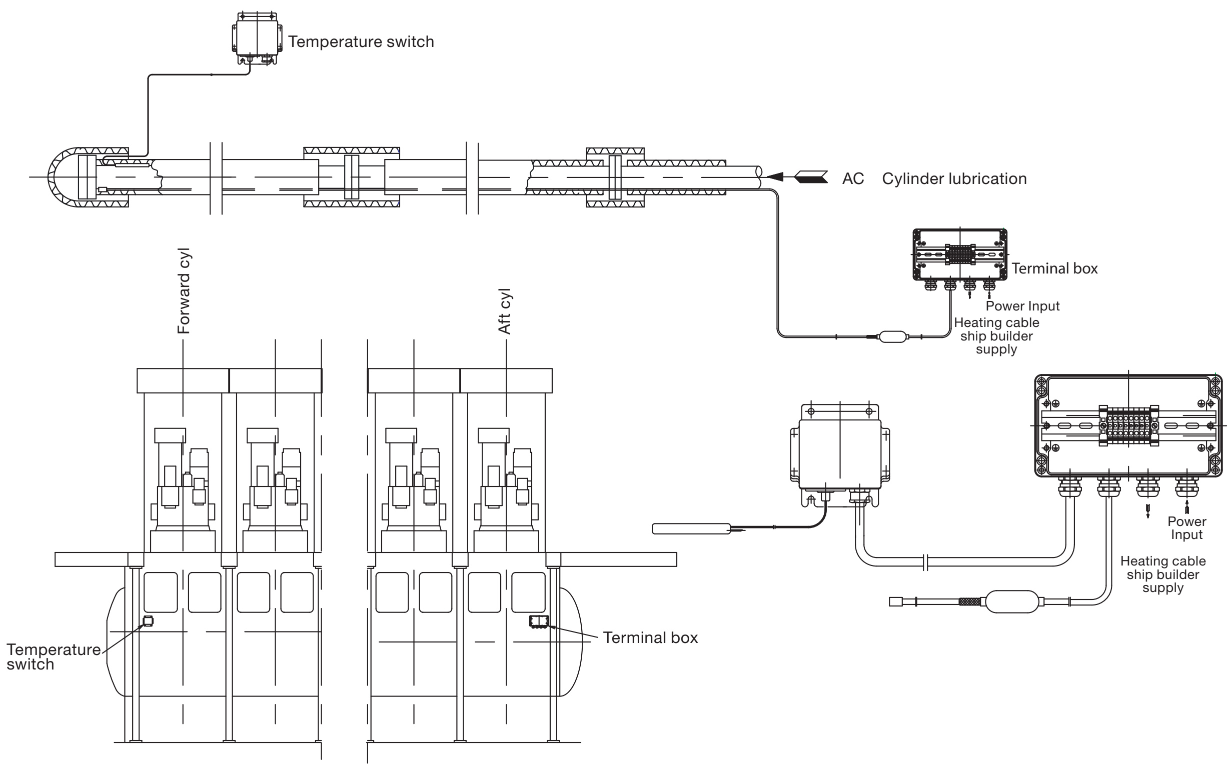
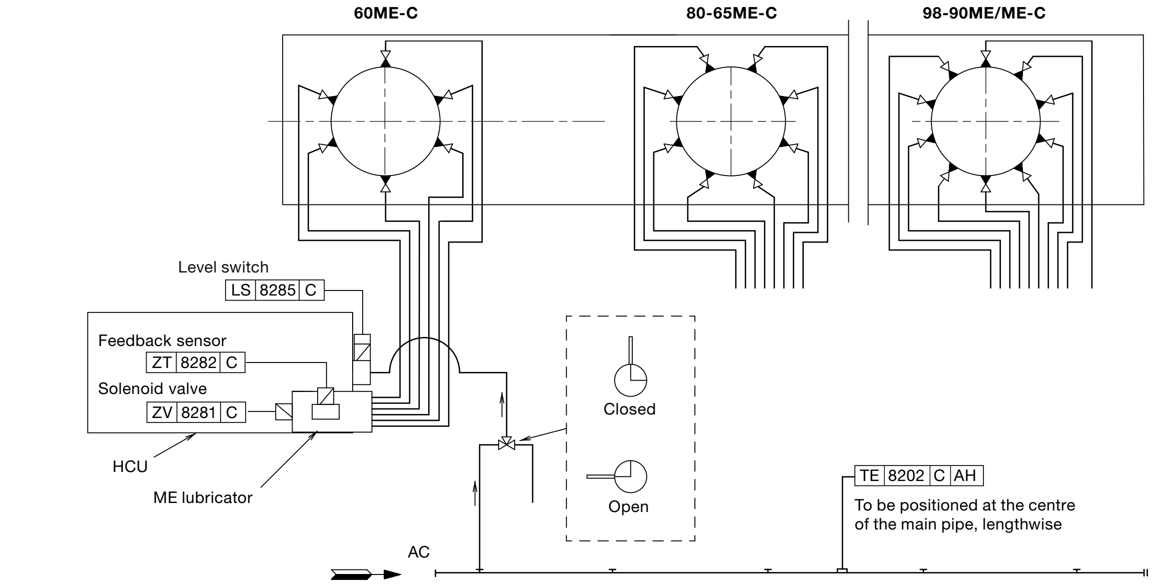


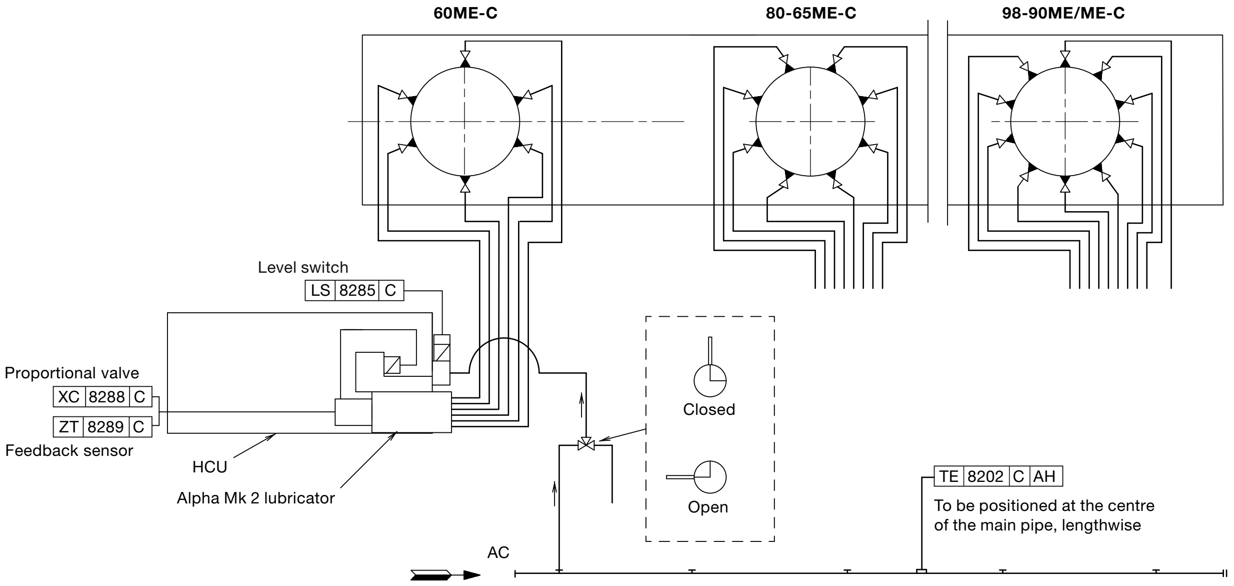
Fig. 9.02.03: Electric heating of cylinder oil pipes



561 67 56-8.1.0

The item no. refer to ‘Guidance Values Automation’. The letters refer to list of ‘Counterflanges’

Fig. 9.02.04a: Cylinder lubricating oil pipes, Alpha/ME lubricator



561 70 02-5.2.0

The item no. refer to ‘Guidance Values Automation’. The letters refer to list of ‘Counterflanges’

Fig. 9.02.04b: Cylinder lubricating oil pipes, Alpha Mk 2 lubricator

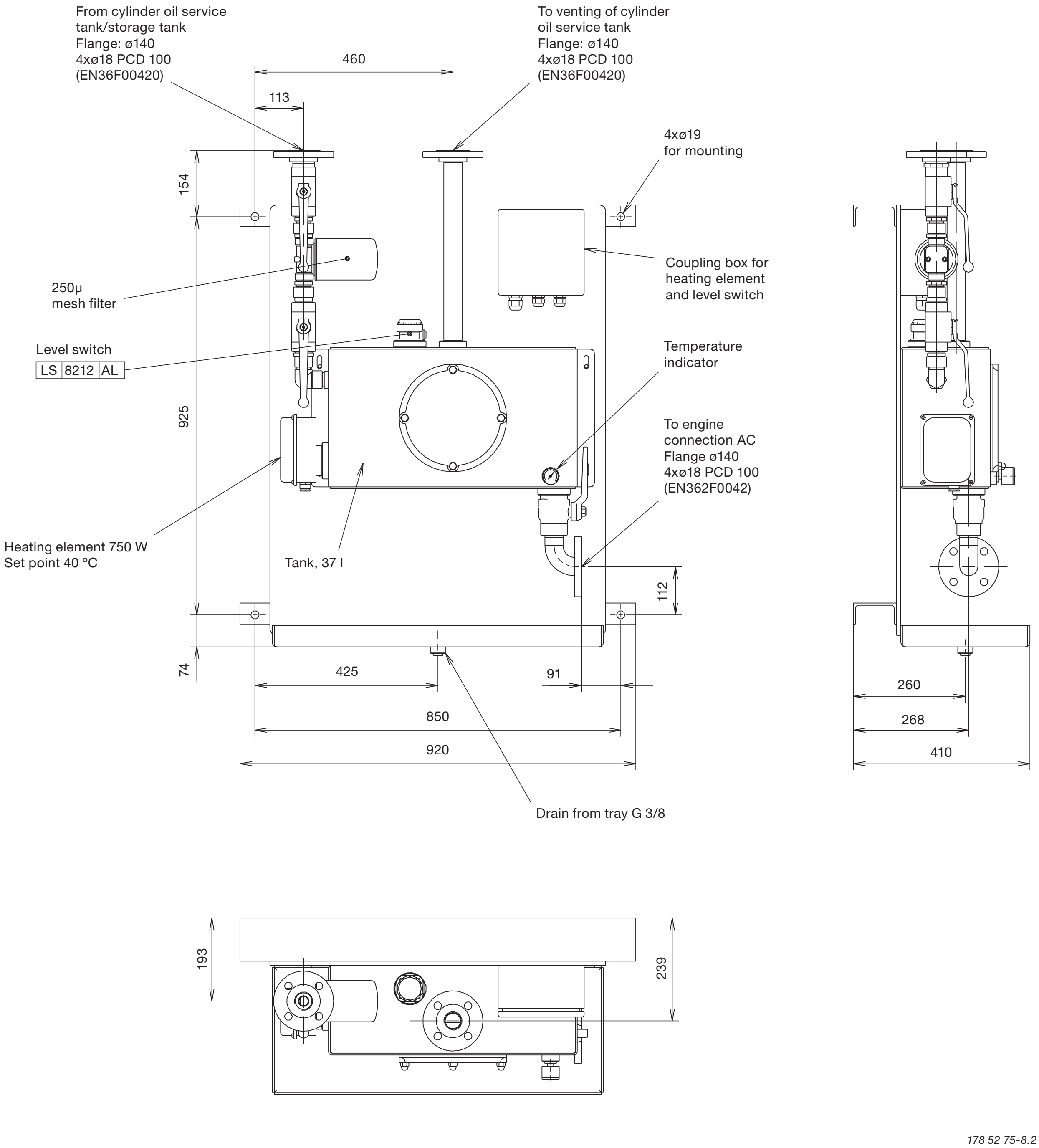


Fig. 9.02.05: Suggestion for small heating tank with filter (for engines without ACOM)

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 typically about 5-10 litres/24 hours per cylinder during normal service. In the running-in period, it can be higher. The drain oil is a mixture of system oil from the crankcase, used cylinder oil, combustion residues and water from humidity in the scavenge air.

The relatively small amount of drain oil is led to the general oily waste drain tank or is burnt in the incinerator, Fig. 10.01.01. (Yard's supply).

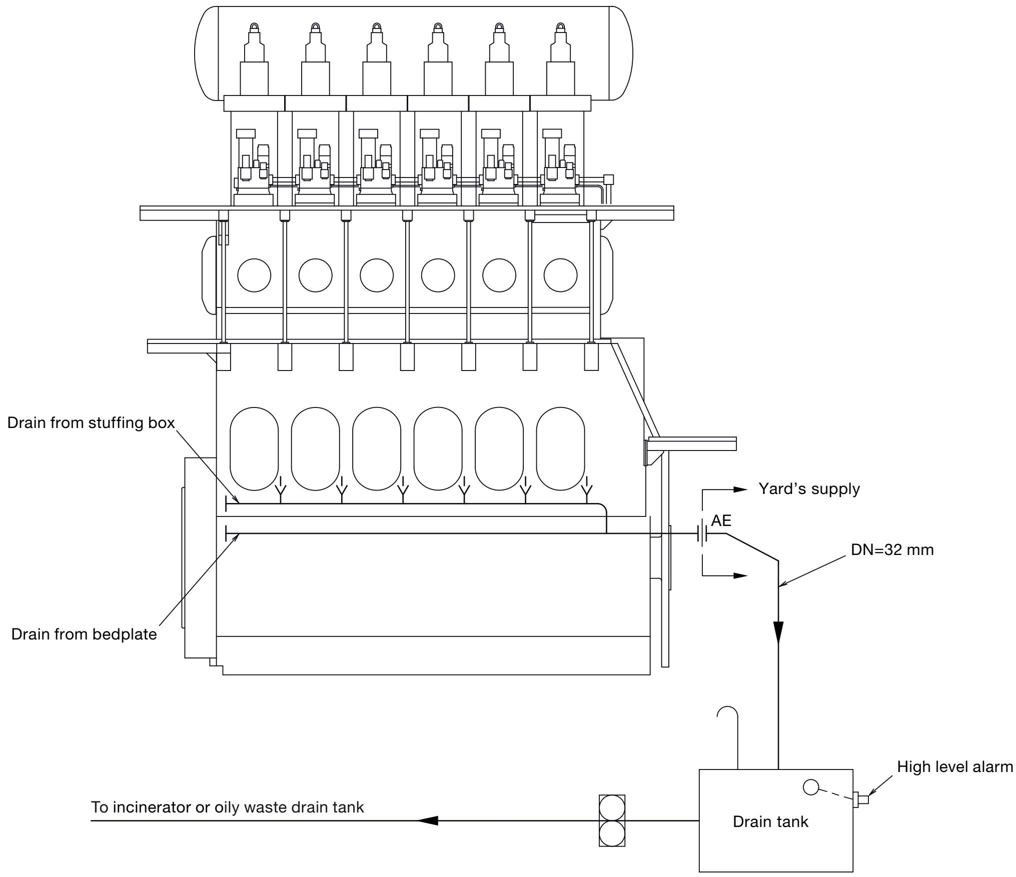


Fig. 10.01.01: Stuffing box drain oil system

Low-temperature Cooling Water

11

Low-temperature Cooling Water System

The low-temperature (LT) cooling water system supplies cooling water for the lubricating oil, jacket water and scavenge air coolers.

The LT cooling water system can be arranged in several configurations like a:

- **Central cooling water system** being the most common system choice and the basic execution for MAN B&W engines, EoD: 4 45 111
- **Seawater cooling system** being the most simple system and available as an option: 4 45 110
- **Combined cooling water system** with seawater-cooled scavenge air cooler but freshwater-cooled jacket water and lubricating oil cooler, available as an option: 4 45 117.

Principle diagrams of the above LT cooling water systems are shown in Fig. 11.01.01a, b and c and descriptions are found later in this chapter.

Further information and the latest recommendations concerning cooling water systems are found in MAN Energy Solutions' Service Letters available at www.marine.man-es.com → 'Two-Stroke' → 'Service Letters'.

Chemical corrosion inhibition

Various types of inhibitors are available but, generally, only nitrite-borate based inhibitors are recommended.

Where the inhibitor maker specifies a certain range as normal concentration, we recommend to maintain the actual concentration in the upper end of that range.

MAN Energy Solutions recommends keeping a record of all tests to follow the condition and chemical properties of the cooling water and notice how it develops. It is recommended to record the quality of water as follows:

- Once a week:

  Take a sample from the circulating water during running, however not from the expansion tank nor the pipes leading to the tank. Check the condition of the cooling water. Test kits with instructions are normally available from the inhibitor supplier.

- Every third month:

  Take a water sample from the system during running, as described above in 'Once a week'. Send the sample for laboratory analysis.

- Once a year:

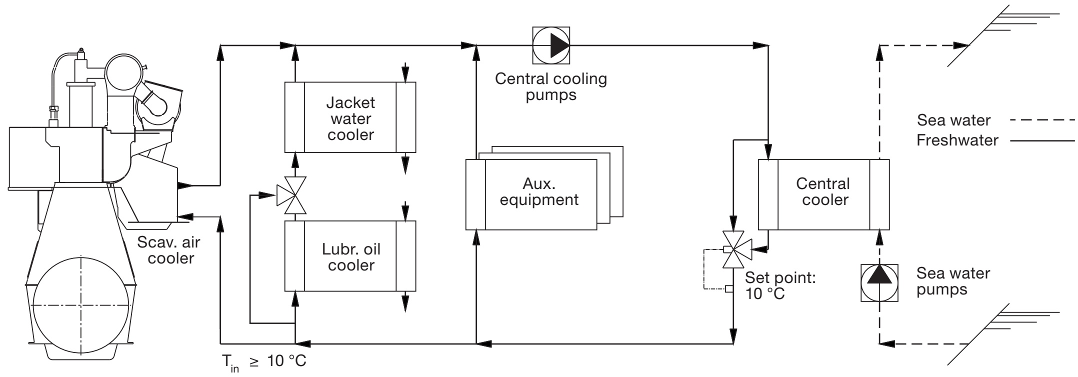
  Empty, flush and refill the cooling water system. Add the inhibitor.

For further information please refer to our recommendations for treatment of the jacket water/freshwater. The recommendations are available from MAN Energy Solutions, Copenhagen.

Cooling system for main engines with EGR

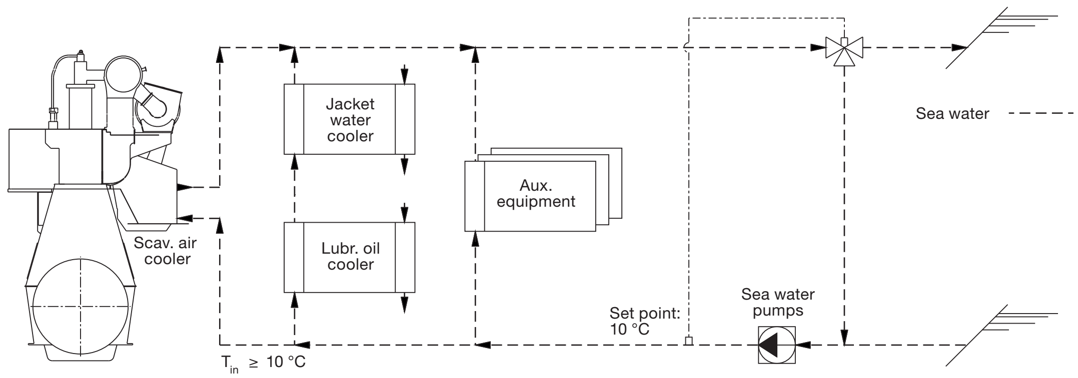
For main engines with exhaust gas recirculation (EGR), a central cooling system using freshwater as cooling media will be specified.

Further information about cooling water systems for main engines with EGR is available from MAN Energy Solutions, Copenhegan.



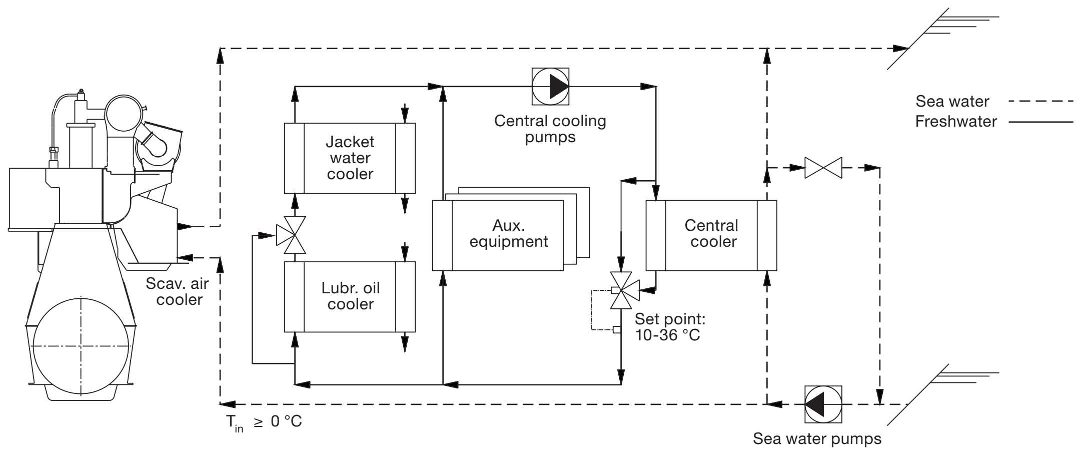
568 25 97-1.0.1a

Fig. 11.01.01a: Principle diagram of central cooling water system



568 25 97-1.0.1b

Fig. 11.01.01b: Principle diagram of seawater cooling system



568 25 97-1.0.1c

Fig. 11.01.01c: Principle diagram of combined cooling water system

Central Cooling Water System

The central cooling water system is characterised by having only one heat exchanger cooled by seawater. The other coolers, including the jacket water cooler, are then cooled by central cooling water.

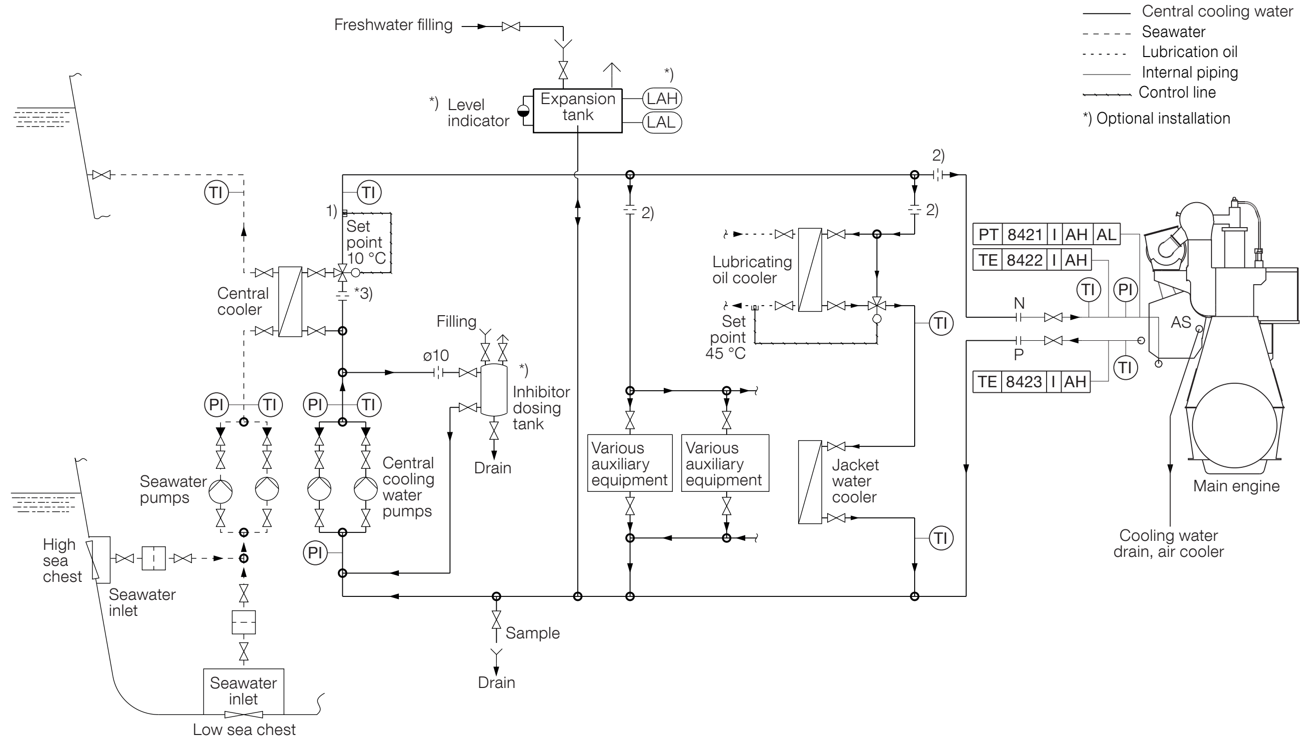
Cooling water temperature

The capacity of the seawater pumps, central cooler and freshwater pumps are based on the outlet temperature of the freshwater being maximum 54 °C after passing through the main engine lubricating oil cooler. With an inlet temperature of maximum 36 °C (tropical conditions), the maximum temperature increase is 18 °C.

To achieve an optimal engine performance regarding fuel oil consumption and cylinder condition, it is important to ensure the lowest possible cooling water inlet temperature at the scavenge air cooler.

MAN Energy Solutions therefore requires that the temperature control valve in the central cooling water circuit is to be set to minimum 10 °C. In this way, the temperature follows the outboard seawater temperature when the central cooling water temperature exceeds 10 °C, see note 1 in Fig. 11.02.01.

Alternatively, in case flow control of the seawater pumps is applied, the set point is to be approximately 4 °C above the seawater temperature but not lower than 10 °C.



*) Optional installation

The letters refer to list of 'Counterflanges'
The item no. refer to 'Guidance Values Automation'

Fig. 11.02.01: Central cooling water system

Cooling water pump capacities

The pump capacities listed by MAN Energy Solutions cover the requirement for the main engine only.

For any given plant, the specific capacities have to be determined according to the actual plant specification and the number of auxiliary equipment. Such equipment include GenSets, starting air compressors, provision compressors, airconditioning compressors, etc.

A guideline for selecting centrifugal pumps is given in Section 6.04.

Cooling water piping

Orifices (or lockable adjustable valves for instance) must be installed in order to create:

- the proper distribution of flow between each of the central cooling water consumers, see note 2)
- a differential pressure identical to that of the central cooler at nominal central cooling water pump capacity, see note 3).

References are made to Fig. 11.02.01.

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

Central cooling water .... 3.0 m/s
Seawater .... 3.0 m/s

Expansion tank volume

The expansion tank shall be designed as open to atmosphere. Venting pipes entering the tank shall terminate below the lowest possible water level i.e. below the low level alarm.

The expansion tank volume has to be 10% of the total central cooling water amount in the system.

The 10% expansion tank volume is defined as the volume between the lowest level (at the low level alarm sensor) and the overflow pipe or high level alarm sensor.

If the pipe system is designed with possible air pockets, these have to be vented to the expansion tank.

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..2.0 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 pump head of the pumps is to be determined based on the total actual pressure drop across the seawater cooling water system.

A guideline for selecting centrifugal pumps is given in Section 6.04.

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. 0.7 bar
Seawater flow..................... see ‘List of Capacities’
Seawater temperature, inlet........................... 32 °C
Pressure drop on
seawater side.......................... maximum 1.0 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 pump head of the pumps is to be determined based on the total actual pressure drop across the central cooling water system.

A guideline for selecting centrifugal pumps is given in Section 6.04.

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 bypasses all or part of the freshwater around the central cooler.

The sensor is to be located at the outlet pipe from the thermostatic valve and is set to keep a temperature of 10 °C.

Lubricating oil cooler thermostatic valve

The lubricating oil cooler is to be equipped with a three-way valve, mounted as a mixing valve, which bypasses all or part of the freshwater around the lubricating cooler.

The sensor is to be located at the lubricating oil outlet pipe from the lubricating oil cooler and is set to keep a lubricating oil temperature of 45 °C.

Chemical corrosion inhibitor and dosing tank

In order to properly mix the inhibitor into the central cooling water system circuit, the tank shall be designed to receive a small flow of jacket cooling water through the tank from the jacket water pumps. The tank shall be suitable for mixing inhibitors in form of both powder and liquid.

Recommended tank size ....0.3 m^3
Design pressure .... max. central cooling water system pressure
Suggested inlet orifice size .... ø10 mm

Lubricating oil cooler

See Chapter 8 ‘Lubricating Oil’.

Jacket water cooler

See Chapter 12 ‘High-temperature Cooling Water’.

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 ..... 0.3-0.8 bar

Cooling water pipes for air cooler

Diagrams of cooling water pipes for scavenge air cooler are shown in Figs. 11.08.01.

Seawater Cooling System

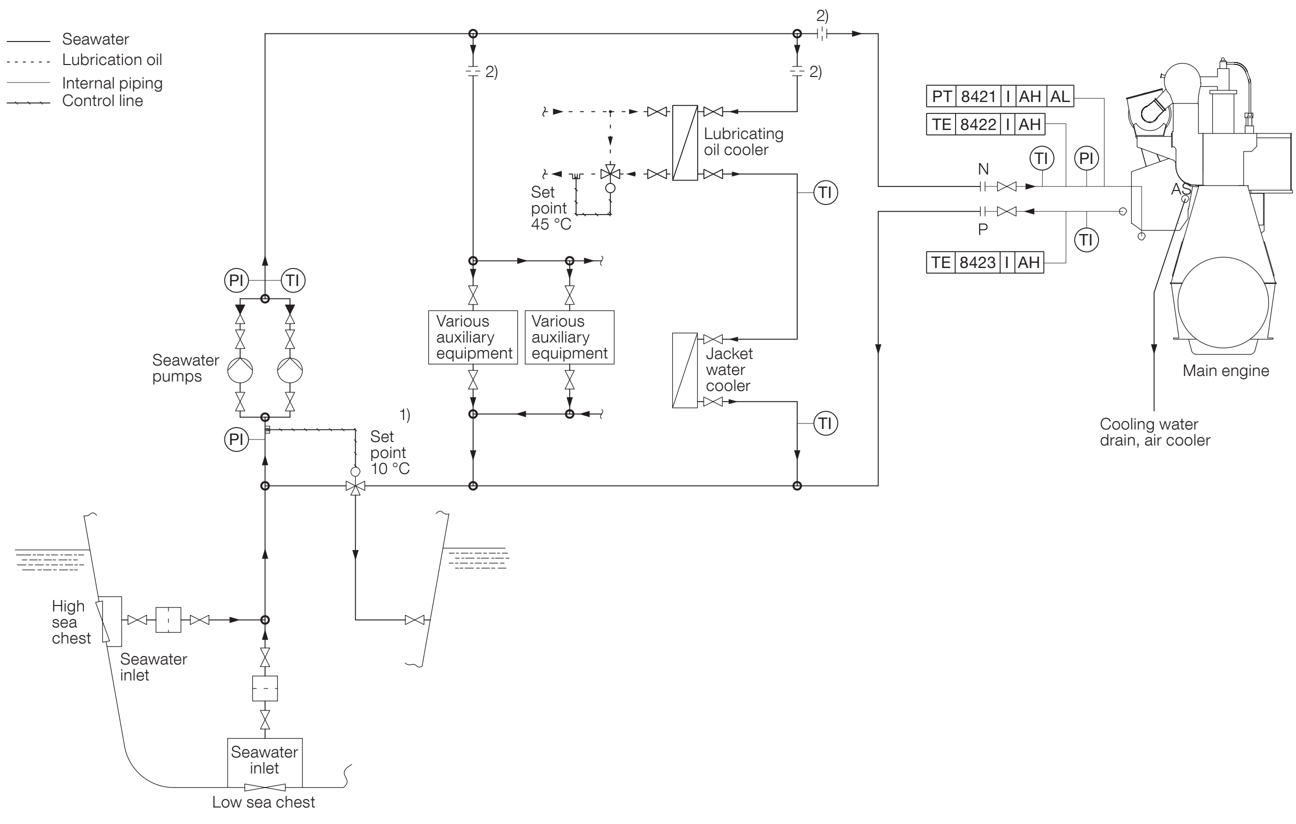
The seawater cooling system is an option for cooling the main engine lubricating oil cooler, the jacket water cooler and the scavenge air cooler by seawater, see Fig. 11.04.01. The seawater system consists of pumps and a thermostatic valve.

Cooling water temperature

The capacity of the seawater pump is based on the outlet temperature of the seawater being maximum 50 °C after passing through the main engine lubricating oil cooler, the jacket water cooler and the scavenge air cooler.

With an inlet temperature of maximum 32 °C (tropical conditions), the maximum temperature increase is 18 °C.

In order to prevent the lubricating oil from stiffening during cold services, a thermostatic valve is to be installed. The thermostatic valve recirculates all or part of the seawater to the suction side of the pumps. A set point of 10 °C ensures that the cooling water to the cooling consumers will never fall below this temperature, see note 1 in Fig. 11.04.01.



The letters refer to list of 'Counterflanges'
The item no. refer to 'Guidance Values Automation'

Fig. 11.04.01: Seawater cooling system

Cooling water pump capacities

The pump capacities listed by MAN Energy Solutions cover the requirement for the main engine only.

For any given plant, the specific capacities have to be determined according to the actual plant specification and the number of auxiliary equipment. Such equipment include GenSets, starting air compressors, provision compressors, airconditioning compressors, etc.

A guideline for selecting centrifugal pumps is given in Section 6.04.

Cooling water piping

In order to create the proper distribution of flow between each of the cooling water consumers, orifices (or lockable adjustable valves for instance) must be installed, see note 2) in Fig. 11.04.01.

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

Seawater .... 3.0 m/s

If the pipe system is designed with possible air pockets, these have to be vented to the expansion tank.

Components for Seawater Cooling 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 rule
Working temperature .... maximum 50 °C

The flow capacity must be within a range from 100 to 110% of the capacity stated.

The pump head of the pumps is to be determined based on the total actual pressure drop across the seawater cooling water system.

A guideline for selecting centrifugal pumps is given in Section 6.04.

Seawater thermostatic valve

The temperature control valve is a three-way mixing valve. The sensor is to be located at the seawater inlet to the lubricating oil cooler, and the temperature set point must be +10 °C.

Seawater flow .... see 'List of Capacities'
Temperature set point .... +10 °C

Lubricating oil cooler

See Chapter 8 'Lubricating Oil'.

Jacket water cooler

See Chapter 12 'High-temperature Cooling Water'.

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 .... 0.3-0.8 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.

Cooling water pipes for air cooler

Diagrams of cooling water pipes for scavenge air cooler are shown in Figs. 11.08.01.

Combined Cooling Water System

The combined cooling water system is characterised by having one heat exchanger and the scavenge air cooler cooled by seawater. The other coolers, including the jacket water cooler, are then cooled by central cooling water.

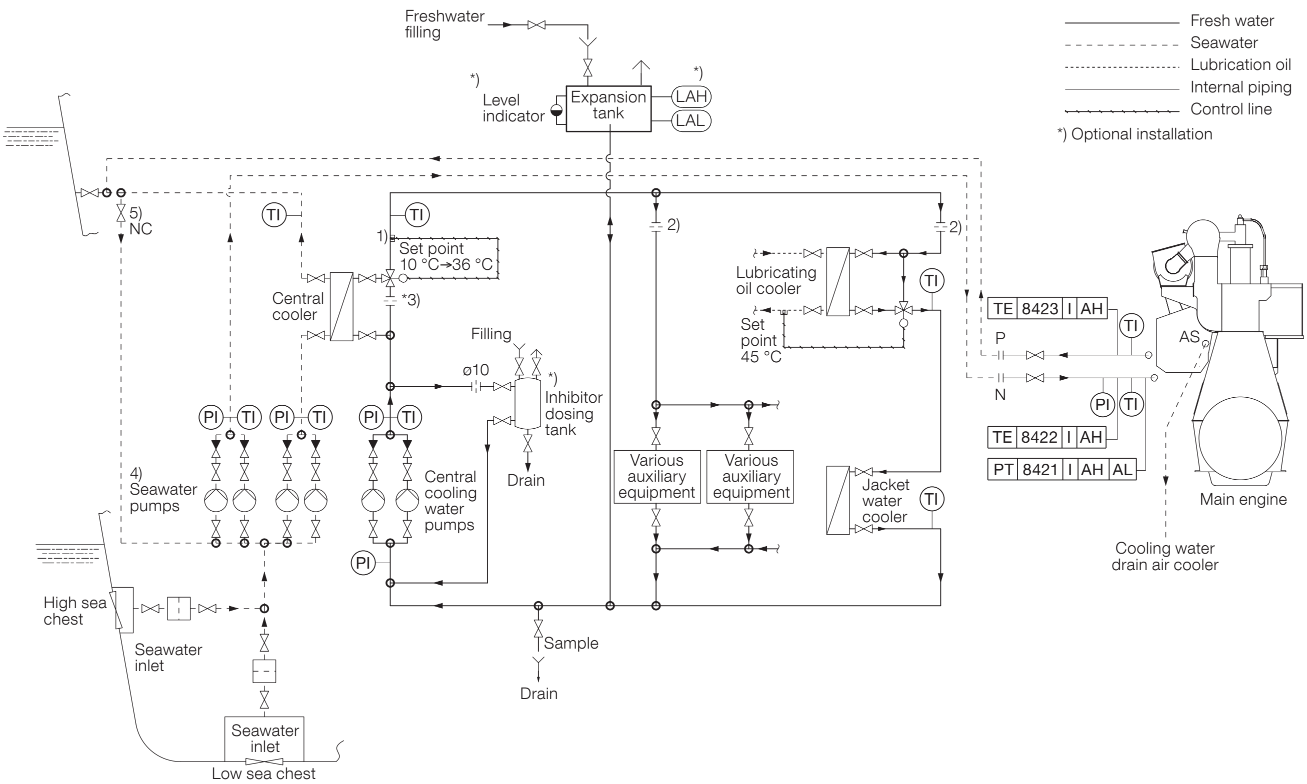
In this system, the cooling water to the scavenge air cooler will always be approx. 4 °C lower than in a central cooling water system.

Cooling water temperature

The capacity of the seawater pumps, central cooler pumps are based on the outlet temperature of the freshwater being maximum 54 °C after passing through the main engine lubricating oil cooler.

With an inlet temperature of maximum 36 °C (tropical conditions), the maximum temperature increase is 18 °C.

The temperature control valve in the central cooling water circuit can be set to minimum 10 °C and maximum 36 °C, see note 1 in Fig. 11.06.01.



*) Optional installation

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The letters refer to list of ‘Counterflanges’
The item no. refer to ‘Guidance Values Automation’

Fig. 11.06.01: Combined cooling water system

Alternatively, in case flow control of the seawater pumps is applied, the set point is to be approximately 4 °C above the seawater temperature but not lower than 10 °C.

In order to avoid seawater temperatures below 0 °C at the scavenge air cooler inlet, a manual bypass valve is installed in the seawater circuit, see note 5) in Fig. 11.06.01. The valve recirculates all or part of the seawater to the suction side of the pumps.

Cooling water pump capacities

The pump capacities listed by MAN Energy Solutions cover the requirement for the main engine only.

For any given plant, the specific capacities have to be determined according to the actual plant specification and the number of auxiliary equipment. Such equipment include GenSets, starting air compressors, provision compressors, airconditioning compressors, etc.

In fig. 11.06.01, note 4 both seawater pumps for main engine scavenge air cooler and for central cooling water system are shown. Alternative common seawater pumps serving both systems can be installed.

A guideline for selecting centrifugal pumps is given in Section 6.04.

Cooling water piping

Orifices (or lockable adjustable valves for instance) must be installed in order to create:

- the proper distribution of flow between each of the central cooling water consumers, see note 2)
- a differential pressure identical to that of the central cooler at nominal central cooling water pump capacity, see note 3).

References are made to Fig. 11.08.01.

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

Central cooling water .... 3.0 m/s
Seawater .... 3.0 m/s

Expansion tank volume

The expansion tank shall be designed as open to atmosphere. Venting pipes entering the tank shall terminate below the lowest possible water level i.e. below the low level alarm.

The expansion tank volume has to be 10% of the total central cooling water amount in the system. The 10% expansion tank volume is defined as the volume between the lowest level (at the low level alarm sensor) and the overflow pipe or high level alarm sensor.

If the pipe system is designed with possible air pockets, these have to be vented to the expansion tank.

Components for Combined Cooling Water System

Seawater cooling pumps

The pumps are to be of the centrifugal type.

Seawater flow..................... see 'List of Capacities'
Pump head..2.0 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 pump head of the pumps is to be determined based on the total actual pressure drop across the seawater cooling water system.

A guideline for selecting centrifugal pumps is given in Section 6.04.

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. 0.7 bar
Seawater flow..................... see 'List of Capacities'
Seawater temperature, inlet...........................32 °C
Pressure drop on
seawater side.......................... maximum 1.0 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 pump head of the pumps is to be determined based on the total actual pressure drop across the central cooling water system.

A guideline for selecting centrifugal pumps is given in Section 6.04.

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 bypasses all or part of the freshwater around the central cooler.

The sensor is to be located at the outlet pipe from the thermostatic valve and is set to keep a temperature of minimum 10 °C and maximum 36 °C.

Lubricating oil cooler thermostatic valve

The lubricating oil cooler is to be equipped with a three-way valve, mounted as a mixing valve, which bypasses all or part of the freshwater around the lubricating cooler.

The sensor is to be located at the lubricating oil outlet pipe from the lubricating oil cooler and is set to keep a lubricating oil temperature of 45 °C.

Chemical corrosion inhibitor and dosing tank

In order to properly mix the inhibitor into the combined cooling water system circuit, the tank shall be designed to receive a small flow of jacket cooling water through the tank from the jacket water pumps. The tank shall be suitable for mixing inhibitors in form of both powder and liquid.

Recommended tank size ....0.3 m^3
Design pressure ...... max. combined cooling water system pressure
Suggested inlet orifice size .... ø10 mm

Lubricating oil cooler

See Chapter 8 'Lubricating Oil'.

Jacket water cooler

See Chapter 12 'High-temperature Cooling Water'.

Scavenge air cooler

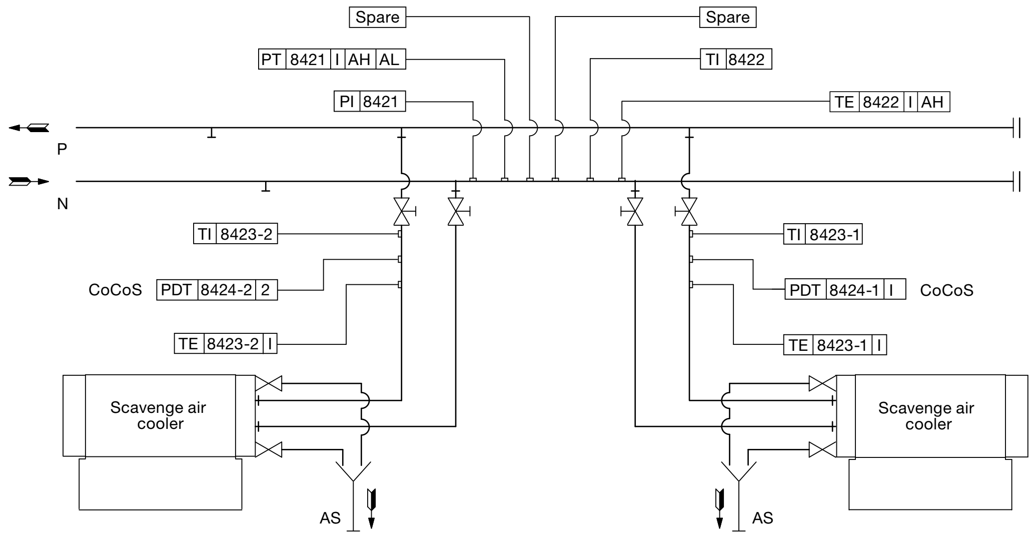
The scavenge air cooler is an integrated part of the main engine.

Heat dissipation .... see 'List of Capacities'
Seawater flow .... see 'List of Capacities'
Central cooling temperature, inlet.................. 32 °C
Pressure drop on seawater side .... 0.3-0.8 bar

Cooling water pipes for air cooler

Diagrams of cooling water pipes for scavenge air cooler are shown in Figs. 11.08.01.

Cooling Water Pipes for Scavenge Air Cooler



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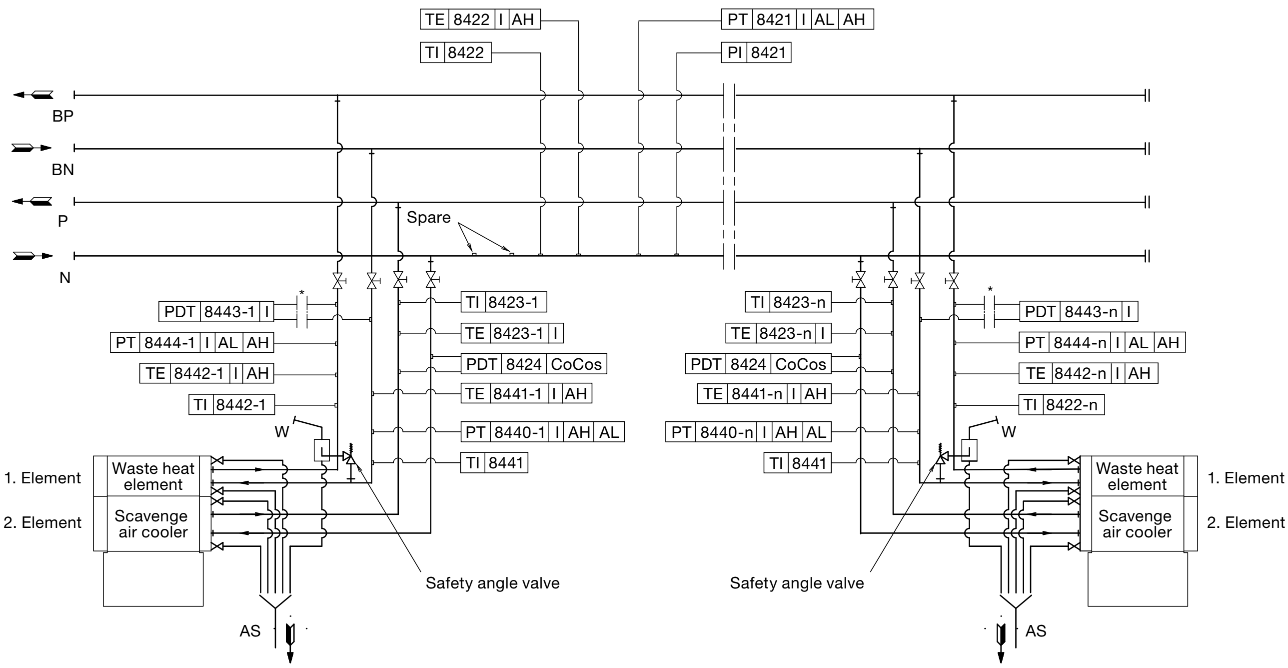
The letters refer to list of 'Counterflanges'. The item no. refer to 'Guidance Values Automation'

Fig. 11.08.01a: Cooling water pipes for engines with two or more turbochargers



521 21 78-2.3.1

The letters refer to list of 'Counterflanges'. The item no. refer to 'Guidance Values Automation'

* Calculated value: PT8444-n subtracted from PT8440-n, if possible
n Refer to number of air coolers

Fig. 11.08.01b: Cooling water pipes with waste heat recovery for engines with two or more turbochargers

High-temperature Cooling Water

12

High-temperature Cooling Water System

The high-temperature (HT) cooling water system, also known as the jacket cooling water (JCW) system, is used for cooling the cylinder liners, cylinder covers and exhaust gas valves of the main engine and heating of the fuel oil drain pipes, see Fig. 12.01.01.

The jacket water pump draws water from the jacket water cooler outlet, through a deaerating tank and delivers it to the engine.

A thermostatically controlled regulating valve is located at the inlet to the jacket water cooler, or alternatively at the outlet from the cooler. The regulating valve keeps the main engine cooling water outlet at a fixed temperature level, independent of the engine load. The controller for the thermostatically controlled regulating valve must be able to receive a remote variable set point from the main Engine Control System (ECS).

A deaerating tank alarm device is installed between the deaerating tank and the expansion tank. The purpose of the alarm device is to give an alarm in case of a large amount of gas in the JCW circuit e.g. caused by a cylinder liner rupture.

To create a sufficient static pressure in the JCW system and provide space for the water to expand and contract, an expansion tank is installed. The expansion tank must be located at least 15 m above the top of the main engine exhaust gas valves.

The engine jacket water must be carefully treated, maintained and monitored so as to avoid corrosion, corrosion fatigue, cavitation and scale formation. Therefore, it is recommended to install a chemical corrosion inhibitor dosing tank and a means to take water samples from the JCW system.

Chemical corrosion inhibition

Various types of inhibitors are available but, generally, only nitrite-borate based inhibitors are recommended.

Where the inhibitor maker specifies a certain range as normal concentration, we recommend to maintain the actual concentration in the upper end of that range.

MAN Energy Solutions recommends keeping a record of all tests to follow the condition and chemical properties of the cooling water and notice how it develops. It is recommended to record the quality of water as follows:

- Once a week:

  Take a sample from the circulating water during running, however not from the expansion tank nor the pipes leading to the tank. Check the condition of the cooling water. Test kits with instructions are normally available from the inhibitor supplier.

- Every third month:

  Take a water sample from the system during running, as described above in ‘Once a week’. Send the sample for laboratory analysis.

- Once a year:

  Empty, flush and refill the cooling water system. Add the inhibitor.

For further information please refer to our recommendations for treatment of the jacket water/freshwater. The recommendations are available from MAN Energy Solutions, Copenhagen.

Cooling water drain for maintenance

For maintenance of the main engine, a drain arrangement is installed at the engine. By this drain arrangement, the jacket cooling water can be drained to e.g. a freshwater drain tank for possible reuse of the chemical corrosion inhibitor-treated water.

Preheater system

During short stays in port (i.e. less than 4-5 days), it is recommended that the engine is kept preheated. The purpose is 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. Preheating could be provided in form of a built-in preheater in the jacket cooling water system or by means of cooling water from the auxiliary engines, or a combination of the two.

Preheating procedure

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.

Normal start of engine, fixed pitch propeller

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% SMCR speed (SMCR rpm) during 30 minutes.

For running up between 90% and 100% SMCR rpm, it is recommended that the speed be increased slowly over a period of 60 minutes.

Start of cold engine, fixed pitch propeller

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% 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

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.

For further information, please refer to our publication titled:

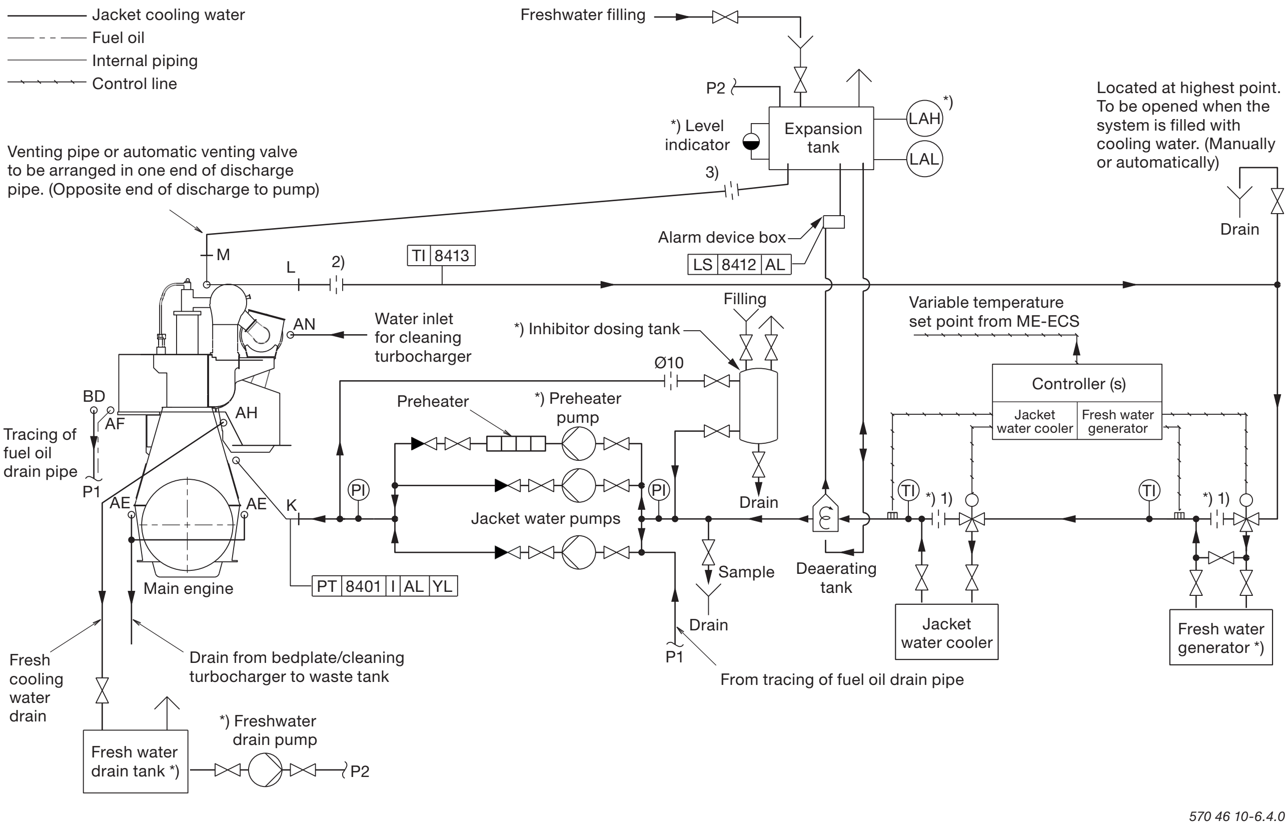
Influence of Ambient Temperature Conditions

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

Freshwater generator

A freshwater generator can be installed in the JCW circuit for utilising the heat radiated to the jacket cooling water from the main engine.

Jacket cooling water piping



Notes:

1) Orifices (or lockable adjustable valves) to be installed in order to create a differential pressure identical to that of the jacket water cooler / freshwater generator at nominal jacket water pump capacity.

2) (Optional) Orifices (or lockable adjustable valves) to be installed in order to create a min. inlet pressure indicated at sensor PT 8401 above the min. pressure stated in the Guidance Values Automation (GVA) at engine inlet connection ‘K’.

3) Orifices with small size hole to be installed for avoiding jacket water flow through the expansion tank.

*) Optional installation

The letters refer to list of ‘Counterflanges’

Fig. 12.01.01: Jacket cooling water system

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

Jacket cooling water .... 3.0 m/s

Components for High-temperature Cooling Water System

Jacket water cooling pump

The pumps are to be of the centrifugal type.

Pump flow rate/Jacket water
flow .... see 'List of Capacities'
Pump head (see below note)........................3.0 bar
Delivery pressure ....depends on location of the expansion tank
Test pressure....................according to Class rules
Working temperature .... 85 °C
Max. temperature (design purpose)............. 100 °C

The flow capacity must be within a range from 100 to 110% of the capacity stated.

The pump head of the pumps is to be determined based on the total actual pressure drop across the cooling water system i.e. pressure drop across the main engine, jacket water cooler, three-way valve, valves and other pipe components

A guideline for selecting centrifugal pumps is given in Section 6.04.

Jacket water cooler

Normally the jacket water cooler is most likely to be of the plate heat exchanger type but could also be of the shell and tube type.

Heat dissipation .... see 'List of Capacities'
Jacket water flow .... see 'List of Capacities'
Jacket water temperature, inlet...................... 85 °C
Max. working temperature..................up to 100 °C
Max. pressure drop
on jacket water side...............................0.5 bar

Cooling water flow.............. see 'List of Capacities'
Cooling water temp., inlet SW cooled.......... ~38 °C
Cooling water temp., inlet FW cooled.......... ~42 °C
Max pressure drop on cooling side ....0.5 bar

The cooler should be built in following materials:
Sea water cooled ....SW resistant (e.g. titanium or Cu alloy for tube coolers)
Freshwater cooled........................... stainless steel

The heat dissipation and flow are based on SMCR output at tropical conditions, i.e. seawater temperature of 32 °C and an ambient air temperature of 45 °C.

Jacket water thermostatic regulating valve

The main engine cooling water outlet should be kept at a fixed temperature of 85 °C, independently of the engine load. This is done by a three-way thermostatic regulating valve.

The controller of the thermostatically controlled regulating valve must be able to receive a remote, variable set point given by the main Engine Control System (ECS). The variable set point corresponds to the main engine jacket water inlet temperature required for keeping the main engine outlet temperature at the specified 85 °C

The reference measurement temperature sensor shall be located after the water has been mixed. I.e. between the cooler/cooler bypass and the jacket water pumps as indicated in Fig. 12.01.01.

Jacket water flow .... see 'List of Capacities'
Max. working temperature..................up to 100 °C
Max. pressure drop...................................~0.3 bar
Actuator type.........................electric or pneumatic
Recommended leak rate.............less than 0.5% of nominal flow

Note:
A low valve leak rate specified for the valve port against the cooler will provide better utilisation of the heat available for the freshwater production.

Valve controller specification:
Remote set point signal standard............. 4-20 mA
Range .... 0-4 mA = 65 °C; 20 mA = 95 °C

Expansion tank

The expansion tank shall be designed as open to atmosphere. Venting pipes entering the tank shall terminate below the lowest possible water level i.e. below the low level alarm.

The expansion tank must be located at least 15 m above the top of the main engine exhaust gas valves.

The expansion tank volume has to be at least 10% of the total jacket cooling water amount in the system.

The 10% expansion tank volume is defined as the volume between the lowest level (at the low level alarm sensor) and the overflow pipe or high level alarm sensor.

Deaerating tank and alarm device

Design and dimensions of the deaerating tank are shown in Fig. 12.02.01 ‘Deaerating tank’ and the corresponding alarm device is shown in Fig. 12.02.02 ‘Deaerating tank, alarm device’.

Chemical corrosion inhibitor and dosing tank

In order to properly mix the inhibitor into the JCW system circuit, the tank shall be designed to receive a small flow of jacket cooling water through the tank from the jacket water pumps. The tank shall be suitable for mixing inhibitors in form of both powder and liquid.

Recommended tank size ....0.3 m^3
Design pressure ....max. JCW system pressure
Suggested inlet orifice size .... ø10 mm

Deaerating tank

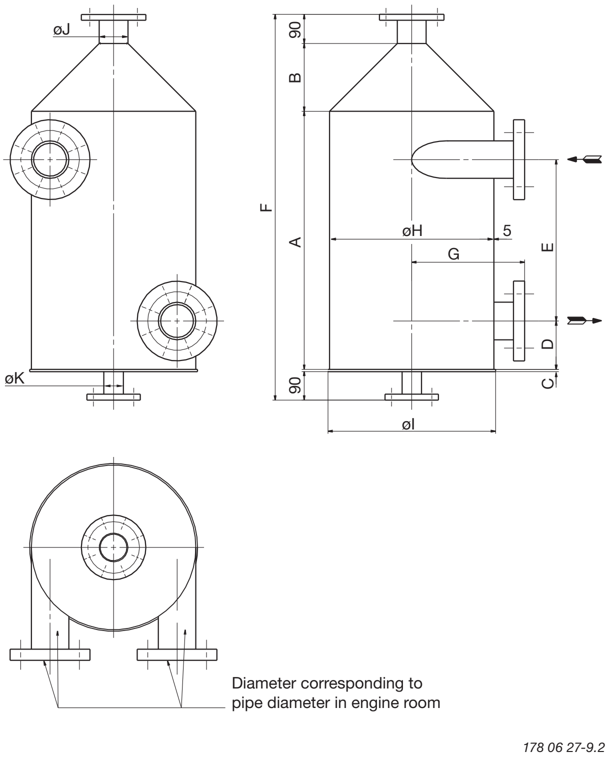


Fig. 12.07.01: Deaerating tank, option: 4 46 640

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.

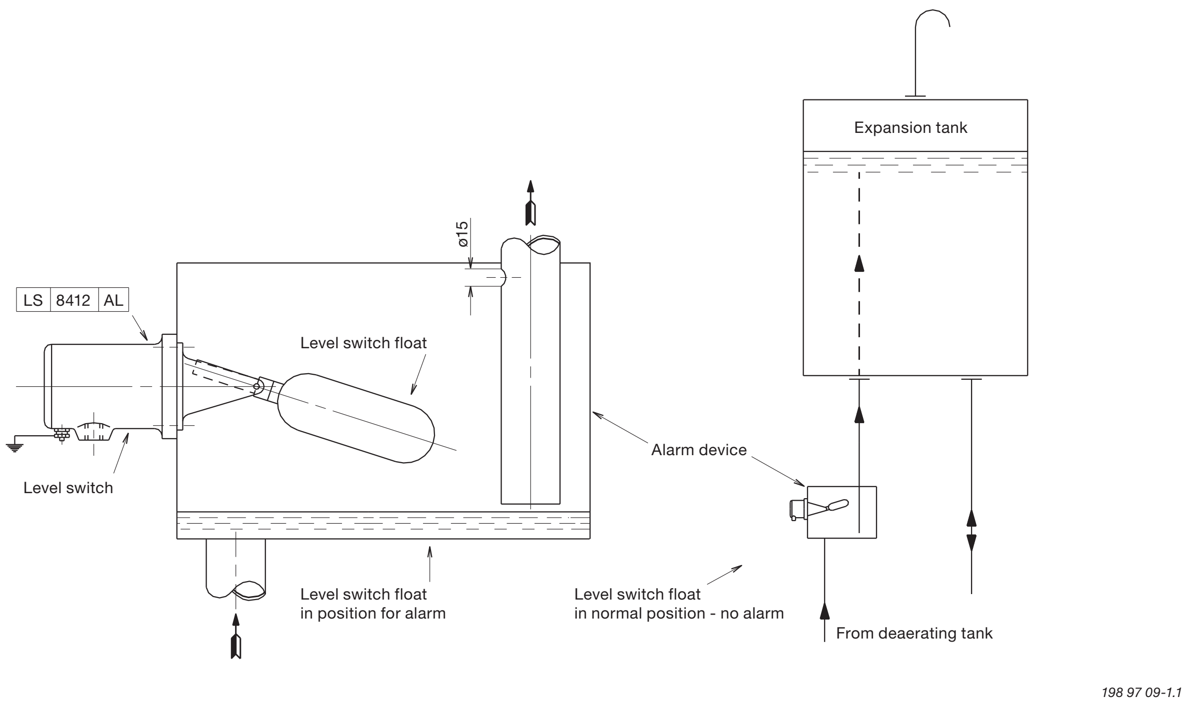


Fig. 12.07.02: Deaerating tank, alarm device, option: 4 46 645

Preheater components

When a preheater system is installed like in Fig. 12.01.01, the components shall be specified as follows:

Preheater pump (optional)

The pump is to be of the centrifugal type.

Pump flow rate ....10% of the Jacket water flow, see 'List of Capacities'
Working temperature .... 50-85 °C
Max. temperature (design purpose.............. 100 °C

A guideline for selecting centrifugal pumps is given in Section 6.04.

The preheater must be relocated if no preheater pump is installed.

Preheater

Heating flow rate ......10% of the Jacket water flow, see 'List of Capacities'
Heating capacity .... see the note below *)
Preheater type........ steam, thermal oil or electrical
Working temperature .... 50-85 °C
Max. working temperature..................up to 100 °C
Max. pressure drop
on jacket water side............................. ~0.2 bar

*) The preheater heating 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. 12.02.03. 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 NMCR power.

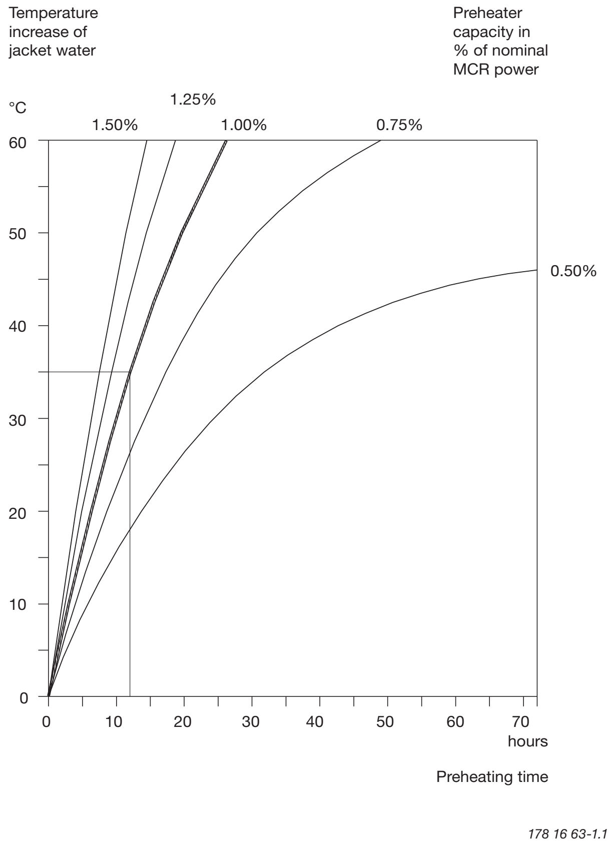


Fig. 12.02.03: Jacket water preheater, example

The preheater pump and JCW pumps should be electrically interlocked to avoid the risk of simultaneous operation.

Freshwater generator installation

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‘.

The reason is that the latter figure is 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 SMCR.

The calculation of the heat actually available at SMCR for a derated diesel engine can be made in the CEAS application described in Section 20.02.

A freshwater generator installation is shown in Fig. 12.01.01.

Calculation method

When using a normal freshwater generator of the single effect vacuum evaporator type, the freshwater production (based on the available jacket cooling water heat for design purpose $Q_{d\text{-}jw}$) may, for guidance, be estimated as 0.03 t/24h per 1 kW heat, i.e.:

$M_{fw} = 0.03 \times Q_{d\text{-}jw}$ t/24h

where
M_{fw} = Freshwater production (tons per 24 hours)
$Q_{d\text{-}jw} = Q_{jw50\%} \times Tol._{-15\%}$ (kW)

where
$Q_{jw50\%}$ = Jacket water heat at 50% SMCR engine load at ISO condition (kW)
$Tol._{-15\%}$ = Minus tolerance of 15% = 0.85

If more heat is utilised than the heat available at 50% SMCR and/or when using the freshwater generator below 50% engine load, a special temperature control system shall be incorporated. The purpose is to ensure, 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 of a thermostatic three-way valve as shown in Fig. 12.01.01 or a special built-in temperature control in the freshwater generator, e.g. an automatic start/stop function, or similar.

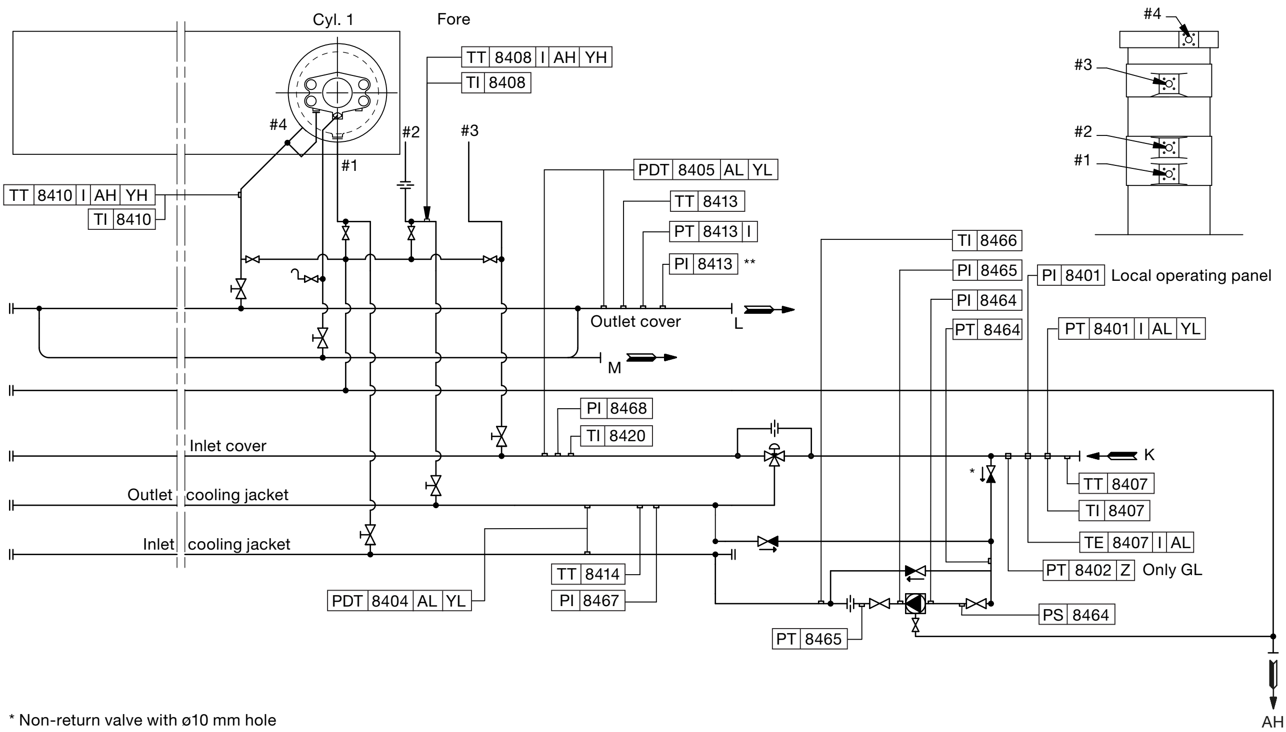
If more heat is utilised than the heat available at 50% SMCR, the freshwater production may for guidance be estimated as:

$M_{fw} = 0.03 \times Q_{d\text{-}jw}$ t/24h

where
M_{fw} = Freshwater production (tons per 24 hours)
$Q_{d\text{-}jw} = Q_{jwNCR} \times Tol._{-15\%}$ (kW)

where
Q_{jwNCR} = Jacket water heat at NCR engine load at ISO condition (kW)
$Tol._{-15\%}$ = Minus tolerance of 15% = 0.85

Jacket Cooling Water Pipes



* Non-return valve with ø10 mm hole

** PI 8413 Optional

As an option, jacket cooling water inlet K and outlet L can be located fore

565 17 29-6.3.0

The letters refer to list of ‘Counterflanges’
The item no. refer to ‘Guidance Values Automation’

Fig. 12.06.01: Jacket cooling water pipes

Starting 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 approx. 7 bar to 'AP' for turbocharger cleaning (soft blast), and a minor volume used for the fuel valve testing unit. The specific air pressure required for turbocharger cleaning is subject to make and type of turbocharger.

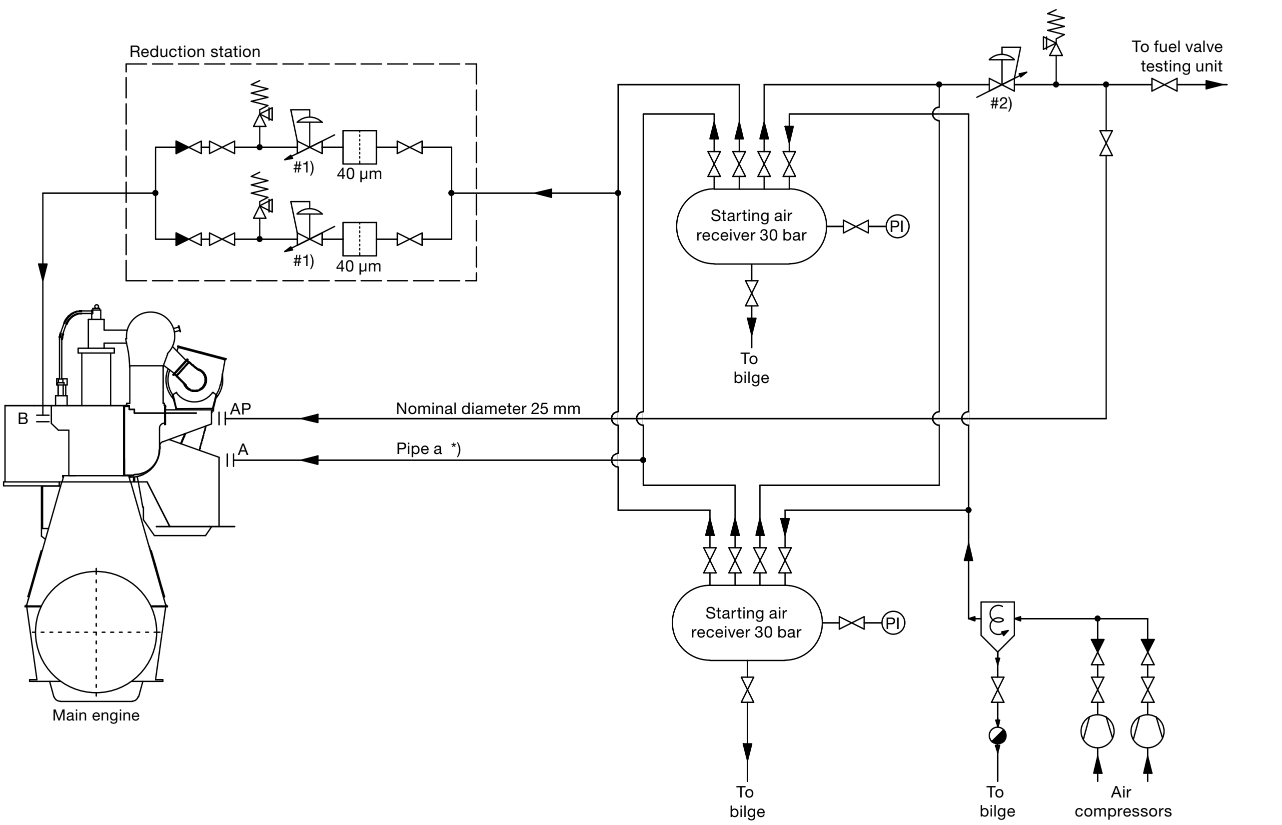
Please note that the air consumption for control air, safety air, turbocharger cleaning, sealing air for exhaust valve and for fuel valve testing unit are momentary requirements of the consumers.

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 Energy Solutions 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-es.com'→Two-Stroke' → 'Technical Papers'.



The letters refer to list of 'Counterflanges'
*) Pipe a nominal dimension: DN125 mm

078 83 76-7.7.0

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 approx. 7 bar *)
*) Subject to make and type of TC (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 50 141, is included in the basic design.

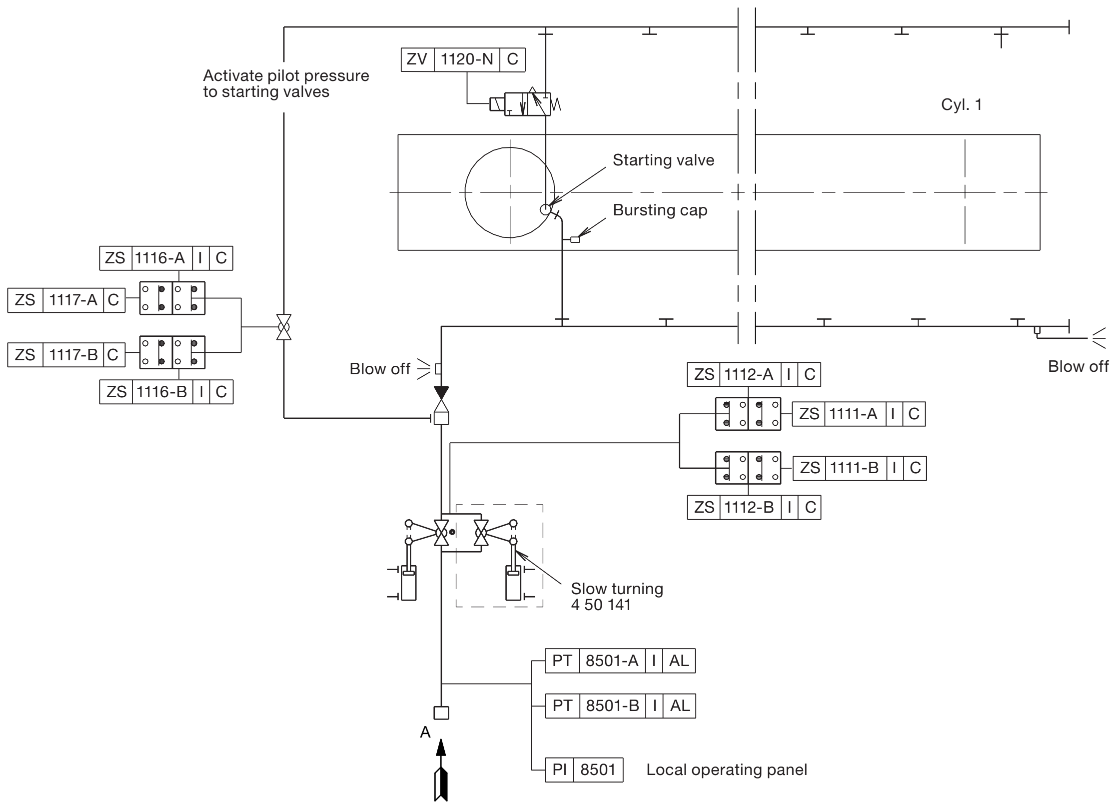
The Engine Control System regulates the supply of control air to the starting valves in accordance with the correct firing sequence and the timing.

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-es.com →'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

198 98 21-5.3.1

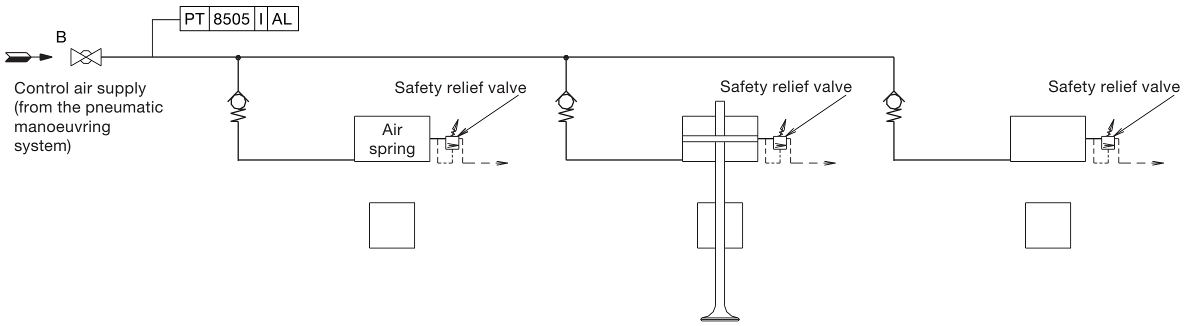
Fig. 13.03.01: Starting air pipes

Exhaust Valve Air Spring Pipes

The exhaust valve is opened hydraulically by a multi-way valve, either an Electronic exhaust Valve Actuation (ELVA) or a Fuel Injection Valve Actuation (FIVA) valve, which is activated by the Engine Control System.

The closing force is provided by an 'air spring' which leaves the valve spindle free to rotate.

The compressed air is taken from the control air supply, see Fig. 13.03.02.



The item nos. refer to 'Guidance values automation'
The piping is delivered with and fitted onto the engine

517 15 68-2.1.1

Fig. 13.03.02: Air spring pipes for exhaust valves

Electric Motor for Turning Gear

MAN Energy Solutions delivers a turning gear with built-in disc brake, option 4 80 101.

A turning gear with an electric motor of another protection or insulation class can be ordered, option 4 80 103. Information about the alterna-tive executions is available on request.

Two basic executions are available for power supply frequencies of 60 and 50 Hz respectively. Nominal power and current consumption of the motors are listed below.

Electric motor and brake, voltage	3 x 440-480 V
Electric motor and brake, frequency	60 Hz
Protection, electric motor and brake	IP 54
Insulation class	F

Number of cylinders	Electric motor	
	Nominal power, kW	Nominal current, A
5-7	4.8	8.1
8	Data is available on request	

Electric motor and brake, voltage	3 x 380-415 V
Electric motor and brake, frequency	50 Hz
Protection, electric motor and brake	IP 54
Insulation class	F

Number of cylinders	Electric motor	
	Nominal power, kW	Nominal current, A
5-7	4	8.1
8	Data is available on request	

555 68 07-5.0.0

Fig. 13.04.01: Electric motor for turning gear, option: 4 80 101

Scavenge Air

14

Scavenge Air System

Scavenge air is supplied to the engine by one or more turbochargers, located on the exhaust side of the engine.

The compressor of the turbocharger draws air from the engine room, through an air filter, and the compressed air is cooled by the scavenge air cooler, one per turbocharger. The scavenge air cooler is provided with a water mist catcher, which prevents condensate water from being carried with the air into the scavenge air receiver and to the combustion chamber.

The scavenge air system (see Figs. 14.01.01 and 14.02.01) is an integrated part of the main engine.

The engine power figures and the data in the list of capacities are based on MCR at tropical conditions, i.e. a seawater temperature of 32 °C, or freshwater temperature of 36 °C, and an ambient air inlet temperature of 45 °C.

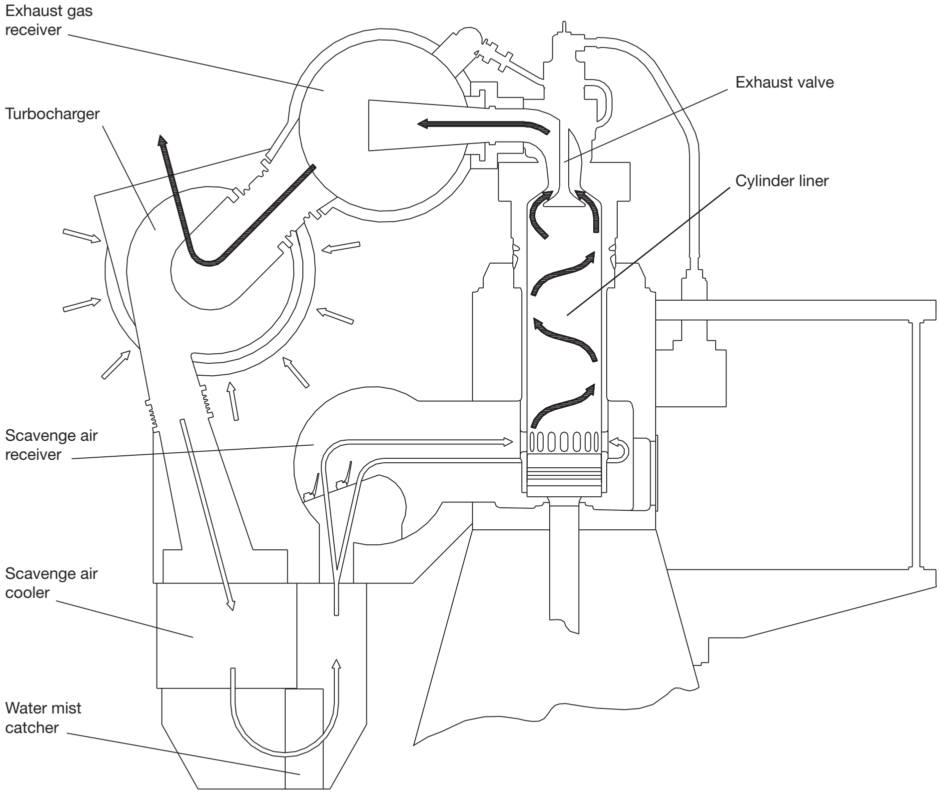


Fig. 14.01.01: Scavenge Air System

Auxiliary Blowers

The engine is provided with a minimum of two electrically driven auxiliary blowers, the actual number depending on the number of cylinders as well as the turbocharger make and amount.

The auxiliary blowers are integrated in the reversing chamber below the scavenge air cooler. Between the scavenge air cooler and the scavenge air receiver, non-return valves are fitted which close automatically when the auxiliary blowers start supplying the scavenge air.

Auxiliary blower operation

The auxiliary blowers start operating consecutively before the engine is started and will ensure complete scavenging of the cylinders in the starting phase, thus providing the best conditions for a safe start.

During operation of the engine, the auxiliary blowers will start automatically whenever the blower inlet pressure drops below a preset pressure, corresponding to an engine load of approximately 25-35%.

The blowers will continue to operate until the blower inlet pressure again exceeds the preset pressure plus an appropriate hysteresis (i.e. taking recent pressure history into account), corresponding to an engine load of approximately 30-40%.

Emergency running

If one of the auxiliary blowers is out of function, the other auxiliary blower will function in the system, without any manual adjustment of the valves being necessary.

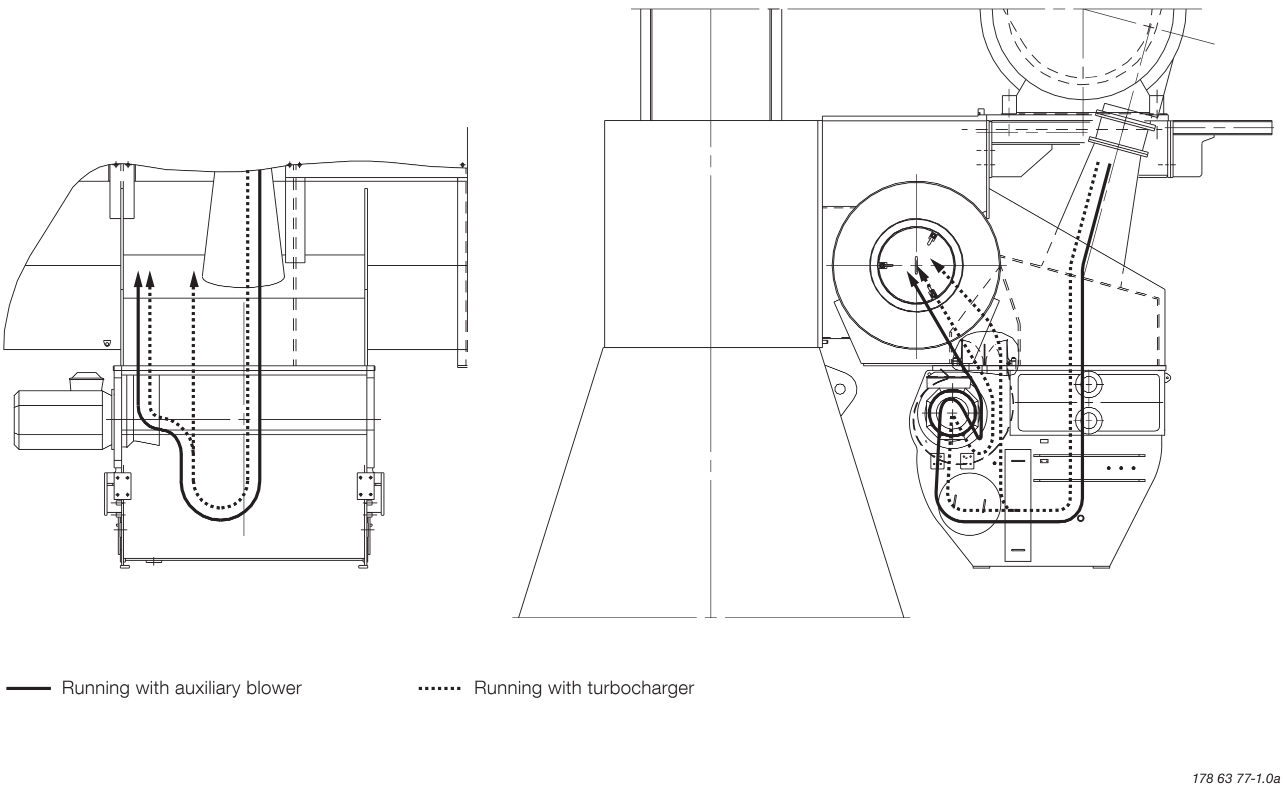


Fig. 14.02.01: Scavenge air system, integrated blower

Control of the Auxiliary Blowers

The control system for the auxiliary blowers is integrated in the Engine Control System. The auxiliary blowers can be controlled in either automatic (default) or manual mode.

In automatic mode, the auxiliary blowers are started sequentially at the moment the engine is commanded to start. During engine running, the blowers are started and stopped according to preset scavenge air pressure limits.

When the engine stops, the blowers are stopped after 30 minutes to prevent overheating of the blowers. When a start is ordered, the blower will be started in the normal sequence and the actual start of the engine will be delayed until the blowers have started.

In manual mode, the blowers can be controlled individually from the ECR (Engine Control Room) panel irrespective of the engine condition.

Referring to Fig. 14.02.02, the Auxiliary Blower Starter Panels control and protect the Auxiliary Blower motors, one panel with starter per blower.

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

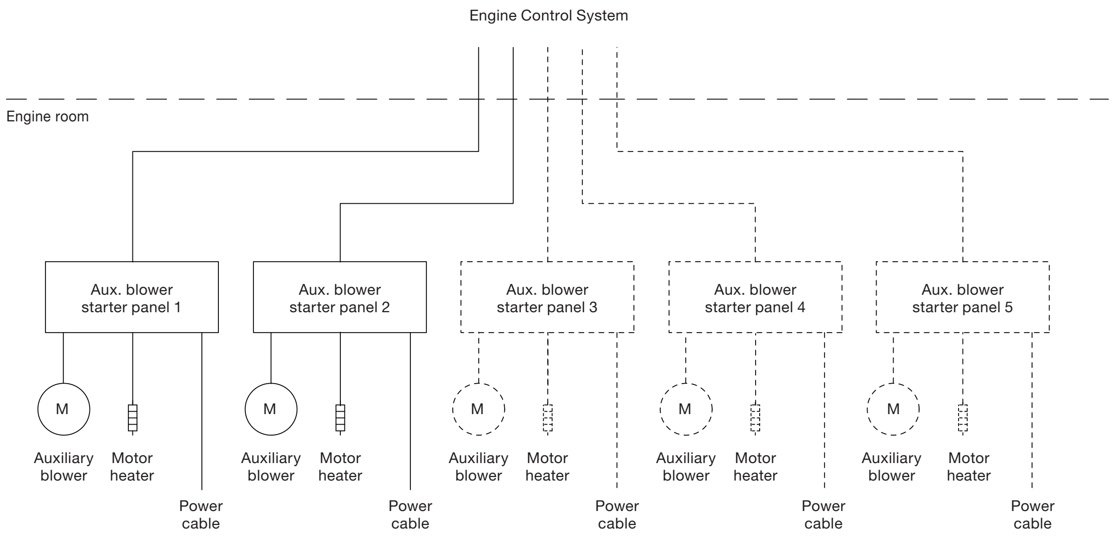
Scavenge air cooler requirements

The data for the scavenge air cooler is specified in the description of the cooling water system chosen.

For further information, please refer to our publication titled:

MAN Energy Solutions Influence of Ambient Temperature Conditions

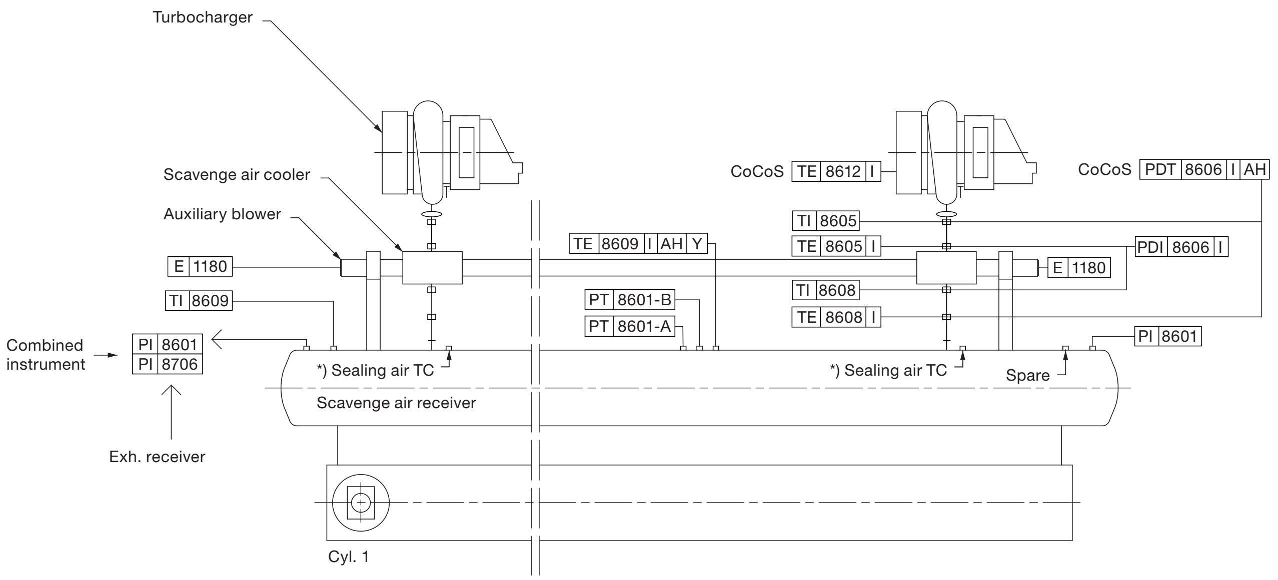
The publication is available at www.marine.man-es.com →'Two-Stroke' → 'Technical Papers'.



178 61 30-2.0

Fig. 14.02.02: Diagram of auxiliary blower control system

Scavenge Air Pipes



The item No. refer to 'Guidance Values Automation'

*) Option, see Fig. 15.02.05: Soft blast cleaning of turbine side

Fig. 14.03.01: Scavenge air pipes

Electric Motor for Auxiliary Blower

The number of auxiliary blowers in a propulsion plant may vary depending on the actual amount of turbochargers as well as space requirements.

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 Energy Solutions, Copenhagen.

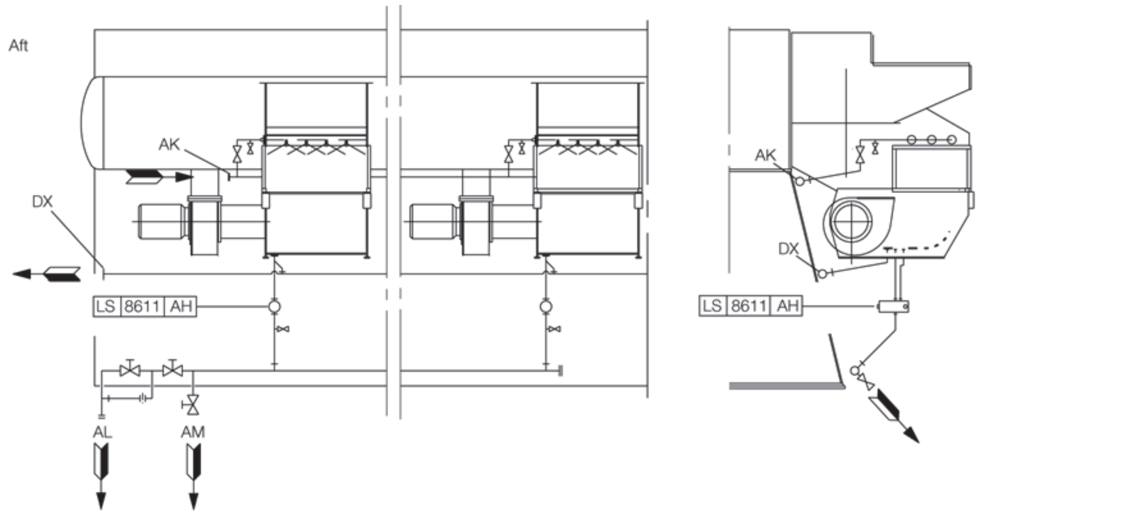
Number of cylinders	Number of turbochargers	Number of auxiliary blowers	Installed power/blower kW
5	1	2	43
6	1	2	54
6	2	2	54
7	1	2	65
7	2	2	65
8	2	2	75

The installed power of the electric motors are based on a voltage supply of 3x440V at 60Hz.

The electric motors are delivered with and fitted onto the engine.

Table 14.04.01: Electric motor for auxiliary blower

Scavenge Air Cooler Cleaning System



The letters refer to list of 'Counterflanges'. The item nos. refer to 'Guidance values automation'.

Fig. 14.05.01: Air cooler cleaning pipes, two or more air coolers

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.

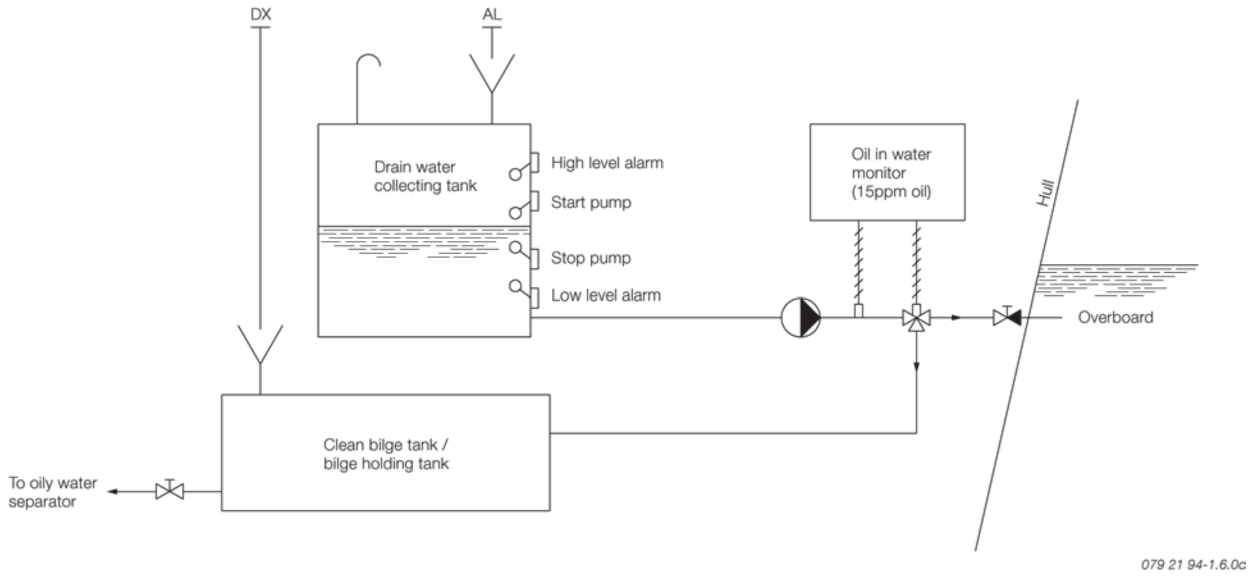
Auto Pump Overboard System

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.

198 76 84-9.2

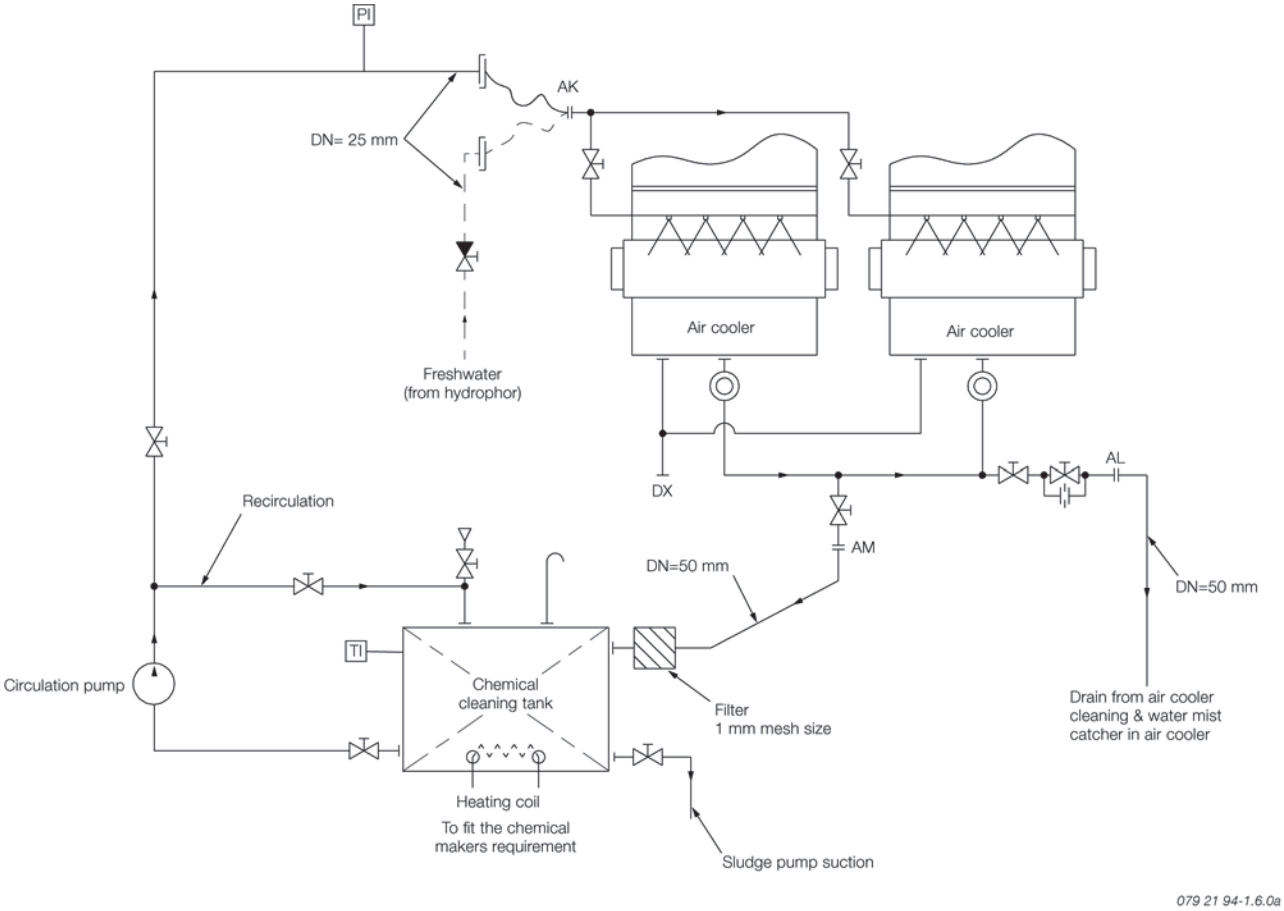
Auto Pump Overboard System



The letters refer to list of 'Counterflanges'.

Fig. 14.05.02: Suggested automatic disposal of drain water, if required by owner (not a demand from MAN Energy Solutions*)*

Air Cooler Cleaning Unit



	No. of cylinders	
	5	6-8
Chemical tank capacity, m^3	0.3	0.6
Circulation pump capacity at 3 bar, m^3/h	1	2

079 21 94-1.6.0

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

Scavenge Air Box Drain System

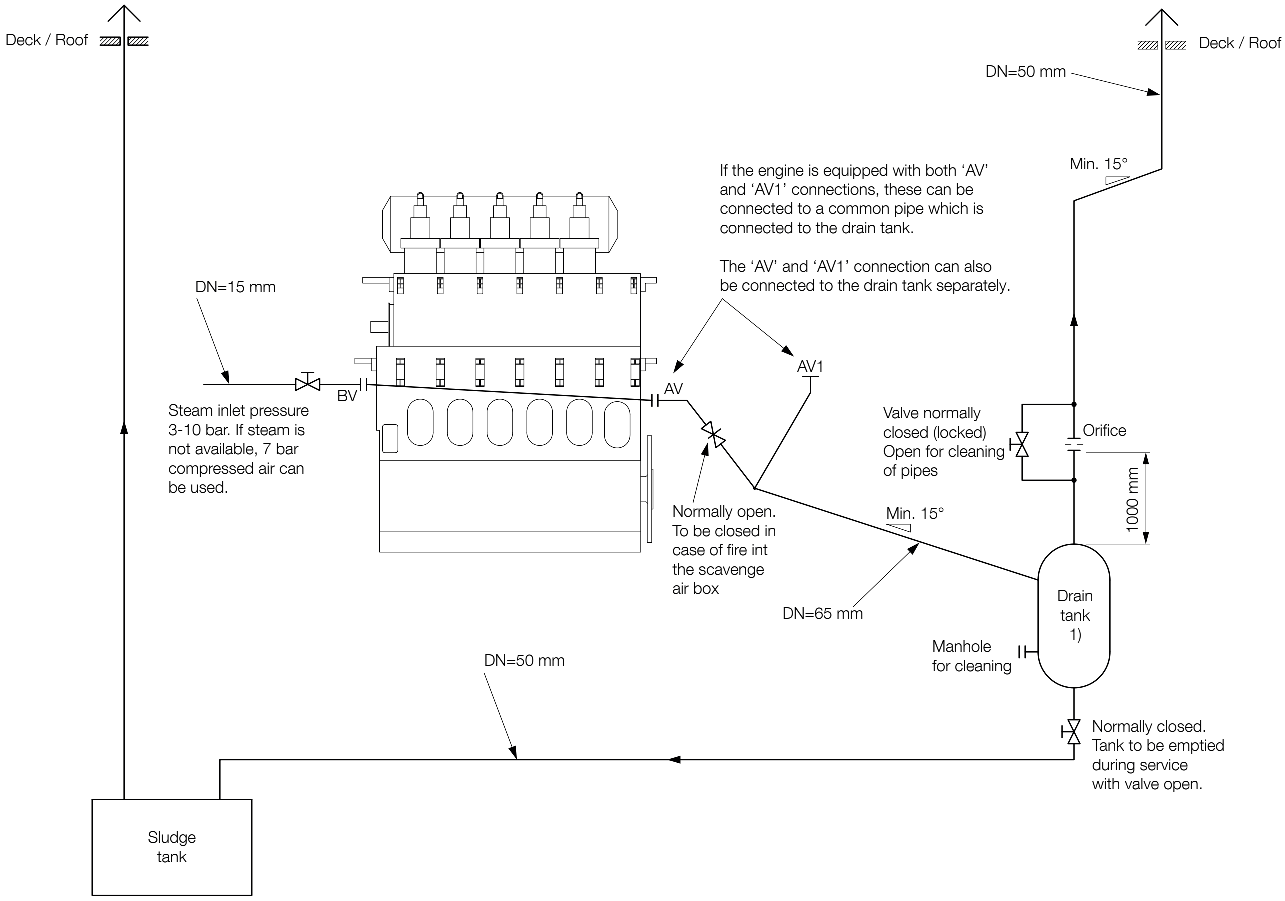
The scavenge air box is continuously drained through 'AV' to a small pressurised drain tank, from where the sludge is led to the sludge tank. Steam can be applied through 'BV', if required, to facilitate the draining. See Fig. 14.06.01.

The continuous drain from the engine scavenge air area must not be directly connected to the sludge tank due to the pressure level.

The drain tank shall be designed according to the pressurised system connected to the BV connection as one of the following:

- Steam maximum working pressure
- Compressed air maximum working pressure

It is recommended that the drain tank is placed close to the engine to avoid lon piping between engine and drain tank and thereby minimize the risk of the pipe being blocked by sludge.



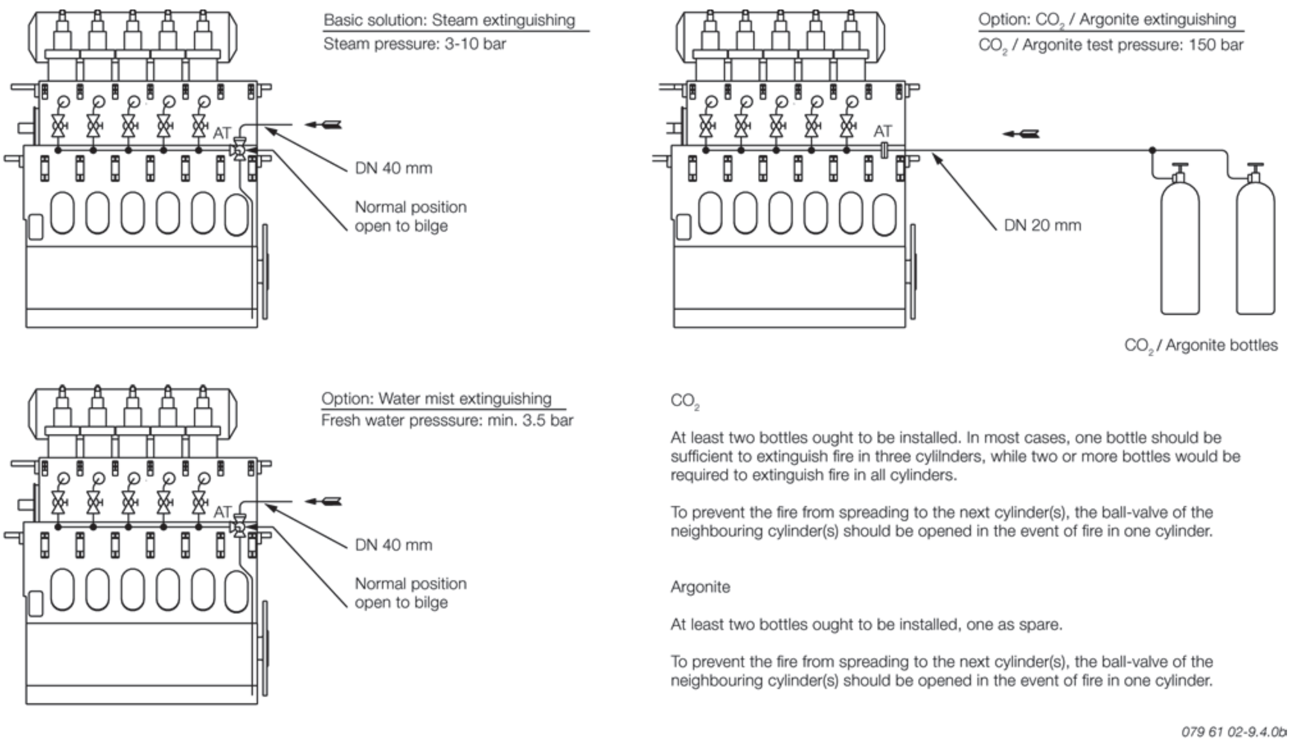
The letters refer to list of 'Counterflanges'

No. of cylinders:	**5-6**	**7-9**	**10-12**	**14**
Drain tank capacity, m^3	0.5	0.7	0.9	1.1

079 61 03-0.8.0

Fig. 14.06.01: Scavenge air box drain system

Fire Extinguishing System for Scavenge Air Space



The letters refer to list of 'Counterflanges'.

Fig. 14.07.01: 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.:	3.2 kg/cyl.

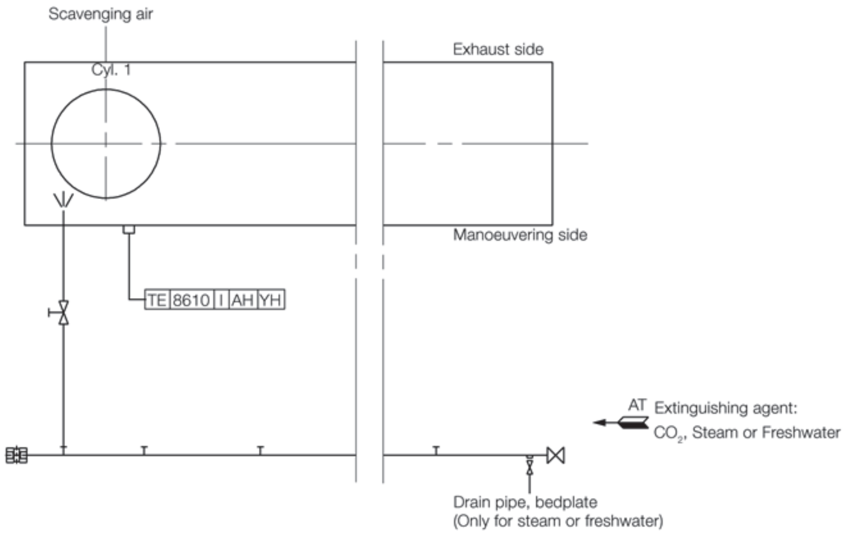
Water mist fire extinguishing for scavenge air space

Freshwater pressure:	min. 3.5 bar
Freshwater quantity, approx.:	2.6 kg/cyl.

CO_2 fire extinguishing for scavenge air space

CO_2 test pressure:	150 bar
CO_2 quantity, approx.:	6.5 kg/cyl.
Argonite quantity approx.:	2.0 kg/cyl.

Fire Extinguishing Pipes in Scavenge Air Space

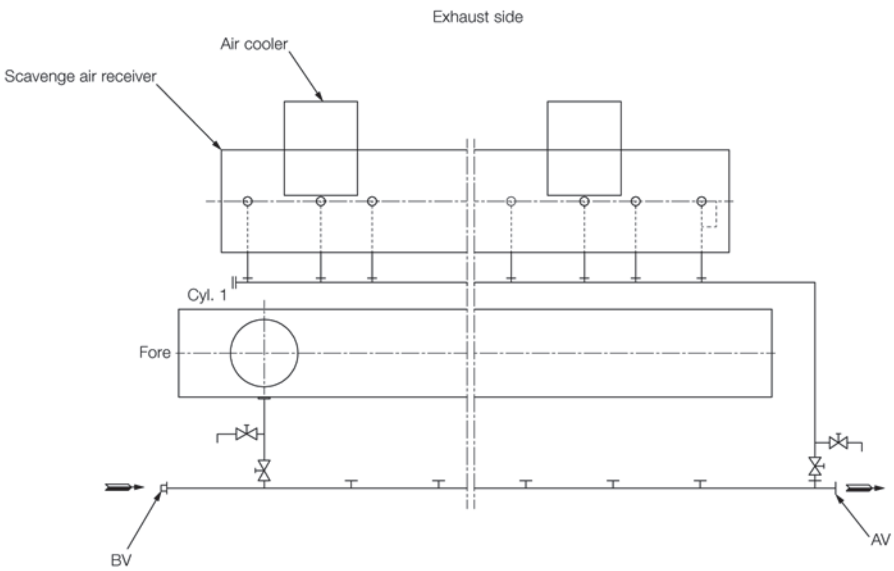


126 40 81-0.9.0

The letters refer to 'List of flanges'.
The item no. refer to 'Guidance Values Automation'.

Fig. 14.07.02: Fire extinguishing pipes in scavenge air space

Scavenge Air Space, Drain Pipes



523 76 96-9.2.0

The letters refer to 'List of flanges'.

Fig. 14.07.03: Scavenge air space, drain pipes

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 turbochargers are located on the exhaust side of the engine.

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

All makes of turbochargers are fitted with an arrangement for water washing of the compressor side, and soft blast cleaning of the turbine side, see Figs. 15.02.02, 15.02.03 and 15.02.04. Washing of the turbine side is only applicable on MAN turbochargers, though not for dual fuel engines.

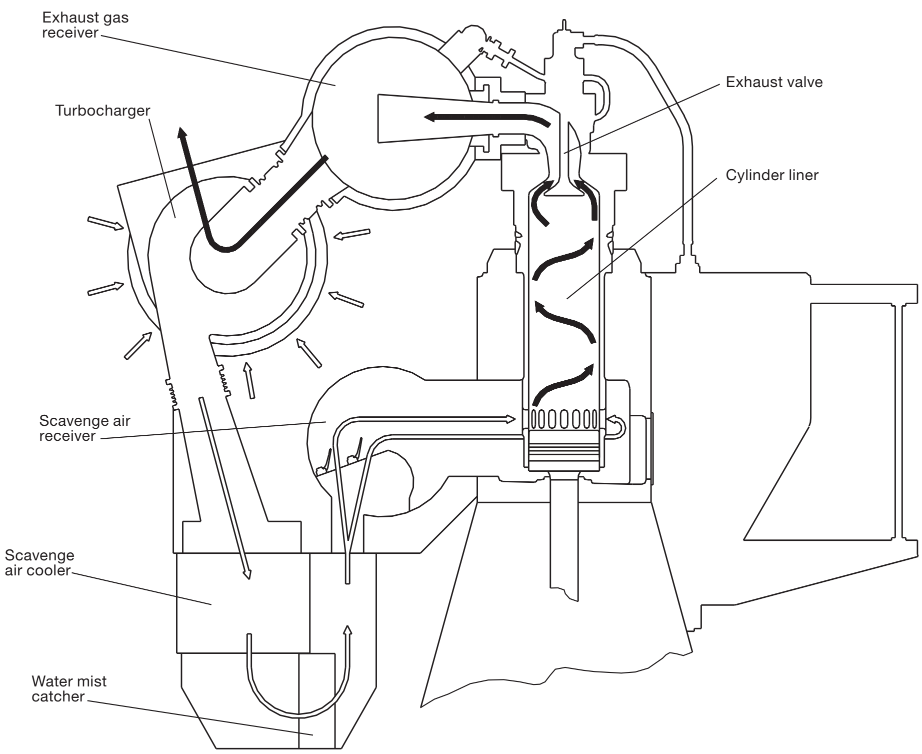
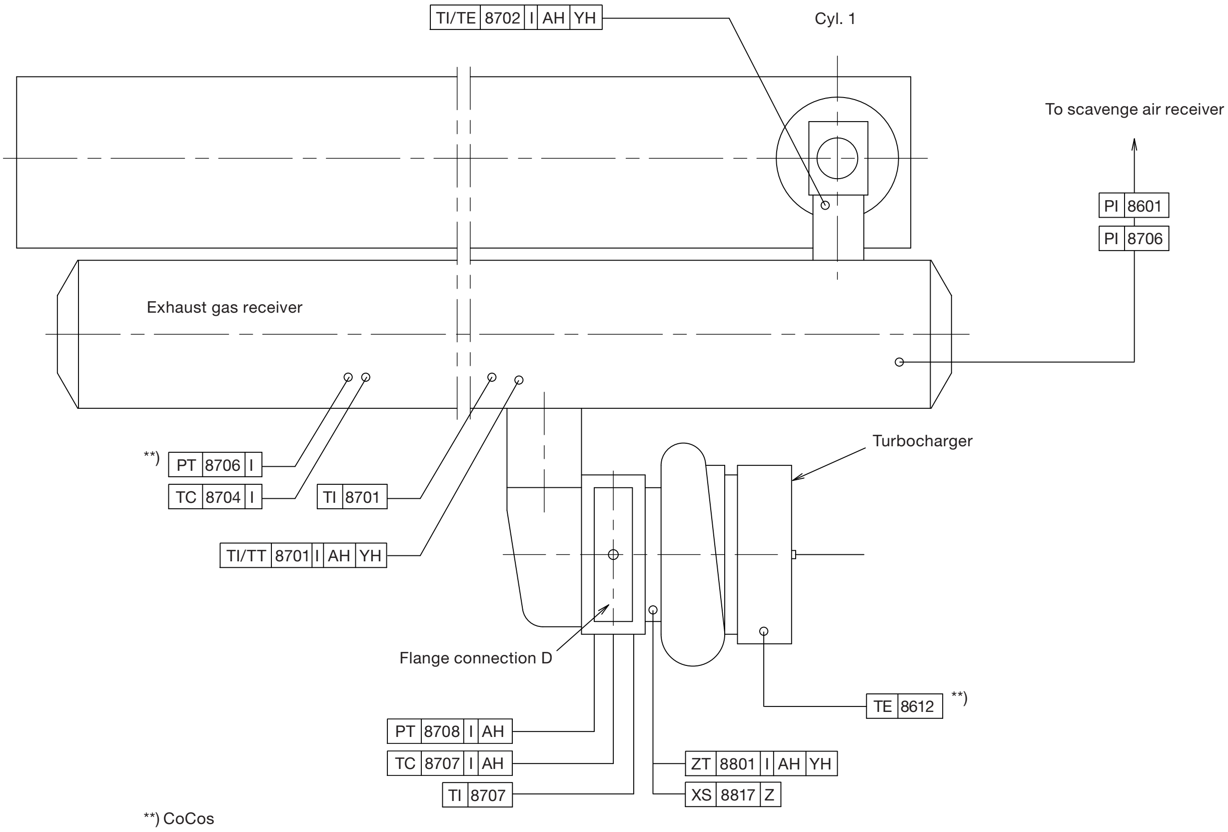


Fig. 15.01.01: Exhaust gas system on engine

Exhaust Gas Pipes



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The item nos. refer to 'Guidance Values Automation'

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Fig. 15.02.01: Exhaust gas pipes

Cleaning Systems

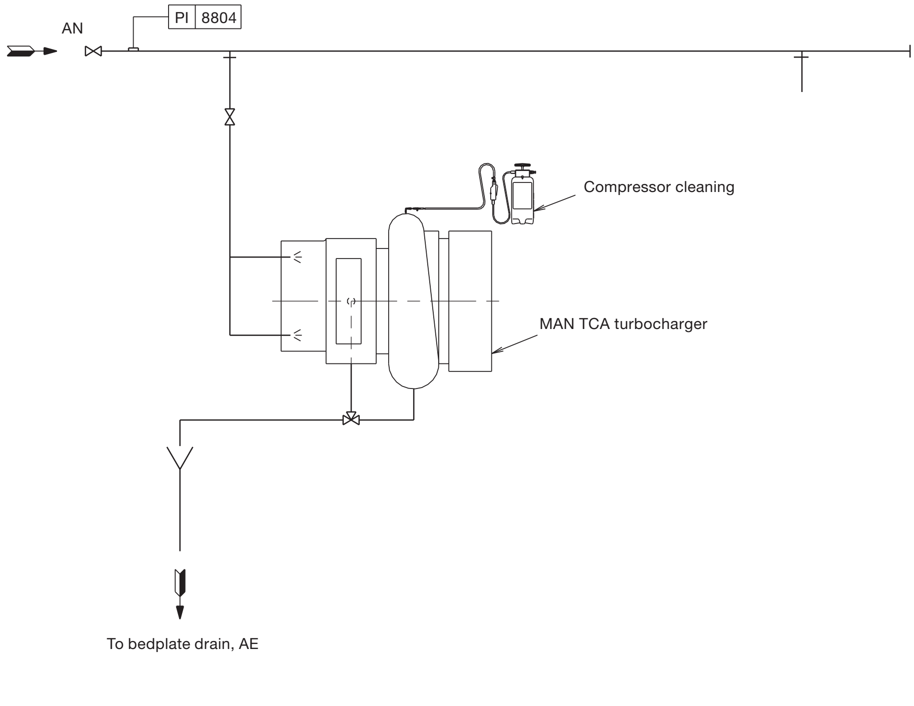


Fig. 15.02.02: MAN TCA turbocharger, water washing of turbine side

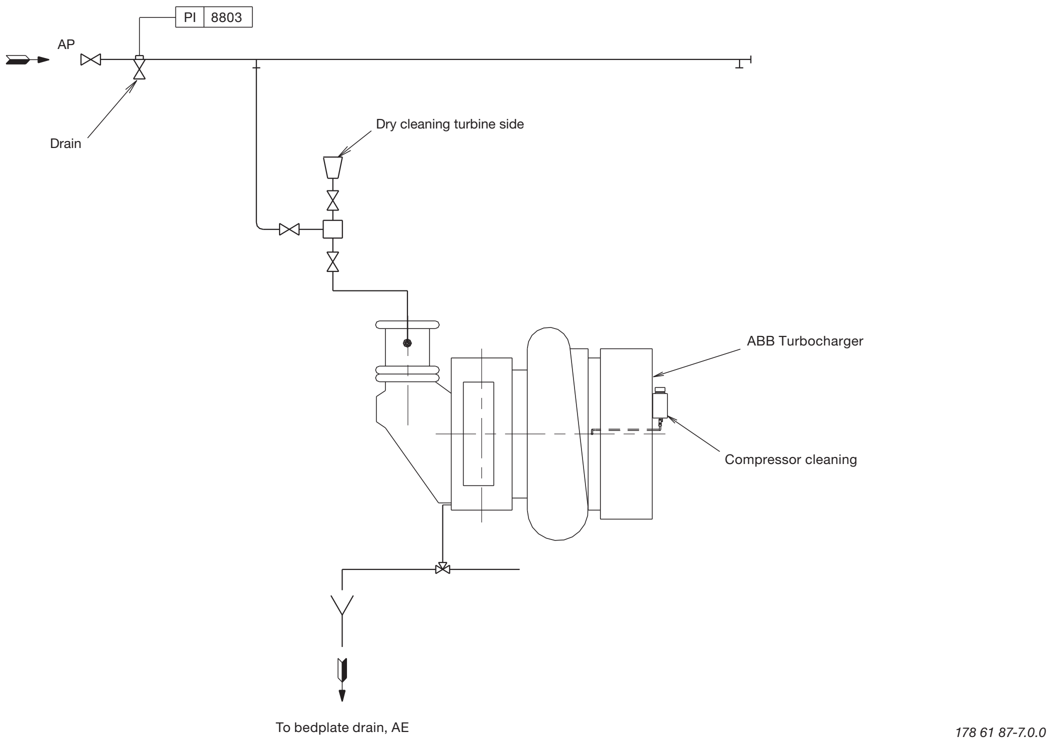
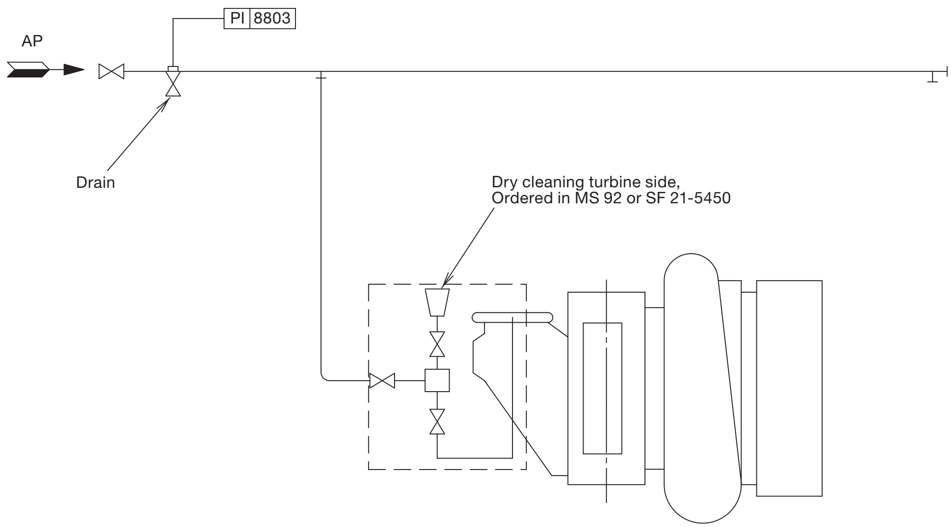


Fig. 15.02.03: Soft blast cleaning of turbine side and water washing of compressor side for ABB turbochargers

Soft Blast Cleaning Systems



514 69 25-5.1.0

Fig. 15.02.04: Soft blast cleaning of turbine side, basic

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.

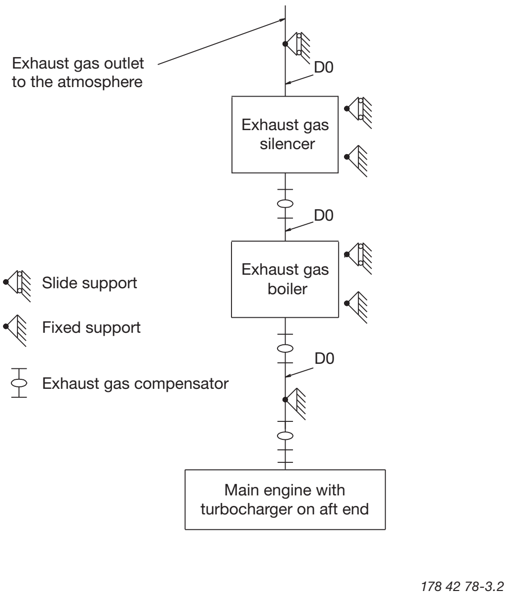


Fig. 15.04.01a: Exhaust gas system, one turbocharger

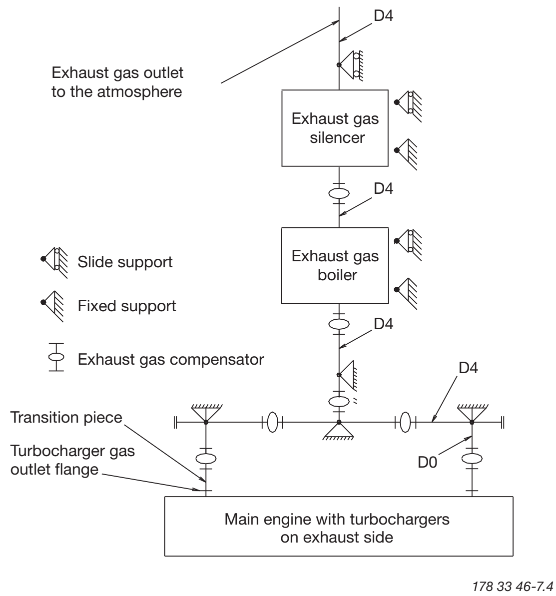


Fig. 15.04.01b: Exhaust gas system, two or more TCs

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.

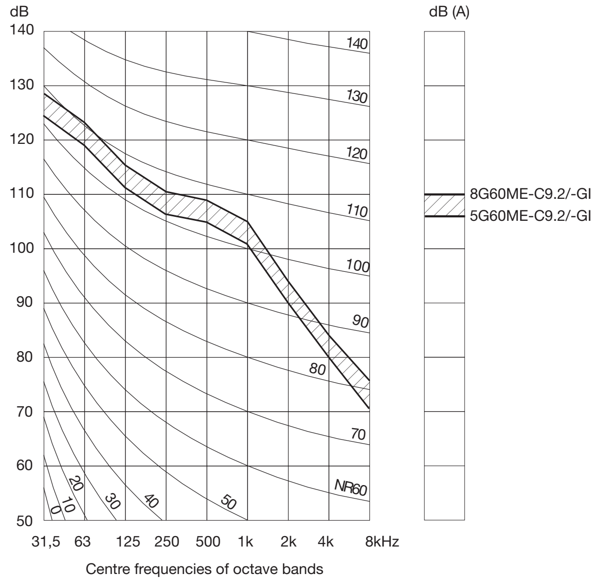
For each doubling of the distance, the noise level will be reduced by about 6 dB (far-field law).

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 65 41-2.0

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:

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

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

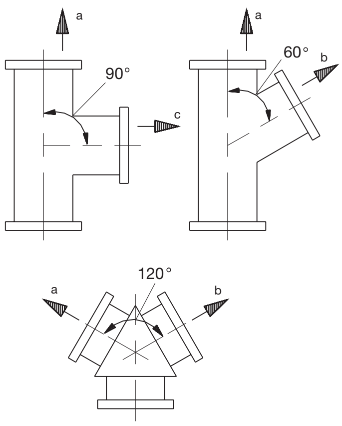
At any given position in the exhaust gas system, the total pressure of the flow can be divided into dynamic pressure (referring to the gas velocity) and static pressure (referring to the wall pressure, where the gas velocity is zero).

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



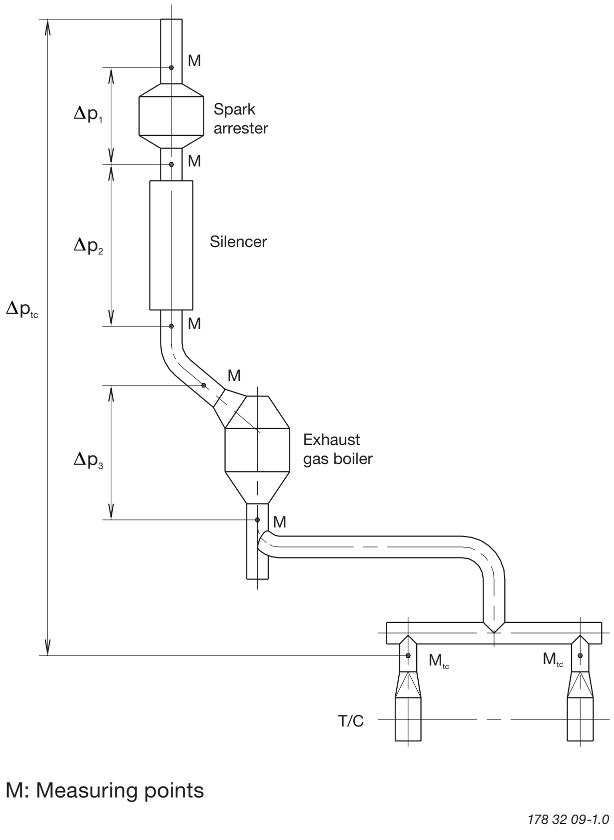
Change-over valves

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

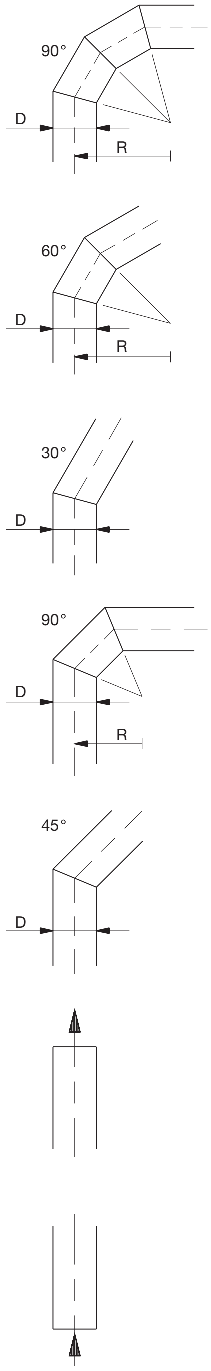
Change-over valve of type with volume

$\zeta a = \zeta b$ = about 2.0



M: Measuring points

178 32 09-1.0

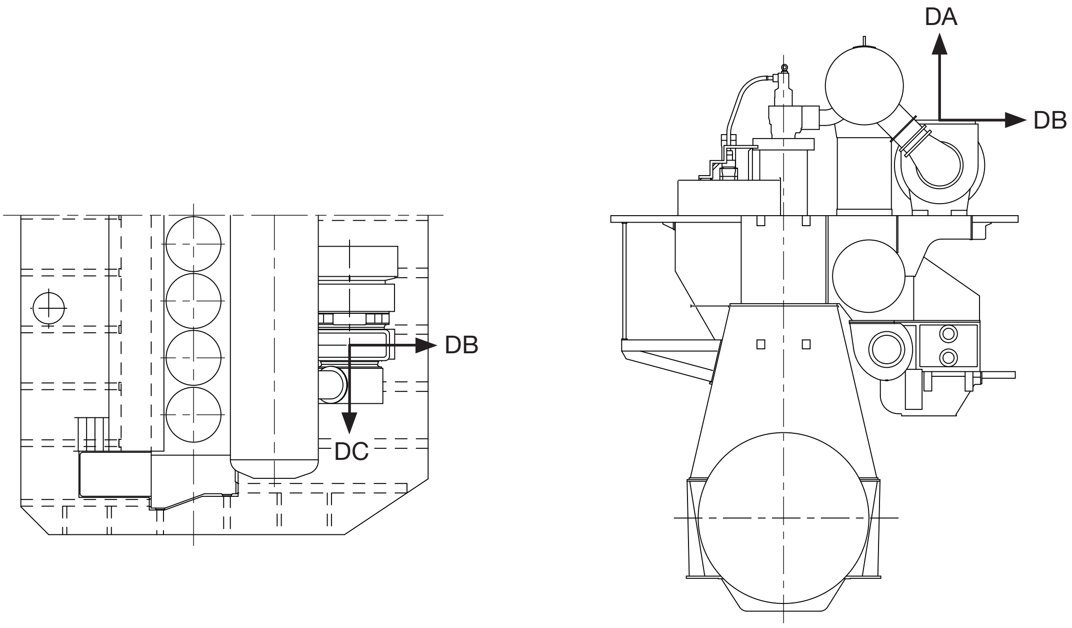


Bend	R	ζ
90°	R = D	ζ = 0.28
	R = 1.5D	ζ = 0.20
	R = 2D	ζ = 0.17
60°	R = D	ζ = 0.16
	R = 1.5D	ζ = 0.12
	R = 2D	ζ = 0.11
30°		ζ = 0.05
90°	R = D	ζ = 0.45
	R = 1.5D	ζ = 0.35
	R = 2D	ζ = 0.30
45°		ζ = 0.14
	Outlet from top of exhaust gas uptake	ζ = 1.00
	Inlet (from turbocharger)	ζ = – 1.00

178 06 85-3.0

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

Forces and Moments at Turbocharger



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. 15.06.01: Vectors of thermal expansion at the turbocharger exhaust gas outlet flange

No. of cylinders		5-8		5	6	7	8
Turbocharger Make	Type	DA mm	DB mm	DC mm	DC mm	DC mm	DC mm
MAN	TCA55	7.7	1.2	1.5	1.7	1.9	2.1
	TCA66	8.1	1.3	1.5	1.7	1.9	2.1
	TCA77	9.3	1.4	1.5	1.7	1.9	2.1
	TCA88	9.8	1.5	1.5	1.7	1.9	2.1
ABB	A165 / A265	6.9	1.2	1.5	1.7	1.9	2.1
	A170 / A270	7.0	1.2	1.5	1.7	1.9	2.1
	A175 / A275	7.6	1.3	1.5	1.7	1.9	2.1
	A180 / A280	8.6	1.4	1.5	1.7	1.9	2.1
	A185 / A285	9.4	1.4	1.5	1.7	1.9	2.1
	A190	10.3	1.5	1.5	1.7	1.9	2.1
MHI	MET53	7.1	1.3	1.5	1.7	1.9	2.1
	MET60	7.6	1.3	1.5	1.7	1.9	2.1
	MET66	7.9	1.3	1.5	1.7	1.9	2.1
	MET71	8.3	1.3	1.5	1.7	1.9	2.1
	MET83	9.0	1.4	1.5	1.7	1.9	2.1

Table 15.06.02: Max. expected movements of the exhaust gas flange resulting from thermal expansion

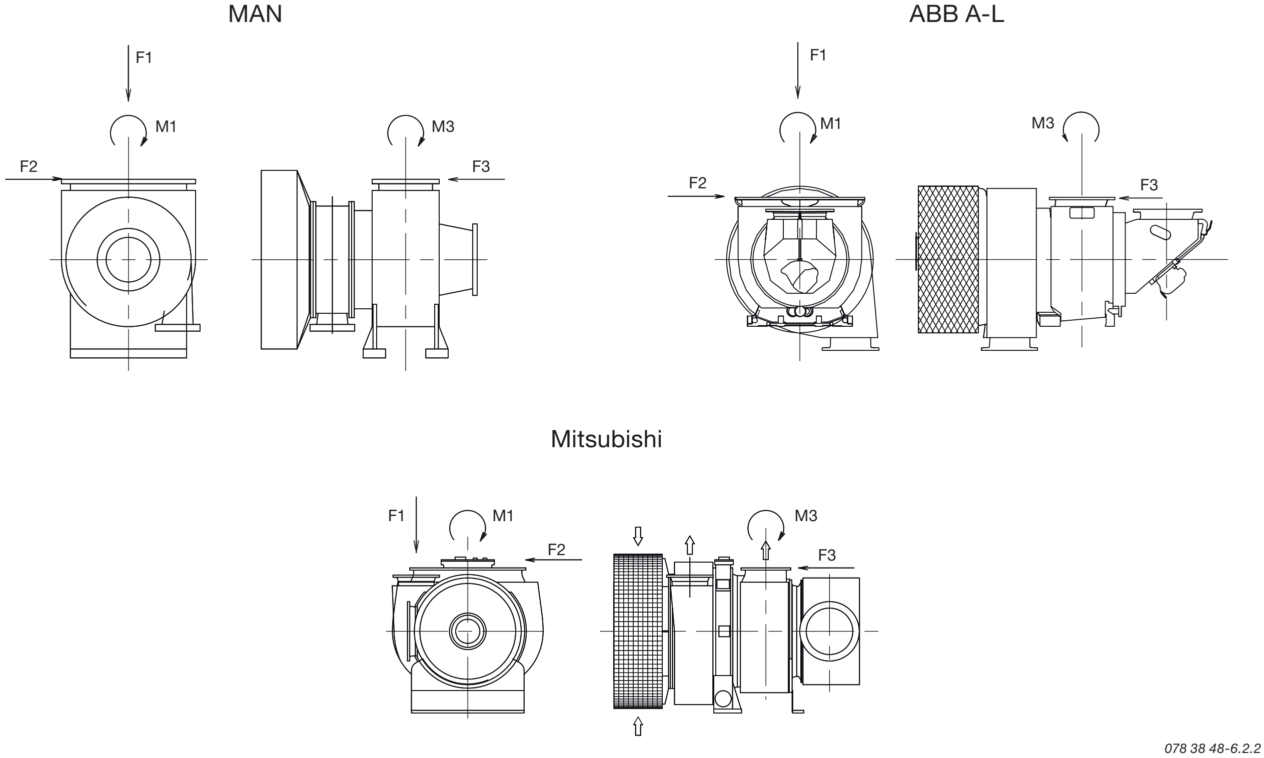


Fig. 15.06.03: Forces and moments on the turbochargers' exhaust gas outlet flange

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	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
	TCA88	4,500	9,100	12,000	12,000	5,900
ABB	A175 / A275	3,300	3,300	5,400	3,500	3,500
	A180 / A280	4,600	4,600	6,800	4,400	4,400
	A185	6,600	6,600	8,500	5,500	5,500
MHI	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
	MET83	9,800	4,900	11,700	4,100	3,700

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.

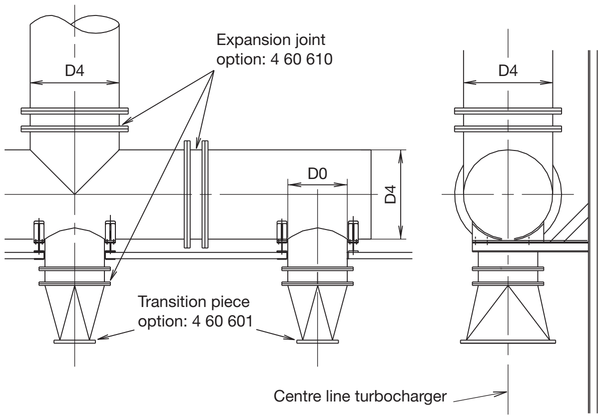


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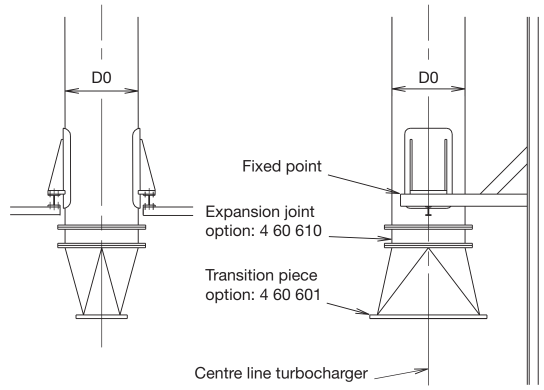
Fig. 15.07.01a: Exhaust pipe system, with turbocharger located on exhaust side of engine, option: 4 59 122



178 31 59-8.1r

Fig. 15.07.01b: Exhaust pipe system, with single turbocharger located on aft end of engine, option: 4 59 124

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]
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
53.6	61.3	68.9	76.6	1,700	1,200	1,000	1,700
60.1	68.7	77.3	85.9	1,800	1,300	1,050	1,800
67.0	76.5	86.1	95.7	N.A.	1,300	1,100	1,900

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

Engine Control System

16

Engine Control System ME

The Engine Control System (ECS) for the ME engine is prepared for conventional remote control, having an interface to the Bridge Control system and the Local Operating Panel (LOP).

A Multi-Purpose Controller (MPC) is applied as control unit for specific tasks described below: ACU, CCU, CWCU, ECU, SCU and EICU. Except for the CCU, the control units are all built on the same identical piece of hardware and differ only in the software installed. For the CCU on ME and ME-C only, a downsized and cost-optimised controller is applied, the MPC10.

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

The ME system has a high level of redundancy. It has been a requirement to its design that no single failure related to the system may cause the engine to stop. In most cases, a single failure will not affect the performance or power availability, or only partly do so by activating a slow down.

It should be noted that any controller could be replaced without stopping the engine, which will revert to normal operation immediately after the replacement of the defective unit.

Main Operating Panel

Two redundant main operating panel (MOP) screens are available for the engineer to carry out engine commands, adjust the engine parameters, select the running modes, and observe the status of the control system. Both MOP screens are located in the Engine Control Room (ECR), one serving as back-up unit in case of failure or to be used simultaneously, if preferred.

Both MOP screens consist of a marine approved Personal Computer with a touch screen and pointing device as shown in Fig. 5.16.02.

Engine Control Unit

For redundancy purposes, the control system comprises two engine control units (ECU) operating in parallel and performing the same task, one being a hot stand-by for the other. If one of the ECUs fail, the other unit will take over the control without any interruption.

The ECUs perform such tasks as:

- Speed governor functions, start/stop sequences, timing of fuel injection, timing of exhaust valve activation, timing of starting valves, etc.
- Continuous running control of auxiliary functions handled by the ACUs
- Alternative running modes and programs.

Cylinder Control Unit

The control system includes one cylinder control unit (CCU) per cylinder. The CCU controls the multi-way valves: Electronic Fuel Injection (ELFI) and Electronic exhaust Valve Actuation (ELVA) or Fuel Injection and exhaust Valve Activation (FIVA) as well as the Starting Air Valves (SAV) in accordance with the commands received from the ECU.

All the CCUs are identical, and in the event of a failure of the CCU for one cylinder only this cylinder will automatically be cut out of operation.

Auxiliary Control Unit

The control of the auxiliary equipment on the engine is normally divided among three auxiliary control units (ACU) so that, in the event of a failure of one unit, there is sufficient redundancy to permit continuous operation of the engine.

The ACUs perform the control of the auxiliary blowers, the control of the electrically and engine driven hydraulic oil pumps of the Hydraulic Power Supply (HPS) unit. On engines fitted with ACOM, it is controlled by one of the ACUs too.

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 Interface Control Unit

The two engine interface control units (EICU) perform such tasks as interface with the surrounding control systems, see Fig. 16.01.01a and b. The two EICU units operate in parallel and ensures redundancy for mission critical interfaces.

The EICUs are located either in the Engine Control Room (recommended) or in the engine room.

In the basic execution, the EICUs are a placed in the Cabinet for EICUs, EoD: 4 65 601.

Control Network

The MOP, the backup MOP and the MPCs are interconnected by means of the redundant Control Networks, A and B respectively.

The maximum length of Control Network cabling between the furthermost units on the engine and in the Engine Control Room (an EICU or a MOP) is 230 meter.

Should the layout of the ship make longer Control Network cabling necessary, a Control Network Repeater must be inserted to amplify the signals and divide the cable into segments no longer than 230 meter. For instance, where the Engine Control Room and the engine room are located far apart. The connection of the two MOPs to the control network is shown in Fig. 5.16.01.

Power Supply for Engine Control System

The Engine Control System requires two separate power supplies with battery backup, power supply A and B.

The ME-ECS power supplies must be separated from other DC systems, i.e. only ME-ECS components must be connected to the supplies.

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.

Local Operating Panel

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

Alternatively, the local operating panel (LOP) can be activated. This redundant control is to be considered as a substitute for the previous Engine Side Control console mounted directly onto the MC engine.

The LOP is as standard placed on the engine.

From the LOP, the basic functions are available, such as starting, engine speed control, stopping, reversing, and the most important engine data are displayed.

Hydraulic Power Supply

The purpose of the hydraulic power supply (HPS) unit is to deliver the necessary high pressure hydraulic oil flow to the Hydraulic Cylinder Units (HCU) on the engine at the required pressure (approx. 300 bar) during start-up as well as in normal service.

In case of the STANDARD mechanically driven HPS unit, at start, one of the two electrically driven start-up pumps is activated. The start¬up pump is stopped 25 seconds after the engine reaches 15% speed.

The multiple pump configuration with standby pumps ensures redundancy with regard to the hydraulic power supply. The control of the engine driven pumps and electrical pumps are divided between the three ACUs.

The high pressure pipes between the HPS unit and the HCU are of the double-walled type, having a leak detector (210 bar system only). Emergency running is possible using the outer pipe as pressure containment for the high pressure oil supply.

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

Engine Control System Layout with Cabinet for EICU

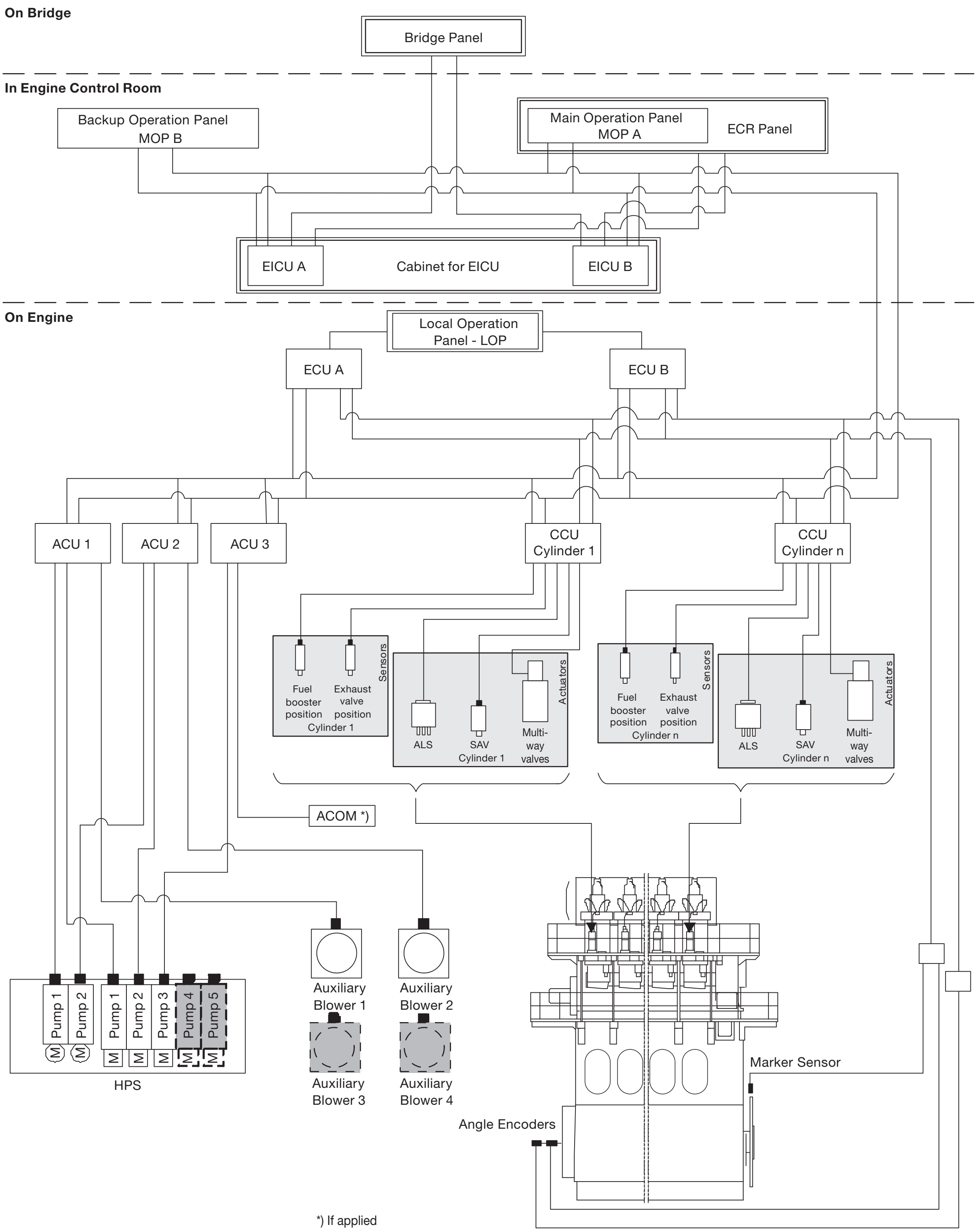


Fig. 16.01.01a: Engine Control System layout with cabinet for EICU for mounting in ECR or on engine, EoD: 4 65 601

Engine Control System Layout with Common Control Cabinet

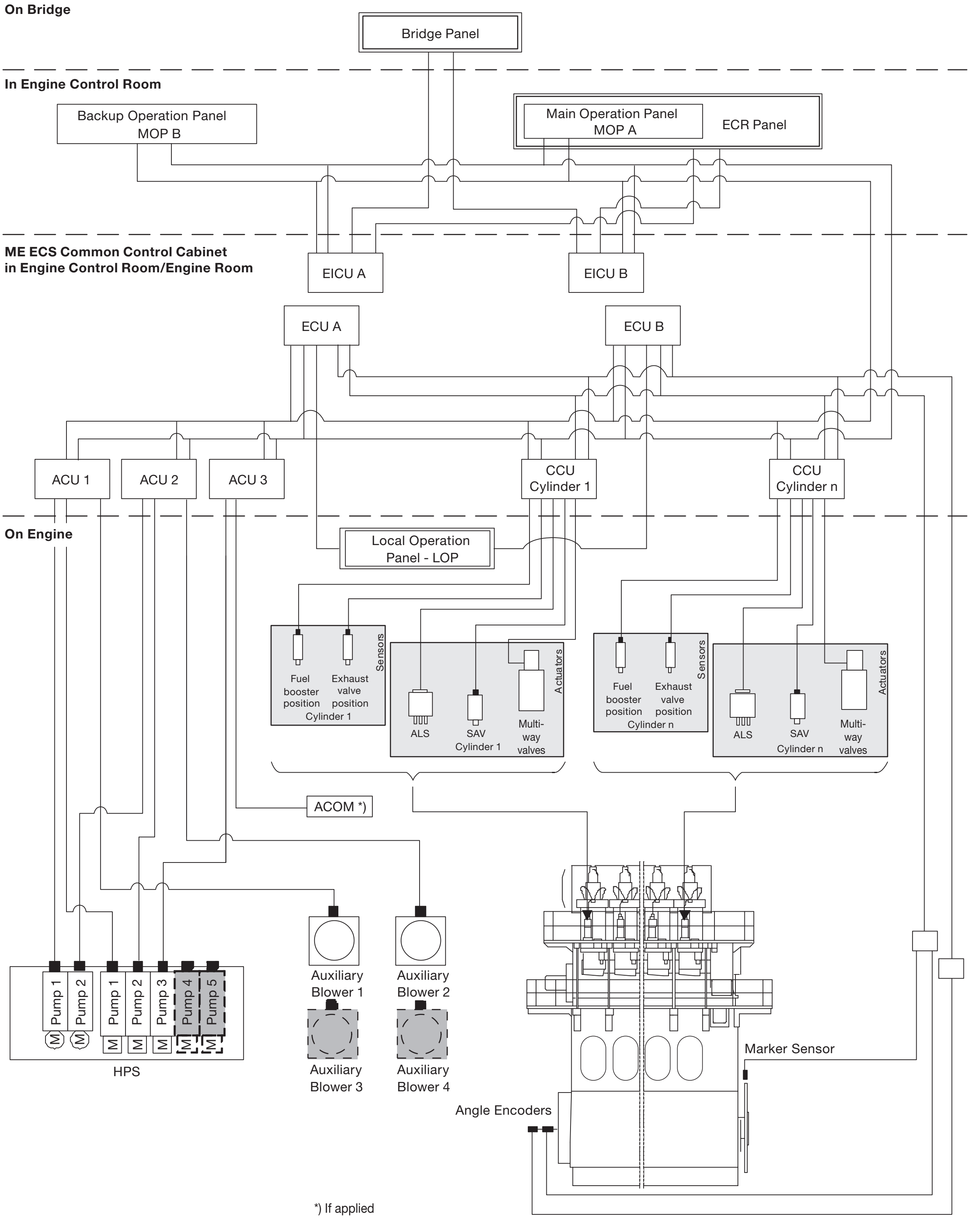


Fig. 16.01.01b: Engine Control System layout with ECS Common Control Cabinet for mounting in ECR or on engine, option: 4 65 602

Mechanical-hydraulic System with Mechanically Driven HPS

This section is available on request

Mechanical-hydraulic System with Electrically Driven HPS

This section is available on request

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

Some of the signals given by the sensors of the alarm system are used for the 'Slow down request' signal to the ECS of the main engine.

Safety system

The engine safety system is an independent system with its respective sensors on the main engine, fulfilling the requirements of the respective classification society and MAN Energy Solutions.

If a critical value is reached for one of the measuring points, the input signal from the safety system must cause either a cancellable or a non-cancellable shut down signal to the ECS.

For the safety system, combined shut down and slow down panels approved by MAN Energy Solutions are available. The following options are listed in the Extent of Delivery:

4 75 631 Lyngsø Marine

4 75 632 Kongsberg Maritime

4 75 633 Nabtesco

4 75 636 Mitsui Zosen Systems Research.

Where separate shut down and slow down panels are installed, only panels approved by MAN Energy solutions must be used.

In any case, the remote control system and the safety system (shut down and slow down panel) must be compatible.

Telegraph system

This system enables the navigator to transfer the commands of engine speed and direction of rotation from the Bridge, the engine control room or the Local Operating Panel (LOP), and it provides signals for speed setting and stop to the ECS.

The engine control room and the LOP are provided with combined telegraph and speed setting units.

Remote Control system

The remote control system normally has two alternative control stations:

- the bridge control
- the engine control room control.

The remote control system is to be delivered by a supplier approved by MAN Energy Solutions.

Bridge control systems from suppliers approved by MAN Energy Solutions are available. The Extent of Delivery lists the following options:

- for Fixed Pitch propeller plants, e.g.:

  4 95 703 Lyngsø Marine

  4 95 704 Mitsui Zosen Systems Research

  4 95 705 Nabtesco

  4 95 715 Kongsberg Maritime

- and for Controllable Pitch propeller plants, e.g.:

  4 95 701 Lyngsø Marine

  4 95 716 Kongsberg Maritime

  4 95 719 MAN Alphatronic.

Power Management System

The system handles the supply of electrical power onboard, i. e. the starting and stopping of the generating sets as well as the activation / deactivation of the main engine Shaft Generator (SG), if fitted.

The normal function involves starting, synchronising, phasing-in, transfer of electrical load and stopping of the generators based on the electrical load of the grid on board.

The activation / deactivation of the SG is to be done within the engine speed range which fulfils the specified limits of the electrical frequency.

Auxiliary equipment system

The input signals for 'Auxiliary system ready' are given partly through the Remote Control system based on the status for:

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

and partly from the ECS itself:

- turning gear disengaged
- main starting valve 'open'
- control air valve for sealing air 'open'
- control air valve for air spring 'open'
- auxiliary blowers running
- hydraulic power supply ready.

Monitoring systems

The Engine Control System (ECS) is supported by the Engine Management Services (EMS), which includes the PMI Auto-tuning and the CoCoS-EDS (Computer Controlled Surveillance-Engine Diagnostics System) applications.

A description of the EMS is found in Chapter 18 of this Project Guide.

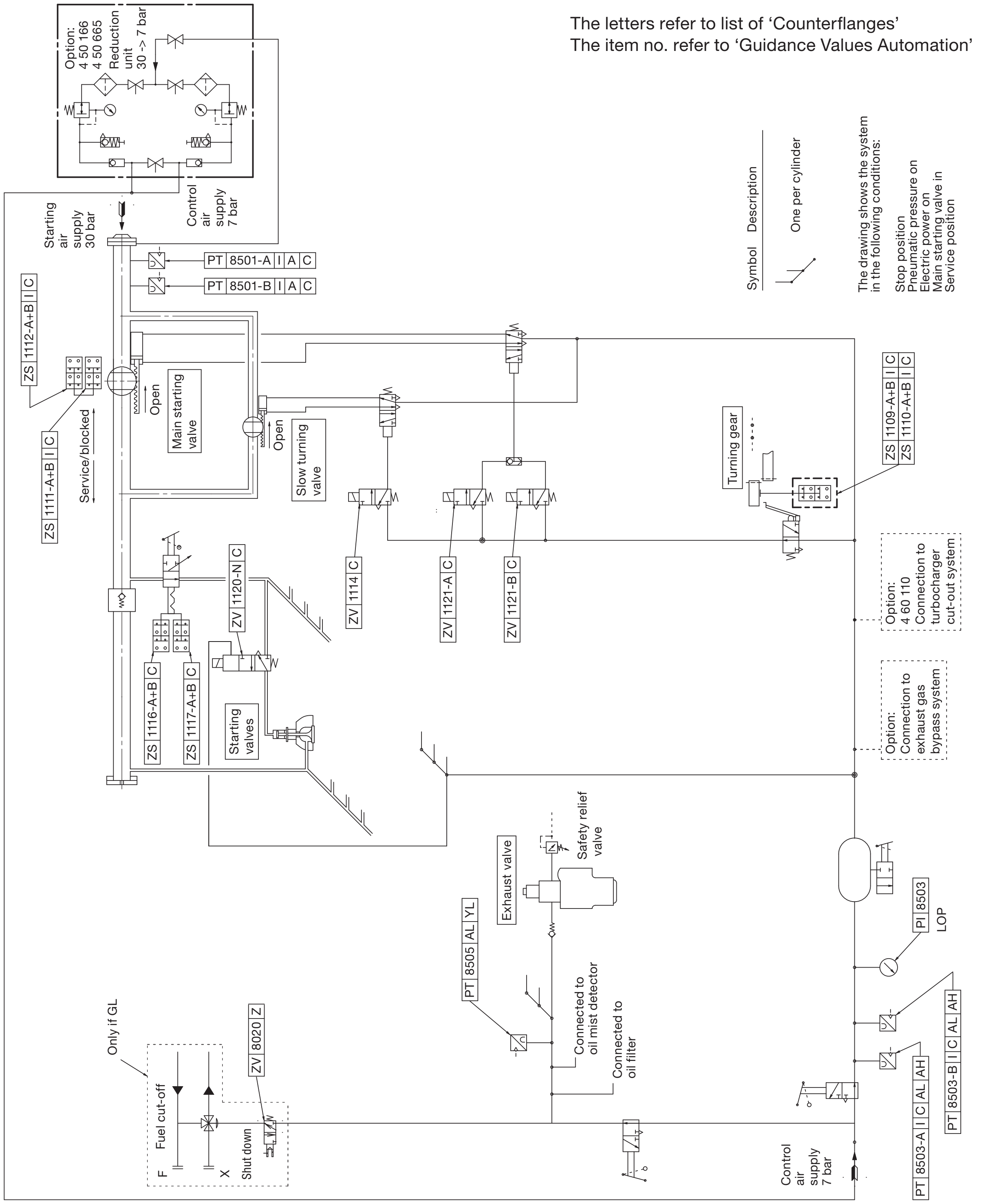
Instrumentation

The following lists of instrumentation are included in Chapter 18:

- The Class requirements and MAN Energy Solutions' requirements for alarms, slow down and shut down for Unattended Machinery Spaces
- Local instruments
- Control devices.

Pneumatic Manoeuvring Diagram

The letters refer to list of 'Counterflanges'
The item no. refer to 'Guidance Values Automation'



507 96 33-3.7.0

Fig. 16.01.03: Pneumatic Manoeuvring Diagram

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.

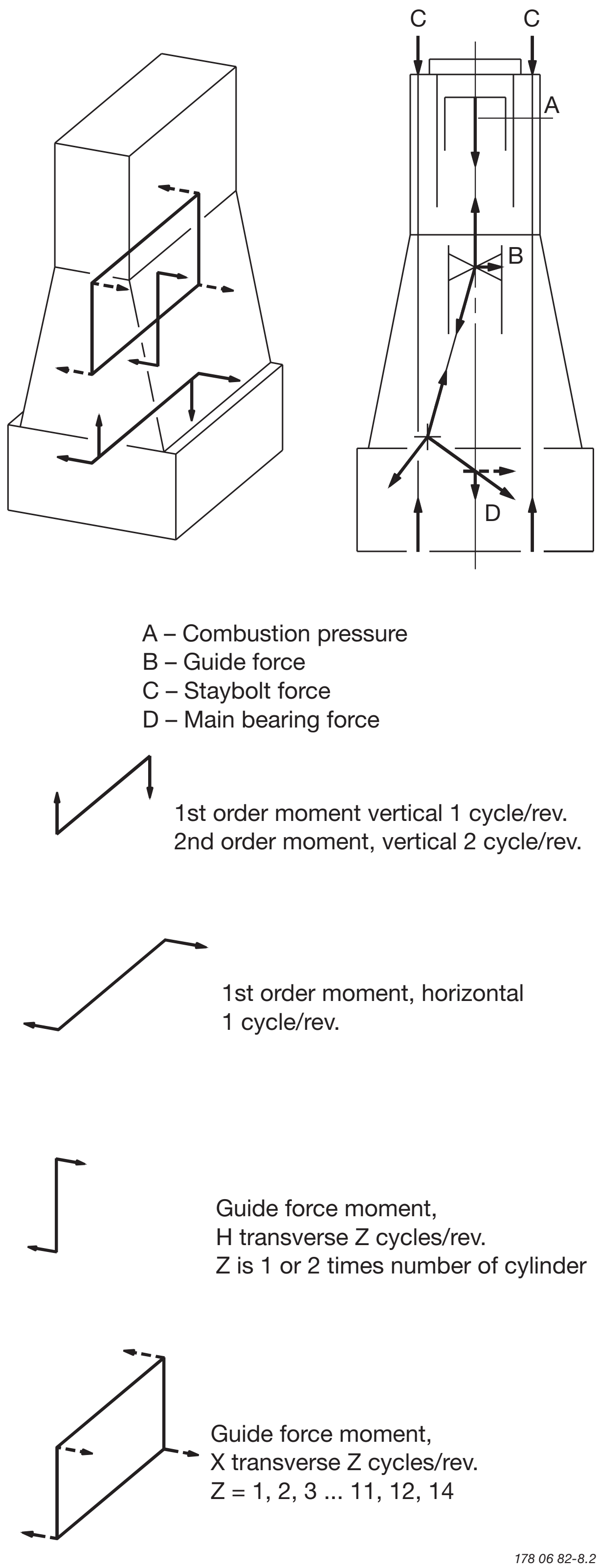


Fig. 17.01.01: External unbalanced moments and guide force moments

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.

A 2nd order moment compensator comprises two counter-rotating masses running at twice the engine speed.

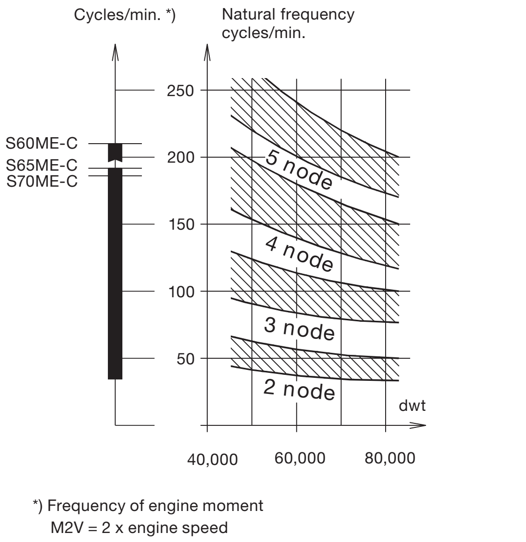


Fig. 17.02.01: Statistics of vertical hull vibrations, an example from tankers and bulk carriers

Compensator solutions

Several solutions are available to cope with the 2nd order moment, as shown in Fig. 17.03.02, out of which the most cost efficient one can be chosen in the individual case, e.g.:

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

2) A compensator mounted on the aft end of the engine, driven by chain, option: 4 31 203.

3) A compensator mounted on the fore end, driven from the crankshaft through a separate chain drive, option: 4 31 213.

As standard, the compensators reduce the external 2nd order moment to a level as for a 7-cylinder engine or less.

Briefly speaking, solution 1) is applicable if the node is located far from the engine, or the engine is positioned more or less between nodes. Solution 2) or 3) should be considered where one of the engine ends is positioned in a node or close to it, since a compensator is inefficient in a node or close to it and therefore superfluous.

Determine the need

A decision regarding the vibrational aspects and the possible use of compensators must be taken at the contract stage. If no experience is available from sister ships, which would be the best basis for deciding whether compensators are necessary or not, it is advisable to make calculations to determine which of the solutions should be applied.

Preparation for compensators

If compensator(s) are initially omitted, the engine can be delivered prepared for compensators to be fitted on engine fore end later on, but the decision to prepare or not must be taken at the contract stage, option: 4 31 212. Measurements taken during the sea trial, or later in service and with fully loaded ship, will be able to show if compensator(s) have to be fitted at all.

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

Basic design regarding compensators

For 5 and 6-cylinder engines with mechanically driven HPS, the basic design regarding 2nd order moment compensators is:

- With compensator aft, EoD: 4 31 203
- Prepared for compensator fore, EoD: 4 31 212

For 5 and 6-cylinder engines with electrically driven HPS, the basic design regarding 2nd order moment compensators is:

- With MAN B&W external electrically driven moment compensator, RotComp, EoD: 4 31 255
- Prepared for compensator fore, EoD: 4 31 212

The available options for 5 and 6-cylinder engines are listed in the Extent of Delivery. For 4-cylinder engines, the information is available on request.

1st Order Moments on 4-cylinder Engines

1st order moments act in both vertical and horizontal direction. For our two-stroke engines with standard balancing these are of the same magnitudes.

For engines with five cylinders or more, the 1st order moment is rarely of any significance to the ship. It can, however, be of a disturbing magnitude in four-cylinder engines.

Resonance with a 1st order moment may occur for hull vibrations with 2 and/or 3 nodes. This resonance can be calculated with reasonable accuracy, and the calculation will show whether a compensator is necessary or not on four-cylinder engines.

A resonance with the vertical moment for the 2 node hull vibration can often be critical, whereas the resonance with the horizontal moment occurs at a higher speed than the nominal because of the higher natural frequency of horizontal hull vibrations.

Balancing 1st order moments

As standard, four-cylinder engines are fitted with 1st order moment balancers in shape of adjustable counterweights, as illustrated in Fig. 17.02.02. These can reduce the vertical moment to an insignificant value (although, increasing correspondingly the horizontal moment), so this resonance is easily dealt with. A solution with zero horizontal moment is also available.

1st order moment compensators

In rare cases, where the 1st order moment will cause resonance with both the vertical and the horizontal hull vibration mode in the normal speed range of the engine, a 1st order compensator can be introduced as an option, reducing the 1st order moment to a harmless value.

Since resonance with both the vertical and the horizontal hull vibration mode is rare, the standard engine is not prepared for the fitting of 1st order moment compensators.

Data on 1st order moment compensators and preparation as well as options in the Extent of Delivery are available on request.

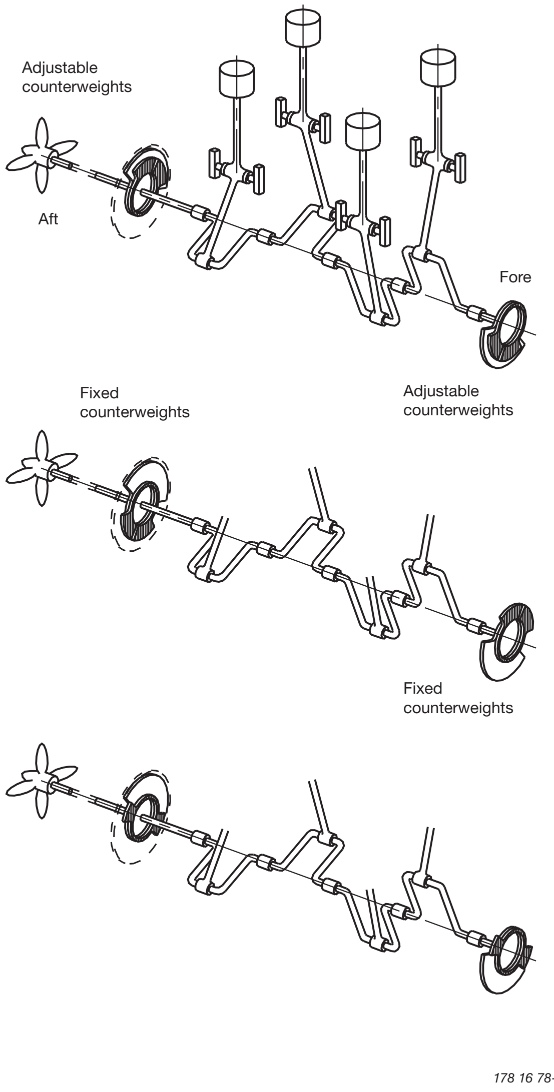


Fig. 17.02.02: Examples of counterweights

Electrically Driven Moment Compensator

If it is decided not to use chain driven moment compensators and, furthermore, not to prepare the main engine for compensators to be fitted later, another solution can be used, if annoying 2nd order vibrations should occur: An external electrically driven moment compensator can neutralise the excitation, synchronised to the correct phase relative to the external force or moment.

This type of compensator needs an extra seating fitted, preferably, in the steering gear room where vibratory deflections are largest and the effect of the compensator will therefore be greatest.

The electrically driven compensator will not give rise to distorting stresses in the hull, but it is more expensive than the engine-mounted compensators. It does, however, offer several advantages over the engine mounted solutions:

- When placed in the steering gear room, the compensator is not as sensitive to the positioning of the node as the compensators 2) and 3) mentioned in Section 17.02.

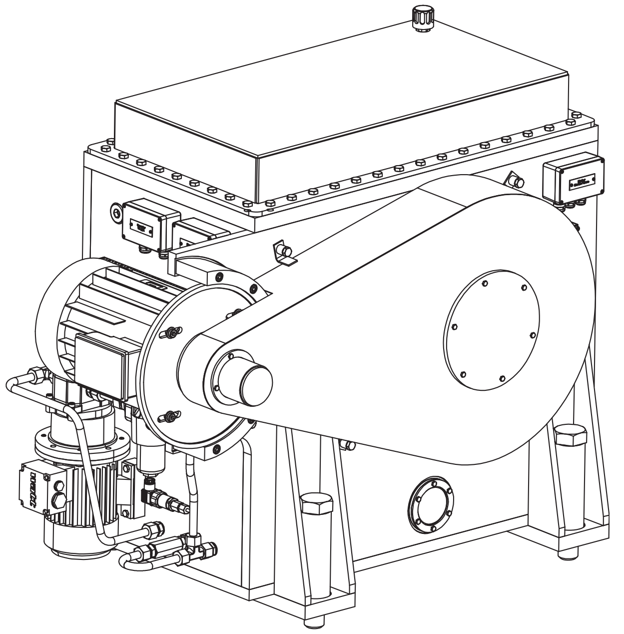


Fig. 17.03.01: MAN B&W external electrically driven moment compensator, RotComp, option: 4 31 255

- 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.
- No preparation for a later installation nor an extra chain drive for the compensator on the fore end of the engine is required. This saves the cost of such preparation, often left unused.
- Compensators could be retrofit, even on ships in service, and also be applied to engines with a higher number of cylinders than is normally considered relevant, if found necessary.
- The compensator only needs to be active at speeds critical for the hull girder vibration. Thus, it may be activated or deactivated at specified speeds automatically or manually.
- Combinations with and without moment compensators are not required in torsional and axial vibration calculations, since the electrically driven moment compensator is not part of the mass-elastic system of the crankshaft.

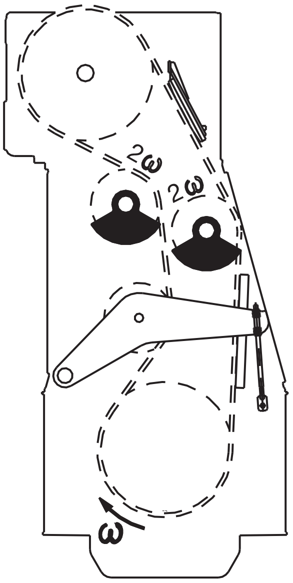
Furthermore, by using the compensator as a vibration exciter a ship's vibration pattern can easily be identified without having the engine running, e.g. on newbuildings at an advanced stage of construction. If it is verified that a ship does not need the compensator, it can be removed and reused on another ship.

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

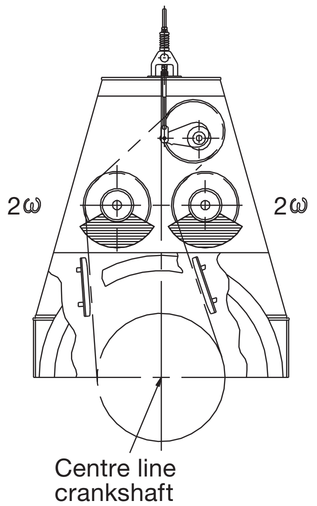
Balancing other forces and moments

Further to compensating 2nd order moments, electrically driven balancers are also available for balancing other forces and moments. The available options are listed in the Extent of Delivery.

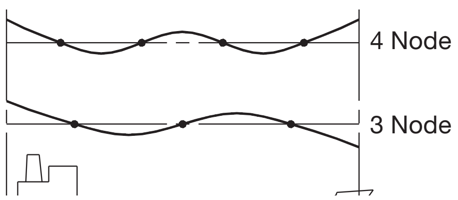
Moment compensator
Aft end, option: 4 31 203



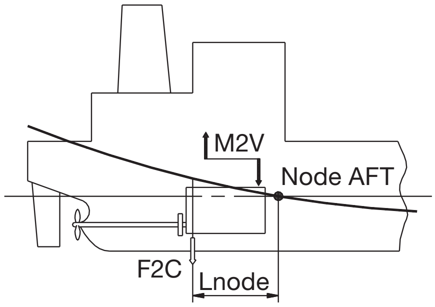
Moment compensator
Fore end, option: 4 31 213



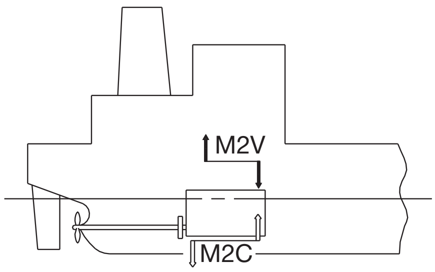
3 and 4-node vertical hull girder mode



Compensating moment
F2C × Lnode
outbalances M2V



Moment from compensator
M2C reduces M2V



Electrically driven moment compensator

Compensating moment
F_D × Lnode
outbalances M2V

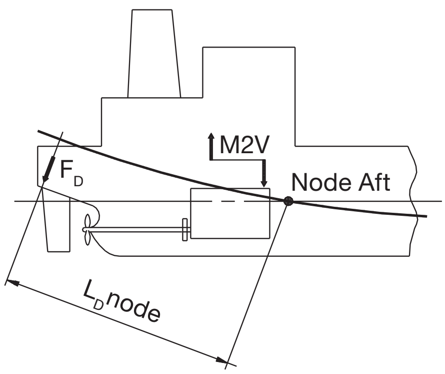


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Fig. 17.03.02: Compensation of 2nd order vertical external moments

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

G60ME-C9.5/-GI – 2,680 kW/cyl at 97 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	16	0	7	20	N.a.	N.a.	N.a.	N.a.	N.a.
PRU acc. to 2nd order, Nm/kW	194	113	28	0	N.a.	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 Energy Solutions 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 Energy Solutions 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.

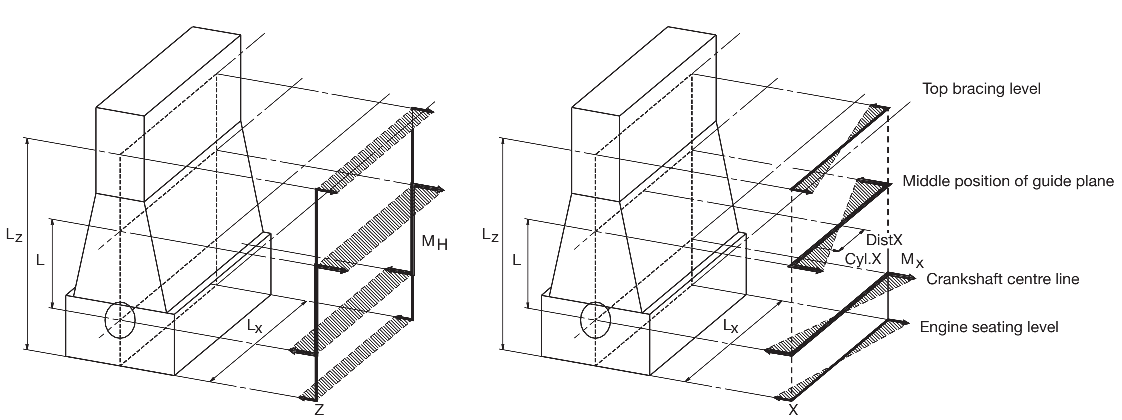


Fig. 17.05.01: H-type and X-type guide force moments

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:

$N \times M_{H(one\ cylinder)}$

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:

$Force_Z = M_H/L_Z$ [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.

$Force_{Z,\ one\ point} = Force_{Z,\ total}/N_{top\ bracing,\ total}$ [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 kNm²

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'.

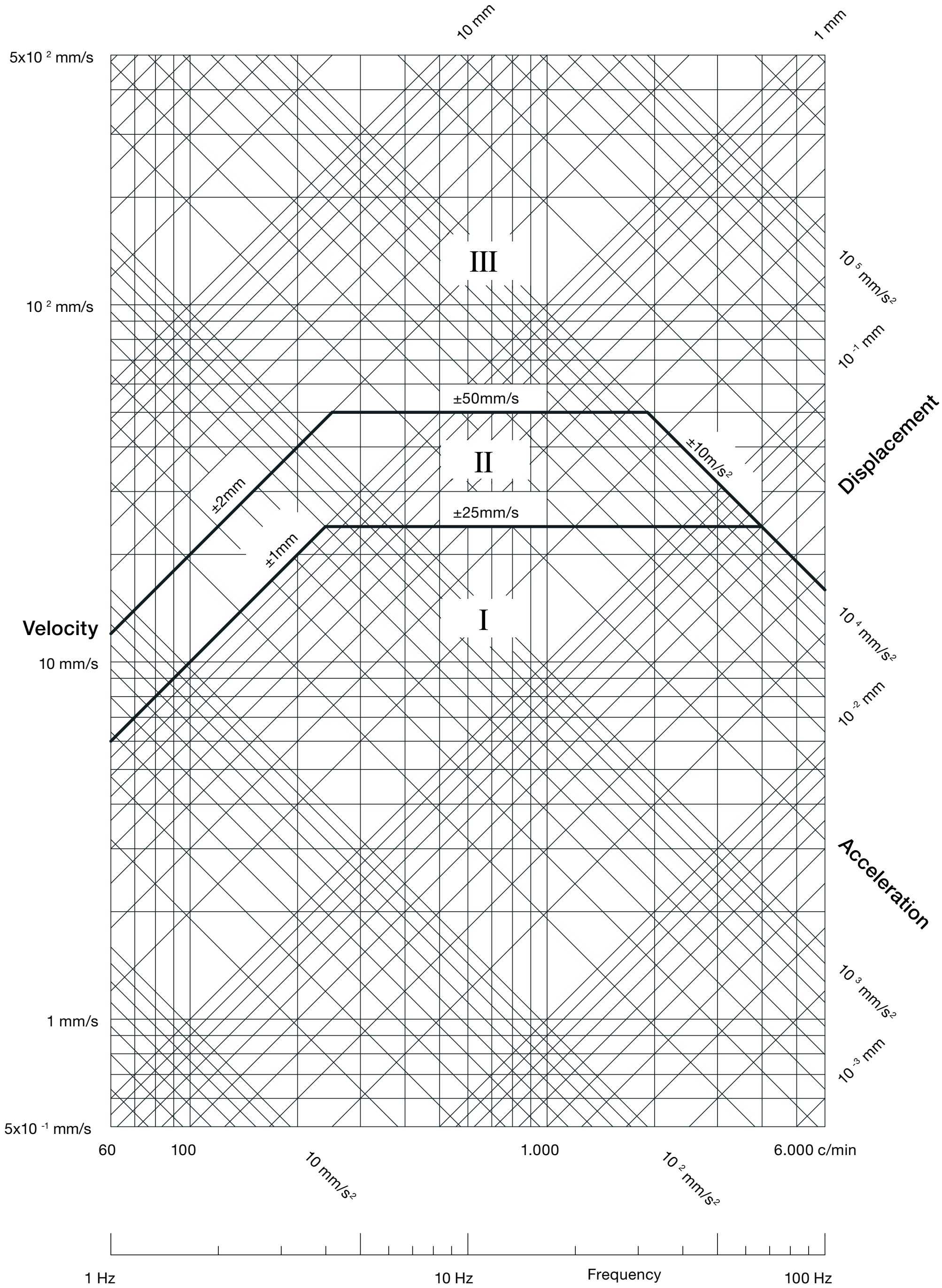
Similar to the situation for the H-type guide force moment, the forces may be applied in positions suitable for the FEM model of the hull. Thus the forces may be referred to another vertical level L_Z above the crankshaft centre line. These forces can be calculated as follows:

$Force_{Z,\ one\ point} = \frac{M_x \times L}{L_x \times L_x}$ [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
G95ME-C9/-GI/-LGI	3,720
G90ME-C10/-GI/-LGI	3,342
S90ME-C9/10/-GI/-LGI	3,600
S90ME-C8/-GI/-LGI	3,270
G80ME-C9/-GI/-LGI	3,720
S80ME-C9/-GI/-LGI	3,450
S80ME-C7/8/-GI/-LGI	3,280
G70ME-C9/-GI/-LGI	3,256
S70ME-C10/-GI/-LGI	2,700
S70ME-C7/8/-GI/-LGI	2,870
S65ME-C8/-GI/-LGI	2,730
G60ME-C9/-GI/-LGI	2,790
S60ME-C10/-GI/-LGI	Available on request
S60ME-C7/8/-GI/-LGI	2,460
G50ME-C9/GI/-LGI	2,500
S50ME-C9/GI/-LGI	2,214
S50ME-C7/8/-GI/-LGI	2,050
G45ME-C9/GI/-LGI	2,250
G40ME-C9/GI/-LGI	2,000

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

078 81 27-6.1

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 Energy Solutions based on final torsional vibration calculations.

Six-cylinder engines, require special attention. On account of the heavy excitation, the natural frequen-cy 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 at about 30-60% of 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.

Governor stability calculation for special plants

The important information regarding the governor stability calculations is, that MAN Energy Solutions shall be contacted for further evaluation in case a plant fulfills one of the below mentioned criteria or deviates from a 'standard' design.

Actually the governor stability calculation, option 4 07 009, is only needed in very rare cases. When needed, the calculation shall be made by MAN Energy Solutions against a fee.

Plants where one of the following criteria is fulfilled require special attention:

- PTO output higher than 15% L_1 MCR for elastically coupled generator types (i.e. not for PTO types DMG/CFE or SMG/CFE)
- 1st node torsional vibration frequency in the propeller shaftline lower than:
  3 Hz for FPP plants
  5 Hz for CPP plants
- Clutch for disconnection of the propeller
- The design deviates from a known 'standard' plant design.

For plants where one of the listed criteria is fulfilled, MAN Energy Solutions shall be consulted. In most cases we can evaluate the plant and provide the required design recommendations based on the torsional vibration calculation for the plant.

Only in very rare cases a deeper investigation with a governor stability calculation is needed. MAN Energy Solutions will give the necessary advice.

The evaluation may lead to changes in the control equipment including the need for more signals from the plant and requirements for design of mechanical components driven by the engine. Such plants have to be handled on an individual basis, preferable at an early stage of the design.

External Forces and Moments, G60ME-C9.5/-GI Layout point L_1

No of cylinder :	5	6	7	8
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

External forces [kN] :				
1. Order : Horizontal.	0	0	0	0
1. Order : Vertical.	0	0	0	0
2. Order : Vertical	0	0	0	0
4. Order : Vertical	0	0	0	0
6. Order : Vertical	0	17	0	0
External moments [kNm] :				
1. Order : Horizontal. a)	219	0	130	438
1. Order : Vertical. a)	219	0	130	438
2. Order : Vertical	2,603 c)	1,810 c)	526	0
4. Order : Vertical	17	130	369	150
6. Order : Vertical	1	0	1	0
Guide force H-moments in [kNm] :				
1 x No. of cyl.	1,726	1,394	1,113	865
2 x No. of cyl.	221	82	22	29
3 x No. of cyl.	-	-	-	-
Guide force X-moments in [kNm] :				
1. Order :	150	0	89	299
2. Order :	129	90	26	0
3. Order :	141	255	279	358
4. Order :	60	459	1,304	530
5. Order :	0	0	134	1,686
6. Order :	40	0	24	0
7. Order :	306	0	0	55
8. Order :	208	145	11	0
9. Order :	12	243	27	24
10. Order :	0	59	169	0
11. Order :	4	0	97	125
12. Order :	26	0	5	21
13. Order :	14	0	1	37
14. Order :	0	4	0	0
15. Order :	0	9	0	1
16. Order :	1	5	1	0

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

c) 5 and 6-cylinder engines can be fitted with 2nd order moment compensators on the aft and fore end, reducing the 2nd order external moment.

Table 17.07.01

Monitoring Systems and Instrumentation

18

Monitoring Systems and Instrumentation

The Engine Control System (ECS) is supported by the Engine Management Services (EMS), which manages software, data and applications for engine monitoring and operation.

The EMS includes the PMI and the CoCoS-EDS (Computer Controlled Surveillance-Engine Diagnostics System) as applications.

In its basic design, the ME/ME-B engine instrumentation consists of:

- Engine Control System (ECS), see Section 16.01
- Shut-down sensors, EoD: 4 75 124
- EMS including PMI and CoCoS-EDS software and support for LAN-based interface to the AMS, EoD: 4 75 217, see Section 18.02
- Sensors for alarm, slow down and remote indication according to the classification society's and MAN Energy Solutions' requirements for UMS, EoD: 4 75 127, see Section 18.04.

All instruments are identified by a combination of symbols and a position number as shown in Section 18.07.

Engine Management Services

Engine Management Services overview

The Engine Management Services (EMS) is used on MAN B&W engines from MAN Energy Solutions for condition monitoring, data logging & data distribution. EMS is integrated with the ECS (Engine Control System) to allow for continuous performance tuning.

EMS is executed on the EMS MOP, an industrial type PC designed by MAN Energy Solutions. EMS is implemented as a hardened platform, robust to virus threats and other unauthorized use and ac-cess.

The EMS network topology is shown in Fig. 18.02.01.

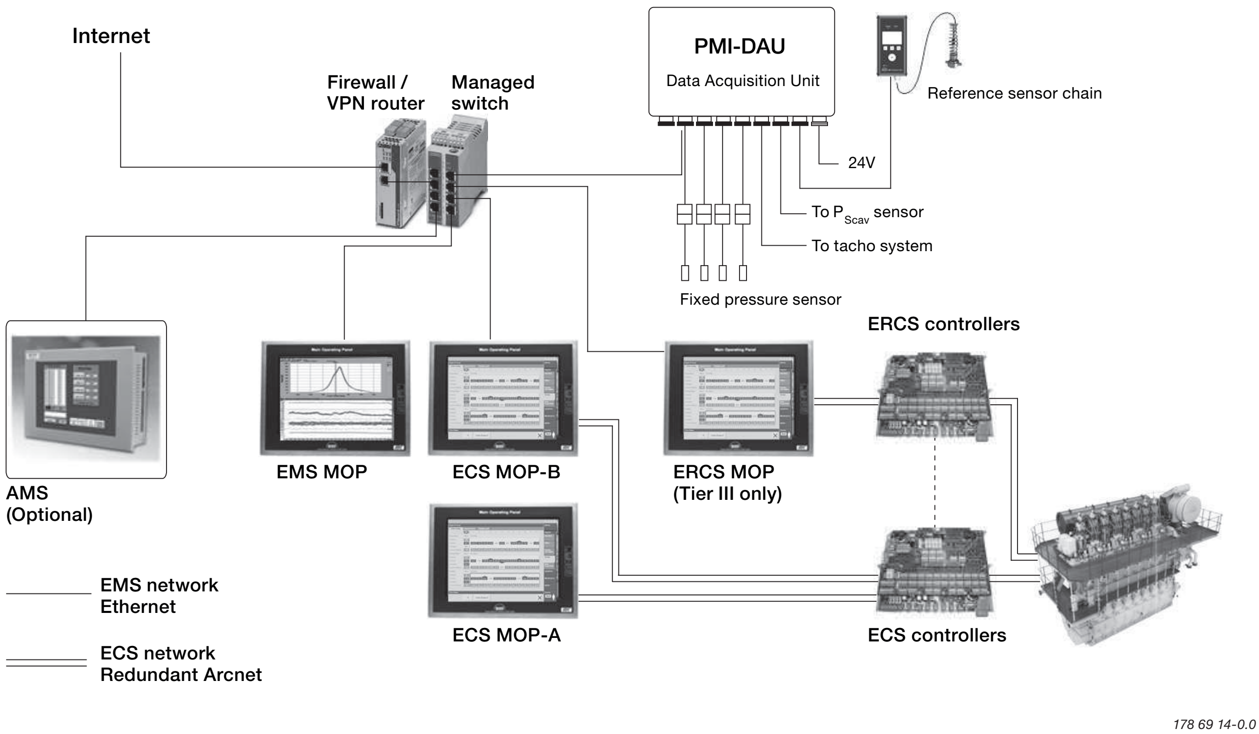


Fig 18.02.01: Engine Management Services, EMS, EoD: 4 75 217

EMS applications

EMS includes the applications PMI Auto-tuning, CoCoS-EDS and EMS manager.

PMI Auto-tuning

- Online cylinder pressure monitoring
- Input to engine control system for closed-loop performance tuning
- Engine power estimation.

PMI Auto-tuning continuously measures the cylinder pressures using online sensors mounted on each cylinder cover. Pressure measurements are presented continuously in real time and the corresponding key performance values are transferred to the Engine Control System.

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 the measured values and the reference. 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).

CoCoS-EDS

- Data logging
- Engine condition monitoring and reporting
- Engine operation troubleshooting.

With CoCoS-EDS, early intervention as well as preventive maintenance, the engine operators are able to reduce the risk of damages and failures.

CoCoS-EDS further allows for easier troubleshooting in cases where unusual engine behavior is observed.

EMS manager

- Installation and supervision of EMS applications
- Network and interface monitoring
- Optional interface for data exchange with AMS (Alarm Monitoring System).

The EMS manager provides a process for integrated installation, commissioning and maintenance of PMI Auto-tuning and CoCoS-EDS.

Further, the EMS Manager includes status information and functionality, e.g. for network status, internal and external interfaces and EMS application execution.

Condition Monitoring System CoCoS-EDS

This section is not applicable

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 Energy Solutions' 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 Energy Solutions 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 Energy Solutions.

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.

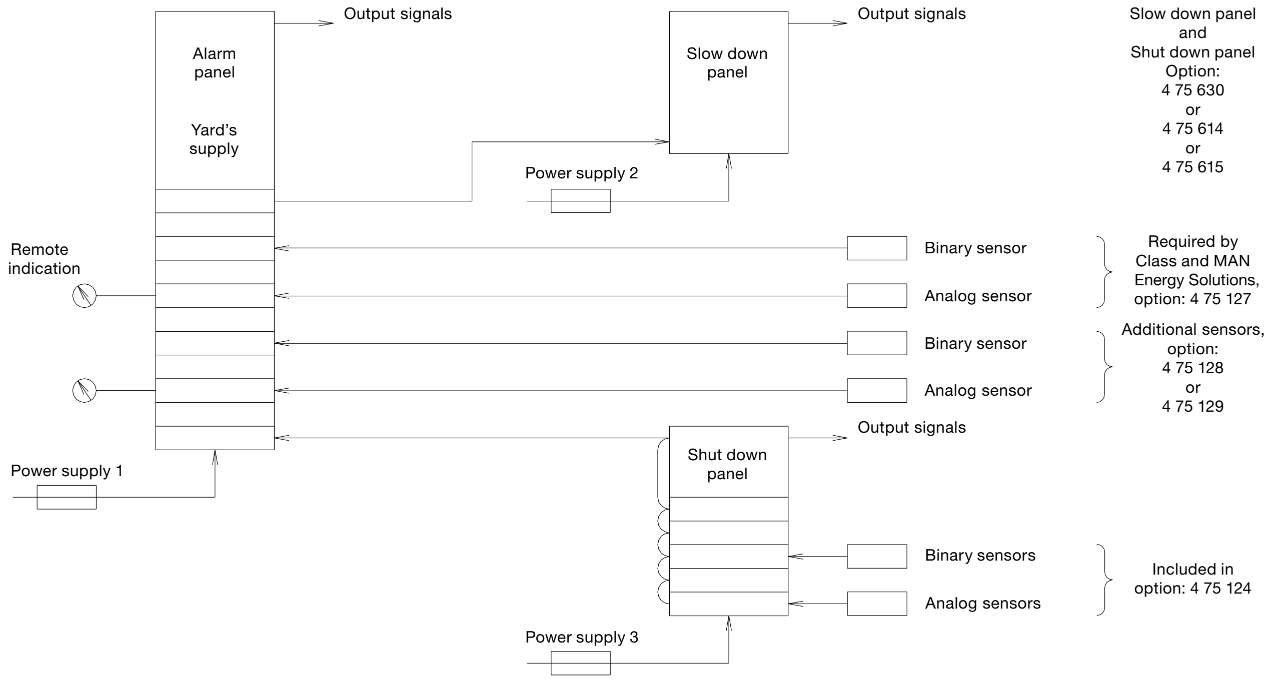


Fig. 18.04.01: Panels and sensors for alarm and safety systems

Alarms for UMS – Class and MAN Energy Solutions requirements

ABS	BV	CCS	DNV	GL	KR	LR	NK	RINA	RS	IACS	MAN ES	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/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	TE 8202 AH	Cylinder lubricating oil temperature
											1	LS 8212 AL	Small tank for heating element, low level (Not for ACOM)
											1	XC 8265 AL	ACOM common alarm (Only for ACOM)

1 Indicates that the sensor is required.
The sensors in the MAN Energy Solutions 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 Energy Solutions requirements

ABS	BV	CCS	DNV	GL	KR	LR	NK	RINA	RS	IACS	MAN ES	Sensor and function	Point of location
													Hydraulic Power Supply
											1	PT 1228 AL	LPS booster, oil presure after pump (Only if LPS pump)
											1	PDS 1231 A	ME (Auto) filter differential pressure across filter
				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 AH	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	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 Energy Solutions 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 Energy Solutions requirements

ABS	BV	CCS	DNV	GL	KR	LR	NK	RINA	RS	IACS	MAN ES	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	ZT 8801 AH	Turbocharger speed/turbocharger
											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 AH	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 Energy Solutions 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 certain engines only, see the list in Section 18.06, Axial Vibration Monitor.

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 Energy Solutions requirements

ABS	BV	CCS	DNV	GL	KR	LR	NK	RINA	RS	IACS	MAN ES	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	1	1		1	1	1		1	1	1	1	TE 8117 YH	Turbocharger lubricating oil outlet/turbocharger
											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					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	ZT 8801 YH	Turbocharger overspeed (Only in case of EGB, VT TC, power turbine/hybrid TC, TC Cut-out, see Table 18.06.03)
											1	WT 8812 YH	Axial vibration monitor 2)
(1)	(1)	( )	(1*)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	1	XS 8813 YH	Oil mist in crankcase/cylinder
				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 Energy Solutions 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 certain engines only, see the list in Section 18.06, Axial Vibration Monitor.

[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 Energy Solutions requirements

ABS	BV	CCS	DNV	GL	KR	LR	NK	RINA	RS	IACS	MAN ES	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
			*									XS 8813 Z	Oil mist in crankcase/cylinder
											1	XS 8817 Z	Turbocharger overspeed (Only in case of EGR or EGB, VT TC, power turbine/hybrid TC, TC Cut-out and system handshake, see Table 18.06.03)

1 Indicates that the sensor is required.
The sensors in the MAN Energy Solutions 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
		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
		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 8212	Small tank for heating element, low level (Not for ACOM)
	XC 8265	ACOM (Only for ACOM)
	LS 8285	Level switch
		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 EGB, VT TC, power turbine/hybrid TC, TC Cut-out, see Table 18.06.03)

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 Energy Solutions. 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 Bear-ing 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 Energy Solutions 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	Graviner Mk 7, make: Kidde Fire Protection
4 75 163	Visatron VN 215/93, make: Schaller Automation GmbH & Co. KG *)
4 75 166	MD-SX, make: Daihatsu Diesel Mfg. Co., Ltd.
4 75 167	Vision III C, make: Specs Corporation
4 75 168	GDMS-OMDN09, make: MSS AG
4 75 271	Triton, make: Heinzmann GmbH & Co. KG
4 75 272	Visatron VN301^{plus}, make: Schaller Automation GmbH & Co. KG
4 75 273	MOT-2R5M7R5MP, make: Meiyo Electric Co., Ltd.
*) Only applicable for S50ME-C8/-GI as well as MC-C and ME-B/-GI/-LGI types 50 and smaller	

Examples of piping diagrams (for Visatron VN 215/93 only) and wiring diagrams (for all other detectors) are shown for reference in Figs. 18.06.01a and 18.06.01b.

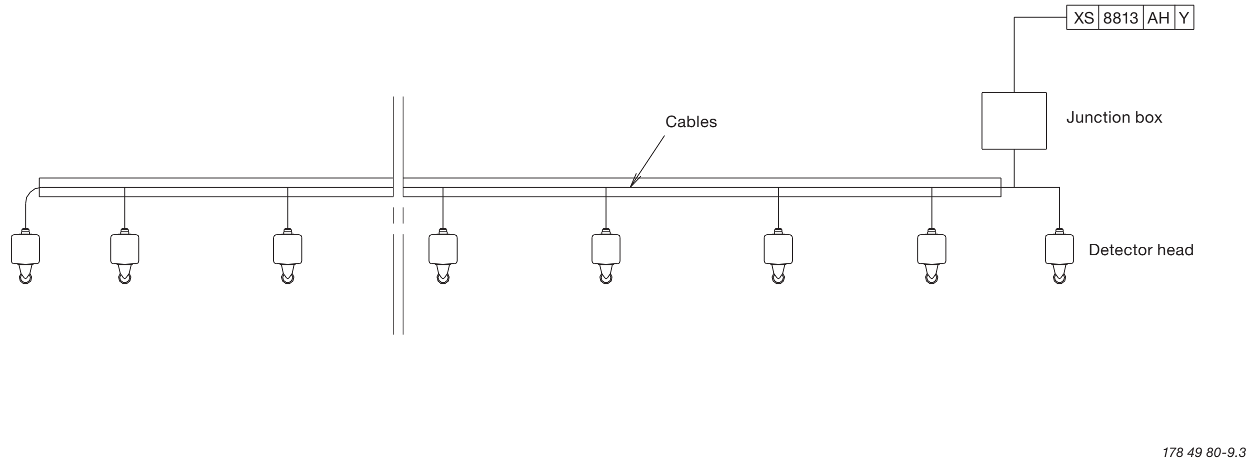


Fig. 18.06.01a: Example of oil mist detector wiring on engine

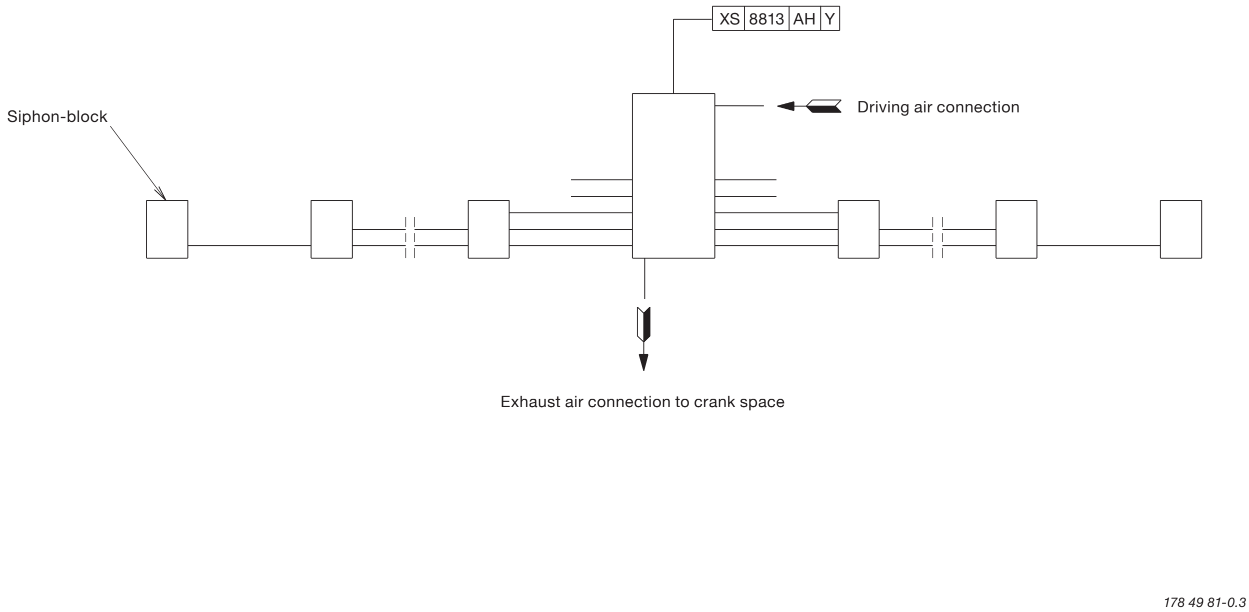


Fig. 18.06.01b: Oil mist detector pipes on engine, type Visatron VN215/93 from Schaller Automation, option: 4 75 163

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.

he Extent of Delivery lists the following Bearing Wear Monitoring options:

4 75 261	XTS-W (BWM), make: AMOT
4 75 262	BDMS (BW&TMS), make: Dr. E. Horn
4 75 263	BWCM, make: Kongsberg Maritime
4 75 265	B-WACS, make: Doosan Engine Co., Ltd.
4 75 266	BWCMS, make: KOMECO
4 75 267	BCM-1, make: Mitsui Zosen Systems Research Inc.

ME, ME-C/-GI/-LGI 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

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.

All types 98 and 90 ME and ME-C engines as well as K80ME-C9 are as standard specified with Liner Wall Monitoring system. For all other engines, the LWM system is available as an option: 4 75 136.

Axial Vibration Monitor

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

An Axial Vibration Monitor (AVM) with indication for condition check of the axial vibration damper and terminals for alarm and slow down ia available as an option: 4 31 117. It is required for the following engines:

- All ME-C9/10 engines incl. their -GI and -LGI variants

- All ME-C7/8 engines with 5 and 6 cylinders incl. their -GI and -LGI variants

- K-ME-C6/7 and K98ME6/7 engines with 11 and 14 cylinders incl. their -GI and -LGI variants.

The requirement for AVM on 4-cylinder engines is available on request.

The alarm and slow down system should include the filtration necessary to prevent the AVM from unintentionally activating the alarm and slow down functions at torsional vibration resonances, i.e. in the barred speed range, and when running Astern.

In the low speed range and when running Astern, the alarm and slow down functions are to be disabled so that the AVM only gives an indication of the vibration level.

The AVM alarm and slow down functions shall be enabled when the engine is running Ahead and at speeds above the barred range.

To prevent rapid hunting of the engine speed in a slow down situation, a holding time function has been introduced in order to delay the automatic re-setting of the slow down function.

The specification of the AVM interface to the alarm and slow down system is available from MAN Energy Solutions, Copenhagen.

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 degree 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.

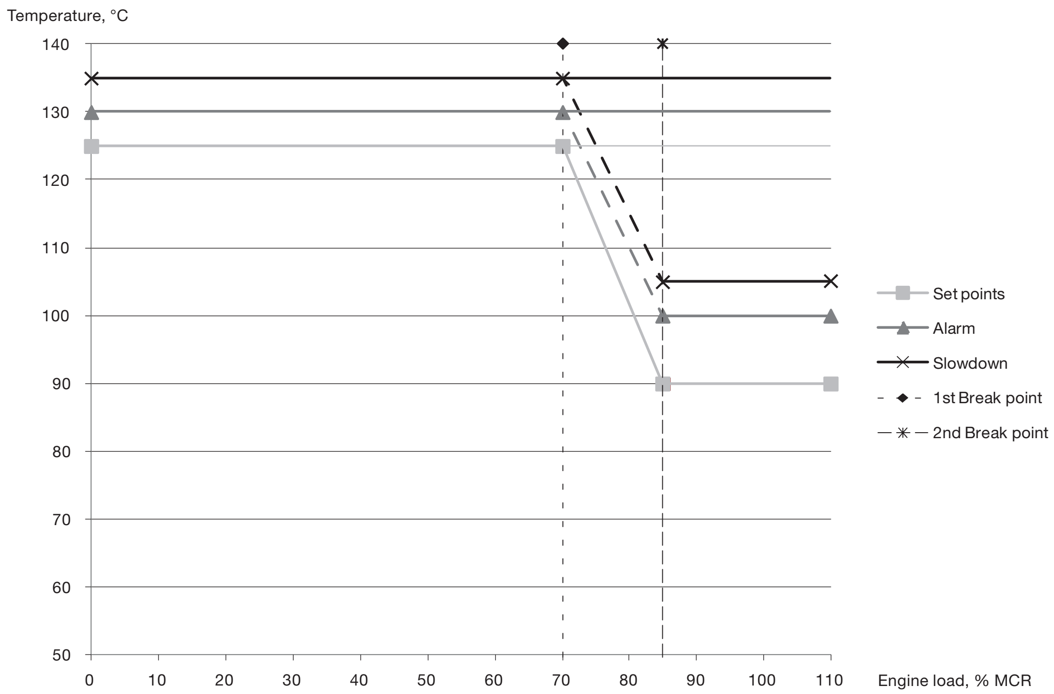
The values of the load dependent limits are defined as a temperature difference (DT) to actual cooling water temperature (which vary relative to the engine load).

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.

Motor start method

Direct Online Start (DOL) is required for all the electric motors for the pumps for the Load Dependent Cylinder Liner (LDCL) to ensure proper operation under all conditions



178 68 07-4.0

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

Turbocharger Overspeed Protection

All engine plants fitted with turbocharger cut-out, exhaust gas bypass (EGB), power turbine / turbo generator (PT), hybrid turbocharger or variable turbocharger (VT) run the risk of experiencing turbocharger overspeed. To protect the turbocharger, such plants must be equipped with a turbocharger overspeed alarm and slow-down function.

However, the handshake interface between the ship's power management system and a waste heat recovery system (WHRS) or a shaft generator (SG) may delay the slowdown for up to 120 seconds. Therefore, the slow-down function must be upgraded to a non-cancellable shutdown for engine plants with handshake interface.

On engine plants designed with exhaust gas recirculation (EGR), a sudden increase of energy to the turbocharger(s) will occur if the EGR system trips. As protection, turbocharger overspeed alarm and non-cancellable shutdown must be fitted.

Consequently, the turbocharger speed must be monitored by the ship alarm system and the safety system(s), triggering slowdown or non-cancellable shutdown if the turbocharger speed exceeds the defined alarm levels.

The protection applicable for individual engine plant and power management configurations is summarised in Table 18.06.03.

Turbocharger overspeed protection		
Engine plant configuration	**No power management system handshake**	**Engine with WHR or shaft generator with power management system handshake**
Traditional exhaust gas train and turbocharger	No monitoring of turbocharger overspeed	No monitoring of turbocharger overspeed
Exhaust gas bypass, variable turbo charger, power turbine or hybrid turbocharger	Turbocharger overspeed slowdown	Turbocharger overspeed shutdown
Exhaust gas recirculation	Turbocharger overspeed shutdown	Turbocharger overspeed shutdown
Turbocharger cut-out	Turbocharger overspeed slowdown	Turbocharger overspeed shutdown

Table 18.06.03: Turbocharger overspeed protection for individual engine plant configurations

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 18.06.04 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, Alpha/ME lubricator
ZV 8281 C	Solenoid valve, lubricator activation
ZT 8282 C	Feedback sensor, lubricator feedback
	Cylinder lubricating oil, Alpha Mk 2 lubricator
XC 8288 C	Propoprtional valve
ZT 8289 C	Feedback sensor
	Scavenge air
PS 8603 C	Scavenge air receiver, auxiliary blower control

Table 18.06.04a: Control devices on engine

Sensor	Point of location
	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 18.06.04b: 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.

078 89 33-9.6.0

Table 18.07.01b: Identification of instruments

Dispatch Pattern, Testing, Spares and Tools

19

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 Energy Solutions' recommendations for pres-ervation 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 Energy Solutions' 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 Energy Solutions, 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 Energy Solutions

The above-mentioned set of spare parts can be extended with the 'Additional Spare Parts Recommended by MAN Energy Solutions', 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/-GIE & ME-LGIM/-LGIP 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 2.5Y 8/14
	ME-LGIM/-LGIP 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 57-9.13.0

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

Dispatch Pattern

The relevant engine supplier is responsible for the actual execution and delivery extent. As differences may appear in the individual suppliers' extent and dispatch variants.

Dispatch Pattern A – short:
Short distance transportation limited by duration of transportation time within a few days or a distance of approximately 1,000 km and short term storage.

Duration from engine delivery to installation must not exceed eight weeks.

Dismantling must be limited.

Dispatch Pattern B – long:
Overseas and other long distance transportation, as well as long-term storage.

Dismantling is effected to reduce the transport volume to a suitable extent.

Long-term preservation and seaworthy packing must always be used.

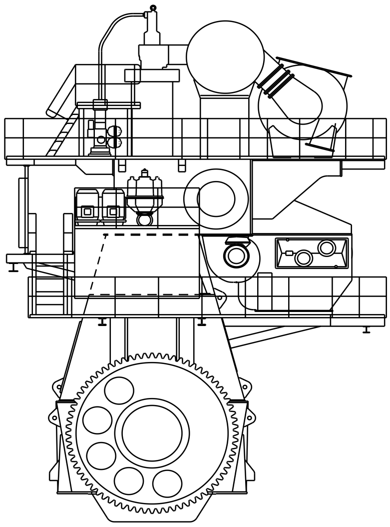
Note
The engine supplier is responsible for the necessary lifting tools and lifting instructions for transportation purposes to the yard. The delivery extent of lifting tools, ownership and lend/lease conditions are to be stated in the contract. (Options: 4 12 120 or 4 12 121)

Furthermore, it must be stated whether a drying machine is to be installed during the transportation and/or storage period. (Option: 4 12 601)

Dispatch pattern variants

Engine complete, i.e. not disassembled

A1 + B1

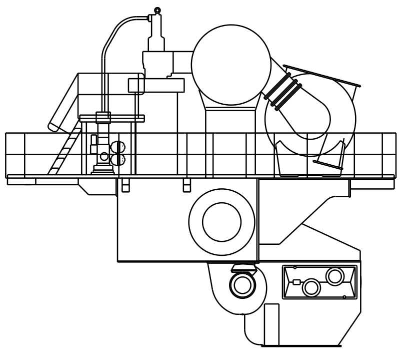


Engine complete

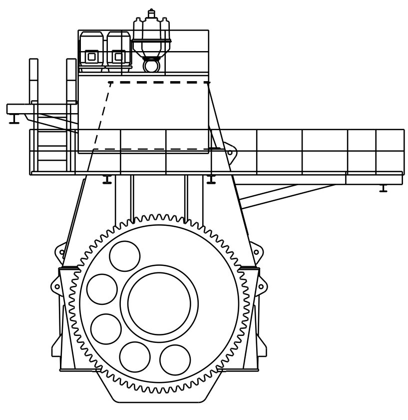
A2 + B2 (option 4 12 022 + 4 12 032)

- Top section including cylinder frame complete, cylinder covers complete, scavenge air receiver including cooler box and cooler insert, turbocharger(s), piston complete and galleries with pipes, HCU units and oil filter
- Bottom section including bedplate complete, frame box complete, connecting rods, turning gear, crankshaft complete and galleries
- Remaining parts including stay bolts, chains, multi-way valves, etc.

A2 + B2



Top section



Bottom section

Fig. 19.03.01: Dispatch pattern, engine with turbocharger on exhaust side (4 59 123)

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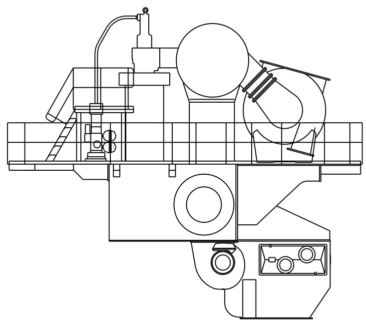
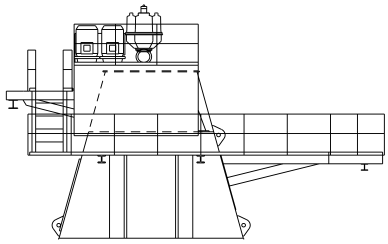
A3 + B3 (option 4 12 023 + 4 12 033)

- Top section including cylinder frame complete, cylinder covers complete, scavenge air receiver including cooler box and cooler insert, turbocharger(s), piston complete and galleries with pipes, HCU Units
- Frame box section including frame box complete, chain drive, connecting rods and galleries, gearbox for hydraulic power supply, hydraulic pump station and oil flter
- Bedplate/crankshaft section including bedplate complete, crankshaft complete with chainwheels and turning gear
- Remaining parts including stay bolts, chains, multi-way valves, etc.

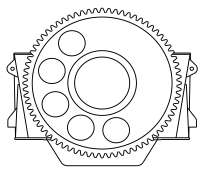
A3 + B3



Top section



Frame box section



Bedplate/crankshaft section

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Fig. 19.03.02: Dispatch pattern, engine with turbocharger on exhaust side (4 59 123)

A4 + B4 (option 4 12 024 + 4 12 034)

- Top section including cylinder frame complete, cylinder covers complete, piston complete and galleries with pipes on manoeuvring side, HCU units
- Exhaust receiver with pipes
- Scavenge air receiver with galleries and pipes
- Turbocharger
- Air cooler box with cooler insert
- Frame box section including frame box complete, chain drive, connecting rods and galleries, gearbox for hydraulic power supply, hydraulic power station and oil flter
- Crankshaft with chain wheels
- Bedplate with pipes and turning gear
- Remaining parts including stay bolts, auxiliary blowers, chains, multi-way valves, etc.

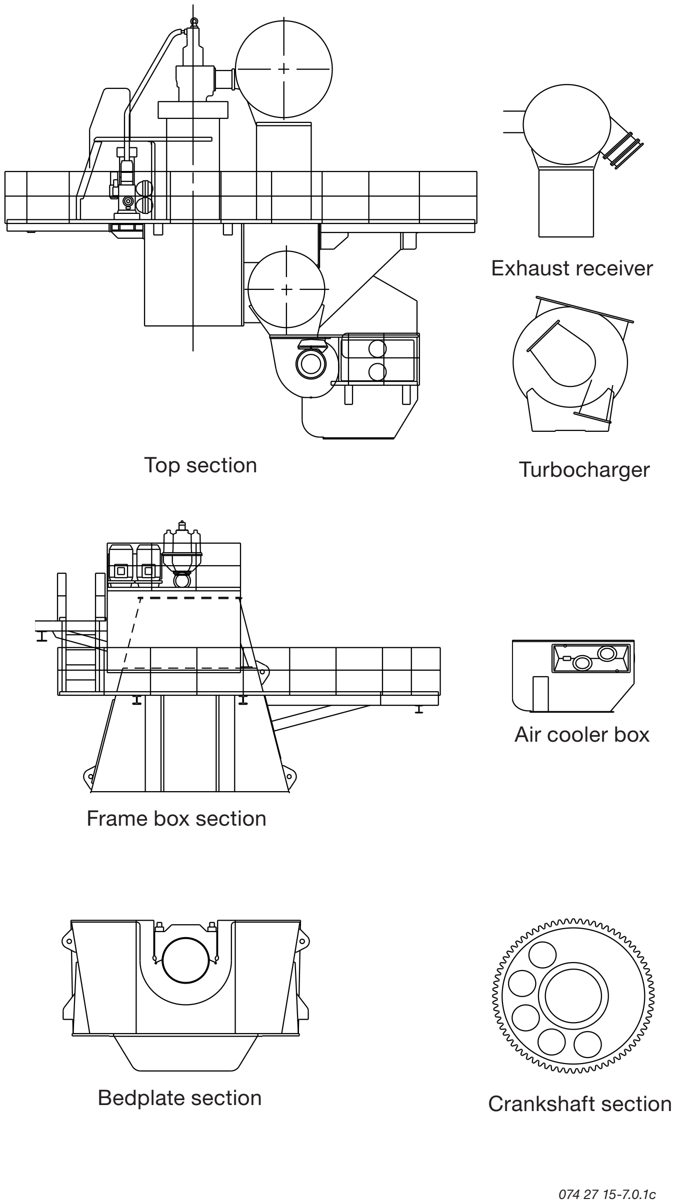


Fig. 19.03.03: Dispatch pattern, engine with turbocharger on exhaust side (4 59 123)

Dispatch pattern, list of masses and dimensions

		5 cylinder6 cylinder7 cylinder8 cylinderAll cylinders									
		Mass	Length	Mass	Length	Mass	Length	Mass	Length	Height	Width
Pattern	Section	in tonsin min tonsin min tonsin min tonsin min min m									
A1 + B1	Engine complete	*)		477	*)						
A2 + B2	Top section	*)		147	*)						
	Bottom section			326							
	Remaining parts			4							
A3 + B3	Top section	*)		145	*)						
	Frame box			118							
	Bedplate/Crankshaft			209							
	Remaining parts			4							
A4 + B4	Top section	*)		108	*)						
	Frame box section			116							
	Bedplate			69							
	Crankshaft			141							
	Scavenge air receiver			23							
	Exhaust receiver			8							
	Air cooler			3							
	Turbocharger(s)			4							
	Remaining parts			4							

*) Available on request

The above data are approximate and for guidance only.

178 68 75-5.0

Table 19.04.01: Dispatch pattern, list of masses and dimensions

Shop Test

The minimum delivery test for MAN B&W two-stroke engines, 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.

and is followed by the below mentioned tests.

Load test at specific load points

The engine performance is recorded running at:

- 25% of specified MCR
- 50% of specified MCR
- 75% of specified MCR
- 90% of specified MCR or at NCR
- 100% of specified MCR *)
- 110% of specified MCR.

Records are to be taken after 15 minutes or after steady conditions have been reached, whichever is shorter.

*) Two sets of recordings are to be taken at a minimum interval of 30 minutes.

Governor test and more:

- Integration test of ECS
- 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 Energy Solutions.

Fuel oil analysis is to be presented. All load point measurements are to be carried out on diesel or gas oil.

The shop tests are all carried out according to:

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

by International Association of Classification Societies LTD. (IACS), www.iacs.org.uk

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 options regarding shop test, see the Extent of Delivery.

List of Spare Parts, Unrestricted Service

Spare parts are **requested** by the following Classification Society only: NK, while just **recommended** by: ABS, DNV, CRS, KR, LR and RS, but neither requested nor recommended by: BV, CCS and RINA.

The final scope of spare parts is to be agreed between the owner and engine builder/yard.

Cylinder cover, plate 2272-0300 (901 and more)
1 Cylinder cover complete with fuel, exhaust and starting valves, indicator valve, cooling jacket and sealing rings (disassembled)
½ set Studs for 1 cylinder cover

Piston and piston rod, plates 2272-0400/0420/0500 (902)
1 Piston complete (with cooling pipe), piston rod, piston rings and stuffing box, studs and nuts
1 set Piston rings for 1 cylinder

Cylinder liner, plate 2272-0600 (903)
1 Cylinder liner complete, including cooling jacket, non-return valves, sealing rings and gaskets (assembled)

Cylinder lubricating oil system, plates 3072-0600, 6670-0100 (903) [1])
1 Lubricator complete
1 Inductive sensor
1 set O-rings and seals
2 Lubricator backup cable

Connecting rod, and crosshead bearing, plates 1472-0300, 2572-0300/0200 (904)
1 Telescopic pipe with bushing for 1 cylinder
1 Crankpin bearing shell (1 upper and 1 lower part) with studs and nuts
1 Crosshead bearing shell lower part with studs and nuts
2 Thrust piece

Thrust block, plate 2572-0600 (905)
1 set Thrust pads, complete FWD set for ‘Ahead’
1 set For KR and NK also 1 set ‘Astern’ if different from ‘Ahead’

HPS - Hydraulic Power Supply, plates 4572-1000/0750, 4572-1100/1200/1250 (906) [1 and 2])
1 Proportional valve for hydraulic pumps
1 Leak indicator
1 Drive shaft for hydraulic pump, of each type (length)
1 Membrane plus seals for accumulator
1 set Minimess for accumulator
1 Compensator, fluid type
6 Chain links. Only for ABS, LR and NK
1 set Flexible hoses, one of each size and length
1 set High-pressure gasket kit
1 Hydraulic pump
1 Coupling for start-up pump

ME filter, plate 4572-0800
1 set Filter cartridges for redundancy filter. Cartridge filtration ability, minimum $Beta_6$=16. Only for filter make Kanagawa

Engine control system, plates 4772-1500/1550, 7072-0800/1100/1250 (906) [2])
1 Multi Purpose Controller MPC
1 Multi Purpose Controller MPC-10, if applied
1 FIVA amplifier. Only if Curtis Wright FIVA
1 Trigger sensor for tacho system. Only if trigger ring and no angular encoder on fore end
1 Marker sensor for tacho system
1 Tacho signal amplifier
1 ID-key
1 Encoder, steel compensator and bearing set
1 Fuse kit

Starting valve, plates 3472-0200/0250 (907)
1 Starting valve, complete [2])
(Included in the Cylinder cover complete)
1 Solenoid valve [1])

Hydraulic cylinder unit, plates 4572-0500/0550/0100/0900, 4272-0500 (906, 907) [1 and 2])
1 Fuel booster top cover, complete with plunger
1 ELFI + ELVA valves complete, or FIFA if applied.
1 Suction valve complete
1 20 %* Flexible high-pressure hoses, one of each size and length. *) Only for DNV
1 High-pressure pipe kit, one of each size and length
1 set Membrane plus seals for accumulator, 1 set for 1 HCU
1 Packing kit (O-rings, square seals and bonded seals)
1 Fuel booster position sensor
1 Exhaust actuator complete

Exhaust valve, plates 2272-0200/0210/0240 (908)
2 Exhaust valves complete
(The 2nd exhaust valve is included in the Cylinder cover complete)
1 High-pressure pipe from actuator to exhaust valve
1 Exhaust valve position sensor

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

Fuel valve, plates 4272-0200 (909)

1 set Fuel valves of each size and type fitted, complete with all fittings, for 1 engine
a)engines with 1 or 2 fuel valves: 1 set of fuel valves for all cylinders on the engine
b)engines with 3 and more fuel valves per cylinder: 2 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

Fuel oil high-pressure pipes, plate 4272-0100 (909)

1 set High-pressure pipe, from fuel oil pressure booster to fuel valve

Turbocharger, plate 5472-0700 (910)

1 set Maker's standard spare parts
1 a) Spare rotor for 1 turbocharger, including compressor wheel, rotor shaft with turbine blades and partition wall, if any

Bedplate, plates 1072-0400, 2572-0400 (912)

1 Main bearing shell (1 upper and 1 lower part) of each size
1 set Studs and nuts for 1 main bearing

1) MAN ES required spare parts.
2) All spare parts are requested by all Classes.
a) Only required for RS. To be ordered separately as option: 4 87 660 for other classification societies

Note: Plate numbers refer to the Instruction Manual containing plates with spare parts (older three-digit numbers are included for reference)

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

Additional Spares

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

The final scope of spare parts is to be agreed between the owner and engine builder/yard.

Cylinder cover, plate 2272-0300 (901)

- 4 Studs for exhaust valve
- 4 Nuts for exhaust valve
- ½ eng O-rings for cooling jacket
- ½ eng Sealing between cylinder cover and liner
- 4 Spring housings for fuel valve. Only for 98-60 ME/ME-C

Hydraulic tool for cylinder cover, plates 2270-0310/0315 (901)

- 1 set Hydraulic hoses with protection hose complete with couplings
- 8 pcs O-rings with backup rings, upper
- 8 pcs O-rings with backup rings, lower

Piston and piston rod, plates 2272-0400/0420 (902)

- 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 (902)

- 15 Self-locking nuts
- 5 O-rings
- 5 Top scraper rings
- 15 Pack sealing rings
- 10 Cover sealing rings
- 120 Lamellas for scraper rings
- 30 Springs for top scraper and sealing rings
- 20 Springs for scraper rings

Cylinder frame, plate 1072-0710 (903)

- ½ set Studs for cylinder cover for 1 cylinder
- 1 Bushing for stuffing box

Cylinder liner and cooling jacket, plate 2272-0600/0660/0665 (903)

- 4 set Non-return valves. For K90ME-C two types/cylinder
- 1 eng O-rings for cylinder liner
- ½ eng Gaskets for cooling water connection
- ½ eng O-rings for cooling water pipes
- 1 set Cooling water pipes with blocks between liner and cover for 1 cylinder
- 1 *) Repair kit for LDCL circulation pump
- 1 *) Repair kit for LDCL three-way control valve

*) if fitted

Cylinder lubricating oil system, plate 3072-0600 (903)

- 1 Solenoid valve
- 1 Level switch for lubricator

Hydaulic power supply, HPS, plates 4572-1000/0750, 4572-1100/1200/1250 (906)

- 1 Electric motor for start-up pump
- 1 Pressure relief valve for start-up pump
- 2 Pressure reducer for pump inlet
- 25% Plug screws for hydraulic system (HPS & HCU)
- 1 Accumulator, complete
- 1 Proportional valve
- 1 Swashplate transducer
- 1 Rubber compensator for inlet

Engine control system, ECS, plate 4772-1550 (906)

- 1 set Fuses for MPC, TSA, CNR

Hydraulic cylinder unit, HCU, plate 4572-0500 (906)

- 1 set Packings for booster & actuator, complete set
- 1 ELFI + ELVA valves, or FIVA if applied
- 1 Ball valve, pos. 420
- 1 Ball valve DN10
- 1 set Accumulator complete
- 25% Plug screws, shared with HPS & accumulator block

Accumulator/safety block, plate 4572-0700 (906)

- 1 Pressure transducer, pos. 320
- 25% Plug screws, shared with HPS & HCU
- 1 Ball valve DN10
- 1 Solenoid valve for valve pos. 310 (shut down)

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

Alarm and safety system, plate 4772-
- 1 Pressure sensor for scavenge air receiver, PT 8601
- 1 Pressure switch for lubricating oil inlet, PS 8109
- 1 Thrust bearing temperature sensor, TS 8107 (sensor only)
- 1 Pressure switch for jacket cooling water inlet, PS 8402

Main starting valve, plate 3472-0300 (907)
The below main starting valve parts are all to be in accordance with the supplier's recommendation:
- 1 Repair kit for main actuator
- 1 Repair kit for main ball valve
- 1 *) Repair kit for actuator, slow turning
- 1 *) Repair kit for ball valve, slow turning

*) if fitted

Starting valve, plate 3472-0200 (907)
- 2 Locking plates
- 2 Pistons
- 2 Springs
- 2 Bushing
- 1 set O-rings
- 1 Valve spindle

Exhaust valve, plates 2272-0200/0210 (908)
- 1 Exhaust valve spindle
- 1 Exhaust valve seat
- ½ eng Sealing rings between exhaust valve and cylinder cover
- 4 Piston rings
- ½ eng Guide rings for air piston
- ½ eng Sealing rings
- ½ eng Safety valves
- 1 eng Gaskets and O-rings for safety valve
- 1 Piston complete
- 1 Opening damper piston
- 1 eng O-rings and sealings between air piston and exhaust valve housing/spindle
- 1 Spindle guide
- 1 eng Gaskets and O-rings for cooling water connection
- 1 Conical ring in 2/2. Only for low-force design
- 1 eng O-rings for spindle/air piston
- 1 eng Non-return valve
- 1 Sealing oil unit. Only for engines without low-force design/COL
- 1 Inductive sensor for exhaust valve positioning

Exhaust valve pipe, plate 2272-0240 (908)
- 1 High pressure pipe from actuator to exhaust valve

Cooling water outlet, plate 5072-0100 (908)
- 2 Ball valve
- 1 Butterfly valve
- 1 Gaskets for butterfly valve
- 1 eng Packings for cooling water compensator. Only for S50ME-C8

Fuel injection system, plate 4272-0500 (909)
- 1 Fuel oil pressure booster complete, for 1 cylinder

Fuel valve, plate 4272-0200 (909)
- 1 eng Spindle guides, complete with fuel nozzle
- 1 eng O-rings and guide rings for fuel valve
- ½ eng Springs
- ½ eng Discs, +30 bar
- 3 Thrust spindles
- 3 Non-return valve, if mounted

Fuel oil high-pressure pipes, plate 4272-0100 (909)
- 1 set High-pressure pipe, from fuel oil pressure booster to fuel valve
- 1 set O-rings for high-pressure pipes

Fuel oil regulating valve, plate 4272-0030 (909)
- 1 Fuel oil regulating valve, complete
- 1 O-ring of each kind

Turbocharger, plate 5472-0700 (910)
- 1 set Spare parts for 1 turbocharger in accordance with the supplier's recommendation

Scavenge air receiver, plates 5472-0400/0630 (910)
- 1 set Non-return valves for turbocharger, complete
- 1 Compensator between TC and air cooler

Exhaust pipes and receiver, plates 5472-0750/0900 (910)
- 1 Compensator between TC and receiver
- 2 Compensator between exhaust valve and receiver
- 1 set Gaskets for each compensator
- 1 Compensator between FWD and Aft part, if any

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

Safety valve, plate 2272-0330 (911)

1 set Gaskets for safety valve. Only for CR and NK
2 Safety valve complete. Only for CR and NK

Air cooler, plate 5472-0100 (910)

1 set Anodes (Corrosion blocks)
1 set Packings. Only for cooler type LKMY

Auxiliary blower, plate 5472-0500 (910)

1 set Bearings for electric motor
1 set Shaft sealings
1 set Bearings/belt/sealings for gearbox. Only for belt-driven blowers

Arrangement of safety cap, plate 3472-0900 (911)

1 eng Bursting disc

ME filter, plate 4572-0800 (912)

1 set Filter cartridges for redundancy filter. Cartridge filtration ability, minimum $Beta_6$=16. Only for filter make Boll & Kirch

Notes:
In the pcs/set column, 'eng' means 'engine set', i.e. a set for one engine, whereas 'set' means a set for the specific component(s).

Section numbers refer to Instruction Book, Vol. III containing plates with spare parts

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

Wearing Parts

MAN Energy Solutions 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 (1 pc per cylinder)												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
▪ Nimonic spindle (1 pc per cylinder)																	x
▪ Bottom piece (1 pc per cylinder)																	x
▪ Piston rings for exhaust valve & oil piston (1 set per cyl.)																	x
▪ O-rings for bottom piece (1 set per cylinder)	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
▪ 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 Parts																	
▪ Hydraulic hoses (1 set per engine)						x						x					x
▪ ELFI + ELVA valves, or FIVA (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 cylinder + 7 pcs)												x					
▪ MOP A (1 pc per engine)												x					
▪ MOP B (1 pc per engine)												x					
▪ CCU amplifier (1 pc per cylinder)												x					
▪ ACU amplifier (3 pcs per engine)												x					
▪ LVDT hydraulic pump amplifier (3 pcs per engine)												x					
▪ LDI hydraulic pump amplifier (3 pcs 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
▪ Fuel booster sensor (1 pc per cylinder)												x					
▪ Exhaust valve sensor (1 pc per cylinder)												x					
▪ Marker sensor (1 pc per engine)												x					
▪ Cables (1 set per engine)																	x
▪ Gear wheel bearings (1 set per engine)																	x

*) According to manufacturer's recommendations.

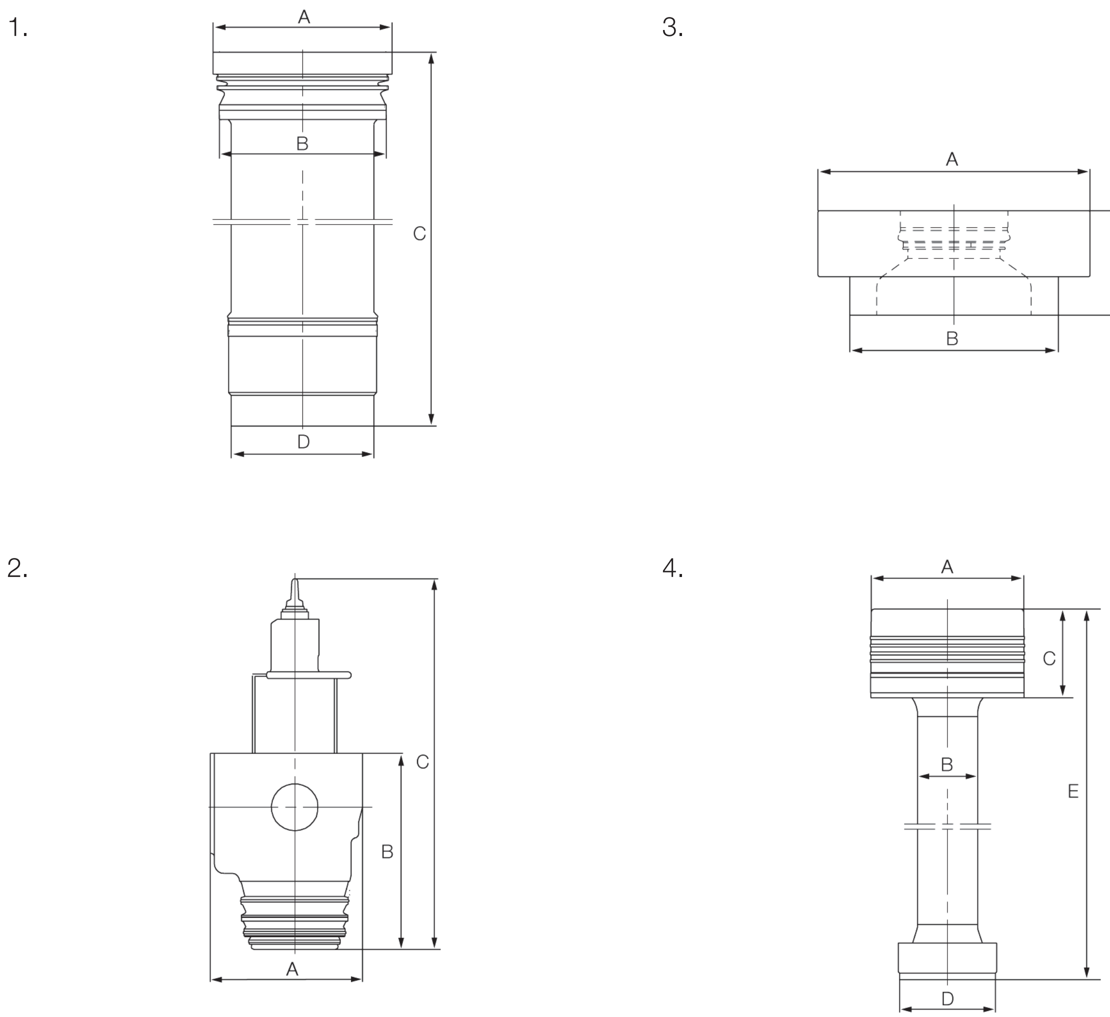
Table 19.08.01b: Wearing parts according to Service Letter SL-509

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**																
ME-GI/-LGI Parts																	
▪ Gas/LFL nozzles (1 set per cylinder) **)			x			x			x			x		x			x
▪ Sealing rings and gaskets for gas/LFL injection valves (1 set per cylinder) **)	x		x		x	x		x	x	x		x	x	x		x	x
▪ Sealing rings for arrangement of control oil pipes (1 set per cylinder) ***)	x		x		x	x		x	x	x		x	x	x		x	x

**) For -GI/-LGI engines only
***) For -GI engines only

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

Large Spare Parts, Dimensions and Masses



178 51 59-7.3.1

Pos.	Sec, Description	MAX Mass	Dimensions (mm)				
		(kg)	A	B	C	D	E
1	Cylinder liner, incl. cooling jacket	3,620	ø860	ø800	3,120	ø680	
2	Exhaust valve	785	600	765	1,694		
3	Cylinder cover, incl. valves	1,715	ø1,085	ø822	497		
4	Piston complete, with piston rod	1,675	ø600	ø235	410	384	3,395

535 20 52-0.3.0

Fig. 19.09.01: Dimensions and masses of tools

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	24	280	469	
TCR20	42	337	566	
TCR22	95	440	739	

561 70 21-6.1.0

ABB

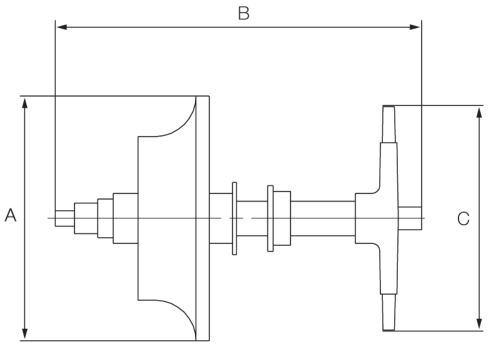
Type	Max Mass	Dimensions (mm)		
	kg.	A (ø)	B	C (ø)
A165-L	90	500	940	395
A170-L	130	580	1,080	455
A175-L	220	700	1,300	550
A180-L	330	790	1,470	620
A185-L	460	880	1,640	690
A190-L	610	970	1,810	760
A265-L	100	500	930	395
A270-L	140	580	1,090	455
A275-L	240	700	1,320	550
A280-L	350	790	1,490	620
A285-L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

List of Standard Tools for Maintenance

The engine is delivered with all necessary special tools for scheduled maintenance. The extent of the tools is stated below. Most of the tools are arranged on steel plate panels. It is recommended to place them close to the location where the overhaul is to be carried out, see Section 19.11.

All measurements are for guidance only.

Cylinder Cover, MF/SF 21-9010

1 pcs Tool panel incl. lifting chains, grinding mandrels, extractor tools etc.
1 pcs Cylinder cover rack
1 set Cylinder cover tightening tools

Cylinder Unit Tools, MF/SF 21-9014

1 pcs Tool panel incl. pressure testing tool, piston ring expander, stuffing box tools, templates etc.
1 pcs Guide ring for piston
1 pcs Lifting tool for piston
1 pcs Support iron for piston
1 pcs Crossbar for cylinder liner, piston
1 set Measuring tool for cylinder liner
1 set Test equipment for accumulator
1 pcs ECU temporary backup cable for indicator

Crosshead and Connection Rod Tools, MF/SF 21-9022

1 pcs Tool panel incl. suspension and lifting tools, protection in crankcase etc.
1 pcs Crankpin shell, lifting tool

Crankshaft and Thrust Bearing Tools, MF/SF 21-9026

1 pcs Tool panel incl. lifting, testing and retaining tools etc.
1 pcs Lifting tool for crankshaft
1 pcs Lifting tool for thrust shaft
1 pcs Main bearing shell, lifting tool
1 set Feeler gauges
1 pcs Measuring instrument for Axial Vibration Damper (Only for engines without Axial Vibration Monitor)

Control Gear Tools, MF/SF 21-9030

1 pcs Tool panel incl. pin gauges, chain assembly tools, camshaft tools etc.
1 set Hook wrenches for accumulator

Exhaust Valve Tools, MF/SF 21-9038

1 pcs Tool panel incl. grinding-, lifting-, adjustment- and test tools etc.

Fuel Oil System Tools, MF/SF 21-9042

1 pcs Tool panel incl. grinding, lifting, adjustment and assembly tools etc.
1 set Fuel valve nozzle tools
1 set Toolbox for fitting of fuel pump seals
1 pcs Probe light
1 pcs Test rig for fuel valve

Turbocharger System Tools, MF/SF 21-9046

1 set Air cooler cleaning tool
1 set Guide rails, air cooler element
1 pcs Compensator, dismantling tool
1 pcs Travelling trolley
1 set Blanking plates

General Tools, MF/SF 21-9058

1 set Pump for hydraulic jacks incl. hydraulic accessories
1 set Set of tackles, trolleys, eye bolts, shackles, wire ropes
1 set Instruments incl. mechanical / digital measuring tools
1 set Working platforms incl. supports
1 set Hand tools incl. wrenches, pliers and spanners

Hydraulic Jacks, MF/SF 21-94

It is important to notice, that some jacks are used on different components on the engine

Personal Safety Equipment, MF/SF 21-9070

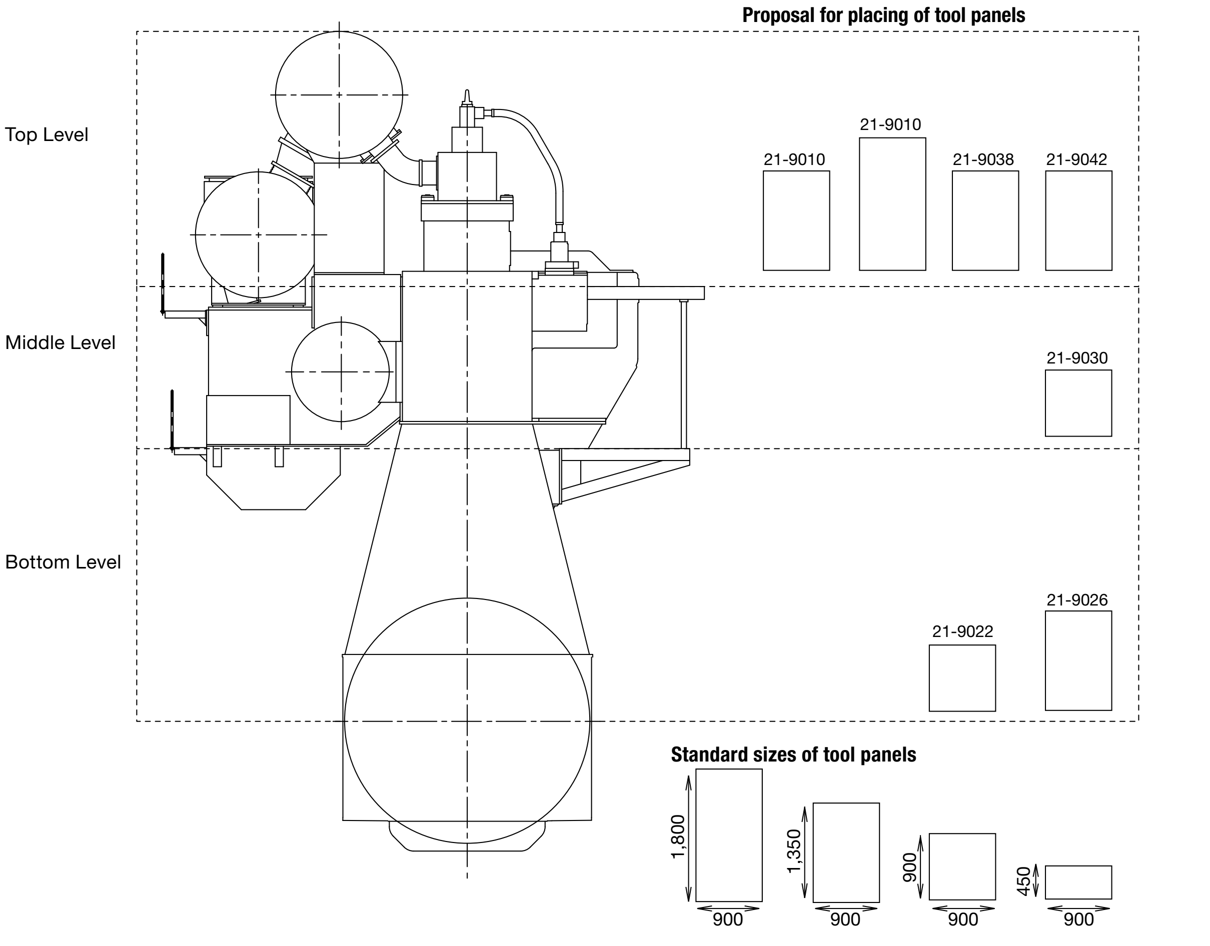
1 pcs Fall arrest block and rescue harness
1 pcs Fall arrest equipment (Optional)

Optional Tools

1 pcs Collar ring for piston
1 pcs Support for tilting tool
1 pcs Valve seat and spindle grinder
1 pcs Wave cutting machine for cylinder liner
1 pcs Wear ridge milling machine
1 pcs Work table for exhaust valve

Mass of the complete set of tools: Approximately 4,300 kg

Tool Panels



Section	Tool Panel	Total mass of tools and panels in kg
21-9010	**Cylinder Cover** Panel incl. lifting chains, grinding mandrels, extractor tools etc.	320
21-9014	**Cylinder Unit Tools,** Panel incl. pressure testing tool, piston ring expander, stuffing box tools, templates etc.	780
21-9038	**Exhaust valve Tools** Panel incl. grinding-, lifting-, adjustment- and test tools, etc.	65
21-9042	**Fuel oil system Tools** Panel incl. grinding-, lifting-, adjustment- and assembly tools, etc.	185
21-9030	**Control gear Tools** Panel incl. pin gauges, chain assembly tools, camshaft tools, etc.	135
21-9022	**Crosshead and Connection rod Tools** Panel incl. suspension-, lifting tools, protection in crank case, etc.	230
21-9026	**Crankshaft and Thrust bearing Tools** Panel incl. lifting-, testing- and retaining tools, etc.	265

Fig. 19.11.01 Tool Panels. 4 88 660

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 Energy Solutions 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 Energy Solutions 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-es.com → '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 Energy Solutions as project support. For this purpose, we have developed the CEAS ap-plication, 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-es.com → 'Two-Stroke' → 'CEAS En-gine 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 Energy Solutions publicat-ions and papers are provided, too.

Supplementary project data on request

Further to the data generated by the CEAS appli-cation, 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 en-gine
- 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 Energy Solutions, Copenhagen in this regard.

Extent of Delivery

MAN Energy Solutions' '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 two different EoDs:

EoD 95-40 ME-C/-GI/-LGI Tier ll Engines
EoD 50-30 ME-B/-GI/-LGI Tier ll Engines

These publications are available in print and at: www.marine.man-es.com → '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 Energy Solutions, 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 col-umn in the EoD.

The Copenhagen Standard Extent of Delivery includes:

- Minimum of alarm sensors recommended by the classification societies and MAN Energy Solutions
- Moment compensator for certain numbers of cylinders
- MAN turbochargers
- The basic engine control system
- Engine Management Services (EMS) incl. PMI software and LAN-based interface to AMS
- Spare parts either required or recommended by the classification societies and MAN Energy Solutions
- Tools required or recommended by the classification societies and MAN Energy Solutions.

MAN Energy Solutions licencees may select a differ-ent 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 Energy Solutions' '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 Energy Solutions 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

Lines, pipes etc.	
	Line, primary process
	Line, secondary process
	Control line, general type
	Control line, capilar type
	Lines connected
	Crossing lines, connected
	Crossing lines, not connected
	Interruption of pipe line
P1	Interruption of pipe line with reference indication
	Pipeline or duct with thermal insulation
	Pipeline with thermal insulation, heated or cooled by a separate circuit, end
	Pipeline with thermal insulation, heated or cooled by a separate circuit
	Pipeline with thermal insulation, heated or cooled by a separate circuit, end
	Jacketed (sleeved) pipeline with thermal insulated
	Jacketed (sleeved) pipeline with thermal insulated, end
	Jacketed (sleeved) pipeline
	Jacketed (sleeved) pipeline, end
	Change of pipe diameter, pipe reducer
	Pipe slope, located above pipe

	Interlocked, located in interlocked line
NO	Indication of valve normally open. With the symbol 'function' field
NC	Indication of valve normally closed. With the symbol 'function' field

Flanges, connections and other in-line pipe fittings	
	Flange, single
	Flange coupling, flange pair, blind flange
	Flange coupling, clamped
	Screw joint
	Quick release coupling
	Quick release coupling, with automatically closing when uncoupled
	End cap, threaded
	End cap
	Orifice
	Swing blind, closed
	Swing blind, open
	Rupture disc
	Siphon
	Boss
	Boss with intersection pipe
	Spray nozzle, single
	Spray nozzle, multiple

Pipe supports	
	Pipe support, fixation type
	Pipe support, sliding type

Wall penetrations, drains and vents	
	Wall or roof penetration, general
	Wall or roof penetration, general, jacketed (sleeved) pipeline
*	Wall or roof penetration, sealed. * Shall be replaced with a designation for the type of seal, e.g. fire
	Drain, funnel etc.
	Drain pan
	Vent, outlet to atmosphere
	Vent, outlet to atmosphere outside enclosure

Valve symbols	
	2-way on-off valve, straight type, general
	2-way on-off valve, angle type, general
	3-way valve, general
	4-way valve, general
	Non-return function, check function, flow left to right
	Control valve, straight type, general
	Control valve, angle type, general
	Control valve, 3-way type, general
	Pre-set control valve, e.g. flow balancing valve
	Safety function, straight type general, inlet / internal side to the left
	Safety function, angle type general, inlet / internal side bottom
	Breather valve, straight type general, with safety function, e.g. tank overpressure / vacuum function
	Breather valve, angle type general, with safety function, e.g. tank overpressure / vacuum function
	3-way plug valve, L-bore, general
	3-way plug valve, T-bore, general
	4-way plug valve, double L-bore, general

Supplementary valve symbols	
	Valve, globe type
	Valve, gate type
	Valve, butterfly type
	Valve, ball type
	Valve, piston or plunger type
	Valve, plug type
	Valve, diaphragm type
	Valve, hose type
	Valve, needle type

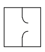
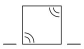
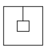
Manual operators	
	Manually operated
	Manually operated, by pushing
	Manually operated, by pulling
	Manually operated, by pulling and pushing
	Manually operated, by a lever
	Manually operated, by a pedal
	Manually operated, incl. locking device

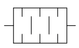
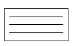
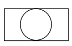
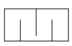
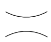
Mechanical operators	
	Mechanically operated, by weight
	Mechanically operated, by float
	Mechanically operated, by spring

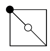
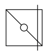
Electric drives	
	Electrical motor
	Electrical motor, adjustable

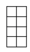
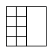
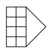
Automatic operators	
	Actuator, without indication of type
	Single-acting hydraulic actuator
	Double-acting hydraulic actuator
	Single-acting pneumatic actuator
	Double-acting pneumatic actuator
	Single-acting diaphragm actuator
	Double-acting diaphragm actuator
	Single- or double-acting fluid actuator. (For double-acting, two pilot lines are needed)
	Electromagnetic actuator
	Self-operated pressure sustaining control diaphragm. Upstream to valve, right side
	Self-operated pressure reducing control diaphragm. Upstream to valve, right side

Spindle information, e.g. safety operators	
	Fail to close
	Fail to open
	Quick-closing
	Quick-opening
	Double-acting, fail freeze
	Double-acting, fail freeze, drifting against open position
	Double-acting, fail freeze, drifting against closed position
	Limit switch, mechanical type

Flow meters	
	Flow meter, general
	Flow meter, propeller, turbine and screw type
	Flow meter, orifice type
	Flow meter, flow nozzle type
	Flow meter, venturi type
	Flow meter, pitot tube type
	Flow meter, vortex type
	Flow meter, ultrasonic in-line type
	Flow meter, ultrasonic clamp-on type
	Flow meter, magnetic type
	Flow meter, Coriolis type
	Flow switch, paddle type

Various	
	Air release valve
	Condensate release valve
	Restrictor, multistage type
	Flow straightener
	Viewing glass
	Silencer
	Flow restriction
	Flow restriction, adjustable

Dampers	
	2-way on-off damper, general
	Multi-leaf damper, louvre type
	3-way on-off damper, general
	Non return damper, general
	Safety damper, general

Safety devices other than valves	
	Flame arrester, general
	Flame arrester, explosion-proof
	Flame arrester, fire-resistant
	Flame arrester, detonation-proof

Expansions	
	Expansion loop
	Expansion sleeve
	Expansion joint / compensator bellow
	Flexible pipe, hose

Liquid pumps	
	Pump, general
	Pump, positive displacement type
	Pump, centrifugal type
	Pump, hand type
	Pump, gear type
	Pump, screw type
	Pump, piston type
	Pump, piston radial type
	Pump, membrane type
	Pump, ejector type

Fans, ventilators and compressors	
	Fan, ventilator, blower, compressor. General
	Fan, ventilator, blower, compressor. Rotary vane type
	Fan, ventilator, blower, compressor. Impeller type
	Fan, ventilator, blower, compressor. Screw type
	Fan, ventilator, blower, compressor. Reciprocating piston type
	Fan, ventilator, blower, compressor. Rotary reciprocating piston type
	Fan, ventilator, blower, compressor. Reciprocating diaphragm type
	Fan, ventilator, blower, compressor. Turbo type
	Fan, ventilator, blower, compressor. Rotary piston type, e.g. Roots type
T C	Turbocharger

Filters, separators	
	Screen, strainer, general
	Screen, strainer with pit for draining
	In-line strainer, general
	Cartridge filter, bag filter etc, general
	Cartridge filter, bag filter etc flow direction outside - in, general
	Cartridge filter, bag filter etc, flow direction inside - out, general
	Permanent magnet filter
	Filter with backflush, Bernoulli type
M	Filter with continuous backflush
	Separator, cyclone type
	Separator, centrifuge type
	Separator, impact type

Heat exchangers	
	Heat exchanger, general
	Condenser with hot well
	Electrical heater, superheater
	Heat exchanger with plate
	Heat exchanger with tubes
	Heat exchanger with u-bend tubes
	Heat exchanger with coil-shaped tubes
	Electrical heating element
	Heating or cooling coil
	Finned tube

Tanks	
	Open tank, basin
	Closed tank
	Closed tank with sloped bottom
	Tank with flat bottom and conical roof
	Tank with flat bottom and dished roof
	Vessel with dished ends
	Vessel with spherical ends
	Accumulator

Instrumentation, general	
	Instrument with two letters, e.g. PI
	Instrument with three letters, e.g. DPI

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Fig. A.01.01: Basic symbols for pipe plants according to MAN Energy Solutions