MAN B&W S60MC-C8.2-TII

Project Guide

Camshaft 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.eu → 'Two-Stroke'.

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

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

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

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May 2014

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

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

If this document is delivered in another language than English and doubts arise concerning the translation, the English text shall prevail.

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Engine Design

1

The Fuel Optimised MC-C Tier II Engine

Whether the freight rates rise or fall, an attractive payback time for newbuildings starts with low investment cost. Once in operation, the ease and flexibility in assigning engineers to operate the engine plant are together with low consumption rates of fuels, lubes, parts and service among the important functional issues which contribute to the cost benefit. The MAN B&W MC-C engine meets both requirements.

The world market-leading two-stroke MC/MC-C engine programme from MAN Diesel has evolved since the early 1980s to embrace bore sizes from 260 mm to 980 mm for propelling ocean-going ships of all types and sizes. Also land-based applications (power plants mainly) have found the MC/MC-C engine types attractive.

The MC-C engine features chain driven camshaft, camshaft controlled fuel injection timing and exhaust valve opening as well as a conventional fuel oil pumps, all well-known and proven technology familiar to marine engineers all over the world.

To conclude, the MAN B&W MC-C engine combines classic virtues of commonly known, well-proven technology continuously upgraded and up-rated to suit the requirements to modern prime movers. Consequently, our latest cutting edge design and manufacturing features are built into each component.

Concept of the MC-C engine

The engine concept is based on a mechanical camshaft system for activation of the fuel injection and the exhaust valves. The engine is provided with a pneumatic/electric manoeuvring system and the engine speed is controlled by an electronic/hydraulic type governor.

Each cylinder is equipped with its own fuel injection pump, which consists of a simple plunger activated by the fuel cam directly. The optimal combination of NOx and SFOC (Specific Fuel Oil Consumption) is achieved by means of the Variable Injection Timing (VIT) incorporated in the fuel pumps (applicable for MC-C engines type 90-46 only).

The cam controlled exhaust valve is opened hydraulically and closed by means of an air spring.

Lubrication is either by means of a uni-lube oil system serving both crankshaft, chain drive, piston cooling and camshaft or a combination of a main lubricating oil system and a separate camshaft lube oil system.

Cylinder lubrication is accomplished by electronically controlled Alpha lubricators, securing a low lube oil consumption, or timed mechanical lubricators alternatively.

The starting valves are opened pneumatically by control air from the starting air distributor(s) and closed by a spring.

Engine design and IMO regulation compliance

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

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

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

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

The main features of the MC engine are described in the following pages.

Tier II fuel optimisation

NO_x regulations place a limit on the SFOC on two-stroke engines. In general, NO_x emissions will increase if SFOC is decreased and vice versa. In the standard configuration, MAN B&W engines are optimised close to the IMO NO_x limit and, therefore, NO_x emissions may not be further increased.

The IMO NO_x limit is given as a weighted average of the NO_x emission at 25, 50, 75 and 100% load. This relationship can be utilised to tilt the SFOC profile over the load range. This means that SFOC can be reduced at part load or low load at the expense of a higher SFOC in the high-load range without exceeding the IMO NO_x limit.

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

- VT: Variable Turbine Area
- EGB: Exhaust Gas Bypass

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

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

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

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

Application of MC-C engines

For further information about the application of MC-C engines based on ship particulars and power demand, please refer to our publications titled:

Propulsion Trends in Container Vessels

Propulsion Trends in Bulk Carriers

Propulsion Trends in Small Tankers

The publications are available at www.marine.man.eu → ’Two-Stroke’ → ’Technical Papers’.

Engine Type Designation

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

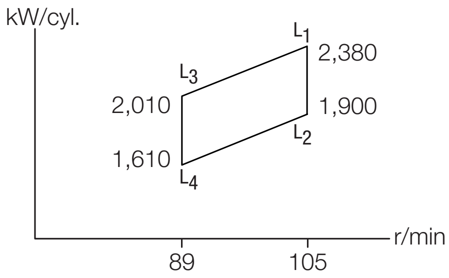
- **-TII** – Emission regulation
  - **TII** IMO Tier level
- **-GI** – Fuel injection concept
  - (blank) Fuel oil only
  - **GI** Gas injection
- **.2** – Version number
- **9** – Mark number
- **-C** – Design
  - **B** Exhaust valve controlled by camshaft
  - **C** Compact engine
- **E** – Concept
  - **E** Electronically controlled
  - **C** Camshaft controlled
- **M** – Engine programme
- **90** – Diameter of piston in cm
- **S** – 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 S60MC-C8.2-TII

Cyl.	L_1 kW
5	11,900
6	14,280
7	16,660
8	19,040

Stroke: 2,400 mm



SFOC for engines with layout on L_1 - L_3 line [g/kWh] — **L_1/L_3 MEP:** 20.0 bar

SFOC optimised load range	Tuning	50%	75%	100%
High load (85%-100%)	-	174.0	169.0	172.0
Part load (50%-85%)	VT	172.0	167.5	174.0
	EGB	172.0	167.5	175.0
Low load (25%-70%)	VT	171.0	168.5	173.0
	EGB	171.0	168.5	174.0

SFOC for engines with layout on L_2 - L_4 line [g/kWh] — **L_2/L_4 MEP:** 16.0 bar

SFOC optimised load range	Tuning	50%	75%	100%
High load (85%-100%)	-	170.0	163.5	166.0
Part load (50%-85%)	VT	168.0	162.0	168.0
	EGB	168.0	162.0	169.0
Low load (25%-70%)	VT	167.0	163.0	167.0
	EGB	167.0	163.0	168.0

Fig 1.03.01: Power, speed and fuel

Engine Power Range and Fuel Oil Consumption

Engine Power

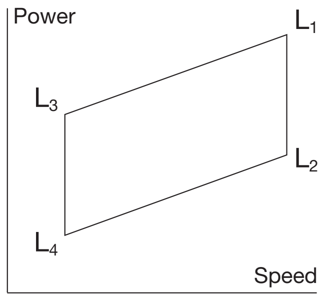
The following tables contain data regarding the power, speed and specific fuel oil consumption of the engine.

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.



178 51 48-9.0

Fig. 1.04.01: Layout diagram for engine power and speed

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

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

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

Specific Fuel Oil Consumption (SFOC)

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

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

The SFOC figures are given in **g/kWh** with a tolerance of 5% (at 100% SMCR) and are based on the use of fuel with a lower calorific value of 42,700 kJ/kg (~10,200 kcal/kg) at ISO conditions:

Ambient air pressure ....1,000 mbar
Ambient air temperature .... 25 °C
Cooling water temperature .... 25 °C

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

Lubricating oil data

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

During running-in periods and under special conditions, feed rates of up to 1.5 times the stated values should be used.

Performance Curves

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

MC-C Engine Description

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

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

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

Bedplate and Main Bearing

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

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

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

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

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

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

Frame Box

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

The cylinder frame is fitted with pipes for the piston cooling oil inlet. The scavenge air receiver, turbocharger, air cooler box, lubricators 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. Oil scraper rings in the stuffing box 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.

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

Cylinder Cover

The cylinder cover is of forged steel, made in one piece, and has bores for cooling water. It has a central bore for the exhaust valve, and bores for the fuel valves, 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 mainly of the semi-built type, made from forged or cast steel throws. In 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, and the flange for the turning wheel and for the coupling bolts to an intermediate shaft.

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

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

Thrust Bearing

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

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

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

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

Turning Gear and Turning Wheel

The turning wheel is fitted to the thrust shaft and 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 gear with brake.

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

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

Axial Vibration Damper

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

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

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

Tuning Wheel/ Torsional Vibration Damper

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

Connecting Rod

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

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

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

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

Piston

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

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

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

Piston Rod

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

Crosshead

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

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

Scavenge Air System

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

Scavenge Air Cooler

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

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

Auxiliary Blower

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

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

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

Further information is given in Chapter 14.

Exhaust Gas System

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

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

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

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

Exhaust Turbocharger

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

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

Camshaft and Cams

The camshaft consists of a number of sections each having a shaft piece with exhaust cams, fuel cams, coupling parts and indicator drive cams.

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

The cam for the indicator drive can be adjusted mechanically. The coupling parts are shrunk onto the shaft and can be adjusted and dismantled hydraulically.

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

Chain Drive

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

The mechanical cylinder lubricators, if fitted, are driven from the camshaft by a separate chain.

Indicator Drive

As separate options, the engine can be supplied with either an indicator drive, a mechanical indicator system, or the so-called PMI system, a pressure analyser system, described in section 18.02.

The indicator drive consists of a cam fitted on the camshaft and a spring-loaded spindle with a roller which moves up and down in accordance with the movement of the piston within the engine cylinder. At the top, the spindle has an eye to which the indicator cord is fastened after the indicator has been installed on the indicator valve.

Governor

The engine is to be provided with a governor of a make approved by MAN Diesel & Turbo, controlling the fuel pump through an actuator. The governor must meet the ISO 3046 standard, part IV, 1997.

The speed setting of the actuator is determined by an electronic signal from the electronic governor based on the position of the main engine regulating handle. The actuator is connected to the fuel regulating shaft by means of a mechanical linkage. Alternatively for engines type 46 without PTO, a mechanical/hydraulic Woodward governor for pneumatic speed setting could be provided.

Fuel Oil Pump and Fuel Oil High Pressure Pipes

The engine is provided with one fuel pump for each cylinder. The fuel pump consists of a pump housing of nodular cast iron, a centrally placed pump barrel, and a plunger of nitrated steel. In order to prevent fuel oil from mixing with the lubricating oil, the pump actuator is provided with a sealing arrangement.

The pump is placed on the roller guide housing and activated by the fuel cam. The volume injected is controlled by turning the plunger by means of a toothed rack connected to the regulating shaft.

For optimal combination of NO_x and SFOC, the fuel pumps incorporate Variable Injection Timing (VIT). The VIT uses the governor fuel setting as the controlling parameter.

The fuel oil pump is provided with a puncture valve, which prevents high pressure from building up during normal stopping and shut down.

The roller guide housing is provided with a semi-automatic (optional on engines type 70, 60 and 50) lifting device which, during rotation of the engine, can lift the roller guide free of the cam. On 46 types, a separate tool is used to lift the roller guide.

The fuel oil high-pressure pipes are either double-walled or of the hose type.

Further information is given in Section 7.01.

Fuel Valves and Starting Air Valve

Each cylinder cover is equipped with two or three fuel valves, starting air valve (SAV), and indicator valve.

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

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

The starting air valve is opened by control air from the starting air distributor and is closed by a spring. The control air supply is regulated so that the starting valves deliver starting air to the cylinders in the correct firing order.

Starting Air System

The starting air system comprises a main starting valve, one or two starting air distributors (one only on 46 types) and a non-return valve, a bursting disc for the branch pipe and a starting valve on each cylinder. The main starting valve is connected with the manoeuvring system, which controls the start of the engine.

A slow turning valve can be ordered as an option. The slow-turning function is actuated manually from the manoeuvring console.

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

Exhaust Valve

The exhaust valve consists of the valve housing and the valve spindle. The valve housing is made of cast iron and is arranged for water cooling. The housing is provided with a water cooled bottom piece of steel with a flame-hardened seat of the W-seat design.

The exhaust valve spindle is a DuraSpindle or made of Nimonic. The housing is provided with a spindle guide.

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

In operation, the valve spindle slowly rotates, driven by the exhaust gas acting on small vanes fixed to the spindle.

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

Cylinder Lubrication

The cylinder lubrication system can be of either the electronic MAN B&W Alpha cylinder lubrication system or a mechanical type.

The cylinder lubrication systems are described in detail in Chapter 9.

Manoeuvring System

The engine is provided with a pneumatic/electric manoeuvring and fuel oil regulating system. The system transmits orders from the separate manoeuvring consoles to the engine.

The regulating system makes it possible to start, stop, reverse the engine and control the engine speed. The speed control on the manoeuvring console gives a speed-setting signal to the governor, dependent on the desired number of revolutions.

At shut-down, the fuel injection is stopped by the puncture valves in the fuel pumps being activated, independently of the speed control. At reversing, the displaceable rollers in the driving mechanism for the fuel pumps are moved to the ‘Astern’ position by air cylinders controlled by the starting air distributor.

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

Reversing

On reversible engines (with Fixed Pitch Propellers mainly), reversing of the engine is performed by means of an angular displaceable roller in the driving mechanism for the fuel pump of each engine cylinder. The reversing mechanism is activated and controlled by compressed air supplied to the engine.

The exhaust valve gear is not to be reversed.

Gallery Arrangement

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

The engine is prepared for top bracings on the exhaust side, or on the manoeuvring side.

Piping Arrangements

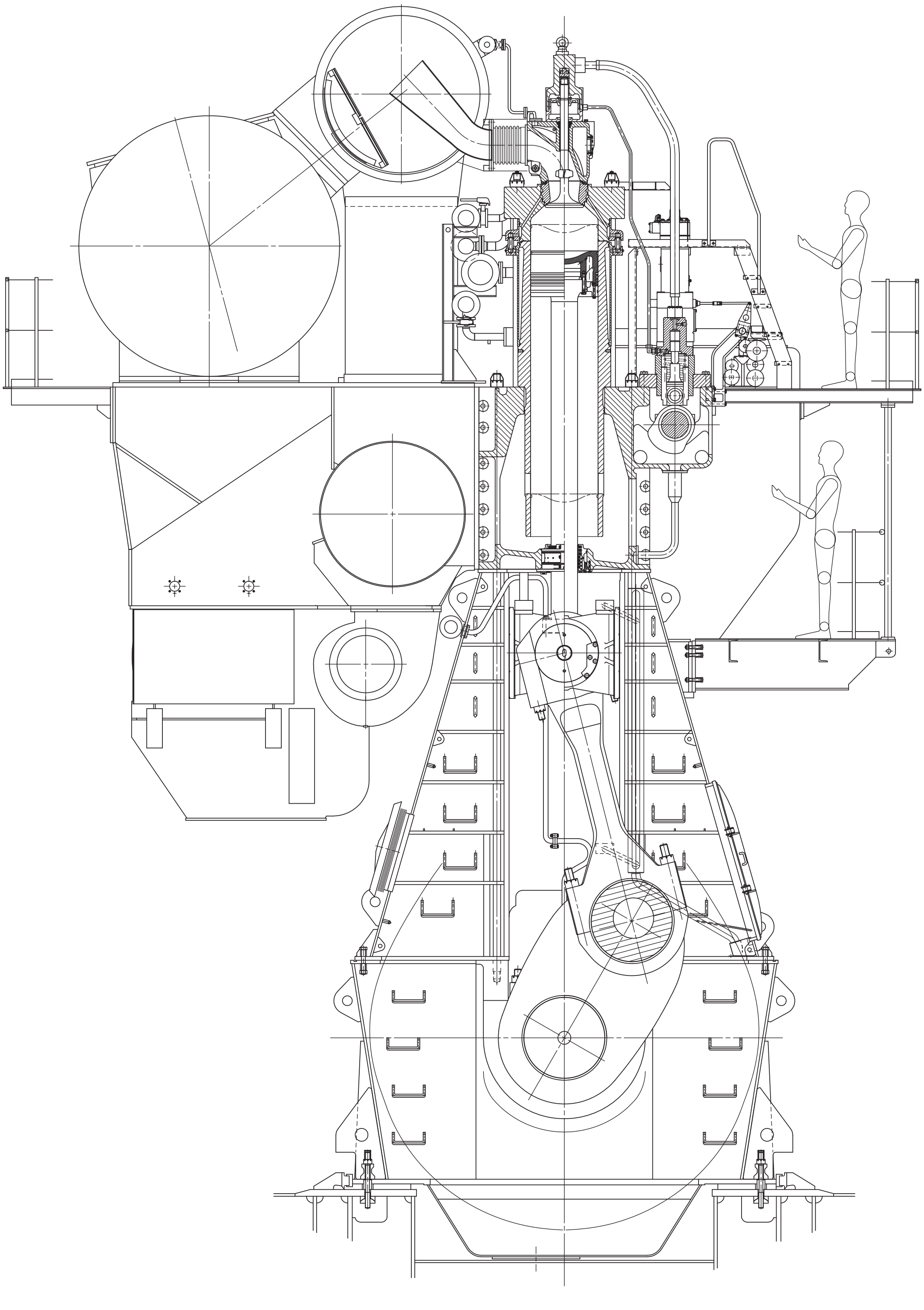
The engine is delivered with piping arrangements for:

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

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

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

Engine Cross Section of S60MC-C



178 56 44-9.0

Fig.: 1.07.01: Engine cross section

Engine Layout and Load Diagrams, SFOC

2

Engine Layout and Load Diagrams

Introduction

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

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

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

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

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

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

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

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

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

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

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

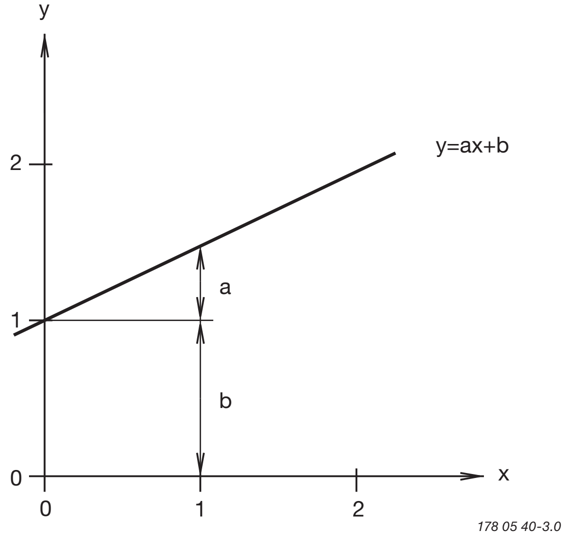


Fig. 2.01.01: Straight lines in linear scales

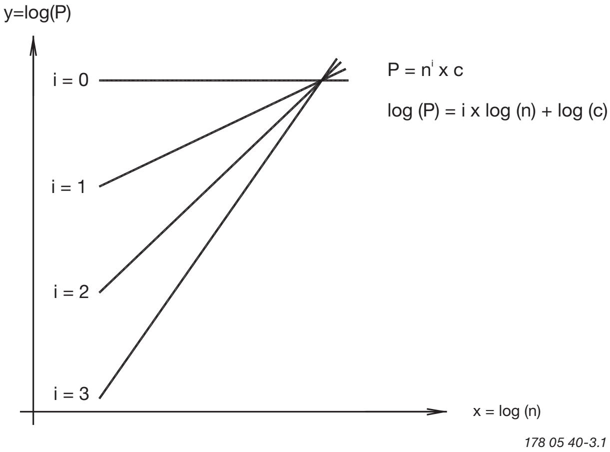


Fig. 2.01.02: Power function curves in logarithmic scales

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

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

Propulsion and Engine Running Points

Propeller curve

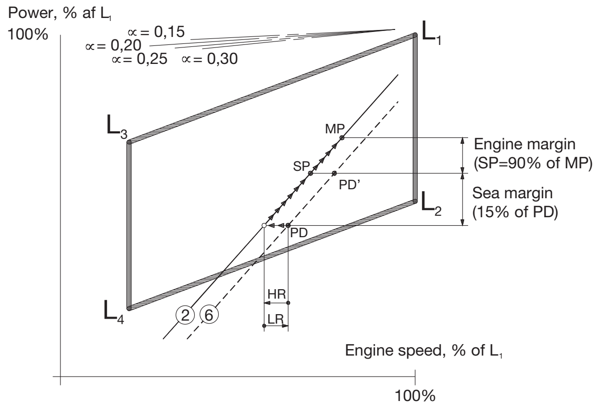
The relation between power and propeller speed for a fixed pitch propeller is as mentioned above described by means of the propeller law, i.e. the third power curve:

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

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

Propeller design point

Normally, estimates of the necessary propeller power and speed are based on theoretical calculations for loaded ship, and often experimental tank tests, both assuming optimum operating conditions, i.e. a clean hull and good weather. The combination of speed and power obtained may be called the ship's propeller design point (PD), placed on the light running propeller curve 6. See below figure. On the other hand, some shipyards, and/or propeller manufacturers sometimes use a propeller design point (PD) that incorporates all or part of the so-called sea margin described below.



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

178 05 41-5.3

Fig. 2.01.03: Ship propulsion running points and engine layout

Fouled hull

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

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

Sea margin and heavy weather

If, at the same time the weather is bad, with head winds, the ship's resistance may increase compared to operating in calm weather conditions. When determining the necessary engine power, it is normal practice to add an extra power margin, the so-called sea margin, which is traditionally about 15% of the propeller design (PD) power.

Engine layout (heavy propeller)

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

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

Engine margin

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

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

Constant ship speed lines

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

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

Propeller diameter and pitch, influence on the optimum propeller speed

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

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

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

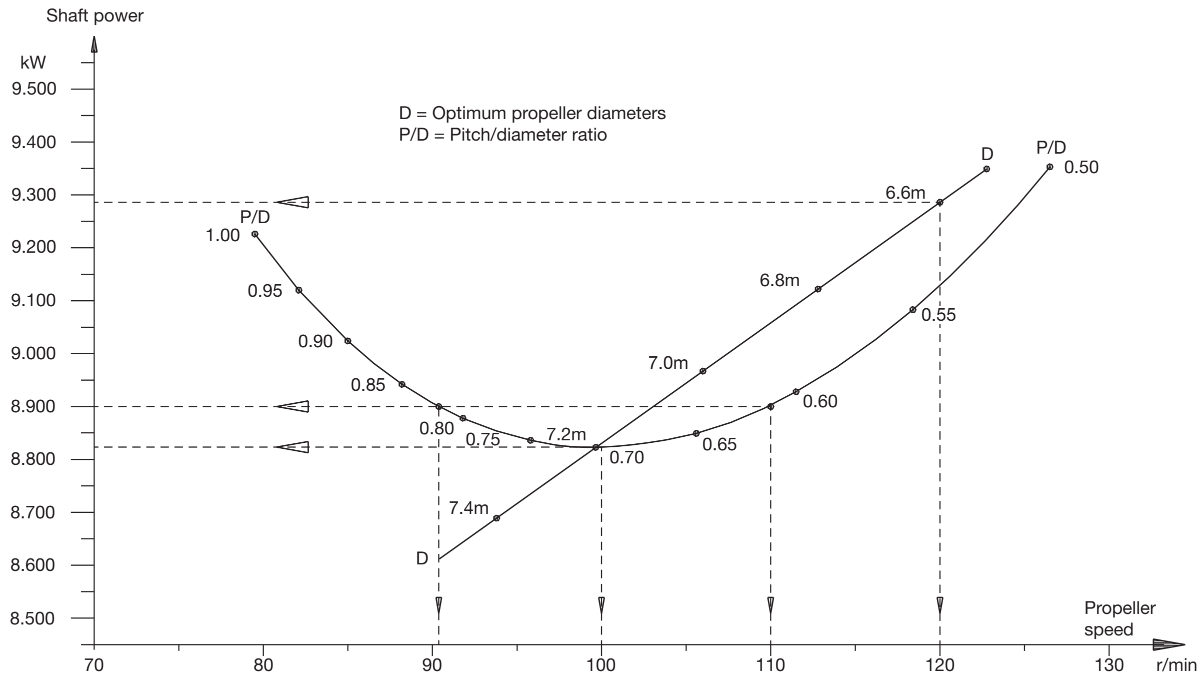
When the optimum propeller diameter D is increased from 6.6 m to 7.2. m, the power demand is reduced from about 9,290 kW to 8,820 kW, and the optimum propeller speed is reduced from 120 r/min to 100 r/min, corresponding to the constant ship speed coefficient ∝ = 0.28 (see definition of ∝ in Section 2.02,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

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

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

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

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



178 47 03-2.0

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

Constant ship speed lines

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

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

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

where:
P = Propulsion power
n = Propeller speed, and
∝= the constant ship speed coefficient.

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

When such a constant ship speed line is drawn into the layout diagram through a specified propulsion MCR point 'MP_1', selected in the layout area and parallel to one of the ∝-lines, another specified propulsion MCR point 'MP_2' upon this line can be chosen to give the ship the same speed for the new combination of engine power and speed.

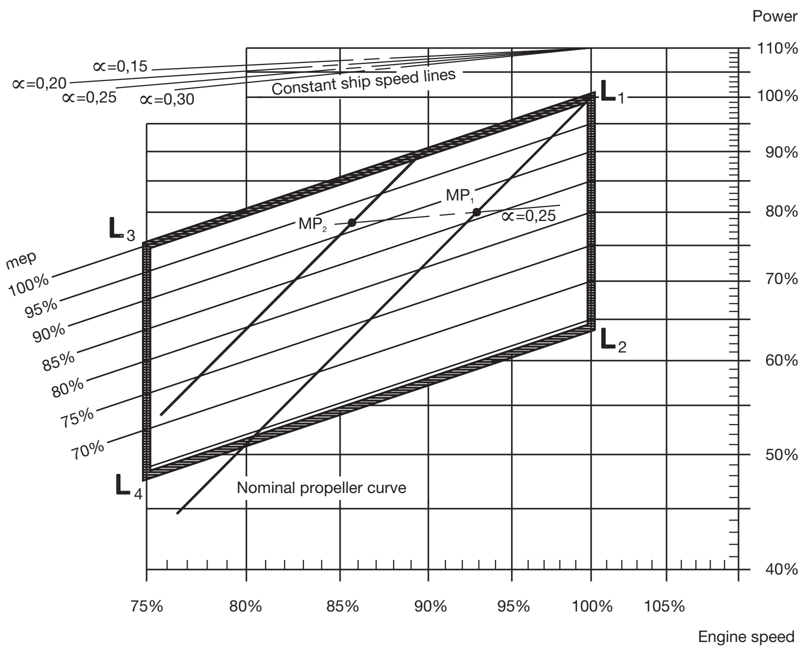
Fig. 2.02.02 shows an example of the required power speed point MP_1, through which a constant ship speed curve ∝= 0.25 is drawn, obtaining point MP_2 with a lower engine power and a lower engine speed but achieving the same ship speed.

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

for general cargo, bulk carriers and tankers
∝= 0.25 -0.30

and for reefers and container vessels
∝= 0.15 -0.25

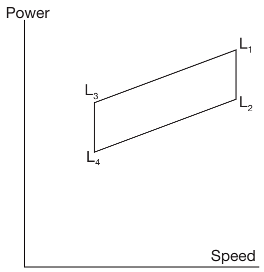
When changing the propeller speed by changing the pitch diameter ratio, the ∝ constant will be different, see above.



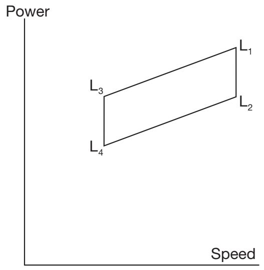
178 05 66-7.0

Fig. 2.02.02: Layout diagram and constant ship speed lines

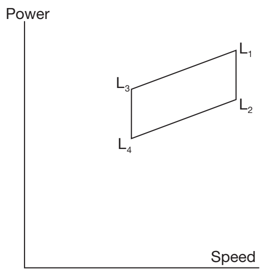
Layout Diagram Sizes



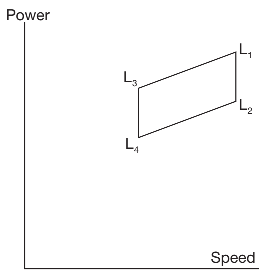
100 - 80% power and
100 - 79% speed range
valid for the types:
G70ME-C9.2
G60ME-C9.2



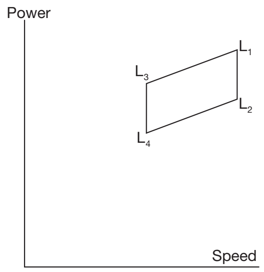
100 - 80% power and
100 - 81% speed range
valid for the types:
G80ME-C9.2-Extended



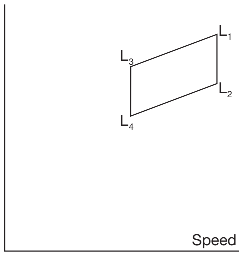
100 - 80% power and
100 - 84% speed range
valid for the types:
L70MC-C/ME-C8.2



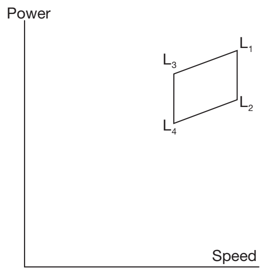
100 - 80% power and
100 - 85% speed range
valid for the types:
G80ME-C9.2-Basic
S70/65MC-C/ME-C8.2
S60MC-C/ME-C/ME-B8.3
L60MC-C/ME-C8.2
G/S50ME-B9.3
S50MC-C/ME-C8.2/ME-B8.3
S46MC-C/ME-B8.3
G45ME-B9.3
G/S40ME-B9.3, S40MC-C
S35MC-C/ME-B9.3
S30ME-B9.3



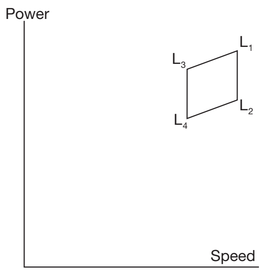
100 - 80% power and
100 - 85.7% speed range
valid for the types:
S90ME-C10.2
S90ME-C9.2
S80ME-C8.2



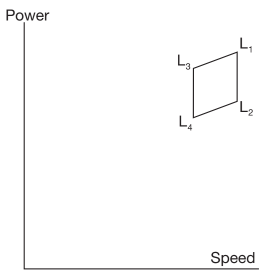
100 - 80% power and
100 - 87.5% speed range
valid for the types:
G95ME-C9.2



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



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



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

See also Section 2.05 for actual project.

178 62 22-5.3

Fig. 2.03.01 Layout diagram sizes

Engine Layout and Load Diagram

Engine Layout Diagram

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

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

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

Specified maximum continuous rating (M)

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

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

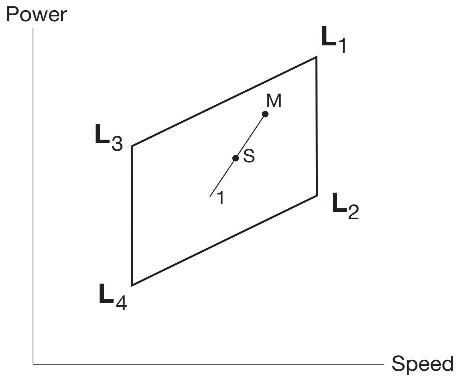
For ME-B engines, only the fuel injection (and not the exhaust valve activation) is electronically controlled over a wide operating range of the engine.

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

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

Continuous service rating (S)

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



178 60 85-8.1

Fig. 2.04.01: Engine layout diagram

Engine Load Diagram

Definitions

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

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

Operating curves and limits for continuous operation

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

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

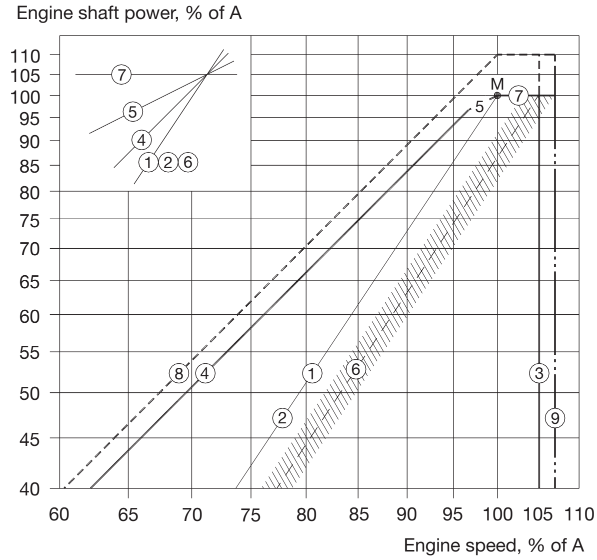
Line 2:
Propeller curve, fouled hull and heavy weather – heavy running.

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

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

The above limits may in general be extended to 105% and during trial conditions to 107% of the nominal L_1 speed of the engine, provided the torsional vibration conditions permit.

The overspeed set-point is 109% of the speed in M, however, it may be moved to 109% of the *nominal speed* in L_1, provided that torsional vibration conditions permit.



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

M Specified MCR point

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

178 05 42-7.6

Fig. 2.04.02: Standard engine load diagram

Running at low load above 100% of the nominal L_1 speed of the engine is, however, to be avoided for extended periods. Only plants with controllable pitch propellers can reach this light running area.

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

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

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

Line 7:
Represents the maximum power for continuous operation.

Limits for overload operation

The overload service range is limited as follows:

Line 8:
Represents the overload operation limitations.

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

Line 9:
Speed limit at sea trial.

Limits for low load running

As the fuel injection for ME engines is automatically controlled over the entire power range, the engine is able to operate down to around 15-20% of the nominal L_1 speed, whereas for MC/MC-C engines it is around 20-25% (electronic governor).

Recommendation

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

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

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

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

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

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

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

Extended load diagram for ships operating in extreme heavy running conditions

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

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

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

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

Such cases could be for:

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

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

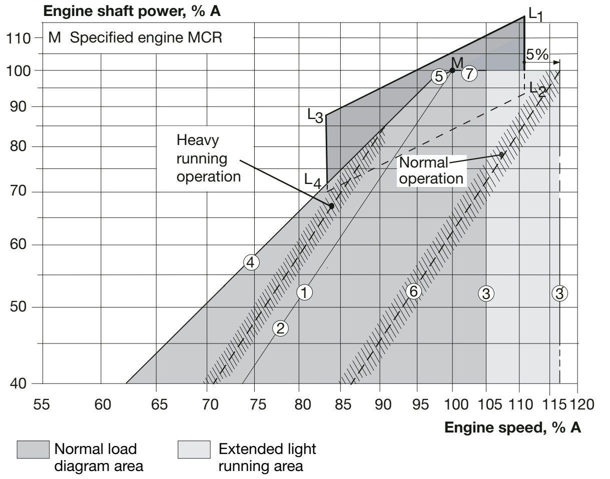
Extended load diagram for speed derated engines with increased light running

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

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

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

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



Line 1: Propeller curve through SMCR point (M)
- layout curve for engine

Line 2: Heavy propeller curve
- fouled hull and heavy seas

Line 3: Speed limit

Line 3': Extended speed limit, provided torsional vibration conditions permit

Line 4: Torque/speed limit

Line 5: Mean effective pressure limit

Line 6: Increased light running propeller curve
- clean hull and calm weather
- layout curve for propeller

Line 7: Power limit for continuous running

178 60 79-9.1

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

Examples of the use of the Load Diagram

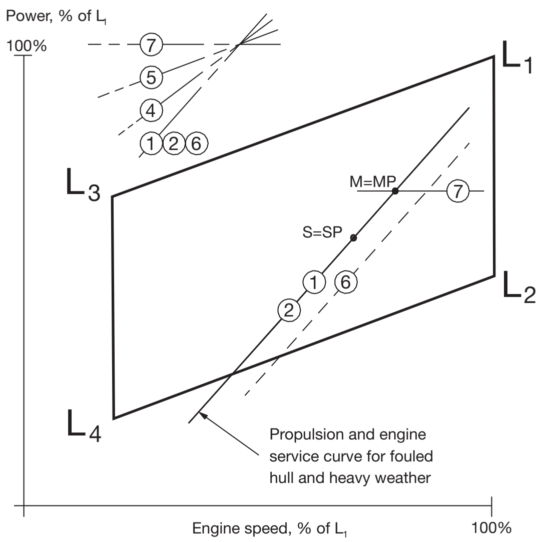
In the following are some examples illustrating the flexibility of the layout and load diagrams.

- Example 1 shows how to place the load diagram for an engine without shaft generator coupled to a fixed pitch propeller.
- Example 2 shows the same layout for an engine with fixed pitch propeller (example 1), but with a shaft generator.
- Example 3 is a special case of example 2, where the specified MCR is placed near the top of the layout diagram.
  In this case the shaft generator is cut off, and the GenSets used when the engine runs at specified MCR. This makes it possible to choose a smaller engine with a lower power output, and with changed specified MCR.
- Example 4 shows diagrams for an engine coupled to a controllable pitch propeller, with or without a shaft generator, constant speed or combinator curve operation.

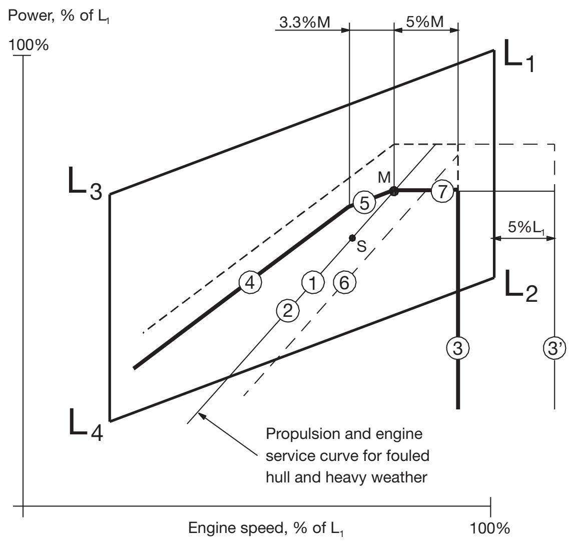
For a specific project, the layout diagram for actual project shown later in this chapter may be used for construction of the actual load diagram.

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

Layout diagram



Load diagram



M	Specified MCR of engine
S	Continuous service rating of engine
MP	Specified MCR for propulsion
SP	Continuous service rating of propulsion

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

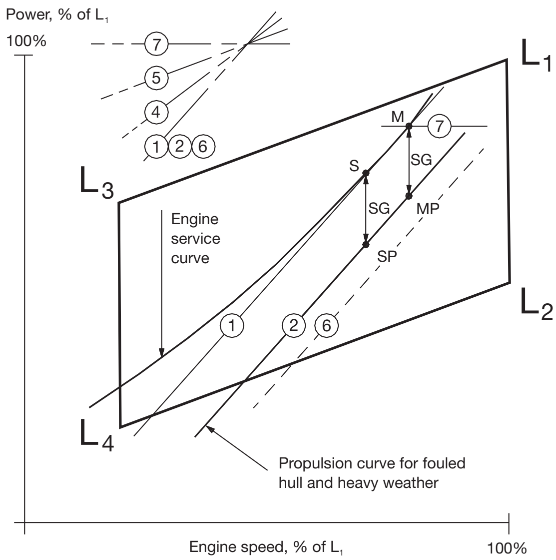
Once point M has been selected in the layout diagram, the load diagram can be drawn, as shown in the figure, and hence the actual load limitation lines of the diesel engine may be found by using the inclinations from the construction lines and the %-figures stated.

178 05 44-0.9

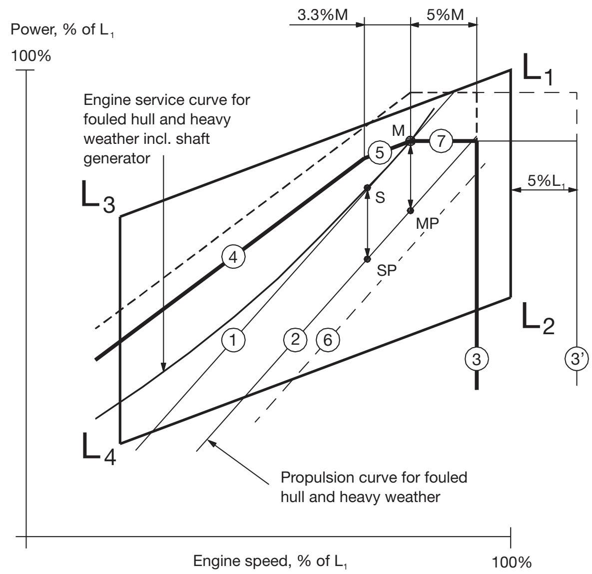
Fig. 2.04.04: Normal running conditions. Engine coupled to a fixed pitch propeller (FPP) and without a shaft generator

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

Layout diagram



Load diagram



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

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

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

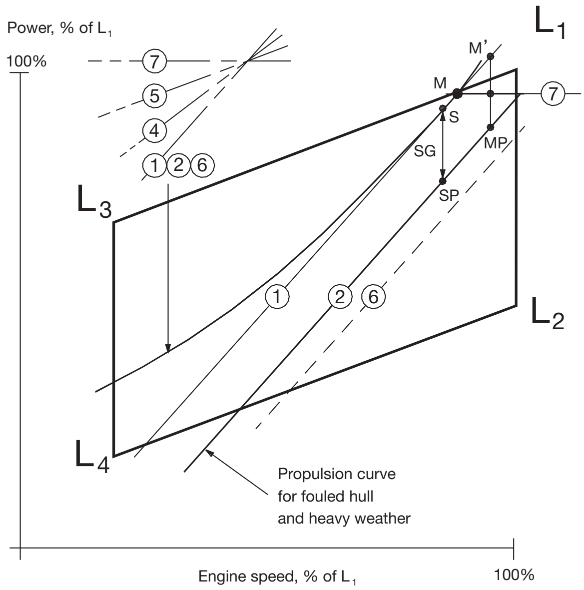
The specified MCR M will then be chosen and the load diagram can be drawn as shown in the figure.

178 05 48-8.9

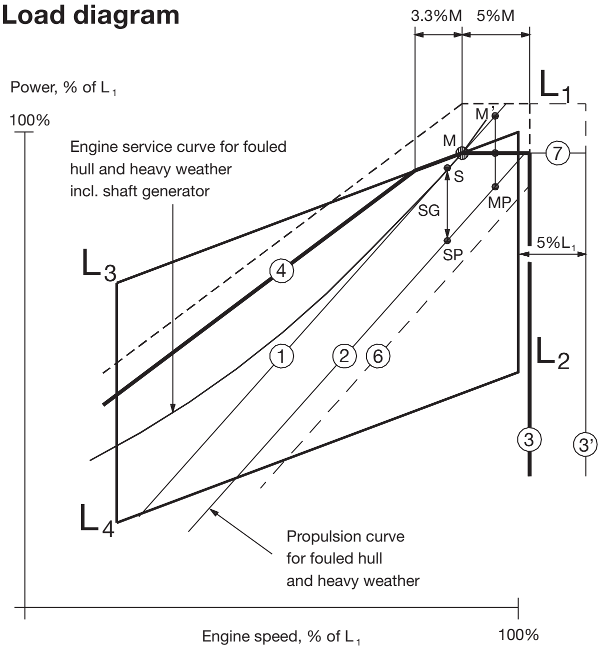
Fig. 2.04.06: Normal running conditions. Engine coupled to a fixed pitch propeller (FPP) and with a shaft generator

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

Layout diagram



Load diagram



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

Point M of the load diagram is found:

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

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

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

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

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

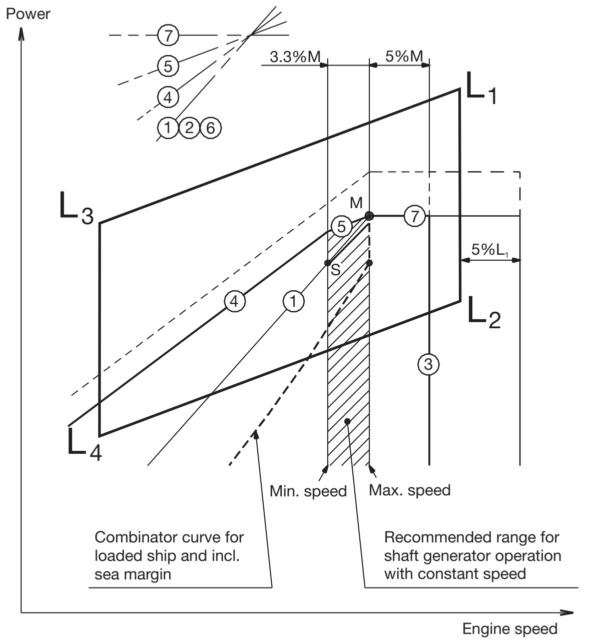
However, such a situation will seldom occur, as ships are rather infrequently running in the upper propulsion power range.

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

178 06 35-1.9

Fig. 2.04.07: Special running conditions. Engine coupled to a fixed pitch propeller (FPP) and with a shaft generator

Example 4: Engine coupled to controllable pitch propeller (CPP) with or without shaft generator



M Specified MCR of engine
S Continous service rating of engine

178 39 31-4.5

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

Layout diagram - without shaft generator
If a controllable pitch propeller (CPP) is applied, the combinator curve (of the propeller) will normally be selected for loaded ship including sea margin.

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

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

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

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

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

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

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

Diagram for actual project

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

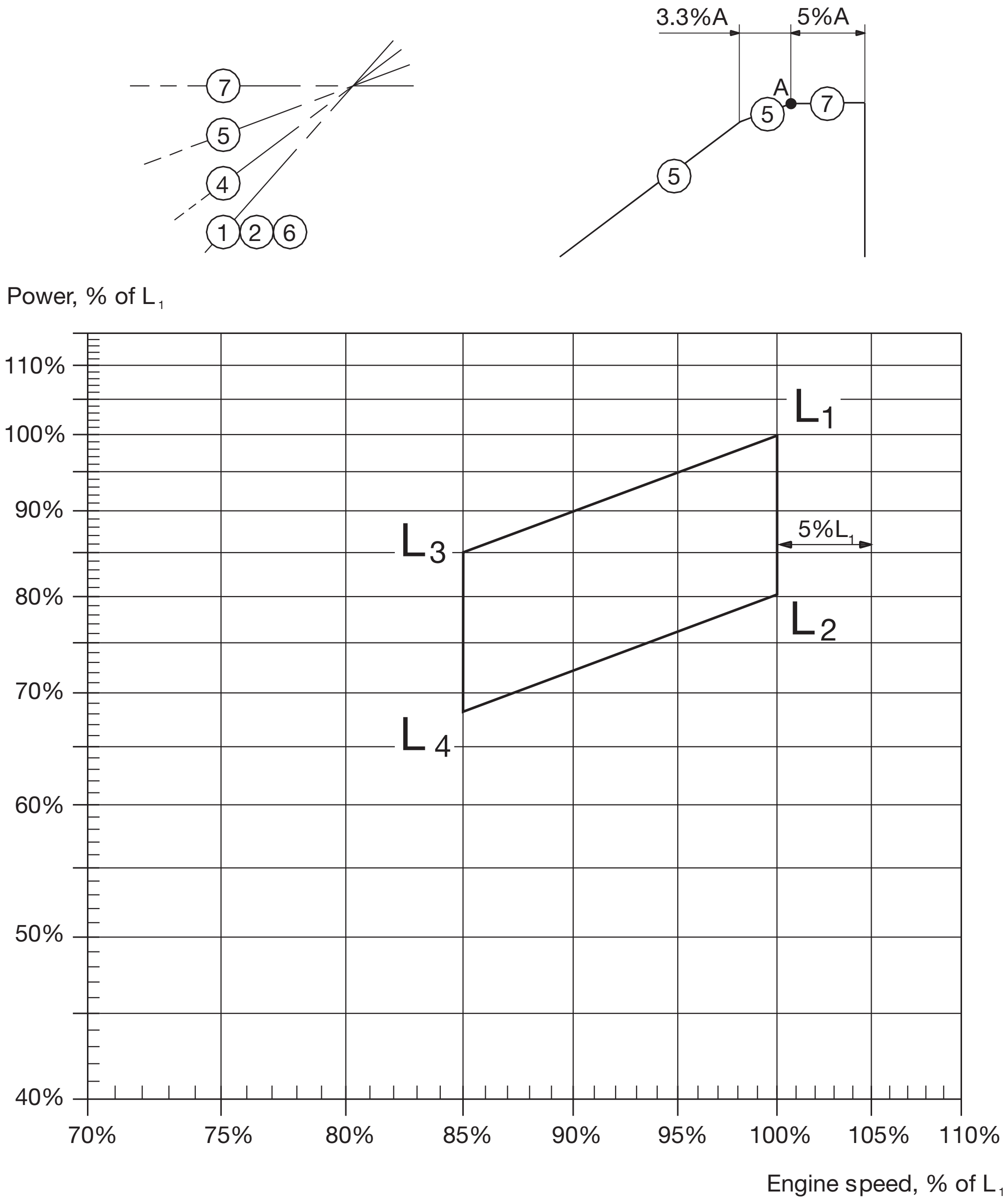


Fig. 2.05.01: Construction of layout diagram

Specific Fuel Oil Consumption, ME versus MC engines

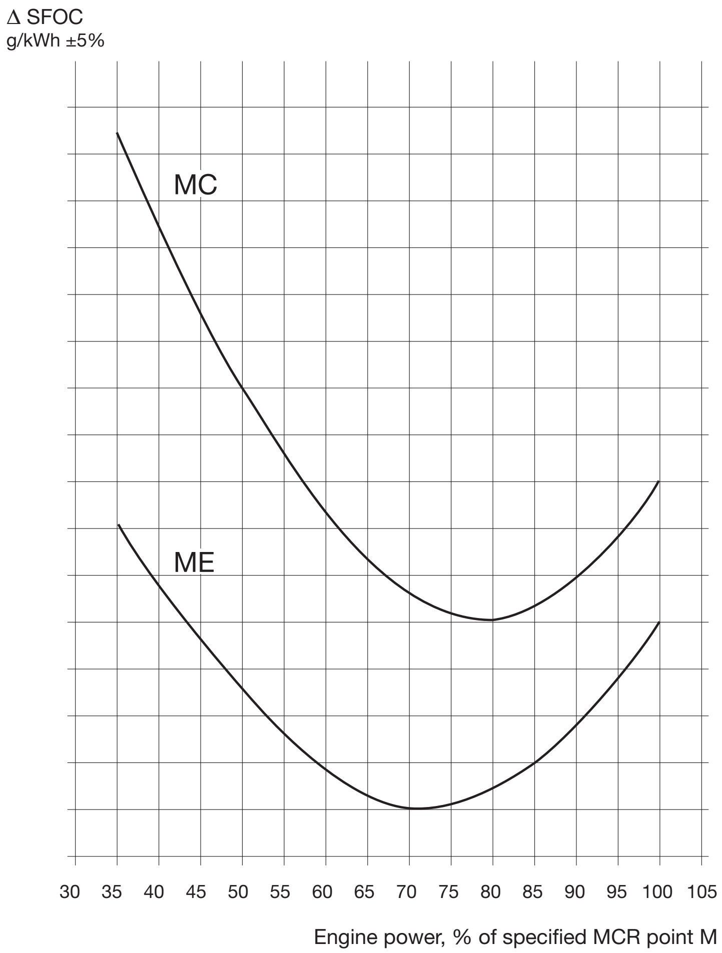
As previously mentioned the main feature of the ME/ME-C engine is that the fuel injection and the exhaust valve timing are optimised automatically over the entire power range, and with a minimum speed down to around 15-20% of the L_1 speed, but around 20-25% for MC/MC-C.

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

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

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

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



198 97 38-9.3

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

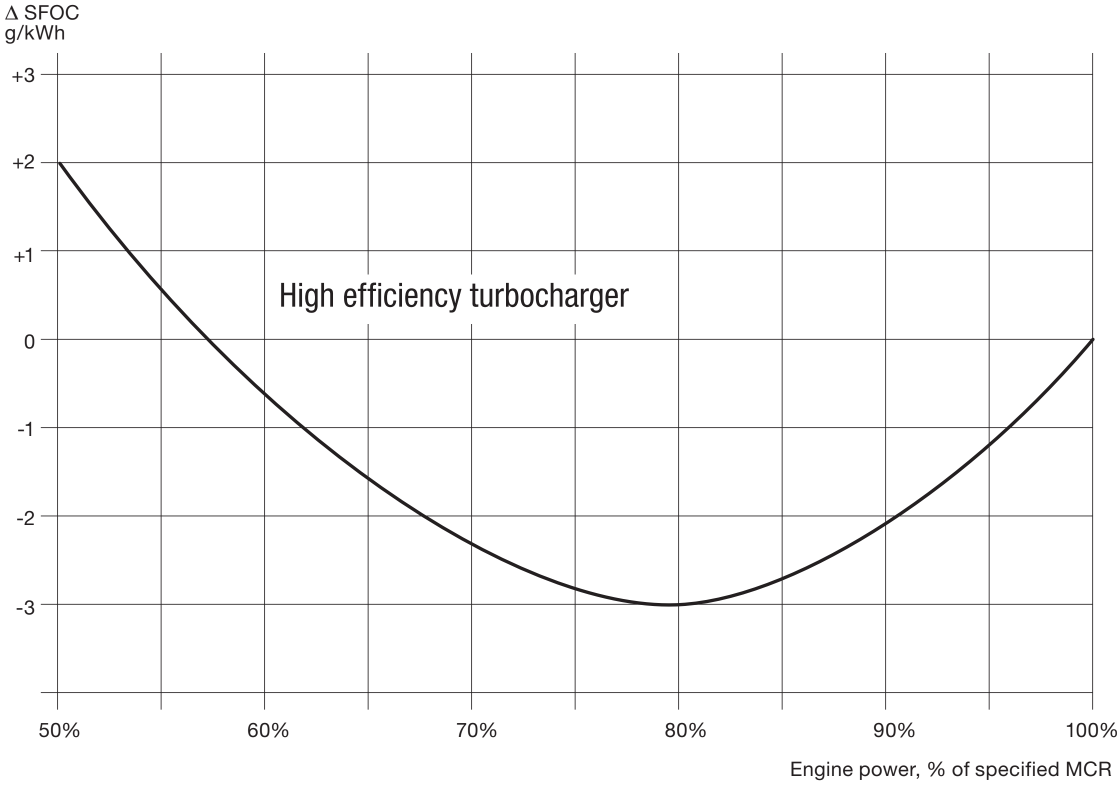
SFOC for High Efficiency Turbochargers

All engines type 50 (inclusive S46MC-C8.2 and S46ME-B8.2) and above are as standard fitted with high efficiency turbochargers, option: 4 59 104.

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

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

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



178 60 99-1.1

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

SFOC reference conditions and guarantee

SFOC at reference conditions

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

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

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

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

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

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

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

SFOC guarantee

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

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

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

Consequently, SFOC guarantee tolerances are:

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

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

Recommended cooling water temperature during normal operation

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

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

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

Examples of Graphic Calculation of SFOC

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

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

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

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

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

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

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

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

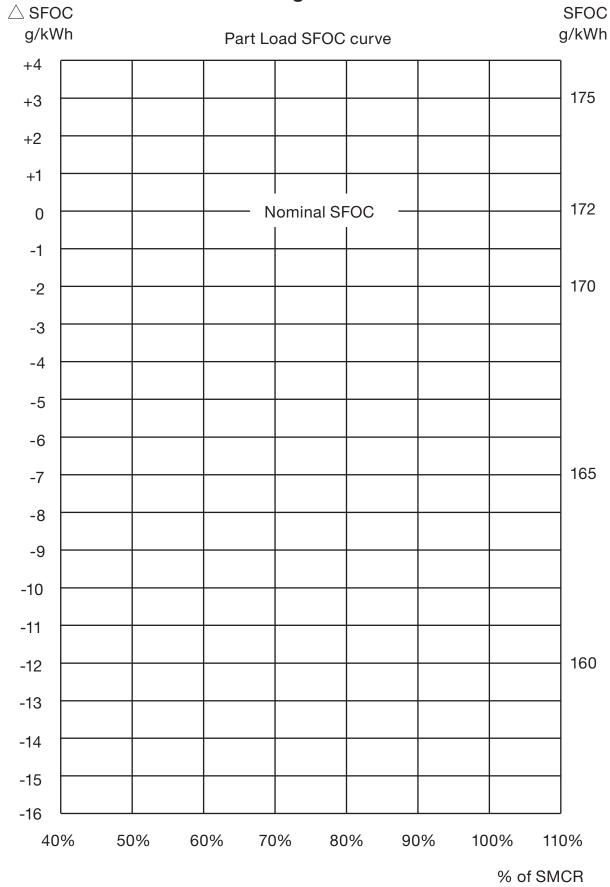
SFOC calculations can be made in the CEAS application, see Section 20.02.

SFOC Calculations for S60MC-C8.2

Data at nominel MCR (L_1)			SFOC at nominal MCR (L_1)
			High efficiency TC
Engine	**kW**	**r/min**	**g/kWh**
5 S60MC-C8.2	11,900	105	172
6 S60MC-C8.2	14,280		
7 S60MC-C8.2	16,660		
8 S60MC-C8.2	19,040		

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

Diagram a



178 59 93-5.1

Fig. 2.09.01

SFOC for S60MC-C8 with fixed pitch propeller

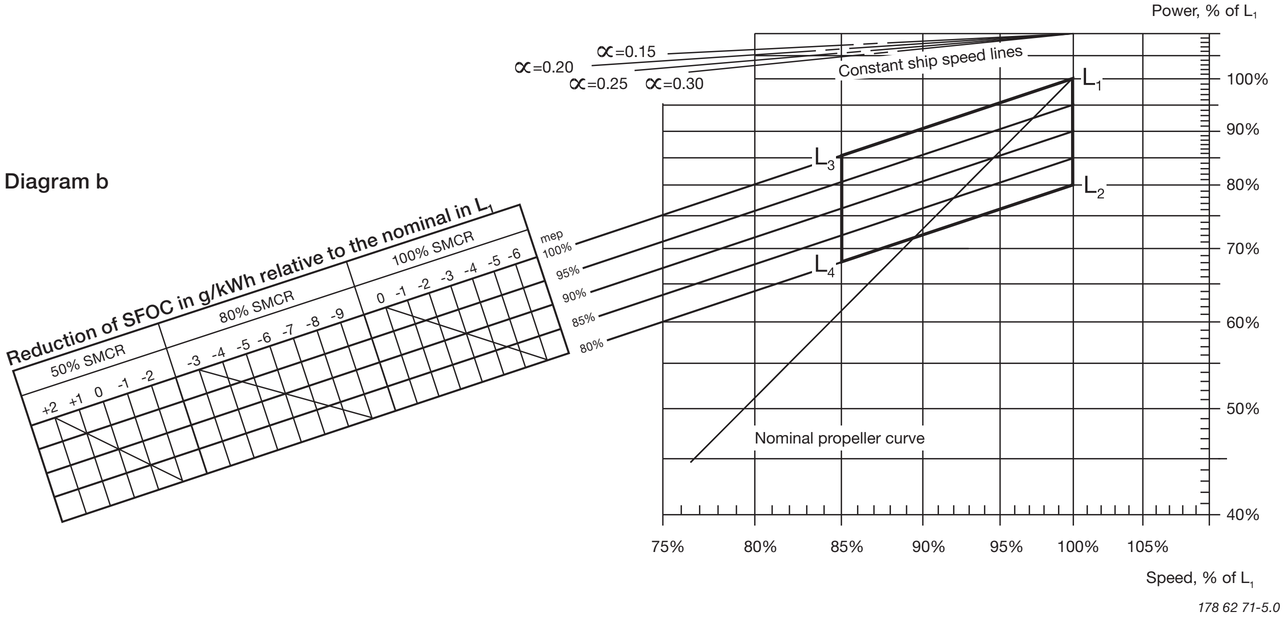


Fig. 2.09.02

SFOC for S60MC-C8 with constant speed

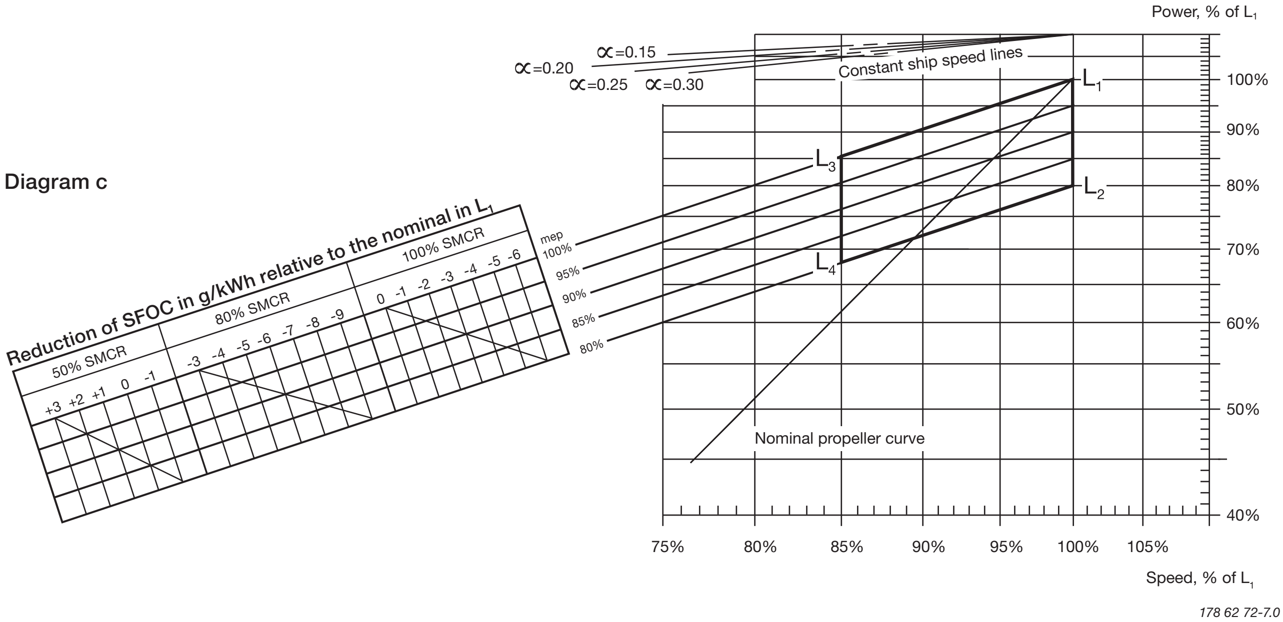


Fig. 2.09.03

SFOC calculations, example

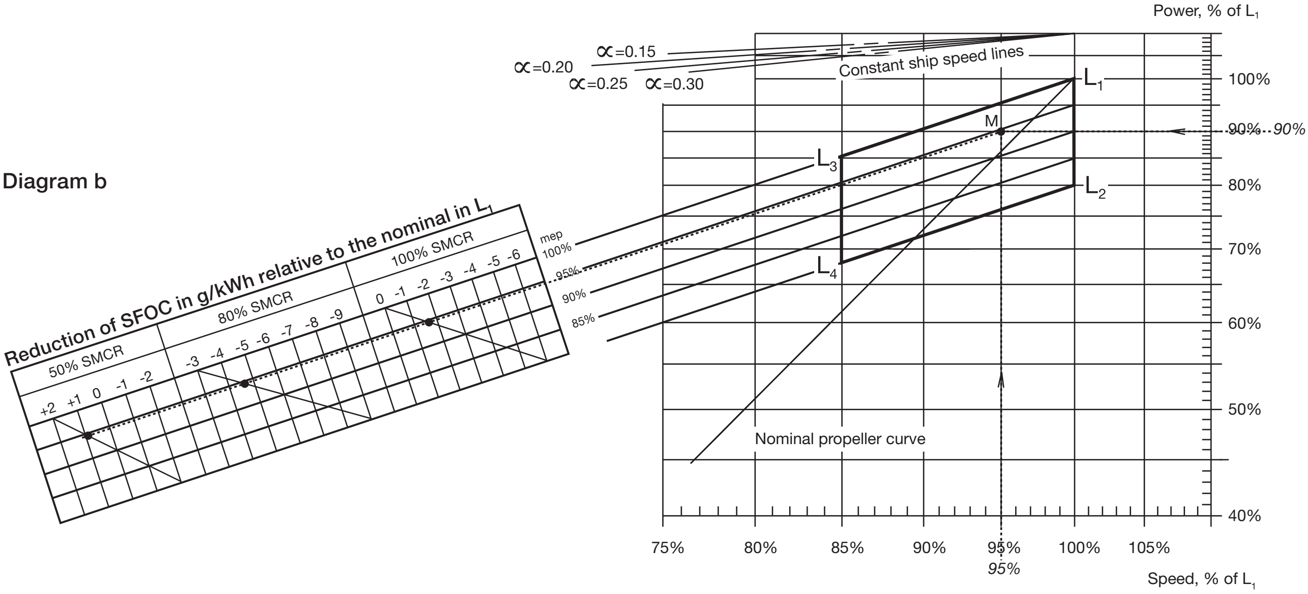
Valid for standard high-load optimised engine	
Data at nominel MCR (L_1): 6S60MC-C8.2	
Power 100%	14,280 kW
Speed 100%	105 r/min
Nominal SFOC: • High efficiency turbocharger	 172 g/kWh

Example of specified MCR = M	
Power	12,852 kW (90% L_1)
Speed	99.8 r/min (95% L_1)
Turbocharger type	High efficiency
SFOC found in M	170.4 g/kWh

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

M = 90% L_1 power and 95% L_1 speed

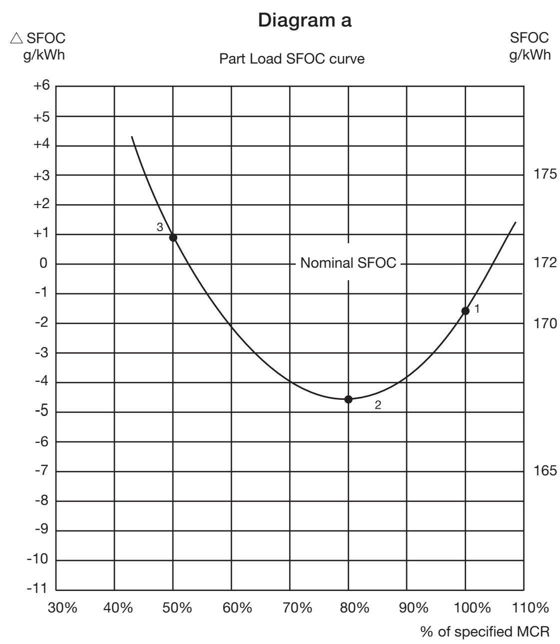
Diagram b



178 62 99-2.0

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

Part load points		SFOC g/kWh	SFOC g/kWh
1	100% M	-1.6	170.4
2	80% M	-4.6	167.4
3	50% M	+0.9	172.9



178 63 46-0.0

Fig. 2.10.01: Example of SFOC for derated 6S60MC-C8.2 with fixed pitch propeller and high efficiency turbocharger

Fuel Consumption at an Arbitrary Load

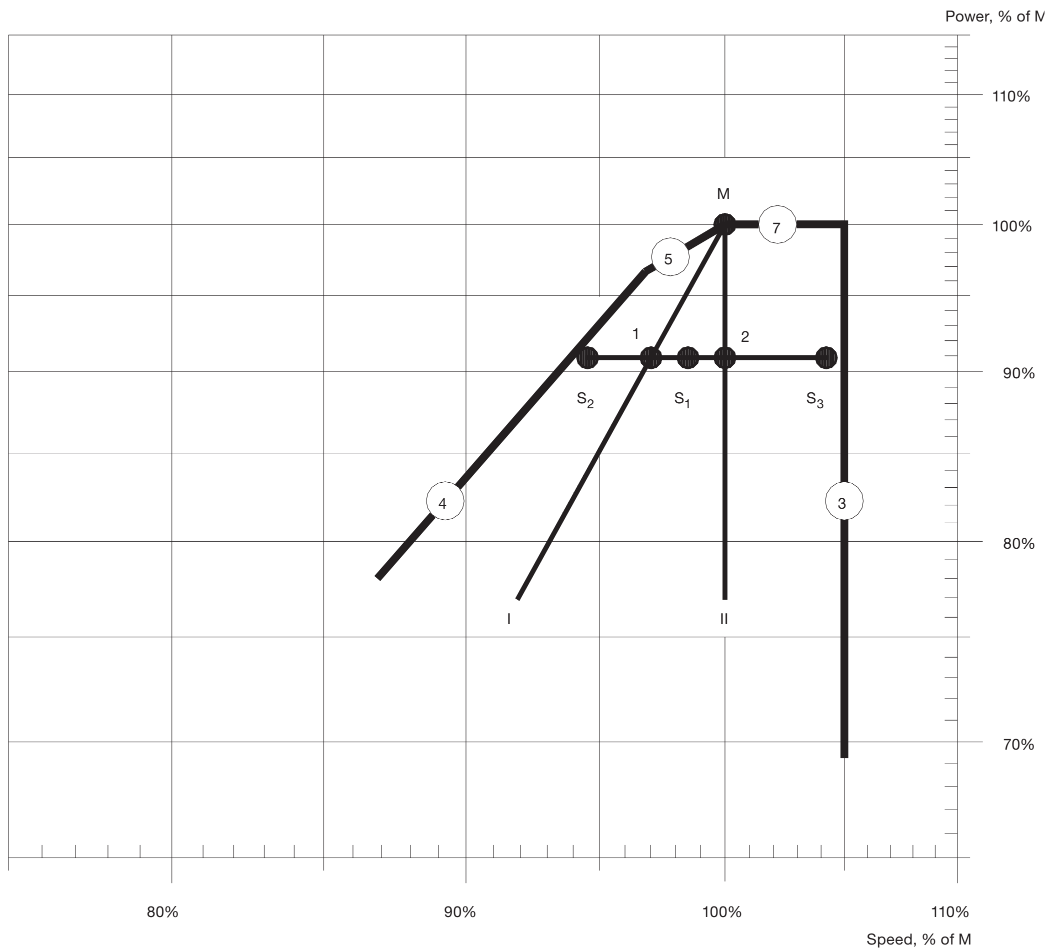
Once the specified MCR (M) of the engine has been chosen, the specific fuel oil consumption at an arbitrary point S_1, S_2 or S_3 can be estimated based on the SFOC at point '1' and '2'.

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

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

The SFOC curve through points S_2, on the left of point 1, is symmetrical about point 1, i.e. at speeds lower than that of point 1, the SFOC will also increase.

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



198 95 96-2.2

Fig. 2.11.01: SFOC at an arbitrary load

Turbocharger Selection & Exhaust Gas By-pass

3

Turbocharger Selection

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

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

The MC/ME engines are designed for the application of either MAN Diesel, 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 the table in Fig. 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' programme 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 S60MC-C8.2 TII engines - L_1 output			
Cyl.	**MAN (TCA)**	**ABB (A-L)**	**MHI (MET)**
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 A275-L	1 x MET71MB
8	1 x TCA88	1 x A280-L	1 x MET83MB

Fig. 3.01.01: High efficiency turbochargers

Climate Conditions and Exhaust Gas Bypass

Extreme ambient conditions

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

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

For further information about the possible countermeasures, please refer to our publication titled:

Influence of Ambient Temperature Conditions

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

Arctic running condition

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

Exhaust gas receiver with variable bypass
Option: 4 60 118

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

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

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

Emergency Running Condition

Exhaust gas receiver with total bypass flange and blank counterflange
Option: 4 60 119

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

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

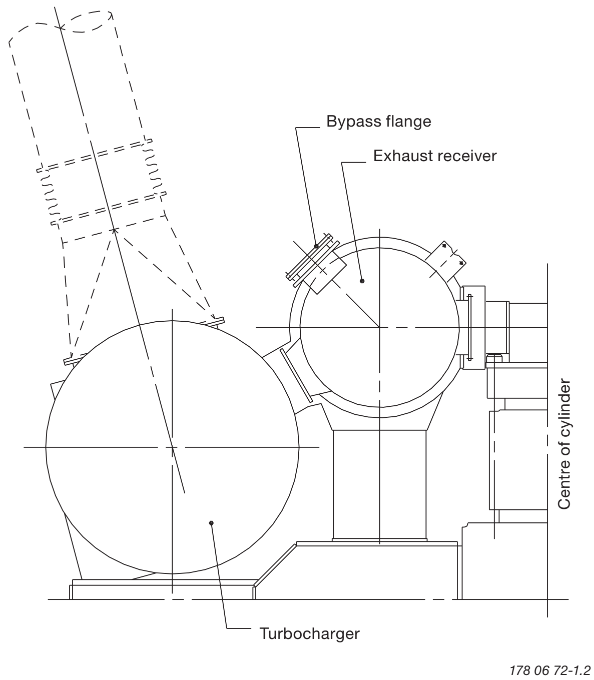


Fig. 3.02.01: Total bypass of exhaust for emergency running

Emission Control

IMO Tier II NO_x emission limits

All MC and MC-C 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.

0-30% NO_x reduction

The MC and MC-C engines are as standard delivered to comply with IMO NO_x emission limitations, EoD: 4 06 200 Economy mode. Engine test cycles E2 and E3 has to be ordered as an option: 4 06 201 and 202, and various conditions can be specified, options: 4 06 206, 207 and 208. Compliance with other emission limits can be specified as an option: 4 06 225.

Regardless of the emission limit specified, the engines are matched for best economy in service.

NO_x reduction methods for IMO Tier III

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

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

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

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

Emission Project Guide

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

Electricity Production

4

Electricity Production

Introduction

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

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

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

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

Power Take Off

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

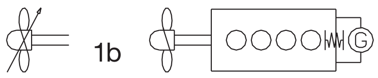
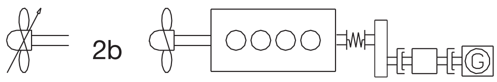
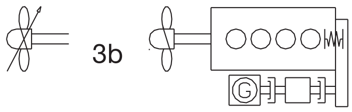
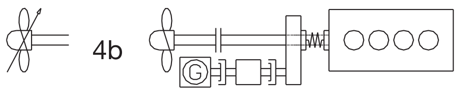
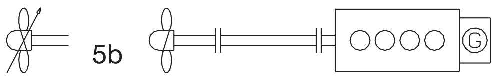
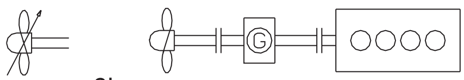
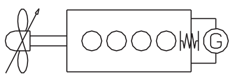
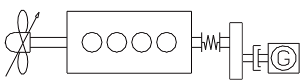
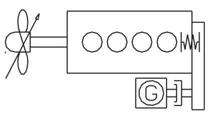
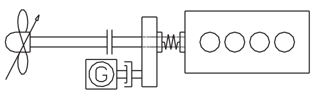
- PTO/RCF
  (Power Take Off/Renk Constant Frequency):
  Generator giving constant frequency, based on mechanical-hydraulical speed control.
- PTO/CFE
  (Power Take Off/Constant Frequency Electrical):
  Generator giving constant frequency, based on electrical frequency control.
- PTO/GCR
  (Power Take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

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

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

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

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

	Alternative types and layouts of shaft generators	Design	Seating	Total efficiency (%)
PTO/RCF	1a 1b 	BW I/RCF	On engine (vertical generator)	88-91
	2a 2b 	BW II/RCF	On tank top	88-91
	3a 3b 	BW III/RCF	On engine	88-91
	4a 4b 	BW IV/RCF	On tank top	88-91
PTO/CFE	5a 5b 	DMG/CFE	On engine	84-88
	6a 6b 	SMG/CFE	On tank top	89-91
PTO/GCR	7 	BW I/GCR	On engine (vertical generator)	92
	8 	BW II/GCR	On tank top	92
	9 	BW III/GCR	On engine	92
	10 	BW IV/GCR	On tank top	92

178 63 68-7.0

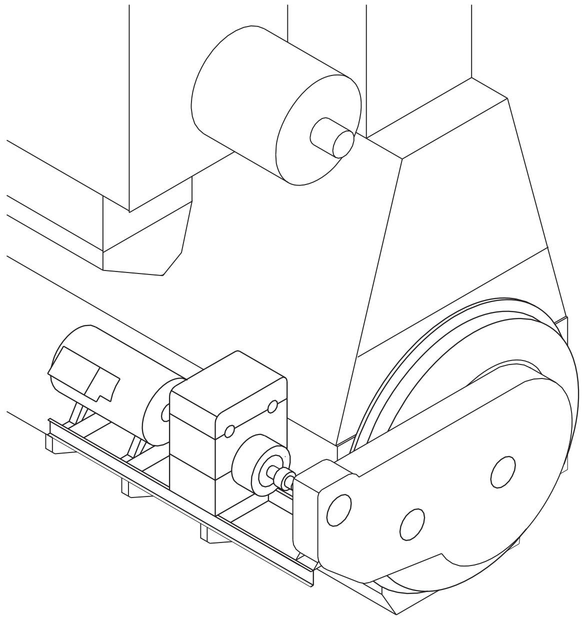
Fig. 4.01.01: Types of PTO

Designation of PTO

For further information, please refer to our publication titled:

Shaft Generators for MC and ME engines

The publications are available at www.marine.man.eu → 'Two-Stroke' → 'Technical Papers'.



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Power take off:

BW **III** S60MC-C7/RCF 700-60

50: 50 Hz
60: 60 Hz

kW on generator terminals

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

Mark version

Engine type on which it is applied

Layout of PTO: See Fig. 4.01.01

Make: MAN Diesel

178 39 55-6.0

Fig. 4.01.02: Example of designation of PTO

PTO/RCF

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

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

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

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

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

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

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

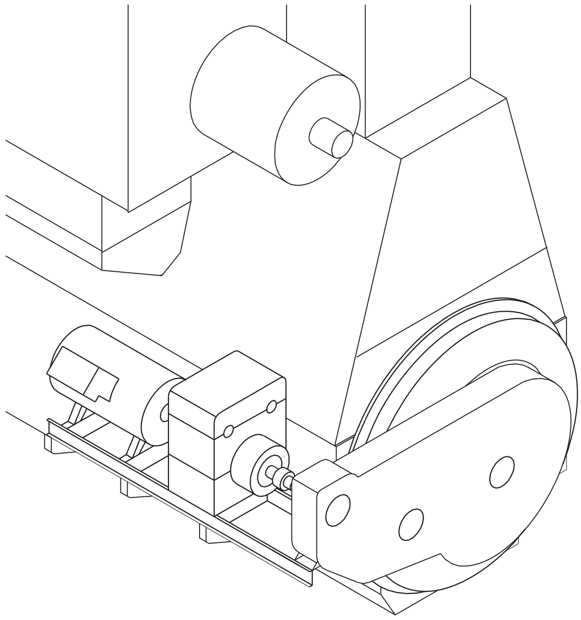

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Fig. 4.01.03: Side mounted BW III/RCF

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

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

The multi-disc clutch, integrated into the gear input shaft, permits the engaging and disengaging of the epicyclic gear, and thus the generator, from the main engine during operation.

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

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

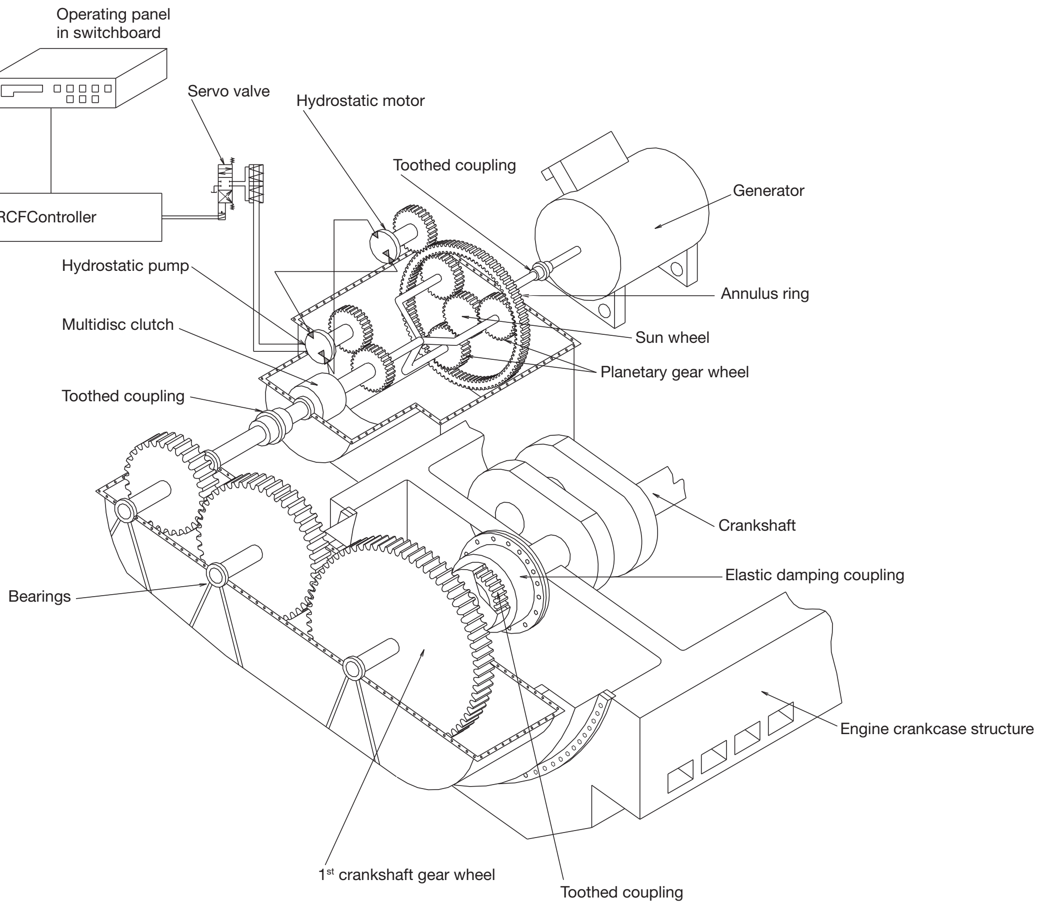


Fig. 4.01.04: Power take off with RENK constant frequency gear: BW III/RCF, option: 4 85 253

Extent of delivery for BW III/RCF units

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

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

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

178 34 89-3.1

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

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

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

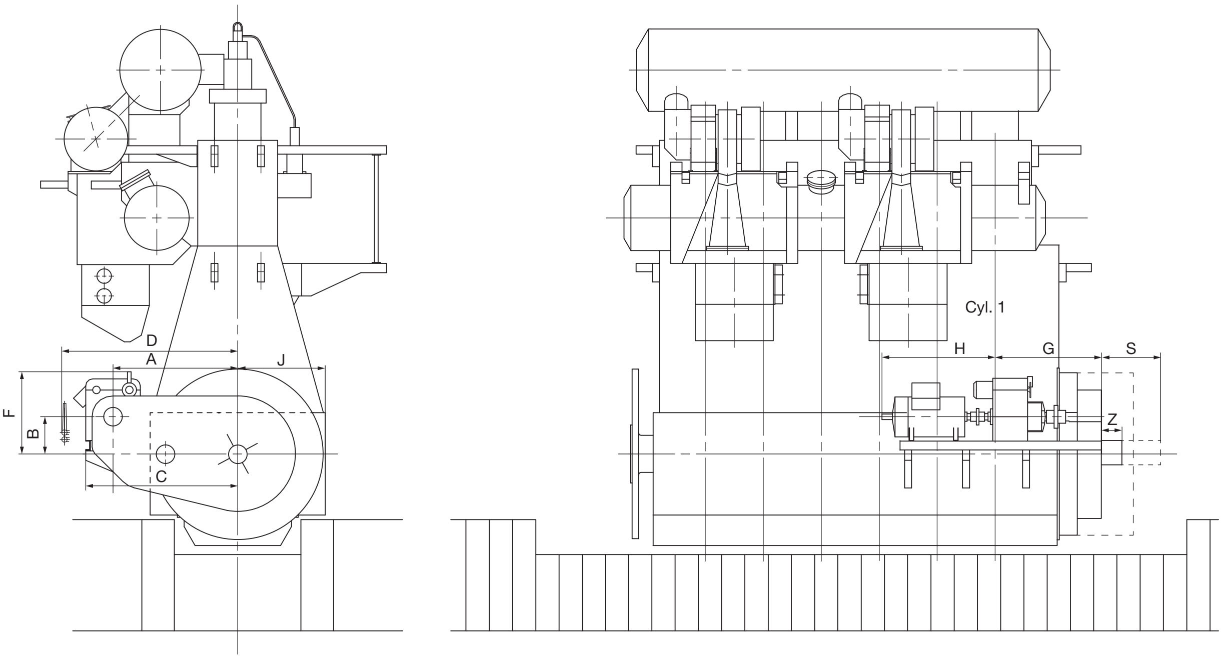
Yard deliveries are:

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

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

Additional capacities required for BW III/RCF

The capacities stated in the ‘List of capacities’ for the main engine in question are to be increased by the additional capacities for the crankshaft gear and the RCF gear stated in Fig. 4.03.02.



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	kW Generator			
	700 kW	**1,200 kW**	**1,800 kW**	**2,600 kW**
A	2,900	2,900	3,100	3,100
B	650	650	650	650
C	3,600	3,600	3,800	3,800
D	4,050	4,050	4,250	4,250
F	1,700	1,800	1,900	2,000
G	2,400	2,400	2,750	2,750
H	2,200	2,700	3,050	4,350
J	1,920	1,920	1,920	1,920
S	1,000	1,000	1,000	1,000
Z	500	500	500	500
	System mass (kg) with generator			
	24,000	28,000	39,000	53,000
	System mass (kg) without generator			
	22,000	25,300	34,700	47,850

The stated kW at the generator terminals is available between 70% and 100% of the engine speed at specified MCR

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

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

Fig. 4.02.01: Space requirement for side mounted generator PTO/RCF type BW lll S60-C/RCF

Engine preparations for PTO

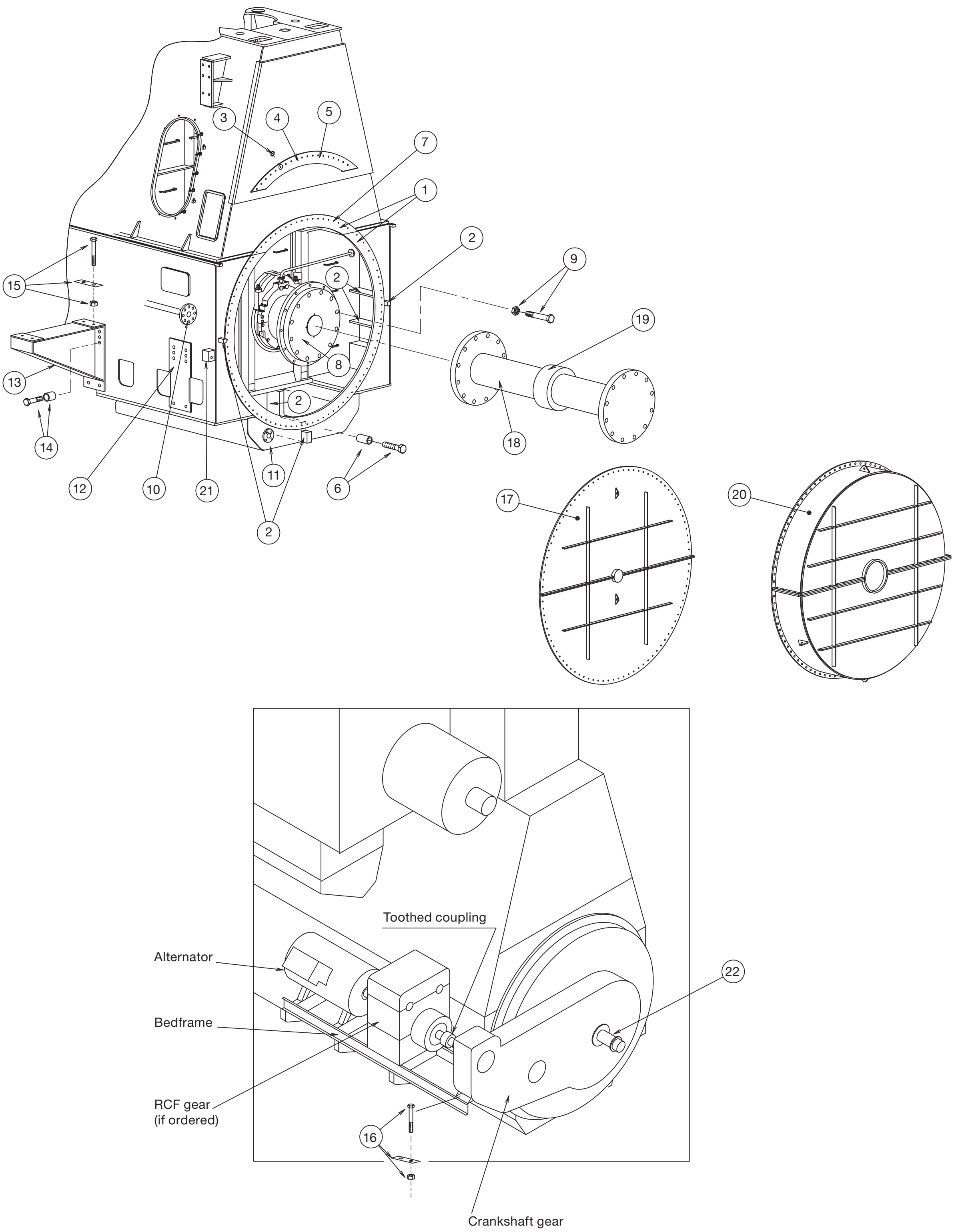

Fig. 4.03.01a: Engine preparations for PTO, BWIII/RCF system

178 57 15-7.1

Pos.

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

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

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

178 89 34-2.0

Table 4.03.01b: Engine preparations for PTO

Crankshaft gear lubricated from the main engine lubricating oil system

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

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

RCF gear with separate lubricating oil system:

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

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

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

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

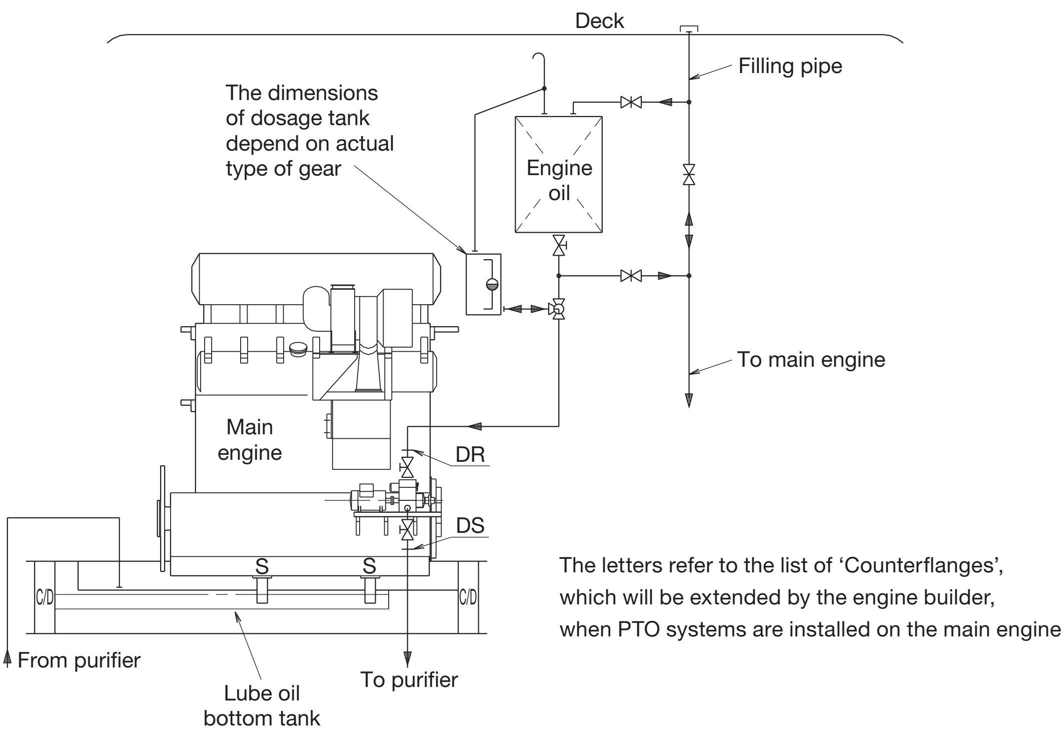

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Fig. 4.03.03: Lubricating oil system for RCF gear

DMG/CFE Generators
Option: 4 85 259

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

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

The DMG/CFE system has been developed in 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.

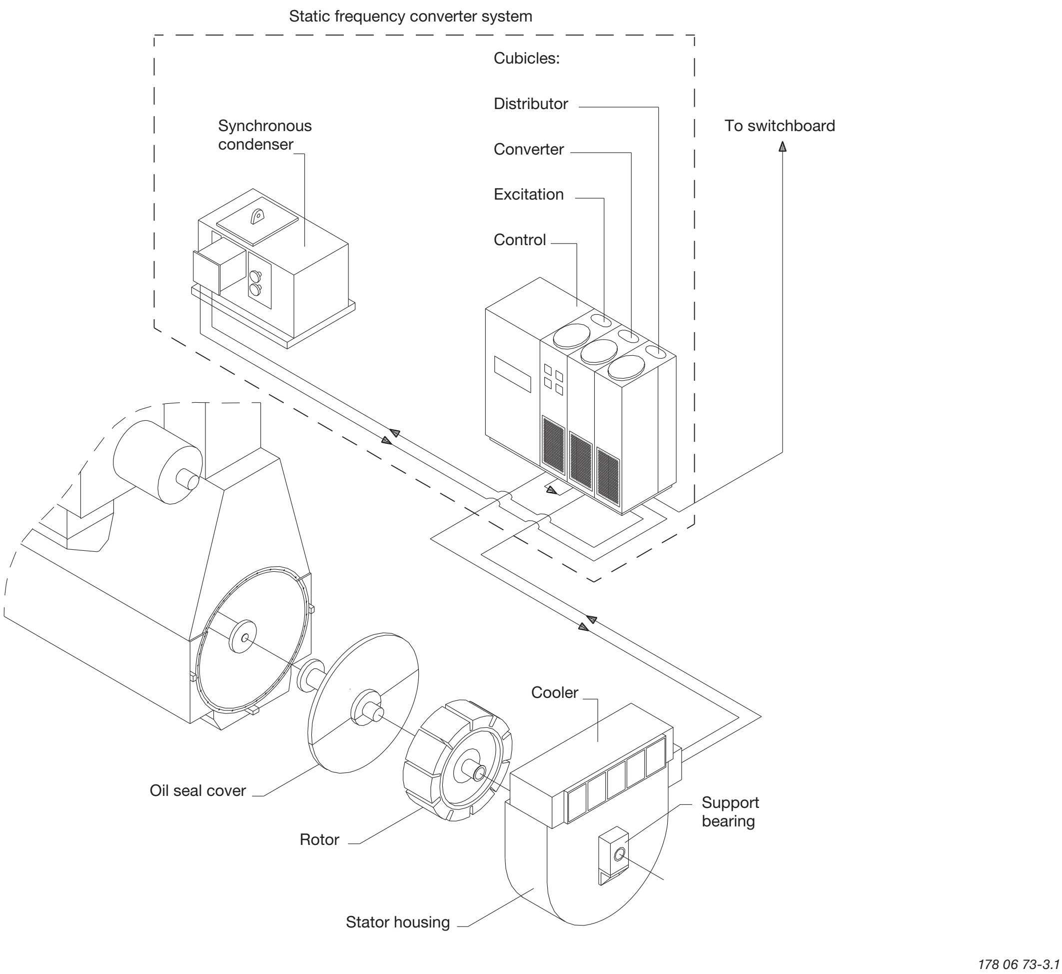

Fig. 4.03.04: Standard engine, with direct mounted generator (DMG/CFE)

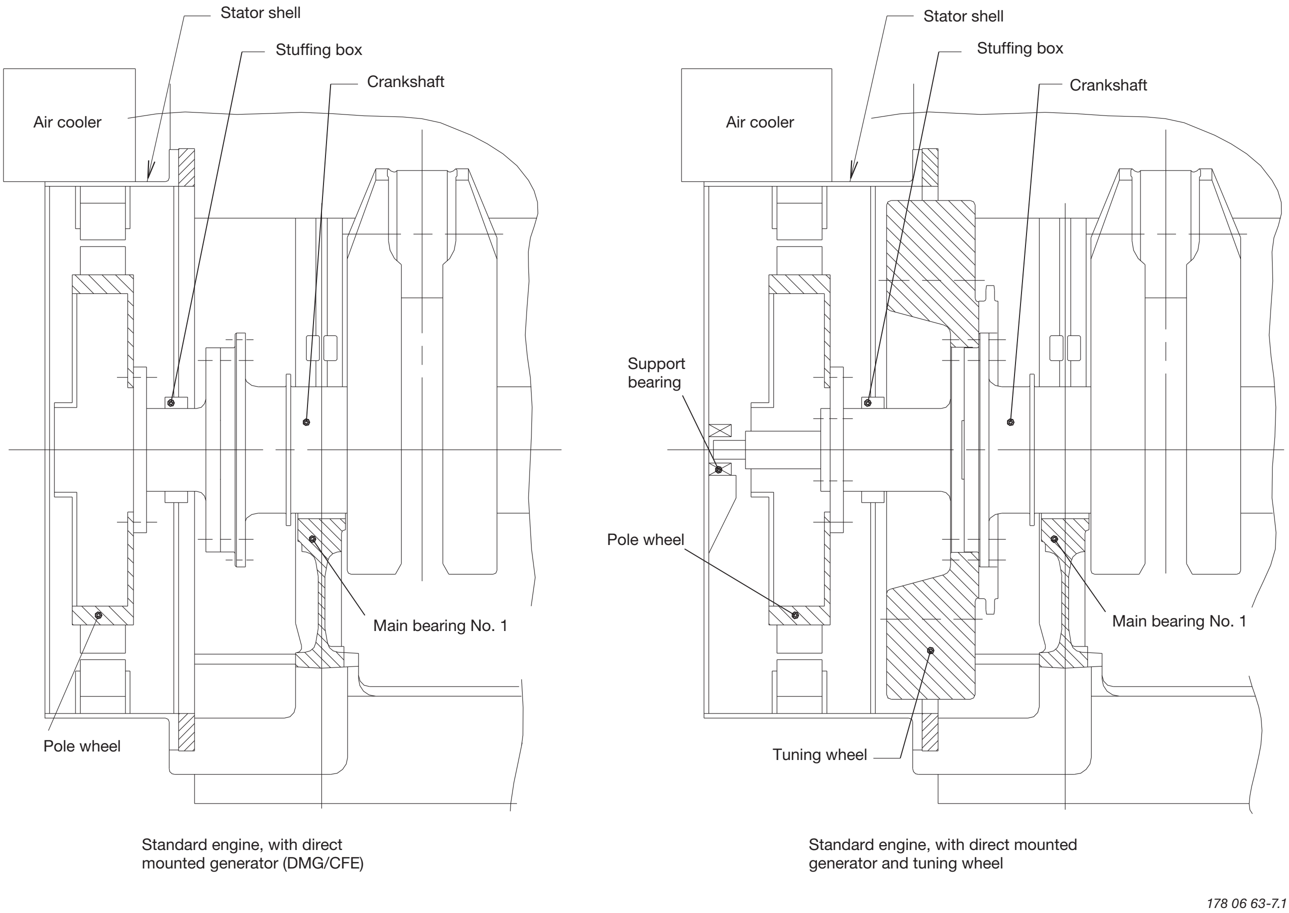

Fig. 4.03.05: Standard engine, with direct mounted generator and tuning wheel

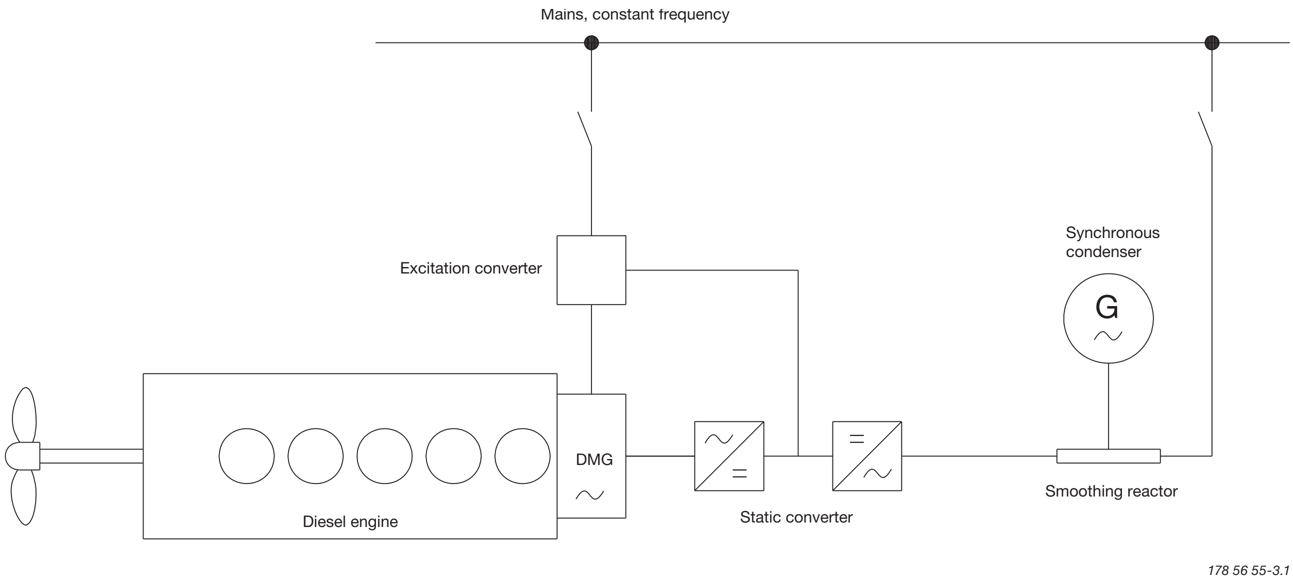

Fig. 4.03.06: Diagram of DMG/CFE with static converter

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

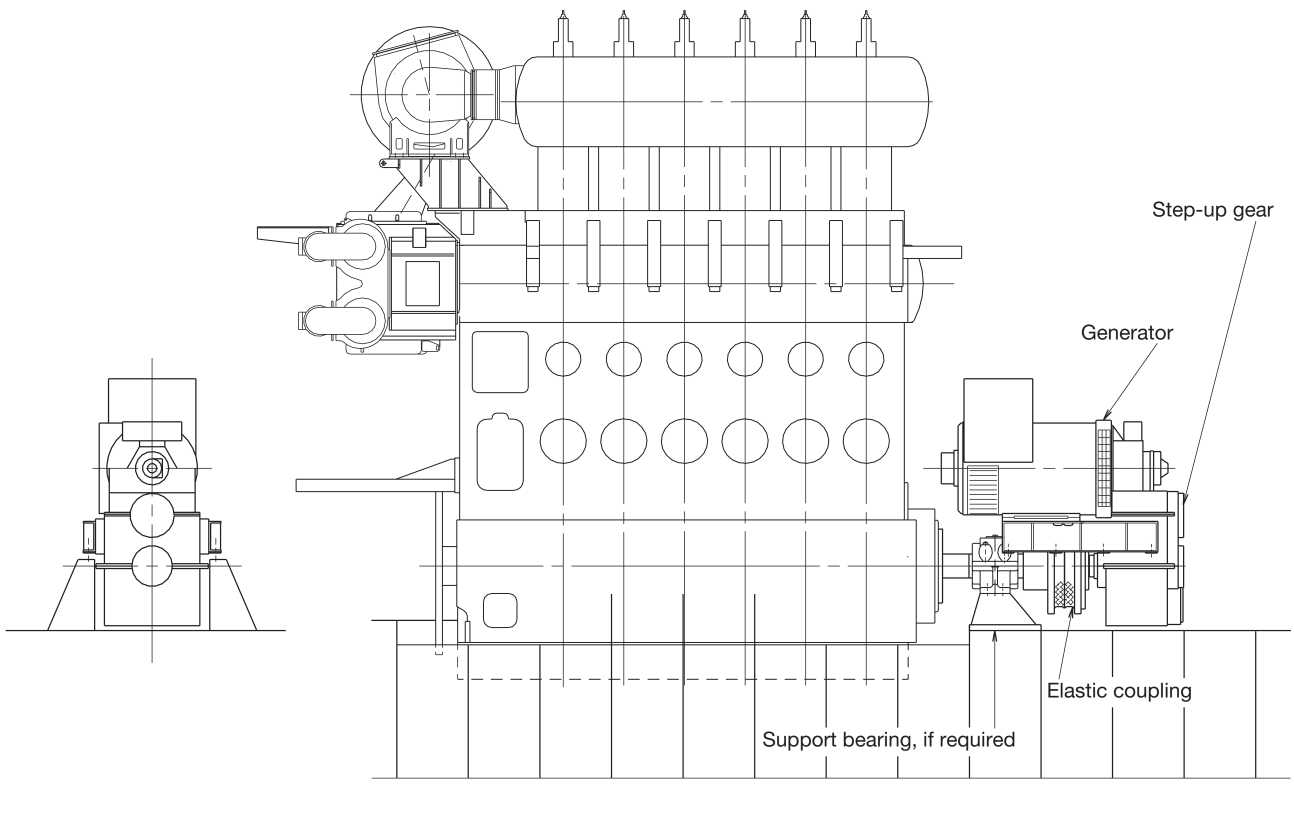

Fig. 4.04.01: Generic outline of Power Take Off (PTO) BW II/GCR

combinator mode. This will, however, require an additional RENK Constant Frequency gear (Fig. 4.01.01 alternative 2) or additional electrical equipment for maintaining the constant frequency of the generated electric power.

Tunnel gear with hollow flexible coupling

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

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

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

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

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

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

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

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

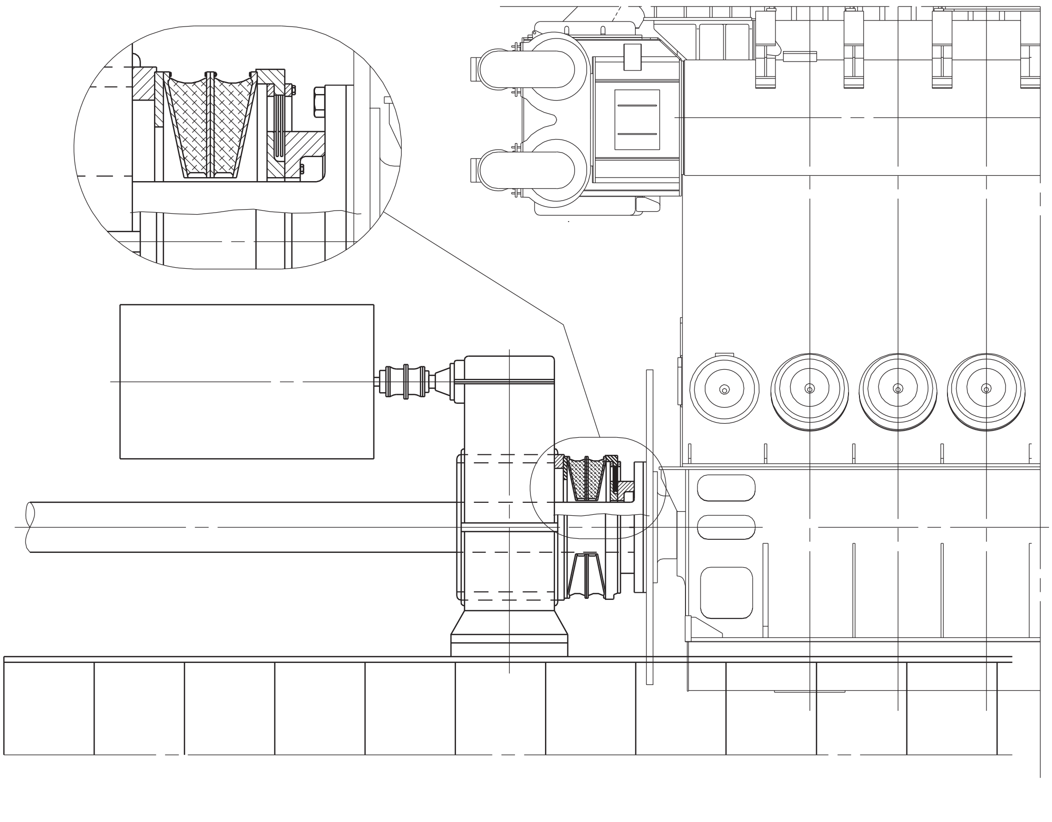

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Fig. 4.04.02: Generic outline of BW IV/GCR, tunnel gear

Auxiliary Propulsion System/Take Home System

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

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

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

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

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

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

Re-establishment of normal operation requires attendance in the engine room and can be done within a few minutes.

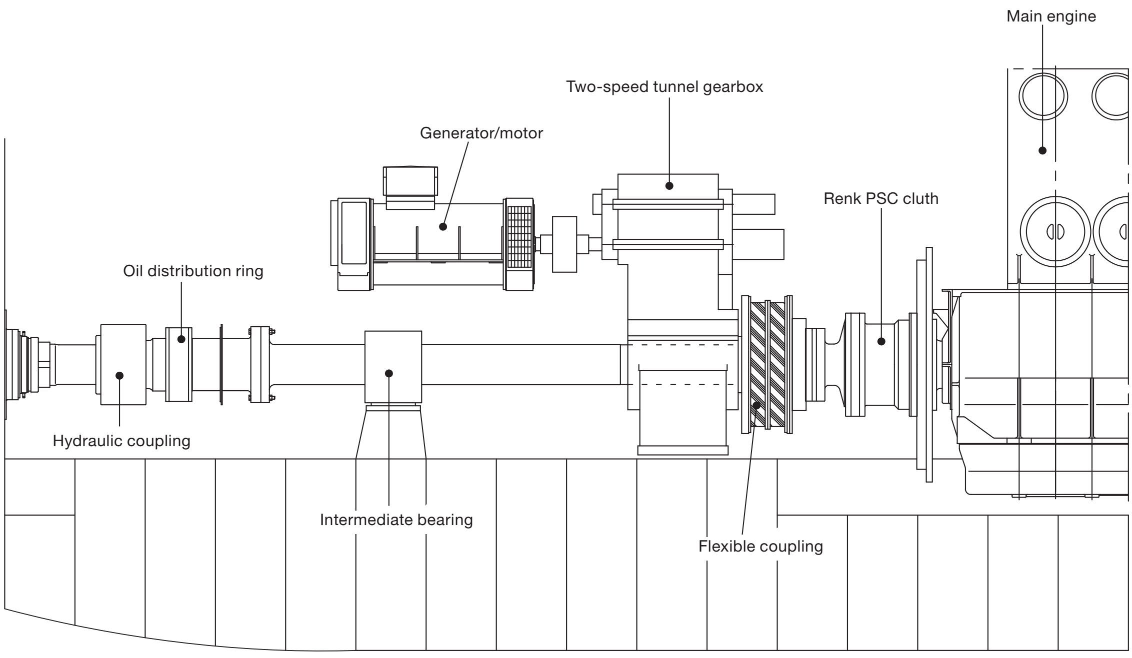

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Fig. 4.04.03: Auxiliary propulsion system

Waste Heat Recovery Systems (WHRS)

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

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

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

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

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

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

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

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

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

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

Power Turbine Generator (PTG)

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

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

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

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

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

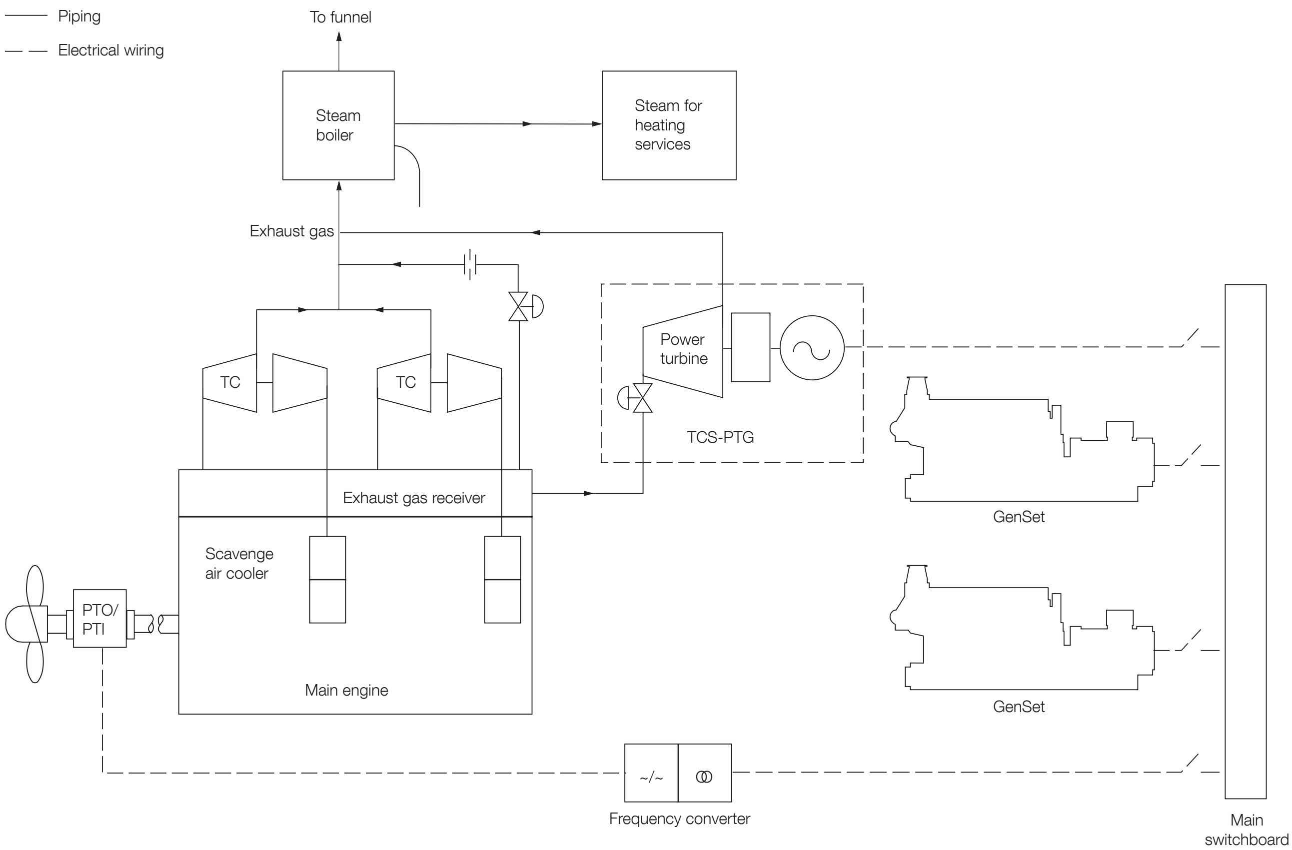

Fig. 4.05.01: PTG diagram

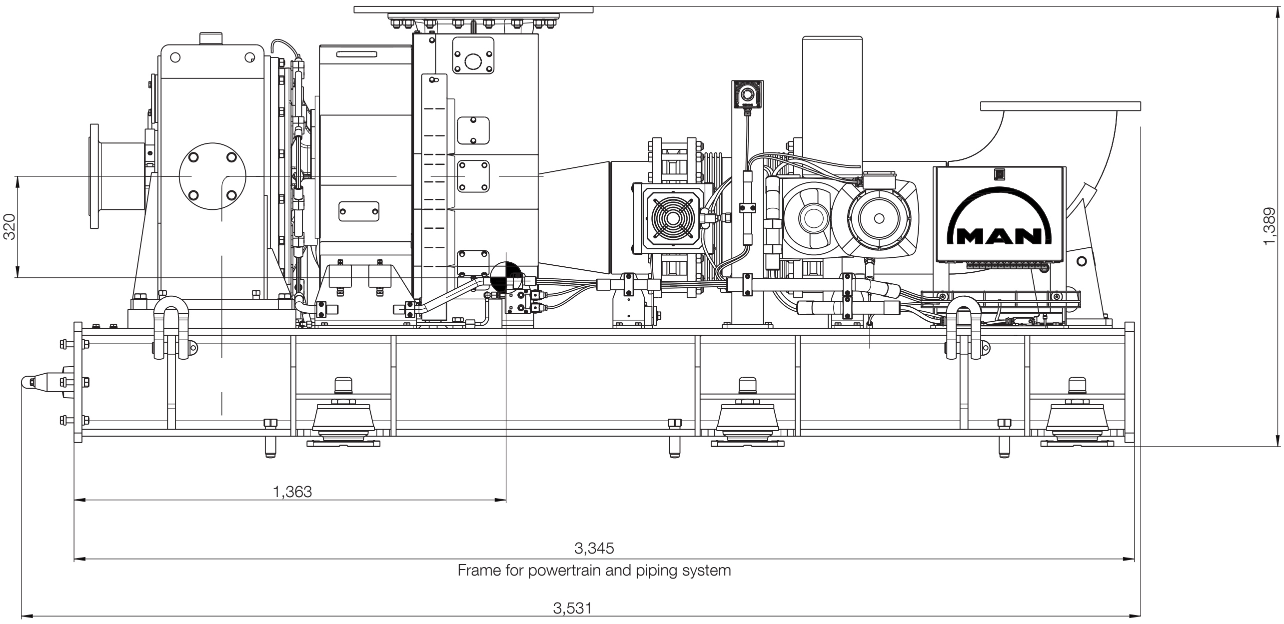

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Fig. 4.05.02: MAN Diesel & Turbo 1,500 kW TCS-PTG solution

Steam Turbine Generator (STG)

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

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

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

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

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

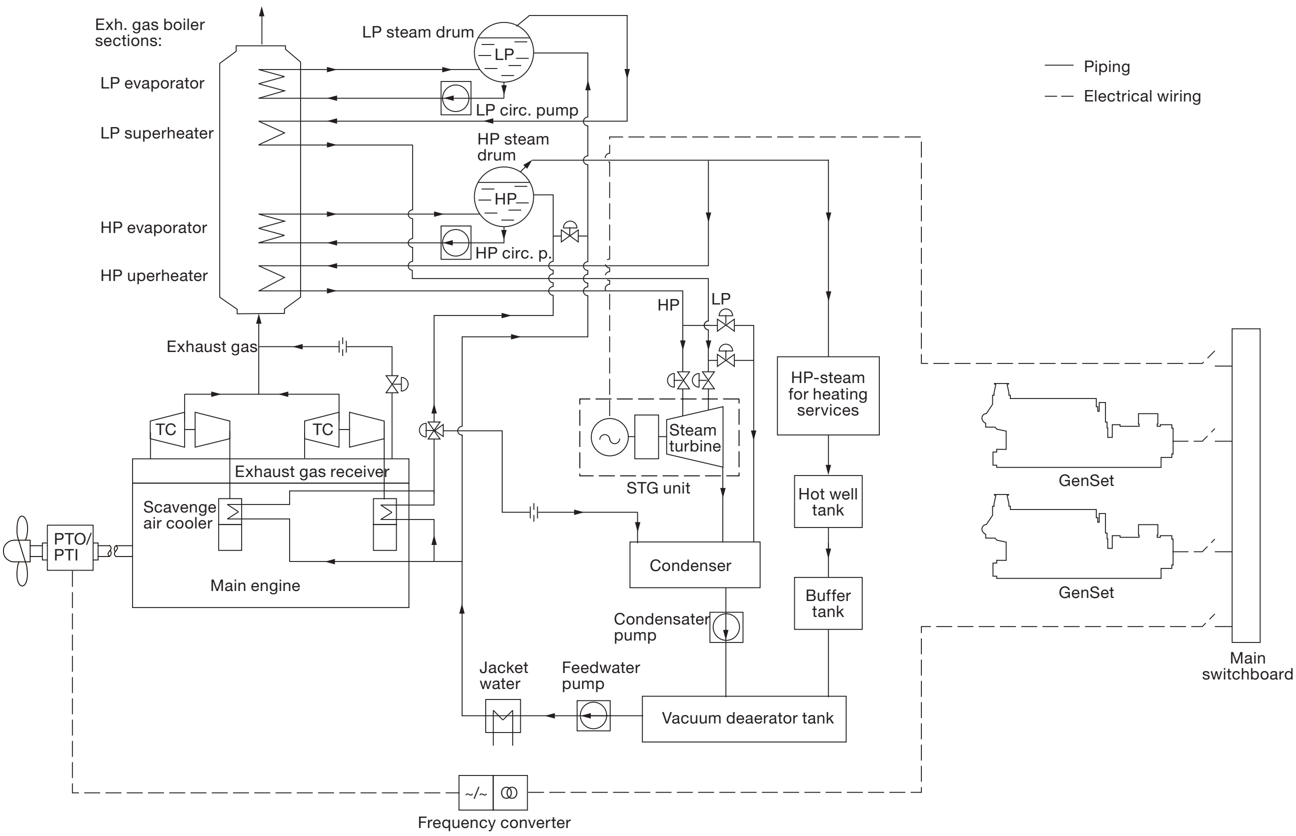

Fig. 4.05.03: STG system diagram

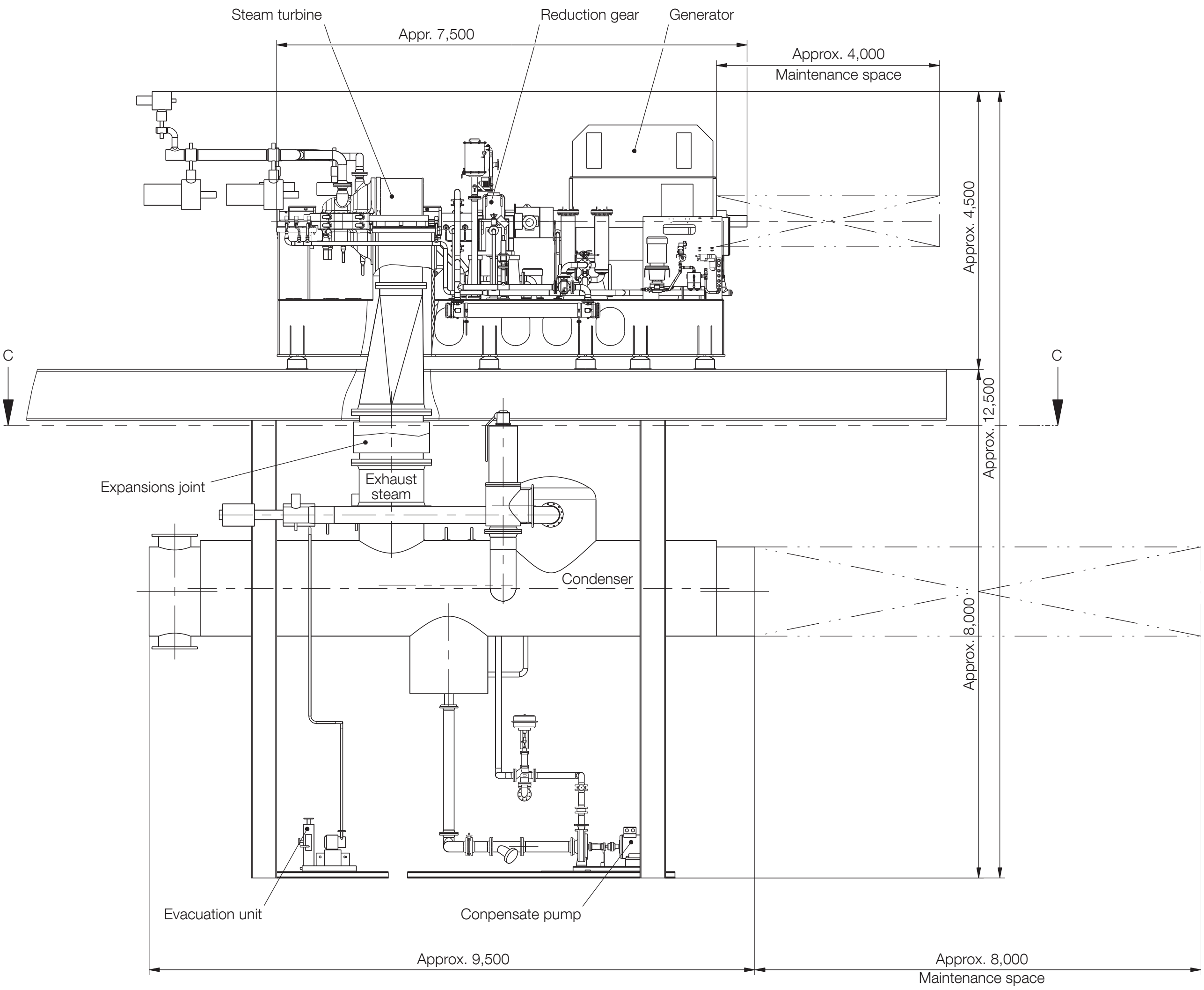

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Fig. 4.05.04: STG steam turbine generator arrangement with condenser - typical arrangement

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.

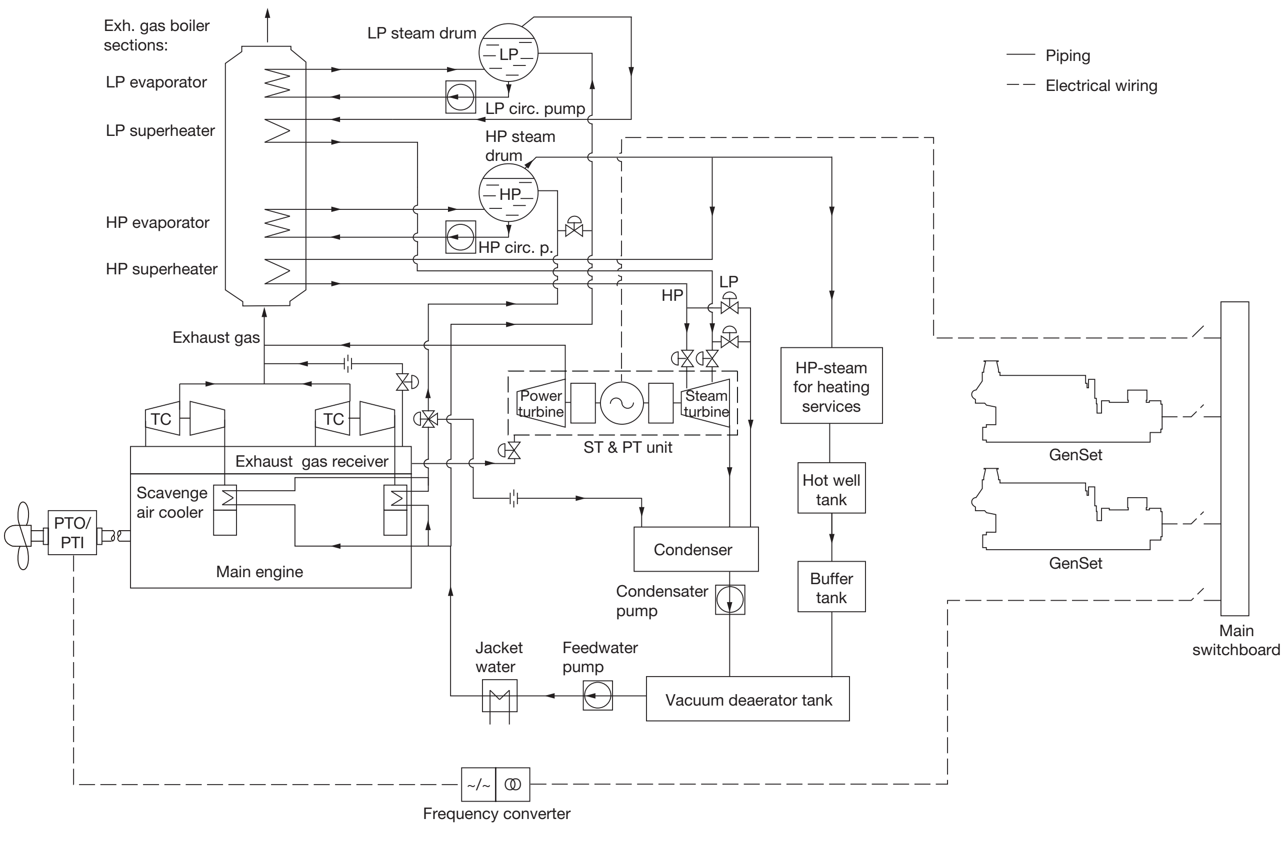

Fig. 4.05.05: Full WHRS with both steam and power turbines

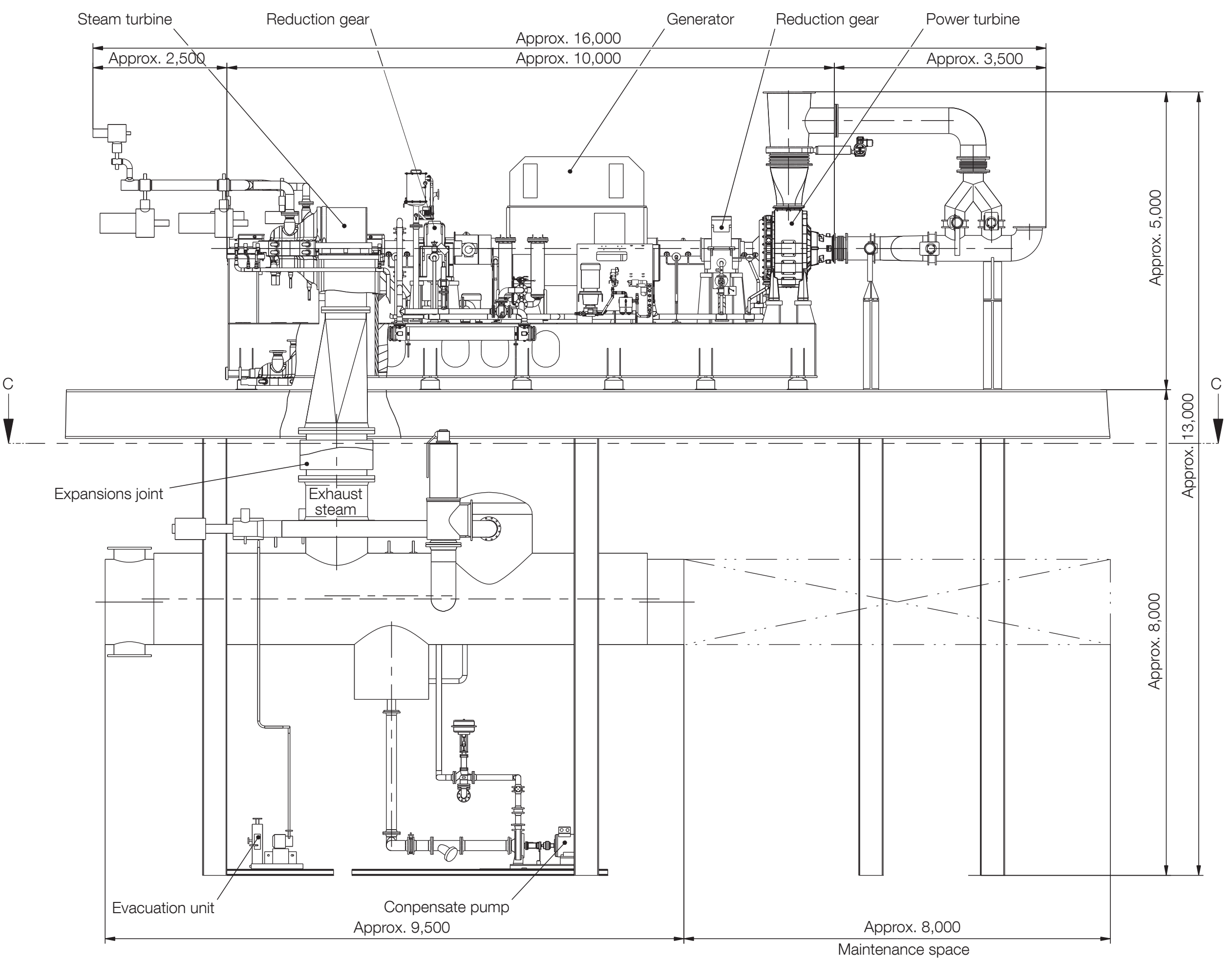

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Fig. 4.05.06: Full ST & PT full waste heat recovery unit arrangement with condenser - typical arrangement

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.

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

Waste Heat Recovery System (WHRS)

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

Guidance output of WHR for S60MC-C8.2-TII, S60ME-B8-TII and S60ME-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	11,900	431	595	978
	75	8,925	274	447	651
6	100	14,280	520	763	1,180
	75	10,710	334	543	787
7	100	16,660	610	896	1,383
	75	12,495	397	640	925
8	100	19,040	701	1,032	1,588
	75	14,280	461	739	1,064

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

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

Table 4.05.07: Theoretically calculated outputs

Waste Heat Recovery Element and Safety Valve

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

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

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

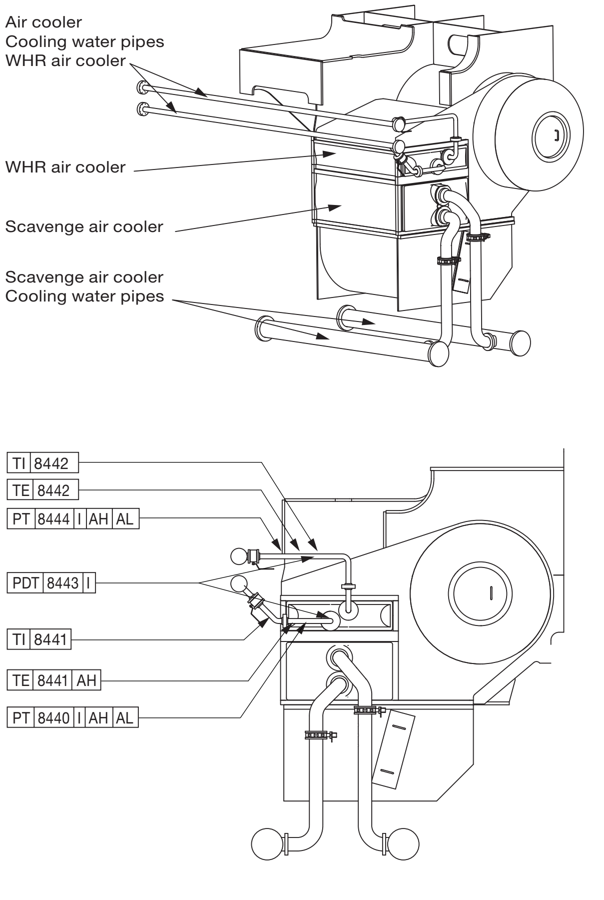


Fig. 4.05.08: WHR element on Scavenge air cooler

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.

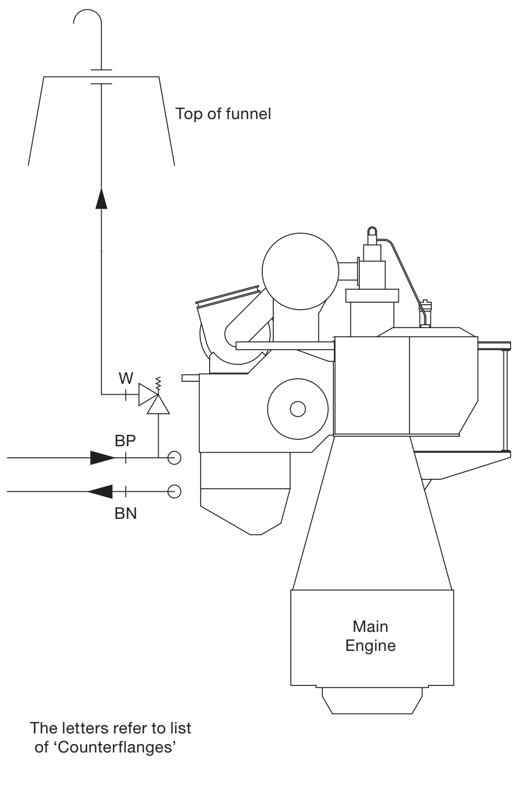
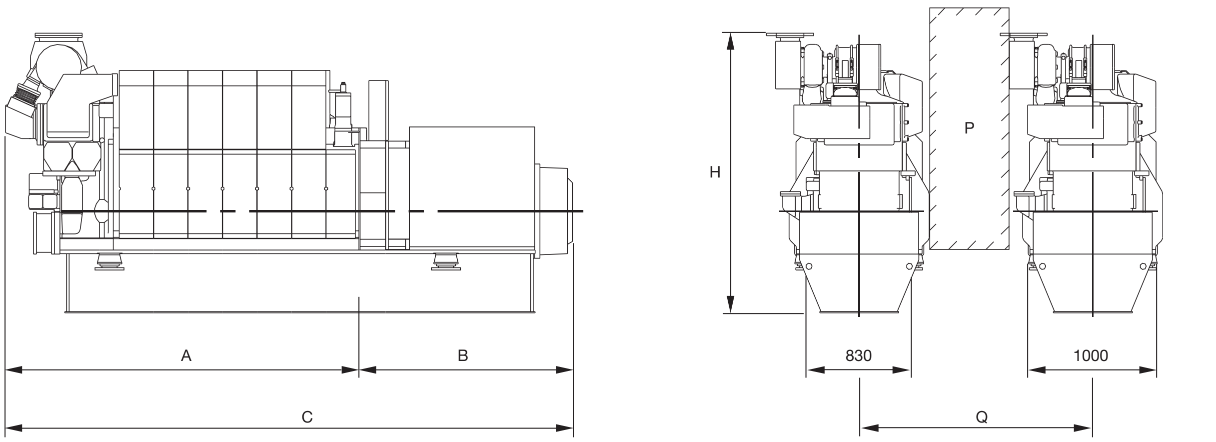


Fig. 4.05.09: WHR safety valve blow-off through connection 'W' to the funnel

L16/24-TII GenSet Data

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



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

P Free passage between the engines, width 600 mm and height 2,000 mm
Q Min. distance between engines: 1,800 mm
* Depending on alternator
** Weight incl. standard alternator (based on a Leroy Somer alternator)
All dimensions and masses are approximate and subject to change without prior notice.

178 33 87-4.4

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

L16/24-TII GenSet Data

5L:90 kW/cyl., 6L-9L: 95 kW/Cyl. at 1,000 rpm						
Reference Condition: Tropic						
Air temperature	°C			45		
LT-water temperature inlet engine (from system)	°C			38		
Air pressure	bar			1		
Relative humidity	%			50		
Temperature basis						
Setpoint HT cooling water engine outlet 1)	°C	79 nominal (Range of mechanical thermostatic element 77 to 85)				
Setpoint LT cooling water engine outlet 2)	°C	35 nominal (Range of mechanical thermostatic element 29 to 41)				
Setpoint Lube oil inlet engine	°C	66 nominal (Range of mechanical thermostatic element 63 to 72)				
Number of Cylinders	-	**5**	**6**	**7**	**8**	**9**
Engine output	kW	450	570	665	760	855
Speed	rpm			1,000		
Heat to be dissipated 3)						
Cooling water (C.W.) Cylinder	kW	107	135	158	181	203
Charge air cooler; cooling water HT	kW	138	169	192	213	234
Charge air cooler; cooling water LT	kW	56	69	80	91	102
Lube oil (L.O.) cooler	kW	98	124	145	166	187
Heat radiation engine	kW	15	19	23	26	29
Flow rates 4)						
Internal (inside engine)						
HT circuit (cylinder + charge air cooler HT stage)	m^3/h	10.9	12.7	14.5	16.3	18.1
LT circuit (lube oil + charge air cooler LT stage)	m^3/h	15.7	18.9	22	25.1	28.3
Lube oil	m^3/h	18	18	30	30	30
External (from engine to system)						
HT water flow (at 40°C inlet)	m^3/h	5.2	6.4	7.4	8.3	9.2
LT water flow (at 38°C inlet)	m^3/h	15.7	18.9	22	25.1	28.3
Air data						
Temperature of charge air at charge air cooler outlet	°C	49	51	52	54	55
Air flow rate	m^3/h 5)	2,721	3,446	4,021	4,595	5,169
	kg/kWh	6.62	6.62	6.62	6.62	6.62
Charge air pressure	bar			4.13		
Air required to dissipate heat radiation (engine)(t_2-t_1=10°C)	m^3/h	4,860	6,157	7,453	8,425	9,397
Exhaust gas data 6)						
Volume flow (temperature turbocharger outlet) Mass flow	m^3/h 7)	5,710	7,233	8,438	9,644	10,849
Temperature at turbine outlet	t/h	3.1	3.9	4.5	5.2	5.8
Heat content (190°C)	°C	375	375	375	375	375
Permissible exhaust back pressure	kW	170	216	252	288	324
	mbar			< 30		
Pumps						
a) Engine driven pumps						
HT circuit cooling water (2.5 bar)	m^3/h	10.9	12.7	14.5	16.3	18.1
LT circuit cooling water (2.5 bar)	m^3/h	15.7	18.9	22	25.1	28.3
Lube oil (4.5 bar)	m^3/h	18	18	30	30	30
b) External pumps 8)						
Diesel oil pump (5 bar at fuel oil inlet A1)	m^3/h	0.32	0.40	0.47	0.54	0.60
Fuel oil supply pump (4 bar discharge pressure)	m^3/h	0.15	0.19	0.23	0.26	0.29
Fuel oil circulating pump (8 bar at fuel oil inlet A1)	m^3/h	0.32	0.40	0.47	0.54	0.60
Starting air data						
Air consumption per start, incl. air for jet assist (IR/TDI)	Nm^3	0.47	0.56	0.65	0.75	0.84
Air consumption per start, incl. air for jet assist (Gali)	Nm^3	0.80	0.96	1.12	1.28	1.44

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

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

L16/24-TII GenSet Data

5L:100 kW/cyl., 6L-9L: 110 kW/Cyl. at 1,200 rpm						
Reference Condition: Tropic						
Air temperature	°C			45		
LT-water temperature inlet engine (from system)	°C			38		
Air pressure	bar			1		
Relative humidity	%			50		
Temperature basis						
Setpoint HT cooling water engine outlet 1)	°C	79 nominal (Range of mechanical thermostatic element 77 to 85)				
Setpoint LT cooling water engine outlet 2)	°C	35 nominal (Range of mechanical thermostatic element 29 to 41)				
Setpoint Lube oil inlet engine	°C	66 nominal (Range of mechanical thermostatic element 63 to 72)				
Number of Cylinders	**-**	**5**	**6**	**7**	**8**	**9**
Engine output	kW	500	660	770	880	990
Speed	rpm			1,200		
Heat to be dissipated 3)						
Cooling water (C.W.) Cylinder	kW	100	132	154	177	199
Charge air cooler; cooling water HT	kW	149	187	211	234	255
Charge air cooler; cooling water LT	kW	66	83	96	109	122
Lube oil (L.O.) cooler	kW	113	149	174	199	224
Heat radiation engine	kW	17	23	26	30	34
Flow rates 4)						
Internal (inside engine)						
HT circuit (cylinder + charge air cooler HT stage)	m^3/h	13.1	15.2	17.4	19.5	21.6
LT circuit (lube oil + charge air cooler LT stage)	m^3/h	19.3	20.7	24.2	27.7	31.1
Lube oil	m^3/h	21	21	35	35	35
External (from engine to system)						
HT water flow (at 40°C inlet)	m^3/h	5.7	7.3	8.4	9.4	10.4
LT water flow (at 38°C inlet)	m^3/h	19.1	20.7	24.2	27.7	31.1
Air data						
Temperature of charge air at charge air cooler outlet	°C	51	53	55	56	57
Air flow rate	m^3/h 5)	3,169	4,183	4,880	5,578	6,275
	kg/kWh	6.94	6.94	6.94	6.94	6.94
Charge air pressure	bar			3.92		
Air required to dissipate heat radiation (engine) (t_2-t_1= 10°C)	m^3/h	5,509	7,453	8,425	9,721	11,017
Exhaust gas data 6)						
Volume flow (temperature turbocharger outlet)	m^3/h 7)	6,448	8,511	9,929	11,348	12,766
Mass flow	t/h	3.6	4.7	5.5	6.3	7.1
Temperature at turbine outlet	°C	356	356	356	356	356
Heat content (190°C)	kW	178	235	274	313	352
Permissible exhaust back pressure	mbar			< 30		
Pumps						
a) Engine driven pumps						
HT circuit cooling water (2.5 bar)	m^3/h	13.1	15.2	17.4	19.5	21.6
LT circuit cooling water (2.5 bar)	m^3/h	19.3	20.7	24.2	27.7	31.1
Lube oil (4.5 bar)	m^3/h	21	21	35	35	35
b) External pumps 8)						
Diesel oil pump (5 bar at fuel oil inlet A1)	m^3/h	0.35	0.47	0.54	0.62	0.70
Fuel oil supply pump (4 bar discharge pressure)	m^3/h	0.17	0.22	0.26	0.30	0.34
Fuel oil circulating pump (8 bar at fuel oil inlet A1)	m^3/h	0.35	0.47	0.54	0.62	0.70
Starting air data						
Air consumption per start, incl. air for jet assist (IR/TDI)	Nm^3	0.47	0.56	0.65	0.75	0.84
Air consumption per start, incl. air for jet assist (Gali)	Nm^3	0.80	0.96	1.12	1.28	1.44

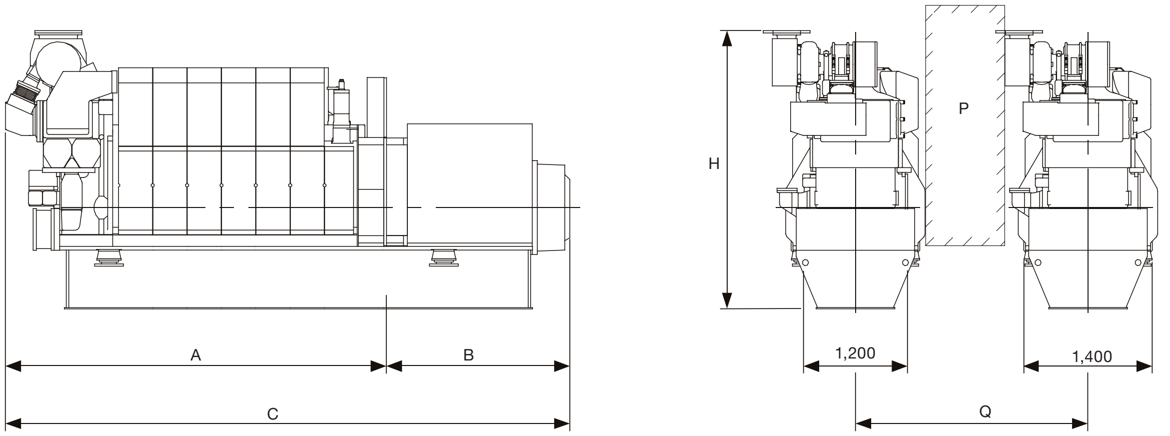
1) LT cooling water flow first through LT stage charge air cooler, then through lube oil cooler, water temperature outlet engine regulated by mechanical thermostat.
2) HT cooling water flow first through HT stage charge air cooler, then through water jacket and cylinder head, water temperature outlet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

Fig. 4.06.02b: List of capacities for L16/24 1,200 rpm, IMO Tier II

L21/31-TII GenSet Data

Bore: 210 mm Stroke: 310 mm

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



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

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

Fig. 4.07.01: Power and outline of L21/31, IMO Tier II

L21/31-TII GenSet Data

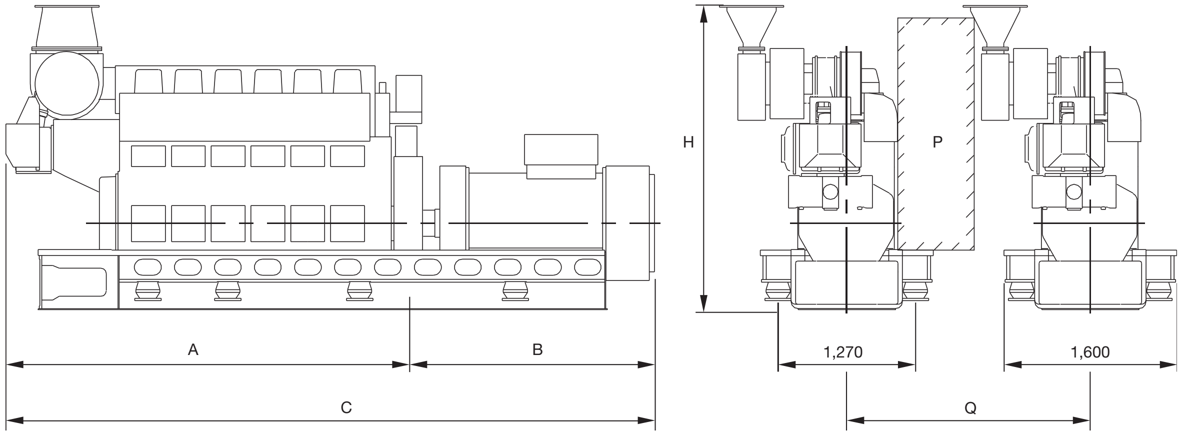
5L:200 kW/cyl., 6L-9L: 220 kW/Cyl. at 1,000 rpm						
Reference Condition: Tropic						
Air temperature	°C			45		
LT-water temperature inlet engine (from system)	°C			38		
Air pressure	bar			1		
Relative humidity	%			50		
Temperature basis						
Setpoint HT cooling water engine outlet [1]	°C	79 nominal (Range of mechanical thermostatic element 77 to 85)				
Setpoint LT cooling water engine outlet [2]	°C	35 nominal (Range of mechanical thermostatic element 29 to 41)				
Setpoint Lube oil inlet engine	°C	66 nominal (Range of mechanical thermostatic element 63 to 72)				
Number of Cylinders	**-**	**5**	**6**	**7**	**8**	**9**
Engine output	kW	1,000	1,320	1,540	1,760	1,980
Speed	rpm			1,000		
Heat to be dissipated [3]						
Cooling water (C.W.) Cylinder	kW	176	233	272	310	349
Charge air cooler; cooling water HT	kW	294	370	418	462	504
Charge air cooler; cooling water LT	kW	163	205	232	258	284
Lube oil (L.O.) cooler	kW	180	237	277	316	356
Heat radiation engine	kW	56	74	86	98	110
Flow rates [4]						
Internal (inside engine)						
HT circuit (cylinder + charge air cooler HT stage)	m^3/h	61	61	61	61	61
LT circuit (lube oil + charge air cooler LT stage)	m^3/h	61	61	61	61	61
Lube oil	m^3/h	34	34	46	46	46
External (from engine to system)						
HT water flow (at 40°C inlet)	m^3/h	10.7	13.5	15.4	17.1	18.8
LT water flow (at 38°C inlet)	m^3/h	61	61	61	61	61
Air data						
Temperature of charge air at charge air cooler outlet	°C	49	52	54	55	56
Air flow rate	m^3/h [5]	6,548	8,644	10,084	11,525	12,965
	kg/kWh	7.17	7.17	7.17	7.17	7.17
Charge air pressure	bar		4.13			
Air required to dissipate heat radiation (engine) (t_2-t_1=10°C)	m^3/h	17,980	23,800	27,600	31,500	35,300
Exhaust gas data [6]						
Volume flow (temperature turbocharger outlet)	m^3/h [7]	13,162	17,324	20,360	23,217	26,075
Mass flow	t/h	7.4	9.7	11.4	13.0	14.6
Temperature at turbine outlet	°C	349	349	349	349	349
Heat content (190°C)	kW	352	463	544	620	696
Permissible exhaust back pressure	mbar			< 30		
Pumps						
a) Engine driven pumps						
HT circuit cooling water (2.5 bar)	m^3/h	61	61	61	61	61
LT circuit cooling water (2.5 bar)	m^3/h	61	61	61	61	61
Lube oil (4.5 bar)	m^3/h	34	34	46	46	46
b) External pumps [8]						
Fuel oil feed pump (4 bar)	m^3/h	0.30	0.39	0.46	0.52	0.59
Fuel booster pump (8 bar)	m^3/h	0.89	1.18	1.37	1.57	1.76
Starting air data						
Air consumption per start, incl. air for jet assist (TDI)	Nm^3	1.0	1.2	1.4	1.6	1.8

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

Fig. 4.07.02a: List of capacities for L21/31, 900 rpm, IMO Tier II

L23/30H-TII GenSet Data

	Bore: 225 mm					Stroke: 300 mm
	Power layout					
	720 r/min Eng. kW	60 Hz Gen. kW	750 r/min Eng. kW	50 Hz Gen. kW	900 r/min Eng. kW	60 Hz Gen. kW
5L23/30H	650	620	675	640		
6L23/30H	780	740	810	770	960	910
7L23/30H	910	865	945	900	1,120	1,065
8L23/30H	1,040	990	1,080	1,025	1,280	1,215



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

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

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Q Min. distance between engines: 2,250 mm
* Depending on alternator
** Weight includes a standard alternator, make A. van Kaick
All dimensions and masses are approximate and subject to change without prior notice.

Fig. 4.08.01: Power and outline of L23/30H, IMO Tier II

L23/30H-TII GenSet Data

5-8L23/30H: 130 kW/Cyl., 720 rpm or 135 kWCyl., 750 rpm					
Reference Condition : Tropic					
Air temperature	°C	45			
LT-water temperature inlet engine (from system)	°C	36			
Air pressure	bar	1			
Relative humidity	%	50			
Temperature basis					
Setpoint HT cooling water engine outlet	°C	82°C (engine equipped with HT thermostatic valve)			
Setpoint Lube oil inlet engine	°C	60°C (SAE30), 66°C (SAE40)			
Number of Cylinders	-	**5**	**6**	**7**	**8**
Engine output	kW	650 / 675	780 / 810	910 / 945	1,040 / 1,080
Speed	rpm	720 / 750			
Heat to be dissipated 1)					
Cooling water (C.W.) Cylinder	kW	182	219	257	294
Charge air cooler; cooling water HT	kW	1 stage cooler: no HT-stage			
Charge air cooler; cooling water LT	kW	251	299	348	395
Lube oil (L.O.) cooler	kW	69	84	98	112
Heat radiation engine	kW	27	33	38	44
Air data					
Temperature of charge air at charge air cooler outlet, max.	°C	55	55	55	55
Air flow rate	m^3/h 4)	4,556	5,467	6,378	7,289
	kg/kWh	7.39	7.39	7.39	7.39
Charge air pressure	bar	3.08			
Air required to dissipate heat radiation (engine) $(t_2-t_1=10°C)$	m^3/h	8,749	10,693	12,313	14,257
Exhaust gas data 5)					
Volume flow (temperature turbocharger outlet)	m^3/h 6)	9,047	10,856	12,666	14,475
Mass flow	t/h	5.1	6.1	7.2	8.2
Temperature at turbine outlet	°C	342	342	342	342
Heat content (190°C)	kW	234	280	327	374
Permissible exhaust back pressure	mbar	< 30			
Pumps					
a) Engine driven pumps					
Fuel oil feed pump (5.5-7.5 bar)	m^3/h	1.0			
HT cooling water pump (1-2.5 bar)	m^3/h	36			
LT cooling water pump (1-2.5 bar)	m^3/h	55			
Lube oil (3-5 bar)	m^3/h	16	16	20	20
b) External pumps 7)					
Diesel oil pump (4 bar at fuel oil inlet A1)	m^3/h	0.48	0.57	0.67	0.76
Fuel oil supply pump 8) (4 bar discharge pressur)	m^3/h	0.23	0.28	0.32	0.37
Fuel oil circulating pump (8 bar at fuel oil inlet A1)	m^3/h	0.48	0.57	0.67	0.76
Cooling water pumps for for "Internal Cooling Water System 1"					
+ LT cooling water pump (1-2.5 bar)	m^3/h	35	42	48	55
Cooling water pumps for for "Internal Cooling Water System 2"					
HT cooling water pump (1-2.5 bar)	m^3/h	20	24	28	32
+ LT cooling water pump (1-2.5 bar)	m^3/h	35	42	48	55
Lube oil pump (3-5 bar)	m^3/h	14	15	16	17
Starting air system					
Air consuption per start	Nm^3	2.0	2.0	2.0	2.0
Nozzle cooling data					
Nozzle cooling data	m^3/h	0.66			

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

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

L23/30H-TII GenSet Data

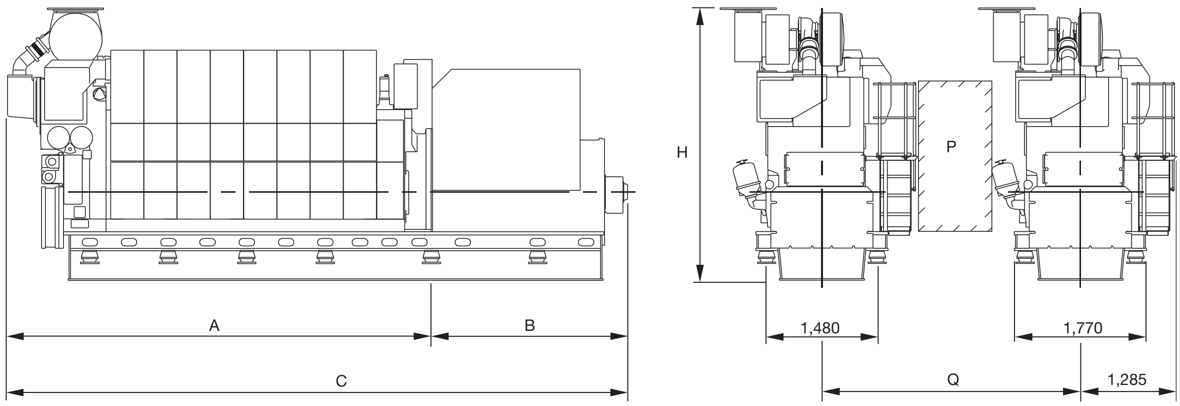
6-8L23/30H: 160 kW/Cyl., 900 rpm					
Reference Condition: Tropic					
Air temperature		°C		45	
LT-water temperature inlet engine (from system)		°C		36	
Air pressure		bar		1	
Relative humidity		%		50	
Temperature basis					
Setpoint HT cooling water engine outlet		°C		82°C (engine equipped with HT thermostatic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

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

Fig. 4.08.02b: List of capacities for L23/30H, 900 rpm, IMO Tier II

L27/38-TII GenSet Data

	Bore: 270 mm					Stroke: 380 mm
	Power layout					
	720 r/min Eng. kW	60 Hz Gen. kW	750 r/min Eng. kW	50 Hz Gen. kW	720/750 r/min (MGO/MDO) Eng. kW	60/50 Hz (MGO/MDO) Gen. kW
5L27/38	1,500	1,440	1,600	1,536	-	-
6L27/38	1,980	1,900	1,980	1,900	2,100	2,016
7L27/38	2,310	2,218	2,310	2,218	2,450	2,352
8L27/38	2,640	2,534	2,640	2,534	2,800	2,688
9L27/38	2,970	2,851	2,970	2,851	3,150	3,024



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

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

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Fig. 4.09.01: Power and outline of L27/38, IMO Tier II

L27/38-TII GenSet Data

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

Reference Condition: Tropic					
Air temperature	°C	45			
LT-water temperature inlet engine (from system)	°C	38			
Air pressure	bar	1			
Relative humidity	%	50			
Temperature basis					
Setpoint HT cooling water engine outlet [1]	°C	79 nominal (Range of mechanical thermostatic element 77 to 85)			
Setpoint LT cooling water engine outlet [2]	°C	35 nominal (Range of mechanical thermostatic element 29 to 41)			
Setpoint Lube oil inlet engine	°C	66 nominal (Range of mechanical thermostatic element 63 to 72)			
Number of Cylinders	-	6	7	8	9
Engine output	kW	2,100	2,450	2,800	3,150
Speed	rpm	720			
Heat to be dissipated [3]					
Cooling water (C.W.) Cylinder	kW	315	368	421	473
Charge air cooler; cooling water HT	kW	668	784	903	1,022
Charge air cooler; cooling water LT	kW	175	200	224	247
Lube oil (L.O.) cooler	kW	282	329	376	423
Heat radiation engine	kW	70	81	93	104
Flow rates [4]					
Internal (inside engine)					
HT circuit (cylinder + charge air cooler HT stage)	m³/h	58	58	58	58
LT circuit (lube oil + charge air cooler LT stage)	m³/h	58	58	58	58
Lube oil	m³/h	64	92	92	92
External (from engine to system)					
HT water flow (at 40°C inlet)	m³/h	21.5	24.8	28.1	31.4
LT water flow (at 38°C inlet)	m³/h	58	58	58	58
Air data					
Temperature of charge air at charge air cooler outlet	°C	50	53	55	56
Air flow rate	m³/h [5]	12,792	14,924	17,056	19,188
	kg/kWh	6.67	6.67	6.67	6.67
Charge air pressure	bar	4.01			
Air required to dissipate heat radiation (engine) (t_2-t_1= 10°C)	m³/h	22,682	26,247	30,135	33,699
Exhaust gas data [6]					
Volume flow (temperature turbocharger outlet)	m³/h [7]	27,381	31,944	36,508	41,071
Mass flow	t/h	14.4	16.8	19.2	21.6
Temperature at turbine outlet	°C	388	388	388	388
Heat content (190°C)	kW	857	1,000	1,143	1,285
Permissible exhaust back pressure	mbar	< 30			
Pumps					
a) Engine driven pumps					
HT circuit cooling water (2.5 bar)	m³/h	58	58	58	58
LT circuit cooling water (2.5 bar)	m³/h	58	58	58	58
Lube oil (4.5 bar)	m³/h	64	92	92	92
b) External pumps [8]					
Diesel oil pump (5 bar at fuel oil inlet A1)	m³/h	1.48	1.73	1.98	2.23
Fuel oil supply pump (4 bar discharge pressure)	m³/h	0.71	0.83	0.95	1.07
Fuel oil circulating pump (8 bar at fuel oil inlet A1)	m³/h	1.48	1.73	1.98	2.23
Starting air data					
Air consumption per start, incl. air for jet assist (IR/TDI)	Nm³	2.9	3.3	3.8	4.3

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

Fig. 4.09.02a: List of capacities for L27/38, 720 rpm, IMO Tier II

L27/38-TII GenSet Data

6-9L27/38: 350 kW/cyl., 750 rpm, MGO

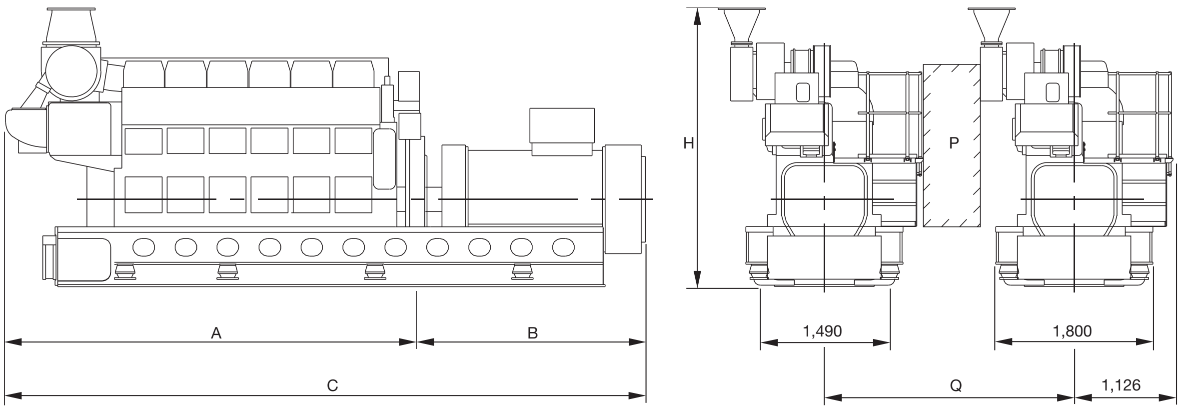
Reference Condition : Tropic					
Air temperature	°C	45			
LT-water temperature inlet engine (from system)	°C	38			
Air pressure	bar	1			
Relative humidity	%	50			
Temperature basis					
Setpoint HT cooling water engine outlet [1]	°C	79 nominal (Range of mechanical thermostatic element 77 to 85)			
Setpoint LT cooling water engine outlet [2]	°C	35 nominal (Range of mechanical thermostatic element 29 to 41)			
Setpoint Lube oil inlet engine	°C	66 nominal (Range of mechanical thermostatic element 63 to 72)			
Number of Cylinders	**-**	**6**	**7**	**8**	**9**
Engine output	kW	2,100	2,450	2,800	3,150
Speed	rpm	750			
Heat to be dissipated [3]					
Cooling water (C.W.) Cylinder	kW	315	368	421	473
Charge air cooler; cooling water HT	kW	679	797	916	1037
Charge air cooler; cooling water LT	kW	181	208	234	258
Lube oil (L.O.) cooler	kW	282	329	376	423
Heat radiation engine	kW	70	81	93	104
Flow rates [4]					
Internal (inside engine)					
HT circuit (cylinder + charge air cooler HT stage)	m^3/h	69	69	69	69
LT circuit (lube oil + charge air cooler LT stage)	m^3/h	69	69	69	69
Lube oil	m^3/h	66	96	96	96
External (from engine to system)					
HT water flow (at 40°C inlet)	m^3/h	21.9	25.4	28.9	32.2
LT water flow (at 38°C inlet)	m^3/h	69	69	69	69
Air data					
Temperature of charge air at charge air cooler outlet	°C	55	55	55	55
Air flow rate	m^3/h [5])	13,003	15,170	17,338	19,505
	kg/kWh	6.78	6.78	6.78	6.78
Charge air pressure	bar	4.09			
Air required to dissipate heat radiation (engine) (t_2-t_1=10°C)	m^3/h	22,682	26,247	30,135	33,699
Exhaust gas data [6]					
Volume flow (temperature turbocharger outlet)	m^3/h [7])	27,567	32,161	36,756	41,350
Mass flow	t/h	14.7	17.1	19.5	22.0
Temperature at turbine outlet	°C	382	382	382	382
Heat content (190°C)	kW	844	985	1,126	1,266
Permissible exhaust back pressure	mbar	< 30			
Pumps					
a) Engine driven pumps					
HT circuit cooling water (2.5 bar)	m^3/h	69	69	69	69
LT circuit cooling water (2.5 bar)	m^3/h	69	69	69	69
Lube oil (4.5 bar)	m^3/h	66	96	96	96
b) External pumps [8]					
Diesel oil pump (5 bar at fuel oil inlet A1)	m^3/h	1.48	1.73	1.98	2.23
Fuel oil supply pump (4 bar discharge pressure)	m^3/h	0.71	0.83	0.95	1.07
Fuel oil circulating pump (8 bar at fuel oil inlet A1)	m^3/h	1.48	1.73	1.98	2.23
Starting air data					
Air consumption per start, incl. air for jet assist (IR/TDI)	Nm^3	2.9	3.3	3.8	4.3

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

Fig. 4.09.02b: List of capacities for L27/38, 750 rpm, IMO Tier II

L28/32H-TII GenSet Data

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



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

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

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

L28/32H-TII GenSet Data

5L-9L: 220 kW/Cyl. at 750 rpm						
Reference Condition: Tropic						
Air temperature	°C			45		
LT water temperature inlet engine (from system)	°C			38		
Air pressure	bar			1		
Relative humidity	%			50		
Number of Cylinders	-	**5**	**6**	**7**	**8**	**9**
Engine output	kW	1,100	1,320	1,540	1,760	1,980
Speed	rpm	750				
Heat to be dissipated 1)						
Cooling water (C.W.) Cylinder	kW	245	294	343	392	442
Charge air cooler; cooling water HT	kW			0 (Single stage charge air cooler)		
Charge air cooler; cooling water LT	kW	387	435	545	587	648
Lube oil (L.O.) cooler	kW	201	241	281	321	361
Heat radiation engine	kW	27	33	38	44	49
Flow rates 2)						
Internal (inside engine)						
HT cooling water cylinder	m^3/h	37	45	50	55	60
LT cooling water lube oil cooler *	m^3/h	7.8	9.4	11	12.7	14.4
LT cooling water lube oil cooler **	m^3/h	28	28	40	40	40
LT cooling water charge air cooler	m^3/h	37	45	55	65	75
Air data						
Temperature of charge air at charge air cooler outlet	°C	52	54	52	52	55
Air flow rate	m^3/h 3)	7,826	9,391	10,956	12,521	14,087
	kg/kWh	7.79	7.79	7.79	7.79	7.79
Charge air pressure	bar			3.07		
Air required to dissipate heat radiation (engine) (t_2-t_1=10°C)	m^3/h	8,749	10,693	12,313	14,257	15,878
Exhaust gas data 4)						
Volume flow (temperature turbocharger outlet)	m^3/h 5)	15,520	18,624	21,728	24,832	27,936
Mass flow	t/h	8.8	10.5	12.3	14.1	15.8
Temperature at turbine outlet	°C	342	342	342	342	342
Heat content (190°C)	kW	401	481	561	641	721
Permissible exhaust back pressure	mbar			< 30		
Pumps						
a) Engine driven pumps						
Fuel oil feed pump (5,5-7,5 bar)	m^3/h	1.4	1.4	1.4	1.4	1.4
HT circuit cooling water (1,0-2,5 bar)	m^3/h	45	45	60	60	60
LT circuit cooling water (1,0-2,5 bar)	m^3/h	45	60	75	75	75
Lube oil (3,0-5,0 bar)	m^3/h	24	24	34	34	34
b) External pumps 6)						
Diesel oil pump (4 bar at fuel oil inlet A1)	m^3/h	0.78	0.93	1.09	1.24	1.40
Fuel oil supply pump (4 bar discharge pressure)	m^3/h	0.37	0.45	0.52	0.60	0.67
Fuel oil circulating pump (8 bar at fuel oil inlet A1)	m^3/h	0.78	0.93	1.09	1.24	1.40
HT circuit cooling water (1,0-2,5 bar)	m^3/h	37	45	50	55	60
LT circuit cooling water (1,0-2,5 bar) *	m^3/h	45	54	65	77	89
LT circuit cooling water (1,0-2,5 bar) **	m^3/h	65	73	95	105	115
Lube oil (3,0-5,0 bar)	m^3/h	22	23	25	27	28

1) Tolerance: + 10% for rating coolers, - 15% for heat recovery
2) Basic values for layout of the coolers
3) Under above mentioned reference conditions
4) Tolerance: quantity +/- 5%, temperature +/- 20°C
5) under below mentioned temperature at turbine outlet and pressure according above mentioned reference conditions
6) Tolerance of the pumps delivery capacities must be considered by the manufactures
* Only valid for engines equipped with internal basic cooling water system no. 1 and 2.
** Only valid for engines equipped with combined coolers, internal basic cooling water system no. 3

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

L28/32H-TII GenSet Data

5L-9L: 210 kW/Cyl. at 720 rpm							
Reference Condition: Tropic							
Air temperature		°C			45		
LT water temperature inlet engine (from system)		°C			38		
Air pressure		bar			1		
Relative humidity		%			50		
Number of Cylinders		-	**5**	**6**	**7**	**8**	**9**
Engine output		kW	1,050	1,260	1,470	1,680	1,890
Speed		rpm			720		
Heat to be dissipated [1]							
Cooling water (C.W.) Cylinder		kW	234	281	328	375	421
Charge air cooler; cooling water HT		kW			0 (Single stage charge air cooler)		
Charge air cooler; cooling water LT		kW	355	397	500	553	592
Lube oil (L.O.) cooler		kW	191	230	268	306	345
Heat radiation engine		kW	26	31	36	42	47
Flow rates [2]							
Internal (inside engine)							
HT cooling water cylinder		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]	7,355	8,826	10,297	11,768	13,239
		kg/kWh	7.67	7.67	7.67	7.67	7.67
Charge air pressure		bar			2.97		
Air required to dissipate heat radiation (engine) (t_2-t_1=10°C)		m^3/h	8,425	10,045	11,665	13,609	15,230
Exhaust gas data [4]							
Volume flow (temperature turbocharger outlet)		m^3/h [5]	14,711	17,653	20,595	23,537	26,479
Mass flow		t/h	8.3	9.9	11.6	13.2	14.9
Temperature at turbine outlet		°C	347	347	347	347	347
Heat content (190°C)		kW	389	467	545	623	701
Permissible exhaust back pressure		mbar			< 30		
Pumps							
a) Engine driven pumps							
Fuel oil feed pump	(5,5-7,5 bar)	m^3/h	1.4	1.4	1.4	1.4	1.4
HT circuit cooling water	(1,0-2,5 bar)	m^3/h	45	45	60	60	60
LT circuit cooling water	(1,0-2,5 bar)	m^3/h	45	60	75	75	75
Lube oil	(3,0-5,0 bar)	m^3/h	24	24	34	34	34
b) External pumps [6]							
Diesel oil pump	(4 bar at fuel oil inlet A1)	m^3/h	0.74	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

Fig. 4.10.02b: List of capacities for L28/32H, 720 rpm, IMO Tier II.

Installation Aspects

5

Space Requirements and Overhaul Heights

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

Space Requirements for the Engine

The space requirements stated in Section 5.02 are valid for engines rated at nominal MCR (L_1).

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

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

Overhaul of Engine

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

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

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

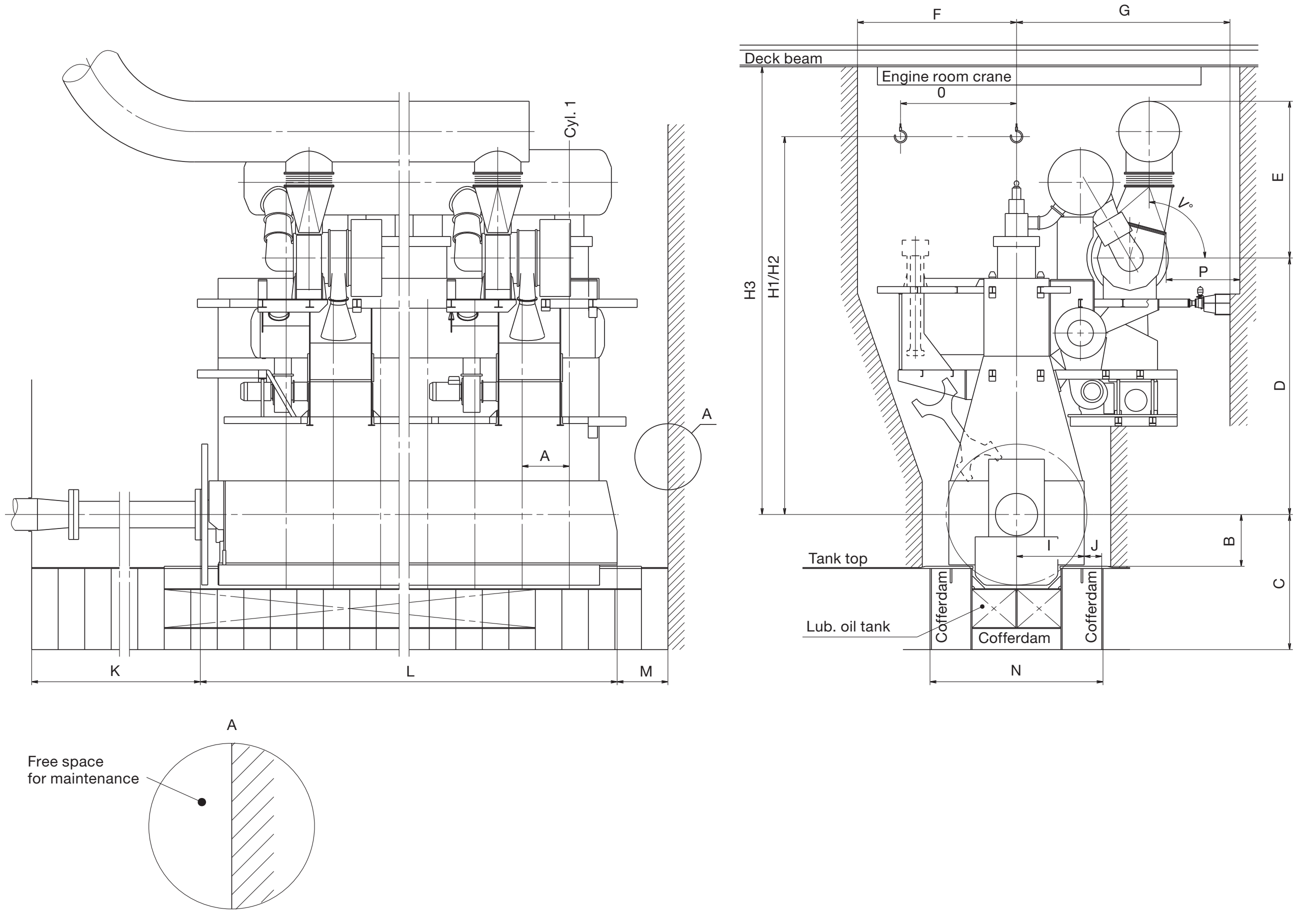
Please note that the distance 'E' in Fig. 5.02.01, given for a double-jib crane is from the centre of the crankshaft to the lower edge of the deck beam.

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

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

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

Space Requirement



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

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

515 90 52-7.2.0

Fig. 5.02.01a: Space requirement for the engine, turbocharger on exhaust side (4 59 122)

Cyl. No.	5	6	7	8		
A	1,020				Cylinder distance	
B	1,350				Distance from crankshaft centre line to foundation	
C	3,705	3,780	3,820	3,890	The dimension includes a cofferdam of 600 mm and must fulfil minimum height to tank top according to classification rules	
D *	6,695	7,045	7,045	7,045	MAN Diesel TCA	Dimensions according to turbocharger choice at nominal MCR
	6,630	6,630	6,630	6,732	ABB A100-L/A200-L	
	6,760	6,760	7,005	7,005	Mitsubishi MET	
E *	3,642	3,987	4,292	4,666	MAN Diesel TCA	Dimensions according to turbocharger choice at nominal MCR
	3,717	3,917	4,222	4,533	ABB A100-L/A200-L	
	3,546	3,871	4,234	4,434	Mitsubishi MET	
F	See text				See drawing: 'Engine Top Bracing', if top bracing fitted on camshaft side	
G	4,825	5,135	5,135	5,395	MAN Diesel TCA	The required space to the engine room casing includes Hydraulic top bracing
	4,925	4,925	4,925	5,395	ABB A100-L/A200-L	
	4,925	4,865	5,395	5,395	Mitsubishi MET	
H1 *	10,725				Minimum overhaul height, normal lifting procedure	
H2 *	9,975				Minimum overhaul height, reduced height lifting procedure	
H3 *	9,725				The minimum distance from crankshaft centre line to lower edge of deck beam, when using MAN B&W Double Jib Crane	
I	1,885				Length from crankshaft centre line to outer side bedplate	
J	345				Space for tightening control of holding down bolts	
K	See text				K must be equal to or larger than the propeller shaft, if the propeller shaft is to be drawn into the engine room	
L *	7,122	8,142	9,162	10,182	Minimum length of a basic engine, without 2nd order moment compensators.	
M	≈ 800				Free space in front of engine	
N	4,410				Distance between outer foundation girders	
O	2,650				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

Fig. 5.02.01b: Space requirement for the engine

560 15 77-5.0.0

Crane beam for overhaul of turbocharger

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

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

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

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

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

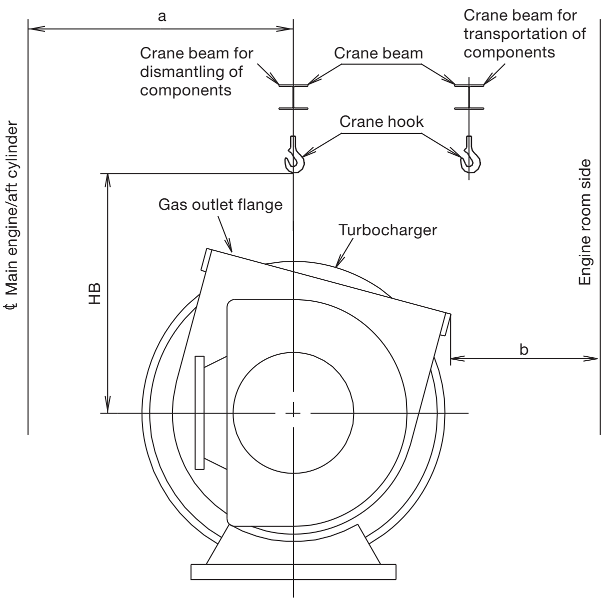
- Exhaust gas inlet casing
- Turbocharger inlet silencer
- Compressor casing
- Turbine rotor with bearings

The crane beams are to be placed in relation to the turbocharger(s) so that the components around the gas outlet casing can be removed in connection with overhaul of the turbocharger(s). The crane beam can be bolted to brackets that are fastened to the ship structure or to columns that are located on the top platform of the engine.

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

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

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



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

Fig. 5.03.01a: Required height and distance

MAN B&W					
	Units	TCA55	TCA66	TCA77	TCA88
W	kg	1,000	1,200	2,000	3,000
HB	mm	1,400	1,600	1,800	2,000
b	m	600	700	800	1,000

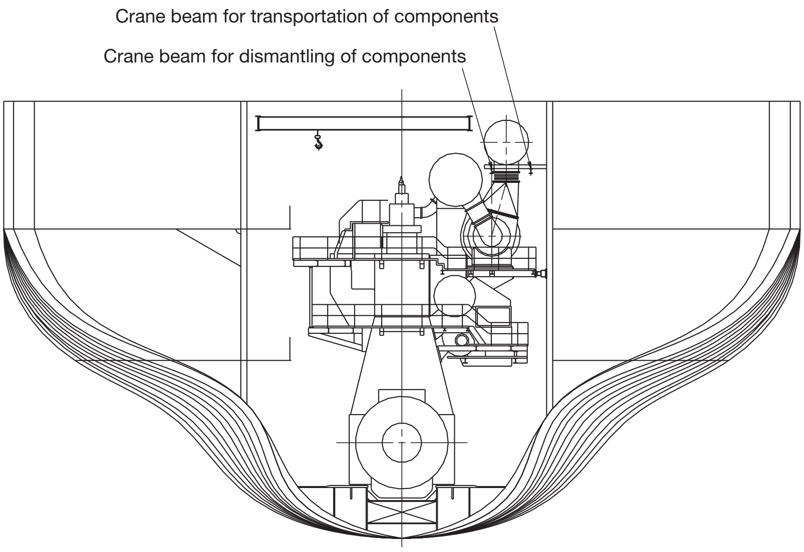
ABB						
	Units	A175	A180	A185	A275	A280
W	kg	*)				
HB	mm	1,725	1,975	2,350	1,900	2,100
b	m	500	600	600	500	600

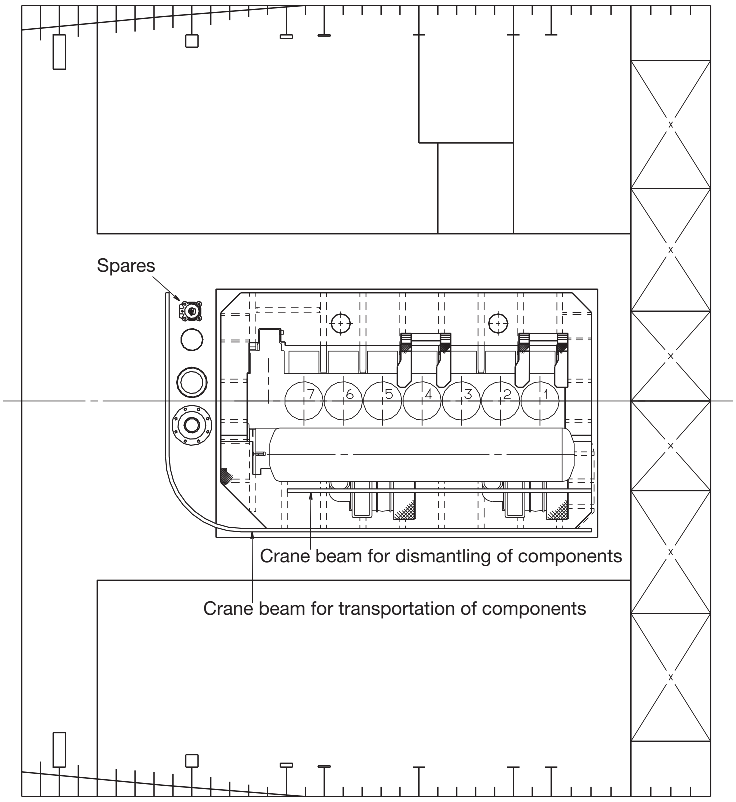
Mitsubishi						
	Units	MET53	MET60	MET66	MET71	MET83
W	kg	1,000	1,000	1,500	1,800	2,700
HB	mm	1,500	1,600	1,800	1,800	2,200
b	m	700	700	800	800	800

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

Fig. 5.03.01b: Required height and distance and weight

Crane beam for turbochargers





178 52 74-6.0

Fig. 5.03.02: Crane beam for turbocharger

Crane beam for overhaul of air cooler

Overhaul/exchange of scavenge air cooler.

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

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

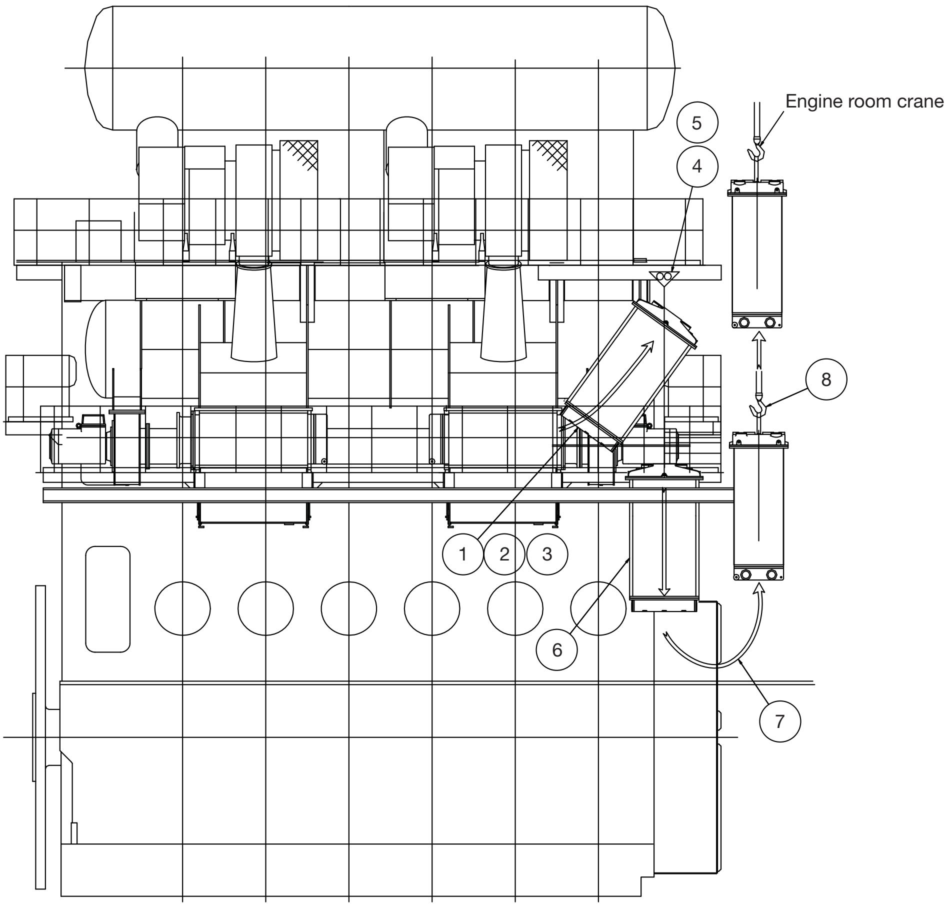
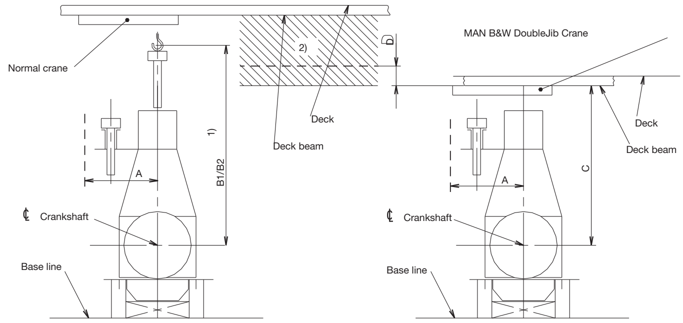


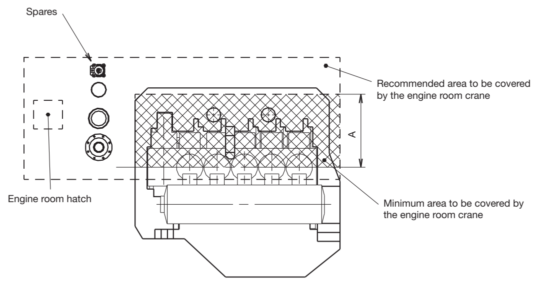
Fig.: 5.03.03: Crane beam for overhaul of air cooler, turbochargers located on exhaust side of the engine

178 52 73-4.0

Engine room crane



079 43 36-7.0.0



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.

Fig. 5.04.01: Engine room crane

Weight 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 piston rod and stuffing box	Normal crane	MAN B&W Double-Jib Crane	A Minimum distance	B1 Minimum height from centre line crankshaft to centre line crane hook	B1 Minimum height from centre line crankshaft to underside deck beam	C Minimum height from centre line crankshaft to under-side deck beam	D Additional height required for removal of exhaust valve without remov-ing any exhaust valve stud
2,625	3,425	1,625	4.0	2x2.0	2,650	10,700	9,925	9,800	375

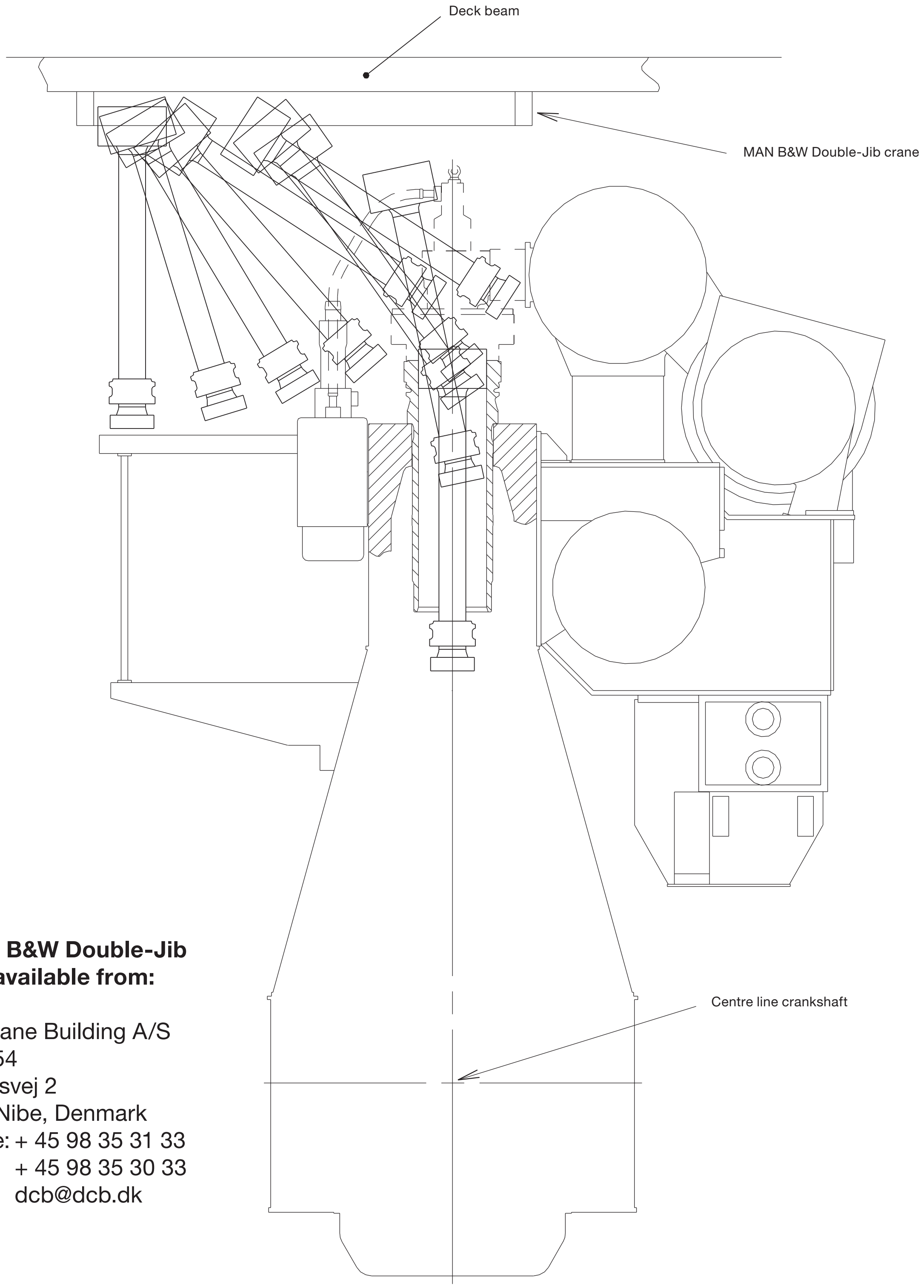
The crane hook travelling area must cover at least the full length of the engine and a width in accordance with dimension A given on the drawing, see cross-hatched area.

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

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

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

Overhaul with MAN B&W Double-Jib Crane



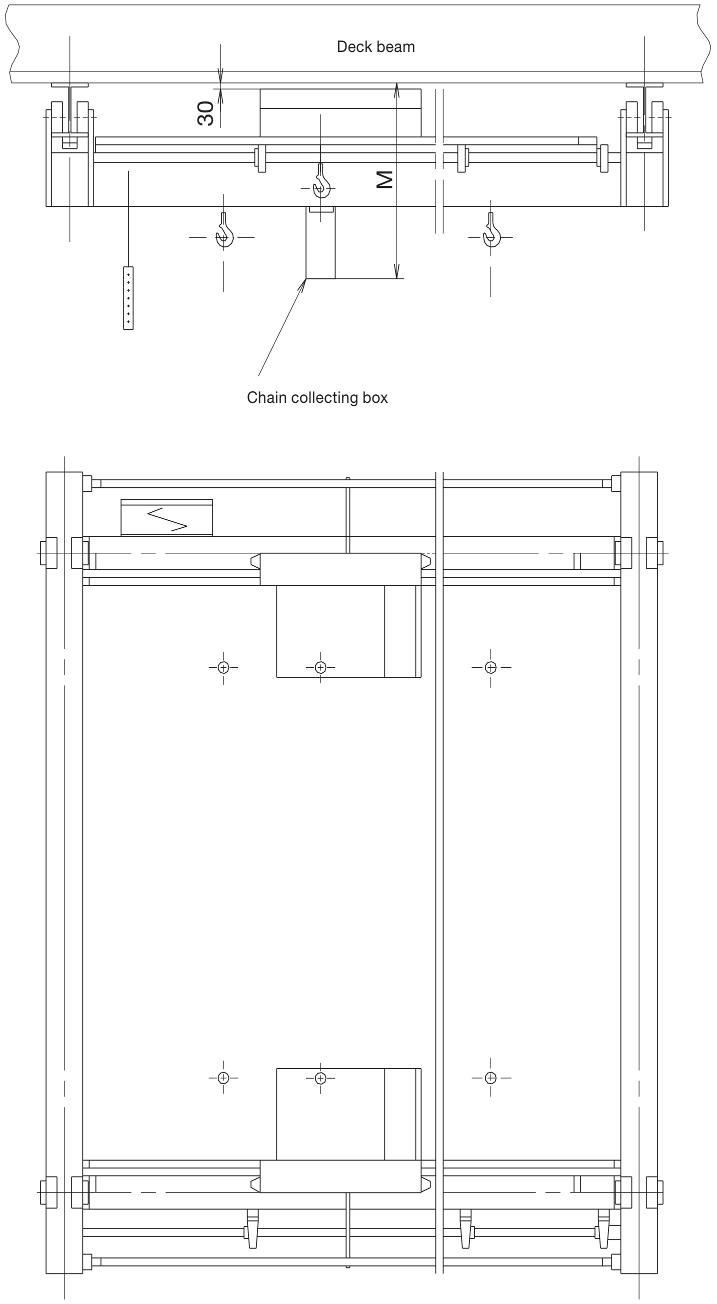
The MAN B&W Double-Jib crane is available from:

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



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

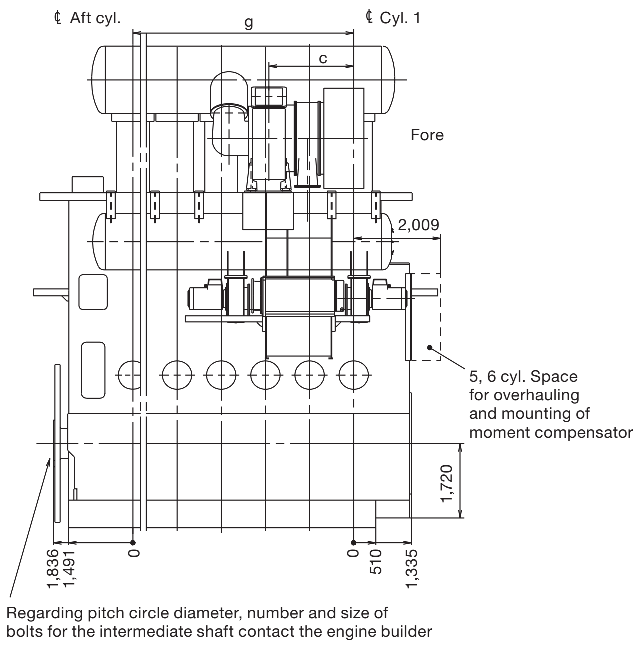
Section 5.06 show the gallery outline for engines rated at nominal MCR (L1).

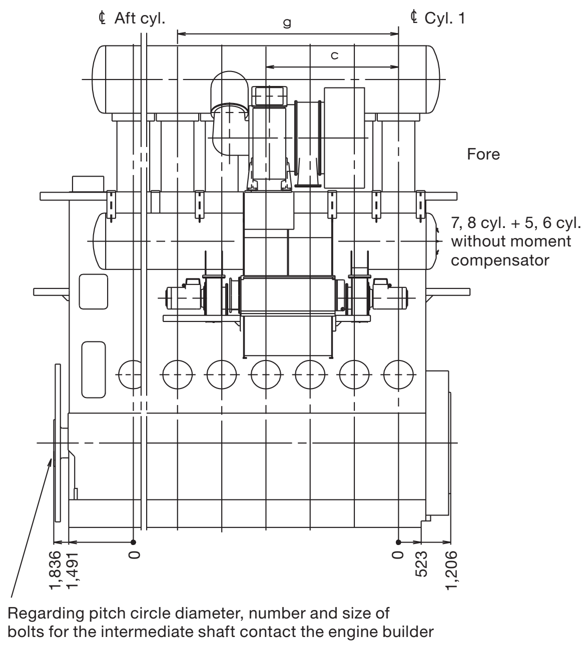
Engine pipe connections

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



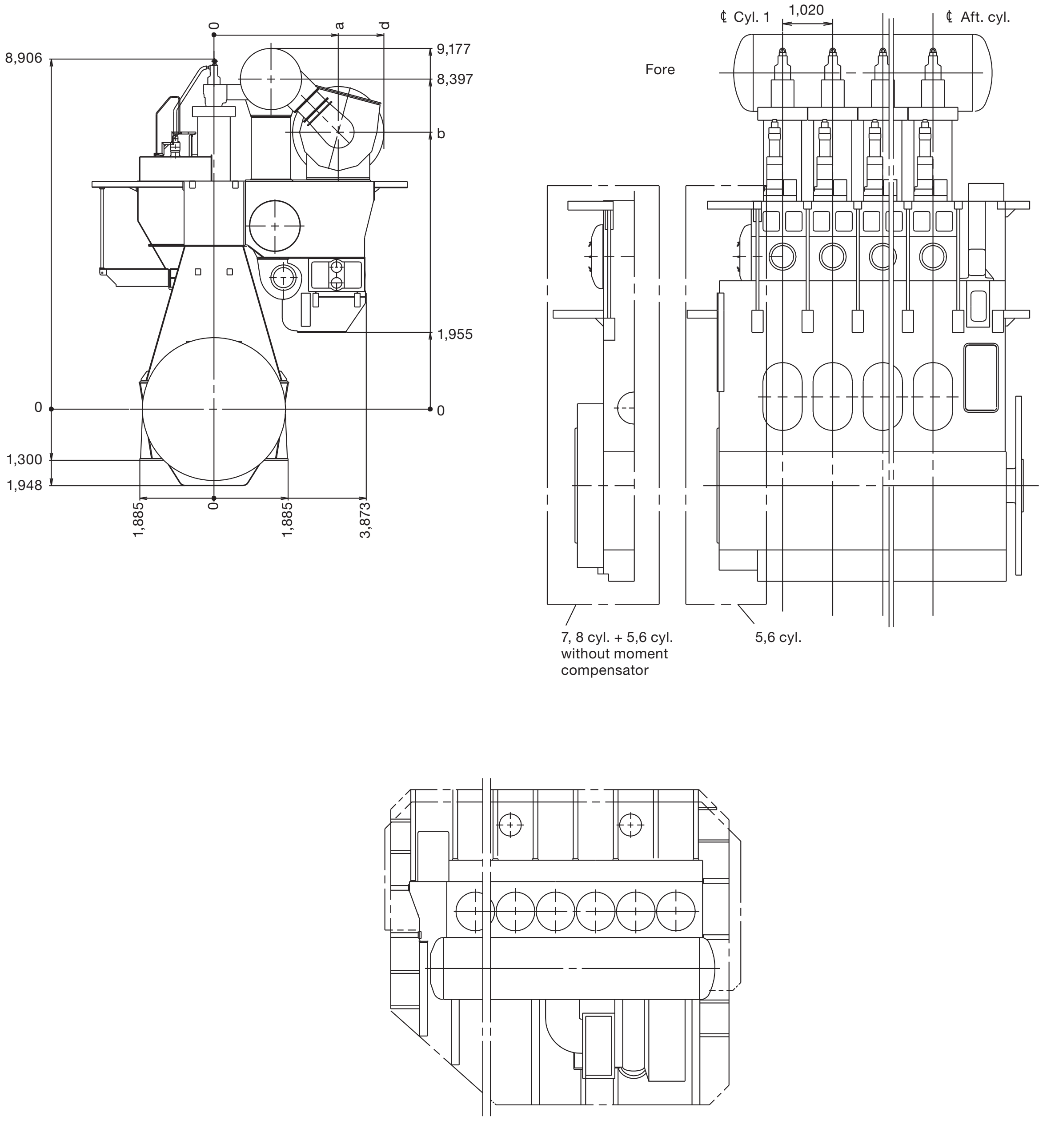


178 45 13-8.1

	T/C Type	a	b	c	d
MAN Diesel	TCA66	Available on request			
	TCA77	Available on request			
	TCA88	Available on request			
ABB	TPL77-B	Available on request			
	TPL80-B	Available on request			
MHI	MET60MA	Available on request			
	MET66MA	Available on request			
	MET71MA	Available on request			
	MET83MA	Available on request			

Cylinder no.	g
5	4,080
6	5,100
7	6,120
8	7,140

Fig. 5.06.01a: Engine outline, S60MC-C with turbocharger on exhaust side

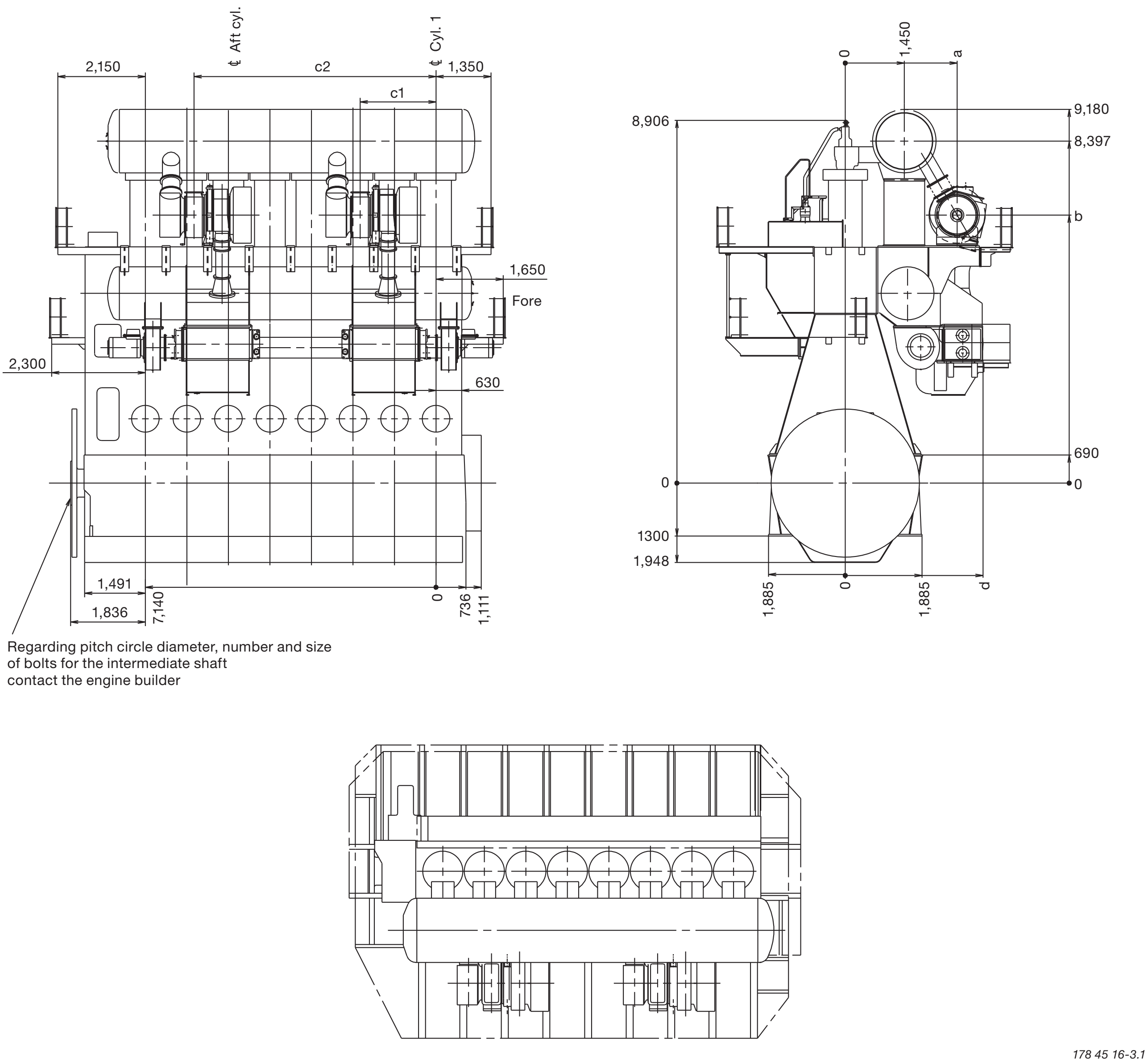


178 45 13-8.1

Please note that the latest version of the dimensioned drawing is available for download at www.marine.man.eu → '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.

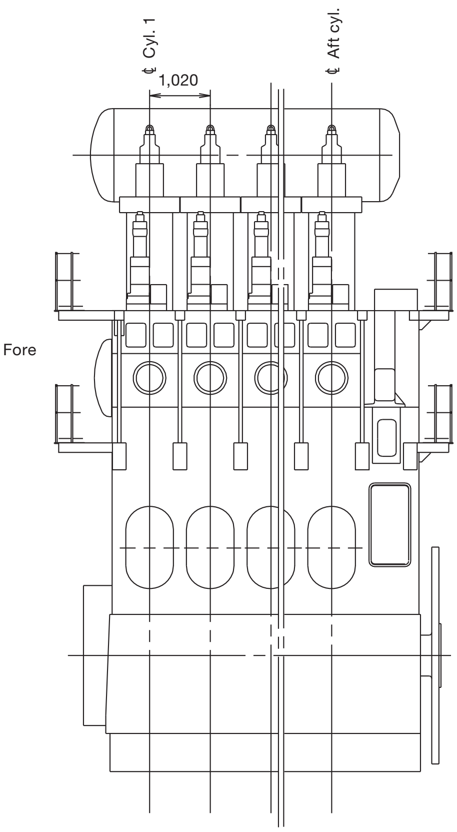
For platform dimensions, see 'Gallery outline'.

Fig. 5.06.01b: Engine outline, S60MC-C with turbocharger on exhaust side



	T/C Type	a	b	c1	c2	d
MAN Diesel	TCA55-21	Available on request				
ABB	TPL73-B12	Available on request				
MHI	MET53MA	Available on request				

Fig. 5.06.02a: Engine outline, S60MC-C with two turbochargers on exhaust side

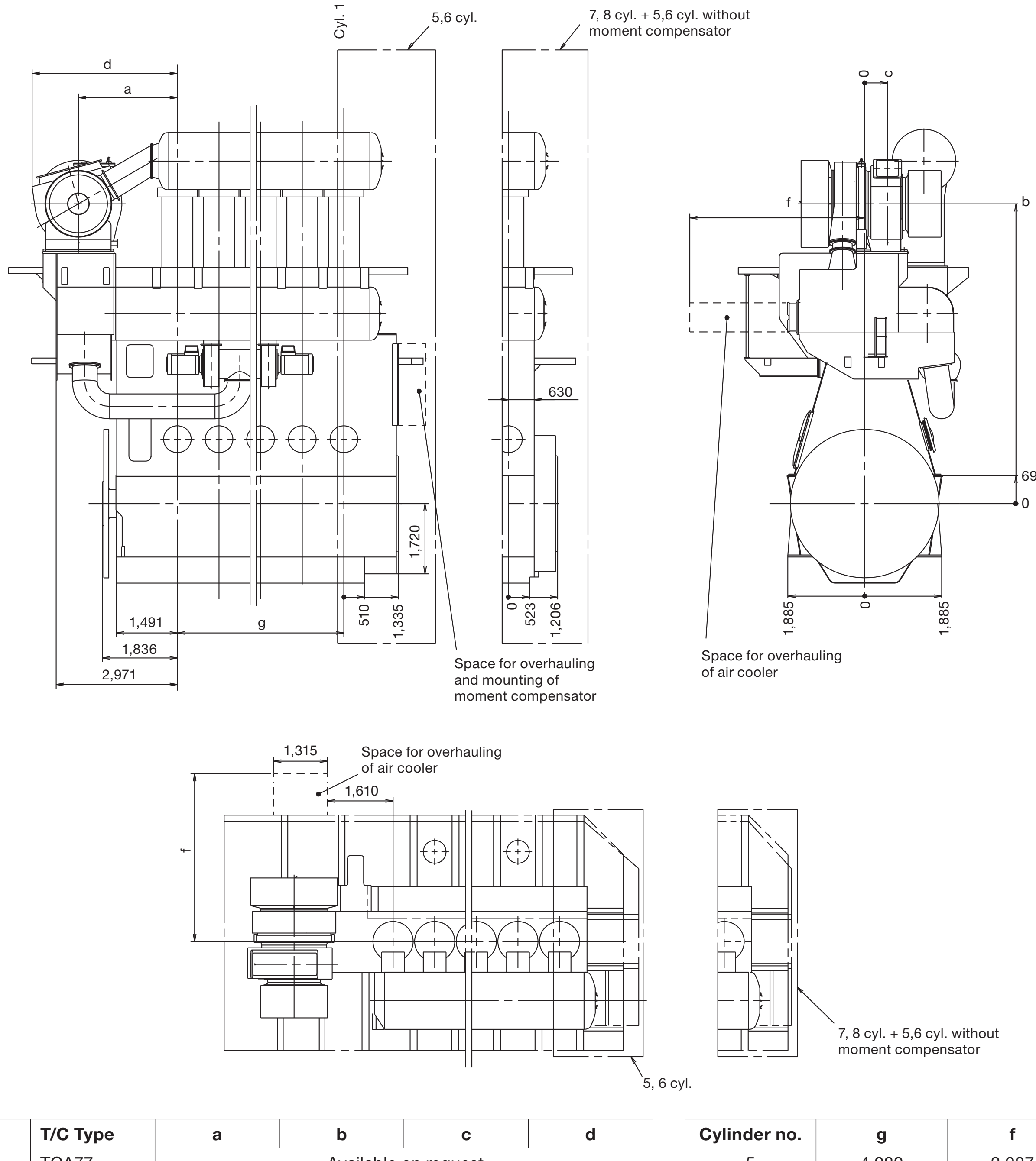


178 45 13-8.1

Please note that the latest version of the dimensioned drawing is available for download at www.marine.man.eu → '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. 5.06.02b: Engine outline, S60MC-C with two turbochargers on exhaust side

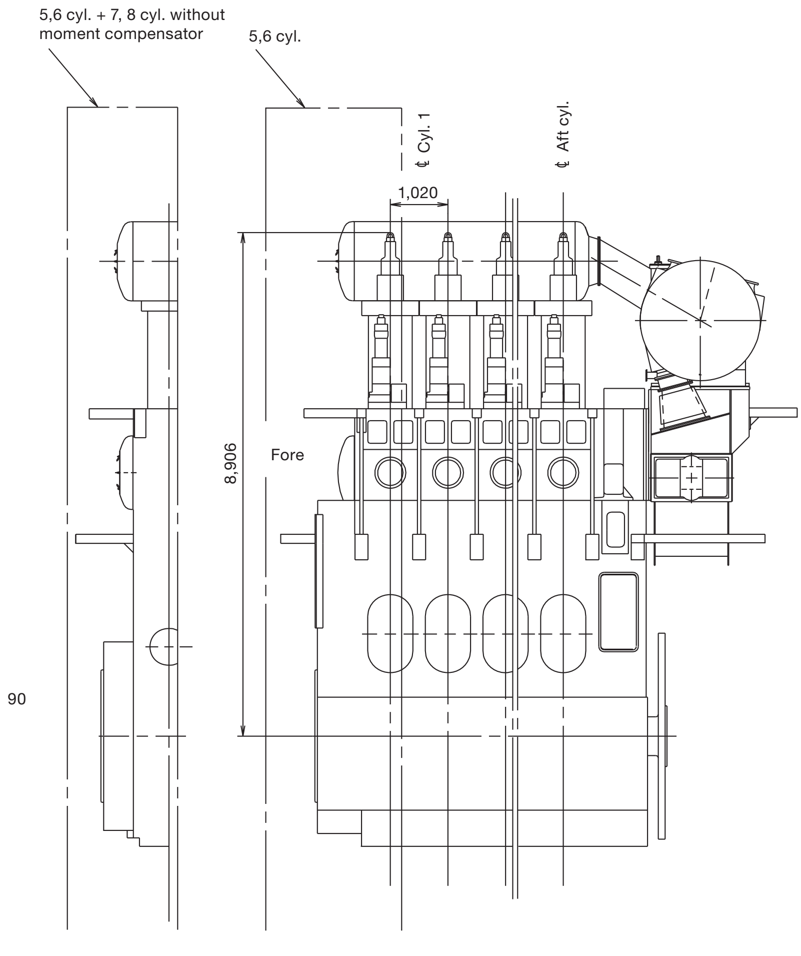


	T/C Type	a	b	c	d
MAN Diesel	TCA77	Available on request			
	TCA88	Available on request			
ABB	TPL77	Available on request			
	TPL80	2,280	7,234	693	3,064
	TPL85	2,463	7,535	394	3,493
MHI	MET66MA	Available on request			
	MET71MA	Available on request			
	MET83MA	Available on request			

Cylinder no.	g	f
5	4,080	3,287
6	5,100	3,287
7	6,120	4,287
8	7,140	4,287

178 45 15-1.1

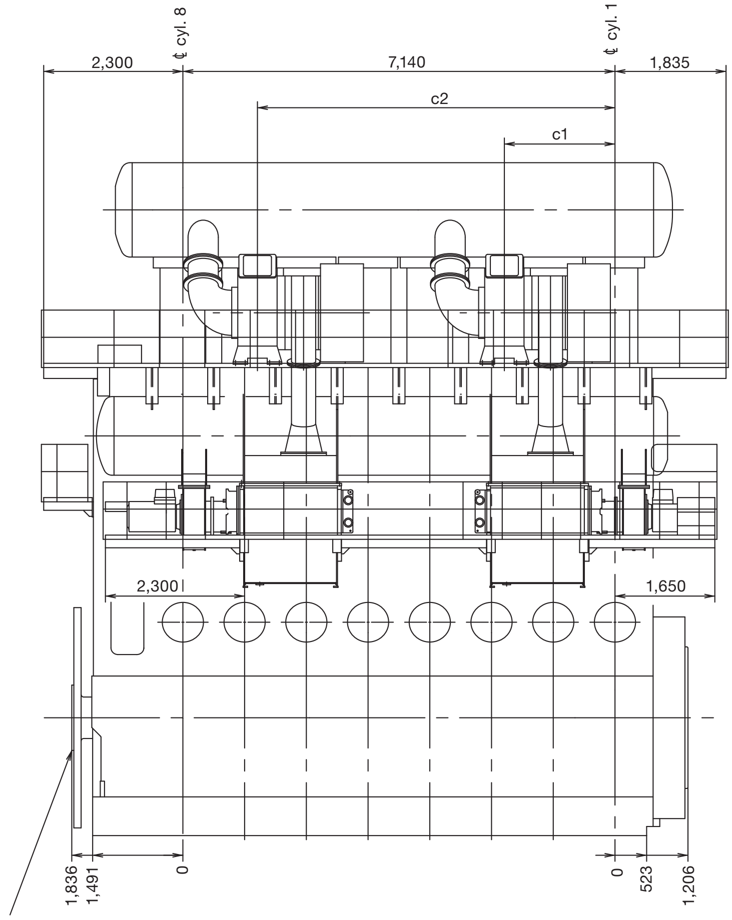
Fig. 5.06.03a: Engine outline, S60MC-C with turbocharger on aft end, option: 4 59 124



Please note that the latest version of the dimensioned drawing is available for download at www.marine.man.eu → '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'.

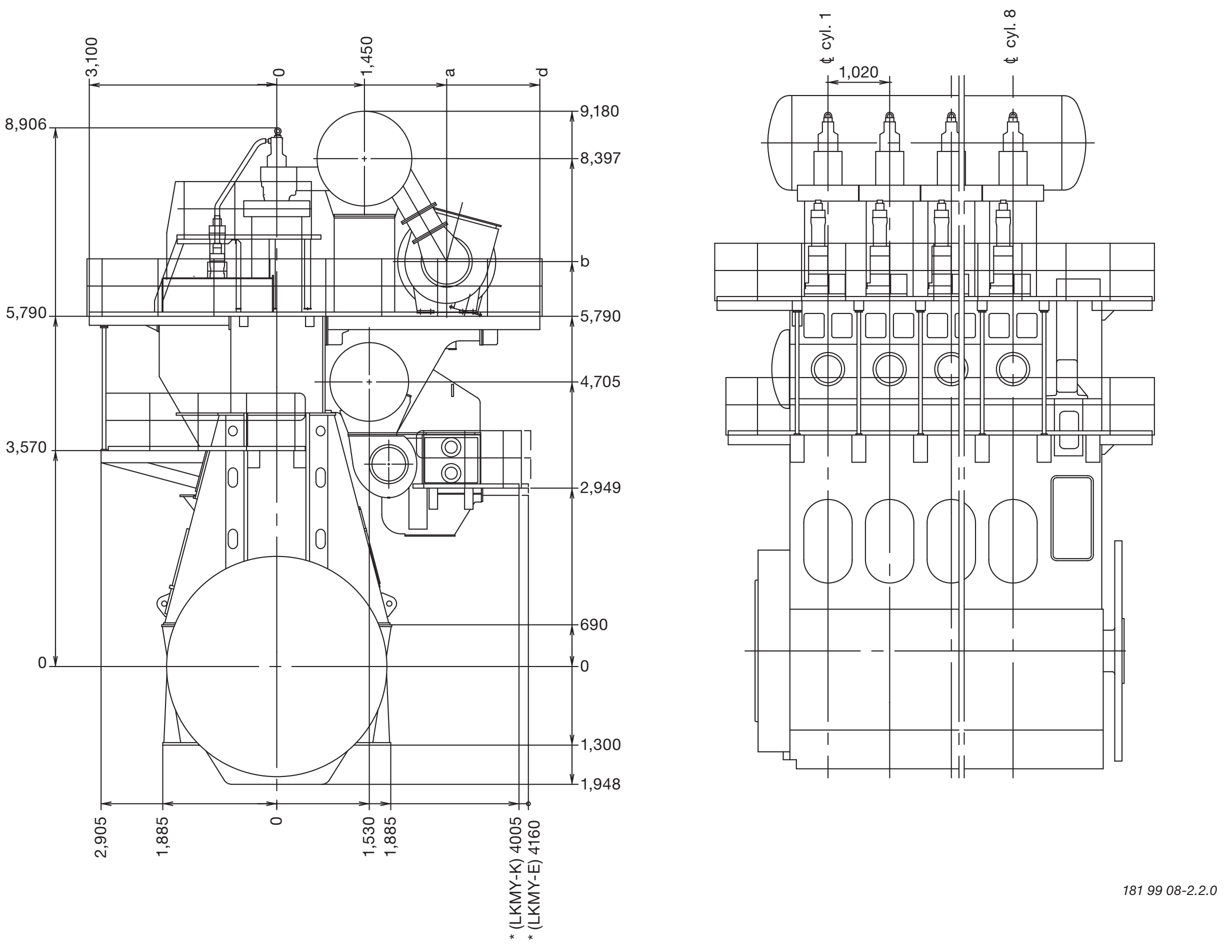
Fig. 5.06.03b: Engine outline, S60MC-C with turbocharger on aft end, option 4 59 124



181 99 08-2.2.0

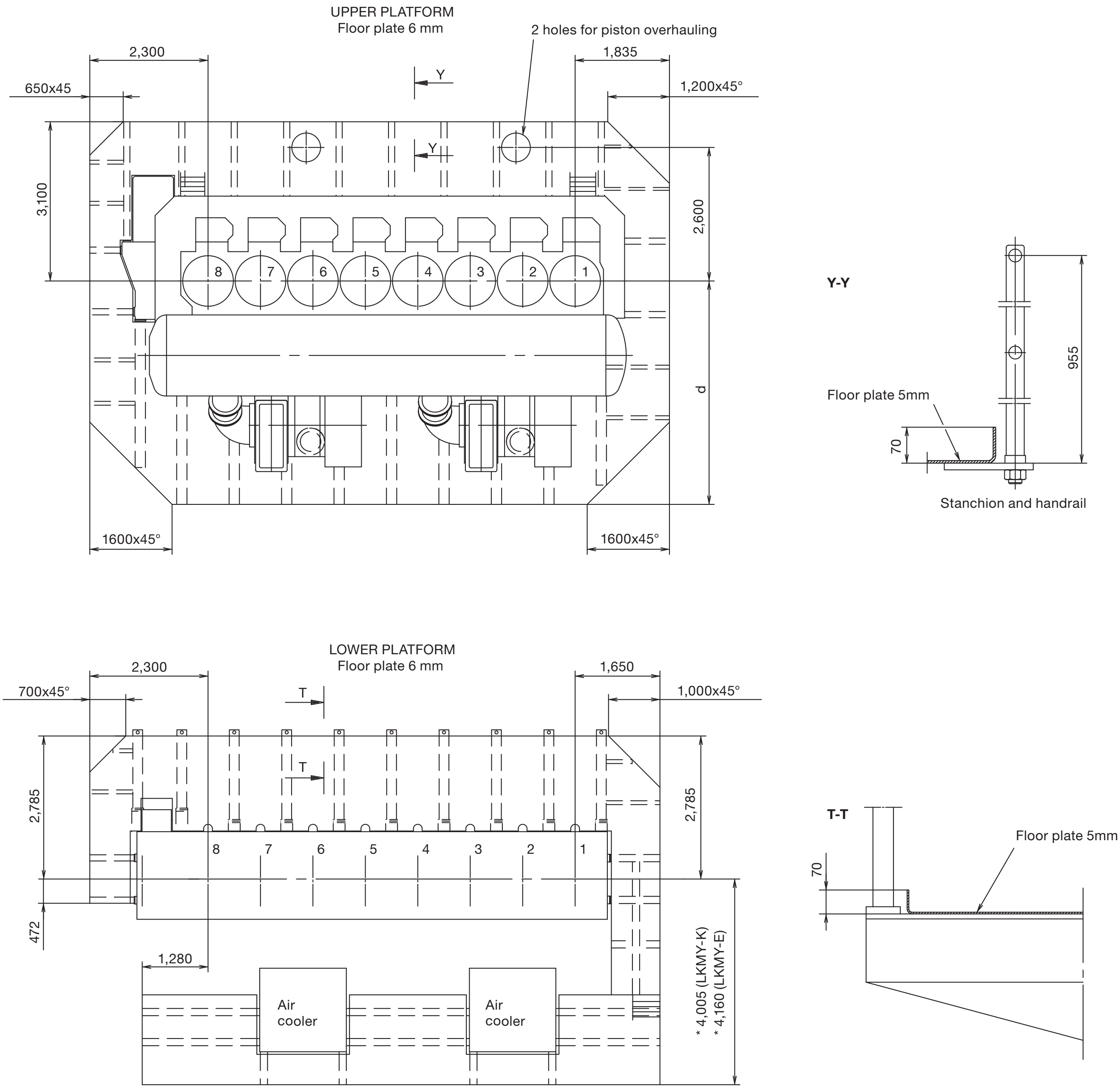
	T/C Type	a	b	c1	c2	d
MAN Diesel	TCA55-21	Available on request				
	TCA66	2,810	6,695	1,812	5,908	4,350
ABB	TPL73-B12	Available on request				
	TPL77-B12	2,655	6,582	1,770	5,850	4,100
MHI	MET53MA	Available on request				
	MET60MA	2,800	6,665	1,920	6,000	4,350
	MET66MA	2,868	6,760	1,877	5,957	4,350

Fig. 5.06.04a: Gallery outline, 5-8S60MC-C with two turbochargers on exhaust side



* LKMY - refers to type of air cooler

Fig. 5.06.04b: Gallery outline, 5-8S60MC-C with two turbochargers on exhaust side



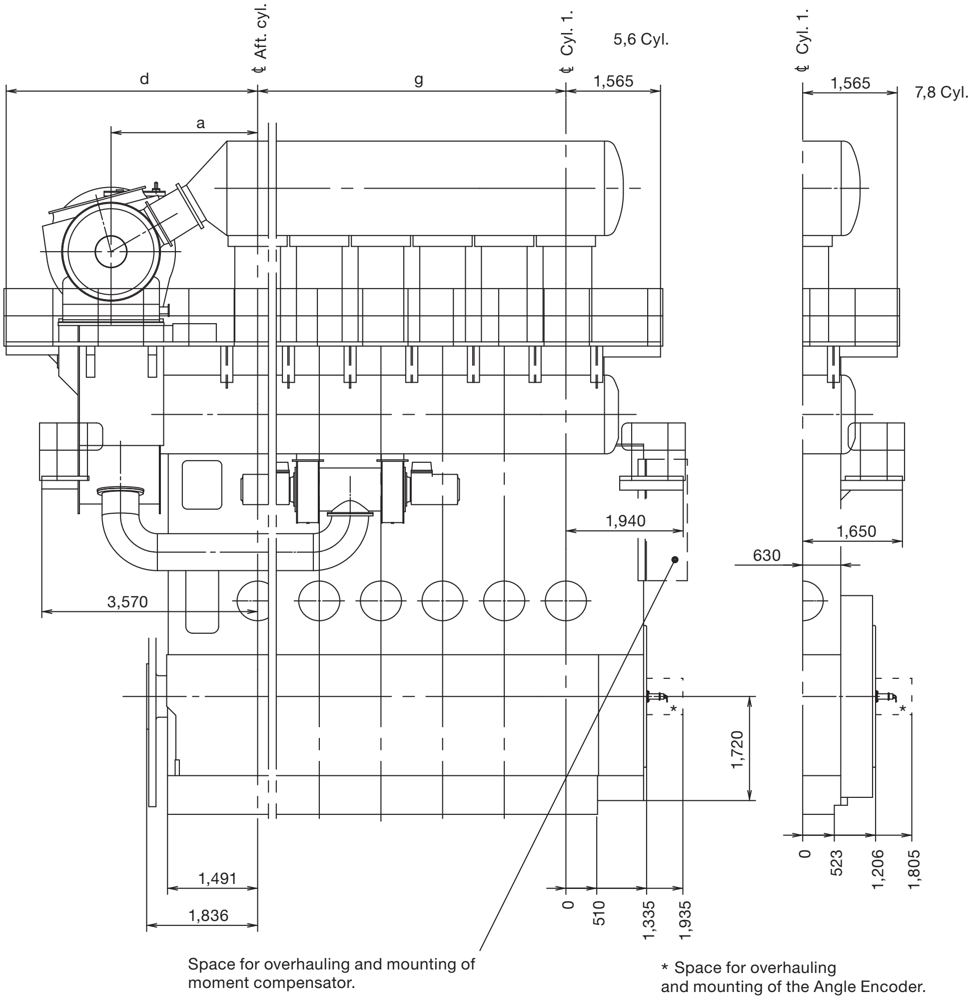
181 99 08-2.2.0

* LKMY - refers to type of air cooler

Please note that the latest version of the dimensioned drawing is available for download at www.marine.man.eu → '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.

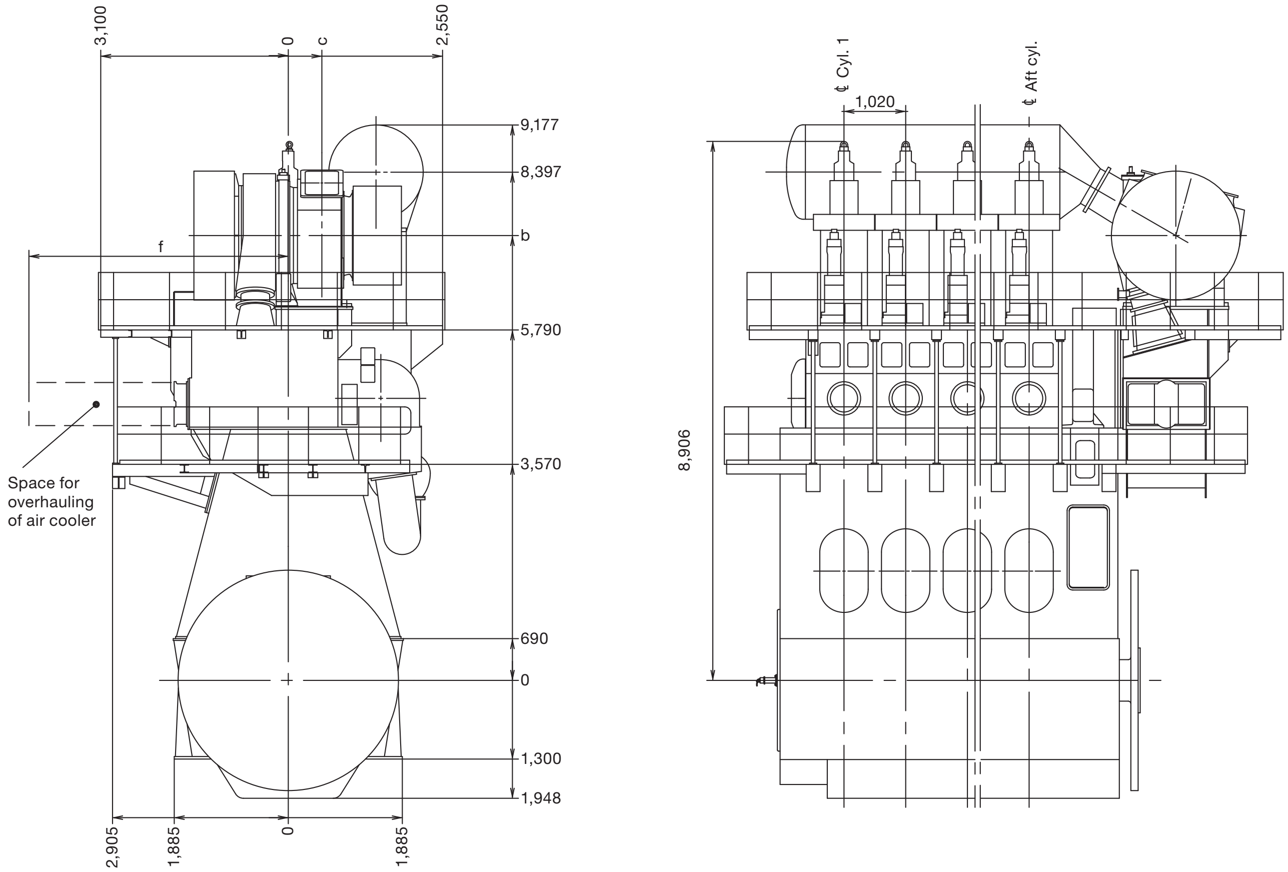
For engine dimensions, see 'Engine outline'.

Fig. 5.06.04c: Gallery outline, 5-8S60MC-C with two turbochargers on exhaust side



	T/C Type	a	b	c	d
MAN Diesel	TCA77	2,355	7,684	530	4,030
	TCA88	2,355	7,684	186	4,160
ABB	TPL77	2,150	7,000	500	3,600
	TPL80	2,280	7,234	693	3,660
	TPL85	2,463	7,535	394	4,160
MHI	MET66MA	Available on request			
	MET71MA	Available on request			
	MET83MA	2,425	7,350	505	4,160

Fig. 5.06.05a: Gallery outline, 5-8S60MC-C with turbocharger on aft end

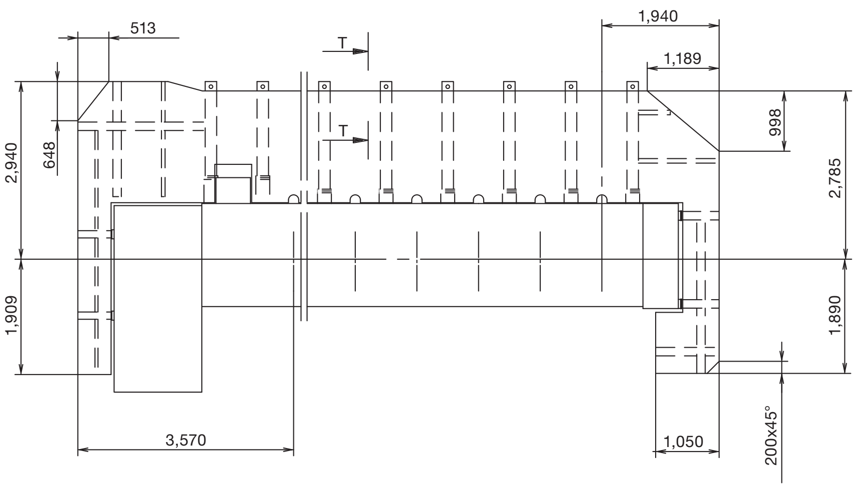


121 97 00-0.2.0

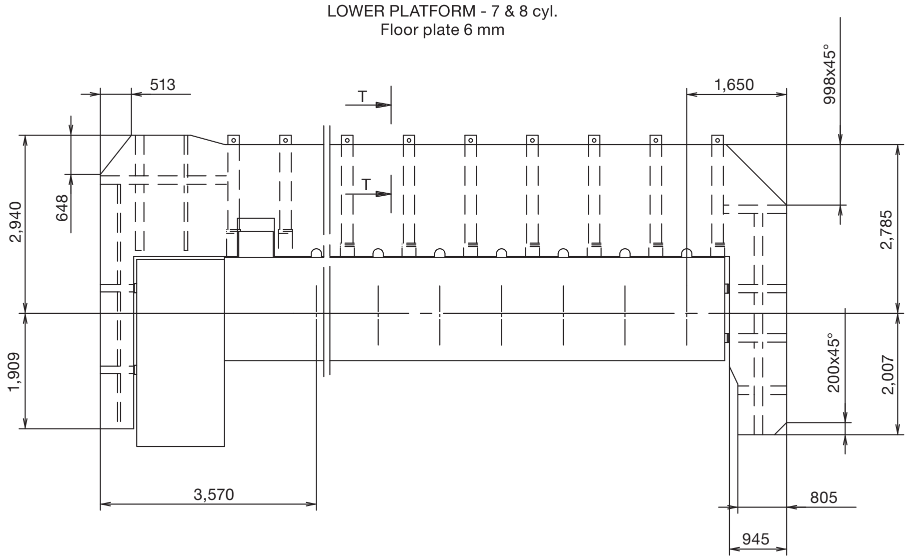
Cylinder no.	g	h
5	4,080	3,287
6	5,100	3,287
7	6,120	4,287
8	7,140	4,287

Fig. 5.06.05b: Gallery outline, 5-8S60MC-C with turbocharger on aft end

LOWER PLARFORM - 5 & 6 cyl.
Floor plate 6 mm

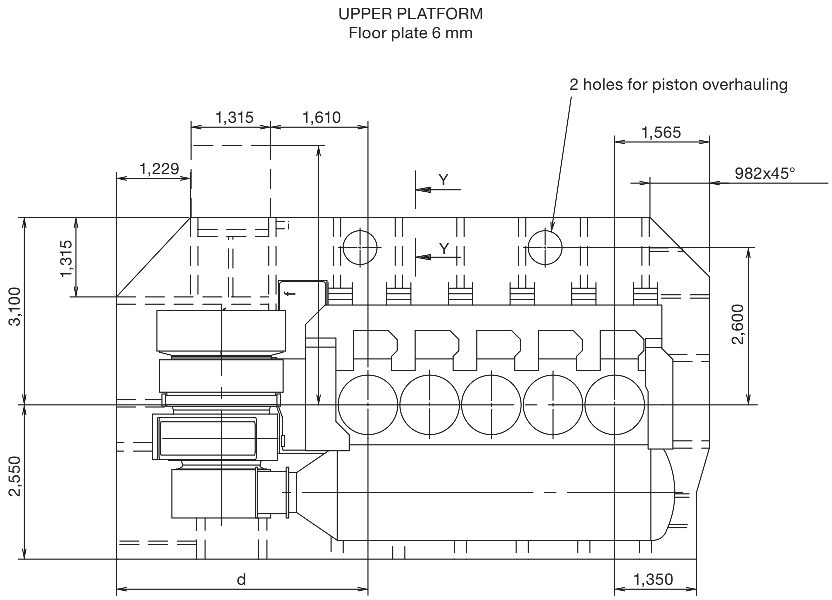


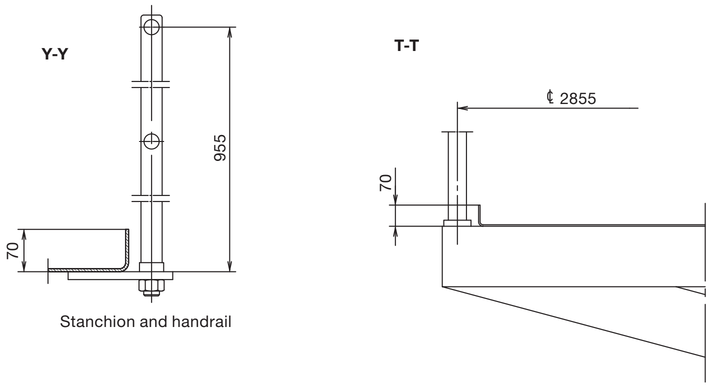
LOWER PLATFORM - 7 & 8 cyl.
Floor plate 6 mm



121 97 00-0.2.0

Fig. 5.06.06c: Gallery outline, 5-8S60MC-C with turbocharger on aft end





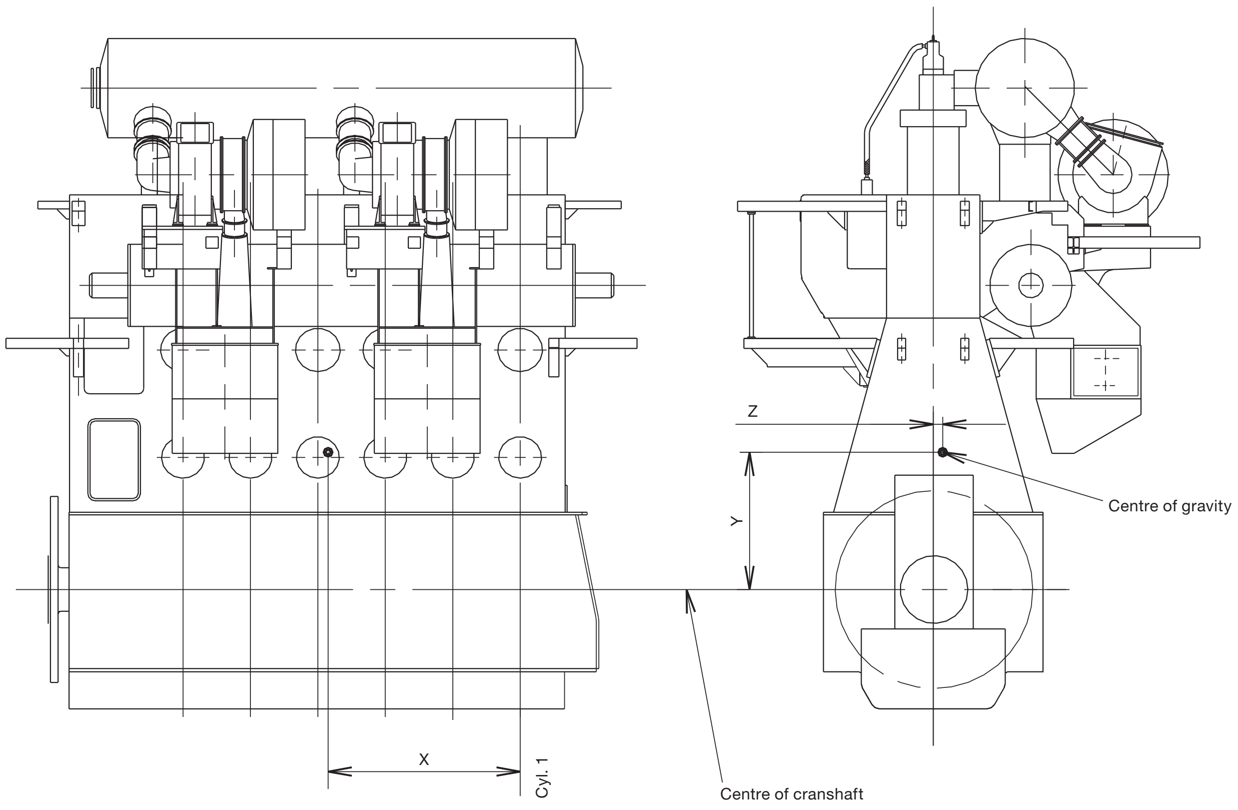
121 97 00-0.2.0

Please note that the latest version of the dimensioned drawing is available for download at www.marine.man.eu → '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 engine dimensions, see 'Engine outline'.

Fig. 5.06.06d: Gallery outline, 5-8S60MC-C with turbocharger on aft end

Centre of Gravity



For engines with two turbochargers*				
No. of cylinders	**5**	**6**	**7**	**8**
Distance X mm	2,530	3,080	3,610	4,300
Distance Y mm	2,820	2,820	2,800	2,860
Distance Z mm	90	110	110	115
DMT**	314	358	Available on request	

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

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

Mass of Water and Oil

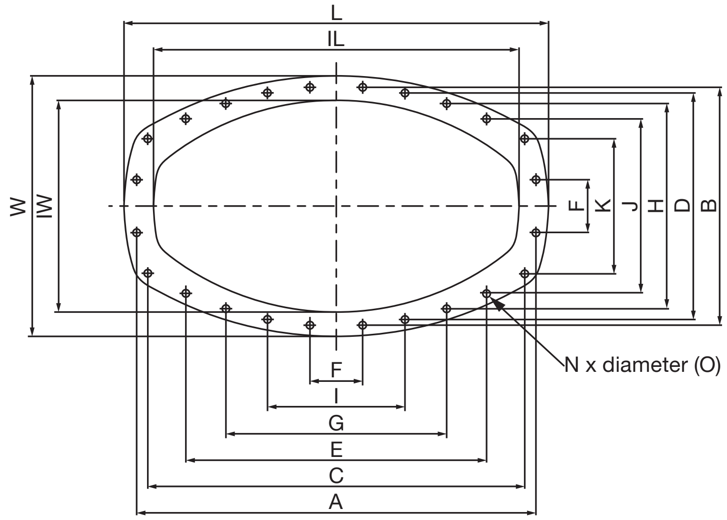
No. of cylinders	Mass of water and oil in engine in service					
	Mass of water			Mass of oil		
	Jacket cooling water kg	Scavenge air cooling water kg	Total kg	Engine system kg	Oil pan kg	Total kg
5	740	414 *	1,154	385	434	819
6	860	414 *	1,274	534	508	1,042
7	990	837 **	1,827	706	582	1,288
8	1,140	957 **	2,097	774	656	1,430

**   1 Air cooler*
*** 2 Air coolers*

Fig. 5.08.01: Water and oil in engine

Counterflanges, Connection D

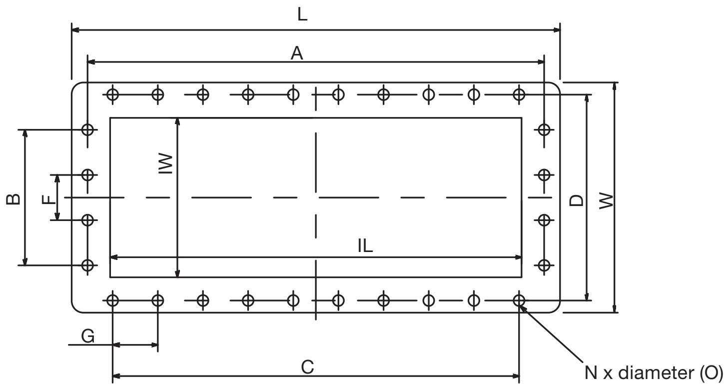
MAN Type TCA33



178 63 96-2.0

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

MAN Type TCA44-99

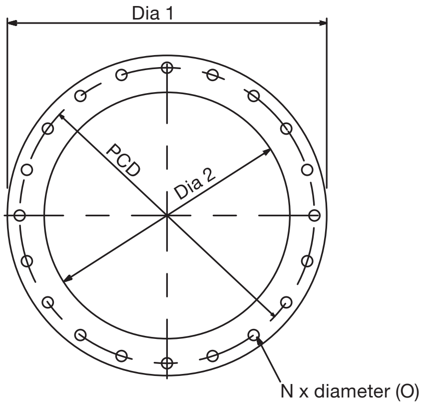


501 29 91-0.13.0a

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

Counterflanges, Connection D

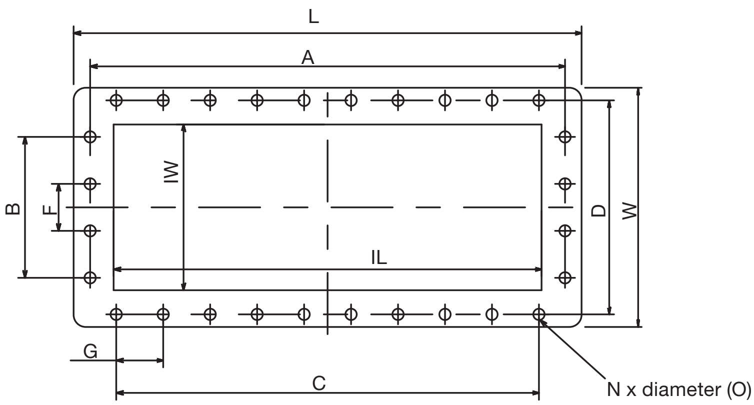
MAN Type TCR



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

501 29 91-0.13.0a

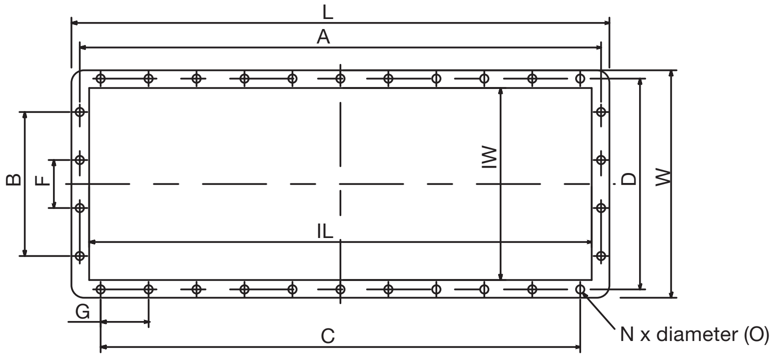
ABB Type A100/A200-L



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

501 29 91-0.13.0b

MHI Type MET



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

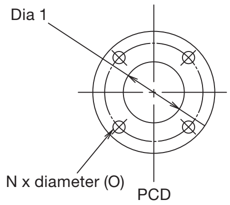
501 29 91-0.13.0d

Fig. 5.10.02: Turbocharger, exhaust outlet

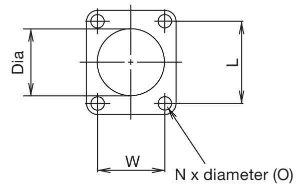
Counterflanges, Connection E

MAN Type TCA

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



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



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

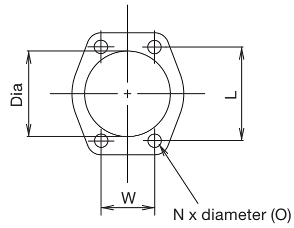
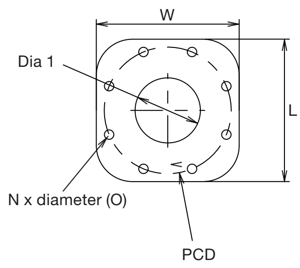


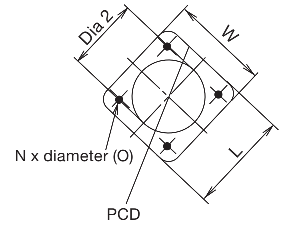
ABB Type A100/A200-L

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

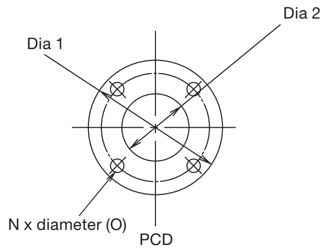


MHI Type MET MB
Air vent

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

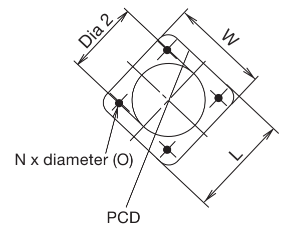


TC	Dia 1	Dia 2	PCD	N	O	Thickness of flanges (A)
MET71MB	180	90	145	4	18	14
MET83MB	200	115	165	4	18	16
MET90MB	200	115	165	4	18	16



MHI Type MET MB
Cooling air

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



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

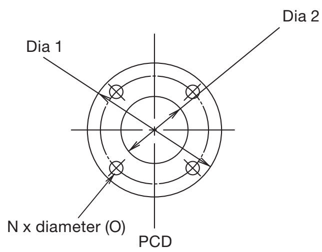
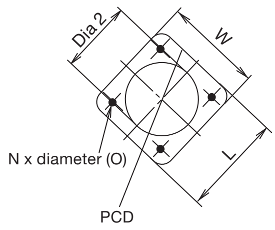


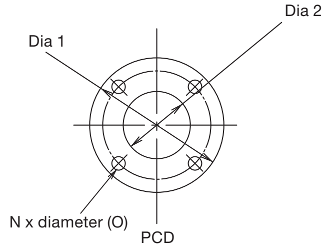
Fig. 5.10.03: Venting of lubricating oil discharge pipe for turbochargers

MHI Type MET MB

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

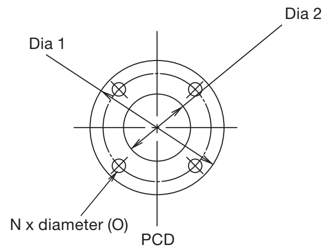


TC	Dia 1	Dia 2	PCD	N	O	Thickness of flanges (A)
MET83MB	180	90	145	4	18	14

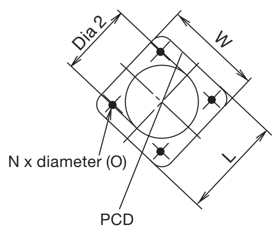


Connection EB

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



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



501 29 91-0.13.0c

Engine Seating and Holding Down Bolts

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

Engine seating and arrangement of holding down bolts

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

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

The epoxy types approved by MAN Diesel & Turbo are:

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

Epoxy Chocks Arrangement

For details of chocks and bolts see special drawings.

For securing of supporting chocks see special drawing.

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

1) The engine builder drills the holes for holding down bolts in the bedplate while observing the toleranced locations indicated on MAN B&W Diesel & Turbos 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 are made in accordance with MAN B&W Diesel & Turbos drawings of these bolts.

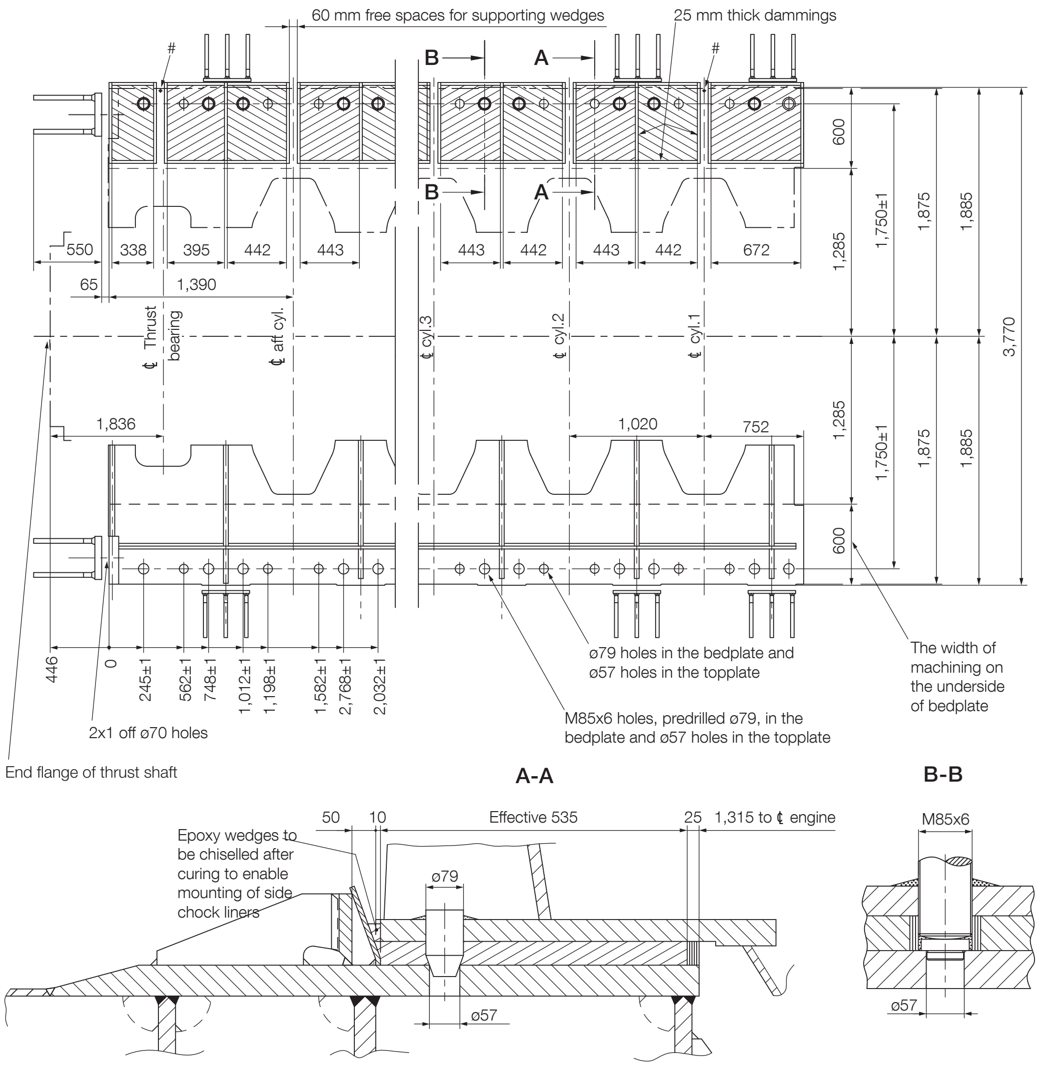
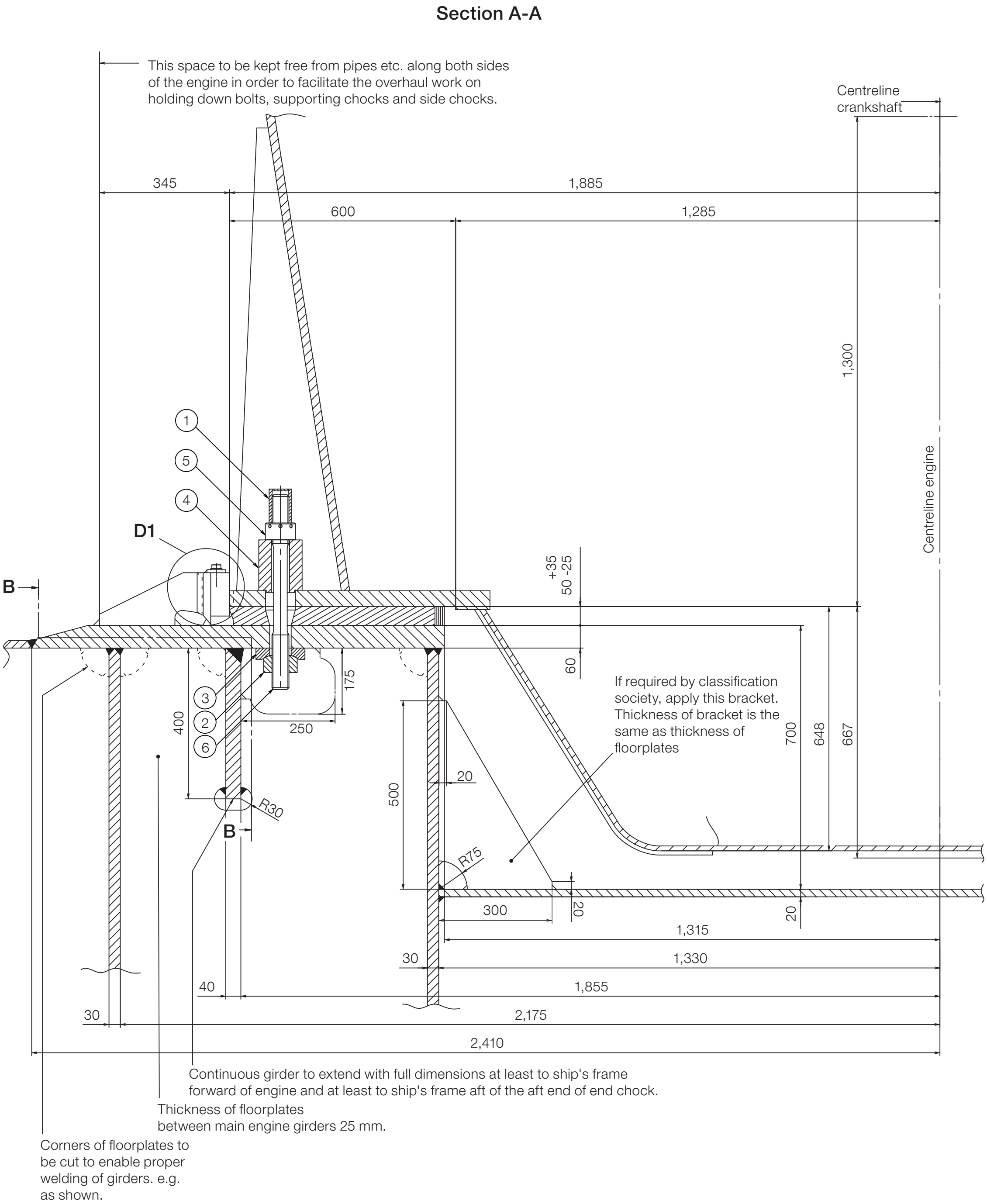


Fig. 5.12.01: Arrangement of epoxy chocks and holding down bolts

079 25 51-2.2.0

Engine Seating Profile

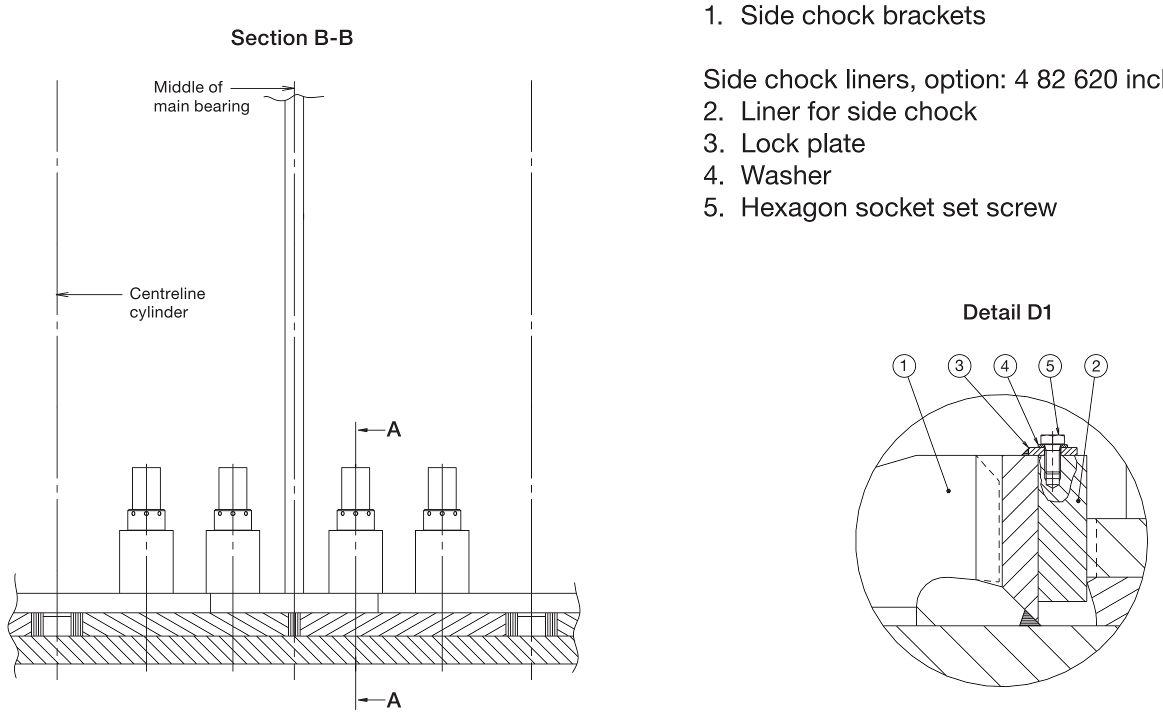


Holding down bolts, option: 4 82 602 include:

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

078 72 73-1.8.0a

Fig.5.12.02a: Profile of engine seating with vertical oil outlet

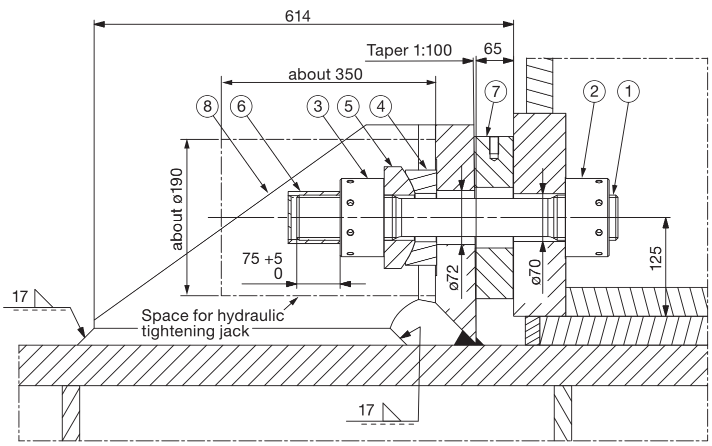


Side chock brackets, option: 4 82 622 includes:
1. Side chock brackets

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

078 72 73-1.7.0b

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



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

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

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

079 29 21-5.2.0

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 Diesel & Turbo recommends that top bracing is installed between the engine's upper platform brackets and the casing side.

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

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

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

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

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

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

Mechanical top bracing

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

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

The mechanical top bracing is to be made by the shipyard in accordance with MAN Diesel & Turbo instructions.

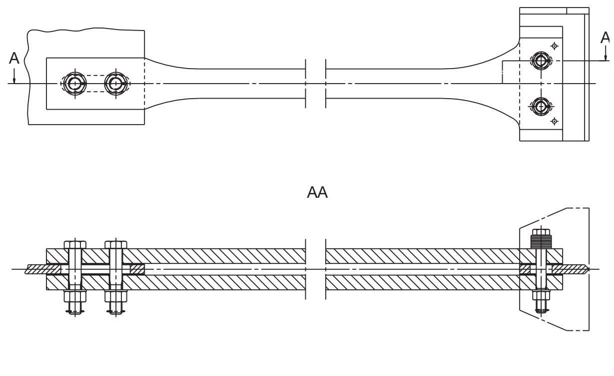


Fig. 5.13.01: Mechanical top bracing stiffener. Option: 4 83 112

Hydraulic top bracing

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

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

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

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

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

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

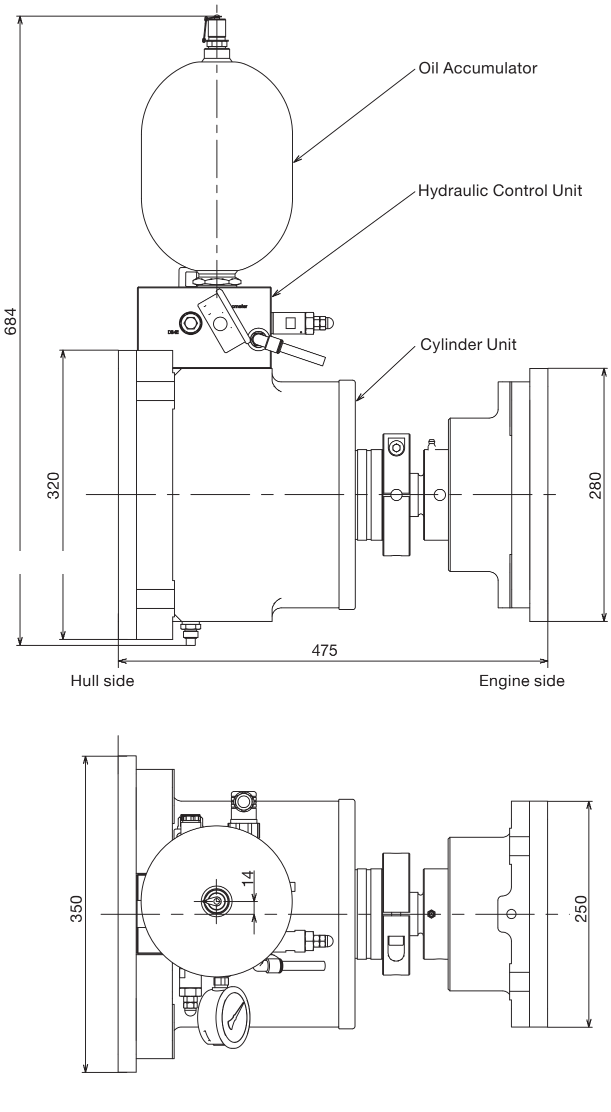
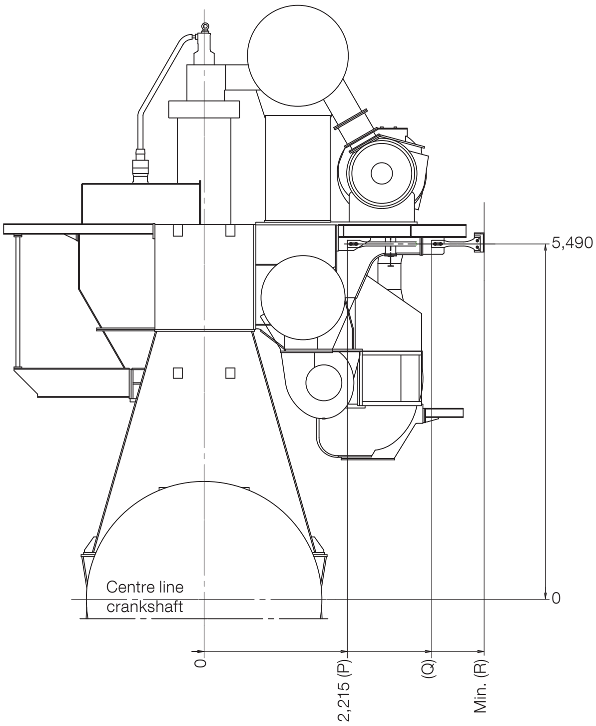
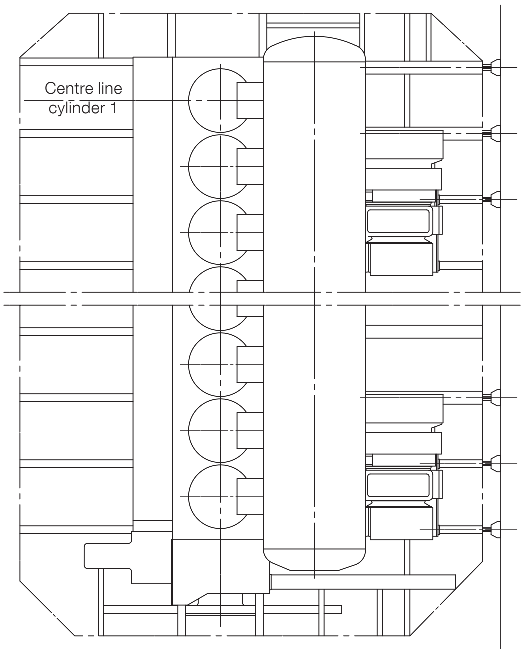
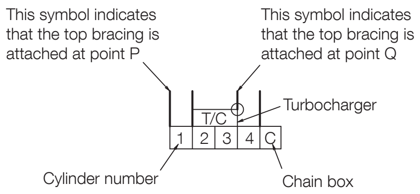


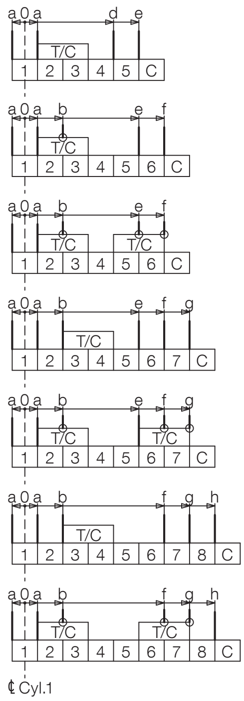
Fig. 5.13.02: Outline of a hydraulic top bracing unit. The unit is installed with the oil accumulator pointing either up or down. Option: 4 83 123

Mechanical Top Bracing









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

a	=	510	f	=	5,610
b	=	1,530	g	=	6,630
d	=	3,570	h	=	7,650
e	=	4,590			

Horizontal vibrations on top of engine are caused by the guide force moments. For 4-7 cylinder engines the H-moment is the major excitation source and for larger cylinder numbers an X-moment is the major excitation source.

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

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

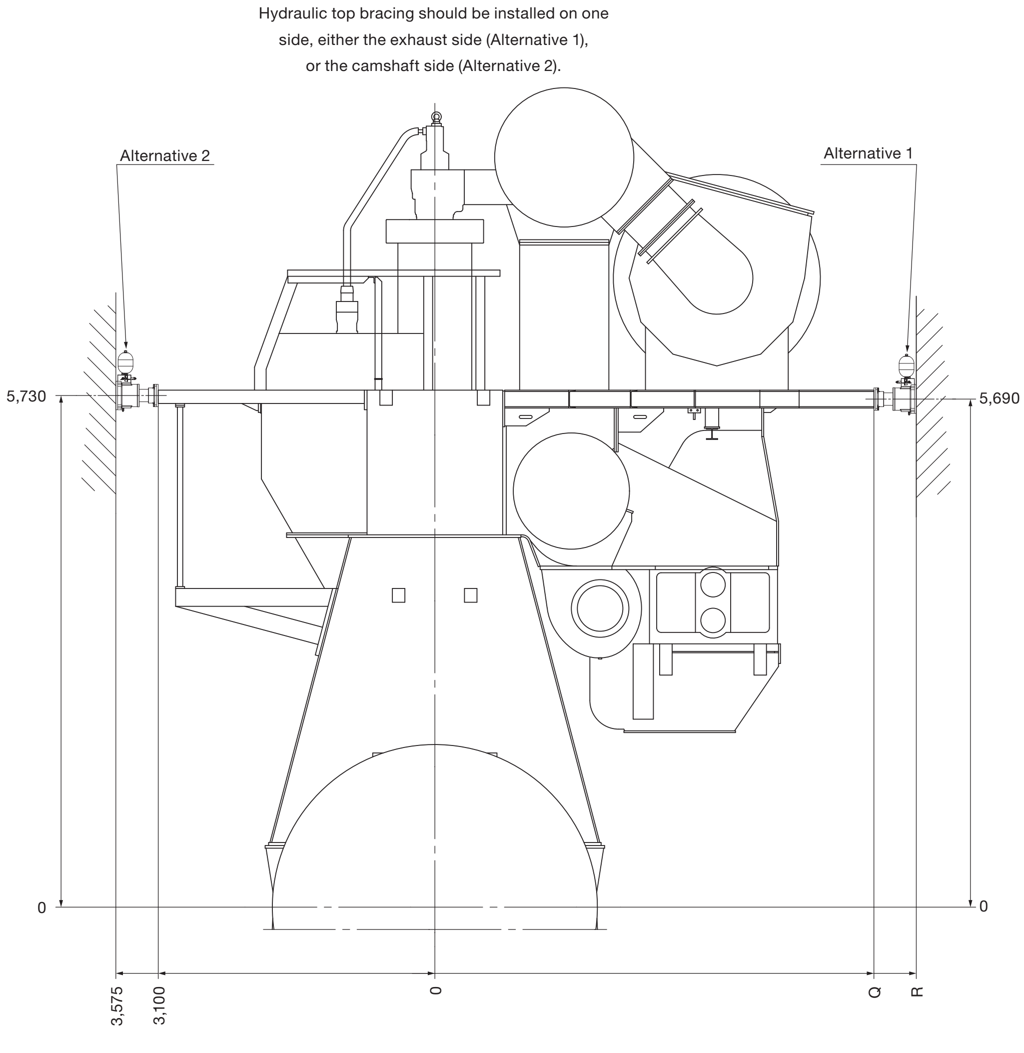
If the minimum built-in length can not be fulfilled, please contact MAN Diesel & Turbo or our local representative.

The complete arrangement to be delivered by the shipyard.

Turbocharger	Q	R
TCA66	3,540	4,535
TCA77	3,855	4,850
A-L	Available on request	
MET53	3,520	4,330
MET60	3,640	4,540
MET66	3,780	4,590
MET71	3,780	4,590
MET83	4,160	5,100

Fig. 5.14: Mechanical top bracing arrangement

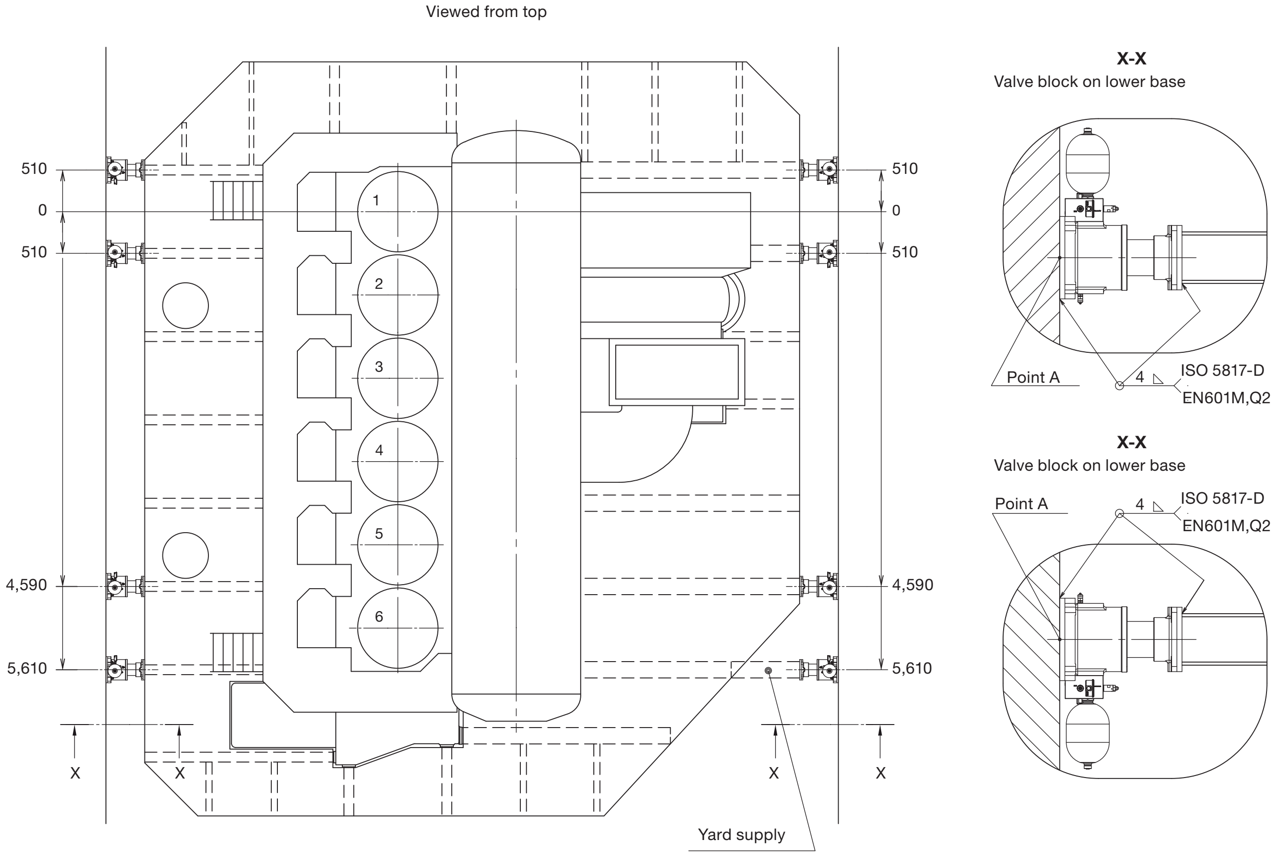
Hydraulic Top Bracing Arrangement



Turbocharger	Q	R
TCA66	4,350	4,825
TCA77	4,660	5,135
A175-L	4,450	4,925
A180-L	4,920	5,395
MET60MA/MB	4,350	4,825
MET66MA/MB	4,450	4,925
MET71MA/MB	4,390	4,865
MET71MA/MB	4,920	5,395

078 78 99-8.1.0

Fig. 5.15.01: Hydraulic top bracing data



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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: 82 kN

Max. corresponding deflection of casing side: 0.32 mm

In the horizontal and vertical direction of the hydraulic top bracing:
Force per bracing: 15 kN

Max. correcponding deflection of casing side : 2.00 mm

Fig. 5.15.01: Hydraulic top bracing data

Components for Engine Control System

This section is not applicable

Shaftline Earthing Device

Scope and field of application

A difference in the electrical potential between the hull and the propeller shaft will be generated due to the difference in materials and to the propeller being immersed in sea water.

In some cases, the difference in the electrical potential has caused spark erosion on the thrust, main bearings and journals of the crankshaft of the engine.

In order to reduce the electrical potential between the crankshaft and the hull and thus prevent spark erosion, a highly efficient shaftline earthing device must be installed.

The shaftline earthing device should be able to keep the electrical potential difference below 50 mV DC. A shaft-to-hull monitoring equipment with a mV-meter and with an output signal to the alarm system must be installed so that the potential and thus the correct function of the shaftline earthing device can be monitored.

Note that only one shaftline earthing device is needed in the propeller shaft system.

Design description

The shaftline earthing device consists of two silver slip rings, two arrangements for holding brushes including connecting cables and monitoring equipment with a mV-meter and an output signal for alarm.

The slip rings should be made of solid silver or back-up rings of cobber with a silver layer all over. The expected life span of the silver layer on the slip rings should be minimum 5 years.

The brushes should be made of minimum 80% silver and 20% graphite to ensure a sufficient electrical conducting capability.

Resistivity of the silver should be less than 0.1μ Ohm x m. The total resistance from the shaft to the hull must not exceed 0.001 Ohm.

Cabling of the shaftline earthing device to the hull must be with a cable with a cross section not less than 45 mm². The length of the cable to the hull should be as short as possible.

Monitoring equipment should have a 4-20 mA signal for alarm and a mV-meter with a switch for changing range. Primary range from 0 to 50 mV DC and secondary range from 0 to 300 mV DC.

When the shaftline earthing device is working correctly, the electrical potential will normally be within the range of 10-50 mV DC depending of propeller size and revolutions.

The alarm set-point should be 80 mV for a high alarm. The alarm signals with an alarm delay of 30 seconds and an alarm cut-off, when the engine is stopped, must be connected to the alarm system.

Connection of cables is shown in the sketch, see Fig. 5.17.01.

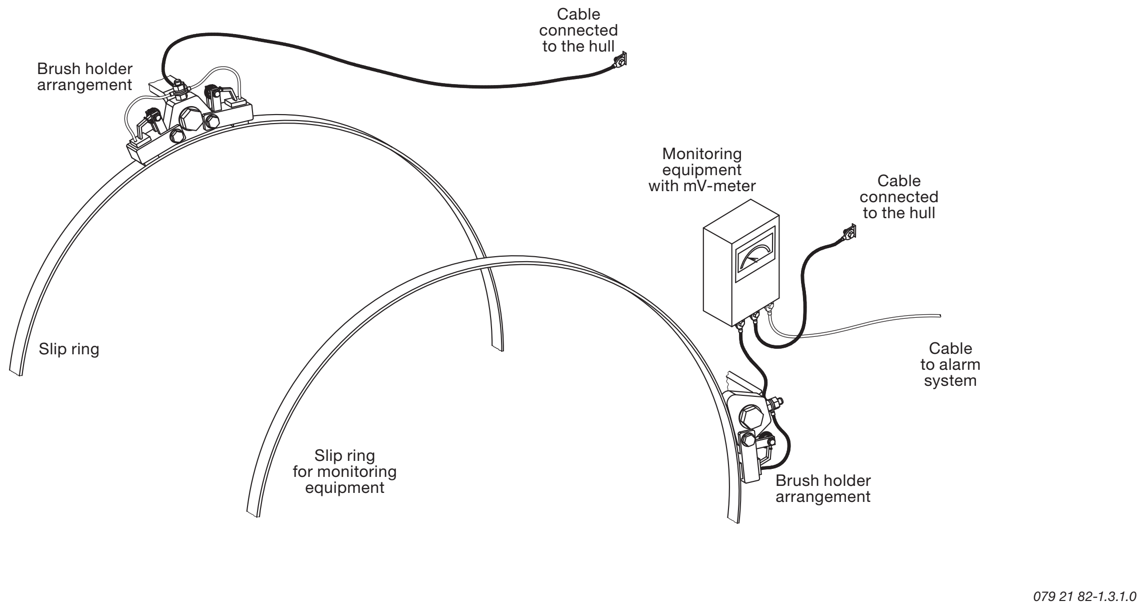

Fig. 5.17.01: Connection of cables for the shaftline earthing device

Shaftline earthing device installations

The shaftline earthing device slip rings must be mounted on the foremost intermediate shaft as close to the engine as possible, see Fig. 5.17.02

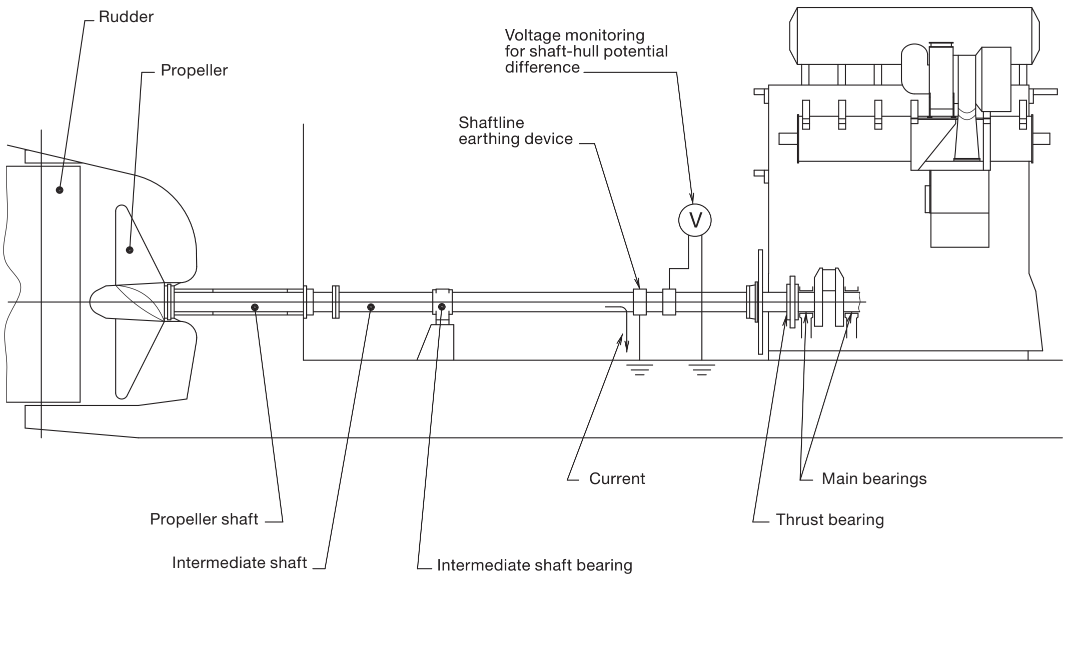

Fig. 5.17.02: Installation of shaftline earthing device in an engine plant without shaft-mounted generator

When a generator is fitted in the propeller shaft system, where the rotor of the generator is part of the intermediate shaft, the shaftline earthing device must be mounted between the generator and the engine, see Fig. 5.17.03

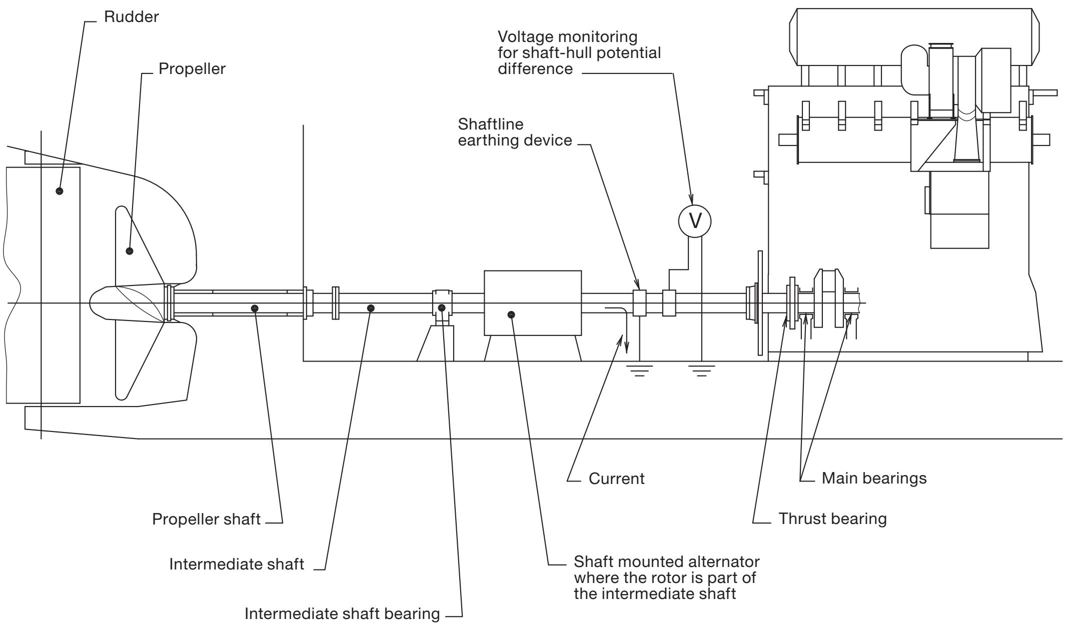

Fig. 5.17.03: Installation of shaftline earthing device in an engine plant with shaft-mounted generator

MAN Alpha Controllable Pitch Propeller and Alphatronic Propulsion Control

MAN Diesel & Turbo's MAN Alpha Controllable Pitch propeller

On MAN Diesel & Turbo's MAN Alpha VBS type Controllable Pitch (CP) propeller, the hydraulic servo motor setting the pitch is built into the propeller hub. A range of different hub sizes is available to select an optimum hub for any given combination of power, revolutions and ice class.

Standard blade/hub materials are Ni-Al-bronze. Stainless steel is available as an option. The propellers are based on 'no ice class' but are available up to the highest ice classes.

VBS type CP propeller designation and range

The VBS type CP propellers are designated according to the diameter of their hubs, i.e. 'VBS2150' indicates a propeller hub diameter of 2,150 mm.

The standard VBS type CP propeller programme, its diameters and the engine power range covered is shown in Fig. 5.18.01.

The servo oil system controlling the setting of the propeller blade pitch is shown in Fig.5.18.05.

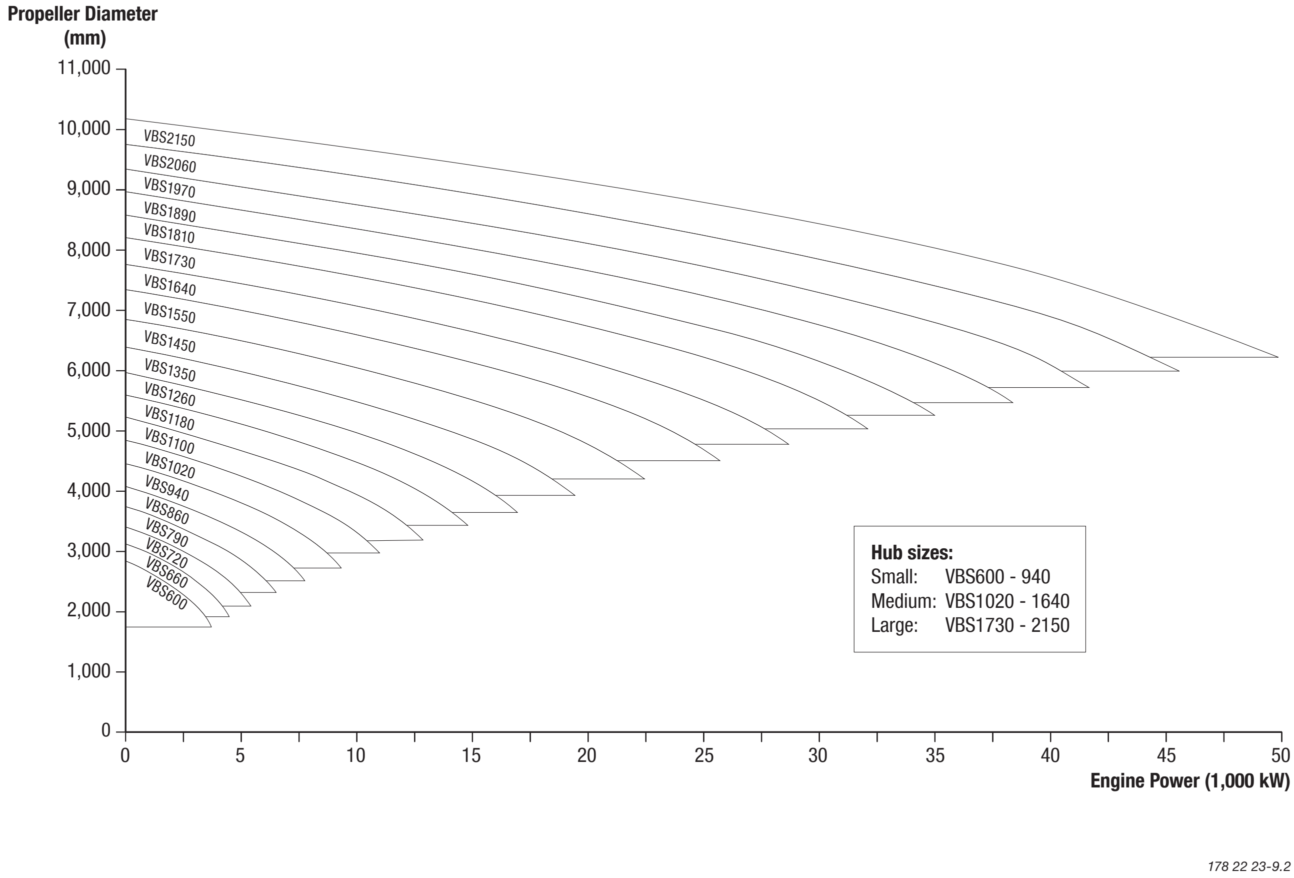

Fig. 5.18.01: MAN Alpha type VBS Mk 5 Controllable Pitch (CP) propeller range. As standard the VBS Mk 5 versions are 4-bladed; 5-bladed versions are available on request

Data Sheet for Propeller

Identification: ______________________________

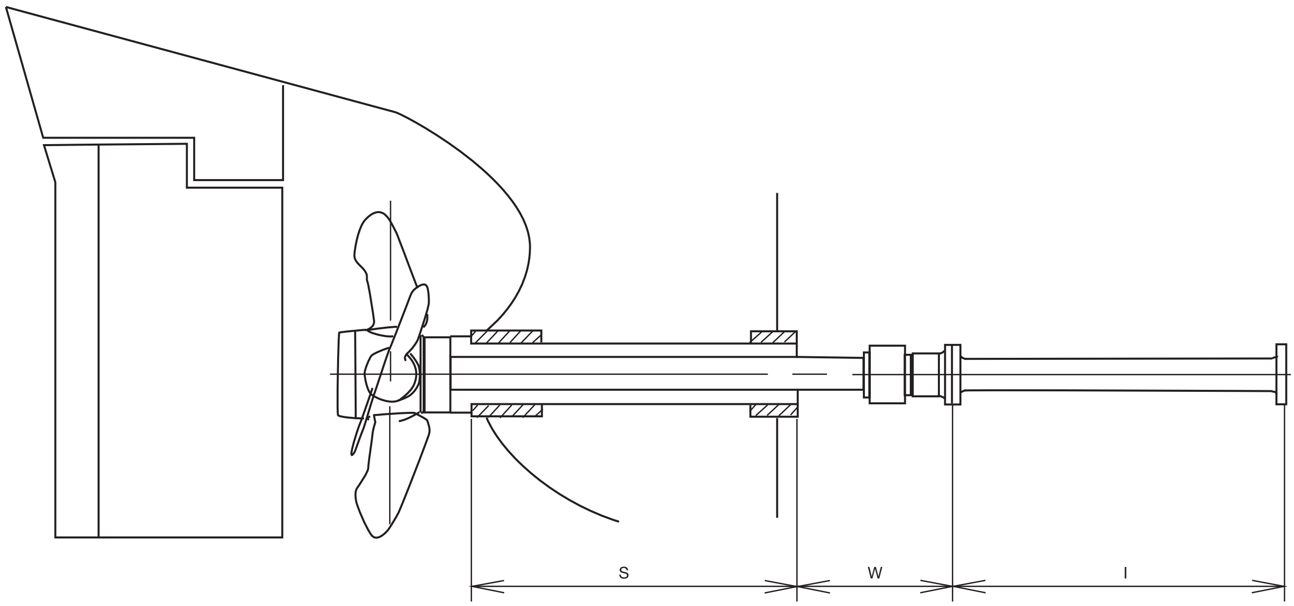

Fig. 5.18.02a: Dimension sketch for propeller design purposes

Type of vessel: ______________________________
For propeller design purposes please provide us with the following information:

1. S: _____________ mm
   W: _____________ mm
   I: _______________ mm (as shown above)

2. Stern tube and shafting arrangement layout

3. Propeller aperture drawing

4. Complete set of reports from model tank (resistance test, self-propulsion test and wake measurement). In case model test is not available the next page should be filled in.

5. Drawing of lines plan

6. Classification Society: _________
   Ice class notation: ____________

7. Maximum rated power of shaft generator: kW

8. Optimisation condition for the propeller:
   To obtain the highest propeller efficiency please identify the most common service condition for the vessel.

   Ship speed: __________________________ kn
   Engine service load: ___________________ %
   Service/sea margin: ___________________ %
   Shaft generator service load: ____________ kW
   Draft: _________________________________ m

9. Comments:

Table 5.18.02b: Data sheet for propeller design purposes

Main Dimensions

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

178 22 97-0.0

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

Propeller clearance

To reduce pressure impulses and vibrations emitted from the propeller to the hull, MAN Diesel & Turbo recommends a minimum tip clearance as shown in Fig. 5.18.04.

For ships with slender aft body and favourable inflow conditions the lower values can be used, whereas full afterbody and large variations in wake field cause the upper values to be used.

In twin-screw ships the blade tip may protrude below the base line.

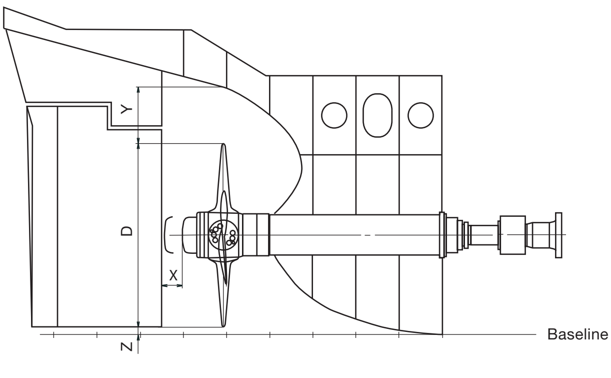

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Fig. 5.18.04: Propeller clearance

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			

216 56 93-7.3.1

Servo oil system for VBS type CP propeller

The design principle of the servo oil system for MAN Diesel & Turbo's MAN Alpha VBS type CP propeller is shown in Fig. 5.18.05.

The VBS system consists of a servo oil tank unit, the Hydraulic Power Unit, and a coupling flange with electrical pitch feedback box and oil distributor ring.

The electrical pitch feedback box continuously measures the position of the pitch feedback ring and compares this signal with the pitch order signal.

If deviation occurs, a proportional valve is actuated. Hereby high pressure oil is fed to one or the other side of the servo piston, via the oil distributor ring, until the desired propeller pitch has been reached.

The pitch setting is normally remote controlled, but local emergency control is possible.

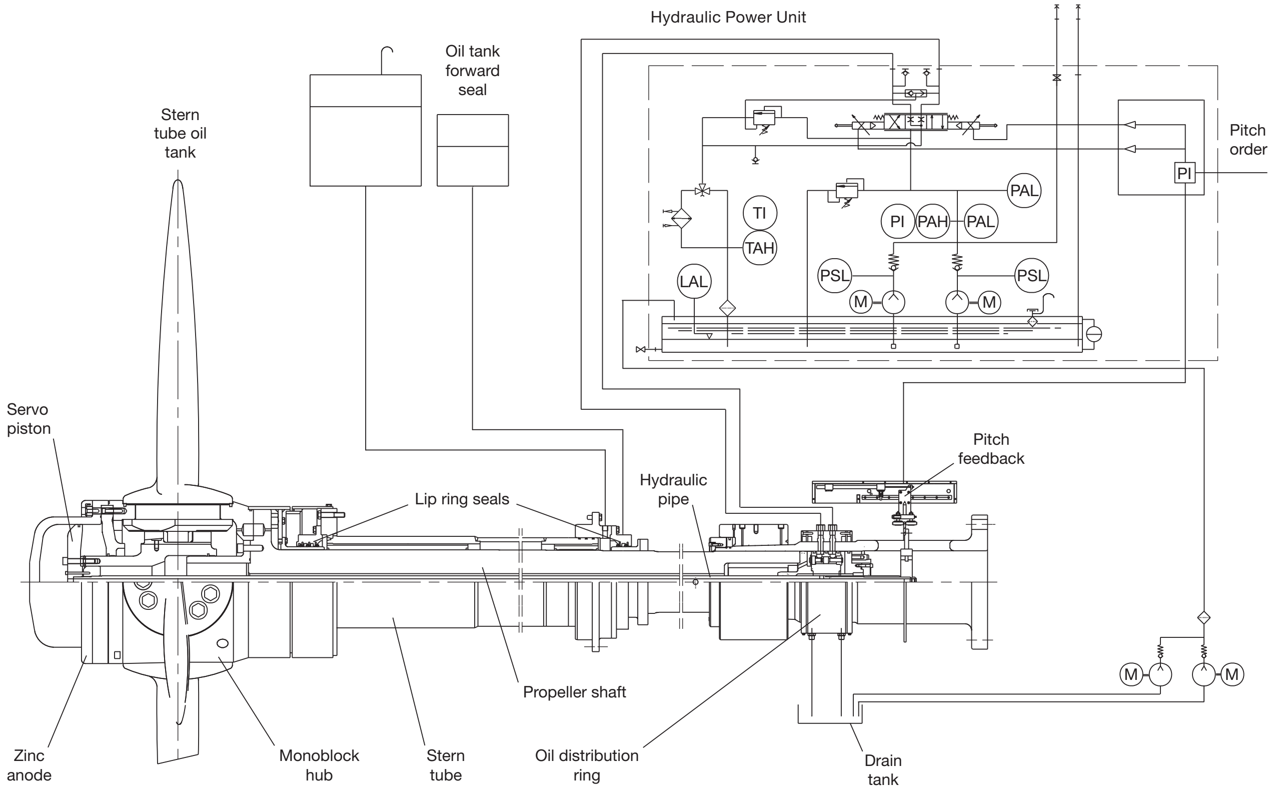

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Fig. 5.18.05: Servo oil system for MAN Alpha VBS type CP propeller

Hydraulic Power Unit for MAN Alpha CP propeller

The servo oil tank unit, the Hydraulic Power Unit for MAN Diesel & Turbo's MAN Alpha CP propeller shown in Fig. 5.18.06, consists of an oil tank with all other components top mounted to facilitate installation at yard.

Two electrically driven pumps draw oil from the oil tank through a suction filter and deliver high pressure oil to the proportional valve.

One of two pumps are in service during normal operation, while the second will start up at powerful manoeuvring.

A servo oil pressure adjusting valve ensures minimum servo oil pressure at any time hereby minimizing the electrical power consumption.

Maximum system pressure is set on the safety valve.

The return oil is led back to the tank via a thermostatic valve, cooler and paper filter.

The servo oil unit is equipped with alarms according to the Classification Society's requirements as well as necessary pressure and temperature indicators.

If the servo oil unit cannot be located with maximum oil level below the oil distribution ring, the system must incorporate an extra, small drain tank complete with pump, located at a suitable level, below the oil distributor ring drain lines.

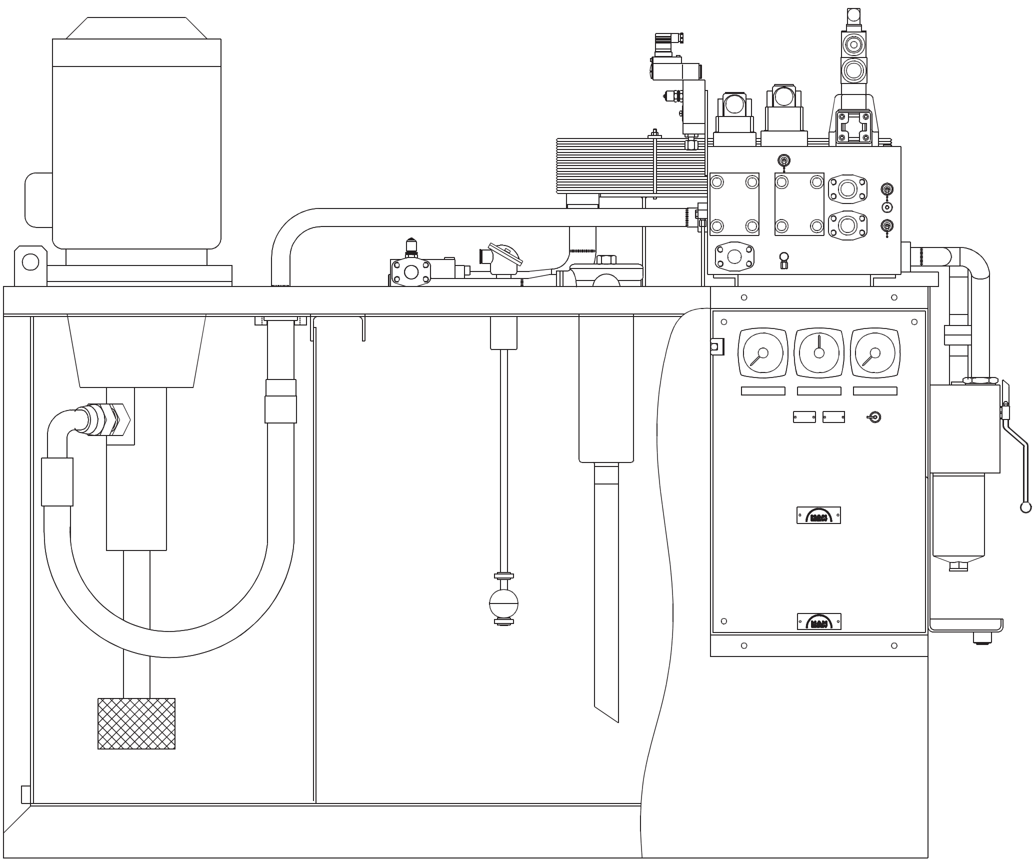

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Fig. 5.18.06: Hydraulic Power Unit for MAN Alpha CP propeller, the servo oil tank unit

MAN Alphatronic 2000 Propulsion Control System

MAN Diesel & Turbo's MAN Alphatronic 2000 Propulsion Control System (PCS) is designed for control of propulsion plants based on diesel engines with CP propellers. The plant could for instance include tunnel gear with PTO/PTI, PTO gear, multiple engines on one gearbox as well as multiple propeller plants.

As shown in Fig. 5.18.07, the propulsion control system comprises a computer controlled system with interconnections between control stations via a redundant bus and a hard wired back-up control system for direct pitch control at constant shaft speed.

The computer controlled system contains functions for:

- Machinery control of engine start/stop, engine load limits and possible gear clutches.
- Thrust control with optimization of propeller pitch and shaft speed. Selection of combinator, constant speed or separate thrust mode is possible. The rates of changes are controlled to ensure smooth manoeuvres and avoidance of propeller cavitation.
- A **Load control** function protects the engine against overload. The load control function contains a scavenge air smoke limiter, a load programme for avoidance of high thermal stresses in the engine, an automatic load reduction and an engineer controlled limitation of maximum load.
- Functions for **transfer of responsibility** between the local control stand, engine control room and control locations on the bridge are incorporated in the system.

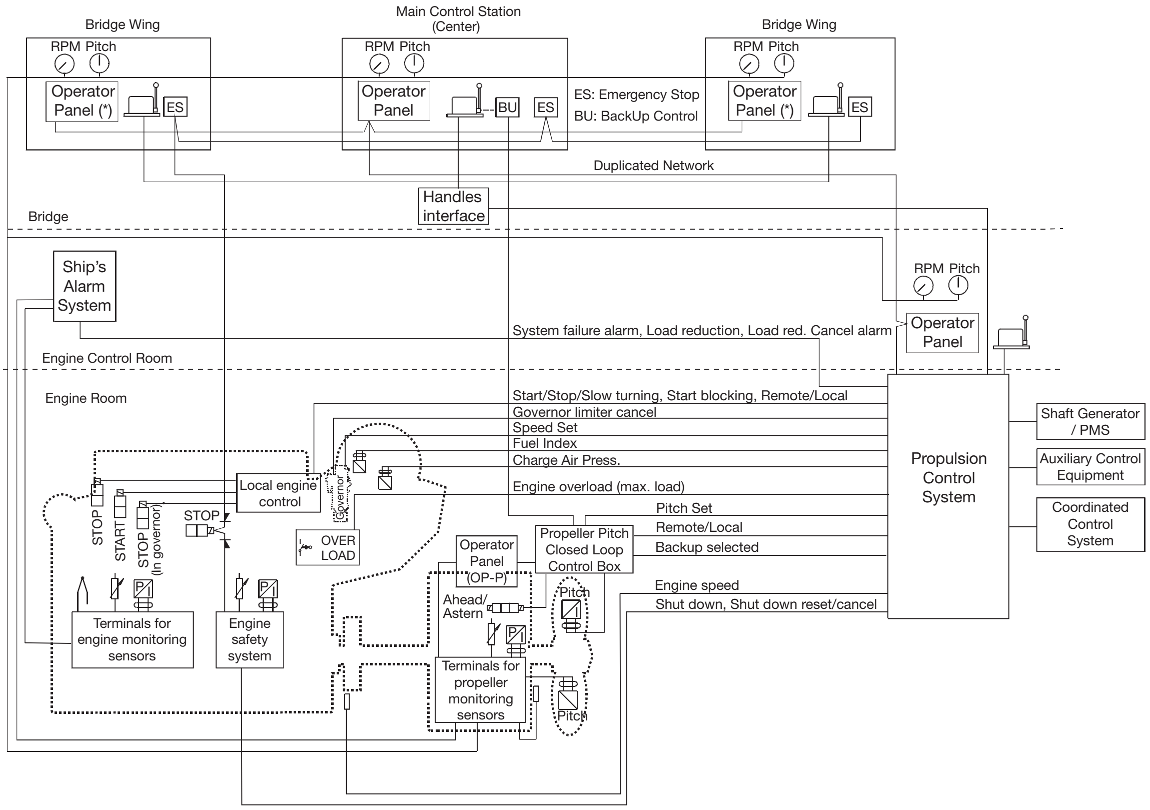

Fig. 5.18.07: MAN Alphatronic 2000 Propulsion Control System

Propulsion control station on the main bridge

For remote control, a minimum of one control station located on the bridge is required.

This control station will incorporate three modules, as shown in Fig. 5.18.08:

- **Propulsion control panel** with push buttons and indicators for machinery control and a display with information of condition of operation and status of system parameters.
- **Propeller monitoring panel** with back-up instruments for propeller pitch and shaft speed.
- **Thrust control panel** with control lever for thrust control, an emergency stop button and push buttons for transfer of control between control stations on the bridge.

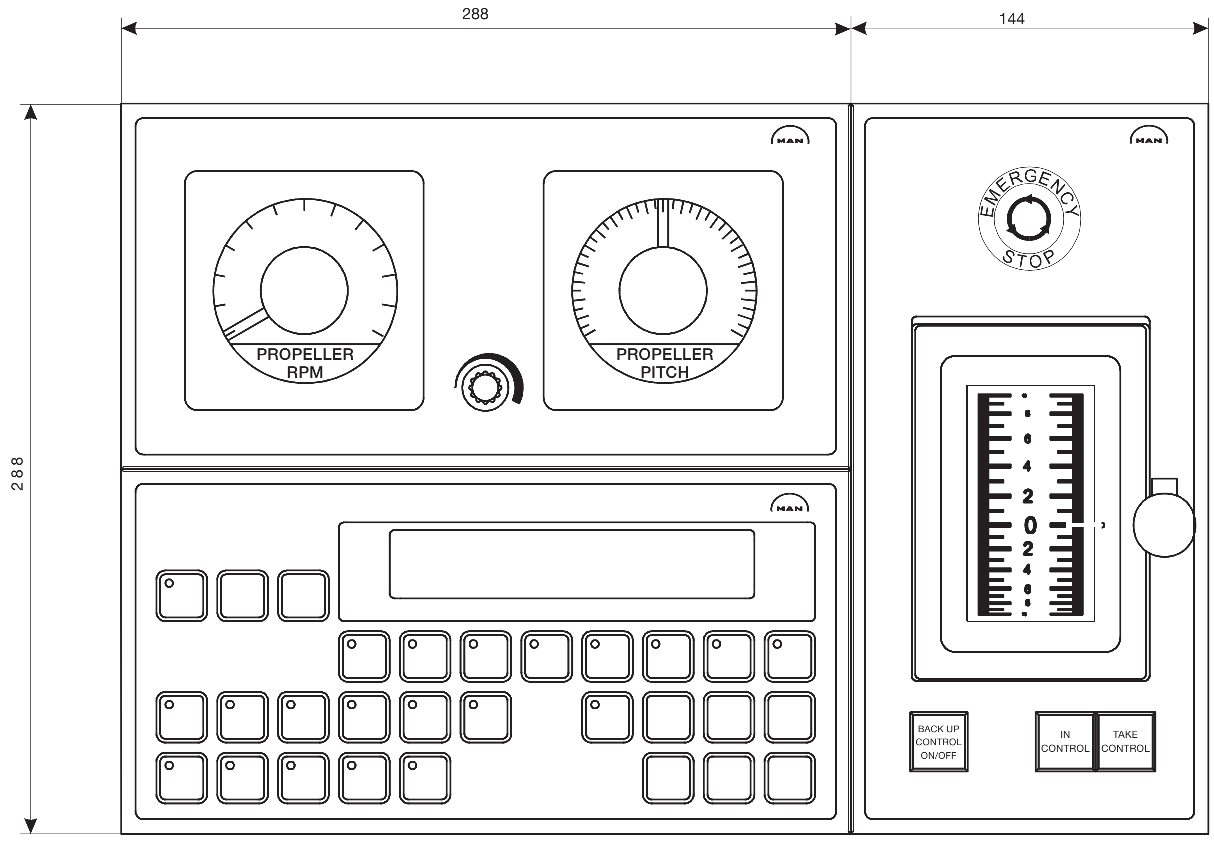

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Fig. 5.18.08: Main bridge station standard layout

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 Diesel & Turbo's MAN Alpha Controllable Pitch (CP) propeller and the Alphatronic 2000 Remote Control System, please refer to our publications:

CP Propeller – Product Information

Alphatronic 2000 PCS Propulsion Control System

The publications are available at www.marine.man.eu → 'Propeller & Aft Ship'.

List of Capacities: Pumps, Coolers & Exhaust Gas

6

Calculation of List of Capacities and Exhaust Gas Data

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

This chapter describes the necessary auxiliary machinery capacities to be used for a nominally rated engine. The capacities given are valid for seawater cooling system and central cooling water system, respectively. For derated engine, i.e. with a specified MCR different from the nominally rated MCR point, the list of capacities will be different from the nominal capacities.

Furthermore, among others, the exhaust gas data depends on the ambient temperature conditions.

Based on examples for a derated engine, the way of how to calculate the derated capacities, freshwater production and exhaust gas amounts and temperatures will be described in details.

Nomenclature

In the following description and examples of the auxiliary machinery capacities, freshwater generator production and exhaust gas data, the below nomenclatures are used:

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

Fig. 6.01.01: Nomenclature of basic engine ratings

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

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

Engine configurations related to SFOC

The engine type is available in the following version only with respect to the efficiency of the turbocharger:

With high efficiency turbocharger, which is the basic design and for which the lists of capacities Section 6.03 are calculated.

List of Capacities and Cooling Water Systems

The List of Capacities contain data regarding the necessary capacities of the auxiliary machinery for the main engine only, and refer to a nominally rated engine. Complying with IMO Tier II NO_x limitations.

The heat dissipation figures include 10% extra margin for overload running except for the scavenge air cooler, which is an integrated part of the diesel engine.

Cooling Water Systems

The capacities given in the tables are based on tropical ambient reference conditions and refer to engines with high efficiency/conventional turbocharger running at nominal MCR (L_1) for:

- **Seawater cooling system,** See diagram, Fig. 6.02.01 and nominal capacities in Fig. 6.03.01
- **Central cooling water system,** See diagram, Fig. 6.02.02 and nominal capacities in Fig. 6.03.01

The capacities for the starting air receivers and the compressors are stated in Fig. 6.03.01.

Heat radiation and air consumption

The radiation and convection heat losses to the engine room is around 1% of the engine nominal power (kW in L_1).

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

Flanges on engine, etc.

The location of the flanges on the engine are shown in: 'Engine pipe connections', and the flanges are identified by reference letters stated in the 'List of flanges'; both can be found in Chapter 5.

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

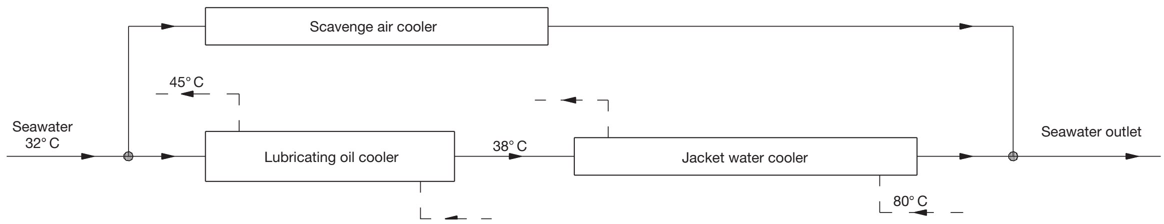


Fig. 6.02.01: Diagram for seawater cooling system

178 11 26-4.1

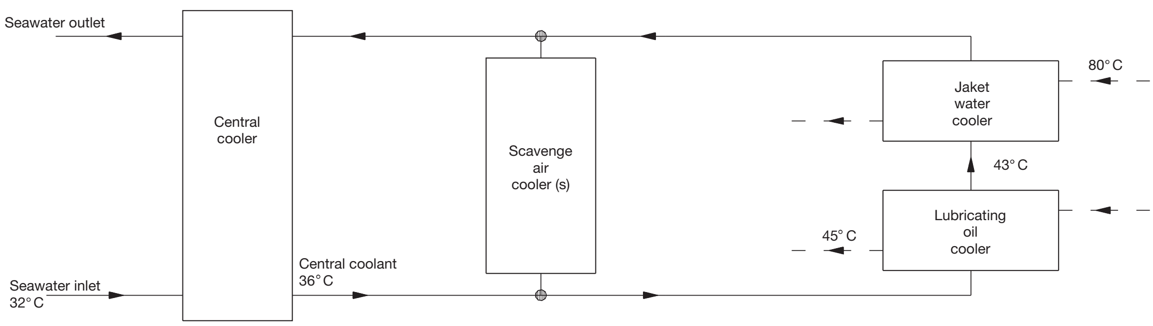


Fig. 6.02.02: Diagram for central cooling water system

178 11 27-6.1

List of Capacities for 5S60MC-C8.2-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 MET60MB	1 x TCA66-26	1 x A175-L35	1 x MET66MB	1 x TCA66-21	1 x A270-L	1 x MET60MB	1 x TCA66-26	1 x A175-L35	1 x MET66MB
Pumps													
Fuel oil circulation	m³/h	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Fuel oil supply	m³/h	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Jacket cooling	m³/h	99	99	99	99	99	99	99	99	99	99	99	99
Seawater cooling *	m³/h	367	368	371	376	382	384	364	365	366	373	375	376
Main lubrication oil *	m³/h	240	240	240	240	240	240	240	240	240	240	240	240
Central cooling *	m³/h	-	-	-	-	-	-	282	283	286	289	294	296
Scavenge air cooler(s)													
Heat diss. app.	kW	4,850	4,850	4,850	5,040	5,040	5,040	4,830	4,830	4,830	5,010	5,010	5,010
Central water flow	m³/h	-	-	-	-	-	-	172	172	172	179	179	179
Seawater flow	m³/h	237	237	237	246	246	246	-	-	-	-	-	-
Lubricating oil cooler													
Heat diss. app. *	kW	890	900	920	890	920	940	890	900	920	890	920	940
Lube oil flow *	m³/h	239	236	237	239	237	239	239	236	237	239	237	239
Central water flow	m³/h	-	-	-	-	-	-	109	110	113	109	114	116
Seawater flow	m³/h	130	131	135	130	135	138	-	-	-	-	-	-
Jacket water cooler													
Heat diss. app.	kW	1,740	1,740	1,740	1,740	1,740	1,740	1,740	1,740	1,740	1,740	1,740	1,740
Jacket water flow	m³/h	105	105	105	105	105	105	100	100	100	100	100	100
Central water flow	m³/h	-	-	-	-	-	-	109	110	113	109	114	116
Seawater flow	m³/h	130	131	135	130	135	138	-	-	-	-	-	-
Central cooler													
Heat diss. app. *	kW	-	-	-	-	-	-	7,460	7,470	7,490	7,640	7,670	7,690
Central water flow	m³/h	-	-	-	-	-	-	282	283	286	289	294	296
Seawater flow	m³/h	-	-	-	-	-	-	364	365	366	373	375	376
Starting air system, 30.0 bar g, 12 starts. Fixed pitch propeller - reversible engine													
Receiver volume	m³	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0
Compressor cap.	m³	300	300	300	300	300	300	300	300	300	300	300	300
Starting air system, 30.0 bar g, 6 starts. Controllable pitch propeller - non-reversible engine													
Receiver volume	m³	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5	2 x 2.5
Compressor cap.	m³	150	150	150	150	150	150	150	150	150	150	150	150
Other values													
Fuel oil heater	kW	97	97	97	96	96	96	97	97	97	96	96	96
Exh. gas temp. **	°C	255	255	255	235	235	235	255	255	255	235	235	235
Exh. gas amount **	kg/h	96,069	96,069	96,069	102,007	102,007	102,007	96,069	96,069	96,069	102,007	102,007	102,007
Air consumption **	kg/s	26.1	26.1	26.1	27.8	27.8	27.8	26.1	26.1	26.1	27.8	27.8	27.8

* For main engine arrangements with built-on power take-off (PTO) of a MAN Diesel & Turbo recommended type and/or torsional vibration damper the engine's capacities must be increased by those stated for the actual system

** ISO based

For List of Capacities for derated engines and performance data at part load please visit http://www.mandieselturbo/ceas/index.htm

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

List of Capacities for 6S60MC-C8.2-TII at NMCR

		Seawater cooling						Central cooling					
		Conventional TC			High eff. TC			Conventional TC			High eff. TC		
		1 x TCA66-26	1 x A175-L37	1 x MET66MB	1 x TCA77-21	1 x A275-L	1 x MET71MB	1 x TCA66-26	1 x A175-L37	1 x MET66MB	1 x TCA77-21	1 x A275-L	1 x MET71MB
Pumps													
Fuel oil circulation	m³/h	7.2	7.2	7.2	7.1	7.1	7.1	7.2	7.2	7.2	7.2	7.2	7.2
Fuel oil supply	m³/h	4.0	4.0	4.0	3.9	3.9	3.9	4.0	4.0	4.0	3.9	3.9	3.9
Jacket cooling	m³/h	119	119	119	119	119	119	119	119	119	119	119	119
Seawater cooling *	m³/h	438	444	446	452	455	463	436	438	439	448	449	452
Main lubrication oil *	m³/h	280	280	280	290	280	290	280	280	280	290	280	290
Central cooling *	m³/h	-	-	-	-	-	-	337	342	344	347	350	356
Scavenge air cooler(s)													
Heat diss. app.	kW	5,820	5,820	5,820	6,050	6,050	6,050	5,790	5,790	5,790	6,020	6,020	6,020
Central water flow	m³/h	-	-	-	-	-	-	207	207	207	215	215	215
Seawater flow	m³/h	284	284	284	296	296	296	-	-	-	-	-	-
Lubricating oil cooler													
Heat diss. app. *	kW	1,050	1,090	1,110	1,070	1,090	1,140	1,050	1,090	1,110	1,070	1,090	1,140
Lube oil flow *	m³/h	283	281	283	287	281	286	283	281	283	287	281	286
Central water flow	m³/h	-	-	-	-	-	-	129	134	136	132	134	140
Seawater flow	m³/h	154	160	162	157	160	167	-	-	-	-	-	-
Jacket water cooler													
Heat diss. app.	kW	2,080	2,080	2,080	2,080	2,080	2,080	2,090	2,090	2,090	2,090	2,090	2,090
Jacket water flow	m³/h	125	125	125	125	125	125	120	120	120	120	120	120
Central water flow	m³/h	-	-	-	-	-	-	129	134	136	132	134	140
Seawater flow	m³/h	154	160	162	157	160	167	-	-	-	-	-	-
Central cooler													
Heat diss. app. *	kW	-	-	-	-	-	-	8,930	8,970	8,990	9,180	9,200	9,250
Central water flow	m³/h	-	-	-	-	-	-	337	342	344	347	350	356
Seawater flow	m³/h	-	-	-	-	-	-	436	438	439	448	449	452
Starting air system, 30.0 bar g, 12 starts. Fixed pitch propeller - reversible engine													
Receiver volume	m³	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0	2 x 5.0
Compressor cap.	m³	300	300	300	300	300	300	300	300	300	300	300	300
Starting air system, 30.0 bar g, 6 starts. Controllable pitch propeller - non-reversible engine													
Receiver volume	m³	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0	2 x 3.0
Compressor cap.	m³	180	180	180	180	180	180	180	180	180	180	180	180
Other values													
Fuel oil heater	kW	116	116	116	115	115	115	116	116	116	116	116	116
Exh. gas temp. **	°C	255	255	255	235	235	235	255	255	255	235	235	235
Exh. gas amount **	kg/h	115,282	115,282	115,282	122,408	122,408	122,408	115,282	115,282	115,282	122,408	122,408	122,408
Air consumption **	kg/s	31.3	31.3	31.3	33.3	33.3	33.3	31.3	31.3	31.3	33.3	33.3	33.3

* For main engine arrangements with built-on power take-off (PTO) of a MAN Diesel & Turbo recommended type and/or torsional vibration damper the engine's capacities must be increased by those stated for the actual system

** ISO based

For List of Capacities for derated engines and performance data at part load please visit http://www.mandieselturbo/ceas/index.htm

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

List of Capacities for 7S60MC-C8.2-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 MET71MB	1 x TCA77-26	1 x A180-L37	1 x MET83MB	1 x TCA77-21	1 x A275-L	1 x MET71MB	1 x TCA77-26	1 x A180-L37	1 x MET83MB
Pumps													
Fuel oil circulation	m³/h	8.4	8.4	8.4	8.3	8.3	8.3	8.4	8.4	8.4	8.3	8.3	8.3
Fuel oil supply	m³/h	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6
Jacket cooling	m³/h	140	140	140	140	140	140	140	140	140	140	140	140
Seawater cooling *	m³/h	511	514	521	524	530	540	509	510	513	522	524	528
Main lubrication oil *	m³/h	330	330	330	330	330	330	330	330	330	330	330	330
Central cooling *	m³/h	-	-	-	-	-	-	393	395	402	402	408	416
Scavenge air cooler(s)													
Heat diss. app.	kW	6,790	6,790	6,790	7,060	7,060	7,060	6,760	6,760	6,760	7,020	7,020	7,020
Central water flow	m³/h	-	-	-	-	-	-	241	241	241	251	251	251
Seawater flow	m³/h	332	332	332	345	345	345	-	-	-	-	-	-
Lubricating oil cooler													
Heat diss. app. *	kW	1,220	1,240	1,290	1,220	1,270	1,330	1,230	1,240	1,300	1,230	1,270	1,330
Lube oil flow *	m³/h	331	325	330	331	327	333	331	325	330	331	327	333
Central water flow	m³/h	-	-	-	-	-	-	151	153	159	151	156	164
Seawater flow	m³/h	179	182	190	179	186	195	-	-	-	-	-	-
Jacket water cooler													
Heat diss. app.	kW	2,440	2,440	2,440	2,440	2,440	2,440	2,440	2,440	2,440	2,440	2,440	2,440
Jacket water flow	m³/h	147	147	147	147	147	147	140	140	140	140	140	140
Central water flow	m³/h	-	-	-	-	-	-	151	153	159	151	156	164
Seawater flow	m³/h	179	182	190	179	186	195	-	-	-	-	-	-
Central cooler													
Heat diss. app. *	kW	-	-	-	-	-	-	10,430	10,440	10,500	10,690	10,730	10,790
Central water flow	m³/h	-	-	-	-	-	-	393	395	402	402	408	416
Seawater flow	m³/h	-	-	-	-	-	-	509	510	513	522	524	528
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	135	135	135	135	135	135	136	136	136	135	135	135
Exh. gas temp. **	°C	255	255	255	235	235	235	255	255	255	235	235	235
Exh. gas amount **	kg/h	134,496	134,496	134,496	142,810	142,810	142,810	134,496	134,496	134,496	142,810	142,810	142,810
Air consumption **	kg/s	36.6	36.6	36.6	38.9	38.9	38.9	36.6	36.6	36.6	38.9	38.9	38.9

* For main engine arrangements with built-on power take-off (PTO) of a MAN Diesel & Turbo recommended type and/or torsional vibration damper the engine's capacities must be increased by those stated for the actual system

** ISO based

For List of Capacities for derated engines and performance data at part load please visit http://www.mandieselturbo/ceas/index.htm

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

List of Capacities for 8S60MC-C8.2-TII at NMCR

		Seawater cooling						Central cooling					
		Conventional TC			High eff. TC			Conventional TC			High eff. TC		
		1 x TCA77-26	1 x A180-L37	1 x MET83MB	1 x TCA88-21	1 x A280-L	1 x MET83MB	1 x TCA77-26	1 x A180-L37	1 x MET83MB	1 x TCA88-21	1 x A280-L	1 x MET83MB
Pumps													
Fuel oil circulation	m³/h	9.6	9.6	9.6	9.5	9.5	9.5	9.6	9.6	9.6	9.5	9.5	9.5
Fuel oil supply	m³/h	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
Jacket cooling	m³/h	159	159	159	159	159	159	159	159	159	159	159	159
Seawater cooling *	m³/h	584	590	600	602	605	615	582	584	587	598	599	602
Main lubrication oil *	m³/h	380	380	380	390	380	380	380	380	380	390	380	380
Central cooling *	m³/h	-	-	-	-	-	-	449	454	462	463	465	473
Scavenge air cooler(s)													
Heat diss. app.	kW	7,760	7,760	7,760	8,060	8,060	8,060	7,720	7,720	7,720	8,020	8,020	8,020
Central water flow	m³/h	-	-	-	-	-	-	276	276	276	286	286	286
Seawater flow	m³/h	379	379	379	394	394	394	-	-	-	-	-	-
Lubricating oil cooler													
Heat diss. app. *	kW	1,400	1,440	1,510	1,420	1,440	1,510	1,400	1,440	1,510	1,420	1,440	1,510
Lube oil flow *	m³/h	380	376	382	385	376	382	380	376	382	385	376	382
Central water flow	m³/h	-	-	-	-	-	-	172	178	186	175	178	186
Seawater flow	m³/h	205	211	221	208	211	221	-	-	-	-	-	-
Jacket water cooler													
Heat diss. app.	kW	2,780	2,780	2,780	2,780	2,780	2,780	2,780	2,780	2,780	2,780	2,780	2,780
Jacket water flow	m³/h	167	167	167	167	167	167	160	160	160	160	160	160
Central water flow	m³/h	-	-	-	-	-	-	172	178	186	175	178	186
Seawater flow	m³/h	205	211	221	208	211	221	-	-	-	-	-	-
Central cooler													
Heat diss. app. *	kW	-	-	-	-	-	-	11,900	11,940	12,010	12,220	12,240	12,310
Central water flow	m³/h	-	-	-	-	-	-	449	454	462	463	465	473
Seawater flow	m³/h	-	-	-	-	-	-	582	584	587	598	599	602
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	155	155	155	154	154	154	155	155	155	154	154	154
Exh. gas temp. **	°C	255	255	255	235	235	235	255	255	255	235	235	235
Exh. gas amount **	kg/h	153,710	153,710	153,710	163,211	163,211	163,211	153,710	153,710	153,710	163,211	163,211	163,211
Air consumption **	kg/s	41.8	41.8	41.8	44.4	44.4	44.4	41.8	41.8	41.8	44.4	44.4	44.4

* For main engine arrangements with built-on power take-off (PTO) of a MAN Diesel & Turbo recommended type and/or torsional vibration damper the engine's capacities must be increased by those stated for the actual system

** ISO based

For List of Capacities for derated engines and performance data at part load please visit http://www.mandieselturbo/ceas/index.htm

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

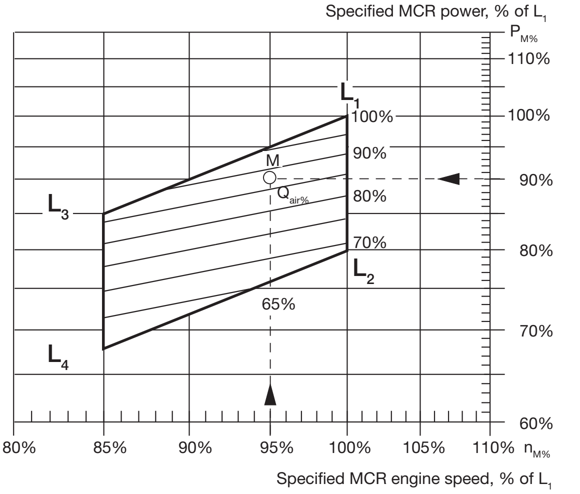
Auxiliary Machinery Capacities

The dimensioning of heat exchangers (coolers) and pumps for derated engines can be calculated on the basis of the heat dissipation values found by using the following description and diagrams. Those for the nominal MCR (L_1), may also be used if wanted.

The nomenclature of the basic engine ratings and coolers, etc. used in this section is shown in Fig. 6.01.01 and 6.01.02.

Cooler heat dissipations

For the specified MCR (M) the following three diagrams in Figs. 6.04.01, 6.04.02 and 6.04.03 show reduction factors for the corresponding heat dissipations for the coolers, relative to the values stated in the ‘List of Capacities’ valid for nominal MCR (L_1).

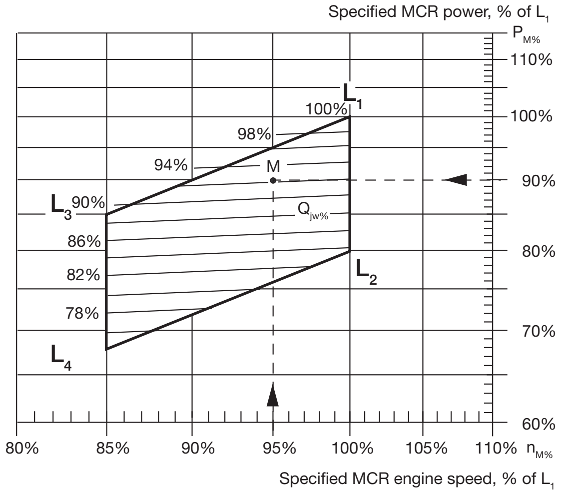


178 63 63-8.0

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

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

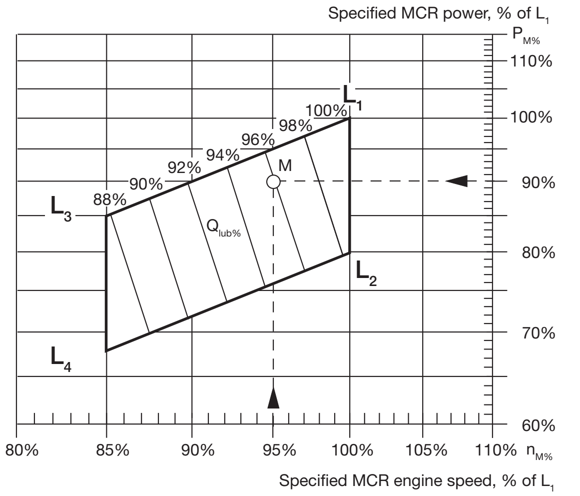
The percentage power ($P_{M\%}$) and speed ($n_{M\%}$) of L_1
ie: $P_{M\%} = P_M/P_{L1} \times 100\%$
$n_{M\%} = n_M/n_{L1} \times 100\%$
for specified MCR (M) of the derated engine is used as input in the above-mentioned diagrams, giving the % heat dissipation figures relative to those in the ‘List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



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

178 63 62-6.1

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



178 63 65-1.1

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

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

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

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

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

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

Pump capacities

The pump capacities given in the 'List of Capacities' refer to engines rated at nominal MCR (L_1). For lower rated engines, a marginal saving in the pump capacities is obtainable.

To ensure proper lubrication, the lubricating oil pump must remain unchanged.

In order to ensure reliable starting, the starting air compressors and the starting air receivers must also remain unchanged.

The jacket cooling water pump capacity is relatively low. Practically no saving is possible, and it is therefore unchanged.

Seawater cooling system

The derated seawater pump capacity is equal to the sum of the below found derated seawater flow capacities through the scavenge air and lube oil coolers, as these are connected in parallel.

The seawater flow capacity for each of the scavenge air, lube oil and jacket water coolers can be reduced proportionally to the reduced heat dissipations found in Figs. 6.04.01, 6.04.02 and 6.04.03, respectively i.e. as follows:

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

However, regarding the scavenge air cooler(s), the engine maker has to approve this reduction in order to avoid too low a water velocity in the scavenge air cooler pipes.

As the jacket water cooler is connected in series with the lube oil cooler, the seawater flow capacity for the latter is used also for the jacket water cooler.

Central cooling water system

If a central cooler is used, the above still applies, but the central cooling water capacities are used instead of the above seawater capacities. The seawater flow capacity for the central cooler can be reduced in proportion to the reduction of the total cooler heat dissipation, i.e. as follows:

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

Pump pressures

Irrespective of the capacities selected as per the above guidelines, the below-mentioned pump heads at the mentioned maximum working temperatures for each system must be kept:

	Pump head bar	Max. working temp. °C
Fuel oil supply pump	4	100
Fuel oil circulating pump	6	150
Lubricating oil pump	4.3	70
Seawater pump	2.5	50
Central cooling water pump	2.5	80
Jacket water pump	3.0	100

Flow velocities

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

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

Calculation of List of Capacities for Derated Engine

Example 1:

Pump and cooler capacities for a *derated 6S60MC-C8.2-TII with 1 high efficiency MAN TCA66-26 turbocharger, high load, fixed pitch propeller and central cooling water system.*

Nominal MCR, (L_1) P_{L1}: 14,280 kW (100.0%) and 105.0 r/min (100.0%)

Specified MCR, (M) P_M: 12,852 kW (90.0%) and 99.8 r/min (95.0%)

The method of calculating the reduced capacities for point M ($n_{M\%}$ = 95.0% and $P_{M\%}$ = 90.0%) is shown below.

The values valid for the nominal rated engine are found in the 'List of Capacities', Figs. 6.03.01 and 6.03.02, and are listed together with the result in the figure on the next page.

Heat dissipation of scavenge air cooler
Fig. 6.04.01 which approximately indicates a $Q_{air\%}$ = 87.4% heat dissipation, i.e.:

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

$Q_{air,M} = 6{,}020 \times 0.874 = 5{,}261$ kW

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

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

$Q_{jw,M} = 2{,}090 \times 0.922 = 1{,}927$ kW

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

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

$Q_{lub,M} = 1{,}070 \times 0.958 = 1{,}025$ kW

Heat dissipation of central water cooler

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

$Q_{cent,M} = 5{,}261 + 1{,}927 + 1{,}025 = 8{,}213$ kW

Total cooling water flow through scavenge air coolers

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

$V_{cw,air,M} = 216 \times 0.874 = 189$ m^3/h

Cooling water flow through lubricating oil cooler

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

$V_{cw,lub,M} = 132 \times 0.958 = 126$ m^3/h

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

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

$V_{cw,cent,M} = 189 + 126 = 315$ m^3/h

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

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

$V_{cw,jw,M} = 126$ m^3/h

Seawater pump for central cooler
As the seawater pump capacity and the central cooler heat dissipation for the nominal rated engine found in the 'List of Capacities' are 448 m^3/h and 9,180 kW the derated seawater pump flow equals:

Seawater pump:

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

$= 448 \times 8{,}213 / 9{,}180 = 401$ m^3/h

		Nominal rated engine (L_1) high efficiency 1 x MAN TCA77-21	Specified MCR (M) high efficiency 1 x MAN TCA66-26
Shaft power at MCR	kW	14,280	12,852
Engine speed at MCR	r/min	105.0	99.8
Pumps:			
Fuel oil circulating	m^3/h	7.2	6.7
Fuel oil supply	m^3/h	3.9	3.5
Jacket cooling water	m^3/h	120	120
Central cooling water	m^3/h	348	315
Seawater	m^3/h	448	401
Lubricating oil	m^3/h	290	280
Coolers:			
Scavenge air cooler			
Heat dissipation	kW	6,020	5,261
Central cooling water flow	m^3/h	216	189
Lub. oil cooler			
Heat dissipation	kW	1,070	1,025
Lubricating oil flow	m^3/h	290	280
Central cooling water flow	m^3/h	132	126
Jacket water cooler			
Heat dissipation	kW	2,090	1,927
Jacket cooling water flow	m^3/h	120	120
Central cooling water flow	m^3/h	132	126
Central cooler			
Heat dissipation	kW	9,180	8,213
Central cooling water flow	m^3/h	348	315
Seawater flow	m^3/h	448	401
Fuel oil heater:	kW	116	104
Gases at ISO ambient conditions*			
Exhaust gas amount	kg/h	122,400	109,900
Exhaust gas temperature	°C	235	231
Air consumption	kg/s	33.0	30.0
Starting air system: 30 bar (gauge)			
Reversible engine			
Receiver volume (12 starts)	m^3	2 x 5.0	2 x 5.0
Compressor capacity, total	m^3/h	300	300
Non-reversible engine			
Receiver volume (6 starts)	m^3	2 x 3.0	2 x 3.0
Compressor capacity, total	m^3/h	180	180
Exhaust gas tolerances: temperature ±5 °C and amount ±15%			

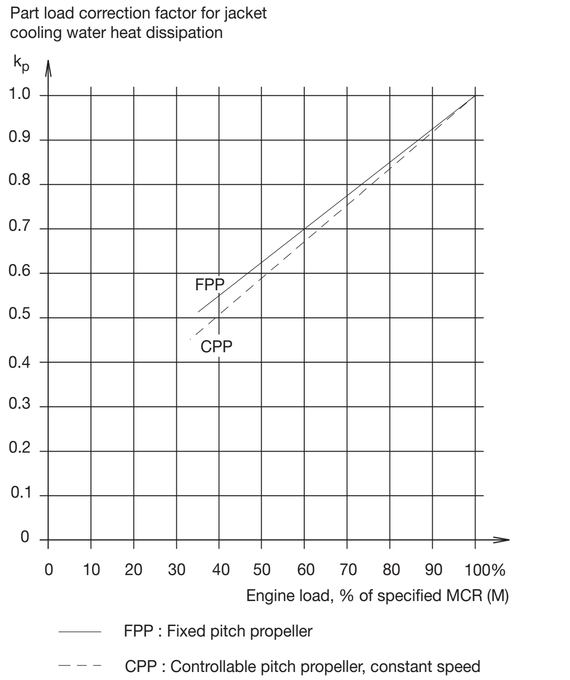
The air consumption and exhaust gas figures are expected and refer to 100% specified MCR, ISO ambient reference conditions and the exhaust gas back pressure 300 mm WC
The exhaust gas temperatures refer to after turbocharger
* Calculated in example 3, in this chapter

Freshwater Generator

If a freshwater generator is installed and is utilising the heat in the jacket water cooling system, it should be noted that the actual available heat in the jacket cooling water system is **lower** than indicated by the heat dissipation figures valid for nominal MCR (L_1) given in the List of Capacities. This is because the latter figures are used for dimensioning the jacket water cooler and hence incorporate a safety margin which can be needed when the engine is operating under conditions such as, e.g. overload. Normally, this margin is 10% at nominal MCR.

Calculation Method

For a derated diesel engine, i.e. an engine having a specified MCR (M) different from L_1, the relative jacket water heat dissipation for point M may be found, as previously described, by means of Fig. 6.04.02.



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

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

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

At part load operation, the actual jacket water heat dissipation will be reduced according to the curves for fixed pitch propeller (FPP) or for constant speed, controllable pitch propeller (CPP), respectively, in Fig. 6.04.04.

With reference to the above, the heat actually available for a derated diesel engine may then be found as follows:

1. Engine power equal to specified power M.

   For specified MCR (M) the diagram Fig. 6.04.02 is to be used, i.e. giving the percentage correction factor '$Q_{jw\%}$' and hence for specified MCR power P_M:

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

2. Engine power lower than specified MCR power.

   For powers lower than the specified MCR power, the value $Q_{jw,M}$ found for point M by means of the above equation [1] is to be multiplied by the correction factor k_p found in Fig. 6.04.04 and hence

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

where
Q_{jw} = jacket water heat dissipation
$Q_{jw,L1}$ = jacket water heat dissipation at nominal MCR (L_1)
$Q_{jw\%}$ = percentage correction factor from Fig. 6.04.02
$Q_{jw,M}$ = jacket water heat dissipation at specified MCR power (M), found by means of equation [1]
k_p = part load correction factor from Fig. 6.04.04
0.9 = factor for safety margin of cooler, tropical ambient conditions

The heat dissipation is assumed to be more or less independent of the ambient temperature conditions, yet the safety margin/ambient condition factor of about 0.88 instead of 0.90 will be more accurate for ambient conditions corresponding to ISO temperatures or lower. The heat dissipation tolerance from -15% to 0% stated above is based on experience.

Jacket Cooling Water Temperature Control

When using a normal freshwater generator of the single-effect vacuum evaporator type, the freshwater production - based on the available jacket cooling water heat Qjw - may, for guidance, be estimated as 0.03 t/24h per 1 kW heat, i.e.:

$M_{fw} = 0.03 \times Q_{jw}$ t/24h -15%/0% [3]

where

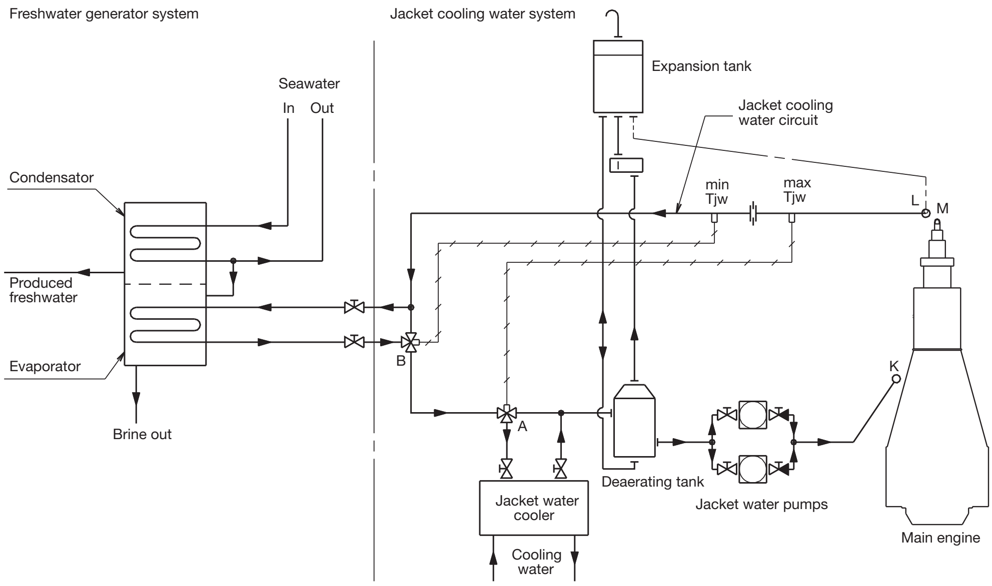
M_{fw} is the freshwater production in tons per 24 hours

and

Q_{jw} is to be stated in kW

If necessary, all the actually available jacket cooling water heat may be used provided that a special temperature control system ensures that the jacket cooling water temperature at the outlet from the engine does not fall below a certain level. Such a temperature control system may consist, e.g., of a special by-pass pipe installed in the jacket cooling water system, see Fig. 6.04.05, or a special built-in temperature control in the freshwater generator, e.g., an automatic start/stop function, or similar.

If such a special temperature control is not applied, we recommend limiting the heat utilised to maximum 50% of the heat actually available at specified MCR, and only using the freshwater generator at engine loads above 50%. Considering the cooler margin of 10% and the minus tolerance of -15%, this heat corresponds to 50 x(1.00-0.15)x0.9 = 38% of the jacket water cooler capacity $Q_{jw,M}$ used for dimensioning of the jacket water cooler.



Valve A: ensures that T_{jw} < 92° C
Valve B: ensures that T_{jw} > 92 – 4° C = 88° C
Valve B and the corresponding by-pass may be omitted if, for example, the freshwater generator is equipped with an automatic start/stop function for too low jacket cooling water temperature
If necessary, all the actually available jacket cooling water heat may be utilised provided that a special temperature control system ensures that the jacket cooling water temperature at the outlet from the engine does not fall below a certain level

178 23 70-0.0

Fig. 6.04.05: Freshwater generators. Jacket cooling water heat recovery flow diagram

Calculation of Freshwater Production for Derated Engine

Example 2:

Freshwater production from a *derated 6S60MC-C8.2-TII with 1 high efficiency MAN TCA66-26 turbocharger, high load and fixed pitch propeller.*

Based on the engine ratings below, this example will show how to calculate the expected available jacket cooling water heat removed from the diesel engine, together with the corresponding freshwater production from a freshwater generator.

The calculation is made for the service rating (S) of the diesel engine being 80% of the specified MCR.

Nominal MCR, (L_1) P_{L1}: 14,280 kW (100.0%) and 105.0 r/min (100.0%)

Specified MCR, (M) P_M: 12,852 kW (90.0%) and 99.8 r/min (95.0%)

Service rating, (S) P_S: 10,281 kW and 92.6 r/min, P_S = 80.0% of P_M

Reference conditions

Air temperature T_{air} .... 20° C
Scavenge air coolant temperature T_{CW} .... 18° C
Barometric pressure p_{bar} .... 1,013 mbar
Exhaust gas back-pressure at specified MCR Δp_M .... 300 mm WC

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

$Q_{jw,L1}$ = 2,090 kW from List of Capacities
$Q_{jw\%}$ = 92.2% using 90.0% power and 95.0% speed for M in Fig. 6.04.02

By means of equation [1], and using factor 0.885 for actual ambient condition the heat dissipation in the SMCR point (M) is found:

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

$$= 2{,}090 \times \frac{92.2}{100} \times 0.885 = 1{,}705 \text{ kW}$$

By means of equation [2], the heat dissipation in the service point (S) i.e. for 80.0% of specified MCR power, is found:

k_p = 0.852 using 80.0% in Fig. 6.04.04
Q_{jw} = $Q_{jw,M} \times k_p$ = 1,705 x 0.852 = 1,453 kW
-15%/0%

For the service point the corresponding expected obtainable freshwater production from a freshwater generator of the single effect vacuum evaporator type is then found from equation [3]:

M_{fw} = 0.03 x Q_{jw} = 0.03 x 1,453 = 43.6 t/24h
-15%/0%

Exhaust Gas Amount and Temperature

Influencing factors

The exhaust gas data to be expected in practice depends, primarily, on the following three factors:

a) The specified MCR point of the engine (point M):

P_M : power in kW at specified MCR point
n_M : speed in r/min at specified MCR point

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

T_{air} : actual ambient air temperature, in °C
p_{bar} : actual barometric pressure, in mbar
T_{CW} : actual scavenge air coolant temperature, in °C
Δp_M : exhaust gas back-pressure in mm WC at specified MCR

c) The continuous service rating of the engine (point S), valid for fixed pitch propeller or controllable pitch propeller (constant engine speed):

P_S : continuous service rating of engine, in kW

Calculation Method

To enable the project engineer to estimate the actual exhaust gas data at an arbitrary service rating, the following method of calculation may be used.

The partial calculations based on the above influencing factors have been summarised in equations [4] and [5].

M_{exh} : exhaust gas amount in kg/h, to be found
T_{exh} : exhaust gas temperature in °C, to be found

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

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

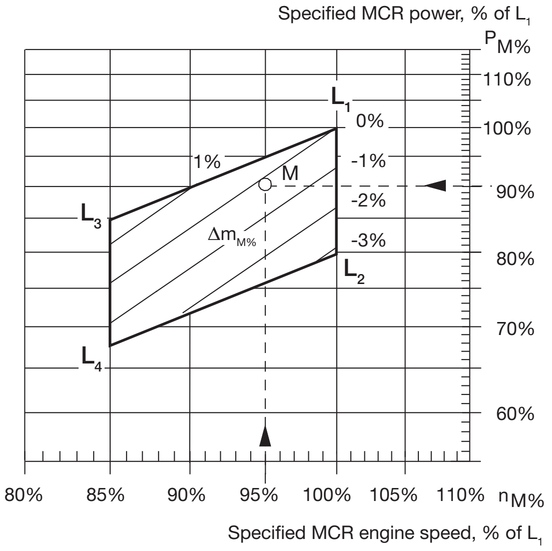
where, according to ‘List of capacities’, i.e. referring to ISO ambient conditions and 300 mm WC back-pressure and specified in L_1:
M_{L1}: exhaust gas amount in kg/h at nominal MCR (L_1)
T_{L1}: exhaust gas temperature after turbocharger in °C at nominal MCR (L_1)

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

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

a) *Correction for choice of specified MCR point*

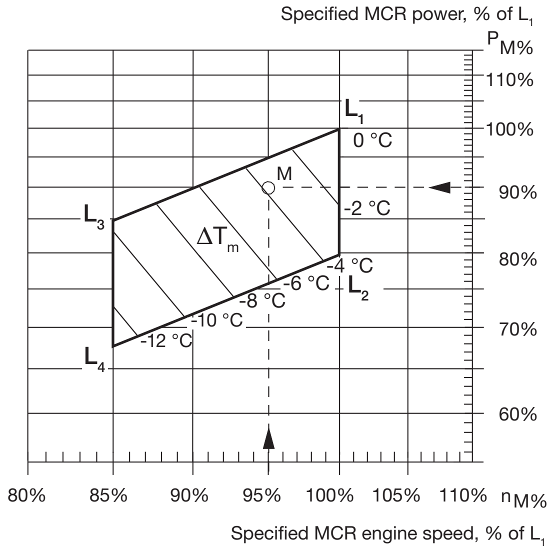
When choosing a specified MCR point ‘M’ other than the nominal MCR point ‘L_1’, the resulting changes in specific exhaust gas amount and temperature are found by using as input in diagrams the corresponding percentage values (of L_1) for specified MCR power $P_{M\%}$ and speed $n_{M\%}$:
$P_{M\%} = P_M/P_{L1}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



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

178 63 66-3.0

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



ΔT_M = 15 x ln (P_M/P_{L1}) + 45 x ln (n_M/n_{L1})

178 63 67-5.0

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

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

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

b) Correction for actual ambient conditions and back-pressure

For ambient conditions other than ISO 3046-1:2002 (E) and ISO 15550:2002 (E), and back-pressure other than 300 mm WC at specified MCR point (M), the correction factors stated in the table in Fig. 6.04.09 may be used as a guide, and the corresponding relative change in the exhaust gas data may be found from equations [7] and [8], shown in Fig. 6.04.10.

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

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

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

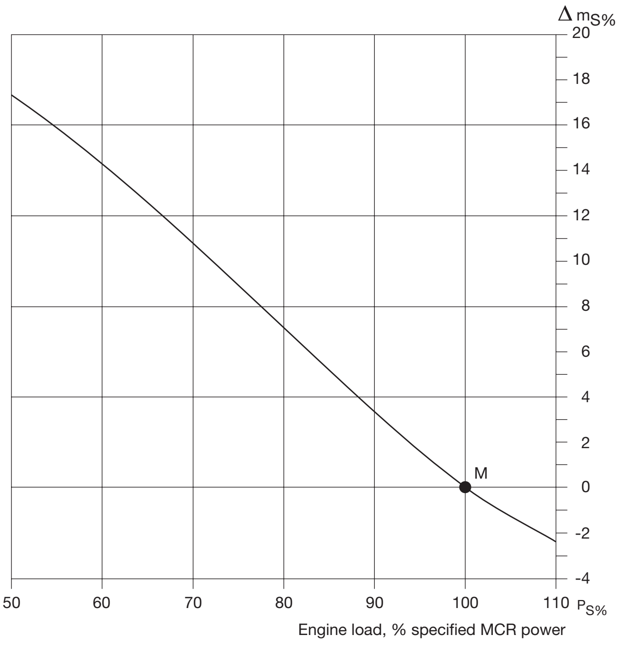
ΔT_{amb} = 1.6 x (T_{air} - 25) - 0.01 x (p_{bar} - 1000) +0.1 x (T_{CW} - 25) + 0.05 x (Δp_M - 300) °C [8]

where the following nomenclature is used:

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

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

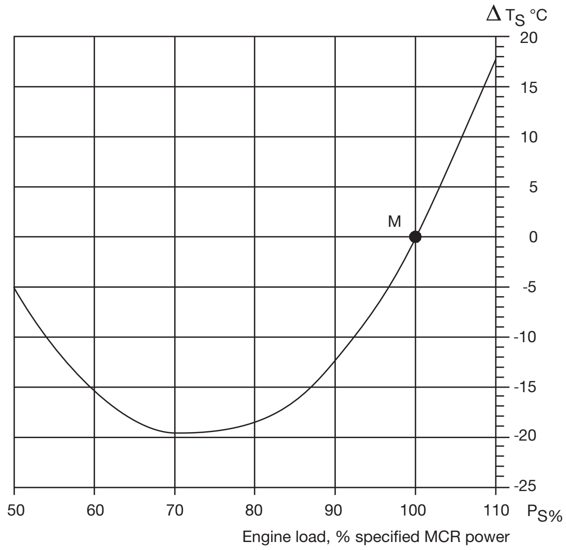
Fig. 6.04.10: Exhaust gas correction formula for ambient conditions and exhaust gas back pressure



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

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

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



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

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

Fig. 6.04.12: Change of exhaust gas temperature, ΔT_S in °C at part load, and valid for FPP and CPP

c) *Correction for engine load*

Figs. 6.04.11 and 6.04.12 may be used, as guidance, to determine the relative changes in the specific exhaust gas data when running at part load, compared to the values in the specified MCR point, i.e. using as input $P_{S\%}$ = (P_S/P_M) x 100%:

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

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

Calculation of Exhaust Data for Derated Engine

Example 3:

Expected exhaust gas data for a *derated 6S60MC-C8.2-TII with 1 high efficiency MAN TCA66-26 turbocharger, high load and fixed pitch propeller.*

Based on the engine ratings below, and by means of an example, this chapter will show how to calculate the expected exhaust gas amount and temperature at service rating, and for a given ambient reference condition different from ISO.

The calculation is made for the service rating (S) of the diesel engine being 80% of the specified MCR.

Nominal MCR, (L_1) P_{L1}: 14,280 kW (100.0%) and 105.0 r/min (100.0%)

Specified MCR, (M) P_M: 12,852 kW (90.0%) and 99.8 r/min (95.0%)

Service rating, (S) P_S: 10,281 kW and 92.6 r/min, P_S = 80.0% of P_M

Reference conditions
Air temperature T_{air} .... 20° C
Scavenge air coolant temperature T_{CW} .... 18° C
Barometric pressure p_{bar} .... 1,013 mbar
Exhaust gas back-pressure at specified MCR Δp_M .... 300 mm WC

a) Correction for choice of specified MCR point M:

$$P_{M\%} = \frac{12,852}{14,280} \times 100 = 90.0\%$$

$$n_{M\%} = \frac{99.8}{105.0} \times 100 = 95.0\%$$

By means of Figs. 6.04.07 and 6.04.08:

$\Delta m_{M\%}$ = -0.26%
ΔT_M = -3.9 °C

b) Correction for ambient conditions and back-pressure:

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

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

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

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

$$\Delta T_{amb} = -\,8.8\ °C$$

c) Correction for the engine load:

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

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

ΔT_S = - 18.8 °C

Final calculation

By means of equations [4] and [5], the final result is found taking the exhaust gas flow M_{L1} and temperature T_{L1} from the 'List of Capacities':

M_{L1} = 122,400 kg/h

$$M_{exh} = 122{,}400 \text{ x } \frac{12{,}852}{14{,}280} \text{ x } (1 + \frac{-0.26}{100}) \text{ x }$$

$$(1 + \frac{1.11}{100}) \text{ x } (1 + \frac{7.1}{100}) \text{ x } \frac{80}{100} = 95{,}185 \text{ kg/h}$$

M_{exh} = 95,200 kg/h ±15%

The exhaust gas temperature

T_{L1} = 235 °C

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

T_{exh} = 203.5 °C ±5 °C

Exhaust gas data at specified MCR (ISO)

At specified MCR (M), the running point may be in equations [4] and [5] considered as a service point where $P_{S\%}$ = 100, $\Delta m_{s\%}$ = 0.0 and ΔT_s = 0.0.

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

$$M_{exh,M} = 122{,}400 \text{ x } \frac{12{,}852}{14{,}280} \text{ x } (1 + \frac{-0.26}{100}) \text{ x } (1 + \frac{0.0}{100})$$

$$\text{x } (1 + \frac{0.0}{100}) \text{ x } \frac{100.0}{100} = 109{,}885 \text{ kg/h}$$

$M_{exh,M}$ = 109,900 kg/h ±15%

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

$T_{exh,M}$ = 231.1 °C ±5 °C

The air consumption will be:

109,885 x 0.982 kg/h = 107,907 kg/h <=>
107,907 / 3,600 kg/s = 30.0 kg/s

Fuel

7

Pressurised Fuel Oil System

The system is so arranged that both diesel oil and heavy fuel oil can be used, see figure 7.01.02.

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.

An in-line viscocity regulator located after the heater controls the heating temperature according to the prescribed viscosity of the specific fuel oil.

Design parameters

To ensure ample filling of the fuel injection pumps, 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.

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 Pumps and Drain

The introduction of the pump sealing arrangement, the so-called 'umbrella' type, has made it possible to omit the separate camshaft lubricating oil system.

The umbrella type fuel oil pump has an additional external leakage rate of clean fuel oil which, through 'AD', is led to a tank and can be pumped to the heavy fuel oil service tank or settling tank.

The flow rate in litres is approximately as listed in Table 7.01.01.

Engine	Flow rate, litres/cyl. h. HFO 12 cSt
K98MC/MC-C,	1.30
S/K90MC-C	1.10
S80MC, S/K80MC-C	1.00
S70MC, S/L70MC-C, S65MC-C	0.80
S60MC, S/L60MC-C	0.60
S50MC	0.50

Table 7.01.01: Approximate flow in HCU leakage drain.

This drained clean oil will, of course, influence the measured SFOC, but the oil is thus not wasted, and the quantity is well within the measuring accuracy of the flowmeters normally used.

The main purpose of the drain 'AD' is to collect pure fuel oil from the fuel pumps. The drain oil is lead to a tank and can be pumped to the Heavy Fuel Oil service tank or to the settling tank.

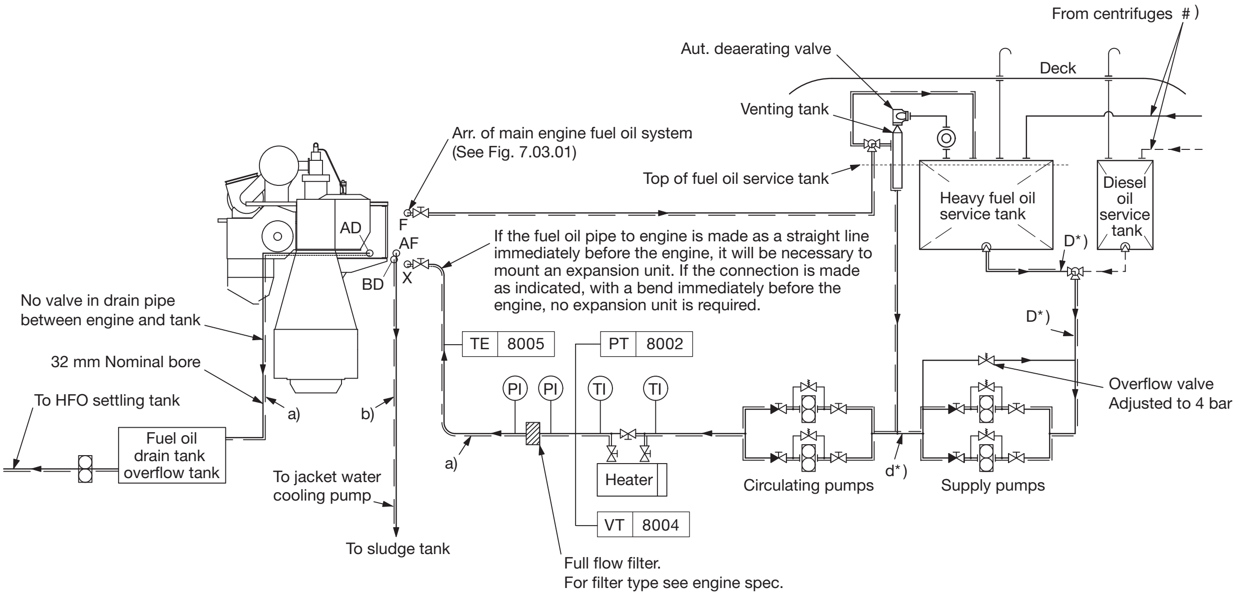
The 'AF' drain is provided with a box for giving alarm in case of leakage in a high pressure pipes.

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' and 'AF' are shown in Fig. 7.03.02.

The main components of the pressurised fuel oil system are further explained in section 7.05.

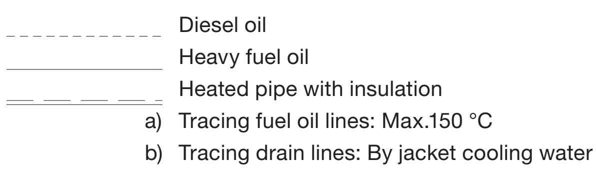
Fuel Oil System



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

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

078 70 37-2.3.0



The letters refer to the list of 'Counterflanges'

Fig. 7.01.02: Fuel oil system

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.

Heating of fuel drain pipe

Owing to the relatively high viscosity of the heavy fuel oil, it is recommended that the drain pipe and the fuel oil drain tank are heated to min. 50 °C, but max. 100 °C.

The drain pipe between engine and tank can be heated by the jacket water, as shown in Fig. 7.01.02 ‘Fuel oil system’ as flange ‘BD’.

Fuel flow velocity and viscosity

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

Marine diesel oil .... 1.0 m/s
Heavy fuel oil .... 0.6 m/s

The fuel viscosity is influenced by factors such as emulsification of water into the fuel for reducing the NO_x emission. This is further described in Section 7.06.

An emulsification arrangement for the main engine is described in our publication:

Exhaust Gas Emission Control Today and Tomorrow

Further information about fuel oil specifications is available in our publication:

Guidelines for Fuels and Lubes Purchasing

The publications are available at www.marine.man.eu → ’Two-Stroke’ → ’Technical Papers’.

Fuel Oils

Marine diesel oil:

Marine diesel oil ISO 8217, Class DMB
British Standard 6843, Class DMB
Similar oils may also be used

Heavy fuel oil (HFO)

Most commercially available HFO with a viscosity below 700 cSt at 50 °C (7,000 sec. Redwood I at 100 °F) can be used.

For guidance on purchase, reference is made to ISO 8217:2012, British Standard 6843 and to CIMAC recommendations regarding requirements for heavy fuel for diesel engines, fourth edition 2003, in which the maximum acceptable grades are RMH 700 and RMK 700. The above-mentioned ISO and BS standards supersede BSMA 100 in which the limit was M9.

The data in the above HFO standards and specifications refer to fuel as delivered to the ship, i.e. before on-board cleaning.

In order to ensure effective and sufficient cleaning of the HFO, i.e. removal of water and solid contaminants, the fuel oil specific gravity at 15 °C (60 °F) should be below 0.991, unless modern types of centrifuges with adequate cleaning abilities are used.

Higher densities can be allowed if special treatment systems are installed.

Current analysis information is not sufficient for estimating the combustion properties of the oil. This means that service results depend on oil properties which cannot be known beforehand. This especially applies to the tendency of the oil to form deposits in combustion chambers, gas passages and turbines. It may, therefore, be necessary to rule out some oils that cause difficulties.

Guiding heavy fuel oil specification

Based on our general service experience we have, as a supplement to the above mentioned standards, drawn up the guiding HFO specification shown below.

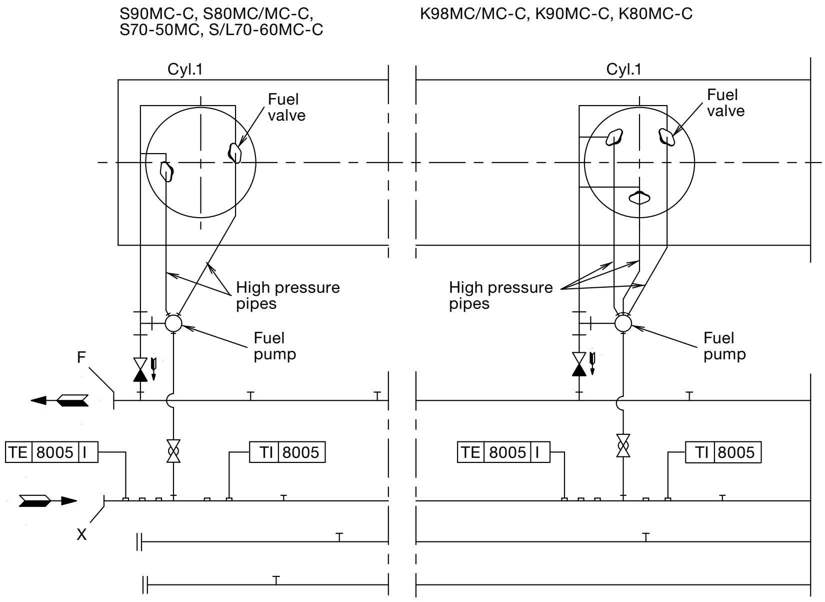
Heavy fuel oils limited by this specification have, to the extent of the commercial availability, been used with satisfactory results on MAN B&W two-stroke low speed diesel engines.

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

Guiding specification (maximum values)		
Density at 15 °C	kg/m^3	≤ 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	

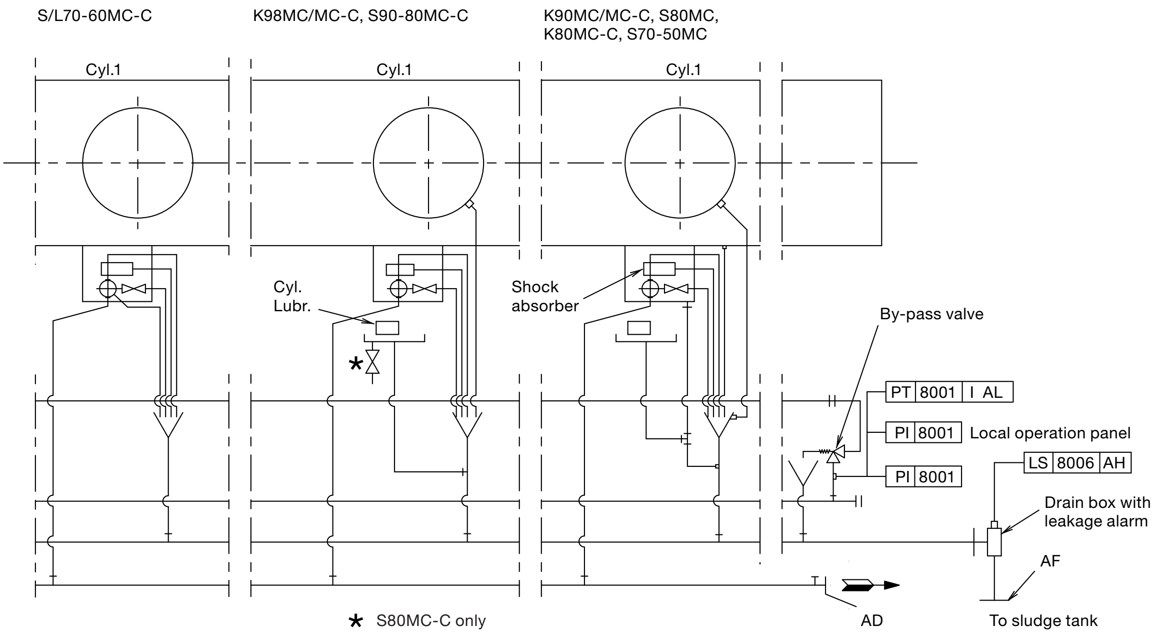
If heavy fuel oils with analysis data exceeding the above figures are to be used, especially with regard to viscosity and specific gravity, the engine builder should be contacted for advice regarding possible fuel oil system changes.

Fuel Oil Pipes and Drain Pipes



178 57 51-5.0

Fig. 7.03.01: Fuel oil pipes



178 57 52-7.0

The letters refer to list of 'Counterflanges'
The item Nos refer to 'Guidance values automation'

Fig. 7.03.02: Fuel oil 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.

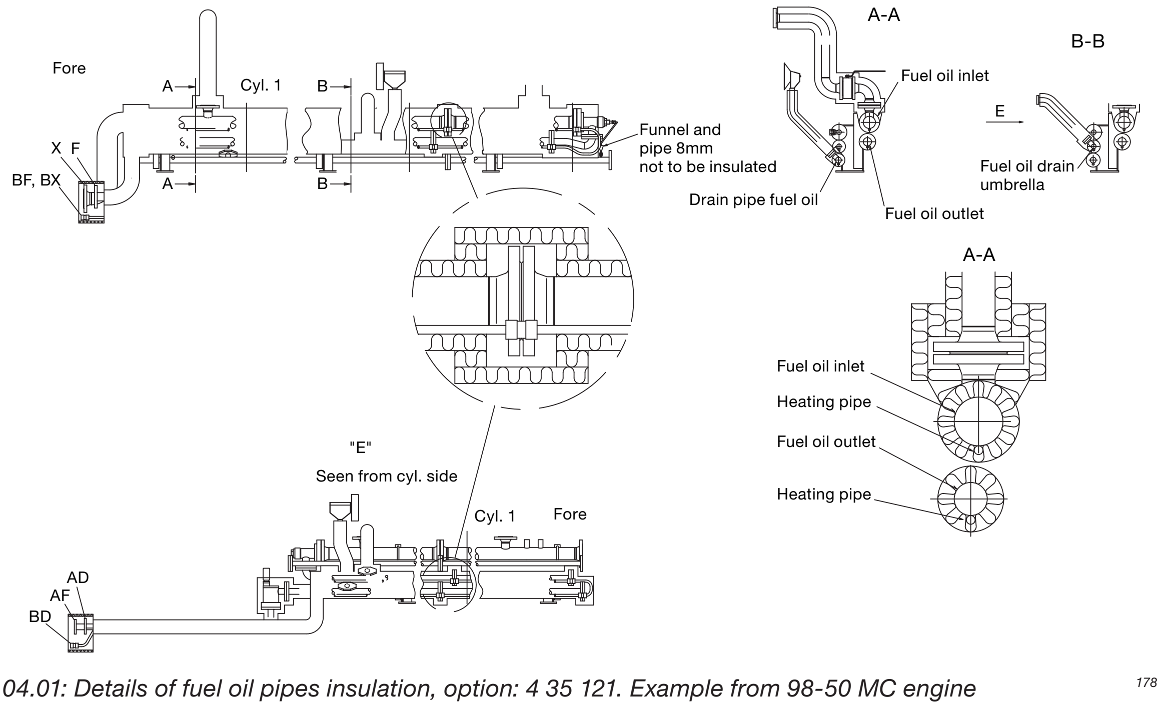


Fig. 7.04.01: Details of fuel oil pipes insulation, option: 4 35 121. Example from 98-50 MC engine

Heat Loss in Piping

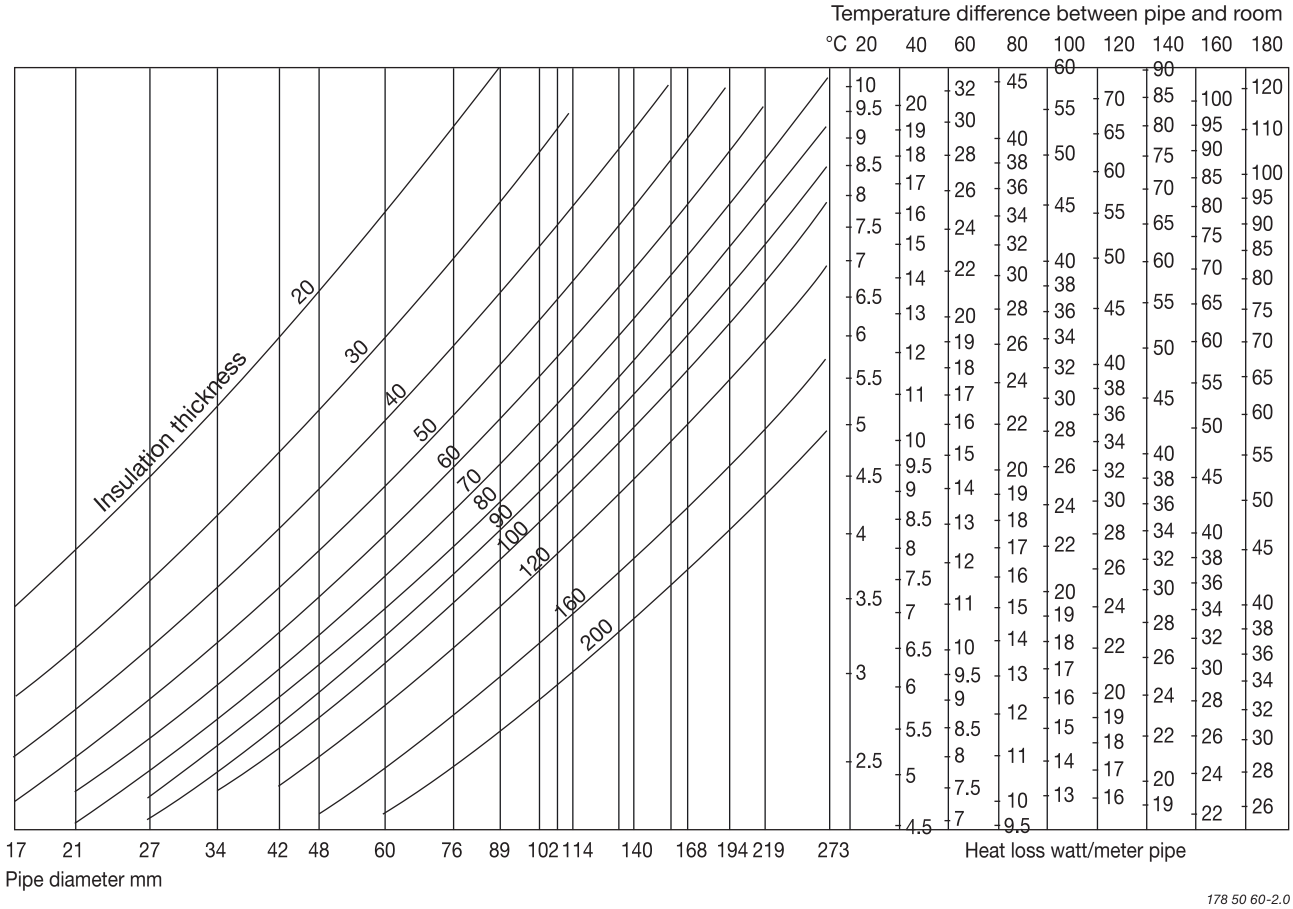


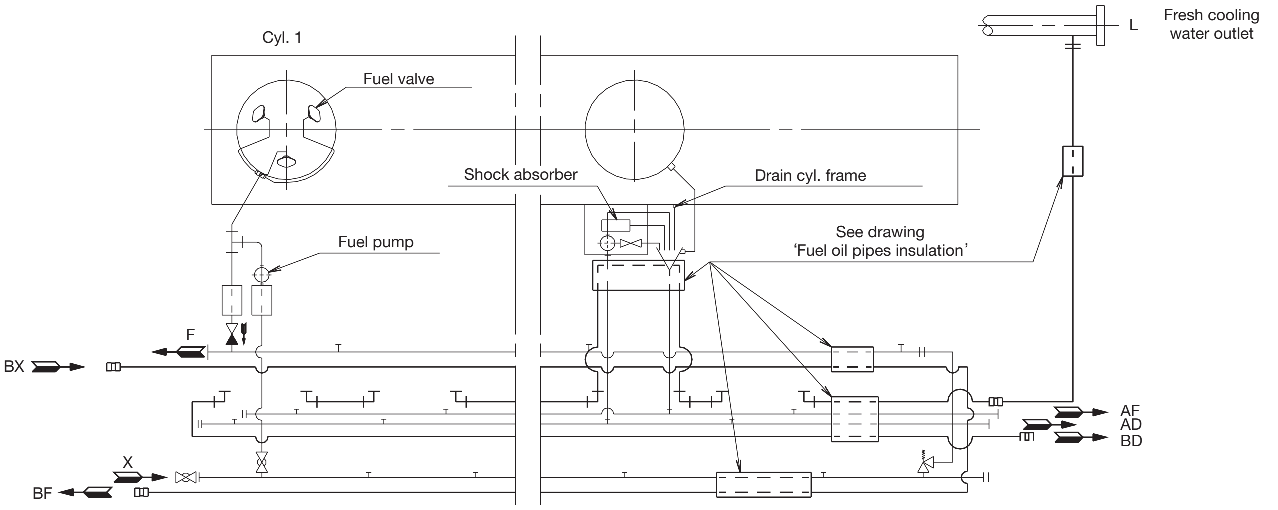
Fig. 7.04.02: Heat loss/Pipe cover

Fuel Oil Pipe Heat Tracing

The steam tracing of the fuel oil pipes is intended to operate in two situations:

1. When the circulation pump is running, there will be a temperature loss in the piping, see Fig. 7.04.02. This loss is very small, therefore tracing in this situation is only necessary with very long fuel supply lines.
2. When the circulation pump is stopped with heavy fuel oil in the piping and the pipes have cooled down to engine room temperature, as it is not possible to pump the heavy fuel oil. In this situation the fuel oil must be heated to pumping temperature of about 50 °C.

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



The letters refer to list of 'Counterflanges'

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Fig. 7.04.03: Fuel oil pipe heat tracing

Fuel Oil and Lubricating Oil Pipe Spray Shields

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

To ensure tightness the spray shields are to be applied after pressure test of the pipe system. as shown in Fig. 7.04.04a and b.

To avoid leaks, the spray shields are to be installed after pressure testing of the pipe system.

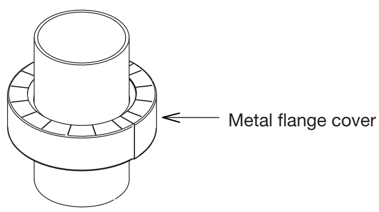


Fig. 7.04.04a: Spray Shields by anti-splashing tape

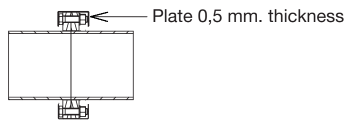


Fig. 7.04.04b: Spray Shields by clamping bands

176 94 23-4.4.0

Components for Fuel Oil System

Fuel oil centrifuges

The manual cleaning type of centrifuges are not to be recommended. Centrifuges must be self-cleaning, either with total discharge or with partial discharge.

Distinction must be made between installations for:

- Specific gravities < 0.991 (corresponding to ISO 8217 and British Standard 6843 from RMA to RMH, and CIMAC from A to H-grades

- Specific gravities > 0.991 and (corresponding to CIMAC K-grades).

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

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

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

0.23 litres/kWh

This figure includes a margin for:

- Water content in fuel oil
- Possible sludge, ash and other impurities in the fuel oil
- Increased fuel oil consumption, in connection with other conditions than ISO standard condition
- Purifier service for cleaning and maintenance.

The size of the centrifuge has to be chosen according to the supplier's table valid for the selected viscosity of the Heavy Fuel Oil. Normally, two centrifuges are installed for Heavy Fuel Oil (HFO), each with adequate capacity to comply with the above recommendation.

A centrifuge for Marine Diesel Oil (MDO) is not a must. However, MAN Diesel & Turbo recommends that at least one of the HFO purifiers can also treat MDO.

If it is decided after all to install an individual purifier for MDO on board, the capacity should be based on the above recommendation, or it should be a centrifuge of the same size as that for HFO.

The *Nominal MCR* is used to determine the total installed capacity. Any derating can be taken into consideration in border-line cases where the centrifuge that is one step smaller is able to cover *Specified MCR*.

Fuel oil supply pump

This is to be of the screw or gear wheel type.

Fuel oil viscosity, specified.... up to 700 cSt at 50 °C
Fuel oil viscosity maximum .... 1,000 cSt
Pump head .... 4 bar
Fuel oil flow .... see 'List of Capacities'
Delivery pressure .... 4 bar
Working temperature .... 100 °C
Minimum temperature .... 50 °C

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

Fuel oil circulating pump

This is to be of the screw or gear wheel type.

Fuel oil viscosity, specified.... up to 700 cSt at 50 °C
Fuel oil viscosity normal .... 20 cSt
Fuel oil viscosity maximum .... 1,000 cSt
Fuel oil flow .... see 'List of Capacities'
Pump head .... 6 bar
Delivery pressure .... 10 bar
Working temperature .... 150 °C

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

Pump head is based on a total pressure drop in filter and preheater of maximum 1.5 bar.

Fuel Oil Heater

The heater is to be of the tube or plate heat exchanger type.

The required heating temperature for different oil viscosities will appear from the 'Fuel oil heating chart', Fig. 7.05.01. The chart is based on information from oil suppliers regarding typical marine fuels with viscosity index 70-80.

Since the viscosity after the heater is the controlled parameter, the heating temperature may vary, depending on the viscosity and viscosity index of the fuel.

Recommended viscosity meter setting is 10-15 cSt.

Fuel oil viscosity specified ... up to 700 cSt at 50°C
Fuel oil flow .... see capacity of fuel oil circulating pump
Heat dissipation .... see 'List of Capacities'
Pressure drop on fuel oil side .... maximum 1 bar
Working pressure .... 10 bar
Fuel oil inlet temperature................. approx. 100 °C
Fuel oil outlet temperature .... 150 °C
Steam supply, saturated .... 7 bar abs

To maintain a correct and constant viscosity of the fuel oil at the inlet to the main engine, the steam supply shall be automatically controlled, usually based on a pneumatic or an electrically controlled system.

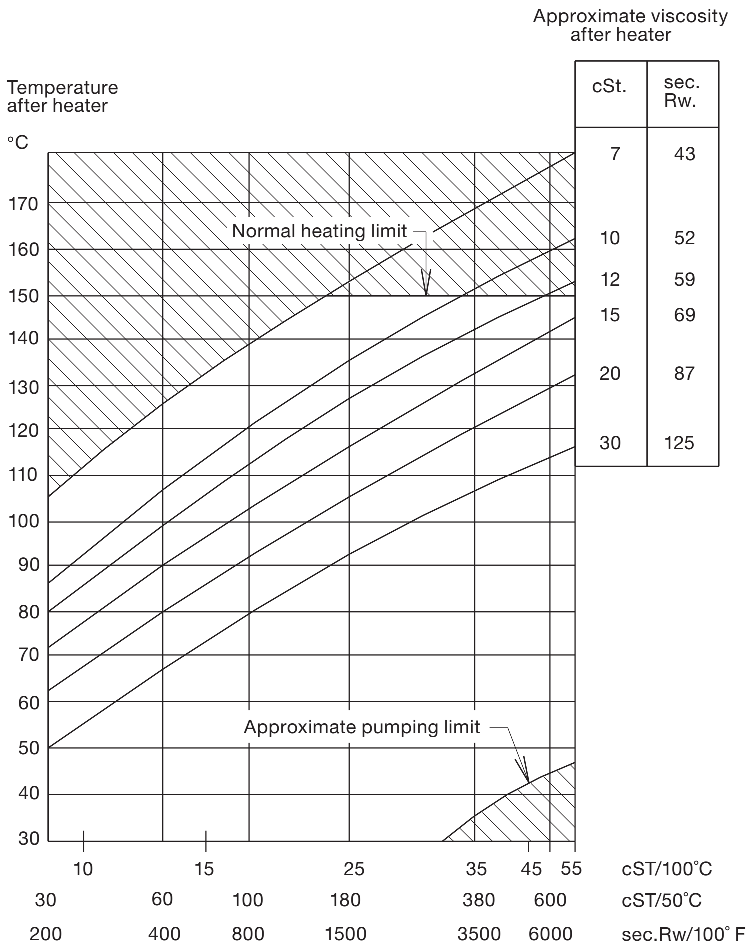


Fig. 7.05.01: Fuel oil heating chart

Fuel oil filter

The filter can be of the manually cleaned duplex type or an automatic filter with a manually cleaned bypass filter.

If a **double filter** (duplex) is installed, it should have sufficient capacity to allow the specified full amount of oil to flow through each side of the filter at a given working temperature with a max. 0.3 bar pressure drop across the filter (clean filter).

If a **filter with backflushing** arrangement is installed, the following should be noted. The required oil flow specified in the 'List of capacities', i.e. the delivery rate of the fuel oil supply pump and the fuel oil circulating pump, should be increased by the amount of oil used for the backflushing, so that the fuel oil pressure at the inlet to the main engine can be maintained during cleaning.

In those cases where an **automatically cleaned filter** is installed, it should be noted that in order to activate the cleaning process, certain makers of filters require a greater oil pressure at the inlet to the filter than the pump pressure specified. Therefore, the pump capacity should be adequate for this purpose, too.

The fuel oil filter should be based on heavy fuel oil of: 130 cSt at 80 °C = 700 cSt at 50 °C = 7000 sec Redwood I/100 °F.

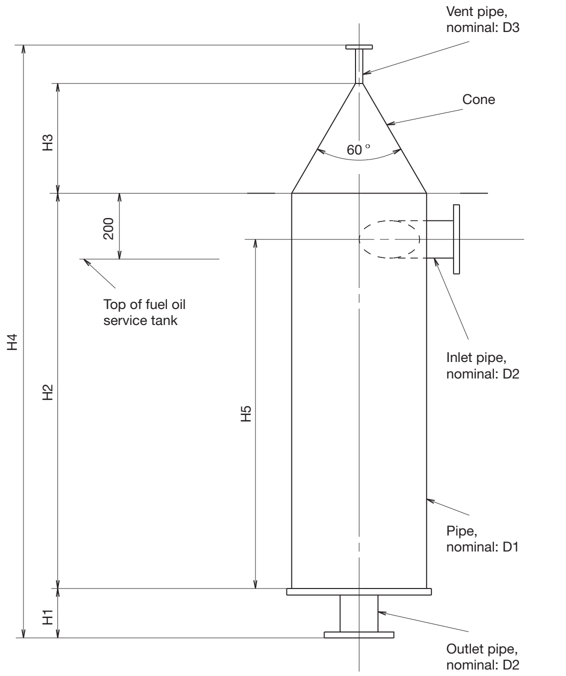
Fuel oil flow .... see 'List of capacities'
Working pressure .... 10 bar
Test pressure...................... according to class rule
Absolute fineness .... 50 µm
Working temperature .... maximum 150 °C
Oil viscosity at working temperature .... 15 cSt
Pressure drop at clean filter .... maximum 0.3 bar
Filter to be cleaned at a pressure
drop of .... maximum 0.5 bar

Note:
Absolute fineness corresponds to a nominal fineness of approximately 35 µm at a retaining rate of 90%.

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

Fuel oil venting box

The design of the Fuel oil venting box is shown in Fig. 7.05.02. The size is chosen according to the maximum flow of the fuel oil circulation pump, which is listed in section 6.03.



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

* The maximum flow of the fuel oil circulation pump

Fig. 07.05.02: Fuel oil venting box

Flushing of the fuel oil system

Before starting the engine for the first time, the system on board has to be flushed in accordance with MAN Diesel & Turbos recommendations 'Flushing of Fuel Oil System' which is available on request.

Water In Fuel Emulsification

The emulsification of water into the fuel oil reduces the NO_x emission with about 1% per 1% water added to the fuel up to about 20% without modification of the engine fuel injection equipment.

A Water In Fuel emulsion (WIF) mixed for this purpose and based on Heavy Fuel Oil (HFO) is stable for a long time, whereas a WIF based on Marine Diesel Oil is only stable for a short period of time unless an emulsifying agent is applied.

As both the MAN B&W two-stroke main engine and the MAN GenSets are designed to run on emulsified HFO, it can be used for a common system.

It is supposed below, that both the main engine and GenSets are running on the same fuel, either HFO or a homogenised HFO-based WIF.

Special arrangements are available on request for a more sophisticated system in which the GenSets can run with or without a homogenised HFO-based WIF, if the main engine is running on that.

Please note that the fuel pump injection capacity shall be confirmed for the main engine as well as the GenSets for the selected percentage of water in the WIF.

Temperature and pressure

When water is added by emulsification, the fuel viscosity increases. In order to keep the injection viscosity at 10-15 cSt and still be able to operate on up to 700 cSt fuel oil, the heating temperature has to be increased to about 170 °C depending on the water content.

The higher temperature calls for a higher pressure to prevent cavitation and steam formation in the system. The inlet pressure is thus set to 13 bar.

In order to avoid temperature chock when mixing water into the fuel in the homogeniser, the water inlet temperature is to be set to 70-90 °C.

Safety system

In case the pressure in the fuel oil line drops, the water homogenised into the Water In Fuel emulsion will evaporate, damaging the emulsion and creating supply problems. This situation is avoided by installing a third, air driven supply pump, which keeps the pressure as long as air is left in the tank ‘S’, see Fig. 7.06.01.

Before the tank ‘S’ is empty, an alarm is given and the drain valve is opened, which will drain off the WIF and replace it with HFO or diesel oil from the service tank.

The drain system is kept at atmospheric pressure, so the water will evaporate when the hot emulsion enters the safety tank. The safety tank shall be designed accordingly.

Impact on the auxiliary systems

Please note that if the engine operates on Water In Fuel emulsion (WIF), in order to reduce the NO_x emission, the exhaust gas temperature will decrease due to the reduced air / exhaust gas ratio and the increased specific heat of the exhaust gas.

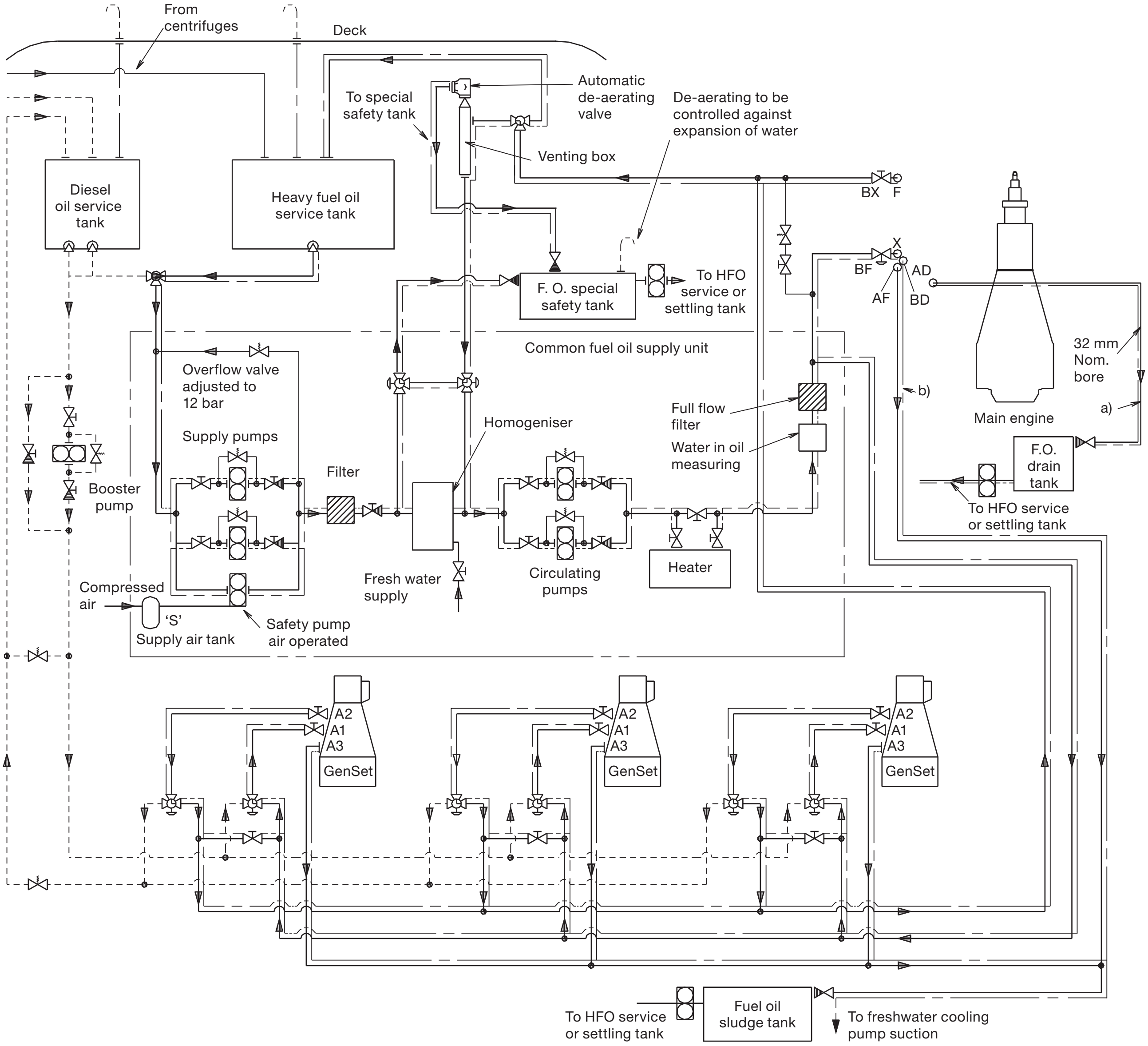
Depending on the water content, this will have an impact on the calculation and design of the following items:

- Freshwater generators
- Energy for production of freshwater
- Jacket water system
- Waste heat recovery system
- Exhaust gas boiler
- Storage tank for freshwater

For further information about emulsification of water into the fuel and use of Water In Fuel emulsion (WIF), please refer to our publication titled:

Exhaust Gas Emission Control Today and Tomorrow

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



- - - - - - - - -	Diesel oil
————————	Heavy fuel oil
═══ - ═══	Heated pipe with insulation

Number of auxiliary engines, pumps, coolers, etc. are subject to alterations according to the actual plant specification.

a) Tracing fuel oil lines: Max. 150 °C
b) Tracing fuel oil drain lines: Max. 90 °C, min. 50 °C for installations with jacket cooling water

The letters refer to the list of 'Counterflanges'.

198 99 01-8.3

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

Lubricating Oil

8

Lubricating and Cooling Oil System

The lubricating oil is pumped from a bottom tank by means of the main lubricating oil pump to the lubricating oil cooler, a thermostatic valve and, through a full-flow filter, to the engine inlet RU, Fig. 8.01.01.

RU lubricates main bearings, thrust bearing, axial vibration damper, crankpin bearings, piston cooling, crosshead, camshaft and turbocharger bearings.

The main lube oil system is common to the camshaft as well. The major part of the oil is divided between piston cooling and crosshead lubrication.

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.

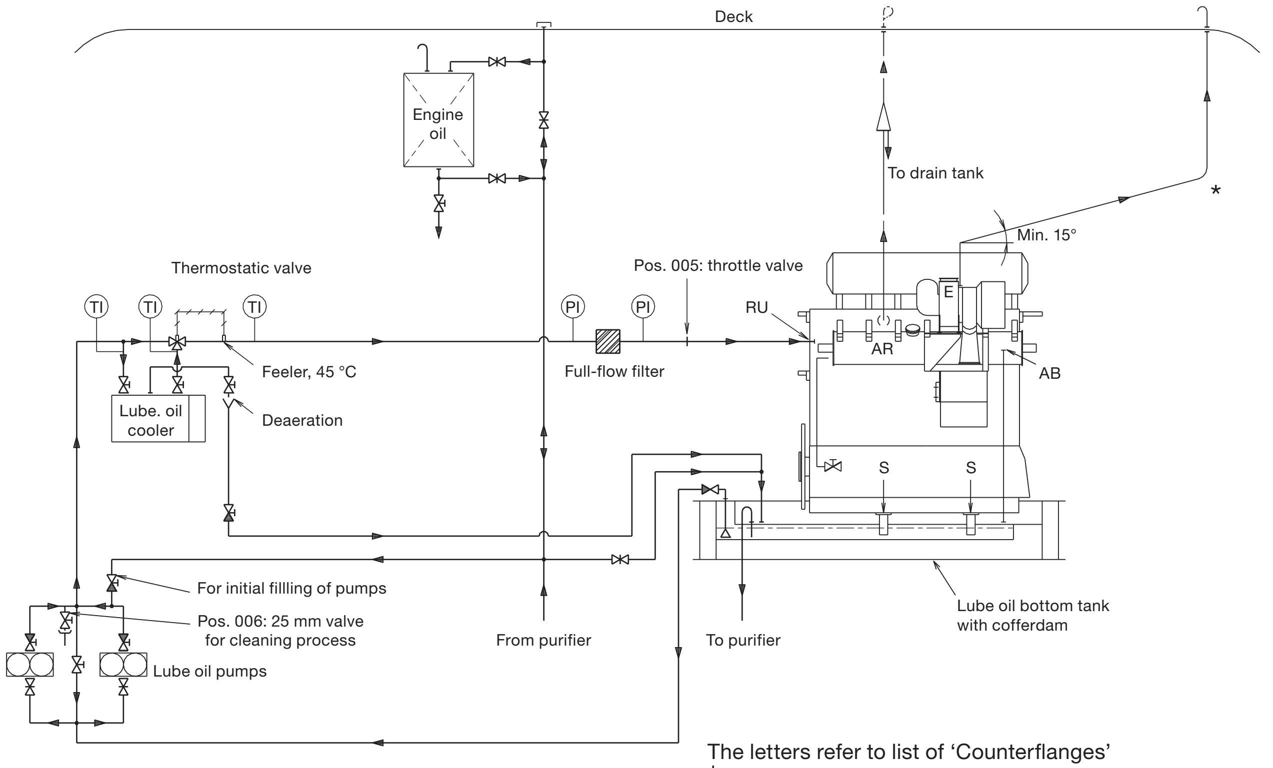
Drains from the engine bedplate 'AE' are fitted on both sides, see Fig. 8.07.02 'Bedplate drain pipes'.

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 8.03.03.

Figs. 8.03.01 to 8.03.03 show the lube oil pipe arrangements for different turbocharger makes.



The letters refer to list of 'Counterflanges'
* Venting for MAN Diesel or Mitsubishi turbochargers only

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Fig. 8.01.01 Lubricating and cooling oil system

Lubricating and Cooling Oil Pipes

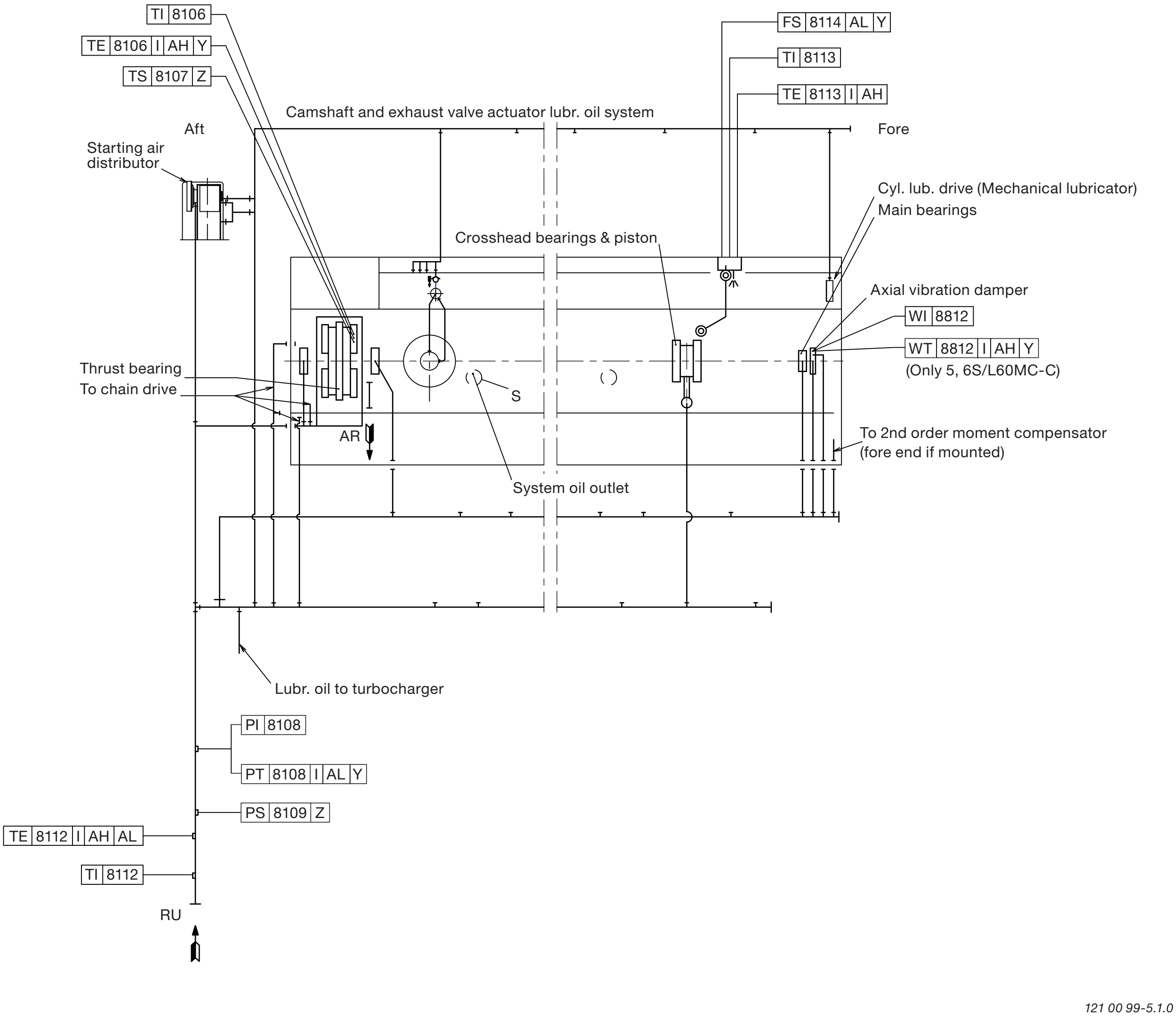


Fig. 8.01.02 Lubricating and Cooling Oil Pipes on engine

Hydraulic power supply unit

This section is not applicable

Lubricating Oil Pipes for Turbochargers

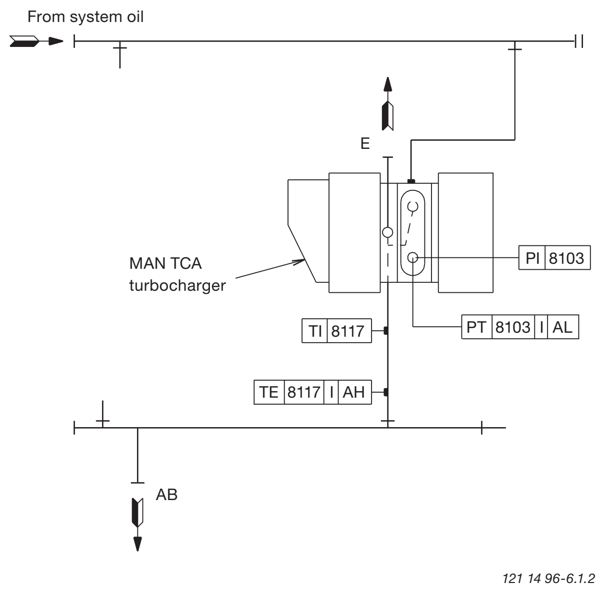


Fig. 8.03.01: MAN turbocharger type TCA

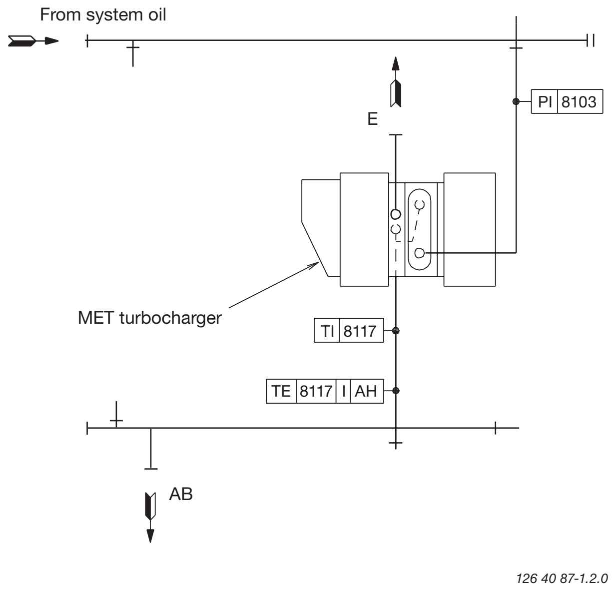


Fig. 8.03.03: Mitsubishi turbocharger type MET

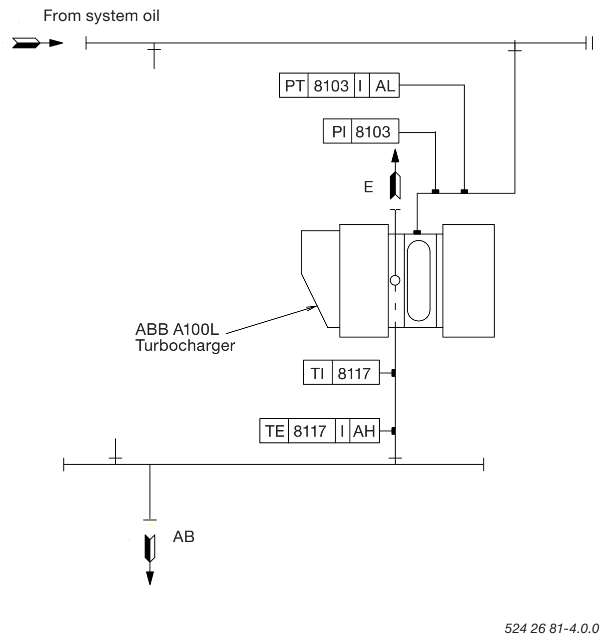


Fig. 8.03.03: ABB turbocharger type A100L

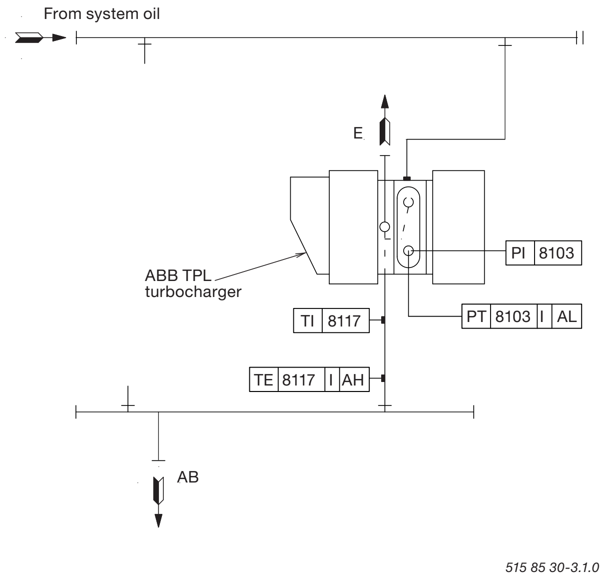


Fig. 8.03.02: ABB turbocharger type TPL85B14-16 / TPL 91B12

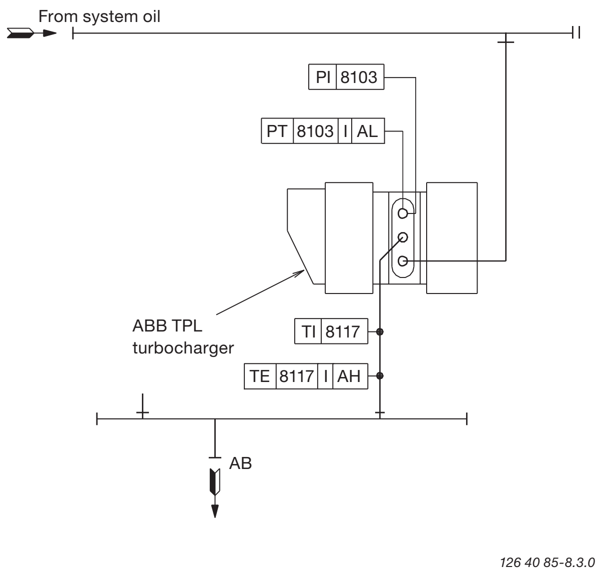


Fig. 8.03.02: ABB turbocharger type TPL65B12 - TPL85B12

Lubricating Oil Consumption, Centrifuges and List of Lubricating Oils

Lubricating oil consumption

The system oil consumption varies for different engine sizes and operational patterns. Typical consumptions are in the range from

negligible to 0.1 g/kWh

subject to load, maintenance condition and installed equipment like PTO.

Lubricating oil centrifuges

Automatic centrifuges are to be used, either with total discharge or partial discharge.

The nominal capacity of the centrifuge is to be according to the supplier's recommendation for lubricating oil, based on the figure:

0.136 litre/kWh

The Nominal MCR is used as the total installed power.

Further information about lubricating oil qualities is available in our publication:

Guidelines for Fuels and Lubes Purchasing

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

List of lubricating oils

The circulating oil (lubricating and cooling oil) must be of the rust and oxidation inhibited type of oil of SAE 30 viscosity grade.

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

- SAE 30 viscosity grade
- BN level 5-10
- adequately corrosion and oxidation inhibited
- adequate detergengy and dispersancy.

The adequate dispersion and detergent properties are in order to keep the crankcase and piston cooling spaces clean of deposits.

Alkaline circulating oils are generally superior in this respect.

The major international system oil brands listed below have been tested in service with acceptable results. Some of the oils have also given satisfactory service results during long-term operation on MAN B&W engines running on heavy fuel oil (HFO).

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

Oils from other companies can be equally suitable. Further information can be obtained from the engine builder or MAN Diesel & Turbo, Copenhagen.

Components for Lubricating Oil System

Lubricating oil pump

The lubricating oil pump can be of the displacement wheel, or the centrifugal type:

Lubricating oil viscosity, specified...75 cSt at 50 °C
Lubricating oil viscosity........... maximum 400 cSt *
Lubricating oil flow .... see 'List of capacities'
Design pump head .... 4.3 bar
Delivery pressure .... 4.3 bar
Max. working temperature .... 70 °C

* *400 cSt is specified, as it is normal practice when starting on cold oil, to partly open the bypass valves of the lubricating oil pumps, so as to reduce the electric power requirements for the pumps.*

The flow capacity must be within a range from 100 to 112% of the capacity stated.

The pump head is based on a total pressure drop across cooler and filter of maximum 1 bar.

Referring to Fig. 8.01.01, the bypass valve shown between the main lubricating oil pumps may be omitted in cases where the pumps have a built-in bypass or if centrifugal pumps are used.

If centrifugal pumps are used, it is recommended to install a throttle valve at position '005' to prevent an excessive oil level in the oil pan if the centrifugal pump is supplying too much oil to the engine.

During trials, the valve should be adjusted by means of a device which permits the valve to be closed only to the extent that the minimum flow area through the valve gives the specified lubricating oil pressure at the inlet to the engine at full normal load conditions. It should be possible to fully open the valve, e.g. when starting the engine with cold oil.

It is recommended to install a 25 mm valve (pos. 006), with a hose connection after the main lubricating oil pumps, for checking the cleanliness of the lubricating oil system during the flushing procedure. The valve is to be located on the underside of a horizontal pipe just after the discharge from the lubricating oil pumps.

Lubricating oil cooler

The lubricating oil cooler must be of the shell and tube type made of seawater resistant material, or a plate type heat exchanger with plate material of titanium, unless freshwater is used in a central cooling water system.

Lubricating oil viscosity, specified...75 cSt at 50 °C
Lubricating oil flow .... see 'List of capacities'
Heat dissipation .... see 'List of capacities'
Lubricating oil temperature, outlet cooler...... 45 °C
Working pressure on oil side........................ 4.3 bar
Pressure drop on oil side .... maximum 0.5 bar
Cooling water flow.............. see 'List of capacities'
Cooling water temperature at inlet:
seawater .... 32 °C
freshwater.. 36 °C
Pressure drop on water side .... maximum 0.2 bar

The lubricating oil flow capacity must be within a range from 100 to 112% of the capacity stated.

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

To ensure the correct functioning of the lubricating oil cooler, we recommend that the seawater temperature is regulated so that it will not be lower than 10 °C.

The pressure drop may be larger, depending on the actual cooler design.

Lubricating oil temperature control valve

The temperature control system can, by means of a three-way valve unit, by-pass the cooler totally or partly.

Lubricating oil viscosity, specified....75 cSt at 50 °C
Lubricating oil flow .... see 'List of capacities'
Temperature range, inlet to engine .... 40 - 47 °C

Lubricating oil full flow filter

Lubricating oil flow .... see 'List of capacities'
Working pressure ....4.3 bar
Test pressure.....................according to class rules
Absolute fineness...40 μm*
Working temperature .... approximately 45 °C
Oil viscosity at working temp. .... 90 - 100 cSt
Pressure drop with clean filter .... maximum 0.2 bar
Filter to be cleaned
at a pressure drop....................... maximum 0.5 bar

** The absolute fineness corresponds to a nominal fineness of approximately 25 μm at a retaining rate of 90%.*

The flow capacity must be within a range from 100 to 112% of the capacity stated.

The full-flow filter should be located as close as possible to the main engine.

If a double filter (duplex) is installed, it should have sufficient capacity to allow the specified full amount of oil to flow through each side of the filter at a given working temperature with a pressure drop across the filter of maximum 0.2 bar (clean filter).

If a filter with a back-flushing arrangement is installed, the following should be noted:

- The required oil flow, specified in the 'List of capacities', should be increased by the amount of oil used for the back-flushing, so that the lubricating oil pressure at the inlet to the main engine can be maintained during cleaning.
- If an automatically cleaned filter is installed, it should be noted that in order to activate the cleaning process, certain makes of filter require a higher oil pressure at the inlet to the filter than the pump pressure specified. Therefore, the pump capacity should be adequate for this purpose, too.

Flushing of lubricating oil components and piping system at the shipyard

During installation of the lubricating oil system for the main engine, it is important to minimise or eliminate foreign particles in the system. This is done as a final step onboard the vessel by flushing the lubricating oil components and piping system of the MAN B&W main engine types MC/MC-C before starting the engine.

At the shipyard, the following main points should be observed during handling and flushing of the lubricating oil components and piping system:

- **Before and during installation**
  Components delivered from subsuppliers, such as pumps, coolers and filters, are expected to be clean and rust protected. However, these must be spot-checked before being connected to the piping system.

  All piping must be ‘finished’ in the workshop before mounting onboard, i.e. all internal welds must be ground and piping must be acid-treated followed by neutralisation, cleaned and corrosion protected.

  Both ends of all pipes must be closed/sealed during transport.

  Before final installation, carefully check the inside of the pipes for rust and other kinds of foreign particles.

  Never leave a pipe end uncovered during assembly.

- **Bunkering and filling the system**
  Tanks must be cleaned manually and inspected before filling with oil.

  When filling the oil system, MAN Diesel & Turbo recommends that new oil is bunkered through 6 µm fine filters, or that a purifier system is used. New oil is normally delivered with a cleanliness level of XX/23/19 according to ISO 4406 and, therefore, requires further cleaning to meet our specification.

- **Flushing the piping with engine bypass**
  When flushing the system, the first step is to bypass the main engine oil system. Through temporary piping and/or hosing, the oil is circulated through the vessel’s system and directly back to the main engine oil sump tank.

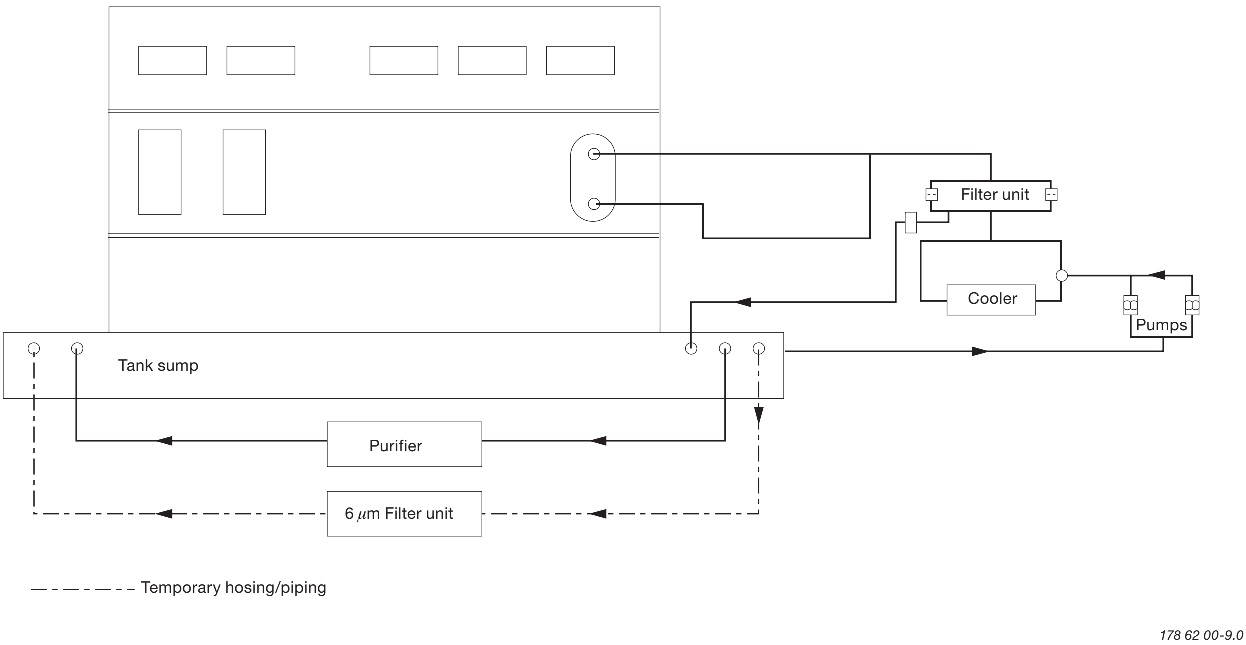


Fig. 8.05.01: Lubricating oil system with temporary hosing/piping for flushing at the shipyard

If the system has been out of operation, unused for a long time, it may be necessary to spot-check for signs of corrosion in the system. Remove end covers, bends, etc., and inspect accordingly.

It is important during flushing to keep the oil warm, approx 60 °C, and the flow of oil as high as possible. For that reason it may be necessary to run two pumps at the same time.

- **Filtering and removing impurities**
  In order to remove dirt and impurities from the oil, it is essential to run the purifier system during the complete flushing period and/or use a bypass unit with a 6 µm fine filter and sump-to-sump filtration, see Fig. 8.05.01.

  Furthermore, it is recommended to reduce the filter mesh size of the main filter unit to 10-25 µm (to be changed again after sea trial). This can lead to a reduction of the flushing time.

  The flushing time depends on the system type, the condition of the piping and the experience of the yard. (15 to 26 hours should be expected).

- **Cleanliness level, measuring kit and flushing log**
  MAN Diesel & Turbo specifies ISO 4406 XX/19/15 as accepted cleanliness level for the MC/MC-C lubricating oil system.

  The amount of contamination contained in system samples can be estimated by means of the Pall Fluid Contamination Comparator combined with the Portable Analysis Kit, HPCA-Kit-0, which is used by MAN Diesel & Turbo. This kit and the Comparator included is supplied by Pall Corporation, USA, www.pall.com

  It is important to record the flushing condition in statements to all inspectors involved. The MAN Diesel & Turbo Flushing Log form, which is available on request, or a similar form is recommended for this purpose.

- **Flushing the engine oil system**
  The second step of flushing the system is to flush the complete engine oil system. The procedure depends on the engine type and the condition in which the engine is delivered from the engine builder. For detailed information we recommend contacting the engine builder or MAN Diesel & Turbo.

- **Inspection and recording in operation**
  Inspect the filters before and after the sea trial.

  During operation of the oil system, check the performance and behaviour of all filters, and note down any abnormal condition. Take immediate action if any abnormal condition is observed. For instance, if high differential pressure occurs at short intervals, or in case of abnormal back flushing, check the filters and take appropriate action.

Further information and recommendations regarding flushing, the specified cleanliness level and how to measure it, and how to use the NAS 1638 oil cleanliness code as an alternative to ISO 4406, are available from MAN Diesel & Turbo.

Lubricating oil outlet

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

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

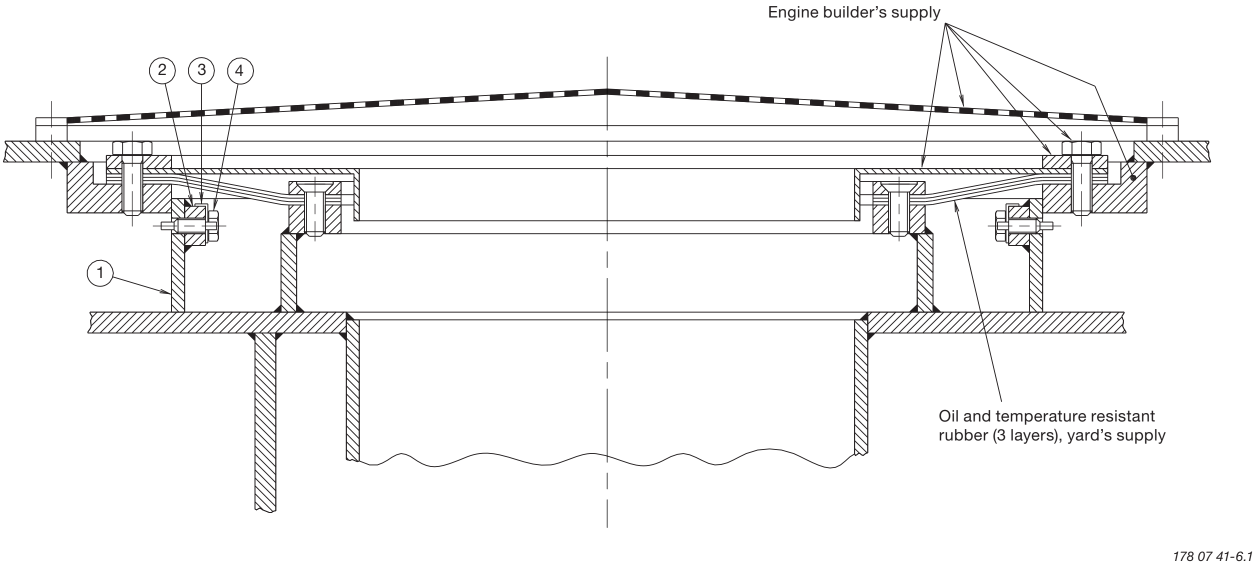


Fig. 8.05.02: Lubricating oil outlet

Lubricating Oil Tank

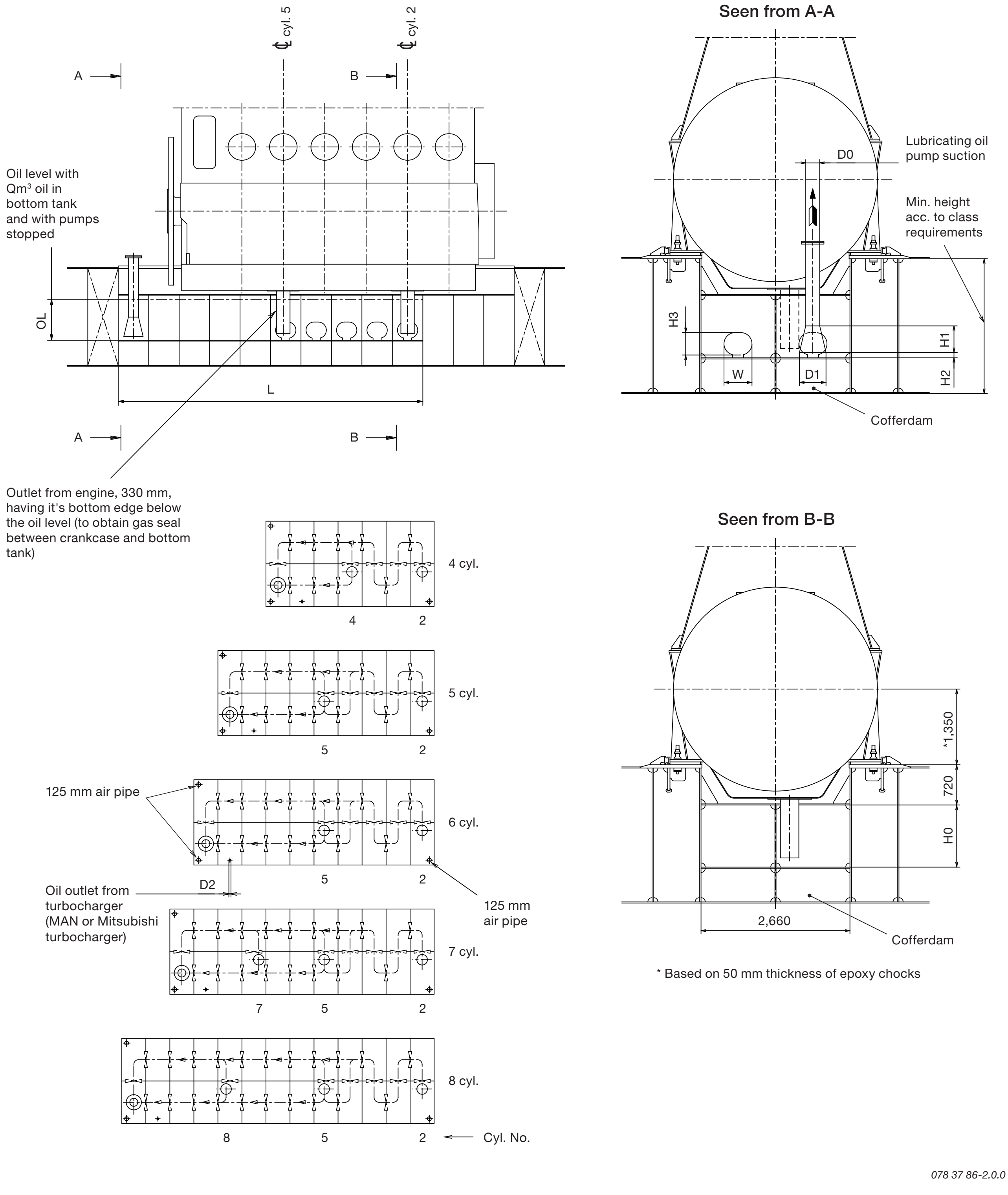


Fig. 8.06.01a: Lubricating oil tank, with cofferdam

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 cylinder No.	D0	D1	D2	H0	H1	H2	H3	W	L	OL	Qm^3
4	2-4	200	425	65	1,000	425	85	300	400	5,250	900	10.5
5	2-5	225	450	100	1,035	450	90	300	400	6,750	935	14.0
6	2-5	250	475	100	1,110	475	95	400	500	7,500	1,010	16.8
7	2-5-7	275	550	100	1,150	550	110	400	500	8,250	1,050	19.2
8	2-5-8	275	550	100	1,220	550	110	400	500	9,750	1,120	24.2

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:

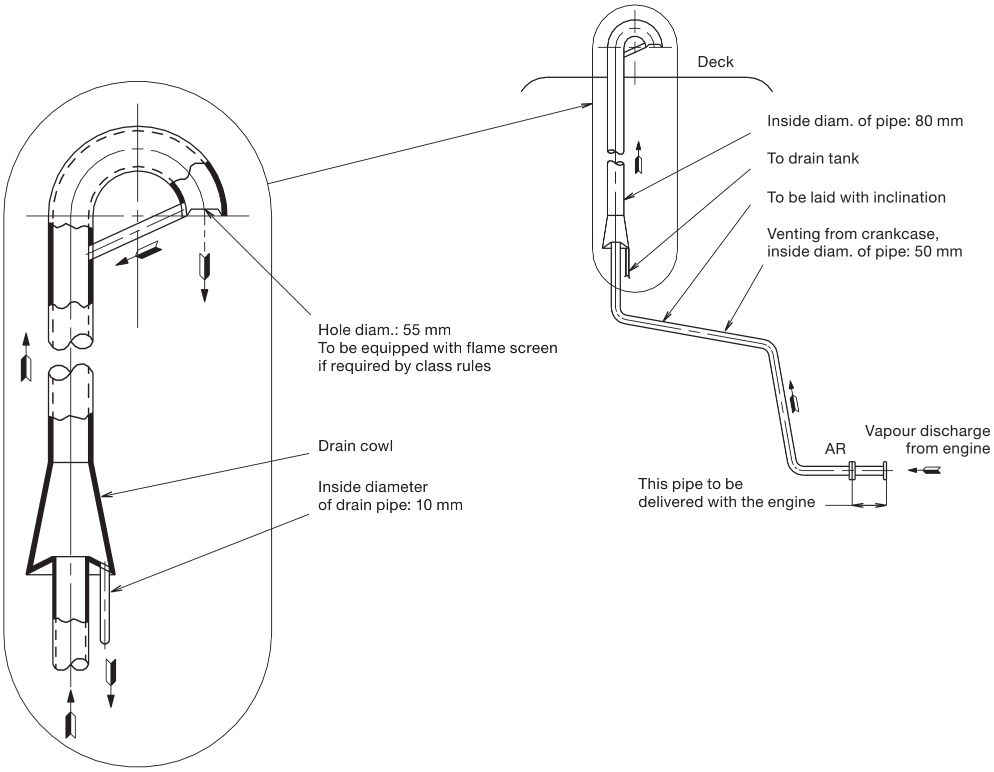
4 cyl.	5 cyl.	6 cyl.	7 cyl.	8 cyl.
10.5	14.0	16.8	19.2	23.0

Lubricating oil tank operating conditions

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

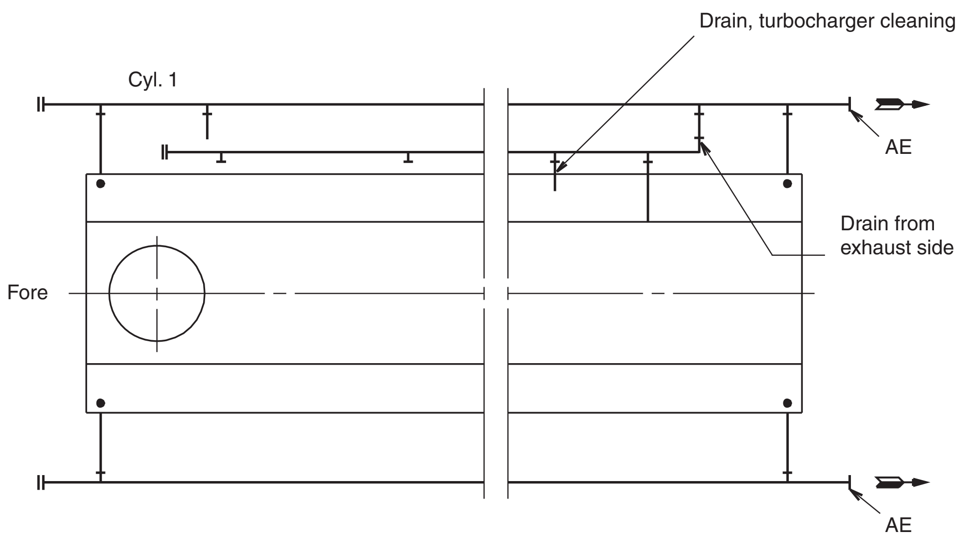
Angle of inclination, degrees			
Athwartships		Fore and aft	
Static	Dynamic	Static	Dynamic
15	22.5	5	7.5

Crankcase Venting and Bedplate Drain Pipes



178 57 78-0.0

Fig. 8.07.01: Crankcase venting



178 57 58-8.0

Fig. 8.07.02: Bedplate drain pipes

Engine and Tank Venting to the Outside Air

Venting of engine plant equipment separately

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

MAN Diesel & Turbo recommends to vent the individual components directly to outside air above deck by separate venting pipes as shown in Fig. 8.07.03a.

It is not recommended to join the individual venting pipes in a common venting chamber as shown in Fig. 8.07.03b.

In order to avoid condensed oil (water) from blocking the venting, all vent pipes must be vertical or laid with an inclination.

Additional information on venting of tanks is available from MAN Diesel & Turbo, Copenhagen.

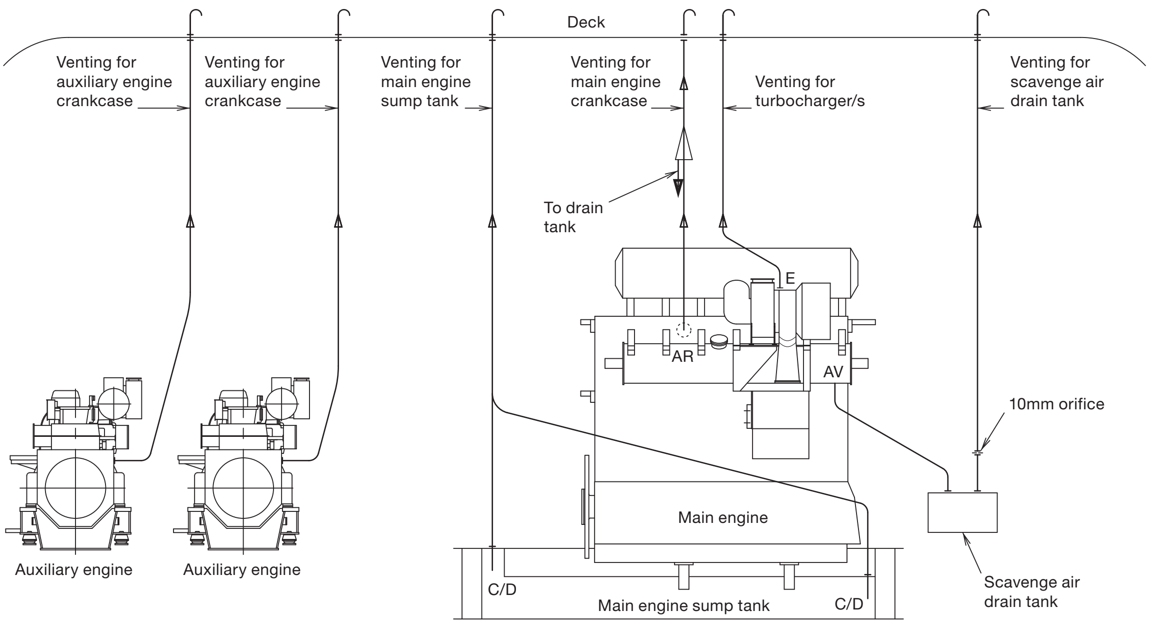
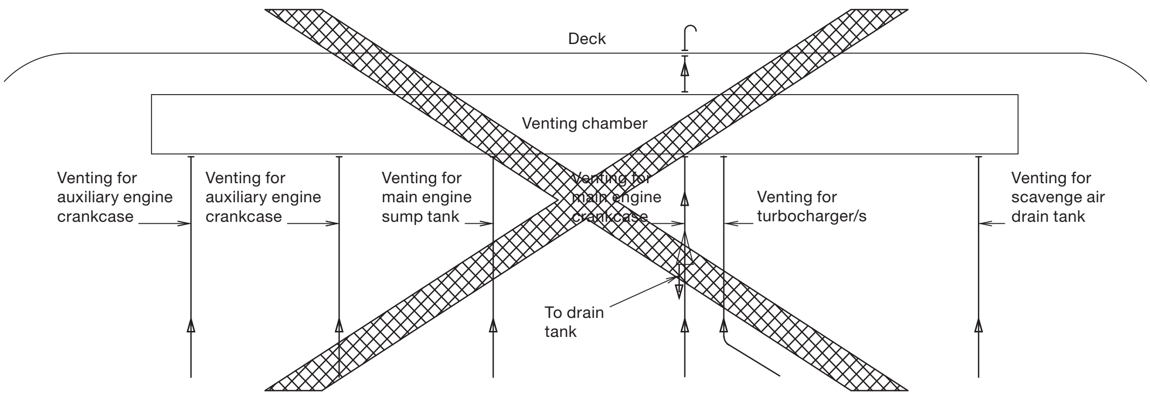


Fig. 8.07.03a: Separate venting of all systems directly to outside air above deck



079 61 00-5.1.1

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

Cylinder Lubrication

9

Cylinder Lubricating Oil System

The cost of the cylinder lubricating oil is one of the largest contributions to total operating costs, next to the fuel oil cost. Another aspect is that the lubrication rate has a great influence on the cylinder condition, and thus on the overhauling schedules and maintenance costs.

It is therefore of the utmost importance that the cylinder lubricating oil system as well as its operation is optimised.

Cylinder oils

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

- SAE 50 viscosity grade
- high detergency
- BN 100 for high-sulphur fuel
- BN 40 for low-sulphur fuel.

A BN 100 cylinder oil is to be used as the default choice of oil and it may be used on all fuel types. However, in case of the engine running on fuel with sulphur content lower than 1.5% for more than 2 weeks, we recommend to change to a lower BN cylinder oil such as a BN 40.

Cylinder lubricators and service tank

The cylinder lubricators can be either the electronic MAN B&W Alpha Cylinder Lubricators or a mechanical type driven by the engine. Basic design is MAN B&W Alpha Cylinder Lubricators, EoD: 4 42 104. The options are listed in the Extent of Delivery.

The cylinder lube oil is supplied from a gravity-feed cylinder oil service tank to where it is being pumped from the cylinder oil storage tank. The size of the cylinder oil service tank depends on the owner's and yard's requirements, and it is normally dimensioned for minimum two days' consumption.

The cylinder lubricating oil consumption could be monitored by installing a flow meter on the pressure side of the pump in the supply line to the service tank, if required by the shipowner.

Provided the oil level in the service tank is kept the same every time the flow meter is being read, the accuracy is satisfactory.

Two-tank cylinder oil supply system

A cylinder lubricating oil supply system for engine plants with MAN B&W Alpha Cylinder Lubricators is shown in Fig. 9.02.02 and for plants with mechanical cylinder lubricators in Fig. 9.03.03. In both cases a dual system for supply of two different BN cylinder oils is shown.

Cylinder oil feed rate (dosage)

The recommendations are valid for all plants, whether controllable pitch or fixed pitch propellers are used.

In case of average sulphur content, the average cylinder oil feed rate at all loads for MAN B&W Alpha Cylinder Lubricator is 0.65 g/kWh. Adjustment of the cylinder oil dosage of the MAN B&W Alpha Cylinder Lubricator to the sulphur content in the fuel being burnt is further explained in Section 9.02.

The nominal cylinder oil feed rate at nominal MCR for a mechanical cylinder lubricator is typically 1.0 - 1.5 g/kWh.

Further information about cylinder lubrication on different fuel types is available in our publication:

Operation on Low-Sulphur Fuels

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

List of cylinder oils

The major international cylinder oil brands listed below have been tested in service with acceptable results. Some of the oils have also given satisfactory service results during long-term operation on MAN B&W engines running on heavy fuel oil (HFO).

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

Oils from other companies can be equally suitable. Further information can be obtained from the engine builder or MAN Diesel & Turbo, Copenhagen.

MAN B&W Alpha Cylinder Lubrication System

The MAN B&W Alpha cylinder lubrication system, see Figs. 9.02.02 and 9.02.03, is designed to supply cylinder oil intermittently, every 2 to 20 engine revolutions with electronically controlled timing and dosage at a defined position.

Cylinder lubricating oil is fed to the engine by means of a pump station which as standard is mounted on the engine, EoD: 4 42 150, or could be placed in the engine room, option: 4 42 152.

The pump station has two pumps (one operating, the other stand-by with automatic start up) with in-line filters and a heater, see Fig. 9.02.02.

The oil fed to the injectors is pressurised by means of one or two Alpha Lubricators placed on each cylinder and equipped with small multi-piston pumps, see Fig. 9.02.03.

Accumulator tanks on the lubricator inlet pipes ensure adequate filling of the lubricator while accumulators on the outlet pipes serve to dampen the pressure fluctuations. The oil pipes fitted on the engine is shown in Fig. 9.02.03.

On engines with double lubricators, a by-pass valve allows for circulating and heating the cylinder oil before starting the engine under cold engine room conditions. On engines with one lubricator per cylinder, this is done by means of the valve on the cylinderblock intended for emptying the accumulator.

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%.

System control units

The cylinder lubrication system is controlled by the Master Control Unit (MCU) which calculates the injection frequency on the basis of the engine-speed signal given by the tacho signal (ZE) and the fuel index.

Lubricating control functions such as ‘mep dependent’ and ‘load change dependent’ are all incorporated in the MAN B&W Alpha cylinder lubrication system.

The MAN B&W Alpha Cylinder Lubricator is preferably to be controlled in accordance with the Alpha Adaptive Cylinder oil Control (Alpha ACC) feed rate system. The Alpha ACC is explained in the following page.

The MCU is equipped with a Backup Control Unit (BCU) which, if the MCU malfunctions, activates an alarm and takes control automatically or manually, via a Switch Board Unit (SBU), Fig. 9.02.04.

The MCU, BCU and SBU together comprise the Alpha Cylinder Lubricator Control Unit (ALCU) in shape of a single steel cabinet which is, as standard, located in the Engine Control Room. Fig. 9.02.05 shows the wiring diagram for the MAN B&W Alpha Cylinder Lubrication System.

The yard supply should be according to the items shown in Fig. 9.02.02 within the broken line.

Alpha Adaptive Cylinder Oil Control (Alpha ACC)

It is a well-known fact that the actual need for cylinder oil quantity varies with the operational conditions such as load and fuel oil quality. Consequently, in order to perform the optimal lubrication – cost-effectively as well as technically – the cylinder lubricating oil dosage should follow such operational variations accordingly.

The Alpha lubricating system offers the possibility of saving a considerable amount of cylinder lubricating oil per year and, at the same time, to obtain a safer and more predictable cylinder condition.

Alpha ACC (Adaptive Cylinder-oil Control) is the lubrication mode for MAN B&W two-stroke engines, i.e. lube oil dosing proportional to the engine load and proportional to the sulphur content in the fuel oil being burnt.

Working principle

The feed rate control should be adjusted in relation to the actual fuel quality and amount being burnt at any given time.

The following criteria determine the control:

- The cylinder oil dosage shall be proportional to the sulphur percentage in the fuel
- The cylinder oil dosage shall be proportional to the engine load (i.e. the amount of fuel entering the cylinders)
- The actual feed rate is dependent of the operating pattern and determined based on engine wear and cylinder condition.

The implementation of the above criteria will lead to an optimal cylinder oil dosage.

Specific minimum dosage with Alpha ACC

The recommendations are valid for all plants, whether controllable pitch or fixed pitch propellers are used. The specific minimum dosage at lower-sulphur fuels is set at 0.6 g/kWh.

After a running-in period of 500 hours, the feed rate sulphur proportional factor is 0.20 - 0.34 g/kWh × S%. The actual ACC factor will be based on cylinder condition, and preferably a cylinder oil feed rate sweep test should be applied.

Examples of average cylinder oil consumption based on calculations of the average worldwide sulphur content used on MAN B&W two-stroke engines are shown in Fig. 9.02.01a and b.

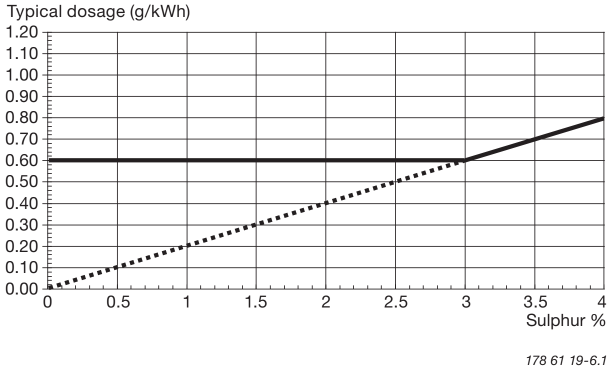


Fig. 9.02.01a: ACC = 0.20 g/kWh × S% and BN100 cylinder oil – average consumption less than 0.65 g/kWh

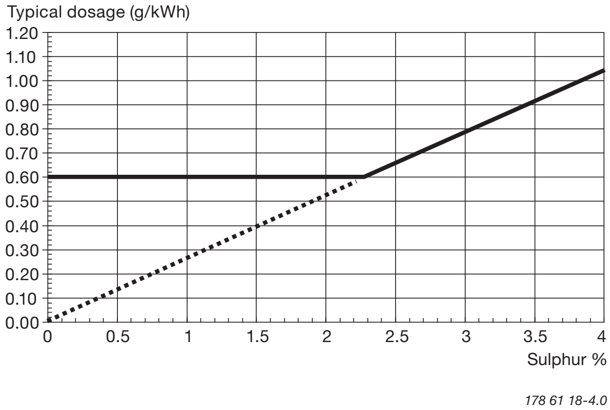
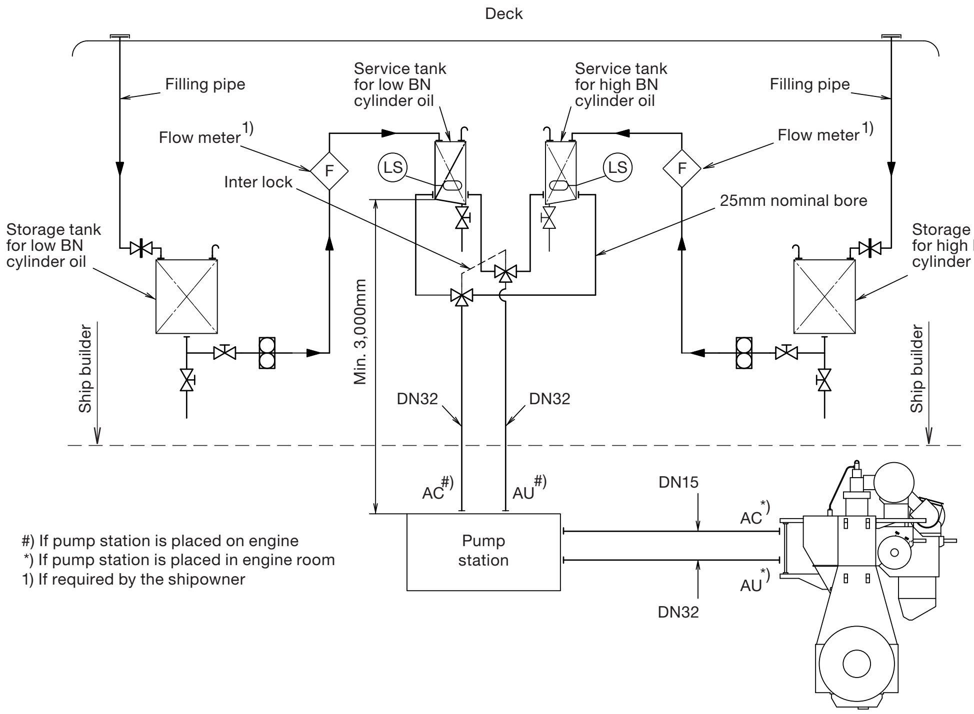


Fig. 9.02.01b: ACC = 0.26 g/kWh × S% and BN100 cylinder oil – average consumption less than 0.7 g/kWh

Further information on cylinder oil as a function of fuel oil sulphur content, alkalinity of lubricating oil and operating pattern as well as assessing the engine wear and cylinder condition is available from MAN Diesel & Turbo, Copenhagen.

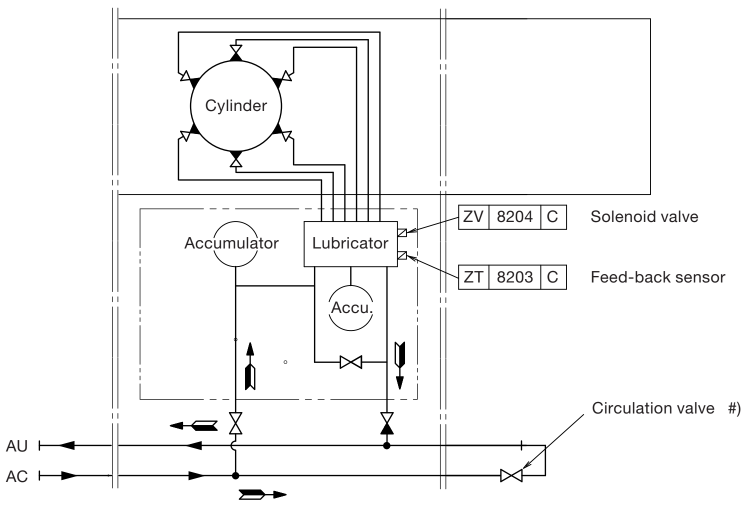
Pump Station and MAN B&W Alpha Cylinder Lubricators on Engine



The letters refer to list of ‘Counterflanges’
The item No. refer to ‘Guidance values Automation’

078 78 46-0.0.0b

Fig. 9.02.02: Cylinder lubricating oil supply system for two different BN oils



The letters refer to list of ‘Counterflanges’
The item No. refer to ‘Guidance values Automation’

#) In case of COLD engine room conditions, open the valve to circulate and heat up the cylinder oil. The valve is then to be closed before starting.

121 36 61-8.4.0c

Fig. 9.02.03: MAN B&W Alpha cylinder lubricators with piping and instrumentation on engine

Lubricator Control System

The external electrical system must be capable of providing the MCU and BCU with an un-interruptible supply of 24 Volt DC power.

The MAN B&W Alpha Cylinder Lubricator System is equipped with the following (Normally Closed) alarms:

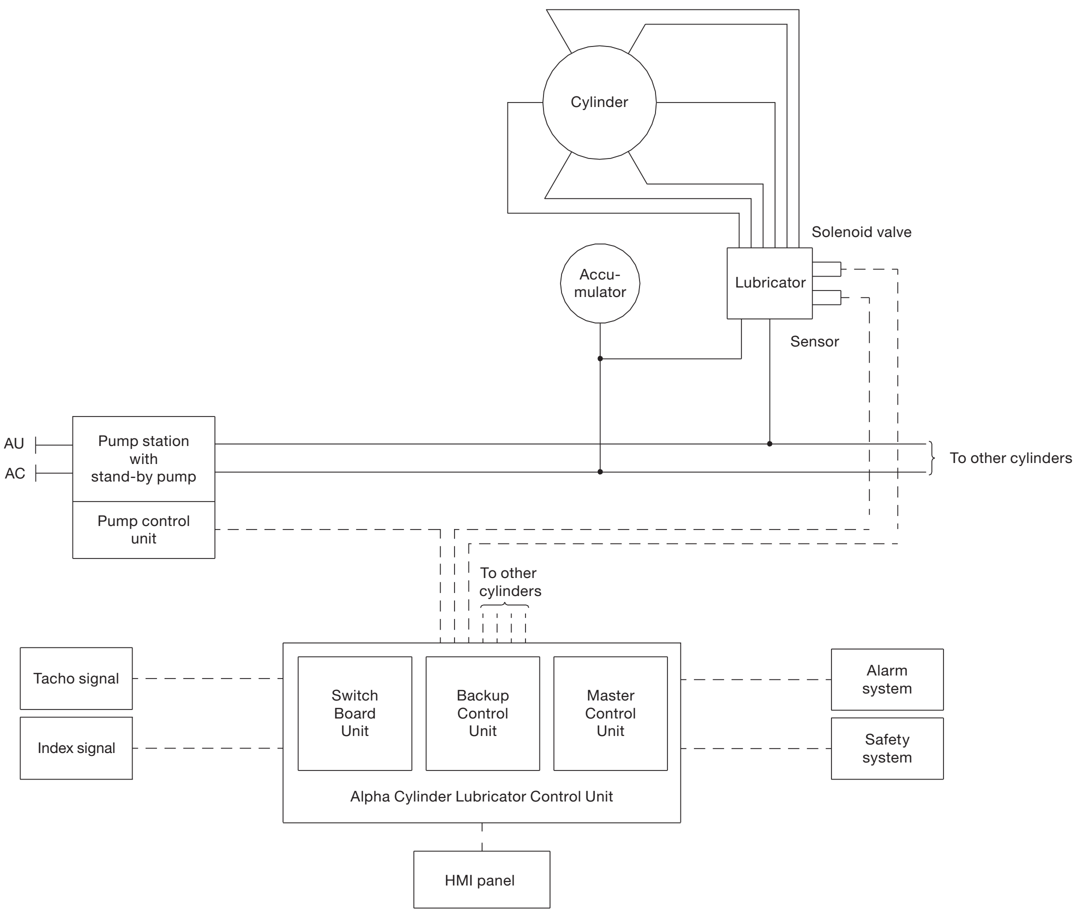
- MCU fail
- MCU power fail
- MCU common alarm
- BCU in control
- BCU fail
- BCU power fail

and slow down (Normally Open) for:

- Electronic cylinder lubricator system

The system has a connection for coupling it to a computer system or a Display Unit (HMI panel) so that engine speed, fuel index, injection frequency, alarms, etc. can be monitored.

The HMI panel for mounting in Engine Control Room (option: 4 42 660) or on the engine (option: 4 42 160) can be delivered separately.



For the actual number of cylinder lubrication points on the specific engine see Fig. 9.02.03

178 47 13-9.3

Fig. 9.02.04: Control of the MAN B&W Alpha Cylinder Lubrication System, one lubricator per cylinder

Wiring Diagram

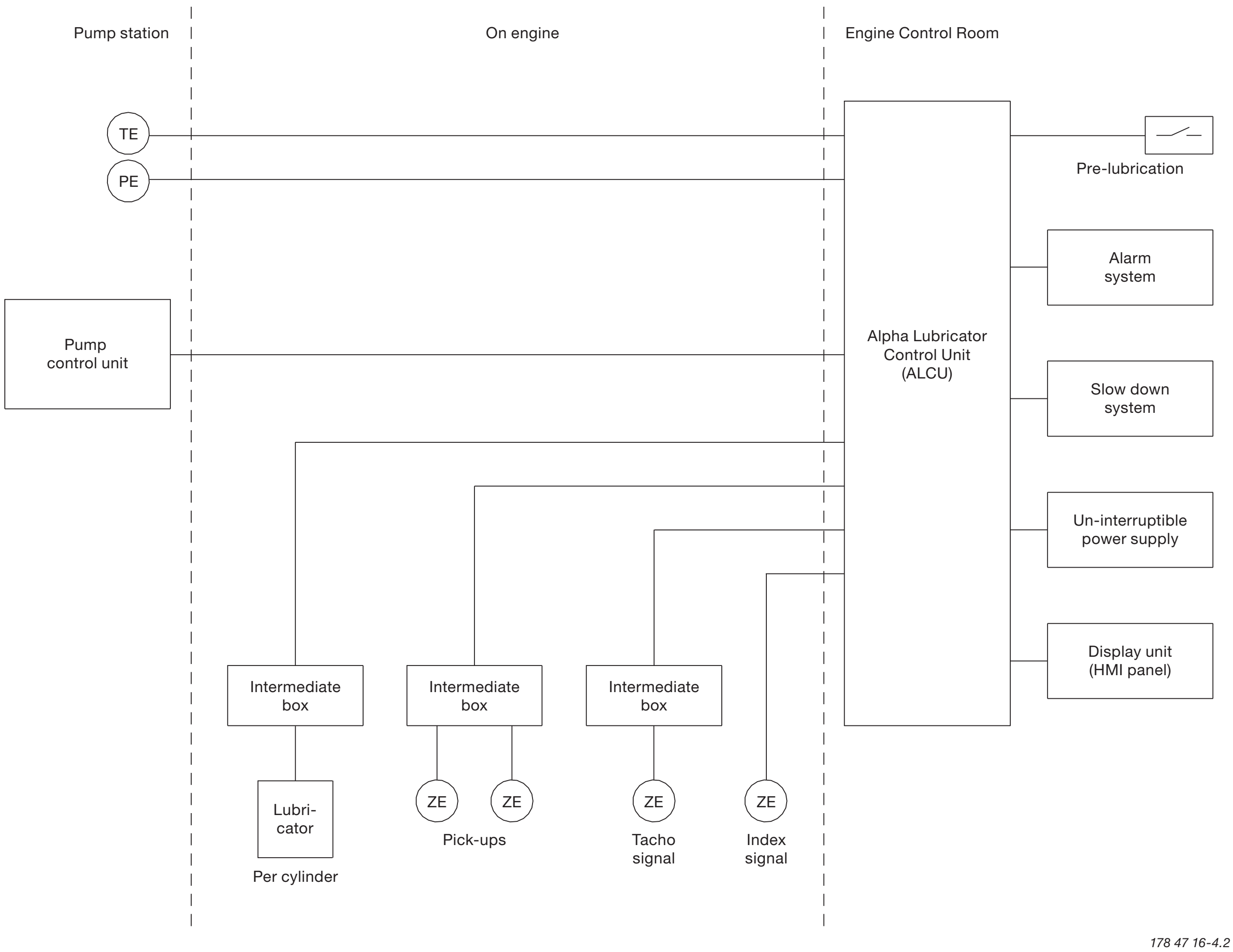
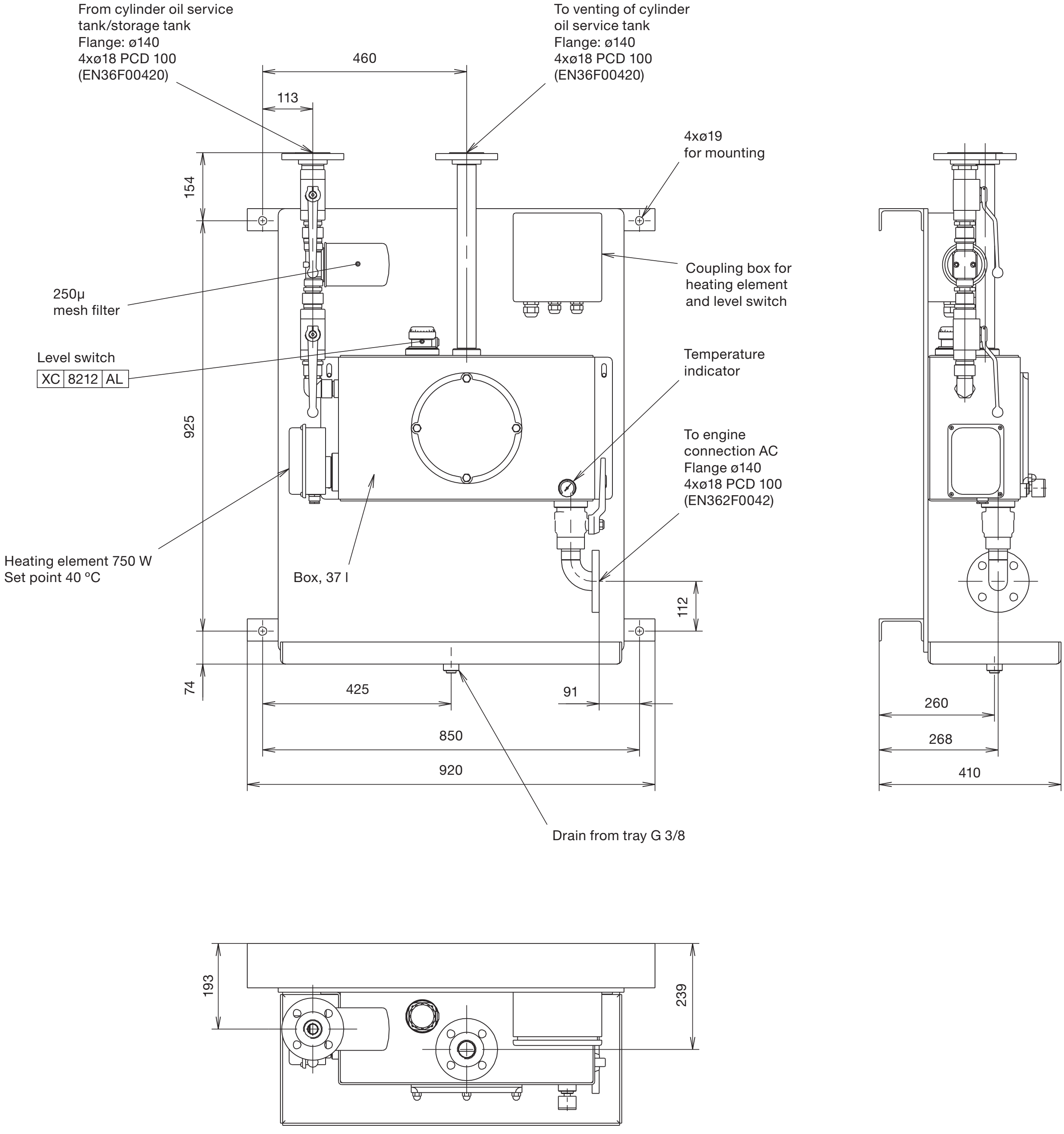


Fig. 9.02.05: Wiring diagram for MAN B&W Alpha Cylinder Lubrication System, one lubricator per cylinder



178 52 75-8.1

Fig. 9.02.05: Suggestion for small heating box with filter

Mechanical Cylinder Lubricators

Mechanical cylinder lubricator(s), can be mounted on the fore end of the engine, the size of which will decide the number of lubricators needed. If driven by the engine in sync with the crankshaft movement, the lubricators could deliver timed injection of the cylinder lubrication oil.

The lubricator(s) should have a built-in capability for adjustment of the oil quantity and be provided with a sight glass for each lubricating point.

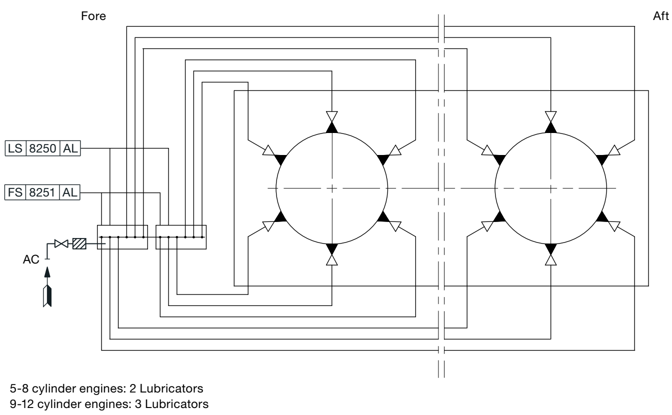
The lubricators should be fitted with:
- Electric heating coils
- Low flow and low level alarms.

In the 'Engine Speed Dependent' design, the lubricator pumps a fixed amount of oil to the cylinders for each engine revolution.

Mainly for plants with controllable pitch propeller, the lubricators could, alternatively, be fitted with a mechanical lubrication system which controls the dosage in proportion to the Mean Effective Pressure (MEP).

An 'Engine Speed Dependent' as well as a 'MEP Dependent' mechanical lubricator could be equipped with a 'Load Change Dependent' system, by which the cylinder feed oil rate is automatically increased during starting, manoeuvring and, preferably, during sudden load changes, see Fig. 9.03.02.

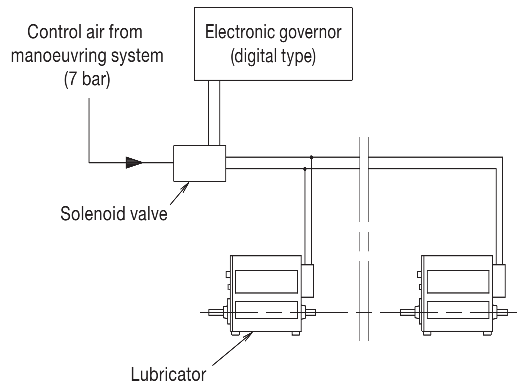
In that case, the signal for the 'Load Change Dependent' system comes from the electronic governor.



The letters refer to list of 'Counterflanges'
The piping is delivered with and fitted onto the engine

178 57 71-8.0

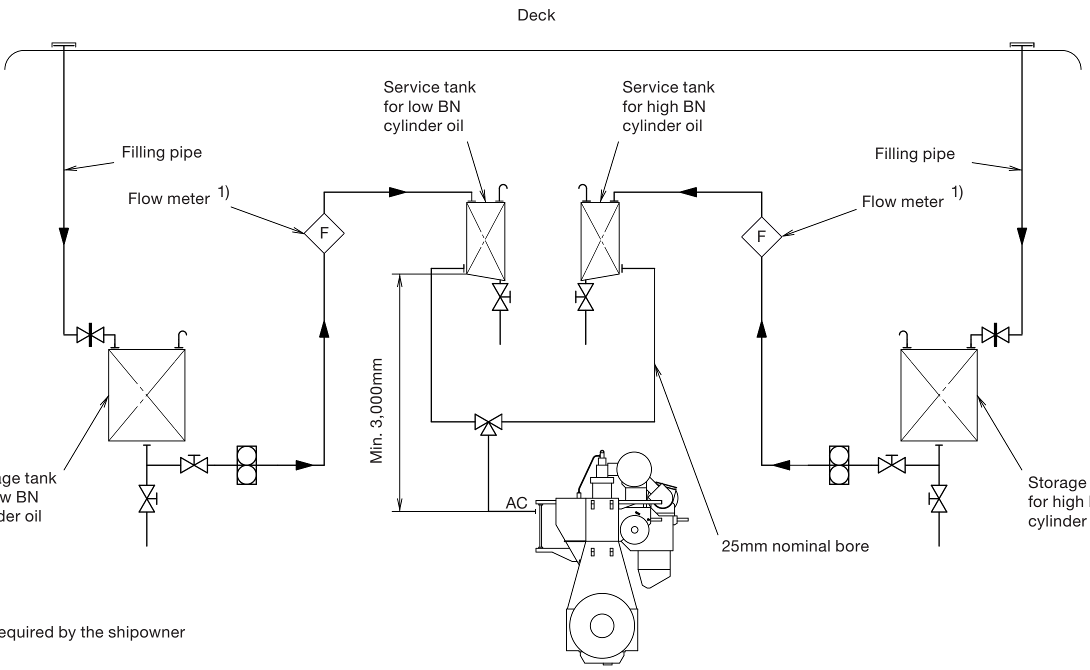
Fig 9.03.01: Piping and instrumentation for a mechanical cylinder lubricator



178 59 50-4.0

Fig 9.03.02: Load change dependent mechanical lubricator

Cylinder Lubricating Oil Supply System



The letters refer to list of 'Counterflanges'

078 78 45-9.0.0

Fig. 9.03.03: Cylinder lubricating oil supply system for two different BN cylinder oils, for mechanical lubricators

Piston Rod Stuffing Box Drain Oil

10

Stuffing Box Drain Oil System

For engines running on heavy fuel, it is important that the oil drained from the piston rod stuffing boxes is not led directly into the system oil, as the oil drained from the stuffing box is mixed with sludge from the scavenge air space.

The performance of the piston rod stuffing box on the engines has proved to be very efficient, primarily because the hardened piston rod allows a higher scraper ring pressure.

The amount of drain oil from the stuffing boxes is about 5 - 10 litres/24 hours per cylinder during normal service. In the running-in period, it can be higher.

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

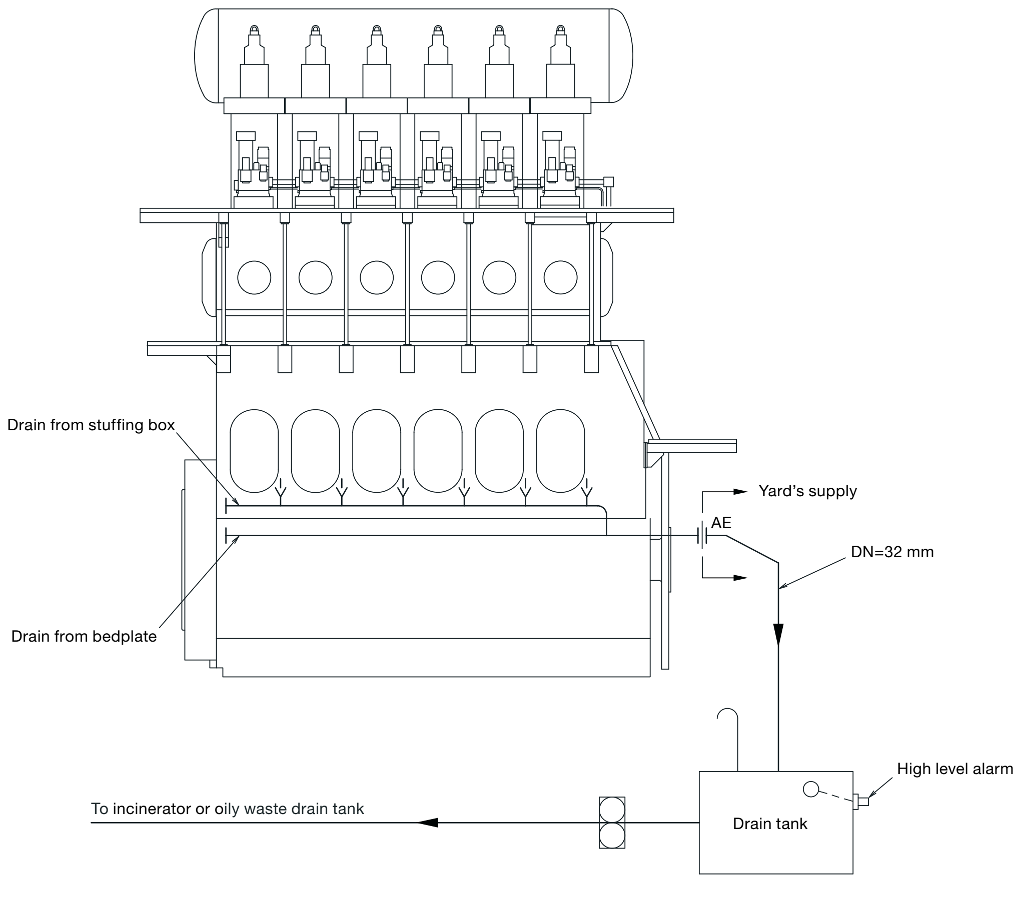


Fig. 10.01.01: Stuffing box drain oil system

Central Cooling Water System

11

Central Cooling

The water cooling can be arranged in several configurations, the most common system choice being a central cooling water system.

Advantages of the central cooling system:

- Only one heat exchanger cooled by seawater, and thus, only one exchanger to be overhauled
- All other heat exchangers are freshwater cooled and can, therefore, be made of a less expensive material
- Few non-corrosive pipes to be installed
- Reduced maintenance of coolers and components
- Increased heat utilisation.

Disadvantages of the central cooling system:

- Three sets of cooling water pumps (seawater, central water and jacket water.
- Higher first cost.

For information on the alternative Seawater Cooling System, see Chapter 12.

An arrangement common for the main engine and MAN Diesel & Turbo auxiliary engines is available on request.

For further information about common cooling water system for main engines and auxiliary engines please refer to our publication:

Uni-concept Auxiliary Systems for Two-Stroke Main Engines and Four-Stroke Auxiliary Engines

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

Central Cooling Water System

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

In order to prevent too high a scavenge air temperature, the cooling water design temperature in the central cooling water system is normally 36 °C, corresponding to a maximum seawater temperature of 32 °C.

Our recommendation of keeping the cooling water inlet temperature to the main engine scavenge air cooler as low as possible also applies to the central cooling system. This means that the temperature control valve in the central cooling water circuit is to be set to minimum 10 °C, whereby the temperature follows the outboard seawater temperature when central cooling water temperature exceeds 10 °C.

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

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

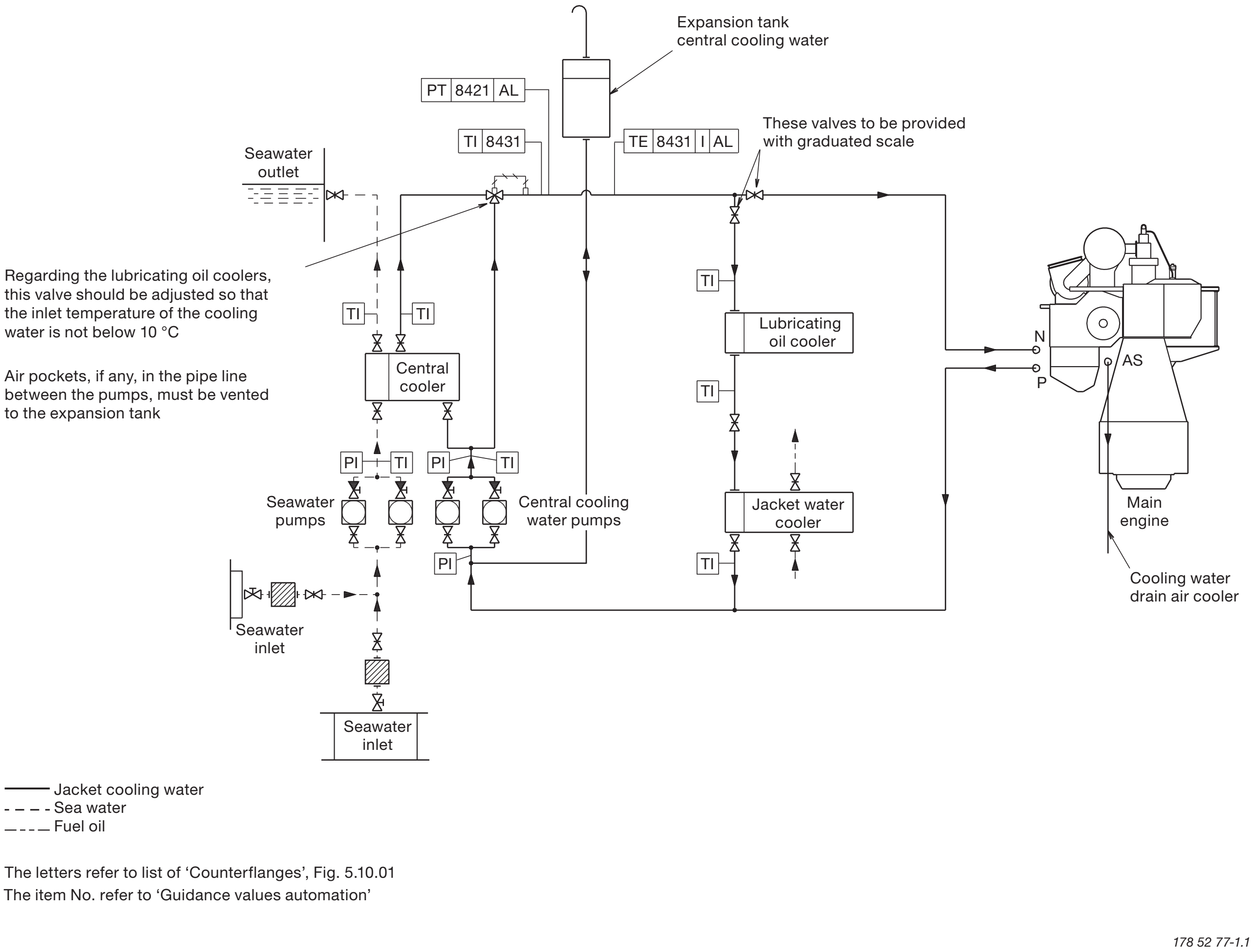


Fig. 11.02.01: Central cooling water system

Components for Central Cooling Water System

Seawater cooling pumps

The pumps are to be of the centrifugal type.

Seawater flow..................... see 'List of Capacities'
Pump head..2.5 bar
Test pressure.....................according to class rules
Working temperature, normal ....0-32 °C
Working temperature .... maximum 50 °C

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

The differential pressure of the pumps is to be determined on the basis of the total actual pressure drop across the cooling water system.

Central cooler

The cooler is to be of the shell and tube or plate heat exchanger type, made of seawater resistant material.

Heat dissipation..................... see 'List of Capacities'
Central cooling water flow ..... see 'List of Capacities'
Central cooling water temperature, outlet......... 36 °C
Pressure drop on central cooling side ....max. 0.2 bar
Seawater flow........................ see 'List of Capacities'
Seawater temperature, inlet .... 32 °C
Pressure drop on
seawater side................................ maximum 0.2 bar

The pressure drop may be larger, depending on the actual cooler design.

The heat dissipation and the seawater flow figures are based on MCR output at tropical conditions, i.e. a seawater temperature of 32 °C and an ambient air temperature of 45 °C.

Overload running at tropical conditions will slightly increase the temperature level in the cooling system, and will also slightly influence the engine performance.

Central cooling water pumps

The pumps are to be of the centrifugal type.

Central cooling water flow... see 'List of Capacities'
Pump head..2.5 bar
Delivery pressure ....depends on location of expansion tank
Test pressure.....................according to class rules
Working temperature .... 80 °C
Design temperature..................................... 100 °C

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

The 'List of Capacities' covers the main engine only. The differential pressure provided by the pumps is to be determined on the basis of the total actual pressure drop across the cooling water system.

Central cooling water thermostatic valve

The low temperature cooling system is to be equipped with a three-way valve, mounted as a mixing valve, which by-passes all or part of the fresh water around the central cooler.

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

Jacket water system

Due to the central cooler the cooling water inlet temperature is about 4 °C higher for for this system compared to the seawater cooling system. The input data are therefore different for the scavenge air cooler, the lube oil cooler and the jacket water cooler.

The heat dissipation and the central cooling water flow figures are based on an MCR output at tropical conditions, i.e. a maximum seawater temperature of 32 °C and an ambient air temperature of 45 °C.

Jacket water cooling pump

The pumps are to be of the centrifugal type.
Jacket water flow .... see 'List of Capacities'
Pump head ....3.0 bar
Delivery pressure ....depends on location of expansion tank
Test pressure.....................according to class rules
Working temperature .... 80 °C
Design temperature...................................... 100 °C

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

The stated of capacities cover the main engine only. The pump head of the pumps is to be determined on the basis of the total actual pressure drop across the cooling water system.

Scavenge air cooler

The scavenge air cooler is an integrated part of the main engine.

Heat dissipation ....see 'List of Capacities'
Central cooling water flow .....see 'List of Capacities'
Central cooling temperature, inlet .... 36 °C
Pressure drop on FW-LT water side.... approx. 0.5 bar

Lubricating oil cooler

See Chapter 8 'Lubricating Oil'.

Cooling water pipes

Diagrams of cooling water pipes are shown in Figs. 12.03.01.

Jacket water cooler

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

Heat dissipation .... see 'List of Capacities'
Jacket water flow .... see 'List of Capacities'
Jacket water temperature, inlet...................... 80 °C
Pressure drop on jacket water side ....max. 0.2 bar
Central cooling water flow... see 'List of Capacities'
Central cooling water
temperature, inlet ....approx. 42 °C
Pressure drop on Central
cooling water side................................max. 0.2 bar

The other data for the jacket cooling water system can be found in Chapter 12.

For further information about a common cooling water system for main engines and MAN Diesel & Turbo auxiliary engines, please refer to our publication:

Uni-concept Auxiliary Systems for Two-Stroke Main Engines and Four-Stroke Auxiliary Engines

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

Seawater Cooling System

12

Seawater Systems

The water cooling can be arranged in several configurations, the most simple system choices being seawater and central cooling water system:

- A **seawater cooling system** and a jacket cooling water system
- The advantages of the seawater cooling system are mainly related to first cost, viz:
- Only two sets of cooling water pumps (seawater and jacket water)
- Simple installation with few piping systems.

Whereas the disadvantages are:

- Seawater to all coolers and thereby higher maintenance cost
- Expensive seawater piping of non-corrosive materials such as galvanised steel pipes or Cu-Ni pipes.

Seawater Cooling System

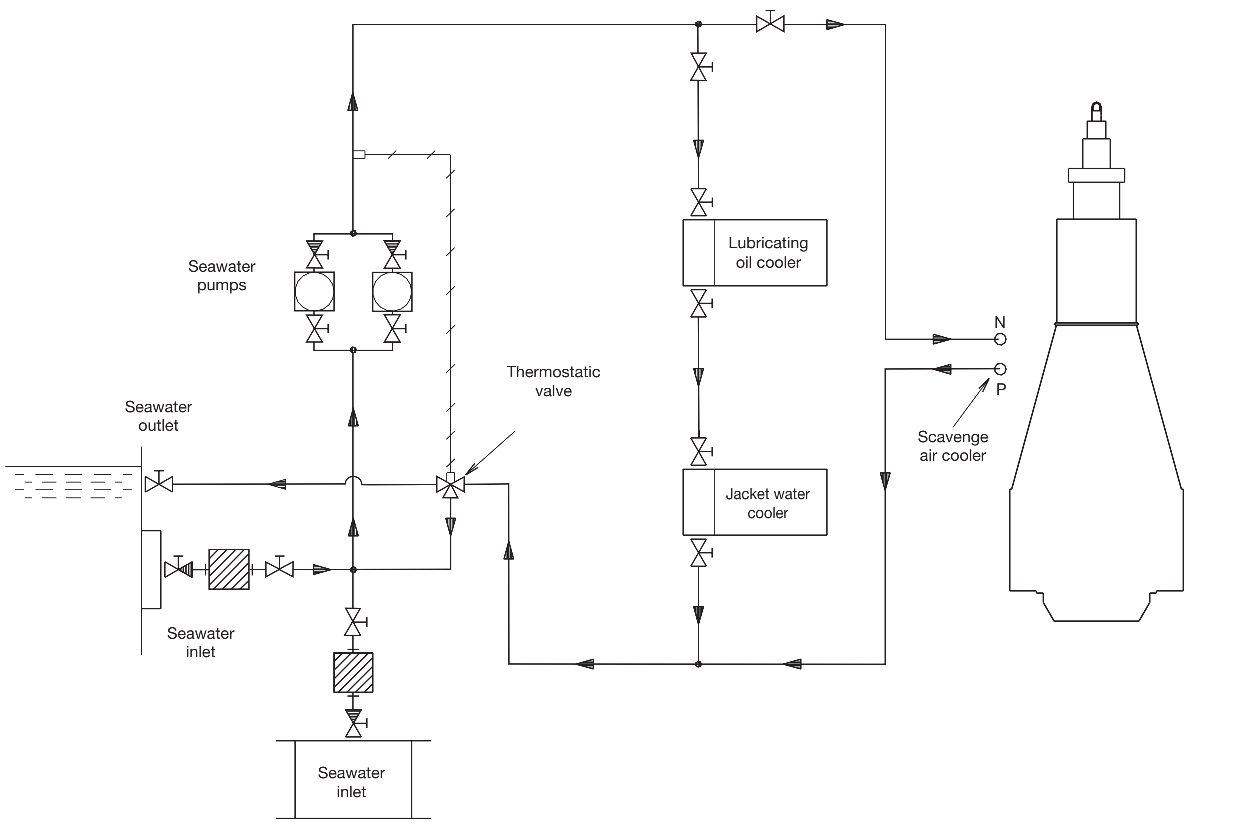
The seawater cooling system is used for cooling, the main engine lubricating oil cooler, the jacket water cooler and the scavenge air cooler, see Fig. 12.02.01.

The lubricating oil cooler for a PTO step-up gear should be connected in parallel with the other coolers. The capacity of the seawater pump is based on the outlet temperature of the seawater being maximum 50 °C after passing through the coolers – with an inlet temperature of maximum 32 °C (tropical conditions), i.e. a maximum temperature increase of 18 °C.

The valves located in the system fitted to adjust the distribution of cooling water flow are to be provided with graduated scales.

The inter-related positioning of the coolers in the system serves to achieve:

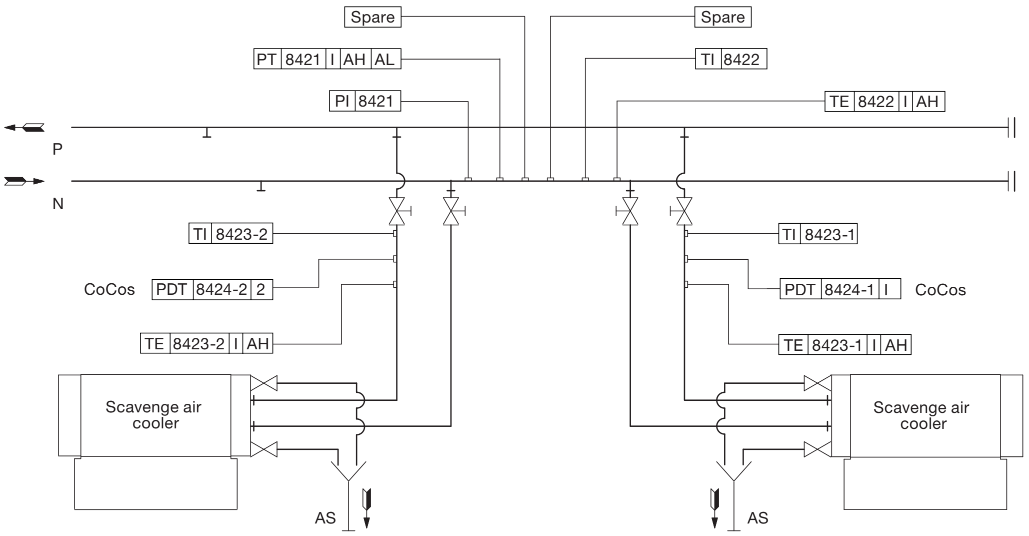
- The lowest possible cooling water inlet temperature to the lubricating oil cooler in order to obtain the cheapest cooler. On the other hand, in order to prevent the lubricating oil from stiffening in cold services, the inlet cooling water temperature should not be lower than 10 °C
- The lowest possible cooling water inlet temperature to the scavenge air cooler, in order to keep the fuel oil consumption as low as possible.



The letters refer to list of 'Counterflanges'

Fig. 12.02.01: Seawater cooling system

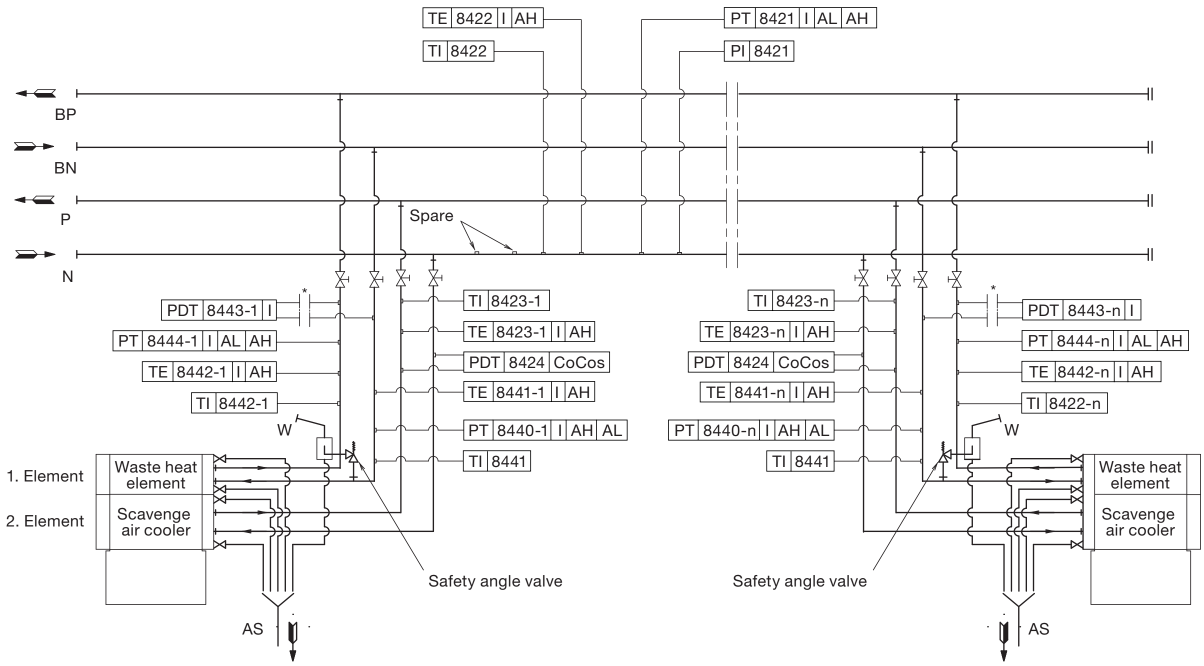
Cooling Water Pipes



121 14 99-1.7.0

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

Fig. 12.03.01a: Cooling water pipes for engines with two or more turbochargers



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521 21 78-2.3.0

* Calculated valve from PT8440/844X if possible
n Refer to number of air coolers

Fig. 12.03.01b: Cooling water cooling pipes with waste heat recovery for engines with two or more turbochargers

Components for Seawater Cooling System

Seawater cooling pump

The pumps are to be of the centrifugal type.

Seawater flow..................... see 'List of Capacities'
Pump head...2.5 bar
Test pressure...................... according to class rule
Working temperature .... maximum 50 °C

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

Lubricating oil cooler

See Chapter 8 'Lubricating Oil'.

Jacket water cooler

The cooler is to be of the shell and tube or plate heat exchanger type, made of seawater resistant material.

Heat dissipation .... see 'List of Capacities'
Jacket water flow .... see 'List of Capacities'
Jacket water temperature, inlet...................... 80 °C
Pressure drop
on jacket water side ....maximum 0.2 bar
Seawater flow..................... see 'List of Capacities'
Seawater temperature, inlet .... 38 °C
Pressure drop on
seawater side ....maximum 0.2 bar

The heat dissipation and the seawater flow are based on an MCR output at tropical conditions, i.e. seawater temperature of 32 °C and an ambient air temperature of 45 °C.

Scavenge air cooler

The scavenge air cooler is an integrated part of the main engine.

Heat dissipation .... see 'List of Capacities'
Seawater flow .... see 'List of Capacities'
Seawater temperature,
for seawater cooling inlet, max. .... 32 °C
Pressure drop on
cooling water side .... between 0.1 and 0.5 bar

The heat dissipation and the seawater flow are based on an MCR output at tropical conditions, i.e. seawater temperature of 32 °C and an ambient air temperature of 45 °C.

Seawater thermostatic valve

The temperature control valve is a three-way valve which can recirculate all or part of the seawater to the pump's suction side. The sensor is to be located at the seawater inlet to the lubricating oil cooler, and the temperature level must be a minimum of +10 °C.

Seawater flow..................... see 'List of Capacities'
Temperature range,
adjustable within ....+5 to +32 °C

Jacket Cooling Water System

The jacket cooling water system is used for cooling the cylinder liners, cylinder covers and exhaust valves of the main engine and heating of the fuel oil drain pipes, see Fig. 12.05.01.

The jacket water pump draws water from the jacket water cooler outlet and delivers it to the engine.

At the inlet to the jacket water cooler there is a thermostatically controlled regulating valve, with a sensor at the engine cooling water outlet, which keeps the main engine cooling water outlet at a temperature between 88 and 92 °C.

The engine jacket water must be carefully treated, maintained and monitored so as to avoid corrosion, corrosion fatigue, cavitation and scale formation. It is recommended to install a preheater if preheating is not available from the auxiliary engines jacket cooling water system.

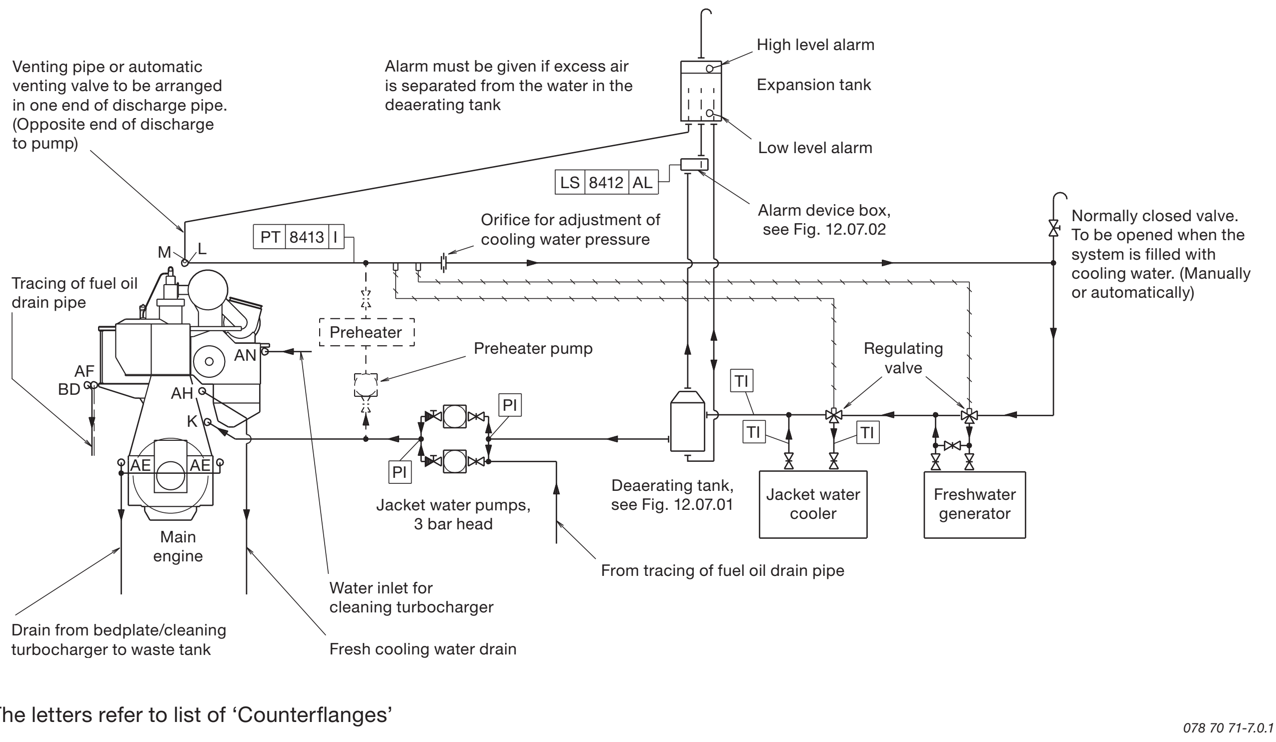
The venting pipe in the expansion tank should end just below the lowest water level, and the expansion tank must be located at least 15 m above the top of the exhaust valves.

The freshwater generator, if installed, may be connected to the seawater system if the generator does not have a separate cooling water pump. The generator must be coupled in and out slowly over a period of at least 3 minutes.

In case it is possible to utilise more than 50% of the heat available, we recommend to install a thermostatic valve at the freshwater generator inlet, adjusted to keep a minimum cooling water outlet temperature of 88 °C.

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

Jacket water..3.0 m/s
Seawater ....3.0 m/s



The letters refer to list of 'Counterflanges'

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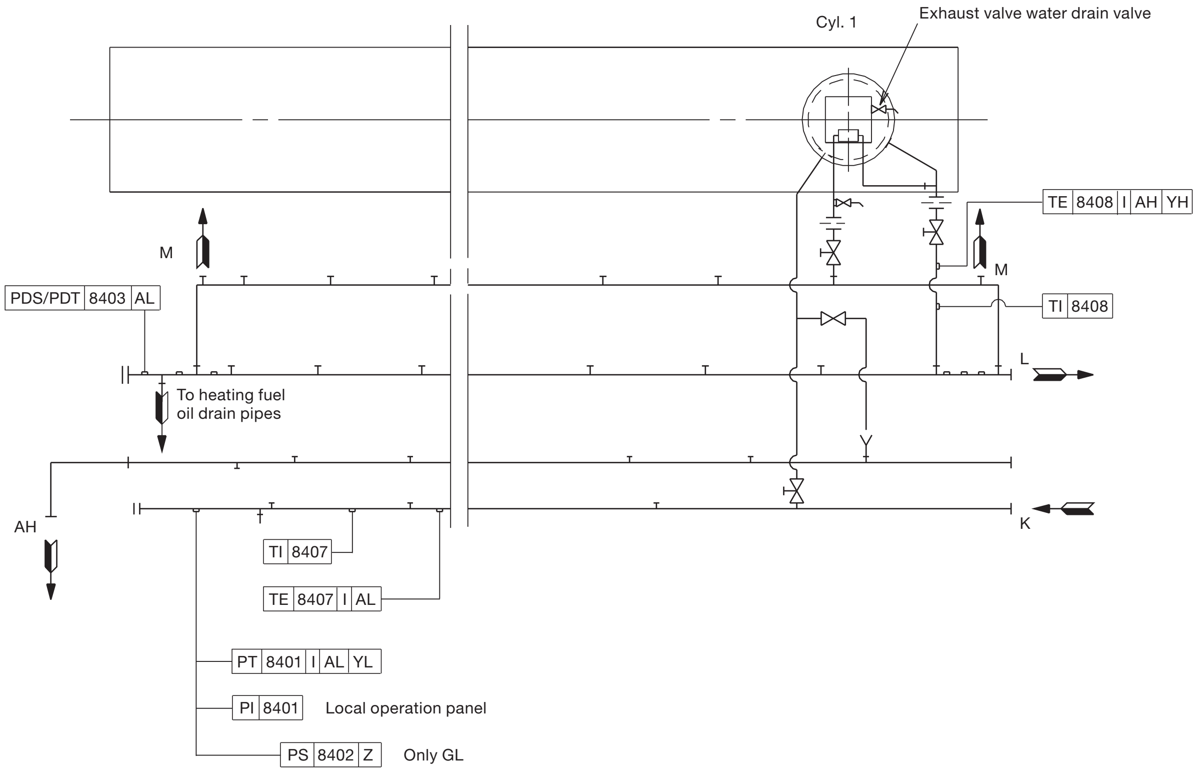
Fig. 12.05.01: Jacket cooling water system

Jacket Cooling Water Pipes



121 15 18-4.3.1

The letters refer to list of 'Counterflanges'
The item No. refer to 'Guidance values automation'

Fig. 12.06.01: Jacket cooling water pipes

Components for Jacket Cooling Water System

Jacket water cooling pump

The pumps are to be of the centrifugal type.

Jacket water flow .... see 'List of Capacities'
Pump head ....3.0 bar
Delivery pressure ....depends on position of expansion tank
Test pressure...................... according to class rule
Working temperature, ... 80 °C, max. 100 °C

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

The stated capacities cover the main engine only. The pump head of the pumps is to be determined based on the total actual pressure drop across the cooling water system.

Freshwater generator

If a generator is installed in the ship for production of freshwater by utilising the heat in the jacket water cooling system it should be noted that the actual available heat in the jacket water system is lower than indicated by the heat dissipation figures given in the 'List of Capacities'. This is because the latter figures are used for dimensioning the jacket water cooler and hence incorporate a safety margin which can be needed when the engine is operating under conditions such as, e.g. overload. Normally, this margin is 10% at nominal MCR.

The calculation of the heat actually available at specified MCR for a derated diesel engine is stated in Chapter 6 'List of Capacities'.

For illustration of installation of fresh water generator see Fig. 12.05.01.

Jacket water thermostatic valve

The temperature control system is equipped with a three-way valve mounted as a diverting valve, which by-pass all or part of the jacket water around the jacket water cooler.

The sensor is to be located at the outlet from the main engine, and the temperature level must be adjustable in the range of 70-90 °C.

Jacket water preheater

When a preheater, see Fig. 12.05.01, is installed in the jacket cooling water system, its water flow, and thus the preheater pump capacity, should be about 10% of the jacket water main pump capacity.

Based on experience, it is recommended that the pressure drop across the preheater should be approx. 0.2 bar. The preheater pump and main pump should be electrically interlocked to avoid the risk of simultaneous operation.

The preheater capacity depends on the required preheating time and the required temperature increase of the engine jacket water. The temperature and time relations are shown in Fig. 12.08.01.

In general, a temperature increase of about 35 °C (from 15 °C to 50 °C) is required, and a preheating time of 12 hours requires a preheater capacity of about 1% of the engine`s nominal MCR power.

Deaerating tank

Design and dimensions of the deaerating tank are shown in Fig. 12.07.01 'Deaerating tank' and the corresponding alarm device is shown in Fig. 12.07.02 'Deaerating tank, alarm device'.

Expansion tank

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

Fresh water treatment

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

Deaerating tank

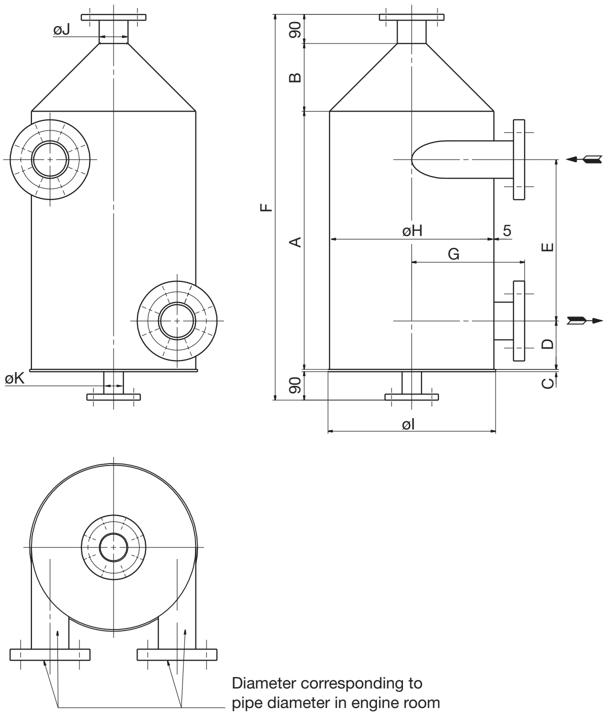


Fig. 12.07.01: Deaerating tank, option: 4 46 640

Deaerating tank dimensions		
Tank size	0.05 m^3	0.16 m^3
Max. jacket water capacity	120 m^3/h	300 m^3/h
	Dimensions in mm	
Max. nominal diameter	125	200
A	600	800
B	125	210
C	5	5
D	150	150
E	300	500
F	910	1,195
G	250	350
øH	300	500
øI	320	520
øJ	ND 50	ND 80
øK	ND 32	ND 50

ND: Nominal diameter

Working pressure is according to actual piping arrangement.

In order not to impede the rotation of water, the pipe connection must end flush with the tank, so that no internal edges are protruding.

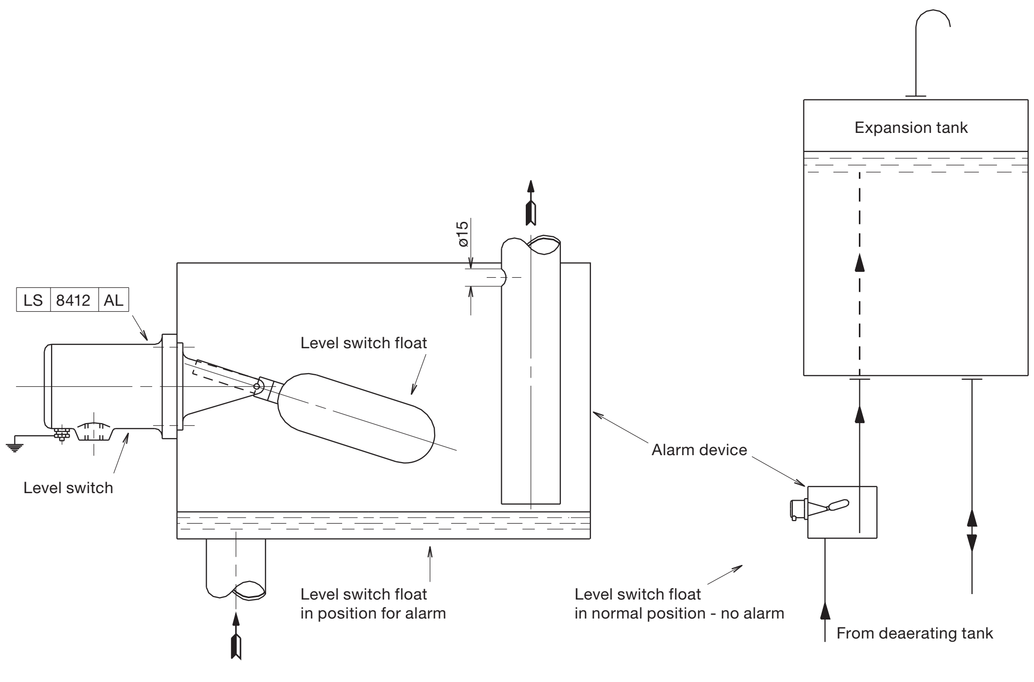


Fig. 12.07.02: Deaerating tank, alarm device, option: 4 46 645

Temperature at Start of Engine

In order to protect the engine, some minimum temperature restrictions have to be considered before starting the engine and, in order to avoid corrosive attacks on the cylinder liners during starting.

The temperature and speed/load restrictions vary with type of propeller as explained below.

Fixed pitch propeller plants

• Normal start of engine:

Normally, a minimum engine jacket water temperature of 50 °C is recommended before the engine may be started and run up gradually from 80% to 90% of specified MCR speed (SMCR rpm) during 30 minutes.

For running up between 90% and 100% of SMCR rpm, it is recommended that the speed be increased slowly over a period of 60 minutes.

• Start of cold engine:

In exceptional circumstances where it is not possible to comply with the above-mentioned recommendation, a minimum of 20 °C can be accepted before the engine is started and run up slowly to 80% of SMCR rpm.

Before exceeding 80% SMCR rpm, a minimum jacket water temperature of 50 °C should be obtained before the above described normal start load-up procedure may be continued.

Controllable pitch propeller plants

• Normal start of engine:

Normally, a minimum engine jacket water temperature of 50 °C is recommended before the engine may be started and run up gradually from 50% to 75% of specified MCR load (SMCR power) during 30 minutes.

For running up between 75% and 100% of SMCR power, it is recommended that the load be increased slowly over a period of 60 minutes.

• Start of cold engine:

In exceptional circumstances where it is not possible to comply with the above-mentioned recommendation, a minimum of 20 °C can be accepted before the engine is started and run up slowly to 50% of SMCR power.

Before exceeding 50% SMCR power, a minimum jacket water temperature of 50 °C should be obtained before above described normal start load-up procedure may be continued.

Jacket water warming-up time

The time period required for increasing the jacket water temperature from 20 °C to 50 °C will depend on the amount of water in the jacket cooling water system, and the engine load.

Note:
The above considerations for start of cold engine are based on the assumption that the engine has already been well run-in.

Preheating of diesel engine

Preheating during standstill periods

During short stays in port (i.e. less than 4-5 days), it is recommended that the engine is kept preheated, the purpose being to prevent temperature variation in the engine structure and corresponding variation in thermal expansions and possible leakages.

The jacket cooling water outlet temperature should be kept as high as possible and should – before starting up – be increased to at least 50 °C, either by means of cooling water from the auxiliary engines, or by means of a built-in preheater in the jacket cooling water system, or a combination.

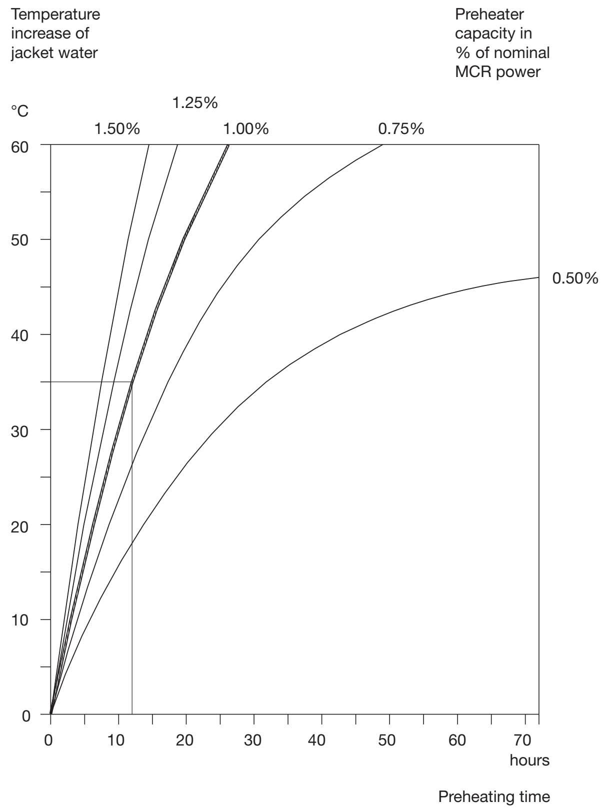


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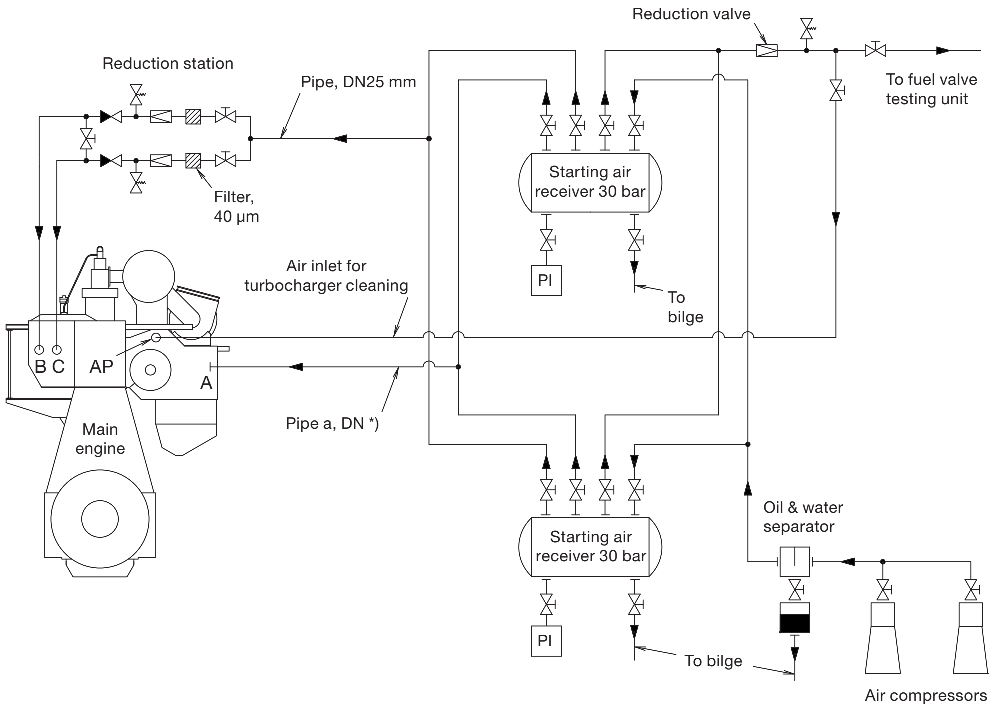
Fig. 12.08.01: Jacket water preheater, example

Starting and Control Air

13

Starting and Control Air Systems



The letters refer to list of 'Counterflanges'
*) Pipe a nominal dimension: DN125 mm

079 61 01-7.1.0

Fig. 13.01.01: 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 engine as:

- Control air for manoeuvring system and for exhaust valve air springs, through engine inlet 'B'
- Safety air for emergency stop, through inlet 'C'.

Through a reduction valve, compressed air is supplied at 10 bar to 'AP' for turbocharger cleaning (soft blast), and a minor volume used for the fuel valve testing unit.

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

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

For information about a common starting air system for main engines and MAN Diesel auxiliary engines, please refer to our publication:

Uni-concept Auxiliary Systems for Two-stroke Main

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

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 starting air receivers shall be provided with man holes and flanges for pipe connections.

The volume of the two receivers is:
Reversible engine,
for 12 starts .... see 'List of capacities' *
Non-reversible engine,
for 6 starts .... see 'List of capacities' *
Working pressure .... 30 bar
Test pressure .... according to class rule

* The volume stated is at 25 °C and 1,000 mbar

Reduction station for control and safety air

In normal operating, each of the two lines supplies one engine inlet. During maintenance, three isolating valves in the reduction station allow one of the two lines to be shut down while the other line supplies both engine inlets, see Fig. 13.01.01.

Reduction .... from 30-10 bar to 7 bar
(Tolerance ±10%)

Flow rate, free air .... 2,100 Normal liters/min
equal to 0.035 m^3/s
Filter, fineness .... 40 μm

Reduction valve for turbocharger cleaning etc

Reduction .... from 30-10 bar to 7 bar
(Tolerance ±10%)

Flow rate, free air .... 2,600 Normal liters/min
equal to 0.043 m^3/s

The consumption of compressed air for control air, exhaust valve air springs and safety air as well as air for turbocharger cleaning and fuel valve testing is covered by the capacities stated for air receivers and compressors in the list of capacities.

Starting and control air pipes

The piping delivered with and fitted onto the main engine is shown in the following figures in Section 13.03:

Fig. 13.03.01 Starting air pipes
Fig. 13.03.02 Air spring pipes, exhaust valves

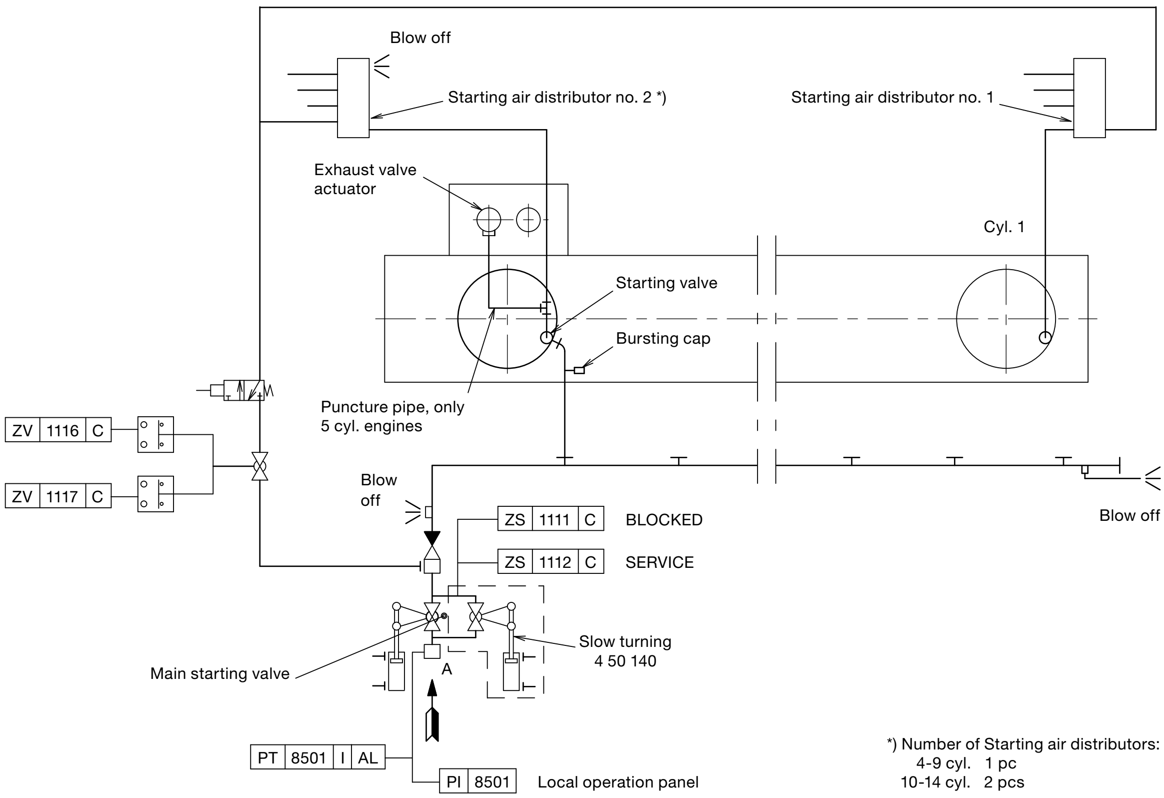
Turning gear

The turning wheel has cylindrical teeth and is fitted to the thrust shaft. The turning wheel is driven by a pinion on the terminal shaft of the turning gear, which is mounted on the bedplate.

Engagement and disengagement of the turning gear is effected by displacing the pinion and terminal shaft axially. To prevent the main engine from starting when the turning gear is engaged, the turning gear is equipped with a safety arrangement which interlocks with the starting air system.

The turning gear is driven by an electric motor with a built-in gear and brake. Key specifications of the electric motor and brake are stated in Section 13.04.

Starting and Control Air Pipes



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

121 36 85-8.0.0

Fig. 13.03.01: Starting air pipes

The starting air pipes, Fig. 13.03.01, contain a main starting valve (a ball valve with actuator), a non-return valve, starting air distributor(s) and starting valves.

The main starting valve is combined with the manoeuvring system, which controls the start of the engine. Slow turning before start of engine is an option: 4 50 140 and is recommended by MAN Diesel, see section 16.01.

The starting air distributor regulates the supply of control air to the starting valves in accordance with the correct firing sequence.

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

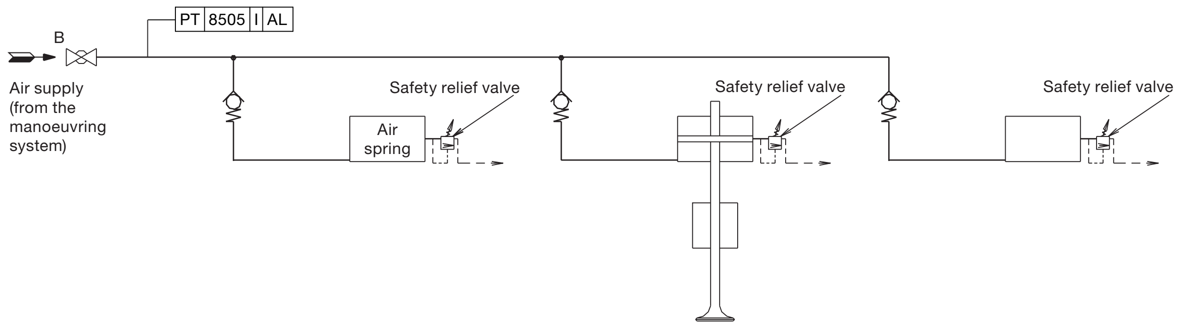
For information about a common starting air system for main engines and auxiliary engines, please refer to the Engine Selection Guide or to our publication:

Uni-concept Auxiliary Systems for Two-stroke Main

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

Exhaust Valve Air Spring Pipes

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



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

121 36 87-1.1.1b

Fig. 13.03.02: Air spring pipes for exhaust valves

Electric Motor for Turning Gear

MAN Diesel & Turbo delivers a turning gear with built-in disc brake, option 40 80 101. Two basic executions are available for power supply frequencies of 60 and 50 Hz respectively. Nominal power and current consumption of the motors are listed below.

Turning gear with electric motor of other protection or insulation classes can be ordered, option 40 80 103. Information about the alternative executions is available on request.

Electric motor and brake, voltage .... 3 x 440-480 V
Electric motor and brake, frequency ....60 Hz
Protection, electric motor / brake ....IP 54
Insulation class .... F

Number of cylinders	Electric motor	
	Nominal power, kW	Normal current, A
5-8	3.6	6.5

Electric motor and brake, voltage .....3 x 380-415 V
Electric motor and brake, frequency ....50 Hz
Protection, electric motor / brake ....IP 54
Insulation class .... F

Number of cylinders	Electric motor	
	Nominal power, kW	Normal current, A
5-8	3.0	6.5

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. However, if the engine is fitted with one turbocharger only, this can be located on the aft end of the engine, option: 4 59 124.

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.

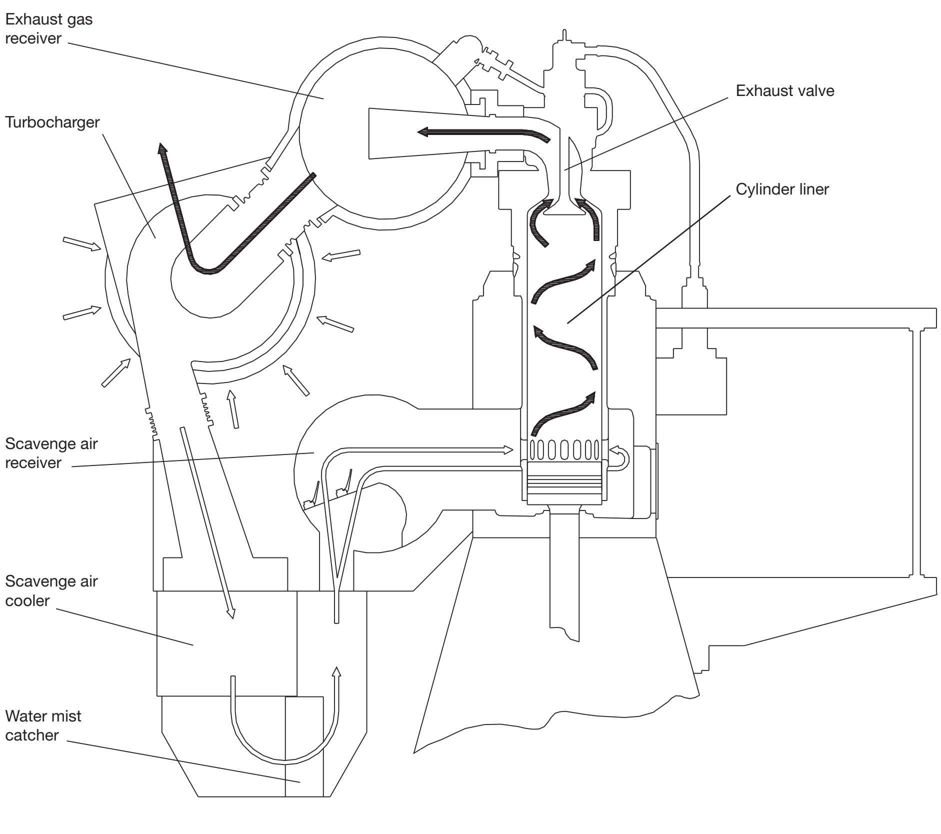


Fig. 14.01.01: Scavenge Air System

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

The auxiliary blowers start operating consecutively before the engine is started and will ensure complete scavenging of the cylinders in the starting phase, thus providing the best conditions for a safe start.

During operation of the engine, the auxiliary blowers will start automatically whenever the blower inlet pressure drops below a preset pressure, corresponding to an engine load of approximately 25-35%. The blowers will continue to operate until the blower inlet pressure again exceeds the preset pressure plus an appropriate hysteresis (i.e. taking recent pressure history into account), corresponding to an engine load of approximately 30-40%.

Emergency running

If one of the auxiliary blowers is out of function, the other auxiliary blower will function in the system, without any manual adjustment of the valves being necessary.

Scavenge air cooler requirements

The data for the scavenge air cooler is specified in the description of the cooling water system chosen.

For further information, please refer to our publication titled:

Influence of Ambient Temperature Conditions

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

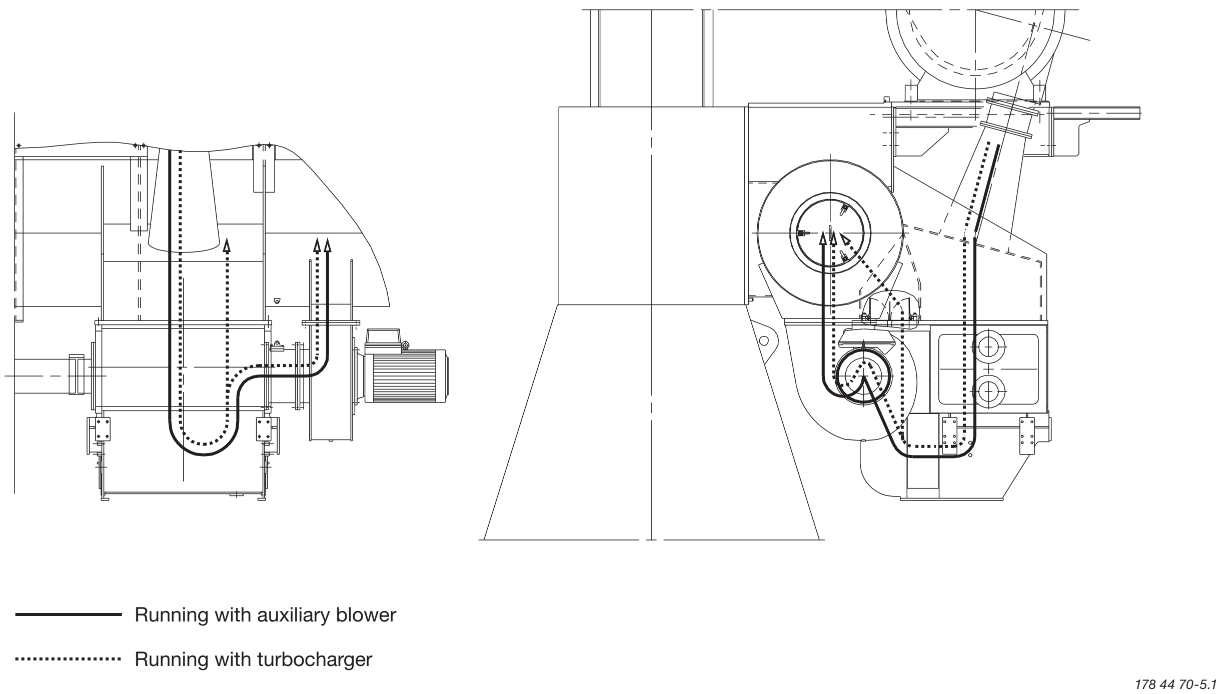


Fig. 14.02.01: Auxiliary blowers for scavenge air system

Control of the Auxiliary Blowers

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

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

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

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

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

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

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

The starter panels with starters for the auxiliary blower motors are not included, they can be ordered as an option: 4 55 653. (The starter panel design and function is according to MAN Diesel’s diagram, however, the physical layout and choice of components has to be decided by the manufacturer).

Heaters for the blower motors are available as an option: 4 55 155.

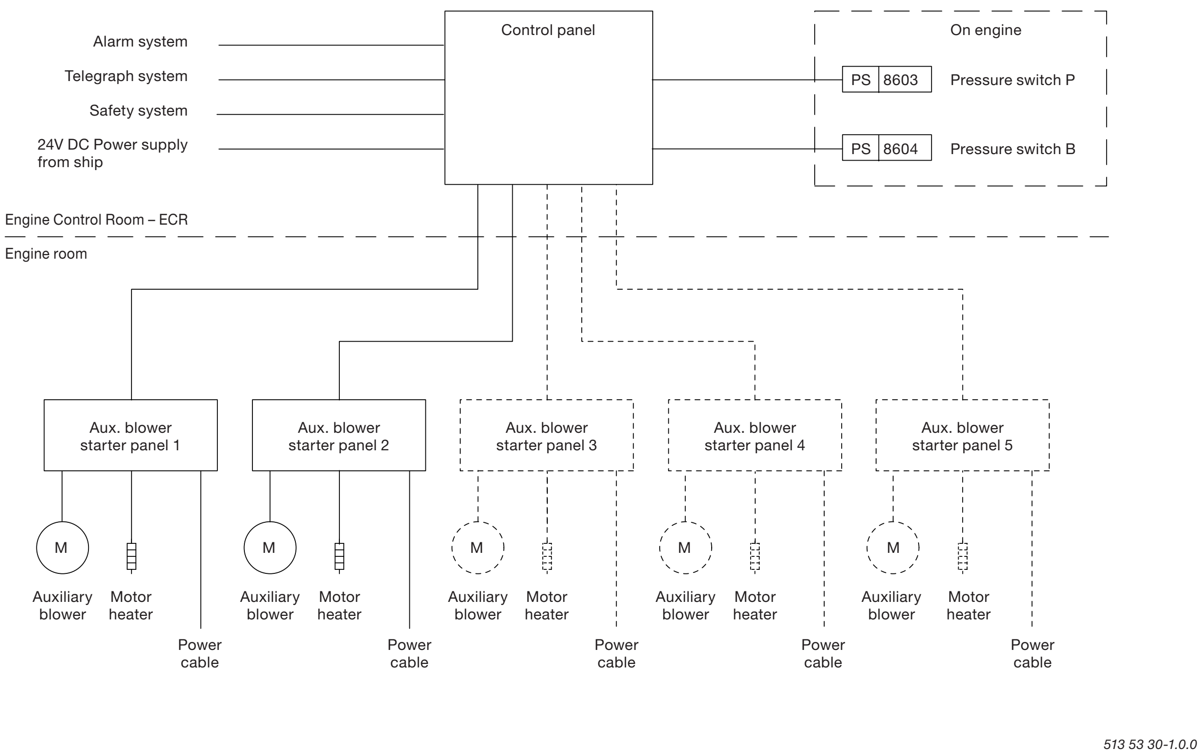


Fig. 14.02.02: Diagram of auxiliary blower control system

Operation Panel for the Auxiliary Blowers

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

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

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

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

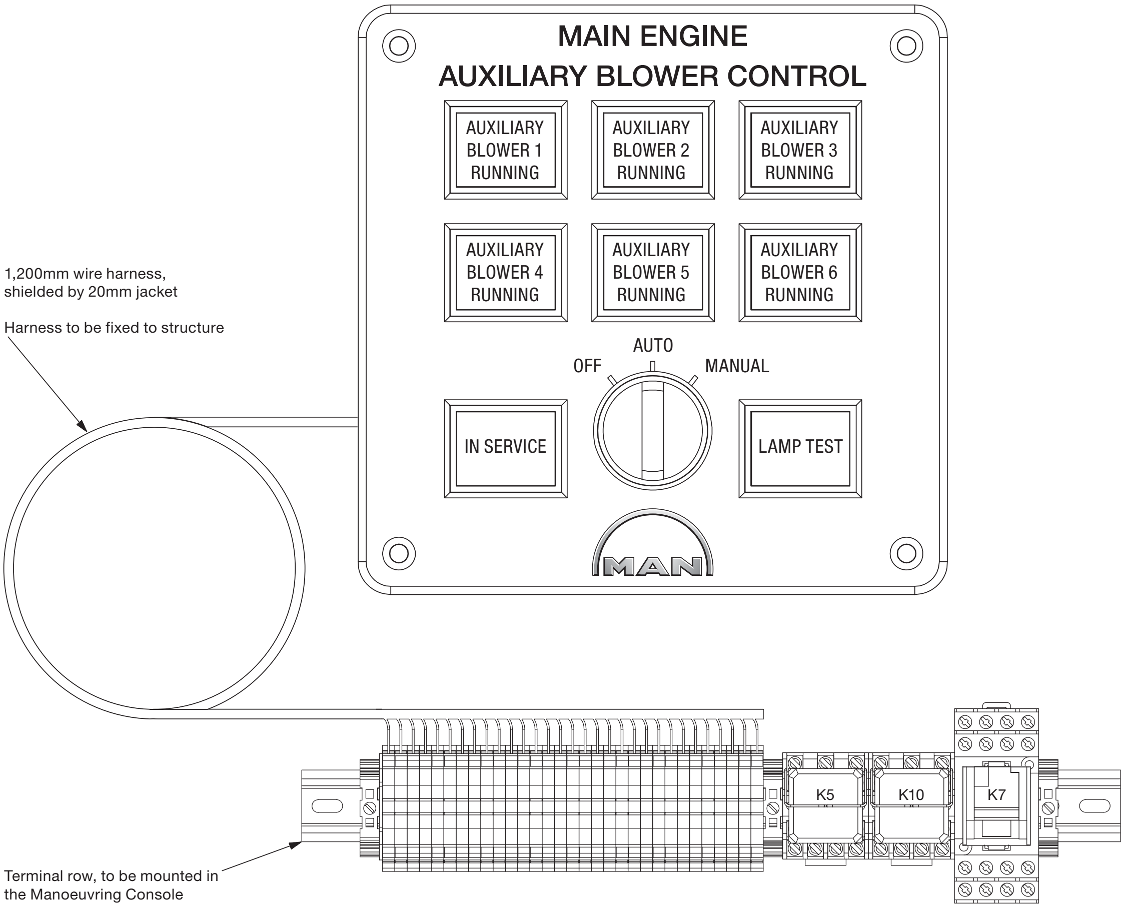
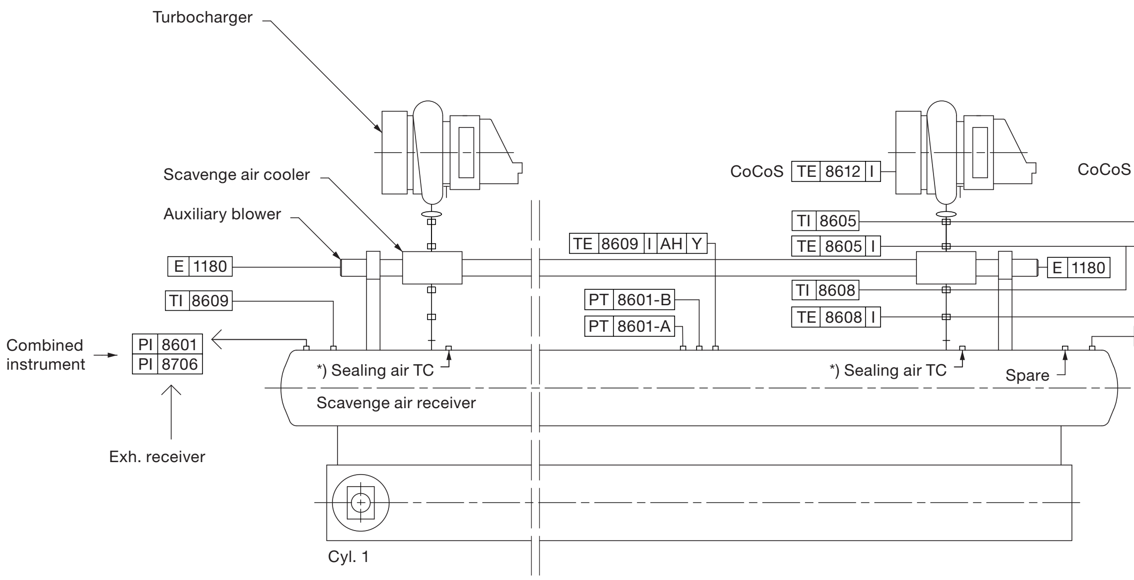


Fig. 14.02.03: Control panel including operation panel, wiring harness and terminal row, option: 4 55 650

Scavenge Air Pipes



525 11 86-5.0.1

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 Diesel & Turbo, Copenhagen.

Number of cylinders	Number of turbochargers	Number of auxiliary blowers	Installed power/blower kW
5	1	2	54
6	1	2	54
6	2	2	54
7	1	2	65
7	2	2	65
8	1	2	86
8	2	2	86

The installed power of the electric motors are based on a voltage supply of 3x440V at 60Hz.

The electric motors are delivered with and fitted onto the engine.

Table 14.04.01: Electric motor for auxiliary blower

Scavenge Air Cooler Cleaning System

The air side of the scavenge air cooler can be cleaned by injecting a grease dissolving media through 'AK' to a spray pipe arrangement fitted to the air chamber above the air cooler element.

Drain from water mist catcher

Sludge is drained through 'AL' to the drain water collecting tank and the polluted grease dissolvent returns from 'AM', through a filter, to the chemical cleaning tank. The cleaning must be carried out while the engine is at standstill.

Dirty water collected after the water mist catcher is drained through 'DX' and led to the bilge tank via an open funnel, see Fig. 14.05.02.

The 'AL' drain line is, during running, used as a permanent drain from the air cooler water mist catcher. The water is led through an orifice to prevent major losses of scavenge air.

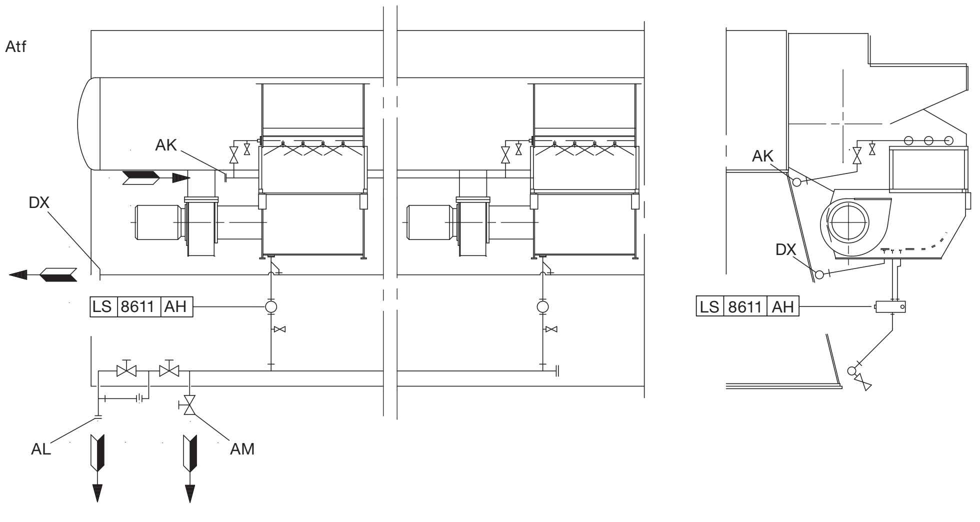
The system is equipped with a drain box with a level switch, indicating any excessive water level.

The piping delivered with and fitted on the engine is shown in Fig 14.05.01.

Auto Pump Overboard System

It is common practice on board to lead drain water directly overboard via a collecting tank. Before pumping the drain water overboard, it is recommended to measure the oil content. If above 15ppm, the drain water should be lead to the clean bilge tank / bilge holding tank.

If required by the owner, a system for automatic disposal of drain water with oil content monitoring could be built as outlined in Fig. 14.05.02.



With two or more air cooler
The letters refer to list of 'Counterflanges'
The item no refer to 'Guidance values automation'

509 22 67-3.5.0

Fig. 14.05.01: Air cooler cleaning pipes

Auto Pump Overboard System

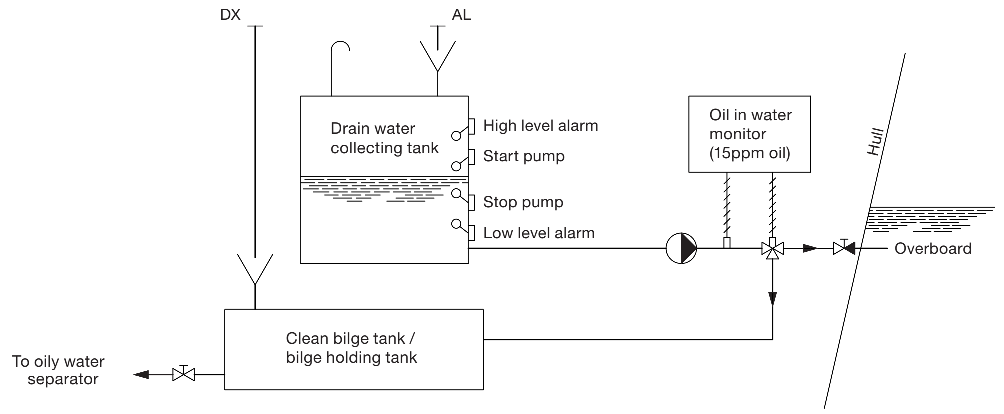
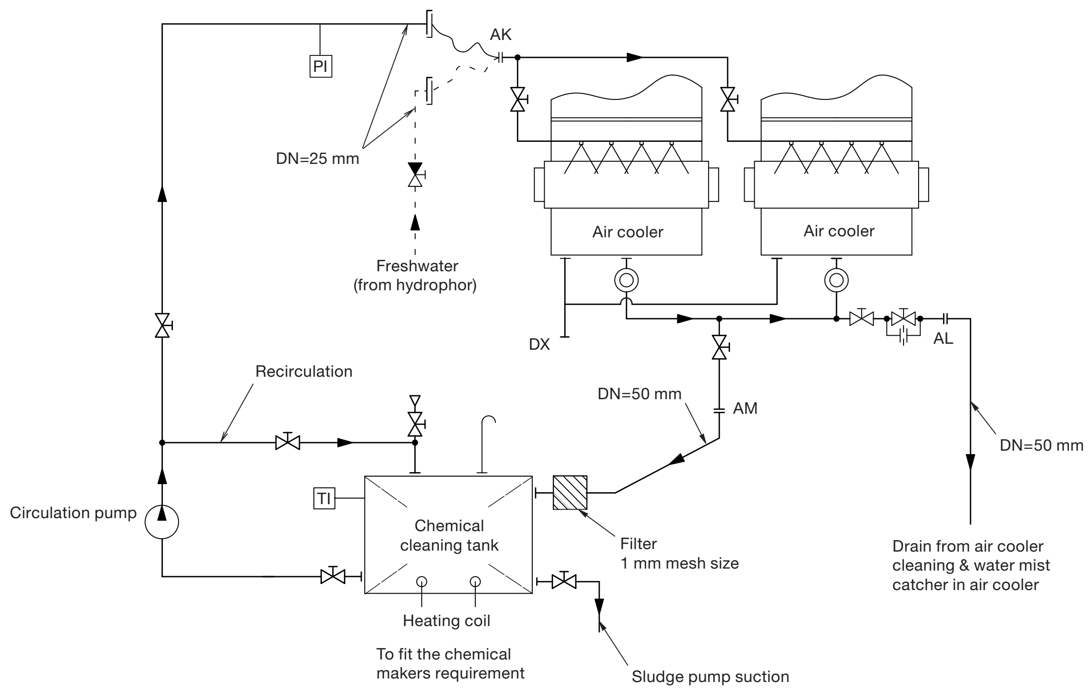


Fig. 14.05.02: Suggested automatic disposal of drain water, if required by owner (not a demand from MAN Diesel & Turbo)

Air Cooler Cleaning Unit



The letters refer to list of 'Counterflanges'

	No. of cylinders	
	5	6-8
Chemical tank capacity, m^3	0.3	0.6
Circulation pump capacity at 3 bar, m^3/h	1	2

079 21 94-1.0.2a

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

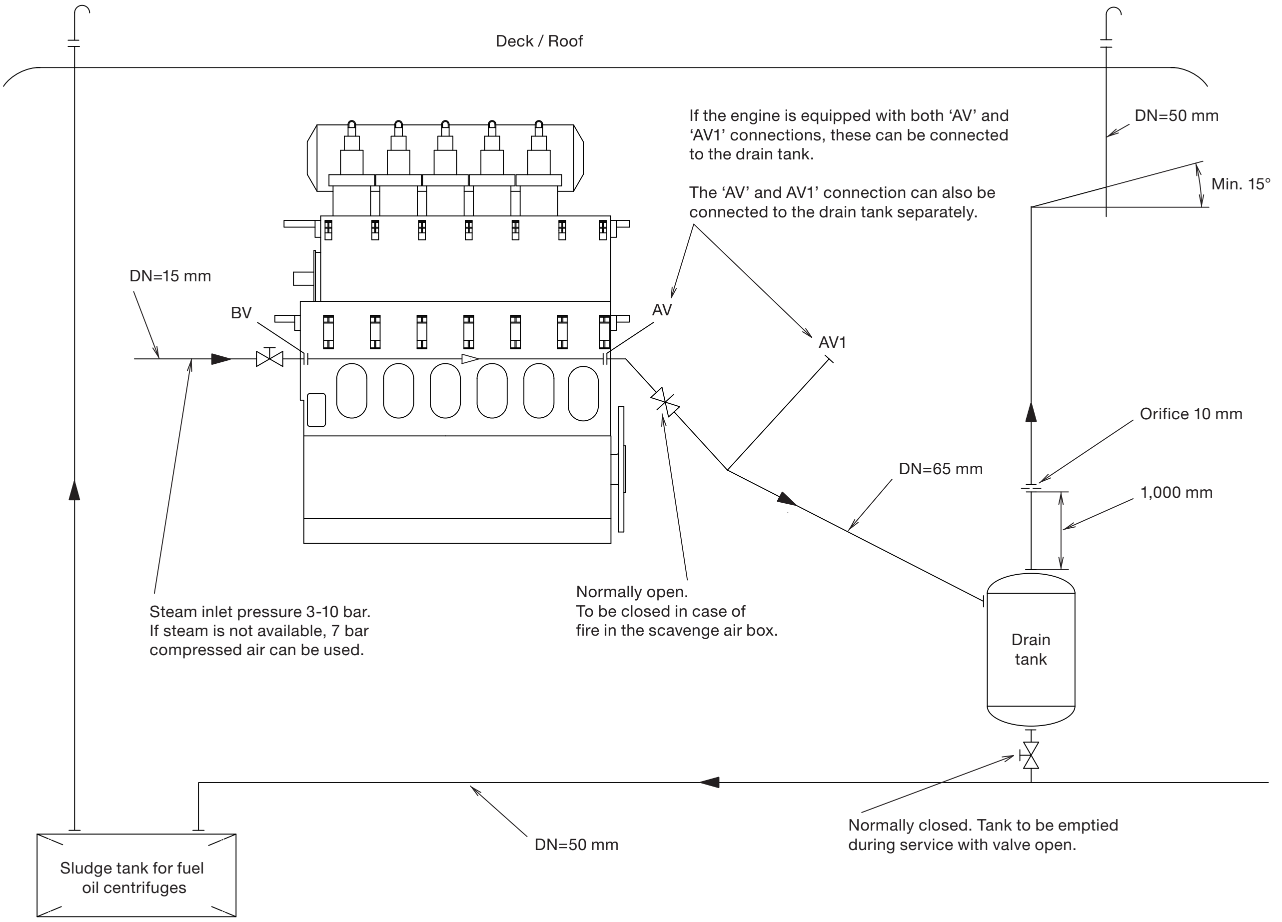
Scavenge Air Box Drain System

The scavenge air box is continuously drained through ‘AV’ to a small pressurised drain tank, from where the sludge is led to the sludge tank. Steam can be applied through ‘BV’, if required, to facilitate the draining. See Fig. 14.06.01.

The continuous drain from the scavenge air box must not be directly connected to the sludge tank owing to the scavenge air pressure.

The pressurised drain tank must be designed to withstand full scavenge air pressure and, if steam is applied, to withstand the steam pressure available.

The system delivered with and fitted on the engine is shown in Fig. 14.07.03 Scavenge air space, drain pipes.



The letters refer to list of ‘Counterflanges’

No. of cylinders:	5-6	7-9
Drain tank capacity, m^3	0.5	0.7

079 61 03-0.4.1

Fig. 14.06.01: Scavenge air box drain system

Fire Extinguishing System for Scavenge Air Space

Fire in the scavenge air space can be extinguished by steam, this being the basic solution, or, optionally, by water mist or CO_2.

The external system, pipe and flange connections are shown in Fig. 14.07.01 and the piping fitted onto the engine in Fig. 14.07.02.

In the Extent of Delivery, the fire extinguishing system for scavenge air space is selected by the fire extinguishing agent:

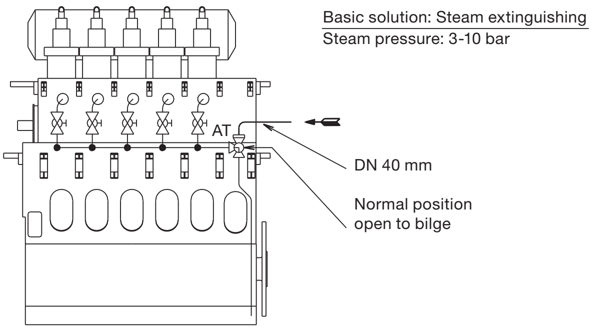
- basic solution: 4 55 140 Steam
- option: 4 55 142 Water mist
- option: 4 55 143 CO_2
- option: 4 55 144 Argonite

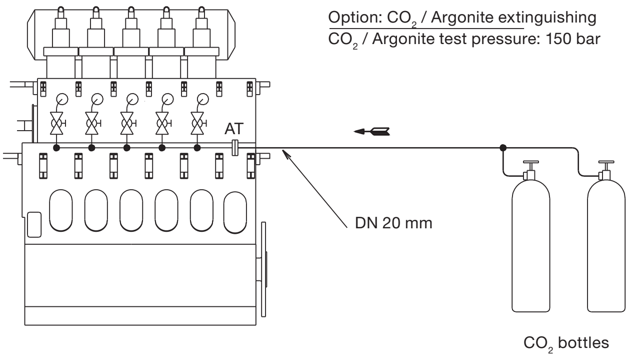
The key specifications of the fire extinguishing agents are:

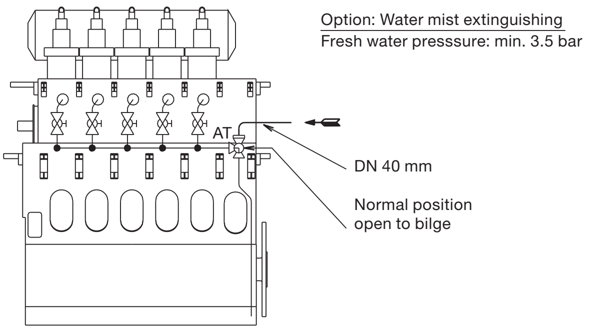
Steam fire extinguishing for scavenge air space
Steam pressure: 3-10 bar
Steam quantity, approx.: 3.2 kg/cyl.

Water mist fire extinguishing for scavenge air space
Freshwater pressure: min. 3.5 bar
Freshwater quantity, approx.: 2.6 kg/cyl.

CO_2/Argonite fire extinguishing for scavenge air space
CO2/Argonite test pressure: 150 bar
CO_2 quantity, approx.: 6.5 kg/cyl.
Argonite quantity approx.: 2.0 kg/cyl.







CO_2

At least two bottles ought to be installed. In most cases, one bottle should be sufficient to extinguish fire in three cylilnders, while two or more bottles would be required to extinguish fire in all cylinders.

To prevent the fire from spreading to the next cylinder(s), the ball-valve of the neighbouring cylinder(s) should be opened in the event of fire in one cylinder.

Argonite

At least two bottles ought to be installed, one as spare.

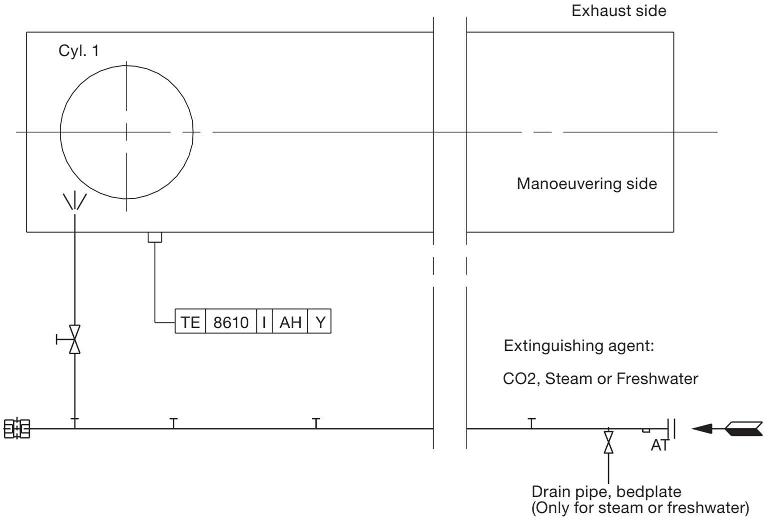
To prevent the fire from spreading to the next cylinder(s), the ball-valve of the neighbouring cylinder(s) should be opened in the event of fire in one cylinder.

079 61 02-9.3.0b

The letters refer to list of 'Counterflanges'

Fig. 14.07.01: Fire extinguishing system for scavenge air space

Fire Extinguishing Pipes in Scavenge Air Space



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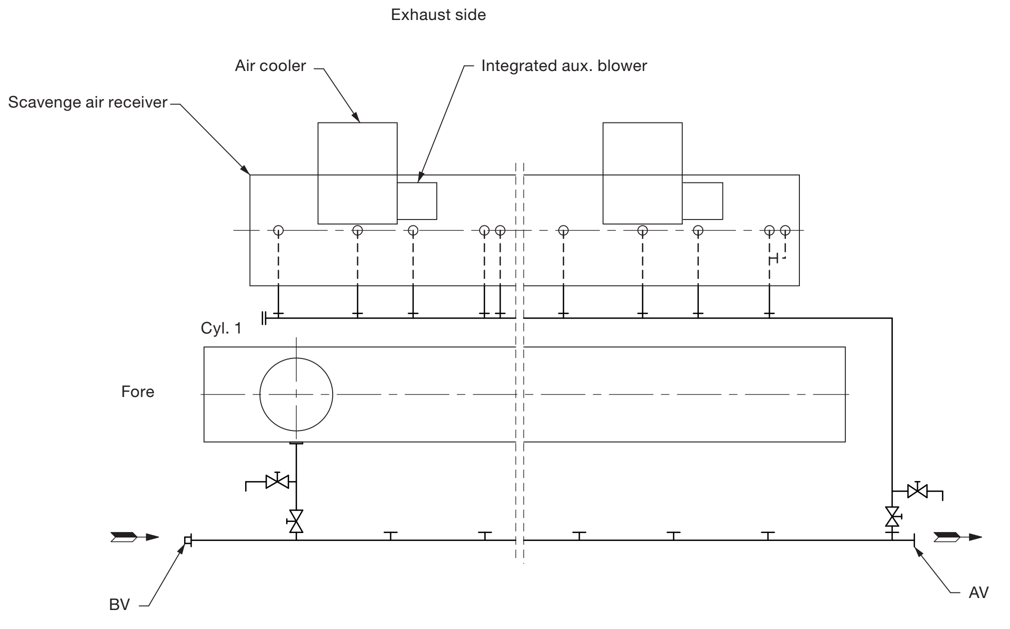
126 40 81-0.6.1a

Fig. 14.07.02: Fire extinguishing pipes in scavenge air space

Scavenge Air Space, Drain Pipes



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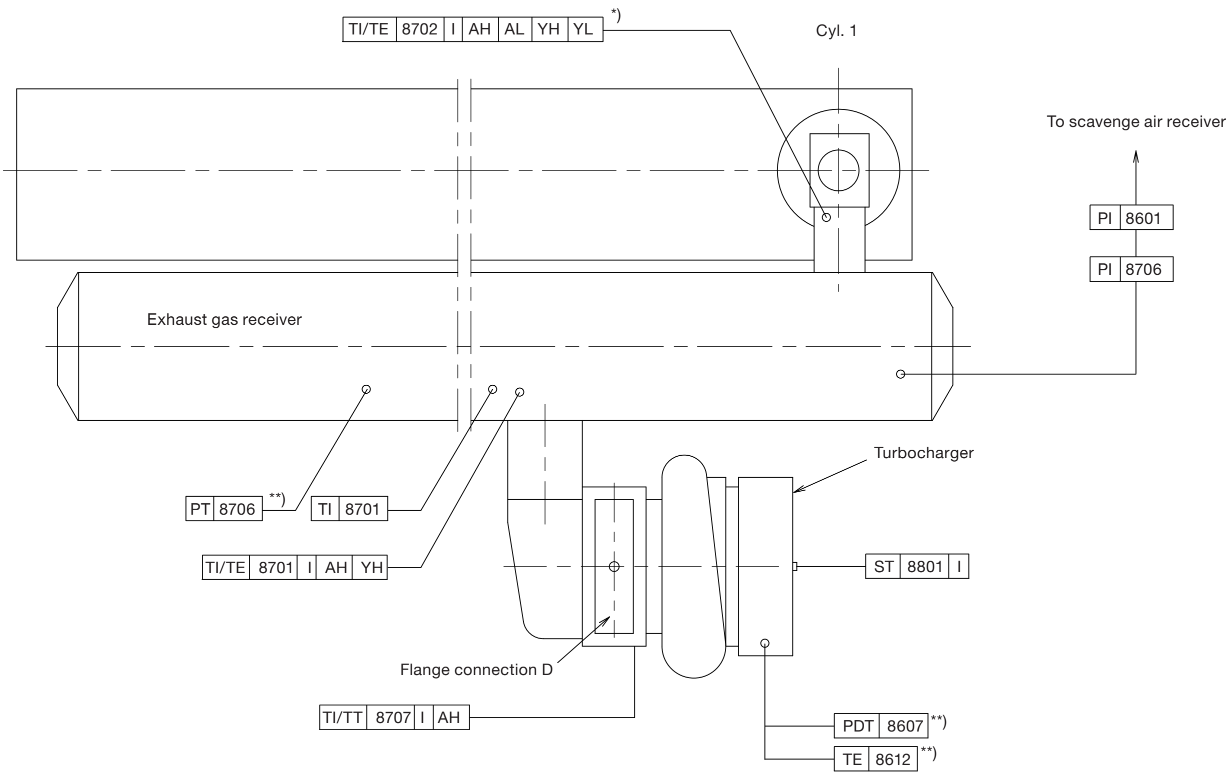
530 79 95-5.0

Fig. 14.07.03: Scavenge air space, drain pipes

Exhaust Gas

15

Exhaust Gas Pipes



*) AL: Deviation alarm/Cylinder ±50ºC
YL: Deviation alarm/Cylinder ±60ºC

**)CoCos

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

121 15 27-9.2.1

Fig. 15.02.01: Exhaust gas pipes

Cleaning Systems

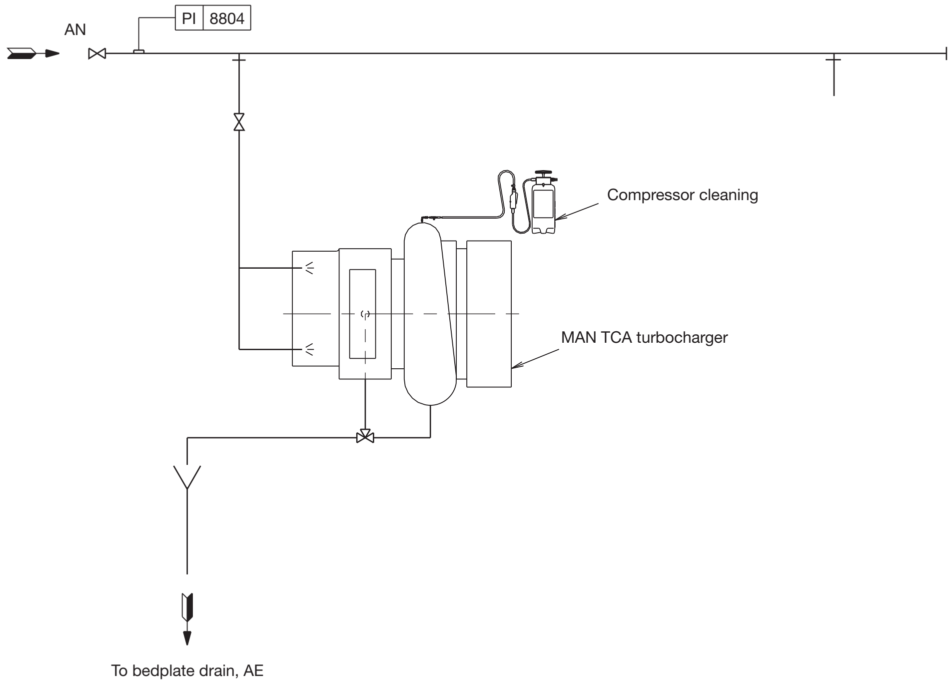


Fig. 15.02.02: MAN TCA turbocharger, water washing of turbine side

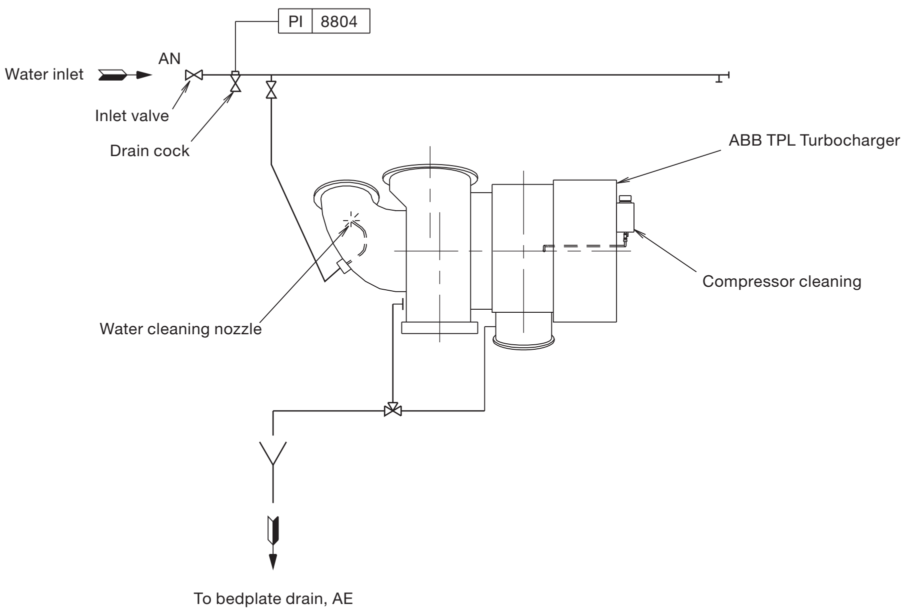
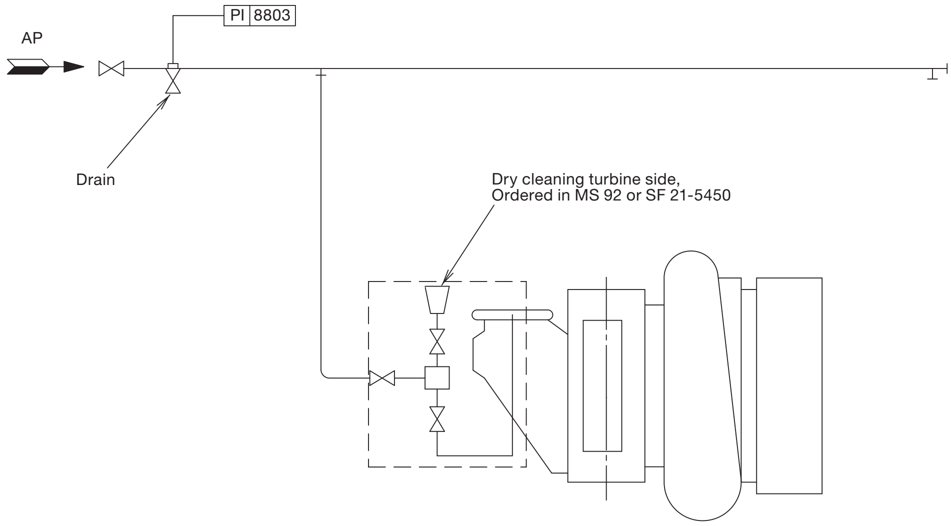


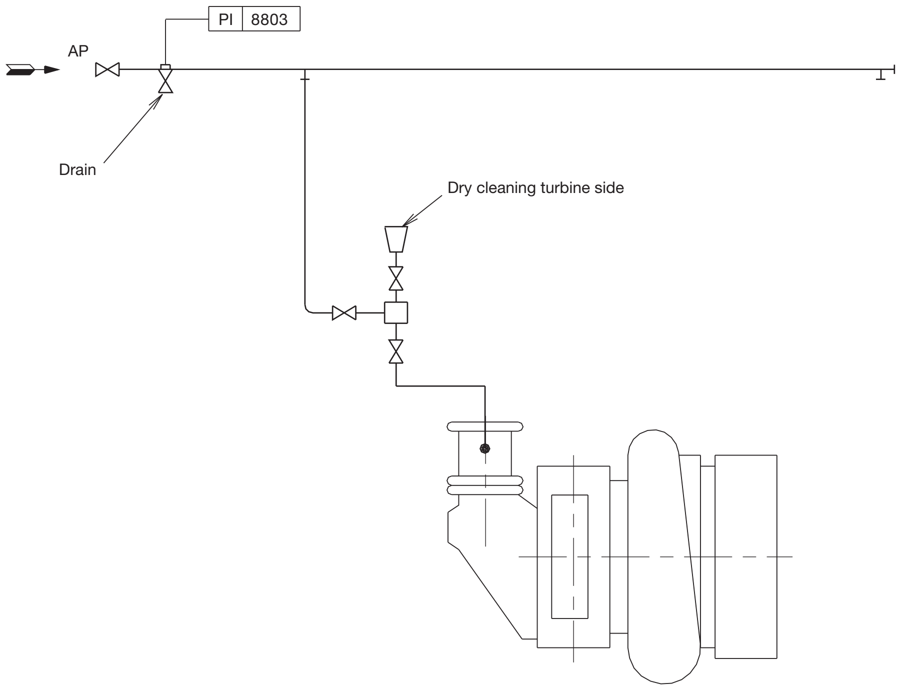
Fig. 15.02.03: Water washing of turbine and compressor sides for ABB TPL turbochargers

Soft Blast Cleaning Systems



514 69 25-5.1.0

Fig. 15.02.04: Soft blast cleaning of turbine side, basic



126 40 93-0.2.0

Fig. 15.02.05: Soft blast cleaning of turbine side, option

Exhaust Gas System for Main Engine

At the specified MCR of the engine, the total back-pressure in the exhaust gas system after the turbocharger (as indicated by the static pressure measured in the piping after the turbocharger) must not exceed 350 mm WC (0.035 bar).

In order to have a back-pressure margin for the final system, it is recommended at the design stage to initially use a value of about 300 mm WC (0.030 bar).

The actual back-pressure in the exhaust gas system at specified MCR depends on the gas velocity, i.e. it is proportional to the square of the exhaust gas velocity, and hence inversely proportional to the pipe diameter to the 4th power. It has by now become normal practice in order to avoid too much pressure loss in the pipings to have an exhaust gas velocity at specified MCR of about 35 m/sec, but not higher than 50 m/sec.

For dimensioning of the external exhaust pipe connections, see the exhaust pipe diameters for 35 m/sec, 40 m/sec, 45 m/sec and 50 m/sec respectively, shown in Table 15.07.02.

As long as the total back-pressure of the exhaust gas system (incorporating all resistance losses from pipes and components) complies with the above-mentioned requirements, the pressure losses across each component may be chosen independently, see proposed measuring points (M) in Fig. 15.05.01. The general design guidelines for each component, described below, can be used for guidance purposes at the initial project stage.

Exhaust gas piping system for main engine

The exhaust gas piping system conveys the gas from the outlet of the turbocharger(s) to the atmosphere.

The exhaust piping is shown schematically in Fig. 15.04.01.

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.

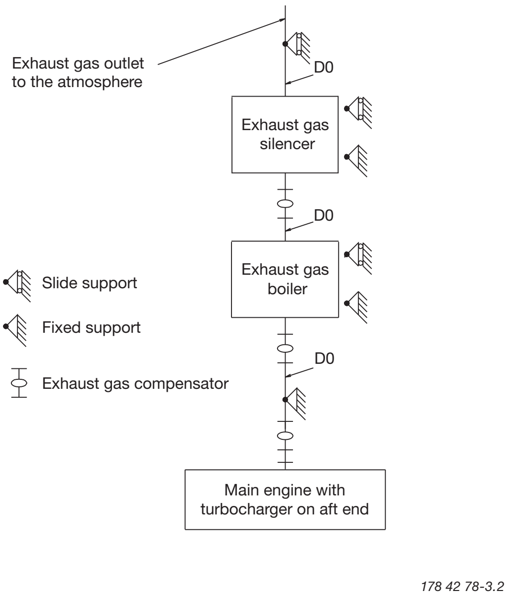


Fig. 15.04.01a: Exhaust gas system, one turbocharger

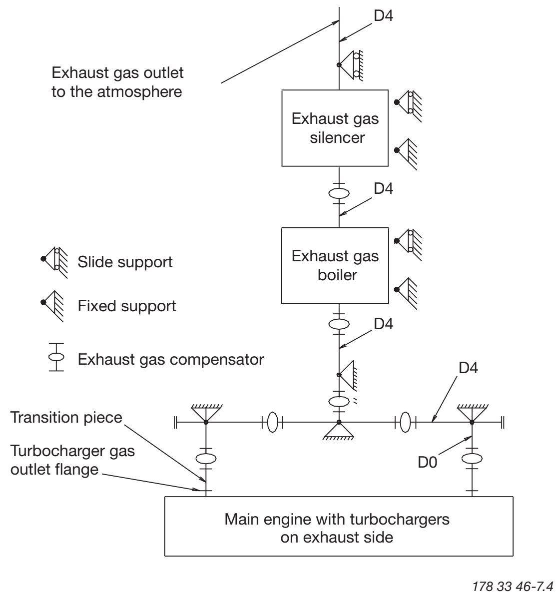


Fig. 15.04.01b: Exhaust gas system, two or more TCs

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.

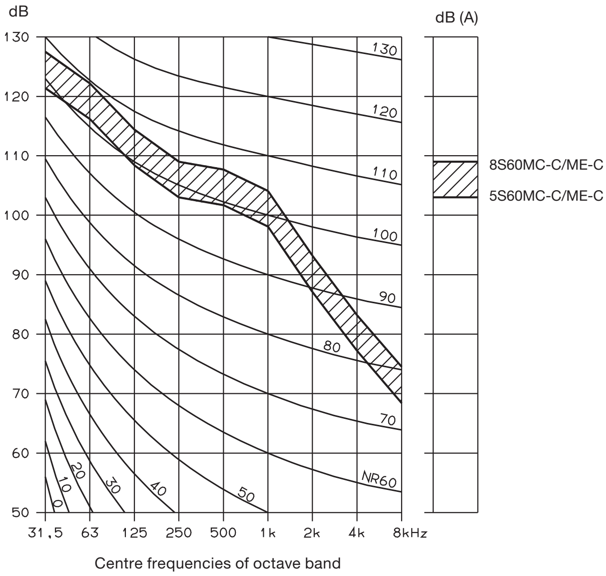
For each doubling of the distance, the noise level will be reduced by about 6 dB (far-field law).

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 16 99-1.2

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

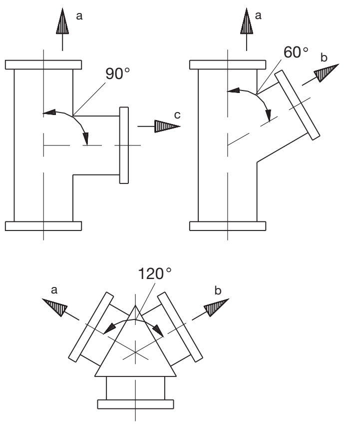
At any given position in the exhaust gas system, the total pressure of the flow can be divided into dynamic pressure (referring to the gas velocity) and static pressure (referring to the wall pressure, where the gas velocity is zero).

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



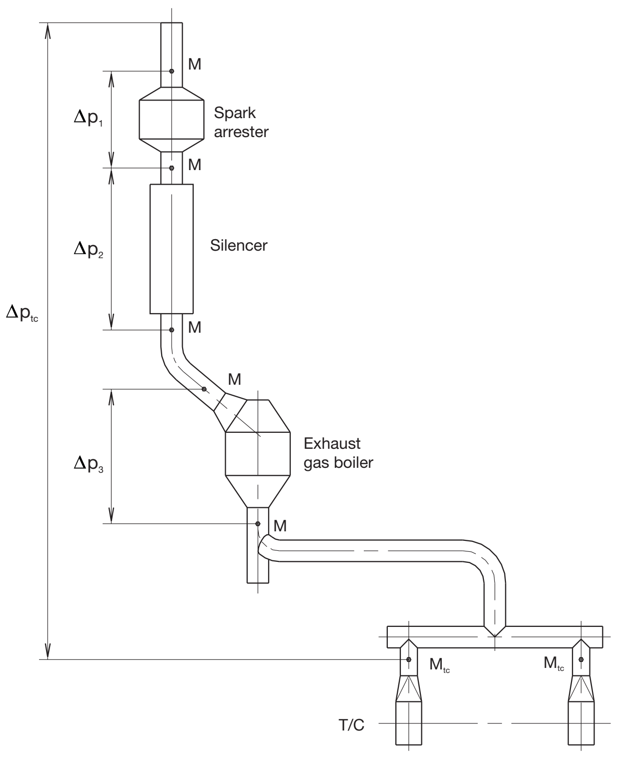
Change-over valves

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

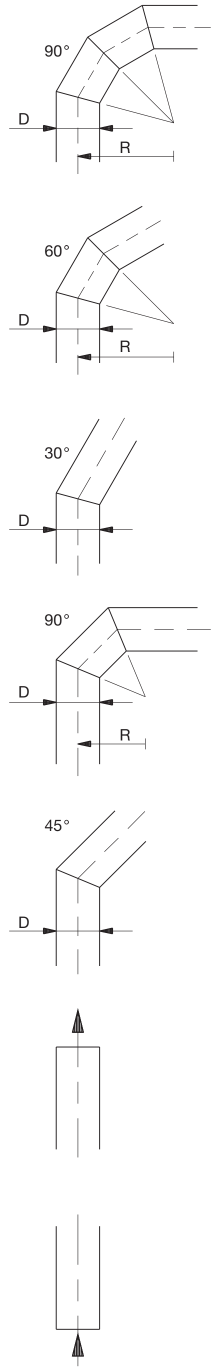
Change-over valve of type with volume

ζa = ζb = about 2.0



M: Measuring points

178 32 09-1.0



R = D ζ = 0.28
R = 1.5D ζ = 0.20
R = 2D ζ = 0.17

R = D ζ = 0.16
R = 1.5D ζ = 0.12
R = 2D ζ = 0.11

ζ = 0.05

R = D ζ = 0.45
R = 1.5D ζ = 0.35
R = 2D ζ = 0.30

ζ = 0.14

Outlet from top of exhaust gas uptake ζ = 1.00

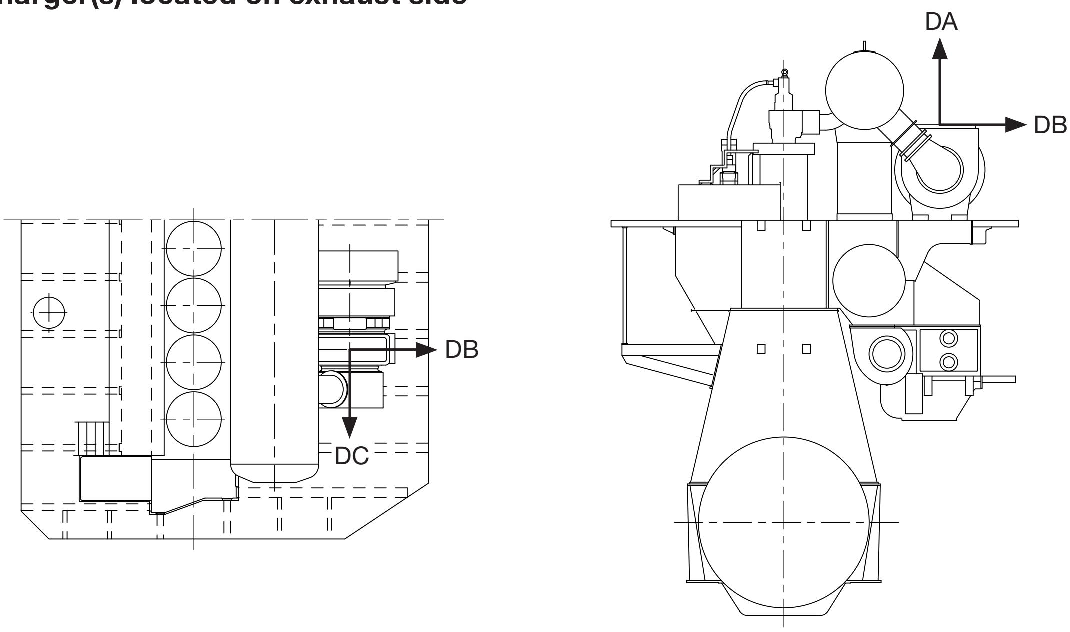
Inlet (from turbocharger) ζ = – 1.00

178 06 85-3.0

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

Forces and Moments at Turbocharger

Turbocharger(s) located on exhaust side



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

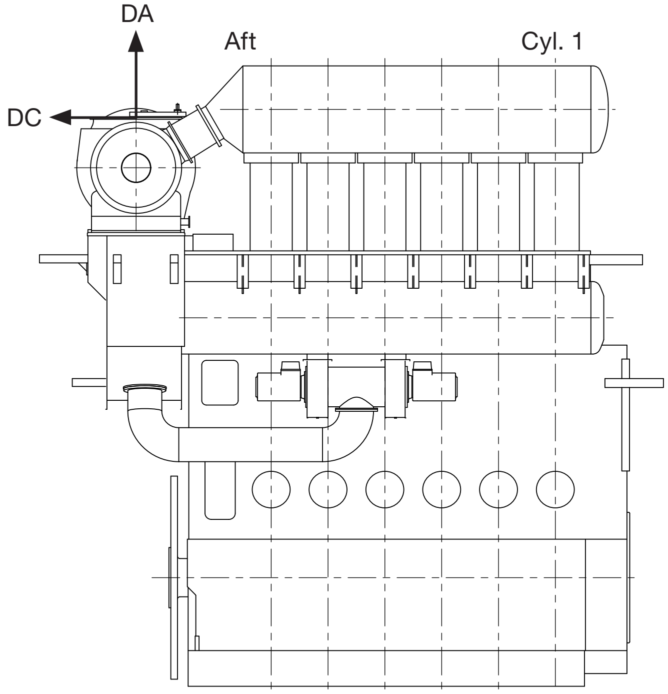
078 87 11-1.0.0b

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

No. of cylinders		**5-8**		**5**	**6**	**7**	**8**
Turbocharger		**DA**	**DB**	**DC**	**DC**	**DC**	**DC**
Make	**Type**	**mm**	**mm**	**mm**	**mm**	**mm**	**mm**
MAN	TCA55	Available on request					
	TCA66						
	TCA77						
	TCA88						
ABB	A175 / A275						
	A180 / A280						
	A185						
MHI	MET48						
	MET53						
	MET60						
	MET66						
	MET71						
	MET83						

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

One turbocharger located on aft end



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

078 87 11-1.0.0a

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

No. of cylinders		5-8	5	6	7	8
Turbocharger		DA	DC	DC	DC	DC
Make	Type	mm	mm	mm	mm	mm
MAN	TCA55	Available on request				
	TCA66					
	TCA77					
	TCA88					
ABB	A175 / A275					
	A180 / A280					
	A185					
MHI	MET48					
	MET53					
	MET60					
	MET66					
	MET71					
	MET83					

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

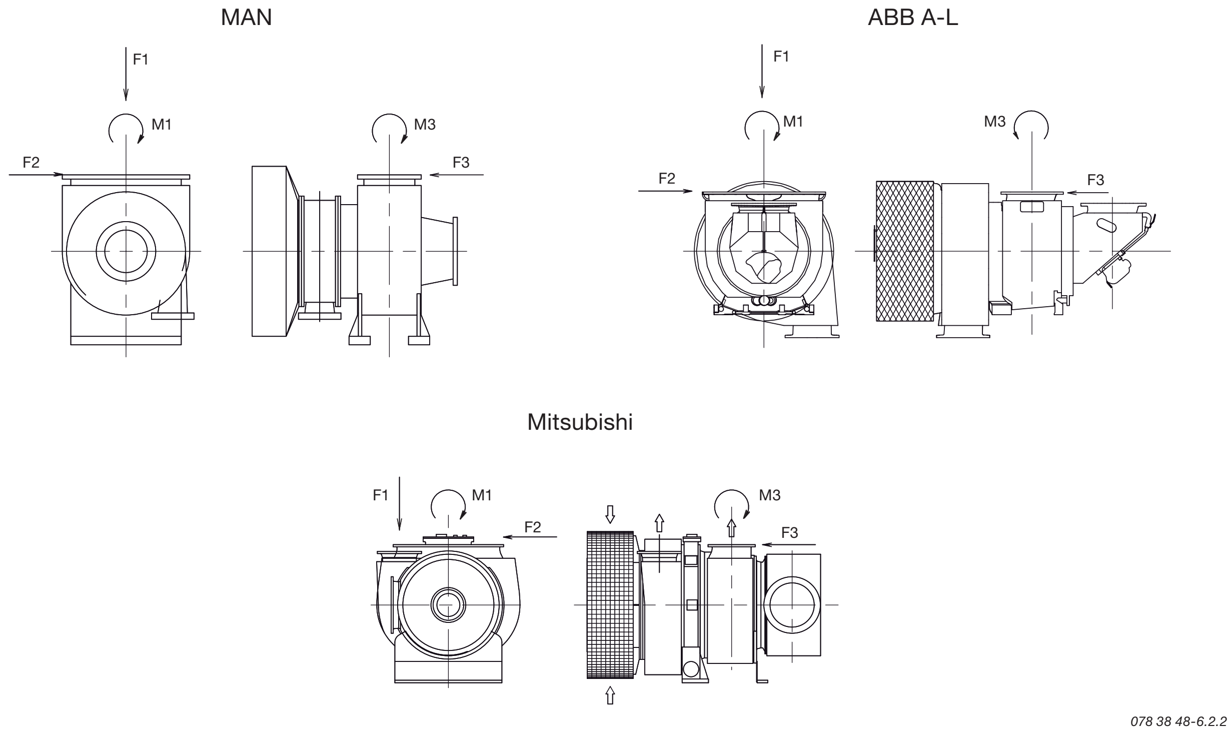


Fig. 15.06.03: Forces and moments on the turbochargers' exhaust gas outlet flange

Table 15.06.04 indicates the maximum permissible forces (F1, F2 and F3) and moments (M1 and M3), on the exhaust gas outlet flange of the turbocharger(s). Reference is made to Fig. 15.06.03.

Turbocharger Make	Type	M1 Nm	M3 Nm	F1 N	F2 N	F3 N
MAN	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	MET48	Available on request				
	MET53	4,900	2,500	7,300	2,600	2,300
	MET60	6,000	3,000	8,300	2,900	3,000
	MET66	6,800	3,400	9,300	3,200	3,000
	MET71	7,000	3,500	9,600	3,300	3,100
	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.

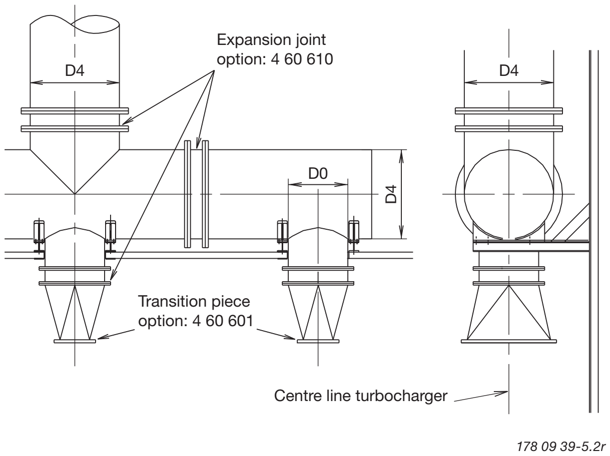


Fig. 15.07.01a: Exhaust pipe system, with turbocharger located on exhaust side of engine, option: 4 59 122

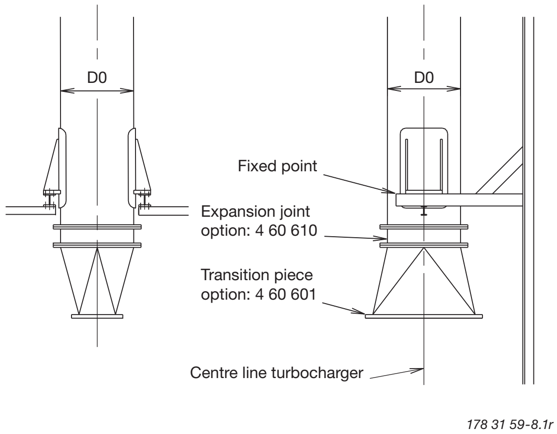


Fig. 15.07.01b: Exhaust pipe system, with single turbocharger located on aft end of engine, option: 4 59 124

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**	**4 T/C**	
kg/s	**kg/s**	**kg/s**	**kg/s**	**[DN]**	**[DN]**	**[DN]**	**[DN]**	**[DN]**
22.4	25.7	28.9	32.1	1,100	800	650	550	1,100
24.5	28.0	31.5	35.1	1,150	800	650	600	1,150
26.7	30.5	34.3	38.2	1,200	850	700	600	1,200
31.4	35.8	40.3	44.8	1,300	900	750	650	1,300
36.4	41.6	46.8	51.9	1,400	1,000	800	700	1,400
41.7	47.7	53.7	59.6	1,500	1,050	850	750	1,500
47.5	54.3	61.1	67.8	1,600	1,150	900	800	1,600
53.6	61.3	68.9	76.6	1,700	1,200	1,000	850	1,700

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

Engine Control System

16

Engine Control System

The engine is provided with a pneumatic/electric manoeuvring and fuel oil regulating system, which transmits orders from the separate manoeuvring consoles to the engine.

By means of the regulating system it is possible to start, stop, reverse the engine and control the engine speed. The speed setting device on the manoeuvring consoles gives a speed setting signal to the governor, dependent on the desired number of rpm.

At shut-down, the fuel injection is stopped by activating the puncture valves in the fuel pumps, independent of the speed position of the speed setting device.

The layout of the Engine Control System is shown in Fig. 16.01.01 and a diagram of the pneumatic manoeuvring system in Fig. 16.01.02.

Manoeuvring Consoles

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

The main Engine Control Room (ECR) manoeuvring console is to be located in the engine control room. The console with buttons, lamps, etc. recommended by MAN Diesel is shown in Fig. 16.01.07. Components for remote control for a typical installation with bridge control is shown in Fig. 16.01.05.

The layout of the Engine Side Console and instrument panel is shown in Fig. 16.01.06a, b and c. The console and an electronic speed setting device, the governor, are located on the manoeuvring side of the engine.

In the event of breakdown of the normal pneumatic/electric manoeuvring system, the engine can be operated from the Engine Side Console.

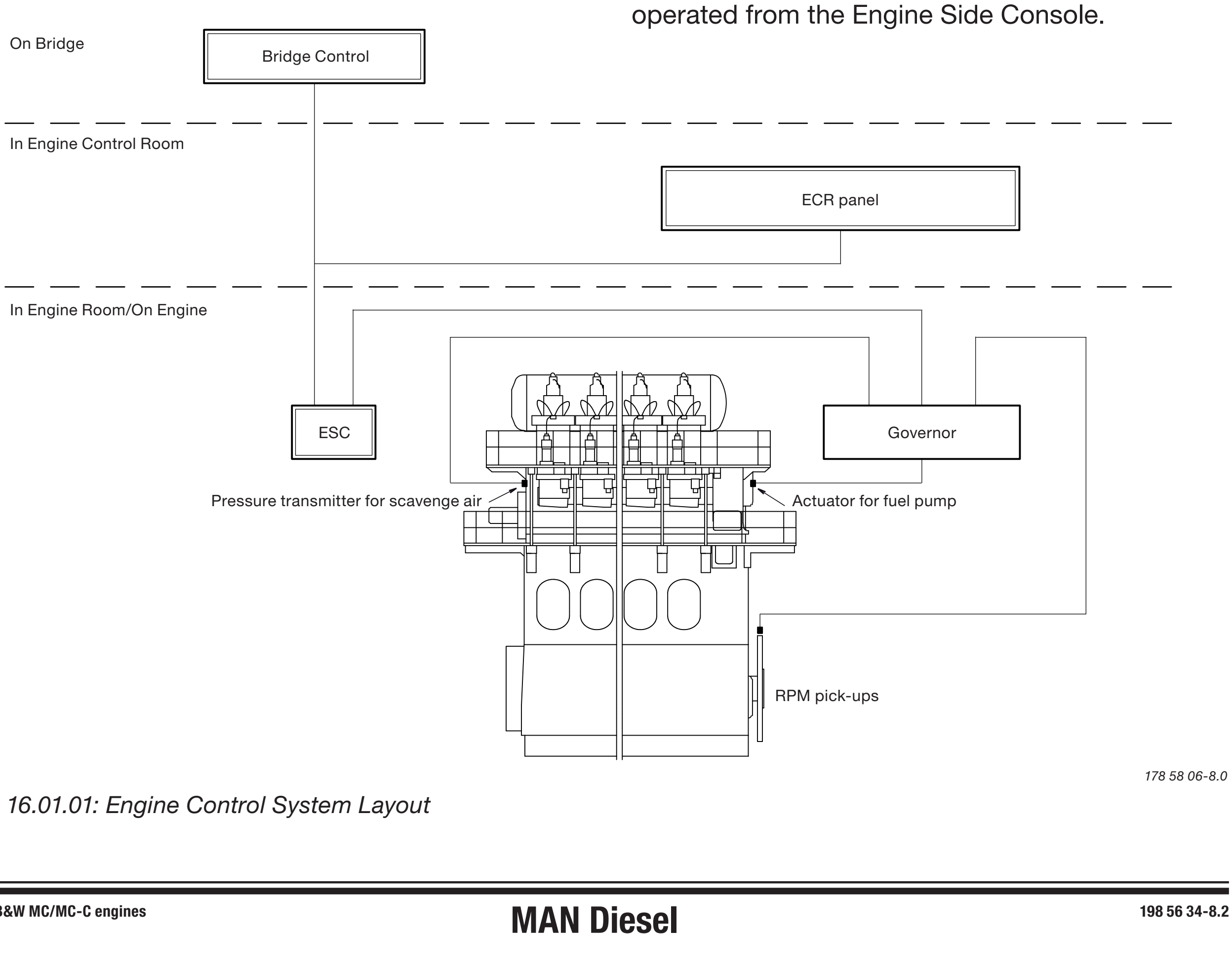
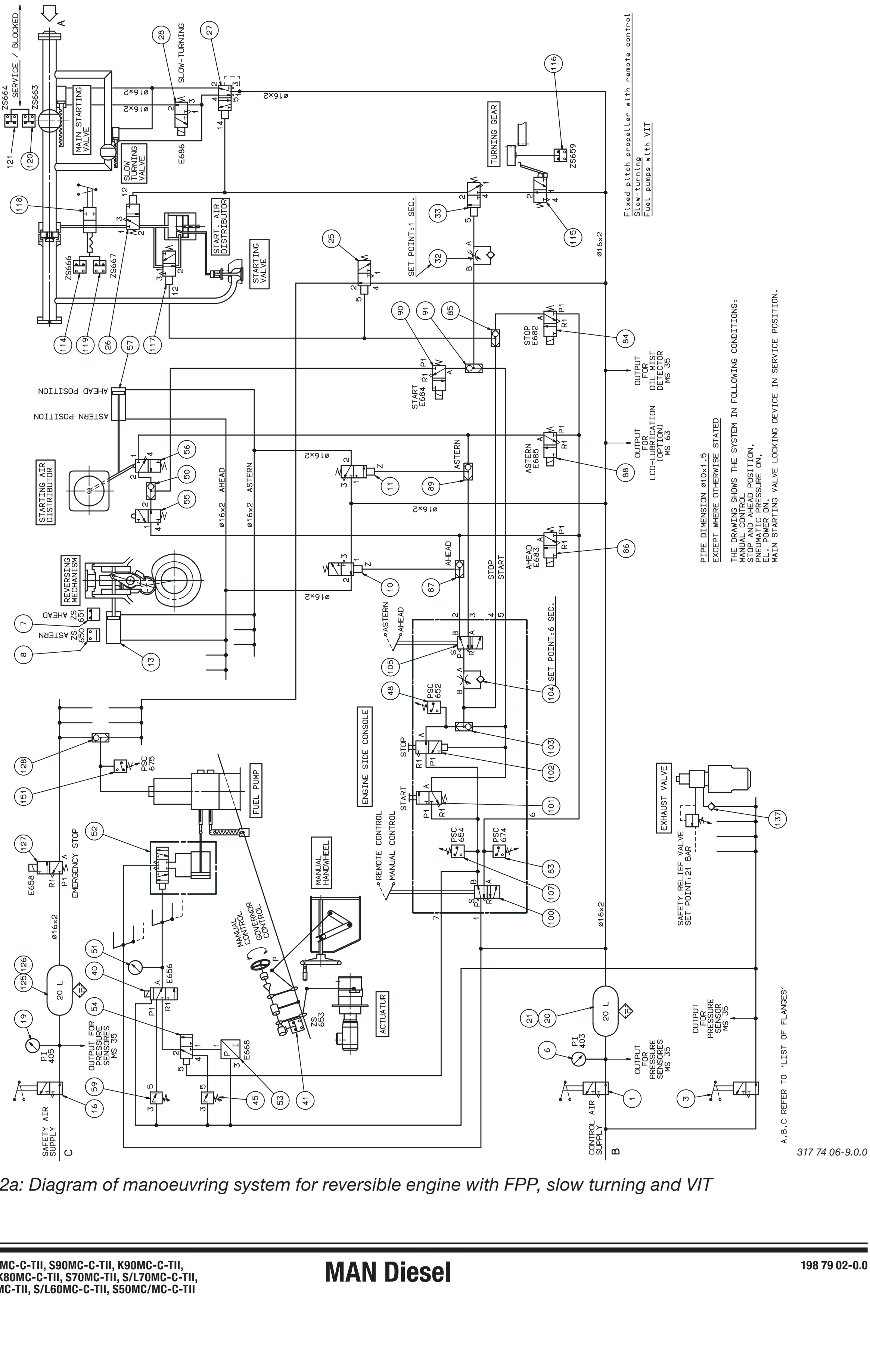


Fig. 16.01.01: Engine Control System Layout

Diagram of Manoeuvring System



317 74 06-9.0.0

Fig. 16.01.02a: Diagram of manoeuvring system for reversible engine with FPP, slow turning and VIT

Manoeuvring System on Engine

The basic manoeuvring diagram is applicable for reversible engines, i.e. those with Fixed Pitch Propeller (FPP), and shown in Fig. 16.01.02.

The lever on the Engine Side Console can be set to either Manual or Remote position, see Fig. 16.01.06a, b and c.

In the Manual position the engine is controlled from the Engine Side Console by the push buttons START, STOP, and the AHEAD/ASTERN. The speed is set by the 'Manual speed setting' by the handwheel.

In the 'Remote' position all signals to the engine are electronic, the START, STOP, AHEAD and ASTERN signals activate the solenoid valves ZV 1137 C, ZV 1136 C, ZV 1141 C and ZV 1142 C respectively, shown in Figs. 16.01.02 and 16.01.05, and the speed setting signal via the electronic governor and the actuator E 1182 C.

The electrical signal comes from the remote control system, i.e. the Bridge Control (BC) console, or from the Engine Control Room (ECR) console.

Shut down system

The engine is stopped by activating the puncture valve located in the fuel pump either at normal stopping or at shut down by activating solenoid valve ZV 1103 C, see Fig. 16.01.02.

Slow turning

The standard manoeuvring system does not feature slow turning before starting, but for Unattended Machinery Spaces (UMS) we strongly recommend the addition of the slow turning device shown in Fig. 16.01.02 as well as Fig. 16.01.03, option: 4 50 140.

The slow turning valve diverts the starting air to partially bypass the main starting valve. During slow turning the engine will rotate so slowly that, in the event that liquids have accumulated on the piston top, the engine will stop before any harm occurs.

Low load operation

For operation at low load, a cylinder cut-out system is provided on engine types 98, 90 and 80, EoD: 4 65 255.

Control System for Plants with CPP
– applicable for engine types 70 and smaller

Where a controllable pitch propeller is installed, the control system is to be designed in such a way that the operational requirements for the whole plant are fulfilled.

Special attention should be paid to the actual operation mode, e.g. combinator curve with/without constant frequency shaft generator or constant engine speed with a power take off.

The following requirements have to be fulfilled:

- The control system is to be equipped with a load control function limiting the maximum torque (fuel pump index) in relation to the engine speed, in order to prevent the engine from being loaded beyond the limits of the load diagram
- The control system must ensure that the engine load does not increase at a quicker rate than permitted by the scavenge air pressure
- Load changes have to take place in such a way that the governor can keep the engine speed within the required range.

Please contact the engine builder to get specific data.

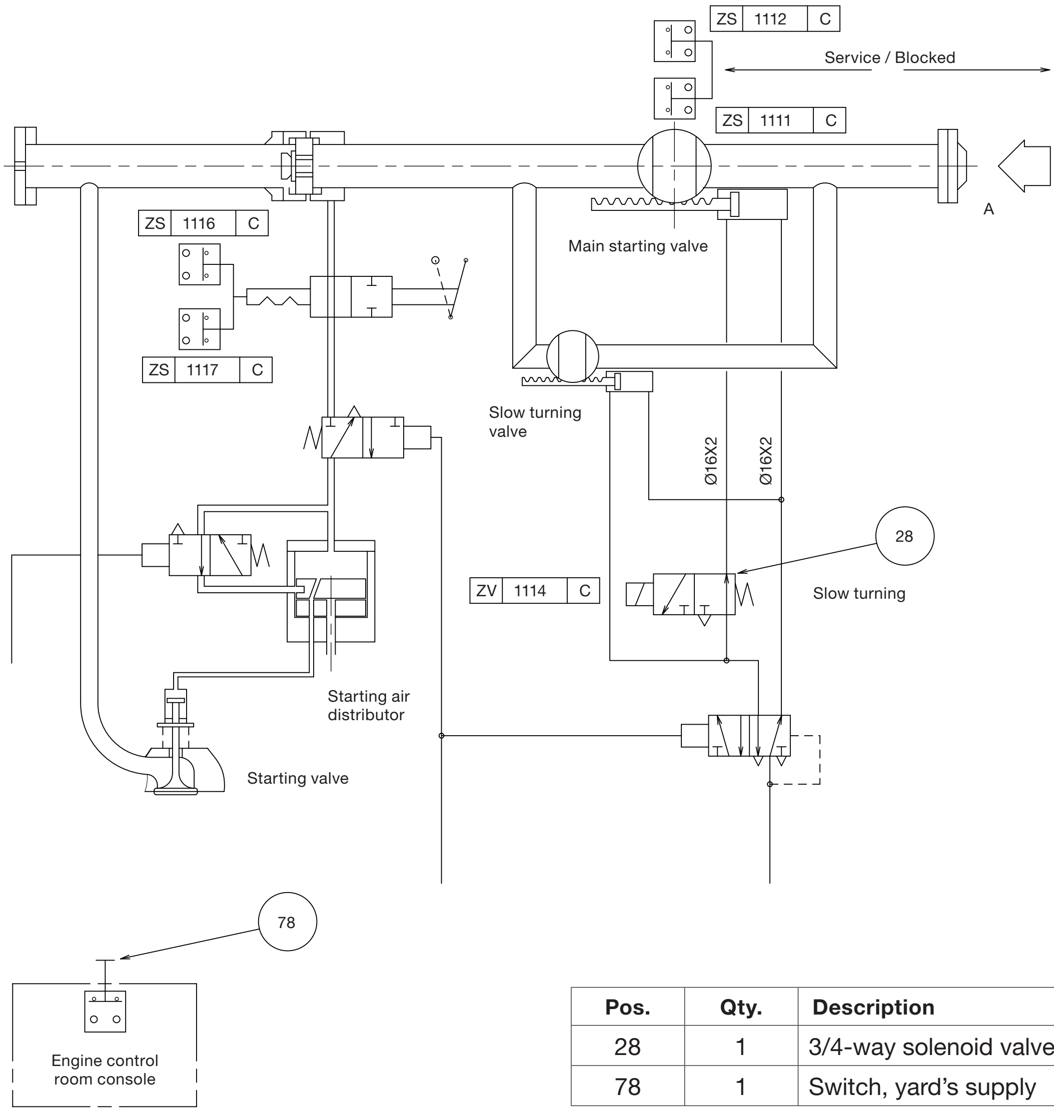
Sequence Diagram

MAN Diesel's requirements for the control system are indicated graphically in Fig. 16.01.08a, 'Sequence diagram'.

The diagram shows the functions as well as the delays which must be considered in respect to starting 'Ahead' and starting 'Astern', as well as for the activation of the slow down and shut down functions.

On the right of the diagram, a situation is shown where the order 'Astern' is over-ridden by an 'Ahead' order – the engine immediately starts 'Ahead' if the engine speed is above the specified starting level.

Starting Air System



Pos.	Qty.	Description
28	1	3/4-way solenoid valve
78	1	Switch, yard's supply

Additional components for slow turning are the slow turning valve in bypass and position nos. 28 and 78
The item No. refers to 'Guidance values 'automation'
The letter refers to list of 'Counterflanges'
The piping is delivered with and fitted onto the engine

178 58 11.5-0

Fig. 16.01.03: Starting air system, with slow turning, option: 4 50 140

Governor Parts and Mode of Operation

The engine is, as standard, provided with an electronic/mechanical type of fuel pump actuator of a make approved by MAN Diesel & Turbo.

The speed setting of the actuator is determined by an electronic signal from the electronic governor of a make approved by MAN Diesel & Turbo. The actuator shaft is connected to the fuel regulating shaft by means of a mechanical linkage.

When selecting the governor, the complexity of the installation has to be considered. We normally distinguish between 'conventional' and 'advanced' marine installations.

The governor consists of the following elements:

- Actuator
- Revolution transmitter (pick-ups)
- Electronic governor panel
- Power supply unit
- Pressure transmitter for scavenge air.

The actuator, revolution transmitter and the pressure transmitter are mounted on the engine.

The electronic governors must be tailor-made, and the specific layout of the system must be mutually agreed upon by the customer, the governor supplier and the engine builder.

It should be noted that the shut down system, the governor and the remote control system must be compatible if an integrated solution is to be obtained.

The minimum speed is 20-25% of the engines nominal speed when an electronic governor is applied.

Governor for 'Conventional' plants

A typical example of a 'conventional' marine installation is:

- An engine directly coupled to a fixed pitch propeller.

With a view to such an installation, the engine is, as standard, equipped with a 'conventional' electronic governor with actuator of a make approved by MAN Diesel & Turbo, e.g.:

4 65 172 Lyngsø Marine

4 65 174 Kongsberg Maritime

4 65 175 Nabtesco

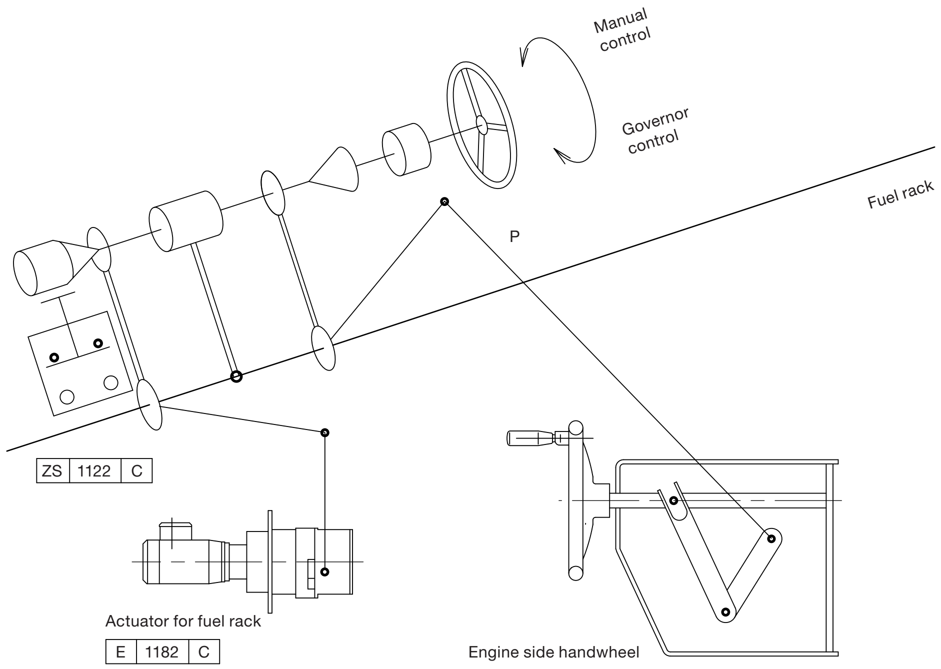
4 65 176 Mitsui Zosen Systems Research.

Governor for 'Advanced' plants

For more 'advanced' marine installations, such as, for example:

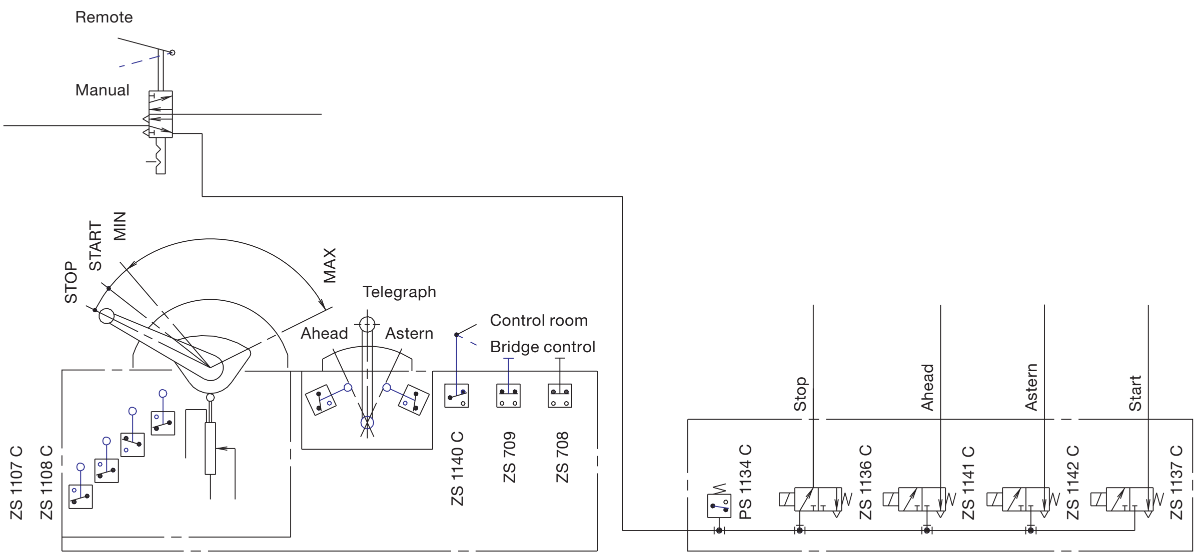
- Plants with flexible coupling in the shafting system
- Geared installations
- Plants with disengageable clutch for disconnecting the propeller
- Plants with shaft generator with great requirement for frequency accuracy.

Governor and Remote Control Components



178 58 12-7.0

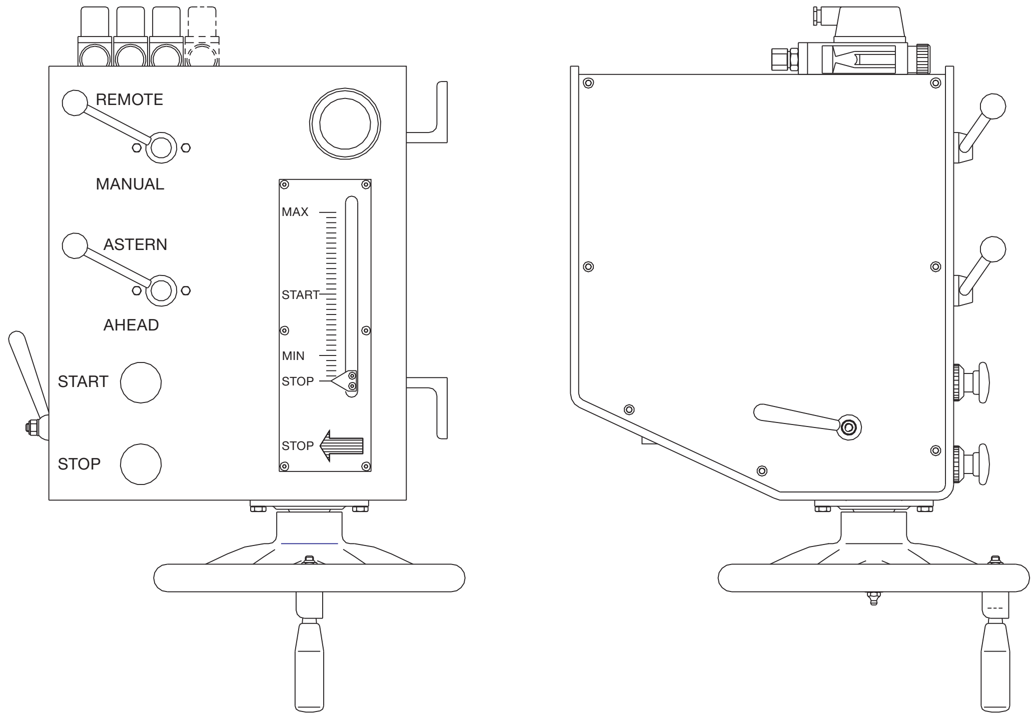
Fig. 16.01.04: Electronic governor



178 58 13-9.0

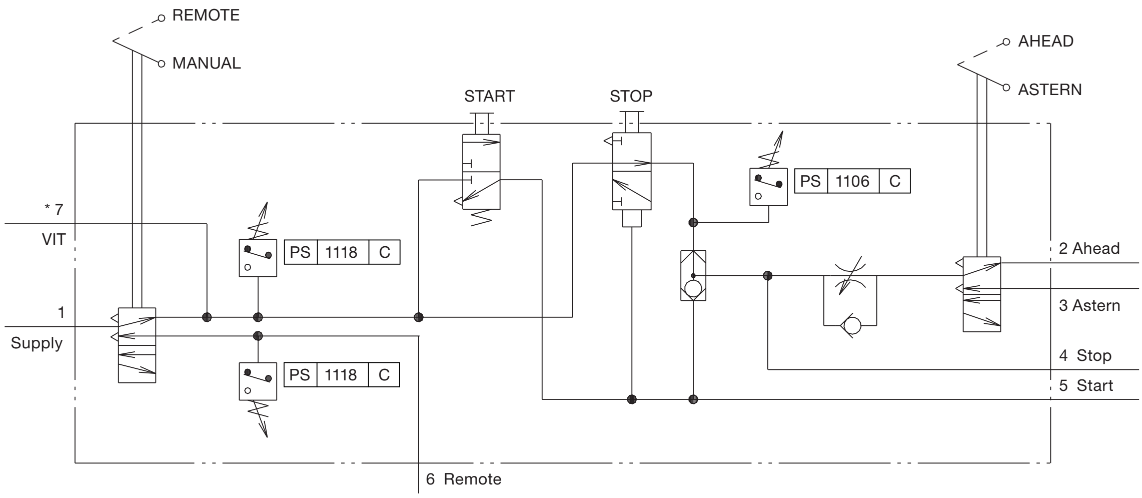
Fig. 16.01.05: Components for remote control of reversible engine with FPP with bridge control

Engine Side Control Console with diagram



178 58 15-2.0

Fig. 16.01.06a: Engine Side Control console, for reversible engine

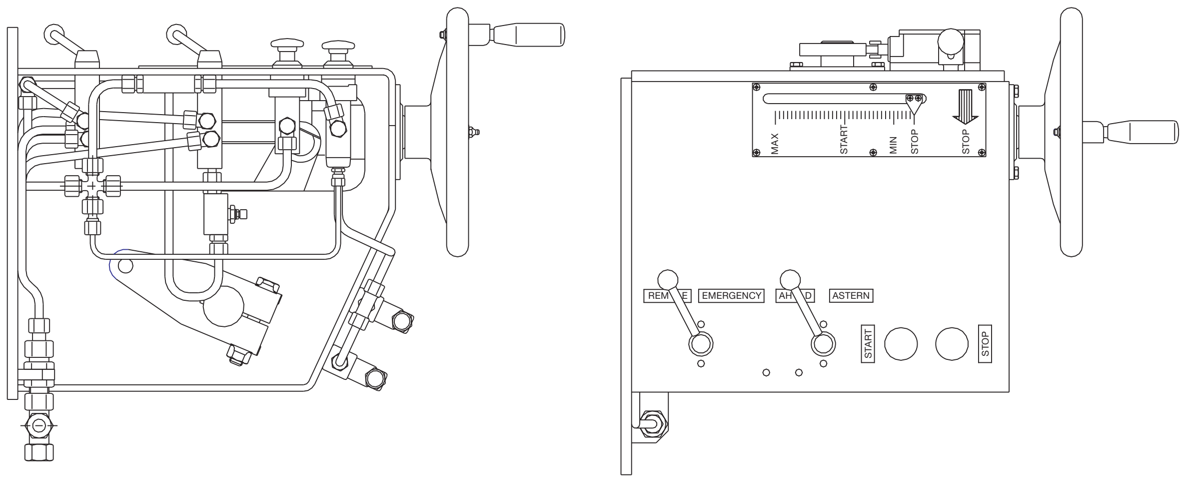


* Terminal 7 only connected on engines with VIT type fuel pumps

178 58 16-4.0

Fig. 16.01.06b: Diagram of Engine Side Control console

Engine Side Control Console and Instrument Panel



Components included for:

Fixed pitch propeller:

- Remote control – manual engine side control
- Ahead – Astern handle
- Start button
- Stop button

The instrument panel includes:

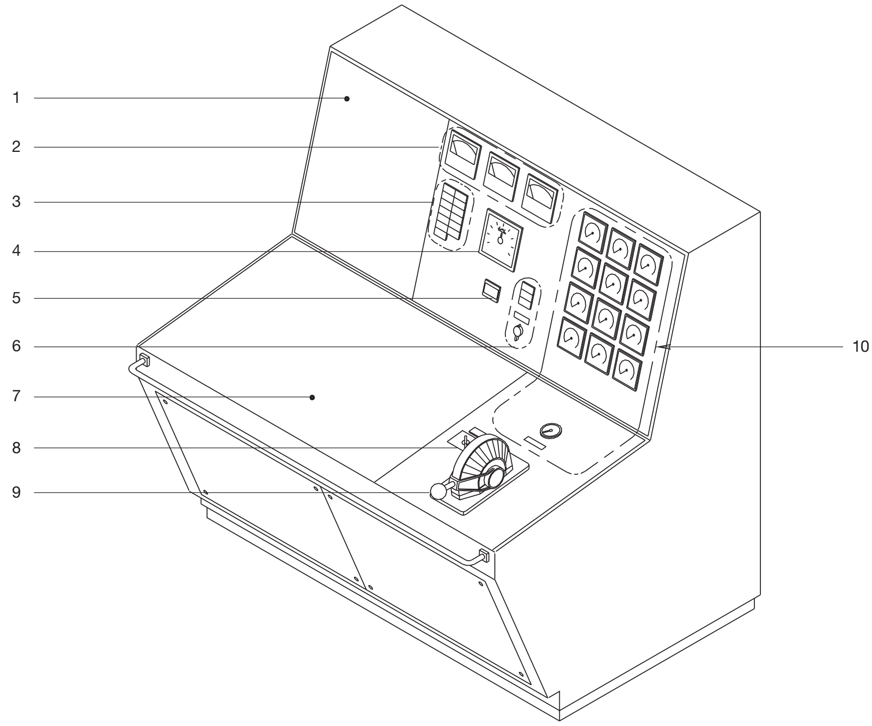
For reversible engine:

- Tachometer for engine
- Indication for engine side control
- Indication for control room control (remote)
- Indication for bridge control (remote)
- Indication for 'Ahead'
- Indication for 'Astern'
- Indication for auxiliary blower running
- Indication and buzzer for wrong way alarm
- Indication for turning gear engaged
- Indication for 'Shut down'
- Push button for canceling 'Shut down', with indication

178 58 14-0.0

Fig. 16.01.06c: Engine Side Control console and instrument panel

Engine Control Room Console



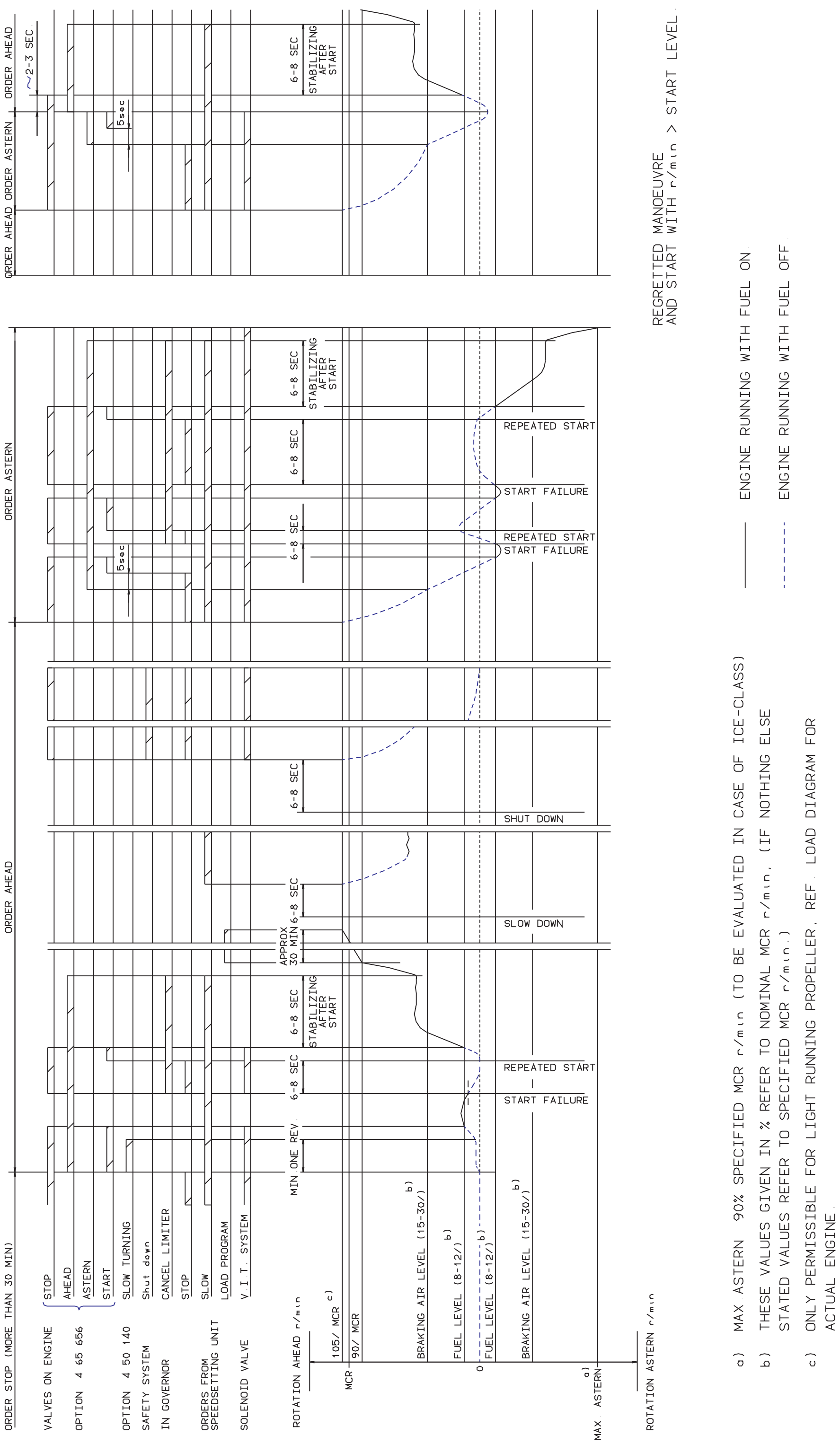
1 Free space for mounting of safety panel
Engine builder's supply
2 Tachometer(s) for turbocharger(s)
3 Indication lamps for:
Ahead
Astern
Engine Side Control
Control Room Control
Wrong way alarm
Turning gear engaged
Main starting valve in service
Main starting valve in blocked mode
Remote control
Shut down
(Spare)
Lamp test
4 Tachometer for main engine
5 Revolution counter
6 Switch and lamps for auxiliary blowers
7 Free spares for mounting of bridge control equipment for main engine
8 Switch and lamp for cancelling of limiters for governor
9 Engine control handle, option: 4 65 625 from engine maker
* 10 Pressure gauges for:
Scavenge air
Lubricating oil, main engine
Cooling oil, main engine
Jacket cooling water
Sea cooling water
Lubricating oil, camshaft
Fuel oil before filter
Fuel oil after filter
Starting air
Control air supply
* 10 Thermometer:
Jacket cooling water
Lubricating oil water

Note: If an axial vibration monitor is ordered (option: 4 31 116) the manoeuvring console has to be extended by a remote alarm/slow down indication lamp.

* These instruments have to be ordered as option: 4 75 645 and the corresponding analogue sensors on the engine as option: 4 75 128.

Fig. 16.01.07: Instruments and pneumatic components for Engine Control Room console, yard's supply

Sequence diagram for engines with Fixed Pitch Propeller



178 58 22-3.0

Fig. 16.01.08a: Sequence diagram for fixed pitch propeller, MC/MC-C types 98-60

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.

The monitoring systems and instrumentation are explained in detail in Chapter 18.

Alarm system

The alarm system has no direct effect on the Engine Control System (ECS). The alarm alerts the operator of an abnormal condition.

The alarm system is an independent system, in general covering more than the main engine itself, and its task is to monitor the service condition and to activate the alarms if a normal service limit is exceeded.

The signals from the alarm sensors can be used for the slow down function as well as for remote indication.

Slow down system

The engine safety system is an independent system with its respective sensors on the main engine, fulfilling the requirements of the respective classification society and MAN Diesel & Turbo.

Safety system

The engine safety system is an independent system with its respective sensors on the main engine, fulfilling the requirements of the respective classification society and MAN Diesel & Turbo.

If a critical value is reached for one of the measuring points, the input signal from the safety system must cause either a cancellable or a non-cancellable shut down signal to the ECS.

The safety system is included as standard in the extent of delivery.

For the safety system, combined shut down and slow down panels approved by MAN Diesel & Turbo are available. The following options are listed in the Extent of Delivery:

4 75 631 Lyngsø Marine

4 75 632 Kongsberg Maritime

4 75 633 Nabtesco

4 75 636 Mitsui Zosen Systems Research.

Where separate shut down and slow down panels are installed only panels approved by MAN Diesel & Turbo must be used.

In any case, the remote control system and the safety system (shut down and slow down panel) must be compatible.

Telegraph system

The telegraph system is an independent system.

This system enables the navigator to transfer the commands of engine speed and direction of rotation from the Bridge, the engine control room or the Engine Side Console (ESC).

Remote Control system

The remote control system normally has two alternative control stations:

- the Bridge Control console
- the Engine Control Room console

The remote control system is to be delivered by a supplier approved by MAN Diesel & Turbo.

Bridge control systems from suppliers approved by MAN Diesel & Turbo are available. The Extent of Delivery lists the following options:

- for Fixed Pitch propeller plants, e.g.:

  4 95 601 Lyngsø Marine

  4 95 607 Nabtesco

  4 95 608 Mitsui Zosen Systems Research

  4 95 615 Kongsberg Maritime

- and for Controllable Pitch propeller plants, e.g.:

  4 95 604 Lyngsø Marine

  4 95 916 Kongsberg Maritime

  4 95 619 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 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 in 'service position'
- control air valve for air spring 'open'
- auxiliary blowers running
- control air valve 'open'
- safety air valve 'open'
- governor 'in control'
- valve for starting air distributor 'open'.

Engine monitoring

In order to assist the engineer in runnning the diesel engine at its optimum performance, a MAN Diesel & Turbo's PMI system, type PT/S off-line or on-line could be applied as an option.

The MAN Diesel & Turbo's PMI system, type PT/S off-line monitors engine parameters such as:

- cylinder pressure
- fuel oil injection pressure
- scavenge air pressure
- engine speed.

This and other engine monitoring systems are further explained in Chapter 18 in this Project Guide.

Instrumentation

Chapter 18 includes lists of instrumentation for:

- The CoCos-EDS on-line system
- The class requirements and MAN Diesel & Turbo's requirements for alarms, slow down and shut down for Unattended Machinery Spaces.

Vibration Aspects

17

Vibration Aspects

The vibration characteristics of the two-stroke low speed diesel engines can for practical purposes be split up into four categories, and if the adequate countermeasures are considered from the early project stage, the influence of the excitation sources can be minimised or fully compensated.

In general, the marine diesel engine may influence the hull with the following:

- External unbalanced moments
  These can be classified as unbalanced 1st and 2nd order external moments, which need to be considered only for certain cylinder numbers
- Guide force moments
- Axial vibrations in the shaft system
- Torsional vibrations in the shaft system.

The external unbalanced moments and guide force moments are illustrated in Fig. 17.01.01.

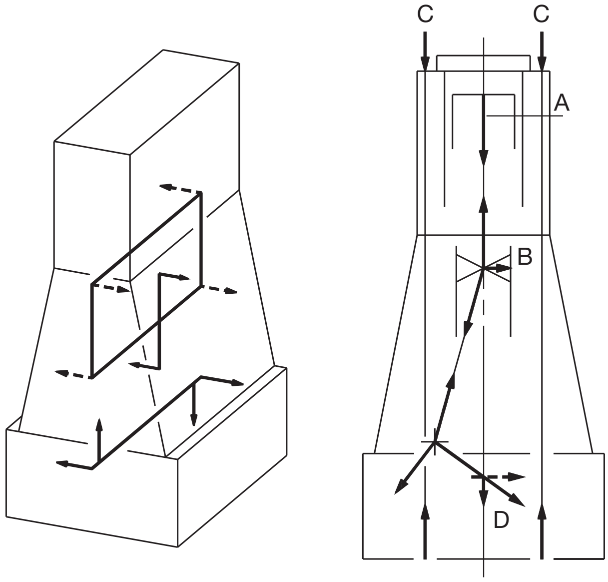
In the following, a brief description is given of their origin and of the proper countermeasures needed to render them harmless.

External unbalanced moments

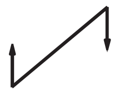
The inertia forces originating from the unbalanced rotating and reciprocating masses of the engine create unbalanced external moments although the external forces are zero.

Of these moments, the 1st order (one cycle per revolution) and the 2nd order (two cycles per revolution) need to be considered for engines with a low number of cylinders. On 7-cylinder engines, also the 4th order external moment may have to be examined. The inertia forces on engines with more than 6 cylinders tend, more or less, to neutralise themselves.

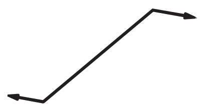
Countermeasures have to be taken if hull resonance occurs in the operating speed range, and if the vibration level leads to higher accelerations and/or velocities than the guidance values given by international standards or recommendations (for instance related to special agreement between shipowner and shipyard). The natural frequency of the hull depends on the hull's rigidity and distribution of masses, whereas the vibration level at resonance depends mainly on the magnitude of the external moment and the engine's position in relation to the vibration nodes of the ship.



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

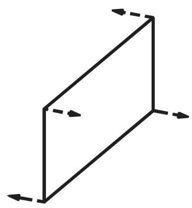


1st order moment vertical 1 cycle/rev.
2nd order moment, vertical 2 cycle/rev.



1st order moment, horizontal
1 cycle/rev.

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



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

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Fig. 17.01.01: External unbalanced moments and guide force moments

2nd Order Moments on 4, 5 and 6-cylinder Engines

The 2nd order moment acts only in the vertical direction. Precautions need only to be considered for 4, 5 and 6-cylinder engines in general.

Resonance with the 2nd order moment may occur in the event of hull vibrations with more than 3 nodes. Contrary to the calculation of natural frequency with 2 and 3 nodes, the calculation of the 4 and 5-node natural frequencies for the hull is a rather comprehensive procedure and often not very accurate, despite advanced calculation methods.

A 2nd order moment compensator comprises two counter-rotating masses running at twice the engine speed.

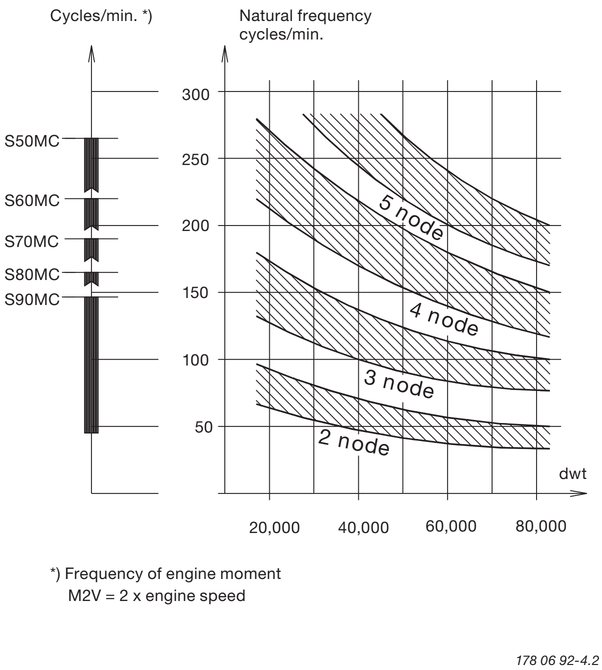


Fig. 17.02.01: Statistics of vertical hull vibrations in tankers and bulk carriers

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 the main chain drive, 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.

4) Compensators on both aft and fore ends, driven from the crankshaft by the main chain drive and a separate chain drive respectively, options: 4 31 203 and 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. Solution 4) should be considered if the engine is positioned over the node.

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.

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.

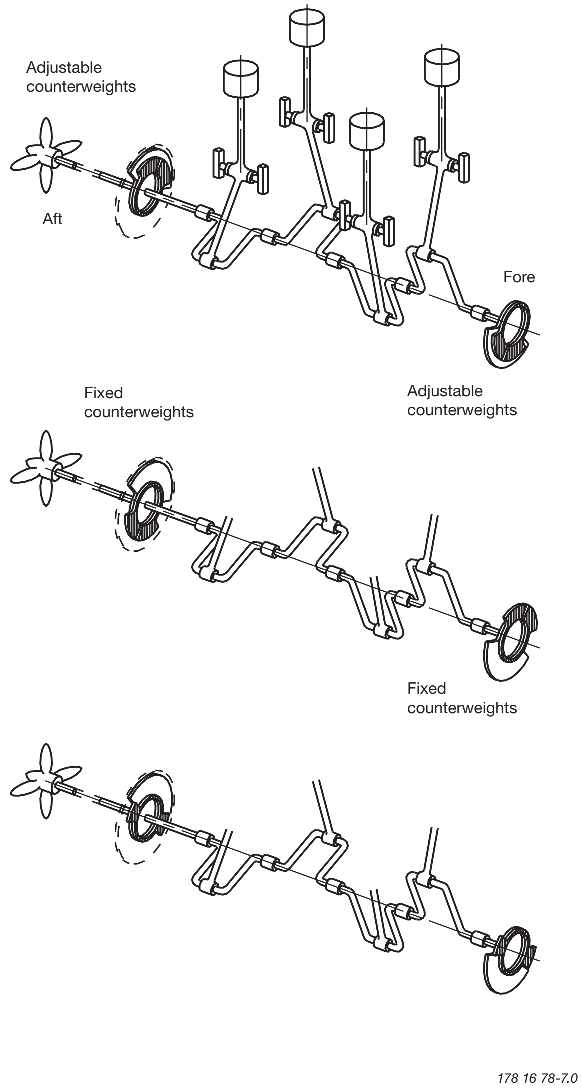


Fig. 17.02.02: Examples of counterweights

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.

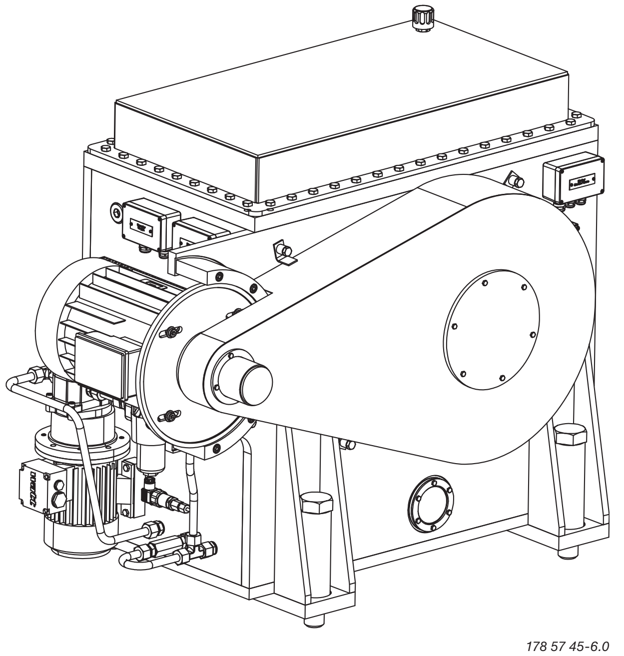


Fig. 17.03.01: MAN B&W external electrically driven moment compensator, RotComp, option: 4 31 255

- 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.

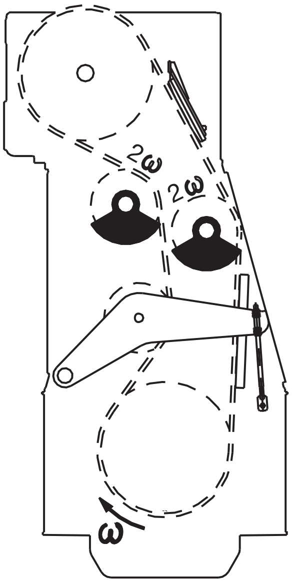
Furthermore, by using the compensator as a vibration exciter a ship's vibration pattern can easily be identified without having the engine running, e.g. on newbuildings at an advanced stage of construction. If it is verified that a ship does not need the compensator, it can be removed and reused on another 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.

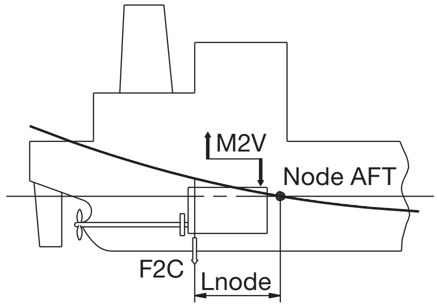
Balancing other forces and moments

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.

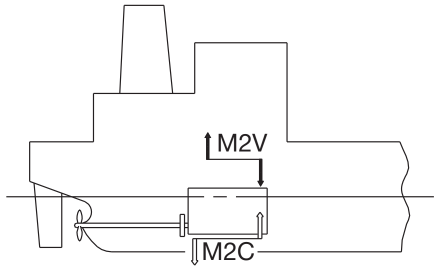
Moment compensator
Aft end, option: 4 31 203



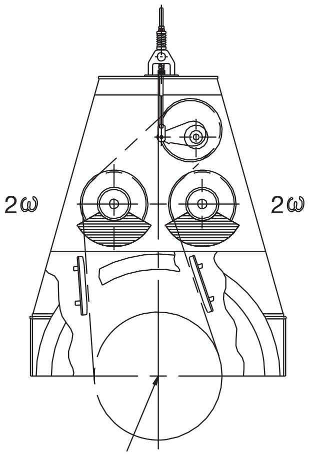
Compensating moment
F2C × Lnode
outbalances M2V



Moment from compensator
M2C reduces M2V

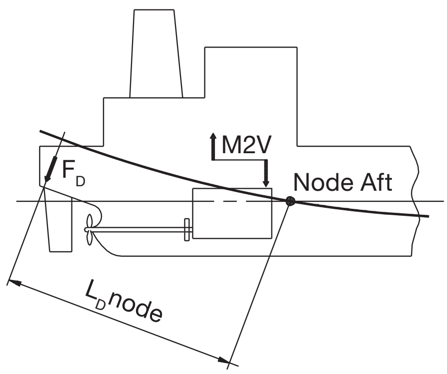


Moment compensator
Fore end, option: 4 31 213



Electrically driven moment compensator

Compensating moment
F_D × Lnode
outbalances M2V



3 and 4-node vertical hull girder mode

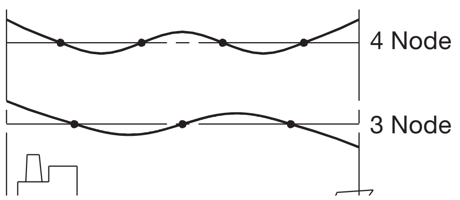


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Fig. 17.03.02: Compensation of 2nd order vertical external moments

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.

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

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

S60MC-C8.2/ME-C8.2/-GI/ME-B8.2 – 2,380 kW/cyl at 105 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	12.7	0.0	5.4	15.8	N.a.	N.a.	N.a.	N.a.	N.a.
PRU acc. to 2nd order, Nm/kW	141.5	82.0	20.4	0.0	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 Diesel & Turbo strongly recommend, as standard, that top bracing is installed between the engine's upper platform brackets and the casing side.

The vibration level on the engine when installed in the vessel must comply with MAN Diesel & Turbo vibration limits as stated in Fig. 17.05.02.

We recommend using the hydraulic top bracing which allow adjustment to the loading conditions of the ship. Mechanical top bracings with stiff connections are available on request.

With both types of top bracing, the above-mentioned natural frequency will increase to a level where resonance will occur above the normal engine speed. Details of the top bracings are shown in Chapter 05.

Definition of Guide Force Moments

Over the years it has been discussed how to define the guide force moments. Especially now that complete FEM-models are made to predict hull/engine interaction, the proper definition of these moments has become increasingly important.

H-type Guide Force Moment (M_H)

Each cylinder unit produces a force couple consisting of:
1. A force at crankshaft level
2. Another force at crosshead guide level. The position of the force changes over one revolution as the guide shoe reciprocates on the guide.

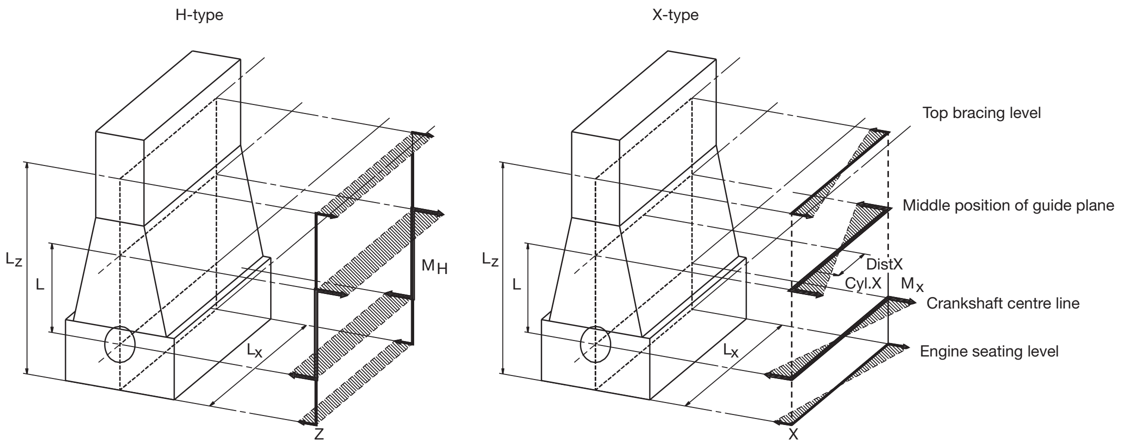

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Fig. 17.05.01: H-type and X-type guide force moments

As the deflection shape for the H-type is equal for each cylinder, the N^{th} order H-type guide force moment for an N-cylinder engine with regular firing order is:

$N \times M_{H(one\ cylinder)}$

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 kNm^2

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

M_X = 'Bi-Moment'/L kNm

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

Force = M_X/L_X [kN]

where:

L_X is the horizontal length between 'force points'.

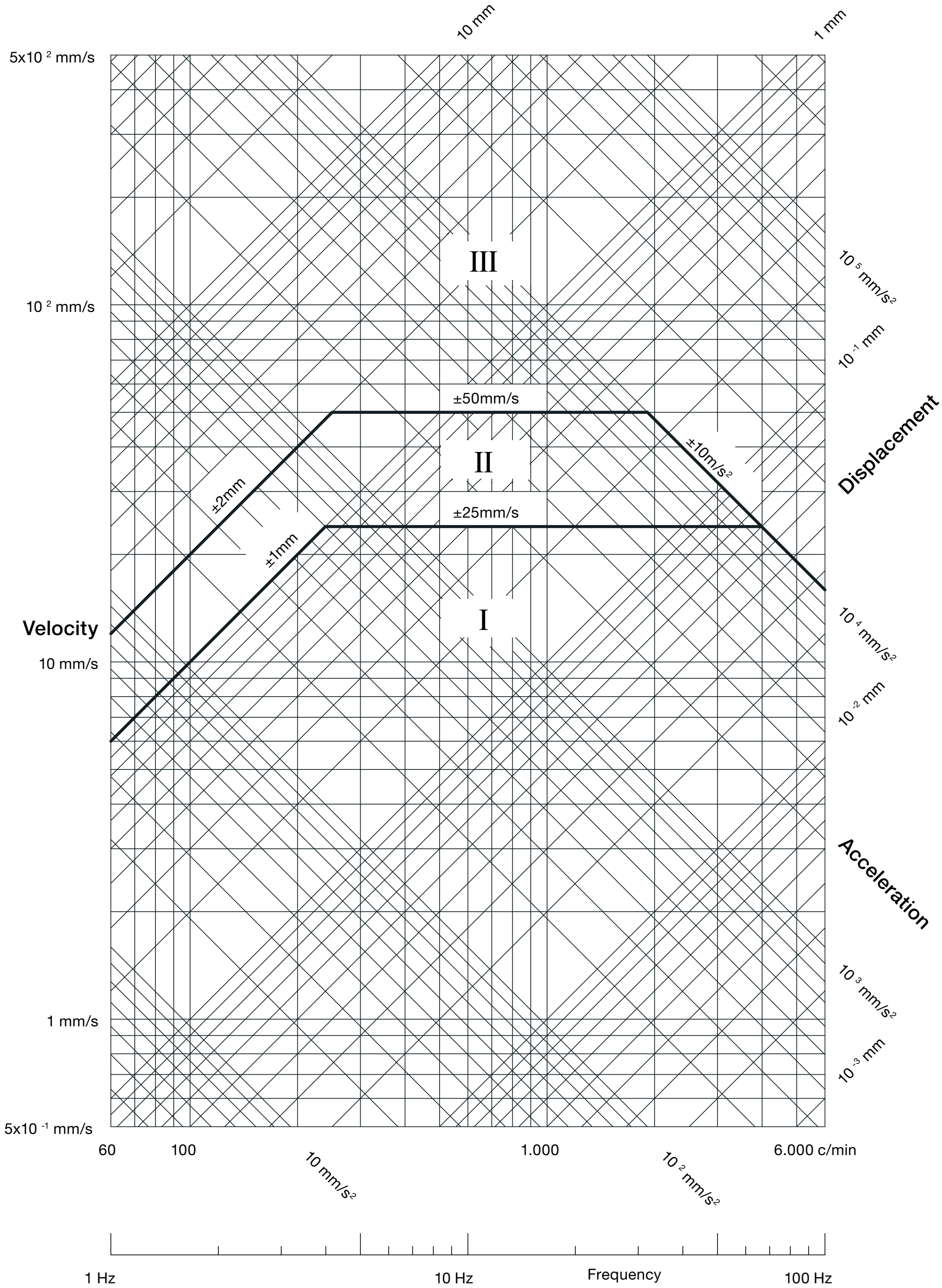
Similar to the situation for the H-type guide force moment, the forces may be applied in positions suitable for the FEM model of the hull. Thus the forces may be referred to another vertical level L_Z above the crankshaft centre line. These forces can be calculated as follows:

$Force_{Z,\ one\ point} = \frac{M_x \times L}{L_x \times L_x}$ [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
K98MC6/7	3,220
K98MC-C6/7	3,090
S90MC-C7/8	3,270
K90MC-C6	3,159
S80MC6	3,504
S80MC-C7/8	3,280
K80MC-C6	2,920
S70MC6	3,066
S70MC-C7/8	2,870
L70MC-C7/8	2,660
S65MC-C8	2,730
S60MC6	2,628
S60MC-C7/8	2,460
L60MC-C7/8	2,280
S50MC6	2,190
S50MC-C7/8	2,050

Vibration Limits Valid for Single Order Harmonics



Zone I: Acceptable

Zone II: Vibration will not damage the main engine, however, under adverse conditions, annoying/harmful vibration responses may appear in the connected structures

Zone III: Not acceptable

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Fig.17.05.02: Vibration limits

Axial Vibrations

When the crank throw is loaded by the gas pressure through the connecting rod mechanism, the arms of the crank throw deflect in the axial direction of the crankshaft, exciting axial vibrations. Through the thrust bearing, the system is connected to the ship's hull.

Generally, only zero-node axial vibrations are of interest. Thus the effect of the additional bending stresses in the crankshaft and possible vibrations of the ship`s structure due to the reaction force in the thrust bearing are to be consideraed.

An axial damper is fitted as standard on all engines, minimising the effects of the axial vibrations, EoD: 4 31 111.

Torsional Vibrations

The reciprocating and rotating masses of the engine including the crankshaft, the thrust shaft, the intermediate shaft(s), the propeller shaft and the propeller are for calculation purposes considered a system of rotating masses (inertias) interconnected by torsional springs. The gas pressure of the engine acts through the connecting rod mechanism with a varying torque on each crank throw, exciting torsional vibration in the system with different frequencies.

In general, only torsional vibrations with one and two nodes need to be considered. The main critical order, causing the largest extra stresses in the shaft line, is normally the vibration with order equal to the number of cylinders, i.e., six cycles per revolution on a six cylinder engine. This resonance is positioned at the engine speed corresponding to the natural torsional frequency divided by the number of cylinders.

The torsional vibration conditions may, for certain installations require a torsional vibration damper, option: 4 31 105.

Plants with 11 or 12-cylinder engines type 98-80 require a torsional vibration damper.

Based on our statistics, this need **may arise** for the following types of installation:

- Plants with controllable pitch propeller
- Plants with unusual shafting layout and for special owner/yard requirements
- Plants with 8-cylinder engines.

The so-called QPT (Quick Passage of a barred speed range Technique), is an alternative to a torsional vibration damper, on a plant equipped with a controllable pitch propeller. The QPT could be implemented in the governor in order to limit the vibratory stresses during the passage of the barred speed range.

The application of the QPT, option: 4 31 108, has to be decided by the engine maker and MAN Diesel & Turbo based on final torsional vibration calculations.

Six-cylinder engines, require special attention. On account of the heavy excitation, the natural frequency of the system with one-node vibration should be situated away from the normal operating speed range, to avoid its effect. This can be achieved by changing the masses and/or the stiffness of the system so as to give a much higher, or much lower, natural frequency, called undercritical or overcritical running, respectively.

Owing to the very large variety of possible shafting arrangements that may be used in combination with a specific engine, only detailed torsional vibration calculations of the specific plant can determine whether or not a torsional vibration damper is necessary.

Undercritical running

The natural frequency of the one-node vibration is so adjusted that resonance with the main critical order occurs about 35-45% above the engine speed at specified MCR.

Such undercritical conditions can be realised by choosing a rigid shaft system, leading to a relatively high natural frequency.

The characteristics of an undercritical system are normally:

- Relatively short shafting system
- Probably no tuning wheel
- Turning wheel with relatively low inertia
- Large diameters of shafting, enabling the use of shafting material with a moderate ultimate tensile strength, but requiring careful shaft alignment, (due to relatively high bending stiffness)
- Without barred speed range.

Critical Running

When running undercritical, significant varying torque at MCR conditions of about 100-150% of the mean torque is to be expected.

This torque (propeller torsional amplitude) induces a significant varying propeller thrust which, under adverse conditions, might excite annoying longitudinal vibrations on engine/double bottom and/or deck house.

The yard should be aware of this and ensure that the complete aft body structure of the ship, including the double bottom in the engine room, is designed to be able to cope with the described phenomena.

Overcritical running

The natural frequency of the one-node vibration is so adjusted that resonance with the main critical order occurs about 30-70% below the engine speed at specified MCR. Such overcritical conditions can be realised by choosing an elastic shaft system, leading to a relatively low natural frequency.

The characteristics of overcritical conditions are:

- Tuning wheel may be necessary on crankshaft fore end
- Turning wheel with relatively high inertia
- Shafts with relatively small diameters, requiring shafting material with a relatively high ultimate tensile strength
- With barred speed range, EoD: 4 07 015, of about ±10% with respect to the critical engine speed.

Torsional vibrations in overcritical conditions may, in special cases, have to be eliminated by the use of a torsional vibration damper.

Overcritical layout is normally applied for engines with more than four cylinders.

Please note:
We do not include any tuning wheel or torsional vibration damper in the standard scope of supply, as the proper countermeasure has to be found after torsional vibration calculations for the specific plant, and after the decision has been taken if and where a barred speed range might be acceptable.

For further information about vibration aspects, please refer to our publications:

An Introduction to Vibration Aspects

Vibration Characteristics of Two-stroke Engines

The publications are available at www.marine.man.eu → 'Two-Stroke' → 'Technical Papers'.

External Forces and Moments, S60MC-C8.2 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	9	0	0
External moments [kNm] :				
1. Order : Horizontal a)	151	0	90	301
1. Order : Vertical a)	151	0	90	301
2. Order : Vertical	1,680 c)	1,169 c)	339	0
4. Order : Vertical	10	74	209	85
6. Order : Vertical	1	0	0	0
Guide force H-moments in [kNm] :				
1 x No. of cyl.	1,366	1,051	811	582
2 x No. of cyl.	126	43	53	55
3 x No. of cyl.	-	-	-	-
Guide force X-moments in [kNm] :				
1. Order :	131	0	78	261
2. Order :	462	322	93	0
3. Order :	388	701	767	983
4. Order :	58	444	1,263	513
5. Order :	0	0	110	1,384
6. Order :	32	0	19	0
7. Order :	232	0	0	42
8. Order :	145	101	8	0
9. Order :	8	150	17	15
10. Order :	0	35	100	0
11. Order :	2	0	54	69
12. Order :	14	0	3	12
13. Order :	13	0	1	33
14. Order :	1	10	0	0
15. Order :	0	26	1	3
16. Order :	1	10	3	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

Engine monitoring and instrumentation can be enhanced by MAN Diesel & Turbo's PMI system for measuring cylinder pressure and by the CoCoS-EDS (Computer Controlled Surveillance – Engine Diagnostics System) for engine performance evaluation.

The monitoring system measures the main parameters of the engine and makes an evaluation of the general engine condition, indicating the measures to be taken. This ensures that the engine performance is kept within the prescribed limits throughout the engines lifetime.

In its basic design the MC engine instrumentation consists of:

- Engine Control System
- Shut-down sensors, option: 4 75 124
- Sensors for alarm, slow down and remote indication according to the classification society's and MAN Diesel & Turbo's requirements for UMS, EoD: 4 75 127, see Section 18.04.

The optional extras are:

- CoCoS-EDS Full version (AMS interface), option: 4 09 660
- PMI Off-line system, option: 4 75 208
- PMI Auto-tuning system, option: 4 75 216.

Sensors for CoCoS can be ordered, if required, as option: 4 75 129. They are listed in Section 18.03.

All instruments are identified by a combination of symbols and a position number as shown in Section 18.07.

PMI System

As an option on the MC engines, the mechanical indicator system can be supported by a pressure analyser system for measurement of the cylinder combustion pressure.

Monitoring of cylinder pressures allows for:

- optimising the engine performance
- optimising the fuel economy
- minimising engine load
- minimising operating cost through condition based maintenance
- complying with emission requirements

Measurements

The cylinder pressure is measured by a high performance piezo-electric pressure transducer, mounted on the indicator valve.

The engine speed signal is obtained from an angle encoder mounted on the crankshaft fore end. Alternatively the signal could be obtained from a trigger arrangement on the aft end of the engine.

The PMI system compensates automatically for the twisting experienced by each section of the crankshaft due to the torque generated at different loads.

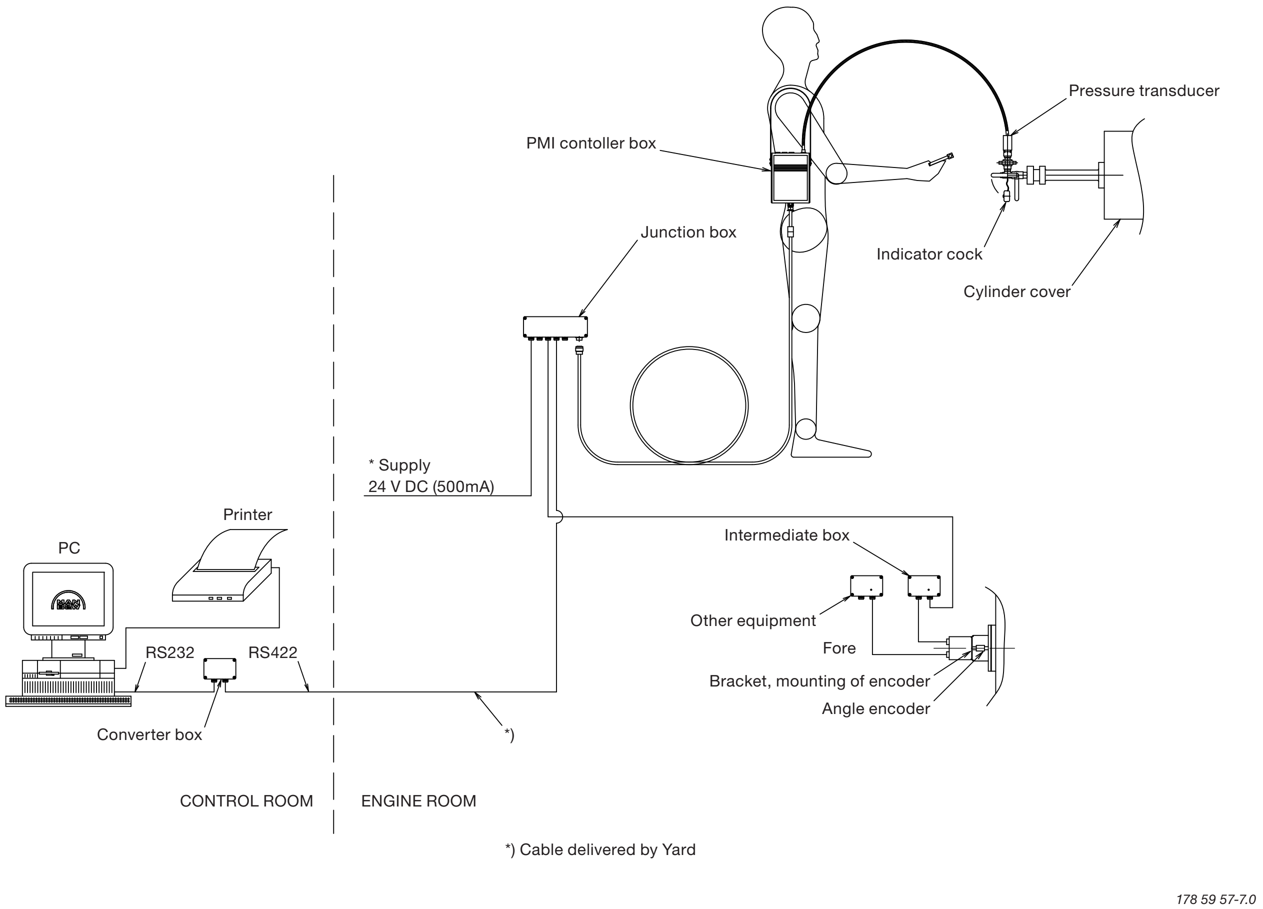


Fig. 18.02.01: PMI type PT/S off-line, option: 4 75 208

PMI System, Off-line and On-line Versions

The PMI system is available in two versions, PT/S off-line and on-line, see Fig. 18.02.01 and 02.

The basic functions of the two different versions are:

- PT/S Off-line version, option 4 75 208:
  The manually operated single transducer is moved from one cylinder to another in order to complete measurements on all cylinders.
- On-line version, option 4 75 215:
  Fixed mounted pressure transducing sensor on each cylinder for continuous measurements, analysis and adjustments.

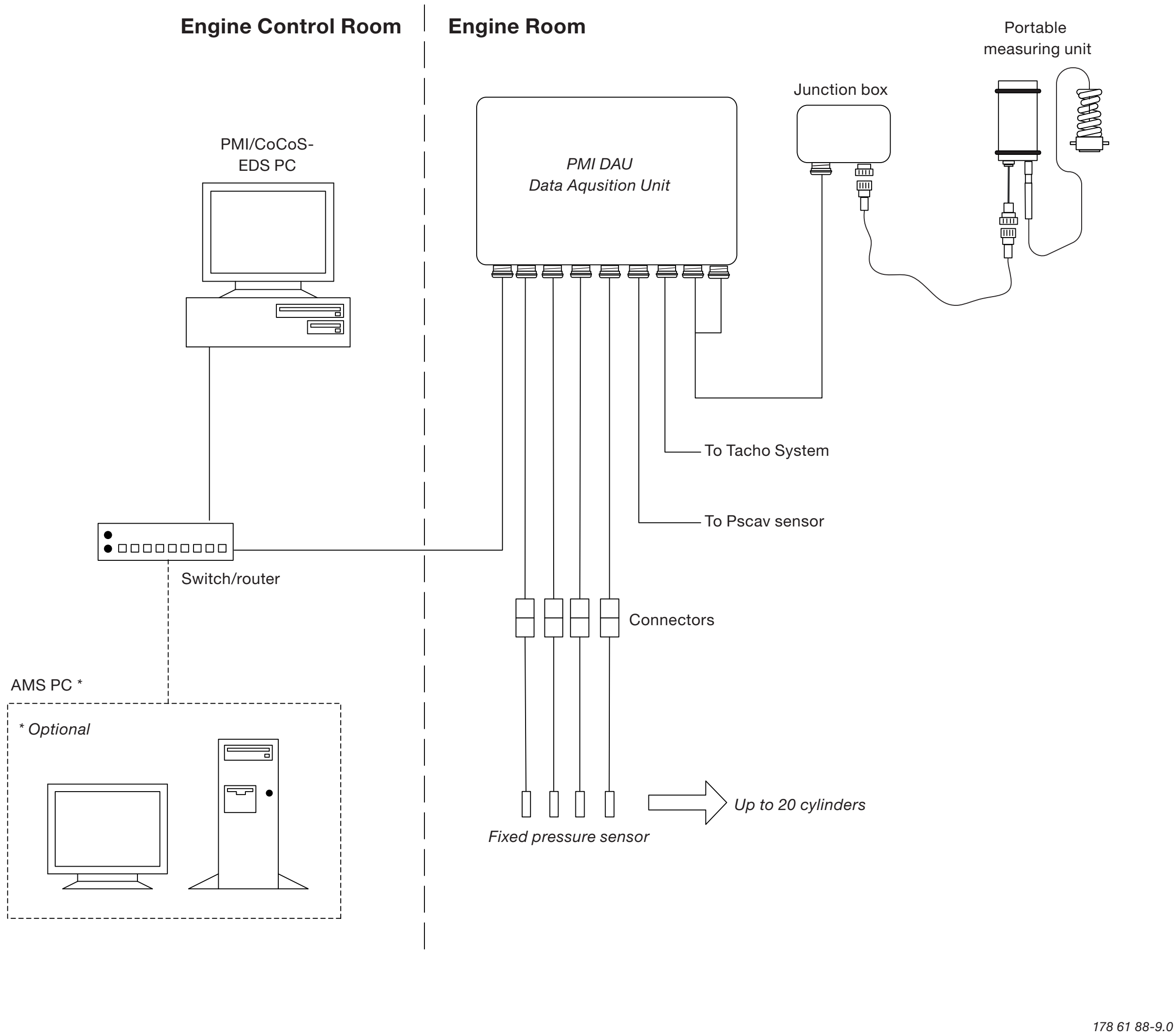


Fig. 18.02.02: PMI type on-line, option: 4 75 215

CoCoS-EDS

The **C**omputer **C**ontrolled **S**urveillance system is the family name of the software application products from the MAN Diesel group.

In order to obtain an easier, more versatile and continuous diagnostics system, the Engine Control System and the PMI System is recommended extended by the CoCoS-EDS products.

CoCoS-EDS features

The CoCoS-EDS, option: 4 09 660, allows for engine condition monitoring through surveillance of operating states and behaviour of diesel engines.

Primary features are:

- Data and trend logging
- Engine performance monitoring, analysis and reporting
- Troubleshooting and diagnostics.

The CoCoS-EDS assists the operator effectively in maintaining the main as well as the auxiliary engines in optimal operating condition.

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 allow for easier troubleshooting in case of unusual engine behaviour.

Connectivity

In order to obtain an easier, more versatile and continuous diagnostics system, the CoCoS-EDS is recommended extended by interfaces to the PMI system and the plant's alarm and monitoring system.

Table 18.03.01 lists the sensors required to enable online diagnostics for CoCoS-EDS, option: 4 75 129.

CoCoS-EDS Sensor List

Sensors required for the CoCoS-EDS online engine performance analysis, option: 4 75 129, see Table 18.03.01. All pressure gauges are measuring relative pressure, except for ‘PT 8802 Ambient pressure’.

Sensor	Parameter name	No. sensors	Recommended range	Resolution 3)	Remark
	Fuel oil system data				
PT 8001	Inlet pressure	1	0 - 10 bar	0.1 bar	
TE 8005	Inlet temperature	1	0 - 200 °C	0.1 °C	
	Cooling water system				
PT 8421	Pressure air cooler inlet	A/C	0 - 4 bar	0.1 bar	
TE 8422	Temperature air cooler inlet	1	0 - 100 °C	0.1 °C	
TE 8423	Temperature air cooler outlet	A/C	0 - 100 °C	0.1 °C	
PDT 8424	dP cooling water across air cooler	A/C	0 - 800 mbar	0.1 mbar	
	Scavenging air system				
PT 8601	Scavenge air receiver pressure	Rec.	0 - 4 bar	1 mbar	1)
TE 8605	Scavenge air cooler air inlet temperature	A/C	0 - 200 °C	0.1 °C	
PDT 8606	dP air across scavenge air cooler	A/C	0 - 100 mbar	0.1 mbar	
TE 8608	Scavenge air cooler air outlet temperature	A/C	0 - 100 °C	0.1 °C	Optional if one T/C
TE 8609	Scavenge air receiver temperature	Rec.	0 - 100 °C	0.1 °C	
TE 8612	T/C air intake temperature	T/C	0 - 100 °C	0.1 °C	
	Exhaust gas system				
TC 8701	Exhaust gas temperature at turbine inlet	T/C	0 - 600 °C	0.1 °C	
TC 8702	Exhaust gas temperature after exhaust valve	Cyl.	0 - 600 °C	0.1 °C	
PT 8706	Exhaust gas receiver pressure	Rec.	0 - 4 bar	0.01 bar	
TC 8707	Exhaust gas temperature at turbine outlet	T/C	0 - 600 °C	0.1 °C	
PT 8708	Turbine back presssure	T/C	0 - 100 mbar	0.1 mbar	
	General data				
ZT 8801	Turbocharger speed	T/C	rpm	1 rpm	
PT 8802	Ambient pressure	1	900 - 1,100 mbar	1 mbar	Absolute!
ZT 4020	Engine speed	1	rpm	0.1 rpm	1)
XC 3003	Governor index (absolute)	1	mm	0.1 mm	
–	Power take off/in from main engine shaft (PTO/PTI)	1	kW	1 kW	With option installed
	Pressure measurement				
XC1401	Mean Indicated Pressure, MIP	Cyl.	bar	0.01 bar	2)
XC1402	Maximum Pressure, Pmax	Cyl.	bar	0.1 bar	2)
XC1403	Compression Pressure, Pcomp	Cyl.	bar	0.1 bar	2)
–	PMI online engine speed	Cyl.	rpm	0.1 rpm	2)

1) Signal acquired from the Alarm Monitoring System
2) In case of MAN Diesel PMI system: signal from PMI system. Other MIP systems: signal from manual input
3) Resolution of signals transferred to CoCoS-EDS (from the Alarm Monitoring System).

Table 18.03.01: List of sensors for CoCoS-EDS

Alarm – Slow Down and Shut Down System

The shut down system must be electrically separated from other systems by using independent sensors, or sensors common to the alarm system and the monitoring system but with galvanically separated electrical circuits, i.e. one sensor with two sets of electrically independent terminals. The list of sensors are shown in Table 18.04.04.

Basic safety system design and supply

The basic safety sensors for a MAN B&W engine are designed for Unattended Machinery Space (UMS) and comprises:

- the temperature sensors and pressure sensors that are specified in the 'MAN Diesel' column for shut down in Table 18.04.04.

These sensors are included in the basic Extent of Delivery, EoD: 4 75 124.

Alarm and slow down system design and supply

The basic alarm and slow down sensors for a MAN B&W engine are designed for Unattended Machinery Space (UMS) and comprises:

- the sensors for alarm and slow down.

These sensors are included in the basic Extent of Delivery, EoD: 4 75 127.

The shut down and slow down panels can be ordered as options: 4 75 630, 4 75 614 or 4 75 615 whereas the alarm panel is yard's supply, as it normally includes several other alarms than those for the main engine.

For practical reasons, the sensors for the engine itself are normally delivered from the engine supplier, so they can be wired to terminal boxes on the engine.

The number and position of the terminal boxes depends on the degree of dismantling specified in the Dispatch Pattern for the transportation of the engine based on the lifting capacities available at the engine maker and at the yard.

Alarm, slow down and remote indication sensors

The International Association of Classification Societies (IACS) indicates that a common sensor can be used for alarm, slow down and remote indication.

A general view of the alarm, slow down and shut down systems is shown in Fig. 18.04.01.

Tables 18.04.02 and 18.04.03 show the requirements by MAN Diesel & Turbo for alarm and slow down and for UMS by the classification societies (Class), as well as IACS' recommendations.

The number of sensors to be applied to a specific plant is the sum of requirements of the classification society, the Buyer and MAN Diesel & Turbo.

If further analogue sensors are required, they can be ordered as option: 4 75 128.

Slow down functions

The slow down functions are designed to safeguard the engine components against overloading during normal service conditions and to keep the ship manoeuvrable if fault conditions occur.

The slow down sequence must be adapted to the actual plant parameters, such as for FPP or CPP, engine with or without shaft generator, and to the required operating mode.

Electrical System, General Outline

The figure shows the concept approved by all classification societies.

The shut down panel and slow down panel can be combined for some makers.

The classification societies permit having common sensors for slow down, alarm and remote indication.

One common power supply might be used, instead of the three indicated, provided that the systems are equipped with separate fuses.

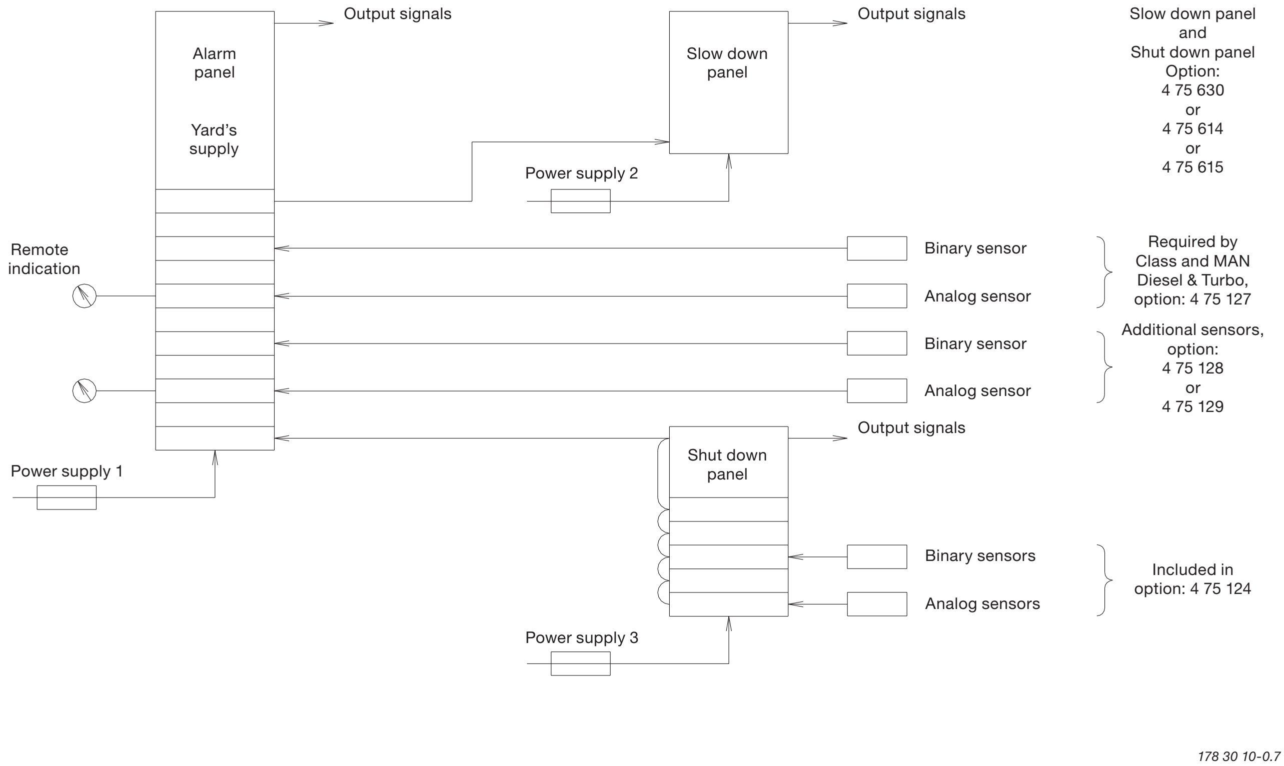


Fig. 18.04.01: Panels and sensors for alarm and safety systems

Alarms for UMS – Class and MAN Diesel & Turbo requirements

ABS	BV	CCS	DNV	GL	KR	LR	NK	RINA	RS	IACS	MAN Diesel	Sensor and function	Point of location
													Fuel oil
1	1	1	1	1	1	1	1	1	1	1	1	PT 8001 AL	Fuel oil, inlet engine
1	1	1	1	1	1	1	1	1	1	1	1	LS 8006 AH	Leakage from high pressure pipes
													Lubricating oil
1	1	1	1	1	1	1	1	1	1	1	1	TE 8106 AH	Thrust bearing segment
1	1	1	1	1	1	1	1	1	1	1	1	PT 8108 AL	Lubricating oil inlet to main engine
1	1	1	1	1	1	1	1	1	1	1	1	TE 8112 AH	Lubricating oil inlet to main engine
1	1	1	1	1	1		1	1	1	1	1	TE 8113 AH	Piston cooling oil outlet/cylinder
1	1	1	1	1	1		1	1	1	1	1	FS 8114 AL	Piston cooling oil outlet/cylinder
1	1	1		1	1	1		1	1	1	1	TE 8117 AH	Turbocharger lubricating oil outlet from turbocharger/turbocharger
											1	TE 8123 AH	Main bearing oil outlet temperature/main bearing (Only MC types 42-26)
											1	XC 8126 AH	Bearing wear (K98MC6/7 and all MC-C types); sensor common to XC 8126/27
											1	XS 8127 A	Bearing wear detector failure (K98MC6/7 and types 98-60MC-C)
											1	XS 8150 AH	Water in lubricating oil (All MC/MC-C types except S80-50MC6); sensor common to XS 8150/51/52
											1	XS 8151 AH	Water in lubricating oil – too high (All MC/MC-C types except S80-50MC6)
											1	XS 8152 A	Water in lubricating oil sensor not ready (All MC/MC-C types except S80-50MC6)

1 Indicates that the sensor is required.
The sensors in the MAN Diesel and relevant Class columns are included in the basic Extent of Delivery, EoD: 4 75 127.
The sensor identification codes and functions are listed in Table 18.07.01.
The tables are liable to change without notice, and are subject to latest Class requirements.

Table 18.04.02a: Alarm functions for UMS

Alarms for UMS – Class and MAN Diesel & Turbo requirements

ABS	BV	CCS	DNV	GL	KR	LR	NK	RINA	RS	IACS	MAN Diesel	Sensor and function	Point of location
													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
				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	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
	1	1		1			1÷				1	TE 8609 AH	Scavenge air receiver
1	1	1	1	1	1	1	1	1	1	1	1	TE 8610 AH	Scavenge air box – fire alarm, cylinder/cylinder
1	1	1		1	1	1	1	1	1	1	1	LS 8611 AH	Water mist catcher – water level

1 Indicates that the sensor is required.
The sensors in the MAN Diesel and relevant Class columns are included in the basic Extent of Delivery, EoD: 4 75 127.
The sensor identification codes and functions are listed in Table 18.07.01.
The tables are liable to change without notice, and are subject to latest Class requirements.

Select one of the alternatives
+ Alarm for high pressure, too
÷ Alarm for low pressure, too

Table 18.04.02b: Alarm functions for UMS

Alarms for UMS – Class and MAN Diesel & Turbo requirements

ABS	BV	CCS	DNV	GL	KR	LR	NK	RINA	RS	IACS	MAN Diesel	Sensor and function	Point of location
													Exhaust gas
1	1	1	1	1	1	(1)	1	1	1	1	1	TC 8701 AH	Exhaust gas before turbocharger/turbocharger
1	1		1		1	1	1	1	1	1	1	TC 8702 AH	Exhaust gas after exhaust valve, cylinder/cylinder
1	1	1	1	1	1	1	1	1	1	1		TC 8707 AH	Exhaust gas outlet turbocharger/turbocharger (Yard's supply)
													Miscellaneous
			1									ZT 8801 AH	Turbocharger overspeed
											1	WT 8812 AH	Axial vibration monitor 2)
1	1	▢	1	1	1	1	1	1	1	1	1	XS 8813 AH	Oil mist in crankcase/cylinder; sensor common to XS 8813/14
	1										1	XS 8814 AL	Oil mist detector failure
											1	XC 8816 I	Shaftline earthing device
											1	TE 8820 AH	Cylinder liner monitoring/cylinder 3)

1 Indicates that the sensor is required.
The sensors in the MAN Diesel and relevant Class columns are included in the basic Extent of Delivery, EoD: 4 75 127.
The sensor identification codes and functions are listed in Table 18.07.01.
The tables are liable to change without notice, and are subject to latest Class requirements.

(1) May be combined with TC 8702 AH where turbocharger is mounted directly on the exhaust manifold.

2) Required for: K-MC-C6/7 and K98MC6/7 engines with 11 and 14 cylinders.
S-MC-C7/8 and L-MC-C7/8 engines with 5 and 6 cylinders.
(For 9-12 cylinder S42MC7, L35MC6, and S26MC6 data is available on request).

3) Required for: K98MC/MC-C6/7, S90MC-C7/8 and K90MC-C6 engines

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

Table 18.04.02c: Alarm functions for UMS

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

ABS	BV	CCS	DNV	GL	KR	LR	NK	RINA	RS	IACS	MAN Diesel	Sensor and function	Point of location
1	1	1	1	1	1	1	1	1	1	1	1	TE 8106 YH	Thrust bearing segment
1	1	1	1*	1	1	1	1	1	1	1	1	PT 8108 YL	Lubricating oil inlet to main engine
				1		1						TE 8112 YH	Lubricating oil inlet to main engine
1	1	1	1	1	1		1	1	1	1	1	TE 8113 YH	Piston cooling oil outlet/cylinder
1	1	1	1	1	1		1	1	1	1	1	FS 8114 YL	Piston cooling oil outlet/cylinder
											1	TE 8123 YH	Main bearing oil outlet temperature/main bearing (Only MC types 42-26)
											1	XC 8126 YH	Bearing wear (K98MC6/7 and all MC-C types)
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
1	1	1	1	1	1	1	1	1	1	1	1	TE 8408 YH	Jacket cooling water outlet, cylinder/cylinder
	1	1					1					TE 8609 YH	Scavenge air receiver
1	1	1	1	1	1	1	1	1	1	1	1	TE 8610 YH	Scavenge air box fire-alarm, cylinder/cylinder
		1	1						1			TC 8701 YH	Exhaust gas before turbocharger/turbocharger
1	1		1	1	1	1	1	1	1	1	1	TC 8702 YH	Exhaust gas after exhaust valve, cylinder/cylinder
			1	1								TC 8702 YH	Exhaust gas after exhaust valve, cylinder/cylinder, deviation from average
											1	WT 8812 YH	Axial vibration monitor 2)
1	1		1*		1	1	1	1	1	1	1	XS 8813 YH	Oil mist in crankcase/cylinder
											1	XS/XT 8817 Y	Turbocharger overspeed (Only in case of VT TC, Waste Heat Recovery, Exhaust Gas Bypass, TC Cut-out)

1 Indicates that the sensor is required.
The sensors in the MAN Diesel and relevant Class columns are included in the basic Extent of Delivery, EoD: 4 75 127.
The sensor identification codes and functions are listed in Table 18.07.01.
The tables are liable to change without notice, and are subject to latest Class requirements.

2) Required for: K-MC-C6/7 and K98MC6/7 engines with 11 and 14 cylinders.
S-MC-C7/8 and L-MC-C7/8 engines with 5 and 6 cylinders.
(For 9-12 cylinder S42MC7, L35MC6, and S26MC6 data is available on request).

Select one of the alternatives

* Or shut down

△ Or alarm for low flow

(*) Or shut down

Or alarm for overheating of main, crank and crosshead bearings, option: 4 75 134.
See also Table 18.04.04: Shut down functions for AMS and UMS

Table 18.04.03: Slow down functions for UMS

Shut down for AMS and UMS – Class and MAN Diesel & Turbo requirements

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

1 Indicates that the sensor is required.
The sensors in the MAN Diesel and relevant Class columns are included in the basic Extent of Delivery, EoD: 4 75 124.
The sensor identification codes and functions are listed in Table 18.07.01.
The tables are liable to change without notice, and are subject to latest Class requirements.

☐ Or alarm for overheating of main, crank and crosshead bearings, option: 4 75 134.
See also Table 18.04.03: Slow down functions for UMS

* Or slow down

International Association of Classification Societies

The members of the International Association of Classification Societies, IACS, have agreed that the stated sensors are their common recommendation, apart from each Class' requirements.

The members of IACS are:
ABS American Bureau of Shipping
BV Bureau Veritas
CCS China Classification Society
CRS Croatian Register of Shipping
DNV Det Norske Veritas
GL Germanischer Lloyd
IRS Indian Register of Shipping
KR Korean Register
LR Lloyd's Register
NK Nippon Kaiji Kyokai
PRS Croatian Register of Shipping
RINA Registro Italiano Navale
RS Russian Maritime Register of Shipping

Table 18.04.04: Shut down functions for AMS and UMS, option: 4 75 124

Local Instruments

The basic local instrumentation on the engine, options: 4 70 120 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**	
		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 (Only engine types 42-26)
		Cylinder lubricating oil
	TE 8202	Cylinder lubricating oil inlet (Alpha cylinder lubricator)
		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
		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 8702	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, option 4 70 120, 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
	PT 8007	Fuel pump roller guide gear activated (Only engine types 98-80)
		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
		Cylinder lubrication
	PT 8201	Cylinder lubrication oil inlet pressure (Alpha lubricator)
	PDI 8206	Pressure drop across 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
	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
PI 8504	PT 8504	Safety air inlet
	PT 8505	Air inlet to air cylinder for exhaust valve
		Scavenge air
PI 8601	PT 8601	Scavenge air receiver (PI 8601 instrument same as PI 8706)
	PS 8604	Scavenge air receiver, auxiliary blower failure
PDI 8606		Pressure drop of air across cooler/air cooler
PI 8613	PT 8613	Pressure compressor scroll housing/turbocharger (NA type)
PDI 8614	PDT 8614	Pressure drop across compressor scroll housing/turbocharger (NA type)
		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

Table 18.05.01b: Local pressure gauges on engine, option: 4 70 120, and remote indication sensors, option: 4 75 127

Local instruments	Remote sensors	Point of location
Other indicators	**Other transmitters/ switches**	
		Fuel oil
	LS 8006	Leakage from high pressure pipes
		Lubricating oil
	FS 8114	Piston cooling oil outlet/cylinder
	XC 8126	Bearing wear (K98MC6/7 and all types 98-46MC-C)
	XS 8127	Bearing wear detector failure (K98MC6/7 and types 98-46MC-C)
	XS 8150	Water in lubricating oil (All MC/MC-C types except S80-50MC6)
	XS 8151	Water in lubricating oil – too high (All MC/MC-C types except S80-50MC6)
	XS 8152	Water in lubricating oil sensor not ready (All MC/MC-C types except S80-50MC6)
		Cylinder lube oil
	LS 8208	Level switch
	LS 8212	Small box for heating element, low level
	LS 8250	Cylinder lubricators (built-in switches)/lubricator (Mechanical lubricator)
	XC 8220	MCU common alarm (Alpha cylinder lubrication system)
	XC 8221	BCU in control (Alpha cylinder lubrication system)
	XC 8222	MCU failure (Alpha cylinder lubrication system)
	XC 8223	BCU failure (Alpha cylinder lubrication system)
	XC 8224	MCU power fail (Alpha cylinder lubrication system)
	XC 8226	BCU power fail (Alpha cylinder lubrication system)
	FS 8251	Cylinder lubricators (built-in switches)/lubricator (Mechanical lubricator)
		Scavenge air
	LS 8611	Water mist catcher – water level
		Miscellaneous functions
	ZT 8801 I	Turbocharger speed/turbocharger
WI 8812	WT 8812	Axial vibration monitor (For certain engines only, see note in Table 18.04.04)
		(WI 8812 instrument is part of the transmitter WT 8812)
	XS 8813	Oil mist in crankcase/cylinder
	XS 8814	Oil mist detector failure
	XC 8816	Shaftline earthing device
	XS/XT 8817	Turbocharger overspeed (Only in case of VT TC, Waste Heat Recovery, Exhaust Gas Bypass, TC Cut-out)

Table 18.05.01c: Other indicators on engine, option: 4 70 120, and remote indication sensors, option: 4 75 127

Other Alarm Functions

Drain Box for Fuel Oil Leakage Alarm

Any leakage from the fuel oil high pressure pipes of any cylinder is drained to a common drain box fitted with a level alarm. This is included in the basic design of MAN B&W engines.

Bearing Condition Monitoring

Based on our experience, we decided in 1990 that all plants must include an oil mist detector specified by MAN Diesel & Turbo. Since then an Oil Mist Detector (OMD) and optionally some extent of Bearing Temperature Monitoring (BTM) equipment have made up the warning arrangements for prevention of crankcase explosions on two-stroke engines. Both warning systems are approved by the classification societies.

In order to achieve a response to damage faster than possible with Oil Mist Detection and Bearing Temperature Monitoring alone we introduce Bearing Wear Monitoring (BWM) systems. By monitoring the actual bearing wear continuously, mechanical damage to the crank-train bearings (main-, crank- and crosshead bearings) can be predicted in time to react and avoid damaging the journal and bearing housing.

If the oil supply to a main bearing fails, the bearing temperature will rise and in such a case a Bearing Temperature Monitoring system will trigger an alarm before wear actually takes place. For that reason the ultimate protection against severe bearing damage and the optimum way of providing early warning, is a combined bearing wear and temperature monitoring system.

For all types of error situations detected by the different bearing condition monitoring systems applies that in addition to damaging the components, in extreme cases, a risk of a crankcase explosion exists.

Oil Mist Detector

The oil mist detector system constantly measures samples of the atmosphere in the crankcase compartments and registers the results on an optical measuring track, where the opacity (degree of haziness) is compared with the opacity of the atmospheric air. If an increased difference is recorded, a slow down is activated (a shut down in case of Germanischer Lloyd).

Furthermore, for shop trials only MAN Diesel & Turbo requires that the oil mist detector is connected to the shut down system.

For personnel safety, the oil mist detectors and related equipment are located on the manoeuvring side of the engine.

The following oil mist detectors are available:

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

Examples of piping diagrams (for make Schaller Automation only) and wiring diagrams (for all other makes) are shown for reference in Figs. 18.06.01a and 18.06.01b.

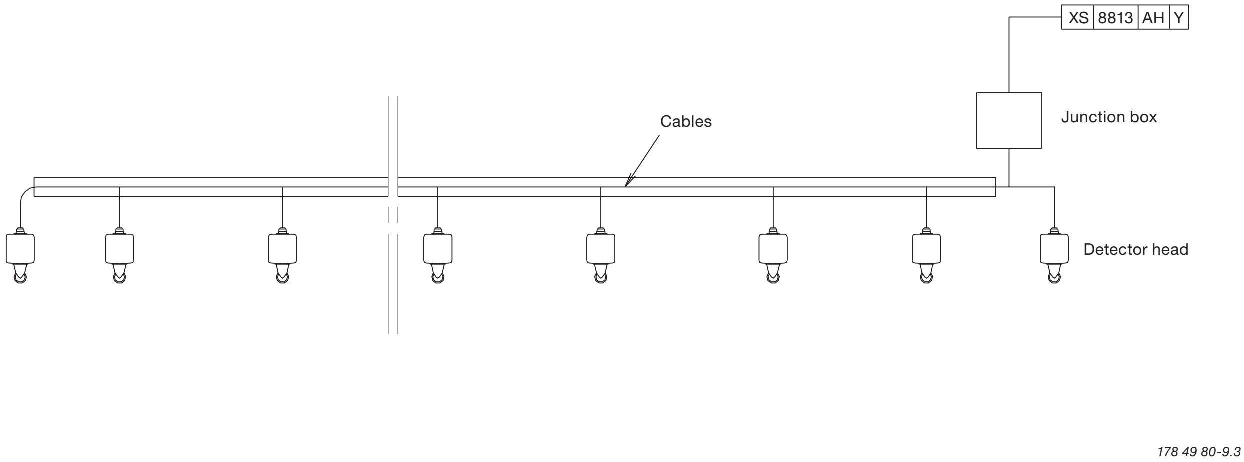


Fig. 18.06.01a: Oil mist detector wiring on engine, example based on type Graviner MK6 from Kidde Fire Protection, option: 4 75 161

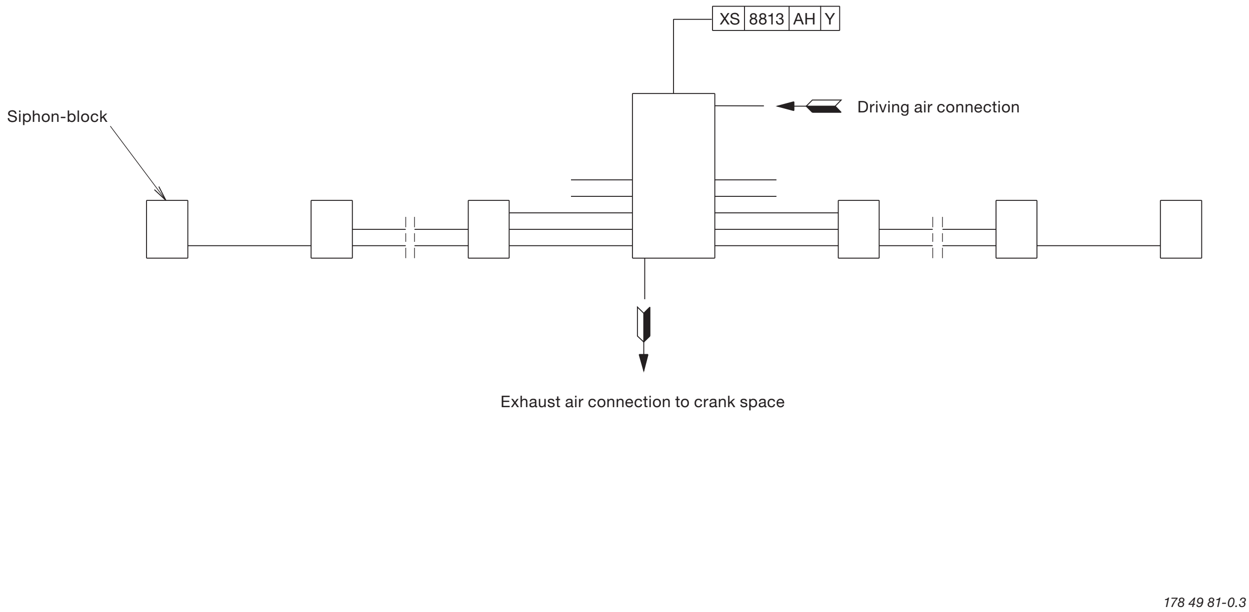


Fig. 18.06.01b: Oil mist detector pipes on engine, type Visatron VN215/93 from Schaller Automation, option: 4 75 163

Bearing Wear Monitoring System

The Bearing Wear Monitoring (BWM) system monitors all three principal crank-train bearings using two proximity sensors forward/aft per cylinder unit and placed inside the frame box.

Targeting the guide shoe bottom ends continuously, the sensors measure the distance to the crosshead in Bottom Dead Center (BDC). Signals are computed and digitally presented to computer hardware, from which a useable and easily interpretable interface is presented to the user.

The measuring precision is more than adequate to obtain an alarm well before steel-to-steel contact in the bearings occur. Also the long-term stability of the measurements has shown to be excellent.

In fact, BWM is expected to provide long-term wear data at better precision and reliability than the manual vertical clearance measurements normally performed by the crew during regular service checks.

For the above reasons, we consider unscheduled open-up inspections of the crank-train bearings to be superfluous, given BWM has been installed.

Two BWM ‘high wear’ alarm levels including deviation alarm apply. The first level of the high wear / deviation alarm is indicated in the alarm panel only while the second level also activates a slow down.

The Extent of Delivery lists four Bearing Wear Monitoring options of which the two systems from Dr. E. Horn and Kongsberg Maritime could also include Bearing Temperature Monitoring:

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

All types MC-C engines and K98MC are as standard specified with Bearing Wear Monitoring for which any of the 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

S40MC-C9, S35MC-C9 as well as S42MC7, S35MC7, L35MC6 and S26MC6 engines are as standard specified with option 4 75 133.

Water In Oil Monitoring System

All MAN B&W types MC-C engines as well as K98MC6/7, S42MC7, L35MC6 and S26MC6 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 MC-C and MC engines are as standard specified with Liner Wall Monitoring system. For all other engines, the LWM system is available as an option: 4 75 136.

LDCL Cooling Water Monitoring System

This section is not applicable

Control Devices

The control devices mainly include a position switch (ZS) or a position transmitter (ZT) and solenoid valves (ZV) which are listed in Table 18.06.02 below. The sensor identification codes are listed in Table 18.07.01.

Sensor	Point of location
	Manoeuvring system
ZV 1103 C	Solenoid valve for engine emergency stop
XS/PS 1106 C	Reset shut down at emergency
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
PS 1118 C	Manoeuvring system in Emergency Control
ZS 1121-A/B C	Activate main starting valves - open
ZS 1122 C	Switch at change-over mechanism - change safety system reset between local telegraph and engine side console
XC 1126 C	I/P converter for VIT control (Only engines with VIT)
ZV 1127 C	Solenoid valve for control of VIT system in stop or Astern funktionl (Only engines with VIT)
PS 1133 C	Cancel of tacho alarm from safety system when Stop is ordered
PS 1134 C	Gives signal when »Bridge control«
ZV 1136 C	Remote stop solenoid valve
ZV 1137 C	Remote start solenoid valve
ZS 1138 C	Reversing cylinder Ahead position
ZS 1139 C	Reversing cylinder Astern position
ZV 1141 C	Solenoid valve for rev.cyl activation, direktion Ahead, during remote control
ZV 1142 C	Solenoid valve for rev.cyl activation, direktion Astern, during remote control
PT 1149	Pilot pressure to actuator for V.I.T. system (Only engines with VIT)
E 1180	Electric motor, auxiliary blower
E 1181	Electric motor, turning gear
E 1182 C	Actuator for electronic governor
	Fuel oil
ZV 8020 Z	Fuel oil cut-off at engine inlet (shut down), Germanischer Lloyd only
	Cylinder lubricating oil
ZT 8203 C	Confirm cylinder lubricator piston movement, cyl/cyl
ZV 8204 C	Activate cylinder lubricator, cyl/cyl
	Scavenge air
PS 8603 C	Scavenge air receiver, auxiliary blower control

Table 18.06.02: Control devices on engine

Identification of Instruments

The instruments and sensors are identified by a position number which is made up of a combination of letters and an identification number.

Measured or indicating variables

First letters:

DS	Density switch
DT	Density transmitter
E	Electrical component
FS	Flow switch
FT	Flow transmitter
GT	Gauging transmitter, index/load transmitter
LI	Level indication, local
LS	Level switch
LT	Level transmitter
PDI	Pressure difference indication, local
PDS	Pressure difference switch
PDT	Pressure difference transmitter
PI	Pressure indication, local
PS	Pressure switch
PT	Pressure transmitter
ST	Speed transmitter
TC	Thermo couple (NiCr-Ni)
TE	Temperature element (Pt 100)
TI	Temperature indication, local
TS	Temperature switch
TT	Temperature transmitter
VS	Viscosity switch
VT	Viscosity transmitter
WI	Vibration indication, local
WS	Vibration switch
WT	Vibration transmitter
XC	Unclassified control
XS	Unclassified switch
XT	Unclassified transmitter
ZS	Position switch (limit switch)
ZT	Position transmitter (proximity sensor)
ZV	Position valve (solenoid valve)

Location of measuring point

Ident. number; first two digits indicate the measurement point and xx the serial number:

11xx	Manoeuvring system
12xx	Hydraulic power supply system (HPS)
13xx	Hydraulic control oil system, separate oil to HPS
14xx	Combustion pressure supervision
15xx	Top bracing pressure, stand alone type
16xx	Exhaust Gas Recirculation (EGR)
20xx	ECS to/from safety system
21xx	ECS to/from remote control system
22xx	ECS to/from alarm system
24xx	ME ECS outputs
29xx	Power supply units to alarm system
30xx	ECS miscellaneous input/output
40xx	Tacho/crankshaft position system
41xx	Engine cylinder components
50xx	VOC, supply system
51xx	VOC, sealing oil system
52xx	VOC, control oil system
53xx	VOC, other related systems
54xx	VOC, engine related components
60xx	GI-ECS to Fuel Gas Supply System (FGSS)
61xx	GI-ECS to Sealing Oil System
62xx	GI-ECS to Control Air System
63xx	GI-ECS to other GI related systems
64xx	GI engine related components
66xx	Selective Catalytic Reduction (SCR) related component. Stand alone
80xx	Fuel oil system
81xx	Lubricating oil system
82xx	Cylinder lubricating oil system
83xx	Stuffing box drain system
84xx	Cooling water systems, e.g. central, sea and jacket cooling water
85xx	Compressed air supply systems, e.g. control and starting air
86xx	Scavenge air system
87xx	Exhaust gas system
88xx	Miscellaneous functions, e.g. axial vibration
90xx	Project specific functions

Table 18.07.01a: Identification of instruments

A0xx	Temporary sensors for projects
xxxx-A	Alternative redundant sensors
xxxx-1	Cylinder/turbocharger numbers
	ECS: Engine Control System
	GI: Gas Injection engine
	VOC: Volatile Organic Compound

Functions

Secondary letters:

A	Alarm
C	Control
H	High
I	Indication, remote
L	Low
R	Recording
S	Switching
X	Unclassified function
Y	Slow down
Z	Shut down

Repeated signals

Signals which are repeated, for example measurements for each cylinder or turbocharger, are provided with a suffix number indicating the location, '1' for cylinder 1, etc.

If redundant sensors are applied for the same measuring point, the suffix is a letter: A, B, C, etc.

Examples

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 Diesel & Turbo’s recommendations for preservation of disassembled / assembled engines are available on request.

Furthermore, it must be considered whether a drying machine, option: 4 12 601, is to be installed during the transportation and/or storage period.

Shop Trials/Delivery Test

Before leaving the engine maker’s works, the engine is to be carefully tested on diesel oil in the presence of representatives of the yard, the shipowner and the classification society.

The shop trial test is to be carried out in accordance with the requirements of the relevant classification society, however a minimum as stated in Section 19.05.

MAN Diesel & Turbo's recommendations for shop trial, quay trial and sea trial are available on request.

In connection with the shop trial test, it is required to perform a pre-certification survey on engine plants with FPP or CPP, options: 4 06 201 Engine test cycle E3 or 4 06 202 Engine test cycle E2 respectively.

Spare Parts

List of spare parts, unrestricted service

The tendency today is for the classification societies to change their rules such that required spare parts are changed into recommended spare parts.

MAN Diesel & Turbo, however, has decided to keep a set of spare parts included in the basic extent of delivery, EoD: 4 87 601, covering the requirements and recommendations of the major classification societies, see Section 19.06.

This amount is to be considered as minimum safety stock for emergency situations.

Additional spare parts recommended by MAN Diesel & Turbo

The above-mentioned set of spare parts can be extended with the 'Additional Spare Parts Recommended by MAN Diesel & Turbo', option: 4 87 603, which facilitates maintenance because, in that case, all the components such as gaskets, sealings, etc. required for an overhaul will be readily available, see Section 19.07.

Wearing parts

The consumable spare parts for a certain period are not included in the above mentioned sets, but can be ordered for the first 1, 2, up to 10 years' service of a new engine, option: 4 87 629.

The wearing parts that, based on our service experience, are estimated to be required, are listed with service hours in Tables 19.08.01 and 19.08.02.

Large spare parts, dimensions and masses

The approximate dimensions and masses of the larger spare parts are indicated in Section 19.09. A complete list will be delivered by the engine maker.

Tools

List of standard tools

The engine is delivered with the necessary special tools for overhauling purposes. The extent, dimensions and masses of the main tools is stated in Section 19.10. A complete list will be delivered by the engine maker.

Tool panels

Most of the tools are arranged on steel plate panels, EoD: 4 88 660, see Section 19.11 'Tool Panels'.

It is recommended to place the panels close to the location where the overhaul is to be carried out.

Specification for painting of main engine

Components to be painted before shipment from workshop	Type of paint	No. of coats / Total Nominal Dry Film Thickness (NDFT) µm	Colour: RAL 840HR DIN 6164 MUNSELL
1. Component/surfaces exposed to oil and air, inside engine			
Unmachined surfaces all over. However, cast type crankthrows, main bearing cap, crosshead bearing cap, crankpin bearing cap, pipes inside crankcase and chainwheel need not to be painted, but the cast surface must be cleaned of sand and scales and be kept free of rust.	In accordance with corrosivity categories C2 Medium ISO 12944-5		
	Engine alkyd primer, weather resistant.	1 - 2 layer(s) Total NDTF 80 µm	Free
	Oil and acid resistant alkyd paint. Temperature resistant to minimum 80 °C.	1 layer Total NDTF 40 µm – – – – – Total NDTF 120 µm	White: RAL 9010 DIN N:0:0.5 MUNSELL N-9.5
2. Components, outside engine			
Engine body, pipes, gallery, brackets, etc. Delivery standard is in a primed and finished-painted condition, unless otherwise stated in the contract.	In accordance with corrosivity categories C2 Medium ISO 12944-5		
	Engine alkyd primer, weather resistant.	1 - 2 layer(s) Total NDTF 80 µm	Free
	Final alkyd paint resistant to salt water and oil, option: 4 81 103.	1 layer Total NDTF 40 µm – – – – – Total NDTF 120 µm	Light green: RAL 6019 DIN 23:2:2 MUNSELL 10GY 8/4
3. Gas pipe (ME-GI/ME-LGI only)			
Chain pipes, supply pipe.	In accordance with corrosivity categories C2 Medium ISO 12944-5		
	Engine alkyd primer, weather resistant.	1 - 2 layer(s) Total NDTF 80 µm	Free
	Final alkyd paint resistant to salt water and oil, option: 4 81 103.	1 layer Total NDTF 40 µm – – – – – Total NDTF 120 µm	Yellow: RAL 1021 MUNSELL 2.5 Y 8114
	ME-LGI only: additional marking tape on pipes acc. to ISO 14726:2008.		Violet: RAL 4001 MUNSELL 2.5P 4/11
4. Heat affected components			
Supports for exhaust receiver. Scavenge air cooler housing inside and outside. No surface in the cooler housing may be left unpainted. Exhaust valve housing (exhaust flange), (Non water cooled housing only).	In accordance with corrosivity categories C3 Medium ISO 12944-5		
	Ethyl silicate based zinc-rich paint, heat resistant to minimum 300 °C.	1 layer – – – – – Total NDTF 80 µm	

Components to be painted before shipment from workshop	Type of paint	No. of coats / Total Nominal Dry Film Thickness (NDFT) μm	Colour: RAL 840HR DIN 6164 MUNSELL
5. Components affected by water, cleaning agents, and acid fluid below neutral Ph			
Scavenge air cooler box inside. (Reversing chamber). Preparation, actual number of coats, film thickness per coat, etc. must be according to the paint manufacturer's specifications. Air flow reversing chamber inside and outside. No surface may be left unpainted. Supervision from manufacturer is recommended in the phase of introduction of the paint system.	In accordance with corrosivity categories C5-M High ISO 12944-5 Two-component epoxy phenolic.	3 layers — — — — — Total NDTF 350 μm See specifications from product data sheet.	Free
6. Gallery plates, top side	Engine alkyd primer, weather resistant.	C2 Medium 1-2 layer(s) — — — — — Total NDTF 80 μm	
7. EGR system Normal air cooler housing with EGR mix point to scavenge air receiver non-return valves (500 μm). Normal air cooler housing inside – from outlet air cooler – through reversing chamber and water mist catcher to non-return valves housing in scavenge air receiver.	Vinyl ESTER acrylic copolymer. Note: Duplex/Stainless steel is not to be painted.	Total NDTF 500 - 1,200 μm	Free
8. Purchased equipment and instruments painted in maker's colour are acceptable, unless otherwise stated in the contract			
Tools are to be surface treated according to specifications stated in the drawings. Purchased equipment painted in maker's colour is acceptable, unless otherwise stated in the contract/drawing.	Electro(-) galvanised.	See specifications from product data sheet.	
Tool panels	Oil resistant paint.	1 - 2 layer(s) — — — — — Total NDTF 80 μm	Light grey: RAL 7038 DIN 24:1:2 MUNSELL N-7.5

All paints must be of good quality. Paints according to builder's standard may be used provided they at least fulfil the above requirements.
The data stated are only to be considered as guidelines. Preparation, number of coats, film thickness per coat, etc., must be in accordance with the paint manufacturer's specifications.

074 33 57-9.11.1

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

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.

Class A (option 4 12 020):
Short distance transportation limited by duration of transportation time within a few days or a distance of approximately 1000 km and short term storage.
Duration from engine delivery to installation must not exceed eight weeks.
Dismantling must be limited.

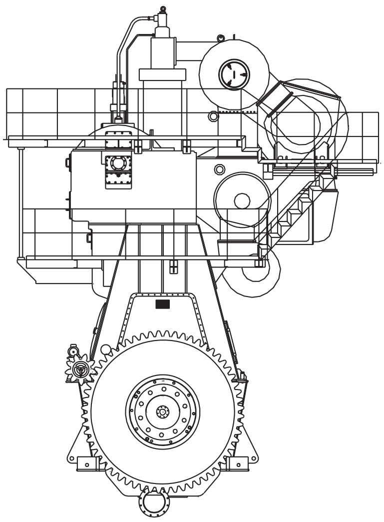
Class B (option 4 12 030):
Overseas and other long distance transportation, as well as long-term storage.
Dismantling is effected to reduce the transport volume to a suitable extent.
Long-term preservation and seaworthy packing must always be used.

Classes A + B comprise the following basic variants:

A1 + B1 (option 4 12 021 + 4 12 031)
• Engine complete

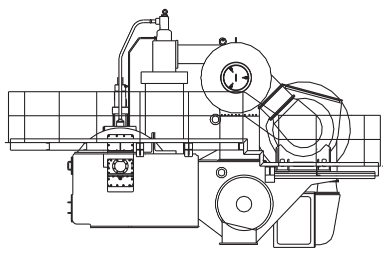
A2 + B2 (option 4 12 022 + 4 12 032)
• Top section including cylinder frame complete, cylinder covers complete, scavenge air receiver including cooler box and cooler insert, turbocharger(s), camshaft, piston rods complete and galleries with pipes.
• Bottom section including bedplate complete, frame box complete, connecting rods, turning gear, crankshaft complete and galleries.
• Remaining parts, stay bolts, auxiliary blowers, chains, etc.

A1 + B1

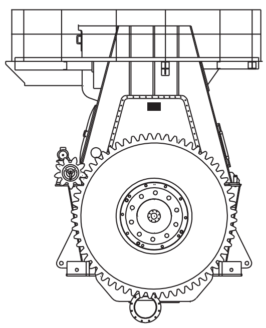


Engine complete

A2 + B2



Top section



Bottom section

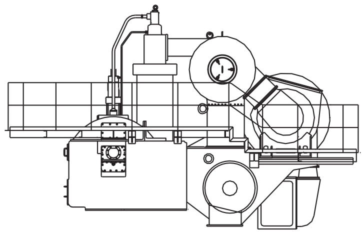
178 44 73-0.0a

Fig. 19.03.01a: Dispatch pattern, engine with turbocharger on exhaust side (4 59 123)

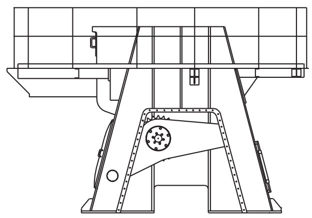
A3 + B3 (option 4 12 023 + 4 12 033)

- Top section including cylinder frame complete, cylinder covers complete, scavenge air receiver including cooler box and cooler insert, turbocharger(s), camshaft, piston rods complete and galleries with pipes.
- Frame box section including frame box complete, chain drive connecting rods and galleries.
- Bedplate/crankshaft section including bedplate complete, crankshaft complete with wheels and turning gear.
- Remaining parts, stay bolts, auxiliary blowers, chains, etc.

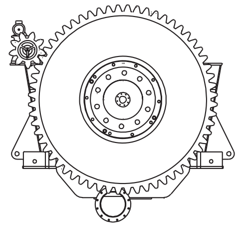
A3 + B3



Top section



Frame box section



Bedplate/cranckshaft section

178 44 73-0.0b

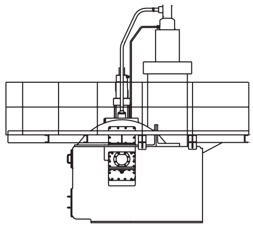
Fig. 19.03.01b: Dispatch pattern, engine with turbocharger on exhaust side (4 59 123)

A4 + B4 (option 4 12 024 + 4 12 034)

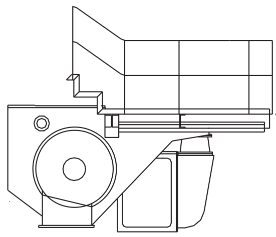
- Top section including cylinder frame complete, cylinder covers complete, camshaft, piston rods complete and galleries with pipes on camshaft side.
- Exhaust receiver with pipes.
- Scavenge air receiver with galleries and pipes.
- Turbocharger.
- Air cooler box with cooler insert.
- Frame box section including frame box complete, chain drive, connecting rods and galleries.
- Crankshaft with wheels.
- Bedplate with pipes and turning gear.
- Remaining parts, stay bolts, auxiliary blowers, chains, etc.

Note!
The engine supplier is responsible for the necessary lifting tools and lifting instructions for transportation purpose to the yard.

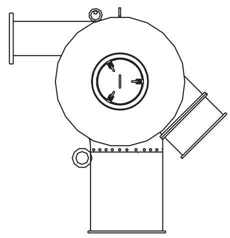
The delivery extent of tools, ownership and lending/lease conditions are to be stated in the contract.
Furthermore, it must be stated whether a dehumidifier is to be installed during the transportation and/or storage period.



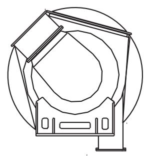
Top section



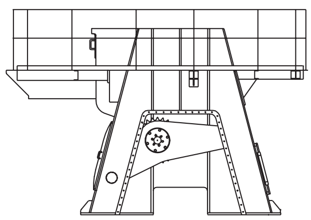
Scavenge air receiver



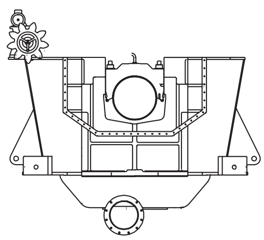
Exhaust receiver



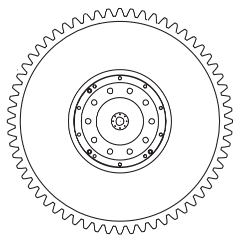
Turbocharger



Frame box section



Bedplate section



Crankshaft section

178 44 73-0.0c

Fig. 19.03.01c: Dispatch pattern, engine with turbocharger on exhaust side (4 59 123)

Dispatch pattern, list of masses and dimensions

Pattern	Section	5 cylinder		6 cylinder		7 cylinder		8 cylinder			
		Mass	Length	Mass	Length	Mass	Length	Mass	Length	Height	Width
		in t	in m	in t	in m	in t	in m	in t	in m	in m	in m
A1+B1	Engine complete	**324.4**	**8.2**	**367.7**	**9.2**	**410.4**	**10.2**	**467.2**	**11.3**	**11.1**	**8.2**
A2+B2	Top section	125.1	7.7	143.8	8.7	163.1	9.7	192.8	10.8	6.7	8.2
	Bottom section	188.2	8.2	212.3	9.2	235.1	10.2	261.8	11.3	6.6	5.1
	Remaining parts	11.1		11.6		12.1		12.6			
A3+B3	Top section	125.1	7.7	143.8	8.7	163.1	9.7	192.8	10.8	6.7	8.2
	Frame box section	71.9	8.2	81.6	9.2	84.1	10.2	94.4	11.3	4.1	5.1
	Bedplate/Crankshaft	116.3	7.0	130.8	8.1	151.0	9.1	167.4	10.1	3.5	4.4
	Remaining parts	11.1		11.6		12.1		12.6			
A4+B4	Top section	88.1	7.7	104.7	8.7	121.3	9.7	138.0	10.8	4.7	3.9
	Exhaust receiver	5.8	6.3	6.3	7.3	7.2	8.4	8.5	9.4	3.5	2.5
	Scavenge air receiver	16.1	6.6	17.5	7.7	18.8	8.7	27.3	9.7	3.4	4.2
	Turbocharger, each	10.0		10.0		10.0		5.1			
	Air cooler, each	2.6		2.6		2.6		4.0			
	Frame box section	73.4	8.2	83.2	9.2	85.9	10.2	96.4	11.3	4.1	5.1
	Crankshaft	64.9	6.9	73.3	7.9	88.9	9.0	99.3	10.0	3.5	3.5
	Bedplate	49.9	6.7	55.8	7.7	60.3	8.7	66.1	9.7	2.7	4.4
	Remaining parts	13.7		14.4		15.4		17.4			

The weights stated are for standard engines with semi-built crankshaft with forged throws, crosshead guides integrated in the frame box, and MAN Diesel turbocharger. The final weights are to be confirmed by the engine supplier, as variations in major engine components due to the use of local standards (plate thickness etc.), size of tuning wheel, type of turbocharger and the choice of cast/welded or forged component designs may increase the total weight by up to 10 %. All masses and dimensions in the dispatch pattern are therefore approximate and do not include packing and lifting tools.

*Note: Some engines are equipped with moment compensator and/or tuning wheel.
However, the weights for these components are not included in dispatch pattern.*

Table 19.04.01: Dispatch pattern, list of masses and dimensions

Shop Test

Minimum delivery test

The minimum delivery test, EoD: 4 14 001, involves:

- Starting and manoeuvring test at no load
- Load test
  Engine to be started and run up to 50% of Specified MCR (M) in 1 hour

Followed by:

- 0.50 hour running at 25% of specified MCR
- 0.50 hour running at 50% of specified MCR
- 0.50 hour running at 75% of specified MCR
- 1.00 hour running at 100% of specified MCR
- 0.50 hour running at 110% of specified MCR

Only for Germanischer Lloyd:

- 0.75 hour running at 110% of specified MCR

Governor tests, etc:

- Governor test
- Minimum speed test
- Overspeed test
- Shut down test
- Starting and reversing test
- Turning gear blocking device test
- Start, stop and reversing from the Local Operating Panel (LOP)

Fuel oil test

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

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

Fuel oil analysis is to be presented.

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

EIAPP certificate

Most marine engines installed on ocean going vessels are required to have an 'Engine International Air Pollution Prevention' (EIAPP) Certificate, or similar. Therefore, a pre-certification survey is to be carried out for all engines according to the survey method described in the engine's NO_x Technical File, which is prepared by the engine manufacturer. For MAN B&W engines, the Unified Technical File (UTF) format is recommended.

The EIAPP certificate documents that the specific engine meets the international NO_x emission limitations specified in Regulation 13 of MARPOL Annex VI. The basic engine 'Economy running mode', EoD: 4 06 200, complies with these limitations.

The pre-certification survey for a 'Parent' or an 'Individual' engine includes NO_x measurements during the delivery test. For 'Member' engines, a survey according to the group definition for the engine group is needed. This survey should be based on the delivery test.

The applicable test cycles are:

- E3, marine engine, propeller law for FPP, option: 4 06 201

or

- E2, marine engine, constant speed for CPP, option: 4 06 202

For further information and options regarding shop test, see Extent of Delivery.

List of Spare Parts, Unrestricted Service

Spare parts are **requested** by the following Classes only: GL, KR, NK and RS, while just **recommended** by: ABS and LR, but neither requested nor recommended by: BV, CCS, DNV and RINA.

Cylinder cover, plate 901 and others

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

Piston, plate 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 903

1	Cylinder liner inclusive of sealing rings and gaskets.

Cylinder lubricator, plate 903 [1])

	Standard Spare parts
1 set	Spares for MAN B&W Alpha lubricator for 1 cyl.
1	Lubricator
2	Feed back sensor, complete
1	Suction filter element for pump station
1	Pressure filter element for pump station
1	Complete sets of O-rings for lubricator (depending on No. of lubricating per. cylinder)
1 set	Ceramic or sand filled fuses 6.3 x 32 mm, for MCU, BCU & SBU (6 pcs 3A and 3 pcs 12A)
2	LED's for visual feed back indication
or	
1 set	LED's for visual feed back indication

Connecting rod, and crosshead bearing, plate 904

1	Telescopic pipe with bushing for 1 cylinder
1	Crankpin bearing shells in 2/2 with studs and nuts
1	Crosshead bearing shell lower part with studs and nuts
2	Thrust piece

Main bearing and thrust block, plate 905

1 set	Thrust pads for one face of each size, if different for 'ahead' and 'astern'

Chain drive, plate 906 [1])

1	Of each type of bearings for camshaft at chain drive, chain tightener and intermediate shaft
6	Camshaft chain links. Only for ABS, LR and NK
1	Mechanically driven cylinder lubricator drive: 6 chain links or gear wheels
1	Guide ring 2/2 for camshaft bearing

Starting valve, plate 907

1	Starting valve, complete

Exhaust valve, plate 908

2	Exhaust valves complete (The 2nd exhaust valve is mounted in the Cylinder cover complete)
1	Pressure pipe for exhaust valve pipe

Fuel pump, plate 909

1	Fuel pump barrel, complete with plunger
1	High-pressure pipe, each type
1	Suction and puncture valve, complete

Fuel valve, plate 909

1 set	Fuel valves of each size and type fitted, complete with all fittings, for one engine a) engines with one or two fuel valves: one set of fuel valves for all cylinders on the engine b) engines with three and more fuel valves per cylinder: two fuel valves complete per cylinder, and a sufficient number of valve parts, excluding the body, to form, with those fitted in the complete valve, a full engine set

Turbocharger, plate 910

1 set	Maker's standard spare parts

Bedplate, plate 912

1	Main bearing shell in 2/2 of each size
1 set	Studs and nuts for 1 main bearing

[1]) MD required spare parts.

Please note: Plate number refers to Instruction Book, Vol. III containing plates with spare parts.

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

Additional Spares

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

Cylinder cover, section 90101

4		Studs for exhaust valve
4		Nuts for exhaust valve
½	set	O-rings for cooling jacket
1		Cooling jacket
½	set	Sealing between cylinder cover and liner
4		Spring housings for fuel valve (applicable for 98-50MC/MC-C only)

Hydraulic tool for cylinder cover, section 901

1	set	Hydraulic hoses with protection hoses complete with couplings
8	pcs	O-rings with backup rings, upper
8	pcs	O-rings with backup rings, lower

Piston and piston rod, section 90201

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, section 90202

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, section 90301

½	set	Studs for cylinder cover for one cylinder
1		Bushing

Cylinder liner and cooling jacket, section 90301

1		Cooling jacket of each kind
4		Non return valves
1	set	O-rings for one cylinder liner
½	set	Gaskets for cooling water connection
½	set	O-rings for cooling water pipes
1	set	Cooling water pipes between liner and cover for one cylinder

Mechanically driven cylinder lubricator drive, section 90305

1		Coupling
3		Discs

MAN B&W Alpha Cylinder Lubricating System, section 90302

1	set	Spares for MAN B&W Alpha lubricator for one cylinder
1		Lubricator
2		Feed back sensor, complete
1		Suction filter element for pump station
1		Pressure filter element for pump station
1		Complete sets of O-rings for lubricator (depending on no. of lubricating per cylinder)
6		3A, 3 pcs. 12A ceramic or sand filled fuses
2		6.3 x 32 mm, for MCU, BCU & SBU LED's (Light Emitting Diodes) for visual feed back indication

Connecting rod and crosshead, section 90401

1		Telescopic pipe
2		Thrust piece

Chain drive and guide bars, section 90601

4		Guide bar
1	set	Locking plates and lock washers

Chain tightener, section 90602

2		Locking plates for tightener

Camshaft, section 90603

1		Exhaust cam (split repair cam if possible)
1		Fuel cam (split repair cam if possible)

Indicator drive, section 90608

1	set	Gaskets for indicator valves
3		Indicator valves/cocks complete

Regulating shaft, section 90618

3		Resilient arm, complete

Arrangement of engine side console, plate 90621

2		Pull rods

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

Main starting valve, section 90702

1		Repair kit for main actuator
1		Repair kit for main ball valve
1		Repair kit for actuator, slow turning [1])
1		Repair kit for ball valve, slow turning [1])

[1]) if fitted

Starting valve, section 90704

2		Locking plates
2		Piston
2		Spring
2		Bushing
1	set	O-ring
1		Valve spindle

Exhaust valve, section 90801

1		Exhaust valve spindle
1		Exhaust valve seat
½	set	O-ring exhaust valve/cylinder cover
4		Piston rings
½	set	Guide rings
½	set	Sealing rings
½	set	Safety valves
1	set	Gaskets and O-rings for safety valve
1		Piston complete
1		Damper piston
1	set	O-rings and sealings between air piston and exhaust valve housing/spindle
1		Liner for spindle guide
1	set	Gaskets and O-rings for cool. water conn.
1		Conical ring in 2/2
1	set	O-rings for spindle/air piston
1	set	Non-return valve

Exhaust valve, section 908

1		Sealing oil control unit

Valve gear, section 908

3		Filter, complete
5		O-rings of each kind

Valve gear, section 90805

1		Roller guide complete
2		Shaft pin for roller
2		Bushing for roller
4		Discs
2		Non return valve
4		Piston rings
4		Discs for spring
2		Springs
2		Roller

Valve gear, details, section 90806

1		High pressure pipe, complete
1	set	O-rings for high pressure pipes
4		Sealing discs

Cooling water outlet, section 908

2		Ball valve
1		Butterfly valve
1		Compensator
1	set	Gaskets for butterfly valve and compensator

Fuel pump, section 909

1		Top cover
1		Plunger/barrel, complete
3		Suction valves
3		Puncture valves
½	set	Sealings, O-rings, gaskets and lock washers

Fuel pump gear, section 909

1		Fuel pump roller guide, complete
2		Shaft pin for roller
2		Bushings for roller
2		Springs
1	set	Sealings
2		Roller

Fuel pump gear, details, section 90910

½	set	O-rings for lifting tool

Fuel pump gear, details, section 90904

1		Shock absorber, complete
1	set	Spring(s)
1	set	Sealing and wearing rings
4		Felt rings

Fuel pump gear, reversing mechanism, plate 90905

1		Reversing mechanism, complete
2		Spare parts set for air cylinder

Fuel valve, section 90911

1	set	Fuel nozzles
1	set	O-rings for fuel valve
3		Spindle guides, complete
½	set	Springs
½	set	Discs, +30 bar
3		Thrust spindles
3		Non return valve (if mounted)

Fuel oil high pressure pipes, section 90914

1		High pressure pipe, complete of each kind
1	set	O-rings for high pressure pipes

Table 19.07.01b: Additional spare parts beyond class requirements or recommendation, option: 4 87 603

Overflow valve, section 90915

1		Overflow valve, complete
1		O-rings of each kind

Scavenge air receiver, section 91002

2		Non-return valves complete
1		Compensator

Exhaust pipes and receiver, section 910

1		Compensator between TC and receiver
2		Compensator between exhaust valve and receiver
1	set	Gaskets for each compensator

Auxiliary blower, section 91003

1	set	Bearings for electric motor
1	set	Shaft sealings
1	set	Bearings/belt/sealings for gearbox (only for belt-driven blowers)

Turbocharger, section 91005

1		Spare rotor for one turbocharger, complete with bearing
1	set	Spare parts for one turbocharger

Arrangement of safety cap, section 911

1	set	Bursting disc

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

Table 19.07.01c: Additional spare parts beyond class requirements or recommendation, option: 4 87 603

Wearing Parts

MAN Diesel & Turbo Service Letter SL-509 provides Guiding Overhaul Intervals and expected service life for key engine components.

The wearing parts expected to be replaced at the service hours mentioned in the Service Letter are listed in the tables below.

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
Actuator gear (1 pc per cylinder)											x						
▪ Sealing rings for actuator gear (1 set per cylinder)						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
Fuel pump																	
▪ Plunger and barrel (1 set per cylinder)								x						x			
▪ Sealing rings for plunger, barrel, suction valve and puncture valve (1 set per cylinder)			x					x			x			x			x
▪ Sealing rings for shock absorber (1 set per cylinder)			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**																
Bearings																	
▪ Crosshead bearing (1 set per cylinder)												x					
▪ Crankpin bearing (1 set per cylinder)																	x
▪ Main bearing (1 set per cylinder)																	x
▪ Thrust bearing (1 set per engine)																	x
Cylinder cover (1 pc per cylinder)																	x
▪ O-rings for cooling water jacket (1 set per cylinder)			x			x			x			x		x			x
▪ O-ring for starting valve (1 pc per cylinder)		x			x		x		x		x		x		x		x
Air cooler(s) (1 pc per turbocharger)									x								x
Chains (1 set per engine)																	x
Chain wheels (1 set per engine)																	x
Rubber guide bars (1 set per engine)						x						x					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 *)																	

*) According to manufacturer's recommendations.

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

Rotor for turbocharger

MAN

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

561 70 21-6.0.0

ABB

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

561 66 78-9.0.0

MHI

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

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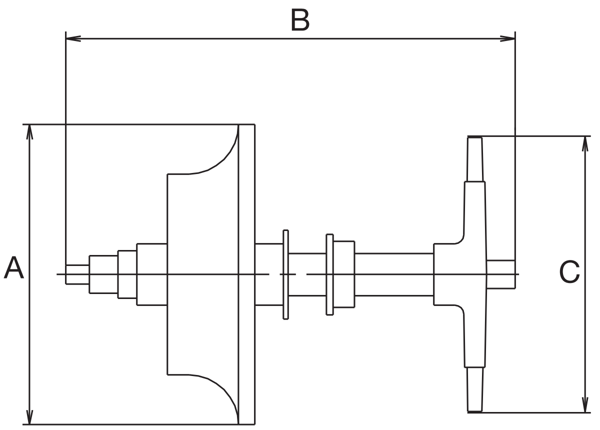

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Fig. 19.09.02: Large spare parts, dimensions and masses

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

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 Alpha Lubricator

Crosshead and Connection Rod Tools, MF/SF 21-9022

1 pcs Tool panel incl. suspension and lifting tools, protection in crankcase etc.
1 pcs Guide shoe extractor
1 pcs Crankpin shell, lifting tool

Crankshaft and Thrust Bearing Tools, MF/SF 21-9026

1 pcs Tool panel incl. lifting, testing and retaining tools etc.
1 pcs Lifting tool for crankshaft
1 pcs Lifting tool for thrust shaft
1 set Feeler gauges

Control Gear Tools, MF/SF 21-9030

1 pcs Tool panel incl. pin gauges, chain assembly tools, camshaft tools etc.

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

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 Hand tools incl. wrenches, pliers and spanners

Optional Tools, MF/SF 21-9062

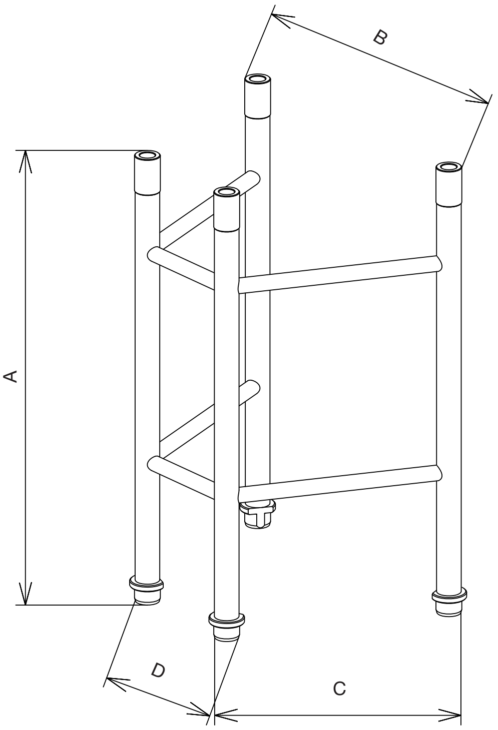
1 pcs Collar ring for piston
1 pcs Support for tilting tool
1 pcs Valve seat and spindle grinder
1 pcs Wave cutting machine for cylinder liner
1 pcs Wear ridge milling machine
1 pcs Work table for exhaust valve

Hydraulic Jacks, MF/SF 21-94

It is important to notice, that some jacks are used on different components on the engine, Fig. 19.10.07

Mass of the complete set of tools: Approximately 3,150 kg

1



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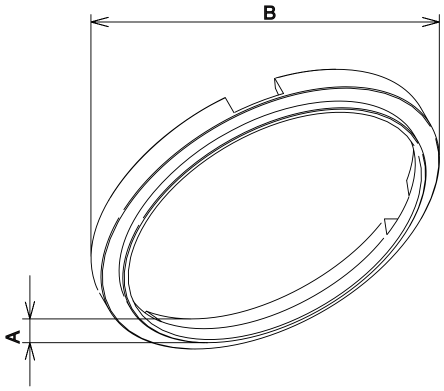

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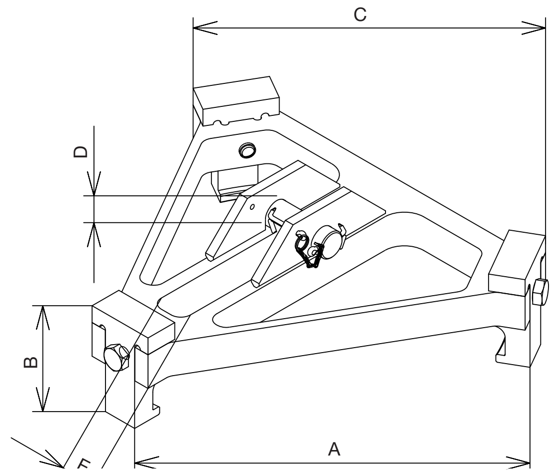
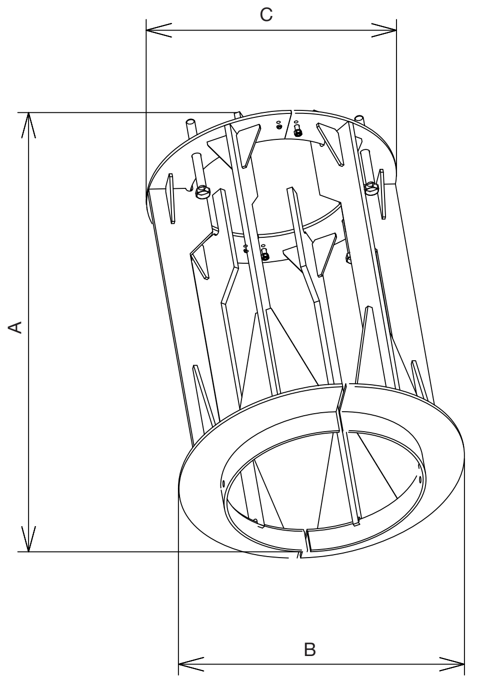
3



122 66 25-7.1.0

4

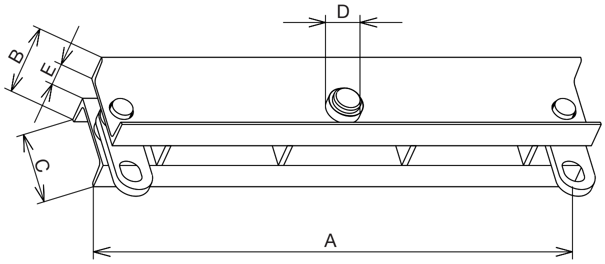


122 66 29-4.1.0

Pos.	Description	Mass	Dimensions (mm)				
		(kg)	A	B	C	D	E
1	Cylinder cover rack	107.0	1,490	700	853	346	
2	Guide ring for piston	29.2	70	737			
3	Lifting tool for piston	37.2	529	120	599	30	35
4	Support iron for piston	70.2	1,123	660	510		

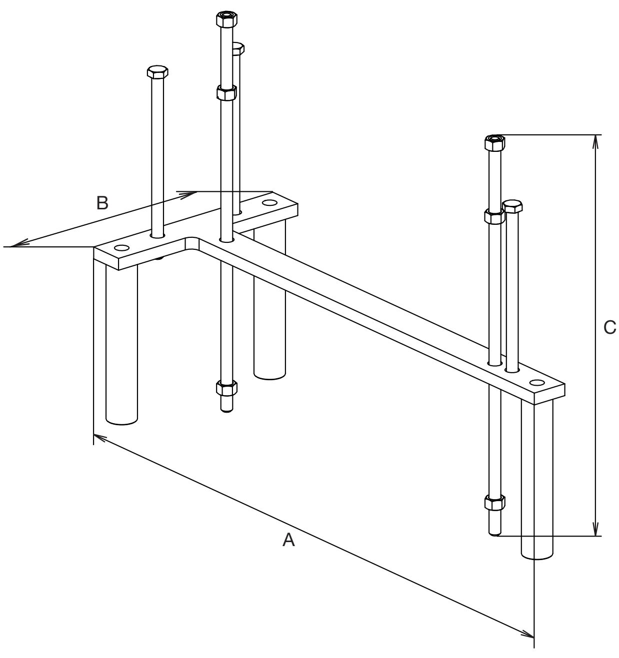
Fig. 19.10.01: Dimensions and masses of tools

1



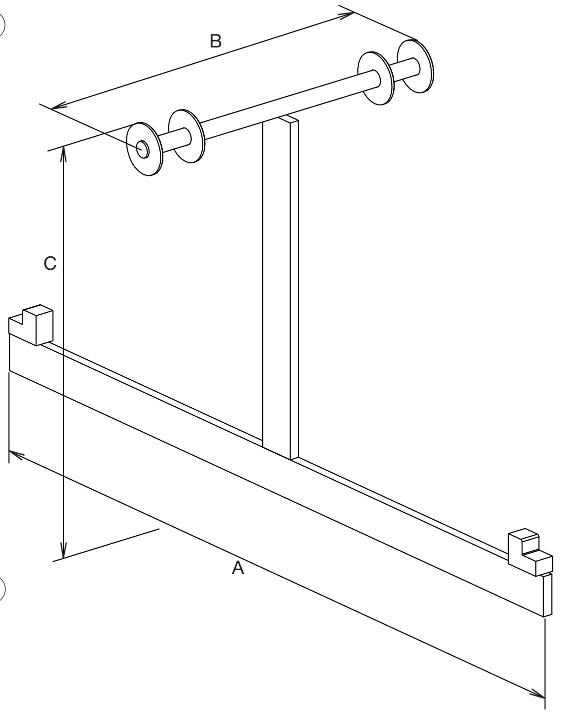
122 66 72-3.1.0

2



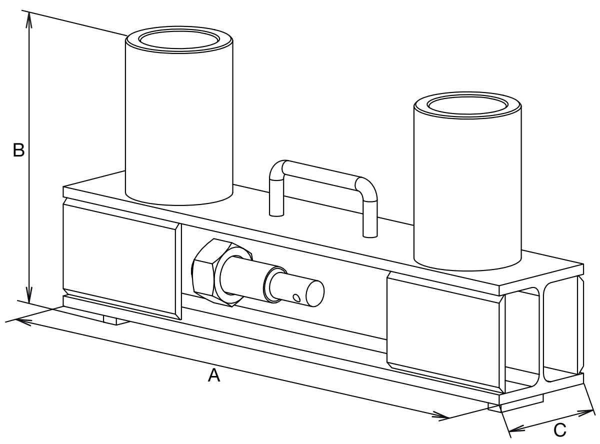
312 69 78-1.2.0

3



310 21 51-7.2.0

4

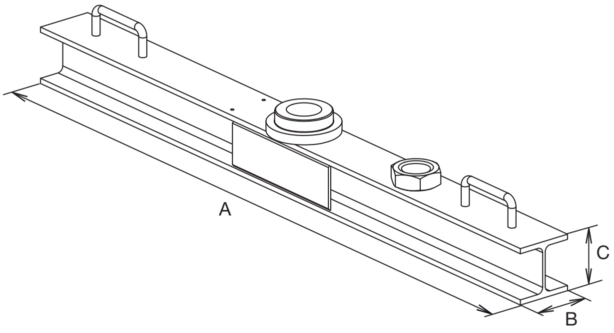


312 69 54-1.4.0

Pos.	Description	Mass	Dimensions (mm)				
		(kg)	A	B	C	D	E
1	Crossbar for cylinder liner, piston	40.4	1,045	170	120	45	60
2	Guide shoe extractor	6.1	590	235	435		
3	Crankpin shell, lifting tool	4.8	780	330	408		
4	Lifting tool for crankshaft	94.5	940	425	150		

Fig. 19.10.02: Dimensions and masses of tools

1

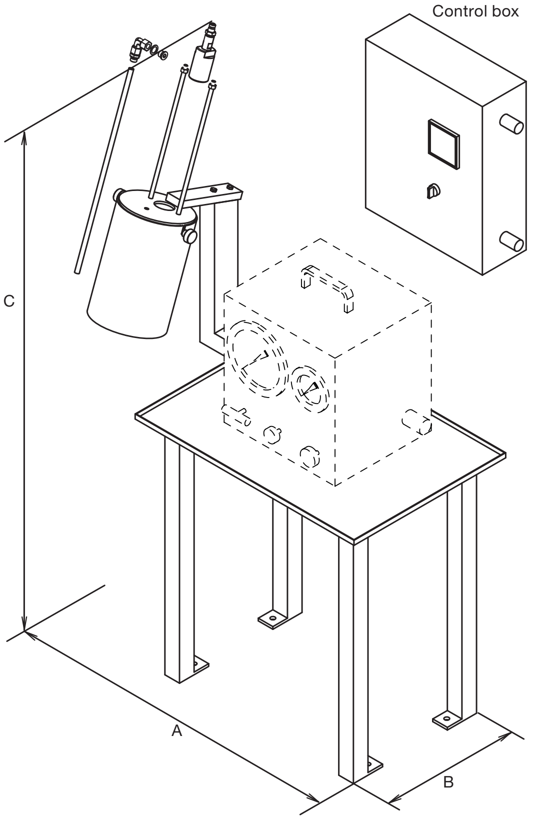


513 02 17-3.1.0

Pos.	Description	Mass	Dimensions (mm)		
		(kg)	A	B	C
1	Lifting tool for thrust shaft	51.9	1.500	120	120

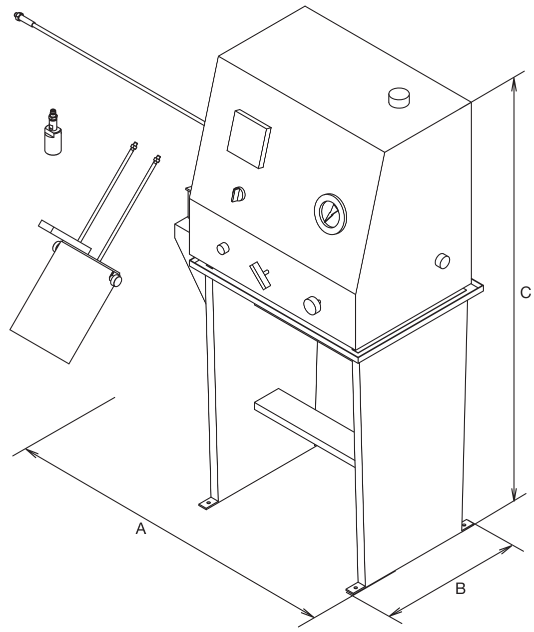
Fig. 19.10.03: Dimensions and masses of tools

1



508 83 09-8.0.0

2

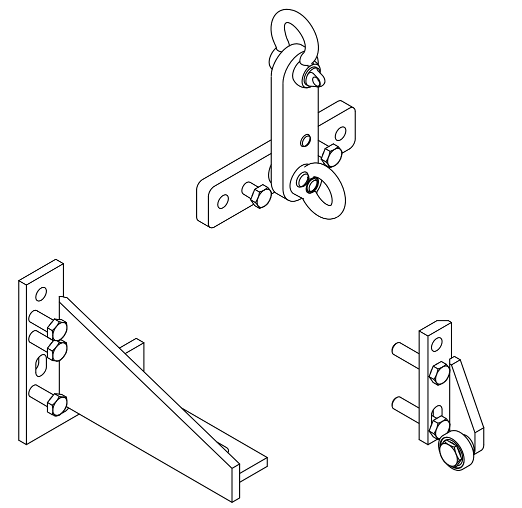


316 79 10-8.3.0

Pos.	Description	Mass	Dimensions (mm)		
		(kg)	A	B	C
1	Test rig for fuel valve, separated hydraulic pump	70	1,025	420	1,630
2	Test rig for fuel valve, integrated hydraulic pump	120	940	520	1,540

Fig. 19.10.04: Dimensions and masses of tools

1

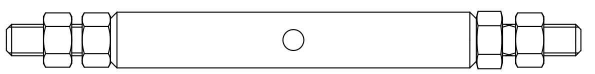


The tools for air cooler, compensator and the tools for the turbocharger system are to be stored in a storage room e.g. a drawer.

Required space for these tools are approx.:
1,000 x 500 x 300 mm.

504 59 65-3.1.0

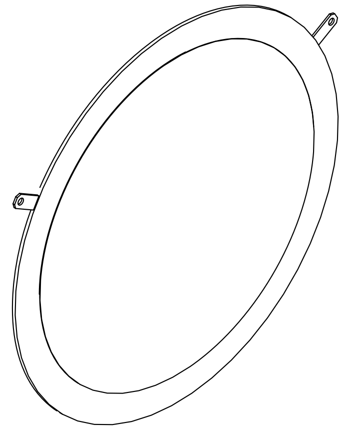
2



Dimensions varies depending on compensator size.

310 20 96-6.1.0

3



Depending on the turbocharger type choosen for the engine, the blanking plates will vary in size from approx. 380 mm in up to 1,180 mm in diameter.
Thickness: 10 to 16 mm.

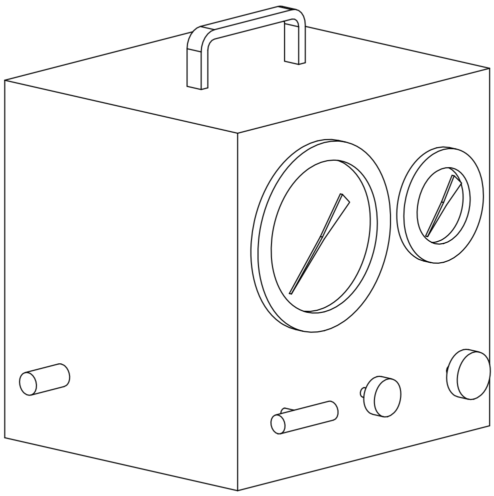
Only engines with two or more turbochargers will be supplied with blanking plates.

504 59 85-6.1.0

Pos.	Description
1	Air cooler cleaning tool
2	Compensator, dismantling tool
3	Blanking plate

Fig. 19.10.05: Dimensions and masses of tools

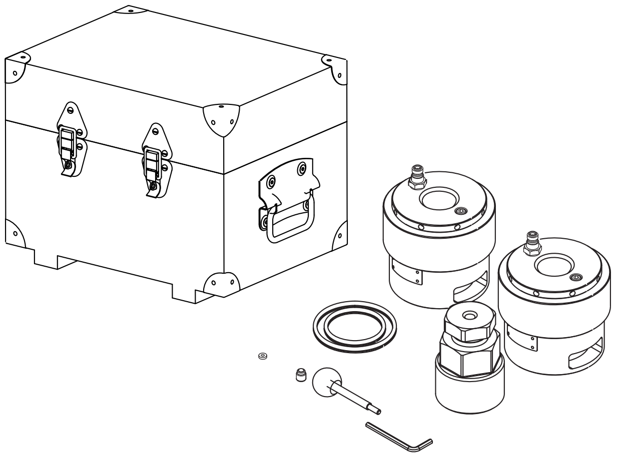
1



340 00 47-5.3.0

Pos.	Description	Mass
		(kg)
1	Pump for hydraulic jacks	30

Fig. 19.10.06: Dimensions and masses of tools



310 18 3-9.3.0

Example of a box containing hydraulic jacks for connecting rod and end chocks.

The exact design and dimensions will be specified by the engine builder or subsupplier.

However, as a minimum, the boxes must be provided with the following:

- supports
- rigid handles
- rigid locks
- reinforced corners
- be resistant to water and oil
- hydraulic jacks must be secured in the box.

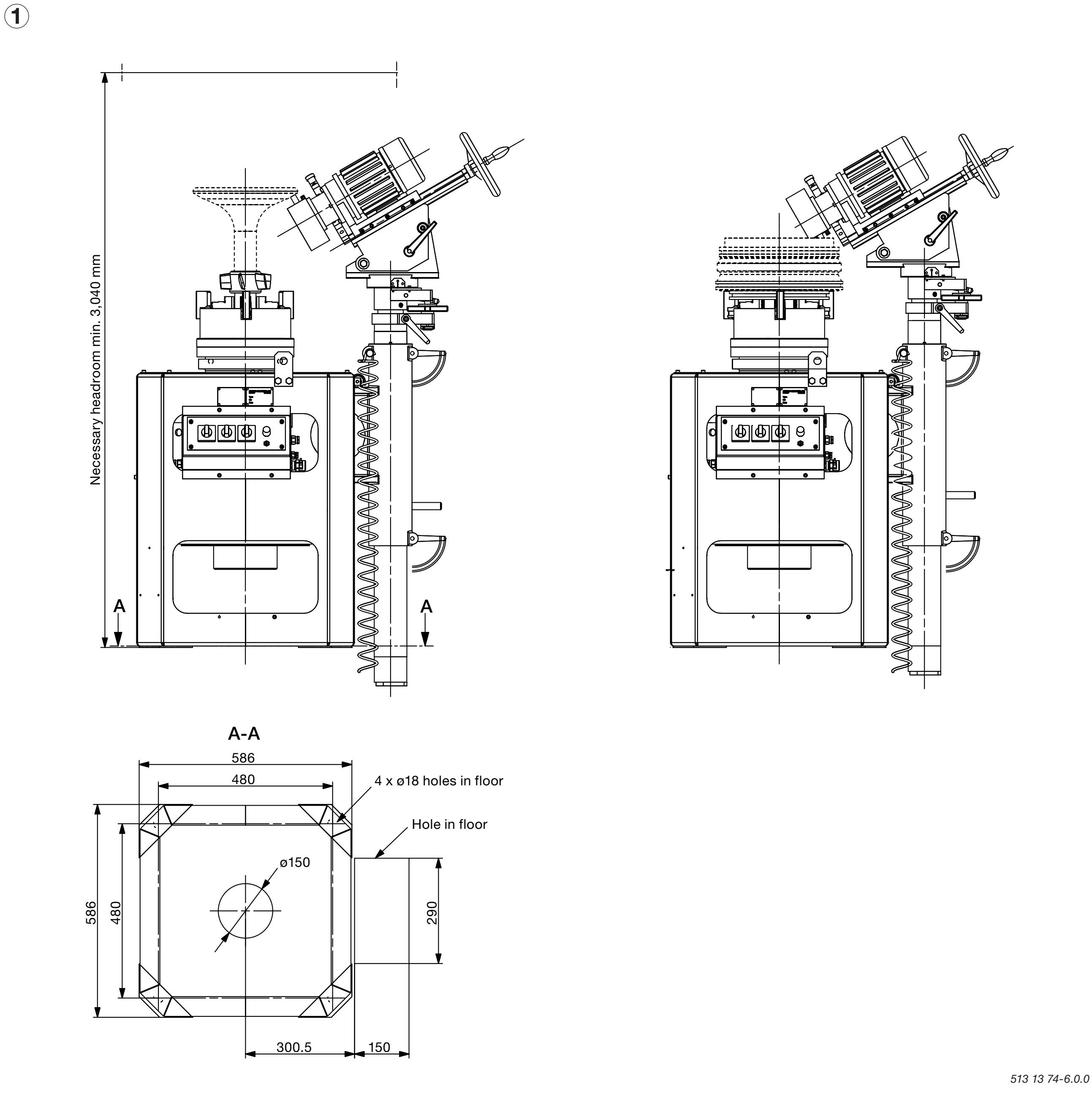
The table indicates the scope and estimated size of boxes for hydraulic jacks.

Hydraulic jacks are often used at different locations, which is why not all fields have been filled in.

Approx. dimensions in mm.	
Size 1.:	300 mm x 400 mm x 500 mm
Size 2.:	500 mm x 700 mm x 500 mm
Size 3.:	900 mm x 1,200 mm x 500 mm

MF-SF		**Number of boxes**	**Size required**
	Hydraulic Jacks:		
21-9410	Cylinder cover	1	3
21-9420	Piston crown		
21-9421	Piston rod		
21-9430	Crosshead	1	2
21-9431	Connecting rod	1	2
21-9440	Main bearing	1	3
21-9441	Tuning wheel		
21-9442	Turning wheel		
21-9443	Chain wheel	1	1
21-9444	AVD	1	2
21-9445	Segment stopper	1	2
21-9446	Counter weight		
21-9447	Torsion damper		
21-9450	Chain tightener		
21-9451	Intermediate shaft		
21-9452	Camshaft bearing		
21-9454	Moment compensator		
21-9460	Exhaust spindle		
21-9461	Exhaust valve	1	2
21-9462	Exhaust valve actuator		
21-9463	HPU block		
21-9464	HCU block		
21-9470	Fuel pump		
21-9480	Stay bolts	1	2
21-9481	Complete set		
21-9490	Holding down bolts / End chock	1	2
21-9491	End Chock		
Total number of boxes containing hydraulic jacks		**10**	

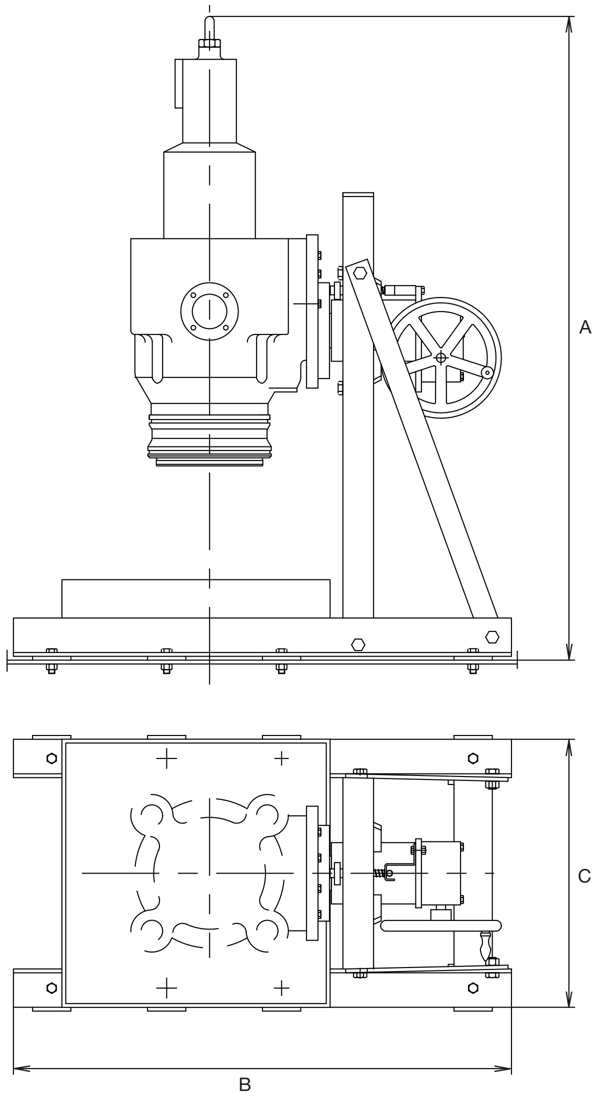
Fig. 19.10.07: Dimensions and masses of tools



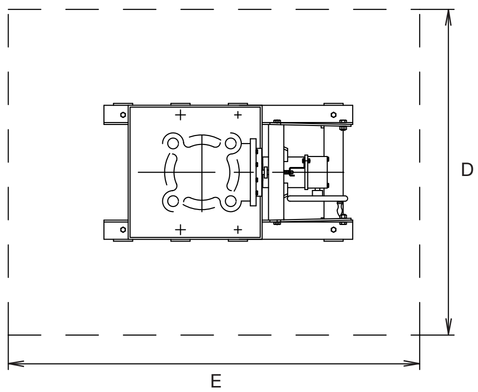
Pos.	Description
1	Valve seat and spindle grinder

Fig. 19.10.08: Dimensions and masses of tools

1



2

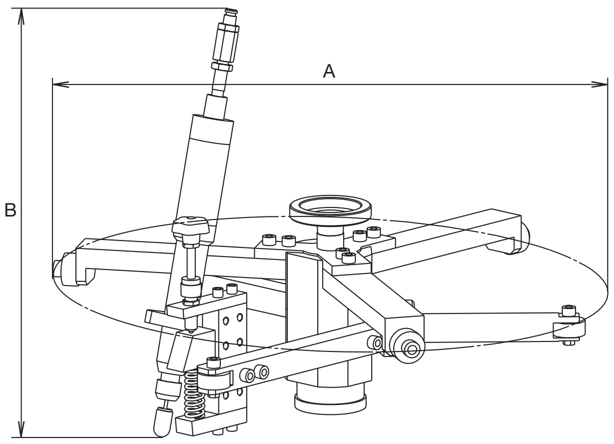


116 55 06-8.1.0

Pos.	Description	Mass	Dimensions (mm)				
		(kg)	A	B	C	D	E
1	Work table for exhaust valve	183	min. 1,920	1,300	720		
2	Suggested working area					1,700	2,150

Fig. 19.10.09: Dimensions and masses of tools

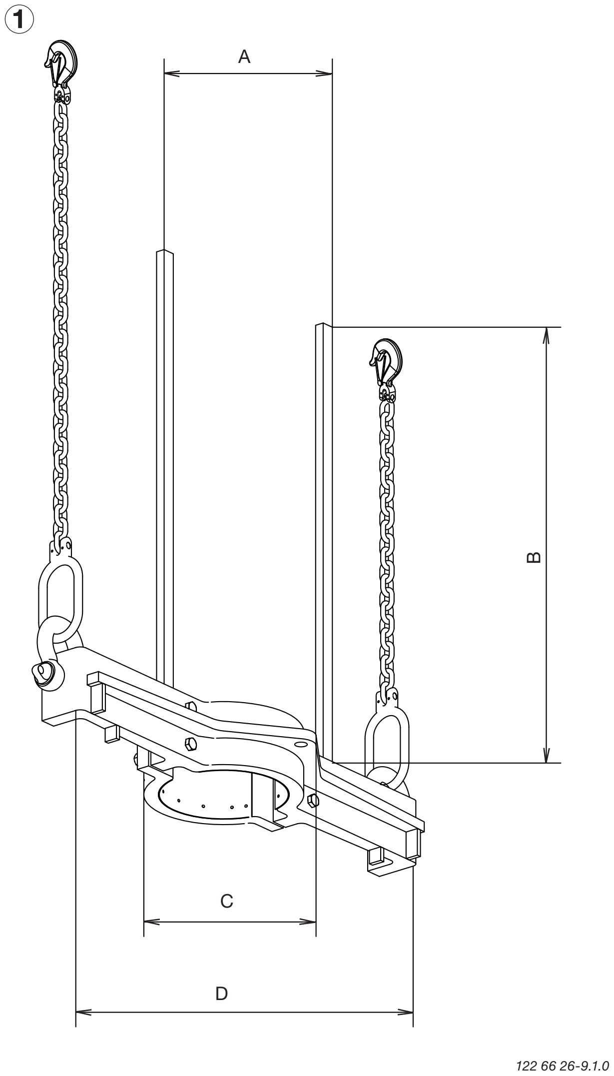
1

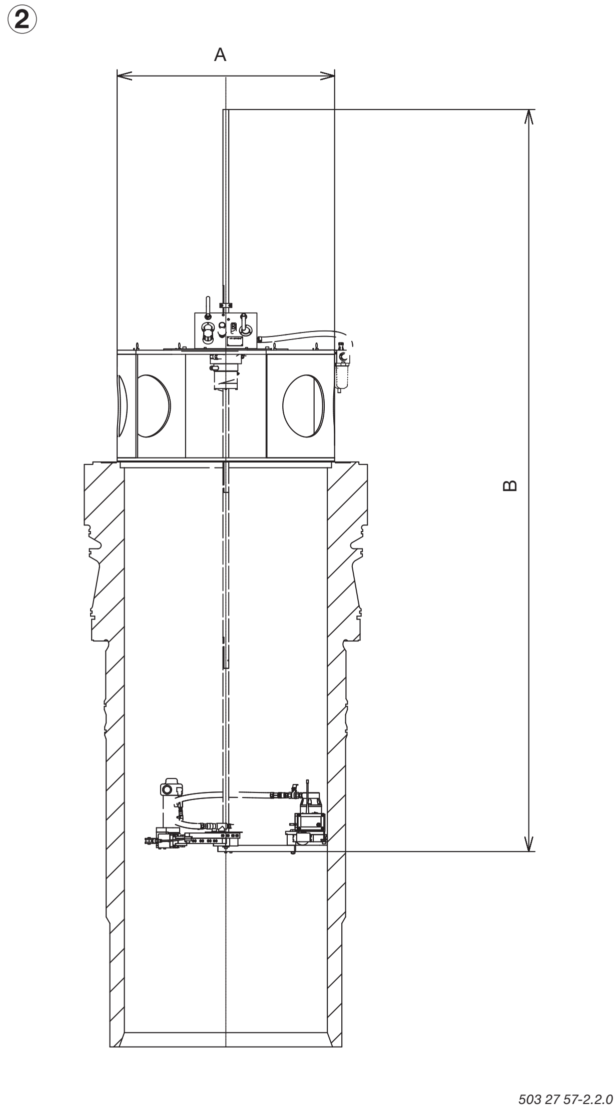


141 32 19-4.1.0

Pos.	Description	Mass	Dimensions (mm)	
		(kg)	A	B
1	Wear ridge milling machine	20	ø670	450

Fig. 19.10.10: Dimensions and masses of tools

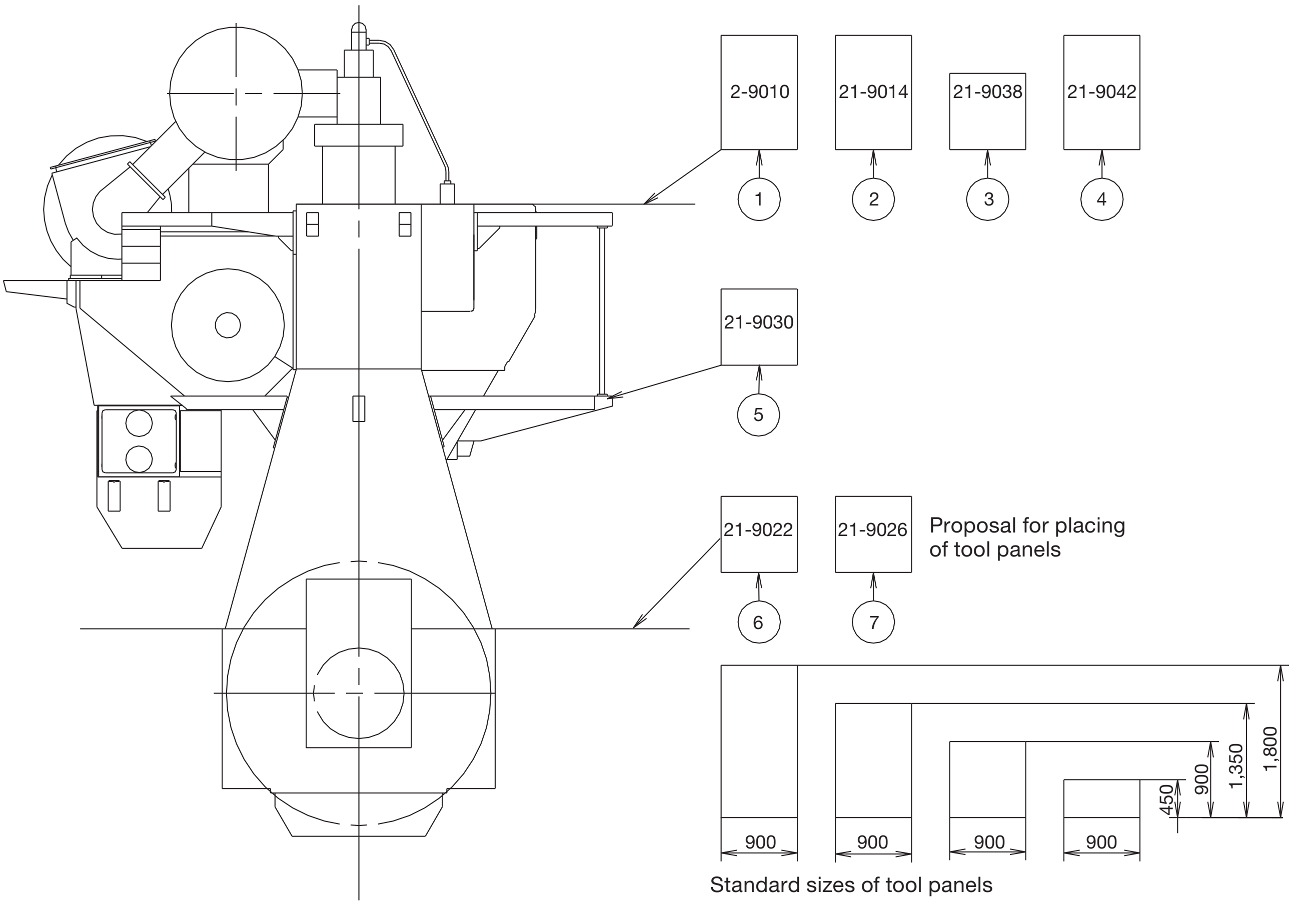




Pos.	Description	Mass	Dimensions (mm)			
		(kg)	A	B	C	D
1	Collar ring for piston	62.4	330	750	352	1,062
2	Wave cutting machine for cylinder liner	230	770	1,075		

Fig. 19.10.11: Dimensions and masses of tools

Tool Panels



178 59 48-2.0

Pos.	Section	Description	Toal mass of tools and panels in kg
1	21-9010	**Cylinder Cover** Tool panel incl. lifting chains, grinding mandrels, extractor tools etc.	219
2	21-9014	**Cylinder Unit Tools** Tool panel incl. pressure testing tool, piston ring expander, stuffing box tools, templates etc.	417
3	21-9038	**Exhaust valve Tools** Tool panel incl. grinding-, lifting-, adjustment- and test tools, etc.	98
4	21-9042	**Fuel oil system Tools** Tool panel incl. grinding-, lifting-, adjustment- and assembly tools, etc.	113
5	21-9030	**Control gear Tools** Tool panel incl. pin gauges, chain assembly tools, camshaft tools, etc.	81
6	21-9022	**Crosshead and Connection rod Tools** Tool panel incl. suspension-, lifting tools, protection in crank case, etc.	117
7	21-9026	**Crankshaft and Thrust bearing Tools** Tool panel incl. lifting-, testing- and retaining tools, etc.	244

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 Diesel & Turbo is able to provide a wide variety of support for the shipping and shipbuilding industries all over the world.

The knowledge accumulated over many decades by MAN Diesel & Turbo covering such fields as the selection of the best propulsion machinery, optimisation of the engine installation, choice and suitability of a Power Take Off for a specific project, vibration aspects, environmental control etc., is available to shipowners, shipbuilders and ship designers alike.

Part of this information can be found in the following documentation:

- Marine Engine Programme
- Turbocharger Selection
- Installation Drawings
- CEAS - Engine Room Dimensioning
- Project Guides
- Extent of Delivery (EOD)
- Technical Papers

The publications are available at:
www.marine.man.eu → 'Two-Stroke'.

Engine Selection Guides

The 'Engine Selection Guides' are intended as a tool to provide assistance at the very initial stage of the project work. The guides give a general view of the MAN B&W two-stroke Programme for MC as well as for ME and ME-B engines and include information on the following subjects:

- Engine data
- Engine layout and load diagrams specific fuel oil consumption
- Turbocharger selection
- Electricity production, including power take off
- Installation aspects
- Auxiliary systems
- Vibration aspects.

After selecting the engine type on the basis of this general information, and after making sure that the engine fits into the ship's design, then a more detailed project can be carried out based on the 'Project Guide' for the specific engine type selected.

Project Guides

For each engine type of MC, ME or ME-B design a 'Project Guide' has been prepared, describing the general technical features of that specific engine type, and also including some optional features and equipment.

The information is general, and some deviations may appear in a final engine documentation, depending on the content specified in the contract and on the individual licensee supplying the engine. The Project Guides comprise an extension of the general information in the Engine Selection Guide, as well as specific information on such subjects as:

- Engine Design
- Engine Layout and Load Diagrams, SFOC
- Turbocharger Selection & Exhaust Gas By-pass
- Electricity Production
- Installation Aspects
- List of Capacities: Pumps, Coolers & Exhaust Gas
- Fuel Oil
- Lubricating Oil
- Cylinder Lubrication
- Piston Rod Stuffing Box Drain Oil
- Central Cooling Water System
- Seawater Cooling
- Starting and Control Air
- Scavenge Air
- Exhaust Gas
- Engine Control System
- Vibration Aspects
- Monitoring Systems and Instrumentation
- Dispatch Pattern, Testing, Spares and Tools
- Project Support and Documentation.

Installation Data Application

Additional customised information can be obtained from MAN Diesel & Turbo as project support. For this purpose, we have developed the CEAS application, by means of which specific calculations can be made during the project stage.

The CEAS application

The CEAS application is found at www.marine.man.eu → 'Two-Stroke' → 'CEAS Engine Calculations'.

On completion of the CEAS application, a report is generated covering the following:

- Main engine room data
- Specified main engine and ratings
- Ambient reference conditions
- Expected SFOC, lube oil consumption, air and exhaust gas data
- Necessary capacities of auxiliary machinery (SMCR)
- Starting air system, engine dimensions, tanks, etc.
- Tables of SFOC and exhaust gas data
- Heat dissipation of engine
- Water condensation separation in air coolers
- Noise – engine room, exhaust gas, structure borne
- Preheating of diesel engine
- Alternative engines and turbochargers, further reading.

Links to related MAN Diesel & Turbo publications and papers are provided, too.

Supplementary project data on request

Further to the data generated by the CEAS application, the following data are available on request at the project stage:

- Estimation of ship's dimensions
- Propeller calculation and power prediction
- Selection of main engine
- Main engines comparison
- Maintenance and spare parts costs of the engine
- Total economy – comparison of engine rooms
- Steam and electrical power – ships' requirement
- Utilisation of exhaust gas heat
- Utilisation of jacket cooling water heat, fresh water production
- Exhaust gas back pressure
- Layout/load diagrams of engine.

Contact MAN Diesel & Turbo, Copenhagen in this regard.

Extent of Delivery

MAN Diesel & Turbo's 'Extent of Delivery' (EoD) is provided to facilitate negotiations between the yard, the engine maker, consultants and the customer in specifying the scope of supply for a specific project involving MAN B&W two-stroke engines.

We provide four different EoDs:

EoD 70-50 MC-C Tier II Engine
EoD 46-35 MC-C Tier II Engines
EoD 98-50 ME/ME-C/ME-C-GI Tier II Engines
EoD 60-30 ME-B Tier II Engines

These publications are available in print and at: www.marine.man.eu → 'Two-Stroke' → 'Extent of Delivery (EoD)'.

Basic items and Options

The 'Extent of Delivery' (EoD) is the basis for specifying the scope of supply for a specific order.

The list consists of 'Basic' and 'Optional' items.

The 'Basic' items define the simplest engine, designed for unattended machinery space (UMS), without taking into consideration any further requirements from the classification society, the yard, the owner or any specific regulations.

The 'Options' are extra items that can be alternatives to the 'Basic', or additional items available to fulfil the requirements/functions for a specific project.

Copenhagen Standard Extent of Delivery

At MAN Diesel & Turbo, Copenhagen, we base our first quotations on a 'mostly required' scope of supply. This is the so-called 'Copenhagen Standard Extent of Delivery', which is made up by options marked with an asterisk * in the far left column in the EoD.

The Copenhagen Standard Extent of Delivery includes:

- Minimum of alarm sensors recommended by the classification societies and MAN Diesel & Turbo
- Moment compensator for certain numbers of cylinders
- MAN turbochargers
- The basic Engine Control System
- CoCoS-EDS ME Basic (for ME/ME-B/-GI only)
- Spare parts either required or recommended by the classification societies and MAN Diesel & Turbo
- Tools required or recommended by the classification societies and MAN Diesel & Turbo.

MAN Diesel & Turbo licencees may select a different extent of delivery as their standard.

EoD and the final contract

The filled-in EoD is often used as an integral part of the final contract.

The final and binding extent of delivery of MAN B&W two-stroke engines is to be supplied by our licensee, the engine maker, who should be contacted in order to determine the execution for the actual project.

Installation Documentation

When a final contract is signed, a complete set of documentation, in the following called 'Installation Documentation', will be supplied to the buyer by the engine maker.

The extent of Installation Documentation is decided by the engine maker and may vary from order to order.

As an example, for an engine delivered according to MAN Diesel & Turbo's 'Copenhagen Standard Extent of Delivery', the Installation Documentation is divided into the volumes 'A' and 'B':

- 4 09 602 Volume 'A'
  Mainly comprises general guiding system drawings for the engine room
- 4 09 603 Volume 'B'
  Mainly comprises specific drawings for the main engine itself.

Most of the documentation in volume 'A' are similar to those contained in the respective Project Guides, but the Installation Documentation will only cover the order-relevant designs.

The engine layout drawings in volume 'B' will, in each case, be customised according to the buyer's requirements and the engine maker's production facilities.

A typical extent of a set of volume 'A' and B' drawings is listed in the following.

For questions concerning the actual extent of Installation Documentation, please contact the engine maker.

Engine-relevant documentation

Engine data, on engine
External forces and moments
Guide force moments
Water and oil in engine
Centre of gravity
Basic symbols for piping
Instrument symbols for piping
Balancing

Engine connections
Engine outline
List of flanges/counterflanges
Engine pipe connections

Engine instrumentation
List of instruments
Connections for electric components
Guidance values automation, engine
Electrical wiring

Engine Control System
Engine Control System, description
Engine Control System, diagrams
Pneumatic system
Speed correlation to telegraph
List of components
Sequence diagram

Control equipment for auxiliary blower
Electric wiring diagram
Auxiliary blower
Starter for electric motors

Shaft line, on engine
Crankshaft driving end
Fitted bolts

Turning gear
Turning gear arrangement
Turning gear, control system
Turning gear, with motor

Spare parts
List of spare parts

Engine paint
Specification of paint

Gaskets, sealings, O-rings
Instructions
Packings
Gaskets, sealings, O-rings

Engine pipe diagrams
Engine pipe diagrams
Bedplate drain pipes
Instrument symbols for piping
Basic symbols for piping
Lubricating oil, cooling oil and hydraulic oil piping
Cylinder lubricating oil pipes
Stuffing box drain pipes
Cooling water pipes, air cooler
Jacket water cooling pipes
Fuel oil drain pipes
Fuel oil pipes
Control air pipes
Starting air pipes
Turbocharger cleaning pipe
Scavenge air space, drain pipes
Scavenge air pipes
Air cooler cleaning pipes
Exhaust gas pipes
Steam extinguishing, in scavenge air box
Oil mist detector pipes, if applicable
Pressure gauge pipes

Engine room-relevant documentation

Engine data, in engine room
List of capacities
Basic symbols for piping
Instrument symbols for piping

Lubricating and cooling oil
Lubricating oil bottom tank
Lubricating oil filter
Crankcase venting
Lubricating and hydraulic oil system
Lubricating oil outlet

Cylinder lubrication
Cylinder lubricating oil system

Piston rod stuffing box
Stuffing box drain oil cleaning system

Seawater cooling
Seawater cooling system

Jacket water cooling
Jacket water cooling system
Deaerating tank
Deaerating tank, alarm device

Central cooling system
Central cooling water system
Deaerating tank
Deaerating tank, alarm device

Fuel oil system
Fuel oil heating chart
Fuel oil system
Fuel oil venting box
Fuel oil filter

Compressed air
Starting air system

Scavenge air
Scavenge air drain system

Air cooler cleaning
Air cooler cleaning system

Exhaust gas
Exhaust pipes, bracing
Exhaust pipe system, dimensions

Engine room crane
Engine room crane capacity, overhauling space

Torsiograph arrangement
Torsiograph arrangement

Shaft earthing device
Earthing device

Fire extinguishing in scavenge air space
Fire extinguishing in scavenge air space

Instrumentation
Axial vibration monitor

Engine seating
Profile of engine seating
Epoxy chocks
Alignment screws

Holding-down bolts
Holding-down bolt
Round nut
Distance pipe
Spherical washer
Spherical nut
Assembly of holding-down bolt
Protecting cap
Arrangement of holding-down bolts

Side chocks
Side chocks
Liner for side chocks, starboard
Liner for side chocks, port side

End chocks
Stud for end chock bolt
End chock
Round nut
Spherical washer, concave
Spherical washer, convex
Assembly of end chock bolt
Liner for end chock
Protecting cap

Engine top bracing
Top bracing outline
Top bracing arrangement
Friction-materials
Top bracing instructions
Top bracing forces
Top bracing tension data

Shaft line, in engine room
Static thrust shaft load
Fitted bolt

Power Take-Off
List of capacities
PTO/RCF arrangement, if fitted

Large spare parts, dimensions
Connecting rod studs
Cooling jacket
Crankpin bearing shell
Crosshead bearing
Cylinder cover stud
Cylinder cover
Cylinder liner
Exhaust valve
Exhaust valve bottom piece
Exhaust valve spindle
Exhaust valve studs
Fuel valve
Main bearing shell
Main bearing studs
Piston complete
Starting valve
Telescope pipe
Thrust block segment
Turbocharger rotor

Gaskets, sealings, O-rings
Gaskets, sealings, O-rings

Material sheets
MAN Diesel & Turbo Standard Sheets Nos.:
- S19R
- S45R
- S25Cr1
- S34Cr1R
- C4

Engine production and installation-relevant documentation

Main engine production records, engine installation drawings
Installation of engine on board
Dispatch pattern 1, or
Dispatch pattern 2
Check of alignment and bearing clearances
Optical instrument or laser
Reference sag line for piano wire
Alignment of bedplate
Piano wire measurement of bedplate
Check of twist of bedplate
Crankshaft alignment reading
Bearing clearances
Check of reciprocating parts
Production schedule
Inspection after shop trials
Dispatch pattern, outline
Preservation instructions

Shop trials
Shop trials, delivery test
Shop trial report

Quay trial and sea trial
Stuffing box drain cleaning
Fuel oil preheating chart
Flushing of lubricating oil system
Freshwater system treatment
Freshwater system preheating
Quay trial and sea trial
Adjustment of control air system
Adjustment of fuel pump
Heavy fuel operation
Guidance values automation

Flushing procedures
Lubricating oil system cleaning instruction

Tools

Engine tools
List of tools
Outline dimensions, main tools

Tool panels
Tool panels

Engine seating tools
Hydraulic jack for holding down bolts
Hydraulic jack for end chock bolts

Auxiliary equipment

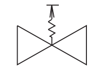
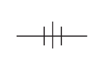
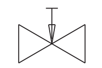
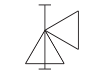
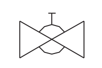
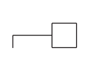
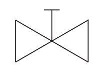
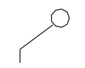
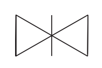
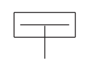
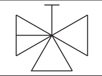
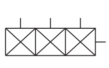
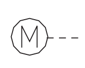
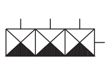
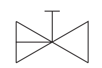
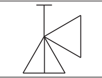
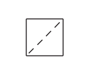
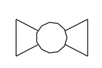
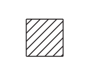
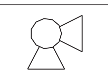
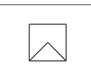
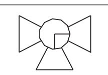
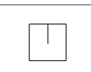
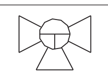
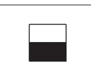
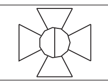
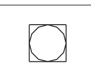
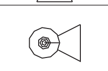
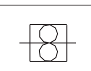
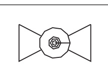
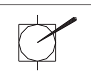
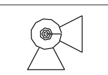
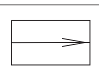
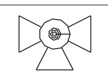
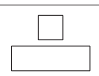
Ordered auxiliary equipment

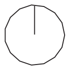
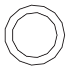
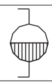
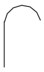
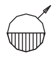
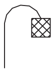
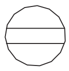
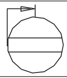
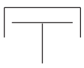
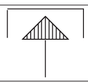
Appendix

A

Symbols for Piping

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

No.	Symbol	Symbol designation	No.	Symbol	Symbol designation
3.14		Quick-opening valve	**4**	**Control and regulation parts**	
3.15		Quick-closing valve	4.1		Hand-operated
3.16		Regulating valve	4.2		Remote control
3.17		Kingston valve	4.3		Spring
3.18		Ballvalve (cock)	4.4		Mass
3.19		Butterfly valve	4.5		Float
3.20		Gate valve	4.6		Piston
3.21		Double-seated changeover valve	4.7		Membrane
3.22		Suction valve chest	4.8		Electric motor
3.23		Suction valve chest with non-return valves	4.9		Electro-magnetic
3.24		Double-seated changeover valve, straight	**5**	**Appliances**	
3.25		Double-seated changeover valve, angle	5.1		Mudbox
3.26		Cock, straight through	5.2		Filter or strainer
3.27		Cock, angle	5.3		Magnetic filter
3.28		Cock, three-way, L-port in plug	5.4		Separator
3.29		Cock, three-way, T-port in plug	5.5		Steam trap
3.30		Cock, four-way, straight through in plug	5.6		Centrifugal pump
3.31		Cock with bottom connection	5.7		Gear or screw pump
3.32		Cock, straight through, with bottom conn.	5.8		Hand pump (bucket)
3.33		Cock, angle, with bottom connection	5.9		Ejector
3.34		Cock, three-way, with bottom connection	5.10		Various accessories (text to be added)

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

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

178 30 61-4.1

Fig. A.01.01: Symbols for piping