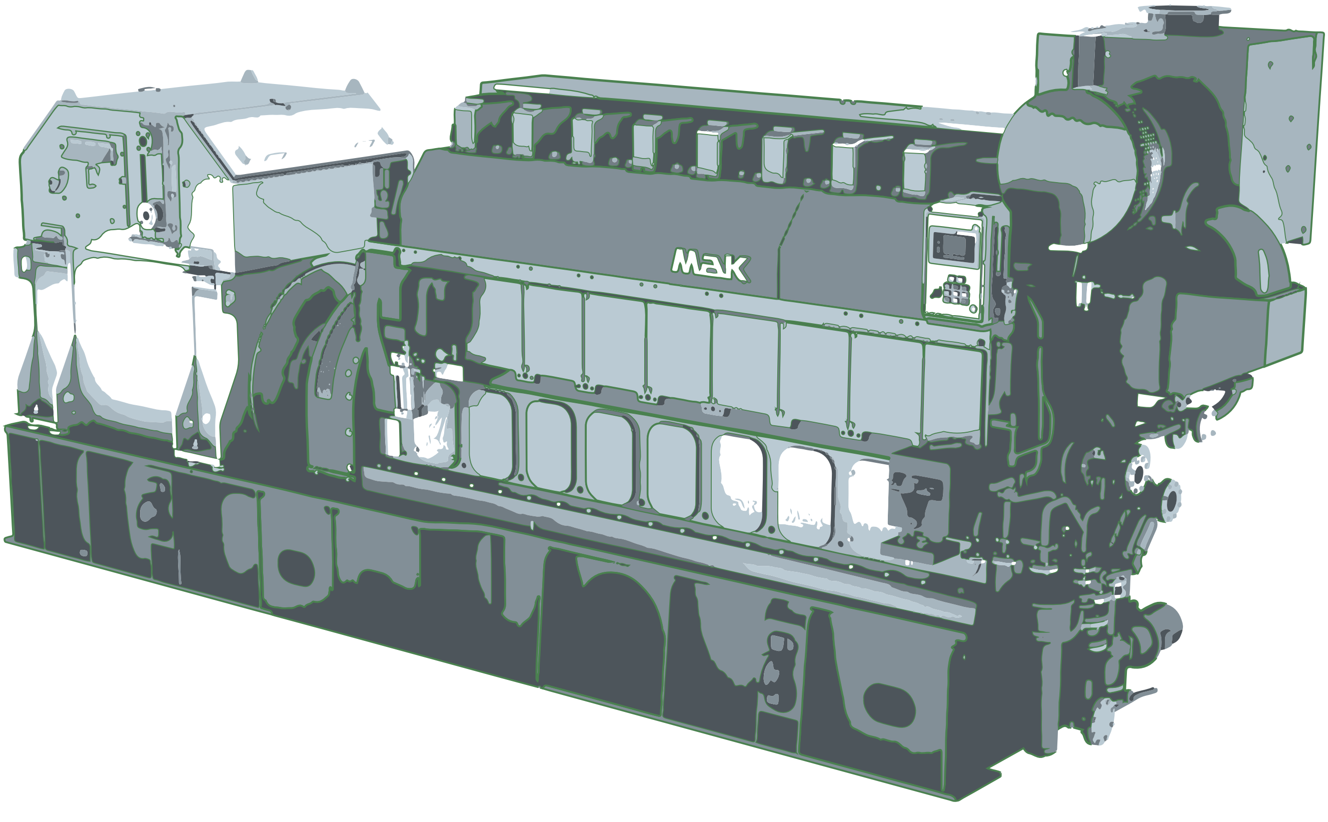
M 25 E

PROJECT GUIDE / GENERATOR SET



MaK

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Binding determination of data is made by means of the Technical Specification and such other agreements as may be entered into in connection with the order. We will supply further binding data, drawings, diagrams, electrical drawings, etc. in connection with a corresponding order.

This edition supersedes the previous edition of this project guide.

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Different kinds of information about MaK marine products

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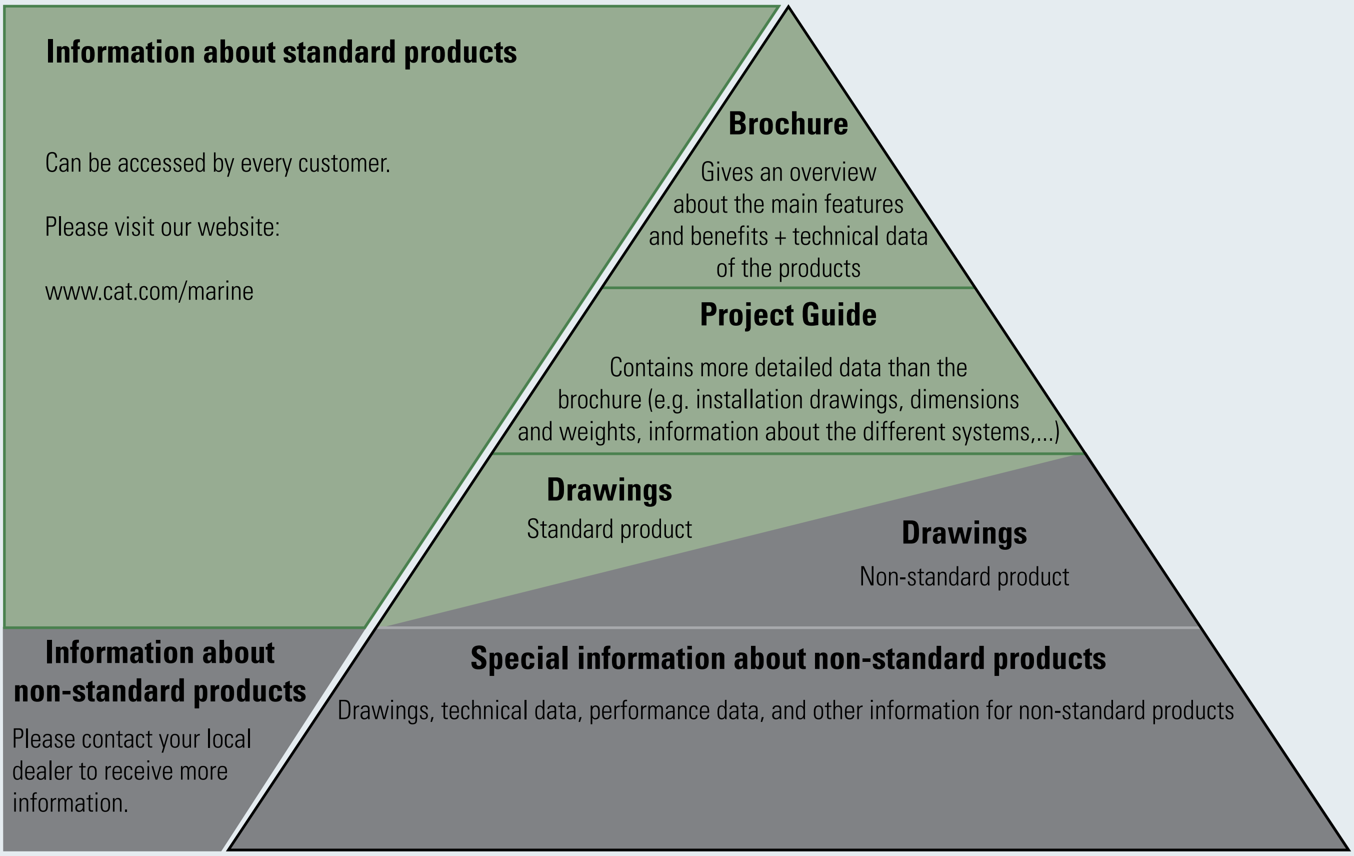

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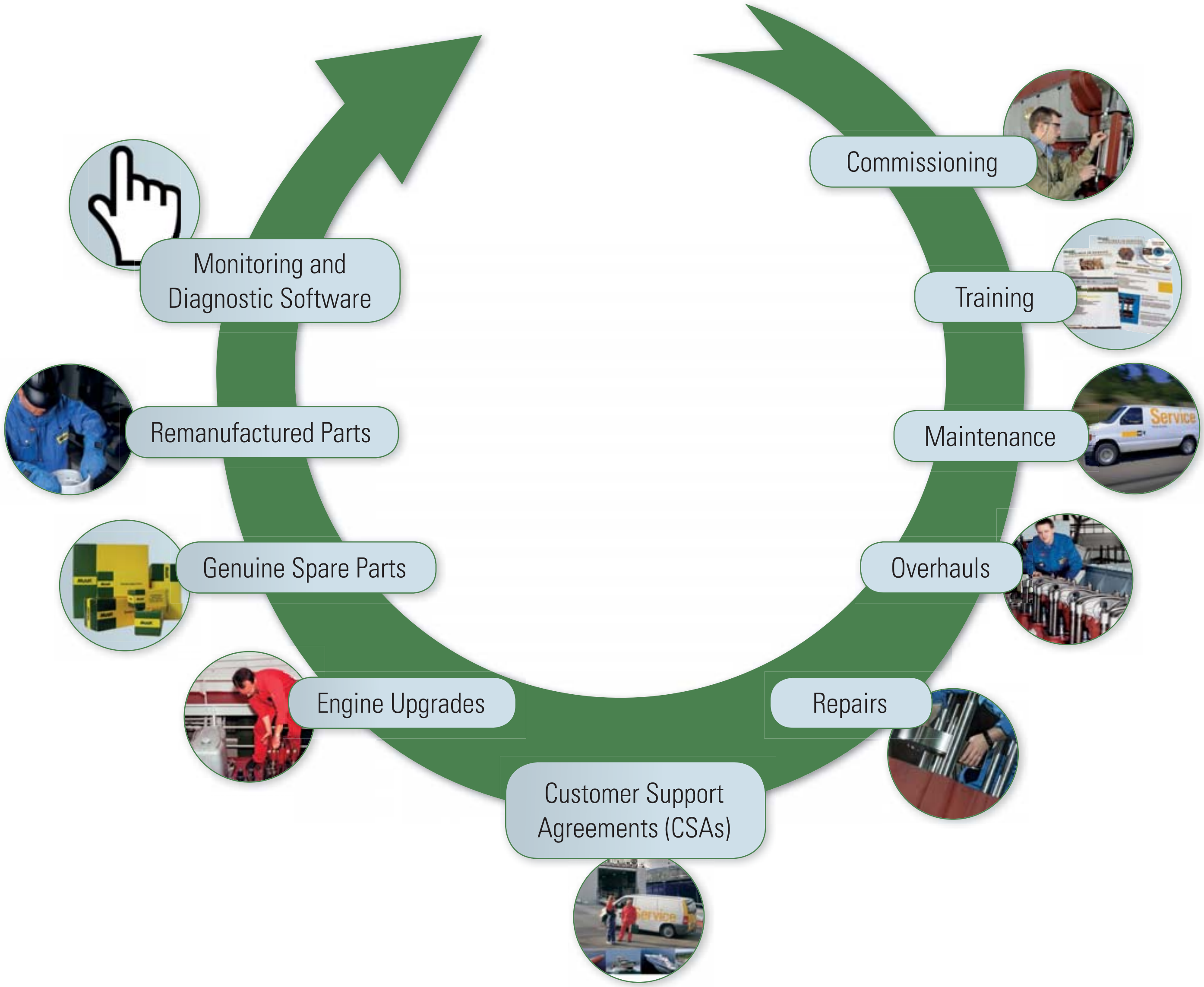

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Certificate No:	Initial certification date:	Valid:
196529-2016-AE-GER-DAkkS	ISO 9001: 03.11.2003 BS OHSAS 18001+ISO 14001: 08.10.2013	26. October 2016 - 07. October 2019

This is to certify that the management system of

Caterpillar Motoren GmbH & Co. KG

Falckensteiner Str. 2, 24159 Kiel, Germany

and the sites as mentioned in the appendix accompanying this certificate

has been found to conform to the Management System standards:

ISO 9001:2015
ISO 14001:2015
BS OHSAS 18001:2007

This certificate is valid for the following scope:

Für Caterpillar Motoren GmbH & Co. KG:
Design, manufacture, sales and service of gas and diesel engines
Für Caterpillar Castings Kiel GmbH:
Manufacturing and selling of qualified handmoulded castings made of grey-, nodular iron and quasiflake
Für Caterpillar Motoren Henstedt-Ulzburg GmbH:
Logistics of spare and serial parts for gas and diesel engines
Für Caterpillar Motoren Rostock GmbH:
Manufacture of gas and diesel engines

Place and date:
Essen, 26. October 2016

DAkkS
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D-ZM-18453-01-00

For the issuing office:
DNV GL - Business Assurance
Schnieringshof 14, 45329 Essen, Germany

Thomas Beck
Technical Manager

Lack of fulfilment of conditions as set out in the Certification Agreement may render this Certificate invalid.
ACCREDITED UNIT: DNV GL Business Assurance Zertifizierung und Umweltgutachter GmbH, Schnieringshof 14, 45329 Essen, Germany.
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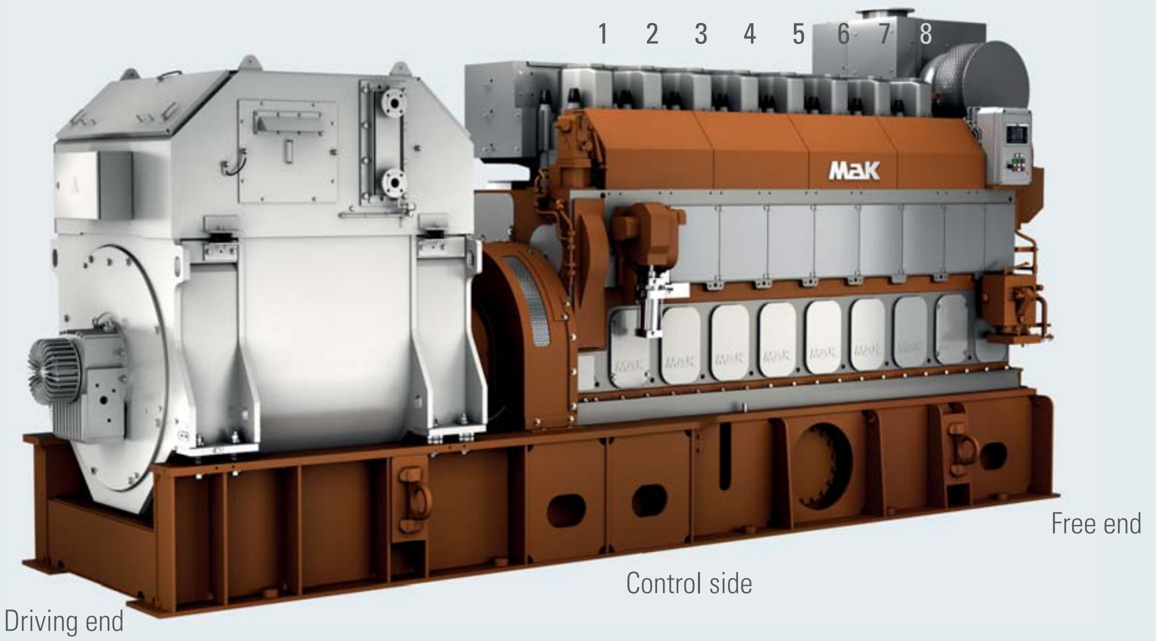
1.1 Definitions



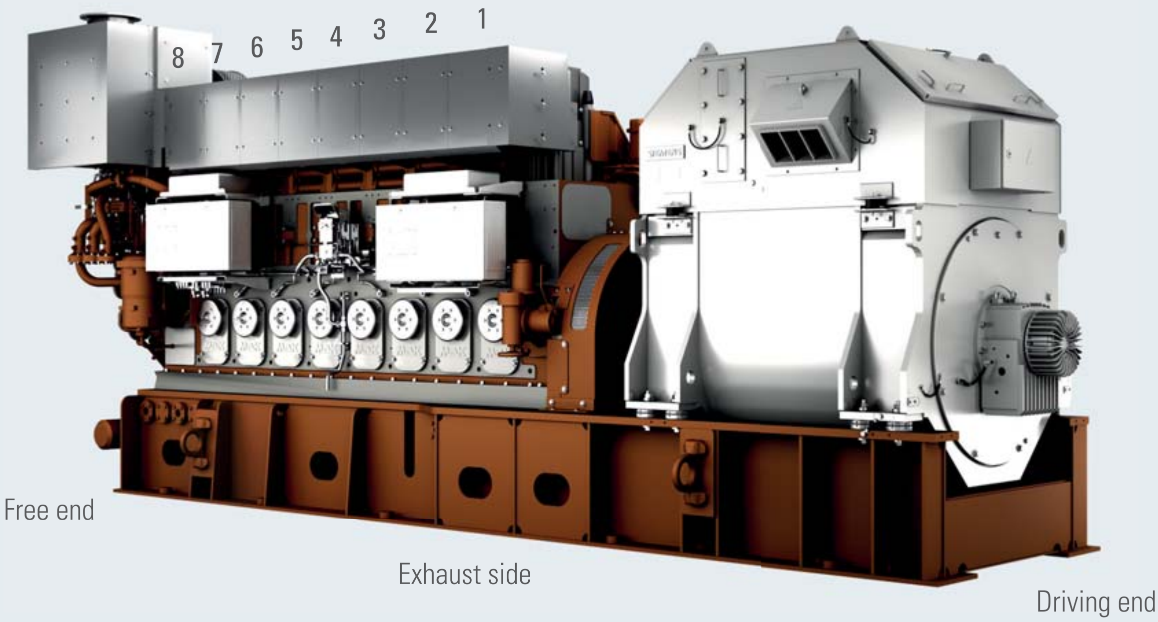


Fig. 1-1 M 25 E

	6 M 25 E	8 M 25 E	9 M 25 E
Output [kW]	2,100	2,800	3,150

Cylinder configuration:	6, 8, 9 in-line
Bore:	255 mm
Stroke:	400 mm
Stroke / bore-ratio:	1.57
Swept volume:	20.4 l/cyl.
Output/cyl:	350 kW
BMEP:	28.56/27.4 bar
Revolutions:	720/750 rpm
Mean piston speed:	9.6/10.0 m/s
Turbocharging:	single log
Direction of rotation:	counter-clockwise, option: clockwise

1.2 Main components and systems

1.2.1 Main features and characteristics

The new M 25 E has been designed to completely meet the ultimate customer requirements, providing the lowest cost of operation while maintaining the highest uptime in the industry.
Since one engine standard typically does not fit all applications, the M 25 E follows a new approach and provides configurations that support various application-specific requirements. Beside a full load version which technically follows the footsteps of its predecessor M 25 C, Caterpillar has designed a part load optimization kit (PLK) for the M 25 E that optimizes engine operation under part load conditions.

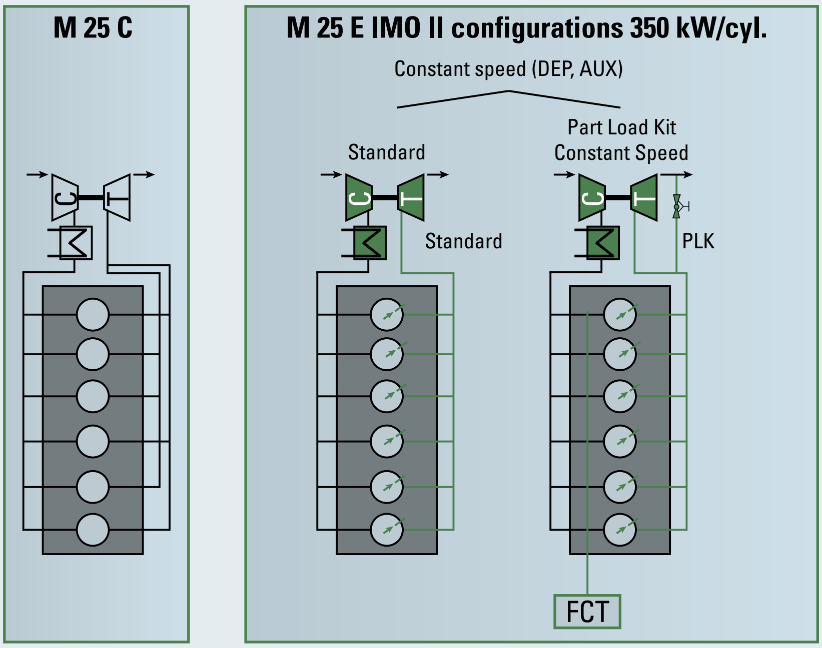


Fig. 1-2 Overview of components

GENSET DESCRIPTION

Based on the proven M 25 C, the M 25 E has been extensively optimized for best fuel consumption and load acceptance, leading reliability and durability, and efficient Selective Catalytic Reduction (SCR) operation.
The service and maintenance-friendly design, remote condition monitoring and diagnostic capabilities, as well as our unmatched global product support, respond to the industry's desire to lower operational costs and downtimes beyond today's standards.
For ultimate efficiency and performance, the M 25 E is available as a part of our integrated propulsion packages with Caterpillar Propulsion controllable pitch propellers (CPP) and Azimuth drives.

1.2.2 Description of components

Cylinder head
- Optimized design from baseline engine M 25 C.
- Material: Nodular cast iron.
- Two inlet and two exhaust valves equipped with valve rotators.
- Exhaust valve seats are directly water cooled.
- Valve and seat design is applicable for different fuel modes: HFO, low sulphur fuel and MDO

Connecting rod and piston
- Common design from baseline engine M 25 C.
- Composite piston with forged steel top and nodular cast iron skirt.
- Three piston rings to minimize lube oil consumption.
- Angle split design for conrod.

Engine block
Core element of the M 25 E is the engine block, which is made of nodular cast iron in one piece.
The advantages of the engine block design are:
- Experienced and identical design from baseline engine M 25 C.
- One-piece design.
- Material: Nodular cast iron.
- High stiffness, robust and warp resistant.
- Integrated main oil supply ducts and charge air channel.
- Free from cooling water.
- Integrated housings for crankshaft and camshaft dampers, for gear train and integrated camshaft channel.
- Main and camshaft bearing bore system.
- Large inspection doors for services for the bearings, crankshaft, camshaft and conrod.

Safe and simple power train
The safe and simple designed power train of cylinder head, piston with liner, connecting rod and camshaft is parted in cylinder compartments, while the crankshaft is one-piece. The advantage is simplification of maintenance work saving costs.
Additional advantages are:
- Service friendly distribution of media in maintenance-free plugged pipes and cast blocks.
- 2-stage fresh water cooling system with 2-stage charge air cooler.
- Turbocharger supplied with inboard plain bearings which are lubricated by engine lube oil.
- Part Load optimization Kit (PLK) for reduced smoke emissions available.

1.3 Prospective life times

General

The expectable TBO (time between overhaul) and actual life time may deviate significantly as a result of, fuel quality, load and operating profile, conditions, quality of maintenance and other external factors.

Core components	Life time operating hours [h] M 25 E Generator Set		
	MDO	HFO	TBO M 25 E
Piston crown (life time incl. 2 stages rework)	90,000	90,000	30,000
Piston skirt cast iron (standard)	60,000	60,000	–
Piston skirt steel (optional)	90,000	90,000	–
Piston rings	30,000	30,000	–
Piston pin bearing	60,000	60,000	–
Cuff / Antipolishing ring	30,000	30,000	–
Cylinder liner	90,000	60,000	–
Cylinder head	90,000	90,000	15,000
Inlet valve	30,000	30,000	15,000
Exhaust valve	30,000	30,000	15,000
Nozzle element	7,500	5,000	–
Pump element	15,000	15,000	–
Main bearing	30,000	30,000	–
Big end bearing	30,000	30,000	–
Camshaft bearing	45,000	45,000	–
Turbocharger plain bearing	12,000	12,000	–
Vibration damper camshaft	15,000	15,000	–
Vibration damper crankshaft	60,000	60,000	30,000

The above mentioned data are only indicative and relate to an average component life time under favourable operating conditions.

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	720 rpm/60 Hz		750 rpm/50 Hz	
	Engine [kW]	Generator [kWe]	Engine [kW]	Generator [kWe]
6 M 25 E	2,100	2,016	2,100	2,016
8 M 25 E	2,800	2,688	2,800	2,688
9 M 25 E	3,150	3,024	3,150	3,024

The generator outputs are based on 96 % efficiency and a power factor of 0.8.

2.1 General definition of reference conditions

The maximum continuous rating (locked output) stated by Caterpillar Motoren refers to the following reference conditions according to „IACS" (International Association of Classification Societies) for main and auxiliary engines (tropical conditions):

Air pressure:	100 kPa (1 bar)
Air temperature:	318 K (45 °C)
Relative humidity:	60 %
Seawater temperature:	305 K (32 °C)

The permissible overload is 10 % for one hour every twelve hours. The maximum fuel rack position is limited to 110 % continuous rating.

2.2 Reference conditions regarding fuel consumption

Fuel consumption data is based on the following reference conditions:

Intake temperature:	298 K (25 °C)
Charge air coolant inlet temperature:	298 K (25°C)
Net heating value of the diesel oil:	42,700 kJ/kg
Tolerance:	5 %

Specification of fuel consumption data without engine driven pumps;
for each pump driven on an additional consumption has to be calculated.

Additional BSFC per engine driven lube oil pump:

Power	100 %	85 %	75 %	50 %	25 %
Constant speed	1.0 %	1.2 %	1.3 %	2.0 %	4.0 %
Prop. curve	1.0 %	1.1 %	1.2 %	1.4 %	2.0 %

Additional BSFC per engine driven cooling water pump:

Power	100 %	85 %	75 %	50 %	25 %
Constant speed	0.4 %	0.47 %	0.53 %	0.8 %	1.6 %
Prop. curve	0.4 %	0.4 %	0.4 %	0.4 %	0.4 %

2.3 Lube oil consumption

Actual data can be inferred from the technical data (Please see chapter 3.).

2.4 Emissions

2.4.1 Exhaust gas

Tolerance:	5 %	Atmospheric pressure:	100 kPa (1 bar)
Relative humidity:	60 %	Constant speed	720/750 1/min

	Output [kW]	Output % [kg/h] [°C]			
		100	90	80	70
Intake air temperature 25 °C					
6 M 25 E	2,100	15,790 330	13,700 330	12,280 320	8,270 360
6 M 25 E (PLK)	2,100	14,270 340	12,700 330	11,340 325	7,210 360
8 M 25 E	2,800	20,530 325	17,900 320	15,530 330	10,420 365
8 M 25 E (PLK)	2,800	20,290 310	17,990 300	16,340 295	11,210 325
9 M 25 E	3,150	22,780 325	19,860 320	17,230 330	11,560 365
9 M 25 E (PLK)	3,150	22,520 310	19,960 300	18,130 295	12,440 325

NOTE:

Definitions regarding ambient conditions

All technical data regarding exhaust gas (exhaust gas mass flow, stack temperature, heat balance) are given at ISO condition. For differing ambient conditions (e.g. IACS tropical conditions) these values have to be corrected.

Suction air temperature

Exhaust gas mass flow	-2.5 % per 10 K suction air temperature
Exhaust gas temperature	+12 K per 10 K suction air temperature
Heat rejection to jacket water	+ 2.0 % per 10 K suction air temperature
Heat rejection to lube oil	+ 0.5 % per 10 K suction air temperature
Heat rejection to HT water	+ 4.0 % per 10 K suction air temperature
Heat rejection to LT water	+ 1.0 % per 10 K suction air temperature

NOTE:

Caterpillar Motoren does not allow to use this technical information for designing or certifying exhaust gas after treatment devices of third party SCR suppliers.

2.4.2 Nitrogen oxide emissions (NO_x-values)

NO_x-limit values according to IMO II: 9.60 g/kWh (n=750 rpm)
Variable speed acc. to cycle E2: 9.50 g/kWh

Genset acc. cycle D2: 9.50 g/kWh

2.4.3 Engine International Air Pollution Prevention Certificate

The MARPOL Diplomatic Conference has agreed about a limitation of NO_x emissions, referred to as Annex VI to MARPOL 73/78.
When testing the engine for NO_x emissions, the reference fuel is marine diesel oil (distillate) and the test is performed according to ISO 8178 test cycles:

	Test cycle type E2				Test cycle type D2				
Speed	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %
Power	100 %	75 %	50 %	25 %	100 %	75 %	50 %	25 %	10 %
Weighting factor	0.2	0.5	0.15	0.15	0.05	0.25	0.3	0.3	0.1

Subsequently, the NO_x value is calculated using different weighting factors for different loads that have been corrected to ISO 8178 conditions.

An NO_x emission evidence will be issued for each engine showing that the engine complies with the regulation. The evidence will come as EAPP (Engine Air Pollution Prevention) Statement of Compliance, EAPP Document of Compliance or EIAPP (Engine International Air Pollution Prevention) Certificate according to the authorization by the flag state and related technical file. For the most part on basis of an EAPP Statement of Compliance or an EAPP Document of Compliance an EIAPP certificate can be applied for.

According to the IMO regulations, a technical file shall be provided for each engine. This technical file contains information about the components affecting NO_x emissions, and each critical component is marked with a special IMO number. Such critical components are piston, cylinder head, injection nozzle (element), camshaft section, fuel injection pump, turbocharger and charge air cooler. (For Common Rail engines the controller and the software are defined as NO_x relevant components instead of the injection pump.) The allowable settings and parameters for running the engine are also specified in the technical file.

The marked components can be easily identified on-board of the ship by the surveyor and thus an IAPP (International Air Pollution Prevention) certificate for the ship can be issued on basis of the EIAPP certificate and the on-board inspection.

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2.5 Genset dimensions and weight

Turbocharger at free end

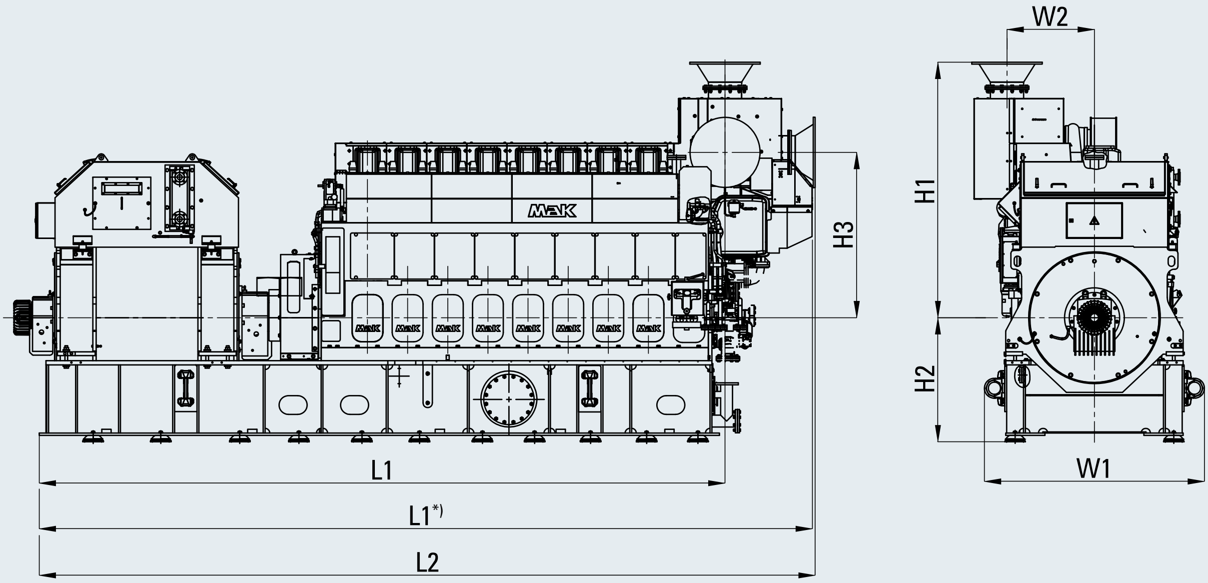

Fig. 2-1 Turbocharger at free end

	Dimensions [mm]								Dry weight **)
	Turbocharger nozzle position 0°						Turbocharger nozzle position 90°		
	L1	L2	H1	H2	W1	W2	L1*)	H3	[t]
6 M 25 E	6,776	7,717	2,555	1,329	2,357	850	7,579	1,734	43.0
8 M 25 E	7,347	8,283	2,700	1,329	2,357	937	8,283	1,770	53.0
9 M 25 E	7,777	8,743	2,700	1,329	2,357	937	8,713	1,770	56.0

*) Depending on generator

2.6 System connecting points

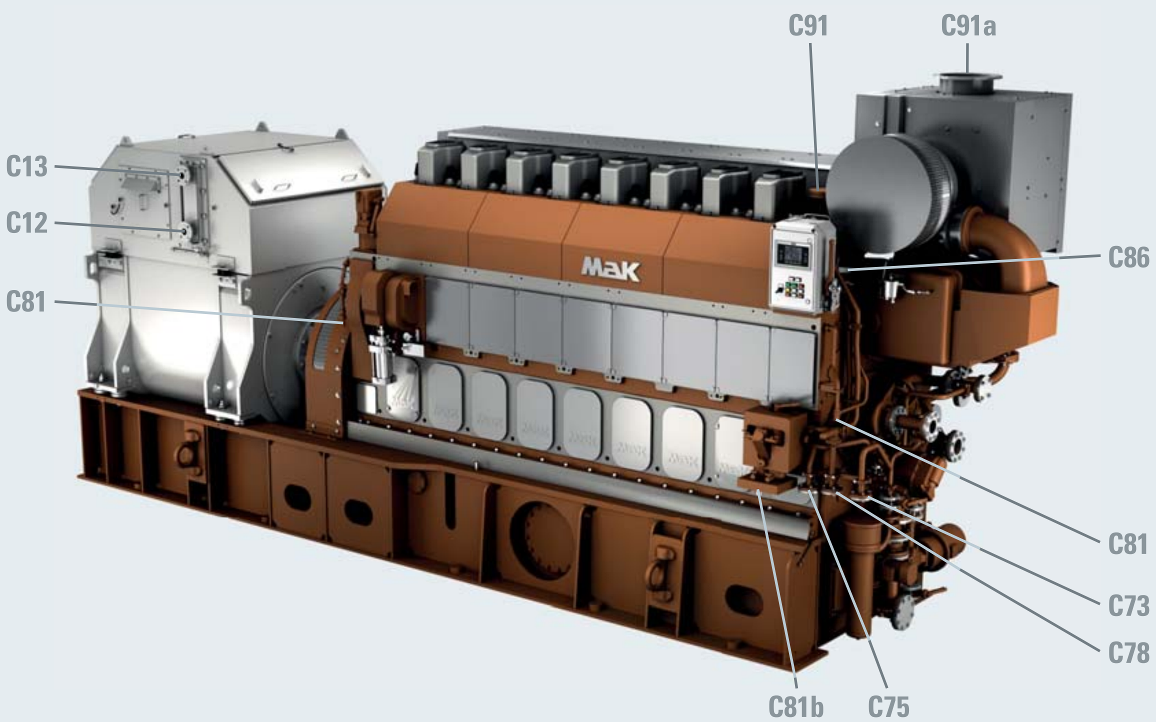

Fig. 2-2 Connecting points at the engine – 1

C12	Generator cooler, inlet	C81	Drip fuel connection
C13	Generator cooler, outlet	C81b	Drip fuel connection (filter pan)
C73	Engine fitted pump, fuel inlet	C86	Connection starting air
C75	Connection stand-by pump	C91	Crankcase ventilation to stack
C78	Fuel outlet	C91a	Exhaust gas outlet

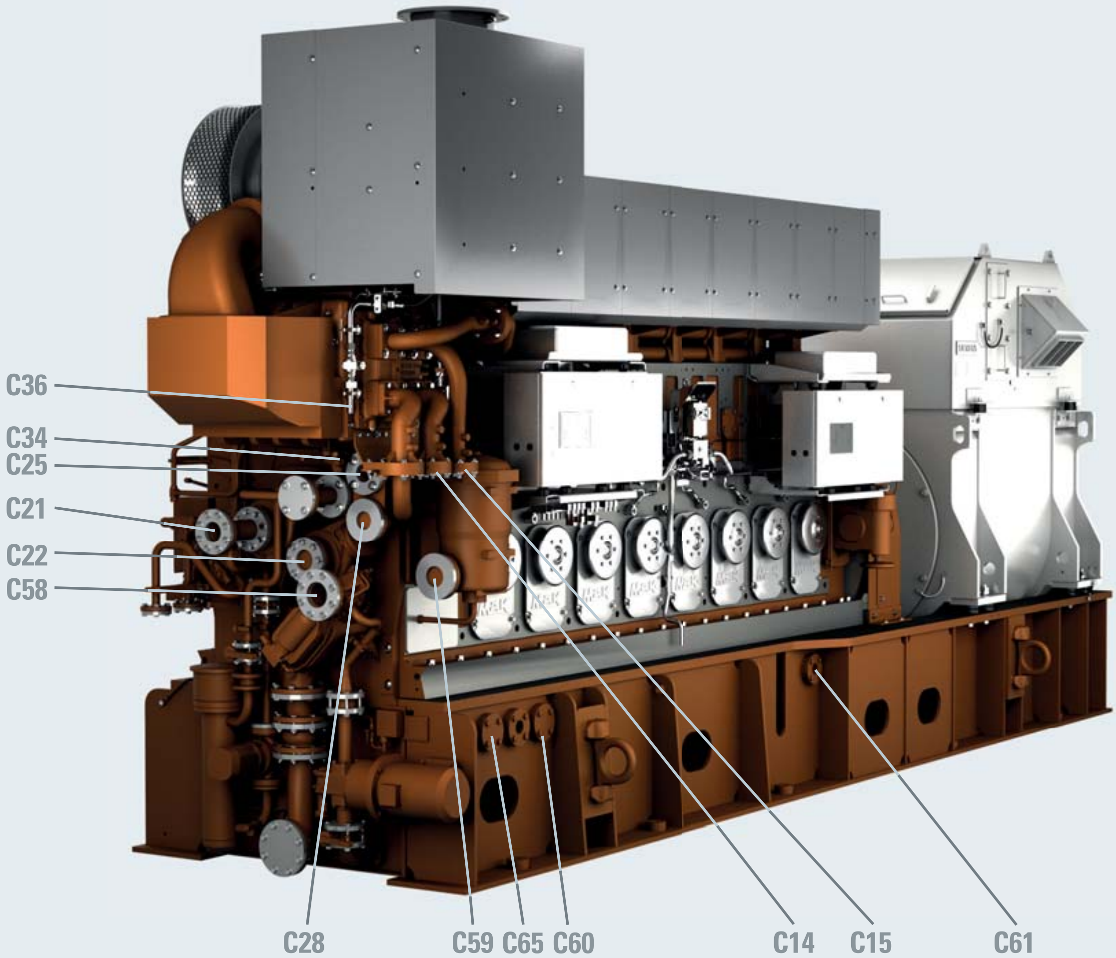

Fig. 2-3 Connecting points at the engine – 2

C14	Charge air cooler LT, inlet
C15	Charge air cooler LT, outlet
C21	Freshwater pump HT, inlet
C22	Freshwater pump LT, inlet
C25	Cooling water, engine outlet
C28	Freshwater pump LT, outlet
C34	Drain, condensate separator, charge air cooler
C36	Drain, turbocharger washing
C58	Force pump, delivery side
C59	Self-cleaning lube oil filter
C60	Separator connection, suction side, drain, filling pipe
C61	Separator connection, delivery side, from by-pass filter
C65	Lube oil filling socket

3.1 Diesel, mechanical – 6 M 25 E

This table does only contain IMO II data.

6 M 25 E			Standard	PLK constant speed
Performance data				
Maximum continuous rating acc. ISO 3046/1		[kW]	2,100	
Speed		[1/min]	750/720	
Minimum speed		[1/min]	250	
Brake mean effective pressure		[bar]	27.4/28.6	
Combustion air demand (ta=25 °C)		[m³/h]	13,150	11,850
Brake specific fuel oil consumption				
Rated operation curve [1) 6)]	100 %	[g/kWh]	187	189
	85 %	[g/kWh]	183	185
	75 %	[g/kWh]	183	184
	50 %	[g/kWh]	191	191
	25 %	[g/kWh]	219	212
Specific lube oil consumption [2)]		[g/kWh]	0.6	
NO_x-emission [5)]		[g/kWh]	9.6/9.69	
Turbocharger type			KBB ST 5	
Fuel				
Engine driven booster pump		[m³/h/bar]	2.1/5.0	
Stand-by booster pump		[m³/h/bar]	1.5/10.0	
Mesh size MDO fine filter		[μm]	25	
Mesh size HFO automatic filter		[μm]	10	
Mesh size HFO fine filter		[μm]	34	
Lube oil				
Engine driven pump		[m³/h/bar]	93/10	
Independent pump		[m³/h/bar]	45/10	
Working pressure on engine inlet		[bar]	4 - 5	
Engine driven suction pump		[m³/h/bar]	–/–	
Independent suction pump		[m³/h/bar]	57/3	
Priming pump		[m³/h/bar]	6.6/5	
Sump tank content		[m³]	2.9	
Temperature at engine inlet		[°C]	60 - 65	
Temperature controller NB		[mm]	80	
Double filter NB		[mm]	80	
Mesh size double filter		[μm]	80	
Mesh size automatic filter		[μm]	30	

6 M 25 E		Standard	PLK constant speed
Fresh water cooling			
Engine content	[dm³]	200	
Pressure at engine inlet min/max	[bar]	2.5 - 6.0	
Header tank capacity	[dm³]	200	
Temperature at engine outlet	[°C]	80 - 90	
Two circuit system			
Engine driven HT pump	[m³/h/bar]	40/4.5	
Independent HT pump	[m³/h/bar]	40/4.0	
HT-controller NB	[mm]	80	
Water demand LT-charge air cooler	[m³/h]	40	
Temperature at LT-charge air cooler inlet	[°C]	32	
Heat dissipation			
Jacket water	[kW]	290	295
Charge air cooler (HT-stage) [3)]	[kW]	510	525
Charge air cooler (LT-stage) [3)]	[kW]	285	295
Lube oil cooler	[kW]	290	
Heat radiation	[kW]	60	
Exhaust gas			
Silencer / spark arrestor NB	[mm]	500	
Pipe diameter NB after turbine	[mm]	500	
Maximum exhaust gas pressure drop	[mbar]	35	
Starting air			
Starting air pressure max.	[bar]	30	
Minimum starting air pressure	[bar]	7	
Air consumption per start [4)]	[m³]	0.8	
Max. allowed crankcase pressure, ND venti-lation pipe	[mbar/mm]	1.5/80	

1) Reference conditions: Please see chapter 2.2 for details. / **2)** Standard value, tolerance ± 50 %, related on full load / **3)** Charge air heat based on 25 °C ambient temperature / **4)** Preheated engine / **5)** Marpol 73/78, Annex VI, cycle E2, D2 / **6)** Please see chapter 10.3 for varying values.

3.2 Diesel, mechanical – 8 M 25 E

This table does only contain IMO II data.

8 M 25 E		Standard	PLK constant speed
Performance data			
Maximum continuous rating acc. ISO 3046/1	[kW]	2,800	
Speed	[1/min]	750/720	
Minimum speed	[1/min]	250	
Brake mean effective pressure	[bar]	27.4/28.6	
Combustion air demand (ta=25 °C)	[m³/h]	17,080	16,870
Brake specific fuel oil consumption			
Rated operation curve [1) 6)] 100 %	[g/kWh]	187	189
85 %	[g/kWh]	183	185
75 %	[g/kWh]	183	184
50 %	[g/kWh]	191	191
25 %	[g/kWh]	219	212
Specific lube oil consumption [2)]	[g/kWh]	0.6	
NO_x-emission [5)]	[g/kWh]	9.6/9.69	
Turbocharger type		KBB ST 6	
Fuel			
Engine driven booster pump	[m³/h/bar]	2.1/5.0	
Stand-by booster pump	[m³/h/bar]	2.0/10.0	
Mesh size MDO fine filter	[µm]	25	
Mesh size HFO automatic filter	[µm]	10	
Mesh size HFO fine filter	[µm]	34	
Lube oil			
Engine driven pump	[m³/h/bar]	93/10	
Independent pump	[m³/h/bar]	60/10	
Working pressure on engine inlet	[bar]	4 - 5	
Engine driven suction pump	[m³/h/bar]	–/–	
Independent suction pump	[m³/h/bar]	70/3	
Priming pump	[m³/h/bar]	10/5	
Sump tank content	[m³]	3.9	
Temperature at engine inlet	[°C]	60 - 65	
Temperature controller NB	[mm]	100	
Double filter NB	[mm]	80	
Mesh size double filter	[µm]	80	
Mesh size automatic filter	[µm]	30	

8 M 25 E		Standard	PLK constant speed
Fresh water cooling			
Engine content	[dm³]	250	
Pressure at engine inlet min/max	[bar]	2.5 - 6.0	
Header tank capacity	[dm³]	250	
Temperature at engine outlet	[°C]	80 - 90	
Two circuit system			
Engine driven HT pump	[m³/h/bar]	55.0/4.5	
Independent HT pump	[m³/h/bar]	55.0/4.0	
HT-controller NB	[mm]	100	
Water demand LT-charge air cooler	[m³/h]	55	
Temperature at LT-charge air cooler inlet	[°C]	32	
Heat dissipation			
Jacket water	[kW]	390	395
Charge air cooler (HT-stage) 3)	[kW]	680	720
Charge air cooler (LT-stage) 3)	[kW]	380	385
Lube oil cooler	[kW]	390	
Heat radiation	[kW]	80	
Exhaust gas			
Silencer / spark arrestor NB	[mm]	600	
Pipe diameter NB after turbine	[mm]	600	
Maximum exhaust gas pressure drop	[mbar]	35	
Starting air			
Starting air pressure max.	[bar]	30	
Minimum starting air pressure	[bar]	7	
Air consumption per start 4)	[m³]	0.8	
Max. allowed crankcase pressure, ND ventilation pipe	[mbar/mm]	1.5/80.0	

1) Reference conditions: Please see chapter 2.2 for details. / **2)** Standard value, tolerance ± 50 %, related on full load / **3)** Charge air heat based on 25 °C ambient temperature / **4)** Preheated engine / **5)** Marpol 73/78, Annex VI, cycle E2, D2 / **6)** Please see chapter 10.3 for varying values.

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3.3 Diesel, mechanical – 9 M 25 E

This table does only contain IMO II data.

9 M 25 E		Standard	PLK constant speed
Performance data			
Maximum continuous rating acc. ISO 3046/1	[kW]	3,150	
Speed	[1/min]	750/720	
Minimum speed	[1/min]	250	
Brake mean effective pressure	[bar]	27.4/28.6	
Combustion air demand (ta=25 °C)	[m³/h]	18,950	18,720
Brake specific fuel oil consumption			
Rated operation curve [1) 6)] 100 %	[g/kWh]	187	189
85 %	[g/kWh]	183	185
75 %	[g/kWh]	183	184
50 %	[g/kWh]	191	188
25 %	[g/kWh]	219	212
Specific lube oil consumption [2)]	[g/kWh]	0.6	
NO_x-emission [5)]	[g/kWh]	9.6/9.69	
Turbocharger type		KBB ST 6	
Fuel			
Engine driven booster pump	[m³/h/bar]	2.1/5.0	
Stand-by booster pump	[m³/h/bar]	2.3/10.0	
Mesh size MDO fine filter	[μm]	25	
Mesh size HFO automatic filter	[μm]	10	
Mesh size HFO fine filter	[μm]	34	
Lube oil			
Engine driven pump	[m³/h/bar]	93/10	
Independent pump	[m³/h/bar]	60/10	
Working pressure on engine inlet	[bar]	4 - 5	
Engine driven suction pump	[m³/h/bar]	–/–	
Independent suction pump	[m³/h/bar]	70/3	
Priming pump	[m³/h/bar]	10/5	
Sump tank content	[m³]	4.3	
Temperature at engine inlet	[°C]	60 - 65	
Temperature controller NB	[mm]	100	
Double filter NB	[mm]	80	
Mesh size double filter	[μm]	80	
Mesh size automatic filter	[μm]	30	

9 M 25 E		Standard	PLK constant speed
Fresh water cooling			
Engine content	[dm³]	280	
Pressure at engine inlet min/max	[bar]	2.5 - 6.0	
Header tank capacity	[dm³]	300	
Temperature at engine outlet	[°C]	80 - 90	
Two circuit system			
Engine driven HT pump	[m³/h/bar]	60.0/4.7	
Independent HT pump	[m³/h/bar]	60.0/4.0	
HT-controller NB	[mm]	100	
Water demand LT-charge air cooler	[m³/h]	60	
Temperature at LT-charge air cooler inlet	[°C]	32	
Heat dissipation			
Jacket water	[kW]	435	440
Charge air cooler (HT-stage) [3]	[kW]	765	770
Charge air cooler (LT-stage) [3]	[kW]	430	435
Lube oil cooler	[kW]	435	
Heat radiation	[kW]	90	
Exhaust gas			
Silencer / spark arrestor NB	[mm]	600	
Pipe diameter NB after turbine	[mm]	600	
Maximum exhaust gas pressure drop	[mbar]	35	
Starting air			
Starting air pressure max.	[bar]	30	
Minimum starting air pressure	[bar]	7	
Air consumption per start [4]	[m³]	0.8	
Max. allowed crankcase pressure, ND ventilation pipe	[mbar/mm]	1.5/80.0	

1) Reference conditions: Please see chapter 2.2 for details. / **2)** Standard value, tolerance ± 50 %, related on full load / **3)** Charge air heat based on 25 °C ambient temperature / **4)** Preheated engine / **5)** Marpol 73/78, Annex VI, cycle E2, D2 / **6)** Please see chapter 10.3 for varying values.

4.1 Load application and recovery behaviour

Recovery behaviour after a sudden load increase according to load steps depending on pme/unloading corresponding ISO 8528-5.

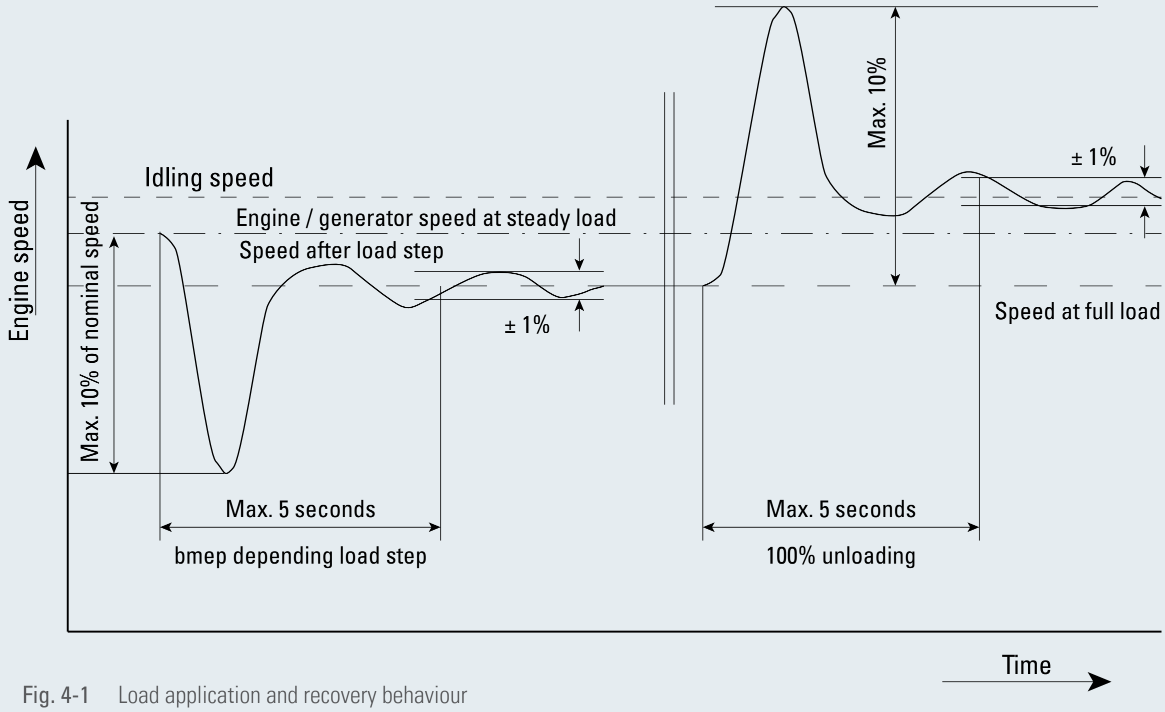

Fig. 4-1 Load application and recovery behaviour

4.1.1 Standard operation

Our standard loading procedure for M 25 E engines to achieve recovery behaviour in accordance with class requirements

The permissible load increase according to ISO 8528-5 and IACS must be carried out in several steps, depending on the mean effective pressure. The ship's network must be designed so that this permissible load increase is kept. The shipyard is to provide the approval of the responsible classification society in time before classification acceptance of the engine. Guide values for maximum possible sudden power increases as a function of brake mean effective pressure, pme, at declared power.

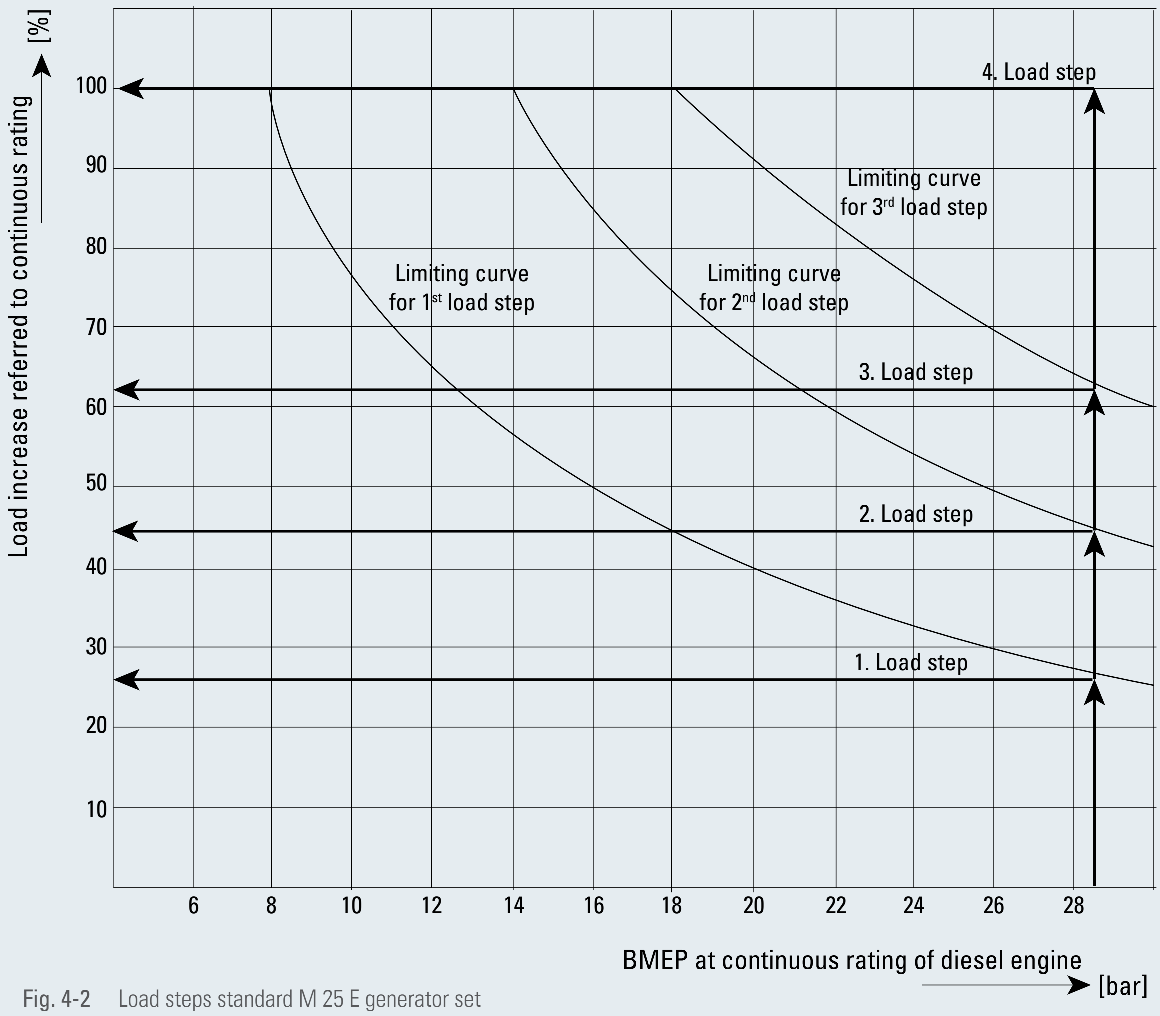

Fig. 4-2 Load steps standard M 25 E generator set

Example: Version standard 6 M 25 E, 2,100 kW, bmep = 28.56 bar
Curves are provided as typical examples.

1. Max. load from 0% to 26% output
2. Max. load from 26% to 44% output
3. Max. load from 44% to 62% output
4. Max. load from 62% to 100% output

4.1.2 Optimized operation

To enable an improved load capacity with three load steps to 100 % load for optimized operation e.g. DP2/DP3 application, our Part Load Kit for constant speed operation is needed. Please find detailed information about the benefits and the scope of supply of the Part Load Kit in chapter 4.5.

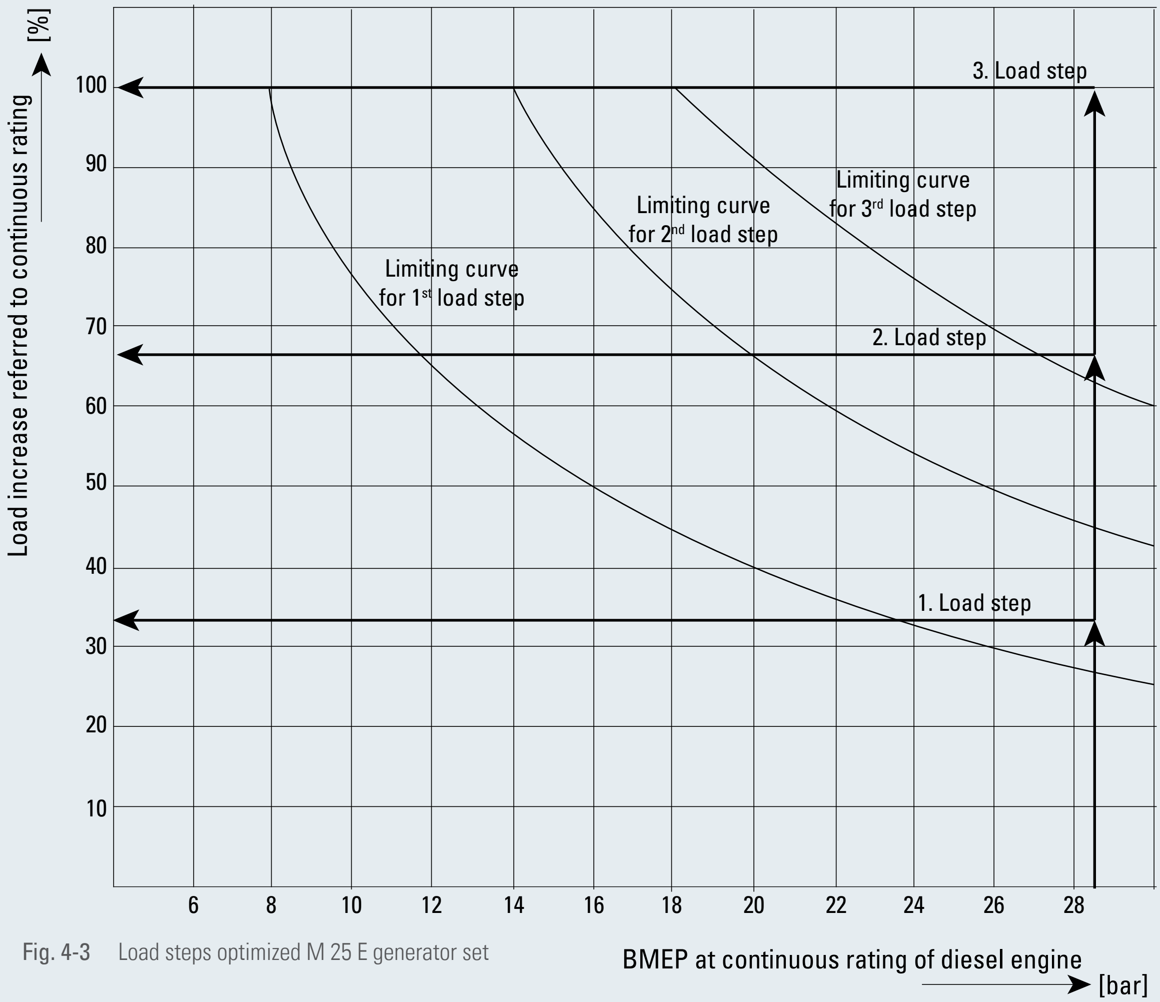

Fig. 4-3 Load steps optimized M 25 E generator set

Example: Version Part Load Kit (constant speed) 6 M 25 E, 2,100 kW, bmep = 28.56 bar
Curves are provided as typical examples.

1. Max. load from 0% to 33% output
2. Max. load from 26% to 66% output
3. Max. load from 44% to 100% output

4.2 Part Load optimization Kit (PLK) for constant speed application

Available as a 6, 8, and 9 cylinder engine platform, the Part Load Kit optimized engine provides the best fuel efficiency and load acceptance at part load without sacrificing low smoke emissions.
Designed for IMO II emissions regulations in its standard configuration, the M 25 E complies with IMO III regulations when combined with SCR systems.

4.2.1 Technology

The PLK consists of our proven Flexible Camshaft Technology and a Waste Gate as well as an intelligent steering software logic integrated into the engine control system. The Waste Gate prevents the turbocharger from running into surge and speed limits. The valve train timing is adjusted to produce higher ignition pressure during low load operation. Before achieving the IMO relevant emission test step the valve train moves back into the "normal" position. This combines lowest possible fuel consumption and IMO II compliance.

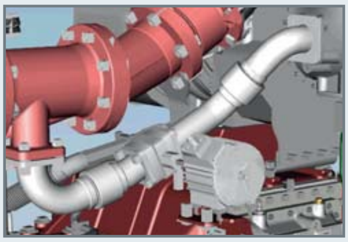

Fig. 4-4 Waste Gate

Fig. 4-5 Flexible Camshaft Technology

4.5.1.1 Benefits and scope of supply

<table>
<tr><th>Part load optimization</th><th>Constant speed</th></tr>
<tr><td rowspan="6">Benefits</td><td>Reduced sfoc at customized load range</td></tr>
<tr><td>Improved load step capacity</td></tr>
<tr><td>Smoke reduction</td></tr>
<tr><td>No influence on power output, lube oil consumption, fuel quality, TBO and life time of all components</td></tr>
<tr><td>SCR capability</td></tr>
<tr><td>Exhaust gas temperature</td></tr>
<tr><td rowspan="5">Additional scope of supply</td><td>Flexible Camshaft Technology</td></tr>
<tr><td>Waste Gate</td></tr>
<tr><td>New valve timing</td></tr>
<tr><td>Adjusted turbocharger</td></tr>
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4.2.2 Diesel electric propulsion (DEP) and auxiliary (AUX) application

As this application may vary from full load under constant speed to part load operation under constant speed, two technical options are available to chose from:

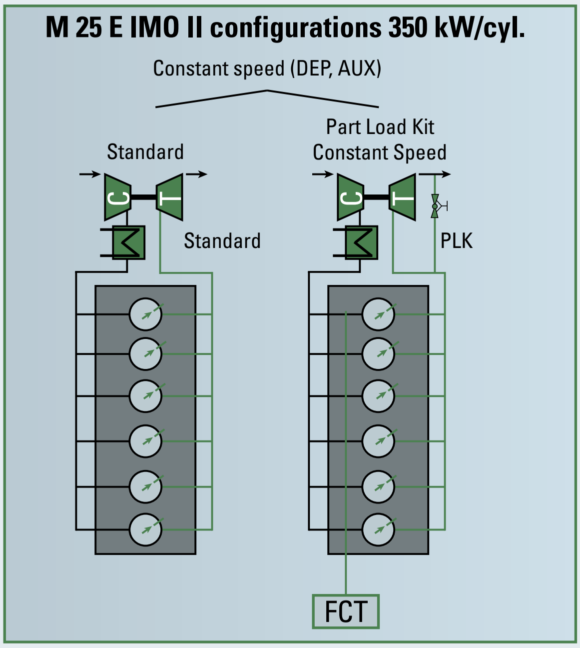

Fig. 4-6 Overview of options

Performance Differences:

Engine speed	Constant speed	Constant speed
Brake specific fuel consumption (BSFC)		Up to 8 g/kWh lower BSFC
Load range	Full load optimized	Part load optimized
Load steps		3 load step capability
Smoke behaviour		Reduced smoke
SCR capability	Optimized exhaust gas conditions	Optimized exhaust gas conditions
System monitoring	Future readiness	Future readiness

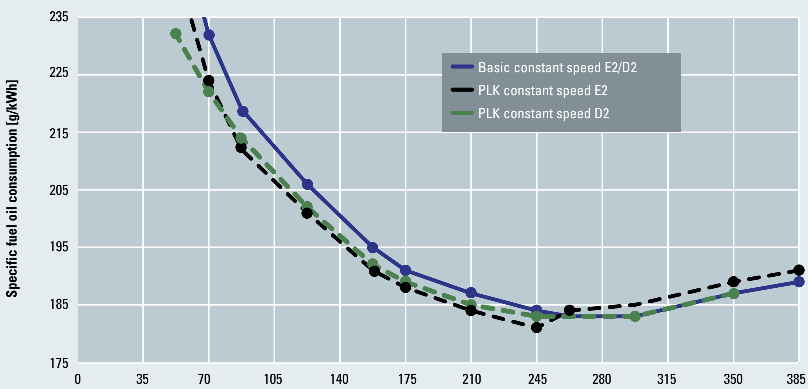

Fig. 4-7 Specific fuel oil consumption

4.3 Restrictions for low load operation

The engine can be started, stopped and run on heavy fuel oil under all operating conditions.
The HFO system of the engine remains in operation and keeps the HFO at injection viscosity.
The temperature of the engine injection system is maintained by circulating hot HFO and heat losses are compensated.
The lube oil treatment system (lube oil separator) remains in operation, the lube oil is separated continuously.
The operating temperature of the engine cooling water is maintained by the cooling water preheater.
Below 25 % output heavy fuel operation is neither efficient nor economical.
A change-over to diesel oil is recommended to avoid disadvantages as e.g. increased wear and tear, contamination of the air and exhaust gas systems and increased contamination of lube oil.

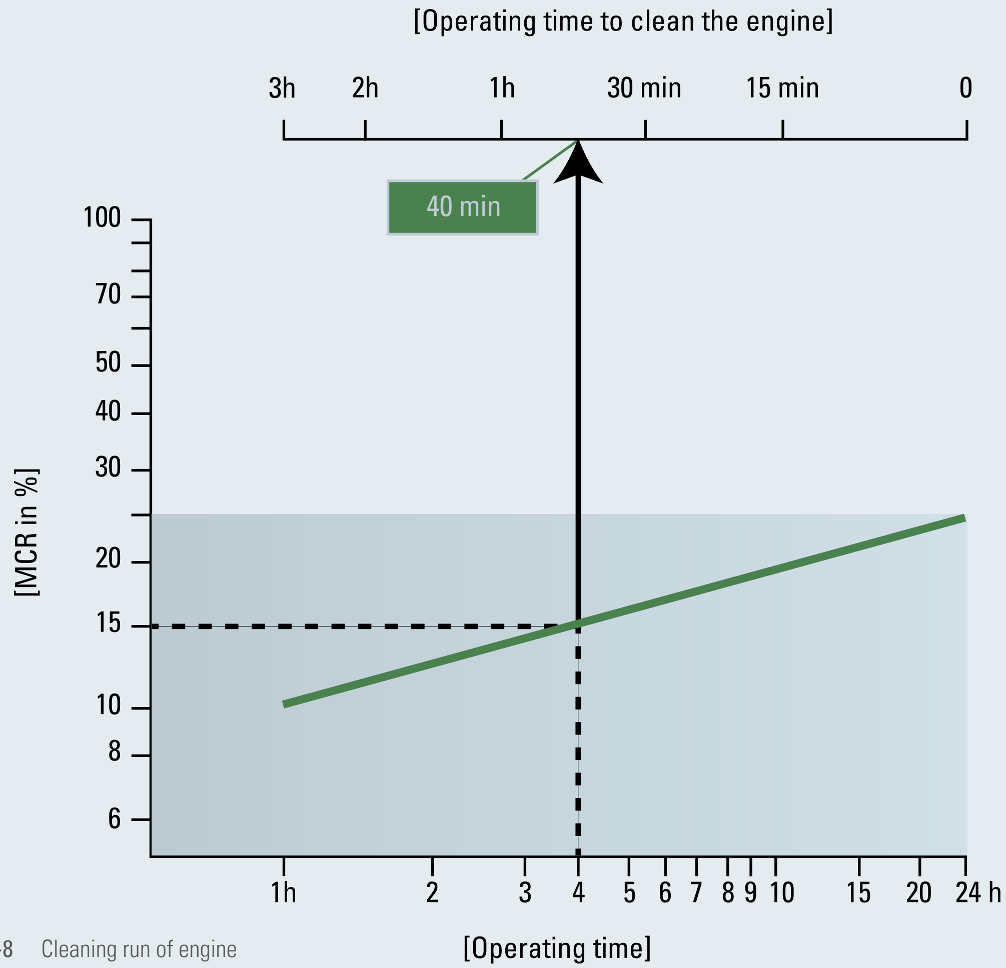

Fig. 4-8 Cleaning run of engine

4.4 Emergency operation without turbocharger

Emergency operation is permissible with MDO only up to approx. 20% of the MCR.

4.5 Operation in inclined position

Inclination angles of ships at which engine running must be possible:

Rotation X-axis:	
Heel to each side:	15 °
Rolling to each side:	22.5 °
Rotation Y-axis:	
Trim by head and stern:	5 °
Pitching:	±7.5 °

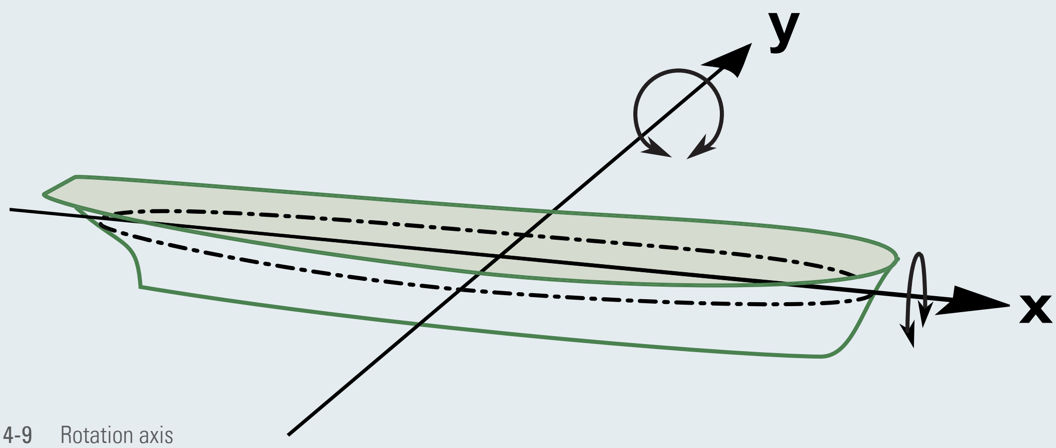

Fig. 4-9 Rotation axis

4.6 Air injection

4.6.1 General

The purpose of the air injection system is to feed additional compressed air into the charge air manifold temporarily. Thus, the load pick up of the engine can be enhanced and the soot emissions are reduced.

Air injection reduces:

- Engine speed drop during the clutch-in procedure
- Frequency deviation when switching on big electrical consumers, like cranes or bow thrusters, in case of PTO-operation.

The design is simple and robust without any changes of the turbocharger housing. The air consumption of the engine will be increased by using air injection and depends on operating modes.

4.6.2 Brief description

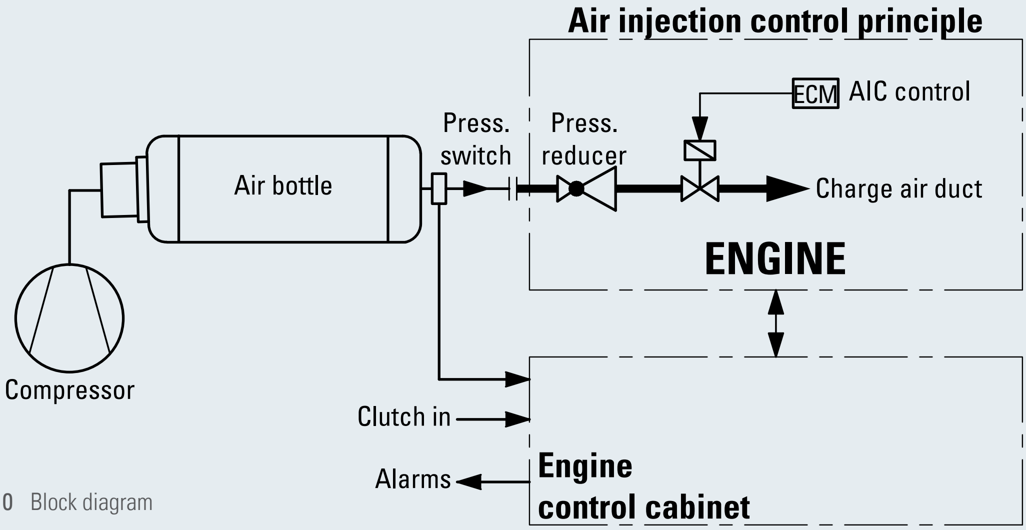

Fig. 4-10 Block diagram

Mechanical devices of AIC, as pressure reducer and electric controlled pneumatic control valve are direct mounted at the engine. Via this valve, compressed air will be inserting into charge air duct.
The AIC-logic is included in the engine mounted Modular Alarm and Control System (MACS) and is used to detect load increases and speed decreases. If one of the above mentioned behaviour is detected, compressed air with a specific air volume will be used and inserted into charge air duct.
The benefit of this system is limited for transient procedure only!
In that mode, the system reaches faster acceleration times and / or less smoke of exhaust gas. The air injection time and pressure value depends on the specific project application (has to be a higher pressure value as the current charge air pressure value, the default pressure value is 5 bar).

NOTE:
It is strongly recommended to install a separate air supply for AIC only (independent from start air system), especially for engine application that needs AIC for a long operation period. Otherwise, the air supply for AIC will be switched off at approx. 19 bar (needed pressure for required number of engine starts according to class rules).

4.6.3 Calculation of air consumption for air injection

The needed air volume for the air injection operation depends on the specific project application and engine type. The air pressure of the inserted air can be adjusted (recommended between 5 to 8 bar). The injection time could be between 1 and 8 seconds, default settings are 5 bar and 5 seconds. For M 25 E diesel engine, the air consumption for 1 injection pulse for 5 seconds with 5 bar needs 1.8 Nm^3.
For a sufficient operation of AIC, the air pressure calculation has to be done accurate and has to be discussed with A&I dept. of Caterpillar Motoren.

Example of air consumption calculation (with separate air supply system):
M 25 E diesel generator set needs 10 pulses of air injection with 5 bar for 5 seconds each per hour.
Calculation (air consumption per second for air injection = 360 l):
Air bottle pressure = 30 bar
5 bar = minimum needed pressure => 25 bar can be used.
360 l x 5 sec. = 1.8 Nm^3
1 AIC pulse => 1.8 Nm^3, 10 AIC pulse => 10 x 1.8 Nm^3 = 18 Nm^3
18 Nm^3, 25 bar usable pressure = 720 liter air bottle (18,000 l / 720 l = 25 bar)

Depending on needed amount of AIC pulses, the air compressor size has to be checked.

4.6.4 Acceleration times M 25 E, engine with MACS

			Standard	Standard + Air Injection	PLK + Air Injection
Minimum time for emergency operation	n = constant	Acceleration from 10 % to 100 % MCR	30 s	24 s	17 s
		Smoke	visible	visible	visible
		Reduction from 100 % to 0 % MCR	8 s	8 s	8 s

			Standard	Standard + Air Injection	PLK + Air Injection
Normal operation	n = constant	Acceleration from 10 % to 60 % MCR	35 s	30 s	25 s
	n = constant	Acceleration from 60 % to 100 % MCR	50 s	50 s	50 s
		Smoke	visible	visible	visible
		Reduction from 100 % to 0 % MCR	20 s	20 s	20 s

OP: Operating point as given in power limit curves VD 8613-4

PLK: Part Load Kit equipped engine (for VD 8613-4 PLK for constant speed FCT and WG is needed)

Remarks:

Acceleration time in seconds, Tol. ± 5 sec., engine warm in operating conditions

Minimum operating time 10 minutes

Lube oil > 50°C

Coolant > 65°C

Start of acceleration at least 10 % MCR, lowest operation point with CPP.

Standard acceleration time will provide longest component lifetimes.

Emergency acceleration possible, but not recommended, due to higher thermal stresses on engine components.

Invisible smoke provided with PLK in normal operation above 20% MCR.

Basic ratings (MCR): 6, 8, 9 M 25 E – 350 kW/Cyl.

5.1 MGO / MDO operation

General

MaK diesel engines are designed to burn a wide variety of fuels.
See the information on fuel requirements in section MDO / MGO, HFO and crude oil operation or consult the Caterpillar Motoren technical product support.
For proper operation of MaK engines the minimum Caterpillar Motoren requirements for storage, treatment and supply systems have to be observed, as shown in the following sections.

5.1.1 Acceptable MGO / MDO characteristics

Two fuel product groups are permitted for MaK engines:

Pure distillates:	Gas oil, marine gas oil, diesel fuel
Distillate/mixed fuels:	Marine gas oil (MGO), marine diesel oil (MDO)

The difference between distillate/mixed fuels and pure distillates are higher density, sulfur content and viscosity.

Marine distillate fuels

Parameter	Unit	Limit	DMX	DMA	DMZ	DMB
Viscosity at 40 °C	[mm²/s]	max	5.5	6.0	6.0	11.0
Viscosity at 40 °C	[mm²/s]	min	1.4	2.0	3.0	2.0
Micro Carbon residue at 10 % residue	[% m/m]	max	0.3	0.0	0.3	–
Density at 15 °C	[kg/m³]	max	–	890	890	900
Micro Carbon residue	[% m/m]	max	–	–	–	0.3
Sulfur [a)]	[% m/m]	max	1.0	1.5	1.5	2.0
Water	[% V/V]	max	–	–	–	0.3 [b)]
Total sediment by hot filtration	[% m/m]	max	–	–	–	0.1 [b)]
Ash	[% m/m]	max	0.01	0.01	0.01	0.01
Flash point	[°C]	min	43	60	60	60
Pour point, summer	[°C]	max	–	0	0	6
Pour point, winter	[°C]	max	–	-6	-6	0
Cloud point	[°C]	max	-16	–	–	–
Calculated Cetane Index		min	45	40	40	35
Acid number	[mgKOH/g]	max	0.5	0.5	0.5	0.5
Oxidation stability	[g/m³]	max	25	25	25	25 [c)]
Lubricity, corrected wear scar diameter (wsd 1.4 at 60 °C) [d)]	[µm]	max	520	520	520	520 [c)]
Hydrogen sulfide [e)]	[mg/kg]	max	2.0	2.0	2.0	2.0
Appearance			clear & bright [f)]			[b), c)]

a) A Sulphur limit of 1.00 % m/m applies in the Emission Control Areas designated by the International Maritime Organization. As there may be local variations, the purchaser shall define the maximum Sulphur content according to the relevant statutory requirements, notwithstanding the limits given in this table. / **b)** If the sample is not clear and bright, total sediment by hot filtration and water test shall be required. / **c)** Oxidation stability and lubricity tests are not applicable if the sample is not clear and bright. / **d)** Applicable if Sulphur is less than 0.050% m/m. /
e) Effective only from 1 July 2012. / **f)** If the sample is dyed and not transparent, water test shall be required. The water content shall not exceed 200 mg/kg (0.02% m/m).

5.1.2 Internal fuel oil system

General

The fuel injectors are utilized to deliver the correct amount of fuel to the cylinders precisely at the moment it is needed.
The diesel fuel supply system must ensure a permanent and clean supply of diesel fuel to the engine internal fuel oil system.

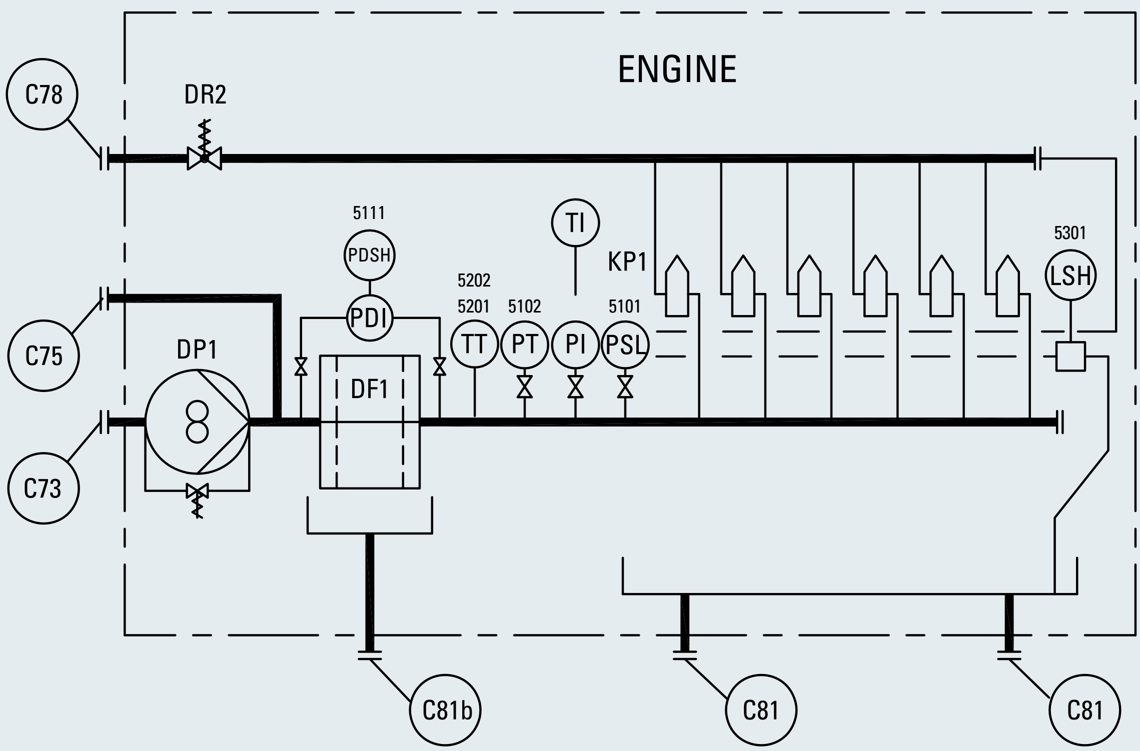

Fig. 5-1 Internal fuel oil system, system diagram

DF1	Fuel fine filter (duplex filter)	PT	Pressure transmitter
DP1	Diesel oil feed pump	TI	Temperature indicator
DR2	Fuel pressure regulating valve	TT	Temperature transmitter (PT100)
KP1	Fuel injection pump		
		C73	Fuel inlet, to engine fitted pump
LSH	Level switch high	C75	Connection, stand-by pump
PDI	Diff. pressure indicator	C78	Fuel outlet
PDSH	Diff. pressure switch high	C81	Drip-fuel connection
PI	Pressure indicator	C81b	Drip-fuel connection (filter pan)
PSL	Pressure switch low		

Diesel oil feed pump DP1 (fitted)

The engine driven fuel transfer pump DP1 is a gear pump, that delivers the fuel through the filter DF1 to each injector. The fuel transfer pump capacity is slightly oversized to deliver sufficient fuel to the fuel injection system. It also transfers the heat generated during injection process, away from the fuel injection system.
To ensure a sufficient diesel oil pressure at the engine, a pressure regulator DR2 is installed and adjusted during commissioning of the engine.

Fuel fine filter (duplex filter) DF1 (fitted)

Duplex change over type (mesh size of 25 μm) is fitted on the engine.

5.1.3 External fuel oil system

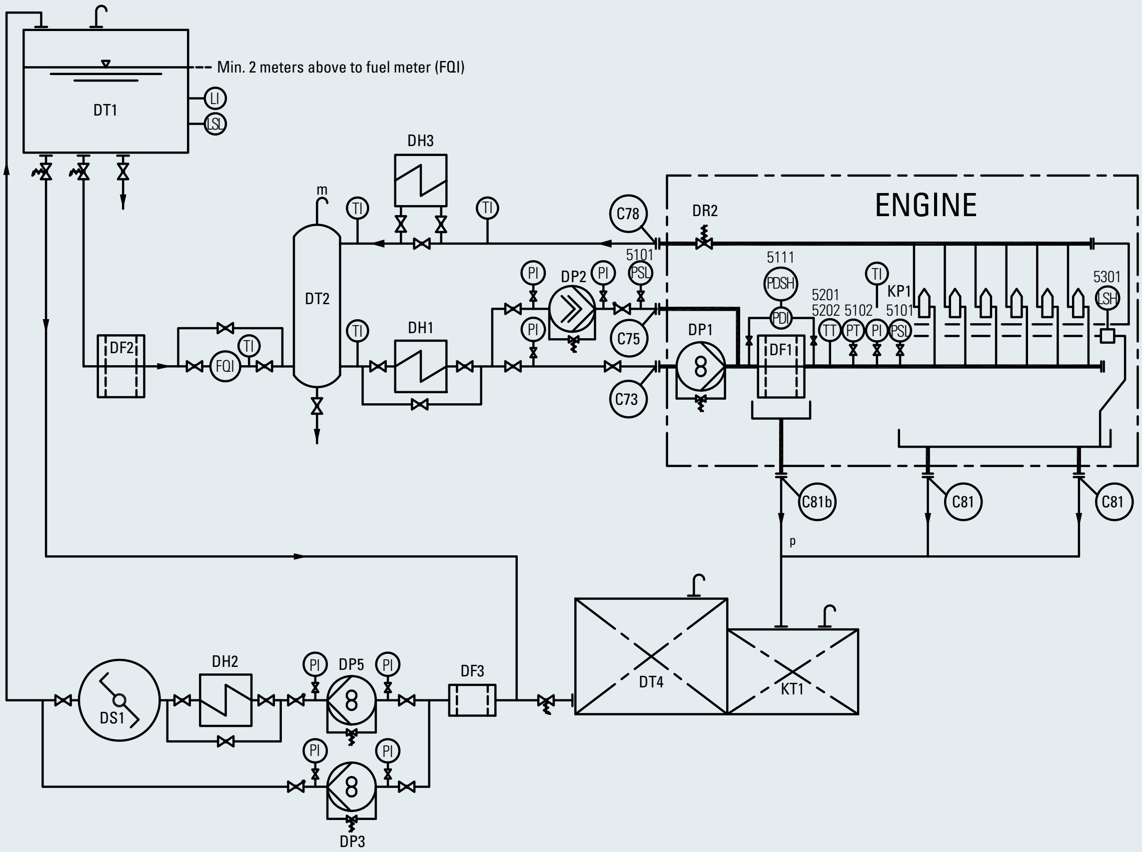

Fig. 5-2 External fuel oil system diagram with intermediate tank

DF1	Fuel fine filter (duplex filter)	LSH	Level switch high
DF2	Fuel primary filter (duplex filter)	LSL	Level switch low
DF3	Fuel coarse filter	PDI	Diff. pressure indicator
DH1	Diesel oil preheater	PDSH	Diff. pressure switch high
DH2	Preheater for diesel oil (separator)	PI	Pressure indicator
DH3	Fuel oil cooler	PSL	Pressure switch low
DP1	Diesel oil feed pump	PT	Pressure transmitter
DP2	Stand-by feed pump	TI	Temperature indicator
DP3	Diesel oil transfer pump (to day tank)	TT	Temperature transmitter (PT100)
DP5	Diesel oil transfer pump (separator)		
DR2	Fuel pressure regulating valve	C73	Fuel inlet, to engine fitted pump
DS1	Diesel oil separator	C75	Connection, stand-by pump
DT1	Diesel oil day tank	C78	Fuel outlet
DT2	Diesel oil intermediate tank	C81	Drip-fuel connection
DT4	Diesel oil storage tank	C81b	Drip-fuel connection (filter pan)
FQI	Flow quantity indicator		
KP1	Fuel injection pump	m	Lead vent pipe beyond service tank
KT1	Drip fuel tank	p	Free outlet required
LI	Level indicator		

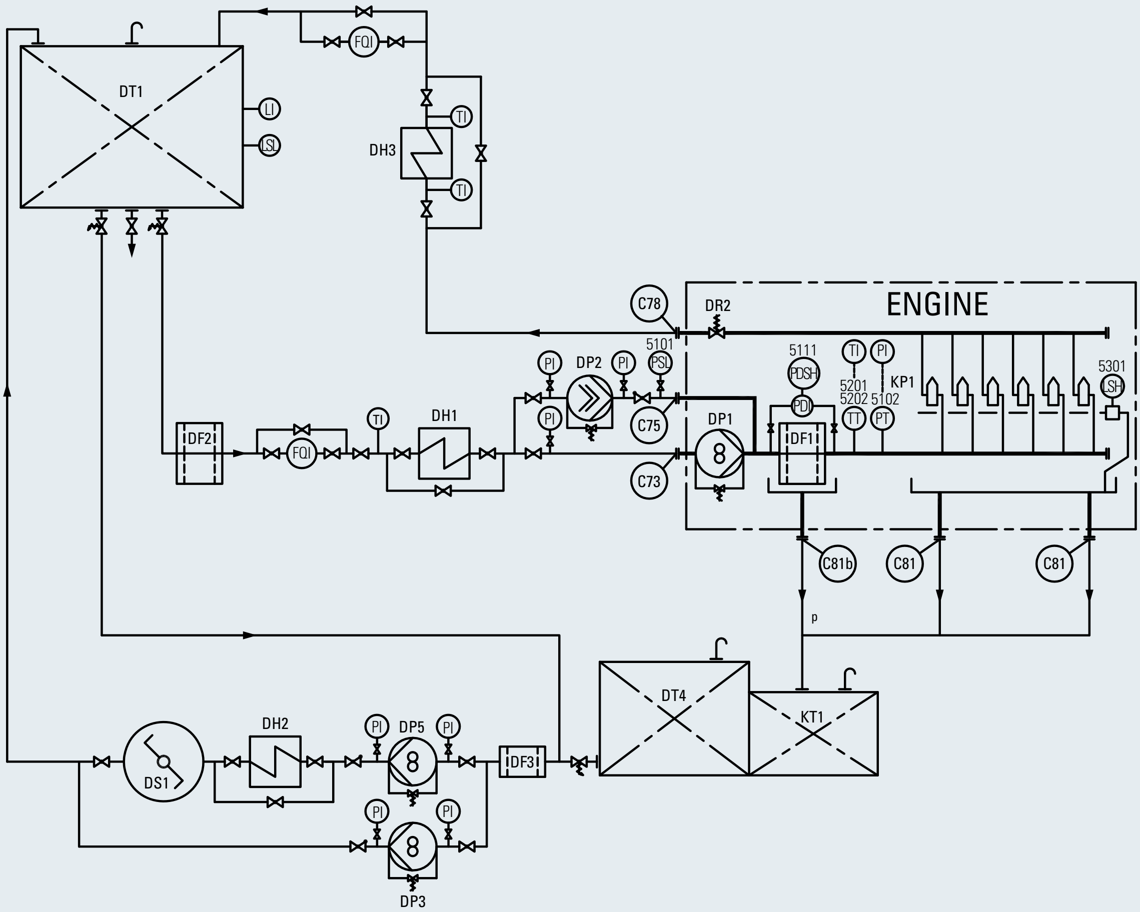

Fig. 5-3 External fuel oil system diagram without intermediate tank

DF1	Fuel fine filter (duplex filter)	LI	Level indicator
DF2	Fuel primary filter (duplex filter)	LSH	Level switch high
DF3	Fuel coarse filter	LSL	Level switch low
DH1	Diesel oil preheater	PDI	Diff. pressure indicator
DH2	Electrical preheater for diesel oil (separator)	PDSH	Diff. pressure switch high
		PI	Pressure indicator
DH3	Fuel oil cooler	PSL	Pressure switch low
DP1	Diesel oil feed pump	PT	Pressure transmitter
DP2	Stand-by feed pump	TI	Temperature indicator
DP3	Diesel oil transfer pump (to day tank)	TT	Temperature transmitter (PT100)
DP5	Diesel oil transfer pump (separator)		
DR2	Fuel pressure regulating valve	C73	Fuel inlet, to engine fitted pump
DS1	Diesel oil separator	C75	Connection, stand-by pump
DT1	Diesel oil day tank	C78	Fuel outlet
DT4	Diesel oil storage tank	C81	Drip-fuel connection
FQI	Flow quantity indicator	C81b	Drip-fuel connection (filter pan)
KP1	Fuel injection pump		
KT1	Drip fuel tank	p	Free outlet required

General

The design of the fuel oil system may vary from ship to ship, the system itself has to provide sufficient, permanent and clean fuel oil of the required viscosity and pressure to each engine. Fuel storage, treatment, temperature and pressure control as well as sufficient circulation must be ensured.

Diesel oil storage tank DT4

The tank design, sizing and location are according to classification society requirements and based on ship application. No heating is necessary because all marine distillate fuels are suitable for pumping.

Diesel oil separator DS1

Depending on the fuel oil quality a diesel oil separator DS1 is recommended for the use of MGO and required for MDO by Caterpillar Motoren. Any fuel oil must always be considered as contaminated upon delivery and should therefore be thoroughly cleaned to remove solid and liquid contaminants before use.
Most of the solid contaminants in the fuel are rust, sand, dust.
Liquid contaminants are mainly water, i.e. fresh water or salt water.
Impurities in the fuel oil can result in

- damage to fuel injection pumps and injectors,
- increased cylinder liner wear,
- deterioration of the exhaust valve seats
- increased fouling of turbocharger blades.

If a diesel oil separator is installed a total diesel oil separator capacity of 100 % of the full load fuel consumption is recommended.
HT-water or electrical heating is normally used as heating medium.
The nominal capacity should be based on a separation time of 22h/day:

$V_{eff.}[l/h] = 0.28 \cdot P_{eng.}\ [kW]$

$V_{eff.}$ = Volume effective [l/h]
$P_{eng.}$ = Power engine [kW]

Diesel oil day tank DT1

The day tank collects clean / treated fuel oil, compensates irregularities in the treatment plant and its standstill periods. Two day tanks are to be provided, each with a capacity according to classification rules. The tank should be provided with a sludge space including a sludge drain valve and an overflow pipe from the MDO/MGO service tank to the settling/storage tank. The level of the tank must ensure a positive static pressure on the suction side of the fuel feed pumps. Usually tank heating is not required.

Fuel primary filter (duplex filter) DF2

The fuel primary filter protects the fuel meter and feed pump from major solids.
A duplex change over type with mesh size of 320 µm is recommended.

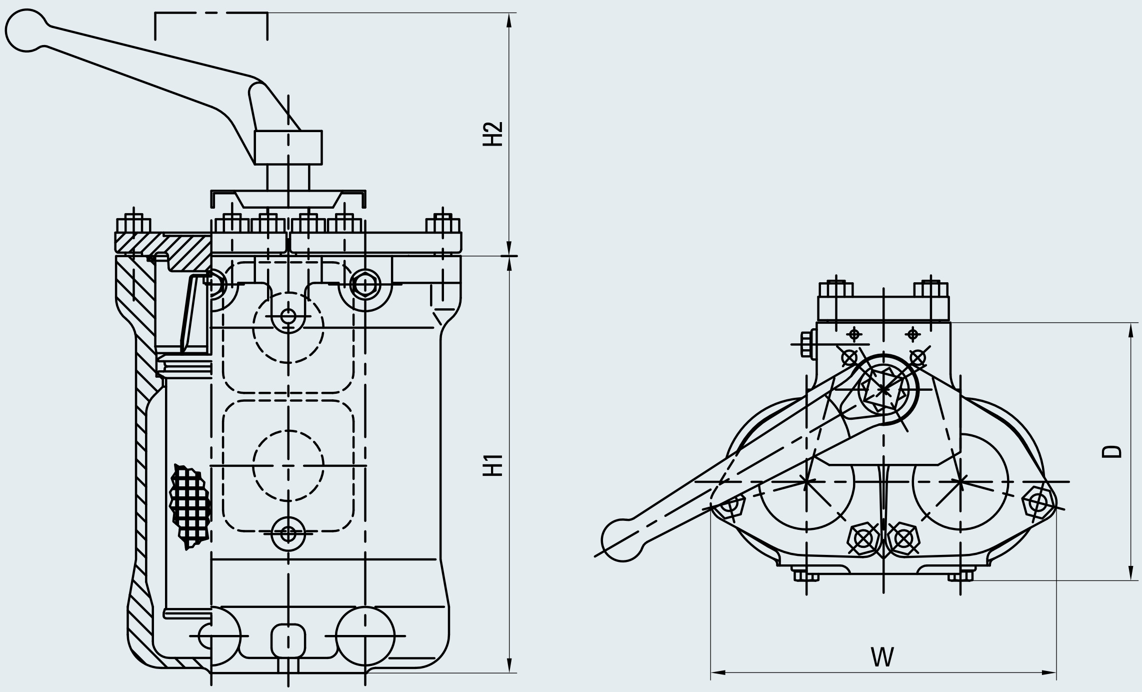

Fig. 5-4 Fuel primary filter DF2

Engine output [kW]	DN	Dimensions [mm]			
		H1	H2	W	D
≤ 2,500	32	249	220	206	159
≤ 4,500	40	330	300	250	189
≤ 10,000	65	523	480	260	244
≤ 16,000	80	690	700	380	307

Flow quantity indicator FQI

One fuel meter is sufficient if the return fuel from the engine is connected to the diesel intermediate tank DT2.
If the fuel return from engine is connected to the day tank, an additional fuel meter in the return line to day tank has to be provided.
A minimum static fuel pressure head of at least 0.2 bar has to be considered. The fuel may be provided by gravity flow from the day tank. The static pressure must exceed the back pressure of the flow meter and prefilter.

Diesel oil intermediate tank DT2

In the intermediate tank DT2 the warm return fuel from the engine mixes with the fuel from the day tank. The tank shall be vented as an open system, with the ventilation line guided to above the day tank level.

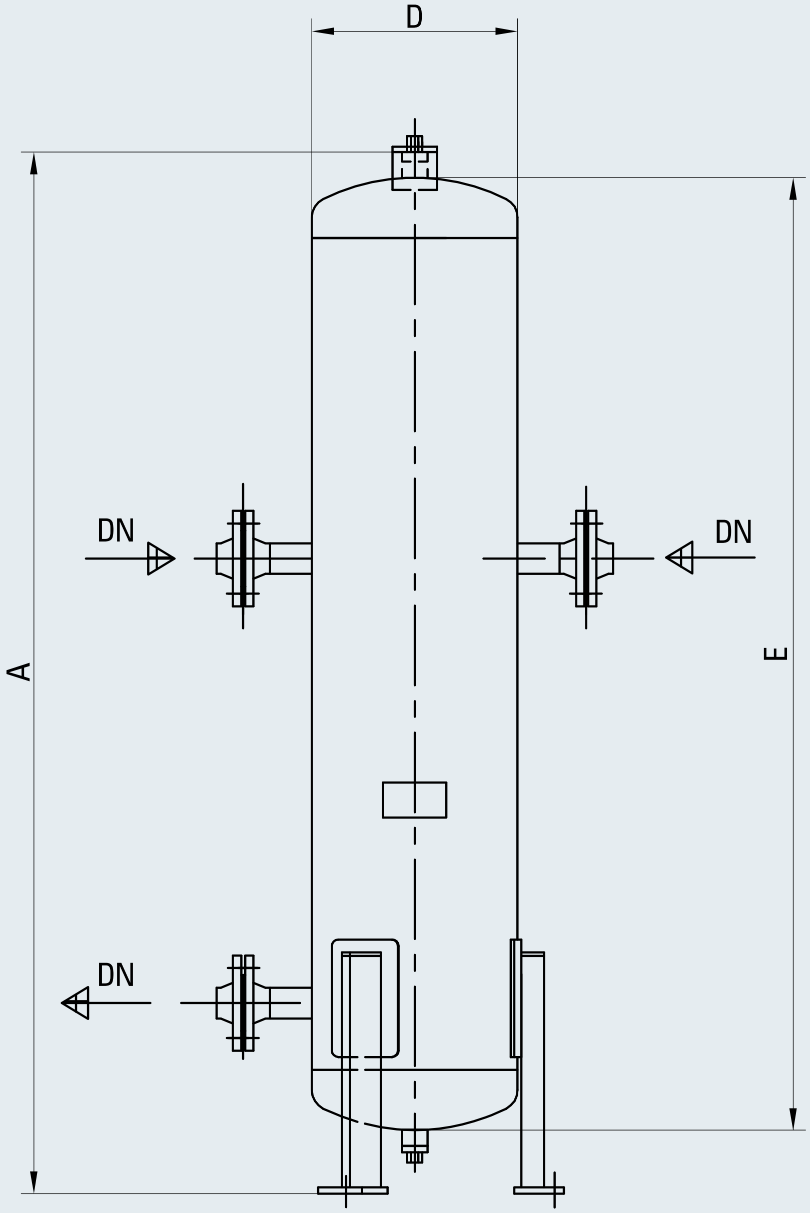

Fig. 5-5 Diesel oil intermediate tank DT2

Plant output	Volume	Dimensions [mm]			DN	Weight
[kW]	l	A	D	E		[kg]
≤ 4,000	49	850	ø 323	750	32	75
≤ 10,000	100	1,600	ø 323	1,500	40	120

Diesel oil preheater DH1 (hot water - standard)

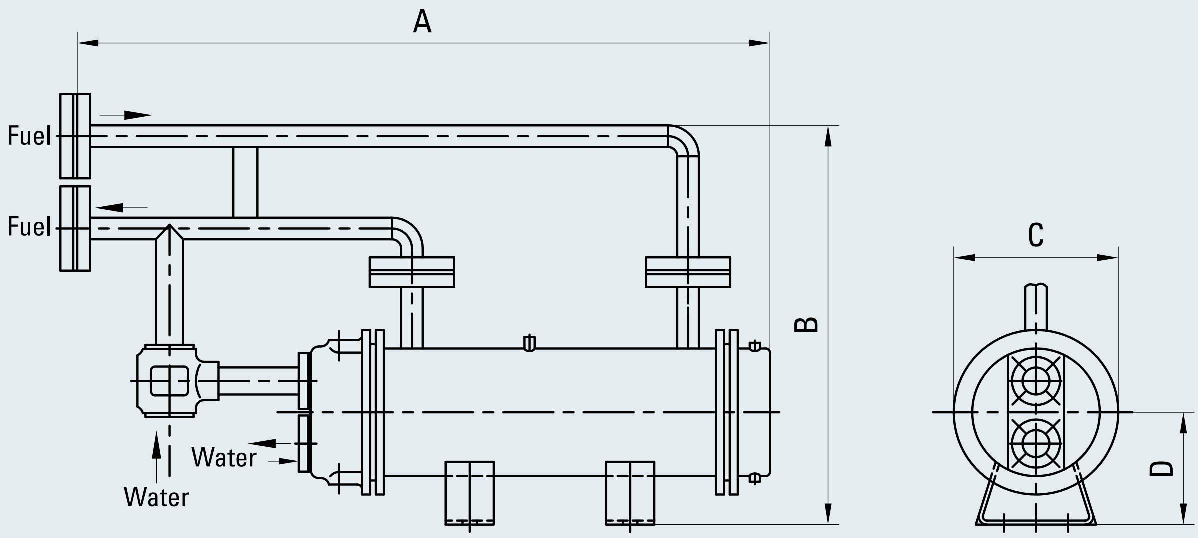

Fig. 5-6 Diesel oil preheater with hot water DH1

	Dimensions [mm]				Weight
	A	B	C	D	[kg]
6/8/9 M 25 E	863	498	Ø 205	140	42

The capacity of the MDO preheater is to determine on the required fuel temperature up to approx. 50 °C.

Heating capacity: $$Q\,[kW] = \frac{P_{eng.}\,[kW]}{166}$$

Q = Heating capacity [kW]
$P_{eng.}$ = Power engine [kW]

A diesel oil preheater is not required

- for gas oil operation.
- with preheated day tanks.

Diesel oil preheater heated by thermal oil,. steam and electrically heated are available on request.

Stand-by feed pump DP2 (separate)

The stand-by feed pump DP2 delivers fuel through the filter DF1 to each injection pump.
The feed pump maintains the pressure at the injection pumps and circulates the fuel in the system.
The capacity is slightly oversized to transfer the heat, which occurs during the injection process, away from the fuel injection system.
A positive static pressure is required at the suction side of the pump.
Capacity see technical data.

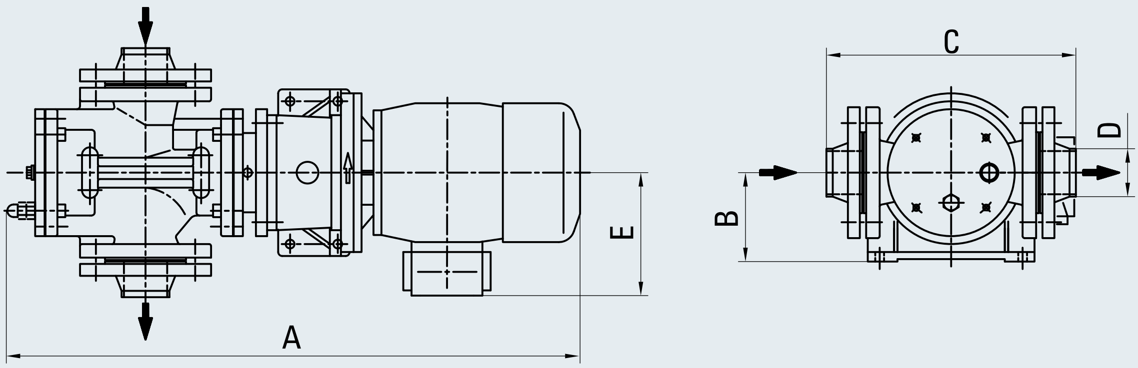

Fig. 5-7 Stand-by feed pump DP2

	Dimensions [mm]					Weight	Motorpower	Voltage / Frequency
	A	B	C	D	E	[kg]	[kW]	[V/Hz]
6 M 25 E	625	112	254	42.2	155 150	42.0 39.0	1.1 0.9	400/50 440/60
8 M 25 E	735	112	314	60.3	155	61.0	1.5 1.8	400/50 440/60
9 M 25 E	735	112	314	60.3	155	61.0	1.5 1.8	400/50 440/60

Fuel oil cooler DH3

To ensure a fuel oil temperature below 50 °C at any time a cooling of diesel oil may be required.
The need for a fuel cooler is system specific and depends on fuel circuit design and type of fuel oil. In case of more than one engine connected to the same fuel supply system, the MDO-cooler capacity has to be increased accordingly.
The heat transfer load into the diesel oil system is approx. 1.2 kW/cyl.
LT-water is normally used as cooling medium.

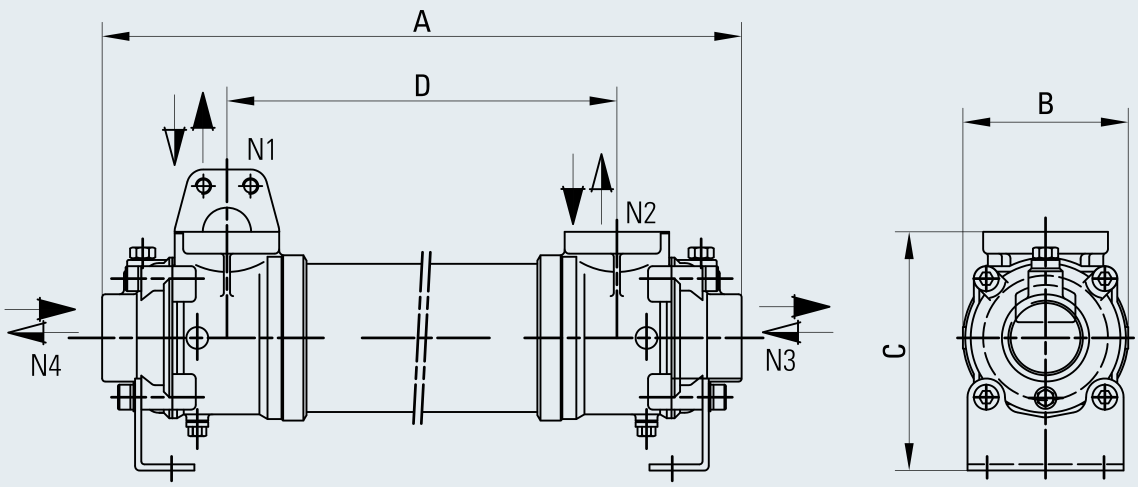

Fig. 5-8 Fuel oil cooler for MDO operation DH3

	Dimensions [mm]						Weight
	A	B	C	D	N1 + N2	N3 + N4	[kg]
6/8/9 M 25 E	710	106	153	550	1 ¼" SAE	1 ½" SAE	16

5.2 HFO operation

The following section is based on the experiences gained in the operation of heavy fuel installations.
Stable and correct viscosity of the fuel before injection pumps (see technical data) must be maintained at any time. Sufficient circulation through every engine connected to the same circuit must be ensured in all operating conditions.
The fuel treatment system should comprise at least one settling tank and two separators.
Correct dimensioning of HFO separators is of great importance, and therefore the recommendations of the separator manufacturer must be closely followed.
Poorly purified fuel is harmful to the engine. A high content of water may also damage the fuel feed system.
Injection pumps generate pressure pulses into the fuel feed and return piping. The fuel pipes between the feed unit and the engine must be clamped properly to rigid structures. The distance between the fixing points should be at close distance next to the engine. (See chapter piping design, treatment and installation.)

ATTENTION:
In multiple engine installations, where several engines are connected to the same fuel feed circuit, it must be possible to close the fuel supply and return lines connected to the engine individually.
(This is a SOLAS requirement.)

NOTE:
It is further stipulated that the means of isolation shall not affect the operation of the other engines, and it shall be possible to close the fuel lines from a position that is not rendered inaccessible due to fire on any of the engines.

Viscosity temperature sheet

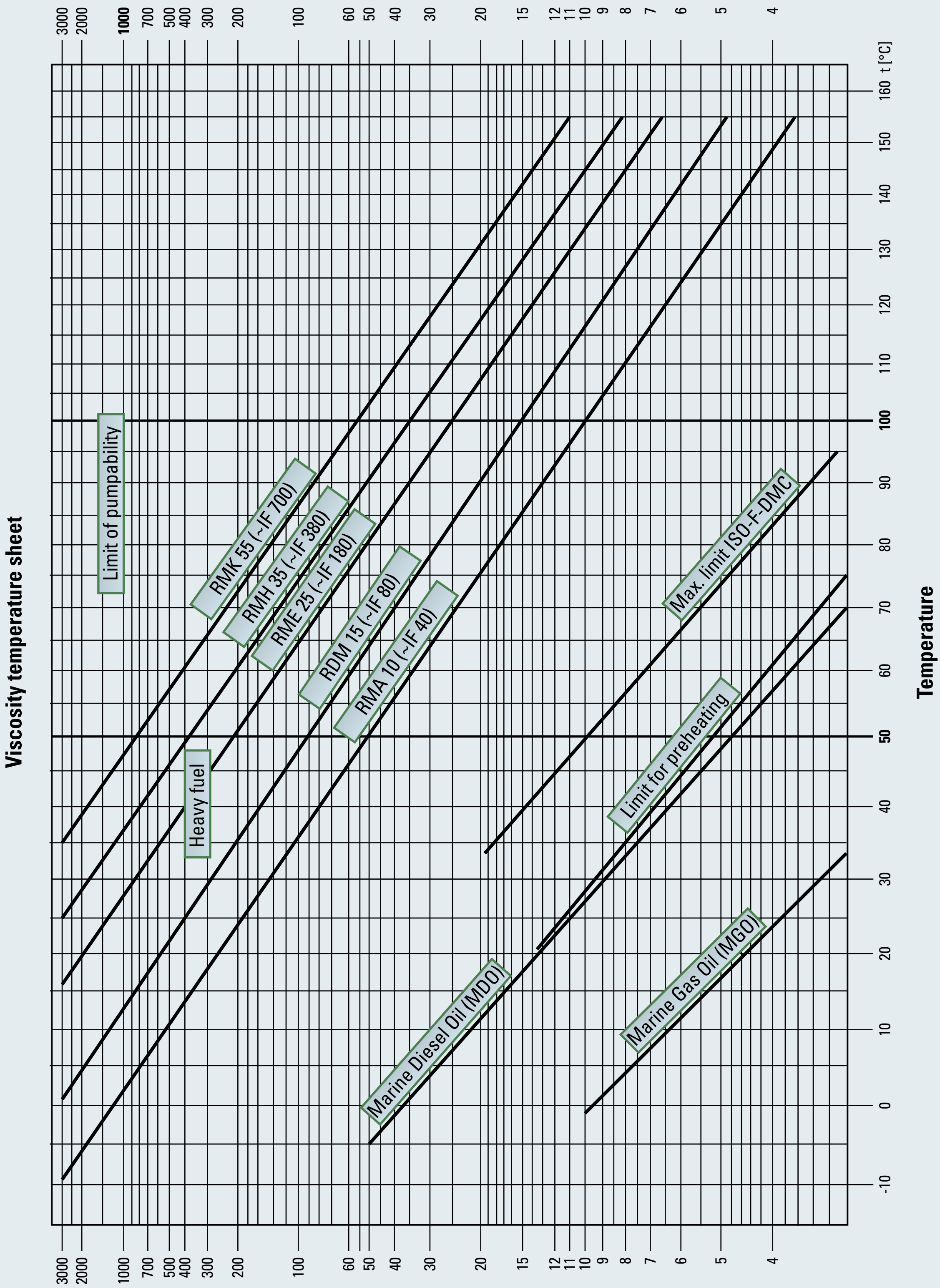

Fig. 5-9 Viscosity / temperature diagram

Fuel oil system

A pressurized fuel oil system, as shown in Fig. 5-10, is necessary when operating on high viscosity fuels. When using high viscosity fuels requiring high preheating temperatures, the fuel oil from the engine fuel oil system to the return line will also have a relatively high temperature. The fuel oil pressure measured on the engine (at fuel pump level) should be about 5 bar. This maintains a pressure margin against gasification and cavitation in the fuel system, even at 150 °C preheating.
In order to ensure correct atomization, the fuel oil temperature must be adjusted according to the specific fuel oil viscosity used. An inadequate temperature can influence the combustion and could cause increased wear on cylinder liners and piston rings, as well as deterioration of the exhaust valve seats.
A too low heating temperature, i.e. too high viscosity, could also result in excessive fuel consumption.
Therefore, optimum injection viscosity of 10 – 12 cSt must be maintained at any rate and with all fuel grades.
Deviations from design recommendations are possible, however, they should be discussed with Caterpillar Motoren.
Trace heating for all heavy fuel pipes is recommended.

5.2.1 CIMAC – Requirements for residual fuels for diesel engines (as delivered)

Fuel shall be free of used lube oil.
Requirements for residual fuels for diesel engines please see table next page.

Characteristic	Designation		CIMAC A10	CIMAC B10	CIMAC C10	CIMAC D15	CIMAC E25	CIMAC F25	CIMAC G35	CIMAC H35	CIMAC K35	CIMAC H45	CIMAC K45	CIMAC H55	CIMAC K55
	Related to ISO8217 (10) F-		RMA 30	RMB 30	RMC 30	RMD 80	RME 180	RMF 180	RMG 380	RMH 380	GMK 380	RMH 500	RMK 500	RMH 700	RMK 700
	Dim.	Limit													
Density at 15°C	kg/m³	max	950 [2]	975 [3]		980 [4]	991		991		1,010	991	1,010	991	1,010
Kin. viscosity at 100°C	cSt. [1]	max	10			15	25		35			45		55	
Kin. viscosity at 100°C	cSt. [1]	min	6 [5]				15 [5]								
Flash point	°C	min	60			60	60		60			60		60	
Pour point winter	°C	max	0												
Pour point summer	°C	max.	6		24	30	30		30			30		30	
Carbon residue	% (m/m)	max	12 [6]		14	14	15	20	18	22		22		22	
Ash	% (m/m)	max	0.10			0.10	0.10	0.15	0.15	0.15		0.15		0.15	
Total sedim. after ageing	% (m/m)	max	0.10			0.10	0.10		0.10			0.10		0.10	
Water	% (V/V)	max	0.5			0.5	0.5		0.5			0.5		0.5	
Sulphur	% (m/m)	max	3.5			4.0	4.5		4.5			4.5		4.5	
Vanadium	mg/kg	max	150		300	350	200	500	300	600		600		600	
Aluminum + Silicon	mg/kg	max	80			80	80		80			80		80	
Zink	mg/kg	max	15			15	15		15			15		15	
Phosphor	mg/kg	max	15			15	15		15			15		15	
Calcium	mg/kg	max	30			30	30		30			30		30	

1) An indication of the approximate equivalents in kinematic viscosity at 50°C and Redw. I sec 100°F is given below:

Kinematic viscosity at 100°C [mm²/s] (cSt.)	7	10	15	25	35	45	55
Kinematic viscosity at 50°C [mm²/s] (cSt.)	30	40	80	180	380	500	700
Kinematic viscosity at 100°F Redw. [I sec.]	200	300	600	1,500	3,000	5,000	7,000

2) ISO: 960 / **3)** ISO: 960 / **4)** ISO: 975 / **5)** ISO: not limited / **6)** ISO: carbon residue 10

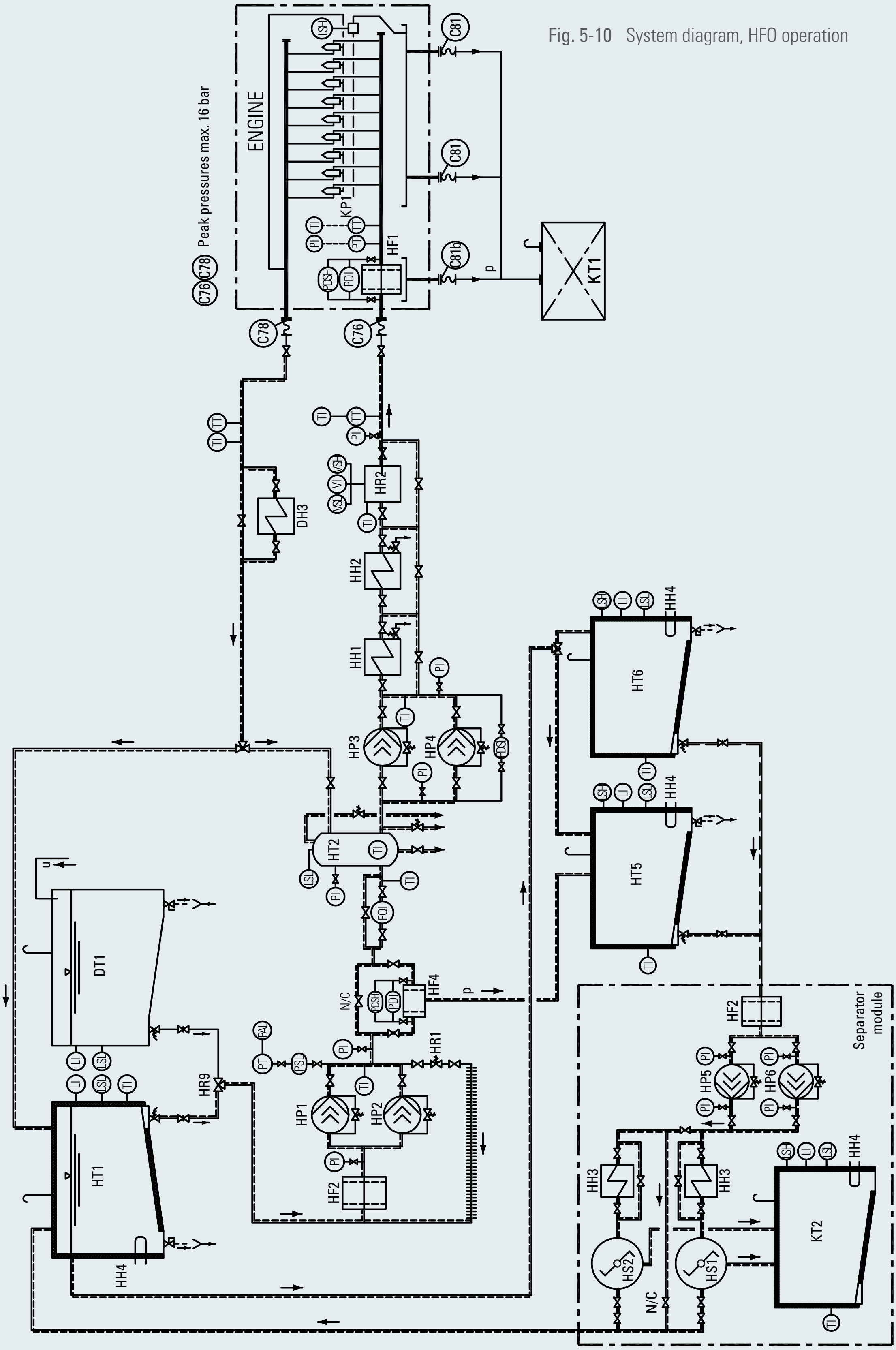

Fig. 5-10 System diagram, HFO operation

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21

General

For location, dimensions and design (e.g. flexible connection) of the disconnecting points see engine installation drawing.
No valve fittings with loose cone must be installed by the shipyard in admission and return lines.

DH3	Fuel oil cooler for MDO operation
DT1	Diesel oil day tank
HF1	Fine filter (duplex filter)
HF2	Primary filter (duplex filter)
HF4	HFO automatic filter
HH1	Heavy fuel final preheater
HH2	Stand-by final preheater
HH3	Heavy fuel preheater (separator)
HH4	Heating coil
HP1	Fuel pressure pump
HP2	Fuel stand-by pressure pump
HP3	Fuel circulating pump
HP4	Stand-by circulating pump
HP5/6	Heavy fuel transfer pump (separator)
HR1	Fuel pressure regulating valve
HR2	Viscosimeter
HR9	Fuel change over main valve
HS1/2	Heavy fuel separator
HT1	Heavy fuel day tank
HT2	Mixing tank
HT5/6	Settling tank
KP1	Injection pump
KT1	Drip fuel tank
KT2	Sludge tank

FQI	Flow quantity indicator
LI	Level indicator
LSH	Level switch high
LSL	Level switch low
PAL	Pressure alarm low
PDI	Diff. pressure indicator
PDSH	Diff. pressure switch high
PDSL	Diff. pressure switch low
PI	Pressure indicator
PSL	Pressure switch low
PT	Pressure temp.
TI	Temperature indicator
TT	Temperature transmitter (PT100)
VI	Viscosity indicator
VSH	Viscosity control switch high
VSL	Viscosity control switch low
C76	Inlet, duplex filter
C78	Fuel outlet
C81	Drip-fuel connection
C81b	Drip-fuel connection
p	Free outlet required
u	Fuel separator or from transfer pump

All heavy fuel pipes have to be insulated.
------ Heated pipe

Storage tanks

The tank design, sizing and location must comply with classification society requirements and are based on ship application.
Heating coils are necessary and are to be designed so that the HFO temperature is at least 10K above the pour point to ensure a pumping viscosity below 1,000 cSt.
Heating is possible by steam, thermal oil, electrical current or hot water.

Settling tanks HT5, HT6

The tank design, sizing, location must comply with classification society requirements and are based on ship application. Two settling tanks are to be provided.
Its function is to remove water and solids by gravity due to higher fuel oil temperature and reduced turbulences. Provide constant oil temperature and avoid interruption of treatment system, due to overflow from HFO day tank.Thermal insulation of the settling tanks is recommended to avoid heat losses.

In order to ensure a sufficient settling effect, the following settling tank designs are permitted:
- 2 settling tanks, each with a capacity sufficient for 24 hours full load operation of all consumers or
- 1 settling tank with a capacity sufficient for 36 hours full load operation of all consumers and automatic filling

Settling tank temperature shall be 70 - 80 °C; the charging level shall be 70 - 90 %.

Heavy fuel preheater (separator) HH3

Heavy fuel oil needs to be heated up to a certain temperature before separating.
The most common heaters on board of ships are steam heaters. Other fluid heating sources are hot water, thermal oil or electrical heaters. Overheating of the fuel may cause fuel cracking. Thus the maximum electric load on the heater element should not exceed 1 Watt/cm^2.
In a cleaning system for HFO the usual processing temperature is 98 °C.
The separator manufacturer’s guidelines have to be observed.

Heavy fuel transfer pumps (separator) HP5, HP6

The separator feed pumps shall be installed as close as possible to the settling tanks.
The separator manufacturer’s guidelines have to be observed.

Heavy fuel separators HS1, HS2

Any fuel oils whether heavy fuel oil, diesel oil or crude oil must always be considered as contaminated upon delivery and should therefore be thoroughly cleaned before use.
Therefore self-cleaning types should be selected.
The purpose of any fuel treatment system is to clean the fuel oil by removal of water, solids, and suspended matter to protect the engine from excessive wear and corrosion.
Liquid contaminants are mainly water, i.e. either fresh water or salt water.
Impurities in the fuel can cause damage to fuel injection pumps and injectors, and can result in increased cylinder liner wear and deterioration of the exhaust valve seats as well as increased fouling of turbocharger blades.
Two separators with independent electrically driven pumps must be provided.

Separator sizing:

The correct sizing of the separators is based on the max. fuel oil consumption at maximum continuous rating (MCR) of the engines. The following formula can be used:
(The fuel consumption of auxiliary engines and boilers, if there are any, must be included)

$V_{eff.} = 0.28\ P\ (l/h)$

$V_{eff.}$ = Volume effective [l/h]
$P_{eng.}$ = Power engine [kW]

The cleaning capacity of the separator must always be higher than the entire fuel consumption of the plant, incl. aux. equipment.

ATTENTION:
The separator outlet pressure is limited, so the pressure in the pipe line between separator outlet and day tank must be observed carefully. Follow the separator manufacturer's guidelines.

Heavy fuel day tank HT1

The tank design, sizing and location must comply with classification society requirements based on ship application. Two day tanks are to be provided. Each day tank capacity must be designed for full load operation of all consumers according to classification requirements. An overflow system into the settling tanks is required.HFO day tanks shall be provided with heating coils and sufficient insulation. Heating is possible by steam, thermal oil or hot water. The day tank temperature shall be above 90 °C.

5.2.2 Fuel booster and supply system

The booster system shall provide a pre-pressure to the mixing tank of approx. 4 - 5 bar. The circulating system provides sufficient flow of the required viscosity to the injection pumps. The circulation flow rate is typically 3.5 - 4 times the fuel consumption at MCR to prevent overheating of the fuel injection system and thus avoiding evaporation in the injection pumps.

Fuel change over main valve HR9

A manually operated three-way valve for changing over from MDO/MGO to HFO operation and back to MDO/MGO equipped with limit switches is necessary.

Primary filter (duplex filter) HF2

A protection strainer with a mesh size 320 µm has to be installed before fuel pressure pumps to prevent any large particles entering the pump.

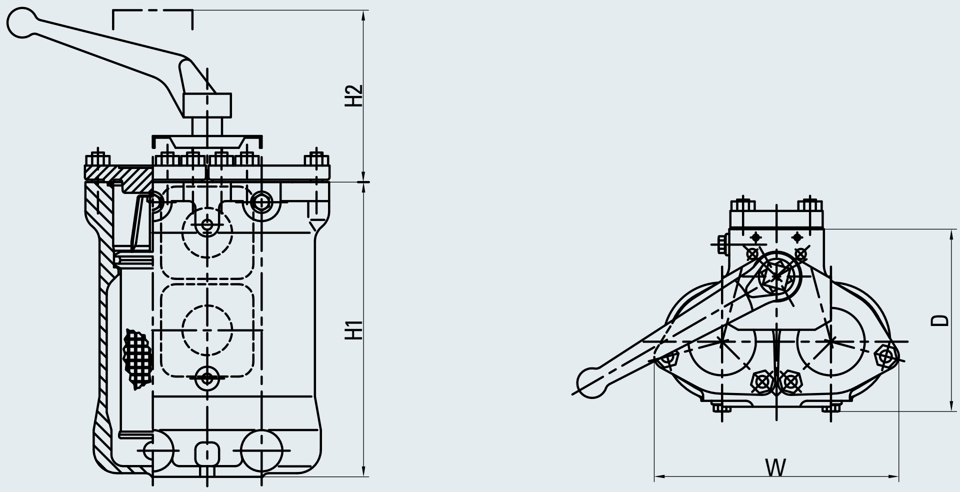

Fig. 5-11 Primary filter HF2

Engine output [kW]	DN	Dimensions [mm]			
		H1	H2	W	D
≤ 10,000	40	330	300	250	189
≤ 16,000	65	523	480	260	244
> 20,000	80	690	700	380	307

Fuel pressure pump HP1, fuel stand-by pressure pump HP2

Two supply pumps in parallel are recommended, one in operation and one on stand-by.
The capacity of the pump must be sufficient to prevent pressure drop during flushing of the automatic filter.
A suction strainer with a mesh size of 320 µm should be installed before each pump.

- Screw type pump with mechanical seal.
- Vertical or horizontal installation is possible.
- Delivery head 5 bar.

Capacity $V\ [m^3/h] = 0.4 \cdot \frac{P_{eng.} \cdot [kW]}{1{,}000}$

$V =$ Volume [m³/h]
$P_{eng.} =$ Power engine [kW]

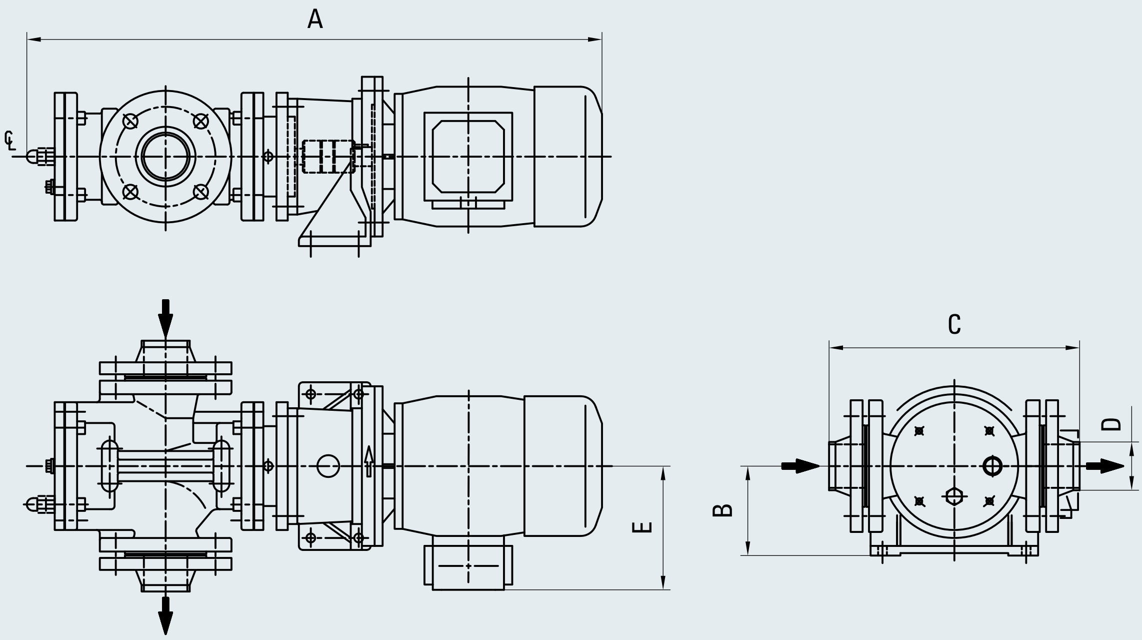

Fig. 5-12 Fuel pressure pump HP1; fuel stand-by pressure pump HP2

Plant output	Dimensions [mm]					Weight	Voltage / frequency
[kW]	A	B	C	D	E	[kg]	[V/Hz]
≤ 2,800	625	112	254	42.4	155	42	400/50
≤ 3,300	650	112	254	42.4	155	42	400/50
≤ 6,600	775	132	314	60.3	180	70	400/50
≤ 9,900	805	132	314	60.3	180	72	400/50

Plant output	Dimensions [mm]					Weight	Voltage / frequency
[kW]	A	B	C	D	E	[kg]	[V/Hz]
≤ 3,300	625	112	254	42.4	155	42	440/60
≤ 4,950	705	112	254	42.4	180	57	440/60
≤ 9,900	775	132	314	60.3	180	70	440/60

Fuel pressure regulating valve HR1

This valve is installed for adjusting a constant and sufficient pressure at engine fuel inlet. Due to the overcapacity of the pressure pumps HP1/HP2 the valve provides a nearly constant pressure under all operating conditions - from engine stop to maximum engine consumption. For MDO/MGO operation the pipes of the fuel return line must be equipped with sufficient fincoolers to reduce the generated heat.

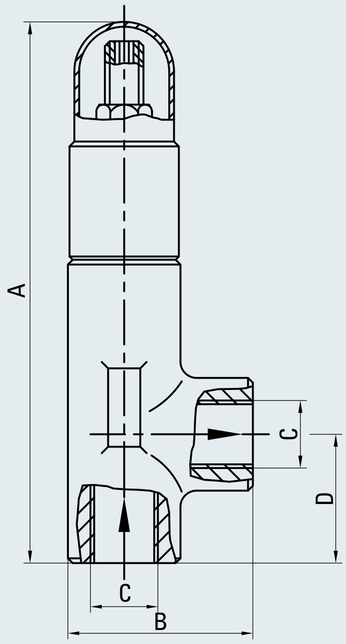

Fig 5-13 Fuel pressure regulating valve HR1, ≤ 3,000 kW

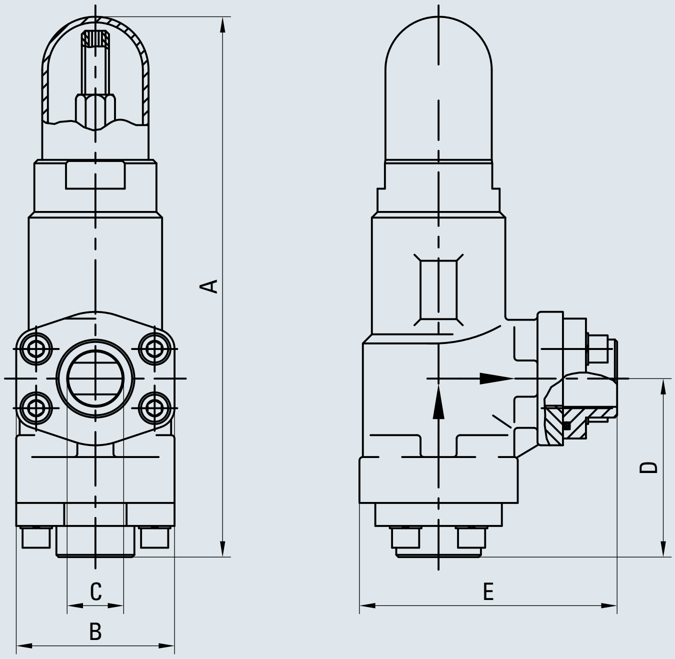

Fig 5-14 Fuel pressure regulating valve HR1, > 3,000 kW

Plant output	Dimensions [mm]					Weight
[kW]	A	B	C	D	E	[kg]
≤ 3,150	168	57.5	G ½"	40		1.5
≤ 8,400	248	70	Ø 25	88	122.5	3.6
> 8,400	279	94	Ø 38	109	150.5	8.4

HFO automatic filter HF4

An automatic filter with a mesh size 10 µm (absolute) is required to remove cat fines from the fuel oil. The filter is installed between day tank and mixing tank.

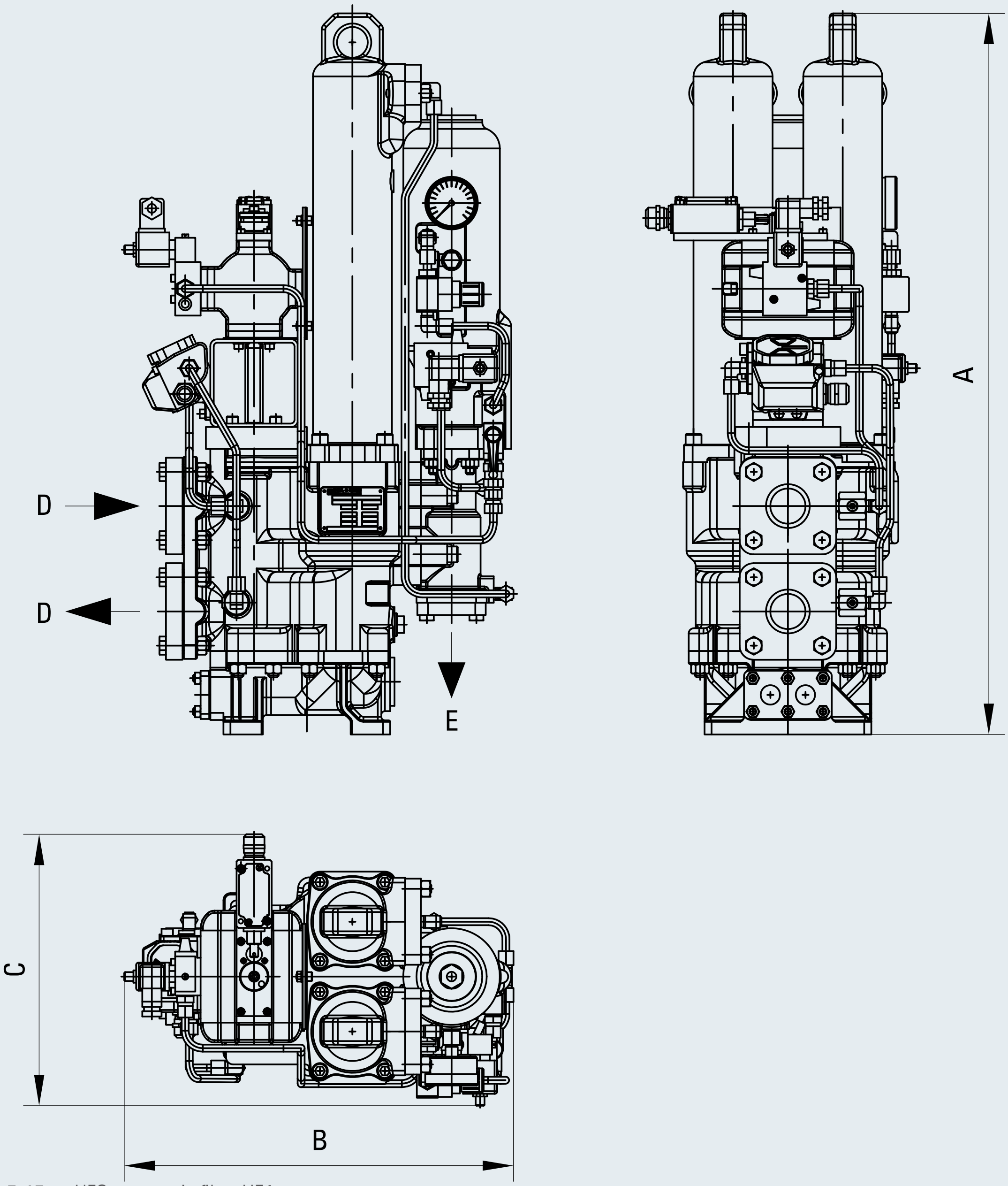

Fig. 5-15 HFO automatic filter HF4

Plant output	Dimensions [mm]				
[kW]	A	B	C	D	E
≤ 4,400	825	445	310	DN 40	DN 32
4,950 - 13,200	890	520	335	DN 65	DN 50
14,850 - 19,800	975	590	410	DN 80	DN 65

Flow quantity indicator FQ1

The fuel meter has to be installed between feed pumps and mixing tank HT2.
Independent fuel consumption measurements for individual engines can be provided by installing two flow meters per engine, one at the feed line and one at the return line.

Mixing tank HT2

The mixing tank acts as a buffer for fuel viscosity and/or fuel temperature, when changing over from HFO to diesel oil and vice versa. In the mixing tank the warm return fuel from the engine is mixed with the fuel delivered from the day tank.
Venting to the day tank is required, if level switch is activated, due to accumulated air or gases in the mixing tank.

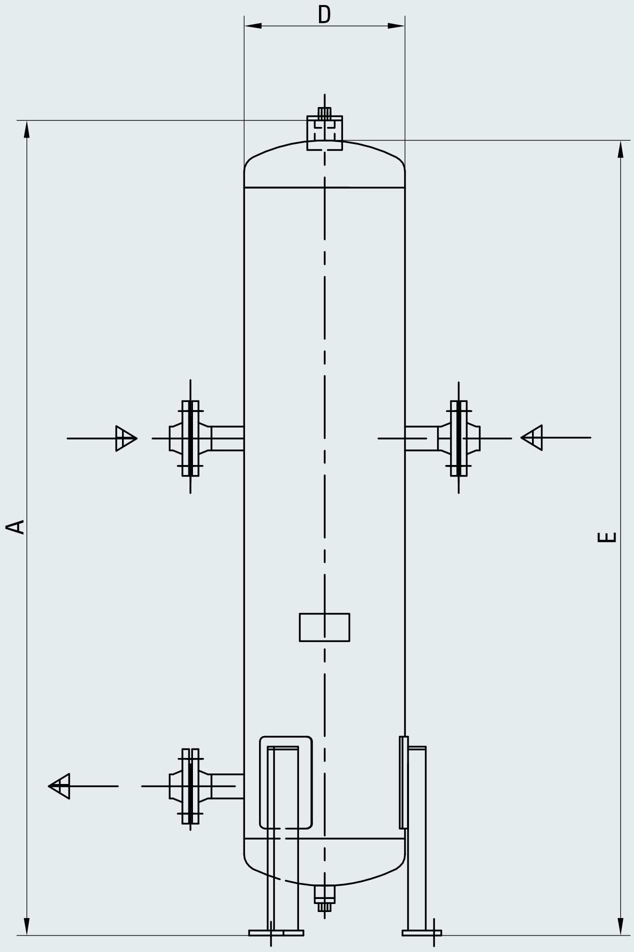

Fig. 5-16 Mixing tank HT2

Plant output	Volume	Dimensions [mm]			Weight
[kW]	[l]	A	D	E	[kg]
≤ 10,000	100	1,700	323	1,500	120
> 10,000	200	1,700	406	1,500	175

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Fuel circulating pump HP3, stand-by circulating pump HP4

Two fuel circulating pumps in parallel are recommended, one in operation and one on stand-by.
The circulating pumps maintain the required fuel circulation through the engine's fuel injection system.

- Screw type pump with mechanical seal
- Vertical or horizontal installation is possible
- Delivery head 5 bar

Capacity $V\,[m^3/h] = 0.7 \cdot \dfrac{P_{eng.} \cdot [kW]}{1{,}000}$

$V =$ Volume [m³/h]
$P_{eng.} =$ Power engine [kW]

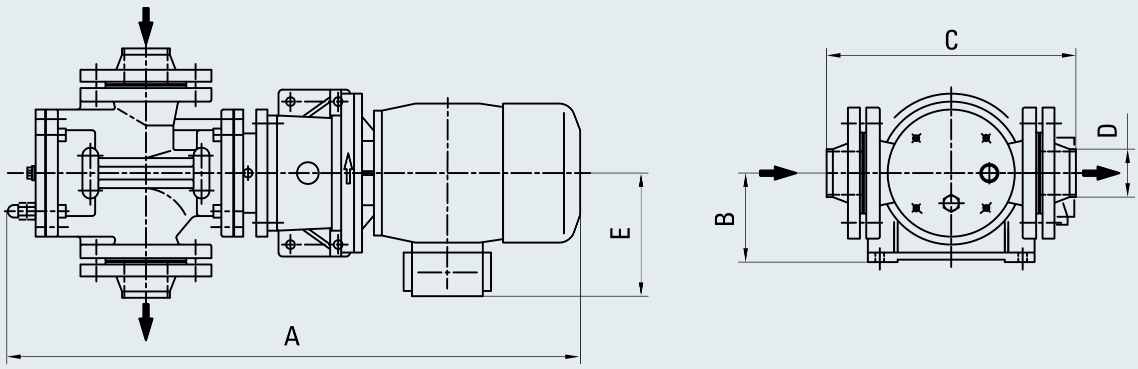

Fig. 5-17 Fuel circulating pump HP3, Stand-by circulating pump HP4

Plant output	Dimensions [mm]					Weight	Voltage / frequency
[kW]	A	B	C	D	E	[kg]	[V/Hz]
≤ 3,300	775	132	314	60.3	180	70	400/50
≤ 4,950	805	132	314	60.3	180	72	400/50
≤ 6,600	820	132	314	60.3	180	80	400/50
≤ 9,900	980	160	345	88.9	210	124	400/50

Plant output	Dimensions [mm]					Weight	Voltage / frequency
[kW]	A	B	C	D	E	[kg]	[V/Hz]
≤ 2,800	705	112	254	42.4	180	57	440/60
≤ 4,400	775	132	314	60.3	180	70	440/60
≤ 6,600	805	132	314	60.3	180	72	440/60
≤ 9,900	820	132	314	60.3	190	80	440/60

Heavy fuel final preheater HH1, stand-by final preheater HH2

The capacity of the final preheater shall be determined based on the injection temperature at the nozzle, to which 4 K must be added to compensate for heat losses in the piping.
The piping for both heaters shall be arranged for separate and series operation.
Parallel operation with half the flow must be avoided due to the risk of sludge deposits.
The arrangement of only one preheater may be approved where it is ensured that the operation with fuel oil which does not need preheating can be temporarily maintained.
NOTE:
Safe return to port requirement, maneuverability must be ensured.

- Two mutually independent final preheaters have to be installed.
- The arrangement of only one preheater may be approved where it is ensured that the operation with fuel oil which does not need preheating can be temporarily maintained.

Heating media:

- Electric current (max. surface power density 1.1 W/cm²)
- Steam
- Thermal oil

Temperature at engine inlet max. 150 °C

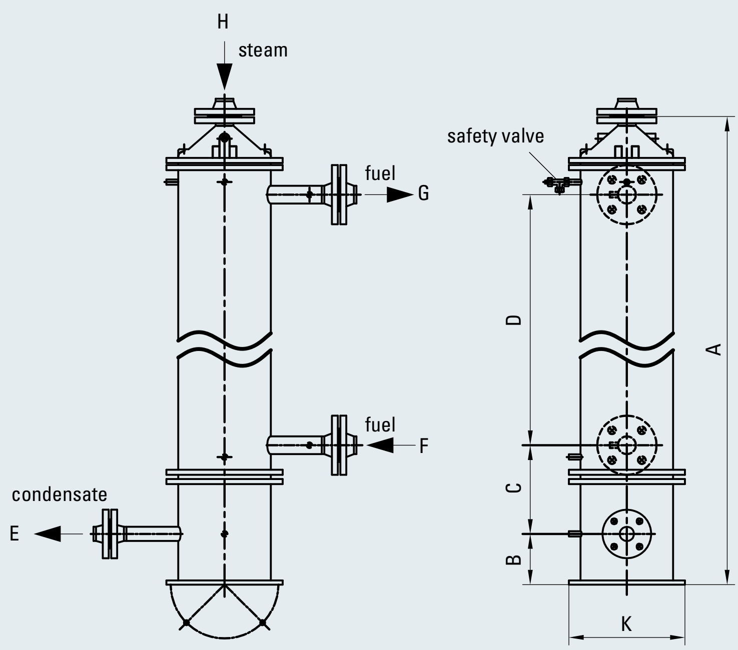

Fig. 5-18 Heavy fuel final preheater HH1, stand-by final preheater HH2 (steam heated)

Plant output	Dimensions [mm]									Weight
[kW]	A	B	C	D	E	F	G	H	K	[kg]
up to 3,300	1,220	120	210	705	DN 25	DN 25	DN 25	DN 32	Ø 275	125
up to 4,950	1,520	120	210	1,005	DN 25	DN 32	DN 32	DN 32	Ø 275	155
up to 8,800	2,065	120	215	1,540	DN 25	DN 40	DN 40	DN 32	Ø 275	272
up to 14,000	1,630	130	235	1,035	DN 40	DN 50	DN 50	DN 50	Ø 390	265
up to 21,000	2,170	130	235	1,555	DN 40	DN 65	DN 65	DN 50	Ø 390	339

Viscosimeter HR2

The viscosimeter is regulating in conjunction with the final preheater the required fuel injection viscosity. This device automatically regulates the heating of the final preheater depending on the viscosity of the bunkered fuel oil, so that the fuel will reach the nozzles with the viscosity required for injection.

Pressure absorber KD1 (optional)

During the injection phases of fuel from the supply line, compression and injection as well as the release of unused fuel into the return line, cyclic pressure pulsations may result. The requirement of installing fuel dampers in the external pipe system depends on the design of the external fuel pipe work and its ability to absorb such pulsations sufficiently. Just in case of enhanced damping requirements additional dampers have to be installed.

Bypass overflow valve HV (optional)

If more than one engine is connected to the fuel booster and supply system a bypass overflow valve between the feed line and the return line can be required.
It serves to secure and stabilize the pressure in the fuel feed line under all circumstances and operation conditions.
The overflow valve must be differential pressure operated.
The opening differential pressure should be 2 bar.

Duplex filter HF1 (fitted)

The fuel duplex filter is installed at the engine.
The two filter chamber construction allows continuous operation without any shut downs for cleaning the filter elements.
The drain connection of the filter is provided with a valve and must be routed to the leak oil tank.
If the filter elements are removed for cleaning, the filter chamber must be emptied. This prevents the dirt particles remaining in the filter casing from migrating to the clean oil side of the filter.

Fuel oil cooler DH3

To ensure a fuel oil temp. below 50 °C a cooling of diesel oil may be required.
The need for fuel cooler is system specific and depends on fuel circuit design and type of fuel oil.
In case of more than one engine are connected to the same fuel supply system, the MDO-cooler capacity has to be increased accordingly.
The diesel oil coolers are always installed in the fuel return line (engine connection C78).
The heat transfer load into the diesel oil system is approx. 1.2 kW/cyl.
LT-water is normally used as cooling medium.

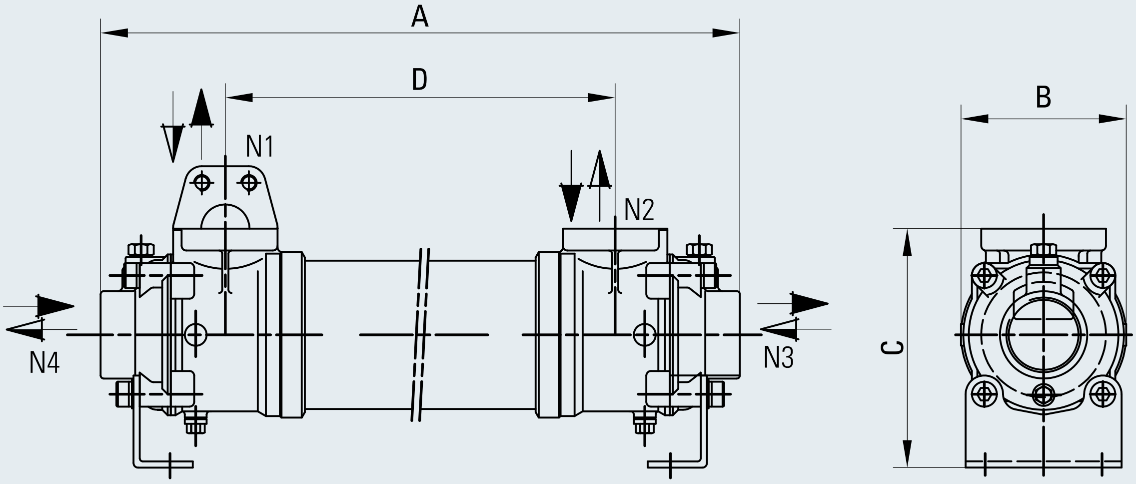

Fig. 5-19 Fuel oil cooler for MDO operation DH3

	Dimensions [mm]						Weight
	A	B	C	D	N1 + N2	N3 + N4	[kg]
6/8/9 M 25 E	710	106	153	550	1 ¼" SAE	1 ½" SAE	16

5.2.3 Fuel booster and supply module

A complete fuel conditioning module, designed for HFO up to 700 cSt / 50 °C, can be supplied.

Caterpillar Motoren standard modules consist of the following components:

- Three-way change over valve
- Booster pumps
- Automatic filter
- Pressure regulating valve
- Fuel flow meter
- Mixing tank
- Circulating pumps
- Fuel preheater (steam, thermal oil or electric)
- Viscosity control
- Diesel oil cooler
- Control cabinet
- Alarm panel

Built on one frame, they include all piping, wiring and trace heating.

Module controlled automatically with alarms and starters

- Pressure pump starters with stand-by automatic
- Circulating pump starters with stand-by automatic
- PI-controller for viscosity controlling
- Starter for the viscosimeter
- Analog output signal 4 - 20 mA for viscosity

Alarms

- Pressure pump stand-by start
- Low level in the mixing tank
- Circulating pump stand-by start
- Self-cleaning fine filter clogged
- Viscosity alarm high/low
- The alarms with potential free contacts
- Alarm cabinet with alarms to engine control room and connection interface for remote start/stop and
- Indicating lamp of fuel pressure and circulating pumps

Size, weight and dimensions

The whole module is tubed and cabled up to the terminal strips in the electric switch boxes which are installed on the module. All necessary components like valves, pressure switches, thermometers, gauges etc. are included. The fuel oil pipes are equipped with trace heating (steam, thermal oil or electrical) where necessary.

NOTE:
The module will be tested hydrostatically and functionally in the workshop without heating and not connected to the engine.

Module size	Capacity up to [kW]	Module size (LxWxH) [mm]	Module weight [kg]
Size 1	1,900	2,800 x 1,200 x 2,100	1,700
Size 2	2,800	2,800 x 1,200 x 2,100	1,800
Size 3	4,200	3,000 x 1,200 x 2,100	2,200
Size 4	6,000	3,200 x 1,300 x 2,100	2,700
Size 5	8,200	3,200 x 1,300 x 2,100	2,700
Size 6	9,300	3,400 x 1,400 x 2,100	3,000
Size 7	11,400	3,600 x 1,400 x 2,100	3,400
Size 8	13,100	3,600 x 1,400 x 2,100	3,400
Size 9	15,900	4,200 x 1,600 x 2,100	3,800
Size 10	19,800	5,000 x 1,700 x 2,100	4,600
Size 11	26,000	6,000 x 2,000 x 2,100	5,600

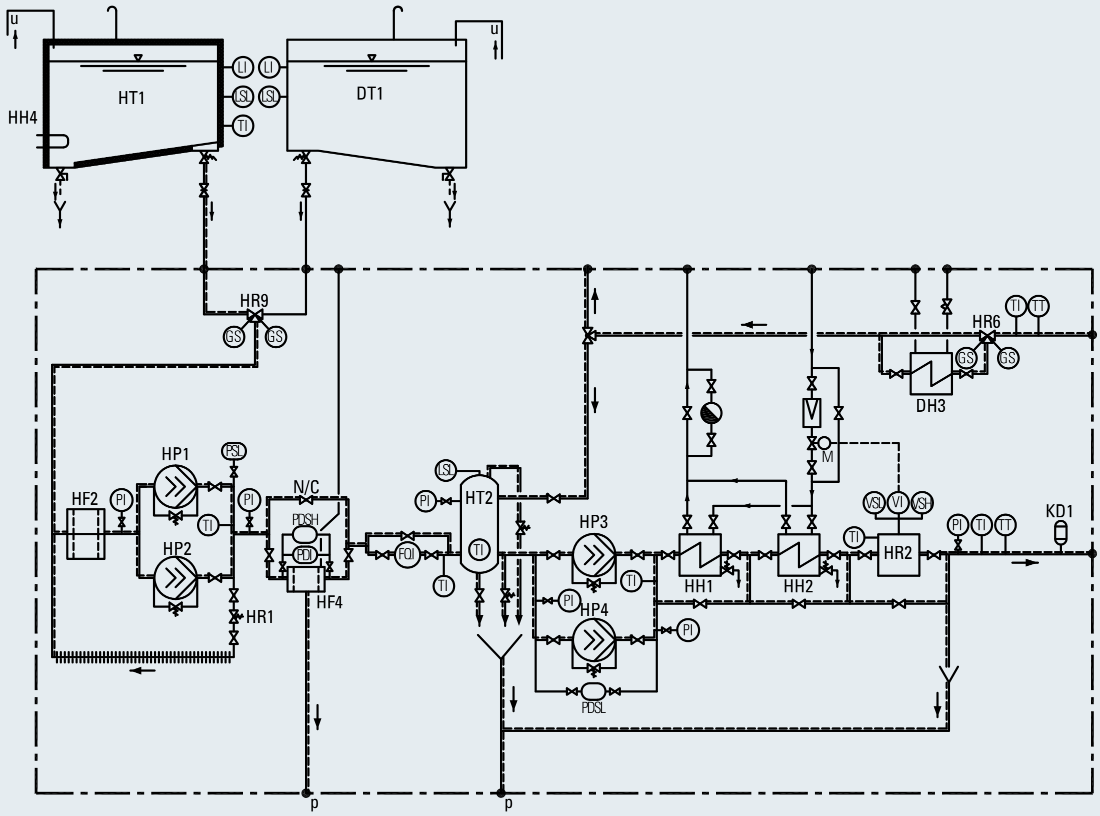

Fig. 5-20 Fuel booster and supply module, system diagram

DH3	Fuel oil cooler for MDO operation	KD1	Pressure absorber
DT1	Diesel oil day tank	FQI	Flow quantity indicator
HF2	Primary filter (duplex filter)	GS	Limit switch
HF4	HFO automatic filter	LI	Level indicator
HH1	Heavy fuel final preheater	LSL	Level switch low
HH2	Stand-by final preheater	PDI	Diff. pressure indicator
HH4	Heating coil	PDSH	Diff. pressure switch high
HP1	Fuel pressure pump	PDSL	Diff. pressure switch low
HP2	Fuel stand-by pressure pump	PI	Pressure indicator
HP3	Fuel circulating pump	PSL	Pressure switch low
HP4	Stand-by circulating pump	TI	Temperature indicator
HR1	Fuel pressure regulating valve	TT	Temperature transmitter (PT100)
HR2	Viscosimeter	VI	Viscosity indicator
HR6	Change over valve (HFO/diesel oil) 3-way-valve	VSH	Viscosity control switch high
		VSL	Viscosity control switch low
HR9	Fuel change over main valve		
HT1	Heavy fuel day tank	p	Free outlet required
HT2	Mixing tank	u	Fuel separator or from transfer pump

All heavy fuel pipes have to be insulated.

- - - - Heated pipe

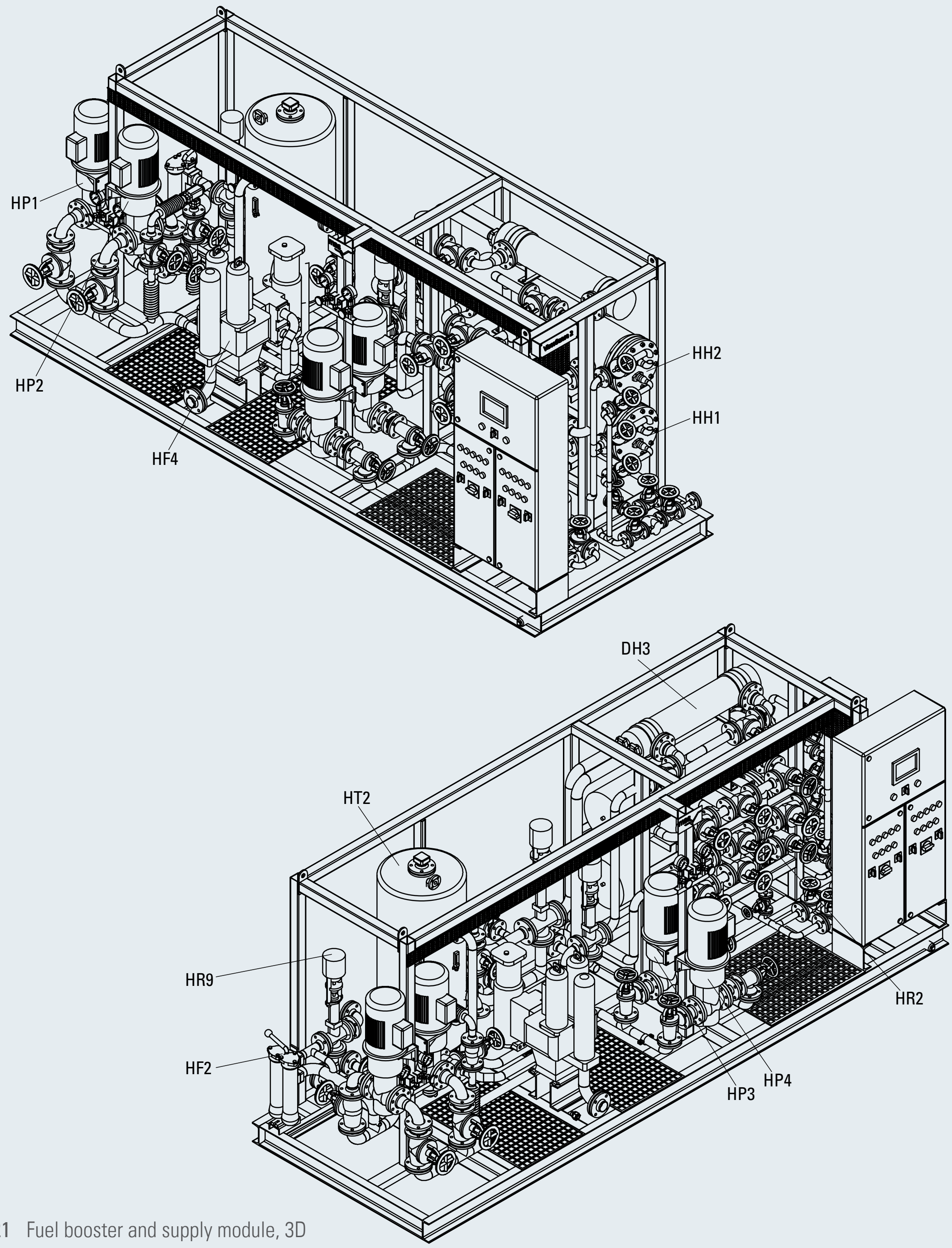

Fig. 5-21 Fuel booster and supply module, 3D

DH3	Fuel oil cooler for MDO operation	HP1	Fuel pressure pump
HF2	Primary filter (duplex filter)	HP2	Fuel stand-by pressure pump
HF3	Coarse filter	HP3	Fuel circulation pump
HF4	HFO automatic filter	HP4	Stand-by circulation pump
HH1	Heavy fuel final preheater	HR9	Fuel change over main valve
HH2	Stand-by final preheater	HT2	Mixing tank

5.3 Switching over from HFO to diesel oil

Continuous operation with HFO is recommended for engines designed for running mainly on HFO.
Starting and stopping the engine on HFO (Pier to Pier) can be provided if a sufficient preheating of the fuel oil system is ensured. The circulating pumps have to be permanently in service, so that a continuous circulation of warm/hot fuel oil through the engine is ensured.
A frequent change over from HFO to diesel oil is only recommended when necessary for flushing purposes, emergencies, special sea area emission requirements, etc.
Changing the fuel oil too quickly and too often may cause high risk of plunger seizure (thermal shock), fuel injection pump leakages, etc. in the fuel injection pump. Only a slow switch over will attenuate that effect.

Pier to Pier operation:
In case of short engine stops, so called Pier to Pier operation, the engine can be stopped on HFO and started on HFO again, without flushing with MDO before.
This requires a permanent circulation with hot HFO throughout the engine and fuel oil system, to keep the system heated. Only in case of a longer engine stop (maintenance), the engine and fuel system shall be flushed with diesel oil before

Typical switch over characteristics (HFO to diesel)

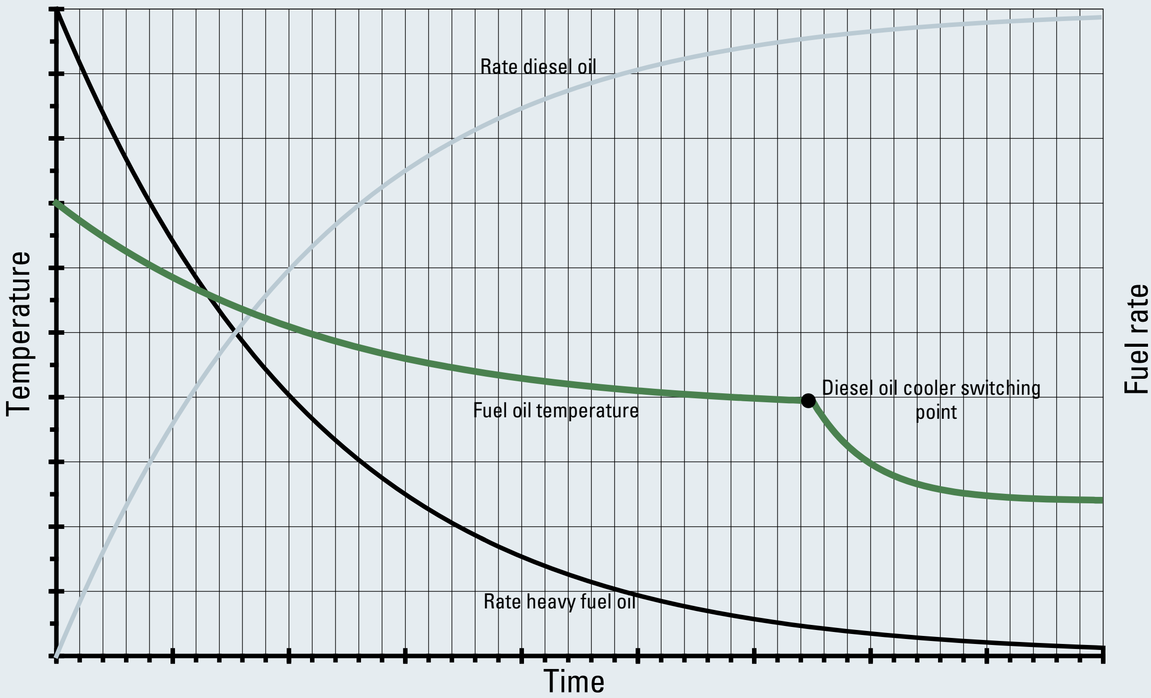

Fig 5-22 Switch over characteristics

5.4 Crude oil operation

The MaK engine can be operated on crude oil, depending on crude oil specification. Due to the wide range of qualities the crude oil system has to be designed appropriate. In any cases please consult Caterpillar Motoren technical product support.

General

The lube oil performs several basic functions:

- It cleans the engine by carrying dirt and wear particles until the filters can extract and store them.
- It cools the engine by carrying heat away from the piston, cylinder walls, valves and cylinder heads to be dissipated in the engine oil cooler.
- It cushions the engines bearings from the shocks of cylinder firing.
- It lubricates the wear surfaces, reducing friction.
- It neutralizes the corrosive combustion products.
- It seals the engines metal surfaces from rust.
- It lubricates the turbocharger bearings.
- It cools the injection nozzles.

6.1 Lube oil requirements

NOTE:
The viscosity class SAE 40 is required.

Wear and tear and thus the service life of the engine depend on the lube oil quality. Therefore high requirements are made for lubricants:

- Constant uniform distribution of the additives at all operating conditions.
- Perfect cleaning (detergent effect) and dispersing power, prevention of deposits from the combustion process in the engine.
- Sufficient alkalinity in order to neutralize acid combustion residues.
- The TBN (total base number) must be between 30 and 40 KOH/g at HFO operation.
  The TBN is 12 - 20 KOH/g for MDO operation depending on Sulfur content

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Manufacturer	Diesel oil / MDO operation	I	II	HFO operation	I	II
AGIP	DIESEL SIGMA S		X	CLADIUM 300 S	X	
	CLADIUM 120		X	CLADIUM 400 S	X	
BP	ENERGOL HPDX 40	X		ENERGOL IC-HFX 304	X	
	ENERGOL DS 3-154	X		ENERGOL IC-HFX 404	X	
	ENERGOL IC-HFX 204	X				
	VANELLUS C3		X			
CAT	DEO	X				
CHEVRON,	DELO 1000 MARINE	X		TARO 30 DP	X	
CALTEX,	TARO 12 XD	X		TARO 40 XL	X	
TEXACO	TARO 16 XD	X		TARO 40 XLX	X	
	TARO 20 DP	X				
	TARO 20 DPX	X				
CASTROL	MARINE MLC	X		TLX PLUS 304	X	
	MHP 154	X		TLX PLUS 404	X	
	TLX PLUS 204	X				
CEPSA	KORAL 1540		X			
ESSO	EXXMAR 12 TP	X		EXXMAR 30 TP	X	
	EXXMAR CM+		X	EXXMAR 30 TP PLUS	X	
	ESSOLUBE X 301		X	EXXMAR 40 TP		X
				EXXMAR 40 TP PLUS	X	
MOBIL	MOBILGARD 412	X		MOBILGARD M430	X	
	MOBILGARD ADL	X		MOBILGARD M440	X	
	MOBILGARD M430	X		MOBILGARD M50	X	
	MOBILGARD 1-SHC [1)]		X			
	DELVAC 1640	X				
SHELL	GADINIA	X		ARGINA T	X	
	GADINIA AL	X		ARGINA X	X	
	ARGINA S	X				
	ARGINA T	X				
TOTAL	RUBIA FP		X	AURELIA TI 4030	X	
LUBMARINE	DISOLA M 4015	X		AURELIA TI 4040	X	
	AURELIA TI 4030	X				
	CAPRANO M40	X				
LUKOIL	NAVIGO 12/40	X		NAVIGO TPEO 40/40	X	
	NAVIGO 15/40	X		NAVIGO TPEO 30/40	X	
GULF				SEA POWER 4030	X	
				SEA POWER 4040	X	

I Approved in operation / II Permitted for controlled use. When these lube oils are used, Caterpillar Motoren GmbH & Co. KG must be informed because at the moment there is insufficient experience available for engines. Otherwise the warranty is invalid. / **1)** Synthetic oil with a high viscosity index (SAE 40 W/40). Only permitted if the oil inlet temperatures can be decreased by 5 - 10 °C.

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6.2 Internal lube oil system

Lube oil force pump LP1 (fitted)

The lube oil force pump is a gear pump, fitted on the engine and mechanically driven by the crankshaft. The lube oil force pump provides the lube oil from the circulating tank LT1 to the engine.
It is designed to provide a sufficient amount of lube oil at the required pressure to the engine even when running at the designed minimum engine speed. Capacity, see technical data.

Self-cleaning lube oil filter LF2 (fitted)

The back flushing filter protects the engine from dirt particles which may accumulate in the circulating tank LT1.
Mesh size 30 µm (absolute). The filter is continuously flushing into the oil pan without flushing oil treatment, without bypass filter. For single-engine plants a filter insert will be delivered as spare part.

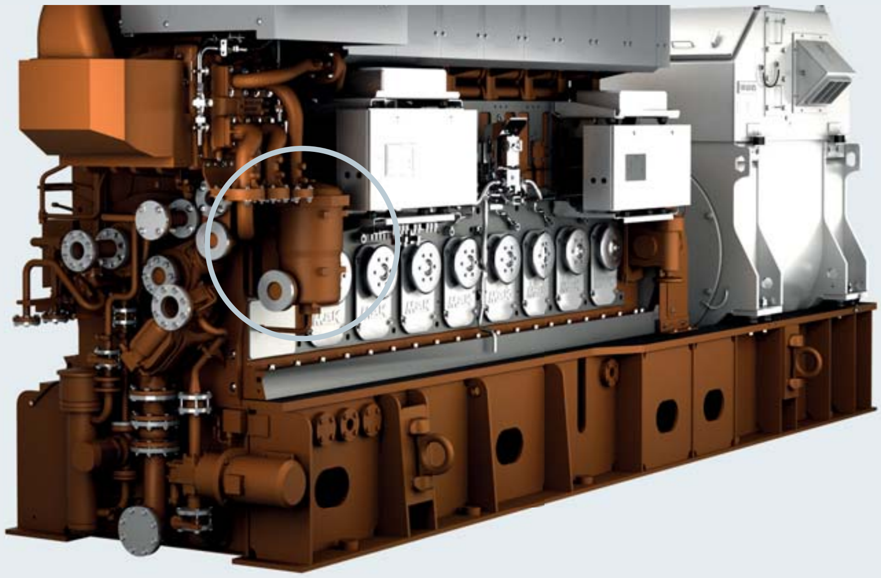

Fig. 6-1 Self-cleaning lube oil filter LF2

Back flushing filter LF2 (separate), option

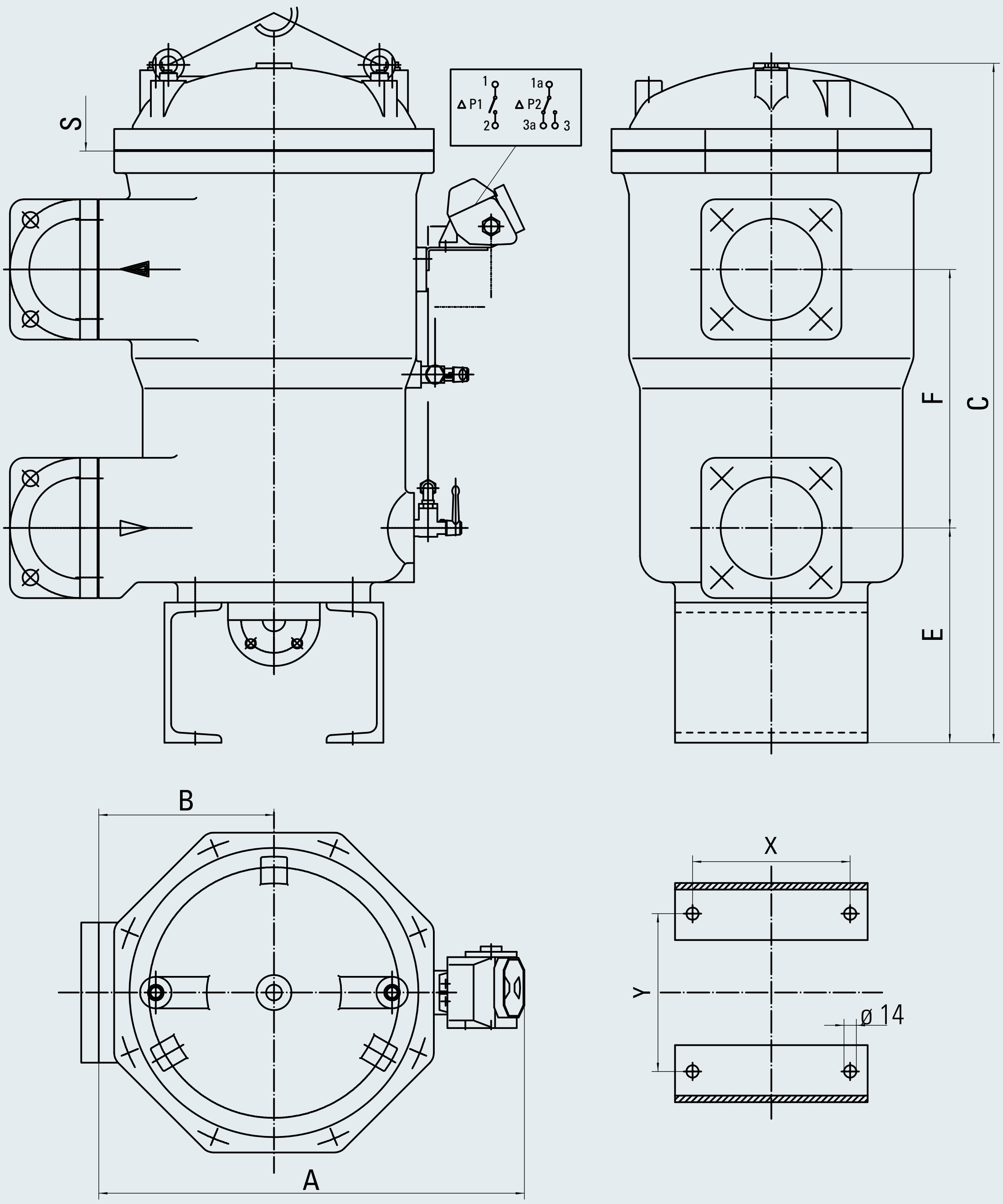

Fig. 6-2 Back flushing filter LF2

	Dimensions [mm]								Weight
	A	B	C	E	F	S	X	Y	[kg]
6 M 25 E	435	170	735	205	225	400	160	160	80
8/9 M 25 E	485	200	775	245	295	400	180	180	112

If the back flushing filter is separate, there will be a duplex filter on the engine.

6.3 External lube oil system

General

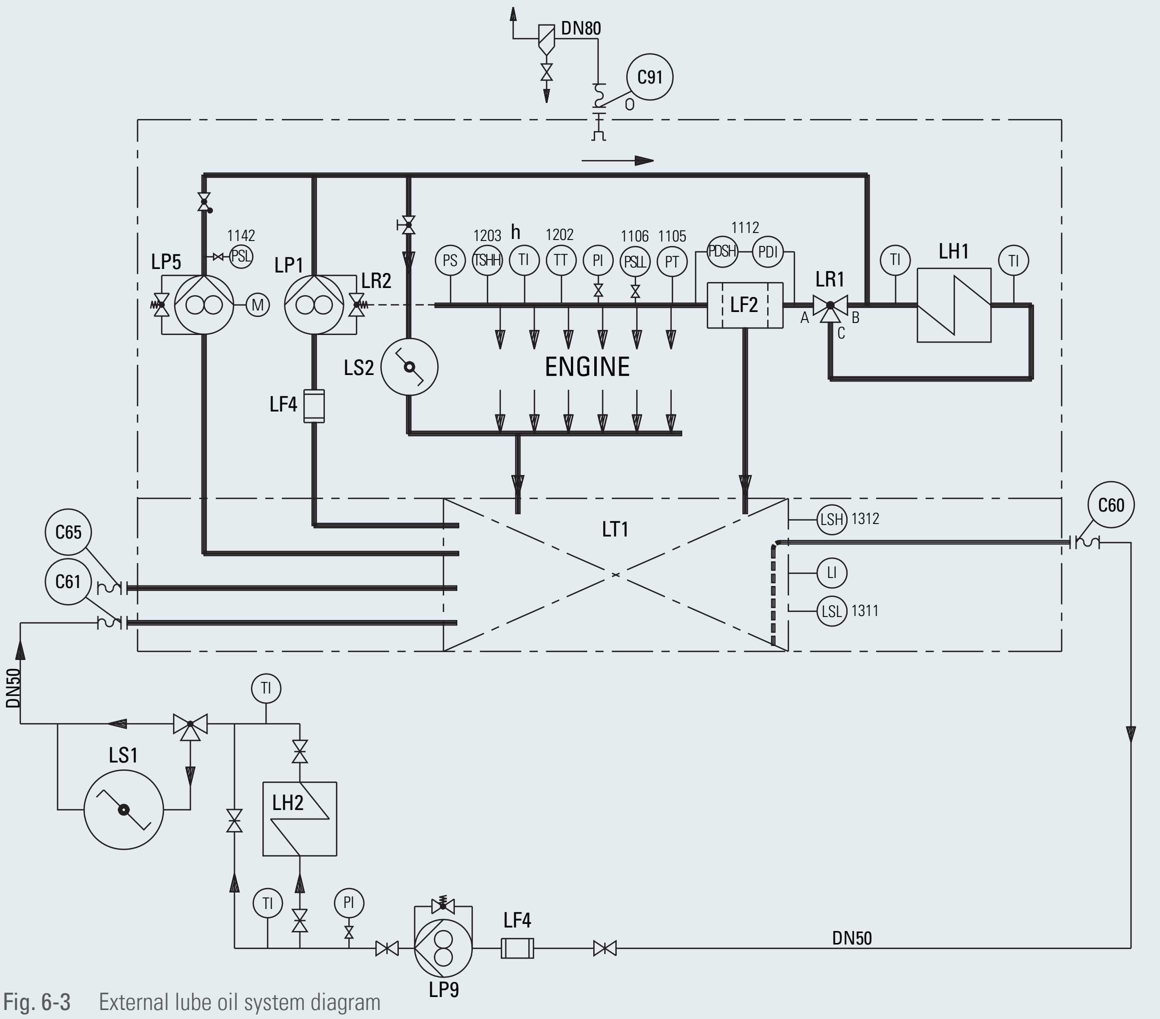

Fig. 6-3 External lube oil system diagram

LF2	Self-cleaning lube oil filter	LI	Level indicator
LF4	Suction strainer	LSL	Level switch low
LH1	Lube oil cooler	LSH	Level switch high
LH2	Lube oil preheater	PDI	Diff. pressure indicator
LP1	Lube oil force pump	PDSH	Diff. pressure switch high
LP5	Prelubrication pump	PI	Pressure indicator
LP9	Transfer pump (separator)	PSL	Pressure switch low
LR1	Lube oil temperature control valve	PSLL	Pressure switch low
LR2	Oil pressure regulating valve	PT	Pressure transmitter
LS1	Lube oil separator	TI	Temperature indicator
LT1	Sump tank	TSHH	Temperature switch high high
		TT	Temperature transmitter (PT100)

C60	Separator connection, suction side or drain filling pipe	h	Please refer to the measuring point list regarding design of the monitoring devices.
C61	Separator connection, delivery side or from bypass filter	o	See "crankcase ventilation" installation instructions 4-A-9570
C65	Lube oil filling		
C91	Crankcase ventilation to stack		

Lube oil cooler LH1

A plate cooler with plates of stainless steel will be used to dissipate the heat to the LT fresh water system. It is mounted at the baseframe
Option: separate

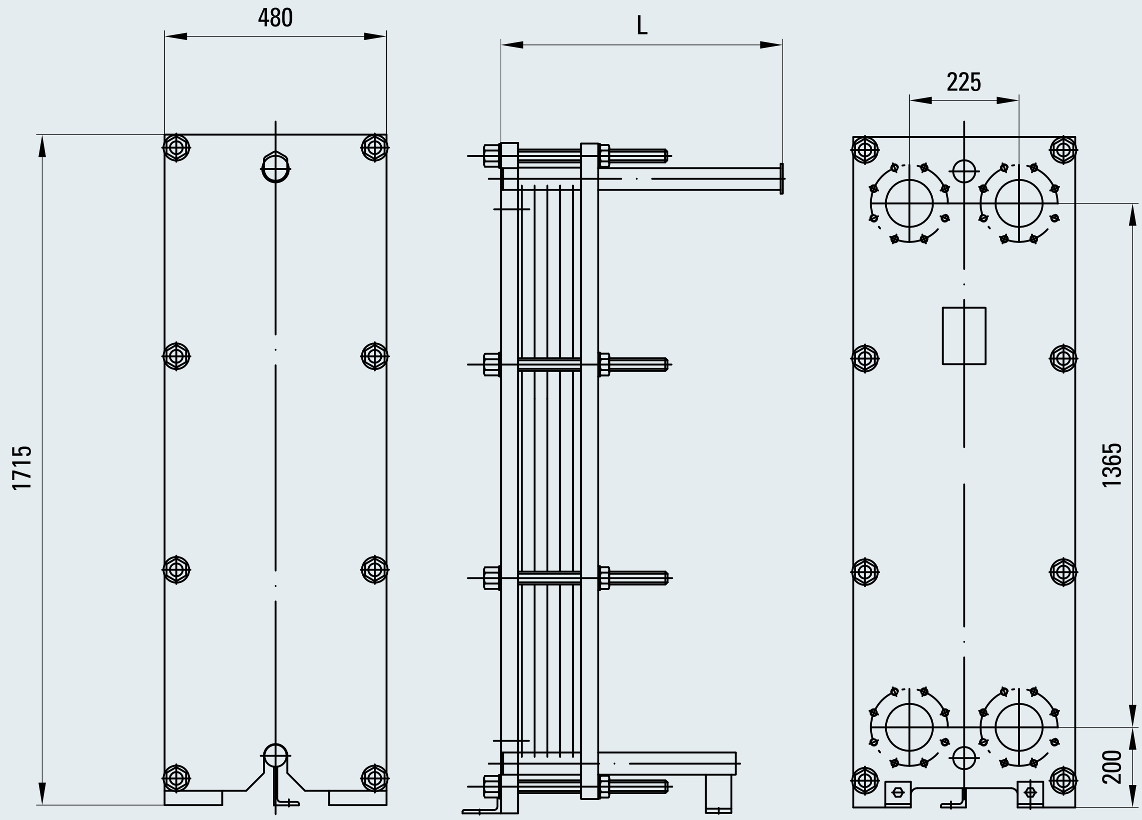

Fig. 6-4 Lube oil cooler LH1

	L [mm]	Weight [kg]
6 M 25 E	534	471
8 M 25 E	634	499
9 M 25 E	634	513

Lube oil temperature control valve LR1 (fitted)

A wax operated control valve will be used to control the oil inlet temperature into the engine. It has an emergency manual adjustment.
Option: separate

Control valve, option

If the cooler is not mounted at the baseframe, the control valve is also separated.

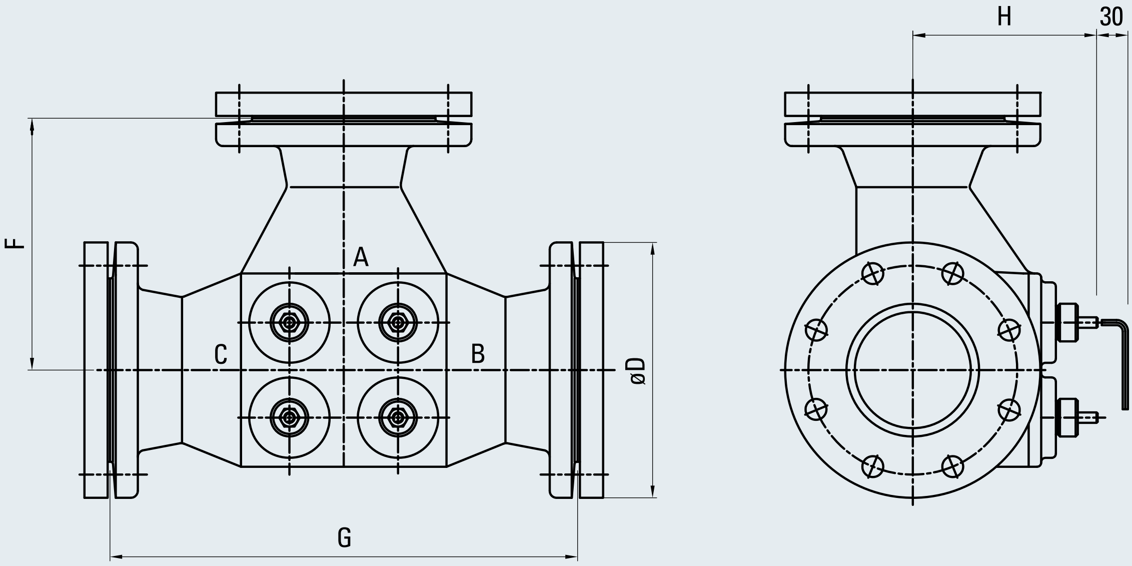

Fig. 6-5 Lube oil temperature control valve LR1

	Dimensions [mm]					Weight
	DN	D	F	G	H	[kg]
6 M 25 E	80	200	171	267	151	27
8/9 M 25 E	100	220	217	403	167	47

Centrifugal filter LS2 (separate)

A centrifugal filter can be used for cleaning of lube oil. This may extend the lube oil change intervals.

Prelubricating pump LP5

This pump is mounted at the baseframe.
This pump can only be used for prelubricating, not as stand-by for the force pump.
Capacity see technical data.

Oil pressure regulating valve LR2 (fitted)

The pressure control valve controls the lube oil pressure at engine inlet by giving only the adequate oil flow to the engine. Excessive oil flow will be led back into the engine oil pan.

Lube oil temperature control valve LR1 (electric driven valve), option

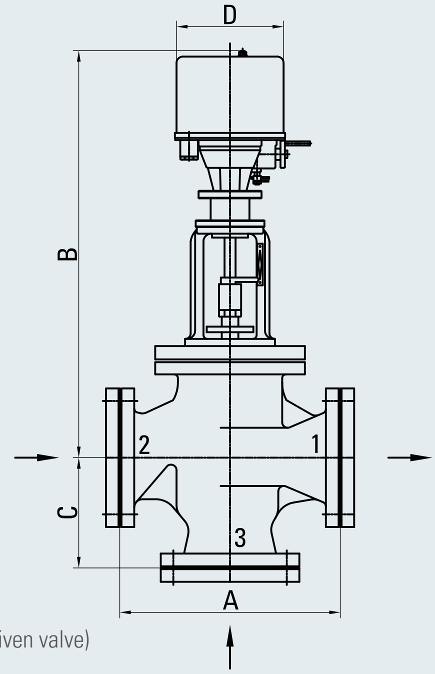

Fig. 6-6 Lube oil temperature control valve LR1 (electric driven valve)

	Dimensions [mm]					Weight
	DN	A	B	C	D	[kg]
6 M 25 E	80	310	624	155	170	58
8/9 M 25 E	100	350	646	175	170	70

Lube oil separator LS1 (separate)

The most effective cleaning of lube oil is carried out by means of separation.
Separation is mandatory for HFO driven plants and highly recommended for MGO/MDO operation.

Layout for MGO/MDO operation

Automatic self-cleaning separator; Operating temperature 85 - 95 °C

V [l/h] = 0.18 · P_{eng} [kW] P_{eng} = Power engine [kW]

Layout for HFO operation

Automatic self-cleaning separator; Operating temperature 95 °C

V [l/h] = 0.29 · P_{eng} [kW] P_{eng} = Power engine [kW]

For the layout of separators, please follow the separator manufacturer‘s guidelines.

6.4 Circulating tanks

The circulating tank LT1 is mounted at the baseframe.

6.5 Crankcase ventilation system

6.5.1 Crankcase ventilation pipe dimensions

- The crankcase ventilation connecting point is DN 80.
- The engine main ventilation line must be at least DN 125.

6.5.2 Crankcase ventilation pipe layout

- The pipes should run upwards.
- Free ventilation under all trim conditions is required.
- To avoid backflow of condensate, a permanent drain of the ventilation pipe is required.

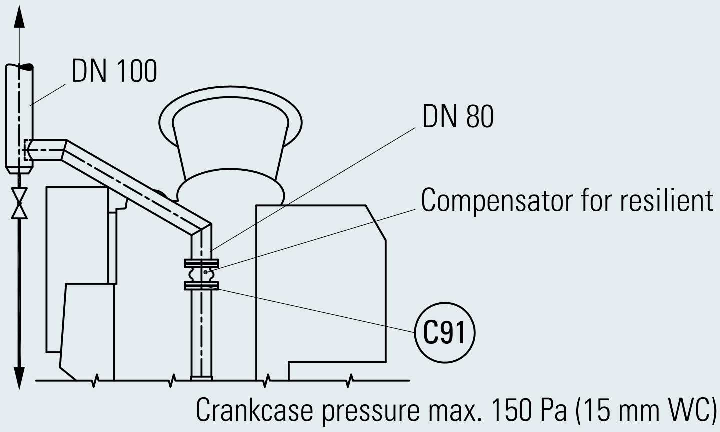

Fig. 6-7 Crankcase ventilation

C91 Crankcase ventilation to stack

7.1 General

MaK engines are cooled by two cooling circuits:

- A high temperature (HT) and
- A low temperature (LT) cooling circuit

The cooling water needs to be treated according to Caterpillar Motoren requirements for MaK engines.

7.1.1 Two circuit cooling system

In this system arrangement, the two cooling systems are designed as two separate water circuits.
Each circuit needs to be fitted with a header tank and a fresh water cooler.

7.1.2 Secondary circuit cooling system

In the "secondary circuit cooling system", HT and LT cooling circuits are combined in sequence to one water circuit.
In order to use the different temperature levels, the HT suction side is connected to the LT delivery side.
The HT circuit uses an amount of warm LT water and further heats it up by cooling the engine. The amount of LT water, that is used by the HT system, depends on the current temperature and engine power. The overrun of the fixed flow of the fresh water pump (fitted on engine) HT (FP1) circulates via bypass line from the temperature control valve HT (FR1) to the suction side as usual.
The advantage of the secondary circuit system is its simplicity. It uses just one water circuit and there is only one header tank and one fresh water cooler instead of two.
In addition the amount of piping is reduced.

7.2 Water quality requirements

7.2.1 General

The engine cooling water must be carefully selected, treated and controlled.
The use of untreated cooling water will cause corrosion, erosion and cavitation on the surfaces of the cooling system. Deposits can impair the heat transfer and may result in thermal overload on components to be cooled.
Therefore the treatment with an anti-corrosion agent has to be effected before the very first commissioning of the plant.

7.2.2 Requirements

The characteristic of the untreated cooling water must be within the following limits:

- Distillate or freshwater free from foreign matter (no seawater or waste water)
- A total hardness of max. 10° dH
- pH-value 6.5 – 8
- Chloride ion content of max. 50 m/l

7.2.3 Supplementary information

Distillate:
If a distillate or fully desalinated water is available, this should preferably be used as engine cooling water.
Hardness:
Water with more than 10° dGH (German total hardness) must be mixed with distillate or softened.

7.2.4 Treatment before operating the engine for the first time

Treatment with an anti-corrosion agent must be done before the engine is operated for the first time to prevent irreparable initial damage.

7.3 Recommendation for cooling water system

7.3.1 Pipes and tanks

Galvanized material should not be used in tanks and pipes, it can cause zinc attack in the engine.

7.3.2 Drain tank with filling pump

It is recommended to collect the treated water in a separate drain tank when carrying out maintenance work (to be installed by the yard).

7.3.3 Electric motor driven pumps

Pumps should be applicable for use in fresh water as well as sea water circuits, vertical design.

Rough calculation of power demand for the electric balance:

$$p = \frac{\rho \cdot H \cdot \dot{V}}{367 \cdot \eta} \text{ [kW]}$$

$P =$	Power [kW]
$P_M =$	Power of electr. motor [kW]
$\dot{V} =$	Flow rate [m³/h]
$H =$	Delivery head [m]
$\rho =$	Density [kg/dm³]
$\eta =$	Pump efficiency, 0.70 for centrifugal pumps

$P_M =$	$1.5 \cdot P$	< 1.5 kW
$P_M =$	$1.25 \cdot P$	1.5 - 4 kW
$P_M =$	$1.2 \cdot P$	4 - 7.5 kW
$P_M =$	$1.15 \cdot P$	7.5 - 40 kW
$P_M =$	$1.1 \cdot P$	> 40 kW

7.4 Cooling water system

General note: The following system siagrams should be regarded as typical examples. Their purpose is to explain the general function of the engine's systems. Numerous other variants and arrangements are possible and can be discussed and developed with the mechanical MaK A&I department.

7.4.1 General

The high temperature (HT) system provides the HT side of the charge air cooler and the engine's cylinder heads and cylinder liner water rings with cooling water. In order to reduce the thermal tension in water-cooled engine parts, it is important to keep the drop in temperature low and therefore the flow high. Therefore the fresh water pump (fitted on engine) HT (FP1) delivers its full flow over the engine. The HT outlet temperature of 90 °C is controlled by the temperature control valve HT (FR1). In case the temperature decreases, the valve delivers more water to the bypass (connection B for mechanical, connection 3 for electrical driven valves) back to the HT pump's suction side.
In order to use the thermal energy of the HT circuit, a heat recovery can be installed as shown in the cooling water diagrams (FH3). For heat recoveries, especially for fresh water generators a high flow over the heat consumer (FH3) is recommended. This can be achieved by using a flow temperature control valve HT (FR3). This valve raises the HT flow temperature and therefore reduces the amount of water that is circulated over the bypass of FR1 and increases the flow through the heat recovery heat consumer (FH3) and the fresh water cooler HT (FH1).

The low temperature (LT) cooling circuit provides cooling for the LT stage of the charge air cooler, the lube oil and the diesel oil coolers and possible other consumers like e.g. gear box and generator coolers.
The LT flow temperature is controlled by FR2. The cooling system is laid out for 38 °C under tropical conditions and full engine load. For better performance, the LT temperature is to be controlled to 32 °C.
Caterpillar Motoren can deliver mechanic P-controllers with a set point range of 20 to 30 °C or electric driven valves with electronic controllers, which must be set to 32 °C.
Depending on the plant design the fresh cooling water pumps can be fitted on the engine. All cooling water pumps also may be designed as separate with electrical drive

Cooling water system diagram

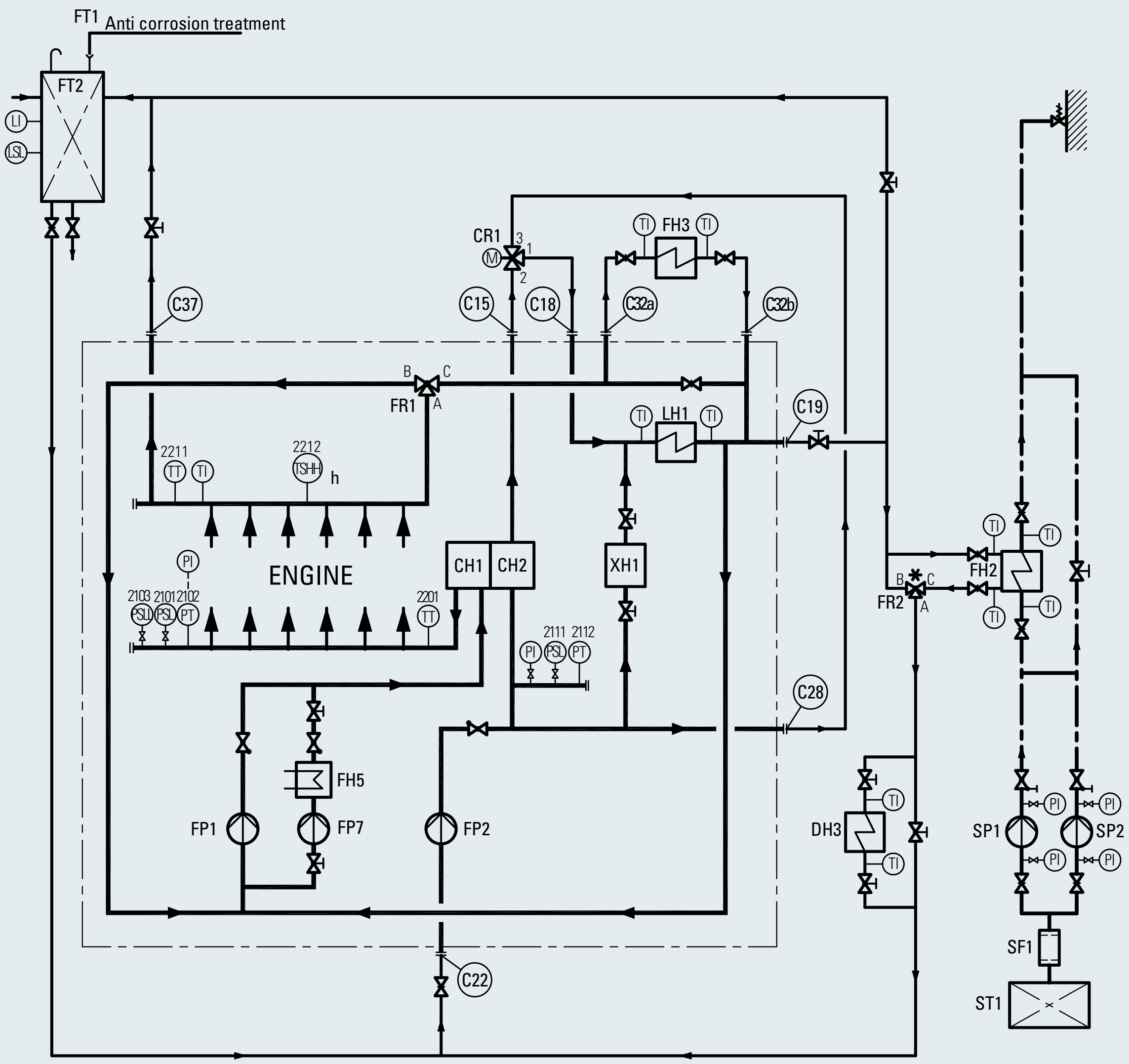

Fig. 7-1 Cooling water system diagram

In plants with skin or box coolers not required: seawater system (SP1, SP2, SF1, ST1).

CH1	Charge air cooler HT
CH2	Charge air cooler LT
CR1	Charge air temperature control valve
DH3	Fuel oil cooler for MDO operation
FH2	Fresh water cooler LT
FH3	Heat consumer
FH5	Fresh water preheater
FP1	Fresh water pump (fitted on engine) HT
FP2	Fresh water pump (fitted on engine) LT
FP7	Preheating pump
FR1	Temperature control valve HT
FR2	Temperature control valve LT
FT2	Compensation tank LT
LH1	Lube oil cooler
SF1	Seawater filter
SP1	Seawater pump
SP2	Seawater stand-by pump
ST1	Sea chest
XH1	Generator cooler

LI	Level indicator
LSL	Level switch low
PI	Pressure indicator
PSL	Pressure switch low
PSLL	Pressure switch low
PT	Pressure transmitter
TI	Temperature indicator
TSHH	Temperature switch high
TT	Temperature transmitter

C15	Charge air cooler LT, outlet
C18	Oil cooler, inlet
C19	Oil cooler outlet
C22	Freshwater pump LT, inlet
C28	Fresh water pump LT, outlet
C32a	Heat recovery, outlet (optional)
C32b	Heat recovery, inlet (optional)
C37	Vent

h Please refer to the measuring point list regarding design of the monitoring devices.

7.4.2 Components

Freshwater cooler LT FH2 (separate)

Plate type, size depending on the total heat to be dissipated.
Most ship cooling systems dump the engines' waste heat in seawater cooled fresh water coolers. Caterpillar Motoren offers standardized titanium plate heat exchangers for this purpose. The size of these coolers will always be individually calculated for the heat dissipation demand of the respective systems.
Alternatively box coolers, radiators and other heat exchanger arrangements and any kind of combined cooling systems can be laid out and delivered.

Compensation tank HT FT1 / LT FT2

- Arrangement: Min. 4 / max. 16 m above crankshaft center line (CL).
- Size according to technical engine data.
- All continuous vents from engine are to be connected.

Main functions of the cooling water header tank:

- It produces static pressure for the cooling water pumps in order to prevent cavitation. Therefore it has to be connected to each pump suction side or in case of a combined system to the suction side of the central cooling water pump.
- The vent lines continuously deliver a small water flow to the header tank. In this flow, air bubbles are carried away and the system gets de-aerated.
  - Vent lines should also be installed in the highest points of the circuits in order to get rid of all air bubbles that accumulate there.
  - Vent lines may not be too large in order to keep the flow over the header tank low. DN 20 is recommended and also valves for adjusting the flow must be installed.
- The flow of the vent lines gradually heats up the header tank by means of the constantly delivered hot water. This flow returns to the system via the pump suction side. As this circulation is very small in relation to the flow of the pump (if adjusted correctly), the temperature rise in the system will not be noticeable.
- The header tanks water volume balances the entire system volume, which changes due to thermal expansion and possibly due to leakages.

Electric driven charge air temperature control valve CR1 (separate)

	Dimensions [mm]					Weight
	DN	A	B	C	D	[kg]
6/8 M 25 E	80	310	624	155	170	58
9 M 25 E	100	350	646	175	170	70
–	125	400	717	200	170	110

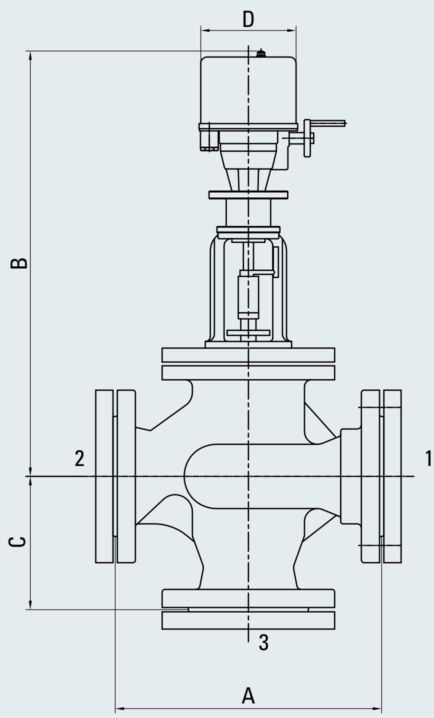

Fig. 7-2 Charge air temperature control valve CR1

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Fresh water pump (separate) HT FP3/FP5 and LT FP4/FP6

Capacity: acc. to heat balance.

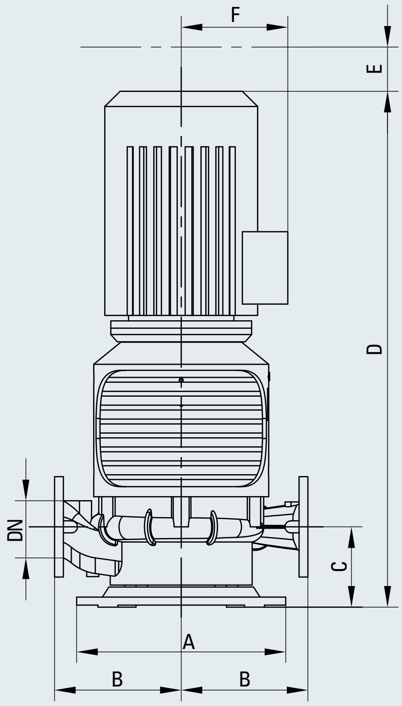

Fig. 7-3 Fresh water pump

Flow	Pressure	Dimensions [mm]							Weight
[m³/h]	[bar]	DN	A	B	C	D	E	F	[kg]
50	3.0	80	400	200	140	1,020	150	188	125
70	3.0	80	400	200	140	1,132	180	250	189
100	3.2	125	520	315	200	1,255	110	250	327

For M 25 E engines there is an option for an engine driven seawater pump.
See exemplary system diagram Fig. 7-1.

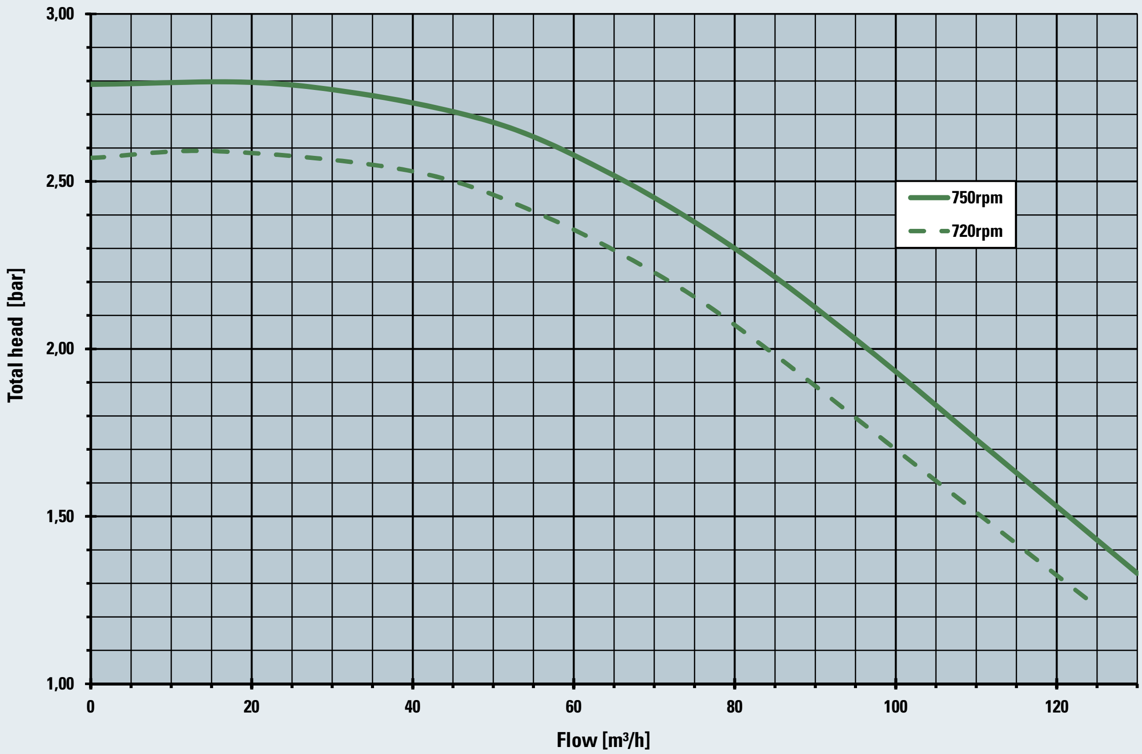

Fig. 7-4 Pump curve with engine driven seawater pumps M 25 E

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21

Temperature control valve HT FR1 (fitted) / LT FR2 / HT flow FR3

P-controller with manual emergency adjustment (basis).
Option: PI-controller with electric drive. See charge air temperature control valve (CR1).

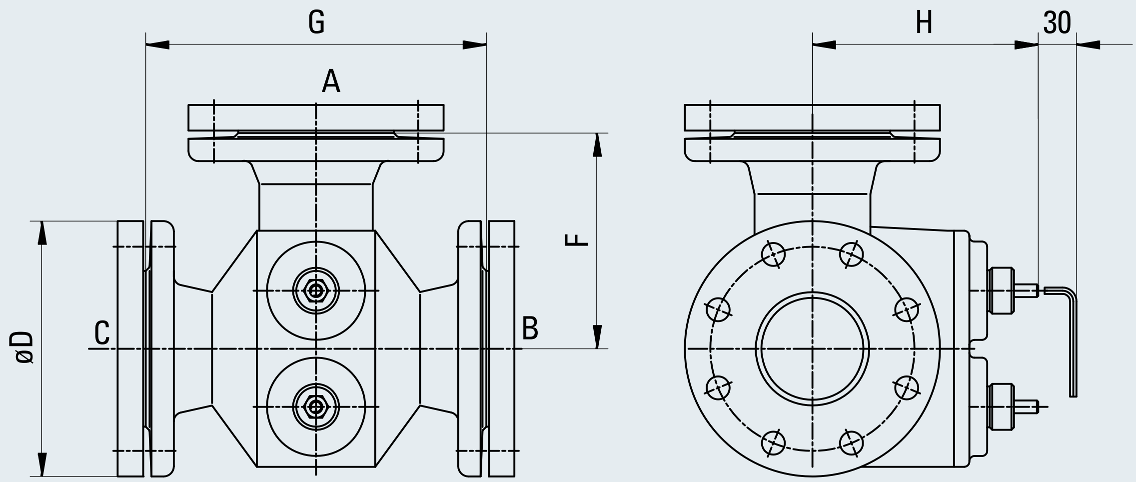

Fig. 7-5 Temperature control valve HT FR1

		Dimensions [mm]					Weight
		DN	D	F	G	H	[kg]
6/8 M 25 E	HT	80	200	171	267	151	27
9 M 25 E	HT	100	220	217	403	167	47
6/8 M 25 E	LT	100*)	220	217	403	167	47
9 M 25 E	LT	125*)	250	241	489	200	67

* Minimum depending on total cooling water flow

7.5 System diagrams heat balance

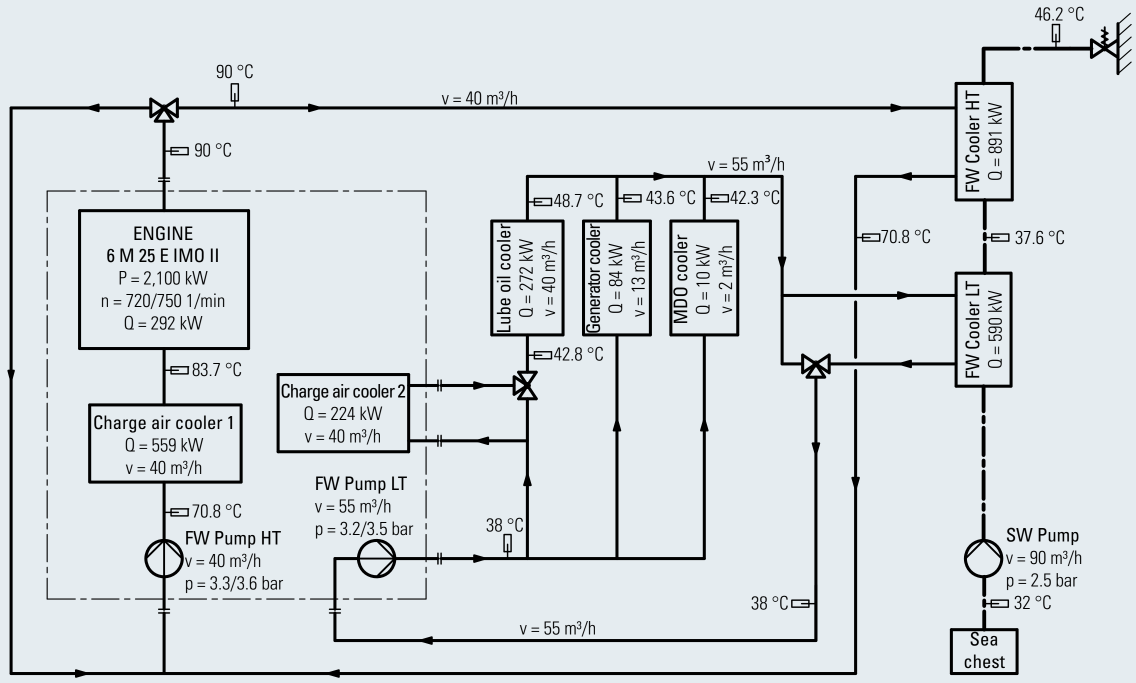

Fig. 7-6 Heat balance, system diagram 6 M 25 E

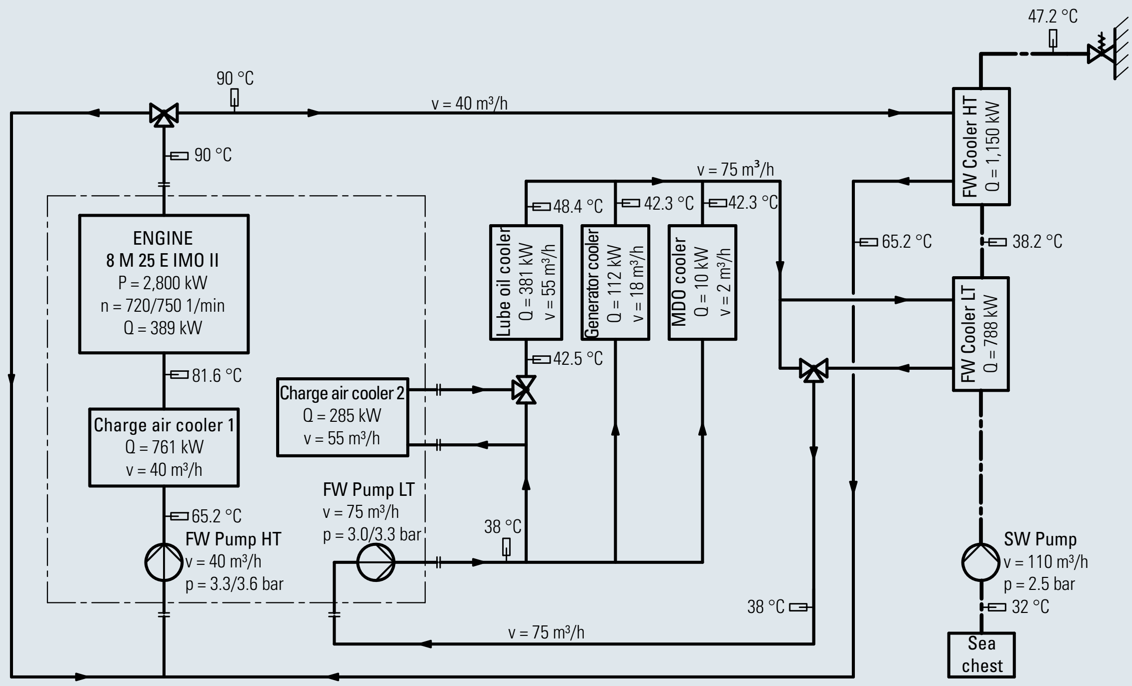

Fig. 7-7 Heat balance, system diagram 8 M 25 E

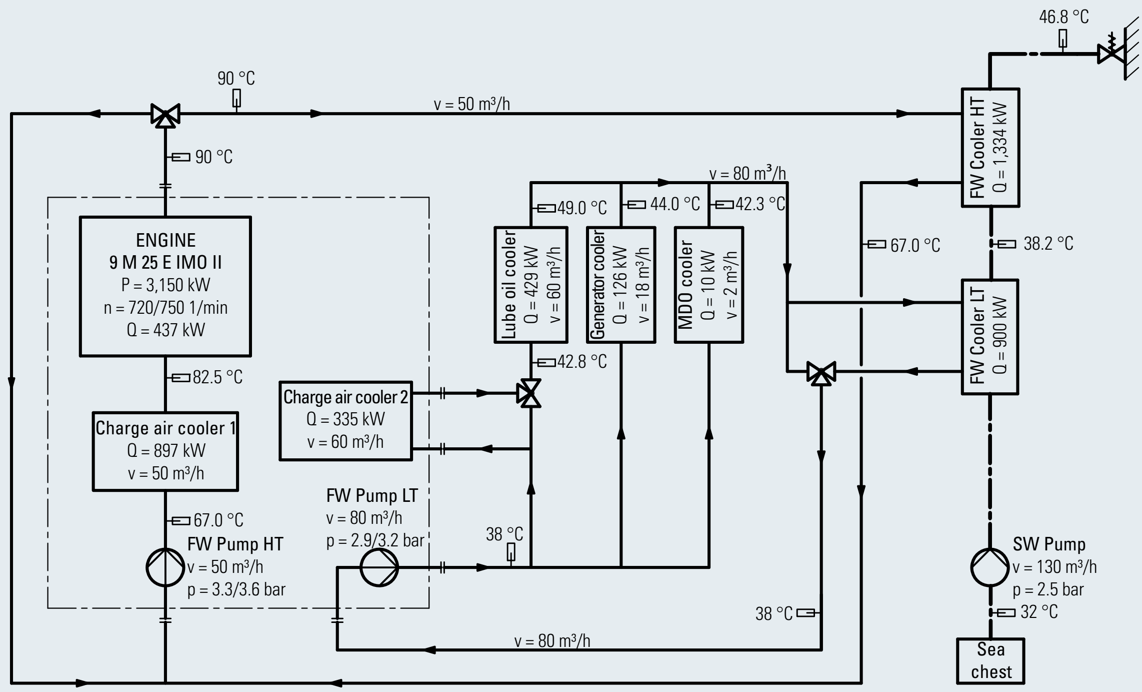

Fig. 7-8 Heat balance, system diagram 9 M 25 E

7.6 Preheating (separate module)

7.6.1 Electrically heated

- The standard preheating system in plants delivered by Caterpillar Motoren is electrically heated.
- Consisting of baseframe mounted preheating pump FP7 (12 m³/h), electric heater FH5 (18 kW) and separate switch cabinet.
  Voltage 400 - 690, frequency 50/60 Hz.

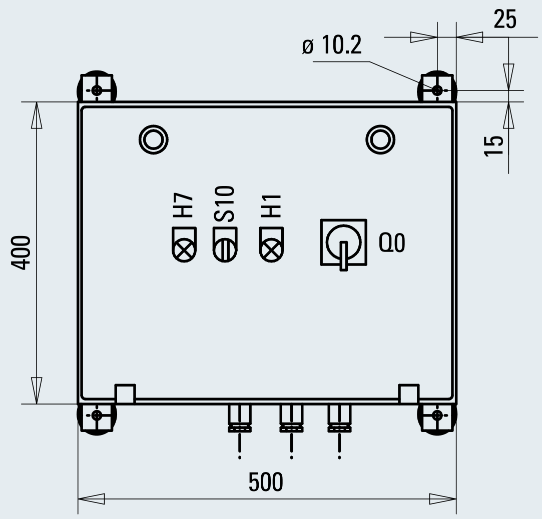

Fig. 7-9 Freshwater preheater FH5, preheating pump FP7

7.6.2 Other preheating systems

On request preheating systems heated by thermal oil or steam can be laid out and delivered by Caterpillar Motoren.

7.7 Box coolers system

On request box coolers can be laid out and delivered by Caterpillar Motoren.

7.8 Cooling circuit layout

The engine driven cooling water pumps are designed to provide the engine and its systems with cooling water.
For a rough layout of these circuits, a pressure drop of 0.5 bar per component can be calculated:
Taking the total estimated pressure loss of the whole circuit in account, the flow delivered by the pump can be read out from the pump performance curve.

Engine driven cooling water pumps (HT and LT)
Performance curve

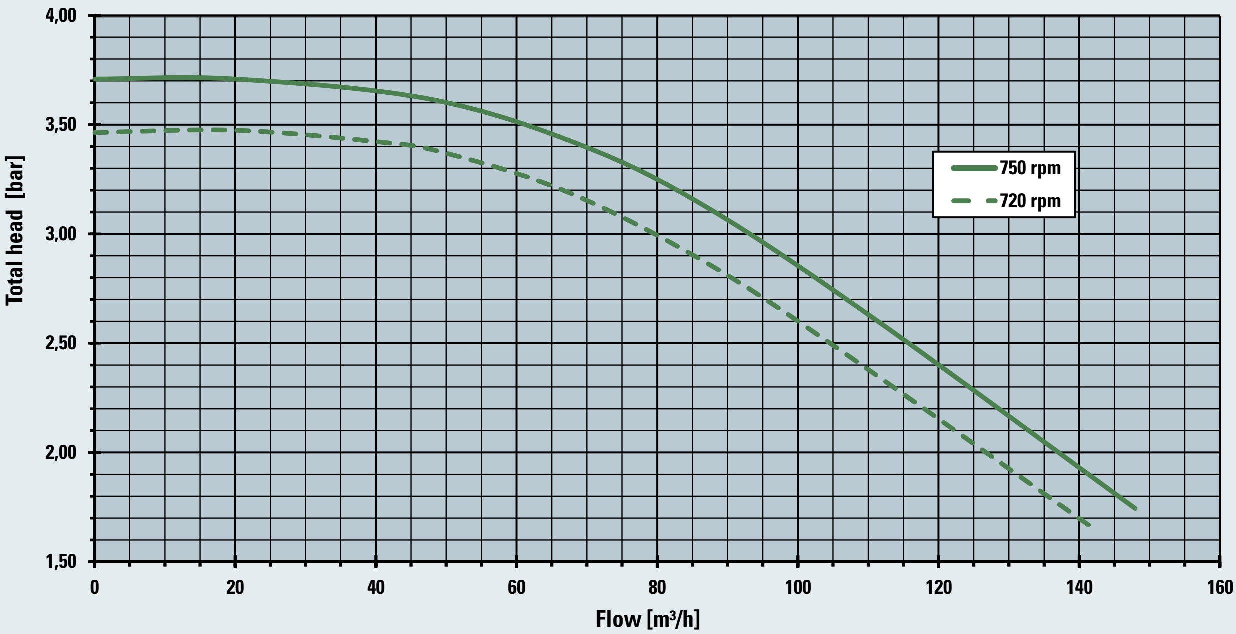

Fig. 7-10 Pump curve

8.1 General

Compressed air is used
- to start the engines
- to provide actuating energy for safety devices.

The compressed air supply to the engine plant requires air receivers and air compressors of a capacity and air delivery rating which will meet the requirements of the respective classification society.
To ensure the functionality of the components in the compressed air system, the compressed air has to be free of solid particles and oil.

8.2 Internal compressed air system

The engine is started by means of compressed air with a nominal pressure of 30 bar.
The start is performed by direct injection of starting air into the cylinder through the starting air valves in the cylinder heads.

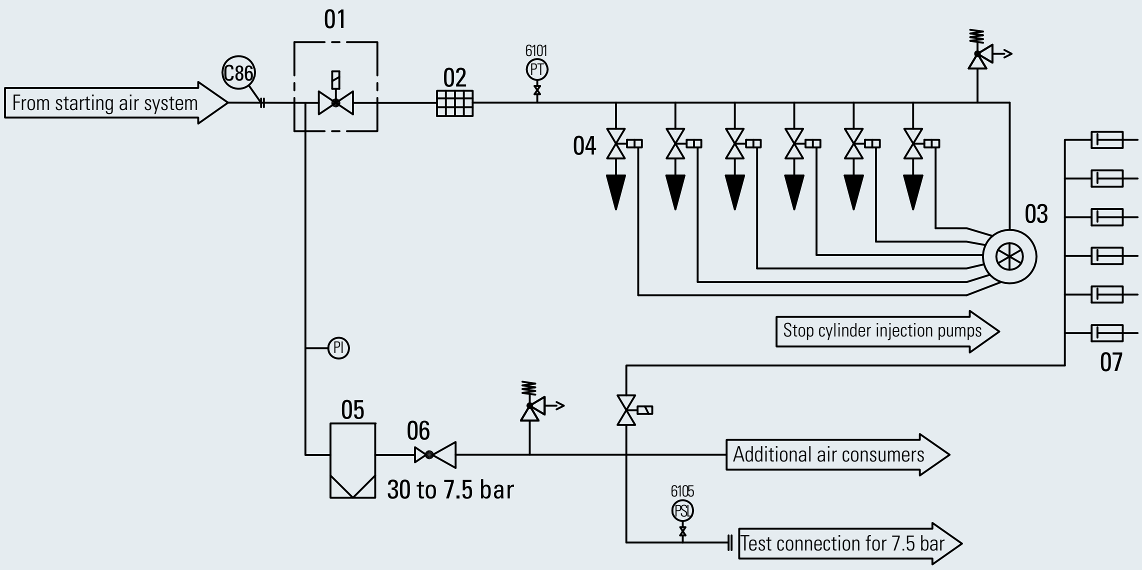

Fig. 8-1 Internal compressed air system, system diagram

01	3/2 way valve	05	Air filter
02	Flame arrester	06	Pressure reducer
03	Air distributer	07	Stop cylinder
04	Starting air values		

8.3 External compressed air system

The design of the compressed air system is partly determined by classification regulations.
Most classification societies require that the total capacity is divided into two equally sized starting air receivers and starting air compressors.
The starting air pipes should always be slightly inclined and equipped with manual or automatic draining at the lowest points.
Caterpillar Motoren requires automatic draining condensate traps at the compressor and air receivers.

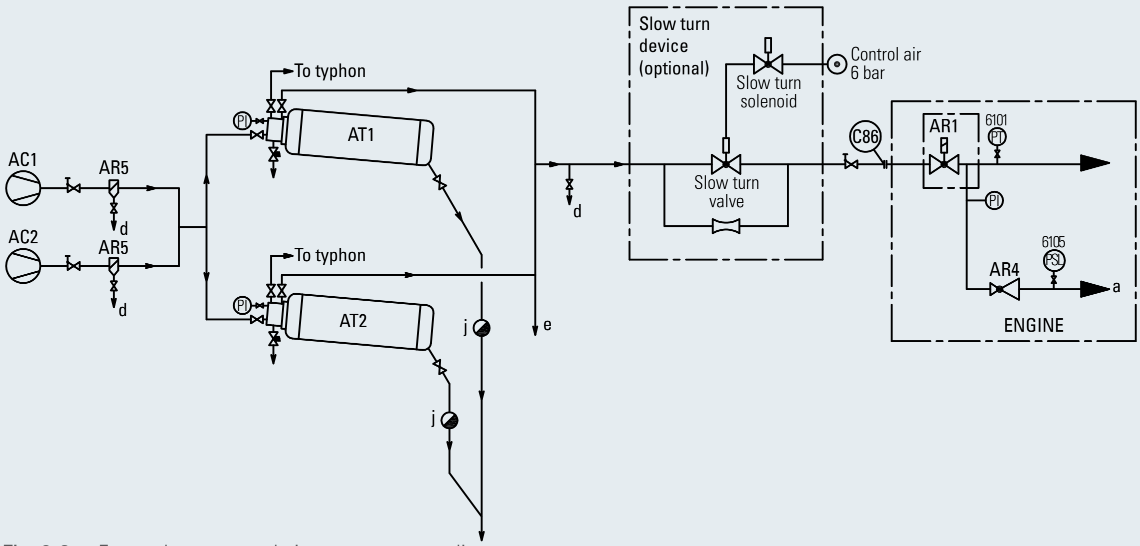

Fig. 8-2 External compressed air system, system diagram

AC1	Compressor	PI	Pressure indicator
AC2	Stand-by compressor	PSL	Pressure switch low, only for main engine
AR1	Starting valve	PT	Pressure transmitter
AR4	Pressure reducing valve	C86	Connection / starting air
AR5	Oil and water separator		
AT1	Starting air receiver (air bottle)	a	Control air
AT2	Starting air receiver (air bottle)	d	Water drain (to be mounted at the lowest point)
		e	To engine no. 2
		j	Automatic drain required

8.3.1 Compressor AC1, stand-by compressor AC2

According to the requirements of the Marine Classification Society there should be minimum 2 starting air compressors with 50% total performance each.
The total performance has to be sufficient for refilling the starting air receivers to their normal pressure of 30 bar within one hour.

Rough calculation of compressor capacity:

$$V_C\ [m^3/h] = \frac{\Sigma\ V\ [m^3]}{[h]} \cdot \frac{P_E - P_A}{P_B}$$

V_C=	Compressor capacity [m³/h]
Σ V=	Sum of all consumers
P_E=	Final bottle pressure (abs. 31 bar)
P_A=	Initial bottle pressure (abs. 1 bar)
P_B=	Barometric pressure (approx. 1 bar)

8.3.2 Air receiver AT1, AT2

The starting air receiver should be dimensioned for a nominal pressure of 30 bar.
The number and the capacity of the air receivers depend on the requirements of the Marine Classification Society and the type of installation.
It is recommended to use a minimum air pressure of 15 bar, when calculating the required volume of the receiver.
The starting air receiver must be equipped with automatic condensate traps, the receiver should be installed in a slightly inclined position to ensure efficient draining.

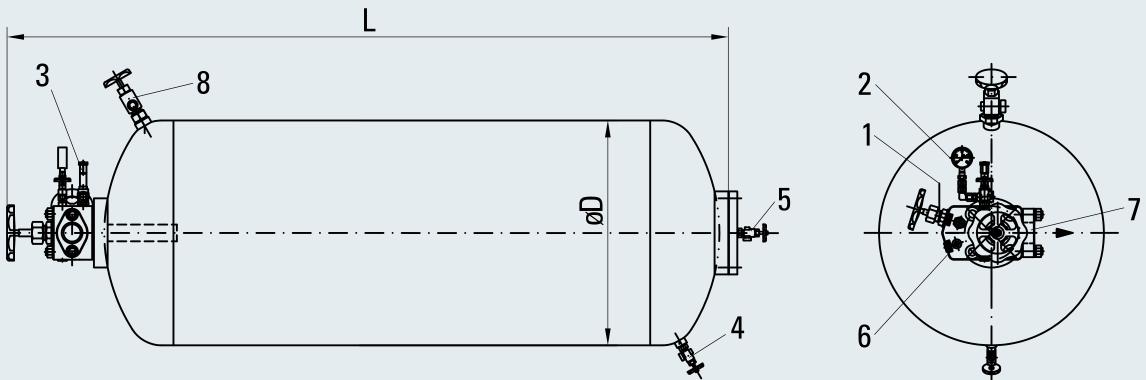

Fig. 8-3 Air receiver AT1, AT2

1	Filling valve	6	Connection G 1/2 with plug
2	Pressure gauge G 1/4	7	Outlet of starting valve at engine
3*	Relief valve DN 7	8	Typhon valve DN 16
4	Drain valve DN 8	Option:	* with pipe connection G 1/2
5	Drain position vertical		

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Normal requirements of classification societies:

No. of starts: 6
No. of receivers: min. 2

Calculation of air receiver volumes:

$$V = \frac{V_2 \cdot n \cdot P_{atm}}{P_{max} - P_{min}}$$

$V =$ Air receiver volume
$V_2 =$ Air consumption per start [Nm^3]
$n =$ Required number of starting procedures in sequence
$P_{atm} =$ Ambient pressure [bar]
$P_{max} =$ Maximum receiver pressure (30 bar)
$P_{min} =$ Minimum receiver pressure (15 bar)

Standard receiver capacities

Receiver capacity [l]	L [mm]	øD [mm]	Valve head	Weight approx. [kg]
250	2,037	480	DN 38	280
500	3,501	480	DN 50	460
750	3,033	650	DN 50	625
1,000	3,853	650	DN 50	810

When CO_2 fire extinguishing plants are arranged in the engine room, the blow-off connection of the safety valve is to be piped to the outside.
Other receiver capacities and sizes on request.

8.4 Air quality requirements

The quality of the instrument air for safety and control devices must fulfill the following requirements.

Instrument air specification:

Max. particle size:	15 µm
Max. particle density:	8 mg/m³
Water pressure dew point:	3 °C
Water:	6.000 mg/m³
Residual oil content:	5 mg/m³

The standard DIN ISO 8573-1 defines the quality cases of compressed air as follows:

- Oil content
  (Specification of aerosols and hydrocarbons which may be contained in the compressed air.)

- Particle size and density
  (Specification of size and concentration of particles which still may be contained in the compressed air.)

- Pressure dew point
  (Specification of the temperature on which the compressed air can cool down without the steam contained in it condensing. The pressure dew point changes with the air pressure.)

8.5 Optional equipment

Compressor module

Caterpillar Motoren can design, offer and deliver integrated compressor modules.
Starting air receivers and compressors can be combined individually.

Fig. 8-4 Compressor module

9.1 Engine room ventilation

To obtain good working conditions in the engine room and to ensure a trouble free operation of all equipment a properly designed engine room ventilation system with cooling air and combustion air is required.

9.2 Combustion air system design

Combustion air describes the air the engine requires to burn fuel.
Combustion air demand see chapter 4, technical data.

9.2.1 Air intake from engine room (standard)

- Fans are to be designed for a slight overpressure in the engine room.
- On system side the penetration of water, sand, dust, and exhaust gas must be avoided.
- When operating under tropical conditions, the air flow must be conveyed directly to the turbocharger.
- The temperature at turbocharger filter should not fall below + 10 °C.
- In cold areas warming up of the air in the engine room must be ensured.

9.2.2 Air intake from outside

- The intake air duct is to be provided with a filter. Penetration of water, sand, dust and exhaust gas must be avoided.
- Connection to the turbocharger is to be established via an expansion joint.
  For this purpose the turbocharger will be equipped with a connection socket.
- At temperatures below + 10 °C Caterpillar Motoren / application engineering must be consulted.

9.3 Cooling air

Cooling air refers to the flow of air that removes radiant heat from the engine, generator, other driven equipment and other engine room components.
To dissipate the radiated heat a slight and evenly distributed air flow is to be led along the engine exhaust gas manifold starting from the turbocharger.

NOTE:
Radiated heat see technical data.

The exhaust gas system discharges the exhaust gases, emitted from the engine, through a piping system to the atmosphere. To provide maximum efficiency of the engine, the resistance to the gas flow should be minimized. The back pressure directly after the turbocharger, influenced by the design of the exhaust gas piping and all installed components like exhaust gas boilers, catalysts and scrubbers is limited to 60 mbar. The given fuel consumption is based on a back pressure of maximum 30 mbar. Higher back pressure values will increase the thermal load of the engine and lead to a higher fuel consumption.
If a particle filter system is requested the maximum back pressure of the whole exhaust gas system by using MDO/MGO fuel before regeneration of the filter in loaded condition is limited to 90 mbar.

10.1 Components

10.1.1 Exhaust gas nozzle

The basic orientation of the exhaust gas nozzle for all M 25 E engines is either 0 ° or 90 ° from the vertical line available.

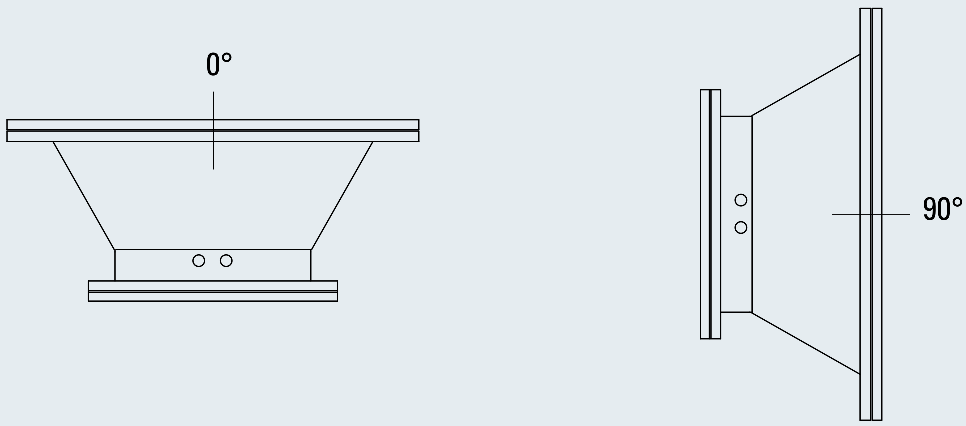

Fig. 10-1 M 25 E nozzle orientation

10.1.2 Exhaust gas compensator

The connection of the engine to the piping system of the ship has to be flexible to compensate possible engine vibrations, movements of resilient mounted engines and to reduce the forces generated by the thermal expansion of the exhaust gas piping acting to the turbocharger. For this connection, a special type of approved exhaust gas compensator, which is flexible in all directions, is available.
It is highly recommended to install these exhaust gas compensator directly after the above mentioned exhaust gas nozzle. If it is necessary to isolate the compensator area it must be possible that the compensator is able to expand and contract freely.

Basic design values of the standard exhaust gas compensators:

	Diameter [mm]	Length [mm]	Weight [kg]
6 M 25 E	500	360	55
8/9 M 25 E	600	450	107

10.1.3 Exhaust gas piping system

To minimize the forces acting through the compensator to the turbocharger and to guarantee a long lifetime of the compensator it is highly recommended to position a fixed point piping support directly after the compensator.

Each engine requires a separate exhaust gas pipe. The exhaust gas piping system from two or more engines is not allowed to be joined in one, otherwise exhaust gases from engines under operation can be forced into cold engines not operating and causes engine damages as a result of condensed water from the exhaust gas.

Also the exhaust gas pipes and/or silencers should be equipped with water separating pockets and a drainage.

In order to minimize the pressure loss of the complete exhaust gas system it is recommended to use a suitable pipe diameter for the entire exhaust gas line.

According to the dimensions of the compensators (see table chapter 10.1.2) there are standard diameters proposed for the respective engine type in relation to the exhaust gas mass flow. In case multiple of bends and other components integrated in the exhaust gas system it might be necessary to increase the pipe diameter.

For guidance the exhaust gas flow velocity should be less than 40 m/s.

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Resistance in exhaust gas piping

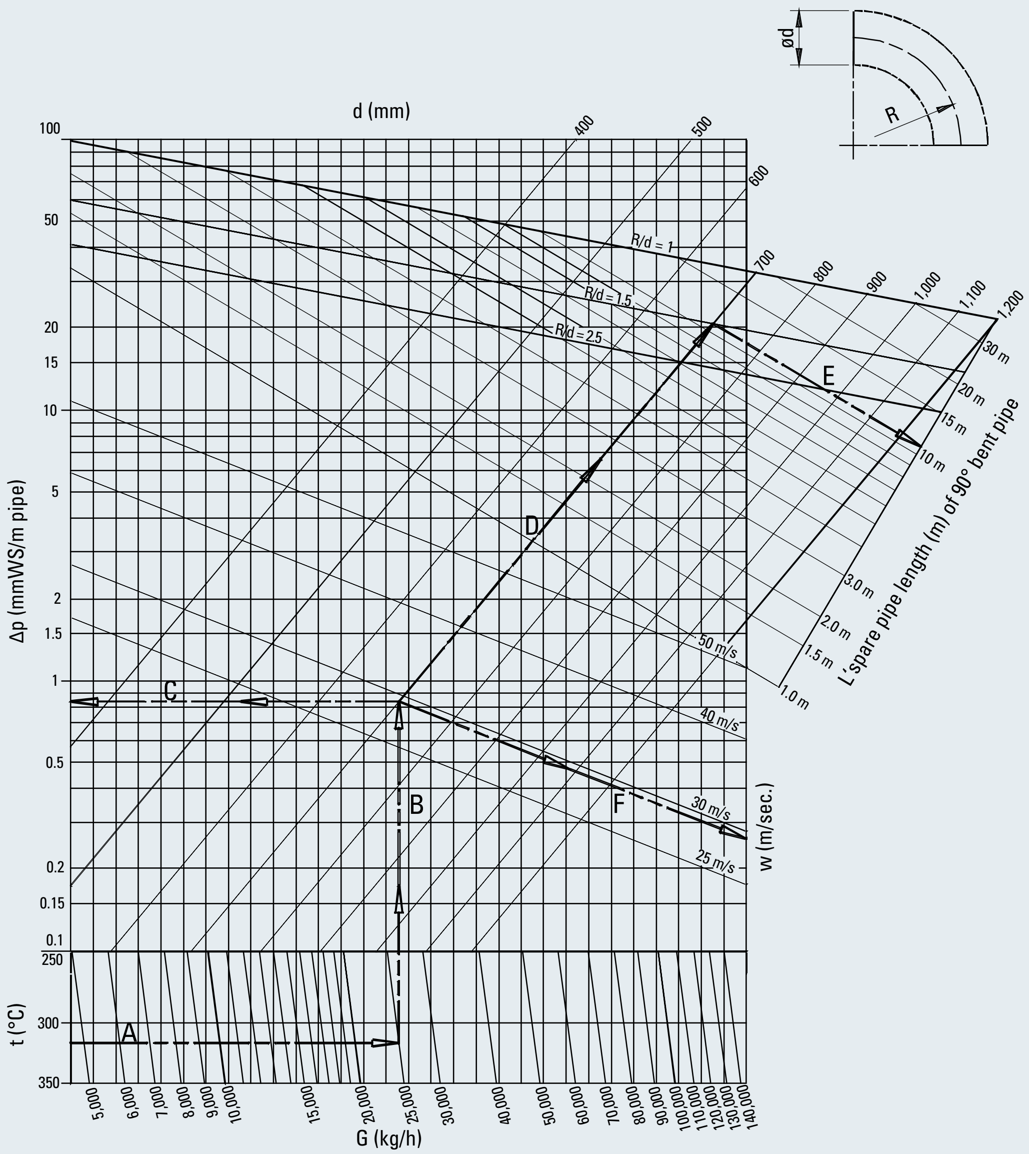

Fig. 10-2 Resistance in exhaust gas piping

Example (based on diagram data A to E):

T = 335 °C, G = 25,000 kg/h

L = 15 m straight pipe length, d = 700 mm

3 off 90 ° bend R/d = 1.5

1 off 45 ° bend R/d = 1.5

ΔPg = ?

Δp = 0.83 mm WC/m

L' = 3 · 11 m + 5.5 m

L = l + L' = 15 m + 38.5 m = 53.5 m

ΔPg = Δp · L = 0.83 mm WC/m - 53.5 m = 44.4 mm WC

t = Exhaust gas temperature [°C]

G = Exhaust gas massflow [kg/h]

Δp = Resistance/m pipe length [mm WC/m]

d = Inner pipe diameter [mm]

w = Gas velocity [m/s]

l = Straight pipe length [m]

L' = Spare pipe length of 90 ° bent pipe [m]

L = Effective substitute pipe length [m]

ΔPg = Total resistance [mmWC]

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10.1.4 Silencer

The exhaust noise emission of the engine has to be reduced by an integration of at least one suitable silencer in the exhaust gas system to fulfil either the specifications of the relating classification company or legal regulations according noise emissions or just to meet the clients comfort demand at open deck. Standard silencers which are especially designed for each engine type are available.
As the silencers are of the absorptive type the flow resistance is low so just a back pressure of approx. 100 mm WC will arise. Long fibre absorbing heat resistant material is used for the noise absorption. The noise attenuation of the standard silencers reaches at least 35 dB(A) and covers a wide frequency range. If necessary also silencers with a higher attenuation can be offered.
As standard the silencer can be provided either with or without a spark arrestor which will be provided with a soot collecting chamber. Each silencer is equipped with a water drain to draw out the condense water. The silencer will be delivered with counter flanges, screws and gaskets. The mounting brackets for either horizontal or vertical installation as the insulation are not included. Optional the silencers can be delivered with loose or welded on mounting brackets according clients requirements.
Special attention has to be paid in the positioning of the silencer in the exhaust gas system to avoid resonance effects in the piping system. A wrong positioning of the silencer in the system can cause high noise levels before or after the silencer and can lead to extreme noise at the funnel end.

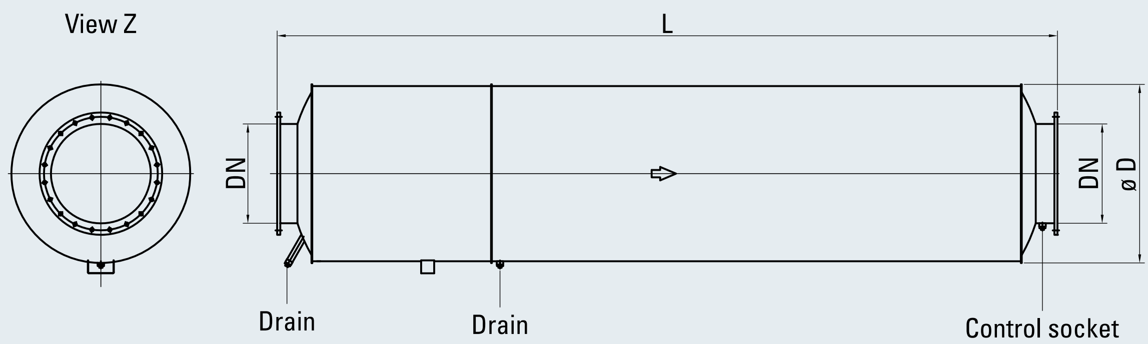

Fig. 10-3 Standard silencer without spark arrestor

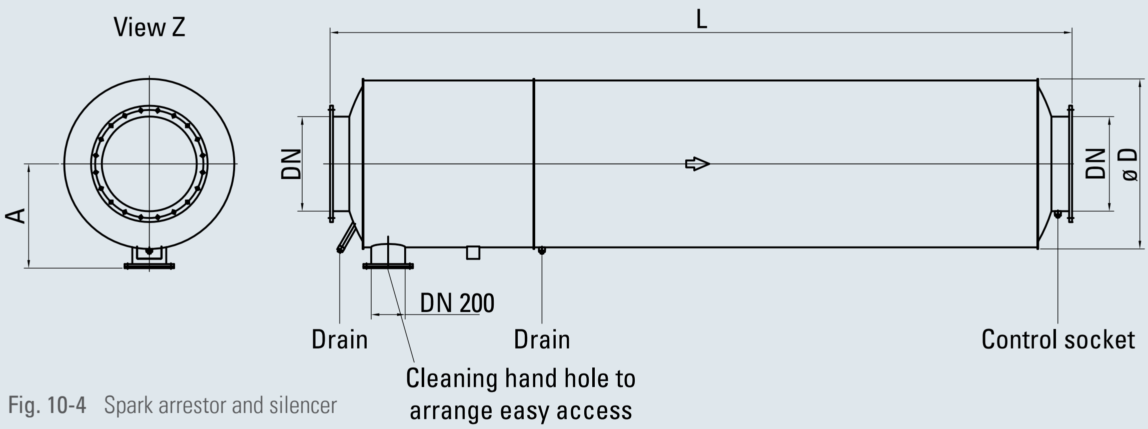

Fig. 10-4 Spark arrestor and silencer

	Dimensions [mm]				Weight	Weight with spark arrestor
	DN	A	D	L	[kg]	[kg]
6 M 25 E	500	600	950	4,170	730	780
8/9 M 25 E	600	675	1,100	4,800	1,250	1,350

10.1.5 Exhaust gas boiler

ATTENTION:
If exhaust gas boilers are used in the exhaust gas line each engine should have a separate exhaust gas boiler. Alternatively, if a common boiler is used for two or more engines the gas sections have to be separate.

Especially when exhaust gas boilers are installed attention must be paid not to exceed the maximum recommended back pressure.

NOTE:
Exhaust gas boilers are available through Caterpillar Marine.

10.2 Turbocharger

10.2.1 Turbine cleaning system

Turbine cleaning is required for HFO operation. The cleaning is carried out with clean fresh water "wet cleaning" during low load operation at regular intervals, depending on the fuel quality, 150 hours.

NOTE:
Duration of the cleaning period is 30-60 minutes due to cooling before and drying after cleaning. Duration of the washing period itself is 10 minutes.
Fresh water of 2.5 - 4.5 bar for 6/8/9 M 25 E is required.

NOTE:
During cleaning the water drain should be checked. Therefore, the shipyard has to install a funnel after connection point C36.

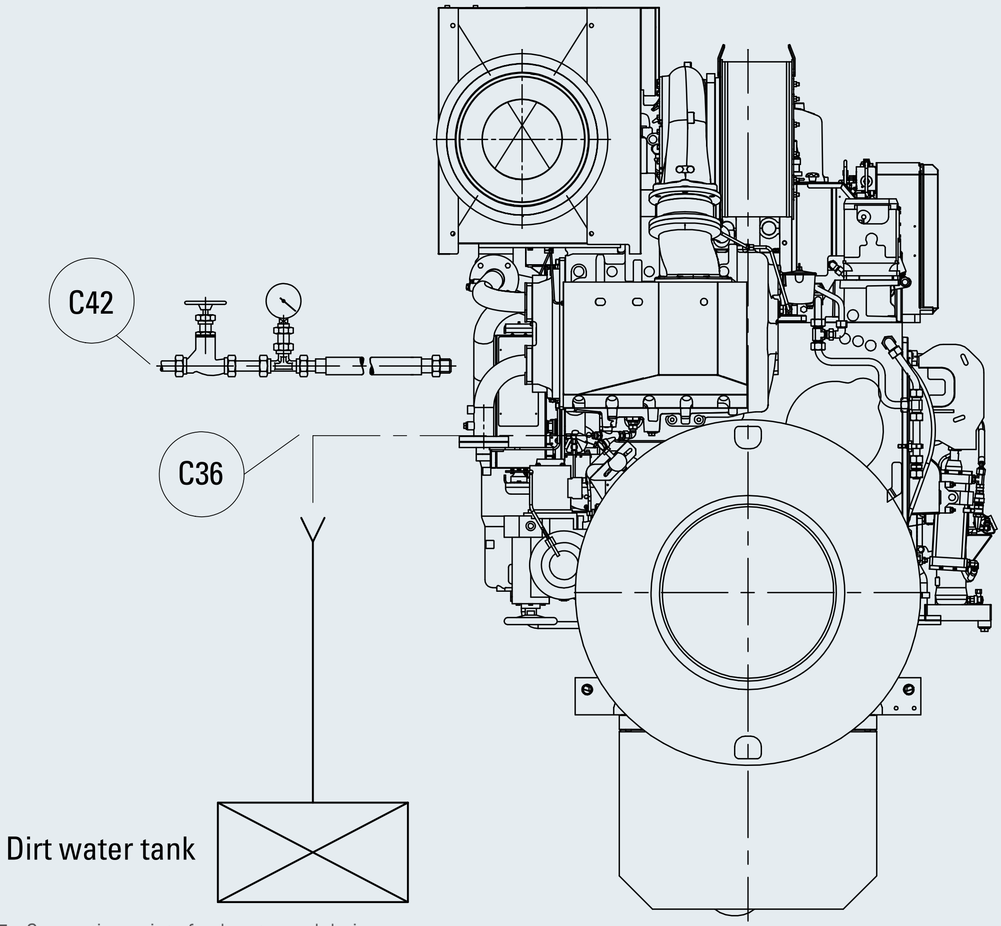

Fig. 10-5 Connection points freshwater and drain

C42 Fresh water supply, DN 12
Connection with C42 with quick coupling device
C36 Drain, DN 30

	Water pressure [bar]	Injection time [min]
6/8/9 M 25 E	2.5 – 4.5	10

10.2.2 Compressor cleaning system

The components for cleaning (dosing vessel, pipes, shut-off valve) are engine mounted.
NOTE:
Water is fed every 24 hours before compressor wheel via injection pipes during full load operation.

10.3 Cat SCR System / IMO III kit

While fulfilling IMO Tier II exhaust gas emissions with engine internal solutions, IMO Tier III compliance will be achieved with exhaust gas after treatment solutions. The Cat SCR System solution is designed by Caterpillar especially for MaK medium-speed engines to meet IMO III emission requirements.

The Cat SCR System is based on selective catalytic reduction technology. DEF (diesel exhaust fluid) is injected into the hot exhaust gas and transformed to NH_3 and CO_2. Inside the SCR module the NH_3 reacts with the exhaust gas NO_x emission to form harmless nitrogen and water vapor, which are major components of ambient air.

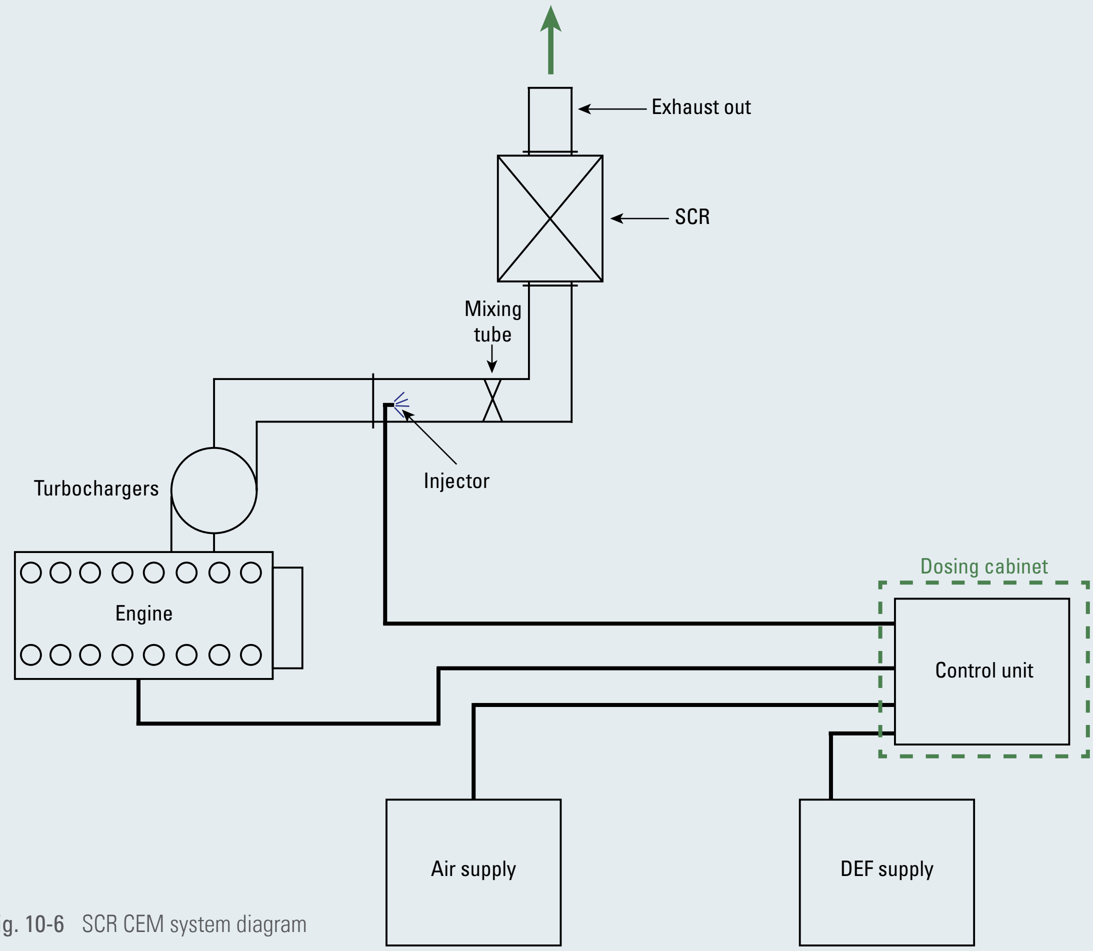

Fig. 10-6 SCR CEM system diagram

To avoid deposit building and ensure an optimal operation of the SCR module, the exhaust gas temperature has to be adjusted to the operating conditions for each application. This is achieved through Caterpillar exhaust gas temperature control unit.

Cat SCR System scope of supply:
- SCR-housing with assembled sensors and sensor boxes
- NO_x reduction catalyst cassettes (number and size depend on engine configuration)
- Mixing tube with assembled sensors and injector lance
- DEF dosing cabinet including Electronic Control Module, dosing pump, DEF buffer tank
- Mating flanges for mixing tube
- Mating flanges for housing
- Insulation blanket for sensor and sensor box of mixing tube
- Insulation blanket for sensor and sendor box of housing
- DEF transfer pump skid optional available

Not included in standard scope of supply:
- DEF storage tank
- Exhaust piping
- Insulation

10.3.1 Portfolio, size and dimensions

Installation of SCR System

The SCR housing design is for vertical installation. The mixing tube should be installed horizontally.

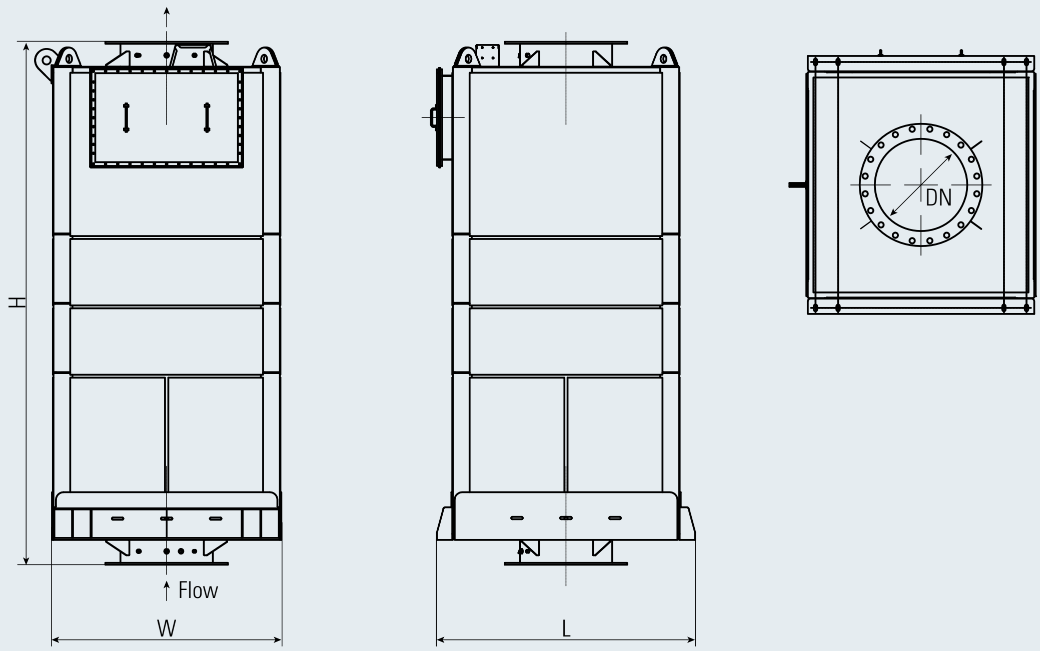

Fig. 10-7 Size and dimensions

	SCR housing			Mixing tube			Dosing cabinet	
	Dimensions	Flange size	Weight	Length	Flange size	Weight	Dimensions	Weight
	L x W x H [mm]	[DN]	[kg]	[mm]	[DN]	[kg]	L x W x H [mm]	[kg]
6 M 25 E	1,712 x 1,521 x 3,010	500	2,176	2,464	500	123	947 x 503 x 579	95
8 M 25 E	1,712 x 1,521 x 3,470	600	2,609					
9 M 25 E			2,715					

Note: Length is inlet flange to outlet flange. Width is of main box and does not include brackets, hatches, blankets, etc.
Dimensions might be subject to change without further notice.

	Max. diesel exhaust fluid (DEF) consumption [g/kWh] UREA solution concentration 32.5 %			
Load	100 %	75 %	50 %	25 %
Standard	12.5	16.5	17.5	14.0
Part Load Kit	12.0	15.0	16.0	18.5

Fuel consumption with Cat SCR aftertreatment:
The SCR housing and the substrate cassettes of the Cat IMO Tier III SCR aftertreatment systems are optimized to be used in combination with the M 25 E engines and their emission behaviour. However the aftertreatment system generates higher exhaust gas back pressure which results in increased fuel consumption, no matter if the engine is operating in IMO Tier II or IMO Tier III mode.
Specific fuel consumption has to be recalculated by + 0.3 g/kWh per 10 mbar higher exhaust back pressure.

Nitrogen oxide emissions (NO_x-values) with Cat SCR aftertreatment
NO_x-limit values according to IMO III: 2.39 g/kWh (n=750 rpm)
NO_x-limit values according to IMO III: 2.41 g/kWh (n=720 rpm)

Technical data with Cat SCR aftertreatment:
The engine technical data may differ in combination with Cat SCR aftertreatment.
Please contact Caterpillar Motoren for further information.

10.3.2 Installation requirements

Caterpillar's SCR is packaged in modules that contain the components necessary to support the specific engine configuration for emissions compliance. The installation will require connections between SCR module, engine, DEF storage tank and pressurized air source. These connections will include engine exhaust piping, electrical harness, air, and urea lines. Following requirements are necessary to operate the Cat SCR System safely.

Dosing cabinet	
Power requirement	240/120 volts AC, 10/20 amps, 50/60 Hz
Air supply	
Air quality	ISO 8573.1 Class 5
Air flow capacity	17 m^3/hr
Air consumption	continuous when system is dosing
Air pressure	4.8 to 10.7 bar gauge
DEF supply	
DEF quality	ISO 22241-1
DEF concentration	32.5 - 40 %
Air consumption	continuous when system is dosing
DEF supply pressure to dosing cabinet	0.35 - 0.7 bar gauge
Engine operating fluids	
Fuel tolerance - Sulfur [ppm]	IMO III - 1,000
Fuel tolerance - quality [2)]	MGO/MDO

2) Heavy fuel operation - ask for availability, for further fuel requirements see chapter 5. MGO/MDO operation

10.3.3 Requirements for material selection of urea tank and piping

Material compatibilities must be considered for the urea solution storage and delivery due to caustic corrosive nature of urea solution (AUS32, aqueous urea solution, 40 %)

Recommended materials:

- Austenitic stainless steel
- Some plastics like Polyethylene or Polypropylene

Materials to avoid:

- Unalloyed steel
- Aluminium
- Brass
- Galvanized steel
- Copper

11.1 Local control panel (LCP)

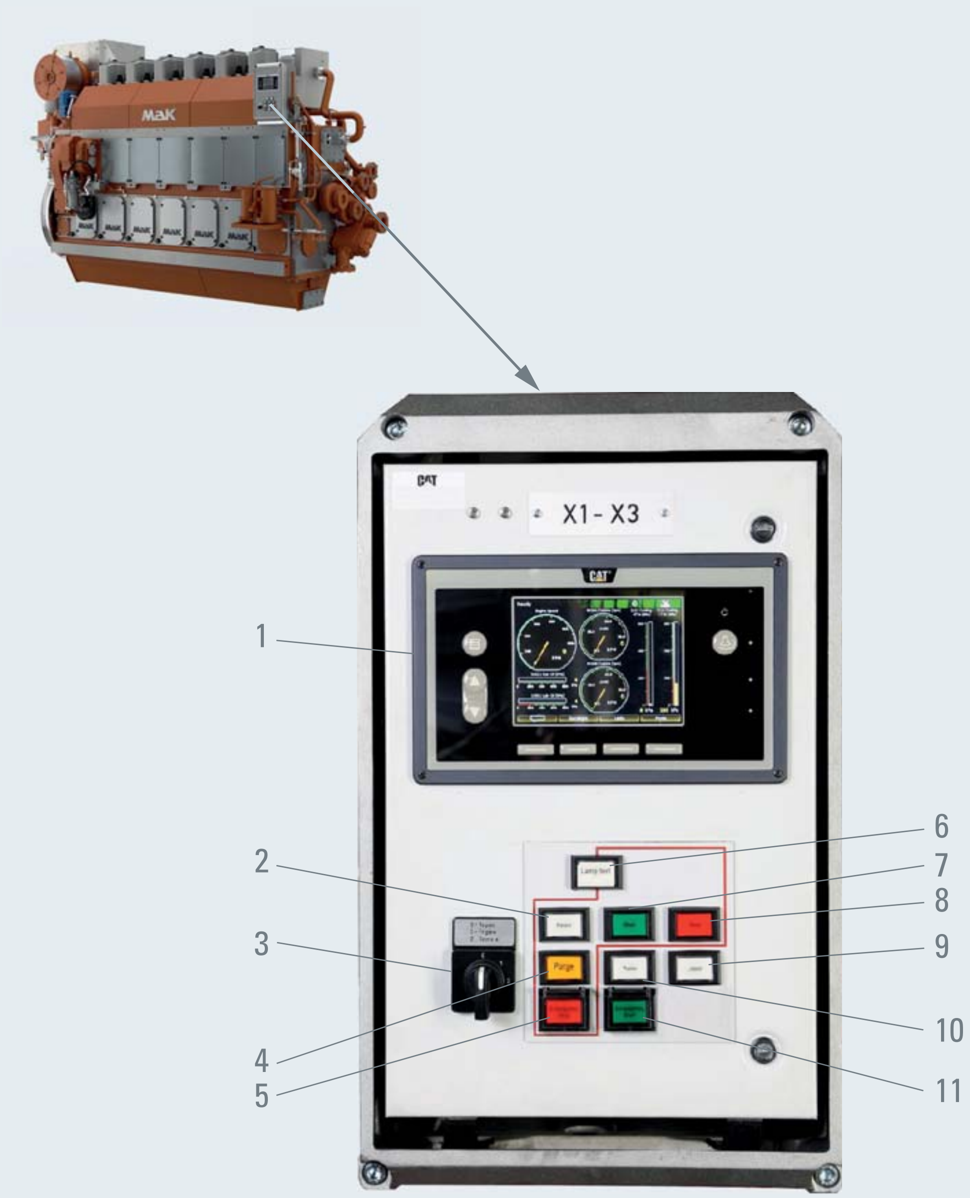

Fig. 11-1 Local control panel LCP

1	Display and alarm system (DCU)	7	Start
2	Reset	8	Stop
3	0 = Repair, 1 = Engine, 2 = Remote	9	Lower
4	Purge *)	10	Raise
5	Emergency stop	11	Emergency start
6	Lamp test		

*) To avoid severe engine damage due to water in the combustion chamber the purge process has to be performed before starting the engine.

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11.2 Data link overview

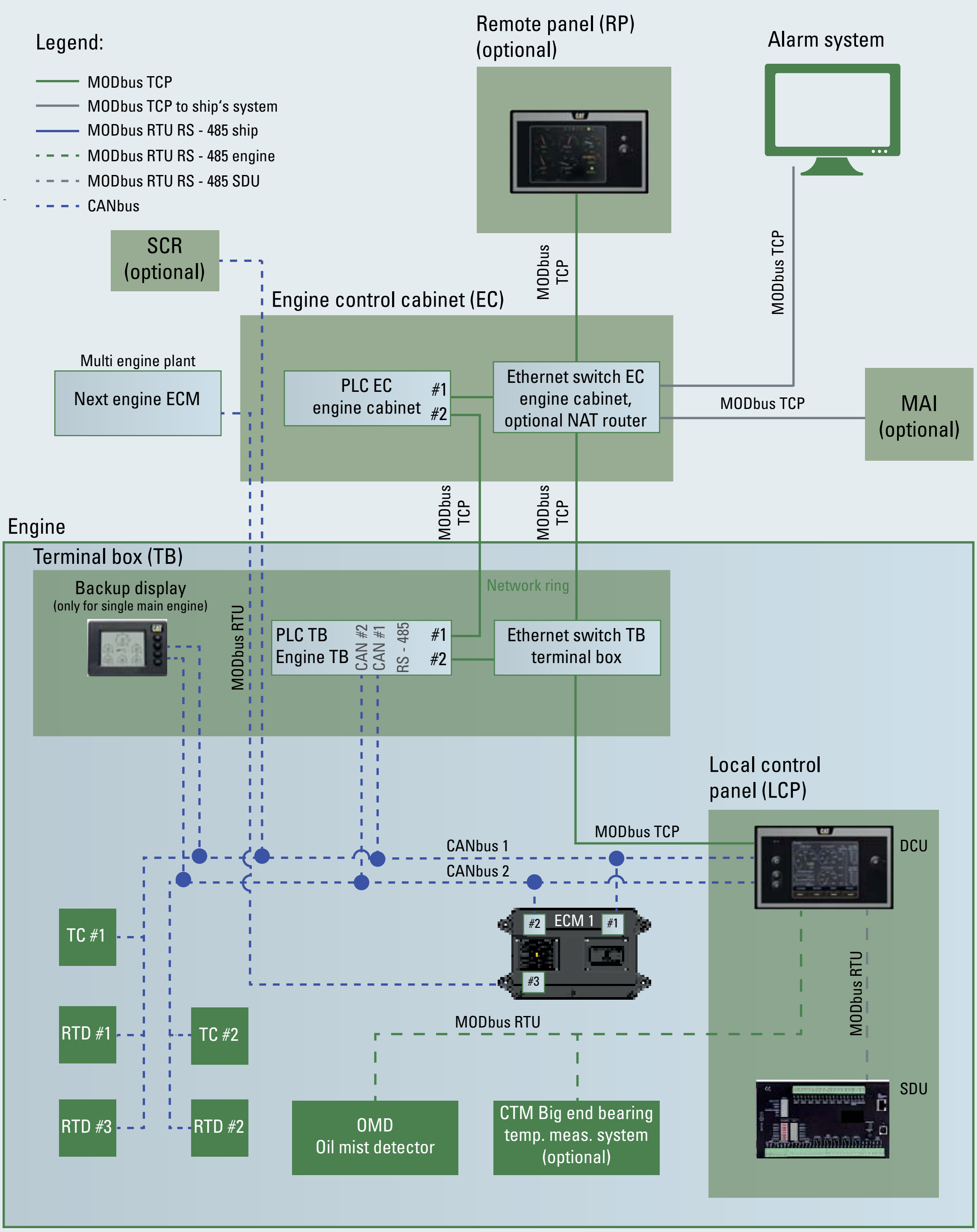


Fig. 11-2 Data link overview - M 25 E

SDU
Protection system in local control panel
DCU
Display and alarm system in local control panel
PLC
PLC in engine cabinet (EC)
PLC in engine terminal box on engine (TB)
RTD
PT100 module for charge air temperature, lube oil temperature, cooling water HT/LT temperature and main bearing temperature
TC
Thermocouple modules for exhaust gas temperature
RP
Remote panel (optional)
External display for engine alarm and monitoring system

MACS

Modular Alarm Control System

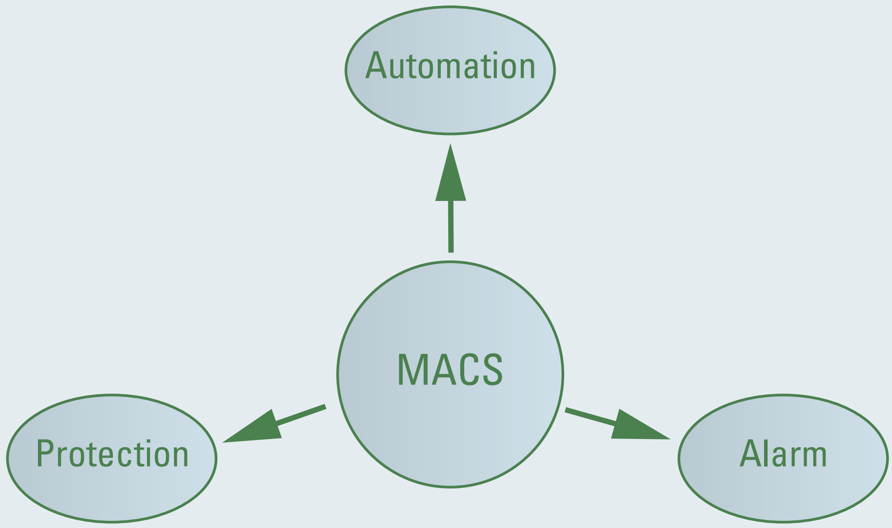
ECM
Engine control module
OMD
The oil mist detector measures each cylinder.
Load sharing system
Load sharing system for isochronous load sharing (optional)
CTM
Big end bearing temperature monitoring (optional)
Each cylinder is measured by the CTM.
MAI
Marine Asset Intelligence, analytics & service tool (please see chapter 11.10)
SCR
Selective Catalytic Reduction System, dosing cabinet, mixing tube, transfer pump (optional), DEF storage tank (optional). For more information please see chapter 10.3

MODbus TCP
At MODbus TCP a connection between server and client will be established. Therefore an IP address will be assigned.

MODbus settings
Type: MODbus TCP
Interface: ethernet
IP: will be assigned
Baud rate: 10 mbit/s / 100 mbit/s
Connector: RJ45

11.3 Components

Modular Alarm and Control System (MACS)



The M 25 E engines will be provided with a new Modular Alarm and Control System, called MACS. The basic engine control and monitoring system will be installed in the local control panel. Where extension modules are necessary, external PLC-based I/O extension modules will be installed.

The main functions of the control systems are:

- Alarm management
- Local start and stop, emergency start and stop from the engine control panel
- Remote start and stop from the power management system (PMS)
- Start and stop sequence control
- Critical parameter monitoring
- Purge control
- Flexible camshaft technology (FCT monitoring)
- Exhaust gas temperature monitoring
- Main and big end bearings temperature monitoring
- SCR status and alarm indication

Engine control module (ECM)

The engine control module controls the fuel system, air fuel ratio, engine speed, air injection system and Flexible Camshaft Technology (FCT). The module has its own set of sensors for all control relevant functions and can operate independently from start/stop system, alarm system (DCU) or protection system (SDU).

Oil mist detector (OMD)

The oil mist detector measures the oil mist concentration for each cylinder compartment and generate an alarm for high oil mist concentration. The data are available by MODbus RTU at the DCU. Hardwired outputs are also provided.

Big end bearing temperature monitoring system (optional)

The big end bearing temperature monitoring system measures the temperature for each big end bearing and generates an alarm for high temperature. The data are available by MODbus RTU at the DCU.

11.4 Genset control

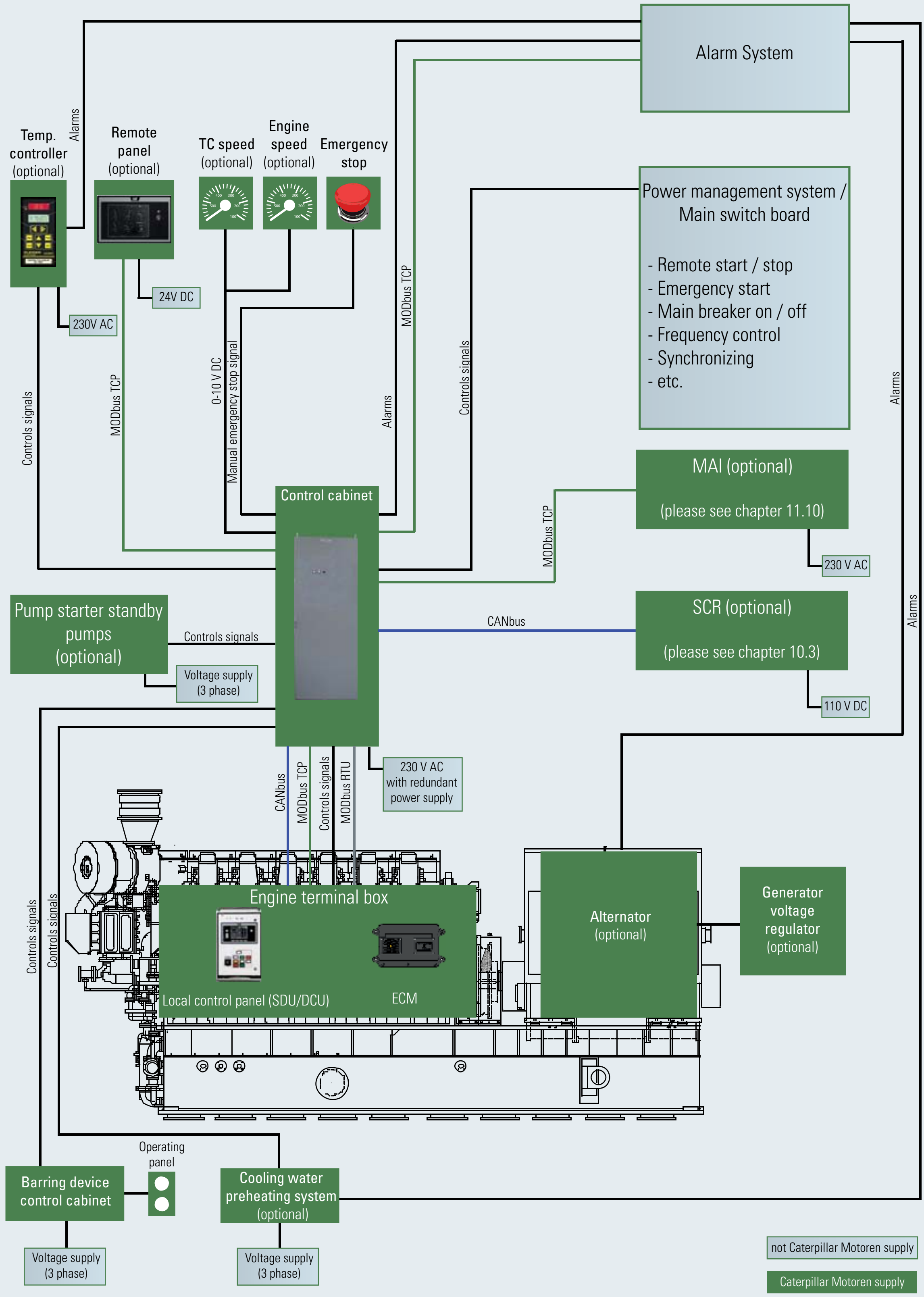
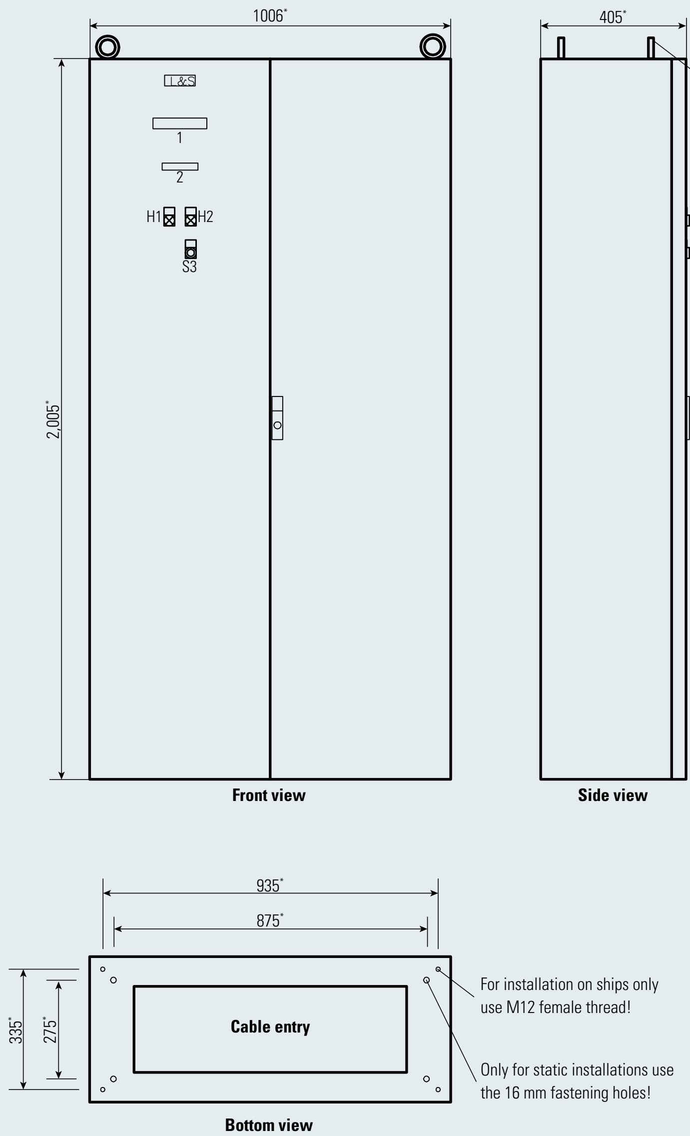


Fig. 11-3 Generator set control M 25 E

11.5 Control cabinet

Each engine is equipped with a separate control cabinet. The control cabinet acts as an interface between engine and external devices. Information about the engine status are available via MODbus TCP.
External signals for the engine control, monitoring and alarm system (for example gearbox, CPP control system,...) can be transferred as 4-20 mA, binary, or PT100 signal.
Safety relevant signals to the PLC are wire break and short circuit monitored.
The remote panel or the temperature controller can be optionally integrated in the control cabinet.



H1:	Main supply without failure
H2:	Back up supply without failure
S1:	Lamp test

Degree of protection: IP54
Weight: Approx. 230 kg

ATTENTION:
A distance of 300 mm on each side for air circulation is necessary. Note: Dimensions are shown in mm.

* Depending on the power supply and the optional devices in the cabinet the size can vary slightly.

Fig. 11-4 Control cabinet

The cabinet must be installed in horizontal position.
The positioning and fastening has to effect corresponding to environmental conditions.

11.6 Requirement on power management system

Standard interface to power management system / main switch board

Power management system / main switch board				Main engine
External starting interlock	Binary contact	→	24 V DC	External starting interlock
External engine shutdown	Binary contact	→	24 V DC	External engine shutdown
Blackout	Binary contact	→	24 V DC	Blackout (start release of starting interlock prelubrication)
Indication shutdown undelayed/delayed	24 V DC	←	Binary contact	Shutdown undelayed/delayed
Load signal from kW transducer	4-20 mA	→	Max. load 250 Ω	Load signal from kW transducer
Raise / lower (remote)	Binary contact	→	24 V DC	Raise / lower (remote)
Isochronous / droop	Binary contact	→	24 V DC	On = isochronous Off = droop
Status circuit breaker	Binary contact	→	24 V DC	Circuit breaker closed (on for closed)
Bus tie signal	Binary contact	→	24 V DC	Tie breaker feedback
Manual activation slow turn	Binary contact	→	24 V DC	Slow turn mode change
Automatic slow turn	Binary contact	→	24 V DC	Slow turn selected for automatic
Start/stop remote	Binary contact	→	24 V DC	Start/stop in remote mode
Change genset	24 V DC	←	Binary contact	Engine fault - change genset
Normal stop indication	24 V DC	←	Binary contact	Normal stop indication
Start initiation indication	24 V DC	←	Binary contact	Start initiation indication
Starting interlock indication	24 V DC	←	Binary contact	Starting interlock indication
Remote control active	24 V DC	←	Binary contact	Remote control active
Ready to start, indication	24 V DC	←	Binary contact	Ready to start, indication
False start indication	24 V DC	←	Binary contact	False start indication
rpm contact	24 V DC	←	Binary contact	rpm contact
Offload	Binary contact	→	24 V DC	Offload
Isochronous selected	24 V DC	←	Binary contact	Isochronous selected
Emergency stop from PMS	Binary contact	→	24 V DC	External emergency stop (from PMS)

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21

11.7 Uninterruptable power supply (UPS)

For the control and monitoring system an uninterruptable power supply (UPS) with a back-up power supply is needed (class requirement). The standard power supply is 24 V DC but on demand another power supply is possible (e.g. 230 V AC or 480 V AC three phase current).
The engine control cabinet has an integrated voltage distribution for the control and monitoring systems at the engine (see fig. 11-3). Each cabinet has its DC/DC converter and its insolation monitoring device.

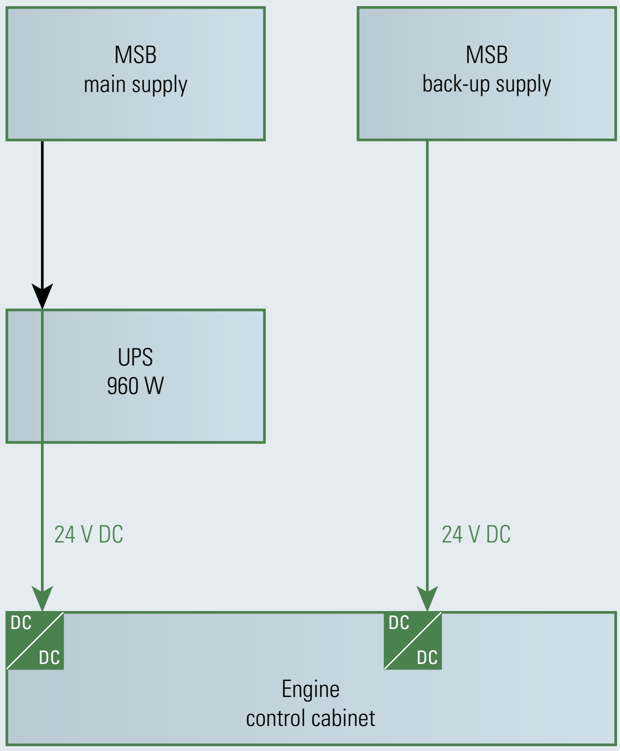


Fig. 11-5 Uninterruptable power supply

11.8 Alarm indication

In general, the engine is equipped with the relevant alarm and safety sensorsaccording to classification society rules.
MACS provides an engine alarm system which is located in the local control panel. The engine alarm system and the local display are consolidated in the DCU. The complete alarm management is handled by the DCU. All information is visualized via the screen in the LCP and additional several remote panels can be added.

The DCU receives measurement values and data from all I/O modules, PLC's and the engine control system (ECM). Furthermore it provides all measurement values, status values and alarms via MODbus TCP (MODbus RTU, optional) for the vessel's system and the remote monitoring system. The engine's alarm system determines critical engine conditions and activates alarms. The DCU has the ability of actuating the secondary safety stop valve. That means the DCU also works as well as a shut down unit and is able to stop the engine as reliable as the shut down unit (SDU). All alarms are stored in an alarm history and are shown in a manner requested by the MACS.

Fig. 11-6 Remote panel

Fig. 11-7 DCU (display and alarm system)

For the interface to ship's alarm system (IAMCS) the following functions are applicable:

- Transmitting measurement data to IAMCS
- Transmitting engine status to IAMCS
- Transmitting alarm to IAMCS
- Receiving ship's time stamp from IAMCS

All data is available via MODbus TCP. Upon request MODbus RTU is also possible. Device fault from the different MACS devices and some special alarms are provided as hardwired alarms.

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21

The table below shows an example of an overview of the different engine systems/modules with their safety functions.

A project related list of measurting points with all necessary MODbus information will be created for each order.

	IND/ FUNC	STBL	Alarm	CHG	SHD
Lube oil	X	X	X	X	X
Oil mist detector	X	X	X		X
Fresh water HT	X		X		X
Fresh water LT	X		X		
Air supply	X	X	X		
Charge air	X		X		
FCT	X		X		X
Electrical status	X	X	X		
Engine status	X	X	X		X
Exhaust gas	X		X	X	
Big end bearing (optional)	X		X		X
Main bearing (optional)	X		X		X
Load share unit (optional)			X		X
ECM	X		X		

Furthermore an evaluation of sensor faults is integrated. Depending on the importance of the failure it causes a STBL, E-STBL and CHG.

NOTE:
An engine shutdown will adtivate a starting interlock (STBL).

FUNC	Used in software function
IND	Only for indication
A	Alarm
STBL	Starting interlock (overrideable by E-start of blackout start)
E-STBL	Emergency starting interlock (not overrideable by E-start or blackout start)
CHG	Change generator set
SHD	Shutdown

11.9 Remote indicators

Local indicators of analogue values on LCP display (DCU)	Remote indicators
Indicated at the engine	96 x 96 mm (optional)
Fuel oil temperature at engine inlet	X 2)
Fuel oil differential pressure at filter	
Lube oil temperature at engine inlet	X 2)
Lube oil differential pressure at filter	
Fresh water temp. at engine inlet (HT circuit)	
Fresh water temp. at engine outlet (HT circuit)	X 2)
Fresh water temperature (LT circuit)	X 2)
Fresh water temperature cooler inlet	
Fresh water temperature cooler outlet	
Charge air temperature cooler inlet	
Charge air temperature engine inlet	X 2)
Fuel oil pressure	X 2)
Lube oil pressure	X 2)
Fresh water pressure (HT circuit)	X 2)
Fresh water pressure (LT circuit)	X 2)
Start air pressure	X 2)
Charge air pressure cooler outlet	X 2)
Stop air pressure	
Engine speed	X 1)
Turbocharger speed	X
Charge air temp. cooler inlet (digital value)	
Exhaust gas temp. after cylinder (digital value)	
Exhaust gas temp. before / after turbocharger (digital value)	

1) 144 x 144 mm possible / **2)** Signal is supplied by the alarm system

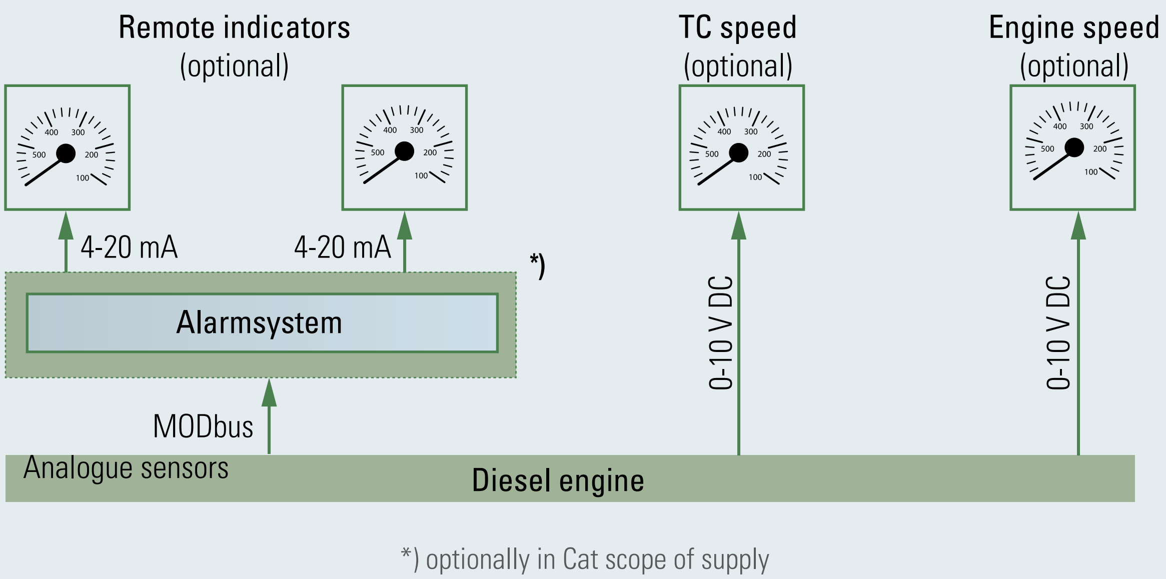


Fig. 11-8 Remote indication interfacing

11.10 Cat Connect for Marine provided by Caterpillar Marine Asset Intelligence (MAI)

MAI provides technology enabled solutions and services, that

- Provide remote monitoring and automated analytics via the internet.
- Combines equipment and application information.
- Applies predictive analytics.
- Utilizes interpretive expertise.

11.10.1 MAI – MaK engine solution only

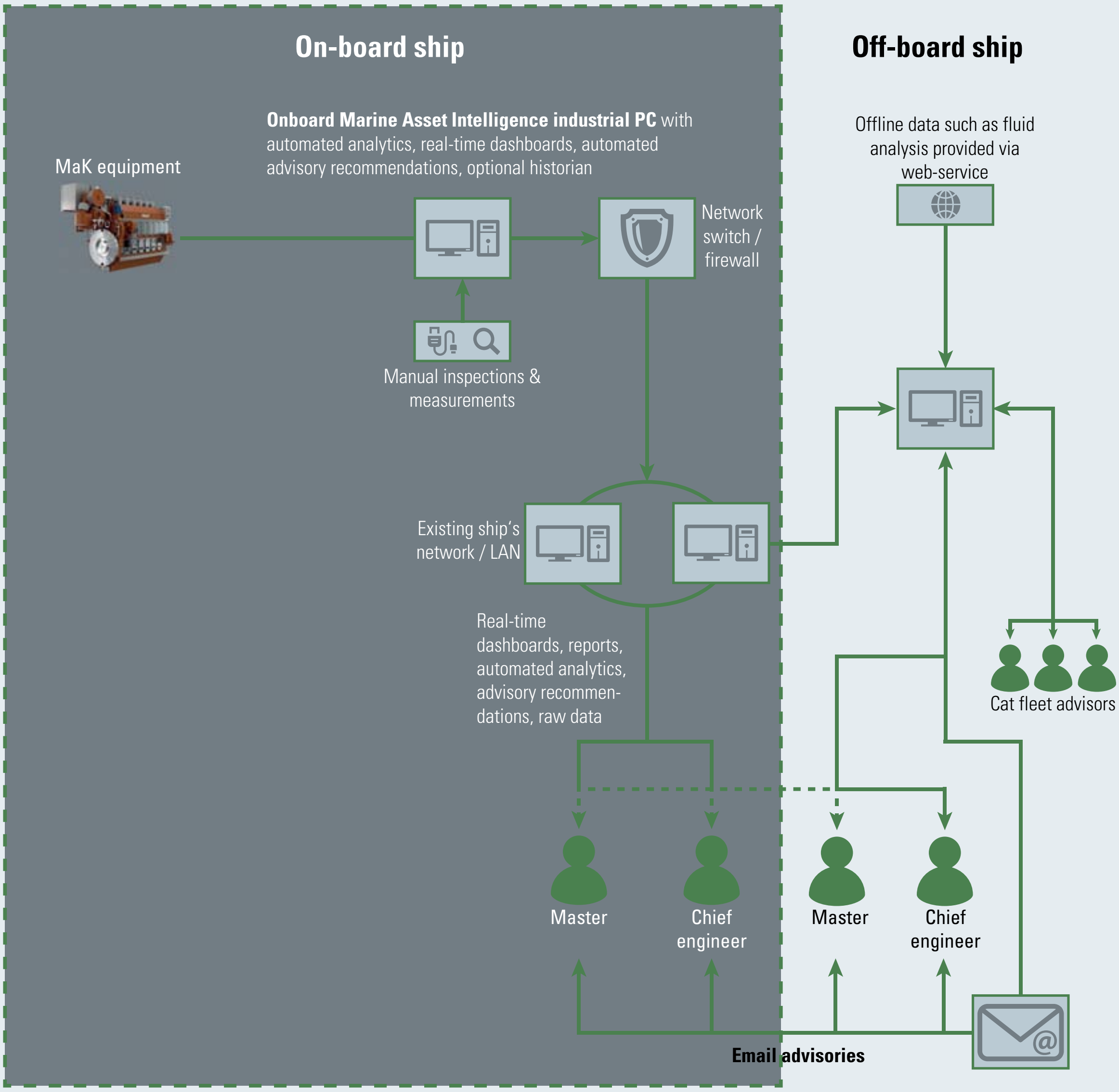


Fig. 11-9 MAI – MaK engine solution only

11.10.2 MAI – Extended solution

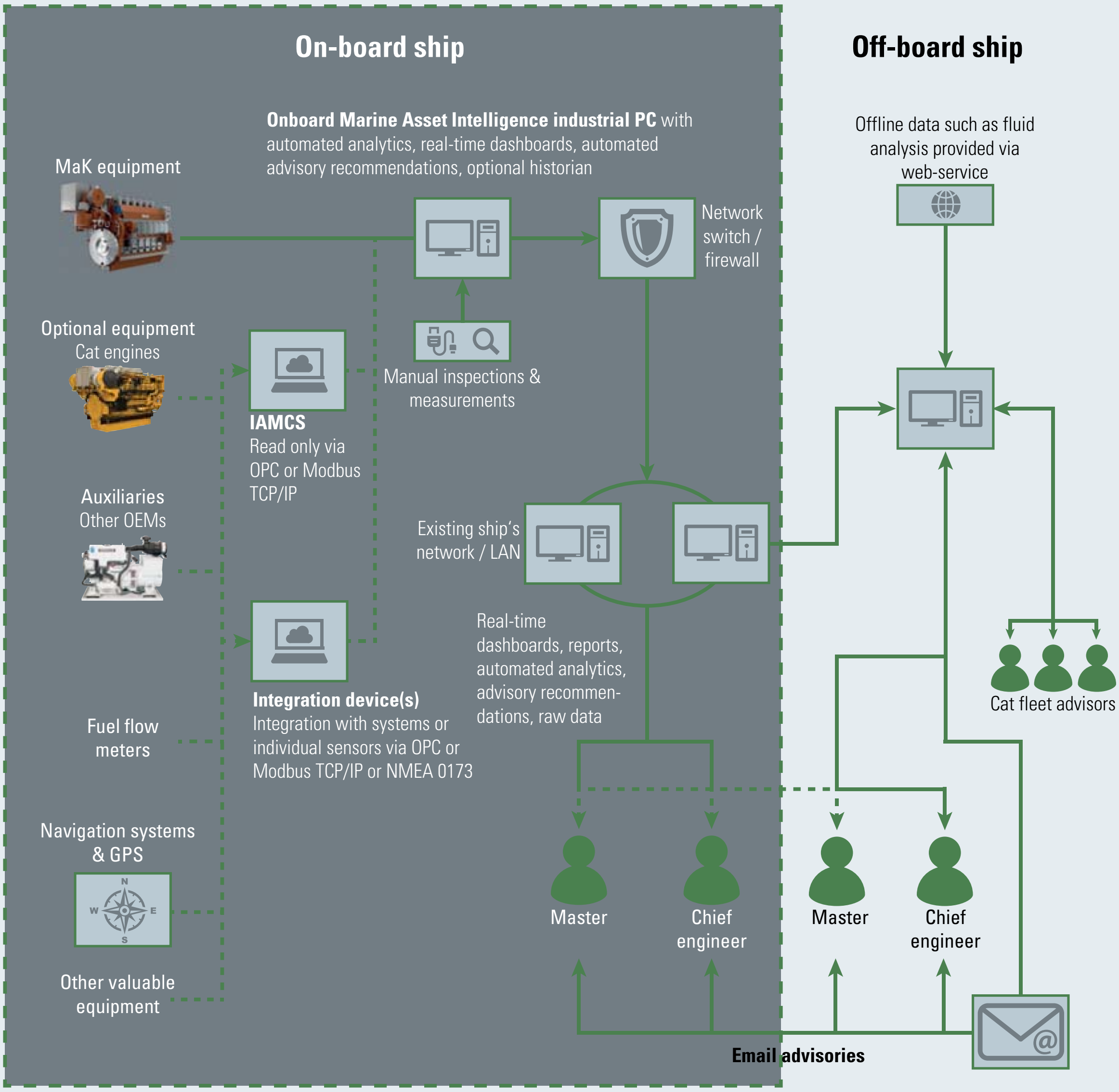


Fig. 11-10 MAI – Extended solution

11.10.3 General information

Capabilities

- Consolidates data and analyzes across all five condition monitoring elements.
- Analyzes data using multiple engines to identify and highlight exceptions.
- Creates a complete view of the equipment and performance.
- Allows more knowledgeable planned maintenance and scheduled repairs.
- Enables optimized tuning of equipment to maximize fuel efficiency.

Comprehensive scope possible

- Monitors and analyzes variety of systems across the total vessel, based on what is important for each vessel.
- Can monitor Caterpillar/MaK equipment as well as non-Caterpillar/MaK equipment.
- Can monitor diesel engines and non-diesel engines.
- Primary services available:
  - Protect: Identify potential problems with equipment before there is a failure, assist onboard crew with remote expert troubleshooting.
  - Improve: Optimize fuel consumption for individual equipment through better maintenance and for entire vessel through operations and maintenance optimization.
  - Optimize: Move to condition based maintenance.
- Supporting services available:
  - Account: Ensure fuel accountability, measure and track fuel bunkering and consumption.
  - Save: Create visibility for unsafe operations or equipment condition.
  - Comply: Ensure equipment is operated and performs in compliance with regulations.
  - Manage: Customized dashboards for different levels of management without custom software development.
  - Integrate: Integrate with other enterprise systems, such as Computerized Maintenance Management System (CMMS).

System Benefits

- Support most cost efficient operation.
- Provides optimized planning of service activities.
- Helps to avoid unexpected downtime.
- Helps reduce fuel cost for both the individual equipment and the entire vessel (depending on scope included).

Scope of delivery

- Electrical engine equipment MACS and Modbus interface for data streaming.
- Industrial PC with interfaces for connection to ship's network, automation system and other onboard systems.
- Software for real-time dashboard with online data view via ships network (from any computer connected to ships network).
- Network router with firewall for data replication via internet.
- Configuration of shore interface for shore customer users.
- Analytics with flexible reports and dashboards that can be configured and modified by the customer.
- Option: connection with additional systems beyond MaK/Caterpillar engines, to include other engines/ generators, auxiliary systems, other systems, individual sensors such as fuel flow sensors, torque meters, anemometers, GPS/ECDIS, etc via OPC, Modbus or NMEA data protocols.

Customer assumption

- Network infrastructure and data transfer via satellite communication to be provided by customer.

12.1 Resilient mounting of baseframe

Engine and generator set are rigidly connected with the baseframe. The whole genset is mounted on the ship's foundation with conical rubber elements to achieve a passive vibration isolation between the genset and the ship. The resilient mounting arrangement is designed to reach the best possible load distribution of the genset weight in respect of the maximal permissible deflection of the conical rubber element. For that arrangement the conical rubber elements will be designed for each individual engine generator combination.
The ship's foundation does not require machining itself, but to achieve the best performance of the resilient mounting and to ensure that individual mountings are not overloaded, unevenness below the conical elements has to be compensated either by using welded-on sheets and shims or alignment plates and resin chocks.
In fact of an internal limiter of the conical elements the installation of additional stoppers is not necessary to limit the movement of the genset.

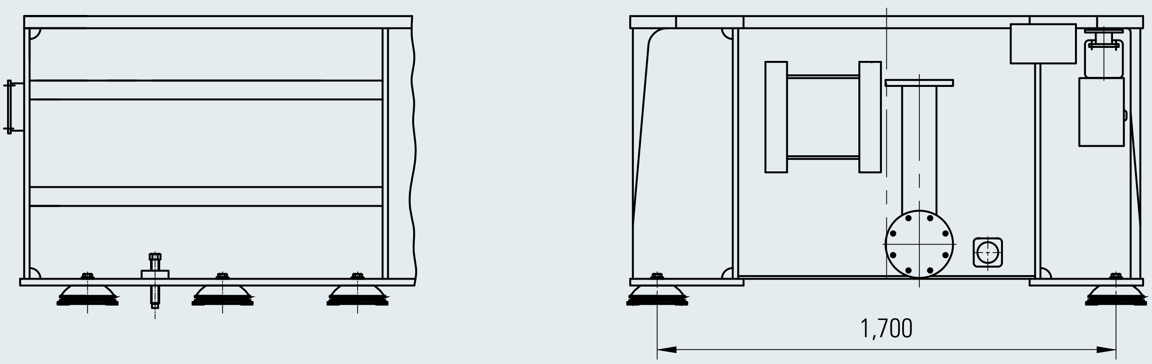


Fig. 12-1 Baseframe foundation

12.2 Earthing of engine

Information about the execution of the earthing

The earthing has to be carried out by the shipyard during the assembly on board.
The engine is already equipped with M 16, 25 mm deep threaded holes with the earthing symbol in the engine foot.
If the engine is resiliently mounted it is important to use flexible conductors.

In case of using welding equipment it is important to earth the welding equipment close to the welding area (the distance should not exceed 10 m).

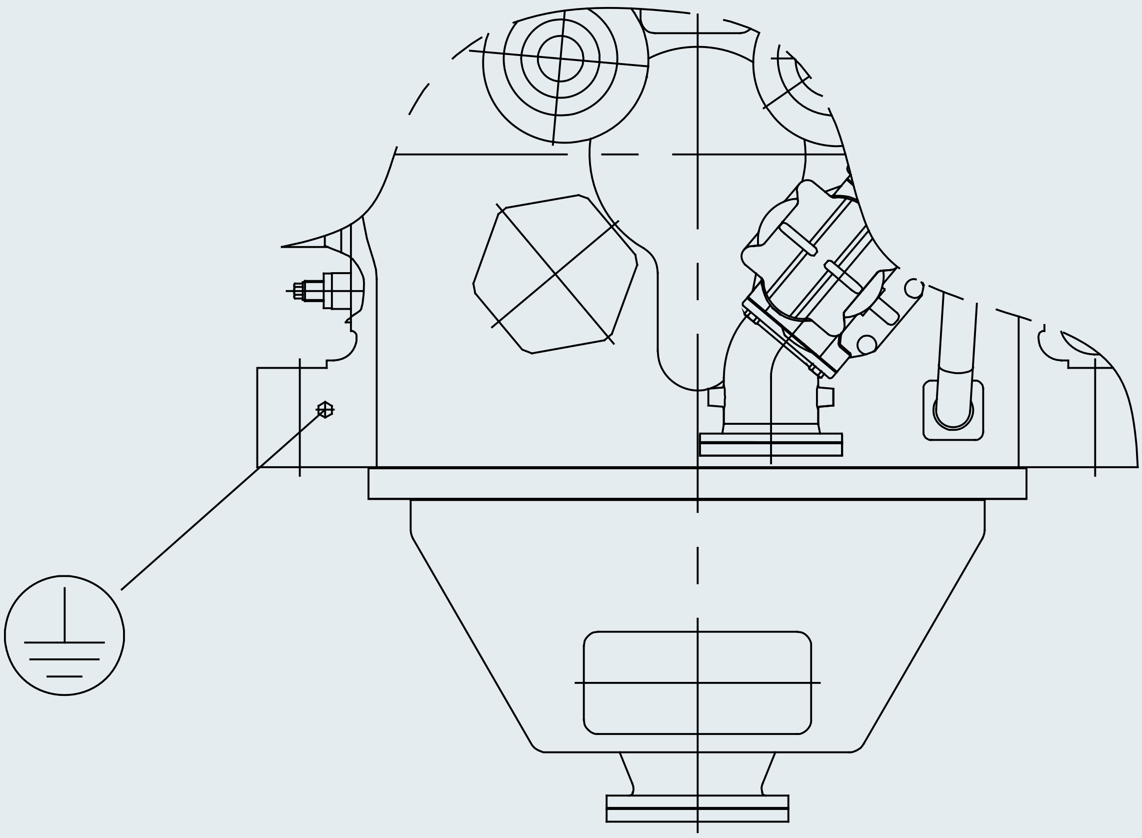


Fig. 12-2 Earthing connection on the engine

13.1 Data for torsional vibration calculation

To determine the location and resonance points of each engine and equipment Caterpillar Motoren calculates the torsional vibration behaviour of the engine, including all components, such as coupling, gearboxes, shaft lines and propellers, pumps, and generators.
The normal as well as the emergency operating mode is covered.
The classification societies require a complete torsional vibration calculation.

To be able to provide a correct torsional vibration calculation, we would like to ask you to fill in the documents in the appendix, according to your scope of supply.

Please send the completed data to your local dealer 6 month prior to the engine delivery at the latest.
For further information please compare the data sheet for torsional vibration calculation.
(following 3 pages).

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21

CAT®

Additional engine plant data part "B"

☐ Main drive
☐ Aux. Engine
☐ DE drive
Ktr.-No.: _____

Shipyard: _____
Shipowner: _____
Type of vessel: _____
Newbuilding No.: _____

Remark:

Please note that the application and installation drawings will be delivered not later than 6 weeks after receiving the completed "Additional engine plant data sheet" part "B". The "Additional engine plant data sheet" part "A" to be delivered together with the order.

General information, required for all applications:

Flag state (needed for EIAPP cert): ______________________________

Please note that Caterpillar Motoren will issue an "EAPP Document of Compliance" or an "EIAPP Certificate" as per flag state authorization only in case the flag state information is provided at least eight (8) weeks prior to the engine delivery date as per the Sales Contract (Appendix 1). In case such information has not been provided to Caterpillar Motoren until such date, Caterpillar Motoren will provide an "EAPP Statement of Compliance" which has to be converted into "EAPP Documents of Compliance" or an "EIAPP Certificate" as per flag state authorization. In this case the application and costs for the before mentioned conversion has to be borne by the Buyer.

Alarm system

☐ yard maker: _____ type: _____ yard contact manager: _____

Make of automation/bus system

☐ yard maker: _____ type: _____ yard contact manager: _____

Additional information for cooling water system:

Add. heat exchanger integrated in LT system, ☐ Yes ☐ No, if "**Yes**" please provide the following data:

☐ number of aux. engine _____
- ☐ heat dissipation _____ kW ☐ required water flow _____ m³/h ☐ pressure drop _____ bar

☐ oil cooler gear box ☐ number of cooler _____
- ☐ heat dissipation _____ kW ☐ required water flow _____ m³/h ☐ pressure drop _____ bar

☐ air cond. unit ☐ number of air cond. unit _____
- ☐ heat dissipation _____ kW ☐ required water flow _____ m³/h ☐ pressure drop _____ bar

☐ others Please specify: _____
- ☐ heat dissipation _____ kW ☐ required water flow _____ m³/h ☐ pressure drop _____ bar

Comments/Remarks:

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Caterpillar Confidential: Green

Fig. 13-1 Additional engine plant data, part "B" (1/3)

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CAT®

Additional engine plant data, part "B"

TVC data - Information for main engine(s) only:

Flex. coupling main engine:

Supplied by Caterpillar ☐ Yes ☐ No, if "**No**" please provide the following data:

☐ Vulkan
Type: _____

☐ Stromag
Size: _____
☐ Drawing attached

☐ Centa
☐ TVC scheme attached
☐ Drawing attached

☐ Other maker _____
Type: _____

Size: _____

☐ TVC scheme attached
☐ Drawing attached

Norminal torque [kNm]: _____
Perm. power loss [kW]: _____
Dyn. torsinal stiffness[kNm/rad]: _____

Perm. vibratory torque [kNm]: _____
Perm. rotational speed [1/min]: _____
Relative damping: _____

Flex. coupling engine PTO shaft (on engine free-end)

Supplied by Caterpillar ☐ Yes ☐ Not applicable ☐ No, if "**No**" please provide the following data:

☐ Vulkan
Type: _____

☐ Stromag
Size: _____
☐ Drawing attached

☐ Centa
☐ TVC scheme attached
☐ Drawing attached

☐ Other maker _____
Type: _____

Size: _____

☐ TVC scheme attached
☐ Drawing attached

Norminal torque [kNm]: _____
Perm. power loss [kW]: _____
Dyn. torsinal stiffness[kNm/rad]: _____

Perm. vibratory torque [kNm]: _____
Perm. rotational speed [1/min]: _____
Relative damping: _____

Flex. coupling gearbox PTO

Supplied by Caterpillar ☐ Yes ☐ Not applicable ☐ No, if "**No**" please provide the following data:

☐ Vulkan
Type: _____

☐ Stromag
Size: _____
☐ Drawing attached

☐ Centa
☐ TVC scheme attached
☐ Drawing attached

☐ Other maker _____
Type: _____

Size: _____

☐ TVC scheme attached
☐ Drawing attached

Norminal torque [kNm]: _____
Perm. power loss [kW]: _____
Dyn. torsinal stiffness[kNm/rad]: _____

Perm. vibratory torque [kNm]: _____
Perm. rotational speed [1/min]: _____
Relative damping: _____

Gearbox

Supplied by Caterpillar ☐ Yes ☐ No, if "**No**" please provide the following data:

Maker: _____
Max. permissible PTO output [kW]: _____

Type: _____

☐ TVC scheme attached
☐ Drawing attached

Front gearbox for engine PTO

Supplied by Caterpillar ☐ Yes ☐ Not applicable ☐ No, if "**No**" please provide the following data:

Maker: _____
Max. permissible PTO output [kW]: _____

Type: _____

☐ TVC scheme attached
☐ Drawing attached

PTO shaft generator/fire fighting pump or similar consumer, driven by engine PTO shaft/front step up gear

Supplied by Caterpillar ☐ Yes ☐ Not applicable ☐ No, if "**No**" please provide the following data:

Maker: _____
Output [kW]: _____
☐ Plain bearing, external lubrication

Type: _____
rpm [1/min]: _____

☐ TVC scheme attached
☐ Drawing attached

Caterpillar Confidential: Green

Fig. 13-2 Additional engine plant data, part "B" (2/3)

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21

CAT

Additional engine plant data, part "B"

TVC data - Information for main engine(s) only:

PTO shaft generator, driven via gearbox

Supplied by Caterpillar ☐ Yes ☐ Not applicable ☐ No, if "**No**" please provide the following data:

Maker: _____ Type: _____

Output [kVA]: _____ rpm [1/min]: _____ ☐ TVC scheme attached

☐ PTI operation PTI output [kW]: _____

Shaft arrangement between engine - gearbox

Supplied by Caterpillar ☐ Yes ☐ No, if "**No**" please provide the following data:

Maker: _____ ☐ TVC scheme attached detail drawing: _____

Propeller and propeller shafting data:

Supplied by Caterpillar ☐ Yes ☐ No, if "**No**" please provide the following data:

☐ CPP ☐ FPP ☐ Voith ☐Rudder FPP/CPP ☐ Others _____

numbers of blades: _____ Ø propeller [mm]: _____

Moments of inertia in water [kgm²]: _____ Moments of inertia in air [kgm²]: _____

Maker: _____ ☐ TVC scheme attached or detail drawing: _____

Propeller and propeller shafting information:

Supplied by Caterpillar ☐ No ☐ Yes, in case of "Yes" please provide the following data:

☐ Wake field attached ☐ Propulsion test attached (tank test) ☐ Length of shafting incl. drawing attached

Comments/Remarks:

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Confirmed by buyer: ____________________

Date: ____________________

Stamp and signature: ____________________

Caterpillar cannot be held liable for any mistakes made by the buyer.

Components not mentioned in Cat's technical specification/No. ______, dd. _____ and essential for installation/operation of the equipment will be buyer's scope of supply.

Caterpillar Confidential: Green

Fig. 13-3 Additional engine plant data, part "B" (3/3)

13.2 Sound levels

13.2.1 Airborne noise

The airborne noise level requirement in the engine room specified by IMO Resolution A.468 will be satisfied by M 25 E (even for multiple installations).

The airborne noise level will be measured in a test cell according to EN ISO 9614-2.

13.3 Vibration

The vibration level of M 25 E engines complies with ISO 8528-9 and ISO 10816-6. From these ISO standards, the following values are an applicable guideline:

Displacement	S_{eff}	< 0.448 mm	f> 2 Hz < 10 Hz
Vibration velocity	V_{eff}	< 28.2 mm/s	f> 10 Hz < 250 Hz
Vibration acceleration	a_{eff}	< 44.2 m/s^2	f> 250 Hz < 1,000 Hz

14.1 Flexible coupling

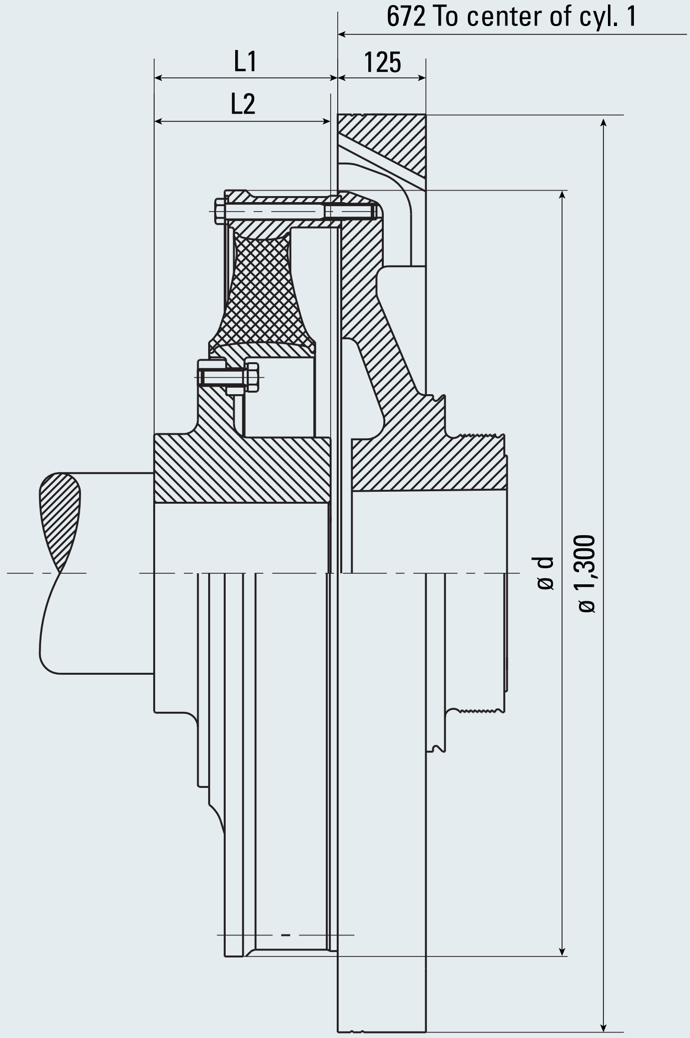

Fig. 14-1 Flywheel and flexible coupling

	Power	Speed	Nominal torque of coupling	Type Vulkan Rato-DS 1)				Weight
				Size Rato-DS	d	L1 3)	L2 2)	
	[kW]	[rpm]	[kNm]		[mm]	[mm]	[mm]	[kg]
6 M 25 E	2,100	720/750	31.5	A3311	1,010	260	250	450
8 M 25 E	2,800	720/750	40.0	A3411	1,085	260	250	549
9 M 25 E	3,150	720/750	50.0	A3415	1,085	260	250	540

1) Final coupling type and dimensions are dependent on generator type and is to be confirmed by the torsional vibration calculation. / **2)** Length of hub / **3)** Alignment control (recess depth 5 mm)

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15.1 Pipe dimensions

The external piping systems are to be installed and connected to the engine by the shipyard.
Piping systems are to be designed so as to keep the pressure losses at a reasonable level. To achieve this at justifiable costs, it is recommended to keep flow rates as indicated below (see chapter 17.2).
Nevertheless, depending on specific conditions of piping systems, it may be necessary to adopt even lower flow rates.

ATTENTION:
Generally it is not recommended to adopt higher flow rates.

15.2 Flow velocities in pipes

	Recommended flow rates [m/s]		
	Suction side	Delivery side	Kind of system
Fresh water (cooling water)	1.5 - 3.0	1.5 - 3.0	Closed
Lube oil	0.5 - 1.0	1.5 - 2.5	Open
Sea water	1.0 - 1.5	1.5 - 2.5	Open
Diesel fuel oil	0.5 - 1.0	1.5 - 2.5	Open
Heavy fuel oil	0.3 - 0.8	1.0 - 1.5	Open / closed pressurized system
Exhaust gas	20 - 40		Open

15.3 Trace heating

Trace heating is highly recommended for all pipes carrying HFO or leak oil. For detailed explanation see fuel oil diagrams, showing the trace heated pipes marked as

15.4 Insulation

All pipes with a surface temperature > 60 °C should be insulated to avoid risk of physical injury.
This applies especially to exhaust gas piping.
To avoid thermal loss, all trace heated pipes should be insulated.
Additionally, lube oil circulating pipes, the piping between engine and lube oil separator as well as the cooling water pipes between engine and preheater set should be insulated.

15.5 Flexible pipe connections

Flexible pipe connections become necessary to connect resilient mounted engines with external piping systems. These components have to compensate the dynamic movements of the engine in relation to the external piping system.

The shipyard's pipe system must be exactly arranged so that the flanges or screw connections fit without lateral or angular offset. It is recommended to adjust the final position of the pipe connections after engine alignment is completed.

It is important to support as close as possible to the flex connection and stronger than normal. The pipes outside the flexible connection must be well fixed and clamped to prevent from vibrations, which could damage the flexible connections.

Installation of steel compensators

Steel compensators can compensate movements in line and lateral to their center line. They are not suitable for compensating twisting movements. Compensators are very stiff against torsion.

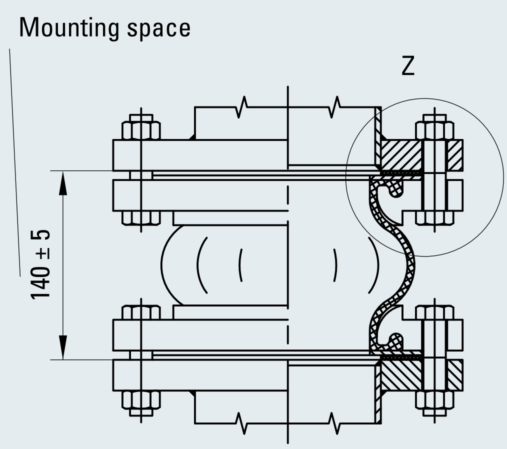


Fig. 15-1 Rubber expansion joint

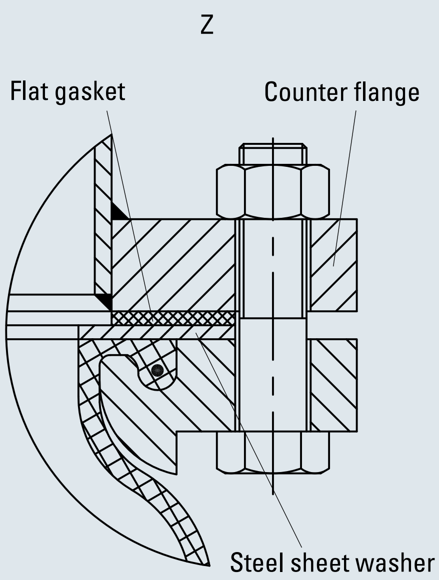


Fig. 15-2 Rubber expansion joint, detail Z

16.1 Genset center distances

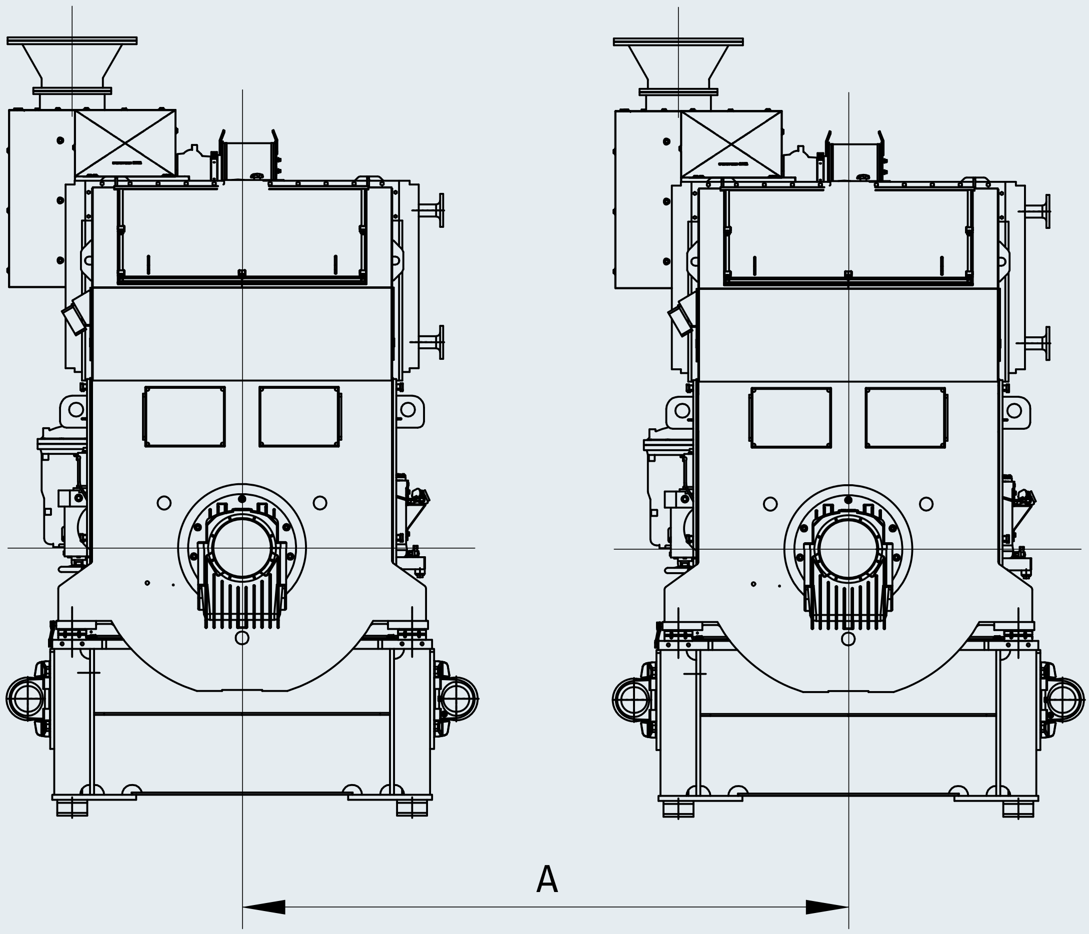
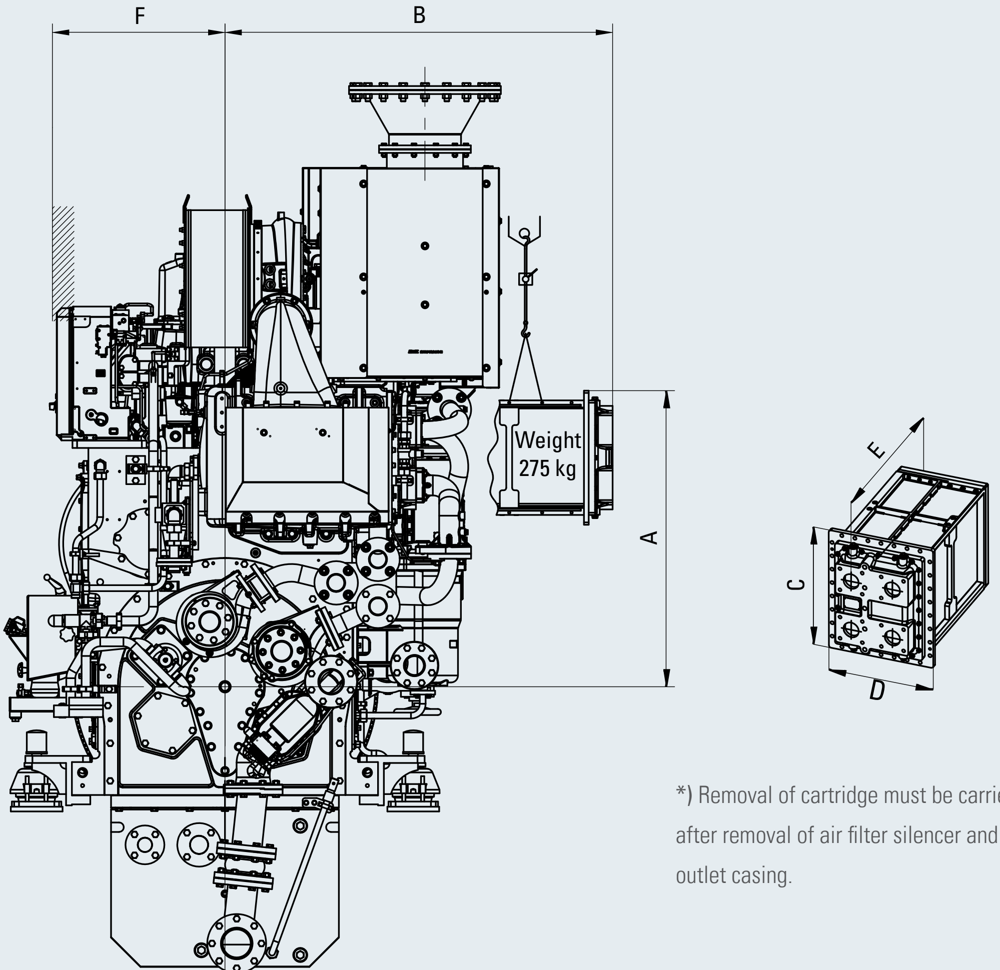


Fig. 16-1 Center distance of twin-engine plants

	Dimensions [mm]
	A
6/8/9 M 25 E	3,000

16.2 Space requirements for maintenance

16.2.1 Removal of charge air cooler and turbocharger cartridge



*) Removal of cartridge must be carried out after removal of air filter silencer and compressor outlet casing.

Fig. 16-2 Space requirement for dismantling of charge air cooler and turbocharger cartridge

	Dimensions [mm]						Weight charge air cooler	Weight turbocharger cartridge
	A	B	C	D	E	F	[kg]	[kg]
6 M 25 E	1,259	1,647	570	480	836	min. 540	275	88
8/9 M 25 E	1,259	1,647	570	480	836	min. 710	275	157

Charge air cooler cleaning

Cleaning is carried out with charge air cooler dismantled. A container to receive the cooler and cleaning liquid is to be supplied by the yard. Intensive cleaning is achieved by using ultra sonic vibrators.

Turbocharger dismantling

Removal of cartridge must be carried out with compressor delivery casing after removal of air filter silencer.

16.2.2 Removal of piston and cylinder liner

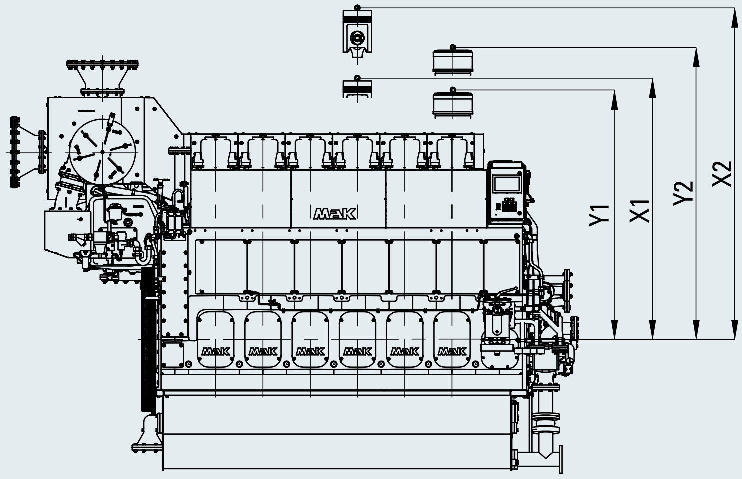


Fig. 16-3 Removal of piston and cylinder liner

Removal of:

Piston:	in transverse direction	X1 = 2,420 mm
	in longitudinal direction	X2 = 3,000 mm
Cylinder liner:	in transverse direction	Y1 = 2,510 mm
	in longitudinal direction	Y2 = 3,735 mm
Reduced height piston and cylinder liner		2,300 mm

A special tool for the removal of the cylinder liner in transverse direction is necessary according to lifting device arrangement.

17.1 Inside preservation

17.1.1 Factory standard N 576-3.3 – Inside preservation

Components

- Main running gear and internal mechanics

Application

- Max. 2 years

NOTE:
Inside preservation does not have to be removed when the engine is commissioned.

17.2 Outside preservation

17.2.1 Factory standard N 576-3.2 – Outside preservation VCI 368

Conditions

- Europe and overseas
- Sea and land transportation
- Storage in the open, protected from moisture max. 2 years with additional VCI packaging

Appearance of the engine

- Castings with red oxide antirust paint
- Pipes and machined surfaces left as bare metal
- Attached components with colours of the manufacturers

NOTE:
Outside preservation must be removed before commissioning of the engines.
Environmentally compatible disposal is to be ensured.
Durability and effect depend on proper packaging, transportation, and storage (i.e. protected from moisture, stored at a dry place and sufficiently ventilated). Inspections are to be carried out at regular intervals.

17.2.2 Factory standard N 576-4.1 – Clear varnish

Conditions

- Europe
- Roofed land transportation
- Storage in a dry and tempered atmosphere, protected from moisture max. 1 year with additional VCI packaging

NOTE:
Clear varnish is not permissible for sea transportation of engine and storage of engines in the open, even if they are covered with tarpaulin.

Appearance of the engine

- Castings with red oxide antirust paint
- Pipes and machined surfaces left as bare metal
- Attached components with colours of the manufacturers
- Surfaces sealed with clear varnish
- Bare metal surfaces provided with VCI 368 preservation

NOTE:
VCI packaging as per factory standard N 576-5.2 is generally required!
Durability and effect depend on proper packaging, transportation, and storage (i.e. the engine is to be protected from moisture, VCI film not ripped or destroyed).
Inspections are to be carried out at regular intervals.
If the above requirements are not met, all warranty claims in connection with corrosion damage shall be excluded.

17.2.3 Factory standard N 576-4.3 – Painting

Conditions

- Europe and overseas
- Sea and land transportation
- Short-term storage in the open, protected from moisture up to max. 4 weeks
- Longer than 4 weeks VCI packaging as per factory standard N 576-5.2 is required
- Max. 2 years with additional VCI packaging

Appearance of the engine

- Surfaces mostly painted with varnish
- Bare metal surfaces provided with VCI 368 preservation

NOTE:
Durability and effect depend on proper packaging, transportation, and storage (i.e. the engine is to be protected from moisture, VCI film not ripped or destroyed).
Inspections are to be carried out at regular intervals.

17.2.4 Factory standard N 576-5.2 – VCI packaging

Conditions

- Engines with outside preservation VCI 368 as per factory standard N 576-3.2
- Engines with clear varnish as per factory standard N 576-4.1
  NOTE:
  These engines are always to be delivered with VCI packaging!
  Nevertheless, they are not suitable for storage in the open!
- Engine or engine generator sets with painting as per factory standard N 576-4.3
- Europe and overseas
- Storage in the open, protected from moisture

NOTE:
Durability and effect depend on proper packaging, transportation, and storage (i.e. the engine is to be protected from moisture, VCI film not ripped or destroyed).
Inspections are to be carried out at regular intervals.

Appearance of the engine

- Bare metal surfaces provided with VCI 368 or VCI oil
- VCI impregnated flexible PU foam mats attached to the engine using tie wraps.
  Kind and scope depending on engine type.
  The attached mats should not come into contact with the painted surface.
- The engines shall be completely covered with Cortec VPCI 126 NF corrugated film. Corrugations pointing towards the inside!
  The VCI corrugated film is lowered over the engines from above and fastened to the transportation skid (wooden frame) by means of wooden laths. Overlaps at the face ends and open lashing points shall be sealed by means of Coroplast 1430 RPX PVC scotch tape.
  In case of engines delivered without oil pan, the overhanging VCI film between engine and transport frame is to be folded back upwards before fastening the corrugated film.

ATTENTION:

The corrosion protection is only effective if the engine is completely wrapped in VCI film. The protective space thus formed around the component can be openend for a short time by slitting the film, but afterwards it must be closed again with adhesive tape.

17.2.5 Factory standard N 576-5.2 Suppl. 1 – Information panel for VCI preservation and inspection

An information panel for VCI preservation and inspection will be supplied.

Application

- Engines with VCI packaging as per factory standard N 576-5.2

Description

- This panel provides information on initial preservation and instructions for inspection.
- Arranged on the transport frame on each side so as to be easily visible.

17.3 Factory standard N 576-6.1 – Protection period, check, and representation

17.3.1 Protection period

There will only be an effective corrosion protection of the engine if the definitions and required work according to factory standard N 576-6.1 are duly complied with.
Normally, the applied corrosion protection is effective for a period of max. 2 years, if the engine or engine generator set is protected from moisture.
After two years representation must be carried out.
However, depending on the execution of the preservation or local conditions shorter periods may be recommended.

17.3.2 Protection check

Every 3 month specific inspections of the engine or engine generator set are to be carried out at defined inspection points.
Any corrosion and existing condensation water are to be removed immediately.

17.3.3 Representation as per factory standard N 576-6.1

After 2 years representation must be carried out.

18.1 Lifting of engines

Caterpillar Motoren will not deliver any lifting devices for generator sets. The heavy loads carrier is responsible for delivering lifting gears such as main beam/transverse beam, chain sling, rope sling, ring or similar gear, hook, clamp, shackle, swivel or eyebolt. Also the responsible behaviour and awareness of the risk inherent in transportation of heavy loads is with the freight carrier.

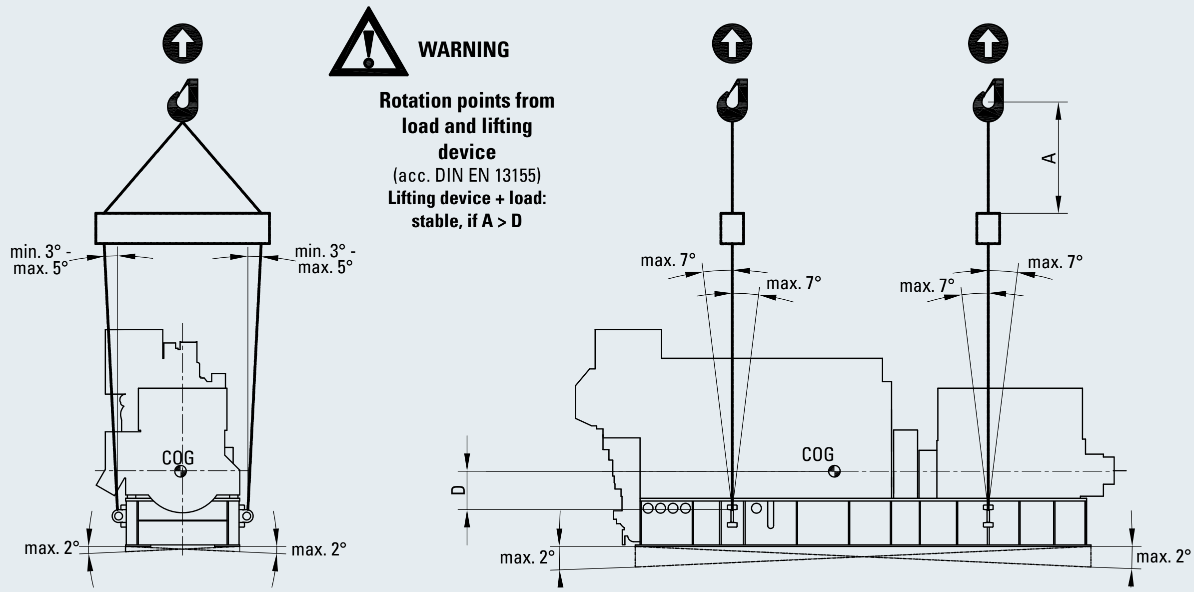


Fig. 18-1 Transport of engine

18.2 Dimensions of main components

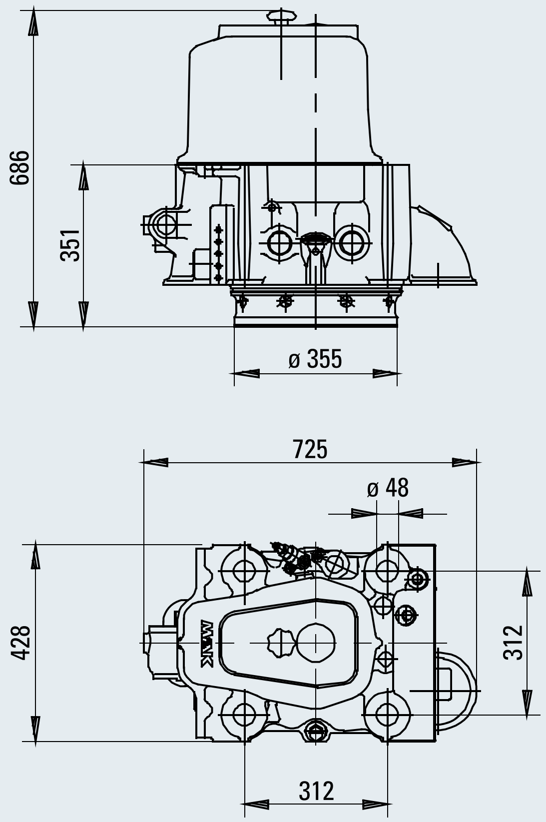


Fig. 18-2 Cylinder head, weight 240 kg

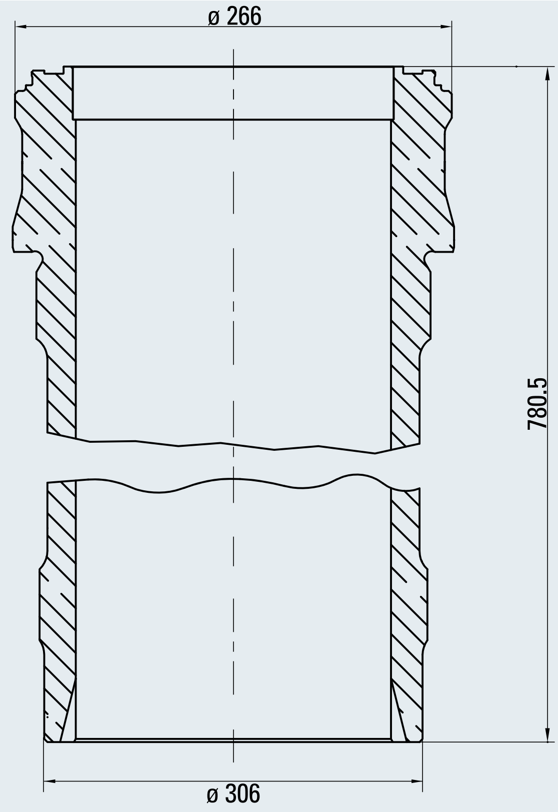


Fig. 18-3 Cylinder liner, weight 162 kg

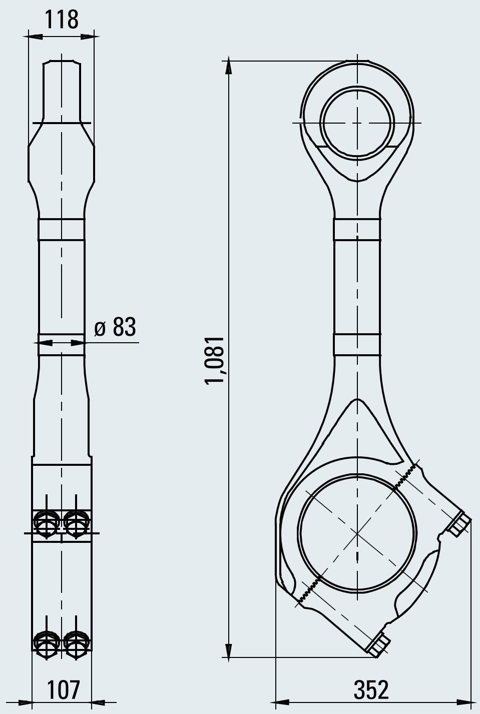


Fig. 18-4 Connecting rod, weight 79 kg

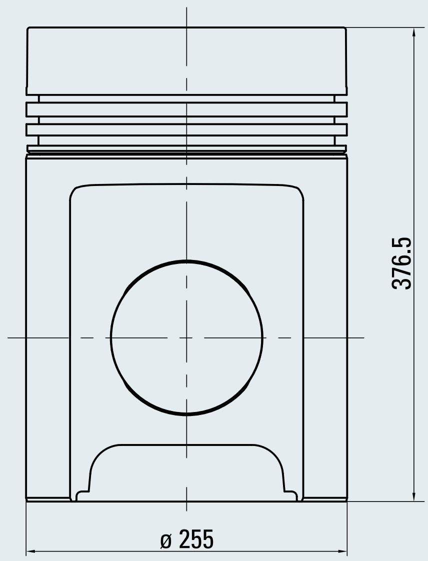


Fig. 18-5 Piston, weight 46.5 kg

19.1 Standard acceptance test run

The acceptance test run is carried out on the testing bed with customary equipment and auxiliaries using exclusively MDO and under the respective ambient conditions of the testing bed. During this test run the fuel rack will be blocked at the contractual output value. In case of deviations from the contractual ambient conditions the fuel consumption will be converted to standard reference conditions.
The engine will be run at the following load stages according to the rules of the classification societies.

Load [%]	Duration [min]
50	20
75	20
100	60
110	30

The load stages above can vary according to the requirements of the classification societies.

After reaching steady state conditions of pressures and temperatures these will be recorded and registered according to the form sheet of the acceptance test certificate:

Additional functional tests

In addition to the acceptance test run the following functional tests will be carried out:

- Governor test
- Overspeed test
- Emergency shut-down via minimum oil pressure
- Start/stop via local engine control
- Starting trials up to a minimum air pressure of 10 bar
- Measurement of crank web deflection (cold/warm condition)
- Test of oil mist detection of alternative systems if available

After the acceptance, main running gear, camshaft drive and timing gear train will be inspected through the opened covers.
Individual inspection of special engine components such as piston or bearings is not intended.

20.1 Required spare parts (Marine Classification Society MCS)

Classification societies	GL	KR	CCS	ClassNK
Rules references	Pt. 1, Ch. 17	Pt. 5, Ch. 1	Ch. 15, Sec.1&2	Pt. 9, Ch. 13
Status	2014	2015	2016	2015
Parts				
Main bearing	1	1	1	–
Thrust washer	1	1	1	–
Cylinder liner, complete	1	1	1	–
Cylinder head, complete	1	1	1	–
Cylinder head, only with valves (w/o injection valve)	–	–	–	–
Set of gaskets for one cylinder head	–	–	–	–
Set bolts and nuts for cylinder head	1/2	1/2	1/2	–
Set of exhaust valves for one cylinder head	1	2	2	1
Set of intake valves for one cylinder head	1	1	1	1
Starting air valve, complete	1	1	1	–
Relief valve, complete	1	1	1	–
Injection valve, complete	–	–	–	–
Set of injection valves, complete, for one engine	1	1	1	1
Set of conrod top & bottom bearing for one cylinder	1	1	1	1
Piston, complete	1	1	1	–
Piston, without piston pin + piston rings	–	–	–	–
Connecting rod	1	1	1	–
Big end bearing	–	–	–	1
Gudgeon pin with bushing for one cylinder	1	1	1	–
Set of piston rings	1	1	1	1
Fuel injection pump	1	1	1	1
Fuel injection piping	1	1	1	1
Set of gaskets and packing for one cylinder	1	1	1	–
Exhaust compensators between cylinders	1	1	1	–
Turbocharger rotor, complete	–	–	–	–
Set of gear wheels	–	–	–	–

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20.2 Recommended spare parts

Classification societies	RS	ABS	DNV	DNVGL	LR	BV **)	RINA **)
Rules references	Pt. 7, Ch. 10	Pt. 4, Ch. 2 Sec. 1	Pt. 4, Ch. 1, Sec. 5	Pt. 4, Ch. 1, Sec. 5	Ch. 1, Sec. 1	Pt. A, Ch. 1, Sec. 1	Pt. A, Ch. 1, Sec. 1
Status	2016	2016	2016	2016	2011	2016	2016
Parts							
Main bearing	1	1	1	1	1	–	–
Thrust washer	1	1	1	1	1	–	–
Cylinder liner, complete	1	1	1	1	1	–	–
Cylinder head, complete	1	1	1	1	1	–	–
Cylinder head, only with valves (w/o injection valve)	–	–	–	–	–	–	–
Set of gaskets for one cylinder head	–	–	–	–	–	–	–
Set bolts and nuts for cylinder head	1/2	1/2	1/2	1/2	1/2	–	–
Set of exhaust valves for one cylinder head	(2)*)	2	2	2	2	–	–
Set of intake valves for one cylinder head	(1)*)	1	1	1	1	–	–
Starting air valve, complete	1	1	1	1	1	–	–
Relief valve, complete	1	1	1	1	1	–	–
Injection valve, complete	–	–	–	1	–	–	–
Set of injection valves, complete, for one engine	1	1	1	–	1	–	–
Set of conrod top & bottom bearing for one cylinder	1	1	1	1	1	–	–
Piston, complete	1	1	1	1	1	–	–
Piston, without piston pin + piston rings	–	–	–	–	–	–	–
Connecting rod	1	1	1	1	1	–	–
Big end bearing	–	–	–	1	–	–	–
Gudgeon pin with bushing for one cylinder	1	1	1	1	1	–	–
Set of piston rings	1	1	1	1	1	–	–
Fuel injection pump	1	1	1	1	1	–	–
Fuel injection piping	1	1	1	1	1	–	–
Set of gaskets and packing for one cylinder	1	1	1	1	1	–	–
Exhaust compensators between cylinders	–	1	1	–	1	–	–
Turbocharger rotor, complete	(1)*)	–	–	–	–	–	–
Set of gear wheels	–	1	–	–	–	–	–

*) Recommendation only / **) Owner's responsibility

Caterpillar recommendation	Caterpillar
Rules references	
Status	2016
Parts	
Main bearing	1
Thrust washer	–
Cylinder liner, complete	1
Cylinder head, complete	–
Cylinder head, only with valves (w/o injection valve)	1
Set of gaskets for one cylinder head	1
Set bolts and nuts for cylinder head	1/2
Set of exhaust valves for one cylinder head	–
Set of intake valves for one cylinder head	–
Starting air valve, complete	–
Relief valve, complete	–
Injection valve, complete	1
Set of injection valves, complete, for one engine	–
Set of conrod top & bottom bearing for one cylinder	–
Piston, complete	–
Piston, without piston pin + piston rings	1
Connecting rod	–
Big end bearing	1
Gudgeon pin with bushing for one cylinder	–
Set of piston rings	1
Fuel injection pump	1
Fuel injection piping	1
Set of gaskets and packing for one cylinder	–
Exhaust compensators between cylinders	1
Turbocharger rotor, complete	–
Set of gear wheels	–
Only for electronic speed setting: Pick-up for electronic speed setting	1
Only if oil mist detector is provided (VN301 is excluded): Sintered bronze filter (for crankcase monitoring)	1

*) Recommendation only

21.1 Scope, systems design & engineering of D/E propulsion

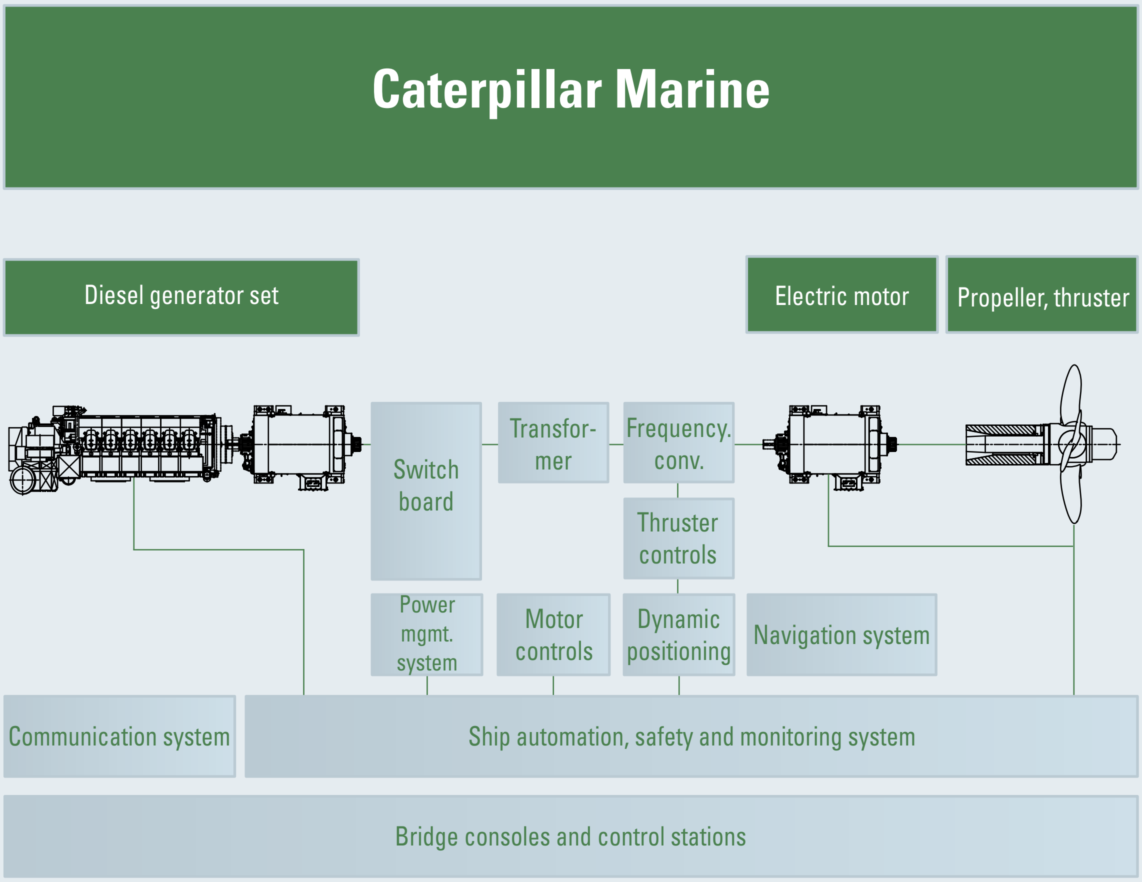

Fig. 21-1 D/E application

21.2 Scope, systems design & engineering of D/M propulsion

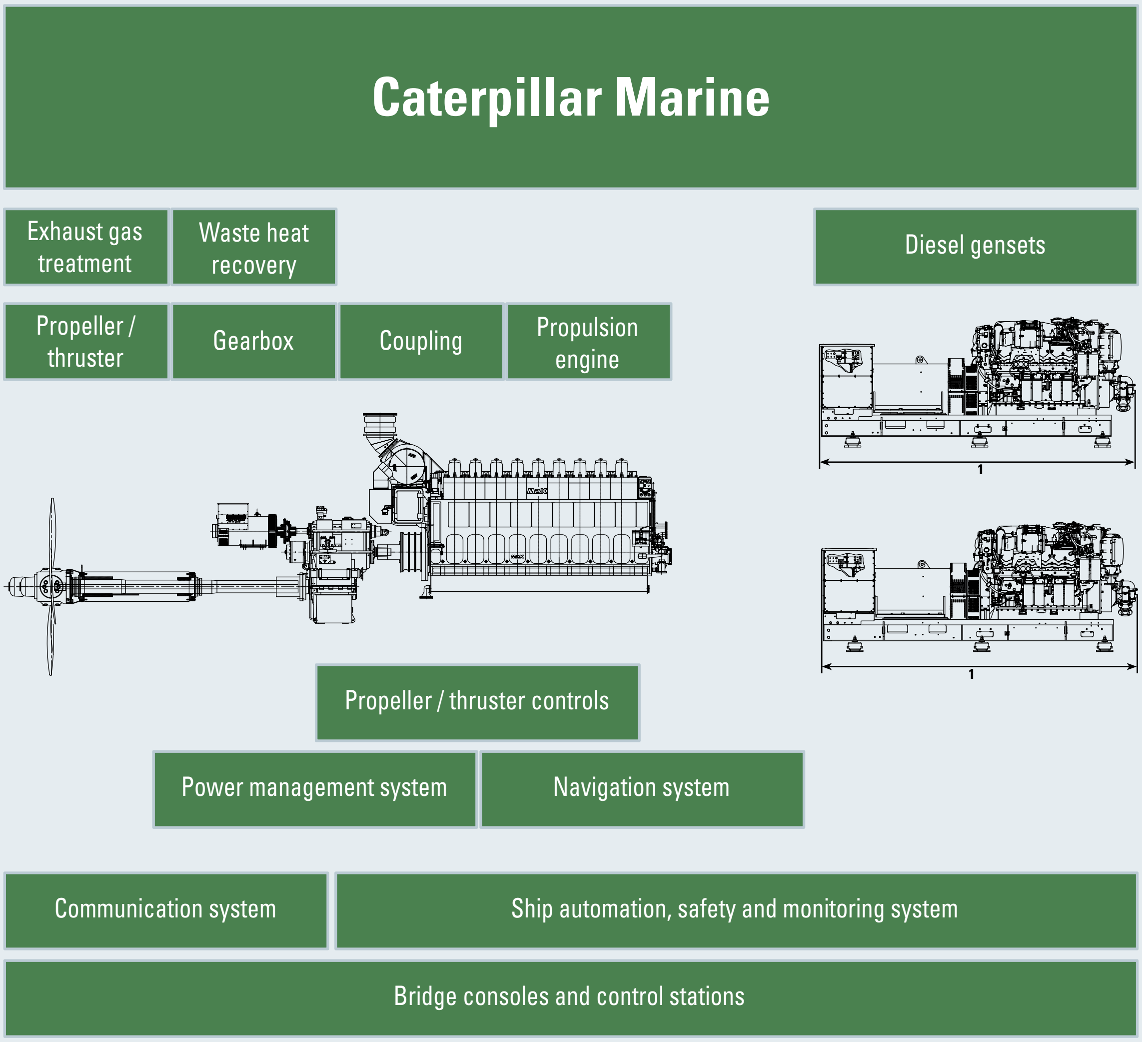

Fig. 21-2 D/M application

21.3 Levels of integration

The following levels of integration, including the listed components are available through Caterpillar Marine:

1.) Exhaust gas system – please refer to chapter 10.
2.) Mechanical propulsion system, consisting of:
- Diesel engines – engines and related auxiliary systems
- Drive lines – gearboxes, propellers, thrusters
- Auxiliary diesel generator sets – engines, generators, baseframes, engine related auxiliary systems

3.) Electrical propulsion systems, consisting of:
- Main diesel generator sets – engines, generators, baseframes, engine related auxiliary systems
- Electric-mechanical propulsion – electric motors, shafts, gearboxes, propellers, thrusters
- Electric propulsion switchboard – drives (switchgears, inverter units, transformers)
- Electric board net switchboard – main and auxiliary switchboard low voltage consumer (transformer)
- Power management system – dynamic control of electric propulsion and electric network
- Dynamic positioning system – DP operator station, DP control unit, thruster balancing and alloca tion algorithm
- Navigation system – radar, compass, autopilot
- Control consols – bridge consols, wing consols, engine control room controls

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21.4 Caterpillar Propulsion

Performance You Can Rely On

Caterpillar Propulsion supplies complete, world-leading propulsion systems.

Custom-designed and optimized for uptime and cost-effective operations, our top-of-the-line controllable pitch propellers, thrusters, gearboxes, control systems, and hubs are all manufactured at our state-of-the-art production facilities in Sweden and Singapore.

Fig. 21-3 Main propeller

We are experts in innovative hydrodynamics to ensure heavy-duty, reliable performance for our customers.

How we deliver uptime

Our guiding principle is to deliver maximum uptime for our customers' peace-of-mind and profitability.

For us, this means using more material to ensure our propulsion systems are built to last even in the most extreme conditions. And with extreme attention to detail, we study your vessel's design, the waters it travels, the job at hand – anything and everything that affects the hydrodynamics.

Using all our expertise, we're not finished until the system is as optimized and reliable as possible.
Please visit us at catpropulsion.com.

Fig. 21-4 Azimuth thrusters

Fig. 21-5 Tunnel thrusters

Fig. 21-6 Remote control system

The Power You Need.

The Cat® and MaK™ brands of Caterpillar Marine offer premier high- and medium-speed propulsion, auxiliary, and generator set solutions, as well as optional dual fuel, diesel-electric, and hybrid system configurations. With the launch of Caterpillar Propulsion our comprehensive and evolving product line gives customers one source for the most extensive engine power range available, complete propulsion systems, controllable pitch propellers, transverse and azimuth thrusters, and controls. Cat and MaK products and technologies are proven reliable and are built to last in all marine applications, demonstrating superior productivity and the lowest lifecycle cost.

The Cat Global Dealer Network, more than 2,200 global service locations strong, ensures that you'll have local expertise, highly-trained technicians, rapid parts delivery, and the proper equipment and services to keep you working – anytime, anywhere.

Construction, term, or repower financing through Cat Financial helps you make Cat and MaK power a reality. With our knowledge of customer needs, local markets, and legal and regulatory requirements, we've been providing tailored financing solutions and exceeding expectations since our start in 1986.

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