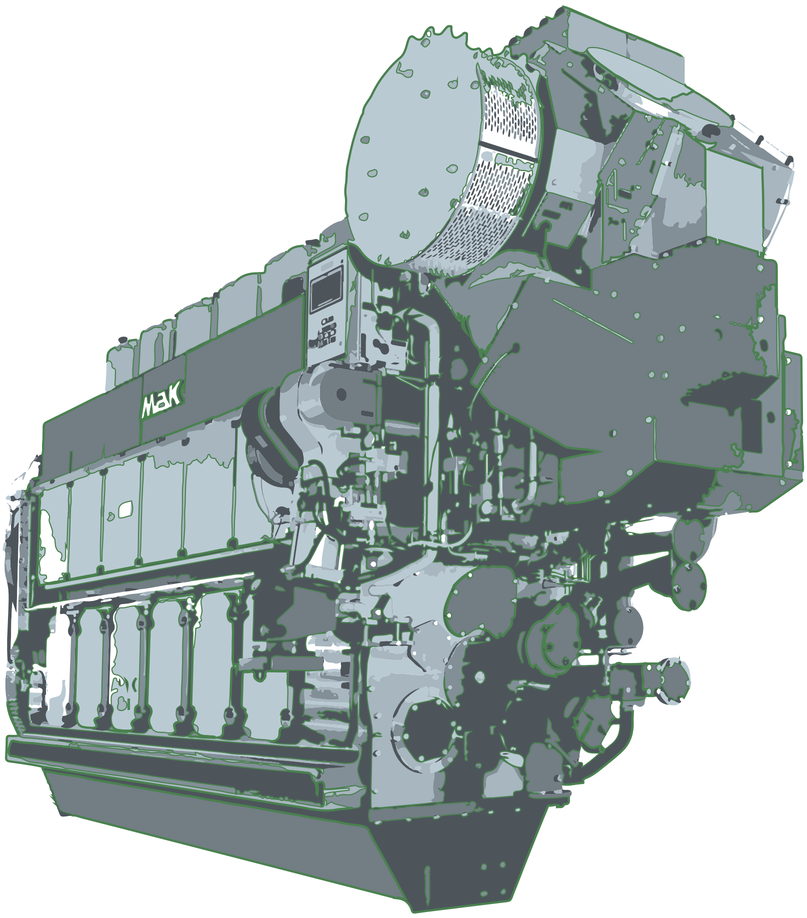
M 32 E

PROJECT GUIDE / PROPULSION



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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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Edition **January 2017**

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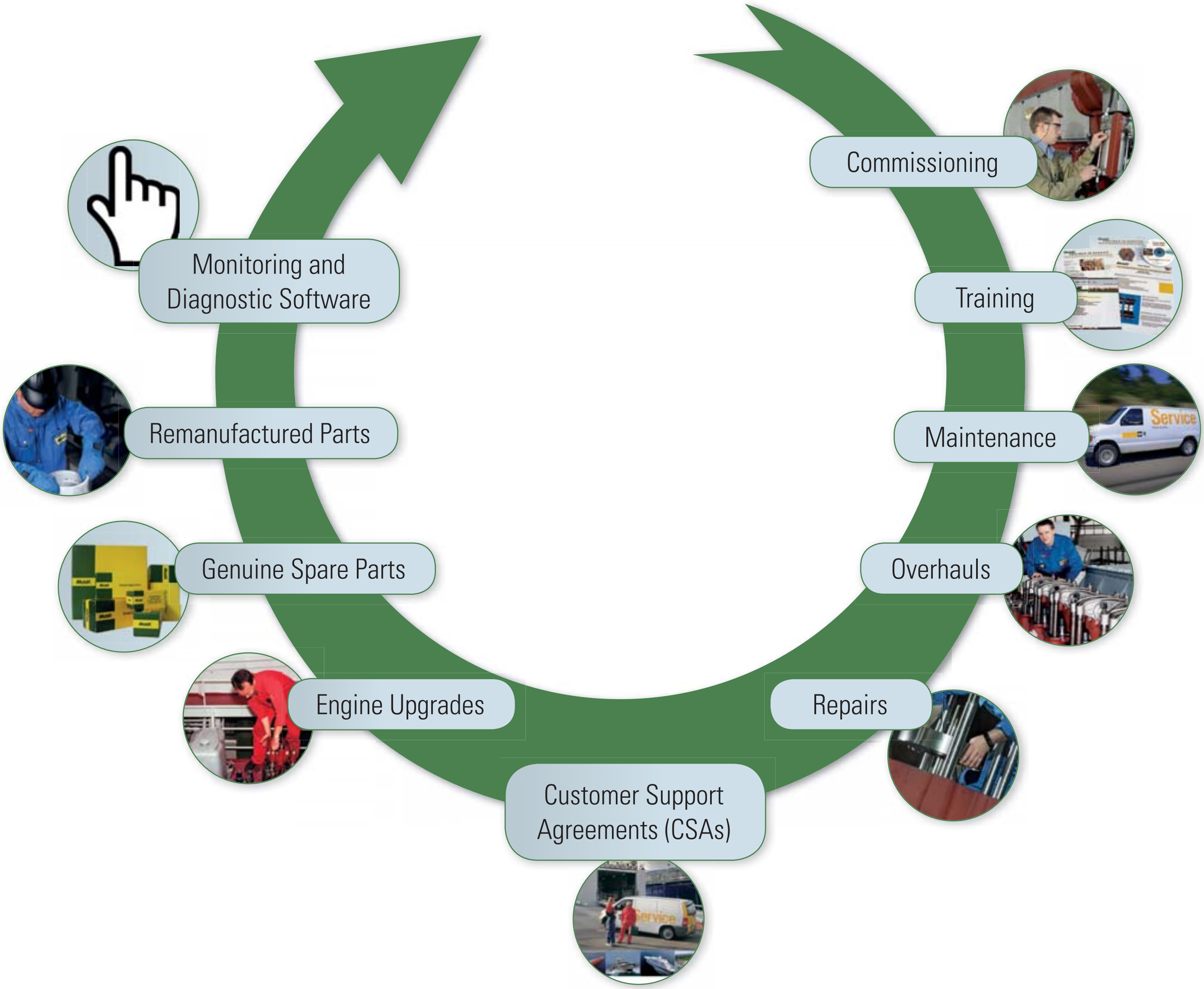

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MANAGEMENT SYSTEM CERTIFICATE

Certificate No:
196529-2016-AE-GER-DAkkS

Initial certification date:
ISO 9001: 03.11.2003
BS OHSAS 18001+ISO 14001: 08.10.2013

Valid:
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
Deutsche Akkreditierungsstelle
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.
TEL:+49 201 7296-222. www.dnvgl.de/assurance

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1.1 Definitions

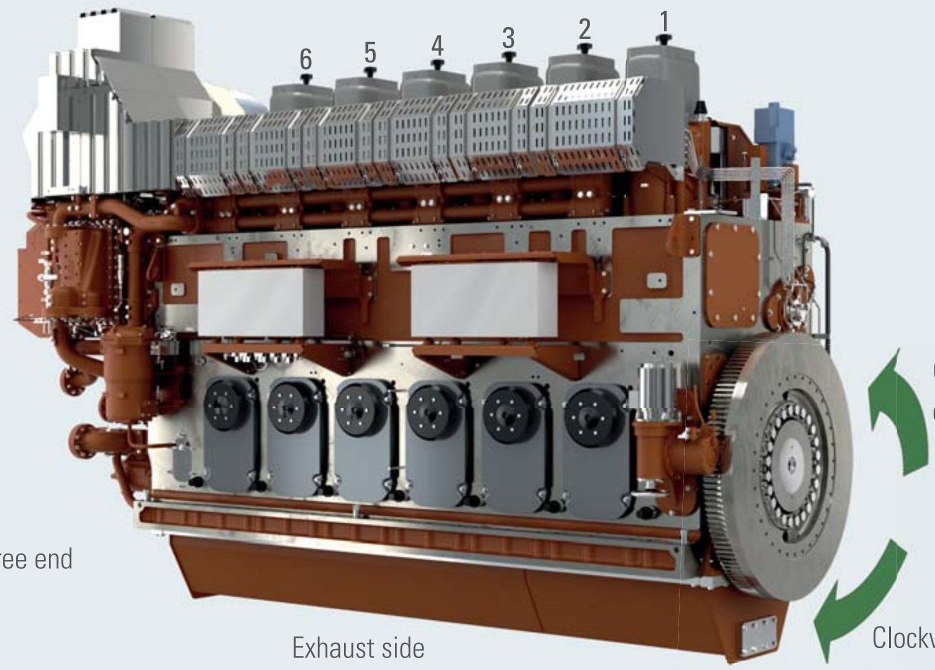

Fig. 1-1 M 32 E

	6 M 32 E	8 M 32 E	9 M 32 E
Output [kW]	3,300	4,400	4,950

Cylinder configuration:	6, 8, 9 in-line
Bore:	320 mm
Stroke:	460 mm
Stroke / bore-ratio:	1.44
Swept volume:	37 l/cyl.
Output/cyl:	550 kW
BMEP:	24.8/23.8 bar
Revolutions:	720/750 rpm
Mean piston speed:	11.0/11.5 m/s
Turbocharging:	single log
Direction of rotation:	clockwise, option: counter-clockwise

1.2 Main components and systems

1.2.1 Main features and characteristics

The M 32 E engine is designed for our customers seeking the greatest reliability and durability in combination with stability at high power output. The M 32 E is based on the most successful M 32 C engine and stands out with the same superior serviceability, HFO capability and class leading maintenance intervals. Additional properties of the M 32 E compared to the M 32 C are a 10% power increase with lower specific fuel consumption at part load with the optional Part Load optimization Kit (PLK). The PLK improves the load acceptance and reduces smoke emissions. The increased power output of 550 kW/ cylinder is offered at both 720 and 750 rpm. The M 32 E is IMO Tier 2 and EPA Tier 2 compliant as are all of the category 3 engines we offer. Low lube oil consumption as well as low sulfur fuel capability characterize the engine as both environmental friendly and cost efficient in times of increasing fuel oil costs. The possibility of dual fuel conversion or SCR retrofitting define the M 32 E as a power unit for the future.

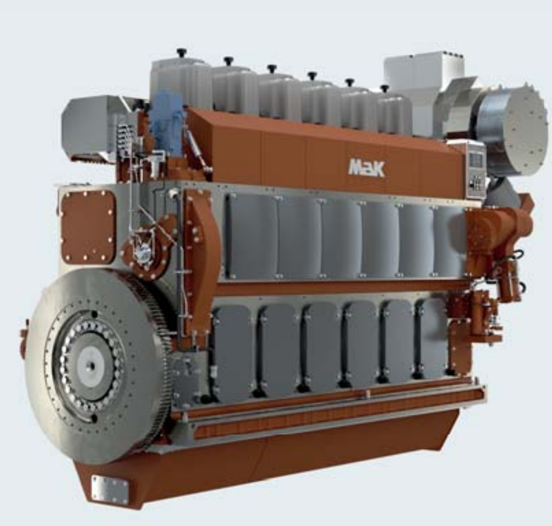

Fig. 1-2 Control side and driving end

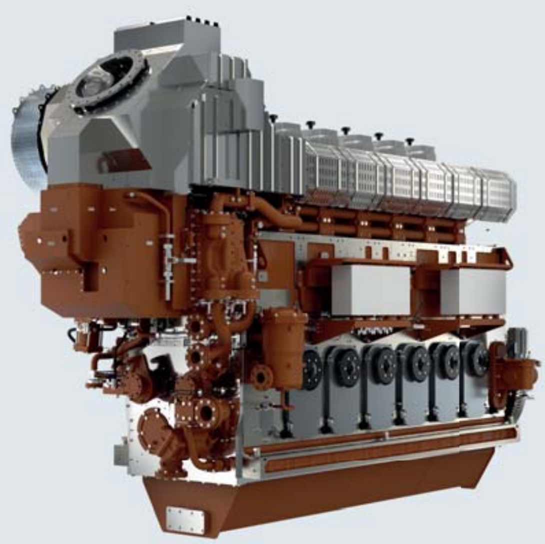

Fig. 1-3 Exhaust side and free end

1.2.2 Description of components

Cylinder head

- The cylinder heads are made of nodular cast iron with 2 inlet and 2 exhaust valves, which are equipped with valve rotators.
- The exhaust valve seats are directly water cooled.
- The injection nozzles for heavy fuel operation are cooled by engine lubricating oil.

Connecting rod and piston

- The pistons are of composite type with steel crown and forged steel or nodular cast iron skirt.
- The piston ring sets consist of two compression rings, first ring with chromium diamant plated running surfaces, the second ring with chromium plated running surfaces, and one chromium diamant plated oil scraper ring.
- All ring grooves are located in the steel crown, which is cooled by lube oil.
- The ring grooves are hardened.
- 3-piece connecting rod, supporting removal of the piston without opening the big end bearing.

Engine block

Core element of the M 32 E is the engine block, which is made of nodular cast iron in one piece.
The advantages of the engine block design are:

- The one-piece design makes the engine block extremely robust and warp resistant.
- The charge air manifold is cast integral, which avoids vibration and leakage problems.
- Lube oil lines are routed through the block in cast and drilled holes, reducing the number of connecting points and leakage problems to a minimum.
- The camshaft housing contains a camshaft, which is made of sections per cylinder allowing a removal of the segments sideways.
- The underslung crankshaft allows the removal of the complete crankshaft without disassembly of the entire engine.
- The engine block is not integrated into the cooling water circuit, therefore the engine block is completely dry.

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 32 E Propulsion		
	MDO	HFO	TBO M 32 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	60,000	60,000	–
Turbocharger plain bearing	12,000	12,000	–
Vibration damper camshaft	15,000	15,000	–
Vibration damper crankshaft	30,000	30,000	15,000

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

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Type	720/750 rpm
	[kW]
6 M 32 E	3,300
8 M 32 E	4,400
9 M 32 E	4,950

The maximum fuel rack position is mechanically limited to 110 % output for CPP applications.

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)

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

- 0.6 g/kWh
- Value is based on rated output
- Tolerance ± 0.3 g/kWh

NOTE:
Please also compare the technical data (see chapter 3).

2.4 Emissions

2.4.1 Exhaust gas

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

Intake air temperature 25 °C

Engine	Output [kW]	Output % [kg/h] [°C]			
		100	85	75	50
6 M 32 E	3,300	22,720 305	19,410 300	17,235 315	11,130 365
8 M 32 E	4,400	30,150 305	25,750 300	22,870 315	14,760 365
9 M 32 E	4,950	34,080 305	29,300 300	25,850 315	16,690 365

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:

It is not allowed 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)
NO_x-limit values according to IMO II:	9.69 g/kWh (n=720 rpm)

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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 E3			
Speed	100 %	100 %	100 %	100 %	100 %	91 %	80 %	63 %
Power	100 %	75 %	50 %	25 %	100 %	75 %	50 %	25 %
Weighting factor	0.2	0.5	0.15	0.15	0.2	0.5	0.15	0.15

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

A 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. 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.

2.5 Engine dimensions and weight

Turbocharger at driving end

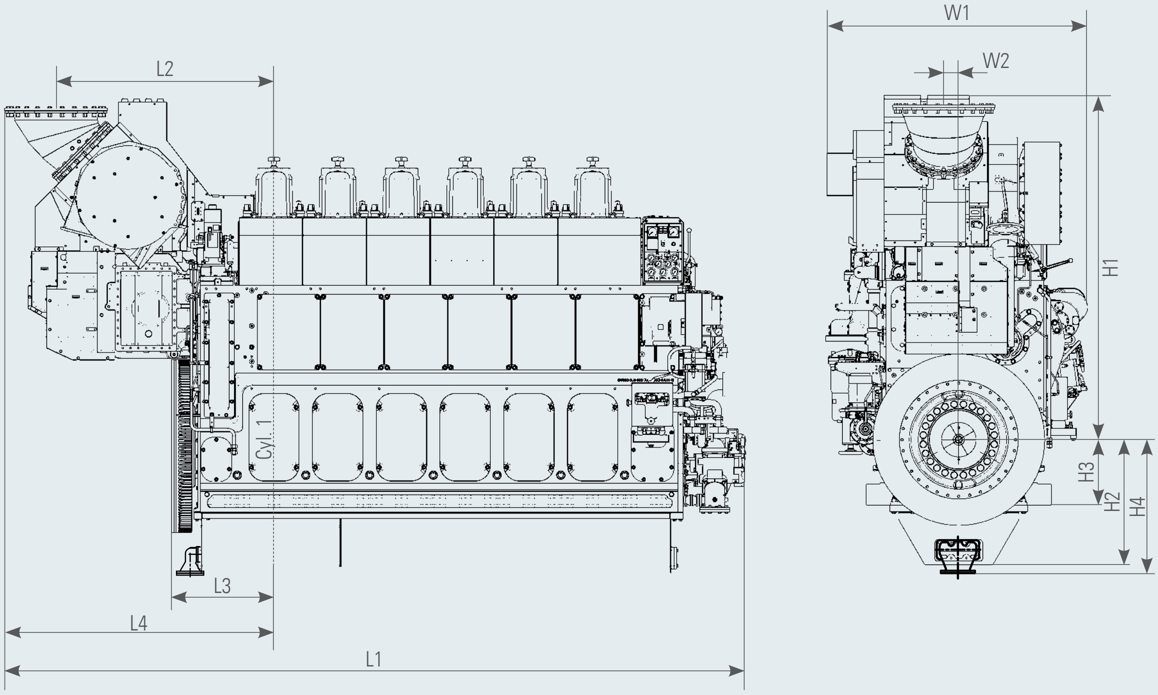

Fig. 2-1 Turbocharger at driving end

Type	Dimensions [mm]										Weight
	L1	L2	L3	L4	H1	H2	H3	H4	W1	W2	[t]
6 M 32 E	6,148	1,812	852	2,240	2,771	1,052	550	1,220	2,368	126	37.5
8 M 32 E	7,318	1,837	852	2,265	2,908	1,052	550	1,220	2,182	190	46.4
9 M 32 E	7,848	1,837	852	2,265	2,908	1,052	550	1,220	2,182	190	49.4

Engine center distance

(2 engines side by side), turbocharger at driving end

Minimum 2,800 mm
(Minimum width at fuel oil filter level approx. 500 mm)

Turbocharger at free end

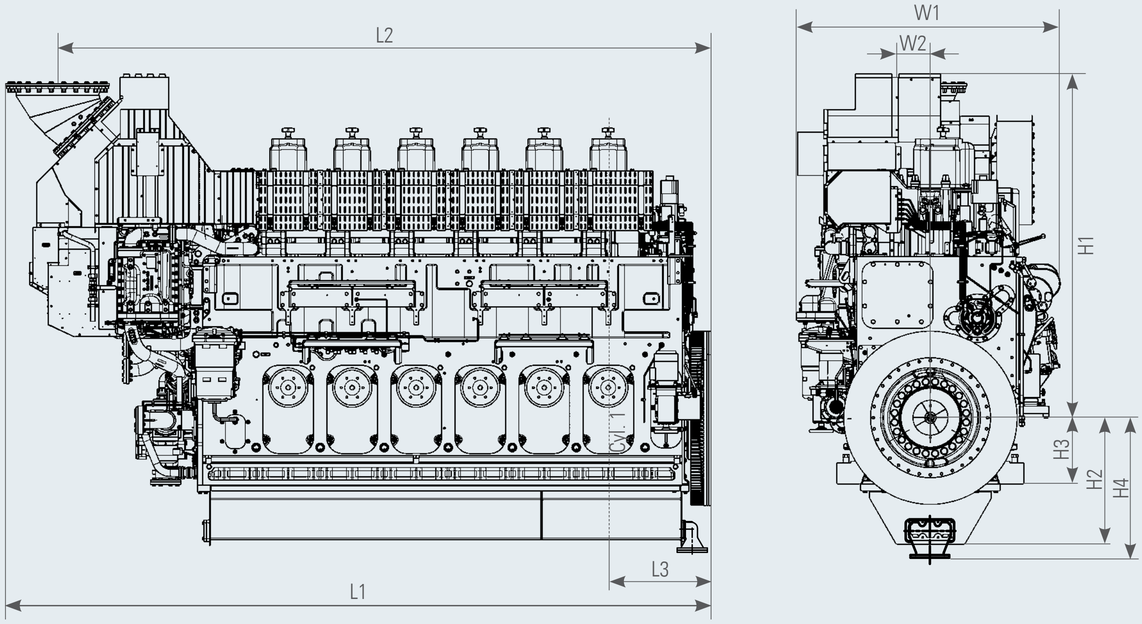

Fig. 2-2 Turbocharger at free end

Type	Dimensions [mm]									Weight
	L1	L2	L3	H1	H2	H3	H4	W1	W2	[t]
6 M 32 E	5,895	5,466	852	2,771	1,052	550	1,220	2,368	126	37.5
8 M 32 E	6,980	6,550	852	2,908	1,052	550	1,220	2,182	190	46.4
9 M 32 E	7,510	7,080	852	2,908	1,052	550	1,220	2,182	190	49.4

Engine center distance

(2 engines side by side), turbocharger at free end

Minimum 2,800 mm
(Minimum width at fuel oil filter level approx. 500 mm)

2.6 System connecting points

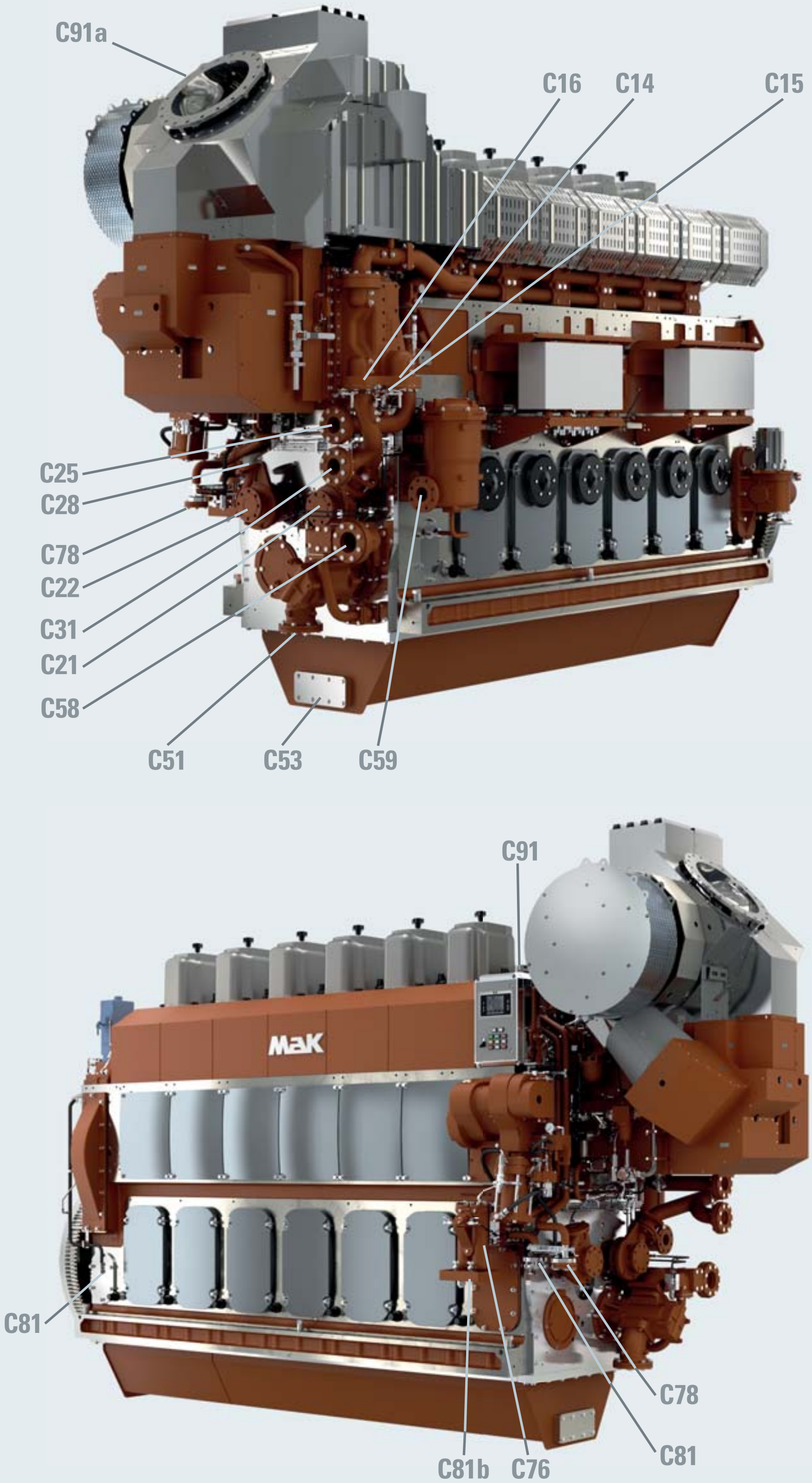

Fig. 2-3 Connecting points at the engine

C14	Charge air cooler LT, inlet
C15	Charge air cooler LT, outlet
C16	Charge air cooler HT, inlet
C21	Fresh water pump HT, inlet
C22	Fresh water pump LT, inlet
C25	Cooling water, engine outlet
C28	Fresh water pump LT, outlet
C31	Fresh water pump HT, outlet
C51	Force pump, suction side
C53	Lube oil discharge
C58	Force pump, delivery side
C59	Lube oil, inlet
C76	Inlet, duplex filter
C78	Fuel outlet
C81	Drip fuel connection
C81b	Drip fuel connection (filter pan)
C91	Crankcase ventilation to stack
C91a	Exhaust gas outlet

3.1 Diesel, mechanical – 6 M 32 E

This table does only contain IMO II data.

6 M 32 E			Standard	PLK variable speed
Performance data				
Maximum continuous rating acc. ISO 3046/1		[kW]	3,300	
Speed		[1/min]	750/720	
Minimum speed		[1/min]	360	
Brake mean effective pressure		[bar]	23.8/24.8	
Combustion air demand (ta=25 °C)		[m³/h]	18,910	23,300
Brake specific fuel oil consumption				
Rated operation curve [1) 6)]	100 %	[g/kWh]	179	183
	85 %	[g/kWh]	178	181
	75 %	[g/kWh]	179	181
	50 %	[g/kWh]	185	181
	25 %	[g/kWh]	210	200
Specific lube oil consumption [2)]		[g/kWh]	0.6	
NO_x-emission [5)]		[g/kWh]	9.6/9.69	
Turbocharger type			Napier NT1-10	
Fuel				
Engine driven booster pump		[m³/h/bar]	2.2/5.0	
Stand-by booster pump		[m³/h/bar]	2.4/5.0	
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]	118/10	
Independent pump		[m³/h/bar]	60/10	
Working pressure on engine inlet		[bar]	4 - 5	
Engine driven suction pump		[m³/h/bar]	168/3	
Independent suction pump		[m³/h/bar]	65/3	
Priming pump		[m³/h/bar]	8/5	
Sump tank content		[m³]	4.5	
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 32 E		Standard	PLK variable speed
Fresh water cooling			
Engine content	[dm³]	300	
Pressure at engine inlet min/max	[bar]	2.5 - 6.0	
Header tank capacity	[dm³]	350	
Temperature at engine outlet	[°C]	80 - 90	
Two circuit system			
Engine driven HT pump	[m³/h/bar]	70.0/4.5	
Independent HT pump	[m³/h/bar]	70.0/4.0	
HT-controller NB	[mm]	100	
Water demand LT-charge air cooler	[m³/h]	40	
Temperature at LT-charge air cooler inlet	[°C]	32	
Heat dissipation			
Lube oil cooler	[kW]	475	
Jacket water	[kW]	935	1,050
Charge air cooler (HT-stage) 3)	[kW]	395	345
Charge air cooler (LT-stage) 3)	[kW]	395	
Heat radiation	[kW]	92	
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]	10	
Air consumption per start 4)	[m³]	1.2	
Max. allowed crankcase pressure, ND ventilation pipe	[mbar/mm]	1.5/80.0	

1) Reference conditions: LCV = 42,700 kJ/kg, ambient temperature 25 °C, charge air coolant temperature 25 °C, tolerance 5 %, for engine driven lube oil pump + 1.0% at 100%, 1.2% at 85%, 1.3% at 75%, 2.0% at 50%, 4.0% at 25%; for engine driven cooling water pump + 0.4% at 100%, 0.47% at 85%, 0.53% at 75%, 0.8% at 50%, 1.6% at 25%, additions to fuel consumption must be considered before tolerance is taken into account. / **2)** Standard value, tolerance ± 0.3 g/kWh, 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 32 E

This table does only contain IMO II data.

8 M 32 E			Standard	PLK variable speed
Performance data				
Maximum continuous rating acc. ISO 3046/1		[kW]	4,400	
Speed		[1/min]	750/720	
Minimum speed		[1/min]	360	
Brake mean effective pressure		[bar]	23.8/24.8	
Combustion air demand (ta=25 °C)		[m³/h]	25,080	31,060
Brake specific fuel oil consumption				
Rated operation curve [1) 6)]	100 %	[g/kWh]	179	183
	85 %	[g/kWh]	178	181
	75 %	[g/kWh]	179	181
	50 %	[g/kWh]	185	181
	25 %	[g/kWh]	210	200
Specific lube oil consumption [2)]		[g/kWh]	0.6	
NO_x-emission [5)]		[g/kWh]	9.6/9.69	
Turbocharger type			Napier NT1-12	
Fuel				
Engine driven booster pump		[m³/h/bar]	3.2/5.0	
Stand-by booster pump		[m³/h/bar]	3.1/5.0	
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]	118/10	
Independent pump		[m³/h/bar]	80/10	
Working pressure on engine inlet		[bar]	4 - 5	
Engine driven suction pump		[m³/h/bar]	168/3	
Independent suction pump		[m³/h/bar]	65/3	
Priming pump		[m³/h/bar]	11/5	
Sump tank content		[m³]	6.0	
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	

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8 M 32 E		Standard	PLK variable speed
Fresh water cooling			
Engine content	[dm³]	400	
Pressure at engine inlet min/max	[bar]	2.5 - 6.0	
Header tank capacity	[dm³]	450	
Temperature at engine outlet	[°C]	80 - 90	
Two circuit system			
Engine driven HT pump	[m³/h/bar]	70.0/4.5	
Independent HT pump	[m³/h/bar]	70.0/4.0	
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			
Lube oil cooler	[kW]	635	
Jacket water	[kW]	1,250	1,405
Charge air cooler (HT-stage) 3)	[kW]	530	550
Charge air cooler (LT-stage) 3)	[kW]	530	
Heat radiation	[kW]	125	
Exhaust gas			
Silencer / spark arrestor NB	[mm]	700	
Pipe diameter NB after turbine	[mm]	700	
Maximum exhaust gas pressure drop	[mbar]	35	
Starting air			
Starting air pressure max.	[bar]	30	
Minimum starting air pressure	[bar]	10	
Air consumption per start 4)	[m³]	1.2	
Max. allowed crankcase pressure, ND ventilation pipe	[mbar/mm]	1.5/80.0	

1) Reference conditions: LCV = 42,700 kJ/kg, ambient temperature 25 °C, charge air coolant temperature 25 °C, tolerance 5 %, for engine driven lube oil pump + 1.0% at 100%, 1.2% at 85%, 1.3% at 75%, 2.0% at 50%, 4.0% at 25%; for engine driven cooling water pump + 0.4% at 100%, 0.47% at 85%, 0.53% at 75%, 0.8% at 50%, 1.6% at 25%, additions to fuel consumption must be considered before tolerance is taken into account. / **2)** Standard value, tolerance ± 0.3 g/kWh, 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.

3.3 Diesel, mechanical – 9 M 32 E

This table does only contain IMO II data.

9 M 32 E			Standard	PLK variable speed
Performance data				
Maximum continuous rating acc. ISO 3046/1		[kW]	4,950	
Speed		[1/min]	750/720	
Minimum speed		[1/min]	360	
Brake mean effective pressure		[bar]	23.8/24.8	
Combustion air demand (ta=25 °C)		[m³/h]	28,470	34,940
Brake specific fuel oil consumption				
Rated operation curve [1) 6)]	100 %	[g/kWh]	179	183
	85 %	[g/kWh]	178	181
	75 %	[g/kWh]	179	181
	50 %	[g/kWh]	185	181
	25 %	[g/kWh]	210	200
Specific lube oil consumption [2)]		[g/kWh]	0.6	
NO_x-emission [5)]		[g/kWh]	9.6/9.69	
Turbocharger type			Napier NT1-12	
Fuel				
Engine driven booster pump		[m³/h/bar]	3.2/5.0	
Stand-by booster pump		[m³/h/bar]	3.5/5.0	
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]	118/10	
Independent pump		[m³/h/bar]	80/10	
Working pressure on engine inlet		[bar]	4 - 5	
Engine driven suction pump		[m³/h/bar]	168/3	
Independent suction pump		[m³/h/bar]	65/3	
Priming pump		[m³/h/bar]	11/5	
Sump tank content		[m³]	6.8	
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 32 E		Standard	PLK variable speed
Fresh water cooling			
Engine content	[dm³]	450	
Pressure at engine inlet min/max	[bar]	2.5 - 6.0	
Header tank capacity	[dm³]	550	
Temperature at engine outlet	[°C]	80 - 90	
Two circuit system			
Engine driven HT pump	[m³/h/bar]	80.0/4.5	
Independent HT pump	[m³/h/bar]	80.0/4.0	
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			
Lube oil cooler	[kW]	715	
Jacket water	[kW]	1,405	1,580
Charge air cooler (HT-stage) 3)	[kW]	595	620
Charge air cooler (LT-stage) 3)	[kW]	595	
Heat radiation	[kW]	140	
Exhaust gas			
Silencer / spark arrestor NB	[mm]	700	
Pipe diameter NB after turbine	[mm]	700	
Maximum exhaust gas pressure drop	[mbar]	35	
Starting air			
Starting air pressure max.	[bar]	30	
Minimum starting air pressure	[bar]	10	
Air consumption per start 4)	[m³]	1.2	
Max. allowed crankcase pressure, ND ventilation pipe	[mbar/mm]	1.5/80.0	

1) Reference conditions: LCV = 42,700 kJ/kg, ambient temperature 25 °C, charge air coolant temperature 25 °C, tolerance 5 %, for engine driven lube oil pump + 1.0% at 100%, 1.2% at 85%, 1.3% at 75%, 2.0% at 50%, 4.0% at 25%; for engine driven cooling water pump + 0.4% at 100%, 0.47% at 85%, 0.53% at 75%, 0.8% at 50%, 1.6% at 25%, additions to fuel consumption must be considered before tolerance is taken into account. / **2)** Standard value, tolerance ± 0.3 g/kWh, 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 Controllable pitch propeller (CPP) operation – standard engine

A load above the output limit curve is to be avoided by the use of the load control device or overload protection device.
Binding data (depending on the type of vessel, rated output, speed and the turbocharging system) will be established upon order processing.

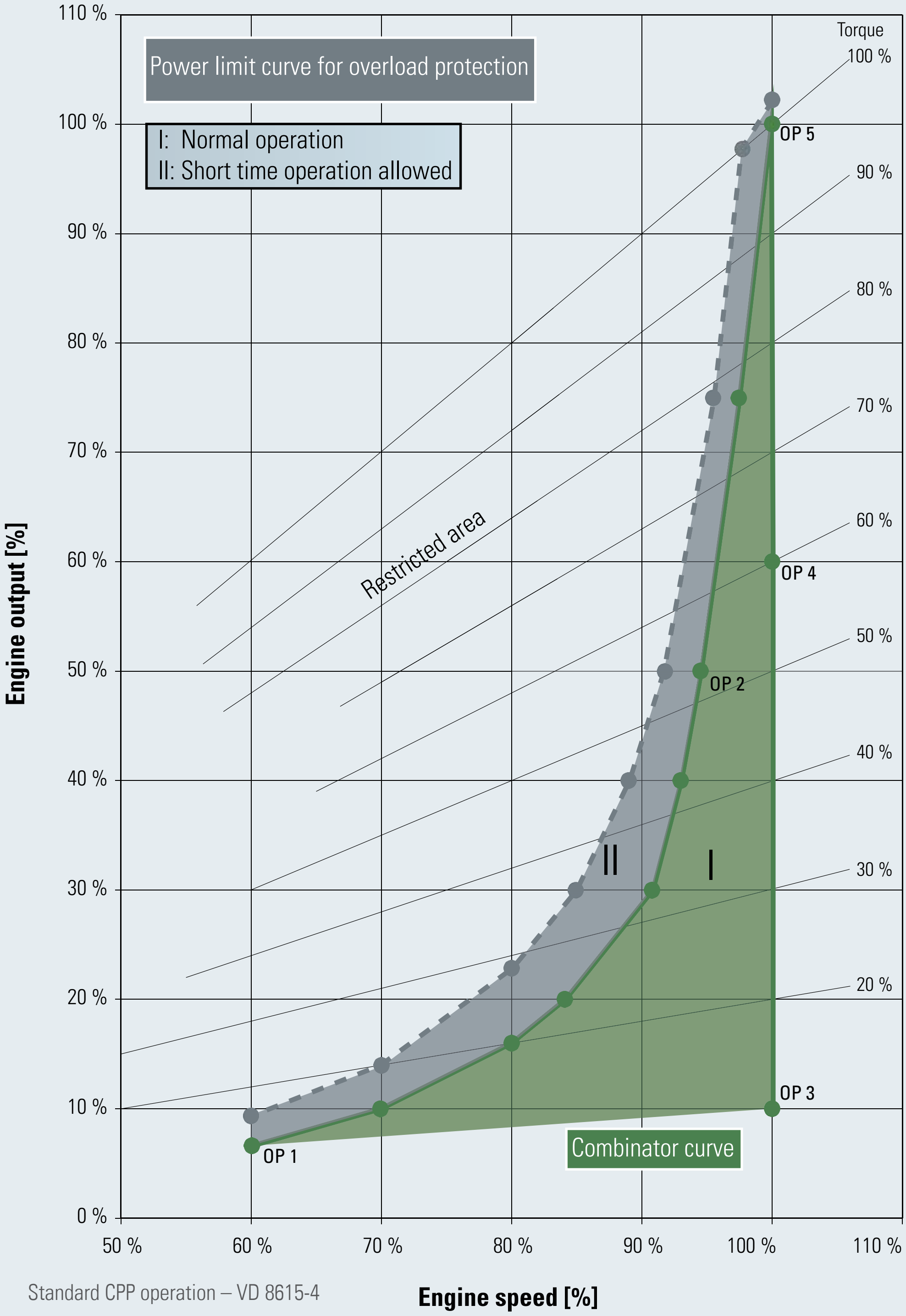


Fig. 4-1 Standard CPP operation – VD 8615-4

Acceleration ramps

			Standard
Minimum time for emergency operation	Combinator	Acceleration from OP 1 to OP 5	40 s
	n = constant	Acceleration from OP 3 to OP 5	30 s
		Smoke	visible
		Reduction from OP 5 to OP 3	8 s

Normal operation	Combinator	Acceleration from OP 1 to OP 2	40 s
	Combinator	Acceleration from OP 2 to OP 5	60 s
	n = constant	Acceleration from OP 3 to OP 4	35 s
	n = constant	Acceleration from OP 4 to OP 5	60 s
		Smoke	visible
		Reduction from OP 5 to OP 3	20 s

OP: Operating point as given in power limit curves VD 8615-4

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 procide 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 32 E – 550 kW/Cyl.

4.2 CPP operation – Part Load Kit (PLK) variable speed optimized engine (with/without air injection)

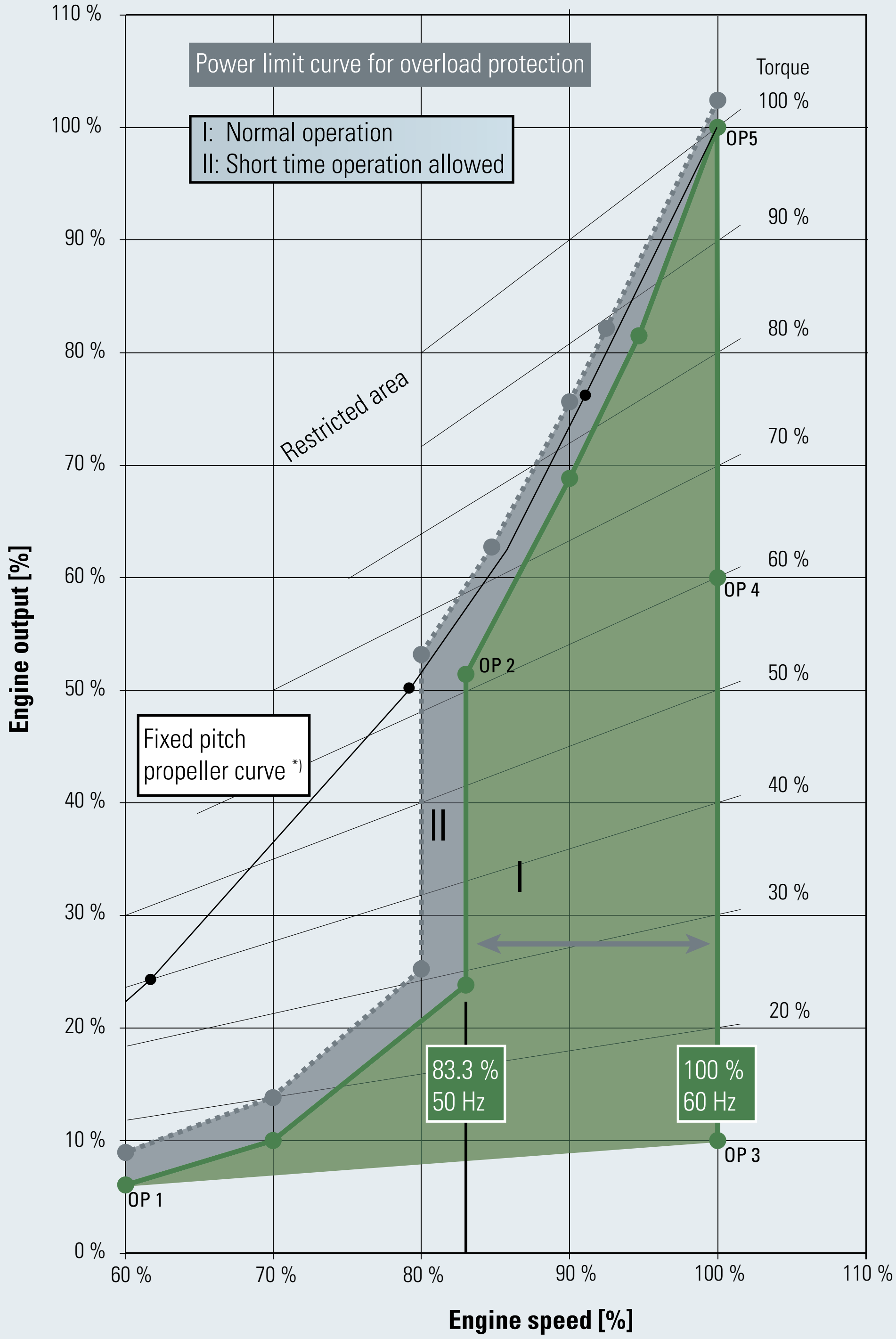


Fig. 4-2 Optimized CPP operation MDO/HFO – VD 8883-4

Special equipment:

1.) Part Load Kit with variable speed
2.) Sliding frequency 50 to 60 Hz
3.) Cylinder Bypass Valve (CBV)

*) Fixed pitch propeller (FPP) operation is not permitted with M 32 E engine with 550 kW/cylinder. Please contact your local dealer for FPP operation with load reduction.

Acceleration ramps

			PLK variable speed without air injection	PLK variable speed with air injection
Minimum time for emergency operation	Combinator	Acceleration from OP 1 to OP 5	39 s	29 s
	n = constant	Acceleration from OP 3 to OP 5	24 s	17 s
		Smoke	visbile	visible
		Reduction from OP 5 to OP 3	8 s	8 s

Normal operation	Combinator	Acceleration from OP 1 to OP 2	44 s	38 s
	Combinator	Acceleration from OP 2 to OP 5	60 s	60 s
	n = constant	Acceleration from OP 3 to OP 4	30 s	25 s
	n = constant	Acceleration from OP 4 to OP 5	60 s	60 s
		Smoke	visible	visible
		Reduction from OP 5 to OP 3	20 s	20 s

OP: Operating point as given in power limit curves VD 8883-4

PLK: Part Load Kit equipped engine (for VD 8883-4 PLK for variable speed including CBV 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 procide 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 32 E – 550 kW/Cyl.

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.

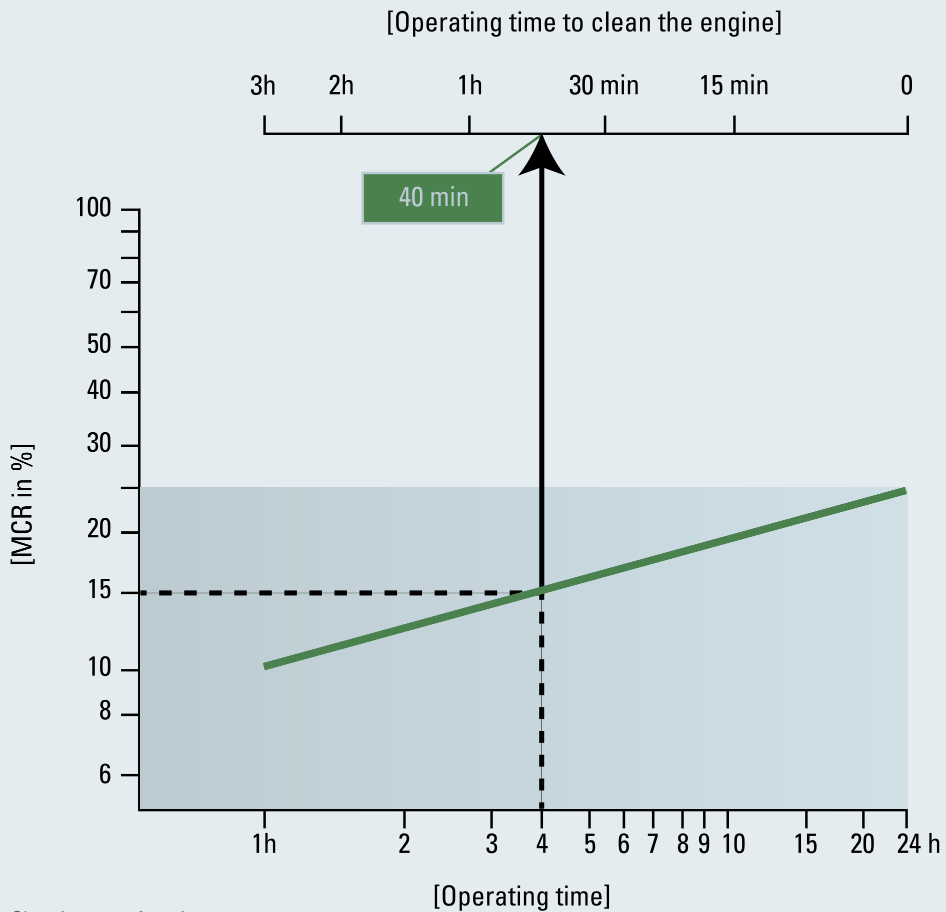


Fig. 4-3 Cleaning run of engine

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22

4.4 Emergency operation without turbocharger

Emergency operation is permissible with MDO only up to approx. 15% 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 °

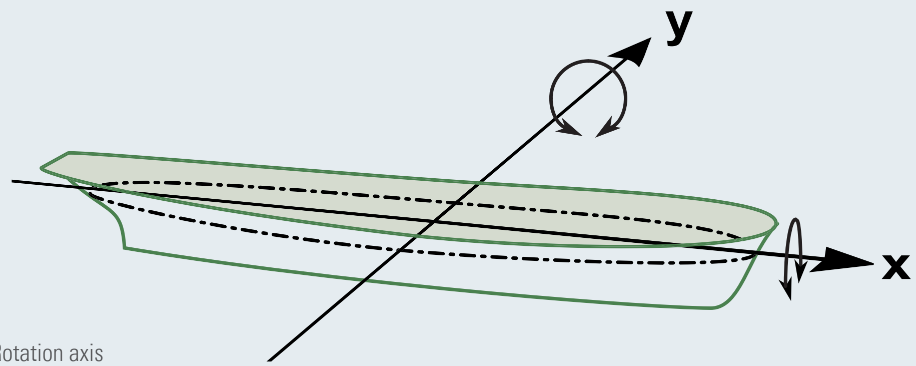


Fig. 4-4 Rotation axis

4.6 Part Load optimization Kit for variable speed application

4.6.1 Benefits

Fuel savings up to 24 g/kWh, and reduced smoke emissions are the benefits of the variable speed Part Load optimization Kit. It is attractive for all customers operating their engines mainly between 15% and 70% load. With the installation of the PLK for variable speed it is possible to operate the engine with higher power output at reduced engine speed compared to the standard M 32 E.

4.6.2 Scope of supply and function

PLK for variable speed includes our proven Flexible Camshaft Technology and a Cylinder Bypass Valve as well as an intelligent steering software logic integrated into the Engine Control System. Cylinder Bypass Valve prevents the turbocharger from running into surge 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.

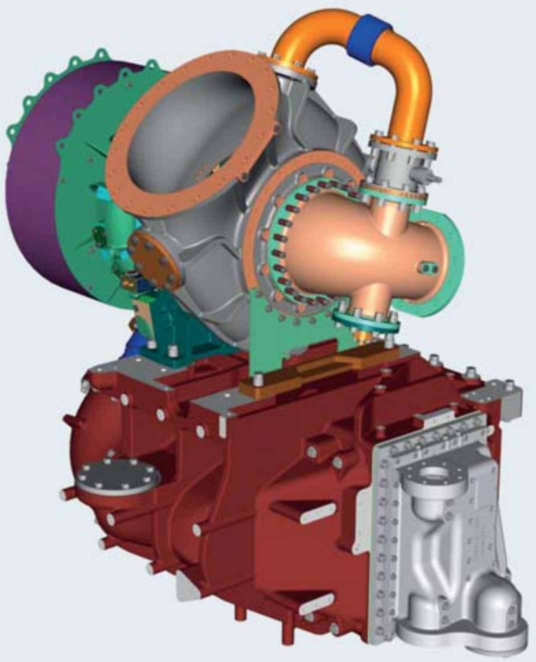


Fig. 4-5 Waste Gate

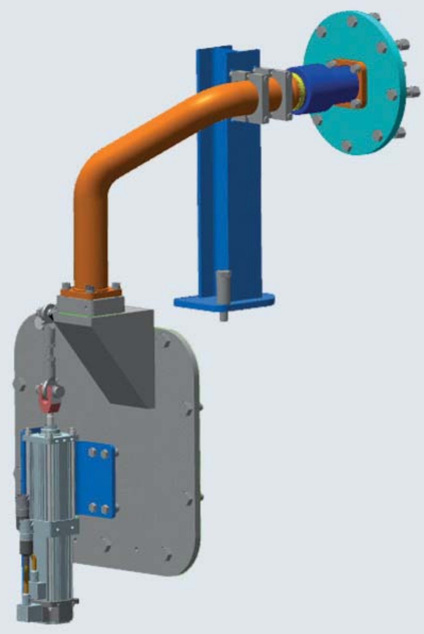


Fig. 4-6 Cylinder Bypass Valve

4.6.3 Customized solutions outside standard operation

This project guide contains some of our optimized solutions regarding fuel efficiency, smoke reduction and load acceptance. Please contact Caterpillar Motoren for further customized solutions.

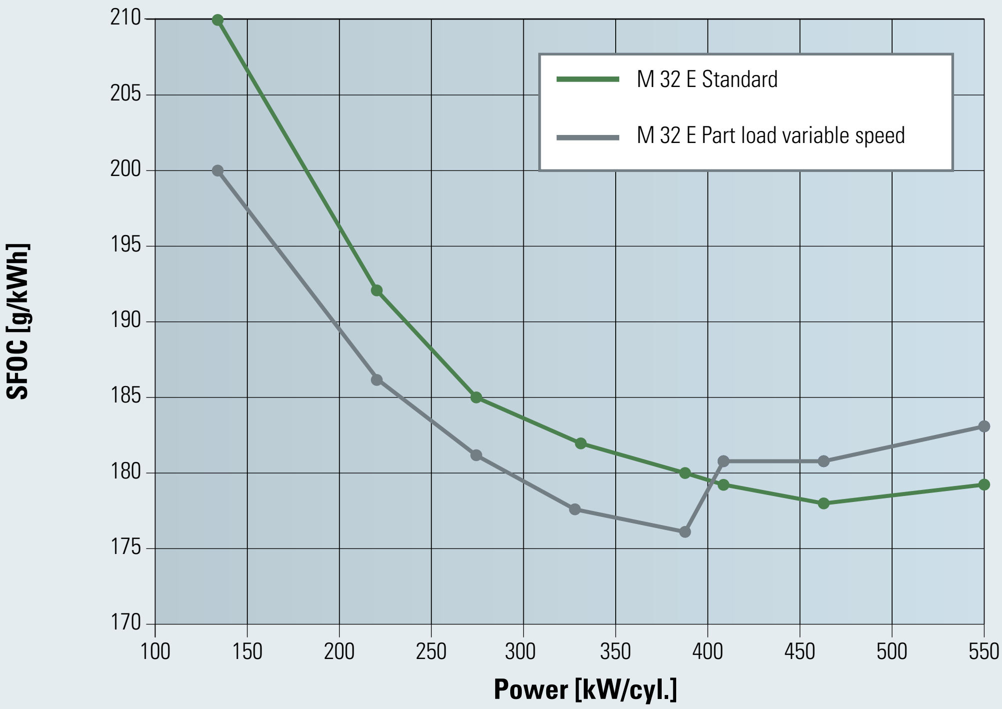


Fig. 4-7 MaK M 32 E fuel consupmtion (standard vs. PLK variable speed)

4.7 Air injection

4.7.1 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.

4.7.2 Brief description

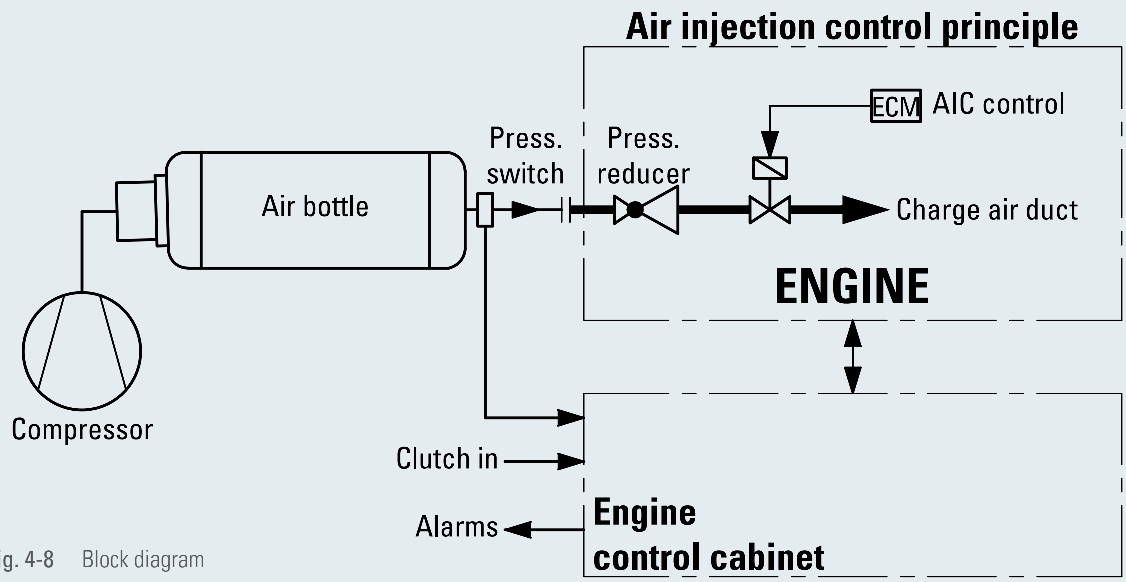


Fig. 4-8 Block diagram

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).

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22

4.7.3 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 32 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 32 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.

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 and HFO 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	DMC
Viscosity at 40 °C	[mm²/s]	max	5.5	6.0	6.0	11.0	14.0
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	920
Micro Carbon residue	[% m/m]	max	–	–	–	0.3	–
Sulfur [a]	[% m/m]	max	1.0	1.5	1.5	2.0	2.0
Water	[% V/V]	max	–	–	–	0.3 [b]	0.3
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	60
Pour point, summer	[°C]	max	–	0	0	6	6
Pour point, winter	[°C]	max	–	-6	-6	0	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.

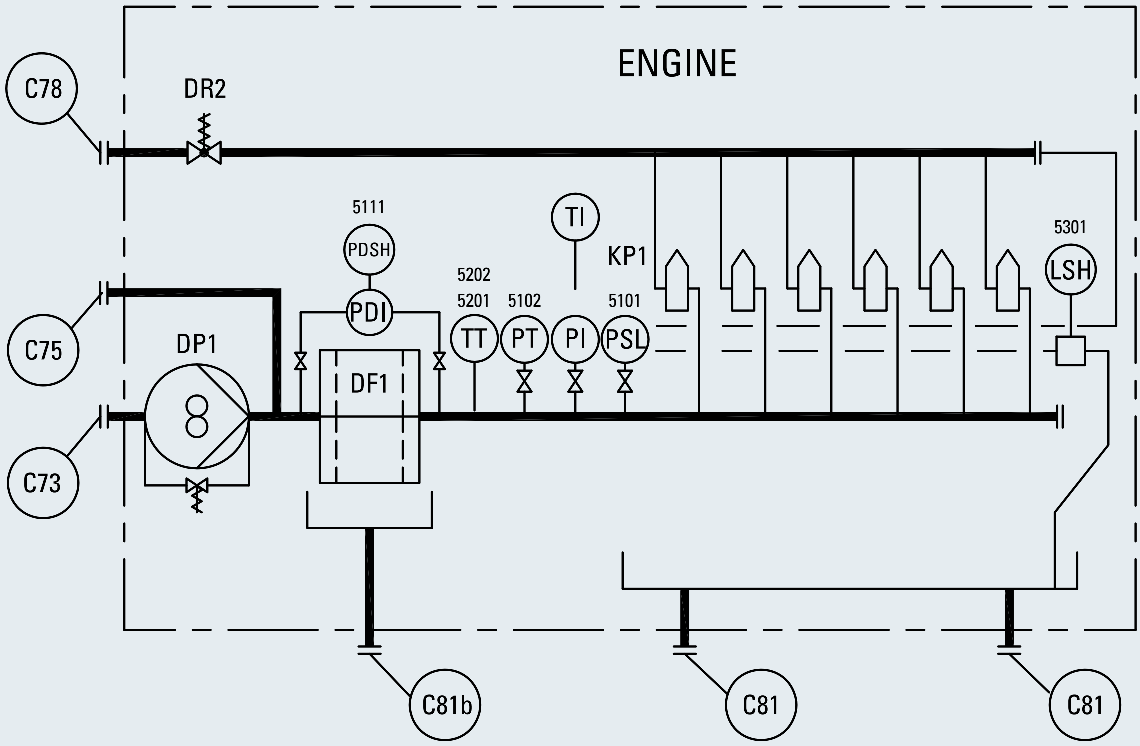


Fig. 5-1 Internal fuel oil system, system diagram

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		
LSH	Level switch high	C73	Fuel inlet, to engine fitted pump
PDI	Diff. pressure indicator	C75	Connection, stand-by pump
PDSH	Diff. pressure switch high	C78	Fuel outlet
PI	Pressure indicator	C81	Drip-fuel connection
PSL	Pressure switch low	C81b	Drip-fuel connection (filter pan)

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

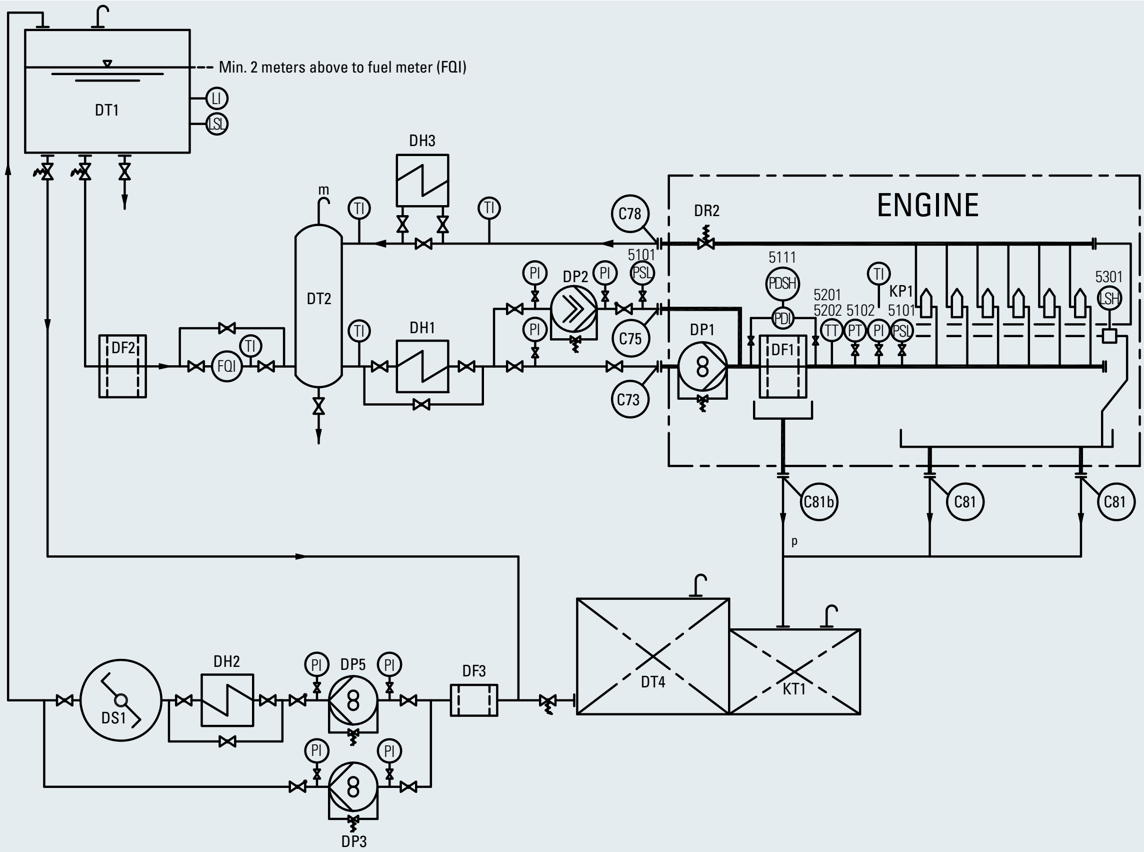


Fig. 5-2 External fuel oil system diagram with intermediate tank

DF1	Fuel fine filter (duplex filter)
DF2	Fuel primary filter (duplex filter)
DF3	Fuel coarse filter
DH1	Diesel oil preheater
DH2	Electrical preheater for diesel oil (separator)
DH3	Fuel oil cooler
DP1	Diesel oil feed pump
DP2	Stand-by booster pump
DP3	Diesel oil transfer pump (to day tank)
DP5	Diesel oil transfer pump (separator)
DR2	Fuel pressure regulating valve
DS1	Diesel oil separator
DT1	Diesel oil day tank
DT2	Diesel oil intermediate tank
DT4	Diesel oil storage tank
FQI	Flow quantity indicator
KP1	Fuel injection pump
KT1	Drip fuel tank

LI	Level indicator
LSH	Level switch high
LSL	Level switch low
PDI	Diff. pressure indicator
PDSH	Diff. pressure switch high
PI	Pressure indicator
PSL	Pressure switch low
PT	Pressure transmitter
TI	Temperature indicator
TT	Temperature transmitter (PT100)
C73	Fuel inlet, to engine fitted pump
C75	Connection, stand-by pump
C78	Fuel outlet
C81	Drip-fuel connection
C81b	Drip-fuel connection (filter pan)
m	Lead vent pipe beyond service tank
p	Free outlet required

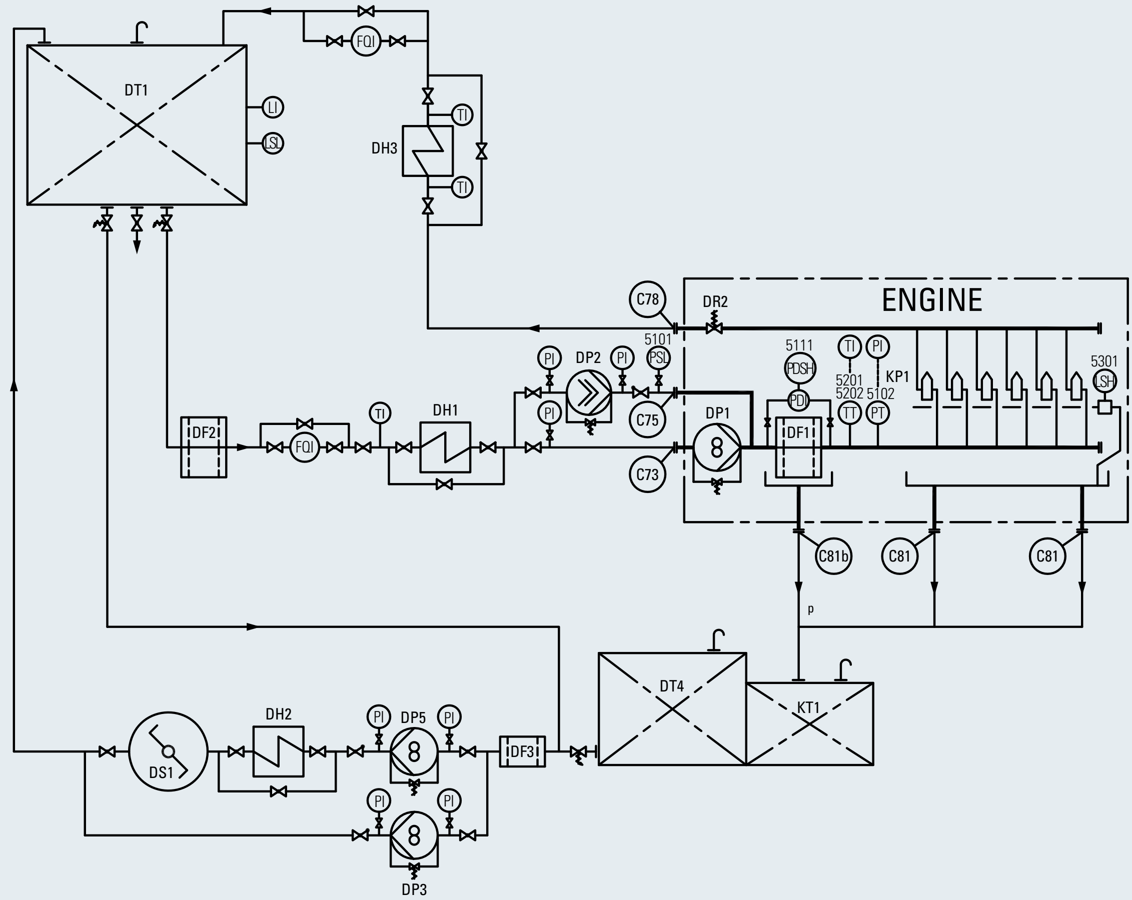


Fig. 5-3 External fuel oil system diagram without intermediate tank

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 for	PSL	Pressure switch low
DP1	Diesel oil feed pump	PT	Pressure transmitter
DP2	Stand-by booster 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 and 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 22 h/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.

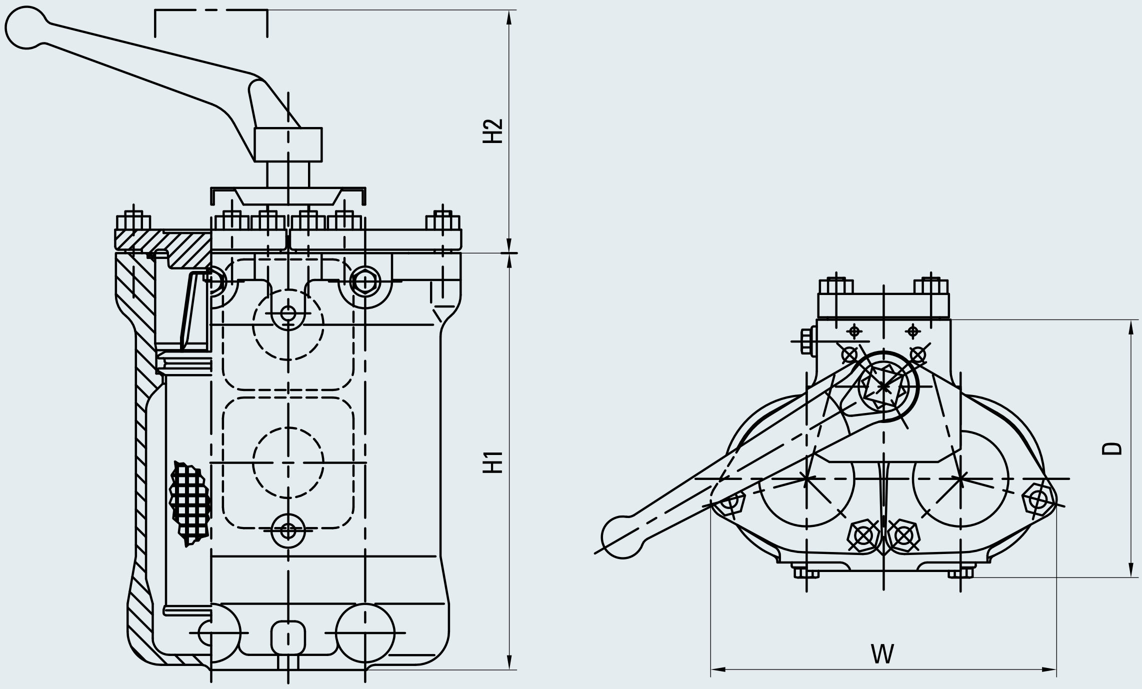


Fig. 5-4 Fuel primary filter DF2

Engine output [kW]	DN	Dimensions [mm]			
		H1	H2	W	D
≤ 5,000	32	249	220	206	180
≤ 10,000	40	330	300	250	210
≤ 20,000	65	523	480	260	355
> 20,000	80	690	700	370	430

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.

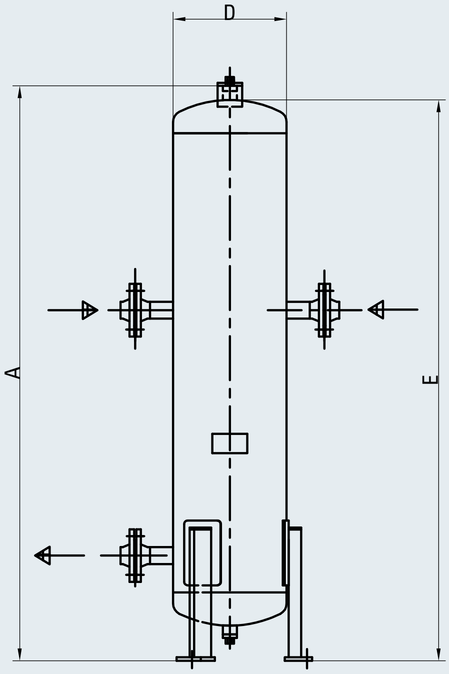


Fig. 5-5 Diesel oil intermediate tank DT2

Plant output	Volume	Dimensions [mm]			Weight
[kW]	[l]	A	D	E	[kg]
≤ 4,000	50	950	323	750	70
≤ 10,000	100	1,700	323	1,500	120
> 10,000	200	1,700	406	1,500	175

Diesel oil preheater DH1 (hot water)

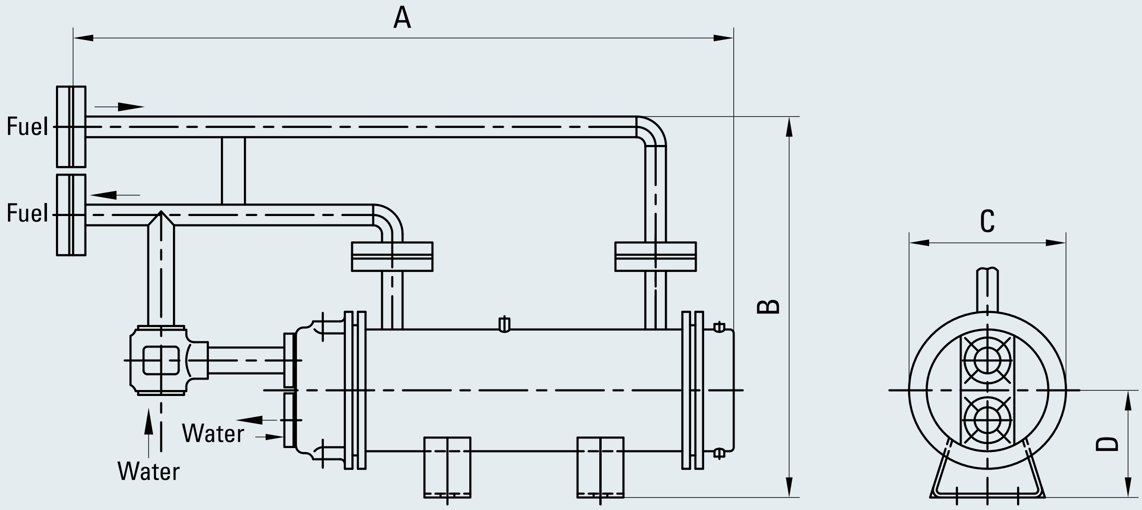


Fig. 5-6 Diesel oil preheater DH1

	Dimensions [mm]				Weight
	A	B	C	D	[kg]
6/8 M 32 E	863	498	Ø 205	140	42
9 M 32 E	1468	484	Ø 205	140	ca. 75

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.

Stand-by booster pump DP2 (separate)

The stand-by booster 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.

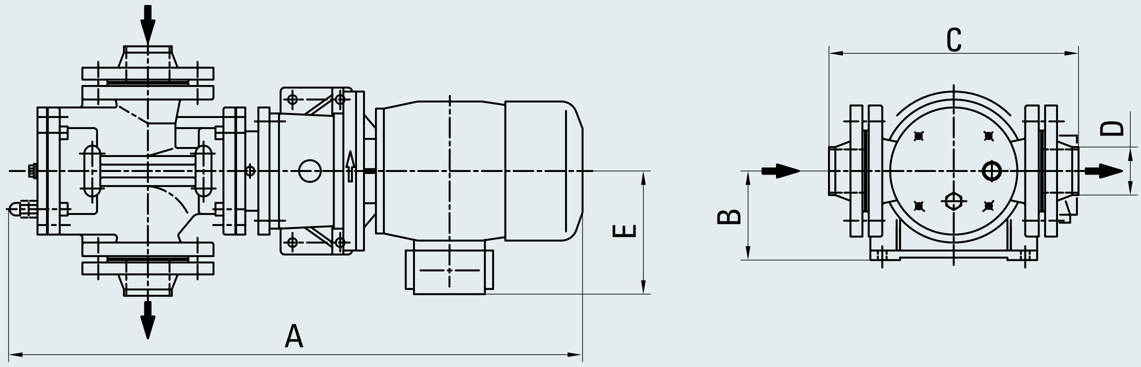


Fig. 5-7 Stand-by booster pump DP2

	Dimensions [mm]					Weight	Motorpower	Voltage / Frequency
	A	B	C	D	E	[kg]	[kW]	[V/Hz]
6/8/9 M 32 E	735	112	314	60.3	155	61	1.5	400/50
6/8 M 32 E	735	112	314	60.3	155	61	1.8	440/60
9 M 32 E	775	132	314	60.3	155	70	2.6	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. 1.6 kW/cyl.
LT-water is normally used as cooling medium.

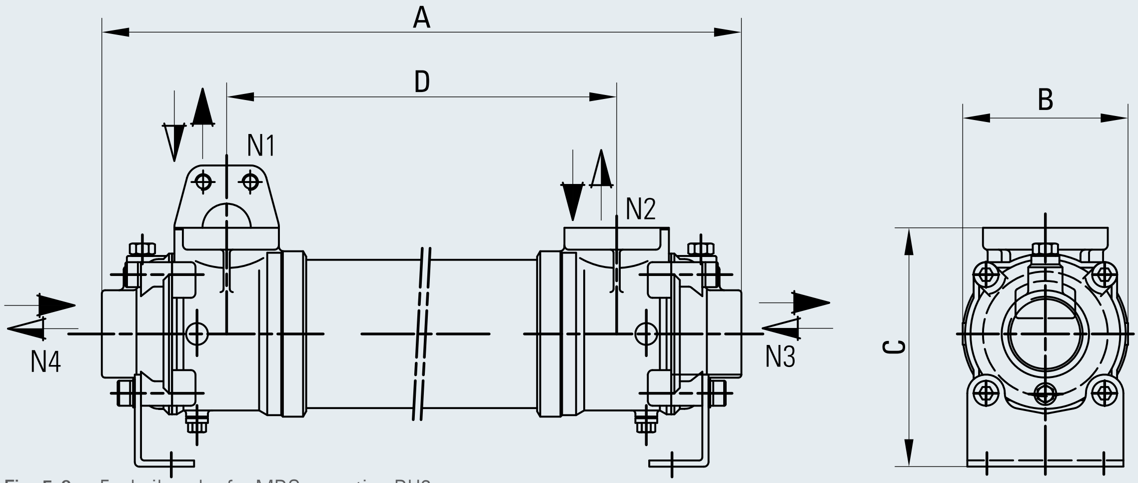


Fig. 5-8 Fuel oil cooler for MDO operation DH3

	Dimensions [mm]						Weight
	A	B	C	D	N1 + N2	N3 + N4	[kg]
6/8/9 M 32 E	910	106	153	750	1 ¼" SAE	1 ½" SAE	19

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

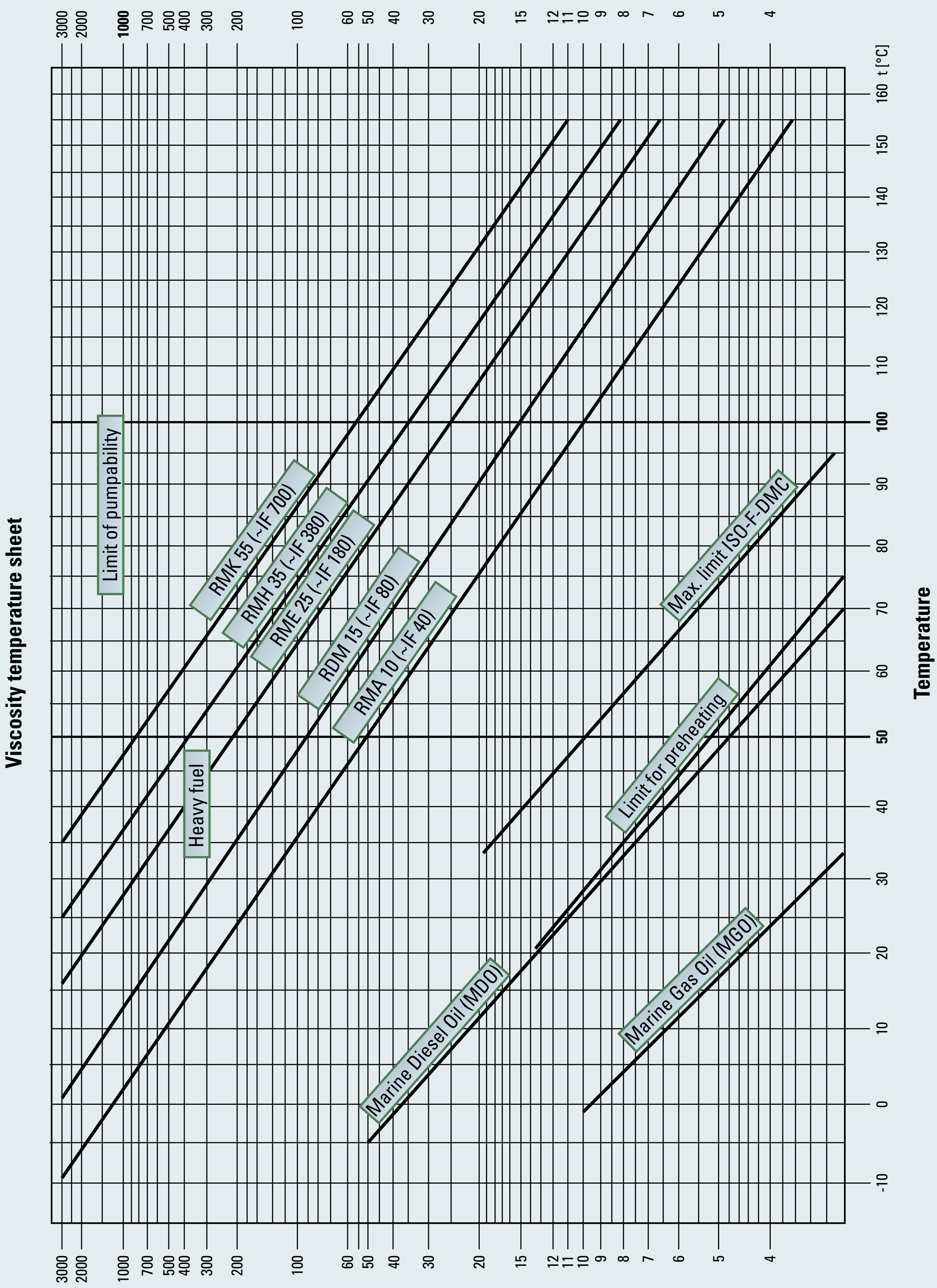


Fig. 5-9 Viscosity / temperature diagram

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 (05) 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

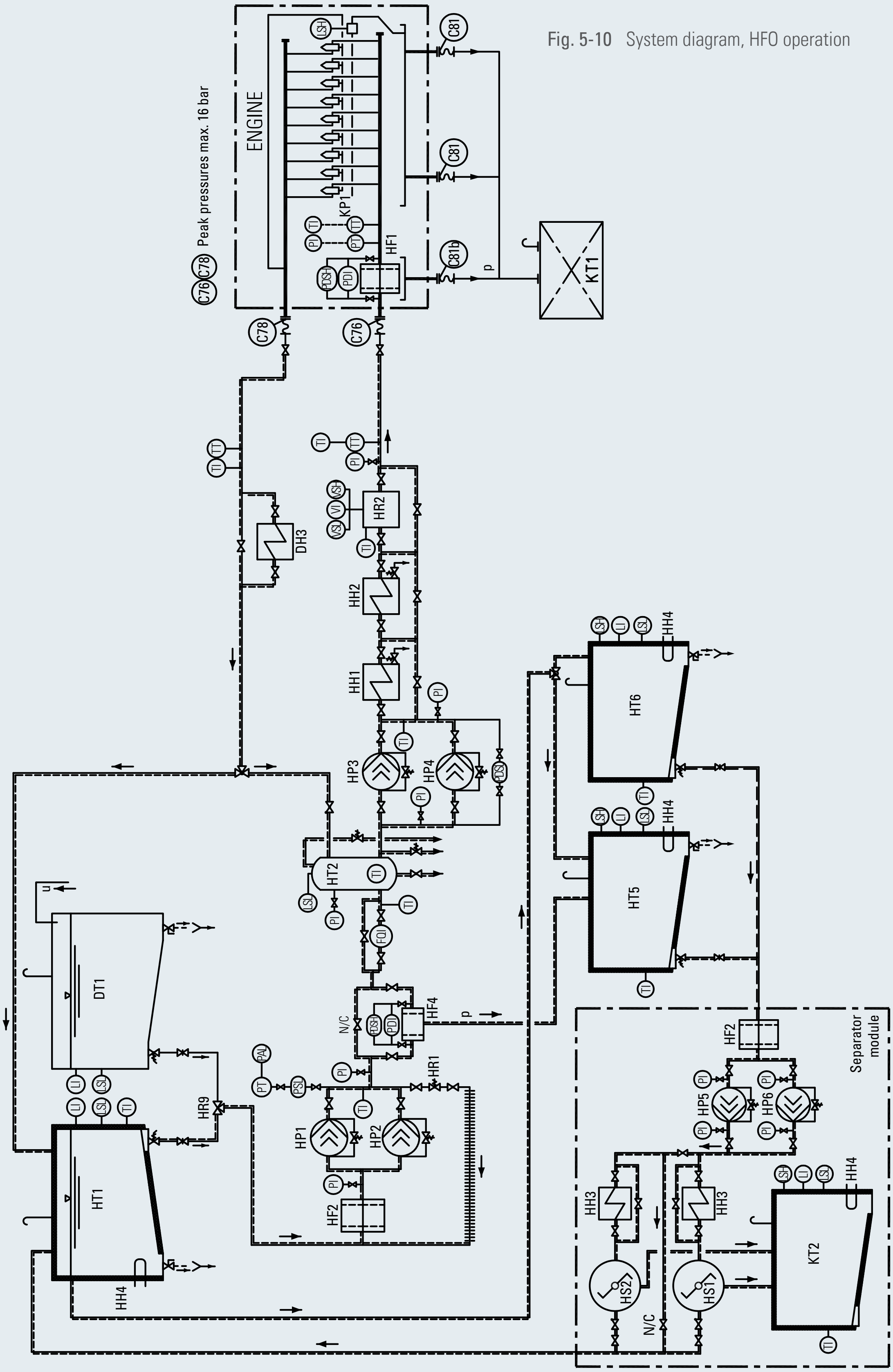


Fig. 5-10 System diagram, HFO operation

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22

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 10 K 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/cm².
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.

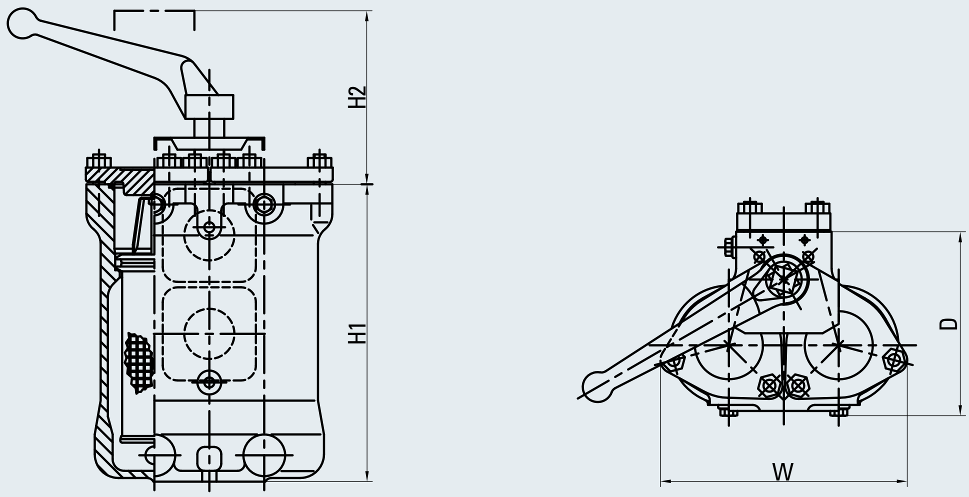


Fig. 5-11 Primary filter HF2

Engine output [kW]	DN	Dimensions [mm]			
		H1	H2	W	D
≤ 10,000	40	330	300	250	210
≤ 20,000	65	523	480	260	355
> 20,000	80	690	700	370	430

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]

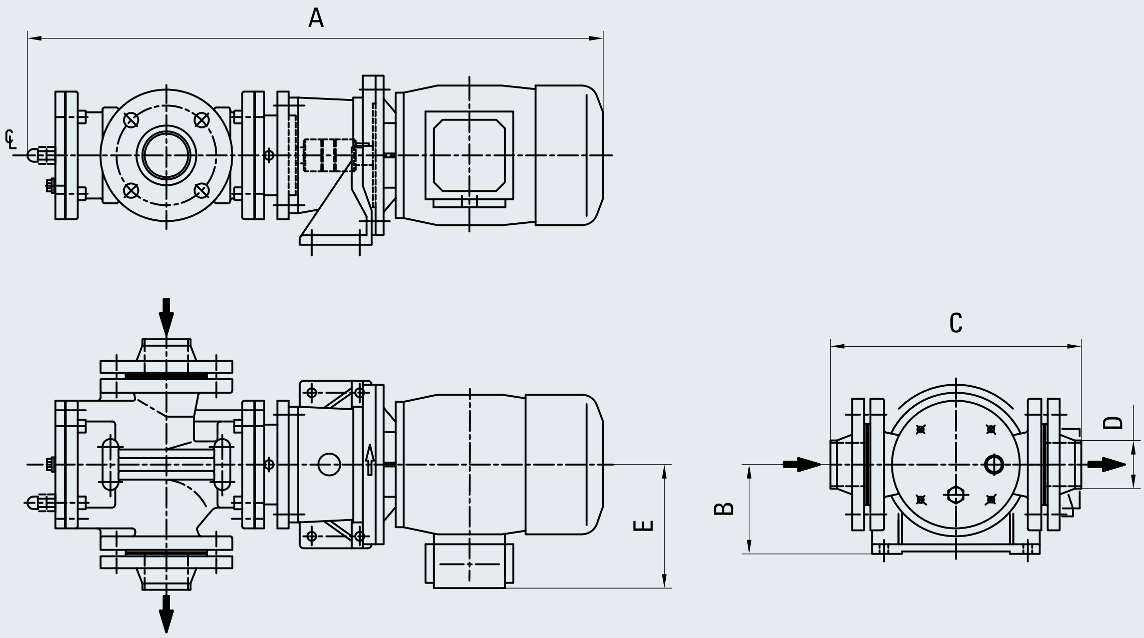


Fig. 5-12 Fuel pressure pump HP1; fuel stand-by pressure pump HP2

Plant output	Dimensions [mm]					Weight	Voltage / frequency
[kW]	A	B	C	D	E	[kg]	[V/Hz]
3,300	650	112	254	42.4	155	42	400/50
4,950 - 6,600	775	132	314	60.3	180	70	400/50
8,800 - 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
4,400 - 4,950	705	112	254	42.4	180	57	440/60
6,600 - 9,900	775	132	314	60.3	180	70	440/60

Fuel pressure valve regulating 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.

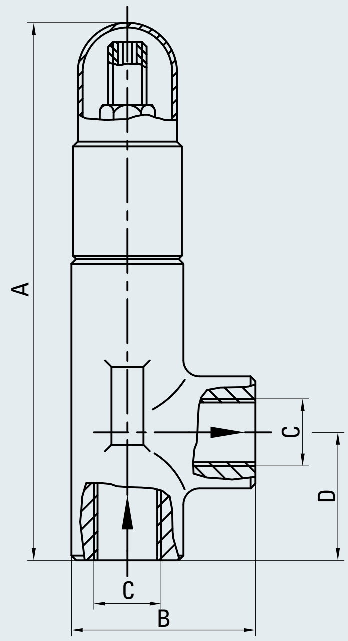


Fig 5-13 Fuel pressure regulating valve HR1, ≤ 3,000 kW

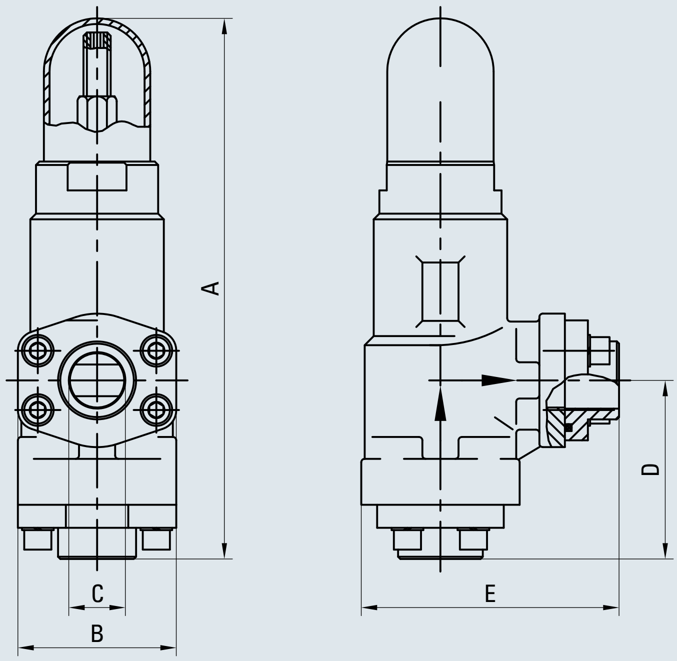


Fig 5-14 Fuel pressure regulating valve HR1, > 3,000 kW

Plant output	Dimensions [mm]					Weight
[kW]	A	B	C	D	E	[kg]
≤ 3,000	168	57.5	G ½"	40		1.5
≤ 8,000	248	70	Ø 25	88	122.5	3.6
> 8,000	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.

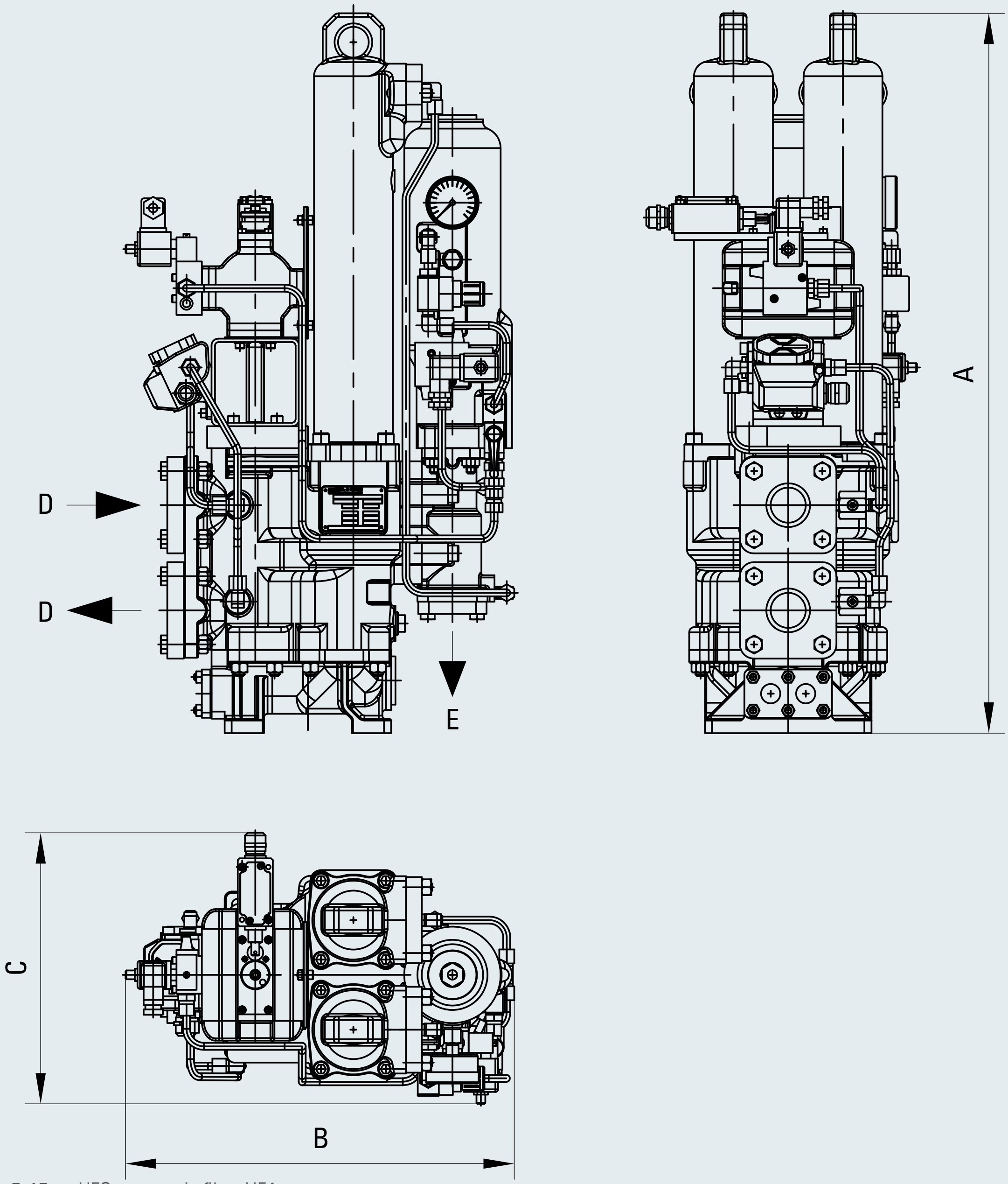


Fig. 5-15 HFO automatic filter HF4

Plant output	Dimensions [mm]				
[kW]	A	B	C	D	E
3,300 - 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.

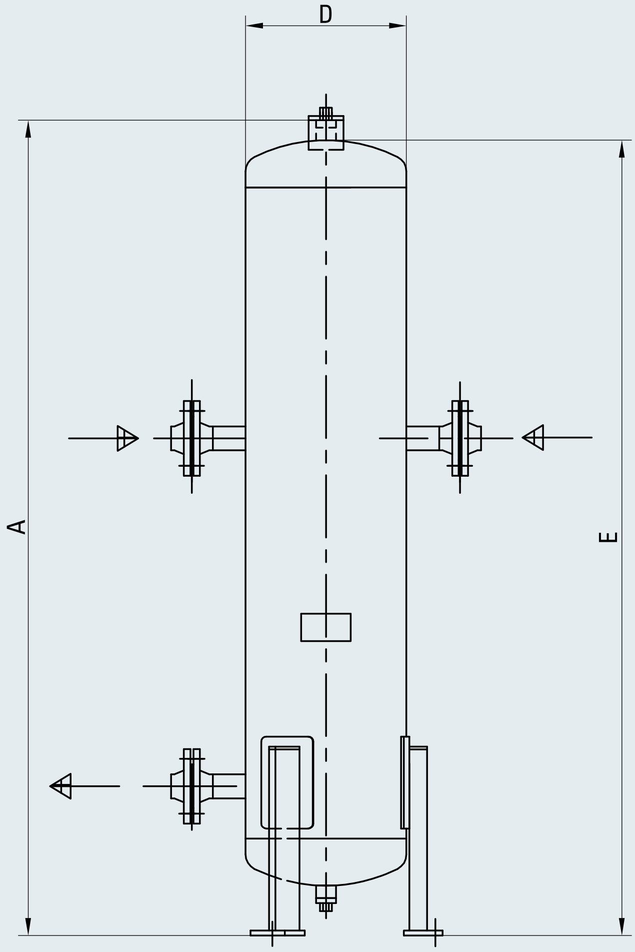


Fig. 5-16 Mixing tank HT2

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

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

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

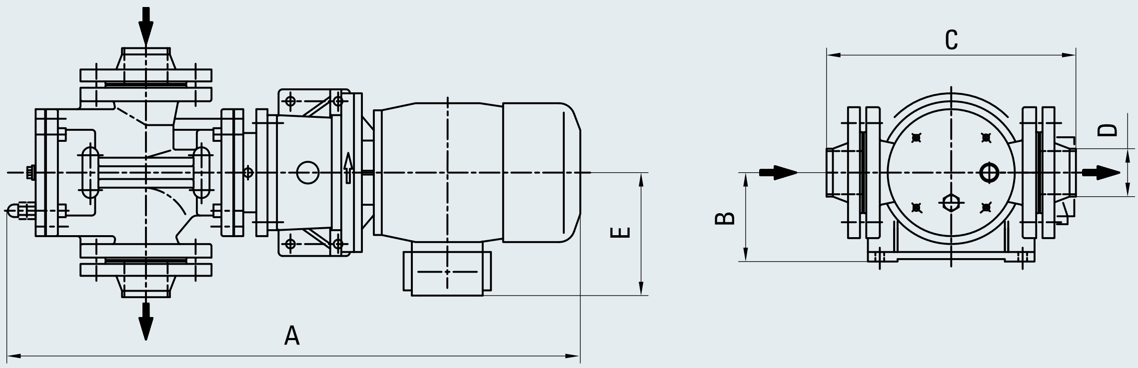


Fig. 5-17 Fuel circulating pump HP3, Stand-by circulating pump HP4

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
4,400 - 4,950	805	132	314	60.3	180	72	400/50
6,600	820	132	314	60.3	180	80	400/50
8,800 - 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]
3,300 - 4,400	775	132	314	60.3	180	70	440/60
4,950 - 6,600	805	132	314	60.3	180	72	440/60
8,800 - 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

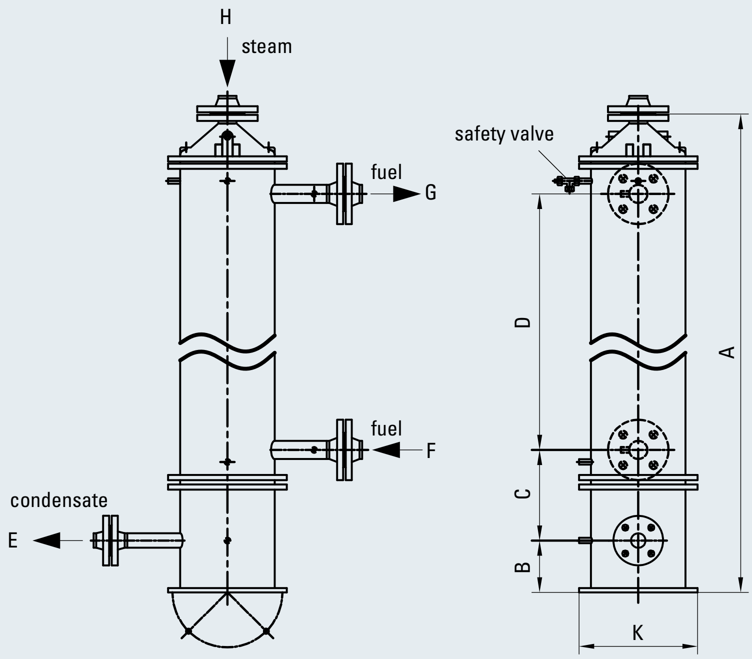


Fig. 5-18 Heavy fuel final preheater HH1, stand-by final preheater HH2 (steam heated)

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 temperature below 50 °C 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 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. 1.6 kW/cyl.
LT-water is normally used as cooling medium.

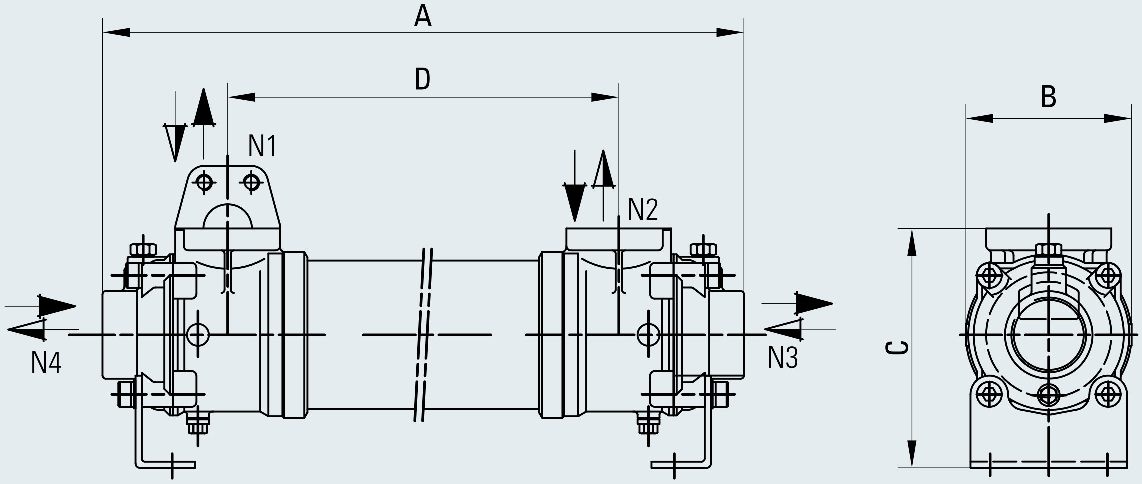


Fig. 5-19 Fuel oil cooler for MDO operation DH3

	Dimensions [mm]						Weight
	A	B	C	D	N1 + N2	N3 + N4	[kg]
6/8/9 M 32 E	910	106	153	750	1 ¼" SAE	1 ½" SAE	19

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 hydrostatical and functional in the workshop without heating and not connected to the engine.

	Module size	Module weight
	[mm]	[kg]
6 M 32 E	2,800 x 1,200 x 2,100	1,800
8 M 32 E	3,000 x 1,200 x 2,100	2,200
9 M 32 E	3,200 x 1,300 x 2,100	2,700

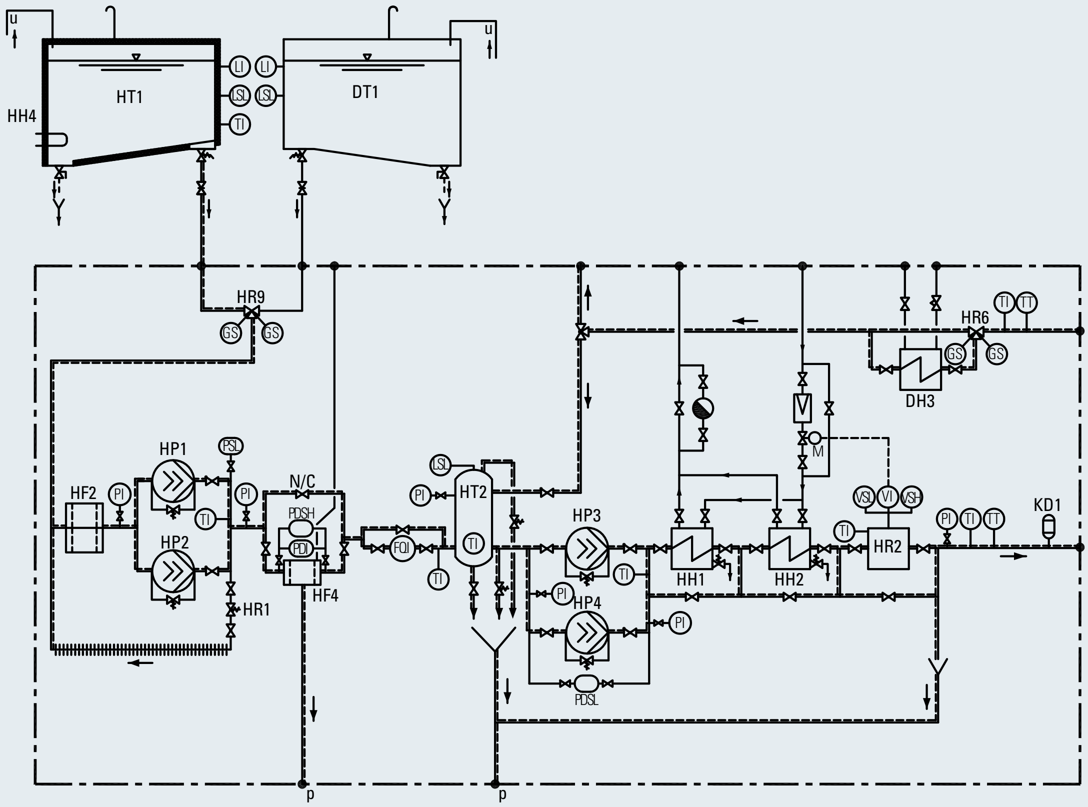


Fig. 5-20 Fuel booster and supply module, system diagram

DH3 Fuel oil cooler for MDO operation
DT1 Diesel oil day tank
HF2 Primary filter (duplex filter)
HF4 HFO automatic filter
HH1 Heavy fuel final preheater
HH2 Stand-by final preheater
HH4 Heating coil
HP1 Fuel pressure pump
HP2 Fuel stand-by pressure pump
HP3 Fuel circulating pump
HP4 Stand-by circulating pump
HR1 Fuel pressure regulating valve
HR2 Viscosimeter
HR6 Change over valve (HFO/diesel oil) 3-way-valve
HR9 Fuel change over main valve
HT1 Heavy fuel day tank
HT2 Mixing tank

KD1 Pressure absorber
FQI Flow quantity indicator
GS Limit switch
LI Level indicator
LSL Level switch low
PDI Diff. pressure indicator
PDSH Diff. pressure switch high
PDSL Diff. pressure switch low
PI Pressure indicator
PSL Pressure switch low
TI Temperature indicator
TT Temperature transmitter (PT100)
VI Viscosity indicator
VSH Viscosity control switch high
VSL Viscosity control switch low

p Free outlet required
u Fuel separator or from transfer pump

All heavy fuel pipes have to be insulated.

------- Heated pipe

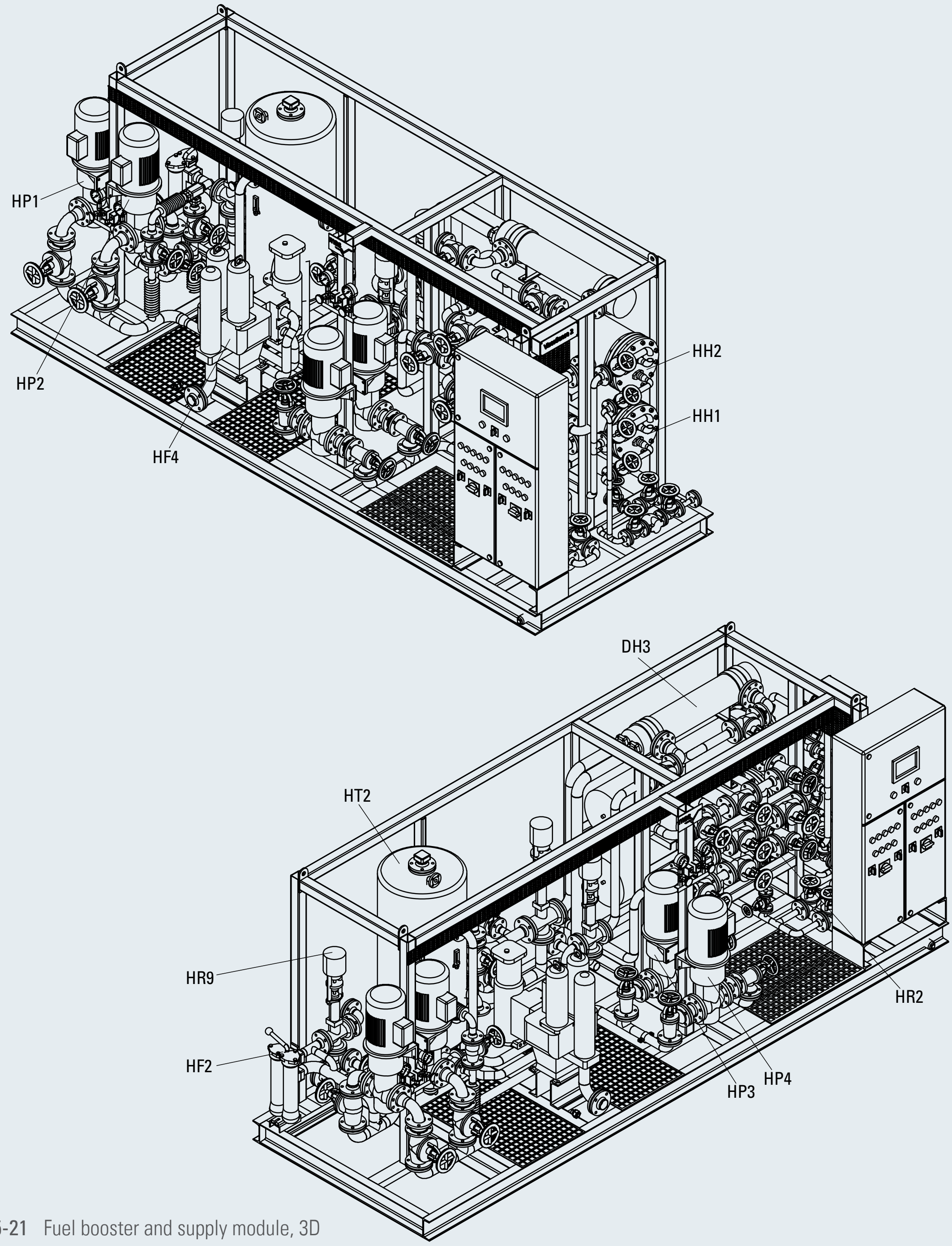


Fig. 5-21 Fuel booster and supply module, 3D

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.

Typical switch over characteristics (HFO to diesel)

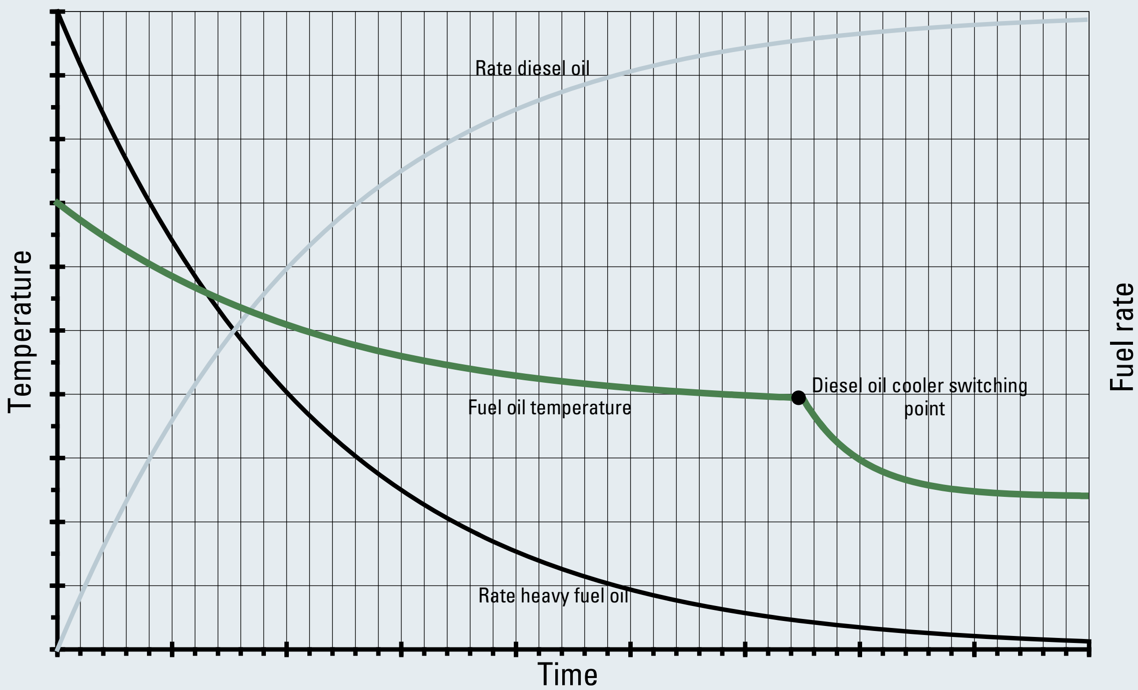


Fig 5-22 Switch over characteristics

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.

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			
CHEVRON, CALTEX, TEXACO	DELO 1000 MARINE	X		TARO 30 DP	X	
	TARO 12 XD	X		TARO 40 XL	X	
	TARGO 16 XD	X		TARO 40 XLX	X	
	TARGO 20 DP	X				
	TARGO 20 DPX	X				
CASTROL	MARINE MLC	X		TLX PLUS 304	X	
	MHP 154	X		TLX PLUS 404	X	
	TLX PLUS 204	X				
CESPA	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 LUBMARINE	RUBIA FP		X	AURELIA TI 4030	X	
	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 4015	X		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.

6.2 Internal lube oil system

General

Pipes are to be connected free of tension to the engine connection points.

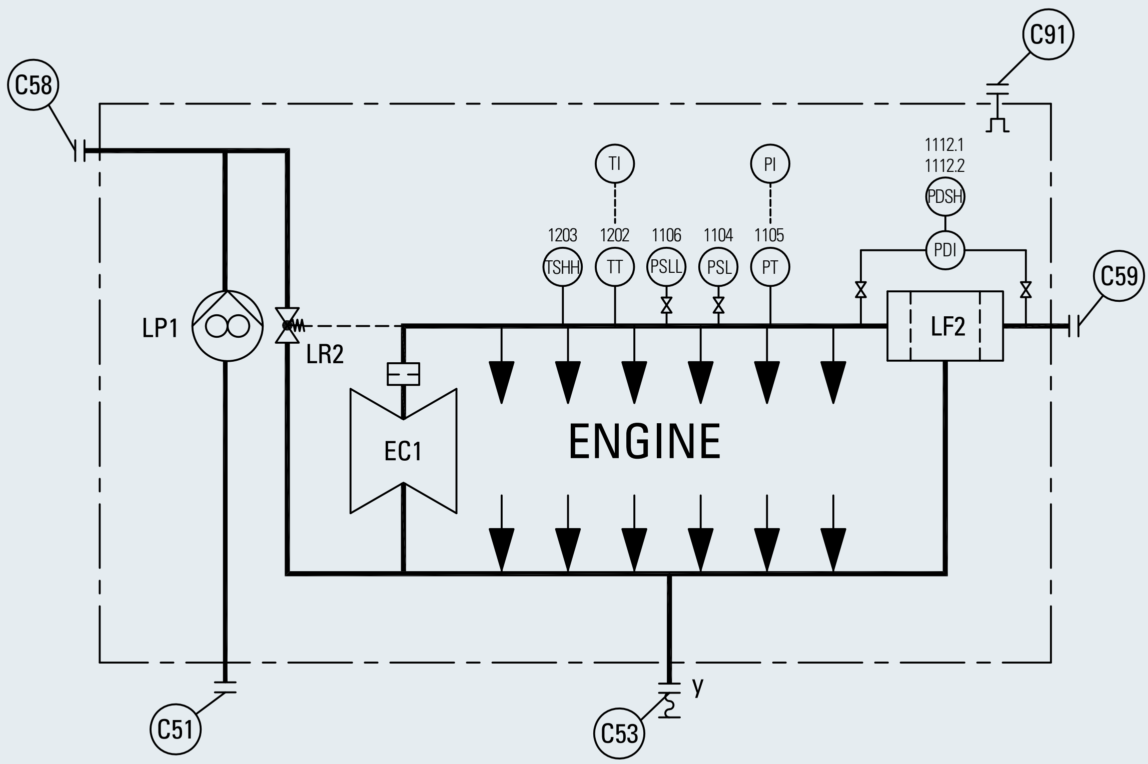


Fig. 6-1 Internal lube oil system, system diagram

EC1	Exhaust gas turbocharger
LF2	Self-cleaning lube oil filter
LP1	Lube oil force pump
LR2	Oil pressure regulating valve
PDI	Diff. pressure indicator
PDSH	Diff. pressure switch high
PI	Pressure indicator
PSL	Pressure switch low
PSLL	Pressure switch low low
PT	Pressure transmitter
TI	Temperature indicator
TSHH	Temperature switch high high
TT	Temperature transmitter (PT100)
C51	Force pump, suction side
C53	Lube oil discharge
C58	Force pump, delivery side
C59	Lube oil inlet, lube oil filter
C91	Crankcase ventilation to stack
y	Provide an expansion joint

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.

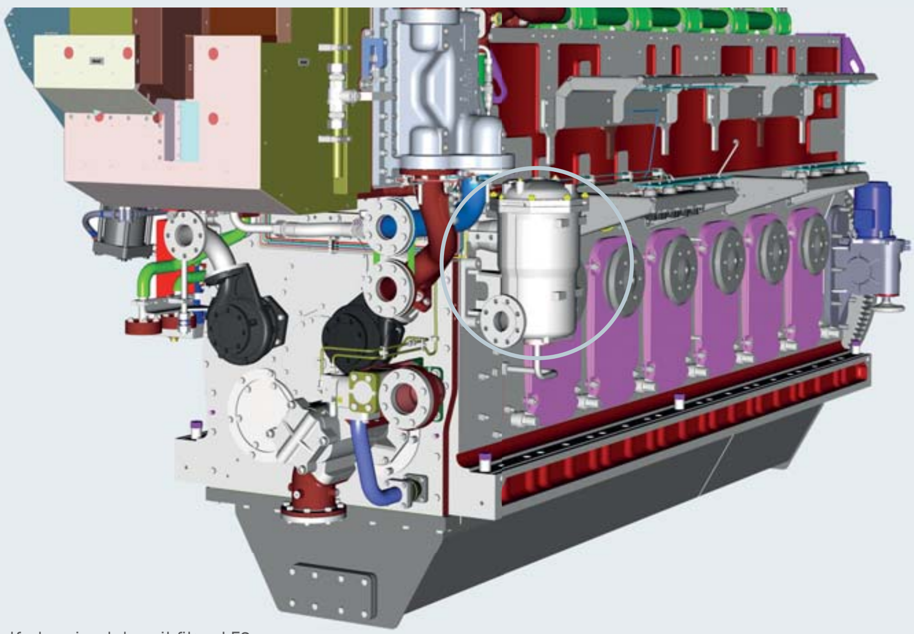


Fig. 6-2 Self-cleaning lube oil filter LF2

Back flushing filter LF2 (separate), option

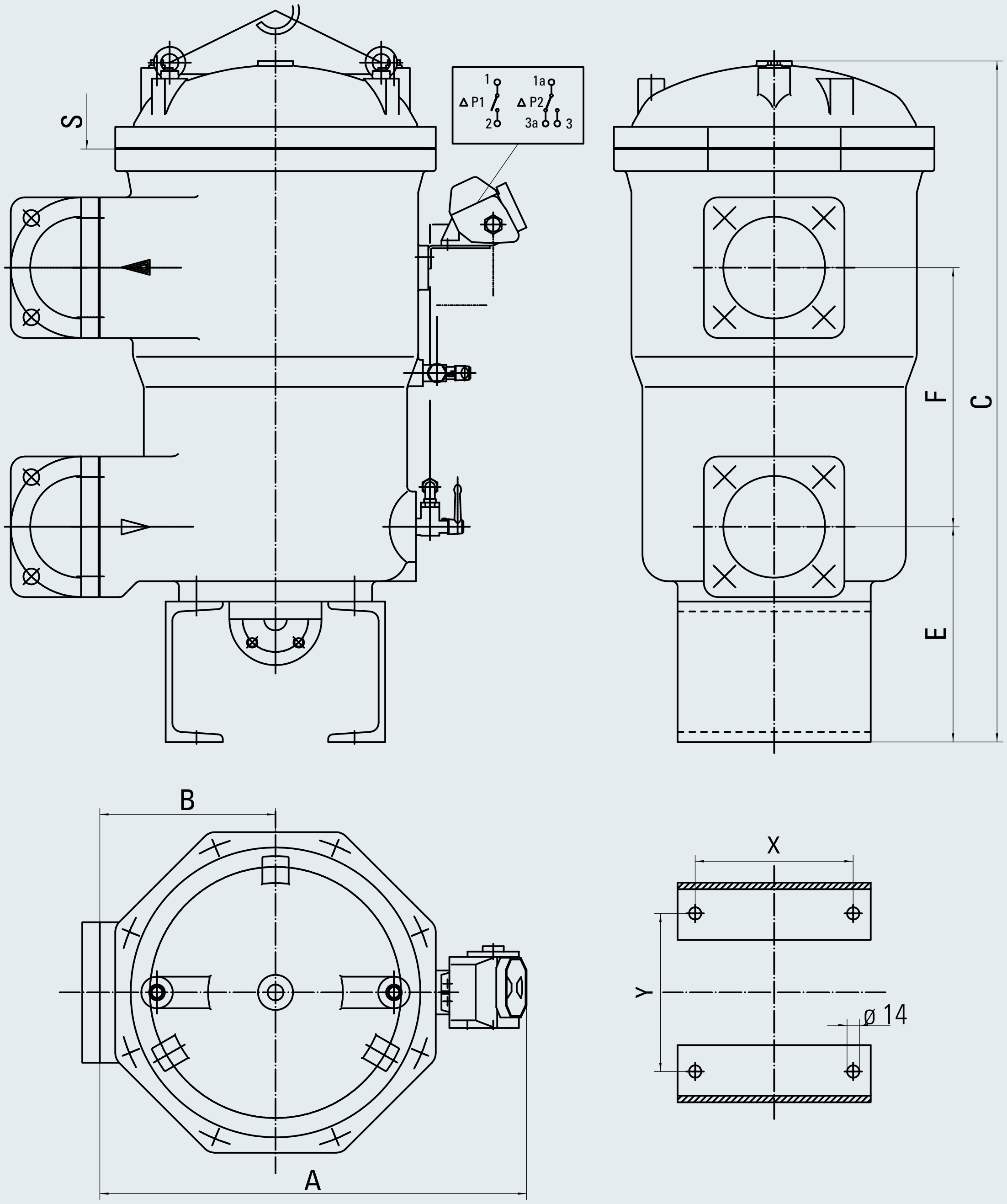


Fig. 6-3 Back flushing filter LF2

	Dimensions [mm]								Weight
	A	B	C	E	F	S	X	Y	[kg]
6/8/9 M 32 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

Pipes are to be connected free of tension to the engine connection points.

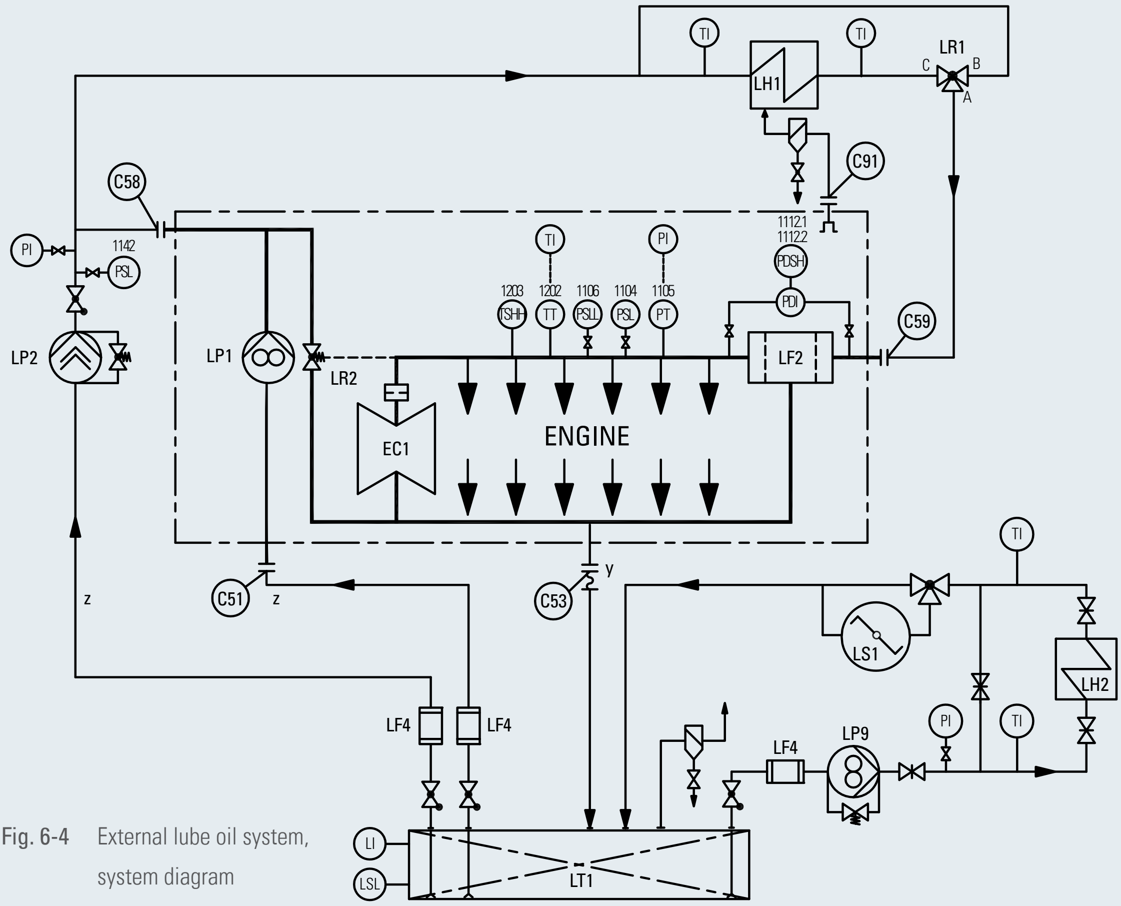


Fig. 6-4 External lube oil system, system diagram

EC1	Exhaust gas turbocharger	PI	Pressure indicator
LF2	Self-cleaning lube oil filter	PSL	Pressure switch low
LF4	Suction strainer	PT	Pressure transmitter
LH1	Lube oil cooler	TI	Temperature indicator
LH2	Lube oil preheater	TSHH	Temperature switch high high
LP1	Lube oil force pump	TT	Temperature transmitter (PT100)
LP2	Lube oil stand-by force pump		
LP9	Transfer pump (separator)	C51	Force pump, suction side
LR1	Lube oil temperature control valve	C53	Lube oil discharge
LR2	Oil pressure regulating valve	C58	Force pump, delivery side
LS1	Lube oil separator	C59	Lube oil inlet, lube oil filter
LT1	Sump tank	C91	Crankcase ventilation to stack
LI	Level indicator		
LSL	Level switch low	y	Provide an expansion joint.
PDI	Diff. pressure indicator	z	Max. suction pressure - 0.4 bar
PDSH	Diff. pressure switch high		

Lube oil stand-by force pump LP2 (separate)

This pump is a stand-by to the force pump LP1.

It is a gear or screw type pump.
It is a requirement of the classification societies for single-engine plants.
This pump will also be used for prelubricating.

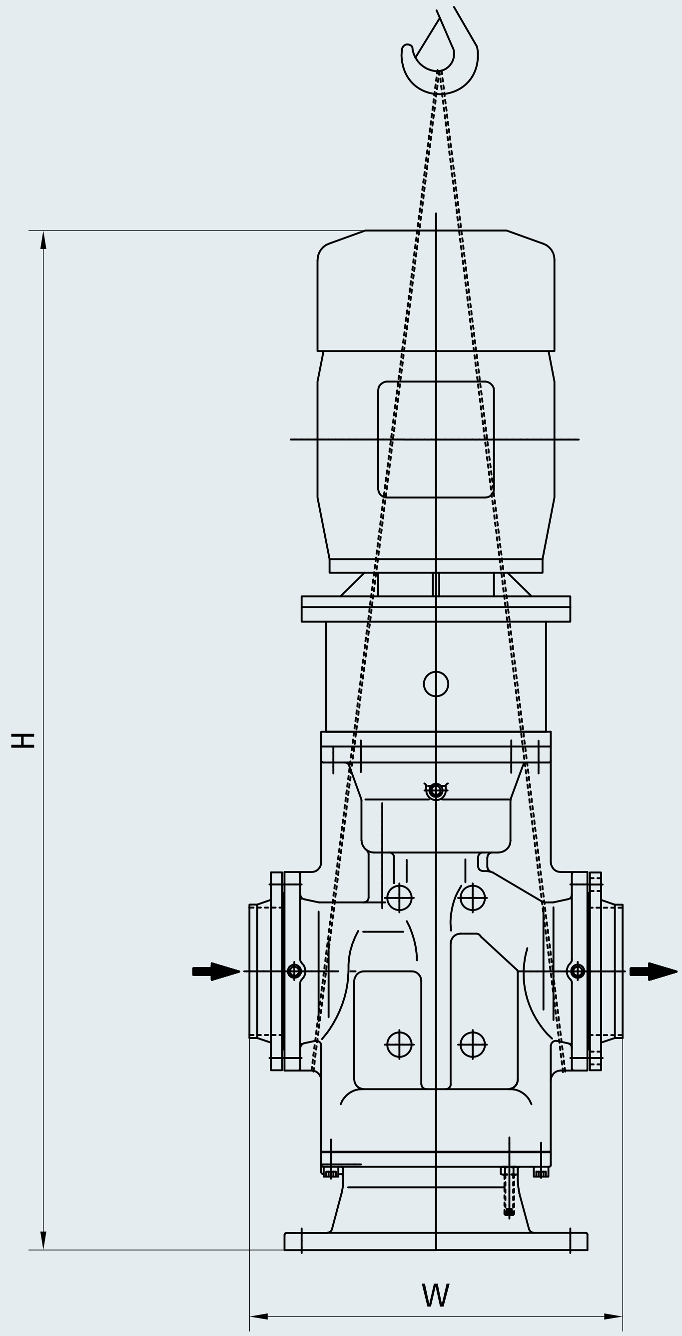


Fig. 6-5 Lube oil stand-by force pump LP2

		Capacity [m³/h]	Motor power [kW]	W [mm]	H [mm]	Weight [kg]
6 M 32 E	400 V / 50 Hz	70	37	628	1,773	701
	440 V / 60 Hz	70	36	628	1,728	588
8/9 M 32 E	400 V / 50 Hz	90	45	764	2,015	786
	440 V / 60 Hz	90	45	764	1,773	601

Prelubricating pump LP5 (separate)

This pump can be installed instead of a stand-by force pump in multiple engines plants.
This pump can only be used for prelubricating, not as stand-by for the force pump.
Capacity, see technical data.

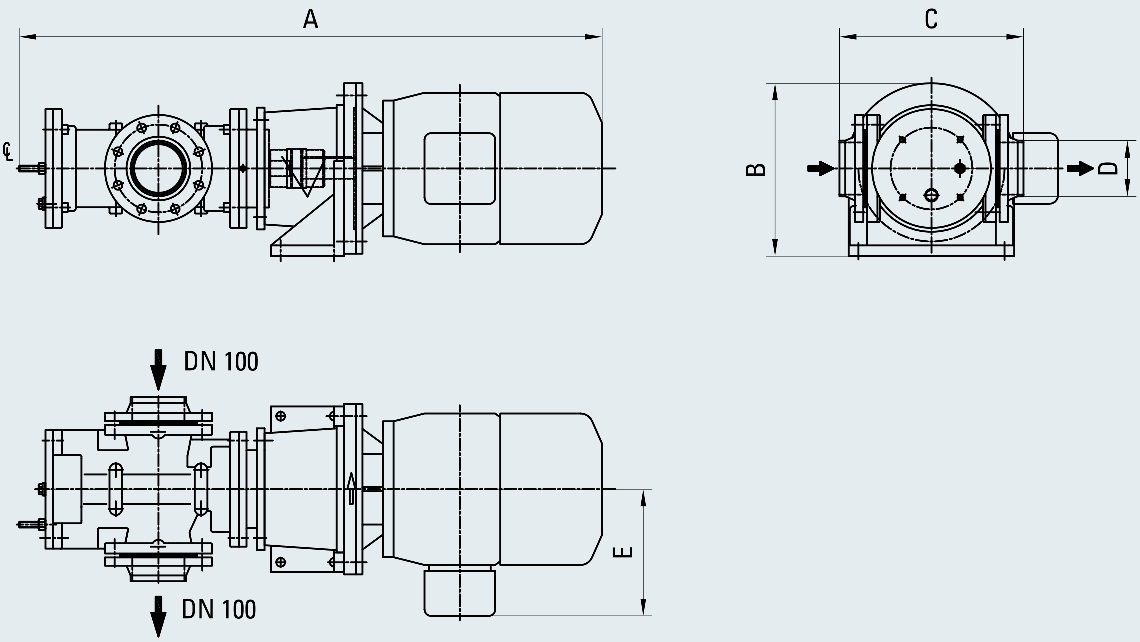


Fig. 6-6 Prelubricating pump LP5

	Dimensions [mm]					Motor power	Weight
	A	B	C	D	E	[kW]	[kg]
400 V / 50 Hz	1,119	355	378	DN 100	260	11	192
440 V / 60 Hz	1,197	355	354	DN 80	260	13.2	172

The pumps can be installed in horizontal or vertical position.

Suction strainer LF4 (separate)

This strainer shall only protect the pumps.
It is not in the Caterpillar Motoren scope of supply.
Mesh size 2 – 3 mm.

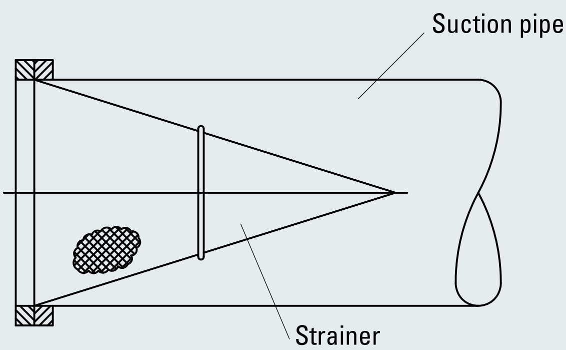


Fig. 6-7 Suction strainer LF4

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 cooler LH1 (separate)

A plate cooler with plates of stainless steel will be used to dissipate the heat to the LT fresh water system.

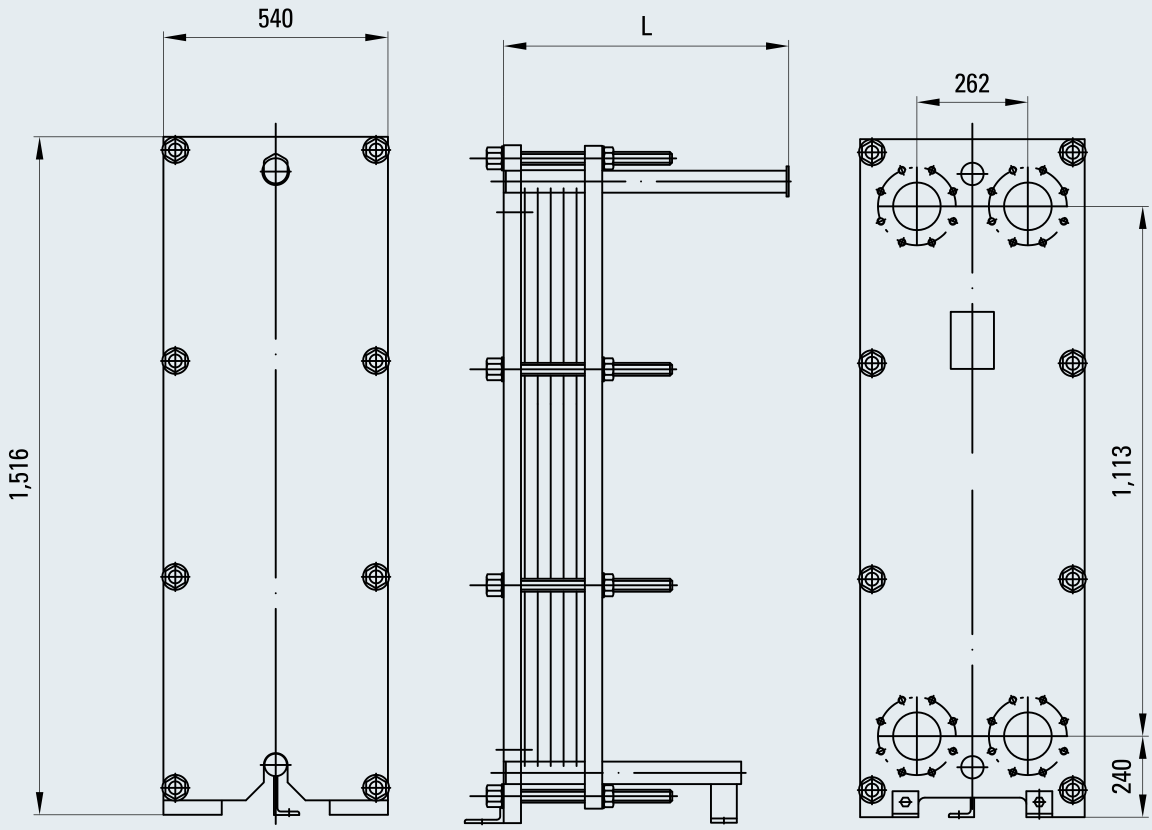


Fig. 6-8 Lube oil cooler LH1

	L	Weight
	[mm]	[kg]
6 M 32 E	545	638
8 M 32 E	765	692
9 M 32 E	765	711

Lube oil temperature control valve LR1 (separate)

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

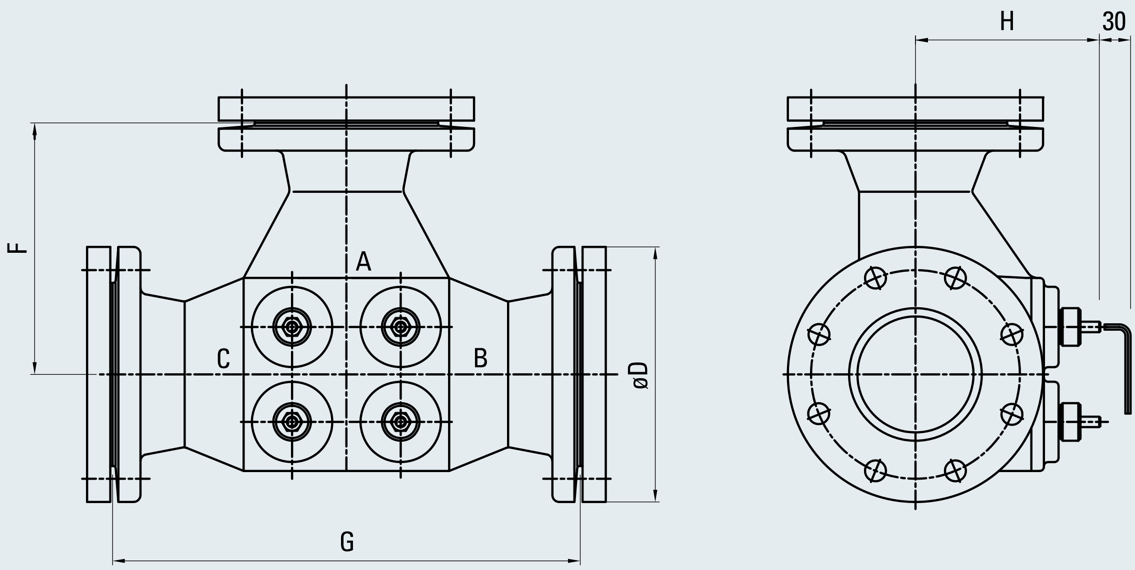


Fig. 6-9 Lube oil temperature control valve LR1

	Dimensions [mm]					Weight
	DN	D	F	G	H	[kg]
6 M 32 E	80	200	171	267	151	27
8/9 M 32 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.

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

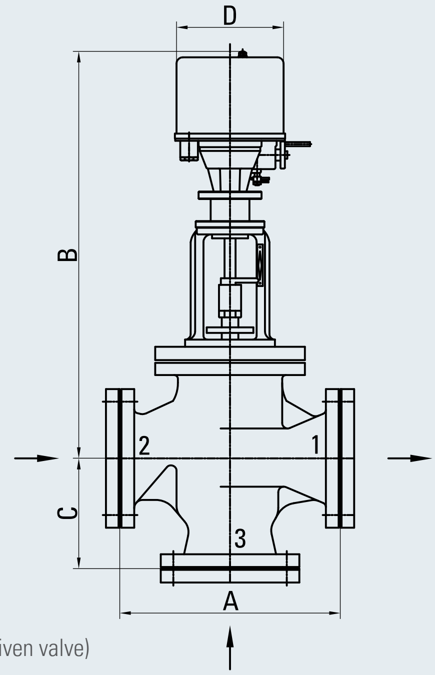


Fig. 6-10 Lube oil temperature control valve LR1 (electric driven valve)

	Dimensions [mm]					Weight
	DN	A	B	C	D	[kg]
6 M 32 E	80	310	624	155	170	58
8/9 M 32 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.

Lube oil system with wet sump

Alternatively a wet sump can be used instead of a separate circulation tank below the engine.

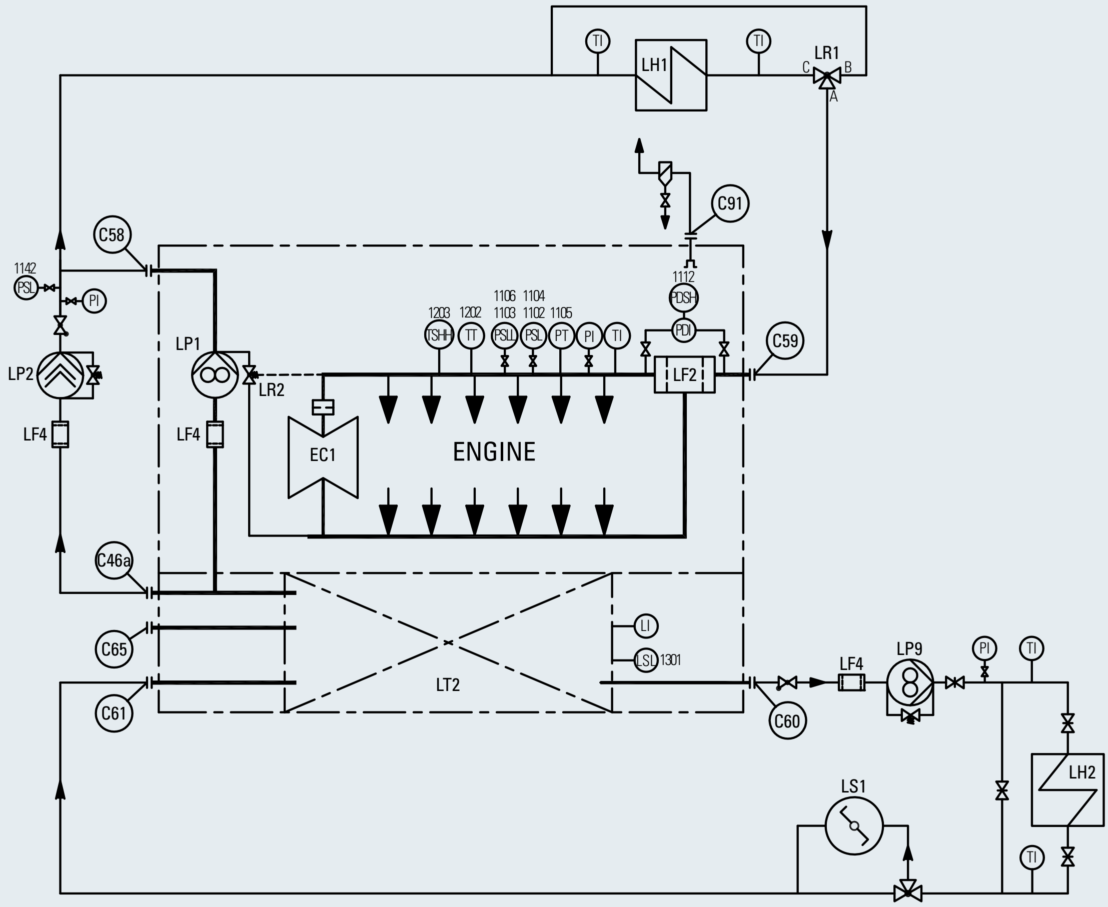


Fig. 6-11 System diagram, wet sump tank

EC1	Exhaust gas turbocharger
LF2	Self-cleaning lube oil filter
LF4	Suction strainer
LH1	Lube oil cooler
LH2	Lube oil preheater
LP1	Lube oil force pump
LP2	Lube oil stand-by force pump
LP9	Transfer pump (separator)
LR1	Lube oil temperature control valve
LR2	Oil pressure regulating valve
LS1	Lube oil separator
LT2	Oil pan
LI	Level indicator
LSL	Level switch low
PDI	Diff. pressure indicator
PDSH	Diff. pressure switch high
PI	Pressure indicator
PSL	Pressure switch low
PSLL	Pressure switch low
PT	Pressure transmitter
TI	Temperature indicator
TSHH	Temperature switch high high
TT	Temperature transmitter
C46a	Stand-by force pump, suction side
C58	Force pump, delivery side
C59	Lube oil inlet, luber oil cooler
C60	Stand-by pump HT, inlet
C61	Separator connection, delivery side
C65	Lube oil filling socket
C91	Crankcase ventilation to stack

Lube oil system with high level circulating tank

If there is no sufficient space for a separate circulating tank below the engine itself and an engine with wet sump is not applicable, a separate circulating tank can be foreseen adjacent to or even above the engine.
The maximum height of the oil level in the circulating tank is limited to 2.5 m above the crankshaft centre.
In this case a lube oil recirculation pump and a respective stand-by pump will be necessary.
Power of recirculation pump and stand-by pump, see technical data.
In this case please contact Caterpillar Motoren.

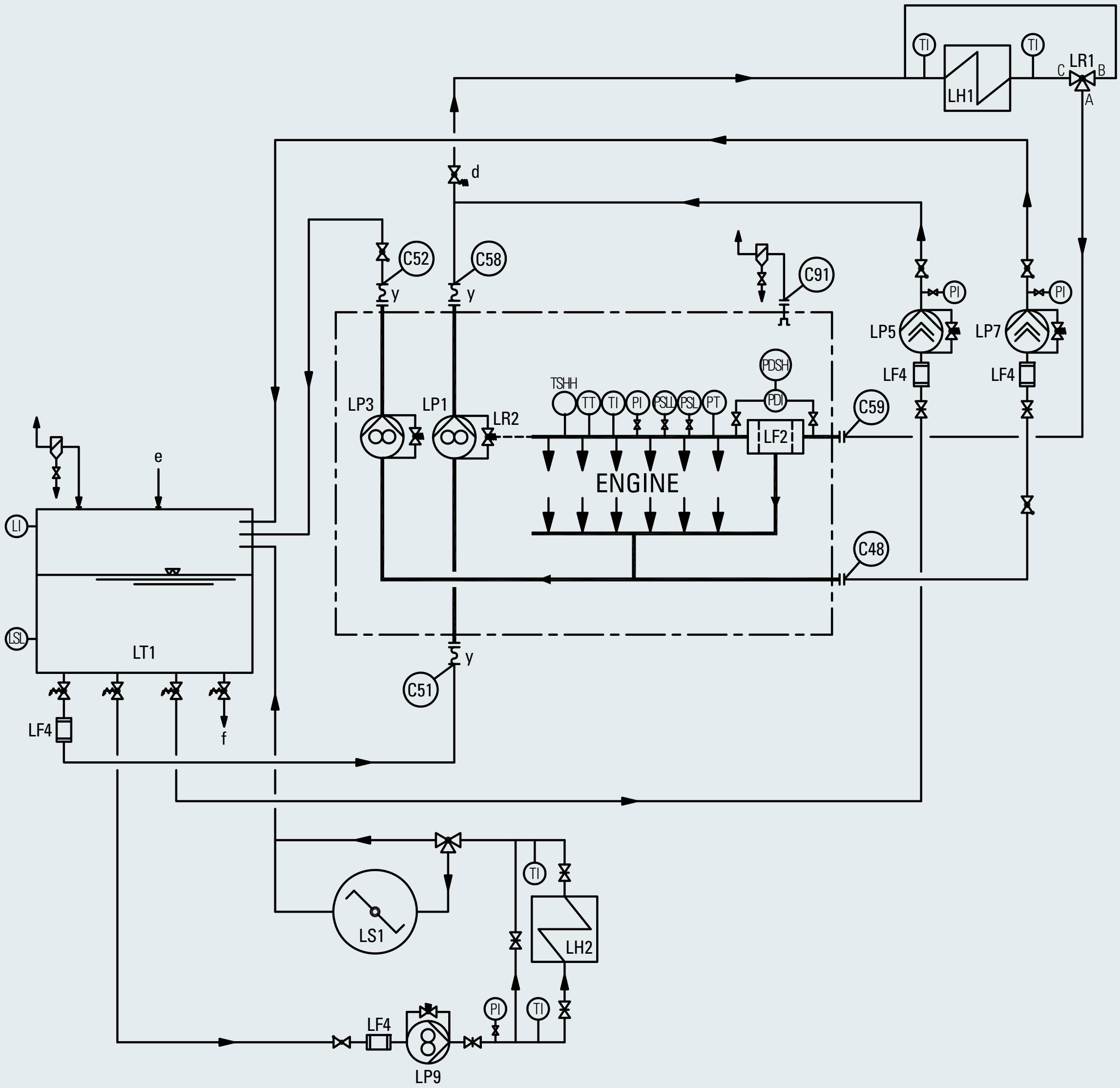


Fig. 6-12 System diagram, high level tank

LF2	Self-cleaning lube oil filter
LF4	Suction strainer
LH1	Lube oil cooler
LH2	Lube oil preheater
LP1	Lube oil force pump
LP3	Lube oil suction pump
LP5	Prelubrication force pump
LP7	Prelubrication suction pump
LP9	Transfer pump (separator)
LR1	Lube oil temperature control valve
LR2	Oil pressure regulating valve
LS1	Lube oil separator
LT1	Lube oil sump tank

LI	Level indicator
LSL	Level switch low
PDI	Diff. pressure indicator
PDSH	Diff. pressure switch high
PI	Pressure indicator
PSL	Pressure switch low
PSLL	Pressure switch low
PT	Pressure transmitter
TI	Temperature indicator
TSHH	Termperature switch high
TT	Temperature transmitter (PT100)

C48	Stand-by suction pump, suction side
C51	Force pump, suction side
C52	Suction pump, delivery side
C58	Force pump, delivery side
C59	Lube oil inlet, duplex filter
C91	Crankcase ventilation to stack

d	Opening pressure 1.0 bar
e	Filling pipe
f	Drain
y	Provide an expansion joint

6.4 Circulating tanks and components

6.4.1 Lube oil drain piping

The oil drain bend is provided separately. In general the oil drain connecting point is located at the driving end of the engine. If the engine is aligned with inclination to the free end, the oil drain bend can be mounted to the free end of the engine. The oil drain piping should be as short as possible.
There should be a compensator between the end of the oil drain bend and the circulating tank.

6.4.2 Circulating tank layout

Circulating tank LT1

The circulating tank contains the engine lube oil. The recommended volume of the circulating tank is calculated as follows:

$$V[m^3] = \frac{1.7 \cdot P_{eng}\,[kW]}{1{,}000} \qquad P_{eng} = \text{Power engine [kW]}$$

On request lower capacities are possible, please contact Caterpillar Motoren. The nominal oil level is at 80 % of circulating tank volume. At 60 % of circulating tank volume there should be a low level switch with monitoring by the MACS.
To make sure, that the engine is provided with lube oil, the lube oil suction pipe should be aligned inside the circulating tank in a position, that is filled with lube oil under any condition.
To avoid any stress to the structure of the engine as well as the circulating tank, the circulating tank should be located below the engine in its total length and width to make sure that the foundation is warmed up equally. In plants with separators the content of the circulating tank should be clarified permanently.
The preheater in the separator should be able to keep the lube oil temperature at min. 40 °C even when the engine is not running.

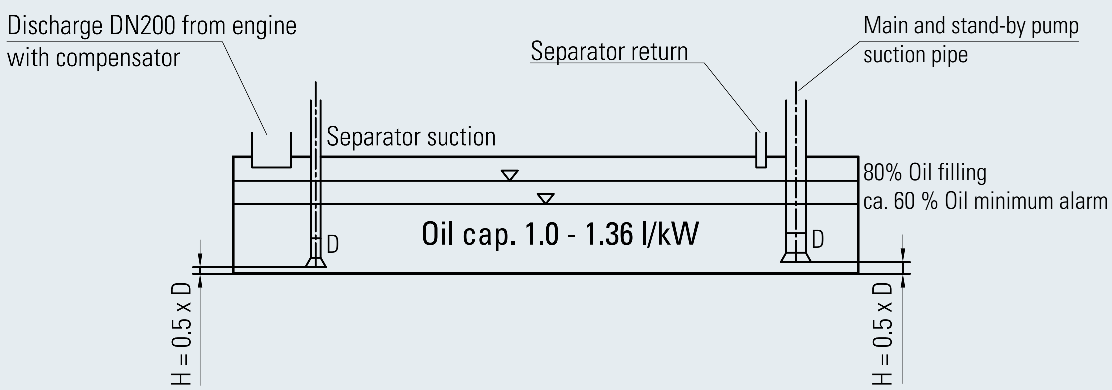


Fig. 6-13 Sump tank LT1

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 100.
- If the engine main ventilation line is joined to the ventilation line of the circulation tank, this line must be at least DN 125 (consider class requirements).
- The maximum pressure in the crankcase is limited to 150 Pa.

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.

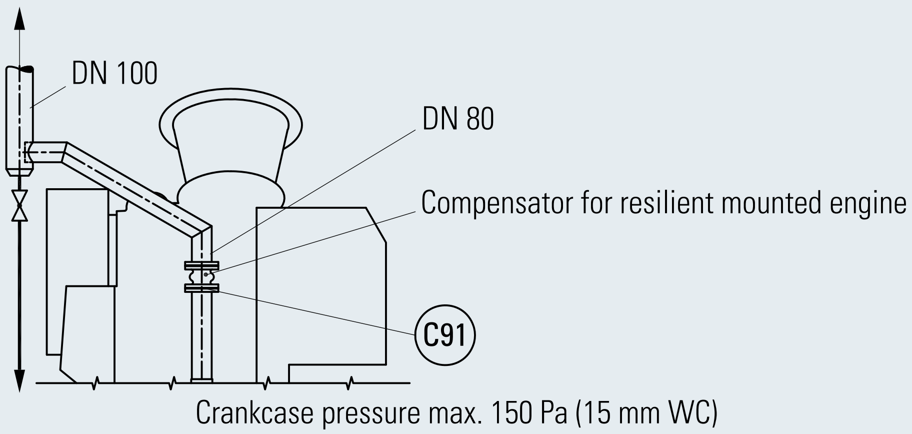


Fig. 6-14 Crankcase ventilation

C91 Crankcase ventilation to stack

6.6 Recommendation for flushing of lube oil system

Required conditions

- The required flow velocity for flushing purposes is minimum 2.0 m/s.
- There should be an external flushing oil filter (30/34 μm mesh size) with differential pressure indicator (0.2 bar) installed on the end of the flushing circuit.
- Lube oil separator must be in operation.
- Lube oil temperature min. 40 °C (140 cSt.), if possible use low-viscosity flushing oil.

Flushing the system from circulation tank to circulation tank

- The flushing oil pump takes the oil from the lube oil circulation tank and presses into the lube oil system.
- During the flushing process the automatic lube oil filter is bypassed.
- Before engine inlet the system is to be disconnected and the flushing oil is to be conducted via a flexible pipe through a crankcase door (near to the oil drain) into the circulating tank.

Flushing time

- Each system is to be flushed for at least 8 hours.
- The main flushing is completed when there is no more differential pressure at the flushing oil filter.
- After the main flushing is completed, re-install all filter inserts and flush the system one more hour with all filters in place not using bypasses.
- Inspect all filters and continue flushing until all filters and inserts stay clean.
- After flushing, all not flushed pipes and filters (e.g. stand-by pump lines, opened pipes) to be cleaned separately.

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).

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22

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]
ρ =	Density [kg/dm³]
η =	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 Internal cooling water system

7.4.1 General

The high temperature (HT) system provides the HT side of the charge air cooler and the engines' 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 pumps' 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).

7.4.2 Internal cooling water system layout

Depending on the plant design the fresh cooling water pumps can be fitted on the engine. All cooling water pumps may be also designed as separate with electrical drive.
Depending on the engine design, whether the turbocharger is at driving end or at free end, the piping arrangements will be different.

Turbocharger at driving end

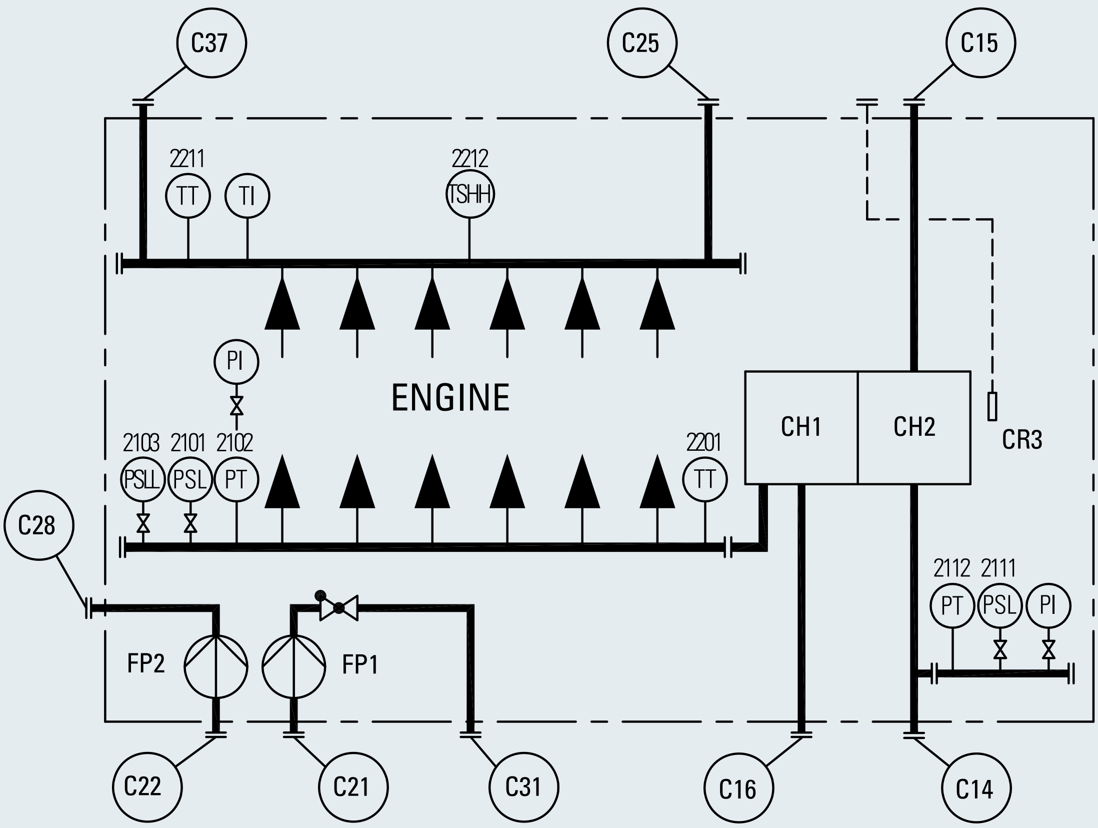


Fig. 7-1 Internal cooling water system, system diagram, turbocharger at driving end

CH1	Charge air cooler HT
CH2	Charge air cooler LT
CR3	Sensor for charge air temperature control valve
FP1	Fresh water pump (fitted on engine) HT
FP2	Fresh water pump (fitted on engine) LT
PI	Pressure indicator
PSL	Pressure switch low
PSLL	Pressure switch low
PT	Pressure transmitter
TI	Temperature indicator
TSHH	Temperature switch high
TT	Temperature transmitter (PT100)
C14	Charge air cooler LT, inlet
C15	Charge air cooler LT, outlet
C16	Charge air cooler HT, inlet
C21	Fresh water pump HT, inlet
C22	Fresh water pump LT, inlet
C25	Cooling water, engine outlet
C28	Fresh water pump LT, outlet
C31	Fresh water pump HT, outlet
C37	Vent

Turbocharger at free end

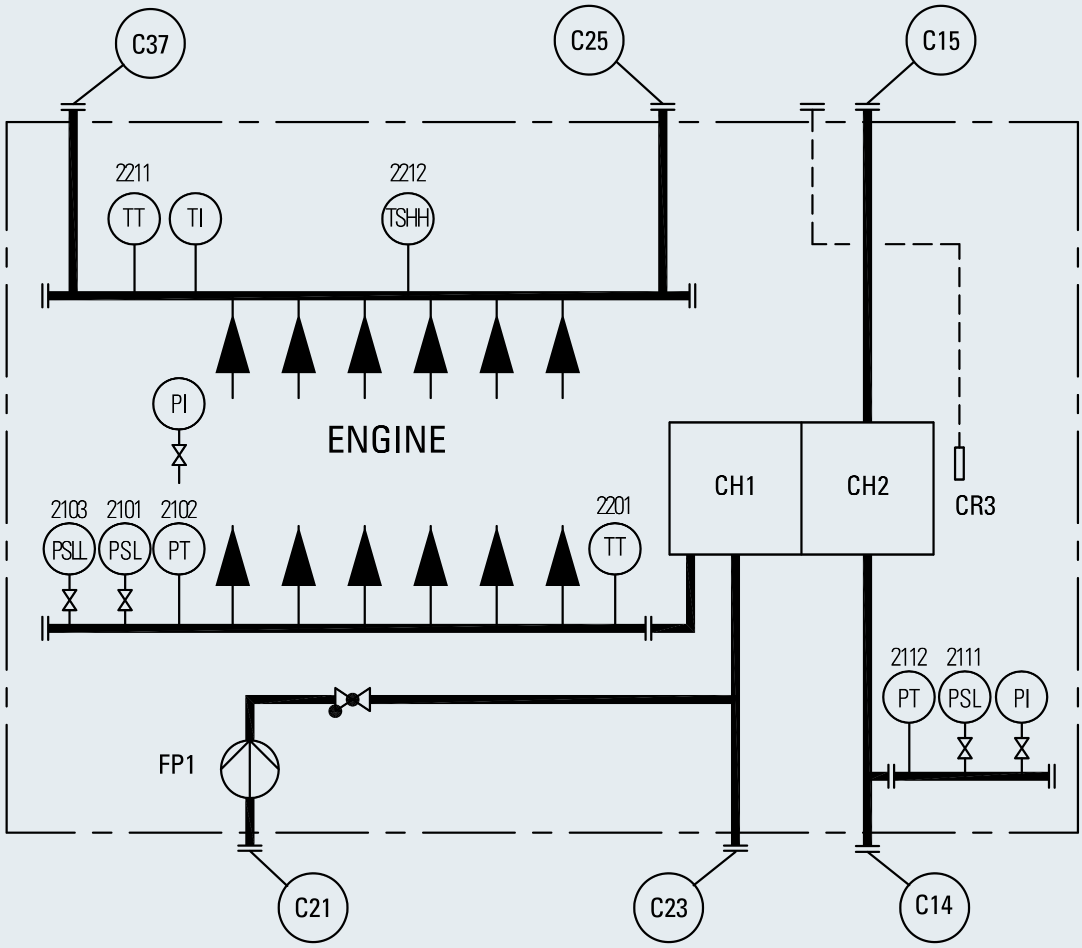


Fig. 7-2 Internal cooling water system, system diagram, turbocharger at free end

CH1	Charge air cooler HT	TI	Temperature indicator
CH2	Charge air cooler LT	TSHH	Temperature switch high
CR3	Sensor for charge air temperature control valve	TT	Temperature transmitter (PT100)
FP1	Fresh water pump (fitted on engine) HT	C14	Charge air cooler LT, inlet
		C15	Charge air cooler LT, outlet
PI	Pressure indicator	C21	Fresh water pump HT, inlet
PSL	Pressure switch low	C23	Stand-by pump HT, inlet
PSLL	Pressure switch low	C25	Cooling water, engine outlet
PT	Pressure transmitter	C37	Vent

7.5 External cooling water system

7.5.1 General

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.

Turbocharger at driving end

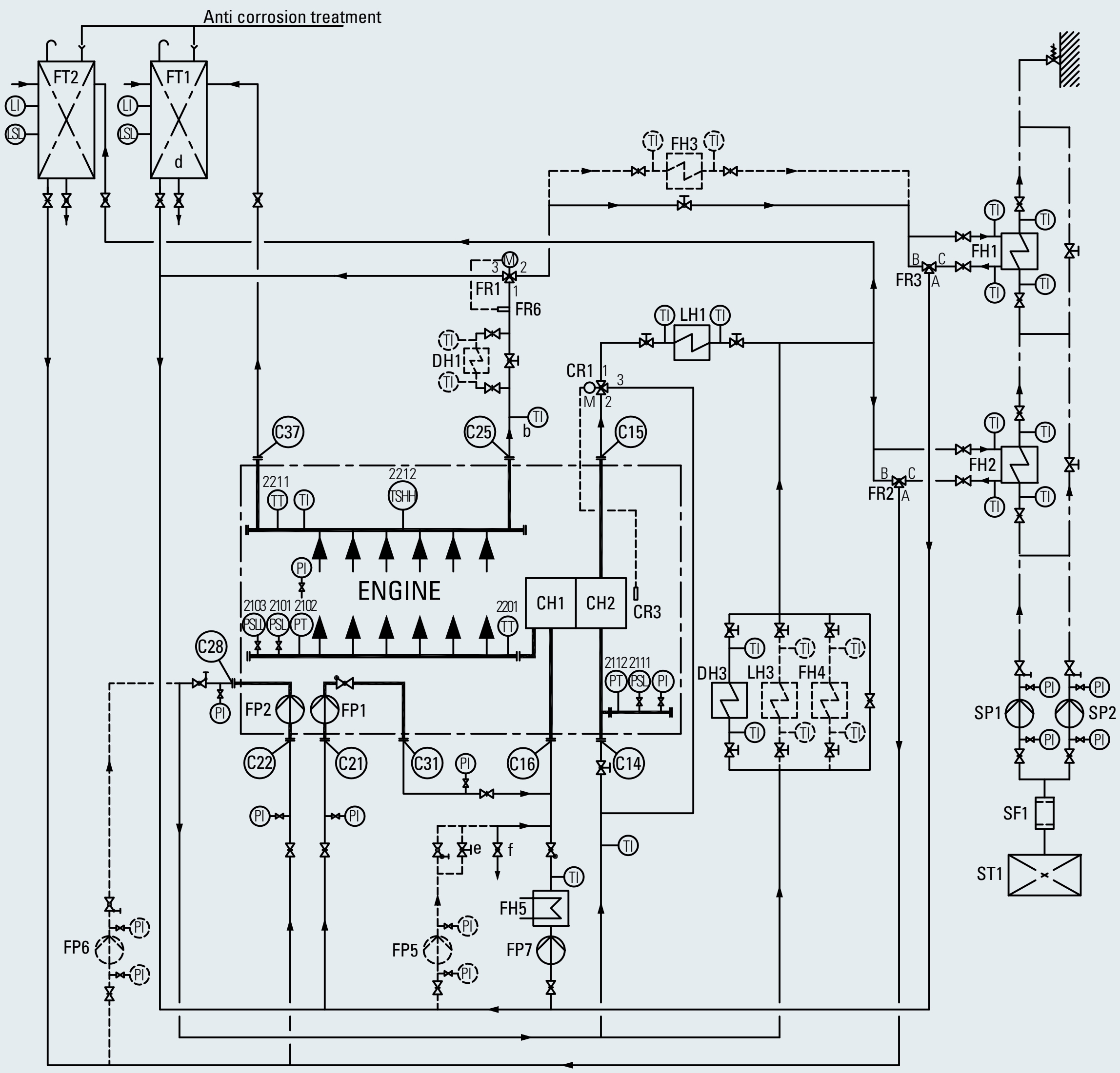


Fig. 7-3 External cooling water system, system diagram, turbocharger at driving end

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
CR3	Sensor for charge air temperature control valve
DH1	MDO preheater
DH3	Fuel oil cooler for MDO operation
FH1	Fresh water cooler HT
FH2	Fresh water cooler LT
FH3	Heat consumer
FH4	Other LT consumers
FH5	Fresh water preheater
FP1	Fresh water pump (fitted on engine) HT
FP2	Fresh water pump (fitted on engine) LT
FP5	Fresh water stand-by pump HT
FP6	Fresh water stand-by pump LT
FP7	Preheating pump
FR1	Temperature control valve HT
FR2	Temperature control valve LT
FR3	Flow temperature control valve HT
FR6	Sensor for temperature control valve
FT1	Compensation tank HT
FT2	Compensation tank LT
LH1	Lube oil cooler
LH3	Gear lube oil cooler
SF1	Seawater filter
SP1	Seawater pump
SP2	Seawater stand-by pump
ST1	Sea chest

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

C14	Charge air cooler LT, inlet
C15	Charge air cooler LT, outlet
C16	Charge air cooler HT, inlet
C21	Freshwater pump HT, inlet
C22	Freshwater pump LT, inlet
C25	Cooling water, engine outlet
C28	Fresh water pump LT, outlet
C31	Fresh water pump HT, outlet
C37	Vent

b	Measurement min. 2.0 m distance to C17
d	Min. 4 m and max. 12 m above engine center
e	Bypass DN 12
f	Drain

Turbocharger at free end

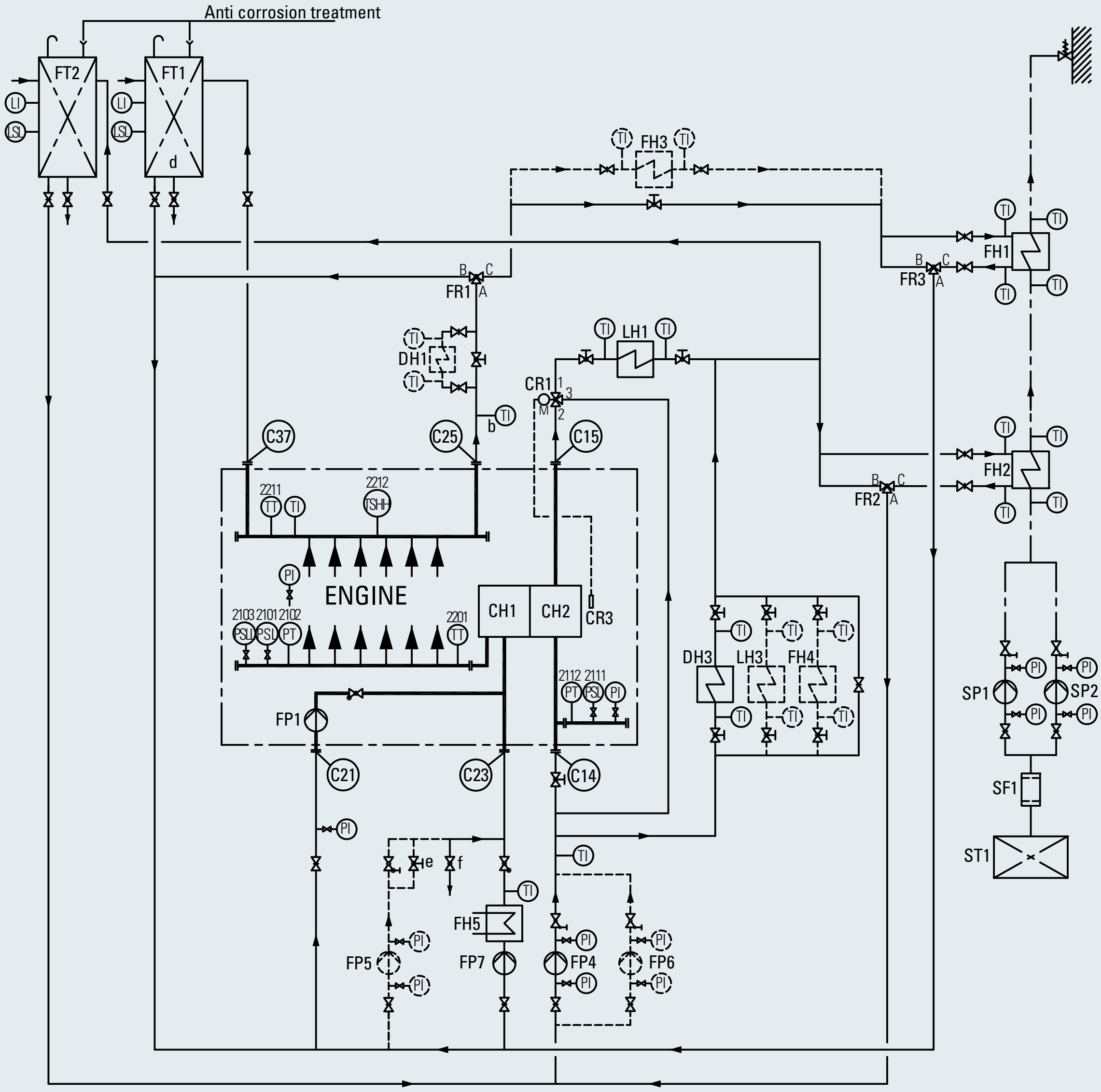


Fig. 7-4 External cooling water system, system diagram, turbocharger at free end

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
CR3	Sensor for charge air temperature control valve
DH1	MDO preheater
DH3	Fuel oil cooler for MDO operation
FH1	Fresh water cooler HT
FH2	Fresh water cooler LT
FH3	Heat consumer
FH4	Other LT consumers
FH5	Fresh water preheater
FP1	Fresh water pump (fitted on engine) HT
FP4	Fresh water pump (separate) LT
FP5	Fresh water stand-by pump HT
FP6	Fresh water stand-by pump LT
FP7	Preheating pump
FR1	Temperature control valve HT
FR2	Temperature control valve LT
FR3	Flow temperature control valve HT
FT1	Compensation tank HT
FT2	Compensation tank LT
LH1	Lube oil cooler
LH3	Gear lube oil cooler
SF1	Seawater filter
SP1	Seawater pump
SP2	Seawater stand-by pump
ST1	Sea chest

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 (PT100)

C14	Charge air cooler LT, inlet
C15	Charge air cooler LT, outlet
C21	Freshwater pump HT, inlet
C23	Stand-by pump HT, inlet
C25	Cooling water, engine outlet
C37	Vent

b	Measurement min. 2.0 m distance to C17
d	Min. 4 m and max. 12 m above engine center
e	Bypass DN12
f	Drain

Secondary circuit cooling system with turbocharger at free end

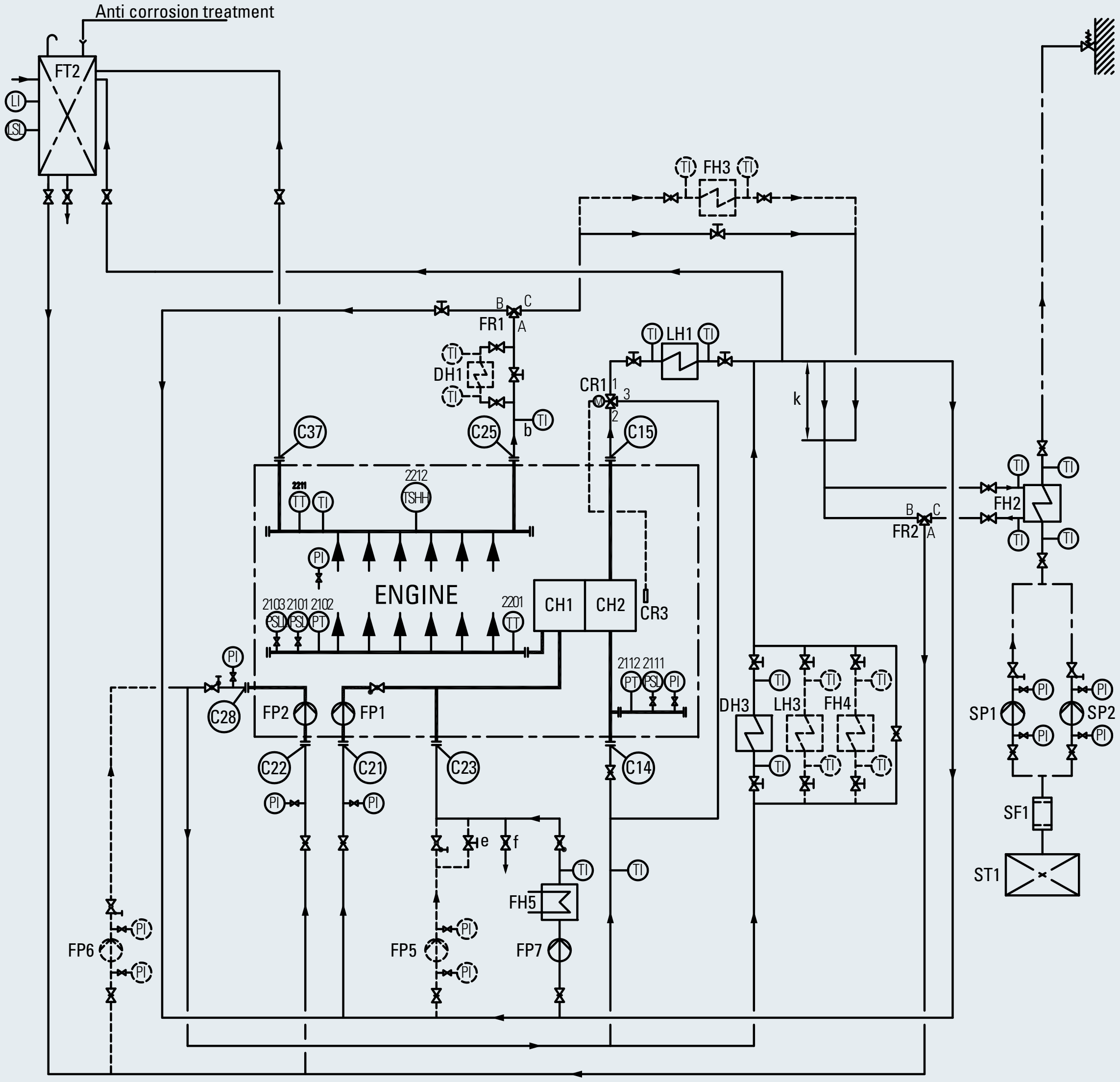


Fig. 7-5 Secondary circuit with turbocharger at free end, system diagram

CH1	Charge air cooler HT
CH2	Charge air cooler LT
CR1	Charge air temperature control valve
CR3	Sensor for charge air temperature control valve
DH1	MDO preheater
DH3	Fuel oil cooler for MDO operation
FH2	Fresh water cooler LT
FH3	Heat consumer
FH4	Other LT consumers
FH5	Fresh water preheater
FP1	Fresh water pump (fitted on engine) HT
FP2	Fresh water pump (fitted on engine) LT
FP5	Fresh water stand-by pump HT
FP6	Fresh water stand-by pump LT
FP7	Preheating pump
FR1	Temperature control valve HT
FR2	Temperature control valve LT
FT2	Compensation tank LT
LH1	Lube oil cooler
LH3	Gear lube oil cooler
SF1	Seawater filter
SP1	Seawater pump
SP2	Seawater stand-by pump
ST1	Sea chest

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 (PT100)

C14	Charge air cooler LT, inlet
C15	Charge air cooler LT, outlet
C21	Freshwater pump HT, inlet
C22	Freshwater pump LT, inlet
C23	Stand-by pump HT, inlet
C25	Cooling water, engine outlet
C28	Fresh water pump LT, outlet
C37	Vent

b	Measurement min. 2.0 m distance to C17
e	Bypass DN 12
f	Drain
k	Distance min. 1 m

7.5.2 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 deaerated.
  - 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]
—	80	310	624	155	170	58
6/8 M 32 E	100	350	646	175	170	70
9 M 32 E	125	400	717	200	170	110

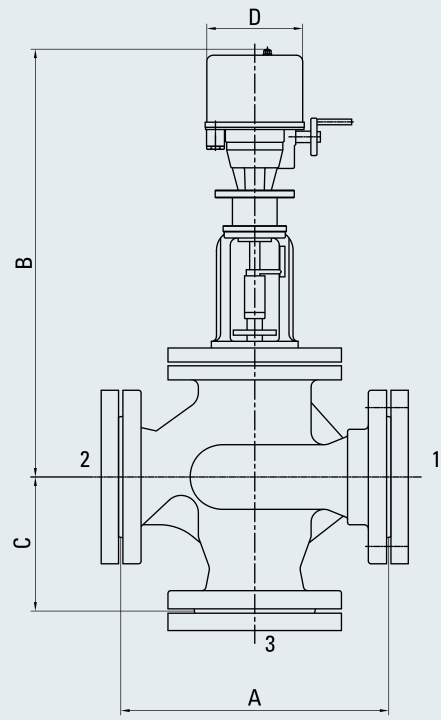


Fig. 7-6 Charge air temperature control valve CR1

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

Capacity: acc. to heat balance.

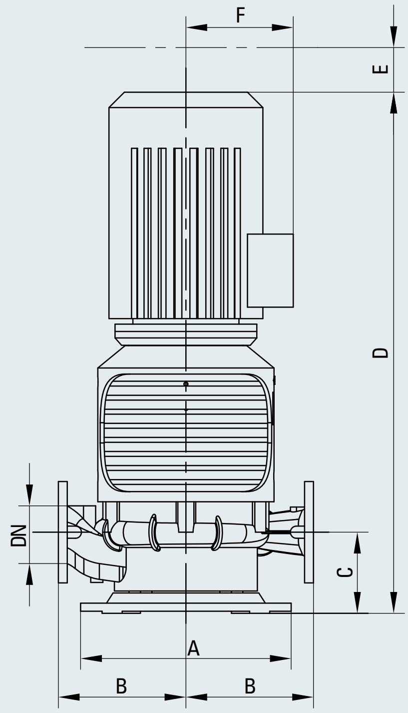


Fig. 7-7 Fresh water pump

Flow	Pressure	Dimensions [mm]							Weight
[m³/h]	[bar]	DN	A	B	C	D	E	F	[kg]
70	3.0	80	400	200	140	1,132	180	250	189
80	3.2	100	520	250	175	1,255	140	250	247
90	3.0	100	520	250	175	1,255	140	250	247
100	3.2	125	520	315	200	1,285	110	265	359

Temperature control valve HT FR1 (separate) / 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).

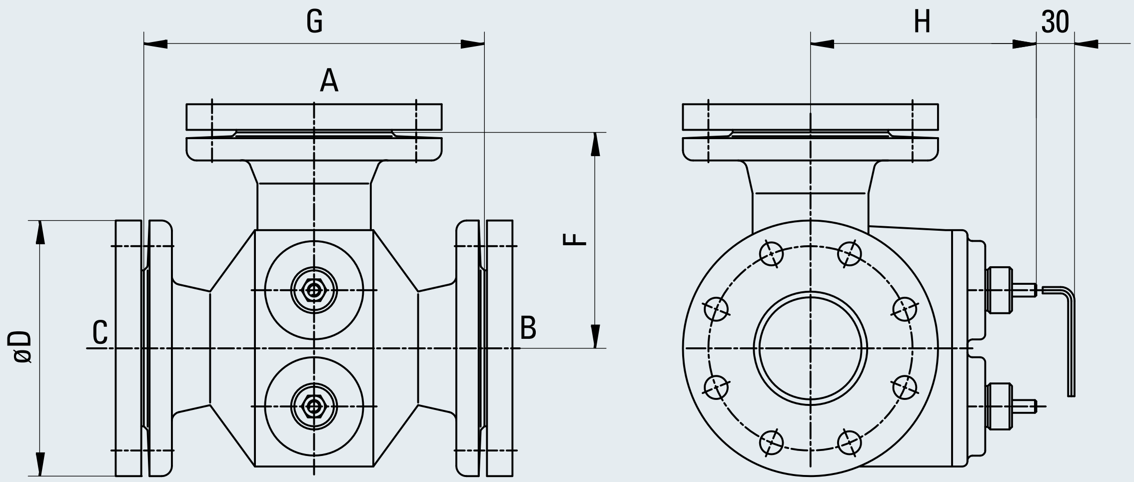


Fig. 7-8 Temperature control valve HT FR1

		Dimensions [mm]					Weight
		DN	D	F	G	H	[kg]
6/8/9 M 32 E	HT	100	220	217	403	167	47
6/8 M 32 E	LT	100*	220	217	403	167	47
9 M 32 E	LT	125*	250	241	489	200	67

* Minimum depending on total cooling water flow

7.6 System diagrams heat balance

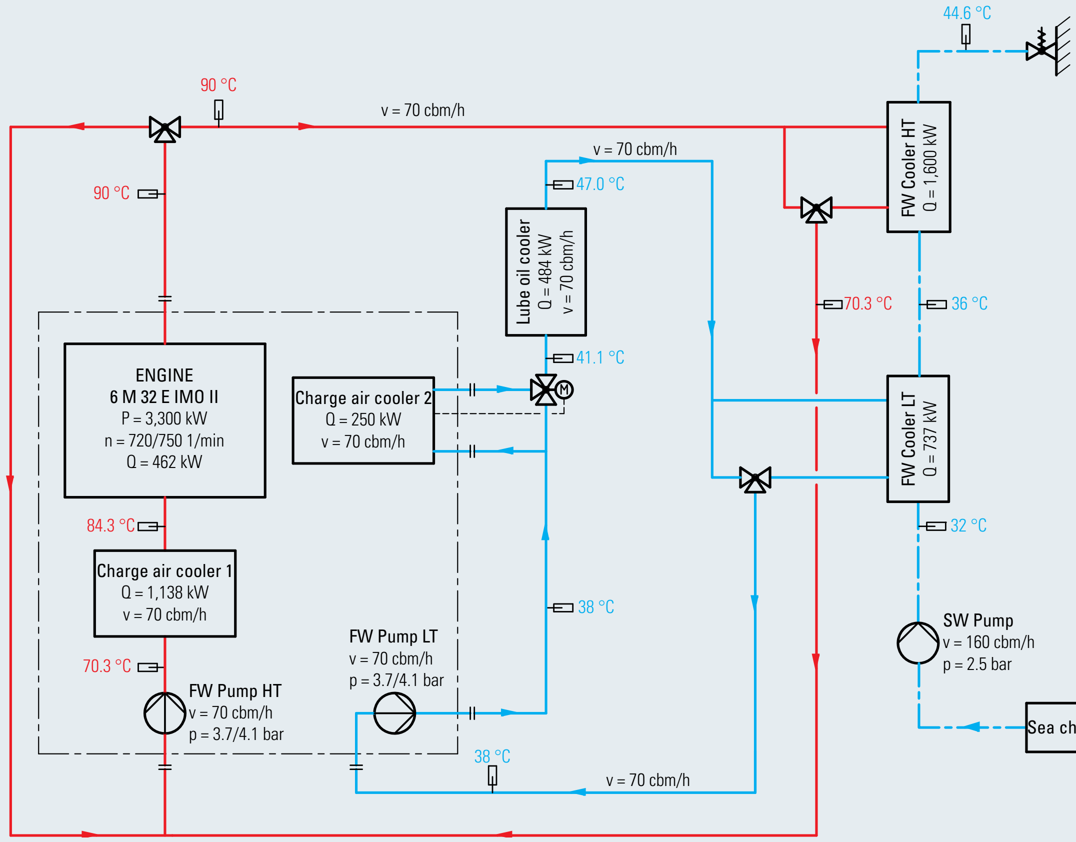


Fig. 7-9 Heat balance, system diagram 6 M 32 E

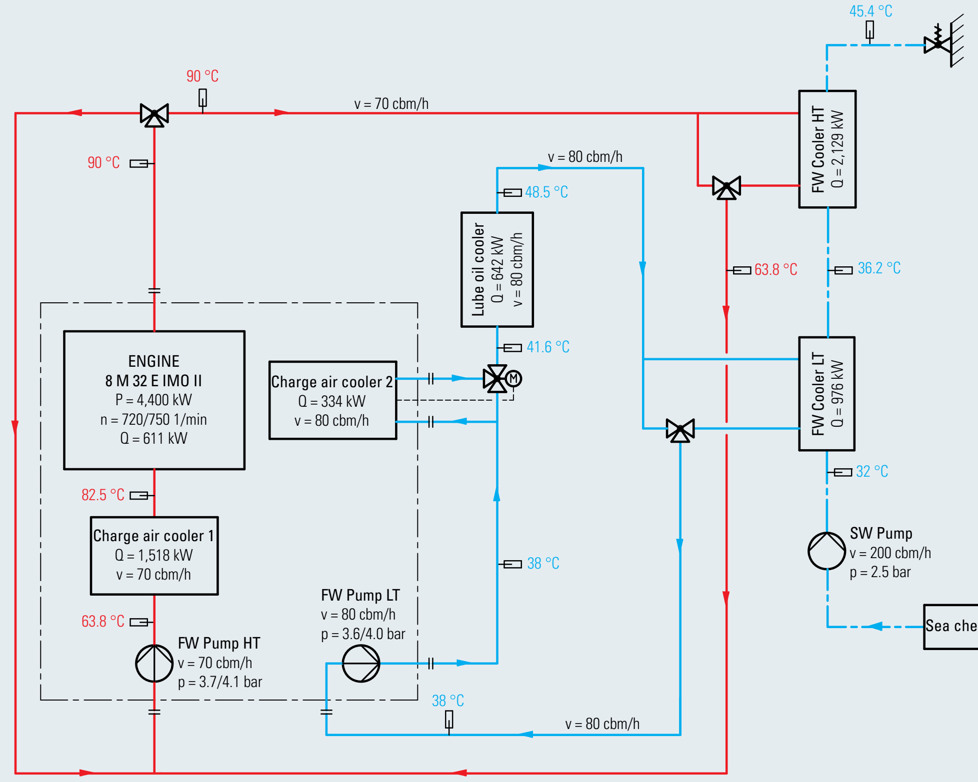


Fig. 7-10 Heat balance, system diagram 8 M 32 E

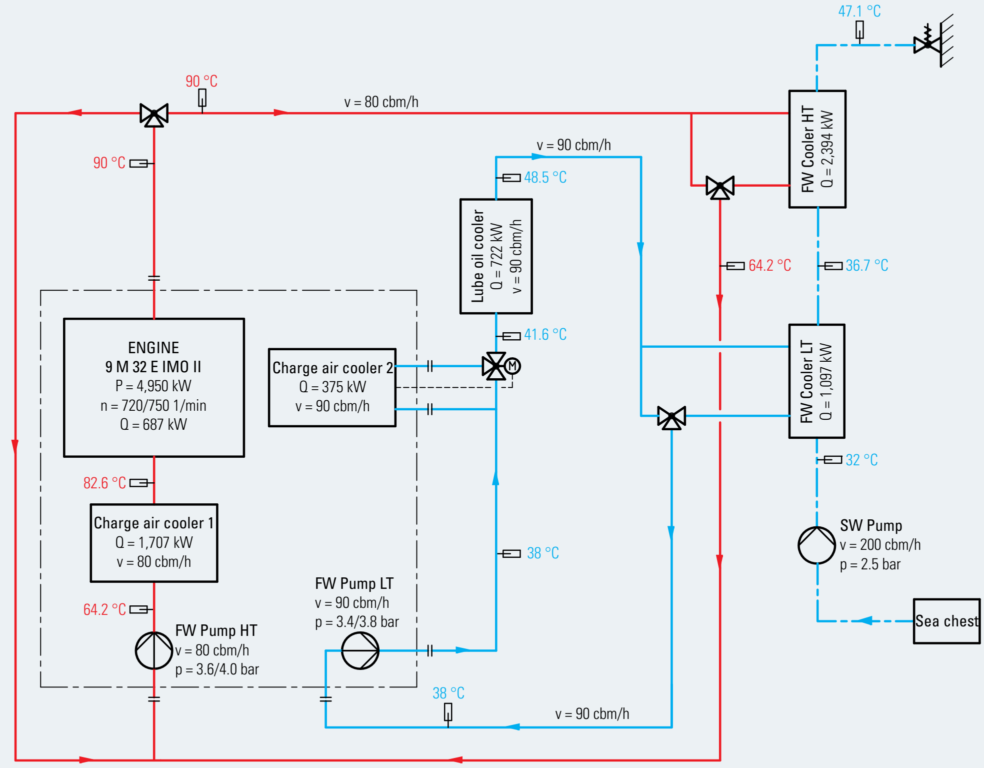


Fig. 7-11 Heat balance, system diagram 9 M 32 E

7.7 Preheating (separate module)

7.7.1 Electrically heated

The standard preheating system in plants delivered by Caterpillar Motoren is electrically heated. Consisting of preheating pump FP7 (12 m³/h), electric heater FH5 (27 kW) and switch cabinet. Voltage 400 - 690, frequency 50/60 Hz., weight 103 kg.

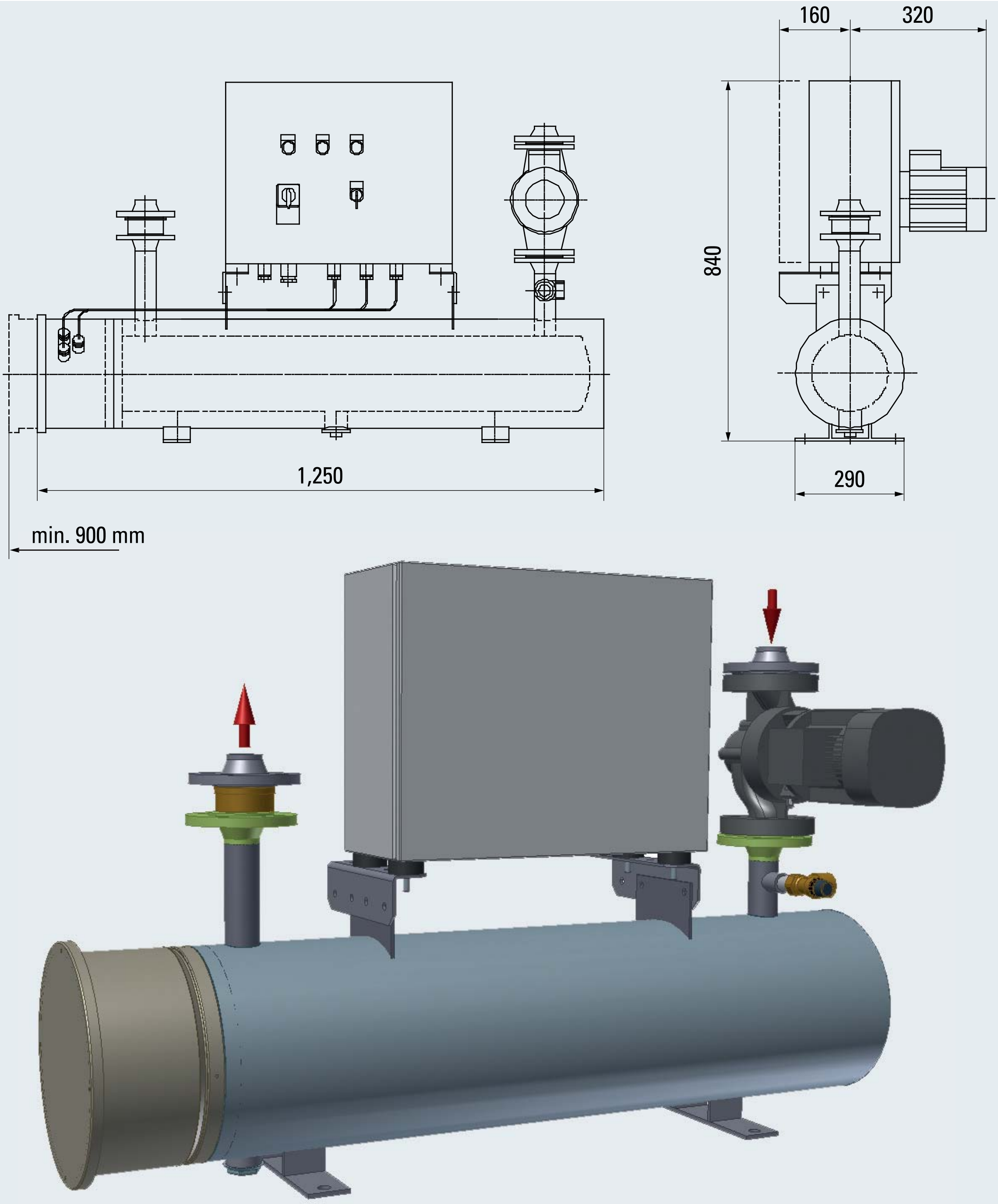


Fig. 7-12 Freshwater preheater FH5, preheating pump FP7

7.7.2 Other preheating systems

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

7.8 Box coolers system

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

7.9 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 M 32 E
Performance curve

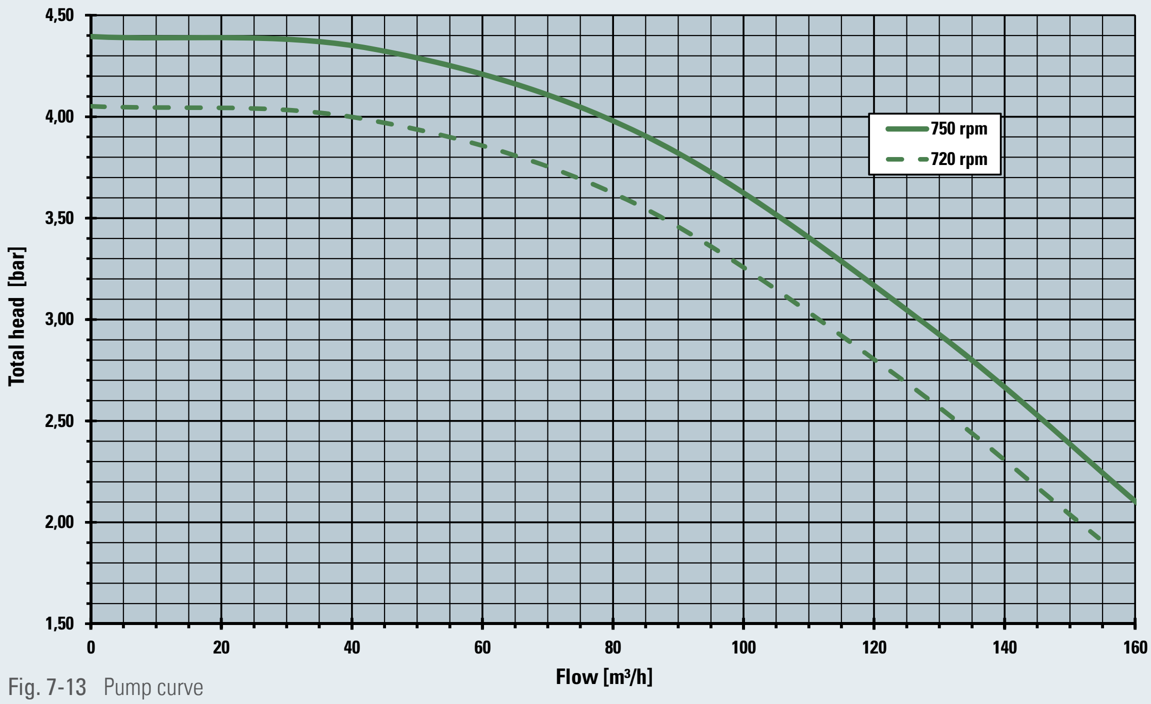


Fig. 7-13 Pump curve

Compressed air is used

- to start the engine.
- 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.

8.1 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.

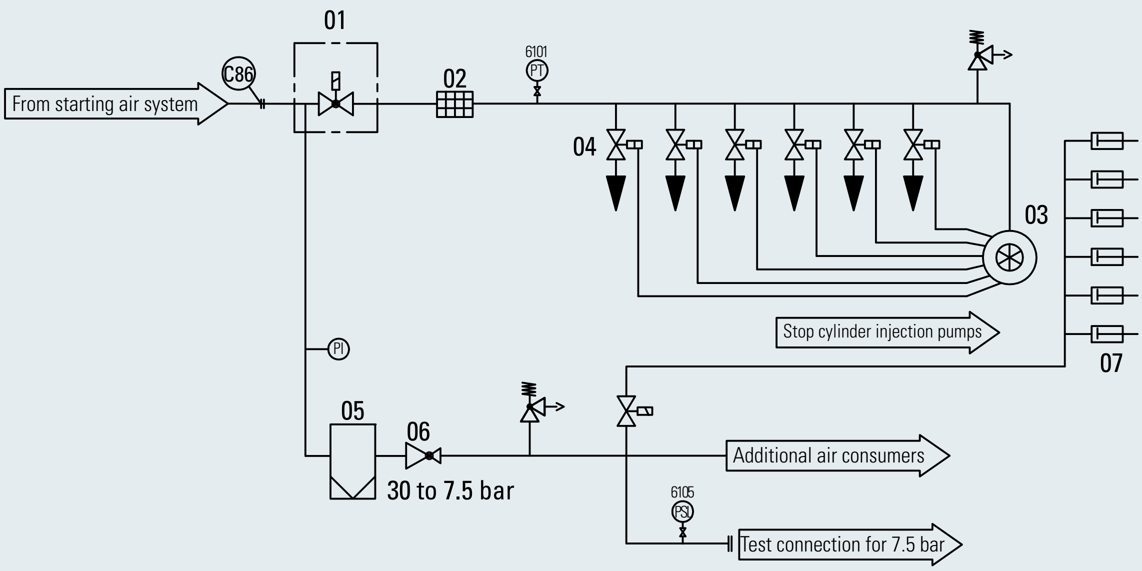


Fig. 8-1 Internal compressed air system, system diagram

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

8.2 External compressed air system

The design of the starting 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 starting air receivers.

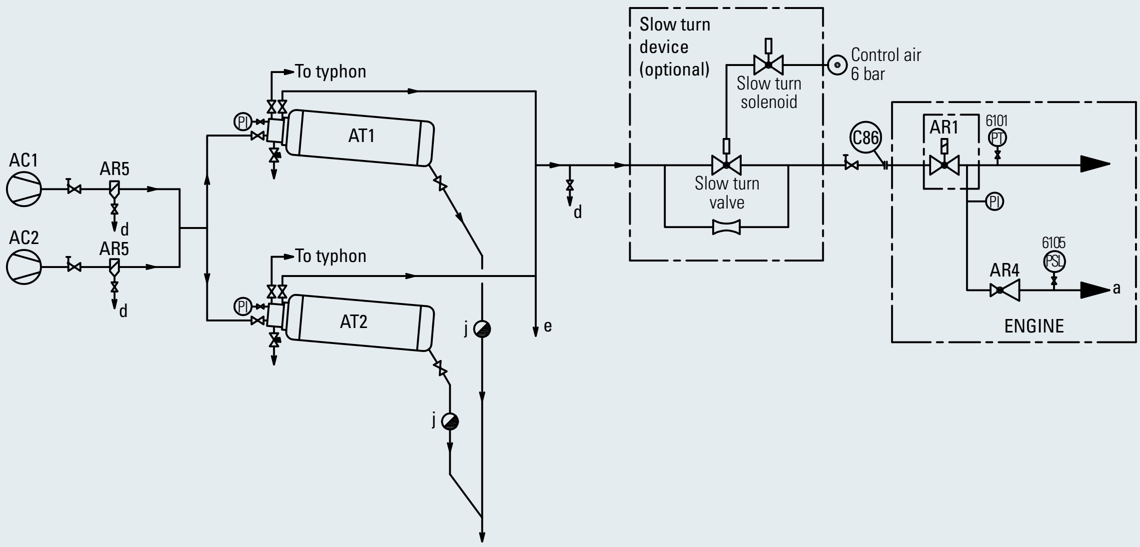


Fig. 8-2 External compressed air system, system diagram

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

8.2.1 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.

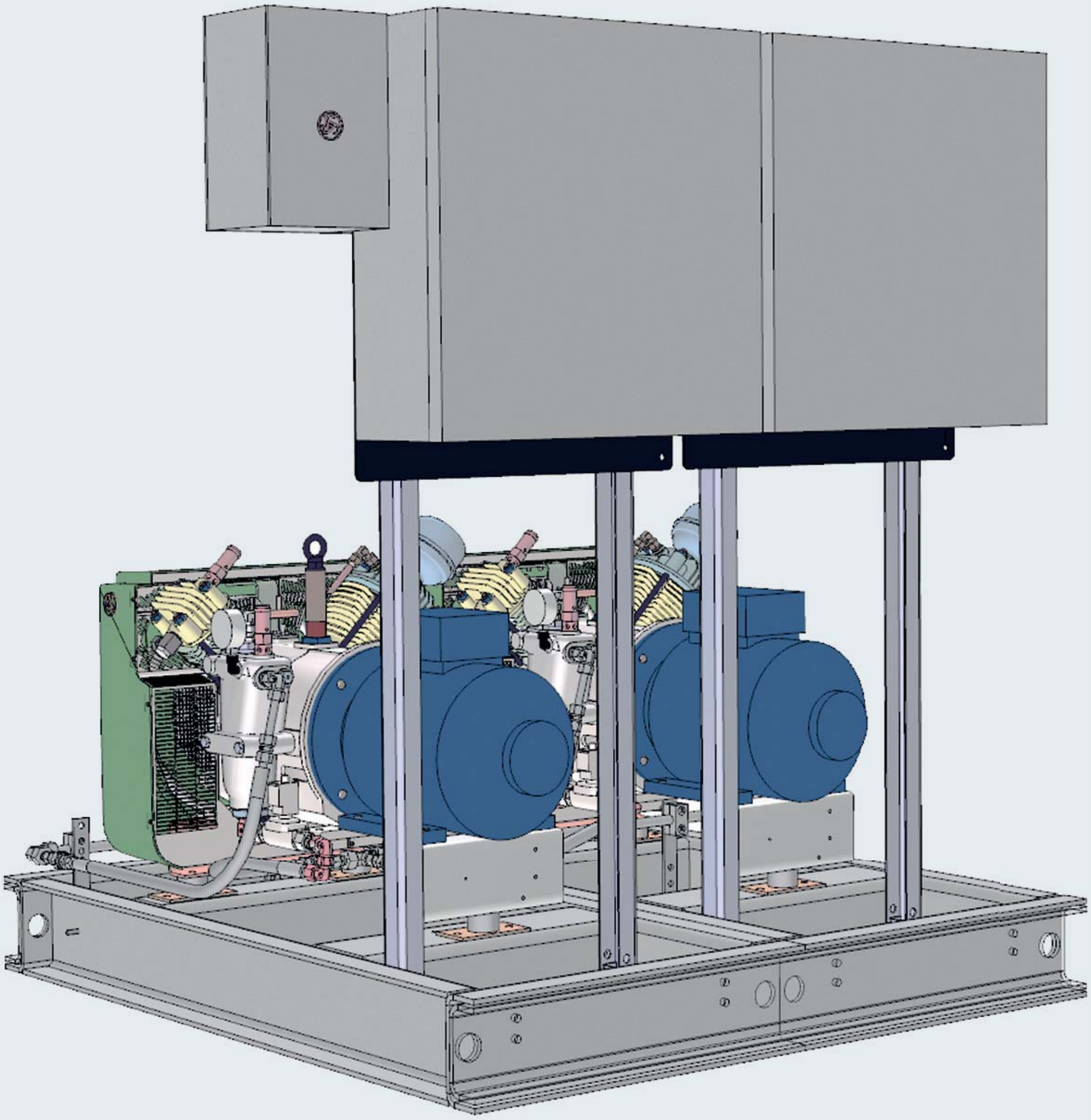


Fig. 8-3 Compressor AC1, stand-by compressor AC2

Dimensions:

Width: 1,250 mm
Length: 1,350 mm
Height: 1,550 mm
The dimensions of the compressor module do not depend on the type of compressor.
Weight of twin compressor assembly incl. electrical cabinet: approx. 600 kg

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]
ΣV= 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)

Type	Final pressure max. bar	Stages	Cylinder	Speed	Technical data for a final pressure of 30 bar			
					Charging capacity	Power consumption	Heat dissipation	Weight
					[m³/h]	[kW]	[kJ/sec]	[kg]
15	40	2	2	1,180	12.0	2.7	5	135
15	40	2	2	1,480	15.0	3.4	5	135
15	40	2	2	1,780	18.0	4.1	6	135
22	40	2	2	1,180	17.0	3.5	5	135
22	40	2	2	1,480	21.0	4.4	7	135
22	40	2	2	1,780	25.0	5.4	8	135
33	35	2	2	1,180	23.0	5.1	6	145
33	35	2	2	1,480	30.0	6.5	9	145
33	35	2	2	1,780	35.0	7.8	10	145

The dimensions and weights are given by approximation.

8.2.2 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.

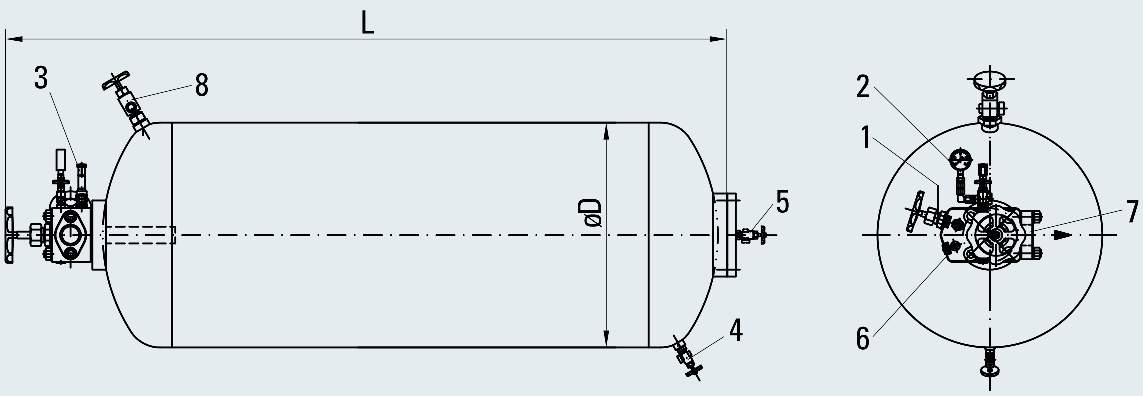


Fig. 8-4 Air receiver AT1, AT2

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		

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)

Receiver capacity acc. to GL recommendation AT1/AT2

Single-engine plant 2 x 250 l
Twin-engine plant 2 x 500 l

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.

8.3 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.)

8.4 Optional equipment

Compressor module

Caterpillar Motoren can design, offer and deliver integrated compressor modules:
Starting air receiver and compressors can be combined individually.
For further information see table Air receiver AT1, AT2 (see chapter 8.2.2)

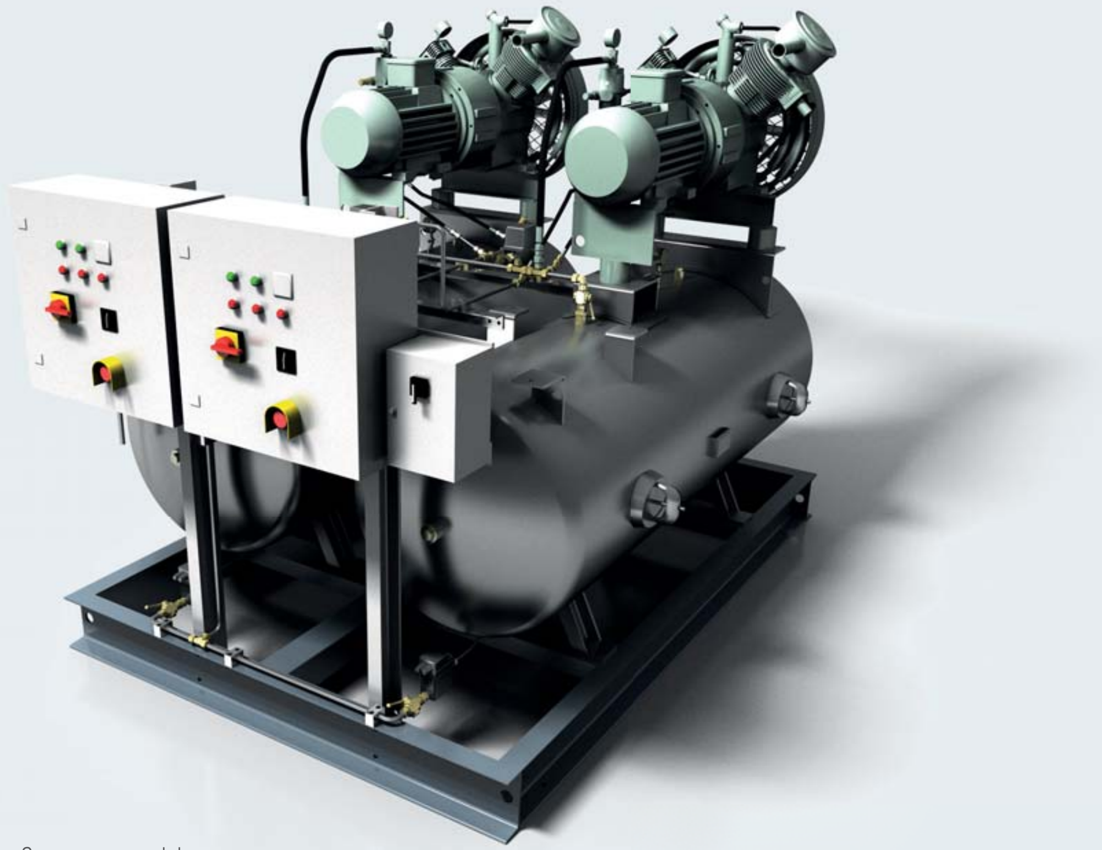


Fig. 8-5 Compressor module

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 3, 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 30 mbar. Higher values will increase the thermal load of the engine and may lead to higher fuel consumption.

10.1 Components

10.1.1 Exhaust gas nozzle

For an optimal integration of the engine in the engine room, regarding the discharge of the emitted exhaust gases different positions of the exhaust gas nozzle are possible.
The basic orientation of the exhaust gas nozzle for all M 32 E engines, achieved by a transition piece from the vertical line, are: 0 °, 30 °and 60 °. For the 8 and 9 M 32 E engines additional standard orientations of 45 ° and 90 ° from the vertical line are available.

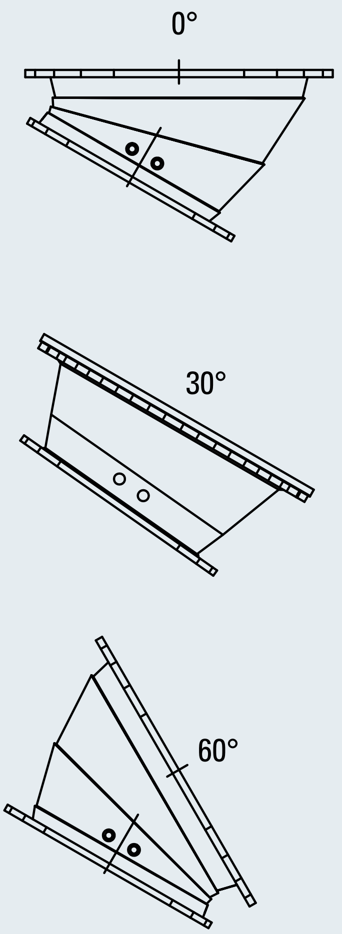


Fig. 10-1 6 M 32 E nozzle orientation

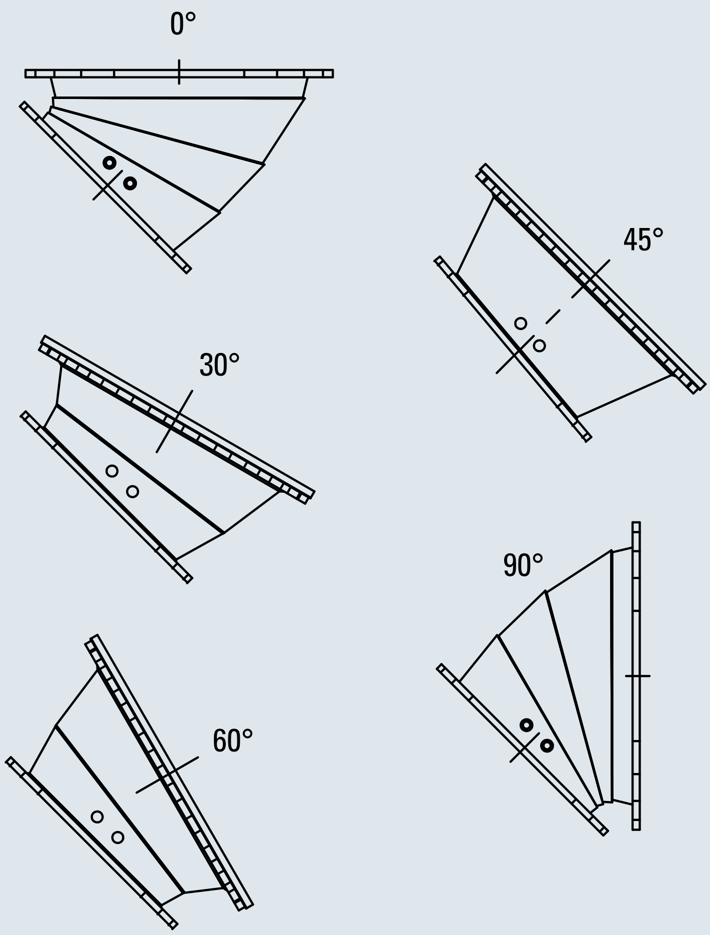


Fig. 10-2 8/9 M 32 E nozzle orientation

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 the 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.

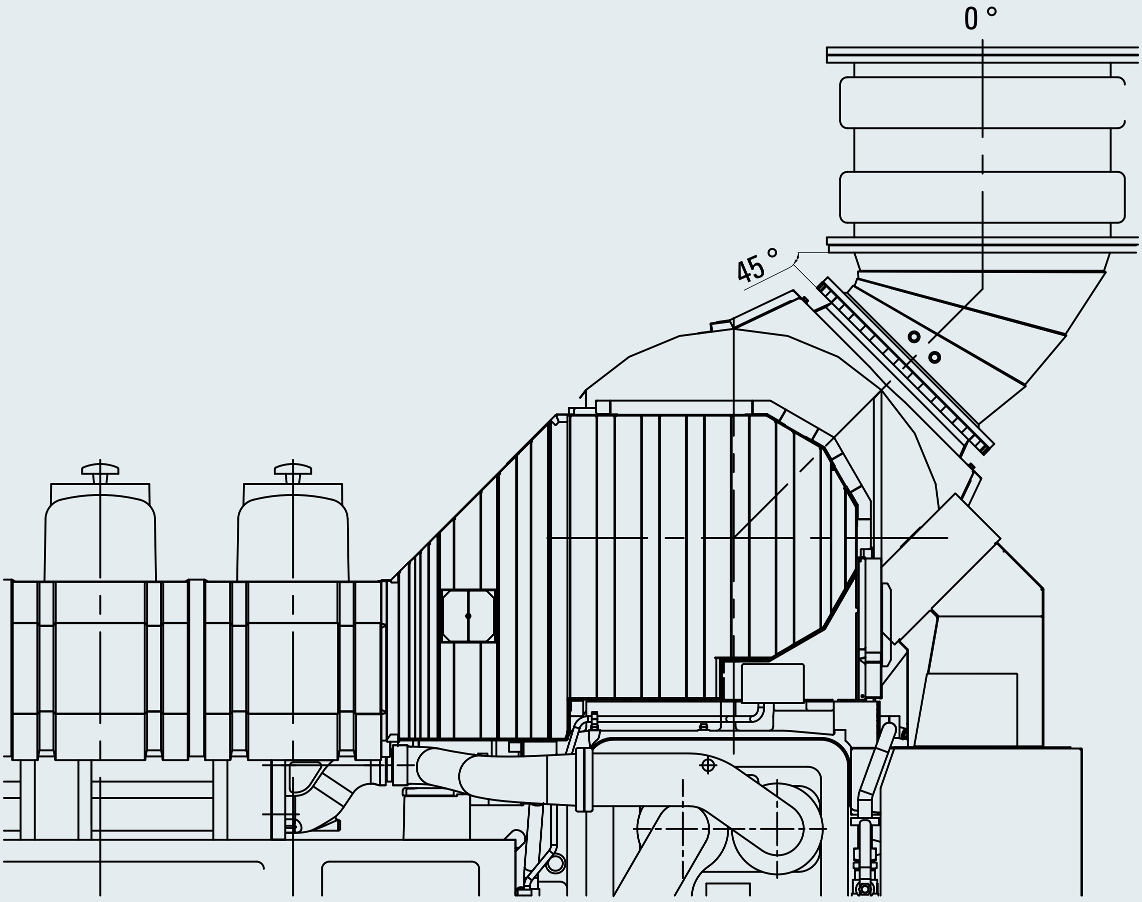


Fig. 10-3 Exhaust gas compensator

Basic design values of the standard exhaust gas compensators.

Type	Diameter [mm]	Length [mm]	Weight [kg]
6 M 32 E	600	450	107
8/9 M 32 E	700	520	137

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.

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.

NOTE:
Max. pressure loss (incl. silencer and exhaust gas boiler): 30 mbar (lower values will reduce thermal load of the engine).

Resistance in exhaust gas piping

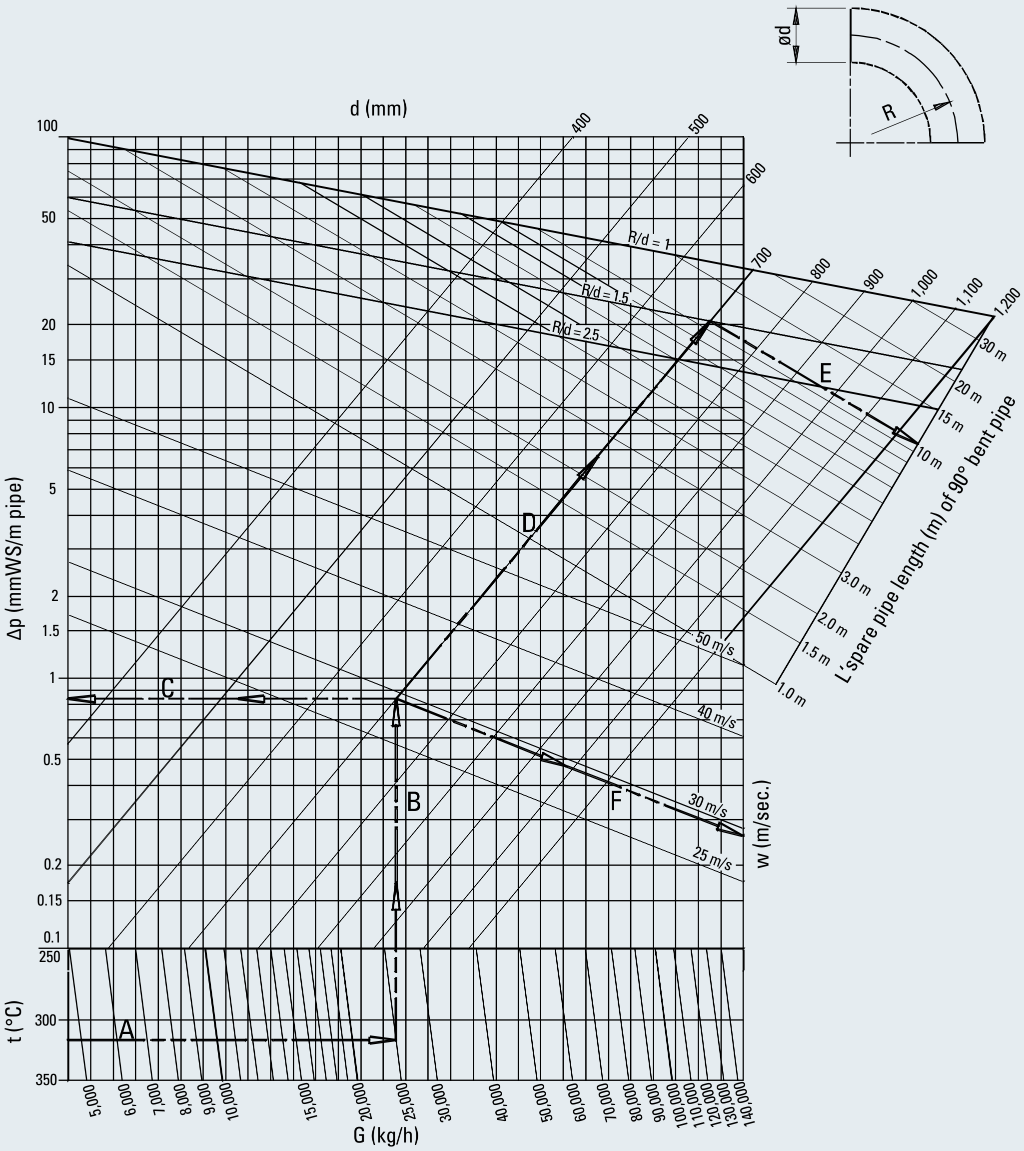


Fig. 10-4 Resistance in exhaust gas piping

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]

10.1.4 Silencer

General

Design according to the absorption principle with wide-band attenuation over a wide frequency range and low pressure loss due to straight direction of flow. Sound absorbing filling consisting of resistant mineral wool.

Dimension

Installation: vertical to horizontal
Flanges according to DIN 86044
Incl. counterflanges, screws and gaskets
Without supports and insulation

Silencer

Sound level reduction 35 dB(A) (standard). Max. permissible flow velocity 40 m/s.

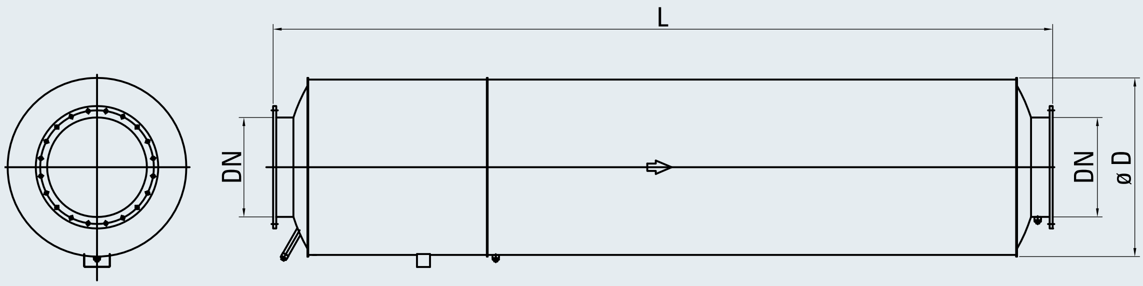


Fig. 10-5 Silencer

Silencer with spark arrestor

Soot separation by means of a swirl device (particles are spun towards the outside and separated in the collecting chamber). Sound level reduction 35 dB(A). Max. permissible flow velocity 40 m/s.
Silencers are to be insulated by the yard. Foundation brackets can be provided as an option.

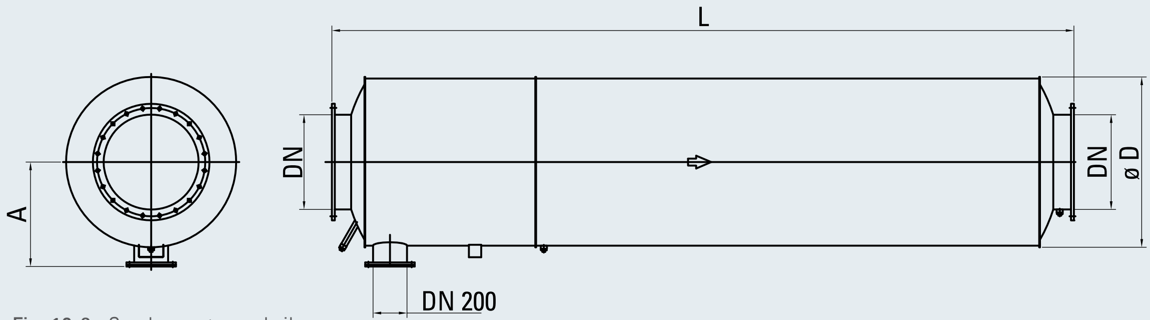


Fig. 10-6 Spark arrestor and silencer

Type	Dimensions [mm]				Weight	Weight with spark arrestor
	DN	A	D	L	[kg]	[kg]
6 M 32 E	600	675	1,100	4,800	1,300	1,350
8/9 M 32 E	700	775	1,300	5,200	1,650	1,800

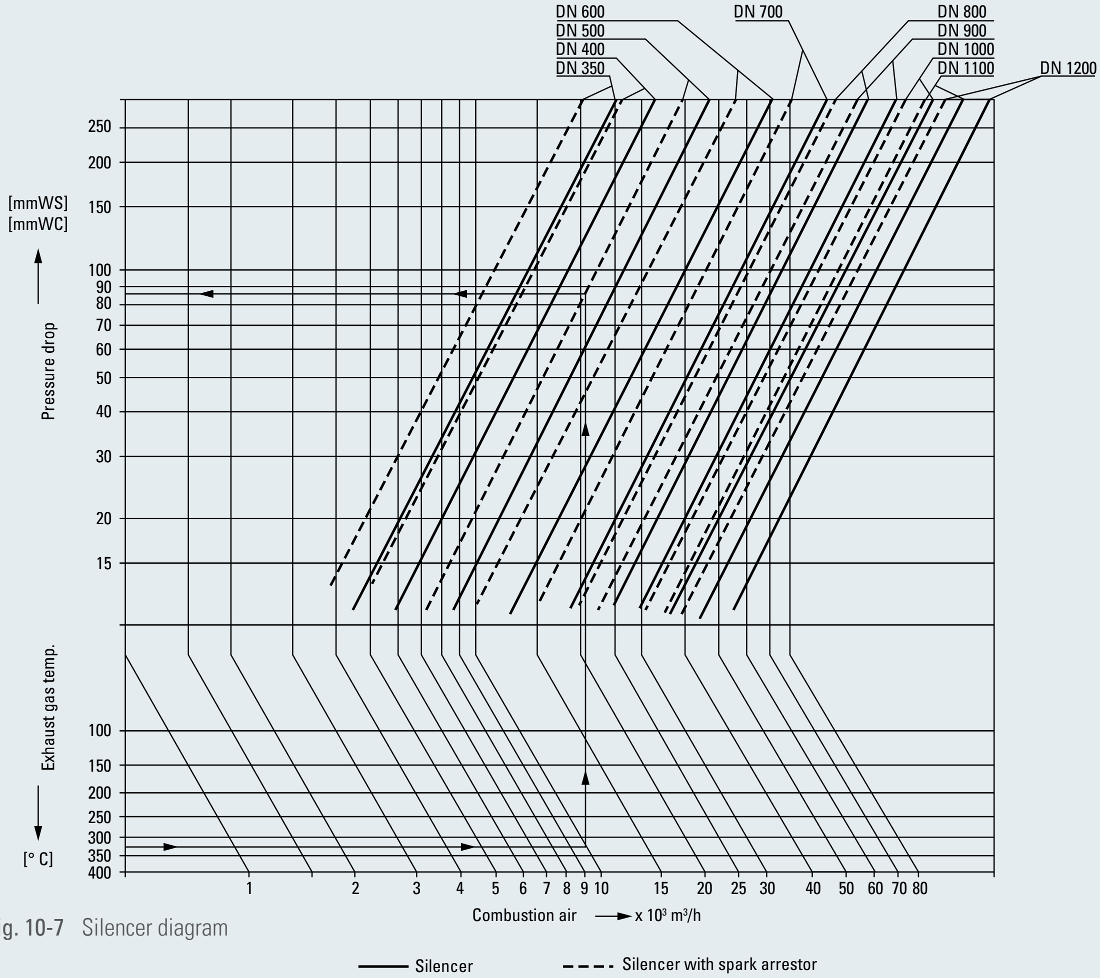


Fig. 10-7 Silencer diagram

10.1.5 Exhaust gas boiler

ATTENTION:
Each engine should have a separate exhaust gas boiler. Alternatively, a common boiler with separate gas sections for each engine is acceptable.

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 approx. 10 minutes (2 intervals). Fresh water of 1.5 bar for 6 M 32 E and 2.5 bar for 8/9 M 32 E is required.

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

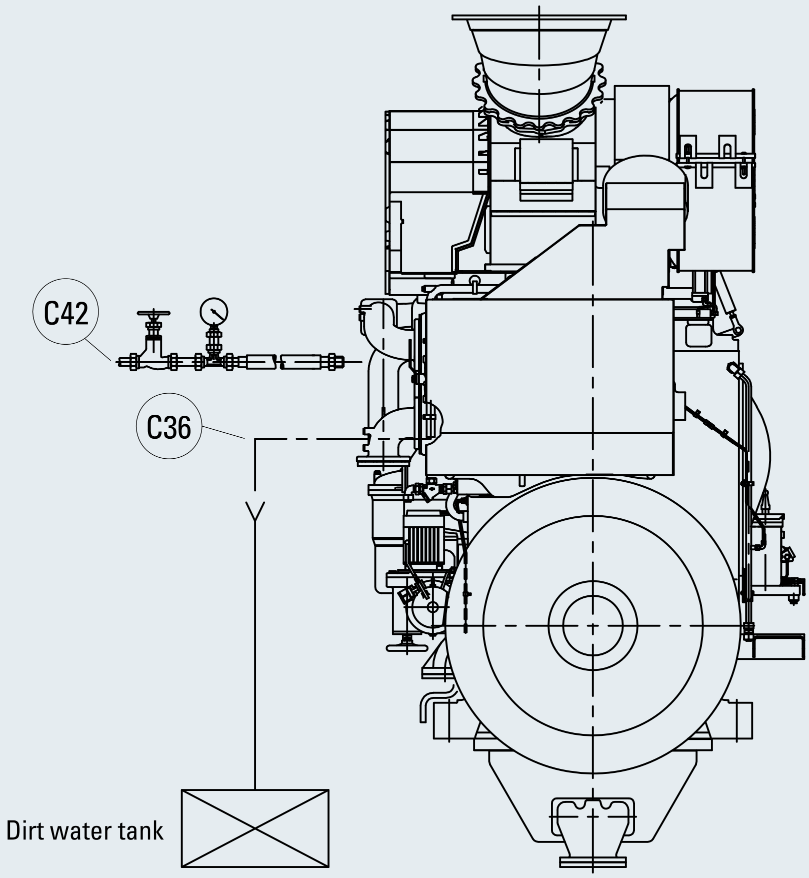


Fig. 10-8 Connection points freshwater and drain

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

C36 Drain, DN 30

Type	Water flow [l/min]	Injection time [min]
6 M 32 E	12	10
8/9 M 32 E	18	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. Urea 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.

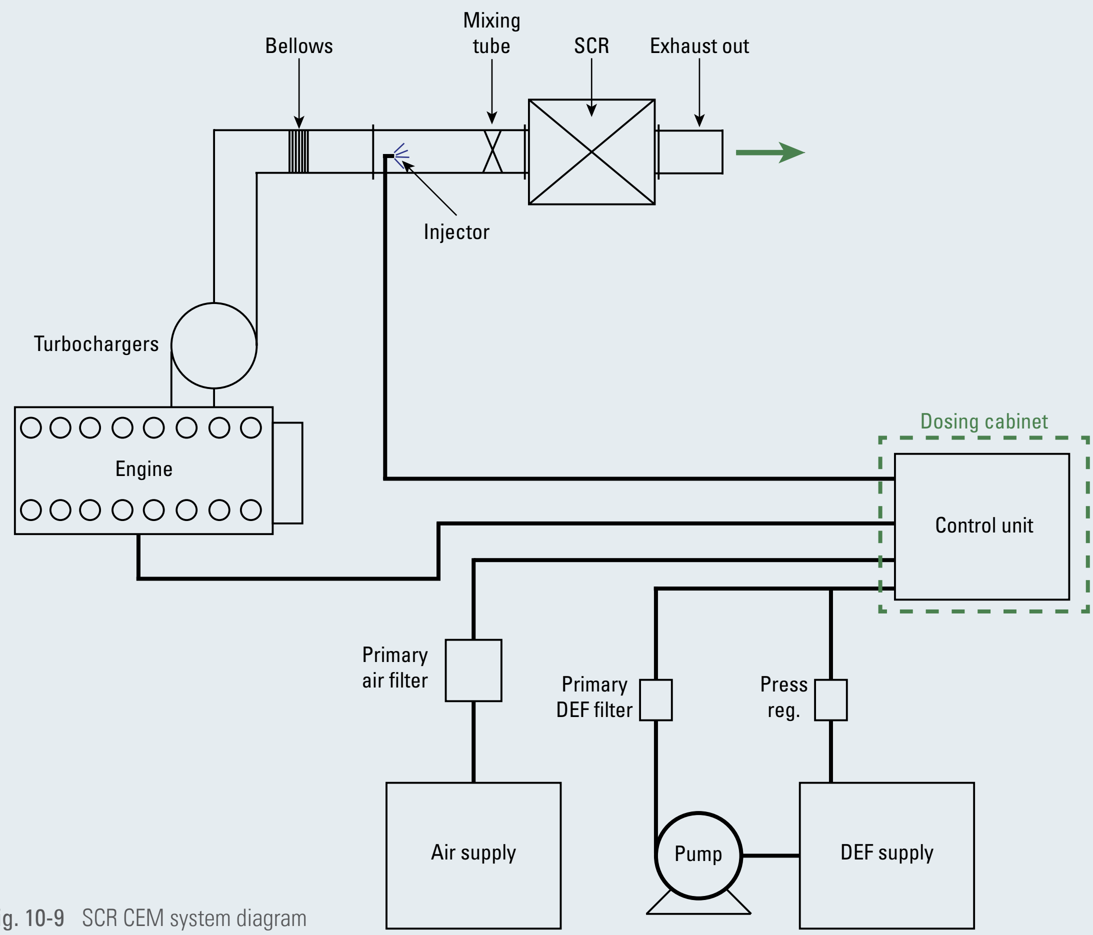


Fig. 10-9 SCR CEM system diagram

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 the exhaust gas temperature control unit.

Cat SCR System standard scope of supply:

- Reactor housing with catalyst
- Mixing tube with urea injection lance
- NO_x, temperature and pressure sensors
- Urea dosing cabinet with ECM and closed loop function
- On-engine exhaust gas temperature control
- Set of flanges
- Scheme A certificate IMO Tier III
- EPA Tier III certificate on request

Cat SCR System optional scope of supply:

- Urea transfer pump skid for transfer of urea from urea tank to dosing cabinet, MCS certified
- Wiring kit for ease of installation, for connecting dosing unit, mixing tube and reactor housing, and plugs, cable and junction box

Not included in standard scope of supply:

- Urea storage tank
- Piping
- Insulation

10.3.1 Portfolio, size and dimensions

Installation of SCR System

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

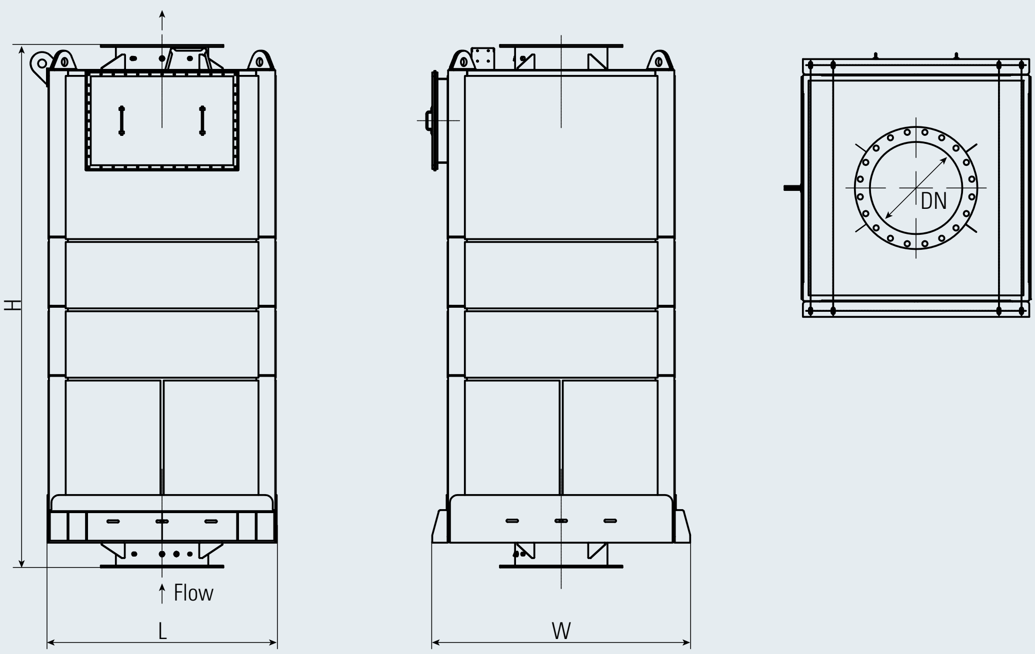


Fig. 10-10 Size and dimensions

	SCR reactor housing			Mixing tube			Dosing cabinet	
	Dimensions	Flange size	Weight incl. catalyst	Length	Flange	Weight	Dimensions	Weight
	L x W x H [mm]	[DN]	[kg]	[mm]	[DN]	[kg]	L x W x H [mm]	[kg]
6 M 32 E	2,160 x 2,363 x 4,455	900	4,289	3,657	700	263.4	940 x 500 x 585	95
8 M 32 E			4,528					
9 M 32 E							1,010 x 553 x 634	140

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.

Load	Typical brake specific urea consumption [g/kWh] Urea solution concentration: 40 %
100 %	12
75 %	15
50 %	16

Tolerance 5%. The values of the urea consumption apply to the basic version of the M 32 E propulsion engine.

Fuel consumption with Cat SCR after treatment:

The reactor housing and the substrate cassettes of the Cat IMO Tier III SCR aftertreatment systems are optimized to be used in combination with the M 32 E engines and their emission behavior. However the aftertreatment system generates a higher exhaust gas pressure which results in a slightly increased fuel consumption of about 1 g/kWh, no matter if the engine is operating in IMO Tier II or IMO Tier III mode.

Nitrogen oxide emissions (NO_x-values) with Cat SCR after treatment

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 after treatment:

The engine technical data may differ in combination with Cat SCR after treatment. 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, urea 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 4
Air flow capacity	17 m³/hr
Air consumption	continuous when system is dosing
Air pressure	4.85 to 10.7 bar gauge
Urea supply	
Urea quality	ISO 22241-1
Urea solution concentration	40 %
Air consumption	continuous when system is dosing
Urea 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 [1)]	MGO/MDO

1) 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 placstics 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 CPP

1	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		

11.2 Remote engine control

Remote control for single-engine plant with one controllable pitch propeller

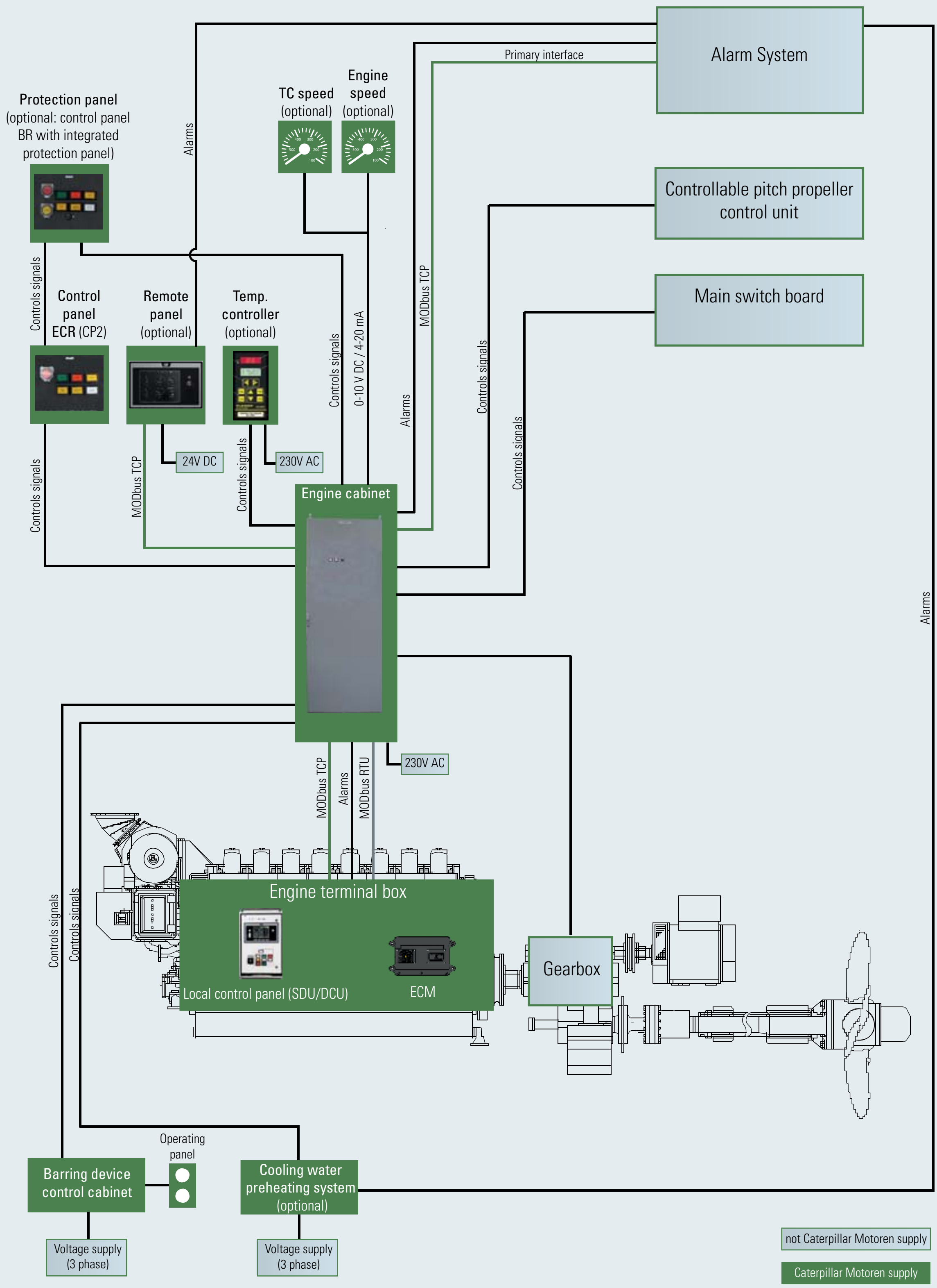


Fig. 11-2 Remote control for single-engine plant with one controllable pitch propeller

Remote control for twin-engine plant with one controllable pitch propeller

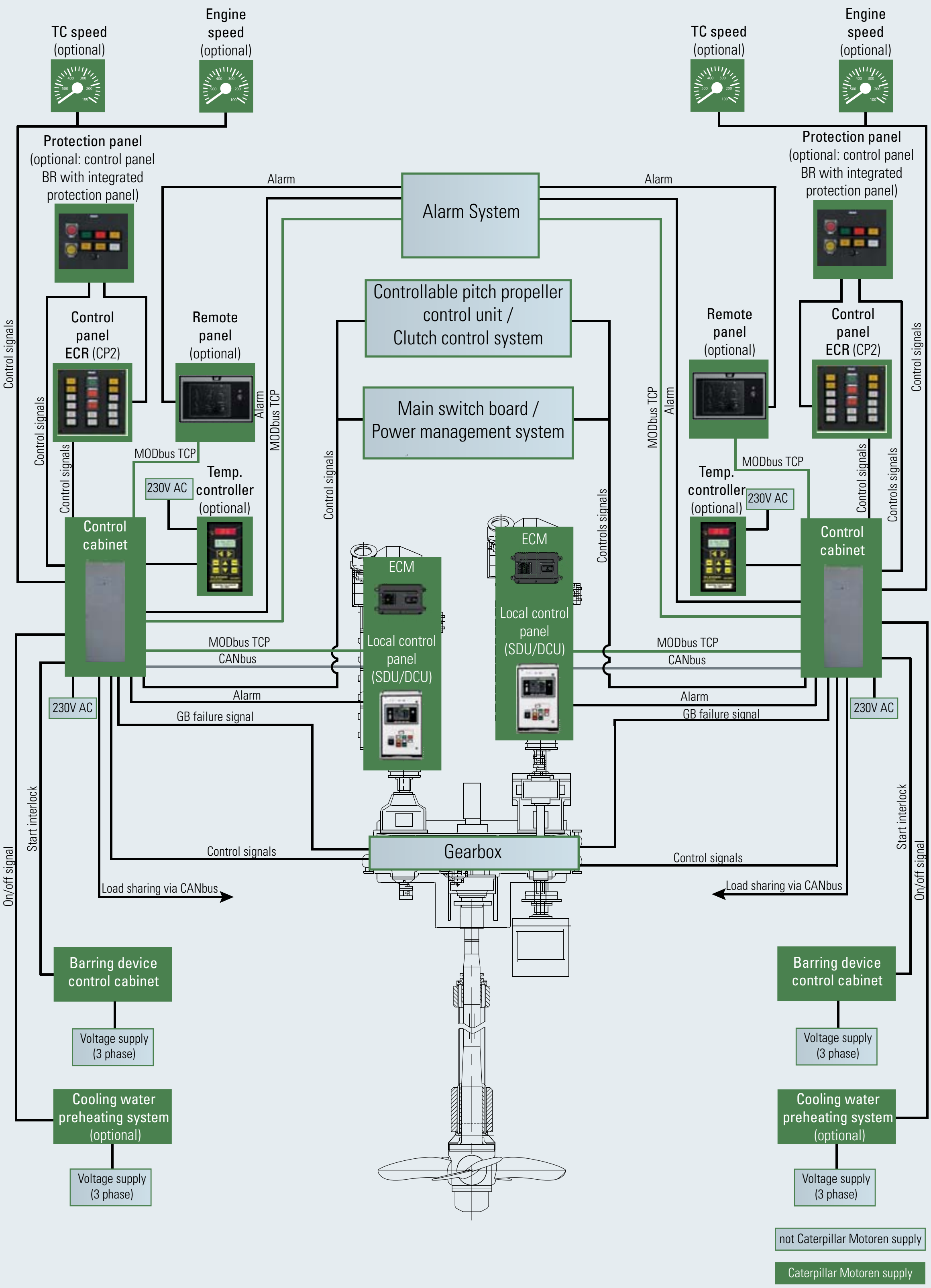


Fig. 11-3 Remote control for twin-engine plant with one controllable pitch propeller

11.3 Data link overview

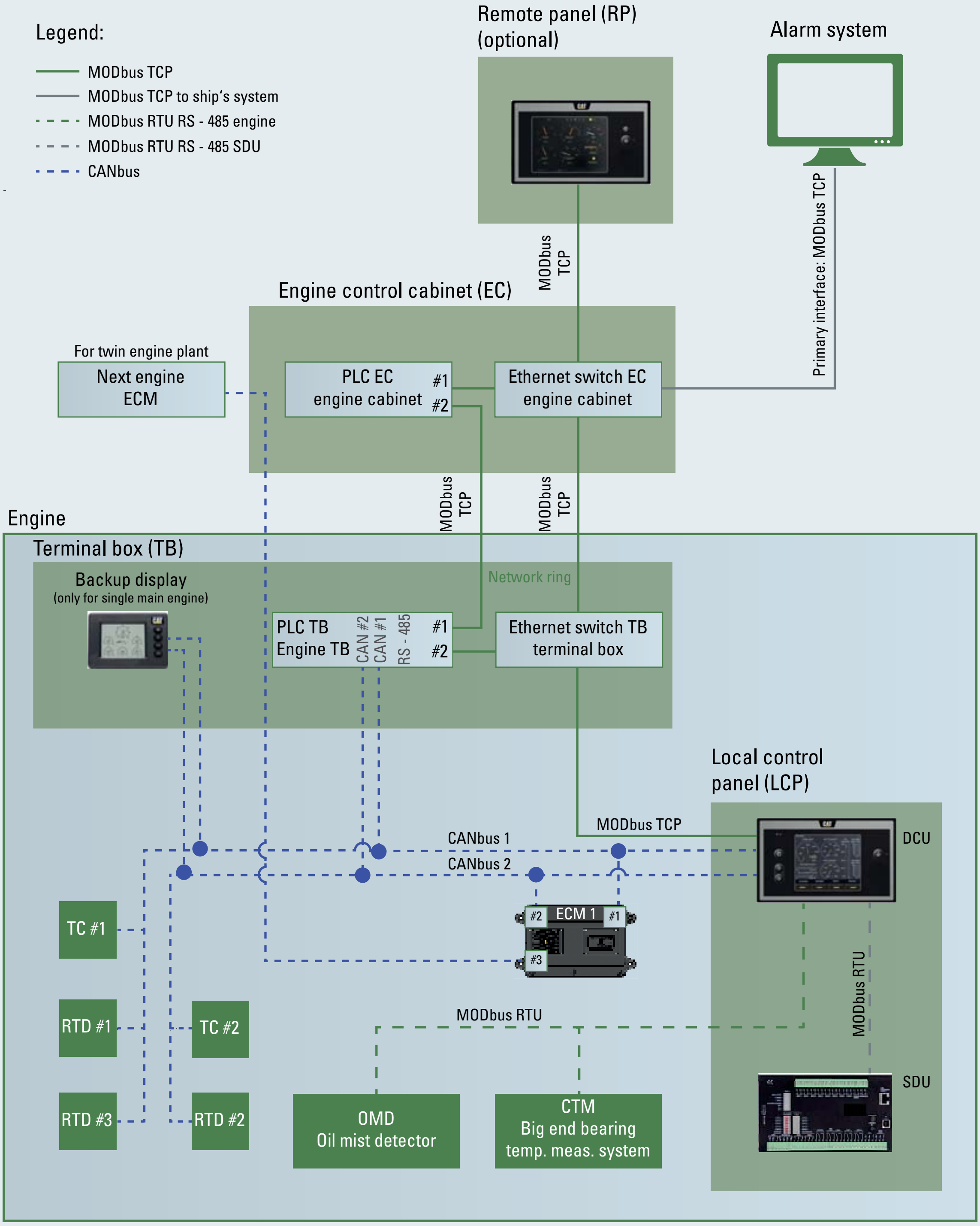


Fig. 11-4 Data link overview – M 32 E

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 #1 e.g. charge air temperature
PT100 module #2 e.g. lube oil temperature
PT100 module #3 e.g. cooling water HT
TC
Exhaust temperature module #1 (thermocouples)
Exhaust temperature module #2 (thermocouples)
RP
Remote panel (optional)

MACS

Modular Alarm Control System

ECM
Engine control module
OMD
The oil mist detector measures each cylinder.
Load sharing system
Load sharing according to master/slave principle for twin engine plant with common gearbox.
CTM
Big end bearing temperature monitoring (optional)
Each cylinder is measured by the CTM.
Back Up Display
Required for single main engine, optional for twin engine plant.

Regardless of RTU or TCP, the MODbus address registers are the same. Just the hardware protocol differs.

MODbus TCP

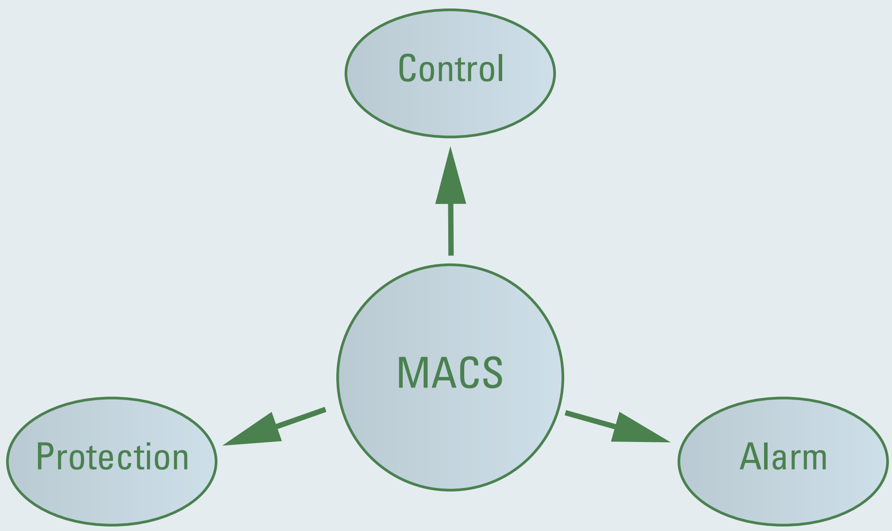
At MODbus TCP a connection between server and client will be established. Therefore an IP address will be assigned.

MODbus settings

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

11.4 Components

Modular Alarm and Control System (MACS)



The M 32 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
- Start and stop sequence control
- Critical parameter monitoring
- Purge control
- Flexible camshaft technology (FCT monitoring)
- Exhaust gas termperature monitoring
- Main and big end bearings temperature monitoring

Engine control module (ECM)

The engine control module controls the fuel system, air fuel ratio, engine speed 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).
For multiple engine operation the ECM provides also load sharing functions. An isochronous load distribution by master/slave principle or droop operation is possible.

Oil mist detector

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)

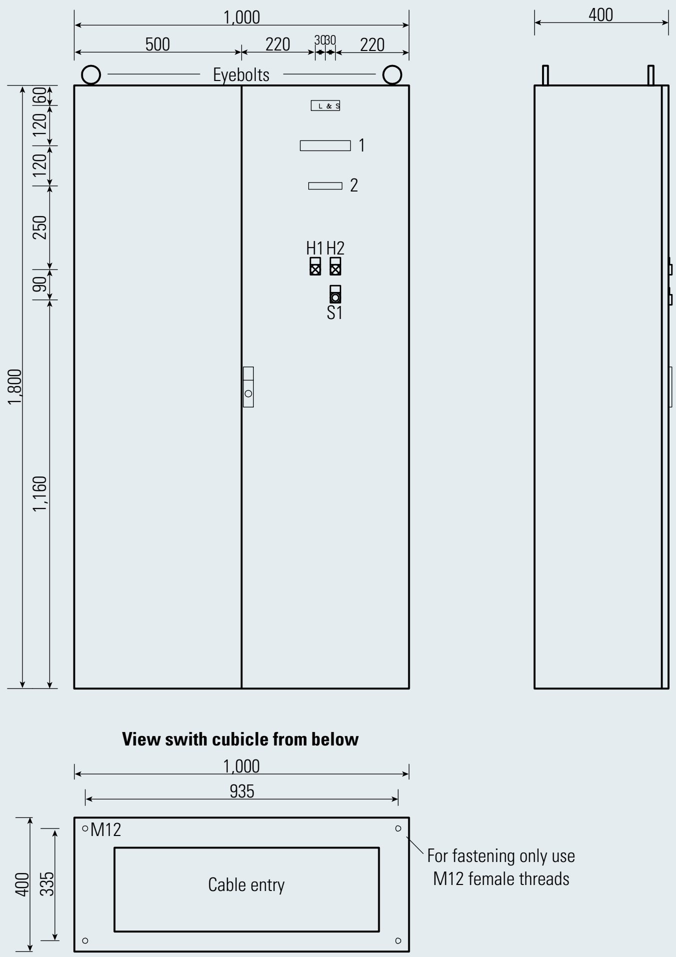
The big end bearing temperature monitoring system measures the temperature for each big end bearing and generates an alarm for high temperature. The data are available by MODbus RTU at the DCU. Hardwired outputs are also provided.

Back up display

In case of main display failure, all important information are available in the back up display.

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
1/2:	Identification labels

Degree of protection: IP54

Switch cubicle weight: Approx. 210 kg

Fig. 11-5 Control panel

The cabinet must be installed in a horizontal position.
The positioning and fastening has to effect corresponding to environmental conditions. For dynamic loads the M12 threads must be used for installation and the cabinet must also be fixed on the top. Only for static installations the 16 mmfastening holes can be used.

NOTE:
After the transport the fastening holes of the eyebolts M12 female thread can be used for switch cubicle fastening.

11.6 Requirement on Control Pitch Propeller (CPP) system

Standard interface to gearbox and controllable pitch propeller for single-engine system

Gearbox	Lube oil pressure low (NO)	binary	→	24 V DC	Starting interlock for engine	Main engine
Gearbox	Common load reduction (NO)	binary	→	24 V DC	Slow down for engine	Main engine
Gearbox	Lube oil pressure low low (NO)	binary	→	24 V DC	Shut down for engine	Main engine
CPP control / clutch control	Actual engine speed		←	4 - 20 mA	Engine speed	Main engine
CPP control / clutch control	Actual fuel rack position		←	4 - 20 mA	Fuel rack position 0 - 110 %	Main engine
CPP control / clutch control	Main engine in overload	24 V DC	←	binary	Used for overload indication	Main engine
CPP control / clutch control	Request remote control	24 V DC	←	binary	Local / remote switch contact at engine	Main engine
CPP control / clutch control	Accept remote control	binary	→	24 V DC	Remote control accepted	Main engine
CPP control / clutch control	Local / remote control	24 V DC	←	binary	Closed contact when main engine 1 is in remote control	Main engine
CPP control / clutch control	Reduce to 40 % load	24 V DC	←	binary	Slowdown at engine	Main engine
CPP control / clutch control	Pitch to zero / auto clutch out	24 V DC	←	binary	Shutdown at engine	Main engine
CPP control / clutch control	Speed setting signal	4 - 20 mA	→		Speed setting signal mechanical governor	Main engine
CPP control / clutch control	Clutch engaged or pitch not zero	binary	→	24 V DC	Starting interlock	Main engine

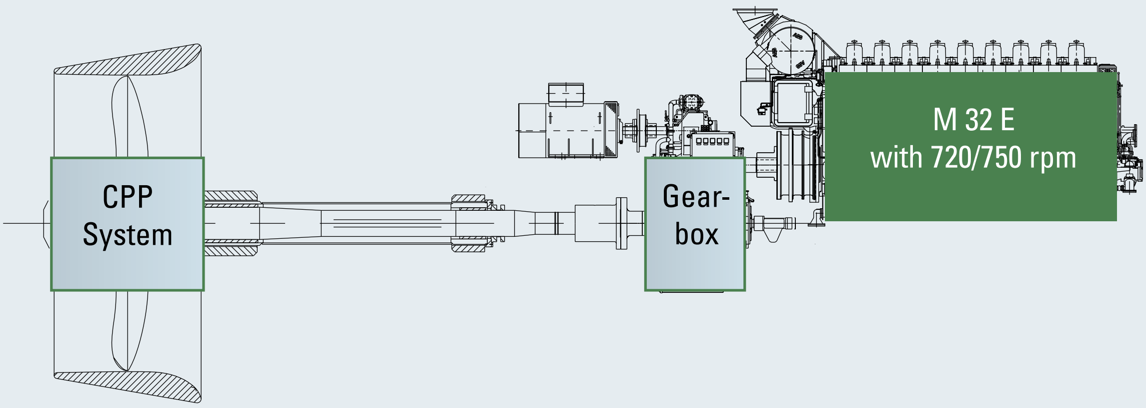


Fig. 11-6 Standard interface to gearbox and controllable pitch propeller for single-engine system

11.6.1 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.

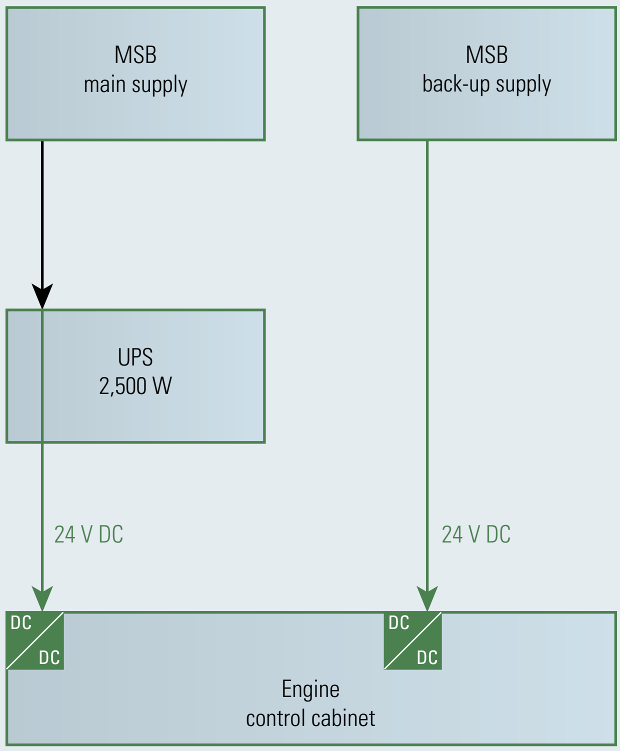


Fig. 11-7 Uninterruptable power supply - variants

11.7 Alarm indication

In general, the engine is equipped with the relevant alarm and safety sensor according 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 received measurement values and data from all I/O modules, PLC's and the engine control systemm (ECM). Furthermore it provides all measurement values, status values and alarms via MODbus TCP (MODbus RTU, optional) for the vessels system and the remote monitoring system. The engines 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 MACS.

Fig. 11-8 Remote panel

Fig. 11-9 DCU (display and alarm system)

For the interface to ships alarm system (IAMCS) the following functions are applicable:

- Transmitting measurement data to IAMCS
- Transmitting engine status to IAMCS
- Transmitting alarm to IAMCS
- Receiving ships 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.

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

A project related list of measuring 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 activate a starting interlock (STBL).

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

11.8 Local and remote indicators

Local indicators	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	
Fuel rack position (mean injection pump rack)	
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

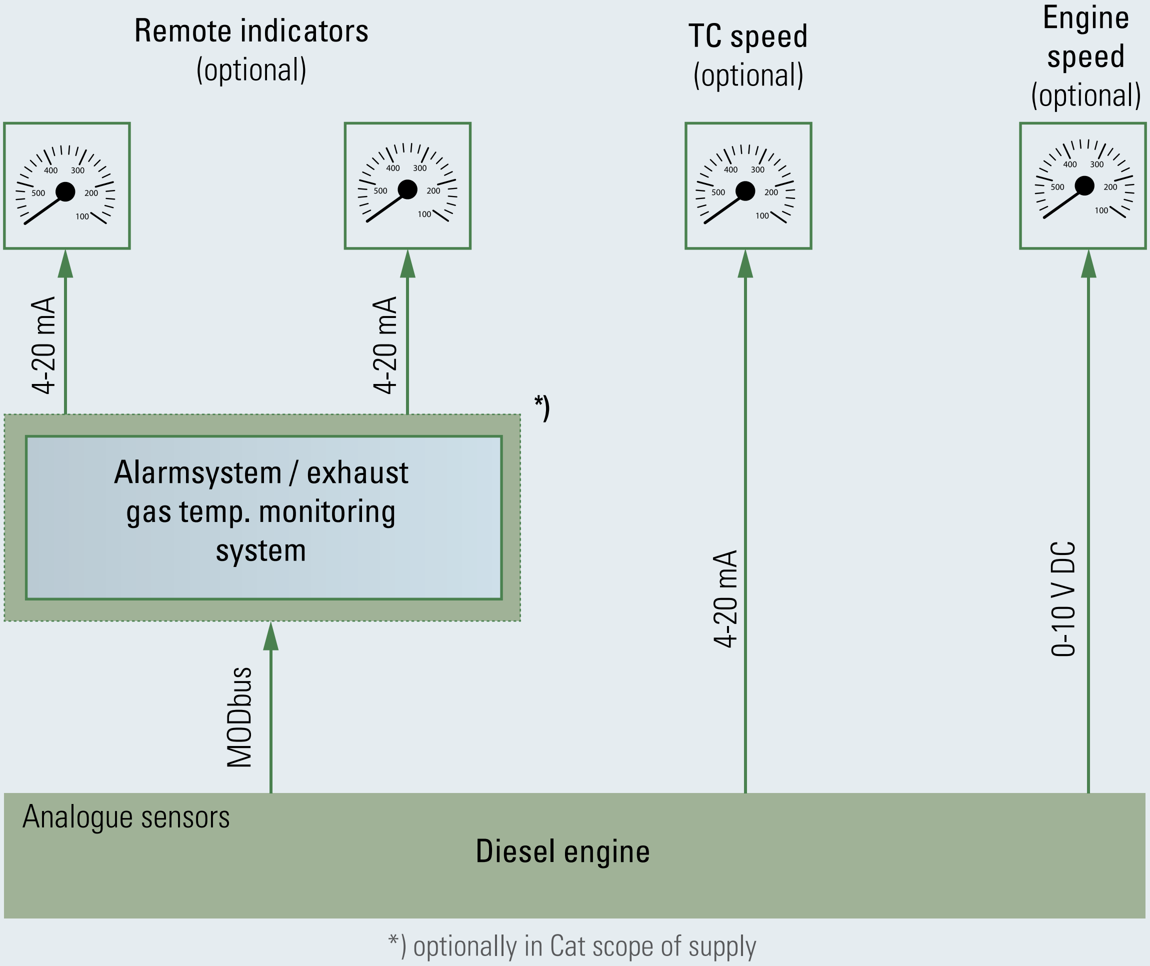


Fig. 11-10 Remote indication interfacing

11.9 Clutch control system

The diagram below shows an example of a typical soft-clutch engagement timeline, required by Caterpillar Motoren for marine main engines.
To avoid engine stalling in case of high speed drop, overload of the flexible couplings and visible smoke, the engaging operation has to be smooth and easily controllable.
Time T_2 is very important in this context: It indicates the real slipping time shich has to be minimum 3 seconds.

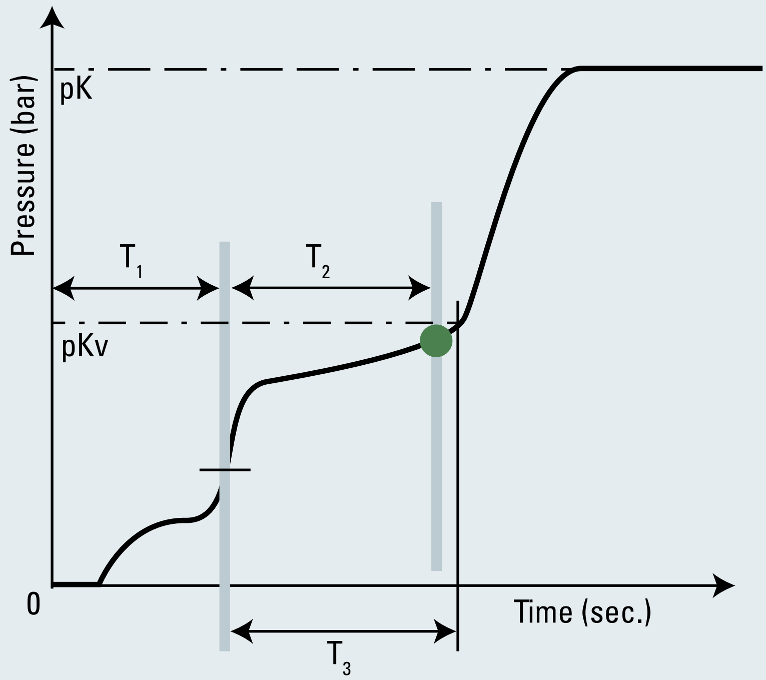


Fig. 11-11 Clutch in procedure for propulsion systems

pK	= Lube oil switching pressure
pK_V	= Control pre-pressure
T_1	= Filling time
T_2	= Slipping time
T_3	= Pressure holding time
●	= Point of synchronization

The clutch-in speed of the engine should be min. 70 % of rated speed, but could be 60 % depending on TVC.

11.10 Cat Connect for Marine provide 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

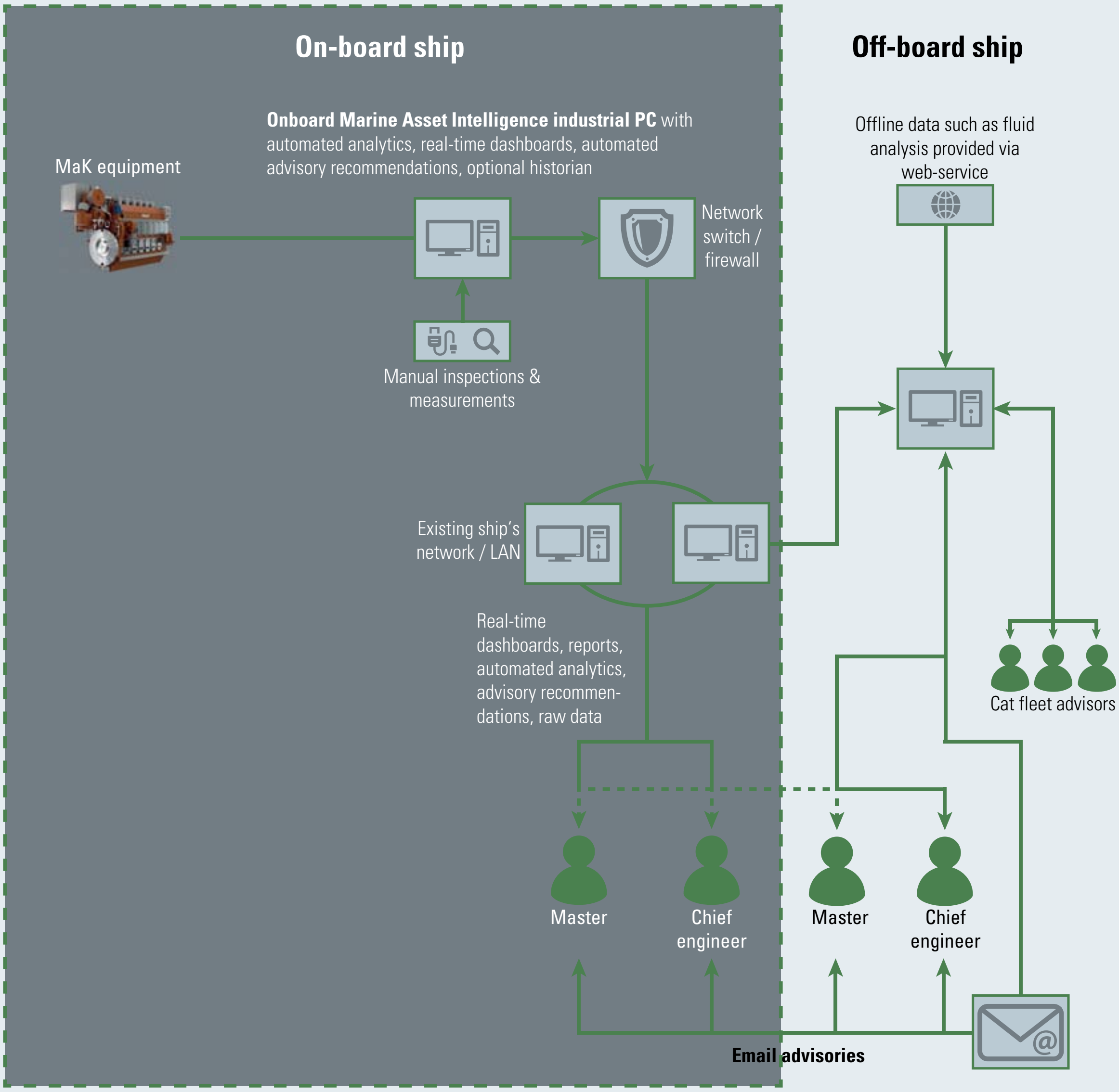


Fig. 11-12 MAI – MaK engine solution only

11.10.2 MAI - Extended solution

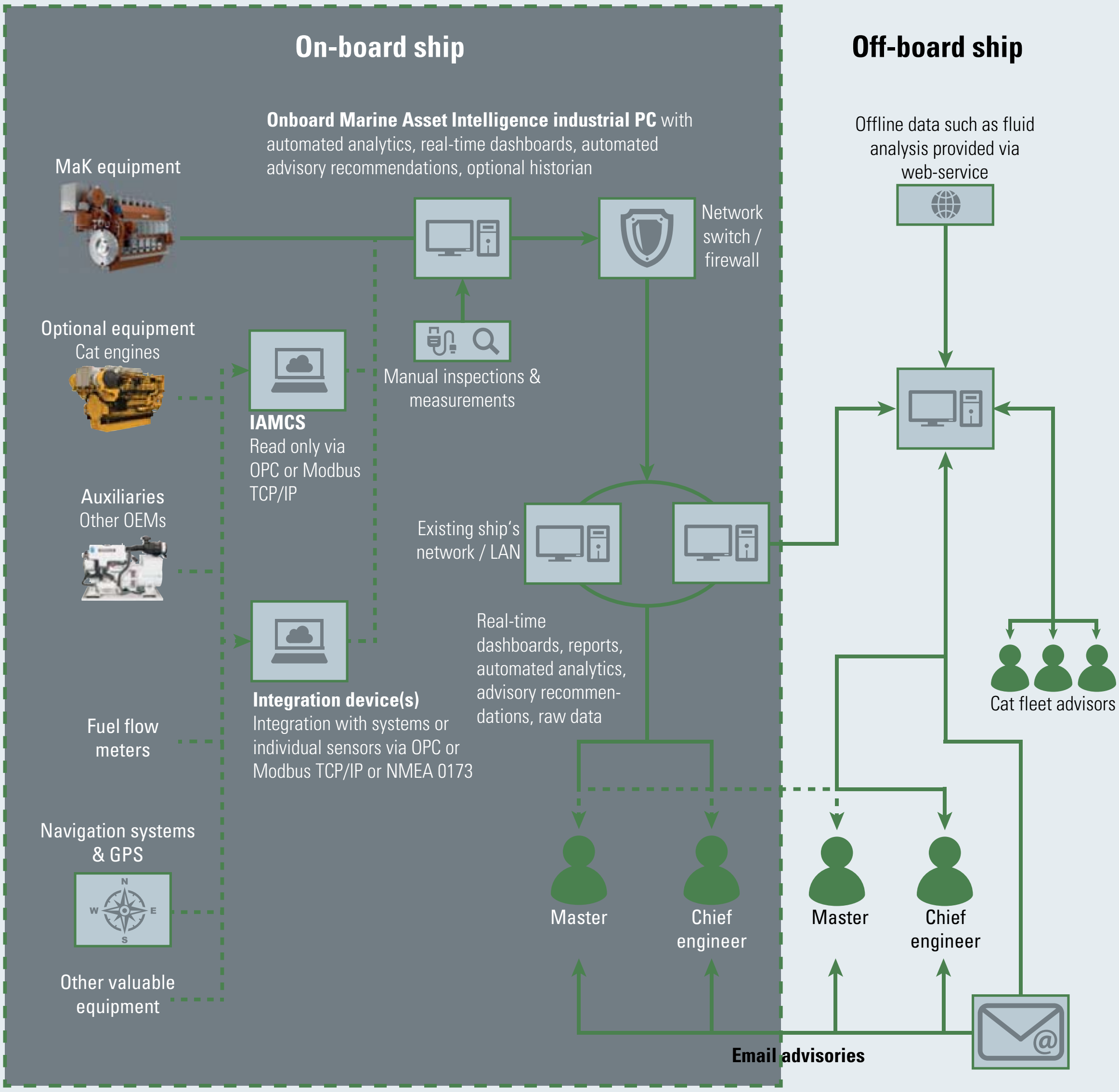


Fig. 11-13 MAI – Extended solution

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 Rigid mounting of main engines and alignment

The vertical reaction forces resulting from the torque variation are the most important disturbances to which the engine foundation is subjected. With regards to dynamic load, the indicated moments only represent the exciting values and can only be compared among each other. The effective forces to which the foundation is subjected depend on the mounting arrangement and the rigidity of the foundation itself.
In order to make sure that there are no local resonant vibrations in the ships structure, the natural frequencies of important components and partial structures should differ sufficiently from the indicated main exciting frequencies.
The dynamic foundation forces can be considerably reduced by means of resilient engine mounting.

12.1.1 General information

- The shipyard is solely responsible for the adequate design and quality of the foundation.
- Information on foundation bolts (required retightening torques, elongation, yield point), steel chocks, side stoppers and alignment bolts is to be gathered from the foundation plans.
- Examples "for information only" for the design of the screw connections will be made available as required.
- If cast resin is used it is recommendable to employ authorized workshops of resin manufacturers approved by the classification societies for design and execution.
- It has to be taken into account that the permissible surface pressure for resin is lower than for steel chocks and therefore the tightening torques for the bolts are reduced correspondingly.
- When installing the engine on steel chocks the top plate should be build with an inclination outwards from engine centerline. Wedge type chocks with the corresponding inclination only be use. The material can be cast iron or steel.

12.1.2 Engine with dry sump

Dimension of foundation dry sump pan

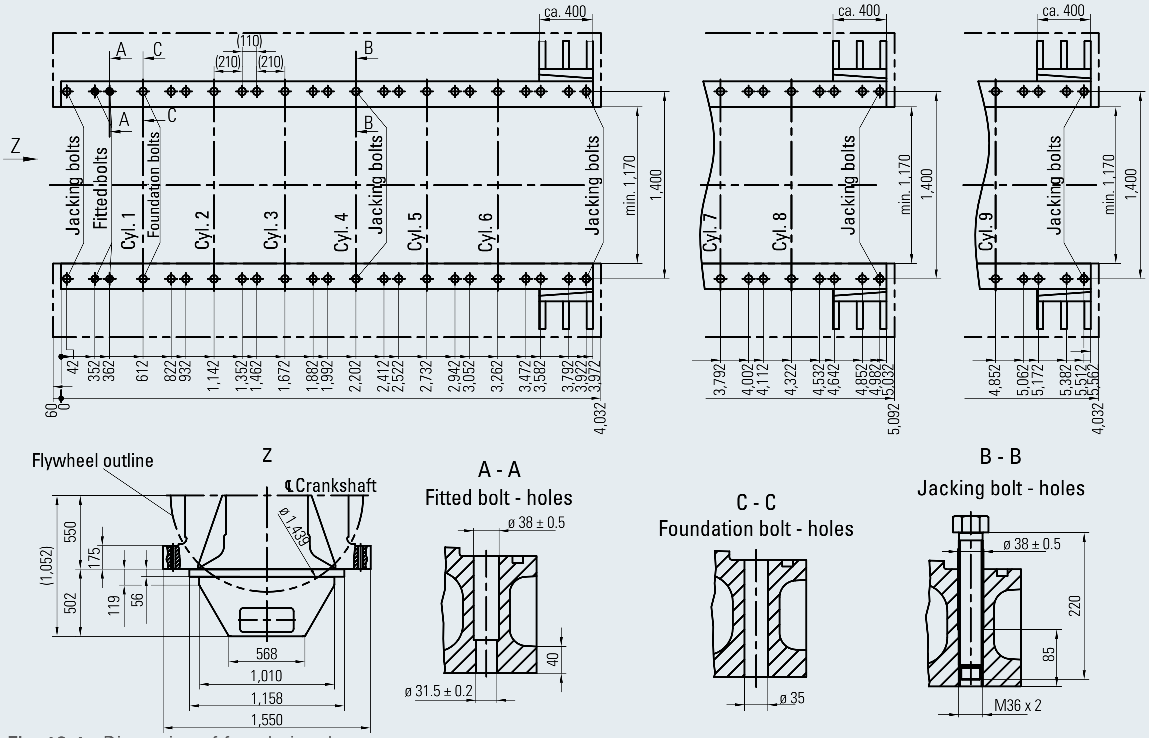


Fig. 12-1 Dimension of foundation dry sump pan

Side stoppers

6 M 32 E	8/9 M 32 E
1 Pair *	2 Pairs **

* 1 pair at the end of the bedplate / ** 1 pair at the end of the bedplate and 1 pair between cyl. 4 and 5

Side stopper to be with 1 wedge (see fig. 12-1). Wedge to be placed at operating temperature and secured by welding. Dimensioning according to classification society and cast resin suppliers requirements.

Number of bolts

	Fitted bolts	Foundation bolts	Jacking bolts
6 M 32 E	4	36	6
8 M 32 E	4	48	6
9 M 32 E	4	54	6

Jacking bolts

- To be protected against contact / bond with resin
- After setting of resin dismantle the jacking screws completely

To be supplied by yard:

Foundation bolts, fitted bolts, nuts and tension sleeves, side stoppers, steel chocks, cast resin.

The shipyard is solely responsible for adequate design and quality of the foundation.

Proposal for rigid mounting

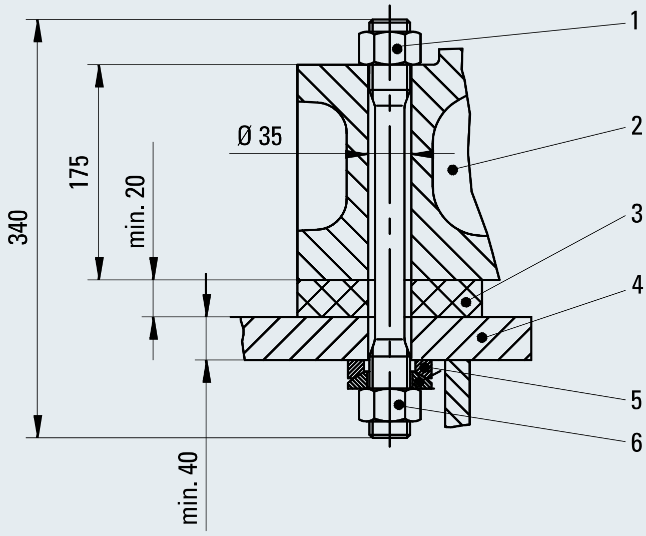


Fig. 12-2 Through bolt

1	Hexagon nut, EN ISO 4032 M36	4	Top plate
2	Engine foot	5	Spheric washers DIN 6319 C37 / D37
3	Cast resin chock	6	Hexagon nut, EN ISO 4032 M36

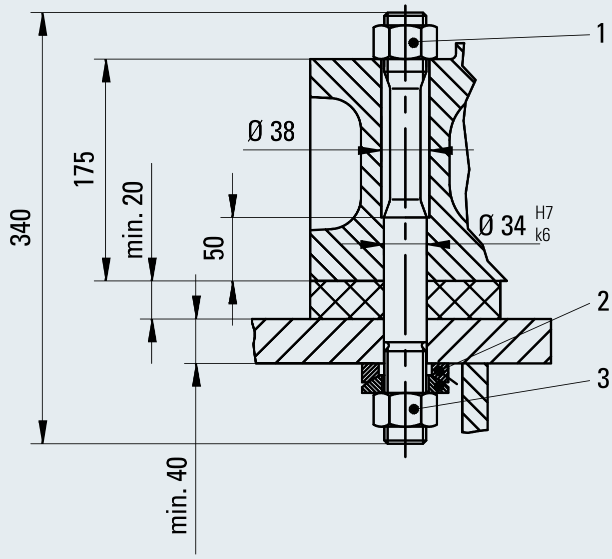


Fig. 12-3 Fitted bolt

1	Hexagon nut, EN ISO 4032 M33	3	Hexagon nut, EN ISO 4032 M36
2	Spheric washers, DIN 6319 C37 / D42		

Tightening force		Pre tightening torque (oil) – angle of rotation			
Through bolts M 33	Fitted bolts M 33	Through bolts M 33		Fitted bolts M 33	
[N]	[N]	M [Nm]	° (grad)	M [Nm]	° (grad)
125,000	125,000	90	70	90	70

Final foundation bolts design and tightening torque by cast resin chock supplier.
Design responsibility is with the shipyard.

12.1.3 Engine with wet sump

Dimension of foundation wet sump (option)

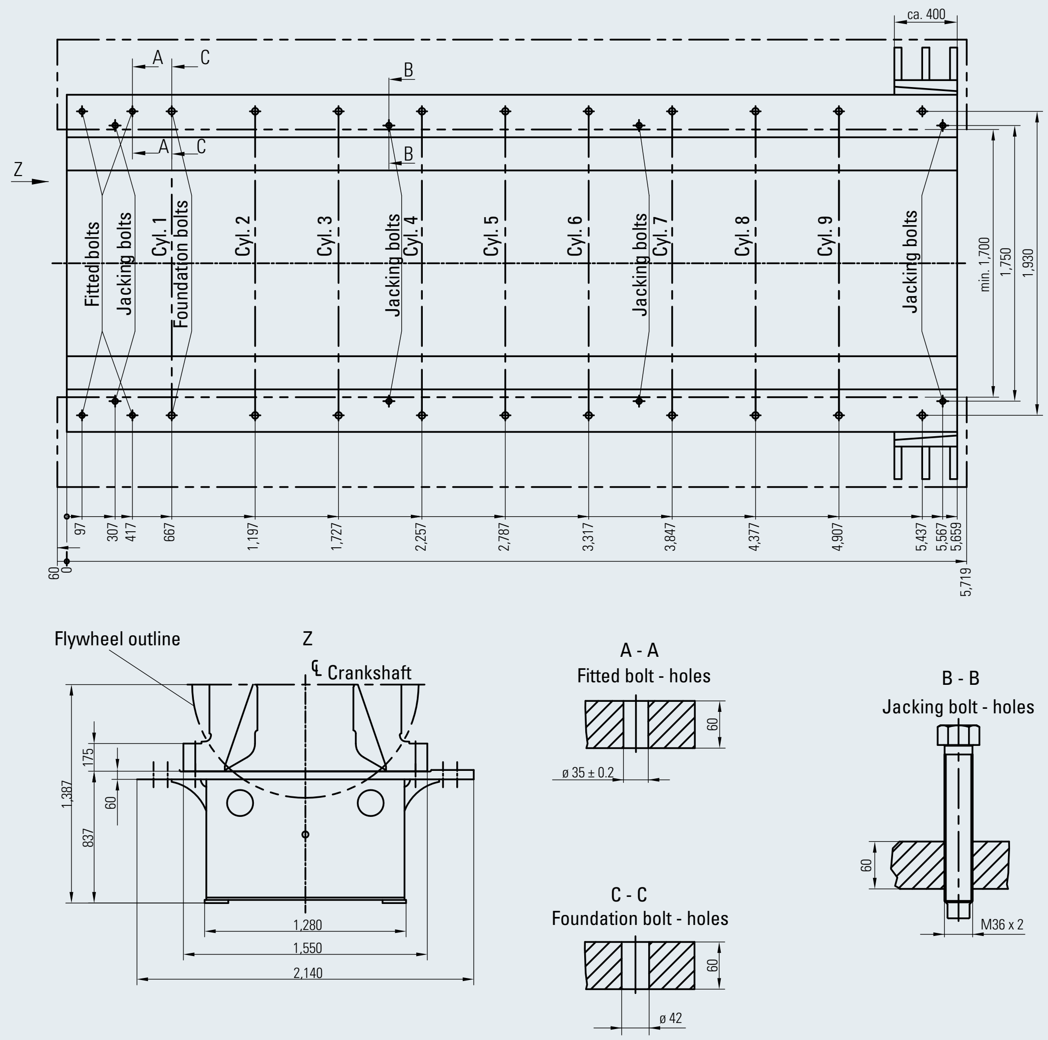


Fig. 12-4 Dimension of foundation wet sump

Side stoppers

6 M 32 E	8/9 M 32 E
1 Pair *	2 Pairs **

* 1 pair at the end of the bedplate

** 1 pair at the end of the bedplate and 1 pair between cyl. 4 and 5

Side stopper to be with 1 wedge (see fig. 12-4). Wedge to be placed at operating temperature and secured by welding. Dimensioning according to classification society and cast resin suppliers requirements.

Number of bolts

	Fitted bolts	Foundation bolts	Jacking bolts
6 M 32 E	4	16	6
8 M 32 E	4	18	8
9 M 32 E	4	20	8

Jacking bolts
To be protected against contact / bond with resin.
After setting of resin dismantle the jacking screws completely.

To be supplied by yard:
Foundation bolts, fitted bolts, nuts and tension sleeves, side stoppers, steel chocks, cast resin.
The shipyard is solely responsible for adequate design and quality of the foundation.

Tightening force		Pre tightening torque (oil) – angle of rotation			
Through bolts M 33	Fitted bolts M 33	Through bolts M 33		Fitted bolts M 33	
[N]	[N]	M [Nm]	° (grad)	M [Nm]	° (grad)
125,000	125,000	90	70	90	70

Final foundation bolts design and tightening torque by cast resin chock supplier.

12.2 Resilient mounting

12.2.1 Basic design and arrangement

The resilient mounting consists of conical rubber elements to achieve a passive isolation of the free moments and forces and emitted structure borne noise of the engine. The resilient mounting arrangement is designed to assure the best possible load distribution of the engine weight in respect of the maximal permissible deflection of the conical rubber element. For each engine configuration (different speed, different side of turbocharging mounted unit, different couplings, with or without PTO, with installation angle) the natural frequencies and the behaviour of the engine during ship movements will be individually calculated and submitted to the respective classification society for approval and to check the design of the resilient installation under different arrangement situations.

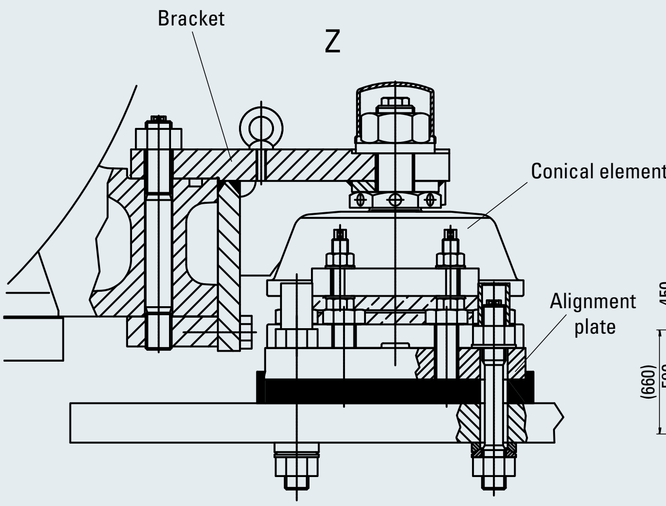
12.2.2 Conical mountings

General
The used conical design provides high deflection and load capacity combined with long service life. The life expectancy of the rubber elements will be approx. 20 years in ideal circumstances. In fact of bad influences out of environmental circumstances the (working) life expectancy will be approx. 10 years.
Specifications
The offered conical mountings have been approved by all relevant classification societies. All mounting rubber inserts are individual tested and selected on stiffness by our supplier. An adjustable central buffer will limit the vertical and horizontal movements of the mounted equipment displacements, so there is no need for separate buffers. About 48 hours after the conical elements are loaded with the complete engine weight during installation more than half of the total creeping figure is achieved. Thereafter the engine will be lowered furthermore by the creeping effect, but just approximately one additional mm within the following 20 years.
The shipyard is solely reaponsible for adequate design and quality of the foundation.

12.2.3 Resilient mounting (dry sump)

Major components

- Brackets for the connection of the conical elements.
- Conical rubber elements.
- Alignment plates.
- Dynamical balanced highly flexible couplings (also for a power take-off).
- Flexible pipe connections for all media.



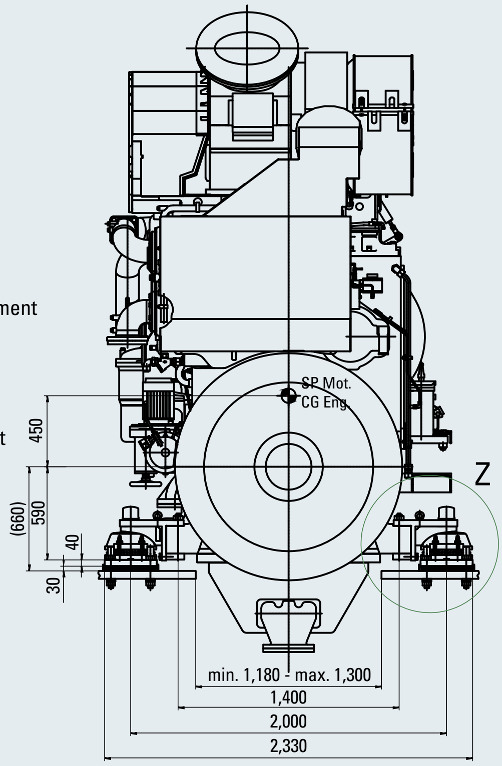


Fig. 12-5 Conical resilient element

Number of rubber elements

	Combined elements
6 M 32 E	6
8 M 32 E	8
9 M 32 E	8

12.2.4 Resilient mounting (wet sump)

Major components

- Oil pan including connections for conical resilient elements.
- Conical rubber elements.
- Dynamical balanced highly flexible coupling (also for a power take-off).
- Flexible pipe connections for all media.
- Alignment plate.

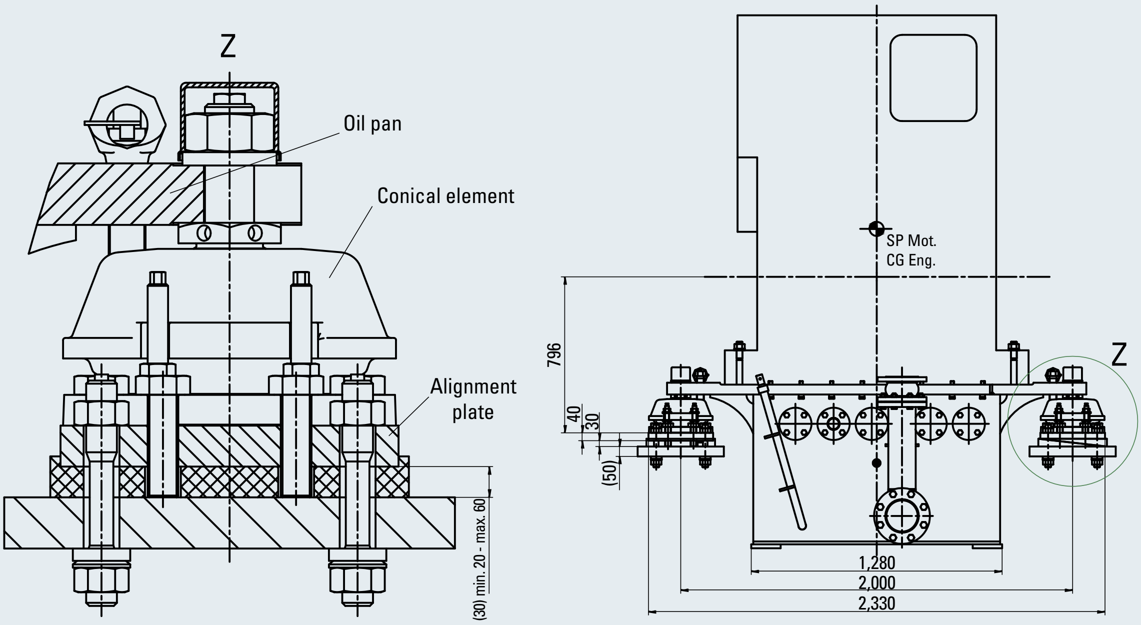


Fig. 12-6 Conical resilient element

Number of rubber elements

	Combined elements
6 M 32 E	6
8 M 32 E	8
9 M 32 E	8

12.3 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).

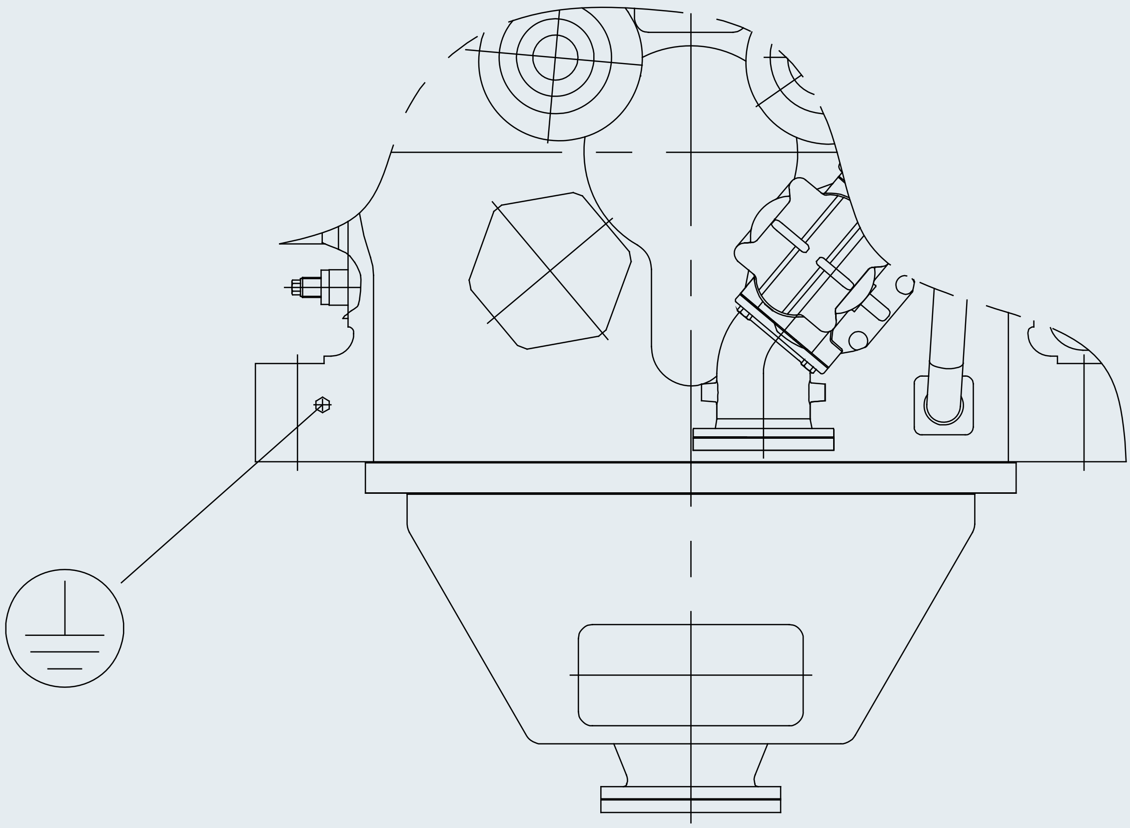


Fig. 12-7 Earthing connection on the engine

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22

13.1 General requirements

The following information is relevant to the foundation design and the aft ship structure.
The engine foundation is subjected to both static and dynamic loads.

13.2 Static load

The static load from the engine weight which is distributed approximately evenly over the engine's foundation supports and the mean working torque T_N resting on the foundation via the vertical reaction forces. T_N increases the weight on one side and reduces it on the other side by the same amount.

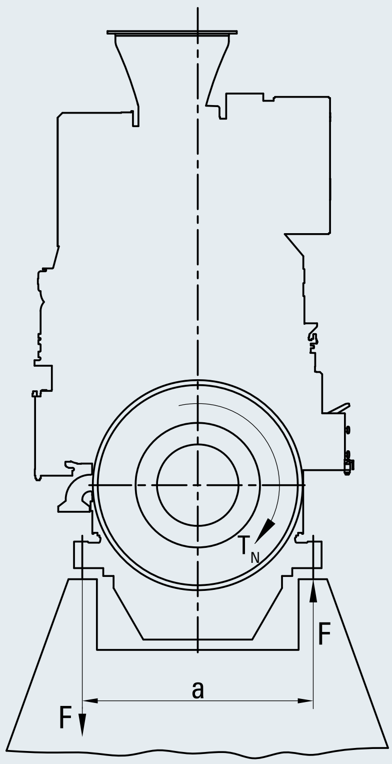


Fig. 13-1 Static load

	Output [kW]	Speed [rpm]	T_N [kNm]
6 M 32 E	3,300	720/750	43.8/42.0
8 M 32 E	4,400	720/750	58.4/56.0
9 M 32 E	4,950	720/750	65.7/63.0

Support distance a = 1,400 mm

F = T_N/a

T_N = Nominal torque

F = Force

a = Support distance

13.3 Dynamic load

The dynamic forces and moments are superimposed on the static forces. They result on the one hand from the firing forces causing a pulsating torque and on the other hand from the external mass forces and mass moments.
The table indicates the dynamic forces and moments as well as the related frequencies.

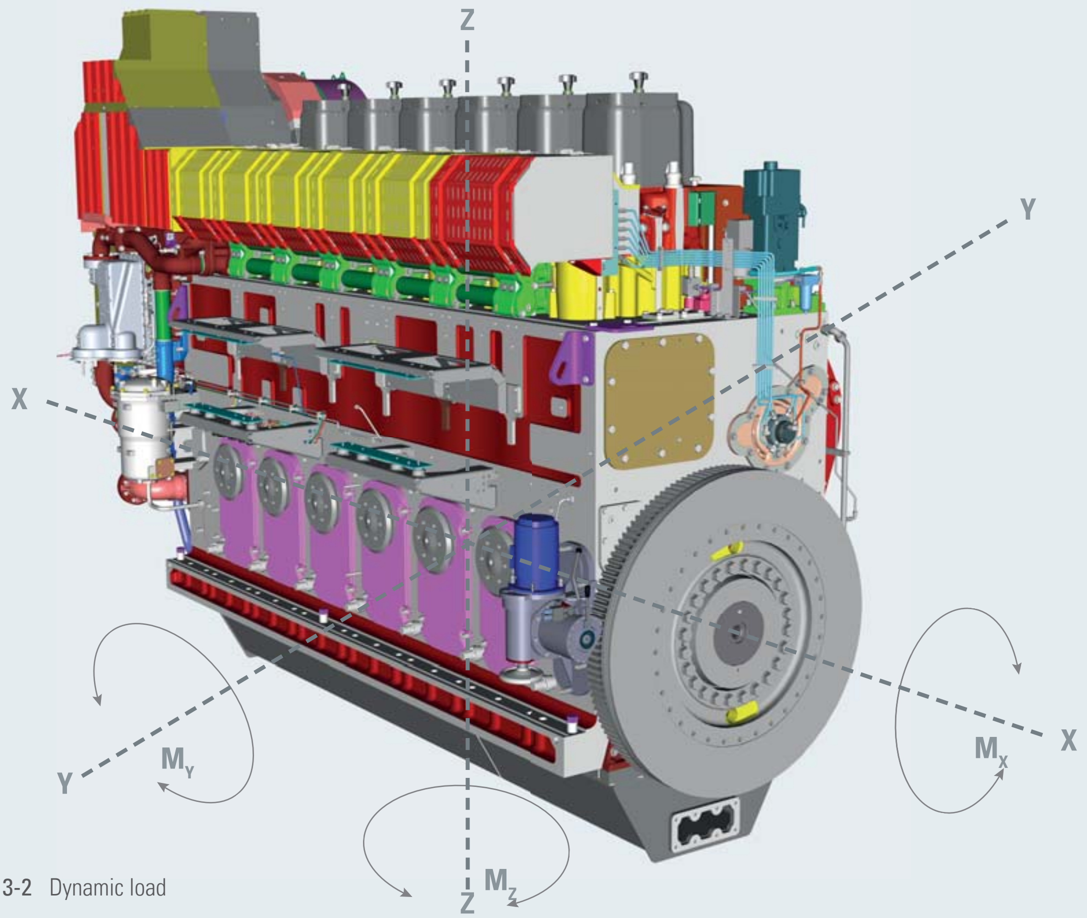


Fig. 13-2 Dynamic load

	Output	Speed	Order-no.	Frequency	M_X	M_Y	M_Z
	[kW]	[rpm]		[Hz]	[kNm]	[kNm]	[kNm]
6 M 32 E	3,300	720/750	3.0 6.0	36.0/37.5 72.0/75.0	22.8/20 17.9/17.2	–	–
8 M 32 E	4,400	720/750	4.0 8.0	48.0/50.0 96.0/100.0	54.1/51.4 8.0/7.7	–	–
9 M 32 E	4,950	720/750	1 2	12.0/12.5 24.0/25.0	– –	17.1/18.6 52.7/57.2	– –
9 M 32 E	4,950	720/750	4.5 9.0	54.0/56.3 108.0/112.5	52.3/50.2 5.7/5.5	– –	– –

All forces and moments not indicated are irrelevant or do not occur. The effect of these forces and moments on the ship's foundation depends on the type of engine mounting.

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22

14.1 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 on the following pages, according to your scope of supply.

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

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. 14-1 Additional engine plant data, part "B" (1/3)

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. vibratory torque [kNm]: _____
Perm. power loss [kW]: _____ Perm. rotational speed [1/min]: _____
Dyn. torsinal stiffness[kNm/rad]: _____ 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. vibratory torque [kNm]: _____
Perm. power loss [kW]: _____ Perm. rotational speed [1/min]: _____
Dyn. torsinal stiffness[kNm/rad]: _____ 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. vibratory torque [kNm]: _____
Perm. power loss [kW]: _____ Perm. rotational speed [1/min]: _____
Dyn. torsinal stiffness[kNm/rad]: _____ Relative damping: _____

Gearbox

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

Maker: _____ Type: _____ ☐ TVC scheme attached
Max. permissible PTO output [kW]: _____ ☐ Drawing attached

Front gearbox for engine PTO

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

Maker: _____ Type: _____ ☐ TVC scheme attached
Max. permissible PTO output [kW]: _____ ☐ 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: _____ Type: _____
Output [kW]: _____ rpm [1/min]: _____ ☐ TVC scheme attached
☐ Plain bearing, external lubrication ☐ Drawing attached

Caterpillar Confidential: Green

Fig. 14-2 Additional engine plant data, part "B" (2/3)

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. 14-3 Additional engine plant data, part "B" (3/3)

14.2 Sound levels

14.2.1 Airborne noise

The airborne noise level requirement in the engine room specified by IMO Resolution A.468 will be satisfied by M 32 E (even for multiple installations).

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

14.3 Vibration

The vibration level of M 32 E engines complies with ISO 20283-4 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

15.1 Flexible coupling

General

For all types of plants the engines will be equipped with flexible flange couplings.
The guards for the flexible couplings should be made of perforated plates or gratings to ensure optimum heat dissipation (yard supply).

15.1.1 Mass moments of inertia

	Speed	Engine *	Flywheel	Total
	[rpm]	[kgm²]	[kgm²]	[kgm²]
6 M 32 E	720/750	518	470	888
8 M 32 E	720/750	593	470	1,063
9 M 32 E	720/750	673	470	1,143

* Running gear with balance weights and vibration damper

15.1.2 Selection of flexible couplings

The calculation of the coupling torque for main couplings is carried out according to the following formula.

$$T_{KN} \geq \cdot \frac{P_0}{\omega} = \frac{P_0}{2 \cdot \pi \cdot n_0}$$

P_0 = Engine output
n_0 = Engine speed
T_{KN} = Nominal torque of the coupling in the catalogue

ATTENTION:
For installations with a gearbox PTO it is recommended to oversize the PTO coupling by the factor 1.5 in order to have sufficient safety in the event of misfiring.

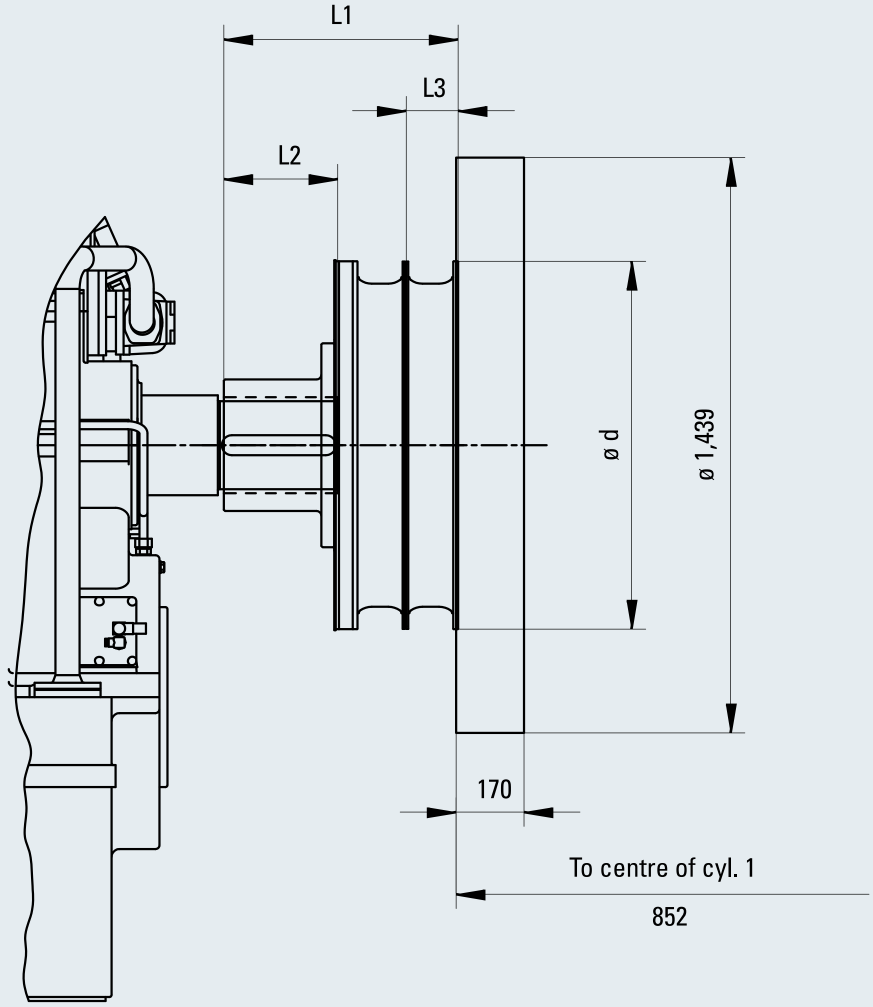


Fig. 15-1 Flywheel and flexible coupling

	Power	Speed	Nominal torque of coupling	d	L1 4)	L2 3)	L3 5)	Weight 1)	Weight 2)
	[kW]	[rpm]	[kNm]	[mm]	[mm]	[mm]	[mm]	[kg]	[kg]
6 M 32 E	3,300	720/750	66.5	920	823 1) / 586 2)	285	132	721	545
8 M 32 E	4,400	720/750	66.5	920	823 1) / 586 2)	285	132	721	545
9 M 32 E	4,950	720/750	80.0	920	823 1) / 586 2)	285	132	721	545

1) Long version / **2)** Short version / **3)** Length of hub / **4)** Alignment control (recess depth 5 mm) / **5)** Length of rubber element

Space requirements for OD-Box (oil distribution box) are to be considered!
Couplings for twin rudder propeller have to be designed with a supplementary torque of 50 %.

15.2 Power take-off from the free end (for CPP only)

The PTO output is limited to:

- 6 M 32 E 3,300 kW
- 8 M 32 E 2,000 kW
- 9 M 32 E 4,950 kW

The connection requires a highly flexible coupling.

A combination (highly flexible coupling/clutch) will not be supplied by Caterpillar Motoren. The weight force of the clutch cannot be absorbed by the engine and must be borne by the succeeding machine.

The coupling hub is to be adapted to suit the PTO shaft journal.

The (definite) final coupling type is subject to confirmation by the torsional vibration calculation.

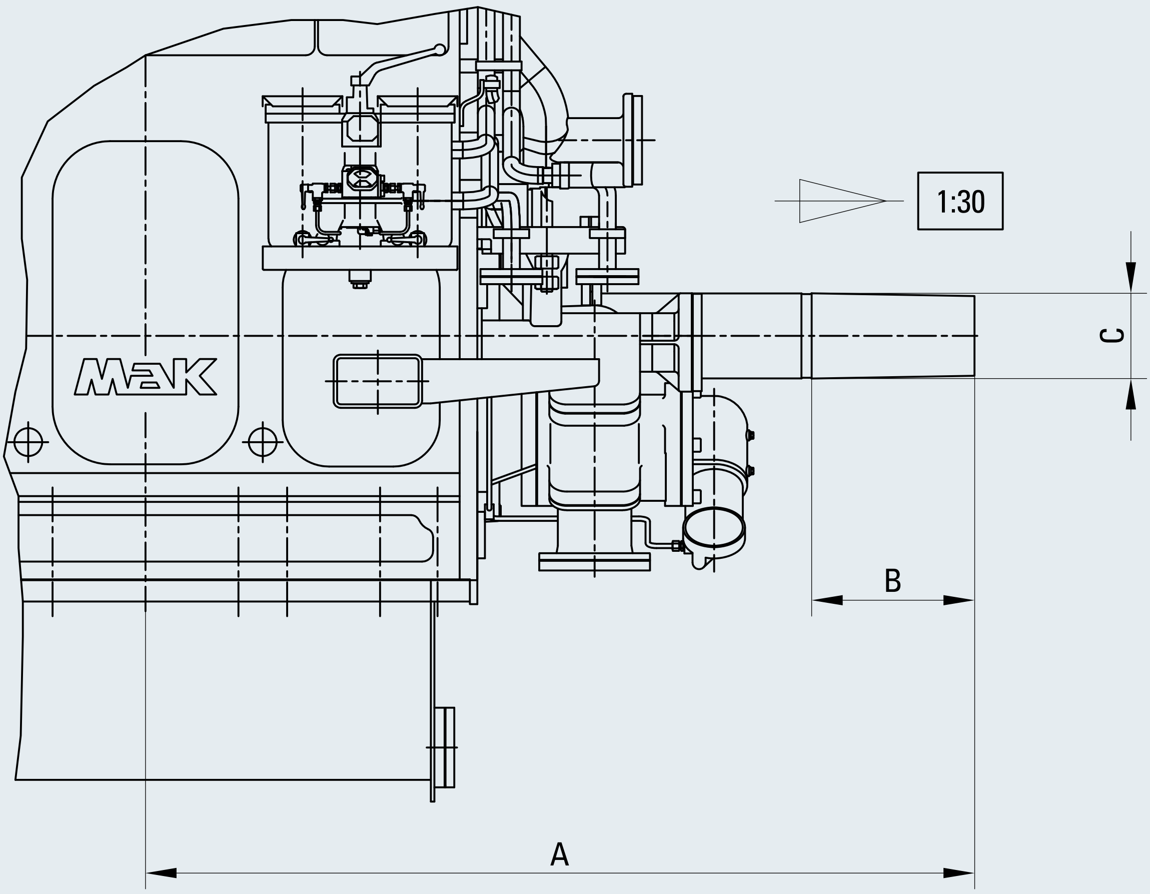


Fig. 15-2 Power take-off from the free end

Power	A	B	C
< 1,800 kW	1,649	230	151
> 1,800 kW	1,874	368	193

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22

16.1 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 16.2).
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.

16.2 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

16.3 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 ------------

16.4 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.

16.5 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 flexible 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 transversal to their center line. They are not suitable for compensating twisting movements. Compensators are very stiff against torsion.

It is very important that all steel compensators are not allowed to be installed on resilient mounted engines in vertical direction.

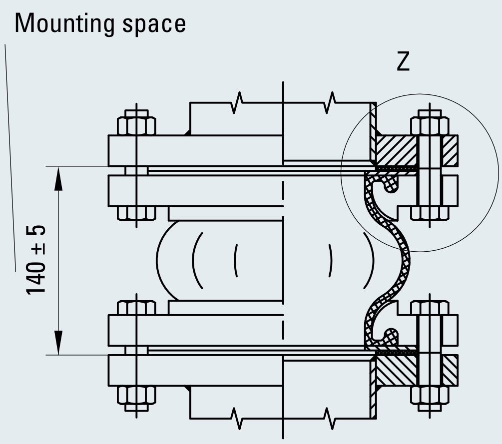


Fig. 16-1 Rubber expansion joint

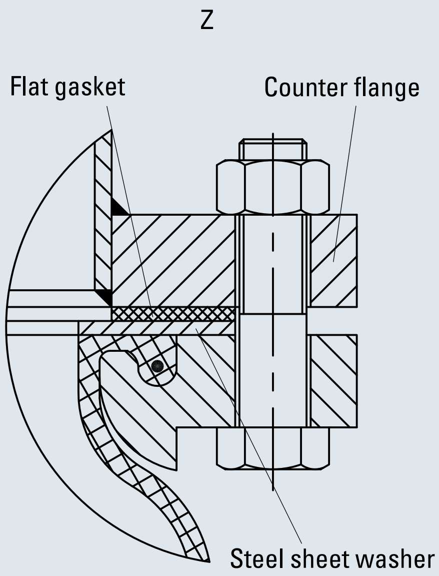


Fig. 16-2 Rubber expansion joint, detail Z

17.1 Engine center distances

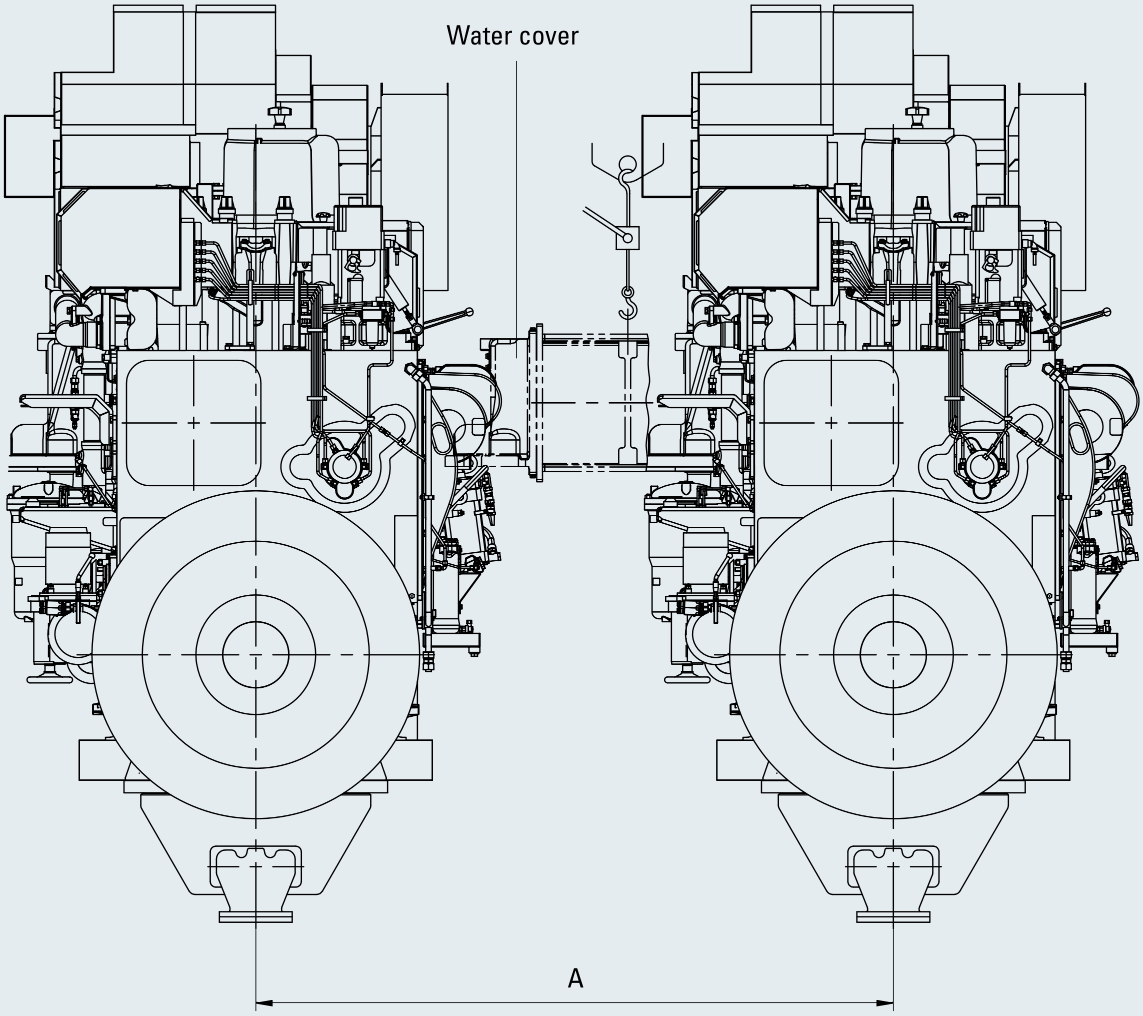


Fig. 17-1 Center distance of twin-engine plants

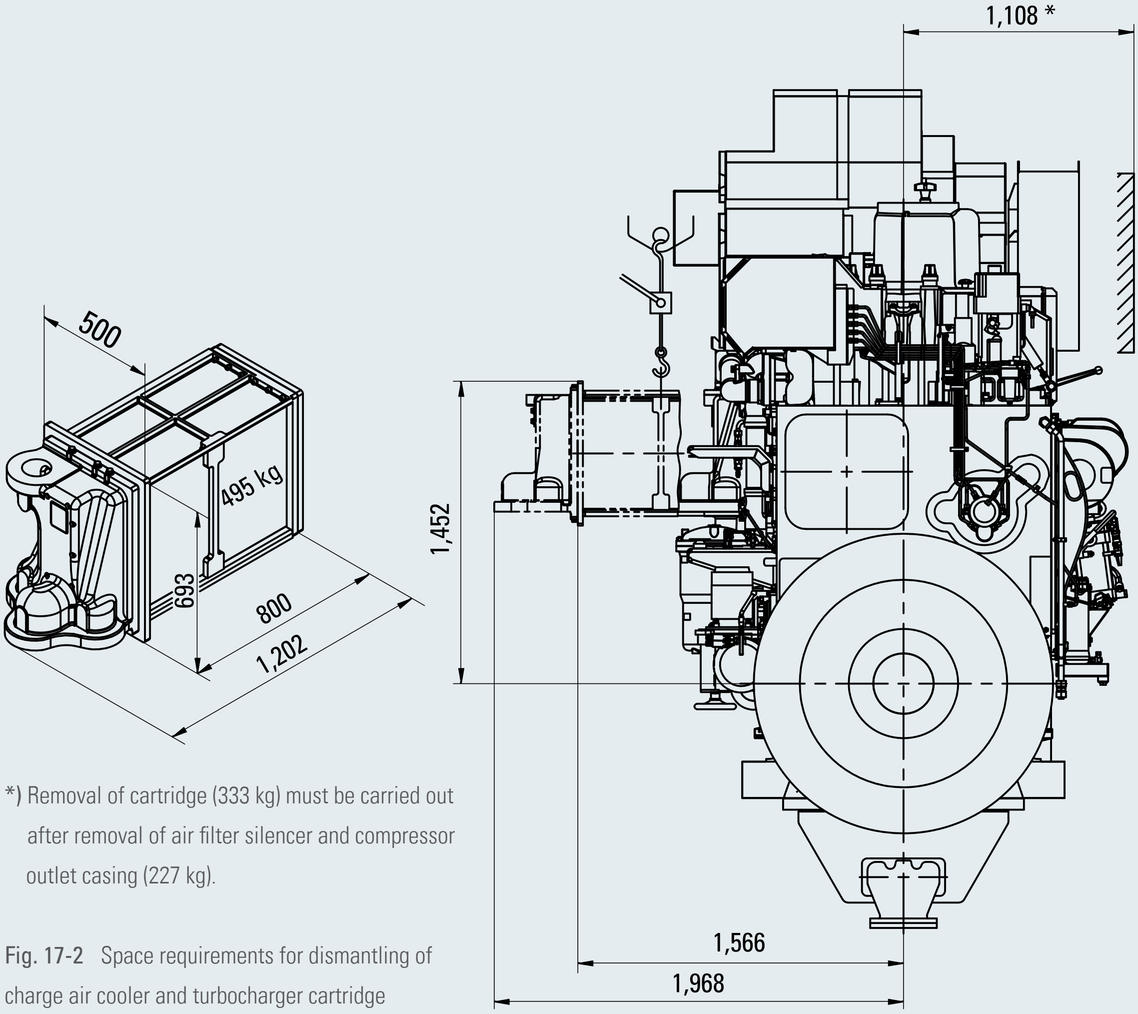
	Dimensions [mm]
	A
6/8/9 M 32 E	2,800*

*) The water cover of the charge air cooler must be dismantled.

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22

17.2 Space requirements for maintenance

17.2.1 Removal of charge air cooler and turbocharger cartridge



*) Removal of cartridge (333 kg) must be carried out after removal of air filter silencer and compressor outlet casing (227 kg).

Fig. 17-2 Space requirements 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 32 E	1,413	1,980	676	520	1,160	850	400	360
8/9 M 32 E	1,625	2,015	870	720	1,180	1,640	948	815

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.

17.2.2 Removal of piston and cylinder liner

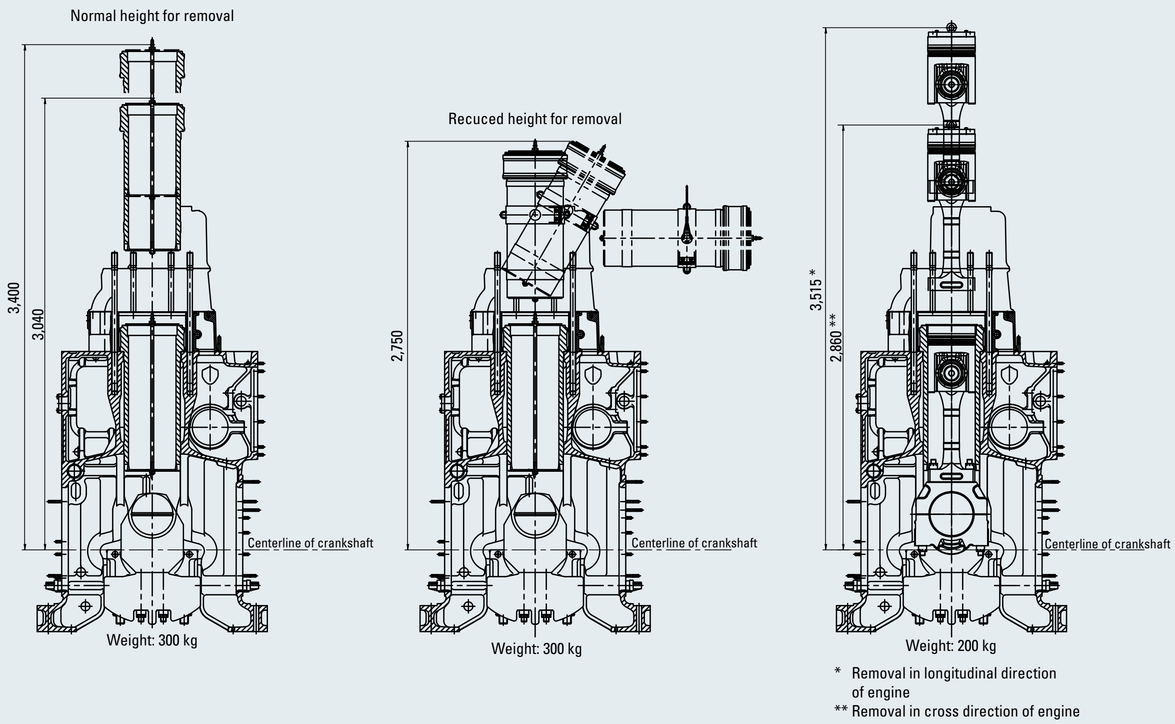


Fig. 17-3 Removal of piston and cylinder liner

18.1 Inside preservation

18.1.1 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.

18.2 Outside preservation

18.2.1 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.

18.2.2 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 engines 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.

18.2.3 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.

18.2.4 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.

Apperance 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.
- Cover the engine completely with air cushion film VCI 126 LP. Air cushions are to face inwards! The air cushion film is fastened to the transportation skid (wooden frame) by means of wooden laths. Overlaps at the face ends and openings for the lifting gear are to be closed by means of 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 air cushion 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.

18.2.5 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.

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

18.3.1 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 2 years represervation must be carried out.
However, depending on the execution of the preservation or local conditions shorter periods may be recommended.

18.3.2 Protection check

Every 3 months 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.

18.3.3 Represervation as per factory standard N 576-6.1

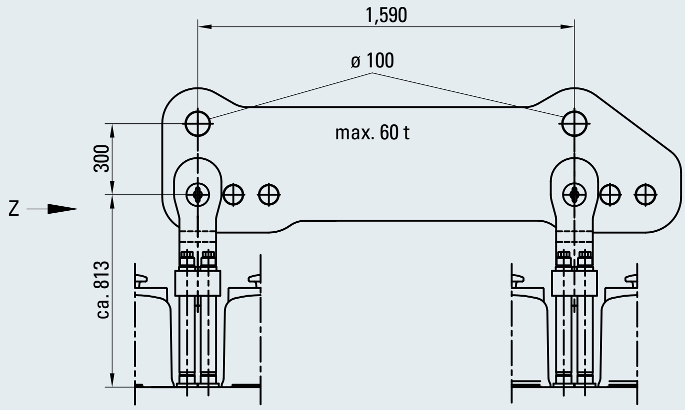
After 2 years represervation must be carried out.

19.1 Lifting of engines

For the purpose of transport the engine is equipped with a lifting device, which shall remain the property of Caterpillar Motoren.
The lifting device has to be returned to Caterpillar Motoren.

Device to be used for transport of engine types 6/8/9 M 32 E only. Max. lifting speed: 5 m/min.

When taking up load, max. 3 ° must not be exceeded all-round, meaning that the rod must have no contact in this area.



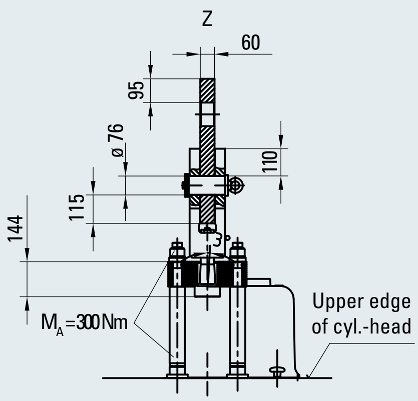


Fig. 19-1 Spreader bar

Wear limit

NOTE:
Total weight for transport includes bracket and traverse (see drawings next page)!

Transport of engine with turbocharger at driving end

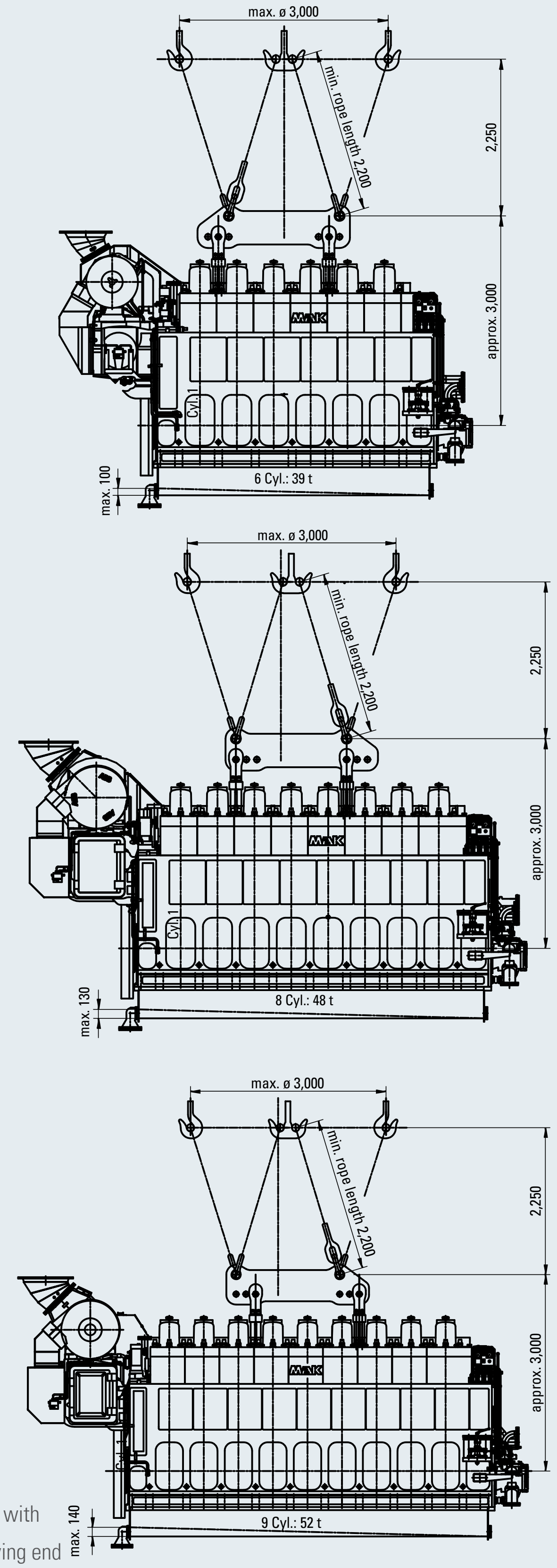


Fig. 19-2 Transport of engine with turbocharger at driving end

Transport of engine with turbocharger at free end

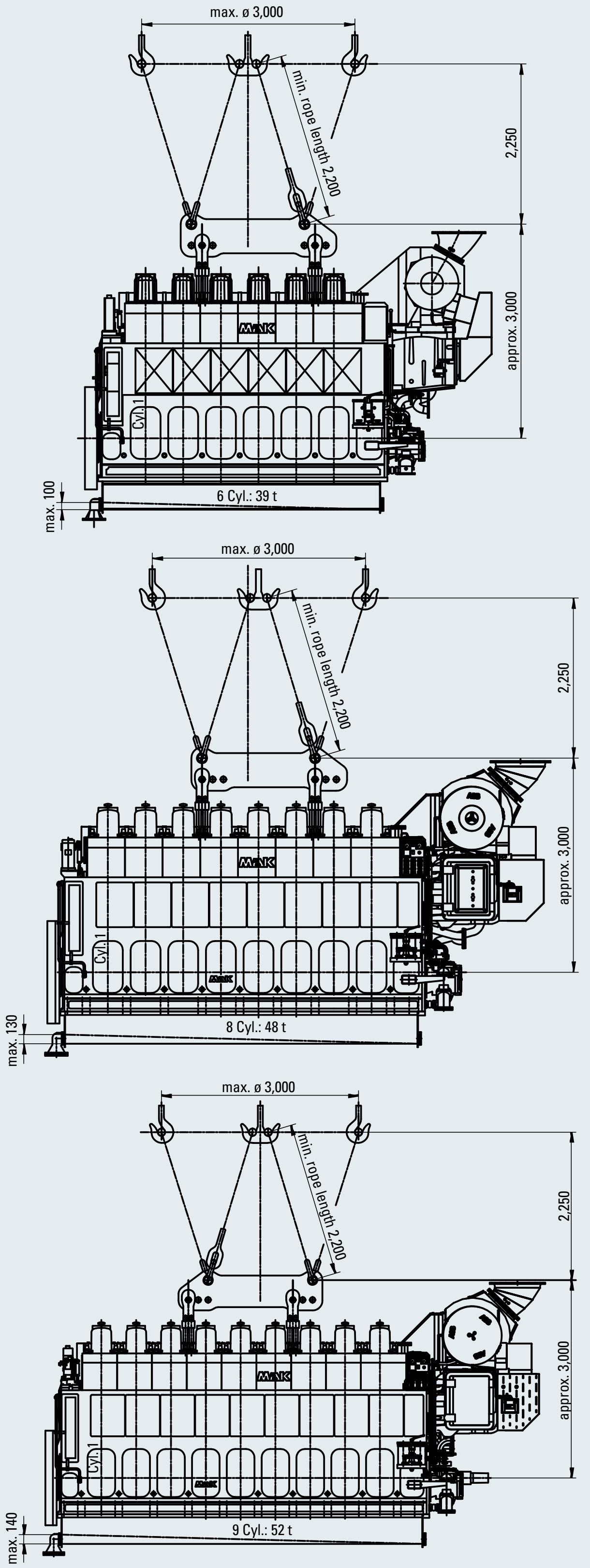


Fig. 19-3 Transport of engine, turbocharger at free end

19.2 Dimensions of main components

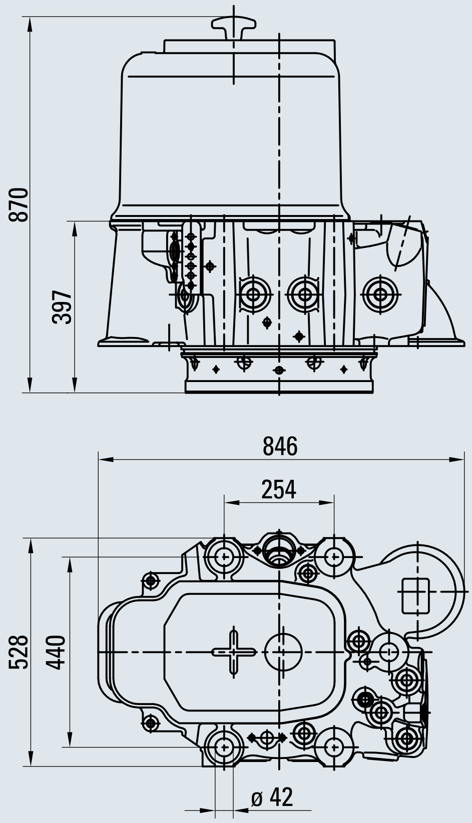


Fig. 19-4 Cylinder head, weight 315 kg

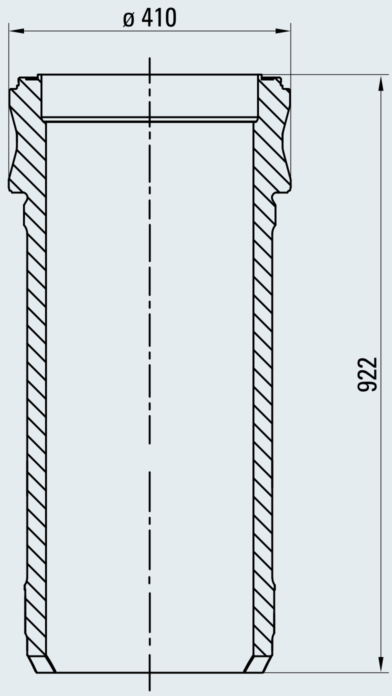


Fig. 19-5 Cylinder liner, weight 248 kg

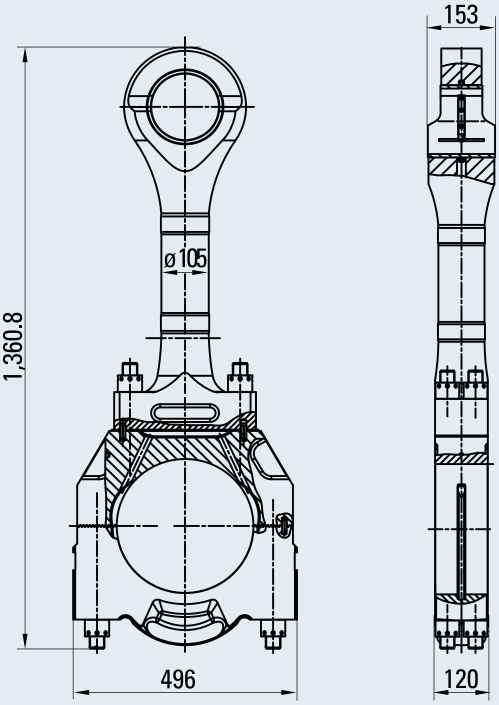


Fig. 19-6 Connecting rod, weight 224 kg

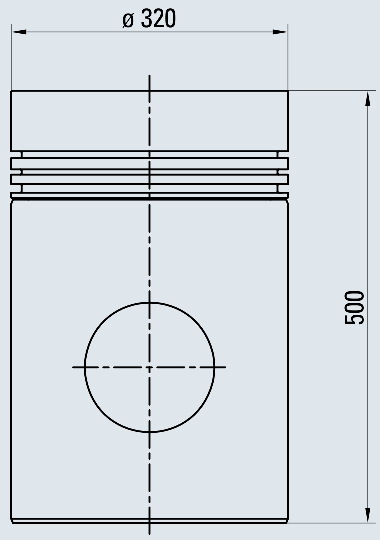


Fig. 19-7 Piston, weight 150 kg

20.1 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	30
85	30
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 central engine control
- Starting trials up to a minimum air pressure of 10 bar
- Measurement of crank web deflection (cold/warm condition)

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, because such inspections are carried out by the classification societies at intervals on series engines.

21.1 Required spare parts (Marine Classification Society MCS)

Classification societies	GL	RS	KR	CCS
Rules references	Pt. 1, Ch. 17	Pt. 7, Ch. 10	Pt. 5, Ch. 1	Ch. 15, Sec. 1&2
Status	2011	2011	2011	2011
Parts				
Main bearing	1	1	1	1
Thrust washer	1	1	1	1
Cylinder liner, complete	1	1	1	1
Cylinder head, complete	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
Set of exhaust valves for one cylinder head	1	(2)*	2	2
Set of intake valves for one cylinder head	1	(1)*	1	1
Starting air valve, complete	1	1	1	1
Relief valve, complete	1	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	1
Piston, without piston pin + piston rings	–	–	–	–
Connecting rod	1	1	1	1
Big end bearing	–	–	–	–
Gudgeon pin with bushing for one cylinder	1	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	1
Exhaust compensators between cylinders	1	–	1	1
Turbocharger rotor, complete	–	(1)*	–	–
Set of gear wheels	–	–	–	–
Only for electronic speed setting Pick up for electronic speed setting	–	–	–	–
Only if oil mist detector is provided Sintered bronze filter (for crankcase monitor)	–	–	–	–

* Recommendation only

21.2 Recommended spare parts

Classification societies	ABS	DNV	LR	BV **	RINA **
Rules references	Pt. 4, Ch. 2 Sec. 1	Pt. 4, Ch. 1, Sec. 5	Pt. 5, Ch. 16, Sec. 1	Pt. A, Ch. 1, Sec. 1	Pt. A, Ch. 1, Sec. 1
Status	2011	2011	2011	2011	2011
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	–	–
Set of intake valves for one cylinder head	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	–	–
Set of conrod top & bottom bearing for one cylinder	1	1	1	–	–
Piston, complete	1	1	1	–	–
Piston, without piston pin + piston rings	–	–	–	–	–
Connecting rod	1	1	1	–	–
Big end bearing	–	–	–	–	–
Gudgeon pin with bushing for one cylinder	1	1	1	–	–
Set of piston rings	1	1	1	–	–
Fuel injection pump	1	1	1	–	–
Fuel injection piping	1	1	1	–	–
Set of gaskets and packing for one cylinder	1	1	1	–	–
Exhaust compensators between cylinders	1	–	1	–	–
Turbocharger rotor, complete	–	–	–	–	–
Set of gear wheels	1	–	–	–	–
Only for electronic speed setting Pick up for electronic speed setting	–	–	–	–	–
Only if oil mist detector is provided Sintered bronze filter (for crankcase monitor)	–	–	–	–	–

* Recommendation only / ** Owner's responsibility

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Caterpillar recommendation	Caterpillar
Rules references	
Status	2011
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 Sintered bronze filter (for crankcase monitor)	1

* Recommendation only

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

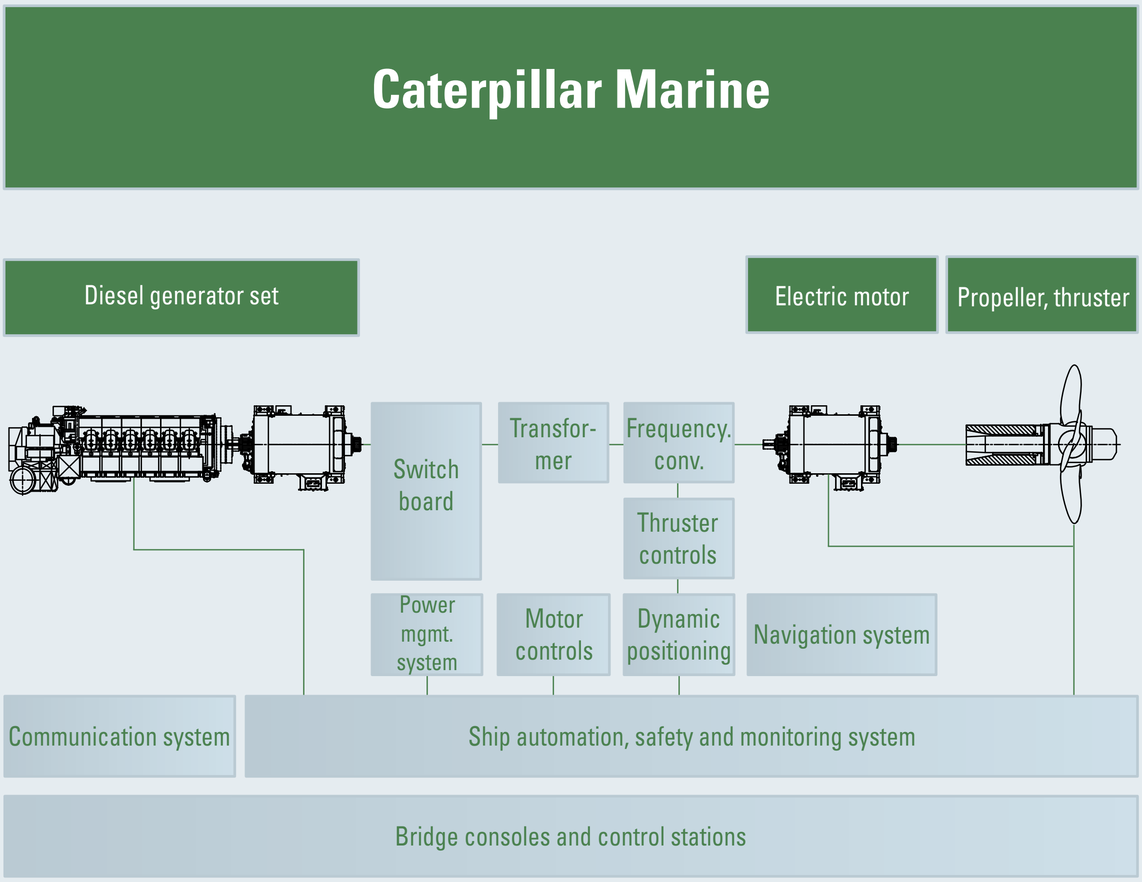

Fig. 22-1 D/E application

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

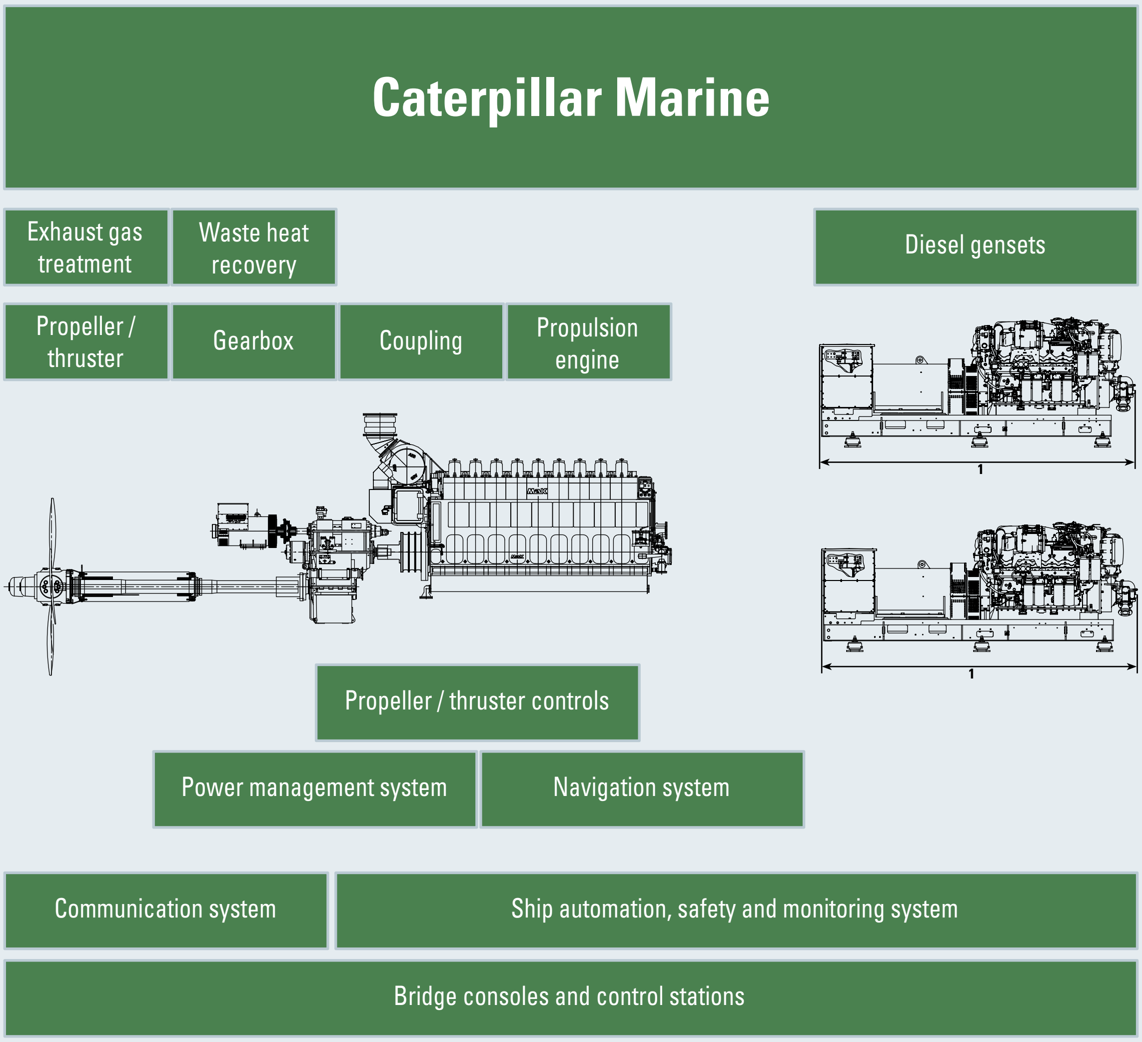

Fig. 22-2 D/M application

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22

22.3 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

22.4 Caterpillar Propulsion

Fig. 22-3 Main propeller

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.

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. 22-4 Azimuth thrusters

Fig. 22-5 Tunnel thrusters

Fig. 22-6 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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