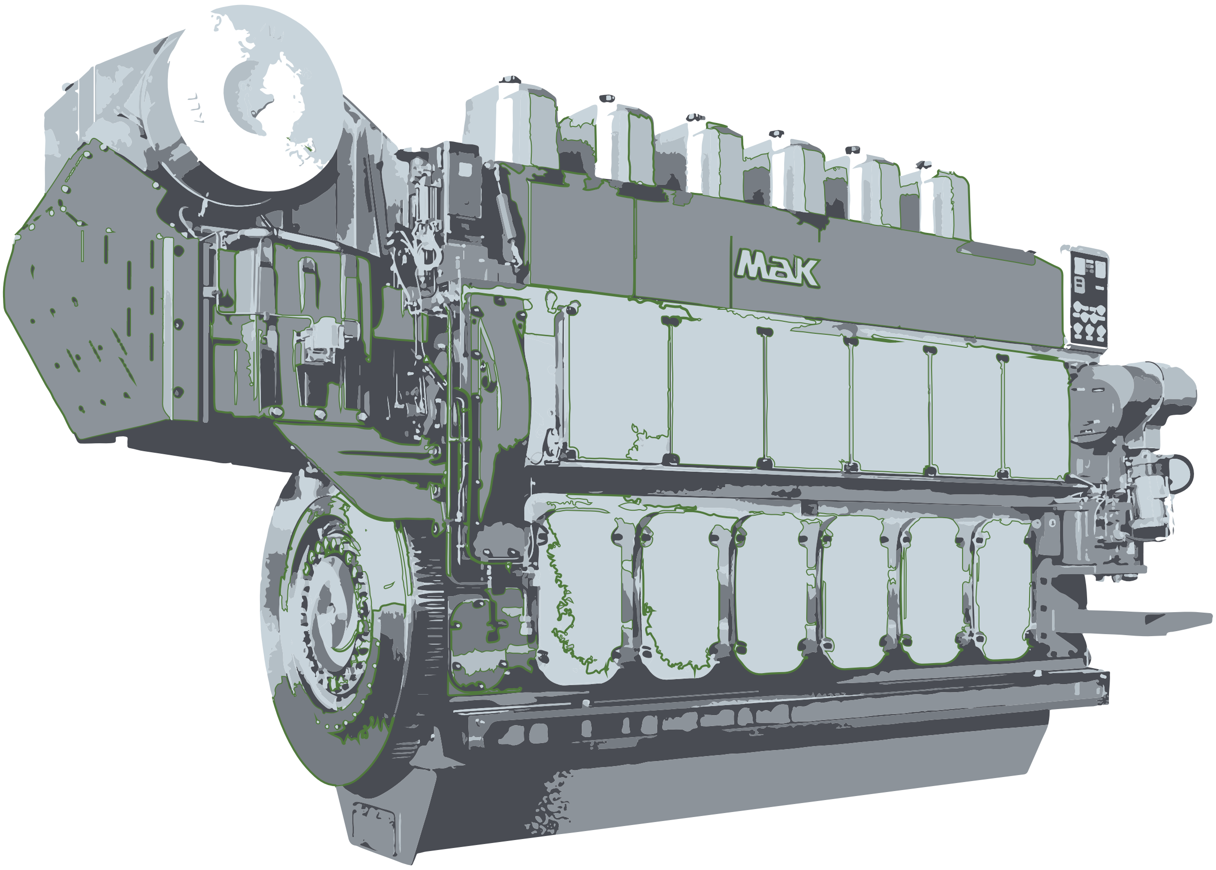
M 32 C

PROJECT GUIDE / PROPULSION



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This edition supersedes the previous edition of this project guide.

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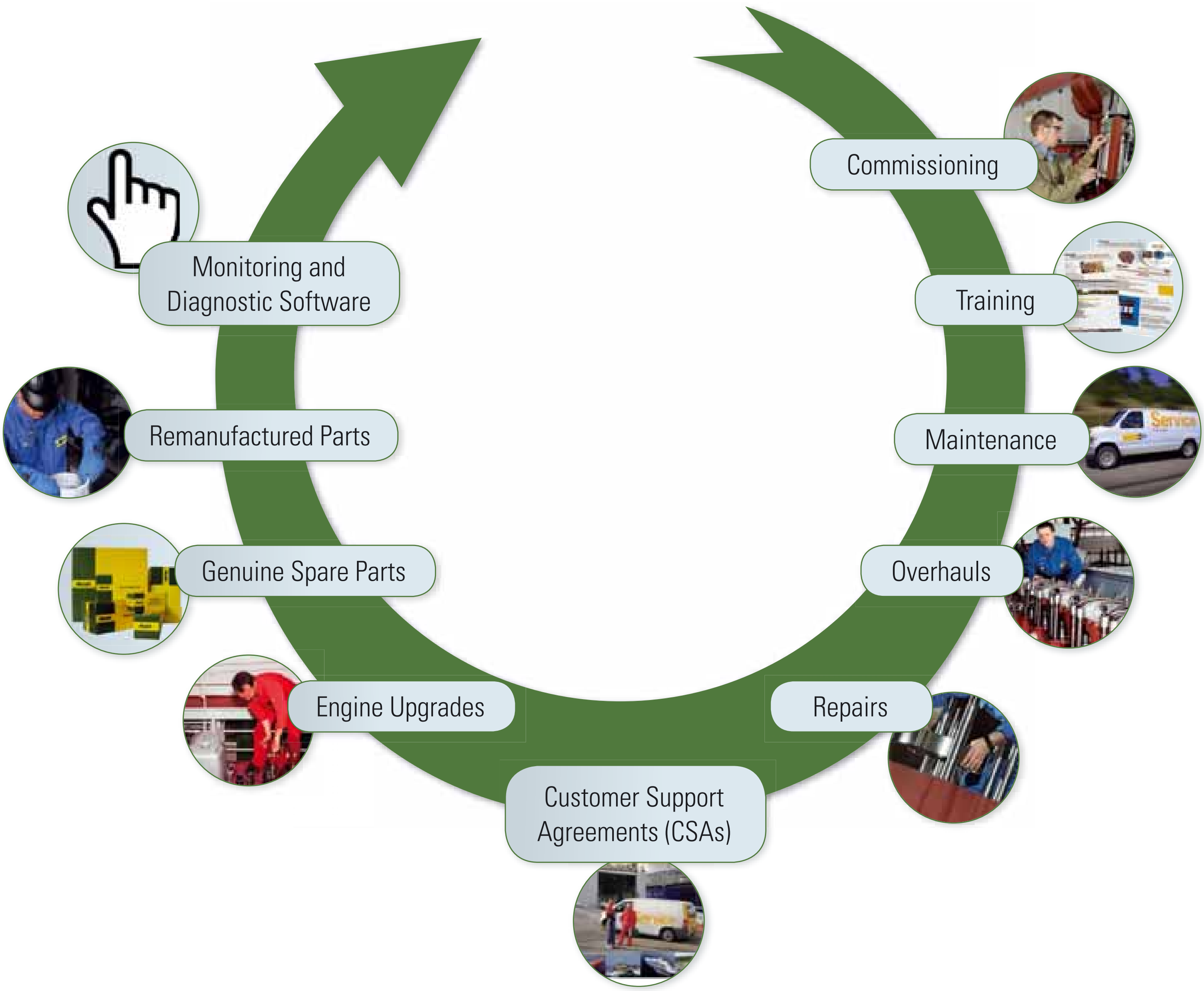

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CONTENTS

CONTENTS

CONTENTS

7. COOLING WATER SYSTEM

CONTENTS

14. CONTROL AND MONITORING SYSTEM

15. INSTALLATION AND ARRAGEMENT

CONTENTS

24. ENGINE PARTS

25. SYSTEMS INTEGRATION

1.1 Definitions

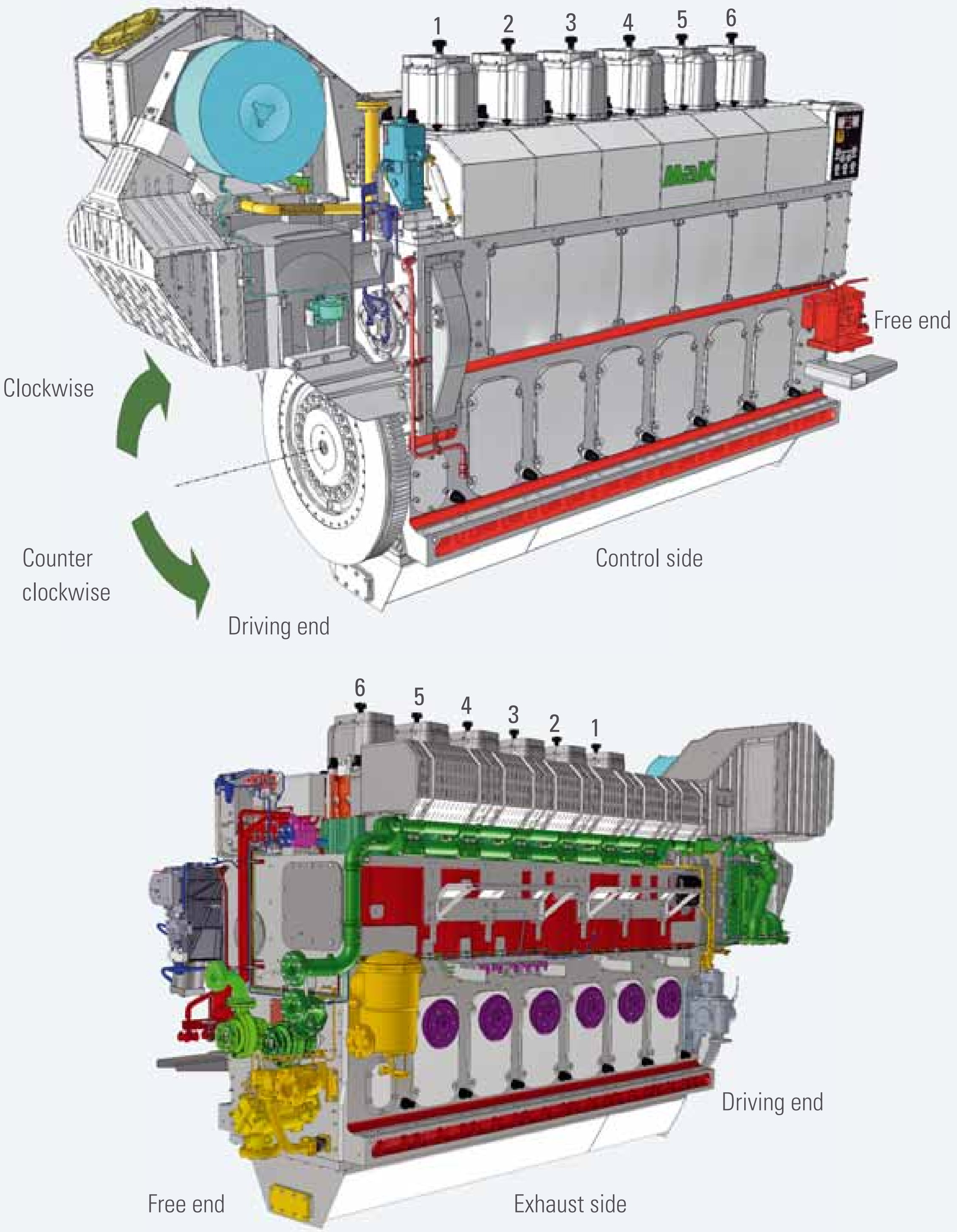

Fig. 1-1 M 32 C

	6 M 32 C	8 M 32 C	9 M 32 C
Output [kW]	3,000	4,000	4,500

Cylinder configuration:	6, 8, 9 in-line
Bore:	320 mm
Stroke:	480 mm
Stroke / bore-ratio:	1.5
Swept volume:	38.7 l/cyl.
Output/cyl:	500 kW
BMEP:	25.9 bar
Revolutions:	600 rpm
Mean piston speed:	9.6 m/s
Turbocharging:	single log, option: pulse
Direction of rotation:	clockwise, option: counter-clockwise

1.2 Main components and systems

1.2.1 Main features and characteristics

Even the engine has been introduced already a couple of years ago it is currently one of the most attractive products in as well cargo as tug/salvage and offshore service shipping markets.
Constantly advanced since its commercial launch the M 32 C have reached very high standards.
Caused by their well-known **durability** and **reliability** these engines are first choice.
The typically low fuel oil and lube oil consumption is an advantage in times of increasing fuel oil costs.
Moreover the above-average long maintenance intervals are known as the most benefiting in its class.
Measures have been taken to reduce the number of parts and simplify maintenance work.
A high-efficient turbo charging in combination with optional Flexible Camshaft Technology and / or Common Rail fuel oil injection make M 32 C be a future-proof decision.

Fig. 1-2 Control side and driving end

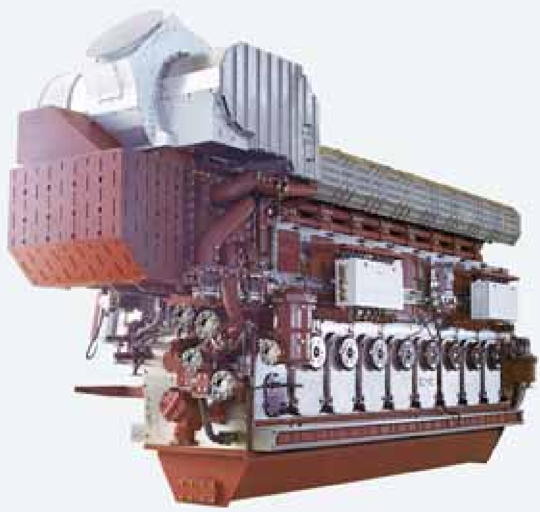

Fig. 1-3 Exhaust side and free end

1.2.2 Description of components

Piston

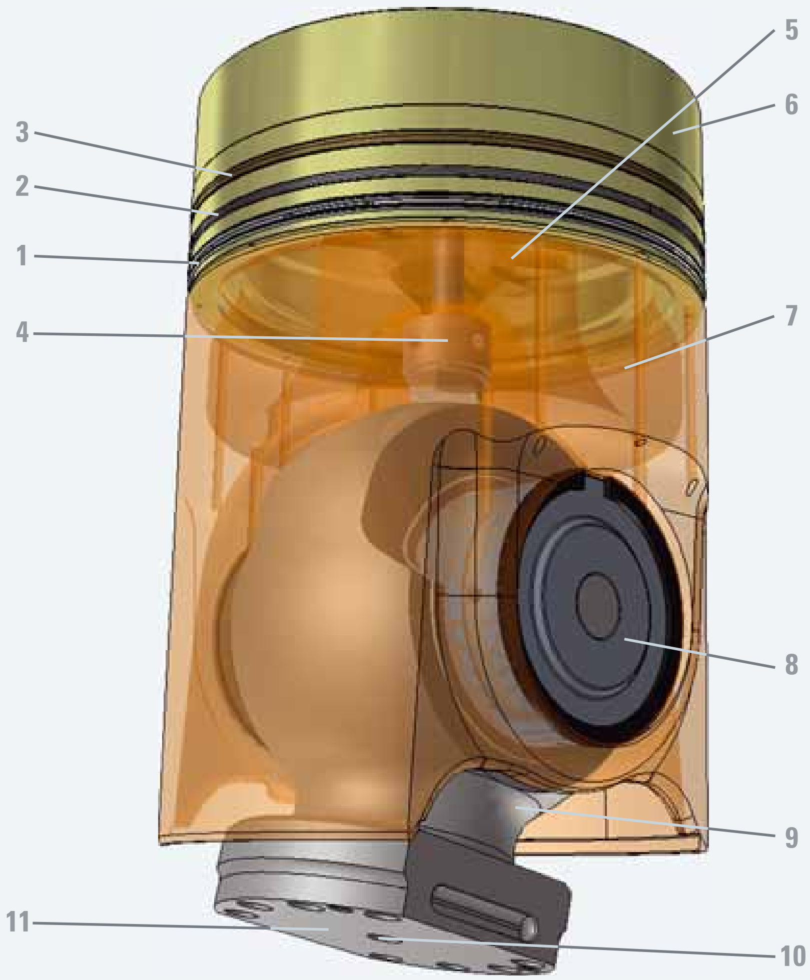

Fig. 1-4 Piston with connecting rod

1	Oil scraper ring	7	Piston skirt
2	Second piston ring	8	Piston pin
3	First piston ring	9	Small end
4	Piston screw	10	Lube oil inlet
5	Lube oil cooled space in piston	11	Mounting flange for connecting rod
6	Piston crown		

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

Engine block

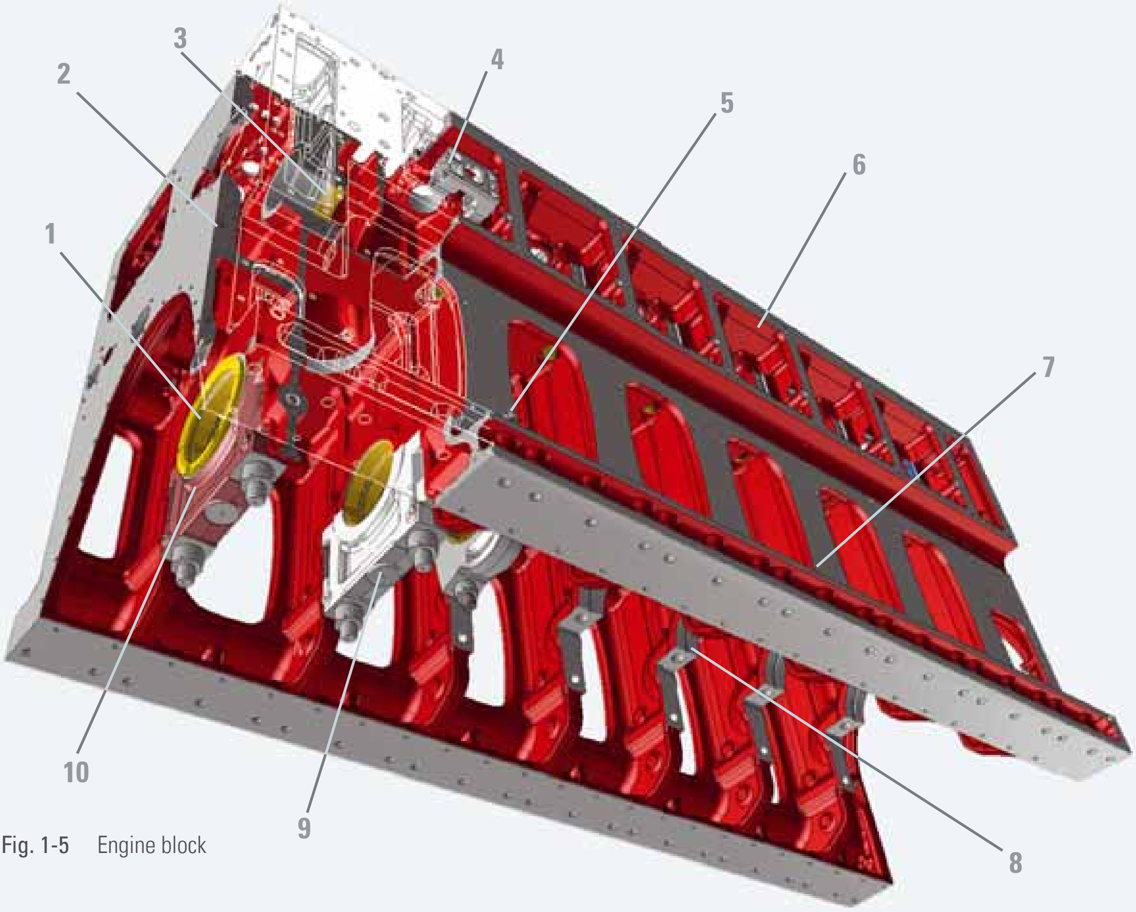

Fig. 1-5 Engine block

1	Corrosion protected main bearings	6	Camshaft housing
2	One-piece nodular cast iron block	7	Foot of engine block with drain chamfer
3	Camshaft bearings	8	Space for underslung crankshaft
4	Bearing for FCT shaft	9	Main bearing cap
5	Side screws	10	Locating (main) bearing

ENGINE DESCRIPTION

Core element of the M 32 C 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 pieces sideways.
- The underslung crankshaft allows the removal of the complete crankshaft without disassembly of the entire engine.
- The natural hardened liners, centrifugally cast with calibration insert, are extremely wear and tear resistant as well as the corrosion protected main and big end bearings.
- The engine block is not integrated into the cooling water circuit, therefore the engine block is completely dry.

Safe and simple power train

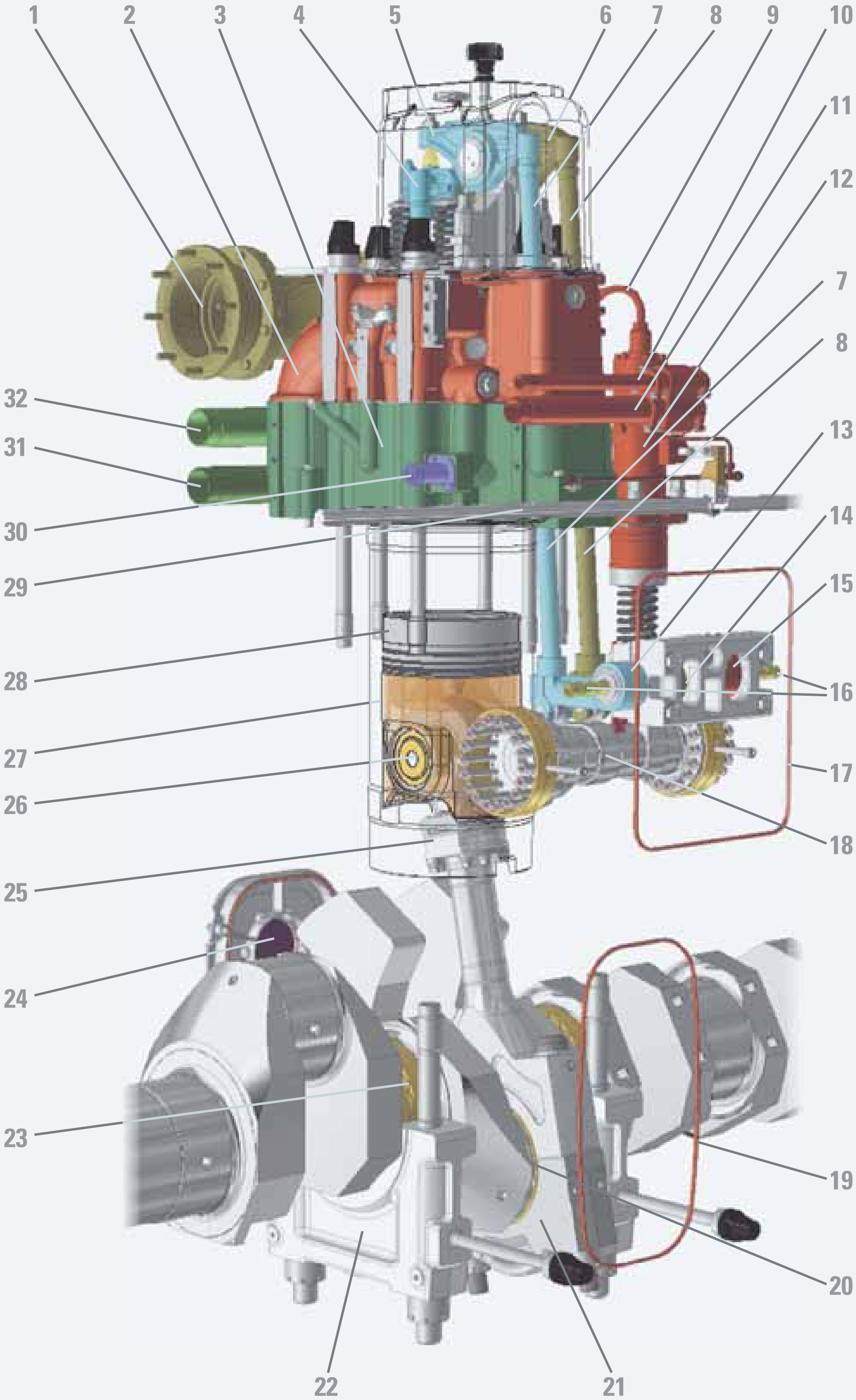

Fig. 1-6 Configurtation of main components of one cylinder compartment

1	Exhaust manifold	17	Position of camshaft cover
2	Combustion air inlet	18	Camshaft
3	Cooling water distributor	19	Position of crankcase door
4	Valve bridge, inlet	20	Big end bearing
5	Rocker arm, inlet	21	Big end bearing cap
6	Rocker arm, outlet	22	Main bearing
7	Push-rod, inlet	23	Bearing shell with oil inlet
8	Push-rod, outlet	24	Explosion relief valve in crankcase door
9	Fuel injector delivery pipe	25	Connecting rod
10	Return fuel tube	26	Small end with piston pin
11	Fuel feed pipe	27	Liner
12	Fuel pump	28	Piston crown
13	Cam follower, inlet	29	Governor shaft
14	Cam follower, outlet	30	Starting air pipe
15	Cam follower, fuel pump	31	Cooling water pipe, inlet
16	Lube oil tube in cam follower shaft	32	Cooling water pipe, outlet

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,
- Cat Common Rail is available,
- For invisible smoke at part load operation Flexible Camshaft Technology is available.

Cylinder head

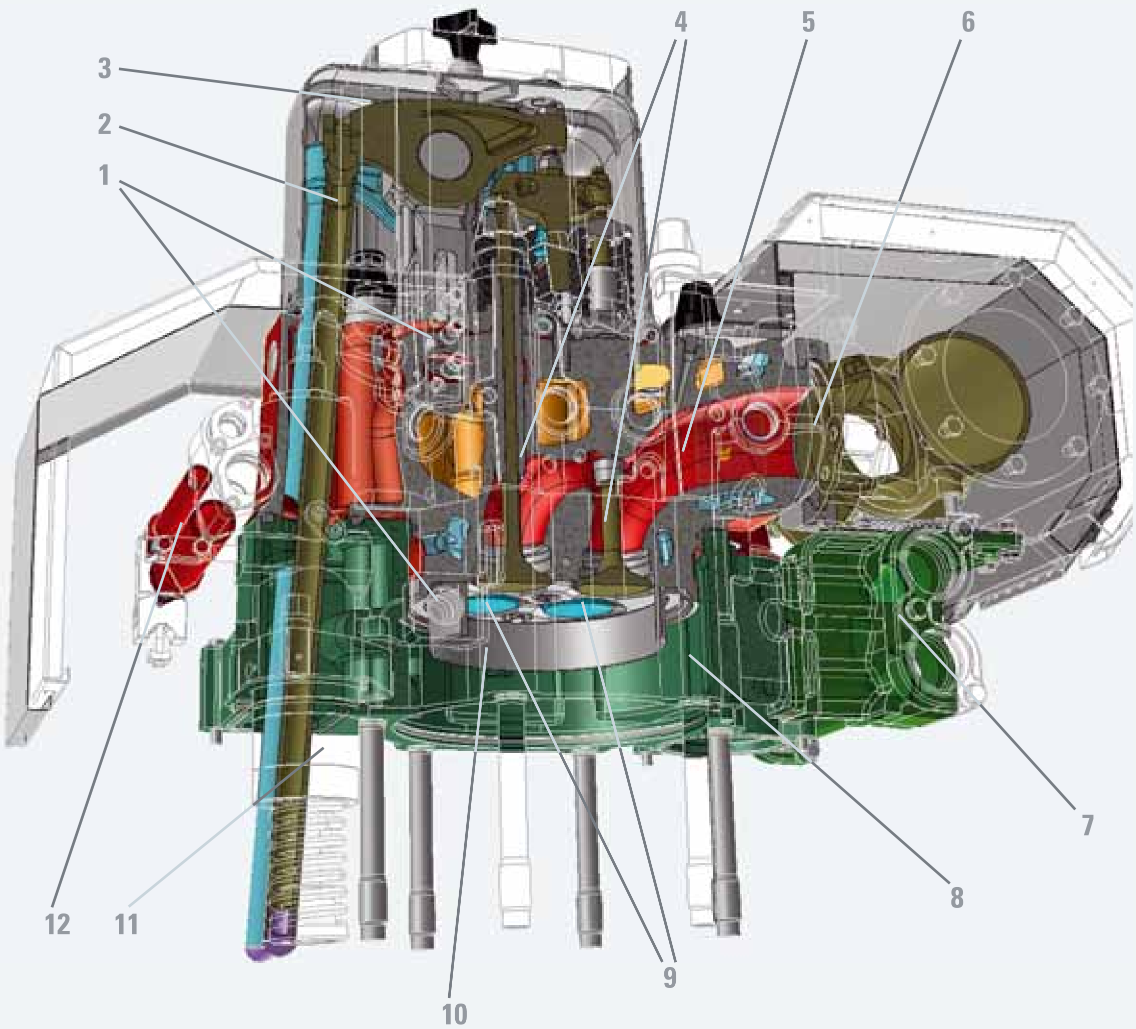

Fig. 1-7 Cylinder head

1	Media ducted through cylinder head	7	Cooling water lines inlet / outlet
2	Push rods	8	Cooling water distributor
3	Rocker arms	9	Combustion air inlet valves
4	Exhaust valves	10	Calibration insert in liner
5	Exhaust gas outlet	11	Fuel pump
6	Flange connection to exhaust gas	12	Fuel lines

- 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.

1.3 Engine running in

All MaK engines delivered have been already completely run in, therefore special guidelines for running in are not necessary.
Under certain circumstances, to which is referred in the respective maintenance guidelines, further running in can be required. This may be for example maintenance work at or changing of:

- pistons,
- piston rings and
- liners.

In these cases a running in period of 8 hours for M 32 C engines is to be adhered.
During this period the load of the preheated engine is raise from 20 % to 100 %.
HFO operated engines should be operated on MGO / MDO below 50 % engine load due to increased generation of combustion residues.
During the running in period pressure and temperature values are to be compared with the respective values of the factory acceptance test run.
Maintenance work or changing of main or big end bearings do not cause running in procedures.

1.4 Prospective life times

General

The expectable TBO (time between overhaul) and actual life time may deviate significantly as a result of, amongst others, fuel quality, load and operating profile / conditions and, however, the quality of maintenance.

Core components	Life time operating hours [h]		
	M 32 C Propulsion		
	MDO	HFO	TBO M 32 C
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 skirt Aluminium	–	–	–
Piston rings	30,000	30,000	–
Piston pin bearing	60,000	60,000	–
Cuff / Antipolishing ring	30,000	30,000	–
Cylinder liner	90,000	90,000	–
Cylinder head	90,000	90,000	15,000
Inlet valve	30,000	30,000	15,000
Exhaust valve	30,000	30,000	15,000
Nozzle element	7,500	5,000	–
Pump element	15,000	15,000	–
Main bearing	30,000	30,000	–
Big end bearing	30,000	30,000	–
Camshaft bearing	45,000	45,000	–
Turbocharger plain bearing	12,000	12,000	–
Vibration damper camshaft	15,000	15,000	–
Vibration damper crankshaft	60,000	60,000	30,000

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

Type	600 rpm
	[kW]
6 M 32 C	3,000
8 M 32 C	4,000
9 M 32 C	4,500

The maximum fuel rack position is mechanically limited to 100 % 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

The fuel consumption data refer to the following reference conditions:

Intake temperature:	298 K (25 °C)
Charge air temperature:	318 K (45°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 the fuel consumption data without fitted-on pumps;
for each pump fitted on an additional consumption of 1 % has to be calculated.

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 4).

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

2.4 Emissions

2.4.1 Exhaust gas

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

Intake air temperature 25 °C

Engine	Output	Output %					
	[kW]	[kg/h] [°C]					
		100	90	80	70	60	50
6 M 32 C A145	3,000	21,029 302	19,267 300	17,493 300	15,719 300	13,610 315	11,501 331
8 M 32 C TPL67	4,000	27,345 314	25,475 308	23,100 300	20,477 303	17,500 317	14,620 332
9 M 32 C TPL67	4,500	32,000 307	29,933 295	27,865 285	24,380 285	21,160 295	17,940 314

Intake air temperature 45 °C

Engine	Output	Output %					
	[kW]	[kg/h] [°C]					
		100	90	80	70	60	50
6 M 32 C A145	3,000	20,190 320	18,500 318	16,795 318	15,090 318	13,065 334	11,040 351
8 M 32 C TPL67	4,000	25,705 335	23,950 326	21,715 318	19,250 321	16,450 336	13,745 352
9 M 32 C TPL67	4,500	30,190 325	28,238 313	26,288 303	23,000 302	19,965 313	16,925 333

All values for single log charging. Pulse charging values: on request.

2.4.2 Nitrogen oxide emissions (NO_x-values)

NO_x-limit values according to IMO II: 10.1 g/kWh (n=600 rpm)
CPP acc. to cycle E2: 9.69 g/kWh

2.4.3 Engine International Air Pollution Prevention Certificate

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

	Test cycle type E2				Test cycle type 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 has to be calculated using different weighting factors for different loads that have been corrected to ISO 8178 conditions.

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

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

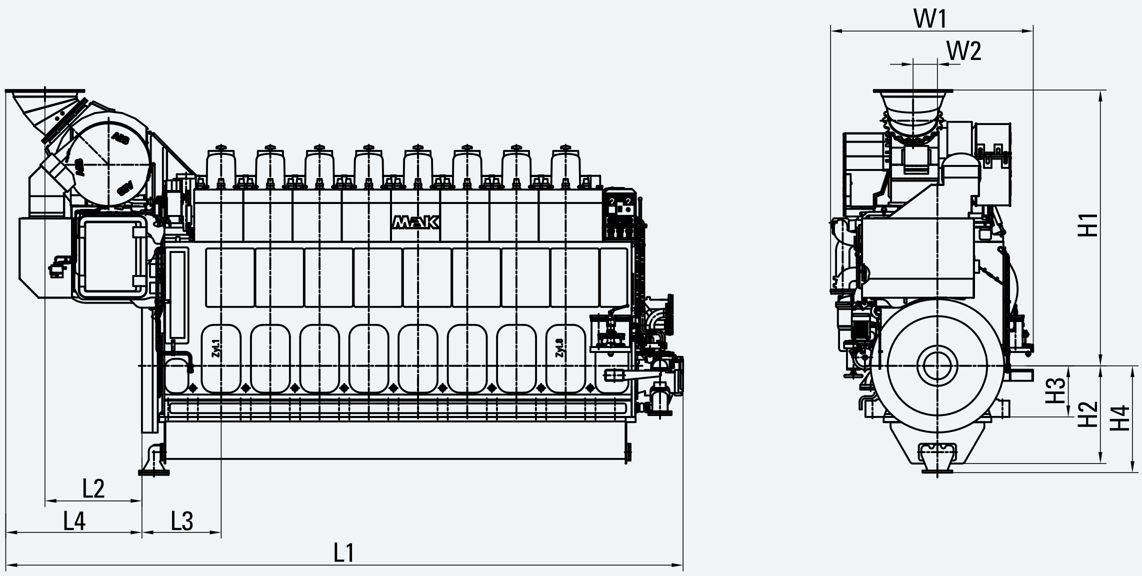

Fig. 2-1 Turbocharger at driving end with exhaust nozzle

Type	Dimensions [mm]										Weight
	L1	L2	L3	L4	H1	H2	H3	H4	W1	W2	[t]
6 M 32 C	5,936	788	852	1,170	2,784	1,052	550	1,150	2,368	962	39.5
8 M 32 C	7,293	1,044	852	1,467	2,969	1,052	550	1,150	2,182	262	49.0
9 M 32 C	7,823	1,044	852	1,467	2,969	1,052	550	1,150	2,182	262	52.0

Engine center distance

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

Recommended 2,800 mm
Minimum 2,600 mm
(Minimum width at fuel oil filter level approx. 500 mm)

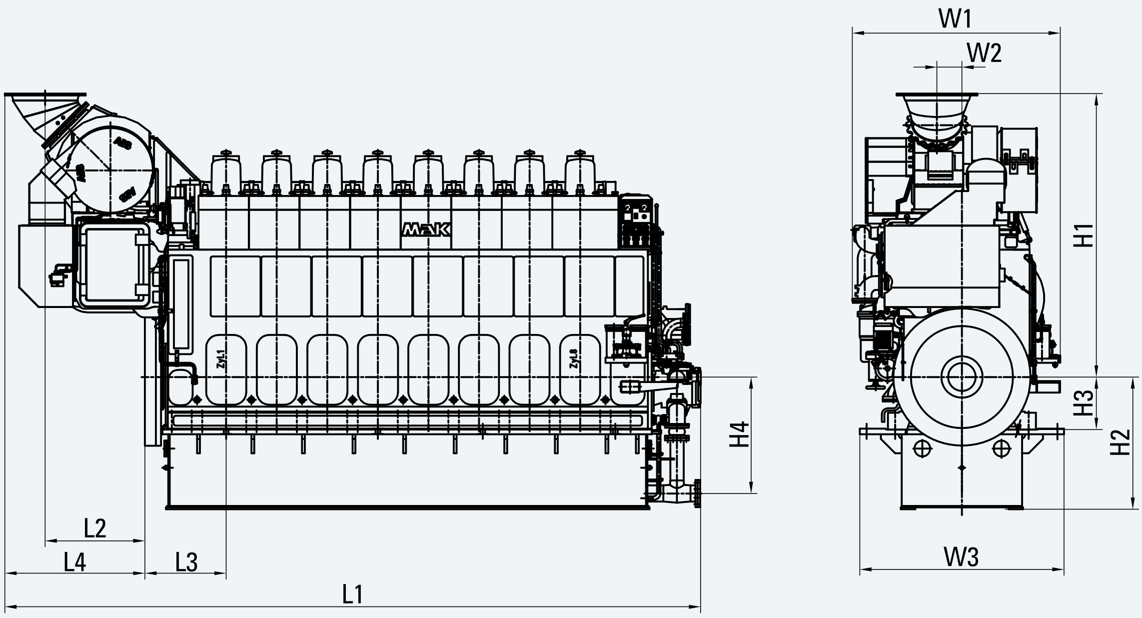

Fig. 2-2 Turbocharger at driving end with exhaust nozzle and sump tank

Type	Dimensions [mm]											Weight
	L1	L2	L3	L4	H1	H2	H3	H4	W1	W2	W3	[t]
6 M 32 C	5,936	788	852	1,170	2,784	1,385	550	1,220	2,368	962	2,140	41.6
8 M 32 C	7,293	1,044	852	1,467	2,969	1,385	550	1,220	2,182	262	2,140	51.7
9 M 32 C	7,823	1,044	852	1,467	2,969	1,385	550	1,220	2,182	262	2,140	55.0

Turbocharger at free end

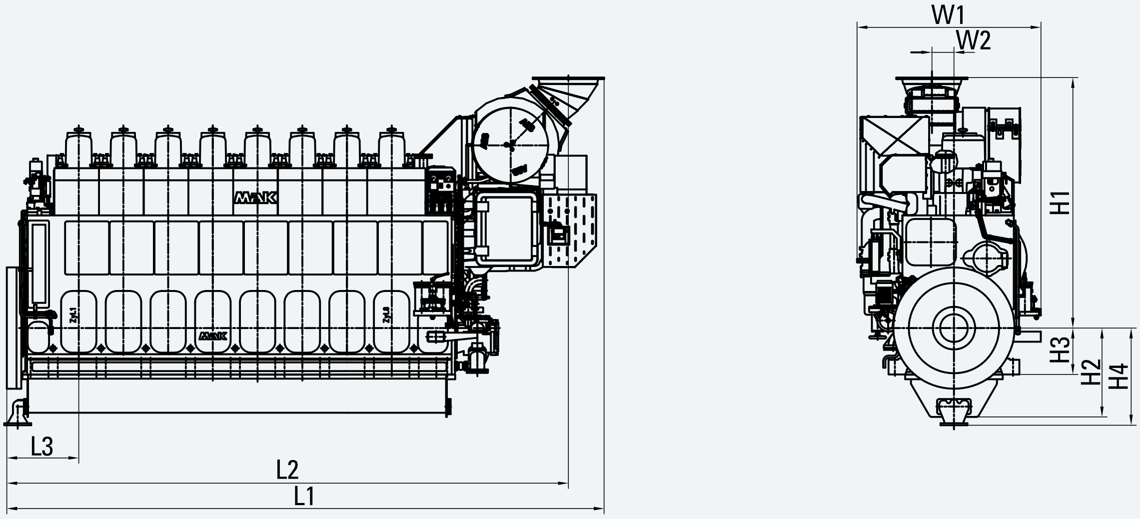

Fig. 2-3 Turbocharger at free end with exhaust nozzle

Type	Dimensions [mm]									Weight
	L1	L2	L3	H1	H2	H3	H4	W1	W2	[t]
6 M 32 C	5,722	5,260	852	2,901	1,052	550	1,150	2,368	962	39.5
8 M 32 C	7,079	6,656	852	2,969	1,052	550	1,150	2,182	262	49.0
9 M 32 C	7,609	7,186	852	2,969	1,052	550	1,150	2,182	262	52.0

Engine center distance

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

Recommended 2,800 mm
Minimum 2,600 mm
(Minimum width at fuel oil filter level approx. 500 mm)

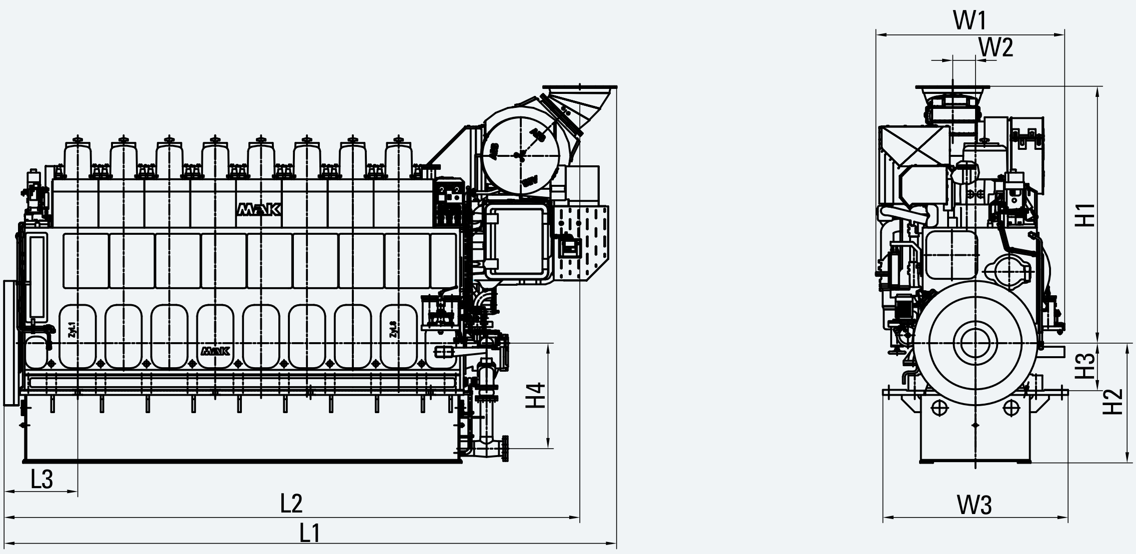

Fig. 2-4 Turbocharger at free end with exhaust nozzle and sump tank

Type	Dimensions [mm]										Weight
	L1	L2	L3	H1	H2	H3	H4	W1	W2	W3	[t]
6 M 32 C	5,722	5,260	852	2,901	1,385	550	1,220	2,368	962	2,140	41.6
8 M 32 C	7,079	6,656	852	2,969	1,385	550	1,220	2,182	262	2,140	51.7
9 M 32 C	7,609	7,186	852	2,969	1,385	550	1,220	2,182	262	2,140	55.0

2.6 System connecting points

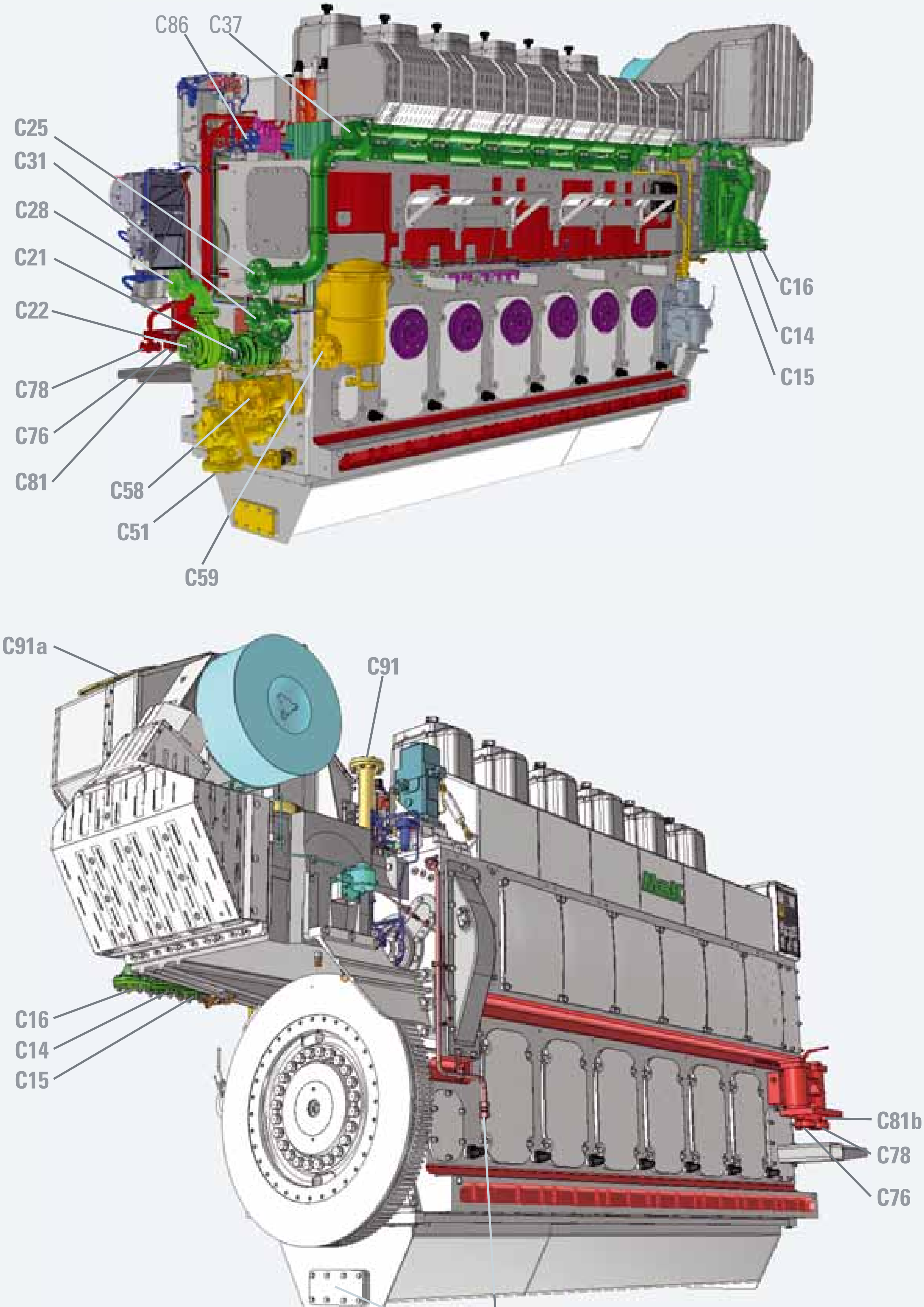

Fig. 2-5 Connecting points at the engine

Fuel oil (at HFO engines)

C76	Inlet, duplex filter
C78	Fuel outlet
C81	Drip fuel connection
C81b	Drip fuel connection (filter pan)

Fuel oil (not shown, only at MDO/MGO engines)

C73	Fuel inlet, to engine fitted pump
C75	Connection, stand-by pump

Cooling water

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	Freshwater pump LT, outlet
C31	Stand-by pump HT, inlet
C37	Ventilation connection

Exhaust

C91a	Exhaust gas outlet

Lube oil

C51	Force pump, suction side
C53	Lube oil discharge
C58	Force pump, delivery side
C59	Lube oil inlet, lube oil filter
C91	Crankcase ventilation

Compressed air

C86	Compressed air (30 bar), inlet

3.1 Controllable pitch propeller (CPP) operation

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.

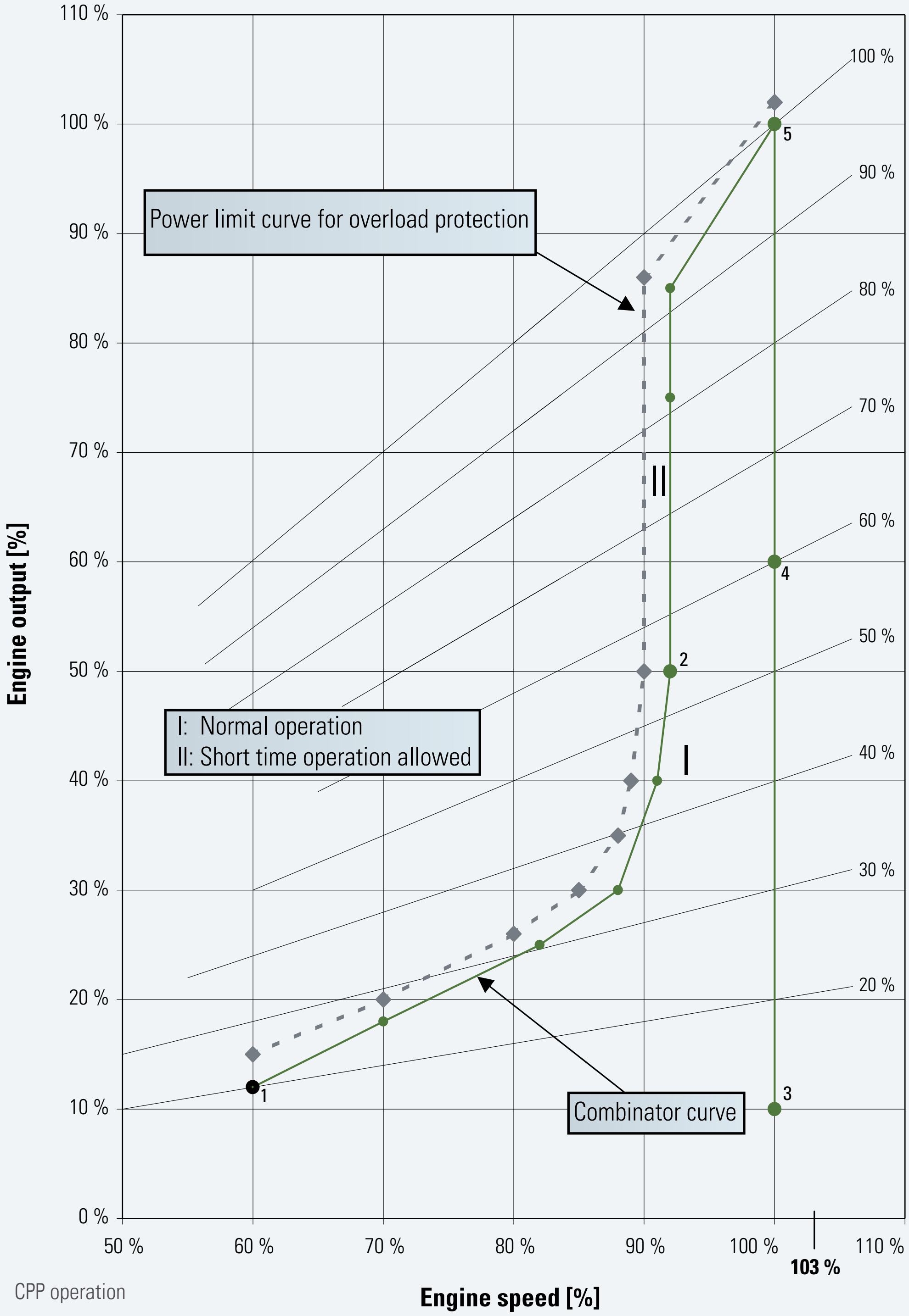

Fig. 3-1 CPP operation

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

Remarks

- Standard acceleration time will provide longest component lifetimes.
- Emergency acceleration possible, but not recommended, due to higher thermal stresses of engine components.
- For tugs and ferries a charge air pressure controlled fuel limiter is recommended.
- Reduction from 100 % to 0 % MCR in 20 s normal operation and 8 s in emergency operation.
- For faster ramp-up time, improved load behavior or reduced soot emission the air injection system is recommended.

Acceleration ramps

		Emergency operation		Normal operation			
		combinator	n constant	combinator		n constant	
		1 to 5	3 to 5	1 to 2	2 to 5	3 to 4	4 to 5
		[s]	[s]	[s]	[s]	[s]	[s]
Standard	6 M 32 C	25	20	35	120	30	120
Standard	8 M 32 C	30	25	40	120	35	120
Standard	9 M 32 C	40	30	40	120	35	120

Optional

Pulse charging	6/8 M 32 C	25	20	35	120	30	120
Pulse charging	9 M 32 C	25	25	35	120	30	120

For tug	See above	30	45	30	45
For ferry	See above	45	45	45	45

3.2 Optimized CPP operation for low fuel consumption with variable speed / frequency

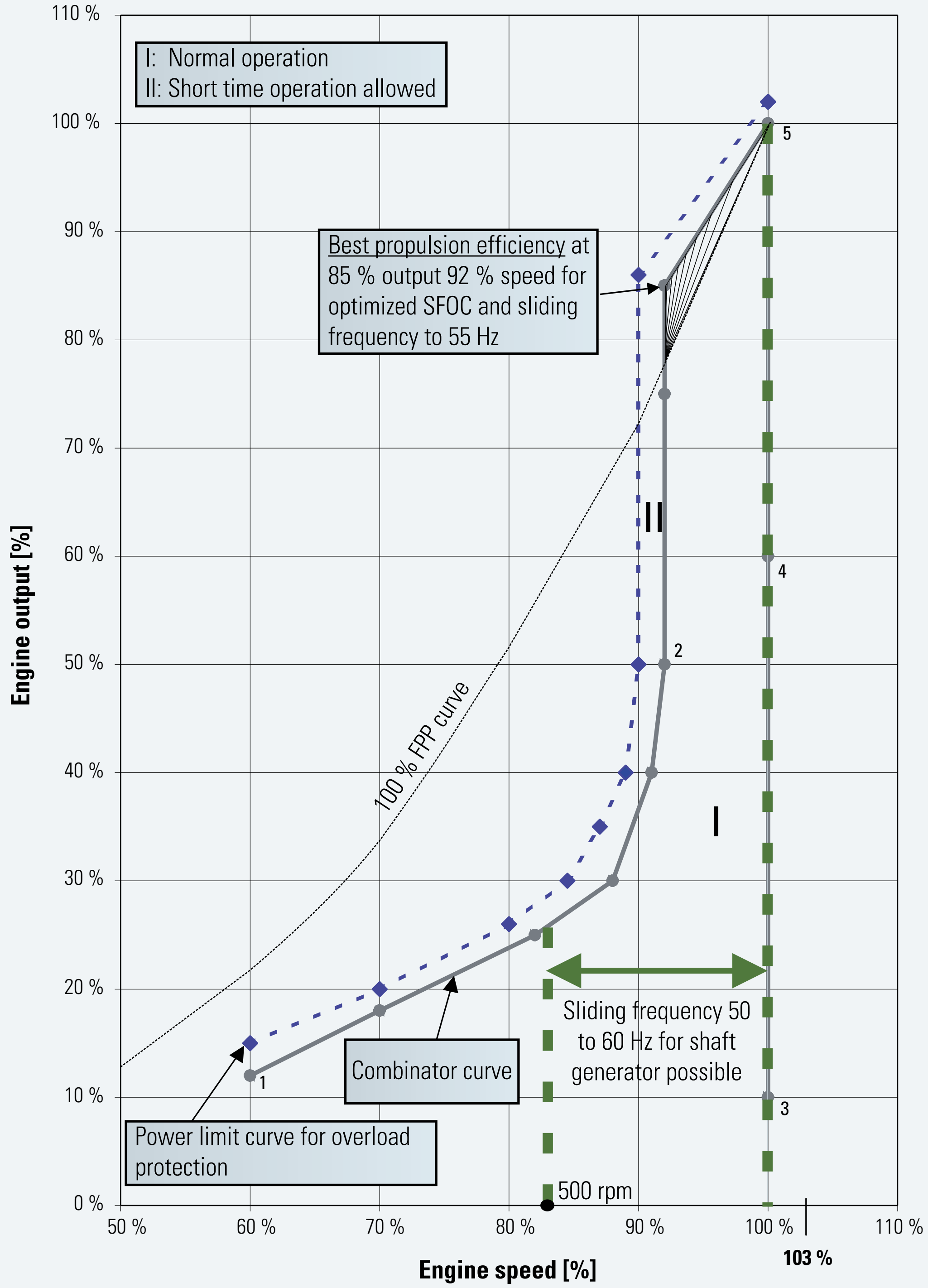

Fig. 3-2 Optimized CPP operation for low fuel consumption with variable speed / frequency

3.3 Fixed pitch propeller (FPP) operation

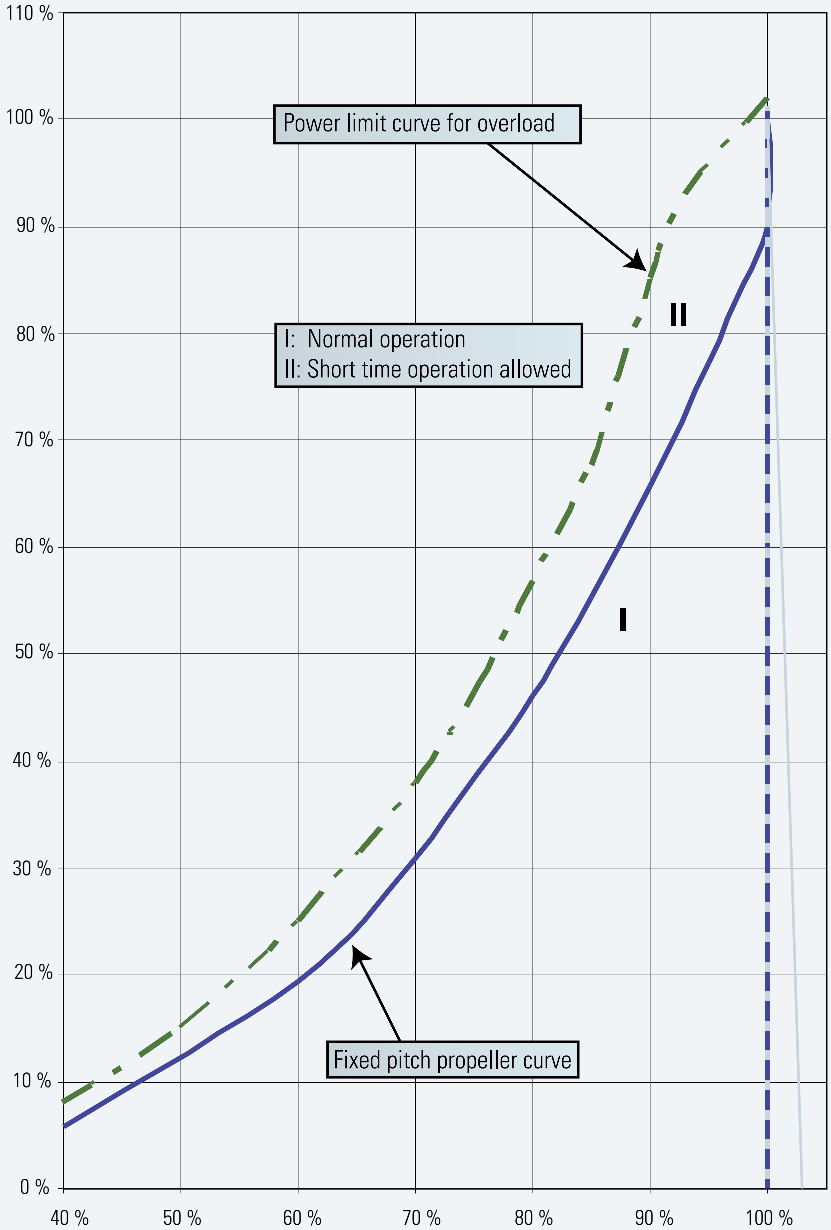

Fig. 3-3 FPP operation

Considering the special FPP-(engine) requirements, the curve can also be used for a CPP-plant.

Engine: 6 M 32 C	100 % output	2,700 [kW]
Engine: 8 M 32 C	100 % output	3,600 [kW]
Engine: 9 M 32 C	100 % output	4,050 [kW]

Special equipment

- Turbocharger optimized for 450 kW/cyl. with partload optimized specification
- Pulse exhaust pipe
- Special camshaft
- Additional oil pressure switch for low engine speed

3.4 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.

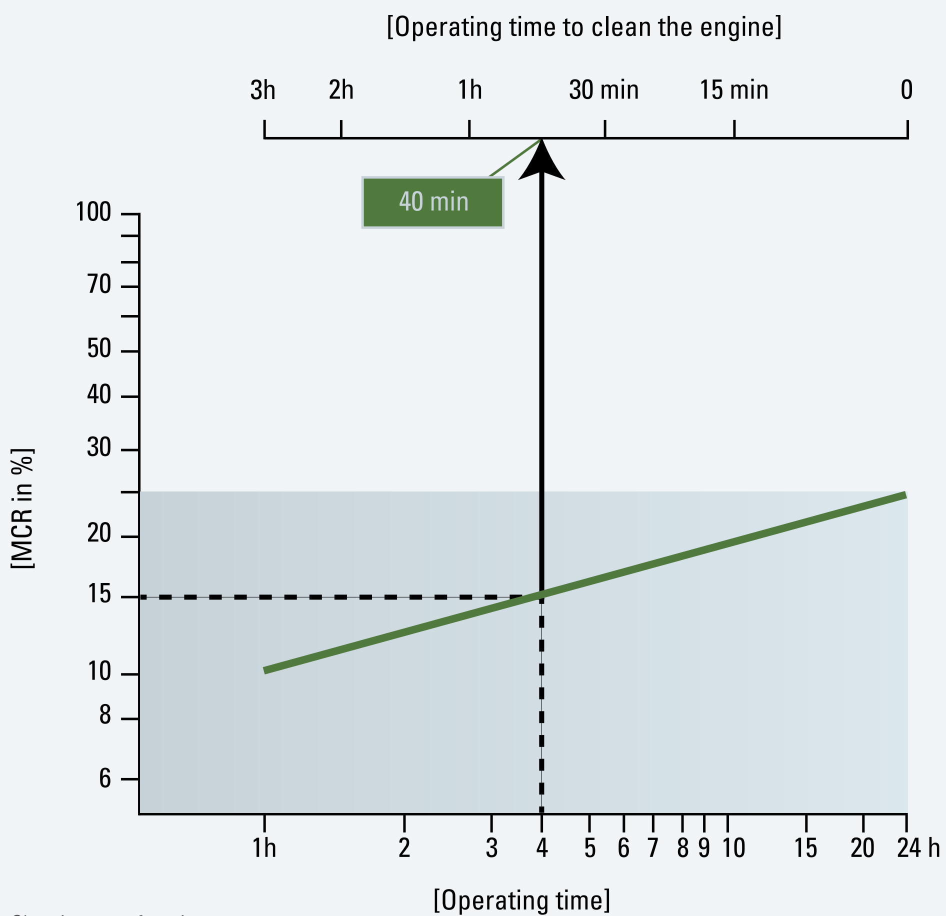

Fig. 3-4 Cleaning run of engine

3.5 Emergency operation without turbocharger

Emergency operation is permissible with MDO only up to approx. 15% of the MCR.

3.6 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 °

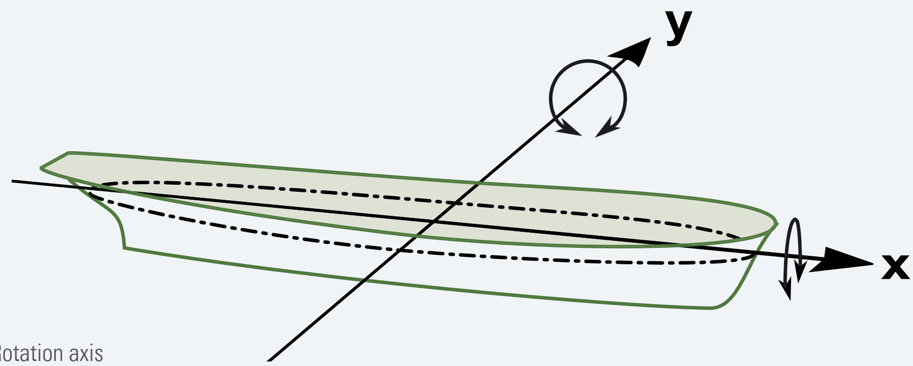

Fig. 3-5 Rotation axis

4.1 Diesel, mechanical

		6 M 32 C	8 M 32 C	9 M 32 C
Performance data				
Maximum continuous rating acc. ISO 3046/1	[kW]	3,000	4,000	4,500
Speed	[1/min]	600	600	600
Minimum speed	[1/min]	360	360	360
Brake mean effective presure	[bar]	25.9	25.9	25.9
Charge air pressure	[bar]	3.8	3.8	3.8
Firing pressure	[bar]	200	200	200
Combustion air demand (ta=20 °C)	[m³/h]	17,150	23,350	26,250
Specific fuel oil consumption				
Propeller n = const [1] 100 %	[g/kWh]	177	177	177
85 %	[g/kWh]	-/176	-/176	-/176
75 %	[g/kWh]	-/177	-/177	-/177
50 %	[g/kWh]	-/185	-/185	-/185
Lube oil consumption [2]	[g/kWh]	0.6	0.6	0.6
NO_x-emission [6]	[g/kWh]	9.8	9.8	9.8
Turbocharger type		ABB A145	ABB TPL67	ABB TPL67
Fuel				
Engine driven booster pump	[m³/h/bar]	2.2/5	3.2/5	3.2/5
Stand-by booster pump	[m³/h/bar]	2.2/10	2.9/10	3.2/10
Mesh size MDO fine filter	[mm]	0.025	0.025	0.025
Mesh size HFO automatic filter	[mm]	0.010	0.010	0.010
Mesh size HFO fine filter	[mm]	0.034	0.034	0.034
Lube oil				
Engine driven pump	[m³/h/bar]	118/10	118/10	118/10
Independent pump	[m³/h/bar]	60/10	80/10	80/10
Working pressure on engine inlet	[bar]	4 - 5	4 - 5	4 - 5
Engine driven suction pump	[m³/h/bar]	140/3	140/3	140/3
Independent suction pump	[m³/h/bar]	65/3	85/3	100/3
Priming pump	[m³/h/bar]	8/5	11/5	11/5
Sump tank content / dry sump content	[m³]	4.1	5.4	6.1
Temperature at engine inlet	[°C]	60 - 65	60 - 65	60 - 65
Temperature controller NB	[mm]	80	100	100
Double filter NB	[mm]	80	80	80
Mesh size double filter	[mm]	0.08	0.08	0.08
Mesh size automatic filter	[mm]	0.03	0.03	0.03
Max. allowed crankcase pressure, ND-ventilationpipe	[mmWs/ mm]	15/80	15/80	15/80

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		6 M 32 C	8 M 32 C	9 M 32 C
Fresh water cooling				
Engine content	[m³]	0.7	0.95	1.05
Pressure at inlet min/max	[bar]	2.5/6.0	2.5/6.0	2.5/6.0
Header tank capacity	[m³]	0.35	0.45	0.55
Temperature at engine outlet	[°C]	80 - 90	80 - 90	80 - 90
Two circuit system				
Engine driven pump HT	[m³/h/bar]	70/3.5	70/3.5	80/3.4
Independent pump HT	[m³/h/bar]	70/3.0	70/3.0	80/3.2
HT-controller NB	[mm]	100	100	100
Water demand LT-charge air cooler	[m³/h]	40	60	60
Temperature at LT-charge air cooler inlet	[°C]	38	38	38
Heat dissipation				
Specific jacket water heat	[kJ/kW]	500	500	500
Specific lube oil heat	[kJ/kW]	525	525	525
Lubricating oil cooler	[kW]	440	590	660
Jacket water	[kW]	420	550	625
Charge air cooler [3]	[kW]	–	–	–
Charge air cooler (HT-stage) [3]	[kW]	1,175	1,530	1,705
Charge air cooler (LT-stage) [3] (HT-stage before engine)	[kW]	300	440	505
Heat radiation engine	[kW]	150	190	210
Exhaust gas				
Silencer / spark arrestor NB	[mm]	600	700	800
Pipe diameter NB after turbine	[mm]	600	700	800
Maximum exhaust gas pressure drop	[bar]	0.03	0.03	0.03
Exhaust gas temperature after turbine (intake air 25 °C) [6]	[°C)	303	315	310
Exhaust gas mass flow (intake air 25 °C) [6]	[kg/h]	21,132	28,860	32,445
Starting air				
Starting air pressure max.	[bar]	30	30	30
Minimum starting air pressure	[bar]	10	10	10
Air consumption per start [4]	[Nm³]	1.2	1.2	1.2

1) Reference conditions: LCV = 42,700 kJ/kg, ambient temperature 25 °C, charge air coolant temperature 25 °C, tolerance 5 %, + 1 % for engine driven pump / **2)** Standard value, tolerance ± 0.3 g/kWh, related on full load / **3)** Charge air heat based on 45 °C ambient temperature / **4)** Preheated engine / **5)** Tolerance 10 %, rel. humidity 60 % / **6)** Marpol 73/78, Annex VI, cycle E2, D2

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.

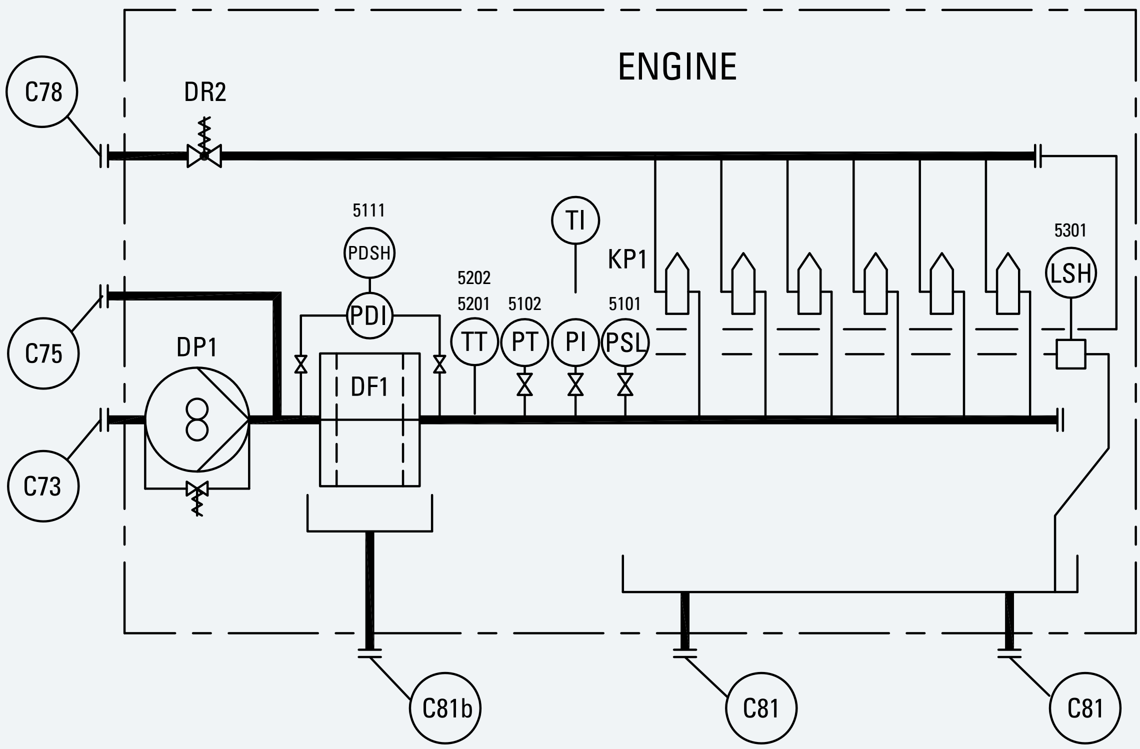

Fig. 5-1 Internal fuel oil system, system diagram

DF1	Fuel fine filter (duplex filter)
DP1	Diesel oil feed pump
DR2	Fuel pressure regulating valve
KP1	Fuel injection pump
LSH	Level switch high
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)

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 transfer the heat, which is 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

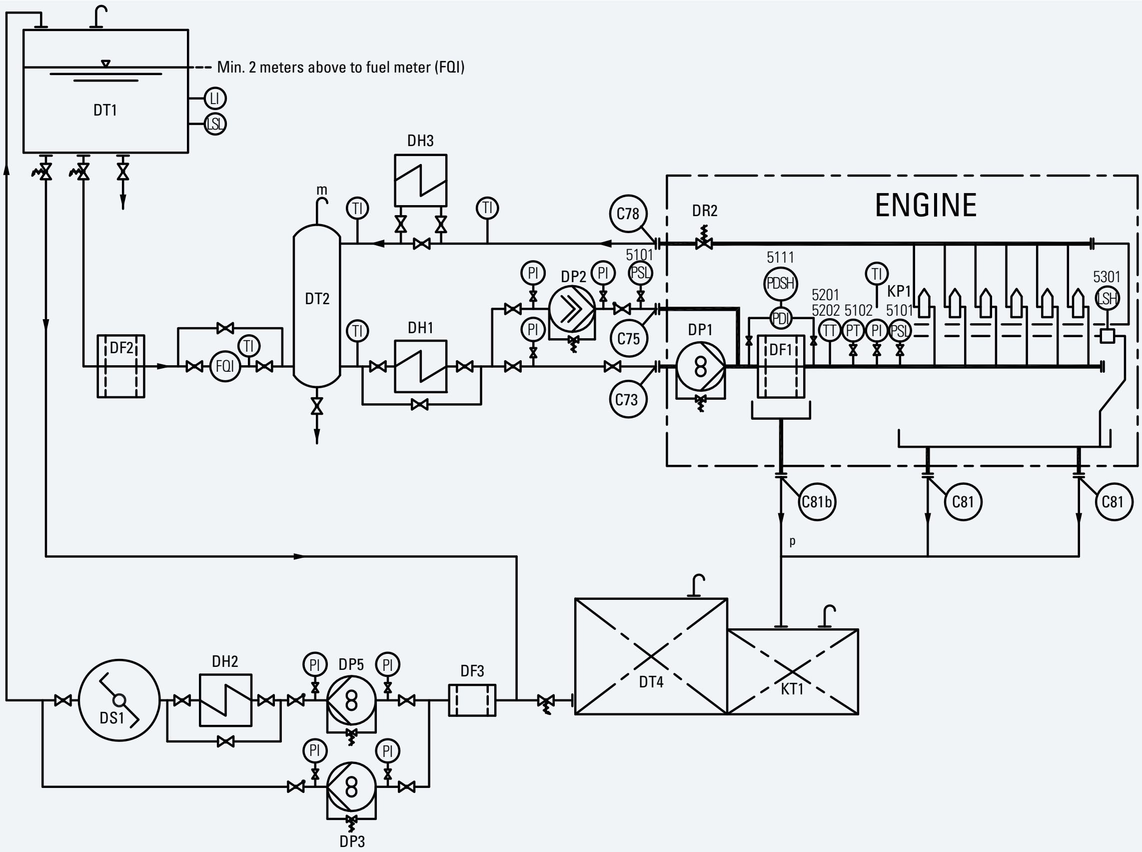

Fig. 5-2 External fuel oil system diagram with intermediate tank

DF1	Fuel fine filter (duplex filter)	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 MDO operation	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
DT2	Diesel oil intermediate tank	C81	Drip-fuel connection
DT4	Diesel oil storage tank	C81b	Drip-fuel connection (filter pan)
FQI	Flow quantity indicator		
KP1	Fuel injection pump	m	Lead vent pipe beyond service tank
KT1	Drip fuel tank	p	Free outlet required

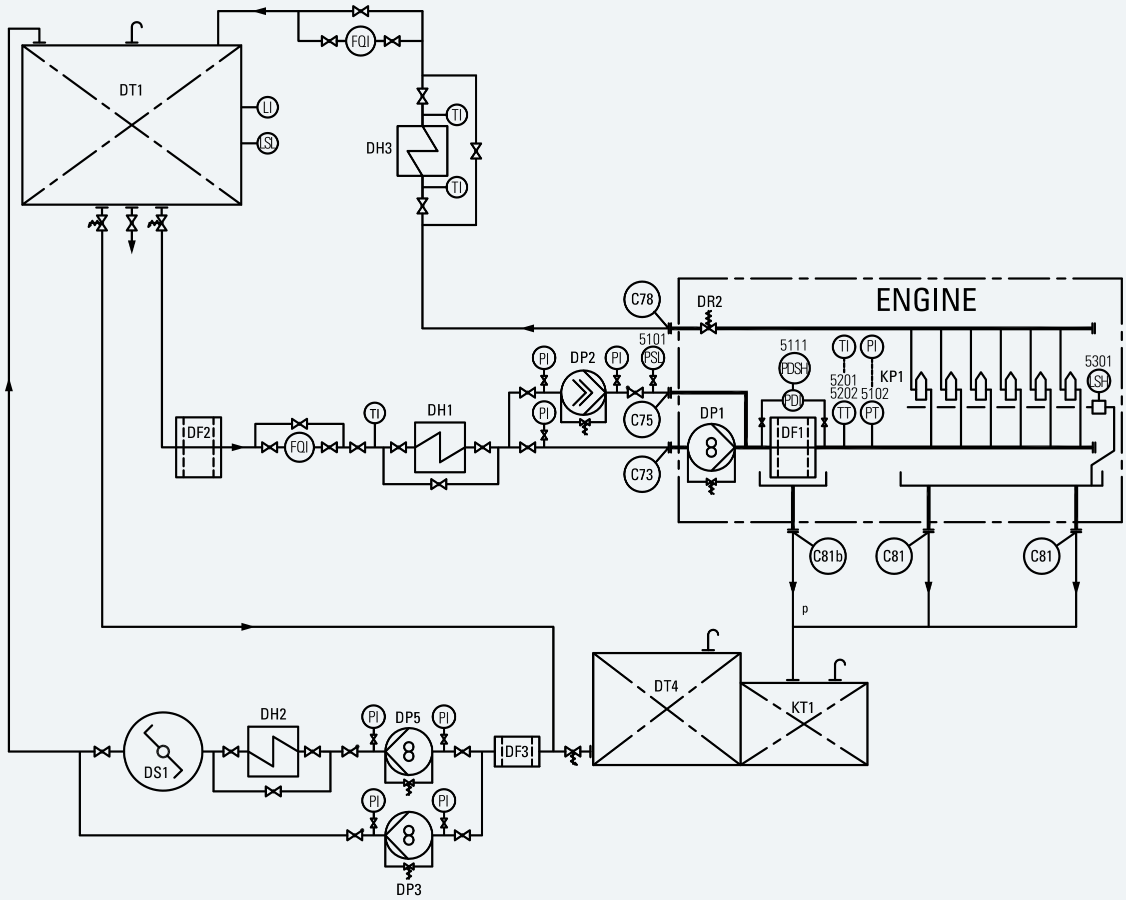

Fig. 5-3 External fuel oil system diagram without intermediate tank

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 for MDO operation
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
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)
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 acc. 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 oils must always be considered as contaminated upon delivery and should therefore be thoroughly cleaned to remove solid and liquid contaminants before use.
Most of the solid contaminants in the fuel are rust, sand, dust.
Liquid contaminants are mainly water, i.e. either 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 or
- increased fouling of turbocharger blades.

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

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

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

Diesel oil day tank DT1

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

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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.

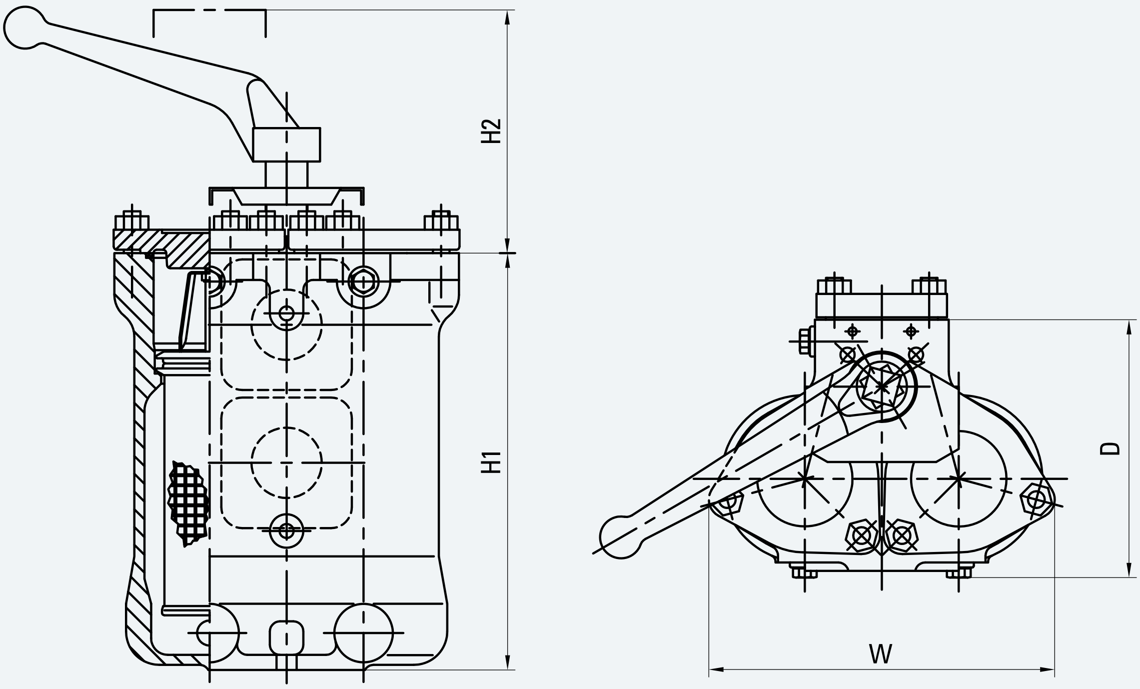

Fig. 5-4 Fuel primary filter DF2

Engine output	DN	Dimensions [mm]			
[kW]		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.

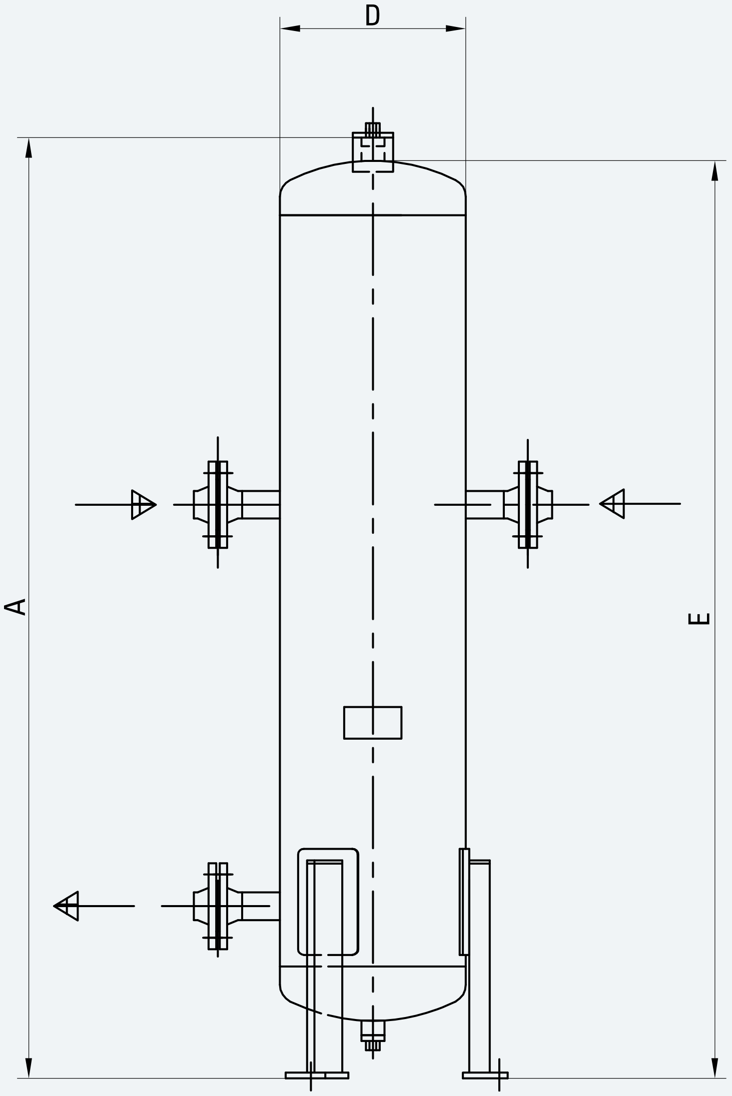

Fig. 5-5 Diesel oil intermediate tank DT2

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

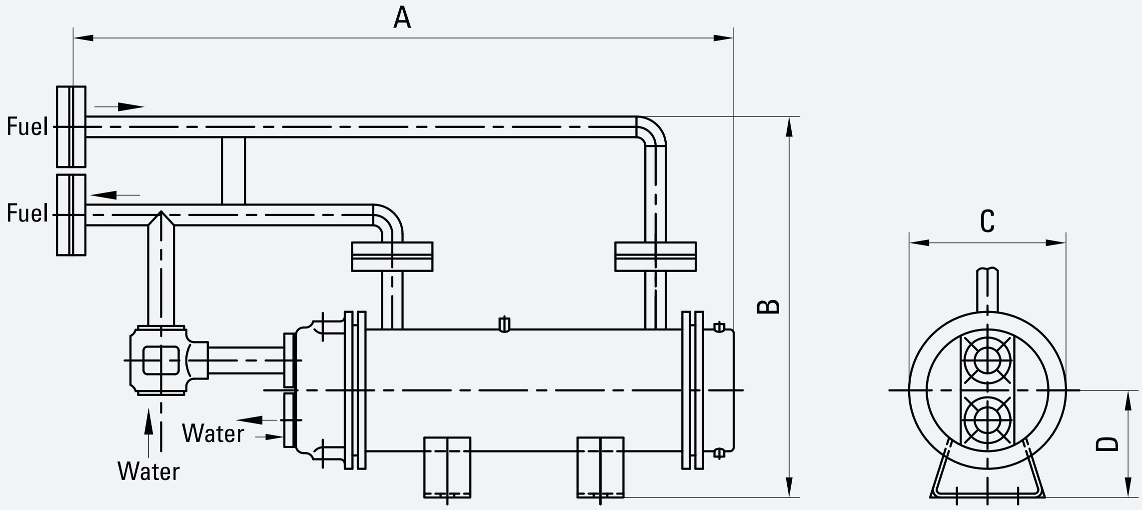

Fig. 5-6 Diesel oil preheater DH1

Engine	Dimensions [mm]				Weight
	A	B	C	D	[kg]
6/8/9 M 32 C	863	498	Ø 205	140	42

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

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

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

A diesel oil preheater is not required

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

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.

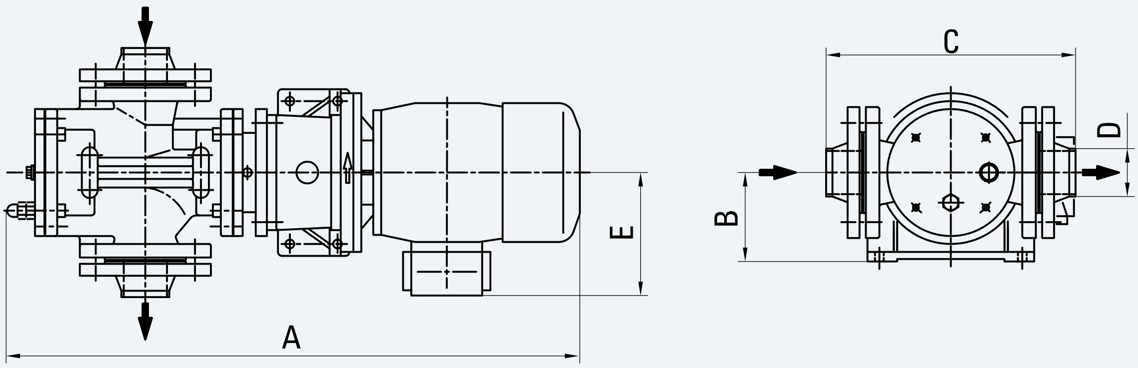

Fig. 5-7 Stand-by booster pump DP2

Engine	Dimensions [mm]					Weight	Motorpower	Voltage / Frequency
	A	B	C	D	E	[kg]	[kW]	[V/Hz]
6/8/9 M 32 C	735	112	314	60.3	155	61	1.5	400/50
6/8 M 32 C	735	112	314	60.3	155	61	1.8	440/60
9 M 32 C	775	132	314	60.3	155	70	2.6	440/60

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Fuel oil cooler for MDO operation 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 or different engines are 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.

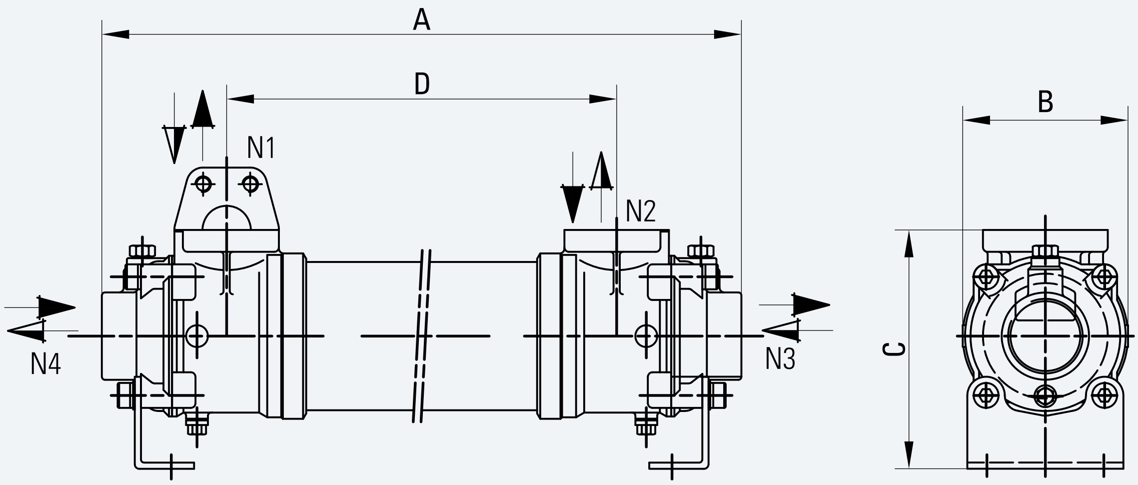


Fig. 5-8 Fuel oil cooler for MDO operation DH3

Engine	Dimensions [mm]						Weight
	A	B	C	D	N1 + N2	N3 + N4	[kg]
6/8/9 M 32 C	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 on heavy fuel installations. Stable and correct viscosity of the fuel before the 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 and 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

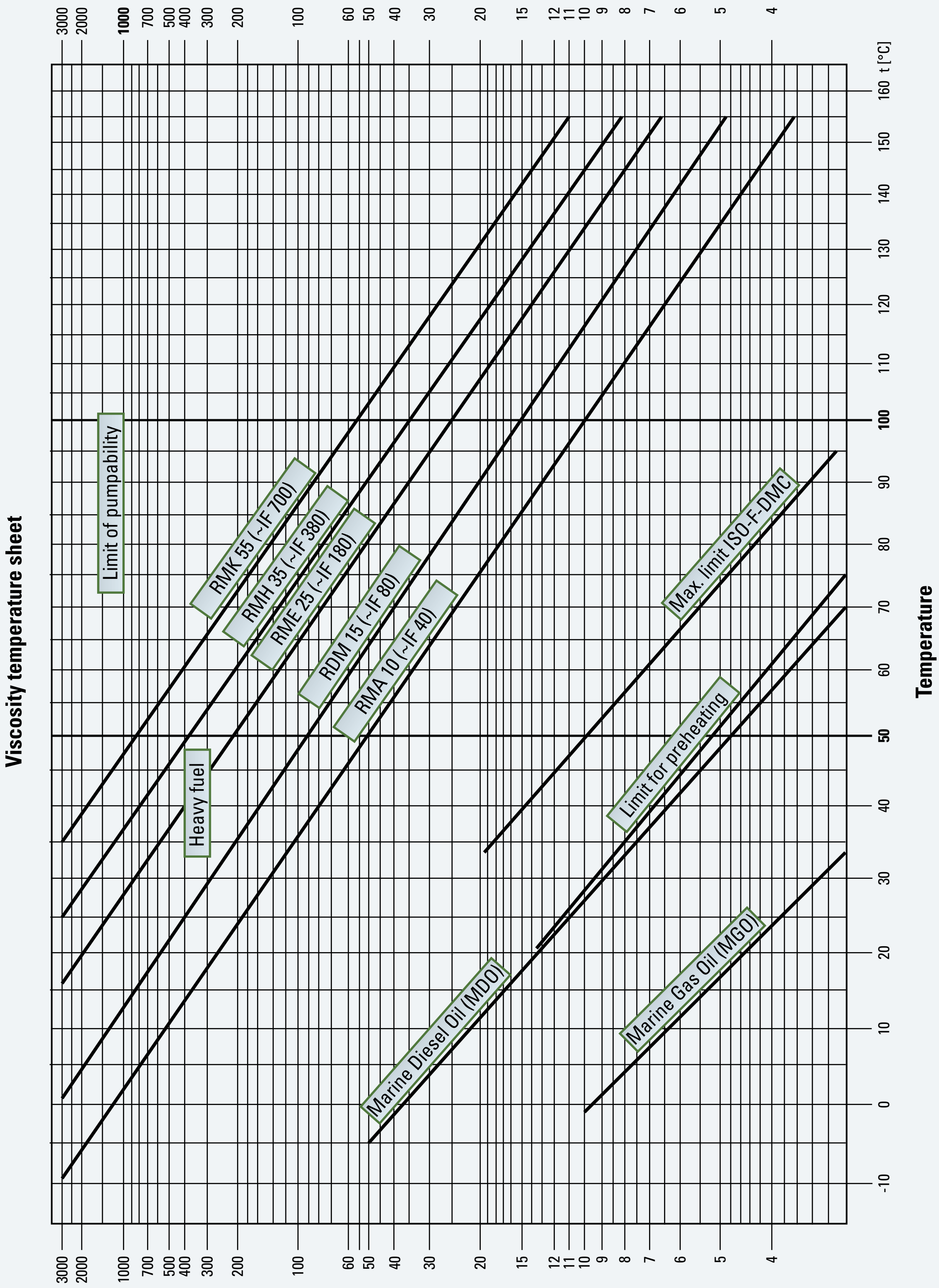


Fig. 5-9 Viscosity / temperature diagram

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 a too high consumption.
Therefore, optimum injection viscosity of 10 – 12 cSt must be maintained at any rate and with all fuel grades.
Deviations from that 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 schedule 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

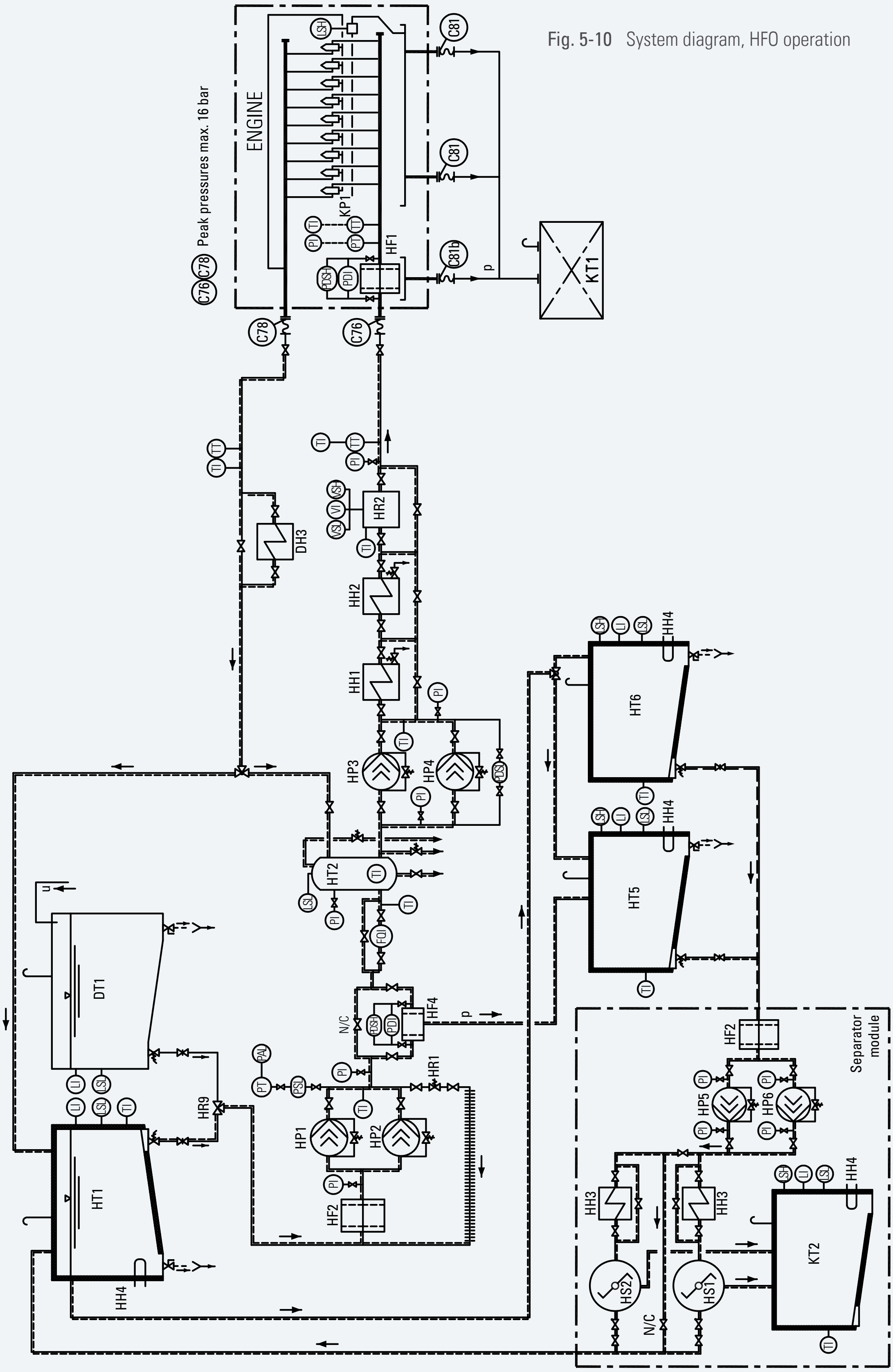


Fig. 5-10 System diagram, HFO operation

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 the admission and return lines.

DH3	Fuel oil cooler for MDO operation	FQI	Flow quantity indicator
DT1	Diesel oil day tank	LI	Level indicator
HF1	Fine filter (duplex filter)	LSH	Level switch high
HF2	Primary filter (duplex filter)	LSL	Level switch low
HF4	HFO automatic filter	PAL	Pressure alarm low
HH1	Heavy fuel final preheater	PDI	Diff. pressure indicator
HH2	Stand-by final preheater	PDSH	Diff. pressure switch high
HH3	Heavy fuel preheater (separator)	PDSL	Diff. pressure switch low
HH4	Heating coil	PI	Pressure indicator
HP1	Fuel pressure pump	PSL	Pressure switch low
HP2	Fuel stand-by pressure pump	PT	Pressure temp.
HP3	Fuel circulating pump	TI	Temperature indicator
HP4	Stand-by circulating pump	TT	Temperature transmitter (PT100)
HP5/6	Heavy fuel transfer pump (separator)	VI	Viscosity indicator
HR1	Fuel pressure regulating valve	VSH	Viscosity control switch high
HR2	Viscosimeter	VSL	Viscosity control switch low
HR9	Fuel change over main valve		
HS1/2	Heavy fuel separator	C76	Inlet, duplex filter
HT1	Heavy fuel day tank	C78	Fuel outlet
HT2	Mixing tank	C81	Drip-fuel connection
HT5/6	Settling tank	C81b	Drip-fuel connection
KP1	Injection pump		
KT1	Drip fuel tank	p	Free outlet required
KT2	Sludge tank	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 based on ship application.
Heating coils are necessary and are to be designed so that the HFO temperature is at least 10K above the pour point to ensure a pumping viscosity below 1,000 cSt.
Heating is possible by steam, thermal oil, electrical current or hot water.

Settling tanks HT5, HT6

The tank design, sizing, location must comply with classification society requirements and 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.

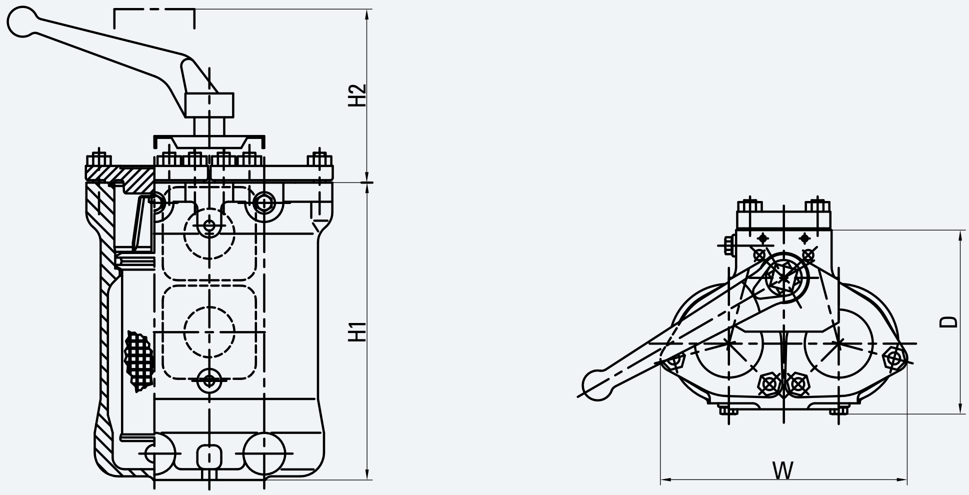


Fig. 5-11 Primary filter HF2

Engine output	DN	Dimensions [mm]			
[kW]		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]

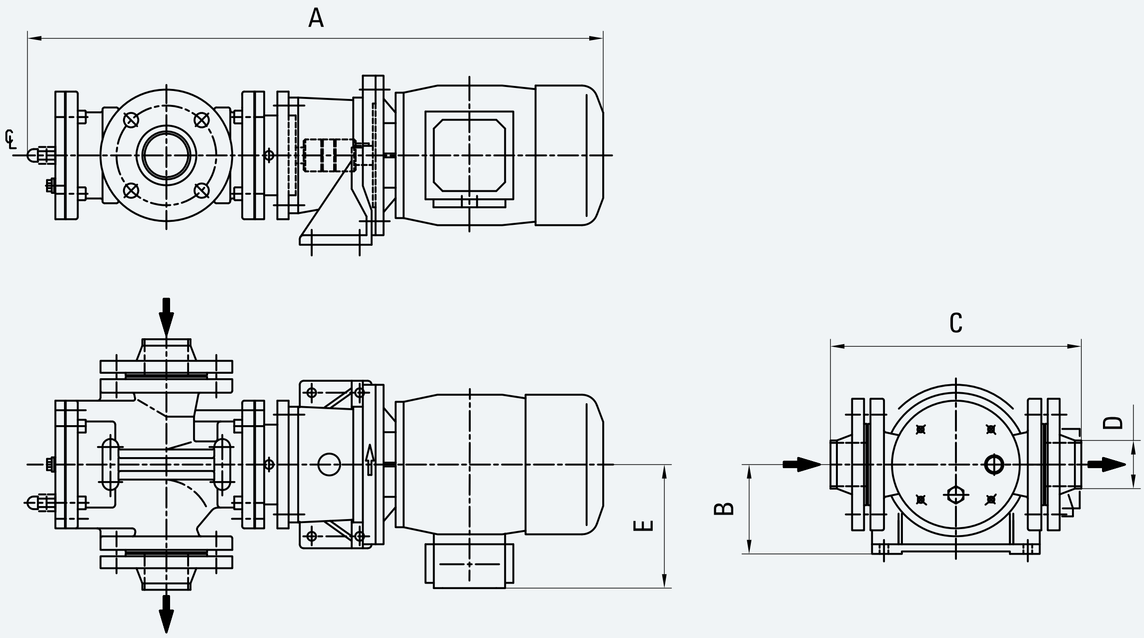


Fig. 5-12 Fuel pressure pump HP1; fuel stand-by pressure pump HP2

Plant output	Dimensions [mm]					Weight	Voltage / frequency
[kW]	A	B	C	D	E	[kg]	[V/Hz]
3,000	650	112	254	42.4	155	42	400/50
4,000 - 6,000	775	132	314	60.3	180	70	400/50
8,000 - 9,000	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]
3,000	625	112	254	42.4	155	42	440/60
4,000	705	112	254	42.4	180	57	440/60
6,000 - 9,000	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.

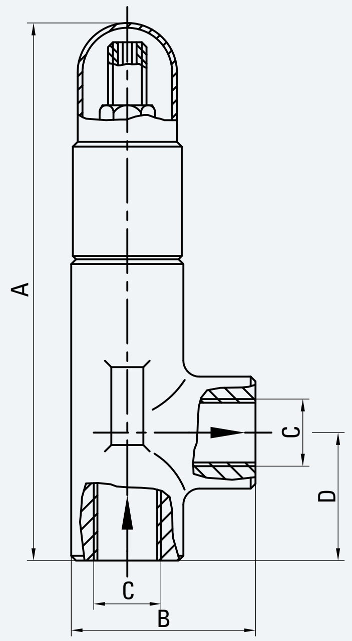


Fig 5-13 Fuel pressure regulating valve HR1, ≤ 3,000 kW

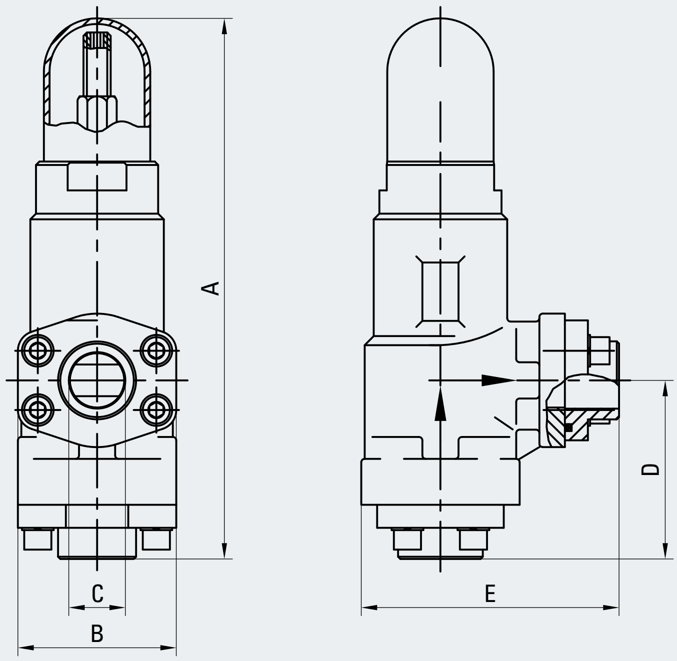


Fig 5-14 Fuel pressure regulating valve HR1, > 3,000 kW

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.

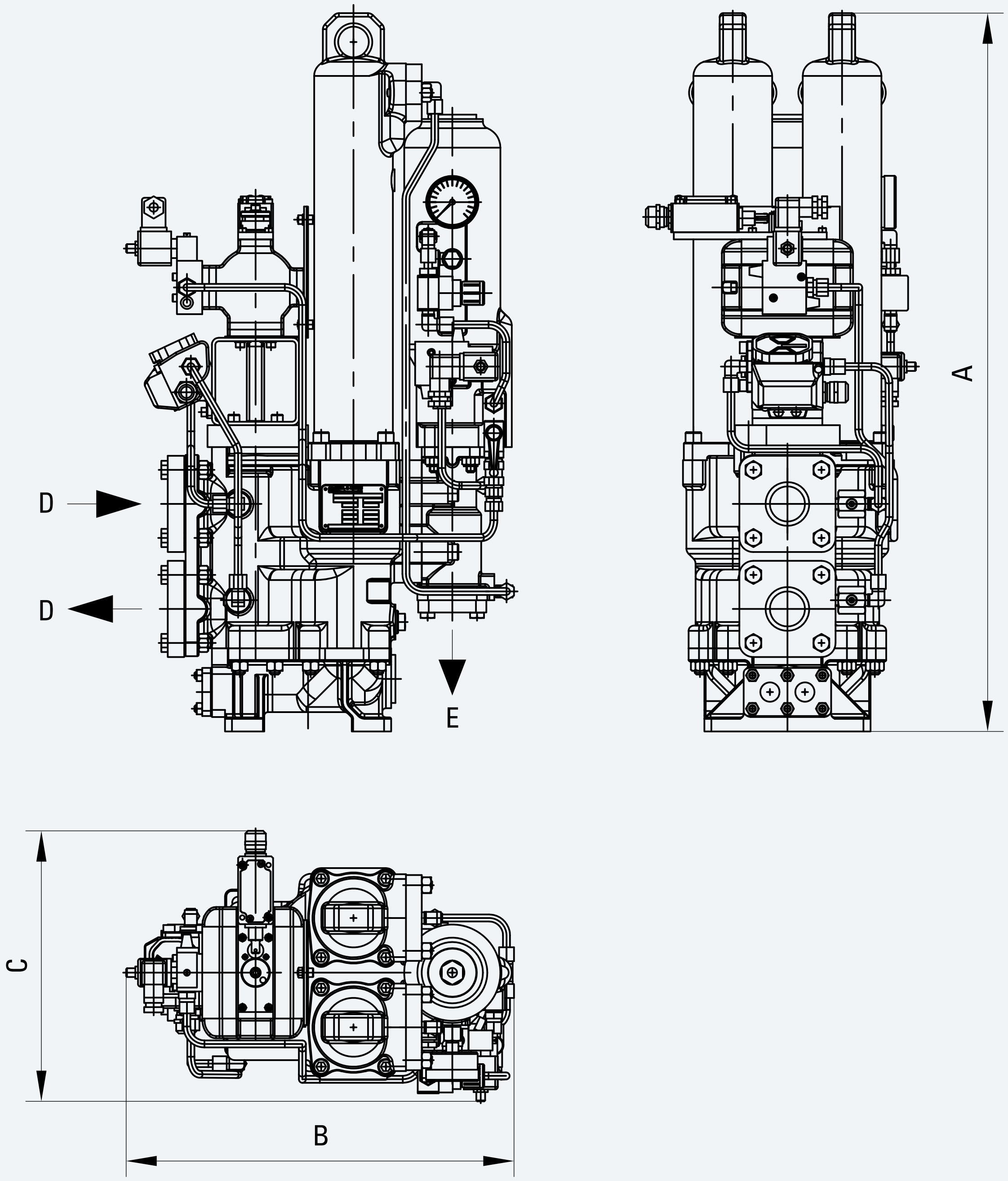


Fig. 5-15 HFO automatic filter HF4

Plant output	Dimensions [mm]				
[kW]	A	B	C	D	E
3,000 - 4,500	825	445	310	DN 40	DN 32
4,501 - 12,000	890	520	335	DN 65	DN 50

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

Function: In the mixing tank the warm return fuel from the engine is mixed with the fuel delivered from the day tank. 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.
Venting to the day tank is required, if level switch is activated, due to accumulated air or gases in the mixing tank.

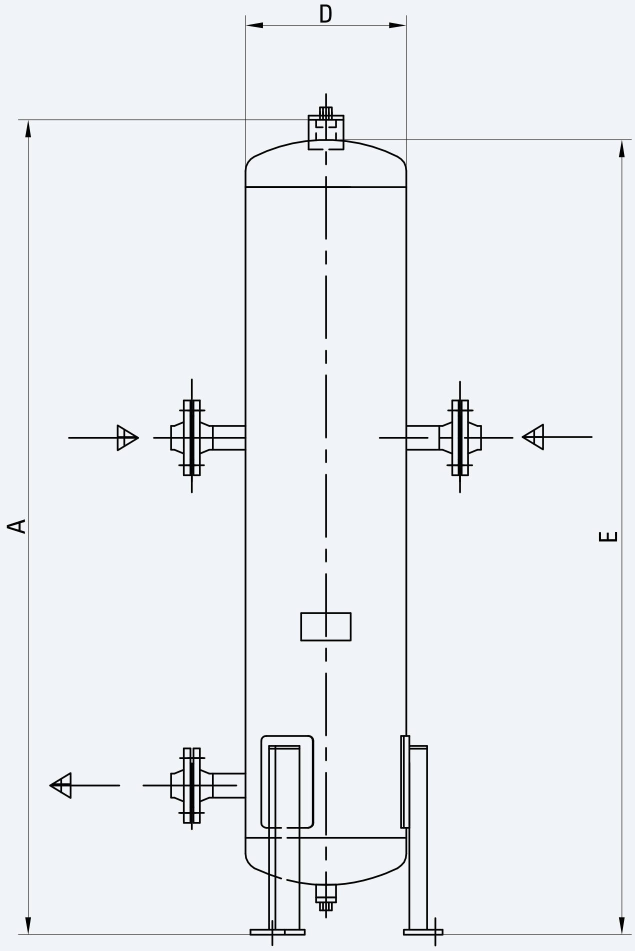


Fig. 5-16 Mixing tank HT2

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

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

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 engines 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 $[m^3/h]$
$P_{eng.} =$ Power engine [kW]

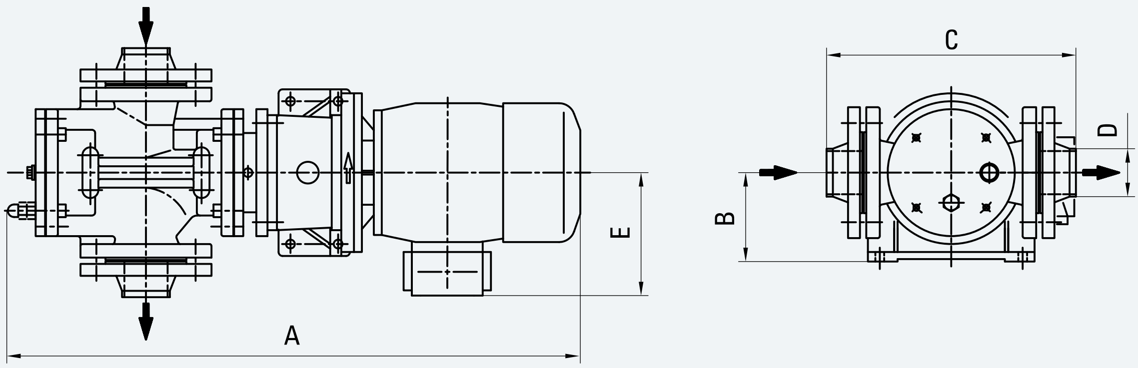


Fig. 5-17 Fuel circulating pump HP3, Stand-by circulating pump HP4

Plant output	Dimensions [mm]					Weight	Voltage / frequency
[kW]	A	B	C	D	E	[kg]	[V/Hz]
3,000 - 4,000	775	132	314	60.3	180	70	400/50
4,500 - 6,000	805	132	314	60.3	180	72	400/50
8,000 - 9,000	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]
3,000 - 4,500	775	132	314	60.3	180	70	440/60
6,000	805	132	314	60.3	180	72	440/60
8,000 - 9,000	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

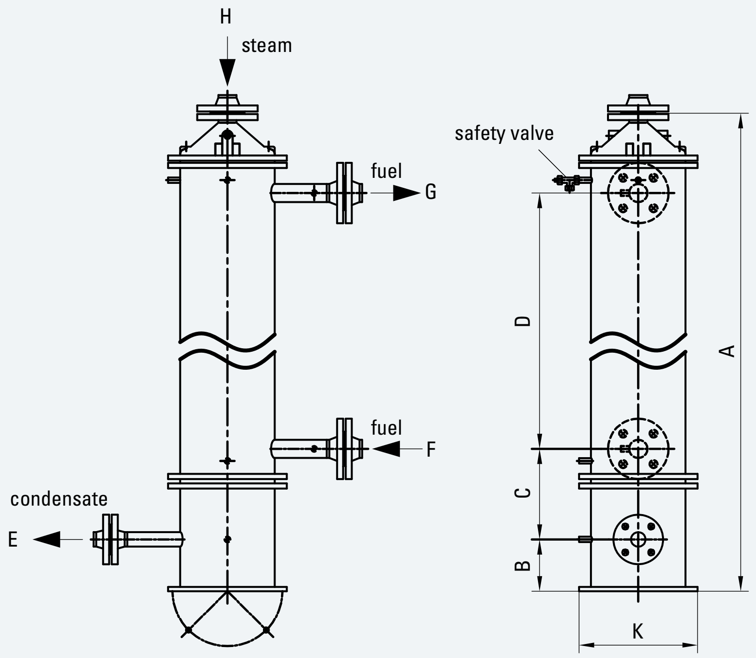


Fig. 5-18 Heavy fuel final preheater HH1, stand-by final preheater HH2

Plant output	Dimensions [mm]									Weight
[kW]	A	B	C	D	E	F	G	H	K	[kg]
up to 3,000	1,220	120	210	705	DN 25	DN 25	DN 325	DN 32	Ø 275	125
3,001 - 4,500	1,520	120	210	1,005	DN 25	DN 32	DN 32	DN 32	Ø 275	155
4,501 - 8,000	2,065	120	215	1,540	DN 25	DN 40	DN 40	DN 32	Ø 275	272
8,001 - 14,000	1,630	130	235	1,035	DN 40	DN 50	DN 50	DN 50	Ø 390	265

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.
Thus 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 for MDO operation DH3

To ensure always a fuel oil temp. below 50 °C a cooling of diesel oil might be required.
The need for fuel cooler is system specific and depends on fuel circuit design and type of fuel oil.
In case of more than one engine, or different engines are connected to the same fuel supply system, the MDO-cooler capacity has to be increased accordingly.
The diesel oil coolers are always installed in the fuel return line (engine connection C78).
The heat transfer load into the diesel oil system is approx. 1.6 kW/cyl.
LT-water is normally used as cooling medium.

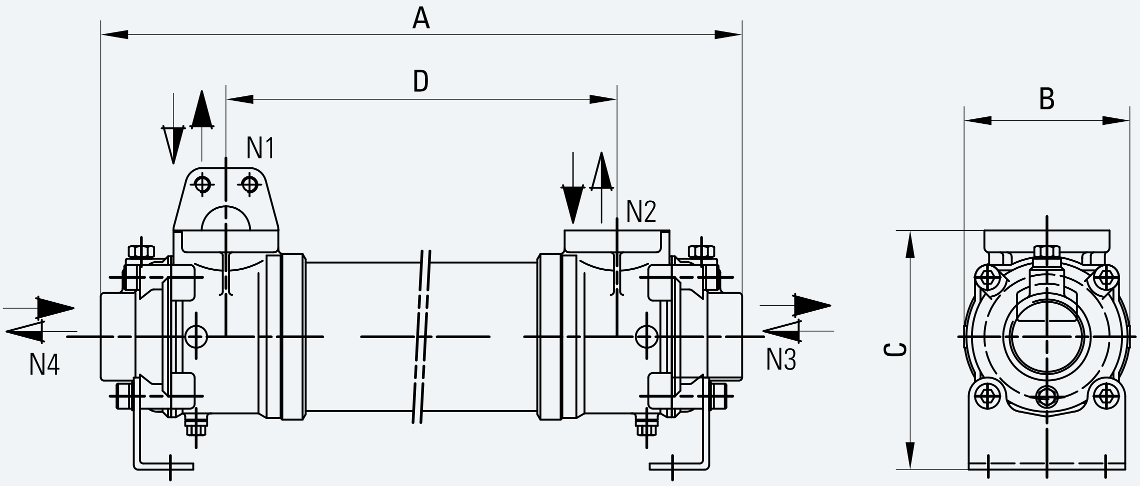


Fig. 5-19 Fuel oil cooler for MDO operation DH3

Engine output	Dimensions [mm]						Weight
[kW]	A	B	C	D	N1 + N2	N3 + N4	[kg]
3,000 - 4,500	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 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 possibility 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.

Capacity	Type	Weight	L x W x H
[kW]		[kg]	[mm]
2,400 – 3,000	Steam / thermal / electric	1,800 1,700	2,800 x 1,200 x 2,000
4,000 – 4,500	Steam / thermal / electric	2,600 2,400	3,000 x 1,200 x 2,100
5,000 – 6,000	Steam / thermal / electric	3,200 3,000	3,200 x 1,300 x 2,100
8,000 – 9,000	Steam / thermal / electric	3,600 3,200	3,400 x 1,400 x 2,100
10,000 – 12,000	Steam / thermal	4,000	3,600 x 1,400 x 2,100
13,400 – 16,000	Steam / thermal	4,200	4,200 x 1,600 x 2,100
19,200 – 24,000	Steam / thermal	5,400	5,000 x 1,700 x 2,100
25,600 – 32,000	Steam / thermal	6,000	6,000 x 2,000 x 2,100

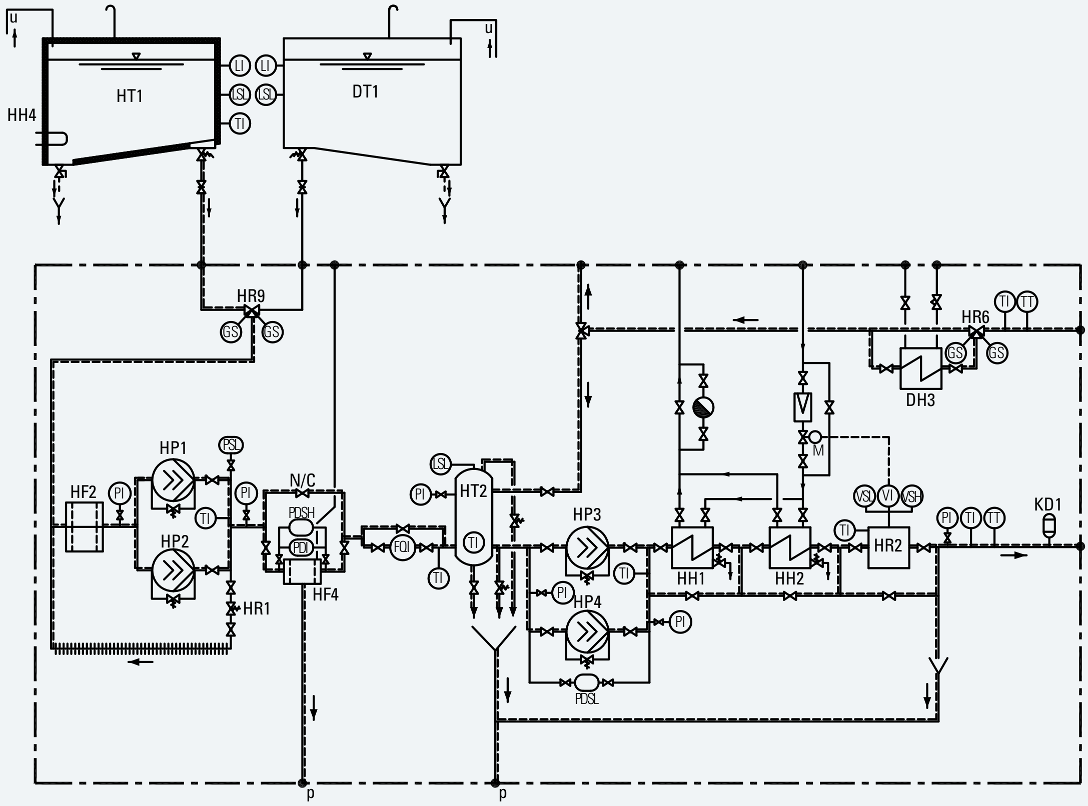


Fig. 5-20 Fuel booster and supply module, system diagram

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

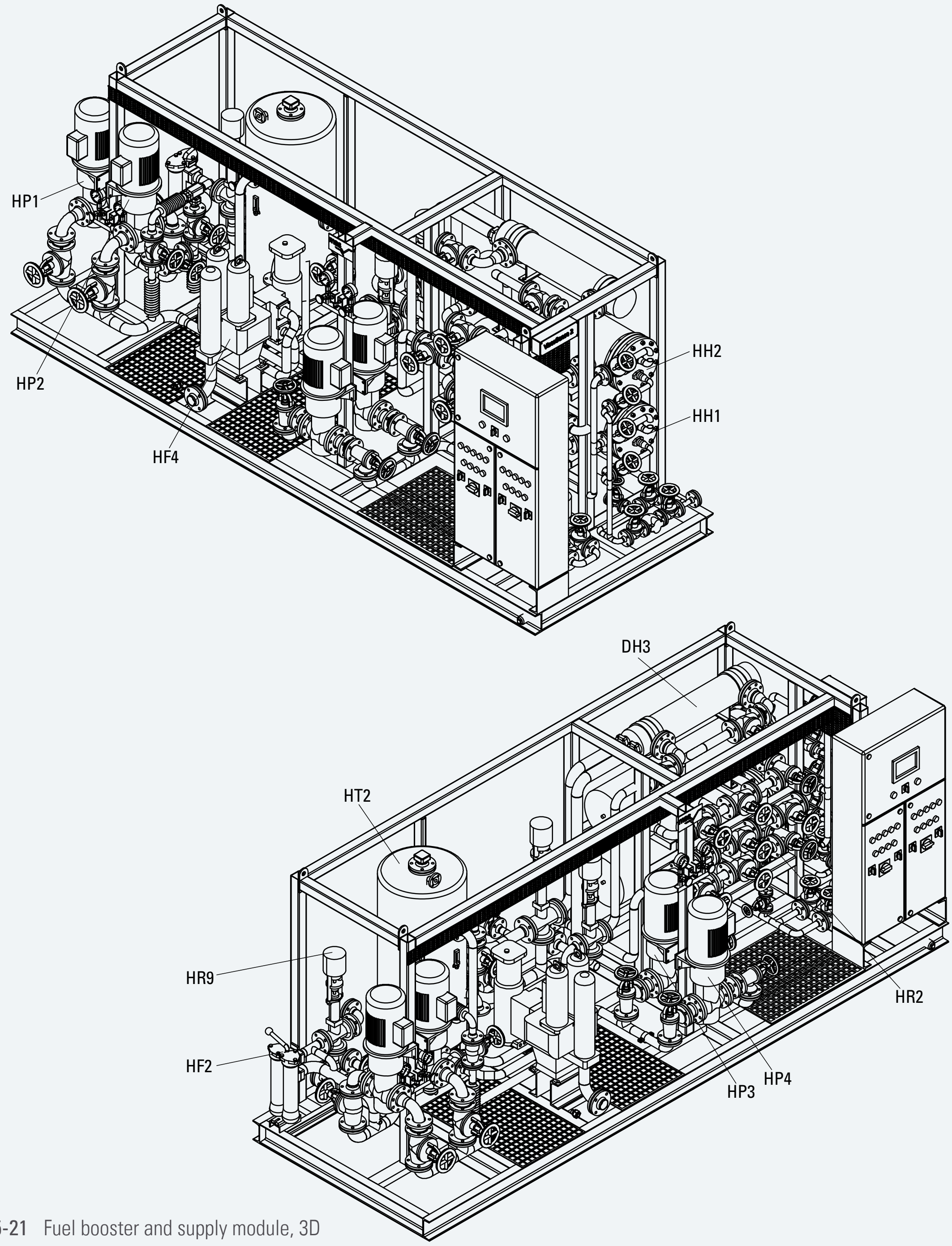


Fig. 5-21 Fuel booster and supply module, 3D

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 on HFO mainly.
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 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 even 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)

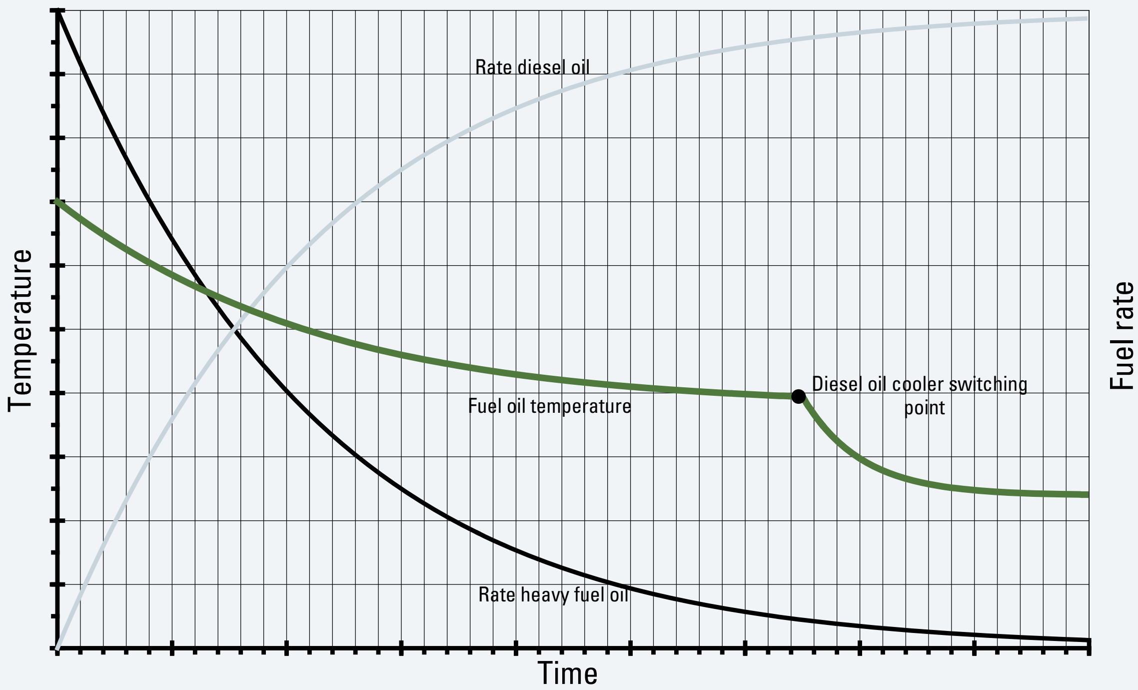


Fig 5-22 Switch over characteristics

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.
  For MDO operation the TBN is 12 - 20 KOH/g 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	
PB	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 LUBMA-RINE	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.

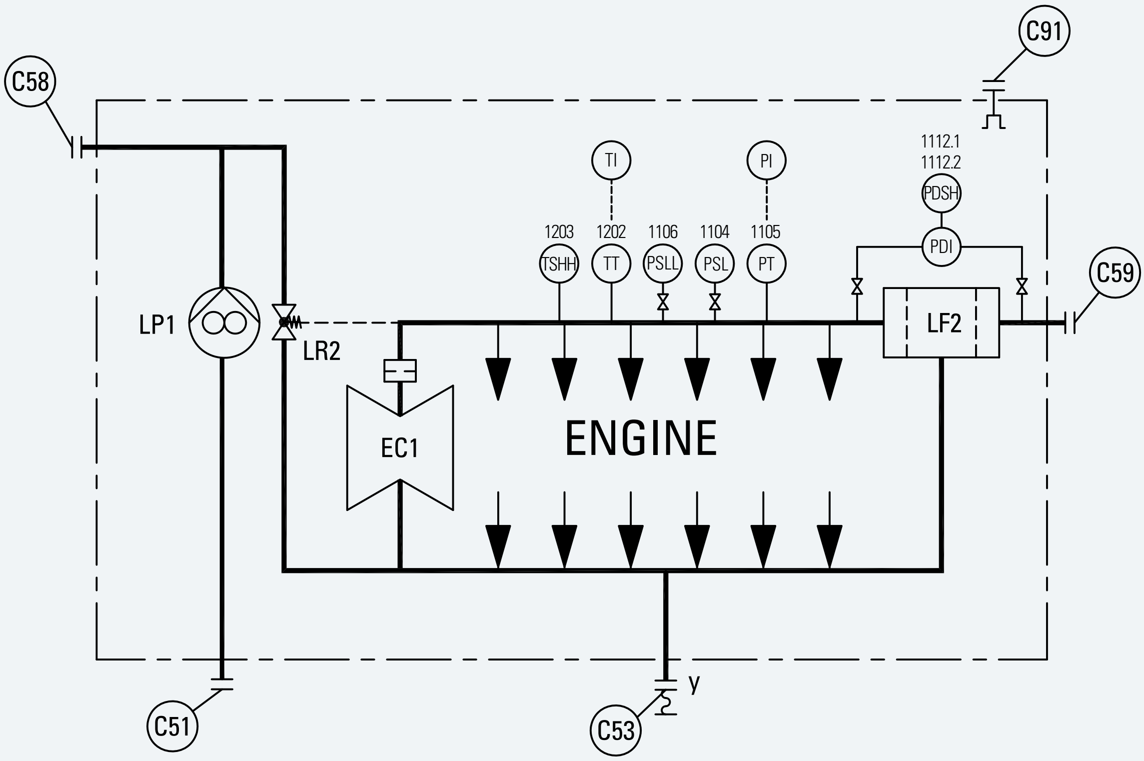


Fig. 6-1 Internal lube oil system, system diagram

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 expansation 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.

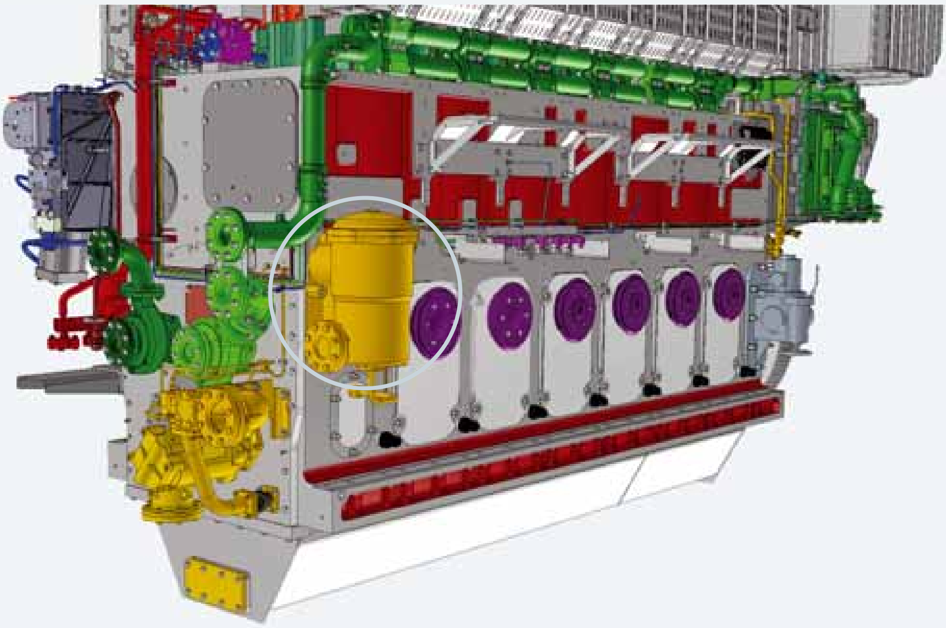


Fig. 6-2 Self-cleaning lube oil filter LF2

Back flushing filter LF2 (separate), option

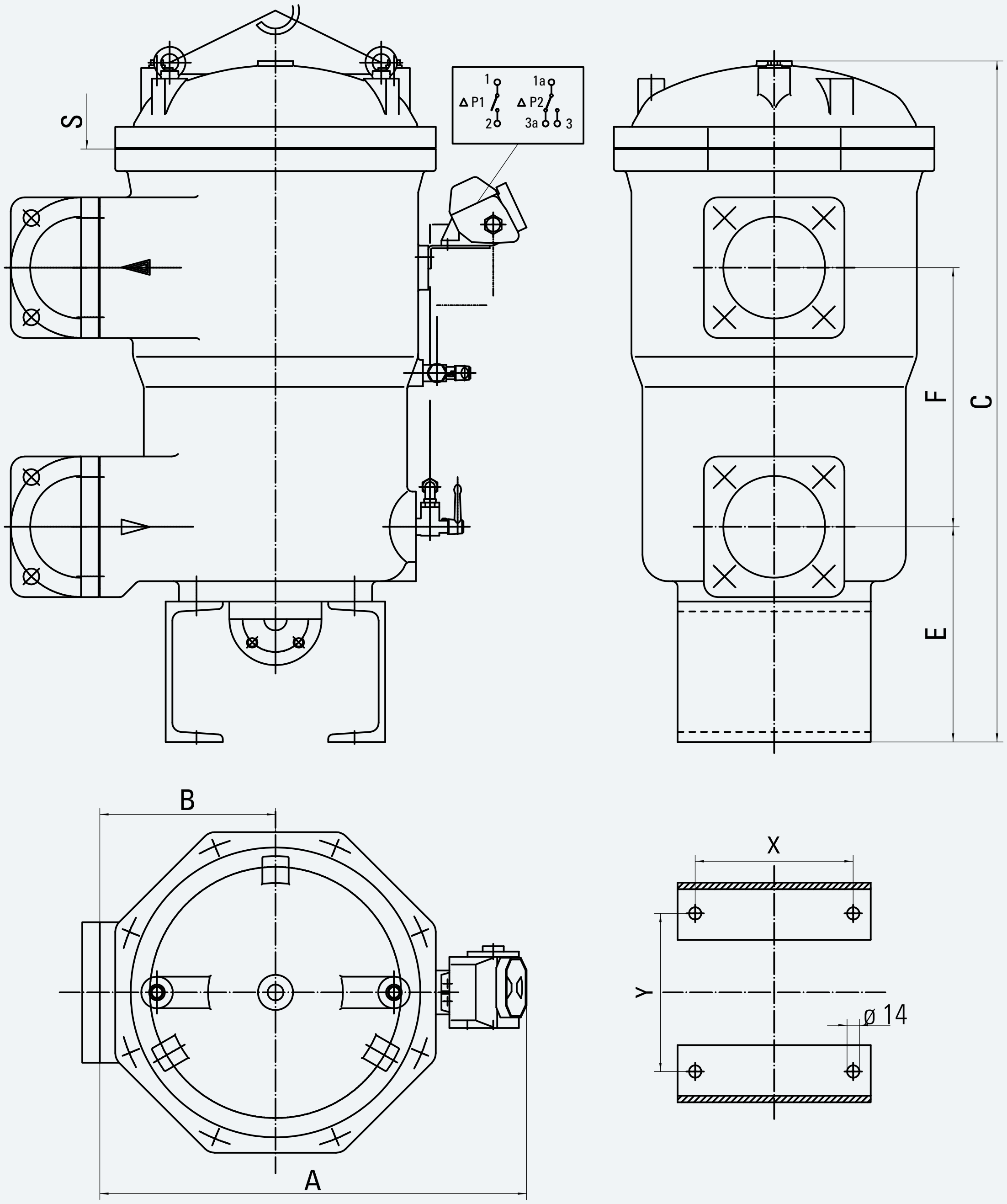


Fig. 6-3 Back flushing filter LF2

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

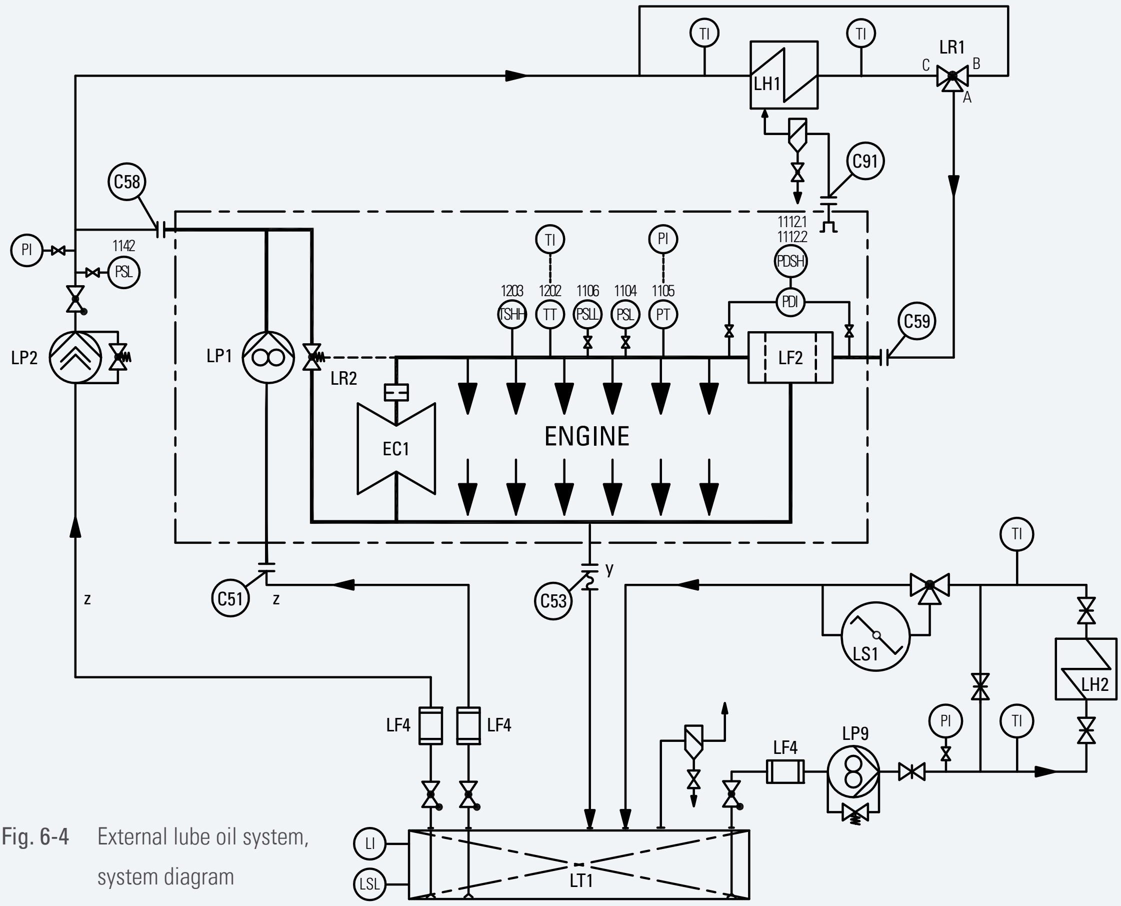


Fig. 6-4 External lube oil system, system diagram

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.

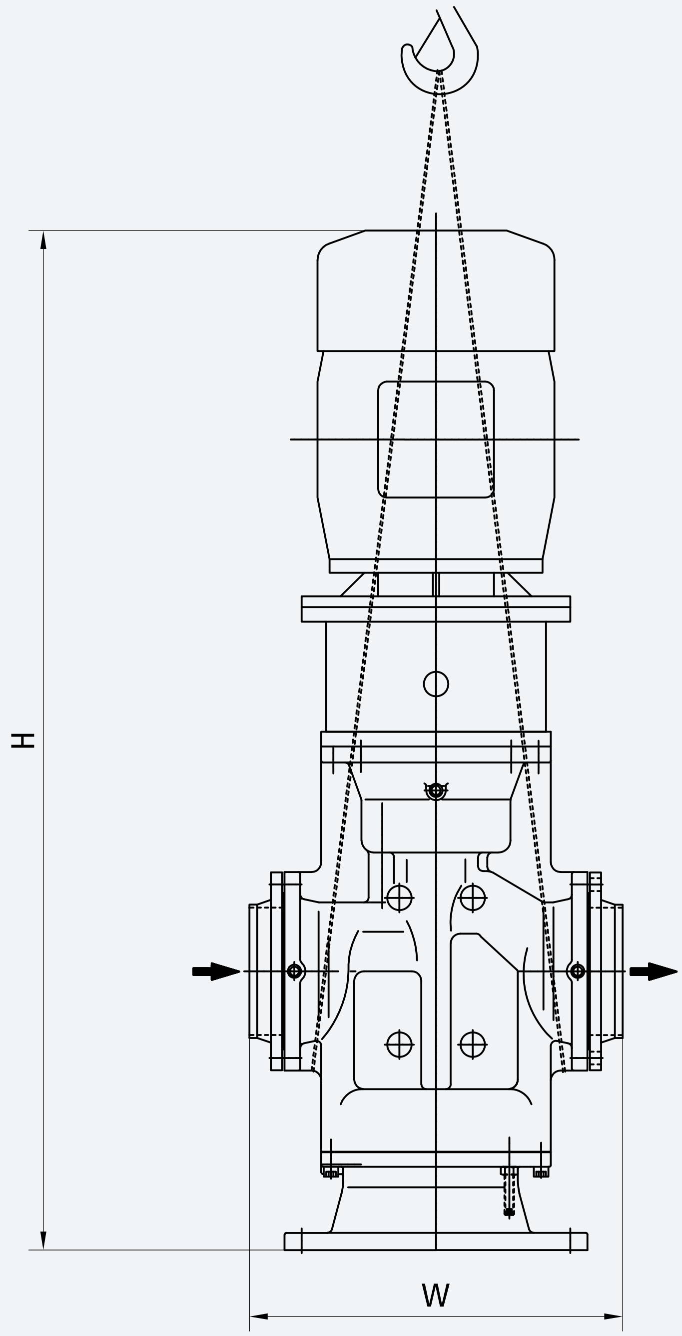


Fig. 6-5 Lube oil stand-by force pump LP2

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

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

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.

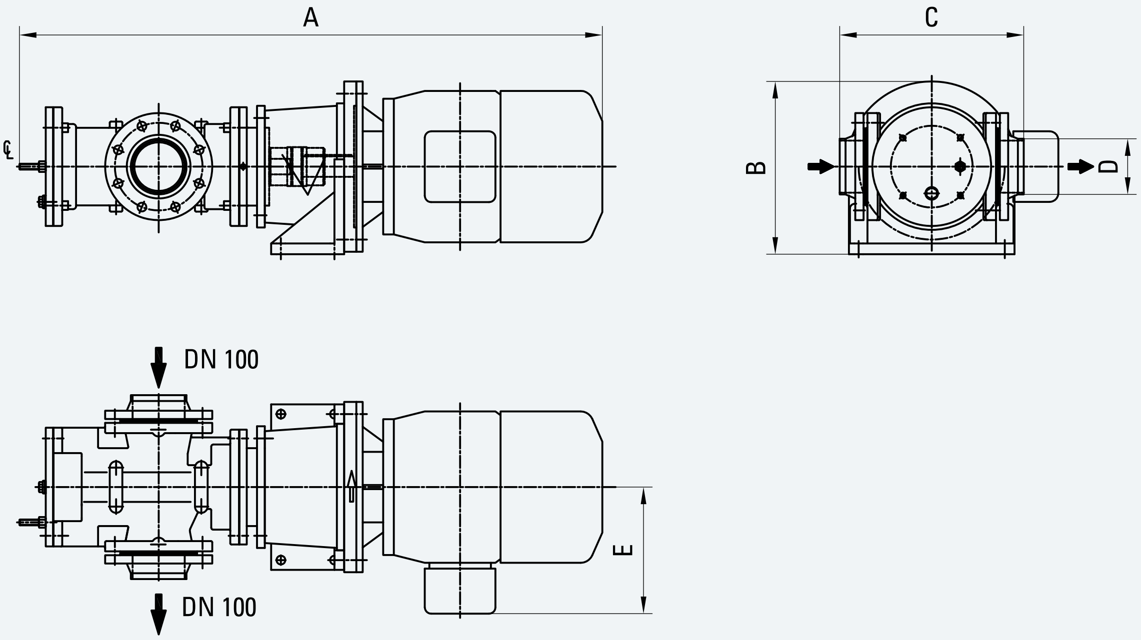


Fig. 6-6 Prelubricating pump LP5

	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.

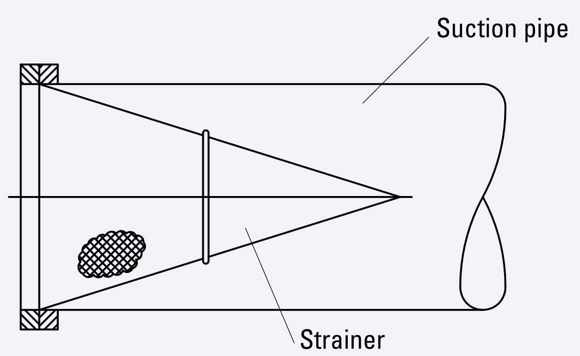


Fig. 6-7 Suction strainer LF4

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. The not needed 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.

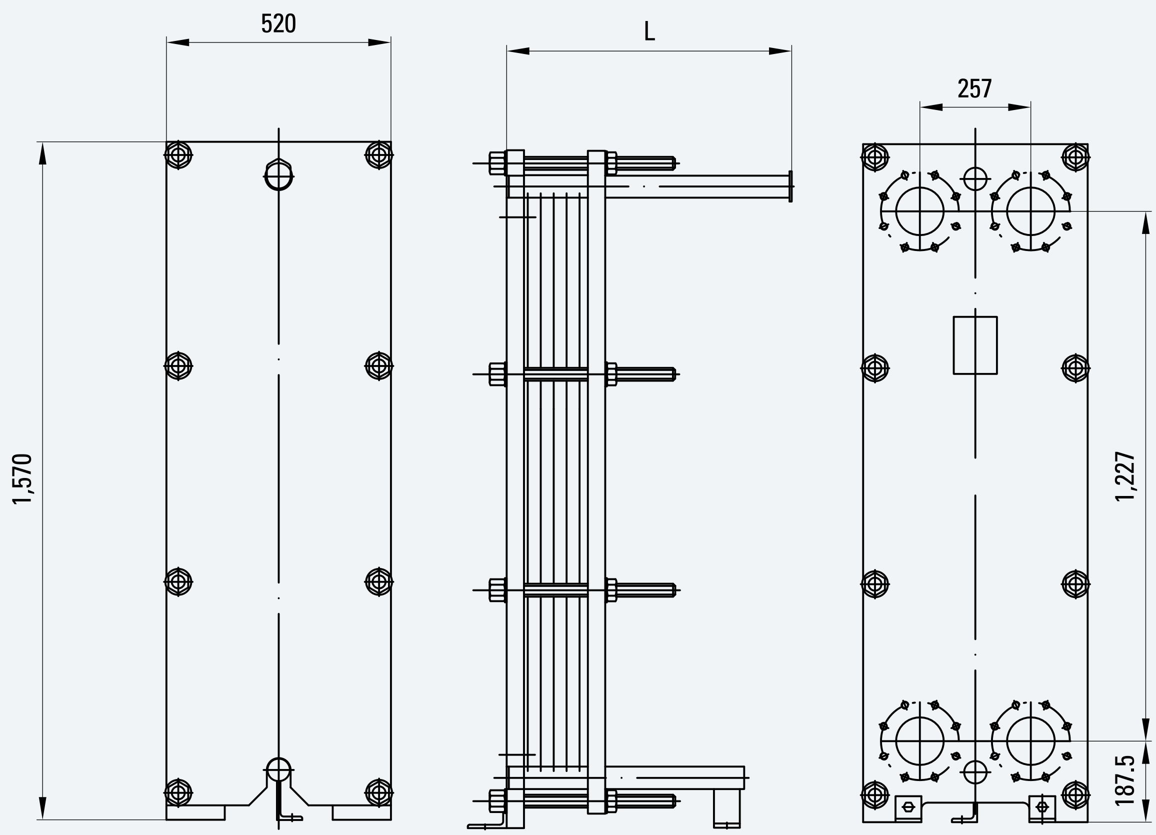


Fig. 6-8 Lube oil cooler LH1

	L	Weight
	[mm]	[kg]
6 M 32 C	660	704
8 M 32 C	897	782
9 M 32 C	897	824

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.

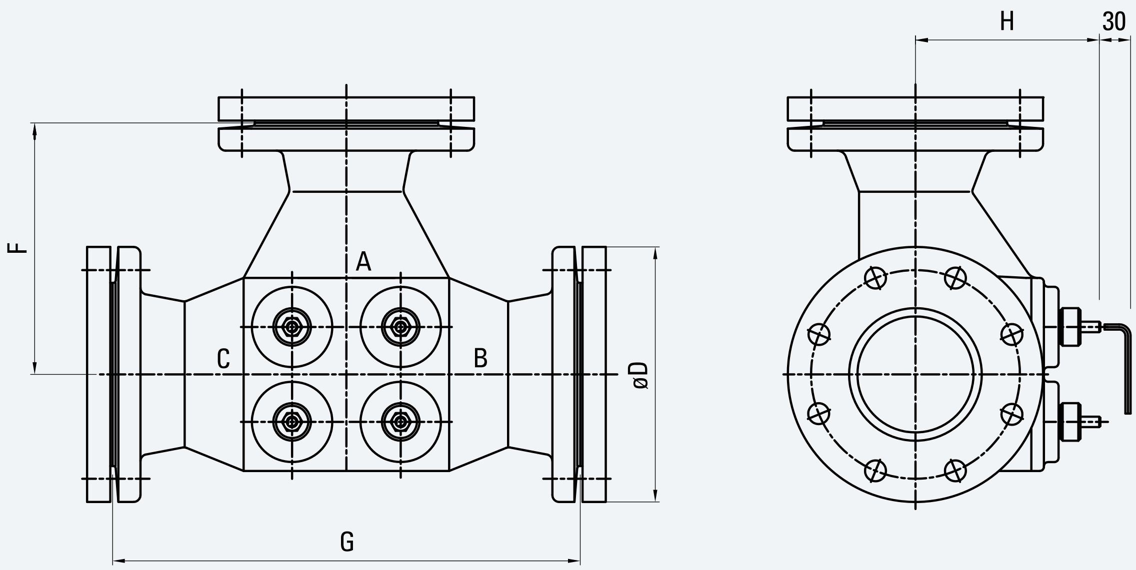


Fig. 6-9 Lube oil temperature control valve LR1

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

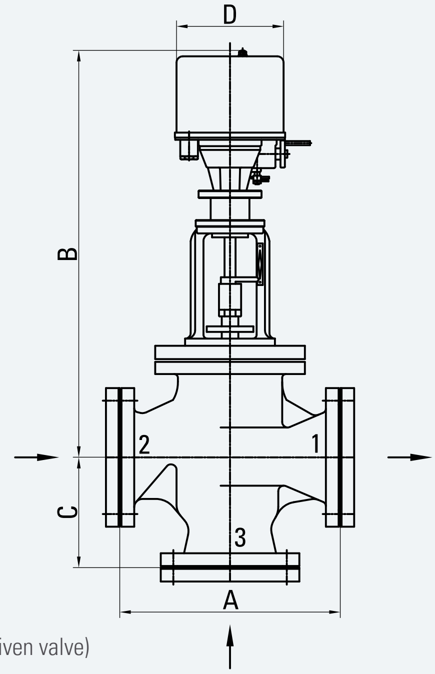


Fig. 6-10 Lube oil temperature control valve LR1 (electric driven valve)

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

$V\ [l/h] = 0.18 \cdot P_{eng}\ [kW]$ $\qquad$ P_{eng} = Power engine [kW]

Layout for HFO operation

Automatic self-cleaning separator; Operating temperature 95 °C

$V\ [l/h] = 0.29 \cdot P_{eng}\ [kW]$ $\qquad$ 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.

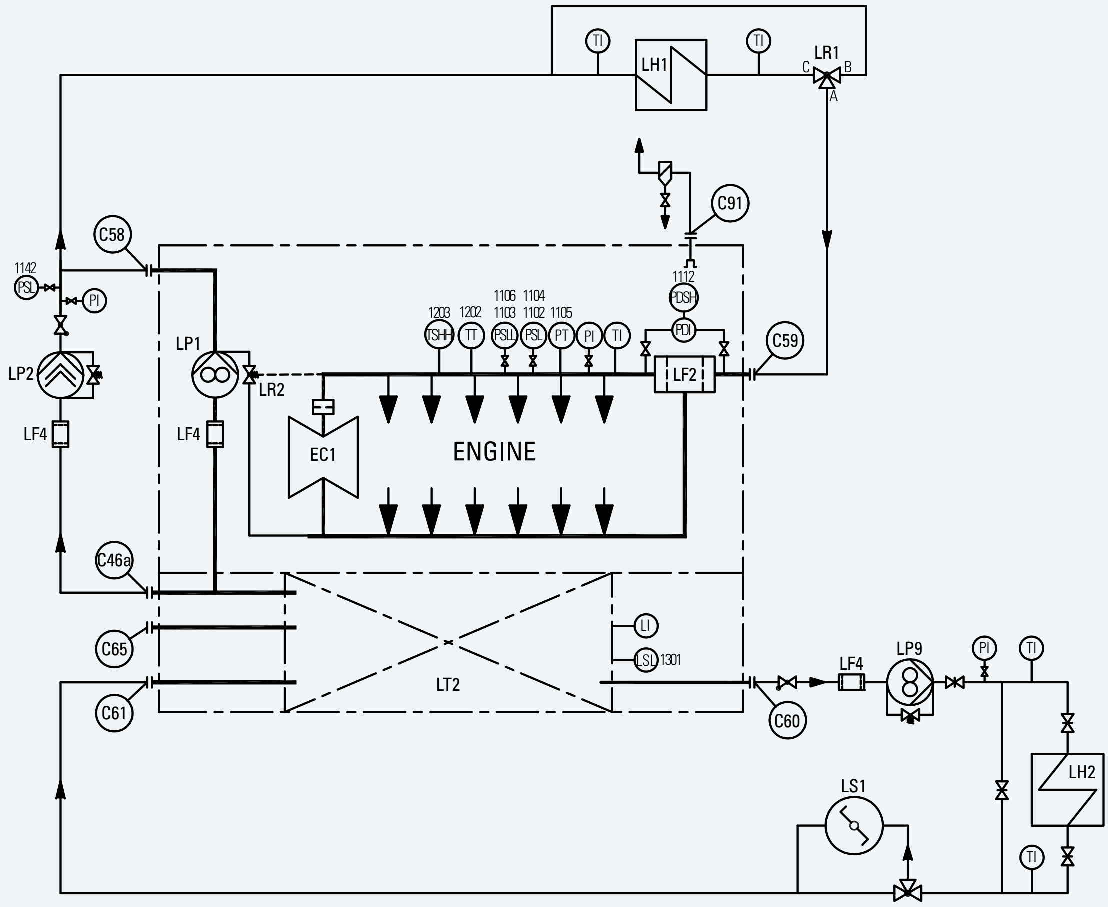


Fig. 6-11 System diagram, wet sump tank

EC1	Exhaust gas turbocharger	PDSH	Diff. pressure switch high
LF2	Self-cleaning lube oil filter	PI	Pressure indicator
LF4	Suction strainer	PSL	Pressure switch low
LH1	Lube oil cooler	PSLL	Pressure switch low
LH2	Lube oil preheater	PT	Pressure transmitter
LP1	Lube oil force pump	TI	Temperature indicator
LP2	Lube oil stand-by force pump	TSHH	Temperature switch high high
LP9	Transfer pump (separator)	TT	Temperature transmitter
LR1	Lube oil temperature control valve		
LR2	Oil pressure regulating valve	C46a	Stand-by force pump, suction side
LS1	Lube oil separator	C58	Force pump, delivery side
LT2	Oil pan	C59	Lube oil inlet, luber oil cooler
		C60	Stand-by pump HT, inlet
LI	Level indicator	C61	Separator connection, delivery side
LSL	Level switch low	C65	Lube oil filling socket
PDI	Diff. pressure indicator	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 standby pump will be necessary.
Power of recirculation pump and standby pump see technical data.
In this case please contact Caterpillar Motoren.

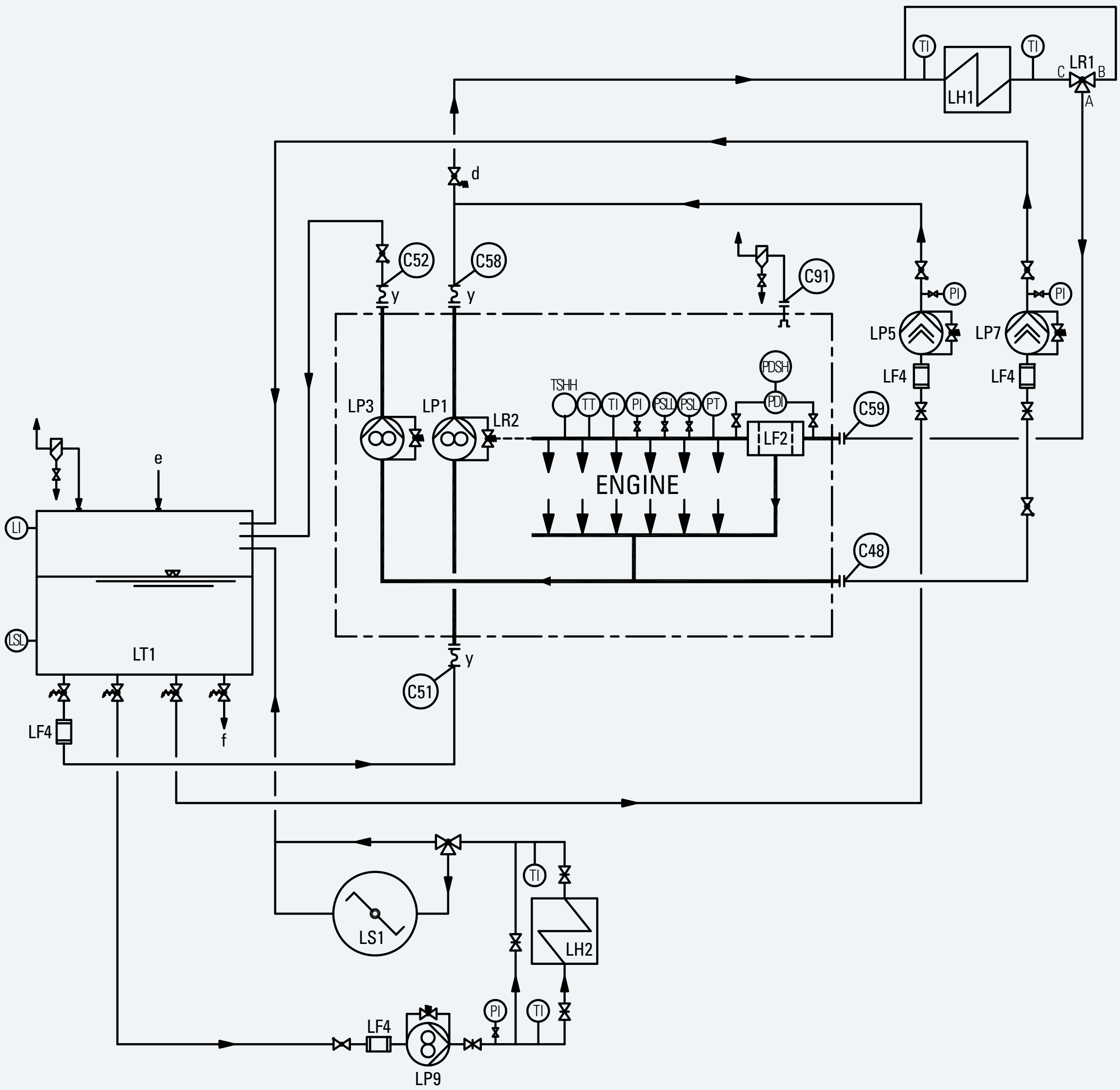


Fig. 6-12 System diagram, high level tank

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 then engine is not running.

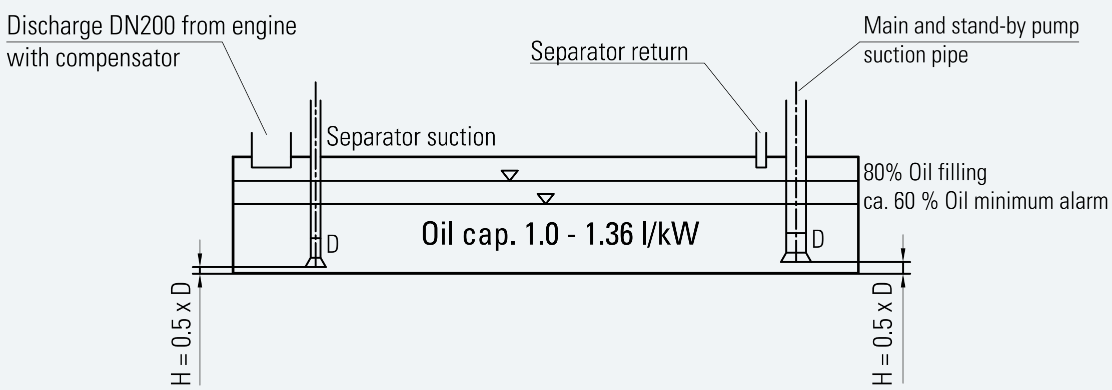


Fig. 6-13 Sump tank LT1

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.

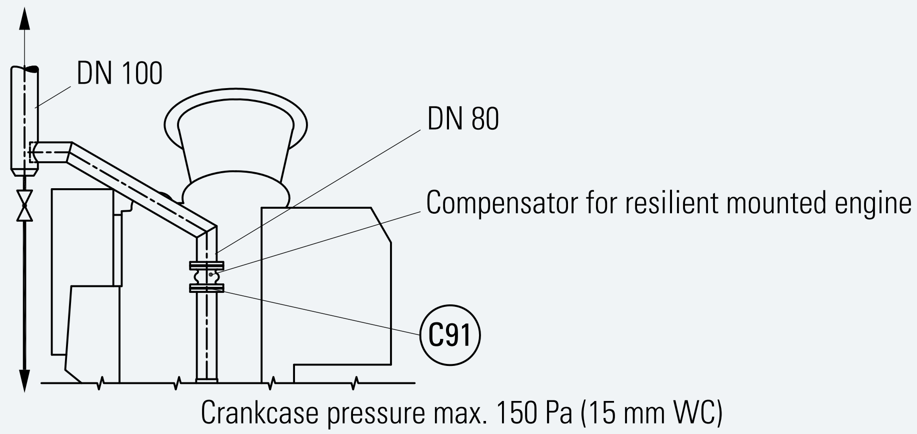


Fig. 6-14 Crankcase ventilation

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.

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

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", the 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 need for only one header tank and one fresh water cooler instead of two.
Moreover also 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, they 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 23 24 25

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 the 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

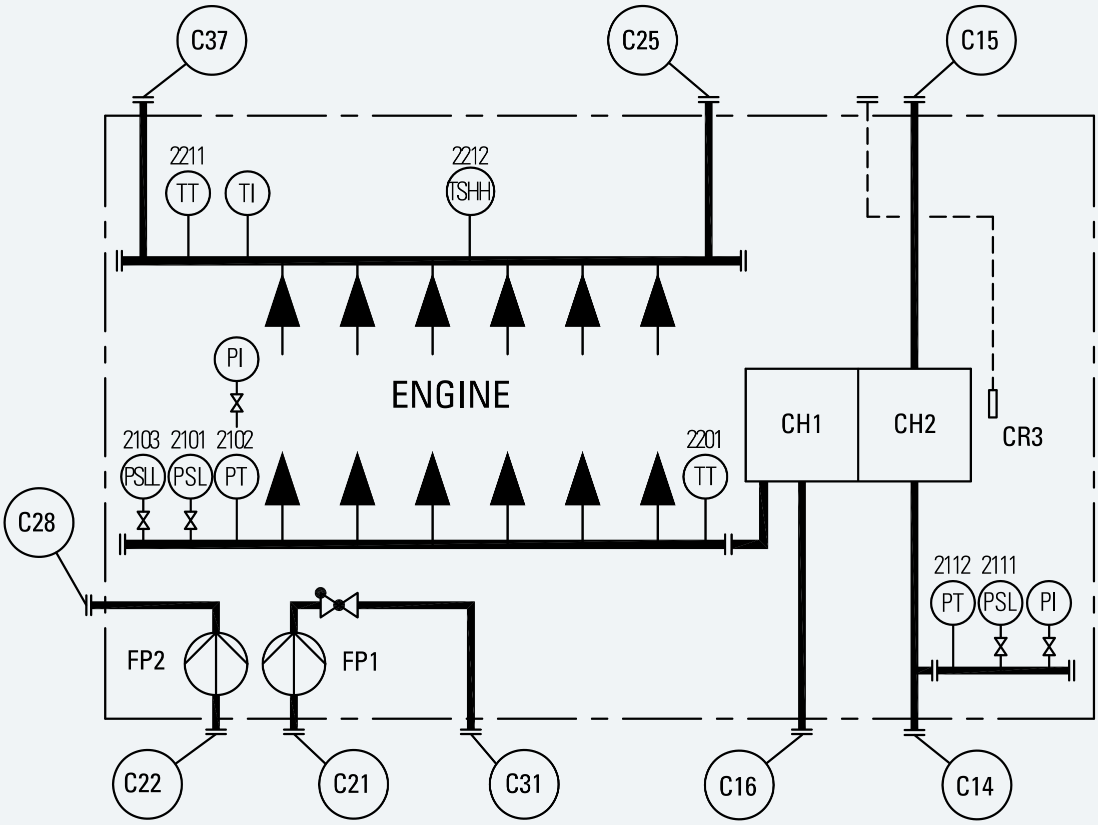


Fig. 7-1 Internal cooling water system, system diagram, turbocharger at driving end

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

Turbocharger at free end

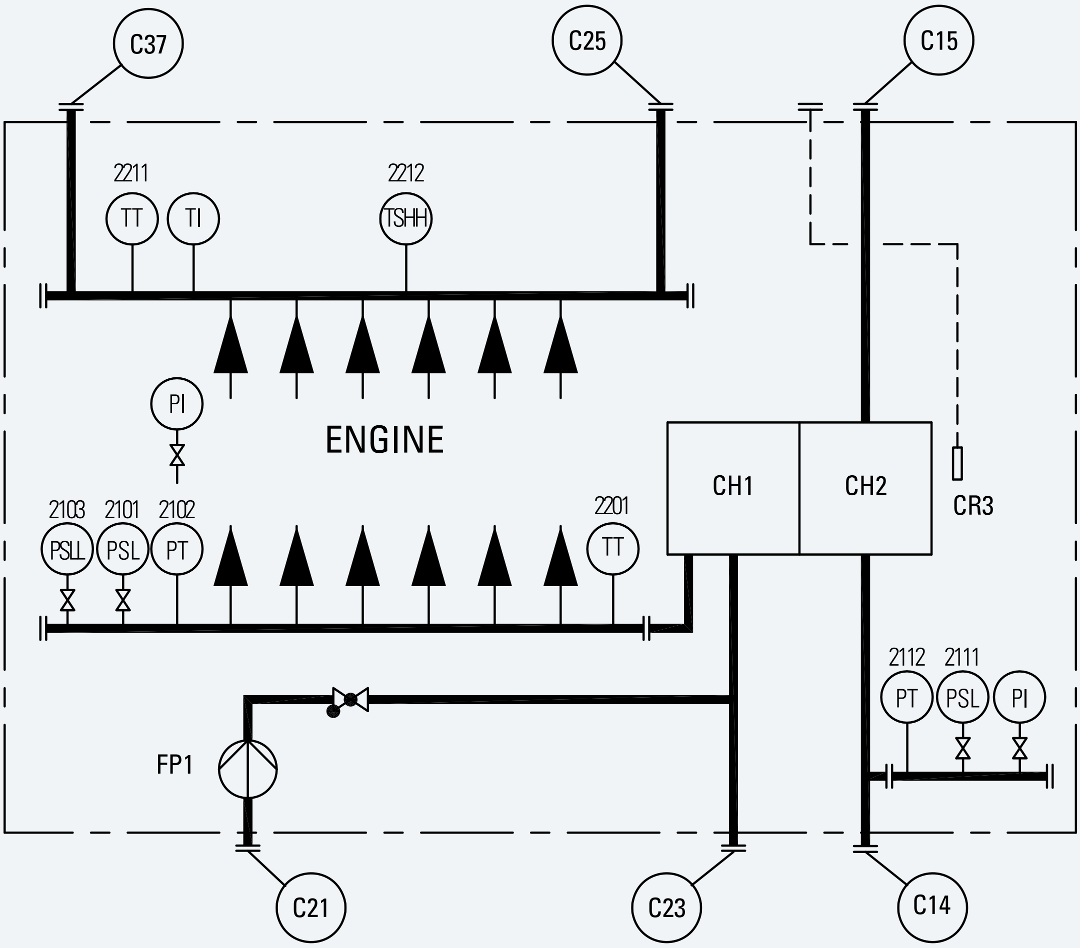


Fig. 7-2 Internal cooling water system, system diagram, turbocharger at free end

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
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	Fresh water pump HT, inlet
C23	Stand-by pump HT, inlet
C25	Cooling water, engine outlet
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

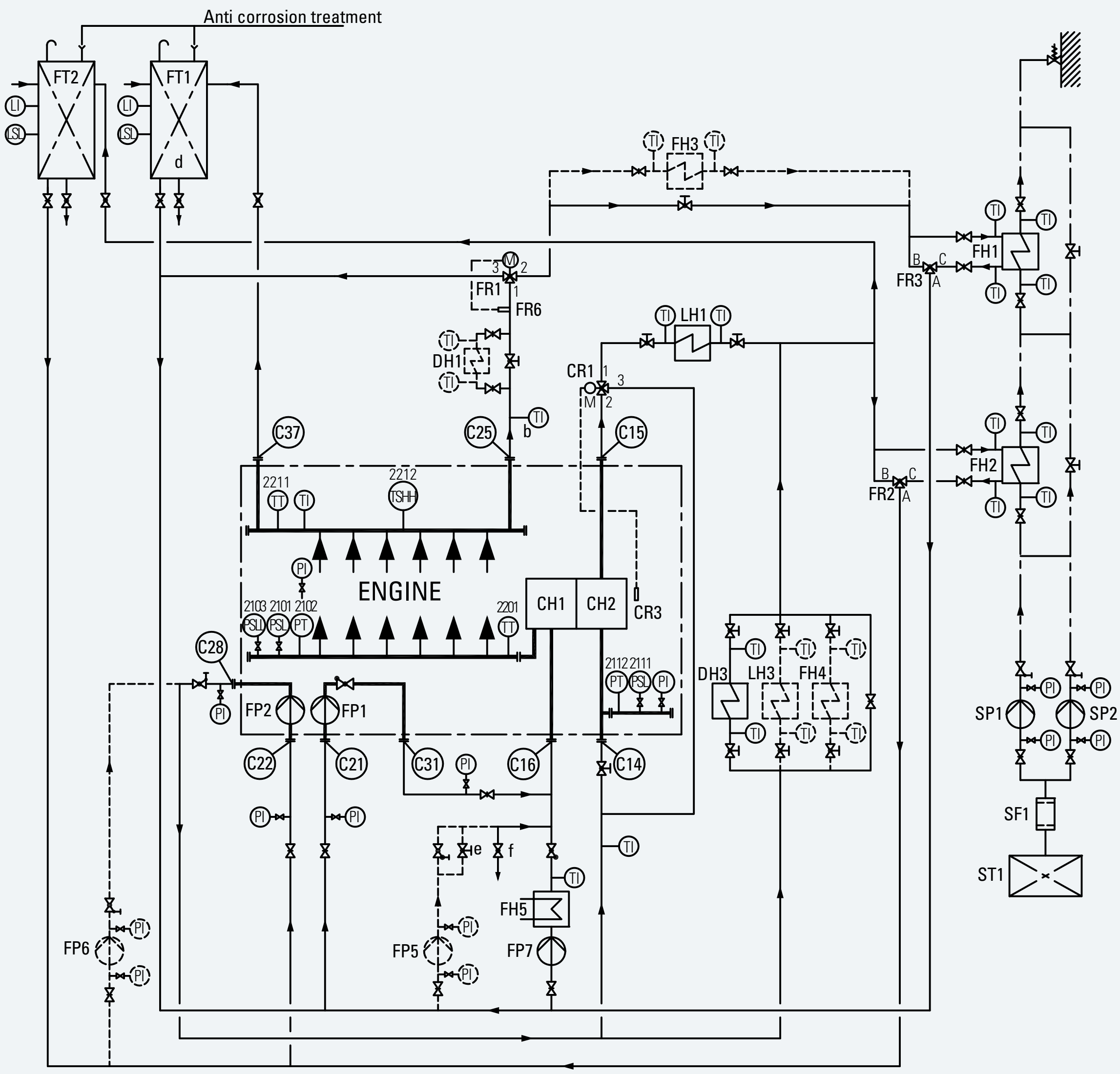


Fig. 7-4 External cooling water system, system diagram, turbocharger at driving end

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

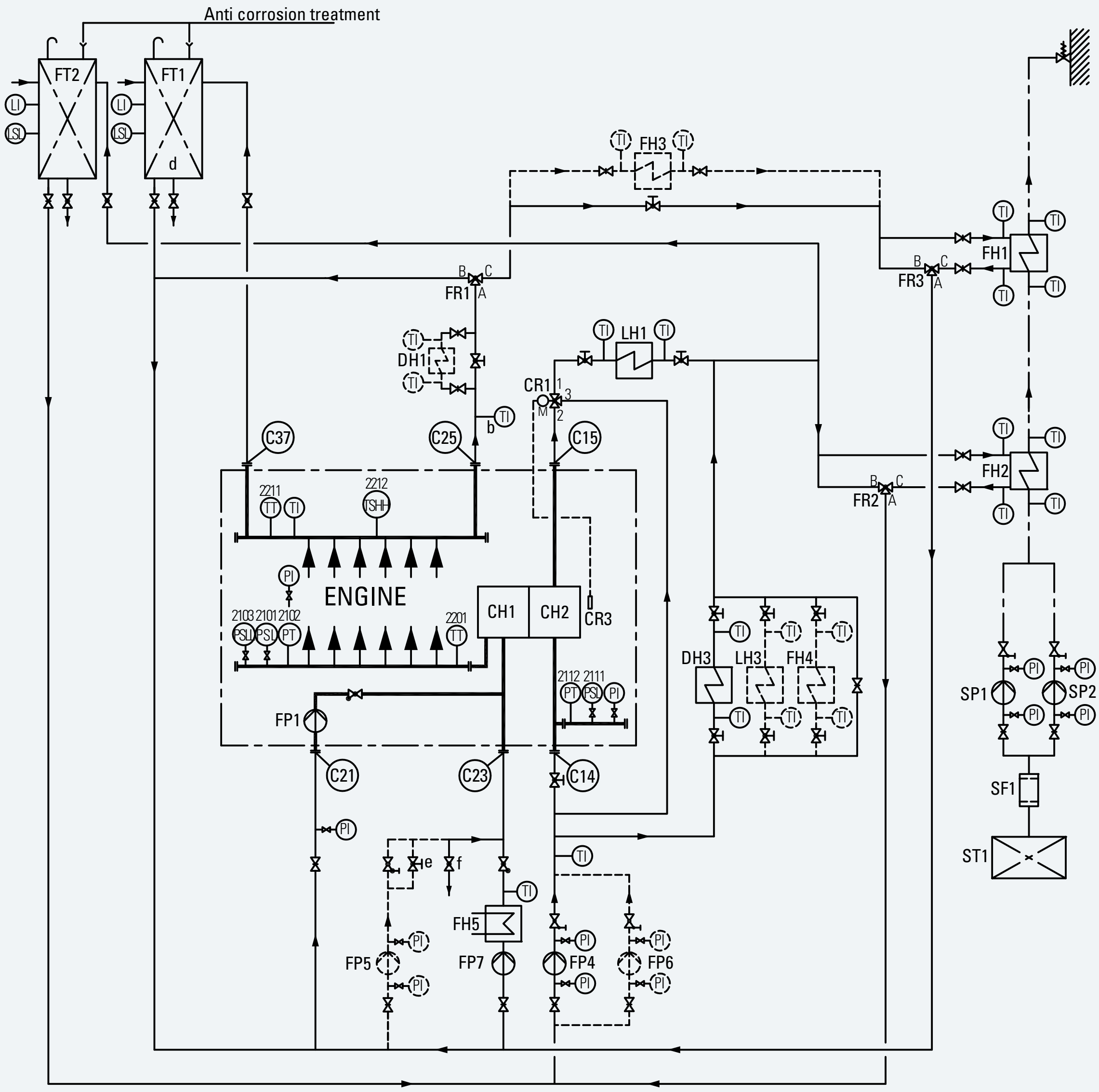


Fig. 7-5 External cooling water system, system diagram, turbocharger at free end

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

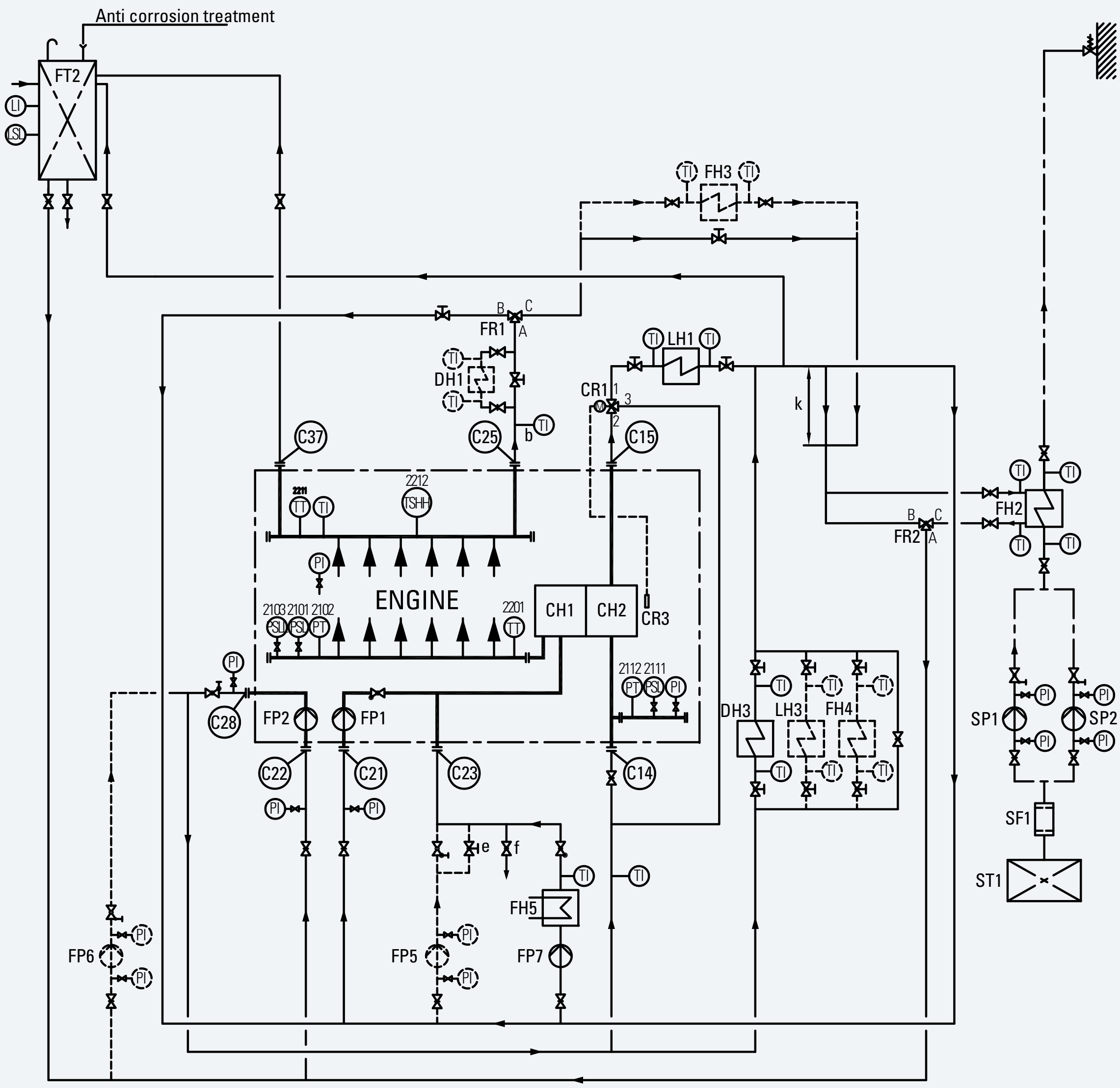


Fig. 7-6 Secondary circuit with turbocharger at free end, system diagram

CH1	Charge air cooler HT	LI	Level indicator
CH2	Charge air cooler LT	LSL	Level switch low
CR1	Charge air temperature control valve	PI	Pressure indicator
CR3	Sensor for charge air temperature control valve	PSL	Pressure switch low
		PSLL	Pressure switch low
DH1	MDO preheater	PT	Pressure transmitter
DH3	Fuel oil cooler for MDO operation	TI	Temperature indicator
FH2	Fresh water cooler LT	TSHH	Temperature switch high
FH3	Heat consumer	TT	Temperature transmitter (PT100)
FH4	Other LT consumers		
FH5	Fresh water preheater	C14	Charge air cooler LT, inlet
FP1	Fresh water pump (fitted on engine) HT	C15	Charge air cooler LT, outlet
FP2	Fresh water pump (fitted on engine) LT	C21	Freshwater pump HT, inlet
FP5	Fresh water stand-by pump HT	C22	Freshwater pump LT, inlet
FP6	Fresh water stand-by pump LT	C23	Stand-by pump HT, inlet
FP7	Preheating pump	C25	Cooling water, engine outlet
FR1	Temperature control valve HT	C28	Fresh water pump LT, outlet
FR2	Temperature control valve LT	C37	Vent
FT2	Compensation tank LT		
LH1	Lube oil cooler	b	Measurement min. 2.0 m distance to C17
LH3	Gear lube oil cooler	e	Bypass DN 12
SF1	Seawater filter	f	Drain
SP1	Seawater pump	k	Distance min. 1 m
SP2	Seawater stand-by pump		
ST1	Sea chest		

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 systems 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 acc. to technical engine data.
- All continuous vents from engine are to be connected.

Main functions of the cooling water header tank:

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

Electric driven charge air temperature control valve CR1 (separate)

	Dimensions [mm]					Weight
	DN	A	B	C	D	[kg]
—	80	310	624	155	170	58
6/8 M 32 C	100	350	646	175	170	70
9 M 32 C	125	400	717	200	170	110

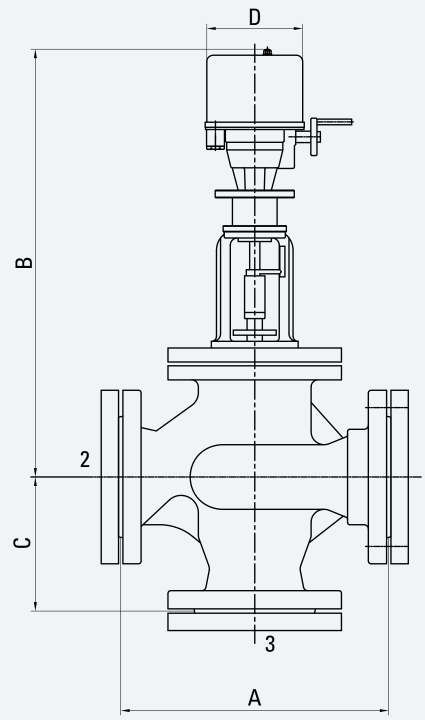


Fig. 7-7 Charge air temperature control valve CR1

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

Capacity: acc. to heat balance.

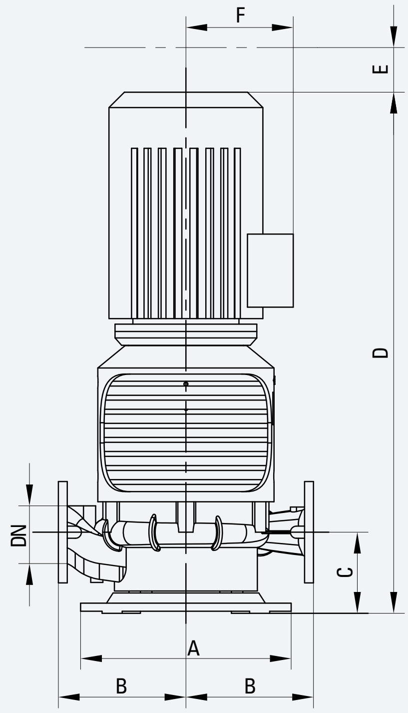


Fig. 7-8 Fresh water pump

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).

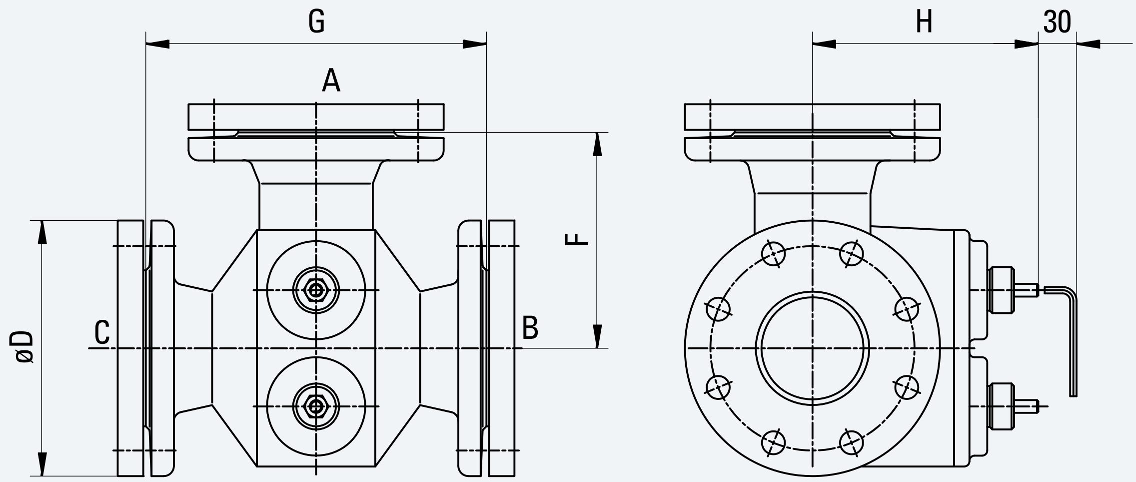


Fig. 7-9 Temperature control valve HT FR1

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

* Minimum depending on total cooling water flow

7.6 System diagrams heat balance

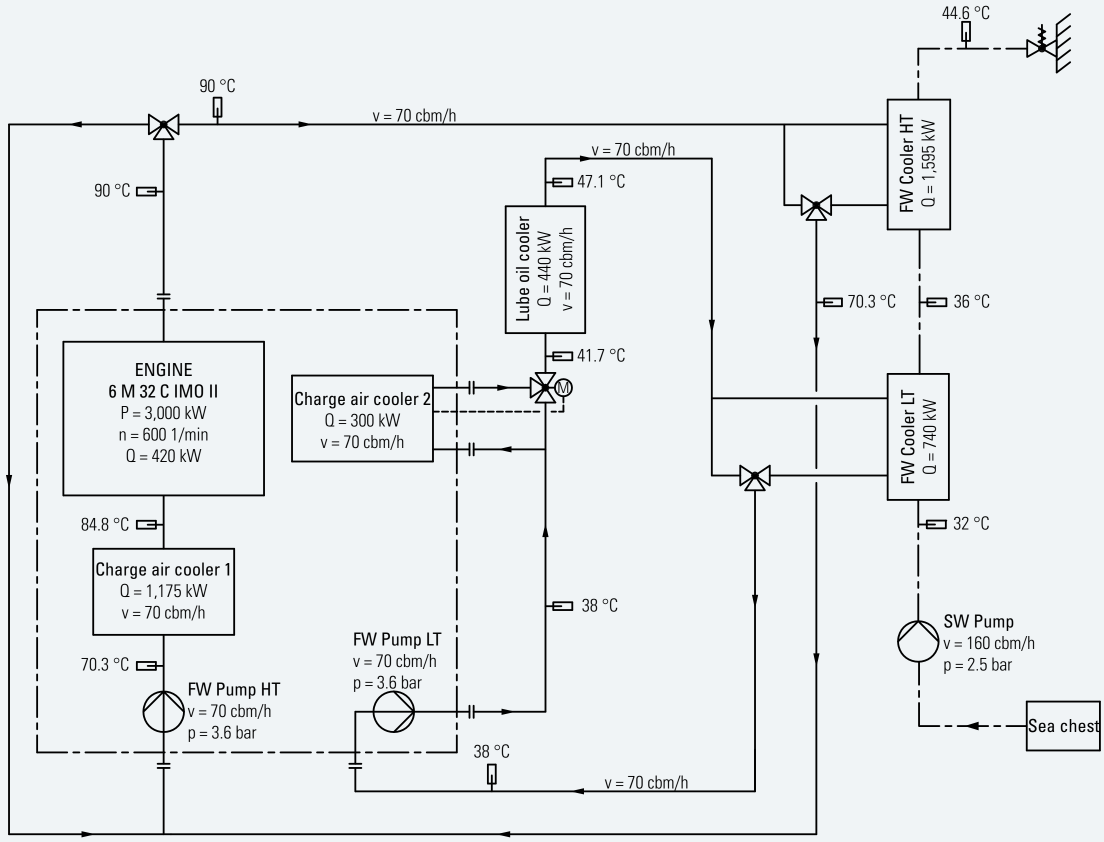


Fig. 7-10 Heat balance, system diagram 6 M 32 C

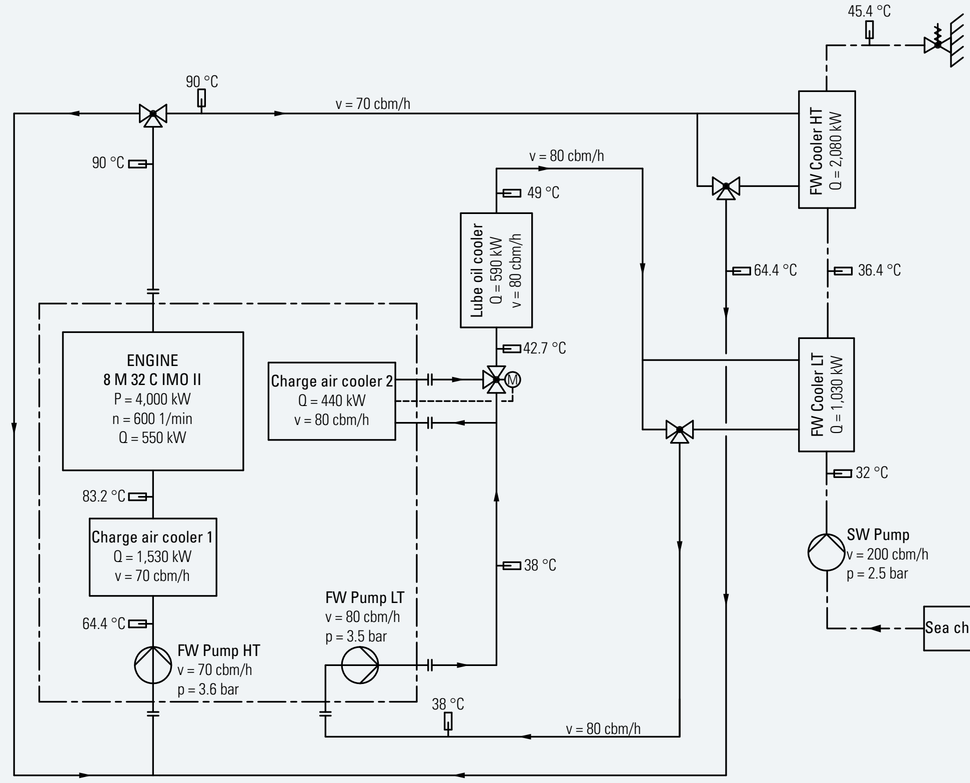


Fig. 7-11 Heat balance, system diagram 8 M 32 C

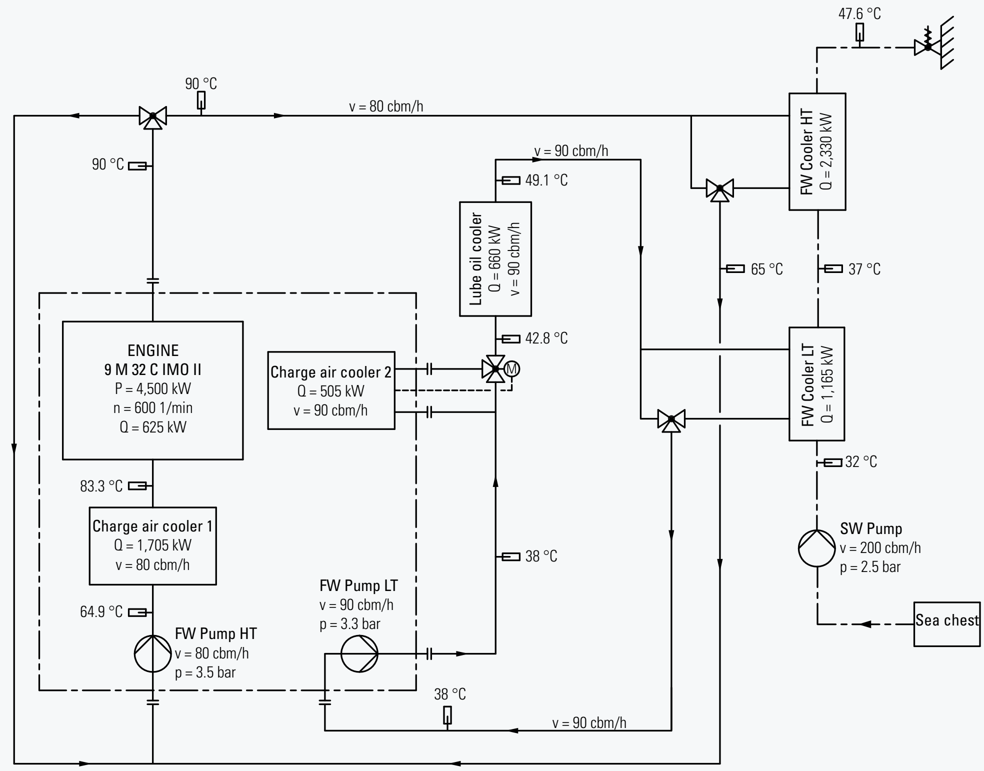
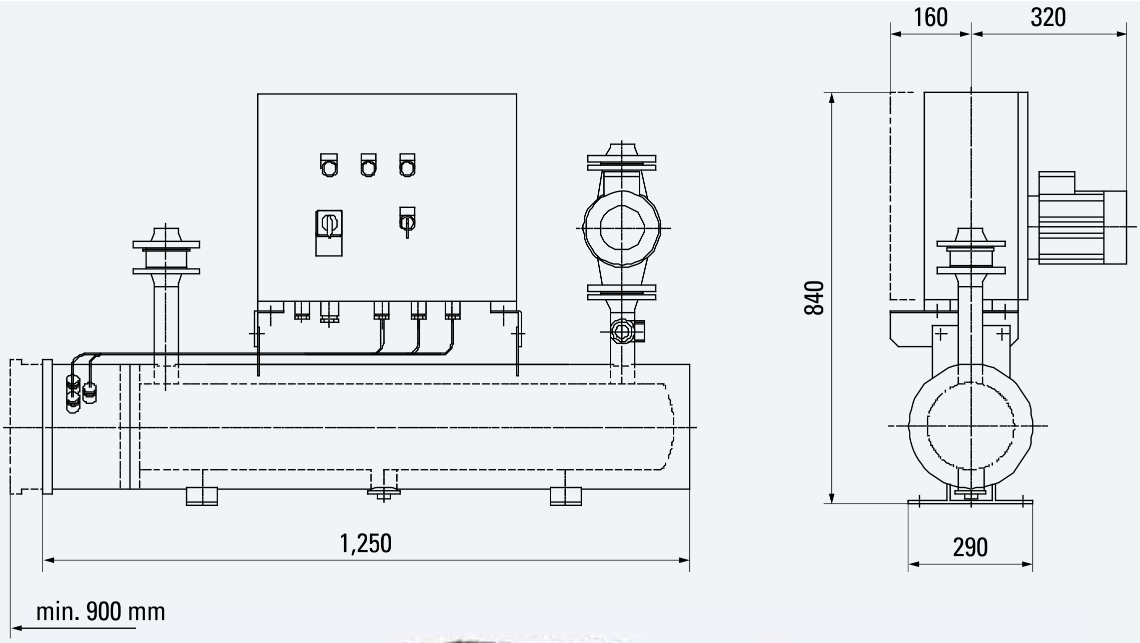


Fig. 7-12 Heat balance, system diagram 9 M 32 C

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.



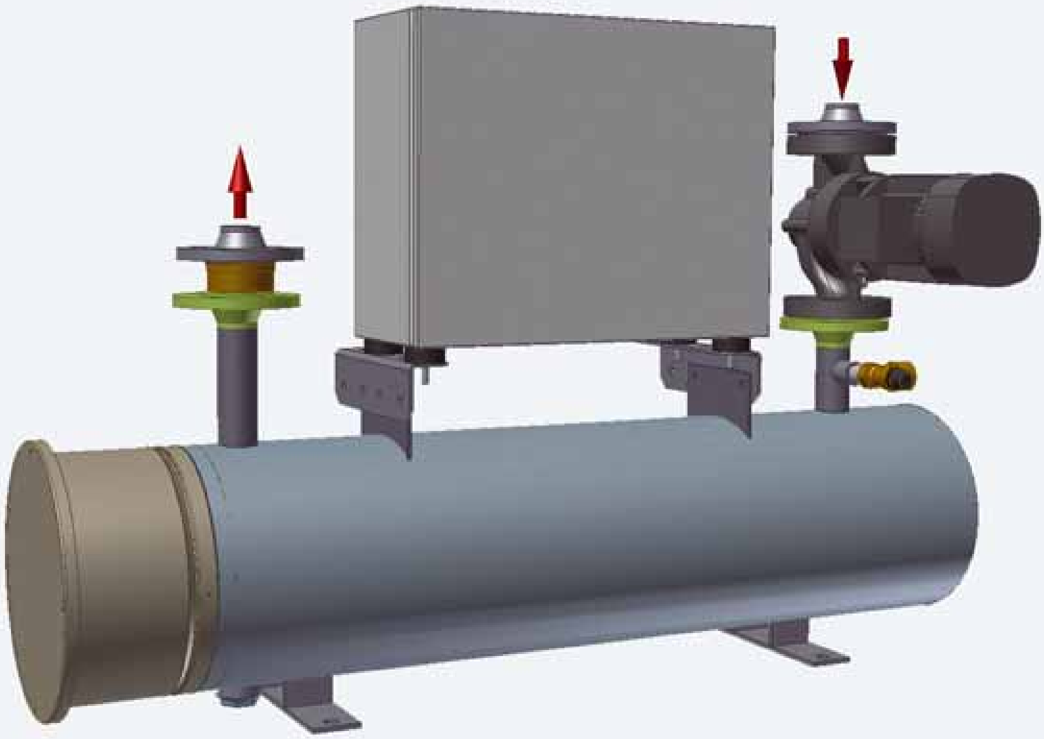


Fig. 7-13 Freshwater preheater FH5, preheating pump FP7

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 (HT and LT)
Performance curve

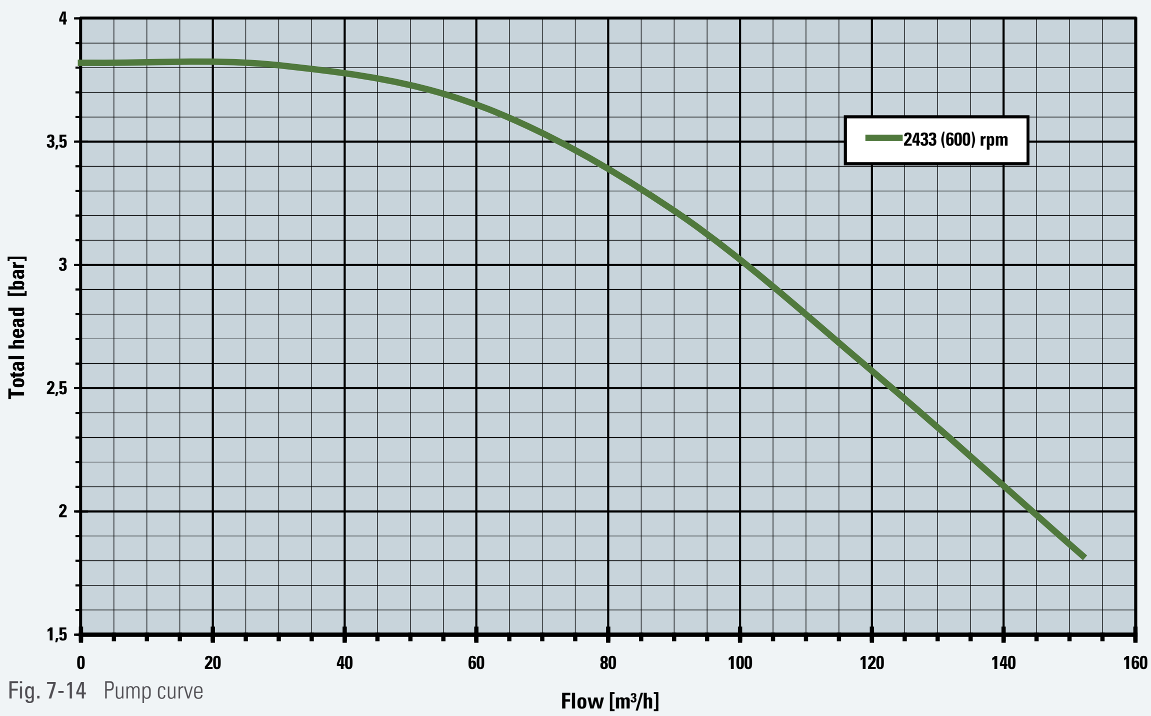


Fig. 7-14 Pump curve

Compressed air is used

- to start the engines and
- 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 from 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.

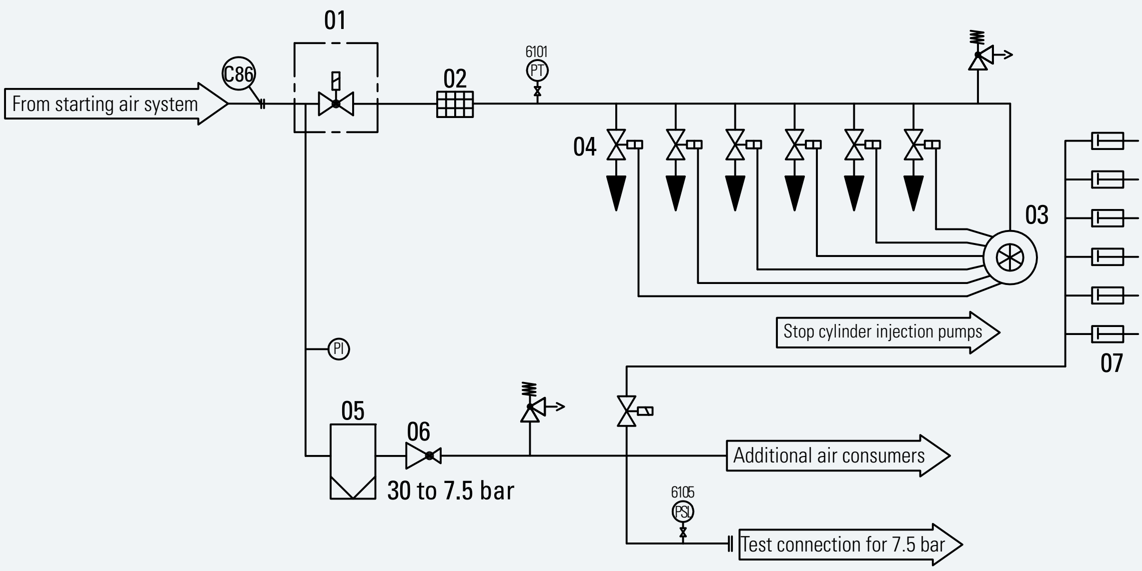


Fig. 8-1 Internal compressed air system, system diagram

01	3/2 way valve	05	Air filter
02	Flame arrester	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.

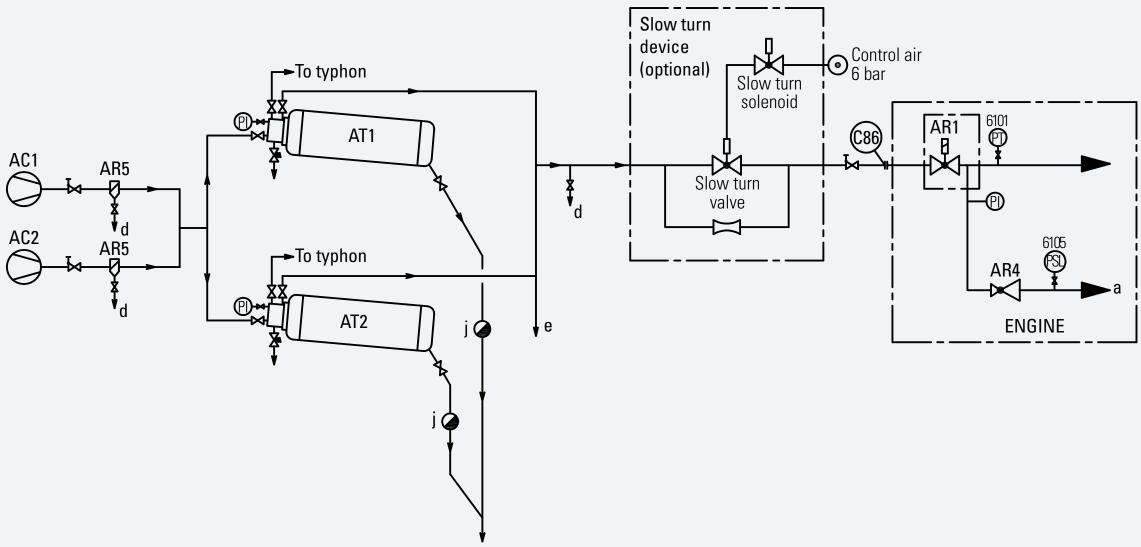


Fig. 8-2 External compressed air system, system diagram

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

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.

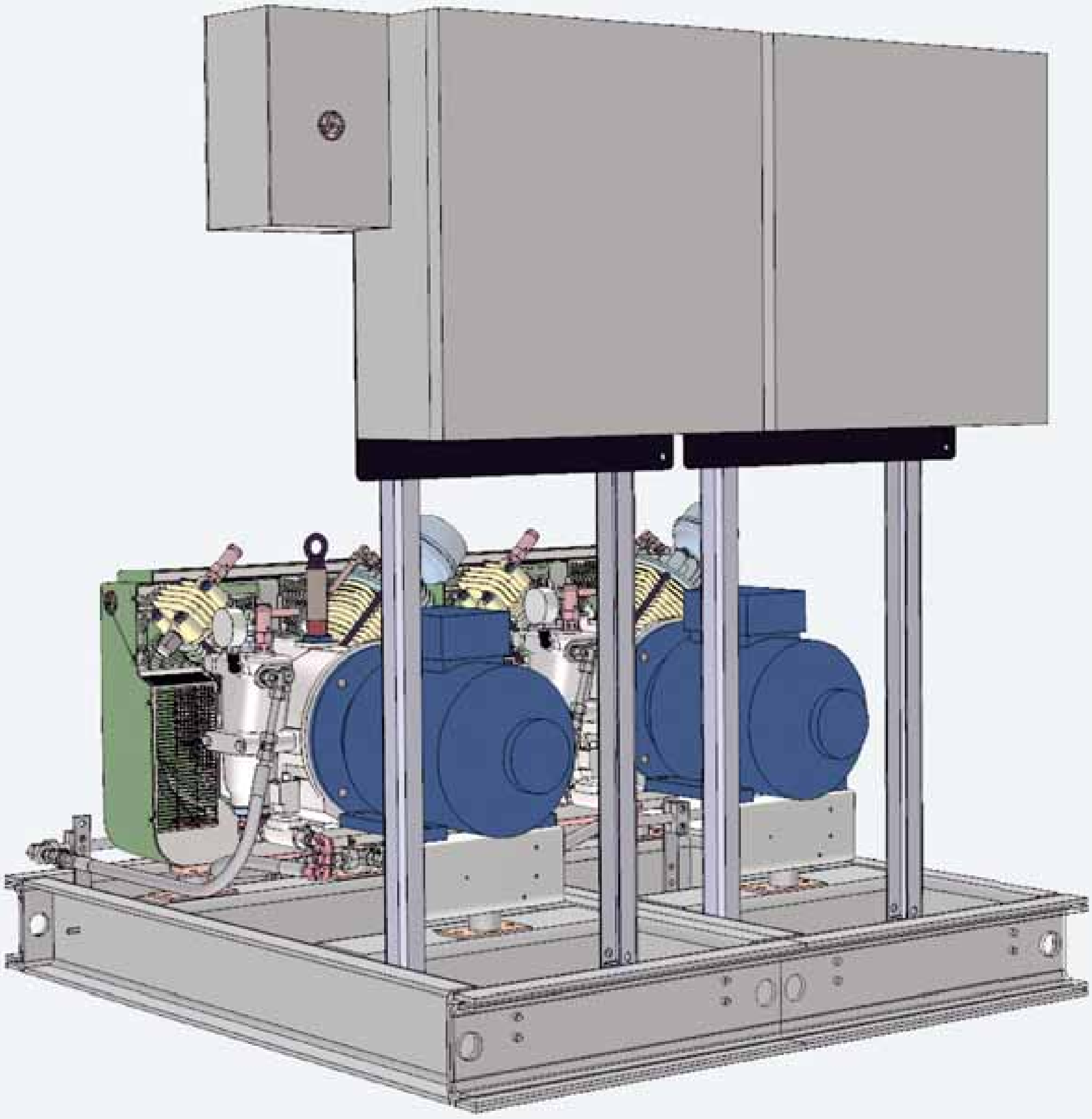


Fig. 8-3 Compressor AC1, stand-by compressor AC2

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

Dimensions:

Width: 1,250 mm
Length: 1,350 mm
Height: 1,550 mm
The dimensions of the compressor module does 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			
					Char-ging capacity	Power con-sumpti-on	Heat dissipa-tion	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.

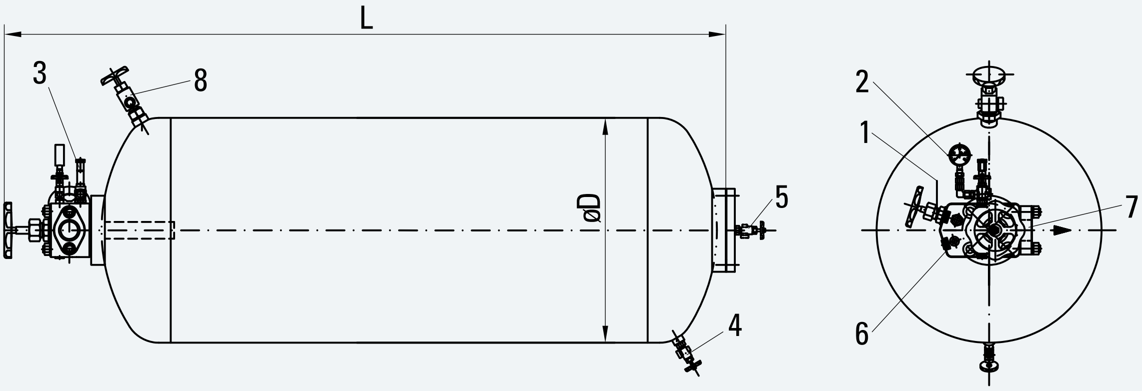


Fig. 8-4 Air receiver AT1, AT2

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		

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

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	øD	Valve head	Weight
[l]	[mm]	[mm]		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)

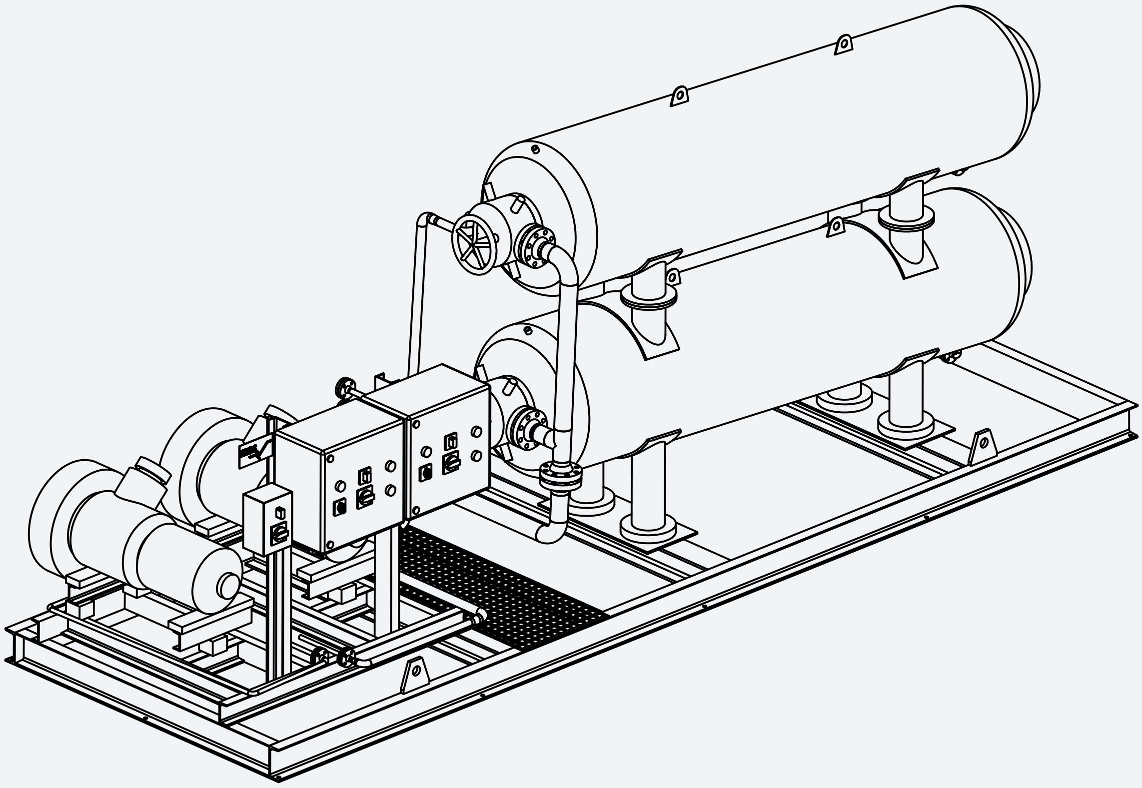


Fig. 8-5 Compressor module

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 4, technical data.

9.2.1 Air intake from engine room (standard)

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

9.2.2 Air intake from outside

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

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

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 C engines, achieved by a transition piece from the vertical line, are: 0 °, 30 °and 60 °. For the 8 and 9 M 32 C engines additional standard orientations of 45 ° and 90 ° from the vertical line are available.

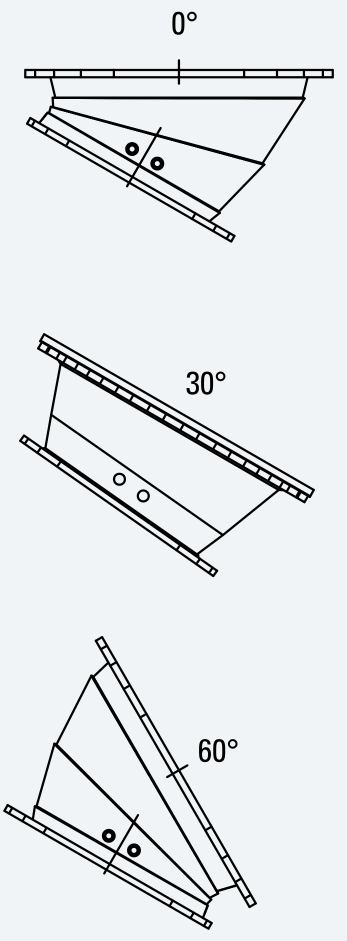


Fig. 10-1 6 M 32 C nozzle orientation

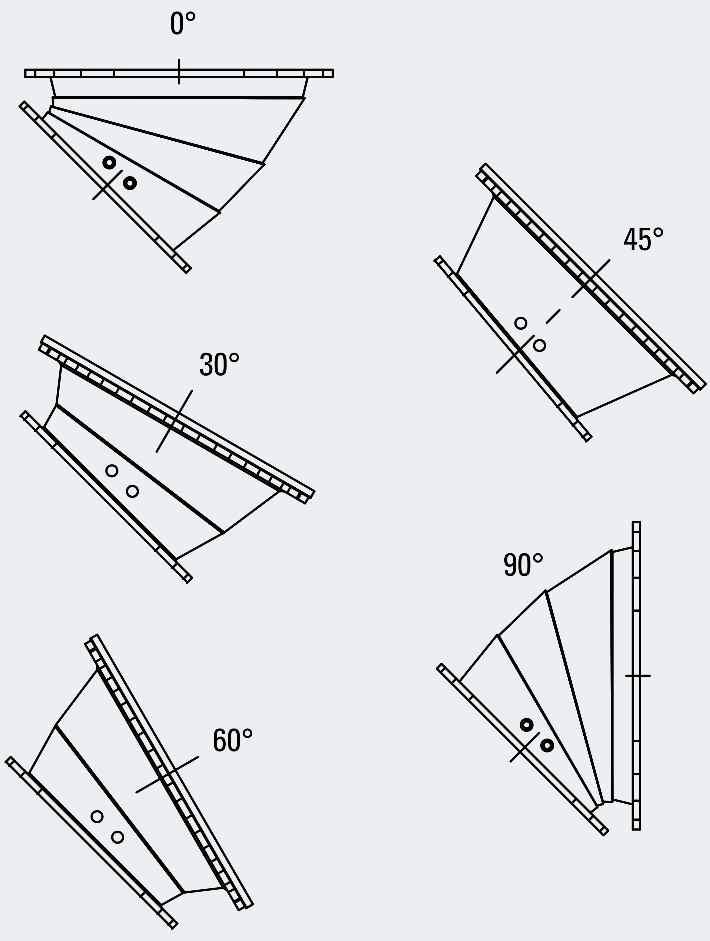


Fig. 10-2 8/9 M 32 C nozzle orientation

10.1.2 Exhaust gas compensator

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

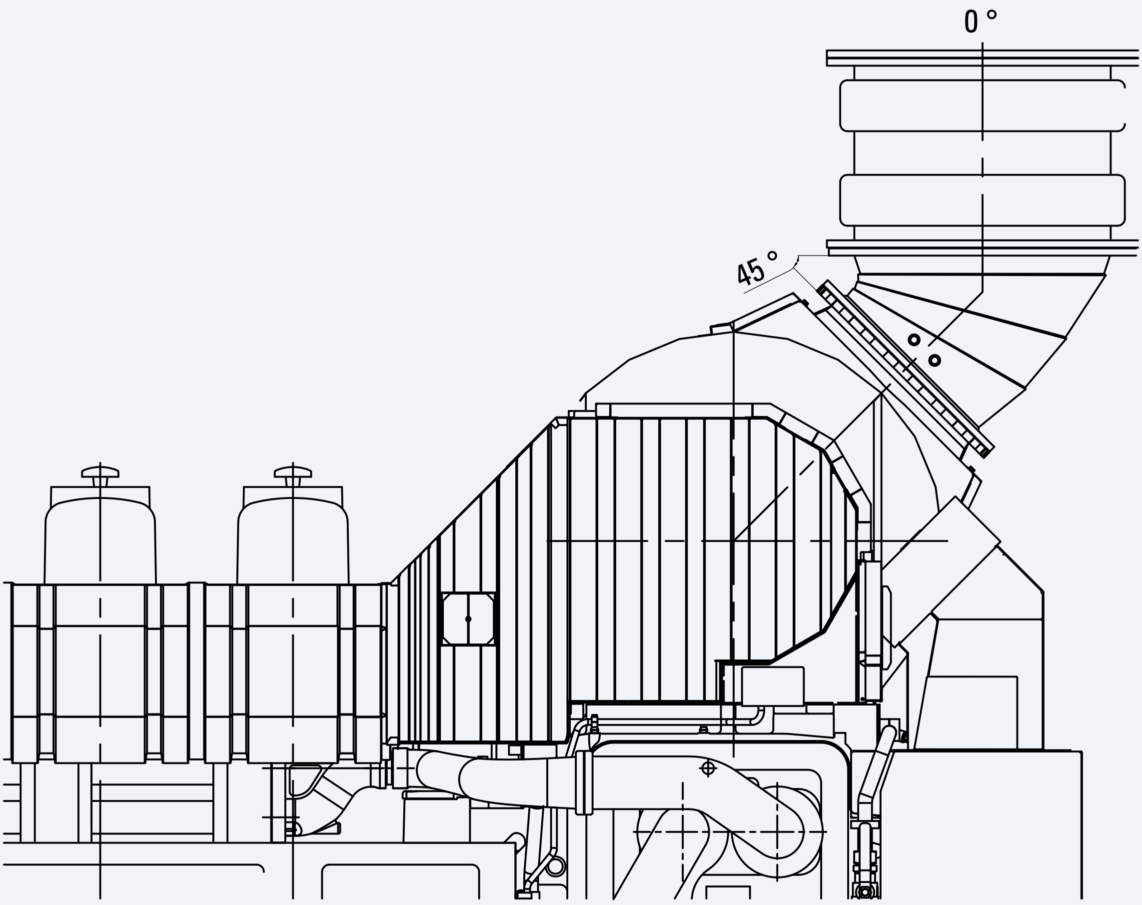


Fig. 10-3 Exhaust gas compensator

Basic design values of the standard exhaust gas compensators.

Type	Diameter [mm]	Length [mm]	Weight [kg]
6 M 32 C	600	450	107
8/9 M 32 C	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 there are a lot 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

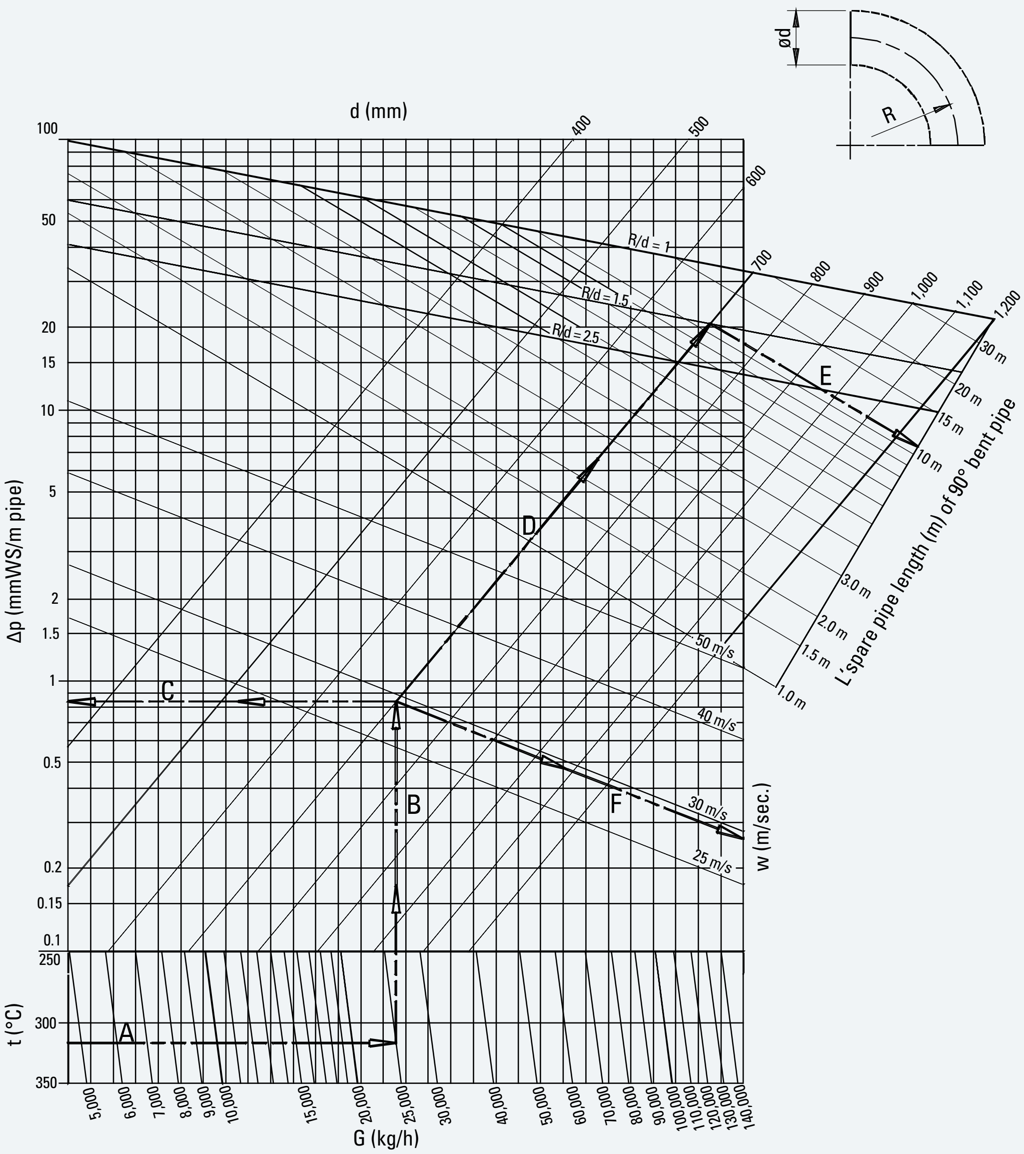


Fig. 10-4 Resistance in exhaust gas piping

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.

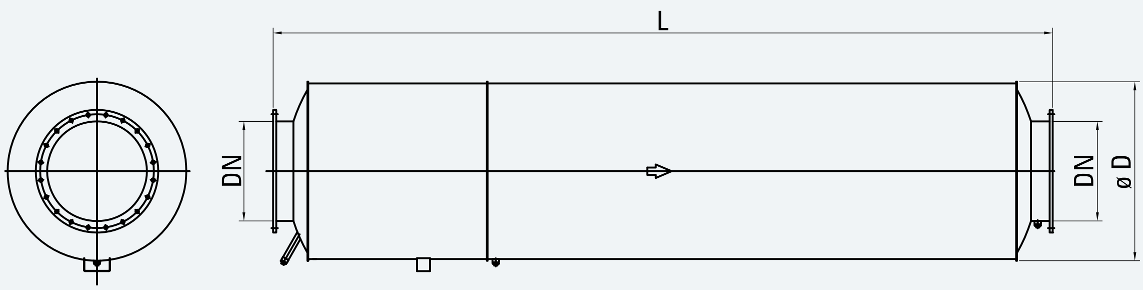


Fig. 10-5 Silencer

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.

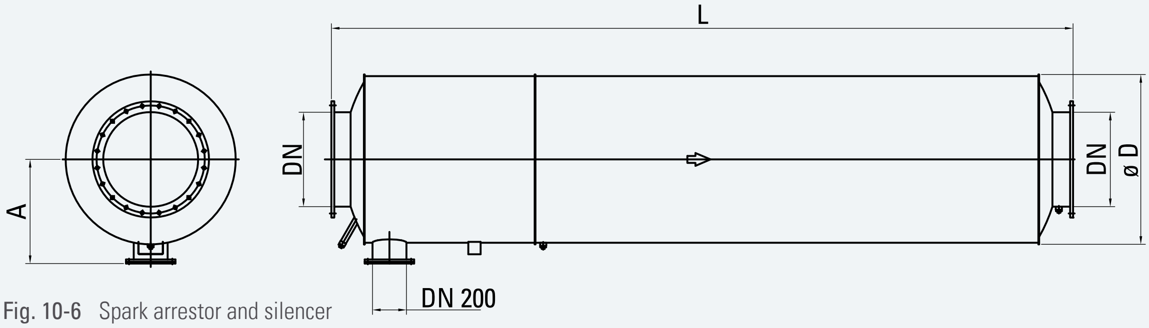


Fig. 10-6 Spark arrestor and silencer

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

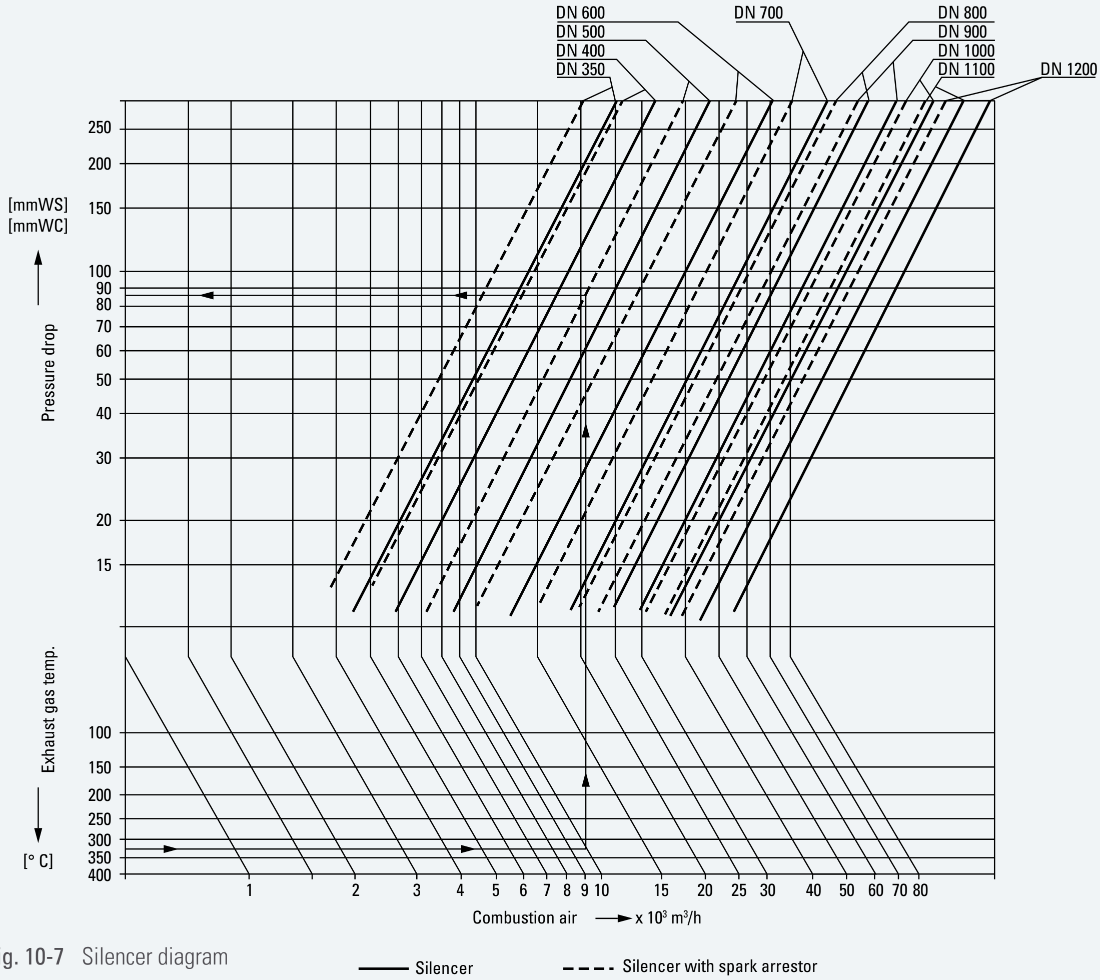


Fig. 10-7 Silencer diagram

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

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 C and 2.5 bar for 8/9 M 32 C is required.

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

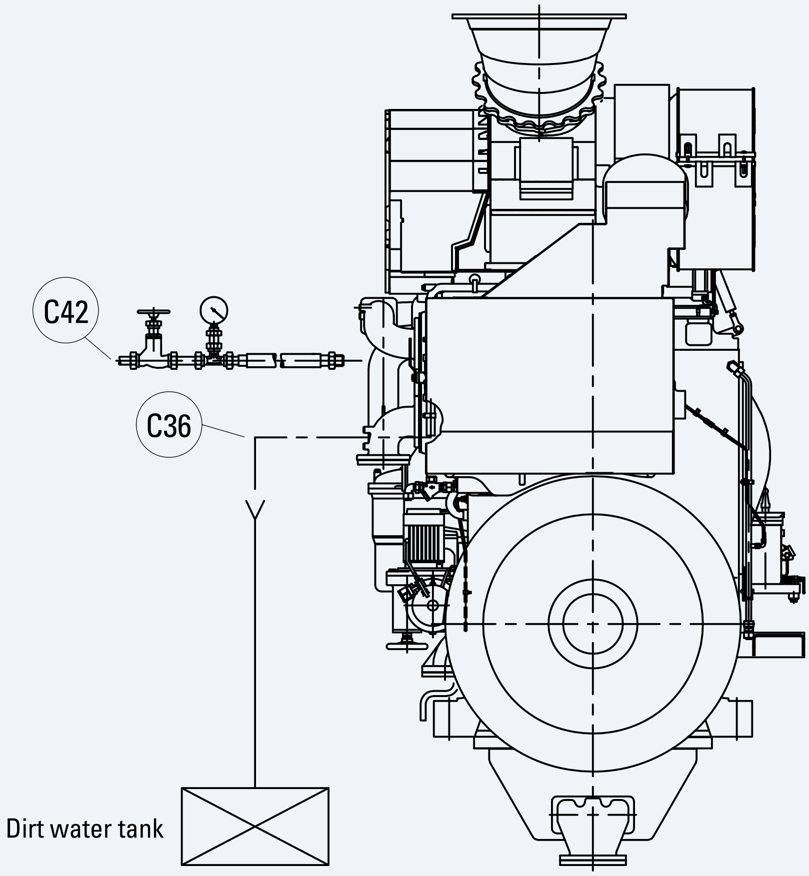


Fig. 10-8 Connection points freshwater and drain

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 C	12	10
8/9 M 32 C	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.

11.1 Technology / benefits

Building upon the Emission Reduction System integration concept, FCT achieves synergy between flexible fuel systems and advanced air systems with maximum utilization of the current engine design. While maintaining high fuel injection pressure over the whole operating range, fuel injection and inlet valve timing are load controlled and influenced by a lever shaft which affects injection timing/pressure and inlet valve events. Valve timing changes at part load to raise effective compression and enhance complete combustion. In addition, shifting the relative position of the lever to the fuel cam increases injection pressure, producing a finer atomization of fuel in a load range where it would otherwise be difficult to control smoke.

Soot emission of inline M 32 C IMO II (constant speed)

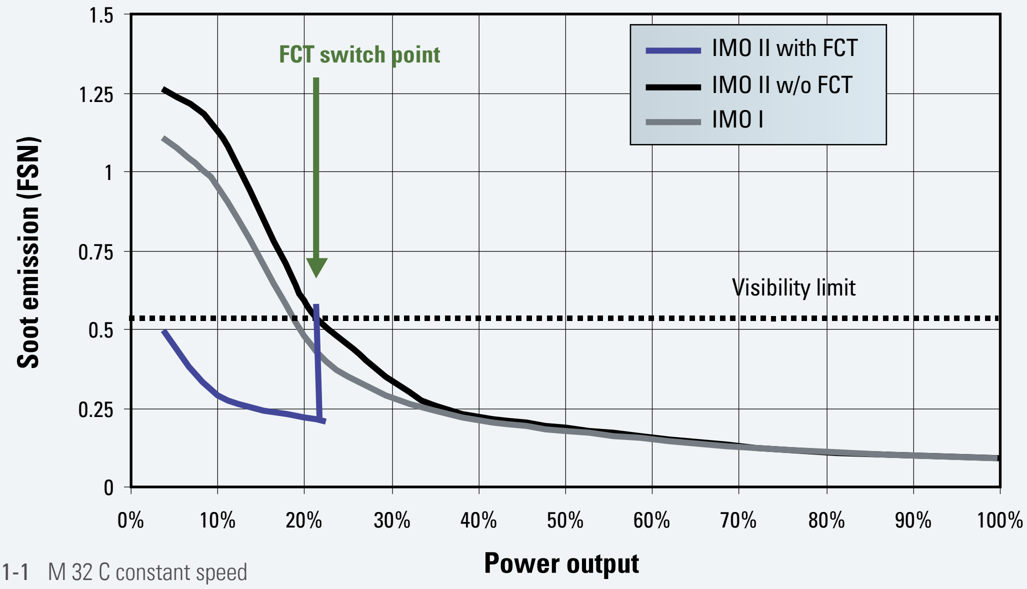


Fig. 11-1 M 32 C constant speed

Soot emission of inline M 32 C IMO II (CPP operation / combinator mode)

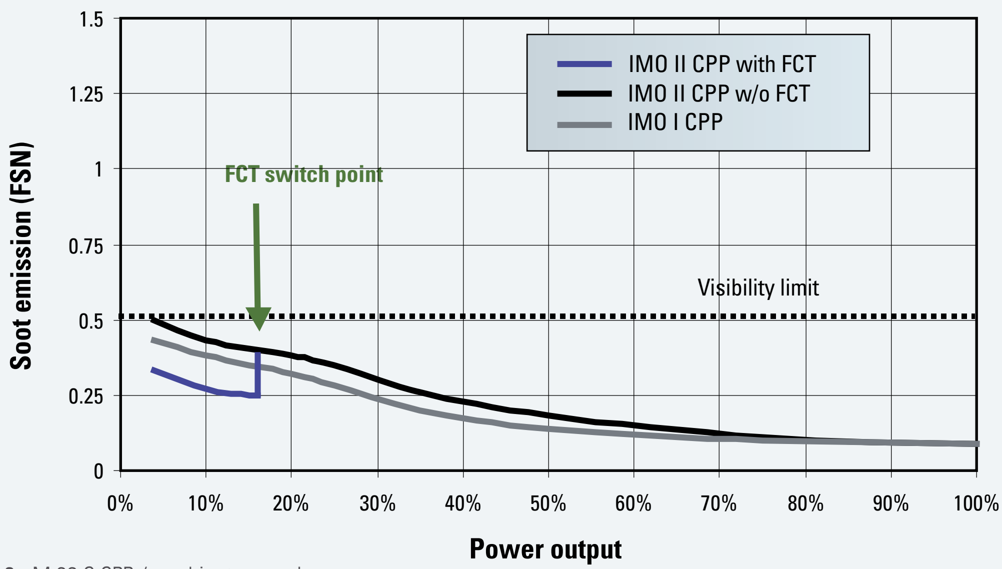


Fig. 11-2 M 32 C CPP / combinatory mode

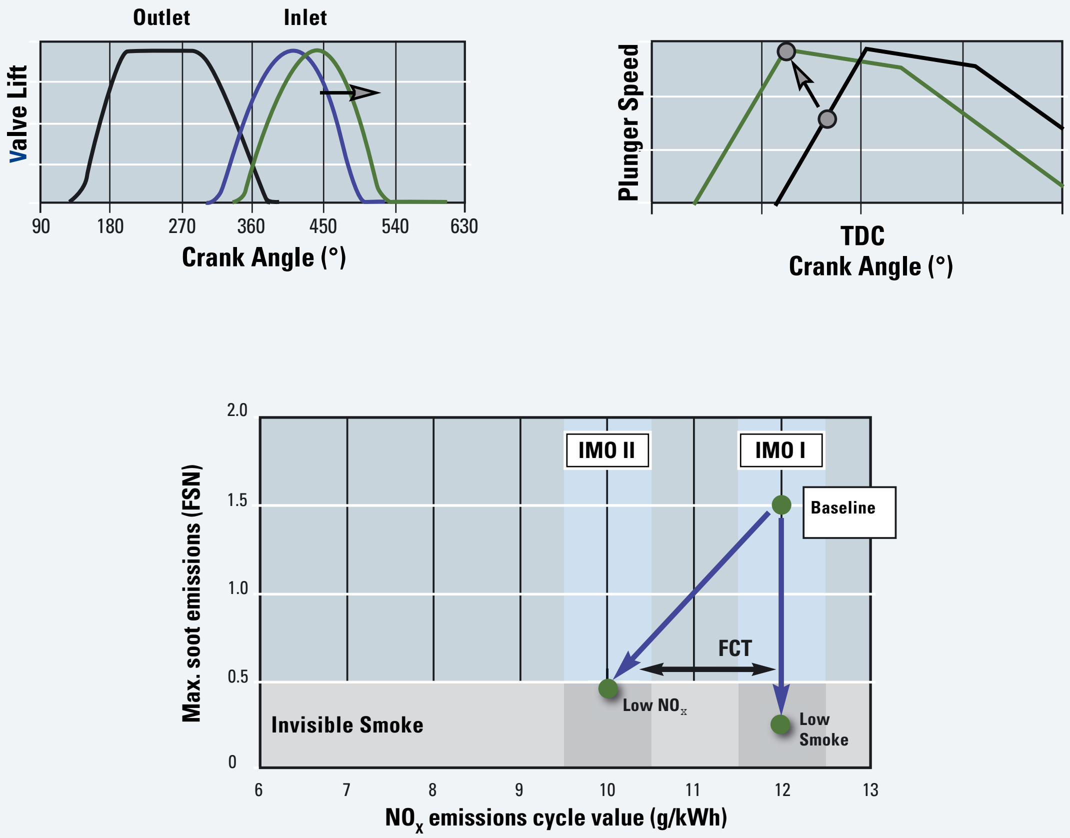


Fig. 11-3 Schematic diagrams

11.2 FCT cabinet

FCT will only be active in the lower load range to reduce soot emissions. The system is self-controlled; a lever shaft is actuated by the speed signal from the turbocharger as well as from the charge air pressure. A pneumatic actuator turns the shaft and changes the characteristic of the engine. If there is a critical failure for the engine, a shut down will be triggered.
For not critical failure the engine goes automatically to normal engine operation without a stop.

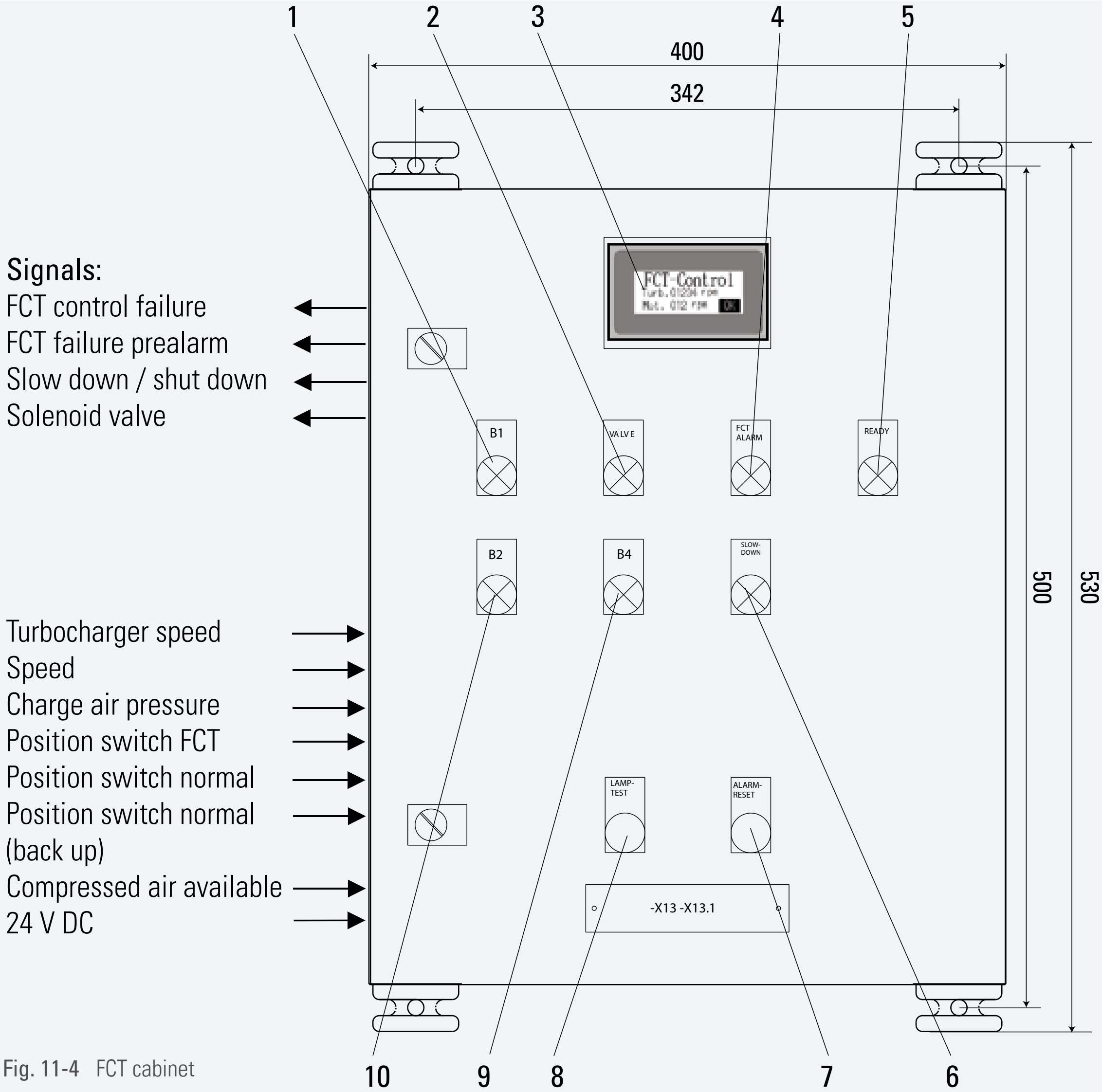


Fig. 11-4 FCT cabinet

1	In FCT position	6	Slow down / shut down
2	Valve (on FCT position, off normal position of the valve)	7	Alarm reset
3	Display with touch screen	8	Lampt test
4	FCT alarm	9	In normal position
5	Ready (PLC ok)	10	In normal position

1 = Display / 2 - 8 = Control lamps / 9 - 10 = Push button

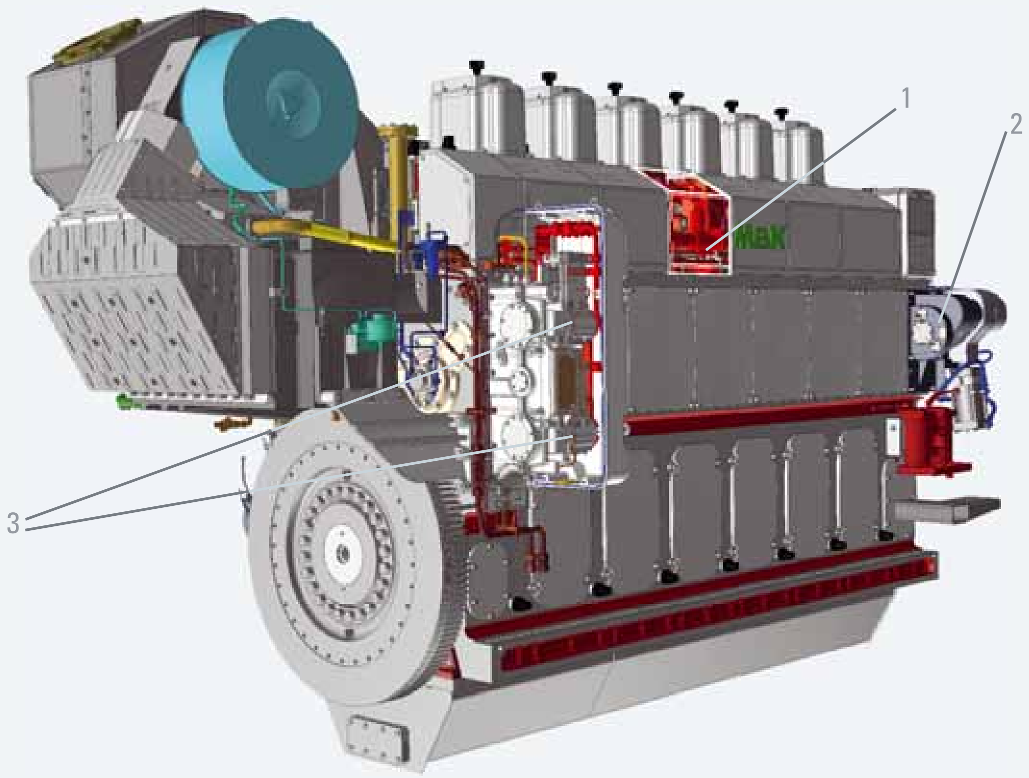


Fig. 12-1 M 32 C Common Rail

1 Rail
2 FCT equipment
3 Two high pressure fuel pumps

From its introduction the MaK long-stroke generation of main diesel engines has been recognized for good performance and reasonable fuel consumption, alongside outstanding reliability and long component life. MaK engines are compliant with current emission regulations without the need for additional after-treatment. To fulfill the upcoming emission legislations the development of new combustion process supporting technologies is necessary.

Key criteria are:

- Prevailing emission limits for the respective power range and timing of their introduction.
- Customer expectations in terms of engine performance, maintenance practices, fuel quality and mode of operation.

After successfully demonstrating its emission reduction technology in the high-speed engine market, Caterpillar started migrating selected elements to its marine program, yet using a modified approach.

By adopting well proven elements of the high-speed engine technology for medium-speed engines, it is our goal to meet and exceed customer expectations by maximizing product value through:

- Superior reliability in heavy fuel operation.
- Best fuel efficiency in its class.
- Lowest engine emissions with minimum additional complexity.

Keeping in mind the high reliability expectations of customers, Caterpillar decided to adopt a two-step approach providing the most effective solutions with lowest complexity.
Flexible Camshaft Technology (FCT) has been developed and put into production. The next milestone in emissions technology is a fully flexible fuel system suitable for HFO, MDO and DO, called the Cat Common Rail (Cat CR) fuel system.
Cat Common Rail is considered one major building block towards low emissions, high performance and highest customer value.

The goals are:

- Invisible smoke under all engine operating conditions.
- Reduce emissions beyond current and future IMO regulations, offering an attractive technology for emissions sensitive areas.
- Maintain or improve engine performance by taking advantage of the capabilities and benefits of a fully flexible fuel system.
- Continue to meet the level of reliability in heavy fuel operation expected by our marine customers.

12.1 Technology

Caterpillar has chosen "inside the engine" measures as the technology with the highest customer value. In combination with the long-stroke concept and high performance air systems the Cat Common Rail (Cat CR) fuel system is the most effective technology to meet emission regulations and customer expectations.

The key features of the Cat Common Rail technology are:

- Well adapted injection pressure over the entire engine operating range.
- Fully flexible fuel injection system enabling optimized emissions and engine perfor-mance.
- Suitable for HFO, MDO and DO.
- 100% retrofittable system.

12.2 Cat CR system

The main components of the Cat Common Rail fuel system are a high pressure (HP) pump, rail, injector and electronics. Caterpillar Motoren's broad experience with electronically controlled engines, range of product lines and in-house design and analysis expertise allow for a unique system approach. All components are developed under Caterpillar design control. In addition Caterpillar Motoren 's expertise in electronics is a major asset to the Cat Common Rail technology.

12.2.1 Safety concept

Safety considerations and high customer value were the main focus throughout the development, resulting in a state-of-the-art design with the following features:

- Two high pressure pumps for redundancy.
- Double-walled lines and rails.

Furthermore, redundant speed pick-ups and pressure sensors, a safety gear between pump and engine, a pressure relief valve and flow limiters all increase operational safety.

12.2.2 High pressure pump

Two high pressure pumps deliver the required amount of fuel to the rail and provide the desired rail pressure in closed loop control. The pump itself is based on a proven design and has been modified for HFO operation. By having two pumps for all in-line engines the amount of HP connections and components is drastically reduced and thus increases reliability. The inlet metering control of the pump ensures a high pump efficiency.

The key features are:

- Two pumps for redundancy.
- Inlet metering control.
- Well adapted injection pressure over a wide operating range.
- Closed loop control of rail pressure.

12.2.3 Rail

The double-walled rails are pressurized and act as an accumulator, with one rail segment feeding fuel to three injectors, i. e. a nine cylinder engine has only three rail segments, an eight cylinder engine has two rail segments, each feeding four injectors. This layout reduces the number of parts and the number of high pressure connections. Flow limiters prevent the cylinders from overfuelling; a safety valve acts as pressure relief in case of an unwanted overpressurized rail.

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

12.2.4 Injector

Caterpillar has chosen a simple and robust approach by using the actual fuel as control fluid, thereby eliminating the need for a separate control fluid system.
The injector nozzle is cooled by lube oil, a typical feature for heavy fuel operation. For the Cat CR injector, the lube oil circuit has been extended to provide cooling to the electrical components within the injector, thereby increasing the lifetime.
The injector design is simple, robust and compact; the key features are:

- Electronically controlled.
- Flexible injection timing and duration.
- Capability of multi shot injections.

12.3 Electronics

The key component is the Caterpillar A4E4 (or ADEM™) Electronic Control Module (ECM). The ECM acts as the brain of the Cat Common Rail fuel system. Pioneered by Caterpillar 20 years ago, the ADEM™ controller coordinates and enhances fuel delivery, air supply and other engine functions to maximize overall performance and reduce emissions output.
Having in-house expertise for core electronic components and software puts Caterpillar in a unique position and allows for an advantageous systems approach.
Based on existing software and engine control strategies, the specific needs of heavy fuel burning engines and applications can be easily adopted. Depending on engine type, application and boundary conditions, a tailor made version allows for optimal operation.
The engine protection system operates independently of the engine control system and has its own independent sensor equipment. This ensures that engine operation is monitored independently of other control systems.
The ECM functions can be divided into a core system and a performance system.
The core system consists of:

- Control device A4E4.
- One crankshaft speed pick-up.
- Two high-pressure sensors.
- Two inlet metering valves
- Injectors.

The performance system ensures optimal engine settings under all operating conditions, using information like exhaust gas temperature, charge air pressure, ambient conditions and lube oil temperature.

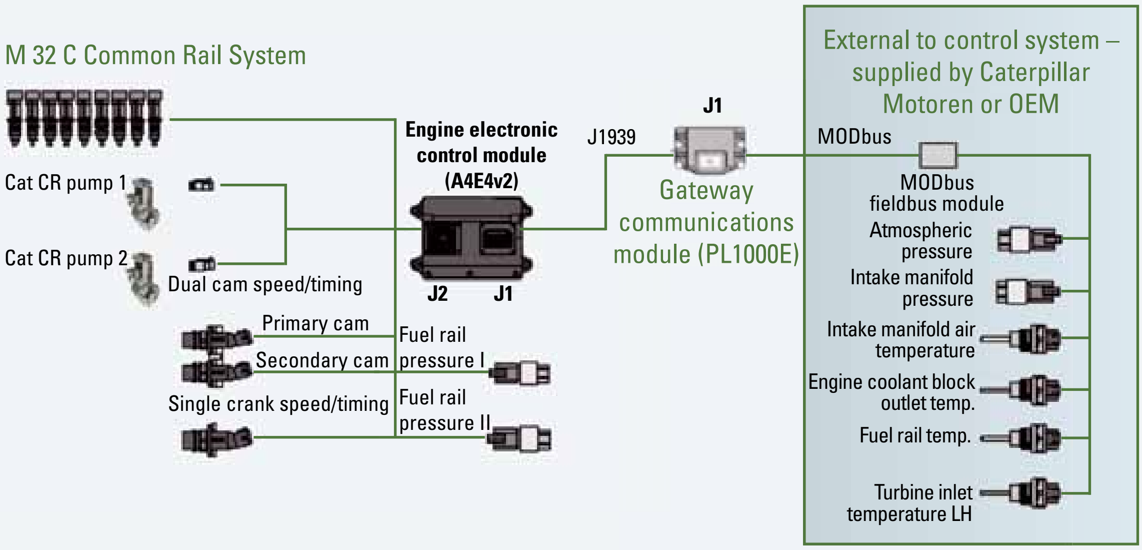


Fig. 12-1

12.4 The benefits

With Cat Common Rail, the injection pressure is independent from load and speed. Utilizing injection maps the injection characteristics are optimized for every engine operating point.
For areas that are especially emissions-sensitive, soot emissions at low engine load remain well below the visibility limit. Furthermore, during normal load operation NOx emissions can be reduced without sacrificing fuel consumption. In general, the Cat Common Rail fuel system enables vessel operation without visible soot throughout the whole operating range.
In addition to that, the fuel system is capable of multiple injection. Multiple injection allows for optimal combustion and low emissions at all loads.
Characteristic of Cat Common Rail is the approach of using the fuel (whether it's heavy fuel oil, marine diesel oil or diesel oil) as the control fluid for the injector, thus avoiding the added complexity of a separate control fluid system.
During the development, the retrofit aspect of the complete system has been emphasized. As a result, the Cat Common Rail fuel system can be retrofitted to existing M 32 C engines. This means increased customer value to reach future environmental regulations.

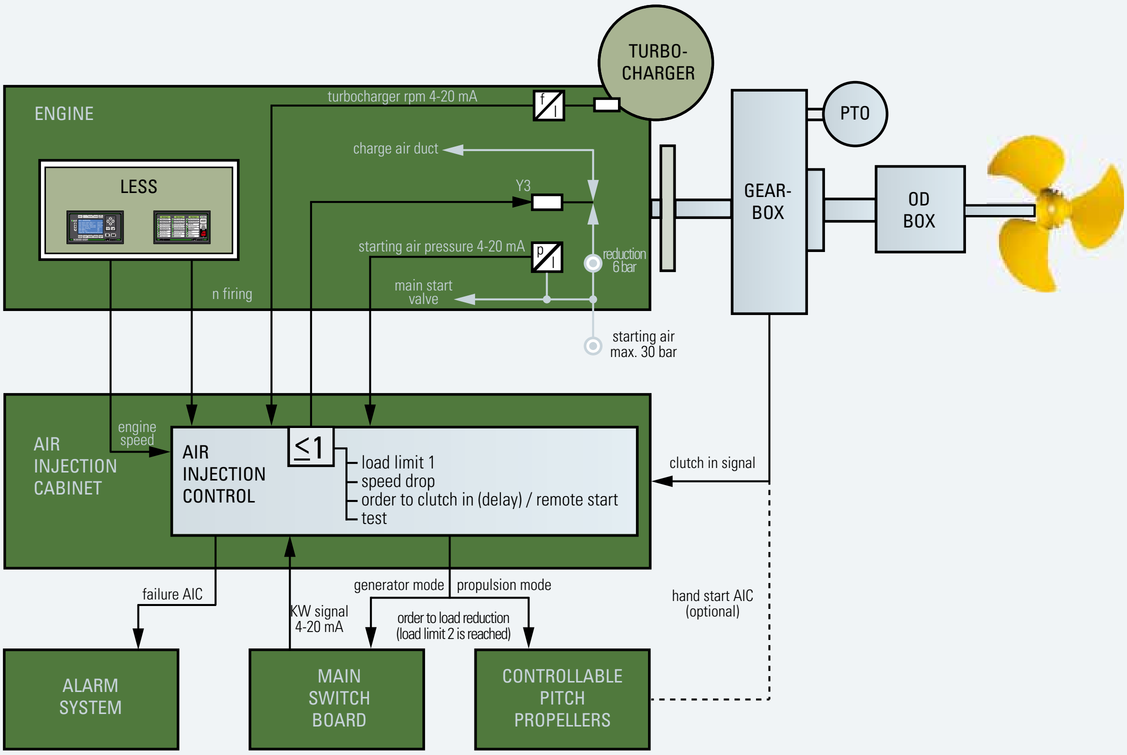


Fig. 13-1 Air injection CPP with PTO

13.1 Functional description

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

- engine speed drop under the clutch in procedure.
- frequency deviation under switching on of big consumers like cranes or bow thrusters in case of PTO-operation .

The design is simple and robust without any changes to the turbo charger housing.

13.2 Advantages

The following diagrams show the advantages from air injection control concerning the reduction of soot emissions, speed drop and run up time of the engine.

M 32 C - Air injection
Load ramp at constant speed (n = 600 min^{-1}) with and without air injection:
Reduction at ramp-up time at same engine performance

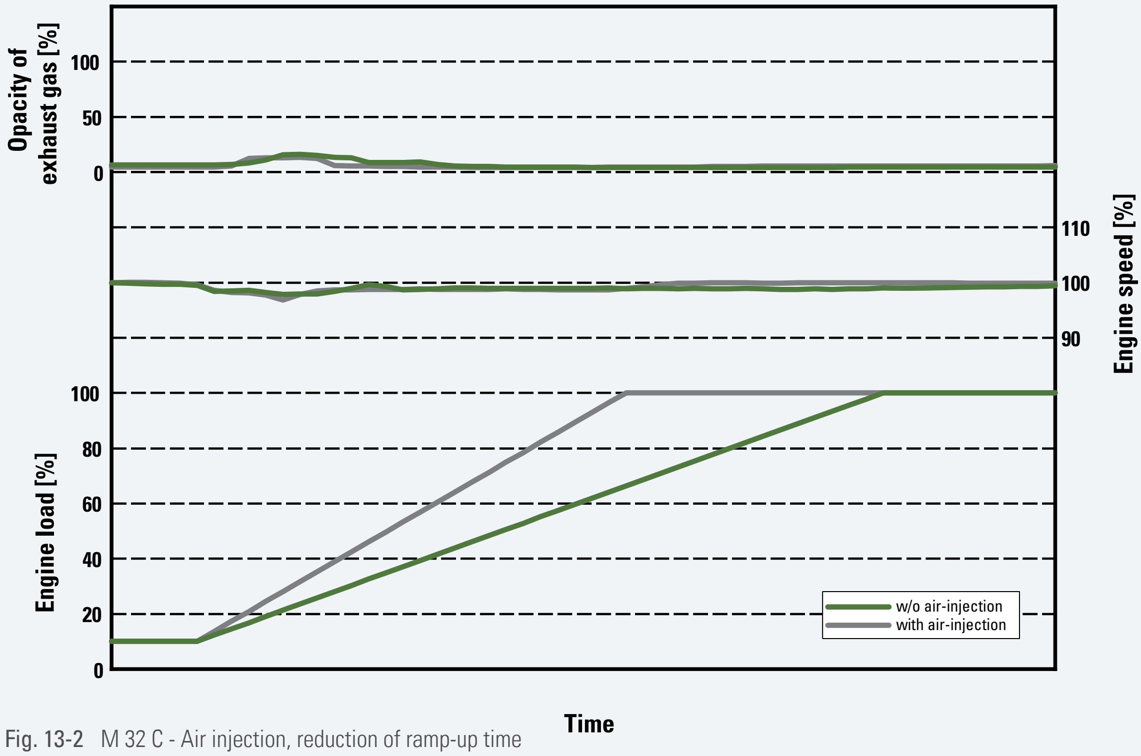


Fig. 13-2 M 32 C - Air injection, reduction of ramp-up time

M 32 C - Air injection
Load ramp at constant speed (n = 600 min^{-1}) with and without air injection:
Significant reduction of soot emissions and speed undershot

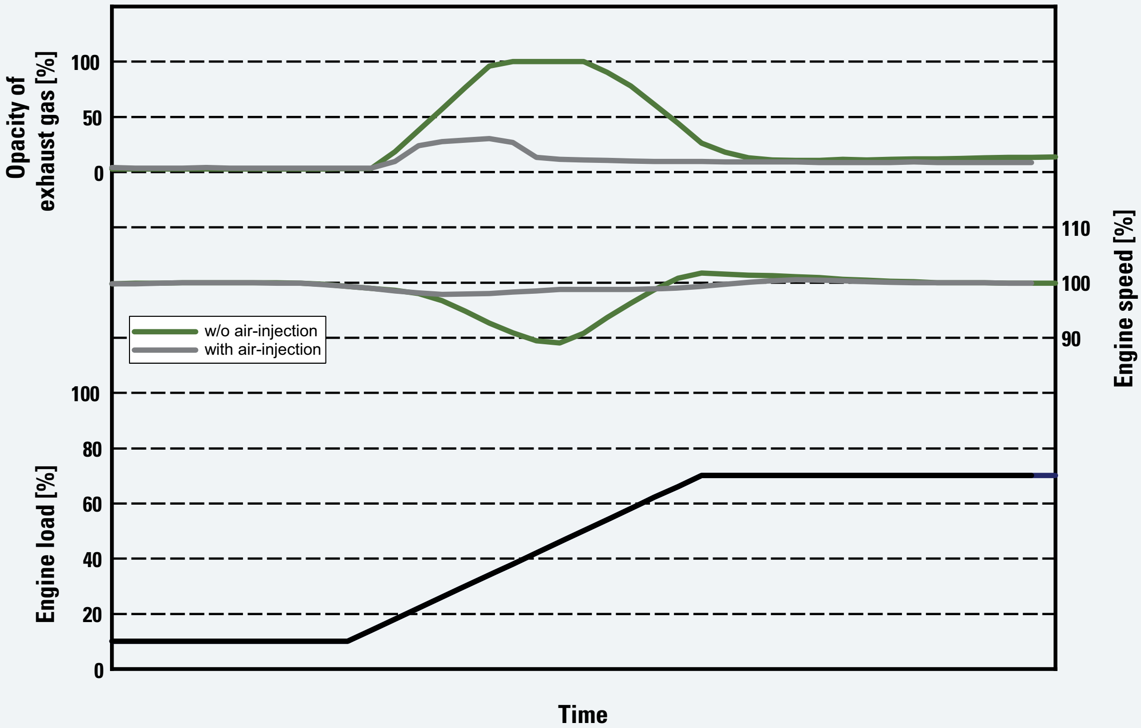


Fig. 13-3 M 32 C - Air injection, significant reduction of soot emissions and speed undershot

13.3 Operation

13.3.1 Activation

Air injection will be activated in case of

- high load increase rate or
- speed drop or
- test start air injection signal (carried out manually).

This depends on the following conditions:

- clutch / circuit breaker is activated and
- engine is running and
- turbocharger rpm falls below switch point and
- start air pressure is 18 - 21 bar.

13.3.2 Deactivation

Air injection will be deactivated if

- start air pressure drops below 18 - 21 bar or
- turbocharger rpm is above switch point or
- clutch / circuit breaker is not activated or
- activation time is expired.

13.3.3 Adjustable parameters

The following parameters can be adjusted:

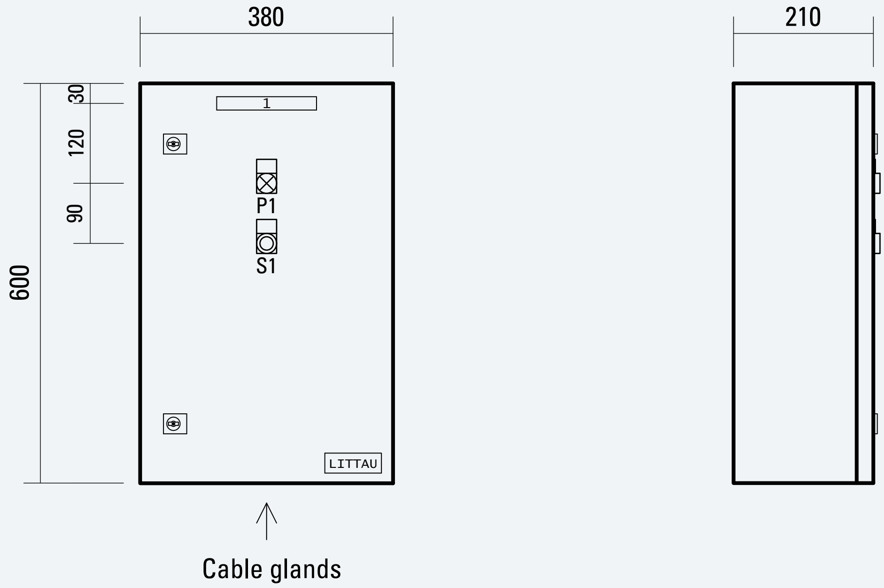
- load limit 1
- load limit 2
- turbocharger rpm switch point
- speed drop

13.3.4 Alarms (air injection cabinet)

Under the following conditions the AIC will generate an alarm:

- voltage failure
- analog values failure

13.4 Air injection cabinet



13-4 Air injection system cabinet dimensions [mm]

1	Identification label "air injection control"
P1	Pilot lamp "air injection activated"
S1	Pushbutton "lamp test"
S2	Pushbutton "test start air injection"

Degree of protection: IP54
Weight: approx. 20 kg

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

14.1 Local engine control

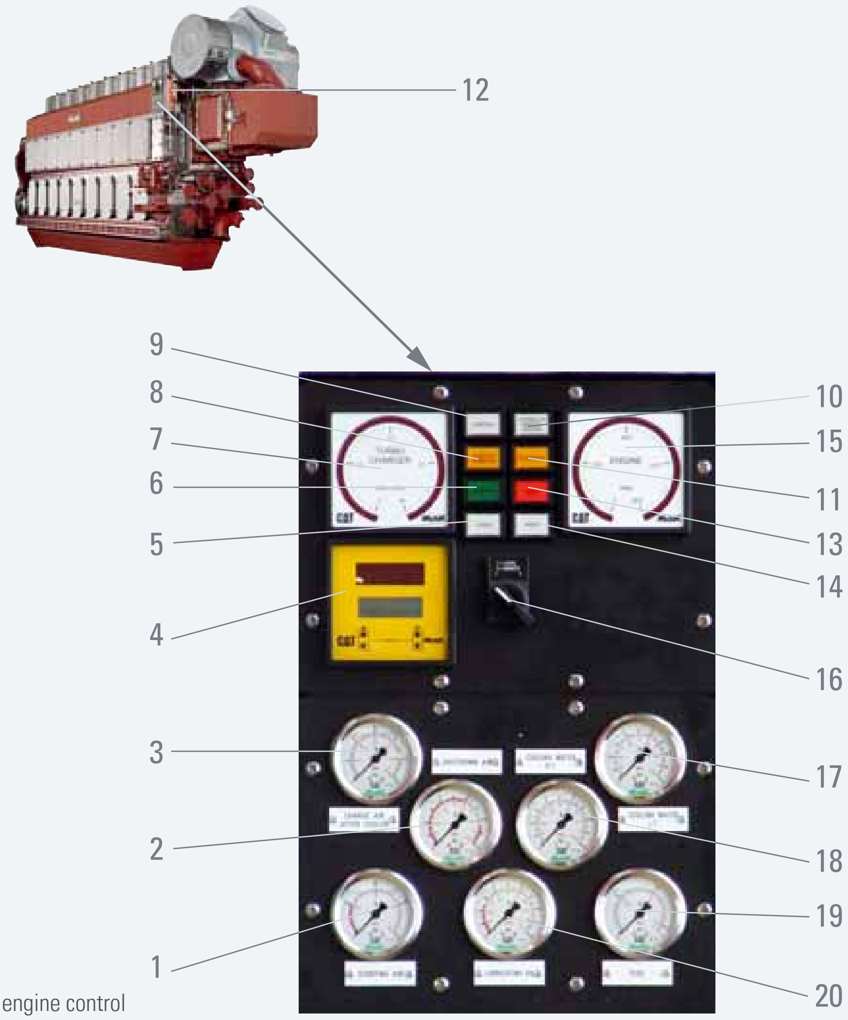


Fig. 14-1 Local engine control

1	Start air pressure	11	False start
2	Stop air pressure	12	Stop lever
3	Charge air pressure	13	Stop
4	Exhaust gas temp.	14	Raise
5	Lower	15	Engine speed
6	Start	16	1 = Local, 2 = remote
7	Speed turbocharger	17	Cooling water pressure LT
8	Starting interlock	18	Cooling water pressure HT
9	Lamp test	19	Fuel oil pressure
10	Remote control	20	Lube oil pressure

14.2 Remote engine control

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

*) Available through Caterpillar Marine Systems Integration
Note: ± 24 V DC supply ± 20 %

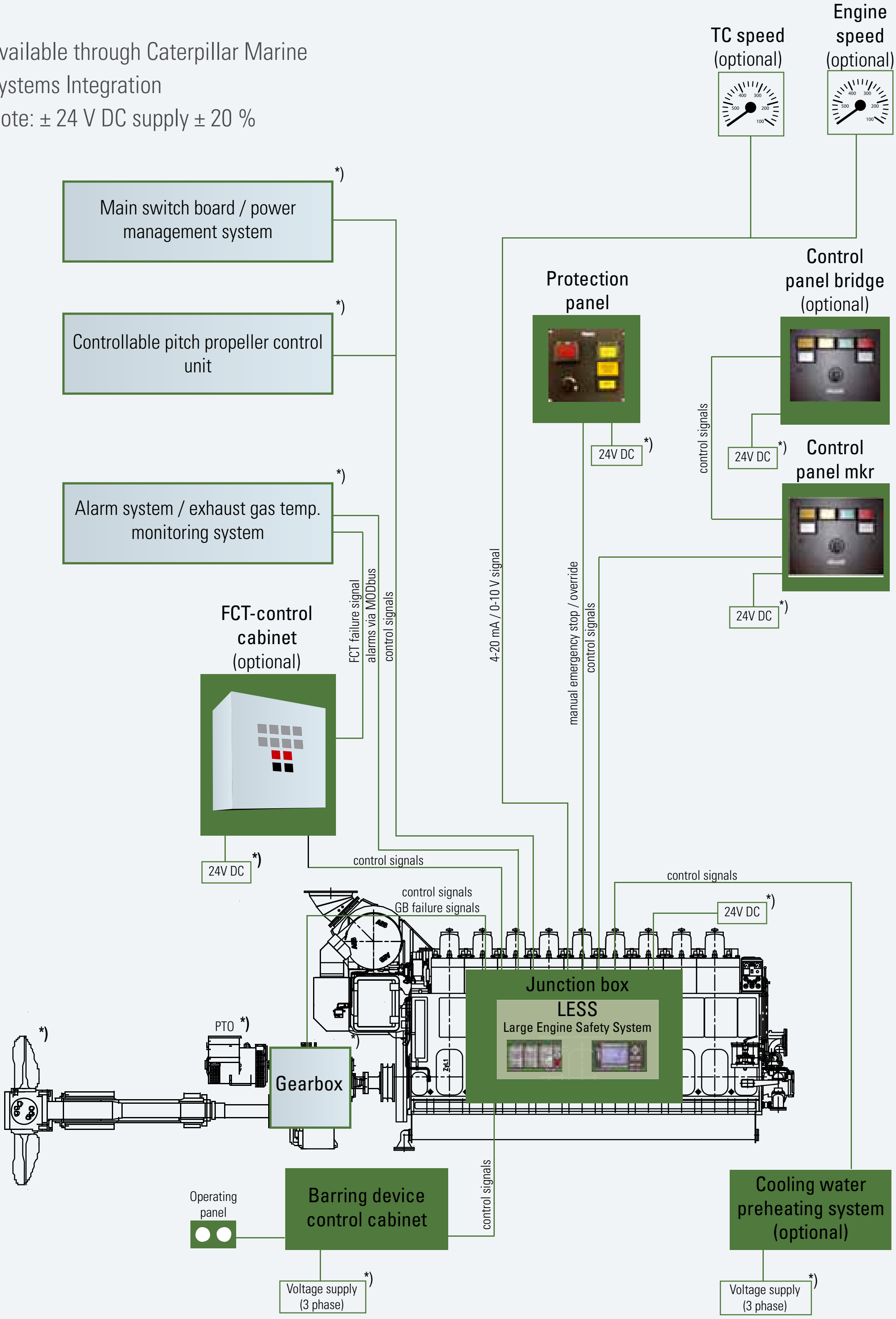


Fig. 14-2 Remote control for single-engine plant with one controllable pitch propeller

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

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

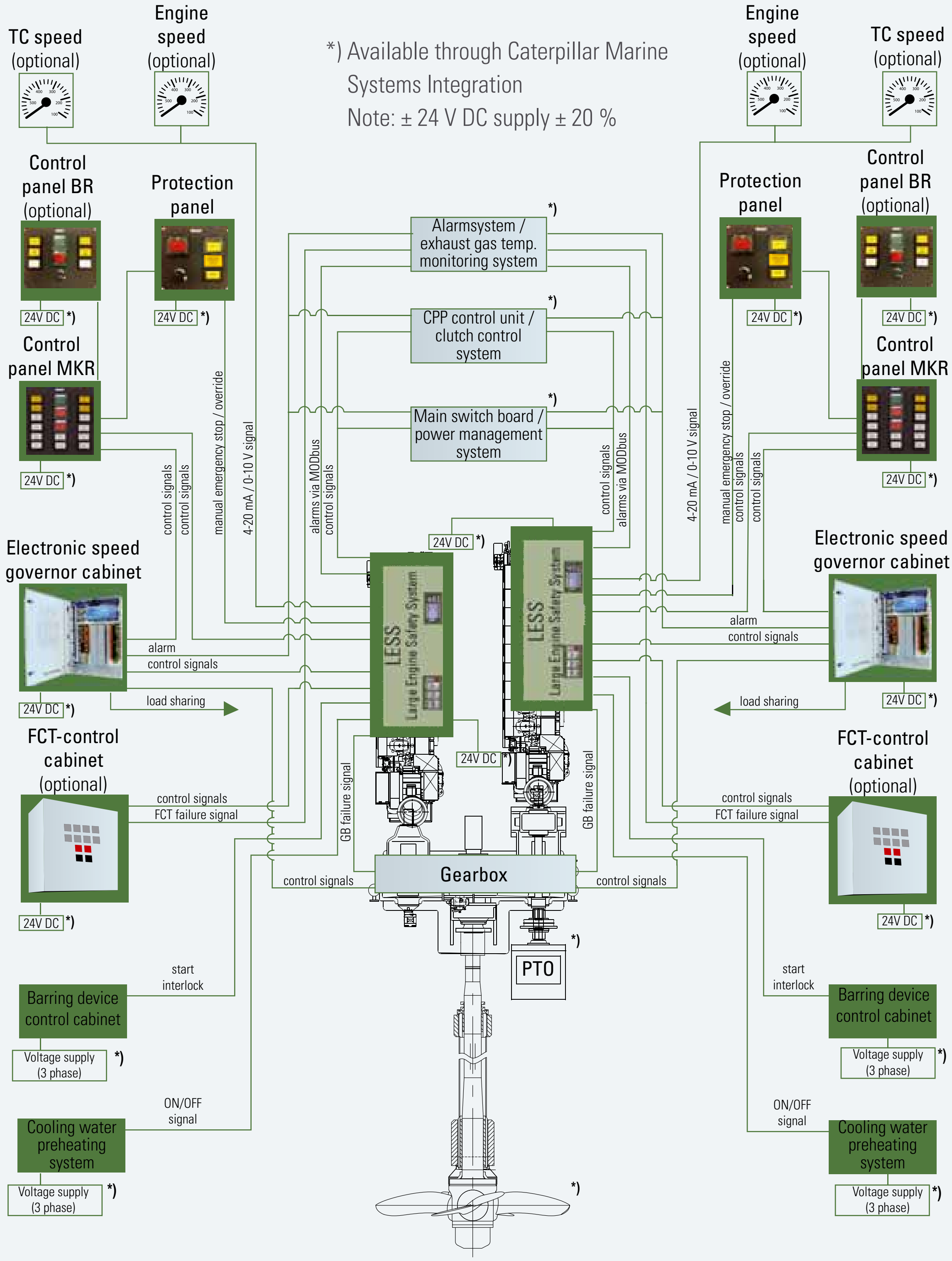


Fig. 14-3 Remote control for twin-engine plant with one controllable pitch propeller

14.3 Large Engine Safety System (LESS)

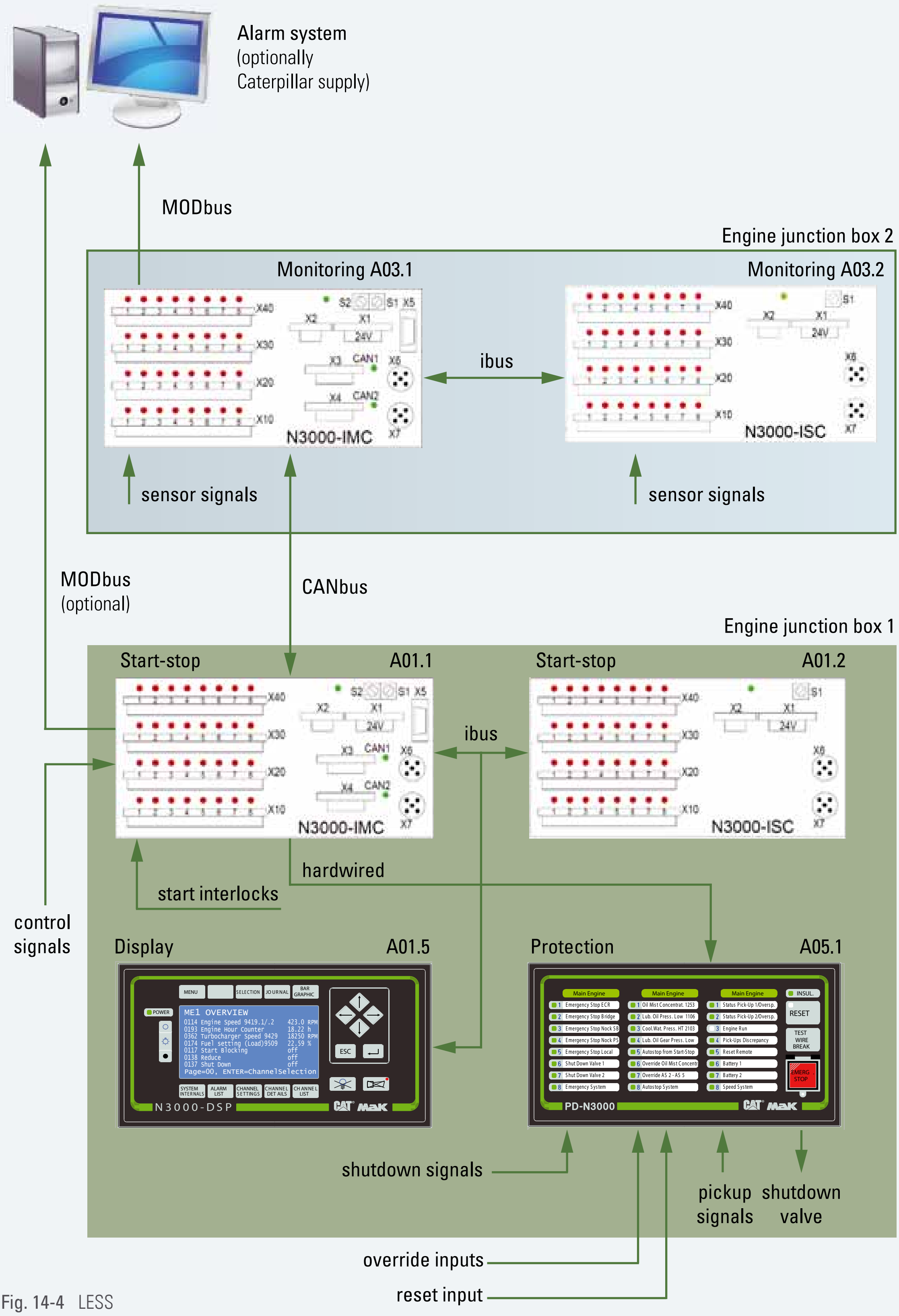


Fig. 14-4 LESS

Engine control boxes include

- Engine protection system
- Speed switch unit
- Start- / stop-control
- Alarm display (LED)
- Graphic display (settings)
- Engine monitoring
- Modbus output to alarm system (MODbus RTU protocol RS 482 / 422)
- Integrated exhaust gas temperature mean value monitoring system (optional)

System Data

Inputs:
- 4 fixed automatic shut down + over speed inputs
- 4 manual emergency stop inputs
- 16 configurable inputs for shut down, load reduce request or staring interlock
- 2 separate override inputs
- 1 remote reset input
- All inputs are wire break- and short circuit monitored

Outputs:
- 4 x 2 adjustable speed contacts
- 3 fuel setting signals (1 x 0 - 10 V DC, 2 x 4 - 20 mA)
- 1 overload contact at rated speed
- 4 speed signals (1 x pulse, 1 x 0 - 10 V DC, 2 x 4 - 20 mA or 0 – 10 V DC configurable)

14.4 Governors / Speed control

Main engines are equipped with a mech. / hydr. speed governor (4-20 mA speed setting) and the following equipment:

- Stepper motor in the top part of the governor for remote speed control,
- Separate stepper motor control with adjustable speed range and speed ramp.
  Voltage supply = 24 V DC.

The control is easily accessible on the engine in the terminal board box (X3) especially provided for control components.

The set speed value from n_{min} = 4 mA up to n_{max} = 20 mA is converted into a current required by the stepper motor.

Design features

- Raise / lower push buttons (emergency speed setting)
- Shut down solenoid (24 V DC / 100 % duty cycle) for remote stop (not for automatic engine stop).
- Stepless adjustable droop on the governor from 0 – 10 %
- Standard setting: 0 %
- Device for optimization of the governor characteristic
- Serrated drive shaft (for easy service)

Single- / twin-engine plant with one controllable pitch propeller

The engines are equipped with a standard actuator (optional with mechanical back-up for twin-engines and in accordance with class requirements with mechanical back-up for single-engine).
The electronic governor is installed in a separate control cabinet.
The governor comprises the following features:

- Speed setting range to be entered via parameters
- Adjustable acceleration and deceleration times
- Starting fuel limiter
- Input for stop (not emergency stop)
- 18 - 32 V DC voltage supply
- Alarm output
- Droop operation (primary shaft generator)
- Isochronous lad distribution by master / slave principle for twin-engine propulsion plants via double reduction gear
- Protection class of equipment: IP 54

Standard
Regulateurs Europa "Propulsion Panel" with electronic governor (one per engine).

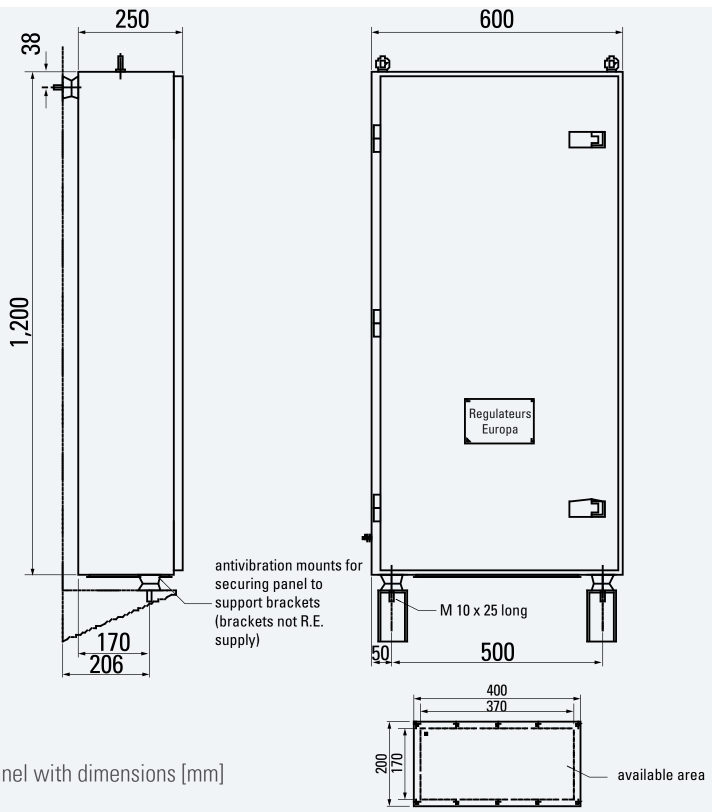


Fig. 14-5 Propulsion panel with dimensions [mm]

Option

Woodward control twin-engine cabinet with Woodward electronic governor.

14.5 Engine monitoring

Fig. 14-6 Engine monitoring

1	Pressure switch arrangement	4	LESS-display
2	Plate for pressure switch identification	5	Terminal board box X55
3	Yard connection	6	LESS Status and Alarm Panel (SAP)
		7	Vibration damper

Protection class of equipment: IP 54

14.6 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)	22 K	→	24 V DC	Starting interlock for engine	Main engine
Gearbox	Common load reduction (NO)	22 K	→	24 V DC	Slow down for engine	Main engine
Gearbox	Lube oil pressure low low (NO	22 K	→	24 V DC	Shut down for engine	Main engine
Controllable pitch propeller	Actual engine speed		←	4 - 20 mA	Engine speed	Main engine
Controllable pitch propeller	Actual fuel rack position		←	4 - 20 mA	Fuel rack position 0 - 110 %	Main engine
Controllable pitch propeller	Main engine in overload	24 V DC	←		Used for overload indication	Main engine
Controllable pitch propeller	Request remote control	24 V DC	←		Local / remote switch contact at engine	Main engine
Controllable pitch propeller	Accept remote control		→	24 V DC	Remote control accepted	Main engine
Controllable pitch propeller	Local / remote control	24 V DC	←		Closed contact when main engine 1 is in remote control	Main engine
Controllable pitch propeller	Reduce to 40 % load	24 V DC	←		Slowdown at engine	Main engine
Controllable pitch propeller	Pitch to zero / auto clutch out	24 V DC	←		Shutdown at engine	Main engine
Controllable pitch propeller	Speed setting signal	4 - 20 mA	→		Speed setting signal mechanical governor	Main engine

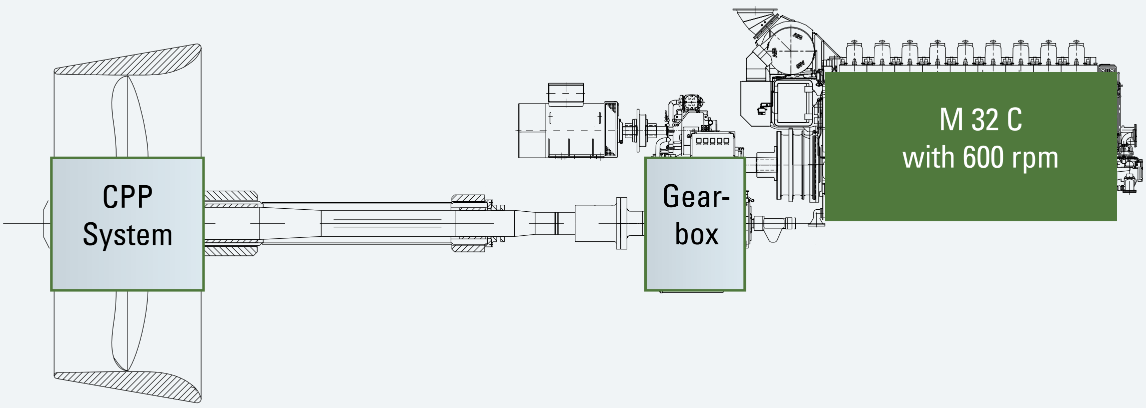


Fig. 14-7 Standard interface to gearbox and controllable pitch propeller for single-engine system

14.7 List of measuring points, exhaust gas monitoring

Meas. point	Description	Signal range	Remarks
1104	Lube oil pressure low – start stand-by pump	binary	
1105	Lube oil pressure low – pre alarm shut down	4 - 20 mA	
1106	Lube oil pressure low – shut down	binary	
1111	Differential pressure lube oil filter high – alarm	binary	not mounted on engine
1111.1	Differential pressure lube oil filter high – indication	4 - 20 mA	depending on class
1112.1 1112.2	Differential pressure lube oil automatic filter high – pre alarm Differential pressure lube oil automatic filter high – alarm	binary	1 evaluation unit for 1112.1/.2
1202	Lube oil temp. at engine inlet high – alarm	PT 100	
1203	Resistance thermometer lube oil temp. at engine inlet high – load reduction	PT 100	
1251 1251.1 1251.2 1253 9631	Oil mist detector VN115/87 plus 1251 Oil mist concentration in crankcase high – alarm 1251.1 Oil mist concentration in crankcase high – pre alarm 1251.2 Opacity 1253 Oil mist concentration in crankcase high – shut down 9631 Oil mist detector failure – alarm	binary 1251.2: 1-14 4 - 20 mA 1253: binary 9631: binary	1 evaluation unit for 1251, 1253, 9631 1251.1 (70 % from 1251)
2101	Cooling water pressure HT at engine inlet low – start stand-by pump	binary	*20 kPa below operating pressure
2102	Cooling water pressure HT at engine inlet low – alarm	4 - 20 mA	* 40 kPa below operating pressure
2111	Cooling water pressure LT at engine inlet low – start stand-by pump	binary	* 20 kPa below operating pressure

Meas. point	Description	Signal range	Remarks
2112	Cooling water pressure LT at engine inlet low – alarm	4 - 20 mA	* 40 kPa below operating pressure
2201	Cooling water temp. HT at engine inlet – alarm	PT 100	
2211	Cooling water temp. HT at engine outlet high – alarm	PT 100	
2212	Cooling water temp. HT at engine outlet high – load reduction	PT 100	
2321	Oil ingress in fresh water cooler outlet	binary	
2229	Cooling water temp. LT at engine inlet – indication	PT 100	
5101	Fuel oil press. at engine inlet low – start stand-by pump	binary	
5102	Pressure transmitter fuel oil pressure at engine inlet low – alarm	4-20 mA	
5105	Fuel oil pressure – start stand-by pump by pump control		Option, external sensor
5111	Differential pressure fuel oil filter high – alarm	binary	
5112	Fuel oil diff. pressure at auto. filter		Option, external sensor
5115	Fuel oil differential pressure – start stand-by pump with pump control		Option, external sensor
5116	Fuel oil diff. pressure at circulating pump		Option, external sensor
5201/ 5202*	**5201** Fuel oil temp. at engine inlet low – alarm **5202** fuel oil temp. at engine inlet high – alarm	PT 100	1 sensor for **5201** + **5202*** *not in use with HFO
5206	Fuel oil temp. after viscosimeter	PT 100	not mounted on engine
5251	Fuel oil viscosity at engine inlet (common alarm 5252)		Option, external sensor
5252	Fuel oil viscosity at engine inlet (common alarm 5251)		Option, external sensor
5253	Fuel oil viscosity at viscosimeter	4-20 mA	not mounted on engine
5301	Leakage oil level at engine high – alarm	binary	

Meas. point	Description	Signal range	Remarks
5333	Fuel oil level mixing tank		Option, external sensor
6101	Starting air at engine inlet low – alarm	4-20 mA	
6105	Stopping air pressure at engine low – alarm	binary	Alarm delayed: 2 s
6181	Intake air pressure in engine room	4-20 mA	
7109	Charge air pressure at engine inlet – alarm	4-20 mA	
7201	Charge air temp. at engine inlet high – alarm	PT 100	
7206	Intake air temperature at turbocharger inlet	PT 100	
7301	Condense water in charge air canal	binary	
7307	Charge air diff. pressure at charge air cooler	4-20 mA	
7309	Charge air temp. at charge air cooler inlet	NiCr-Ni (mV)	
8211.1	Exhaust gas temp. after cylinder 1	NiCr-Ni (mV)	Information about alarm and load reduction see requirements for exhaust gas temp. monitoring system. See following diagrams!
8211.2	Exhaust gas temp. after cylinder 2	NiCr-Ni (mV)	
8211.3	Exhaust gas temp. after cylinder 3	NiCr-Ni (mV)	
8211.4	Exhaust gas temp. after cylinder 4	NiCr-Ni (mV)	
8211.5	Exhaust gas temp. after cylinder 5	NiCr-Ni (mV)	
8211.6	Exhaust gas temp. after cylinder 6	NiCr-Ni (mV)	
8211.7	Exhaust gas temp. after cylinder 7	NiCr-Ni (mV)	
8211.8	Exhaust gas temp. after cylinder 8	NiCr-Ni (mV)	
8211.9	Exhaust gas temp. after cylinder 9	NiCr-Ni (mV)	
8221	Exhaust gas temp. at turbocharger outlet	NiCr-Ni (mV)	
8231	Exhaust gas temp. at turbocharger inlet	NiCr-Ni (mV)	
R1	Resistance thermometer terminal set A03.1 temperature compensation thermocouples	PT 100	
R2	Resistance thermometer, temperature compensation thermocouples	PT 100	
R16	Resistance thermometer electr. charge air temp. control	PT 100	
9404	Over speed – alarm	binary	
9406	Switch off lube oil stand-by pump	binary	
9419	Engine speed signal from RPM switching equipment	4-20 mA	586.7 Hz = 0-800 rpm FCT
9419.1	Pick up RPM switching equipment	0-15 KHz	
9419.2	Pick up RPM switching equipment	0-15 KHz	

Meas. point	Description	Signal range	Remarks
9419.4	Pick up electronic governor	0-15 KHz	
9429	Pick up / transmitter turbine speed – alarm turbine speed – indication	4 - 20 mA 0 - 10 V	* DNV
9503	Control lever at fuel rack – stop position	binary	
9509	Distance sensor / switching device fuel setting	0 - 20 mA	
9531	Engine overload at rated speed	binary	
9532	Engine load signal	4 - 20 mA	
9561	Turning gear engaged – starting interlock	binary	
9602	CANbus failure – alarm	binary	
9614	Governor fault – alarm	binary	for mechanical governor
9615	Failure electrical governor – minor alarm	binary	for electronic governor
9616	Failure mechanical governor – major alarm	binary	for electronic governor with back up
9671.1	Auto.-stop failure – alarm	binary	
9671.2	Overspeed failure – alarm	binary	
9671.3	Emergency failure – alarm	binary	
9674	Auto.-stop – alarm	binary	
9675	Emergency stop – alarm	binary	
9676	Common alarm load reduction	binary	
9677.1	Override oil mist detector activated	binary	
9677.2	Override load reduction activated	binary	
9717	Voltage failure at terminal X55 – alarm	binary	
9751	Voltage fails at charge air temp. controller	binary	Option, external sensor
9771	Fresh water preheater voltage failure	binary	Option, external sensor
9836.1	Sensor / isolation fault A01 – alarm	binary	
9836.2	Sensor / isolation fault A03 – alarm	binary	
9962.1	Common alarm A01 – alarm	binary	
9962.2	Common alarm A03 – alarm	binary	

Exhaust gas temperature monitoring for 6,8 M 32 C

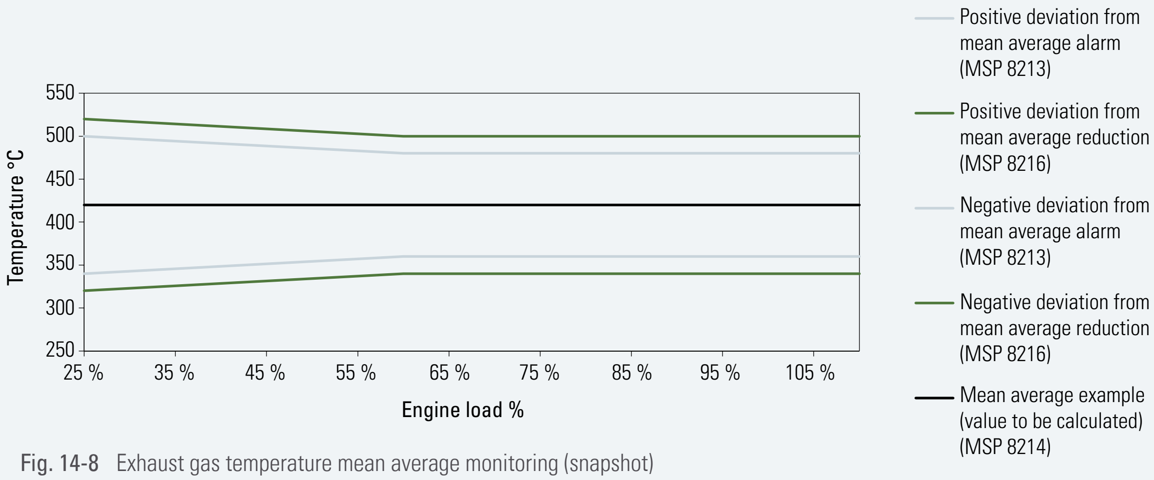


Fig. 14-8 Exhaust gas temperature mean average monitoring (snapshot)

Engine group 1	Positive deviation from mean average alarm (MSP 8213)	Positive deviation from mean average reduction (MSP 8216)	Negative deviation from mean average alarm (MSP 8213)	Negative deviation from mean average reduction (MSP 8216)	Mean ave-rage example (value to be calculated) (MSP 8214)
25 %	80	100	80	100	420
60 %	60	80	60	80	420
100 %	60	80	60	80	420
110 %	60	80	60	80	420

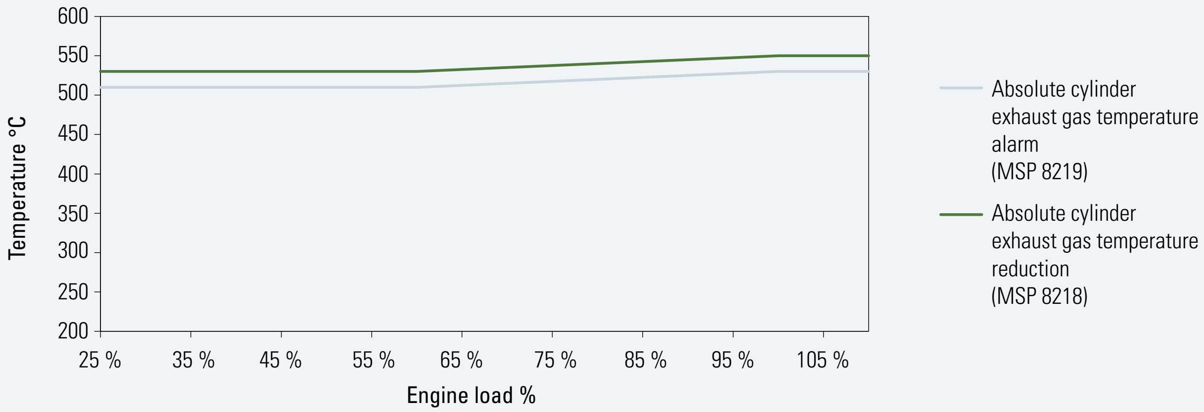


Fig. 14-9 Absolute exhaust gas temperature monitoring limits after cylinder

Engine group 1	Absolute cylinder exhaust gas temperature alarm (MSP 8219)	Absolute cylinder exhaust gas temperature reduction (MSP 8218)
25 %	510	530
60 %	510	530
100 %	530	550
110 %	530	550

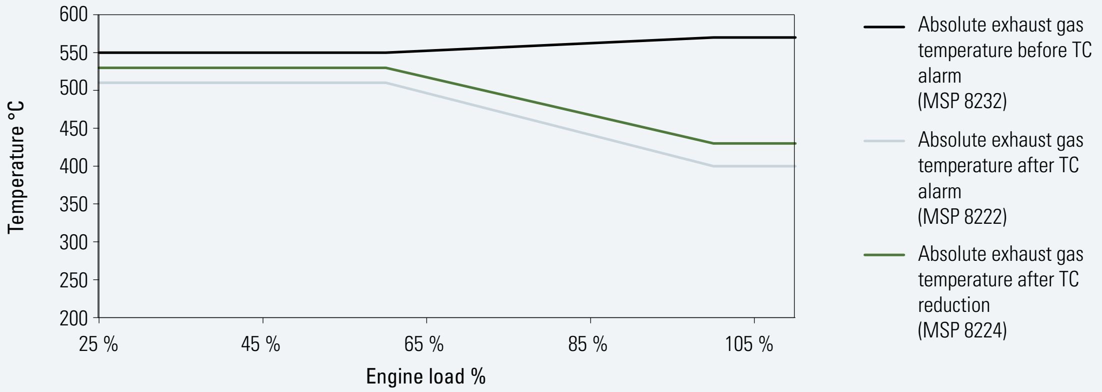


Fig. 14-10 Absolute exhaust gas temperature monitoring limits for turbocharger

Engine group 1	Absolute exhaust gas temperature before TC alarm (MSP 8232)	Absolute exhaust gas temperature after TC alarm (MSP 8222)	Absolute exhaust gas temperature after TC reduction (MSP 8224)
25 %	550	510	530
60 %	550	510	530
100 %	570	400	430
110 %	570	400	430

NOTE:
The exhaust gas temperatures at each cylinder outlet are to be monitored in the alarm system (optional in LESS). The limit values for the max. and min. temperatures depend on the engine load.

The temperatures for 25 %, 60 % and for 100 % have to be adjusted during commissioning. Therefore the alarm system has to be capable of adjusting these setpoints and the temperature spread.
If the absolute max. temperature at cylinder or turbocharger inlet or outlet exceed their limit values or if the reduction limits of the deviation thresholds are exceeded a binary NO contact from the alarm system has to be given to the engine's safety system.

The mean average value in the "exhaust gas temperature mean average monitoring"-diagram is a calculated value, which permanently needs to be recalculated during engine operation. The diagram is only to be seen as a snapshot of one specific calculated mean average value.

Exhaust gas temperature monitoring for 9 M 32 C pulse charging

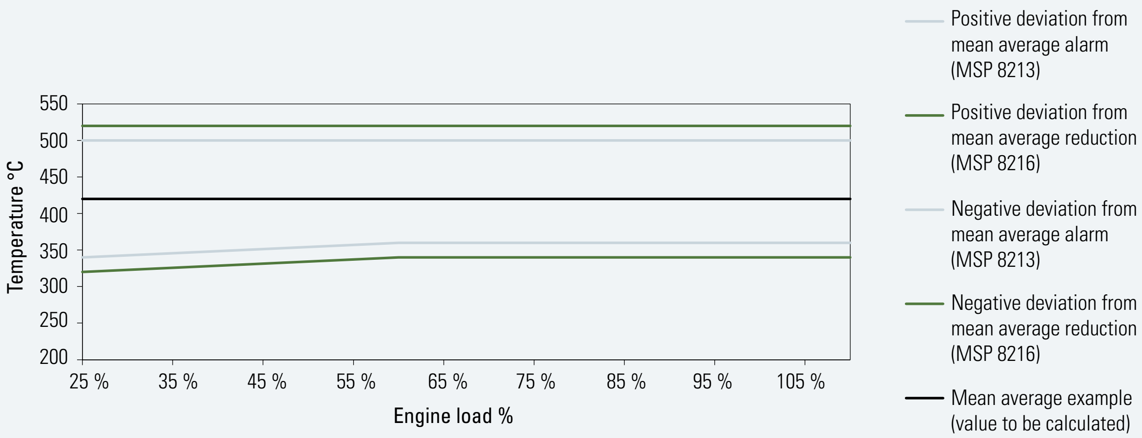


Fig. 14-11 Exhaust gas temperature mean average monitoring

Engine group 4	Positive deviation from mean average alarm (MSP 8213)	Positive deviation from mean average reduction (MSP 8216)	Negative deviation from mean average alarm (MSP 8213)	Negative deviation from mean average reduction (MSP 8216)	Mean average example (value to be calculated) (MSP 8214)
25 %	80	100	80	100	420
60 %	80	100	60	80	420
100 %	80	100	60	80	420
110 %	80	100	60	80	420

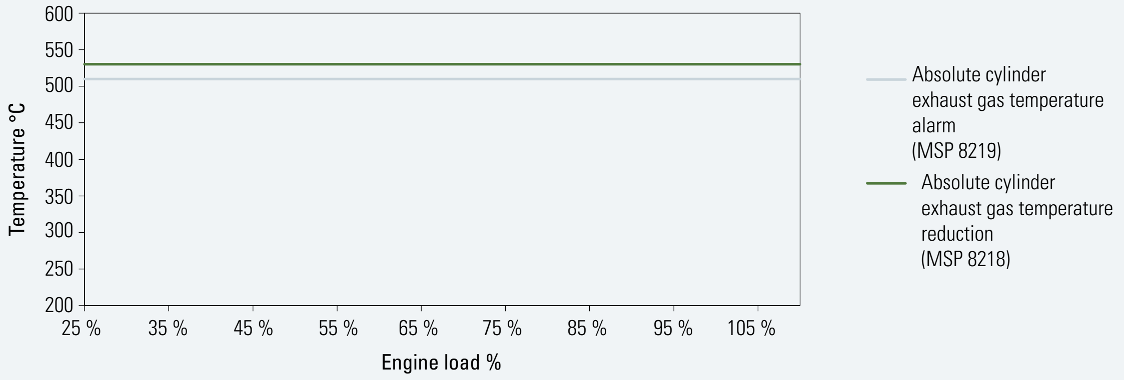


Fig. 14-12 Absolute exhaust gas temperature monitoring limits after cylinder

Engine group 4	Absolute cylinder exhaust gas temperature alarm (MSP 8219)	Absolute cylinder exhaust gas temperature reduction (MSP 8218)
25 %	510	530
60 %	510	530
100 %	510	550
110 %	510	550
Cylinder 9 100 %	540	560

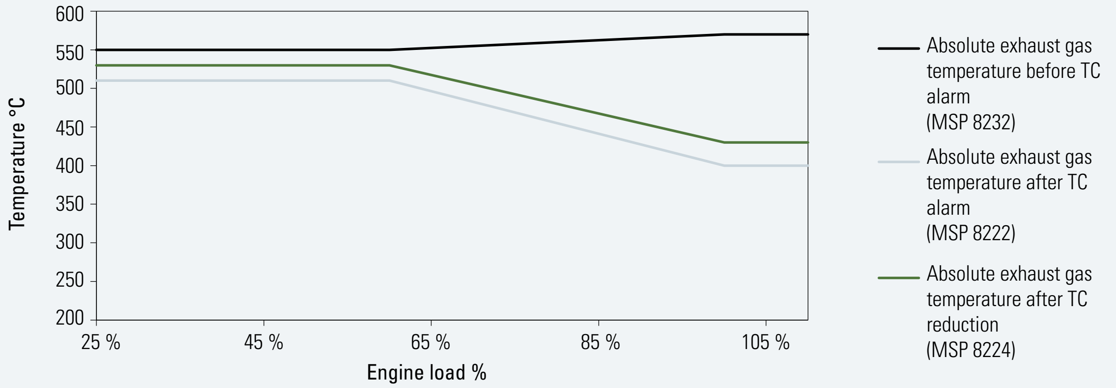


Fig. 14-13 Absolute exhaust gas temperature monitoring limits for turbocharger

Engine group 4	Absolute exhaust gas temperature before TC alarm (MSP 8232)	Absolute exhaust gas temperature after TC alarm (MSP 8222)	Absolute exhaust gas temperature after TC reduction (MSP 8224)
25 %	550	510	530
60 %	550	510	530
100 %	570	400	430
110 %	570	400	430

14.8 Local and remote indicators

Local indicators	Remote indicators
Installed 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 cooler outlet	X 2)
Installed at the engine (gauge board)	
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

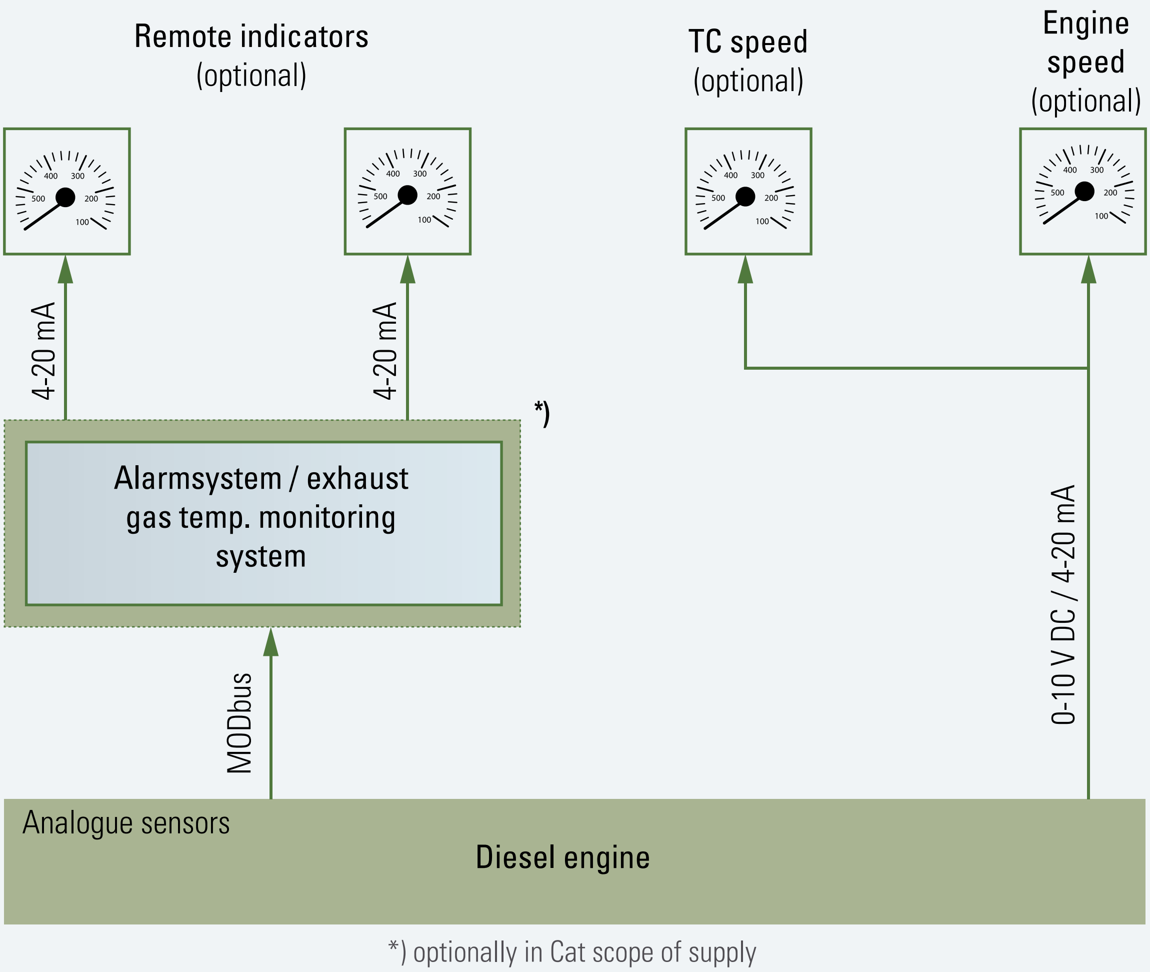


Fig. 14-14 Remote indication interfacing

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

14.9 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.

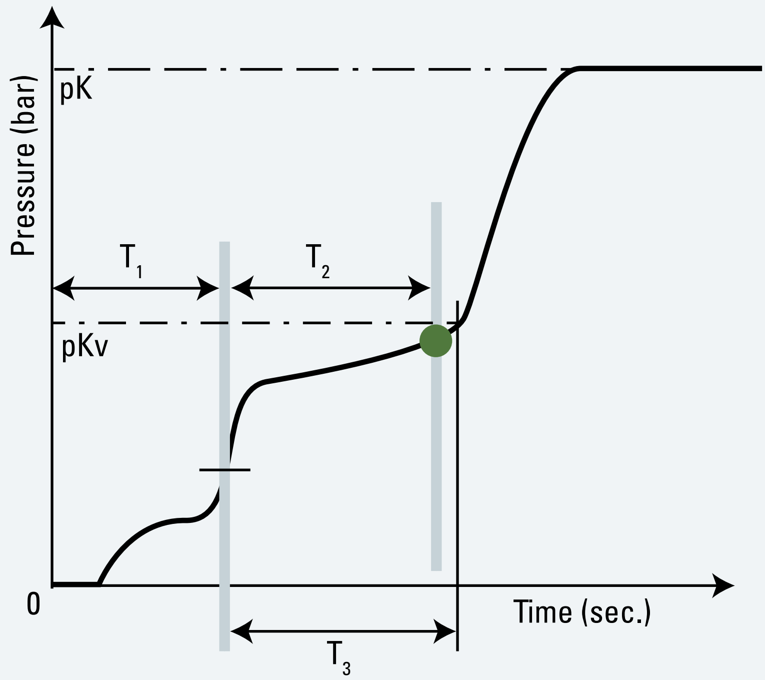


Fig. 14-15 Clutch in procedure for propulsion systems

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.

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14.10 Condition monitoring

New diagnostic system for on-line engine data transmission

Based on several years of Caterpillar experience, Caterpillar Motoren will launch a new diagnostic system in early 2015.

The new system will be based on data transfer via internet to a central Caterpillar warehouse and offers intensive diagnostics by Caterpillar engine specialists and use of a common data base. The DICARE system has been discontinued and will not be offered due to lack of ability to support the software platform in the future.

For detailed information please contact Caterpillar Motoren, application and installation department, + (49) 431-39 95 01.

15.1 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 ship`s 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.

15.1.1 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.

15.1.2 Engine with dry sump

Dimension of foundation dry sump pan

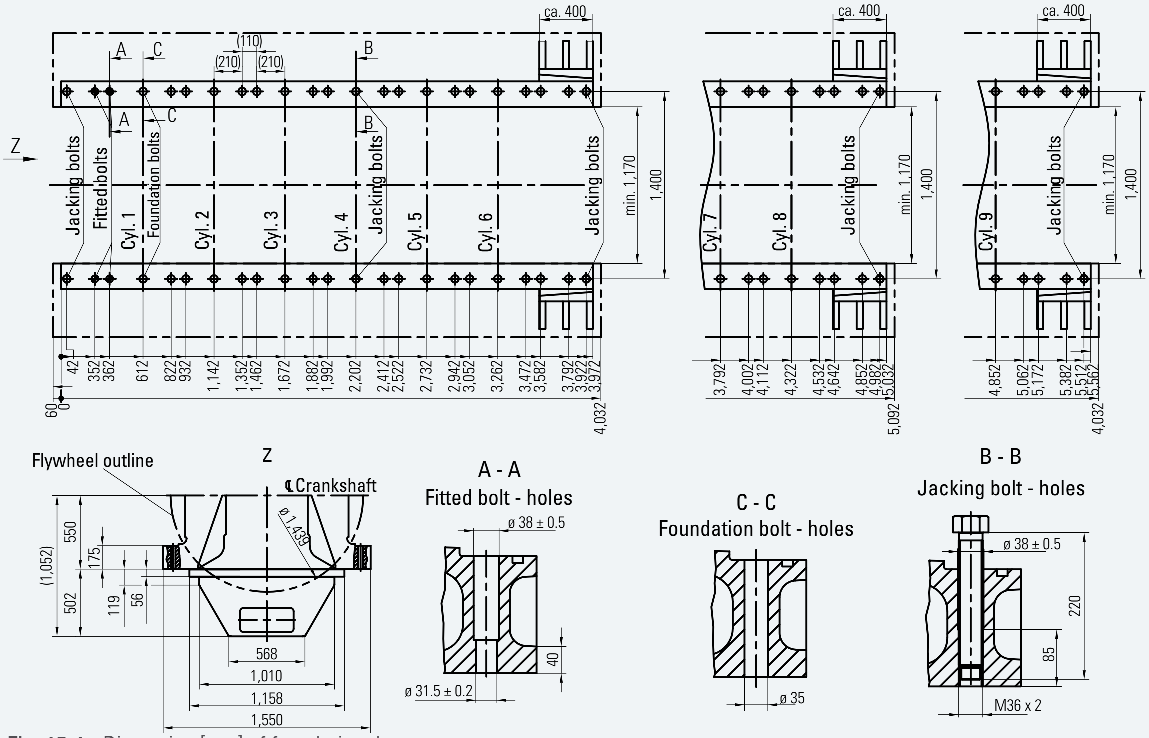

Fig. 15-1 Dimension [mm] of foundation dry sump pan

Side stoppers

6 M 32 C	8/9 M 32 C
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. 14-1). 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 C	4	36	6
8 M 32 C	4	48	6
9 M 32 C	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

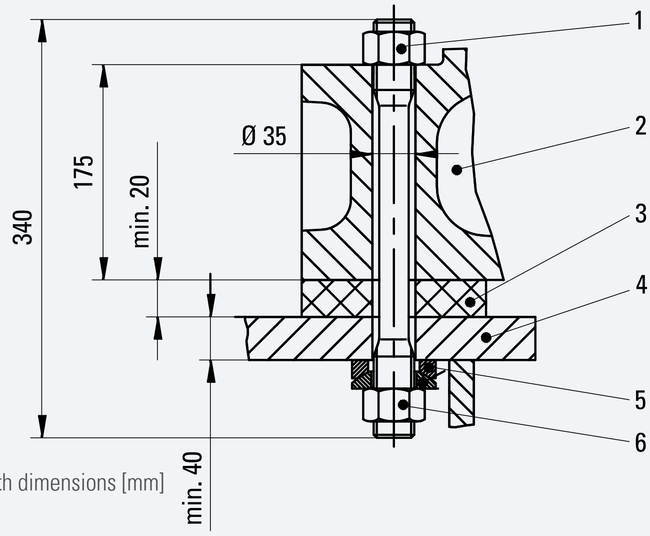

Fig. 15-2 Through bolt with dimensions [mm]

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

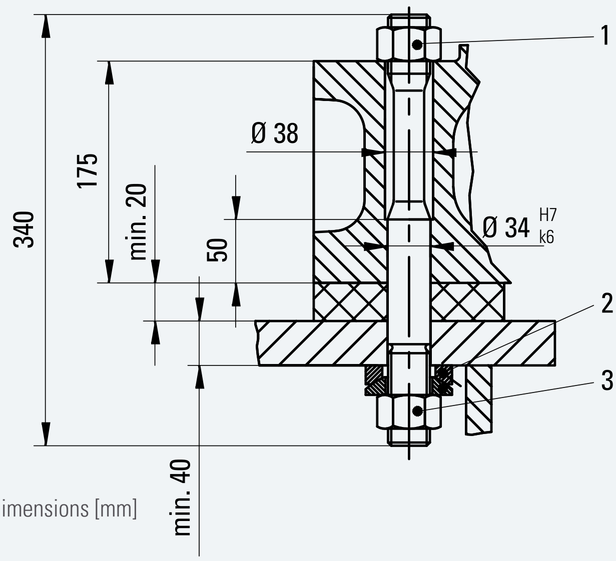

Fig. 15-3 Fitted bolt with dimensions [mm]

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.

15.1.3 Engine with wet sump

Dimension of foundation wet sump (option)

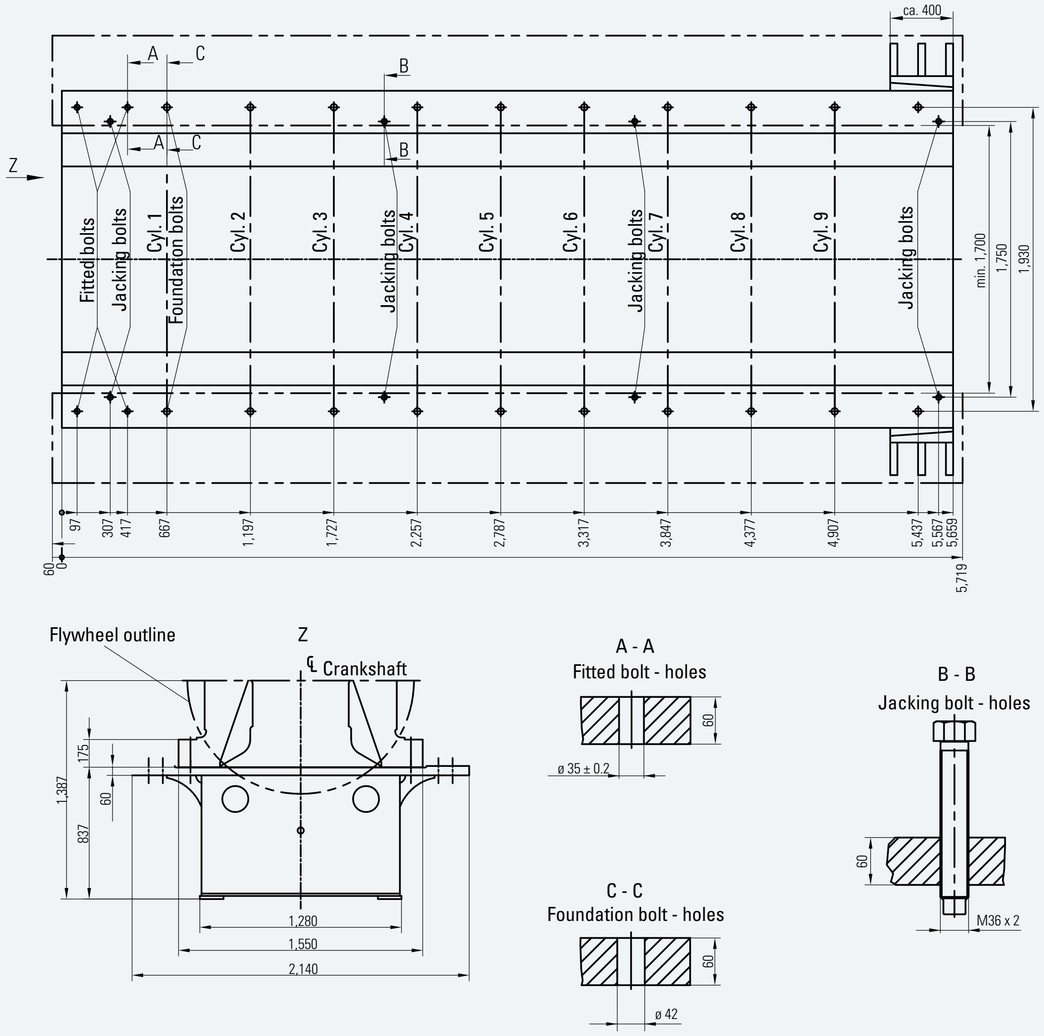

Fig. 15-4 Dimension [mm] of foundation wet sump

Side stoppers

6 M 32 C	8/9 M 32 C
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. 14-4). 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 C	4	16	6
8 M 32 C	4	18	8
9 M 32 C	4	20	8

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

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.

15.2 Resilient mounting

15.2.1 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 behavior 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.

15.2.2 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.

15.2.3 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.

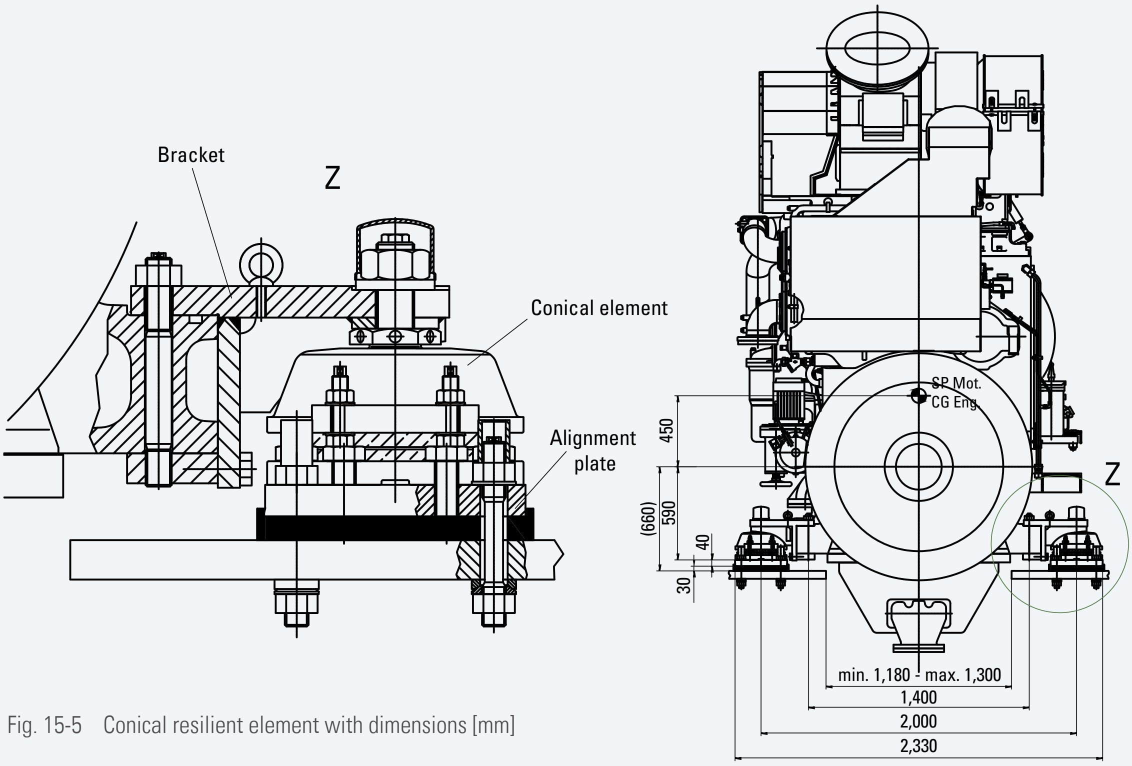

Fig. 15-5 Conical resilient element with dimensions [mm]

Number of rubber elements

	Combined elements
6 M 32 C	6
8 M 32 C	8
9 M 32 C	8

15.2.4 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.

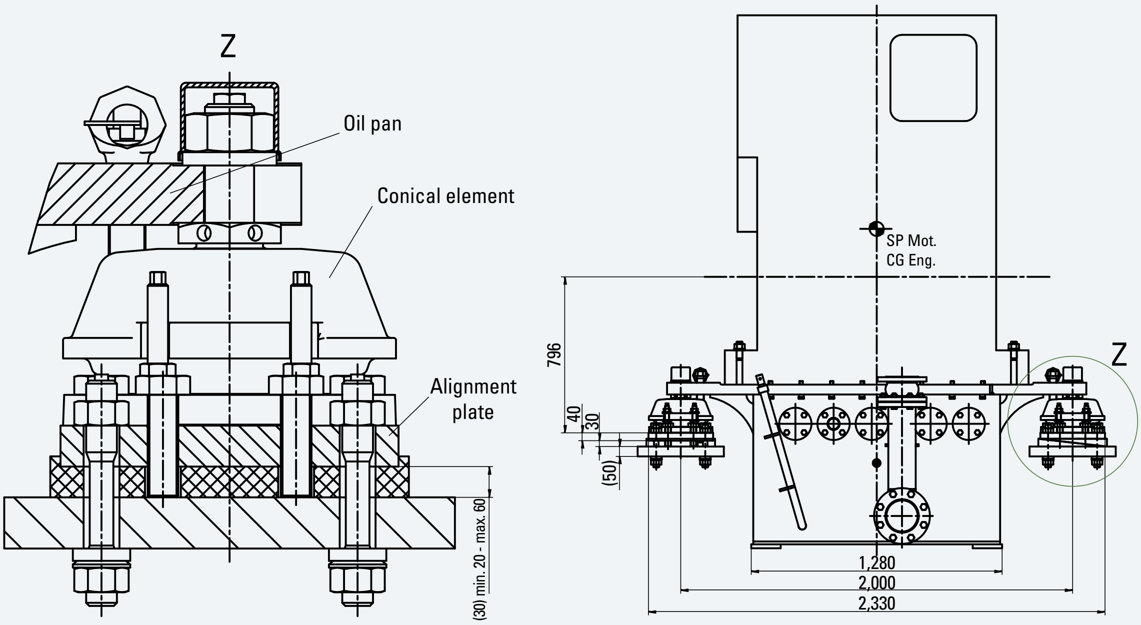

Fig. 15-6 Conical resilient element with dimensions [mm]

Number of rubber elements

	Combined elements
6 M 32 C	6
8 M 32 C	8
9 M 32 C	8

15.3 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 already is 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).

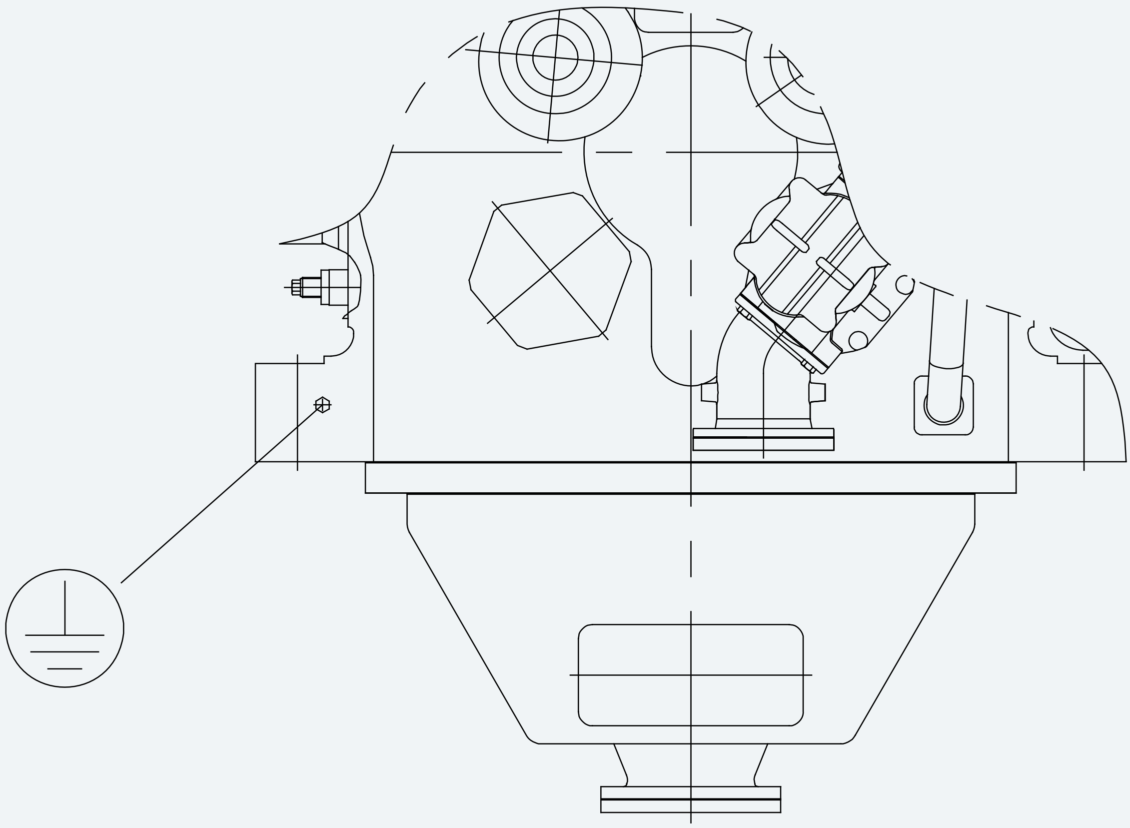

Fig. 15-7 Earthing connection on the engine

16.1 General requirements

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

16.2 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 same amount.

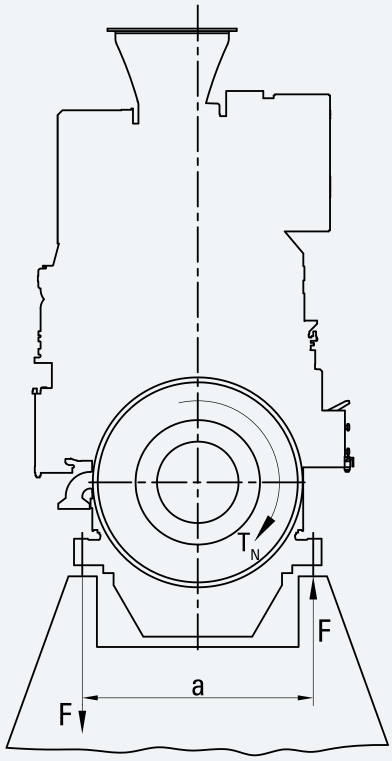

Fig. 16-1 Static load

	Output	Speed	T_N
	[kW]	[1/min]	[kNm]
6 M 32 C	3,000	600	47.8
8 M 32 C	4,000	600	63.7
9 M 32 C	4,500	600	71.6

Support distance a = 1,400 mm

F = T_N/a

T_N = Nominal torque

F = Force

a = Support distance

16.3 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.

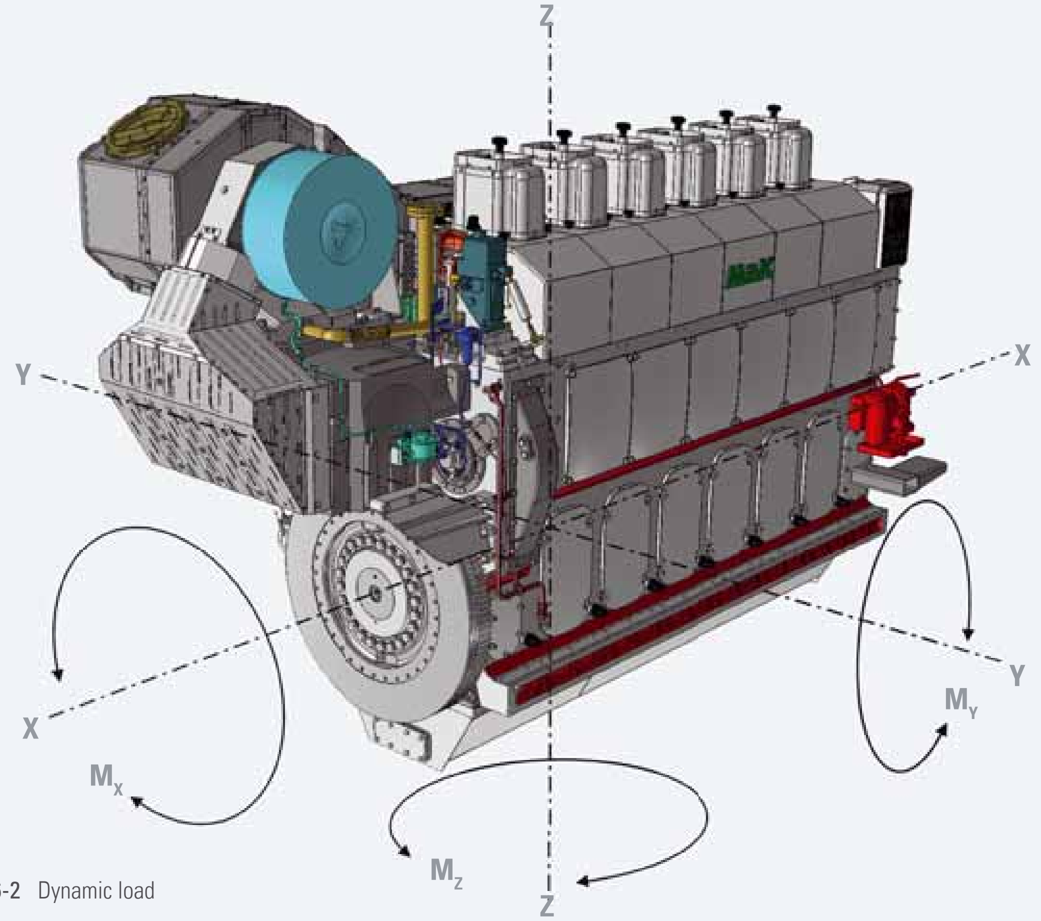

Fig. 16-2 Dynamic load

	Output [kW]	Speed [rpm]	Order-no.	Frequency [Hz]	M_X [kNm]	M_Y [kNm]	M_Z [kNm]
6 M 32 C	3,000	600	3.0 6.0	30 60	37.4 17.8	–	–
8 M 32 C	4,000	600	4.0 8.0	40 80	63.9 8.0	–	–
9 M 32 C	4,500	600	1 2	10 20	– –	21.7 15.5	– –
9 M 32 C	4,500	600	4.5 9.0	45 90	59.2 5.1	– –	– –

All forces and moments not indicated are irrelevant or do not occur. The effect of these forces and moments on the ship's foundations 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 23 24 25

17.1 Data for torsional vibration calculation

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

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

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

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

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. 17-1 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. power loss [kW]: _____
Dyn. torsinal stiffness[kNm/rad]: _____
Perm. vibratory torque [kNm]: _____
Perm. rotational speed [1/min]: _____
Relative damping: _____

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

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

☐ Vulkan
Type: _____

☐ Stromag
Size: _____
☐ Drawing attached

☐ Centa
☐ TVC scheme attached
☐ Drawing attached

☐ Other maker _____
Type: _____
Size: _____
☐ TVC scheme attached
☐ Drawing attached

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

Flex. coupling gearbox PTO

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

☐ Vulkan
Type: _____

☐ Stromag
Size: _____
☐ Drawing attached

☐ Centa
☐ TVC scheme attached
☐ Drawing attached

☐ Other maker _____
Type: _____
Size: _____
☐ TVC scheme attached
☐ Drawing attached

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

Gearbox

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

Maker: _____
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

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Fig. 17-2 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. 17-3 Additional engine plant data, part "B" (3/3)

17.2 Sound levels

17.2.1 Airborne noise

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

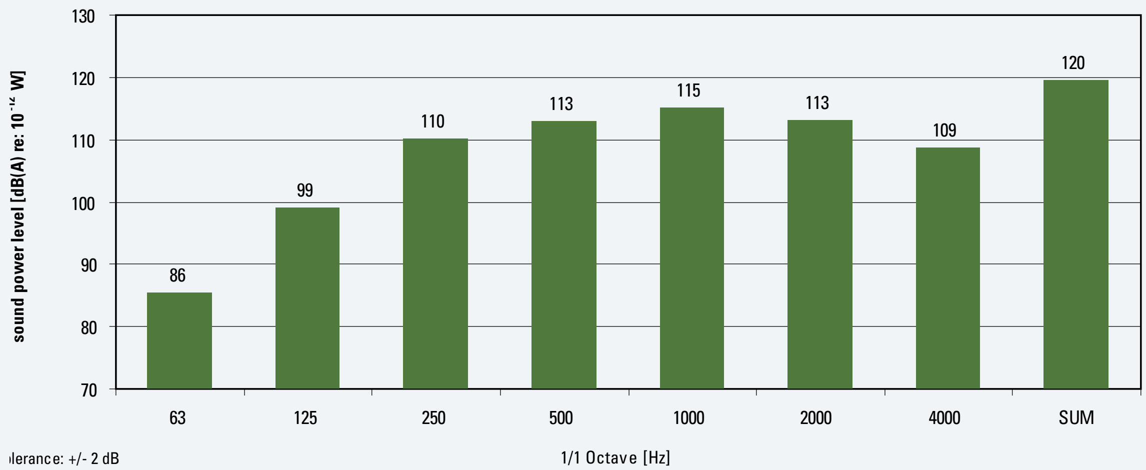

Fig. 17-4 Airborne sound power level 6 M 32 C

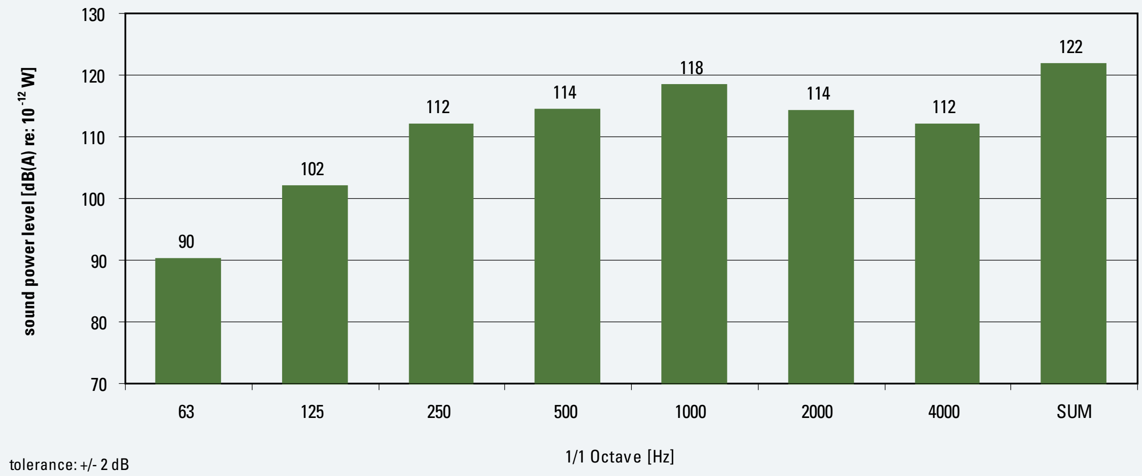

Fig. 17-5 Airborne sound power level 8 M 32 C

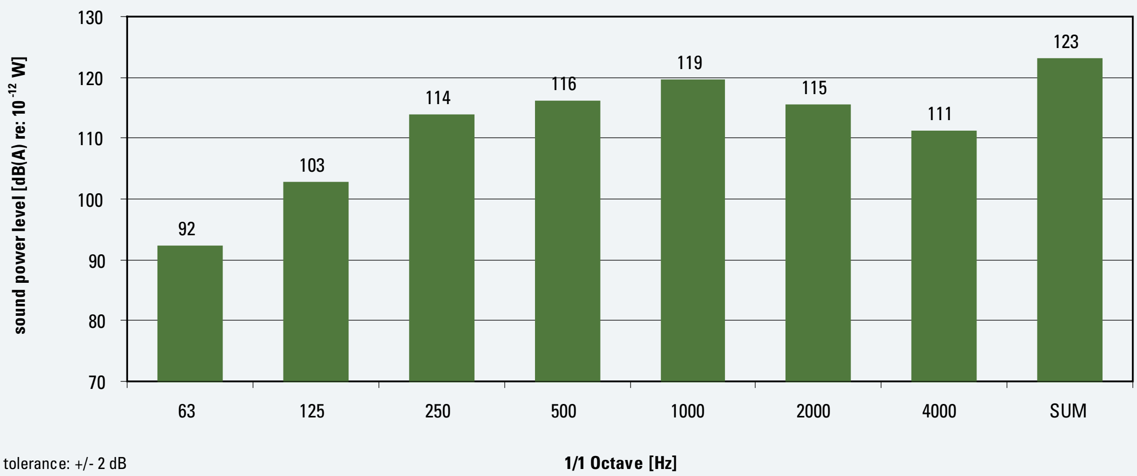

Fig. 17-6 Airborne sound power level 9 M 32 C

17.2.2 Structure borne noise

above / below resilient mounting measured at testbed in Kiel

(values below resilient mounting depend on resilient element type and foundation mobility)

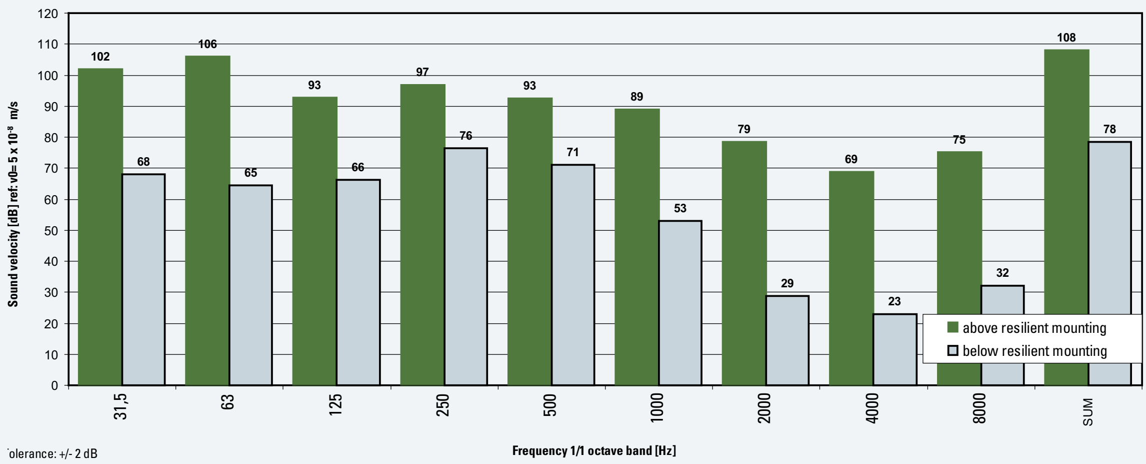

Fig. 17-7 Structure borne noise level M 32 C

Engine movement due to vibration referred to the global vibration characteristics of the engine:
The basis for assessing vibration severity are the guidelines ISO 10816-6.

According to these guideline the MaK engine will be assigned to vibration severity grade 28, class 5.
On the engine block the following values will not be exceeded:

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/s2	f> 250 Hz < 1,000 Hz

17.2.3 Exhaust gas noise

MaK M 32 C
(to be expected directly after turbocharger at open pipe (A_0 = 1 m²), values measured with a probe inside the exhaust gas pipe)

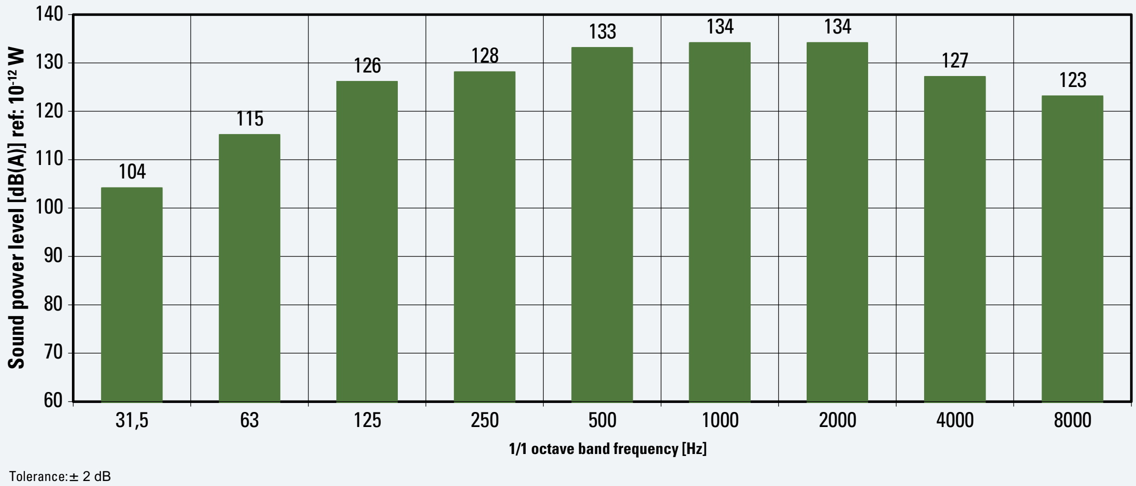

Fig. 17-8 Exhaust gas sound power level M 32 C

18.1 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 plate or gratings to ensure optimum heat dissipation (yard supply).

18.1.1 Mass moments of inertia

	Speed	Engine *	Flywheel	Total
	[rpm]	[kgm²]	[kgm²]	[kgm²]
6 M 32 C	600	430	470	900
8 M 32 C	600	604	470	1,074
9 M 32 C	600	636	470	1,106

* Running gear with balance weights and vibration damper

18.1.2 Selection of flexible couplings

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

$$T_{KN} \geq \cdot \frac{9.55 \cdot P0}{n0}$$

P0 = Engine output
n0 = 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 2 in order to have sufficient safety in the event of misfiring.

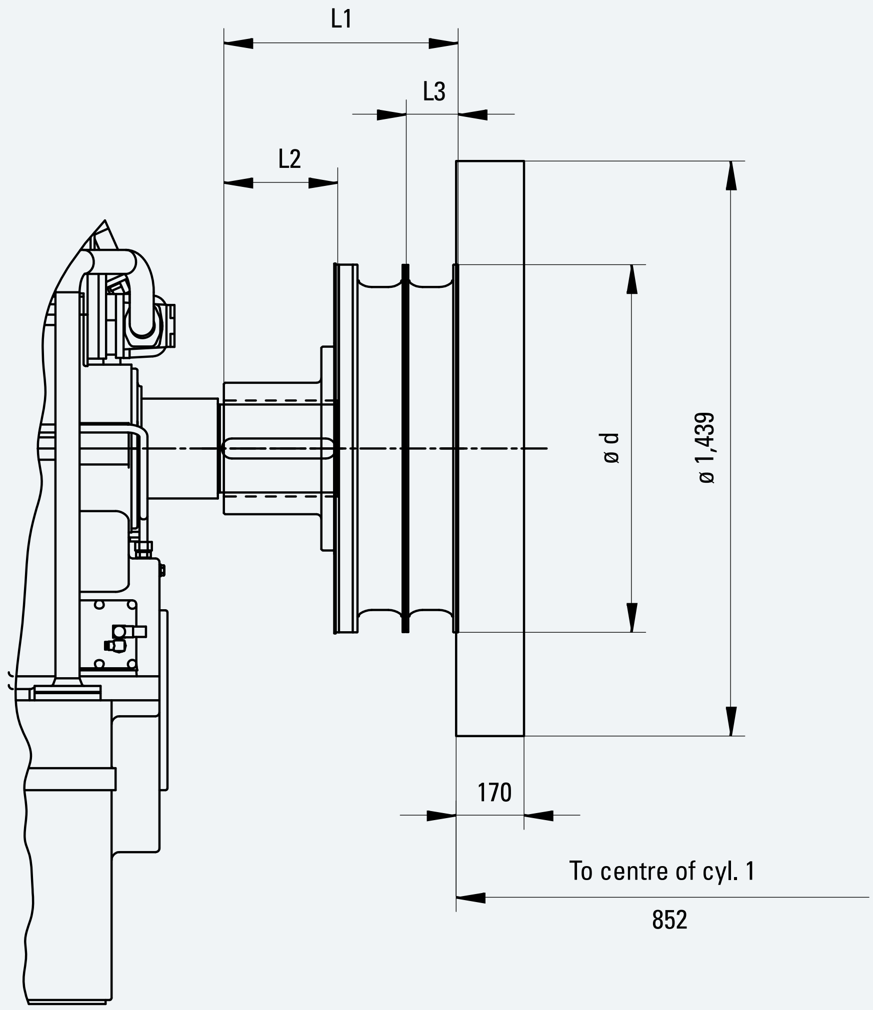

Fig. 18-1 Flywheel and flexible coupling

	Power	Speed	Nominal torque of coupling					Weight	
				d	L1 [4]	L2 [3]	L3 [5]	[1]	[2]
	[kW]	[rpm]	[kNm]	[mm]	[mm]	[mm]	[mm]	[kg]	[kg]
6 M 32 C	3,000	600	66.5	920	823 [1] / 586 [2]	285	132	721	545
8 M 32 C	4,000	600	66.5	920	823 [1] / 586 [2]	285	132	721	545
9 M 32 C	4,500	600	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 %.

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

The PTO output is limited to:

- 6 M 32 C 3,000 kW
- 8 M 32 C 4,000 kW
- 9 M 32 C 4,500 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.

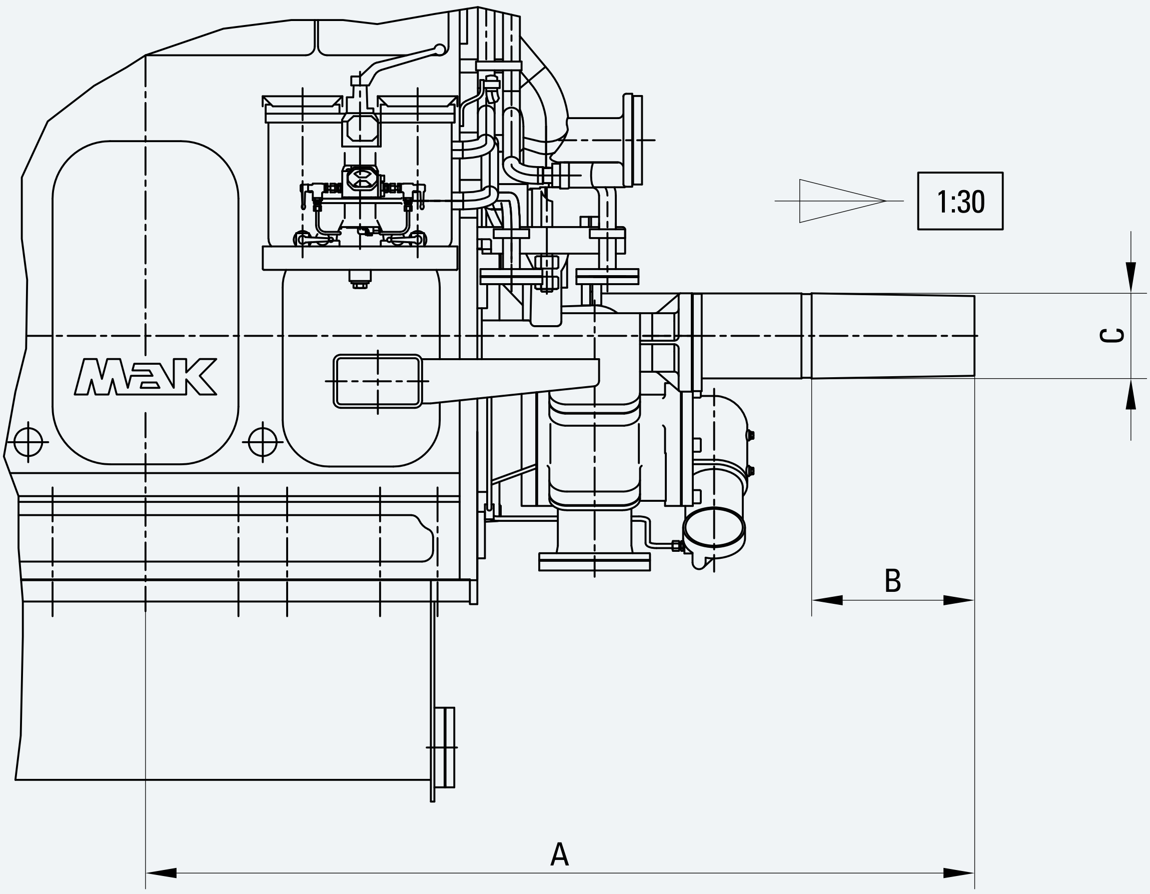

Fig. 18-3 Power take-off from the free end

Power	A	B	C
< 1,500 kW	1,649	230	151
> 1,500 kW	1,874	368	193

19.1 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 19.2).
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.

19.2 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

19.3 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 ------------

19.4 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.

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19.5 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 do 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 near as possible to the flex connection and stronger as 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 nor 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.

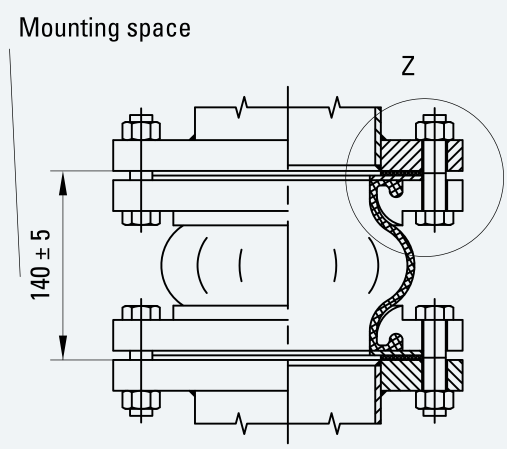

Fig. 19-1 Rubber expansion joint with dimensions [mm]

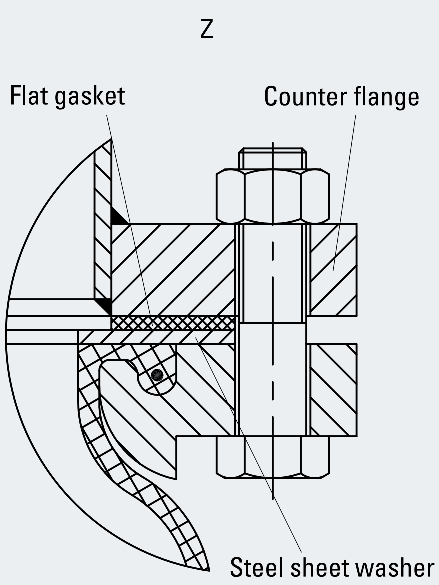

Fig. 19-2 Rubber expansion joint, detail Z

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20.1 Engine centre distances

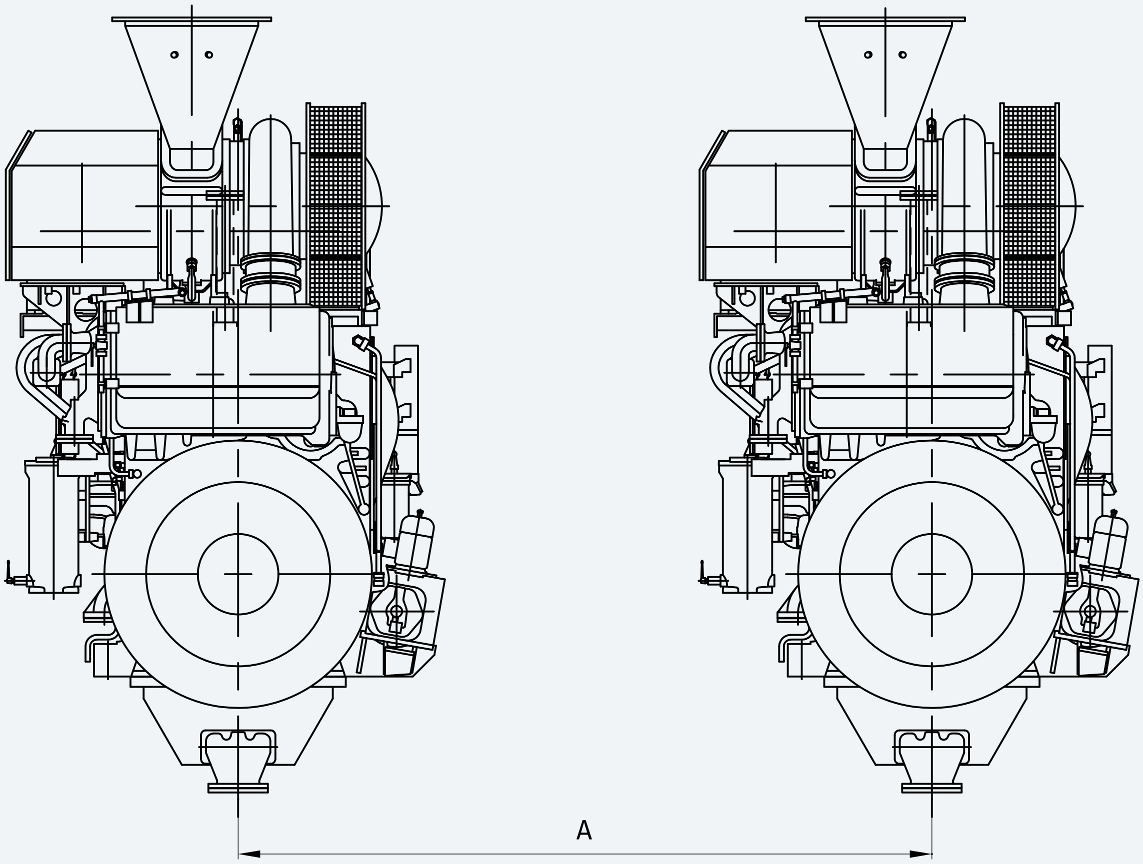

Fig. 20-1 Centre distance of twin-engine plants

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

*) Minimum distance: 2,600 mm (Minimum width at fuel oil filter level approx. 500 mm)

If turbocharger is located at the free end, the water cover of the charge air cooler must be dismantled.

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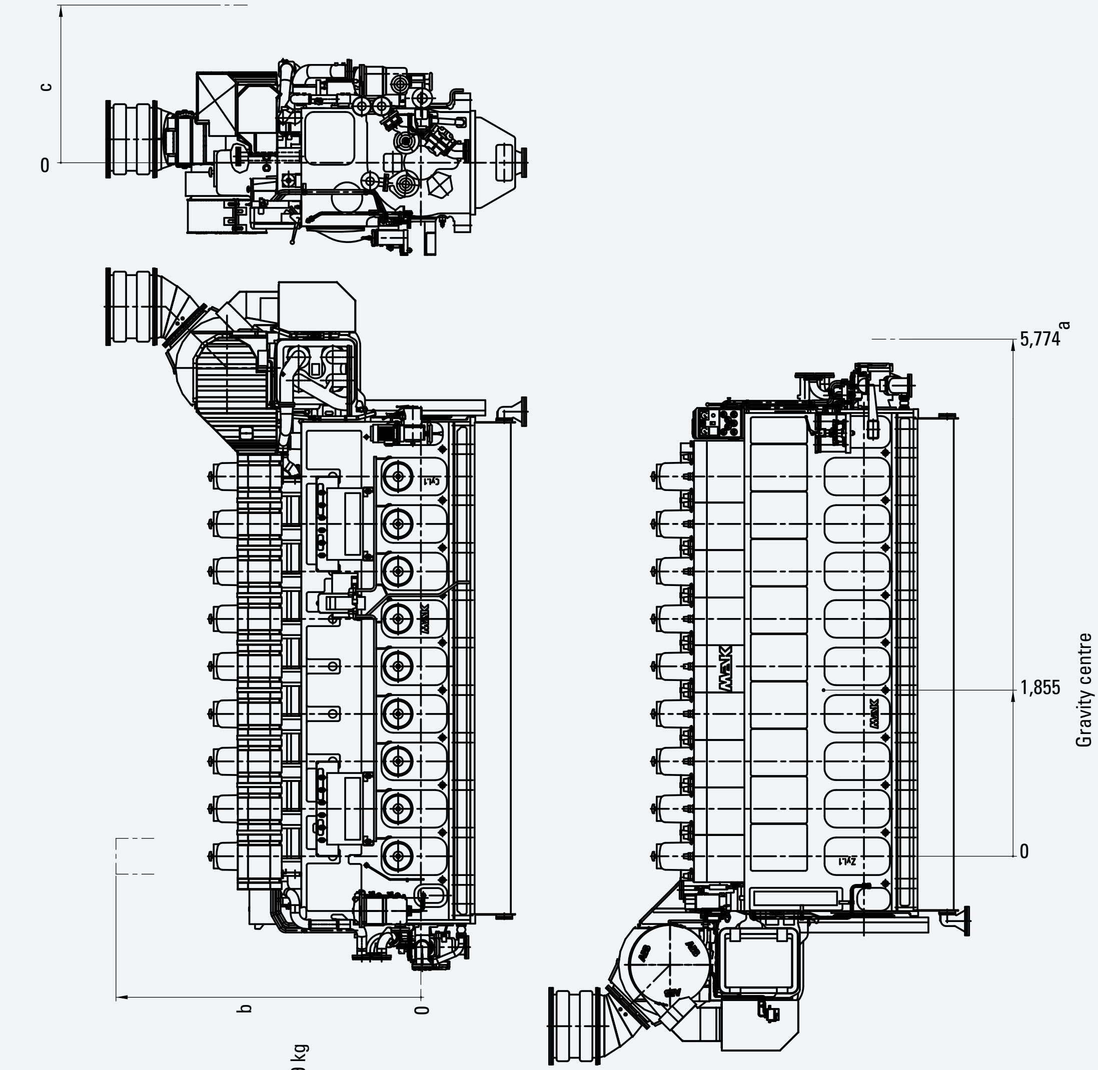
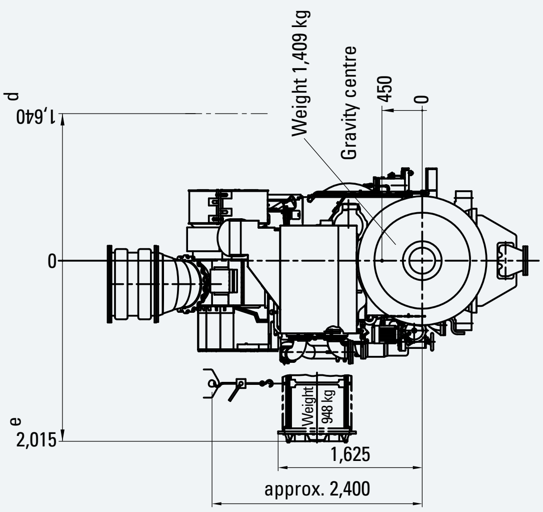
20.2 Space requirements for maintenance





a = Space required for measuring vibrations, and removal of the vibration damper and the lube oil pump
b = See chapter 19.2.2
c = See chapter 19.2.1
d = Space required for turbocharger shaft removing
e = Space required for charge air cooler removing

Fig. 20-2 Space requirement for maintenance, dimensions [mm]

20.2.1 Removal of charge air cooler and turbocharger cartridge

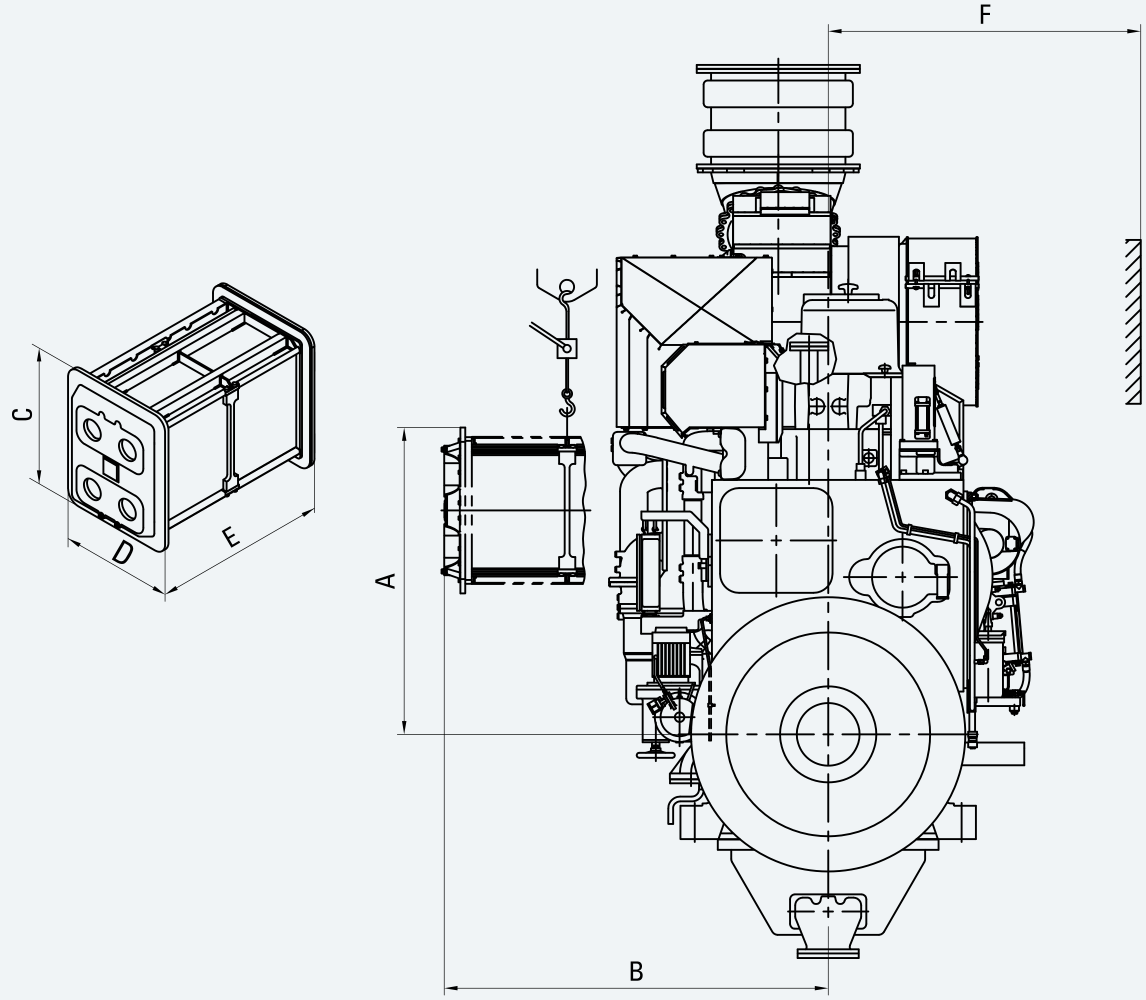


Fig. 20-3 Space requirement for dismantling of charge air cooler and turbocharger cartridge

Type	Dimensions [mm]						Weight charge air cooler	Weight turbocharger cartridge
	A	B	C	D	E	F	[kg]	[kg]
6 M 32 C	1,413	1,980	676	520	1,160	850	400	360
8/9 M 32 C	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.

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20.2.2 Removal of piston and cylinder liner

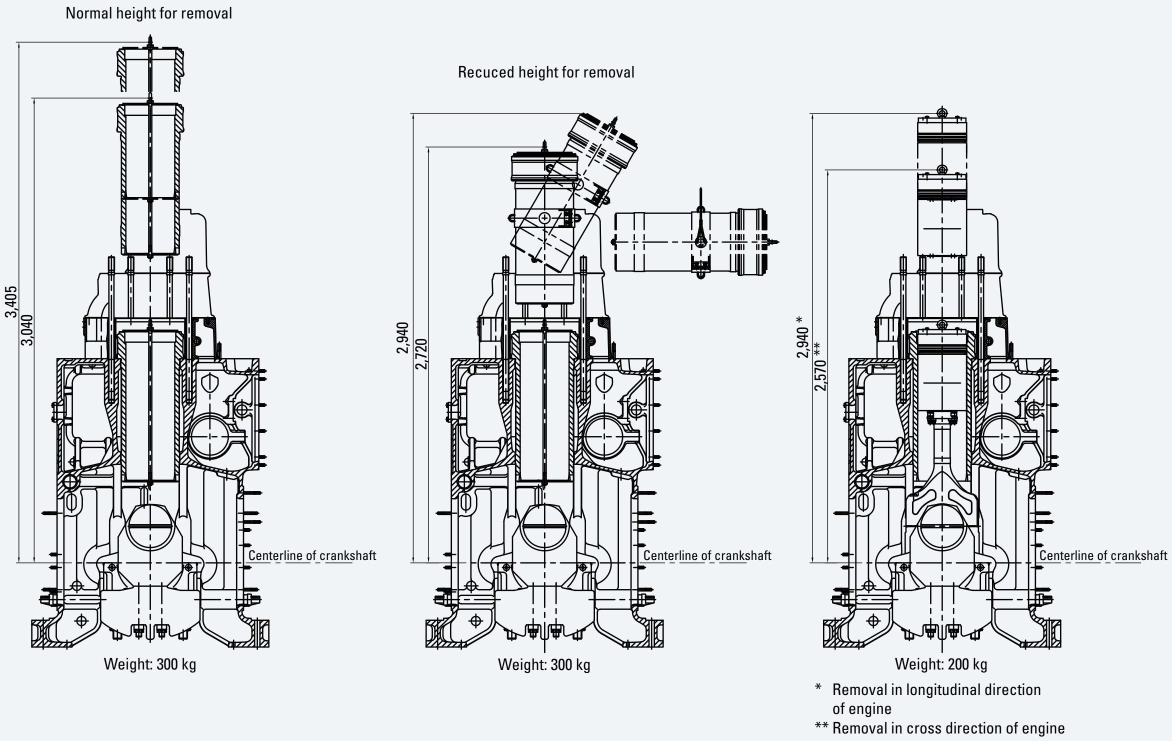


Fig. 20-4 Removal of piston and cylinder liner, dimensions [mm]

21.1 Inside preservation

21.1.1 Works standard N 576-3.3

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.

21.2 Outside preservatio

21.2.1 Works standard VCI 368 N 576-3.2

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.

21.2.2 Works standard clear varnish N 576-4.1

Conditions

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

NOTE:
Works standard clear carnish N 576-4.1 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 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.

21.2.3 Works standard painting N 576-4.3

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 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.

21.2.4 Works standard VCI packaging N 576-5.2

Conditions

- Engines with outside preservation VCI 368 as per N 576-3.2
- Engines with clear varnish according to application group 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 according to application group 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
- Cortec 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.

21.3 Works standard information panel

A works standard information panel for VCI preservation and inspection N 576-5.2 suppl. 1 will be supplied.

Application

- Engines with VCI packaging as per application group 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.

21.4 Protection period, check, and representation N 576-6.1

21.4.1 Protection period

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

21.4.2 Protection check

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

21.4.3 Represervation N 576-6.1

After 2 years represervation must be carried out.

22.1 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 C 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.

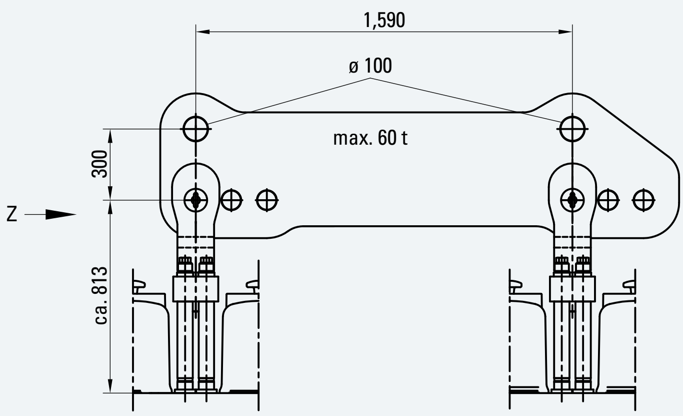
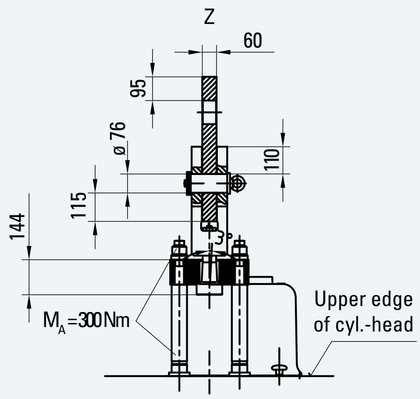


Fig. 22-1 Spreader bar with dimensions [mm]



Wear limit with dimensions [mm]

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

Transport of engine with turbocharger at driving end

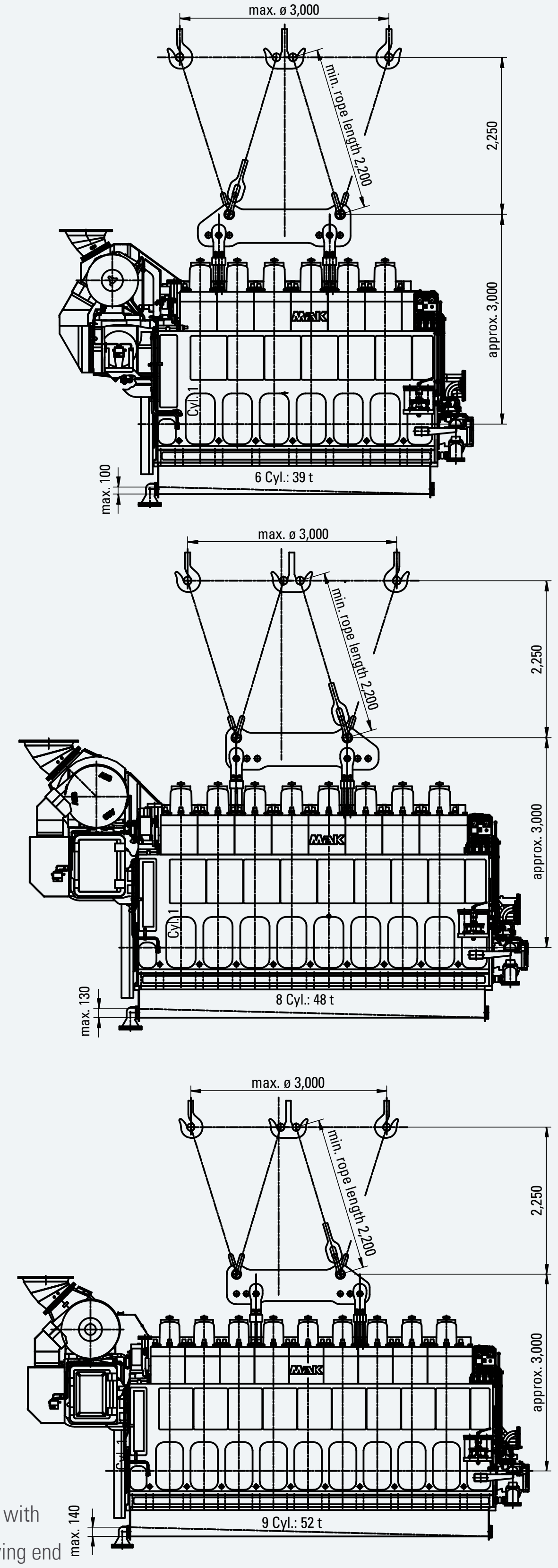


Fig. 22-2 Transport of engine with turbocharger at driving end

dimensions [mm]

Transport of engine with turbocharger at free end

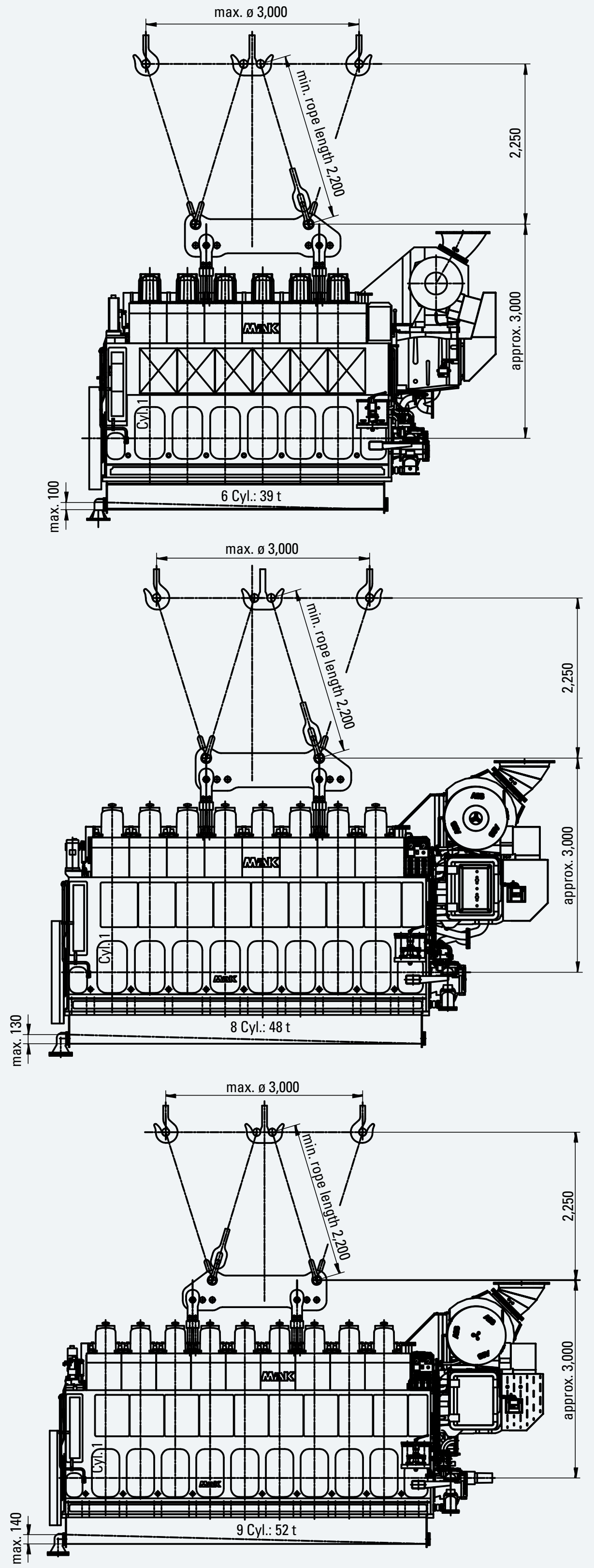


Fig. 22-3 Transport of engine, turbocharger at free end with dimensions [mm]

22.2 Dimensions of main components

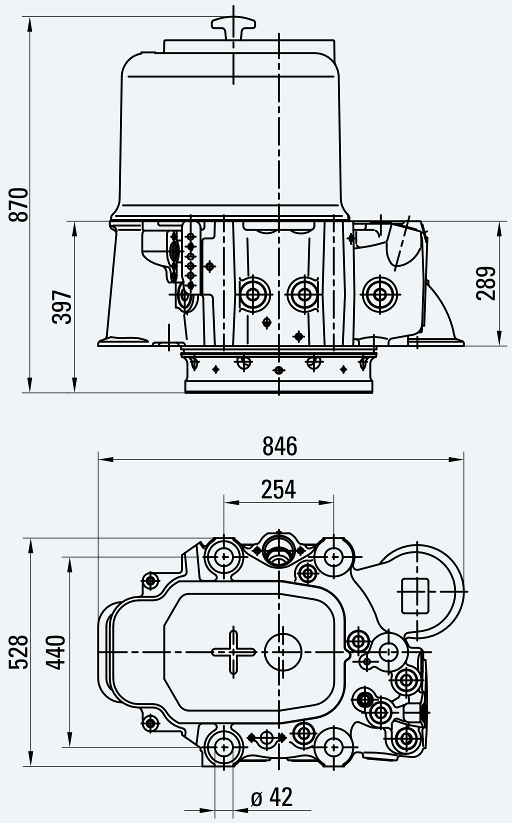


Fig. 22-4 Cylinder head, weight 315 kg

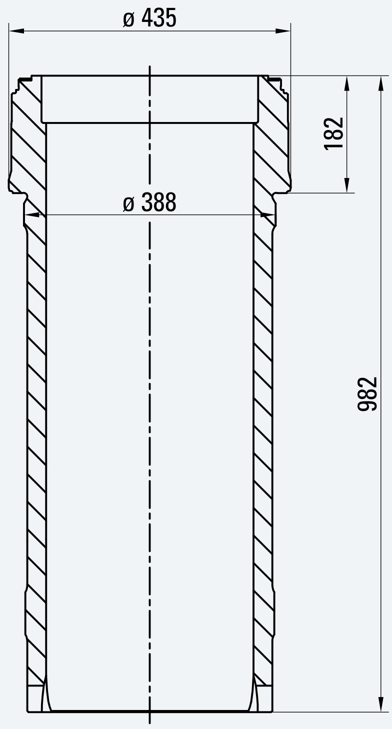


Fig. 22-5 Cylinder liner, weight 280 kg

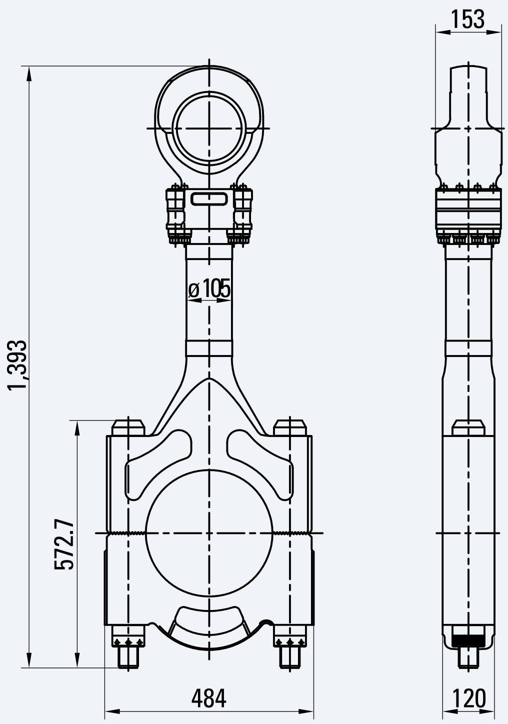
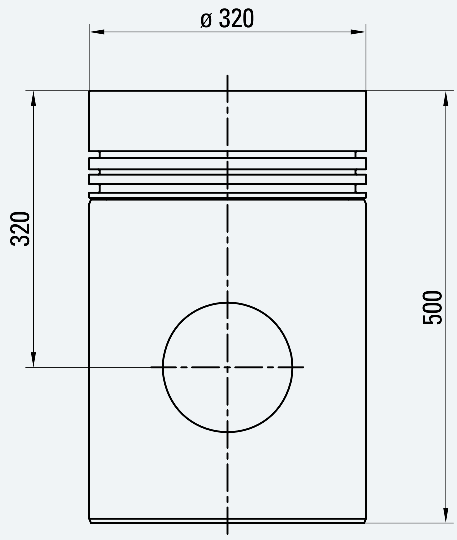


Fig. 22-6 Connecting rod, weight 236 kg



Please note, the dimensions are shown in mm!

Fig. 22-7 Piston, weight 150 kg

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

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.

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24.1 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

24.2 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

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

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

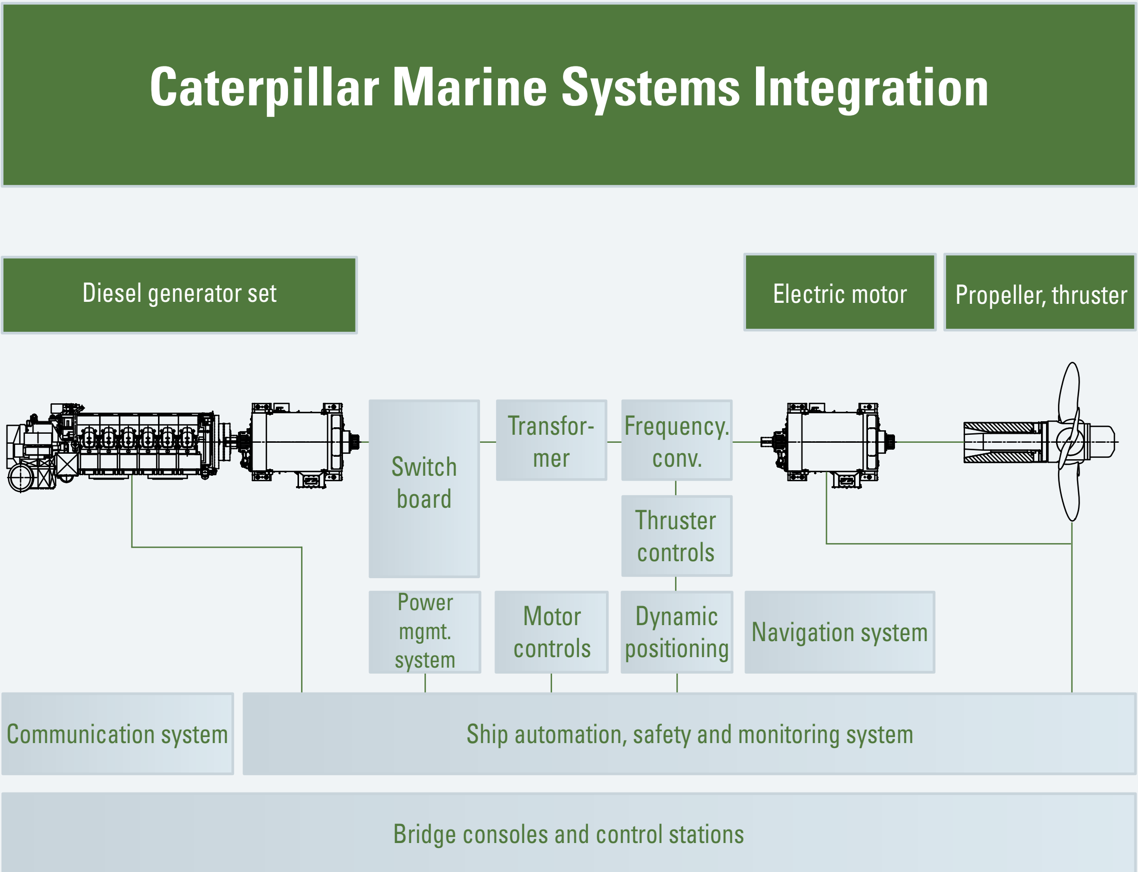

Fig. 25-1 D/E application

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

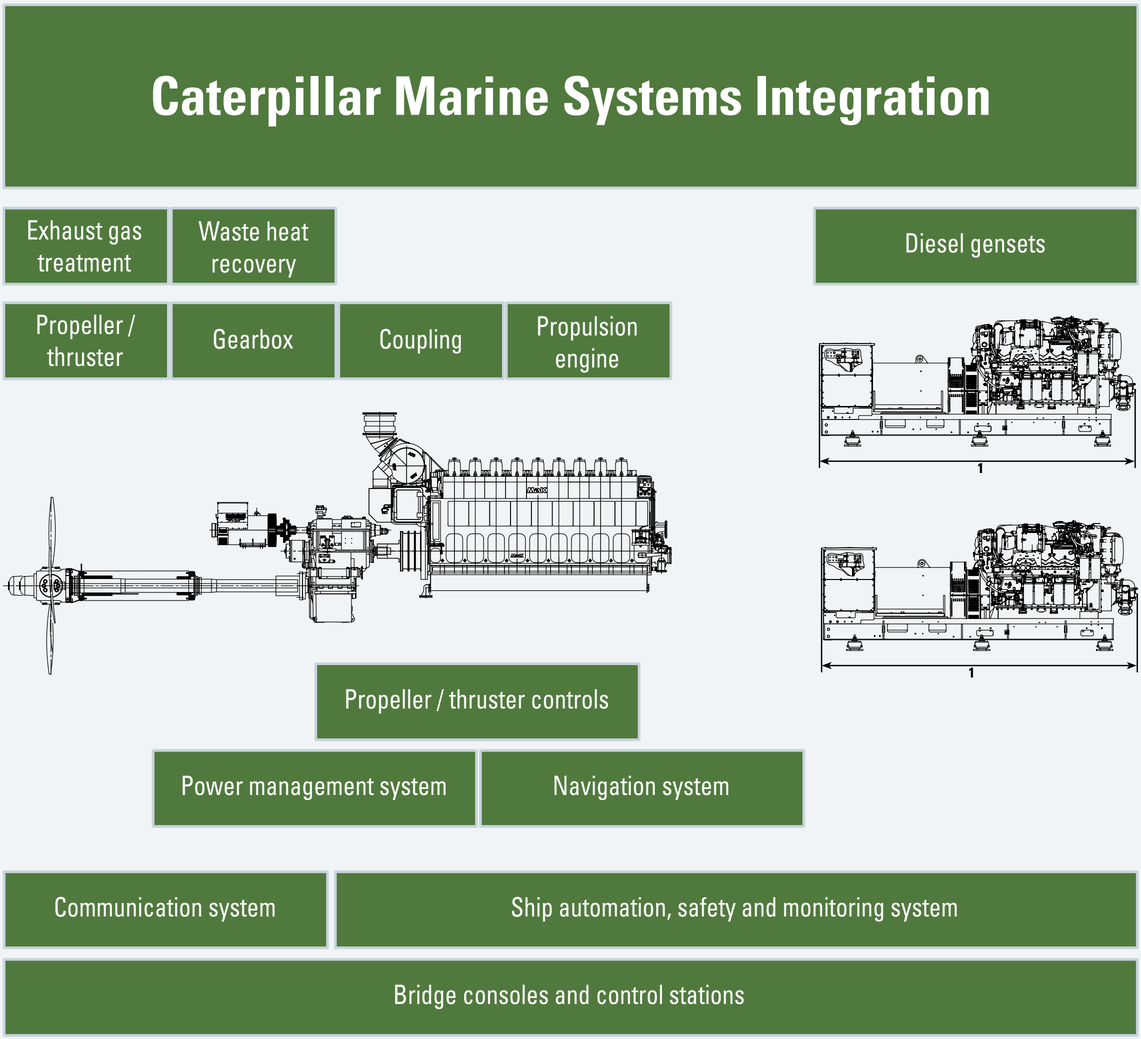

Fig. 25-2 D/M application

25.3 Levels of integration

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

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 allocation algorithm
- Navigation system – radar, compass, autopilot
- Control consols – bridge consols, wing consols, engine control room controls

Caterpillar Marine

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