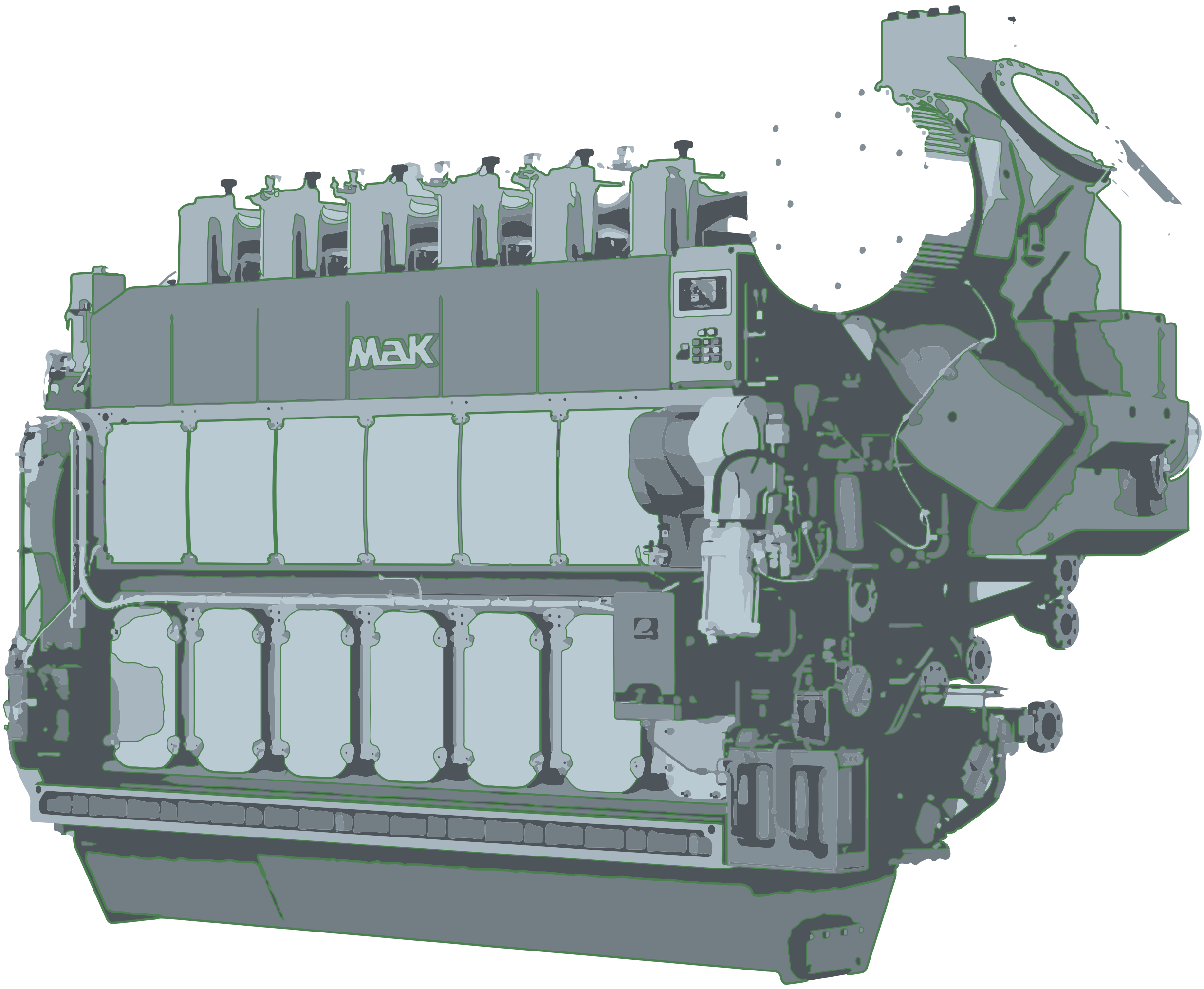
M 34 DF

PROJECT GUIDE / PROPULSION



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

This edition supersedes the previous edition of this project guide.

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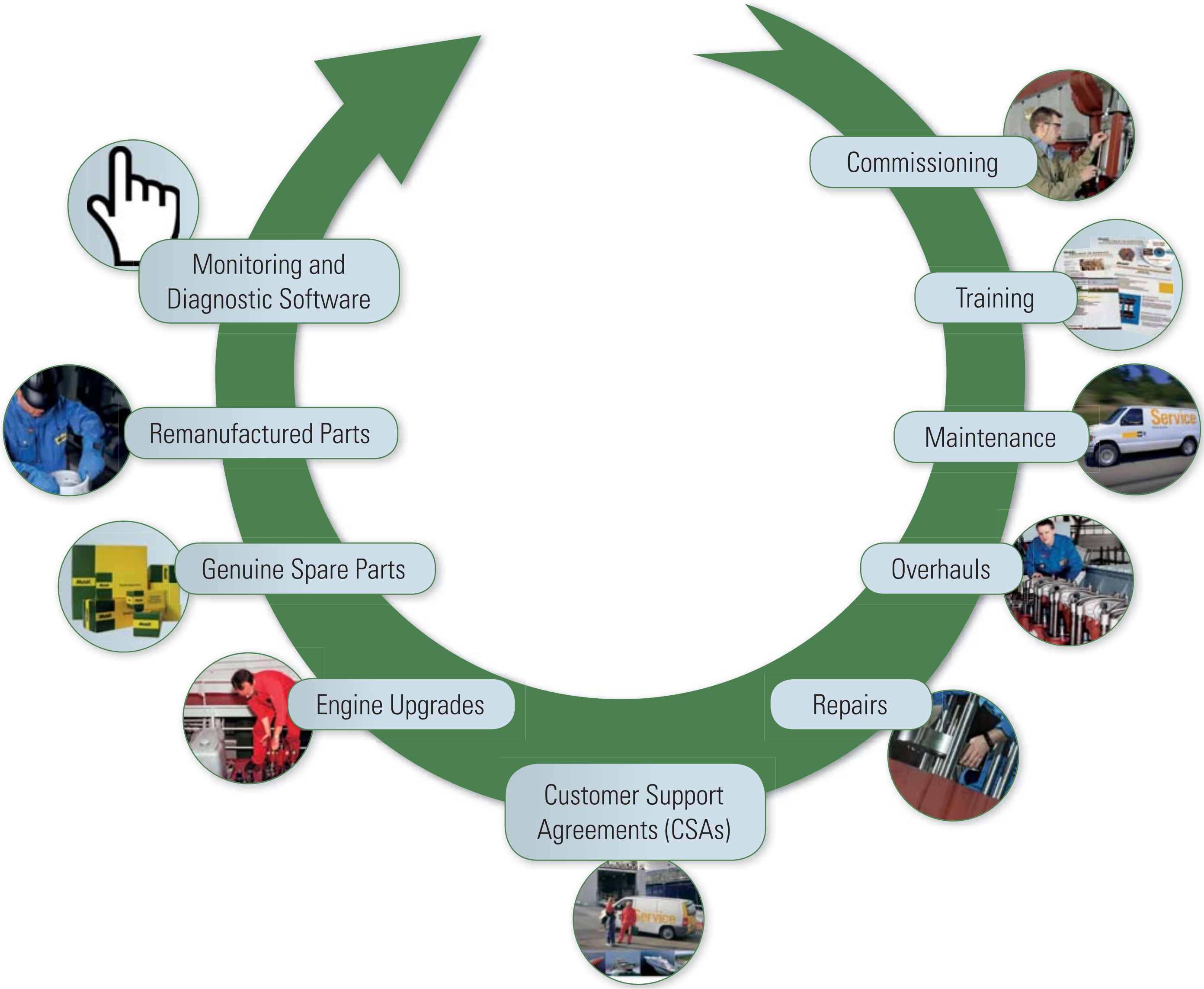

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Initial Certification date:
03.11.2003

This certificate is valid until:
14.11.2016

The audit has been performed under the supervision of

Stephan Ekat
Lead Auditor

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CONTENTS

7. LUBE OIL SYSTEM

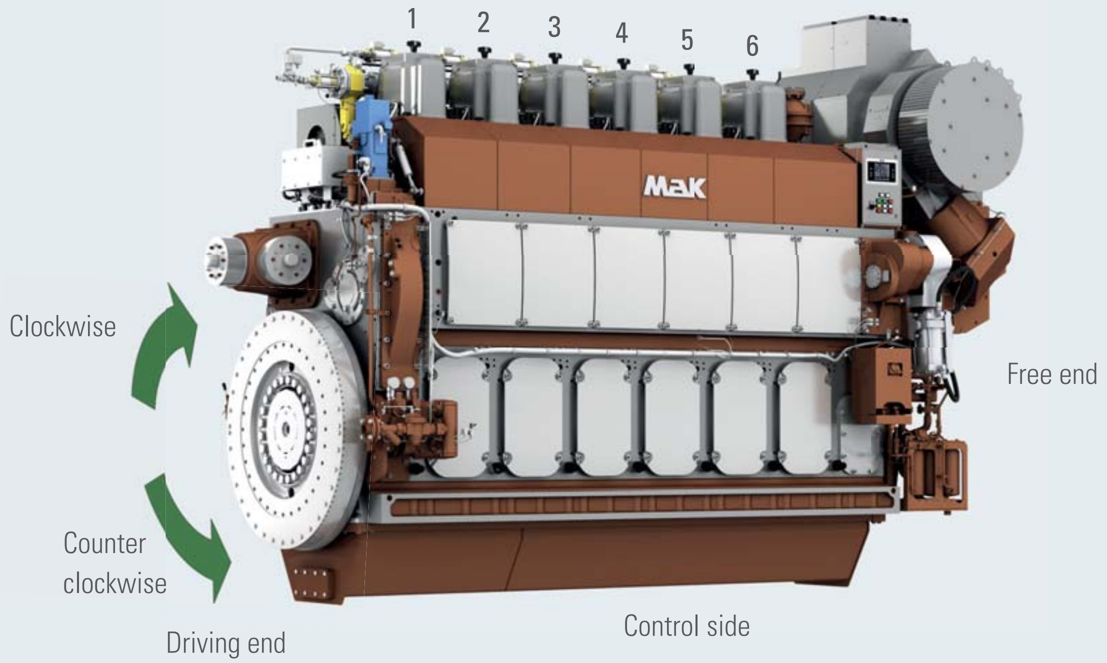
8. COOLING WATER SYSTEM

12. FLEXIBLE CAMSHAFT TECHNOLOGY (FCT)

13. CONTROL AND MONITORING SYSTEM

CONTENTS

1.1 Definitions



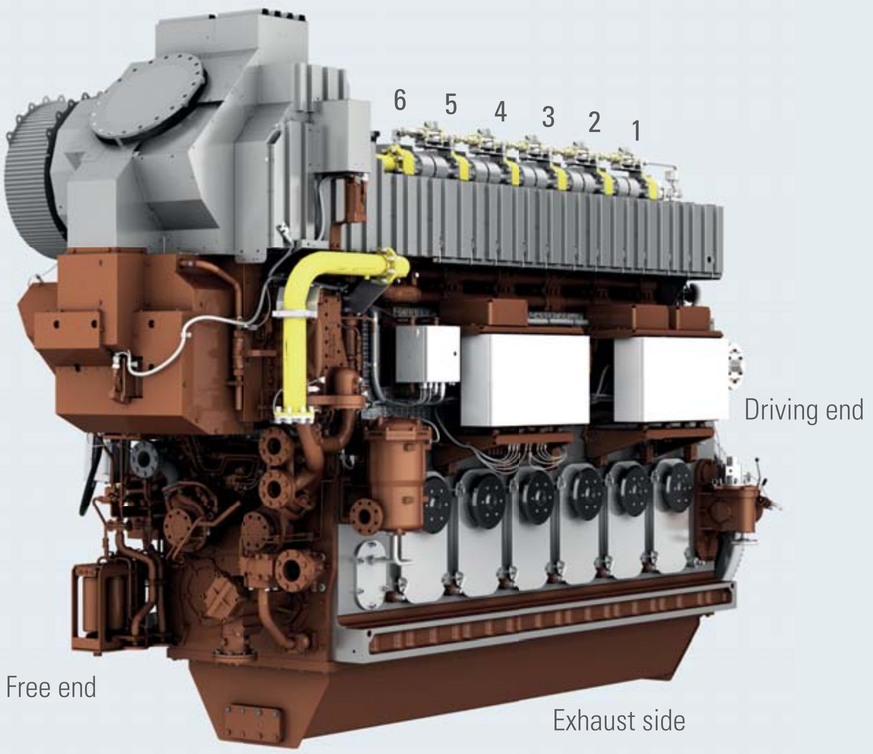


Fig. 1-1 M 34 DF

	6 M 34 DF	8 M 34 DF	9 M 34 DF
Output [kW]	3,000	4,000	4,500

Cylinder configuration:	6, 8, 9 in-line
Bore:	340 mm
Stroke:	460 mm
Stroke / bore-ratio:	1.35
Swept volume:	42 l/cyl.
Output/cyl:	500 kW
BMEP:	19.9/19.1 bar
Revolutions:	720/750 rpm
Mean piston speed:	11.0/11.5 m/s
Turbocharging:	single log
Direction of rotation:	clockwise, option: counter-clockwise

1.2 Main components and systems

1.2.1 Main features and characteristics

Caterpillar Motoren designed the M 34 DF based on the reliable M 32 C engine series. It is capable of operating on multiple fuels without sacrificing the typical MaK marine engine features like superior serviceability and class-leading maintenance intervals. Caterpillar has leveraged more than 60 years experience with thousands of spark-ignited gas engines operating in the field to develop the M 34 DF.
The M 34 DF offers high fuel efficiency and lower exhaust gas emissions as an answer to increasing operating costs and upcoming fuel sulfur and NO_X regulations in Emission Control Areas (ECA).
It saves cost by using natural gas while retaining the traditional performance and durability of diesel engines. HFO operation is supported for use outside of ECAs.
High efficieny and proven reliability make the M 34 DF an excellent propulsion engine for operation inside and outside of environmentally protected areas as well as waters with HFO limitations. Redundant controls and safety systems even support single main engine installations.
The M 34 DF is an attractive alternative to expensive low-sulphur MDO or large and complex scrubber installations to comply with future IMO III exhaust gas regulations.

Fig. 1-2 Control side and driving end

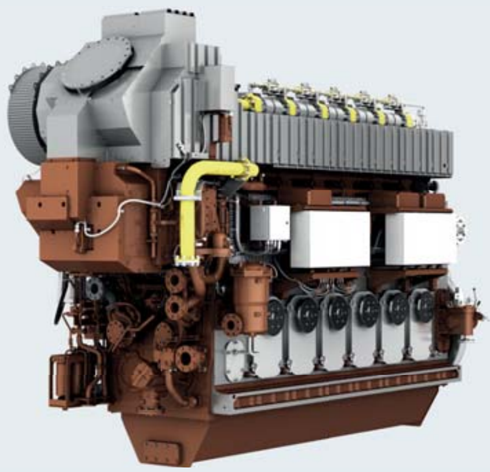


Fig. 1-3 Exhaust side and free end

1.2.2 Description of components

Cylinder head

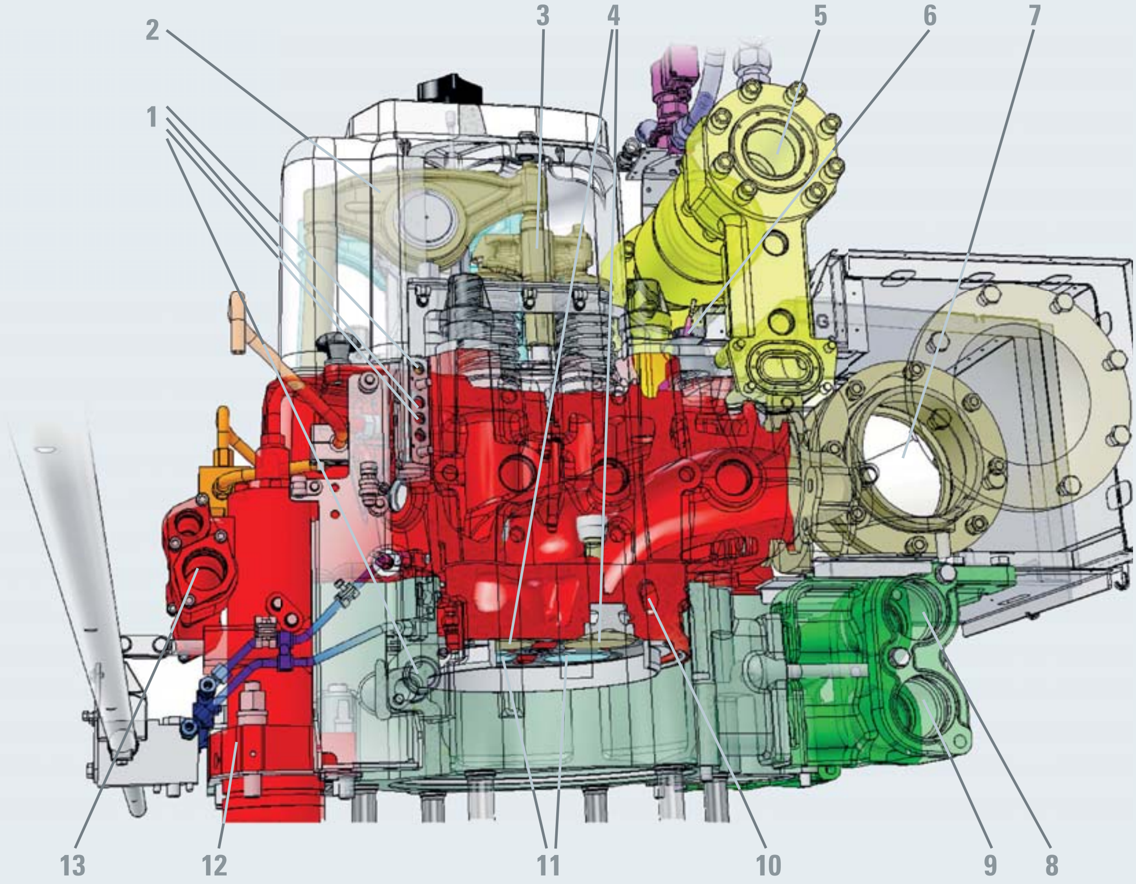


Fig. 1-4 Cylinder head

1	Media ducted through cylinder head	8	Cooling water line, outlet
2	Rocker arm, outlet	9	Cooling water line, inlet
3	Valve bridge, outlet	10	Cooling water spaces in cylinder head
4	Exhaust gas valves, water cooled	11	Combustion air inlet valves
5	Double walled gas pipe	12	Fuel feed pump
6	Ignition fuel injector	13	Fuel feed pipe
7	Exhaust gas line		

- 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 lube oil.

Connecting rod and piston

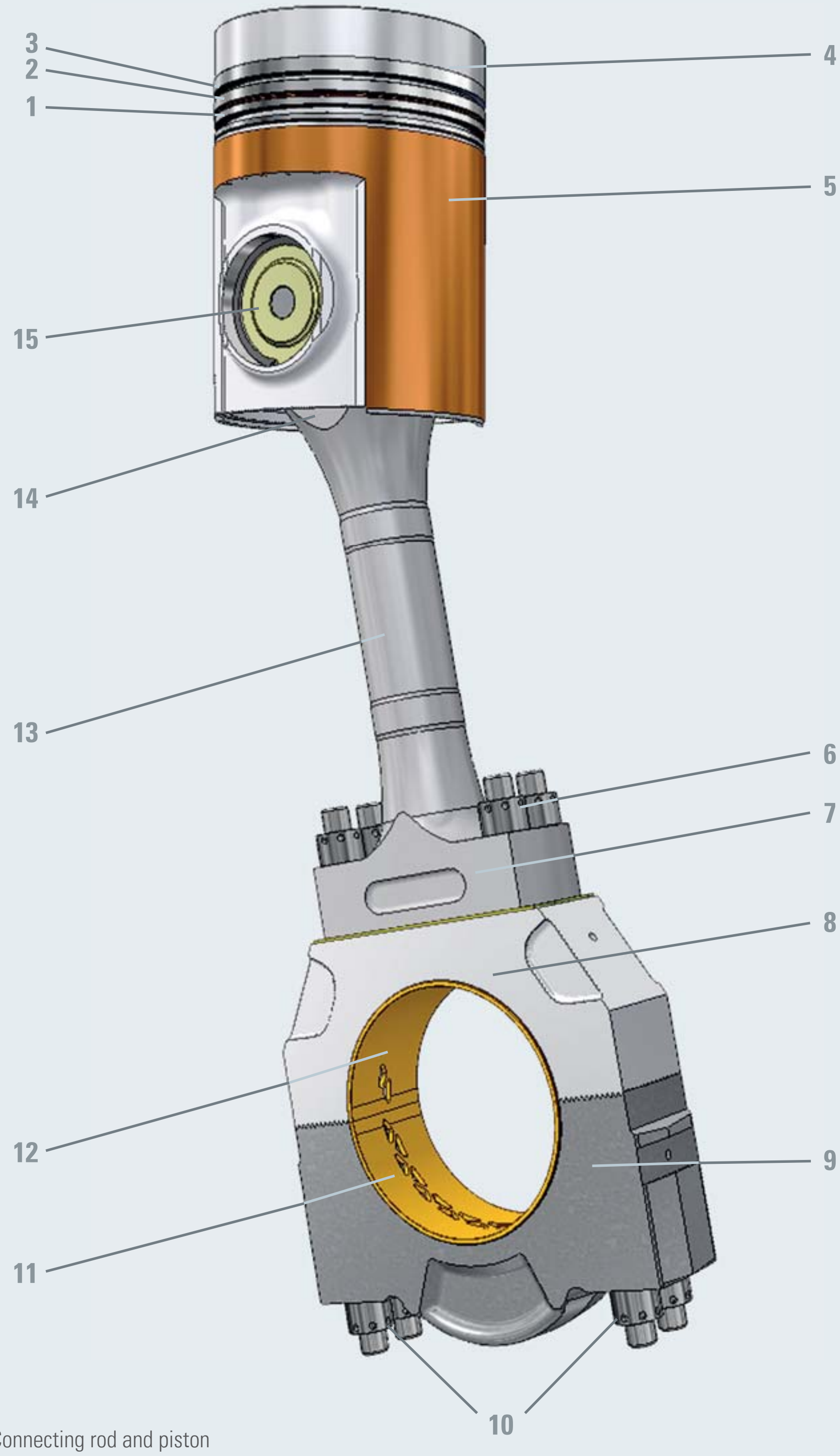


Fig. 1-5 Connecting rod and piston

1	Oil scraper ring	9	Big end bearing cap
2	Second piston ring	10	Big end bearing bolts
3	First piston ring	11	Lower big end bearing shell with oil inlet
4	Piston crown	12	Upper big end bearing shell
5	Piston skirt	13	Connecting rod
6	Connecting rod bolts	14	Small end in marine head design
7	Connecting rod flange	15	Piston pin
8	Big end bearing		

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

Engine block

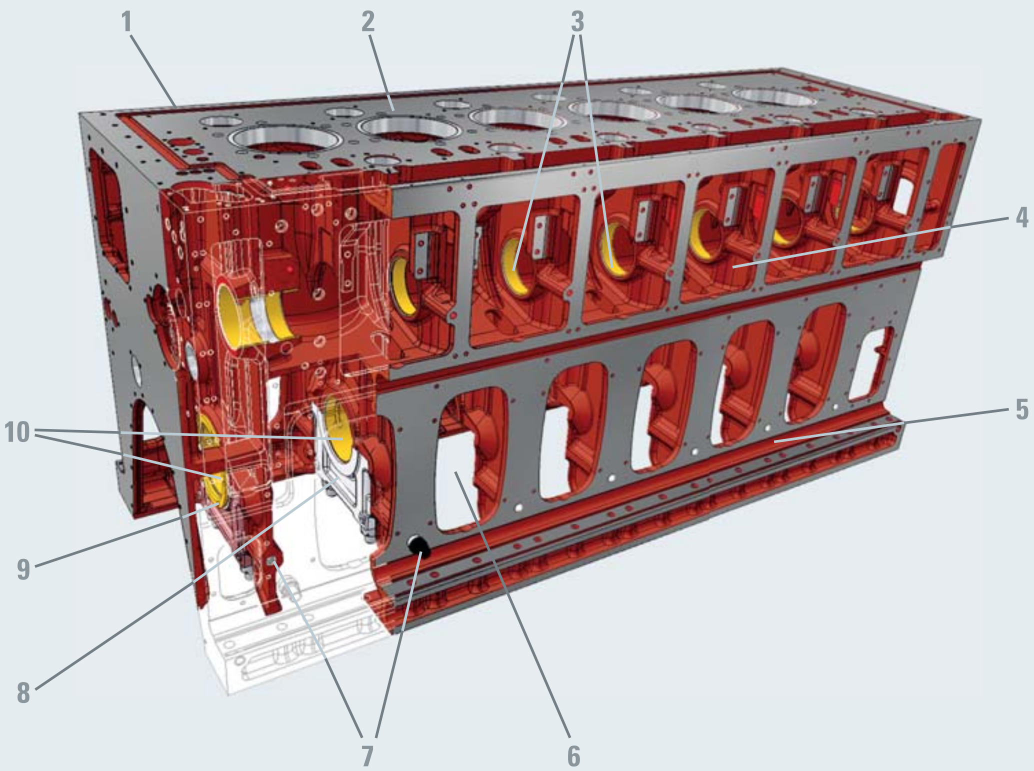


Fig. 1-6 Engine block

1 One-piece nodular cast iron block
2 Top plate with seating flanges for the cylinder liners
3 Camshaft bearings
4 Camshaft housing
5 Foot of engine block with drain chamfer
6 Space for underslung crankshaft
7 Side screws
8 Main bearing
9 Locating (main) bearing
10 Corrosion protected main bearings

Core element of the M 34 DF is the engine block, which is made of nodular cast iron in one piece.

The advantages of the engine block design are:

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

Safe and simple power train

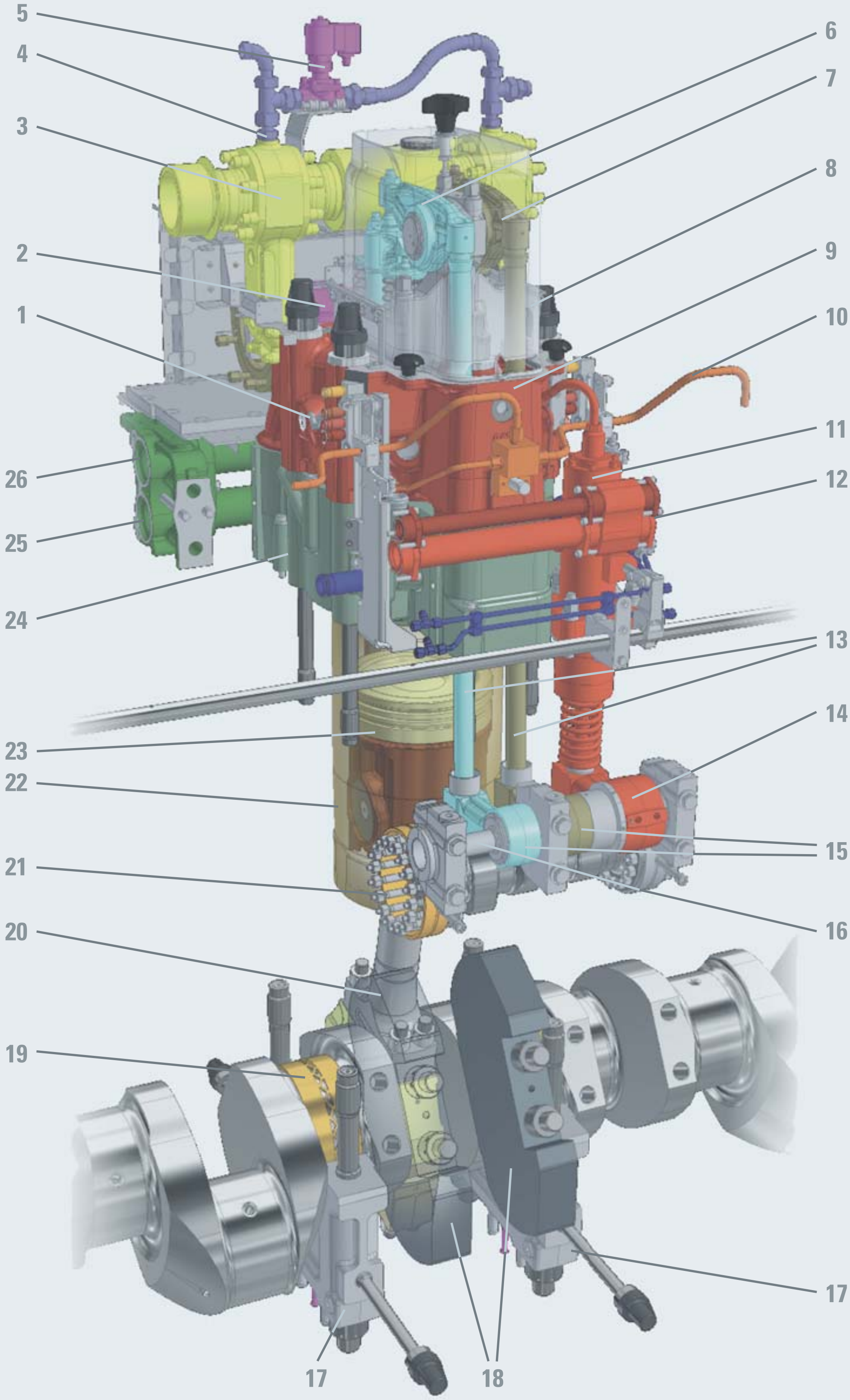


Fig. 1-7 Configuration of main components of one cylinder compartment

1	Media duct on cylinder head	17	Main bearing cap
2	Cylinder head stud bolts	18	Counterweights on crankshaft
3	Double walled gas pipe	19	Upper main bearing shell with oil inlet
4	Leakage detection pipe	20	Connecting rod, marine design
5	Solenoid valve	21	Camshaft segment
6	Rocker arm, inlet	22	Cylinder liner
7	Rocker arm, outlet	23	Piston crown
8	Head cover	24	Cooling water distributor
9	Cylinder head	25	Cooling water pipe, inlet
10	Ignition fuel oil pipe	26	Cooling water pipe, outlet
11	Fuel feed pump		
12	Fuel feed pipe		
13	Push rod		
14	Cam follower, fuel feed pump		
15	Cam follower, outlet		
16	Lube oil tube in cam follower shaft		

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
- Service friendly Gas admission valve and ignition fuel injector location

1.3 Engine running in

All MaK engines delivered have already been completely run in, therefore special guidelines for running in are not necessary.
Under certain circumstances, referred to 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 E engines is to be adhered.
During this period the load of the preheated engine is increased 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, fuel quality, load and operating profile, conditions, the quality of maintenance and other external factors.

Core components	Life time operating hours [h]		
	M 34 DF Propulsion		
	MDO	HFO	TBO M 34 DF
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	30,000	30,000	15,000
Ignition fuel injector	–	–	7,500
Gas admission valve	–	–	7,500
Cylinder pressure sensor	–	–	7,500
Ignition fuel oil filter element	–	–	2,000

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

Type	720/750 rpm
	[kW]
6 M 34 DF	3,000
8 M 34 DF	4,000
9 M 34 DF	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

Fuel consumption data is based on 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 %
Fuel gas minimum lower heating vylue (LHV)	28 MJ/Nm³
Fuel gas methane number for rated output	> 80

Specification of fuel consumption data without engine driven pumps;
for each pump driven 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).

2.4 Emissions

2.4.1 Exhaust gas – preliminary

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

Intake air temperature 25 °C

Engine	Output [kW]	Output [%] [kg/h] [°C]					
		100	90	80	70	60	50
6 M 34 DF	3,000	22,000 305	21,050 300	18,580 310	16,130 315	13,730 330	11,780 345
8 M 34 DF	4,000	29,355 310	28,060 305	24,700 315	21,460 317	18,265 335	15,670 350
9 M 34 DF	4,500	33,000 305	31,575 300	27,870 310	24,195 315	20,590 330	17,650 345

Intake air temperature 45 °C

Engine	Output [kW]	Output [%] [kg/h] [°C]					
		100	90	80	70	60	50
6 M 34 DF	3,000	20,680 324	19,785 319	17,465 330	15,160 335	12,910 351	11,070 367
8 M 34 DF	4,000	27,590 329	26,375 324	23,215 335	20,170 337	17,170 356	14,730 372
9 M 34 DF	4,500	31,020 325	29,675 320	26,195 330	22,740 335	19,365 351	16,600 367

2.4.2 Nitrogen oxide emissions (NO_x-values)

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

2.4.3 Engine International Air Pollution Prevention Certificate

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

	Test cycle type E2			
Speed	100 %	100 %	100 %	100 %
Power	100 %	75 %	50 %	25 %
Weighting factor	0.2	0.5	0.15	0.15

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

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

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

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

2.5 Engine dimensions and weight – preliminary

Turbocharger at free end

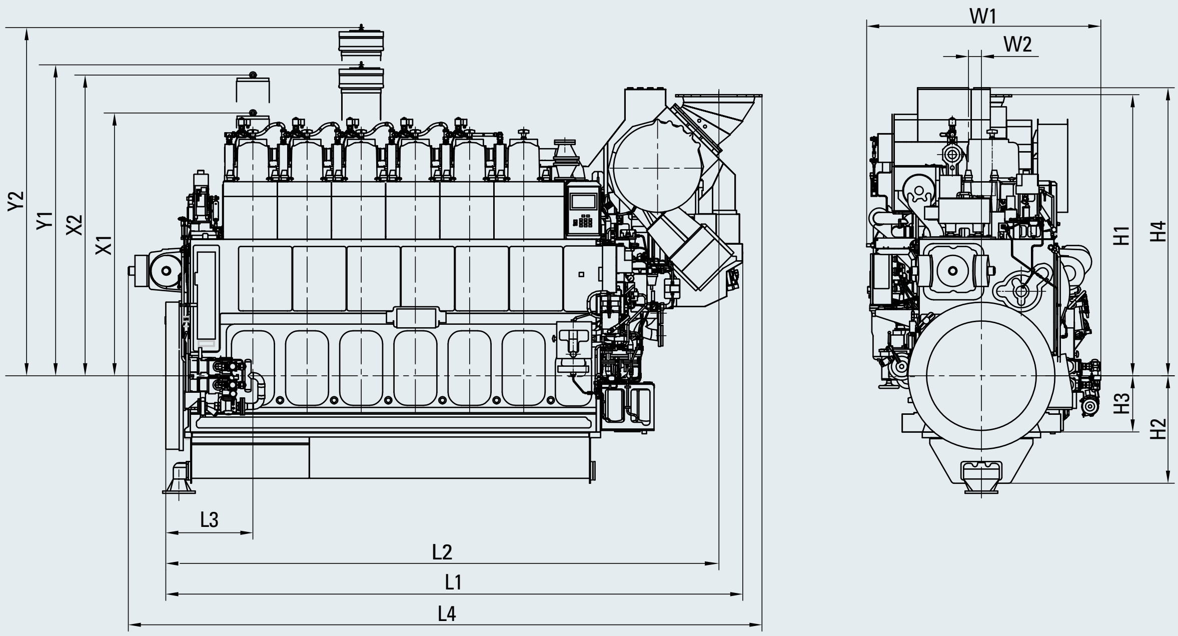


Fig. 2-1 Turbocharger at free end – control side

Type	Dimensions [mm]										Weight
	L1	L2	L3	L4	H1	H2	H3	H4	W1	W2	[t]
6 M 34 DF	5,895	5,466	852	6,325	2,749	1,052	550	2,817	2,460	127	39.5
8 M 34 DF	6,980	6,550	852	7,410	2,925	1,052	550	2,995	2,460	190	49.0
9 M 34 DF	7,510	7,080	852	7,940	2,925	1,052	550	2,995	2,460	190	52.0

Removal of:

Piston:	in transverse direction	X1 = 2,570 mm
	in longitudinal direction	X2 = 2,940 mm
Cylinder liner:	in transverse direction	Y1 = 3,040 mm
	in longitudinal direction	Y2 = 3,405 mm

Engine center distance
(2 engines side by side)
Minimum distance 2,800 mm

Turbocharger at driving end

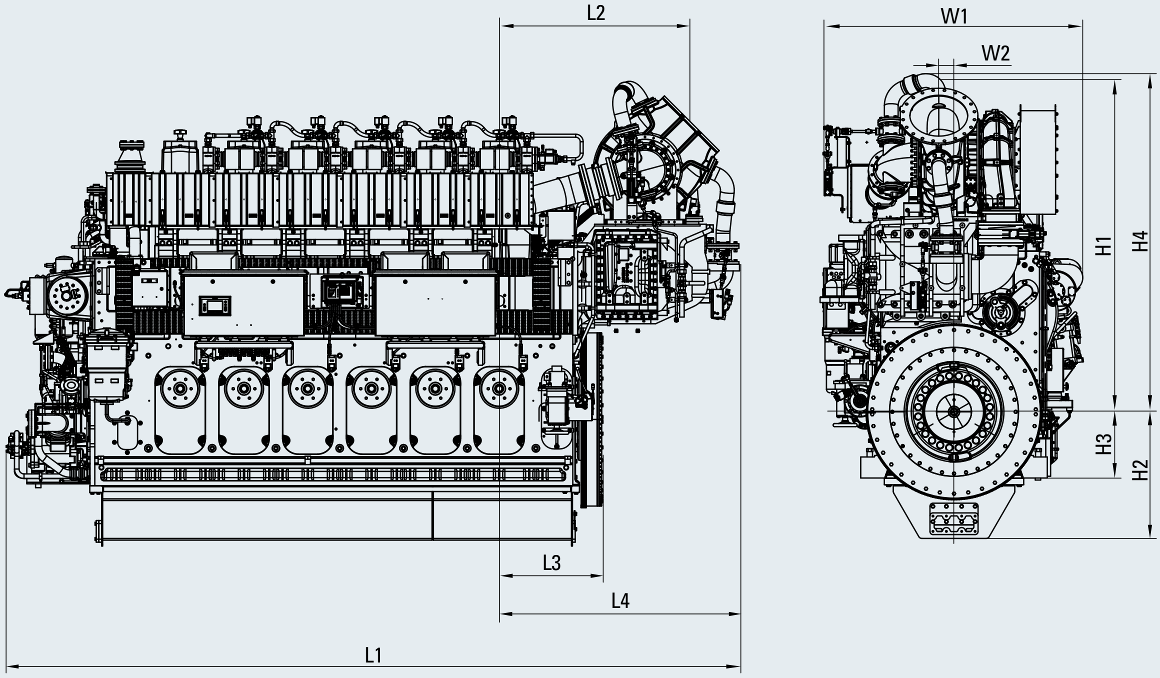


Fig. 2-2 Turbocharger at driving end – exhaust side

Type	Dimensions [mm]										Weight
	L1	L2	L3	L4	H1	H2	H3	H4	W1	W2	[t]
6 M 34 DF	6,340	1,812	852	2,240	2,771	1,052	550	1,220	2,500	127	39.5
8 M 34 DF	7,420	1,837	852	2,265	2,908	1,052	550	1,220	2,500	190	49.0
9 M 34 DF	7,950	1,837	852	2,265	2,908	1,052	550	1,220	2,500	190	52.0

2.6 System connecting points – preliminary

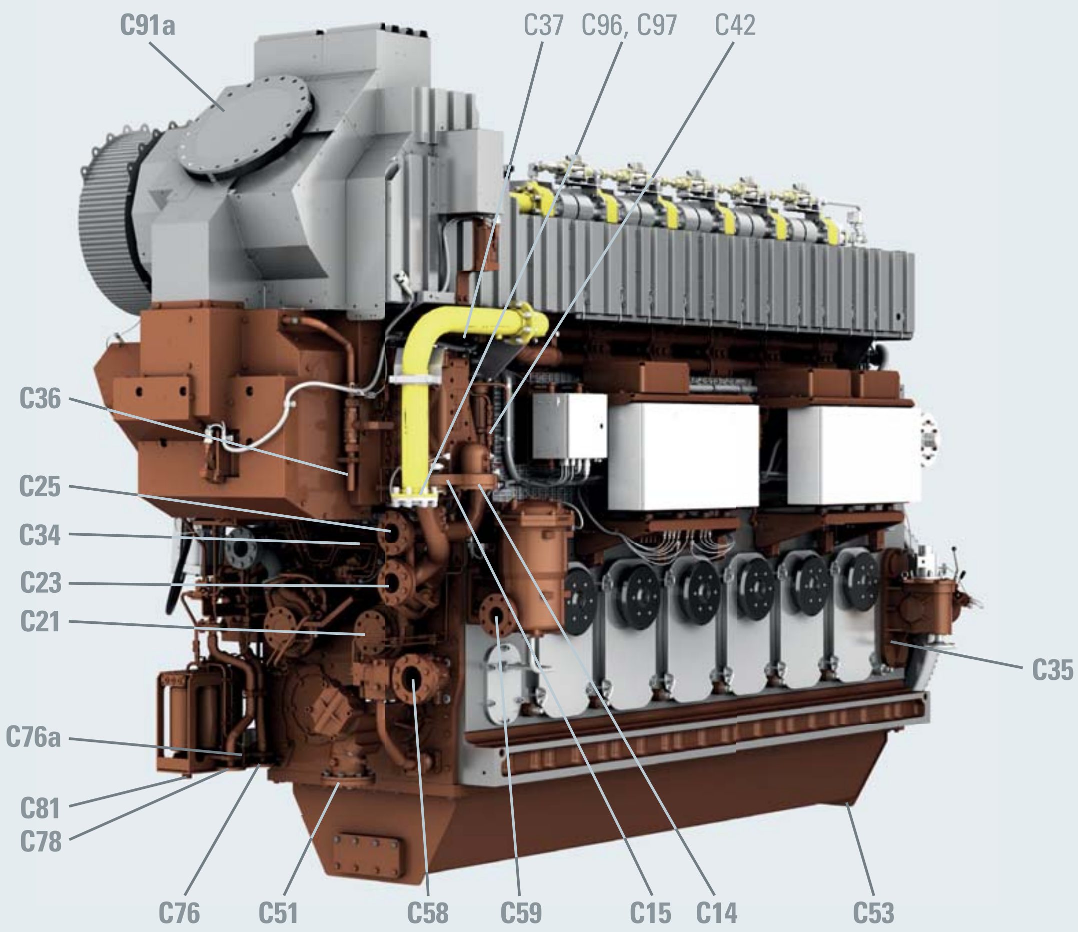


Fig. 2-3 Connecting points at the engine

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
C34	Drain condensate separator, charge air cooler
C35	Drain charge air duct
C36	Turbocharger washing, drain
C37	Ventilation connection
C42	Turbine cleaning connection
C51	Force pump, suction side
C53	Lube oil discharge
C58	Force pump, delivery side
C59	Lube oil inlet, lube oil filter
C76	Duplex filter, inlet
C76a	Pilot fuel, inlet
C78	Fuel outlet
C81	Drip fuel connectin
C91a	Exhaust gas outlet
C96	Gas inlet
C97	Flushing connection gas pipe (inertgas)

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 of overload protection device.
Binding data (depending on the type of vessel, rated output, speed and the turbocharging system) will be established upon order processing.

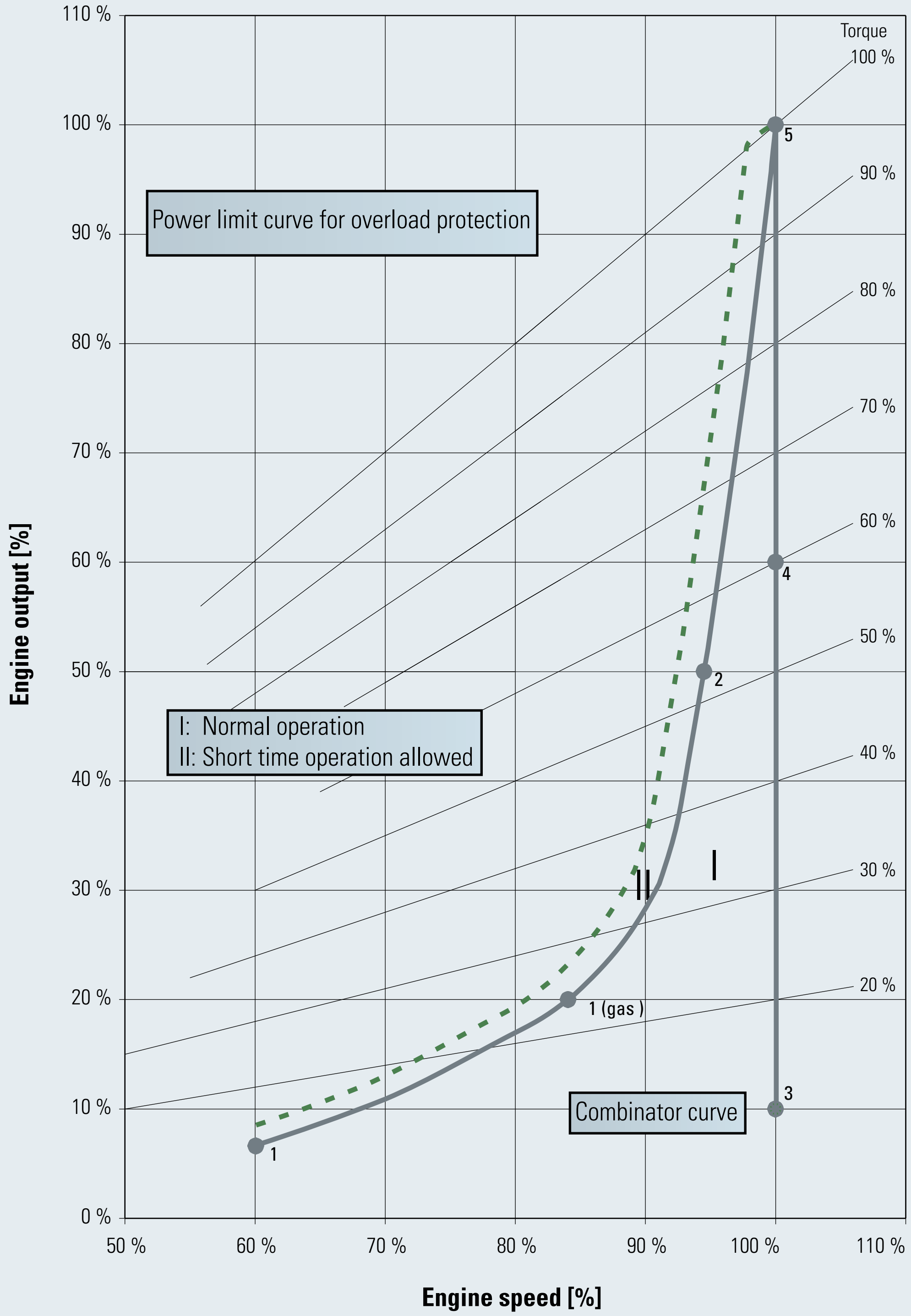


Fig. 3-1 CPP operation - diesel and gas mode

Remarks

- Standard acceleration time will provide longest component lifetimes.
- Emergency acceleration possible, but not recommended due to higher thermal stresses of engine components.
- Reduction from 100% to 0% MCR in 20 s normal operation and 8 s in emergency operation.
- In gas mode the engine changes at 20 % MCR from diesel fuel to liquified petroleum gas

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]
Diesel	6 M 34 DF	25	20	35	120	30	120
Diesel	8 M 34 DF	30	25	40	120	35	120
Diesel	9 M 34 DF	40	30	40	120	35	120
Gas	6-9 M 34 DF	40	30	40	120	45	120

3.1.1 Controllable pitch propeller operation – diesel mode

	Time in seconds	
	0 to 70%	70 to 100%
Standard operation	50	180
Emergency	25	15

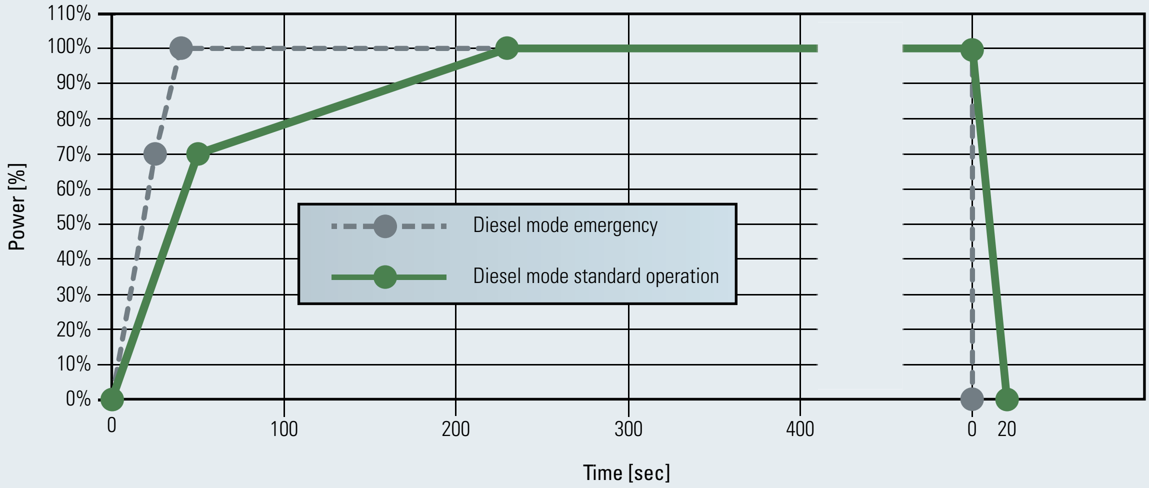


Fig. 3-2 Ramp up time M 34 DF in diesel mode

Remarks:

Loading time in seconds, Tol ± 10 sec., engine warmed up in operating conditions
Minimum operating time 10 minutes
Lube oil > 50 °C
Coolant > 65 °C

Standard ramp up time will provide longest component life times.
Emergency ramp up is possible, but not recommended, due to hogher thermal stresses of the engine components. In emergency mode with liquid fuel smoke will be visible.

Same ramprates even during fuel transfer.

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

3.1.2 Controllable pitch propeller operation – gas mode

	Time in seconds	
	0 to 70%	70 to 100%
Standard operation	50	180
Emergency	25	25

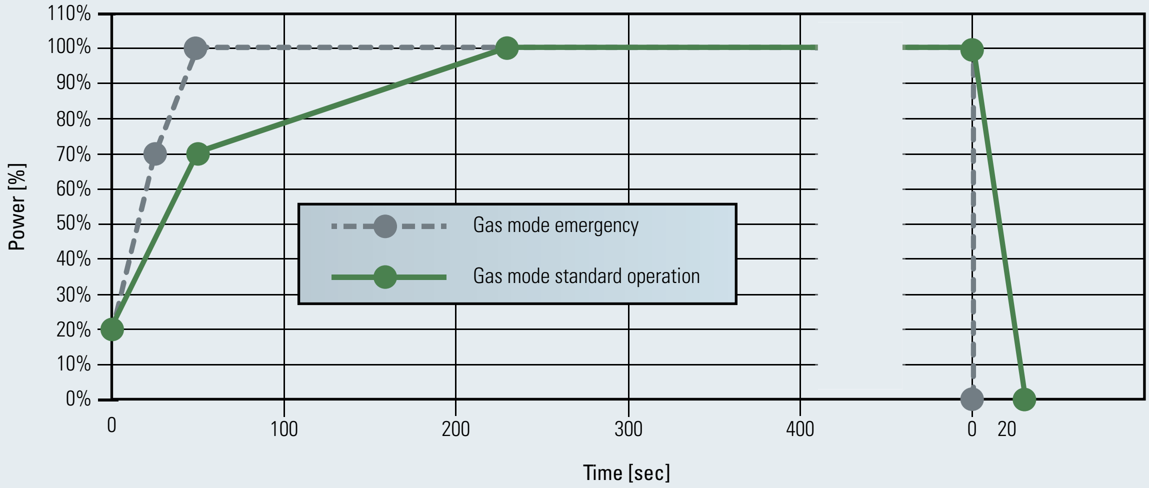


Fig. 3-3 Ramp up time M 34 DF in gas mode

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Same ramprates even during fuel transfer.

3.2 Restrictions for low load operation

3.2.1 Load restrictions in diesel mode

- 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.

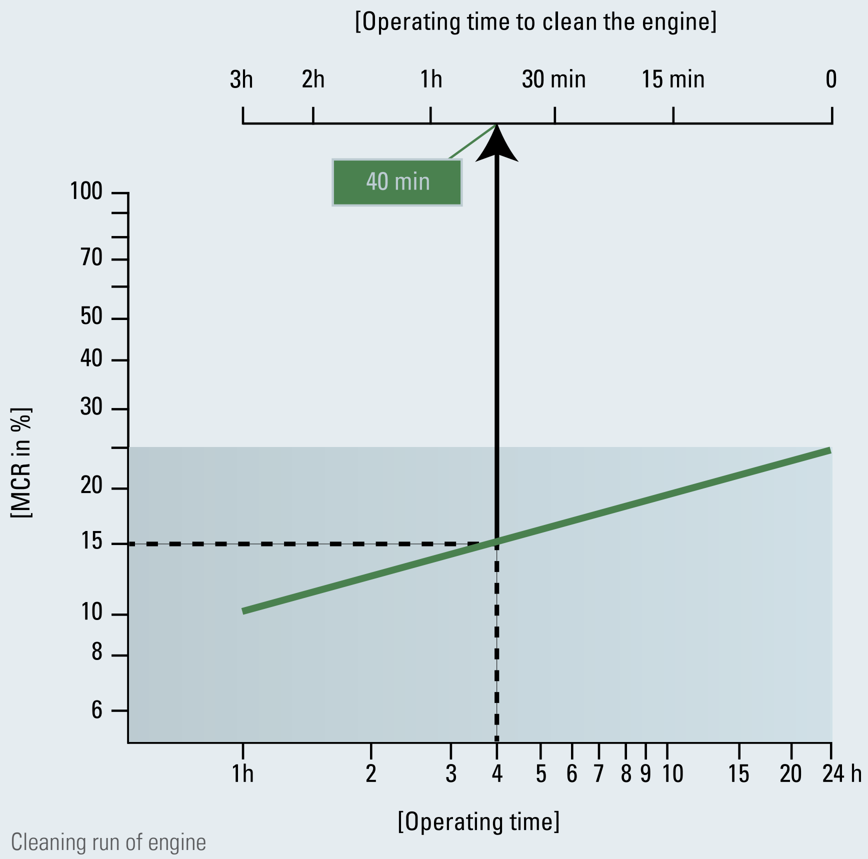

Fig. 3-4 Cleaning run of engine

3.2.2 Load restrictions in gas mode

According to the low load restrictions given by the required air to fuel ratio, the engine starts and stops only in diesel operation. A gas operation above 100% load is prohibited. A gas operation below 20% load is not possible or limited for a certain time. A direct fuel change over from HFO operation to gas operation is prohibited. The engine needs to run a certain time with MDO before change over to gas operation.

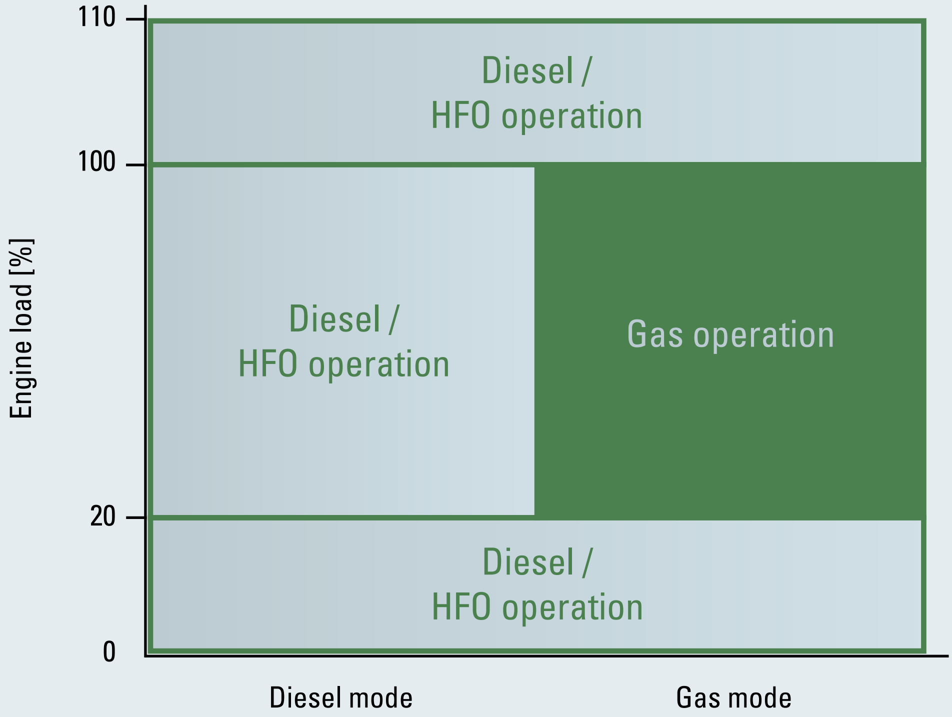

Fig. 3-5 Load restirctions in gas mode

3.3 Emergency operation without turbocharger

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

3.4 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 °

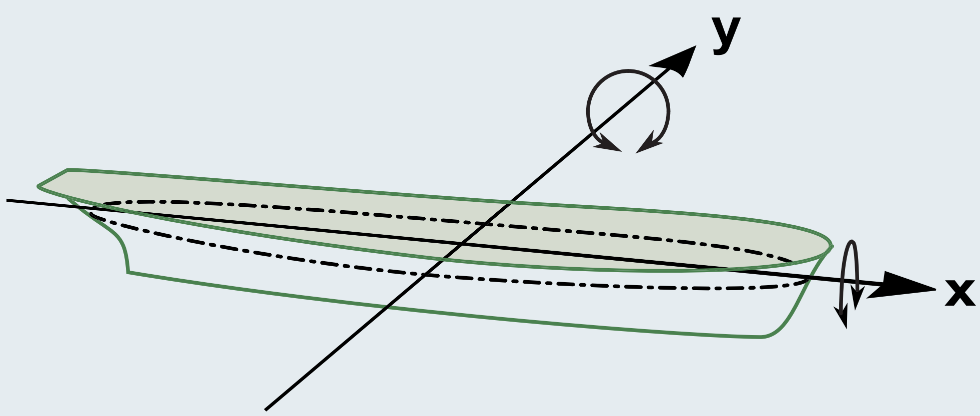

Fig. 3-6 Rotation axis

3.5 Fuel changeover and recovery behaviour

a) Changeover from gas to diesel operation:

- Changeover from gas to diesel fuel operation is done within approx. 1 second at any load, if required due to emergency switch over. The normal switchover takes approx. 50 seconds.
- Changeover can be started manually by operator or automatically by MACS, if the gas operation conditions are not given anymore (e.g. load window for gas operation has been left).

  - Main liquid fuel injection activated
  - Gaseous fuel slowly cut back / liquid fuel amount rises
  - FCT: Valve timing adjusts depending on running condition (e.g. load)
  - Air fuel ratio control is shut-off (Blow-Off and Waste Gate)
  - Ignition shot is still active

b) Changeover from diesel to gas operation:

- Changeover from diesel to gas fuel operation is possible in the load range between 20 and 100% power.
- If gas mode is activated, the load is constant in the correct range and all systems are running, the engine control will change over to gas operation:

  - Start air fuel ratio control with exhaust Waste Gate and Blow-Off
  - Change valve timing over to gas operation depending on running conditions
  - Start gas supply and raise gas amount, if gas pressure is sufficient
  - Main liquid fuel injection cuts back and switches off, if minimum fuel rack position is reached

- The procedure will take approx. 2 minutes, which depends on gas supply system and self check procedures.
- If the procedure is completed, power ramp up to 100% power or instant loading is possible.

3.6 Derating

In case of a fuel gas methane number lower than 80, the power output has to be redetermined in gas operation.

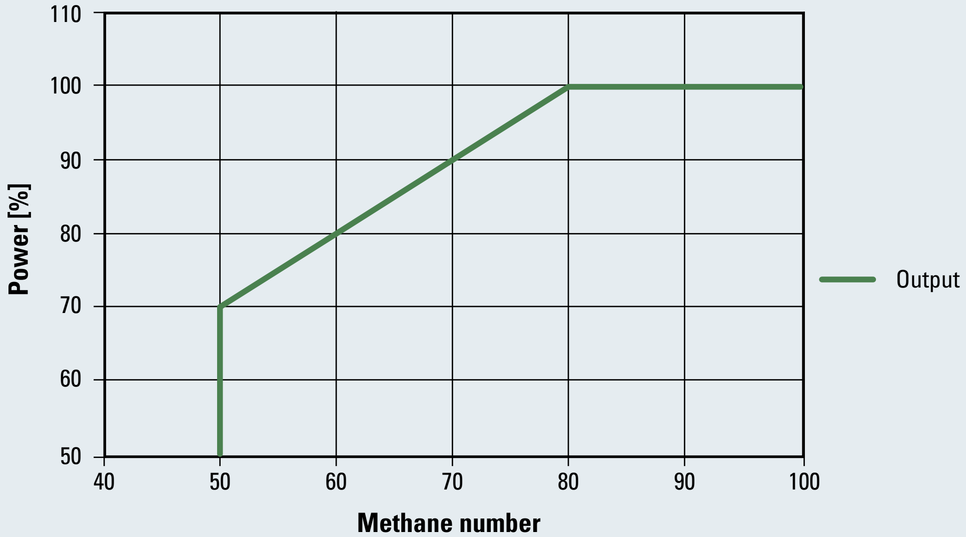

Fig. 3-7 Power as function of methane number

4.1 Diesel, mechanical

		6 M 34 DF	8 M 34 DF	9 M 34 DF
Performance data				
Maximum continuous rating acc. ISO 3046/1	[kW]	3,000	4,000	4,500
Speed	[rpm]	720/750	720/750	720/750
Minimum speed	[rpm]	435	435	435
Brake mean effective presure	[bar]	19.9/19.1	19.9/19.1	19.9/19.1
Charge air pressure	[bar]	3.55	3.55	3.55
Firing pressure	[bar]	200	200	200
Combustion air demand (ta=20 °C)	[m³/h]	17,800	23,750	26,710
Specific fuel oil consumption diesel/gas				
Propeller n = const [1] 100 %	[g/kWh] [kJ/kWh]	188/7,665	188/7,665	188/7,665
85 %	[g/kWh] [kJ/kWh]	187/7,777	187/7,777	187/7,777
75 %	[g/kWh] [kJ/kWh]	189/7,925	189/7,925	189/7,925
50 %	[g/kWh] [kJ/kWh]	195/8,290	195/8,290	195/8,290
Lube oil consumption [2]	[g/kWh]	0.6	0.6	0.6
Pilot injection gas operating	[%]	1	1	1
NO_x-emission [6]	[g/kWh]	9.6	9.6	9.6
NO_x-emission gas [6]	[g/kWh]	2.39	2.39	2.39
Turbocharger type		Napier NT10	Napier NT12	Napier NT12
Fuel				
Engine driven booster pump	[m³/h/bar]	3.2/5	3.2/5	3.2/5
Stand-by booster pump	[m³/h/bar]	2.2/5	2.9/5	3.2/5
Stand-by booster pump (CCR-system)	[m³/h/bar]	0.66/8	0.88/8	1.0/8
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

		6 M 34 DF	8 M 34 DF	9 M 34 DF
Lube oil				
Engine driven pump	[m³/h/bar]	141/10	141/10	141/10
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]	168/3	168/3	168/3
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
Fresh water cooling				
Engine content	[m³]	0.7	0.95	1.05
Pressure at engine inlet min/max	[bar]	4.5/6.0	4.5/6.0	4.5/6.0
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]	118/4.5	118/4.5	118/4.5
Independent pump HT	[m³/h/bar]	70/4.0	70/4.0	80/4.0
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
Lube oil cooler	[kW]	440	590	660
Jacket water	[kW]	420	550	625
Charge air cooler [3)]	[kW]	–	–	–
Charge air cooler (HT-stage) [3)]	[kW]	996	1,330	1,496
Charge air cooler (LT-stage) [3)] (HT-stage before engine)	[kW]	290	388	436
Heat radiation engine	[kW]	150	190	210

		6 M 34 DF	8 M 34 DF	9 M 34 DF
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) [5)]	[°C)	305	310	305
Exhaust gas mass flow (intake air 25 °C) [5)]	[kg/h]	22,000	29,335	33,000
Exhaust gas temperature after turbine (intake air 25 °C) (gas) [5)]	[°C]	345	355	350
Exhaust gas mass flow (intake air 25 °C) (gas) [5)]	[kg/h]	18,920	25,230	28,400
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
Max. allowed crankcase pressure, ND ventilation pipe	[mmWs/mm]	15/80	15/80	15/80

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

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

5.1.2 Internal fuel oil system

General

The fuel injectors are utilized to deliver the correct amount of fuel to the cylinders precisely at the moment it is needed.

The diesel fuel supply system must ensure a permanent and clean supply of diesel fuel to the engine internal fuel oil system.

NOTE: In diesel mode operation the ignition fuel system is always active.

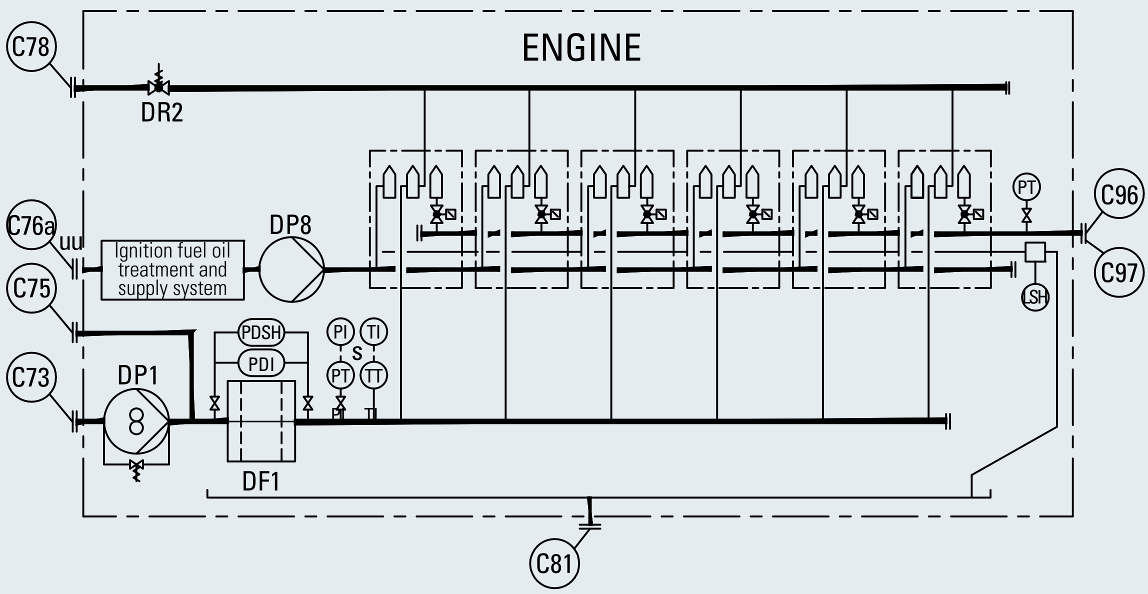

Fig. 5-1 Internal fuel oil system, system diagram

DF1	Fuel fine filter (duplex filter)
DP1	Diesel oil feed pump
DP8	Common rail high pressure pump
DR2	Fuel pressure regulating valve
LSH	Level switch high
PDI	Diff. pressure indicator
PDSH	Diff. pressure switch high
PI	Pressure indicator
PT	Pressure transmitter
TI	Temperature indicator
TT	Temperature transmitter (PT100)

C73	Fuel inlet, to engine fitted pump
C75	Connection, stand-by pump
C76a	Inlet, ignition fuel
C78	Fuel outlet
C81	Drip-fuel connection
C96	Gas inlet
C97	Flushing connection gas pipe (inertgas)
s	Please refer to the measuring point list regarding design of the monitoring devices.
uu	Ignition fuel quality requirements only MDO fuel acc. ISO-F-DMA, DMB to be used

Diesel oil feed pump DP1 (fitted)

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

Fuel fine filter (duplex filter) DF1 (fitted)

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

5.1.3 External fuel oil system

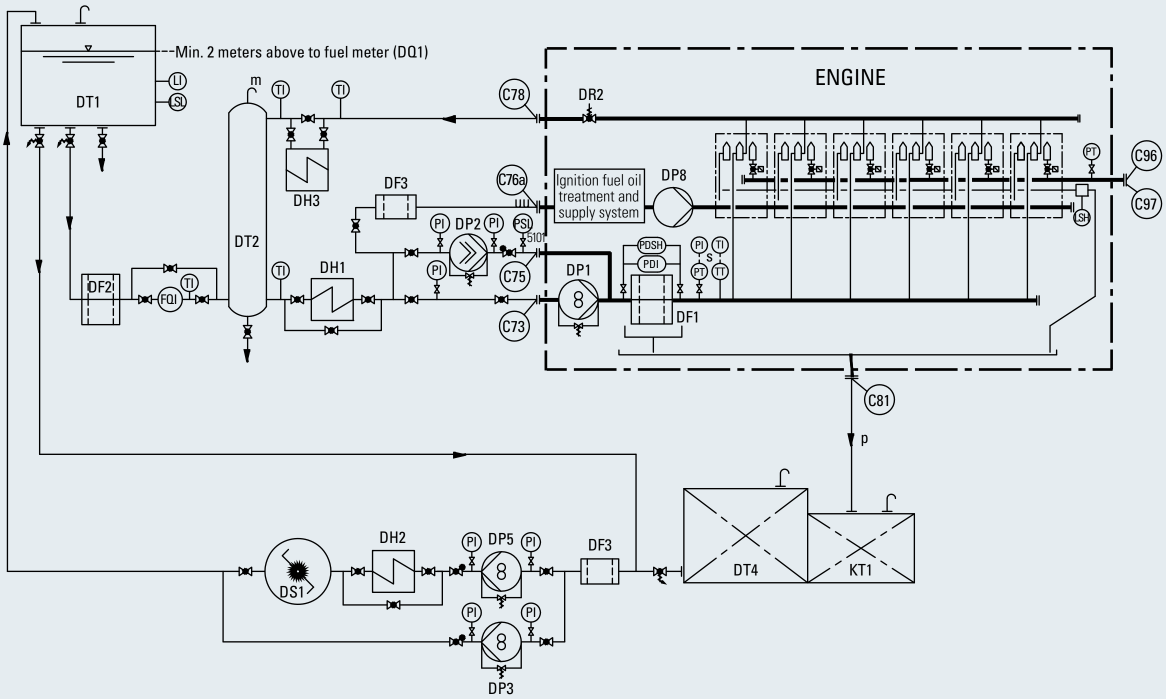

Fig. 5-2 External fuel oil system diagram with intermediate tank

DF1	Fuel fine filter (duplex filter)	FQI	Flow quantity indicator
DF2	Fuel primary filter (duplex filter)	LI	Level indicator
DF3	Fuel coarse filter	LSH	Level switch high
DH1	Diesel oil preheater (if required)	LSL	Level switch low
DH2	Electrical preheater for diesel oil (separator)	PDI	Diff. pressure indicator
		PDSH	Diff. pressure switch high
DH3	Diesel oil cooler	PI	Pressure indicator
DP1	Diesel oil feed pump	PSL	Pressure switch low
DP2	Diesel oil stand-by feed pump	PT	Pressure transmitter
DP3	Diesel oil transfer pump (to day tank)	TI	Temperature indicator
DP5	Diesel oil transfer pump (separator)	TT	Temperature transmitter (PT100)
DP8	Common rail high pressure pump		
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	C96	Gas inlet
KP1	Fuel injection pump	C97	Flushing connection gas pipe (inertgas)
KT1	Drip fuel tank		
		s	Please refer to the measuring point list regarding design of the monitoring devices
m	Lead vent pipe beyond service tank level		
p	Free outlet required	uu	Ignition fuel quality requirements only MDO fuel acc. ISO-F-DMA, DMB to be used

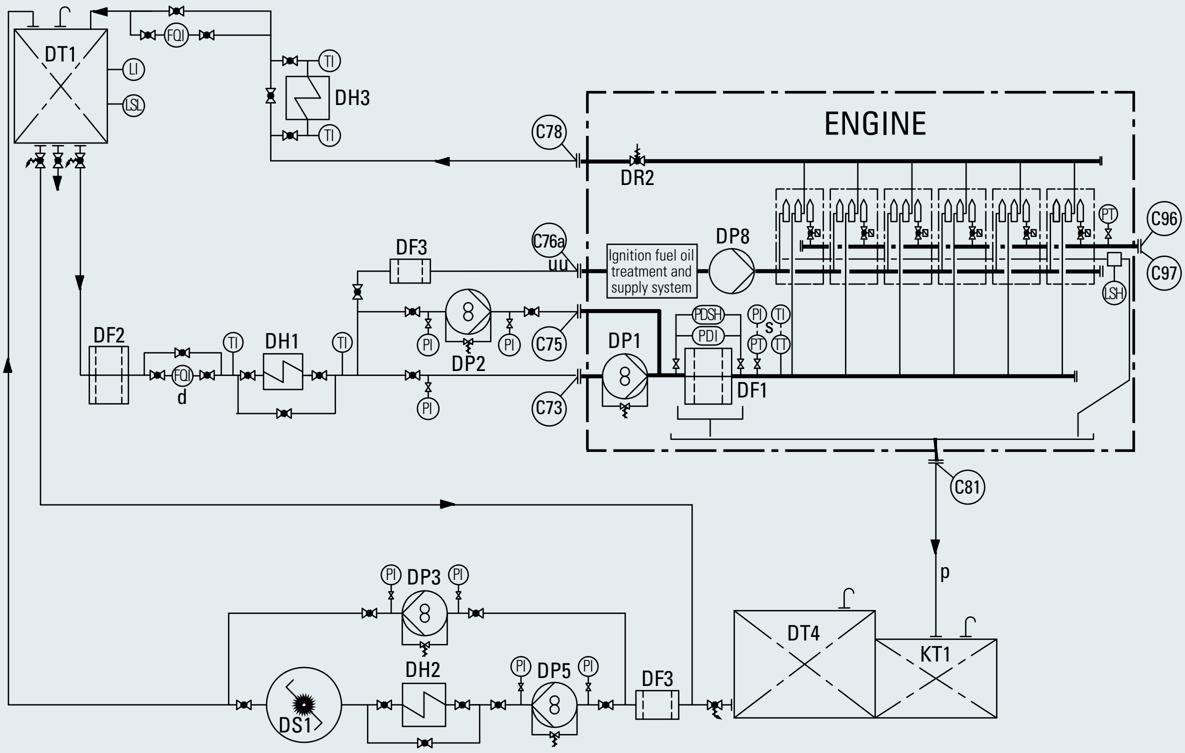

Fig. 5-3 External fuel oil system diagram without intermediate tank

DF1	Fuel fine filter (duplex filter)
DF2	Fuel primary filter (duplex filter)
DF3	Fuel coarse filter
DH1	Diesel oil preheater (if required)
DH2	Electrical preheater for diesel oil (separator)
DH3	Fuel oil cooler for MDO operation
DP1	Diesel oil feed pump
DP2	Diesel oil stand-by feed pump
DP3	Diesel oil transfer pump (to day tank)
DP5	Diesel oil transfer pump (separator)
DP8	Common rail high pressure pump
DR2	Fuel pressure regulating valve
DS1	Diesel oil separator
DT1	Diesel oil day tank
DT4	Diesel oil storage tank
KT1	Drip fuel tank
FQI	Flow quantity indicator
LSH	Level switch high
PDI	Diff. pressure indicator
PDSH	Diff. pressure switch high
PI	Pressure indicator
PT	Pressure transmitter
TI	Temperature indicator
TT	Temperature transmitter (PT100)
C73	Fuel inlet, to engine fitted pump
C75	Connection, stand-by pump
C76a	Inlet, ignition fuel
C78	Fuel outlet
C81	Drip-fuel connection
C96	Gas inlet
C97	Flushing connection gas pipe (inertgas)
p	Free outlet required
s	Please refer to the measuring point list regarding design of the monitoring devices
uu	Ignition fuel quality requirements only MDO fuel acc. ISO-F-DMA, DMB to be used.

General

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

Diesel oil storage tank DT4

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

Diesel oil separator DS1

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

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

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

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

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

Diesel oil day tank DT1

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

Fuel primary filter (duplex filter) DF2

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

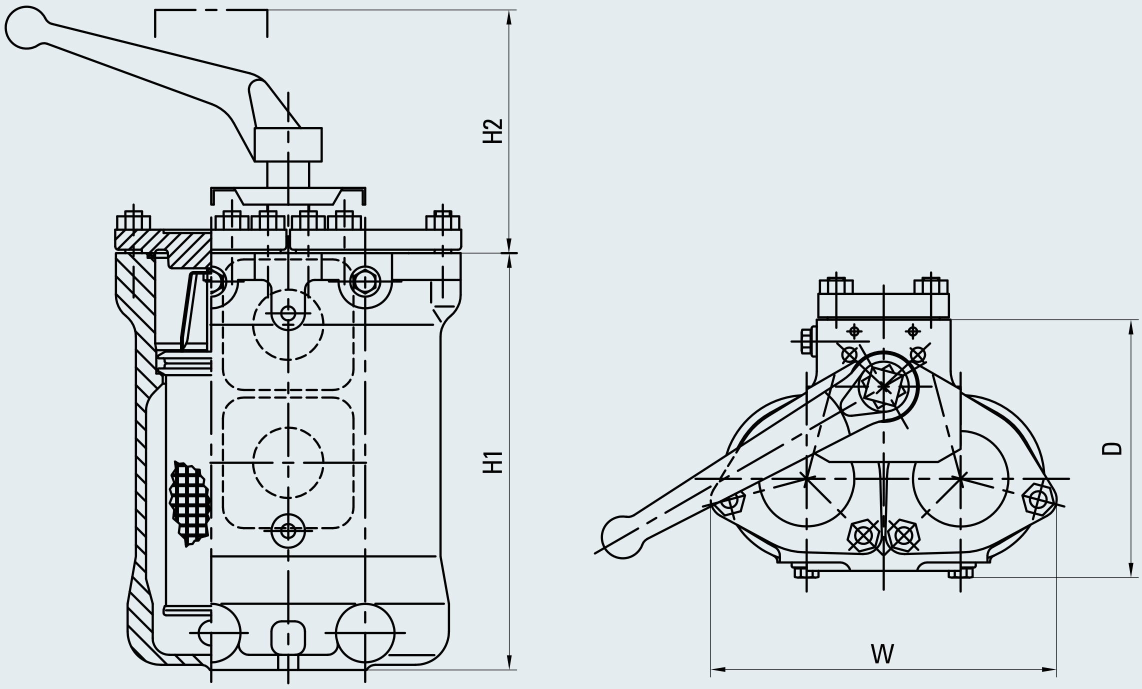

Fig. 5-4 Fuel primary filter DF2

Engine output	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.

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Diesel oil intermediate tank DT2

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

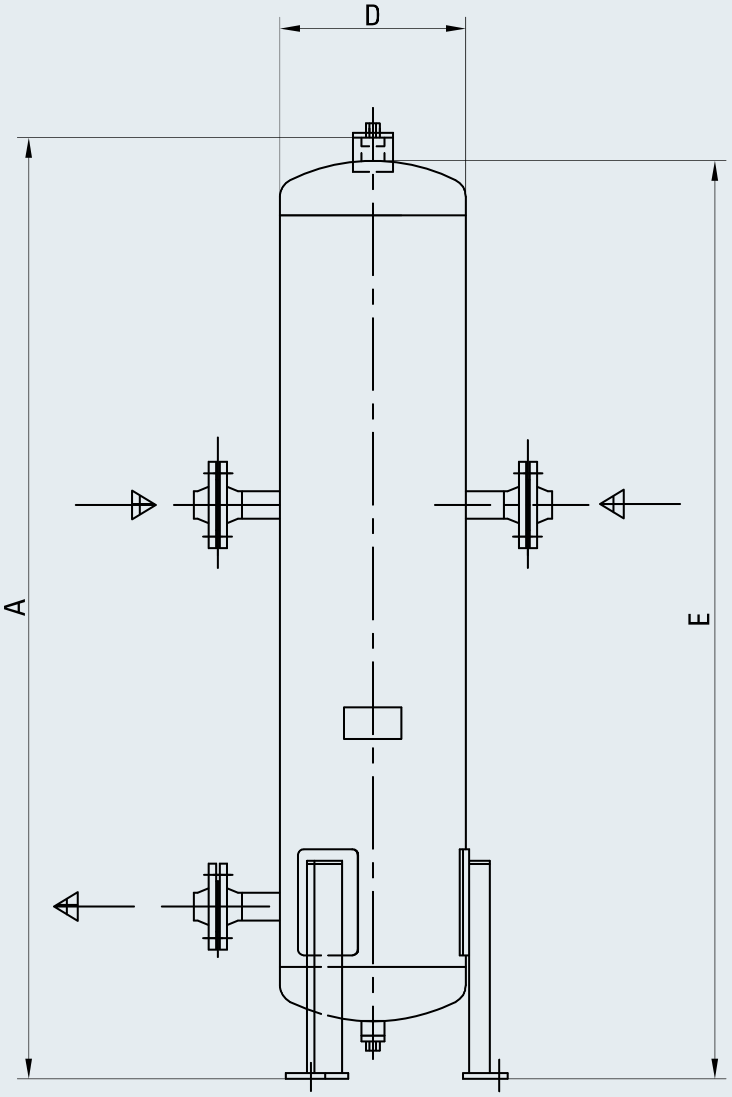


Fig. 5-5 Diesel oil intermediate tank DT2

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

Diesel oil preheater DH1 (hot water)

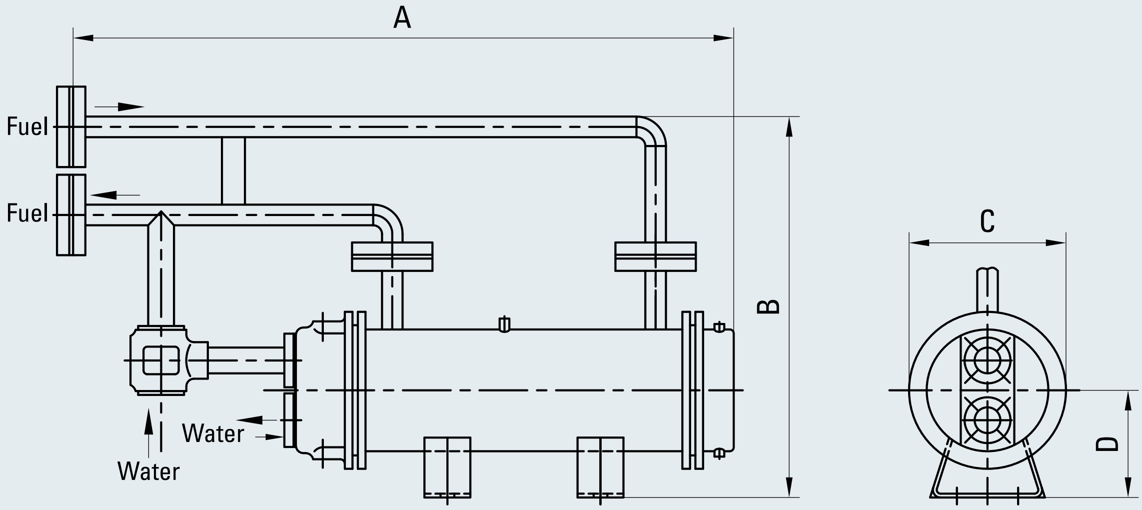


Fig. 5-6 Diesel oil preheater DH1

Engine	Dimensions [mm]				Weight
	A	B	C	D	[kg]
6/8 M 34 DF	863	498	Ø 205	140	42
9 M 34 DF	1,468	484	Ø 205	140	ca. 75

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

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

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

A diesel oil preheater is not required

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

Stand-by booster pump DP2 (separate)

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

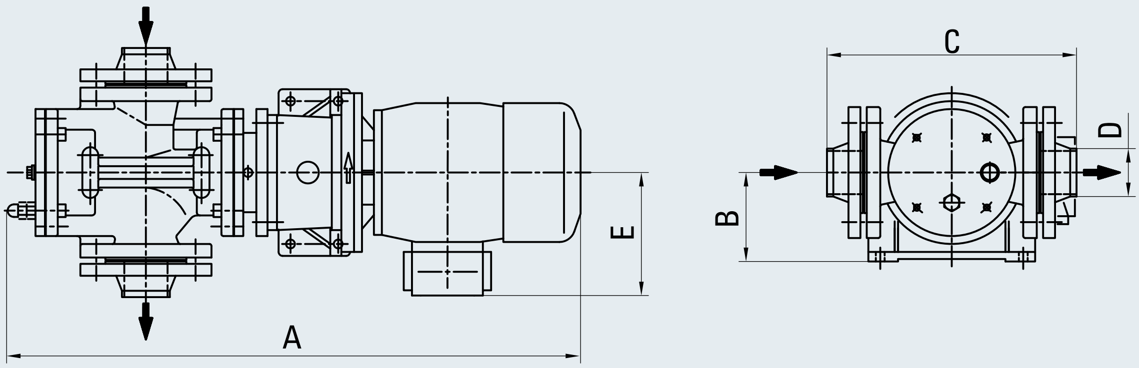


Fig. 5-7 Stand-by booster pump DP2

Engine	Dimensions [mm]					Weight	Motorpower	Voltage / Frequency
	A	B	C	D	E	[kg]	[kW]	[V/Hz]
6/8/9 M 34 DF	735	112	314	60.3	155	61	1.5	400/50
6/8 M 34 DF	735	112	314	60.3	155	61	1.8	440/60
9 M 34 DF	775	132	314	60.3	155	70	2.6	440/60

Fuel oil cooler DH3

To ensure a fuel oil temperature below 50 °C at any time a cooling of diesel oil may be required.
The need for a fuel cooler is system specific and depends on fuel circuit design and type of fuel oil. In case of more than one engine connected to the same fuel supply system, the MDO-cooler capacity has to be increased accordingly.
The heat transfer load into the diesel oil system is approx. 1.6 kW/cyl.
LT-water is normally used as cooling medium.

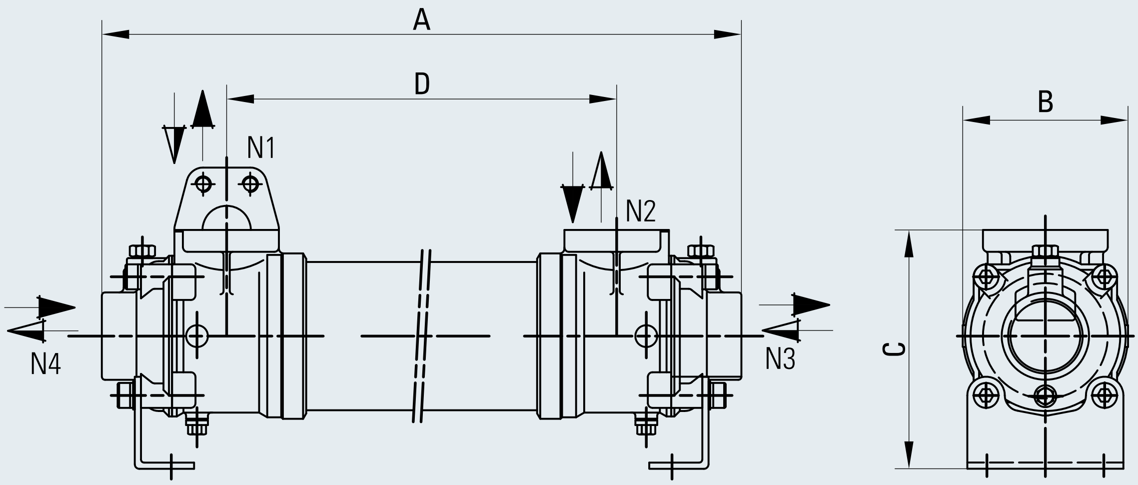


Fig. 5-8 Fuel oil cooler for MDO operation DH3

Engine	Dimensions [mm]						Weight
	A	B	C	D	N1 + N2	N3 + N4	[kg]
6/8/9 M 34 DF	910	106	153	750	1 ¼" SAE	1 ½" SAE	19

5.2 Ignition fuel system

The MaK dual fuel engine is equipped with an ignition fuel system to ignite the gas fuel / air mixture in the combustion chamber. This ignition system is a common rail system which injects only a small amount of MDO fuel.

5.2.1 Ignition fuel quality requirements

Only MDO fuel acc. to ISO-F-DMA, DMB is to be used.

5.2.2 System diagram

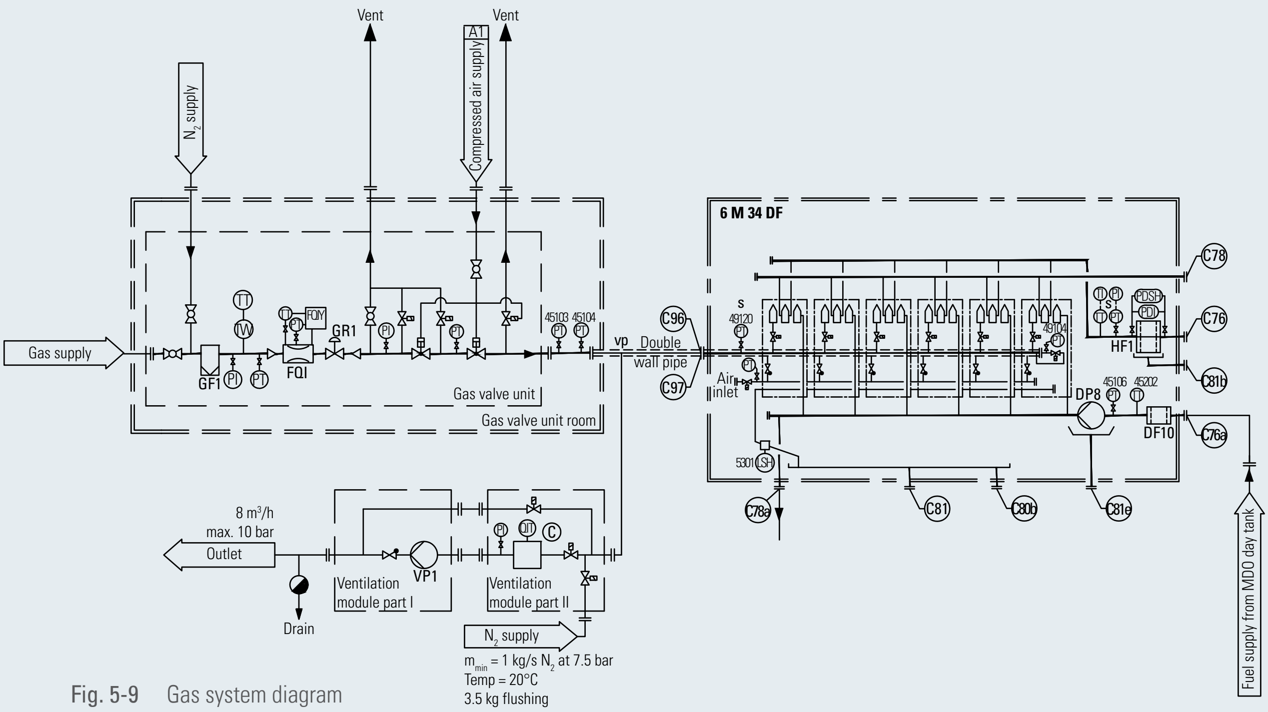


Fig. 5-9 Gas system diagram

DF10	Ignition fuel oil fine filter
DP8	Common rail high pressure pump
GF1	Gas filter
GR1	Gas pressure regulating valve
HF1	Fine filter (duplex filter)
VP1	Vaccuum pump
FQI	Flow quantity indicator
LSH	Level switch high
PI	Pressure indicator
PT	Pressure transmitter
QIT	Gas indicator and transmitter
TI	Termperature indicator
TT	Temperature transmitter (PT100)
TW	Protective sleeve

C76	Inlet, fuplex filter
C76a	Inlet, ignition fuel
C78	Fuel outlet
C78a	Outlet, ignition fuel
C80b	Drip-fuel connection (sealing oil injection pump)
C81	Drip fuel connection
C81b	Drip fuel connection (filter pan)
C81e	Drip fuel connection
C96	Gas inlet
C97	Flushing connection gas pipe (inertgas)
s	Please refer to the measuring point list regarding design of the monitoring devices.
vp	Distance between GVU and engine max. 10 m (piping length).

5.2.3 Pilot fuel ignition system components

Ignition fuel injector

Weight: 0.7 kg
The ignition fuel injector enables the injection of pressurized fuel directly into the cylinder.

The injector design is simple and compact, the key features are:

- Electronically controlled
- Flexible injection timing and duration

Fig. 5-10 Ignition fuel injector

High pressure pump

Weight: 8 kg

One high pressure pump delivers the required amount of ignition fuel to the injectors and provides the desired pressure in closed loop control. The pump itself is based on a proved design.

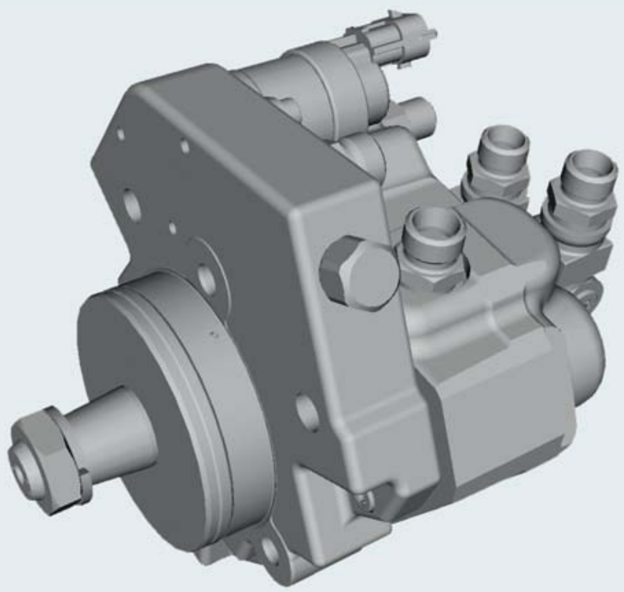


Fig. 5-11 High pressure pump

5.3 HFO operation

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

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

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

In HFO mode operation the ignition fuel system is always active.

Fuel oil system

A pressurized fuel oil system, as shown in Fig. 5-13, is necessary when operating on high viscosity fuels. When using high viscosity fuels requiring high preheating temperatures, the fuel oil from the engine fuel oil system to the return line will also have a relatively high temperature. The fuel oil pressure measured on the engine (at fuel pump level) should be about 5 bar. This maintains a pressure margin against gasification and cavitation in the fuel system, even at 150 °C preheating.
In order to ensure correct atomization, the fuel oil temperature must be adjusted according to the specific fuel oil viscosity used. An inadequate temperature can influence the combustion and could cause increased wear on cylinder liners and piston rings, as well as deterioration of the exhaust valve seats. A too low heating temperature, i.e. too high viscosity, could also result in excessive fuel consumption.
Therefore, optimum injection viscosity of 10 – 12 cSt must be maintained at any rate and with all fuel grades.
Deviations from design recommendations are possible, however, they should be discussed with Caterpillar Motoren.
Trace heating for all heavy fuel pipes is recommended.

Viscosity temperature sheet

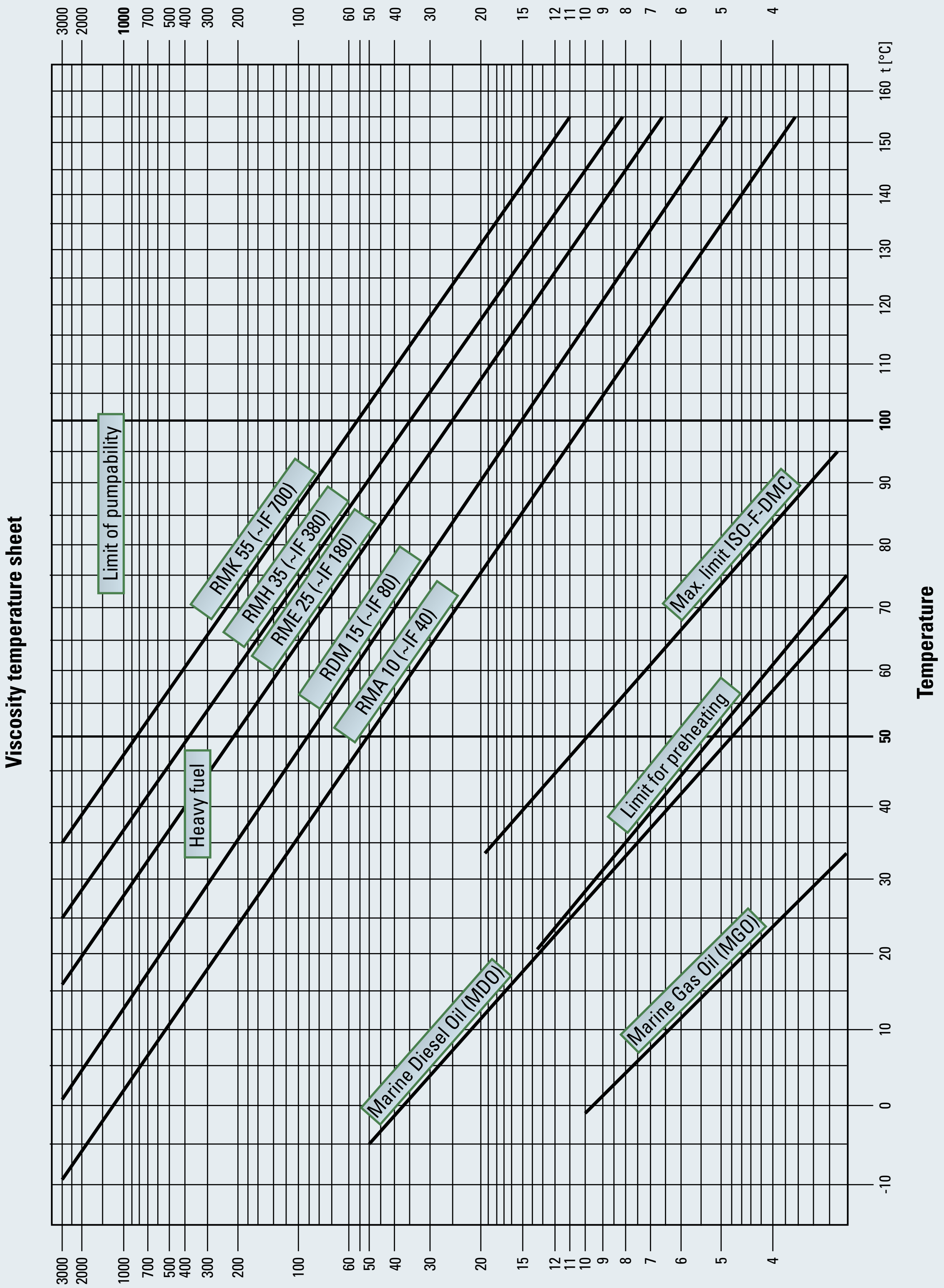


Fig. 5-12 Viscosity / temperature diagram

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

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

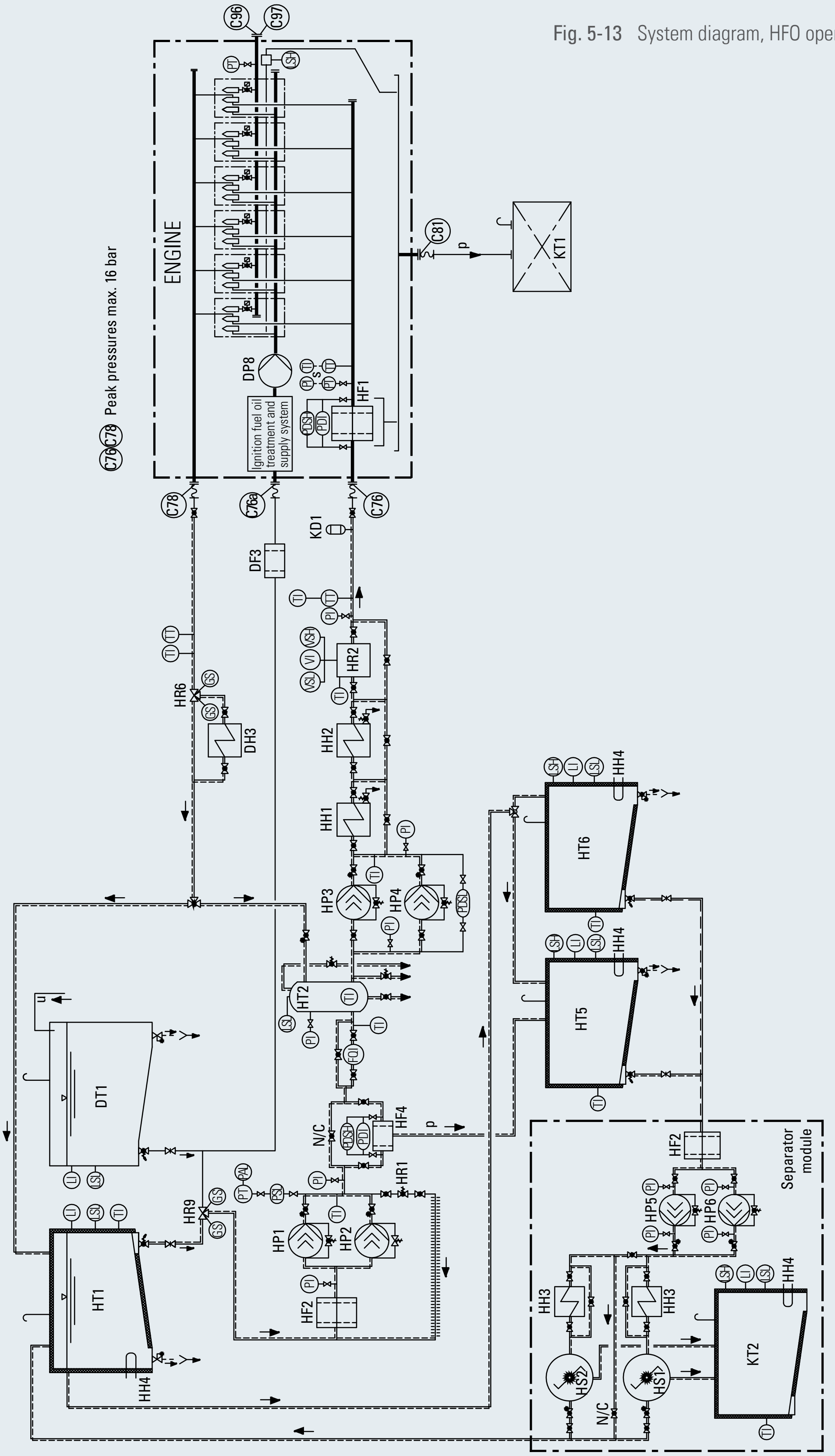
	Designation		CIMAC A10	CIMAC B10	CIMAC C10	CIMAC D15	CIMAC E25	CIMAC F25	CIMAC G35	CIMAC H35	CIMAC K35	CIMAC H45	CIMAC K45	CIMAC H55	CIMAC K55
Characteristic	Related to ISO8217 (05) F-		RMA 30	RMB 30	RMC 30	RMD 80	RME 180	RMF 180	RMG 380	RMH 380	GMK 380	RMH 500	RMK 500	RMH 700	RMK 700
	Dim.	Limit													
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. 5-13 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 admission and return lines.

DH3	Fuel oil cooler for MDO operation
DF3	Fuel coarse filter
DP8	Common rail high pressure pump
DT1	Diesel oil day tank
HF1	Fine filter (duplex filter)
HF2	Primary filter (duplex filter)
HF4	Self cleaning filter
HH1	Heavy fuel final preheater
HH2	Stand-by final preheater
HH3	Heavy fuel preheater (separator)
HH4	Heating coil
HP1	Fuel pressure pump
HP2	Fuel stand-by pressure pump
HP3	Fuel circulating pump
HP4	Stand-by circulating pump
HP5/6	Heavy fuel transfer pump (separator)
HR1	Fuel pressure regulating valve
HR2	Viscosimeter
HR6	Change over valve
HR9	Fuel change over main valve
HS1/2	Heavy fuel separator
HT1	Heavy fuel day tank
HT2	Mixing tank
HT5/6	Settling tank
KD1	Pressure absorber
KP1	Injection pump
KT1	Drip fuel tank
KT2	Sludge tank

All heavy fuel pipes have to be insulated.

- - - - - -	Heated pipe
⦀⦀⦀⦀	Fintube heat exchanger

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

C76	Inlet, duplex filter
C76a	Inlet, pilot fuel
C78	Fuel outlet
C81	Drip-fuel connection
C96	Gas inlet
C97	Flushing connection gas pipe (inertgas)

p	Free outlet required
s	Please refer to the measuring point list regarding design of the monitoring devices
u	Fuel from separator or from transfer pump
uu	Ignition fuel quality requirements only MDO fuel acc. ISO-F-DMA, DMB to be used.

Storage tanks

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

Settling tanks HT5, HT6

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

In order to ensure a sufficient settling effect, the following settling tank designs are permitted:

- 2 settling tanks, each with a capacity sufficient for 24 hours full load operation of all consumers or
- 1 settling tank with a capacity sufficient for 36 hours full load operation of all consumers and automatic filling

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

Heavy fuel preheater (separator) HH3

Heavy fuel oil needs to be heated up to a certain temperature before separating.
The most common heaters on board of ships are steam heaters. Other fluid heating sources are hot water, thermal oil or electrical heaters. Overheating of the fuel may cause fuel cracking. Thus the maximum electric load on the heater element should not exceed 1 Watt/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.

5.3.2 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.

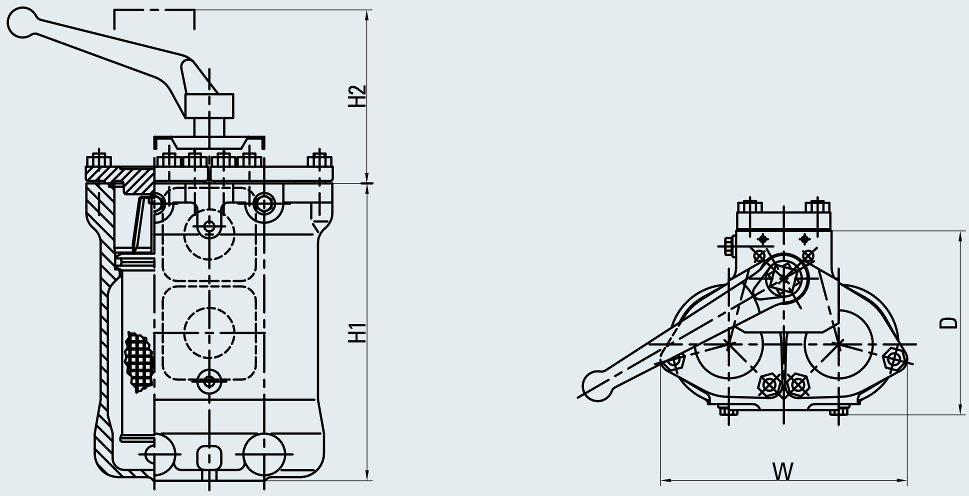


Fig. 5-14 Primary filter HF2

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

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

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

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

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

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

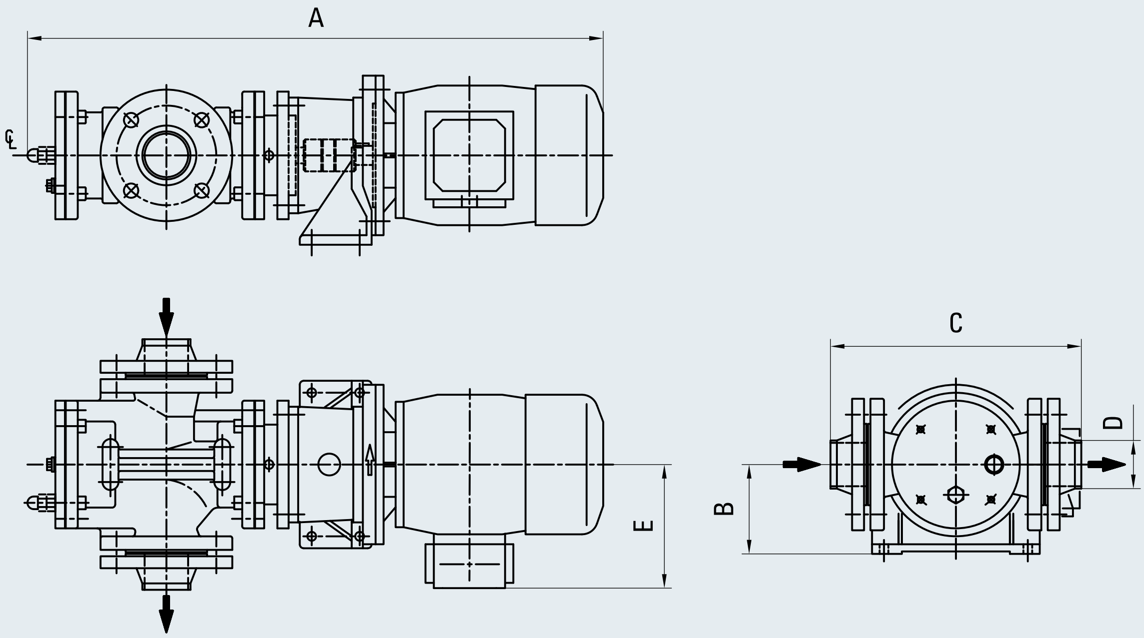


Fig. 5-15 Fuel pressure pump HP1; fuel stand-by pressure pump HP2

Plant output	Dimensions [mm]					Weight	Voltage / frequency
[kW]	A	B	C	D	E	[kg]	[V/Hz]
3,300	650	112	254	42.4	155	42	400/50
4,950 - 6,600	775	132	314	60.3	180	70	400/50
8,800 - 9,900	805	132	314	60.3	180	72	400/50

Plant output	Dimensions [mm]					Weight	Voltage / frequency
[kW]	A	B	C	D	E	[kg]	[V/Hz]
3,300	625	112	254	42.4	155	42	440/60
4,400 - 4,950	705	112	254	42.4	180	57	440/60
6,600 - 9,900	775	132	314	60.3	180	70	440/60

Fuel pressure valve regulating HR1

This valve is installed for adjusting a constant and sufficient pressure at engine fuel inlet. Due to the over-capacity 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.

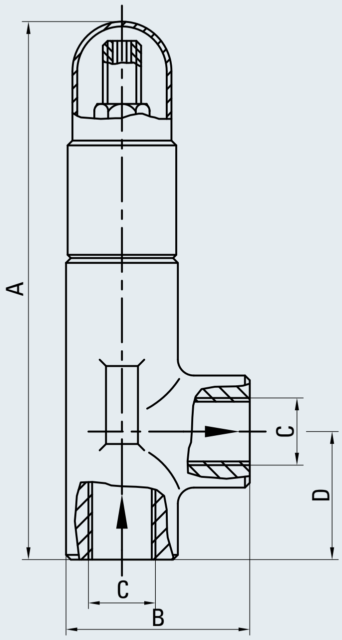


Fig 5-16 Fuel pressure regulating valve HR1, ≤ 3,000 kW

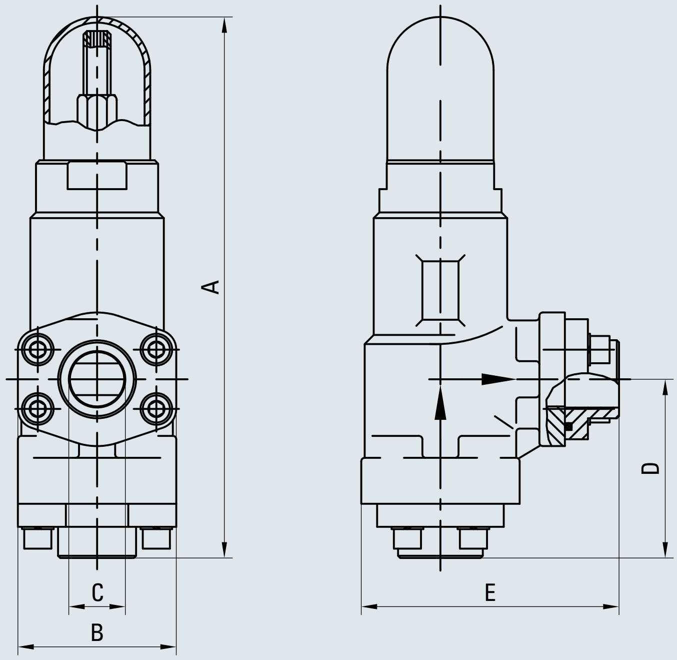


Fig 5-17 Fuel pressure regulating valve HR1, > 3,000 kW

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.

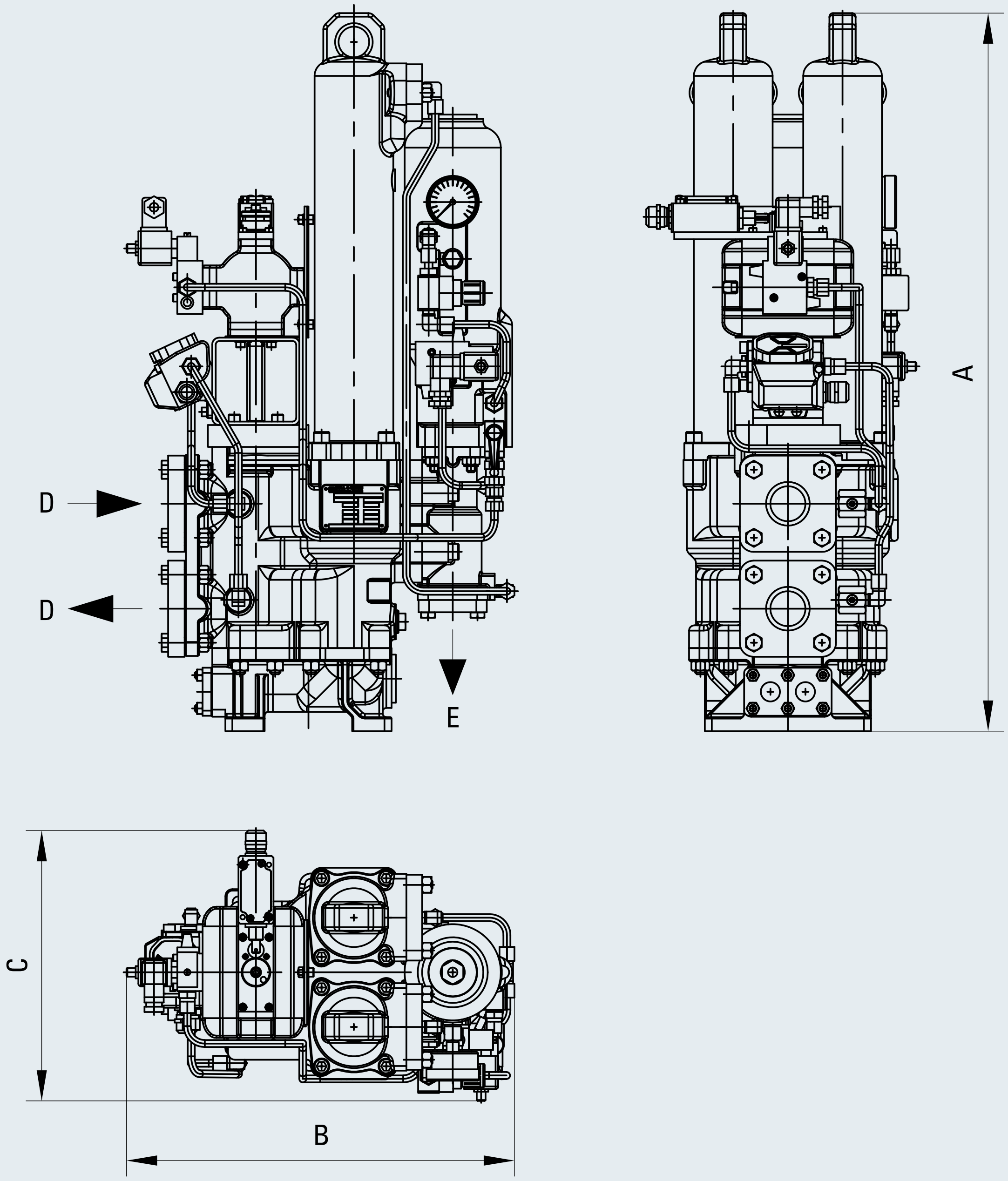


Fig. 5-18 HFO automatic filter HF4

Plant output	Dimensions [mm]				
[kW]	A	B	C	D	E
3,300 - 4,400	825	445	310	DN 40	DN 32
4,950 - 13,200	890	520	335	DN 65	DN 50
14,850 - 19,800	975	590	410	DN 80	DN 65

Flow quantity indicator FQ1

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

Mixing tank HT2

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

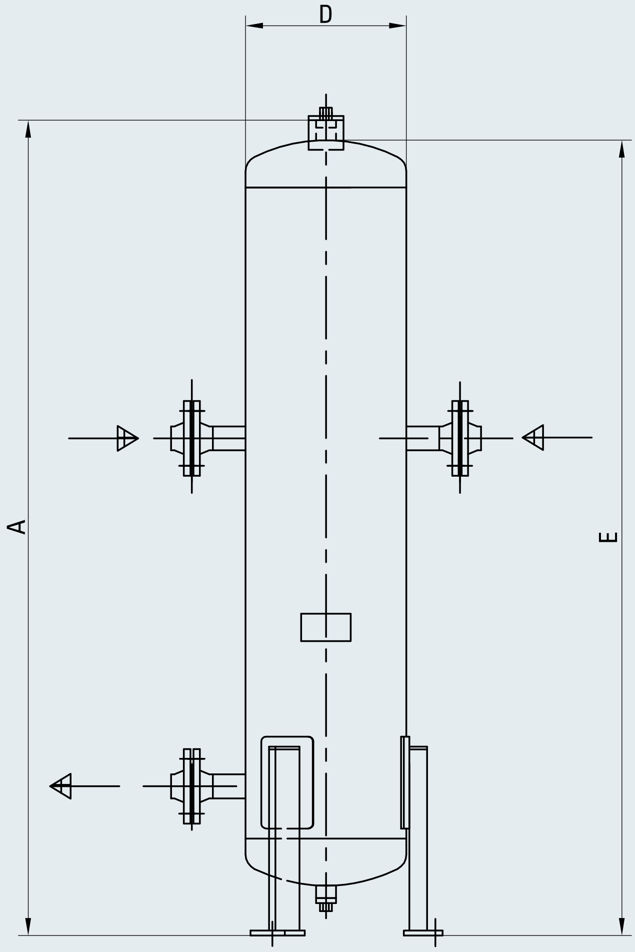


Fig. 5-19 Mixing tank HT2

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

Fuel circulating pump HP3, stand-by circulating pump HP4

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

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

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

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

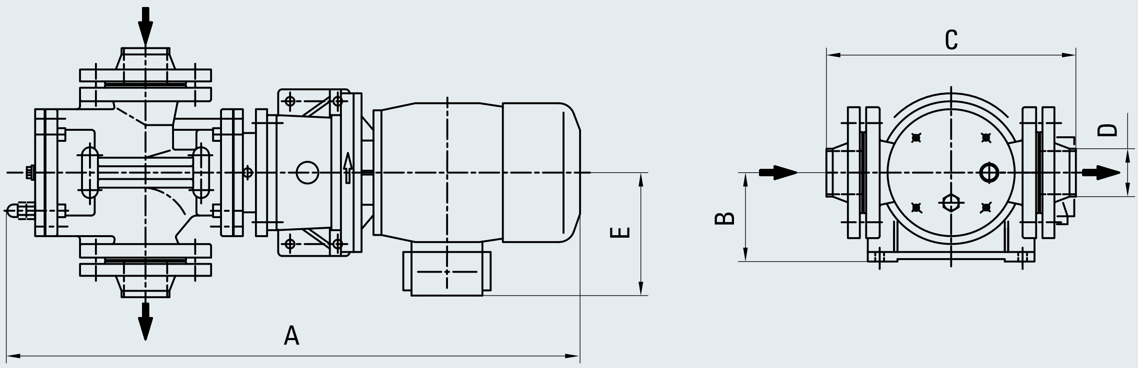


Fig. 5-20 Fuel circulating pump HP3, Stand-by circulating pump HP4

Plant output	Dimensions [mm]					Weight	Voltage / frequency
[kW]	A	B	C	D	E	[kg]	[V/Hz]
3,300	775	132	314	60.3	180	70	400/50
4,400 - 4,950	805	132	314	60.3	180	72	400/50
6,600	820	132	314	60.3	180	80	400/50
8,800 - 9,900	980	160	345	88.9	210	124	400/50

Plant output	Dimensions [mm]					Weight	Voltage / frequency
[kW]	A	B	C	D	E	[kg]	[V/Hz]
3,300 - 4,400	775	132	314	60.3	180	70	440/60
4,950 - 6,600	805	132	314	60.3	180	72	440/60
8,800 - 9,900	820	132	314	60.3	190	80	440/60

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

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

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

Heating media:

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

Temperature at engine inlet max. 150 °C

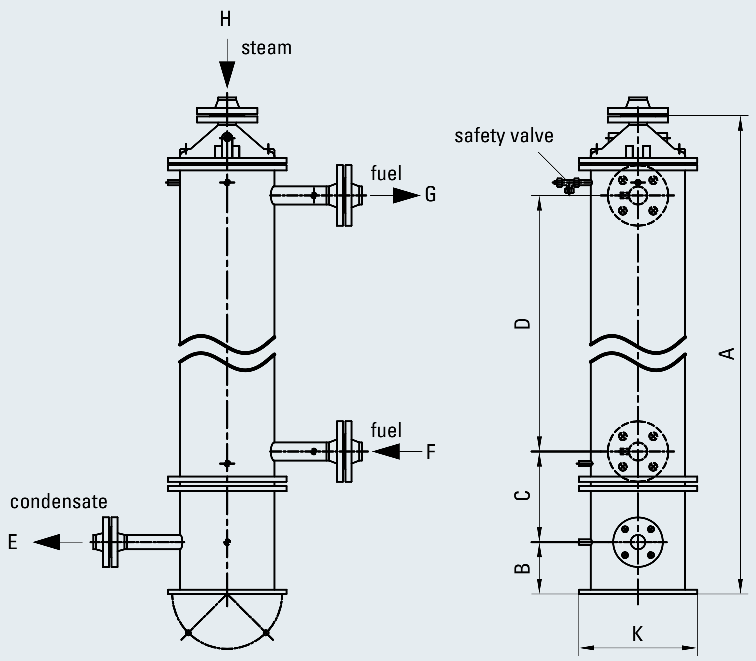


Fig. 5-21 Heavy fuel final preheater HH1, stand-by final preheater HH2 (steam heated)

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

Viscosimeter HR2

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

Pressure absorber KD1 (optional)

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

Bypass overflow valve HV (optional)

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

Duplex filter HF1 (fitted)

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

Fuel oil cooler DH3

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

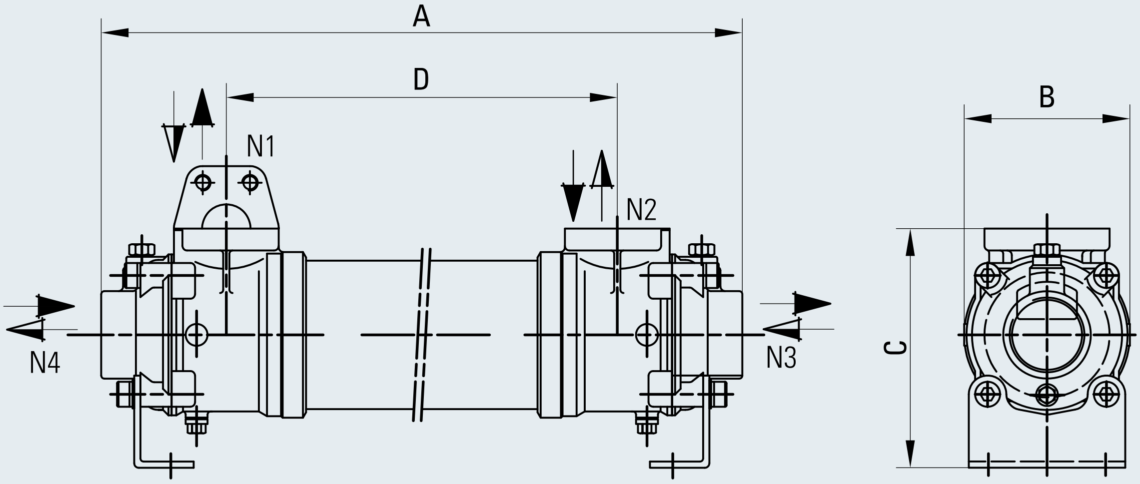


Fig. 5-22 Fuel oil cooler for MDO operation DH3

Engine	Dimensions [mm]						Weight
	A	B	C	D	N1 + N2	N3 + N4	[kg]
6/8/9 M 34 DF	910	106	153	750	1 ¼" SAE	1 ½" SAE	19

5.3.3 Fuel booster and supply module

A complete fuel conditioning module, designed for HFO up to 700 cSt / 50 °C, can be supplied.
Caterpillar Motoren standard modules consist of the following components:

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

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

Module controlled automatically with alarms and starters

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

Alarms

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

Size, weight and dimensions

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

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

Fuel oil standard module

Engine	Module size [mm]	Module weight [kg]
6 M 34 DF	2,800 x 1,200 x 2,100	1,800
8 M 34 DF	3,000 x 1,200 x 2,100	2,200
9 M 34 DF	3,200 x 1,300 x 2,100	2,700

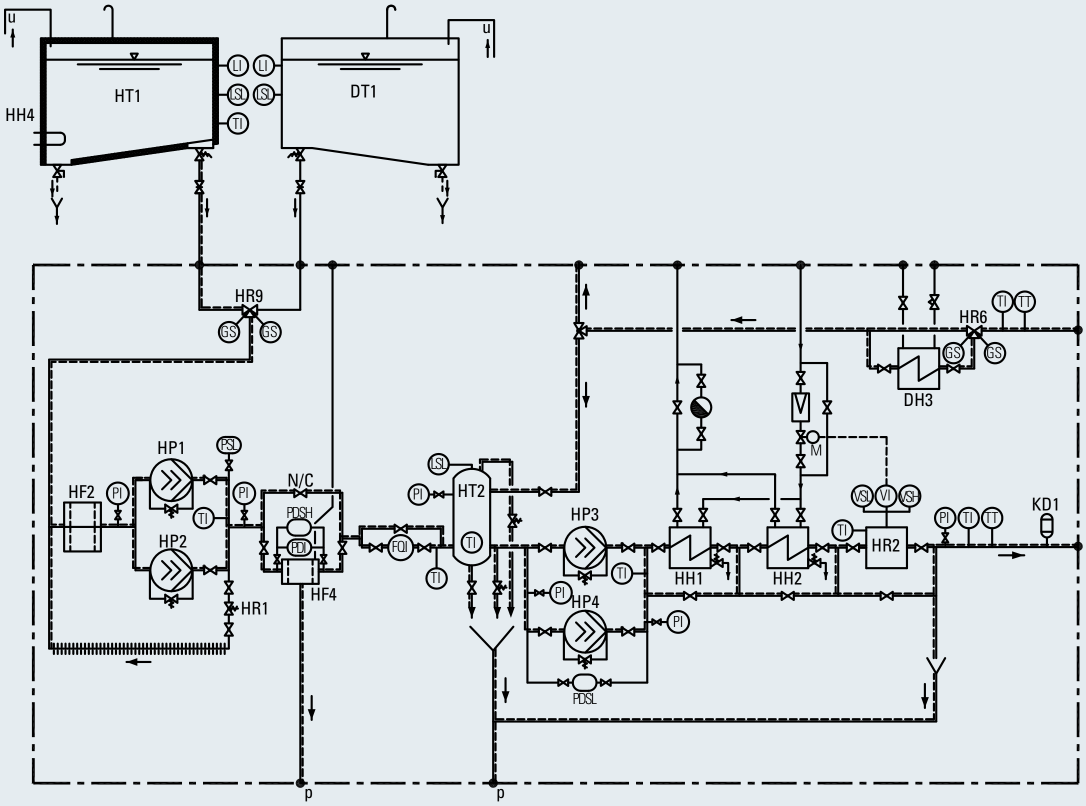


Fig. 5-23 Fuel booster and supply module, system diagram

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

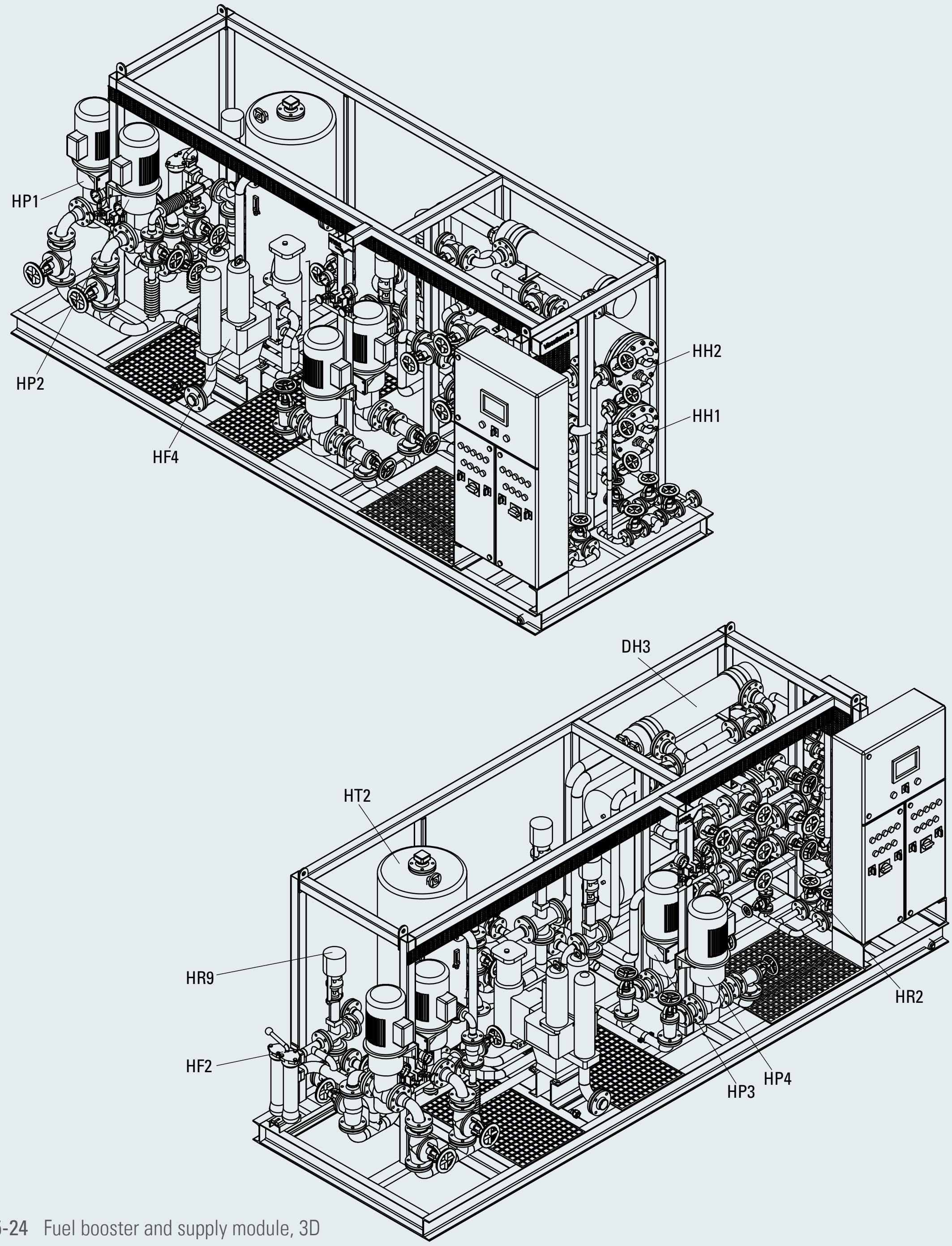


Fig. 5-24 Fuel booster and supply module, 3D

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

5.4 Switching over from HFO to diesel oil

Continuous operation with HFO is recommended for engines designed for running mainly on HFO.
Starting and stopping the engine on HFO (Pier to Pier) can be provided if a sufficient preheating of the fuel oil system is ensured.
The circulating pumps have to be permanently in service, so that a continuous circulation of warm/hot fuel oil through the engine is ensured.

A frequent change over from HFO to diesel oil is only recommended when necessary for flushing purposes, emergencies, special sea area emission requirements, etc.

Changing the fuel oil too quickly and too often may cause high risk of plunger seizure (thermal shock), fuel injection pump leakages, etc. in the fuel injection pump.
Only a slow switch over will attenuate that effect.

Typical switch over characteristics (HFO to diesel)

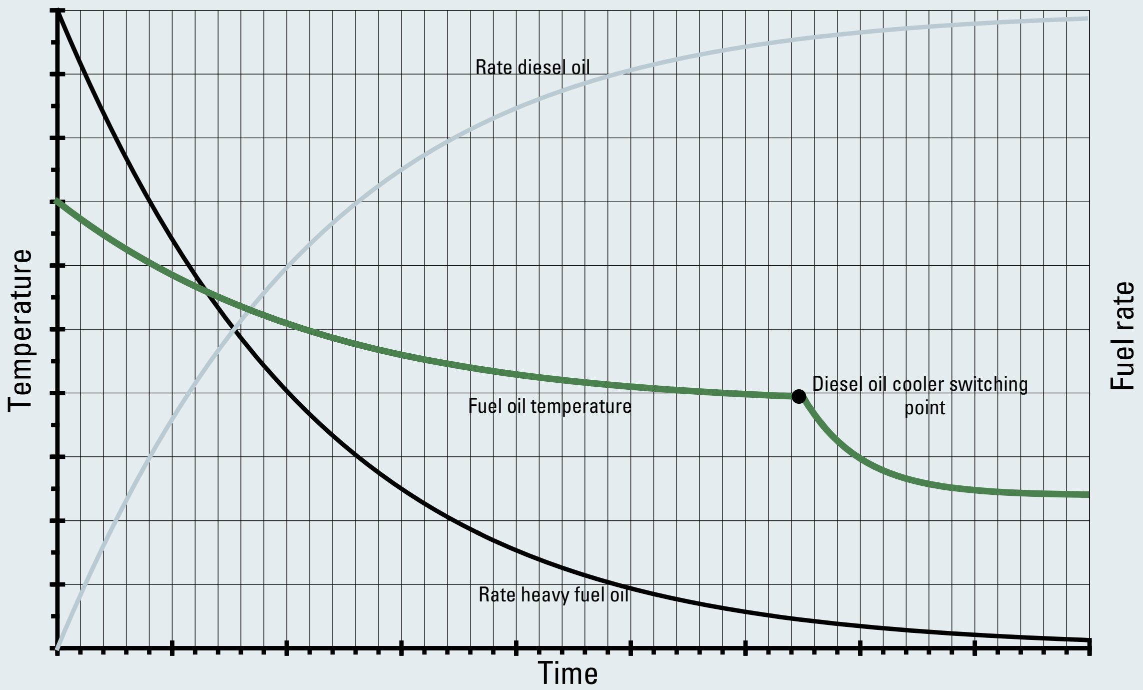


Fig 5-25 Switch over characteristics

6.1 General

The gas fuel system will be provided from the Gas Valve Unit (GVU) to the engine acc. to the Caterpillar gas fuel specification VD8768 for dual fuel engines.

The key features of the gas system are:
- Double walled designed
- With leak detection
- Double wall is separated in sections
- Optional leakage location system available

6.1.1 Gas fuel quality requirements

Gas fuel to be complied with the Caterpillar gas fuel specification VD8768 for dual fuel engines.

Gas specification M 34 DF		
Gas temperature before engine inlet	°C	0 - 60
Gas pressure before GVU without flow meter	bar (g)	6 - 10
Gas pressure before GVU with flow meter	bar (g)	6.5 - 10
Maximum gas pressure fluctuation	mbar/s	+/- 80
Maximum rate for gas pressure changes	bar/min	1
Minimum lower heating value (LHV)	MJ/mn³	28
Minimum Methane number (MN) (rated output)	-	80
Maximum Sulphur as H_2S	Vol %	0.05 (= 770 mg/mn³)
Maximum Ammonia (NH_4)	mg/mn³	25
Maximum Fluorines	mg/mn³	Σ = 50
Maximum Chlorine	mg/mn³	Σ = 50
Maximum oil content	mg/mn³	50
Maximum particles content	mg/mn³	50
Maximum particle size	µm	5
Maximum Tar content	mg/mn³	10
Maximum Silicium	mg/mn³	10
Maximum water		Saturated fuel or water and condensates at gas control unit are not allowed

6.1.2 System diagram

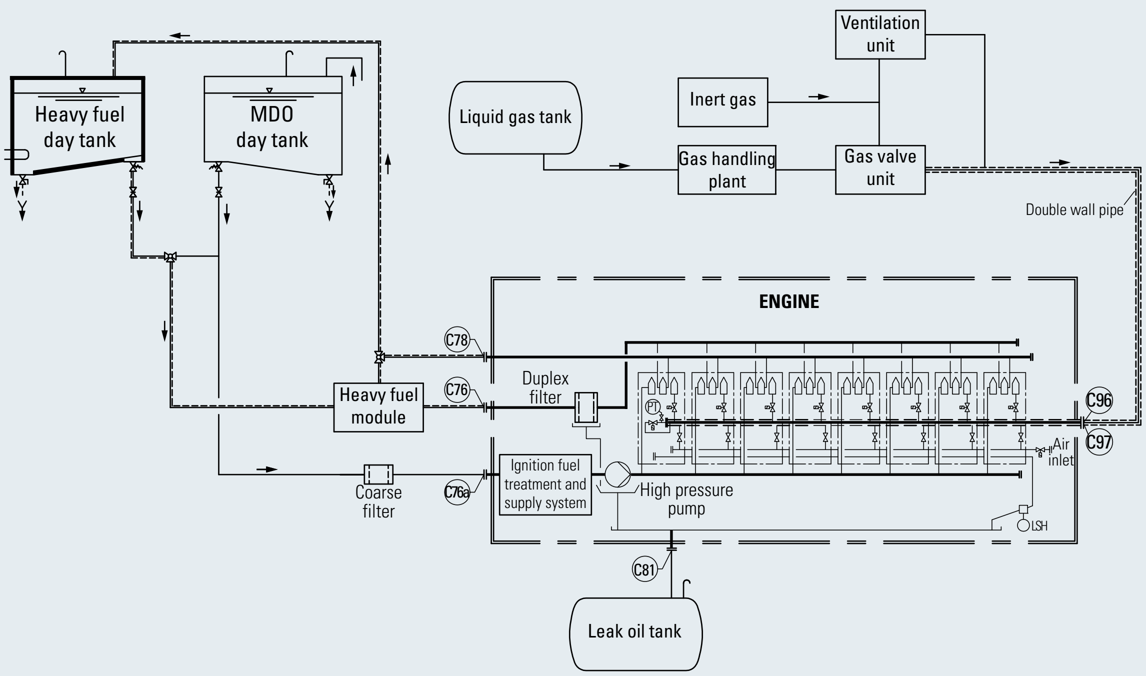


Fig. 6-1 Gas system diagram

C76	Inlet, duplex filter	C81b	Drip fuel connection, filter pan
C76a	Inlet, pilot fuel	C81e	Drip fuel connection, pilot fuel
C78	Fuel outlet	C96	Gas inlet
C81	Drip fuel connection	C97	Flushing connection gas pipe (inert gas)

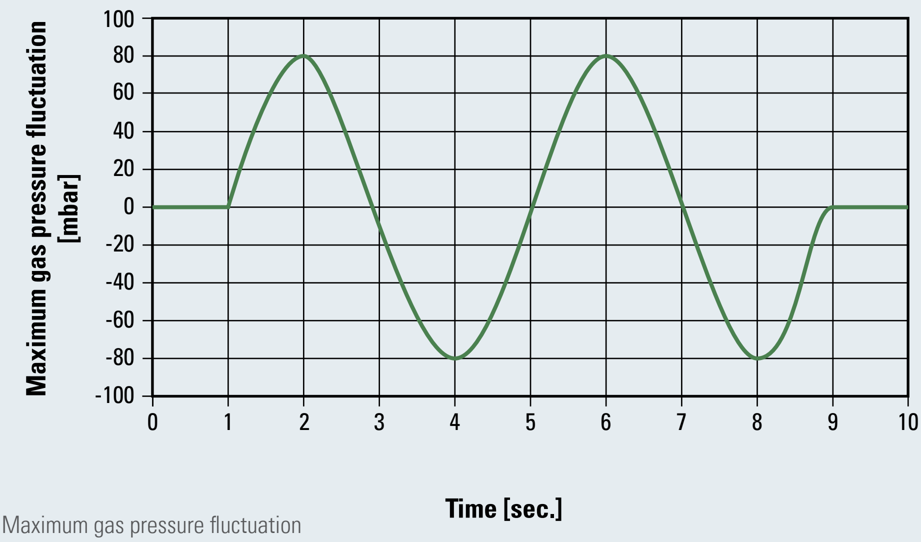


Fig. 6-2 Maximum gas pressure fluctuation

6.1.3 Gas system components

Gas admission valve

A gas admission valve is necessary ti introduce the fuel gas acc. to the engine load demand. The gas admission valve is solenoid activated.

The key features of the gas admission valve are:

- Gas tight cable outlet
- Solenoid activated
- Gas valve is normally closed

Weight: 3.7 kg

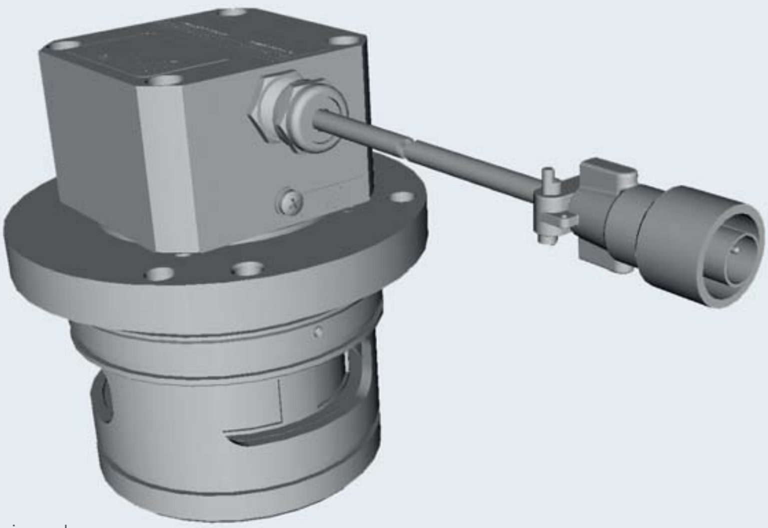


Fig. 6-3 Gas admission valve

Gas Valve Unit (GVU)

The gas valve unit is an off-engine component. It provides fuel gas to the engine with the required pressure and flow. It shuts off the gas supply to the engine while not operating on gas. It depressurizes the gas piping between GVU and engine. Control air is being used to switch the valves. GVU is single walled designed and need to be installed in an ESD compliant machinery space.
The GVU is optionally available with a gas fuel flow meter.

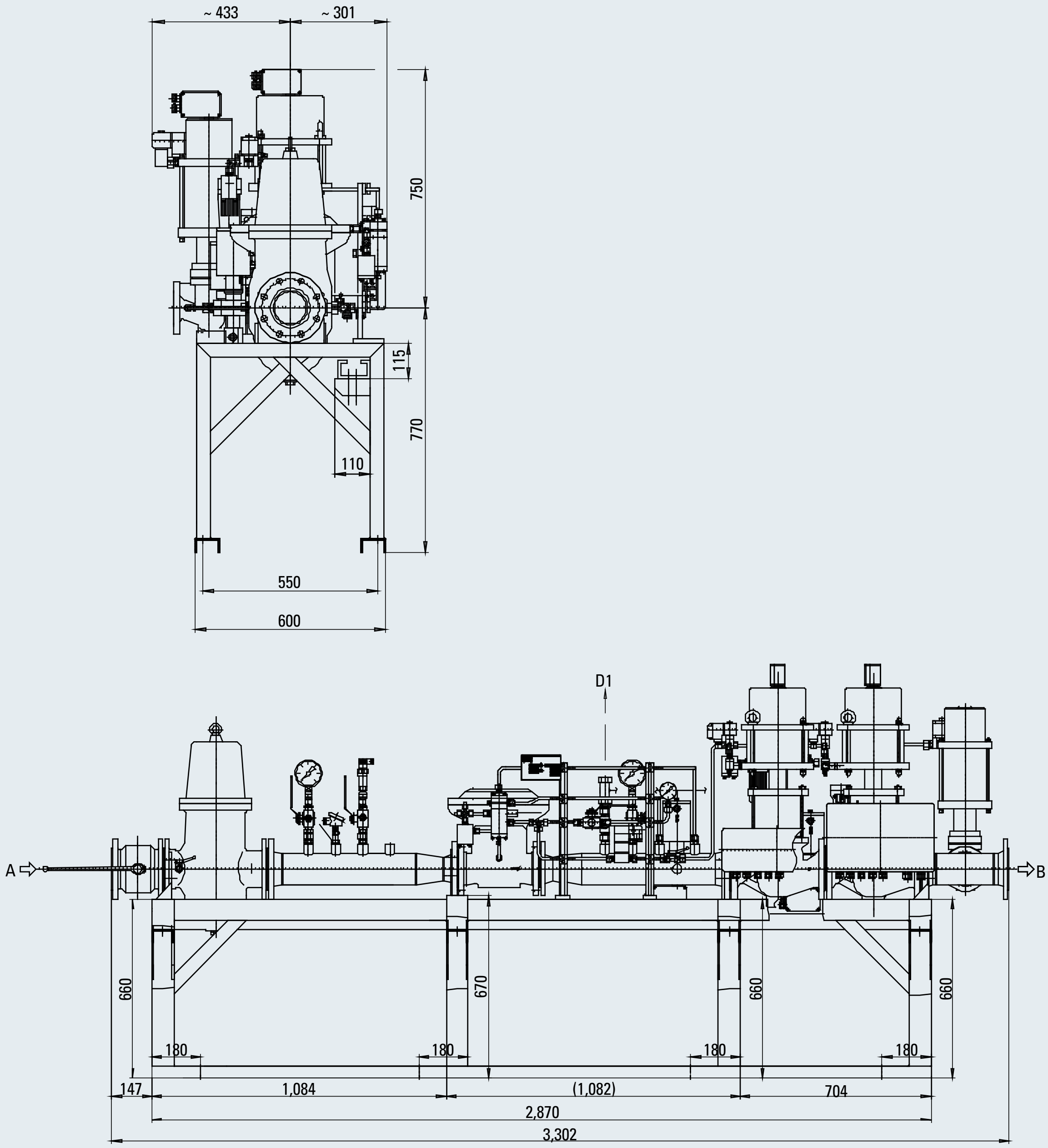


Fig. 6-4 Gas valve unit

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.

7.1 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 30 KOH/g at HFO operation
  The TBN is 12 - 20 KOH/g for MDO operation depending on Sulfur content

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

7.2 Internal lube oil system

General

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

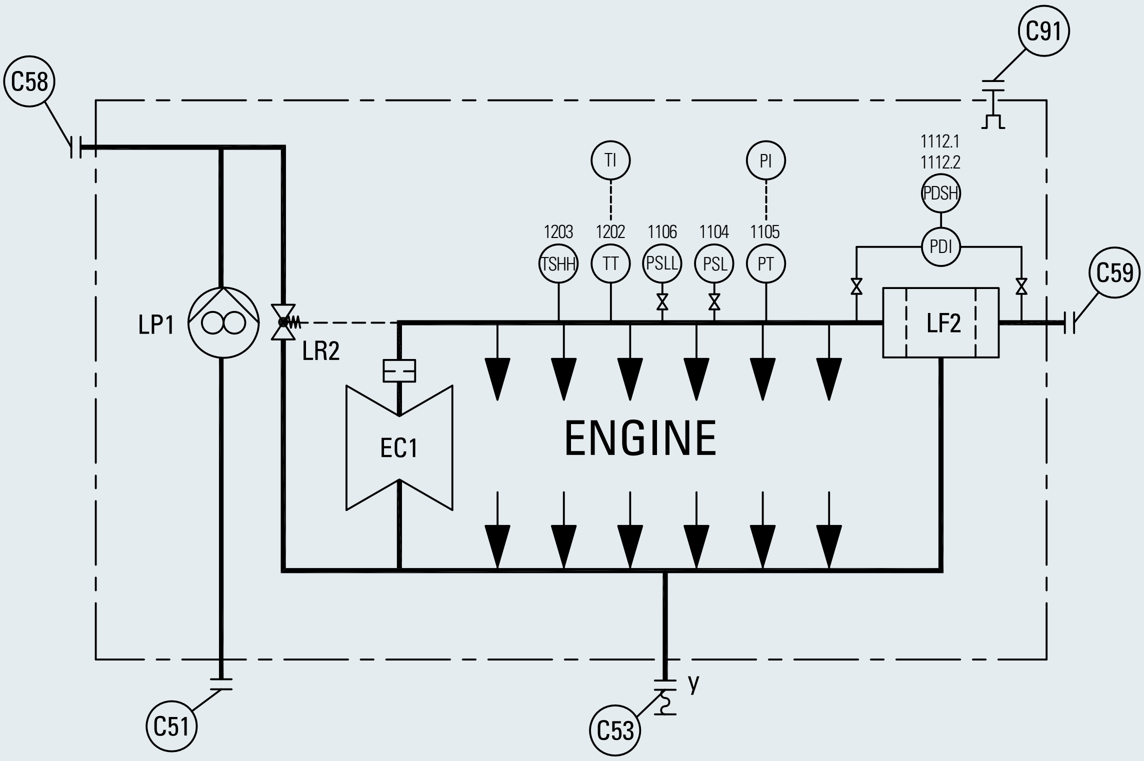


Fig. 7-1 Internal lube oil system, system diagram

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.

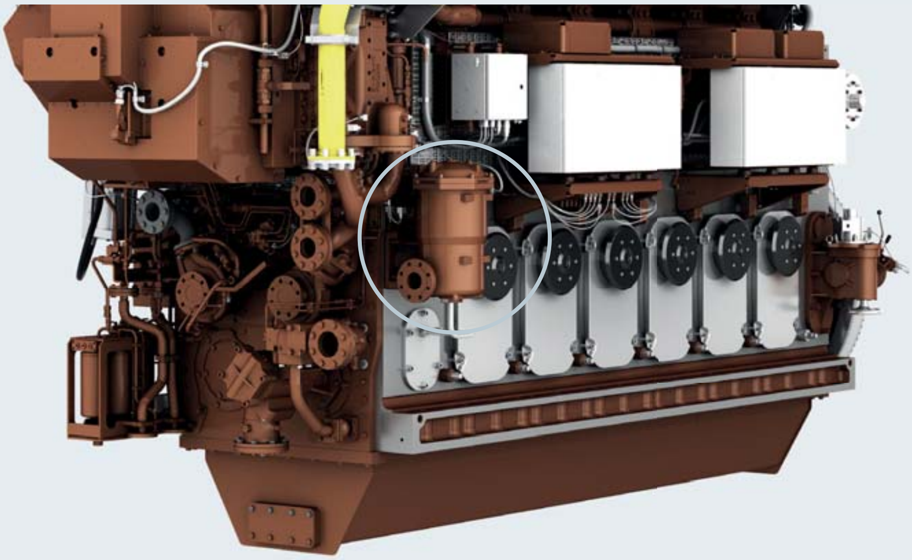


Fig. 7-2 Self-cleaning lube oil filter LF2

Back flushing filter LF2 (separate), option

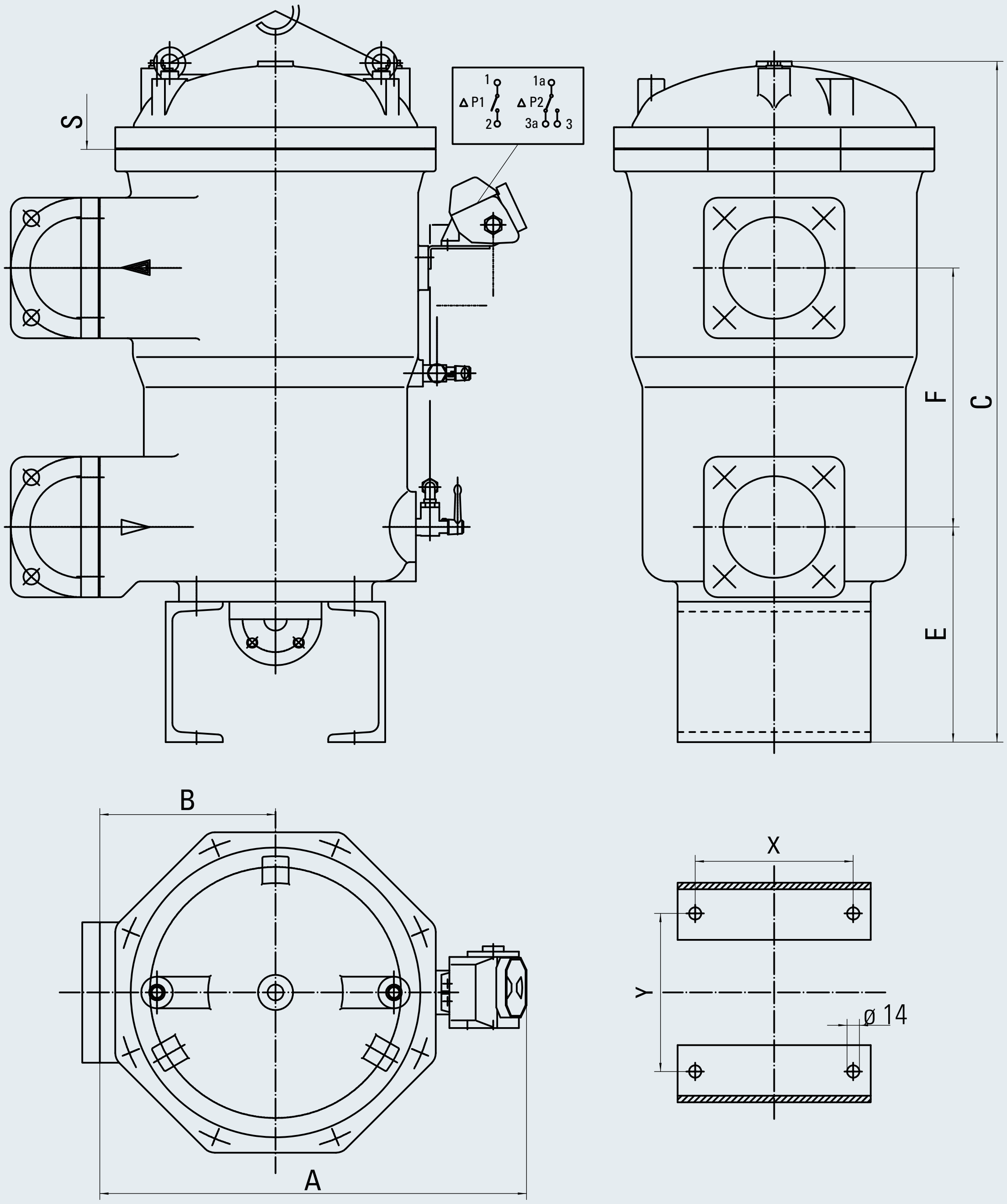


Fig. 7-3 Back flushing filter LF2

	Dimensions [mm]								Weight
	A	B	C	E	F	S	X	Y	[kg]
6/8/9 M 34 DF	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.

7.3 External lube oil system

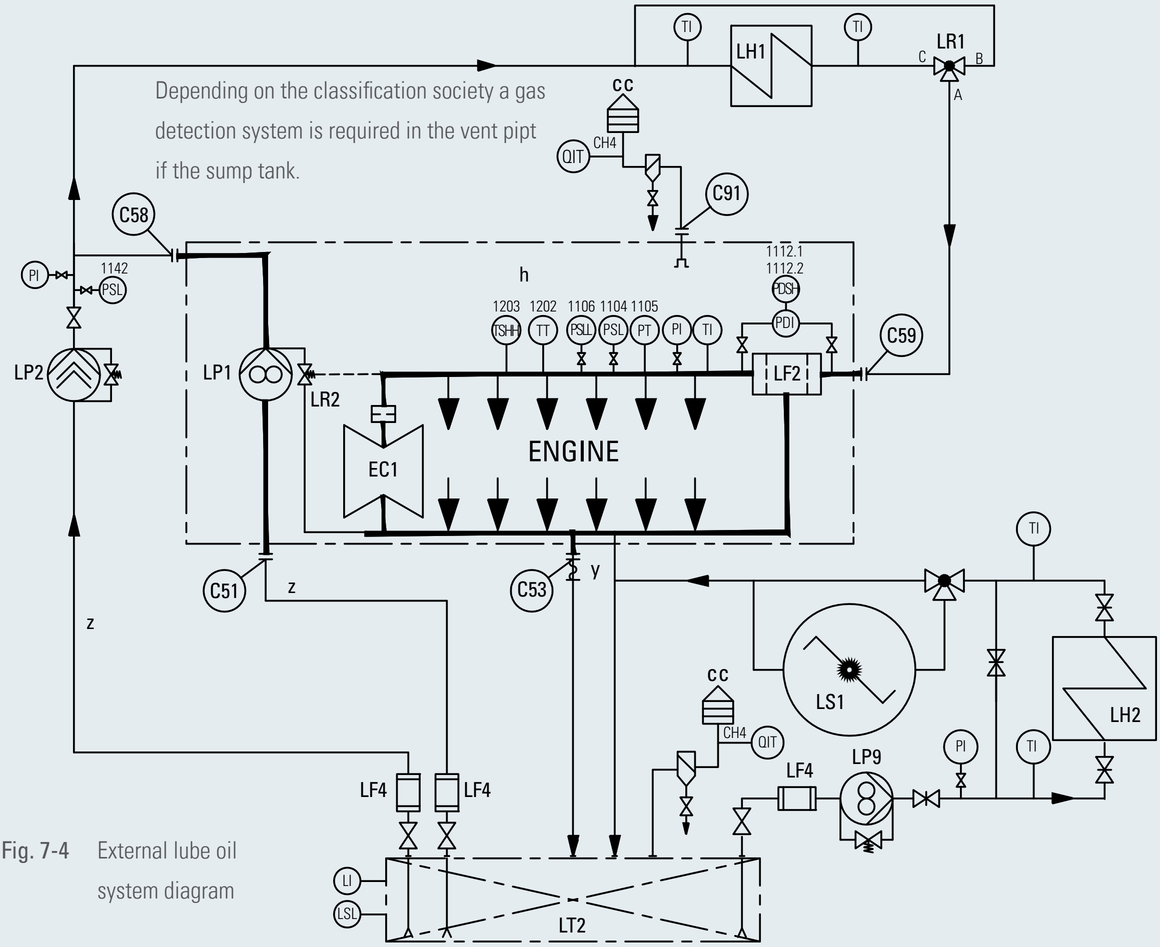


Fig. 7-4 External lube oil system diagram

EC1	Exhaust gas turbocharger	PT	Pressure transmitter
LF2	Self-cleaning lube oil filter	QIT	Gas indicator and transmitter
LF4	Suction strainer	TI	Temperature indicator
LH1	Lube oil cooler	TSHH	Temperature switch high high
LH2	Lube oil preheater	TT	Temperature transmitter (PT100)
LP1	Lube oil force pump		
LP2	Lube oil stand-by force pump	C51	Force pump, suction side
LP9	Transfer pump (separator)	C53	Lube oil discharge
LR1	Lube oil temperature control valve	C58	Force pump, delivery side
LR2	Oil pressure regulating valve	C59	Lube oil inlet, lube oil cooler
LS1	Lube oil separator	C91	Crankcase ventilation to stack
LT2	Oil pan		
LI	Level indicator	cc	Flame arrestor must be provided
LSL	Level switch low	h	Please refer to the measuring point list
PDI	Diff. pressure indicator		regarding design of the monitoring devices.
PDSH	Diff. pressure switch high	y	Provide an expansion joint
PI	Pressure indicator	z	Max. suction pressure - 0.4 bar
PSL/PSLL	Pressure switch low		

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.

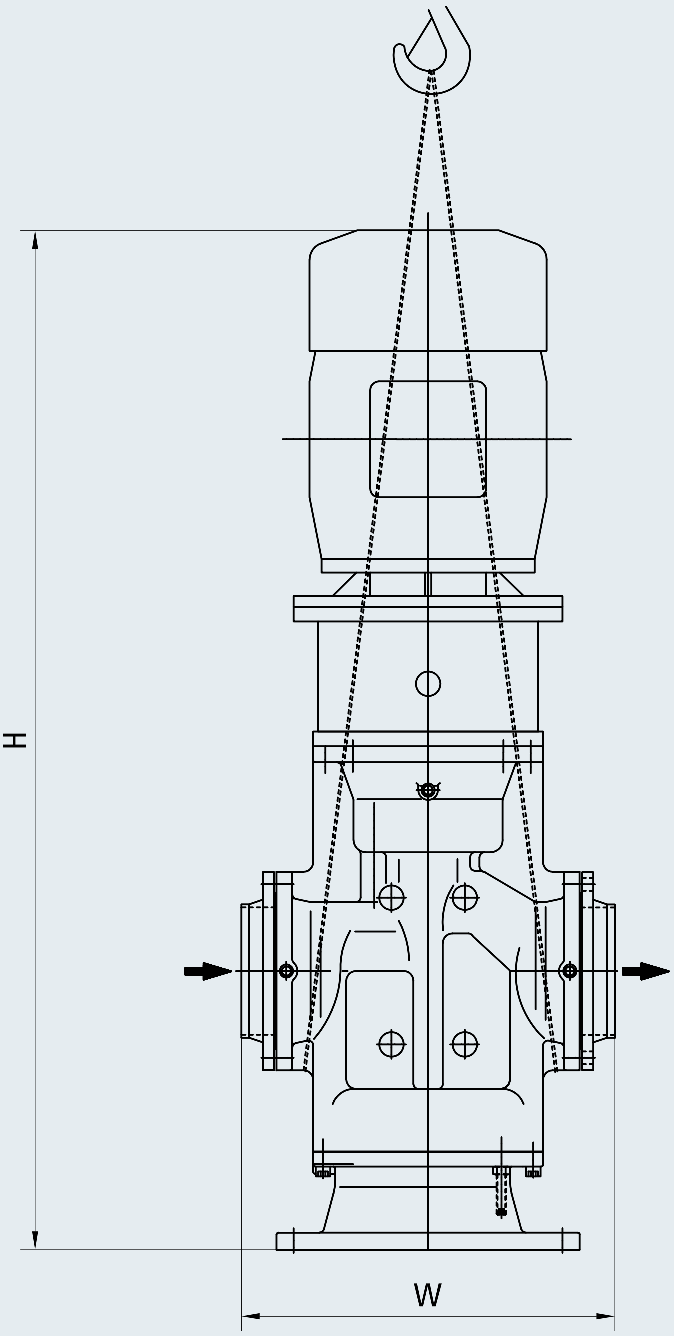


Fig. 7-5 Lube oil stand-by force pump LP2

		Capacity [m³/h]	Motor power [kW]	W [mm]	H [mm]	Weight [kg]
6 M 34 DF	400 V / 50 Hz	70	37	628	1,773	701
	440 V / 60 Hz	70	36	628	1,728	588
8/9 M 34 DF	400 V / 50 Hz	90	45	764	2,015	786
	440 V / 60 Hz	90	45	764	1,773	601

Prelubricating pump LP5 (separate)

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

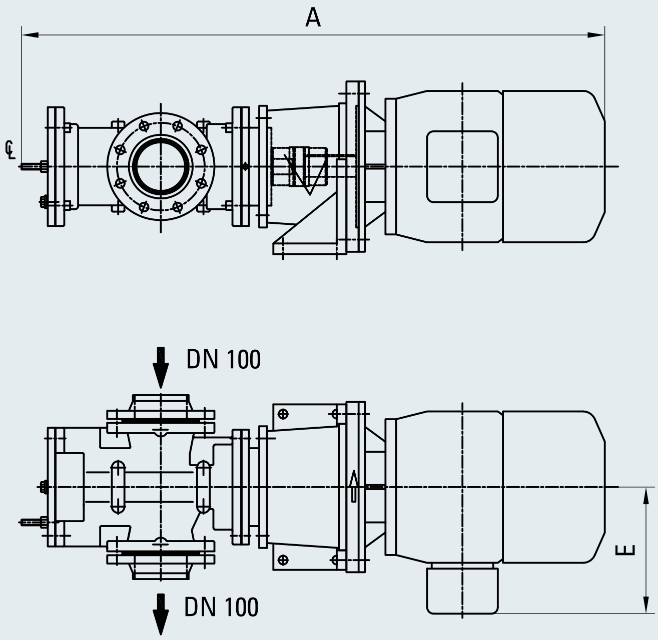


Fig. 7-6 Prelubricating pump LP5

	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.

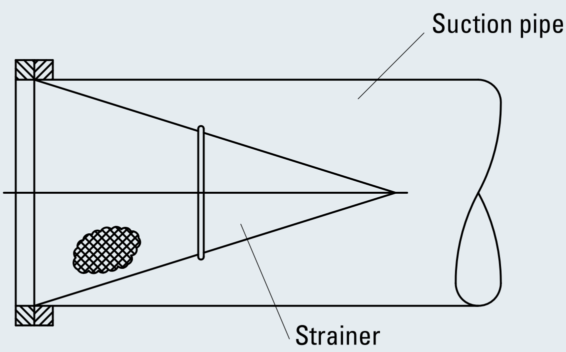


Fig. 7-7 Suction strainer LF4

Oil pressure regulating valve LR2 (fitted)

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

Lube oil cooler LH1 (separate)

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

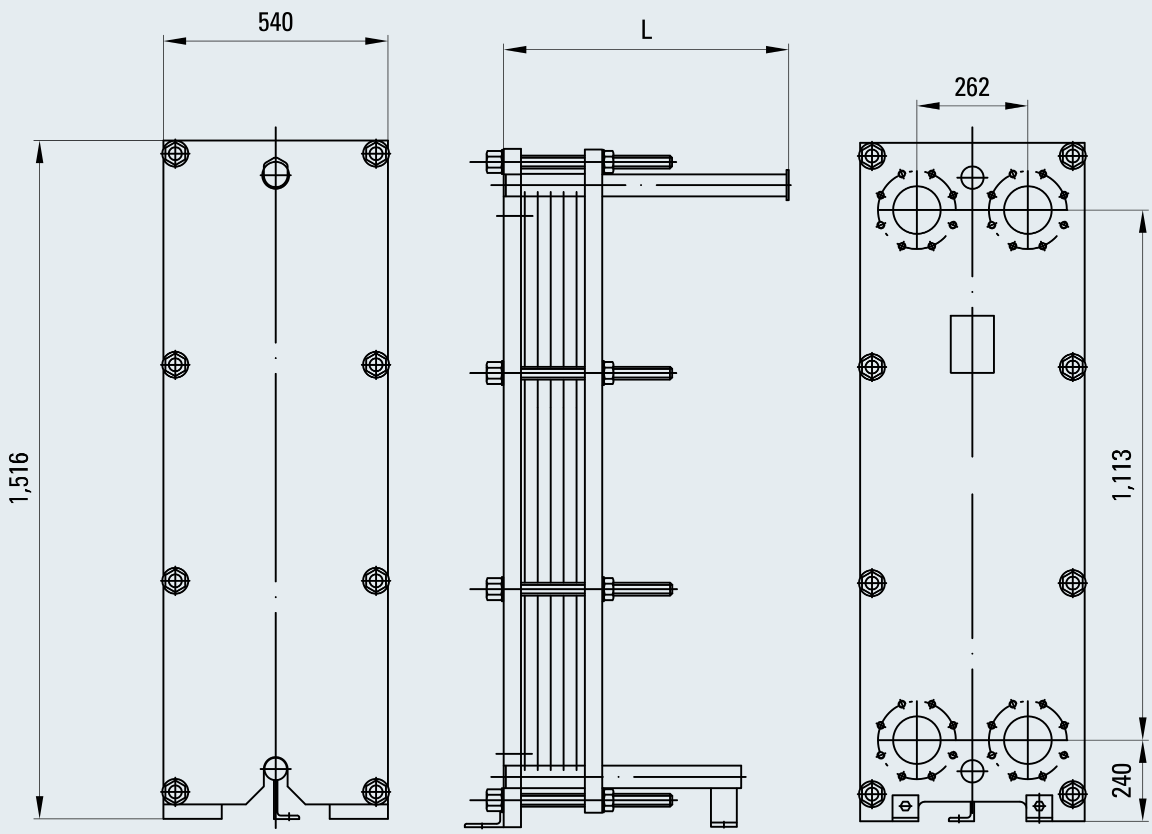


Fig. 7-8 Lube oil cooler LH1

	L	Weight
	[mm]	[kg]
6 M 34 DF	545	638
8 M 34 DF	765	692
9 M 34 DF	765	711

Lube oil temperature control valve LR1 (fitted)

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

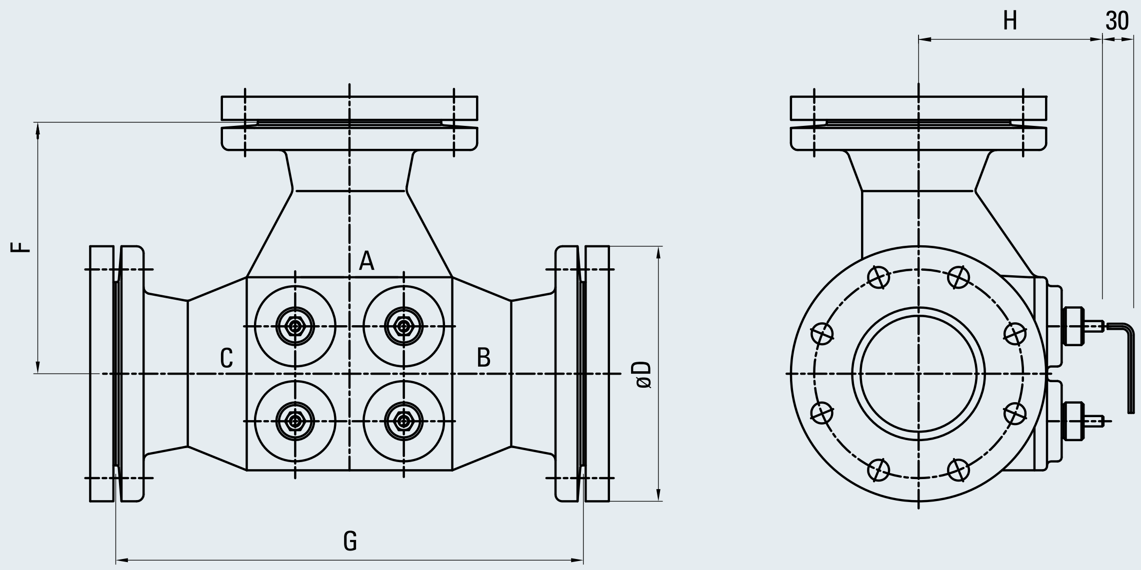


Fig. 7-9 Lube oil temperature control valve LR1

	Dimensions [mm]					Weight
	DN	D	F	G	H	[kg]
6 M 34 DF	80	200	171	267	151	27
8/9 M 34 DF	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

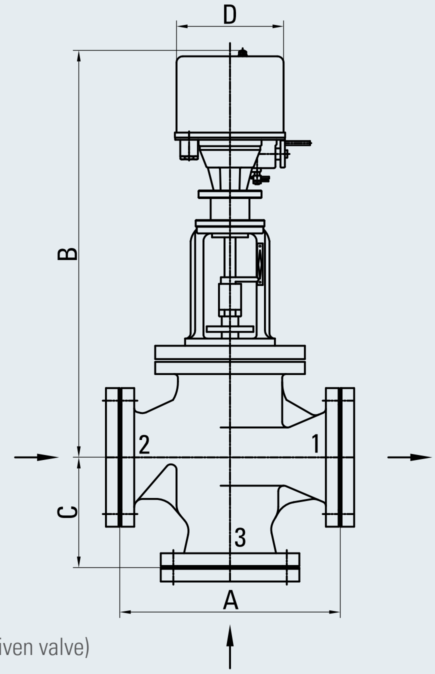


Fig. 7-10 Lube oil temperature control valve LR1 (electric driven valve)

	Dimensions [mm]					Weight
	DN	A	B	C	D	[kg]
6 M 34 DF	80	310	624	155	170	58
8/9 M 34 DF	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 and gas operation

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

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

Layout for HFO and gas operation

Automatic self-cleaning separator; Operating temperature 95 °C

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

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

Lube oil system with wet sump

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

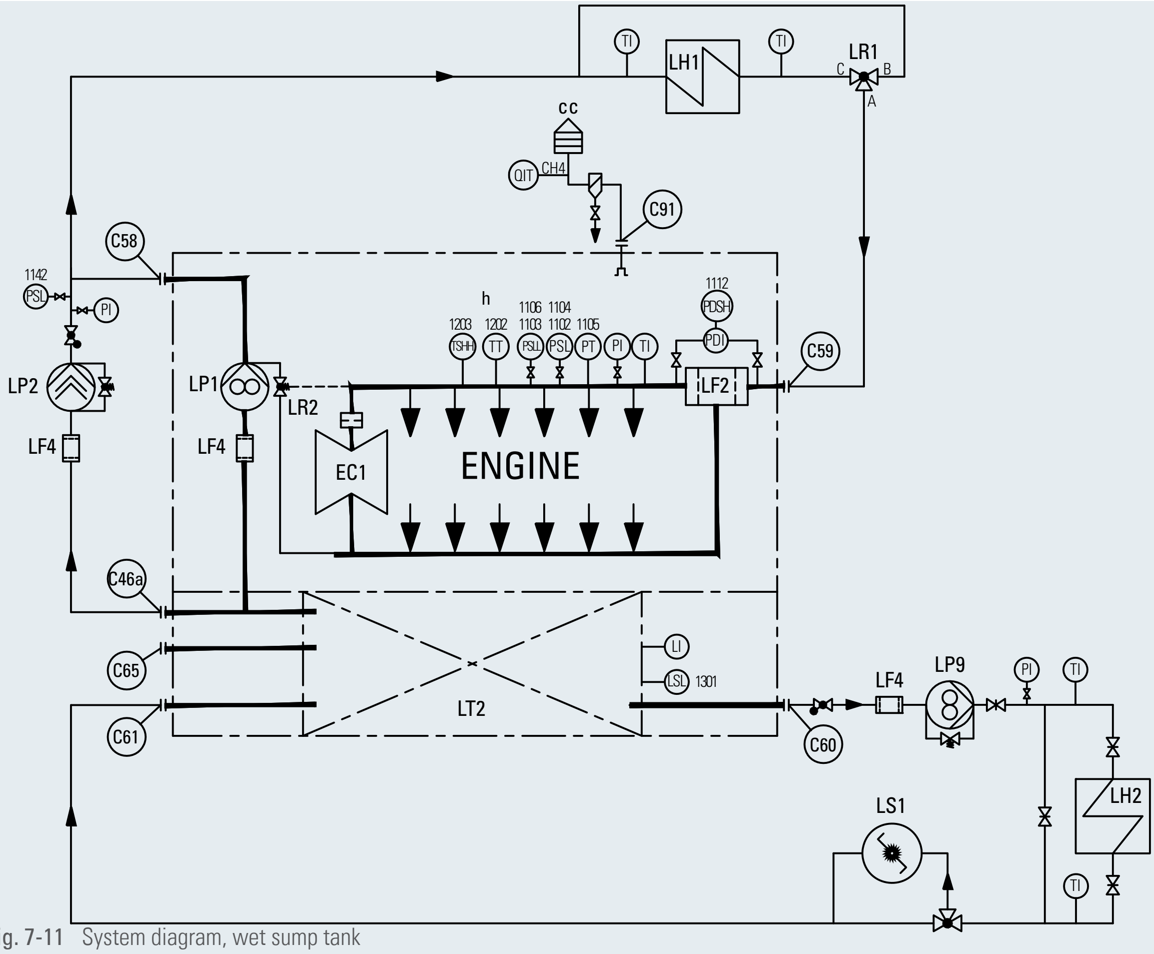


Fig. 7-11 System diagram, wet sump tank

EC1	Exhaust gas turbocharger
LF2	Self-cleaning lube oil filter
LF4	Suction strainer
LH1	Lube oil cooler
LH2	Lube oil preheater
LP1	Lube oil force pump
LP2	Lube oil stand-by force pump
LP9	Transfer pump (separator)
LR1	Lube oil temperature control valve
LR2	Oil pressure regulating valve
LS1	Lube oil separator
LT2	Oil pan
LI	Level indicator
LSL	Level switch low
PDI	Diff. pressure indicator
PDSH	Diff. pressure switch high
PI	Pressure indicator
PSL/ PSLL	Pressure switch low
PT	Pressure transmitter
QIT	Gas indicator and transmitter
TI	Temperature indicator
TSHH	Temperature switch high high
TT	Temperature transmitter
C46a	Stand-by force pump, suction side
C58	Force pump, delivery side
C59	Lube oil inlet, luber oil cooler
C60	Stand-by pump HT, inlet
C61	Separator connection, delivery side
C65	Lube oil filling socket
C91	Crankcase ventilation to stack
cc	Flame arrestor must be provided
h	Please refer to the measuring point list regarding design of the monitoring devices

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.

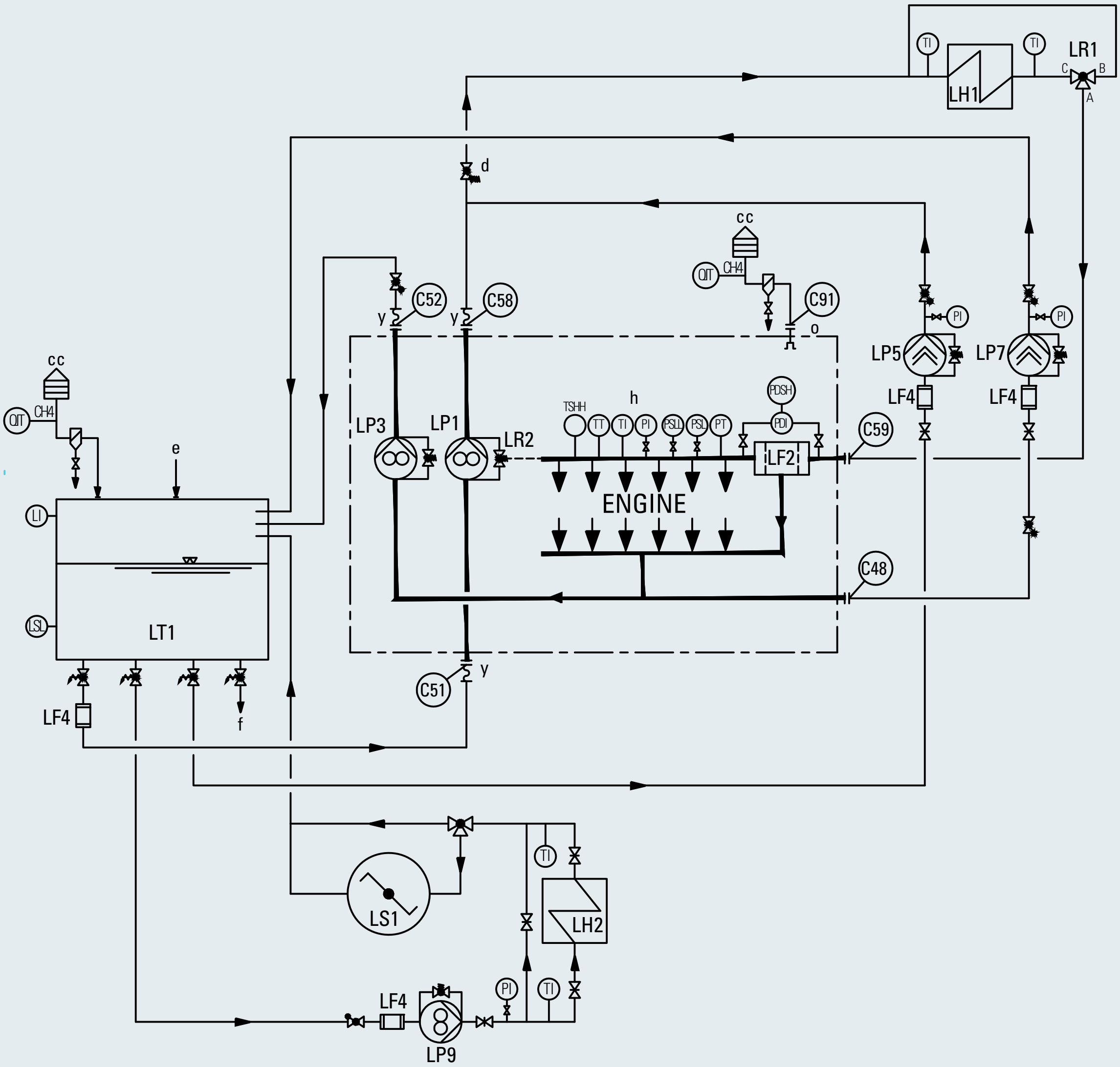


Fig. 7-12 System diagram, high level tank

LF2	Lube oil automatic 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

cc	Flame arrestor must be provided
d	Opening pressure 1.0 bar
e	Filling pipe
f	Drain
h	Please refer to the measuring point list regarding design of the monitoring devices
o	See "crankcase ventilation installation - instructions" 4-A-9570
y	Provide an expansation joint

Depending on the classification society a gas detection system is required in the vent pipt if the sump tank.

7.4 Circulating tanks and components

7.4.1 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.

7.4.2 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.

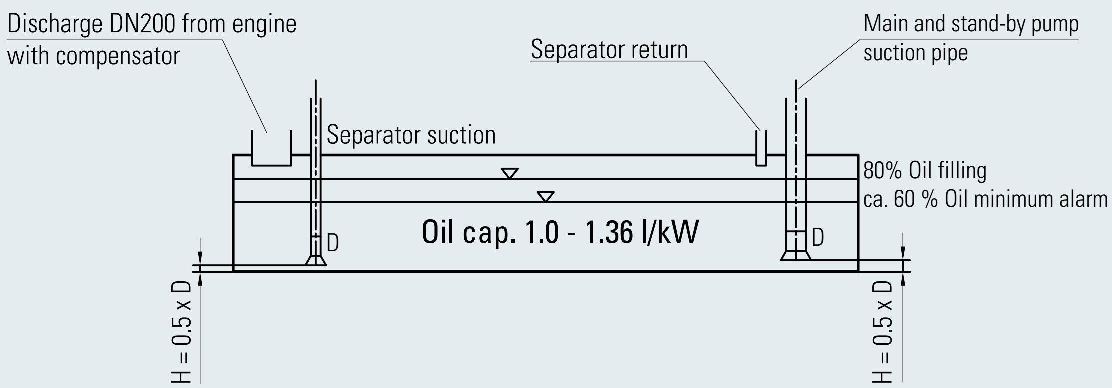


Fig. 7-13 Sump tank LT1

7.5 Crankcase ventilation system

7.5.1 Crankcase ventilation pipe dimensions

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

7.5.2 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.

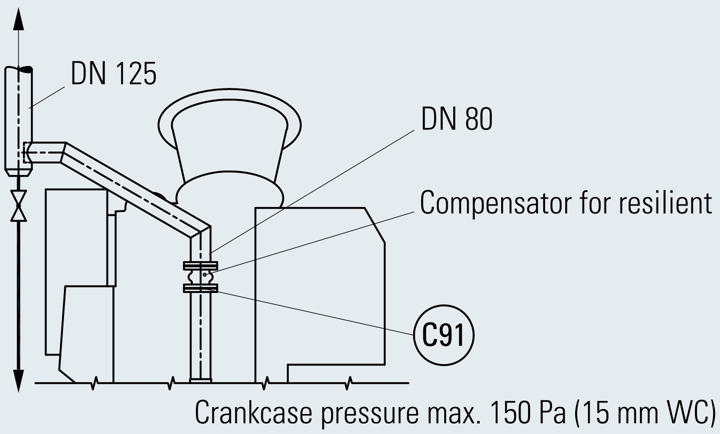


Fig. 7-14 Crankcase ventilation

C91 Crankcase ventilation to stack

7.5.3 Gas detection sensor

A gas detection sensor has to be installed in the crankcase vent pipe.

7.6 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.

8.1 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.

8.1.1 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.

8.1.2 Secondary circuit cooling system

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

8.2 Water quality requirements

8.2.1 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.

8.2.2 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

8.2.3 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.

8.2.4 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.

8.3 Recommendation for cooling water system

8.3.1 Pipes and tanks

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

8.3.2 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).

8.3.3 Electric motor driven pumps

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

Rough calculation of power demand for the electric balance:

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

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

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

8.4 Cooling water system

8.4.1 General

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

8.4.2 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

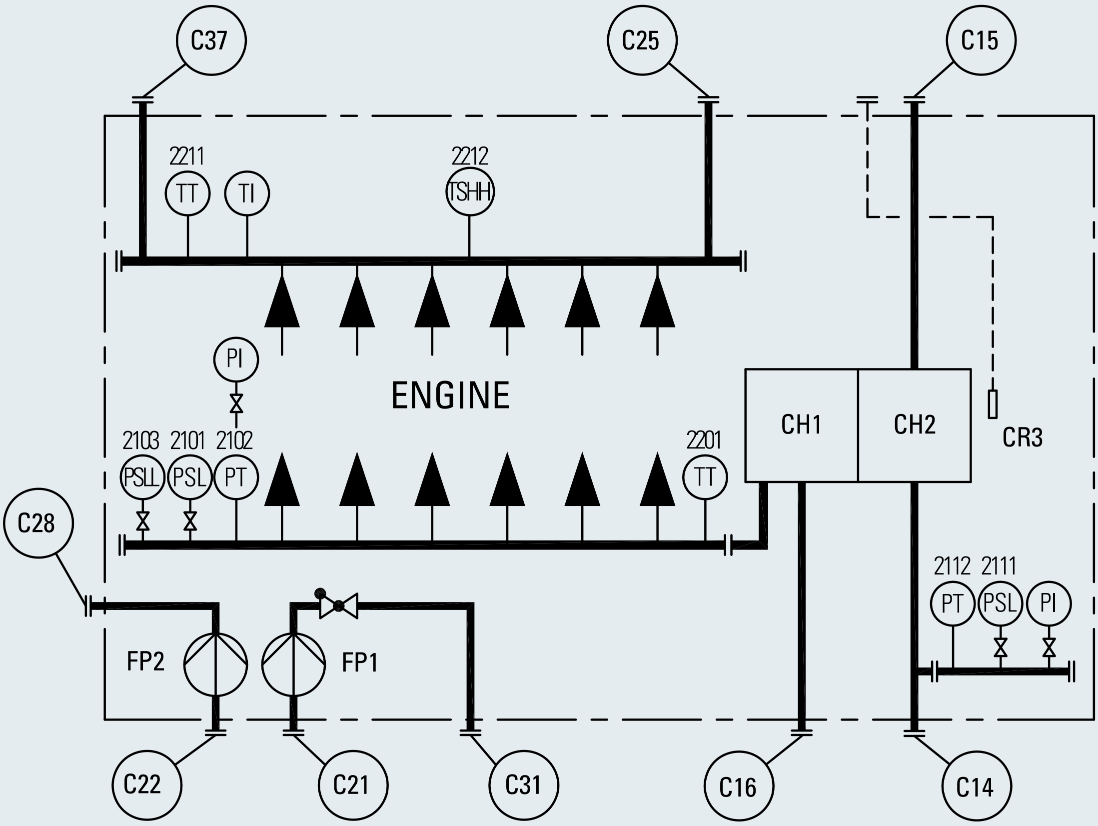


Fig. 8-1 Internal cooling water system, system diagram, turbocharger at driving end

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	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	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

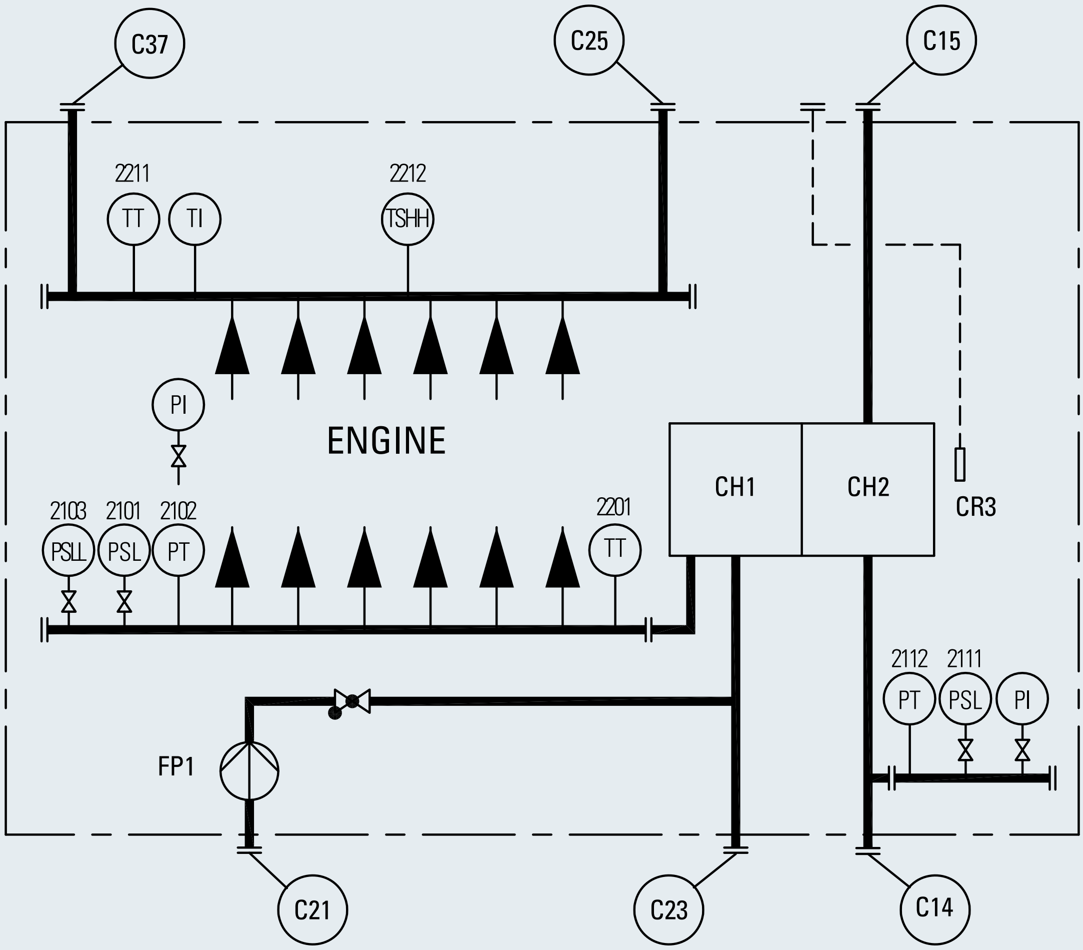


Fig. 8-2 Internal cooling water system, system diagram, turbocharger at free end

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

8.5 External cooling water system

8.5.1 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. gearbox 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

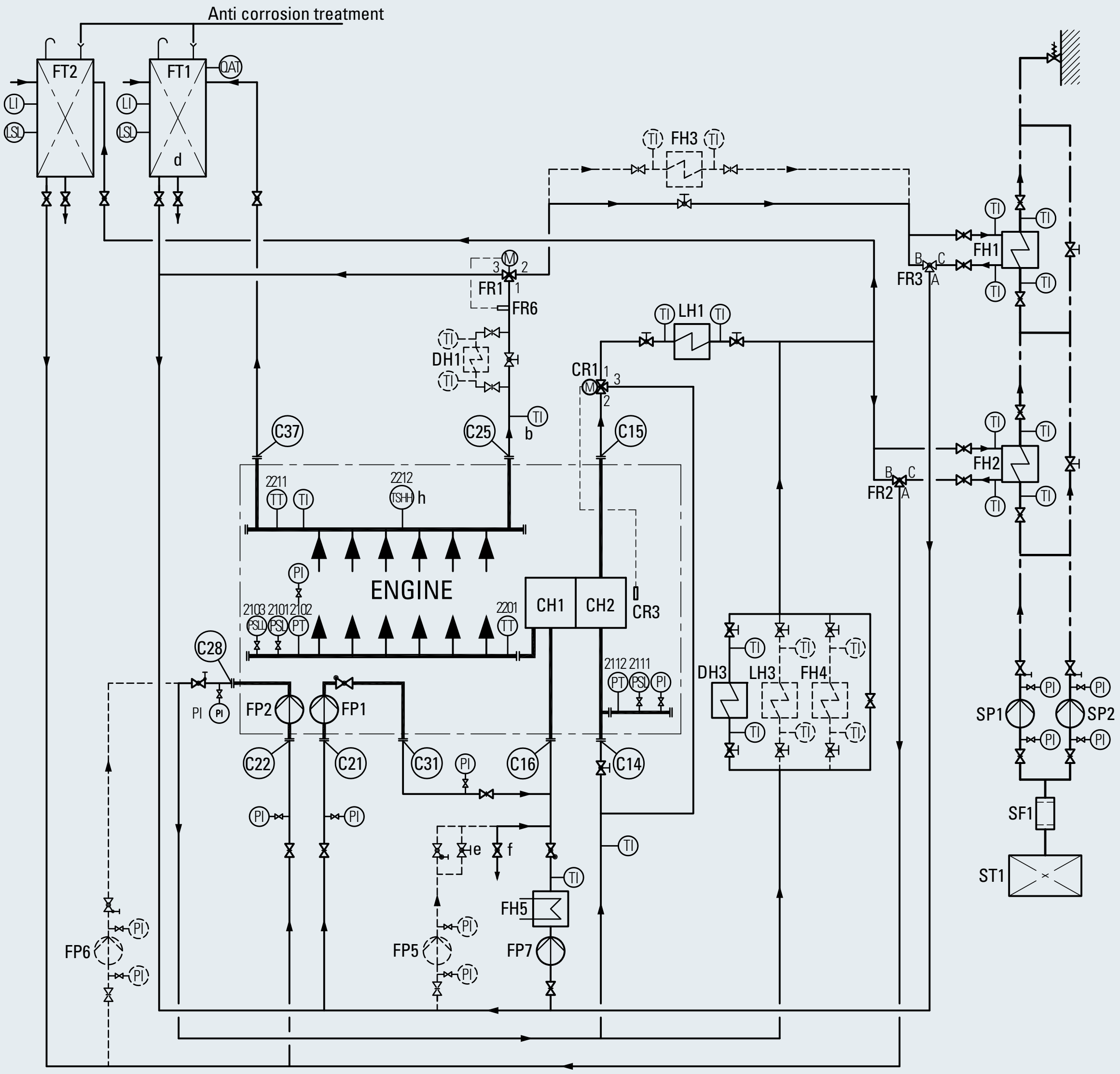


Fig. 8-3 External cooling water system, system diagram, turbocharger at driving end

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

CH1	Charge air cooler HT
CH2	Charge air cooler LT
CR1	Charge air temperature control valve
CR3	Sensor for charge air temperature control valve
DH1	MDO preheater
DH3	Fuel oil cooler for MDO operation
FH1	Fresh water cooler HT
FH2	Fresh water cooler LT
FH3	Heat consumer
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
ST1	Sea chest

LI	Level indicator
LSL	Level switch low
PI	Pressure indicator
PSL	Pressure switch low
PSLL	Pressure switch low
PT	Pressure transmitter
QAT	Gas sensor
TI	Temperature indicator
TSHH	Termperature switch high
TT	Temperature transmitter (PT100)

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

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

Turbocharger at free end

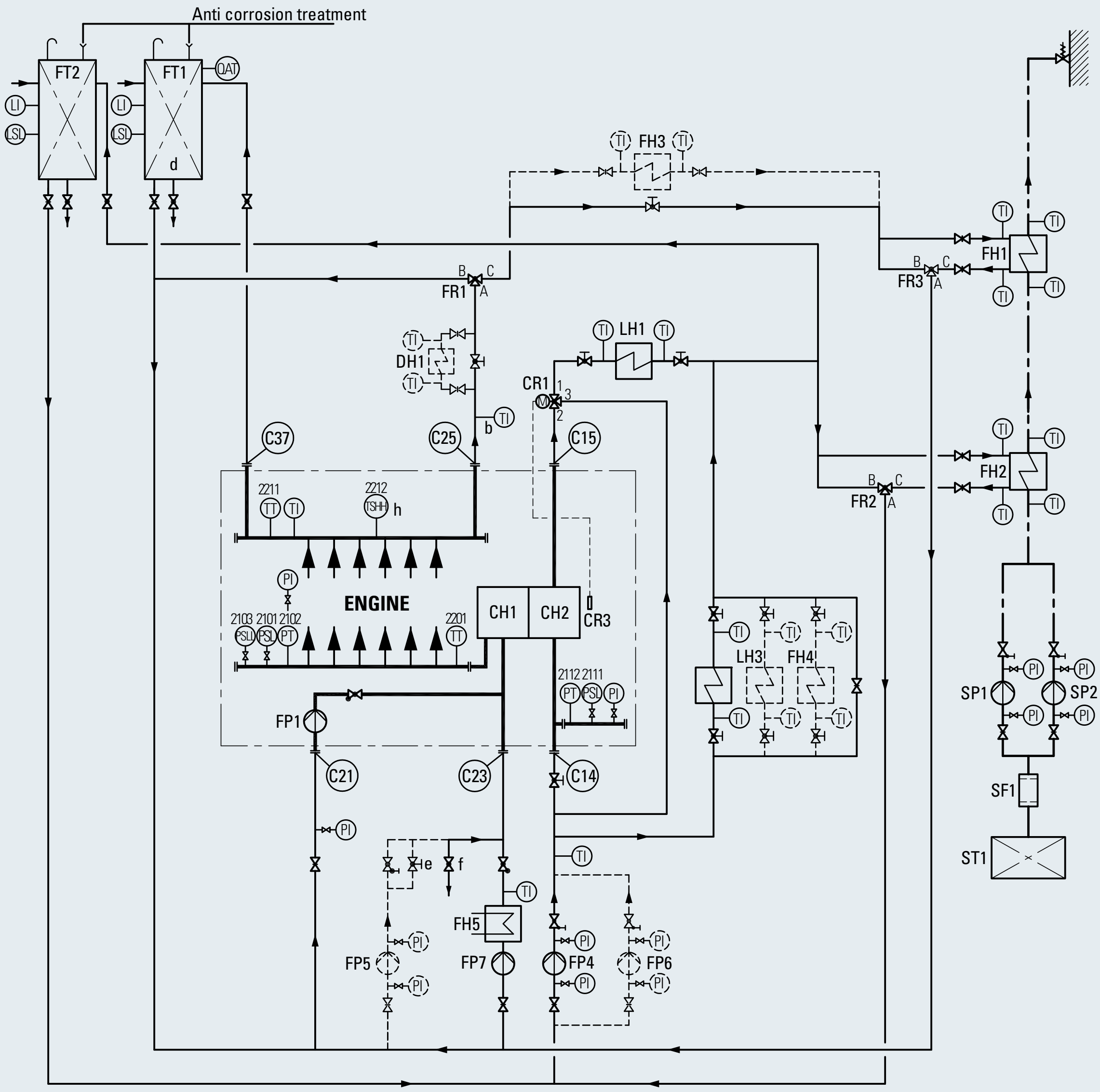


Fig. 8-4 External cooling water system, system diagram, turbocharger at free end

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

CH1	Charge air cooler HT
CH2	Charge air cooler LT
CR1	Charge air temperature control valve
CR3	Sensor for charge air temperature control valve
DH1	MDO preheater
DH3	Fuel oil cooler for MDO operation
FH1	Fresh water cooler HT
FH2	Fresh water cooler LT
FH3	Heat consumer
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
QAT	Gas sensor
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
C21	Fresh water 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
h	Please refer to the measuring point list regarding design of the monitoring devices.

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Secondary circuit cooling system with turbocharger at free end

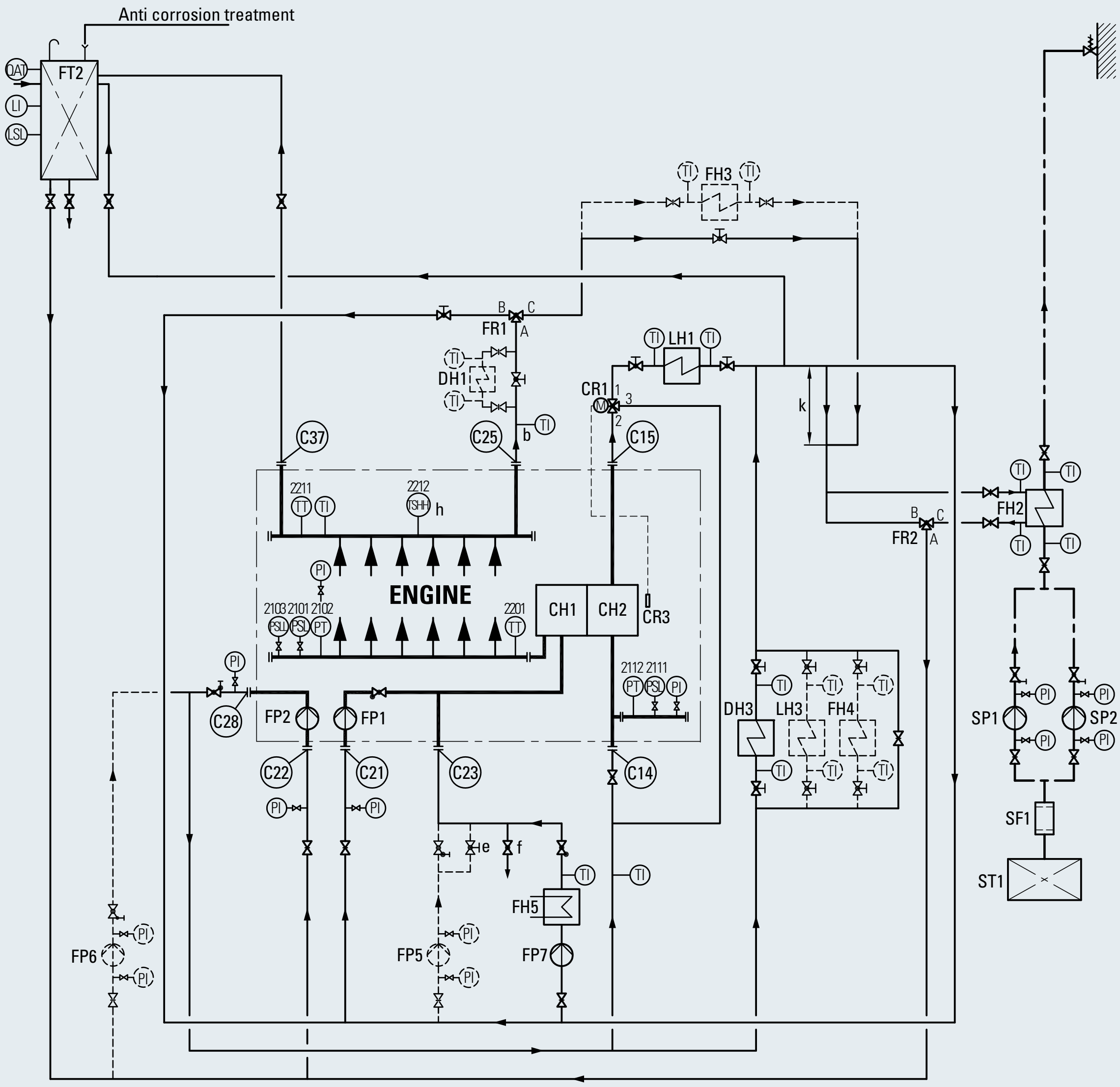


Fig. 8-5 Secondary circuit cooling system, system diagram, turbocharger at free end

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

CH1	Charge air cooler HT
CH2	Charge air cooler LT
CR1	Charge air temperature control valve
DH1	MDO preheater
DH3	Fuel oil cooler for MDO operation
FH2	Fresh water cooler LT
FH3	Heat consumer
FH4	Other LT consumers
FH5	Fresh water preheater
FP1	Fresh water pump (fitted on engine) HT
FP2	Fresh water pump (fitted on engine) LT
FP5	Fresh water stand-by pump HT
FP6	Fresh water stand-by pump LT
FP7	Preheating pump
FR1	Temperature control valve HT
FR2	Temperature control valve LT
FT2	Compensation tank LT
LH1	Lube oil cooler
LH3	Gear lube oil cooler
QAT	Gas sensor
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
C21	Fresh water pump HT, inlet
C22	Fresh water pump LT, inlet
C23	Stand-by pump HT, inlet
C25	Cooling water, engine outlet
C28	Fresh water pump LT, outlet
C37	Vent
b	Measurement min. 2.0 m distance to C17
d	Min. 4 m and max. 12 m above engine center
e	Bypass DN12
f	Drain
h	Please refer to the measuring point list regarding design of the monitoring devices.
k	Distance min. 1 m

8.5.2 Components

Freshwater cooler LT FH2 (separate)

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

Compensation tank HT FT1 / LT FT2

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

Main functions of the cooling water header tank:

- It produces static pressure for the cooling water pumps in order to prevent cavitation. Therefore it has to be connected to each pump suction side or in case of a combined system to the suction side of the central cooling water pump.
- The vent lines continuously deliver a small water flow to the header tank. In this flow, air bubbles are carried away and the system gets 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.

NOTE: Due to class rules, the HT compensation tank has to be fitted with a gas sensor.

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 34 DF	100	350	646	175	170	70
9 M 34 DF	125	400	717	200	170	110

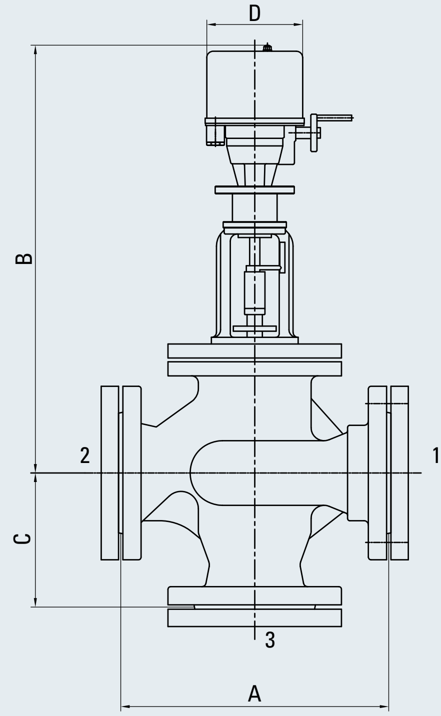


Fig. 8-6 Charge air temperature control valve CR1

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

Capacity: acc. to heat balance.

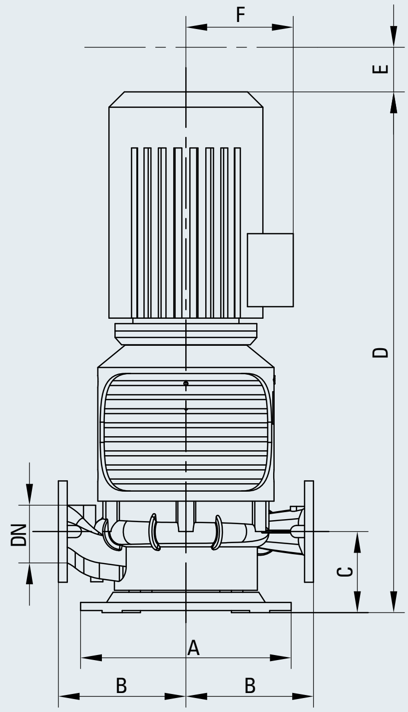


Fig. 8-7 Fresh water pump

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

Temperature control valve HT FR1 / 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).

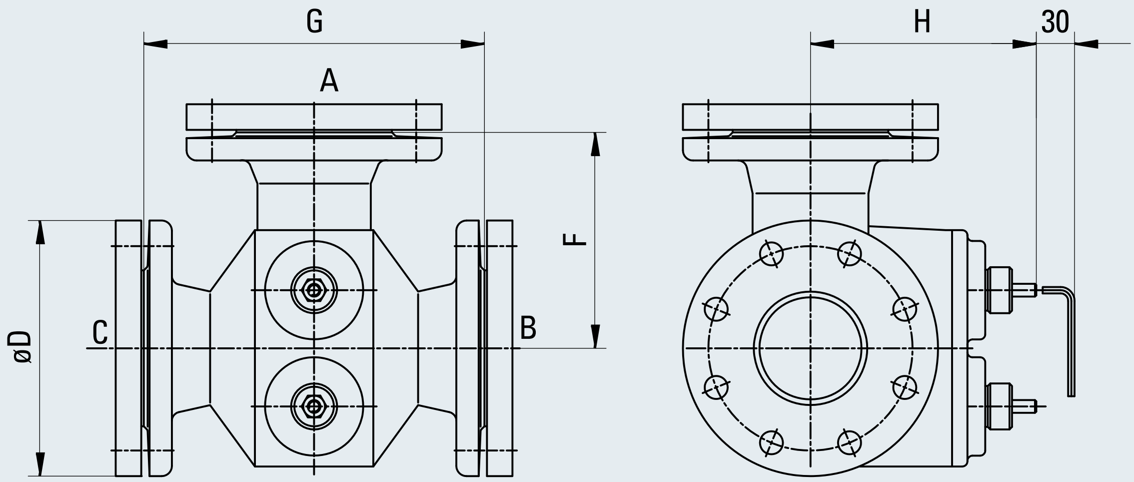


Fig. 8-8 Temperature control valve HT FR1

		Dimensions [mm]					Weight
		DN	D	F	G	H	[kg]
6/8/9 M 34 DF	HT	180	200	171	267	151	27
6/8 M 34 DF	LT	100*	220	217	403	167	47
9 M 34 DF	LT	125*	250	241	489	200	67

* Minimum depending on total cooling water flow

8.6 System diagrams heat balance

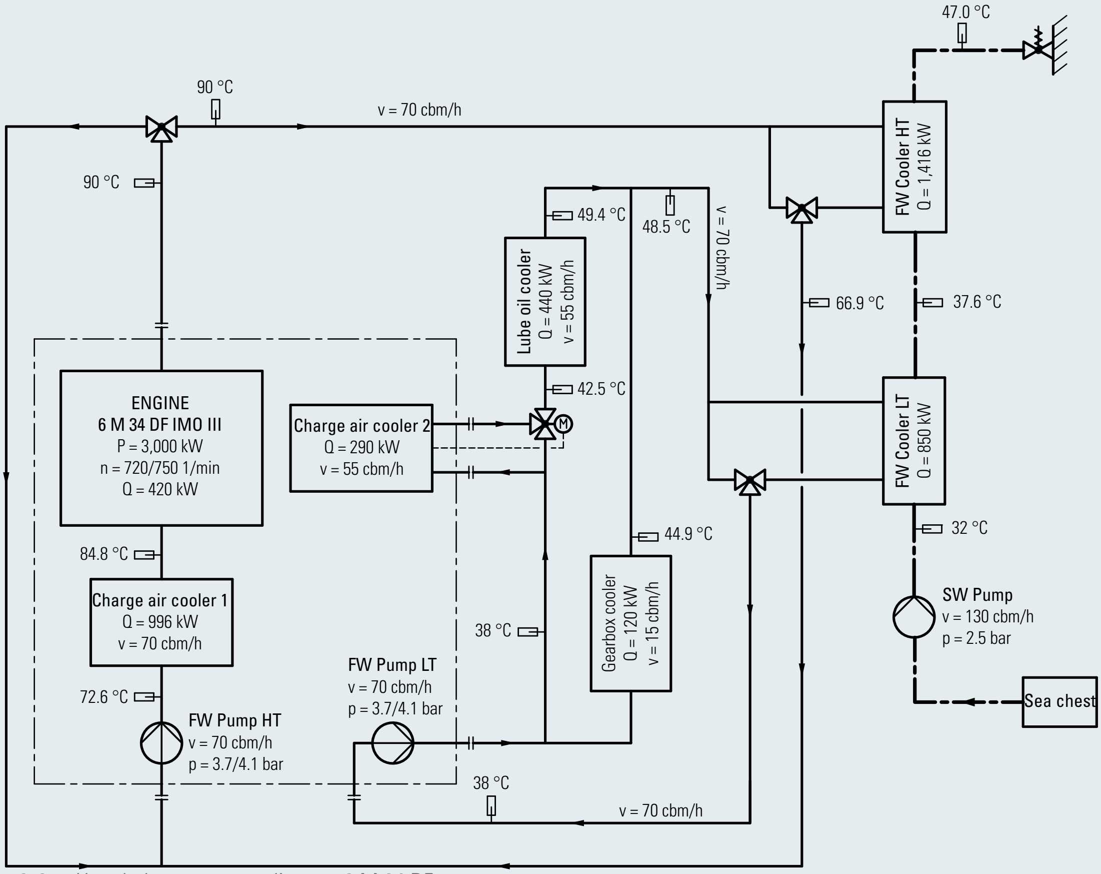


Fig. 8-9 Heat balance, system diagram 6 M 34 DF

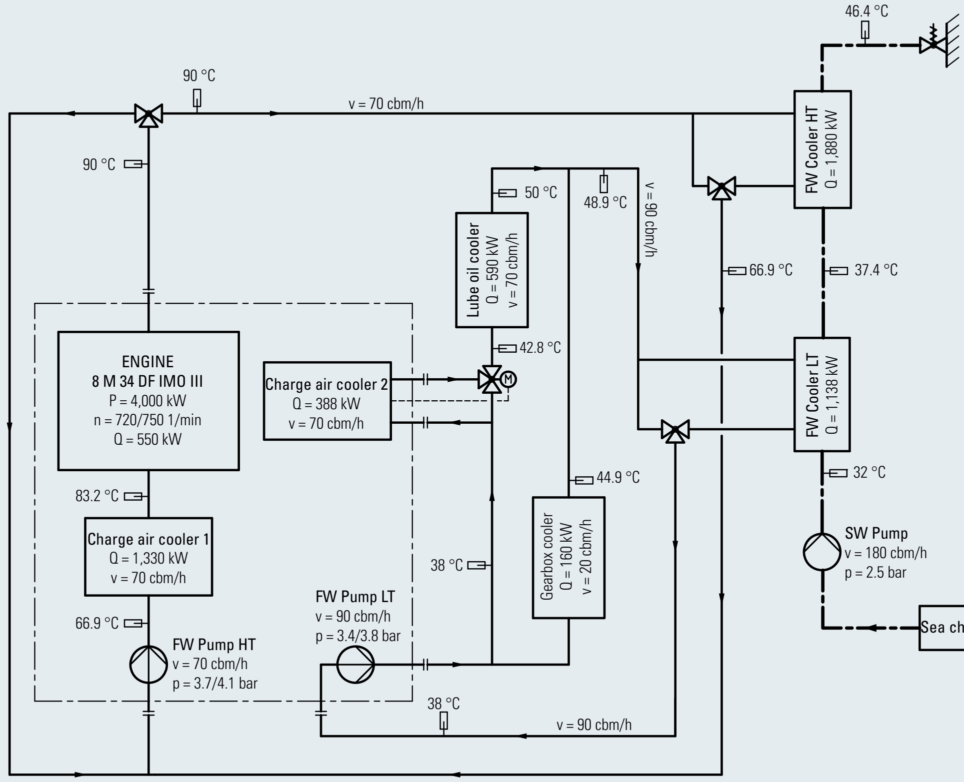


Fig. 8-10 Heat balance, system diagram 8 M 34 DF

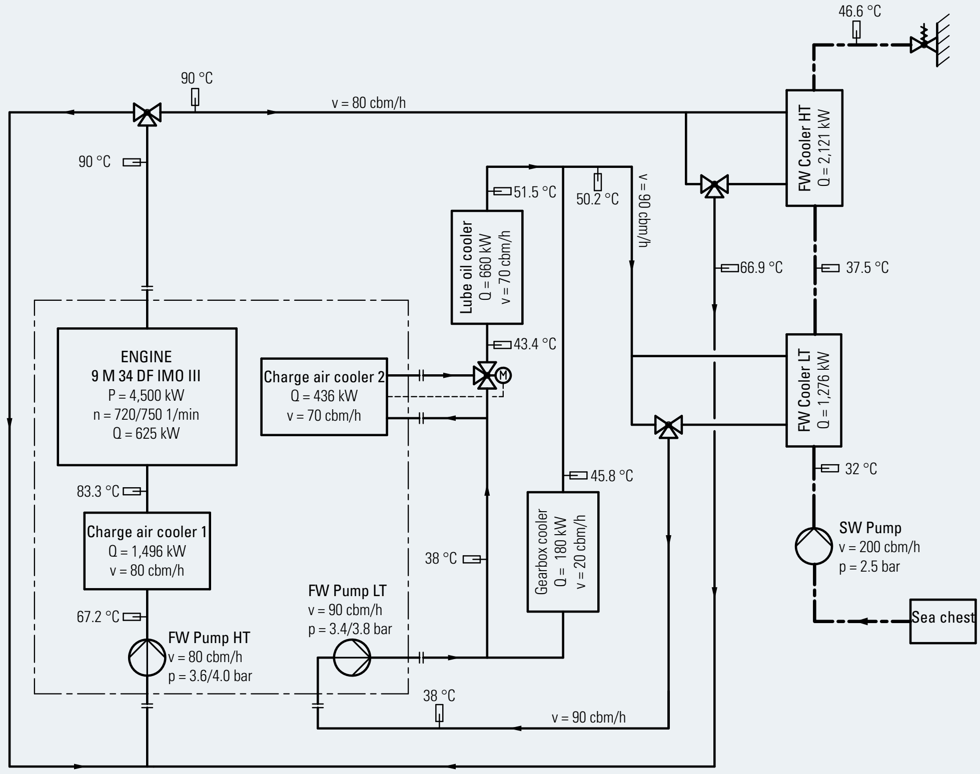


Fig. 8-11 Heat balance, system diagram 9 M 34 DF

8.7 Preheating (separate module)

8.7.1 Electrically heated

- The standard preheating system in plants delivered by Caterpillar Motoren is electrically heated.
- Consisting of baseframe mounted preheating pump FP7 (12 m³/h), electric heater FH5 (24 kW) and separate switch cabinet.
  Voltage 400 - 690, frequency 50/60 Hz.

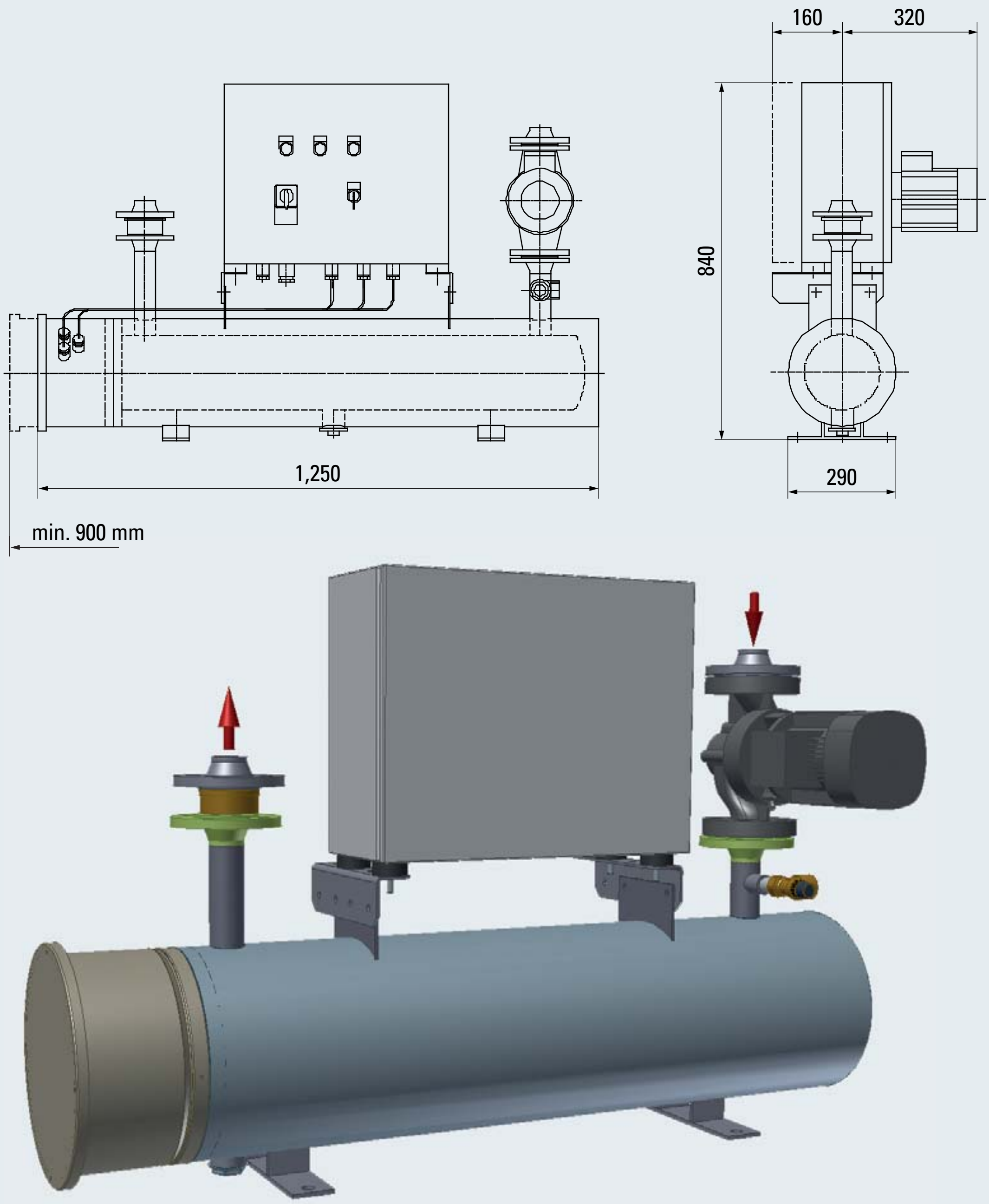


Fig. 8-12 Freshwater preheater FH5, preheating pump FP7

8.7.2 Other preheating systems

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

8.8 Box coolers system

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

8.9 Cooling circuit layout

The engine driven cooling water pumps are designed to provide the engine and it's 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

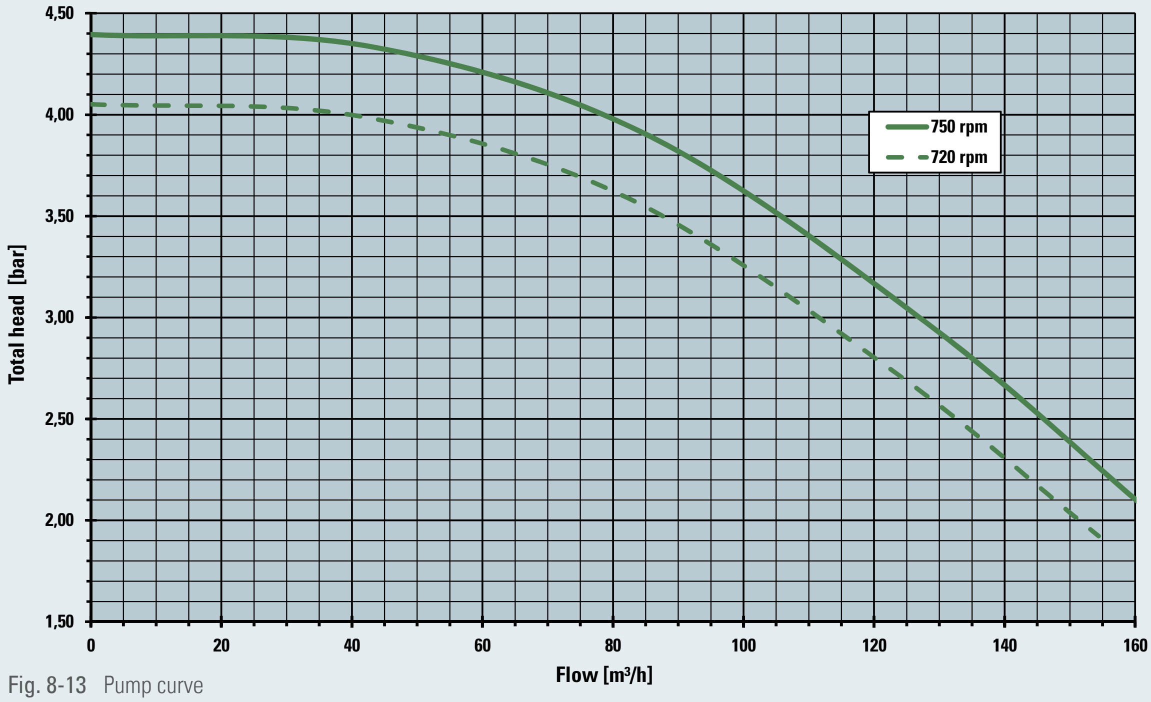


Fig. 8-13 Pump curve

9.1 General

M 34 DF engines require compressed air for starting the engine and providing actuating energy for safety and control devices as well as for Flexible Camshaft Technology (FCT).

The compressed air system consists at least of two compressors, two air receivers and its accessories such as filters, dryers, regulating and control valves and the piping system, of a capacity and air delivery rating dependent of the load profile of the ship and to meet the requirements of the respective classification society.

To ensure always the functionality of the compressed air system, it has to be free of solid particles and oil, see chapter 9.4 Compressed air quality.

9.2 Internal compressed air system

The M 34 DF engine is started by means of compressed air with a nominal pressure of 30 bar by using air starting motors.

The start is performed by engaging the air starting motor that drives the flywheel to the required cranking speed.

9.3 External compressed air system

The entire external compressed air system has to be slightly inclined and equipped with manual or automatic draining at the lowest points.

Caterpillar Motoren recommends installing automatic drain valves.

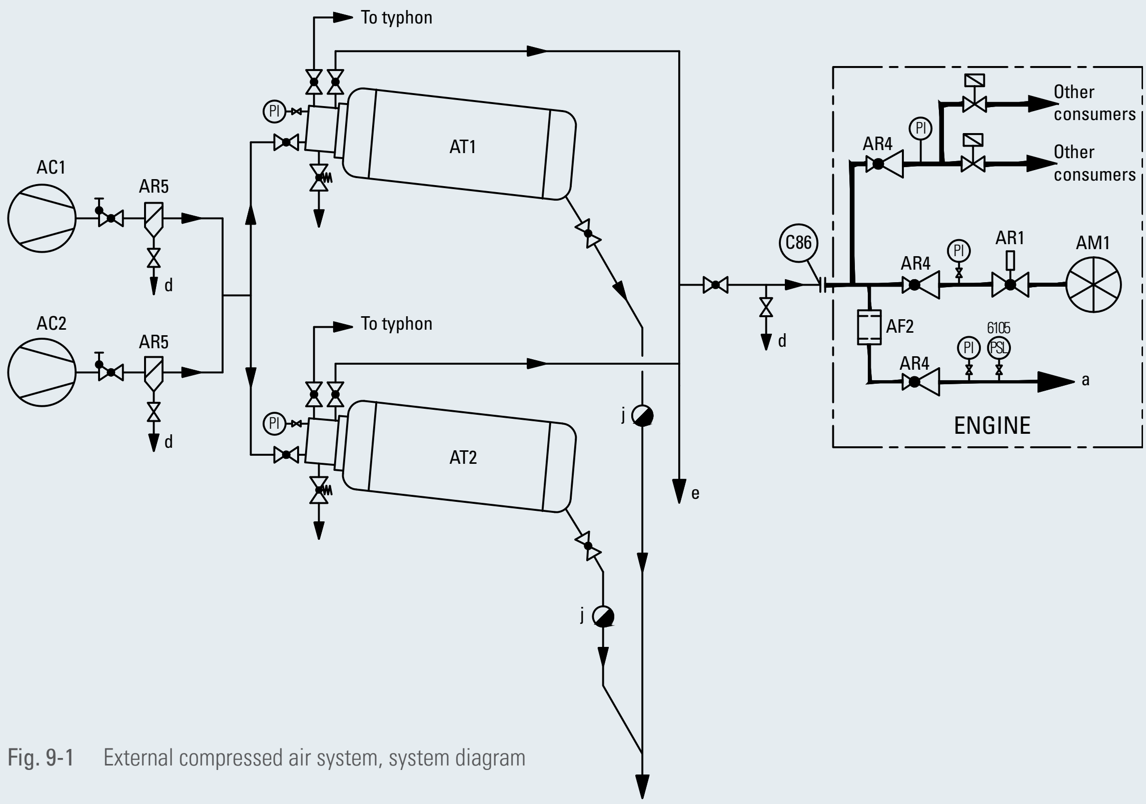


Fig. 9-1 External compressed air system, system diagram

AC1	Compressor	a	Engine shutdown
AC2	Stand-by compressor	d	Water drain (to be mounted at the lowest point)
AF2	Control air filter	e	To engine no. 2
AM1	Starting air motor	h	Please refer to the measuring point list regarding design
AR1	Starting valve	j	Automatic drain required
AR4	Pressure reducing valve		
AR5	Oil and water separator		
AT1	Starting air receiver (air bottle)		
AT2	Starting air receiver (air bottle)		

AT1/AT2 Option:
- Typhon valve
- Relief valve with pipe connection

PI	Pressure indicator
PSL	Pressure switch low, only for main engine
C86	Connection / starting air

9.3.1 Compressor AC1, stand-by compressor AC2

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

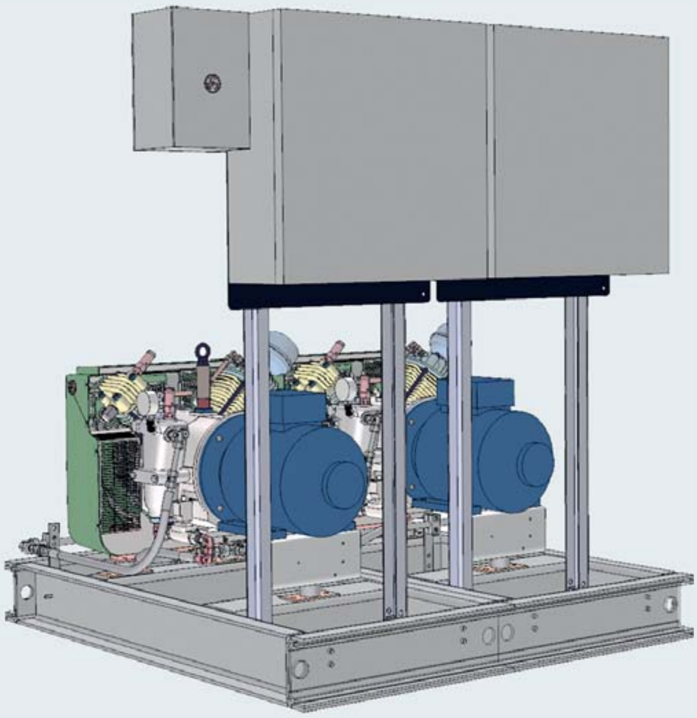


Fig. 9-2 Compressor AC1, AC2

Capacity:

$V\ [m^3/h] = \Sigma\ V_{Rec.} \cdot 30$

$V_{Rec.}$ Total receiver volume [m³]

Dimensions (approx.):

Width: 1,250 mm
Length: 1,350 mm
Height: 1,550 mm
Weight: 600 kg

9.3.2 Air receiver AT1, AT2

The starting air receivers are to be dimensioned for a nominal pressure of 30 bar.
M 34 DF engines require at least 15 bar as a minimum starting air pressure.
The total amount of air receivers and their capacity depend on the requirements of the classification societies and the type of installation.
It is required to install the receivers in a way, so that it can always sufficiently be drained manually or automatically at the deepest point of the receivers.

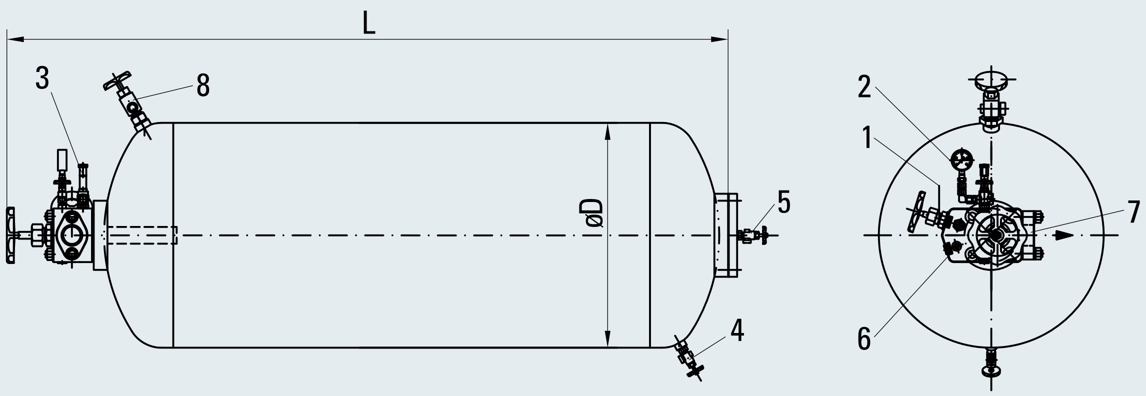


Fig. 9-3 Air receiver AT1, AT2

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

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.

9.4 Compressed air quality

For a proper operation of the engine a compressed air quality of class 4 according ISO 8573-1 is required.

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

- 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.)

9.5 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 please contact Caterpillar Motoren, technical department.

Fig. 9-4 Compressor module

10.1 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.

10.2 Combustion air system design

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

10.2.1 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.

10.2.2 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.

10.2.3 Air intake temperature from engine room and from outside

- Standard engine operation is possible with an air temperature at the turbocharger inlet above 0 °C.
- Engine operation below 0 °C requires an ignition pressure reduction via waste gate interaction (standard scope of supply) which could occur in a load reduction and / or in higher fuel consumption.

10.3 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.

10.4 Condensed water from charge air duct

Operating the engine in tropical conditions, high ambient temperature and high humidity, may generate condensate (water) that needs to be drained.

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.

11.1 Components

11.1.1 Exhaust gas nozzle – preliminary

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 34 DF engines, achieved by a transition piece from the vertical line, are: 0 °, 30 °and 60 °. For the 8 and 9 M 34 DF engines additional standard orientations of 45 ° and 90 ° from the vertical line are available.

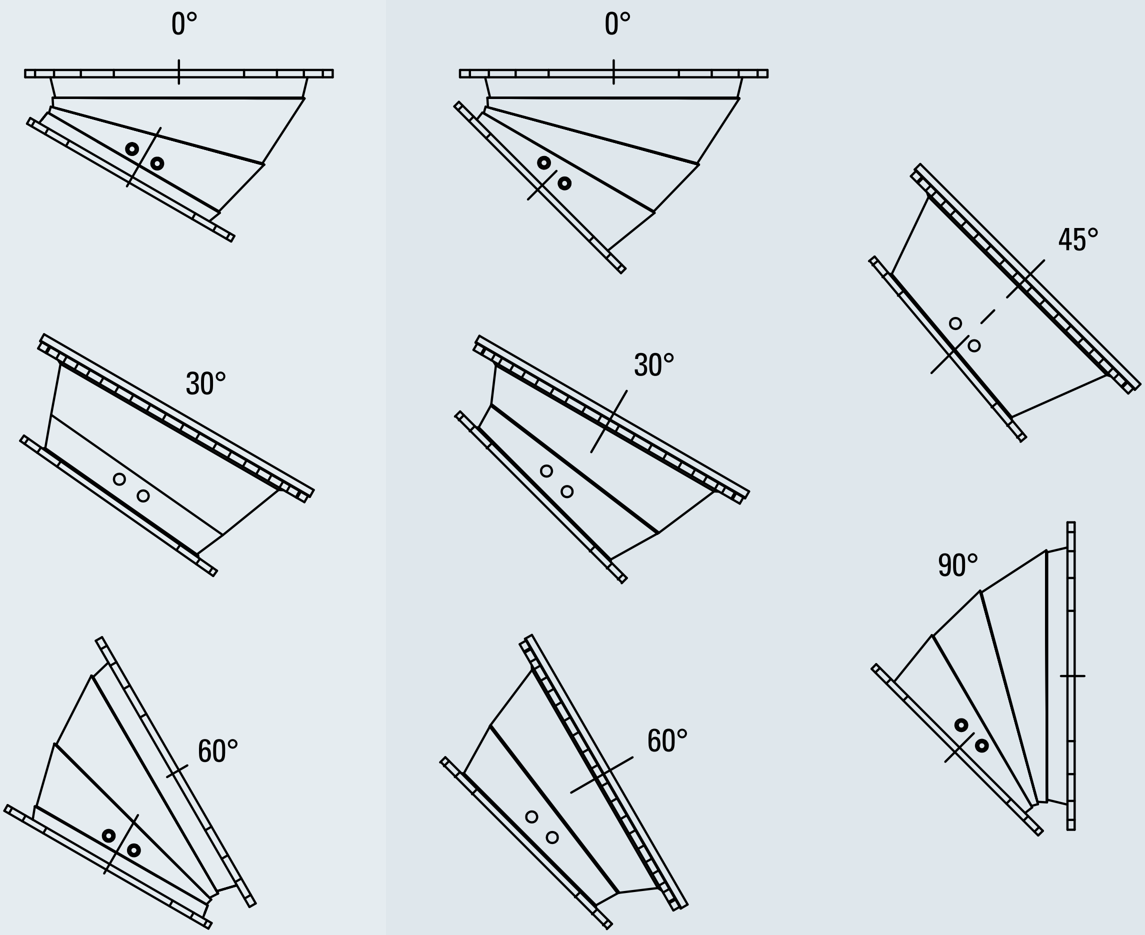


Fig. 11-1 6 M 34 DF nozzle orientation

Fig. 11-2 8/9 M 34 DF nozzle orientation

11.1.2 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.

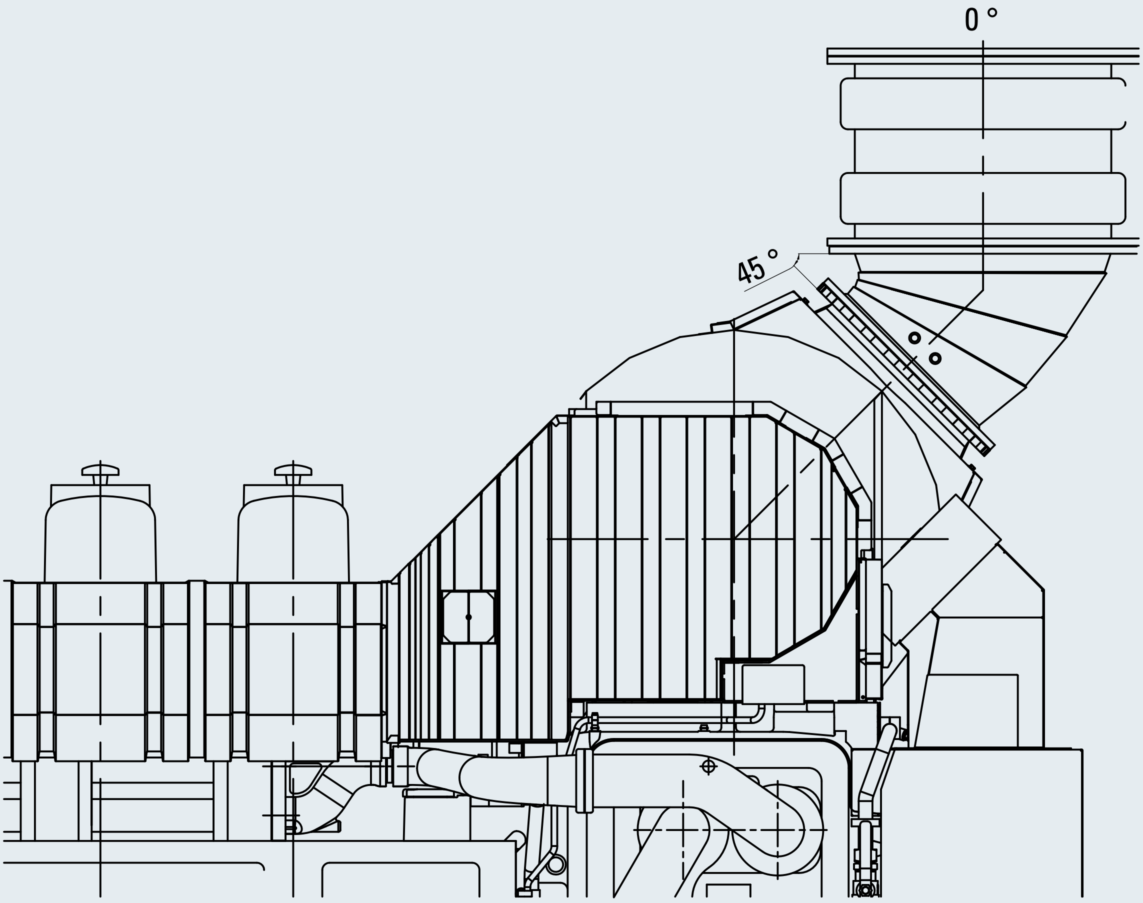


Fig. 11-3 Exhaust gas compensator

Basic design values of the standard exhaust gas compensators.

Type	Diameter [mm]	Length [mm]	Weight [kg]
6 M 34 DF	600	450	107
8 M 34 DF	700	520	137
9 M 34 DF	800	500	145

11.1.3 Exhaust gas piping system

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

Each engine requires a separate exhaust gas pipe. The exhaust gas piping system from two or more engines is not allowed to be joined in one.

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

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

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

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

Resistance in exhaust gas piping

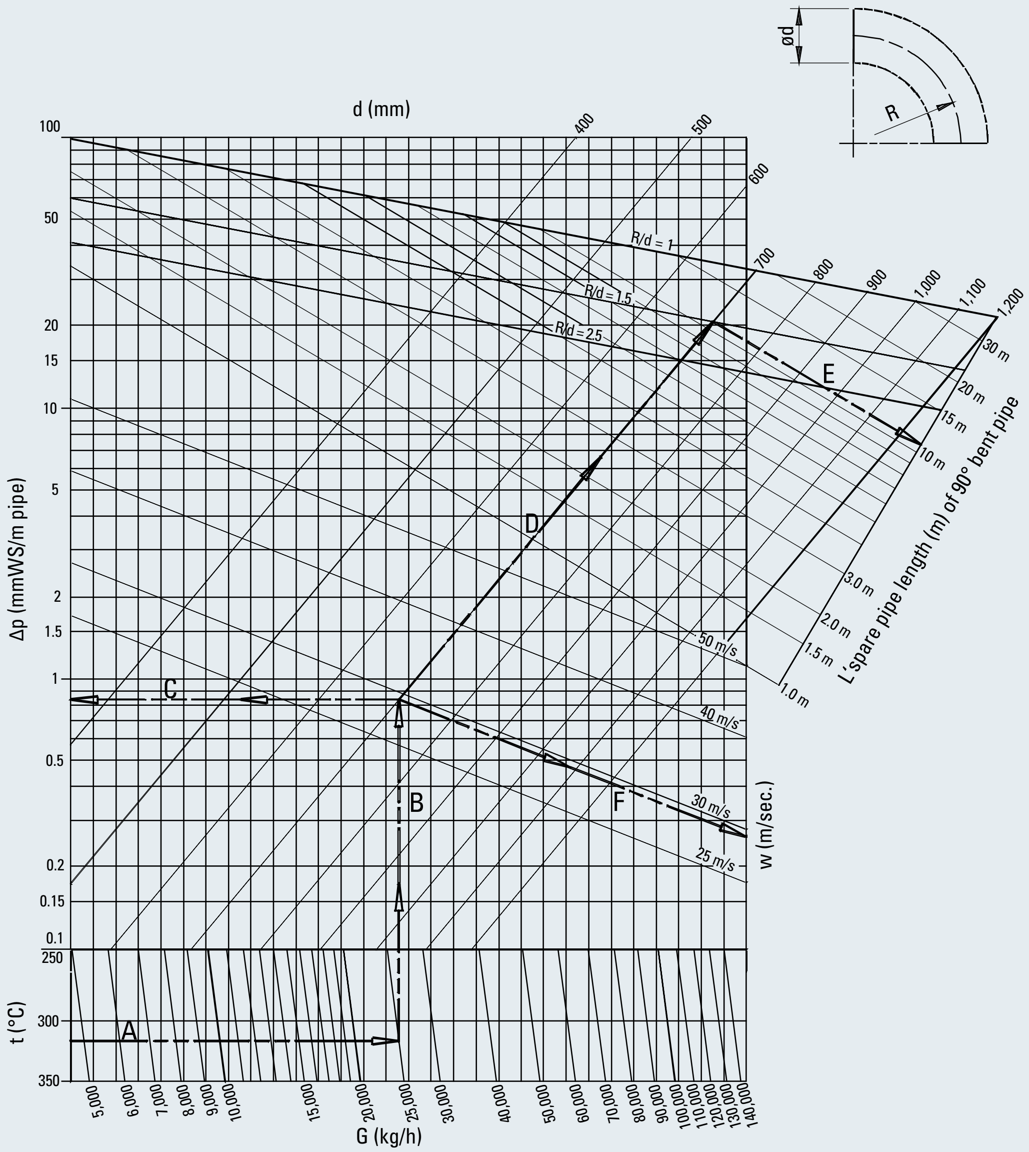


Fig. 11-4 Resistance in exhaust gas piping

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]

11.1.4 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.

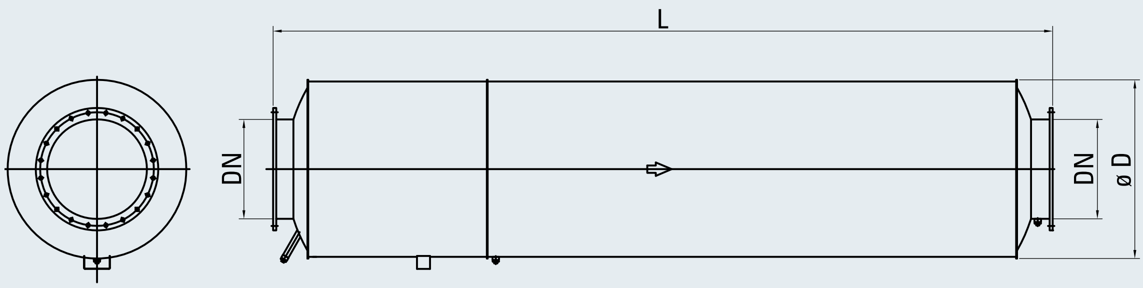


Fig. 11-5 Silencer

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.

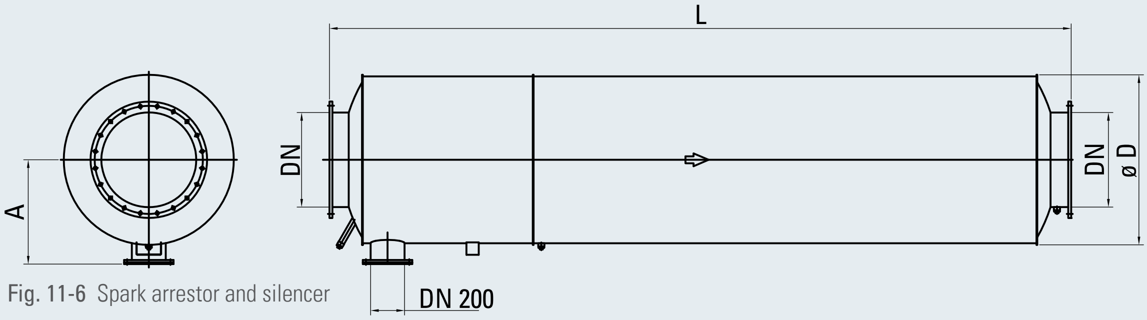


Fig. 11-6 Spark arrestor and silencer

Type	Dimensions [mm]				Weight	Weight with spark arrestor
	DN	A	D	L	[kg]	[kg]
6 M 34 DF	600	675	1,100	4,800	1,300	1,350
8 M 34 DF	700	775	1,300	5,200	1,650	1,800
9 M 34 DF	800	875	1,500	5,600	2,200	2,350

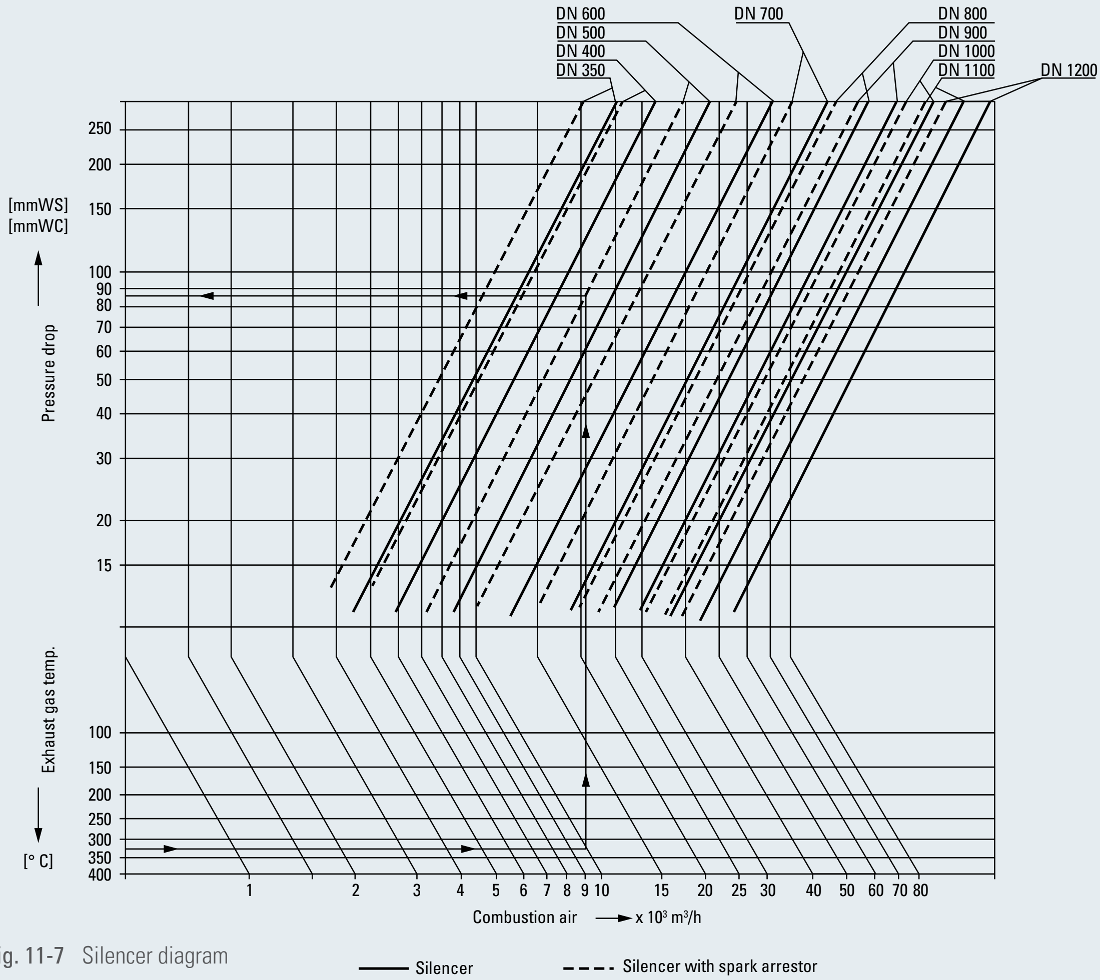


Fig. 11-7 Silencer diagram

11.1.5 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.

11.2 Turbocharger

11.2.1 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 34 DF and 2.5 bar for 8/9 M 34 DF is required.

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

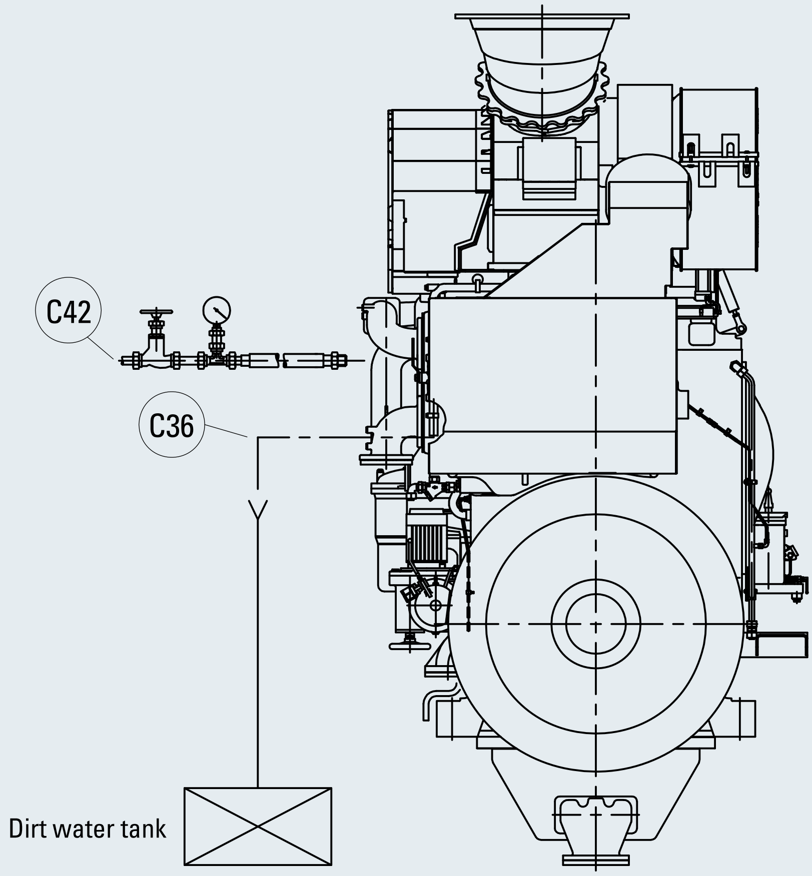


Fig. 11-8 Connection points fresh water and drain

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 34 DF	12	10
8/9 M 34 DF	18	10

11.2.2 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.

12.1 Flexible Camshaft Technology (FCT)

The dual fuel engine has a modified FCT system, to ensure an optimal engine operation in all operating modes over the entire load range. The FCT system is basically known from the M 32 C diesel engine, where this technology is already validated.

Flexible Camshaft Technology (FCT):

- High potential for smoke reduction
- Low complexity
- Low technical risk-application of existing technology
- Minimized methane slip

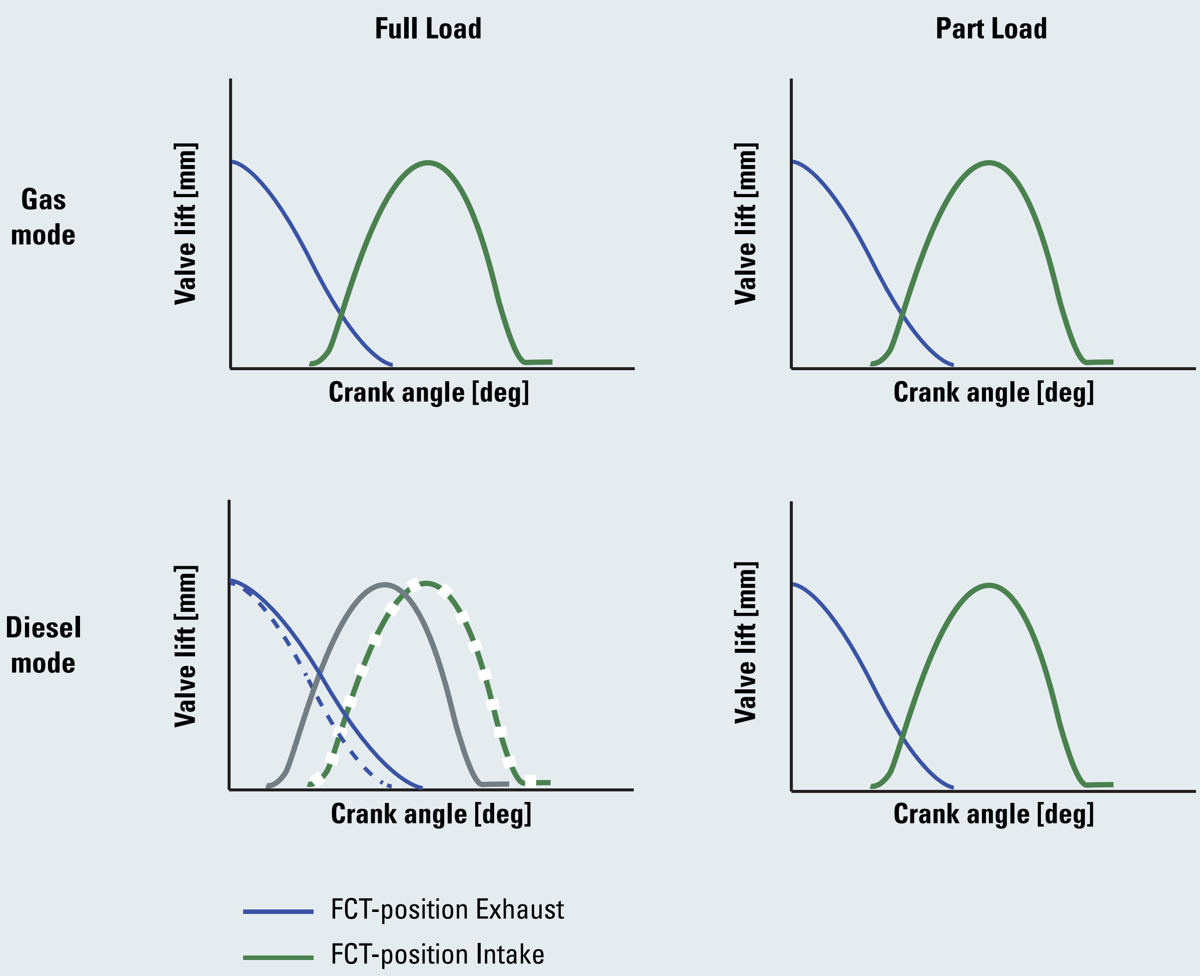


Fig. 12-1 FCT-positions – Intake & Exhaust

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

13.1 Local control panel (LCP)

Fig. 13-1 Local control panel

1	DCU
2	Reset
3	0 = Repair, 1 = Engine, 2 = Remote
4	Slow turn
5	Emergency stop
6	Diesel mode indication, lamp test
7	Gas mode indication
8	Start
9	Stop
10	Lower
11	Raise
12	Gas shut-off
13	Emergency start

13.2 Data link overview

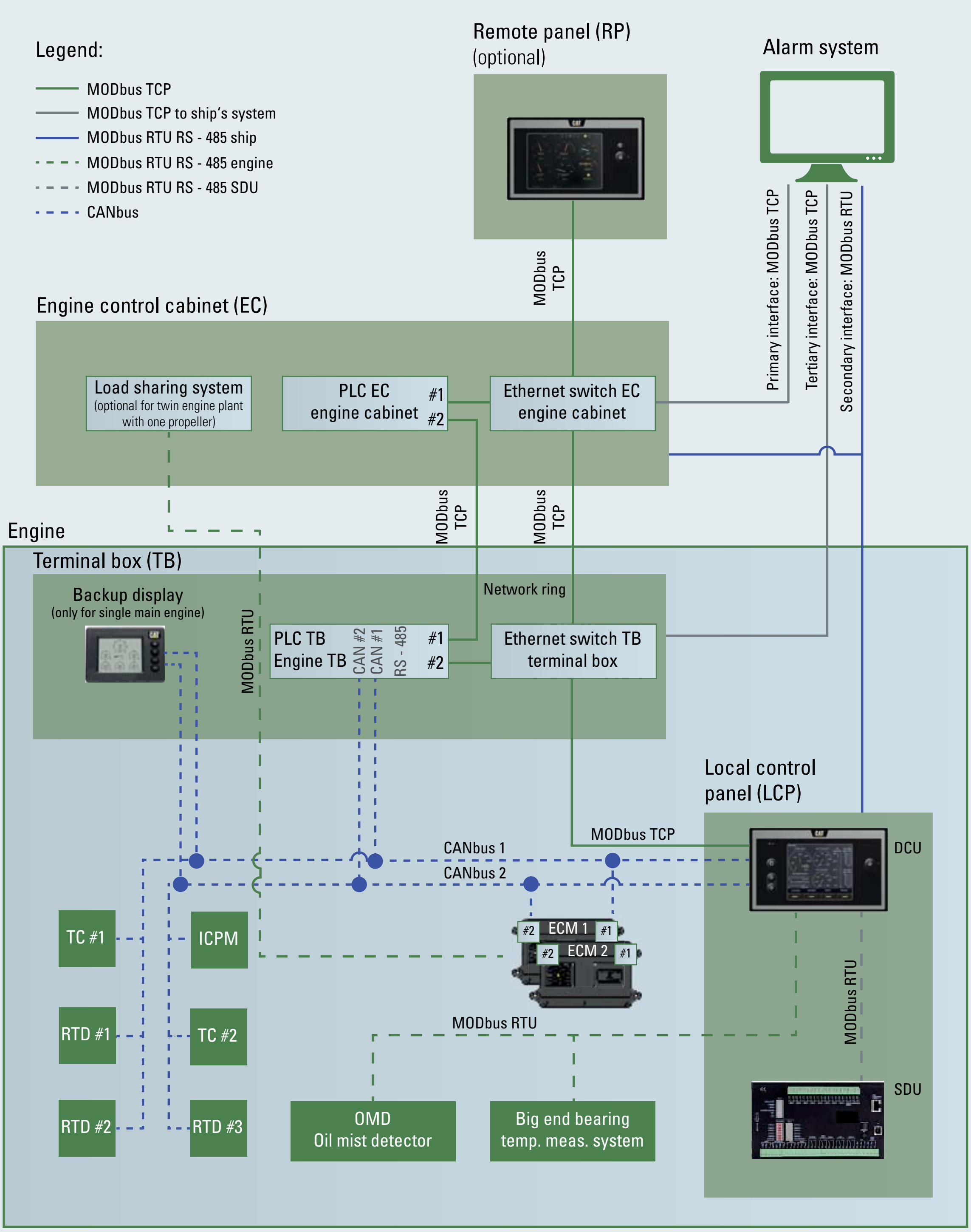


Fig. 13-2 Data link overview - M 34 DF

MACS

Modular Alarm Control System

SDU
Protection system in local control panel
DCU
Display and alarm system in local control panel
PLC
PLC in engine cabinet (EC)
PLC in engine terminal box on engine (TB)
RTD
PT100 module #1 e.g. charge air temperature
PT100 module #2 e.g. lube oil temperature
PT100 module #3 e.g. cooling water HT
TC
Exhaust temperature module #1 (thermocouples)
Exhaust temperature module #2 (thermocouples)
RP
Remote panel (optional)
ECM
Engine control module
OMD
The oil mist detector measures each cylinder.
Load sharing system
Load sharing system for isochronous load sharing (optional)
CTM
Big end bearing temperature monitoring (optional)
Each cylinder is measured by the CTM.
ICPM
The "In-cylinder pressure monitoring" computes combustion characteristics for each cylinder including knock intensity per cylinder
Back Up Display
Required for single main engine, optional for twin engine plant.

.

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

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

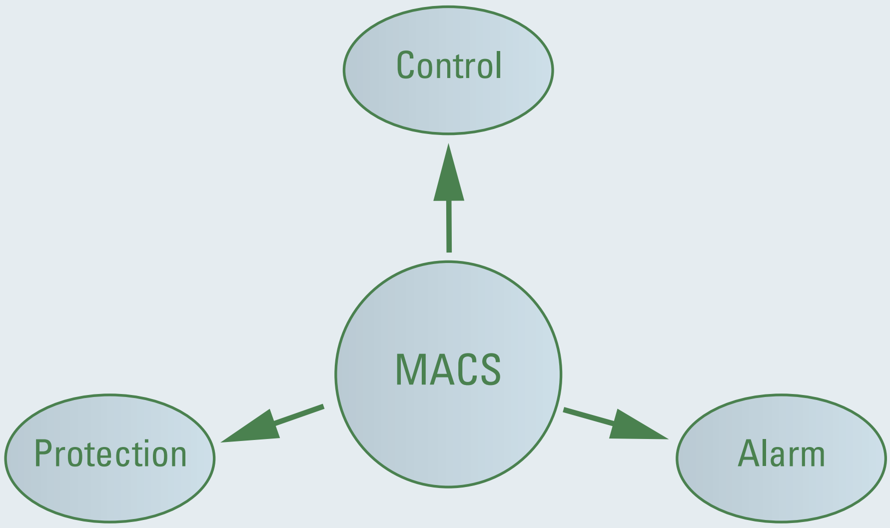
MODbus RTU
The MODbus device address will be assigned.

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

MODbus settings
Type: MODbus RTU
Baud rate: 19,200
Device address (ID): will be assigned
Interface: RS-485

13.3 Components

Modular Alarm and Control System (MACS)



The M 34 DF engines will be provided with a new Modular Alarm and Control System, called MACS. The basic engine control and monitoring system will be installed in the local control panel. Where extension modules are necessary external plc based I/O extension modules will be installed.

The main functions of the control systems are:
- Alarm management
- Local start and stop, emergency start and stop from the engine control panel
- Remote start and stop from the power management system (PMS)
- Start and stop sequence control
- Critical parameter monitoring
- Slow turn control
- Flexible camshaft technology (FCT monitoring)
- Exhaust gas tempertature monitoring
- Main and big end bearings temperature monitoring (optional)
- Ignition fuel control
- Ventilation module control
- Crankcase gas detection module control

Engine control module (ECM)

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

Load sharing system (optional)

For isochronous load sharing a load sharing system is necessary. The load sharing system is determining the desired load and system status for each engine to the ECM via MODbus RTU.

Oil mist detector

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

Big end bearing temperature measuring system (optional)

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

Gas valve unit

The gas valve unit provides the engine with the desired gas fuel pressure and is controlled by the engine's control and monitoring system (MACS). It has several features (e.g. double block and bleed valve) to safety cut the engine from the gas train and to removce the gas fuel from the piping system (flushing).

Crankcase gas detection

The crankcase gas detection system monitors the actual concentration of explosive atmosphere in the crankcase. If the concentration increases above a fixed value an alarm is triggered and in a second step the engine switches back to diesel mode.

Ventilation module

The aim of the ventilation module is to detect a leakage in the double walled gas pipes at the engine. The air in the double walled gas pipe will be ventilated and the gas concentration will be measured.

Ignition fuel control system

The ignition fuel control system provides the required ignition fuel oil quality for the engine's ignition system.

Exhaust gas ventilation module

The exhaust gas module is installed to ventilate the ship side exhaust gas system after an emergency stop of the engine in gas mode. The module consists of a ventilation fan, a separation butterfly valve and exhaust gas compensator for the conntection to the exhaust gas system.

Slow turn

The slow turn function is used to detect water in the combustion chamber, e.g. after a long non-operation period.

13.4 Remote engine control

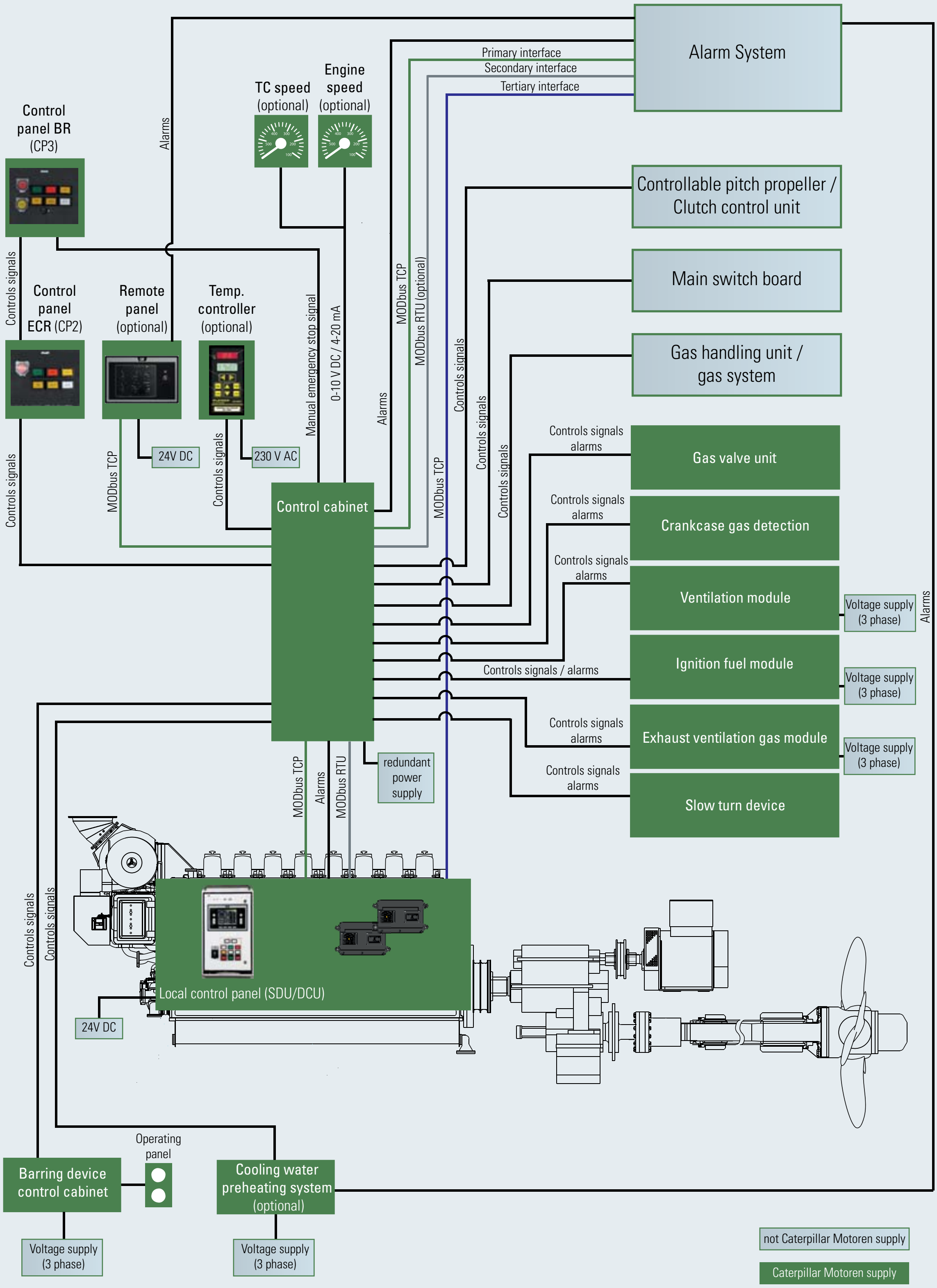
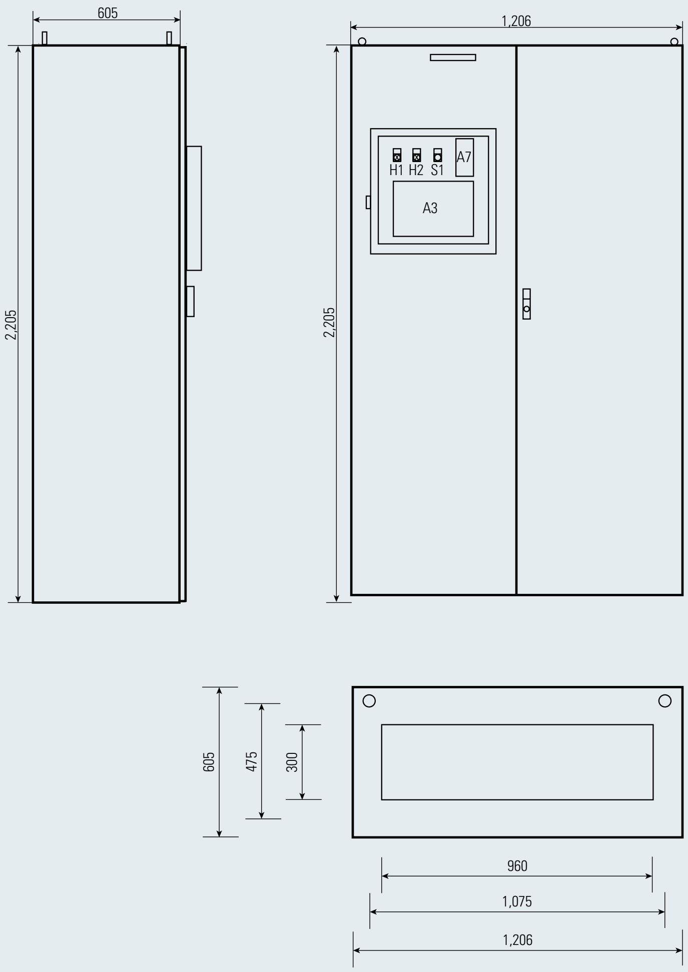


Fig. 13-3 Remote control for single-engine plant with one controllable pitch propeller

13.5 Control cabinet

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



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

Optional in the control cabinet integrated

A3: Remote panel
A7: Charge air temperature controller

Degree of protection: IP54
Weight: Approx. 246 kg

Fig. 13-4 Control panel

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

The engines are equipped with a Caterpillar standard actuator in accordance with class requirements for single engine.
The electronic governor is installed in a separate control cabinet and 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 load distribution by master/slave principle for twin-engine propulsion plants via double reduction gear
- Protection class of equipment: IP54

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

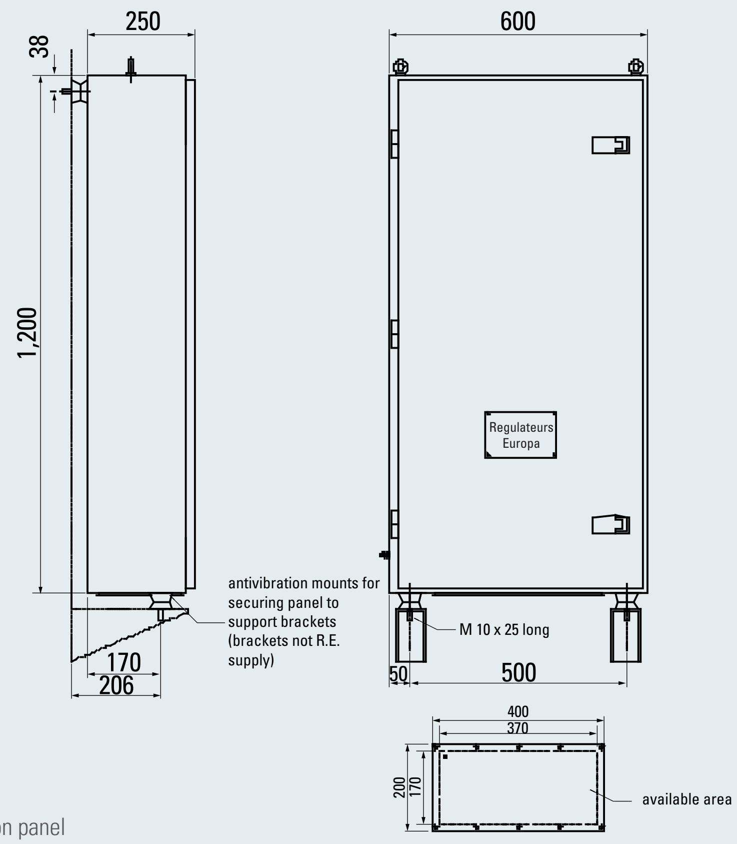

Fig. 13-5 Propulsion panel

Option
Woodward control cabinet with electronic speed governor.

13.6 Requirements

13.6.1 Requirements on Control Pitch Propeller (CPP) System

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

Gearbox	Lube oil pressure low (NO)	binary	→	24 V DC	Starting interlock for engine	Main engine
Gearbox	Common load reduction (NO)	binary	→	24 V DC	Slow down for engine	Main engine
Gearbox	Lube oil pressure low (NO)	binary	→	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	M.E. in overload		←	binary	Used for overload indication	Main engine
Controllable pitch propeller	Request remote control	24 V DC	←	binary	Local/remote switch contact at engine	Main engine
Controllable pitch propeller	Accept remote control	binary	→	24 V DC	Remote control accepted	Main engine
Controllable pitch propeller	Local/remote control	24 V DC	←	binary	Closed contact when ME1 is in remote control	Main engine
Controllable pitch propeller	Reduce to 40% load	24 V DC	←	binary	Slow down at engine	Main engine
Controllable pitch propeller	Pitch to zero / auto clutch out	24 V DC	←	binary	Shut down at engine	Main engine
Controllable pitch propeller	Engine in back up mode	24 V DC	←	binary	ECM ready / no back up mode (only for single main engine)	Main engine
Controllable pitch propeller	Gas combinator curve in use (only for different diesel/gas curves)	24 V DC	←	binary	Gas mode	Main engine
Controllable pitch propeller	Speed setting signal	4-20 mA	→	24 V DC	Speed setting signal for load share unit (ECM)	Main engine
Controllable pitch propeller	Clutch engaged or pitch not zero	binary	→	24 V DC	Starting interlock	Main engine

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

13.6.2 Requirements on gas system

The table below shows the standard interface between the gas system and the dual fuel engine.

Standard interface to the gas system

Gas system	Signal	Gas system side	Direction	Engine cabinet side	Engine cabinet
	Indication diesel mode	24 V DC	←	binary	
	Indication gas mode	24 V DC	←	binary	
	Activate gas supply to gas valve unit	24 V DC	←	binary	
	Switch over to gas operation failed	24 V DC	←	binary	
	Gas operation shut off machinery space	24 V DC	←	binary	
	Gas operation shut off engine	24 V DC	←	binary	
	Gas mode interlock	24 V DC	←	binary	
	Gas operation shut down	binary	→	24 V DC	
	Gas mode interlock	binary	→	24 V DC	
	Diesel mode select	binary	→	24 V DC	
	Gas mode select	binary	→	24 V DC	
	Inert gas supply pressure	4-20 mA	→	Analogue output	
	Pressure transmitter fuel gas supply to engine room	4-20 mA	→	Analogue output	

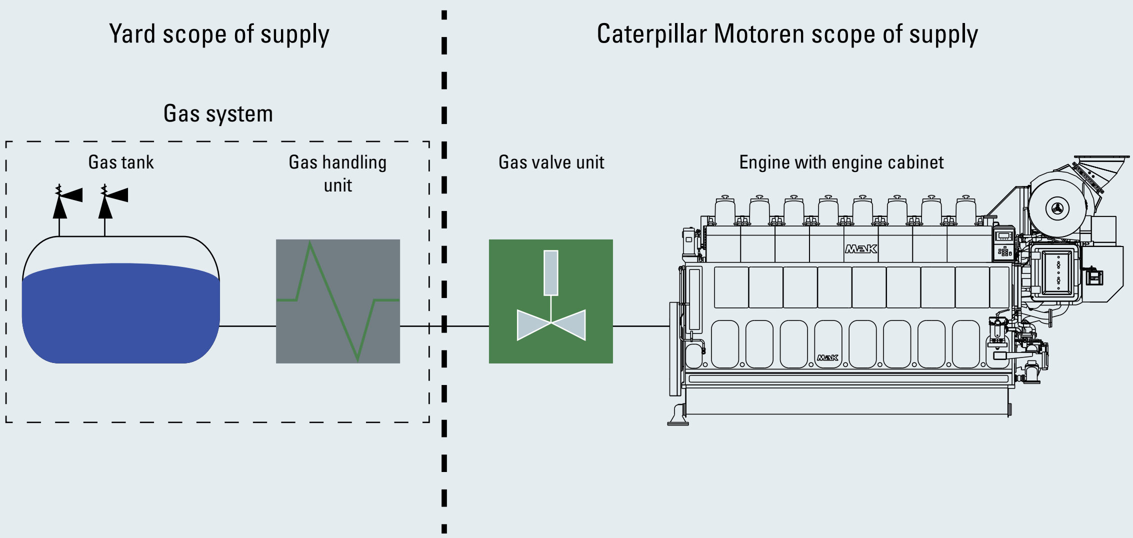

Fig. 13-6 Basic overview: dual fuel engine gas system

13.7 List of measuring points, exhaust gas monitoring

This list is only a general overview for propulsion application.

Meas. point	Description		Signal range	Remarks
Lube oil				
1104	Pressure switch lube oil pressure low	start pump	binary	
1105	Pressure switch lube oil pressure low	alarm	4-20 mA	
1106	Pressure switch lube oil pressure low	shutdown	binary	
1112.1 1112.2	Differential pressure lube oil automatic filter high	pre-alarm alarm	binary	1 evaluation unit for 1112.1/.2 Only existing, when automatic filter is mounted on the engine.
1142	Pre lube oil pressure low	start interlock	binary	
1202 1203	Lube oil temperature at engine inlet high	alarm change genset	PT 100	
1311	Lube oil level low	alarm	binary	
1312	Lube oil level high	alarm	binary	
Oil mist detector				
1251 1251.1 1253	Oil mist concentration in crankcase high	alarm pre-alarm shutdown	binary	
1254	Indication of opacity for compartment (each cyl.)	indication		
9631	Oil mist detector failure	alarm	binary	
Fresh water HT				
2102	Cooling water pressure HT at engine inlet low	alarm	4-20 mA	40 kPa below operating pressure
2103	Cooling water pressure HT at engine inlet low	shutdown	binary	60 kPa below operating pressure delay: 20s
2201	Cooling water temperature HT at engine inlet	alarm	PT 100	
2211 2213	Cooling water temperature HT at engine outlet high	alarm shutdown	PT100	
2321	Oil ingress in fresh water at cooler outlet	alarm	binary	Depending on HT and LT system
Fresh water LT				
2112	Cooling water pressure LT at engine outlet low	alarm	binary	40 kPa below operating pressure
2229	Cooling water temperature LT at engine inlet	alarm	PT 100	

Meas. point	Description		Signal range	Remarks
Fuel oil				
5102	Fuel oil pressure at engine inlet low	alarm	4-20 mA	
5111	Differential pressure fuel oil filter high	alarm	binary	
5201 5202	Fuel oil temperature at engine inlet low Fuel oil temperature at engine inlet high	alarm alarm	PT 100 PT 100	1 sensor for 5201 + 5202 (not in use with HFO)
5301	Leakage fuel oil niveau at engine high	alarm	binary	
Air				
6101	Starting air at engine inlet low	alarm	4-20 mA	
6108	Stopping air pressure at engine low	alarm	4-20 mA	Alarm delayed: 2s
6181	Intake air pressure in engine room	indication	4-20 mA	
Charge air				
7109	Charge air pressure at engine inlet	indication	4-20 mA	
7201	Charge air temperature at engine inlet high	alarm	PT 100	
7206	Intake air temperature at turbocharger inlet	indication	PT 100	
7301	Condense water in charge air canal	alarm	binary	
7307	Charge air differential pressure at charge air cooler	indication	4-20 mA	
7309	Charge air temperature at charge air cooler inlet	indication	NiCr-Ni (mV)	
FCT				
49323 49335 49332 49336 49338	FCT position failure in gas and diesel mode	shutdown	binary	
49315	FCT common alarm	common alarm	binary	
49317 49318 49319 49401	Data link error Load signal ECM driver position Charge air pressure	alarm	binary	
49324 49335	FCT position failure	alarm	binary	
49337	Actual FCT position doesn't match gas operation	SHOGE		
Electrical status				
9717.1 - 9717.11	Voltage failure electrical devices	alarm	binary	
9751.1	Voltage failure at charge air temperature controller	alarm	binary	

Meas. point	Description		Signal range	Remarks
Electrical status				
9971	Emergency stop ECR diabled	alarm	binary	
99935.1	Status network failure MODbus TCP	alarm	binary	
99937.1	Status failure RS232	alarm	binary	
99938.1	Status CAN 1CANbus J1939 failure	alarm	binary	
99938.2	Status CAN 2CANbus J1939 failure	alarm	binary	
99939	Fuel bus failure - common alarm	alarm	binary	
99940	Sensor / Isolation fault - common alarm	alarm	binary	
99941	Device status monitoring system - common alarm	alarm	binary	
99942	Device status protection system	alarm	binary	
99970	Alarm system / DCU common alarm	alarm	binary	
Engine status				
9404	Engine overspeed	shutdown	binary	Overspeed alarm generated via 9419.1 / 9419.2
9419.1 - 9419.11	Engine speed, pick-up signal	indication		Used for indication and functions
9429	Turbocharger speed	indication	4-20 mA	
9509	Distance sensor, fuel setting	indication	0-20 mA	
9513.1	Ready primary ECM diesel ready	start interlock	binary	
9561	Turning gear engaged	start interlock	binary	
Power supply engine cabinet				
99973.1	Main power supply failure	alarm	binary	
99973.2	Back-up power supply failure	alarm	binary	
99974	Power supply isolation failure	alarm	binary	
Exhaust gas				
8211	Exhaust gas temperature after cylinder (each cylinder)	indication	NiCr-Ni (mV)	
8218	Exhaust gas temperature after cylinder (each cylinder)	change genset	binary	Calculated from 8211
8219	Exhaust gas temperature after cylinder (aech cylinder)	alarm	binary	Calculated from 8211
8214	Mean average exhaust gas temperature	indication	function	Calculated from 8211
8213 8216	Deviation from mean average (each cylinder)	alarm change genset	binary	Calculated from 8214
8221	Exhaust gas temperature at turbocharger outlet	indication	NiCr-Ni (mV)	
8222	Exhaust gas temperature at turbocharger outlet	alarm	binary	Calculated from 8221

Meas. point	Description		Signal range	Remarks
Exhaust gas				
8224	Exhaust gas temperature at turbocharger outlet	change genset	binary	Calculated from 8221
8231	Exhaust gas temperature at turbocharger inlet	indication	NiCr-Ni (mV)	
8232	Exhaust gas temperature at turbocharger inlet	alarm	binary	Calculated from 8231
Big end bearing (optional)				
1231	High temperature conrod big end bearing (each bearing)	indication	analogue	
1232	High temperature conrod big end bearing (each bearing)	alarm	binary	Calculated from 1231
1238	High temperature conrod big end bearing (each bearing)	shutdown	binary	Calculated from 1231
1235	Mean average temperature of big end bearings	indication	function	Calculated from 1231
1236 1237	Max. positive temperature deviation from mean average	alarm shutdown	binary	Calculated from 1235
Main bearing (optional)				
1211	High temperature main bearing (each bearing)	indication	analogue	
1212 1218	High temperature main bearing (each bearing)	alarm shutdown	binary	Calculated from 1211
1215	Mean average temperature of main bea-rings	indication	function	Calculated from 1211
1216 1217	Max. positive deviation from mean average of main bearing	alarm shutdown	binary	Calculated from 1215
Load share unit (optional)				
9615	Minor alarm load share unit	alarm	binary	
9616	Major alarm load share unit	shutdown	binary	
Fuel oil module (optional)				
5105	Fuel oil pressure low	stand-by pump		
5112	Fuel oil differential pressure at automatic filter	alarm		
5115	Fuel oil differential pressure at circulating pump	stand-by pump		
5116	Fuel oil differential pressure at circulating pump	alarm		
5251 5252	Fuel oil viscosity at engine inlet high	alarm		
5333	Fuel oil level mixing tank	indication		

Meas. point	Description		Signal range	Remarks
Gas valve unit				
45301 45302	Position of block valve 1 open/close	alarm/SHOGE	binary	
45303 45304	Position of block valve 2 open/close	alarm/SHOGE	binary	
45305 45306	Position of bleed valve 1 open/close	alarm/SHOGE	binary	
45307 45308	Position of bleed valve 2 open/close	alarm/SHOGE	binary	
45309 45310	Position of bleed valve 3 open/close	alarm/SHOGE	binary	
45101	Fuel gas pressure at GVU inlet	alarm/SHOGE	4-20 mA	
45102	Pressure between block valve 1 and 2 at GVU	function	4-20 mA	
45108 45122	Flow of fuel gas volume at GVU inlet	indication function	4-20 mA pulse	
45103 45104	Fuel gas pressure at GVU outlet	SHOGE indication	4-20 mA 4-20 mA	
45201	Fuel gas temperature at GVU inlet	alarm/SHOGE	PT 100	
Ignition fuel module				
45312 45313 45315	HIHI Level switch circulation tank HI Level switch circulation tank LOLO Level switch circulation tank	alarm	binary	
45314 45316 45317 45318 45319	LSLL Level switch feed tank HIHI Level switch feed tank HI Level switch feed tank LO Level switch feed tank LOLO Level switch feed tank	alarm	binary	
45320	Filling valve	function	binary	
45321 45322	Limit switch 1 filling valve Limit switch 2 filling valve	function	binary	
45323	Transfer valve	function	binary	
45324 45325	Limit switch 1 transfer valve Limit switch 2 transfer valve	function	binary	
45326	Circulation pump	function	binary	
45327	Feeding pump	function	binary	
45109 45110	Differential pressure switch duplex filter 1	status alarm	binary	
45111 45112	Differential pressure switch duplex filter 2	status alarm	binary	
49121	ESD active – circulation and feeding pump	alarm	binary	

SHOGE: Shut-off gas supply to individual engine

Meas. point	Description		Signal range	Remarks
Ignition fuel module				
45105.1 45105.2	Differential pressure ignition fuel oil filter high	pre-alarm alarm	binary	
45329.1 - 45329.8	Diesel oil circulation pump DP10, DP11, (on, off tripped...)	indication alarm	binary	
45329.9 45329.10	Change over valce DR4 manual/auto	indication	binary	
45329.11 45329.12	Change over valve DR5 manual/auto	indication	binary	
45328	Feeding pump in back-up	alarm	binary	
49122	ESD active – back-up feeding pump	alarm	binary	
45301 45302 45303 45304	Diesel oil ignition supply pump DP12 on Diesel oil ignition supply pump DP12 manual Diesel oil ignition supply pump DP12 auto Diesel oil ignition supply pump DP12 tipped	indication	binary	
Crankcase gas detection				
45401	Gas detector fuel gas concentration high	alarm/SHOGE	4-20 mA 0-100% LEL	
45403	Media flow monitor	indication	binary	
45404	Media pump control	indication	binary	
Exhaust gas ventilation				
99989	Start exhaust gas ventilation	function	binary	
99990 99991	Motor flap EGMV command open Motor flap EGMV command close	function	binary	
99992	Ventilator fault	function	binary	
99993	Motor flap fault	function	binary	
99994 99995	Motor flap position switch open Motor flap position switch close	function	binary	
99996	Differential pressure switch / air after fan	function	binary	
99997	Temperature air after fan	function	binary	
Slow turn device				
9829.1 9829.2	Stop position switch close Stop position switch open	function	binary	
99950	Mode change	indication	binary	
9846	Automatic mode	indication	binary	

SHOGE: Shut-off gas supply to individual engine

13.8 Local and remote indicators

Local indication	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)	X 2)
Lube oil temperature at engine inlet	X 2)
Lube oil differential pressure at filter	
Fresh water temp. at engine inlet (HT circuit)	
Fresh water temp. at engine outlet (HT circuit)	X 2)
Fresh water temperature (LT circuit)	X 2)
Fresh water temperature cooler inlet	
Fresh water temperature cooler outlet	
Charge air temperature cooler inlet	
Charge air temperature engine inlet	X 2)
Fuel oil pressure	X 2)
Lube oil pressure	X 2)
Fresh water pressure (HT circuit)	X 2)
Fresh water pressure (LT circuit)	X 2)
Start air pressure	X 2)
Charge air pressure cooler outlet	X 2)
Stop air pressure	
Engine speed	X 1)
Turbocharger speed	X 1)
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

13.9 Clutch control system

The diagram below shows an example of a typical soft-clutch engagenemt 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 which has to be minimum 3 seconds.

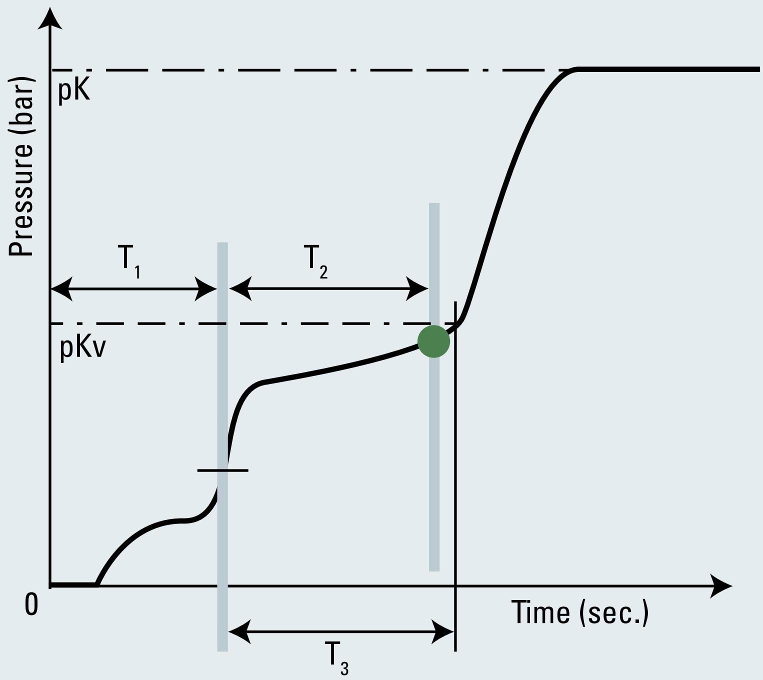

Fig. 13-7 Clutch in procedure for propulsion systems

pK = Lube oil switching pressure
pK_V = Control pre-pressure
T_y = 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.

13.10 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 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.

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

13.11 Safety

Selected mode \ Potential operation	Diesel operation	Gas operation
Diesel mode	Yes	No
Gas mode	Possible	Yes

Fig. 13-8 Definition: "Mode" vs. "Operation"

"Mode" specifies the desired engine operation.

"Operation" specifies the actually burned fuel.

Additional safety requirements need to be fulfilled to operate a dual fuel engine in a marine application. The safety concept for the MaK dual fuel engine is designed according the upcoming IGF code to provide a gas safe machinery space.

13.11.1 Safety concept

The main intention of the safety concept for the new dual fuel engine is to prevent the formation of a hazardous explosive atmosphere. Therefore a gas detection system is used in combination with automatic safety actions that will finally result in changeover to diesel and flushing of the gas supply line. Additionally a ventilation system for the exhaust pipe will inhibit an accumulation of fuel gas.

Already during the design phase ignition sources have been considered and were excluded where possible. The aim was to create a robust design.

This safety concept for the dual fuel engine is based on a gas-safe machinery space.
This means that in case of a malfunction the dual fuel engine won't shut down, instead the fuel supply will switch over to fuel oil. The switchover from fuel oil to fuel gas or vice versa will be bumpless and without any losses in power performance of the engine.

To create a gas-safe machinery space the fuel gas pipes in the machinery space are double-walled from the gas valve unit throughout the cylinders. A leakage monitoring system is installed. To ensure the gas safe machinery space at all times the following requirements need to be fulfilled in addition:

- Fuel gas piping in machinery space needs to be double-walled.
- All parts of the engine's fuel gas supply system inside the machinery space need to be double-walled.
- The double wall permanently needs to be checked for leakage while containing fuel gas.
- Purging the fuel gas line with inert gas needs to be possible.
- Machinery space ventilation needs to be monitored (30 air changed per hour by two separate systems).
- Gas concentration of the crankcase outlet needs to be monitored.

- Means are to be provided to inert and vent the crankcase for maintenance reasons.
- No direct access to gas hazardous areas is allowed.
- In case of an emergency shut down of the engine while running on fuel gas, the exhaust system needs to be ventilated.
- At each engine stop after gas operation the fuel gas supply lines need to be flushed.

Additionally to the machinery space special attention needs to be paid to the gas handling room and all rooms adjacent to possibly hazardous areas.

The engine control, monitoring and protection system, called MACS (Modular Alarm Control System), consists of different functional components. It will include the start-stop system, the gas management, the monitoring system and the engine protection system. A screen is fitted in the local control panel and will show measurement data as well as disgnostics and engine status.

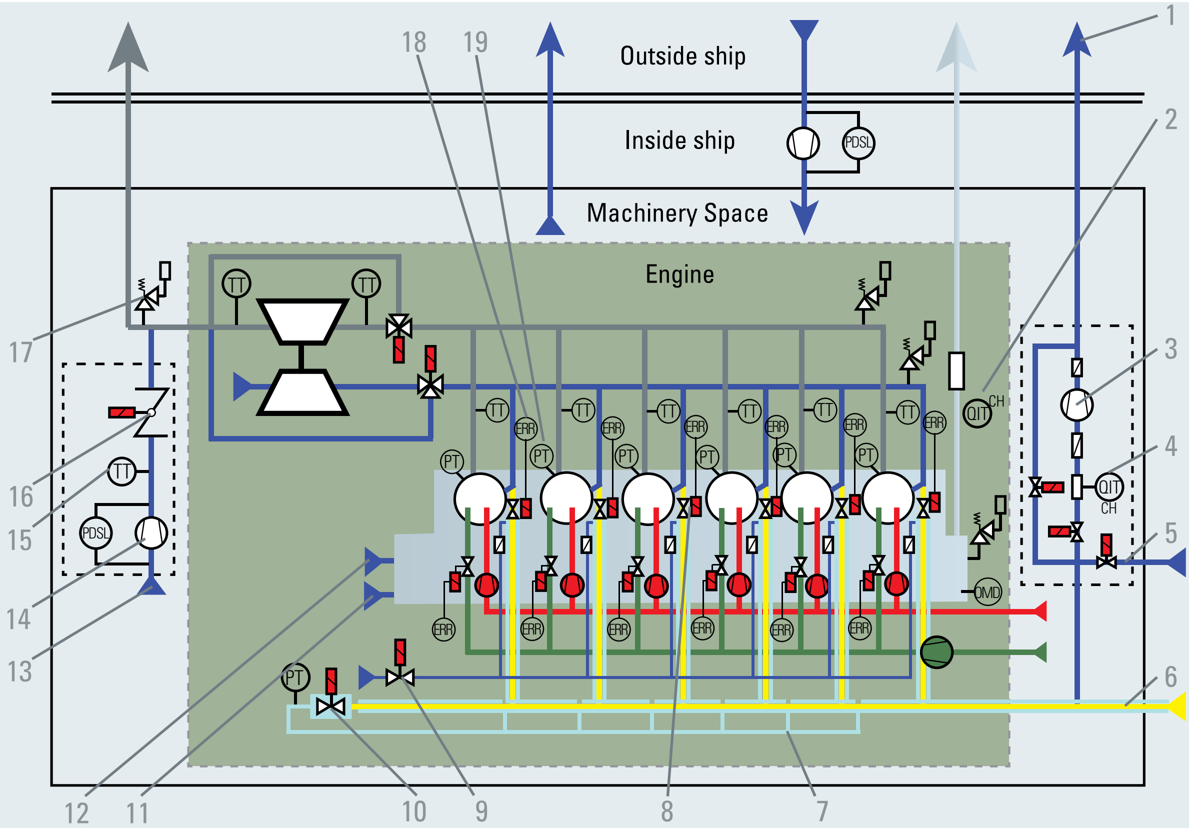

Fig. 13-9 Gas related safety equipment

1	Inertgas ventilation outlet	11	Crankcase flushing valve for inertgas
2	Gas sensor in crankcase ventilation line	12	Crankcase purging valve for compressed air
3	Vacuum module	13	Air inlet for exhaust gas duct purging
4	Gas sensor in vacuum module	14	Fan for exhaust gas duct purging
5	Inertgas supply inlet	15	Temperature transmitter
6	Fuel gas supply	16	Butterfly isolation valve
7	Inertgas compartment	17	Explosion relief valve
8	GAV (Gas Admission Valve)	18	In cylinder pressure sensor
9	Fresh air flushing valve	19	In cylinder pressure transmitter
10	Inertgas flushing valve		

14.1 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.

14.1.1 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.

14.1.2 Engine with dry sump

Dimension of foundation dry sump pan

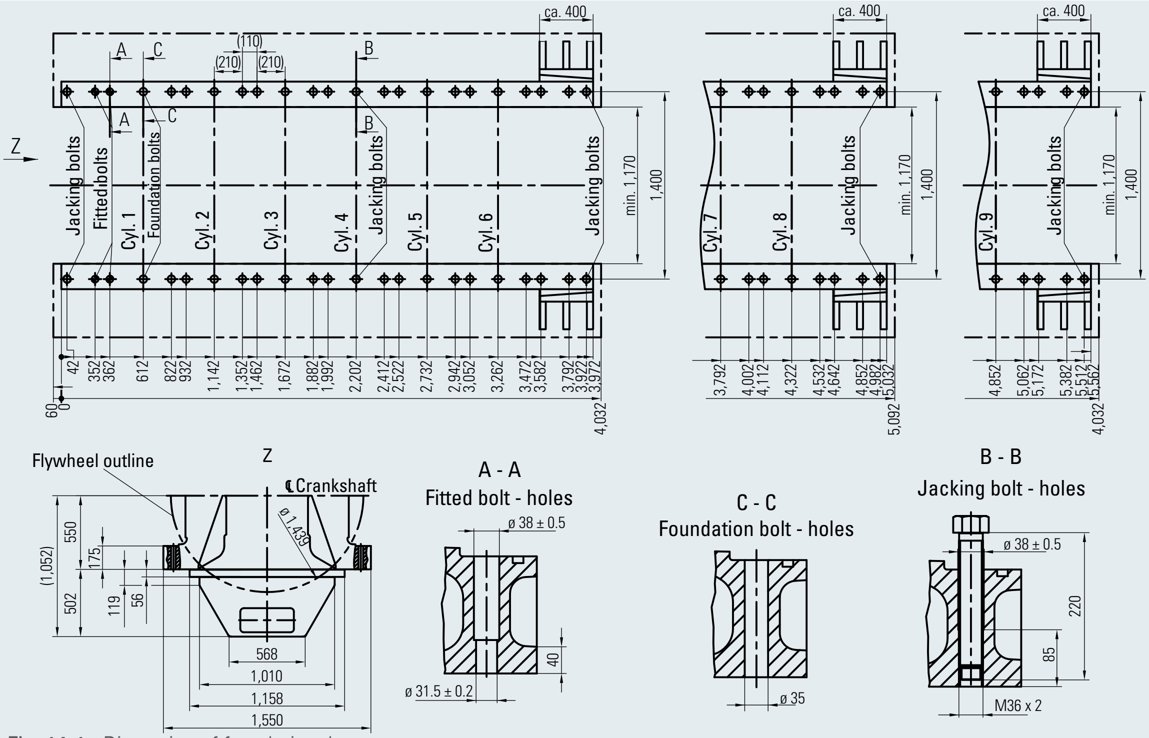

Fig. 14-1 Dimension of foundation dry sump pan

Side stoppers

6 M 34 DF	8/9 M 34 DF
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 34 DF	4	36	6
8 M 34 DF	4	48	6
9 M 34 DF	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.

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Proposal for rigid mounting

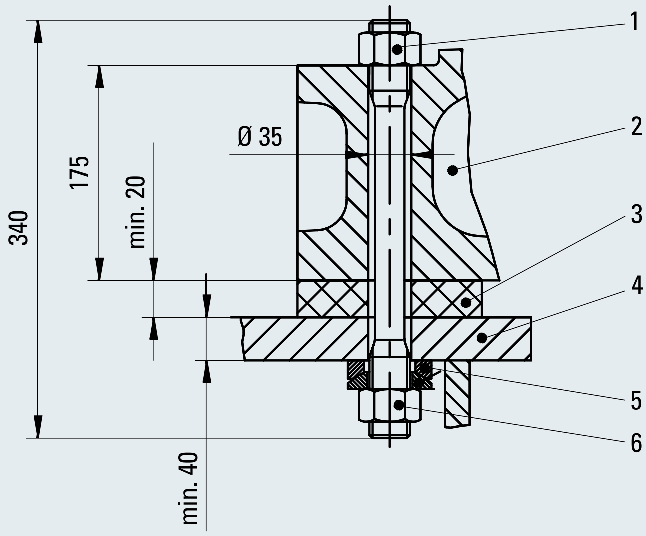

Fig. 14-2 Through bolt

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

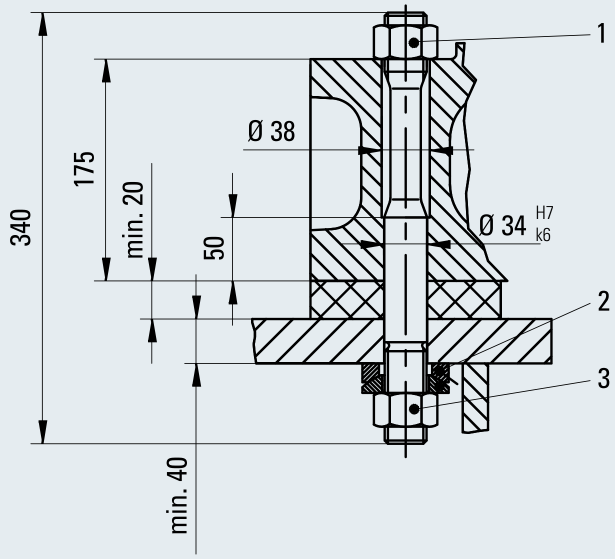

Fig. 14-3 Fitted bolt

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

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

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

14.1.3 Engine with wet sump

Dimension of foundation wet sump (option)

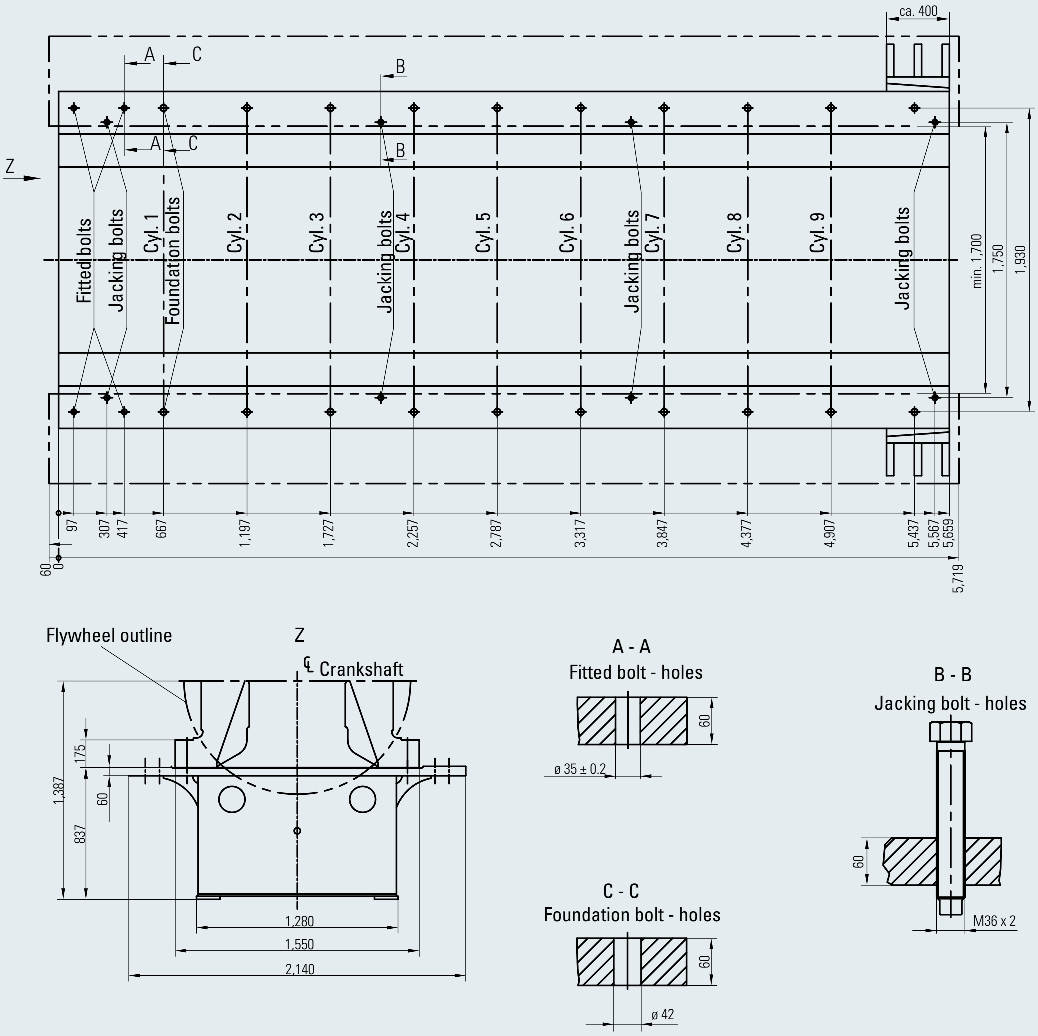

Fig. 14-4 Dimension of foundation wet sump

Side stoppers

6 M 34 DF	8/9 M 34 DF
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 34 DF	4	16	6
8 M 34 DF	4	18	8
9 M 34 DF	4	20	8

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

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

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

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

14.2 Resilient mounting

14.2.1 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.

14.2.2 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.

14.2.3 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.

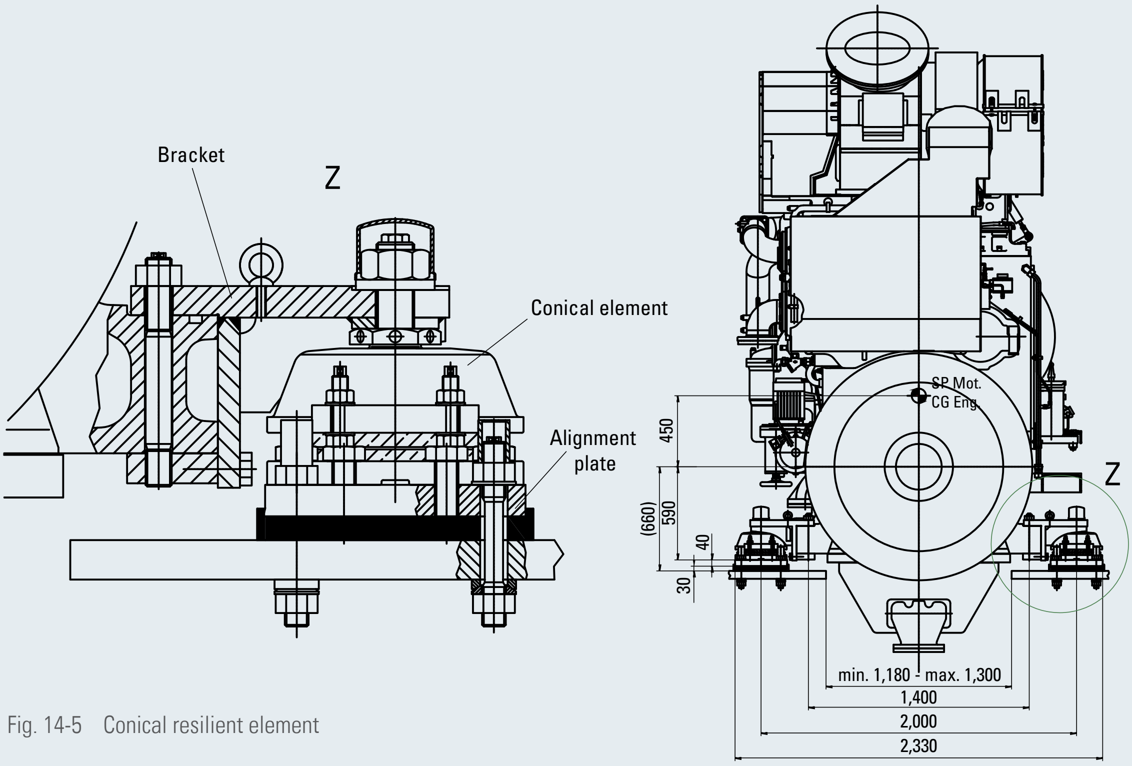

Fig. 14-5 Conical resilient element

Number of rubber elements

	Combined elements
6 M 34 DF	6
8 M 34 DF	8
9 M 34 DF	8

14.2.4 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.

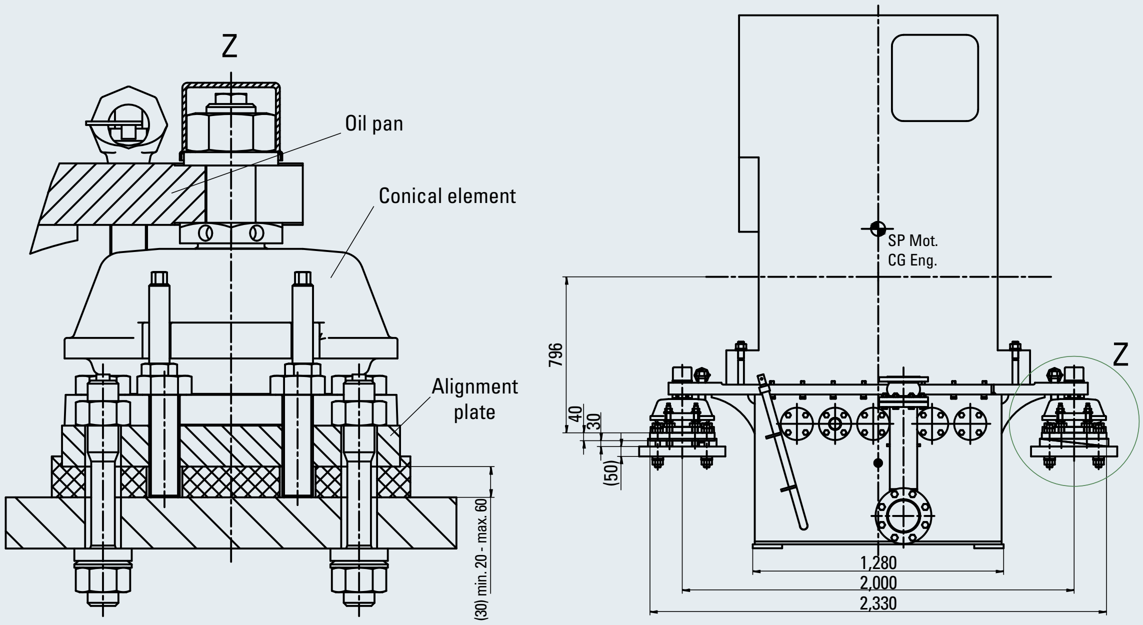

Fig. 14-6 Conical resilient element

Number of rubber elements

	Combined elements
6 M 34 DF	6
8 M 34 DF	8
9 M 34 DF	8

14.3 Earthing of engine

Information about the execution of the earthing

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

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

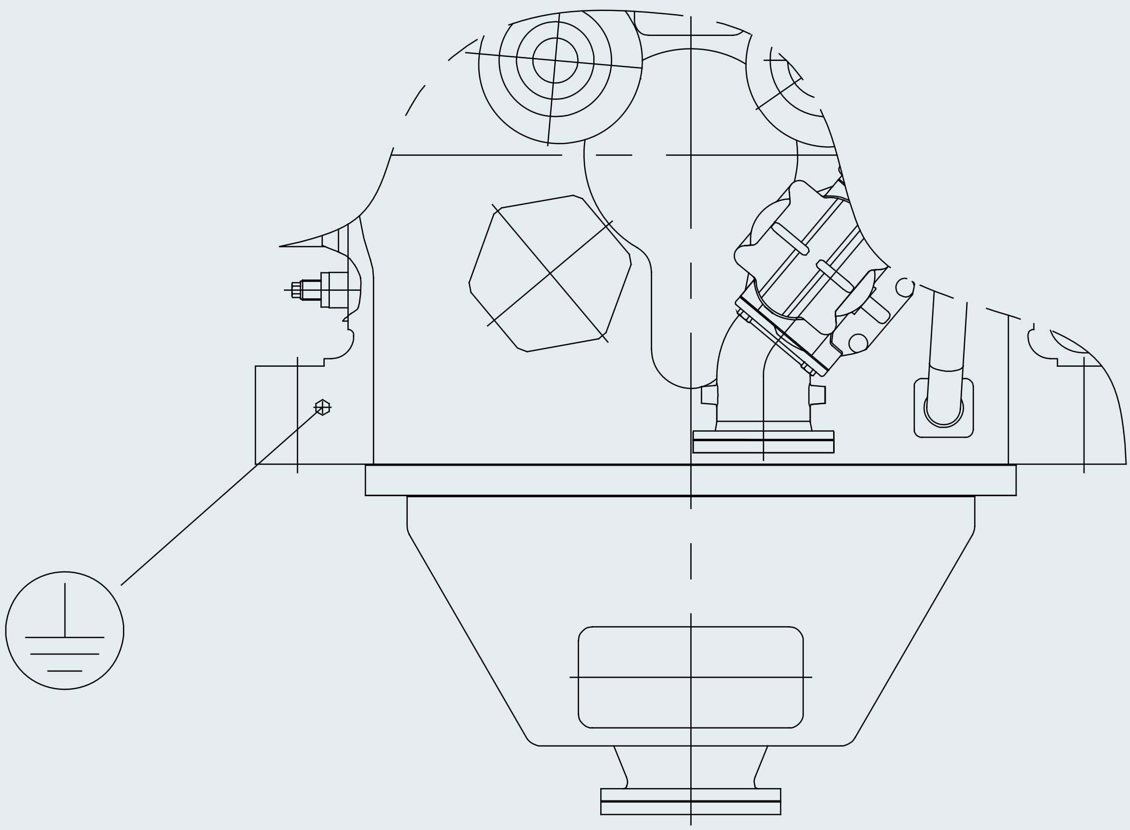

Fig. 14-7 Earthing connection on the engine

15.1 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.

15.2 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.

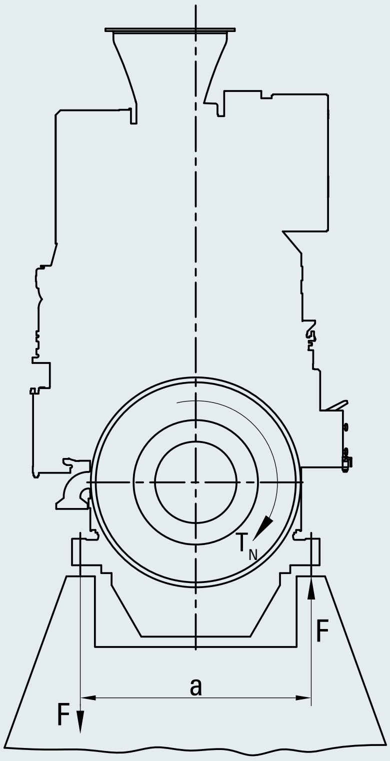

Fig. 15-1 Static load

	Output [kW]	Speed [rpm]	T_N [kNm]
6 M 34 DF	3,000	720/750	39.8/38.2
8 M 34 DF	4,000	720/750	53.1/50.9
9 M 34 DF	4,500	720/750	59.7/57.3

Support distance a = 1,400 mm

F = T_N/a
T_N = Nominal torque
F = Force
a = Support distance

15.3 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.

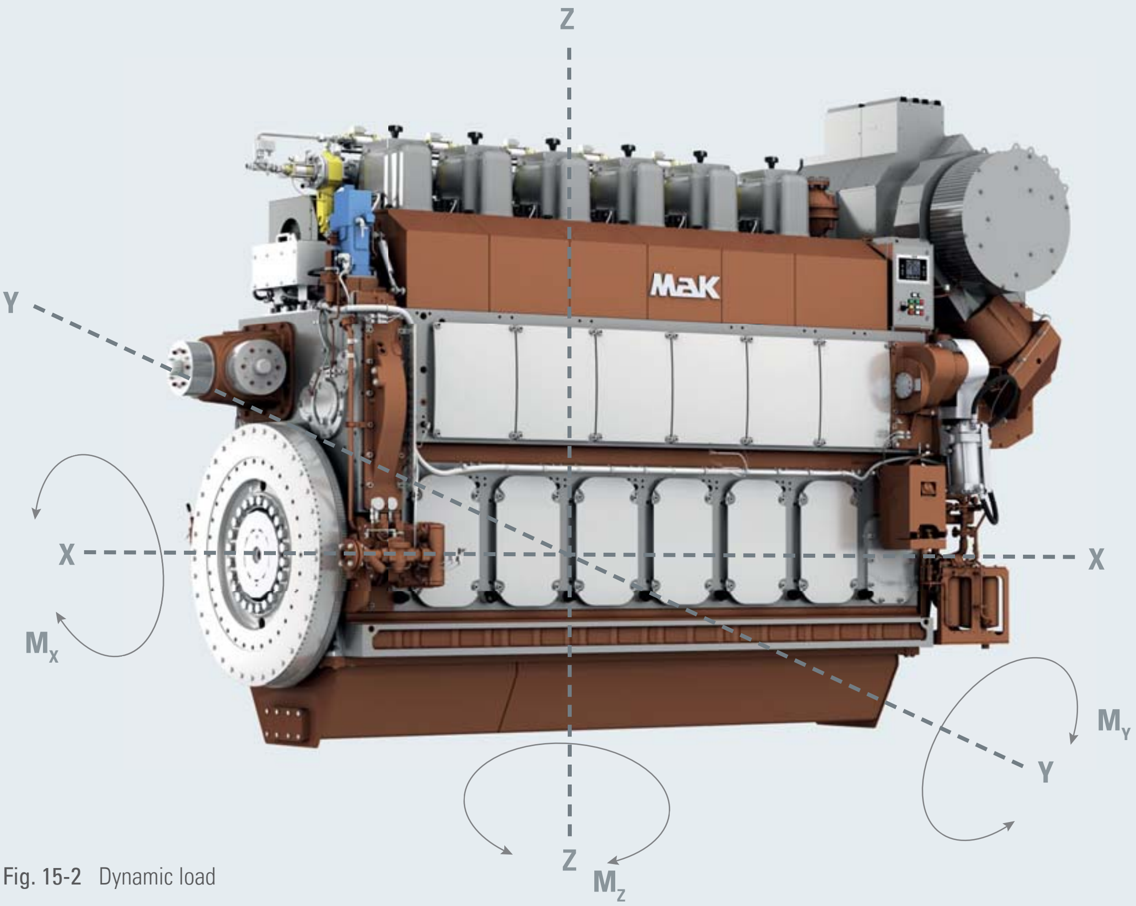

Fig. 15-2 Dynamic load

	Output [kW]	Speed [rpm]	Order-no.	Frequency [Hz]	M_X [kNm]	M_Y [kNm]	M_Z [kNm]
6 M 34 DF	3,000	720/750	3.0 6.0	36.0/37.5 72.0/75.0	13.1/11.7 15.3/14.7	–	–
8 M 34 DF	4,000	720/750	4.0 8.0	48.0/50.0 96.0/100.0	46.6/44.5 7.3/7.0	–	–
9 M 34 DF	4,500	720/750	1 2	12.0/12.5 24.0/25.0	– –	17.1/18.6 52.7/57.2	– –
9 M 34 DF	4,500	720/750	4.5 9.0	54.0/56.3 108.0/112.5	46.1/44.4 5.1/4.9	– –	– –

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.

16.1 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).

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. 16-1 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: _____
Max. permissible PTO output [kW]: _____
Type: _____
☐ TVC scheme attached
☐ Drawing attached

Front gearbox for engine PTO

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

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

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

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

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

Caterpillar Confidential: Green

Fig. 16-2 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. 16-3 Additional engine plant data, part "B" (3/3)

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16.2 Sound levels

16.2.1 Airborne noise

The airborne noise level requirement in the engine room specified by IMO Resolution A.468 will be satisfied by M 34 DF (even for multiple installations).

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

16.3 Vibration

The vibration level of M 34 DF engines complies with ISO 20283-4 and ISO 10816-6. From these ISO standards, the following values are an applicable guideline:

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

17.1 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).

17.1.1 Mass moments of inertia

	Speed	Engine *	Flywheel	Total
	[rpm]	[kgm²]	[kgm²]	[kgm²]
6 M 34 DF	720/750	518	470	888
8 M 34 DF	720/750	593	470	1,063
9 M 34 DF	720/750	673	470	1,143

* Running gear with balance weights and vibration damper

17.1.2 Selection of flexible couplings

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

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

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

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

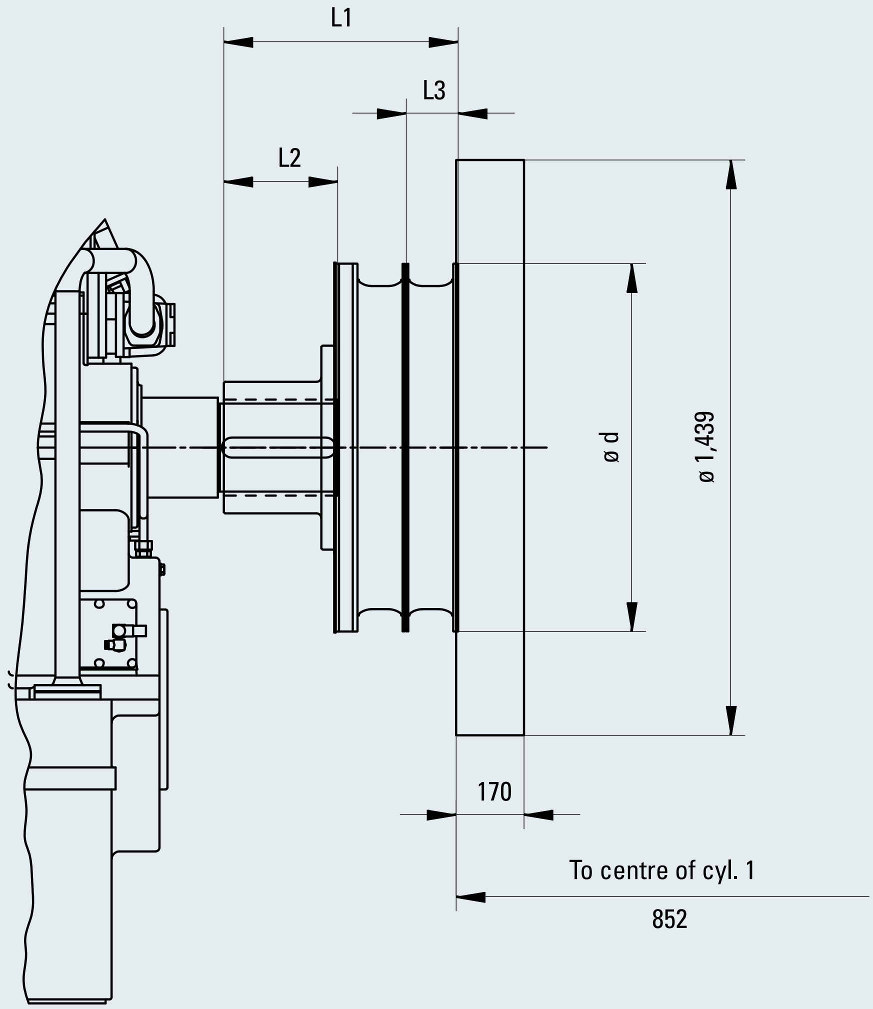

Fig. 17-1 Flywheel and flexible coupling

	Power	Speed	Nominal torque of coupling	d	L1 4)	L2 3)	L3 5)	Weight 1)	Weight 2)
	[kW]	[rpm]	[kNm]	[mm]	[mm]	[mm]	[mm]	[kg]	[kg]
6 M 34 DF	3,000	720/750	66.5	920	823 1) / 586 2)	285	132	721	545
8 M 34 DF	4,000	720/750	66.5	920	823 1) / 586 2)	285	132	721	545
9 M 34 DF	4,500	720/750	70.0	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 %.

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

The PTO output is limited to:

- 6 M 34 DF 3,000 kW
- 8 M 34 DF 3,200 kW
- 9 M 34 DF 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.

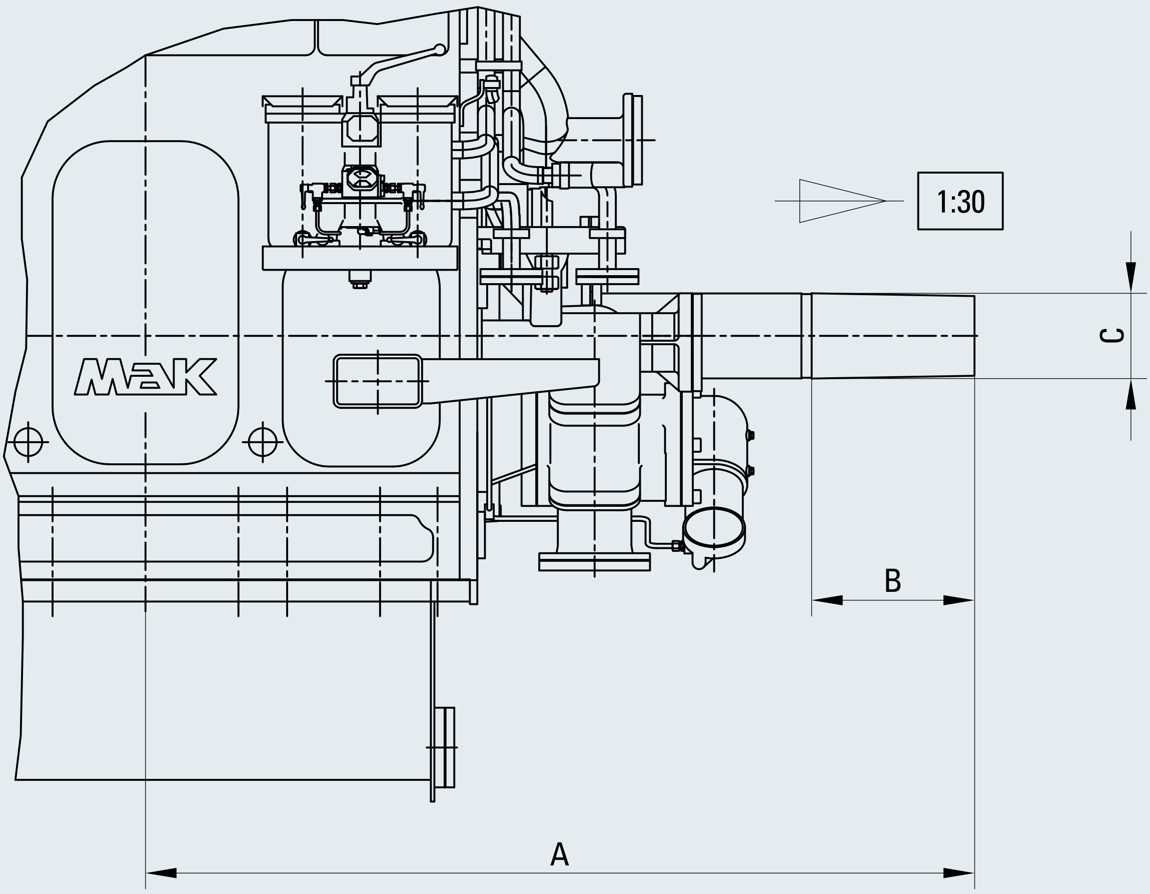

Fig. 17-2 Power take-off from the free end

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

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18.1 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.

18.2 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

18.3 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 - - - - - - - - - - - -

18.4 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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18.5 Flexible pipe connections

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

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

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

Installation of steel compensators

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

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

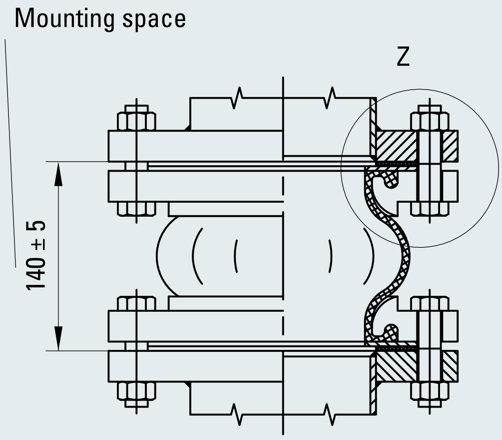

Fig. 18-1 Rubber expansion joint

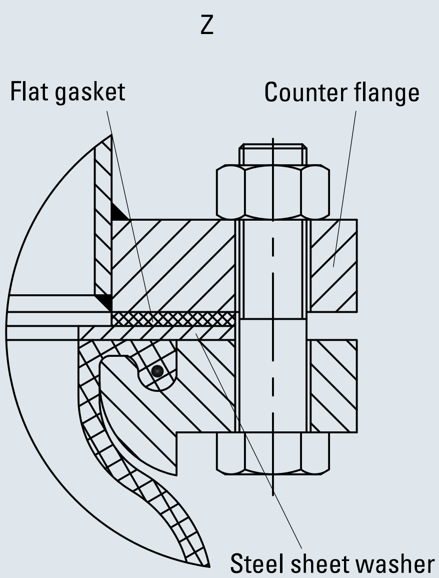

Fig. 18-2 Rubber expansion joint, detail Z

19.1 Engine center distances

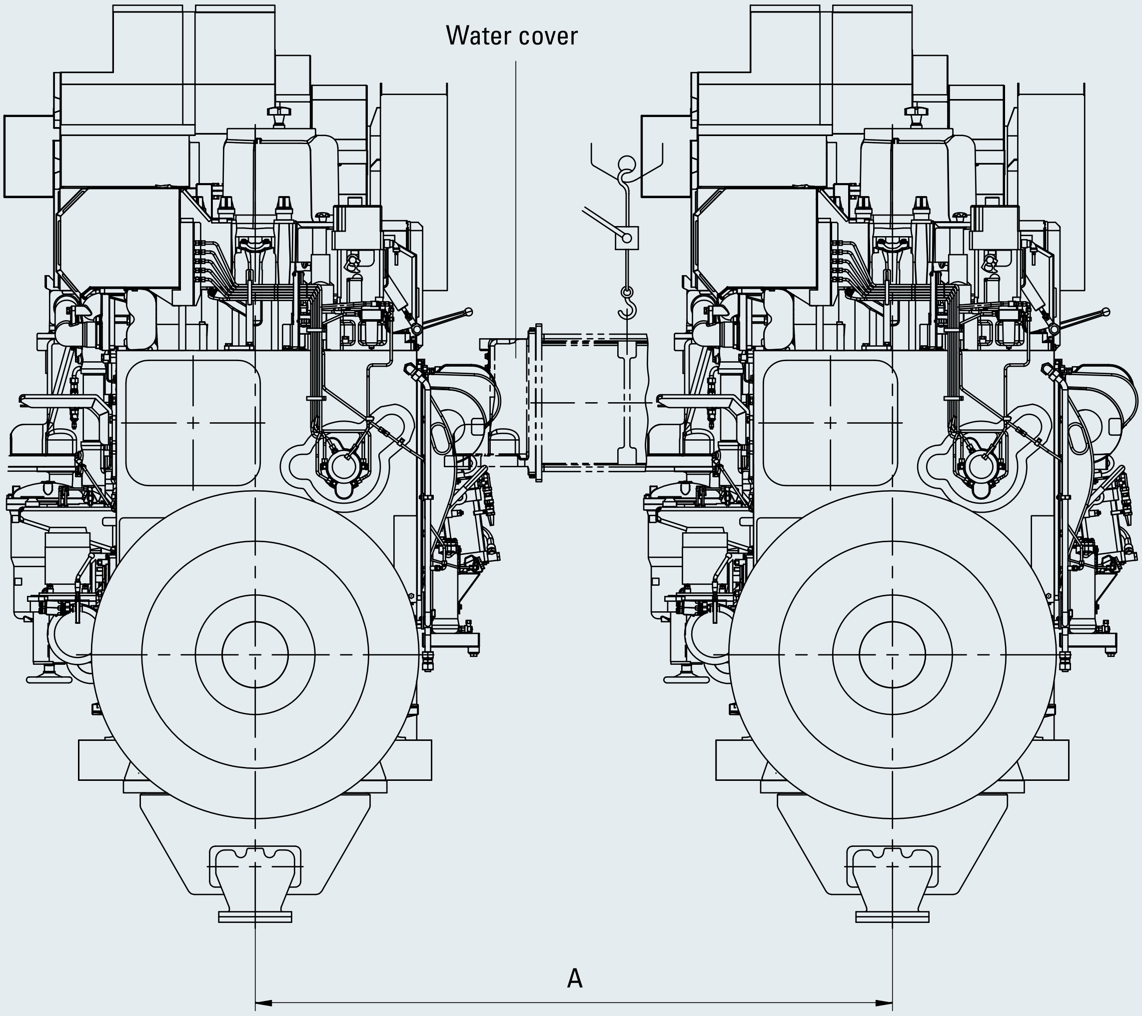

Fig. 19-1 Center distance of twin-engine plants

Type	Dimensions [mm]
	A
6/8/9 M 34 DF	3,000

19.2 Space requirement for maintenance

19.2.1 Removal of charge air cooler and turbocharger cartridge

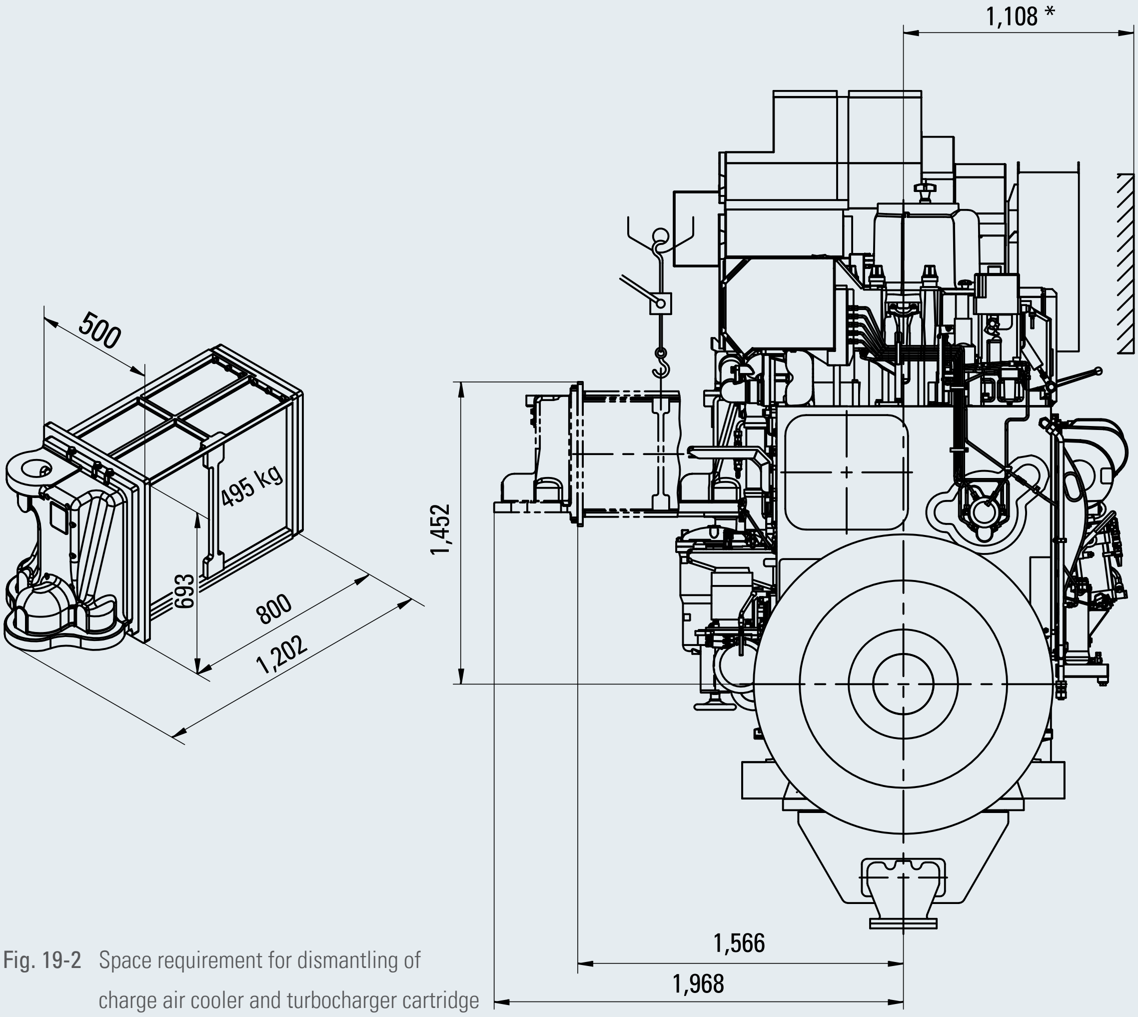

Fig. 19-2 Space requirement for dismantling of charge air cooler and turbocharger cartridge

Type	Dimensions [mm]						Weight charge air cooler	Weight turbocharger cartridge
	A	B	C	D	E	F	[kg]	[kg]
6 M 34 DF	1,413	1,980	676	520	1,160	850	495	1,200
8/9 M 34 DF	1,625	2,015	870	720	1,180	1,640	495	2,000

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.

19.2.2 Removal of piston and cylinder liner

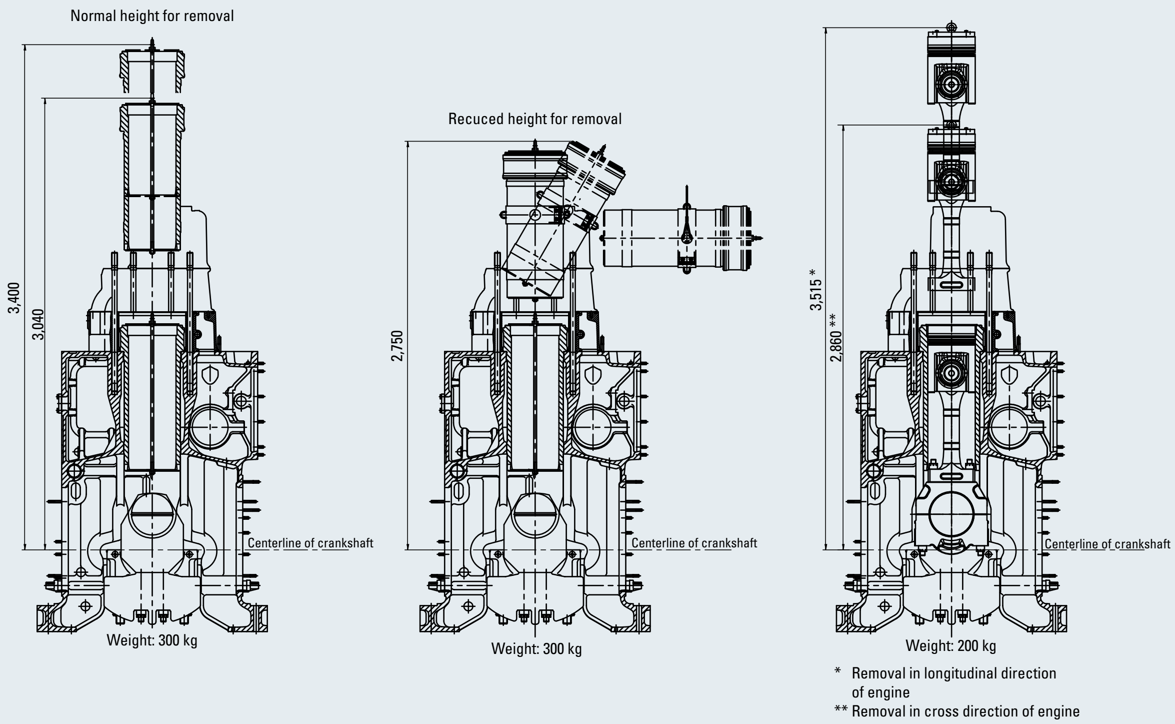

Fig. 19-3 Removal of piston and cylinder liner

20.1 Inside preservation

20.1.1 Factory standard N 576-3.3 – Inside preservation

Components

- Main running gear and internal mechanics

Application

- Max. 2 years

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

20.2 Outside preservation

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

Conditions

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

Appearance of the engine

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

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

20.2.2 Factory standard N 576-4.1 – Clear varnish

Conditions

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

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

Appearance of the engine

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

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

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20.2.3 Factory standard N 576-4.3 – Painting

Conditions

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

Appearance of the engine

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

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

20.2.4 Factory standard N 576-5.2 – VCI packaging

Conditions

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

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

Apperance of the engine

- Bare metal surfaces provided with VCI 368 or VCI oil
- VCI impregnated flexible PU foam mats attached to the engine using tie wraps.
  Kind and scope depending on engine type.
  The attached mats should not come into contact with the painted surface.
- Cover the engine completely with air cushion film VCI 126 LP. Air cushions are to face inwards! The air cushion film is fastened to the transportation skid (wooden frame) by means of wooden laths. Overlaps at the face ends and openings for the lifting gear are to be closed by means of PVC scotch tape.
  In case of engines delivered without oil pan, the overhanging VCI film between engine and transport frame is to be folded back upwards before fastening the air cushion film.

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

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

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

Application

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

Description

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

20.3 Factory standard N 576-6-1 – Protection period, check, and representation

20.3.1 Protection period

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

20.3.2 Protection check

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

20.3.3 Representation as per factory standard N 576-6.1

After 2 years representation must be carried out.

21.1 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 lifitng device has to be returned to Caterpillar Motoren.

Device to be used for transport of engine types 6/8/9 M 34 DF only. Max. lifting speed: 5 m/min.

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

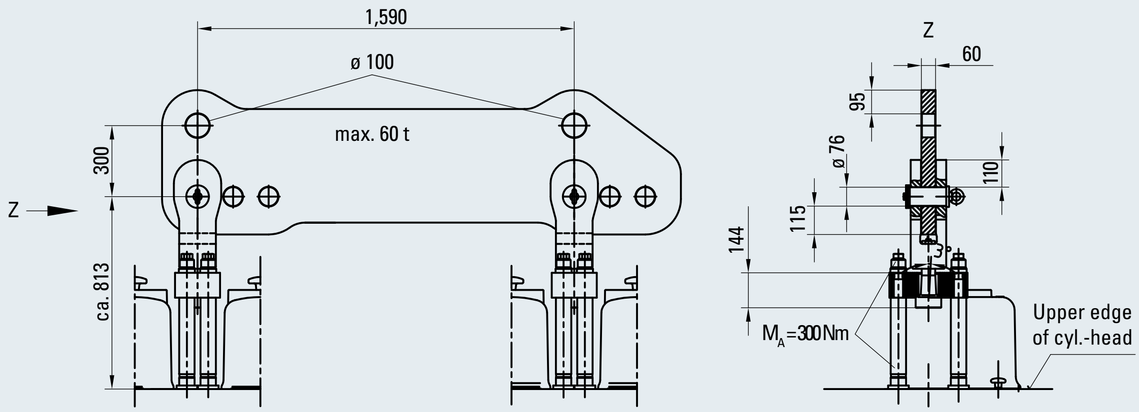

Fig. 21-1 Spreader bar

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

Transport of engine with turbocharger at driving end

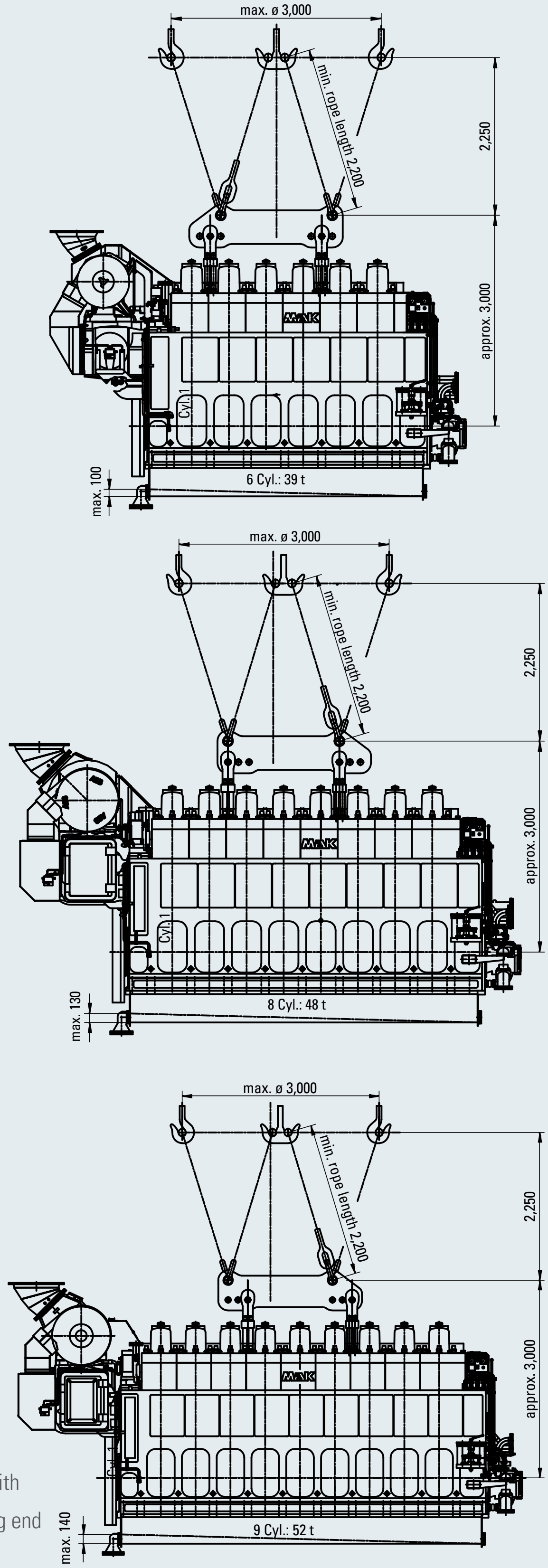

Fig. 21-2 Transport of engine with turbocharger at driving end

Transport of engine with turbocharger at free end

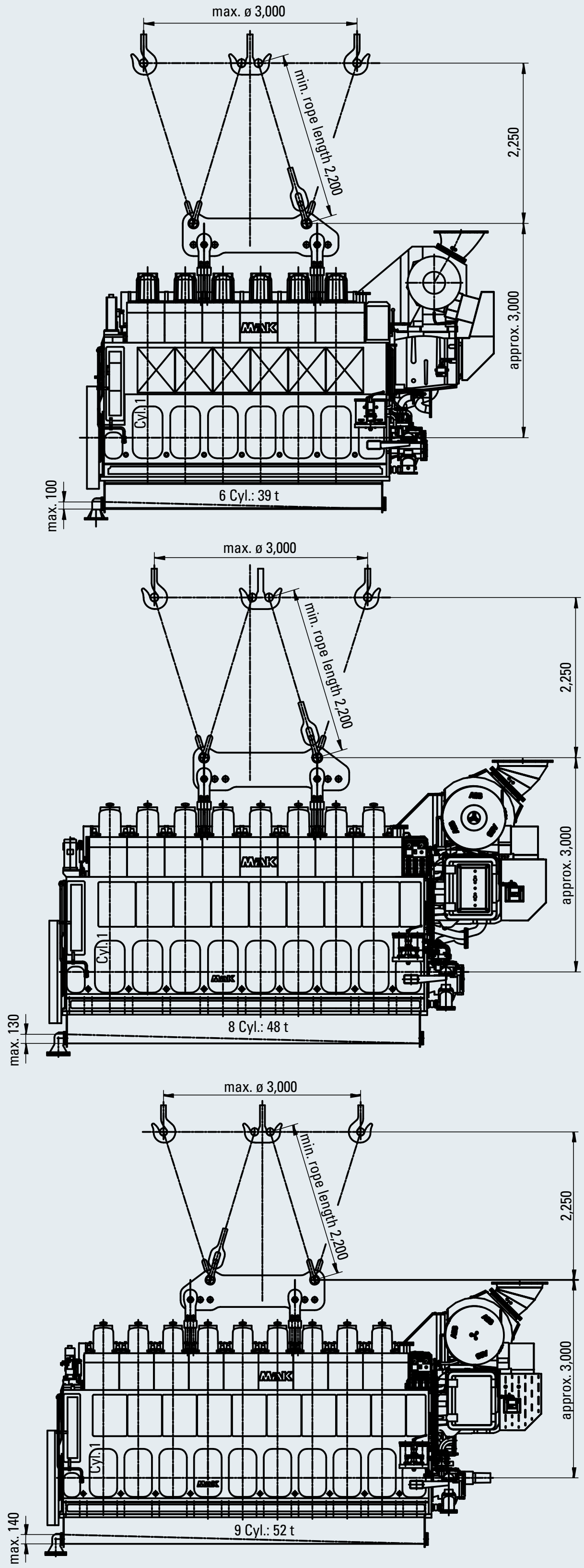

Fig. 21-3 Transport of engine with turbocharger at free end

21.2 Dimensions of main components

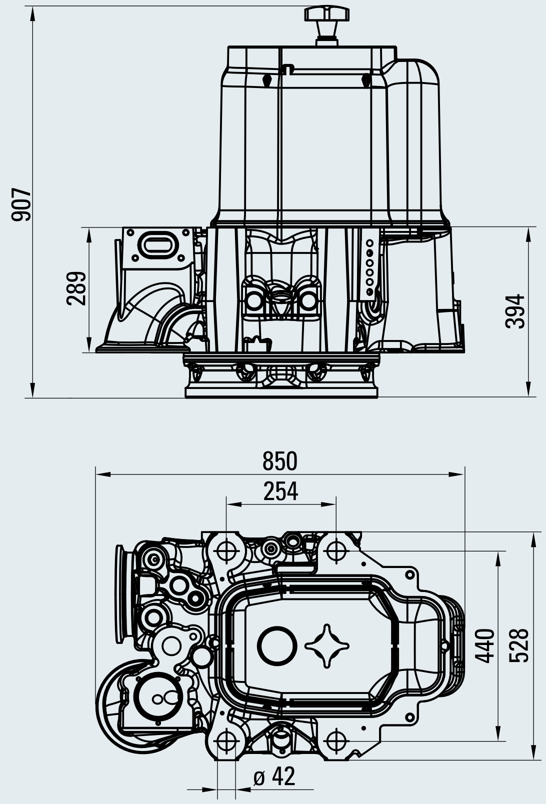

Fig. 21-4 Cylinder head, weight 460 kg

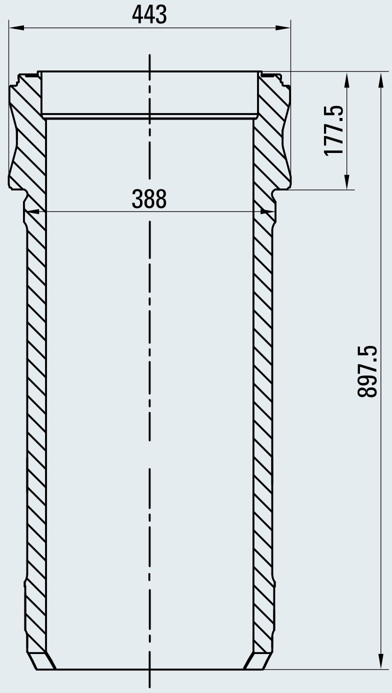

Fig. 21-5 Cylinder liner, weight 221 kg

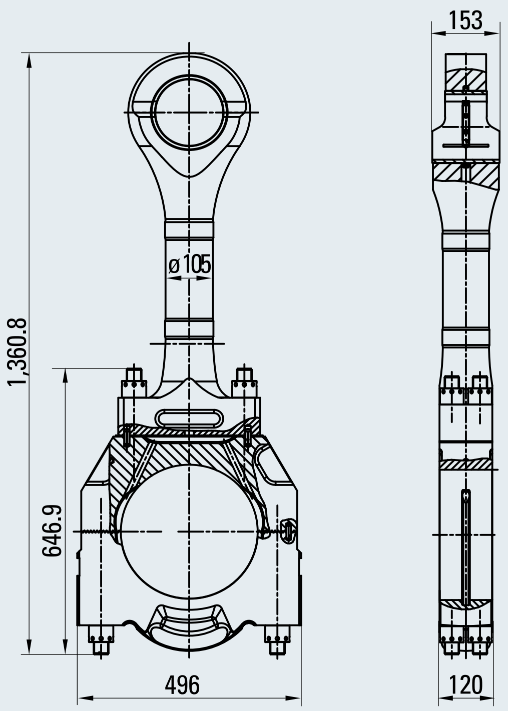

Fig. 21-6 Connecting rod, weight 224 kg

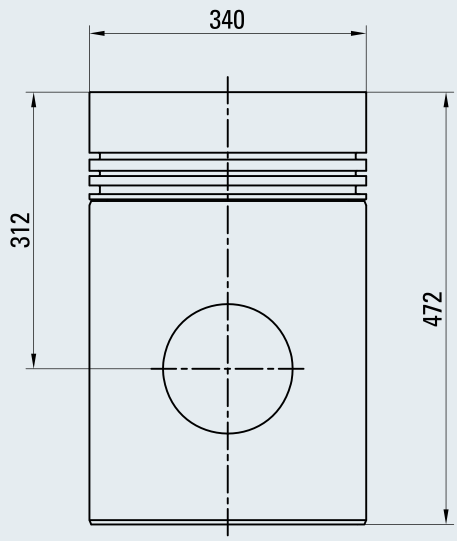

Fig. 21-7 Piston, weight 97.6 kg

22.1 Standard acceptance test run

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

Diesel mode

Load [%]	Duration [min]
Diesel mode	
25	20
50	20
75	20
85	30 (contractual fuel consumption measurement)
100	60
110	45
Gas mode	
25	20
50	20
75	20
85	30 (contractual fuel consumption measurement)
100	20

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

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

Additional functional tests

In addition to the acceptance test run the following functional tests will be carried out:
- Governor test
- Overspeed test
- Emergency shut-down via minimum oil pressure
- Start/stop via central engine control
- Starting trials up to a minimum air pressure of 10 bar
- Measurement of crank web deflection (cold/warm condition)

After the acceptance, main running gear, camshaft drive and timing gear train will be inspected through the opened covers. Individual inspection of special engine components such as piston or bearings is not intended, because such inspections are carried out by the classification societies at intervals on series engines.

23.1 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
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

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23.2 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
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	2	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	
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

Caterpillar recommendation	Caterpillar
Rules references	
Dual fuel diesel mode	
ECM	1
Speed pick up camshaft	1
Speed pick up crankshaft	1
Dual fuel gas mode	
Gas admission valve	2
Ingnition injector	2
Cylinder pressure sensor	1
Set of DF gaskets	1
Rail pressure sensor	1
Gas compensator	1
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

24.1 Gas systems technology – Scope of supply

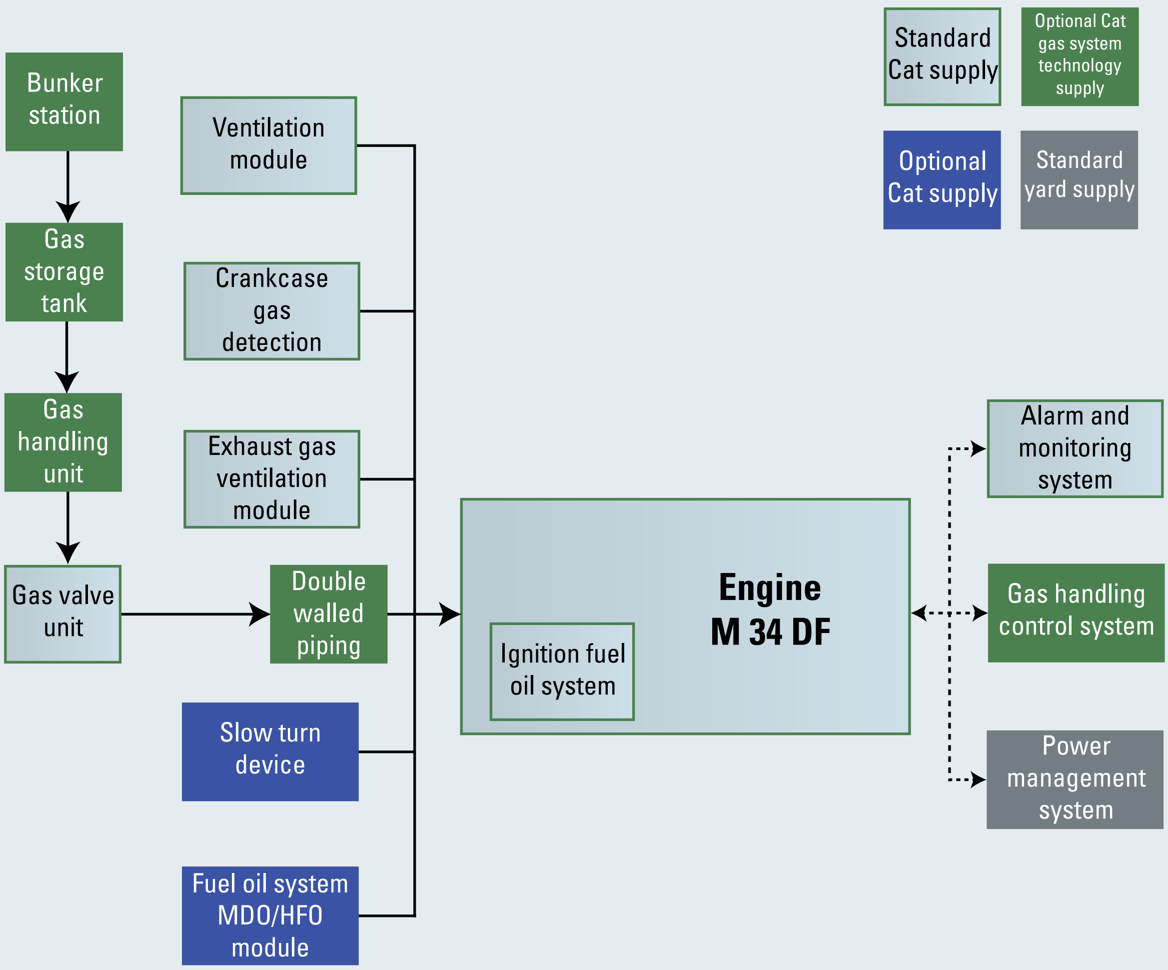

Fig. 24-1 Scope of supply M 34 DF Gas systems technology – block diagram

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

24.2 Caterpillar Propulsion

Performance You Can Rely On

Caterpillar Propulsion supplies complete, world-leading propulsion systems.

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

Fig. 24-2 Main propeller

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

How we deliver uptime

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

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

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

Fig. 24-3 Azimuth thrusters

Fig. 24-4 Tunnel thrusters

Fig. 24-5 Remote control system

The Power You Need.

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

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

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

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