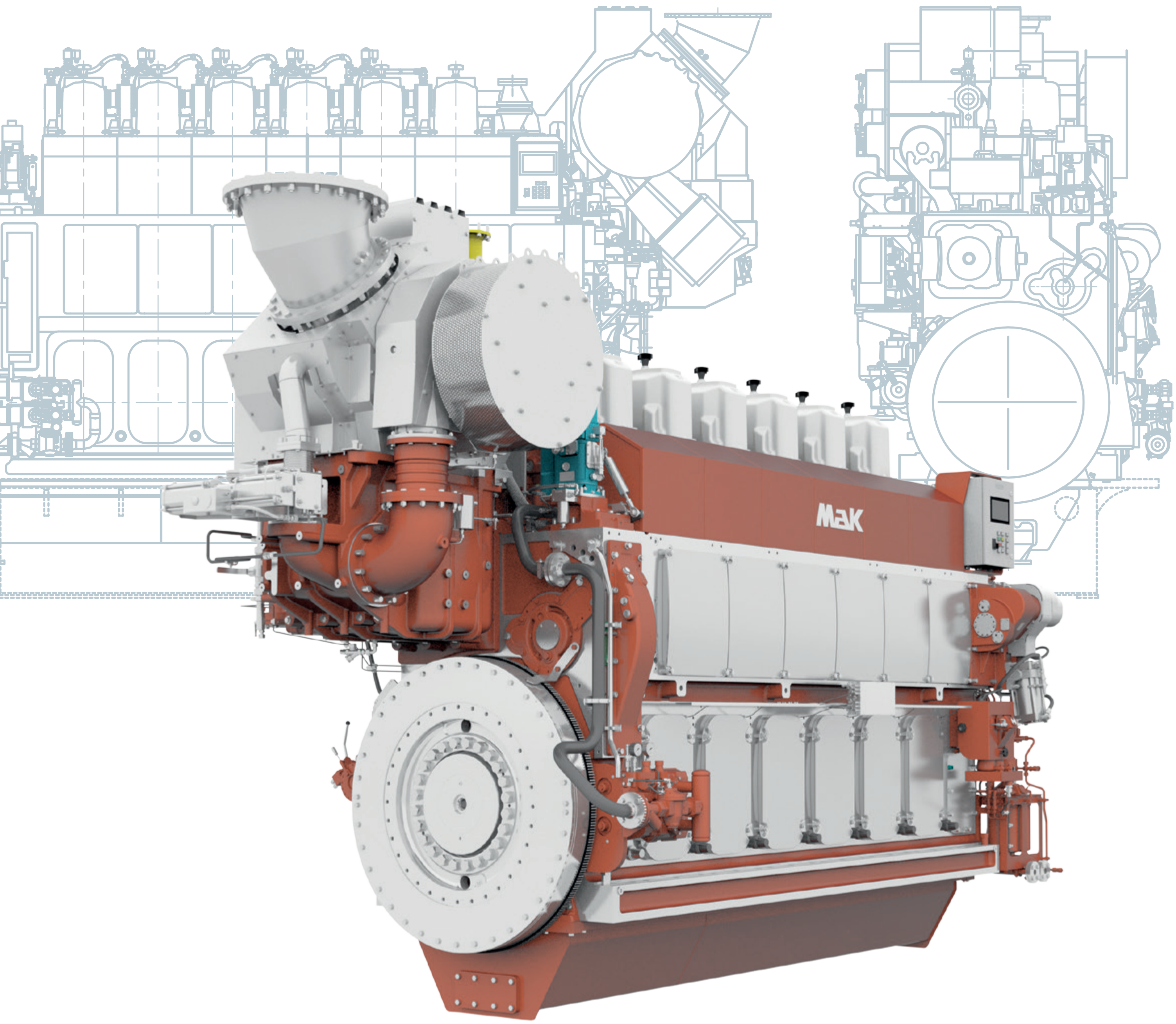
M 34 DF

Dual Fuel Engine
6 • 8 • 9 Cylinder

PROJECT GUIDE • PROPULSION



MaK

Information for the user of this project guide

The project information, technical data and reference specifications contained in the following are not binding.

Caterpillar Motoren GmbH & Co. KG (CM) reserves the right to modify and amend data at any time. Any liability for the accuracy of information provided herein is excluded. Caterpillar Motoren will supply further detailed and binding data, drawings, diagrams, electrical drawings, etc. in connection with a corresponding sales order.

This edition supersedes the previous edition of this project guide.

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Edition **September 2020**

Nothing is more important than safety. It is imperative for Caterpillar Motoren that all of our employees, customers, visitors – anyone who interacts with our globalorganization – are safe. Whenever you choose a Caterpillar Motoren product, it is built according to environmentally friendly processes. Our perfectly educated workforce is equipped with robust machining and assembly processes to ensure optimum quality for your product. Our processes are audited according to the standards of Det Norske Veritas – Germanischer Lloyd (DNV GL).

DNV·GL

MANAGEMENT SYSTEM CERTIFICATE

Certificate No: 196529-2016-AE-GER-DAkkS
Initial certification date: 04. November 2016
Valid: 08. October 2019 - 07. October 2022

This is to certify that the management system of

Caterpillar Motoren GmbH & Co. KG
Falckensteiner Str. 2-4, 24159 Kiel, Germany
and the sites as mentioned in the appendix accompanying this certificate

has been found to conform to the Quality Management System standard:
ISO 9001:2015

This certificate is valid for the following scope:

Place and date: Essen, 21. September 2019

DNV·GL

MANAGEMENT SYSTEM CERTIFICATE

Certificate No: 279096-2018-AE-GER-DAkkS
Initial certification date: 04. November 2016
Valid: 08. October 2019 - 07. October 2022

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has been found to conform to the Environmental Management System standard:
ISO 14001:2015

This certificate is valid for the following scope:

Place and date: Essen, 21. September 2019

DNV·GL

MANAGEMENT SYSTEM CERTIFICATE

Certificate No: 287920-2019-AHSO-GER-DAkkS
Initial certification date: 04. November 2016
Valid: 08. October 2019 - 11. March 2021

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has been found to conform to the Occupational Health and Safety Management System standard:
BS OHSAS 18001:2007

This certificate is valid for the following scope:
Caterpillar Motoren GmbH & Co. KG: Design, manufacture, sales and service of gas and diesel engines

Caterpillar Castings Kiel GmbH: Manufacturing and selling of qualified handmoulded castings made of grey-, nodular iron and quasiflake

Caterpillar Motoren Henstedt-Ulzburg GmbH: Logistics of spare and serial parts for gas and diesel engines

Caterpillar Motoren Rostock GmbH: Manufacture of gas and diesel engines

Place and date:
Essen, 23. September 2019

DAkkS Deutsche Akkreditierungsstelle D-ZM-18453-01-00

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

Thomas Beck
Management Representative

Lack of fulfilment of conditions as set out in the Certification Agreement may render this Certificate invalid.
ACCREDITED UNIT: DNV GL Business Assurance Zertifizierung & Umweltgutachter GmbH, Schnieringshof 14, 45329 Essen, Germany.
TEL:+49 201 7296-555. www.dnvgl.de/assurance

CONTENTS

4. OPERATING RANGES

5. FUEL OIL SYSTEM

6. GAS FUEL SYSTEM

7. LUBE OIL SYSTEM

8. COOLING WATER SYSTEM

9. COMPRESSED AIR SYSTEM

10. COMBUSTION AIR SYSTEM

11. EXHAUST GAS SYSTEM

CONTENTS

14. INSTALLATION AND ARRANGEMENT

15. FOUNDATION

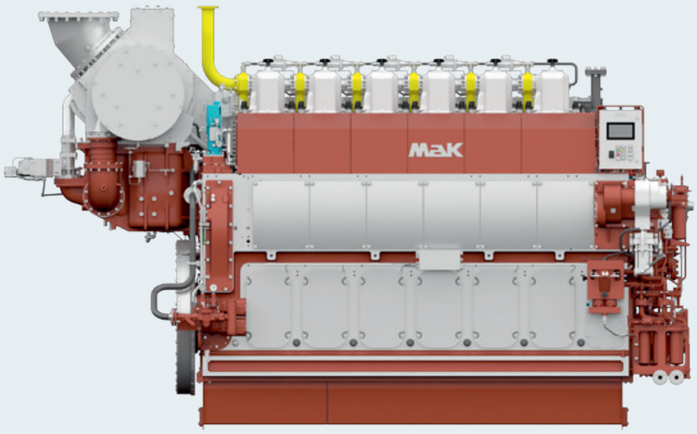
16. VIBRATION AND NOISE

CONTENTS

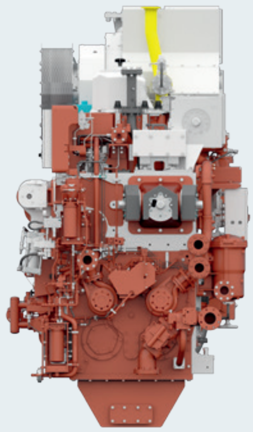
24. CATERPILLAR MARINE

1.1 Definitions

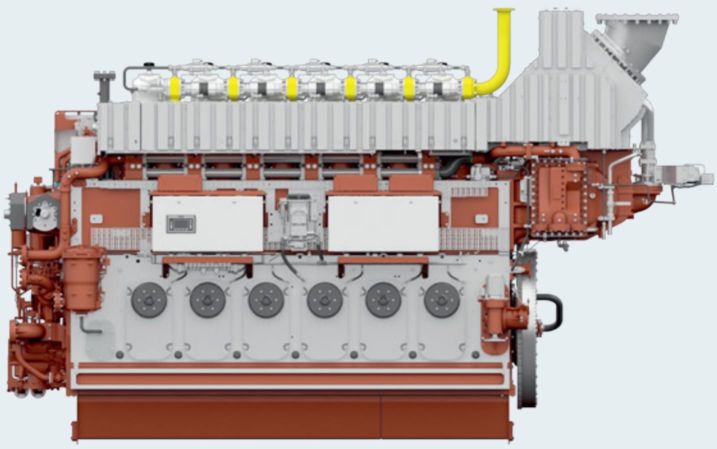
Control side



Free end



Exhaust side



Driving end
(Counter clockwise
or clockwise)

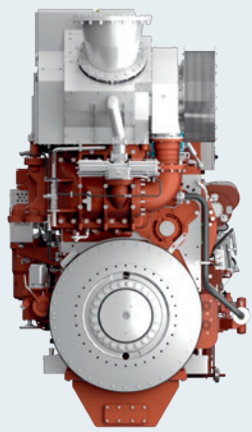


Fig. 1-1 M 34 DF

All pictures shown are for illustration purpose only. Actual product may vary due to product enhancement.

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:	530/550 kW
BMEP:	21.2/21.1 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 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 the dual fuel technology development and field experience from the M 46 DF platform 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

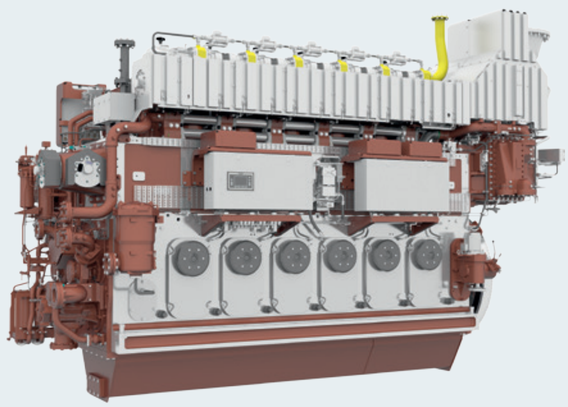


Fig. 1-3 Exhaust side and free end

All pictures shown are for illustration purpose only. Actual product may vary due to product enhancement.

1.3 Prospective life times

General

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

Core components	M 34 DF Propulsion	
	Life time operating hours [h]	
	Gas mode	Diesel mode
Piston	120,000	120,000
Piston rings	30,000	30,000
Piston pin bearing	60,000	60,000
Cylinder liner	120,000	120,000
Cylinder head	120,000	120,000
Inlet valve	30,000	30,000
Exhaust valve	30,000	30,000
Main bearing	30,000	30,000
Big end bearing	30,000	30,000
Camshaft bearing	75,000	60,000
Ignition fuel injector / High pressure pump	22,500 / 7,500	22,500 / 7,500
Pump element	–	15,000
Gas admission valve	15,000	–
Nozzle element	9,000	7,500

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

Type	720/750 rpm [kW]	
6 M 34 DF	3,180	3,300
8 M 34 DF	4,240	4,400
9 M 34 DF	4,770	4,950

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 %
Net heating value of Natural Gas (LNG):	49.500 kJ/kg
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 has to be calculated.

Additional BSFC per engine driven lube oil pump:

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

Additional BSFC per engine driven cooling water pump:

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

2.3 Lube oil consumption

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

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

2.4 Emissions

2.4.1 Exhaust gas

Atmospheric pressure: 100 kPa (1 bar)
Relative humidity: 60 %
Intake air temperature: 25 °C

550 kW/cyl. at 750 rpm in diesel mode

Engine	Output [kW]	Output [%] [kg/h] [°C]				
		100	85	75	50	25
6 M 34 DF	3,300	25,300 304	23,000 282	21,100 277	15,200 294	8,400 361
8 M 34 DF	4,400	33,700 304	30,700 282	28,100 277	20,300 294	11,200 361
9 M 34 DF	4,950	38,000 304	34,500 282	31,700 277	22,800 294	12,600 361

550 kW/cyl. at 750 rpm in gas mode

Engine	Output [kW]	Output [%] [kg/h] [°C]				
		100	85	75	50	25
6 M 34 DF	3,300	21,700 340	19,400 360	17,800 368	12,900 384	7,800 404
8 M 34 DF	4,400	28,900 340	25,900 360	23,700 368	17,200 384	10,400 404
9 M 34 DF	4,950	32,600 340	29,100 360	26,700 368	19,400 384	11,700 404

Tolerance for exhaust flow: 10 %
Tolerance for exhaust temperature: 20 K

530 kW/cyl. at 720 rpm in diesel mode

Engine	Output [kW]	Output [%] [kg/h] [°C] 100	85	75	50	25
6 M 34 DF	3,180	24,200 294	21,900 282	20,000 283	13,800 312	7,550 378
8 M 34 DF	4,240	32,300 294	29,200 282	26,700 283	18,400 312	10,100 378
9 M 34 DF	4,770	36,300 294	32,900 282	30,000 283	20,700 312	11,300 378

530 kW/cyl. at 720 rpm in gas mode

Engine	Output [kW]	Output [%] [kg/h] [°C] 100	85	75	50	25
6 M 34 DF	3,180	21,900 342	19,600 362	17,700 372	12,400 390	7,300 421
8 M 34 DF	4,240	29,200 342	26,100 362	23,600 372	16,500 390	9,700 421
9 M 34 DF	4,770	32,900 342	29,400 362	26,600 372	18,600 390	11,000 421

Tolerance for exhaust flow: 10 %
Tolerance for exhaust temperature: 20 K

2.4.2 Nitrogen oxide emissions (NO_x-values)

NO_x-limit values according to IMO II: 9.60 g/kWh (n=750 rpm)
NO_x-limit values according to IMO III: 2.40 g/kWh (n=750 rpm)

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.

2.4.4 EEDI (Energy Efficiency Design Index)

The Energy Efficiency Design Index (EEDI) was developed and implemented by the International Maritime Organization (IMO) in 2013. Its objective is to simulate/encourage the merchant fleet to reduce emissions by using innovative and more energy efficient propulsion concepts. The EEDI is based on technical design parameters. It is a calculated, specific figure for an individual ship design. It is uttered in grams of carbon dioxide per ship capacity-mile.

The CO_2 reduction level (grams of CO_2 per ton/mile) for the first phase is set to 10% and will be tightened every five years. Reduction rates have been established until 2030 when a 30% reduction is mandated for applicable ship types calculated from a reference line representing the average efficiency for ships built between 2000 and 2010.

Every defined and measured IMO group for each engine type has a specific EEDI value.
It was defined and agreed upon using the 75% MCR value for propulsion and the 50% MCR value for genset engines.

Caterpillar Motoren GmbH & Co. KG is continuously working on optimizing our engines to improve the specific fuel oil consumption.
The EEDI values for every defined and measured IMO group are specific.

(*) These values are subject to change without notice depending on engine group under which the engine is certified.

Please contact our sales team, if you need more information about the EEDI SFOC for your engine and application.

2.5 Engine dimensions and weight – preliminary

Turbocharger at free end

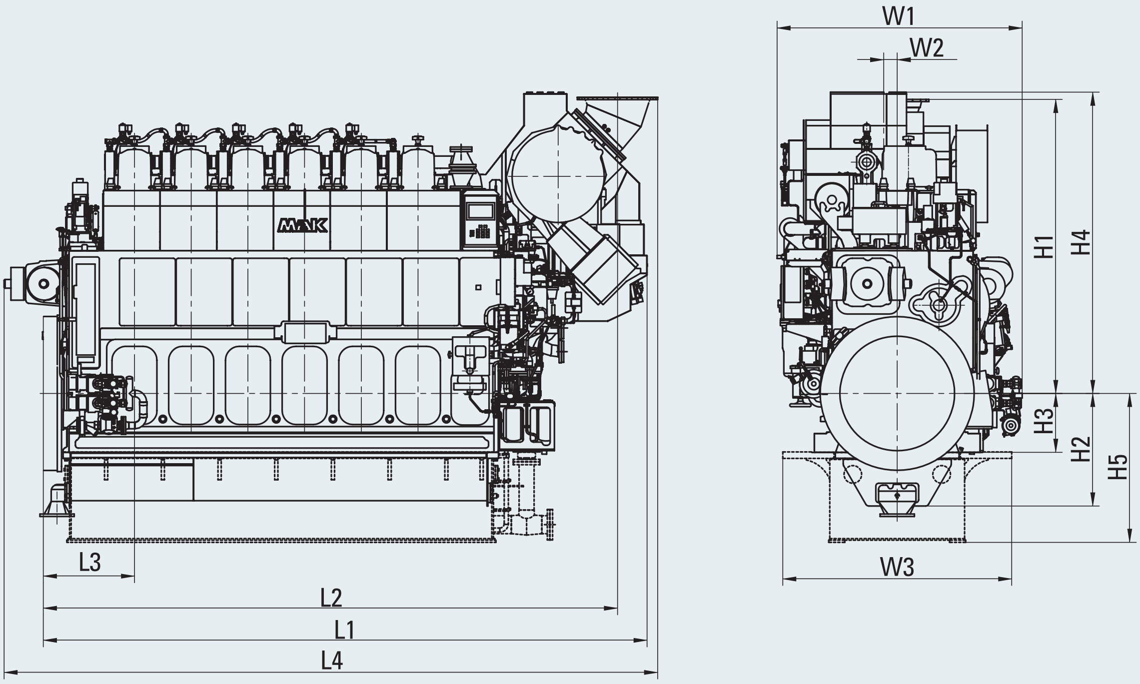


Fig. 2-1 Turbocharger at free end – control side

Type	Dimensions [mm]												Weight
	L1	L2	L3	L4	H1	H2	H3	H4	H5	W1	W2	W3	[t]
6 M 34 DF	6,079	5,366	852	6,109	2,767	1,052	550	2,817	1,392	2,303	126	2,140	39.5
8 M 34 DF	7,139	6,533	852	7,325	2,970	1,052	550	2,995	1,392	2,303	191	2,140	49.0
9 M 34 DF	7,669	7,063	852	7,855	2,970	1,052	550	2,995	1,392	2,303	191	2,140	52.0

Engine center distance

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

Turbocharger at driving end

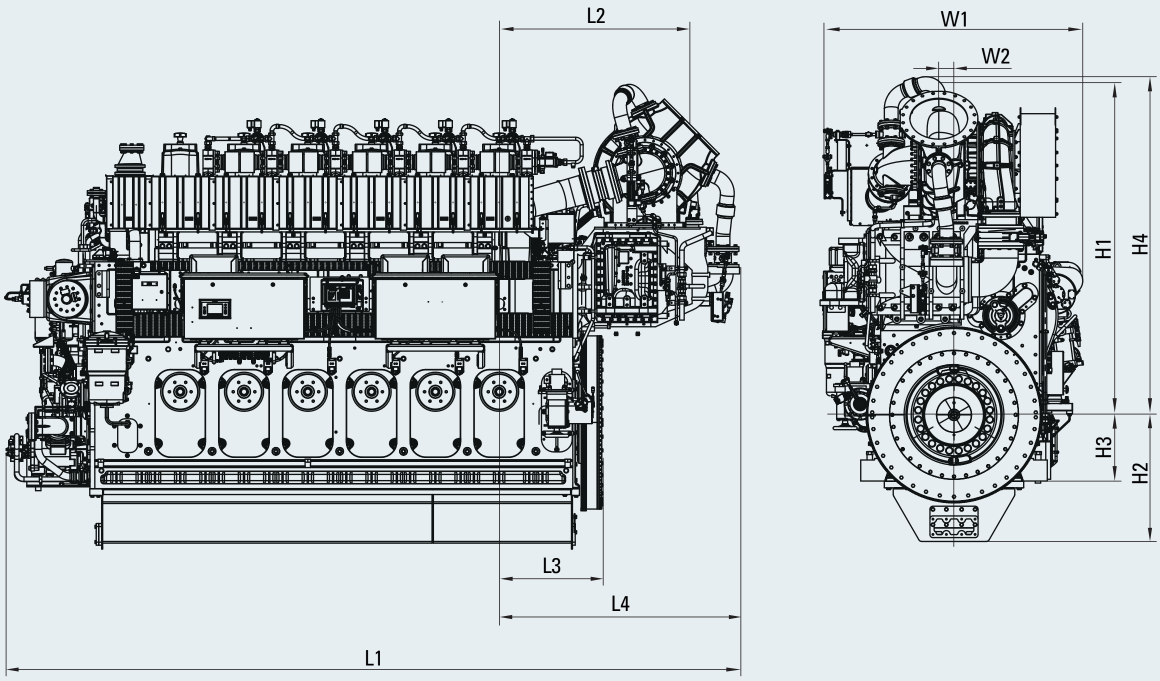


Fig. 2-2 Turbocharger at driving end – exhaust side

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

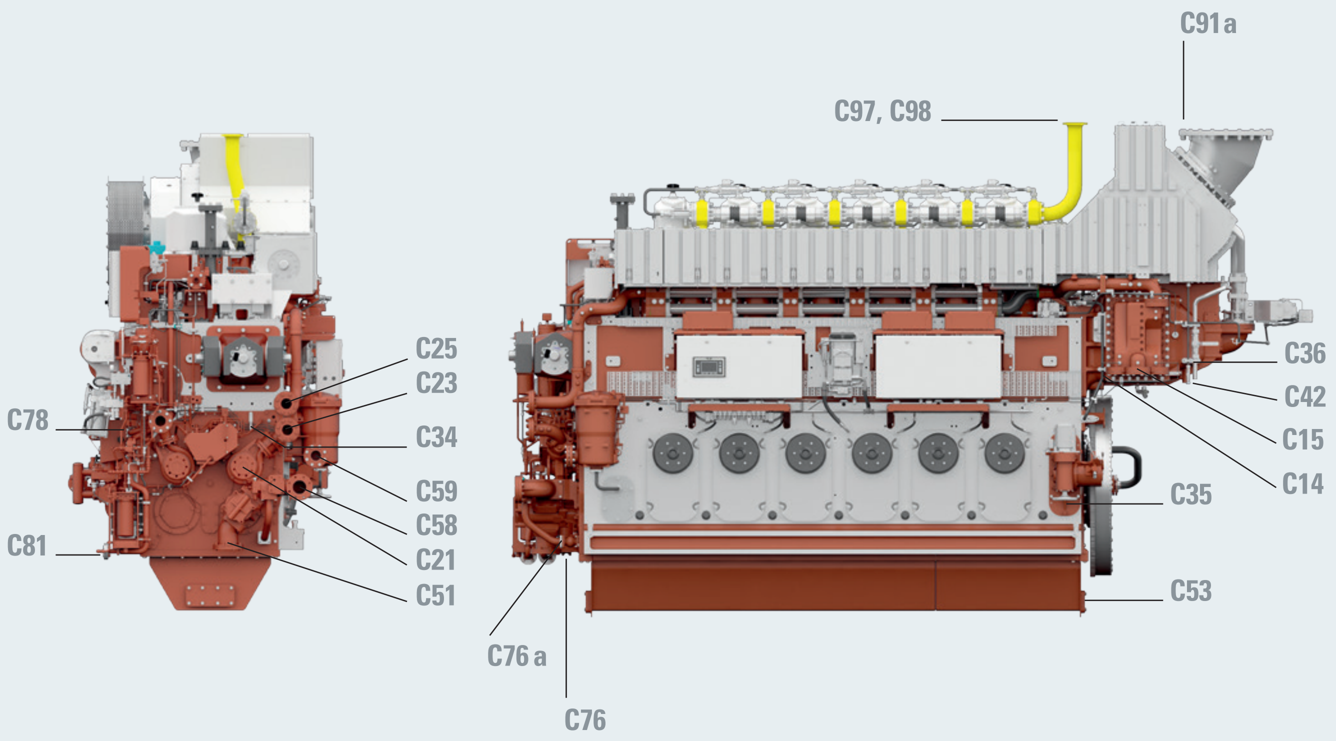


Fig. 2-3 Connecting points at the engine

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, outlet
C34	Drain condensate separator, charge air cooler
C35	Drain charge air duct
C36	Turbocharger washing, drain
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 connection
C91a	Exhaust gas outlet
C98	Gas inlet
C97	Flushing connection gas pipe (inertgas)

All pictures shown are for illustration purpose only. Actual product may vary due to product enhancement.

3.1 Diesel and gas, mechanical

		6 M 34 DF				8 M 34 DF				9 M 34 DF			
Performance data													
Maximum continuous rating acc. ISO 3046/1	[kW]	3,300		3,180		4,400		4,240		4,950		4,770	
Speed	[rpm]	750		720		750		720		750		720	
Minimum speed	[rpm]	435		435		435		435		435		435	
Brake mean effective presure	[bar]	21.1		21.2		21.1		21.2		21.1		21.2	
Charge air pressure	[bar]	4.4		4.3		4.4		4.3		4.4		4.3	
Firing pressure	[bar]	200		200		200		200		200		200	
Combustion air demand	[m³/h]	19,100		18,200		25.500		24.300		28.700		27.300	
Specific fuel oil consumption [3]		diesel-mode	gas-mode	diesel-mode	gas-mode	diesel-mode	gas-mode	diesel-mode	gas-mode	diesel-mode	gas-mode	diesel-mode	gas-mode
Total energy heatrate 100%	[kJ/kWh]	7,942	7,560	7,814	7,450	7,942	7,560	7,814	7,450	7,942	7,560	7,814	7,450
Total energy heatrate 85%	[kJ/kWh]	7,942	7,730	7,814	7,620	7,942	7,730	7,814	7,620	7,942	7,730	7,814	7,620
Total energy heatrate 75%	[kJ/kWh]	7,985	7,860	7,857	7,750	7,985	7,860	7,857	7,750	7,985	7,860	7,857	7,750
Total energy heatrate 50%	[kJ/kWh]	8,198	8,360	8,070	8,250	8,198	8,360	8,070	8,250	8,198	8,360	8,070	8,250
SFOC 100% [1]	[g/kWh]	186		183		186		183		186		183	
SFOC 85% [1]	[g/kWh]	186		183		186		183		186		183	
SFOC 75% [1]	[g/kWh]	187		184		187		184		187		184	
SFOC 50% [1]	[g/kWh]	192		189		192		189		192		189	
Specific gas consumption without pilot fuel													
Gas / LNG 100% [2]	[g/kWh]		151		149		151		149		151		149
Gas / LNG 85% [2]	[g/kWh]		154		152		154		152		154		152
Gas / LNG 75% [2]	[g/kWh]		156		154		156		154		156		154
Gas / LNG 50% [2]	[g/kWh]		165		163		165		163		165		163
Pilot fuel													
Pilot fuel heat rate 100%	[kJ/kWh]	35	90	35	80	35	90	35	80	35	90	35	80
Pilot fuel heat rate 85%	[kJ/kWh]	41	105	41	100	41	105	41	100	41	105	41	100
Pilot fuel heat rate 75%	[kJ/kWh]	47	125	47	115	47	125	47	115	47	125	47	115
Pilot fuel heat rate 50%	[kJ/kWh]	70	190	70	190	70	190	70	190	70	190	70	190
Pilot fuel [1] 100%	[g/kWh]	0.8	2.1	0.8	1.9	0.8	2.1	0.8	1.9	0.8	2.1	0.8	1.9
Pilot fuel [1] 85%	[g/kWh]	1.0	2.5	1.0	2.3	1.0	2.5	1.0	2.3	1.0	2.5	1.0	2.3
Pilot fuel [1] 75%	[g/kWh]	1.1	2.9	1.1	2.7	1.1	2.9	1.1	2.7	1.1	2.9	1.1	2.7
Pilot fuel [1] 50%	[g/kWh]	1.6	4.4	1.6	4.4	1.6	4.4	1.6	4.4	1.6	4.4	1.6	4.4
Lube oil consumption [4]	[g/kWh]	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
NO_x-emissions [5]	[g/kWh]	9.6	2.4	9.6	2.4	9.6	2.4	9.6	2.4	9.6	2.4	9.6	2.4
Turbocharger		Napier NT1-10		Napier NT1-10		Napier NT1-12		Napier N1-12		Napier N1-12		Napier N1-12	

1) LCV diesel fuel 42,700 kJ/kg / **2)** LCV gas and LNG 49,500 kJ/kg / **3)** Reference conditions acc. to ISO 3046/1, ambient temperature 25°C, charge air coolant 25°C, ambient pressure 1000 hPa, tolerance 5%, without engine driven pumps /

	Additional fuel consumption for engine driven pumps [%]				
	100%	85%	75%	50%	
Lube oil pump	1.0	1.2	1.3	2.0	Lube oil pump is mandatory,
Cooling water pump	0.40	0.47	0.53	0.80	LT and HT cooling water pumps are optional

4) Standard value, tolerance +/- 0.3 g/kWh, related on full load / **5)** Marpol 73/78 Annex VI, cycle E2/D2, ISO 8178

		6 M 34 DF		8 M 34 DF		9 M 34 DF	
Performance data							
Maximum continuous rating acc. ISO 3046/1	[kW]	3,300	3,180	4,400	4,240	4,950	4,770
Speed	[rpm]	750	720	750	720	750	720
Fuel							
Engine driven booster pump	[m³/h]/[bar]	3.2/10	3.2/10	3.2/10	3.2/10	3.2/10	3.2/10
Stand-by booster pump	[m³/h]/ [bar]	2.2/10	2.2/10	2.9/10	2.9/10	3.2/10	3.2/10
Stand-by booster pump ignition fuel	[m³/h]/[bar]	0.66/8	0.66/8	0.88/8	0.88/8	1.0/8	1.0/8
Mesh size MDO fine filter	[mm]	0.025	0.025	0.025	0.025	0.025	0.025
Mesh size HFO automatic filter	[mm]	0.010	0.010	0.010	0.010	0.010	0.010
Mesh size HFO fine filter	[mm]	0.034	0.034	0.034	0.034	0.034	0.034
Lube oil							
Engine driven pump	[m³/h]/[bar]	118/10	113/10	118/10	113/10	118/10	113/10
Independent pump	[m³/h]/[bar]	60/10	60/10	80/10	80/10	90/10	90/10
Working pressure at engine inlet	[bar]	4 - 5	4 - 5	4 - 5	4 - 5	4 - 5	4 - 5
Engine driven suction pump	[m³/h]/[bar]	168/3	161/3	168/3	161/3	168/3	161/3
Stand-by pump	[m³/h]/[bar]	65/3	65/3	85/3	85/3	100/3	100/3
Priming pump	[m³/h]/[bar]	8/5	8/5	11/5	11/5	11/5	11/5
Sump tank content	[m³]	4.1	4.1	5.4	5.4	6.1	6.1
Temperature at engine inlet	[°C]	60 - 65	60 - 65	60 - 65	60 - 65	60 - 65	60 - 65
Temperature controller NB	[mm]	80	80	100	100	100	100
Double filter	[mm]	80	80	80	80	80	80
Mesh size double filter	[mm]	0.08	0.08	0.08	0.08	0.08	0.08
Mesh size automatic filter	[mm]	0.03	0.03	0.03	0.03	0.03	0.03
Fresh water							
Engine content	[m³]	0.7	0.7	0.95	0.95	1.05	1.05
Pressure at engine inlet min/max	[bar]	4.5/6.0	4.5/6.0	4.5/6.0	4.5/6.0	4.5/6.0	4.5/6.0
Header tank capacity	[m³]	0.35	0.35	0.45	0.45	0.45	0.45
Temperature at engine outlet	[°C]	80 - 90	80 - 90	80 - 90	80 - 90	80 - 90	80 - 90
Two circuit cooling water system							
Engine driven pump	[m³/h]/[bar]	70/3.5	70/3.3	70/3.5	70/3.3	80/3.3	80/3.1
Independent pump	[m³/h]/[bar]	70/4	70/4	70/4	70/4	80/4	80/4
Temperature controller NB	[mm]	100	100	100	100	100	100
Water demand LT charge air cooler	[m³/h]	40	40	60	60	60	60
Max. temperature at LT-charge air cooler inlet	[°C]	38	38	38	38	38	38
LT-coolant temperature set point	[°C]	32	32	32	32	32	32

		6 M 34 DF				8 M 34 DF				9 M 34 DF			
Performance data													
Maximum continuous rating acc. ISO 3046/1	[kW]	3,300		3,180		4,400		4,240		4,950		4,770	
Speed	[rpm]	750		720		750		720		750		720	
Heat dissipation [6)]		diesel-mode	gas-mode	diesel-mode	gas-mode	diesel-mode	gas-mode	diesel-mode	gas-mode	diesel-mode	gas-mode	diesel-mode	gas-mode
Specific jacket water heat	[kJ/kWh]	450	430	440	420	450	430	440	420	450	430	440	420
Specific lube oil heat	[kJ/kWh]	460	450	460	450	460	450	460	450	460	450	460	450
Lube oil cooler	[kW]	425	415	425	415	567	553	567	553	638	623	638	623
Jacket water	[kW]	410	395	400	385	547	527	533	513	615	593	600	578
Charge air cooler (HT-stage) [6)]	[kW]	1,060	545	990	495	1,410	727	1,320	660	1,590	818	1,485	743
Charge air cooler (LT-stage) [6)]	[kW]	340	275	330	260	453	367	440	347	510	413	495	390
Heat radiation engine	[kW]	95	95	90	90	127	127	120	120	143	143	135	135
Exhaust gas [6)]													
Silencer / Spark arrestor NB	[mm]	600		600		700		700		800		800	
Pipe diameter NB after turbine	[mm]	600		600		700		700		800		800	
Nominal exhaust gas backpressure	[mbar]	30		30		30		30		30		30	
Max. exhaust gas backpressure with SCR	[mbar]	60		60		60		60		60		60	
		diesel-mode	gas-mode	diesel-mode	gas-mode	diesel-mode	gas-mode	diesel-mode	gas-mode	diesel-mode	gas-mode	diesel-mode	gas-mode
Exhaust gas temperature after turbine [7)]	[°C]	304	340	294	342	304	340	294	342	304	340	294	342
Exhaust gas mass flow	[kg/h]	25,300	21,700	24,200	21,900	33,700	28,900	32,300	29,200	38,000	32,600	36,300	32,900
Starting air													
Maximum starting air pressure	[bar]	30		30		30		30		30		30	
Minimum starting air pressure	[bar]	15		15		15		15		15		15	
Air consumption per start	[Nm^3]	6.0		6.0		7.0		7.0		7.5		7.5	
Crankcase ventilation													
Maximum crankcase pressure	[mbar]	1.5		1.5		1.5		1.5		1.5		1.5	
Crankcase ventilation ND	[mm]	80		80		80		80		80		80	

6)Tolerance for heat and exhaust flow +/- 10%; Load specific values for ISO: ambient temperature = 25°C, rel. humidity = 30%, p0 = 1,000 mbar, charge air = 45°C; Tolerance of +10% for rating of coolers and -15% for heat recovery / **7)** Tolerance for exhaust gas temperature: 20 K

4.1 Controllable pitch propeller (CPP) operation – standard

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.

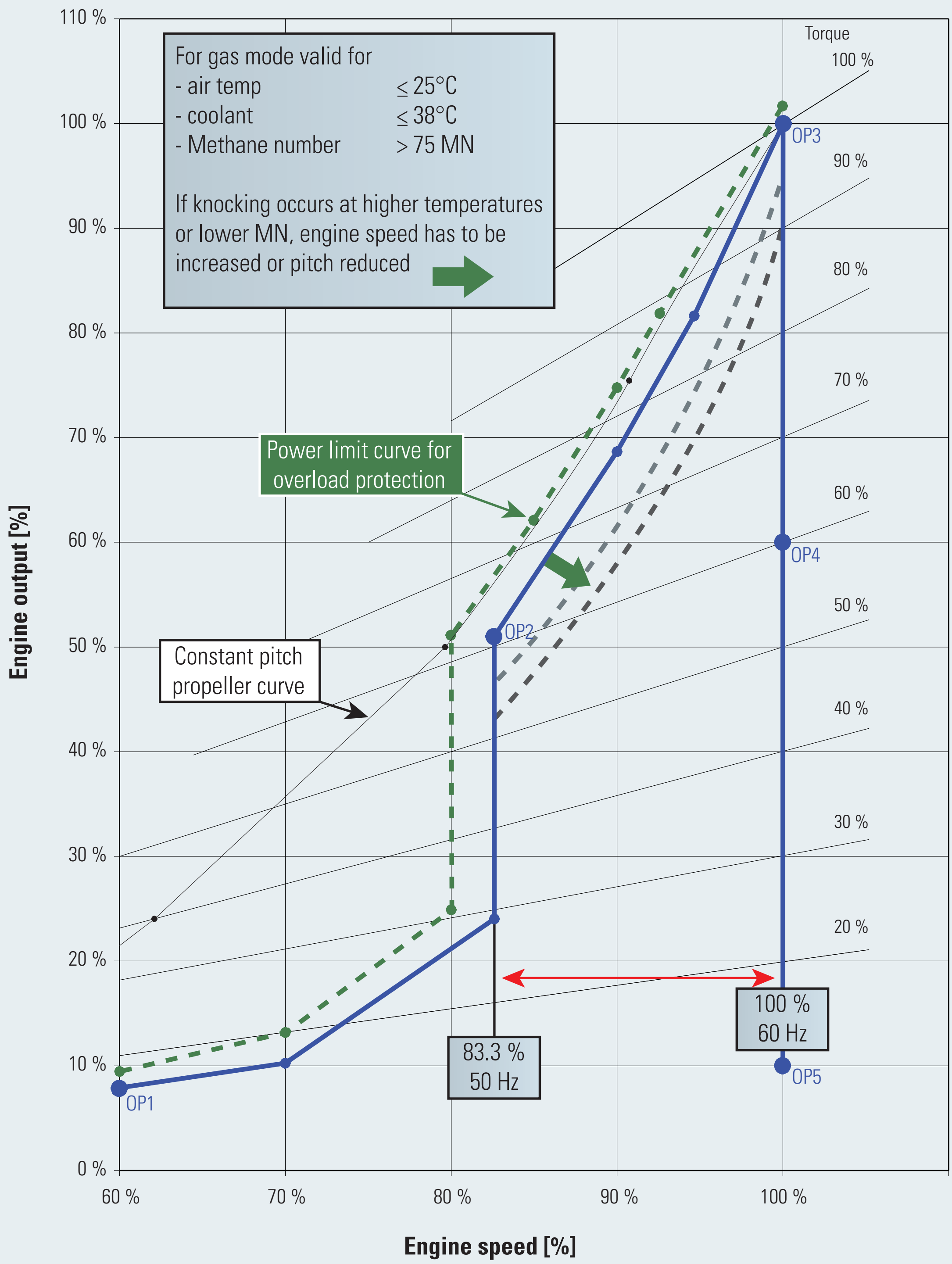


Fig. 4-1 Power limit curve for CPP and sliding frequency 50 to 60 Hz – M 34 DF with 720 / 750 rpm (VD8883-4)

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

4.1.1 Acceleration ramps

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.
- Acceleration time in seconds, Tol. ± 5 sec., engine warm in operating conditions
  Minimum operating time 10 minutes
  Lube oil > 50°C
  Coolant > 65°C
- Start of acceleration at least 10% MCR, lowest operation point with CPP.

Acceleration ramps

		Emergency operation		Normal operation			
		combinator	n constant	combinator		n constant	
		OP1 to OP5	OP3 to OP5	OP1 to OP2	OP2 to OP5	OP3 to OP4	OP4 to OP5
		[s]	[s]	[s]	[s]	[s]	[s]
Diesel	6 M 34 DF	35	30	40	50	40	40
Diesel	8 M 34 DF	35	30	40	50	40	40
Diesel	9 M 34 DF	35	30	40	50	40	40
Gas	6-9 M 34 DF	35	30	40	60	45	40

OP: Operating point as given in power limit curves

4.1.2 Controllable pitch propeller (CPP) operation – option

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.

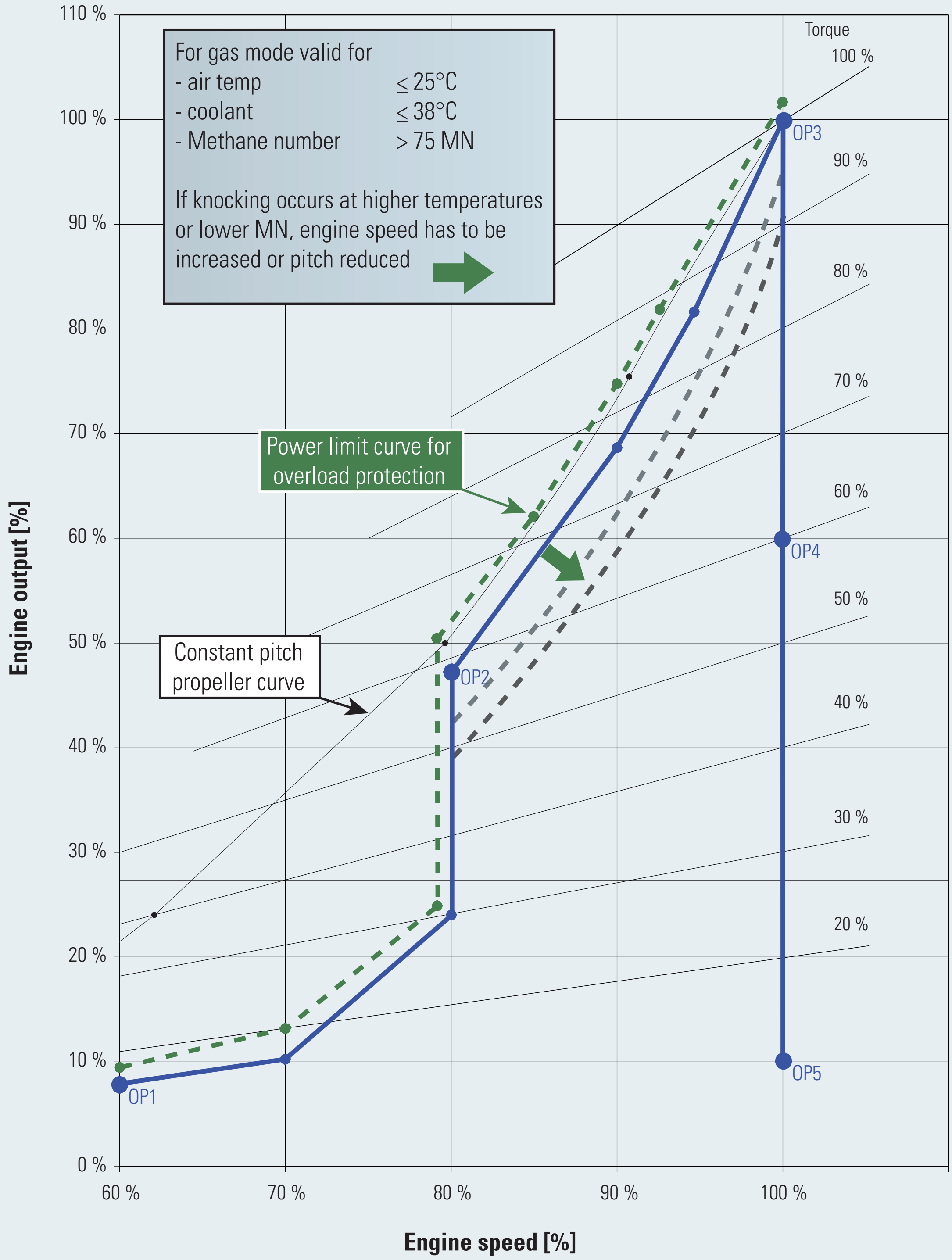


Fig. 4-2 Power limit curve for CPP and sliding frequency 50 to 60 Hz – M 34 DF with 750 rpm (VD9034-4)

4.1.3 Controllable pitch propeller operation – diesel mode

	Time in seconds	
	0 to 70%	70 to 100%
Standard operation	55	25
Emergency	20	10

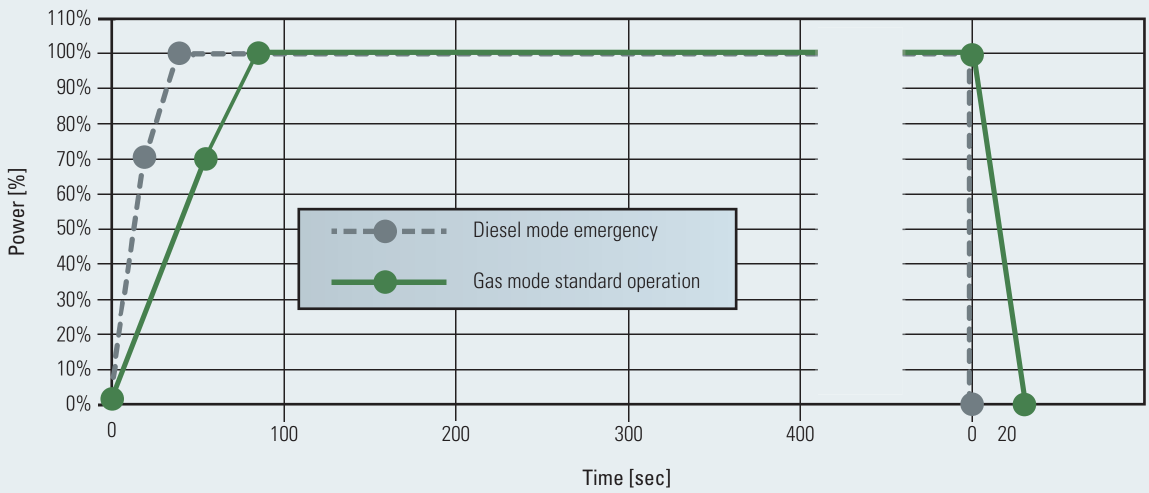


Fig. 4-3 Ramp up time M 34 DF in diesel mode

4.1.4 Controllable pitch propeller operation – gas mode

	Time in seconds	
	0 to 70%	70 to 100%
Standard operation	55	25
Emergency	20	10

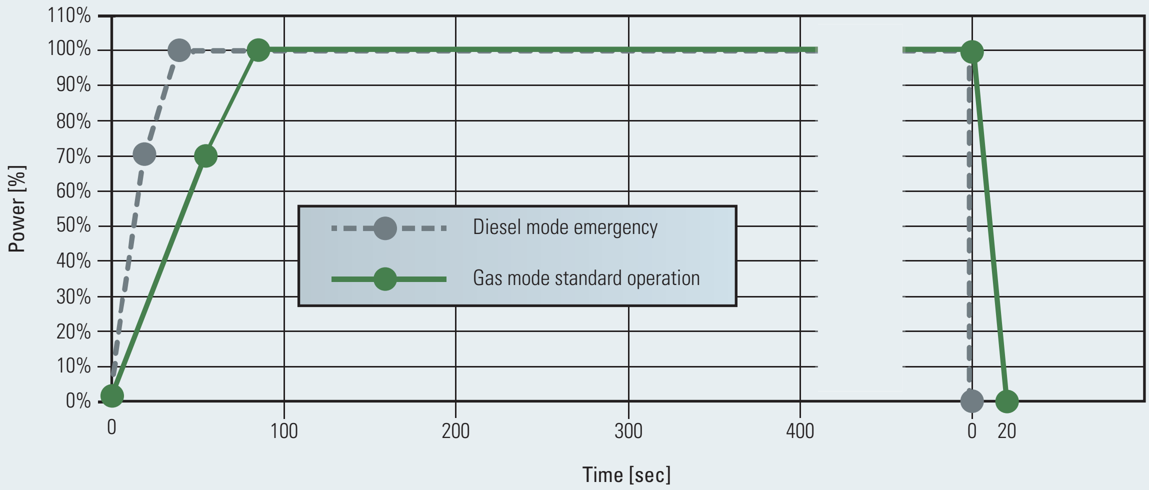


Fig. 4-4 Ramp up time M 34 DF in gas mode

4.2 Restrictions for low load operation

4.2.1 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.

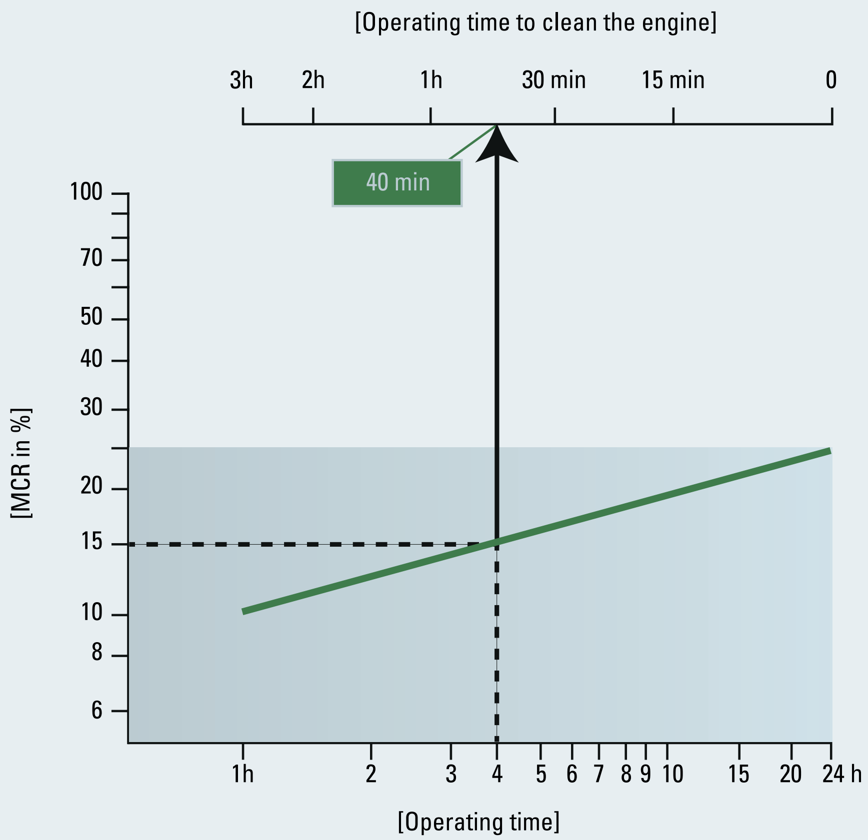


Fig. 4-5 Cleaning run of engine

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

4.2.2 Load restrictions in gas mode

Standard Dual Fuel engines are started and stopped in Diesel operation, due to challenges on air fuel ratio control in low load.
A gas start function is available. Clutch In procedures need to be optimized and agreed.
A gas operation above 100 % is prohibited, but overload is covered in Diesel operation without interruption.
A direct fuel change over from HFO operation gas isn't recommended. The engine needs to run a certain time with MDO before change over to gas operation.

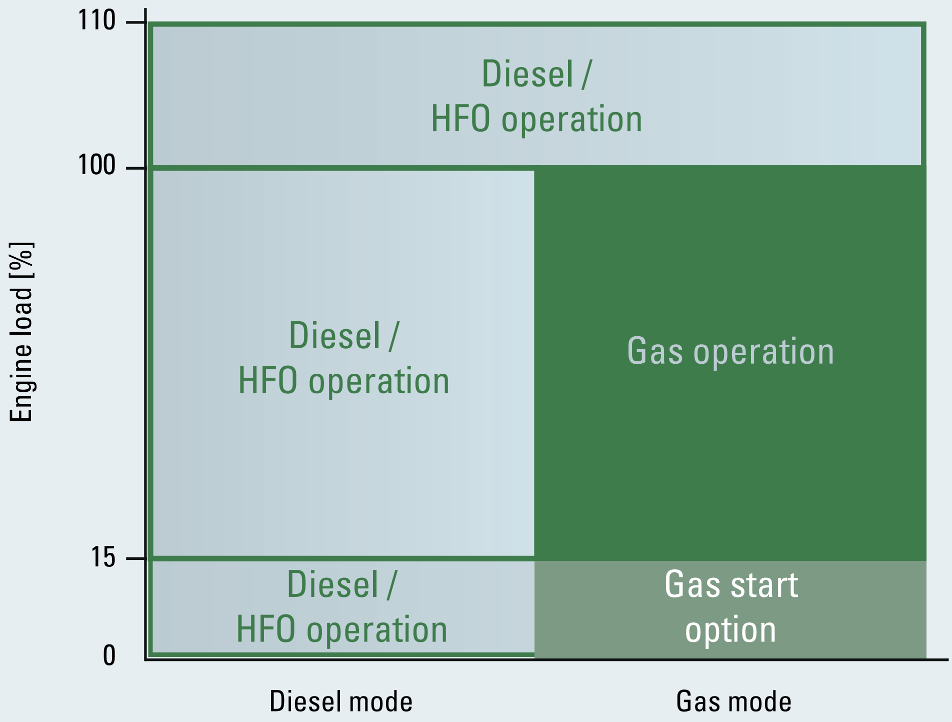


Fig. 4-6 Load restrictions in gas mode

Duration in low load (gas mode)

Load factor	Unit/Period	Duration
0–5% load	h/12 h	5
5–12% load	h/12 h	10
> 12% load	h/12 h	unlimited

4.3 Emergency operation without turbocharger

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

4.4 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 °

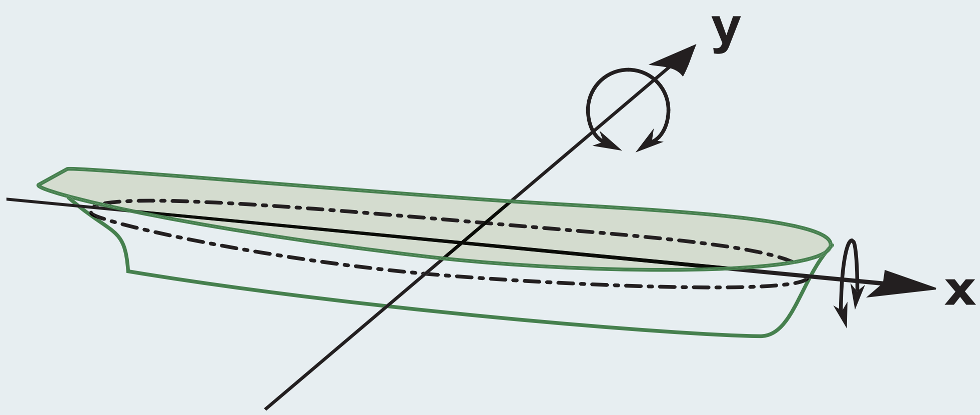


Fig. 4-7 Rotation axis

4.5 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.
- 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).

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
- 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.

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	DFA	DMZ	DFZ	DMB	DFB
Viscosity at 40 °C	[mm²/s] [a]	max	5,500	6,000		6,000		11,000	
Viscosity at 40 °C	[mm²/s]	min	1,400	2,000		3,000		2,000	
Density at 15 °C	[kg/m³]	max	–	890		890		900	
Cetane index		min	45	40		40		35	
Sulfur [b]	[mass %]	max	1.0	1.0		1.0		1.5	
Flash point	[°C]	min	43	60		60		60	
Hydrogen sulfide	[mg/kg]	max	2.0	2.0		2.0		2.0	
Acid number	[mg KOH/g]	max	0.5	0.5		0.5		0.5	
Total sediment by hot filtration	[mass %]	max	–	–		–		0.10 [c]	
Oxidation stability	[g/m³]	max	25	25		25		25 [d]	
Fatty acid methyl ester (FAME)	[volume %]	max	–	–	7.0	–	7.0	–	7.0
Carbon residue – micro method on the 10% volume distillation residue	[mass %]	max	0.3	0.3		0.3		–	
Carbon residue – micro method	[mass %]	max	–	–		–		0.3	
Cloud point [e] – winter	[°C]	max	-16	report		report		–	
Cloud point [e] – summer	[°C]	max	-16	–		–		–	
Cold filter plugging point [e] – winter	[°C]	max	–	report		report		–	
Cold filter plugging point [e] – summer	[°C]	max	–	–		–		–	
Pour point (upper) [e] - winter	[°C]	max	–	-6		-6		–	
Pour point (upper) [e] - summer	[°C]	max	–	0		0		6	
Appearance			Clear and bright [f]					[c]	
Water	[volume %]	max	–	–		–		0.3 [c]	
Ash	[mass %]	max	0.010	0.010		0.010		0.010	
Lubricity, corrected wear scar diameter (WSD) at 60 °C [g]	[µm]	max	520	520		520		520 [d]	

a) mm²/s = 1 cSt. / **b)** Notwithstanding the limits given, the purchaser shall define the maximum sulfur content in accordance with relevant statutory limitations. / **c)** If the sample is not clear and bright, the total sediment by hot filtration and water tests shall be required. / **d)** If the sample is not clear and bright, the test cannot be undertaken and therefore, compliance with this limit cannot be shown. / **e)** Pour point cannot guarantee operability for all ships in all climates. The purchaser should confirm that the cold flow characteristics (pour point, cloud point, cold filter plugging point) are suitable for the ship's design and intended voyage. / **f)** If the sample is dyed and not transparent, another test method shall apply. / **g)** This requirement is applicable to fuels with a sulfur content below 500 mg/kg (0.050 mass %).

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.

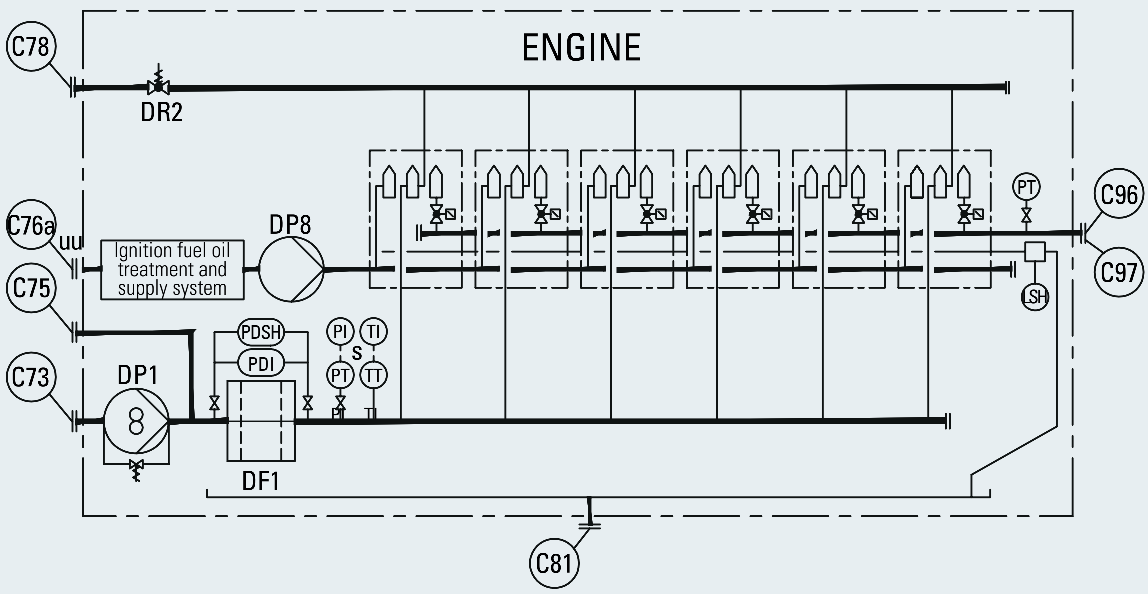


Fig. 5-1 Internal fuel oil system, system diagram

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

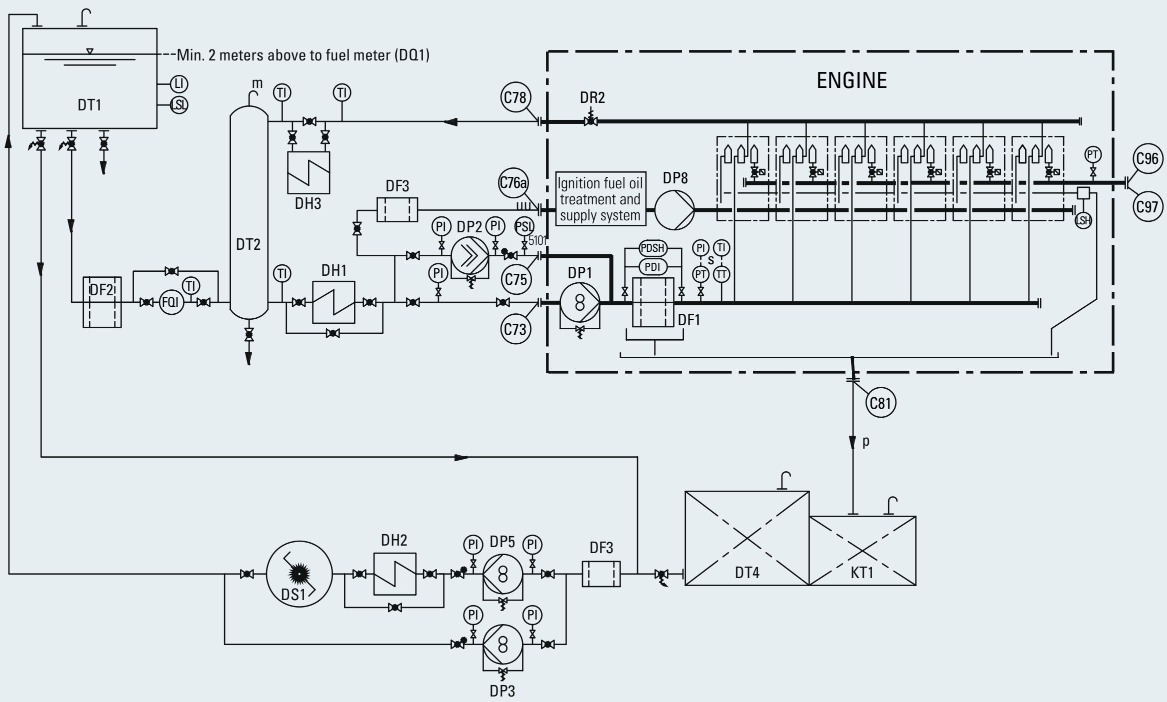


Fig. 5-2 External fuel oil system diagram with intermediate tank

DF1	Fuel fine filter (duplex filter)
DF2	Fuel primary filter (duplex filter)
DF3	Fuel coarse filter
DH1	Diesel oil preheater (if required)
DH2	Electrical preheater for diesel oil (separator)
DH3	Diesel oil cooler
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
DT2	Diesel oil intermediate tank
DT4	Diesel oil storage tank
KP1	Fuel injection pump
KT1	Drip fuel tank
m	Lead vent pipe beyond service tank level
p	Free outlet required

FQI	Flow quantity indicator
LI	Level indicator
LSH	Level switch high
LSL	Level switch low
PDI	Diff. pressure indicator
PDSH	Diff. pressure switch high
PI	Pressure indicator
PSL	Pressure switch low
PT	Pressure transmitter
TI	Temperature indicator
TT	Temperature transmitter (PT100)
C73	Fuel inlet, to engine fitted pump
C75	Connection, stand-by pump
C78	Fuel outlet
C81	Drip-fuel connection
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

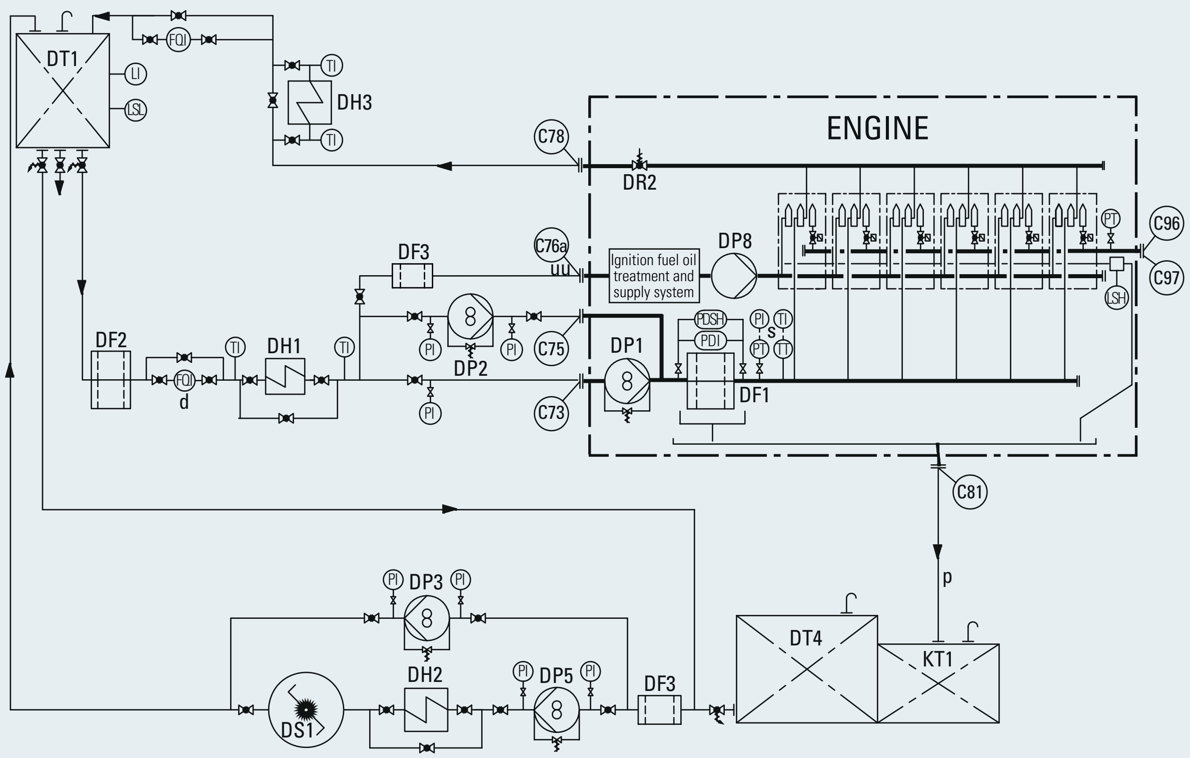


Fig. 5-3 External fuel oil system diagram without intermediate tank

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.

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

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. Filter size designed for amount of circulating fuel. By using an intermediate tank DT2, the DF2 only needs to filter the fuel oil consumption. In this case, please use design table for HFO prefilter HF2.

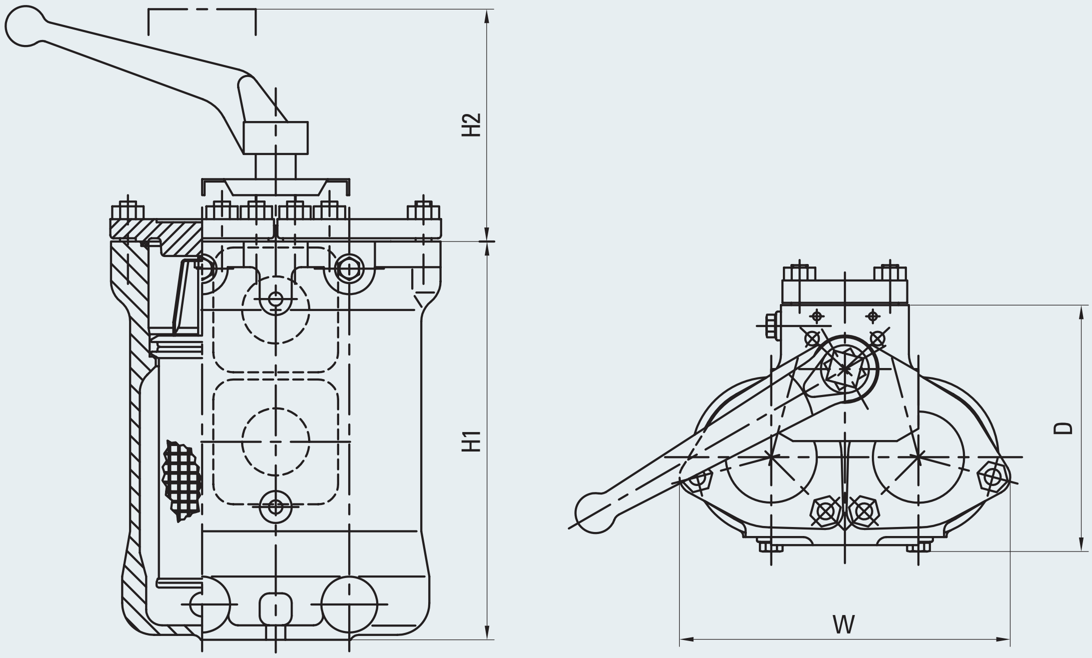


Fig. 5-4 Fuel primary filter DF2

Engine output	Filter	Dimensions [mm]			
[kW]	DN	H1	H2	W	D
≤ 3,000	25	199	170	219	164
≤ 4,500	32	249	220	206	180
≤ 9,000	40	330	300	250	210
≤ 12,000	50	385	350	252	193
≤ 18,000	65	523	480	260	355
≤ 30,000	80	690	700	370	430

Flow quantity indicator FQI

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

Diesel oil intermediate tank DT2

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

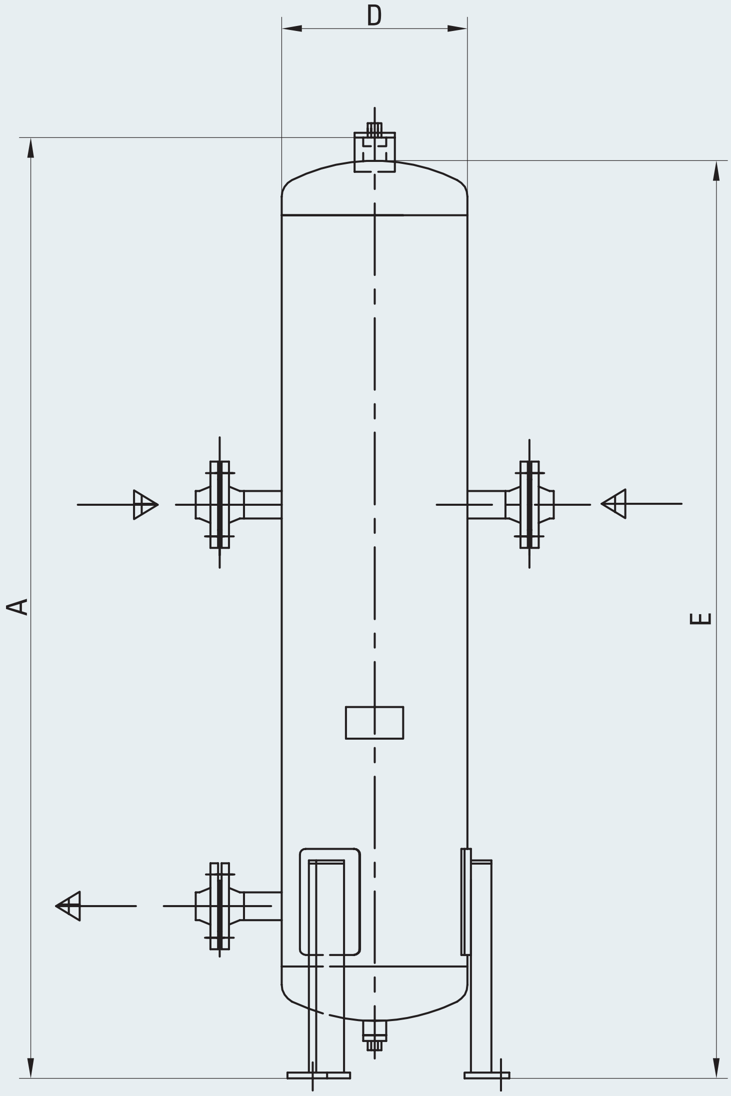


Fig. 5-5 Diesel oil intermediate tank DT2

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

Diesel oil preheater DH1 (hot water)

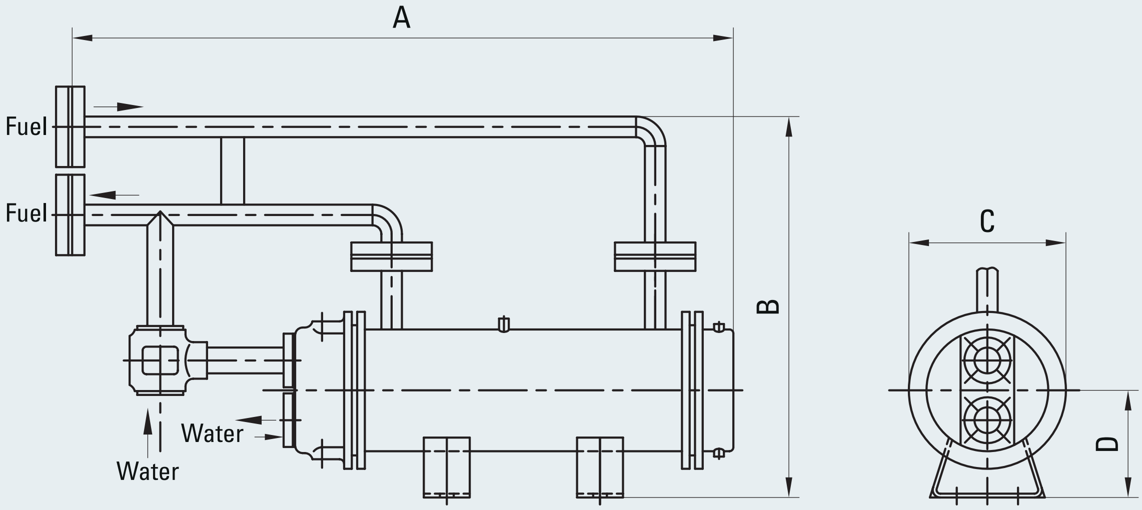


Fig. 5-6 Diesel oil preheater DH1

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.

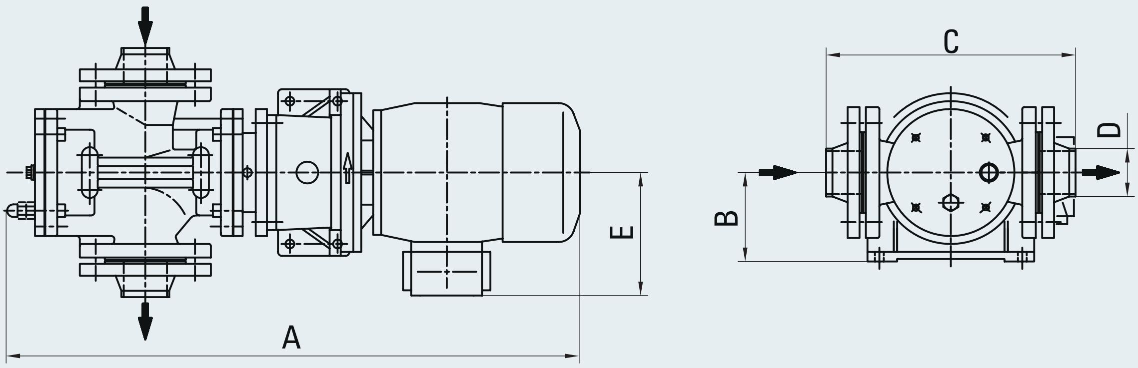


Fig. 5-7 Stand-by booster pump DP2

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.

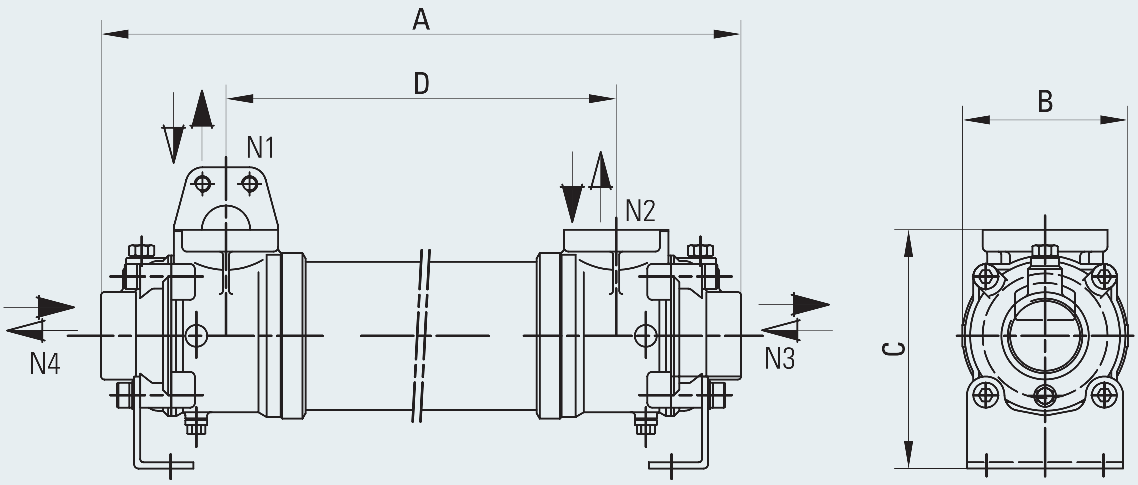


Fig. 5-8 Fuel oil cooler for MDO operation DH3

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 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

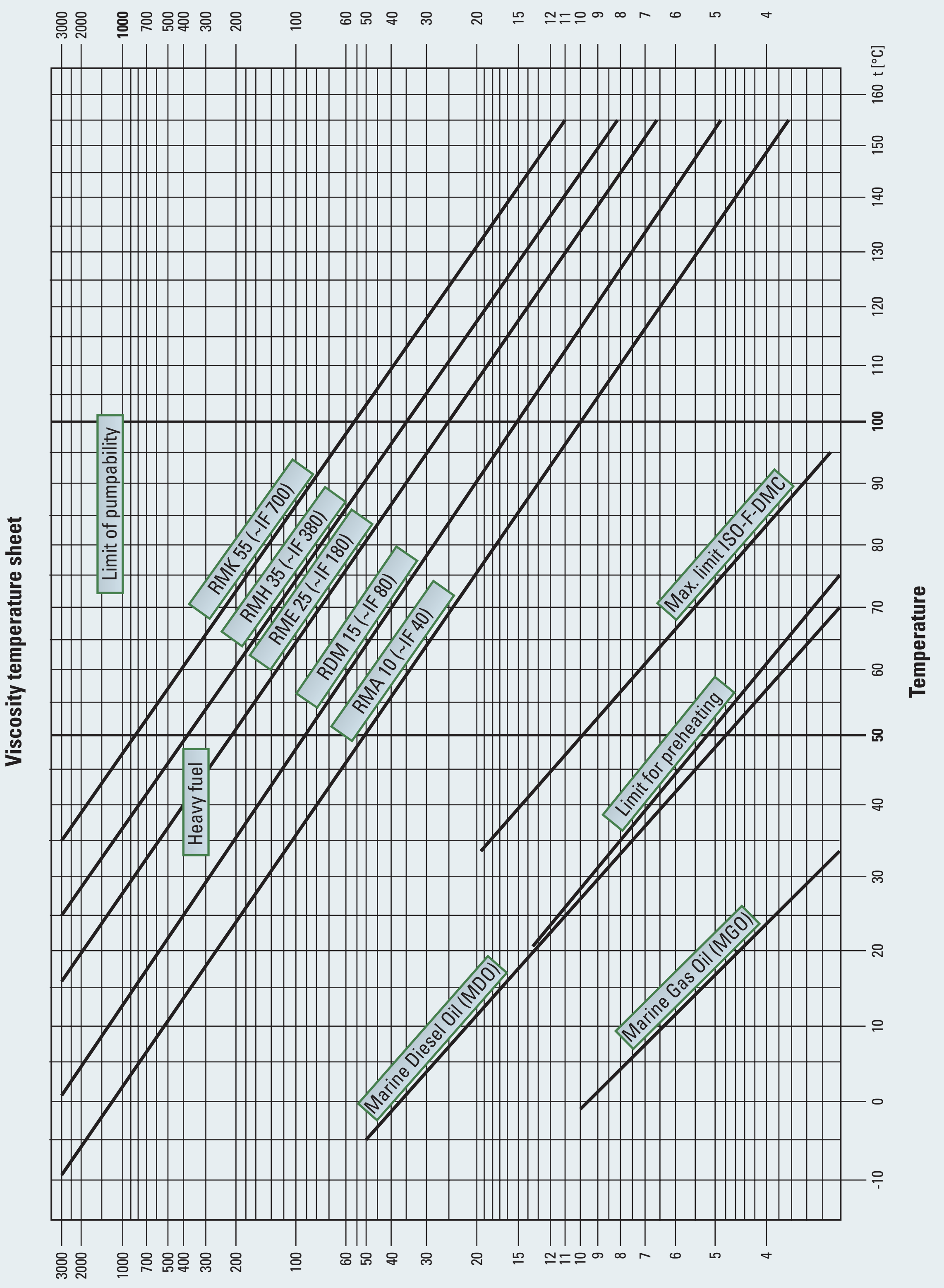


Fig. 5-9 Viscosity/temperature diagram

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

- Fuel shall be free of used lube oil.

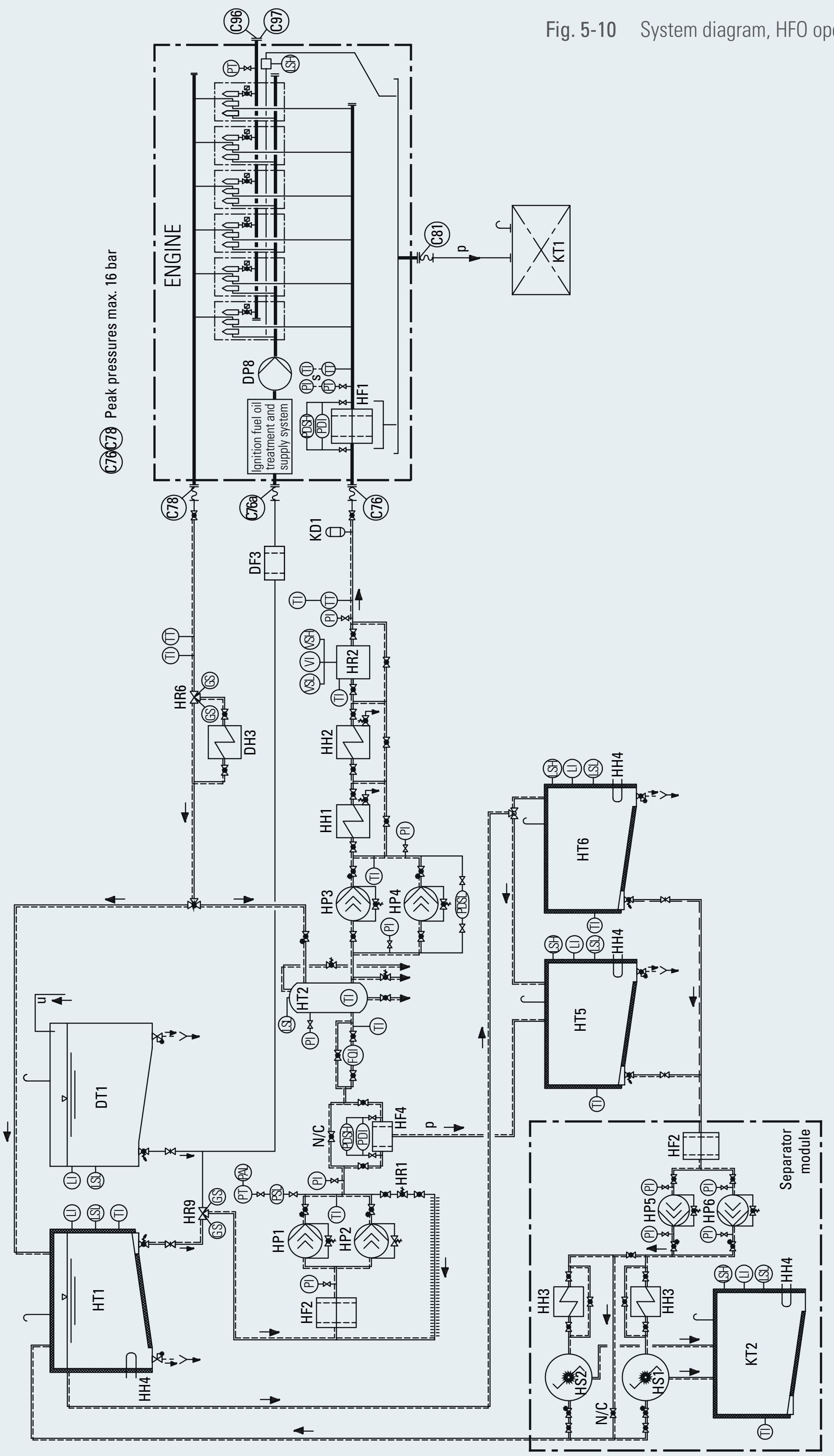
Characteristic	Designation		CIMAC A10	CIMAC B10	CIMAC C10	CIMAC D15	CIMAC E25	CIMAC F25	CIMAC G35	CIMAC H35	CIMAC K35	CIMAC H45	CIMAC K45	CIMAC H55	CIMAC K55
	Related to ISO8217 (10) F-		RMA 30	RMB 30	RMC 30	RMD 80	RME 180	RMF 180	RMG 380	RMH 380	GMK 380	RMH 500	RMK 500	RMH 700	RMK 700
	Dim.	Limit		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

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

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

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

Fig. 5-10 System diagram, HFO operation



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.

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

Storage tanks

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

Settling tanks HT5, HT6

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

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

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

Heavy fuel preheater (separator) HH3

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

Heavy fuel transfer pumps (separator) HP5, HP6

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

Heavy fuel separators HS1, HS2

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

Separator sizing:

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

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

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

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

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

Heavy fuel day tank HT1

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

5.2.2 Fuel booster and supply system

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

Fuel change over main valve HR9

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

Primary filter (duplex filter) HF2

A protection strainer with a mesh size 320 µm has to be installed before fuel pressure pumps to prevent any large particles entering the pump. Filter size also designed for MDO operation with intermediate tank DT2.

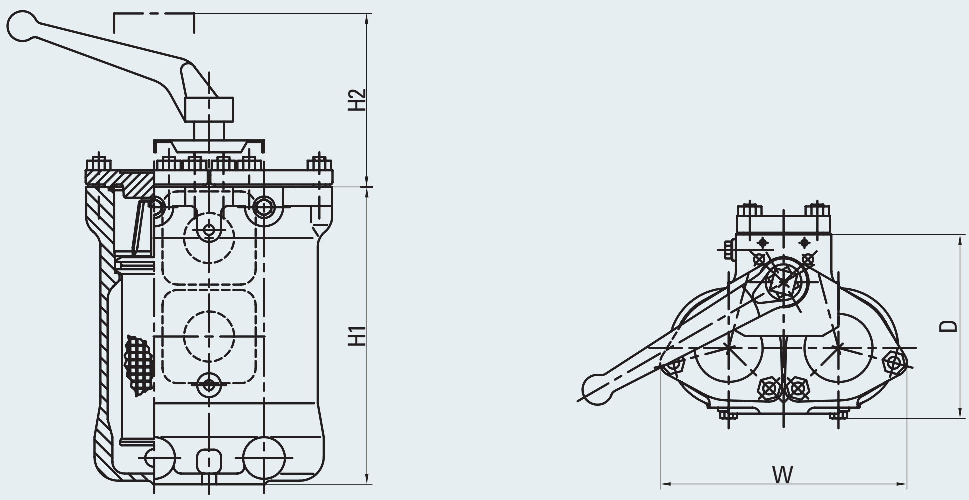


Fig. 5-11 Primary filter HF2

Engine output	Filter	Dimensions [mm]			
[kW]	DN	H1	H2	W	D
≤ 7,000	25	199	170	219	164
≤ 12,000	32	249	220	206	180
≤ 22,000	40	330	300	250	210
≤ 30,000	50	385	350	252	193
≤ 45,000	65	523	480	260	355
≤ 80,000	80	690	700	370	430

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

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

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

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

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

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

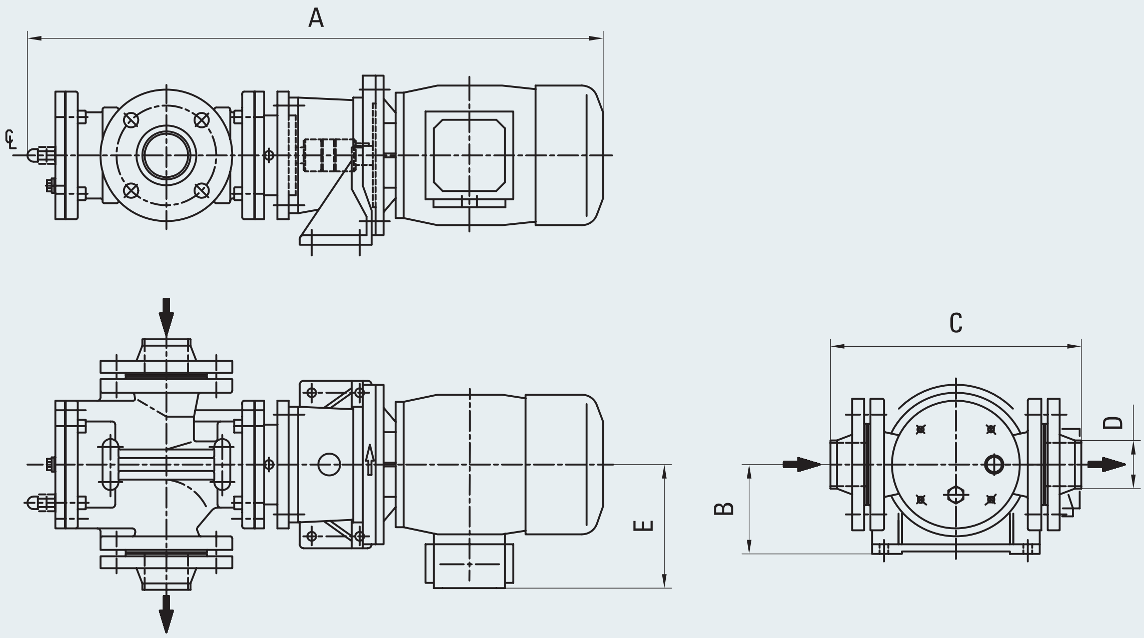


Fig. 5-12 Fuel pressure pump HP1; fuel stand-by pressure pump HP2

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

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

Fuel pressure valve regulating HR1

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

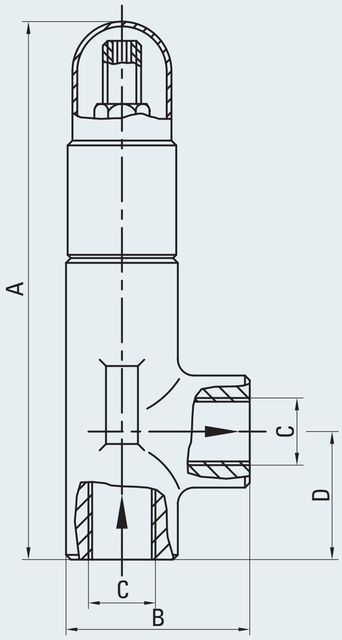


Fig 5-13 Fuel pressure regulating valve HR1, ≤ 3,000 kW

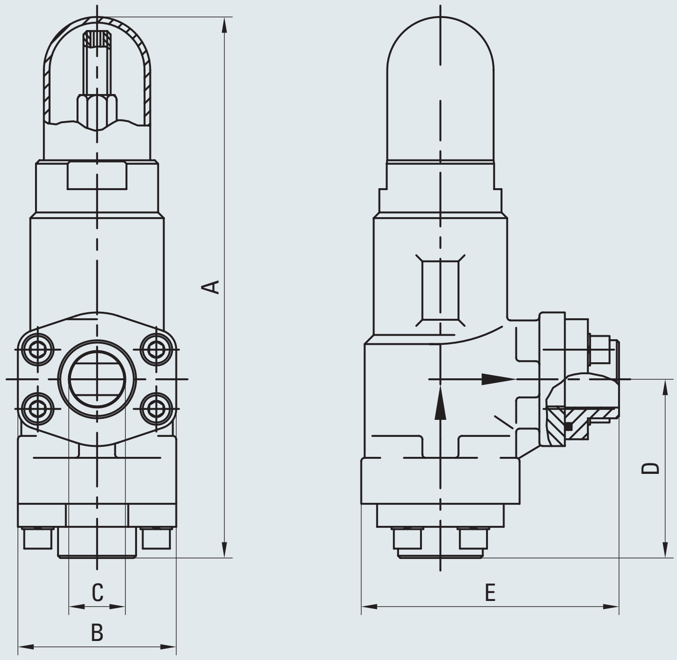


Fig 5-14 Fuel pressure regulating valve HR1, > 3,000 kW

Plant output	Dimensions [mm]					Weight
[kW]	A	B	C	D	E	[kg]
≤ 3,000	168	57.5	G ½"	40		1.5
≤ 8,000	248	70	Ø 25	88	122.5	3.6
> 8,000	279	94	Ø 38	109	150.5	8.4

HFO automatic filter HF4

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

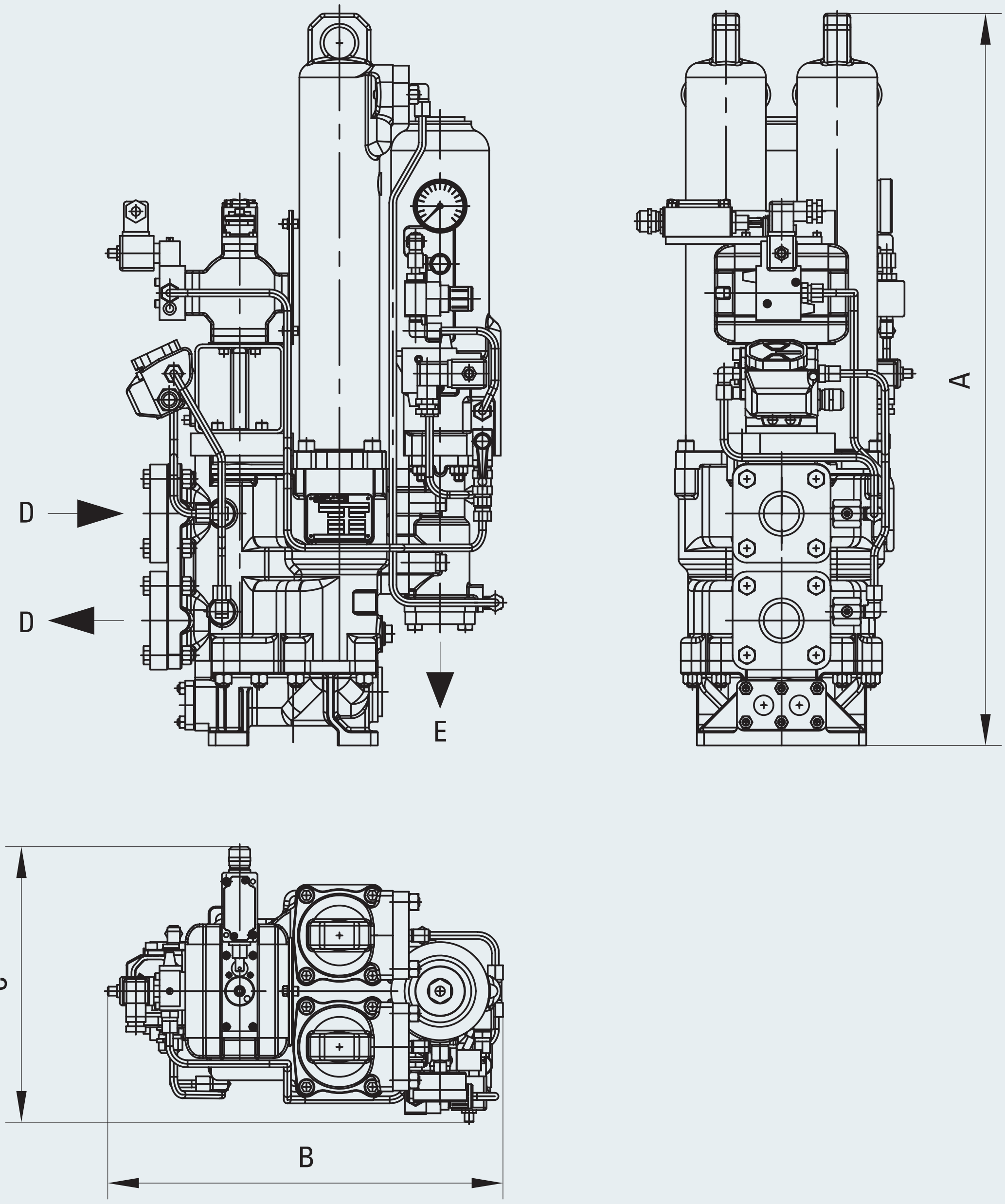


Fig. 5-15 HFO automatic filter HF4

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

Flow quantity indicator FQ1

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

Mixing tank HT2

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

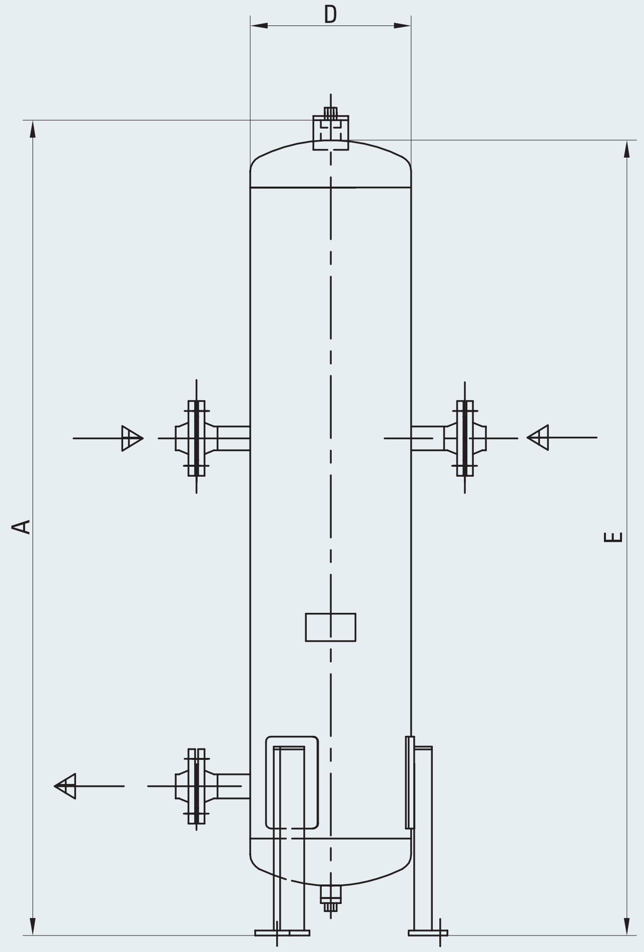


Fig. 5-16 Mixing tank HT2

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

Fuel circulating pump HP3, stand-by circulating pump HP4

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

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

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

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

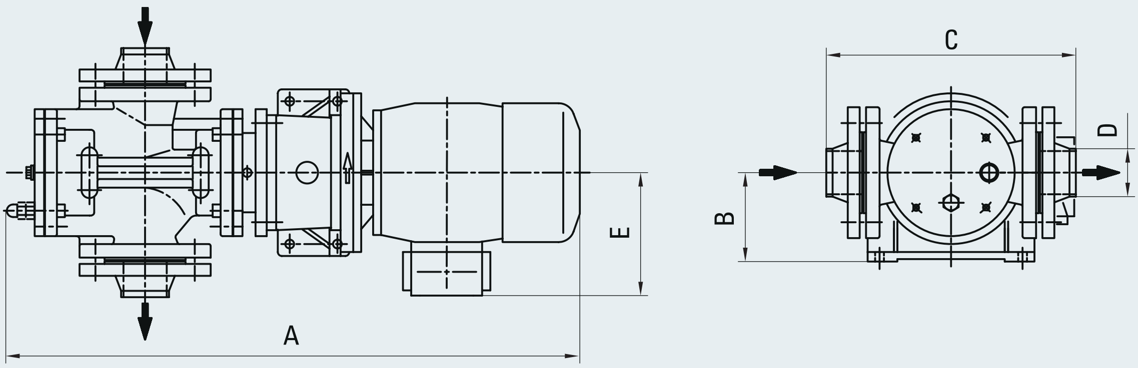


Fig. 5-17 Fuel circulating pump HP3, Stand-by circulating pump HP4

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

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

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

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

Heating media:

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

Temperature at engine inlet max. 150 °C

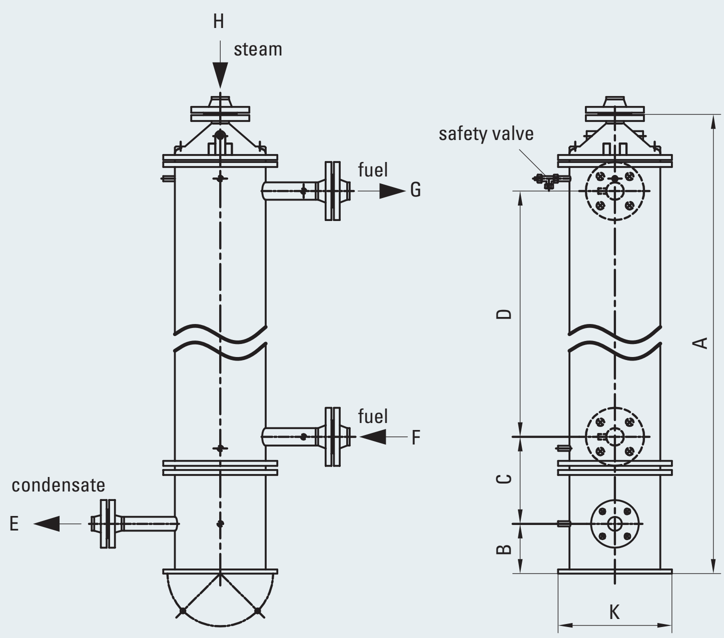


Fig. 5-18 Heavy fuel final preheater HH1, stand-by final preheater HH2 (steam heated)

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

Viscosimeter HR2

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

Pressure absorber KD1 (optional)

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

Bypass overflow valve HV (optional)

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

Duplex filter HF1 (fitted)

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

Fuel oil cooler DH3

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

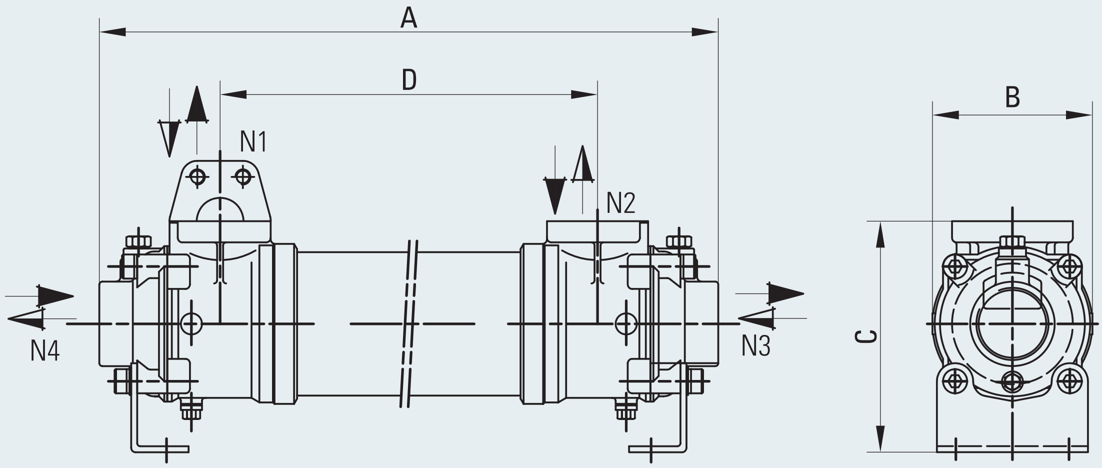


Fig. 5-19 Fuel oil cooler for MDO operation DH3

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

5.2.3 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

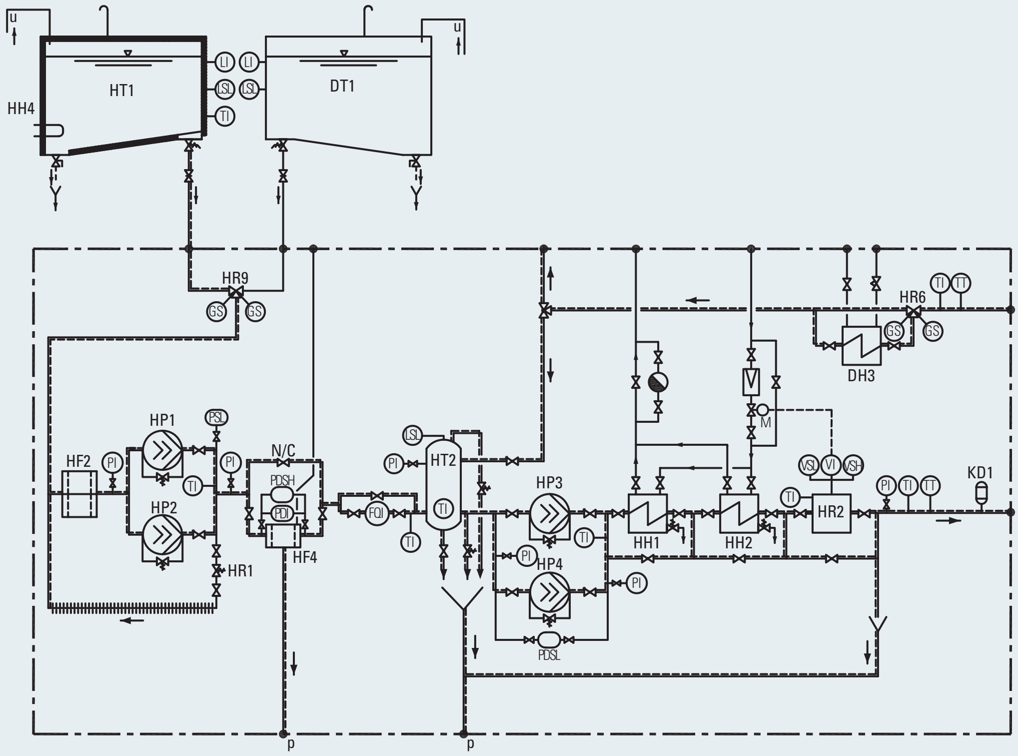


Fig. 5-20 Fuel booster and supply module, system diagram

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

All heavy fuel pipes have to be insulated.

------- Heated pipe

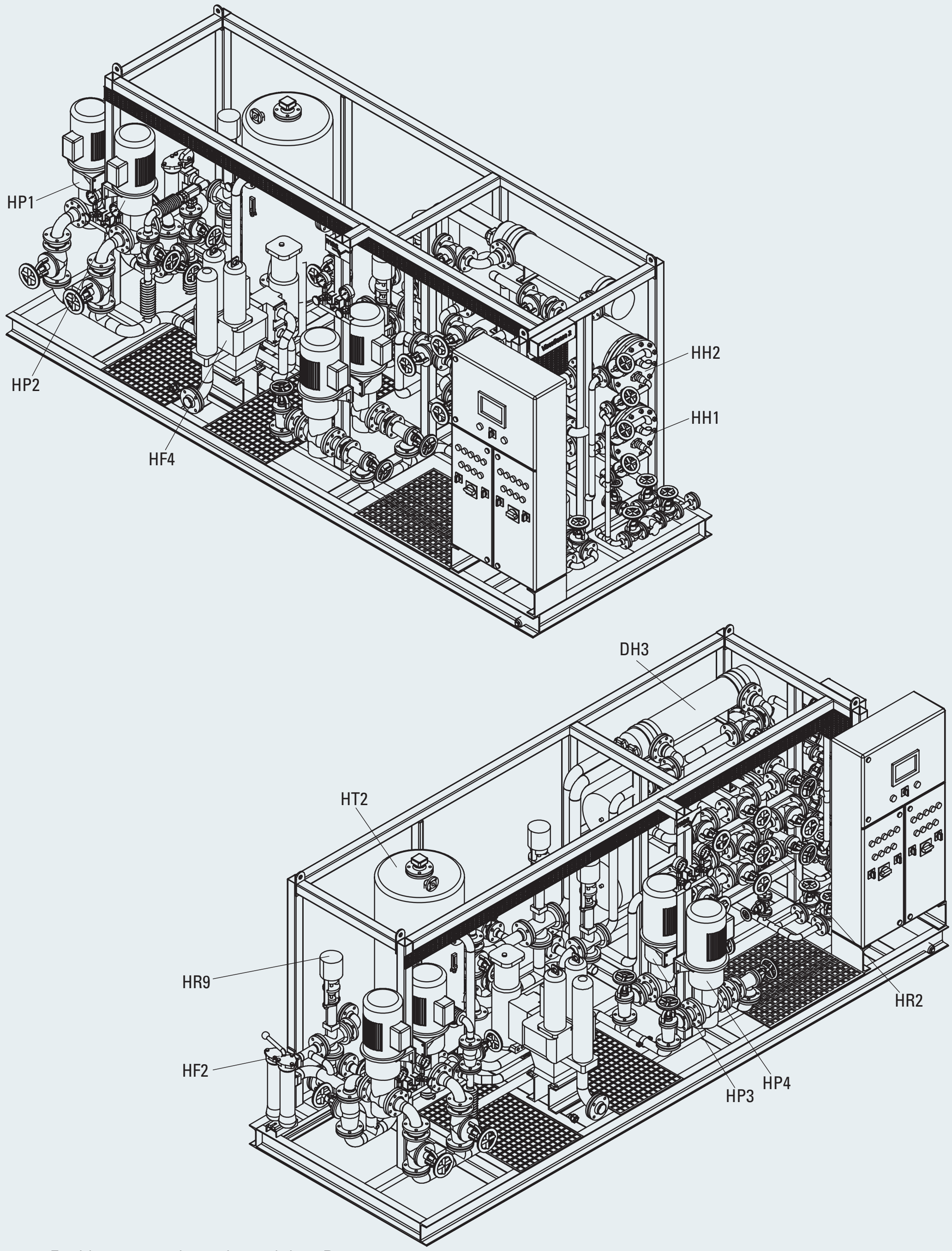


Fig. 5-21 Fuel booster and supply module, 3D

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

5.3 Switching over from HFO to diesel oil

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

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

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

Typical switch over characteristics (HFO to diesel)

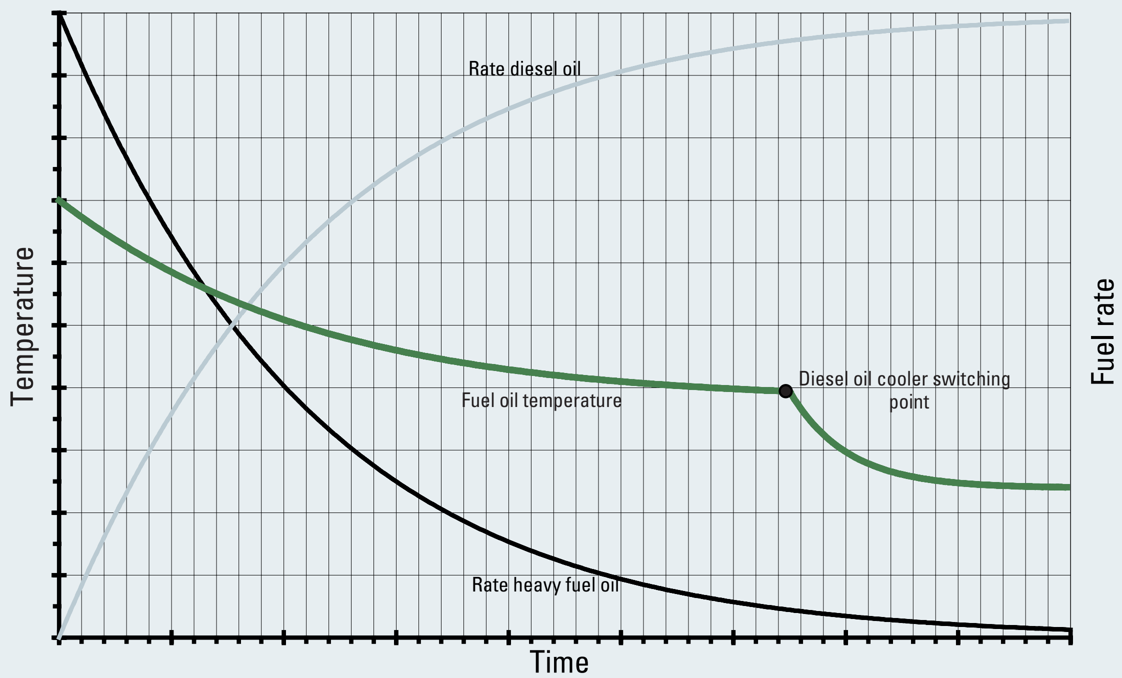


Fig 5-22 Switch over characteristics

5.4 Crude oil operation

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

6.1 General

The gas system provides the fuel gas from the Gas Valve Unit (GVU) to the gas admission valves on the engine.

The fuel gas flow to the engine is controlled by the GVU. The GVU is part of the Caterpillar Motoren standard scope of supply. One individual GVU per engine has to be provided. A maximum pipe length of 10 m between the GVU and the engine must not be exceeded.
For applications, where the GVU is located directly in the machinery space, a gas-proof cover is available as an option to comply with the gas safe machinery space requirements.

The complete gas manifold on the engine is double walled and leak detected to comply with the gas safe machinery space requirements. A leakage location system to decrease the maintenance effort is available as an option.

The fuel gas will be port injected by solenoid gas valves, these gas valves are integrated in the cylinder head design.

6.1.1 Gas fuel quality requirements

Natural gas specification M 34 DF with 720/750 rpm (VD9029)		
Gas temperature before engine inlet	[°C]	0 - 60
Gas pressure before at gas valve unit inlet	[bar (g)]	9
Maximum gas pressure fluctuation	[mbar/s]	+/- 80
Minimum lower heating value	[MJ/mn³]	28
Maximum inert gas content	[Vol.%]	2
Maximum Sulphur as H_2S	[mg/m³]	20
Maximum Ammonia (NH_4)	[mg/m³]	25
Maximum Fluorines Maximum Chlorine	[mg/m³]	Σ = 50
Maximum oil content	[mg/m³]	50
Maximum particles content	[mg/m³]	50
Maximum particles size	[µm]	5
Maximum Tar content	[mg/m³]	10
Maximum Silicium	[mg/m³]	10
Saturated fuel or water and condensates at gas control unit are not allowed		

6.1.2 Derating

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

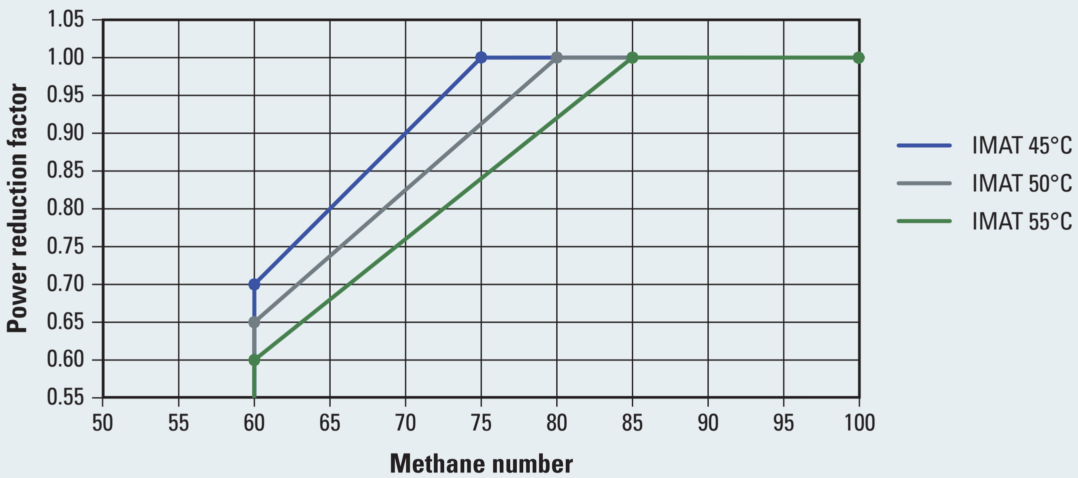


Fig. 6-1 Power reduction factor depending on Methane number and IMAT

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6.1.3 Inert gas quality requirements

Inert gas to be complied with Caterpillar's inert gas specification VD8836 for dual fuel engines.

Inert gas specification Dual Fuel		
Gas temperature range at interfaces to engine	[°C]	0 - 60
Minimum pressure difference (min. inert gas - max. fuel gas)	[bar(g)]	1
Maximum inert gas pressure	[bar(g)]	7
Allowed gases		Nitrogen ≥ 95 % Carbon Dioxid 2.5
Maximum Sulphur as H_2S	[%]	0,05 (= 770 mg/mn³)
Maximum Ammonia (NH_3)	[mg/m³]	25
Maximum Fluorines Maximum Chlorine	[mg/m³]	Σ = 50
Maximum oil content	[mg/m³]	50
Maximum particles content	[mg/m³]	50
Maximum particle size	[µm]	5
Maximum dew point	[°C]	-20

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6.2 Gas system overview

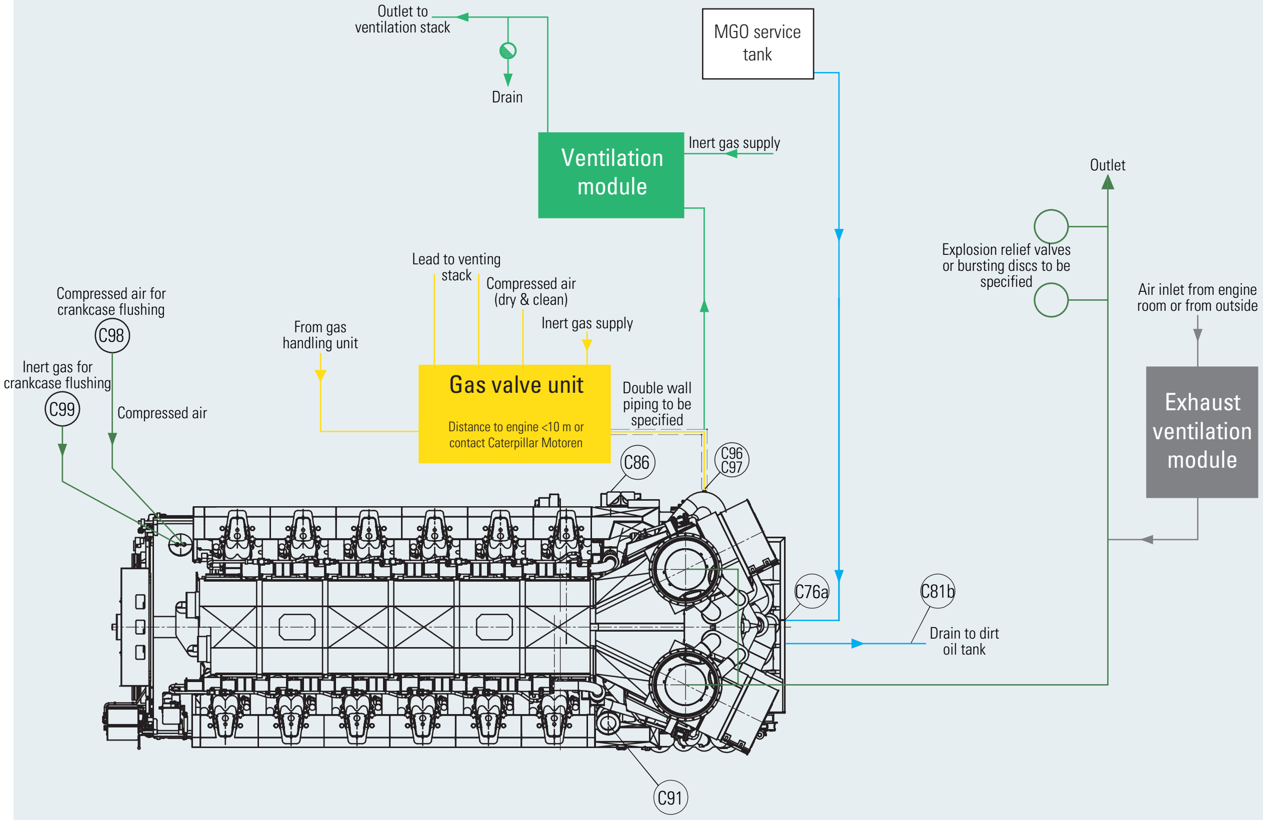


Fig. 6-2 Gas system overview

6.2.1 Gas valve unit (GVU)

The gas valve unit provides the engine with the desired fuel gas pressure and fuel gas quantity.
It is controlled by the engine's control and monitoring system and the engine's speed governor. The maximum distance between the GVU and the engine is 10 m. If more distance is requested please contact Caterpillar Motoren.
It has several features to safely cut the engine from the gas train and to remove the gas fuel from the piping system (flushing). In case of flushing the gas fuel is pushed by inert gas over the engine via the GVU towards the ship's vent system.

GVU's can be supplied in horizontal and vertical design, as U-type and also mounted within an enclosure.
The gas valve unit is an off-engine component. GVU is single walled designed and needs to be installed in an ESD compliant machinery space or within an enclosure.
The GVU is optionally available with a gas fuel flow meter.

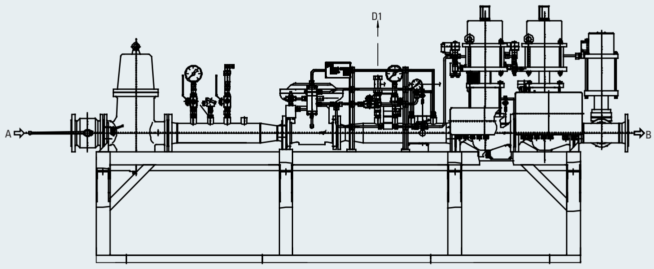


Fig. 6-3 Gas valve unit

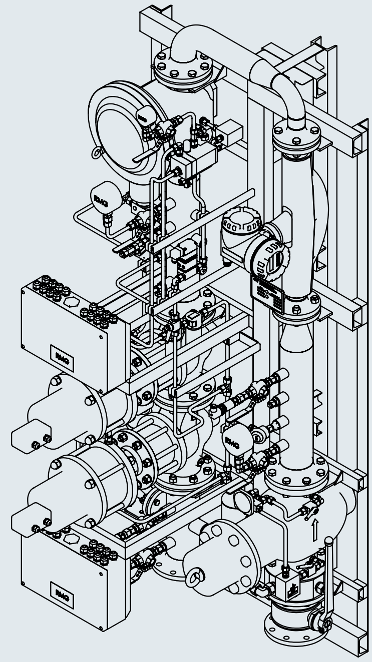


Fig. 6-4 Gas valve unit, U-form vertical

6.2.1.1 GVU enclosure

In case of installing the GVU inside the machinery room and to ensure its definition as a safe machinery room the GVU needs to be encased and the gas pipe needs to be of double wall pipe.
The GVU housing is seen as an extension of the annular space of double wall fuel gas pipe in front of the GVU.

6.2.2 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.
Ignition fuel is to be used also during operation with liquid fuel, for cooling of injector needles. To achieve the cleanliness of the ignition fuel an on engine filtering system assures the necessary cleanliness level of the ignition fuel.

6.2.2.1 Ignition fuel quality requirements

Only MDO fuel types DMA and DMZ acc. to ISO 8271 are to be used. For usage of DMB or DMX please consult Caterpillar Motoren in advance.

6.2.2.2 Ignition fuel components

The ignition fuel filter system contains of two filter loops. The first is driven by the fuel loop pump combined with 3 filter elements. The second filter loop is driven by the fuel transfer pump and a single filter. The fuel transfer pump is attached on the high pressure pump. Differential pressure gauges in combination with an alarm will indicate the need for filter exchange. For this service the engine has to be stopped.

Ignition fuel injector

Weight: 2 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

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.

6.2.3 Ventilation system (annular space)

For a permanent ventilation of the annular space in the double wall piping a vacuum created by extraction fans must be ensured to monitor any possible gas leakages.

The system is divided into two independent ventilation systems:

- Engine ventilation system
- GVU ventilation system (enclosed GVUs only)

and consist of at least one extraction fan/pump and one gas sensor (redundancy might be required, depending on classification requirements).
These two systems enable a more targeted and fast localization of a possible gas leakage which results in a more reliable operation in fuel gas mode.
Formation of condensate in annular space due to low fuel gas temperature may occur.
Appropriate material selection and/or drainage must be ensured.

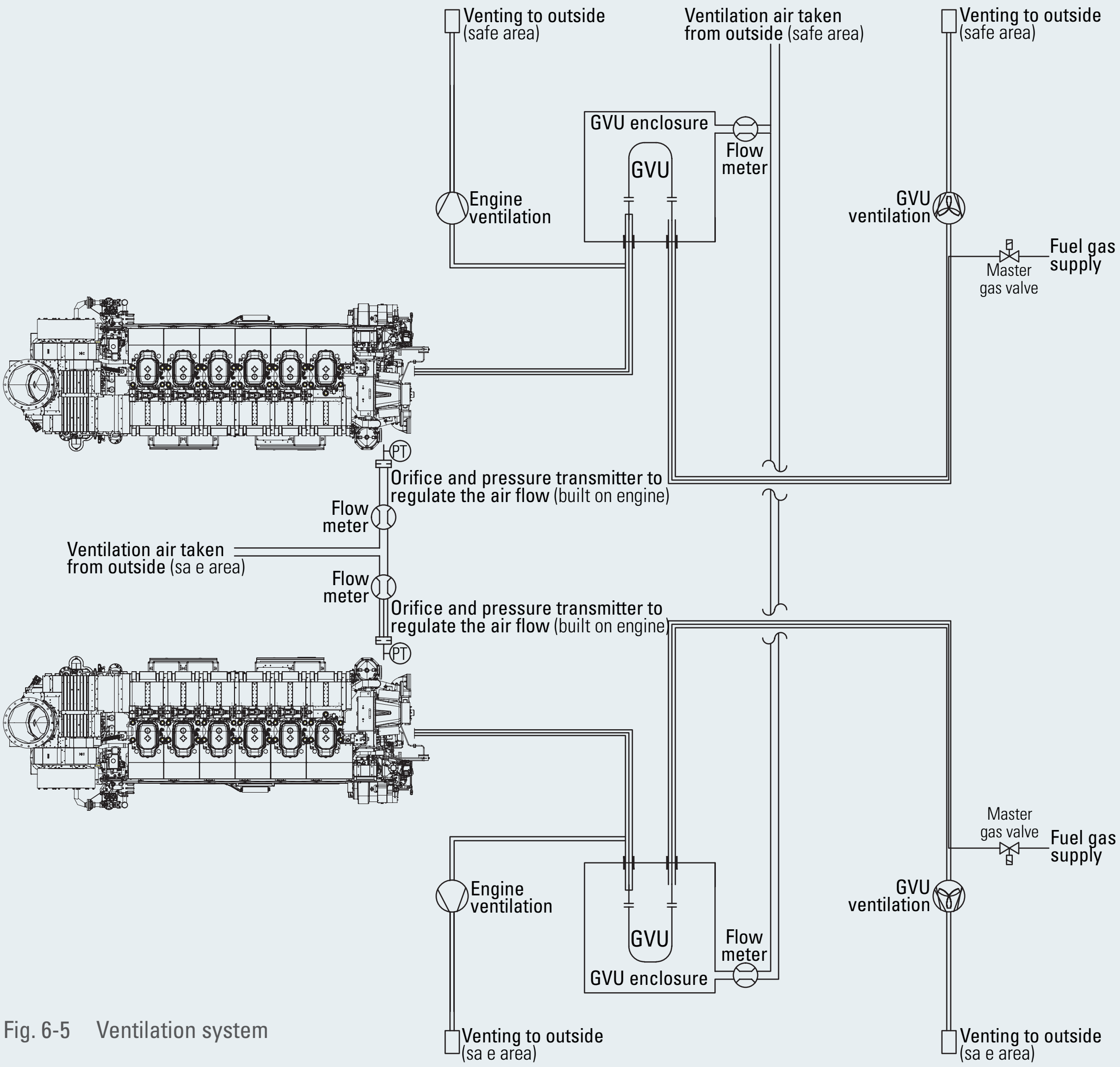


Fig. 6-5 Ventilation system

6.2.3.1 Engine ventilation system

The engine ventilation system is used to permanently ventilate the engine and adjacent piping system with air during fuel gas operation.
Ventilation equipment is mounted on a skid and installed as close as possible inside the engine room (safe area) to the gas valve unit. Air has to be supplied from the outside (safe zone).
In case of a leakage in the annular space nitrogen (supply by others) will be used for purging. Nitrogen pressure will be constantly monitored.
Each engine has its own ventilation system, controlled by the engine control system.

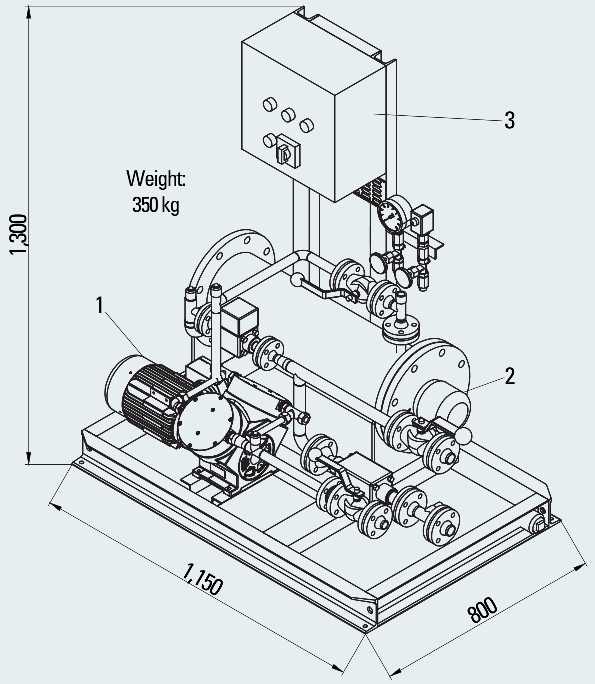


Fig. 6-6 Engine ventilation system – basic

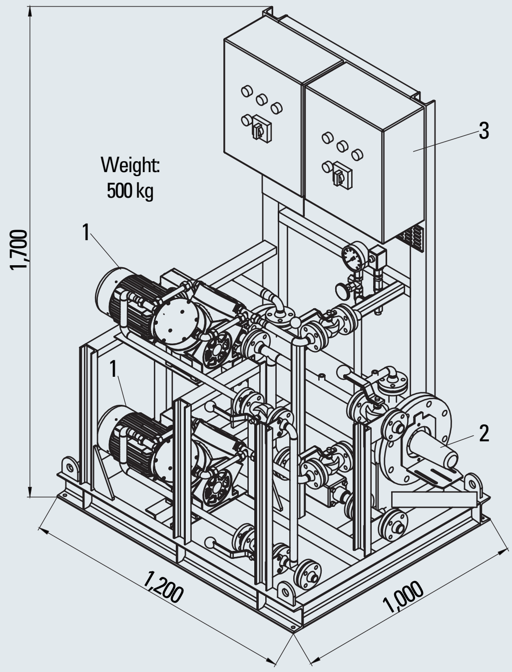


Fig. 6-7 Engine ventilation system – redundant

1	Vacuum pump
2	Gas sensor
3	Junction box

1	Vacuum pump
2	Gas sensor
3	Junction box

6.2.3.2 GVU ventilation system

Similar to the engine ventilation system (chapter 6.2.3.1) the GVU ventilation system is used for permanent ventilation of the GVU enclosure and its annular space of the double wall piping to the master gas valve.
A GVU ventilation module is equipped with extraction fan(s) (ex-proof) and gas detector(s).
A flow meter (supplied by others) must be installed to ensure a sufficient air flow at inlet of GVU enclosure.
Ventilation air must be absorbed and directed back to the outside (safe area).
In case of gas detection the annular space must be purged by nitrogen (supplied by others).
Each GVU should get its own GVU ventilation system.

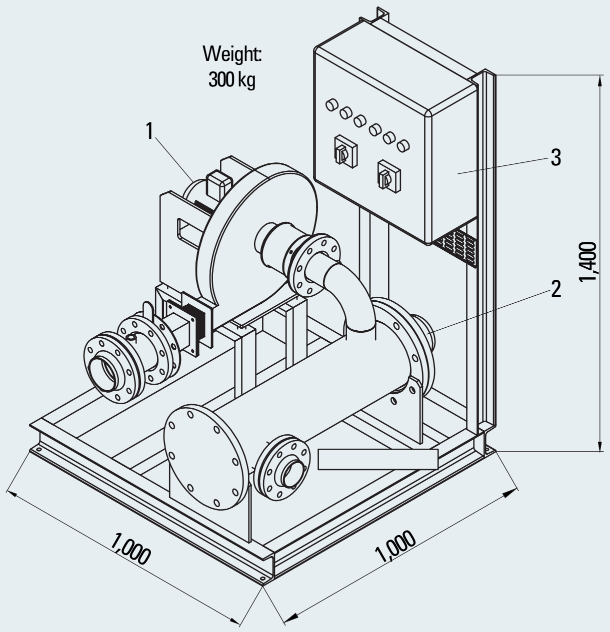


Fig. 6-8 GVU ventilation system

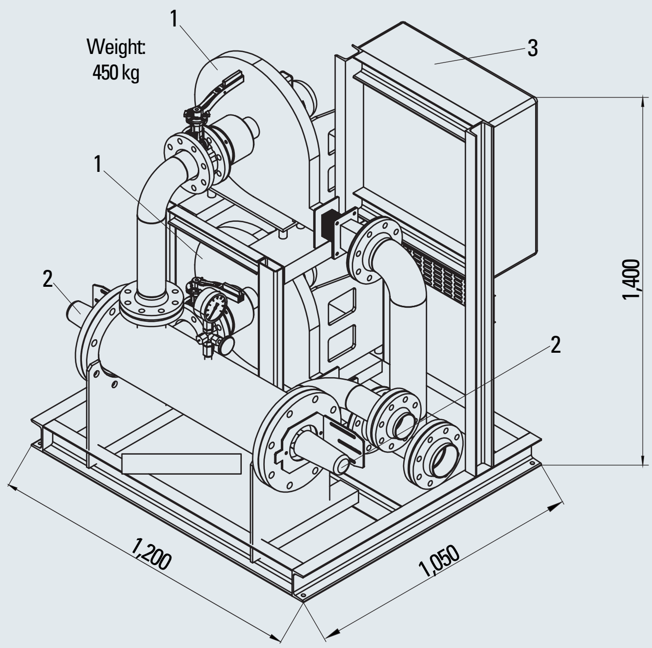


Fig. 6-9 GVU ventilation system

1	Vacuum pump
2	Gas sensor
3	Junction box

1	Vacuum pump
2	Gas sensor
3	Junction box

6.2.4 Exhaust gas ventilation system

The exhaust gas ventilation module is used to purge the exhaust piping system after an engine stop, trigged by an emergency stop in gas mode. The module is equipped with an extraction fan, automatic shut-off valve and an exhaust gas compensator, to connect to the exhaust gas piping system.
The ventilation air has to be taken from outside (safe zone).
The automatic shut-off valve isolates the exhaust gas system to protect the engine room against exhaust gas inrush and is of gas-tight design and high temperature resistant.
The engine start is blocked, if the automatic shut-off valve is not completely closed, monitored by a position switch and temperature transmitter. The extraction fan is sized to remove the total volume of the exhaust gas system.
The exhaust gas ventilation system is a class requirement and shall be located inside machinery room and as close as possible to the turbocharger. Each engine has to have its own exhaust gas ventilation system.

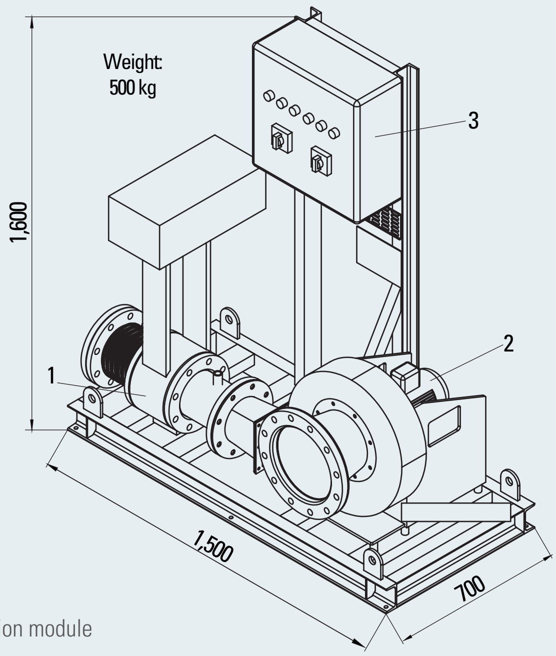


Fig. 6-10 Exhaust gas ventilation module

1 Automatic shut-off valve
2 Extraction fan
3 Junction box

6.2.5 Explosion relief devices

During gas operation it might be possible that unburned gas enters the exhaust gas piping and gets ignited by i.e. sparks.
To avoid unburned gas accumulation in the exhaust gas piping which results in an explosive atmosphere, the exhaust gas pipe shall be routed steadily ascending and shall be equipped with explosion relief devices such as relief valves or rupture discs (depending on classification society requirements).

Care must be taken in the design of the exhaust gas piping, so that horizontally laid pipes and equipment are reduced to a minimum and to reduce the amount of explosion relief devices.
The amount and location of required explosion relief devices needs to be identified by a calculation or simulation and must be sufficient to protect the exhaust gas system adequately.
The final exhaust gas piping needs to be available in 3D.

Relief valves are equipped with a flame arrestor.

Compared to rupture discs, relief valves will reseal after discharge and no flame transmission occurs.
Nevertheless, the outlets of the relief devices are to be discharged to a safe place, where no danger for people and other equipment is given (see classification regulations).
The exhaust gas equipment must be designed to withstand the maximum overpressure achieved by an explosion.
Installation of additional relief devices might not result in a lower peak pressure.

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 is 12 - 20 KOH/g for MDO operation depending on Sulfur content
  Please see the Operating Media Guide for the TBN (total base number) at HFO operation

NOTE:
Please see the Operating Media Guide for a list of approved lube oils.

7.2 Internal lube oil system

General

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

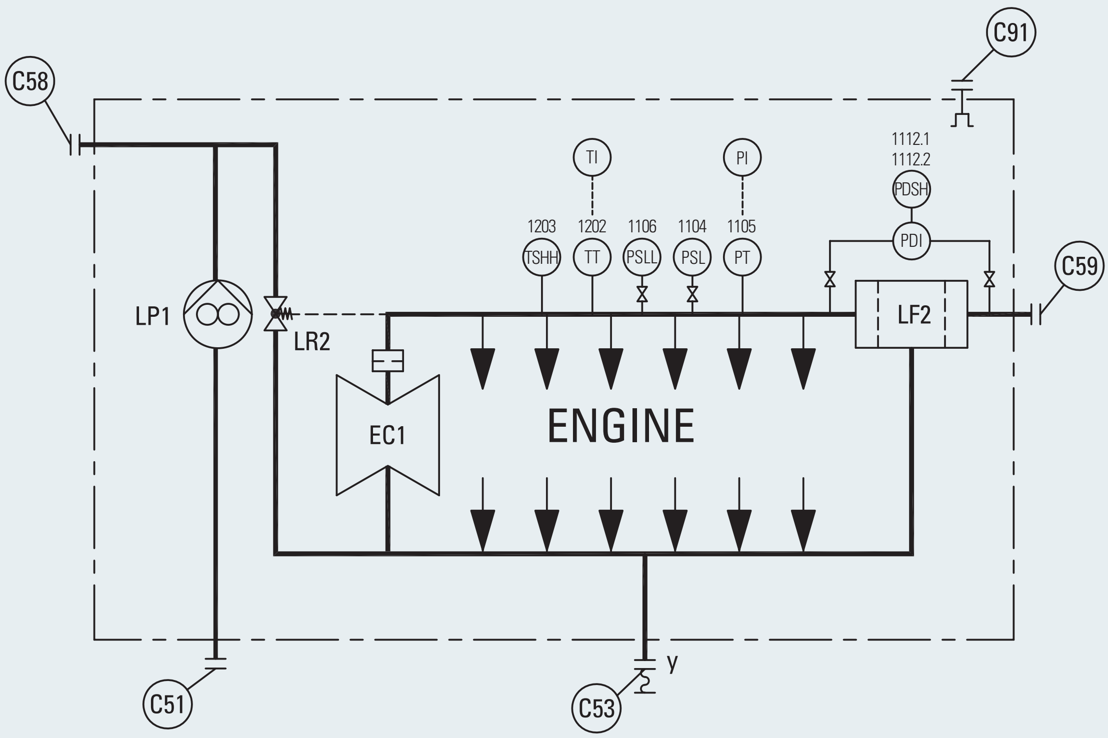


Fig. 7-1 Internal lube oil system, system diagram

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

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.

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.

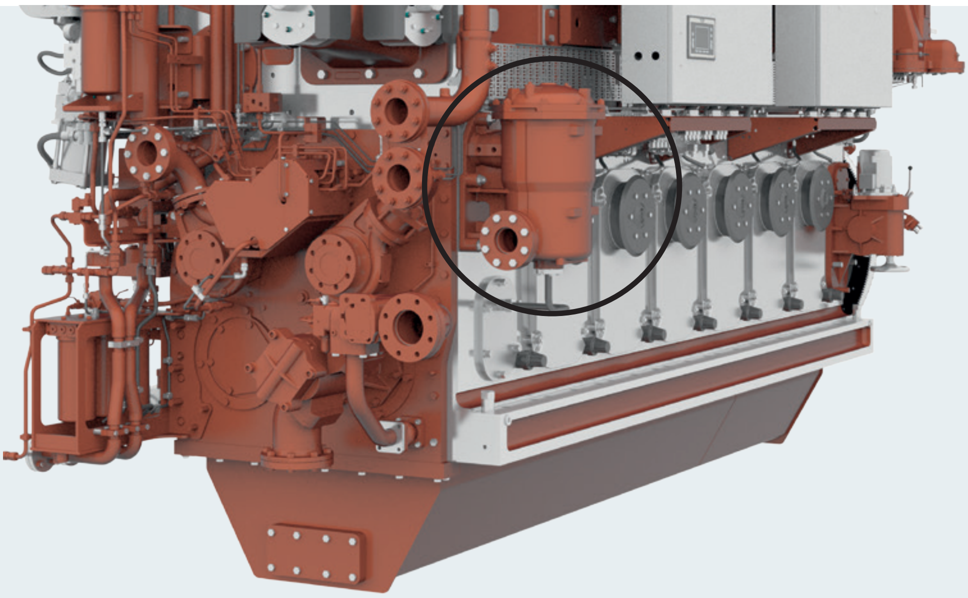


Fig. 7-2 Self-cleaning lube oil filter LF2

All pictures shown are for illustration purpose only. Actual product may vary due to product enhancement.

Back flushing filter LF2 (separate), option

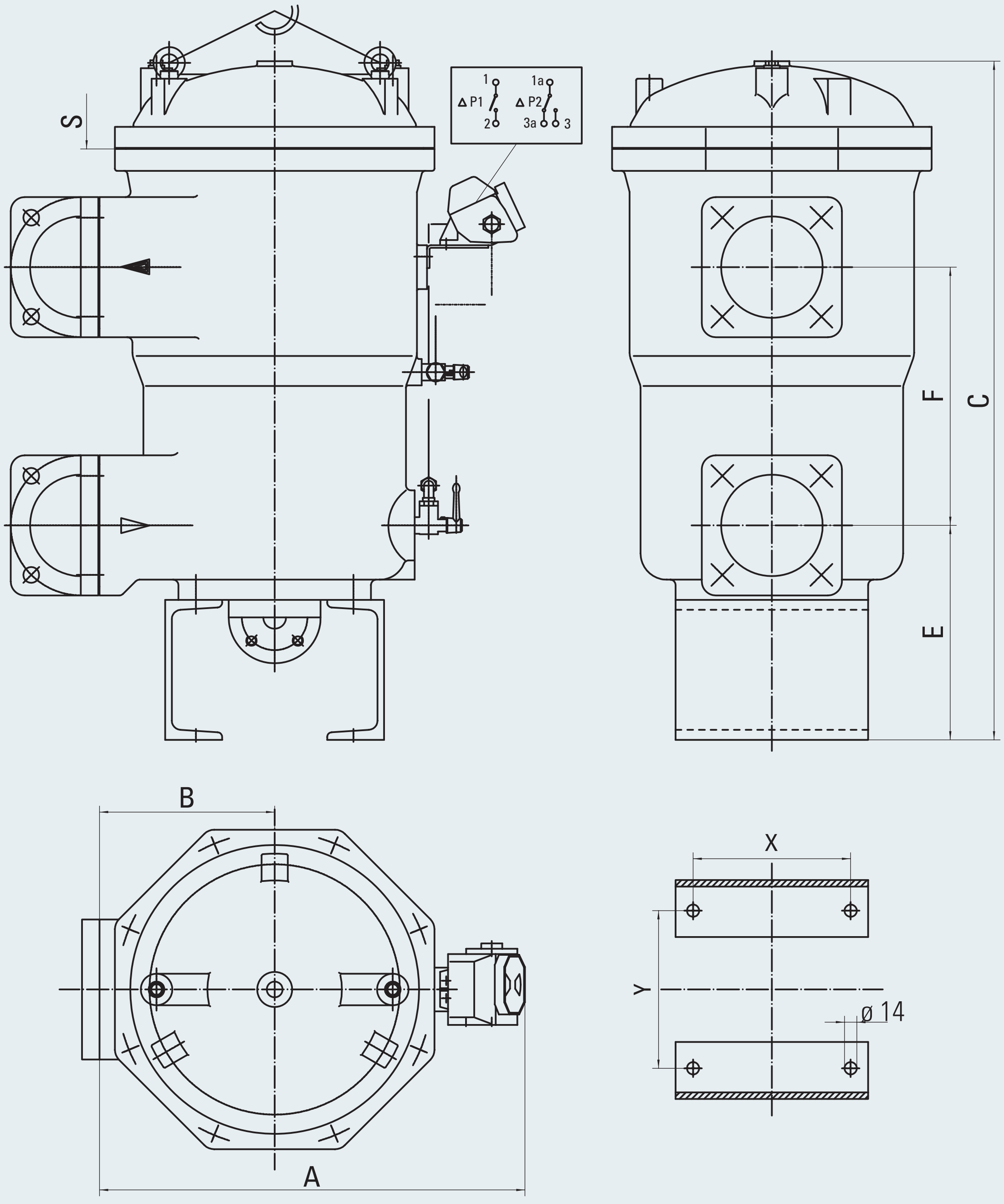


Fig. 7-3 Back flushing filter LF2

	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.

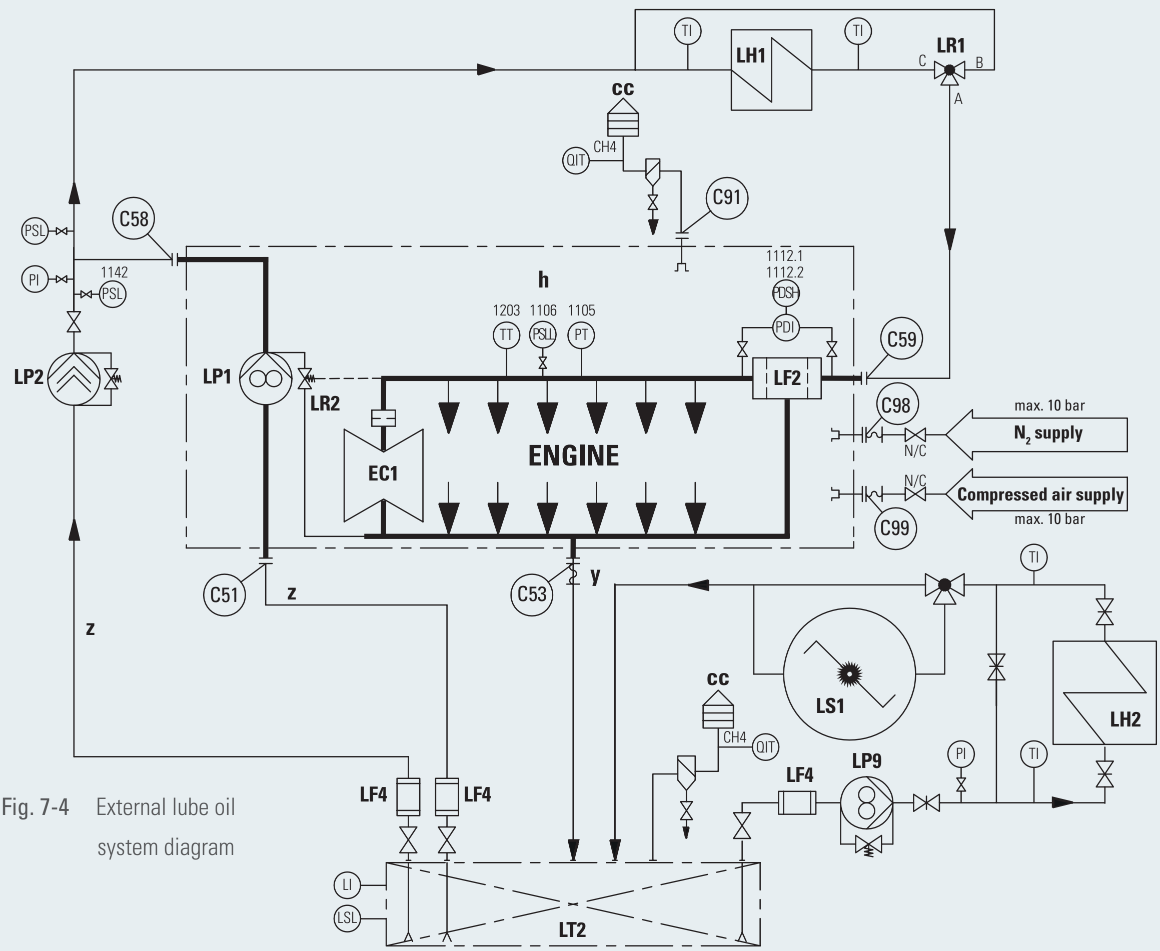


Fig. 7-4 External lube oil system diagram

EC1	Exhaust gas turbocharger	LI	Level indicator
LF2	Self-cleaning lube oil filter	LSL	Level switch low
LF4	Suction strainer	PDI	Diff. pressure indicator
LH1	Lube oil cooler	PDSH	Diff. pressure switch high
LH2	Lube oil preheater	PI	Pressure indicator
LP1	Lube oil force pump	PSL/PSLL	Pressure switch low
LP2	Lube oil stand-by force pump	PT	Pressure transmitter
LP9	Transfer pump (separator)	QIT	Gas indicator and transmitter
LR1	Lube oil temperature control valve	TI	Temperature indicator
LR2	Oil pressure regulating valve	TT	Temperature transmitter (PT100)
LS1	Lube oil separator		
LT2	Oil pan	C51	Force pump, suction side
		C53	Lube oil discharge
cc	Flame arrestor must be provided	C58	Force pump, delivery side
h	Please refer to the measuring point list regarding design of the monitoring devices.	C59	Lube oil inlet, lube oil cooler
		C91	Crankcase ventilation to stack
y	Provide an expansation joint	C98	Flushing connection crankcase (inertgas)
z	Max. suction pressure - 0.4 bar	C99	Flushing connection crankcase (air)

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.

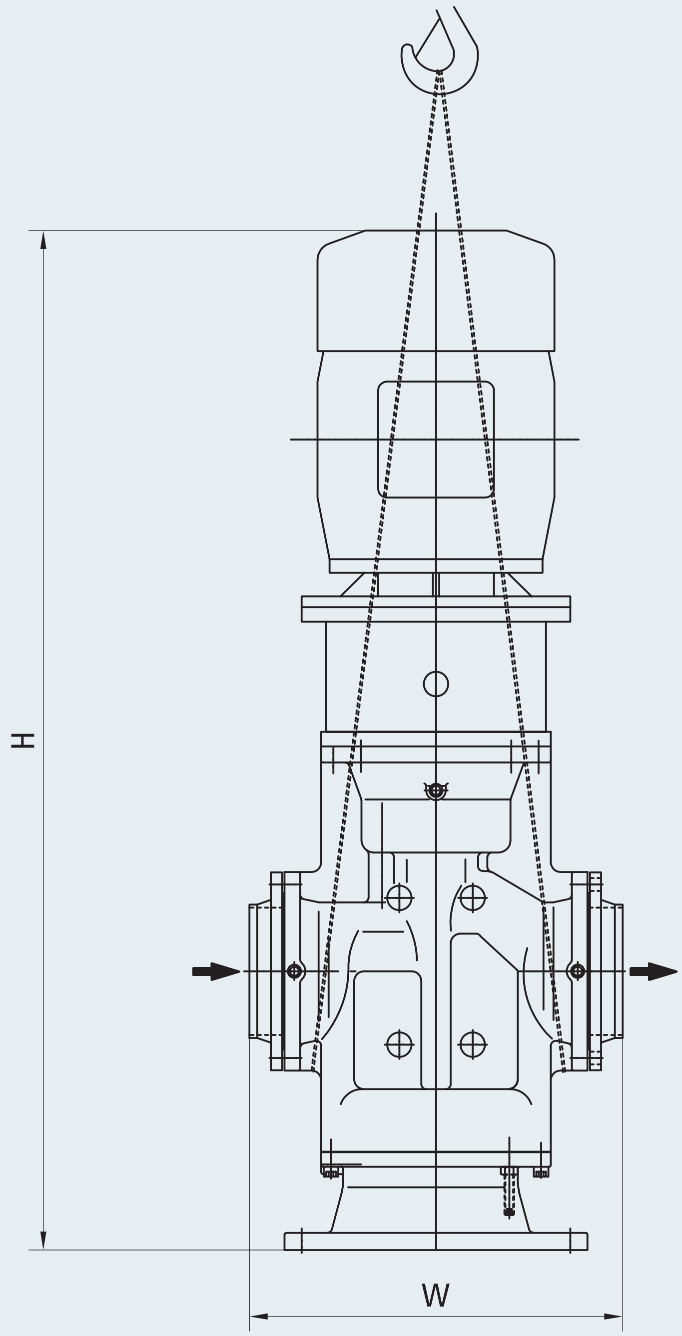


Fig. 7-5 Lube oil stand-by force pump LP2

		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.

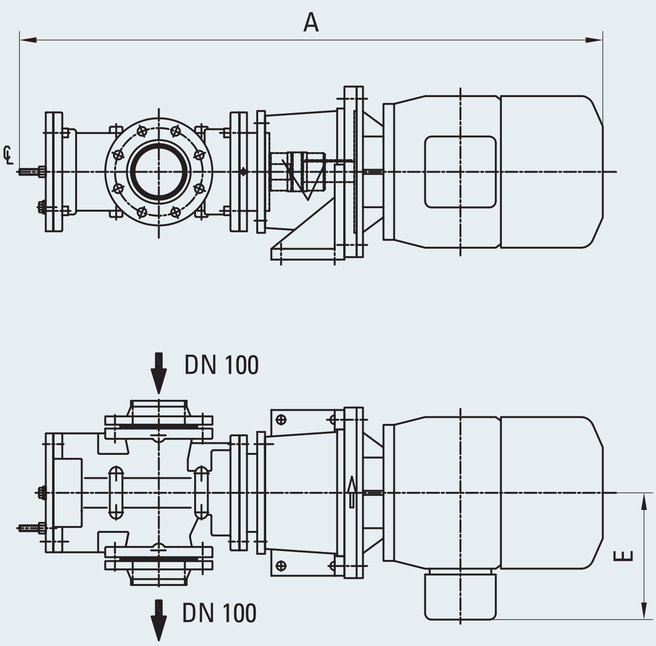


Fig. 7-6 Prelubricating pump LP5

	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.

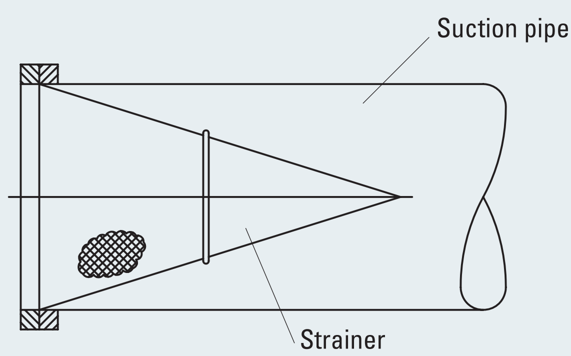


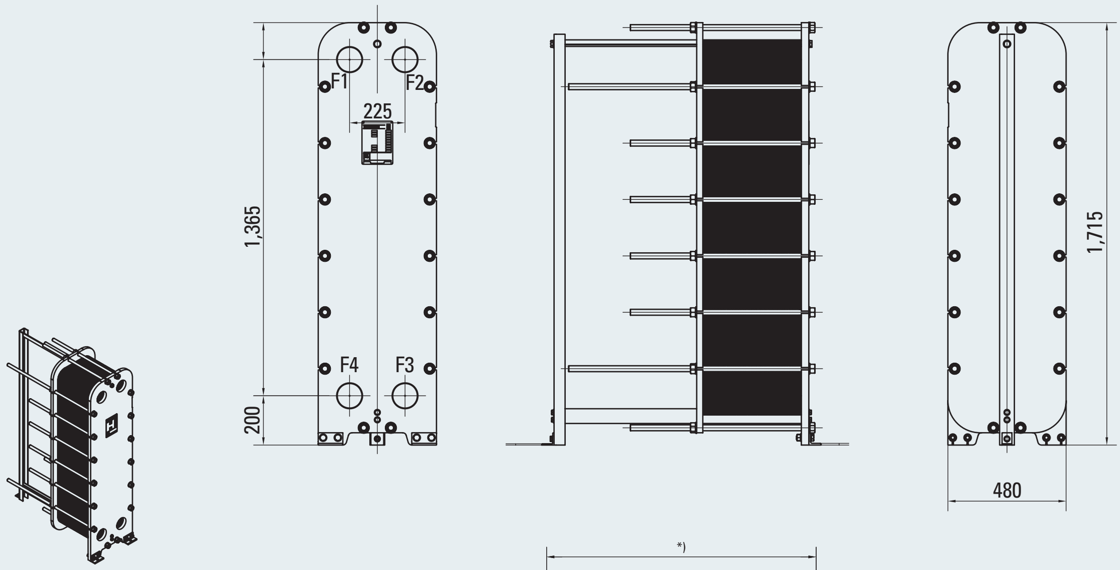
Fig. 7-7 Suction strainer LF4

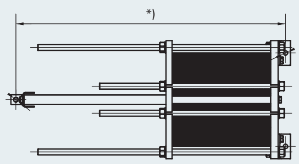
Oil pressure regulating valve LR2 (fitted)

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.





Lube oil cooler 6 M 34 DF connection positions:
F1 – DN100/PN16 – Lube oil inlet
F4 – DN100/PN16 – Lube oil outlet
F2 – DN100/PN16 – LT water outlet
F3 – DN100/PN16 – LT water inlet

*) 6 M 34 DF: 634 mm, 8 M 34 DF: 734 mm, 9 M 34 DF: 1,134 mm

Fig. 7-8 Lube oil cooler LH1

Lube oil temperature control valve LR1 (separate)

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

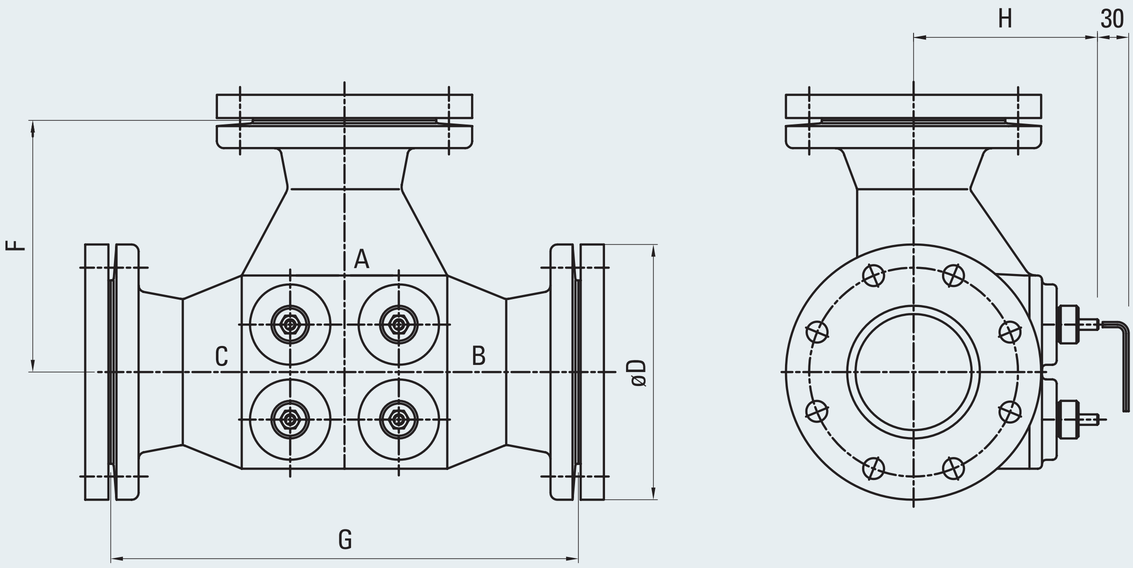


Fig. 7-9 Lube oil temperature control valve LR1

	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.

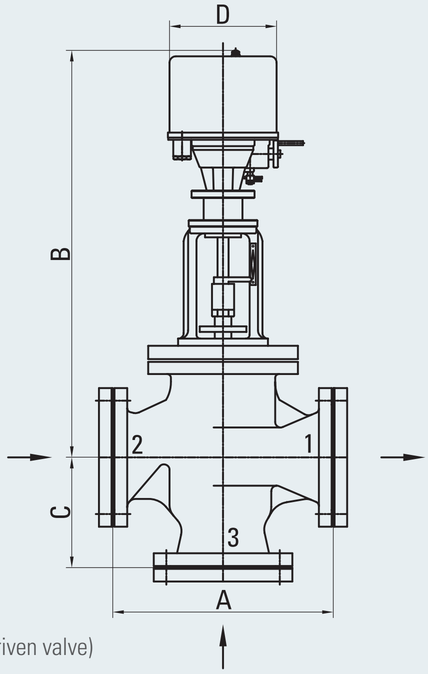


Fig. 7-10 Lube oil temperature control valve LR1 (electric driven valve)

	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

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

Layout for HFO and gas operation

Automatic self-cleaning separator; Operating temperature 95 °C

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

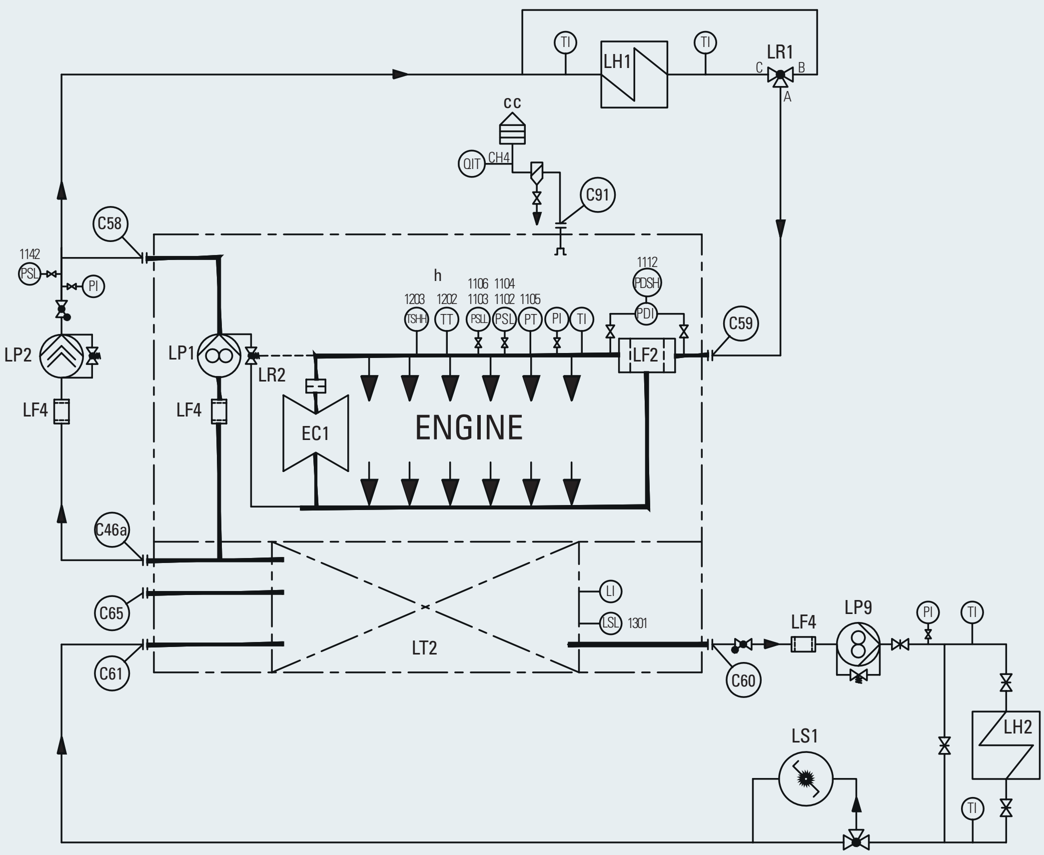


Fig. 7-11 System diagram, wet sump tank

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

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

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.

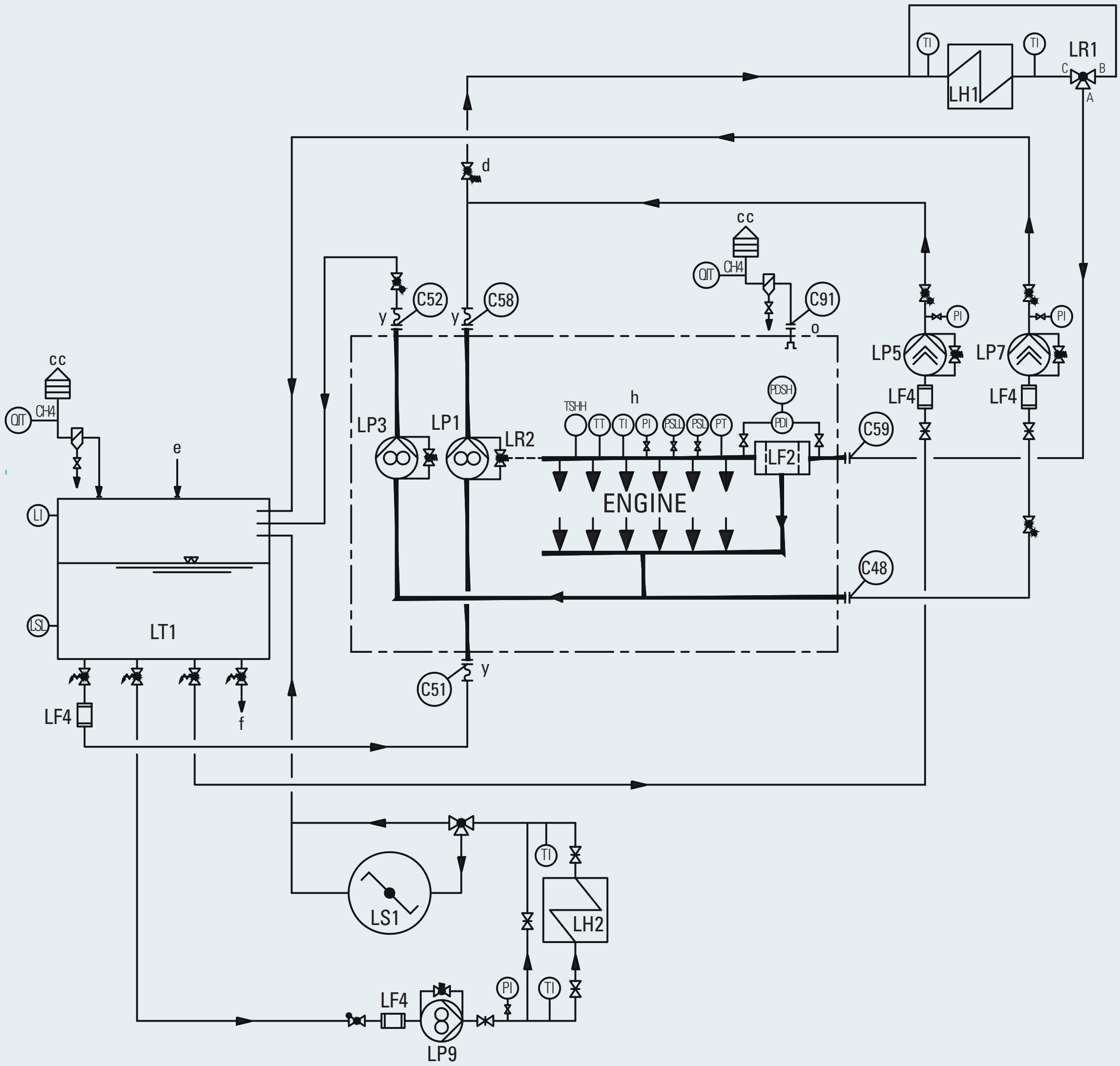


Fig. 7-12 System diagram, high level tank

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.

7.3 Circulating tanks and components

7.3.1 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.

7.3.2 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.

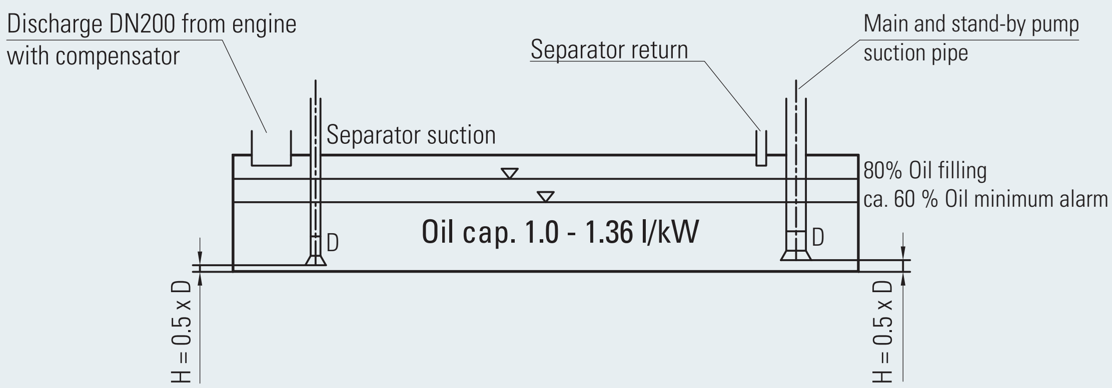


Fig. 7-13 Sump tank LT1

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

- 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.

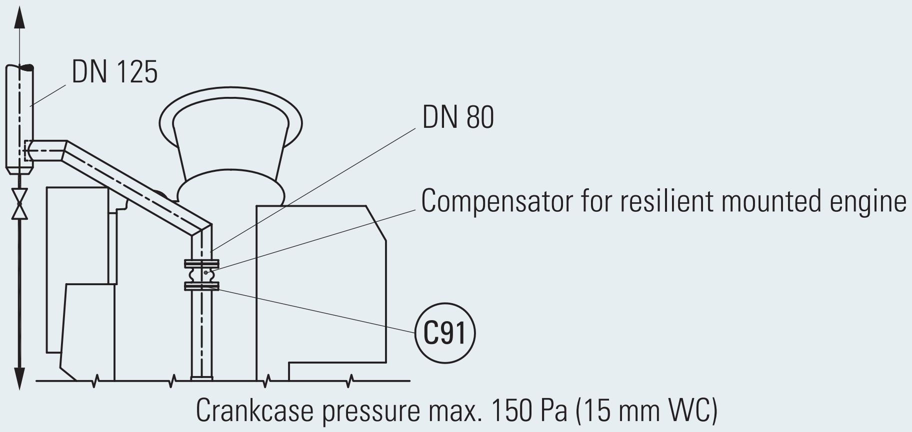


Fig. 7-14 Crankcase ventilation

C91 Crankcase ventilation to stack

7.4 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.

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° dGH
- pH-value 6.5 – 8
- Chloride ion content of max. 100 mg/l

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.

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

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

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

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8.2.2 Electric motor driven pumps

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

Rough calculation of power demand for the electric balance:

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

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

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

8.3 Cooling water system

8.3.1 General

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

The low temperature (LT) cooling circuit provides cooling for the LT stage of the charge air cooler, the lube oil and the diesel oil coolers and possible other consumers like e.g. 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

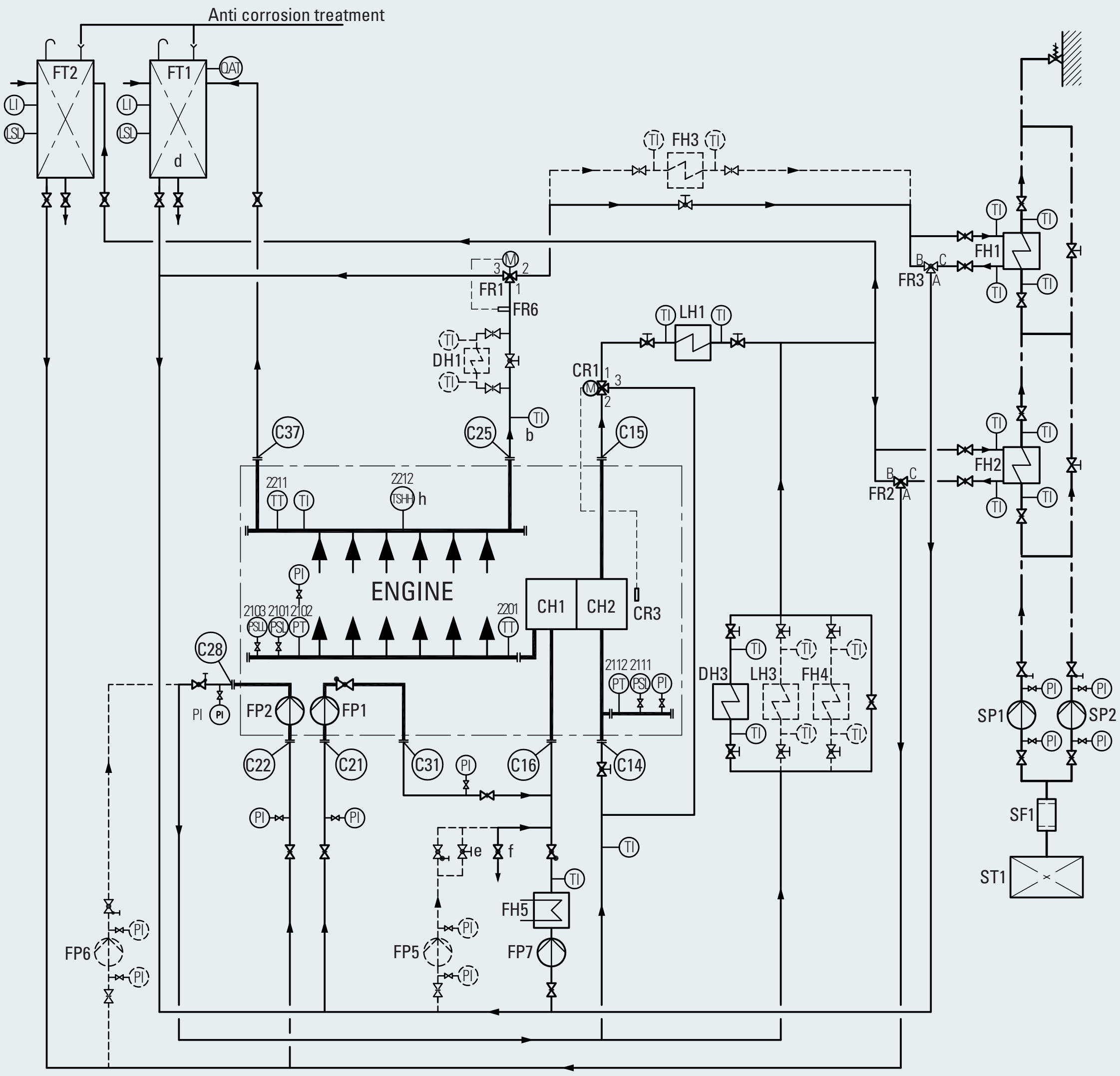


Fig. 8-1 External cooling water system, system diagram, turbocharger at driving end

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

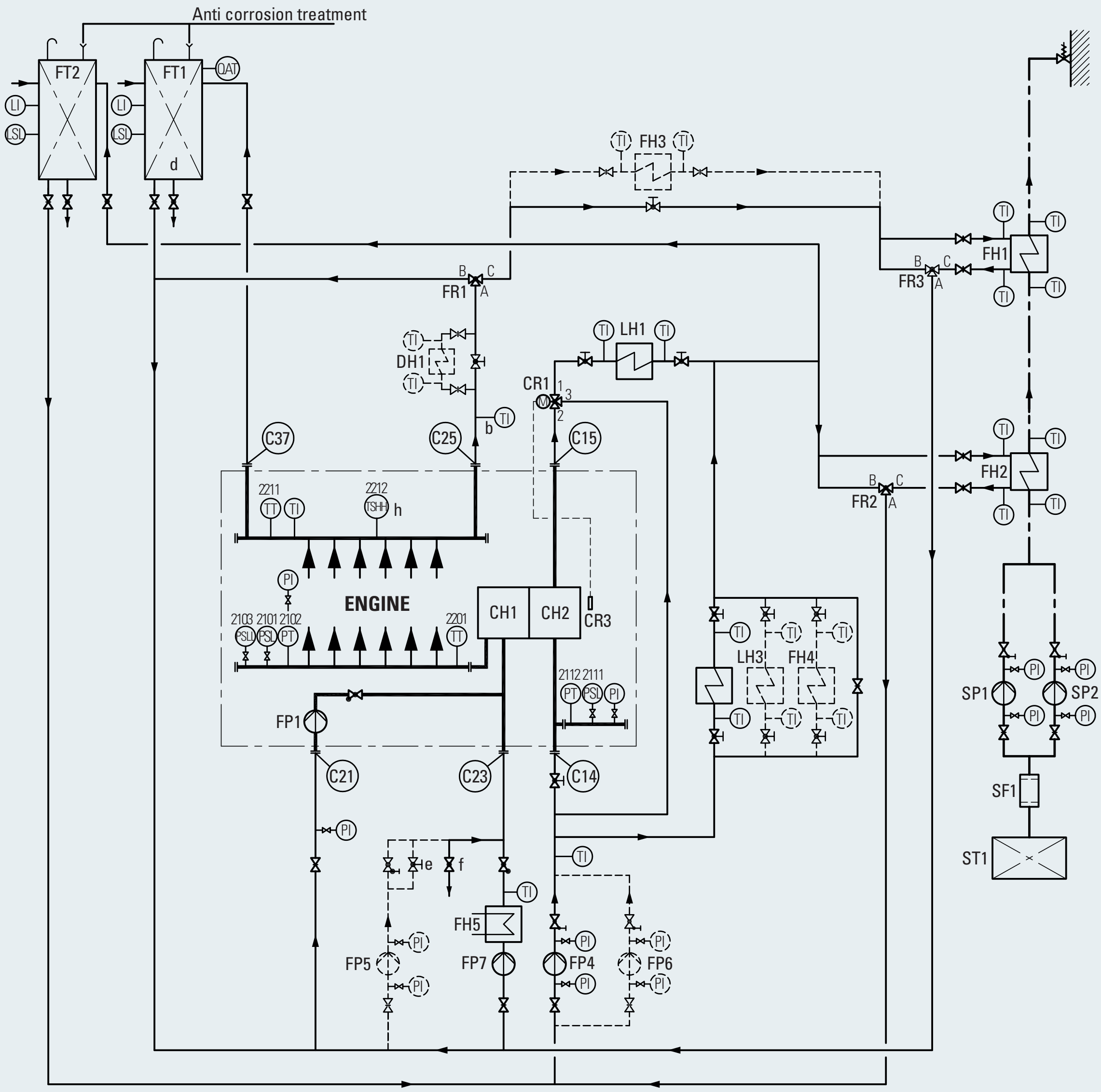


Fig. 8-2 External cooling water system, system diagram, turbocharger at free end

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.

Secondary circuit cooling system with turbocharger at free end

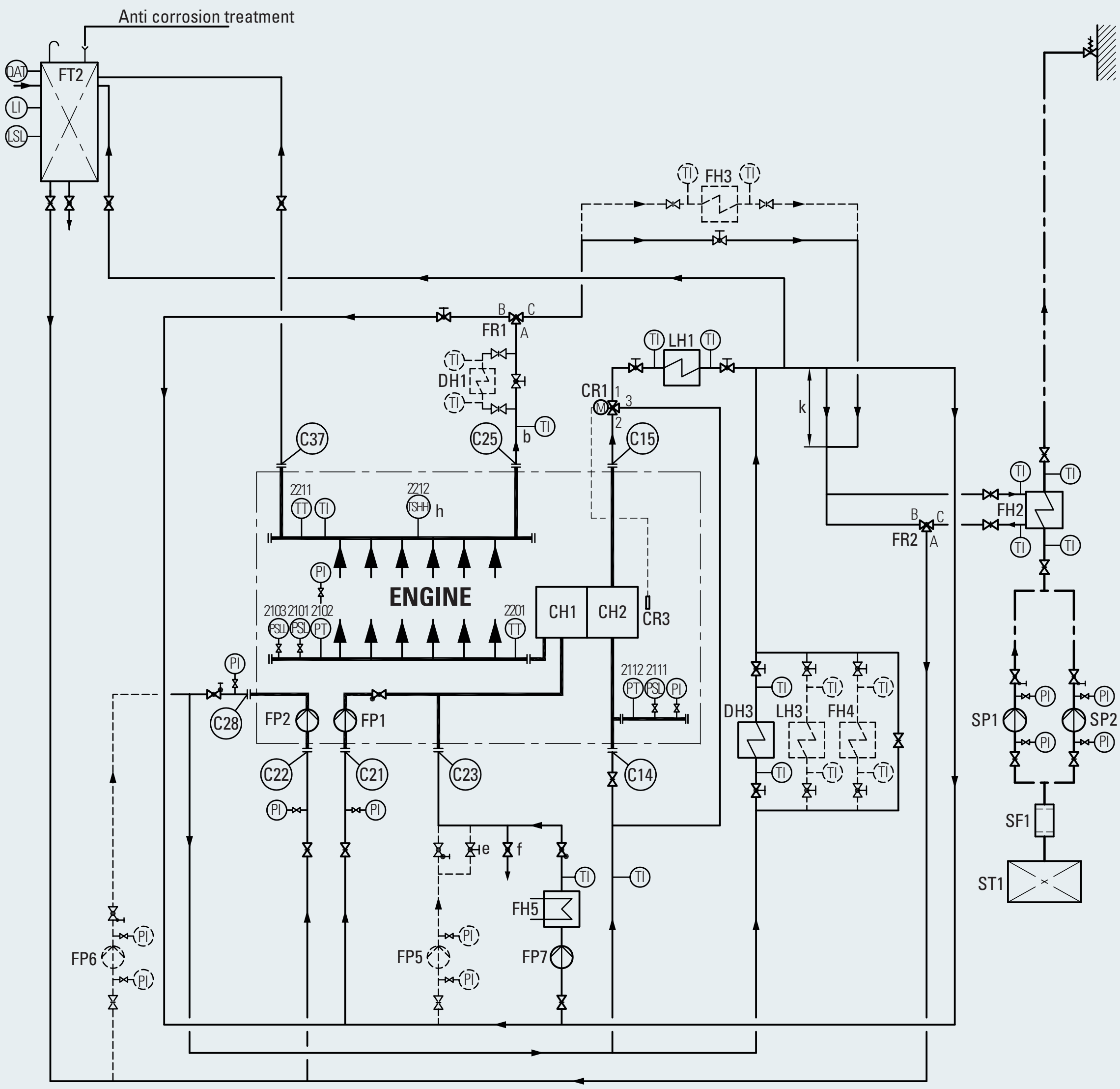


Fig. 8-3 Secondary circuit cooling system, system diagram, turbocharger at free end

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

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

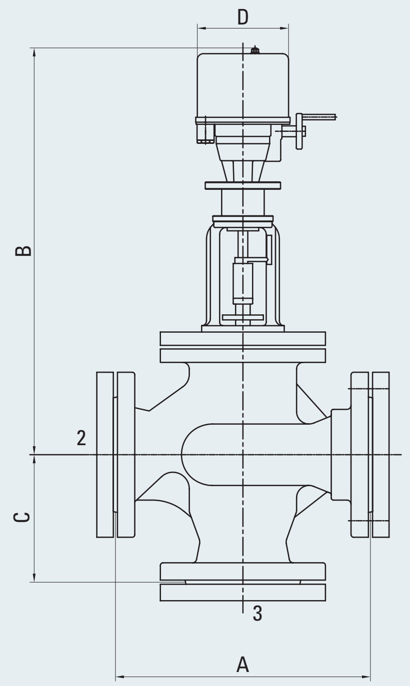


Fig. 8-4 Charge air temperature control valve CR1

Capacity: acc. to heat balance.

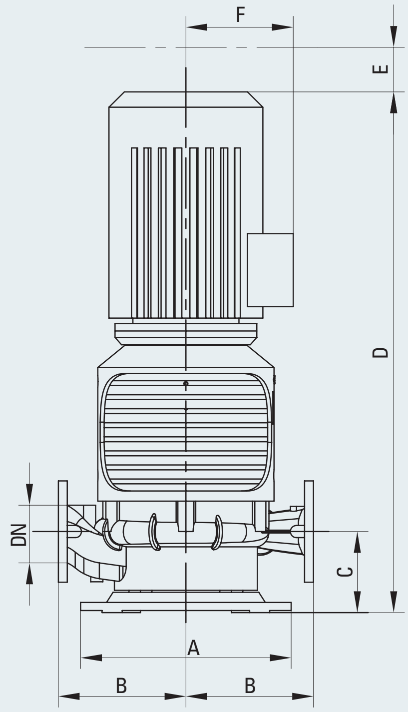


Fig. 8-5 Fresh water pump

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).

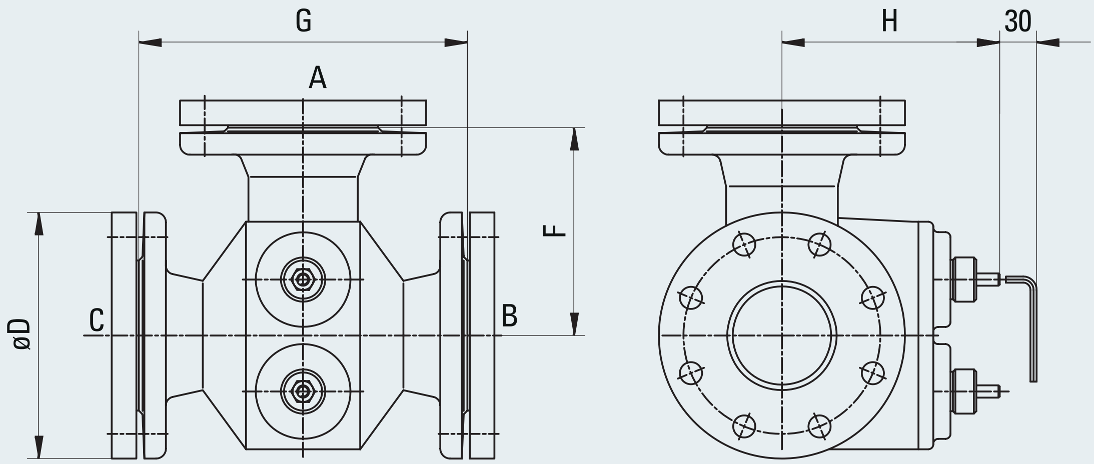


Fig. 8-6 Temperature control valve HT FR1

		Dimensions [mm]					Weight
		DN	D	F	G	H	[kg]
6/8/9 M 34 DF	HT	80	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

8.4 System diagrams heat balance

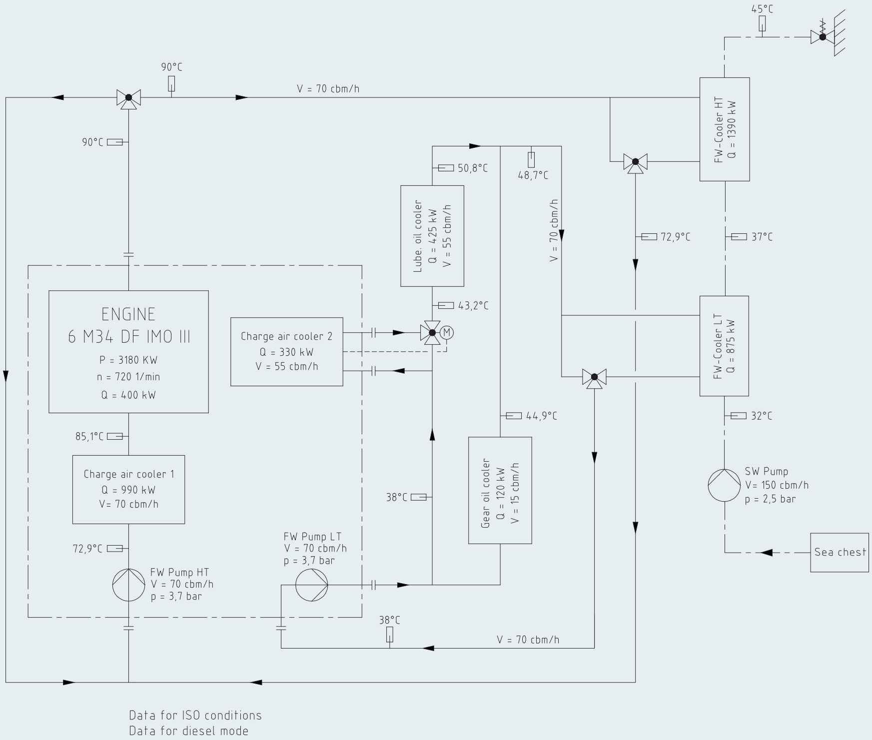


Fig. 8-7 Heat balance, system diagram 6 M 34 DF – 3,180 kW

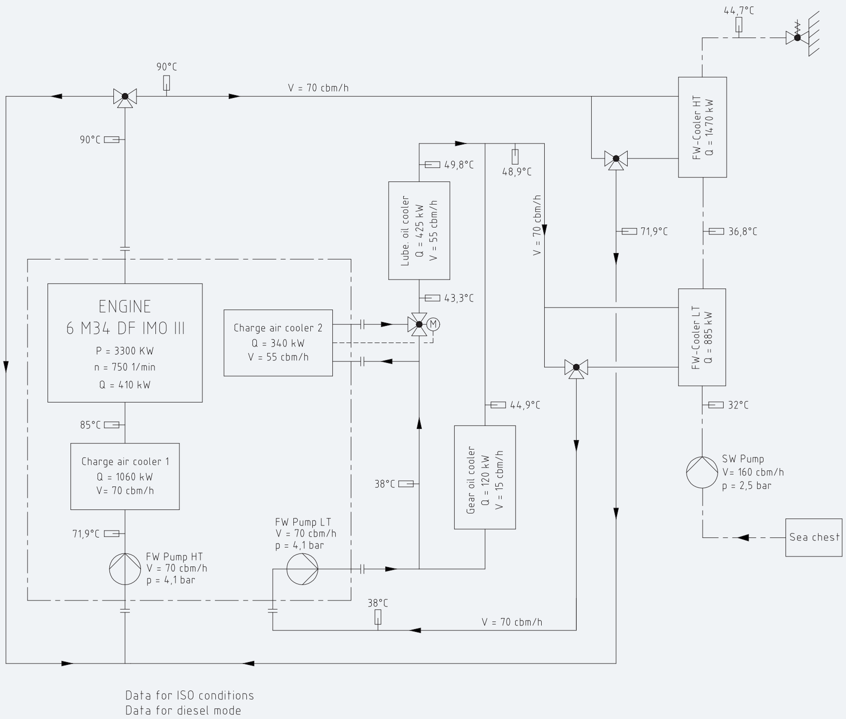


Fig. 8-8 Heat balance, system diagram 6 M 34 DF – 3,300 kW

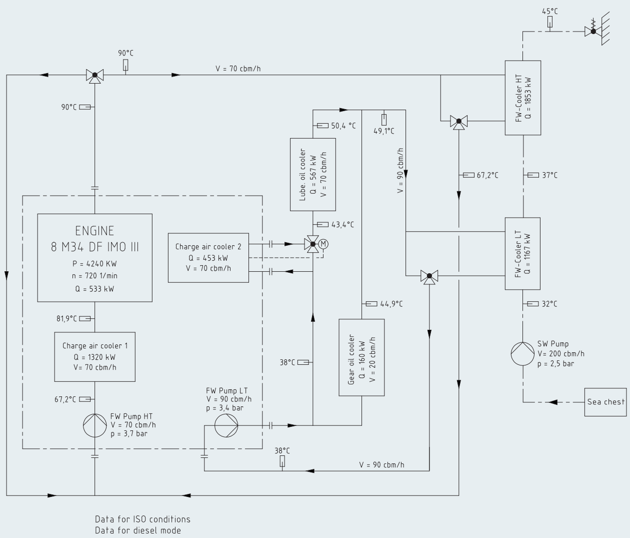


Fig. 8-9 Heat balance, system diagram 8 M 34 DF – 4,240 kW

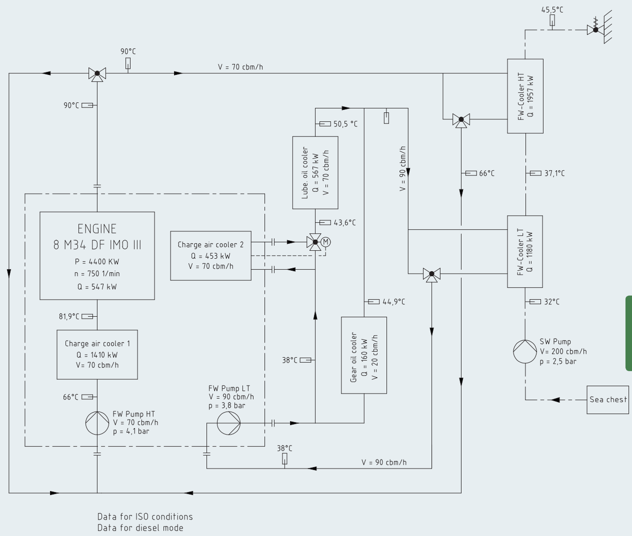


Fig. 8-10 Heat balance, system diagram 8 M 34 DF – 4,400 kW

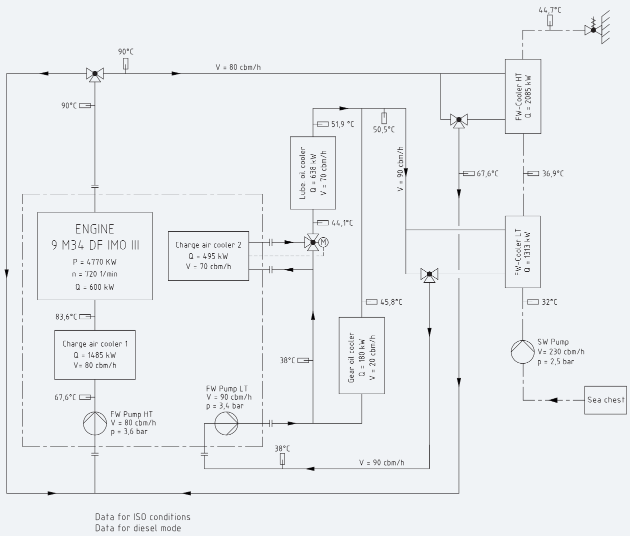


Fig. 8-11 Heat balance, system diagram 8 M 34 DF – 4,770 kW

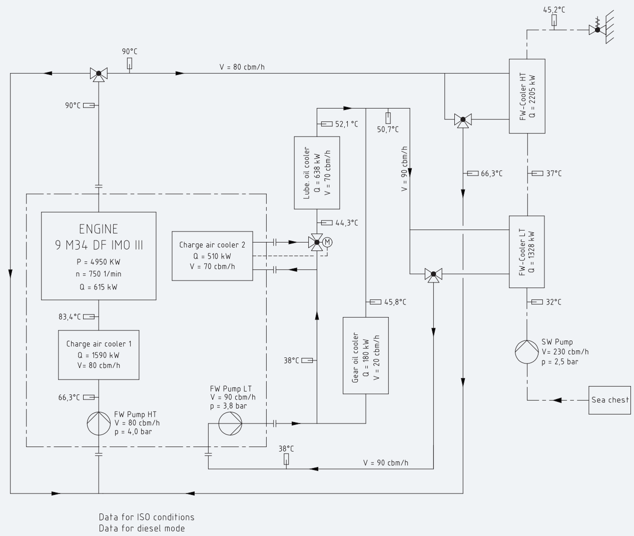


Fig. 8-12 Heat balance, system diagram 8 M 34 DF – 4,950 kW

- 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.

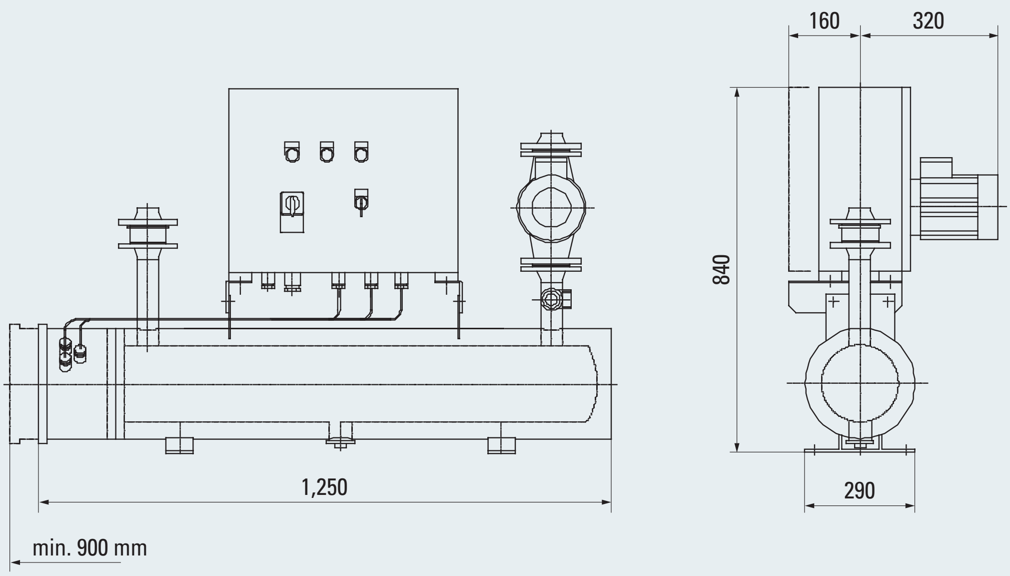
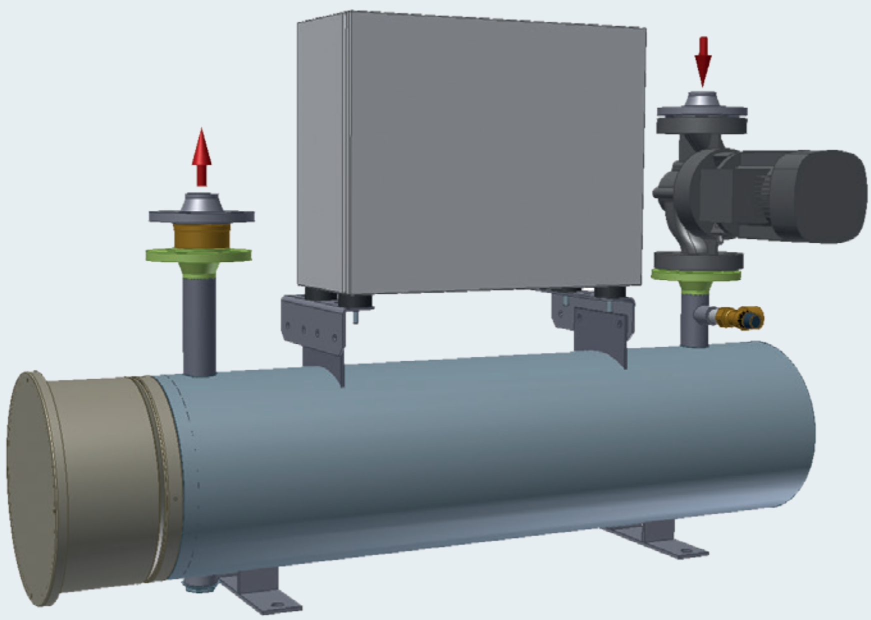


Fig. 8-13 Freshwater preheater FH5, preheating pump FP7



8.4.1 Other preheating systems

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

8.4.2 Box coolers system

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

8.4.3 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

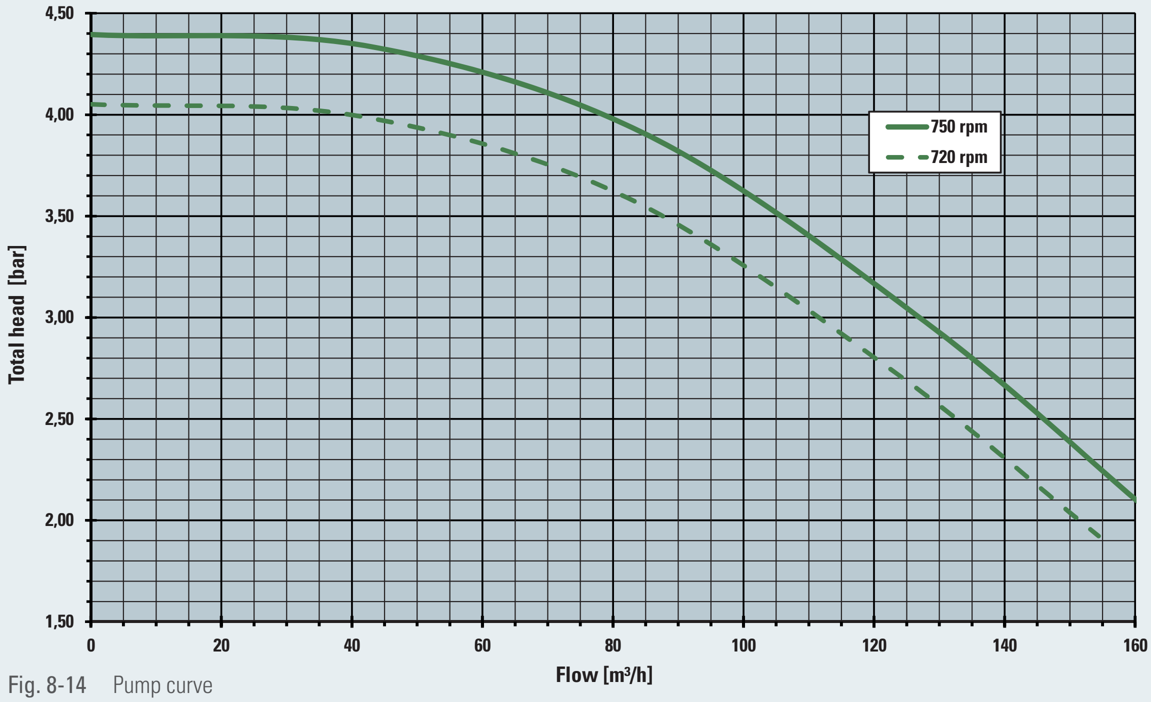


Fig. 8-14 Pump curve

9.1 General

The engine starting system consists of air starting motor(s) attached to the side of the engine.

The external 30 bar compressed air system is providing compressed air to the engine air starting motor(s) and via pressure reducer sufficient control air for safety and control devices, with one external compressed air supply connection only (engine connecting point C86).

Prior to each engine start compressed air engages a slow turn mode first. After two full revolutions the starting process is fully activated and drives the flywheel to the required cranking speed.

The compressed air system consists of at least two compressors, two air receivers and its accessories such as filter(s), dryer(s), regulating and control valve(s) and 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.

At least two equally sized starting air compressors and starting air receivers are to be provided.
Both starting air compressors shall refill the volume of both starting air receivers in less than one hour to 30 barg. Classification requirements might differ and need to be considered in case of multiple engine plants.

The compressed air system must be free of solid particles, water and oil. The entire external compressed air system must be slightly inclined and equipped with draining at lowest points.

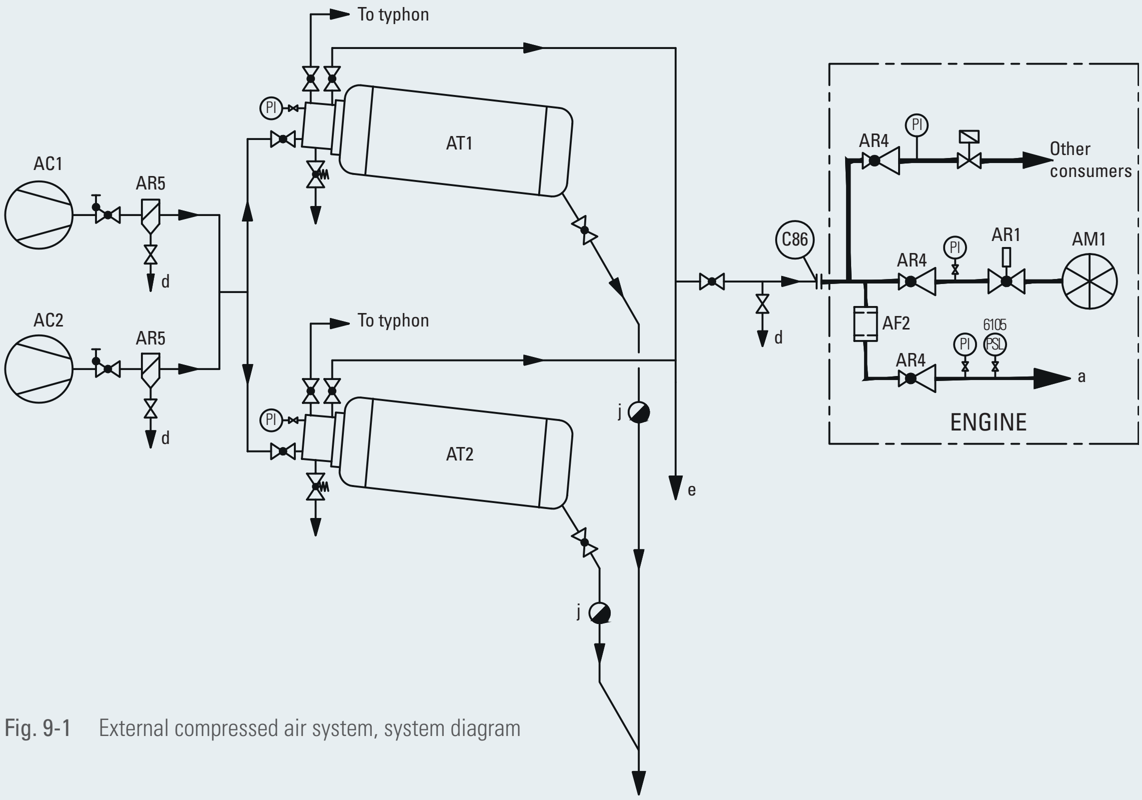


Fig. 9-1 External compressed air system, system diagram

AC1	Compressor	a	Engine shutdown
AC2	Compressor	d	Water drain (to be mounted at the lowest point)
AF2	Control air filter	e	To engine no. 2
AM1	Air starting motor	j	Automatic drain required
AR1	Starting valve		
AR4	Pressure reducing valve		
AR5	Oil and water separator	AT1/AT2 Option:	
AT1	Starting air receiver		- Typhon valve
AT2	Starting air receiver		
PI	Pressure indicator		
PSL	Pressure switch low, only for main engine		
C86	Connection / starting air		

9.2 Starting air compressor (AC1 + AC2)

According to the requirements of the Marine Classification Society there should be minimum two starting air compressors with 50% of total capacity.
The total capacity has to be sufficient for refilling the starting air receivers from empty conditions to 30 bar within one hour.
A modular starting air skid incl. compressor(s), receiver(s), dryer(s), control panel(s) can be provided.

9.3 Starting 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 needs to be considered in case of multiple engine plants.
It is required to install the receivers in a way, so that it can always be sufficiently drained manually or automatically at the deepest point of the receivers.

Horizontal and vertical receiver design is available.
Horizontally installed air receivers should have an inclination of 5° towards drain valve.

Recommended air receiver sizing for starting and slow turn consumption:

$V = (V_2 \cdot n + ST/P_{max} - P_{min})$

V = Air receiver volume [m³]
V_2 = Air consumption per start [Nm³]
n = Required number of starting procedures in sequence (acc. to classification societies and to consider multiple engine plants applications)
P_{max} = Maximum receiver pressure (30 bar)
P_{min} = Minimum receiver pressure (15 bar)
ST = Slow Turn [Nm³]

9.4 Compressed air quality

To ensure always the functionality of the compressed air system, it has to be free of solid particles, condensed water and oil.

9.5 Slow turn

On large engines an accumulation of water in the combustion chamber cannot be avoided due to a failure or carelessness during maintenance work after engine standstill for a long time. Water in the combustion chamber would cause a severe damage when the engine is started. The Purge function, known from diesel engines, to purge the cylinders with compressed air is not available on Dual Fuel egnines. Instead the Slow Turn function is used to detect water in the combustion chamber. Therefore the Slow Turn function is mandatory for Dual Fuel engines.

	6 M 34 DF	8 M 34 DF	9 M 34 DF
Compressed air consumption per slow turn manoeuvre [Nm^3]	6.0	7.0	7.5

9.6 Additional consumers

The starting air receiver capacity does not include the compressed air demand for other consumers as SCR system, working air, other control air, etc.

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 3, 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

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.

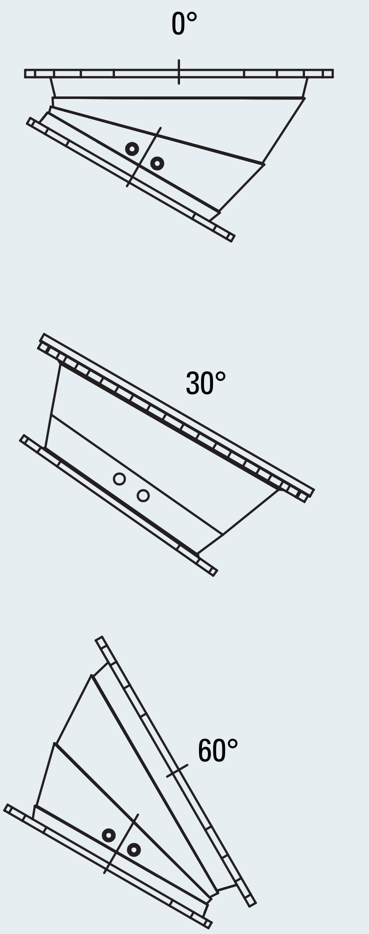


Fig. 11-1 6 M 34 DF nozzle orientation

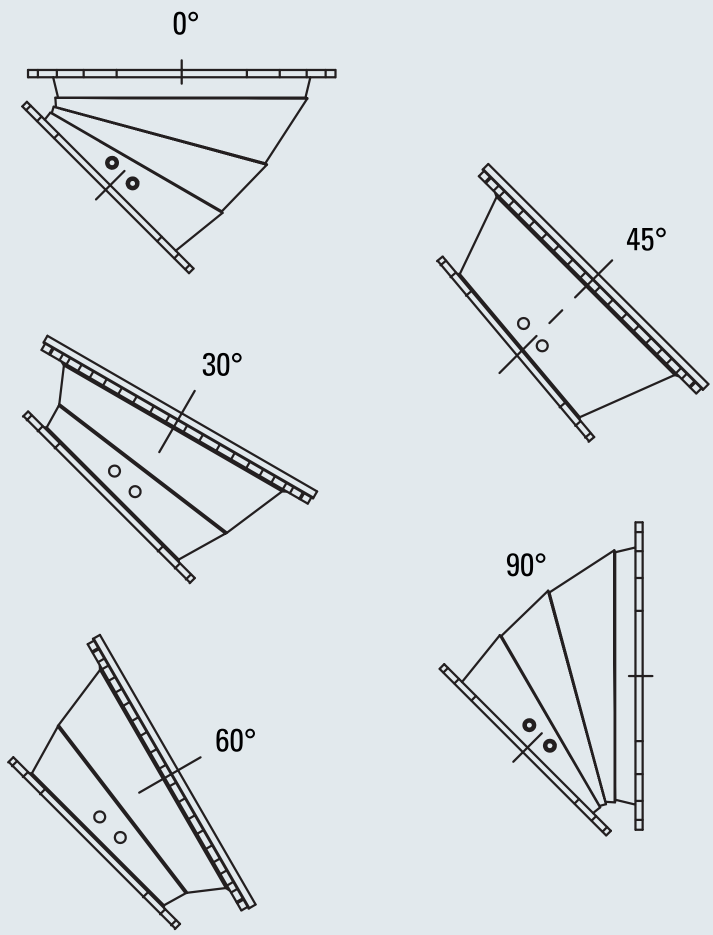


Fig. 11-2 8/9 M 34 DF nozzle orientation

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.

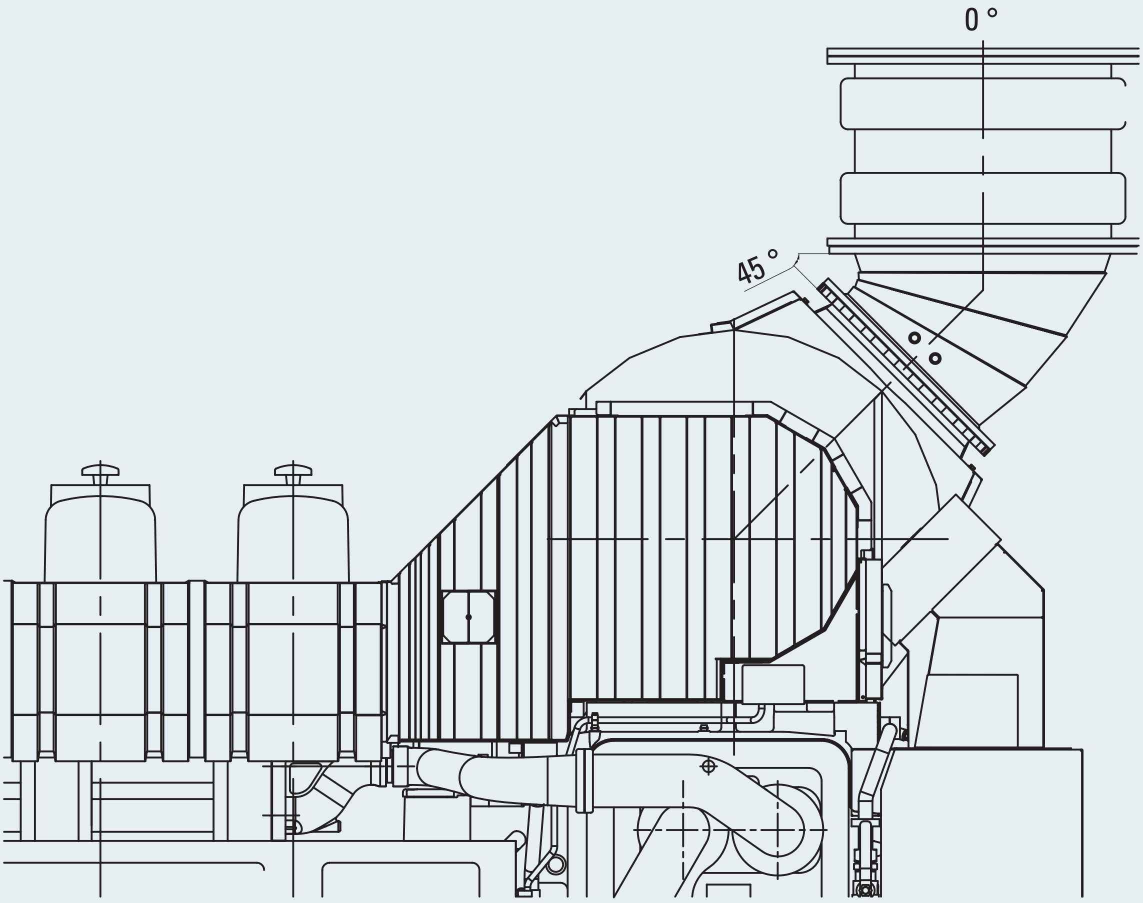


Fig. 11-3 Exhaust gas compensator

Basic design values of the standard exhaust gas compensators.

Type	Diameter	Length	Weight
	[mm]	[mm]	[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

TTo minimize the forces acting through the compensator to the turbo charger 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 so a common exhaust gas piping system of two or more engines is not allowed, other wise exhaust gases from engines under operation be forced into cold engines not operating and causes engine damages as a result of condensed water from the exhaust gas.
Also the exhaust gas pipes and/or silencers should be equipped with water separating pockets and a drainage.
In order to minimize the pressure loss of the complete exhaust gas system it is recommended to use a suitable pipe diameter for the exhaust gas line. According the dimensions of the compensators there are standard diameters proposed for the respective engine type in relation to the exhaust gas mass flow.
In case there are a lot of bends and other components integrated in the exhaust gas system it might be necessary to increase the pipe diameter. For guidance the exhaust gas flow velocity should be less than 40 m/s.
For flushing the exhaust gas piping system after engine operation in gas mode an installation of a forced ventilation system is required.
According class requirements explosion relief valves for single main engines and for multi engine installations at least burst discs for explosion release device must be installed in the exhaust gas system.
For each individual installation the number and size of these devices will be determined by a simulation.

11.1.4 Silencer

The exhaust noise emission of the engine must be reduced by an integration of at least one suitable silencer in the exhaust gas system to fulfil either the specifications of the relating classification company or legal regulations according noise emissions or just to meet the clients comfort demand at open deck.

Standard silencers which are especially designed for each engine type are available. As the silencers are of the absorptive type the flow resistance is low so just a back pressure of approximately 100 mm WC will arise. Long fibre absorbing heat resistant material is used for the noise absorption.

The noise attenuation of the standard silencers reaches at least 35 dB(A) and covers a wide frequency range. If necessary, also silencers with a higher attenuation can be offered.

As standard the silencer can be provided either with or without a spark arrestor which will be provided with a soot collecting chamber. Each silencer is equipped with a water drain to draw out the condense water. The silencer will be delivered with counter flanges, screws and gaskets. The mounting brackets for either horizontal or vertical installation as the insulation are not included. Optional the silencers can be delivered with loose or welded on mounting brackets according client's requirements.

Special attention must be paid in the positioning of the silencer in the exhaust gas system to avoid resonance effects in the piping system. A wrong positioning of the silencer in the system can cause high noise levels before or after the silencer and can lead to extreme noise at the funnel end.

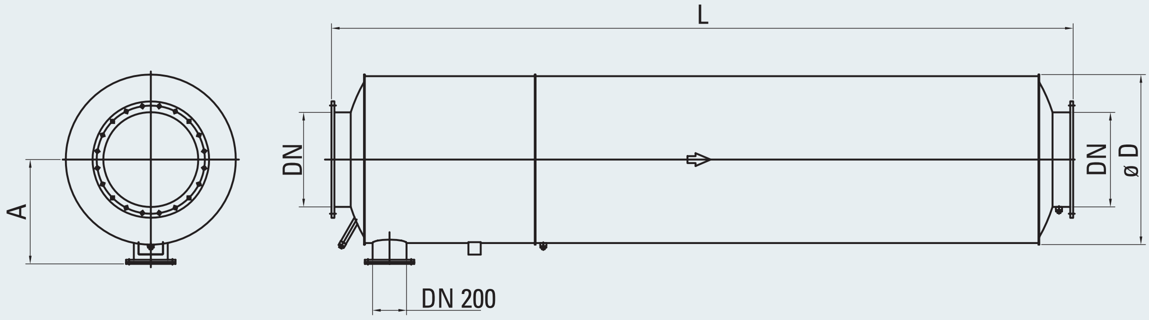


Fig. 11-4 Spark arrestor and silencer

Type	Dimensions [mm]				Weight	Weight with spark arrestor
	DN	A	D	L	[kg]	[kg]
6 M 34 DF	600	700	1,200	5,000	1,400	1,450
8 M 34 DF	700	825	1,400	5,500	1,950	2,000
9 M 34 DF	800	875	1,500	5,500	2,350	2,400

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.

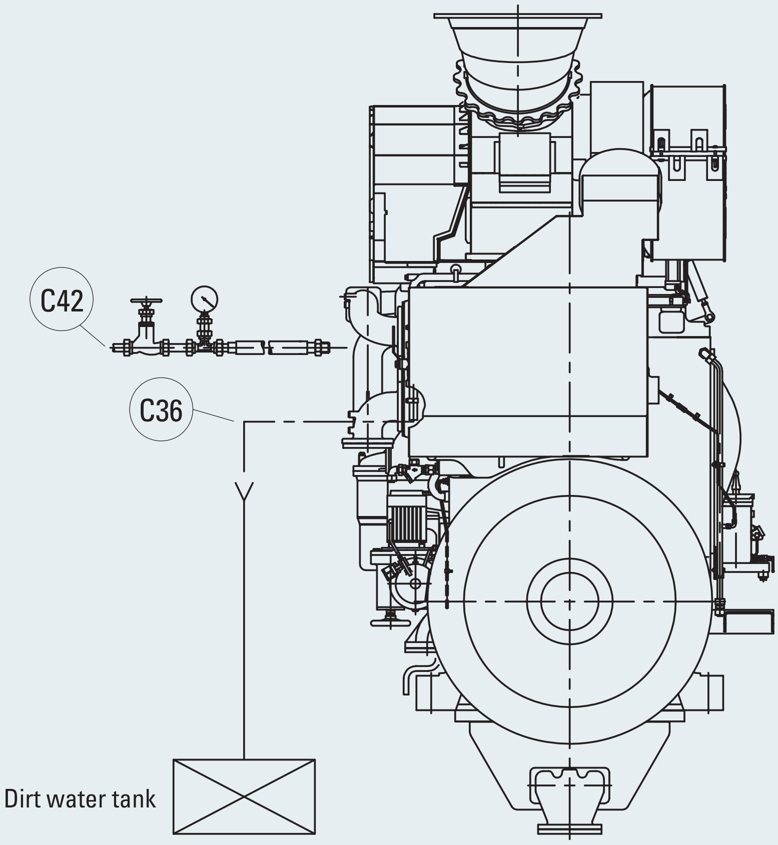


Fig. 11-5 Connection points fresh water and drain

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.

11.3 SCR System / IMO III kit

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

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

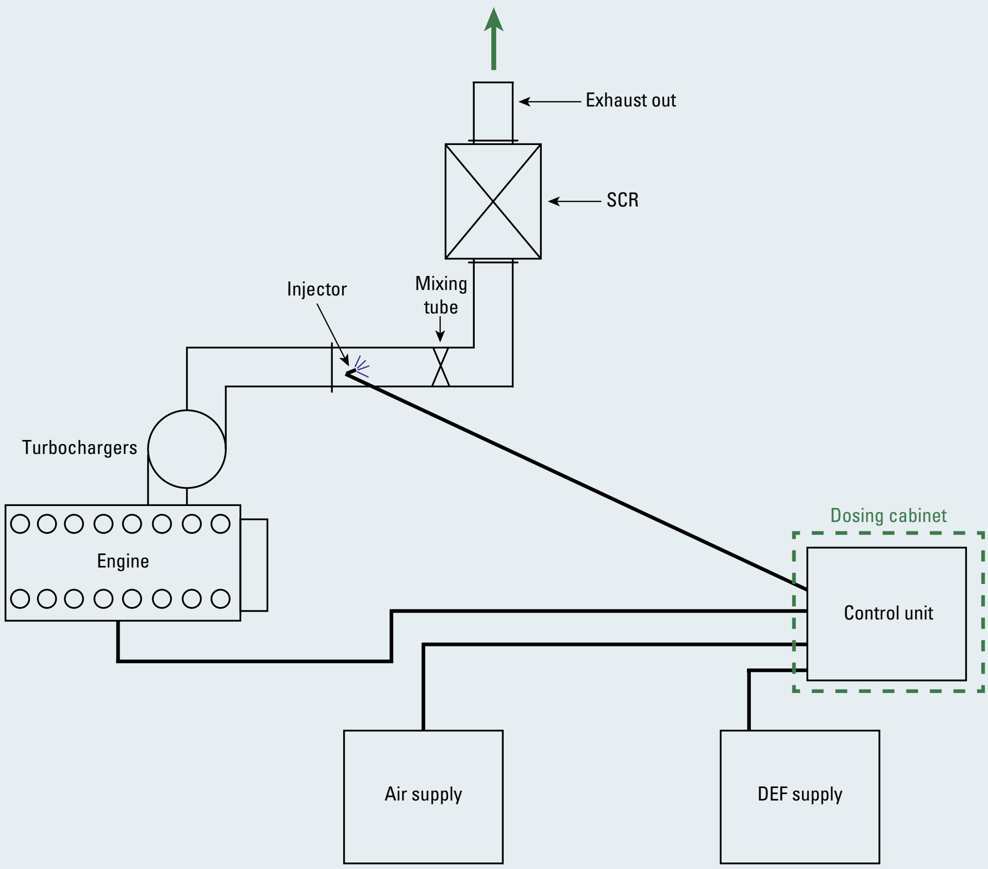


Fig. 11-6 Typical SCR system diagram – MDO

Additional equipment is required for HFO operation.
Please contact Caterpillar Motoren for more information.

SCR System scope of supply:

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

Not included in standard scope of supply:

- DEF storage tank
- Urea piping
- Exhaust piping
- Insulation

11.3.1 Portfolio, size and dimensions

The SCR System is available for all MaK diesel and dual fuel engines. Technical information about size, weight and interfaces will be given within the technical specification as part of the quotation

Installation of SCR System

The SCR housing design is for vertical or horizontal installation.

Fuel consumption with SCR aftertreatment:

The SCR housing and the substrate cassettes of the IMO Tier III SCR aftertreatment systems are optimized to be used in combination with the M 34 DF engines and their emission behavior. However, the aftertreatment system generates higher exhaust gas back pressure which results in increased fuel consumption (only in diesel mode, not in gas mode), no matter if the engine is operating in IMO Tier II or IMO Tier III mode. Specific fuel consumption has to be recalculated by + 0.3 g/kWh per 10 mbar higher exhaust back pressure.

Nitrogen oxide emissions (NO_X-values) with SCR aftertreatment

NO_X-limit values according to IMO III: 2.40 g/kWh (n = 750 rpm)

Technical data with SCR aftertreatment:

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

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

11.3.2 Installation requirements

Caterpillar's SCR is packaged in modules that contain the components necessary to support the specific engine configuration for emissions compliance. The installation will require connections between SCR module, engine, DEF storage tank and pressurized air source. These connections will include engine exhaust piping, electrical harness, air and urea lines and won't be part of delivery. For detailed information get in contact with Caterpillar Motoren GmbH & Co. KG.

11.3.3 Requirements for material selection of urea tank and piping

Material compatibilities must be considered for the urea solution storage and delivery due to caustic corrosive nature.

Required materials:
- DEF pipe/tank material: Austenitic stainless steel (EN 1.4571 – AISI 316 Ti or similar)
- Mixing tube and SCR housing material: EN 1.4512 – AISI 409SST or similar

Materials to avoid:
- Unalloyed steel
- Aluminium
- Brass
- Galvanized steel
- Copper

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

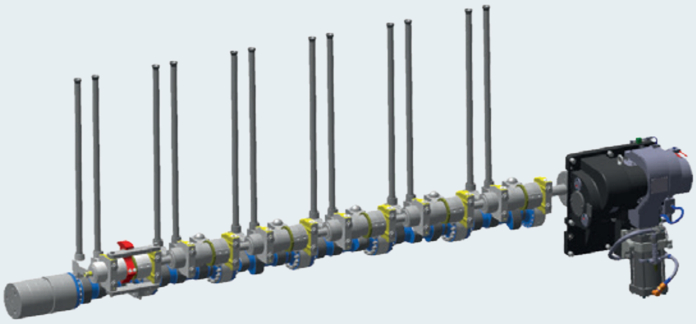


Fig. 12-1 Valve train with Flexible Camshaft Technology

Fig. 12-2 Flexible Camshaft Technology mounted at the engine

All pictures shown are for illustration purpose only. Actual product may vary due to product enhancement.

13.1 Components

Modular Alarm and Control System (MACS)

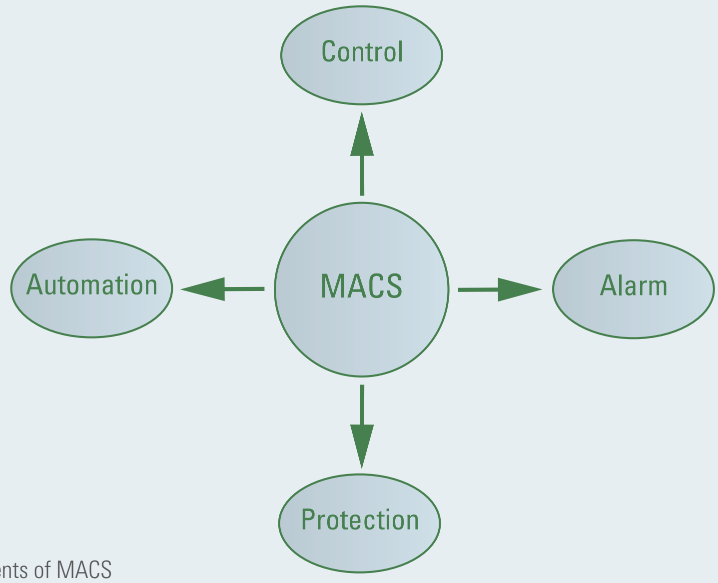


Fig. 13-1 Components of MACS

The M 34 DF engines will be provided with a Modular Alarm and Control System, called MACS.
The engine control and monitoring system will be installed on the engine and in an off-engine control panel. Where needed, optional devices can be installed in the control panel (see 13.5.2 Options).

MACS consists of the following software functions:

- Start Stop Function
- Engine Diesel and Gas Automation
- Monitoring and Alarm System
- Protection System
- Engine Control and Load Sharing

Start Stop Function

This module provides start and stop sequence function enabling the operator to start and stop the engine. The engine can be started and stopped from the local MACS control panel as well as from external systems as the PMS or Cat remote panels. This function includes automatic start repetition, blackout start, local electrical emergency start, false start detection, repair mode and of course starting interlock processing.

Engine Diesel and Gas Automation

MACS provides additional automation functions located in the PLC. It includes complete gas/diesel changeover control incl. emergency changeover to diesel, slow turn and charge air preheating activation. Additionally gas relevant modules, e.g. GVU, ignition fuel module, double wall and exhaust gas ventilation modules are controlled and monitored by MACS.

Monitoring and Alarm System

The Modular Alarm and Control System MACS provides a monitoring and alarm system located in the DCU and PLC. Measurement values are monitored for critical thresholds.
States and measurement values of most subsystems are also displayed on the local and remote displays. Monitoring of prelubrication, FCT, crankcase oil mist concentration, main bearing and conrod big end bearing are included. Also gas related modules are monitored, e.g. GVU, double wall ventilation module, exhaust gas ventilation module. The alarm and monitoring system covers the complete engine including gas leakage monitoring for gas pipes on the engine, inert gas and gas pressure monitoring as well as conditions for gas operation and gas mode. The DCU includes a complete alarm management providing alarm list, alarm history and acknowledgement. The alarms are logged in the DCU and will be displayed on the local and the remote panel. All status, measurement and alarm data are transmitted via Modbus TCP (Modbus RTU optional) to external systems like the ships alarm system IAMCS.

Protection System

The Modular Alarm and Control System contains a safety system to protect the engine against severe damages. The protection system is a dedicated unit herein called PLC Safety (EPS).
The protection system has dedicated sensors and control outputs to stop the engine and to stop the gas supply to the engine. Therefore it's acting independently from control, monitoring and alarm system.
All EPS switch inputs provide wire break detection. The output for actuating the safety stop valve is also monitored for wire break.
The EPS provides local LED indications providing a basic and independent indication to the operator. Besides the shutdown status, overspeed event, speed pickup status and communication status with the DCU are indicated.
Any failure and event at the EPS is transmitted via serial interface to the DCU and shown in the alarm list.

Engine Control and Load Sharing

The engine control module (ECM) is provided to control all essential engine parameters as there are
- engine speed
- engine load
- air fuel ratio (AFR) incl. control of WG/CBV/BOV

In addition a complete load sharing system is integrated. It provides droop mode and optionally isochronous mode with Master/Slave control supporting up to 16 load groups. It provides droop mode and optionally isochronous mode for multi engine propulsion on common gearbox.

Sensors and actuators that are necessary for engine control are hardwired to the ECM. Additional sensors for monitoring purposes are also connected to the ECM or other I/O modules (PLC, RTD, TC, DCU) and are transmitted on CANbus.

Engine speed and power are controlled by a closer loop (PI) controller. The desired engine speed is determined based on a combination of switches and analogue inputs, determined by the ECM and MACS. The engine speed control uses three speed pickups on the camshaft and crankshaft. Three sensors are deemed necessary for redundancy and to determine the exact position for fuel injection. If at least one sensor has healthy data, the engine can continue to run on diesel. The main controlled outputs are the fuel rack actuator that controls the flow of liquid fuel to the cylinders and the gas inlet valves that control the gaseous fuel flow to the cylinders. The engine is equipped with Caterpillar's standard actuator in accordance with class requirement for twin or single engine mode. In single mode, a mechanical backup speed governor is included.

13.2 Local control panel (LCP)

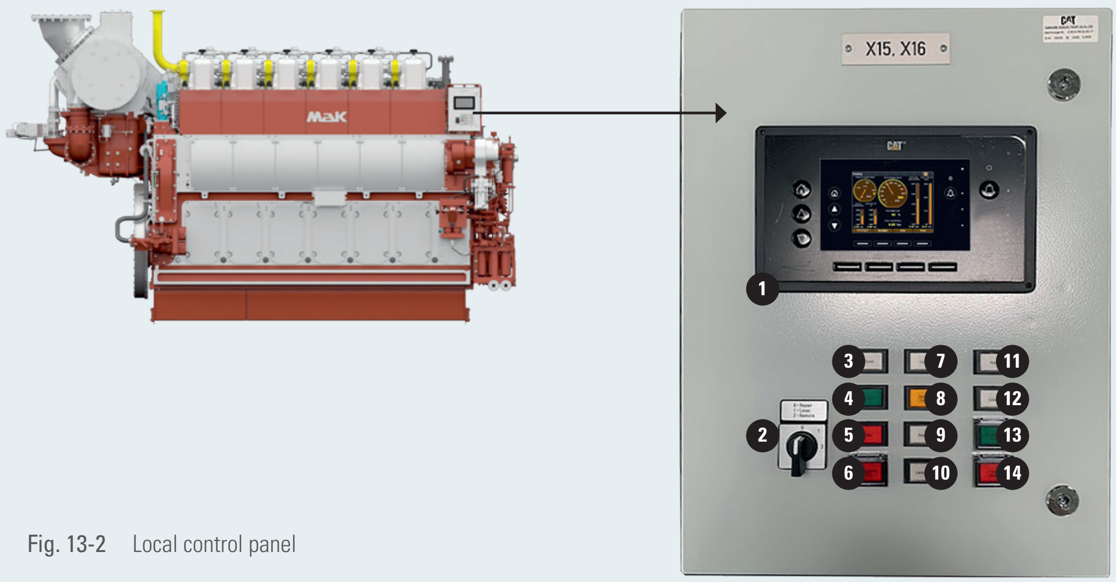


Fig. 13-2 Local control panel

1	DCU	8	Slow turn
2	0 = Repair, 1 = Local, 2 = Remote	9	Reset
3	Diesel mode indication	10	Lamp test
4	Start	11	Raise speed
5	Stop	12	Lower speed
6	Emergency stop	13	Emergency start
7	Gas mode indication	14	Gas shut-off

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13.3 Remote engine control

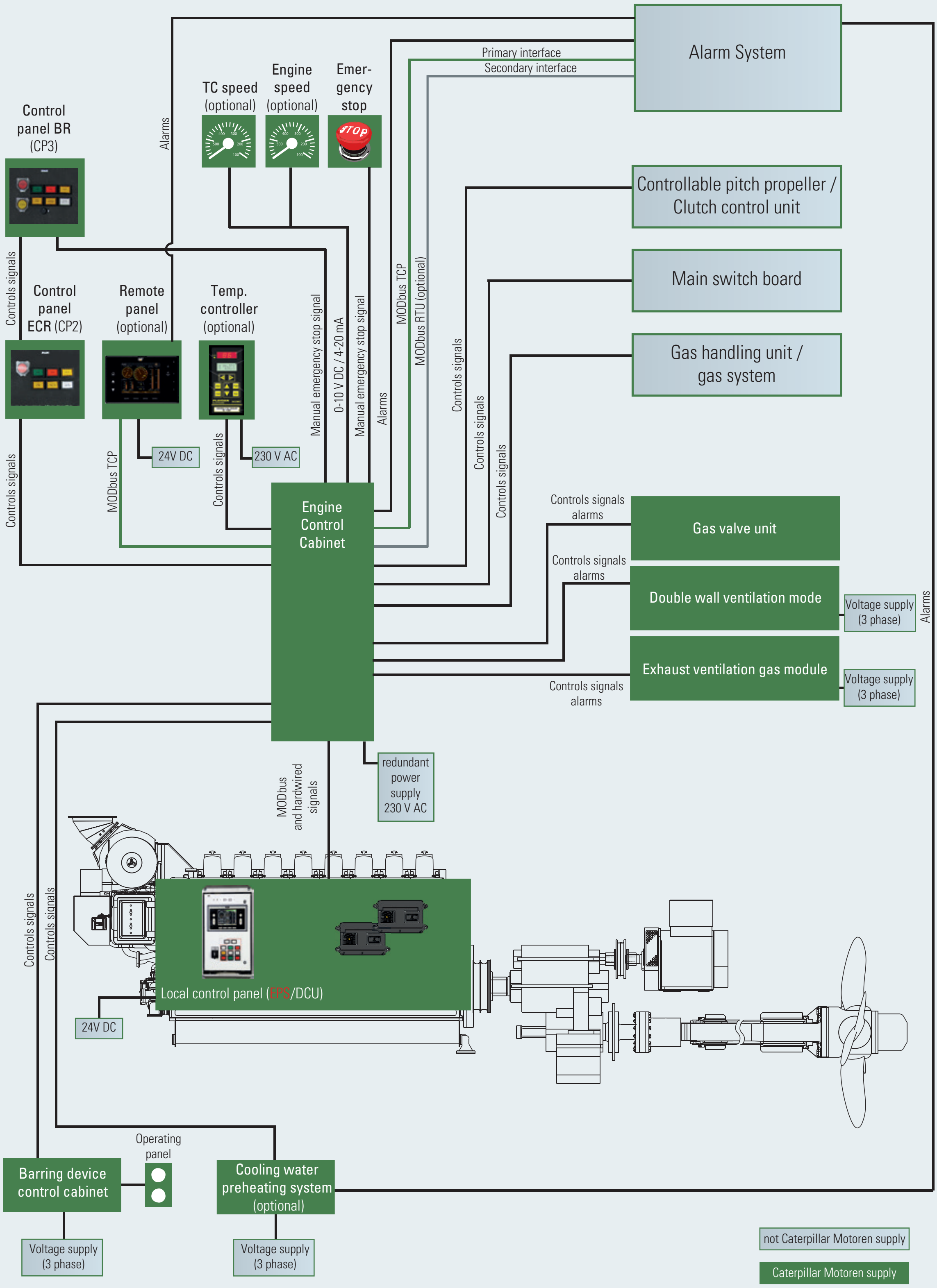


Fig. 13-3 Remote control for single-engine plant with one controllable pitch propeller

13.4 Data link overview

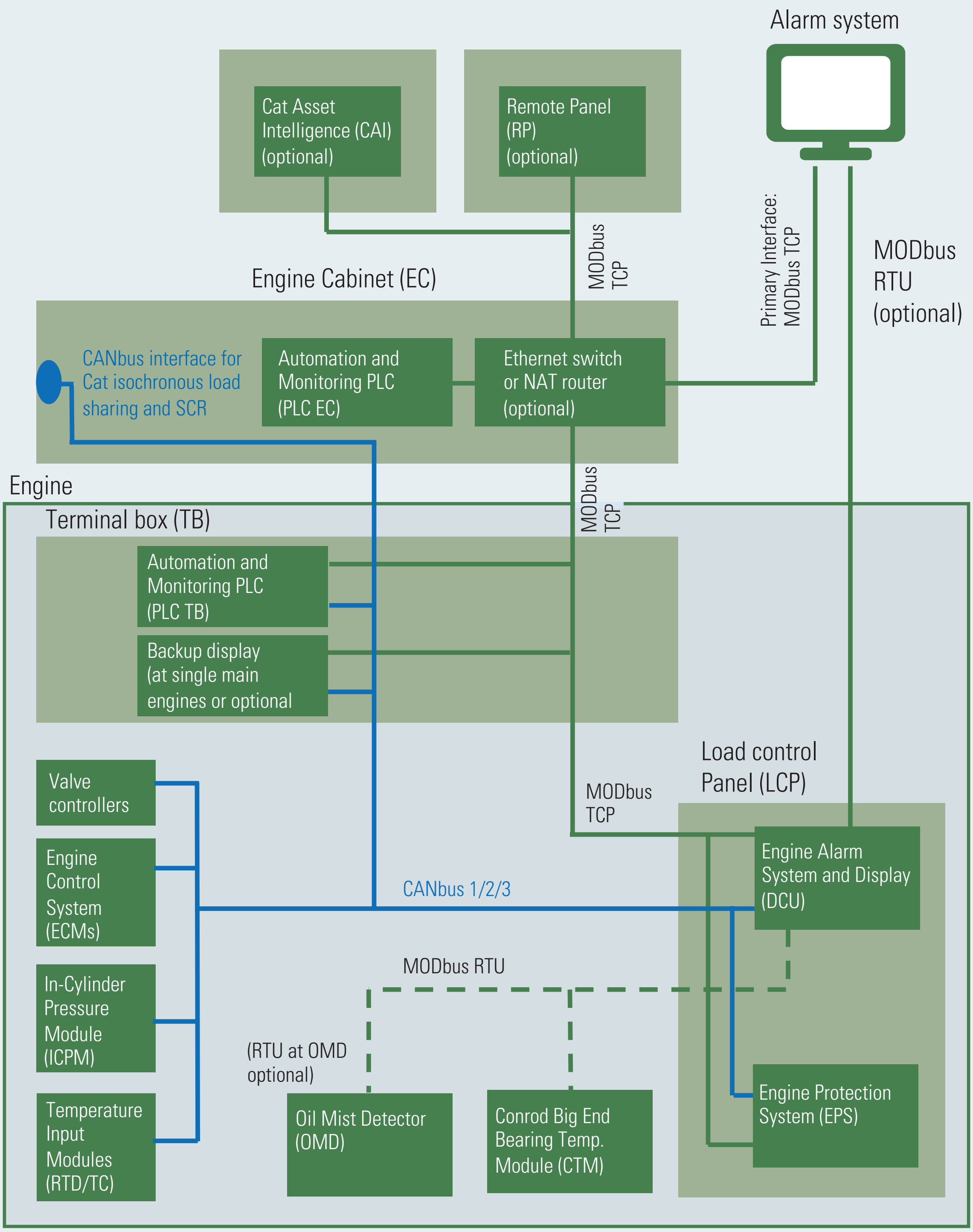


Fig. 13-4 Data link overview - M 34 DF

MACS

Modular Alarm Control System

Backup Display
Backup indication of sensor values at single main engines
EPS
Independent engine protection system in local control panel
DCU
Display and alarm system in local control panel
PLC
Part of monitoring and automation system.
Consisting of PLC EC in engine cabinet and
PLC TB in engine terminal box.
Temperature sensor input modules (RTD/TC)
For PT100 and TC temperature measuring at engine
Remote panel (RP) – optional
Remote indication and alarm display
Engine control system (ECMs)
Sensor inputs and control of engine speed,
air injection, WG/CBV/BOV and load sharing
OMD
The oil mist detector measures oil mist concentration in crankcase
Load sharing system
Load sharing system for isochronous load sharing included in ECM (optional)
CTM
Each cylinder compartment is measured
Each conrod big end bearing is measured
ICPM
The "In-cylinder pressure module" computes combustion characteristics for each cylinder including knock intensity and pressure per cylinder
NAT router
optional to adapt engine IP address to customer network
CAI (optional)
Cat Asset Intelligence, remote monitoring analytics and service tool (please see chapter CAI)
SCR (optional)
Selective Catalytic Reduction System, dosing cabinet, mixing tube, transfer pump (optional), DEF storage tank (optional). For more information please see chapter 11.3.
Regardless of RTU or TCP, the MODbus address registers are the same. Just the hardware protocol differs.

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

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

MODbus RTU
The MODbus device address will be assigned.

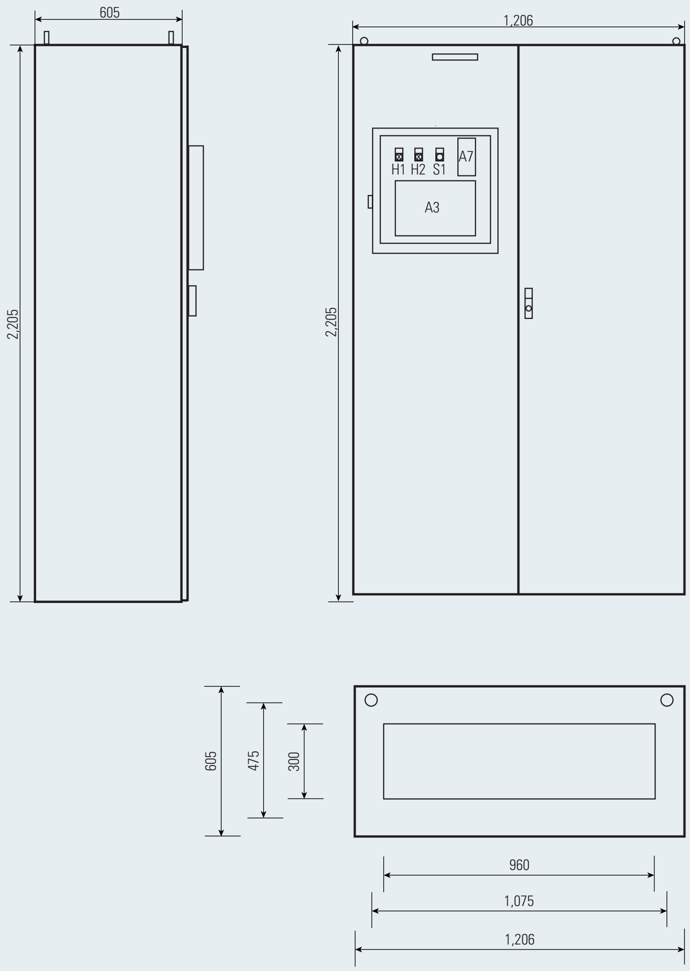
MODbus settings
Type: MODbus RTU
Baud rate: 19,200
Device address (ID): will be assigned
Interface: RS-485

Maximum length of ethernet and RS485 installation must be considered by yard.

13.5 Control cabinet

13.5.1 Descprition and dimensions

Each engine is equipped with a separate engine 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 are wire break monitored.
The remote panel or the temperature controller can be integrated in the control cabinet optionally.



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. 13-5 Control panel

13.5.2 Options

Option	
DC/DC converter	DC/DC converter optional for galvanic isolation of 24V power supply from yard, with insulation monitoring included in engine cabinet.
NAT router	NAT router for connection to ship interface. Included in engine cabinet (cabinet).
Power supply	24 V DC power adapter, optional included in engine cabinet (otherwise delivery by the yard)

13.6 Requirements

13.6.1 Requirements for the Remote Control System

Signals from and to remote control systems (e.g. controllable pitch propeller remote control system) are pre-adjusted as standard interface signals.
This means that binary signals must be potential-free, pulses require at least 1 second contact time and analog signals will be 4-20mA signals.
The following table shows typical standard signals. Signals deviating from these must be discussed in the project phase.

Gearbox	Lube oil pressure low (NO)	binary	→	24 V DC	Starting interlock for engine	Main engine
	Common load reduction (NO)	binary	→	24 V DC	Slow down for engine	
	Lube oil pressure low (NO)	binary	→	24 V DC	Shut down for engine	
Controllable pitch propeller	Actual engine speed		←	4-20 mA	Engine speed	
	Actual engine load		←	4-20 mA	Engine load [1]	
	M.E. in overload		←	binary	Used for overload indication	
	Request remote control	24 V DC	←	binary	Local/remote switch contact at engine	
	Accept remote control	binary	→	24 V DC	Remote control accepted	
	Local/remote control	24 V DC	←	binary	Closed contact when ME is in remote control	
	Reduce to 40% load [2]	24 V DC	←	binary	Slow down at engine	
	Pitch to zero / auto clutch out	24 V DC	←	binary	Shut down at engine	
	Engine in back up mode	24 V DC	←	binary	ECM ready / no back up mode	
	Gas combinator curve in use (only for different diesel/gas curves)	24 V DC	←	binary	Gas mode	
	Speed setting signal	4-20 mA	→	24 V DC	Speed setting signal for load share unit (ECM)	
	Clutch engaged or pitch not zero	binary	→	24 V DC	Starting interlock	

1) Clarify signal accuracy requirements during project execution.

2) If slow down occurs during gas operation, switching-over to Diesel operation will be propriated.

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	Indication diesel and gas mode	24 V DC	←	binary	Engine cabinet
	Activate gas supply to gas valve unit	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 and gas mode select	binary	→	24 V DC	
	Inert gas supply pressure	4-20 mA	→	Analogue output	

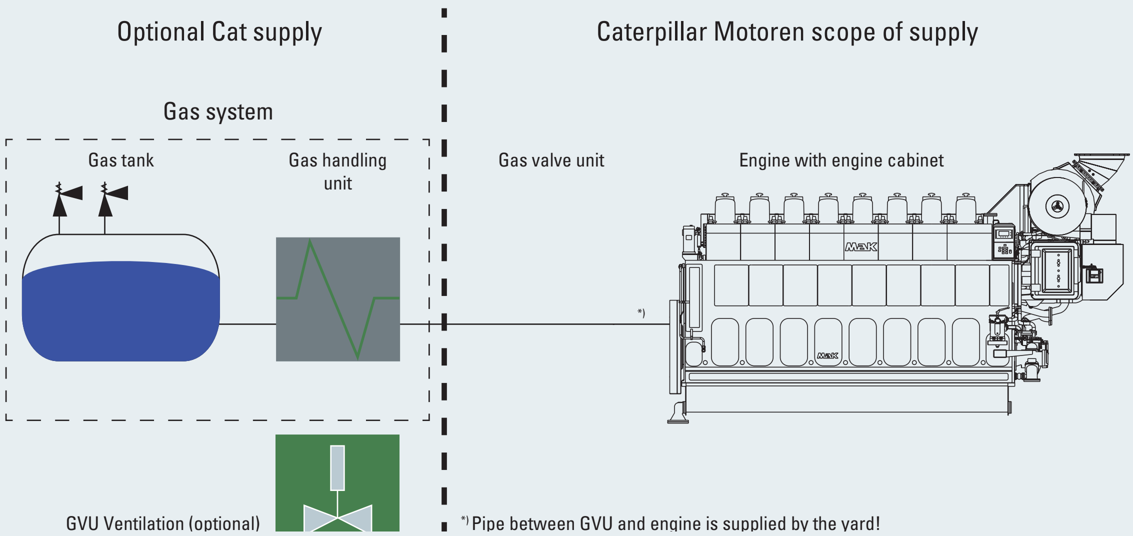


Fig. 13-6 Basic overview: dual fuel engine gas system

13.7 Uninterruptable power supply (UPS)

An uninterruptible power supply (UPS) with a back-up power supply is required for the control and monitoring system (class requirement). The voltage supply for the motor control cabinet (MACS) is 230V AC as standard, optionally 24V DC.
The following external supply voltages are possible for the UPS: 230V AC or AC three-phase.
The engine control cabinet has an integrated 24V DC voltage distribution for the engine control and monitoring systems (see fig. 11-8). DC/DC converter and its insolation monitoring device is optionally.

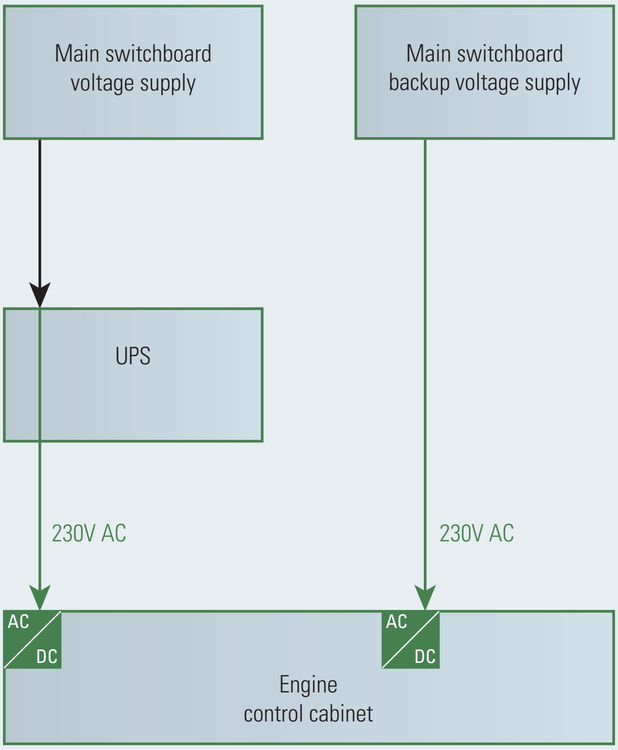


Fig. 13-7 Example uninterruptable power supply

13.8 Alarm indication

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

The DCU receives measurement values and data from all I/O modules, PLC and the engine control system (ECM). Furthermore it provides all measurement values, status values and alarms via MODbus TCP (MODbus RTU optional) for the vessels system, Cat remote panels and Cat Asset Intelligence (CAI). The engines alarm system determines critical engine conditions and activates alarms. The DCU has the ability to trigger shutdown events and to shut down the engine independent from the engine safety system. All alarms are stored in an alarm history and are shown in a manner requested by the Marine Class Societies.

Fig. 13-8 Remote panel

Fig. 13-9 DCU (display and alarm system)

For the interface to ship alarm and/or power management system the following functions are applicable:

- Transmitting measurement data to ship alarm and/or power management system
- Transmitting engine status to ship alarm and/or power management system
- Transmitting alarms to ship alarm and/or power management system
- Receiving ships time stamp from ship alarm and/or power management system

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

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

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

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

	IND/ FUNC	STBL	Alarm	RED	SHD	GMI	SHOGE	SHOGM
Lube oil	X	X	X	X	X			
Oil mist detector	X		X		X			
Fresh water HT	X		X	X	X			
Fresh water LT	X		X					
Air supply	X	X	X					
Charge air	X		X				X	
FCT	X		X		X		X	
Electrical status	X	X	X					
Engine status	X	X	X		X			
Combustion monitoring	X		X		X	X	X	
Exhaust gas	X		X	X			X	
Big end bearing	X		X		X			
Main bearing	X		X		X			
ECM	X		X				X	
Inert gas system	X					X	X	X
Ignition fuel system engine	X	X	X		X	X	X	
Fuel gas system engine	X						X	
Fuel gas leakage monitoring	X		X				X	
Diesel gas mode control signals	X		X			X	X	X
Gas valve unit	X		X			X	X	X
Ignition fuel module	X	X	X				X	
Exhaust gas module	X	X			X	X	X	
Slow turn	X	X						
Ventilation modules	X							

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

NOTE:
An active gas operation shut off (SHOGE/SHOGM) will activate gas mode interlock (GMI) and an engine shutdown will adtivate a starting interlock (STBL) as well as a gas shut off for the engine (SHOGE). A load reduction GMI will trigger a SHOGE.

FUNC	Used in software function
IND	Only for indication
A	Alarm
STBL	Starting interlock (overrideable by E-start of blackout start)
E-STBL	Emergency starting interlock (not overrideable by E-start or blackout start)
CHG	Change generator set
SHD	Shutdown
GMI	Gas mode interlock
SHOGE	Gas shut off for engine / Shut off gas supply to engine. The double block and bleed group in the gas valve unit (GVU) is closed.
SHOGM	Gas shut off for engine and machinery space. The master gas valve has to be closed.

13.9 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 external (e. g. vessel) alarm system

13.10 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.

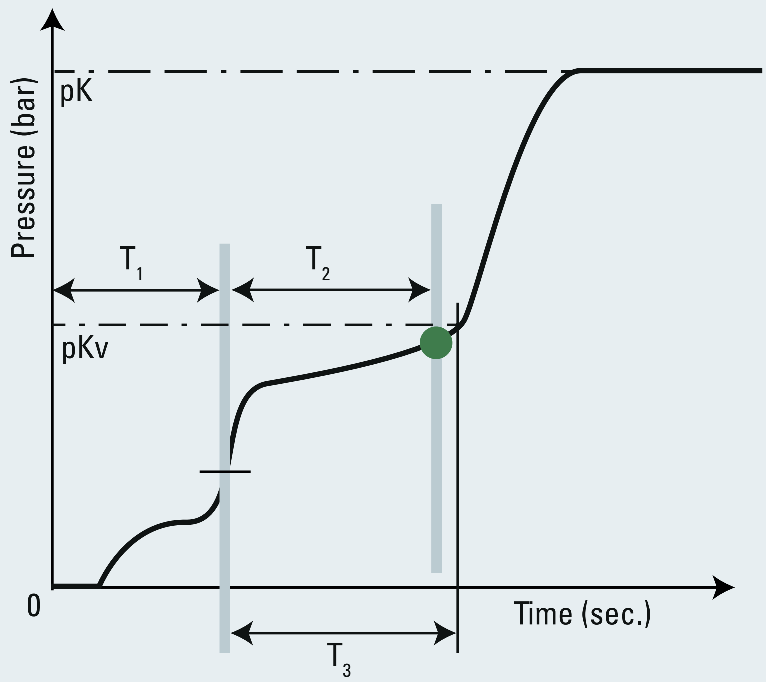


Fig. 13-10 Clutch in procedure for propulsion systems

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.

13.11 Safety

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

"Mode" specifies the desired engine operation.

"Operation" specifies the actually burned fuel.

Fig. 13-11 Definition: "Mode" vs. "Operation"

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.

Sensors installed in hazardous zone 2 at engine are selected according to fulfill requirements by IGF-Code (International Code of Safety for Ship Using Gases or Other Low-flashpoint Fuels). This Code represents an international standard for ships using low flashpoint fuel. It provides mandatory requirements for the location, installation, control and monitoring of machinery, equipment and systems using low flashpoint fuel. The aim is to minimise the risk to the ship, its crew and the environment, taking into account the nature of the fuels concerned.

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.

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

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.

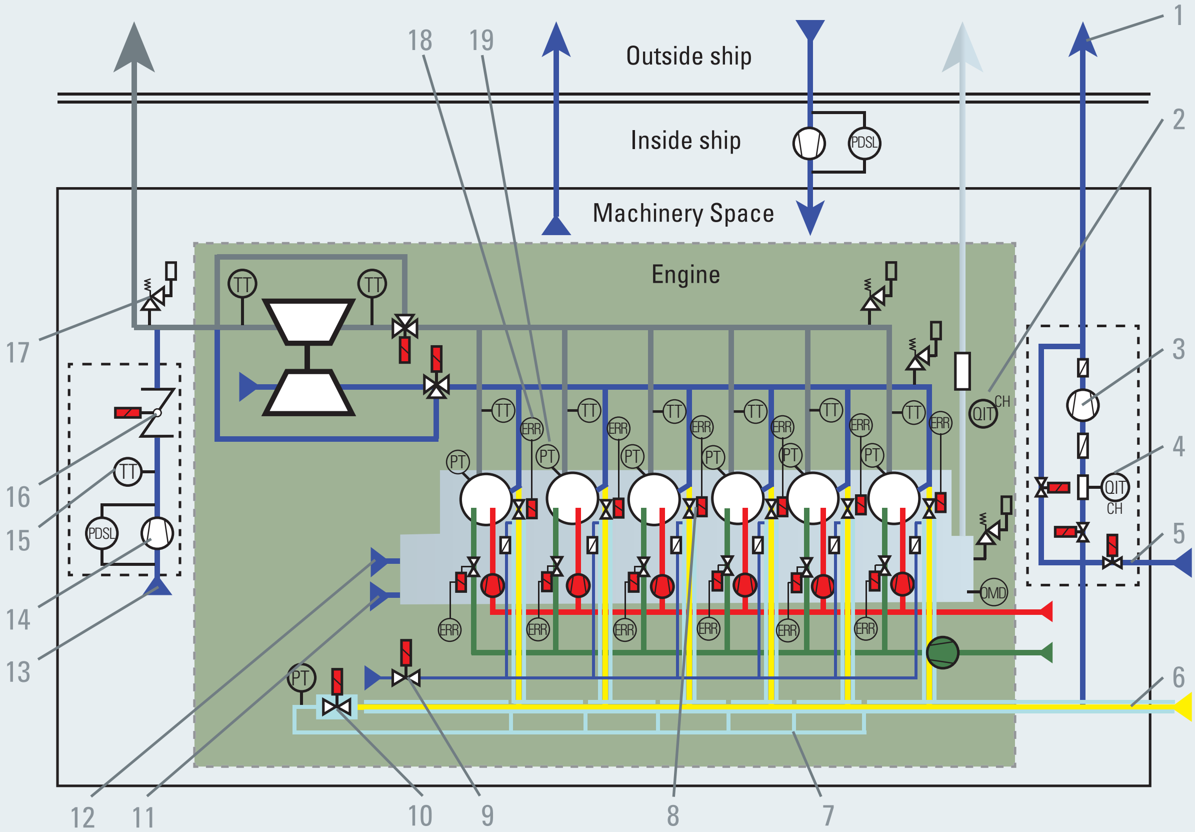


Fig. 13-12 Gas related safety equipment

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

PT = pressure transmitter
ERR = device fault monitoring
TT = temperature transmitter
QIT = gas sensor
PDSL = differential pressure switch low

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

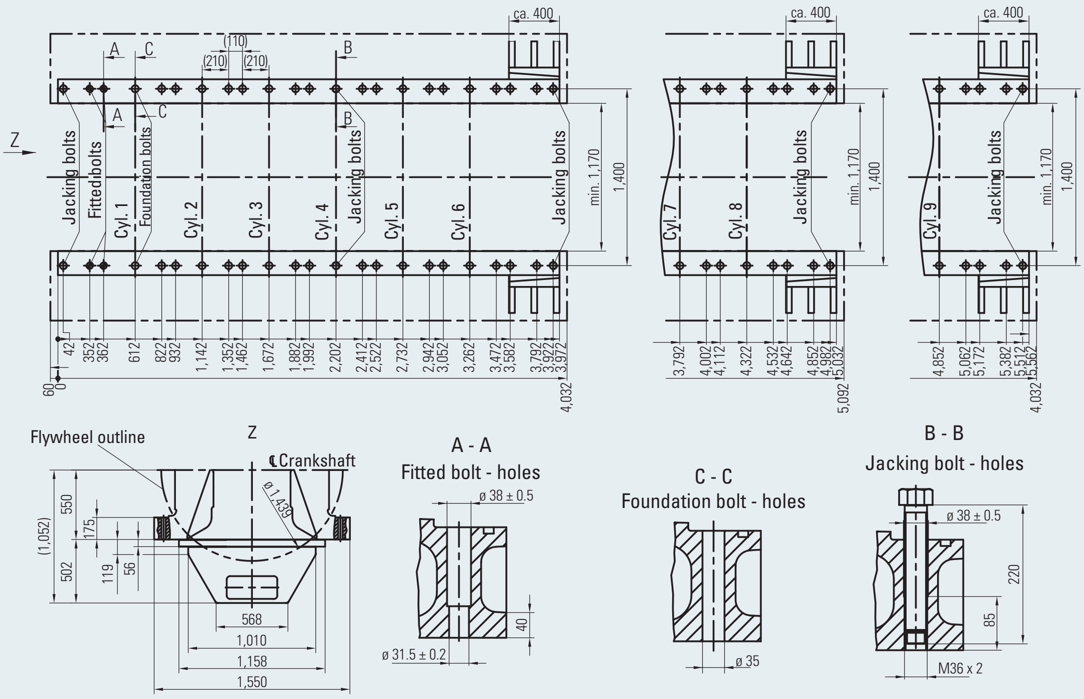


Fig. 14-1 Dimension of foundation dry sump pan

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.

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

Proposal for rigid mounting

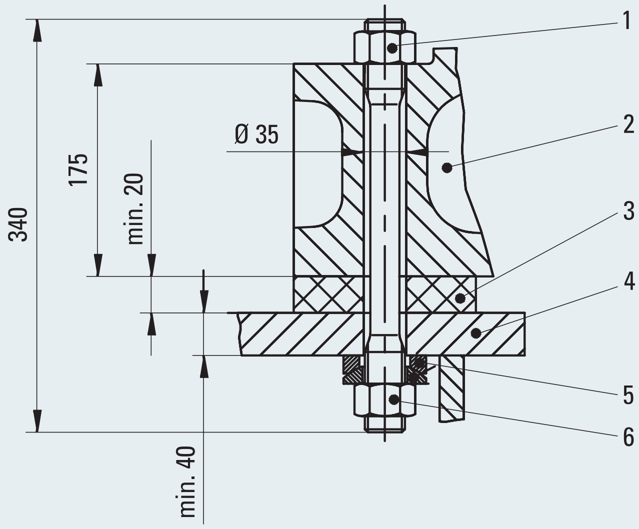


Fig. 14-2 Through bolt

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

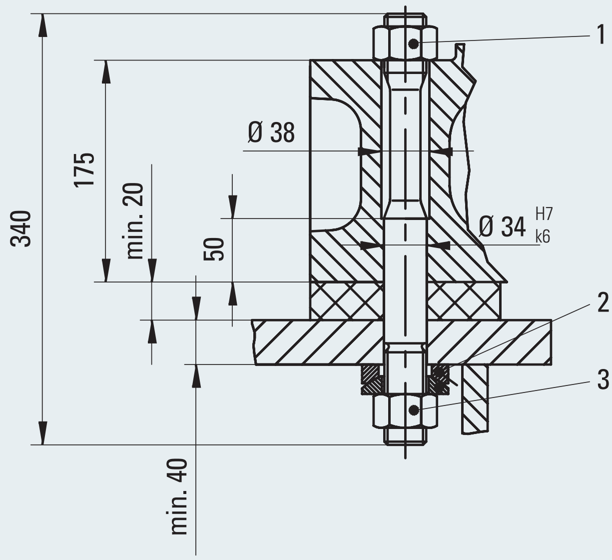


Fig. 14-3 Fitted bolt

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)

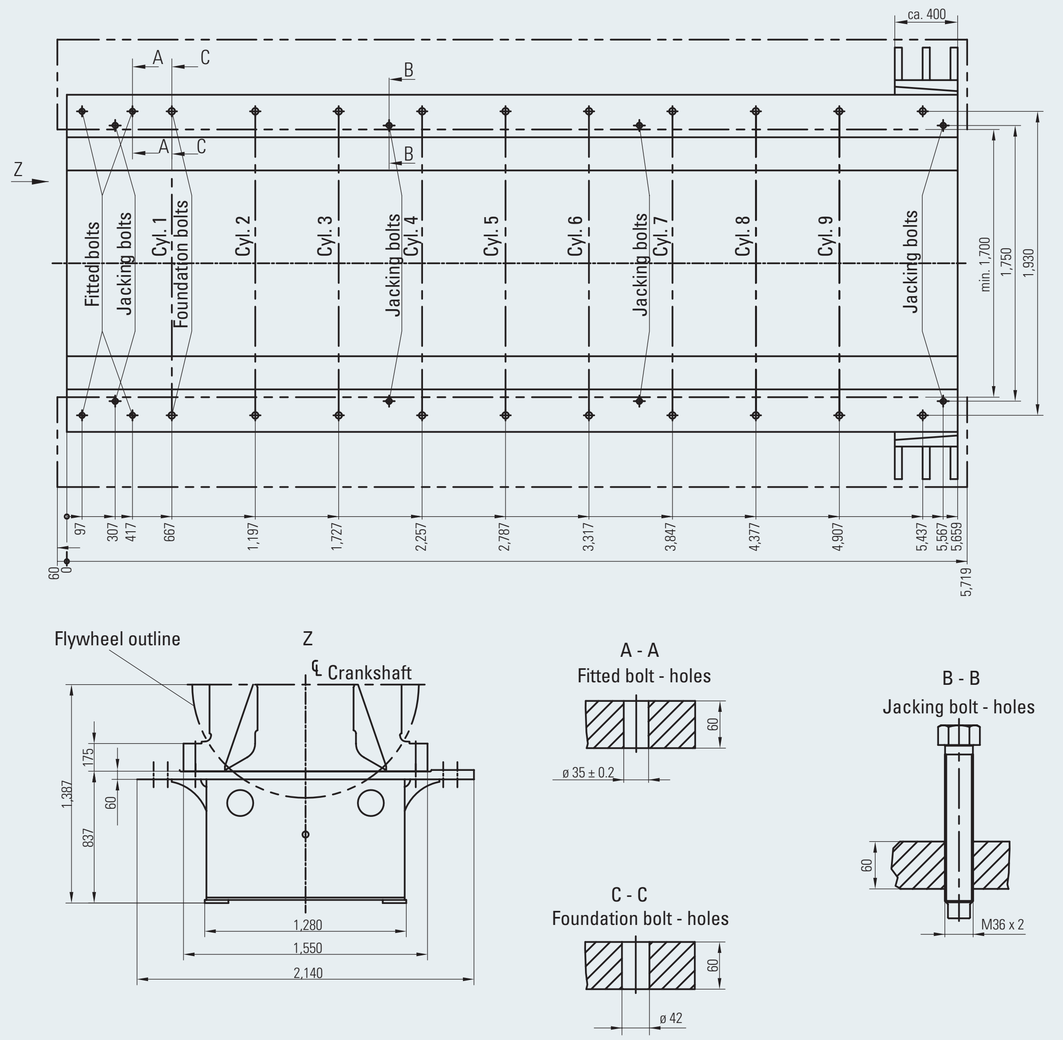


Fig. 14-4 Dimension of foundation wet sump

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

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24

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.

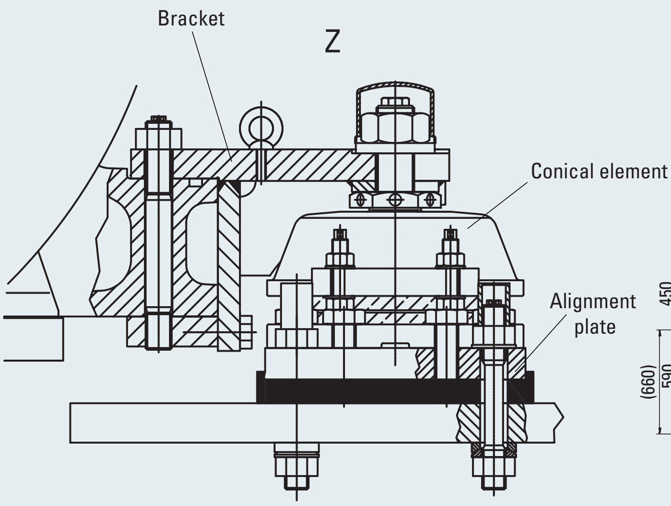
14.2.2 Conical mountings

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.



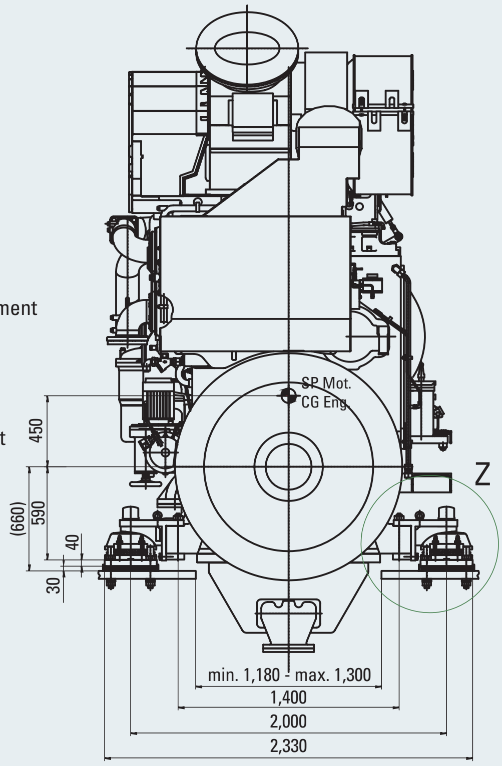


Fig. 14-5 Conical resilient element

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.

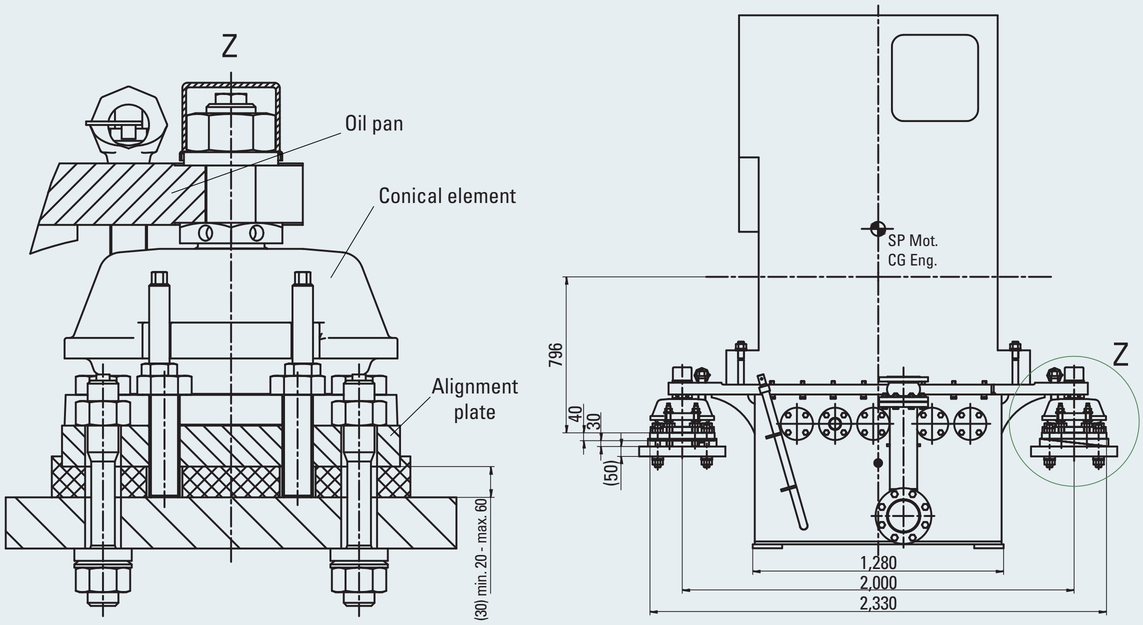


Fig. 14-6 Conical resilient element

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).

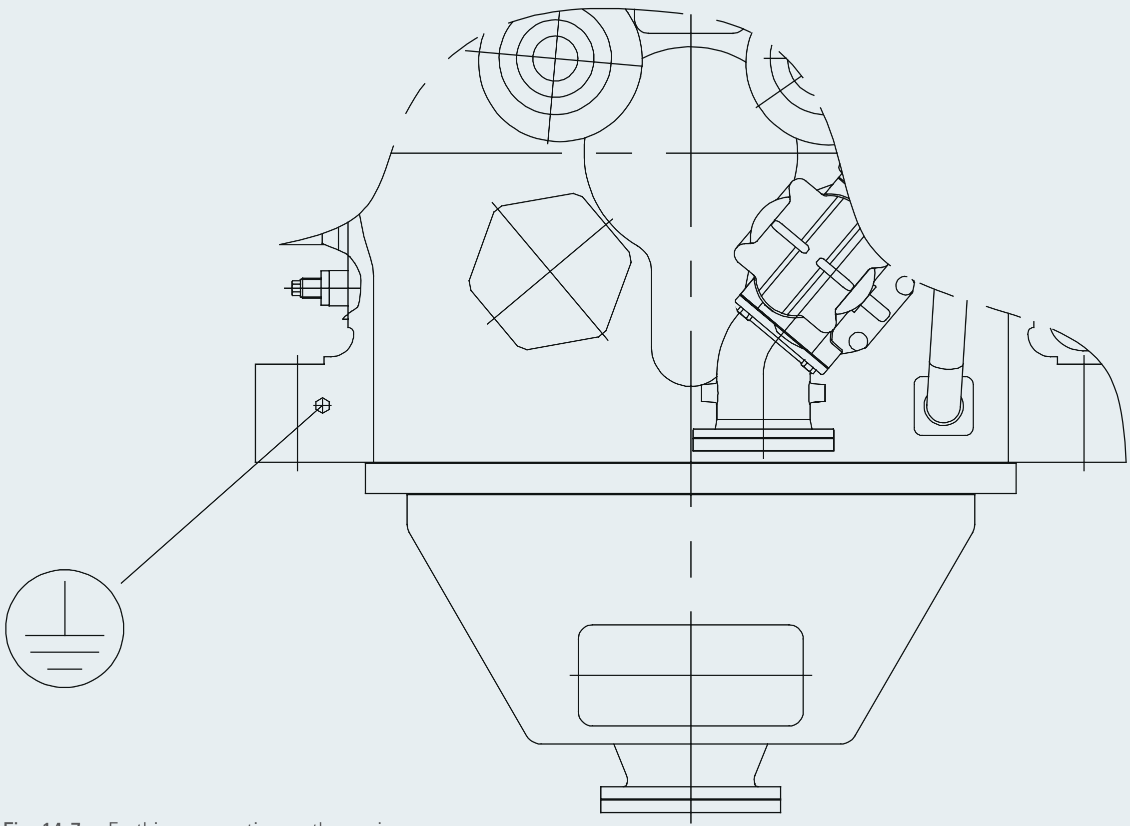


Fig. 14-7 Earthing connection on the engine

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.

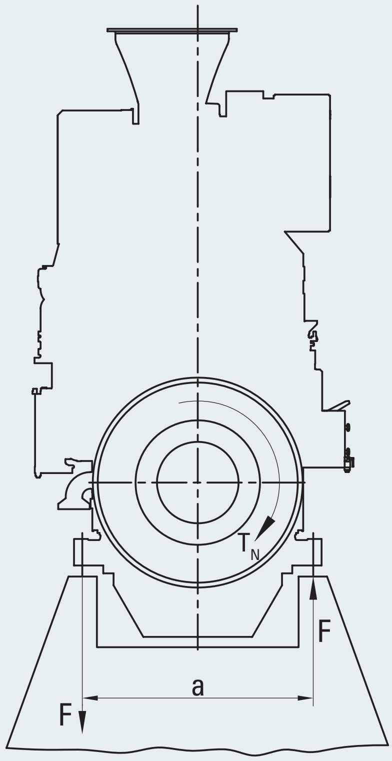


Fig. 15-1 Static load

	Output [kW]	Speed [rpm]	T_N [kNm]
6 M 34 DF	3,180/3,300	720/750	42.2/42.0
8 M 34 DF	4,240/4,400	720/750	56.2/56.0
9 M 34 DF	4,770/4,950	720/750	63.3/63.0

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.

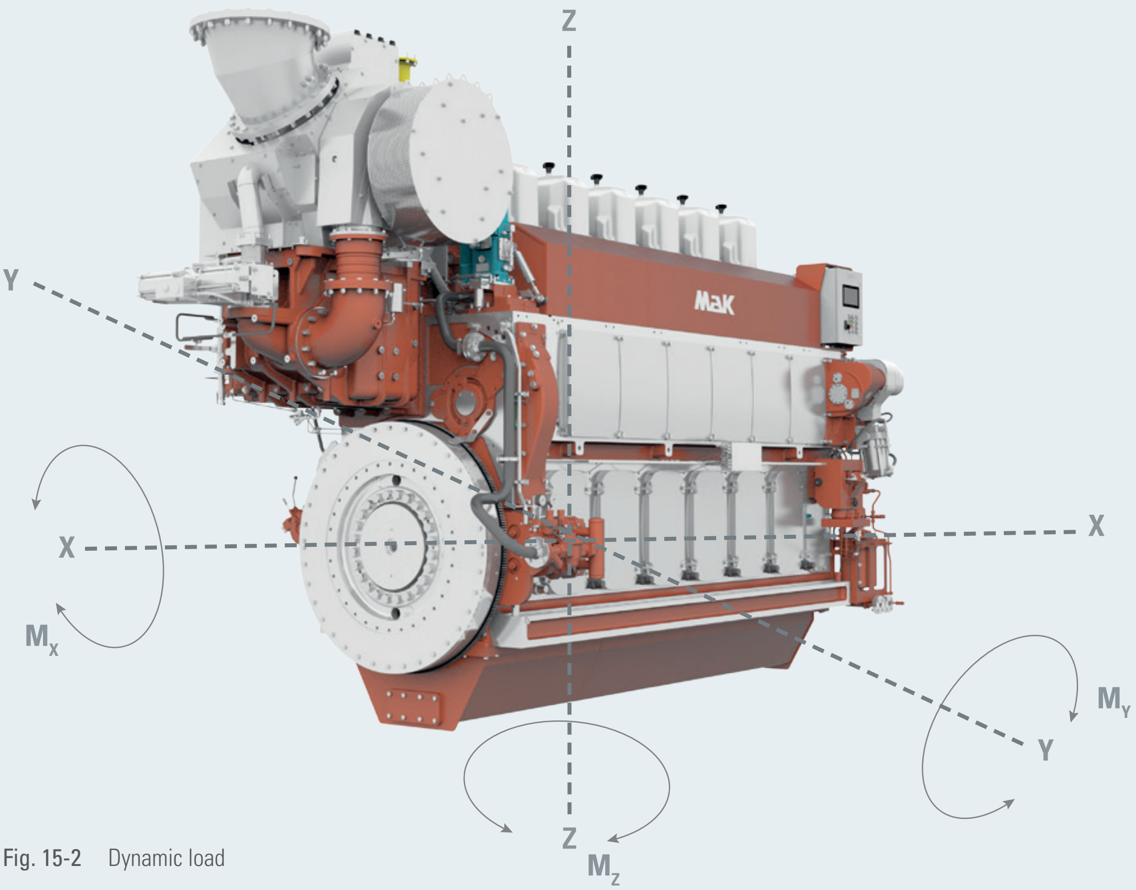


Fig. 15-2 Dynamic load

	Output [kW]	Speed [rpm]	Order-no.	Frequency [Hz]	M_X [kNm]	M_Y [kNm]	M_Z [kNm]
6 M 34 DF	3,180/3,300	720/750	3.0 6.0	36.0/37.5 72.0/75.0	13.07 19.73	–	–
8 M 34 DF	4,240/4,400	720/750	4.0 8.0	48.0/50.0 96.0/100.0	55.94 11.77	–	–
9 M 34 DF	4,770/4,950	720/750	1 2	12.0/12.5 24.0/25.0	– –	15.49 47.58	– –
9 M 34 DF	4,770/4,950	720/750	4.5 9.0	54.0/56.26 108.0/112.5	56.36 9.76	– –	– –

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.

All pictures shown are for illustration purpose only. Actual product may vary due to product enhancement.

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).

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).

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 Mass moments of inertia

	Speed [rpm]	Engine * [kgm²]	Flywheel [kgm²]	Total [kgm²]
6 M 34 DF	720/750	417	436	853
8 M 34 DF	720/750	591	438	1,029
9 M 34 DF	720/750	670	438	1,108

* Running gear with balance weights and vibration damper

17.2 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).

17.2.1 Selection of flexible couplings

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

$$T_{KN} \geq \cdot \frac{P_0}{\omega} = \frac{P_0 \cdot 60}{2 \cdot \pi \cdot n_0}$$

P_0 = Engine output [kW]
n_0 = Engine speed [rpm]
T_{KN} = Nominal torque of the coupling in the catalogue [kNm]

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.

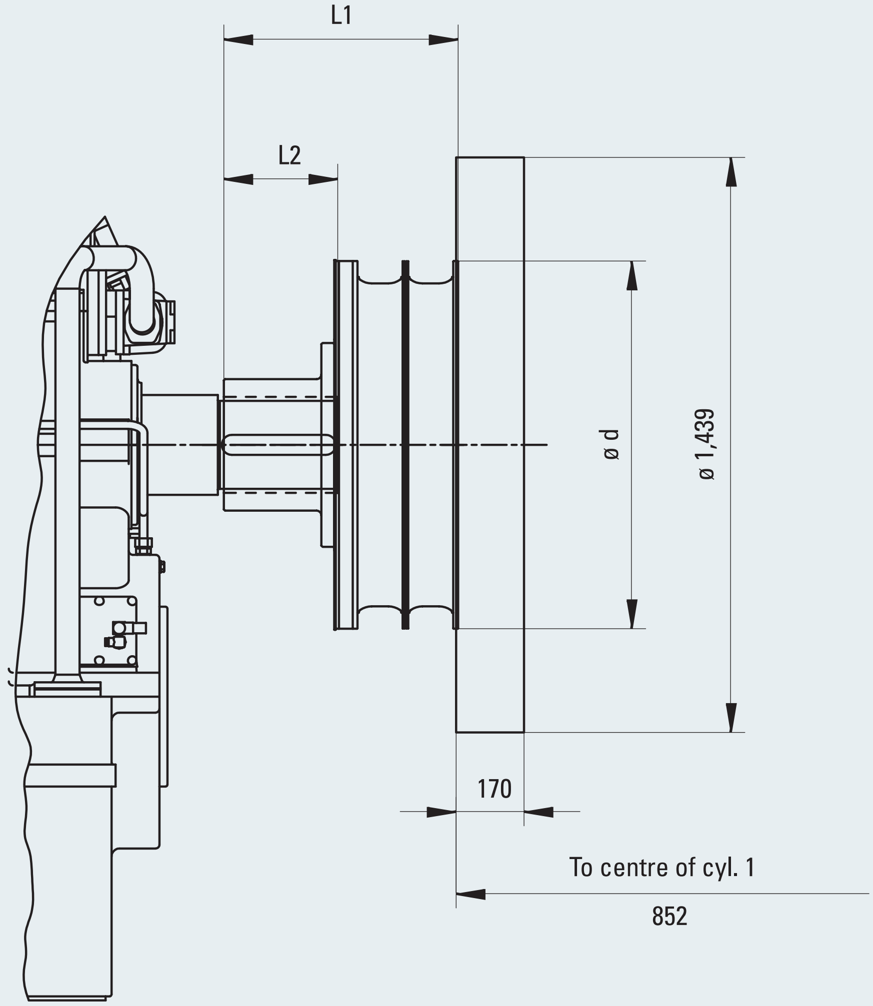


Fig. 17-1 Flywheel and flexible coupling

	Power	Speed	Nominal torque of coupling	Type Vulkan Rato-R+				Weight	
				Size	d	L1 4)	L2 3)	1)	2)
	[kW]	[rpm]	[kNm]		[mm]	[mm]	[mm]	[kg]	[kg]
6 M 34 DF	3,180/3,300	720/750	66.5	G3B2S	920	823 1) / 586 2)	285	721	545
8 M 34 DF	4,240/4,400	720/750	66.5	G3B2S	920	823 1) / 586 2)	285	721	545
9 M 34 DF	4,770/4,950	720/750	70.0	G3B2M	920	823 1) / 586 2)	285	721	545

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

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 %.

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

The PTO output is limited to:

- 6 M 34 DF 3,300 kW
- 8 M 34 DF 3,000 kW
- 9 M 34 DF 4,950 kW

The connection requires a highly flexible coupling.

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

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

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

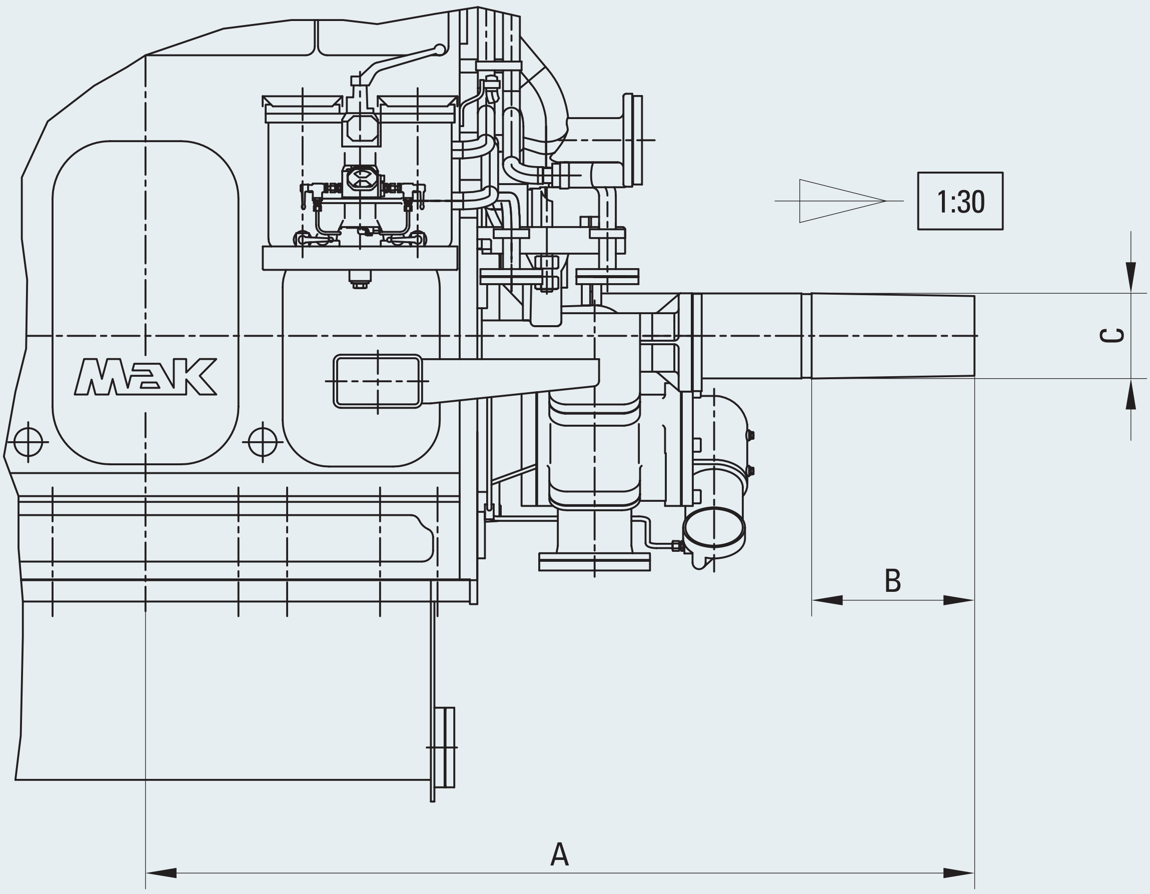


Fig. 17-2 Power take-off from the free end

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

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 18.2).
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.

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.

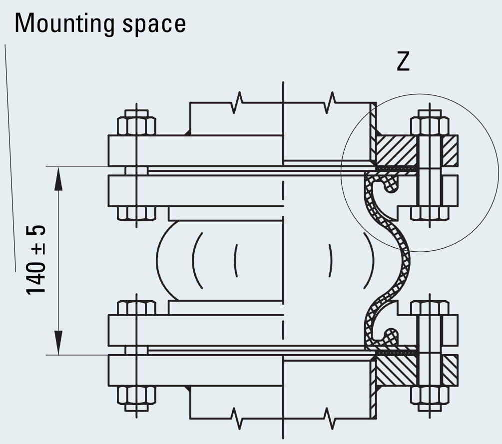


Fig. 18-1 Rubber expansion joint

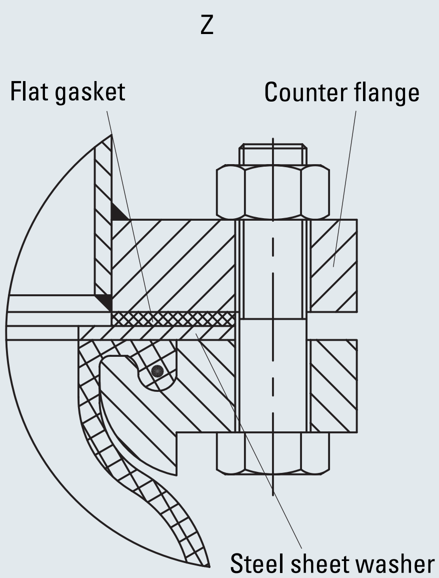


Fig. 18-2 Rubber expansion joint, detail Z

19.1 Engine center distances

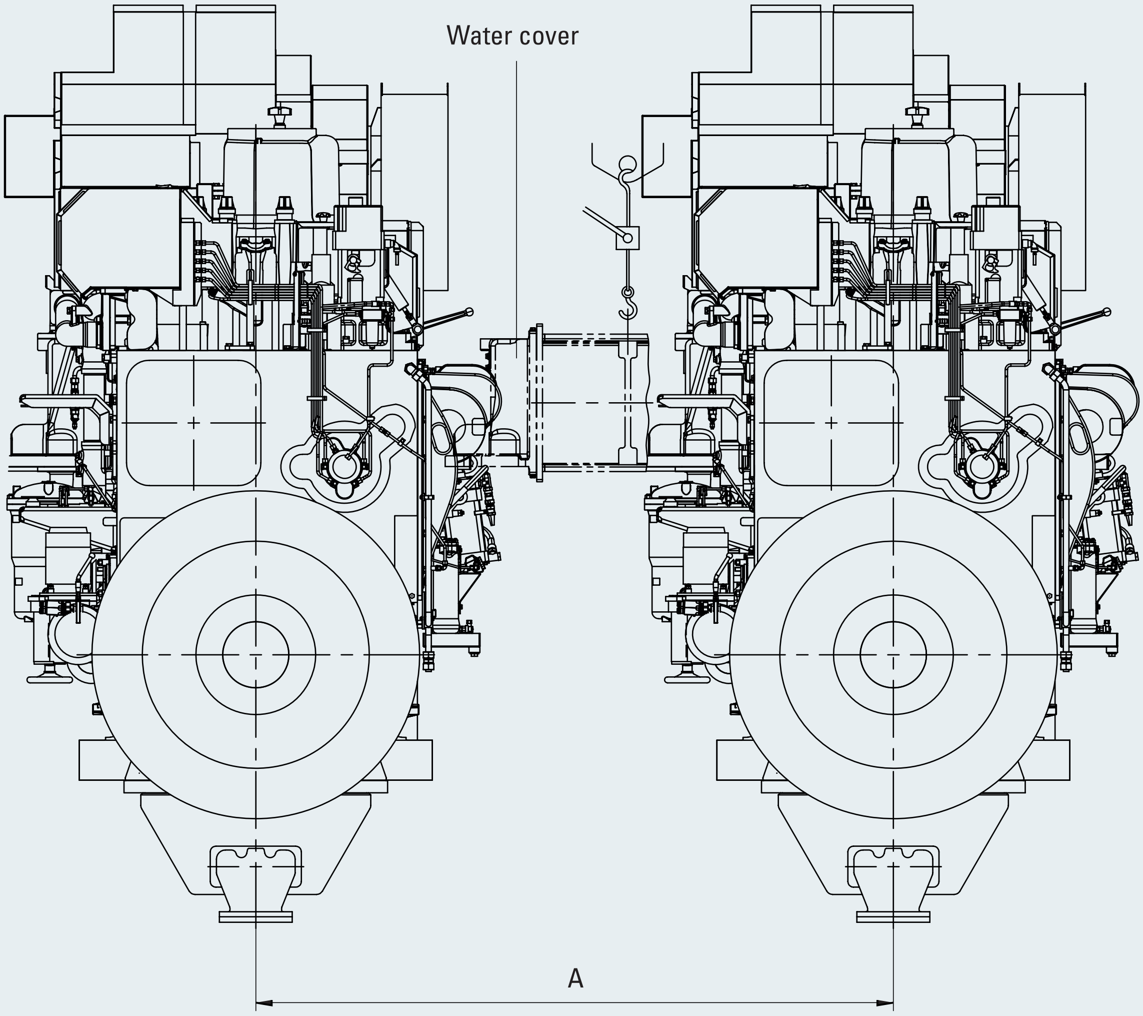


Fig. 19-1 Center distance of twin-engine plants

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

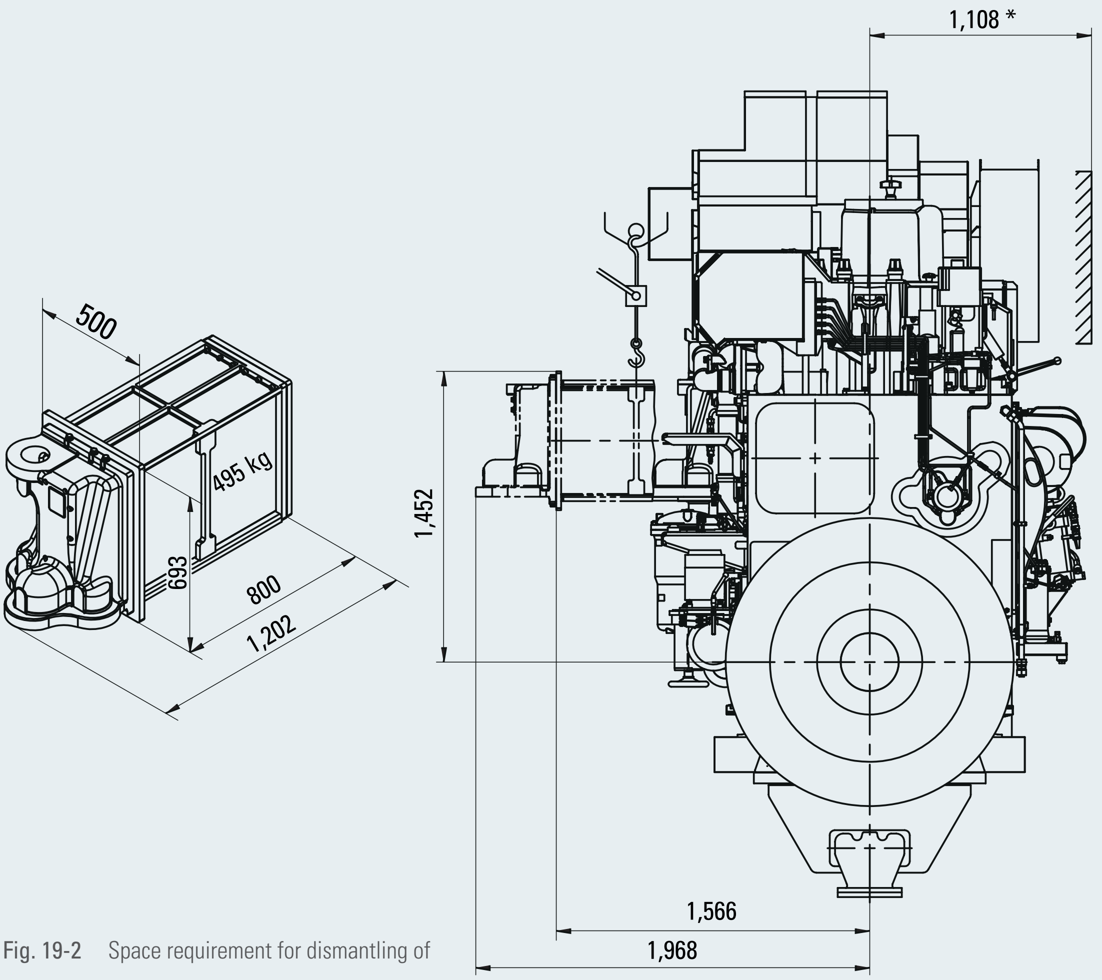


Fig. 19-2 Space requirement for dismantling of charge air cooler and turbocharger cartridge

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

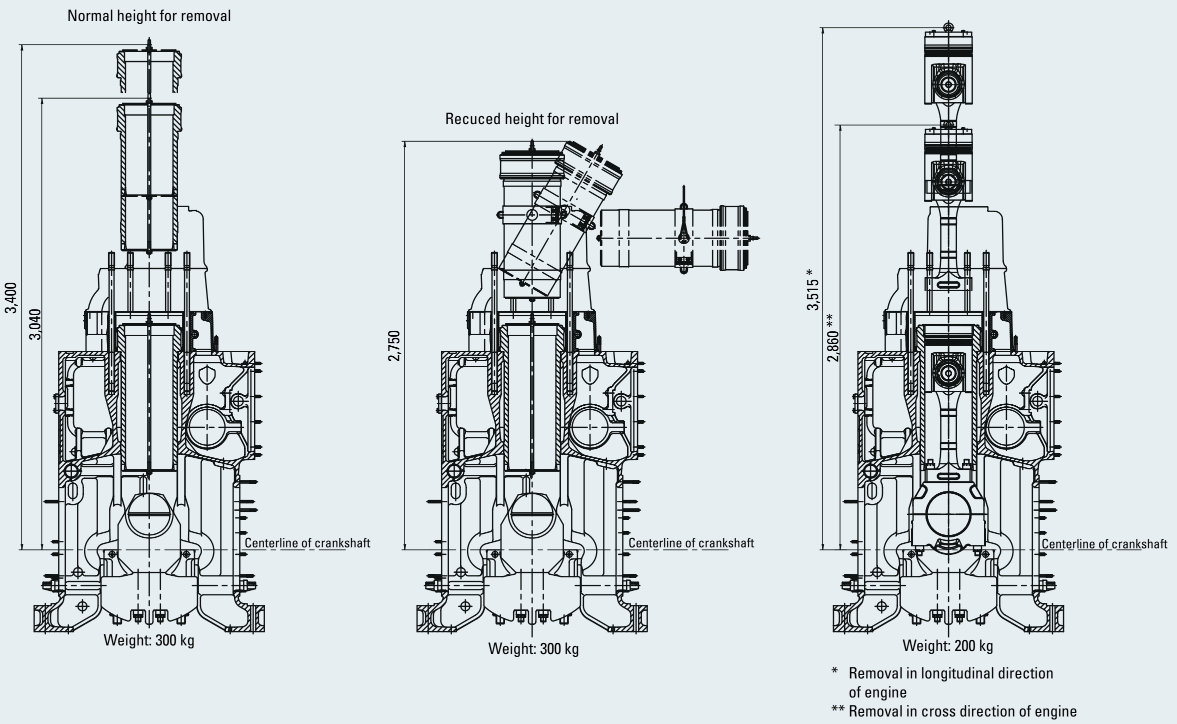


Fig. 19-3 Removal of piston and cylinder liner

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 engines and storage of engines in the open, even if they are covered with tarpaulin.

Appearance of the engine

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

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

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.

Appearance of the engine

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

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

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 represervation

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 represervation 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 Represervation as per factory standard N 576-6.1

After 2 years represervation 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.

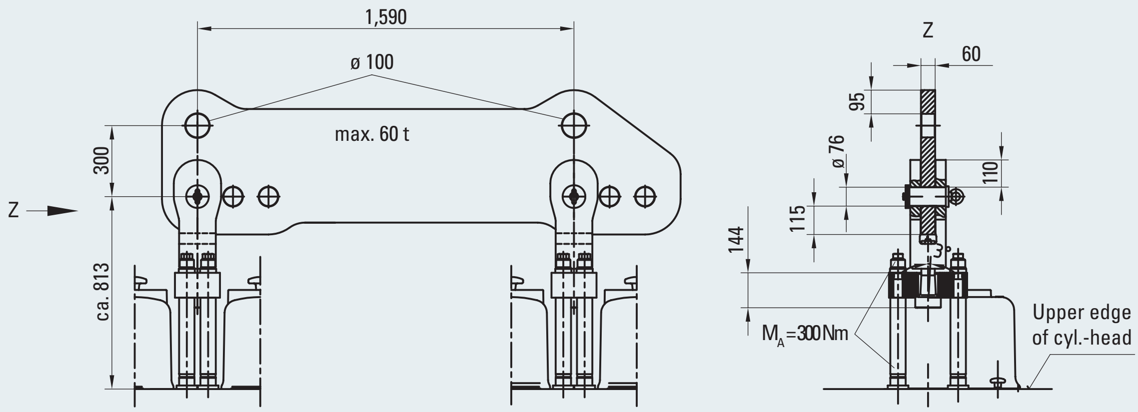


Fig. 21-1 Spreader bar

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

Transport of engine with turbocharger at driving end

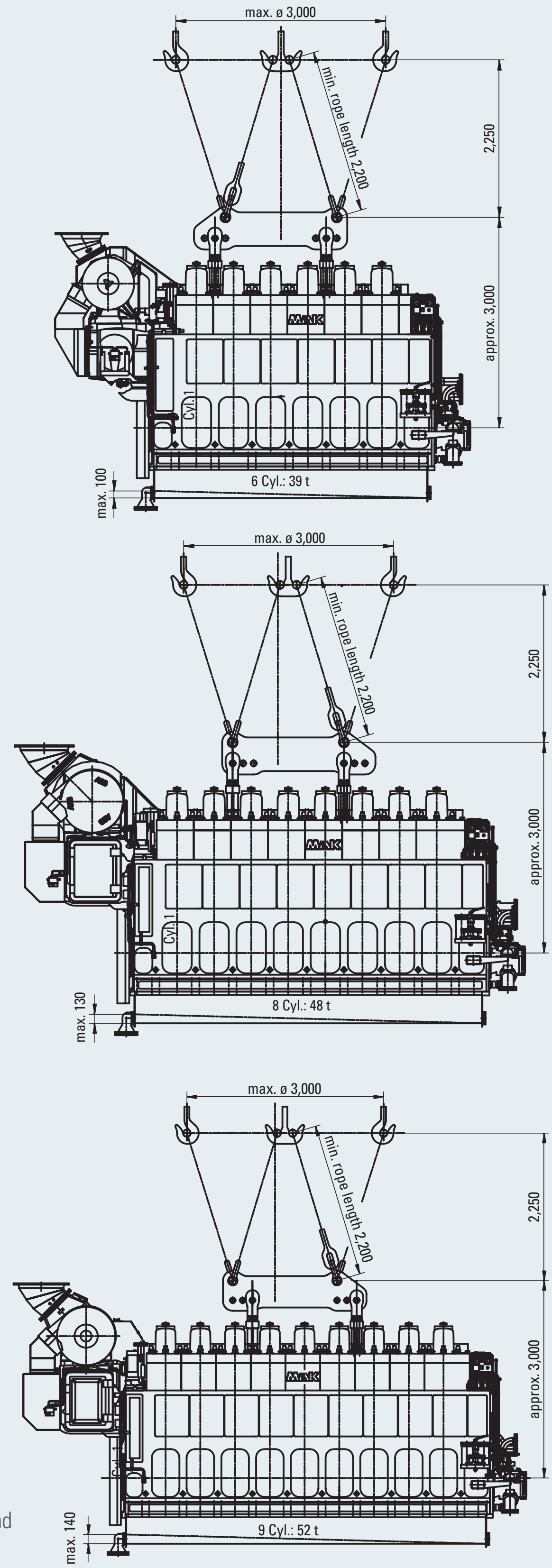


Fig. 21-2 Transport of engine with turbocharger at driving end

Transport of engine with turbocharger at free end

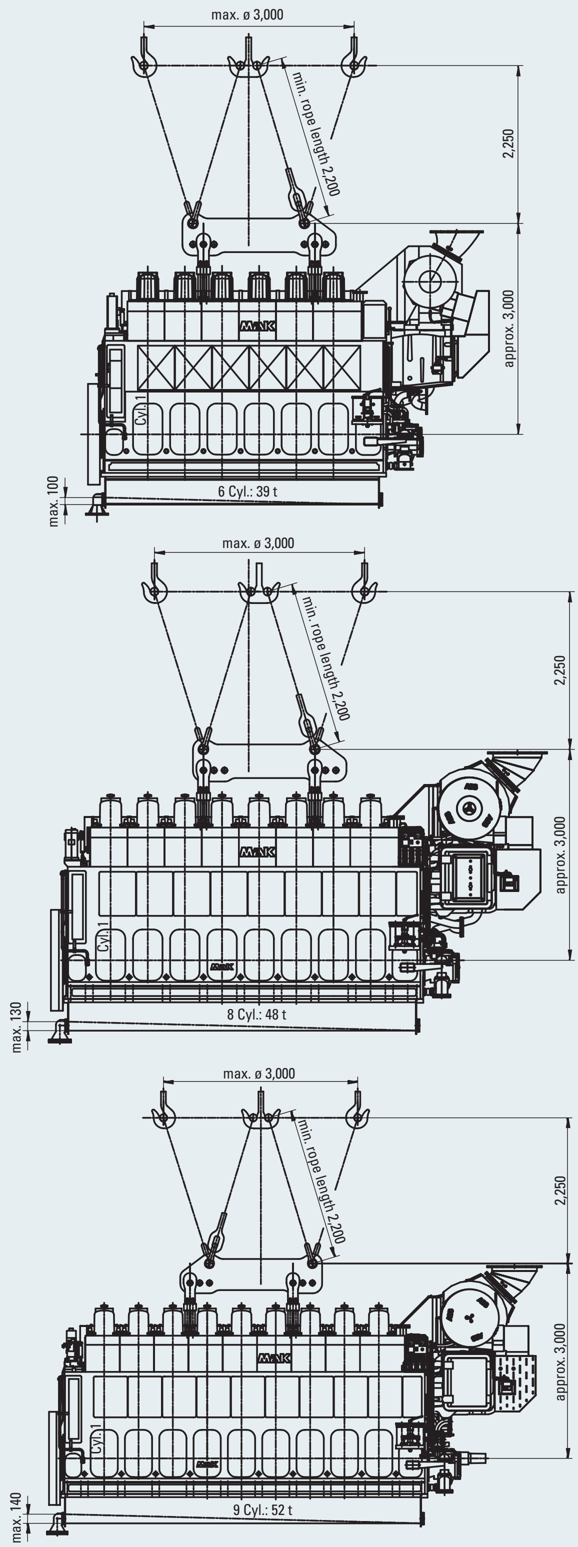


Fig. 21-3 Transport of engine with turbocharger at free end

21.2 Dimensions of main components

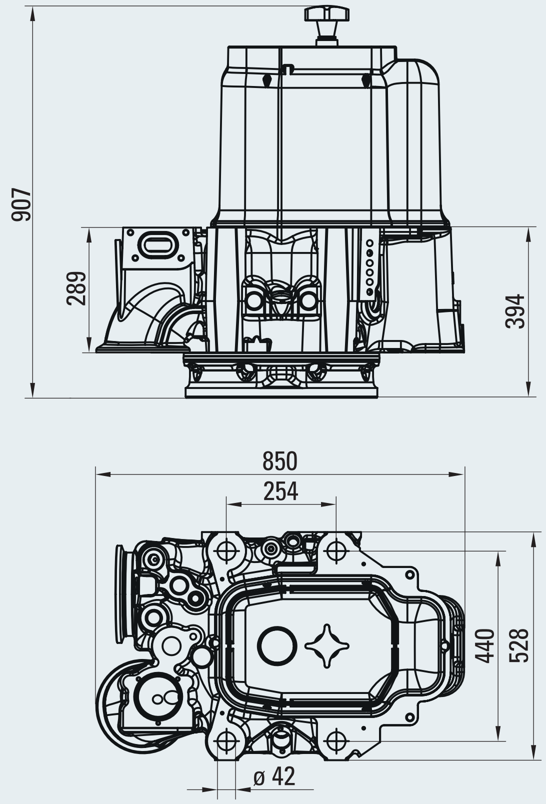


Fig. 21-4 Cylinder head, weight 460 kg

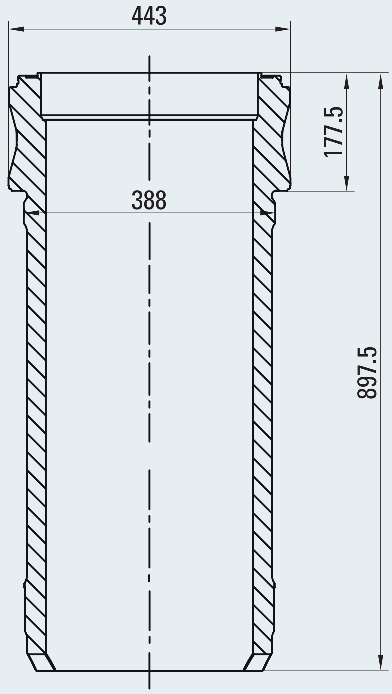


Fig. 21-5 Cylinder liner, weight 221 kg

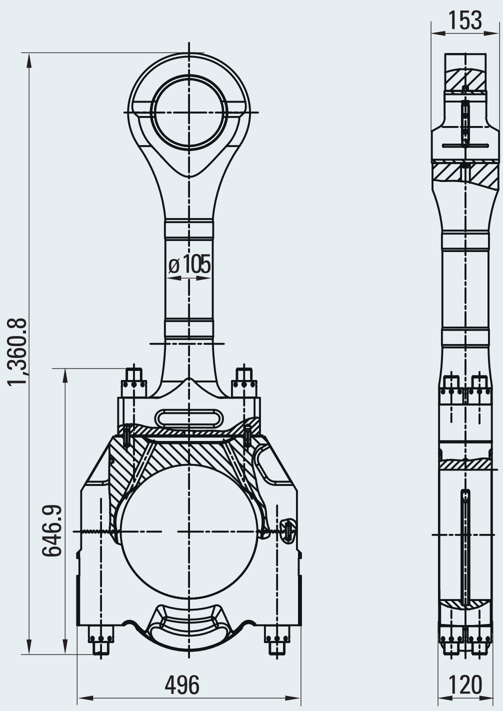


Fig. 21-6 Connecting rod, weight 224 kg

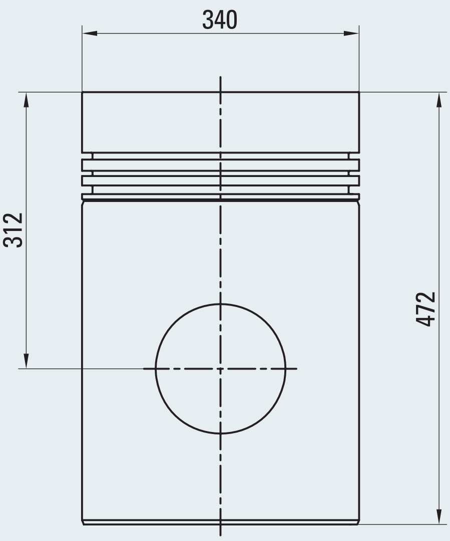


Fig. 21-7 Piston, weight 97.6 kg

22.1 Standard acceptance test run

The acceptance test run of the engine is carried out on the test bed with test bed own equipment and auxiliaries using exclusively MDO during diesel operation and ignition fuel as well as natural gas during gas operation under the respective ambient condition of the test 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 referende conditions.
The engine will be run at the following load stages according to the rules of the classification society.

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

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

23.1 Required spare parts (Marine Classification Society MCS)

Classification societies	GL	KR	CCS	Class NK	Türk Loyd
Rules references	Pt.1, Ch.17	Pt.5, Ch.1 5:1.5	Ch.15, Sec.1&2	Pt.D, Ch.21	Sec.10
Parts					
Main bearing	1	1	1	1 set	1
Thrust washer	1	1	1	–	–
Cylinder liner, complete	1	1	1	1	1
Cylinder head, complete	1	1	1	1	1
Cylinder head, only with valves (w/o injection valve)	–	–	–		–
Set of gaskets for one cylinder head	–	–	–	1	
Set bolts and nuts for cylinder head	1/2	1/2	1/2	1/2	1/4
Set of exhaust valves for one cylinder head	1	2	2	2	1 set
Set of intake valves for one cylinder head	1	1	1	1	1 set
Starting air valve, complete	1	1	1	1	1 set
Relief valve, complete	1	1	1	1	1 set
Injection valve, complete	–	–	–	–	1
Set of injection valves, complete, for one engine	1	1	1	1	1 set
Set of conrod top & bottom bearing for one cylinder	1	1	1	1	1 set
Piston, complete	1	1	1	1	1
Piston, without piston pin + piston rings	–	–	–	–	–
Connecting rod	1	1	1	–	1
Big end bearing	–	–	–	–	1
Gudgeon pin with bushing for one cylinder	1	1	1	–	1 set
Set of piston rings	1	1	1	1	1 set
Fuel injection pump	1	1	1	1	1
Fuel injection piping	1	1	1	1	1
Set of gaskets and packing for one cylinder	1	1	1	–	
Exhaust compensators between cylinders	1	1	1	–	1
Turbocharger rotor, complete	–	–	–	1**	(1 set)*
Set of gear wheels	–	–	–	–	
ECU	1	1	1	–	
Speed pick-up camshaft	1	1	1	–	
Speed pick-up crankshaft	1	1	1	–	
DCU	1			–	

*) Recommendation only

**) Not needed if turbocharger blocking device will be delivered to the customer / TC blocking test to be performed during engine type test for the engine

23.2 Recommended spare parts

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

*) Recommendation only

**) Not needed if turbocharger blocking device will be delivered to the customer / TC blocking test to be performed during engine type test for the engine

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	–
ECU	1
Speed pick-up camshaft	1
Speed pick-up crankshaft	1
DCU	1
Gas admission valve	2
Ignition injector	2
Cylinder pressure sensor	1
Set of dual fuel gaskets	1
Rail pressure sensor	1
Gas compensator	1
External speed pickup for electronic speed governor	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
Sintered bronze filter (for crankcase monitor)	1

* Recommendation only

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

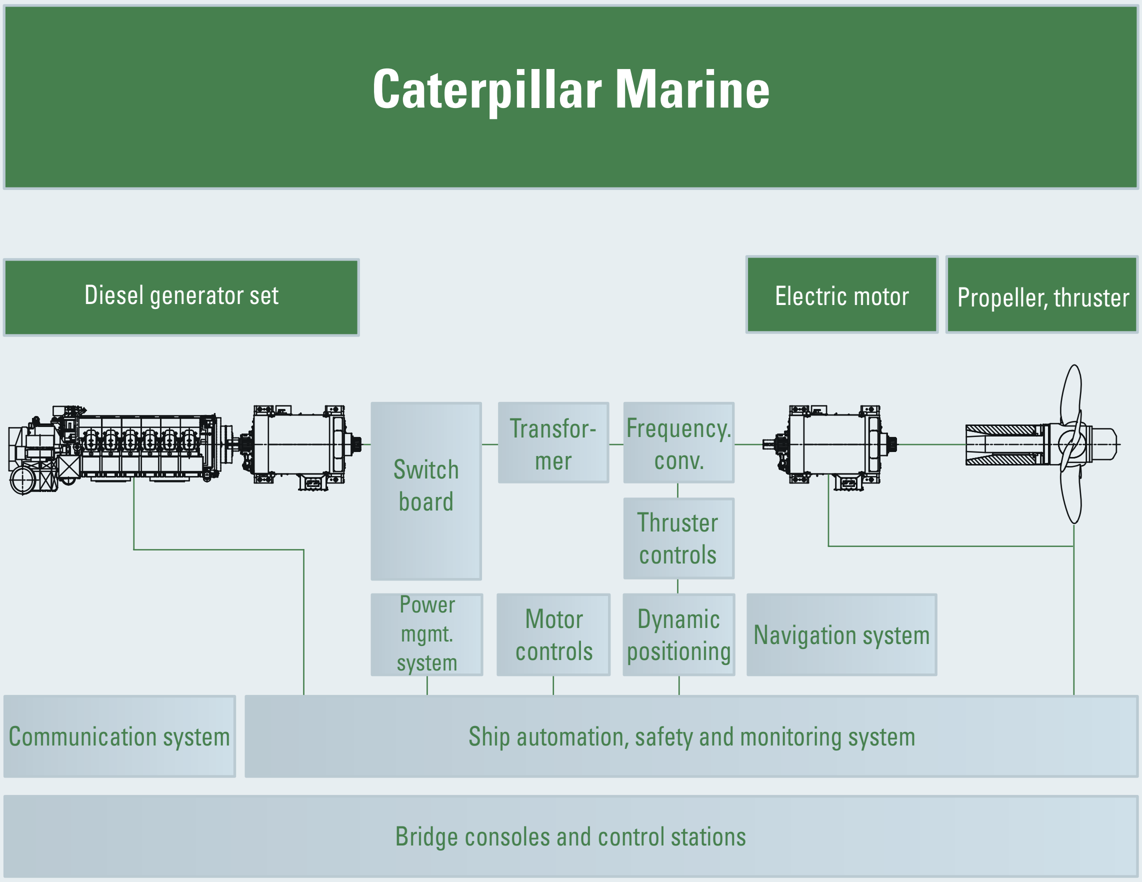


Fig. 24-1 D/E application

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

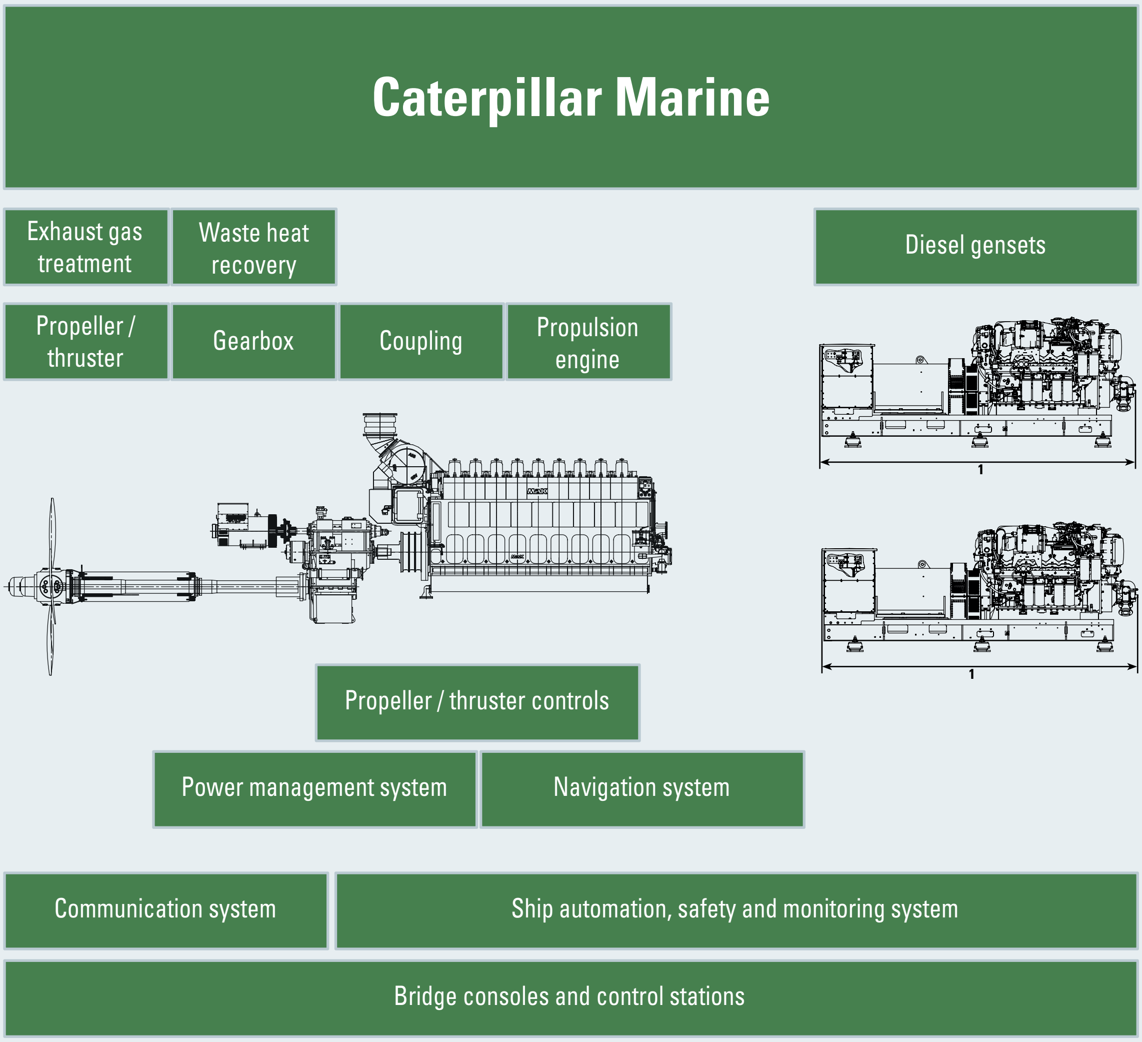


Fig. 24-2 D/M application

24.3 Levels of integration

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

1.) Exhaust gas system – please refer to chapter 11.
2.) Mechanical propulsion system, consisting of:
- Diesel engines – engines and related auxiliary systems
- Drive lines – gearboxes, propellers, thrusters
- Auxiliary diesel generator sets – engines, generators, baseframes, engine related auxiliary systems

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

24.4 Gas systems technology – Scope of supply

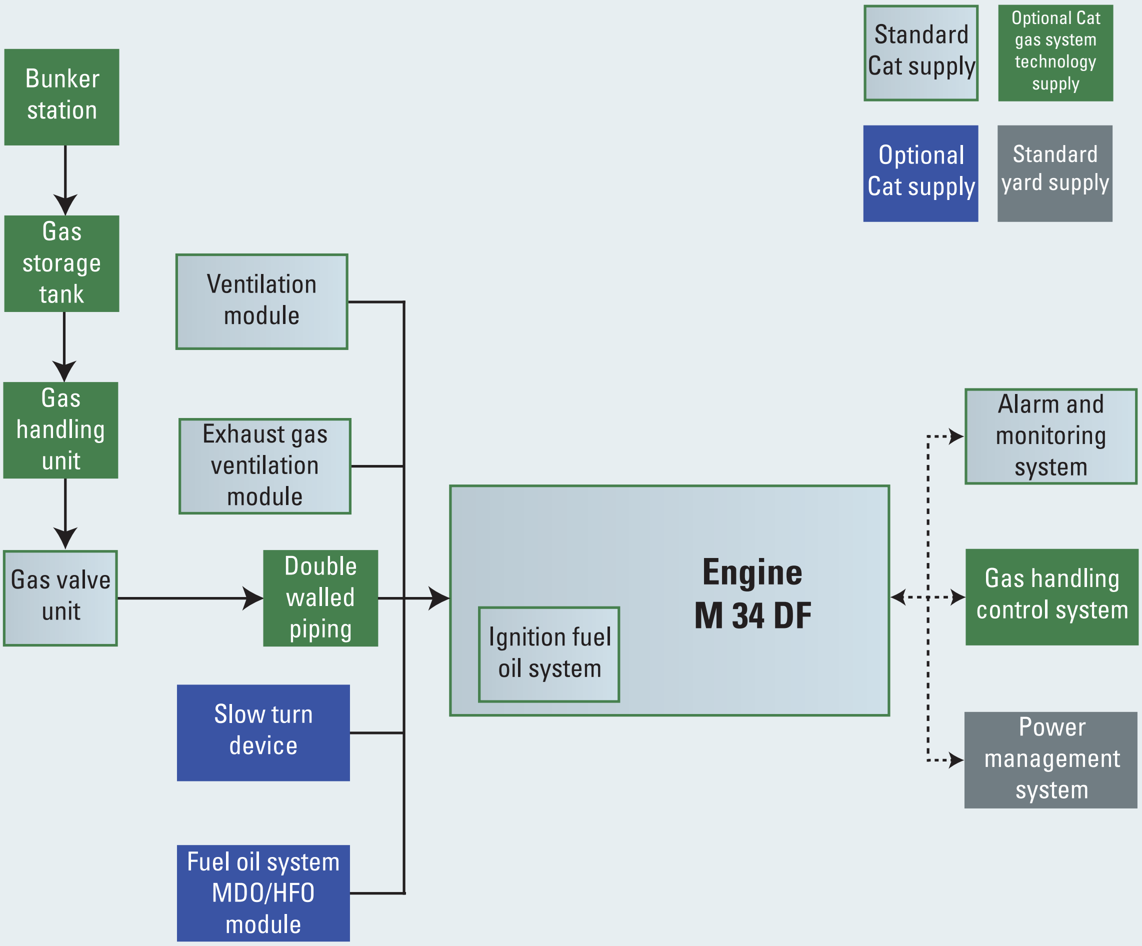


Fig. 24-3 Scope of supply M 34 DF Gas systems technology – block diagram

24.5. Cat Digital Technology

24.5.1 Cat® Remote Fleet Vision – Inform

Get a comprehensive view of engine health, identify potential issues and schedule service and repairs proactively. Cat Remote Fleet Vision works with your engine's Product Link™ hardware to monitor status, condition and performance from a remote location.

With Cat Remote Fleet Vision, it's fast and easy to determine if issues lie with the engine or with other equipment such as a generator, transmission or pump. The system works with any brand of equipment and is ideal for those with vessels spread over a wide geographic area.

24.5.2 Cat® Asset Intelligence – Advice

Take advantage of advanced, automated predictive analytics with the option of expert advisory service across your vessel – or across your entire fleet. Cat Asset Intelligence helps you maximize efficiency, increase productivity and decrease operating costs by providing the right information to the right people at the right time.

When environmental regulations require you to submit ship-specific reports, for example, Cat Asset Intelligence makes compliance easy. As soon as your vessel enters an ECA zone, the system logs critical data points and automatically generates reports on fuel consumption and emissions.

24.6 Genuine MaK Parts

You Get What You Pay For

Quick access to quality parts is critical for your business – often making all the difference in uptime and staying profitable. Genuine MaK components are designed to function reliably as a complete system.

Our manufacturing techniques are improved continuously to ensure that using original MaK parts enhances engine performance and lowers emissions while increasing reliability.

Genuine MaK parts may often be rebuilt for a second life, adding value to your investment and reducing overall owning and operating costs – benefits you may not get from non-original competitive parts. As you would expect, all emission relevant genuine MaK parts conform to IMO requirements (as applicable), ensuring that your engine remains compliant with the relevant MARPOL Annex VI regulations and EIAPP certification (as applicable). Equally important, all of our MaK spare parts are backed by the Caterpillar Motoren parts warranty.

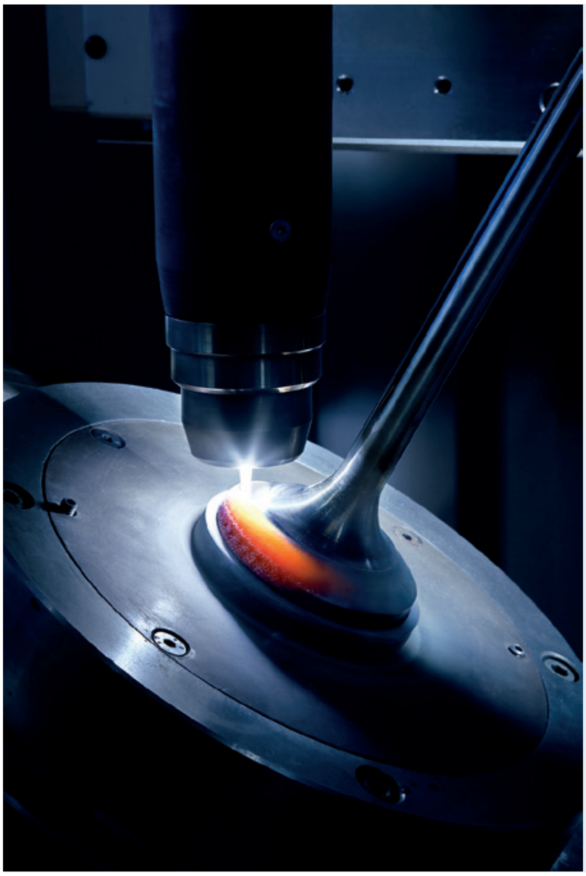
Why Insist on Genuine MaK Parts

Lower Operating Cost
For many MaK owners and operators, the ability to run vessels safely at low speeds or consituously slow steaming is a major factor in reducing total operating expenditure.

Peace of Mind
MaK engines operatings with genuine MaK parts perform longer with fewer unplanned maintenance events or risk of failure.

Availability
All parts can be dispatched within 24 hours through our strategically located distribution center and delivered globally by our authorized distributors.

Quality
The quality material and stringent process controls ensure our products are durable and OEM guaranteed to offer long service life within minimal risk of failure.



24.7 MaK REParts™

Our Mission

Caterpillar Motoren provides its customers with the most cost effective and adequate service solutions available in the industry. Our MaK REParts™ are produced to the same quality standards as our original OEM parts.

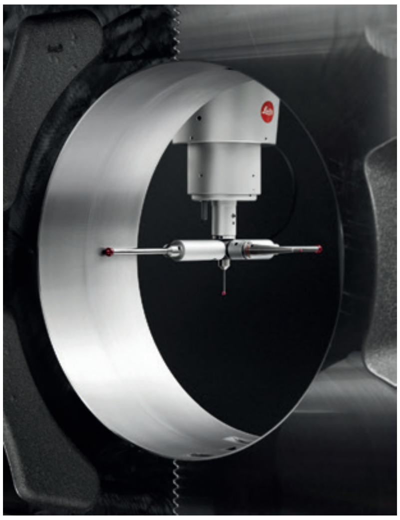
Introduction

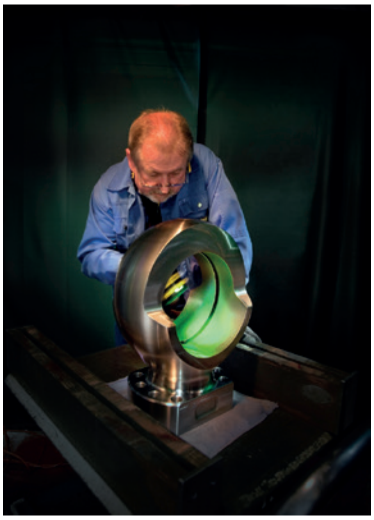
Many of our genuine MaK parts are rebuild for a second life, adding value to your investment and reducing overall owning and operating costs. Through our new MaK Repair and Exchange Parts (REParts) program, we are able to offer our customers extensive repair and exchange options, which provide same-as-new performance and reliability at a fraction of new price. The results are maximum engine productivity and lower life cycle costs; while reducing the impact on the environment. MaK REParts provide you with an option to lower owning and operating costs by reusing many of the original components.
With the return of your used genuine components, you can save up to 65% of the repair and replacement costs. We inspect the used components, providing an immediate decision on core conditions and aligned credit, in order to better estimate the total repair costs.

How does the REParts process work?

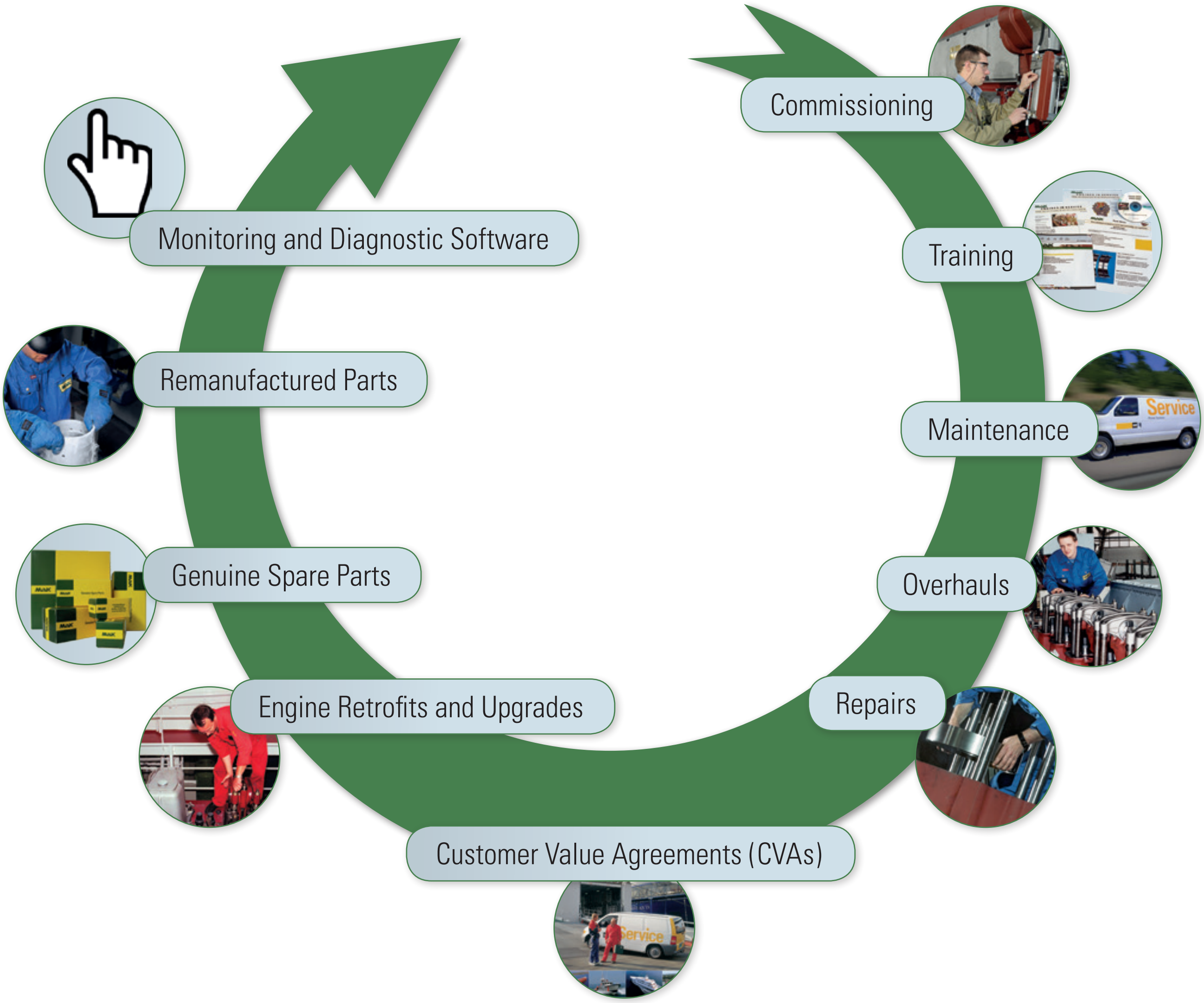
MaK REParts are produced to the same quality standards as our original OEM parts.
By utilizing our state-of-the-art salvage and cleaning techniques, quality control, and stringent testing, MaK parts are returned to their original specifications. MaK REParts are ready to use, easy to exchange and install.

If you need more information on this topic, please contact us via email:
REParts_Center@cat.com





24.8 Global Dealer Network



Global Dealer Network
Providing integrated solutions for your power system means much more than just supplying you with engines. Beyond complete auxiliary and propulsion power systems, we offer a broad portfolio of customer support solutions. Our global dealer network supports you wherever you are – worldwide. Offer onsite technical expertise through marine specialists and an extensive inventory of all the spare parts you might need.

To find your nearest dealer, simply go to **WWW.MARINE.CAT.COM**

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