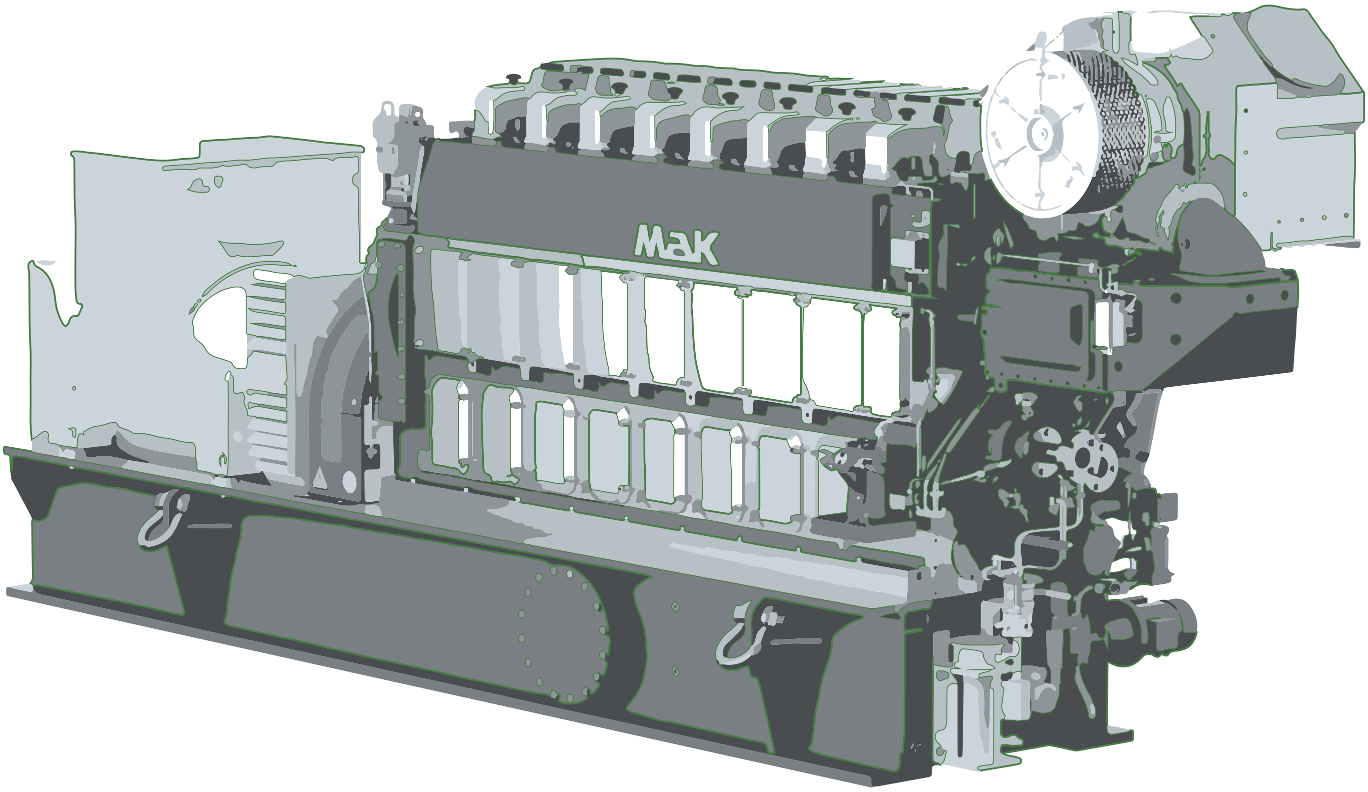
M 20 C

PROJECT GUIDE / GENERATOR SET



MaK

Information for the user of this project guide

The project information contained in the following is not binding, since technical data of products may especially change due to product development and customer requests. Caterpillar reserves the right to modify and amend data at any time. Any liability for accuracy of information provided herein is excluded.

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

This edition supersedes the previous edition of this project guide.

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Edition **July 2019**

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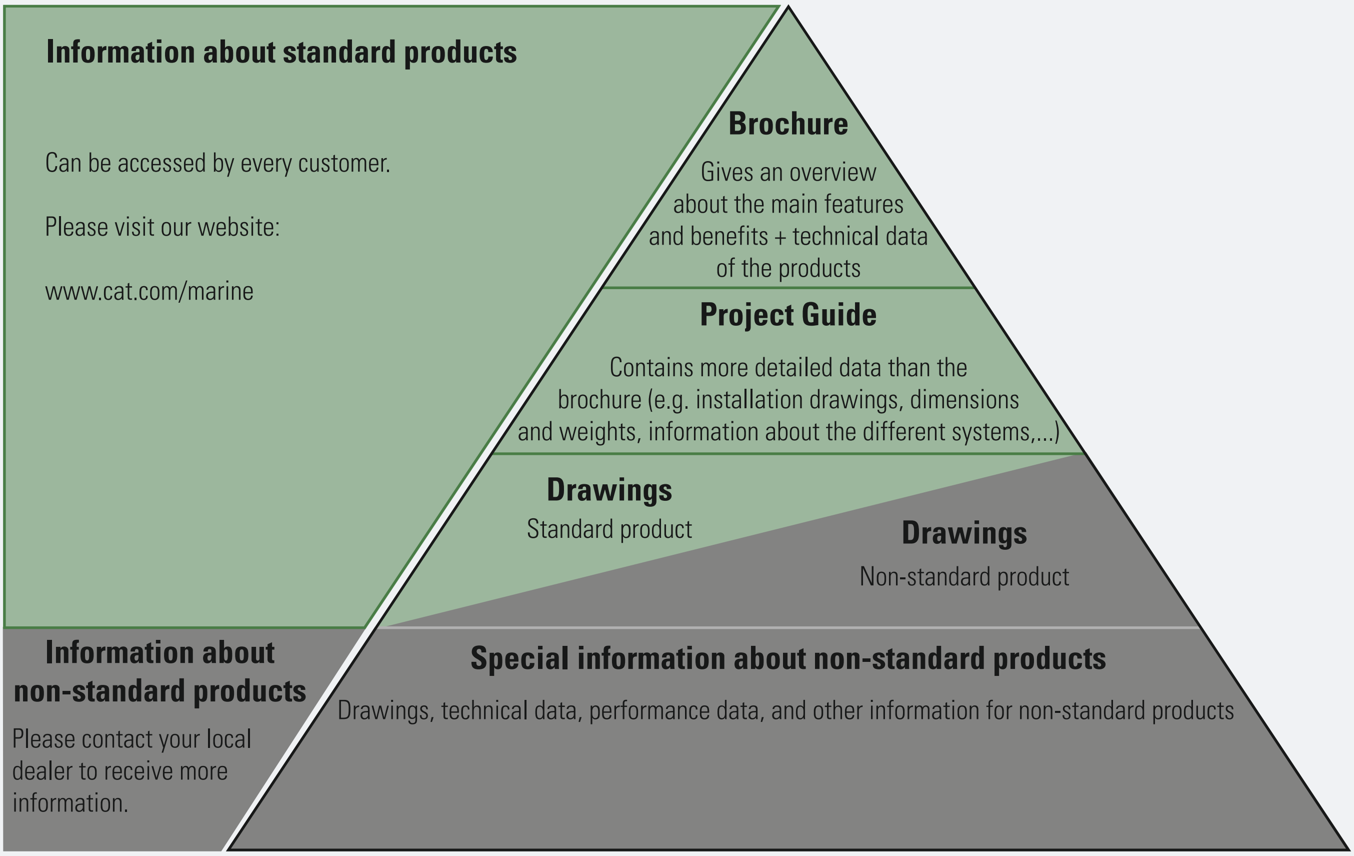
Different kinds of information about MaK marine products

The following illustration shows how to find and download information about the MaK products in the internet.



Global Resource from One Source

When you select Cat Marine Power for your vessel, look to Cat Financial for worldclass financial support. With marine lending offices in Europe, Asia and the US supporting Caterpillar's worldwide marine distribution network, Cat Financial is anchored in your homeport. We also have over 20 years of marine lending experience, so we understand your unique commercial marine business needs. Whether you're in the offshore support, cargo, ship assist, towing, fishing or passenger vessel industry, you can count on Cat Financial for the same high standard you expect from Caterpillar.

Marine Financing Guidelines

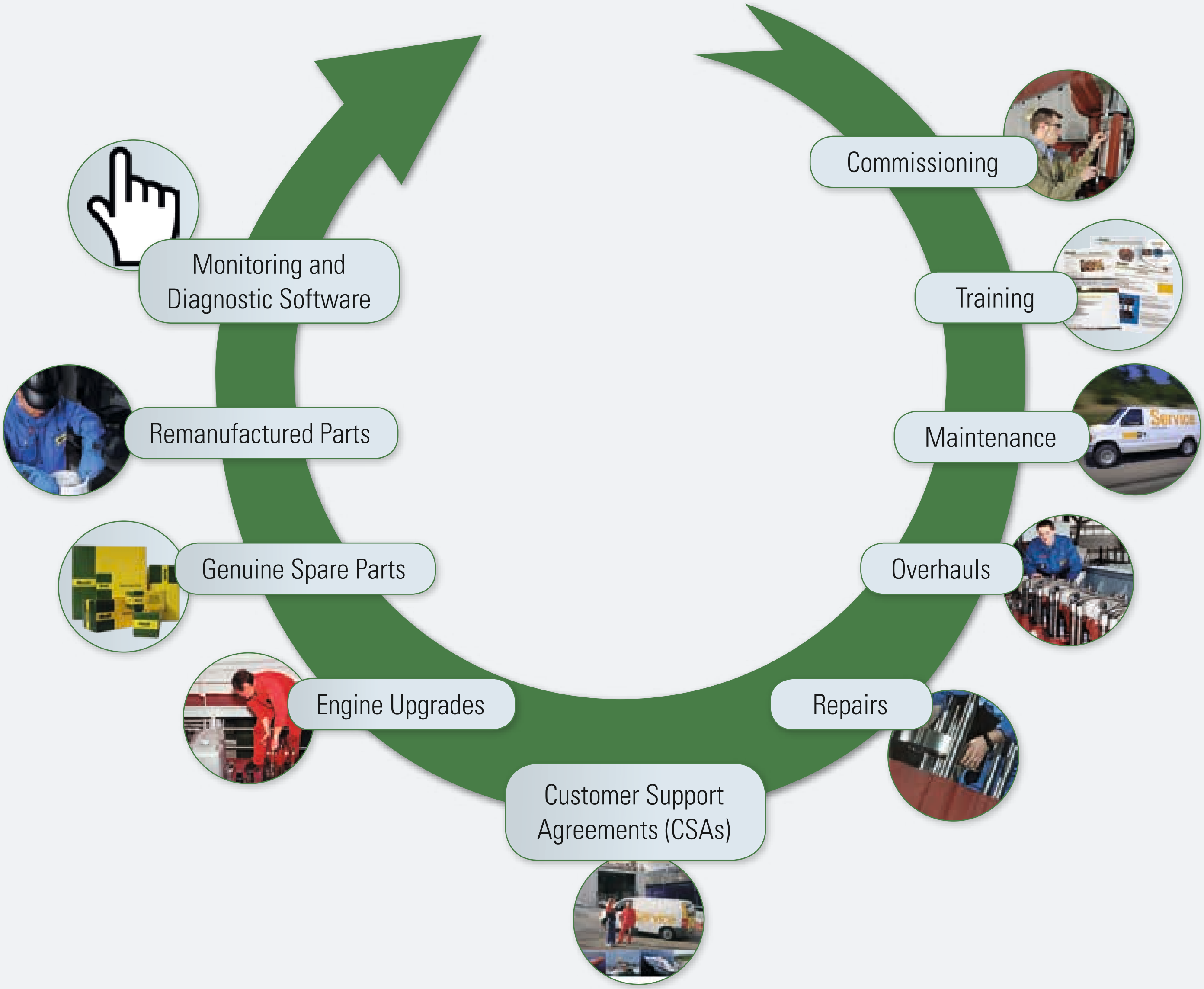
Power:	Cat and MaK
Financial Products:	Construction, term and repower financing
Repayment:	Loan terms up to 10 years, with longer amortizations available
Financed Amount:	Up to 80% of your vessel cost
Rates:	Fixed or variable
Currency:	US Dollars, Euros and other widely traded currencies

www.cat.com/CatMarineFinance

Visit our website or see your local Cat dealer to learn how our marine financing plans and options can help your business succeed.



Global Dealer Network



Providing integrated solutions for your power system means much more than just supplying your engines. Beyond complete auxiliary and propulsion power systems, we offer a broad portfolio of customer support solutions and financing options. Our global dealer network takes care of you wherever you are – worldwide. Localized dealers 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.cat.com/marine**

Original Engine/Equipment Manufacturer (OEM) 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.

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

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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.

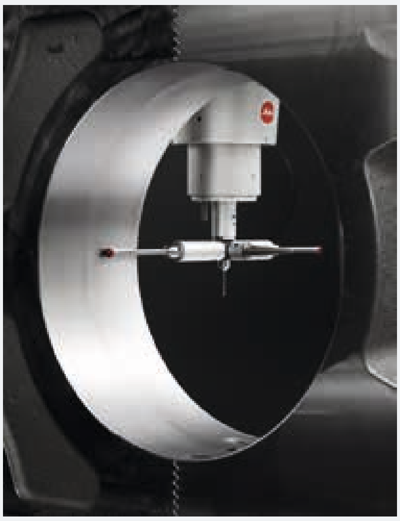
Introduction

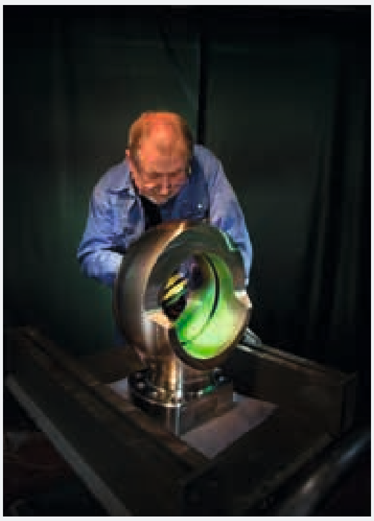
Many of our genuine MaK parts are rebuild for a second life, adding value to your investment and reducing overall owning and operating costs. Through our new MaK Repair and Exchange Parts (REParts) program, we are able to offer our customers extensive repair and exchange options, which provide same-as-new 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





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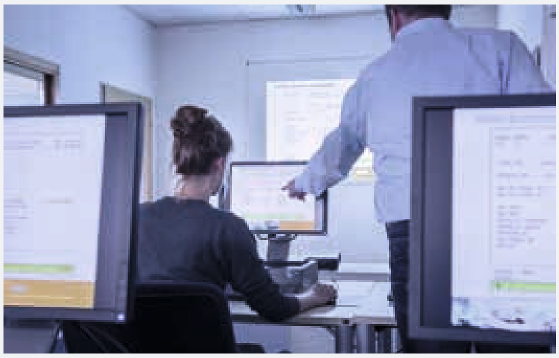
Kiel Engine Training Center

The Caterpillar Engine Training Center in Kiel / Germany provides customized engine training for customer and dealer personnel.

The courses can refer individually to your engine application, but also to all current engine types, new technologies and control and monitoring systems.

All courses are on request and held in small groups from four up to eight people.



For further information, course contents, open training slots and other questions please contact:
Training_Center_Kiel@cat.com

DNV·GL

MANAGEMENT SYSTEM CERTIFICATE

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

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

Valid:
26. October 2016 - 07. October 2019

This is to certify that the management system of

Caterpillar Motoren GmbH & Co. KG

Falckensteiner Str. 2, 24159 Kiel, Germany

and the sites as mentioned in the appendix accompanying this certificate

has been found to conform to the Management System standards:

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

This certificate is valid for the following scope:

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

Place and date:
Essen, 26. October 2016

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

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

Thomas Beck
Technical Manager

Lack of fulfilment of conditions as set out in the Certification Agreement may render this Certificate invalid.
ACCREDITED UNIT: DNV GL Business Assurance Zertifizierung und Umweltgutachter GmbH, Schnieringshof 14, 45329 Essen, Germany.
TEL:+49 201 7296-222. www.dnvgl.de/assurance

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1.1 Definitions

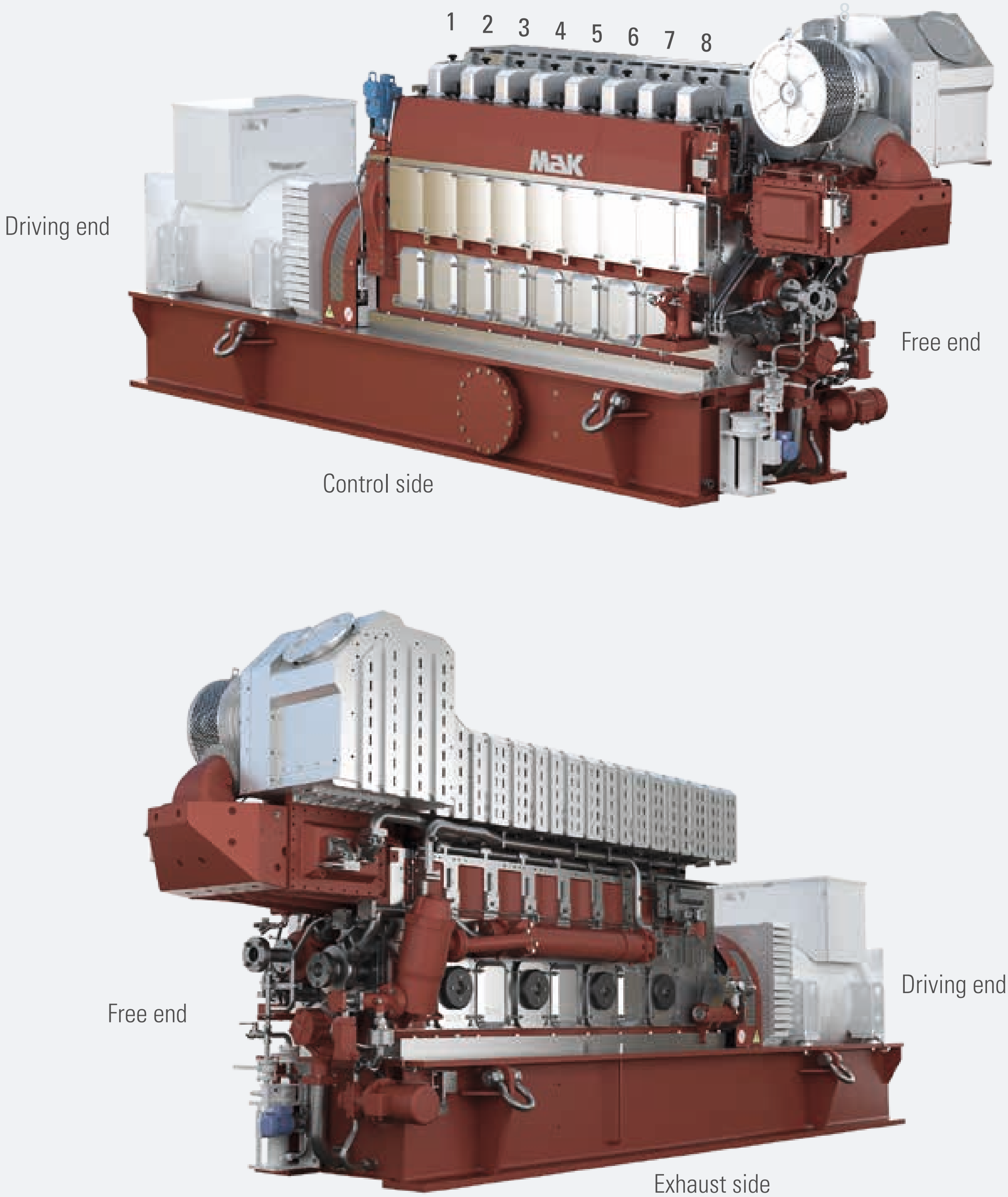

Fig. 1-1 M 20 C

	6 M 20 C	8 M 20 C	9 M 20 C
Output [kW]	1,080/1,200	1,440/1,600	1,620/1,800

Cylinder configuration:	6, 8, 9 in-line
Bore:	200 mm
Stroke:	300 mm
Stroke / bore-ratio:	1.5
Output/cyl:	180/200 kW
BMEP:	25.5 bar
Revolutions:	900/1,000 rpm
Mean piston speed:	9.0/10.0 m/s
Turbocharging:	single log
Direction of rotation:	counter-clockwise, option: clockwise

1.2 Main components and systems

1.2.1 Main features and characteristics

Developed and designed in response to the special requirements of marine applications, the most striking features of this engine are its high reliability and economy. These features help to explain the continued high market demand for the M 20 C as an engine for both marine propulsion and marine generator sets. The long-stroke design principle is the backbone of an excellent combustion process with low fuel and lube oil consumption, as well low NO_x emission. The M 20 C engine is SOLAS compliant. Its intelligent simplicity means the high functional integration of fewer components. Fewer components mean greater reliability and easier maintenance.
Overall, this leads to outstandingly low operating costs and rapid returns on investment. Reliability and ease of maintenance are convincing arguments in favour of the engines of this series.

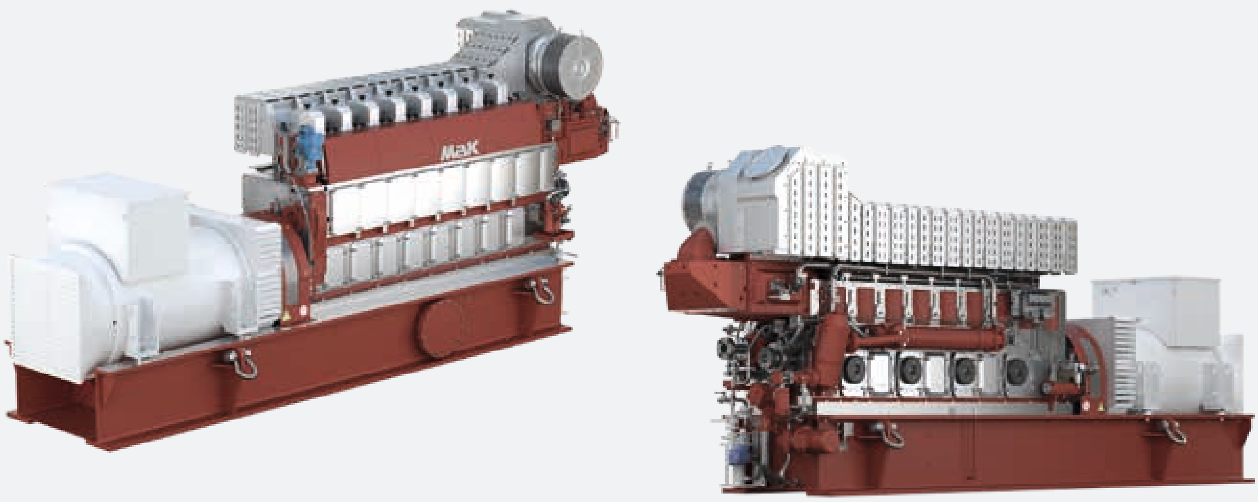

Fig. 1-2 M 20 C Generator Set

1.2.2 Description of components

- Designed for heavy fuel operation up to 700 cSt/50°C
- One-piece dry engine block made of nodular cast iron. It includes the crankshaft bearings, camshaft bearings, charge air duct, vibration damper housing and gear drive housing.
- Underslung crankshaft with corrosion resistant main and big end bearing shells.
- Natural hardened liners, centrifugally cast, with calibration insert.
- Composite type pistons with steel crown and aluminium skirt.
- Piston ring set consisting of two chromium plated compression rings, first ring with chromium-ceramic layer and one chromium plated oil scraper ring. All ring grooves are hardened and located in the steel crown.
- Two-piece connecting rod, fully machined, obliquely split with serrated joint.
- Cylinder head made of nodular cast iron with two inlet and two exhaust valves with valve rotators. Directly cooled exhaust valve seats.
- Camshaft consisting of individual cylinder sections allowing a removal of the pieces sideways.
- Turbocharger supplied with integrated plain bearings lubricated by engine lube oil system.
- No water cooling for turbocharger.
- Singe stage charge air cooler in LT circuit.
- Nozzle cooling for heavy-fuel operation with engine lube oil.

1.3 Prospective life times

General

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

Core components	Life time operating hours [h]		
	M 20 C Generator Set		
	MDO	HFO	TBO M 20 C
Piston crown (life time incl. 2 stages rework)	–	–	–
Piston skirt cast iron (standard)	–	–	–
Piston skirt steel (optional)	–	–	–
Piston skirt Aluminium	60,000	60,000	–
Piston rings	30,000	30,000	–
Piston pin bearing	60,000	60,000	–
Cuff / Antipolishing ring	30,000	30,000	–
Cylinder liner	90,000	60,000	–
Cylinder head	90,000	90,000	15,000
Inlet valve	30,000	30,000	15,000
Exhaust valve	30,000	30,000	15,000
Nozzle element	7,500	5,000	–
Pump element	15,000	15,000	–
Main bearing	30,000	30,000	–
Big end bearing	30,000	30,000	–
Camshaft bearing	45,000	45,000	–
Turbocharger plain bearing	12,000	12,000	–
Vibration damper camshaft (Visco)	15,000	15,000	–
Vibration damper crankshaft	–	–	15,000

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

	900 rpm/60 Hz		1,000 rpm/50 Hz	
	Engine [kW]	Generator [kWe]	Engine [kW]	Generator [kWe]
6 M 20 C	1,080	1,037	1,200	1,152
8 M 20 C	1,440	1,382	1,600	1,536
9 M 20 C	1,620	1,555	1,800	1,728

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

2.1 General definition of reference conditions

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

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

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

2.2 Reference conditions regarding fuel consumption

Fuel consumption data is based on the following reference conditions:

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

Specification of fuel consumption data without engine driven pumps;
for each engine driven pump an additional brake specific fuel consumption of 1% has to be calculated.

2.3 Lube oil consumption

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

2.4 Emissions

2.4.1 Exhaust gas

Tolerance: ± 10% / ± 20 K Atmospheric pressure: 100 kPa (1 bar) Constant speed

			IMO II, constant speed			
Intake air temperature 25°C						
Output [%]			100	85	75	50
Engine	Speed [rpm]	Output [kW]	Exhaust gas mass flow [kg/h] Exhaust gas temperature after turbocharger [°C]			
6 M 20 C	900	1,080	7,510 355	6,490 360	5,780 370	4,020 385
6 M 20 C	1,000	1,200	8,580 380	7,220 375	6,490 370	4,320 405
8 M 20 C	900	1,440	11,420 300	9,890 295	8,880 300	6,280 330
8 M 20 C	1,000	1,600	11,975 365	10,310 350	9,250 355	6,515 380
9 M 20 C	900	1,620	12,850 325	11,250 315	10,145 315	7,140 335
9 M 20 C	1,000	1,800	13,480 335	11,600 310	10,410 310	7,330 330

Additional information for IMO III applications:
To achieve IMO III emission values, a Caterpillar SCR System has to be used. The allowable exhaust back pressure with an SCR system is 6 kPa total, higher EBP requires a PAR. The SFOC will increase for EBP values above 3 kPa by + 0.33 g/kWh per 10 mbar.
The use of a wastegate might be necessary for IMO III applications especially for HFO use. This will further affect the SFOC and other technical data. Technical data for IMO III applications are available on request.

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

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

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

2.4.2 Nitrogen oxide emissions (NO_x-values)

NO_x-limit values according to IMO II:	8.98 g/kWh (n=1,000 rpm)
Constant speed main propulsion acc. to cycle E2:	8.90 g/kWh
Genset acc. cycle D2:	8.80 g/kWh

2.4.3 Engine International Air Pollution Prevention Certificate

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

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

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

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

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

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

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.
The M 20 C propulsion engine has a calculated and guaranteed EEDI of 201.2 g/kWh (*), based on one specific IMO group.

(*) 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 Genset dimensions and weight

Turbocharger at free end

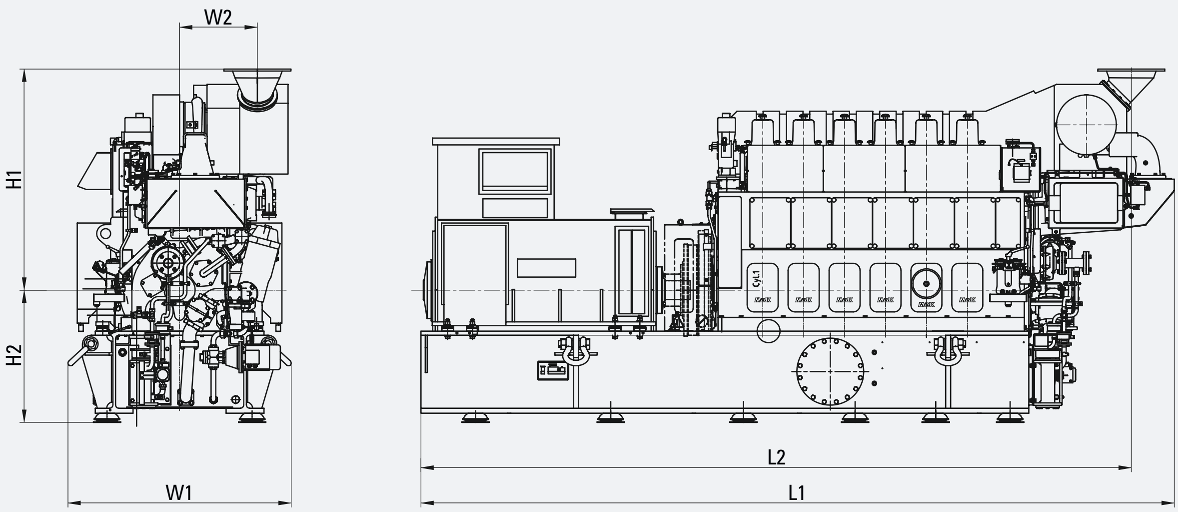

Fig. 2-1 Turbocharger at free end

	Dimensions [mm]						Dry weight *)
	L1	L2	H1	H2	W1	W2	[t]
6 M 20 C	6,073	5,727	1,779	1,065	1,800	627	21.2
8 M 20 C	6,243	5,897	1,955	1,065	1,800	710	23.1
9 M 20 C	7,438	7,116	1,955	1,065	1,800	710	26.0

*) Depending on generator weight

Prime mover and generator are always flexibly coupled.

Genset center distance

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

6/8/9 M 20 C min. 2,010 mm

Note: The required center distance can be increased by generator dimensions.

2.6 System connecting points

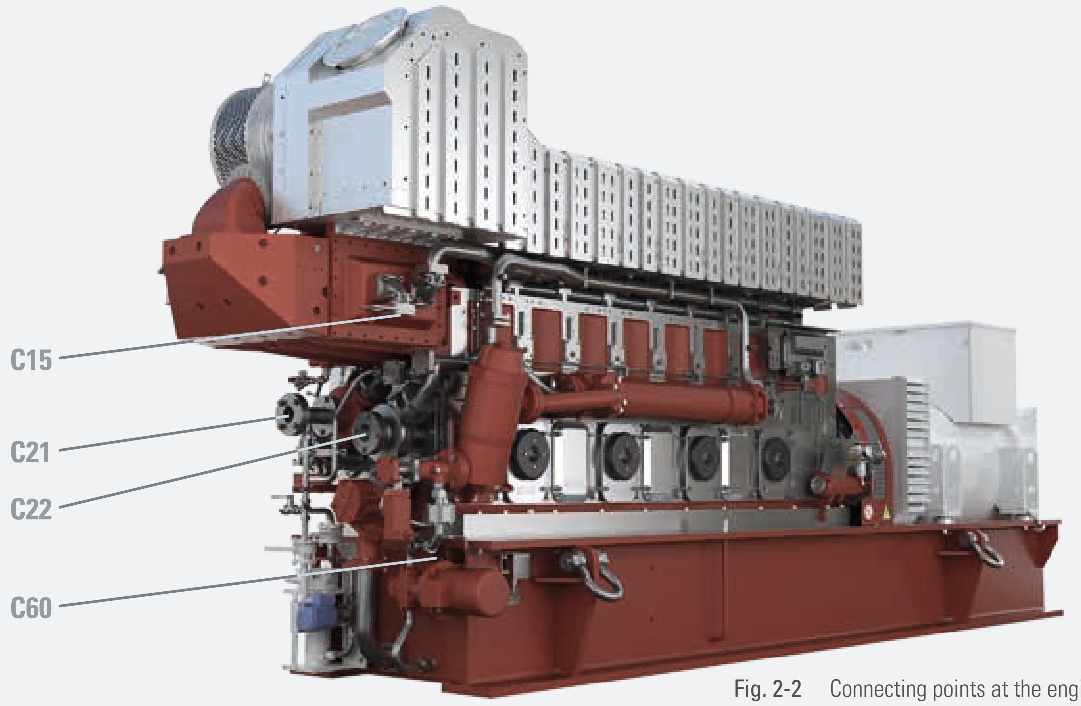

Fig. 2-2 Connecting points at the engine – 1

C15	Charge cooler LT, outlet	C22	Fresh water pump LT, inlet
C21	Fresh water pump HT, inlet	C60	Separator connection, suction side

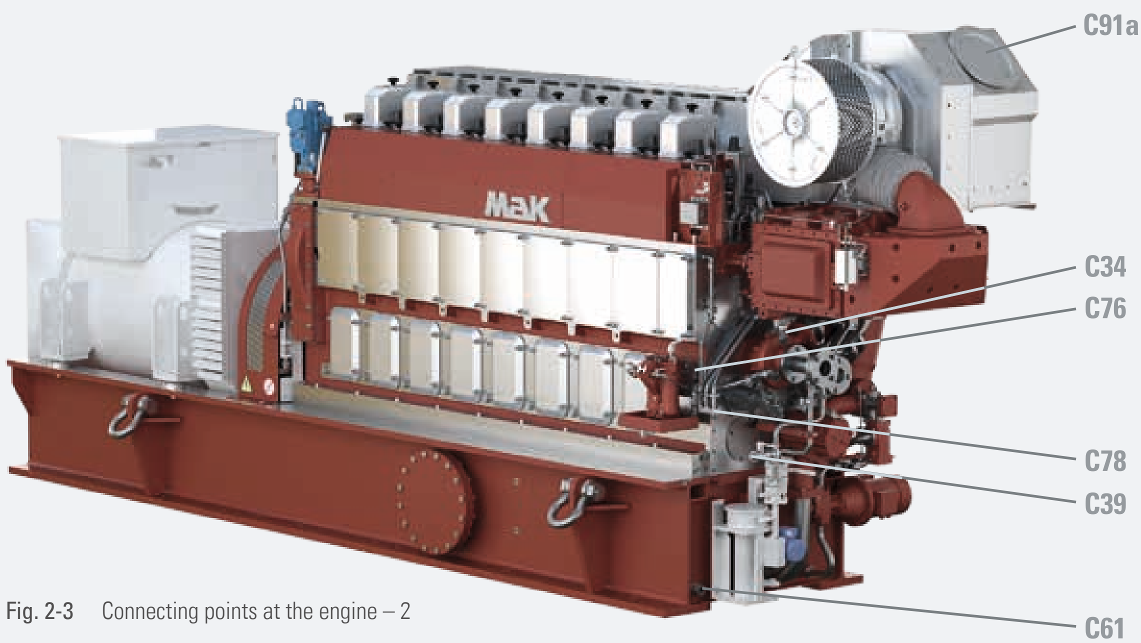

Fig. 2-3 Connecting points at the engine – 2

C34	Drain, charge air cooler	C76	Inlet duplex filter
C39	Drain	C78	Fuel outlet
C61	Separator connection, delivery side	C91a	Exhaust gas outlet

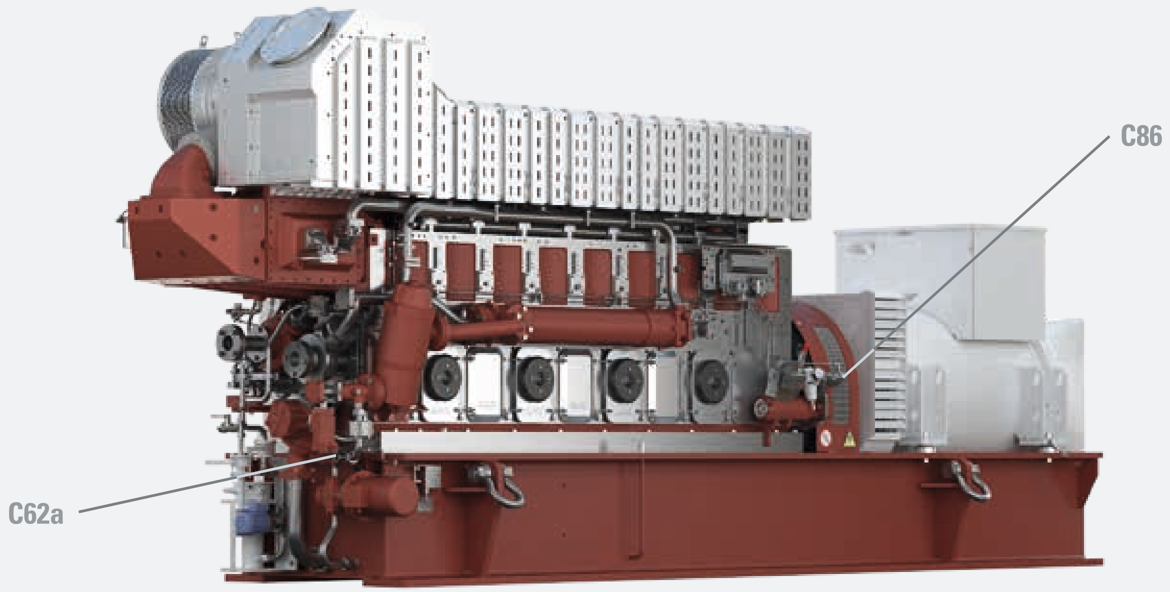

Fig. 2-4 Connecting points at the engine – 3

C62a	Oil drain, prelubricating pump	C86	Starting air, connection

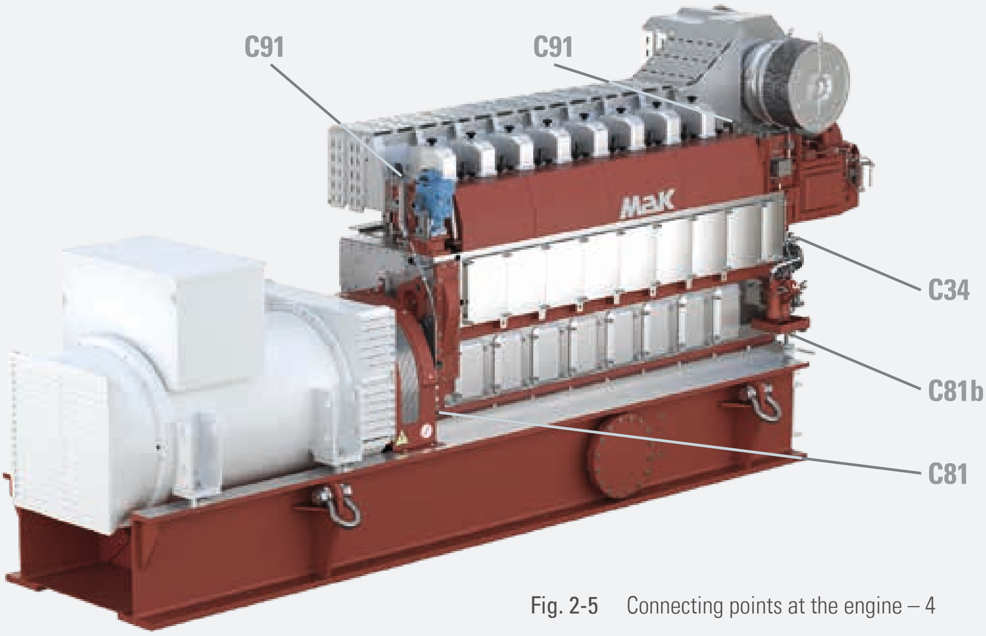

Fig. 2-5 Connecting points at the engine – 4

C34	Drain, charge air cooler	C81b	Drip fuel connection (filter pan)
C81	Drip fuel connection	C91	Crankcase ventilation to stack

3.1 Diesel, mechanical – 6 M 20 C

This table does only contain IMO II data.

6 M 20 C				
Performance data				
Maximum continuous rating acc. ISO3046/1[1)]		[kW]	1,200	1,080
Maximum electrical power (depending on generator efficiency)		[kWe]	1,151	1,036
Speed (nominal)		[1/min]	1,000	900
Minimum speed		[1/min]	300	280
Brake mean effective pressure		[bar]	25.5	
Operation curve / Limit curve		[Hz]	50	60
Brake specific fuel oil consumption				
see notes [1) 2) 7)] for details	100 %	[g/kWh]	192	191
	85 %	[g/kWh]	190	189
	75 %	[g/kWh]	190	
	70 %	[g/kWh]	191	
	60 %	[g/kWh]	195	196
	50 %	[g/kWh]	202	203
Brake specific energy consumption				
see notes [1) 2) 7)] for details	100 %	[kJ/kWh]	8,198	8,156
	85 %	[kJ/kWh]	8,113	8,070
	75 %	[kJ/kWh]	8,113	
	70 %	[kJ/kWh]	8,156	
	60 %	[kJ/kWh]	8,327	8,369
	50 %	[kJ/kWh]	8,625	8,668
Specific lube oil consumption [3)]	100 %	[g/kWh]	0.6	
NO_x-emission limit [6)]		[g/kWh]	8.98	9.2
Charge air system				
Charge air demand (ISO 25°C) [4)]		[kg/h]	8,350	7,320
Max. turbocharger inlet air temperature		[°C]	50	
Max. air inlet pressure drop		[kPa]	1.5	
Charge air control			WG/BoV/CBV/FCT: no/no/no/no	
Turbocharger			KBB HPR4000	
Fuel				
Engine driven booster pump		[m³/h/bar]	1.2/5.0	
Independent booster pump		[m³/h/bar]	0.9/5.0	0.8/5.0
Mesh size primary filter MDO/HFO		[μm]	320	
Mesh size fine filter MDO/HFO		[μm]	25/34	
Mesh size HFO automatic filter		[μm]	10	
HFO capability			yes	
Crude oil capability			yes	

6 M 20 C			
Lubricating oil			
Engine-driven pressure pump	[m³/h/bar]	58.8/10.0	52.5/10.0
Independent pressure pump	[m³/h/bar]	50/8.0	
Priming pump	[m³/h/bar]	5.0/5.0	
Lubricating oil pressure (min/max)	[bar]	4.0/5.0	
Lube oil circulation tank (capacity/filling)	[m³]	2.0/1.7	1.8/1.5
Lube oil temperature (min/max)	[°C]	55/65	
Mesh size lube oil automatic filter	[µm]	30	
Cooling water – fresh water			
Cooling water content engine	[dm³]	120	
Cooling water header tank capacity	[dm³]	100	
Header tank pos. above CS (min/max)	[m]	4/16	
Cooling water pressure (min/max)	[bar]	2.5/6.0	
Cooling water temperature (min/max)	[°C]	80/90	
Engine-driven HT pump (capacity/pressure)	[m³/h/bar]	30/4.2	25/3.4
Independent HT pump (capacity/pressure)	[m³/h/bar]	30/4.0	
Temperature at LT CAC inlet	[°C]	38	
HT temperature regulating valve size	[mm]	50	
Exhaust gas			
Silencer / spark arrestor diameter	[mm]	400	
Exhaust pipe diameter after turbocharger	[mm]	400	
Max. exhaust TOTAL back pressure from system [8)]	[mbar]	35	
Recom. max. flow velocity in exhaust system	[m/s]	40	
Starting air			
Min. ambient temperature	[°C]	10	
Starting air pressure (min/max)	[bar]	7.0/30.0	
Starting air consumption (preheated engine)	[m³/start]	0.5	
Required air quality acc. to ISO8573-1		Class 4	
Crankcase ventilation			
Vent. pipe - nominal size		50 mm (max. pressure 0.25 kPa)	

6 M 20 C										
Heat rejection (inlet air acc. to ISO) [4]		100%		85%		75%		50%	
Jacket water (engine only)	[kW]	175	155	150	135	135	120	105	95
Charge air cooler LT [5]	[kW]	440	380	370	330	335	295	220	205
Lubricating oil cooler	[kW]	165	145	150	135	145	135	135	110
Heat radiation engine	[kW]	52		50		48		44	

1) Reference conditions: Please see chapter 2.1 and 2.2 for details. / **2)** BSFC tolerance and attached pumps see chapter 2.2 / **3)** Standard value, tolerance ± 50 %, related on full load / **4)** Please see chapter 2.4.1 for details / **5)** Charge air heat based on 25 °C suction air temperature / **6)** Marpol 73/78, Annex VI, cycle E2/D2 / **7)** Please see chapter 10.3 for varying values / **8)** For values above 35 mbar and below 60 mbar: exhaust stack temperature + 3 K per 10 mbar and fuel consumption + 0.33 g/kWh; values above 60 mbar: PAR required

3.2 Diesel, mechanical – 8 M 20 C

This table does only contain IMO II data.

8 M 20 C				
Performance data				
Maximum continuous rating acc. ISO3046/1 [1)]		[kW]	1,600	1,440
Maximum electrical power (depending on generator efficiency)		[kWe]	1,534	1,381
Speed (nominal)		[1/min]	1,000	900
Minimum speed		[1/min]	300	280
Brake mean effective pressure		[bar]	25.5	
Operation curve / Limit curve		[Hz]	50	60
Brake specific fuel oil consumption				
see notes [1) 2) 7)] for details	100 %	[g/kWh]	192	191
	85 %	[g/kWh]	190	189
	75 %	[g/kWh]	190	
	70 %	[g/kWh]	191	
	60 %	[g/kWh]	195	196
	50 %	[g/kWh]	202	203
Brake specific energy consumption				
see notes [1) 2) 7)] for details	100 %	[kJ/kWh]	8,198	8,156
	85 %	[kJ/kWh]	8,113	8,070
	75 %	[kJ/kWh]	8,113	
	70 %	[kJ/kWh]	8,156	
	60 %	[kJ/kWh]	8,327	8,369
	50 %	[kJ/kWh]	8,625	8,668
Specific lube oil consumption [3)]	100 %	[g/kWh]	0.6	
NO_x-emission limit [6)]		[g/kWh]	8.98	9.2
Charge air system				
Charge air demand (ISO 25°C) [4)]		[kg/h]	11,670	11,165
Max. turbocharger inlet air temperature		[°C]	50	
Max. air inlet pressure drop		[kPa]	1.5	
Charge air control			WG/BoV/CBV/FCT: no/no/no/no	
Turbocharger			KBB HPR4000	
Fuel				
Engine driven booster pump		[m³/h/bar]	1.2/5.0	
Independent booster pump		[m³/h/bar]	1.2/5.0	1.1/5.0
Mesh size primary filter MDO/HFO		[µm]	320	
Mesh size fine filter MDO/HFO		[µm]	25/34	
Mesh size HFO automatic filter		[µm]	10	
HFO capability			yes	
Crude oil capability			yes	

8 M 20 C			
Lubricating oil			
Engine-driven pressure pump	[m³/h/bar]	58.8/10.0	52.5/10.0
Independent pressure pump	[m³/h/bar]	50/8.0	
Priming pump	[m³/h/bar]	8.0/5.0	
Lubricating oil pressure (min/max)	[bar]	4.0/5.0	
Lube oil circulation tank (capacity/filling)	[m³]	2.7/2.2	2.4/2.0
Lube oil temperature (min/max)	[°C]	55/65	
Mesh size lube oil automatic filter	[μm]	30	
Cooling water – fresh water			
Cooling water content engine	[dm³]	160	
Cooling water header tank capacity	[dm³]	100	
Header tank pos. above CS (min/max)	[m]	4/16	
Cooling water pressure (min/max)	[bar]	2.5/6.0	
Cooling water temperature (min/max)	[°C]	80/90	
Engine-driven HT pump (capacity/pressure)	[m³/h/bar]	35/4.2	30/3.4
Independent HT pump (capacity/pressure)	[m³/h/bar]	40/4.0	
Temperature at LT CAC inlet	[°C]	38	
HT temperature regulating valve size	[mm]	65	
Exhaust gas			
Silencer / spark arrestor diameter	[mm]	500	
Exhaust pipe diameter after turbocharger	[mm]	500	
Max. exhaust TOTAL back pressure from system [8)]	[mbar]	35	
Recom. max. flow velocity in exhaust system	[m/s]	40	
Starting air			
Min. ambient temperature	[°C]	10	
Starting air pressure (min/max)	[bar]	7.0/30.0	
Starting air consumption (preheated engine)	[m³/start]	0.5	
Required air quality acc. to ISO8573-1		Class 4	
Crankcase ventilation			
Vent. pipe - nominal size		50 mm (max. pressure 0.25 kPa)	

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8 M 20 C										
Heat rejection (inlet air acc. to ISO) 4)		100%		85%		75%		50%	
Jacket water (engine only)	[kW]	230	210	200	180	180	160	140	125
Charge air cooler LT 5)	[kW]	620	490	535	n.a	480	n.a	335	n.a
Lubricating oil cooler	[kW]	220	200	205	185	190	175	165	150
Heat radiation engine	[kW]	74		72		69		65	

1) Reference conditions: Please see chapter 2.1 and 2.2 for details. / **2)** BSFC tolerance and attached pumps see chapter 2.2 / **3)** Standard value, tolerance ± 50 %, related on full load / **4)** Please see chapter 2.4.1 for details / **5)** Charge air heat based on 25 °C suction air temperature / **6)** Marpol 73/78, Annex VI, cycle E2/D2 / **7)** Please see chapter 10.3 for varying values / **8)** For values above 35 mbar and below 60 mbar: exhaust stack temperature + 3 K per 10 mbar and fuel consumption + 0.33 g/kWh; values above 60 mbar: PAR required

3.3 Diesel, mechanical – 9 M 20 C

This table does only contain IMO II data.

9 M 20 C				
Performance data				
Maximum continuous rating acc. ISO3046/1 [1)]		[kW]	1,800	1,620
Maximum electrical power (depending on generator efficiency)		[kWe]	1,726	1,553
Speed (nominal)		[1/min]	1,000	900
Minimum speed		[1/min]	300	280
Brake mean effective pressure		[bar]	25.5	
Operation curve / Limit curve		[Hz]	50	60
Brake specific fuel oil consumption				
see notes [1) 2) 7)] for details	100 %	[g/kWh]	192	191
	85 %	[g/kWh]	190	189
	75 %	[g/kWh]	190	
	70 %	[g/kWh]	191	
	60 %	[g/kWh]	195	196
	50 %	[g/kWh]	202	203
Brake specific energy consumption				
see notes [1) 2) 7)] for details	100 %	[kJ/kWh]	8,198	8,156
	85 %	[kJ/kWh]	8,113	8,070
	75 %	[kJ/kWh]	8,113	
	70 %	[kJ/kWh]	8,156	
	60 %	[kJ/kWh]	8,327	8,369
	50 %	[kJ/kWh]	8,625	8,668
Specific lube oil consumption [3)]	100 %	[g/kWh]	0.6	
NO_x-emission limit [6)]		[g/kWh]	8.98	9.2
Charge air system				
Charge air demand (ISO 25°C) [4)]		[kg/h]	13,130	12,560
Max. turbocharger inlet air temperature		[°C]	50	
Max. air inlet pressure drop		[kPa]	1.5	
Charge air control			WG/BoV/CBV/FCT: no/no/no/no	
Turbocharger			KBB HPR4000	
Fuel				
Engine driven booster pump		[m³/h/bar]	1.2/5.0	
Independent booster pump		[m³/h/bar]	1.3/5.0	1.2/5.0
Mesh size primary filter MDO/HFO		[µm]	320	
Mesh size fine filter MDO/HFO		[µm]	25/34	
Mesh size HFO automatic filter		[µm]	10	
HFO capability			yes	
Crude oil capability			yes	

9 M 20 C			
Lubricating oil			
Engine-driven pressure pump	[m³/h/bar]	58.8/10.0	52.5/10.0
Independent pressure pump	[m³/h/bar]	50/8.0	
Priming pump	[m³/h/bar]	8.0/5.0	
Lubricating oil pressure (min/max)	[bar]	4.0/5.0	
Lube oil circulation tank (capacity/filling)	[m³]	3.1/2.5	2.8/2.3
Lube oil temperature (min/max)	[°C]	55/65	
Mesh size lube oil automatic filter	[μm]	30	
Cooling water – fresh water			
Cooling water content engine	[dm³]	180	
Cooling water header tank capacity	[dm³]	100	
Header tank pos. above CS (min/max)	[m]	4/16	
Cooling water pressure (min/max)	[bar]	2.5/6.0	
Cooling water temperature (min/max)	[°C]	80/90	
Engine-driven HT pump (capacity/pressure)	[m³/h/bar]	40/4.2	35/3.4
Independent HT pump (capacity/pressure)	[m³/h/bar]	45/4.0	
Temperature at LT CAC inlet	[°C]	38	
HT temperature regulating valve size	[mm]	65	
Exhaust gas			
Silencer / spark arrestor diameter	[mm]	500	
Exhaust pipe diameter after turbocharger	[mm]	500	
Max. exhaust TOTAL back pressure from system [8)]	[mbar]	35	
Recom. max. flow velocity in exhaust system	[m/s]	40	
Starting air			
Min. ambient temperature	[°C]	10	
Starting air pressure (min/max)	[bar]	7.0/30.0	
Starting air consumption (preheated engine)	[m³/start]	0.5	
Required air quality acc. to ISO8573-1		Class 4	
Crankcase ventilation			
Vent. pipe - nominal size		50 mm (max. pressure 0.25 kPa)	

9 M 20 C									
Heat rejection (inlet air acc. to ISO) [4]		100%		85%		75%		50%	
Jacket water (engine only)	[kW]	260	235	225	200	200	180	160	140
Charge air cooler LT [5]	[kW]	690	565	595	495	535	440	375	305
Lubricating oil cooler	[kW]	250	225	230	205	215	195	190	170
Heat radiation engine	[kW]	84		81		79		75	

1) Reference conditions: Please see chapter 2.1 and 2.2 for details. / **2)** BSFC tolerance and attached pumps see chapter 2.2 / **3)** Standard value, tolerance ± 50 %, related on full load / **4)** Please see chapter 2.4.1 for details / **5)** Charge air heat based on 25 °C suction air temperature / **6)** Marpol 73/78, Annex VI, cycle E2/D2 / **7)** Please see chapter 10.3 for varying values / **8)** For values above 35 mbar and below 60 mbar: exhaust stack temperature + 3 K per 10 mbar and fuel consumption + 0.33 g/kWh; values above 60 mbar: PAR required

4.1 Load application and recovery behaviour

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

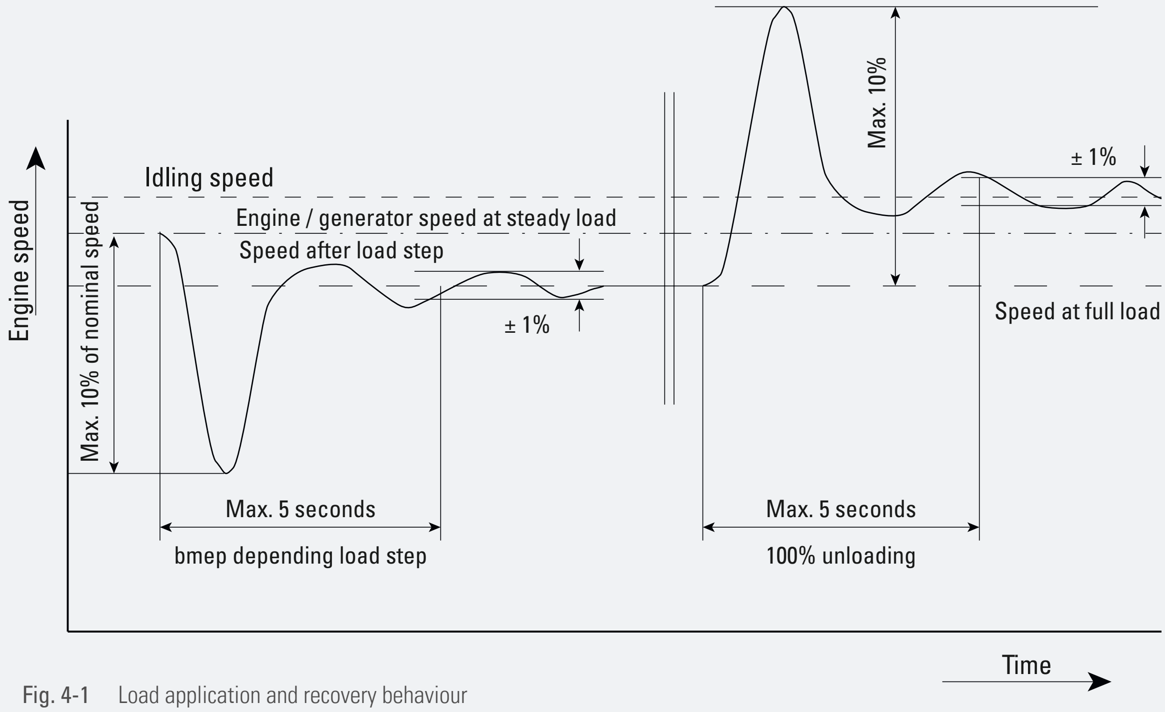

Fig. 4-1 Load application and recovery behaviour

4.1.1 Standard operation

Our standard loading procedure for M 20 C engines to achieve recovery behaviour in accordance with class requirements

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

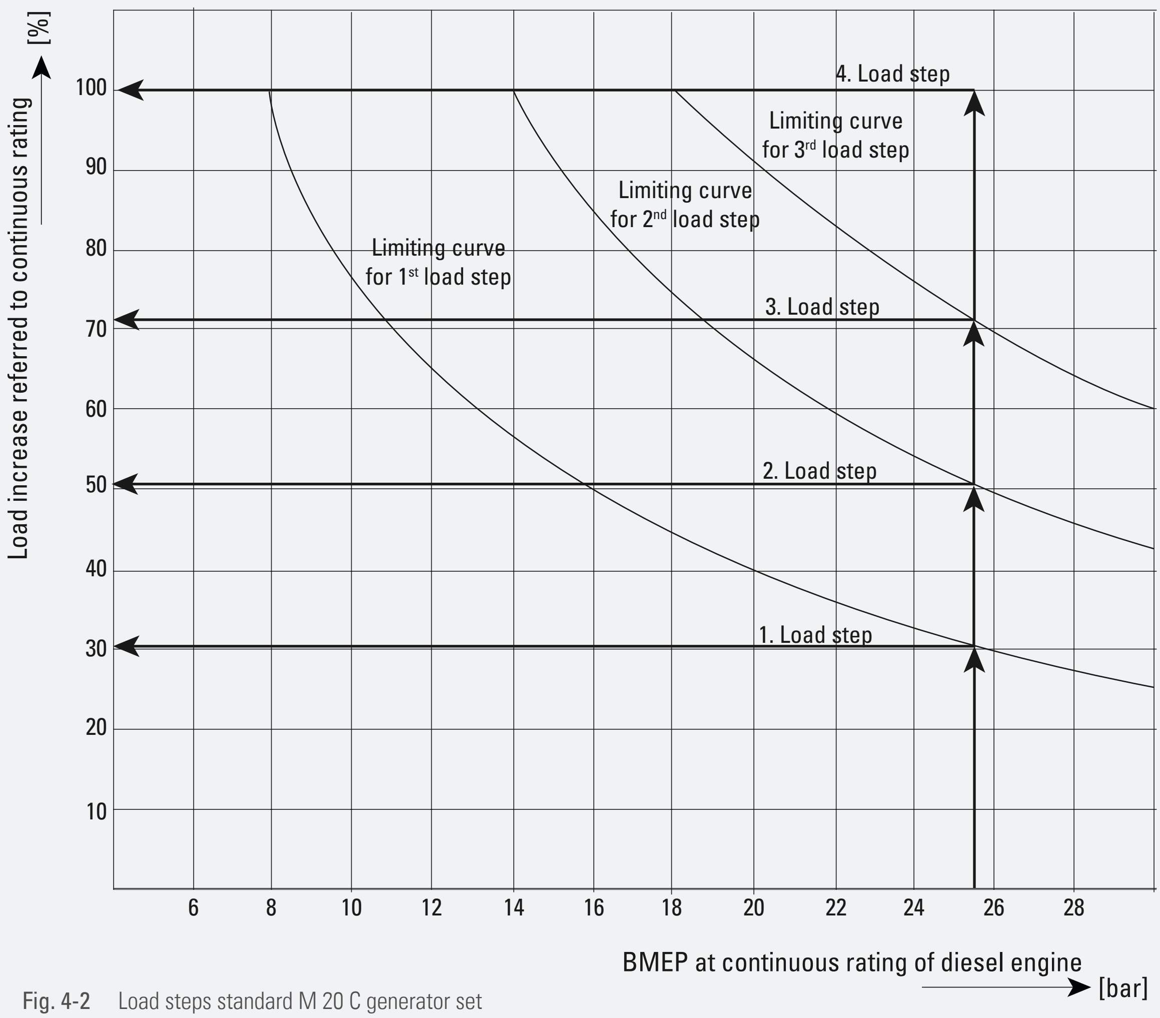

Fig. 4-2 Load steps standard M 20 C generator set

Example: Version standard 6 M 20 C, 1,200 kW, bmep = 25.5 bar
Curves are provided as typical examples.

1. Max. load from 0% to 31% output
2. Max. load from 31% to 51% output
3. Max. load from 51% to 72% output
4. Max. load from 72% to 100% output

4.1.2 Optimized operation

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

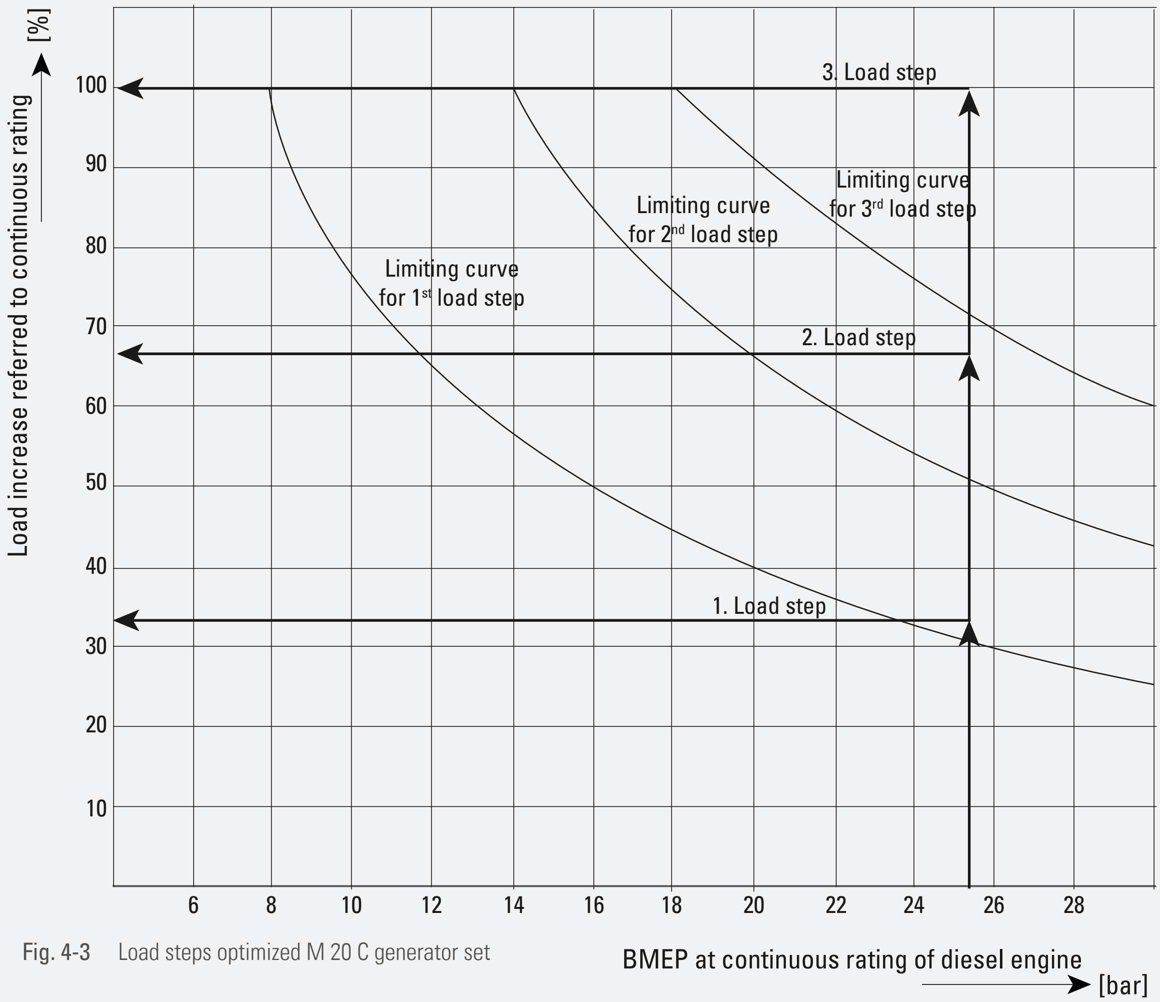

Fig. 4-3 Load steps optimized M 20 C generator set

Example: Version 6 M 20 C, 1,200 kW, bmep = 25.5 bar with air injection
Curves are provided as typical examples.

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

4.2 Restrictions for low load operation

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

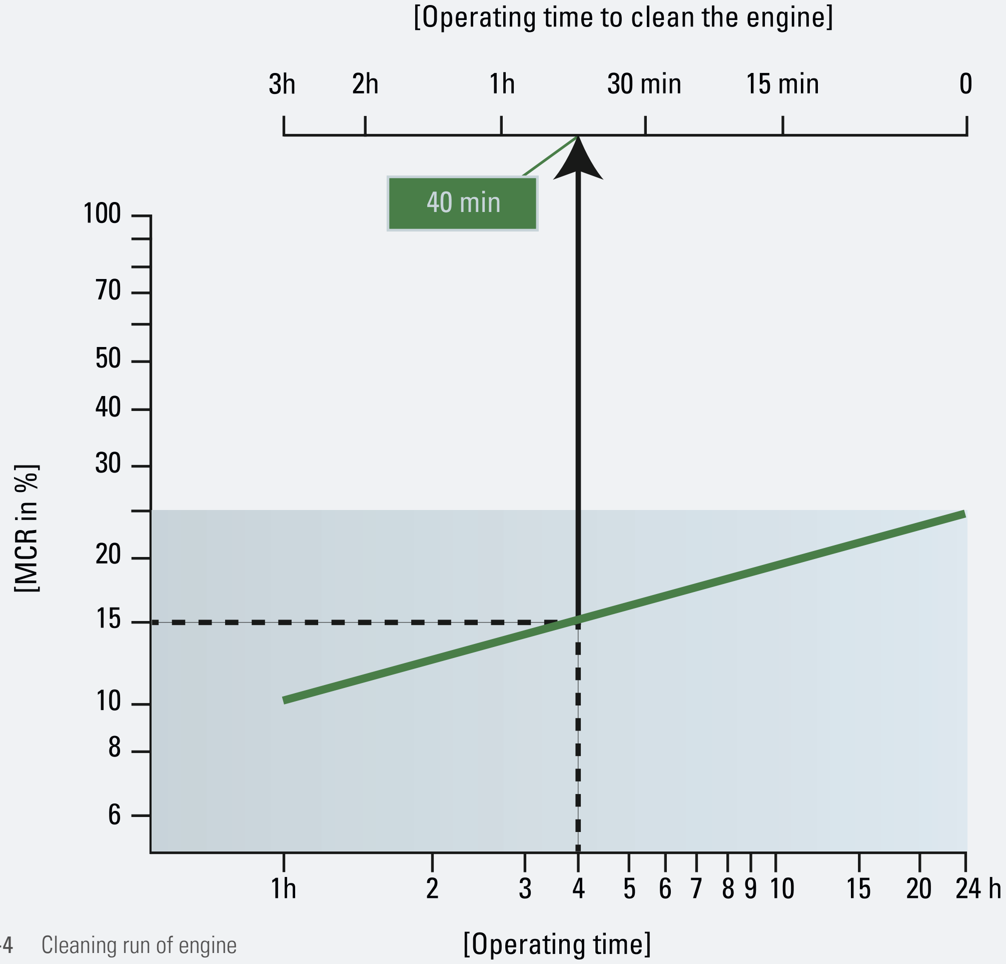

Fig. 4-4 Cleaning run of engine

4.3 Emergency operation without turbocharger

Emergency operation is permissible with MDO only up to approx. 20% 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 °

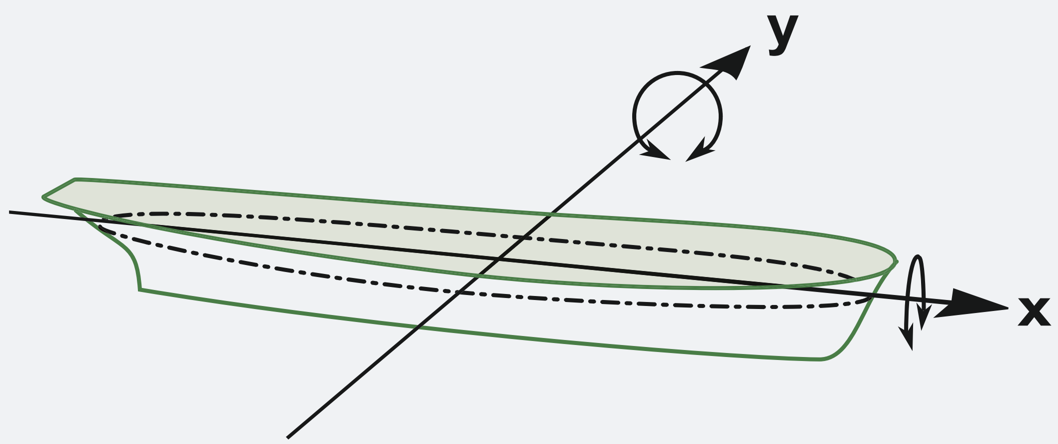

Fig. 4-5 Rotation axis

4.5 Air injection

4.5.1 General

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

Air injection reduces:

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

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

4.5.2 Brief description

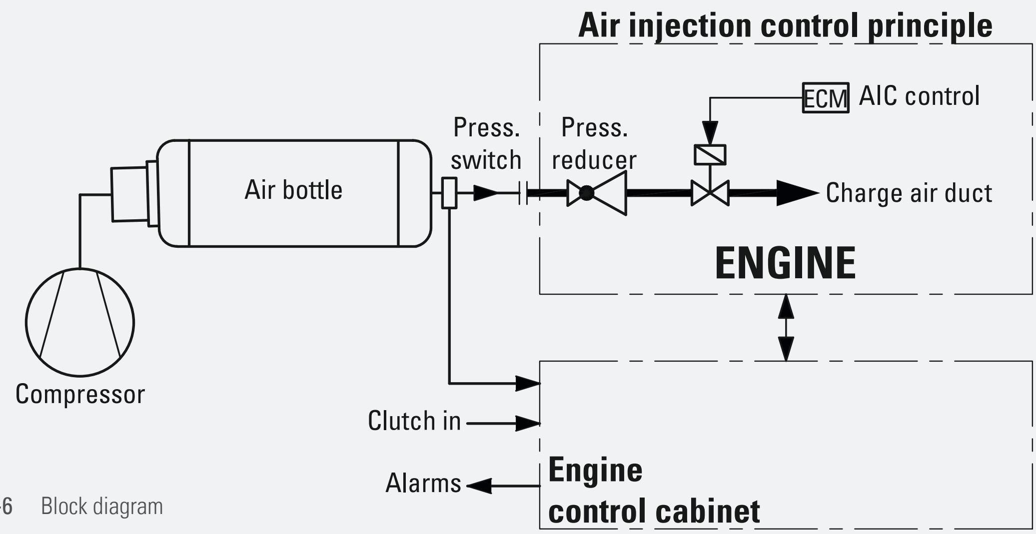

Fig. 4-6 Block diagram

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

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

4.5.3 Calculation of air consumption for air injection

The needed air volume for the air injection operation depends on the specific project application and engine type. The air pressure of the inserted air can be adjusted (recommended between 5 to 8 bar). The injection time can be set to values between 1 and 8 seconds, default settings are 5 bar and 5 seconds. For M 20 C diesel engines, the air consumption for 1 injection pulse for 5 seconds with 5 bar is approx. 0.75 Nm³.
For a sufficient operation of AIC, the air pressure calculation has to be done accurate and has to be discussed with A&I dept. of Caterpillar Motoren.

Example of air consumption calculation (with separate air supply system):
M 20 C diesel engine application needs 10 pulses of air injection with 5 bar for 5 seconds each per hour.
Calculation (air consumption per second for air injection = 150 l):
Air bottle pressure = 30 bar
5 bar = minimum needed pressure => 25 bar can be used.
150 l x 5 sec. = 0.75 Nm³
1 AIC pulse => 0.75 Nm³, 10 AIC pulse => 10 x 0.75 Nm³ = 7.5 Nm³
7.5 Nm³, 25 bar usable pressure = 300 liter air bottle (7,500 l / 300 l = 25 bar)

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

4.5.4 Acceleration times M 20 C, engine with aMACS

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

Normal operation	n = constant	Acceleration from 10 % to 60 % MCR	30 s	25 s
	n = constant	Acceleration from 60 % to 100 % MCR	50 s	50 s
		Smoke	slightly visible	slightly visible
		Reduction from 100 % to 0 % MCR	20 s	20 s

Remarks:
Acceleration time in seconds, Tol. ± 5 sec., engine warm in operating conditions
Minimum operating time 10 minutes
Lube oil > 50°C
Coolant > 65°C
Start of acceleration at least 10 % MCR, lowest operation point with CPP.
Standard acceleration time will provide longest component lifetimes.
Emergency acceleration possible, but not recommended, due to higher thermal stresses on engine components.

Basic ratings (MCR): 6, 8, 9 M 20 C – 200 kW/Cyl.

5.1 MGO / MDO operation

General

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

5.1.1 Acceptable MGO / MDO characteristics

Two fuel product groups are permitted for MaK engines:

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

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

Marine distillate fuels

Parameter	Unit	Limit	DMX	DMA	DFA	DMZ	DFZ	DMB	DFB
Viscosity at 40 °C	[mm^2/s] [a]	max	5,500	6,000		6,000		11,000	
Viscosity at 40 °C	[mm^2/s]	min	1,400	2,000		3,000		2,000	
Density at 15 °C	[kg/m^3]	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/m^3]	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) mm^2/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.

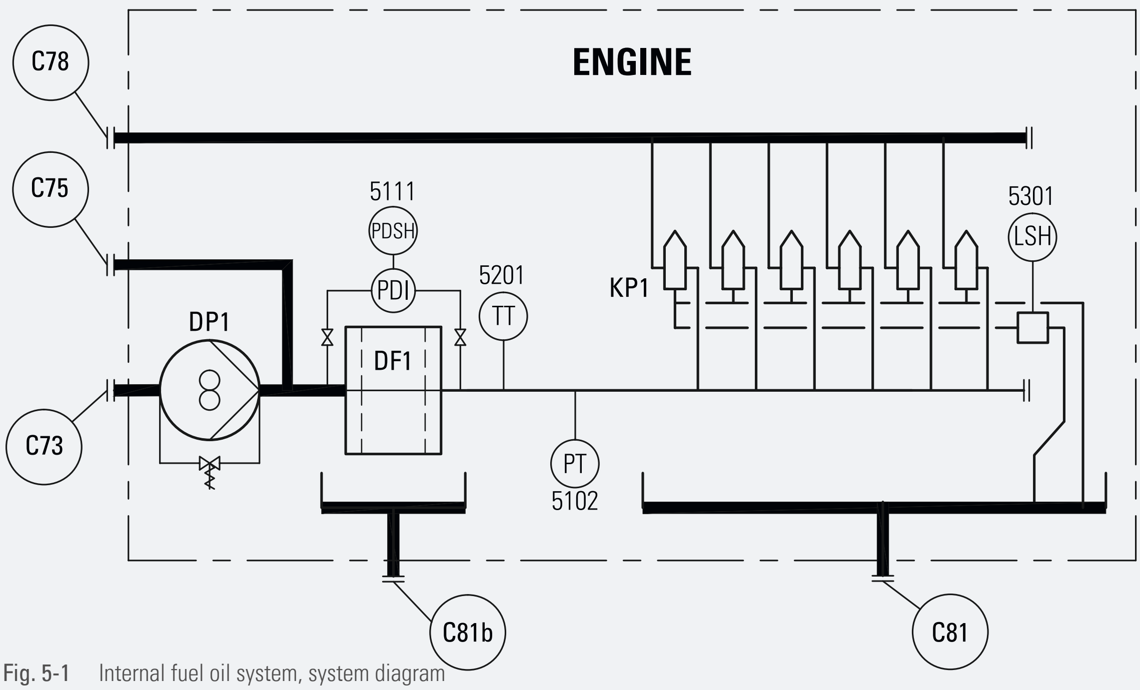

Fig. 5-1 Internal fuel oil system, system diagram

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

Diesel oil feed pump DP1 (fitted)

The engine driven fuel transfer pump DP1 is a gear pump, that delivers the fuel through the filter DF1 to each injector. The fuel transfer pump capacity is slightly oversized to 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 shall be 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.

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5.1.3 External fuel oil system

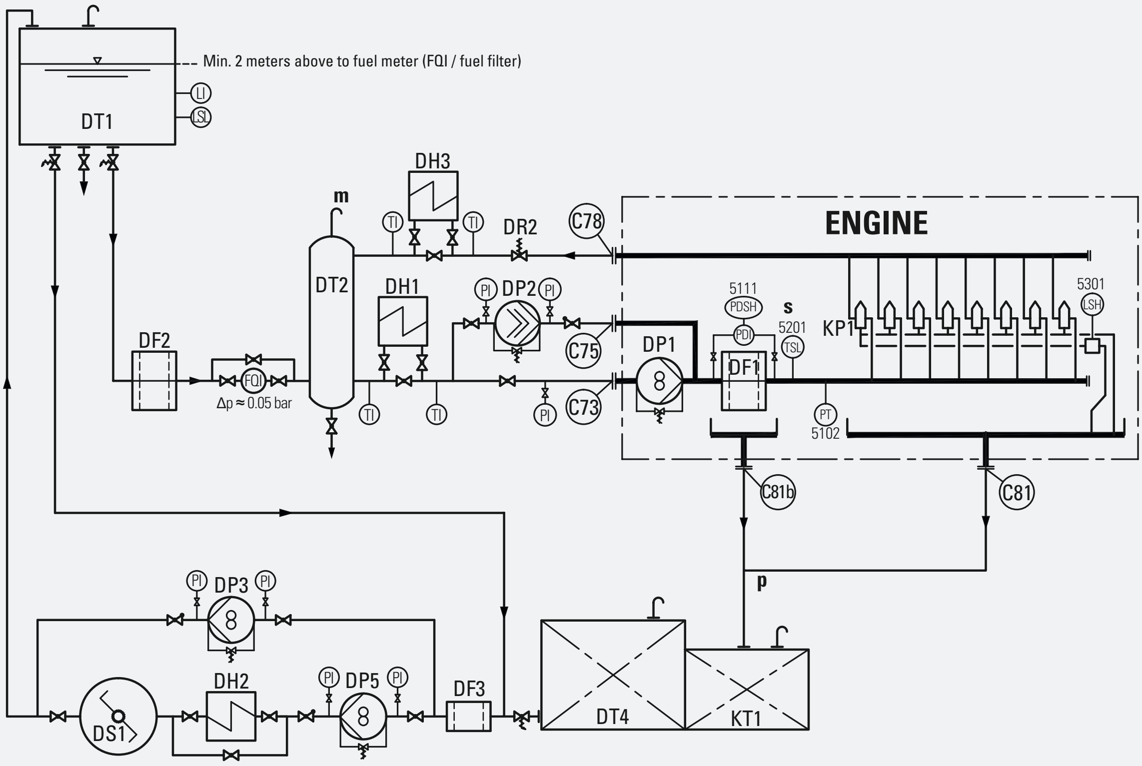


Fig. 5-2 External fuel oil system diagram with intermediate tank

DF1	Fuel fine filter (duplex filter)
DF2	Fuel primary filter (duplex filter)
DF3	Fuel coarse filter
DH1	Fuel oil preheater
DH2	Preheater for fuel oil (separator)
DH3	Fuel 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)
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

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
PT	Pressure transmitter
TI	Temperature indicator
TT	Temperature transmitter

C73	Fuel inlet, to engine fitted pump
C75	Connection, stand-by pump
C78	Fuel outlet
C81	Drip-fuel connection
C81b	Drip-fuel connection (filter pan)

m	Lead vent pipe beyond service tank
p	Free outlet required
s	Please refer to the measuring points list regarding design of the monitoring devices.

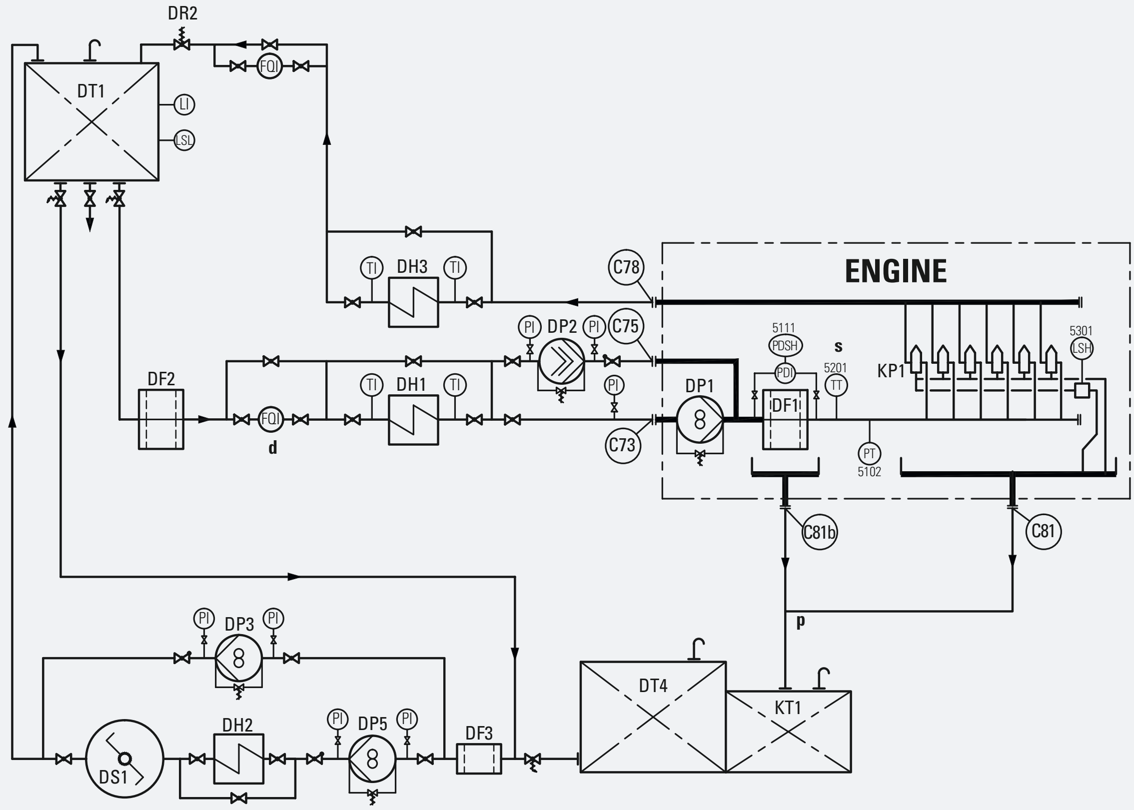


Fig. 5-3 External fuel oil system diagram without intermediate tank

DF1	Fuel fine filter (duplex filter)
DF2	Fuel primary filter (duplex filter)
DF3	Fuel coarse filter
DH1	Diesel oil preheater
DH2	Preheater for uel oil (separator)
DH3	Fuel 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)
DR2	Fuel pressure regulating valve
DS1	Diesel oil separator
DT1	Diesel oil day tank
DT4	Diesel oil storage tank
KP1	Fuel injection pump
KT1	Drip fuel tank
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
PT	Pressure transmitter
TI	Temperature indicator
TT	Temperature transmitter

C73	Fuel inlet, to engine fitted pump
C75	Connection, stand-by pump
C78	Fuel outlet
C81	Drip-fuel connection
C81b	Drip-fuel connection (filter pan)

d	Take care for feeding height
p	Free outlet required
s	Please refer to the measuring points list regarding design of the monitoring devices.

General

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

Diesel oil storage tank DT4

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

Diesel oil separator DS1

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

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

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

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

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

Diesel oil day tank DT1

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

Fuel primary filter (duplex filter) DF2

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

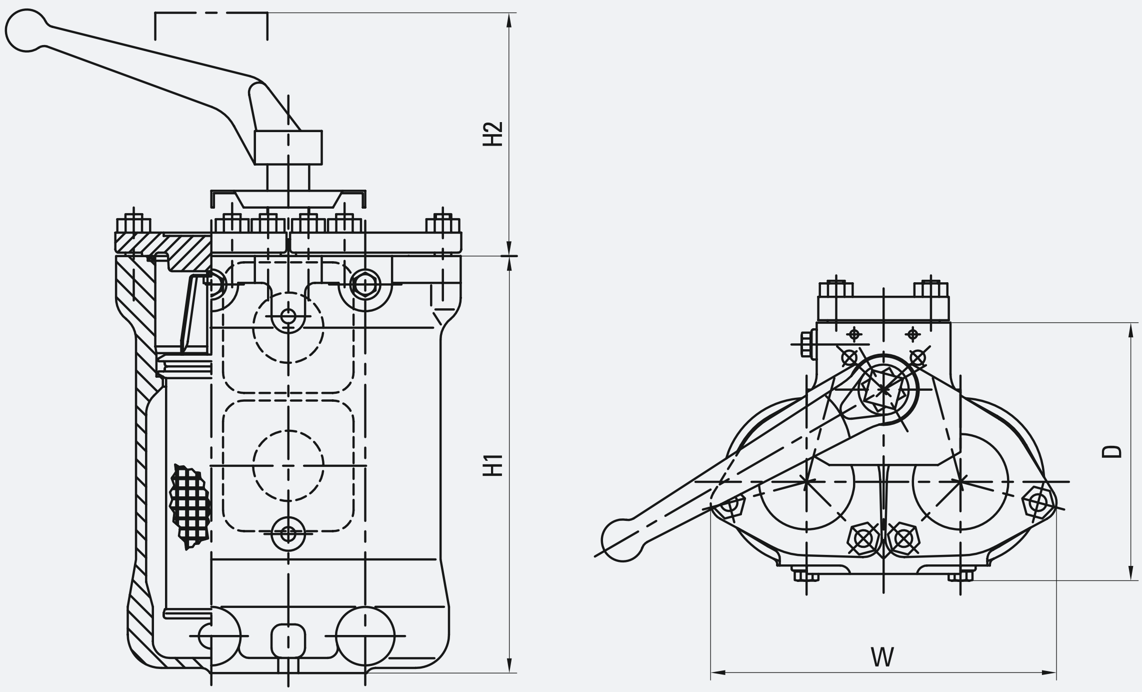


Fig. 5-4 Fuel primary filter DF2

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

Flow quantity indicator FQI

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

Diesel oil intermediate tank DT2

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

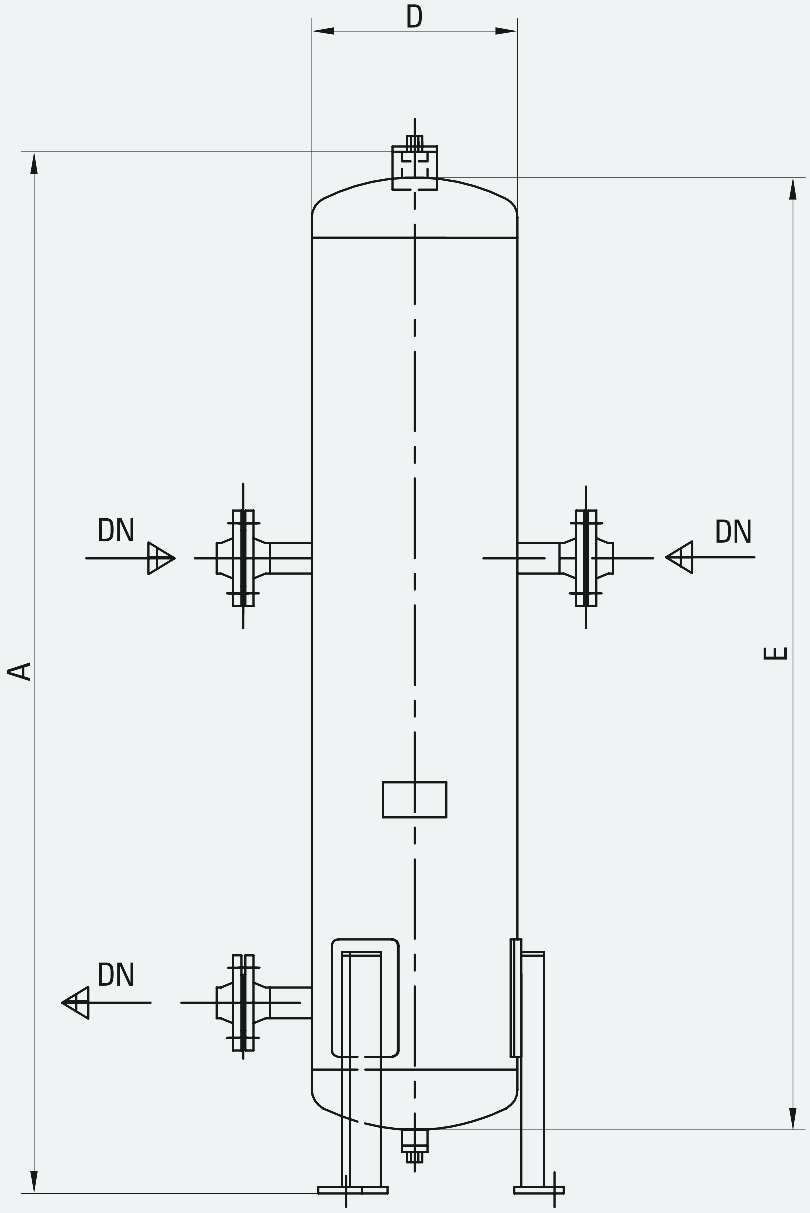


Fig. 5-5 Diesel oil intermediate tank DT2

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

Diesel oil preheater DH1 (hot water - standard)

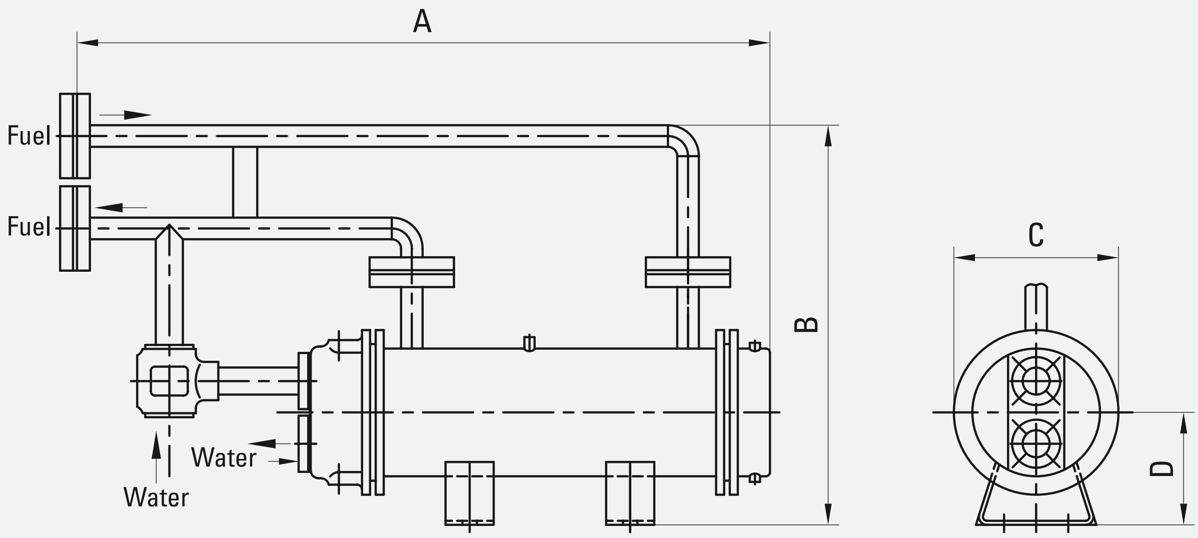


Fig. 5-6 Diesel oil preheater with hot water DH1

	Dimensions [mm]				Weight
	A	B	C	D	[kg]
6/8/9 M 20 C	863	498	Ø 205	140	42

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

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

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

A diesel oil preheater is not required

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

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

Stand-by feed pump DP2 (separate)

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

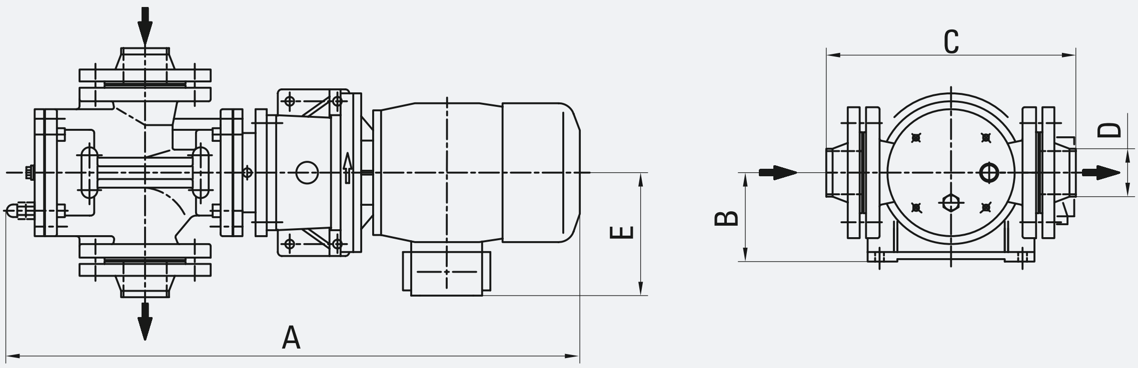


Fig. 5-7 Stand-by feed pump DP2

	Dimensions [mm]					Weight	Motorpower	Voltage / Frequency
	A	B	C	D	E	[kg]	[kW]	[V/Hz]
6 M 20 C	625	112	254	42.4	150	38.0 39.0	0.8 0.9	400/50 440/60
8 M 20 C	625	112	254	42.4	155 150	42.0 39.0	1.1 0.9	400/50 440/60
9 M 20 C	625	112	254	42.4	155 150	42.0 39.0	1.1 0.9	400/50 440/60

Fuel oil cooler DH3

To ensure a fuel oil temperature below 50 °C at any time a cooling of diesel oil may be required.
The need for a fuel cooler is system specific and depends on fuel circuit design and type of fuel oil. In case of more than one engine connected to the same fuel supply system, the MDO-cooler capacity has to be increased accordingly.
The heat transfer load into the diesel oil system is approx. 0.8 kW/cyl.
LT-water is normally used as cooling medium.
Please contact Caterpillar Motoren when using other cooling media.

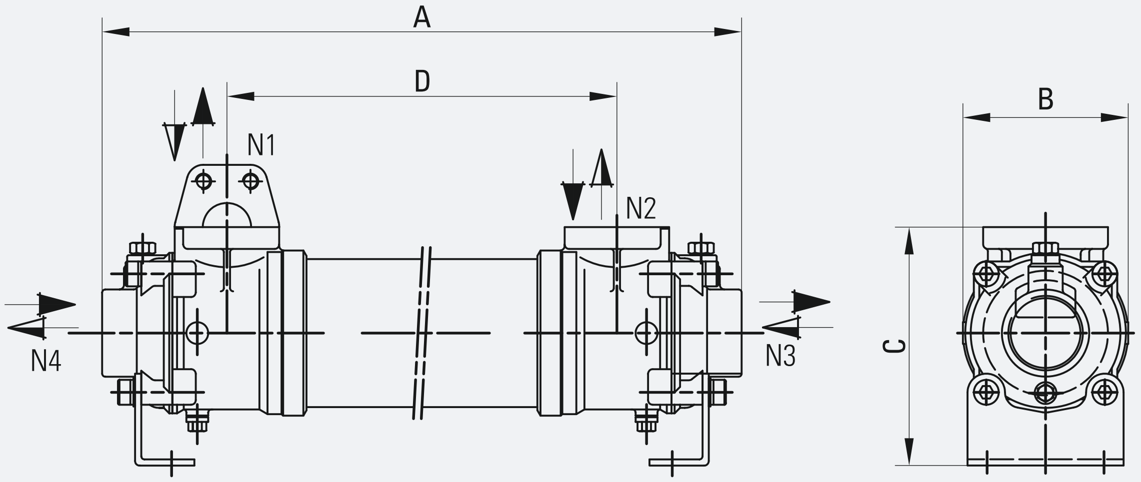


Fig. 5-8 Fuel oil cooler for MDO operation DH3

	Dimensions [mm]						Weight
	A	B	C	D	N1 + N2	N3 + N4	[kg]
6/8/9 M 20 C	710	106	153	550	1 ¼" SAE	1 ½" BSP	16

5.2 HFO operation

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

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

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

Viscosity temperature sheet

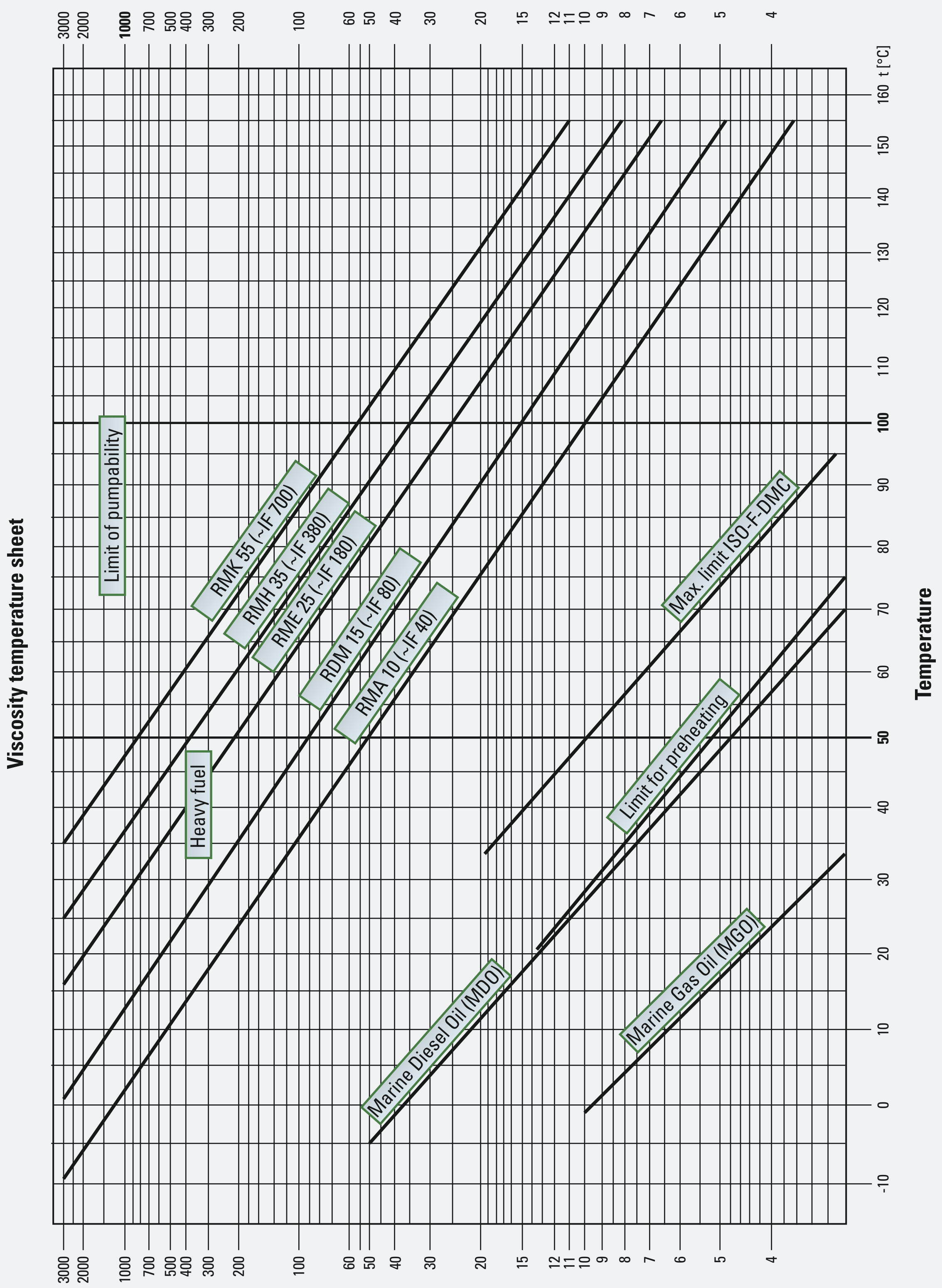


Fig. 5-9 Viscosity / temperature diagram

Fuel oil system

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

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

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

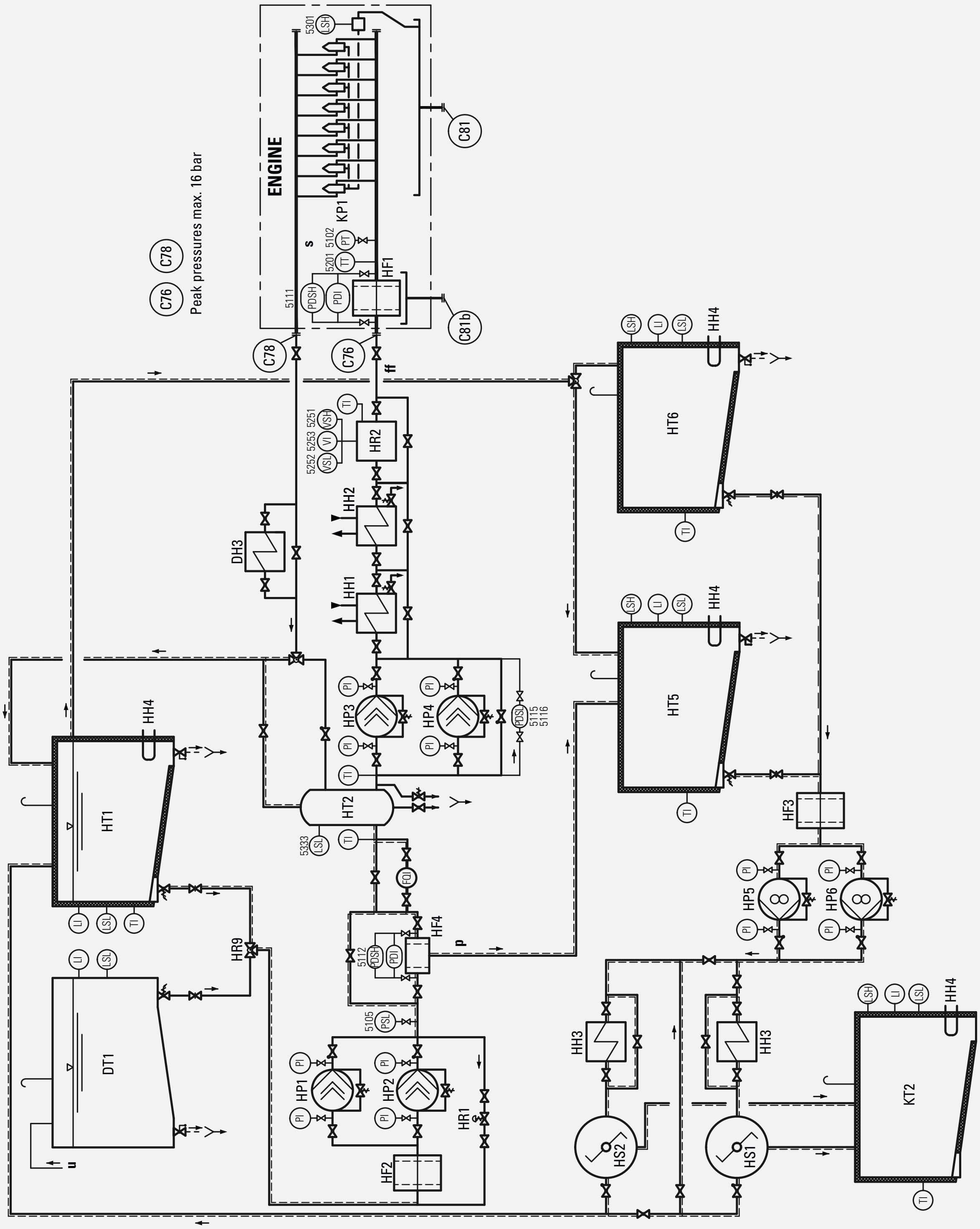
Characteristic	Designation		CIMAC A10	CIMAC B10	CIMAC C10	CIMAC D15	CIMAC E25	CIMAC F25	CIMAC G35	CIMAC H35	CIMAC K35	CIMAC H45	CIMAC K45	CIMAC H55	CIMAC K55
	Related to ISO8217 (10) F-		RMA 30	RMB 30	RMC 30	RMD 80	RME 180	RMF 180	RMG 380	RMH 380	GMK 380	RMH 500	RMK 500	RMH 700	RMK 700
	Dim.	Limit		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

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

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

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

Fig. 5-10 System diagram, HFO operation



General

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

DH3	Fuel oil cooler for MDO operation
DT1	Diesel oil day tank
HF1	Fuel fine filter (duplex filter)
HF2	Fuel primary filter
HF3	Fuel coarse filter
HF4	HFO automatic filter
HH1	Heavy fuel final preheater
HH2	Heavy fuel stand-by final preheater
HH3	Heavy fuel preheater
HH4	Heating coil
HP1	Fuel pressure pump
HP2	Fuel stand-by pressure pump
HP3	Fuel circulating pump
HP4	Fuel stand-by circulating pump
HP5	Heavy fuel transfer pump (separator)
HP6	Heavy fuel stand-by transfer pump (separator)
HR1	Fuel pressure regulating valve
HR2	Viscosimeter
HR9	Fuel change over main valve
HS1/2	Heavy fuel separators 1 and 2
HT1	Heavy fuel day tank
HT2	Mixing tank
HT5/6	Settling tanks 1 and 2
KP1	Fuel injection pump
KT2	Sludge tank

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

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

C76	Inlet, duplex filter
C78	Fuel outlet
C81	Drip-fuel connection
C81b	Drip-fuel connection

ff	Flow velocity in circuit system $\leq$ 0.5 m/s
p	Free outlet required
s	Please refer to the measuring points list regarding design of the monitoring devices.
u	From diesel oil separator or diesel oil transfer pump

Storage tanks

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

Settling tanks HT5, HT6

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

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

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

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

Heavy fuel preheater (separator) HH3

Heavy fuel oil needs to be heated up to a certain temperature before separating.
The most common heaters on board of ships are steam heaters. Other fluid heating sources are hot water, thermal oil or electrical heaters. Overheating of the fuel may cause fuel cracking. Thus the maximum electric load on the heater element should not exceed 1 Watt/cm².
In a cleaning system for HFO the usual processing temperature is 98 °C.
The separator manufacturer’s guidelines have to be observed.

Heavy fuel transfer pumps (separator) HP5, HP6

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

Heavy fuel separators HS1, HS2

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

Separator sizing:

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

$V_{eff.} = 0.28 \cdot P$ (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.

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

5.2.2 Fuel booster and supply system

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

Fuel change over main valve HR9

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

Primary filter (duplex filter) HF2

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

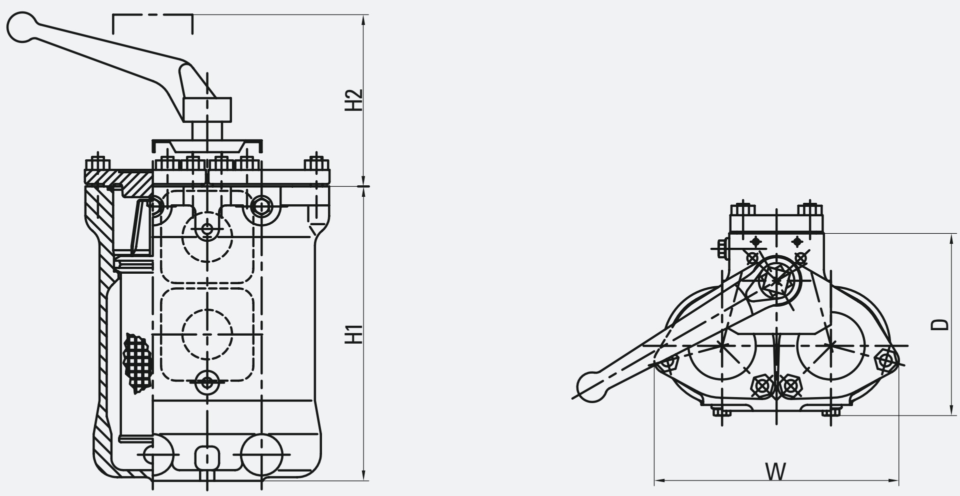


Fig. 5-11 Primary filter HF2

Engine output [kW]	DN	Dimensions [mm]			
		H1	H2	W	D
≤ 5,000	32	249	220	206	159
≤ 10,000	40	330	300	250	189

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]

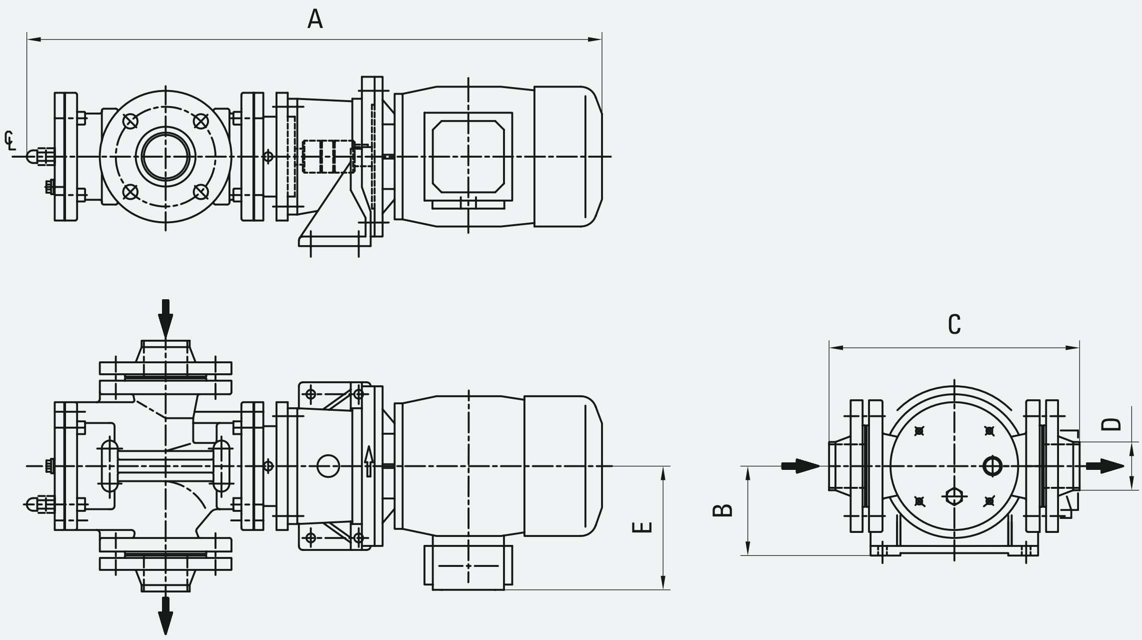


Fig. 5-12 Fuel pressure pump HP1; fuel stand-by pressure pump HP2

Plant output	Dimensions [mm]					Weight	Voltage / frequency
[kW]	A	B	C	D	E	[kg]	[V/Hz]
≤ 1,800	625	112	254	42.4	155	42	400/50 440/60
≤ 3,300	625	112	254	42.4	155	42	400/50 440/60
≤ 4,950	775 705	132 112	314 254	60.3 42.4	180	70.0 57.5	400/50 440/60
≤ 6,600	775	132	314	60.3	180	70	400/50 440/60
≤ 9,900	805 775	132	314	60.3	180	72 70	400/50 440/60

Fuel pressure regulating valve HR1

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

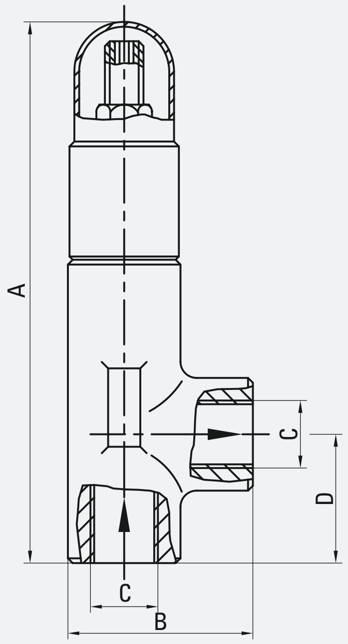


Fig 5-13 Fuel pressure regulating valve HR1, ≤ 3,000 kW

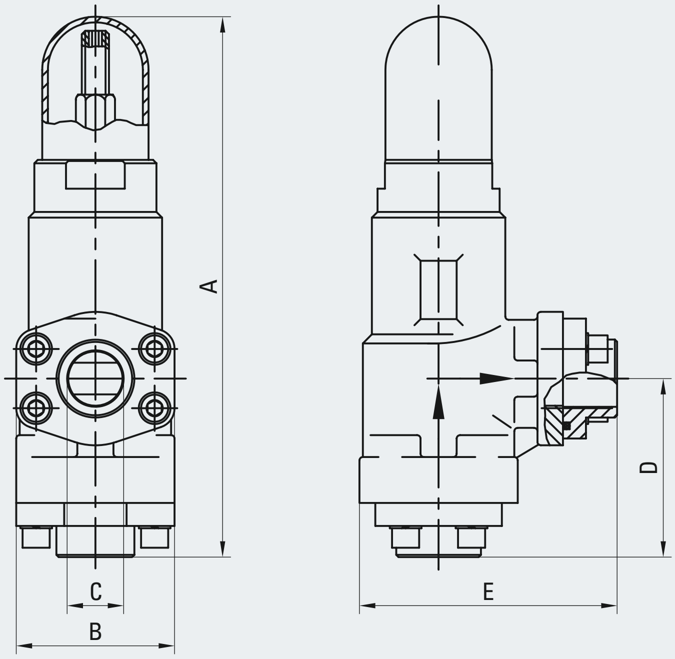


Fig 5-14 Fuel pressure regulating valve HR1, > 3,000 kW

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

HFO automatic filter HF4

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

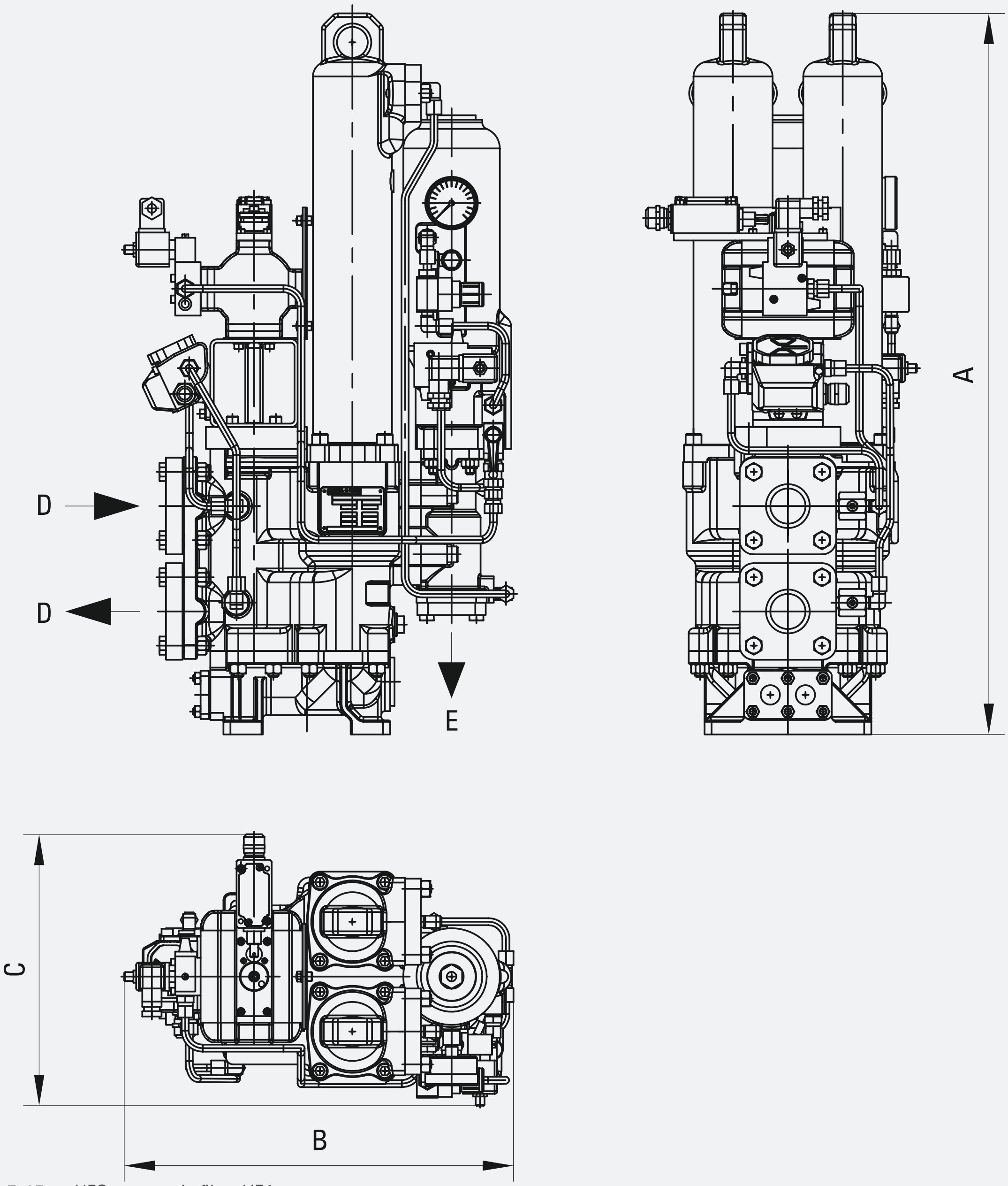


Fig. 5-15 HFO automatic filter HF4

Plant output	Dimensions [mm]				
[kW]	A	B	C	D	E
≤ 4,400	825	445	310	DN 40	DN 32
4,950 - 13,200	890	520	335	DN 65	DN 50

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21

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.

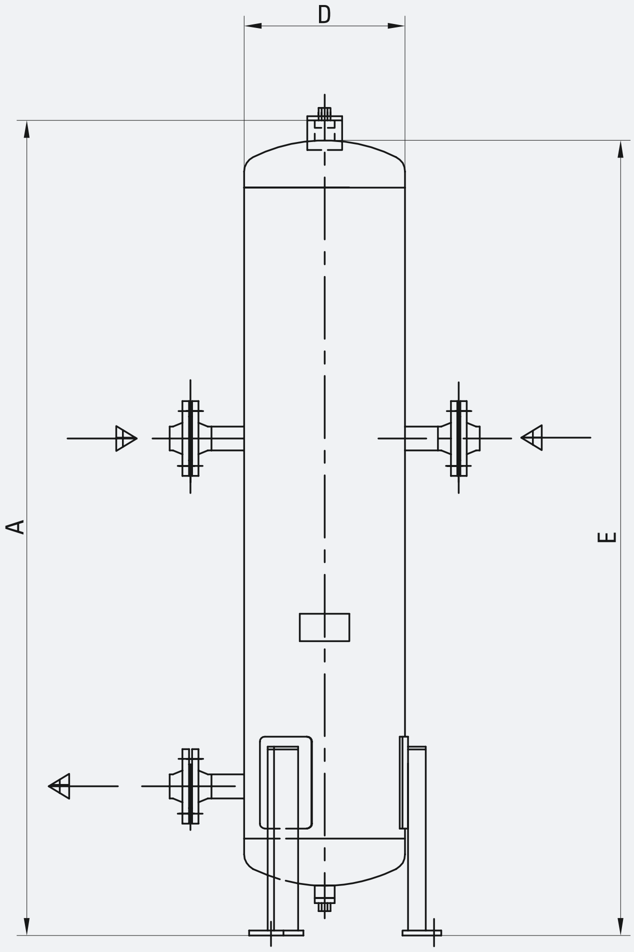

Fig. 5-16 Mixing tank HT2

Plant output	Volume	Dimensions [mm]			Weight
[kW]	[l]	A	D	E	[kg]
≤ 4,000	49	900	323	850	75
≤ 10,000	100	1,640	323	1,600	120
> 10,000	200	1,655	406	1,600	120

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]

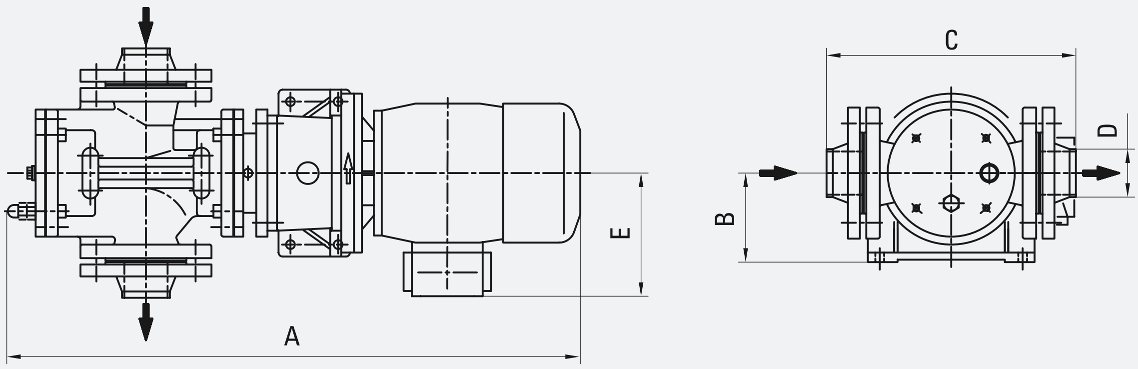

Fig. 5-17 Fuel circulating pump HP3, Stand-by circulating pump HP4

Plant output	Dimensions [mm]					Weight	Voltage / frequency
[kW]	A	B	C	D	E	[kg]	[V/Hz]
≤ 2,800	775 705	132 112	314 254	60.3 42.4	180	70 57	400/50 440/60
≤ 3,300	775	132	314	60.3	180	70	400/50 440/60
≤ 4,950	805	132	314	60.3	180	72 70	400/50 440/60
≤ 6,600	820 805	132	314	60.3	180	80 72	400/50 440/60
≤ 9,900	980 820	160 132	345 314	88.9 60.3	210 190	124 80	400/50 440/60

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

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

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

Heating media:

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

Temperature at engine inlet max. 150 °C

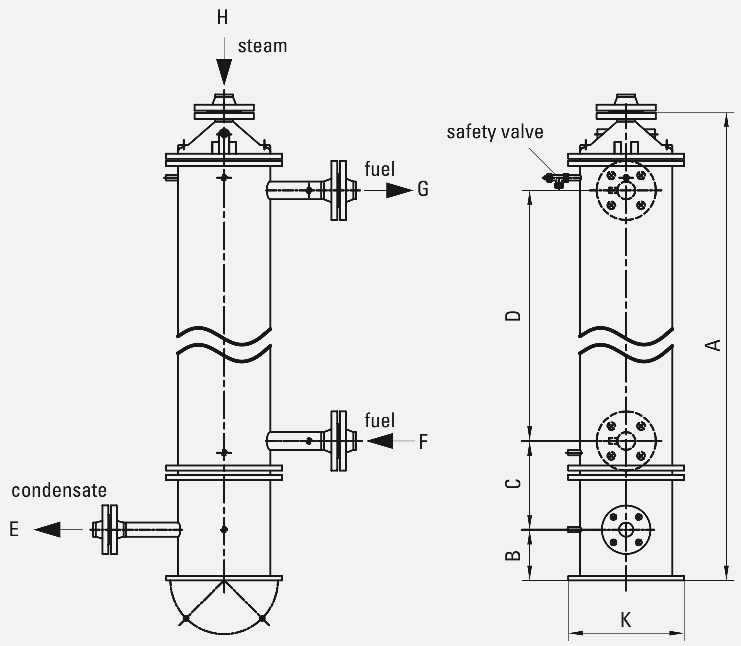

Fig. 5-18 Heavy fuel final preheater HH1, stand-by final preheater HH2 (steam heated)

Plant output	Dimensions [mm]									Weight
[kW]	A	B	C	D	E	F	G	H	K	[kg]
up to 3,300	1,220	120	210	705	DN 25	DN 25	DN 25	DN 32	Ø 275	125
up to 4,950	1,520	120	210	1,005	DN 25	DN 32	DN 32	DN 32	Ø 275	155
up to 8,800	2,065	120	215	1,540	DN 25	DN 40	DN 40	DN 32	Ø 275	272

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. 0.8 kW/cyl.
LT-water is normally used as cooling medium.
Please contact Caterpillar Motoren when using other cooling media.

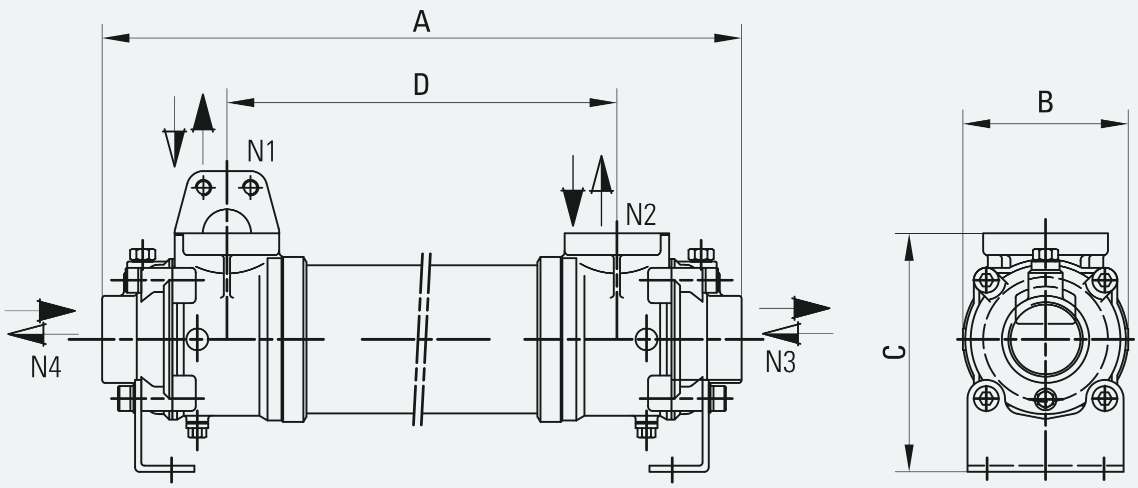

Fig. 5-19 Fuel oil cooler for MDO operation DH3

	Dimensions [mm]						Weight
	A	B	C	D	N1 + N2	N3 + N4	[kg]
6/8/9 M 20 C	710	106	153	550	1 ¼" SAE	1 ½" BSP	16

5.2.3 Fuel booster and supply module

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

Caterpillar Motoren standard modules consist of the following components:

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

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

Module controlled automatically with alarms and starters

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

Alarms

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

Size, weight and dimensions

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

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

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

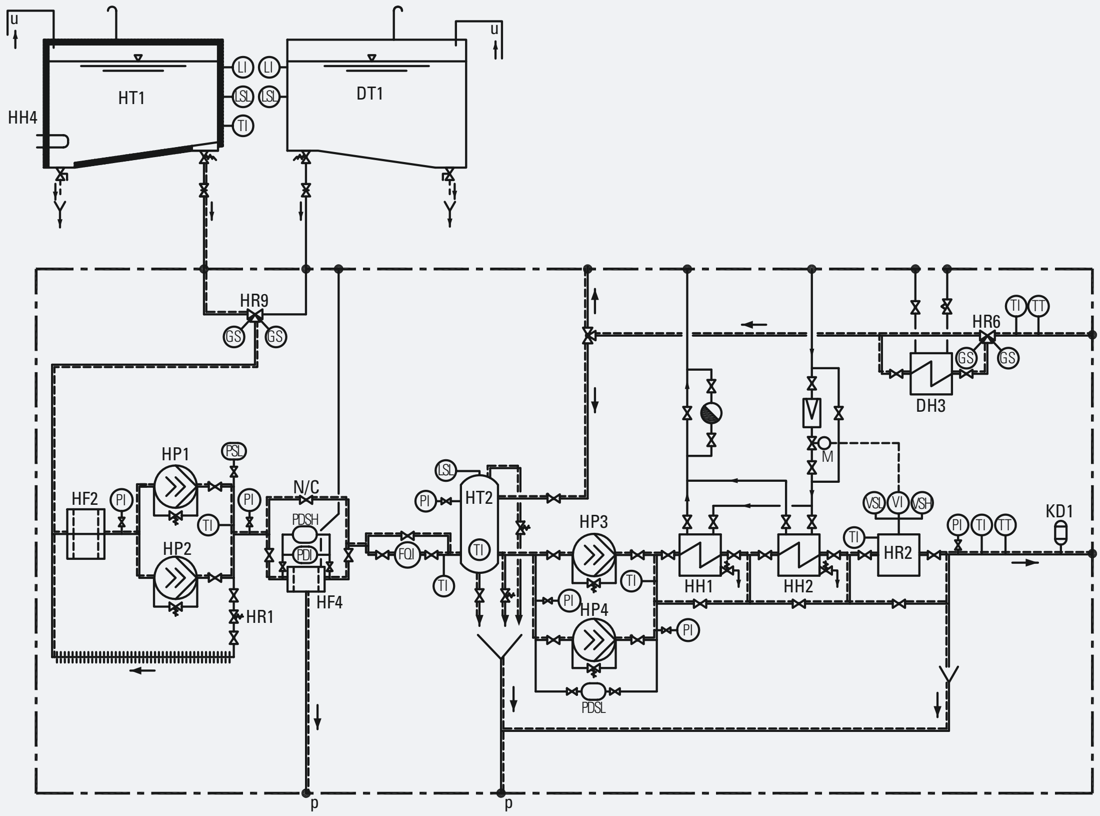

Fig. 5-20 Fuel booster and supply module, system diagram

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)	VSH	Viscosity control switch high
	3-way-valve	VSL	Viscosity control switch low
HR9	Fuel change over main valve		
HT1	Heavy fuel day tank	p	Free outlet required
HT2	Mixing tank	u	Fuel separator or from transfer pump

All heavy fuel pipes have to be insulated.

- - - - - - Heated pipe

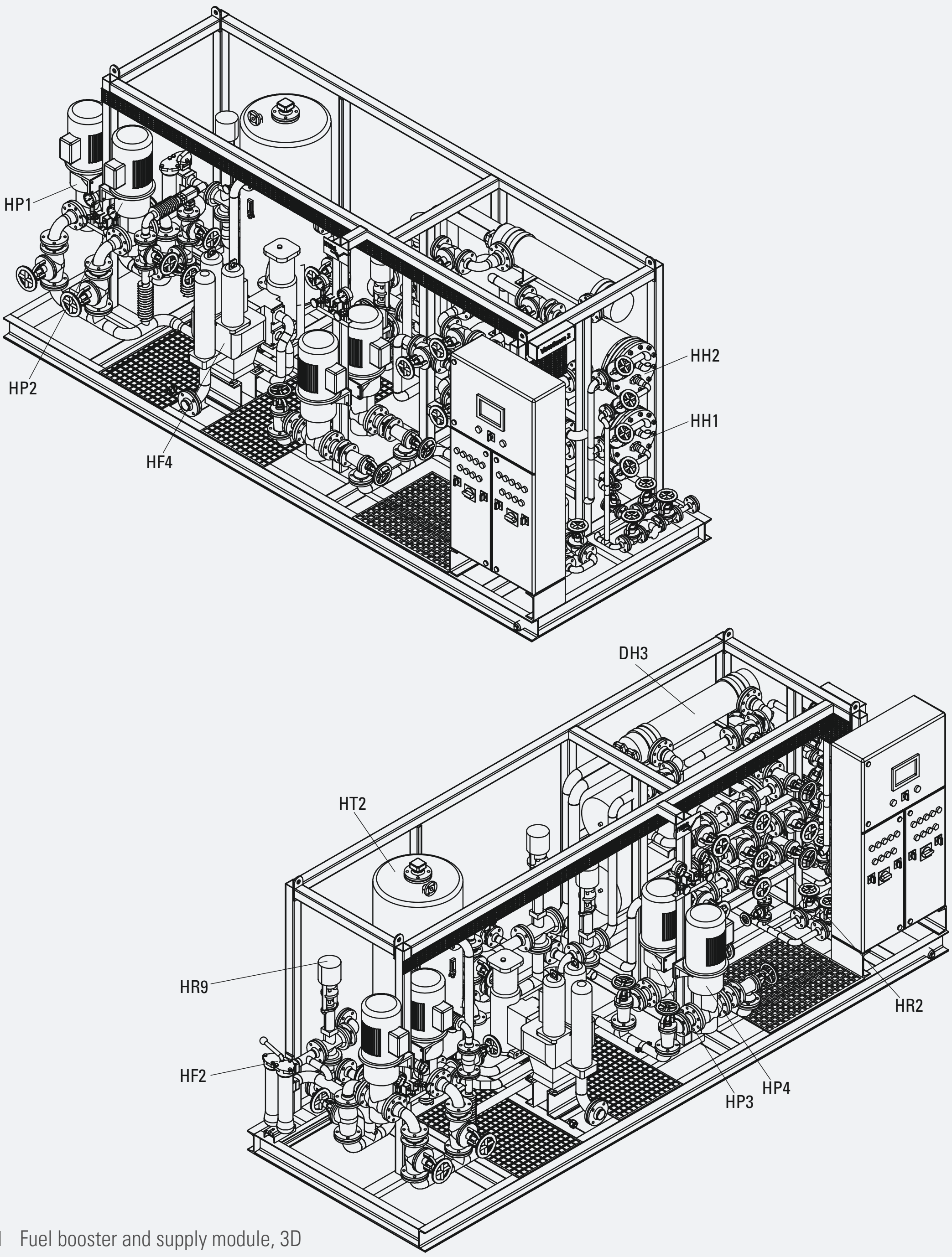

Fig. 5-21 Fuel booster and supply module, 3D

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

5.3 Switching over from HFO to diesel oil

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

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

Typical switch over characteristics (HFO to diesel)

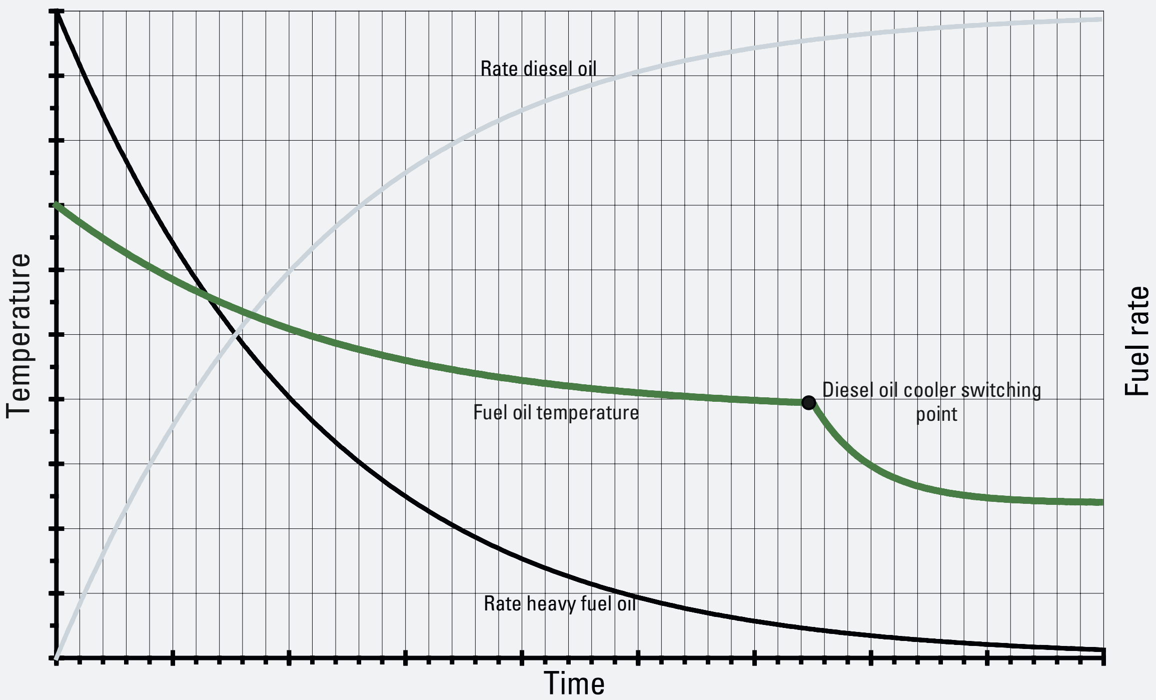

Fig 5-22 Switch over characteristics

5.4 Crude oil operation

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

General

The lube oil performs several basic functions:

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

6.1 Lube oil requirements

NOTE:
The viscosity class SAE 40 is required.

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

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

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

6.2 Internal lube oil system

Lube oil force pump LP1 (fitted)

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

Self-cleaning lube oil filter LF2 (fitted)

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

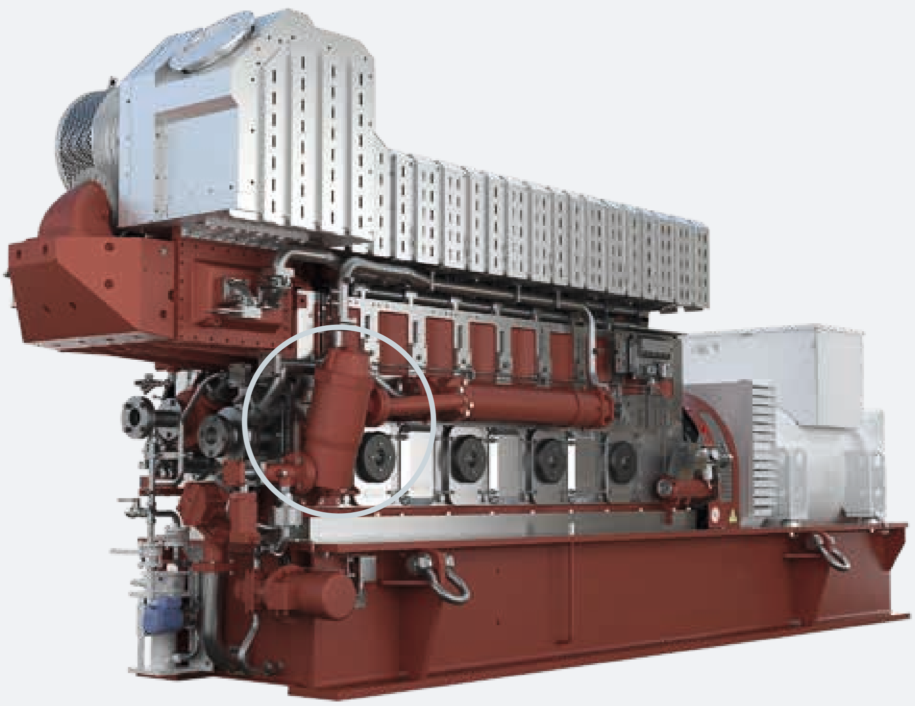

Fig. 6-1 Self-cleaning lube oil filter LF2

6.3 External lube oil system

General

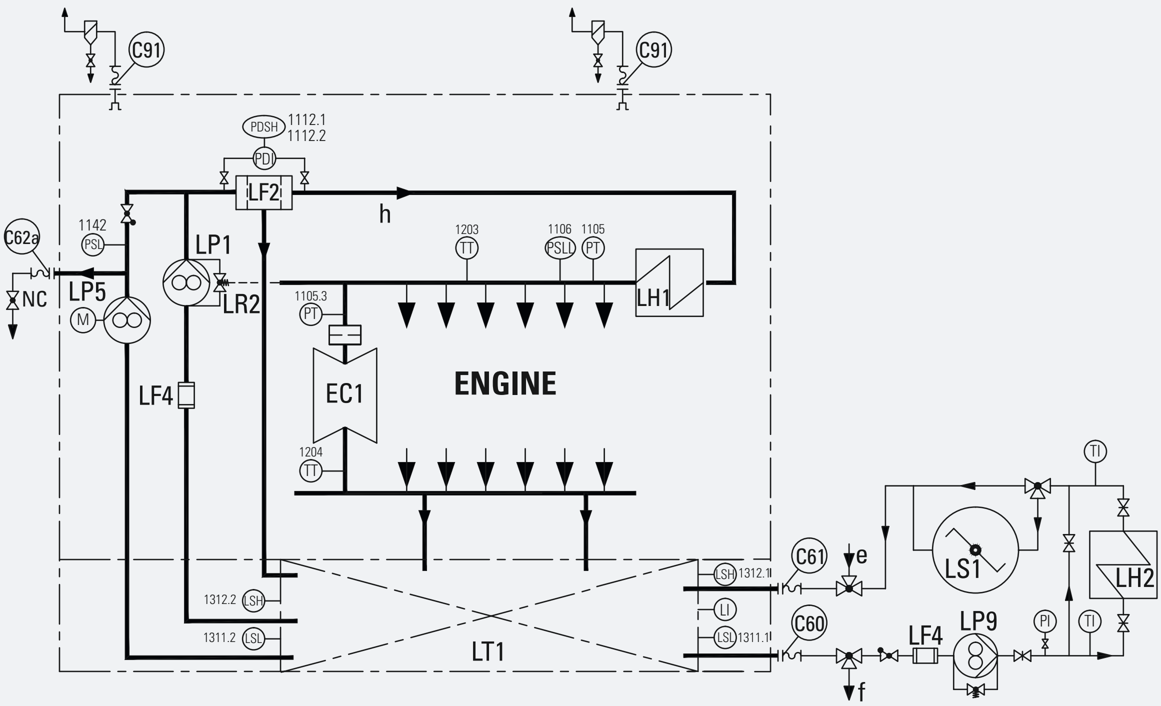

Fig. 6-2 External lube oil system diagram

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
LP5	Prelubrication pump
LP9	Transfer pump (separator)
LR2	Oil pressure regulating valve
LS1	Lube oil separator
LT1	Sump tank

LI	Level indicator
LSL	Level switch low
LSH	Level switch high
PDSH	Diff. pressure switch high
PI	Pressure indicator
PSL	Pressure switch low
PSLL	Pressure switch low
PT	Pressure transmitter
TI	Temperature indicator
TT	Temperature transmitter

C60	Separator connection, suction side
C61	Separator connection, delivery side
C62a	Oil drain republicating pump
C91	Crankcase ventilation to stack

e	Filling pipe
f	Drain
h	Please refer to the measuring point list regarding design of the monitoring devices.

Lube oil cooler LH1

A tubular cooler will be used to dissipate the heat to the LT fresh water system.
It is mounted at the engine.

Centrifugal filter LS2 (optional)

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

Prelubricating pump LP5

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

Oil pressure regulating valve LR2 (fitted)

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

Lube oil separator LS1

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

Layout for MGO/MDO operation

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

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

Layout for HFO operation

Automatic self-cleaning separator; Operating temperature 95 °C

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

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

6.4 Circulating tanks

The circulating tank LT1 is mounted at the baseframe and level monitored.

6.5 Crankcase ventilation system

6.5.1 Crankcase ventilation pipe dimensions

- The crankcase ventilation connecting points DN 50. Both connections have to be used.
- The engine main ventilation line must be at least DN 65.

6.5.2 Crankcase ventilation pipe layout

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

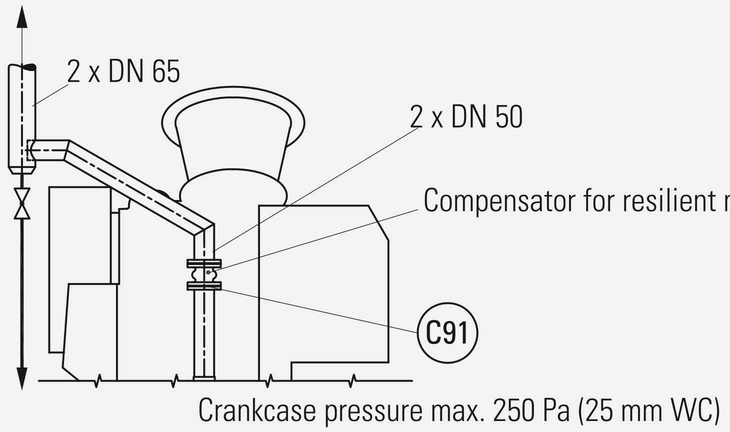

Fig. 6-3 Crankcase ventilation

C91 Crankcase ventilation to stack

7.1 General

MaK engines are cooled by two cooling circuits:

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

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

7.1.1 Two circuit cooling system

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

7.1.2 Secondary circuit cooling system

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

7.2 Water quality requirements

7.2.1 General

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

7.2.2 Requirements

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

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

7.2.3 Supplementary information

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

7.2.4 Treatment before operating the engine for the first time

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

7.3 Recommendation for cooling water system

7.3.1 Pipes and tanks

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

7.3.2 Drain tank with filling pump

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

7.3.3 Electric motor driven pumps

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

Rough calculation of power demand for the electric balance:

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

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

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

7.4 Cooling water system

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

7.4.1 General

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

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

Cooling water system diagram 6 M 20 C Genset with 900 rpm

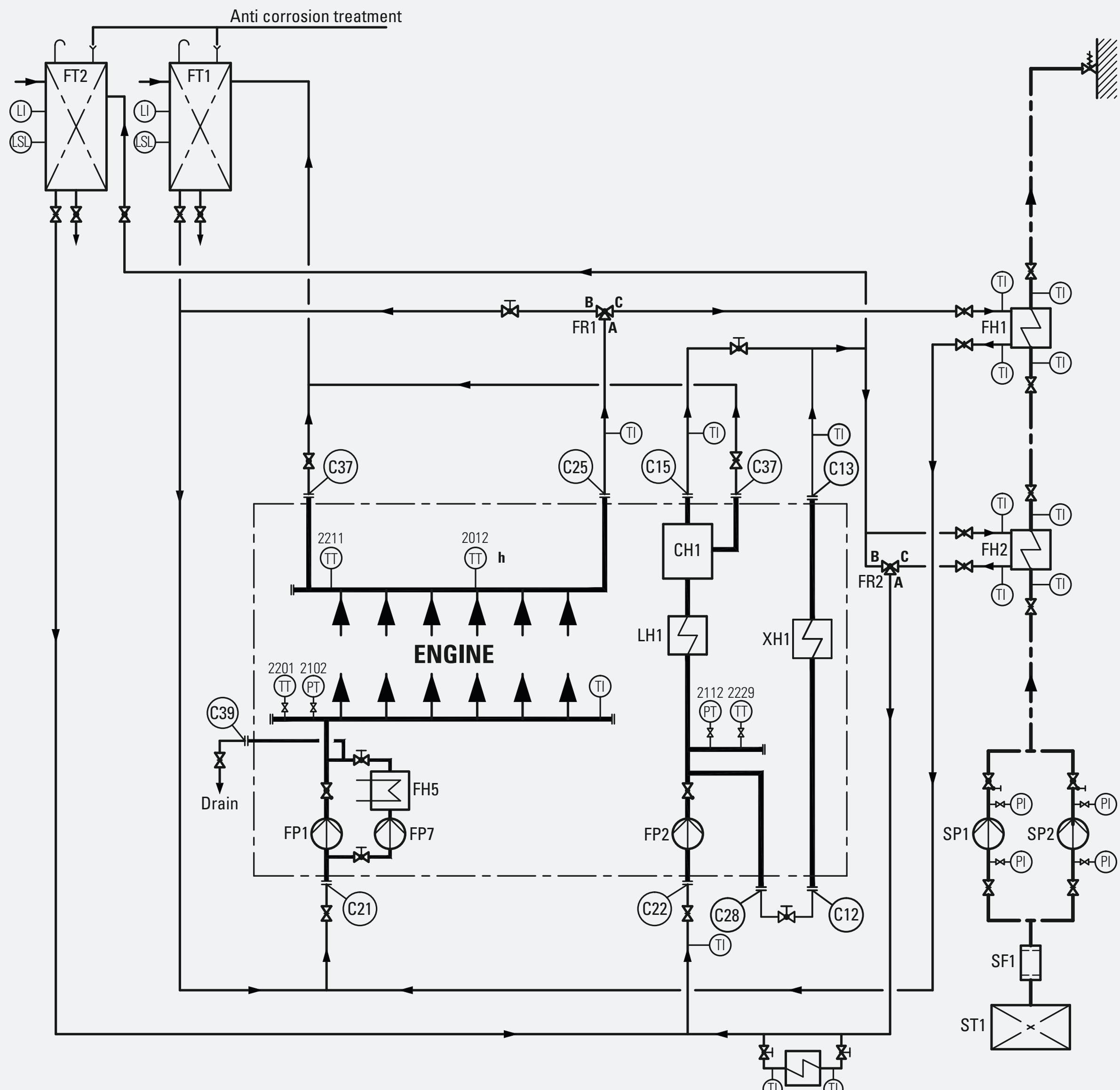

Fig. 7-1 Cooling water system diagram, 6 M 20 C Genset with 900 rpm

In plants with skin or box coolers not required: seawater system (SP1, SP2, SF1, ST1).
Maximal flow through the generator cooler is 5 m³/h. Otherwise use an additional pump or cooling device.

CH1	Charge air cooler LT	LI	Level indicator
DH3	Fuel oil cooler for MDO operation	LSL	Level switch low
FH1	Fresh water cooler HT	PI	Pressure indicator
FH2	Fresh water cooler LT	PT	Pressure transmitter
FH5	Fresh water preheater	TI	Temperature indicator
FP1	Fresh water pump (fitted on engine) HT	TT	Temperature transmitter
FP2	Fresh water pump (fitted on engine) LT		
FP7	Preheating pump	C12	Generator cooler, inlet
FR1	Temperature control valve HT	C13	Generator cooler, outlet
FR2	Temperature control valve LT	C15	Charge air cooler LT, outlet
FT1	Compensation tank HT	C21	Freshwater pump HT, inlet
FT2	Compensation tank LT	C22	Freshwater pump LT, inlet
LH1	Lube oil cooler	C25	Cooling water engine, outlet
SF1	Seawater filter	C37	Vent
SP1	Seawater pump	C39	Drain
SP2	Seawater stand-by pump		
ST1	Sea chest	h	Please refer to the measuring point list regarding design of the monitoring devices.
XH1	Generator cooler		

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Cooling water system diagram 6 M 20 C Genset with 1,000 rpm

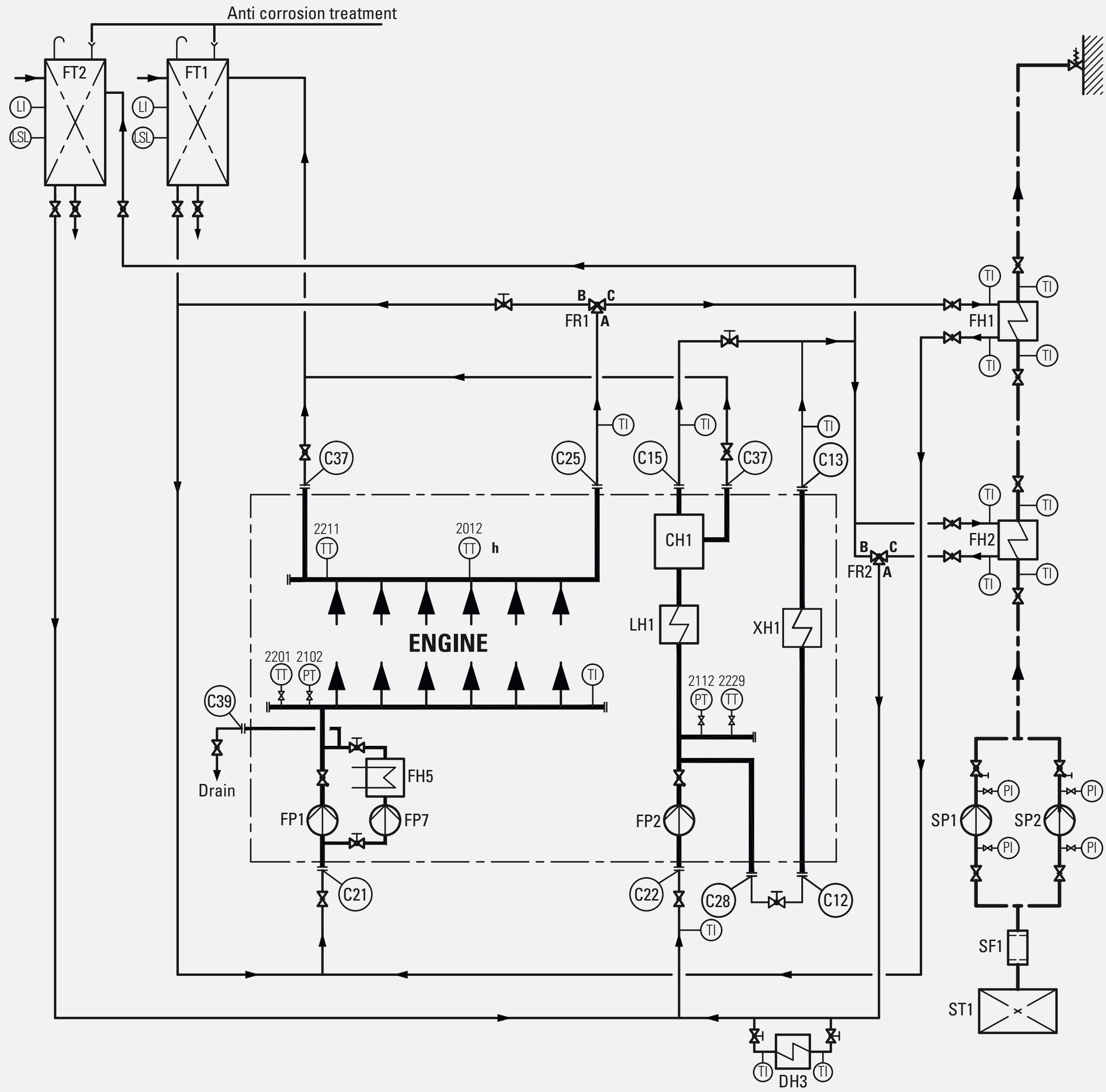


Fig. 7-2 Cooling water system diagram, 6 M 20 C Genset with 1,000 rpm

Maximal flow through the generator cooler is 8 m³/h. Otherwise use an additional pump or cooling device

CH1	Charge air cooler LT
DH3	Fuel oil cooler for MDO operation
FH1	Fresh water cooler HT
FH2	Fresh water cooler LT
FH5	Fresh water preheater
FP1	Fresh water pump (fitted on engine) HT
FP2	Fresh water pump (fitted on engine) LT
FP7	Preheating pump
FR1	Temperature control valve HT
FR2	Temperature control valve LT
FT1	Compensation tank HT
FT2	Compensation tank LT
LH1	Lube oil cooler
SF1	Seawater filter
SP1	Seawater pump
SP2	Seawater stand-by pump
ST1	Sea chest
XH1	Generator cooler

LI	Level indicator
LSL	Level switch low
PI	Pressure indicator
PT	Pressure transmitter
TI	Temperature indicator
TT	Temperature transmitter

C12	Generator cooler, inlet
C13	Generator cooler, outlet
C15	Charge air cooler LT, outlet
C21	Freshwater pump HT, inlet
C22	Freshwater pump LT, inlet
C25	Cooling water engine, outlet
C28	Fresh water pump LT, outlet
C37	Vent
C39	Drain

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

Cooling water system diagram 8 M 20 C Genset with 1,000 rpm

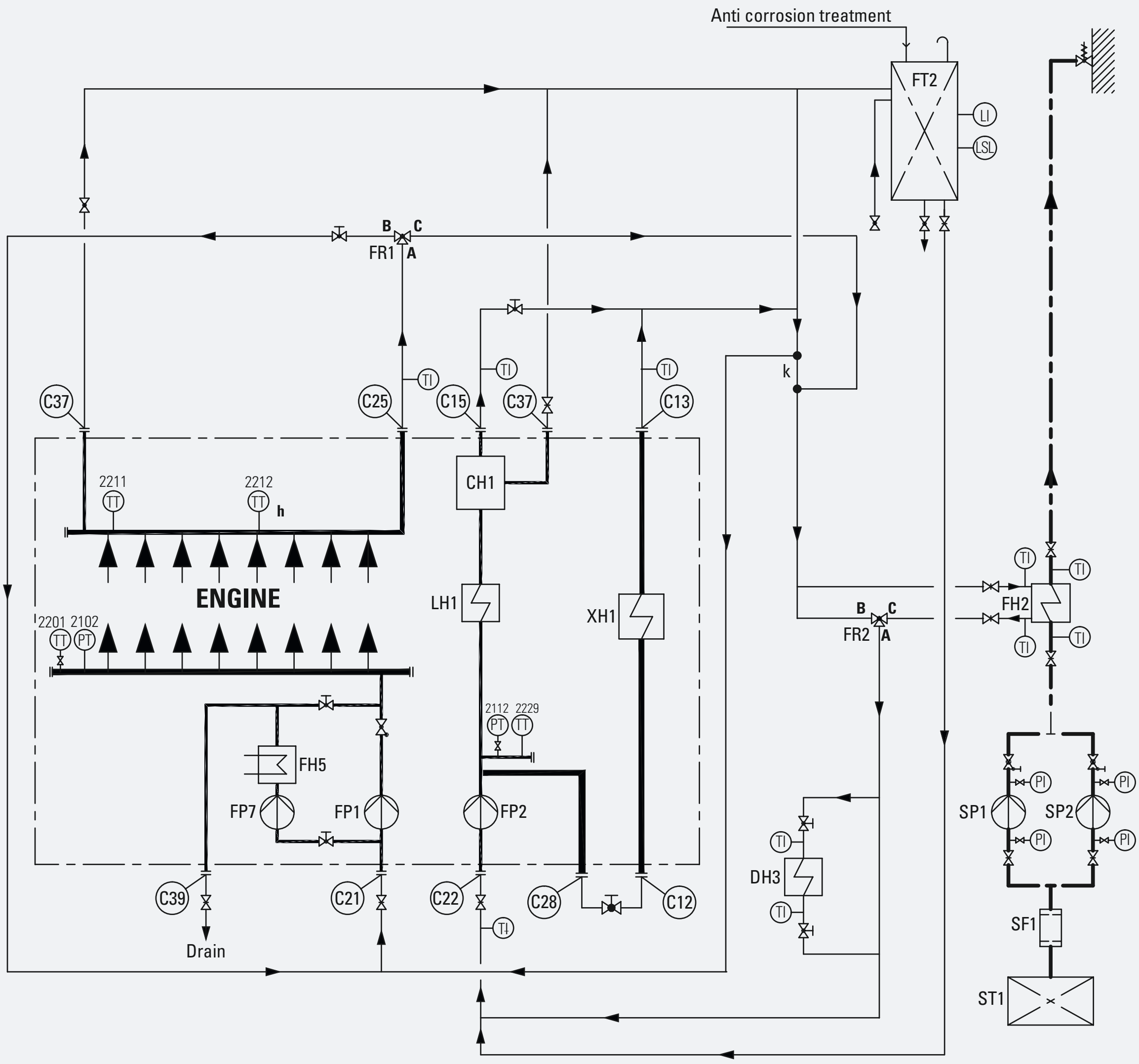


Fig. 7-3 Cooling water system diagram, 8 M 20 C Genset with 1,000 rpm

Maximal flow through the generator cooler is 8 m³/h. Otherwise use an additional pump or cooling device

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

LI	Level indicator
LSL	Level switch low
PI	Pressure indicator
PT	Pressure transmitter
TI	Temperature indicator
TT	Temperature transmitter
C12	Generator cooler, inlet
C13	Generator cooler, outlet
C15	Charge air cooler LT, outlet
C21	Freshwater pump HT, inlet
C22	Freshwater pump LT, inlet
C25	Cooling water engine, outlet
C37	Vent
C39	Drain
h	Please refer to the measuring point list regarding design of the monitoring devices.
k	Distance min. 2 m

7.4.2 Components

Freshwater coolers HT FH1 (separate), LT FH2 (separate)

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

Compensation tank HT FT1 / LT FT2

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

Main functions of the cooling water header tank:

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

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

Capacity: acc. to heat balance.

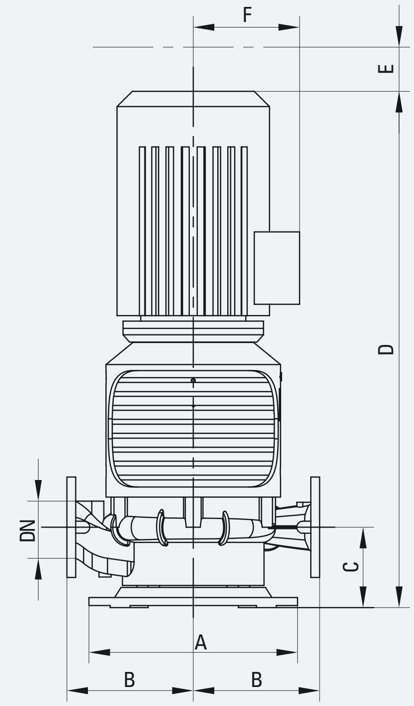


Fig. 7-4 Fresh water pump

Flow	Pressure	Dimensions [mm]							Weight	Motor power	Voltage/ Frequency
[m³/h]	[bar]	DN	A	B	C	D	E	F	[kg]	[kW]	[V/Hz]
30	3.0	65	360	180	125	1,005	150	188	111	5.5 6.3	400/50 440/60
40	3.0	65	360	180	125	1,005	150	188	120 111	7.5 6.3	400/50 440/60
45	3.0	65	360	180	125	1,005	150	188	125 120	7.5 8.6	400/50 440/60
50	3.0	80	400	200	140	1,020	150	188	125	7.5 8.6	400/50 440/60
60	3.0	80	400	200	140	1,132 1,020	180 150	250 188	189 125	11.0 8.6	400/50 440/60

Temperature control valve HT FR1 / LT FR2 / HT flow FR3

P-controller with manual emergency adjustment (basis).
Option: PI-controller with electric drive.

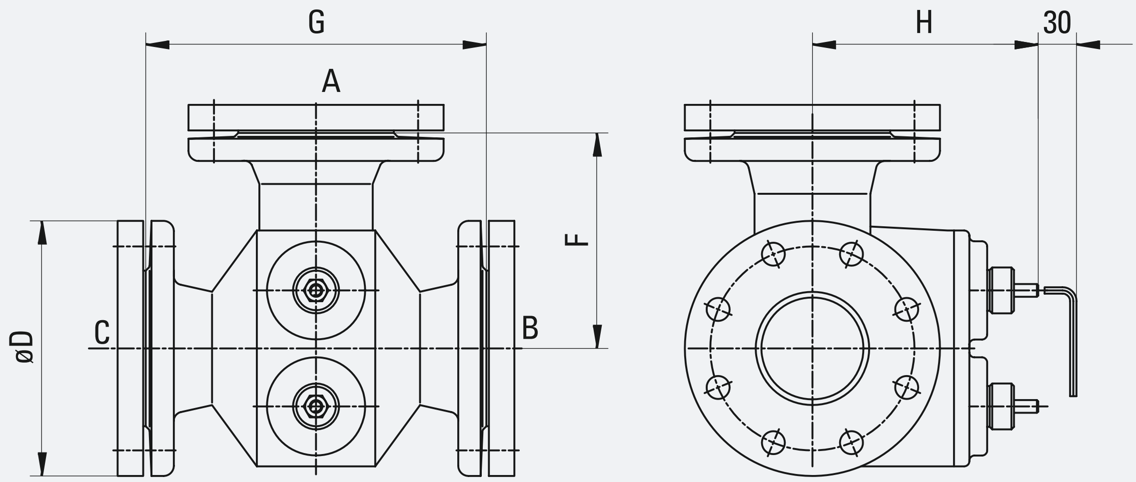


Fig. 7-5 Temperature control valve HT FR1

		Dimensions [mm]					Weight
		DN	D	F	G	H	[kg]
6/8/9 M 20 C	HT	65	185	165	254	158	26
6/8/9 M 20 C	LT	80	200	171	267	151	27

* Minimum depending on total cooling water flow

7.5 System diagrams heat balance

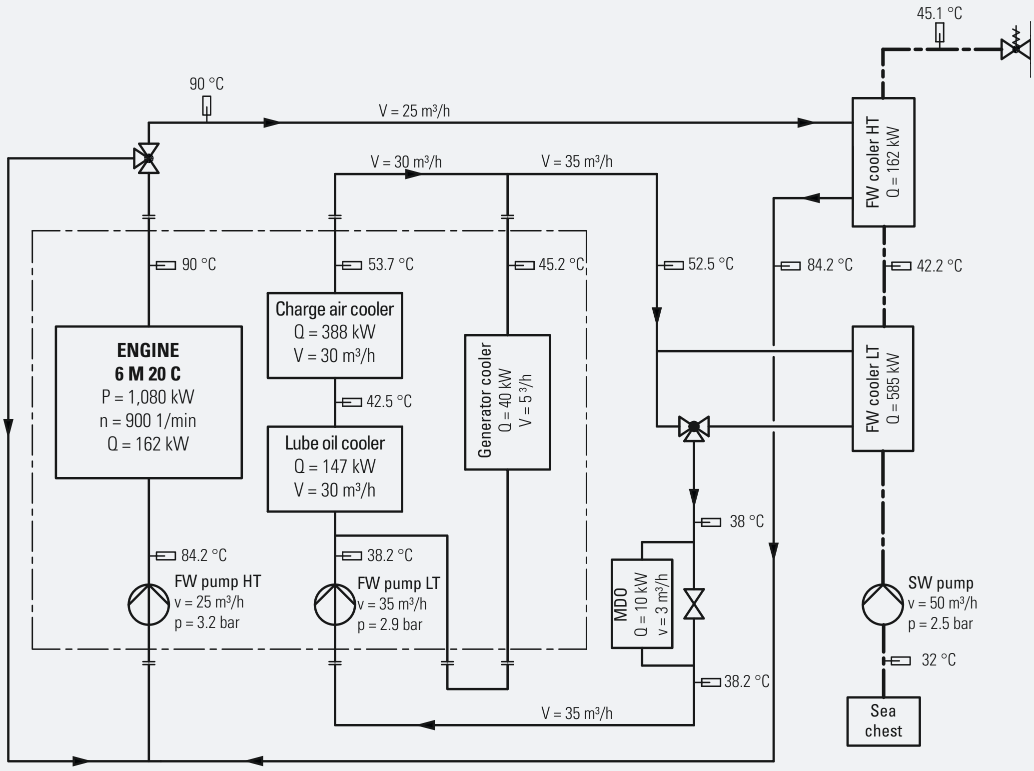


Fig. 7-6 Heat balance, system diagram 6 M 20 C with 900 rpm

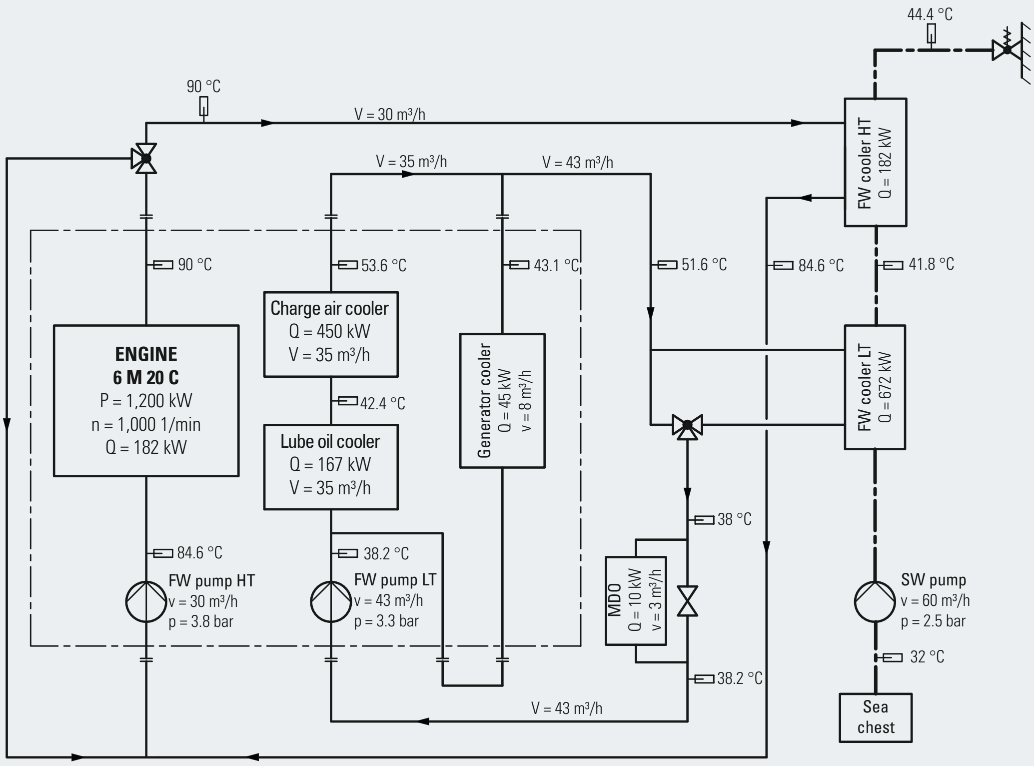


Fig. 7-7 Heat balance, system diagram 6 M 20 C with 1,000 rpm

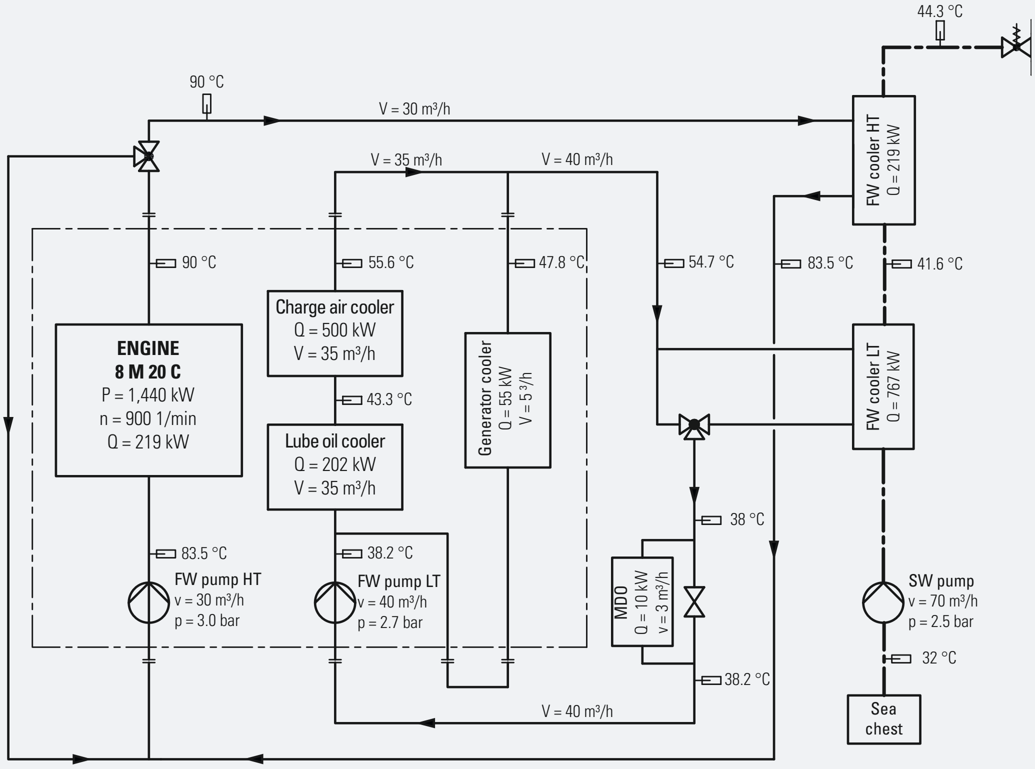


Fig. 7-8 Heat balance, system diagram 8 M 20 C with 900 rpm

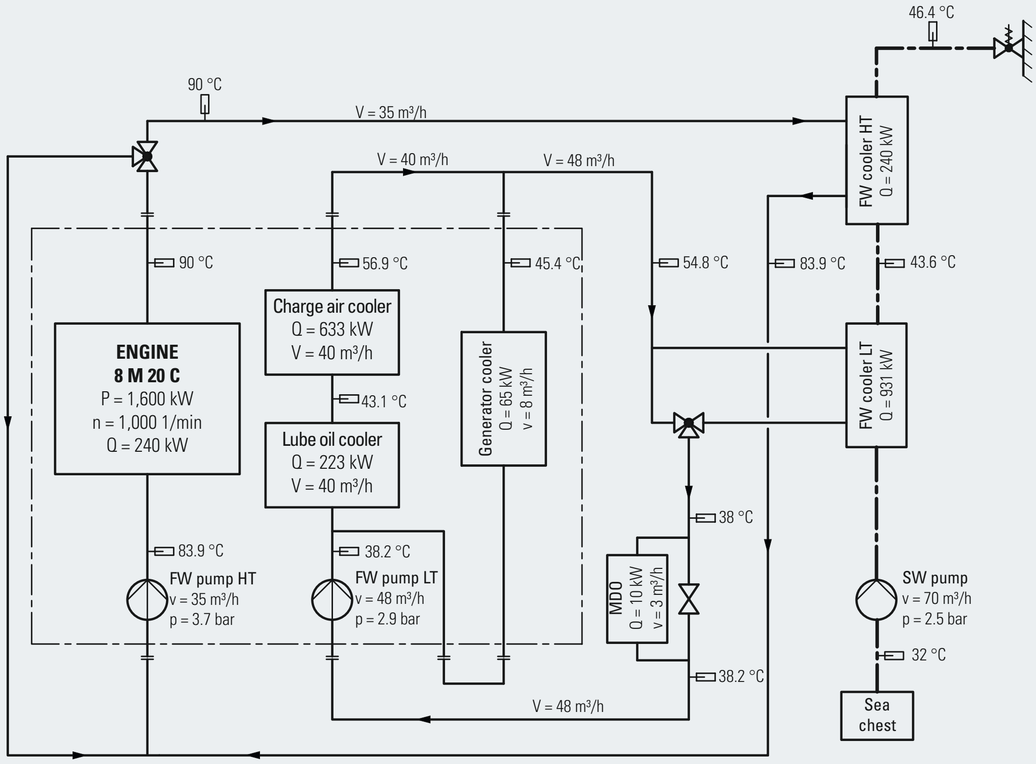


Fig. 7-9 Heat balance, system diagram 8 M 20 C with 1,000 rpm

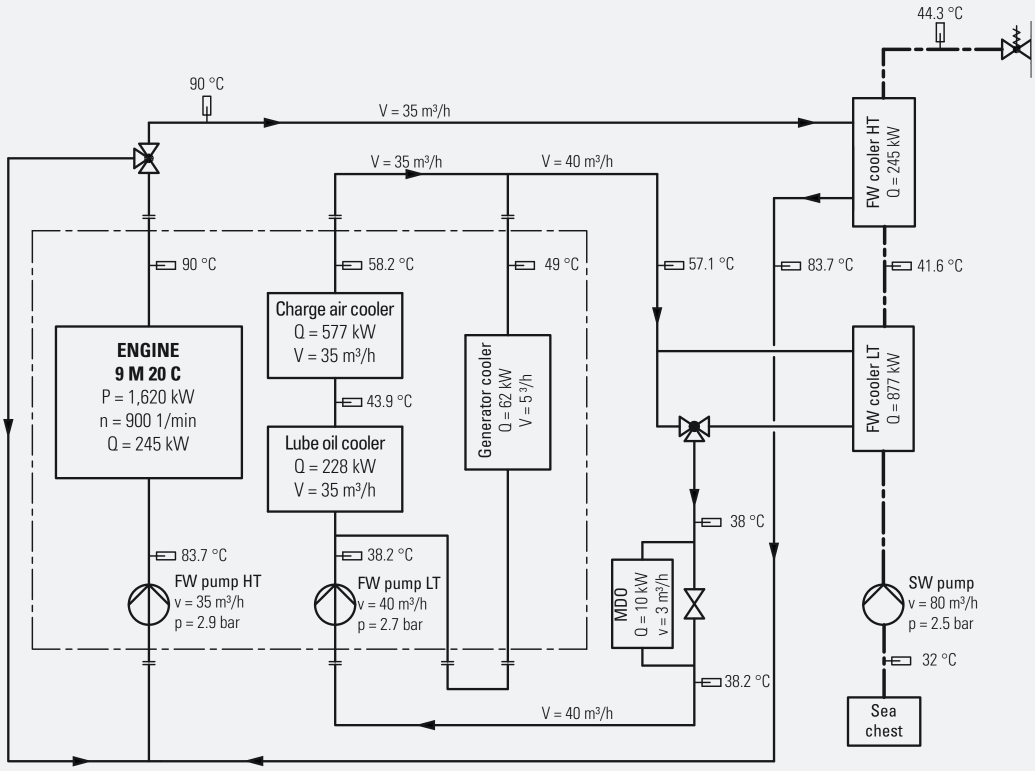


Fig. 7-10 Heat balance, system diagram 9 M 20 C with 900 rpm

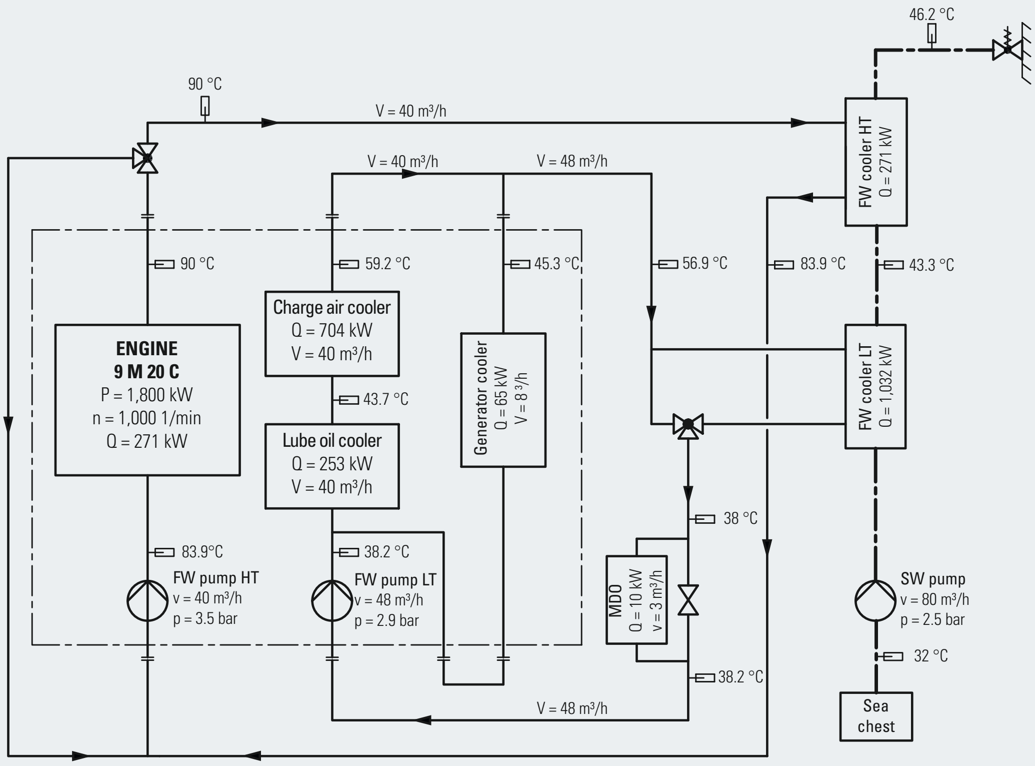
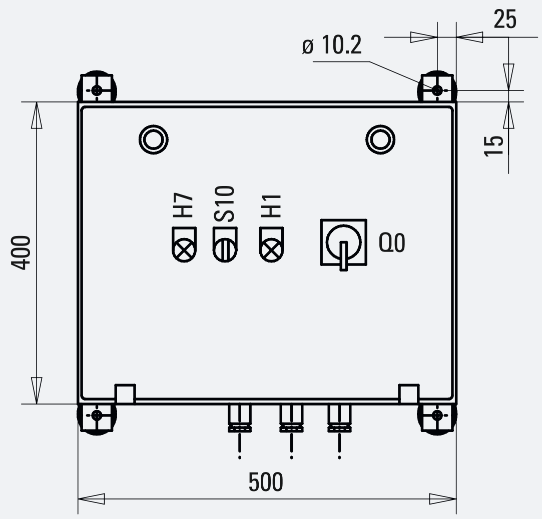


Fig. 7-11 Heat balance, system diagram 9 M 20 C with 1,000 rpm

7.6 Preheating (separate module)

7.6.1 Electrically heated

- The standard preheating system in plants delivered by Caterpillar Motoren is electrically heated.
- Consisting of baseframe mounted preheating pump FP7 (3.5 m³/h), electric heater FH5 (7.5 kW) and separate switch cabinet.
  Voltage 380 - 690, frequency 50/60 Hz.



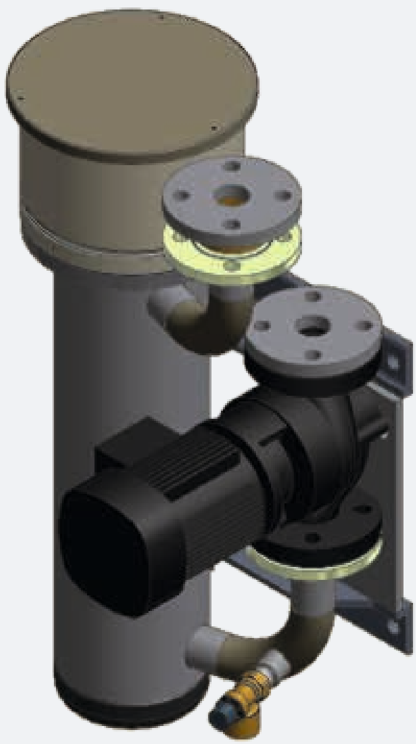


Fig. 7-12 Freshwater preheater FH5, preheating pump FP7

7.6.2 Other preheating systems

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

7.7 Box coolers system

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

7.8 Cooling circuit layout

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

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

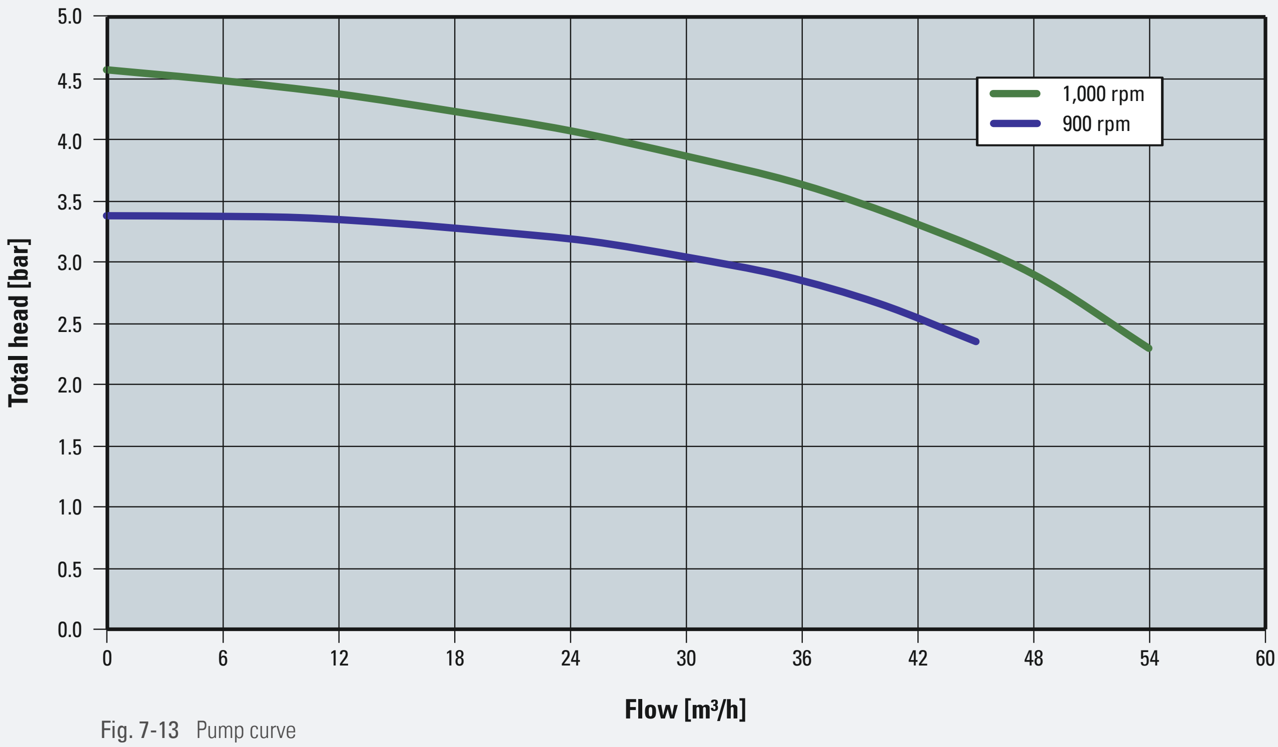


Fig. 7-13 Pump curve

8.1 General

Compressed air is used

- to start the engines
- to provide actuating energy for safety devices.

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

8.2 Internal compressed air system

The M 20 C engine is started by means of compressed air with a nominal pressure of 30 bar by using air starting motors.

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

8.3 External compressed air system

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

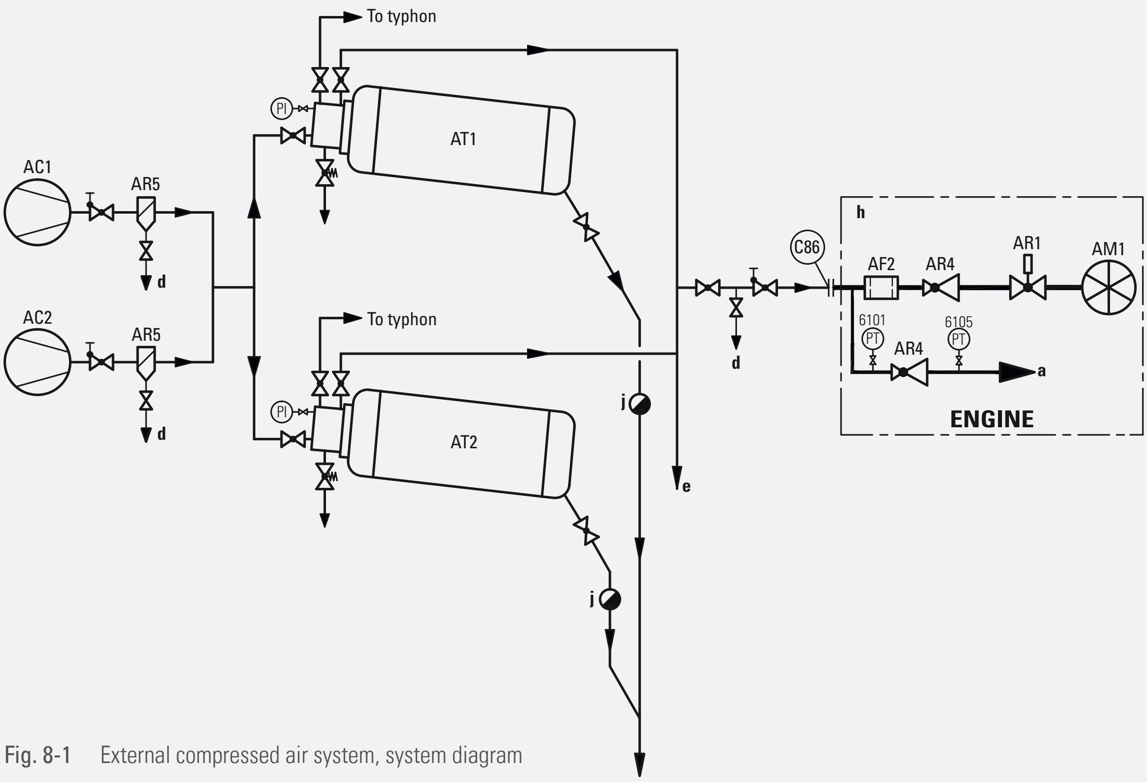


Fig. 8-1 External compressed air system, system diagram

AC1	Compressor
AC2	Stand-by compressor
AF2	Control air filter
AM1	Starting air motor
AR1	Starting valve
AR4	Pressure reducing valve
AR5	Oil and water separator
AT1	Starting air receiver (air bottle)
AT2	Starting air receiver (air bottle)

C86	Connection / starting air
a	Control air
d	Water drain (to be mounted at the lowest point)
e	To engine no. 2
h	Please refer to the measuring points list regarding design of the monitoring devices.
j	Automatic drain required

PI	Pressure indicator
PT	Pressure transmitter

8.3.1 Compressor AC1, stand-by compressor AC2

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

Rough calculation of compressor capacity:

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

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

8.3.2 Air receiver AT1, AT2

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

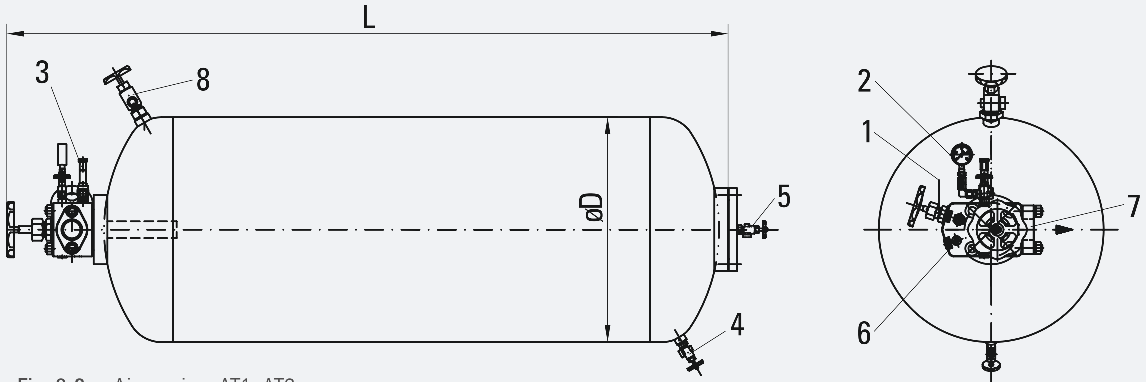


Fig. 8-2 Air receiver AT1, AT2

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

Normal requirements of classification societies:

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

Calculation of air receiver volumes:

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

$V =$ Air receiver volume
$V_2 =$ Air consumption per start [Nm³]
$n =$ Required number of starting procedures in sequence
$P_{atm} =$ Ambient pressure [bar]
$P_{max} =$ Maximum receiver pressure (30 bar)
$P_{min} =$ Minimum receiver pressure (15 bar)

Standard receiver capacities

Receiver capacity [l]	L [mm]	øD [mm]	Valve head	Weight approx. [kg]
125	2,076	324	DN 38	170
250	2,037	480	DN 38	280
500	3,501	480	DN 50	460
750	3,033	650	DN 50	625
1,000	3,853	650	DN 50	810

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

8.4 Air quality requirements

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

Instrument air specification:

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

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

- Oil content
  (Specification of aerosols and hydrocarbons which may be contained in the compressed air.)
- Particle size and density
  (Specification of size and concentration of particles which still may be contained in the compressed air.)
- Pressure dew point
  (Specification of the temperature on which the compressed air can cool down without the steam contained in it condensing. The pressure dew point changes with the air pressure.)

8.5 Optional equipment

Compressor module

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

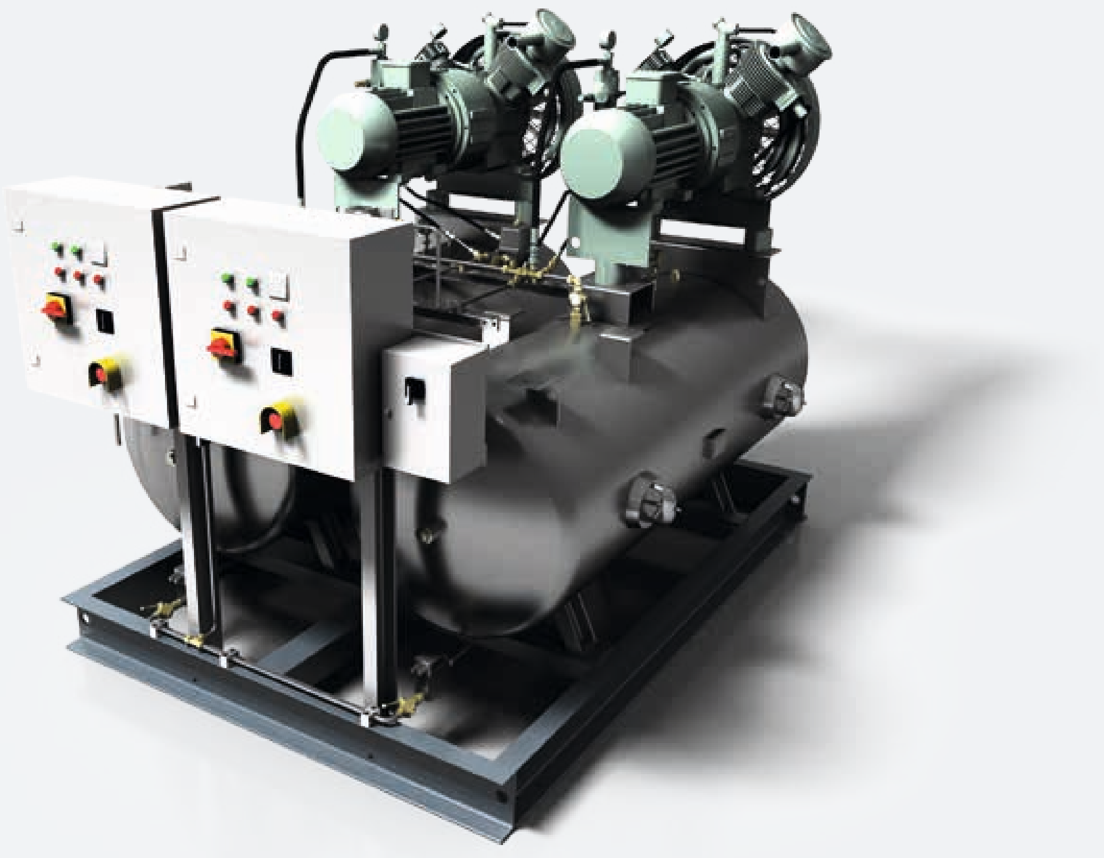


Fig. 8-3 Compressor module

9.1 Engine room ventilation

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

9.2 Combustion air system design

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

9.2.1 Air intake from engine room (standard)

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

9.2.2 Air intake from outside

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

9.3 Cooling air

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

NOTE:
Radiated heat see technical data.

Basic design

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 backpressure directly after the turbocharger, influenced by the design of the exhaust gas piping and all installed components like exhaust gas boilers, catalysts and scrubbers is limited to 60 mbar. Higher values will increase the thermal load of the engine and may lead to higher fuel consumption.
If a particle filter system is requested the maximum back pressure of the whole exhaust gas system by using MDO/MGO fuel before regeneration of the filter in loaded condition is limited to 90 mbar.

10.1 Components

10.1.1 Exhaust gas nozzle

For an optimal integration of the engine in the engine room regarding the discharge of the emitted exhaust gases different orientations of the exhaust gas nozzle are possible.
The basic orientation of the exhaust gas nozzle for all M 20 C engines is 45°. A nozzle position of 0°, 30°, 60° and 90° from the vertical is possible by using a transition piece.

10.1.2 Exhaust gas compensator

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

Basic design values of the standard exhaust gas compensators:

	Diameter [mm]	Length [mm]	Weight [kg]
6 M 20 C	400	365	43
8/9 M 20 C	500	360	55

10.1.3 Exhaust gas piping system

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

Each engine requires a separate exhaust gas pipe so a common exhaust gas piping system of two or more engines is not allowed, otherwise exhaust gases from engines under operation are 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.

10.1.4 Silencer

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

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

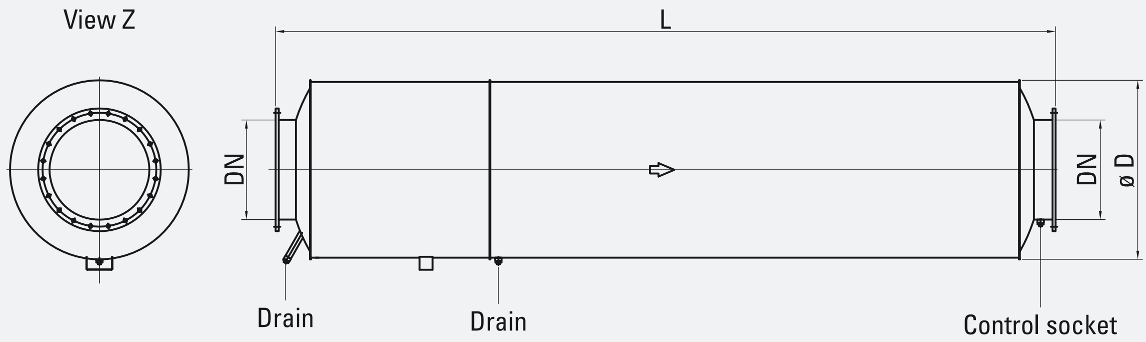


Fig. 10-1 Standard silencer without spark arrestor

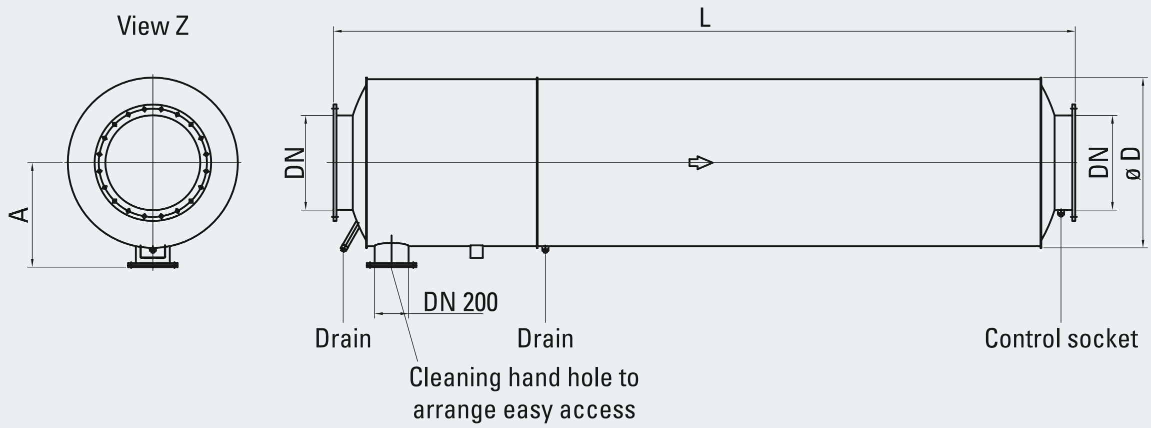


Fig. 10-2 Spark arrestor and silencer

	Dimensions [mm]				Weight	Weight with spark arrestor
	DN	A	D	L	[kg]	[kg]
6 M 20 C	400	540	850	3,770	570	680
8/9 M 20 C	500	590	950	4,170	730	780

10.1.5 Exhaust gas boiler

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

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

NOTE:
Exhaust gas boilers are available through Caterpillar Marine.

10.2 Turbocharger

10.2.1 Turbine cleaning system

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

NOTE:
Duration of the cleaning period is 30-60 minutes due to cooling before and drying after cleaning. Duration of the washing period itself is 3 x 30 seconds.
Fresh water of 2.5 - 4.5 bar for 6/8/9 M 20 C is required.

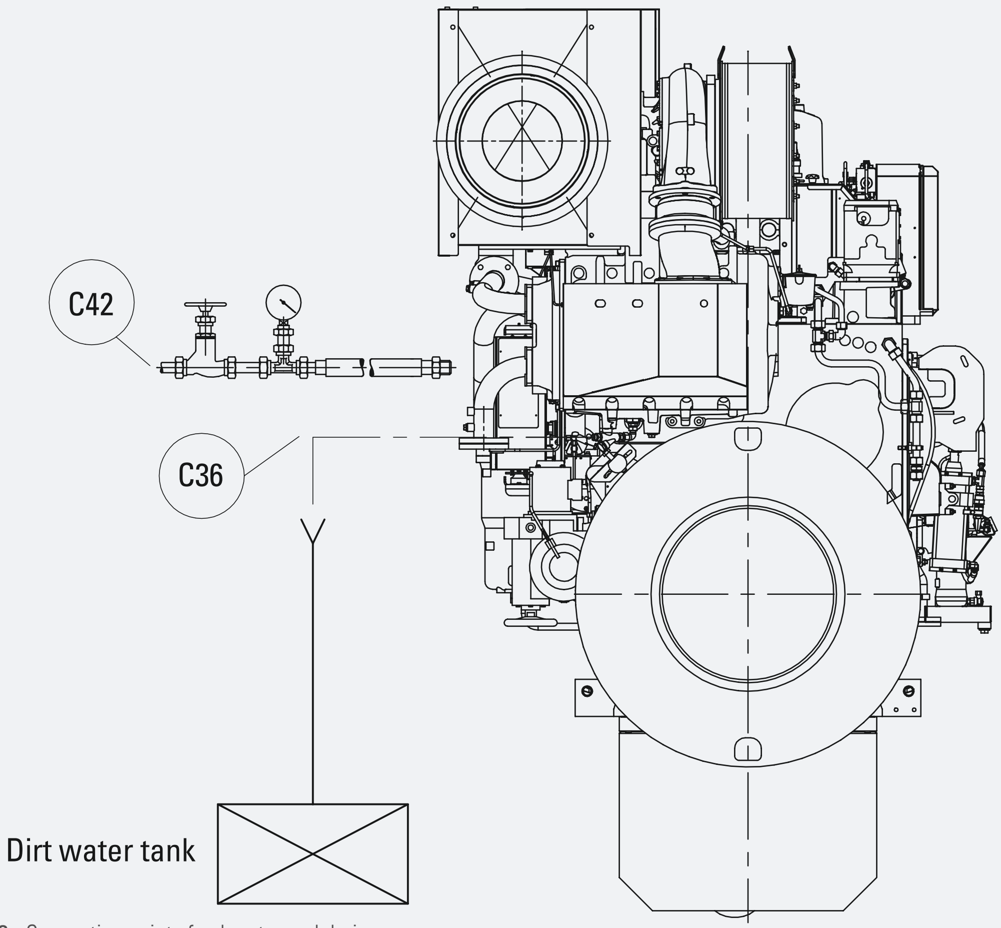


Fig. 10-3 Connection points freshwater and drain

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

	Water pressure [bar]	Injection procedure [sec]
6/8/9 M 20 C	2.5 – 4.5	3 x 30

10.2.2 Compressor cleaning system

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

10.3 Cat SCR System / IMO III kit

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

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

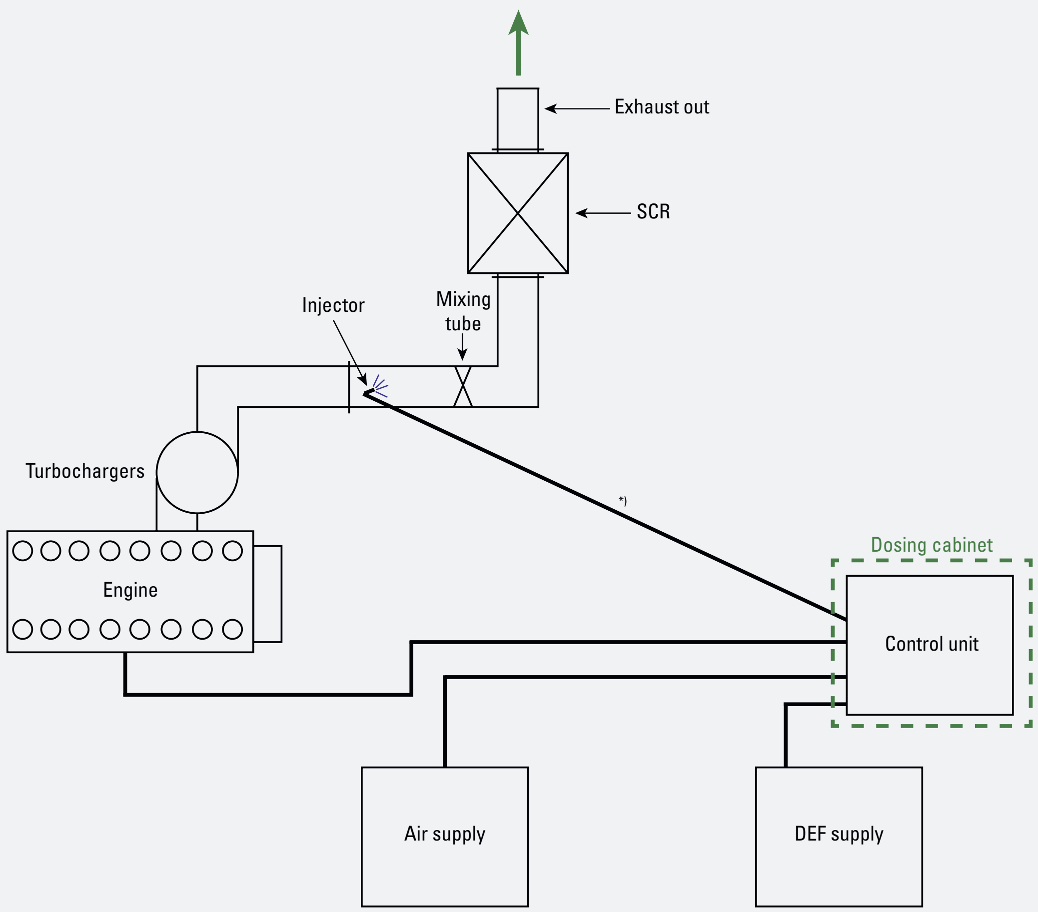


Fig. 10-4 SCR CEM system diagram – MDO

*) Pipe has to slope down without any steps (length: max. 6 m)

Additional equipment (soot blower) is required for HFO operation.
Please contact Caterpillar Motoren for more information.

Cat SCR System scope of supply:

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

Not included in standard scope of supply:

- DEF storage tank
- Exhaust piping
- Insulation

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

10.3.1 Portfolio, size and dimensions

Installation of SCR System

The SCR housing design is for vertical installation.

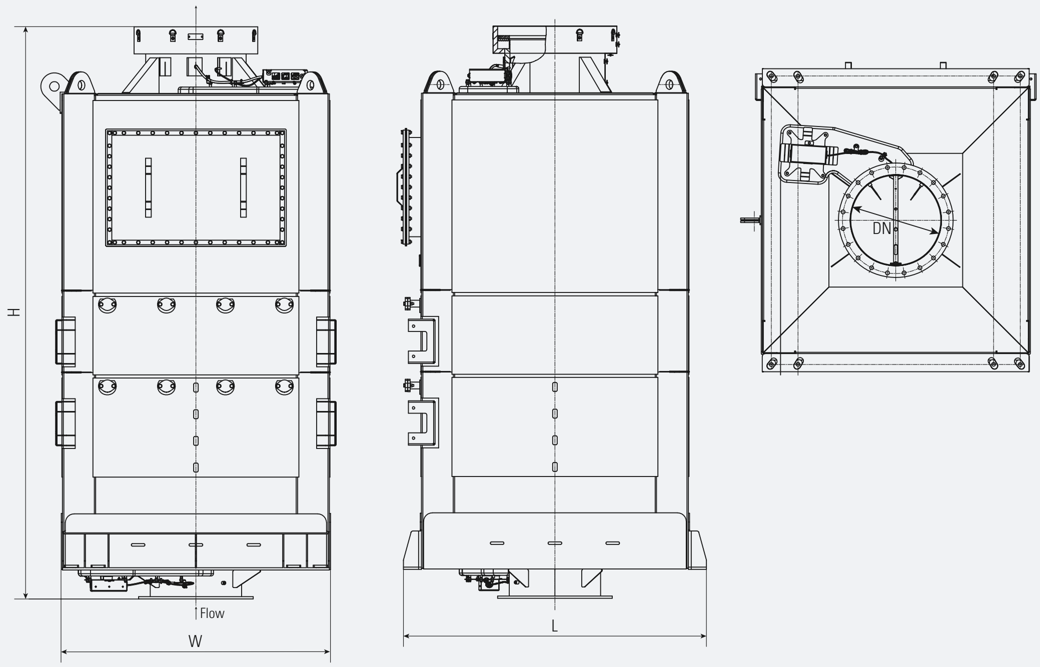


Fig. 10-5 Size and dimensions – MDO

	SCR housing			Mixing tube			Dosing cabinet	
	Dimensions	Flange size	Weight	Length	Flange size	Weight	Dimensions	Weight
	L* x W x H [mm]	[DN]	[kg]	[mm]	[DN]	[kg]	L x W x H [mm]	[kg]
6 M 20 C	1,705 x 1,514 x 3,020	500	1,742	2,464	500	123	947 x 503 x 579	95
8 M 20 C			1,848					
9 M 20 C			1,954					

Note: Length is inlet flange to outlet flange. Width is of main box and does not include brackets, hatches, blankets, etc.
Dimensions might be subject to change without further notice.
*) For HFO operation a soot blower is mounted at the housing and the length will increase about +680 mm.

	Max. diesel exhaust fluid (DEF) consumption [g/kWh] UREA solution concentration 32.5 %			
Load	100 %	75 %	50 %	25 %
Standard	14.5	18.0	18.0	17.5

Fuel consumption with Cat SCR aftertreatment:
The SCR housing and the substrate cassettes of the Cat IMO Tier III SCR aftertreatment systems are optimized to be used in combination with the M 20 C engines and their emission behaviour. However the aftertreatment system generates higher exhaust gas back pressure which results in increased fuel consumption, no matter if the engine is operating in IMO Tier II or IMO Tier III mode.
Specific fuel consumption has to be recalculated by + 0.3 g/kWh per 10 mbar higher exhaust back pressure.

Nitrogen oxide emissions (NO_x-values) with Cat SCR aftertreatment
NO_x-limit values according to IMO III: 2.31 g/kWh (n=900 rpm)
NO_x-limit values according to IMO III: 2.26 g/kWh (n=1,000 rpm)

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

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

10.3.2 Installation requirements

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

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

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

10.3.3 Requirements for material selection of urea tank and piping

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

Required materials:

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

Materials to avoid:

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

11.1 Components

advanced Modular Alarm and Control System (aMACS)

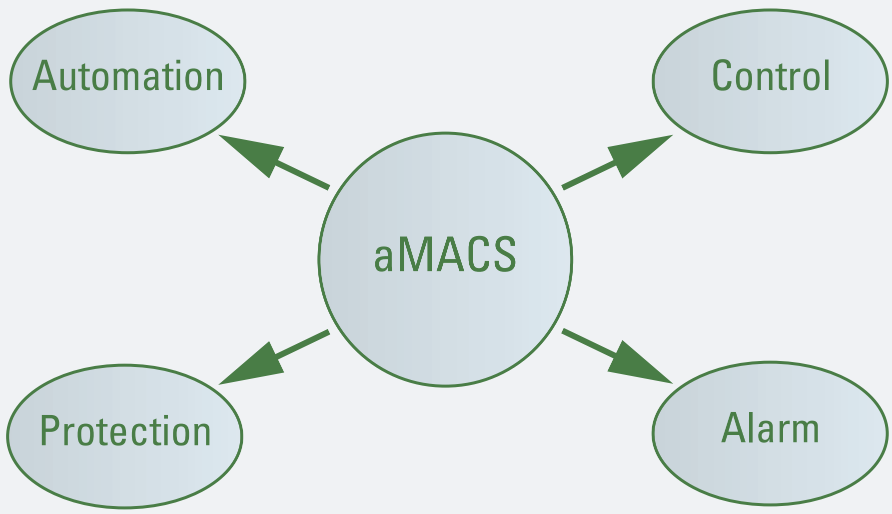


Fig. 11-1 Components of aMACS

The diesel engines will be provided with a new Modular Alarm and Control System, called aMACS. 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 11.5.2 Options).

aMACS consists of the following software functions:

- Start Stop Function
- Engine Diesel 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 aMACS panel as well as from external systems as the PMS or Caterpillar 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 Automation

aMACS provides additional automation functions located in the PLC or DCU. It includes purge, slow turn (optional) and charge air preheating activation.

Monitoring and Alarm System

The advanced Modular Alarm and Control System aMACS provides a monitoring and alarm system located in the DCU and some options in the PLC (optional). Measurement values are monitored for critical thresholds.
States and measurement values of most subsystems including SCR are also displayed on the local and remote displays. Monitoring of prelubrication and FCT monitoring (optional) are included. 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 advanced 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 shutdown unit (SDU 410).
The protection system has dedicated sensors and control outputs to stop the engine. Therefore it's acting independently from control, monitoring and alarm system.
All SDU switch inputs provide wire break detection. The output for actuating the safety stop valve is also monitored for wire break.
The SDU provides local LED indications providing a basic and independent indication to the operator. For each switch input, override input and the safety stop valve output the status and signal failure are shown. Besides the shutdown status, overspeed event, speed pickup status and communication status with the DCU are indicated.
Any failure and event at the SDU is transmitted via serial interface to the DCU and shown in the alarm list.

Engine Control and Load Sharing

For load sharing, droop mode and isochronous mode are implemented. The engine control module (ECM) is provided to control all essential engine parameters in closed loop manner as there are

- engine speed
- engine load
- air fuel ratio (AFR) incl. air injection and control of WG/CBV/BOV

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 aMACS. The engine speed control uses two speed pickups on the camshaft. Two sensors are deemed necessary for redundancy. If at least one sensor has healthy data, the engine speed can be determined. The main controlled output is the fuel rack actuator that controls the flow of liquid fuel to the cylinders.

11.2 Marine Control Panel

Fig. 11-2 Front of Basic & Advanced Panel

1	Digital control unit (DCU 410E)	7	Emergency stop button (E-stop)
2	Menu button	8	Power indicator
3	Up button	9	Alarm list button
4	Down button	10	Start button
5	Soft buttons	11	Stop button
6	Engine control switch (ECS)	12	Speed lower/raise

11.3 Genset control

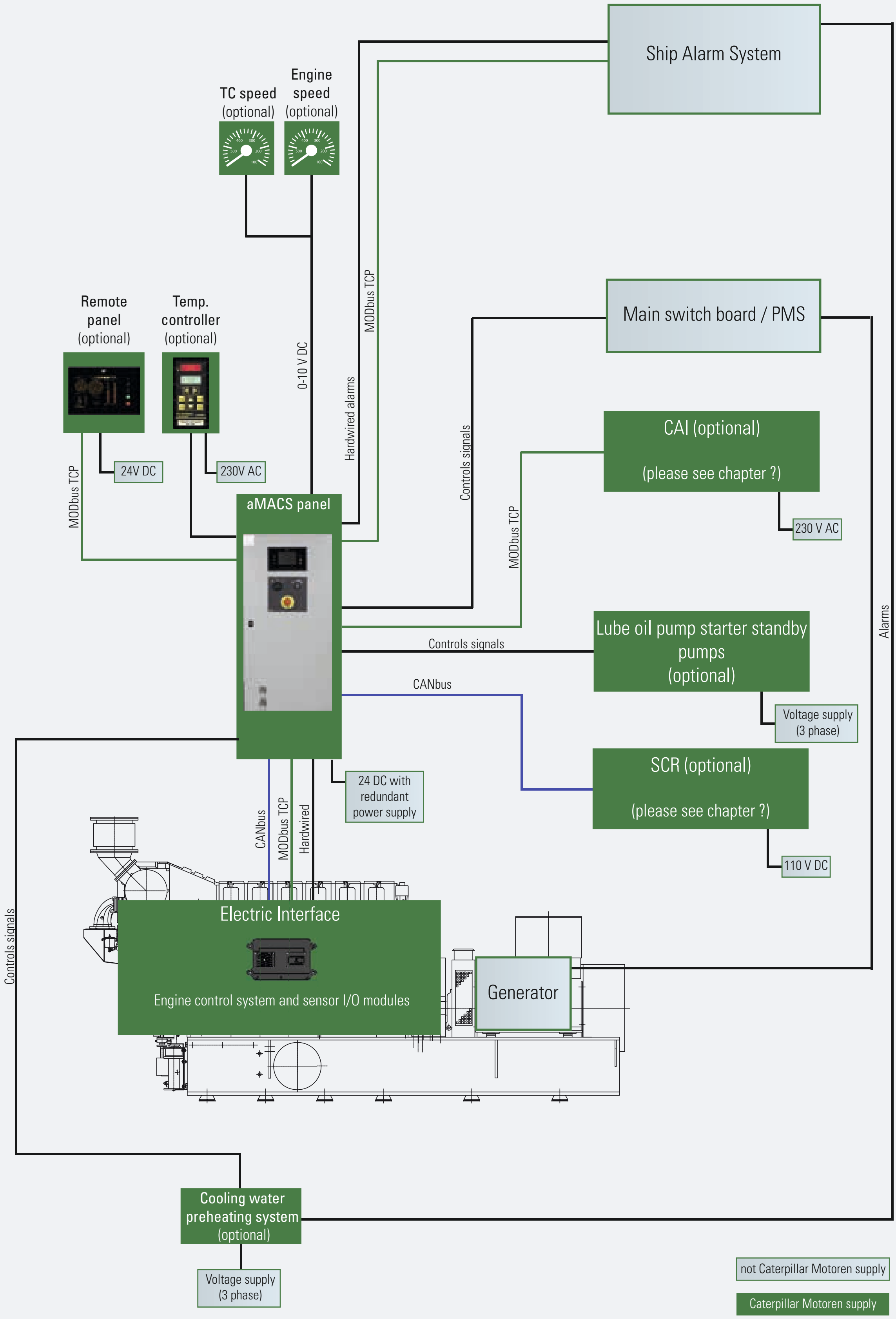
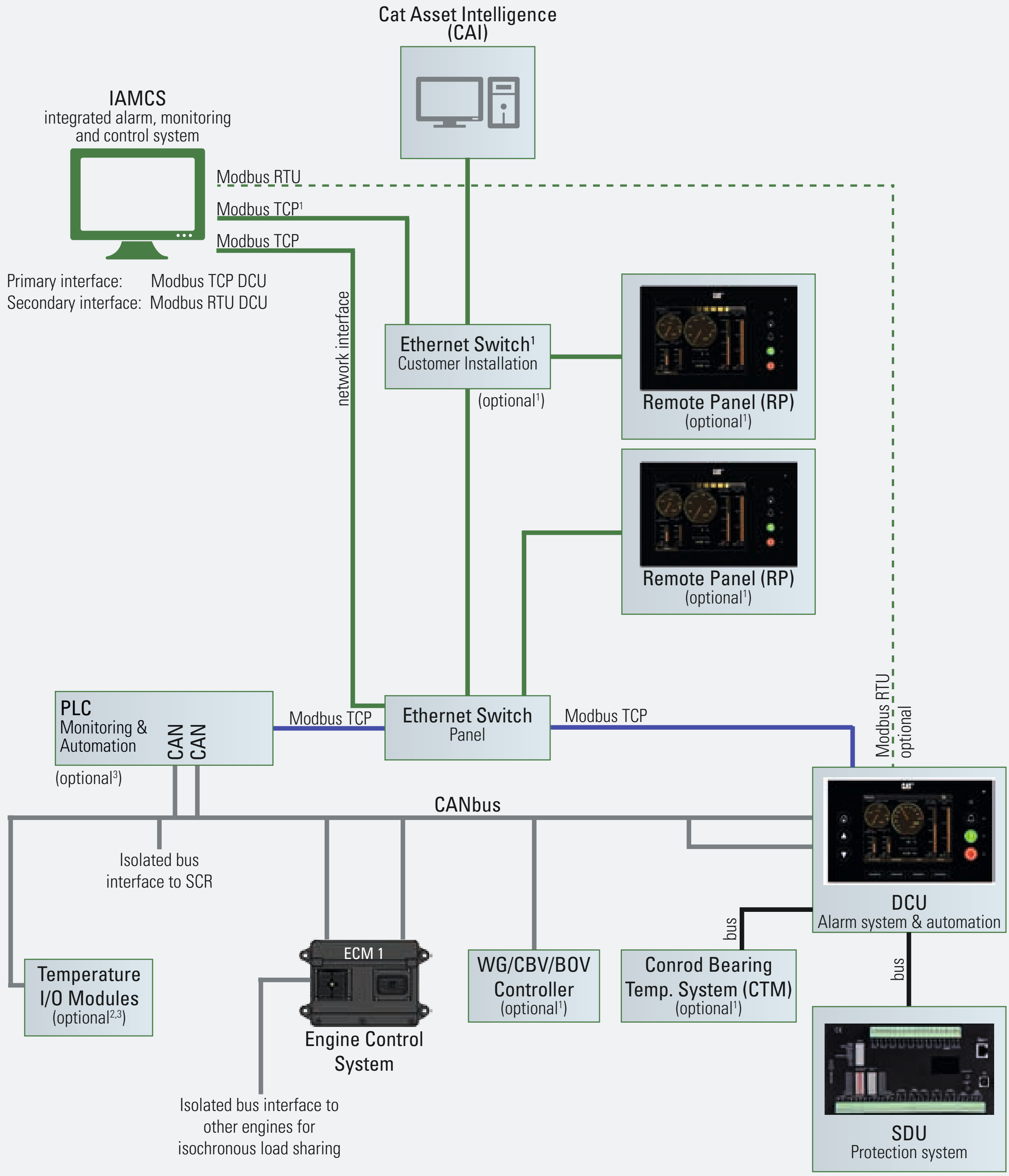


Fig. 11-3 Genset control

11.4 Data link overview



Notes:

[1] Customer option or required for optional functions.

[2] Customer option for main bearing temperature monitoring (one or two modules)

[3] Customer option or required for exhaust gas temperature monitoring per cylinder (one or two modules)

Fig. 11-4 Data link overview – M 20 C

SDU
Independent engine safety system in local control panel
DCU
Display, start-stop and alarm system
PLC (optional)
PLC, only in advanced panel
Engine Control System
Sensor inputs and control of engine speed, air injection, WG/CBV/BOV and load sharing
Temperature Sensor I/O Module
for PT100 and TC module temperature measuring at engine
CTM (optional)
Conrod bearing temperature monitoring at engine
Remote Panel (optional)
also as: remote start-stop control and remote alarm display
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 10.3

11.5 Control panel

11.5.1 Description and dimensions

Each engine is equipped with a separate control cabinet. The control cabinet acts as an interface between engine and external devices. Information about the engine status are available via MODbus TCP.
External signals for the engine control, monitoring and alarm system (for example gearbox, CPP control system,...) can be transferred as 4-20 mA, binary, or PT100 signal.
Safety relevant signals to the safety system are wired break monitored. Additional signals (alarms, STBL and normal shutdowns) to the PLC are wired partly break and short circuit monitored.

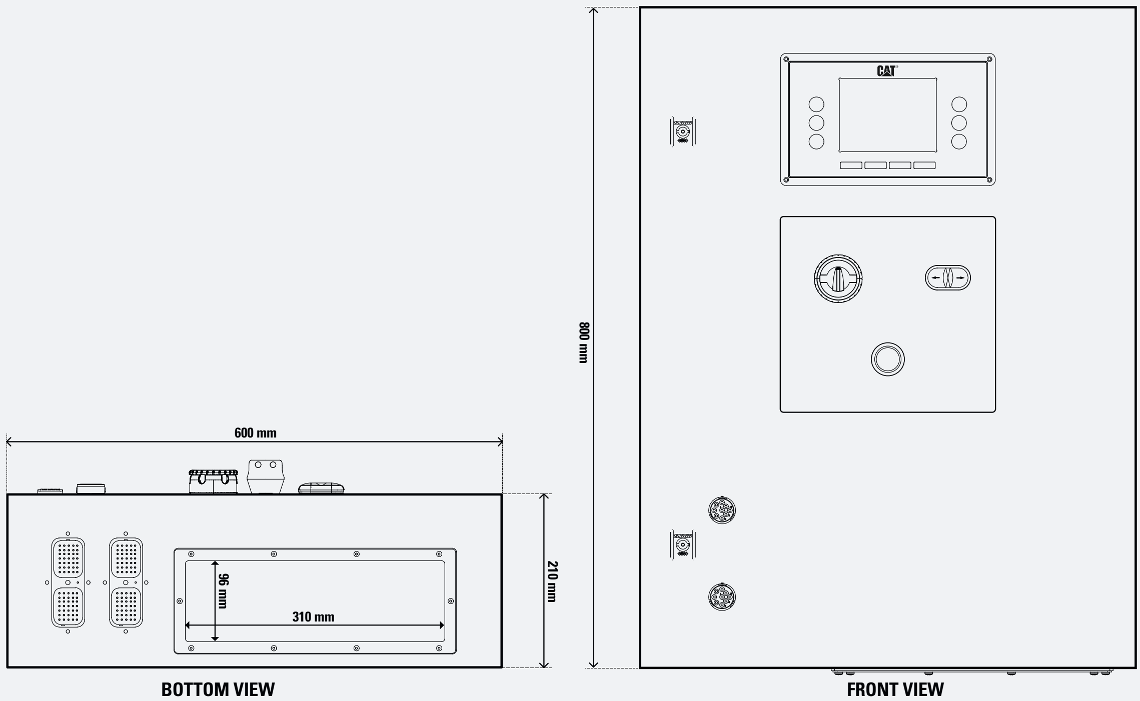


Fig. 11-5 Basic control panel

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

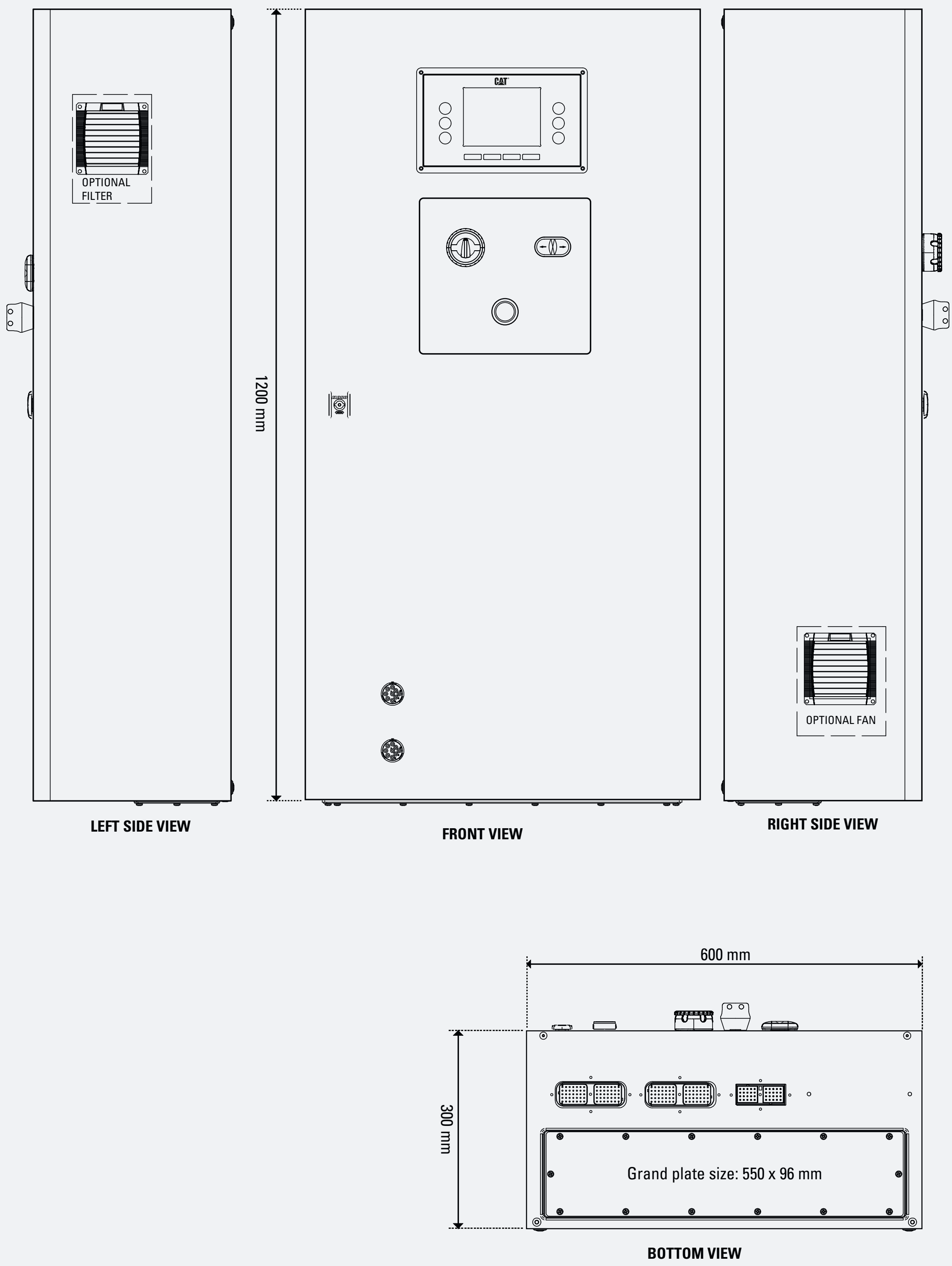


Fig. 11-6 Advanced control panel

11.5.2 Options

Option		Basic Panel	Advanced Panel
DC/DC converter	DC/DC converter required for galvanic isolation of power supply, with insulation monitoring. Included in local control panel (cabinet).		X
NAT router	NAT router for connection to ship interface. Included in local control panel (cabinet). Needed for multiple engine plant, because same network addresses are used on engines.	X	X
Galvanic isolation	Galvanic isolation for analog I/O signals. Included in local control panel (cabinet).		X
Fan & filter	Fan and filter for air circulation in local control panel (cabinet).		X

11.6 Requirements on control pitch propeller (CPP) system

Standard interface to gearbox and controllable pitch propeller for main engine system

Gearbox	Common load reduction (NO)	binary	→	24 V DC	Slow down for engine (only available for advanced panel)	
Gearbox	Lube oil pressure low low (NO)	binary	→	24 V DC	Shut down for engine	
CPP control / clutch control	Actual engine speed		←	4 - 20 mA	Engine speed	
CPP control / clutch control	Actual engine load		←	4 - 20 mA	Load signal 0 - 110 %	
CPP control / clutch control	Main engine in overload	24 V DC	←	binary	Overload indication at rated speed	
CPP control / clutch control	Request remote control	24 V DC	←	binary	Local / remote switch contact at engine	
CPP control / clutch control	Accept remote control	binary	→	24 V DC	Remote control accepted	
CPP control / clutch control	Local / remote control	24 V DC	←	binary	Closed contact when main engine 1 is in remote control	
CPP control / clutch control	Reduce to 40 % load	24 V DC	←	binary	Slowdown at engine	
CPP control / clutch control	Pitch to zero / auto clutch out	24 V DC	←	binary	Shutdown at engine	
CPP control / clutch control	Speed setting signal	0 - 5 V	→		Speed setting signal to ECM	
CPP control / clutch control	Clutch engaged or pitch not zero	binary	→	24 V DC	Starting interlock	

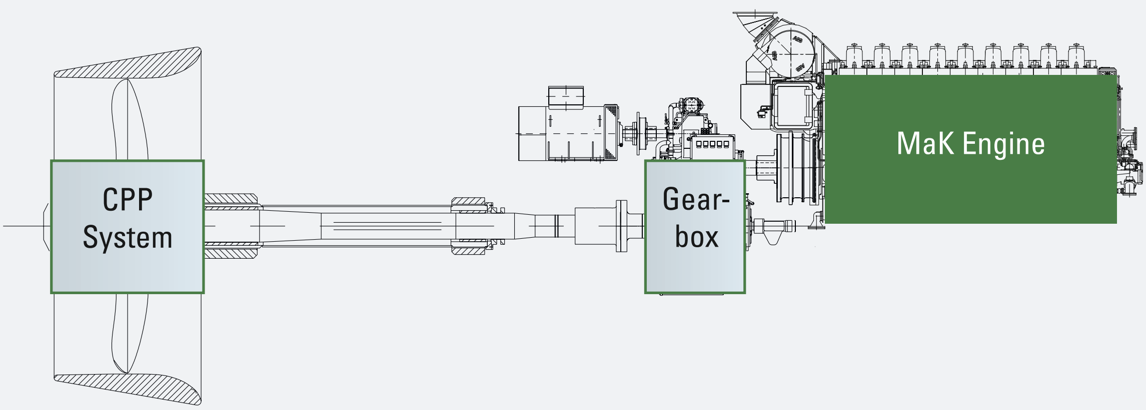


Fig. 11-7 Standard interface to gearbox and controllable pitch propeller for main engine system

11.7 Uninterruptable power supply (UPS)

For the control and monitoring system an uninterruptable power supply (UPS) with a back-up power supply is needed (class requirement). The Power supply for the Local Control Panel (aMACS) is 24 V DC. For the UPS 24 V DC, 230 V AC or 480 V AC three phase UPS power supply is possible.
The engine control cabinet has an integrated voltage distribution for the control and monitoring systems at the engine (see fig. 11-8). DC/DC converter and its insolation monitoring device is optional and only available with the advanced panel.

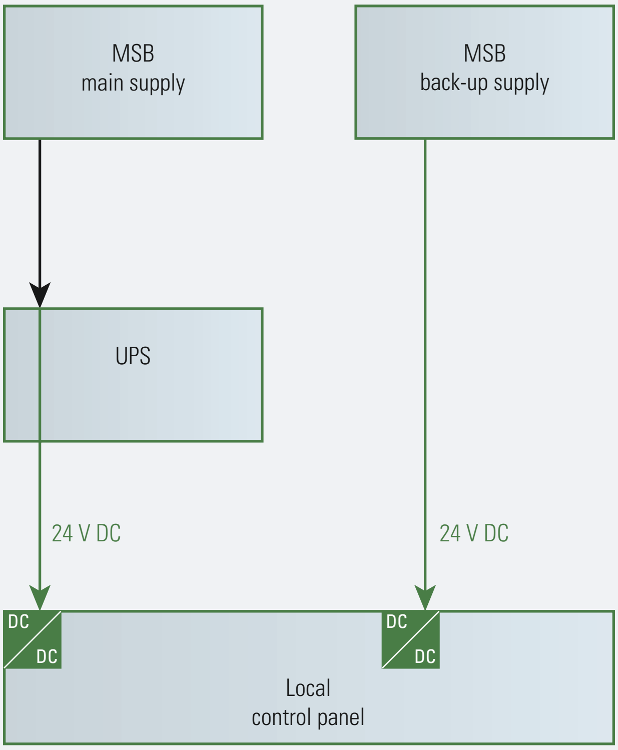


Fig. 11-8 Example uninterruptable power supply

11.8 Alarm indication

In general, the engine is equipped with the relevant alarm and safety sensors according to classification society rules.
aMACS 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, Caterpillar 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. 11-9 Remote panel

Fig. 11-10 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.

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

*) Depending on the application (CPP or generator set) only RED/CHG or SHD are activated.

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

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

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

11.9 Remote indicators

	Remote indicators 96 x 96 mm (optional)
Fuel oil temperature at engine inlet	X [2)]
Lube oil temperature at engine inlet	X [2)]
Fresh water temp. at engine outlet (HT circuit)	X [2)]
Fresh water temperature (LT circuit)	X [2)]
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)]
Engine speed and engine load	X [1)]
Turbocharger speed	X [1)]

1) 144 x 144 mm possible / **2)** Data is supplied by the DCU, but signals are supplied by the ships alarm system

11.10 Clutch control system

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

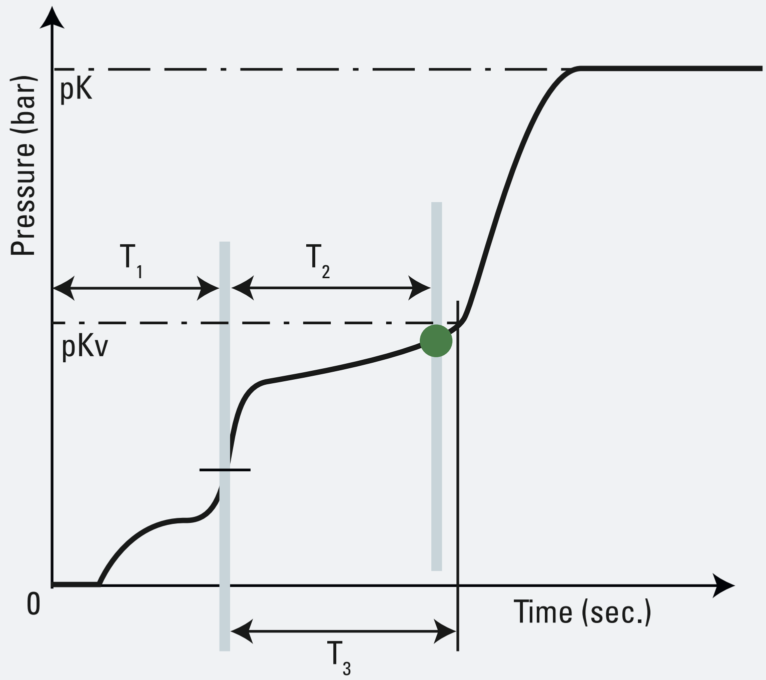


Fig. 11-11 Clutch in procedure for propulsion systems

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

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

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

11.11 Cat Connect Analytics provided by Caterpillar Asset Intelligence (CAI)

CAI provides technology enabled solutions and services, that

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

11.11.1 CAI – MaK engine solution only

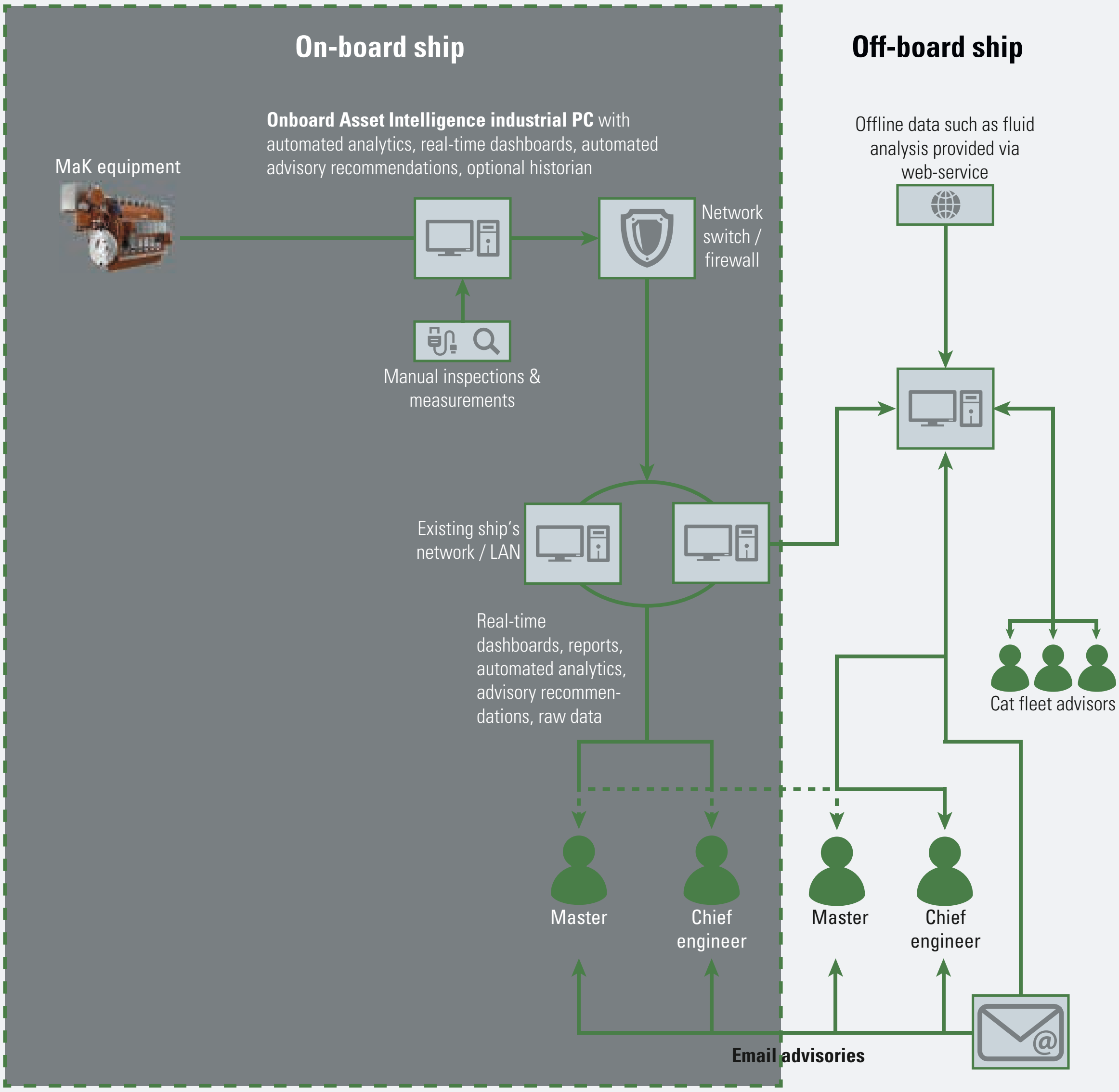


Fig. 11-12 CAI – MaK engine solution only

11.11.2 CAI – Extended solution

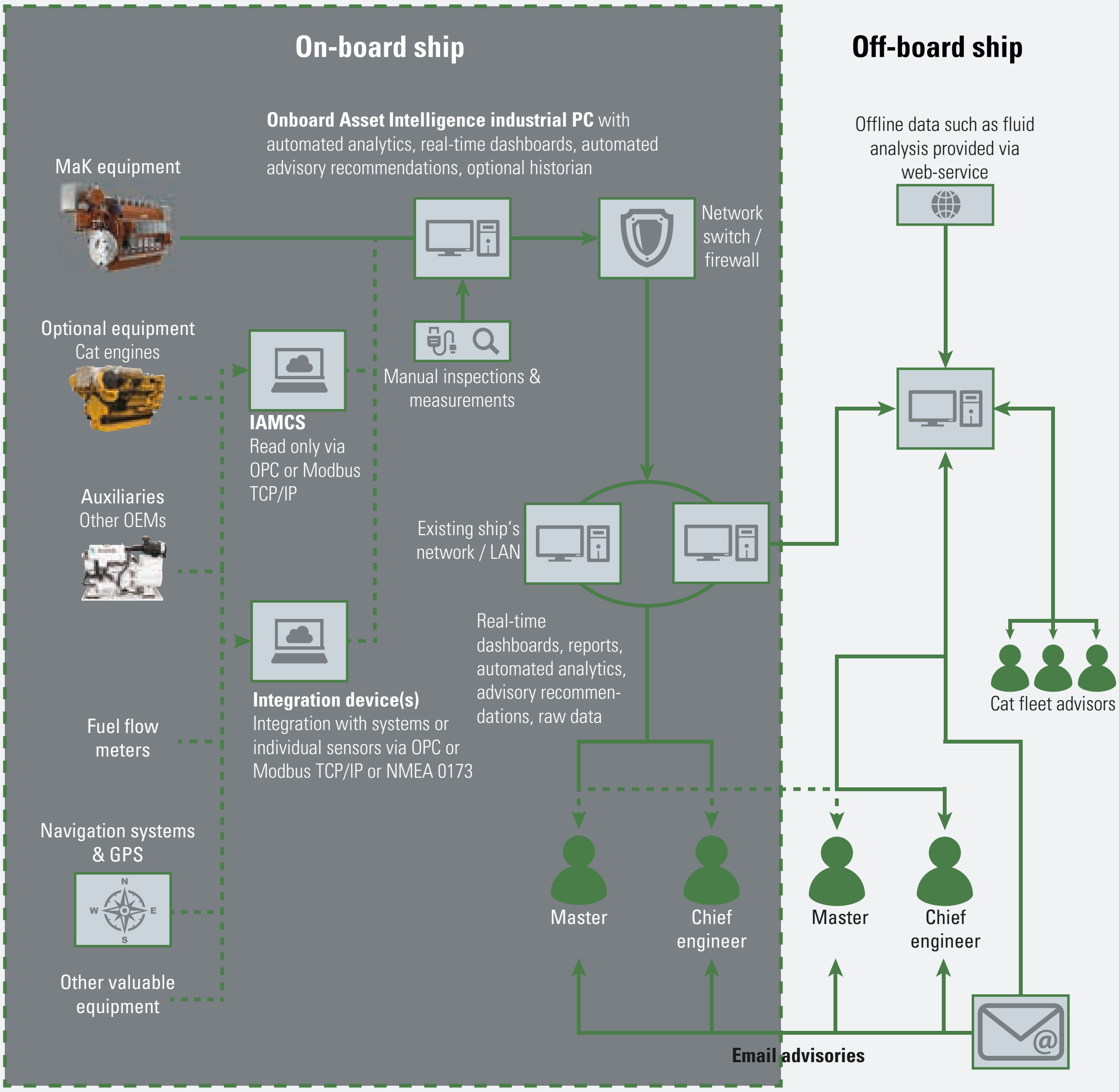


Fig. 11-13 CAI – Extended solution

11.11.3 General information

Capabilities

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

Comprehensive scope possible

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

System Benefits

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

Scope of delivery

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

Customer assumption

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

12.1 Resilient mounting of genset

12.1.1 Basic design and installation

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

Engine type	Resilient elements
6 M 20 C	10*
8/9 M 20 C	12*

*) No. of elements can vary due to genset weight

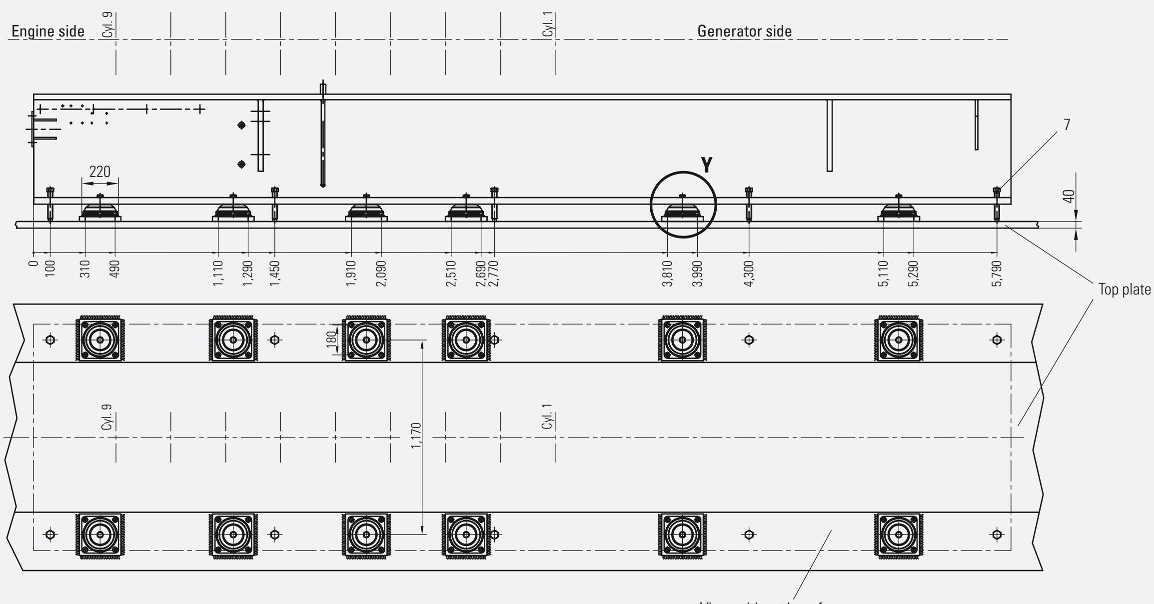


Fig. 12-1 Example of 9 M 20 C foundation plan

12.2 Earthing of engine

Information about the execution of the earthing

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

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

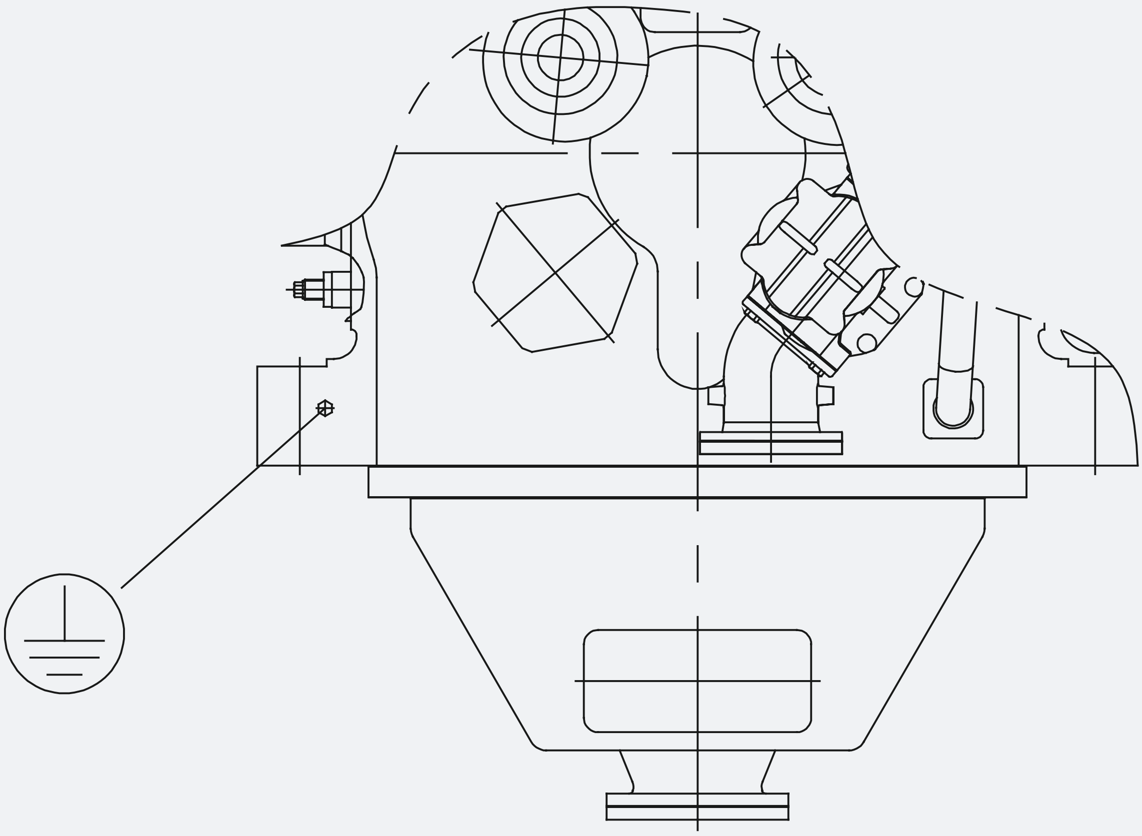


Fig. 12-2 Earthing connection on the engine

13.1 Sound levels

13.1.1 Airborne noise

The airborne noise level requirement in the engine room specified by IMO Resolution A.468 will be satisfied by M 20 C (even for multiple installations).

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

13.2 Vibration

The vibration level of M 20 C engines complies with ISO 8528-9 and ISO 10816-6. From these ISO standards, the following values are an applicable guideline:

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

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

14.1 Flexible coupling

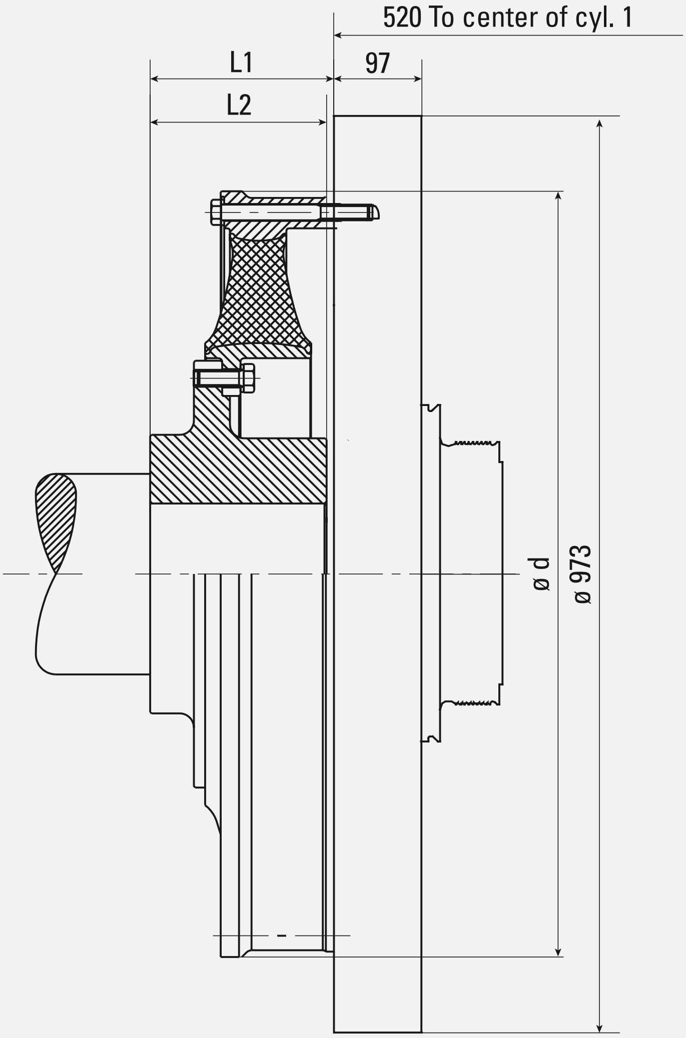


Fig. 14-1 Flywheel and flexible coupling

	Power	Speed	Nominal torque of coupling	Vulkan Rato-DS [1]				Weight
				Type	d	L1 [3]	L2 [2]	
	[kW]	[rpm]	[kNm]		[mm]	[mm]	[mm]	[kg]
6 M 20 C	1,200/1,080	1,000/900	12.5	A2511	740	265	200	194
8 M 20 C	1,600/1,440	1,000/900	16.0	A2515	740	265	200	194
9 M 20 C	1,800/1,620	1,000/900	20.0	A2911	870	265	250	330

1) Final coupling type and dimensions are dependent on generator type and is to be confirmed by the torsional vibration calculation /

2) Length of hub / **3)** Alignment control (recess depth 5 mm)

15.1 Pipe dimensions

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

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

15.2 Flow velocities in pipes

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

15.3 Trace heating

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

15.4 Insulation

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

15.5 Flexible pipe connections

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

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

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

Installation of steel compensators

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

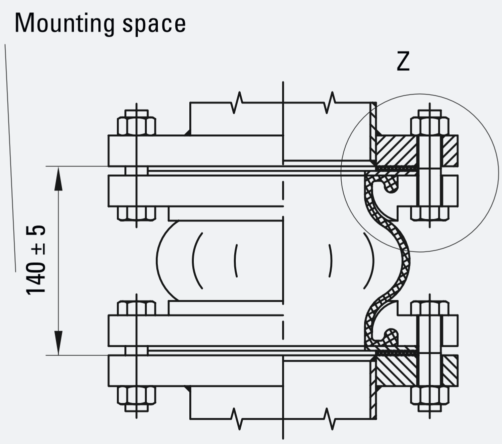


Fig. 15-1 Rubber expansion joint

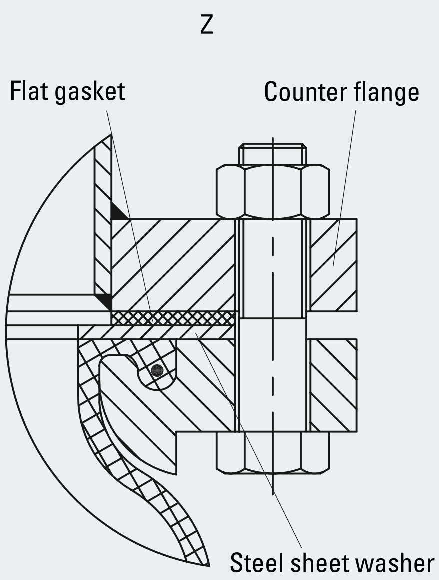


Fig. 15-2 Rubber expansion joint, detail Z

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16.1 Space requirements for maintenance

16.1.1 Removal of charge air cooler and turbocharger cartridge

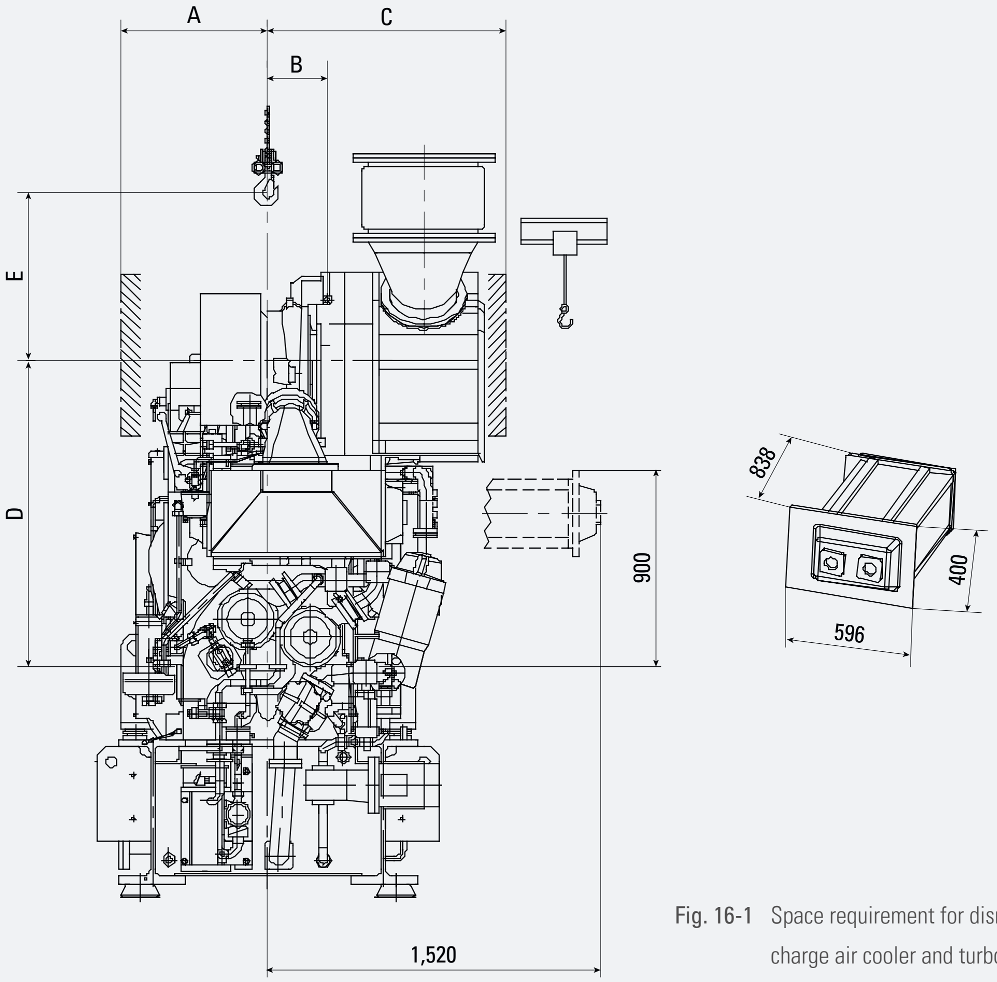

Fig. 16-1 Space requirement for dismantling of charge air cooler and turbocharger cartridge

	Dimensions [mm]					Weight of turbocharger [kg]					
	A	B	C	D	E	TC complete	Silencer	Compressor housing	Turbine housing	Cartridge	Rotor
6 M 20 C	515	268	892	1,330	830	236	25	46	51	54	13
8/9 M 20 C	670	276	1,025	1,400	910	354	55	87	87	88	20

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

Caterpillar recommends to provide a lifting device above the bearing housing of the turbocharger.

16.1.2 Removal of piston and cylinder liner

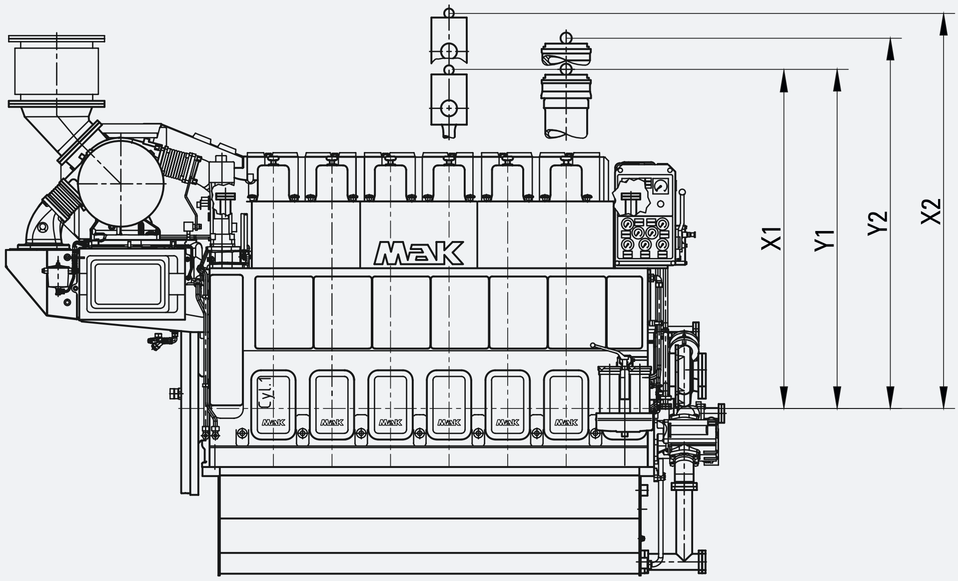

Fig. 16-2 Removal of piston and cylinder liner

Removal of:

Piston:	in transverse direction	X1 = 1,905 mm
	in longitudinal direction	X2 = 2,225 mm
Cylinder liner:	in transverse direction	Y1 = 1,910 mm
	in longitudinal direction	Y2 = 2,085 mm

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

17.1 Inside preservation

17.1.1 Factory standard N 576-3.3 – Inside preservation

Components

- Main running gear and internal mechanics

Application

- Max. 2 years

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

17.2 Outside preservation

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

Conditions

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

Appearance of the engine

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

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

17.2.2 Factory standard N 576-4.1 – Clear varnish

Conditions

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

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

Appearance of the engine

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

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

17.2.3 Factory standard N 576-4.3 – Painting

Conditions

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

Appearance of the engine

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

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

17.2.4 Factory standard N 576-5.2 – VCI packaging

Conditions

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

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

Appearance of the engine

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

ATTENTION:

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

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

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

Application

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

Description

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

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

17.3.1 Protection period

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

17.3.2 Protection check

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

17.3.3 Represervation as per factory standard N 576-6.1

After 2 years represervation must be carried out.

18.1 Lifting of engines

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

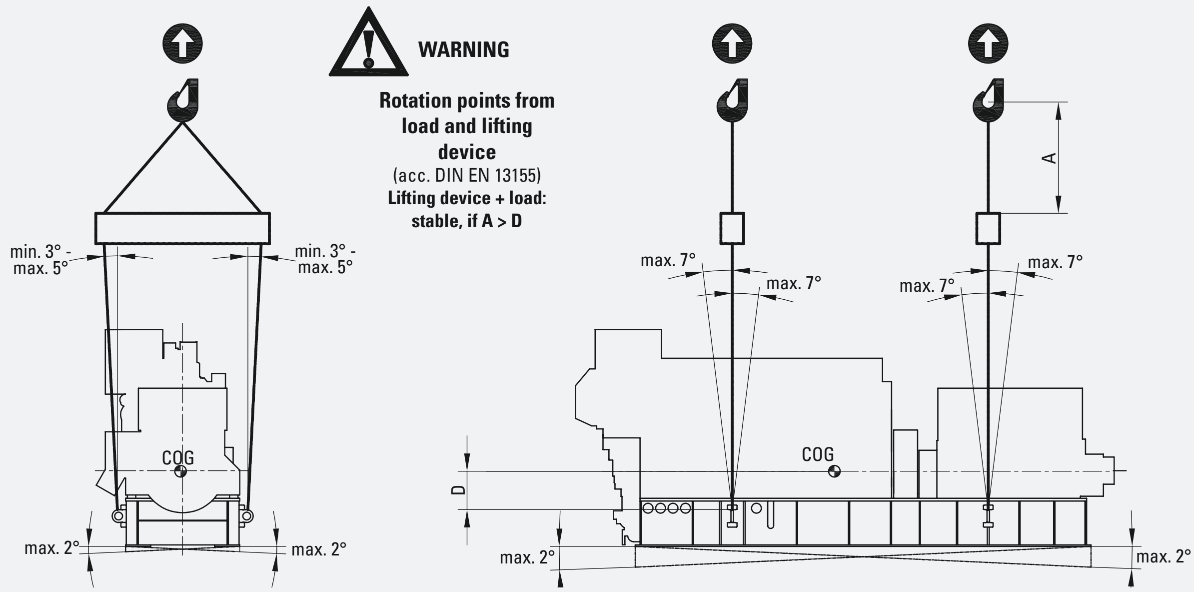

Fig. 18-1 Transport of engine

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

18.2 Dimensions of main components

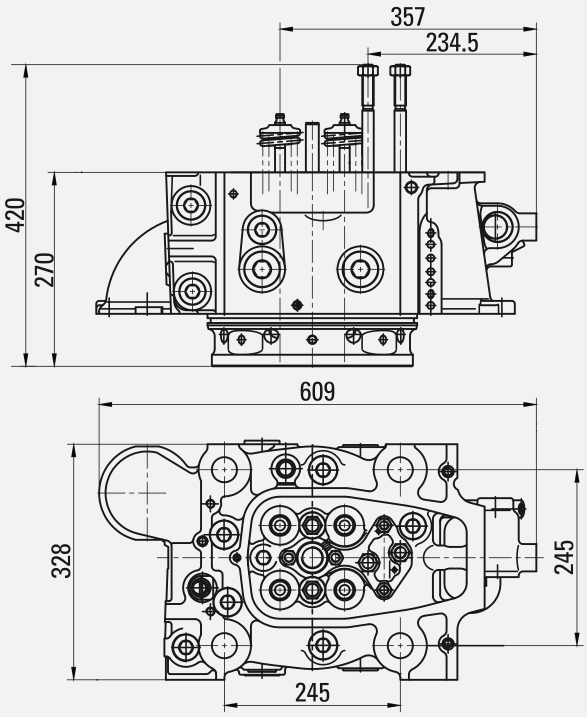

Fig. 18-2 Cylinder head, weight 91.5 kg

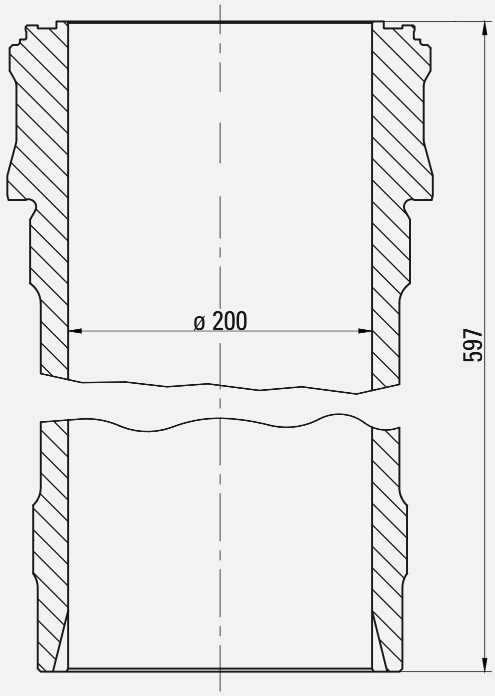

Fig. 18-3 Cylinder liner, weight 60 kg

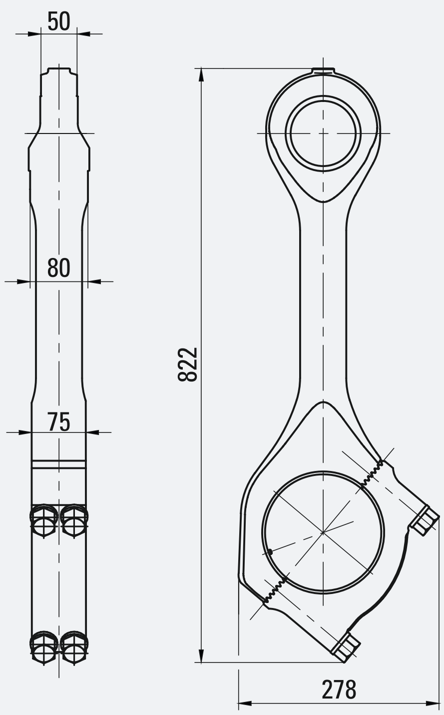

Fig. 18-4 Connecting rod, weight 38.7 kg

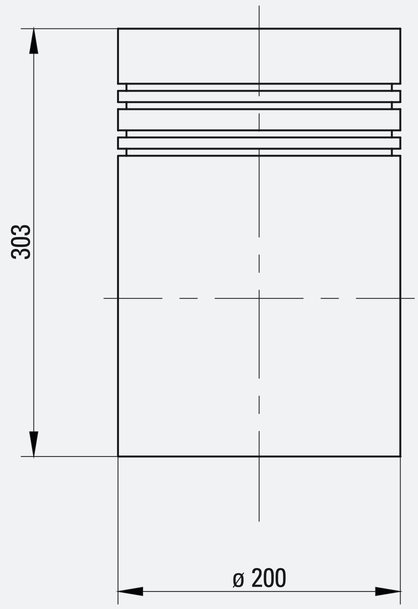

Fig. 18-5 Piston, weight 39.5 kg

19.1 Standard acceptance test run

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

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

The load stages above can vary according to the requirements of the classification societies or special contractual agreements.

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

Additional functional tests

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

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

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

20.1 Required spare parts (Marine Classification Society MCS)

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

20.2 Recommended spare parts

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

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

Caterpillar recommendation	Caterpillar
Rules references	
Status	2016
Parts	
Main bearing	1
Thrust washer	–
Cylinder liner, complete	–
Cylinder head, complete	–
Cylinder head, only with valves (w/o injection valve)	–
Set of gaskets for one cylinder head	1
Set bolts and nuts for cylinder head	–
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	–
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	1
Exhaust compensators between cylinders	–
Turbocharger rotor, complete	–
Set of gear wheels	–
Only for electronic speed setting: Pick-up for electronic speed setting	1
Only for M 20 C main single engine: Starter	1
Only if oil mist detector is provided (VN301 is excluded): Sintered bronze filter (for crankcase monitoring)	1

*) Recommendation only

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

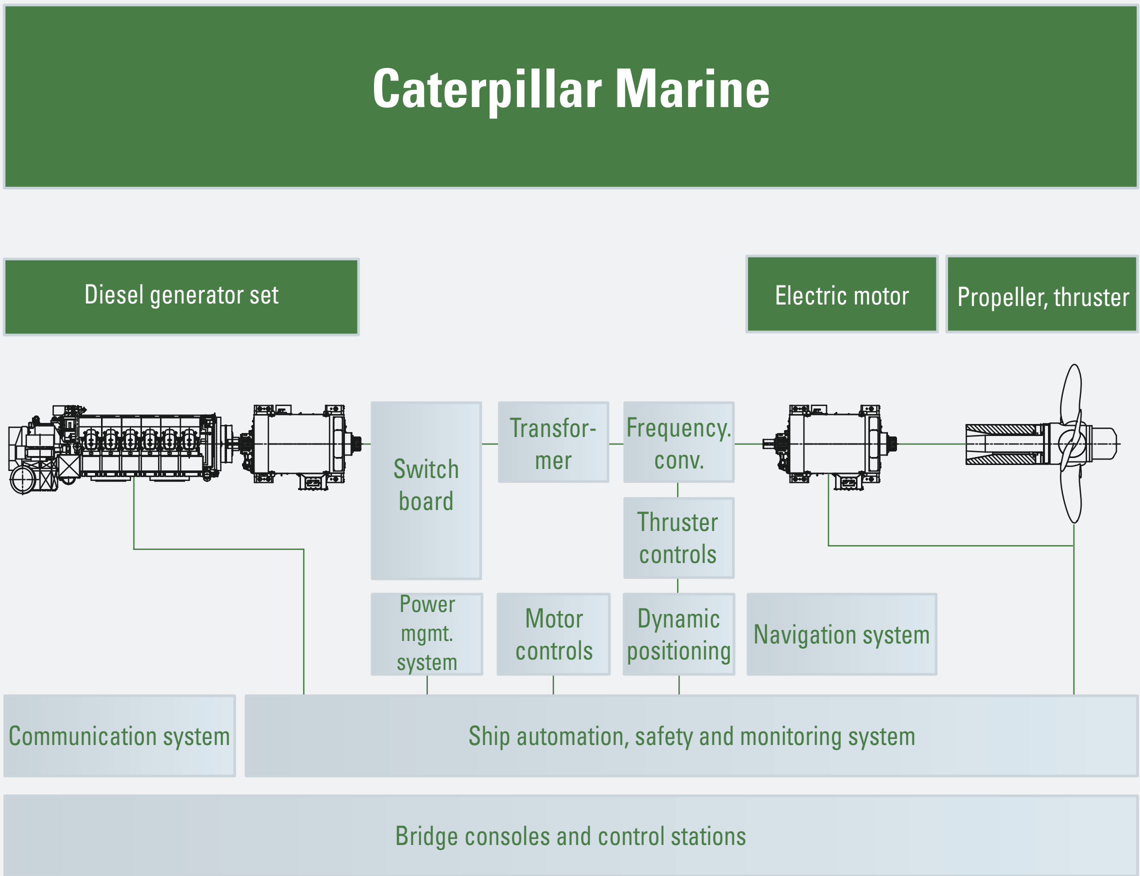

Fig. 21-1 D/E application

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

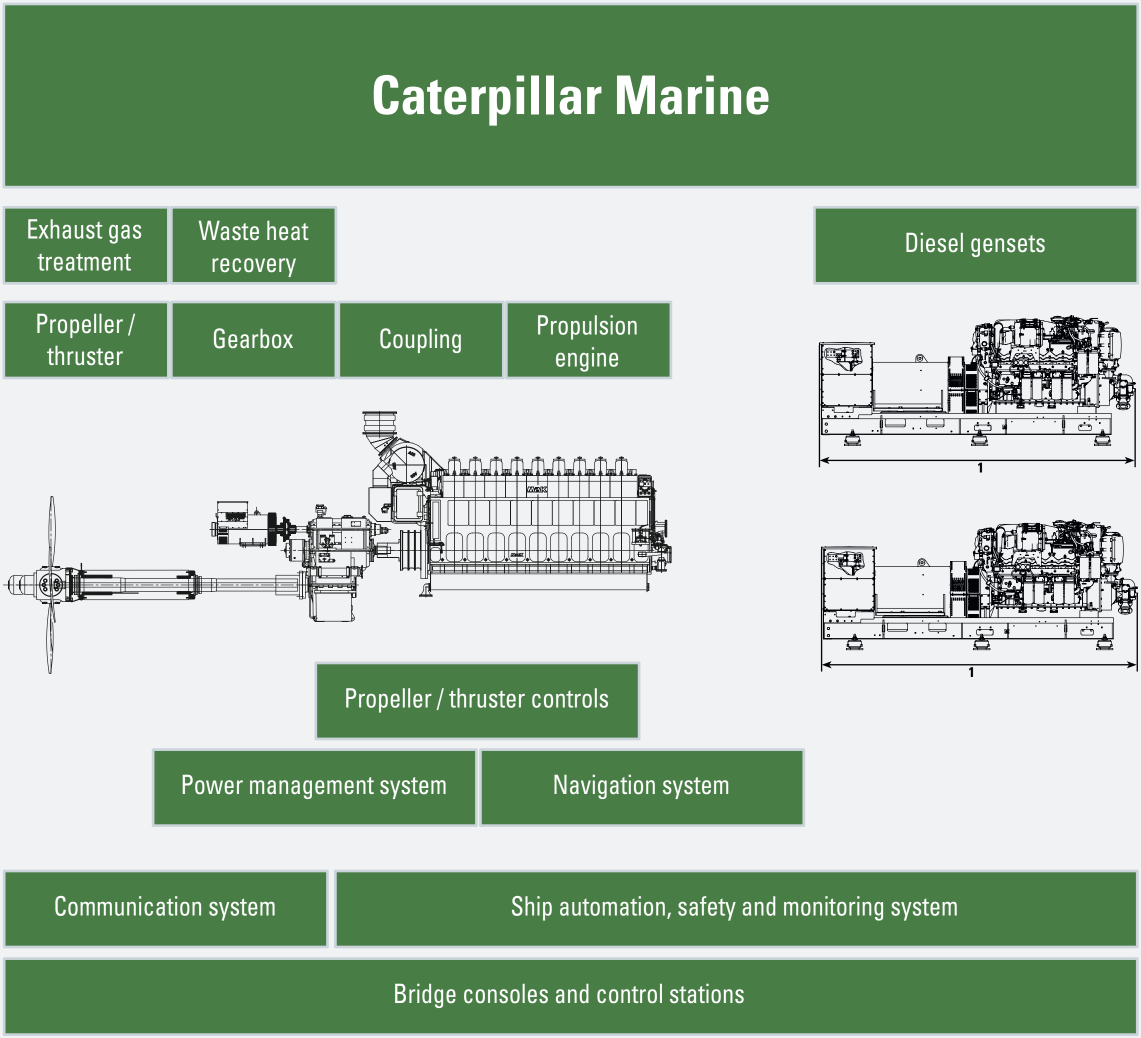

Fig. 21-2 D/M application

21.3 Levels of integration

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

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

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

21.4 Caterpillar Propulsion

Performance You Can Rely On

Caterpillar Propulsion supplies complete, world-leading propulsion systems.

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

Fig. 21-3 Main propeller

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

How We Deliver Uptime

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

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

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

Fig. 21-4 Azimuth thrusters

Fig. 21-5 Tunnel thrusters

Fig. 21-6 Remote control system

The Power You Need.

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

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

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

For more information and to find your local dealer, please visit our website: **www.cat.com/marine**
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