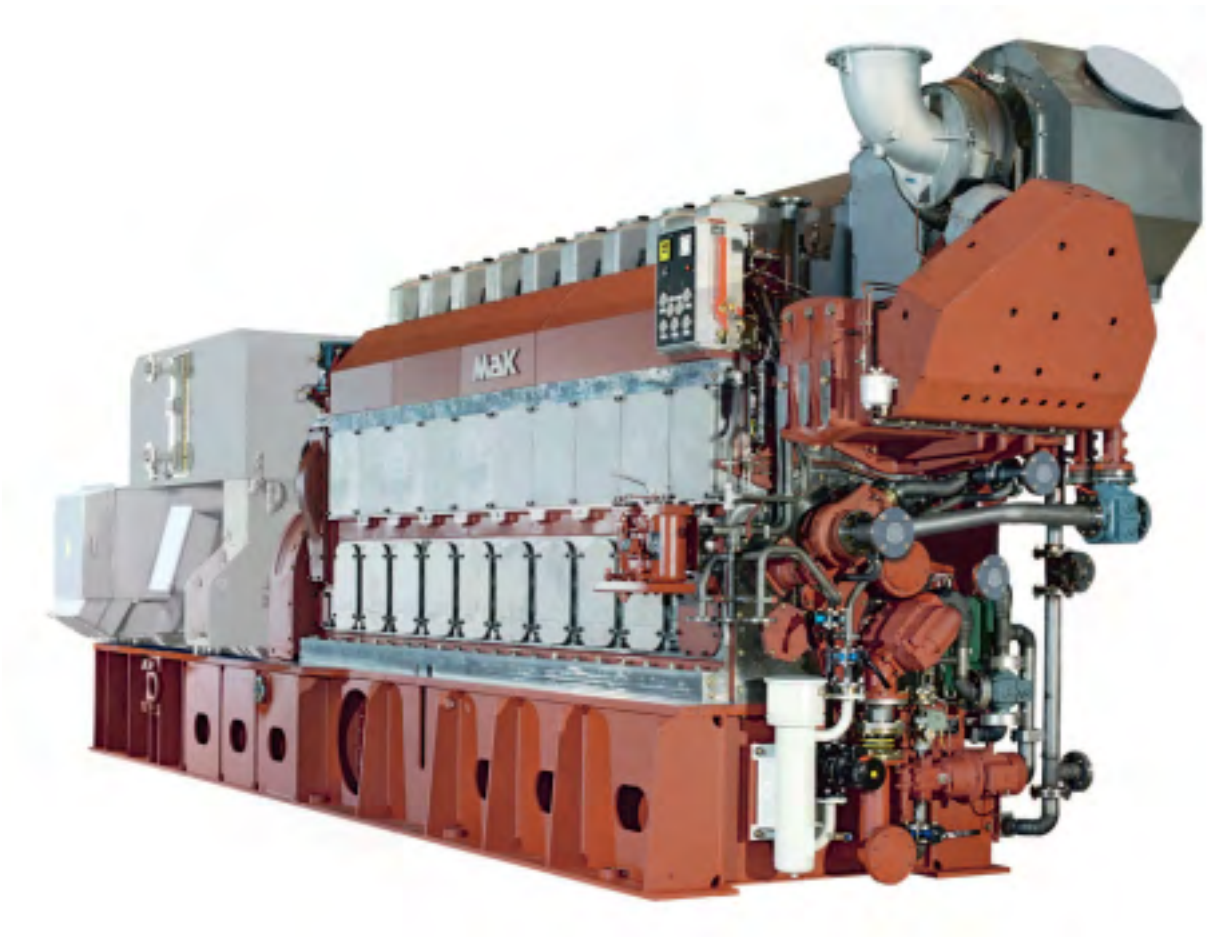
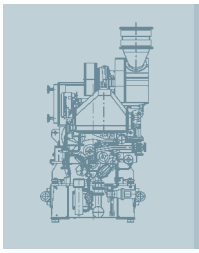
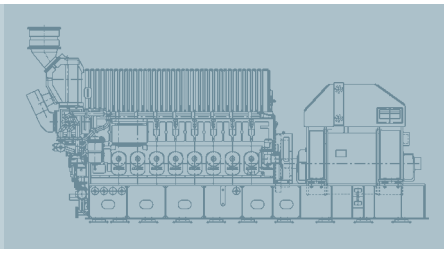
M 25 C

Contents

Project Guide • Generator Set







Introduction

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 Motoren 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.

Caterpillar Motoren GmbH & Co. KG
P. O. Box, D-24157 Kiel
Germany
Phone +49 431 3995-01
Telefax +49 431 3995-2193

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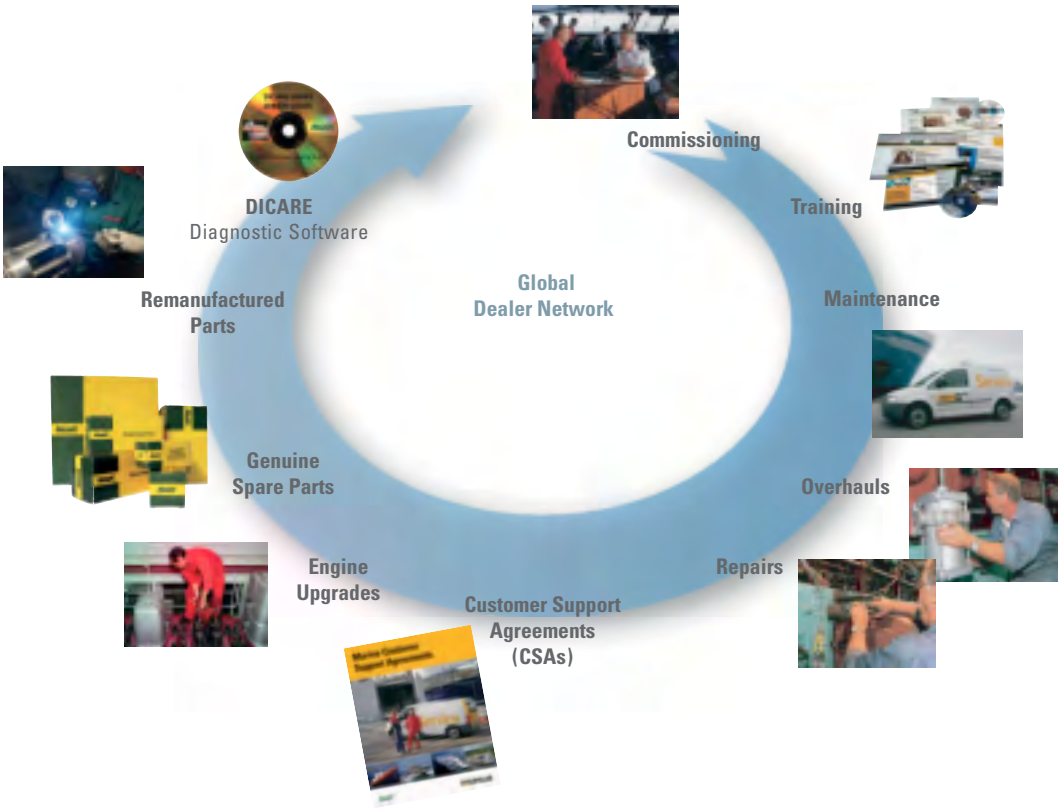

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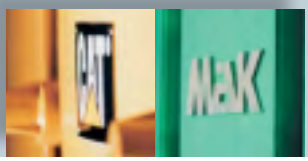

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MANAGEMENT SYSTEM CERTIFICATE

Certificate No.: 81311-2010-AQ-GER-TGA

This is to certify that

Caterpillar Motoren GmbH & Co. KG

Falckensteiner Str. 2
24159 Kiel - Germany

and the sites

Caterpillar Motoren Rostock GmbH
Werftallee 13
18119 Rostock

Caterpillar Power Generation Systems
Koboldstraße 2-4
24118 Kiel

Caterpillar Motoren Henstedt-Ulzburg GmbH
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24558 Henstedt-Ulzburg

Caterpillar Motoren Guangdong Co. Ltd.
Shizhou Industrial Estate
Chencun Town
Shunde District, Foshan City
528341 P. R. China

has been found to conform to the Management System Standard

ISO 9001:2008

This certificate is valid for the following product or service ranges:

For Catarpillar Motoren Kiel:
Design, manufacture, sales and service of gas and diesel engines
For Catarpillar Motoren Rostock:
Manufacture of gas and diesel engines
For Caterpillar Motoren Guangdong:
Production of diesel engines
For Caterpillar Power Generation Systems:
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For Caterpillar Motoren Henstedt-Ulzburg GmbH:
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Initial Certification date:
03.11.2003

This certificate is valid until:
14.11.2013

The audit has been performed under the supervision of
Jürgen Weißbauer
Lead Auditor

Deutscher Akkreditierungs Rat
DAR
TGA-ZM-04-92-00

Place and date:
Essen, 15.11.2010

for the Accredited Unit:
DNV ZERTIFIZIERUNG UND UMWELTGUTACHTER GMBH

Nikolaus Kim
Management Representative

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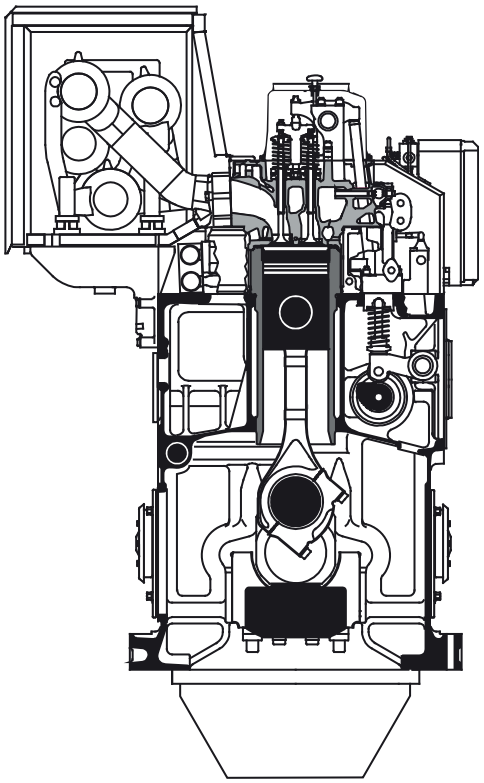
13. Appendix

1. Engine description

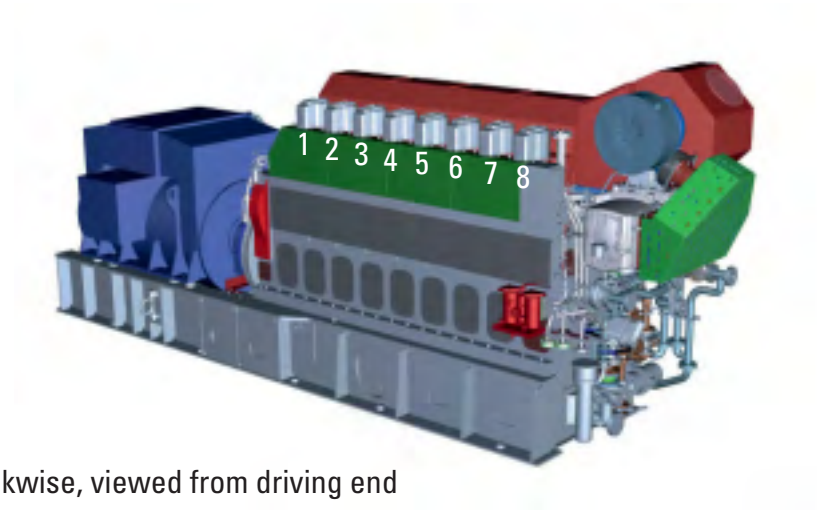
1.1 Engine description

The M 25 C is a four-stroke diesel engine, non-reversible, turbocharged and intercooled with direct fuel injection.

In-line engine M 25 C



Cylinder configuration:	6,8,9 in-line
Bore:	255 mm
Stroke:	400 mm
Stroke/bore ratio:	1.57
Swept volume:	20.4 l/Cyl.
Output/cyl.:	333 kW
BMEP:	26.1/27.2 bar
Revolutions:	720/750 rpm
Mean piston speed:	9.6/10.0 m/s
Turbocharging:	pulse
Direction of rotation:	counter-clockwise, viewed from driving end



1. Engine description

1.2 Engine design features

- Baseframe
- Generator
- Compact Genset fitted lube oil cooler
- Designed for heavy fuel operation up to 700 cSt/50°C, fuel grade acc. to CIMAC H55 K55, ISO 8217, 1996 (E), ISO-F-RMH55 RMK55.
- 1-piece dry engine block made of nodular cast iron. It includes the crankshaft bearing, camshaft bearing, 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 anti-polishing ring.
- Composite type pistons with steel crown and nodular cast iron skirt.
- Piston ring set consisting of 2 chromium plated compression rings, first ring with chromium-ceramic plated running surfaces and 1 chromium plated oil control ring. All ring grooves are hardened and located in the steel crown.
- 2-piece connecting rod, fully machined, obliquely split with serrated joint.
- Cylinder head made of nodular cast iron with 2 inlet and 2 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 lubricating oil.
- 2-stage fresh water cooling system with 2-stage charge air cooler.
- Nozzle cooling for heavy fuel operation with engine lubricating oil.
- For invisible smoke at part load operation Flexible Camshaft Technology is available.

2. General data and operation of the engine

	720 rpm / 60 Hz		750 rpm / 50 Hz	
	Engine kW	Generator kWe	Engine kW	Generator kWe
6 M 25 C	2,000	1,920	2,000	1,920
8 M 25 C	2,666	2,559	2,666	2,559
9 M 25 C	3,000	2,880	3,000	2,880

Remark:
The generator outputs are based on 96% effiency and a power factor of 0.8.

2.1 General data and ouputs

2.1.1 Output definition

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

Reference conditions according to IACS (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.

2.1.2 Fuel consumption

The fuel consumption data refer to the following reference conditions:

Intake temperature	298 K (25°C)
Charge air temperature	318 K (45°C)
Charge air coolant inlet temperature	298 K (25°C)
Net heating value of the diesel oil	42,700 kJ/kg
Tolerance	5 %

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

2. General data and operation of the engine

2.1.3 Lubricating oil consumption

Actual data can be inferred from the technical data.

2.1.4 Nitrogen oxide emissions (NO_x values)

NO_x limit values according to MARPOL 73/78 Annex VI:	9.69 g/kWh (n = 720 rpm) 9.60 g/kWh (n = 750 rpm)
Generator according to cycle D2:	9.60 g/kWh (n = 720 rpm) 9.60 g/kWh (n = 750 rpm)

2.1.5 General installation aspect

Inclination angles at which gensets and essential aux. machinery is to operate satisfactorily:

Heel to each side:	15°
Rolling to each side:	± 22.5°
Trim by head and stern:	5°
Pitching:	± 7.5°

2. General data and operation of the engine

2.1.6 Technical data

Performance Data	Cylinder	6		8		9	
Maximum continuous rating acc. ISO 3046/1	kW	2,000	2,000	2,666	2,666	3,000	3,000
Speed	1/min	720	750	720	750	720	750
Minimum speed	1/min	240	250	240	250	240	250
Brake mean effective pressure	bar	27.2	26.1	27.2	26.1	27.2	26.1
Charge air pressure	bar	3.2	3.2	3.2	3.2	3.3	3.2
Firing pressure	bar	210	210	210	210	210	210
Combustion air demand (ta = 20°C)	m³/h	11,390	11,505	14,460	14,605	17,035	17,190
Specific fuel oil consumption							
n = const [1] 100%	g/kWh	188	186	189	187	189	187
85%	g/kWh	185	184	185	184	185	184
75%	g/kWh	185	184	185	184	185	184
50%	g/kWh	193	193	193	193	193	193
Lubricating oil consumption [2]	g/kWh	0.6		0.6		0.6	
NO_x-emission [6]	g/kWh	9.6		9.6		9.6	
Turbocharger type		KBB HPR6000		KBB HPR6000		KBB HPR6000	
Fuel							
Engine driven booster pump	m³/h/bar	1.5/3		1.5/3		1.5/3	
Stand-by booster pump	m³/h/bar	2.2/10	2.3/10	2.7/10	2.8/10	2.7/10	2.8/10
Mesh size MDO fine filter	mm	0.025		0.025		0.025	
Mesh size HFO automatic filter	mm	0.010		0.010		0.010	
Mesh size HFO fine filter	mm	0.034		0.034		0.034	
Lubricating Oil							
Engine driven pump	m³/h/bar	89/10	93/10	89/10	93/10	89/10	93/10
Independent pump	m³/h/bar	45/10		60/10		60/10	
Working pressure at engine inlet	bar	4 - 5		4 - 5		4 - 5	
Independent suction pump	m³/h/bar	57/3		70/3		70/3	
Primimg pump pressure/suction pump	m³/h/bar	6.6/8/5		10/13/5		10/13/5	
Sump tank content/dry sump content	m³	2.6	2.7	3.4	3.6	3.9	4.0
Temperature at engine inlet	°C	60 - 65		60 - 65		60 - 65	
Temperature controller NB	mm	80		100		100	
Double filter NB	mm	80		80		80	
Mesh size double filter	mm	0.08		0.08		0.08	
Mesh size automatic filter	mm	0.03		0.03		0.03	

2. General data and operation of the engine

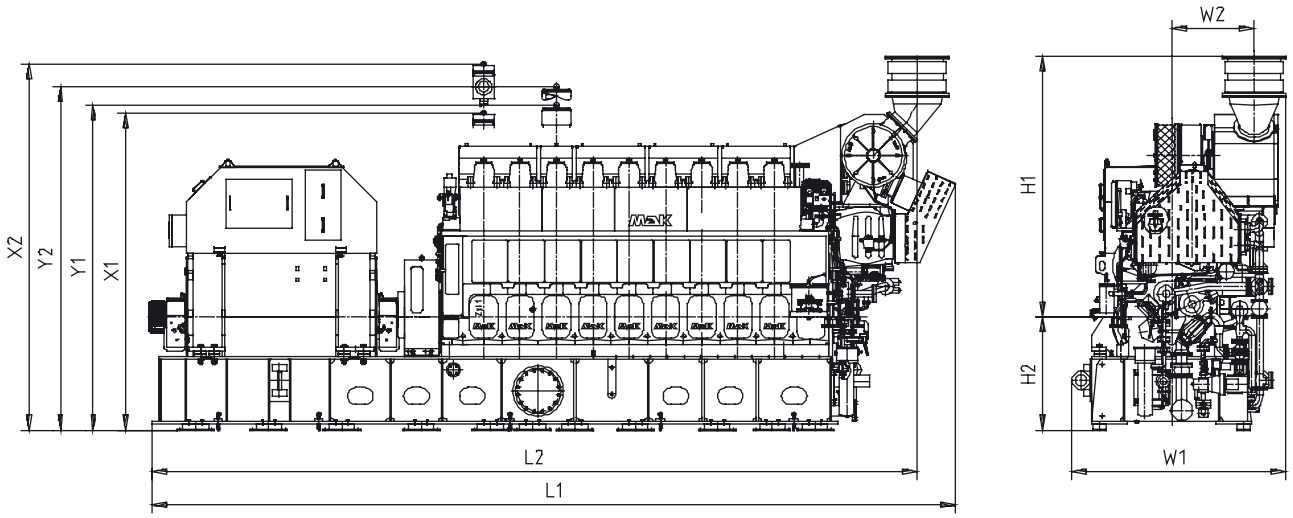
Fresh water cooling	Cylinder	6		8		9	
Engine content	m³	0.4		0.5		0.6	
Pressure at engine inlet min/max	bar	4.6/6.0		4.5/6.0		4.5/6.0	
Header tank capacity	m³	0.2		0.25		0.3	
Temperature at engine outlet	°C	80 - 90		80 - 90		80 - 90	
Two-circuit system							
Engine driven pump HT	m³/h/bar	40/4.5		55/4.5		60/4.7	
Independent pump HT	m³/h/bar	40/4.0		55/4.0		60/4.0	
HT-controller NB	mm	80		100		100	
Water demand LT-charge air cooler	m³/h	40		55		60	
Temperature at LT-charger air cooler inlet	°C	38		38		38	
Heat dissipation							
Specific jacket water heat	kJ/kW	500		500		500	
Specific lube oil heat	kJ/kW	490		490		490	
Lube oil cooler	kW	273		362		410	
Jacket water	kW	278		370		417	
Charge air cooler (HT stage) [3]	kW	570	576	744	752	799	807
Charge air cooler (LT stage) [3] (HT stage after engine)	kW	194	196	253	256	272	275
Heat radiation engine	kW	85		113		128	
Exhaust gas							
Silencer/spark arrestor NB 25 dBA	mm	500/500		600/600		600/600	
Pipe diameter NB after turbine	mm	500		600		600	
Maximum exhaust gas pressure drop	bar	0.03		0.03		0.03	
Exhaust gas temp after turbine (25°C intake air) [5]	°C	333		335	333	360	342
Exhaust gas mass flow (25°C intake air) [5]	kg/h	14,080	14,220	17,870	18,050	21,040	21,250
Starting air							
Starting air pressure max.	bar	30		30		30	
Minimum starting air pressure	bar	7		7		7	
Air consumption per start [4]	Nm³	0.8		0.8		0.8	
Max. crankcase pressure, nominal diameter ventilation pipe	mmWs/ mm	15/80		15/80		15/80	

[1] Reference conditions: LCV = 42,700 kJ/kg, ambient temperature 25 °C
charge air coolant temperature 25 °C, tolerance 5 %, + 1 % for engine driven pump
[2] Standard value, tolerance ± 0.3 g/kWh, related on full load
[3] Charge air heat based on 45 °C ambient temperature
[4] Preheated engine
[5] Tolerance 10 %, rel. humidity 60 %
[6] MARPOL 73/78 Annex VI, Cycle E2, E3, D2

2. General data and operation of the engine

2.2 Engine dimensions

2.2.1 Turbocharger at free end



Engine Type	Dimensions [mm]						Dry weight *
	L1	L2	H1	H2	W1	W2	[t]
6 M 25 C	8,070	7,638	2,950	1,340	2,479	977	43.0
8 M 25 C	9,130	8,727	3,097	1,340	2,534	977	53.0
9 M 25 C	9,516	9,057	3,097	1,340	2,534	977	56.0

* depending on generator weight

Prime mover and generator are always flexibly coupled.

Removal of:

Piston	in transverse direction	X1	= 3,760 mm
	in longitudinal direction	X2	= 4,340 mm
	in transverse dir. reduced	X1red	= 3,640 mm
Cylinder liner	in transverse direction	Y1	= 3,850 mm
	in longitudinal direction	Y2	= 4,075 mm
	in transverse dir. reduced	Y1red	= 3,640 mm

Reduced removal height with special tools only.
Min. centre distance of 2 gensets: 2,700 mm

2. General data and operation of the engine

2.3 Restrictions for low load operation and stand-by mode

The engine can be started, stopped and run on heavy fuel oil under all operating conditions.

The HFO system of the engine remains in operation and keeps the HFO at injection viscosity. The temperature of the engine injection system is maintained by circulating hot HFO and heat losses are compensated (stand-by mode).

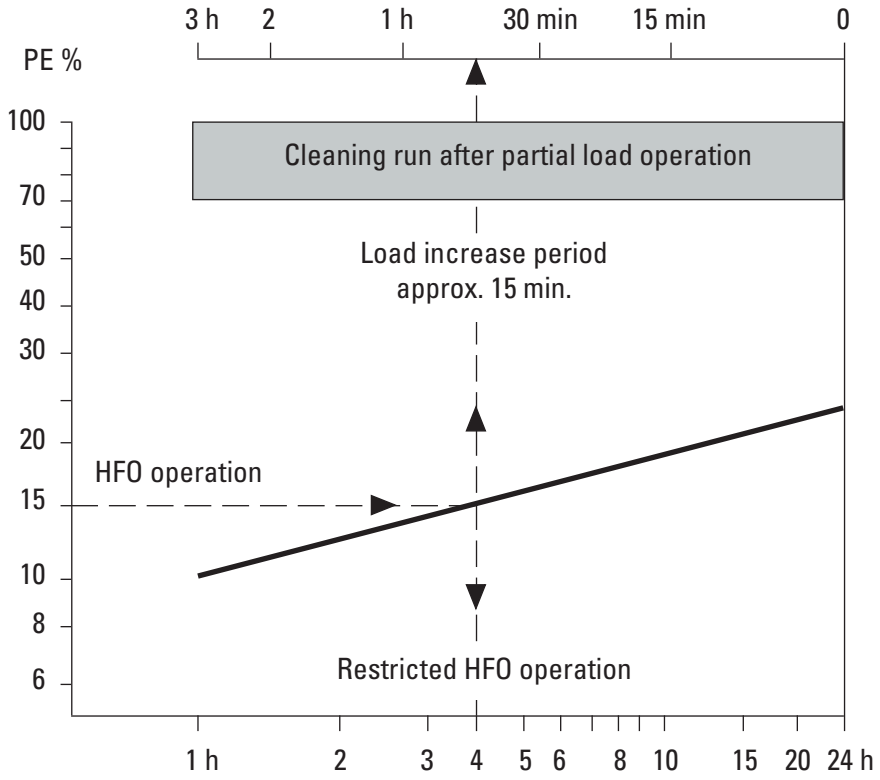
The lube oil treatment system (lube oil separator) remains in operation, the lube oil is separated continuously (stand-by mode).

The operating temperature of the engine cooling water is maintained by the cooling water preheater (stand-by mode).

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.

Cleaning run of engine



2. General data and operation of the engine

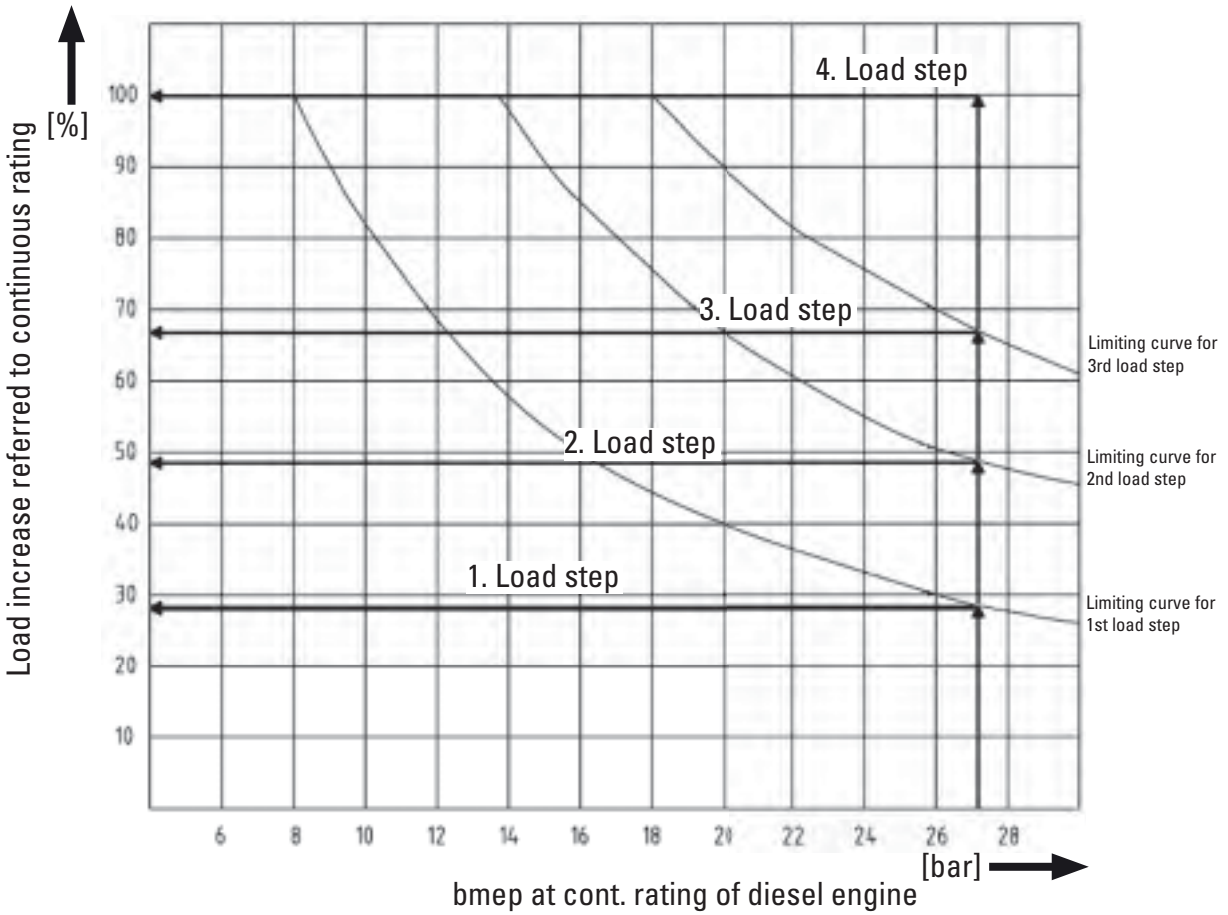
2.4 Load application and recovery behaviour

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 has to provide the approval of the responsible classification society in time before classification of the engine.

Guide values for maximum possible sudden power increases as a function of brake mean effective pressure, pme at declared power.

M 25 C in-line engines

To achieve recovery behaviour according to class requirements



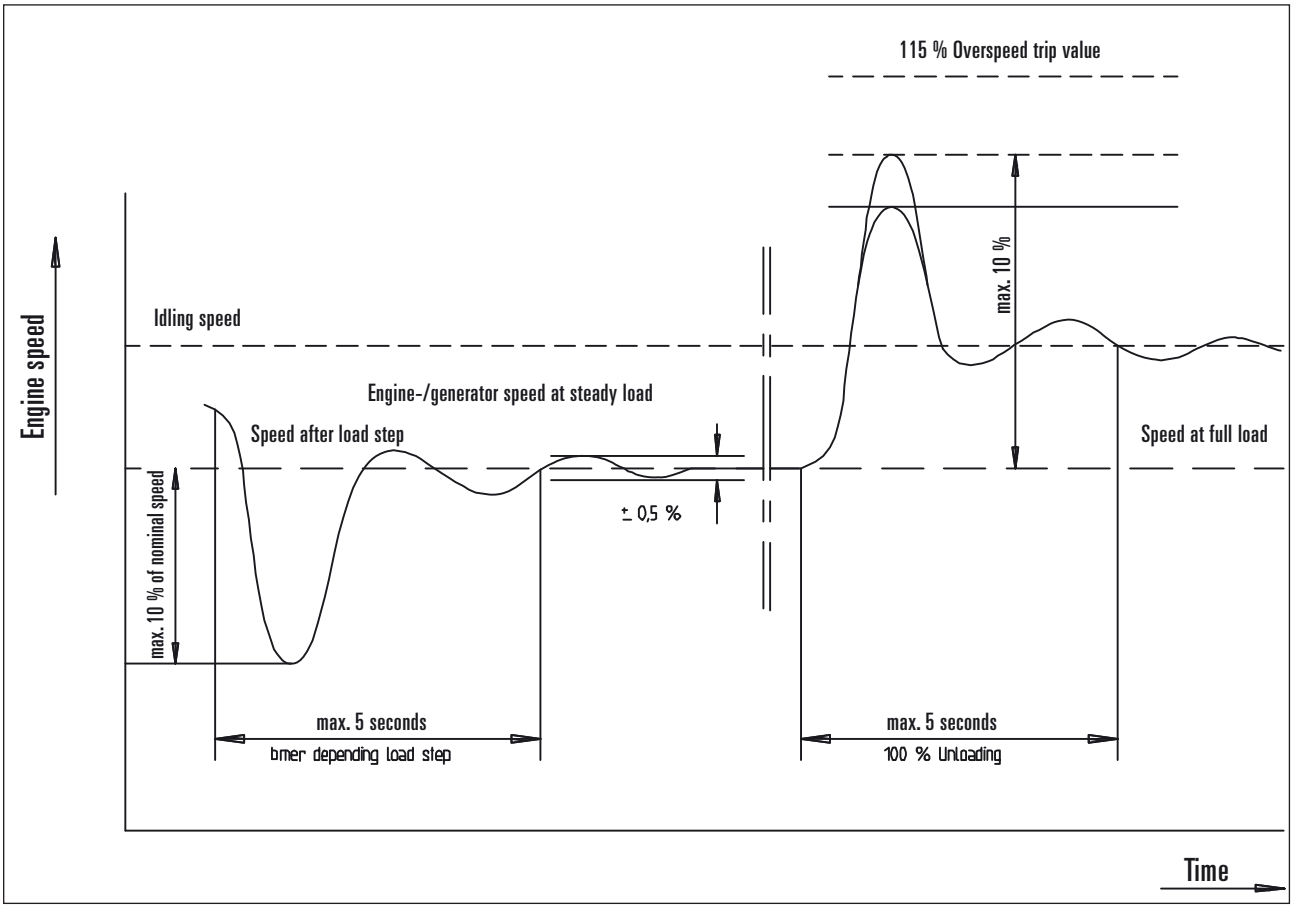
Example: 9 M 25 C, 3,000 kW, 720 rpm, bmep = 27.2 bar
Curves are provided as typical examples.

1. max. load from 0 % to 28 % power
2. max. load from 28 % to 48 % power
3. max. load from 48 % to 67 % power
4. max. load from 67 % to 100 % power

2. General data and operation of the engine

2.4 Load application and recovery behaviour

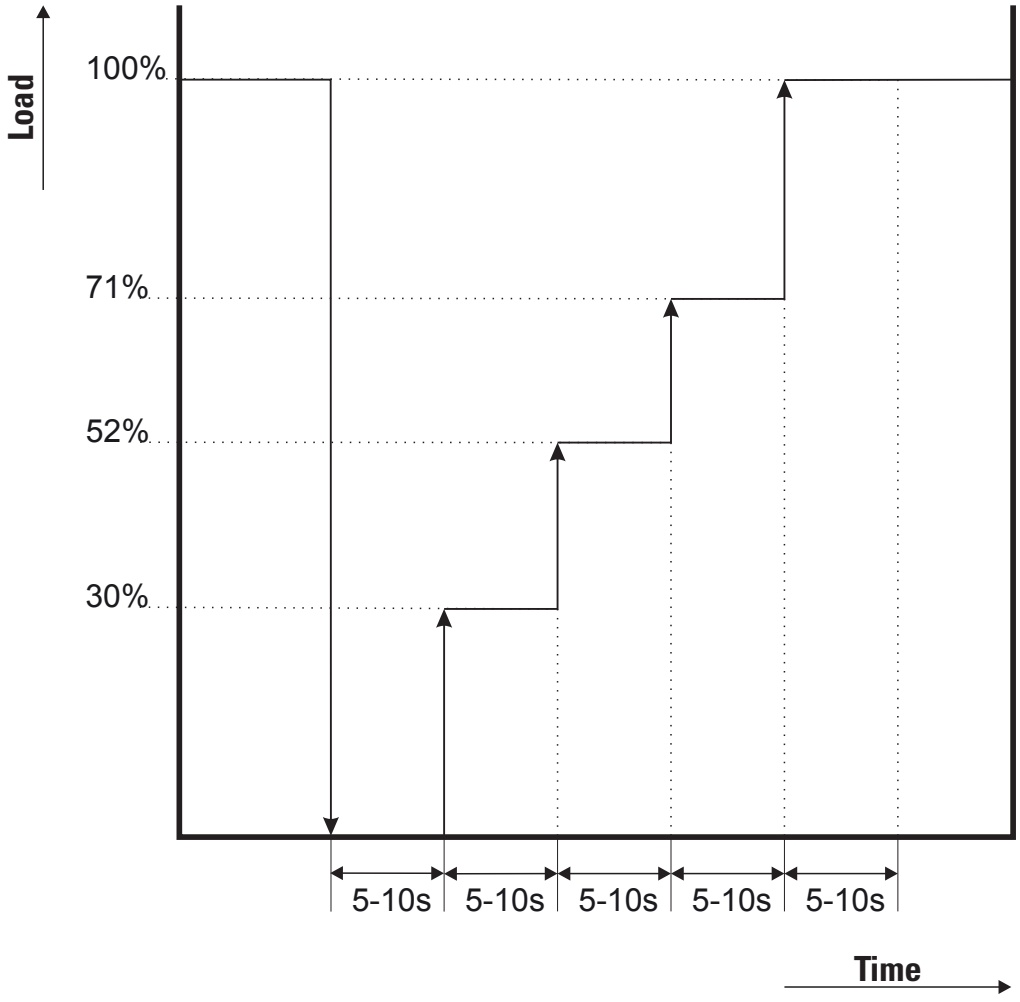
Recovery behaviour after load increase based on reference values for load steps as well as unloading.



2. General data and operation of the engine

2.4.1 Standard loading up procedure

Our standard loading procedure for M 25 C in-line engines to achieve recovery behaviour in accordance with class requirements.
For higher power increments or different loading procedures FCT (Flexible Camshaft Technology) is recommended.



2. General data and operation of the engine

2.4.2 Speed control of auxiliary generating sets / DE - drive

Electronic governor system maker Regulateurs Europa (RE)

Type:	Actuator	2221	Optional:	Actuator UG40
	Governor	Viking 35	WOODWARD:	Governor 723+

The engine is equipped with an actuator without mech. back-up governor. The electronic governor is delivered as a separate part for installation by the shipyard at a suitable place (e.g. switchboard).

On request the governor can be installed inside a separate cabinet.

The governor comprises the following functions:

- Speed setting range to be entered via parameters
- Adjustable acceleration and declaration times
- Adjustable synchronizing ramp rates
- Starting fuel limiter
- Input for stop (not emergency stop)
- 18 - 32 V DC voltage supply
- Alarm output
- Isochronous load sharing by master / slave principle
- Droop operation selectable

2.4.3 Speed control of auxiliary generating sets

Mechanical governor (optional electronic governor)

Standard settings:
- Droop 4 %
- Fuel rack 110 %
- Speed setting range + 5 %

Standard speed governor, maker RE, type 1102, equipped with:
- Speed setting motor (24 V DC/100 % continuous duty) for a setting speed of 4 - 8 sec/Hz
- Start fuel limiter
- Shut-down solenoid (24 V DC/100 % continuous duty) for remote stop (not for automatic engine stop)
- Infinitely adjustable from the outside at the governor, 0 - 10 % droop

3. Systems

3.1 Combustion air system

3.1.1 General

To obtain good working conditions in the engine room and to ensure trouble-free operation of all equipment attention shall be paid to the engine room ventilation and the supply of combustion air.

The combustion air required and the heat radiation of all consumers/heat producers must be taken into account.

3.1.2 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 prevented.
- 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.

3.1.3 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 prevented.
- Connection to the turbocharger is to be established via an expansion joint (to be supplied by the yard). For this purpose the turbocharger will be equipped with a connection socket.
- At temperatures below + 10 °C the Caterpillar Motoren/Application Engineering must be consulted.

3.1.4 Radiated heat

See technical data

To dissipate the radiated heat a slight and evenly distributed air flow is to be conveyed along the engine exhaust gas manifold starting from the turbocharger.

3. Systems

3.2 Starting air system

As required by the classification societies, two air compressors compress the starting air to a nominal pressure of 30 bar. The starting air must have a defined quality, be free from solid particles, oil, and water.

3.2.1 Starting air quality requirements

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

Class	Particle size max. in µm	Particle density max. in mg/m³	Water pressure dew point in °C	Water mg/m³	Oil Residual oil content in mg/m³
1	0.1	0.1	-70	3	0.01
2	1	1	-40	120	0.1
3	5	5	-20	880	1
4	15	8	3	6,000	5
5	40	10	7	7,800	25
6			10	9,400	

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

Oil content

Specification of the residual quantity of aerosols and hydrocarbons which may be contained in the compressed air.

Particle size and density

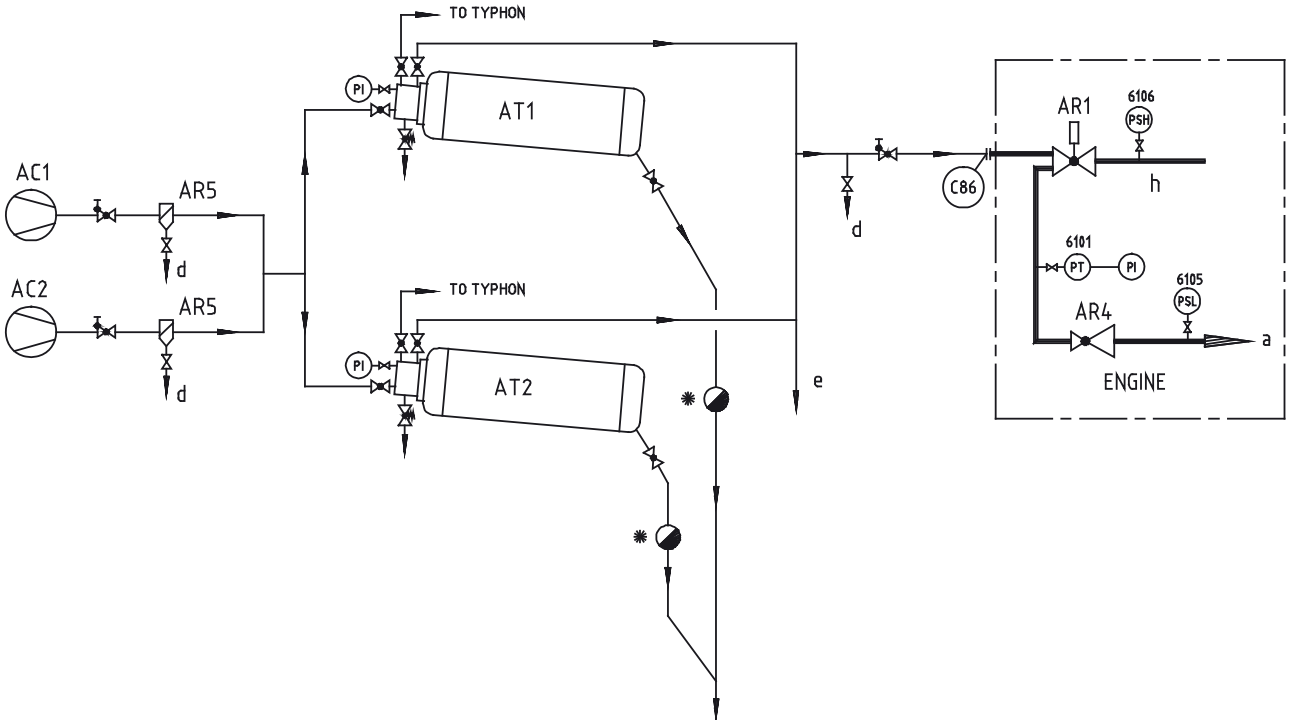
Specification of size and concentration of particles which may still be contained in the compressed air.

Pressure dew point

Specification of the temperature to which compressed air may be cooled down without condensation of the contained vapor. The pressure dew point changes with the air pressure.

3. Systems

3.2.2 System diagram



General notes:
For location, dimensions, and design (e.g. flexible connection) of the disconnecting points see engine installation drawing.

Clean and dry starting air is required. A starting air filter has to be installed before engine, if required.

Notes:
a Control air
d Water drain (to be mounted at the lowest point)
e To engine No. 2
h Please refer to the measuring point list regarding design of the monitoring devices.

* Automatic drain required

Connecting points:
C86 Connection, starting air

Accessories and fittings:
AC1 Compressor
AC2 Stand-by compressor
AR1 Starting valve
AR4 Pressure reducing valve
AR5 Oil and water separator
AT1 Starting air receiver (air bottle)
AT2 Starting air receiver (air bottle)
PI Pressure indicator
PSL Pressure switch low, only for main engine
PT Pressure transmitter

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

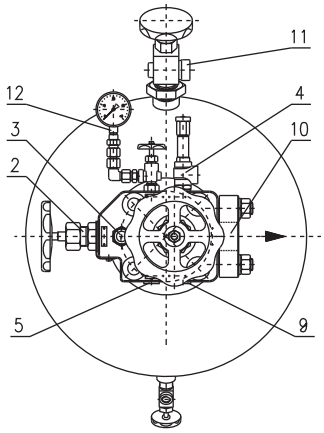
3. Systems

3.2.3 Starting air system components

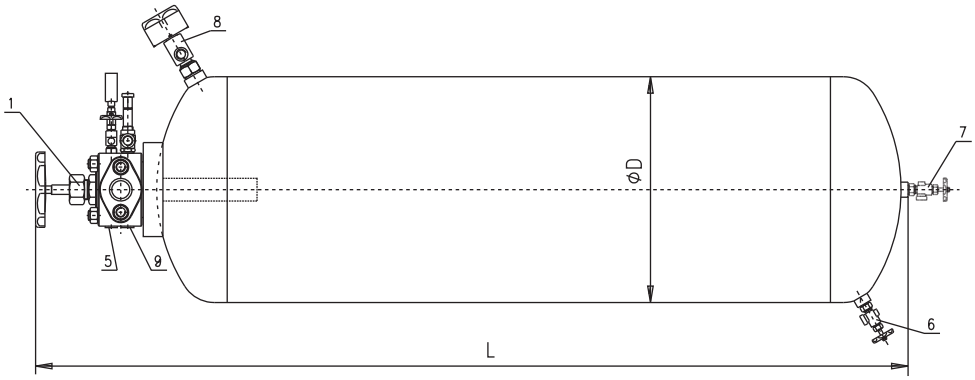
a) Receiver capacity acc. to GL recommendation AT1/AT2

Number of gensets	Number of receivers	Receiver capacity available [l]	L mm	D ø mm	Valve head	Weight approx. kg
2	2	250	1,868	480	DN 40	230
3, 4	2	500	3,355	480	DN 50	320

1 Starting valve DN 38
2 Filling valve DN 18
3 Inlet filling valve
4 Safety valve G1/2"
5 Free connection G1/2"
6 Drainage horizontal
7 Drainage vertical
9 Connection G1/2" for vent
10 Outlet starting-air valve
12 Pressure gauge



Option:
8 Typhon valve DN 16
11 Outlet typhon valve



If a CO_2 fire extinguishing system is installed in the engine room, the blow-off connection of the safety valve is to be piped to the outside.

Requirement of classification societies (regarding design)

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

3. Systems

b) Compressor AC1/AC2:

2 compressors with a total output of 50 % each are required.
The filling time from 0 to 30 bar must not exceed 1 hour.

Capacity

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

$V_{Rec.}$ - Total receiver volume [m^3]

3.3 Exhaust system

The exhaust system carries the engines exhaust gases out of the engine room, through piping, to the atmosphere. A good exhaust system will have a minimum back pressure. Exhaust back pressure is generally detrimental, as it tends to reduce the air flow through the engine. Indirectly, exhaust back pressure tends to raise exhaust temperature which will reduce exhaust valve and turbocharger life.

3.3.1 General

Position of exhaust gas nozzle:

A nozzle position of 0, 30, 45, 60 and 90° from the vertical is possible.
The basic position is 45°. The other positions are reached by using a transition piece.

Design of the pipe cross-section:

The pressure loss is to be minimized in order to optimize fuel consumption and thermal load of the engine.

Max. flow velocity: 40 m/s (guide value).

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

3.3.2 Exhaust expansion joint

	Diameter DN	Length [mm]
6 M 25 C	500	360
8/9 M 25 C	600	450

3. Systems

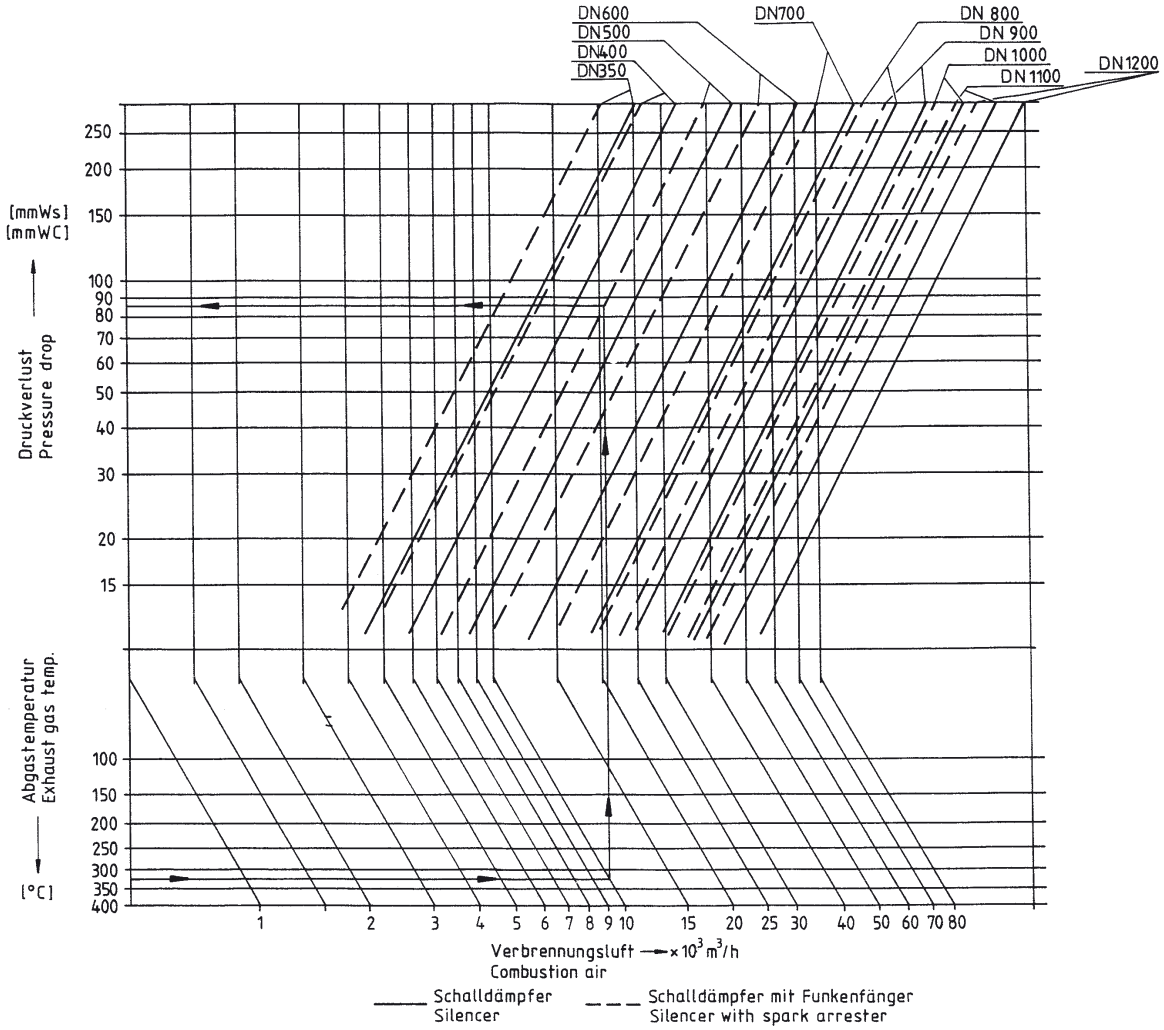
3.3.3 Silencer

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

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

Silencer with spark arrester: Soot separation by means of a swirl device (particles are spun towards the outside and separated in the collecting chamber). Sound level reduction 35 dB(A). Max. permissible flow velocity 40 m/s.

Silencers are to be insulated by the yard. Foundation brackets are to be provided as an option.

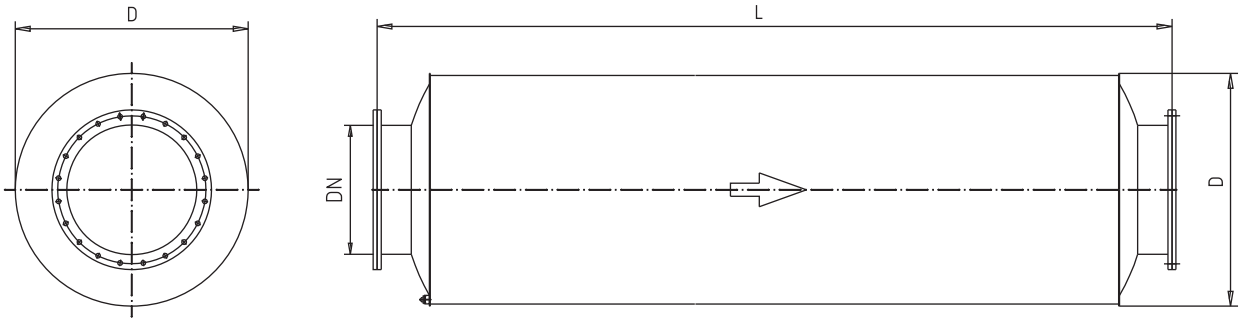


3. Systems

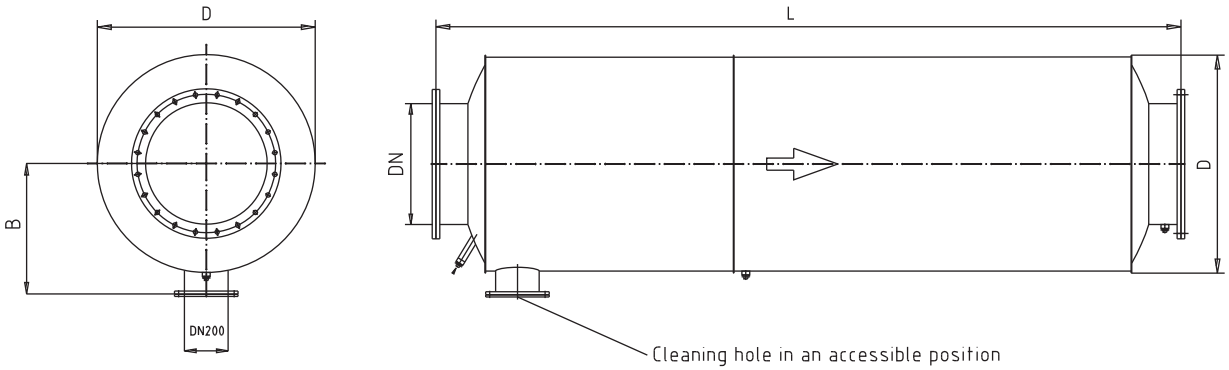
Dimension of silencer/spark arrestor and silencer:

Installation: vertical/horizontal
Flange according to DIN 86044
Counterflanges, screws and gaskets are included, without supports and insulation

Silencer



Spark arrestor and silencer



	Attenuation			35 dB (A)	
	DN	D	B	L	kg
6 M 25 C	500	950	588	3,940	750
8/9 M 25 C	600	1,100	659	4,760	1,300

3.3.4 Exhaust gas boiler

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

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

3. Systems

3.3.5 Turbocharger cleaning device

Cleaning the turbocharger compressor:

The components for cleaning (dosing vessel, pipes, shut-off valve) are installed on the engine.

Water is fed before compressor wheel via injection pipes during full load operation every 24 hours.

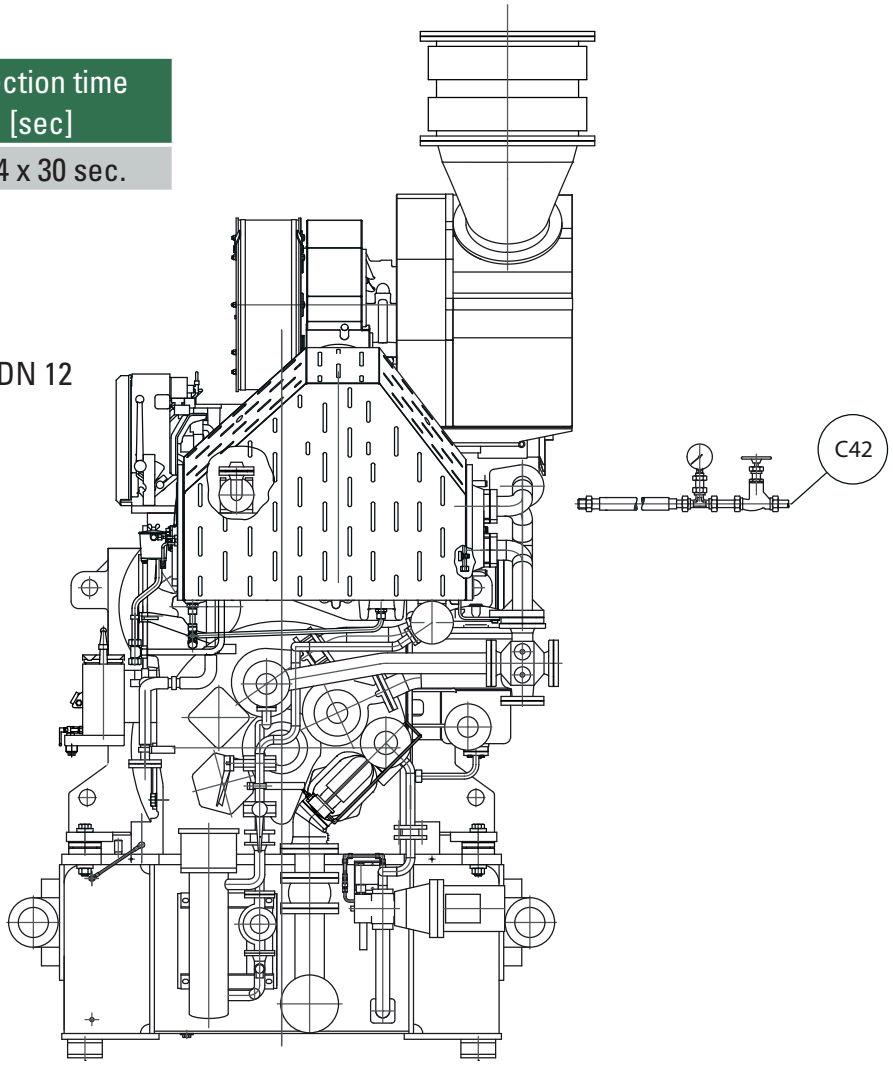
Cleaning the turbine blade and nozzle ring:

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

Cleaning in 3 - 4 intervals of 30 seconds each.
Fresh water of 2 - 2.5 bar is required.

Water flow [l/min]	Injection time [sec]
17	3 - 4 x 30 sec.

C42 Fresh water supply, DN 12



3. Systems

3.4 Cooling water system

MaK engines generally use two closed water cooling circuits. The High Temperature (HT) cooling water circuit is used to cool the charge air - in first stage - and the engine jacket. The Low Temperature (LT) cooling water circuit cools the charge air - in second stage - and the lube oil. Moreover, the LT cooling water circuit can be used to cool additional equipment, e.g. a generator or gearbox.
The cooling water needs to be treated to ensure a certain quality.

3.4.1 Cooling water quality requirements

The engine cooling water is a medium, which must be carefully selected, treated and controlled. In case of using untreated cooling water corrosion, erosion and cavitation may occur on the walls of the cooling system.

Deposits may impair the heat transfer and result in thermal overload of the components to be cooled. The treatment with an anti-corrosion additive has to be effected before the first commissioning of the plant.

Requirements

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

- distillate or freshwater free from foreign matter (no sea water or waste water)
- a total hardness of max. 10° dH
- pH-value 6.8 - 8
- chloride ion content of max. 50 mg/l

Supplementary information

Distillate: If distilled 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 be softened.

Treatment before operating the engine for the first time

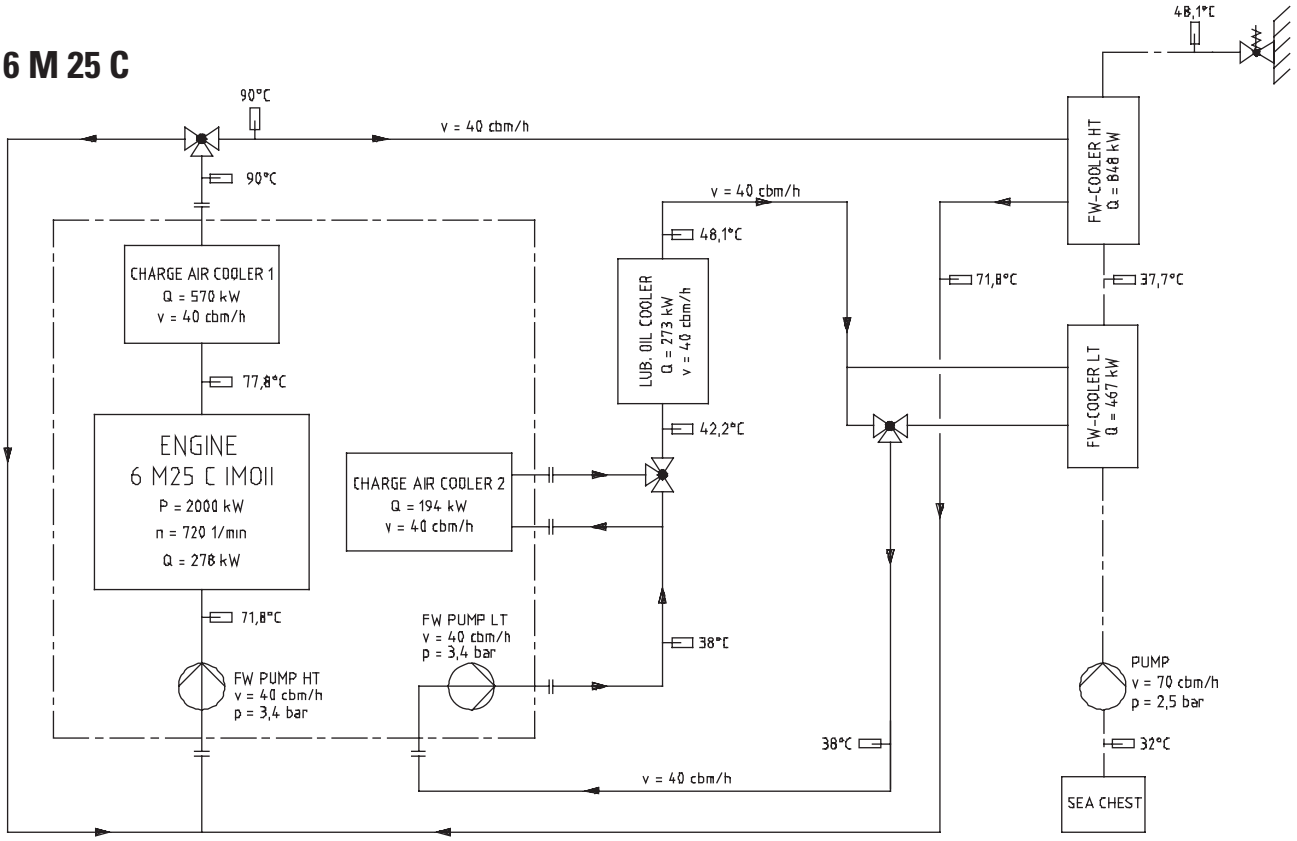
Treatment with an anti-corrosion additive should be done prior to the first operation of the engine to prevent irreparable initial damage.

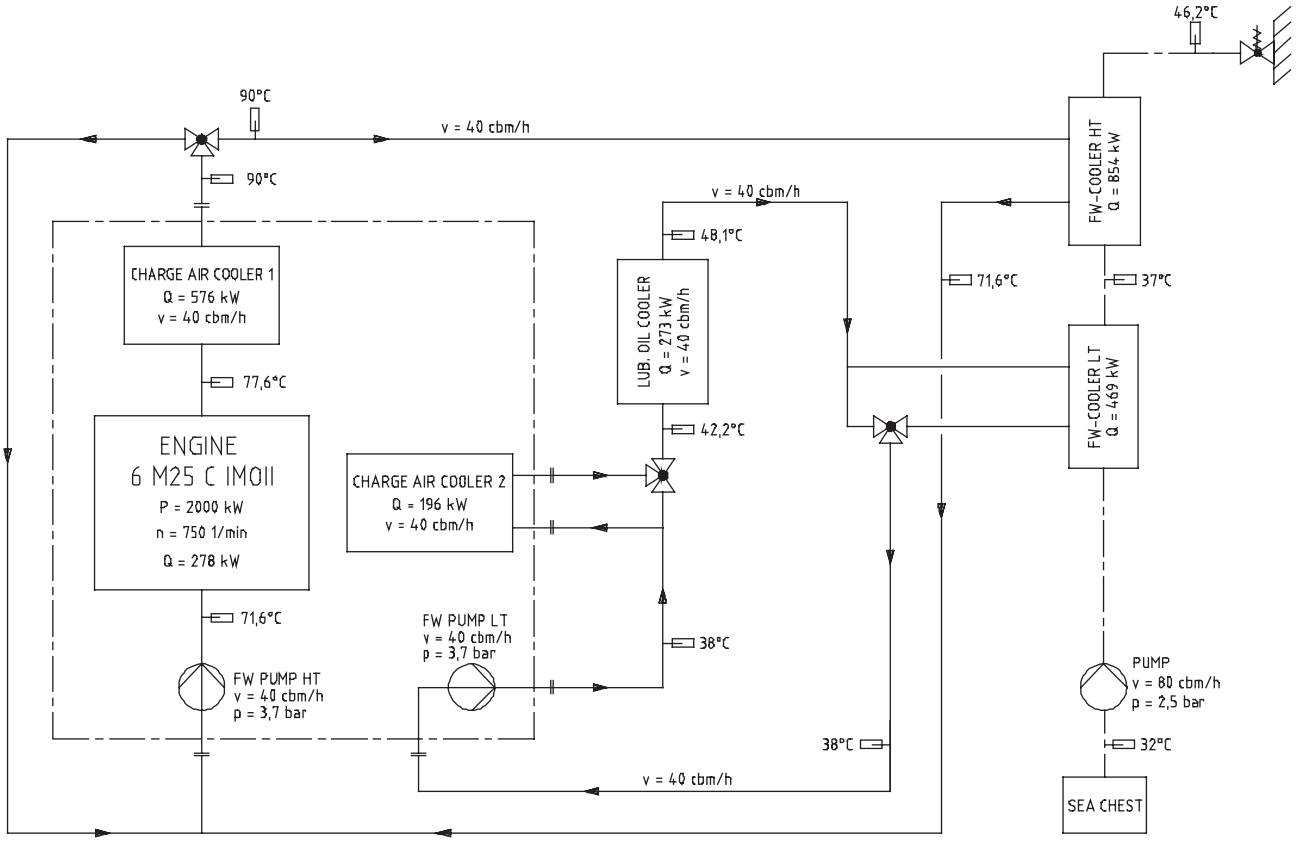
It is not allowed to run the engine without cooling water treatment!

3. Systems

3.4.2 System diagram heat balance

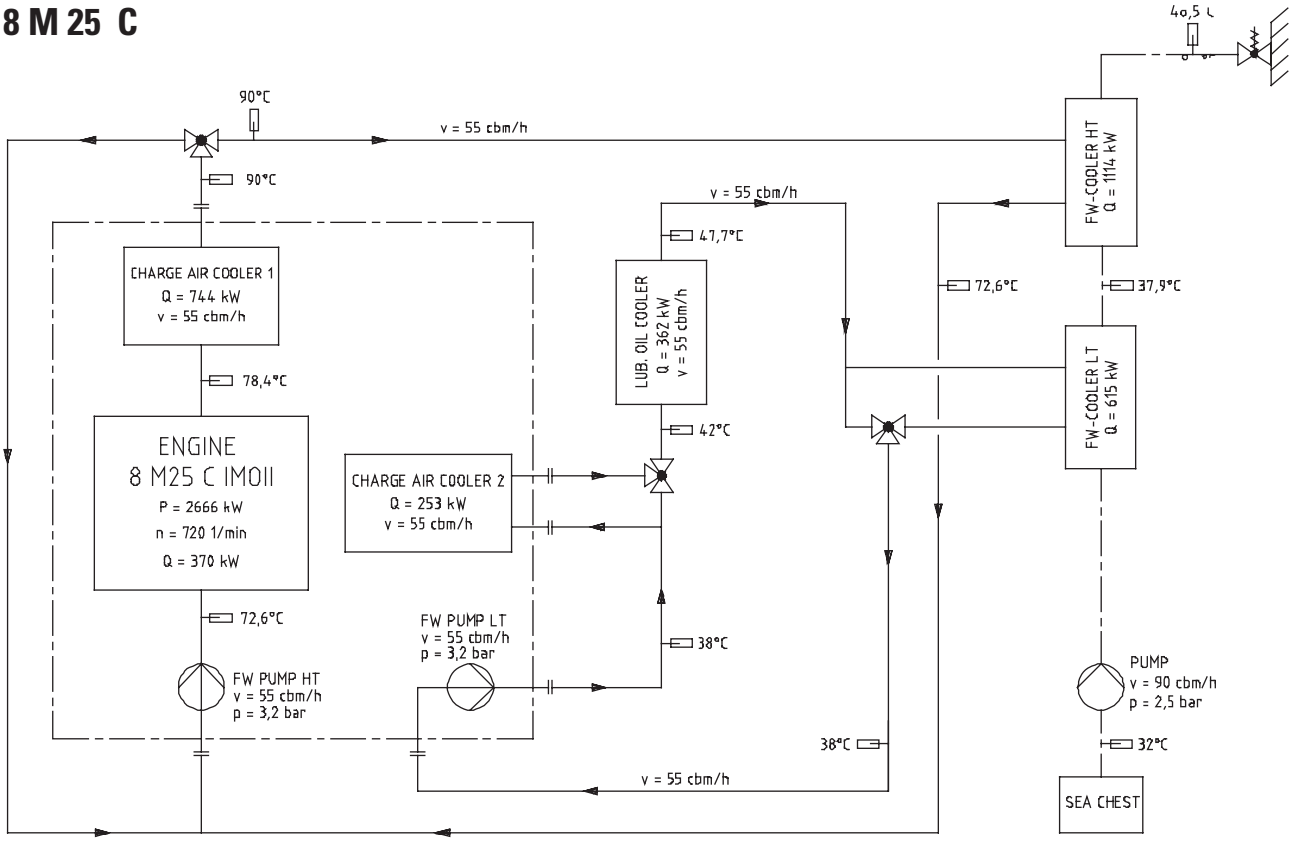
6 M 25 C

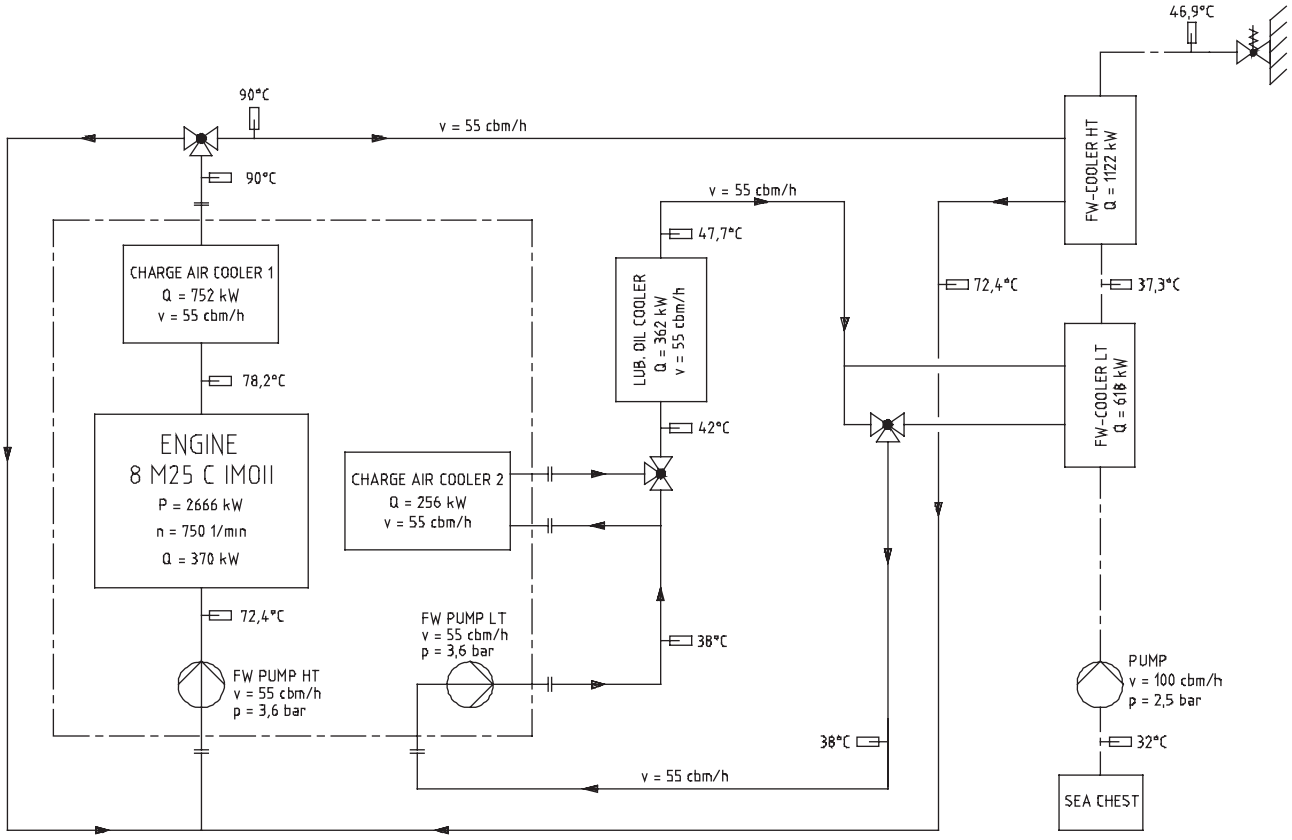




3. Systems

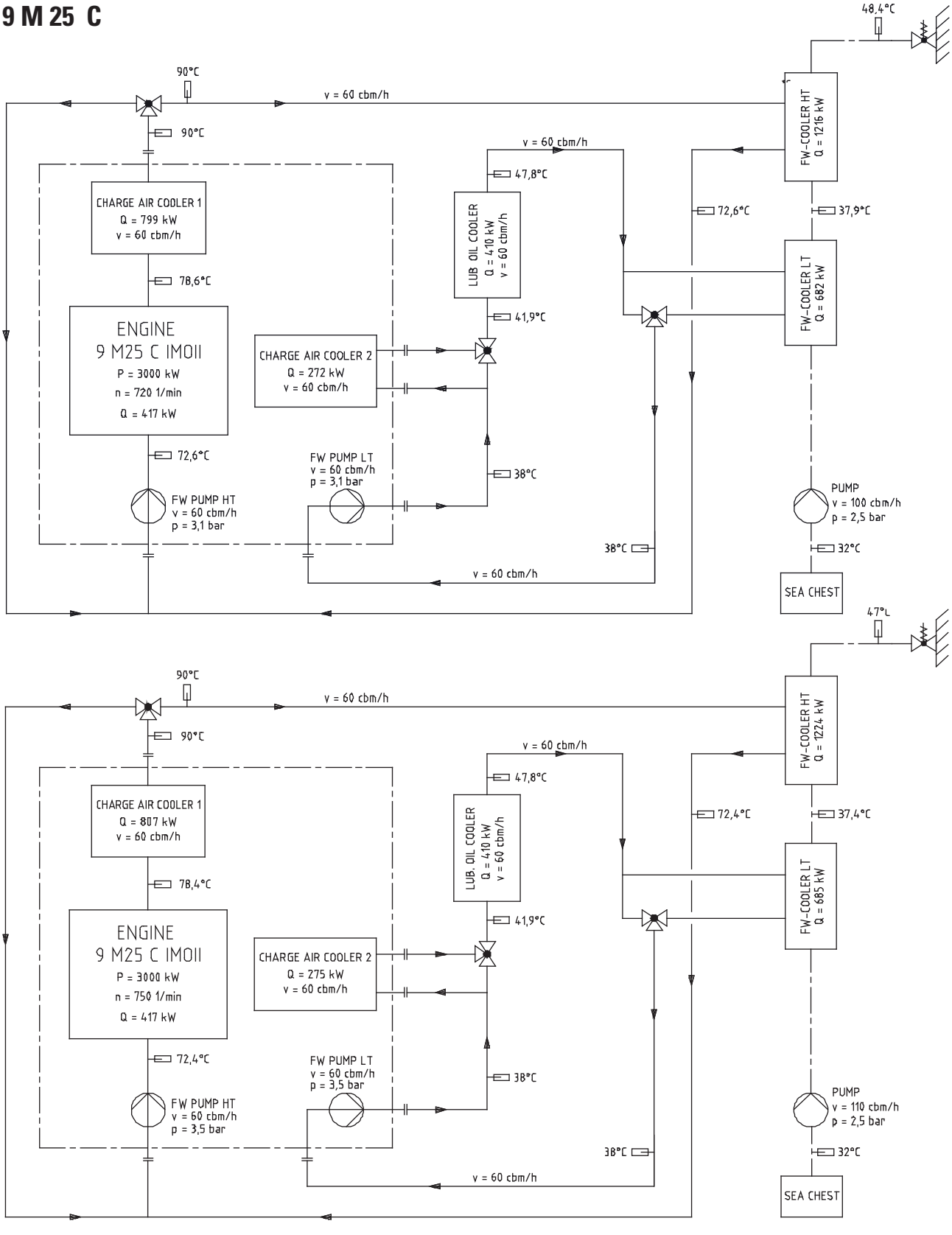
8 M 25 C





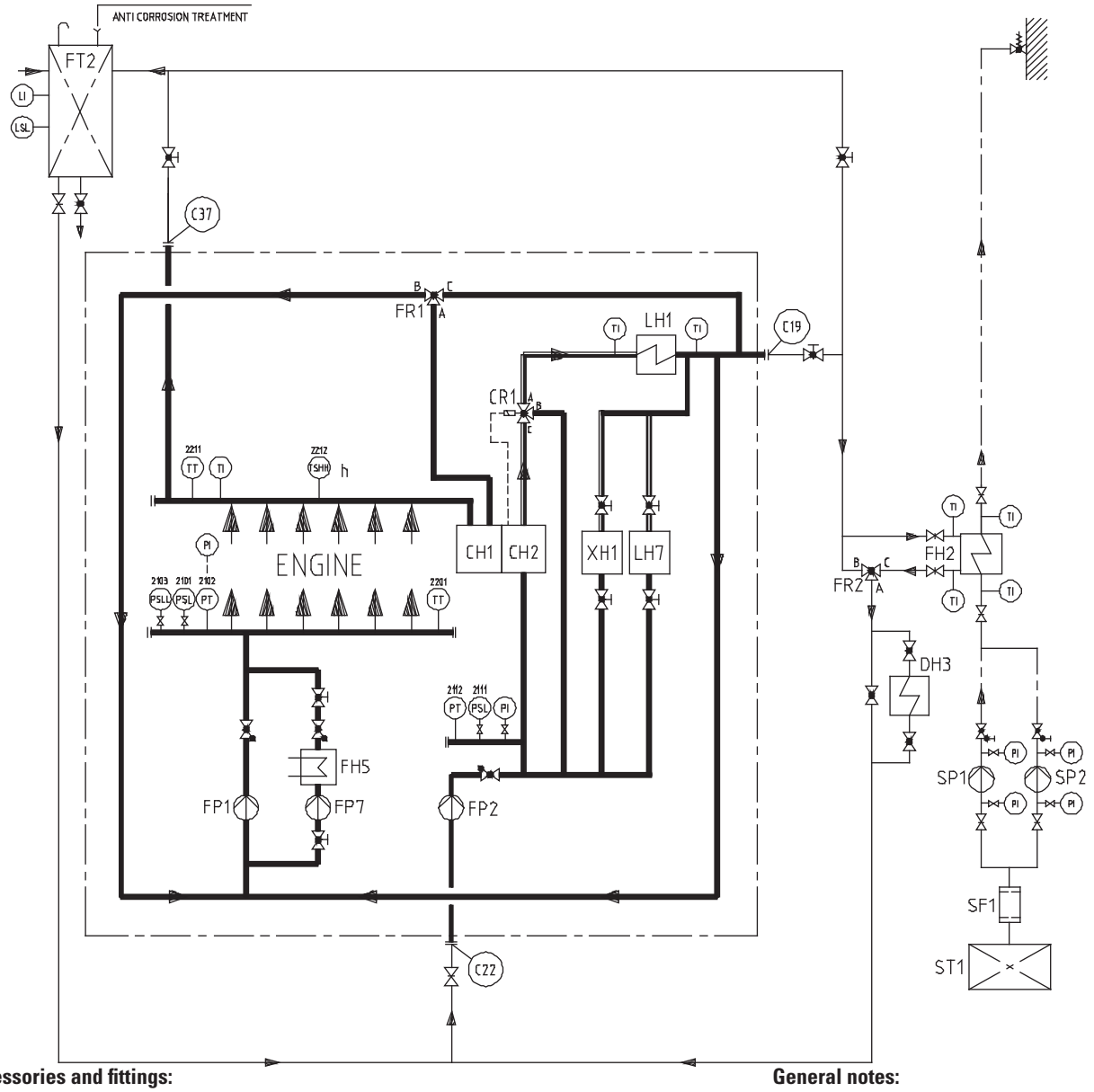
3. Systems

9 M 25 C



3. Systems

3.4.3 System diagram cooling water



Accessories and fittings:

CH1 Charge air cooler HT
CH2 Charge air cooler LT
CR1 Charge air temperature control valve
DH3 Fuel oil cooler for MDO operation
FH2 Freshwater cooler LT
FH5 Freshwater preheater
FP1 Freshwater pump (fitted on engine) HT
FP2 Freshwater 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
LH7 Generator bearing 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
PSL Pressure switch low
PSLL Pressure switch low low
PT Pressure transmitter
TI Temperature indicator
TSHH Temperature switch high
TT Temperature transmitter (PT 100)

General notes:

For location, dimensions and design (e.g. flexible connection) of the connecting points see engine installation drawing.

Disconnecting points:

C19 Oil cooler, outlet
C22 Freshwater pump LT, inlet
C37 vent connection

Notes:

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

3. Systems

3.4.4 Cooling water system components

The heat generated by the engine (cylinder, charge air and lube oil) is to be dissipated by treated freshwater acc. to the MaK coolant regulations.

The system components of the LT cooling water circuit are designed for a max. LT cooling water temperature of 38 °C with a corresponding seawater temperature of 32 °C in tropical conditions.

Two-circuit cooling: with two-stage charge air cooler.

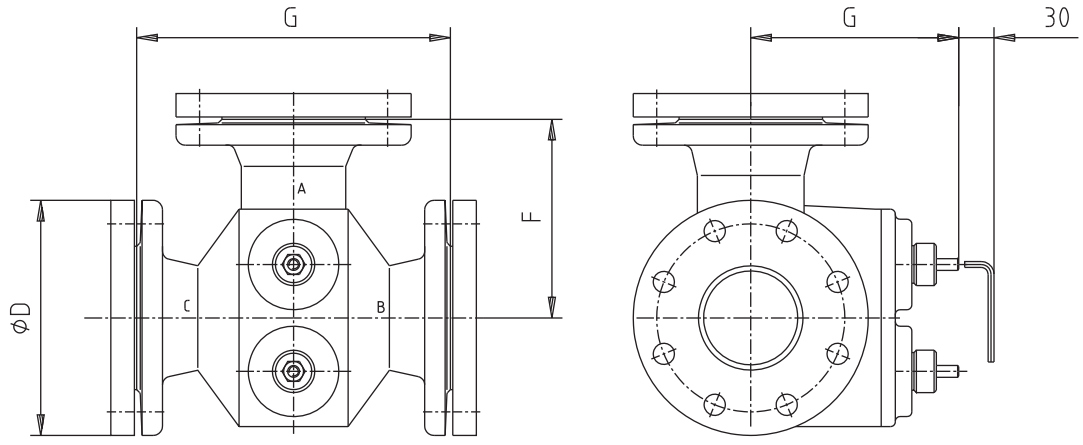
a) LT cooling water pump FP2 (fitted on engine): **Option: separate (FP4)**
Capacity: acc. to heat balance

b) LT cooling water stand-by pump (optional) FP6: Capacity: acc. to heat balance

c) HT cooling water pump (fitted) FP1: **Option: separate (FP3)**
Capacity: acc. to heat balance

d) HT cooling water stand-by pump (optional) FP5: Capacity: acc. to heat balance

e) HT temperature controller (fitted) FR1: **Option: separate**
P-controller with manual emergency adjustment (basis). Option: PI-controller with electric drive (sep. only)



		Dimensions [mm]					Weight [kg]
		DN	D	F	G	H	
6 M 25 C	HT	80	200	171	267	151	27
8/9 M 25 C	HT[1)]	100	220	217	403	167	47
6/8 M 25 C	LT	100*	220	217	403	167	47
9 M 25 C	LT	125*	250	241	489	200	67

[1)] separate
* Minimum, depending on total cooling water flow

3. Systems

f) LT temperature controller (separate) FR2: P-controller with manual emergency adjustment (basis). Option: PI-controller with electric drive.

g) Pre-heater (fitted) FH5/FP7: Consisting of circulating pump [1], electric preheater [2] and control cabinet (separate: W x H x D = 500 x 400 x 200 mm).

[1]	Capacity	8 m³/h
[2]	Output	18 kW

h) Charge air temperature controller CR1 (fitted): P-controller for charge air heating in part load condition.
Option: PI-controller with electric drive (separate only)

i) HT cooler (optional, separate) FH1: Plate type (plates made of titanium), size depending on the total heat to be dissipated.

j) LT cooler (separate) FH2: Plate type (plates made of titanium), size depending on the total heat to be dissipated.

k) Header tank FT2:

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

Option: Header tank HT FT1 for two-circuit-cooling

3. Systems

3.4.5 Recommendation for cooling water system

Drain tank with filling pump:

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

Electric motor driven pumps:

Option for fresh and seawater, vertical design.
Rough calculation of power demand for the electric balance.

$$P = \frac{\rho \bullet H \bullet V}{367 \bullet \eta} \quad [kW]$$

P - Power [kW]
P_M - Power of electr. motor [kW]
V - Flow rate [m³/h]
H - Delivery head [m]
ρ - Density [kg/dm³]
η - Pump efficiency
0.70 for centrifugal pumps

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

3. Systems

3.5 Fuel oil system, MGO/MDO operation

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

3.5.1 Quality requirements for MGO/MDO fuel/permitted fuels

Two fuel product groups are permitted for MaK engines:

Pure distillates: Gas oil, marine gas oil, diesel fuel

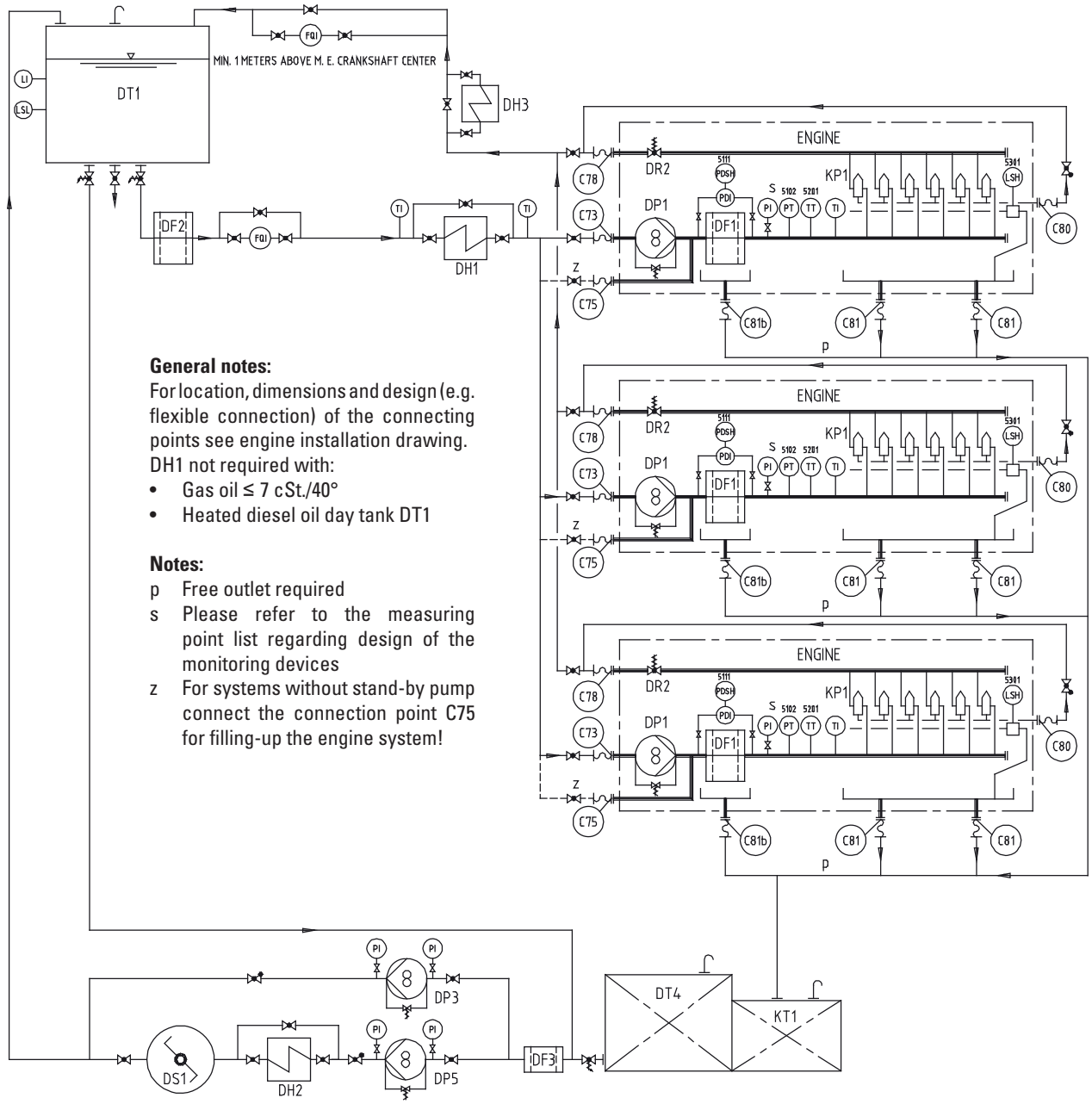
Distillate/mixed fuels: Marine gas oil (MGO), marine diesel oil (MDO). The difference between distillate/mixed fuels and pure distillates is in their higher density, sulphur content and viscosity.

	MGO		MDO	
	Designation	Max. viscosity [cSt/40 °C]	Designation	Max. viscosity [cSt/40 °C]
ISO 8217:2010	ISO-F-DMA	2.0 - 6.0	ISO-F-DMB ISO-F-DMZ	11 6
ASTM D 975-78	No. 1 D No. 2 D	2.4 4.1	No. 2 D No. 4 D	4.1 24.0
DIN	DIN EN 590	8		

Max. injection viscosity 12 cSt (2 °E)

3. Systems

3.5.2 System diagram - Fuel oil system, MGO/MDO operation



General notes:
For location, dimensions and design (e.g. flexible connection) of the connecting points see engine installation drawing.
DH1 not required with:
- Gas oil ≤ 7 cSt./40°
- Heated diesel oil day tank DT1

Notes:
p Free outlet required
s Please refer to the measuring point list regarding design of the monitoring devices
z For systems without stand-by pump connect the connection point C75 for filling-up the engine system!

Accessories and fittings:
DF1 Fine filter (duplex filter)
DF2 Primary filter (duplex filter)
DF3 Coarse filter
DH1 Preheater
DH2 Electrical preheater (separator)
DH3 Fuel oil cooler for MDO operation
DP1 Diesel oil feed pump
DP3 Transfer pump (to day tank)
DP5 Transfer pump (separator)
DR2 Pressure regulating valve
DS1 Separator
DT1 Day tank, min. 1 m above crankshaft level
DT4 Storage tank
KP1 Fuel injection pump
KT1 Drip fuel tank
FQ1 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 (PT 100)

Connecting points:
C73 Fuel inlet, to engine fitted pump
C75 Connection, stand-by pump
C78 Fuel outlet
C80 Drip fuel
C81 Drip fuel
C81b Drip fuel

3. Systems

3.5.3 MGO/MDO fuel system components

a) Fine filter (fitted) DF1:

Duplex filter, mesh size see technical data.

b) Strainer (separate) DF2:

Mesh size 0.32 mm, dimensions see HFO-system.

c) Pre-heater (separate) DH1:

Heating capacity

$$Q\ [kW] = \frac{P_{eng.}\ [kW]}{166}$$

Not required:
- MGO ≤ 7 cSt/40°C
- Heated day tank

d) MGO/MDO cooler DH3:

Required if the heat cannot be removed by heating up of the day tank.

e) Feed pump (fitted) DP1:

Capacity see technical data.

f) Feed pump (separate) DP1/DP2:

Capacity see technical data.
Screw type pump with mechanical seal.
Installation vertical or horizontal.
Delivery head 5 bar.

3. Systems

g) MGO/MDO service tank DT1:

The classification societies specify that at least two service tanks are required. The minimum volume of each tank should, in addition to the MDO/MGO consumption of the generating sets, enable an eight hours full load operation of the main engine.

Cleaning the MDO/MGO by an additional separator should, in the first place, be designed to meet the requirements of the diesel generator sets on board.

The tank should be provided with a sludge compartment including a sludge drain valve and an overflow pipe from the MDO/MGO service tank.

h) Intermediate tank (separate) DT2:

Capacity 49 l

i) Separator DS1:

Recommended for MGO
Required for MDO

The utilisation must be in accordance with the makers official recommendation (details from the head office).

V_{eff} [kg/h] = 0.22 • $P_{eng.}$ [kW]

3.6 Fuel oil system, HFO operation

3.6.1 Quality requirements for HFO/permitted fuels

Minimum requirements for storage, treatment and supply systems

Bunker tanks:

In order to avoid severe operational problems due to incompatibility, each bunkering must be made in a separate storage tank.

Requirements for residual fuels for diesel engines (as bunkered)

	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 (2010):E-		RMA10	RMB30	RMB30	RMD80	RME180	RMF180	RMG380	RMH380	RMK380	RMH500	RMK500	RMH700	RMK700
Characteristic	Dim.	Limit													
Density at 15°C	kg/m³	max	960 [2]	975 [3]		980 [4]	991		991		1,010	991	1,010	991	1,010
Kin. viscosity at 100°C		max	10			15	25		35			45		55	
	cSt [1]	min	6 [5]				15 [5]								
Flash point	°C	min	60			60	60		60			60		60	
Pour point (winter) (summer)	°C	max	0 6		24	30	30		30			30		30	
Carbon residue (Conradson)	% (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	0.3	0.5		0.5	0.5		0.5			0.5		0.5	
Sulphur	% (m/m)	max	3.5			3.5	3.5		3.5			3.5		3.5	
Vanadium	mg/kg	max	50	150		150	200	350	350		450	450		450	
Aluminium + silicon	mg/kg	max	25	40		40	60		60			60		60	
Zinc	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

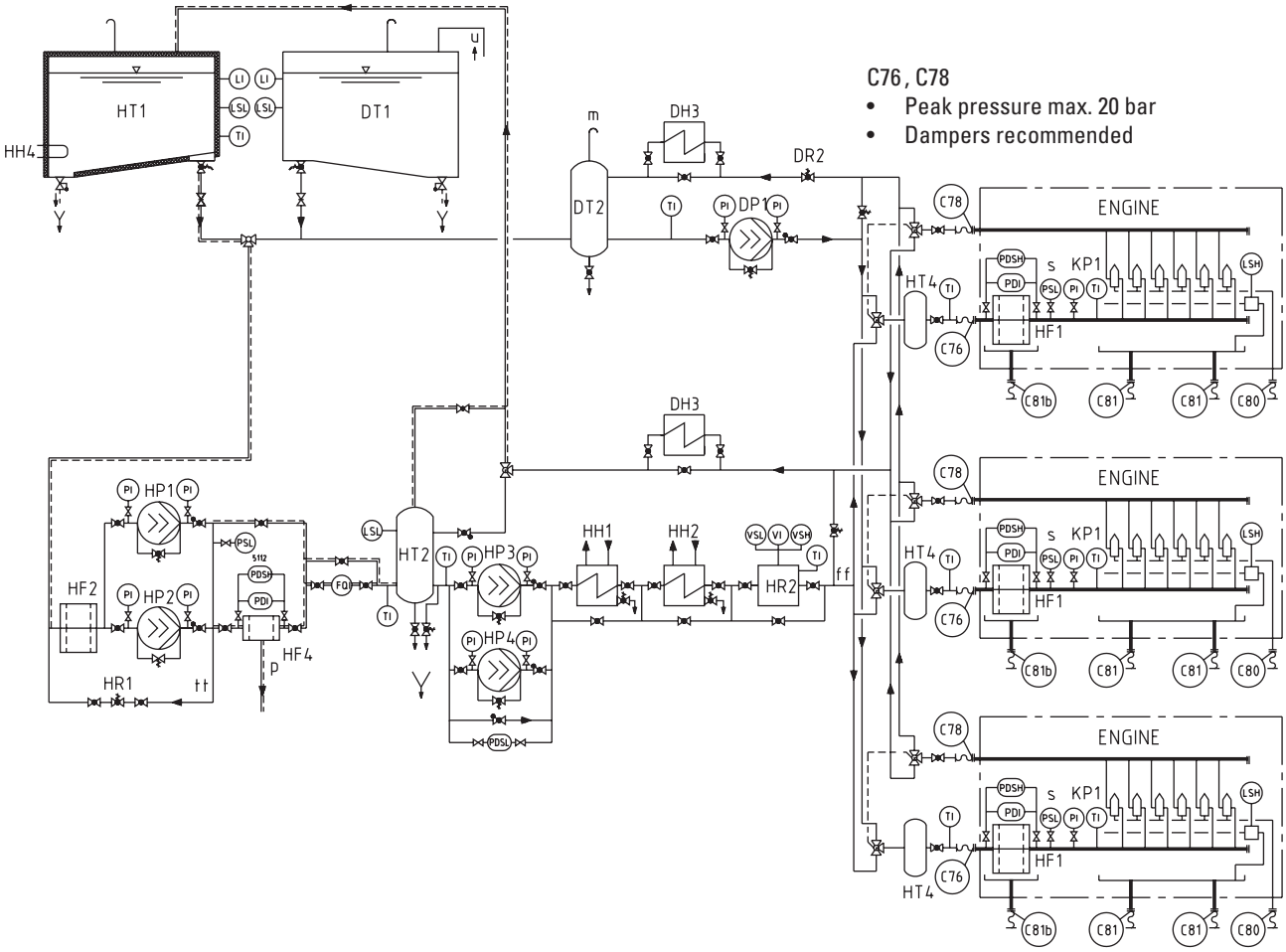
Fuel shall be free of used lube oil (ulo)

[2] ISO: 920
[3] ISO: 960
[4] ISO: 975
[5] ISO: not limited
[6] ISO: Carbon residue 2.5/10

Contents

3. Systems

3.6.2 System diagram - Heavy fuel oil operation



General notes:
For location, dimensions and design (e.g. flexible connection) of the connecting points see engine installation drawing.
If a "Fuel oil supply and booster module" is supplied by Caterpillar Motoren, arrangement and scope of the supply components are to be gathered from the module scheme.
Non-return valves have to be spring loaded due to pulsation in the fuel lines.

Accessories and fittings:

DH3	MGO/MDO cooler	HT4	Mixing receiver
DP1	Diesel oil feed pump	KP1	Injection pump
DR2	Pressure regulating valve	FQ1	Flow quantity indicator
DT1	Diesel oil day tank	LI	Level indicator
DT2	Diesel oil intermediate tank	LSH	Level switch high
HF1	Fine filter (duplex filter)	LSL	Level switch low
HF2	Primary filter	PDI	Diff. pressure indicator
HF4	Self cleaning filter	PDSH	Diff. pressure swith high
HH1	Heavy fuel final preheater	PDSL	Diff. pressure switch low
HH2	Stand-by final preheater	PI	Pressure indicator
HH4	Heating coil	PSL	Pressure switch low
HP1/HP2	Pressure pump	PT	Pressure transmitter
HP3/HP4	Circulating pump	TI	Temperature indicator
HR1	Pressure regulating valve	VI	Viscosity indicator
HR2	Viscosimeter	VSH	Viscosity control switch high
HT1	Heavy fuel day tank	VSL	Viscosity control switch low
HT2	Mixing tank		

Notes:
ff Flow velocity in circuit system ≤ 0.5 m/s
m Lead vent pipe beyond day tank level
p Free outlet required
s Please refer to the measuring point list regarding design of the monitoring devices
tt Pipe not insulated nor heated
u From diesel oil separator or diesel oil transfer pump

All heavy fuel pipes have to be insulated.
═══ heated pipe

Connecting points:

C76	Inlet duplex filter
C78	Fuel outlet
C80	Drip fuel
C81	Drip fuel
C81b	Drip fuel (filter pan)

3. Systems

3.6.3 HFO system components

Supply system (separate components):

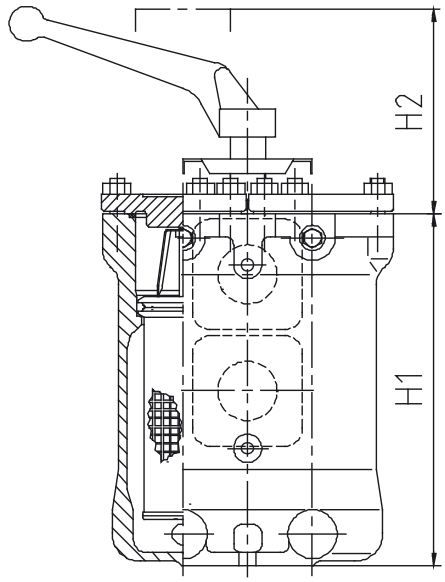
A closed **pressurized system** between day tank and engine is required as well as the installation of an automatic backflushing filter with a mesh size of 10 µm (absolute).

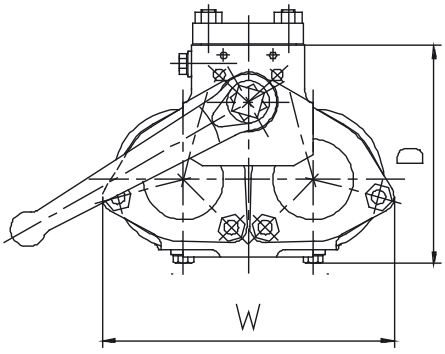
a) Fine filter (fitted) HF1:

- Mesh size 34 µm
- **Without** heating
- Differential pressure indication and alarm contact fitted

b) Strainer HF2:

Mesh size 0.32 mm





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

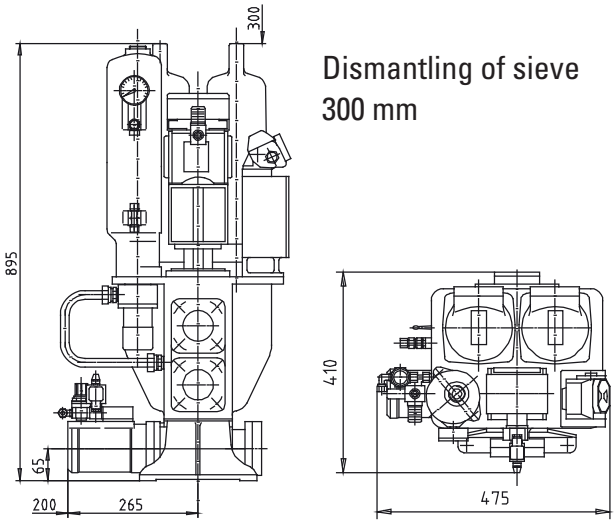
3. Systems

c) Self cleaning filter HF4:

Mesh size 10 µm (absolute), make Boll & Kirch*, **without** bypass filter.

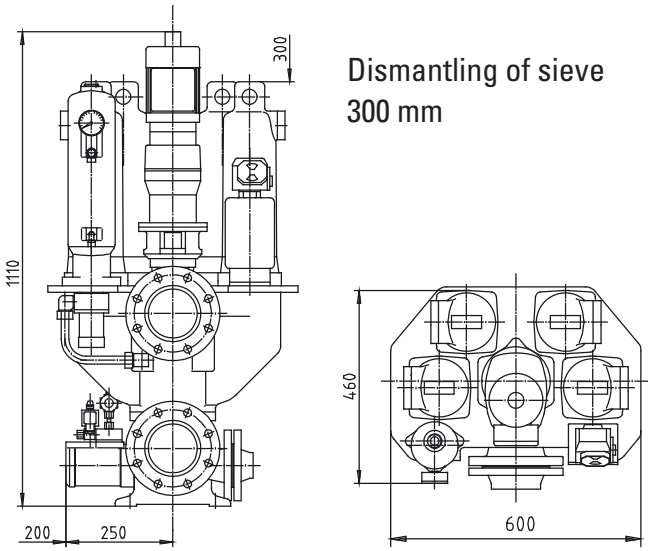
* In case of Caterpillar Motoren supply.

≤ 8,000 kW, Type 6.60, DN 50



Dismantling of sieve 300 mm

> 8,000 kW, Type 6.61, DN 100



Dismantling of sieve 300 mm

d) Viscosimeter HR2:

This device regulates automatically 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.

e) Pressurizing pumps HP1/HP2:

Screw type pump with mechanical seal.
Installation vertical or horizontal. Delivery head 5 bar.

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

f) Circulating pumps HP3/HP4:

Screw type pump with mechanical seal.
Installation vertical or horizontal. Delivery head 5 bar.

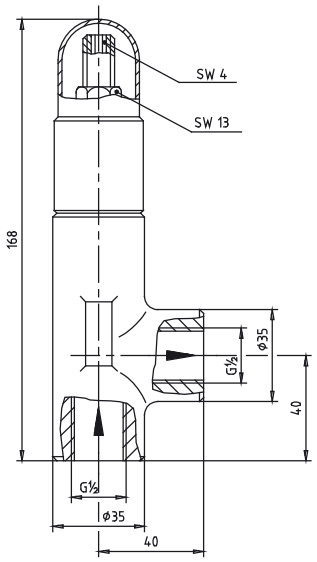
$$\text{Capacity} \quad V\,[m^3/h] = 0.7 \bullet \frac{P_{eng.}\,[kW]}{1{,}000}$$

3. Systems

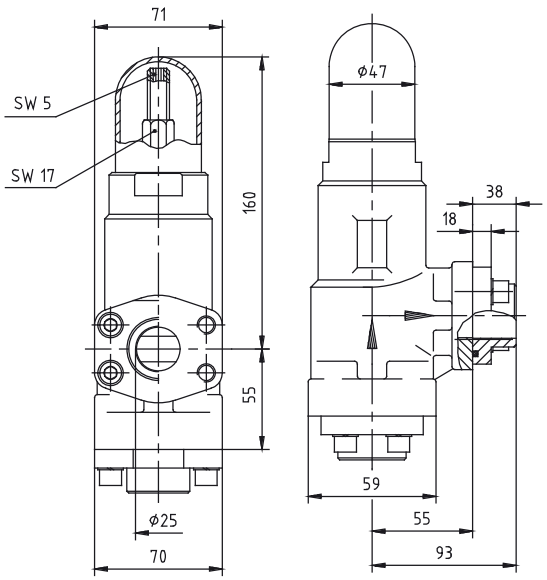
g) Pressure regulating valve HR1 / DR2: Controls the pressure at the engine inlet, approx. 4 bar.

Engine outputs

≤ 3,000 kW



> 3,000 kW



h) Final preheater HH1/HH2:

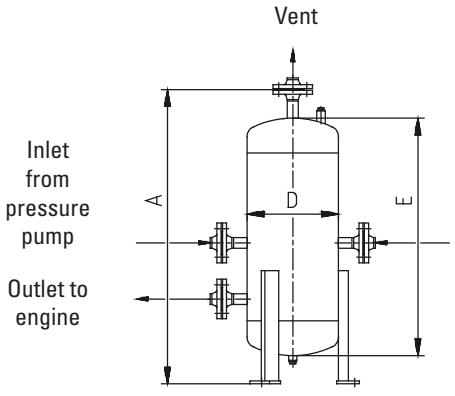
Heating media:

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

Temperature at engine inlet max. 150 °C. The piping for both heaters shall be arranged for separate and series operation. Parallel operation with half the throughout must be avoided due to the risk of sludge deposits.

i) Mixing tank (without insulation) HT2:

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



The mixing tank compensates pressure surges which occur in the pressurized part of the fuel system. For this purpose there has to be an air cushion in the tank.

3. Systems

j) Settling tanks HT5/HT6:

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
- 1 settling tank with a capacity sufficient for 36 hours full load operation of all consumers and automatic filling
- Settling tank temperature 70 - 80 °C

k) Day tank DT1/HT1:

Two day tanks are required. The day tank capacity must cover at least 4 hours/max. 24 hours full load operation of all consumers. An overflow system into the settling tanks and sufficient insulation are required. The tank should have a sludge space with a tank bottom inclination of preferably 10°, with sludge drain valves at the lowest point, and is to be equipped with heating coils.

Guide values for temperatures

Fuel viscosity cSt/50 °C	Tank temperature [°C]
30 - 80	70 - 80
80 - 180	80 - 90
> 180 - 700	max. 98

l) Separators HS1/HS2:

Caterpillar Motoren recommends to install two self-cleaning separators. Design parameters as per supplier recommendation. Separating temperature 98 °C! Maker and type are to be advised by Caterpillar Motoren.

3. Systems

3.6.4 Heavy fuel oil supply and booster standard module

(Pressurized System), up to IFO 700 for steam and thermal oil heating, up to IFO 180 for electr. heating

Technical specification of the main components:

a) Primary filter FIL1
1 pc. duplex strainer 540 microns

b) Fuel pressure pumps, vertical installation SP1/SP2
2 pcs. screw pumps with mechanical seal

c) Pressure regulating system PCV1
1 pc. pressure regulating valve

d) Self-cleaning fine filter AF1
1 pc. automatic self cleaning fine filter 10 microns absolute (without by-pass filter)

e) Consumption measuring system FLOW1
1 pc. flowmeter with local totalizer

f) Mixing tank with accessories T1

1 pc. pressure mixing tank	approx. 49 l volume up to 4,000 kW approx. 99 l volume from 4,001 - 20,000 kW (with quick-closing valve)

g) Circulating pumps, vertical installation BP1/BP2
2 pcs. screw pumps with mechanical seal

h) Final preheater H1/H2

2 pcs. shell and tube heat exchangers	each 100 % (saturated 7 bar or thermal oil 180 °C) each 100 % electrical

- **Heating medium control valve CV1** (steam/thermal oil)
- **Control cabinet** (electrical)

1 pc. control valve with built-on positioning drive, 1 pc. control cabinet for electr. preheater

Viscosity control system VA1
1 pc. automatic viscosity measure and control system VAF

Cooler CL1
1 pc. shell and tube heat exchanger for operating on MGO/MDO

3. Systems

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

Alarms
Pressure pump stand-by start
Low level in the mixing tank
Circulating pump stand-by start
Self cleaning fine filter clogged
Viscosity alarm high/low
The alarms with potential free contacts

Alarm cabinet with alarms to engine control room and connection possibility for remote start/stop and indicating lamp of fuel pressure and circulating pumps

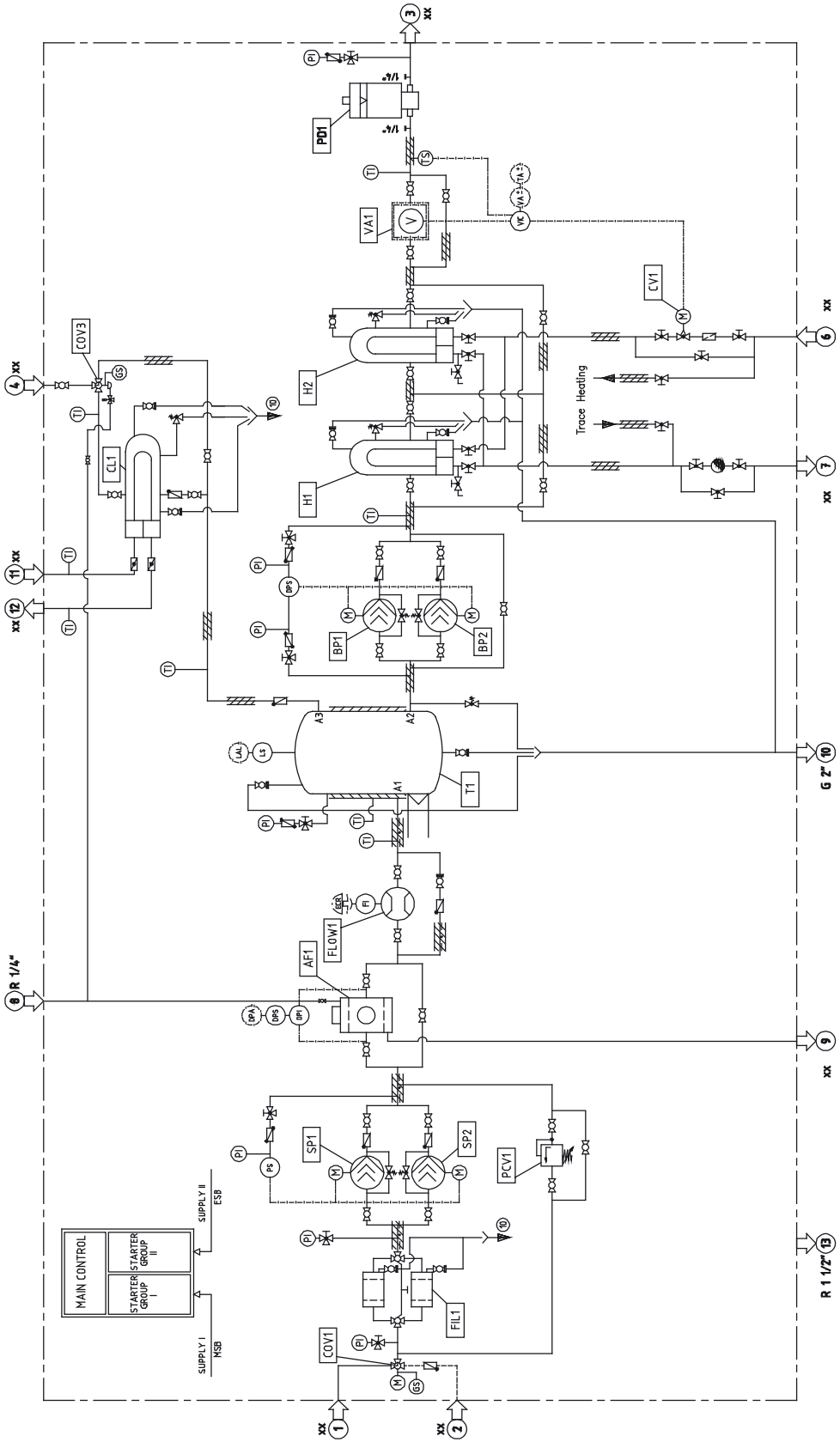
Performance and materials:
The whole module is piped and cabled up to the terminal strips in the electric switch boxes which are installed on the module. All necessary components like valves, pressure switches, thermometers, gauges etc. are included. The fuel oil pipes are equipped with trace heating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

The module will be tested hydrostatically and functionally in the workshop without heating.

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

3. Systems

Steam heated



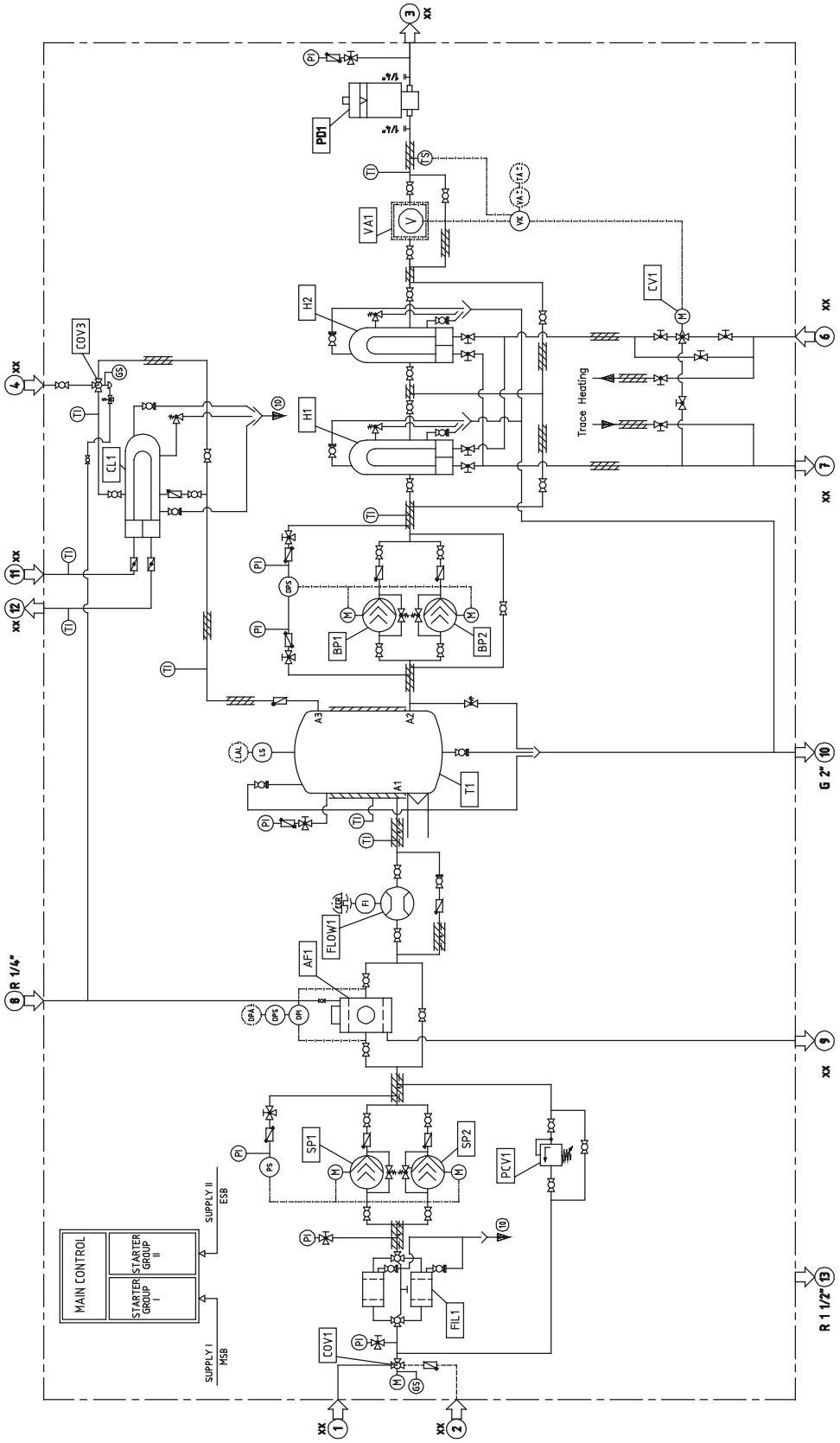
Symbols

	FLOW1	Flowmeter
	SP1/SP2 BP1/BP2	Screw displacement pump
	H1/H2	steam heater
	CL1	Cooler
	VA1	Viscosimeter
	FIL1	Duplex filter
	AF1	Automatic filter
	T1	Mixing tank
	PD1	Metal bellows accumulator
	COV1 COV3	Change over valve
	PCV1	Pressure regulating valve
	CV1	Control valve
		Y-strainer
		Steam trap
		Globe valve
		Non-return valve
		Safety valve, angle
		Magnet valve
		test valve
		Brass pres. gauge shock absorber
		Ball valve locking device
		Ball valve
		Butterfly valve
		Pipe with insulation
		Pipe with insulation & trace heating
		Scope of supply module

DPA	Diff. pressure alarm
DPI	Diff. pressure indicator
DPS	Diff. pressure switch
FI	Flow indicator
GS	Limit switch
LAL	Level alarm low
LS	Level switch
M	Motor drive
PI	Pressure indicator
PS	Pressure switch
TA	Temperature alarm
TI	Temperature indicator
TS	Temperature sensor
VA	Viscosity alarm
VIC	Viscosity controller

3. Systems

Thermal oil heated



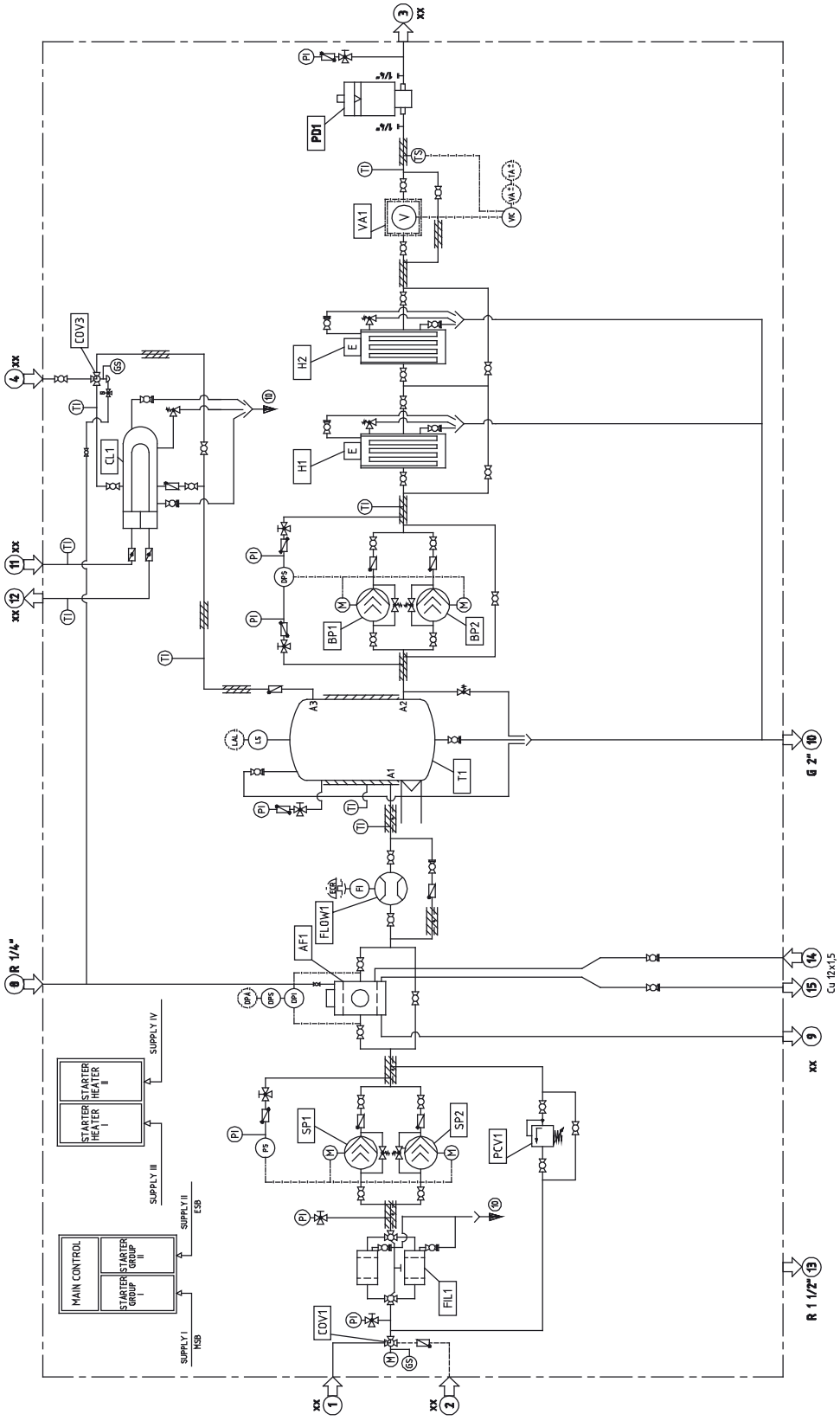
Symbols

	FLOW1	Flowmeter
	SP1/SP2 BP1/BP2	Screw displacement pump
	H1/H2	steam heater
	CL1	Cooler
	VA1	Viscosimeter
	FIL1	Duplex filter
	AF1	Automatic filter
	T1	Mixing tank
	PD1	Metal bellows accumulator
	COV1 COV3	Change over valve
	PCV1	Pressure regulating valve
	CV1	Control valve
		Y-strainer
		Steam trap
		Globe valve
		Non-return valve
		Safety valve, angle
		Magnet valve
		test valve
		Brass pres. gauge shock absorber
		Ball valve locking device
		Ball valve
		Butterfly valve
		Pipe with insulation
		Pipe with insulation & trace heating
		Scope of supply module

DPA	Diff. pressure alarm
DPI	Diff. pressure indicator
DPS	Diff. pressure switch
FI	Flow indicator
GS	Limit switch
LAL	Level alarm low
LS	Level switch
M	Motor drive
PI	Pressure indicator
PS	Pressure switch
TA	Temperature alarm
TI	Temperature indicator
TS	Temperature sensor
VA	Viscosity alarm
VIC	Viscosity controller

3. Systems

Electric heated



Symbols

	FLOW1	Flowmeter
	SP1/SP2 BP1/BP2	Screw displacement pump
	H1/H2	steam heater
	CL1	Cooler
	VA1	Viscosimeter
	FIL1	Duplex filter
	AF1	Automatic filter
	T1	Mixing tank
	PD1	Metal bellows accumulator
	COV1 COV3	Change over valve
	PCV1	Pressure regulating valve
	CV1	Control valve
		Y-strainer
		Steam trap
		Globe valve
		Non-return valve
		Safety valve, angle
		Magnet valve
		test valve
		Brass pres. gauge shock absorber
		Ball valve locking device
		Ball valve
		Butterfly valve
		Pipe with insulation
		Pipe with insulation & trace heating
		Scope of supply module

DPA	Diff. pressure alarm
DPI	Diff. pressure indicator
DPS	Diff. pressure switch
FI	Flow indicator
GS	Limit switch
LAL	Level alarm low
LS	Level switch
M	Motor drive
PI	Pressure indicator
PS	Pressure switch
TA	Temperature alarm
TI	Temperature indicator
TS	Temperature sensor
VA	Viscosity alarm
VIC	Viscosity controller

3. Systems

3.7 Lube oil system

3.7.1 Lube oil system quality requirements

The lube oil performs several basic functions:

- Cleaning the engine from dirt and wear particles.
- Transportation of dirt and wear particles to the filters
- Cooling of heat-affected parts, such as piston, cylinder liner, valves or cylinder head
- Protection of bearings from shocks of cylinder firing
- Lubrication of metal surfaces / reduction of wear and friction
- Neutralisation of corrosive combustion products
- Corrosion protection of metal surfaces

The viscosity class SAE 40 is required.

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

Constant uniform distribution of the additives at all operating conditions. Perfect cleaning (detergent effect) and dispersing power, prevention of deposits from the combustion process in the engine. Sufficient alkalinity in order to neutralize acid combustion residues. The TBN (total base number) must be between 30 and 40 KOH/g at HFO operation. For MDO operation the TBN is 12 - 20 depending on sulphur content.

3. Systems

The following oils have been tested and approved by Caterpillar Motoren GmbH & Co. KG:

Manufacturer	Diesel oil/marine-diesel oil operation	I	II	HFO operation	I	II
AGIP	DIESEL SIGMA S		x	CLADIUM 300 S	x	
	CLADIUM 120		x	CLADIUM 400 S	x	
BP	ENERGOL HPDX 40	x		ENERGOL IC-HFX 304	x	
	ENERGOL DS 3-154	x		ENERGOL IC-HFX 404	x	
	ENERGOL IC-HFX 204	x				
	VANELLUS C3		x			
CHEVRON, CALTEX, TEXACO	DELO 1000 MARINE	x		TARO 30 DP	x	
	TARO 12 XD	x		TARO 40 XL	x	
	TARO 16 XD	x		TARO 40 XLX	x	
	TARO 20 DP	x				
	TARO 20 DPX	x				
CASTROL	MARINE MLC	x		TLX PLUS 304	x	
	MHP 154	x		TLX PLUS 404	x	
	TLX PLUS 204	x				
CEPSA	KORAL 1540		x			
ESSO	EXXMAR 12 TP	x		EXXMAR 30 TP	x	
	EXXMAR CM+		x	EXXMAR 40 TP		x
	ESSOLUBE X 301		x	EXXMAR 30 TP PLUS	x	
				EXXMAR 40 TP PLUS	x	
MOBIL	MOBILGARD 412	x		MOBILGARD M 430	x	
	MOBILGARD ADL	x		MOBILGARD M 440	x	
	MOBILGARD M 430	x		MOBILGARD M 50	x	
	MOBILGARD 1-SHC [1]		x			
	DELVAC 1640	x				
SHELL	GADINIA	x		ARGINA T	x	
	GADINIA AL	x		ARGINA X	x	
	ARGINA S	x				
	ARGINA T	x				
TOTAL LUBMARINE	RUBIA FP		x	AURELIA TI 4030	x	
	DISOLA M 4015	x		AURELIA TI 4040	x	
	AURELIA TI 4030	x				

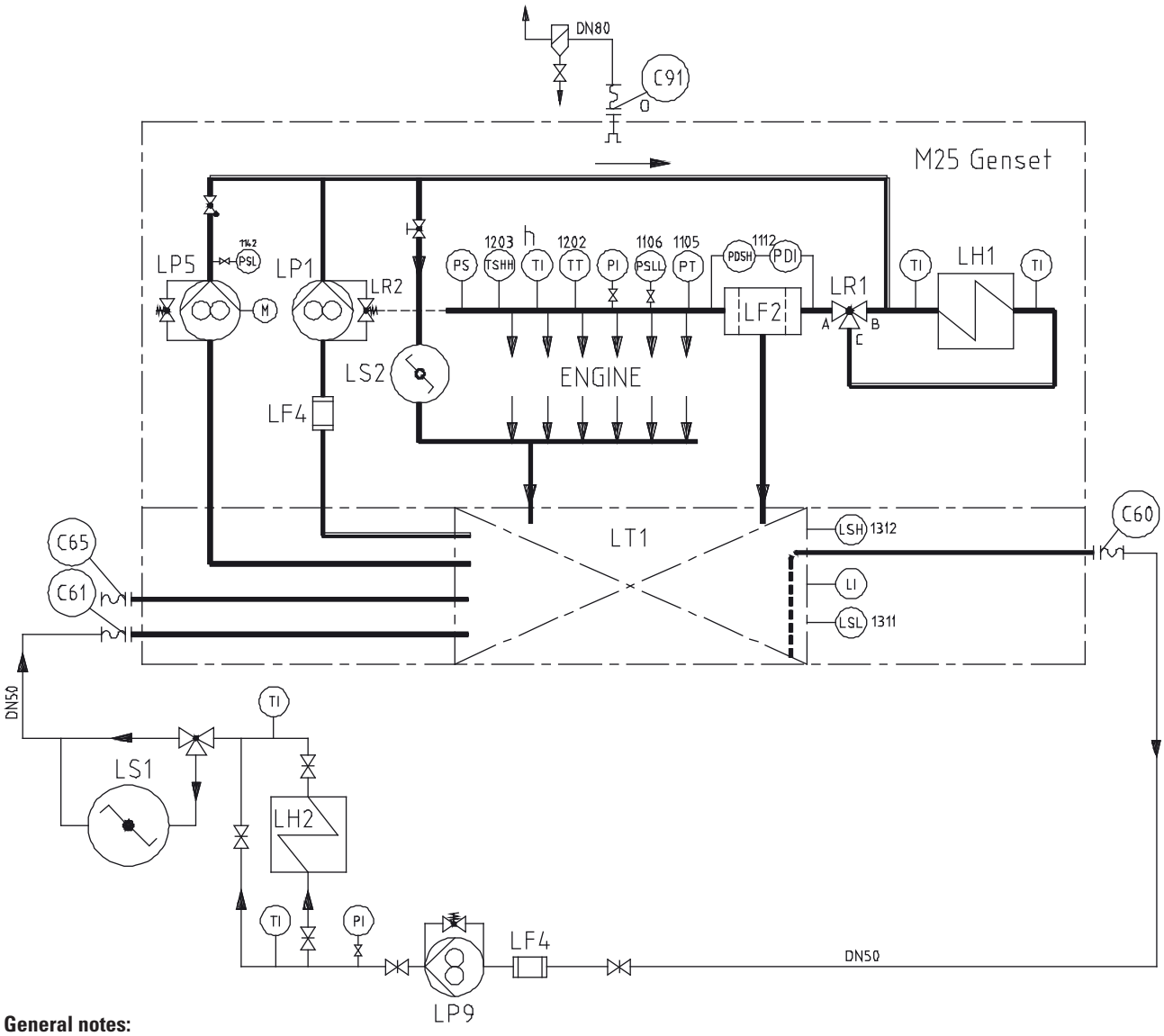
I Approved in operation

II Permitted for controlled use
When these lube oils are used, Caterpillar Motoren must be informed because at the moment there is insufficient experience available for MaK engines. Otherwise the warranty is invalid.

[1] Synthetic oil with a high viscosity index (SAE 15 W/40). Only permitted if the oil inlet temperatures can be decreased by 5 - 10 °C:

3. Systems

3.7.2 System diagram



General notes:
For location, dimensions and design (e.g. flexible connection) of the connecting points see engine installation drawing.

Notes:
- h Please refer to the measuring point list regarding design of the monitoring devices
- o See "crankcase ventilation" installation instructions 57

Connecting points:

C60	Separator connection, suction side or drain or filling pipe
C61	Separator connection, delivery side or from bypass filter
C91	Crankcase ventilation to stack
C65	Lube oil filling

Accessories and fittings:

LF2	Self cleaning luboil filter
LF4	Suction strainer
LH1	Lube oil cooler
LH2	Lube oil preheater
LP1	Lube oil force pump
LP5	Prelubrication pump
LP9	Transfer pump (separator)
LR1	Lube oil thermostat valve
LR2	Oil pressure regulating valve
LS1	Lube oil separator
LT1	Lube oil sump tank

LI	Level indicator
LSL	Level switch low
LSH	Level switch high
PDI	Diff. pressure indicator
PDSH	Diff. pressure switch high
PI	Pressure indicator
PS	Pressure indicator
PSL	Pressure switch low
PSLL	Pressure switch low low
PT	Pressure transmitter
TI	Temperature indicator
TSHH	Temperature switch high
TT	Temperature transmitter (PT 100)

3. Systems

3.7.3 Lube oil system components

a) Force pump (fitted) LP1:

Gear pump

b) Prelubrication pump (fitted) LP5:

Delivery head 5 bar.
Continuous lubrication is carried out with stopped genset.
Starter to be supplied by the yard.

c) Stand-by force pump (separate) LP2:

- per engine according to classification society requirement
- screw type/gear type pump

d) Strainer LF4:

Mesh size 2 - 3 mm

e) Self-cleaning filter (fitted) LF2:

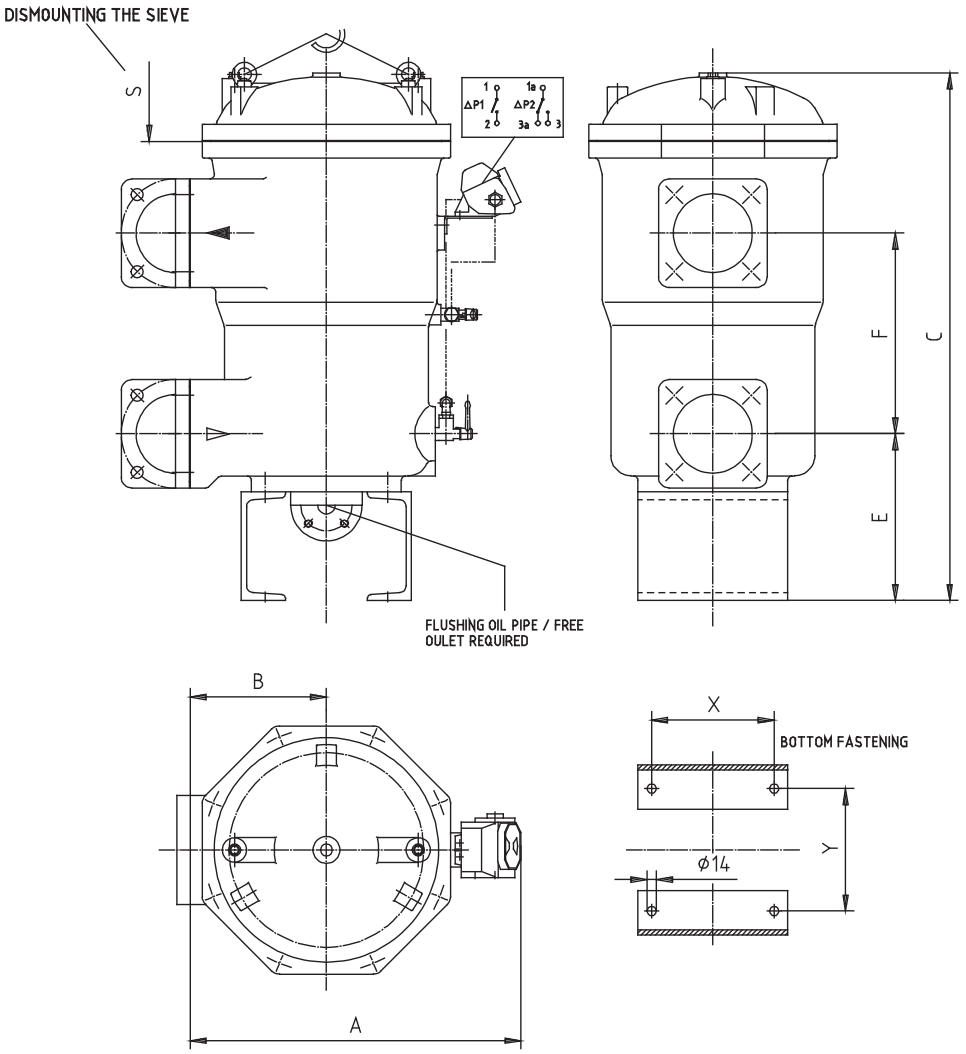
The self-cleaning filter protects the engine against dirt particles which may have accumulated in the oil tank.

The filter is fitted and replaces the duplex filter. Separate self-cleaning filter as an option possible. Dimension see next page.

Mesh size 30 µm (absolute), type 6.46 DN 100, make Boll & Kirch. **Without** by-pass filter. **Without** flushing oil treatment.

3. Systems

Self-cleaning filter separate LF2 (option)



Engine	A	B	C	E	F	S	X	Y	Weight [kg]	ND
6 M 25 C	435	170	735	205	225	400	160	160	77	80
8/9 M 25 C	485	200	775	245	295	400	180	180	112	100

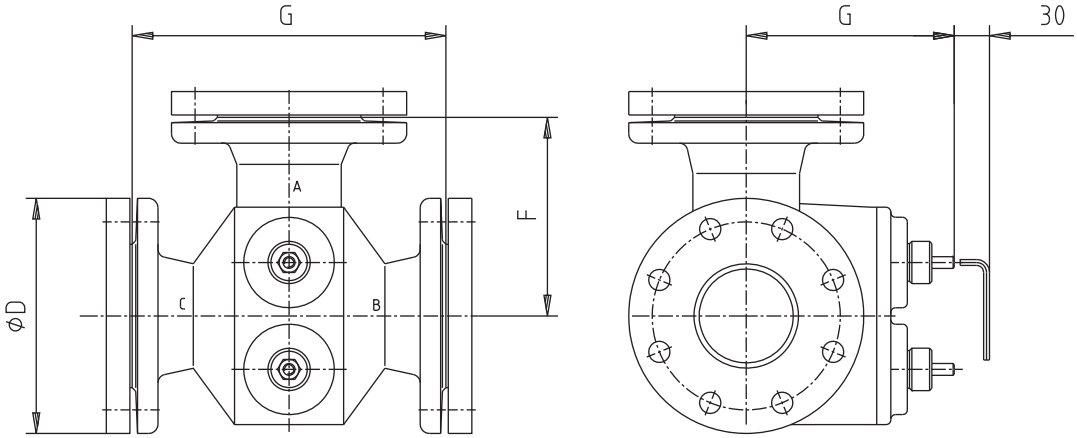
f) Cooler (fitted on base frame) LH1:

Option:
separate plate type (plates made of stainless steel)

3. Systems

g) Temperature controller (fitted on base frame) LR1:

Option:
separate P-controller with manual emergency adjustment



	Dimensions [mm]					Weight
	DN	D	F	G	H	[kg]
6 M 25 C	80	200	171	267	151	27
8/9 M 25 C	100	220	217	403	167	47

h) Circulation tank LT1:

Located in the base frame, equipped with high/low level switch and level control stick.

i) Crankcase ventilation C91:

At engine 1 x DN 80. Approx. 1 m after the connection point has to be enlarged to DN 100.

It must be equipped with a condensate trap and continuous drain. It has to be arranged separately for each genset. Crankcase pressure max. 150 Pa.

3. Systems

j) Separator; treatment at MGO/MDO operation LS1:

Required with the following design:
- Separating temperature 85 - 95 °C
- Quantity to be cleaned three times/day
- Self-cleaning type

V_{eff} [l/h] = 0.18 • P_{eng} [kW]

k) Separator; treatment at HFO operation LS1:

Required with the following design:
- Separating temperature 95 °C
- Quantity to be cleaned five times/day
- Self-cleaning type

V_{eff} [l/h] = 0.29 • P_{eng} [kW]

3.7.4 Recommendation for lube oil system

For each engine a separate lube oil system is recommended.

Lube oil quantities/change intervals:

The circulating quantity is approx. 1.1 l/kW output.

The change intervals depend on:
- fuel quality
- quality of lube oil treatment (filter, separator)
- engine load

By continuous checks of lube oil samples (decisive are the limit values as per "MaK Operating Media") an optimum condition can be reached.

External lube oil piping system information

After bending and welding all pipes must be cleaned by using an approved acid cleaning process.

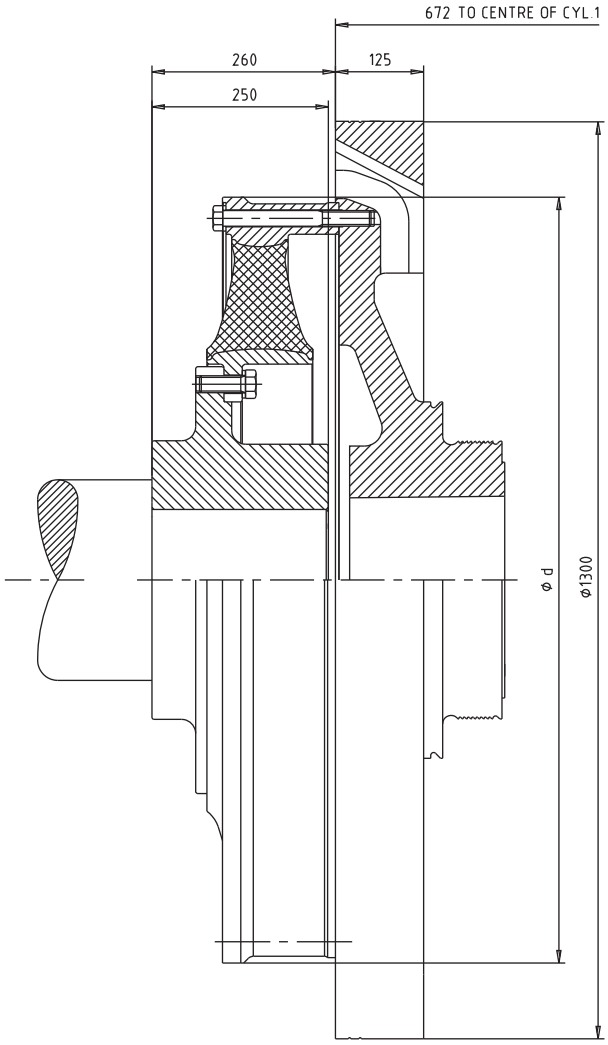
A proper inspection of the inner walls of the pipes is needed by our service engineers before starting the engine to ensure that no weld spatter, slag, rust and oxide remain.

Expansion joints

Pipe expansion joints are necessary in systems that convey high-temperature substances in this case hot oil. The bellows are designed to withstand the internal pressures of the pipe, but are flexible enough to accept the axial, lateral and angular deflections.

4. Connecting parts engine

Flywheel and flexible coupling



Engine type	Power	Speed	Nominal torque of coupling	Type Vulkan Rato-DS [1]	Weight
				d	
	[kW]	[rpm]	[kNm]	[mm]	[kg]
6 M 25 C	2,000	750	25.47	955	450
8 M 25 C	2,666	750	33.95	1,070	549
9 M 25 C	3,000	750	38.20	1,070	540

[1] final coupling type and dimensions dependent on generator type

4. Connecting parts engine

4.1 Data for torsional vibration calculation

To determine the location and resonance points of each engine and equipment Caterpillar Motoren GmbH & Co. KG calculates the torsional vibration behaviour of the engine, coupling and generators.

The classification societies require a complete Torsional Vibration Calculation.

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

Please send the completed data to your local dealer 6 months prior to the engine delivery at the latest.

For further information please compare point 13.6 of the appendix.

4. Connecting parts engine

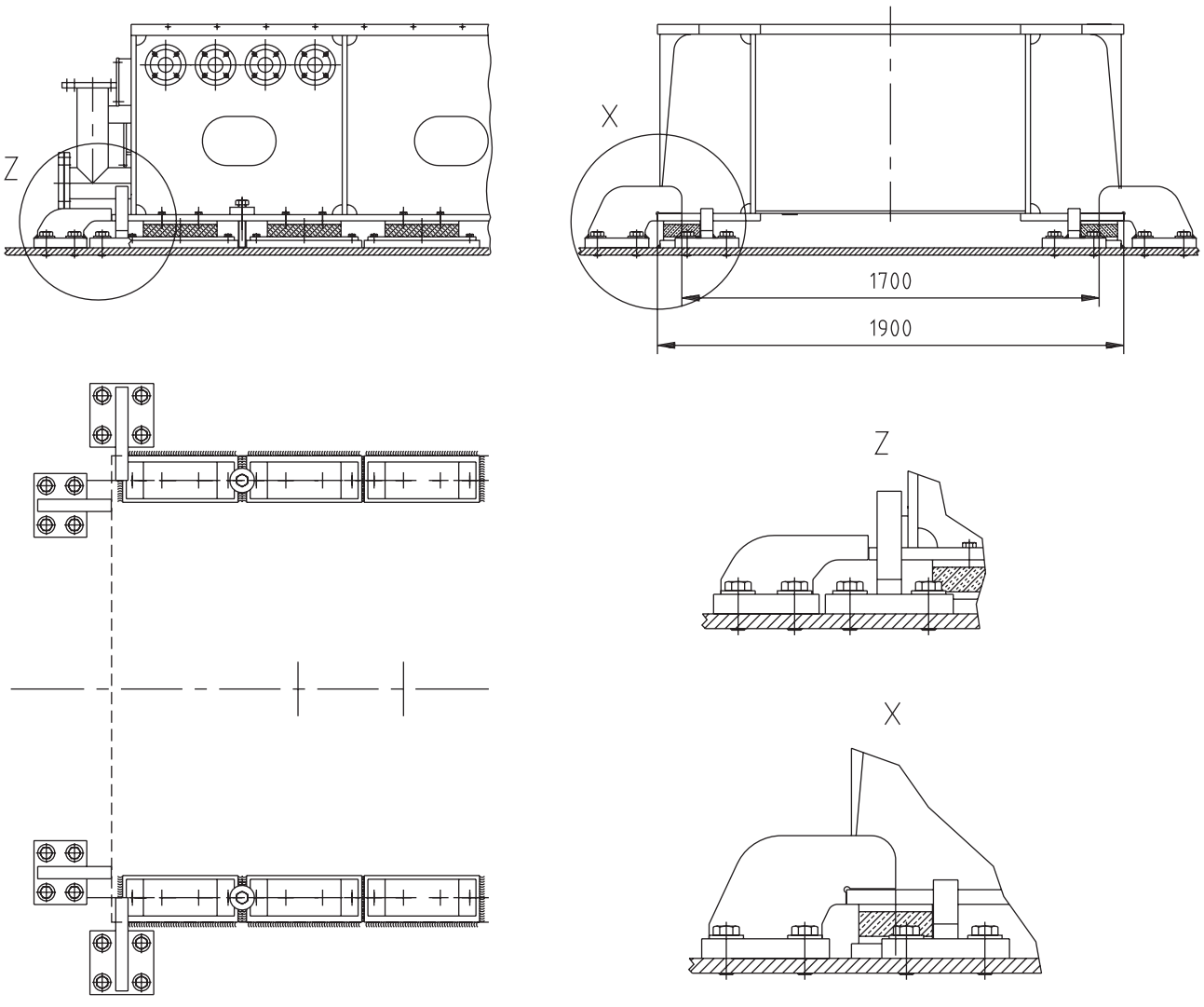
4.2 Resilient mounting of base frame

Engine and generator are rigidly connected with the base frame. The base frame is connected with the ship's foundation via rubber elements.
The ship's foundation does not require machining. Unevenness is to be compensated by design and thickness of the welded-on sheets in order to achieve a roughly even pressure on the rubber elements.

The rubber elements (height = 80 mm) are fastened to the ship's foundation via welded-on sheets (thickness about 30 mm) and shims for compensation of differences in height.

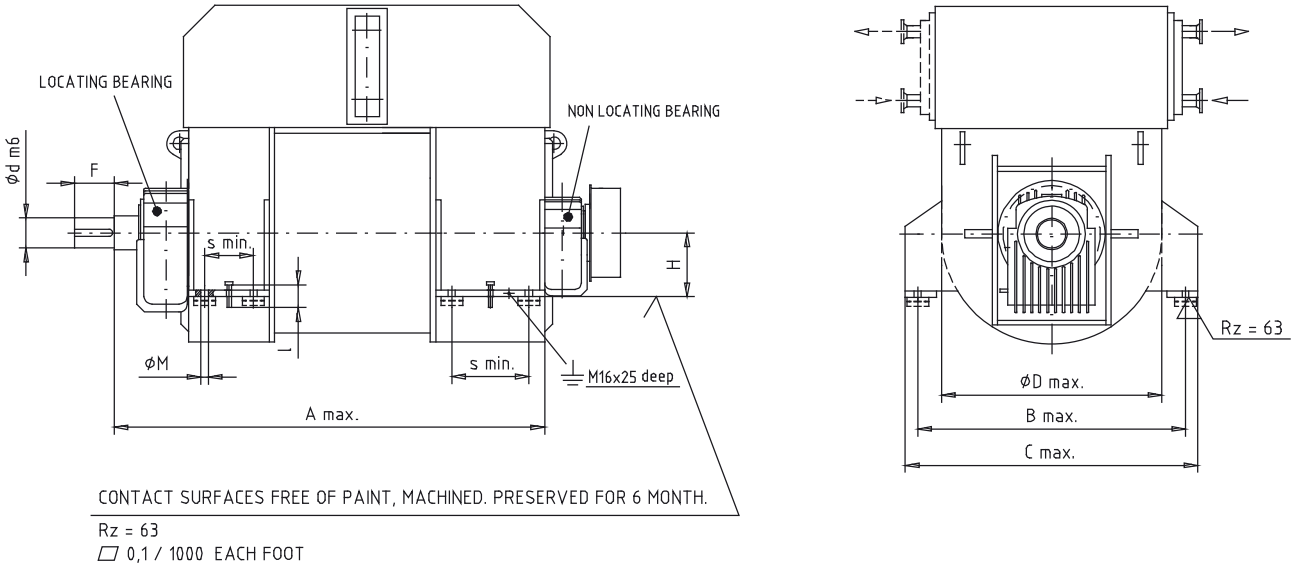
Further notes (inter alia regarding alignment) are given in the binding installation drawing. Transverse and longitudinal stoppers and welding sheets are to be provided by the shipyard.

Base frame foundation



4. Connecting parts engine

4.3 Generators structural requirements for MaK diesel gensets M 25 C



- Mounting flap for anti-condensation heater above the mounts
- With air cooling the air outlet above the mounts
- The mounts are to be designed with 4 alignment screws
- Plain bearings must be removable without coupling removal

Type	Stator design	A max.	B	C	Ø D max.	Ø d	F	H	Ø M	S min.
6 M 25 C	B 20	2,700	1,700	1,900	1,500	200	250	405	45	220
8 M 25 C		3,000								
9 M 25 C		2,900				200	250			

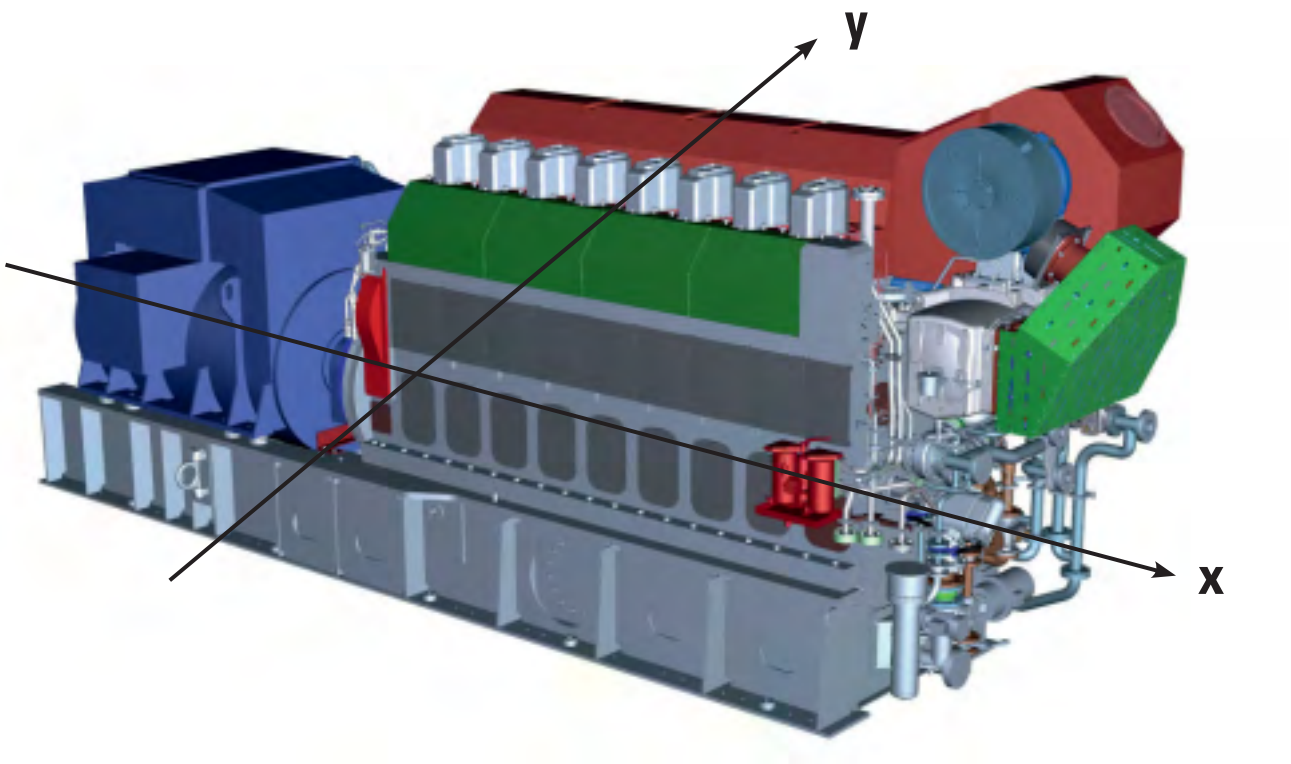
5. Installation and Arrangement

5.1 General installation aspect

Inclination angles of ships at which engine running must be possible:

Rotation X-axis:
Static: heel to each side: 15 °C
Dynamic: rolling to each side: 22.5 °C

Rotation Y-axis:
Static: trim by head and stern: 5 °C
Dynamic: pitching: ± 7.5 °C



5. Installation and Arrangement

5.2 System connections engine

Starting Air
C86 Connection starting air

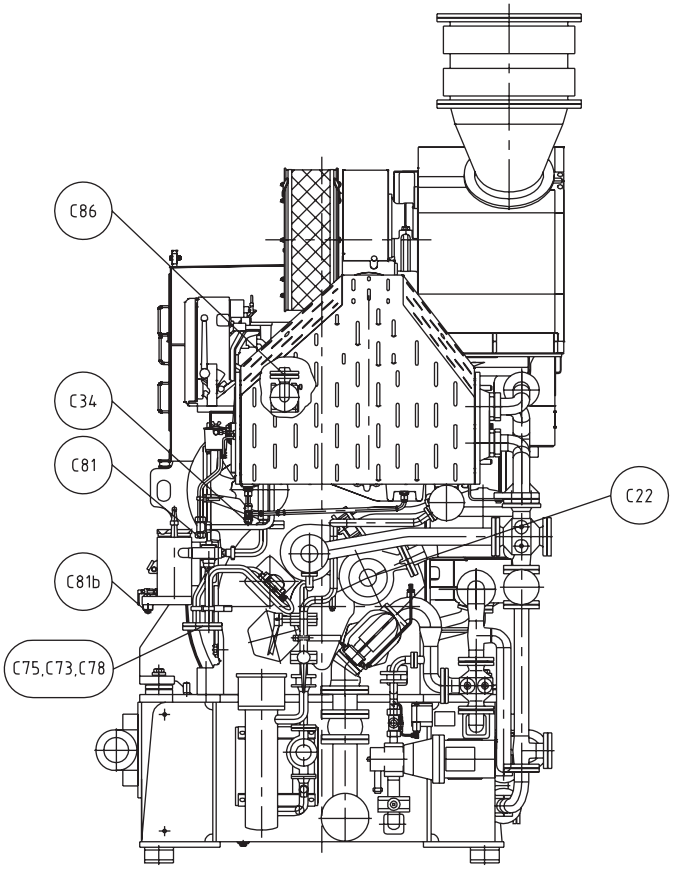
Fuel Oil
C80 Drip fuel connection
C81 Drip fuel connection

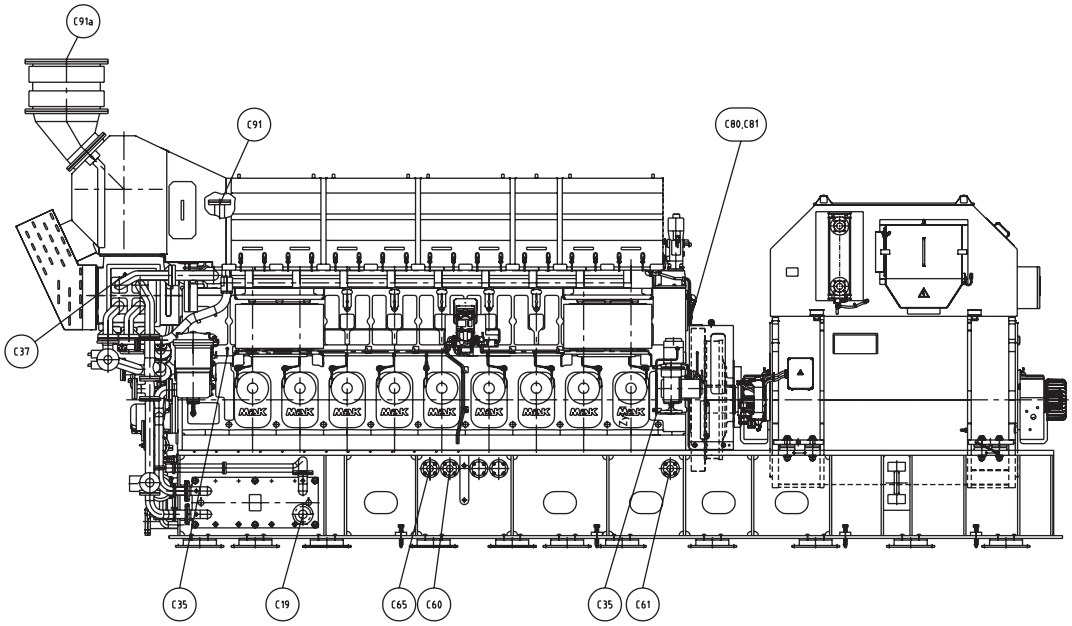
Exhaust
C91a Exhaust gas outlet

Cooling Water
C19 Cooling water outlet, oilcooler
C22 Freshwater pump LT, inlet
C37 Ventilation connection

Lubricating oil
C60 Separator, suction side
C61 Separator, delivery side
C65 Lube oil, filling socket
C91 Crankcase ventilation

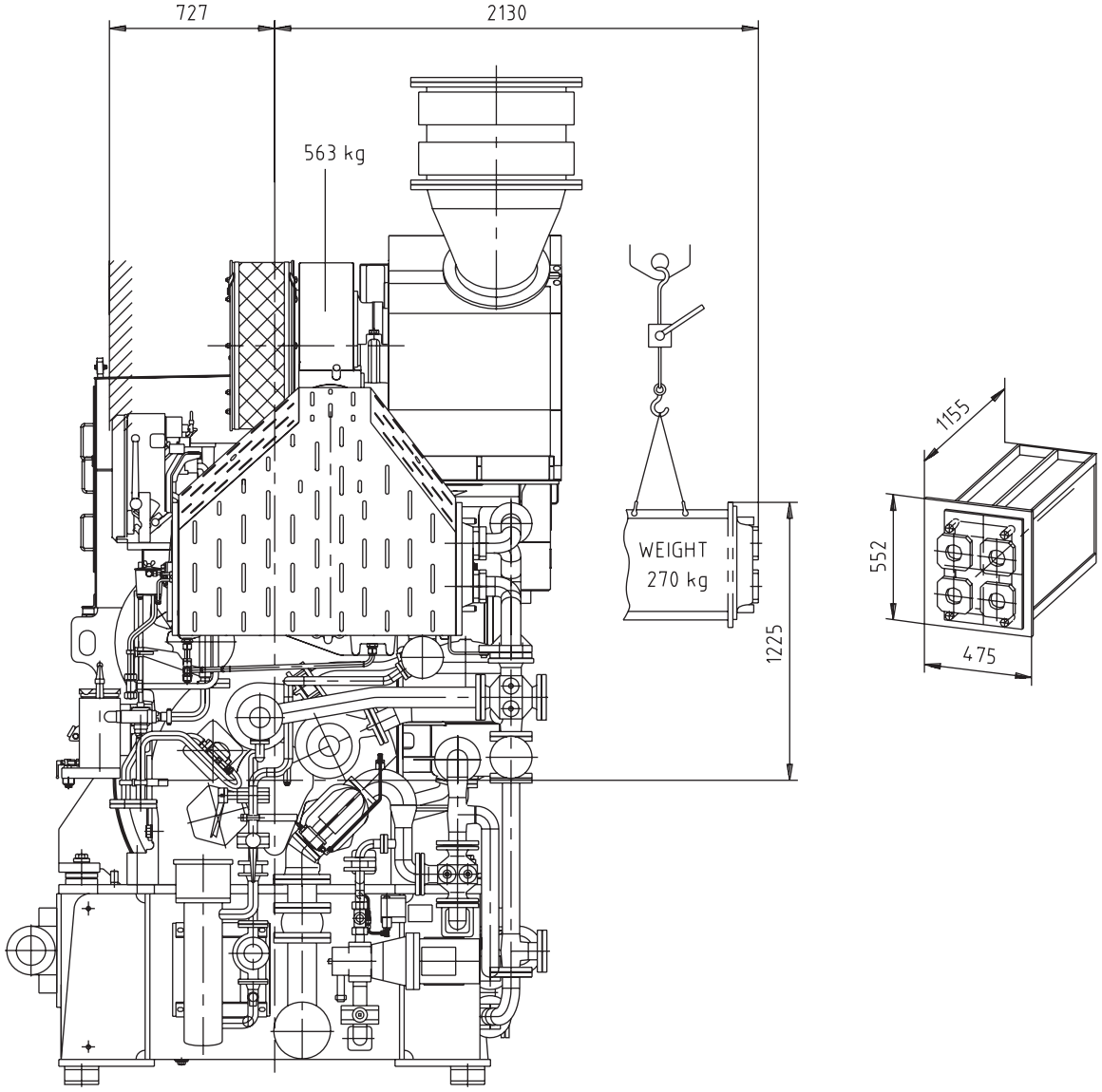
Others
C34 Drain charge air cooler
C35 Drain charge air duct





5. Installation and Arrangement

5.3 Space requirement for dismantling of charge air cooler and turbocharger cartridge



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 ultrasonic vibrators.

Turbocharger dismantling

Removal of cartridge with compressor delivery casing after removal of air filter silencer.

	R [mm]	Weight [kg]
6 M 25 C	727	563
8/9 M 25 C	727	563

5. Installation and Arrangement

5.4 Installation of flexible pipe connections

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

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

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

Installation of steel expansion joints

Steel expansion joints can compensate movements in line and transversal to their center line. They are not for compensating twisting movements. Expansion joints are very stiff against torsion.

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

5.5 Notes regarding installation exhaust system

- Arrangement of the first expansion joint directly on the transition pipe
- Arrangement of the first fixed point in the conduit directly after the expansion joint
- Drain opening to be provided (protection of turbocharger and engine against water)
- Each engine requires an exhaust gas pipe (one common pipe for several engines is **not permissible).**

During commissioning and maintenance work, checking of the exhaust gas counter pressure by means of a temporarily connected measuring device may become necessary.

For this reason, a measuring socket is to be provided approx. 1 - 2 m after the exhaust gas outlet of the turbocharger at an easily acceptance place.

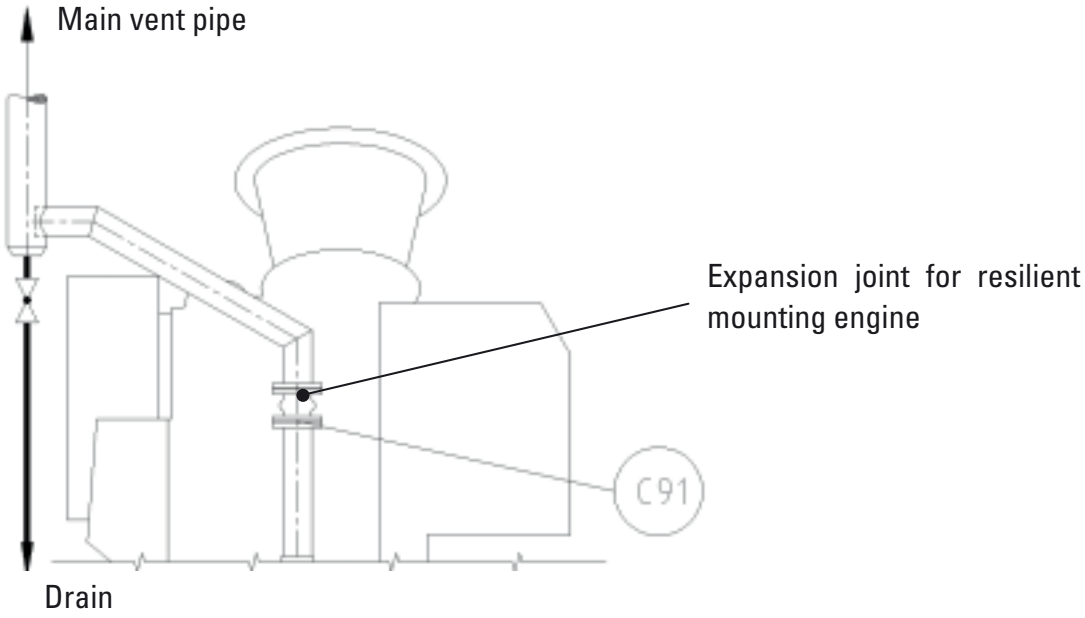
If it should be impossible to use standard transition piece supplied by Caterpillar Motoren, the weight of the transition piece manufactured by the shipyard must not exceed the weight of the standard transition piece. A drawing including the weight will then have to be submitted approval.

5. Installation and Arrangement

5.6 Installation of crankcase ventilation on the engine

Please consider the following design criteria for the piping of crankcase ventilation:

- Outlet crankcase ventilation has to be arranged separately for each engine
- The pipes should run upwards
- A free ventilation under all trim conditions
- Condensate backflow into crankcase has to be prevented
- Provide a permanent drain



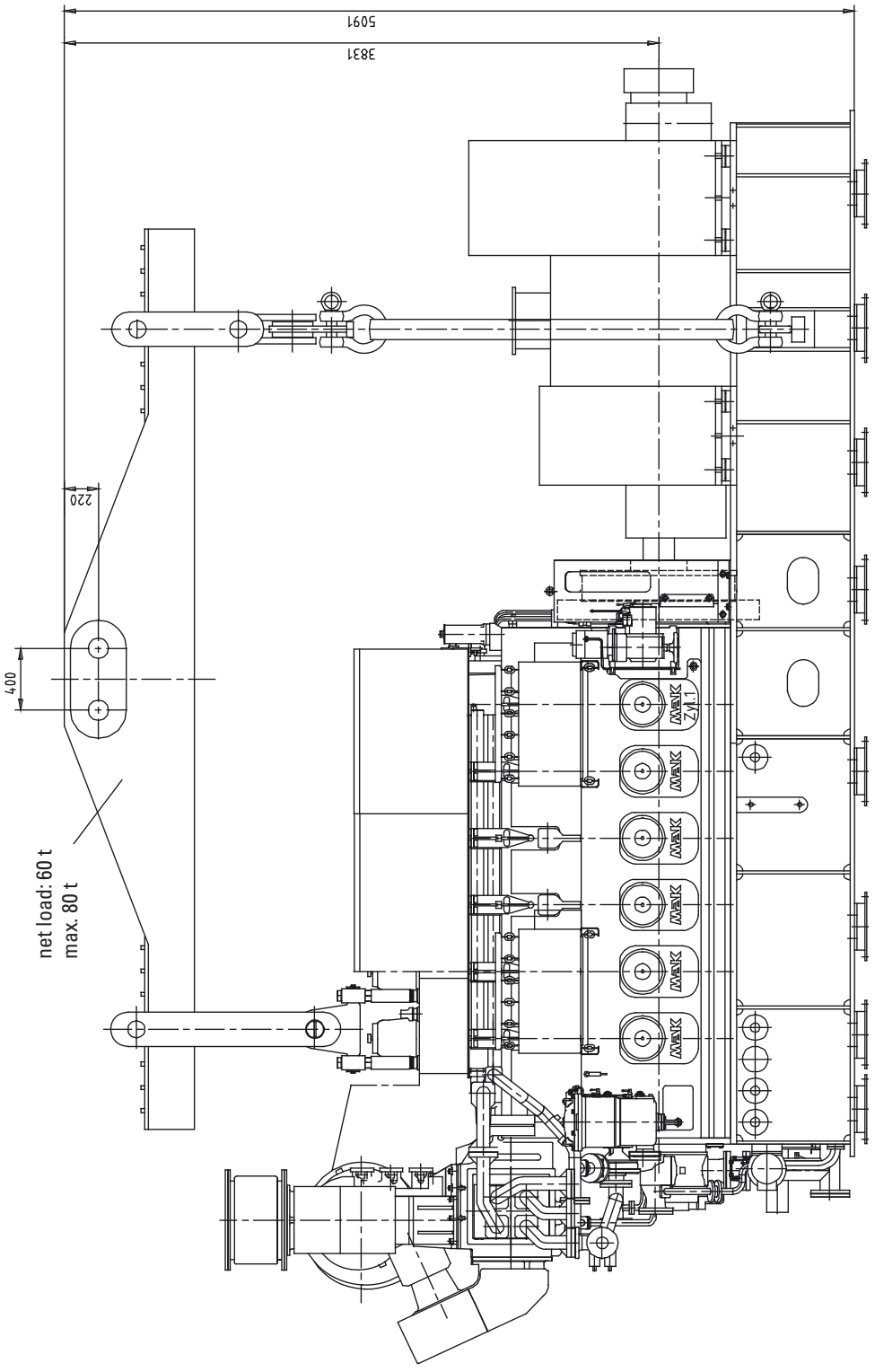
Piping sizes for crankcase ventilation

Engine Type	Engine connecting point(s)	Main vent pipe	Collecting vent with lubricating oil circulation tank (observe class rules)
6/8/9 M 25 C	1 x DN 80	1 x DN 100	DN 125

5. Installation and Arrangement

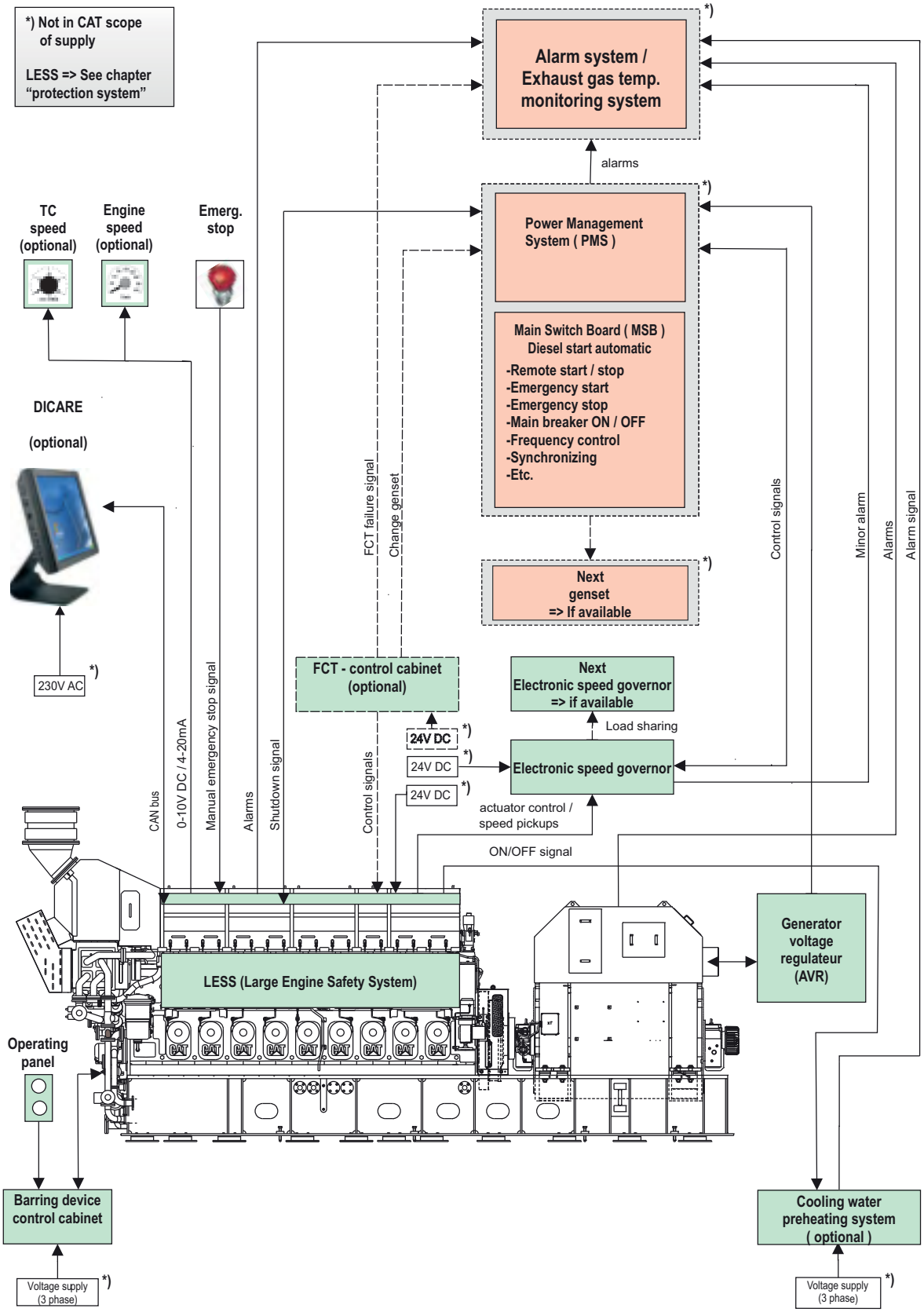
5.7 Lifting of the engine

For the purpose of transport the genset is equipped with a lifting device which shall remain the property of Caterpillar Motoren. It has to be returned in a useable condition free of charge.



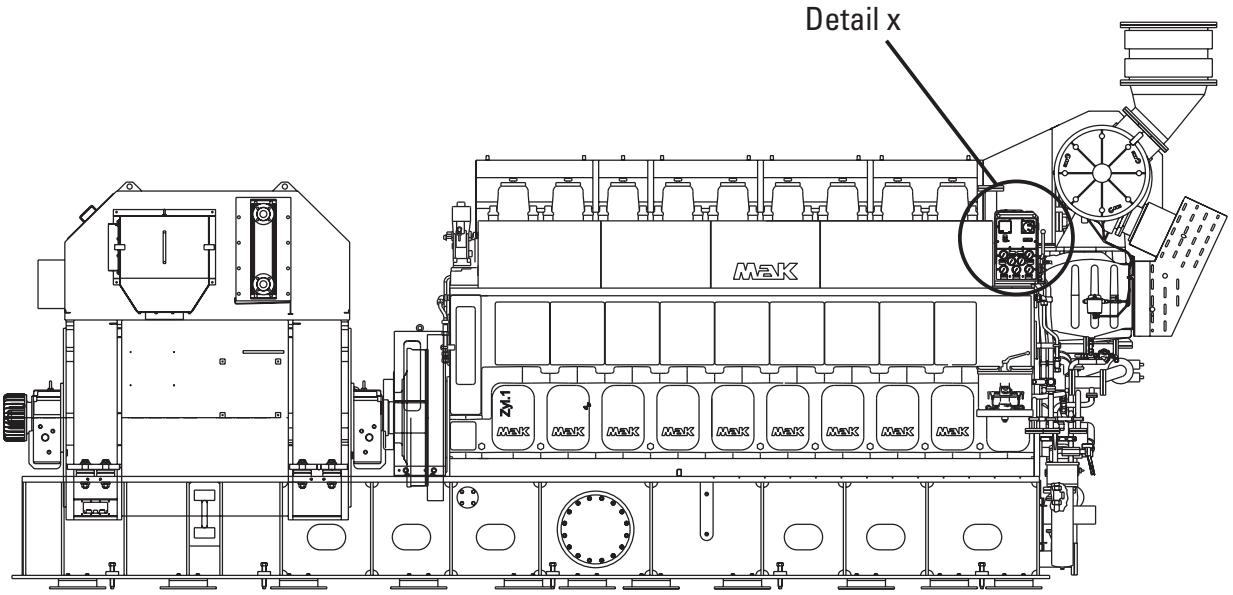
6. Control and monitoring system

6.1 Engine control panel

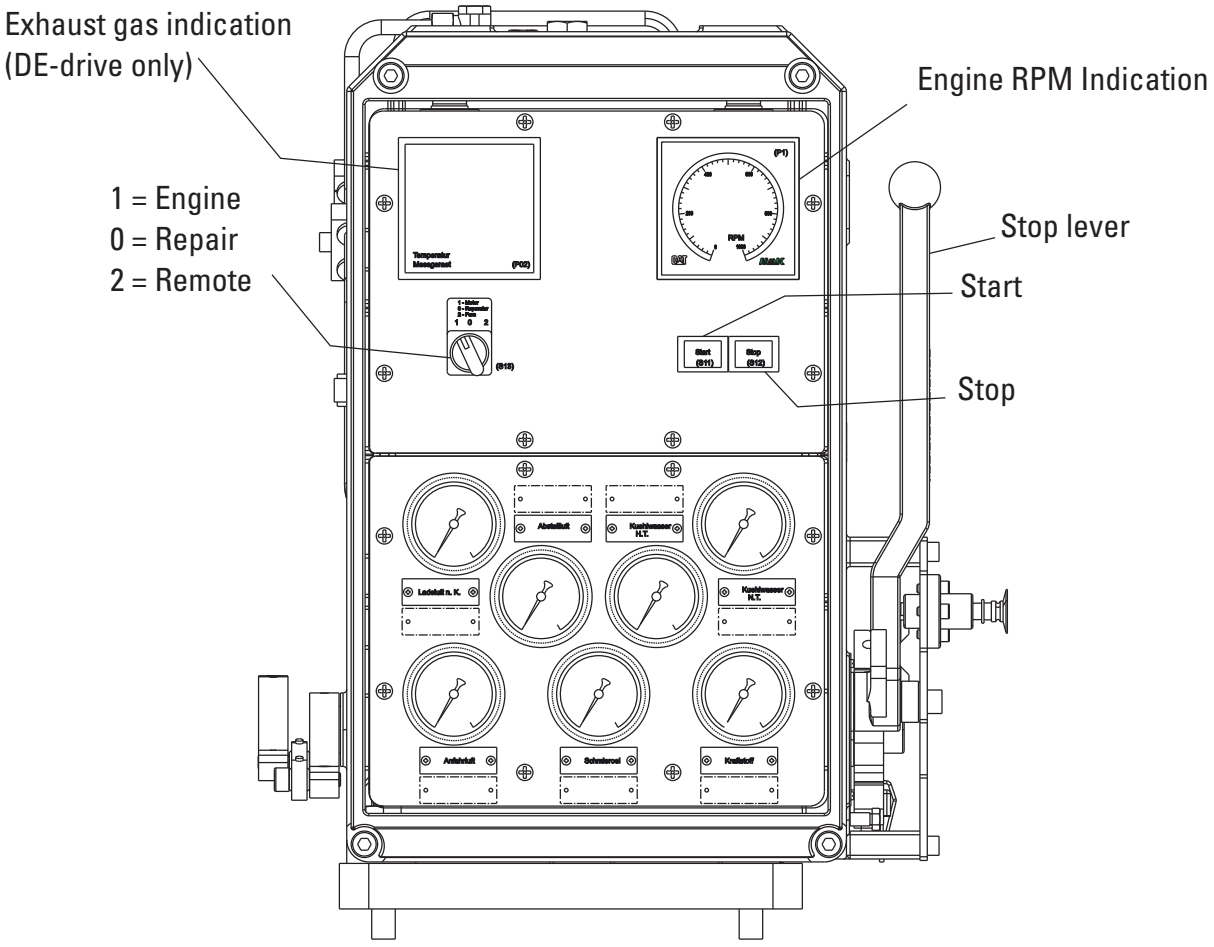


6. Control and monitoring system

6.2 Genset control

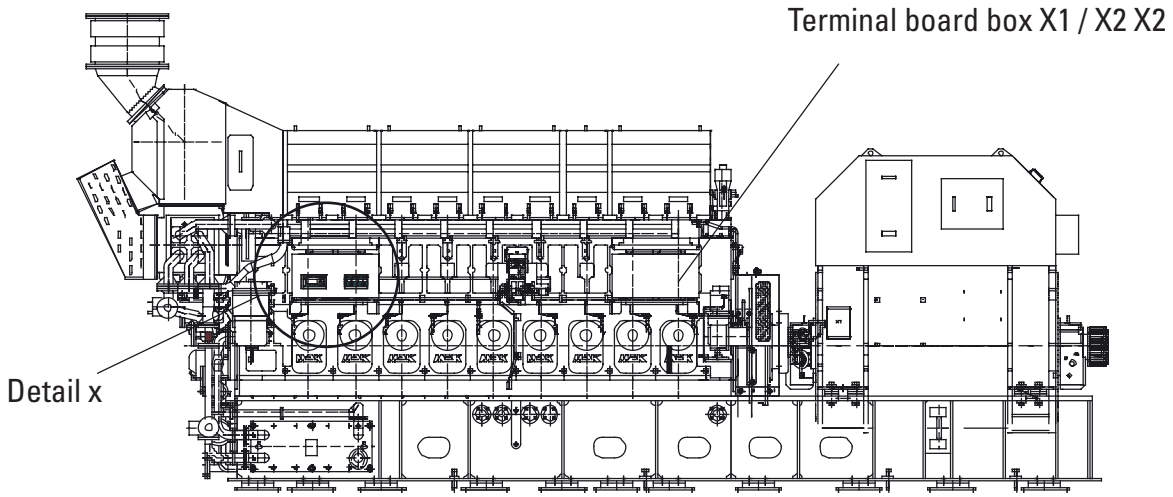


Detail x: Equipment for local engine control

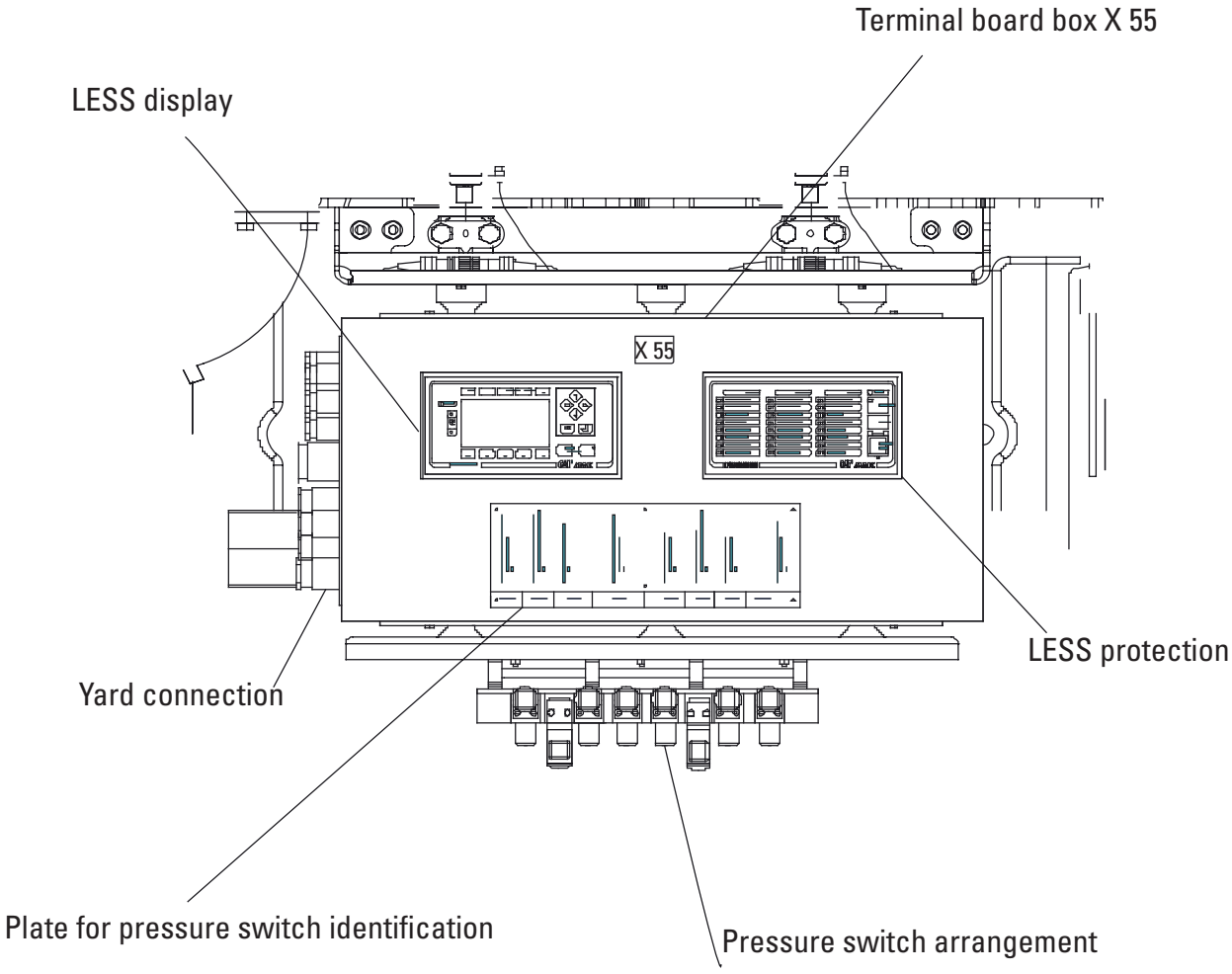


6. Control and monitoring system

6.3 Engine monitoring



Detail x: Arrangement of terminal board box X 55 / pressure switch



6. Control and monitoring system

6.4 Measuring points

Meas. Point MOD-bus-Address	Description	Sensor range	Remarks
1105 30009	Pressure transmitter Lube oil pressure low - pre-alarm shutdowm	4-20 mA	
1106 10113	Pressure switch Lube oil pressure low - shutdown	binary	
1112.1 10034 **1112.2** 10035	Differential pressure lube oil automatic filter high - pre-alarm Differential pressure lube oil automatic filter high - alarm	binary binary	1 evaluation unit for 1112.1/.2 Only exhist when aut.-filter is mounted on engine
1142 10116	Pressure switch Pre lube oil pressure low - start interlock	binary	
1202 30010	Resistance thermometer Lube oil temp. at engine inlet high - alarm	PT 100	
1203 30119	Resistance thermometer Lube oil temp. at engine inlet high - shutdown	PT 100	
1251 10045 **1251.1** 10001 **1251.2** **1253** 10112 **9631** 10047	Oil mist detector VN115/87 Plus **1251** Oil mist concentration in crankcase high - alarm **1251.1** Oil mist concentration in crankcase high - Pre-alarm **1251.2** Opacity **1253** Oil mist concentration in crankcase high - shutdown **9631** Oil mist detector failure - alarm	**1251:** binary **1251.2:** 4-20 mA **1253:** binary **9631:** binary	1 evaluation unit for 1251, 1253 ,9631 **1251.1** (70% from **1251**)
1311 10034	Level probe/switch unit Lube oil level low - alarm	binary	
1312 10035	Level probe/switch unit Lube oil level high - alarm	binary	
2102 30011	Pressure transmitter Cooling water pressure HT at engine inlet low - alarm	4-20 mA	40 kPa below operating pressure
2103 10114	Pressure switch Cooling water pressure HT at engine inlet low - shutdown	binary	60 kPa below operating pressure stop delay: 20s
2112 30012	Pressure transmitter Cooling water pressure LT at engine outlet low - alarm	4-20 mA	40 kPa below operating pressure
2201 30013	Resistance thermometer Cooling water temp. HT at engine inlet low - alarm	PT 100	
2211 30014	Resistance thermometer Cooling water temp. HT at engine outlet high - alarm	PT 100	

6. Control and monitoring system

Meas. Point MOD-bus-Address	Description	Sensor range	Remarks
2213 30120	Resistance thermometer Cooling water temp. HT at engine outlet high - shutdown	PT 100	
2229 30015	Resistance thermometer Cooling water temp. LT at engine inlet high - alarm	PT 100	
5102 30021	Pressure transmitter Fuel oil pressure at engine inlet low - alarm	4-20 mA	
5111 10036	Differential pressure indicator Differential pressure fuel oil filter high - alarm	binary	
5201/5202* 30022	Resistance thermometer **5201** Fuel oil temp. at engine inlet low - alarm ***5202** Fuel oil temp. at engine inlet high - alarm	PT 100	1 sensor for 5201 + 5202* * not in use with HFO
5206 30090	Fuel oil temp. after viscomat - DICARE	PT 100	Not mounted on engine
5253 30089	Fuel oil viscosity at viscomat - DICARE	4-20 mA	Not mounted on engine
5301 10003	Level probe/switch unit Leakage oil level at engine high - alarm	binary	
6101 30032	Pressure transmitter Starting air at engine inlet low - alarm	4-20 mA	
6105 10048	Pressure switch Stopping air pressure at engine low - alarm	binary	Alarm delay: 2s
6181 30019	Absolute pressure transmitter Intake air pressure in engine room - DICARE	4-20 mA	
7109 30017	Pressure transmitter Charge air pressure at engine inlet - Indication	4-20 mA	
7201 30016	Resistance thermometer Charge air temp. at engine inlet high - alarm	PT 100	
7206 30020	Resistance thermometer Intake air temp. at turbocharger inlet - DICARE	PT 100	
7301 10004	Level probe/switch Condense water in charge air canal	binary	
7307 30018	Differential pressure transmitter Charge air diff. pressure at charge air cooler - DICARE	4-20 mA	
7309 30087	Thermocouple type K Charge air temp. at charge air cooler inlet - DICARE	NiCr-Ni (mV)	
8211.1 30073	Thermocouple type K Exhaust gas temp. after cylinder 1 high high	NiCr-Ni (mV)	Load depended alarm delay: 16s

6. Control and monitoring system

Meas. Point MOD-bus-Address	Description	Sensor range	Remarks
8211.2 30074	Thermocouple type K Exhaust gas temp. after cylinder 2 high high	NiCr-Ni (mV)	Load depended alarm delay: 16s
8211.3 30075	Thermocouple type K Exhaust gas temp. after cylinder 3 high high	NiCr-Ni (mV)	Load depended alarm delay: 16s
8211.4 30076	Thermocouple type K Exhaust gas temp. after cylinder 4 high high	NiCr-Ni (mV)	Load depended alarm delay: 16s
8211,5 30077	Thermocouple type K Exhaust gas temp. after cylinder 5 high high	NiCr-Ni (mV)	Load depended alarm delay: 16s
8211.6 30078	Thermocouple type K Exhaust gas temp. after cylinder 6 high high	NiCr-Ni (mV)	Load depended alarm delay: 16s
8211.7 30079	Thermocouple type K Exhaust gas temp. after cylinder 7 high high	NiCr-Ni (mV)	Load depended alarm delay: 16s
8211.8 30080	Thermocouple type K Exhaust gas temp. after cylinder 8 high high	NiCr-Ni (mV)	Load depended alarm delay: 16s
8211.9 30081	Thermocouple type K Exhaust gas temp. after cylinder 9 high high	NiCr-Ni (mV)	Load depended alarm delay: 16s
8212.1 to 8212.9	Exhaust gas temp. absolute after cyl. 1 to 9 - alarm	4-20 mA	Alarm from exhaust gas temp. system, has to be created in the EGTS
8213.1 to 8213.9	Exhaust gas temp. deviation from mean average cyl. 1 to 9 - alarm	binary	Alarm from exhaust gas temp. system, has to be created in the EGTS
8216	Deviation of mean average value reduct alarm cyl. - shutdown	4-20 mA	Included in meas. Point 8234 from alarm system to (EGTS) LESS
8218	Exhaust gas temp. reduct alarm of each cyl. absolute - shutdown	4-20 mA	Included in meas. Point 8234 from alarm system to (EGTS) LESS
8221 30082	Thermocouple type K Exhaust gas temp. at turbocharger outlet	NiCr-Ni (mV)	Load depended alarm delay. 16s
8224	Exhaust gas temp. reduction alarm of turbocharger outlet - shutdown		Included in meas. Point 8234 from alarm system to (EGTS) LESS
8231.1 30083	Thermocouple type K Exhaust gas temp. at turbocharger inlet - Indication	NiCr-Ni (mV)	
8231.2 30084	Thermocouple type K Exhaust gas temp. at turbocharger inlet - Indication	NiCr-Ni (mV)	
8231.3 30085	Thermocouple type K Exhaust gas temp. at turbocharger inlet - Indication	NiCr-Ni (mV)	
8234 10136	Common alarm exhaust gas temp. monitoring load reduction included 8216, 8218, 8224	binary	Common alarm from alarm system to (EGTS) LESS

6. Control and monitoring system

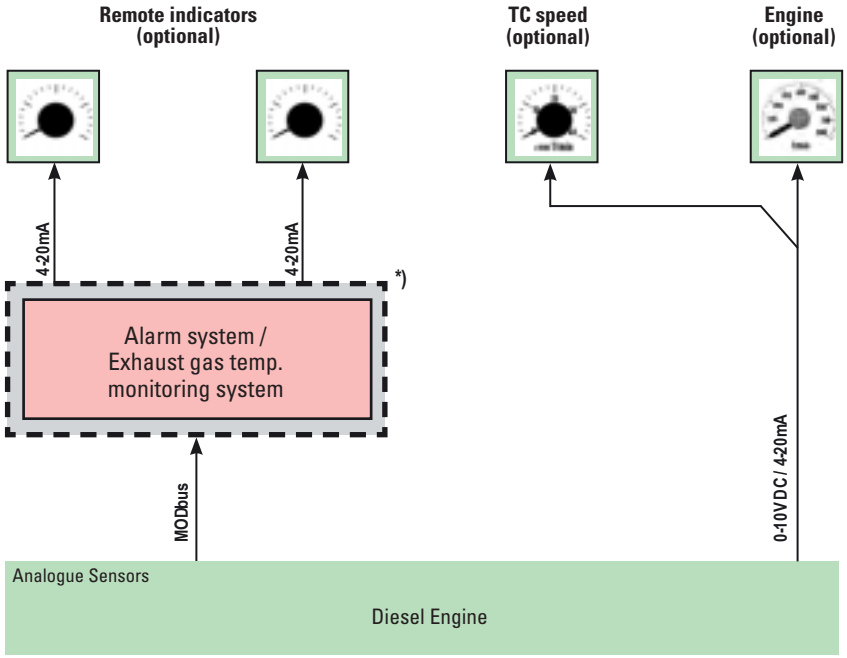
Meas. Point MOD-bus-Address	Description	Sensor range	Remarks
R1 30086	Resistance thermometer, terminal set A02-1-X40 Temperature compensation thermocouples	PT 100	
R2	Resistance thermometer, socket X2.1 Temperature compensation thermocouples	PT 100	
R16	Resistance thermometer Electr. charge air temp. control	PT 100	
9401.1	Suppression of alarms	binary	To be created in alarm system; Alarm system received the engine rpm signal via MODBUS (plant specific)
9401.2	Fresh water pre-heater switch on / off	binary	Hardwired to CW-preheating control (plant specific)
9401.3	Engine is running n > n_min	binary	Hardwired to PMS (plant specific)
9402	Pre lube oil pump switch on / off	binary	**Option** Hardwired to yard supplied pumpcontrol (plant specific)
9404	Relay contact Overspeed - shutdown	binary	1,15 x n rated
9419 30051	Engine speed signal	4-20 mA	683.3 Hz = 0-1000 rpm
9419.1	Pick up RPM switching equipment	0-15 KHz	
9419.2	Pick up RPM switching equipment	0-15 KHz	
9419.3	Pick up Electronic governor	0-900 Hz	
9419.4	Pick up Electronic governor	0-15 KHz	
9429 30042	Pick up / transmitter Turbine speed high - alarm* Turbine speed - Indication	4-20 mA 0-10 V	* DNV to be created in alarm system
9503 10222	Limit switch Control level at fuel rack - stop position	binary	
9509 30031	Distance sensor / switching device Fuel setting	4-20 mA	Switching device not mounted on engine (plant specific)
9532.1	Engine fuel rack position	4-20 mA	Hardwired to PMS
9532.2	Engine fuel rack position	4-20 mA	Spare
9532.3	Engine fuel rack position	0-10 V	**Option** Hardwired to exhaust gas temp. (plant specific)

6. Control and monitoring system

Meas. Point MOD-bus-Address	Description	Sensor range	Remarks
9561 10117	Limit switch Turning gear engaged - starting interlock	binary	Start blocking
9602 10005	Relay contact CANbus Failure - alarm	binary	
9609 10223	From power management system (PMS) - start interlock		Start blocking (plant specific)
9615	Trouble at electronic speed governor - alarm	binary	Hardwired to alarm system
9616 10045	Trouble at electronic speed governor - shutdown		Pick up fault, Actuator wire break
9735 10226	From power management system (PMS) - shutdown		Generator protection shutdown
9836.1 10107	Relay contact Sensor / isolation fault A01.1 - alarm	binary	Hardwired to alarm system
9836.2 10007	Relay contact Sensor / isolation fault A03.1 - alarm	binary	Hardwired to alarm system
9962.1 30108	Relay contact Common alarm A01.1 - alarm	binary	Hardwired to alarm system
9962.2 30008	Relay contact Common alarm A03.1 - alarm	binary	Hardwired to alarm system
9671.1	Relay contact Aut stop failure - alarm	binary	Hardwired to alarm system
9671.2	Relay contact Overspeed failure - alarm	binary	Hardwired to alarm system
9671.3	Relay contact Emergency stop failure - alarm	binary	Hardwired to alarm system
9674	Relay contact Aut stop / PLC A01 common - shutdown	binary	Hardwired to alarm system
9675	Relay contact Emergency stop - alarm	binary	Hardwired to alarm system
9751.1	Voltage fail at charge air temp. controller - alarm	binary	plant specific
9771	Fresh water preheater voltage failure - alarm	binary	plant specific
9828 10221	Blackout - alarm	binary	plant specific
Y1.1	Solenoid valve Safety shutdown	24V DC / 6W	
Y1.2	Solenoid valve Start	24V DC / 6W	
Y1.6	Solenoid valve Starting interlock for manual emergenccy start	24V DC / 18,5W	

6. Control and monitoring system

6.5 Local and remote indicators



*) optinally in CAT scope of supply

Local indicators	Remote indicators
Installed at the engine	96 x 96mm (optionally)
Fuel oil temperature at engine inlet	X
Fuel oil differential pressure at filter	
Fuel rack position (mean injection pump rack)	X
Lube oil temperature at engine inlet	
Lube oil differential pressure at filter	
Fresh water temperature ar engine inlet (HT circuit)	
Fresh water temperature at engine outlet (HT circuit)	X
Fresh water temperature (LT circuit)	X
Fresh water temperature cooler inlet	
Fresh water temperature cooler outlet	
Charge air temperature cooler inlet	
Charge air temperature engine inlet	X
Installed at the engine (gauge board)	
Fuel oil pressure	X
Lube oil pressure	X
Fresh water pressure (HT circuit)	X
Fresh water pressure (LT circuit)	X
Start air pressure	X
Charge air pressure cooler outlet	X
Engine speed	X [1]
Charge air temperature cooler inlet (digital valve)	
Exhaust gas temperature after cylinder (digital valve)	X
Exhaust gas temperature before/after turbocharger (digital valve)	X

[1] 144 x 144 mm possible

6. Control and monitoring system

6.6 LESS: Large Engine Safety System

Engine control boxes include

- Engine protection system
- Speed switch unit
- Start-/stop-control
- Alarm display (LED)
- Graphic display (settings)
- Engine monitoring
- Modbus output to alarm system (Modbus RTU protocol RS 482 / 422)
- Data transfer via CAN-bus to DICARE-PC (optional)
- Exhaust gas temperature mean value system (optional)

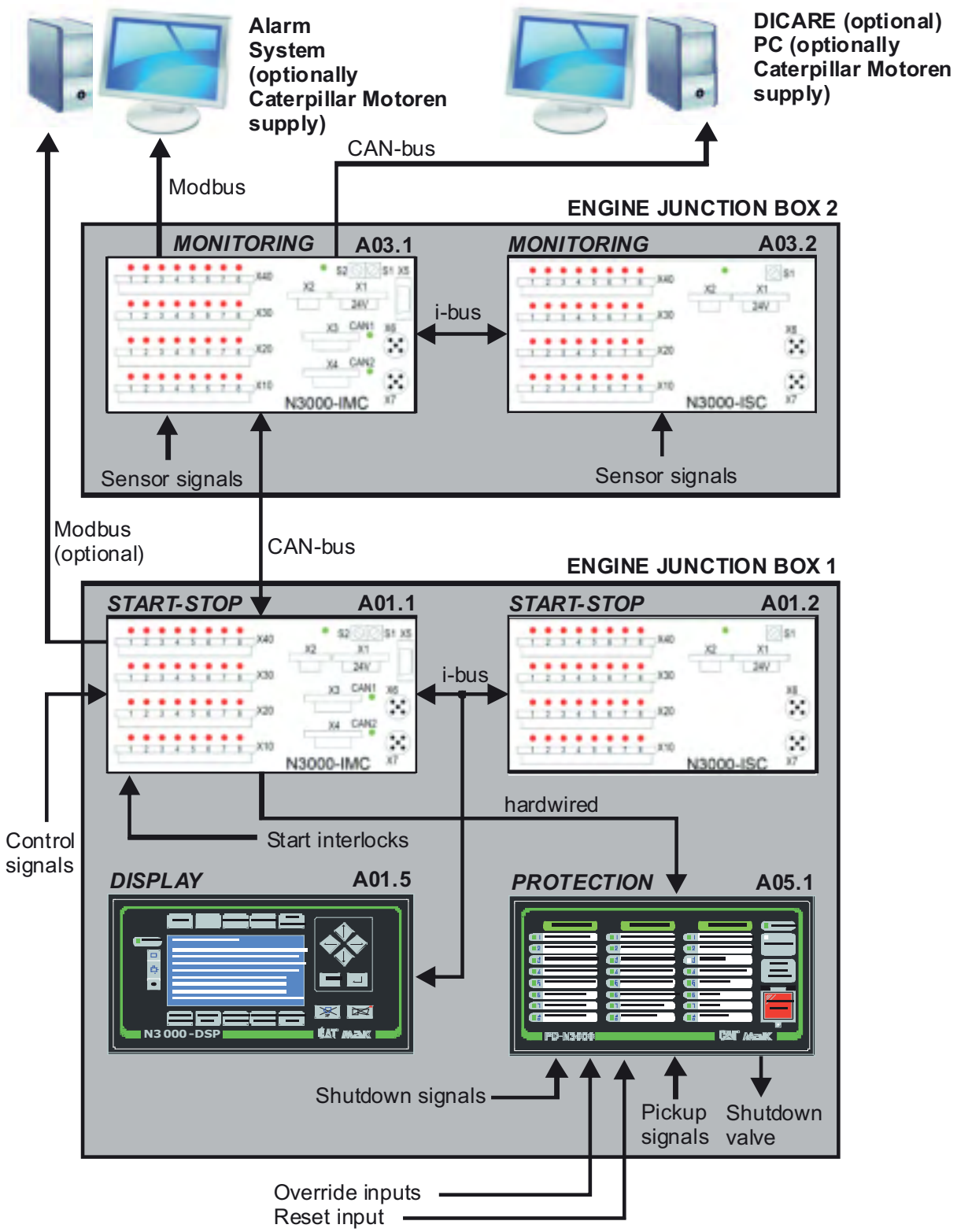
System data

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

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

6. Control and monitoring system

6.6 LESS

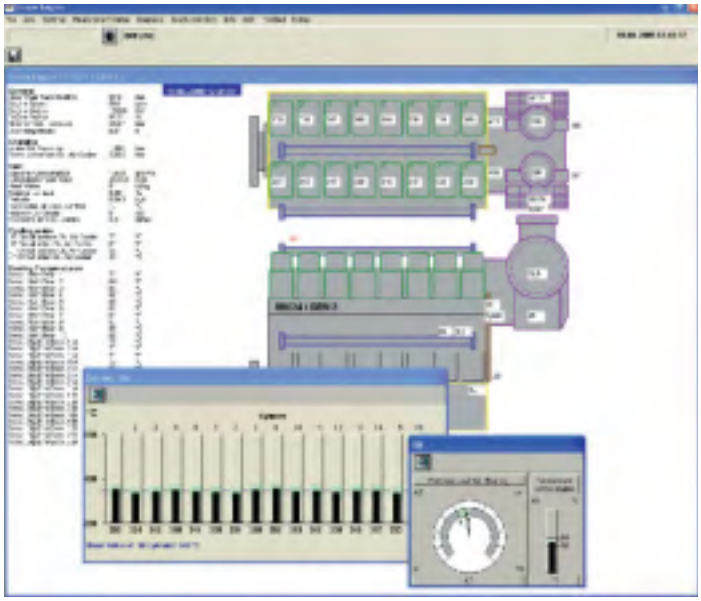


7. Diagnostic Trending Monitoring (DICARE)

With MaK DICARE, you can have an expert aboard at all times, ready to serve your needs. The latest, completely revised version combines well-established features with faster signal processing and improved usability, based on common industry standards.
Cat and MaK engines with MaK DICARE remote engine monitoring software provide reliable, condition-specific maintenance suggestions. DICARE continually compares current engine condition to desired state and tells you when maintenance is required. You get the diagnostics you need in easy-to-understand words and graphics so you can take action to keep your engines running strong.
DICARE is only available for medium-speed engines not for high-speed engines.

About 700 MaK engines worldwide, on vessels and in power stations ashore, are currently supervised with DICARE. Malfunctions are indicated immediately and at a glance, taking into account empirical data, plausibility considerations, and built-in expertise from decades of MaK diesel engine design. For ease of use, the initial report is subdivided into the diagnostic sectors of exhaust gas, turbocharger, fuel oil, lube oil, and cooling water, using a simple color-coding of regular versus irregular values. In a second step, the complete set of measured values and detailed troubleshooting instructions can be displayed, also with recommended actions priority-coded.
Special attention is placed on monitoring the following criteria:

- Overall temperature levels to identify thermal overload at an early stage.
- Intake air pressure and temperature to identify performance drops due to fouling or wear.
- Charge air pressure, temperature and dew point to identify fouling or misadjustment.
- Fuel temperature and viscosity to identify any malfunction of the viscosity control unit.
- Fuel rack position and power output to identify injection pump wear.
- Lube oil consumption to identify any possible wear.
- Cooling water pressure and temperature for optimum operation.
- Exhaust gas temperatures to identify deviations in the fuel or air system at an early stage.



7. Diagnostic system DICARE

Transmitter for DICARE ON-LINE M 25 C CAN open

Designation	Meas. point no. CM
Fuel viscosity	5253
Fuel temperature after viscomat	5206
Fuel temperature at engine inlet	5201
Injection pump rack position	9509
Lube oil pressure	1105
Lube oil temperature at engine inlet	1202
Freshwater pressure HT	2102
Freshwater temperature at engine inlet HT	2201
Freshwater temperature at engine outlet HT	2211
Differential pressure charge air cooler	7307
Intake air pressure	6181
Intake air pressure before turbocharger	7206
Charge air pressure after intercooler	7109
Charge air temperature before intercooler	7309
Charge air temperature at engine inlet	7201
Exhaust gas temperature for each cylinder and after turbocharger	8211/8221
Exhaust gas temperature before turbocharger	8231
Engine speed	9419
Turbocharger speed	9429
Service hour counter (manual input)	9409

8. Engine acceptance test

Standard acceptance test run

The acceptance test run is carried out on the testbed with customary equipment and auxiliaries using exclusively MDO and under the respective ambient conditions of the testbed. 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 acc. to the rules of the classification societies. After reaching steady state condition of pressures and temperatures these will be recorded and registered acc. to the form sheet of the acceptance test certificate:

- with puric ohmic load (cos ρ = 1)
- load application acc. to ISO 8528
- without parallel operation

Load [%]	Duration [min]
50	30
85	30
100	60
110	30

Additional functional tests

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

- governor test
- overspeed test
- emergency shut-down via minimum oil pressure
- start/stop via central engine control
- starting trials up to a minimum air pressure of 10 bar
- measurement of crank web deflection (cold/warm condition)

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

Engine movement due to vibration referred to the global vibration characteristics of the engine:

The basis for assessing vibration severity are the guidelines ISO 10816-6.

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

Displacement	S_{eff}	< 0.448 mm	f > 2 Hz < 10 Hz
Vibration velocity	V_{eff}	< 28.2 mm/s	f > 10 Hz < 250 Hz
Vibration acceleration	a_{eff}	< 44.2 m/s²	f > 250 Hz < 1,000 Hz

9. 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 has to be calculated using different weighting factors for different loads that have been corrected to ISO 8178 conditions.

An NO_x emission evidence will be issued for each engine showing that the engine complies with the regulation. The evidence will come as EAPP (Engine Air Pollution Prevention) Statement of Compliance, EAPP (Engine Air Pollution Prevention) 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 IMO regulations, a technical file shall be prepared for each engine. This technical file contains information about the components affecting NO_x emissions, and each critical component is marked with a special IMO number. Such critical components are piston, cylinder head, injection nozzle (element), camshaft section, fuel injection pump, turbocharger and charge air cooler. (For Common Rail engines the controller and the software are defined as NO_x relevant components instead of the injection pump.) The allowable setting values and parameters for running the engine are also specified in the technical file.

The marked components can later, on-board the ship, be easily identified 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.

10. Painting/Preservation

Inside preservation

N 576-3.3
The preservation is sufficient for a period of max. 2 years.
It needs to be removed when the engine is commissioned!
- Main running gear and internal mechanics

Outside preservation

VCI 368 N 576-3.2
Engine outside preservation with Cortec VCI 368 is applicable for Europe and overseas.
It applies for sea and land transportation and storage of the engines in the open, protected from moisture.
The duration of protection with additional VCI packaging is max. 2 years.

It must be removed before commissioning of the engines! Environmentally compatible disposal is to be ensured.

Durability and effect are determined by 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.

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

N 576-4.1 - Clear Varnish
Clear varnish painting is applicable within Europe for land transportation with protection from moisture.
It is furthermore applicable for storage in a dry and tempered atmosphere.

Clear varnish painting is not permissible for:
- Sea transportation of engines
- Storage of engines in the open, even if they are covered with tarpaulin

The duration of protection with additional VCI packaging is max. 1 year.

VCI packaging as per N 576-5.2 is generally required!
Durability and effect are determmined by 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.

10. Painting/Preservation

If the above requirements are not met, all warranty claims in connection with corrosion damage shall be excluded.

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

N 576-4.3 - Painting
The painting is applicable for Europe and overseas.
It applies for sea and land transportation and short-term storage in the open (protected from moisture) up to max. 4 weeks.

In case of Europe and overseas shipment and storage in the open longer than 4 weeks VCI packaging as per N 576-5.2 is required.

The duration of protection with additional VCI packaging is max. 2 years.

Durability and effect are determined by proper packaging, transportation, and storage, i.e. protected from moisture, VCI film not ripped or destroyed. Inspections are to be carried out at regular intervals.

Appearance of the engine:
- Surfaces mostly painted with varnish
- Bare metal surfaces provided provided with VCI 368 preservation

N 576-5.2 - VCI packaging
Corrosion protection with VCI packaging applies for:
- Engines with outside preservation VCI 368 as per N 576-3.2
- Engines with clear varnish according to application group N 576-4.1
  These engines are always to be delivered with VCI packaging!
  Nevertheless, they are not suitable for storage in the open!
- Engines or engine generator sets with painting according to application group N 576-4.3 for shipment to Europe and overseas or storage in the open (protected from moisture).

10. Painting/Preservation

Durability and effect are determined by proper packaging, transportation, and storage, i.e. protected from moisture, VCI film not ripped or destroyed. Inspections are to be carried out at regular intervals.

- Bare metal surfaces provided with VCI 368 or VCI oil
- Cortec VCI impregnated flexible PU foam mats hung up on the engine using tie wraps. Kind and scope depending on engine type.
  The mats are to be hung up in free position and should not come into contact with the painted surface.
- Cover the engine completely with air cushion film VCI 126 LP. Air cushions are to point towards the inside!
  The air cushion film is fastened to the transportation skid (wooden frame) by means of wooden laths. Overlaps at the face ends and openings for the lifting gear are to be closed by means of PVS 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 towards the engine before fastening the air cushion film.

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

N 576-5.2 Suppl. 1 - Information panel for VCI preservation and inspection
Applies for all engines with VCI packaging as per application group N 576-5.2.

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

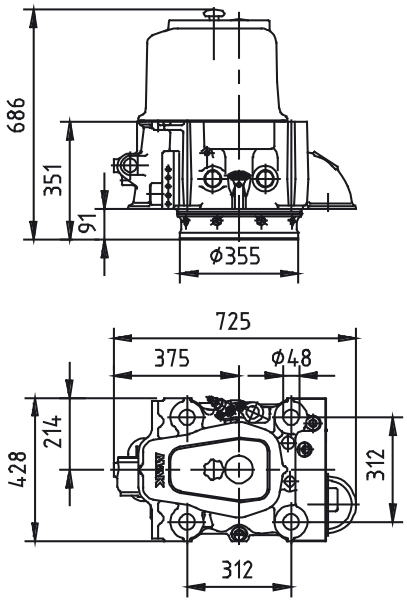
N 576-6.1 - Corrosion Protection Period, Check, and Represervation
There will only be an effective corrosion protection of the engine if the definitions and required work according to factory standard N 576-6.1 are duly complied with.
Normally, the applied corrosion protection is effective for a period of max. 2 years if the engines or engine generator sets are protected from moisture. However, depending on the execution of the preservation shorter periods may be applicable.

After 2 years represervation must be carried out.

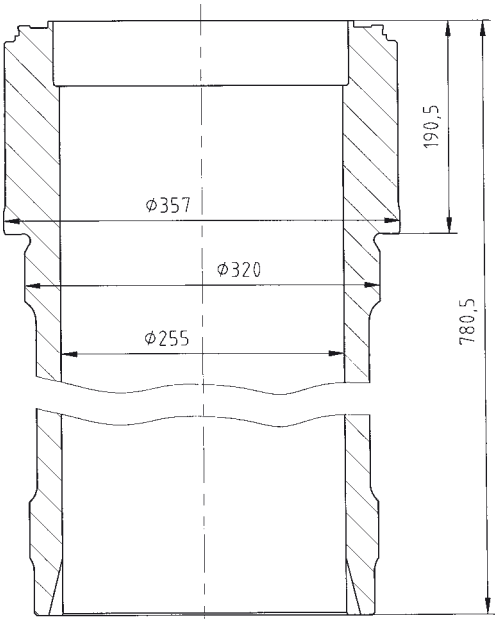
Every 3 months specific inspections are to be carried out the engine or engine generator set at defined inspection points. Any corrosion that is found and existing condensation water are to be removed immediately.

11. Engine parts

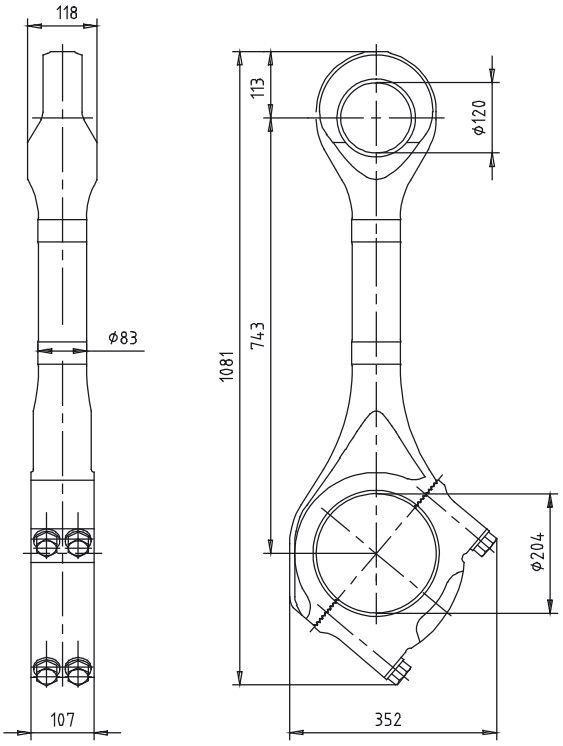
Cylinder head, weight 240 kg



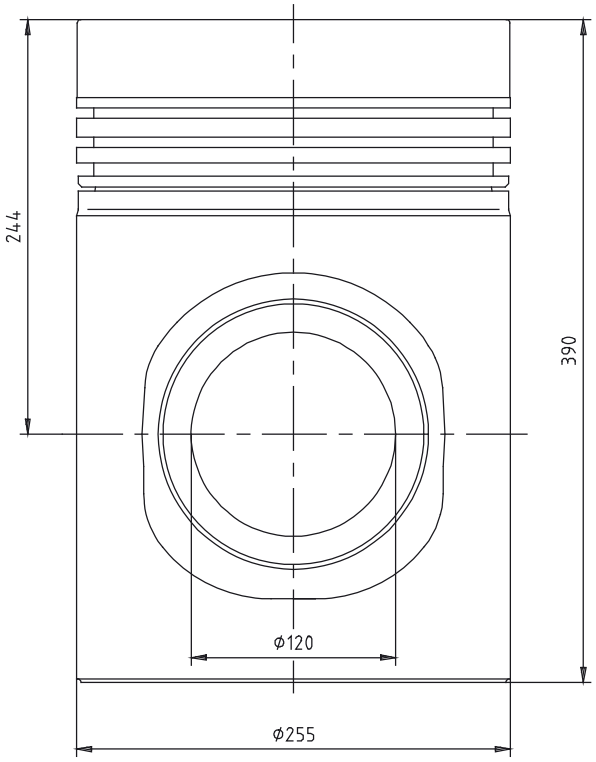
Cylinder liner, weight 162kg



Connecting rod, weight 79 kg

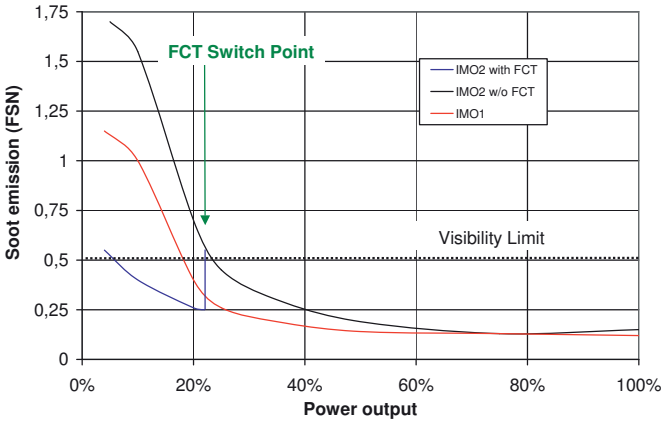


Piston, weight 46 kg

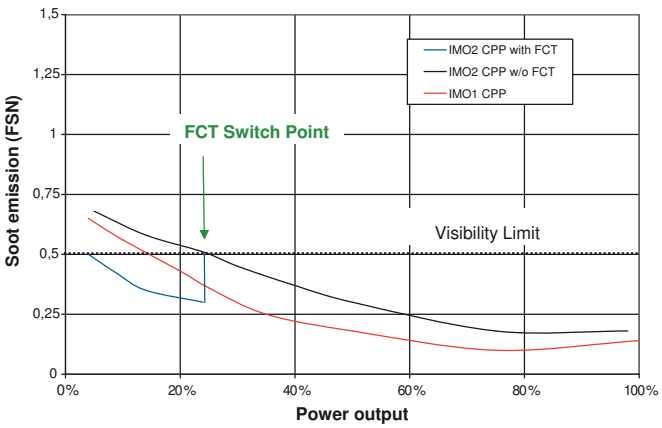


12. Flexible Camshaft Technology - FCT

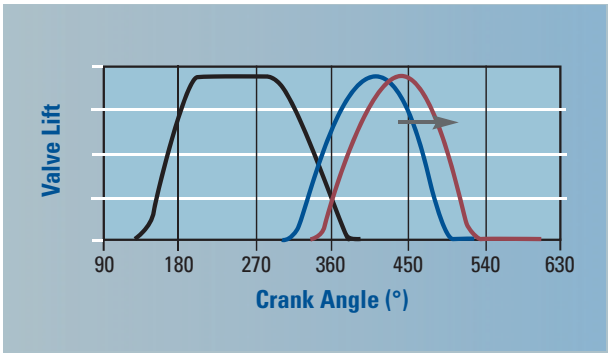
Building upon the Emission Reduction System integration concept, FCT achieves synergy between flexible fuel systems and advanced air systems with maximum utilization of the current engine design. While maintaining high fuel injection pressure over the whole operating range, fuel injection and inlet valve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



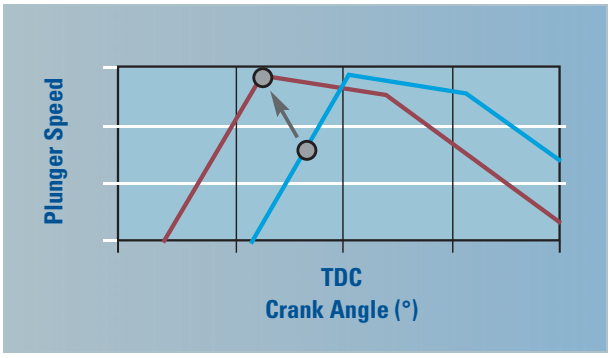
M 25 C constant speed

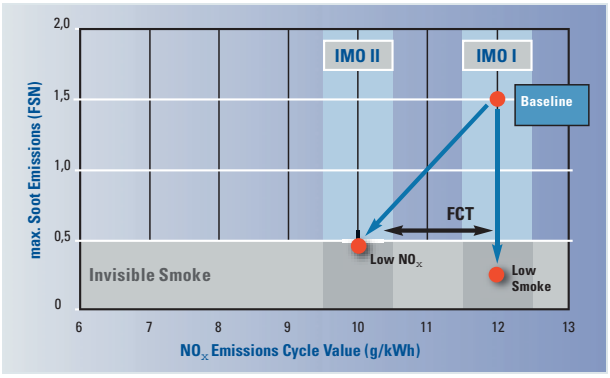


M 25 C CPP/combinator mode



schematic diagram



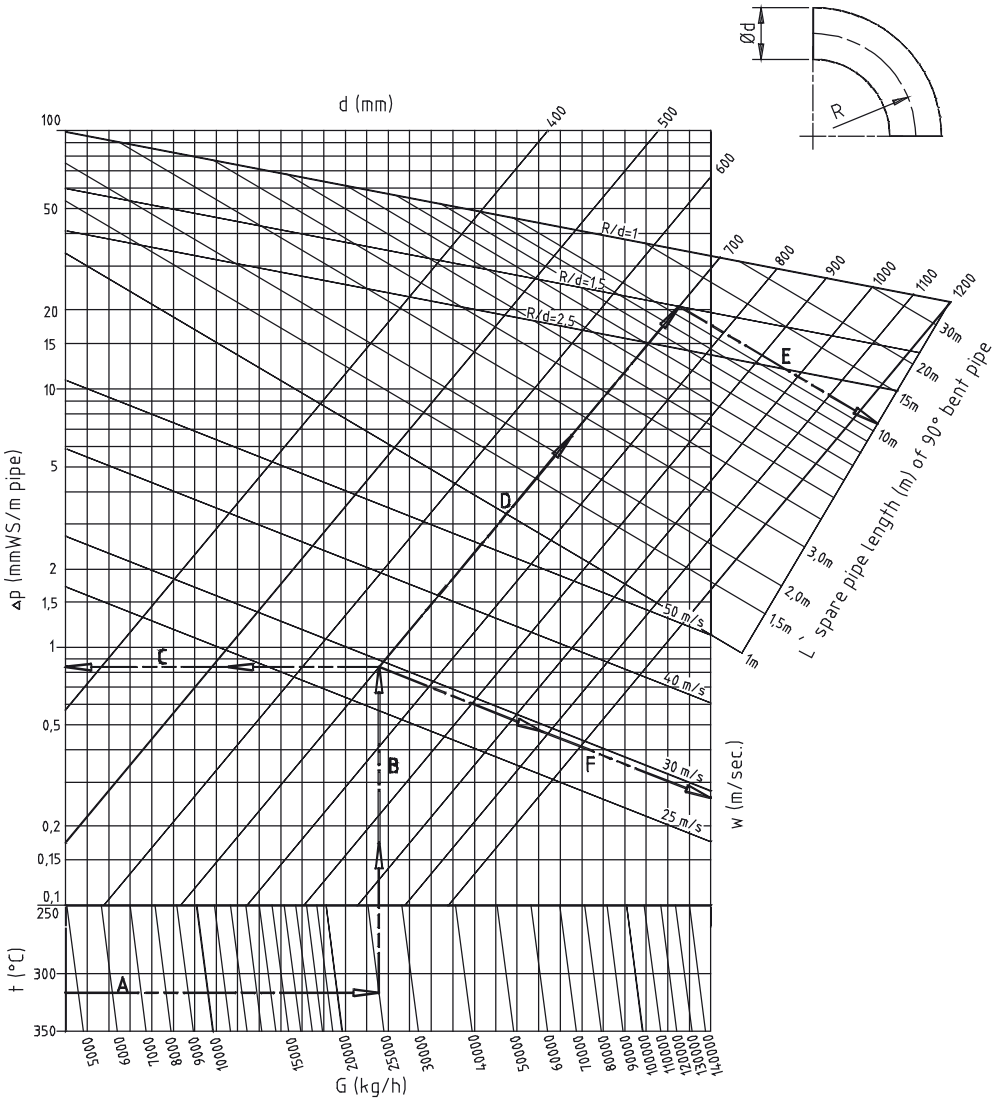


schematic diagram

13. Appendix

13.1 Exhaust system

13.1.1 Resistance in exhaust gas piping



Example (based on diagram data A to E):

t = 335 °C, G = 25,000 kg/h
l = 15 m straight pipelength, d = 700 mm
3 off 90° bent R/d = 1.5
1 off 45° bent R/d = 1.5
ΔPg = ?

Δp = 0.83 mm WC/m
L' = 3 • 11 m + 5.5 m
L = l + L' = 15 m + 38.5 m = 53.5 m
ΔPg = Δp • L = 0.83 mm WC/m • 53.5 m = 44.4 mm WC

t	= Exhaust gas temperature	(°C)
G	= Exhaust gas massflow	(kg/h)
Δp	= Resistance/m pipe length	(mm WC/m)
d	= Inner pipe diameter	(mm)
w	= Gas velocity	(m/s)
l	= Straight pipe length	(m)
L'	= Spare pipe length of 90° bent pipe	(m)
L	= Effective substitute pipe length	(m)
ΔPg	= Total resistance	(mm WC)

13. Appendix

13.1.2 Exhaust data

Tolerance: 5 %
Atmospheric pressure: 1 bar
Relative humidity: 60 %
Constant speed

Intake air temperature: 25 °C

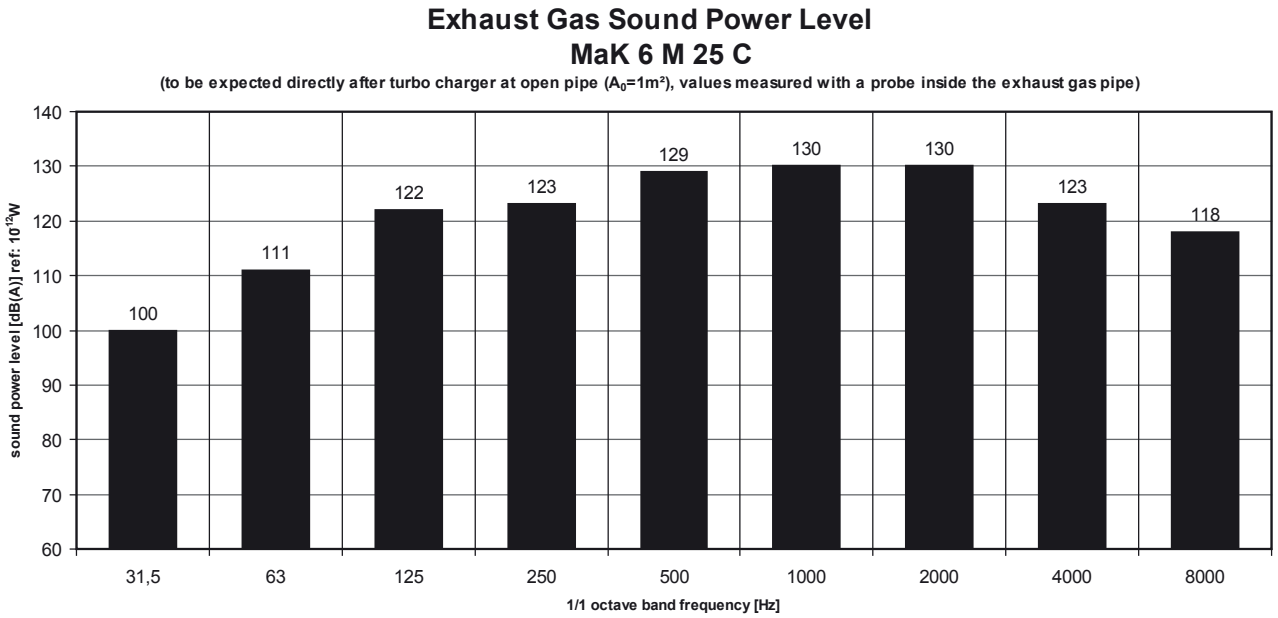
	Output [kW]	• Output % • [kg/h] • [°C]					
		100	90	80	70	60	50
6 M 25 C	2,000	14,080	12,850	11,025	9,653	8,285	6,880
	720	333	337	357	357	372	375
8 M 25 C	2,666	17,870	16,335	14,650	12,820	11,200	9,575
	720	335	344	355	355	370	375
9 M 25 C	3,000	21,040	19,260	17,310	15,150	13,260	11,370
	720	360	355	350	350	365	372

Intake air temperature: 45 °C

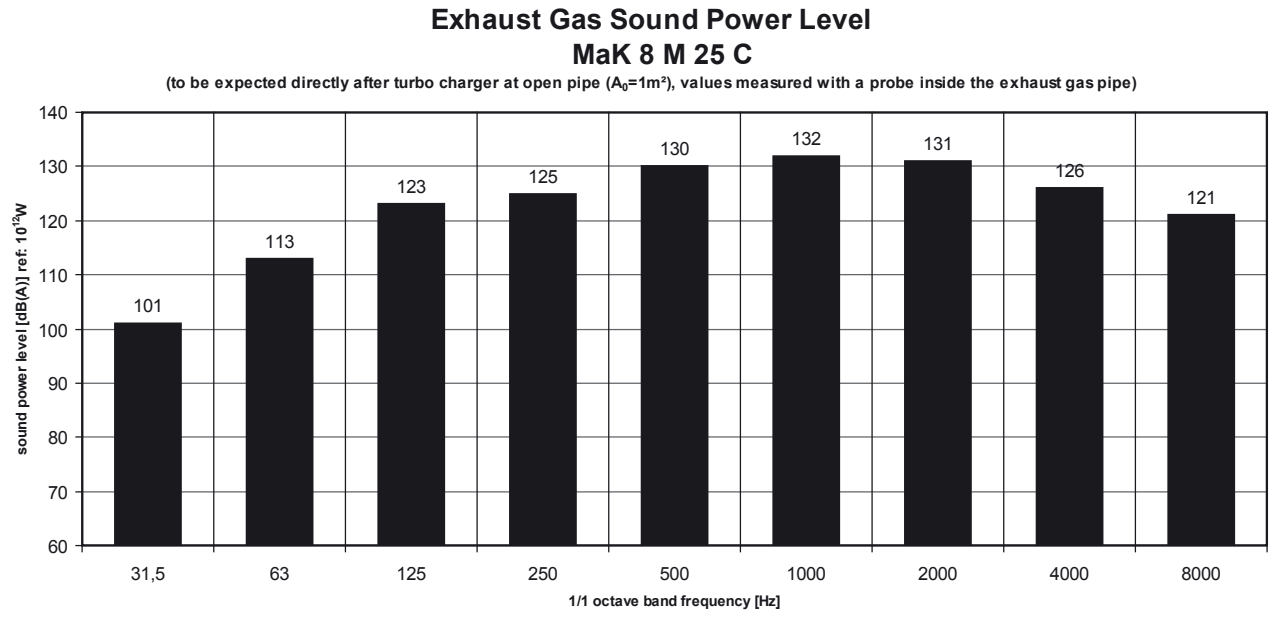
	Output [kW]	• Output % • [kg/h] • [°C]					
		100	90	80	70	60	50
6 M 25 C	2,000	13,517	12,336	10,584	9,267	7,954	6,605
	720	353	357	378	378	394	398
8 M 25 C	2,666	17,155	15,682	14,064	12,307	10,752	9,192
	720	355	365	376	376	392	398
9 M 25 C	3,000	20,198	18,490	16,618	14,544	12,730	10,915
	720	382	376	371	371	387	394

13. Appendix

13.1.3 Exhaust gas sound power level



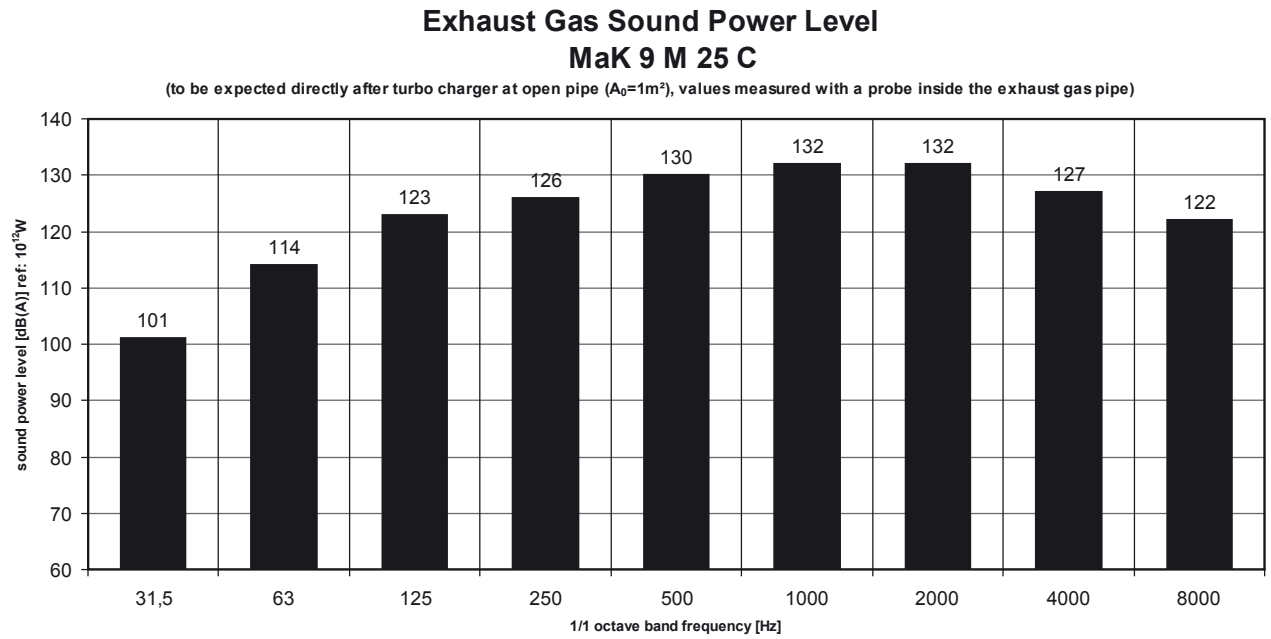
Tolerance: ± 2 dB



Tolerance: ± 2 dB

13. Appendix

13.1.3 Exhaust gas sound power level

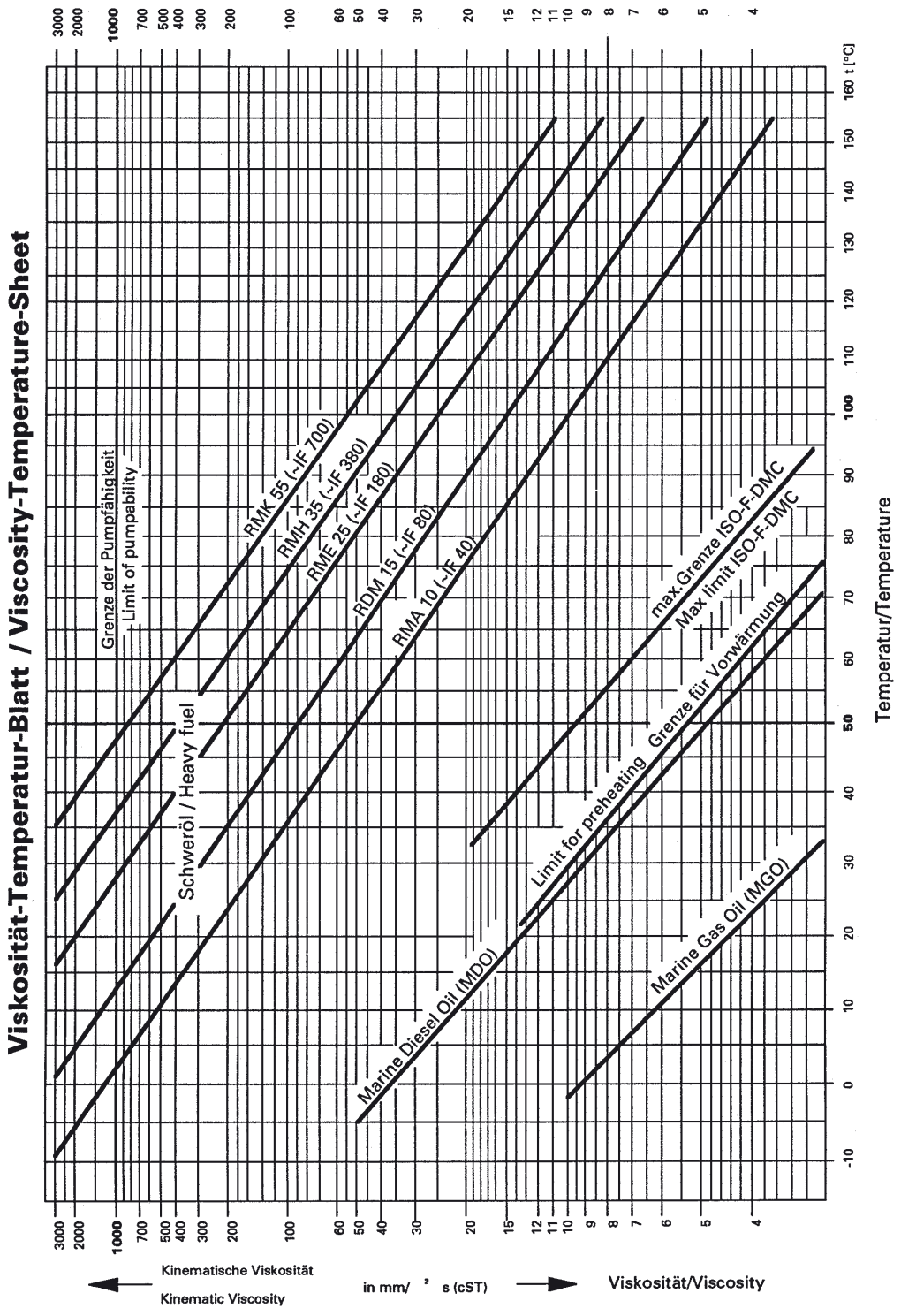


Tolerance: ± 2 dB

13. Appendix

13.2 Fuel oil system

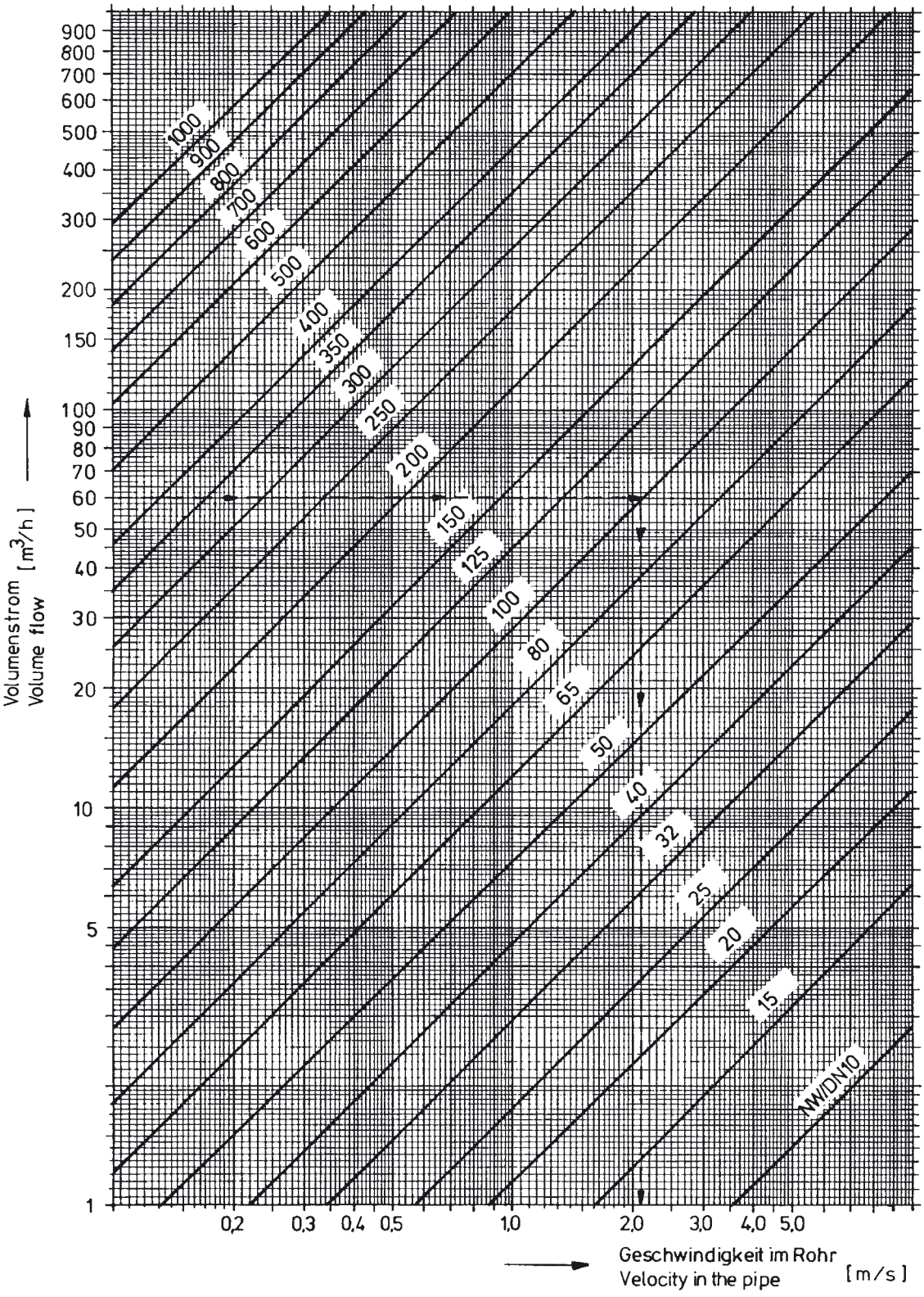
13.2.1 Viscosity/temperature diagram



13. Appendix

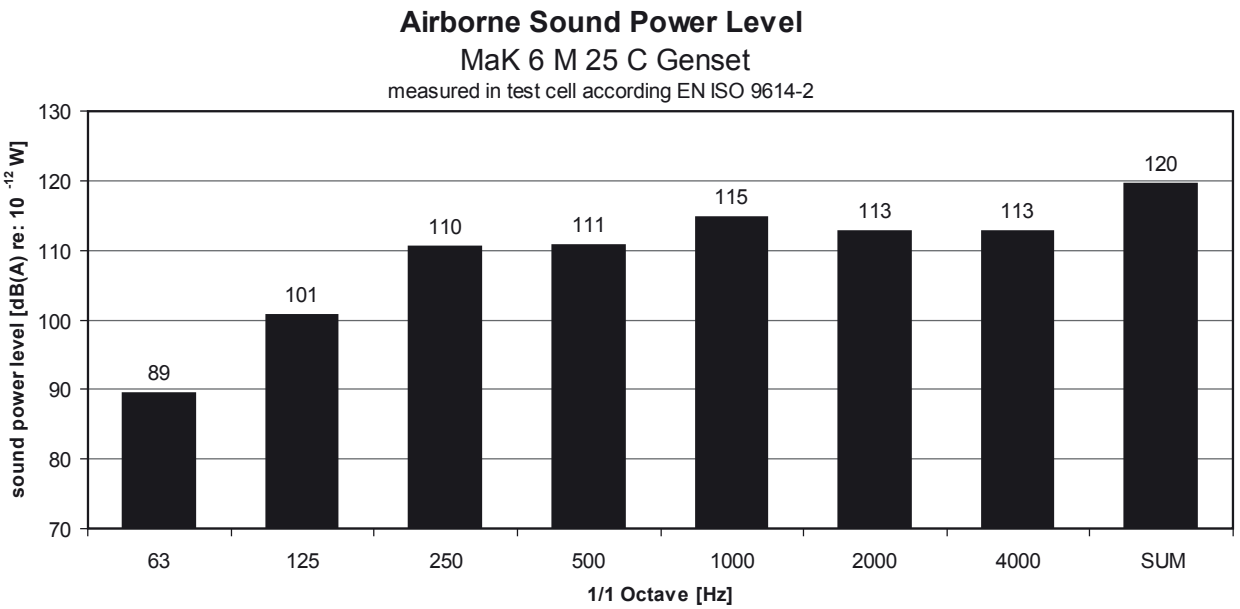
13.3 Cooling water system

13.3.1 Flow velocities

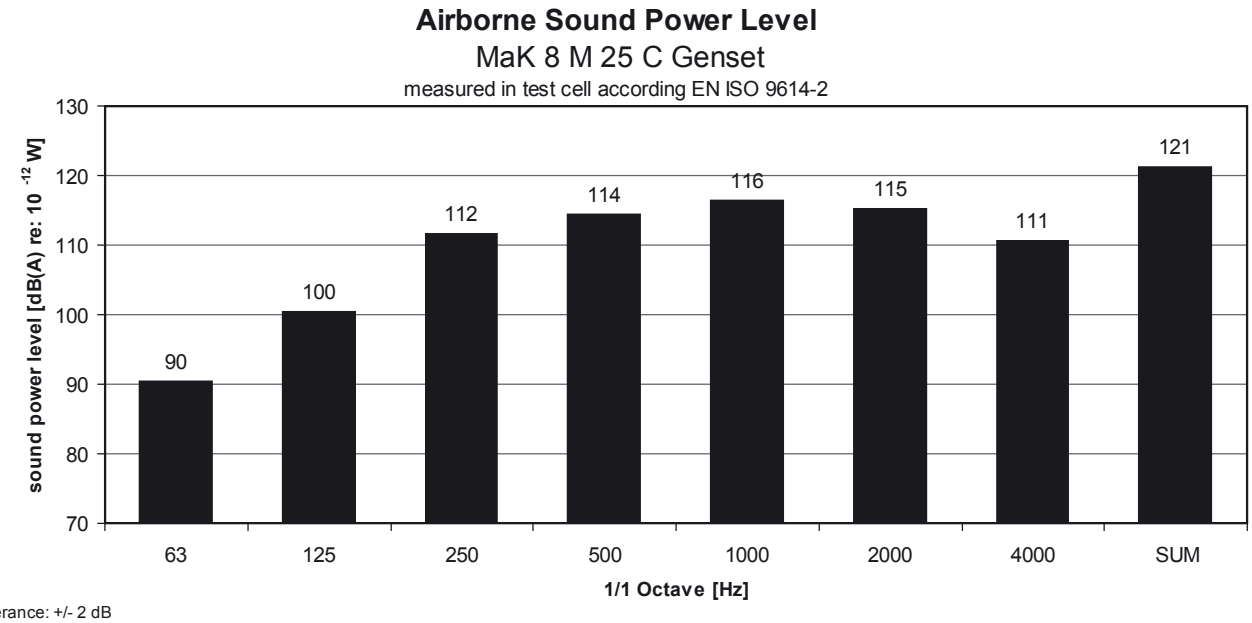


13. Appendix

13.4 Air-borne sound power level



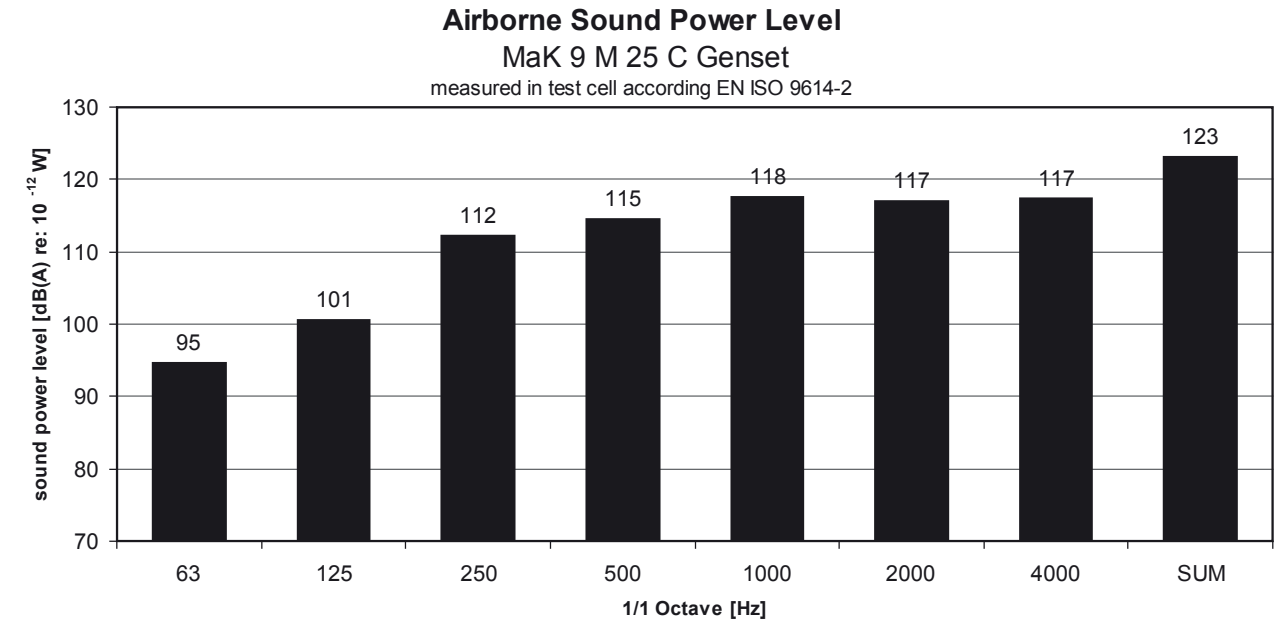
tolerance: +/- 2 dB



tolerance: +/- 2 dB

13. Appendix

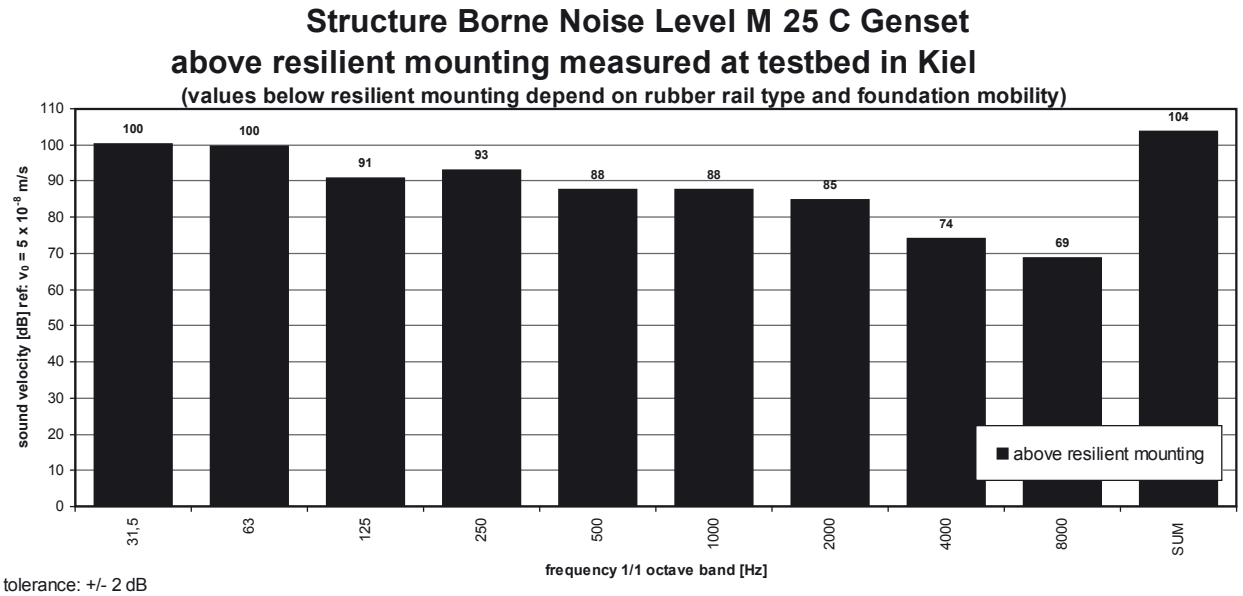
13.4 Air-borne sound power level



tolerance: +/- 2 dB

13. Appendix

13.5 Structure-borne sound level L_V, expected (measured in the test cell)



tolerance: +/- 2 dB

13. Appendix

13.6 Data sheet for torsional vibration calculation

CAT — **Additional engine plant data, part "A"**

Information for auxiliary engine(s) or Diesel Electric (DE) drive only:

Maneuvering modes (engine at operating temperature), pay attention on dynamic positioning operation

Load increment according to project guide: ☐ yes

☐ no, approved project application is enclosed

Generator for auxiliary engine(s) / DE application

☐ Engine and generator on a common base frame (standard for M20C, M25 and M32C)

☐ Engine and generator separate on ship foundation (standard for M43C – DE plants)

Yard supply ☐ No ☐ Yes, if "YES" please provide the following data:

Maker: _____ Type: _____

Output [kVA]: _____ rpm [1/min]: _____ ☐ TVC scheme attached

☐ Dimensions as per drawings "Generator Structural Requirements for Cat Diesel Gensets" observed!

Cooling system

☐ per DE engine ☐ for _____ DE engines

☐ Auxillary engines separate ☐ Auxillary engines integrated in the main engine LT - system

Caterpillar standard: HT and NT cooler (both seawater cooled)

☐ HT system, number of cooler(s) _____, designed for _____ % of total capacity (Titanium cooler required)

☐ NT system, number of cooler(s) _____, designed for _____ % of total capacity (Titanium cooler required)

☐ Alternatively: Central cooling system - HT (freshwater cooled via NT system) and NT (seawater cooled) cooler

☐ HT system, number of cooler(s) _____, designed for _____ % of total capacity (Stainless steel or equal)

☐ NT system, number of cooler(s) _____, designed for _____ % of total capacity (Titanium cooler required)

☐ Alternatively: Integrated cooling system

☐ HT circuit cooled by means of NT cooling water (mixing)

☐ NT system, number of cooler(s) _____, designed for _____ % of total capacity (Titanium cooler required)

☐ Alternatively: Box cooling system

☐ Box cooler

Comments/Remarks:

Caterpillar Confidential: Green

Contents

Caterpillar Marine Power Systems

Headquarters

Caterpillar Marine Power Systems
A Division of
Caterpillar Motoren GmbH & Co.KG
Neumühlen 9
22763 Hamburg/Germany

Phone: +49 40 2380-3000
Telefax: +49 40 2380-3535

Europe, Africa, Middle East

Caterpillar Marine Power Systems
A Division of
Caterpillar Motoren GmbH & Co.KG
Neumühlen 9
22763 Hamburg/Germany

Phone: +49 40 2380-3000
Telefax: +49 40 2380-3535

Americas

MaK Americas Inc.

3450 Executive Way
Miramar Park of Commerce
Miramar, FL. 33025/USA

Phone: +1 954 885 3200
Telefax: +1 954 885 3131

Asia Pacific

Caterpillar Marine Trading (Shanghai) Co., Ltd.

25/F, Caterpillar Marine Center
1319, Yan'an West Road
200050 Shanghai/P. R. China

Phone: +86 21 6226 2200
Telefax: +86 21 6226 4500

Caterpillar Marine Asia Pacific Pte Ltd

No. 5 Tukang Innovation Grove
Singapore 618304
Republic of Singapore

Phone: +65 68287-600
Telefax: +65 68287-625

For more information please visit our website:
MARINE.CAT.COM

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