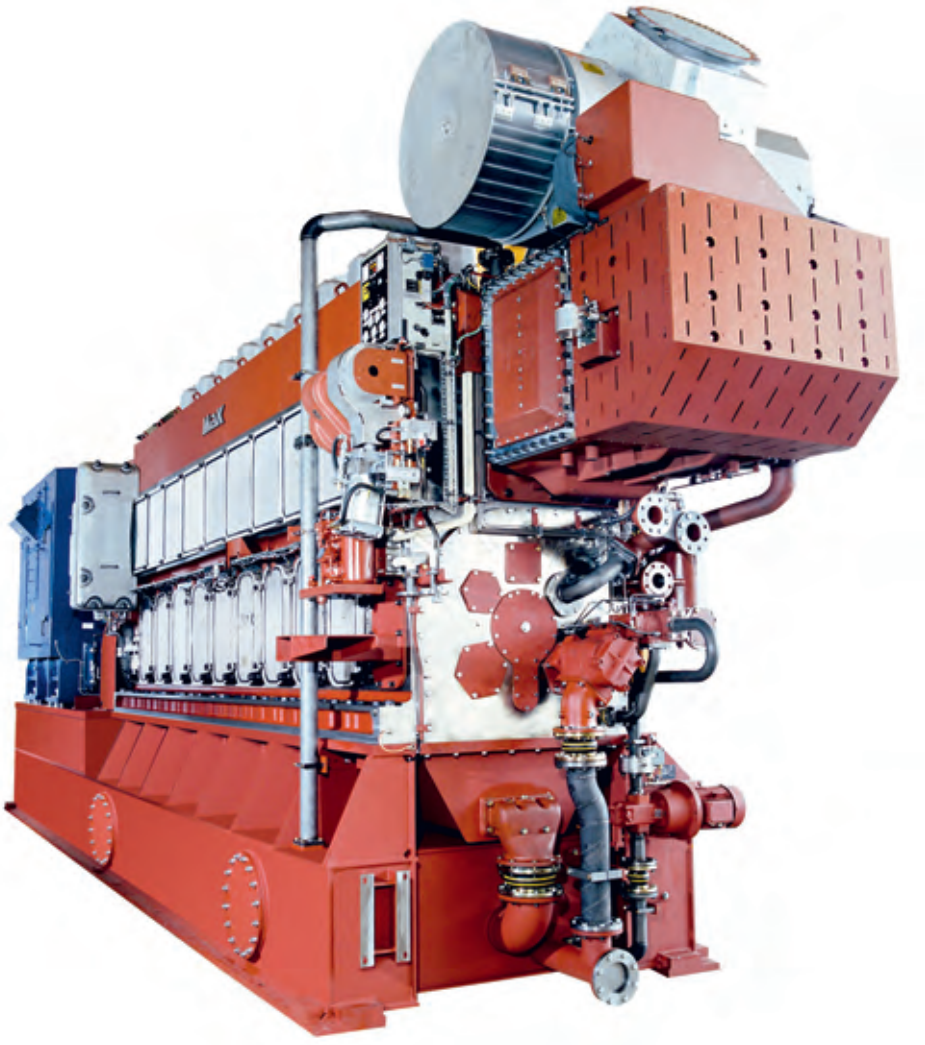
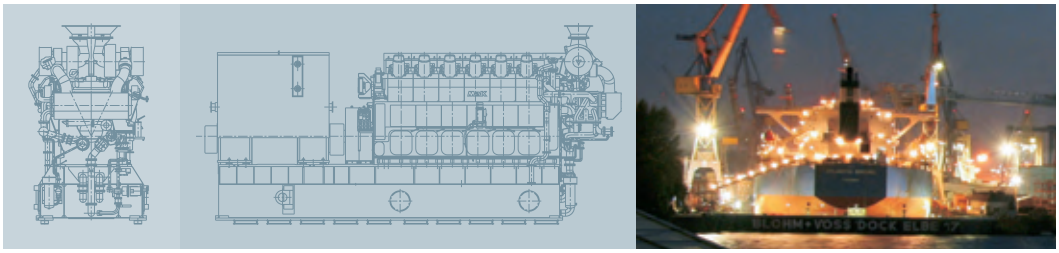
M 32 C

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.

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Financed Amount:	Up to 80 % of your vessel cost.
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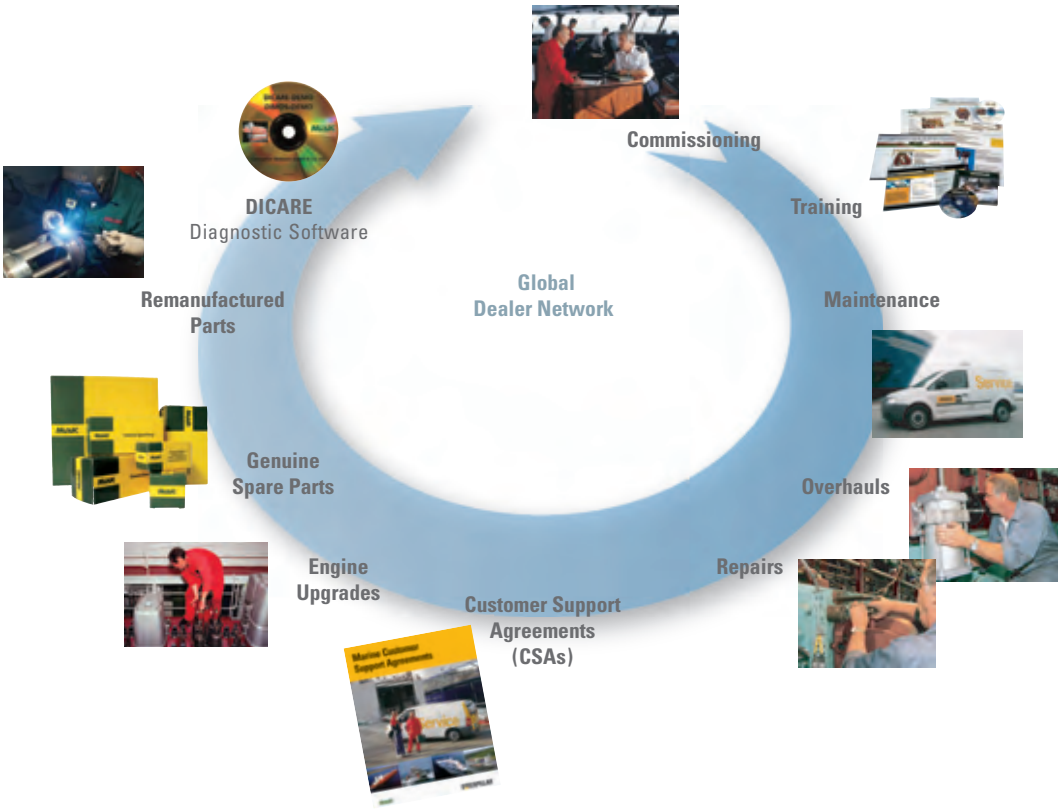

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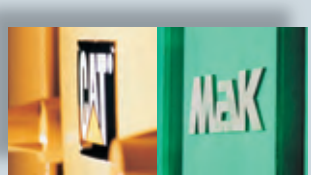

DET NORSKE VERITAS

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
Rudolf-Diesel Straße 5-9
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:
Sales, Engineering, Project Procurement, Project Management, Commissioning and Product Support Services for Power Plant based on Medium Speed Diesel and Gas Engines including turn.key installations
For Caterpillar Motoren Henstedt-Ulzburg GmbH:
Logistcs services for shipment of service and production parts for medium-speed large engines for the marine and electric power generation sectors as well as the oil and gas industry

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

Lack of fulfilment of conditions as set out in the Certification Agreement may render this Certificate invalid.
DNV Zertifizierung und Umweltgutachter GmbH, Schnieringshof 14, 45329 Essen, Tel: +49 201 7296 300 Fax: +49 201 7296 333 - www.dnv.de/zertifizierung

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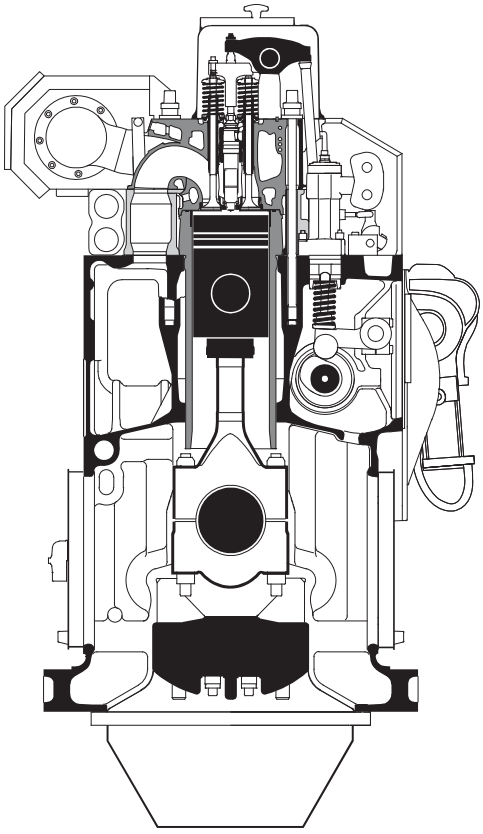
1. Engine description

1.1 Engine description

The M 32 C is a four stroke diesel engine, non-reversible, turbocharged and intercooled with direct fuel injection.

In-line engine M 32 C



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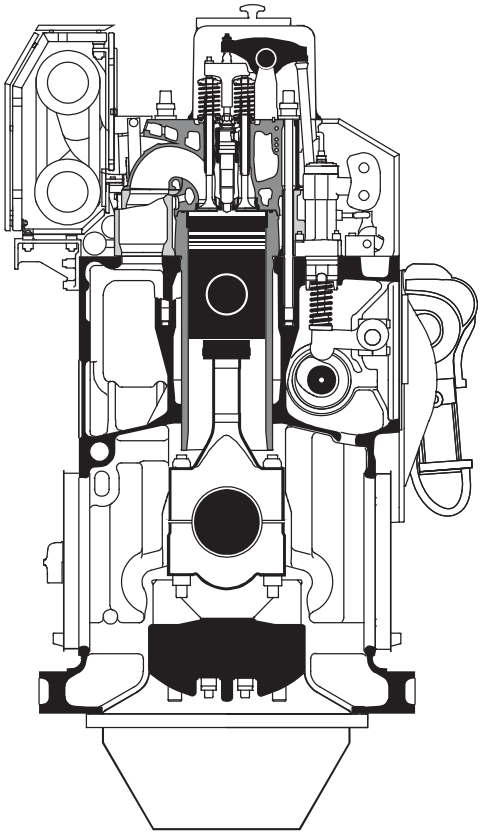
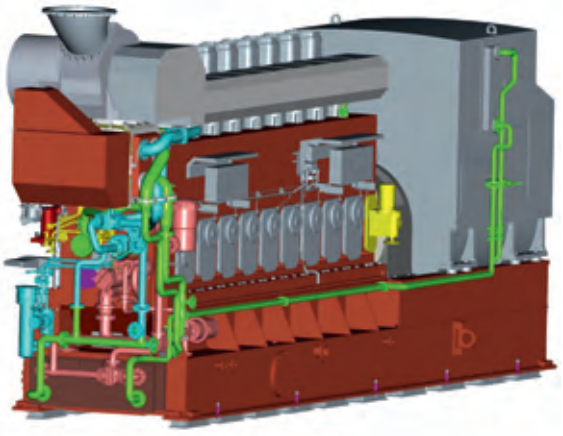




Cylinder configuration:	6,8,9 in-line
Bore:	320 mm
Stroke:	480 mm
Stroke/Bore-Ratio:	1.5
Swept volume:	38.7 l/Cyl.
Output/cyl.:	500 kW
BMEP:	25.9 bar
Revolutions:	600 rpm
Mean piston speed:	9.6 m/s
Turbocharging:	single log, option: pulse
Direction of rotation:	clockwise, option: counter-clockwise

1. 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 incorporates the crankshaft bearings, camshaft bearings, charge air receiver, vibration damper housing and gear drive housing.
- Underslung crankshaft with corrosion resistant main and big end bearing shells.
- Natural hardened liners, centrifugally casted, with calibration insert.
- Composite type pistons with steel crown and forged steel skirt or 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 scraper ring. All ring grooves are located in the steel crown. The first ring groove is chromium plated. The other ring grooves are hardened.
- 3-piece connecting rod with the possibility to dismount the piston without opening the big end bearing.
- Cylinder head made of nodular cast iron with 2 inlet and 2 exhaust valves with valve rotators. Directly cooled exhaust valve seats.
- Camshaft made of sections per cylinder allowing a removal of the pieces sideways.
- Turbocharger supplied with inboard 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 only with engine lubricating oil.
- Cat Common Rail will be available on request.
- For invisible smoke at part load operation Flexible Camshaft Technology is available.

2. General data and operation of engine

Engine output (P_M) / Electrical output (P_W)

Type	Engine rating	Generator rating 60/50 Hz Speed: 600 rpm		Mean eff. pressure	Mean piston speed
	kW	kWe	kVA	bar	m/s
6 M 32 C	3,000	2,880	3,600	25.9	9.6
8 M 32 C	4,000	3,840	4,800	25.9	9.6
9 M 32 C	4,500	4 320	5,400	25.9	9.6

2.1 General data and outputs

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)

An overload of 10 % is permitted for one hour within 12 hours of operation. The blocking will be fixed to 10 % above the maximum continuous rating.

2. General data and operation of engine

2.1.2 Fuel consumption

The fuel consumption data refers to the follwing 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 of the stated consumption data	5 %

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

2.1.3 Lubricating oil consumption

Lubricating oil consumption:	0.6 g/kWh; value is based on rated output, tolerance ± 0.3 g/kWh.

Actual data can be taken from the technical data.

2.1.4 Nitrogen oxide emissions (NO_x - values)

NO_x - limit values according to IMO II:	10.1 g/kWh (n = 600 rpm)
Main engine: Diesel electric drive, according to cycle E2:	9.6 g/kWh
Auxiliary Genset, according to cycle D2:	9.8 g/kWh

2. General data and operation of engine

2.1.5 Technical data

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

2. General data and operation of engine

2.1.5 Technical data

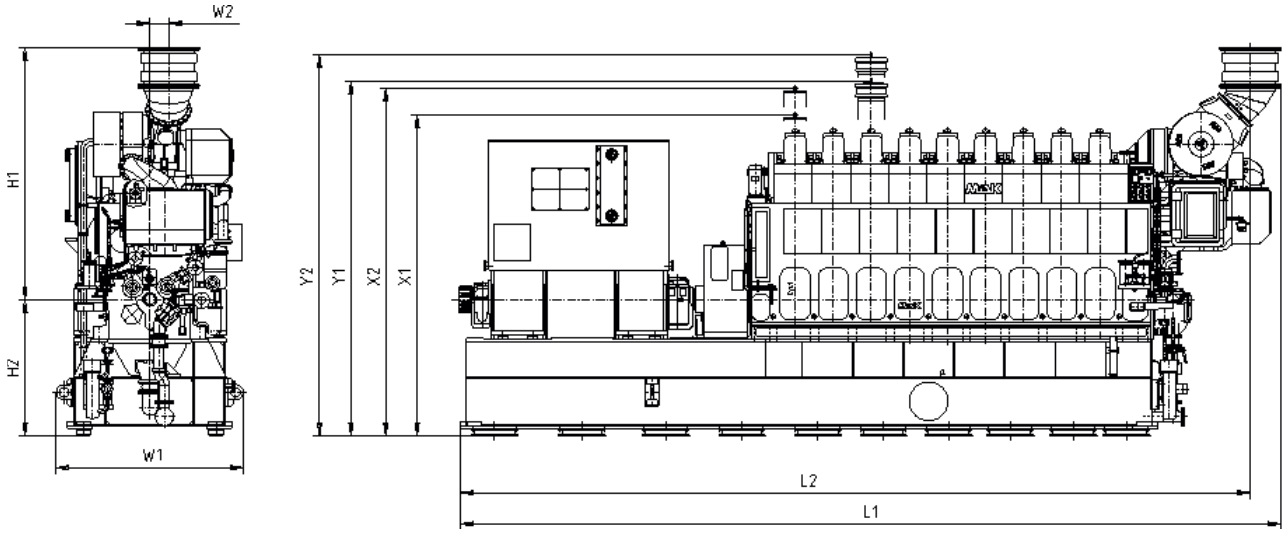
Fresh water cooling	Cylinder	6	8	9
Engine content	m³	0.7	0.95	1.05
Pressure at engine inlet min/max	bar	4.5/6.0	4.5/6.0	4.5/6.0
Header tank capacity	m³	0.35	0.45	0.55
Temperature at engine outlet	°C	80 - 90	80 - 90	80 - 90
Two circuit system				
Engine driven pump HT	m³/h/bar	70/4.5	70/4.5	80/4.5
Independent pump HT	m³/h/bar	70/4.0	70/4.0	80/4.0
HT-controller NB	mm	100	100	100
Water demand LT-charge air cooler	m³/h	40	60	60
Temperature at LT-charge air cooler inlet	°C	38	38	38
Heat Dissipation				
Specific jacket water heat	kJ/kW	500	500	500
Specific lub oil heat	kJ/kW	525	525	525
Lub oil cooler	kW	440	590	660
Jacket water	kW	420	550	625
Charge air cooler (HT-Stage) [4]	kW	1,175	1,530	1,705
Charge air cooler (LT-Stage) [4] (HT-Stage before engine)	kW	300	440	505
Heat radiation engine	kW	150	190	210
Exhaust gas				
Silencer/spark arrester NB	mm	600	700	800
Pipe diameter NB after turbiine	mm	600	700	800
Maximum exhaust gas pressure drop	bar	0.03	0.03	0.03
Exhaust gas temperature after turbine (intake air 25 °C) [5]	°C	303	315	310
Exhaust gas mass flow (intake air 25 °C)	kg/h	21,132	28,860	32,445
Starting air				
Starting air pressure max.	bar	30	30	30
Minimum starting air pressure	bar	10	10	10
Air consumption per Start [6]	Nm³	1.2	1.2	1.2

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

2. General data and operation of 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 32 C	9,302	8,869	3,375	1,900	2,639	962	73
8 M 32 C	10,886	10,461	3,513	1,900	2,611	262	92
9 M 32 C	11,419	10,991	3,513	1,900	2,611	262	98

* depending of generator weight

Prime mover and generator are always flexibly coupled.

Removal of:

Piston	in transverse direction	X1 = 4,470 mm
	in longitudinal direction	X2 = 4,840 mm
Cylinder Liner	in transverse direction	Y1 = 4,940 mm
	in longitudinal direction	Y2 = 5,305 mm

Reduced removal height with special tools only.

Min. centre distance of 2 gensets: 3000 mm

2. General data and operation of engine

2.3 Restrictions for low load operation

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

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

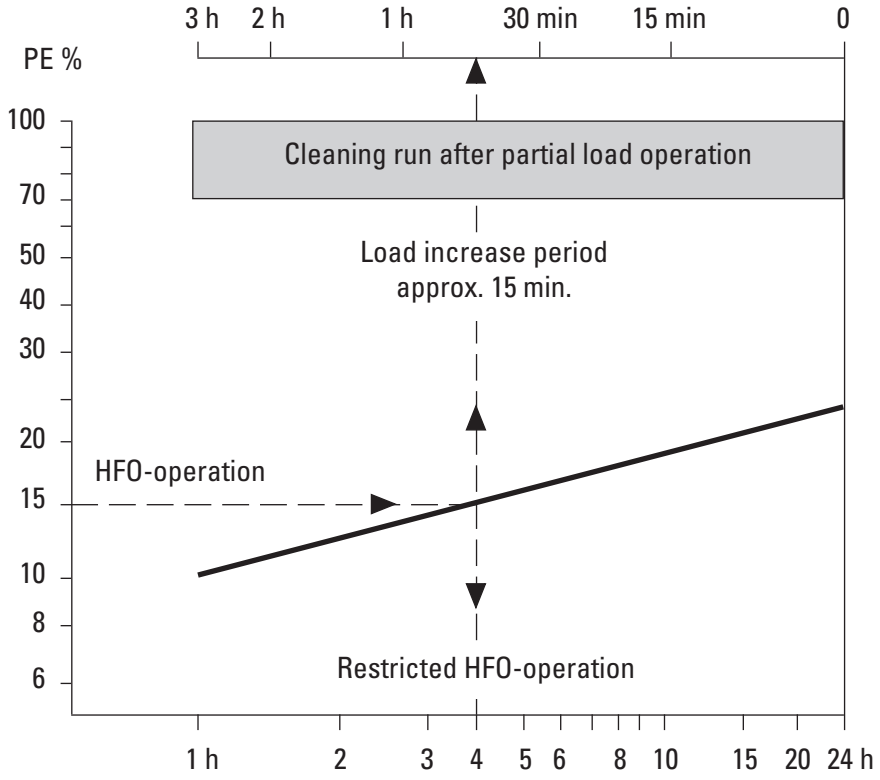
The lube oil treatment system (lube oil separator) remains in operation, the lube oil is separated continuously.

The operating temperature of the engine cooling water is maintained by the cooling water preheater.

Below 25 % output heavy fuel operation is neither efficient nor economical.

A change-over to diesel oil is recommended to avoid disadvantages as e.g. increased wear and tear, contamination of the air and exhaust gas systems and increased contamination of lube oil.

Cleaning run of engine



2. General data and operation of engine

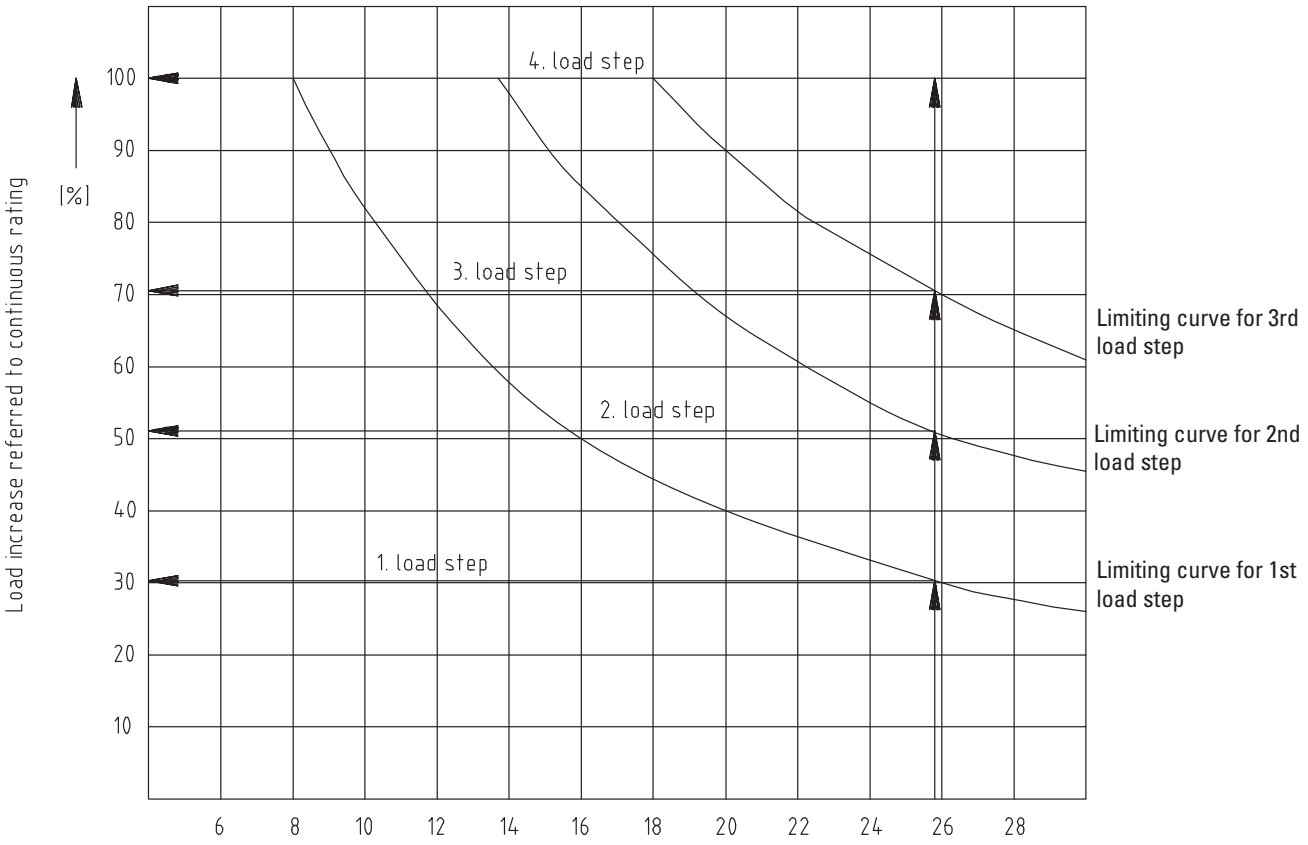
2.4 Load application and recovery behaviour

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

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

M 32 C Inline engines

To achieve recovery behaviour according to class requirements



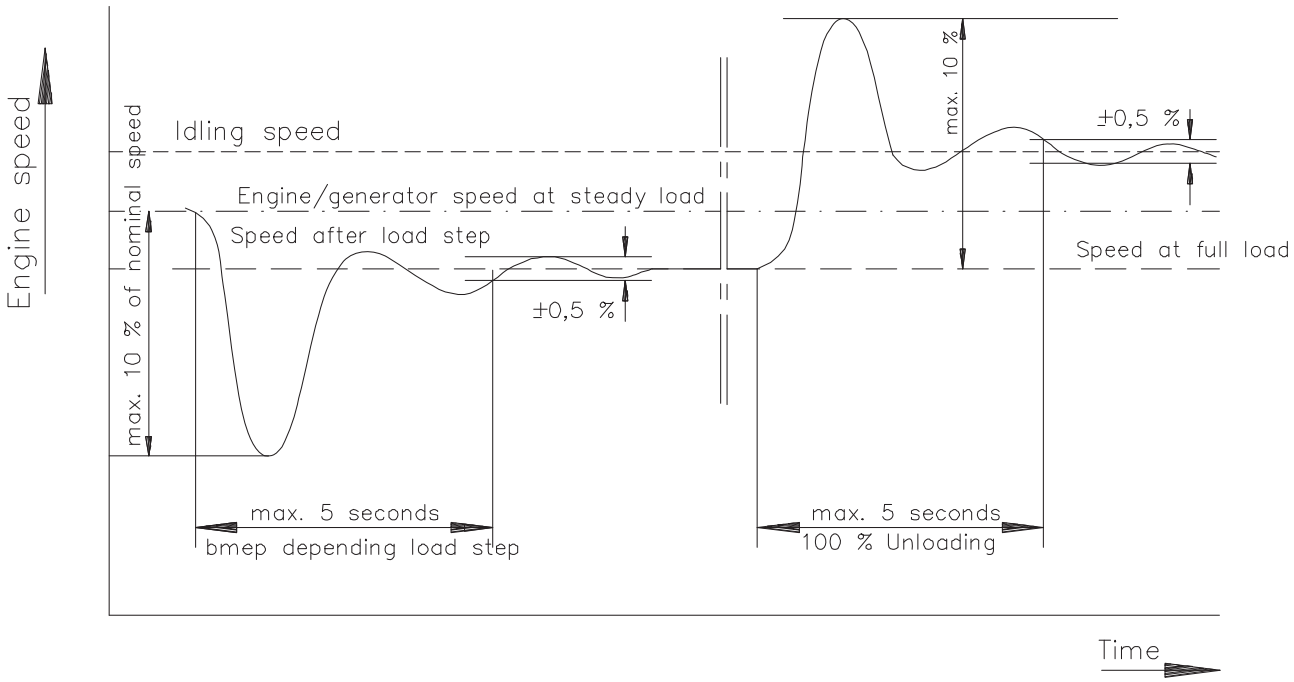
Example: 9 M 32 C, 3,000 kW, 600 rpm, bmep = 25.9 bar
Curves are provided as typical examples.

1. max. load from 0 % to 30 % output
2. max. load from 30 % to 52 % output
3. max. load from 52 % to 71 % output
4. max. load from 71 % to 100 % output

2. General data and operation of engine

2.4 Load application and recovery behaviour

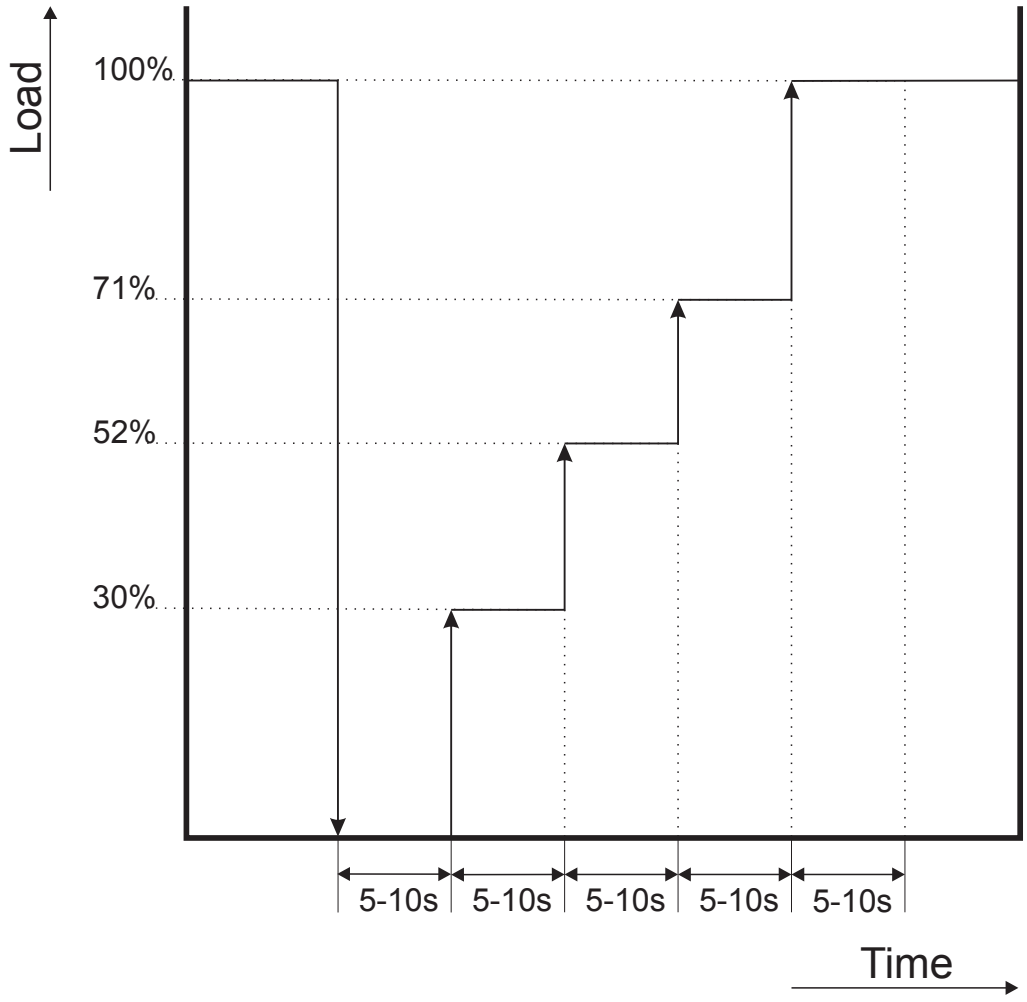
Recovery behaviour after a sudden load increase according to load steps depending on pme / unloading corresponding ISO 8528-5.



2. General data and operation of engine

2.4.1 Standard loading up procedure

Our standard loading procedure for M 32 C in-line engines to achieve recovery behaviour in accordance with class requirements.
For higher load stages or different loading procedures FCT (Flexible Camshaft Technology) is recommended.



2. General data and operation of engine

2.4.2 Speed control of auxiliary generating sets / DE - drive

Electronic governor system maker Regulateur Europa (RE)

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

The engine is equipped with an actuator without mech. back-up governor (optional: with back-up). 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 deceleration 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 princip
- Droop operation selectable

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 avoided.
- When operating under tropical conditions the air flow must be conveyed directly to the turbocharger.
- The temperature at turbocharger filter should not fall below + 10 °C
- In cold areas warming up 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 avoided.
- 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 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 current is to be led 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 has to have a certain quality, be free from solid particles, oil, and water.

3.2.1 Quality requirements of starting air

For the faultness operation of engine a staring 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 define the quality cases of compressed air as follows:

Oil content

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

Particle size and density

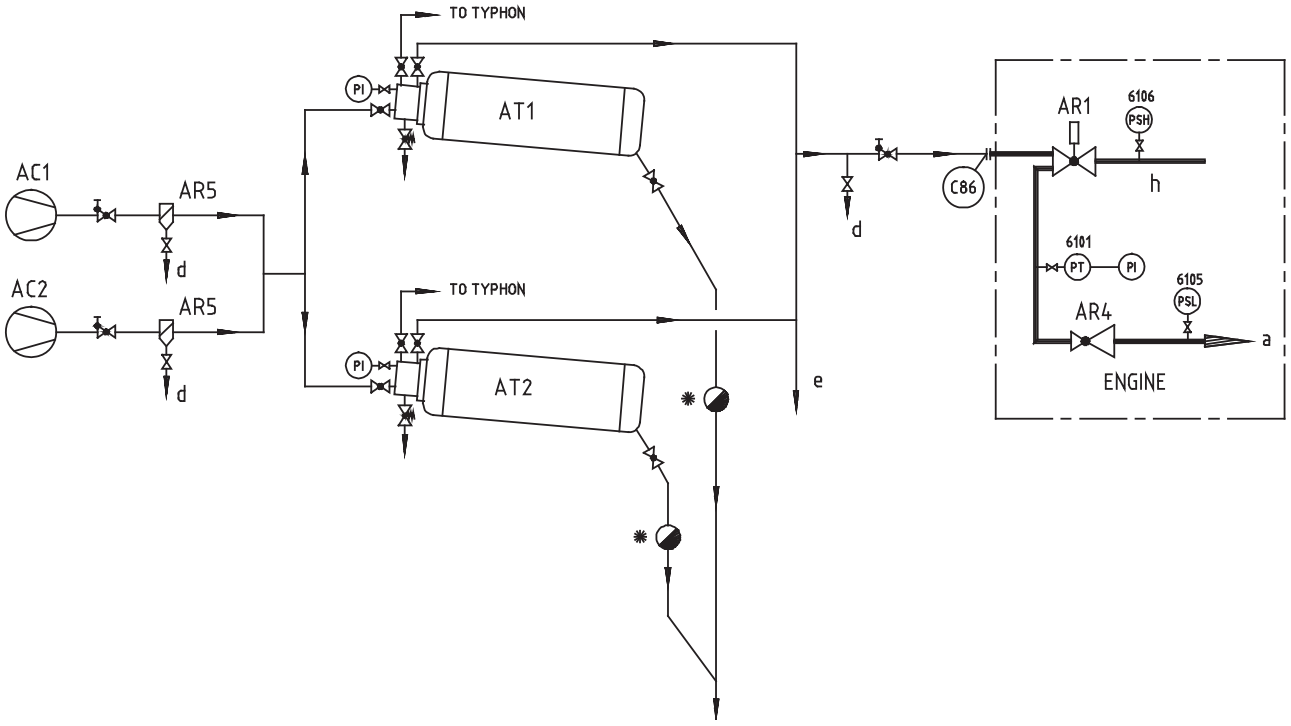
Specification of size and concentration of particles which still may be contained in the compressed air.

Pressure dew point

Specification of the temperature on which the compressed air can cool down without the steam contained in it condensing. The pressure dewpoint 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.

* Automatic drain 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

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

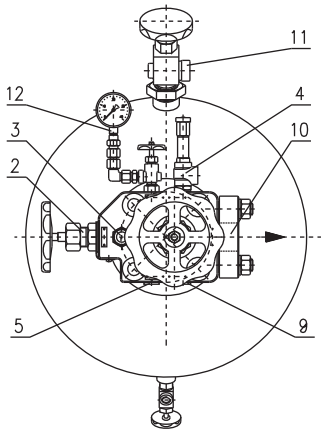
3. Systems

3.2.3 Starting air system components

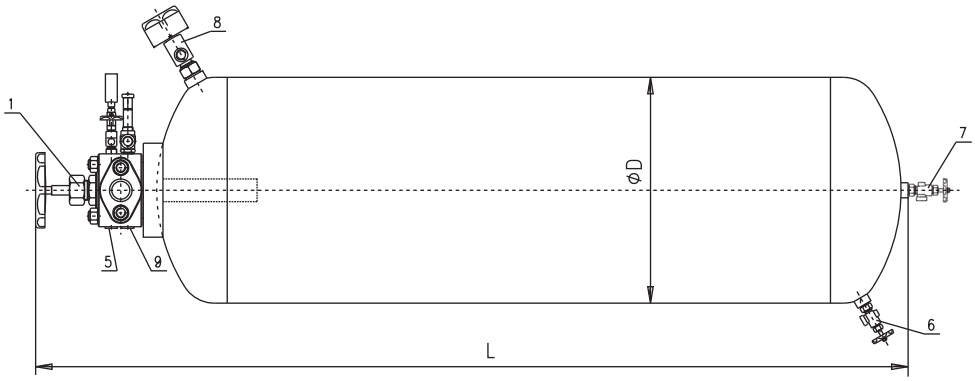
a) Receiver capacity acc. to GL recommendation AT1/AT2

Number of gensets	Number of receivers	Receiver capacity available [l]	L mm	D ø mm	Valve head	Weight approx. kg
2	2	500	3,355	480	DN 50	320
3, 4	2	1,000	3,670	650	DN 50	620

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



When CO_2 fire extinguishing plants are arranged in the engine room, the blow-off connection of the safety valve is to be piped to the outside.

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 backpressure. Exhaust backpressure is generally detrimental, as it tends to reduce the air flow through the engine. Indirectly, exhaust backpressure 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 and 60 is possible.
The basic position is 30°, 0° or 60° are reached by using an elbow.

Design of the pipe cross-section:

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

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

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

3.3.2 Exhaust compensator

	Diameter DN	Length [mm]
6 M 32 C	600	450
8/9 M 32 C	700	520

3. Systems

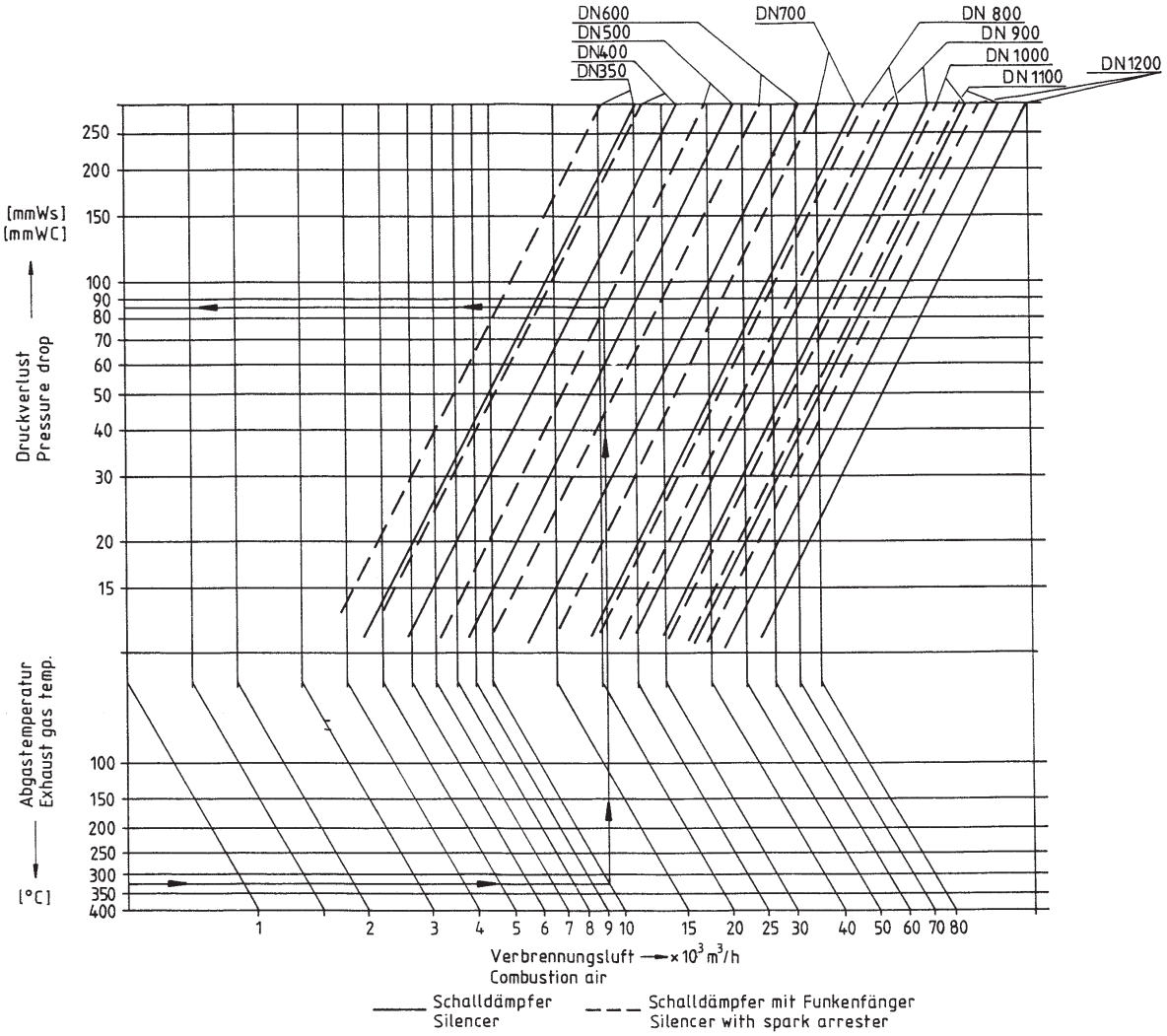
3.3.3 Silencer

Design according to the absorbtion principle with wide-band attentuation 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.

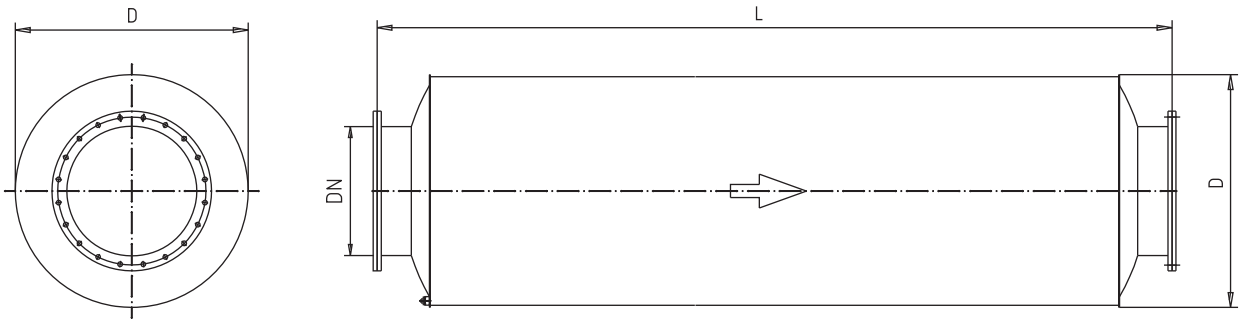


3. Systems

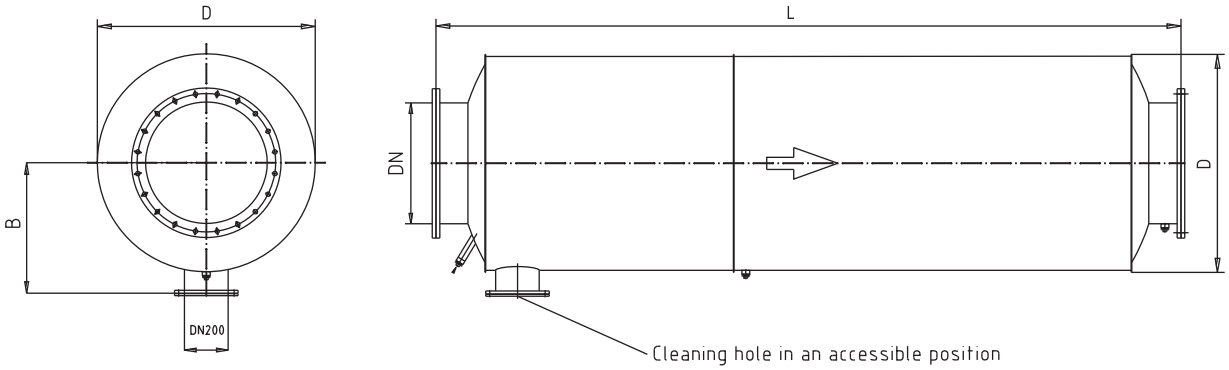
Dimension of silencer/spark arrestor and silencer:

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

Silencer



Spark arrestor and silencer



	Attentuation				35 dB (A)	
	DN	D	A	B	L	kg
6 M 32 C	600	1,100	320	669	4,759	1,300
8/9 M 32 C	700	1,300	320	785	5,049	1,650

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 engine mounted.

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, depending on the fuel quality, 150 hours.

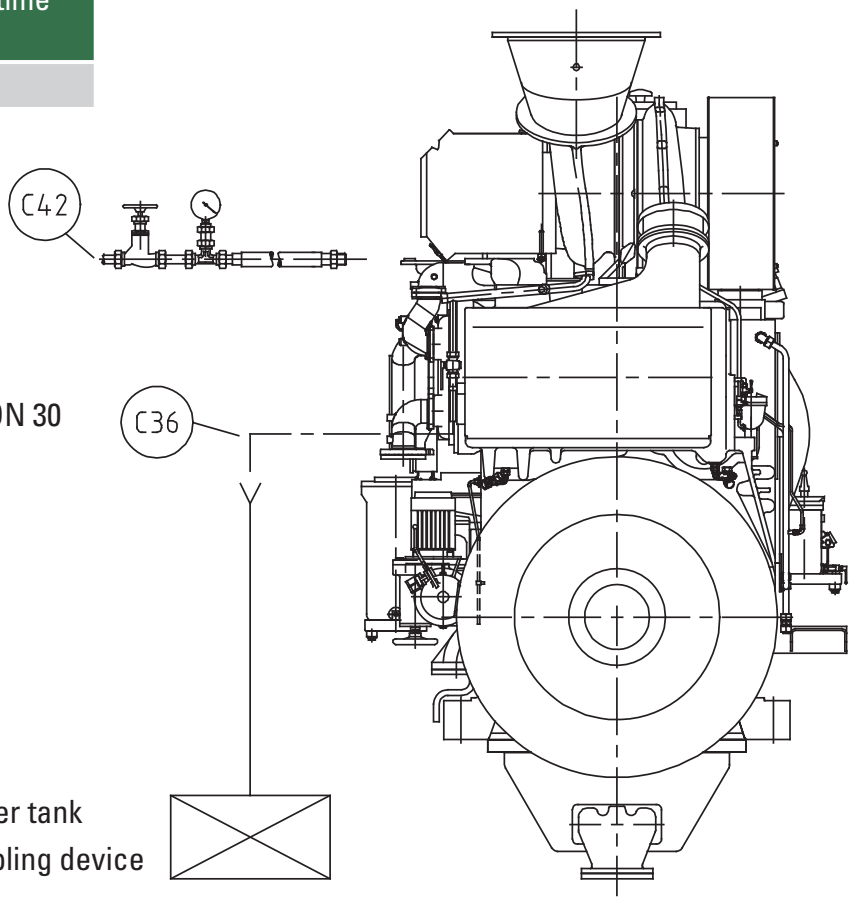
Duration of the cleaning period is approx. 15 minutes (2 intervals). Fresh water of 2 - 2.5 bar is required.

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

Water flow [l/min]	Injection time [min]
25 - 30	2 x 5

C42 Fresh water supply, DN 12

C36 Drain, DN 30



Connection of C42 with quick coupling device

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 lub 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 guarantee a certain quality.

3.4.1 Quality requirements of cooling water

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 caviation can occur on the walls of the cooling system.

Deposits can impair the heat transfer and may result in thermal overload on the components to be cooled. The treatment with an anti-corrosion agent 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 a distillate or fully desalinated water is available, this should preferably be used as engine cooling water.

Hardness: Water with more than 10° dGH (German total hardness) must be mixed with distillate or be softened.

Treatment before operating the engine for the first time

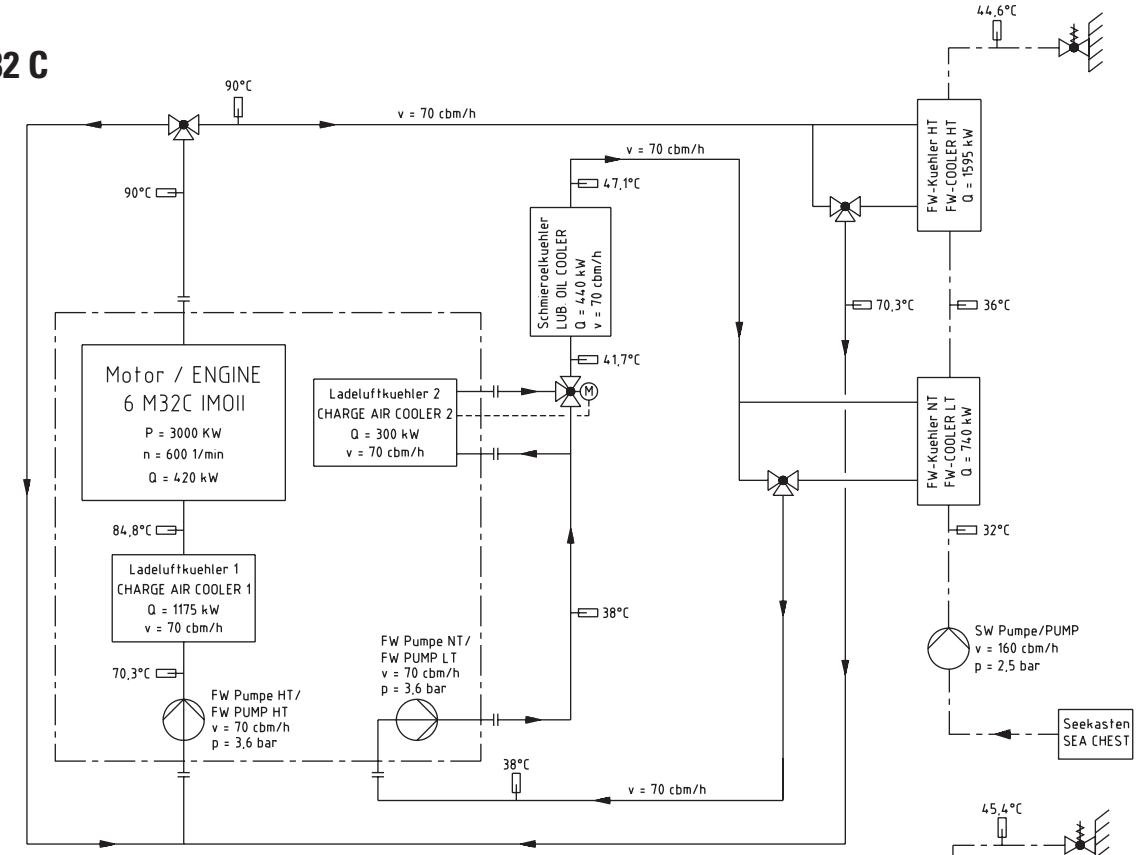
Treatment with anti-corrosion agent should be done before the engine is operated for the first time so as to prevent irreparable initial damage.

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

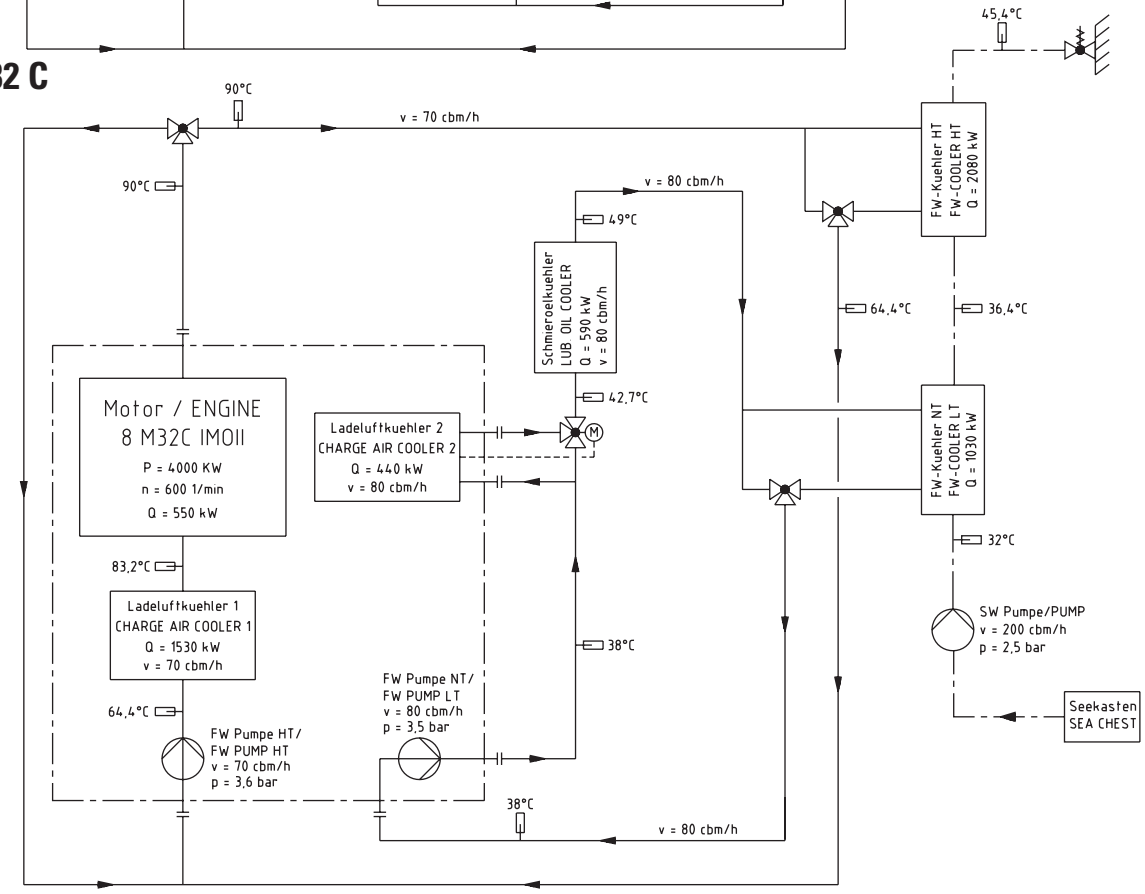
3. Systems

3.4.2 System diagram heat balance

6 M 32 C

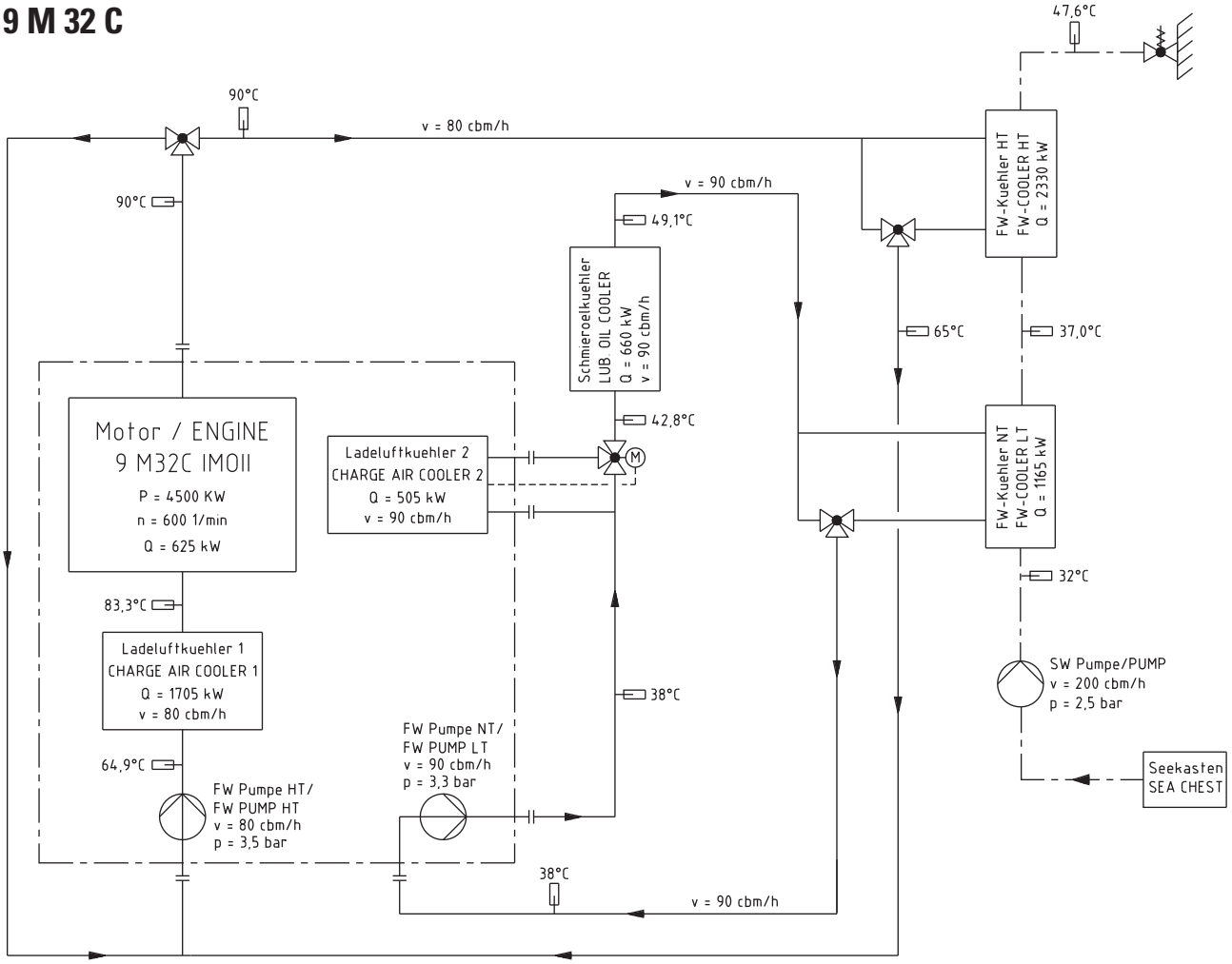


8 M 32 C



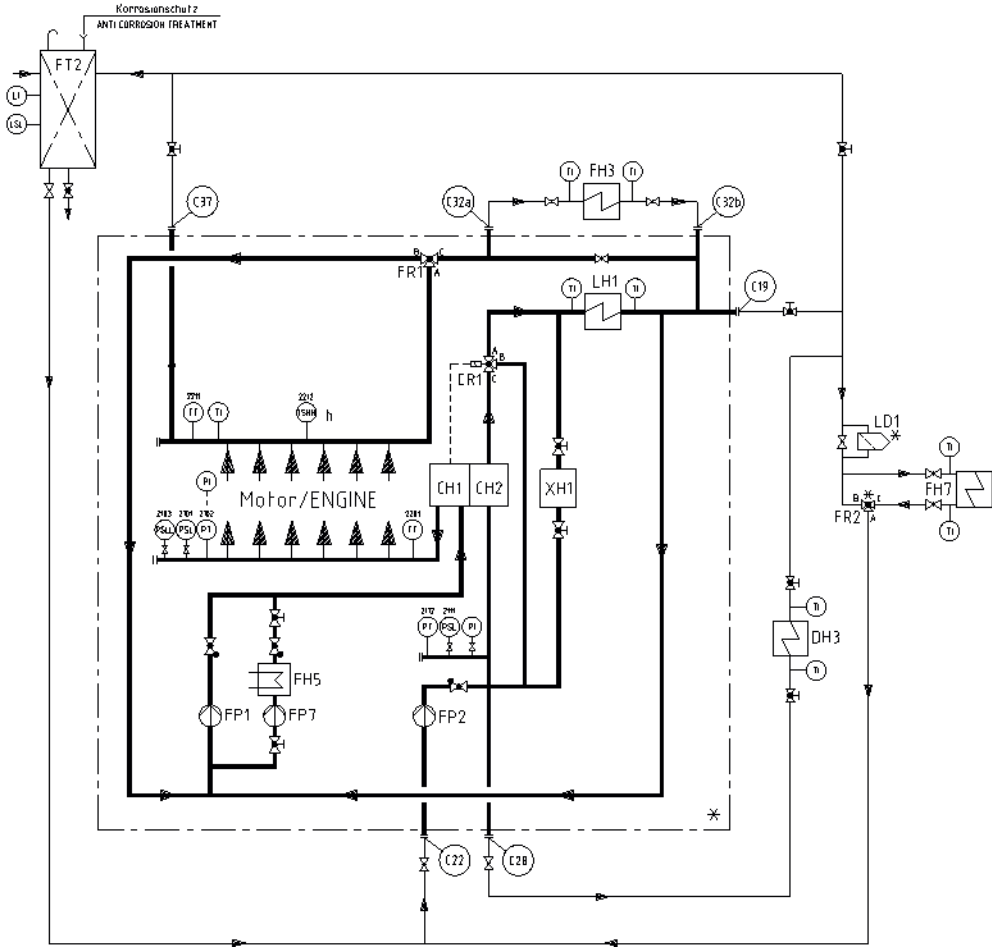
3. Systems

9 M 32 C



3. Systems

3.4.3 System diagram cooling water



Notes:

b Measurement min. 2.0 m distance to C17
d Min. 4 m and max. 12 m above engine center
e Bypass DN 12
f Drain
h Please refer to the measuring point list regarding design of the monitoring devices
m Air supply 2 - 10 bar

Accessories and fittings:

CH1 Charge air cooler HT
CH2 Charge air cooler LT
CR1 Charge air temperature control valve
CR3 Sensor for charge air temperature control valve
FH1 Freshwater cooler HT
FH2 Freshwater cooler LT
FH3 Heat consumer
FH5 Freshwater preheater
FP1 Freshwater pump (fitted on engine) HT
FP2 Freshwater pump (fitted on engine) LT
FP5 Freshwater stand-by pump HT
FP6 Freshwater stand-by pump LT
FP7 Preheating pump
FR1 Temperature control valve HT
FR2 Temperature control valve LT
FR3 Flow temperature control valve HT
FT1 Compensation tank HT
FT2 Compensation tank LT
LH1 Luboil cooler
LH3 Gear luboil cooler
SF1 Seawater filter
SP1 Seawater pump
SP2 Seawater stand-by pump
ST1 Sea chest
LI Level indicator
LSL Level switch low
PI Pressure indicator
PSL Pressure switch low
PSLL Pressure switch low 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 disconnecting points see engine installation drawing.

With skin cooler not required:

- Seawater system (SP1, SP2, SF1, ST1)

Connecting points:

C14 Charge air cooler LT, inlet
C15 Charge air cooler LT, outlet
C16 Charge air cooler HT, inlet
C21 Freshwater pump HT, inlet
C22 Freshwater pump LT, outlet
C25 Cooling water, engine outlet
C28 Freshwater pump LT, outlet
C31 Freshwater pump HT, outlet
C37 Vent
C45 Connection, pressure swith LT, pressure gauge

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.

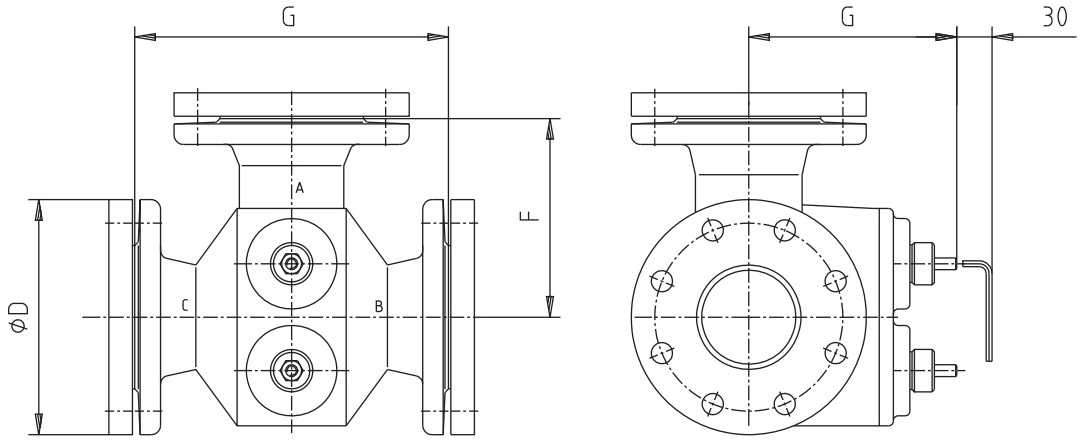
a) LT-cooling water pump FP4: **Option: fitted (FP2)**
Capacity: acc. to heat balance

b) LT-cooling water stand-by pump 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 FP5: Capacity: acc. to heat balance

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



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

* Minimum, depending on total cooling water flow

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 = 450 x 300 x 200).

[1]	Capacity	8m³/h
[2]	Output	24 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 (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 FT1/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.

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

PM = 1.5 • P	< 1.5 kW
PM = 1.25 • P	1.5 - 4 kW
PM = 1.2 • P	4 - 7.5 kW
PM = 1.15 • P	> 7.5 - 40 kW
PM = 1.1 • 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 Caterpillar Motoren technical product support. For a faultless operation of MaK engines the minimum Caterpillar Motoren requirements for storage, treatment and supply systems have to be observed; as shown in the following sections.

3.5.1 Quality requirements of MGO/MDO fuel/permitted fuels

Two fuel product groups are permitted for MaK engines:

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

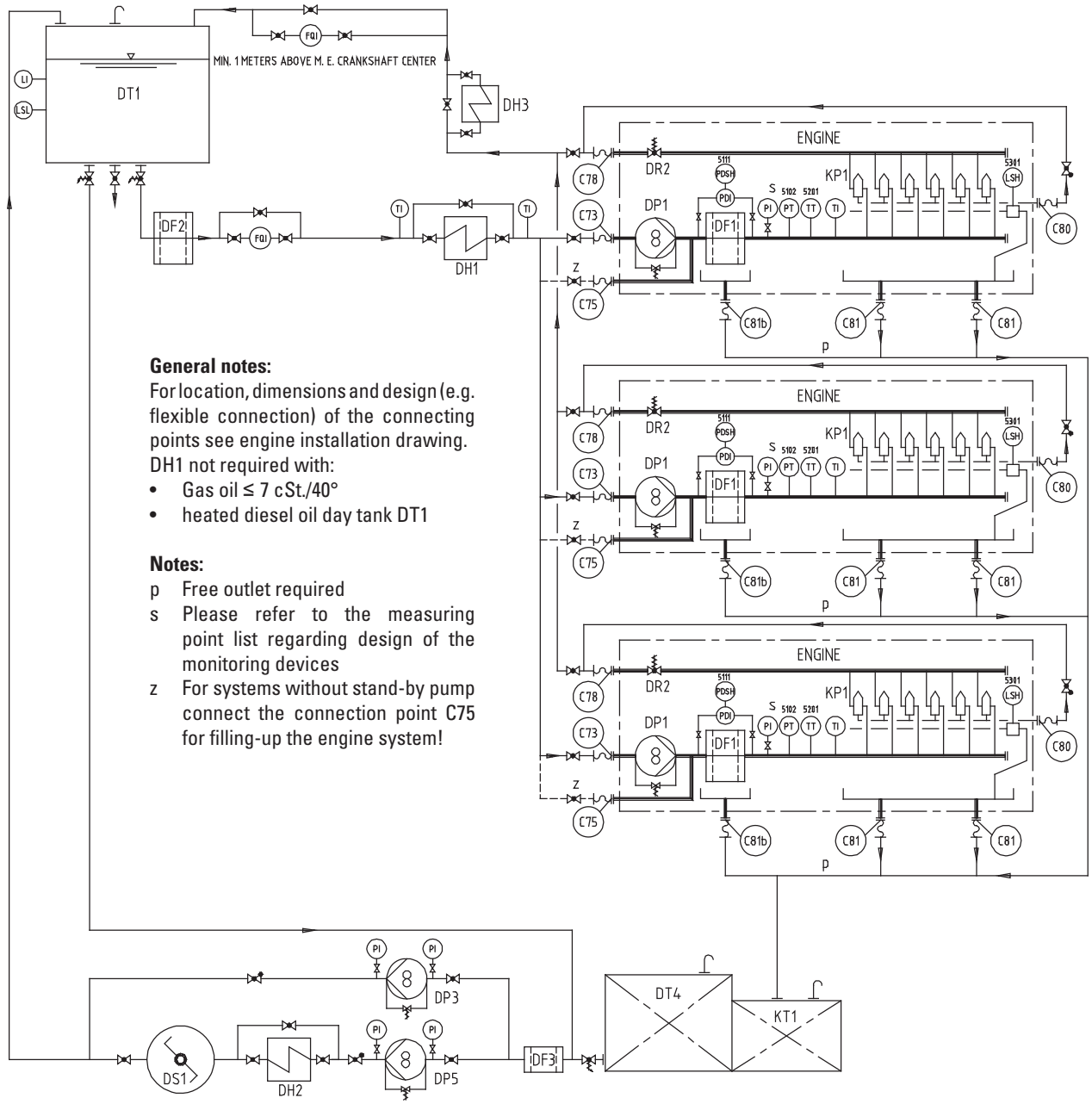
Distillate/mixed fuels: Marine gas oil (MGO), marine diesel oil (MDO). The difference between distillate/mixed fuels and pure distillates are higher density, sulphur content and viscosity.

	MGO		MDO	
	Designation	Max. viscosity [cSt/40 °C]	Designation	Max. viscosity [cSt/40 °C]
ISO 8217:2005	ISO-F-DMA	1.5 - 6.0	ISO-F-DMB ISO-F-DMC	11 14
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 can not be removed by radiation 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 hour 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 space including a sludge drain valve and an overflow pipe from the MDO/MGO service tank.

h) Intermediate tank (separate) DT2:

Capactiy 100 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 of 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.

3. Systems

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 (2005):F-		RMA30	RMB30	RMB30	RMD80	RME180	RMF180	RMG380	RMH380	RMK380	RMH500	RMK500	RMH700	RMK700
Characteristic	Dim.	Limit													
Density at 15°C	kg/m³	max	950 [2]	975 [3]		980 [4]	991		991		1,010	991	1,010	991	1,010
Kin. viscosity at 100°C		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 [7]		0.15 [7]		0.15 [7]	
Total sedim, after ageing	% (m/m)	max	0.10			0.10	0.10		0.10			0.10		0.10	
Water	% (V/V)	max	0.5			0.5	0.5		0.5			0.5		0.5	
Sulphur	% (m/m)	max	3.5			4.0	4.5		4.5			4.5		4.5	
Vanadium	mg/kg	max	150		300	350	200	500	300	600		600		600	
Aluminium + Silicon	mg/kg	max	80			80	80		80			80		80	
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:

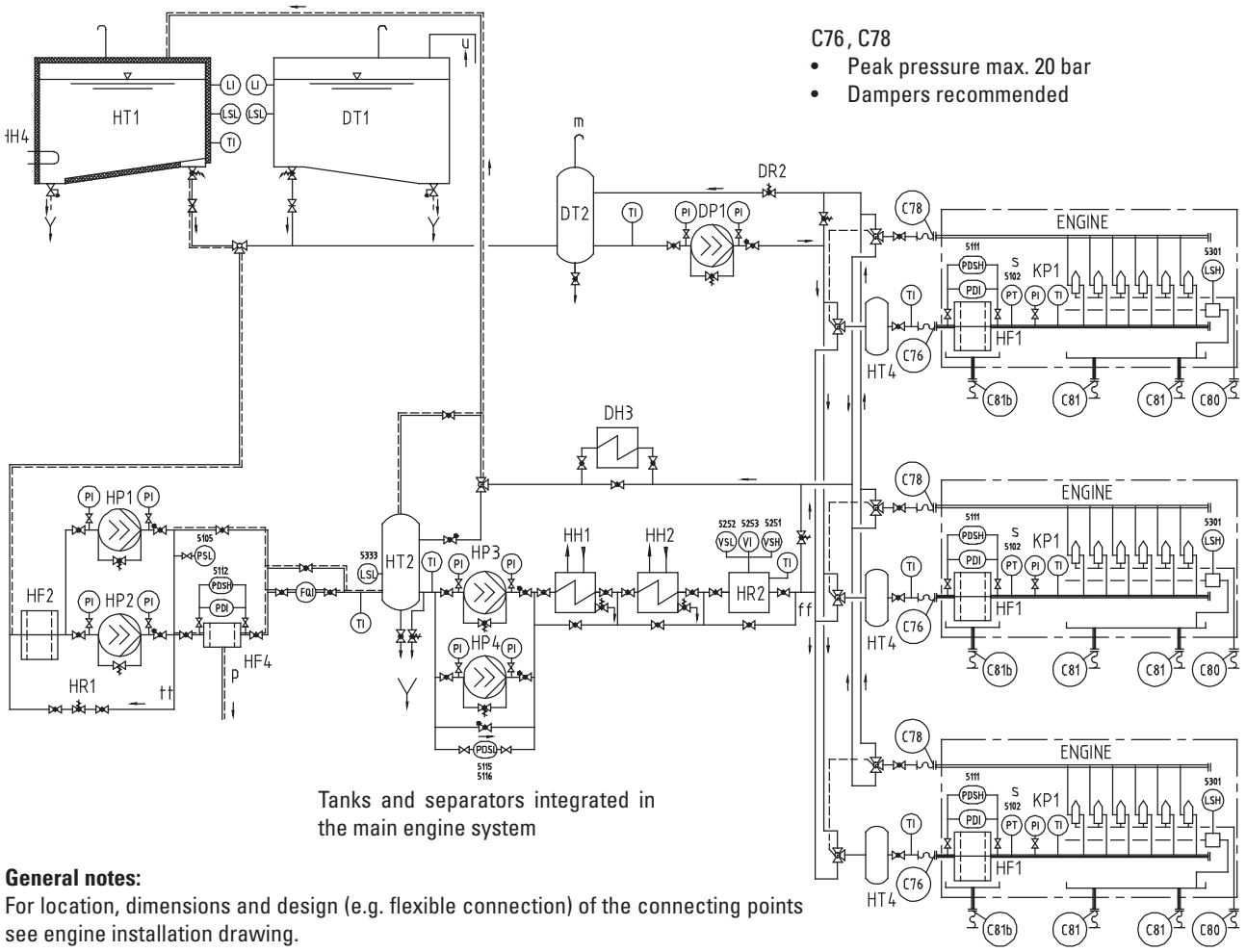
Kinematic viscosity at 100 °C mm²/s (cSt)	7	10	15	25	35	45	55
Kinematic viscosity at 50 °C mm²/s (cSt)	30	40	80	180	380	500	700
Kinematic viscosity at 100 °F Redw. I sec.	200	300	600	1500	3000	5000	7000

Fuel shall be free of used lubricating oil (ulo)

2) ISO: 975
3) ISO: 981
4) ISO: 985
5) ISO: not limited
6) ISO: Carbon Residue 10
7) ISO: 0.20

3. Systems

3.6.2 Heavy fuel operation



Tanks and separators integrated in the main engine system

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.
Valve fittings with loose cones are not accepted in the admission and return lines

Accessories and fittings:

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

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	Neither insulated nor heated pipe
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):

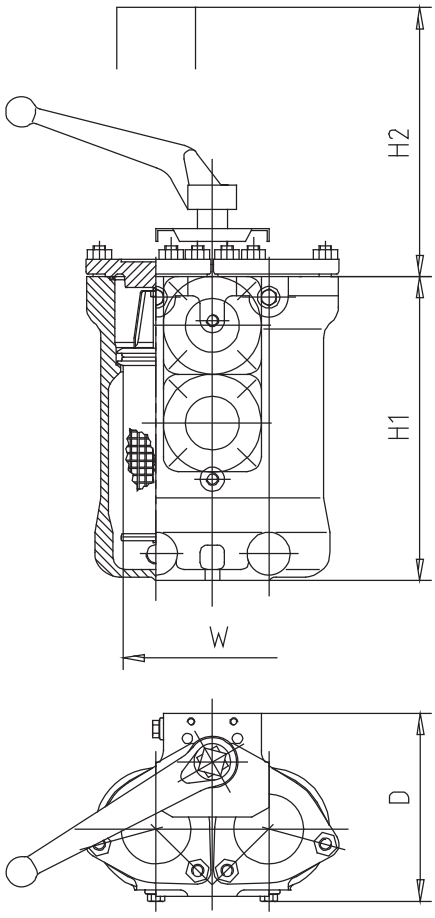
A closed **pressurized system** between daytank and engine is required as well as the installation of an automatic backflushing filter with a mesh size of 10 µm (absolute).

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

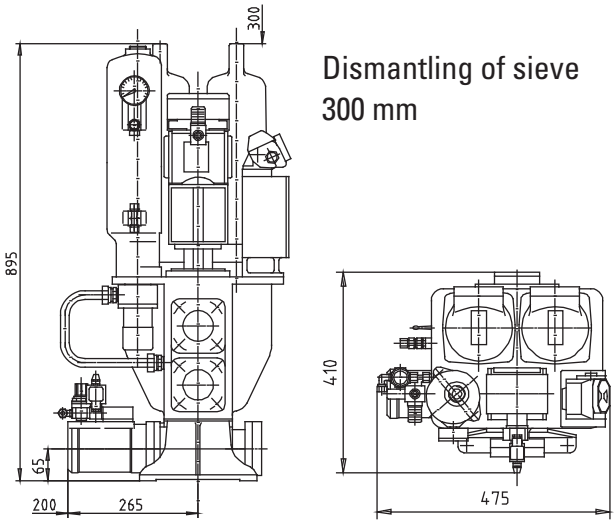
3. Systems

c) Self cleaning filter HF4:

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

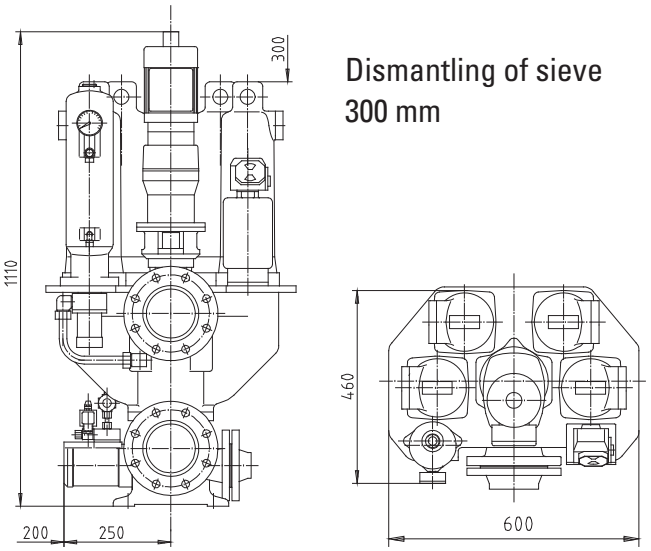
* In case of Caterpillar Motoren supply.

≤ 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.

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

f) Circulating pumps HP3/HP4:

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

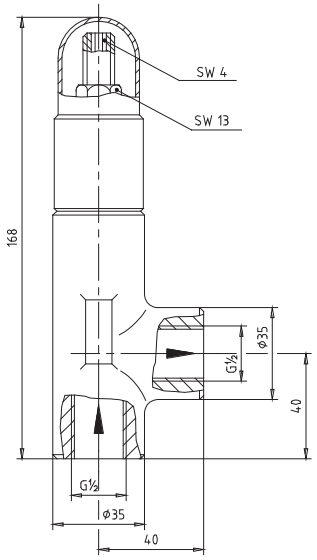
$$\text{Capacity} \qquad V\ [m^3/h] = 0.7 \bullet \frac{P_{eng.}\ [kW]}{1{,}000}$$

3. Systems

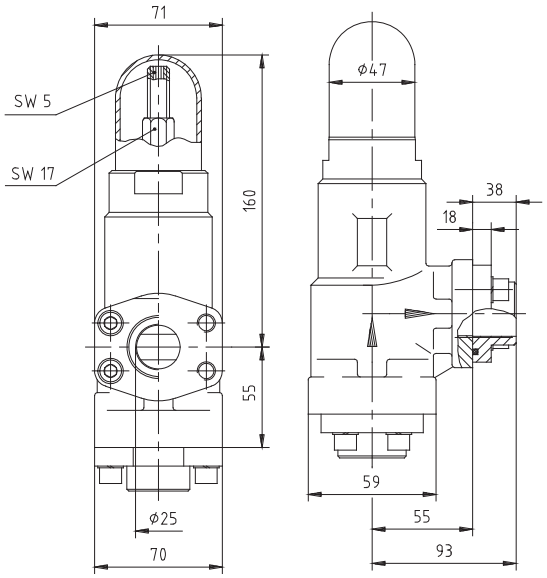
g) Pressure regulating valve HR1: Controls the pressure at the engine inlet, approx. 4 bar.

Engine outputs

≤ 3,000 kW



> 3,000 kW



h) Final preheater HH1/HH2:

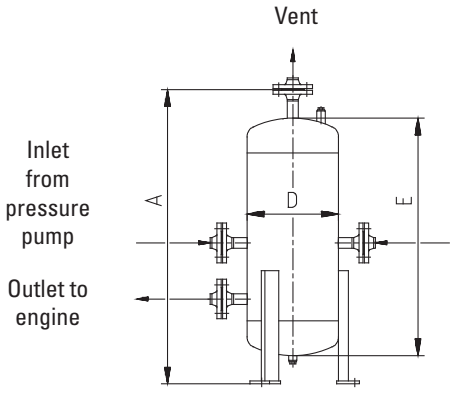
Heating media:

- 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 missing tank compensates pressure surges which occur in the pressurised 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 permissible:

- 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 days 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 thermaloil heating, up to IFO 180 for elect. 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 absolut (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/thermaloil)
- **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

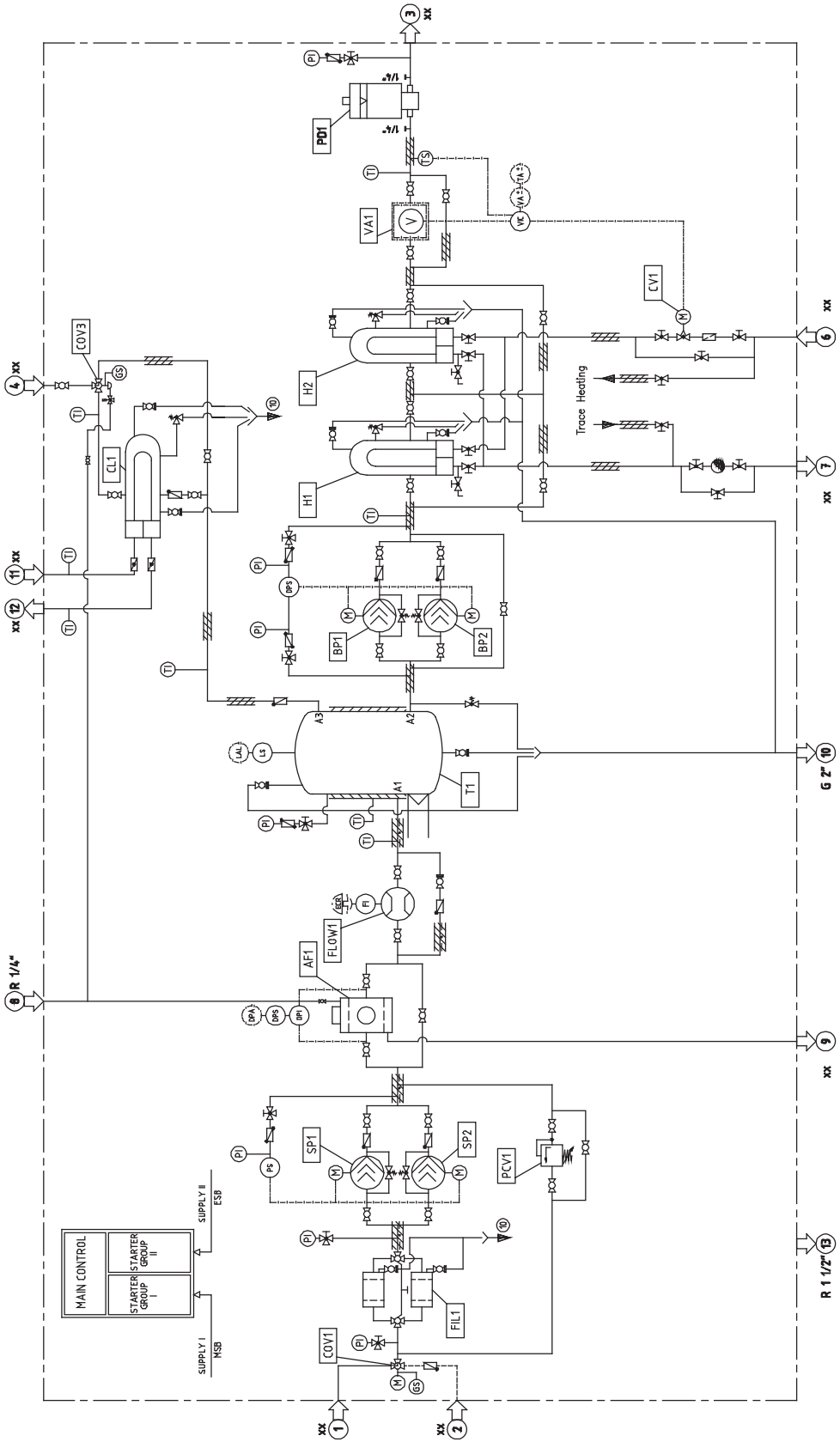
Performance and materials:
The whole module is tubed and cabled up to the terminal strips in the electric switch boxes which are installed on the module. All necessary components like valves, pressure switches, thermometers, gauges etc. are included. The fuel oil pipes are equipped with trace heating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

The module will be tested hydrostatical and functional 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



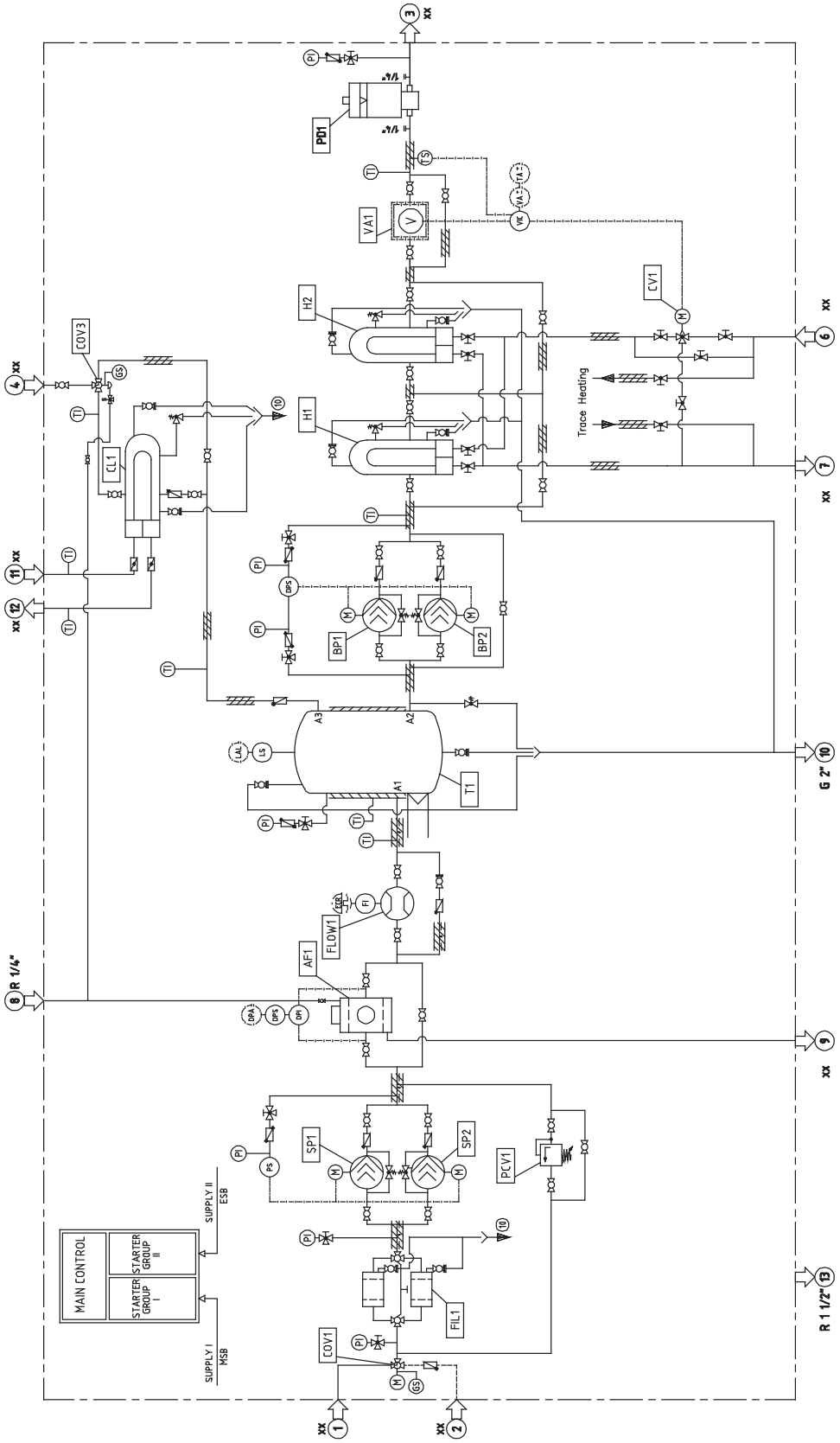
Symbols

	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



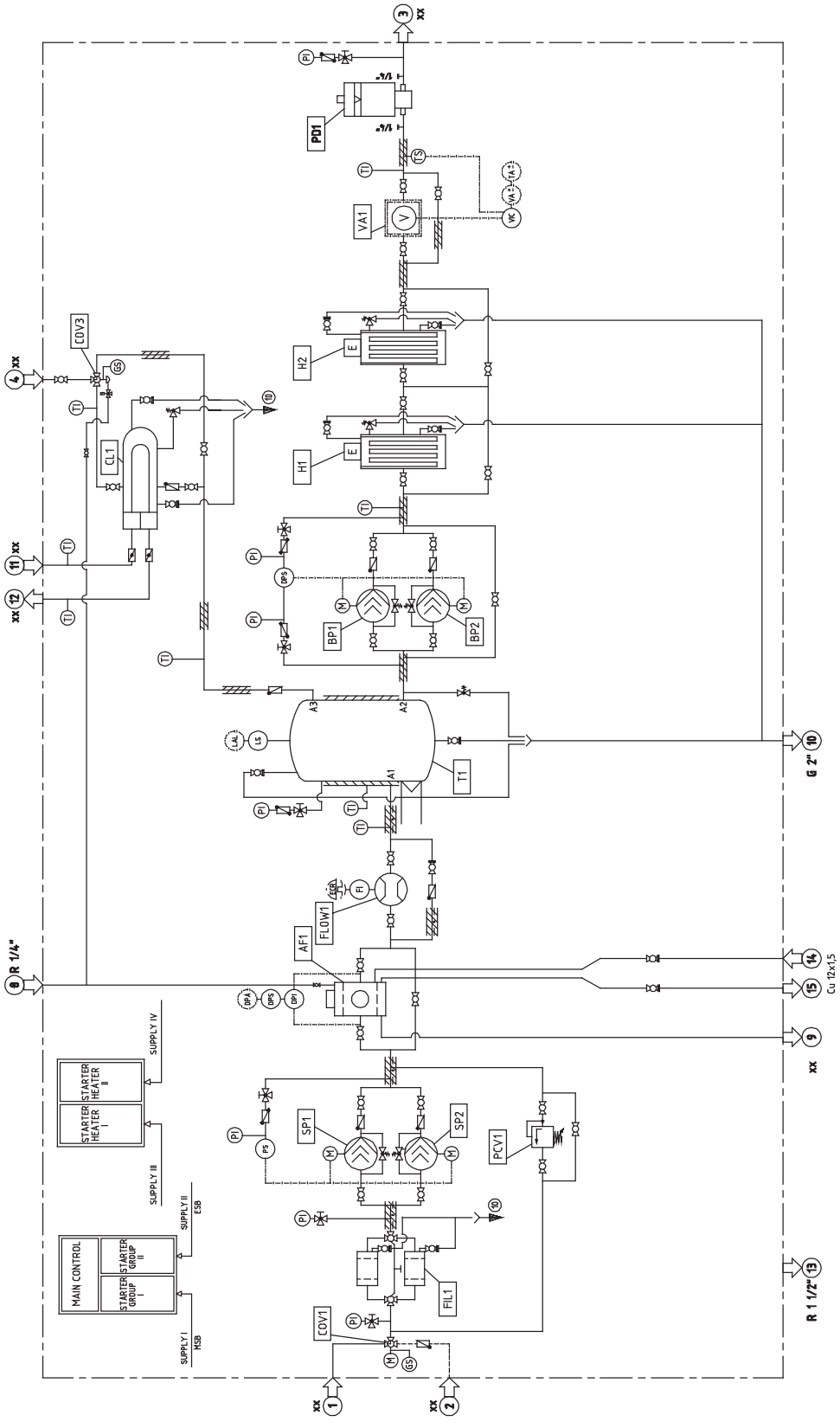
Symbols

	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 Lubricating oil system

The lubricating oil performs several basic functions:

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

3.7.1 Quality requirements of lubricating oil system

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 were 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	
	MXD 154	x		TLX PLUS 404	x	
	TLX PLUS 204	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 M50	x	
	MOBILGARD 1-SHC [1]		x			
	DELVAC 1640	x				
SHELL	GADINIA	x		ARGINA T	x	
	GADINIA AL	x		ARGINA X	x	
	ARGINA S	x				
	ARGINA T	x				
TOTAL LUBMARINE	RUBIA FP		x	AURELIA XL 4030	x	
	DISOLA M 4015	x		AURELIA XL 4040	x	
	AURELIA XL 4030	x		AURELIA TI 4030	x	
	AURELIA TI 4030	x		AURELIA TI 4040	x	

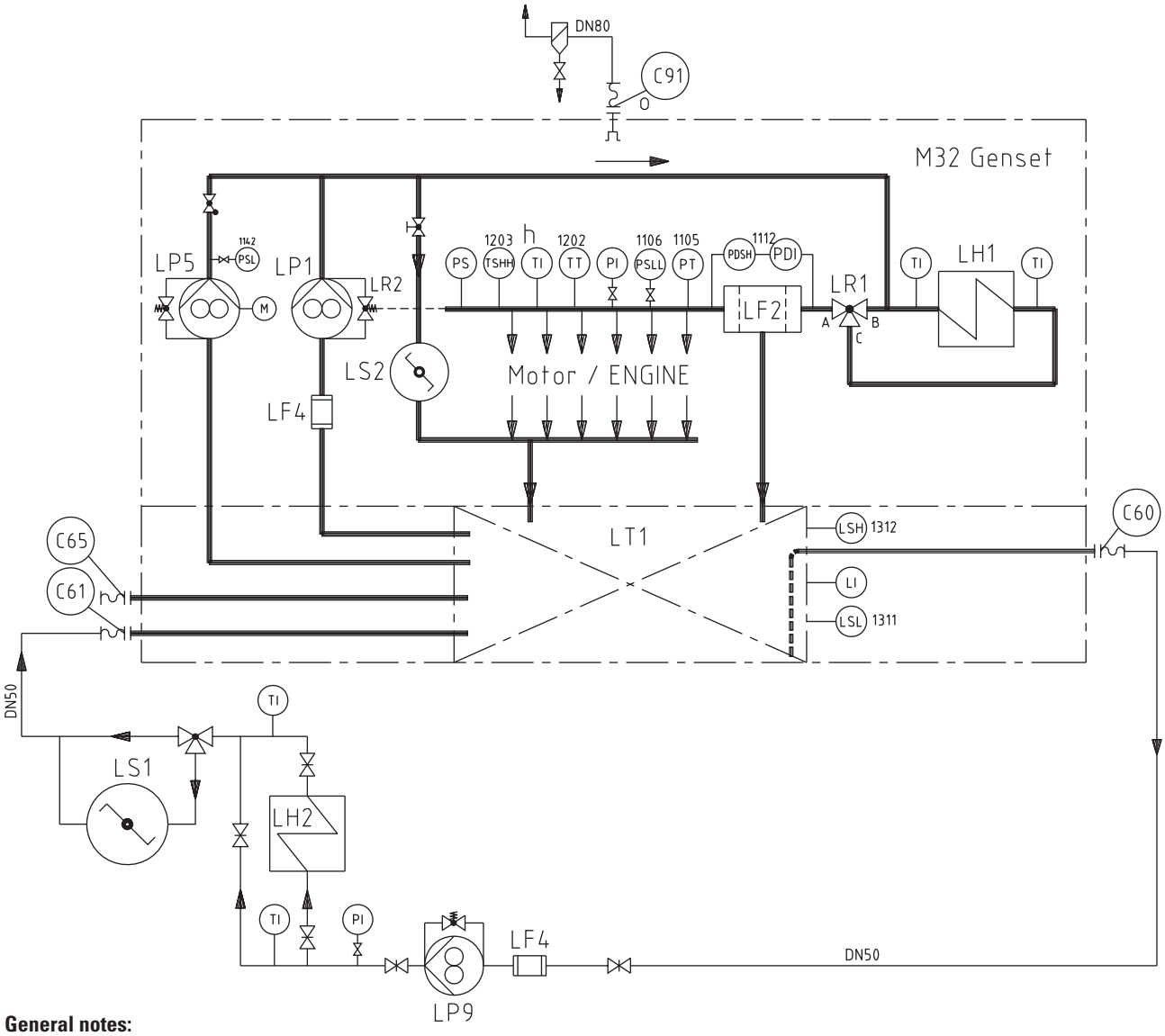
I Approved in operation

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 4-A-9570

Connecting points:

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

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 Lubricating 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:

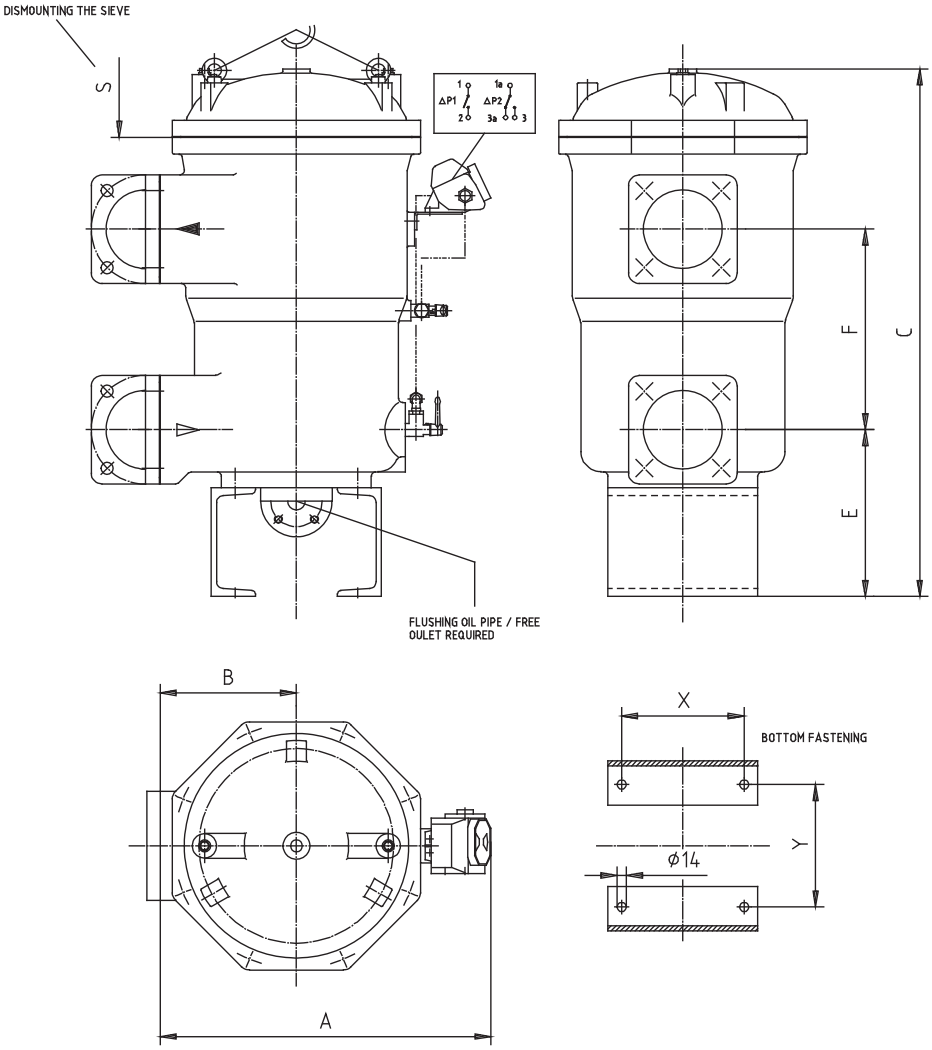
The self-cleaning filter protects the engine against dirt particals which may have accumulated in the oil tank.

The filter is fitted and replaces the duplex filter. Separate self-cleaning filter as 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	6/8/9 M 32 C
A	485
B	200
C	775
E	245
F	295
S	400
X	180
Y	180
Weight [kg]	112

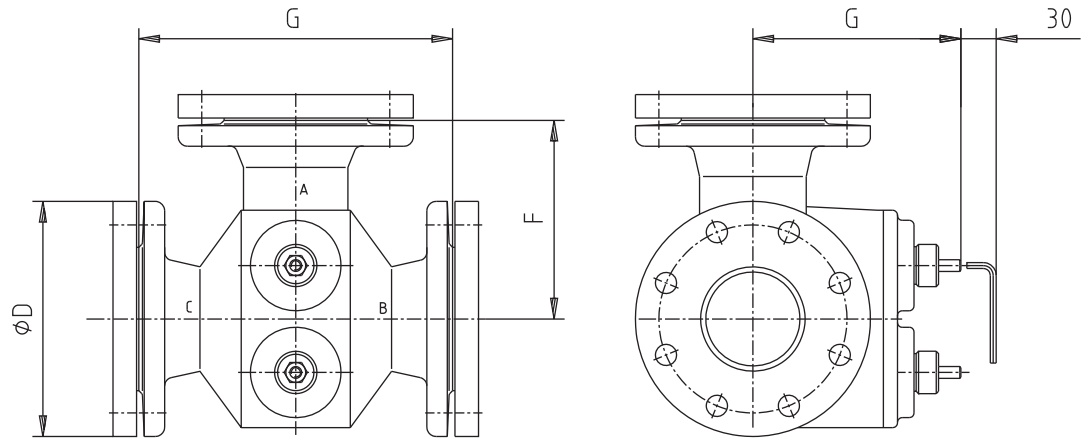
f) Cooler (separate) LH1:

Option: fitted on base frame
Plate type (plates made of stainless steel)

3. Systems

g) Temperature controller (separate) LR1:

Option: fitted on baseframe
P-controller with manual emergency adjustment



	Dimensions [mm]					Weight
	DN	D	F	G	H	[kg]
6 M 32 C	80	200	171	267	151	27
8/9 M 32 C	100	220	217	403	167	47

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 enlarged to DN 125.

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 lubricating 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 lubricating oil piping system information

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

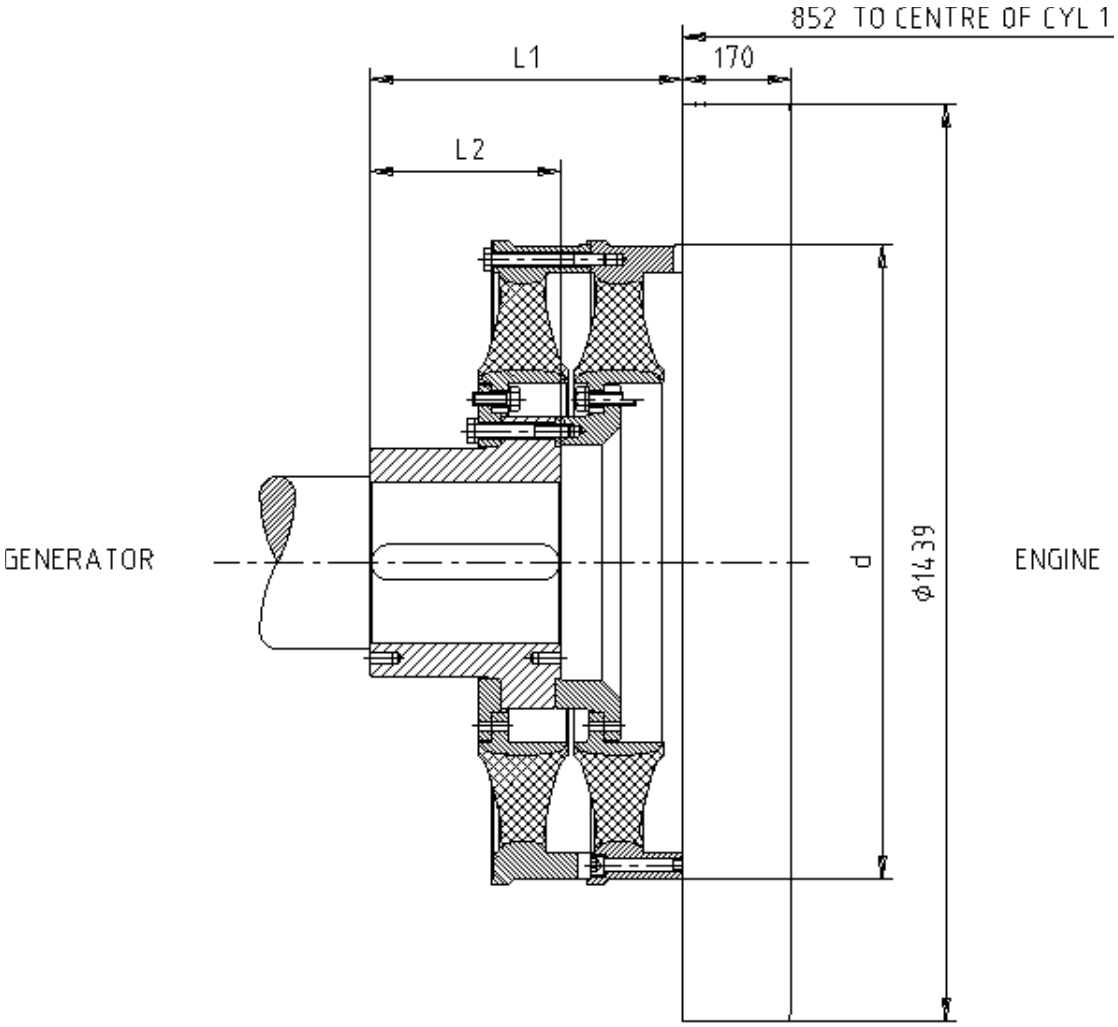
A proper inspection of the inner walls of the pipes is needed by our service engineers before starting the engine to ensure that no weld spatter, slag, rust and oxide remain.

Expansion joints

Pipe expansion joints are necessary in systems that convey high temperature commodities 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

Fly wheel and flexible coupling



	Power	Speed	Nominal torque of coupling	Type Vulkan Rato-DS			Weight	
				d	L1 [4]	L2 [3]	[1]	[2]
	[kW]	[rpm]	[kNm]	[mm]	[mm]	[mm]	[kg]	[kg]
6 M 32 C	3,000	600	47.8	1,010	495	300	381	465
8 M 32 C	4,000	600	63.7	1,010	495	300	381	465
9 M 32 C	4,500	600	71.7	1,070	530	310	464	556

[1] without torsional limit device
[2] with torsional limit device
[3] length of hub
[4] alignment control (recess depth 5 mm)

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

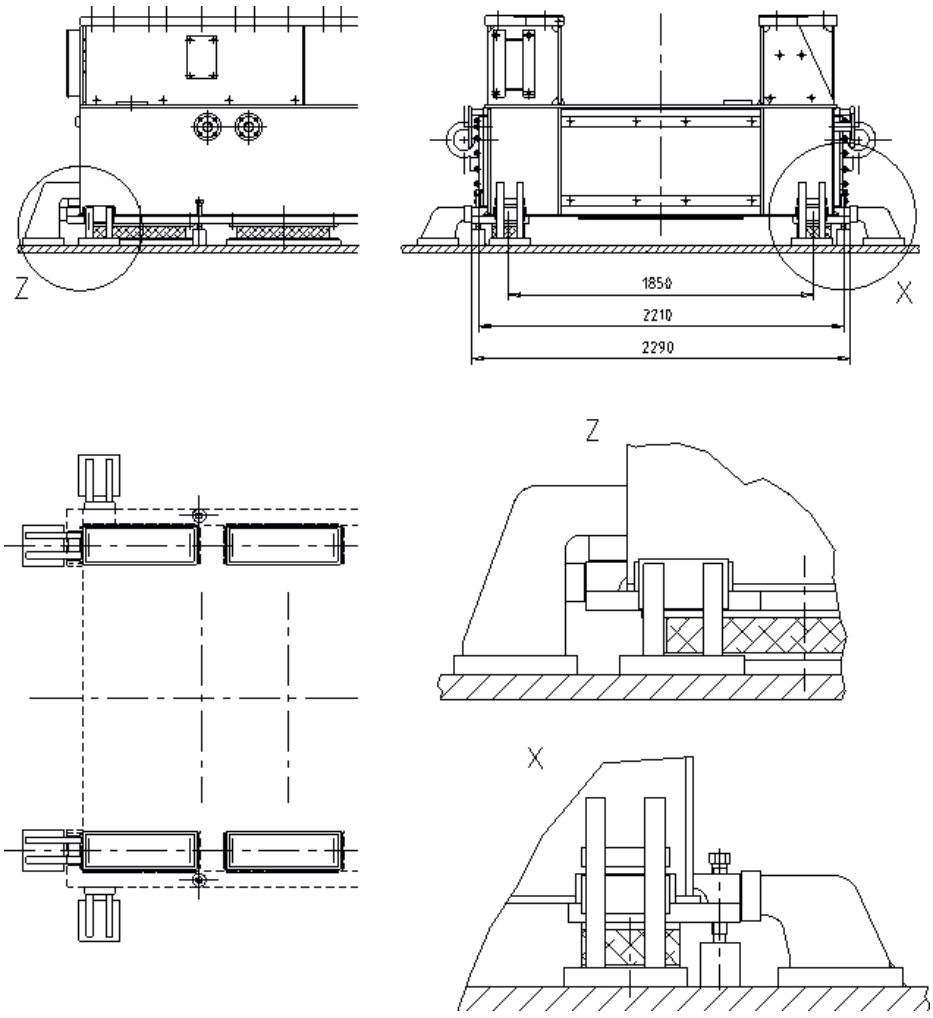
4.2 Resilient mounting of base frame

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 = 100 mm) are fastened to the ship's foundation via welded-on sheets (thickness about 30 mm) and shims for compensation of differences in height.

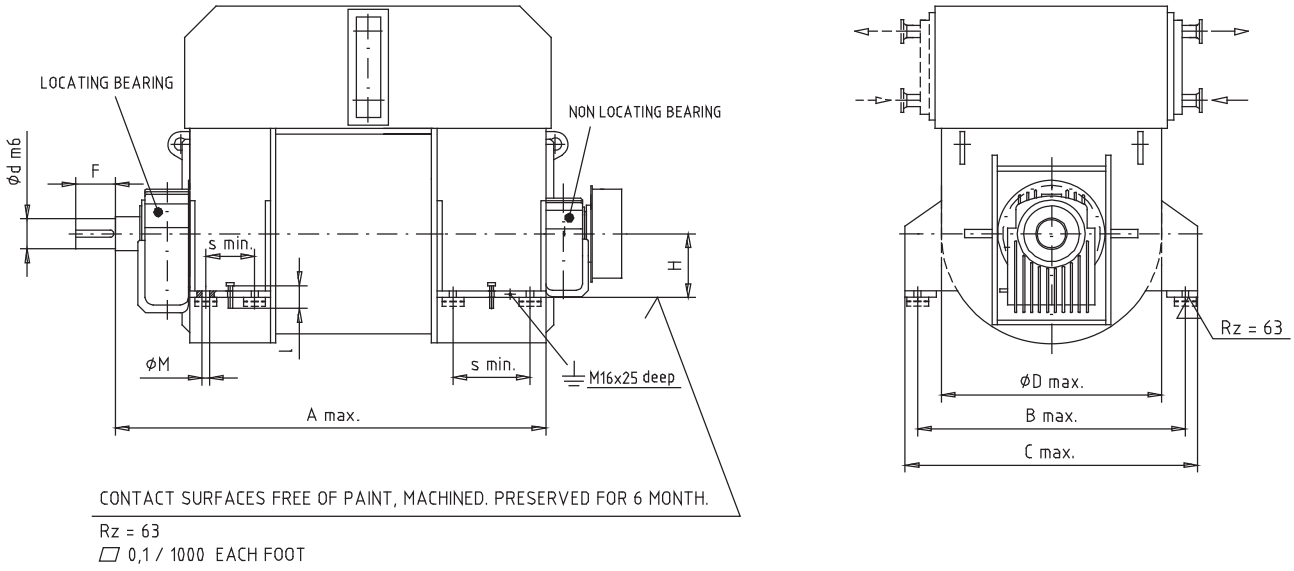
Further notes (inter alia regarding alignment) are given in the binding installation drawing. Transverse and longitudinal stoppers and welding sheets are to be provided by the shipyard.

Base frame foundation



4. Connecting parts engine

4.3 Generators structural requirements for MaK diesel gensets M 32 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 32 C	B 20	2,900	1,930	2,130	1,960	240	300	495	39	300
8 M 32 C		3,000								
9 M 32 C		3,200				260	310			

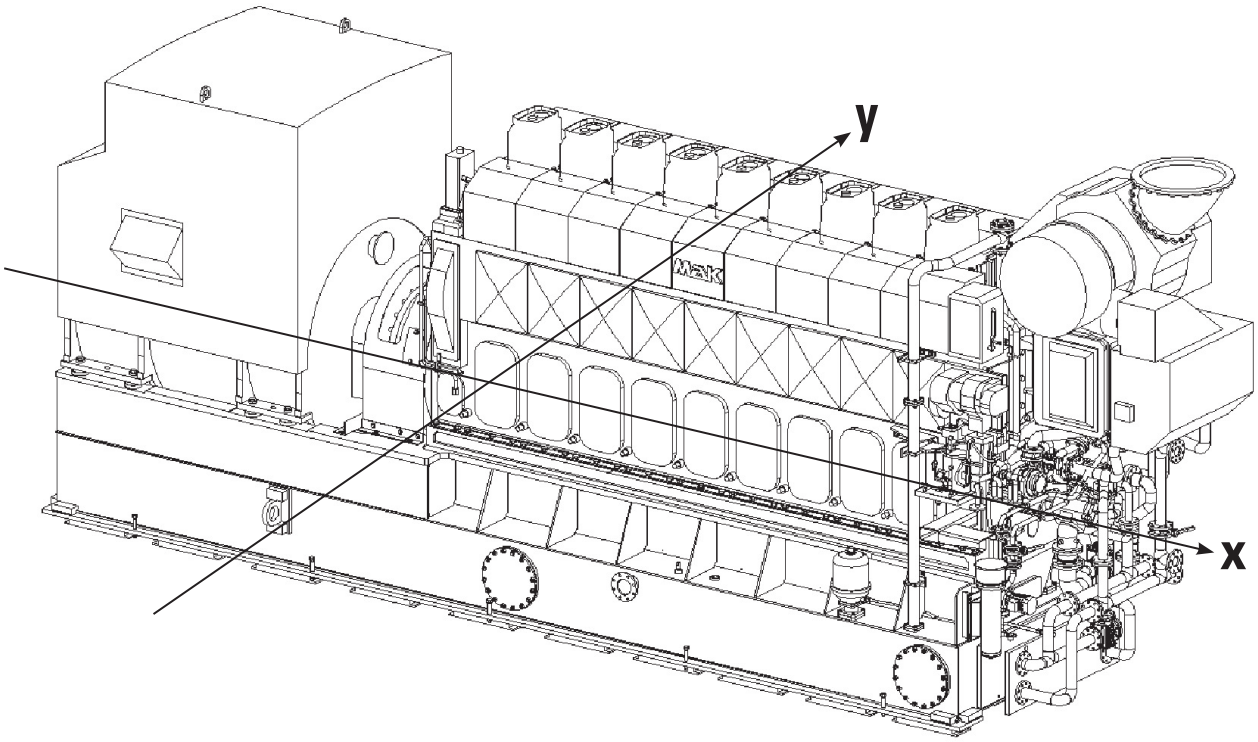
5. Installation and Arrangement

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 °
Dynamic: rolling to each side: 22.5 °

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



5. Installation and Arrangement

5.2 System connections engine

Starting Air

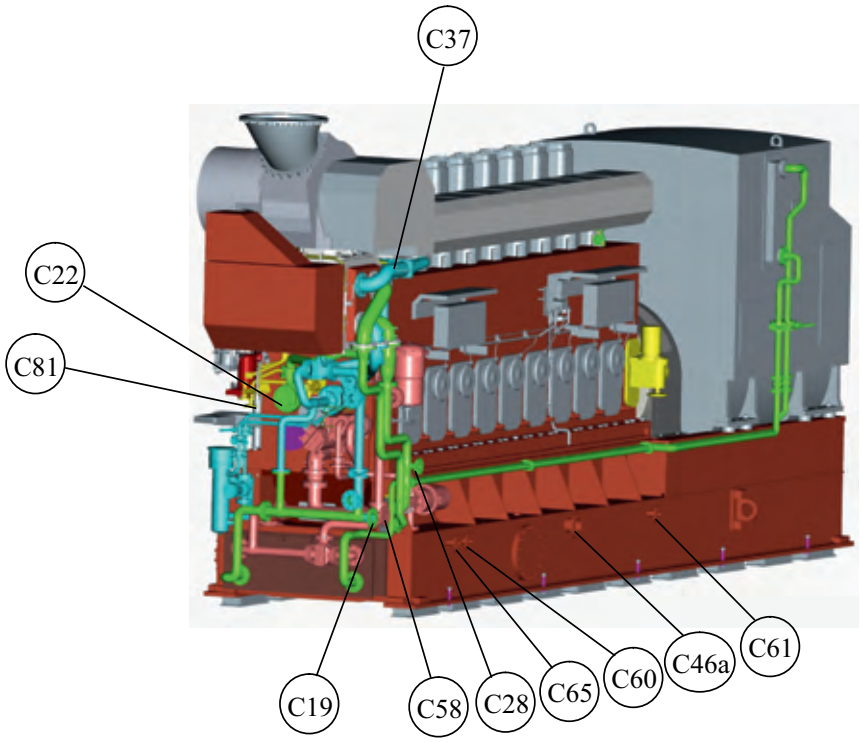
C86 Connection, starting air

Fuel Oil

C73 Fuel inlet
C75 Connection, stand-by pump
C78 Fuel outlet
C80 Drip fuel connection
C81 Drip fuel connection
C81b Drip fuel connection (filter pan)

Exhaust

C91a Exhaust gas outlet

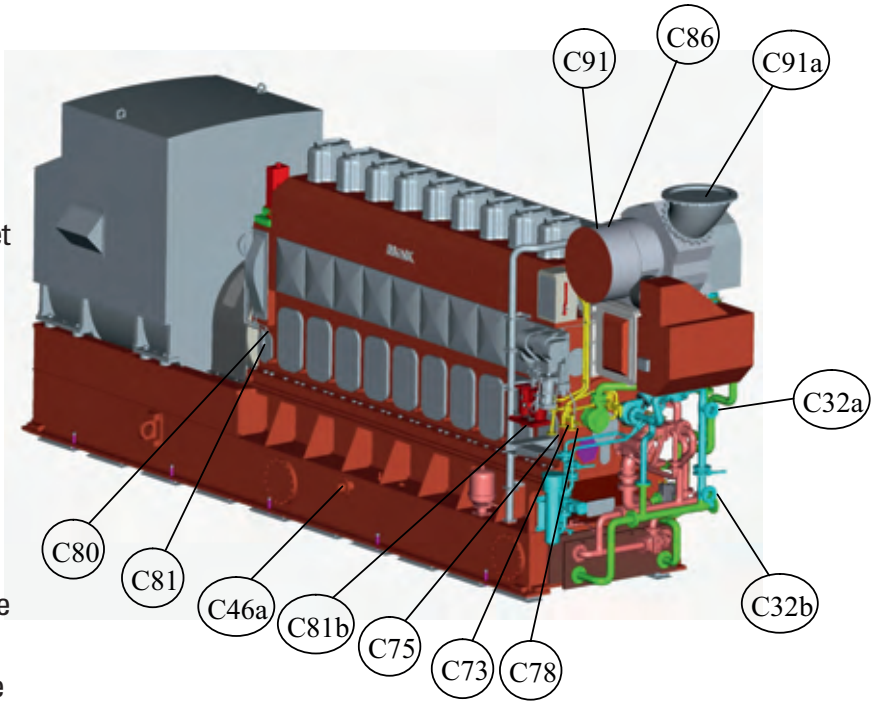


Cooling Water

C19 Cooling water outlet oilcooler
C22 Freshwater pump LT, inlet
C28 Freshwater pump LT, outlet
C32a/b Outlet/inlet heat recovery
C37 Ventilation connection

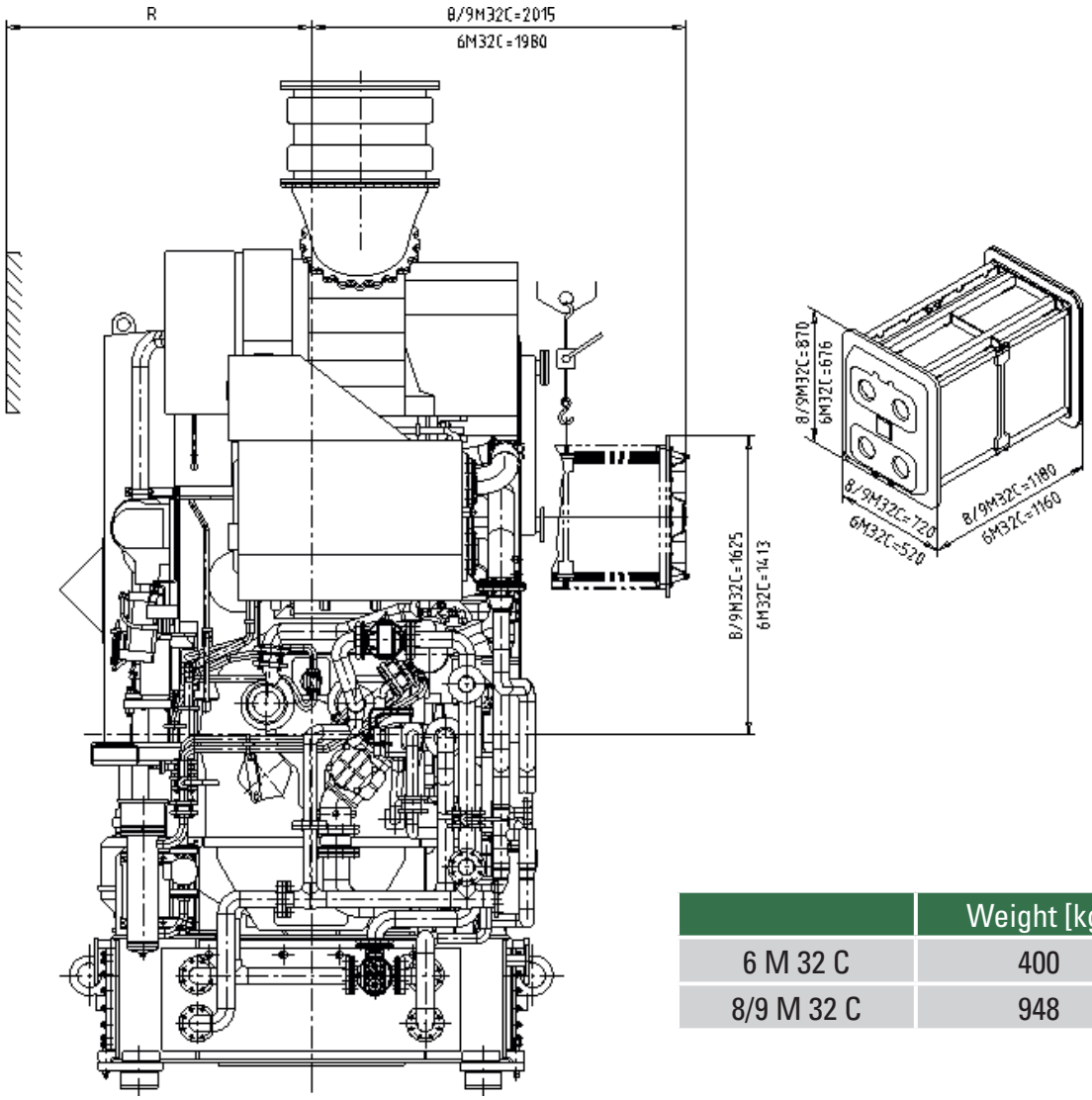
Lubricating oil

C46a Suction side, stand-by force pump
C58 Force pump, delivery side
C60 Separator, suction side
C61 Separator, delivery side
C65 Lube oil, filling socket
C91 Crankcase ventilation



5. Installation and Arrangement

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



	Weight [kg]
6 M 32 C	400
8/9 M 32 C	948

Charge air cooler cleaning

Cleaning is carried out with charge air cooler dismantled. A container to receive the cooler and cleaning liquid is to be supplied by the **yard.** Intensive cleaning is achieved by using ultra sonic vibrators.

Turbocharger dismantling

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

	R [mm]	Weight [kg]
6 M 32 C	850	360
8/9 M 32 C	1,640	815

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 exactly arranged so that the flanges or screw connections do fit without lateral or angular offset. It is recommended to adjust the final position of the pipe connections after engine alignment is completed.

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

Installation of steel compensators

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

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

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 eyhaust 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.

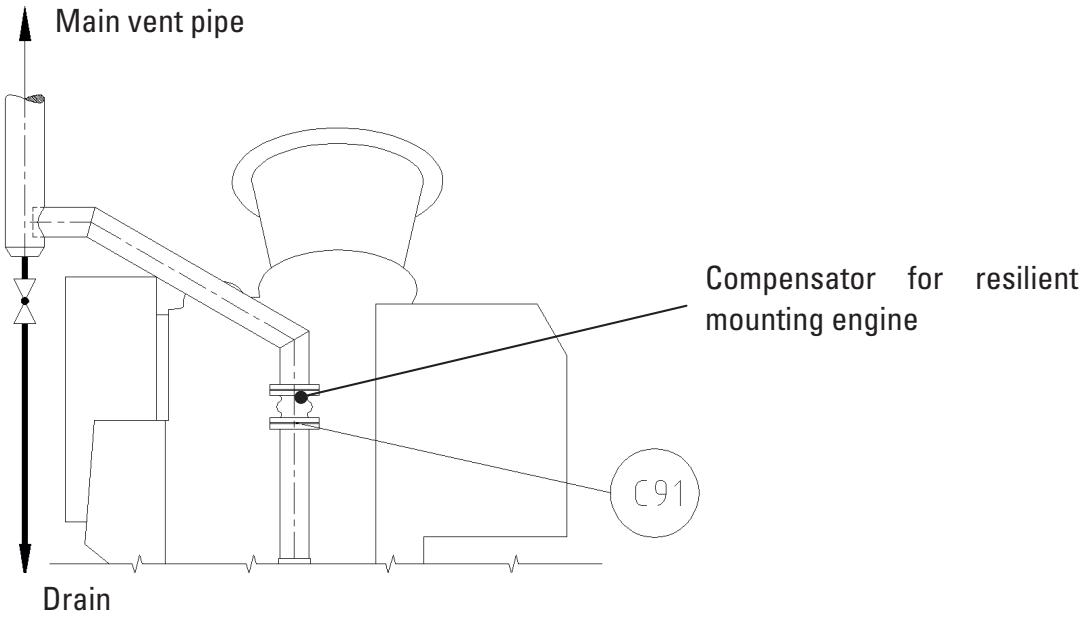
If it should be impossible to use standard transition piece supplied by Caterpillar Motoren, the weight of the transition piece manufactured by the shipyard must not exceed the weight of the standard transition piece. A drawing including the weight will then have to be submitted approval.

5. Installation and Arrangement

5.6 Installation of crankcase ventilation at engine

Please consider for the piping of crankcase ventilation design criteria as follows:

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



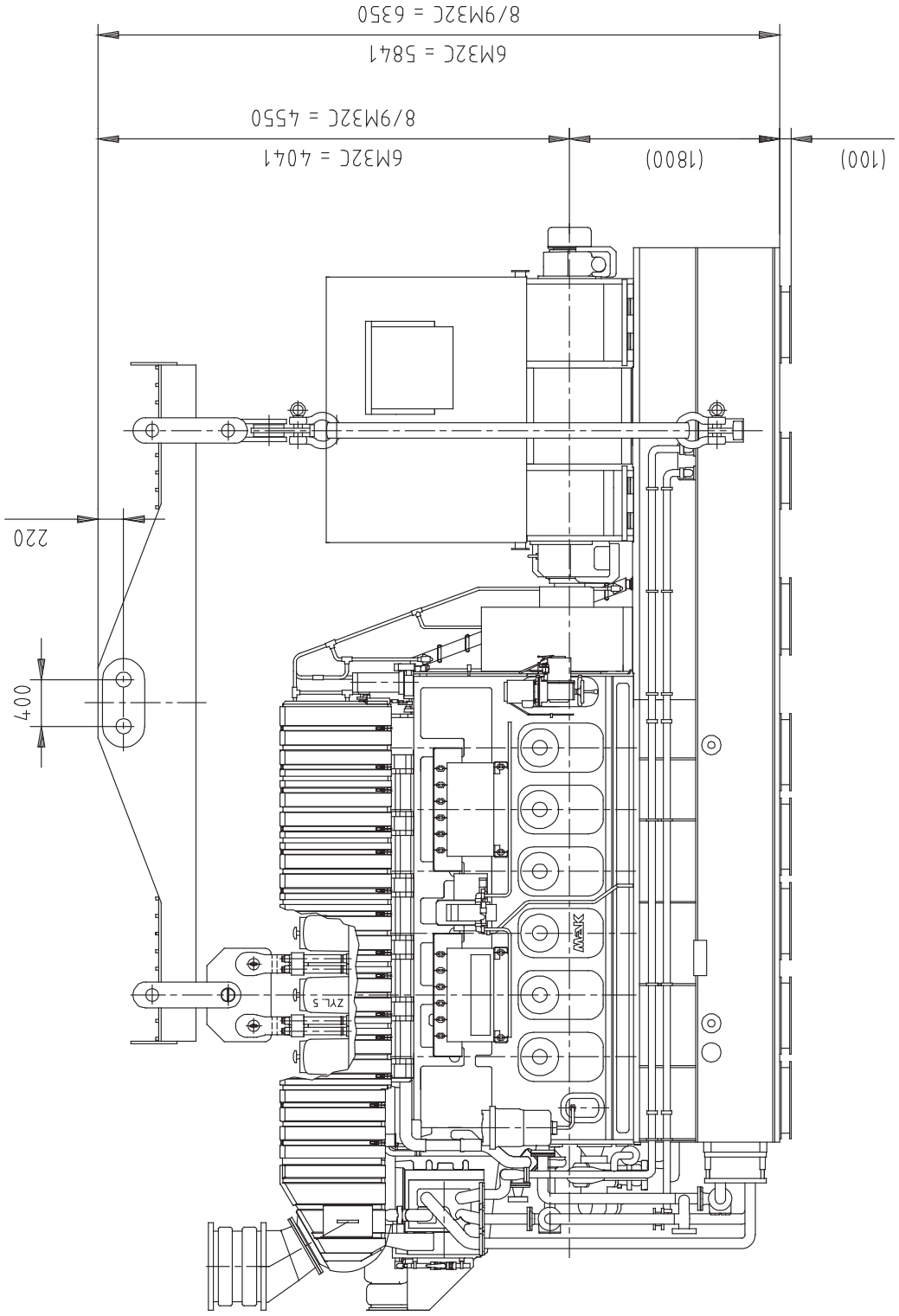
Piping sizes for crankcase ventilation

Engine type	Engine connecting point(s)	Main vent pipe	Collecting vent with lubricating oil circulation tank (observe class rules)
6/8/9 M 32 C	1 x DN 80	1 x DN 100	DN 125

5. Installation and Arrangement

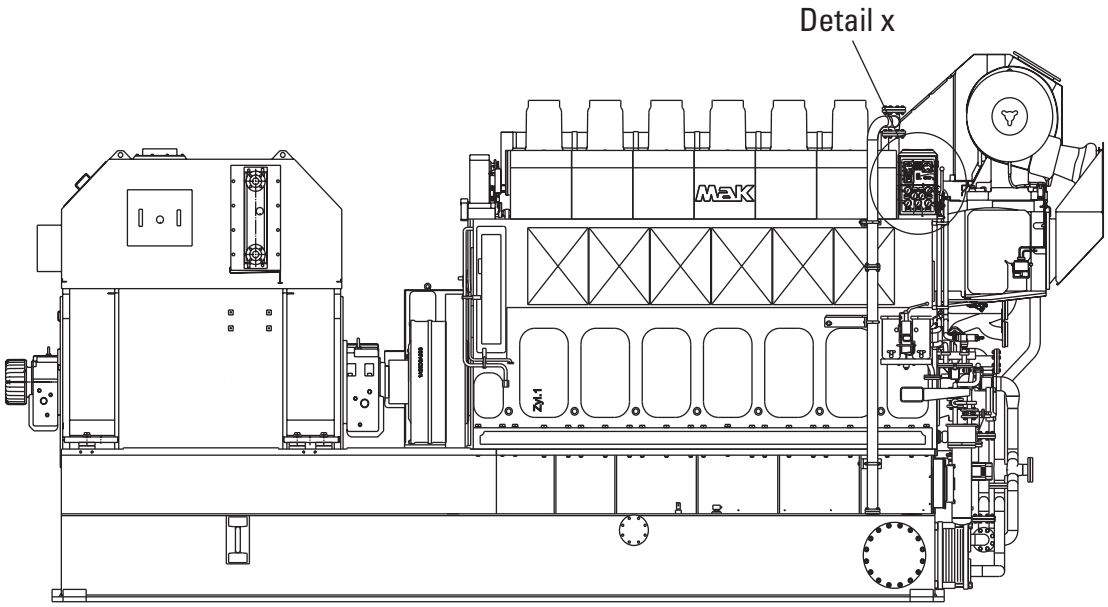
5.7 Lifting of engines

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.

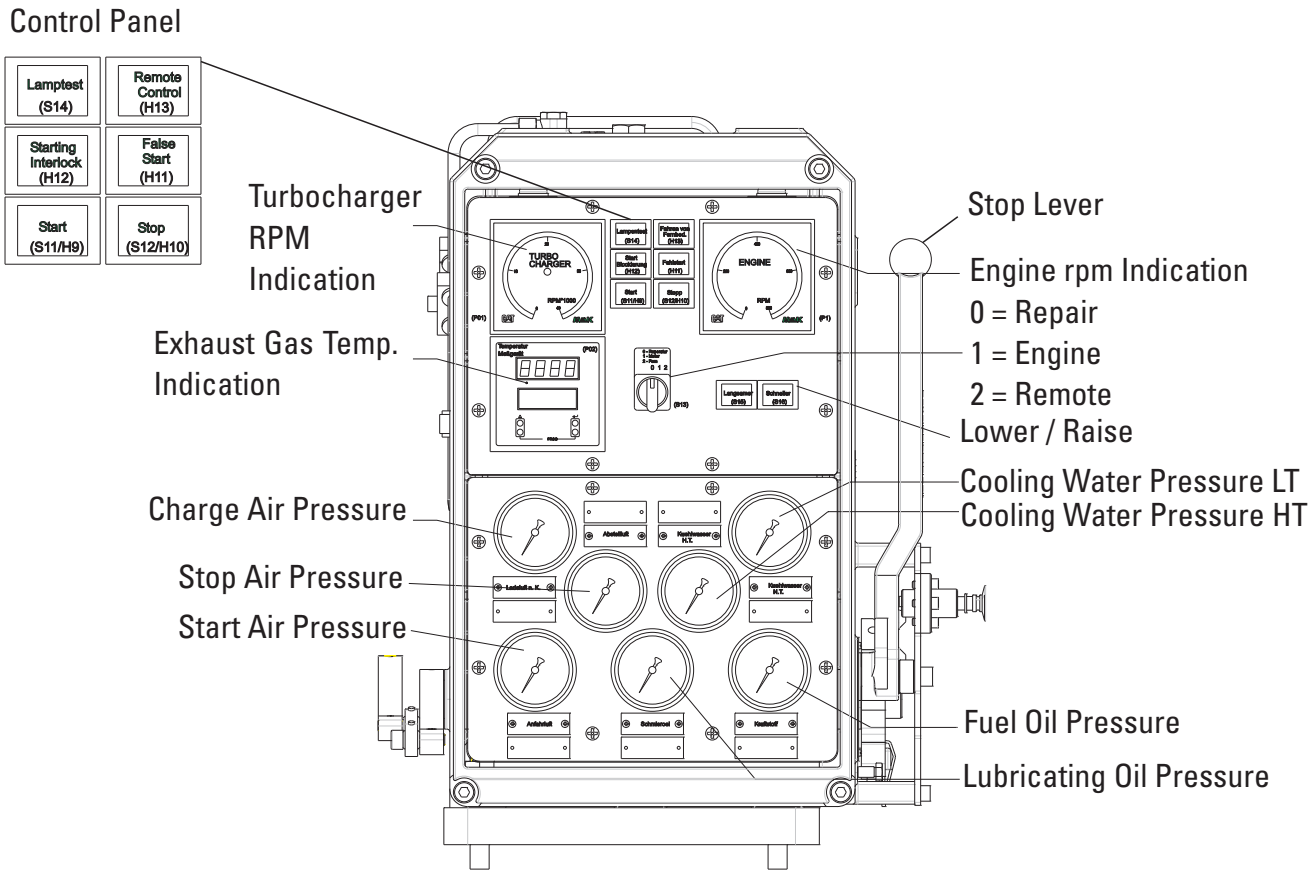


6. Control and monitoring system

6.1 Engine control panel

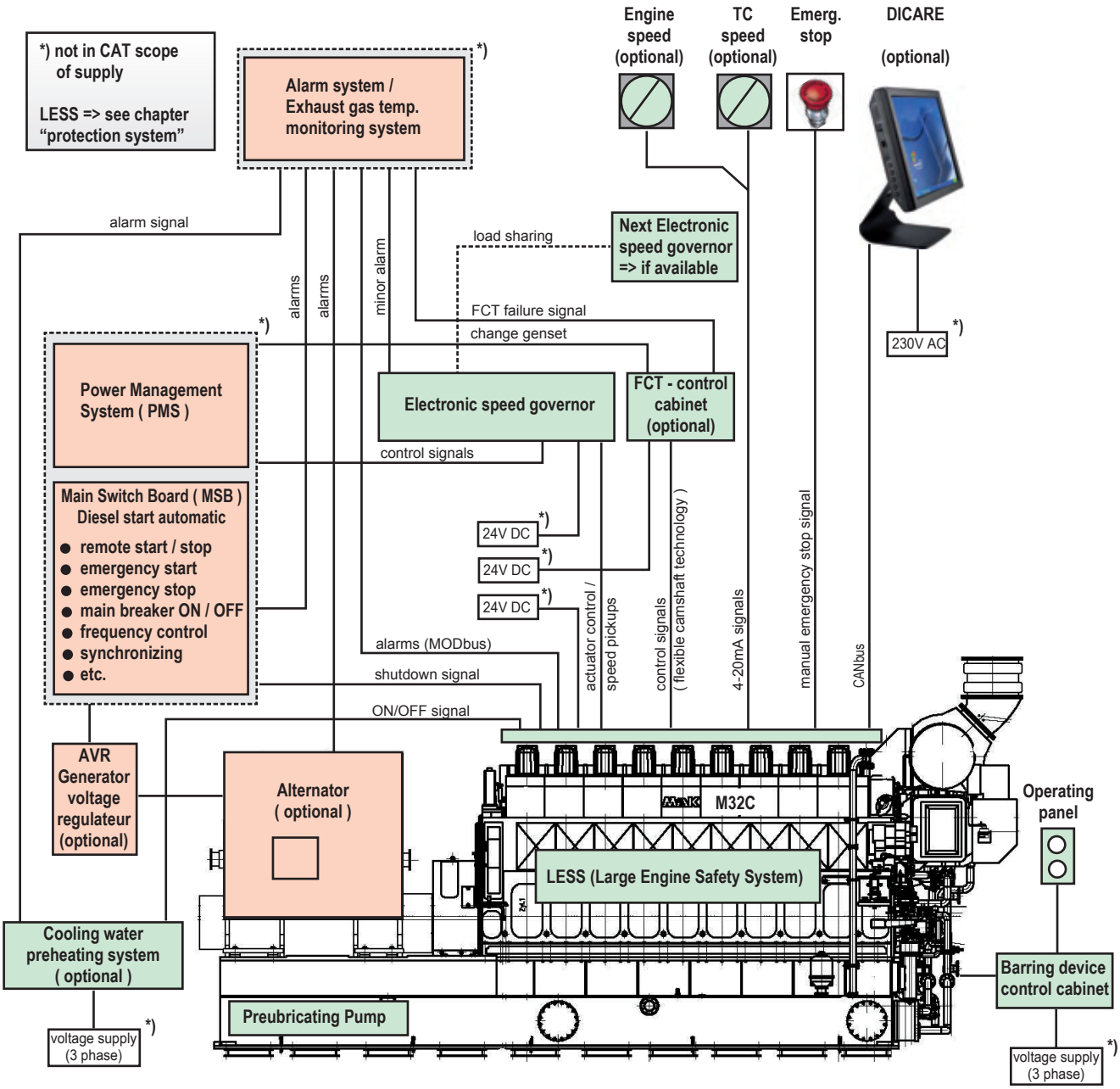


Detail x: Equipment for local engine control



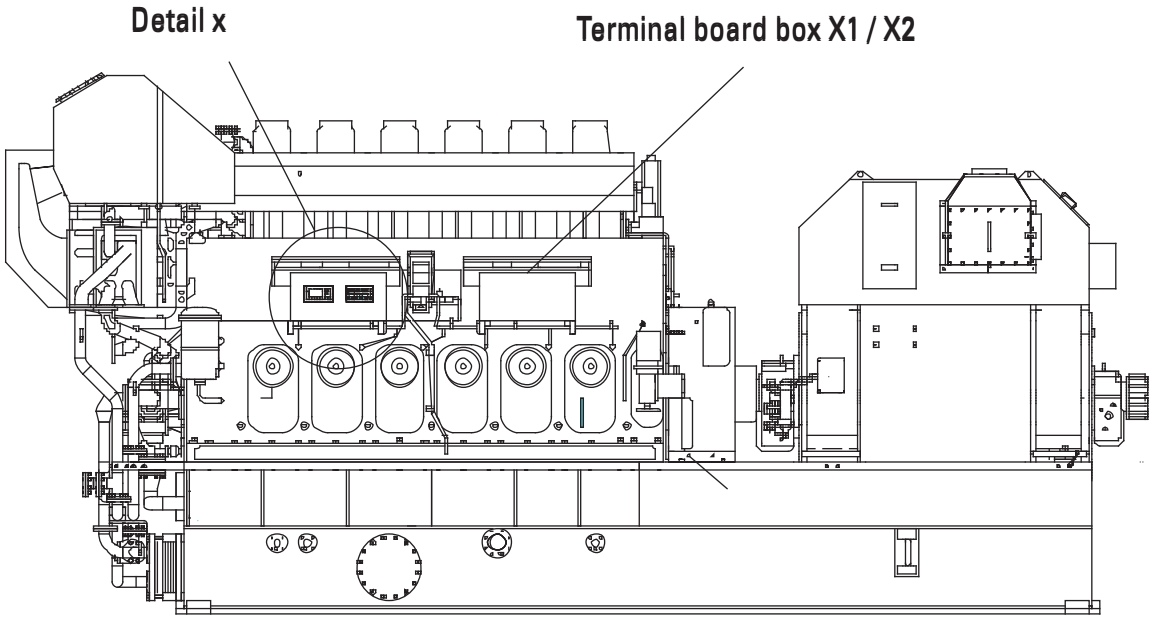
6. Control and monitoring system

6.2 Genset control

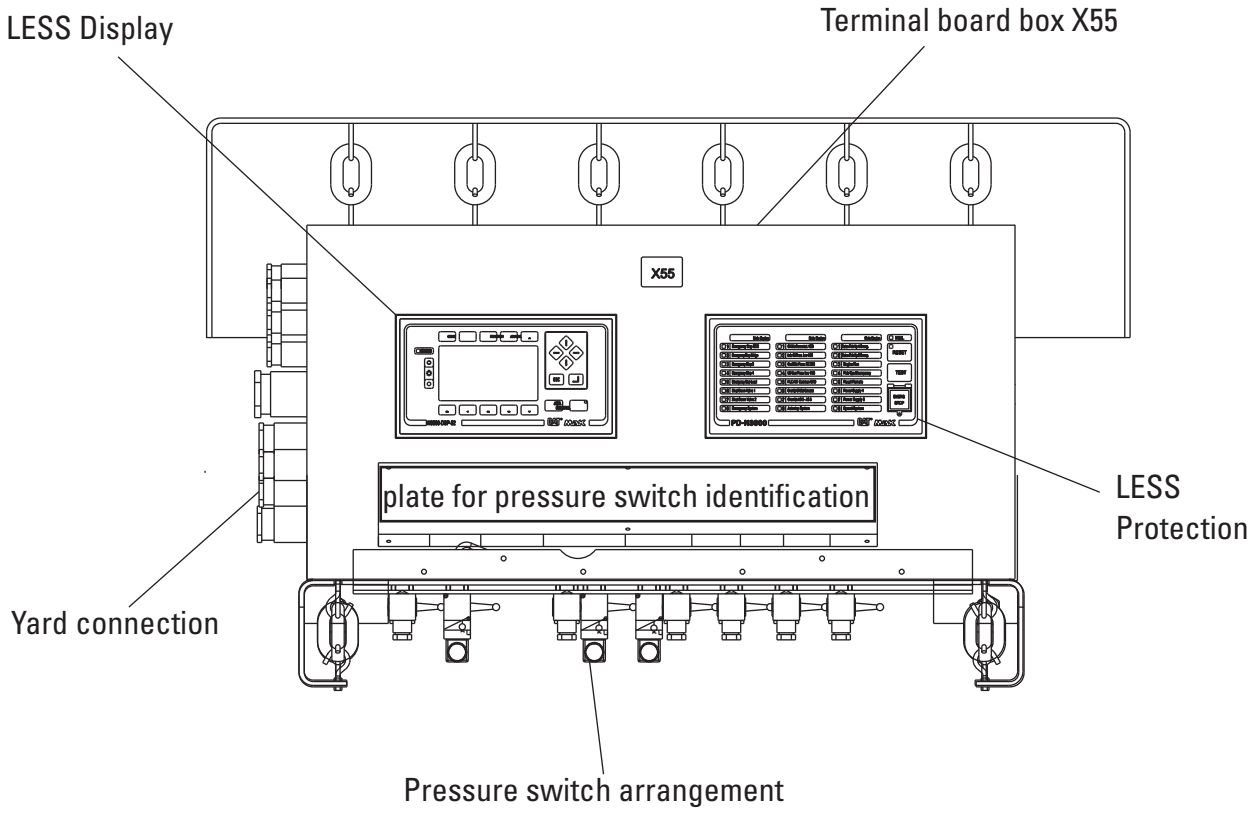


6. Control and monitoring system

6.3 Engine monitoring



Detail x: Arrangement of terminal board box X55 / pressure switch



6. Control and monitoring system

6.4 Measuring points

Meas. Point MODbus-Address	Description	Sensor range	Remarks
1102 **1105** 30009	**1102** Lube oil pressure low - pre alarm shut down **1105** Lube oil pressure low - pre alarm shut down / DICARE	4-20 mA	**1102** Activated at n > n full load 1 sensor 1102 + 1105
1103 11195	Lube oil pressure low - shut down	binary	Activated at n > n full load
1106 10113	Lube oil pressure low - shut down	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	1 evaluation unit for 1112.1/.2 Only existing, when automatic filter is mounted on engine
1142 10116	Pre lube oil pressure low - start interlock	binary	
1202 30010	Lube oil temperature at engine inlet high - alarm	PT 100	
1203 30119	Lube oil temperature at engine inlet high - shut down	PT 100	
1251 10046 **1251.1** 10001 **1251.2** **1253** 10112 **9631** 10047	Oil mist detector VN115787 Plus **1251** Oil mist concentration in crankcase high - alarm **1251.1** Oil mist concentration in crankcase high - pre alarm **1251.2** Opacity **1253** Oil mist concentration in crankcase high - shut down **9631** Oil mist detector failure - alarm	 **1251:** binary **1251.1:** binary **1251.2:** 4-20mA **1253:** binary **9631:** binary	1 evaluation unit for 1251, 1253, 9631 **1251.1** (70 % from **1251**)
1311 10034	Lube oil level low - alarm	binary	
1312 10035	Lube oil level high - alarm	binary	
2102 30246	Cooling water pressure HT at engine inlet low - alarm	4-20 mA	* 40 kPa below operating pressure
2103 30246	Cooling water pressure HT at engine inlet low - shut down	binary	* 60 kPa below operating pressure stop delay: 20s
2112 30250	Cooling water pressure LT at engine outlet low - alarm	4-20 mA	* 40 kPa below operating pressure
2201 30013	Cooling water temperature HT at engine inlet low - alarm	PT 100	

6. Control and monitoring system

Meas. Point MODbus-Address	Description	Sensor range	Remarks
2211 30014	Cooling water temperature HT at engine outlet high - alarm	PT 100	
2213 30120	Cooling water temperature HT at engine outlet high - shut down	PT 100	
2229 30015	Cooling water temperature LT at engine inlet high - alarm	PT 100	
2321	Oil ingress in fresh water at cooler outlet - alarm	binary	Option for DE-drive only external signal
5102 30021	Fuel oil pressure at engine inlet low - alarm	4-20 mA	
5105	Fuel oil pressure at pressure pump low - alarm	binary	Starting stand-by pump from pump control
5111 10036	Differential pressure fuel oil filter high - alarm	binary	
5112	Fuel oil differential pressure at fuel oil filter high - alarm	binary	External signal
5115	Fuel oil differential pressure at automatic fuel oil filter low	binary	Starting stand-by pump from pump control, external signal
5116	Fuel oil differential pressure at circulating pump low - alarm	binary	
5201/5202* 30022	**5201** Fuel oil temperature at engine inlet low - alarm **5202** Fuel oil temperature at engine inlet high - alarm	PT 100	1 sensor for 5201 + 5202* * Not in use with HFO
5206 30090	Fuel oil temperature after viscomat - DICARE	PT 100	External sensor
5251/5252	**5251** Fuel oil viscosity at engine inlet high - alarm **5252** Fuel oil viscosity at engine inlet low - alarm	binary	1 sensor for 5251 + 5252 External signal
5253 30089	Fuel oil viscosity at viscomat - DICARE	4-20 mA	Only if DICARE is available External signal
5301 10003	Leakage oil niveau at engine high - alarm	binary	
5333	Fuel oil level mixing tank low - alarm	binary	in use with HFO External signal
6101 30032	Starting air at engine inlet low - alarm	4-20 mA	
6105 10048	Stopping air pressure at engine low - alarm	binary	Alarm delay: 2s
6181 30019	Intake air pressure in engine room - DICARE	4-20 mA	Only for DICARE

6. Control and monitoring system

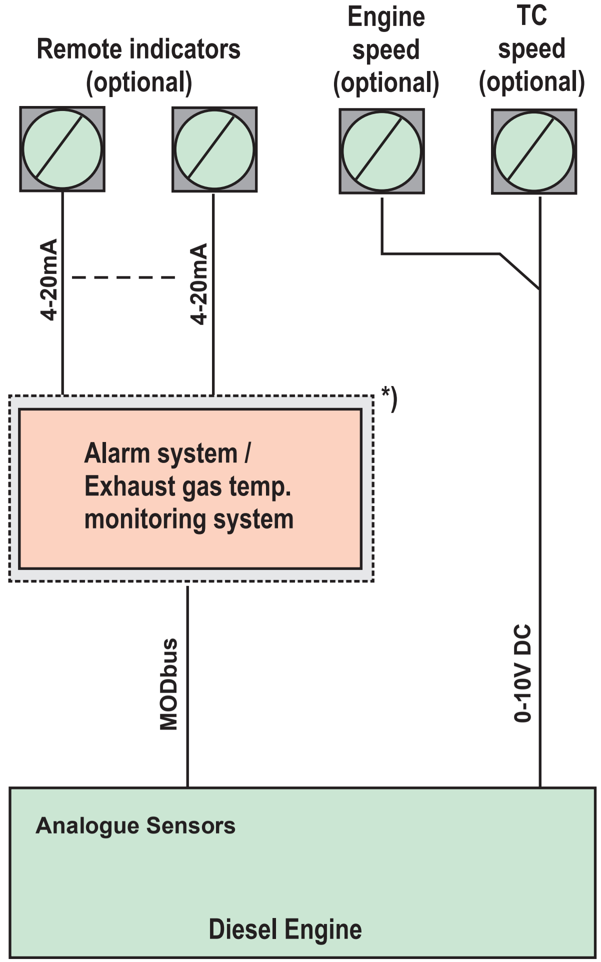
Meas. Point MODbus-Address	Description	Sensor range	Remarks
7109 30248	Charge air pressure at engine inlet - Indication	4-20 mA	4-20 mA for FCT
7201 30016	Charge air temperature at engine inlet high - alarm	PT 100	
7206 30020	Intake air temperature at turbocharger inlet - DICARE	PT 100	
7301 10004	Condense water in charge air canal high	binary	
7307 30018	Charge air diff. pressure at charge air cooler - DICARE	4-20 mA	Only for DICARE
7309 30087	Charge air temperature at charge air cooler inlet - DICARE	NiCr-Ni (mV)	Only for DICARE
8211.1 30073	Exhaust gas temperature after cylinder 1 high high - shut down	NiCr-Ni (mV)	Load depended alarm with delay: 16 seconds
8211.2 30074	Exhaust gas temperature after cylinder 2 high high - shut down	ONiCr-Ni (mV)	Load depended alarm with delay: 16 seconds
8211.3 30075	Exhaust gas temperature after cylinder 3 high high - shut down	NiCr-Ni (mV)	Load depended alarm with delay: 16 seconds
8211.4 30076	Exhaust gas temperature after cylinder 4 high high - shut down	NiCr-Ni (mV)	Load depended alarm with delay: 16 seconds
8211.5 30077	Exhaust gas temperature after cylinder 5 high high - shut down	NiCr-Ni (mV)	Load depended alarm with delay: 16 seconds
8211.6 30078	Exhaust gas temperature after cylinder 6 high high - shut down	NiCr-Ni (mV)	Load depended alarm with delay: 16 seconds
8211.7 30079	Exhaust gas temperature after cylinder 7 high high - shut down	NiCr-Ni (mV)	Load depended alarm with delay: 16 seconds
8211.8 30080	Exhaust gas temperature after cylinder 8 high high - shut down	NiCr-Ni (mV)	Load depended alarm with delay: 16 seconds
8211.9 30081	Exhaust gas temperature after cylinder 9 high high - shut down	NiCr-Ni (mV)	Load depended alarm with delay: 16 seconds
8221 30082	Exhaust gas temperature at turbocharger outlet high high - shut down	NiCr-Ni (mV)	Load depended alarm with delay: 16 seconds
8231 30083	Exhaust gas temperature at turbocharger inlet - alarm	NiCr-Ni (mV)	
9404	Overspeed - alarm	binary	1,15 x n rated
9409	Engine running signal	binary	For working hour meter
9419 30050	Engine speed signal	4-20 mA	586,7 Hz = 0-800 rpm FCT

6. Control and monitoring system

Meas. Point MODbus-Address	Description	Sensor range	Remarks
9429 30042	Turbine speed high - alarm* Turbine speed - Indication	4-20 mA / 0-10 V	*DNV 4-20 mA for FCT
9503 10222	Control lever at fuel rack - stop position	binary	
9509 30031	Fuel rack signal (engine load)	4-20 mA	
9561 10117	Turning gear engaged - starting interlock	binary	
9602 10005	CANbus failure - alarm	binary	
9615	Failure electronic speed governor MINOR-alarm	binary	With electronic speed governor only, external signal
9616	Failure electronic speed governor MAJOR-alarm	binary	With electronic speed governor only, external signal
9671.1	Automatic stop failure - alarm	binary	
9671.2	Overspeed failure - alarm	binary	
9671.3	Emergency stop failure - alarm	binary	
9674	Auto stop / PLC A01 common - shut down	binary	
9675	Emergency stop - alarm	binary	
9717	Voltage failure terminal set X55 (engine control)	binary	
9751	Voltage failure temperature controller	binary	Depending of system application, external signal
9761	Voltage failure fuel oil viscosity controller	binary	Depending of system application, external signal
9771	Voltage failure fresh water pre heater	binary	Depending of system application, external signal
9775	Voltage failure fuel oil pre heater	binary	Depending of system application, external signal
9836.1 10107	Sensor / isolation fault A01.1 - alarm	binary	
9836.2 10007	Sensor / isolation fault A03.1 - alarm	binary	
9962.1 30108	Common alarm A01.1 - alarm	binary	
9962.2 30008	Common alarm A03.1 - alarm	binary	

6. Control and monitoring system

6.5 Local and remote indicators



*) optinally in Caterpillar Motoren 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 at 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 CANbus to DICARE-PC (optional)
- Exhaust gas temperature mean value system (optional)

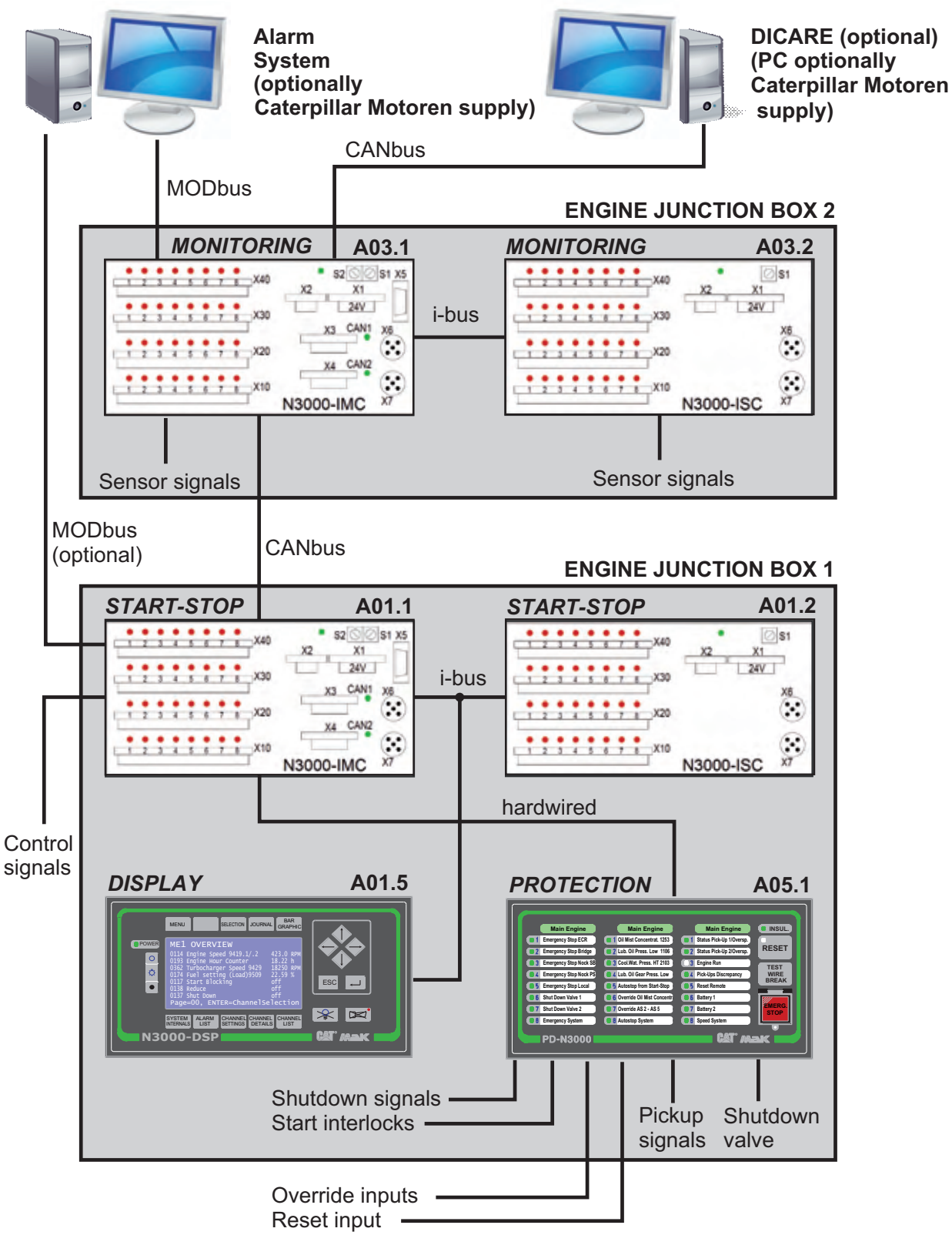
System data

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

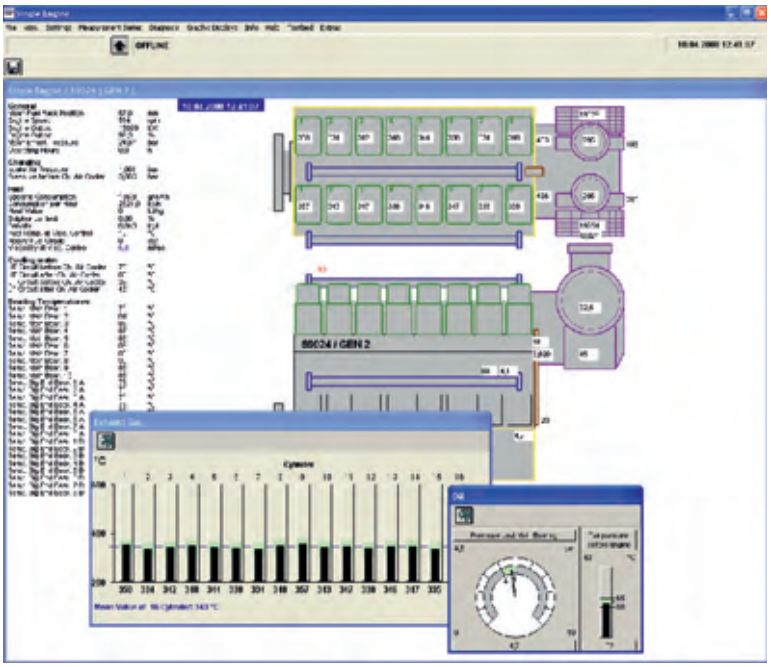


7. Diagnostic trending monitoring - DICARE

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 trending monitoring - DICARE

Transmitter for DICARE ON-LINE M 32 C CANbus

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 **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 series 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 < 1000 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 made for each engine. This Technical File contains information about the components affecting NO_x emissions, and each critical component is marked with a special IMO number. Such critical components are piston, cylinder head, injection nozzle (element), camshaft section, fuel injection pump, turbocharger and charge air cooler. (For Common Rail engines the controller and the software are defined as NO_x relevant components instead of the injection pump.) The allowable setting values and parameters for running the engine are also specified in the Technical File.

The marked components can 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
Up to 1 year, engine protected from moisture.
- Main running gear and internal mechanics

Outside preservation

N 576-3.1 - Tectyl light
Europe
Storage in the open, protected from moisture, up to 1 year

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 576-3.2 - Tectyl heavy-duty
Overseas
Storage in the open, protected from moisture, up to 1 year

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

VCI packaging as per N 576-5.2 is always required!
Durability and effectiveness are dependent on proper packing, transportation, and storage, i.e. the engine must be protected from moisture, the VCI foil must not be torn or destroyed.
Checks are to be carried out at regular intervals.
If the above requirements are not met, all warranty claims in connection with corrosion damages shall be excluded.

10. Painting/Preservation

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 with light preservation

N 576-4.3 - Painting
- No VCI packaging:
  Short-term storage in the open, protected from moisture, max. 4 weeks
- With VCI packaging:
  Storage in the open, protected from moisture, up to 1 year

Appearance of the engine:
- Surfaces mostly painted with varnish
- Bare metal surfaces provided with light or heavy-duty preservation

N 576-5.2 - VCI packaging
Storage in the open, protected from moisture, up to 1 year.
Applies for engines with painting as per application groups N 576-4.1 to -4.4
Does not apply for engines with Tectyl outside preservation as per application groups N 576-3.1 and -3.2.

Description:
- Engine completely wrapped in VCI air cushion foil, with inserted VCI-impregnated flexible PU-foam mats.

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.

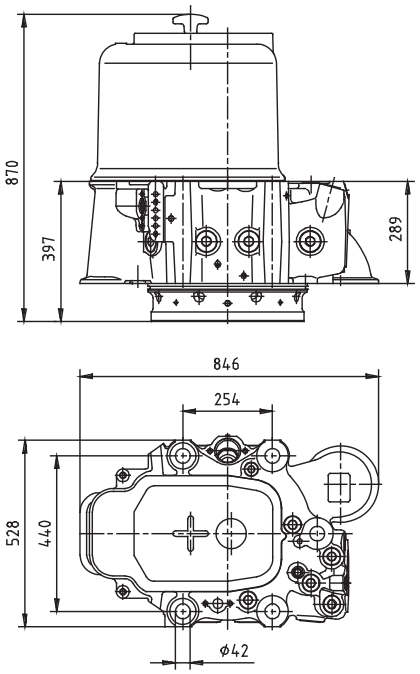
Description:
- This panel provides information on the kind of initial preservation and instructions for inspection.
- Arranged on the transport frame on each side so as to be easily visible.

N 576-6.1 - Corrosion Protection Period, Check, and Represervation
Applies to all engines with inside and outside storage

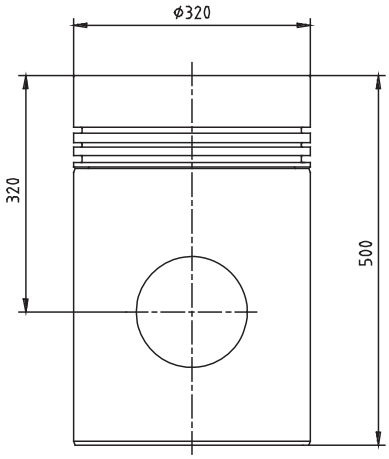
Description:
- Definitions of corrosion protection period, check, and represervation

11. Engine parts

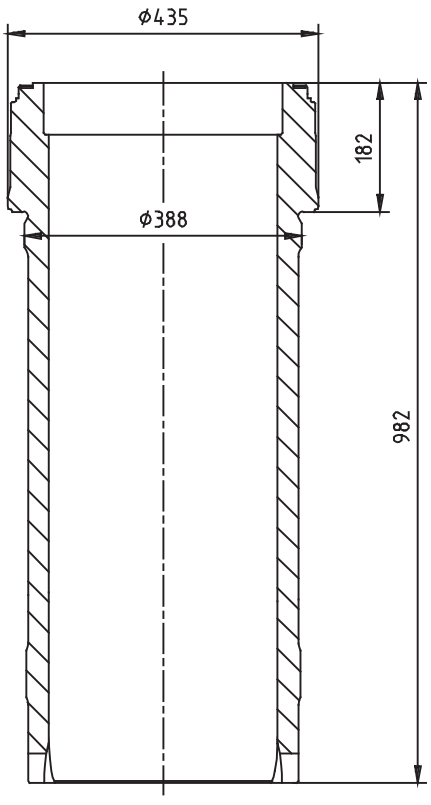
Cylinder head, Weight 315 kg



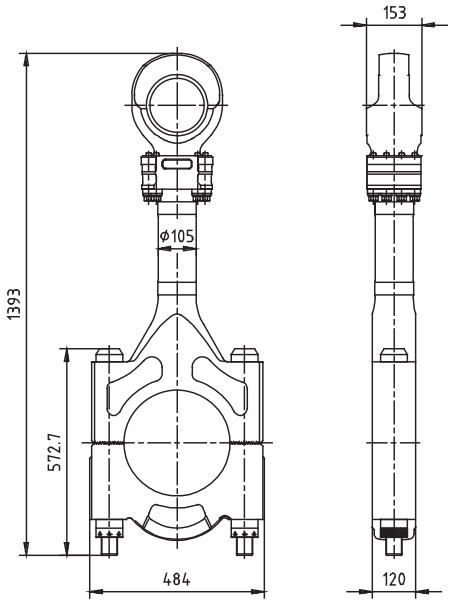
Piston, Weight 150 kg



Cylinder liner, Weight 280 kg

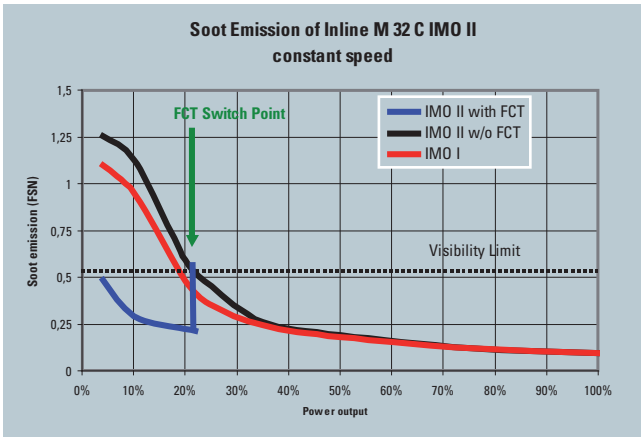


Connecting rod, Weight 236 kg

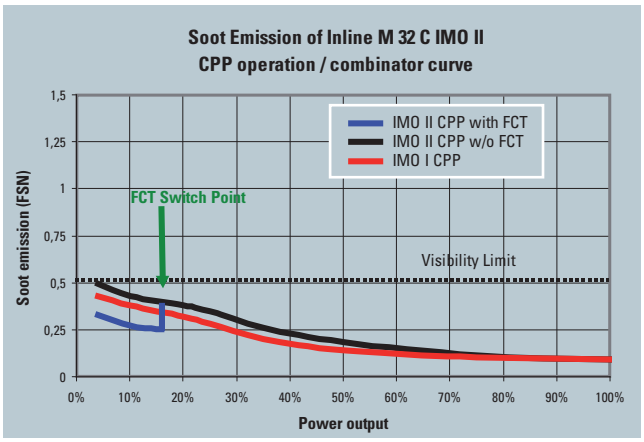


12. Flexible Camshaft Technology - FCT

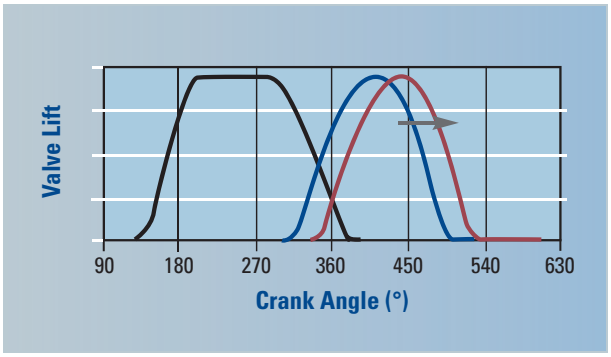
Building upon the Emission Reduction System integration concept, FCT achieves synergy between flexible fuel systems and advanced air systems with maximum utilization of the current engine design. While maintaining high fuel injection pressure over the whole operating range, fuel injection and inlet valve 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.



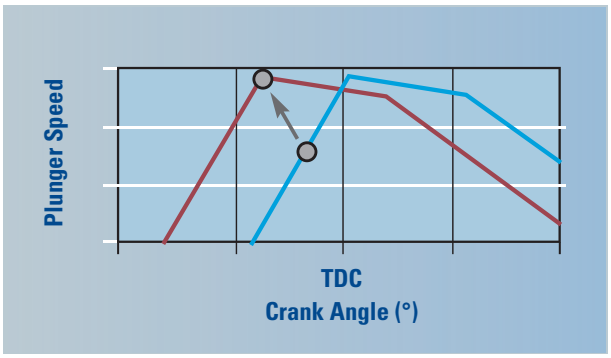
M 32 C constant speed

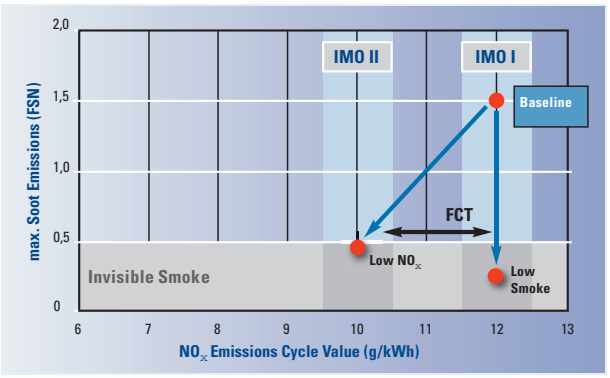


M 32 C CPP/combinator mode



schematic diagram





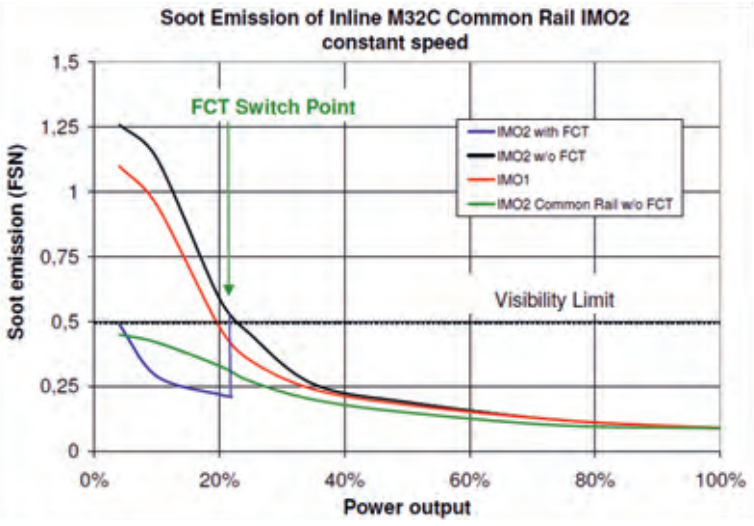
schematic diagram

13. Cat Common Rail

13.1 Fuel System

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

Caterpillar has made a huge investment to develop an emission reduction technology now marketed as ACERT® Technology for Caterpillar high-speed engines. After a successful demonstration in the on-highway high-speed engines, Caterpillar will now embark on a stepwise migration of selected elements of ACERT® Technology across the entire product line and range of applications. The broad range of Caterpillar's marine program calls for a differentiated approach.



13. Cat Common Rail

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

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

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

Keeping in mind the high reliability expectations of customers, Caterpillar decided to adopt a two step approach providing the most effective solutions with lowest complexity.

Flexible Camshaft Technology (FCT) has been developed and put into production. The next milestone in emissions technology is a fully flexible fuel system suitable for HFO, MDO and DO, called the Cat Common Rail (Cat CR) fuel system. Cat Common Rail is considered one major building block towards low emissions, high performance and highest customer value.

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

13.2 Technology

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

The key features of the Cat Common Rail technology are:
- Well adapted injection pressure over the entire engine operating range.
- Fully flexible fuel injection system enabling optimized emissions and engine performance.
- Suitable for HFO, MDO and DO.
- 100% retrofittable system.

13. Cat Common Rail

13.2.1 Cat CR System

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

13.2.2 Safety Concept

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

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

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

13.2.3 High pressure pump

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

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

13.2.4 Rail

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

13. Cat Common Rail

13.2.5 Injector

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

The injector design is simple, robust and compact; the key features are:
- Electronically controlled.
- Flexible injection timing and duration.
- Capability of multi shot injections.

13.2.6 Electronics

The key component is the Caterpillar A4E4 (or ADEM™) Electronic Control Module (ECM). The ECM acts as the brain of the Cat Common Rail fuel system. Pioneered by Caterpillar 20 years ago, the ADEM™ controller coordinates and enhances fuel delivery, air supply and other engine functions to maximize overall performance and reduce emissions output.

Having in-house expertise for core electronic components and software puts Caterpillar in a unique position and allows for an advantageous systems approach.

Based on existing software and engine control strategies, the specific needs of heavy fuel burning engines and applications can be easily adopted. Depending on engine type, application and boundary conditions, a tailor made version allows for optimal operation.

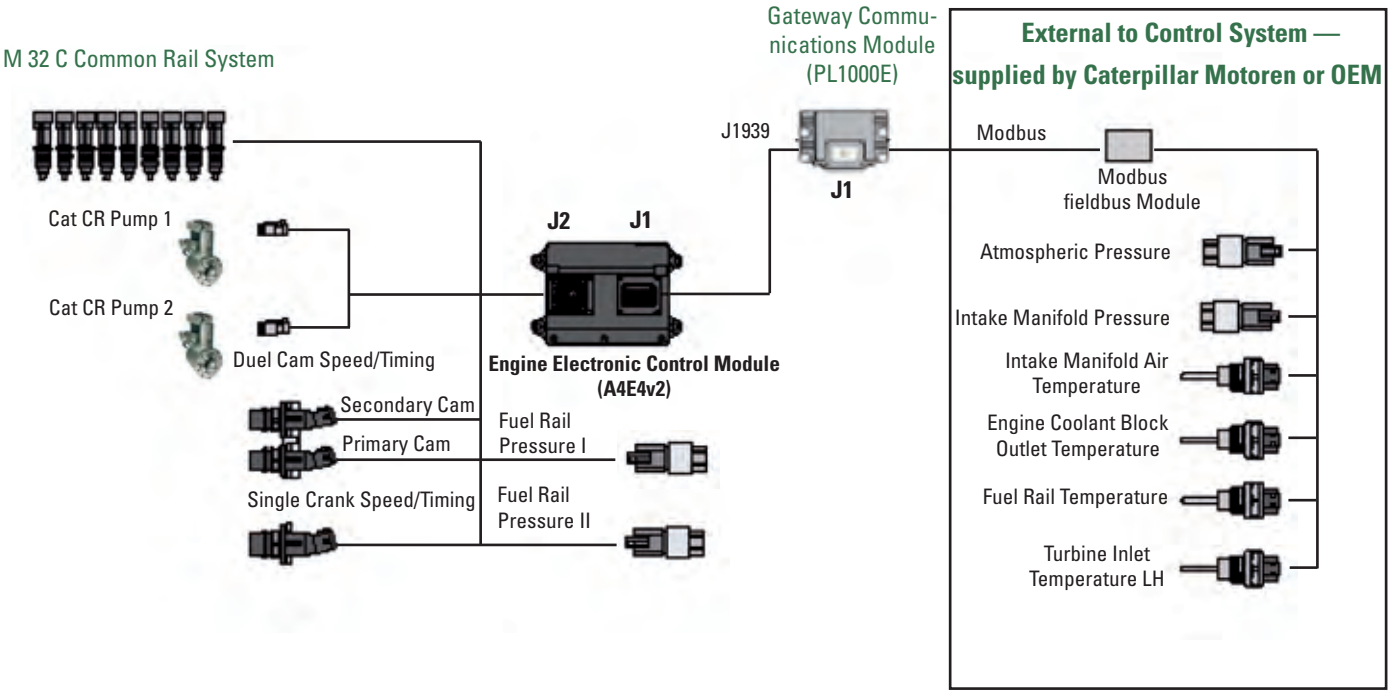
he engine protection system operates independently of the engine control system and has its own independent sensor equipment. This ensures that engine operation is monitored independently of other control systems.

The ECM functions can be divided into a core system and a performance system.

The core system consists of:
- Control device A4E4.
- One crankshaft speed pick-up.
- Two high-pressure sensors.
- Two inlet metering valves
- Injectors.

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

13. Cat Common Rail



13.3 The Benefits

With Cat Common Rail, the injection pressure is independent from load and speed. Utilizing injection maps the injection characteristics are optimized for every engine operating point.

For areas that are especially emissions-sensitive, soot emissions at low engine load remain well below the visibility limit. Furthermore, during normal load operation NO_x emissions can be reduced without sacrificing fuel consumption. In general, the Cat Common Rail fuel system enables vessel operation without visible soot throughout the whole operating range.

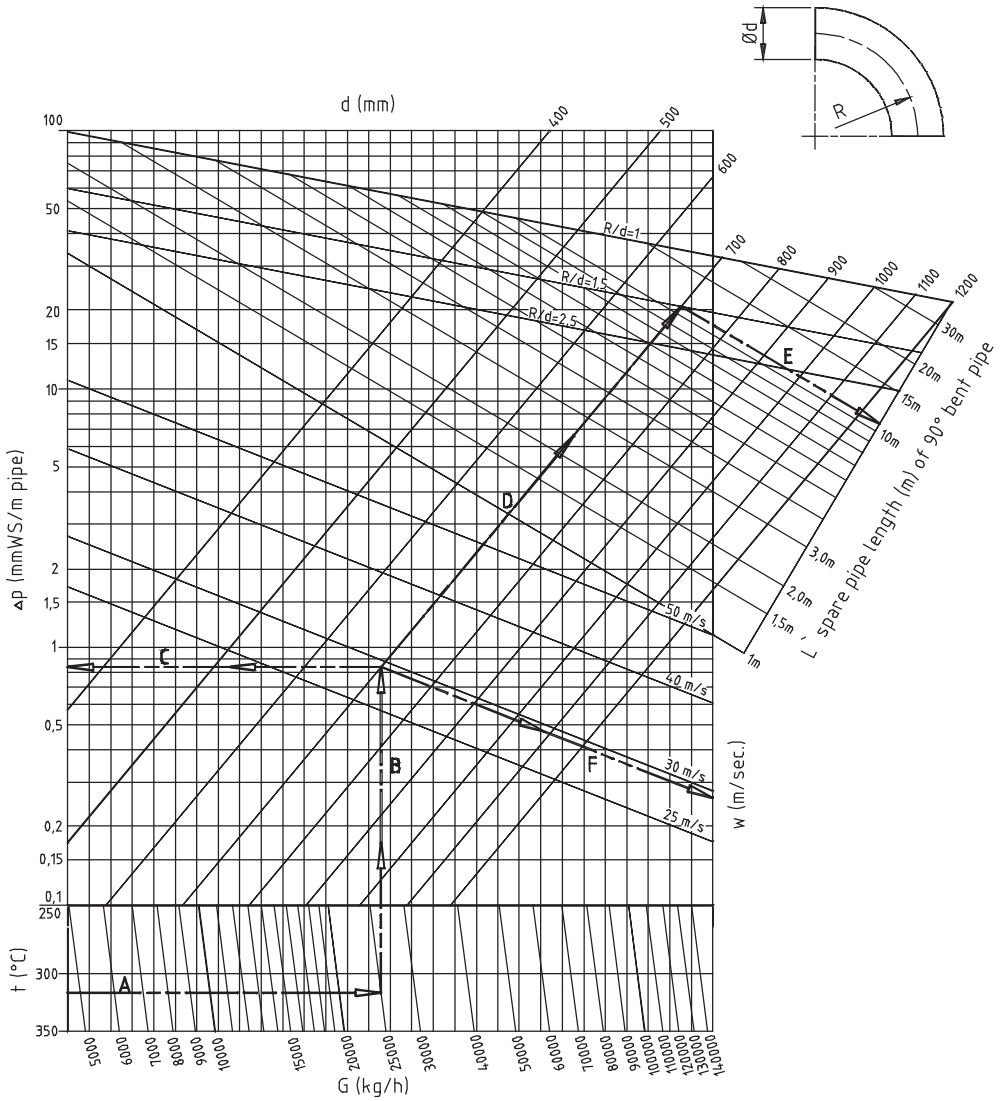
In addition to that, the fuel system is capable of multiple injection. Multiple injection allows for optimal combustion and low emissions at all loads. Characteristic of Cat Common Rail is the approach of using the fuel (whether it's heavy fuel oil, marine diesel oil or diesel oil) as the control fluid for the injector, thus avoiding the added complexity of a separate control fluid system.

During the development, the retrofit aspect of the complete system has been emphasized. As a result, the Cat Common Rail fuel system can be retrofitted to existing M 32 C engines. This means increased customer value to reach future environmental regulations.

14. Appendix

14.1 Exhaust system

14.1.1 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)

14. Appendix

14.1.2 Exhaust data (preliminary)

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 32 C	3,000	21,029	19,267	17,493	15,719	13,610	11,501
		302	300	300	300	315	331
8 M 32 C	4,000	27,345	25,475	23,100	20,477	17,500	14,620
		314	308	300	303	317	332
9 M 32 C	4,500	32,000	29,933	27,865	24,380	21,160	17,940
		307	295	285	285	295	314

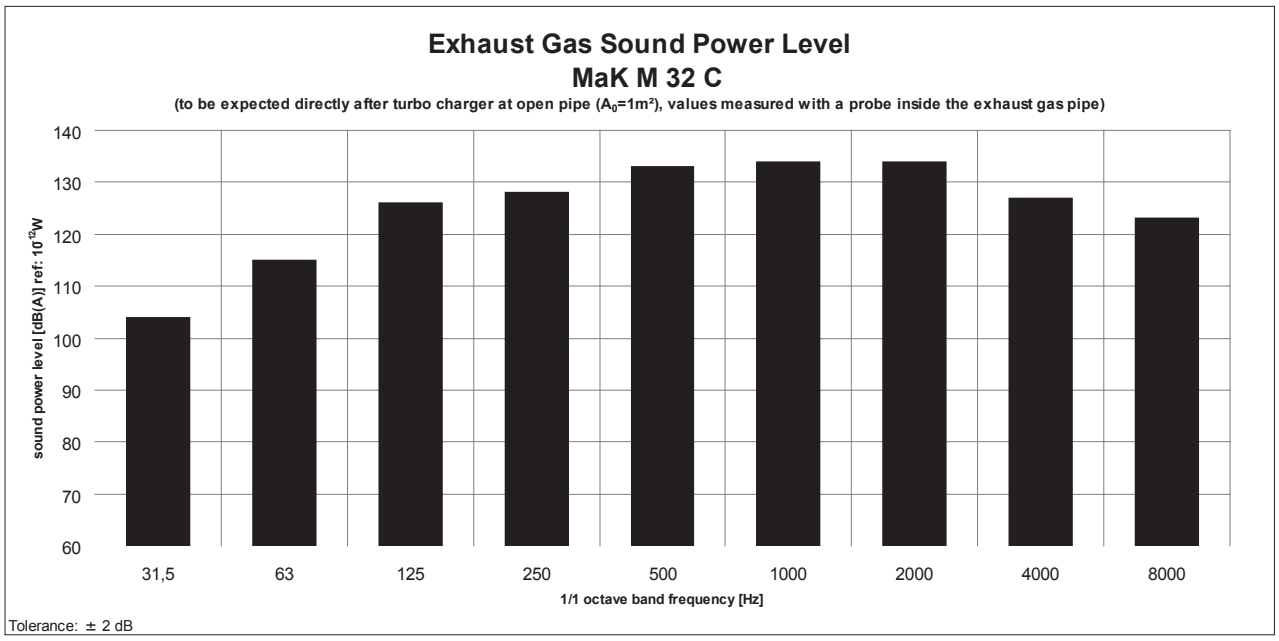
Intake air temperature: 45 °C

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

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

14. Appendix

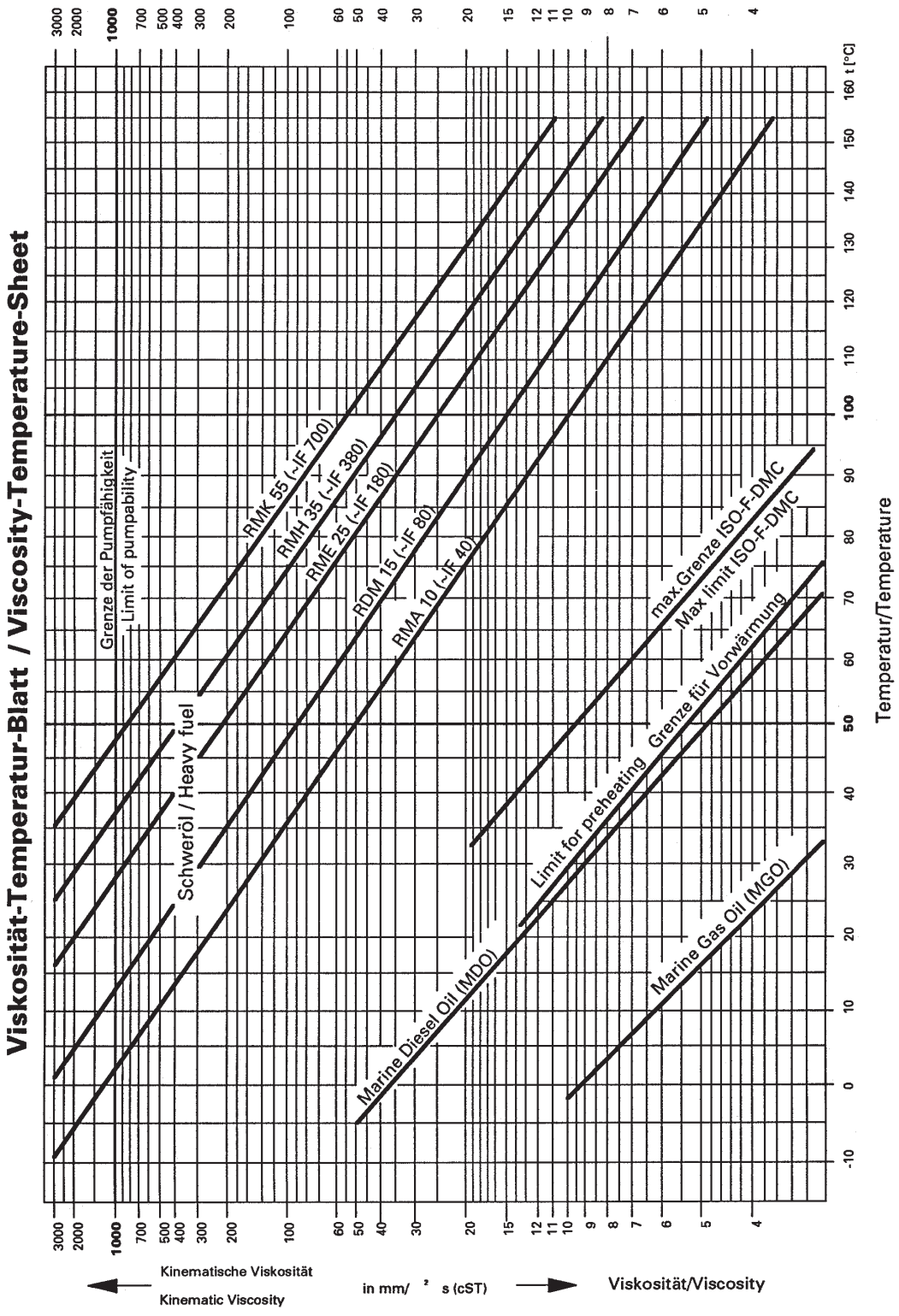
14.1.3 Exhaust gas sound power level



14. Appendix

14.2 Fuel oil system

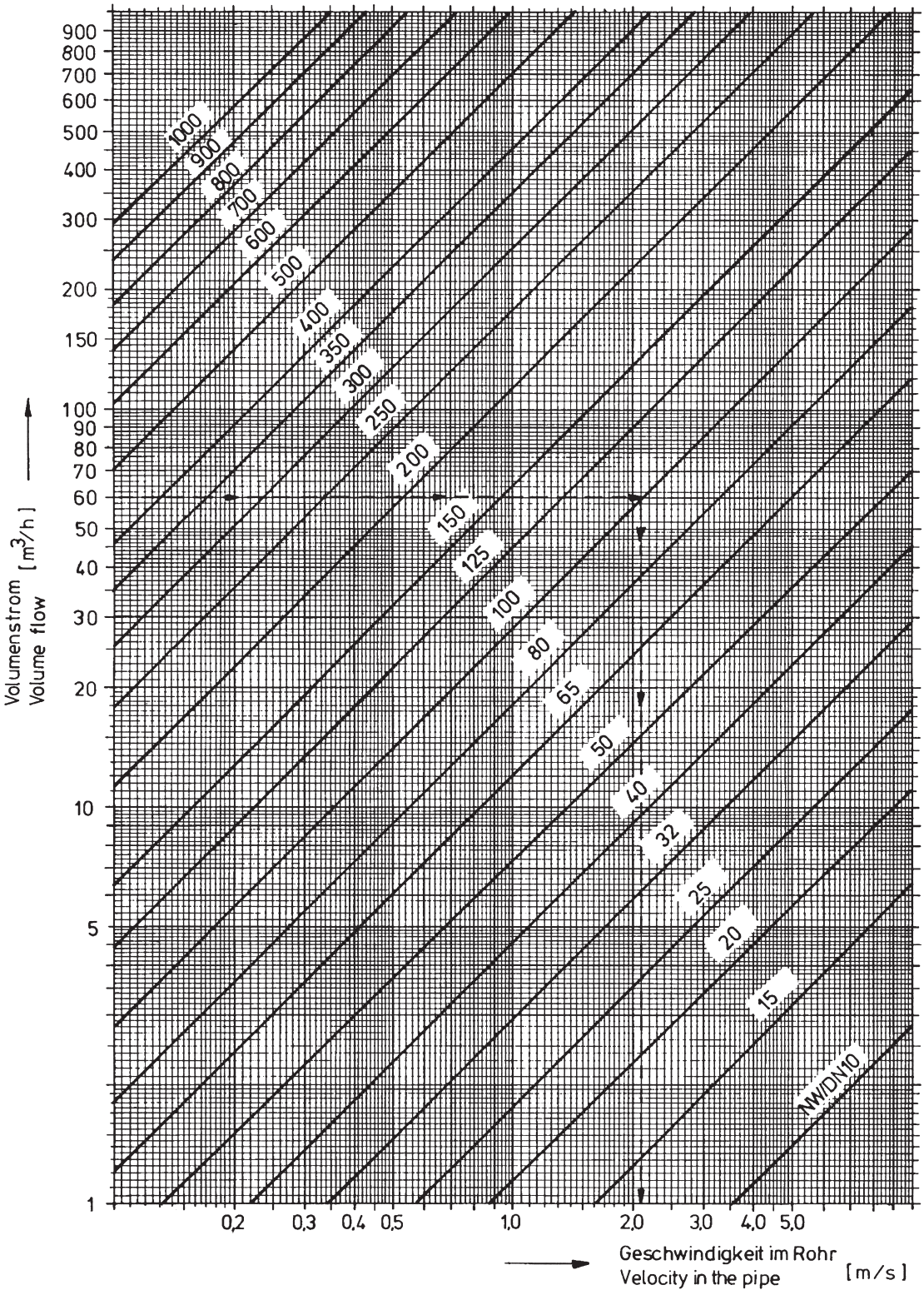
14.2.1 Viscosity/temperature diagram



14. Appendix

14.3 Cooling water system

14.3.1 Flow velocities

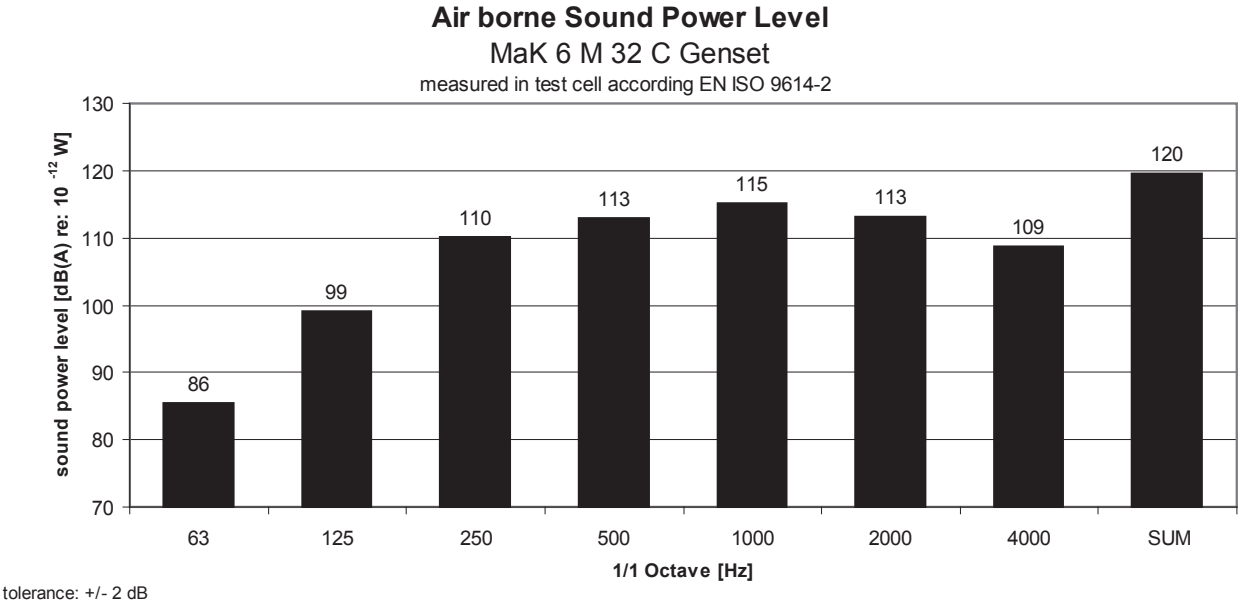


14. Appendix

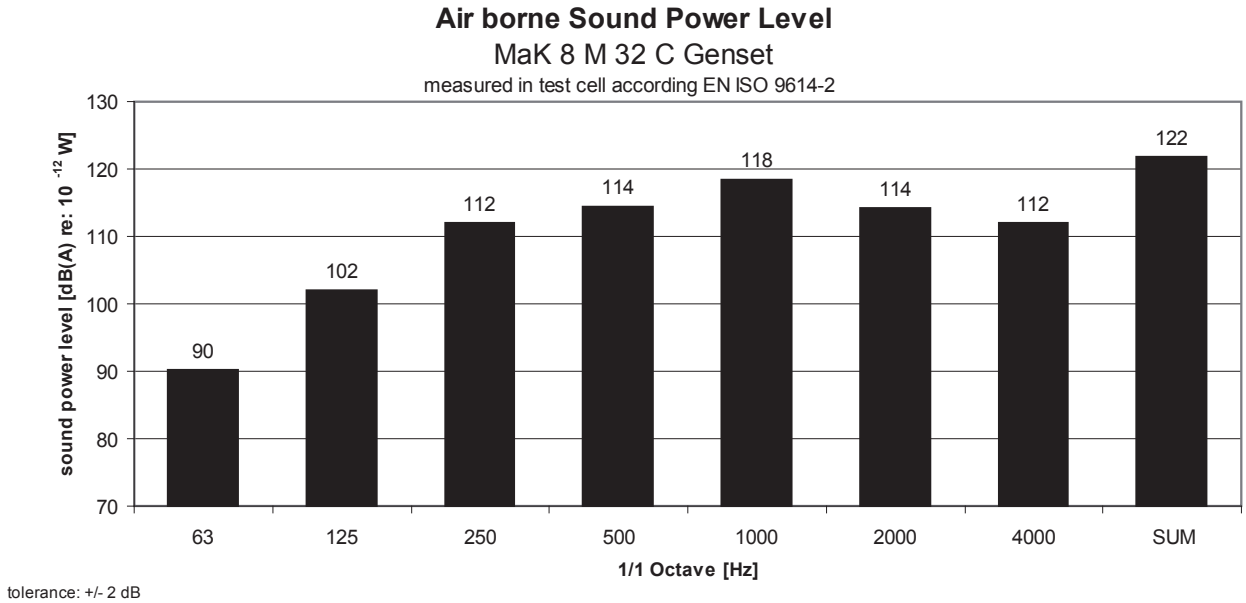
14.4 Air borne sound power level

The air borne sound power level is measured in a test cell according to EN ISO 9614-2.

Noise level for M 32 C engines



tolerance: +/- 2 dB



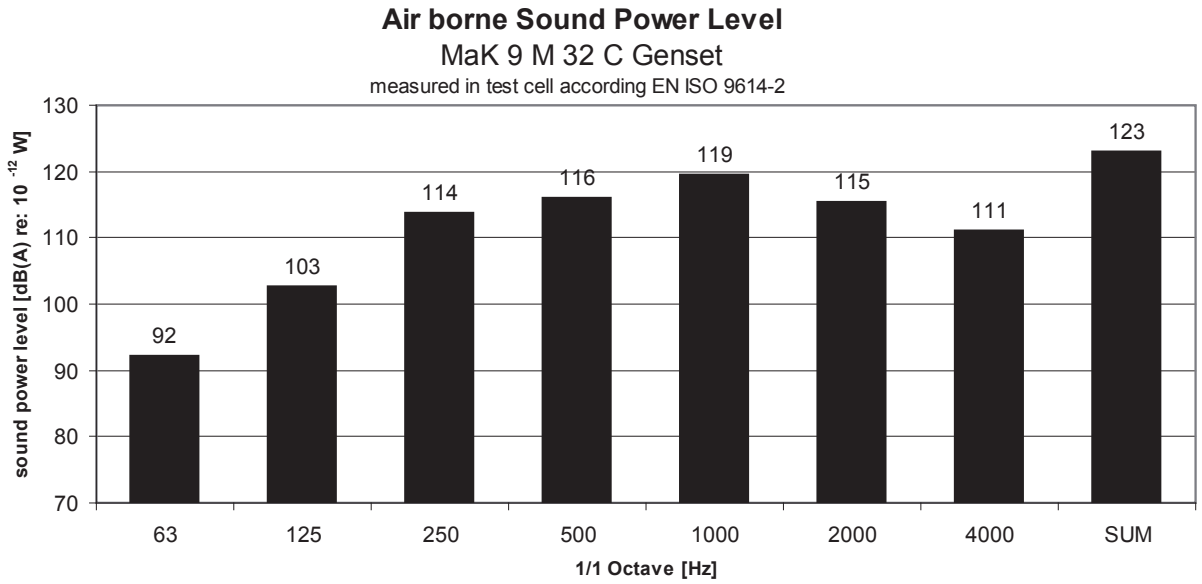
tolerance: +/- 2 dB

14. Appendix

14.4 Air borne sound power level

The air borne sound power level is measured in a test cell according to EN ISO 9614-2.

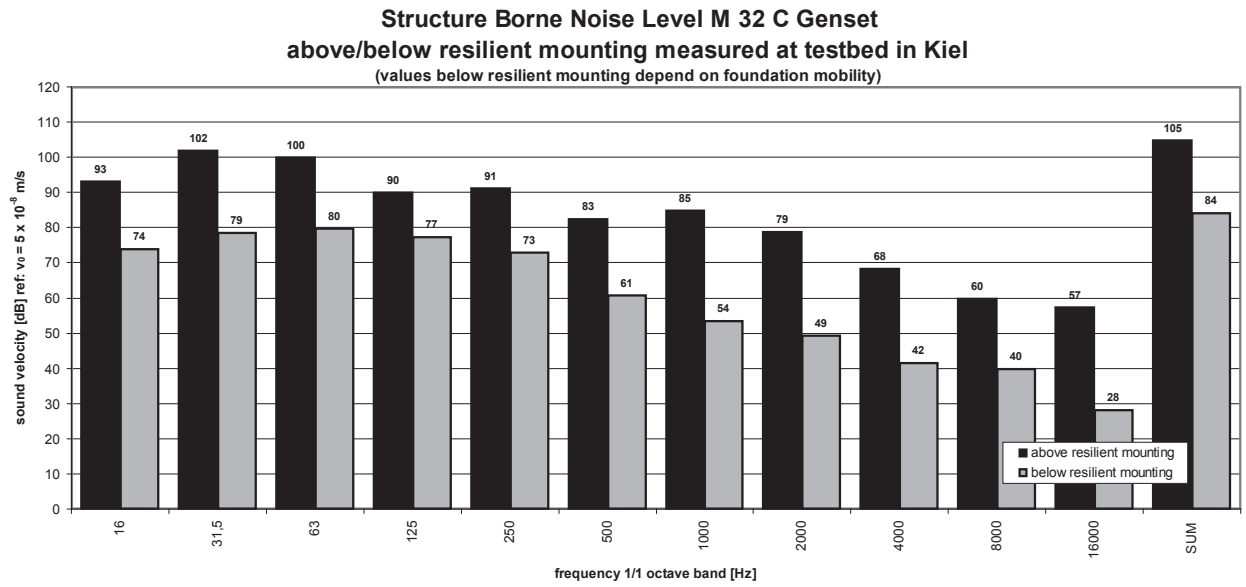
Noise level for M 32 C engines



tolerance: +/- 2 dB

14. Appendix

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



tolerance: +/- 2 dB

14. Appendix

14.6 Data sheet for torsional vibration calculation

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

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