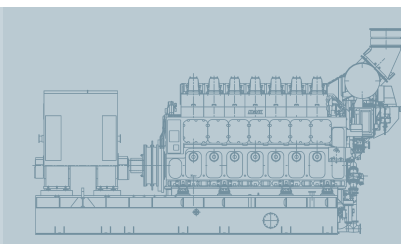
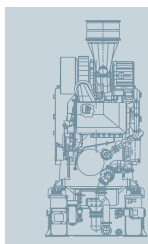
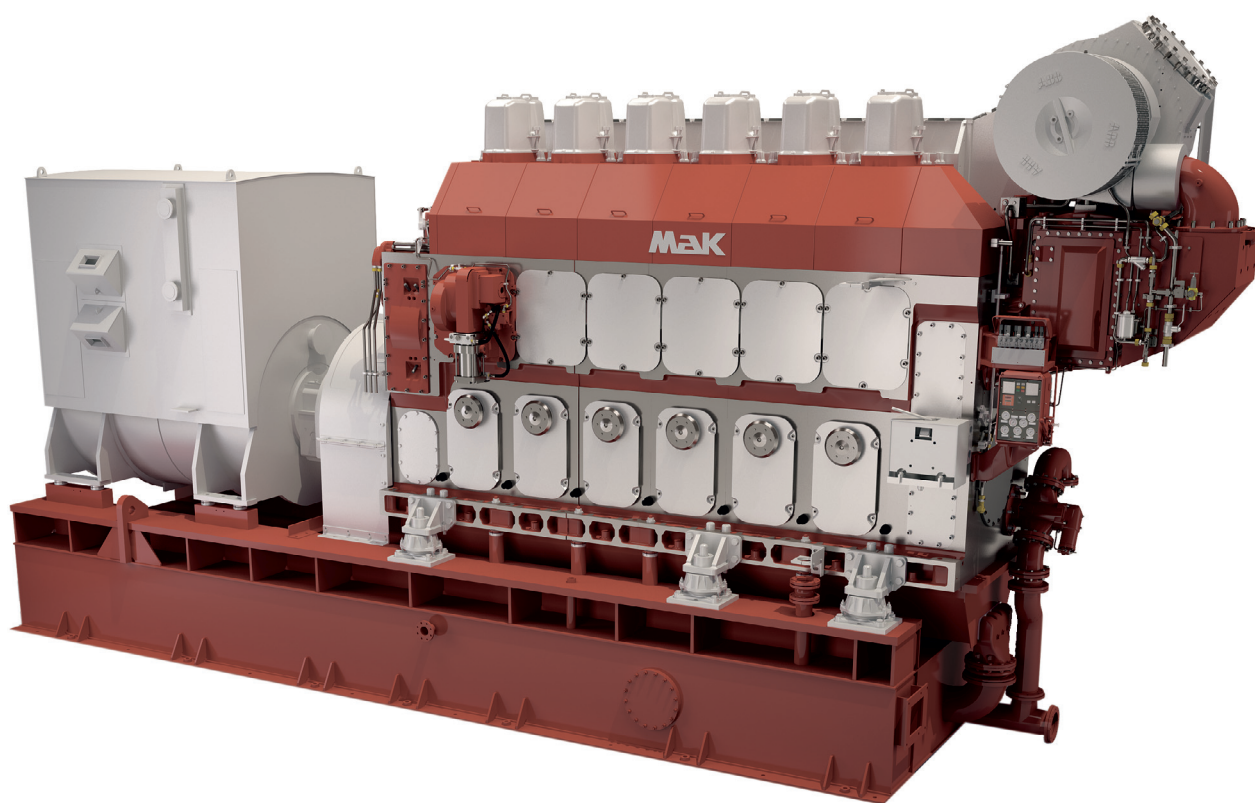


M 43 C

Project Guide • Generator Set



Introduction

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Edition August 2012

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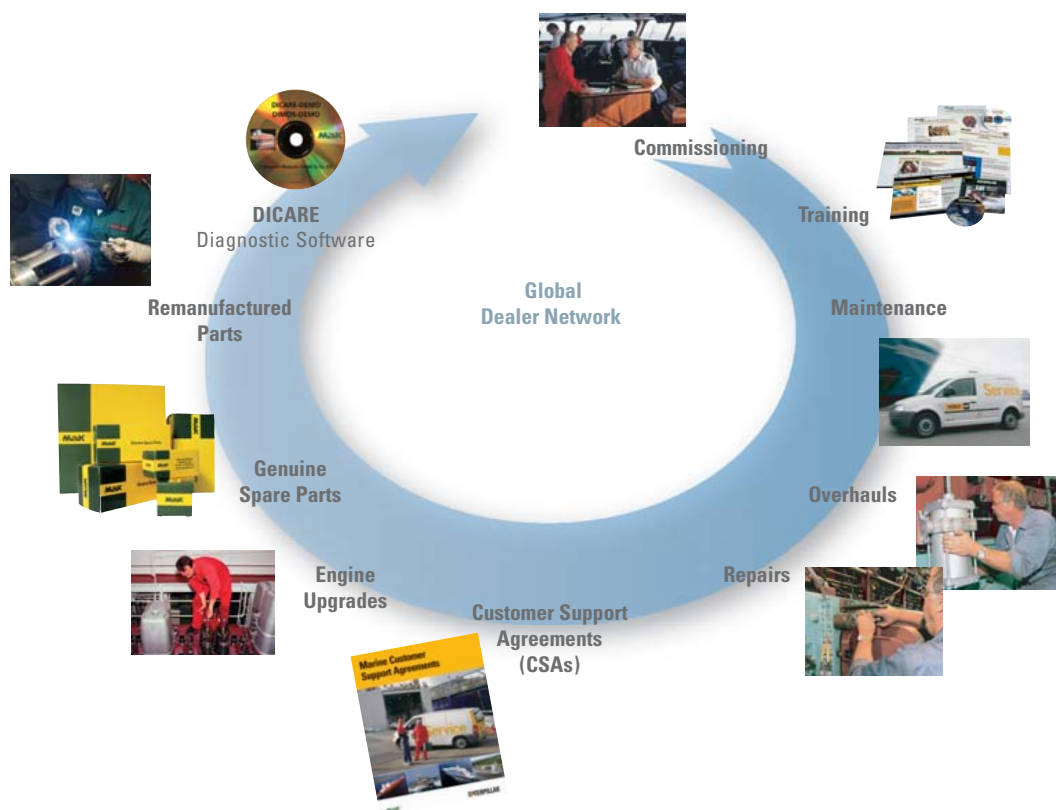
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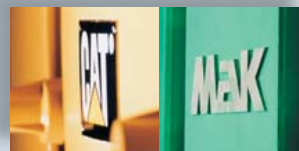
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*The audit has been performed under the
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Jürgen Weißbauer
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Place and date:

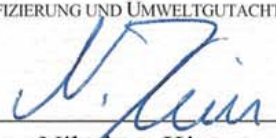
Essen, 15.11.2010

for the Accredited Unit:

DNV ZERTIFIZIERUNG UND UMWELTGUTACHTER GMBH



TGA-ZM-04-92-00


Nikolaus Kim
Management Representative

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Contents

	Page
1. Genset description	
1.1 Genset description	1
1.2 Genset design features.....	2
2. General data and operation of the genset	
2.1 General data and outputs	3
2.1.1 Output definition	3
2.1.2 Fuel consumption	3
2.1.3 Lube oil consumption	4
2.1.4 Nitrogen oxide emissions (NO _x values) IMO II.....	4
2.1.5 Technical data	5
2.2 Genset dimensions	7
2.2.1 Turbocharger at free end.....	7
2.2.2 Genset centre distance.....	8
2.3 Restrictions for low load operation	9
2.4 Load application and recovery behaviour	10
2.4.1 Standard loading up procedure.....	12
2.4.2 Speed control of auxiliary generating sets / DE-drive	13
3. Systems	
3.1 Combustion air system	14
3.1.1 General.....	14
3.1.2 Air intake from engine room (standard)	14
3.1.3 Air intake from outside	14
3.1.4 Radiated heat.....	14

3.2	Starting air system	15
3.2.1	Starting air quality requirements.....	15
3.2.2	System diagram.....	16
3.2.3	Starting air system components.....	17
	a) Receiver capacity acc. to GL recommendation AT1/AT2.....	17
	b) Compressor AC1/AC2.....	18
3.3	Exhaust system	18
3.3.1	General.....	18
3.3.2	Exhaust expansion joint	18
3.3.3	Silencer	19
3.3.4	Exhaust gas boiler (if needed)	20
3.3.5	Turbocharger cleaning device.....	21
3.4	Cooling water system	22
3.4.1	Cooling water quality requirements.....	22
3.4.2	System diagram – Heat balances	23
3.4.3	System diagram – Cooling water system.....	25
3.4.4	Cooling water system components.....	26
	a) LT cooling water pump (separate) FP4/FP6.....	26
	b) HT cooling water pump (separate) FP3/FP5.....	26
	c) HT temperature controller (separate) FR1.....	26
	d) LT temperature controller (separate) FR2.....	26
	e) Pre-heater (fitted) FH5/FP7.....	27
	f) HT cooler (optional, separate) FH1	27
	g) LT cooler (separate) FH2.....	27
	h) Header tank FT1/FT2.....	28
	i) Charge air temperature controller (separate) CR1	28
3.4.5	Recommendation for cooling water system.....	29
3.5	Fuel oil system, MGO/MDO operation	29
3.5.1	Quality requirements for MGO/MDO fuel/permitted fuels	29
3.5.2	System diagram – Fuel oil system, MGO/MDO operation	30

3.5.3	MGO/MDO fuel system components	31
a)	Fine filter (fitted) DF1	31
b)	Strainer (separate) DF2.....	31
c)	Pre-heater (separate) DH1	31
d)	MGO/MDO cooler DH3.....	31
e)	Feed pump (separate) DP1	31
f)	MGO/MDO service tank DT1.....	32
g)	Separator DS1	32
3.6	Fuel oil system, HFO operation	32
3.6.1	Quality requirements for HFO/permitted fuels	32
3.6.2	Viscosity / temperature diagram	34
3.6.3	System diagram – Heavy fuel oil operation	35
3.6.4	HFO system components	36
a)	Fine filter (fitted) HF1	36
b)	Strainer HF2	36
c)	Self cleaning filter HF4	37
d)	Viscosimeter HR2.....	37
e)	Pressure pumps HP1/HP2	37
f)	Circulating pumps HP3/HP4	37
g)	Pressure regulating valve HR1/DR2.....	38
h)	Final preheater HH1/HH2.....	38
i)	Mixing tank HT2	38
j)	Bunker tanks.....	39
k)	Settling tanks HT5/HT6.....	39
l)	Day tank DT1/HT1	39
m)	Separators HS1/HS2.....	39
3.6.5	System diagram – Standard HFO supply and booster module.....	40
3.6.6	Standard heavy fuel oil supply and booster module	41
a)	Primary filter FIL1	41
b)	Fuel pressure pumps SP1/SP2.....	41
c)	Pressure regulating system PCV1.....	41
d)	Self cleaning fine filter AF1	41
e)	Consumption measuring system FLOW1	41
f)	Mixing tank with accessories T1	41
g)	Circulating pumps BP1/BP2	41
h)	Final preheater H1/H2	41
i)	Viscosity control system VA1.....	41
j)	Cooler CL1	41

3.7	Lube oil system	43
3.7.1	Quality requirements of lube oil.....	43
3.7.2	System diagram – Lube oil system.....	45
3.7.3	Lube oil system components.....	46
	a) Force pump (fitted) LP1	46
	b) Prelubrication pump (separate) LP5.....	46
	c) Stand-by force pump (separate) LP2	46
	d) Strainer LF4.....	46
	e) Self cleaning filter (separate) LF2	46
	f) Duplex filter (fitted) LF1	47
	g) Cooler (separate) LH1	47
	h) Temperature controller LR1.....	47
	i) Circulation tank LT1	47
	j) Crankcase ventilation C91	48
	k) Separator; treatment at MGO/MDO operation LS1	48
	l) Separator; treatment at HFO operation LS1	48
3.7.4	Recommendation for lube oil system	49

4. Connecting parts engine

4.1	Data for torsional vibration calculation	49
4.2	Mounting of genset	50
4.2.1	Structure-borne sound level L_v	52
4.3	Generators structural requirements for MaK diesel gensets M 43 C	53

5. Installation and arrangement

5.1	General installation aspect	54
5.2	General design	54
5.3	M 43 C applications.....	55
5.3.1	MaK 8 M 43 C genset.....	55
5.3.2	M 43 C genset	56
5.3.3	M 43 C genset – close-up	56

5.4	Space requirement for dismantling of charge air cooler, torsional vibration damper and turbocharger cartridge	57
5.5	Installation of flexible pipe connections	58
5.6	Notes regarding installation exhaust system	58
5.7	Installation of crankcase ventilation on the engine	59
5.8	Lifting of the engine	60
6.	Control and monitoring system	
6.1	Engine control panel	61
6.2	Genset control	62
6.3	Engine monitoring	63
6.4	Measuring points.....	64
6.5	Local and remote indicators.....	69
6.6	LESS: Large Engine Safety System	70
7.	Diagnostic trending monitoring – DICARE.....	72
8.	Engine acceptance test.....	74
9.	Engine International Air Pollution Prevention Certificate.....	75

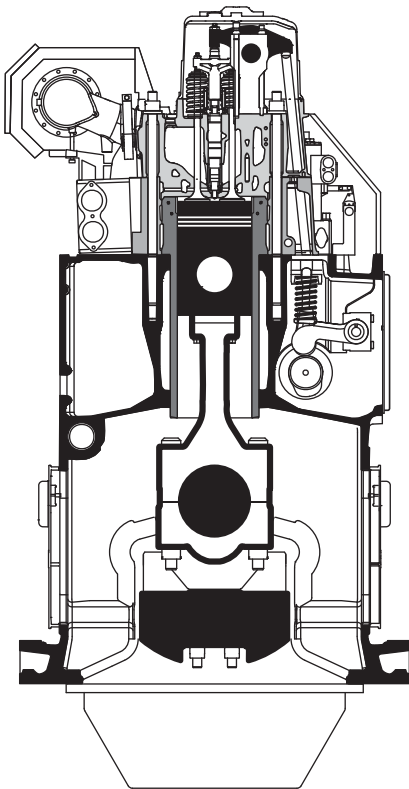
10.	Painting / preservation	76
11.	Engine parts.....	79
12.	Flexible Camshaft Technology – FCT.....	80
13.	Caterpillar Marine Systems Integration.....	81
13.1	The Scope	81
14.	Appendix	82
14.1	Exhaust system	82
14.1.1	Resistance in exhaust gas piping.....	82
14.1.2	Exhaust data	83
14.1.3	Exhaust gas sound power level	84
14.2	Air-borne sound power level.....	86

1. Genset description

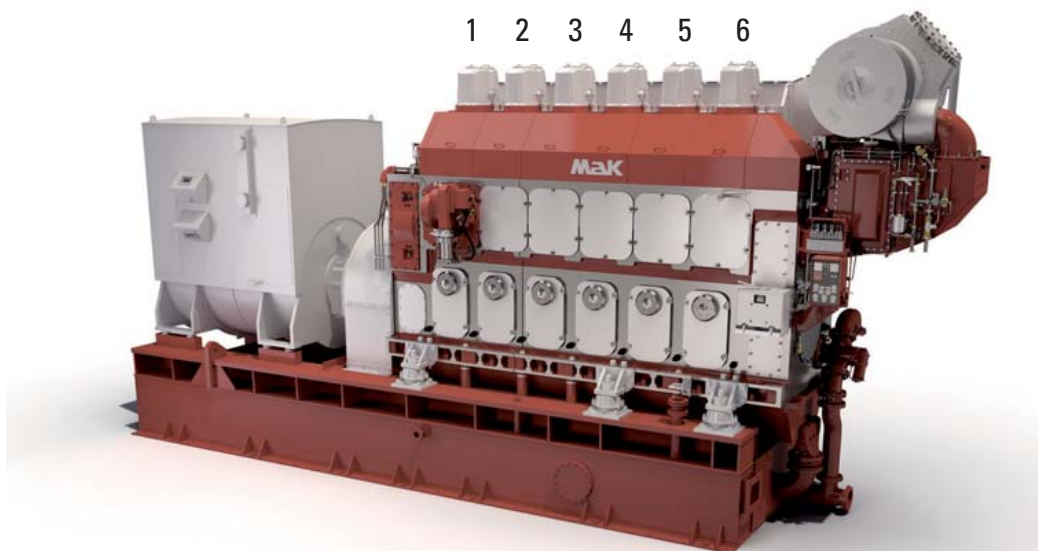
1.1 Genset description

The M 43 C is a four-stroke diesel engine, non-reversible, turbocharged and intercooled with direct fuel injection.

In-line engine M 43 C



Cylinder configuration:	6,7,8,9 in-line
Bore:	430 mm
Stroke:	610 mm
Stroke/bore ratio:	1.42
Swept volume:	88.6 l/Cyl.
Output/cyl.:	1,000 kW
BMEP:	27.1/26.4 bar
Revolutions:	500/514 rpm
Mean piston speed:	10.2/10.5 m/s
Turbocharging:	single log
Direction of rotation:	clockwise, option: counter-clockwise



1. Genset description

1.2 Genset design features

- Baseframe
- Generator
- Designed for heavy fuel operation up to 700 cSt/50°C, fuel grade acc. to CIMAC H55 K55, ISO 8217, 1996 (E), ISO-F-RMH55 RMK55.
- 1-piece dry engine block made of nodular cast iron. It includes the crankshaft bearing, camshaft bearing, charge air duct, vibration damper housing and gear drive housing.
- Underslung crankshaft with corrosion resistant main and big end bearing shells.
- Natural hardened liners, centrifugally cast, with anti-polishing ring.
- Composite type pistons with steel crown and nodular cast iron skirt.
- Piston ring set consisting of 2 chromium plated compression rings, first ring with chromium-ceramic plated running surfaces and 1 chromium plated oil control ring. All ring grooves are hardened and located in the steel crown.
- 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 consisting of individual cylinder sections allowing a removal of the pieces sideways.
- Turbocharger supplied with integrated plain bearings lubricated by engine lubricating oil.
- 2-stage fresh water cooling system with 2-stage charge air cooler.
- Nozzle cooling for heavy fuel operation with engine lubricating oil.
- For invisible smoke at part load operation Flexible Camshaft Technology is available.

2. General data and operation of the genset

	514 rpm / 60 Hz		500 rpm / 50 Hz	
	Engine kW	Generator kWe	Engine kW	Generator kWe
6 M 43 C	6,000	5,760	6,000	5,760
7 M 43 C	7,000	6,720	7,000	6,720
8 M 43 C	8,000	7,680	8,000	7,680
9 M 43 C	9,000	8,640	9,000	8,640

Remark:

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

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)

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

2. General data and operation of the genset

2.1.2 Fuel consumption

The fuel consumption data refer to the following reference conditions:

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

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

2.1.3 Lubricating oil consumption

Actual data can be inferred from the technical data.

2.1.4 Nitrogen oxide emissions (NO_x values)

NO _x limit values according to MARPOL 73/78 Annex VI:	10.53 g/kWh (n = 500 rpm)
	10.47 g/kWh (n = 514 rpm)

Generator according to cycle D2:	10.53 g/kWh (n = 500 rpm)
	10.47 g/kWh (n = 514 rpm)

2. General data and operation of the genset

2.1.5 Technical data

Performance Data	Cylinder	6	7	8	9
Maximum continuous rating acc. ISO 3046/1	kW	6,000	7,000	8,000	9,000
Speed	1/min	500/514	500/514	500/514	500/514
Minimum speed	1/min	300	300	300	300
Brake mean effective pressure	bar	27.1/26.4	27.1/26.4	27.1/26.4	27.1/26.4
Charge air pressure	bar	3.65	3.65	3.65	3.65
Firing pressure	bar	208	208	208	208
Combustion air demand (ta = 20°C)	m³/h	33,100	34,830	43,920	49,410
Specific fuel oil consumption					
n = const ¹⁾	100%	g/kWh	176	176	176
	85%	g/kWh	175	175	175
	75%	g/kWh	-/177	-/177	-/177
	50%	g/kWh	-/184	-/184	-/184
Lube oil consumption ²⁾	g/kWh	0.6	0.6	0.6	0.6
NO _x -emission ⁶⁾	g/kWh	10	10	10	10
Turbocharger type		ABB TPL76	ABB TPL76	ABB TPL76	ABB TPL76
Fuel					
Engine driven booster pump	m³/h/bar	—	—	—	—
Stand-by booster pump	m³/h/bar	4.2/10	4.9/10	5.6/10	6.3/10
Mesh size MDO fine filter	mm	0.025	0.025	0.025	0.025
Mesh size HFO automatic filter	mm	0.010	0.010	0.010	0.010
Mesh size HFO fine filter	mm	0.034	0.034	0.034	0.034
Lube Oil					
Engine driven pump	m³/h/bar	146/10	146/10	203/10	203/10
Independent pump	m³/h/bar	120/10	140/10	160/10	180/10
Working pressure at engine inlet	bar	4 - 5	4 - 5	4 - 5	4 - 5
Independent suction pump	m³/h/bar	175/3	175/3	240/3	240/3
Priming pump pressure/suction pump	m³/h/bar	16/5	16/5	20/5	20/5
Sump tank content/dry sump content	m³	9.4	9.8	11.2	12.6
Temperature at engine inlet	°C	60 - 65	60 - 65	60 - 65	60 - 65
Temperature controller NB	mm	125	125	150	150
Double filter NB	mm	150	150	150	150
Mesh size double filter	mm	0.08	0.08	0.08	0.08
Mesh size automatic filter	mm	0.03	0.03	0.03	0.03

2. General data and operation of the genset

Fresh water cooling	Cylinder	6	7	8	9
Engine content	m ³	0.6	0.7	0.8	0.9
Pressure at engine inlet min/max	bar	2.5/6.0	2.5/6.0	2.5/6.0	2.5/6.0
Header tank capacity	m ³	0.6	0.6	0.6	0.6
Temperature at engine outlet	°C	80 - 90	80 - 90	80 - 90	80 - 90
Two-circuit system					
Engine driven pump HT	m ³ /h/bar	—	—	—	—
Independent pump HT	m ³ /h/bar	100/4.5	110/4.6	120/4.6	130/4.5
HT-controller NB	mm	125	125	150	150
Water demand LT-charge air cooler	m ³ /h	80	100	100	100
Temperature at LT-charger air cooler inlet	°C	38	38	38	38
Heat dissipation					
Specific jacket water heat	kJ/kW	500	500	500	500
Specific lube oil heat	kJ/kW	490	490	490	490
Lube oil cooler	kW	820	960	1,090	1,225
Jacket water	kW	835	975	1,115	1,250
Charge air cooler (HT stage) ³⁾	kW	1,964	2,280	2,606	2,932
Charge air cooler (LT stage) ³⁾ (HT stage after engine)	kW	447	519	593	667
Heat radiation engine	kW	260	300	330	390
Exhaust gas					
Silencer/spark arrestor NB 25 dBA	mm	900	1,000	1,000	1,000
Pipe diameter NB after turbine	mm	900	1,000	1,000	1,000
Maximum exhaust gas pressure drop	bar	0.03	0.03	0.03	0.03
Exhaust gas temp after turbine (25°C intake air) ⁵⁾	°C	316	312	311	312
Exhaust gas mass flow (25°C intake air) ⁵⁾	kg/h	40,920	47,500	54,285	61,075
Starting air					
Starting air pressure max.	bar	30	30	30	30
Minimum starting air pressure	bar	14	14	14	14
Air consumption per start ⁴⁾	Nm ³	2.4	2.4	3.0	3.0
Max. crankcase pressure, nominal diameter ventilation pipe	mmWs/ mm	15/160	15/160	15/160	15/160

¹⁾ Reference conditions: LCV = 42,700 kJ/kg, ambient temperature 25 °C
charge air coolant temperature 25 °C, tolerance 5 %, + 1 % for engine driven pump

²⁾ Standard value, tolerance ± 0.3 g/kWh, related on full load

³⁾ Charge air heat based on 45 °C ambient temperature

⁴⁾ Preheated engine

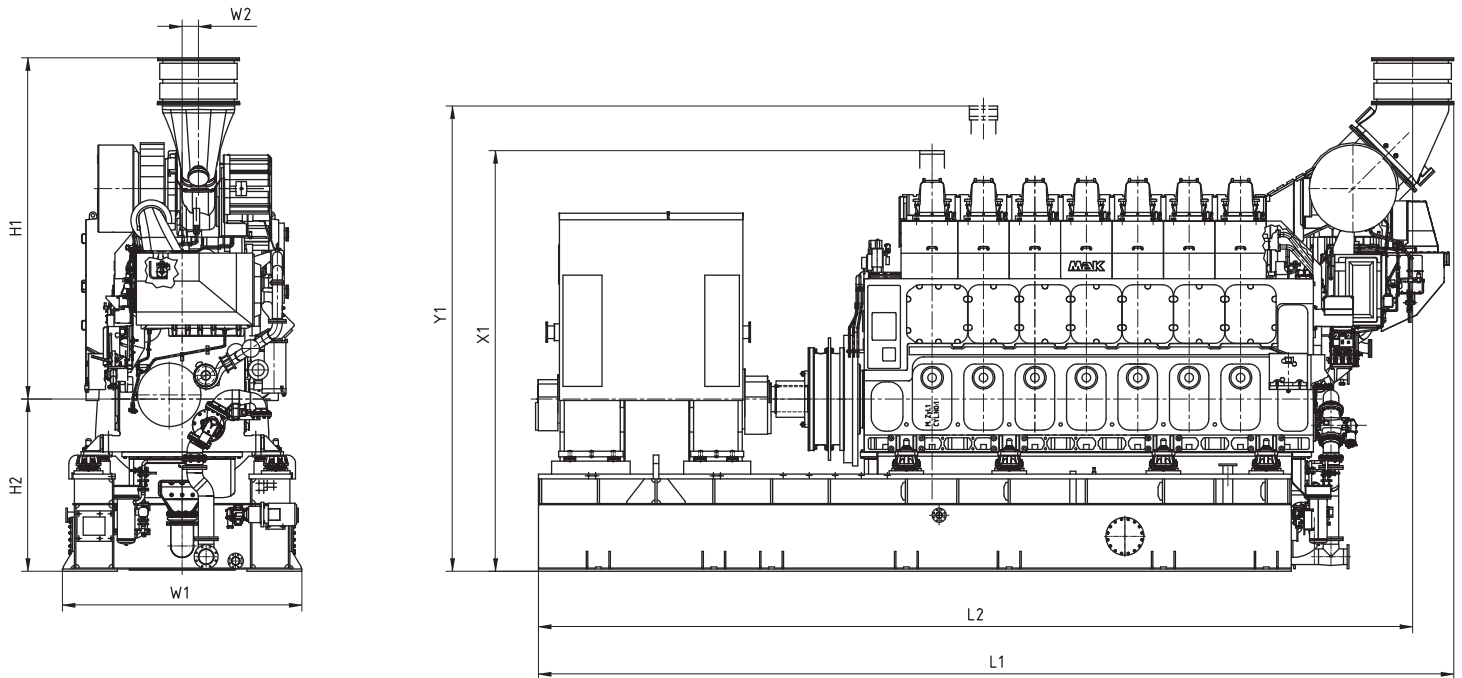
⁵⁾ Tolerance 10 %, rel. humidity 60 %

⁶⁾ MARPOL 73/78 Annex VI, Cycle E2, E3, D2

2. General data and operation of the genset

2.2 Genset dimensions

2.2.1 Turbocharger at free end



Engine Type	Dimensions [mm]						Dry weight *
	L1	L2	H1	H2	W1	W2	[t]
6 M 43 C	12,202	11,651	4,358	2,444	3,400	215	178
7 M 43 C	12,999	12,414	4,849	2,444	3,400	232	195
8 M 43 C	13,729	13,144	4,849	2,444	3,400	232	210
9 M 43 C	14,459	43,874	4,849	2,444	3,400	232	240

* depending on generator weight

Prime mover and generator are always flexibly coupled.

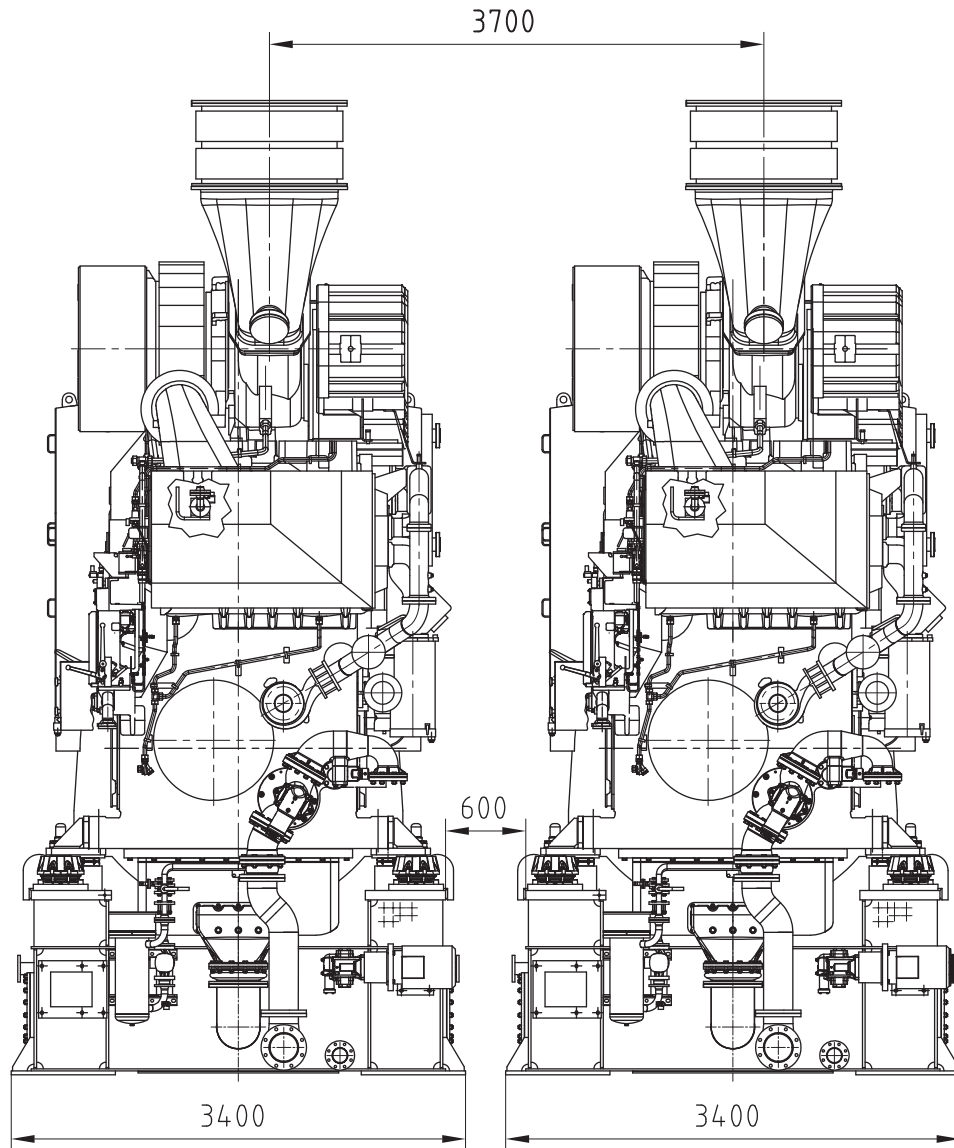
Removal of:

Piston in transverse direction X1 = 5,974 mm

Cylinder liner in transverse direction Y1 = 6,609 mm

2. General data and operation of the genset

2.2.2 Genset centre distance



Min. centre distance of 2 gensets:

3,700 mm

2. General data and operation of the genset

2.3 Restrictions for low load operation and stand-by mode

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

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

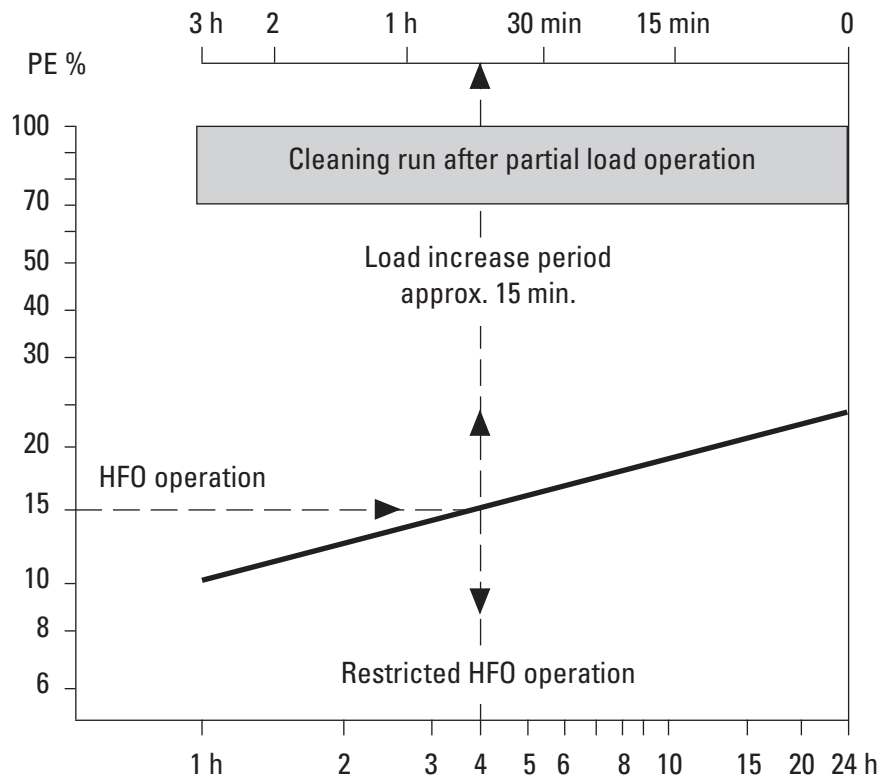
The lube oil treatment system (lube oil separator) remains in operation, the lube oil is separated continuously (stand-by mode).

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

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

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

Cleaning run of engine



2. General data and operation of the genset

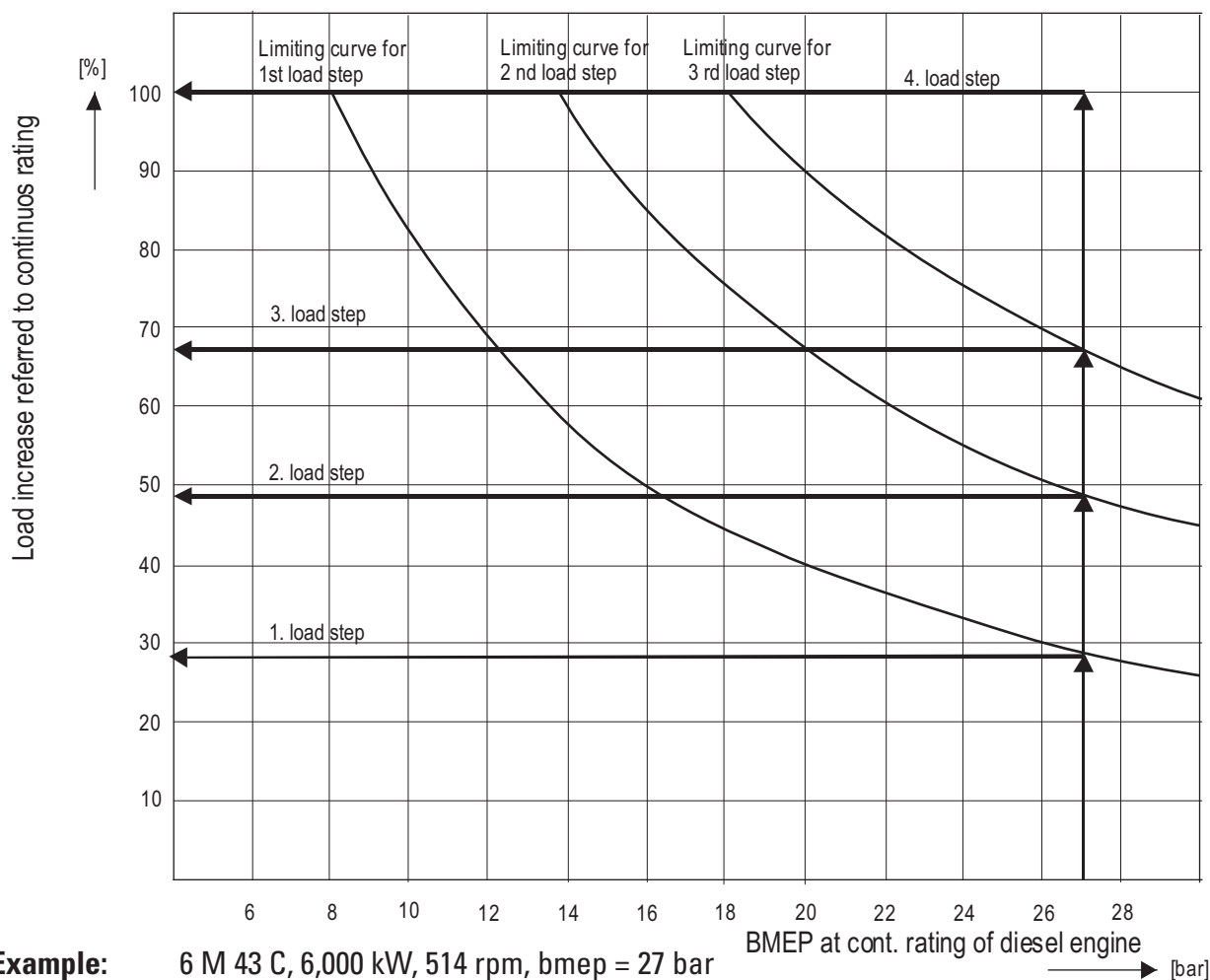
2.4 Load application and recovery behaviour

The permissible load increase according to ISO 8528-5 and IACS must be carried out in several steps, depending on the mean effective pressure. The ship's network must be designed so that this permissible load increase is kept. The shipyard has to provide the approval of the responsible classification society in time before classification of the engine.

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

M 43 C in-line engines

To achieve recovery behaviour according to class requirements

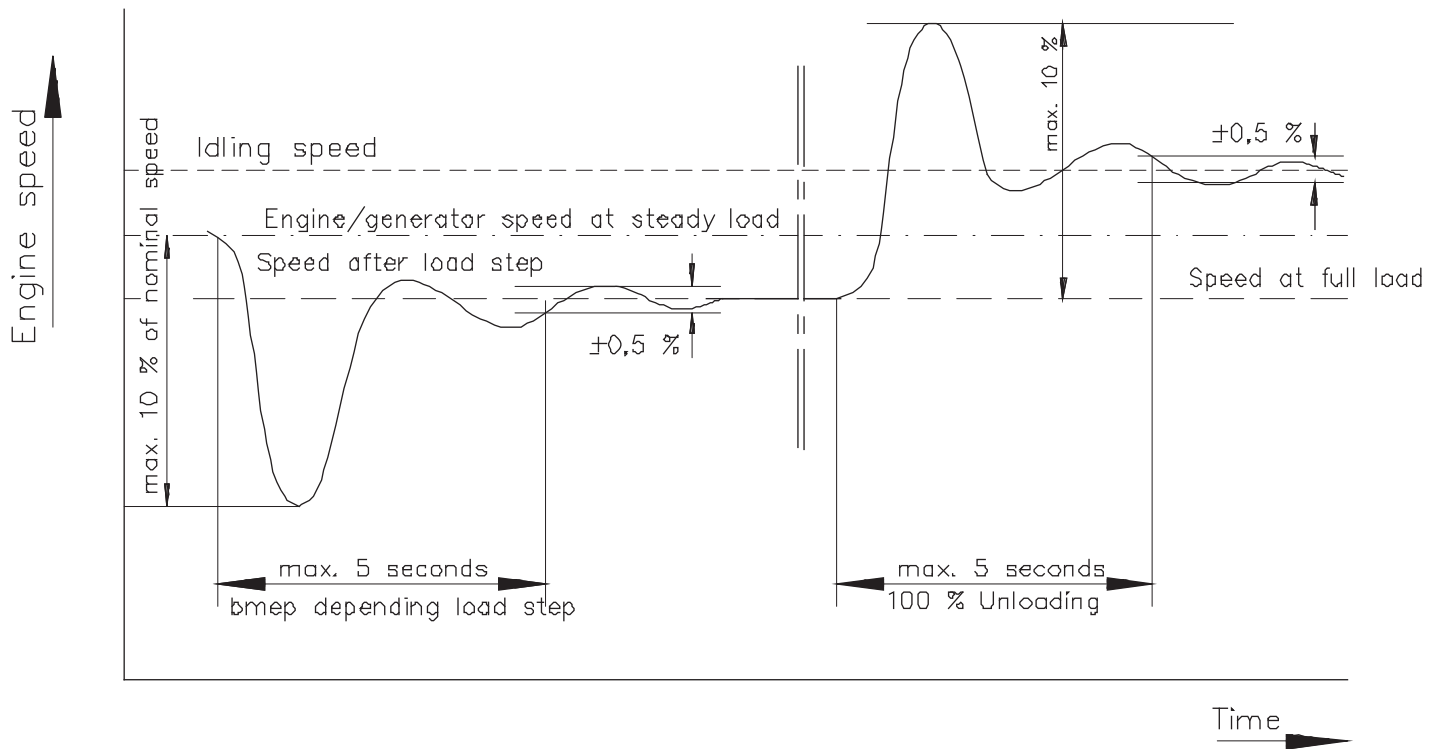


Example: 6 M 43 C, 6,000 kW, 514 rpm, bme_p = 27 bar
Curves are provided as typical examples.

1. max. load from 0 % to 28 % output
2. max. load from 29 % to 48 % output
3. max. load from 49 % to 67 % output
4. max. load from 68 % to 100 % output

2. General data and operation of the genset

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

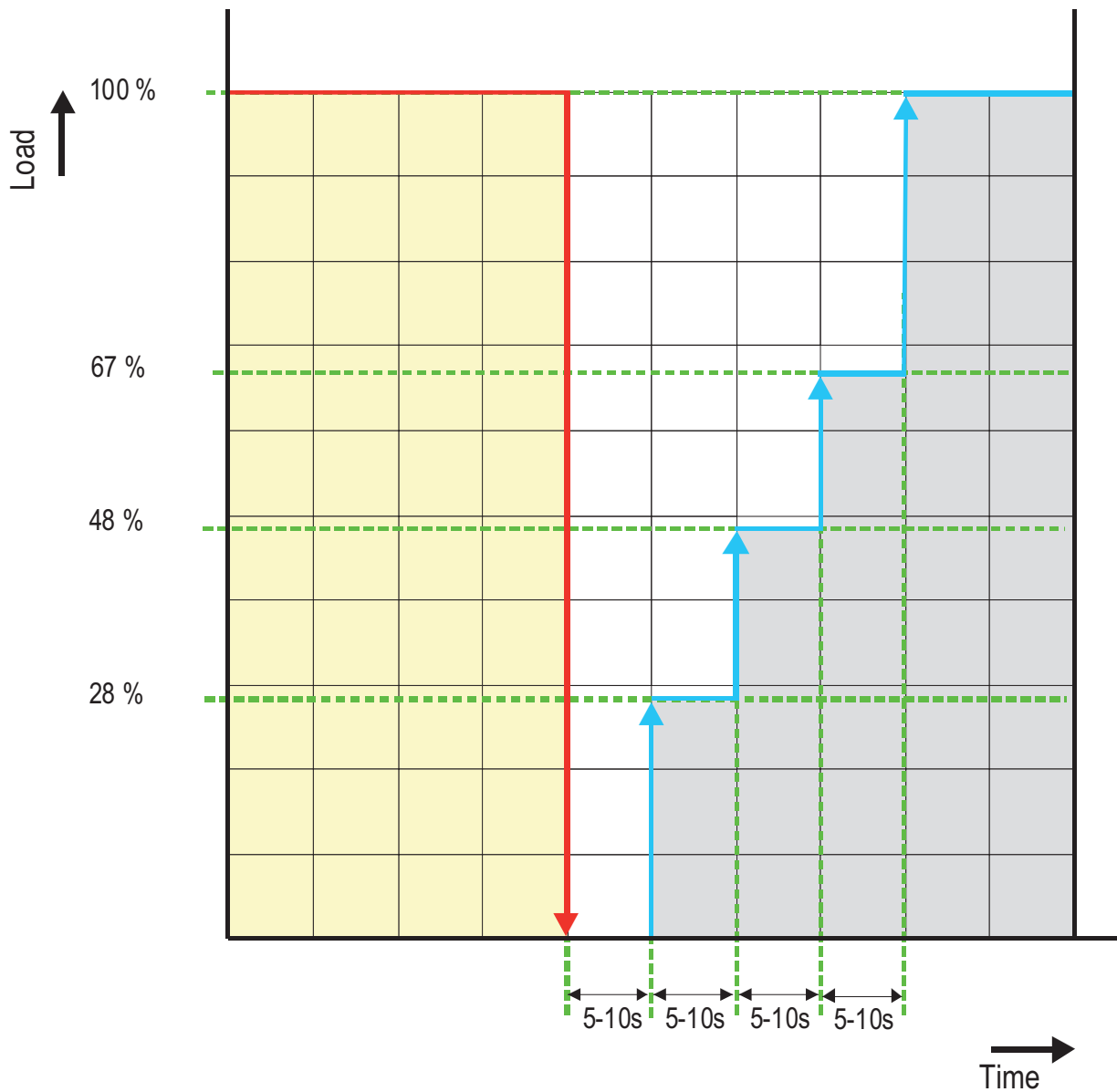


2. General data and operation of the genset

2.4.1 Standard loading up procedure

Our standard loading procedure for M 43 C in-line engines to achieve recovery behaviour in accordance with class requirements.

For higher power increments or different loading procedures FCT (Flexible Camshaft Technology) is recommended.



2. General data and operation of the genset

2.4.2 Speed control of auxiliary generating sets / DE - drive

Electronic governor system, maker Regulateurs Europa (RE)

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

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

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

The governor comprises the following functions:

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

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 (except cruise vessels).
- On system side the penetration of water, sand, dust, and exhaust gas must be prevented.
- The air flow must be conveyed directly to the turbocharger.
- The temperature at turbocharger filter should not fall below + 10 °C.
- In cold areas warming up of the air in the engine room must be ensured.

3.1.3 Air intake from outside

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

3.1.4 Radiated heat

See technical data

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

3. Systems

3.2 Starting air system

As required by the classification societies, at least two air compressors are required. The nominal starting air gauge pressure for all MaK engines is 30 bar. The starting air must have a defined quality, be free from solid particles, oil, and water.

3.2.1 Starting air quality requirements

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

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

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

Oil content

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

Particle size and density

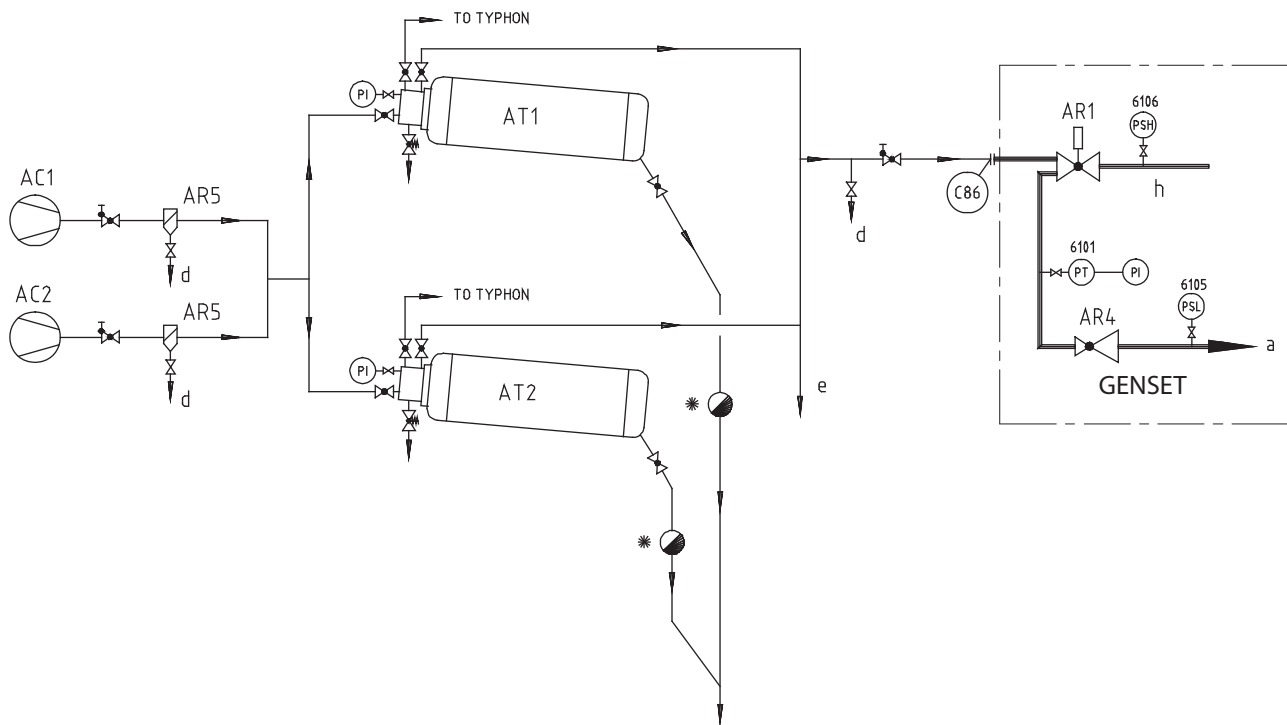
Specification of size and concentration of particles which may still be contained in the compressed air.

Pressure dew point

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

3. Systems

3.2.2 System diagram



General notes:

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

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

Notes:

- a Control air
- d Water drain (to be mounted at the lowest point)
- e To genset No. 2/3 ...
- h Please refer to the measuring point list regarding design of the monitoring devices.

* Automatic drain valve required

Connecting points:

C86 Connection, starting air

Accessories and fittings:

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

AT1 / AT2 Option:

- Typhon valve
- Relief valve with pipe connection

3. Systems

3.2.3 Starting air system components

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

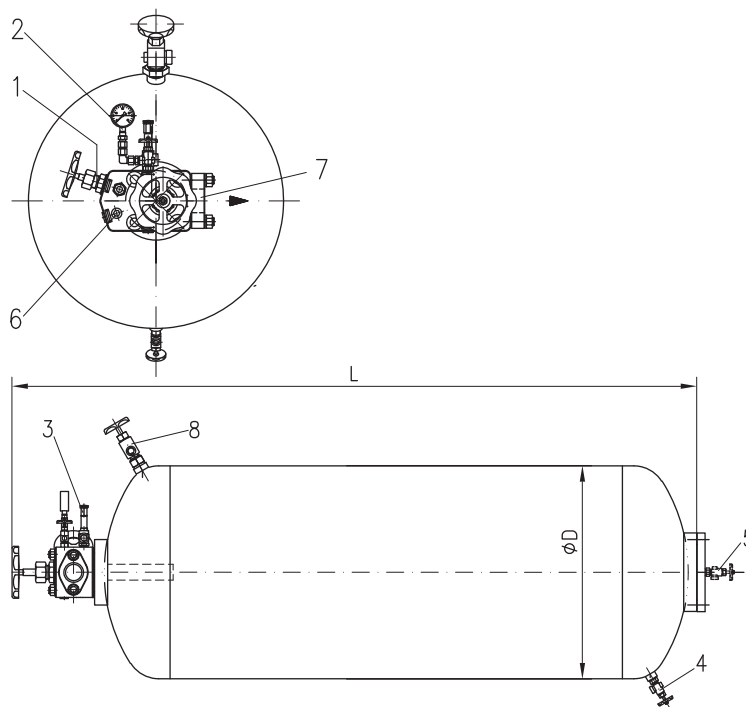
	6/7 Cyl.	8/9 Cyl.
Single-engine plant	2 x 500 l	2 x 750 l
Twin-engine plant	2 x 1,000 l	2 x 1,500 l

Receiver capacity [l]	L [mm]	D ø [mm]	Valve head	Weight approx [kg]
500	3,355	480	DN 50	320
750	2,810	650	DN 50	480
1,000	3,670	650	DN 50	620
1,500	3,650	800	DN 50	880

- 1 Filling valve DN 18
- 2 Pressure gauge G 1/4
- 3* Relief valve DN 7
- 4 Drain valve DN 8
- 5 Drain valve DN 8 (for vertical position)
- 6 Connection aux. air valve G 1/2
- 7 To starting valve at engine
- 8 Typhon valve DN 16 **optional**

Option:

- * with pipe connection G 1/2



If a CO₂ fire extinguishing system is installed in the engine room, the blow-off connection of the safety valve is to be piped to the outside.

Requirement of classification societies (regarding design)

- No. of starts: 3 per genset
- 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

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

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

3.3 Exhaust system

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

3.3.1 General

Position of exhaust gas nozzle:

A nozzle position of 0°, 30°, 45°, 60° and 90° from the vertical is possible.

The basic position is 45°. The other positions are reached by using a transition piece.

Design of the pipe cross-section:

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

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

Max. pressure loss (incl. silencer and exhaust gas boiler):
30 mbar

(lower values will reduce thermal load of the engine).

3.3.2 Exhaust expansion joint

	Diameter DN	Length [mm]	Weight [kg]
6 M 43 C	900	500	158
7/8/9 M 43 C	1,000	620	209

3. Systems

3.3.3 Silencer

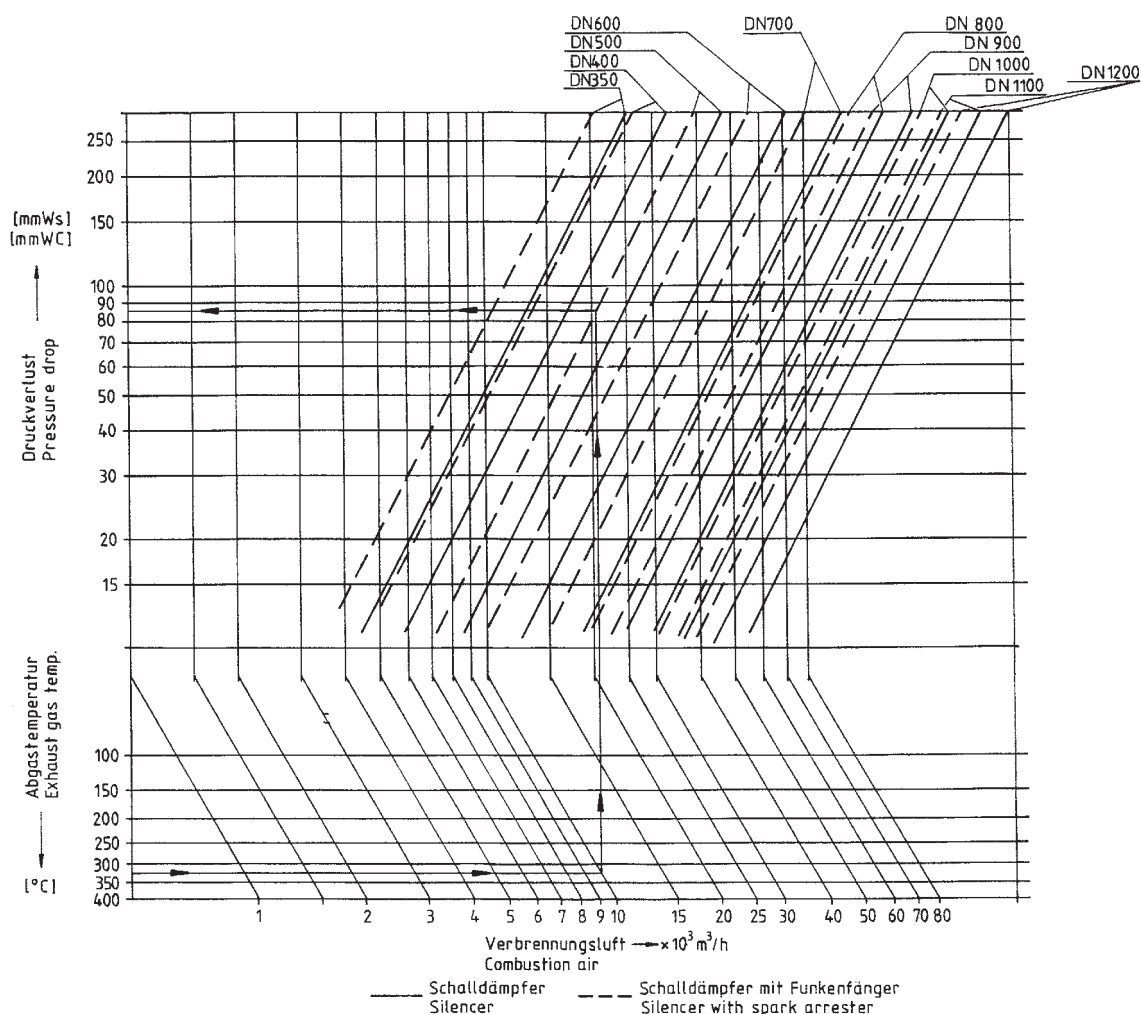
Design according to the absorption principle with wide-band attenuation over great frequency range and low pressure loss due to straight direction of flow. Sound absorbing filling consisting of resistant mineral wool.

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

Silencer with spark arrester:

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

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



3. Systems

Dimension of silencer/spark arrestor and silencer

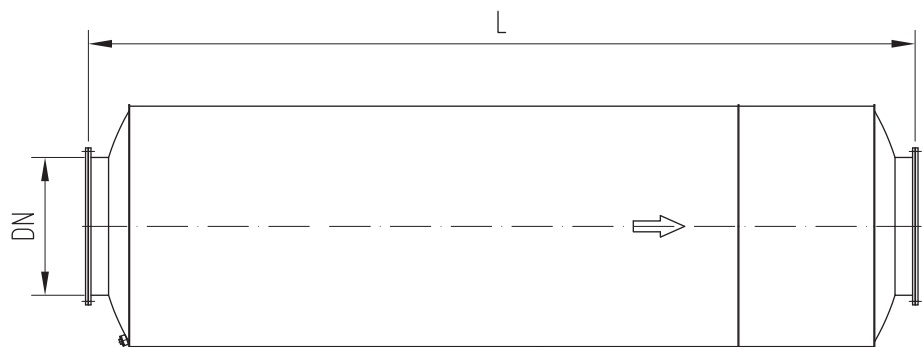
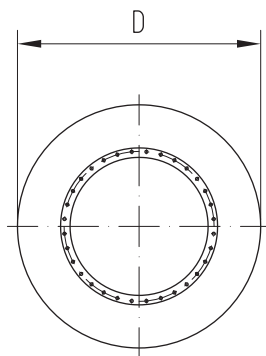
(in case of Caterpillar supply):

Installation: vertical/horizontal

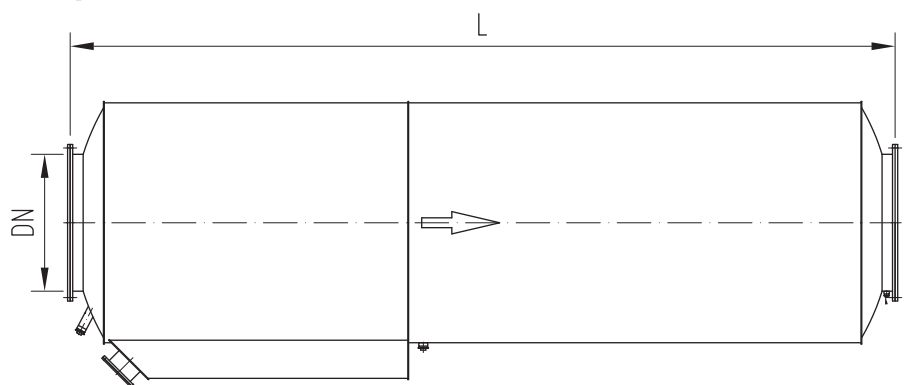
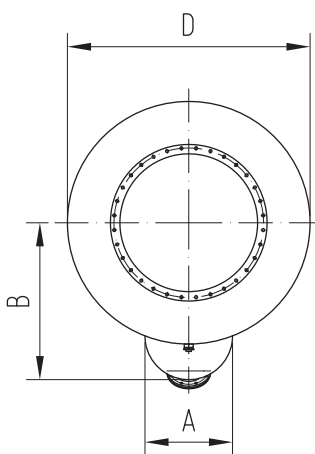
Flange according to DIN 86044

Counterflanges, screws and gaskets are included, without supports and insulation

Silencer



Spark arrestor and silencer



	Attenuation 35 dB (A)					
	DN	D [mm]	A [mm]	B [mm]	L [mm]	m [kg]
6 M 43 C	900	1,700	650	1,100	5,620	3,000
7/8/9 M 43 C	1,000	1,800	650	1,160	6,120	3,750

3.3.4 Exhaust gas boiler (if installed)

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

Particularly if exhaust gas boilers are installed attention must be paid to the maximum recommended back pressure.

3. Systems

3.3.5 Turbocharger cleaning device

Cleaning the turbocharger compressor:

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

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

Cleaning the turbine blade and nozzle ring:

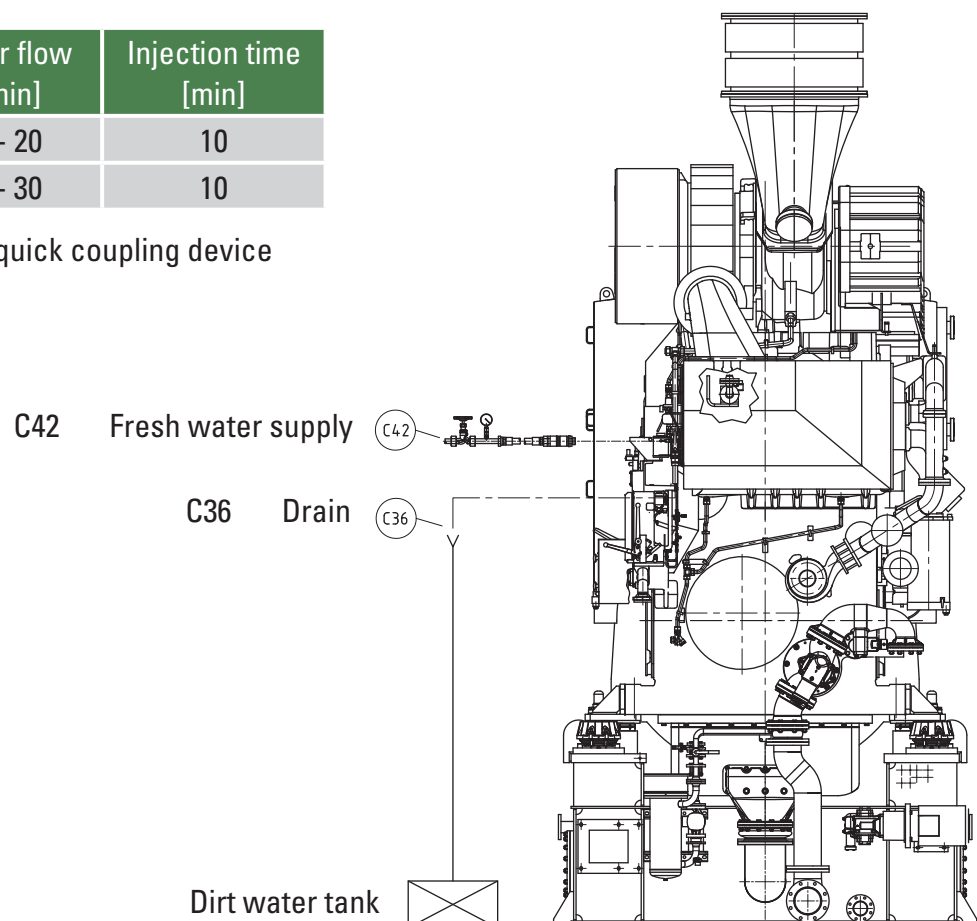
The cleaning is carried out with clean fresh water "wet cleaning" during low load operation at regular intervals of 150 hours, depending on the fuel quality.

Duration of the cleaning period is approx. 20 minutes. Fresh water of 1.8 - 2.2 bar is required.

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

	Water flow [l/min]	Injection time [min]
6 M 43 C	17 - 20	10
7/8/9 M 43 C	36 - 30	10

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 and the engine. The Low Temperature (LT) cooling water circuit cools the charge air and the lube oil. Moreover, the LT cooling water circuit can be used to cool additional equipment, e.g. a generator or gearbox.

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

3.4.1 Cooling water quality requirements

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

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

Requirements

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

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

Supplementary information

Distillate: If distilled or fully desalinated water is available, this should preferably be used as engine cooling water.

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

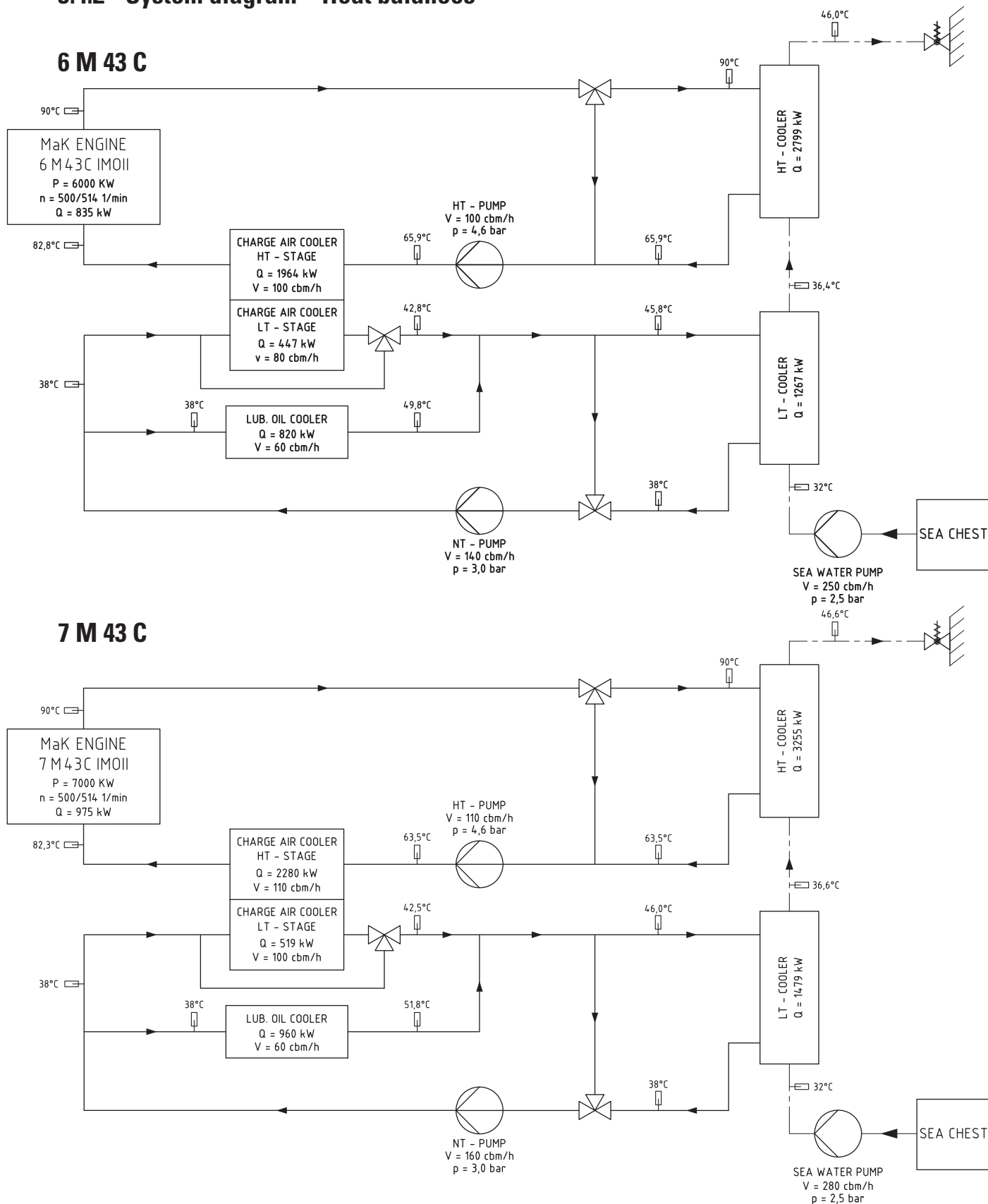
Treatment before operating the engine for the first time

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

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

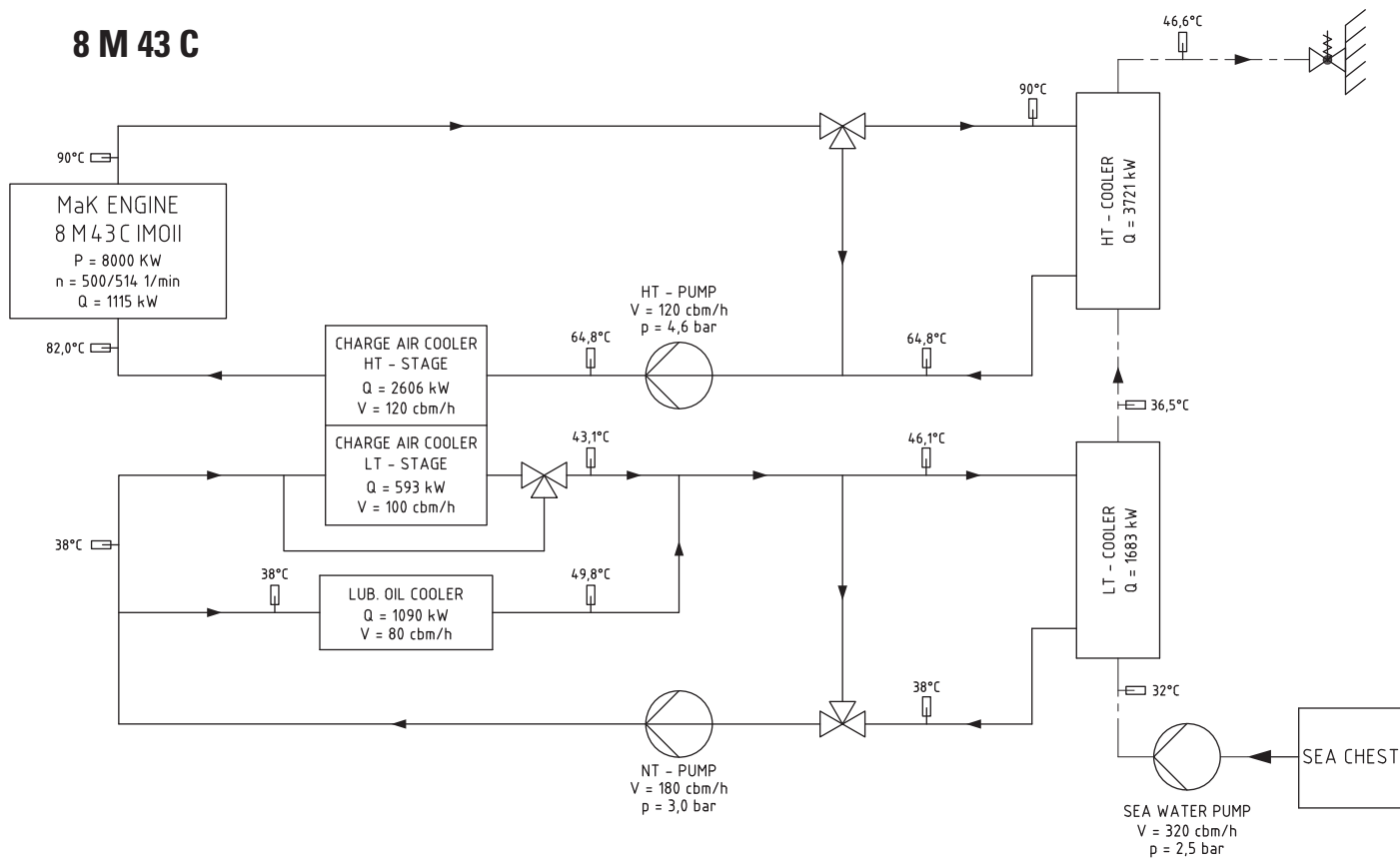
3. Systems

3.4.2 System diagram – Heat balances

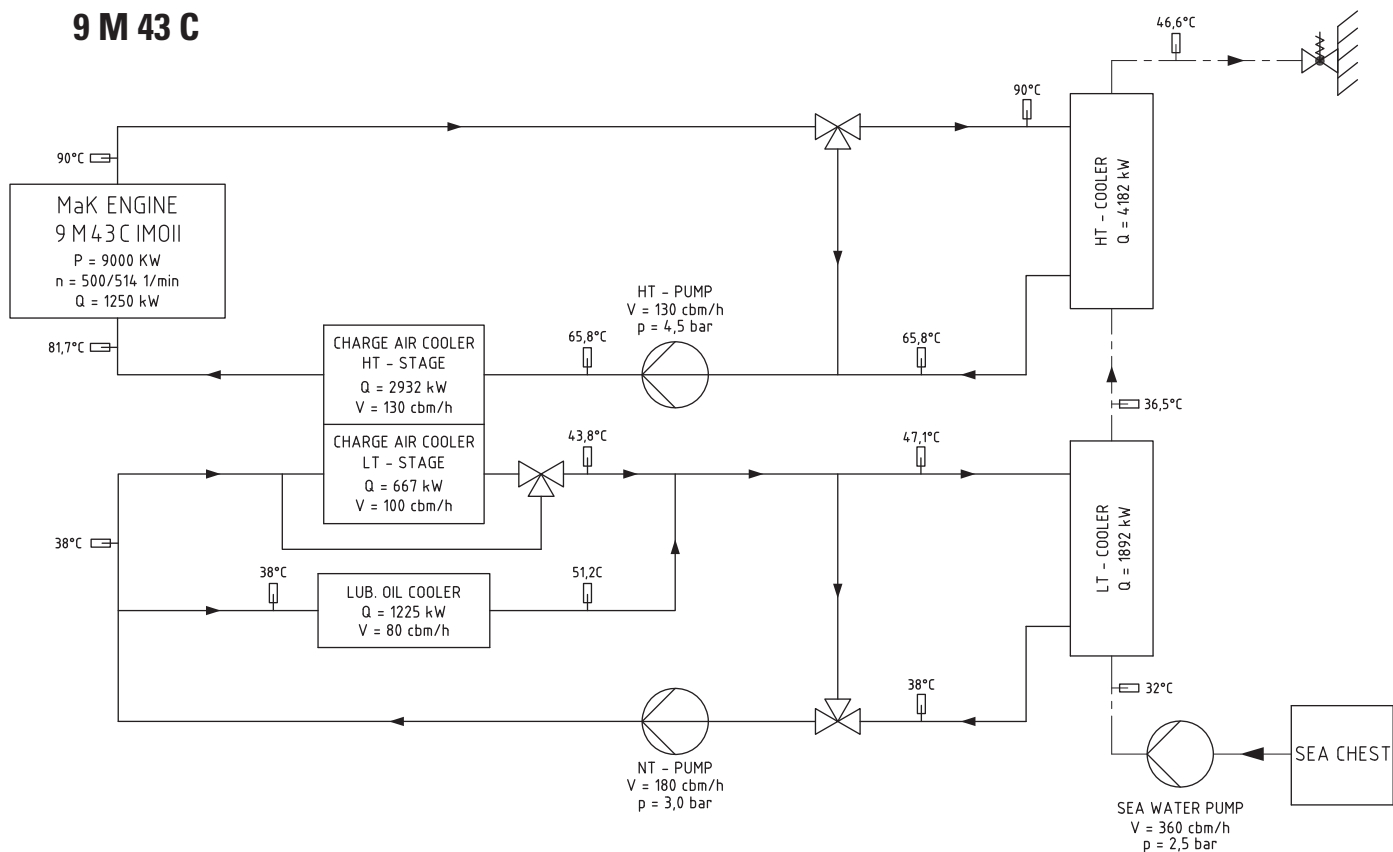


3. Systems

8 M 43 C

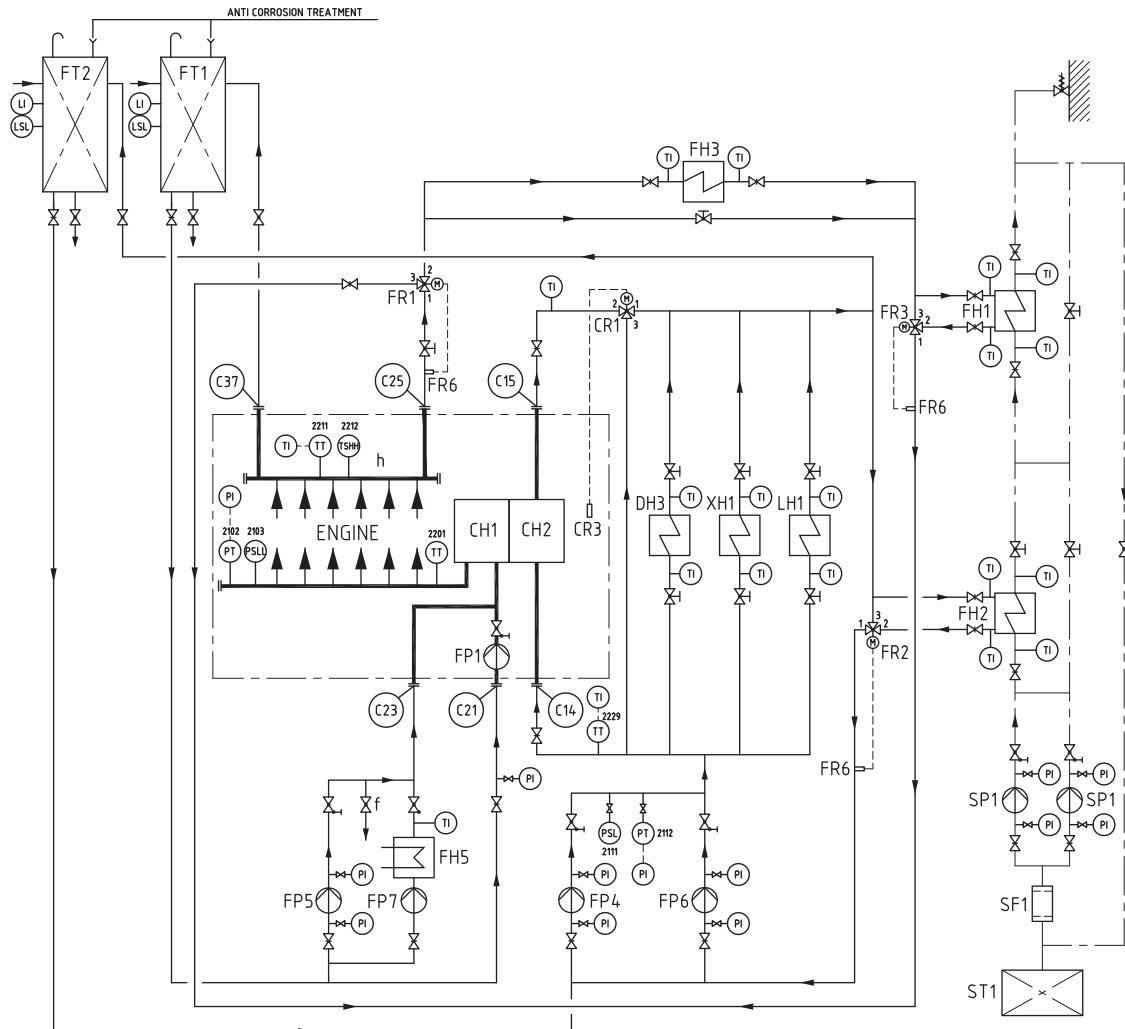


9 M 43 C



3. Systems

3.4.3 System diagram – Cooling water system



General notes:

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

With skin cooler not required.

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

Accessories and fittings:

CH1 Charge air cooler HT
CH2 Charge air cooler LT
CR1 Sensor for charge air temperature control valve
DH3 Fuel oil cooler for MDO operation
FH1 Freshwater cooler HT
FH2 Freshwater cooler LT
FH3 Heat consumer
FH5 Freshwater preheater
FP1 Freshwater pump (fitted on engine) HT
FP4 Freshwater pump (separate) 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
FR6 Sensor for temperature control valve

FT1 Compensation tank HT
FT2 Compensation tank LT
LH1 Lube oil cooler
SF1 Seawater filter
SP1 Seawater pump
SP2 Seawater stand-by pump
ST1 Sea chest
XH1 Generator cooler

LI Level indicator
LSL Level switch low
PI Pressure indicator
PSL Pressure switch low
PSLL Pressure switch low low
PT Pressure transmitter
TI Temperature indicator
TSHH Temperature switch high
TT Temperature transmitter (PT 100)

Disconnecting points:

C14 Charge air cooler LT, inlet
C15 Charge air cooler LT, outlet
C16 Charge air cooler HT, inlet
C21 Freshwater pump HT, inlet
C23 Stand-by pump HT, inlet
C25 Cooling water, engine outlet
C37 vent connection

Notes:

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

3. Systems

3.4.4 Cooling water system components

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

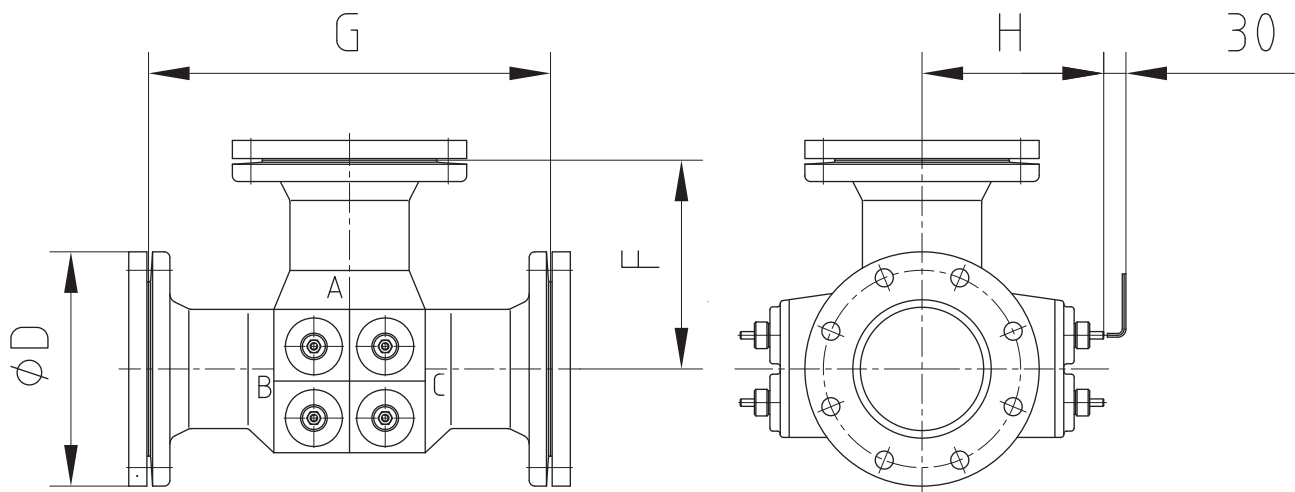
The system components of the LT cooling water circuit are designed for a max. LT cooling water temperature of 38 °C with a corresponding seawater temperature of 32 °C in tropical conditions.

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

a) LT cooling water pump (separate) FP4/FP6:

b) HT cooling water pump (separate) FP3/FP5: Option: fitted

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



		Dimensions [mm]					Weight [kg]
		DN	D	F	G	H	
6/7 M 43 C	HT	125	250	241	489	200	67
8/9 M 43 C	HT	150	285	254	489	200	80
6/7/8/9 M 43 C	LT	150*	285	254	489	200	80

* Minimum, depending on total cooling water flow

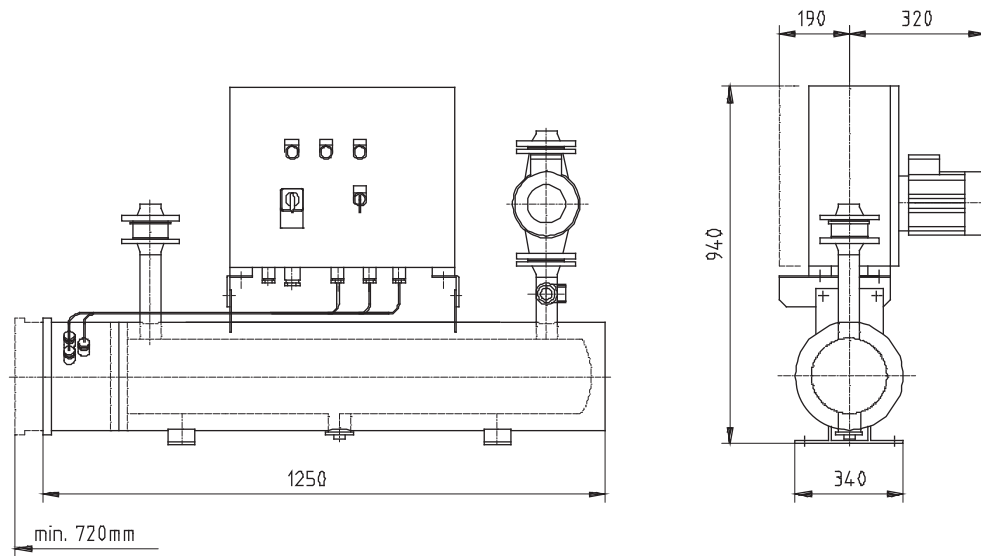
3. Systems

d) LT temperature controller (separate) FR2:

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

e) Pre-heater (fitted) FH5/FP7:

Consisting of circulating pump (12 m³/h), electric preheater (45 kW) and control cabinet.
Voltage 400 - 480, frequency 50/60 Hz.
Weight: 145 kg



f) HT cooler (optional, separate) FH1:

Plate type, size depending on the total heat to be dissipated.

g) LT cooler (separate) FH2:

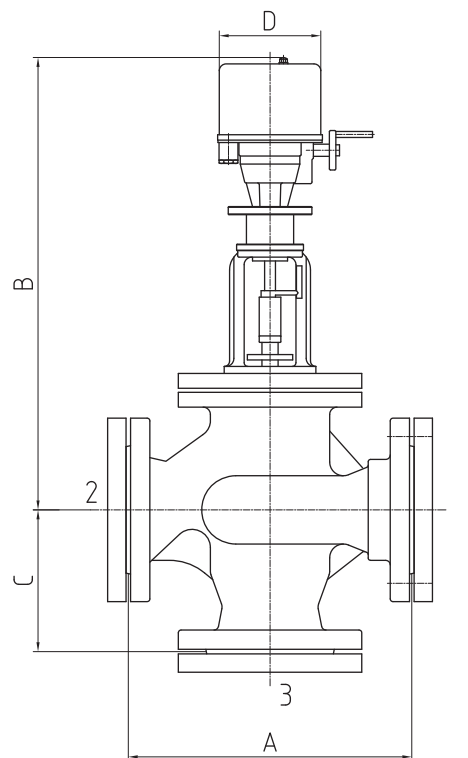
Plate type (plates made of titanium), size depending on the total heat to be dissipated.

3. Systems

h) 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.

f) Charge air temp. controller (separate) CR1: PI-controller with electric drive.



	Dimensions [mm]					Weight [kg]
	DN	A	B	C	D	
6/7 M 43 C	100	350	646	175	170	70
8/9 M 43 C	125	400	717	200	170	110
—	150	480	742	240	170	149

3. Systems

3.4.5 Recommendation for cooling water system

Drain tank with filling pump:

It is recommended to collect the treated water during 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.

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

P - Power [kW]

P_M - Power of electr. motor [kW]

V - Flow rate [m³/h]

H - Delivery head [m]

ρ - Density [kg/dm³]

η - Pump efficiency

0.70 for centrifugal pumps

$$P_M = 1.5 \cdot P$$

< 1.5 kW

$$P_M = 1.25 \cdot P$$

1.5 - 4 kW

$$P_M = 1.2 \cdot P$$

4 - 7.5 kW

$$P_M = 1.15 \cdot P$$

> 7.5 - 40 kW

$$P_M = 1.1 \cdot P$$

> 40 kW

3.5 Fuel oil system, MGO/MDO operation

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

3.5.1 Quality requirements for MGO/MDO fuel/permitted fuels

Two fuel product groups are permitted for MaK engines:

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

Min. injection viscosity 1.5 mm²/s (cSt)

Max. injection viscosity 12 mm²/s (cSt)

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.

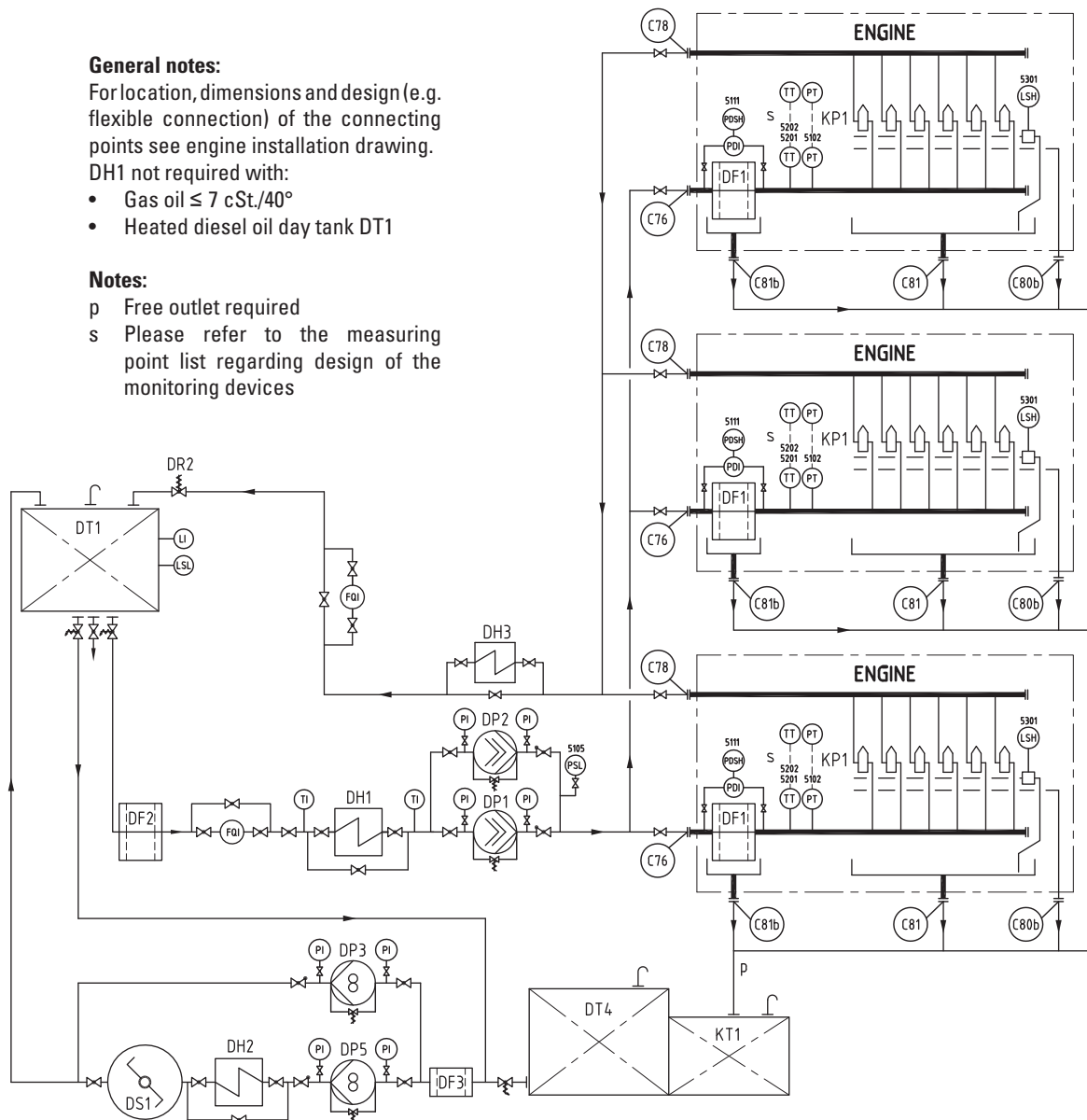
DH1 not required with:

- 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


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
- DP2 Diesel oil stand-by feed pump
- DP3 Diesel oil transfer pump (to day tank)
- DP5 Diesel oil 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

FQI Flow quantity indicator

LI Level indicator

LSH Level switch high

LSL Level switch low

PDI Diff. pressure indicator

PDSH Diff. pressure switch high

PI Pressure indicator

PSL Pressure switch low

PT Pressure transmitter

TI Temperature indicator

TT Temperature transmitter (PT 100)

Connecting points:

- C76 Inlet duplex filter
- C78 Fuel outlet
- C80b Drip fuel connection (cut-off pump)
- C81 Drip fuel connection
- C81b Drip fuel connection

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: | <p>Heating capacity</p> $Q \text{ [kW]} = \frac{P_{\text{eng.}} \text{ [kW]}}{166}$ <p>Not required:</p> <ul style="list-style-type: none"> • MGO $\leq 7 \text{ cSt/40}^\circ\text{C}$ • Heated day tank |
| d) MGO/MDO cooler DH3: | Required to prevent overheating of the day tank. |
| e) Feed pump (separate) DP1: | Capacity see technical data. |

3. Systems

f) MGO/MDO service tank DT1:

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

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

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

g) Separator DS1:

Recommended for MGO

Required for MDO

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

$$\dot{V}_{\text{eff}} [\text{kg/h}] = 0.28 \cdot P_{\text{eng.}} [\text{kW}]$$

3.6 Fuel oil system, HFO operation

3.6.1 Quality requirements for HFO/permitted fuels

Minimum requirements for storage, treatment and supply systems

Bunker tanks:

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

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 (2010):E-	RMA10	RMB30	RMB30	RMD80	RME180	RMF180	RMG380	RMH380	RMK380	RMH500	RMK500	RMH700	RMK700
Characteristic	Dim.													
Density at 15°C	kg/m ³	max	960 ²⁾	975 ³⁾	980 ⁴⁾	991	991	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
Ash	% (m/m)	max	0.10		0.10	0.10	0.15	0.15		0.15				0.15
Total sedim, after ageing	% (m/m)	max	0.10		0.10	0.10			0.10		0.10			0.10
Water	% (V/V)	max	0.3	0.5	0.5	0.5			0.5		0.5			0.5
Sulphur	% (m/m)	max	3.5		3.5	3.5			3.5		3.5			3.5
Vanadium	mg/kg	max	50	150	150	200	350	350		450				450
Aluminium + silicon	mg/kg	max	25	40	40	60			60		60			60
Zinc	mg/kg	max		15	15	15			15		15			15
Phosphor	mg/kg	max	15	15	15	15			15		15			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 mm ² /s (cSt)	7	10	15	25	35	45	55
Kinematic viscosity at 50 °C mm ² /s (cSt)	30	40	80	180	380	500	700
Kinematic viscosity at 100 °F Redw. I sec.	200	300	600	1,500	3,000	5,000	7,000

²⁾ ISO: 920

³⁾ ISO: 960

⁴⁾ ISO: 975

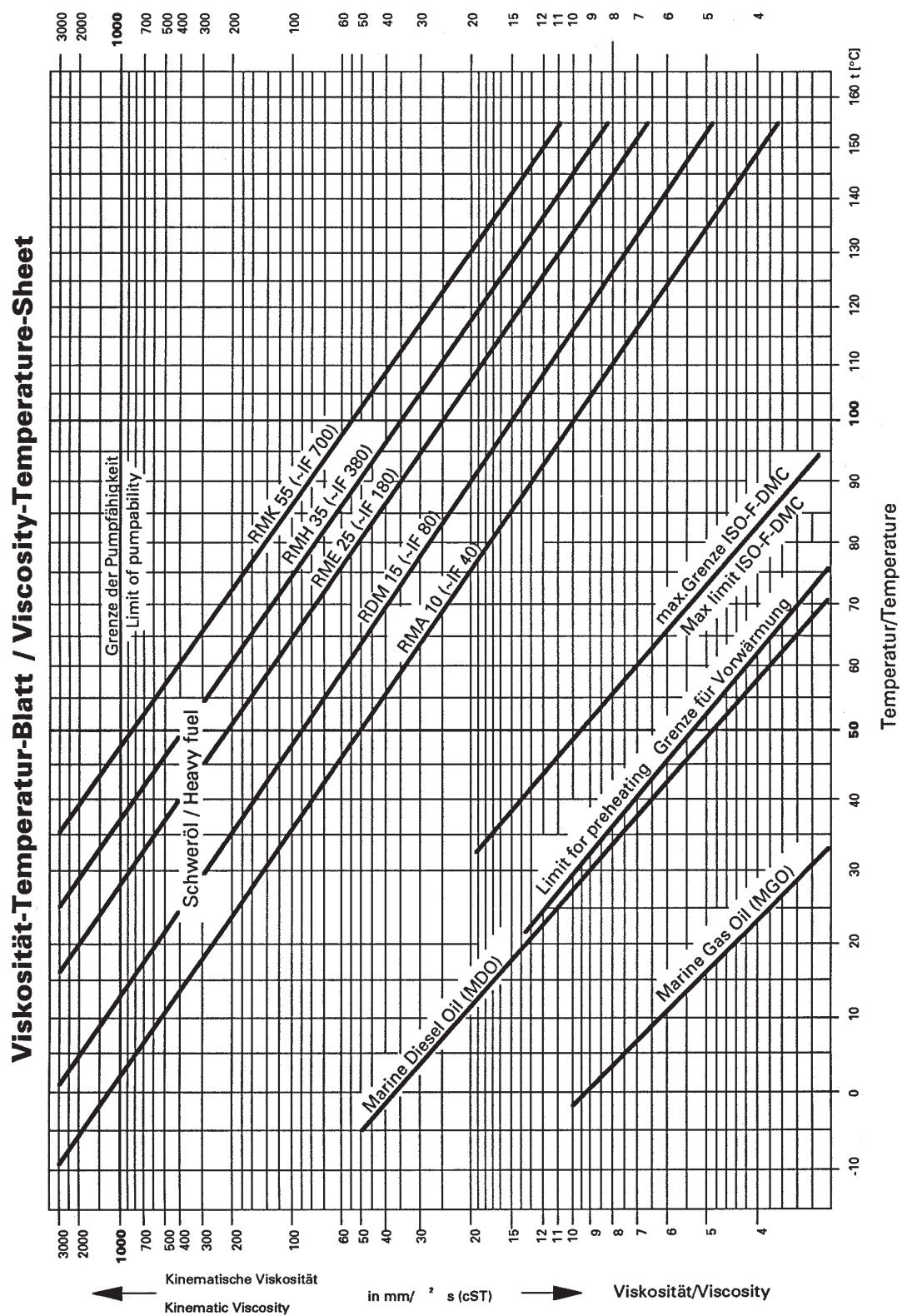
⁵⁾ ISO: not limited

⁶⁾ ISO: Carbon residue 2.5/10

Fuel shall be free of used lubricating oil (ulo)

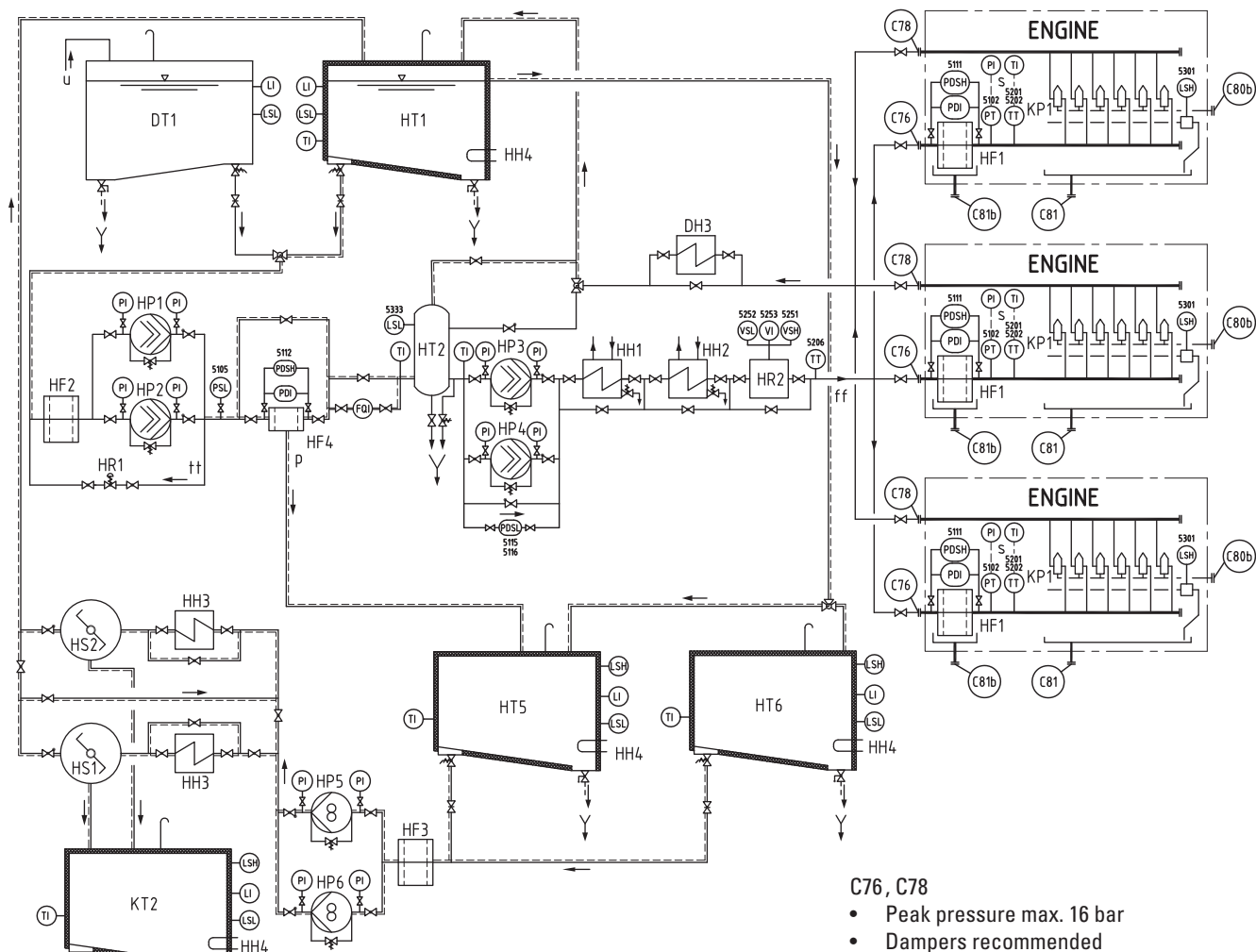
3. Systems

3.6.2 Viscosity/temperature diagram



3. Systems

3.6.3 System diagram – Heavy fuel oil operation



General notes:

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

Accessories and fittings:

DH3	Gas oil cooler
DT1	Diesel oil day tank
HF1	Fine filter (duplex filter)
HF2	Primary filter
HF3	Coarse filter
HF4	Self cleaning fuel filter
HH1	Heavy fuel final preheater
HH2	Stand-by final preheater
HH3	Heavy fuel preheater (separator)
HH4	Heating coil
HP1/HP2	Pressure pump
HP3/HP4	Circulating pump
HP5/HP6	Heavy fuel transfer pump (separator)
HR1	Pressure regulating valve
HR2	Viscosimeter
HS1/HS2	Heavy fuel separator
HT1	Heavy fuel day tank
HT2	Mixing tank

HT5/HT6	Settling tank
HT8	Compensation damping tank
KP1	Injection pump
KT2	Sludge tank
FQI	Flow quantity indicator
LI	Level indicator
LSH	Level switch high
LSL	Level switch low
PDI	Diff. pressure indicator
PDSH	Diff. pressure switch high
PDSL	Diff. pressure switch low
PI	Pressure indicator
PSL	Pressure switch low
PT	Pressure transmitter
TI	Temperature indicator
TT	Temperature transmitter (PT 100)
VI	Viscosity indicator
VSH	Viscosity control switch high
VSL	Viscosity control switch low

Notes:

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

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

Connecting points:

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

3. Systems

3.6.4 HFO system components

Supply system:

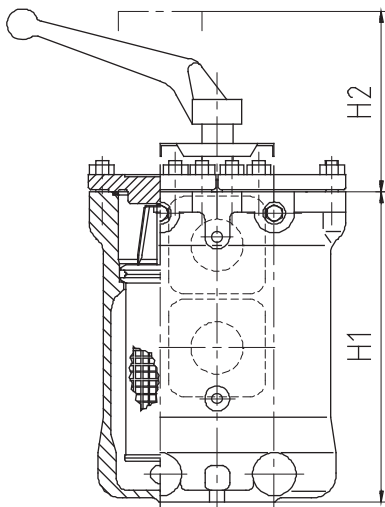
A closed **pressurized system** between day tank and engine is required as well as the installation of an automatic backflushing filter with a mesh size of 10 µm (absolute).

a) Fine filter (fitted) HF1:

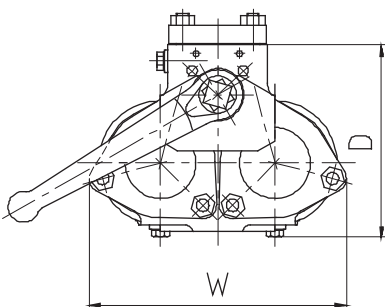
- Mesh size 34 µm
- Differential pressure indication and alarm contact fitted

b) Strainer HF2:

Mesh size 0.32 mm



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



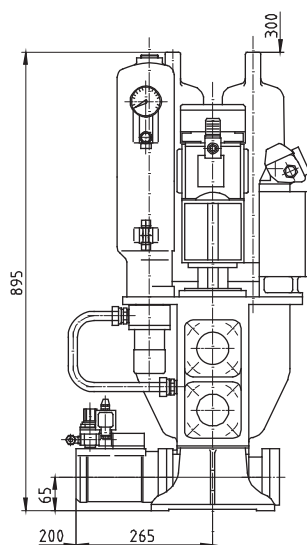
3. Systems

c) Self cleaning filter HF4:

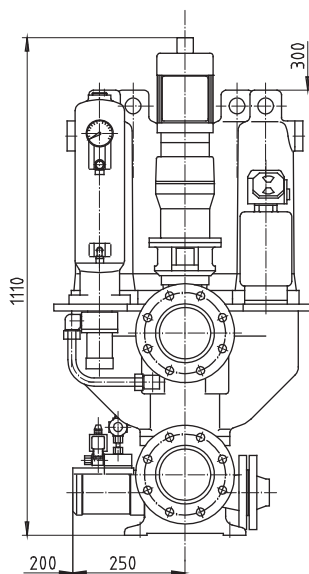
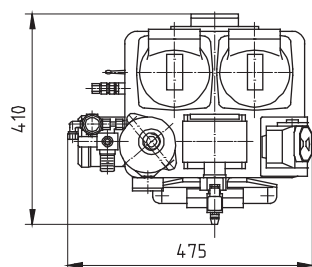
Mesh size 10 µm (absolute).

≤ 8,000 kW, DN 50

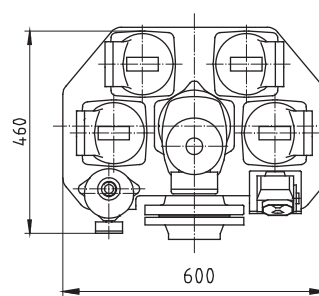
> 8,000 kW, DN 100



Dismantling of filter
element
300 mm



Dismantling of filter
element
300 mm



d) Viscosimeter HR2:

This device automatically regulates the heating of the final-preheater depending on the viscosity of the bunkered fuel oil, so that the fuel will reach the nozzles with the viscosity required for injection.

e) Pressure pumps HP1/HP2:

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

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

f) Circulating pumps HP3/HP4:

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

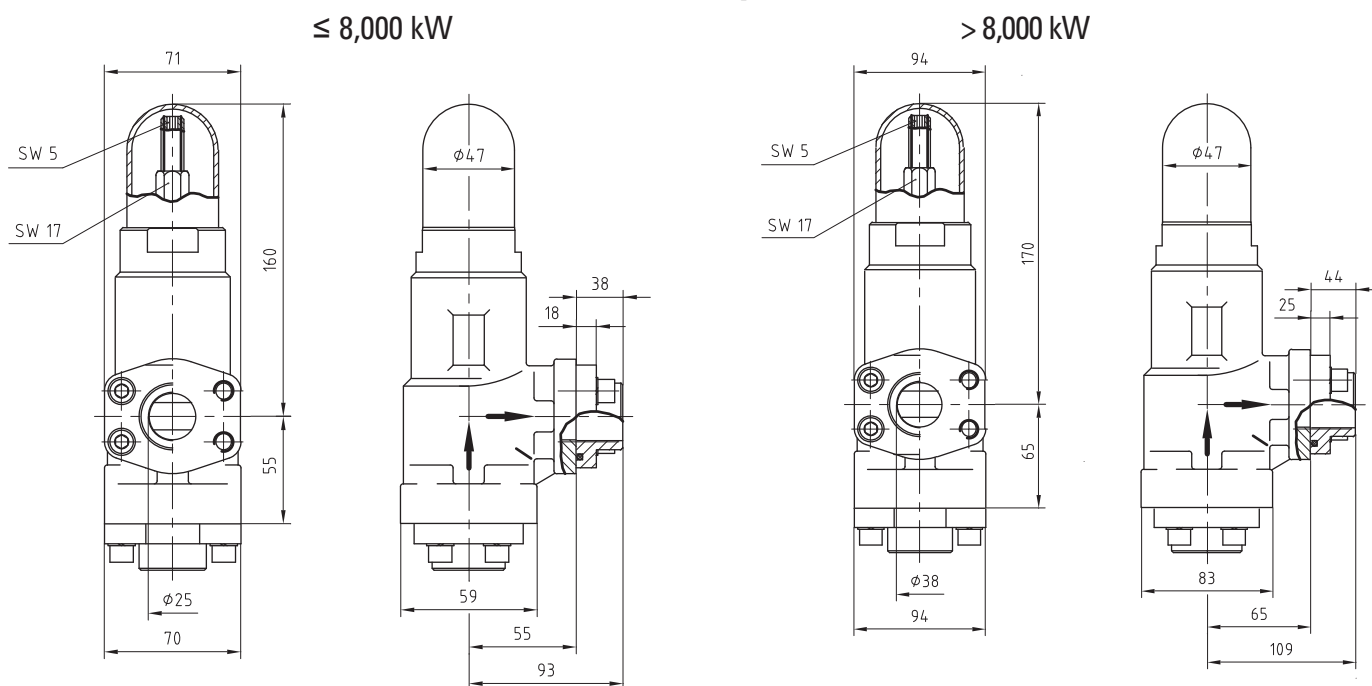
$$\text{Capacity } \dot{V} [\text{m}^3/\text{h}] = 0.7 \cdot \frac{P_{\text{eng.}} [\text{kW}]}{1,000}$$

3. Systems

g) Pressure regulating valve HR1 / DR2:

Controls the pressure at the engine inlet, approx. 4 bar.

Engine outputs



h) Final preheater HH1/HH2:

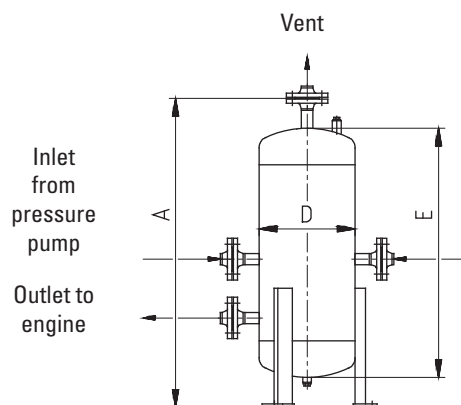
Heating media:

- Electric current (max. surface power density 1.1 W/cm^2)
- Steam
- Thermal oil

Temperature at engine inlet max. 150°C .

i) Mixing tank (without insulation) HT2:

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



3. Systems

j) Bunker tanks:

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

k) Settling tanks HT5/HT6:

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

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

Settling tank temperature 70 - 80 °C

l) 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.

Guide values for temperatures

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

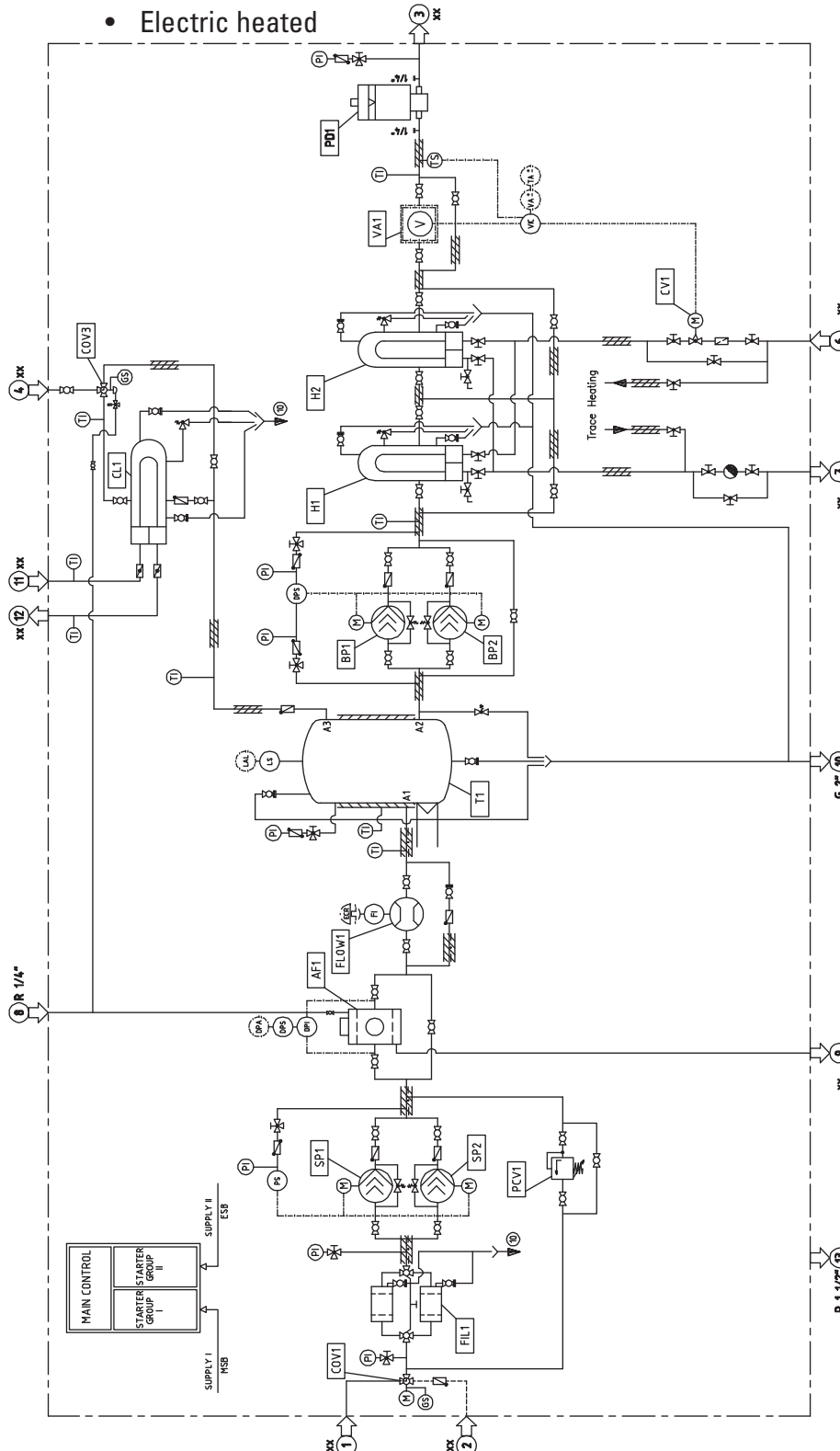
m) Separators HS1/HS2:

Caterpillar 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.

3.6.5 System diagram – Standard HFO supply and booster module

Steam heated

- Option: • Thermal oil heated
• 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
*	option: thermal oil heater or electric heater

3. Systems

3.6.6 Standard heavy fuel oil supply and booster module

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

Technical specification of the main components:

a) Primary filter FIL1

1 pc. duplex strainer 540 microns

b) Fuel pressure pumps, vertical installation SP1/SP2

2 pcs. screw pumps with mechanical seal

c) Pressure regulating system PCV1

1 pc. pressure regulating valve

d) Self-cleaning fine filter AF1

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

e) Consumption measuring system FLOW1

1 pc. flowmeter with local totalizer

f) Mixing tank with accessories T1

1 pc. pressure mixing tank

approx. 99 l volume from 4,001 - 20,000 kW
(with quick-closing valve)

g) Circulating pumps, vertical installation BP1/BP2

2 pcs. screw pumps with mechanical seal

h) Final preheater H1/H2

2 pcs. shell and tube heat exchangers

each 100 % (saturated 7 bar or thermal oil 180 °C)
each 100 % electrical

- **Heating medium control valve CV1** (steam/thermal oil)
- **Control cabinet** (electrical)
- 1 pc. control valve with built-on positioning drive
- 1 pc. control cabinet for electr. preheater

i) Viscosity control system VA1

1 pc. automatic viscosity measure and control system

j) Cooler CL1

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

3. Systems

Module controlled automatically with alarms and starters

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

Alarms

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

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

Performance and materials:

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

Capacity [kW]	Type	Weight [kg]	L x B x H [mm]
< 6,000	Steam / Thermal	3,200	3,200 x 1,300 x 2,100
	Electric	3,000	
< 9,000	Steam / Thermal	3,600	3,400 x 1,400 x 2,100
	Electric	3,200	
< 12,000	Steam / Thermal	4,000	3,600 x 1,400 x 2,100
< 16,000	Steam / Thermal	4,200	4,200 x 1,600 x 2,100
< 24,000	Steam / Thermal	5,400	5,000 x 1,700 x 2,100
< 32,000	Steam / Thermal	6,000	6,000 x 2,000 x 2,100

3. Systems

3.7 Lube oil system

The engine lube oil fulfils several basic functions:

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

3.7.1 Quality requirements of lube oil

The viscosity class SAE 40 is required.

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

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

3. Systems

The following oils have been tested and approved by Caterpillar:

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

I Approved in operation

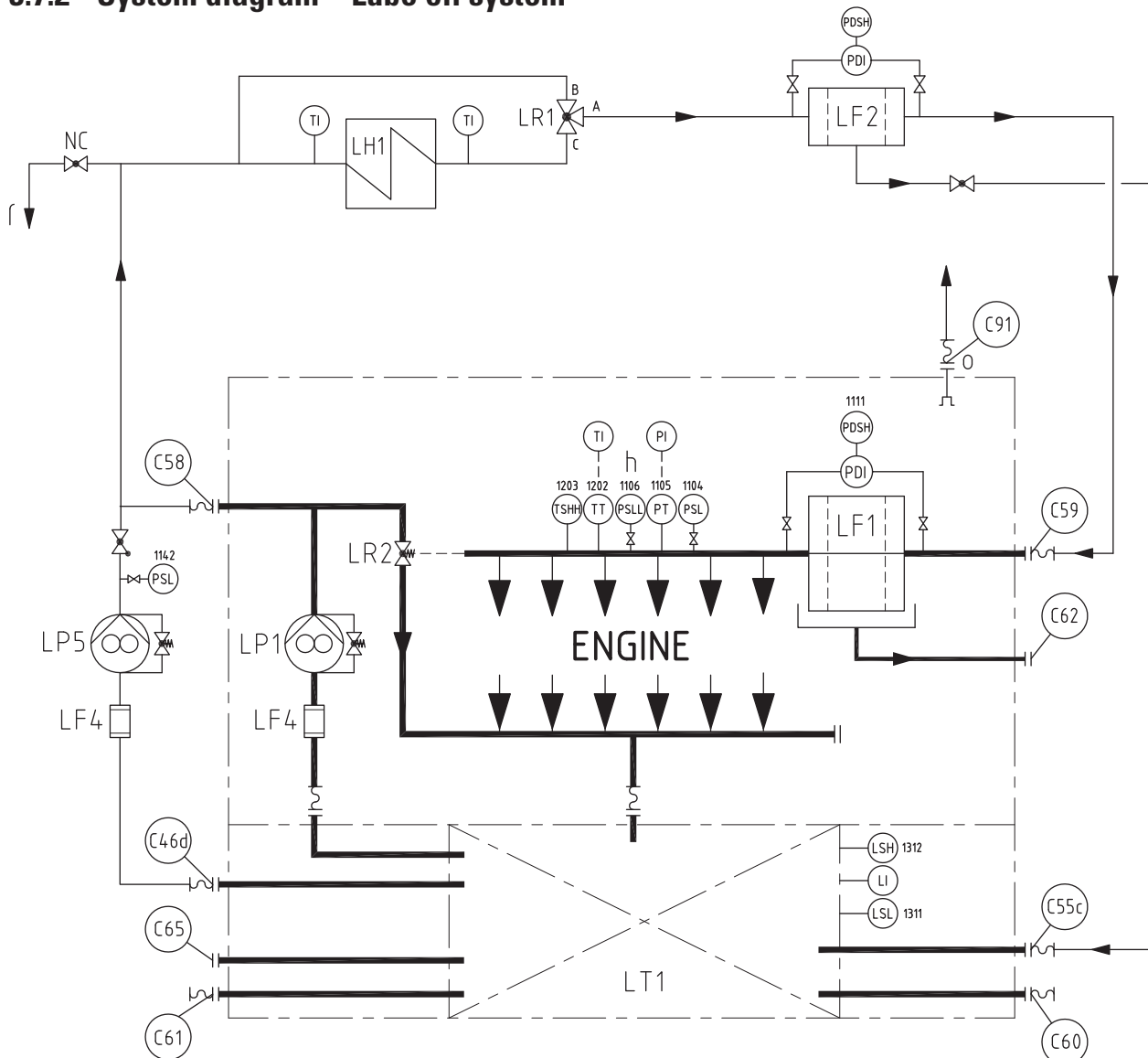
II Permitted for controlled use

When these lube oils are used, Caterpillar 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 – Lube oil system



Notes:

- f Drain
- h Please refer to the measuring point list regarding design of the monitoring devices
- o See "crankcase ventilation" installation instructions 5.7

General notes:

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

Connecting points:

- C46d Prelubrication pump, suction side
- C55c Connection flushing pipe aut. filter
- C58 Force pump, delivery side
- C59 Lube oil inlet, lube oil cooler
- C60 Separator connection, suction side
- C61 Separator connection, delivery side
- C62 Drip oil, duplex filter
- C65 Lube oil filling socket
- C91 Crankcase ventilation to stack

Accessories and fittings:

- LF1 Duplex lube oil filter
- LF2 Self cleaning lube oil filter
- LF4 Suction strainer
- LH1 Lube oil cooler
- LP1 Lube oil force pump
- LP5 Prelubrication force pump
- LR1 Lube oil thermostat valve
- LR2 Oil pressure regulating valve
- LT1 Lube oil sump tank
- LI Level indicator
- LSL Level switch low

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

3. Systems

3.7.3 Lube oil system components

a) Force pump (fitted) LP1:

Gear pump

b) Prelubrication pump (separate) LP5:

Delivery head 5 bar.

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

d) Strainer LF4:

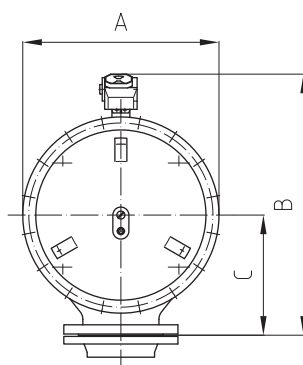
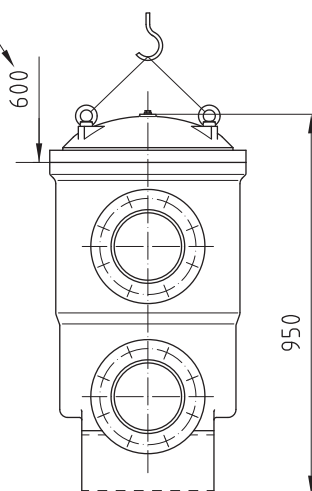
Mesh size 2 - 3 mm

e) Self-cleaning filter (separate) LF2:

The self-cleaning filter protects the engine against particles.

Mesh size 30 μm (absolute). **Without** by-pass filter.
Without flushing oil treatment.

Dismounting
of sieve



Engine	DN	A	B	C	Weight [kg]
6/7 M 43 C	125	440	580	260	195
8/9 M 43 C	150	490	665	300	250

3. Systems

f) Duplex filter (fitted) LF1:

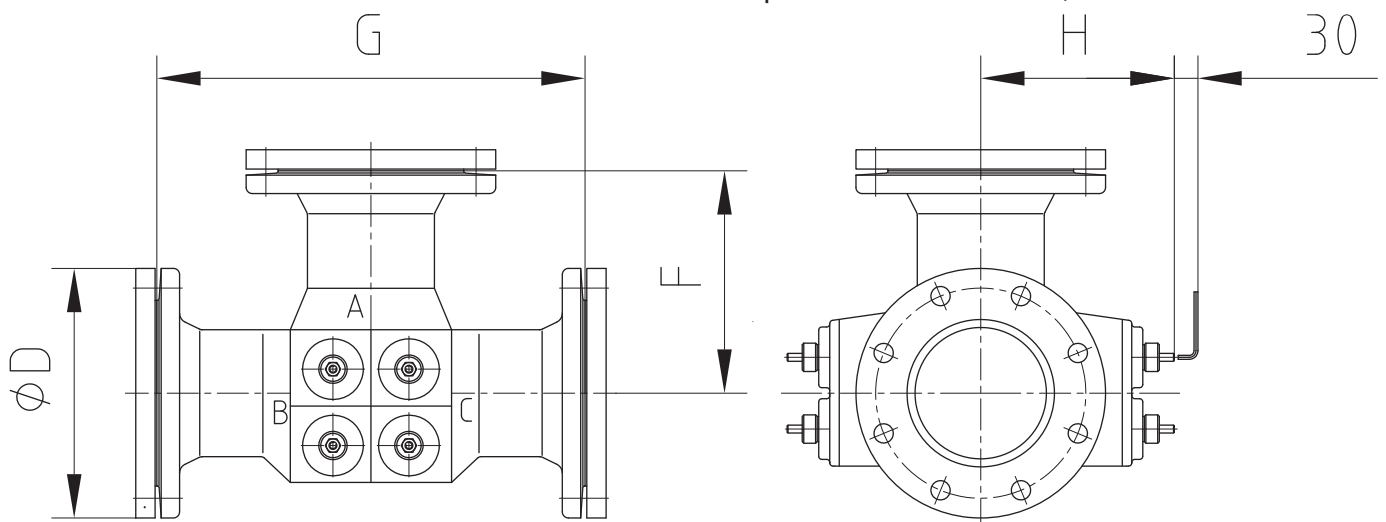
Mesh size 80 µm
Differential pressure indication and alarm contact fitted.

g) Cooler (separate) LH1:

Plate type (plate material: stainless steel)

h) Temperature controller LR1:

P-controller with manual emergency adjustment
Option: PI-controller with electric drive (see Charge air temperature controller CR1)



	Dimensions [mm]					Weight [kg]
	DN	D	F	G	H	
6/7 M 43 C	125	250	241	489	200	67
8/9 M 43 C	150	285	254	489	200	80

i) Circulation tank LT1:

Oil filling approx. 80 % of tank volume.

3. Systems

j) Crankcase ventilation C91:

One vent pipe connection DN 150 is located on top of the engine block near the turbocharger (see system connections C91).

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

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

Recommended with the following design:

- Separating temperature 85 - 95 °C
- Quantity to be cleaned three times/day
- Self-cleaning type

$$\dot{V}_{\text{eff}} [\text{l/h}] = 0.18 \cdot P_{\text{eng}} [\text{kW}]$$

l) 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

$$\dot{V}_{\text{eff}} [\text{l/h}] = 0.29 \cdot P_{\text{eng}} [\text{kW}]$$

3. Systems

3.7.4 Recommendation for lube oil system

For each engine a separate lube oil system is recommended.

Lube oil quantities/change intervals:

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

The change intervals depend on:

- fuel quantity
- 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.

Suction pipes

Suction pipes must be dimensioned for the total resistance (including pressure drop for the suction filter) not exceeding the pump suction head.

Maximum oil flow velocity 1.0 m/s.

In order to prevent lube oil backflow when the engine has been stopped a non-return flap must be installed close to the lube oil tank.

External lube oil piping system information

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

4.1 Data for torsional vibration calculation

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

The classification societies require a complete Torsional Vibration Calculation.

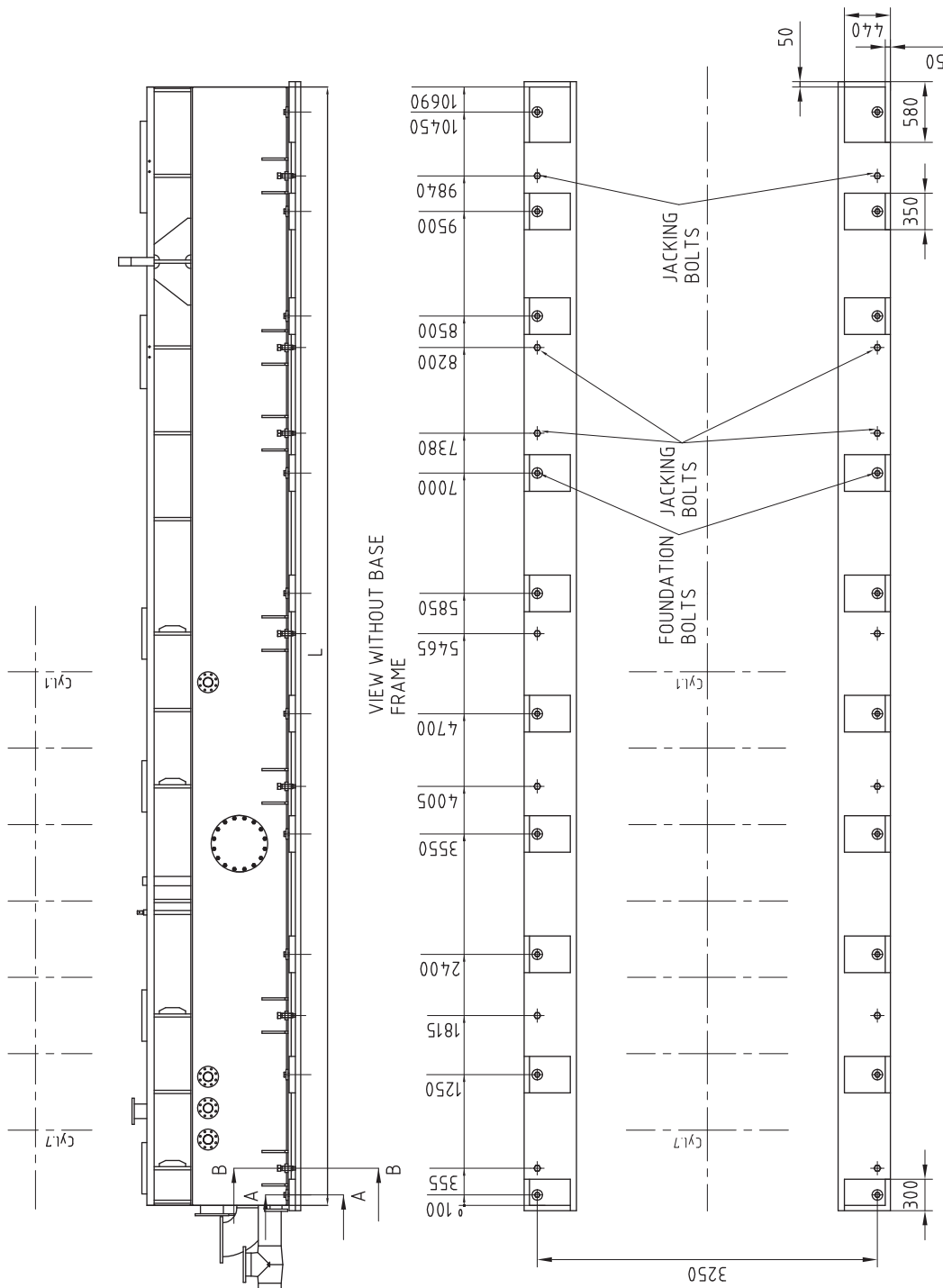
To be able to provide a correct Torsional Vibration Calculation, we would like to ask you to fill in the documents in the appendix, according to your scope of supply.

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

4. Connecting parts engine

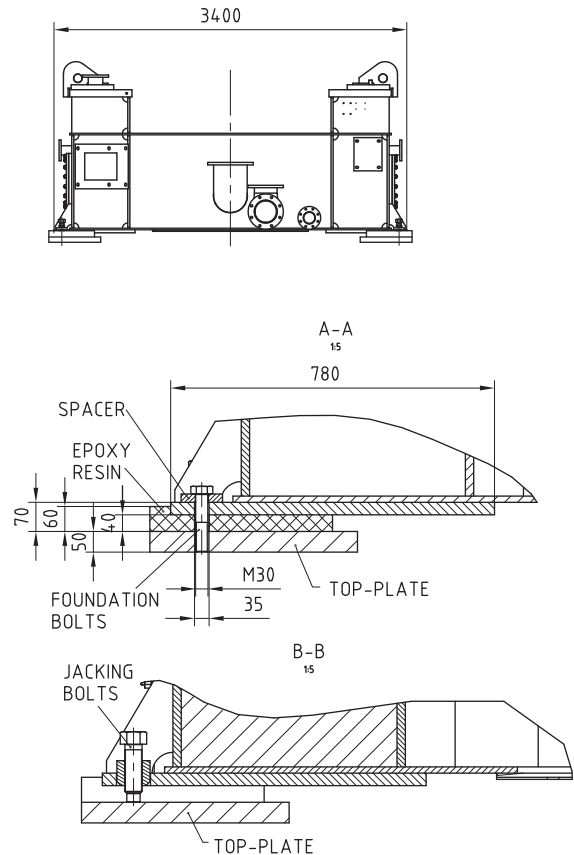
4.2 Mounting of genset

M 43 C gensets have resilient mounted engines on the baseframe and rigid mounted baseframe on ship's foundation.



4. Connecting parts engine

	Foundation bolts	Jacking bolts	L
6 M 43 C	16	14	9,960
7 M 43 C	20	14	10,690
8 M 43 C	20	14	11,420
9 M 43 C	22	16	12,150



General note:

The shipyard is solely responsible for the adequate design and quality of foundation.

Information on foundation bolts, steel chocks, side stoppers and alignment bolts can be found in the foundation plans.

If pourable resin is used it is recommendable to employ authorized workshops of resin manufacturers approved by the classification societies for design and execution.

It has to be taken into account that the permissible surface pressure for resin is lower than for steel chocks and therefore the tightening torques for the bolts are reduced correspondingly.

When installing the engine on steel chocks the top plate should be build with an inclination outwards from the engine centerline. Wedge type chocks with the corresponding inclination have to be used.

The material can be cast iron or steel.

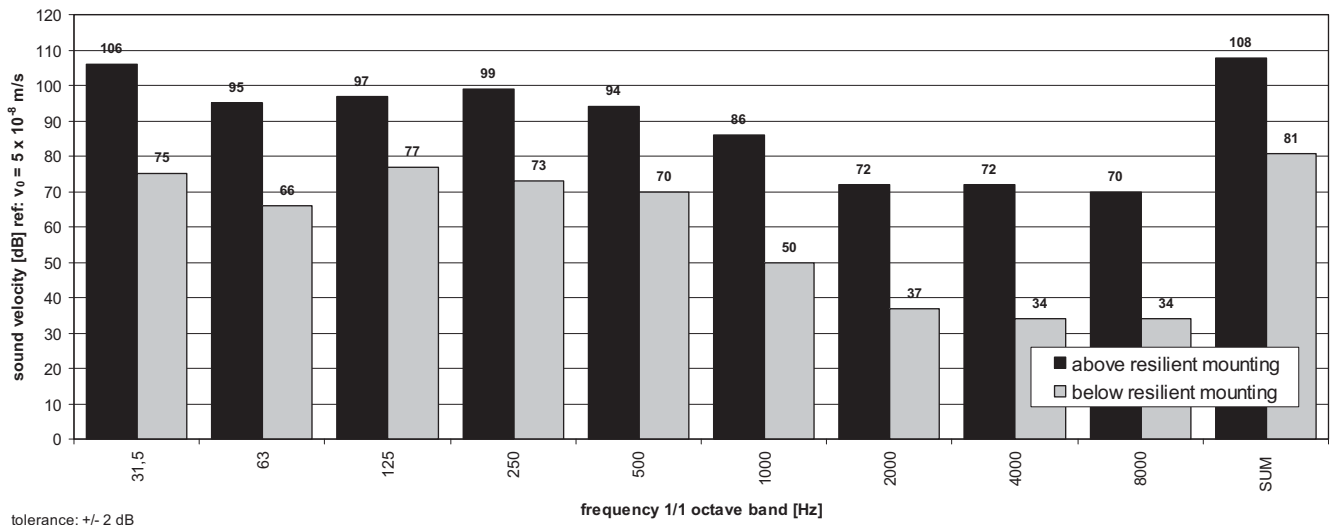
Surface treatment:

The supporting surface of the top plate has to be milled. When fitting the chocks, a bearing contact of min. 80 % is to be obtained.

4. Connecting parts engine

4.2.1 Structure-borne sound level L_v expected (measured in the test cell)

Structure borne noise level M 43 C Genset
above/below resilient mounting measured at testbed in Rostock
 (values below resilient mounting depend on resilient element type and foundation mobility)



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

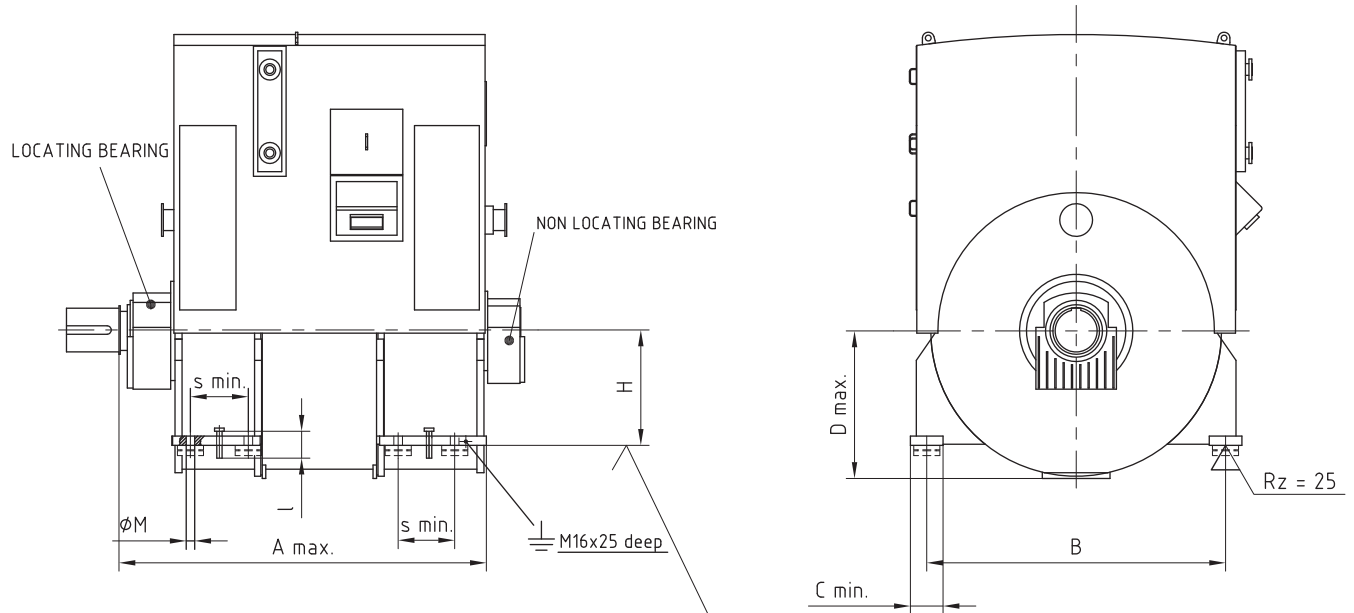
The basis for assessing vibration severity are the guidelines ISO 10816-6.

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	$f > 2 \text{ Hz} < 10 \text{ Hz}$
Vibration velocity	V_{eff}	< 28.2 mm/s	$f > 10 \text{ Hz} < 250 \text{ Hz}$
Vibration acceleration	a_{eff}	< 44.2 m/s ²	$f > 250 \text{ Hz} < 1000 \text{ Hz}$

4. Connecting parts engine

4.3 Generators structural requirements for MaK diesel gensets M 43 C



CONTACT SURFACES FREE OF PAINT, MACHINED. PRESERVED FOR 6 MONTH.

Rz = 25

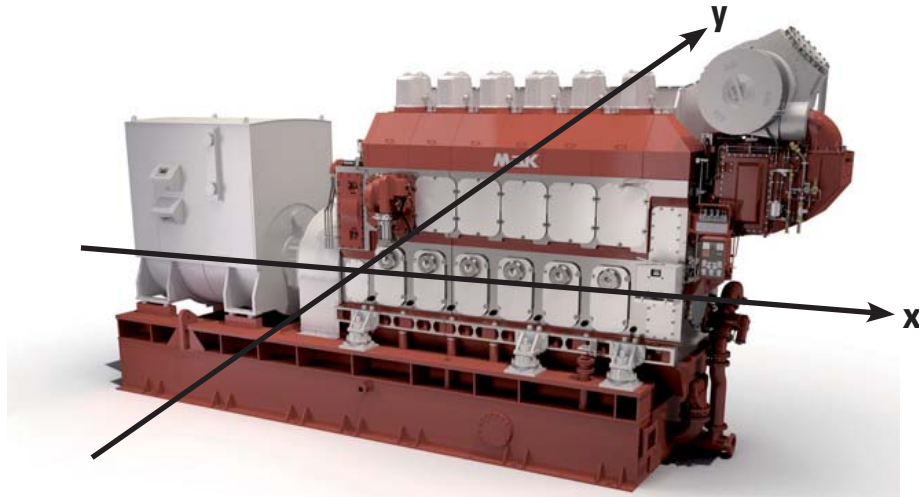
□ 0,1 / 1000 EACH FOOT

- 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	A max.	B	C min.	D max.	H	Ø M	S min.
6/7/8/9 M 43 C	3,350	2,240	180	1,300	955	46	300

5. Installation and Arrangement

5.1 General installation aspect



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

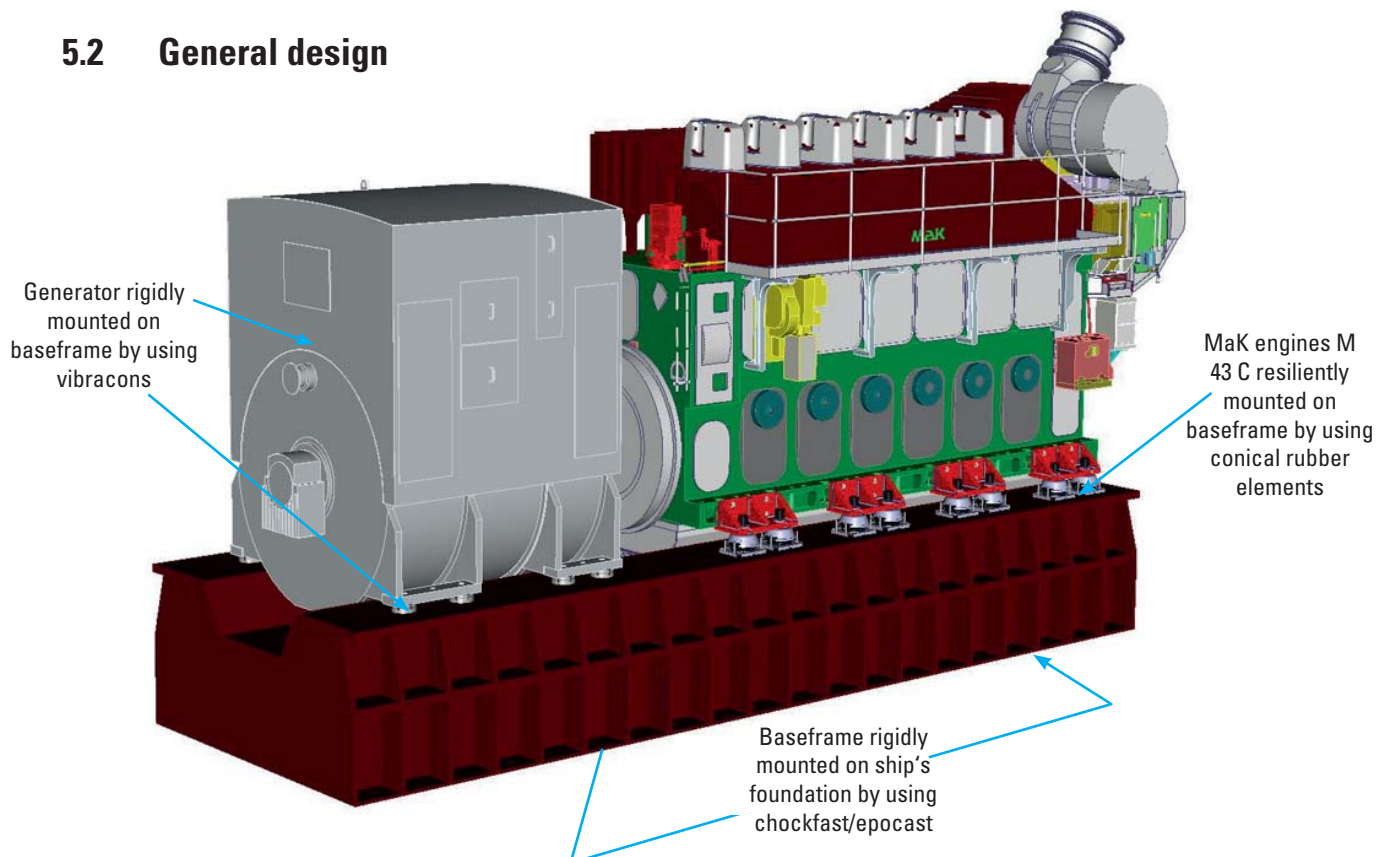
Rotation X-axis:

Static: heel to each side: 15 °C
Dynamic: rolling to each side: 22.5 °C

Rotation Y-axis:

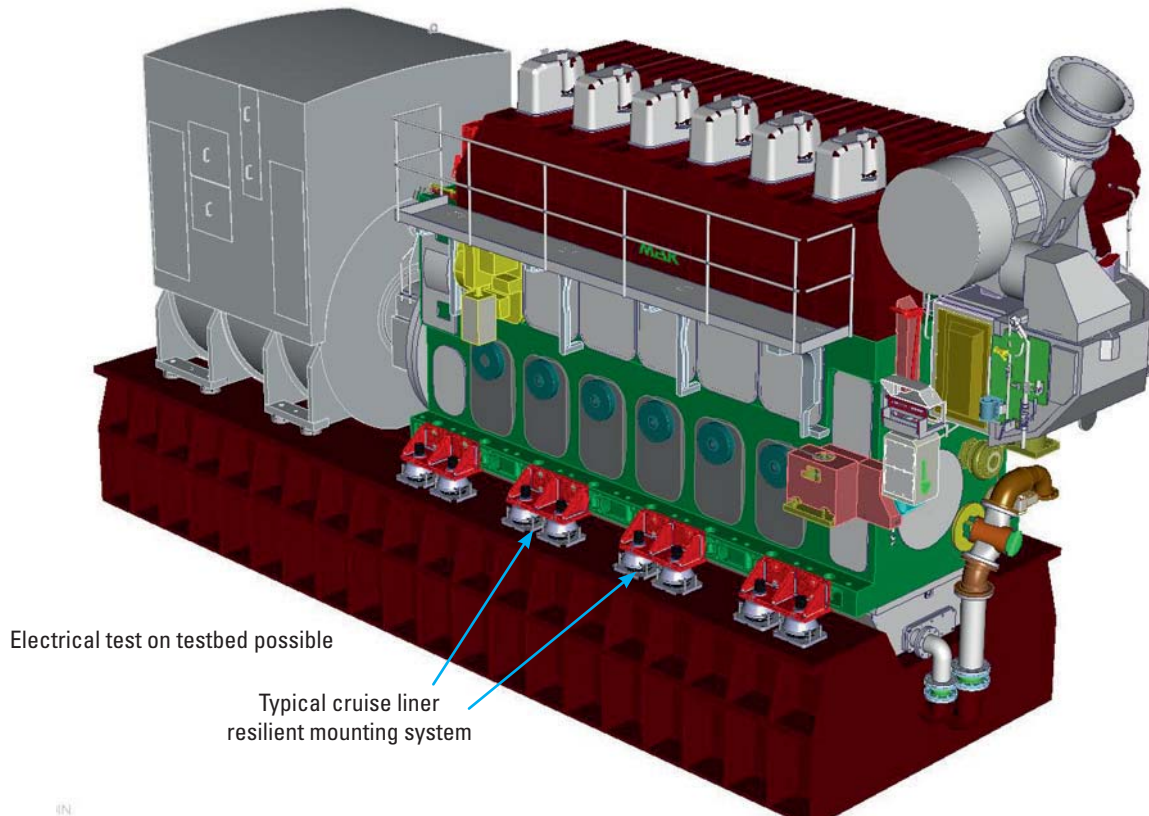
Static: trim by head and stern: 5 °C
Dynamic: pitching: ± 7.5 °C

5.2 General design

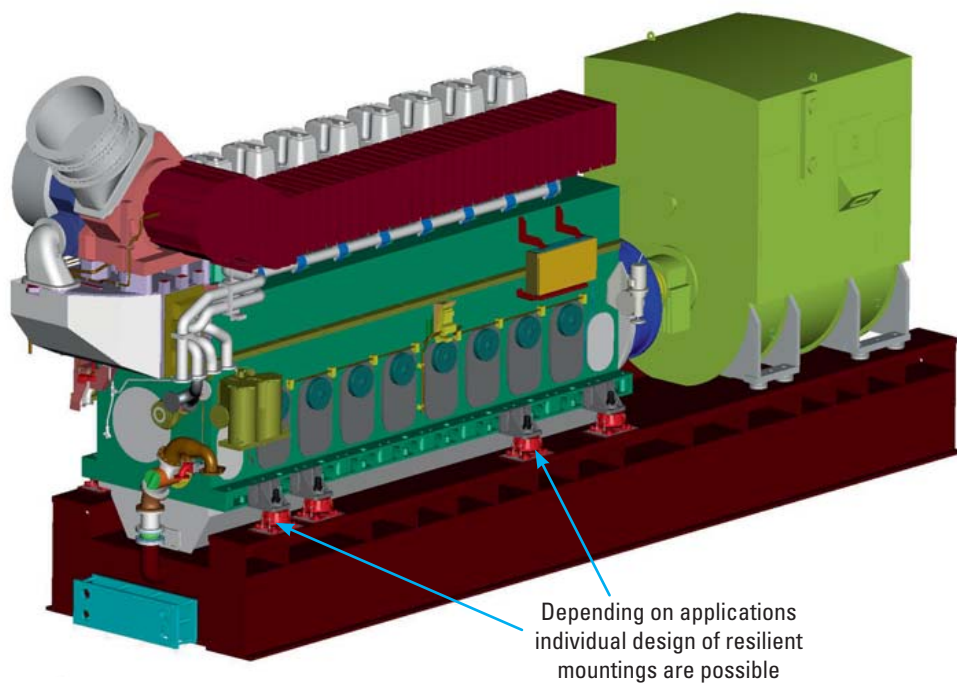


5. Installation and Arrangement

5.3 M 43 C genset applications

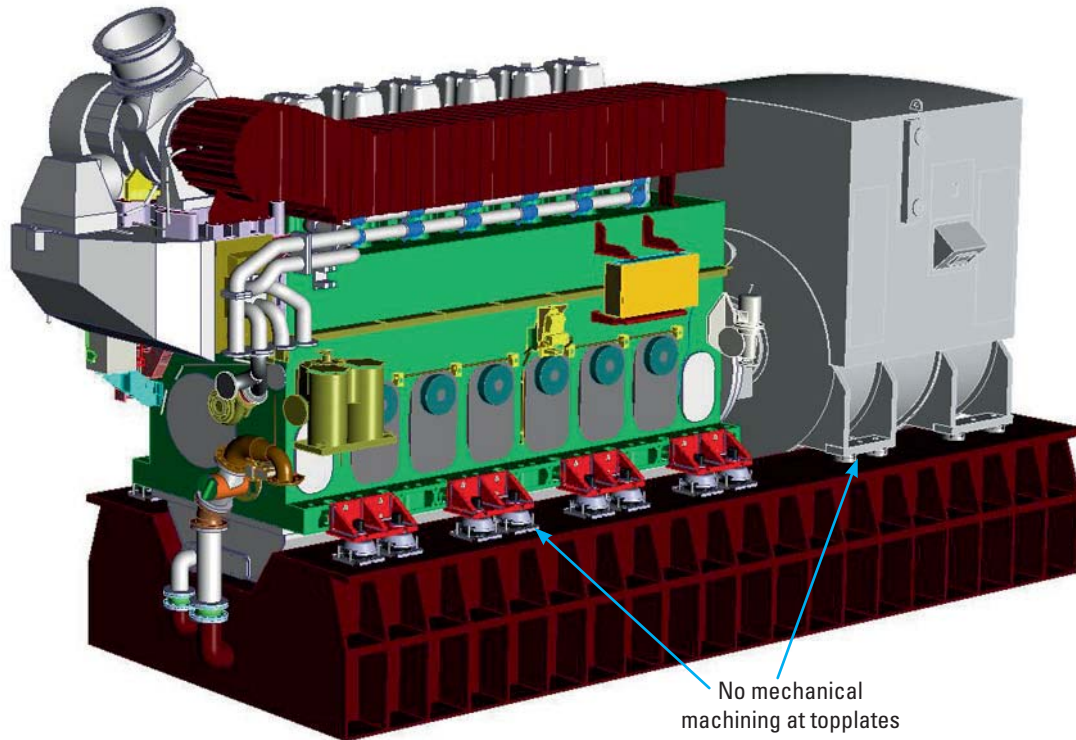


5.3.1 MaK genset 8 M 43 C

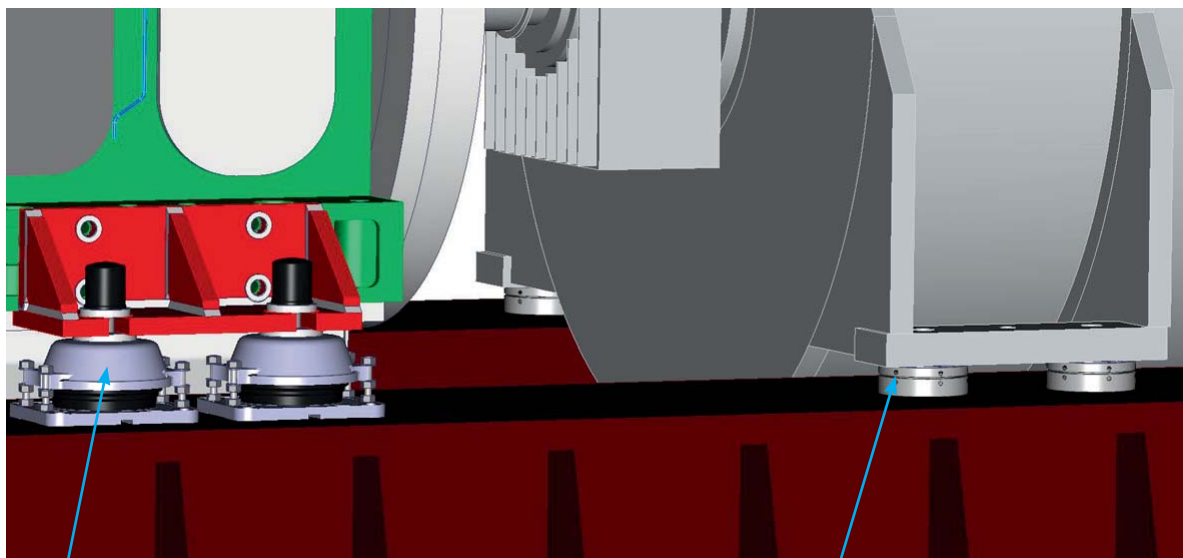


5. Installation and Arrangement

5.3.2 M 43 C genset



5.3.3 M 43 C genset – close-up

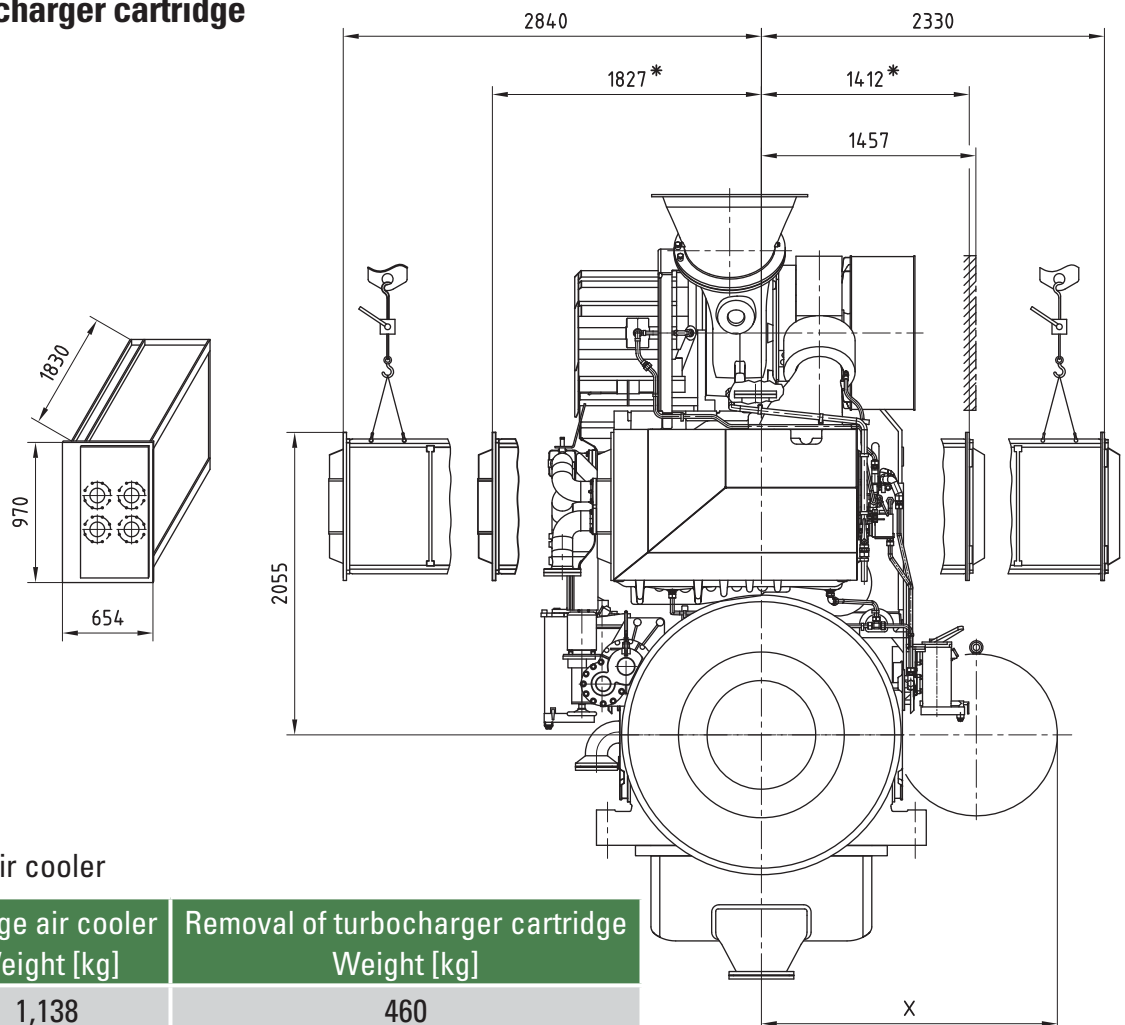


MaK engine M 43 C
resilient mounting
element

Generator
rigid mounting element

5. Installation and Arrangement

5.4 Space requirement for dismantling of charge air cooler, torsional vibration damper and turbocharger cartridge



* splitted charge air cooler

Engine type	Charge air cooler Weight [kg]	Removal of turbocharger cartridge Weight [kg]
6 M 43 C	1,138	460
7/8/9 M 43 C	1,124	820

Charge air cooler cleaning

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

Engine type	kW	Damper ø mm	Weight kg	X mm
6 M 43 C	1,000	1,100	960	2,010
7 M 43 C	1,000	1,340	1,538	2,250
8 M 43 C	1,000	1,480	2,527	2,390
9 M 43 C	1,000	1,480	2,527	2,390

Turbocharger removal/maintenance

Caterpillar recommends to provide a lifting rail with a travel-ing trolley right above the center of the turbocharger in order to carry out scheduled maintenance work.

5. Installation and Arrangement

5.5 Installation of flexible pipe connections

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

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

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

Installation of steel expansion joints

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

5.6 Notes regarding installation exhaust system

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

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

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

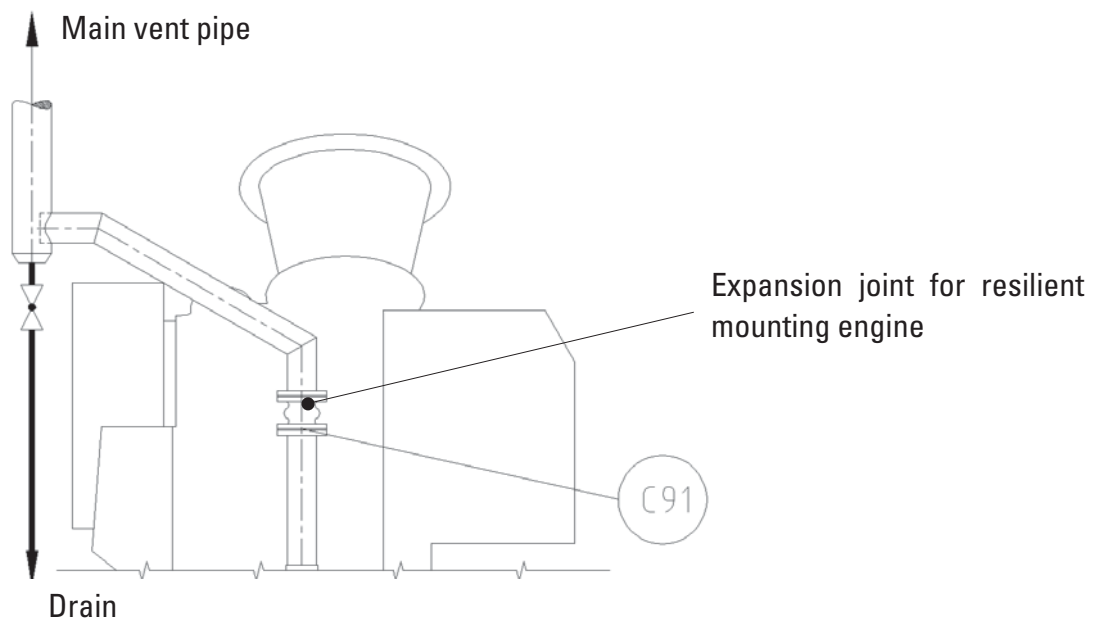
If it should be impossible to use standard transition piece supplied by Caterpillar Motoren, the weight of the transition piece manufactured by the shipyard must not exceed the weight of the standard transition piece. A drawing including the weight will then have to be submitted approval.

5. Installation and Arrangement

5.7 Installation of crankcase ventilation on the engine

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

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



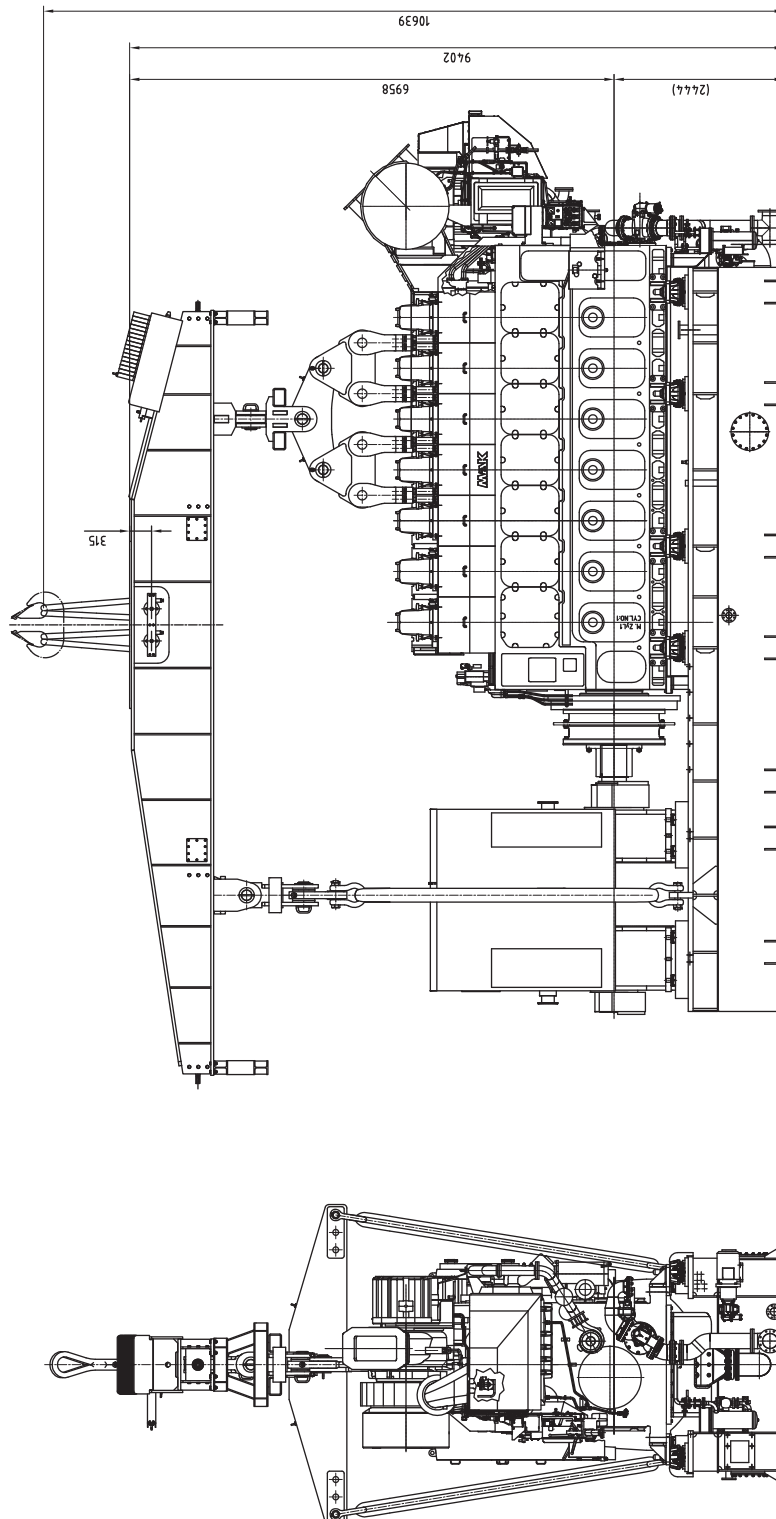
Piping sizes for crankcase ventilation

Engine Type	Engine connecting point(s)	Main vent pipe	Collecting vent with lubricating oil circulation tank (observe class rules)
6/7/8/9 M 43 C	1 x DN 150	1 x DN 150	1 x DN 150

5. Installation and Arrangement

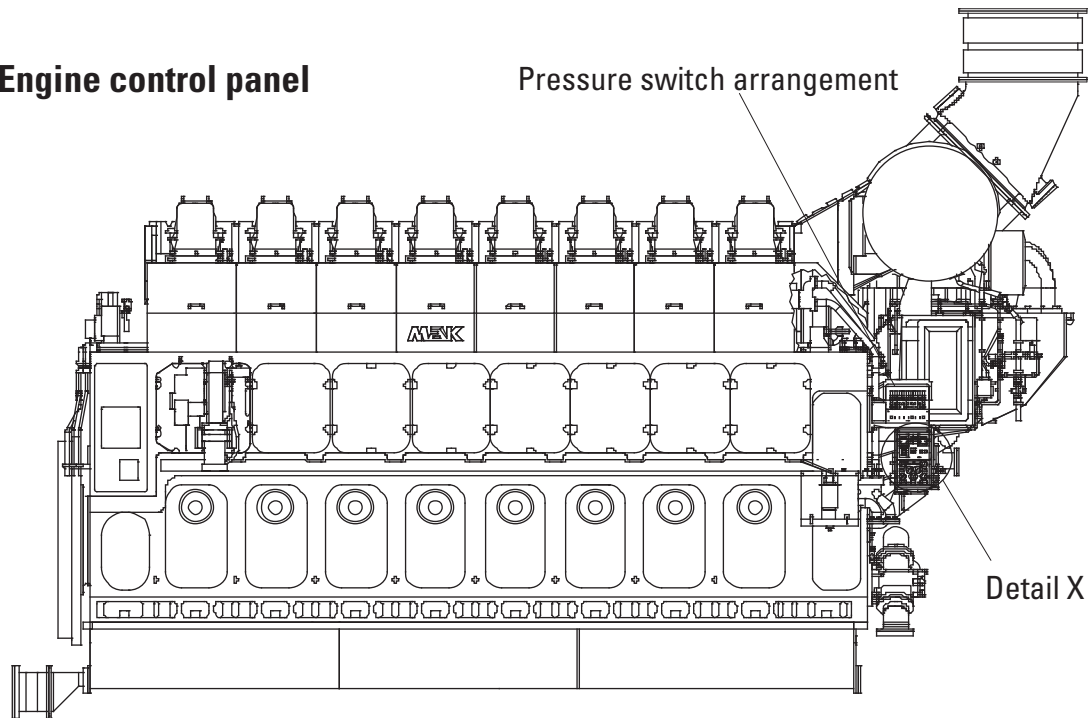
5.8 Lifting of the engine

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

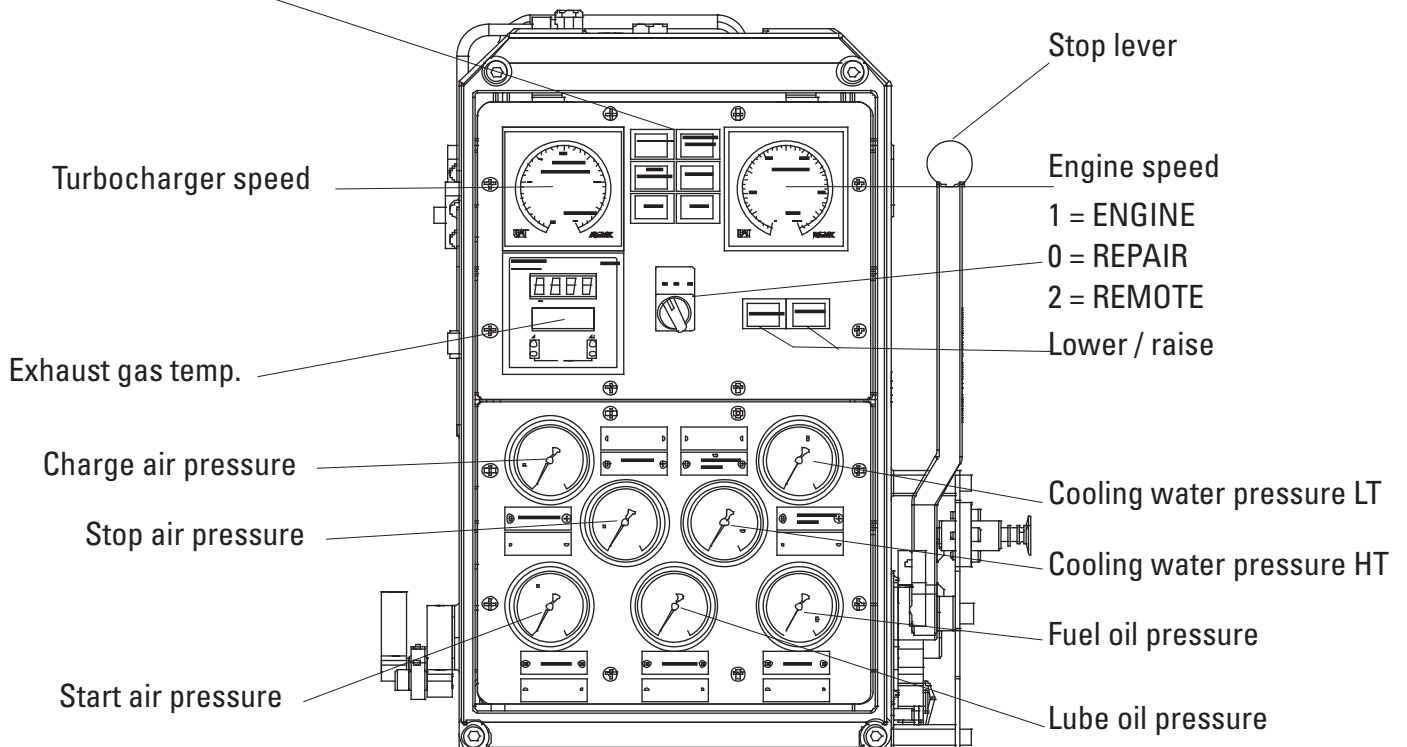
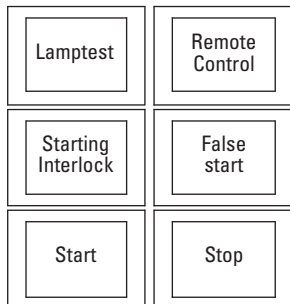


6. Control and monitoring system

6.1 Engine control panel



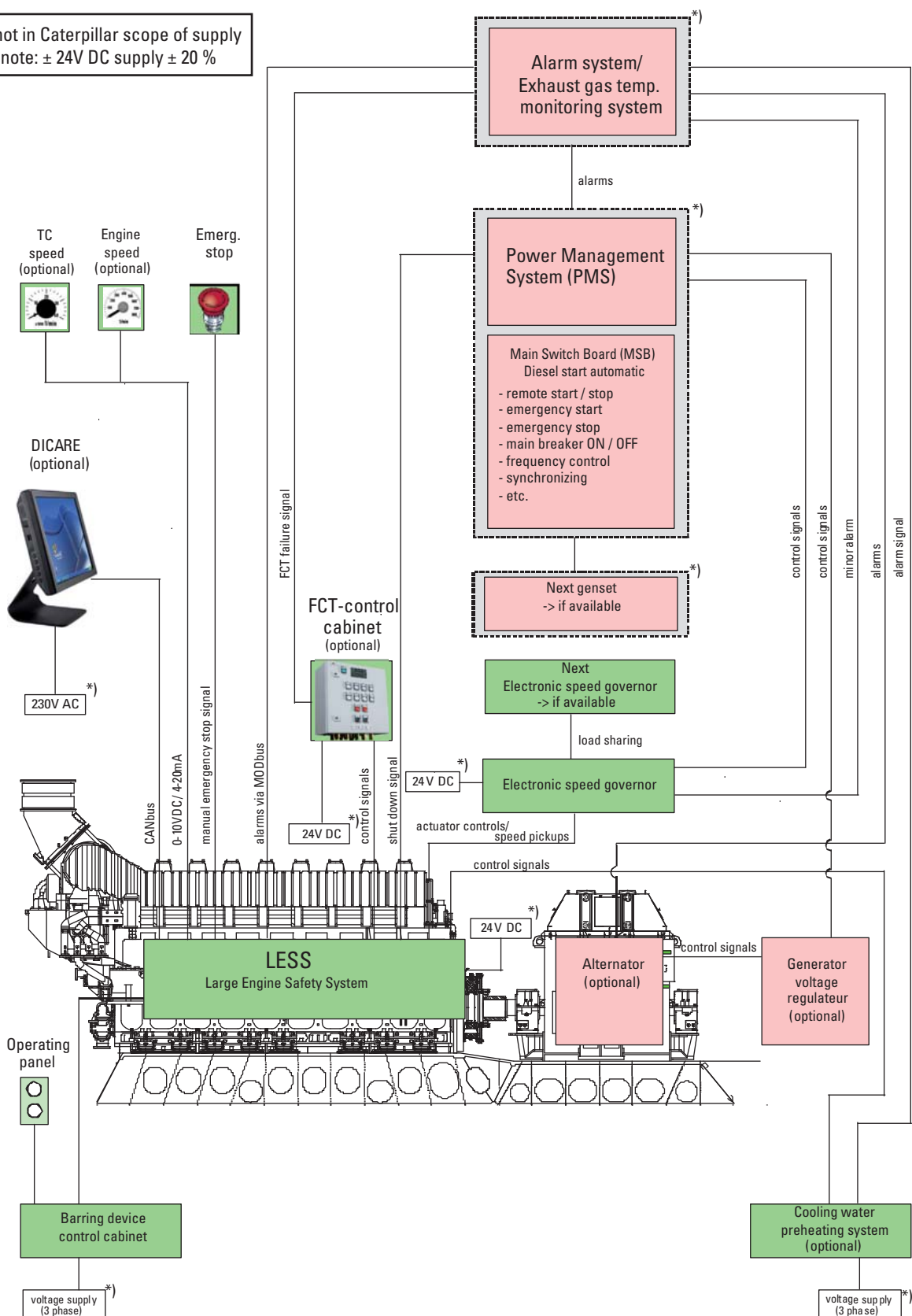
Detail X



6. Control and monitoring system

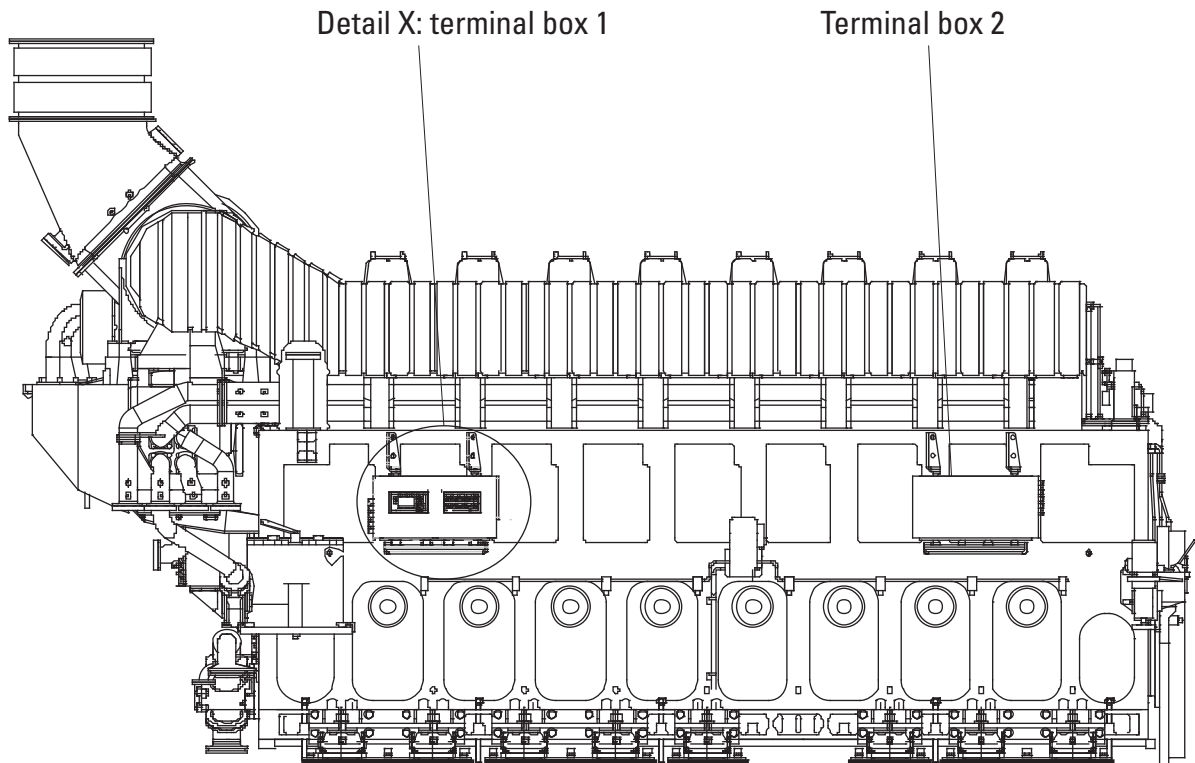
6.2 Genset control

*) not in Caterpillar scope of supply
note: $\pm 24V$ DC supply $\pm 20\%$

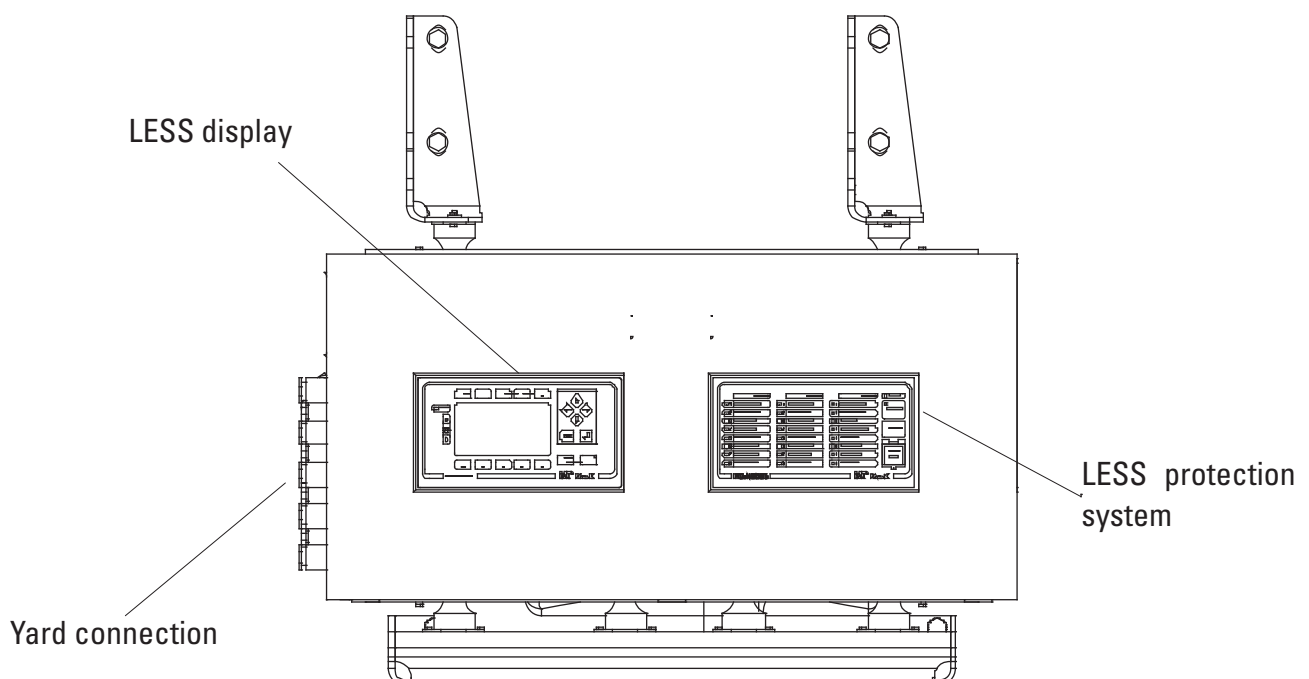


6. Control and monitoring system

6.3 Engine monitoring



Detail x: The LESS (Large Engine Safety System) arrangement at terminal box 1



6. Control and monitoring system

6.4 Measuring points

Meas. Point	Description	Sensor range	Remarks
1104	Pressure switch Lube oil pressure low – start stand-by pump	binary	
1105	Pressure transmitter Lube oil pressure low – pre alarm shut down	4-20 mA	
1106	Pressure switch Lube oil pressure low – shut down	binary	
1111	Differential pressure lube oil filter high – alarm	binary	
1111.1	Differential pressure lube oil filter high – indication	4-20 mA	
1112.1	Lube oil differential pressure automatic filter – pre alarm	binary	
1112.2	Lube oil differential pressure automatic filter – alarm	4-20 mA	
1142	Pressure switch Pre lube oil pressure low – start interlock	binary	
1202	Resistance thermometer Lube oil temp. at engine inlet high – alarm	PT 100	
1203	Resistance thermometer Lube oil temp. at engine inlet high – shut down	PT 100	
1251	Oil mist detector VN115/87 Plus 1251 Oil mist concentration in crankcase high – alarm	1251: binary	1 evaluation unit for 1251, 1253, 9631 1251.1 (70% from 1251)
1251.1	1251.1 Oil mist concentration in crankcase high – Pre-alarm		
1251.2	1251.2 Opacity	1251.2: 4-20 mA	
1253	1253 Oil mist concentration in crankcase high – shut down	1253: binary	
9631	9631 Oil mist detector failure – alarm	9631: binary	
2102	Pressure transmitter Cooling water pressure HT at engine inlet low – alarm	4-20 mA	40 kPa below operating pressure
2103	Pressure switch Cooling water pressure HT at engine inlet low – shut down	binary	60 kPa below operating pressure stop delay: 20s
2112	Pressure transmitter Cooling water pressure LT at engine outlet low – alarm	4-20 mA	40 kPa below operating pressure
2201	Resistance thermometer Cooling water temp. HT at engine inlet low - alarm	PT 100	
2211	Resistance thermometer Cooling water temp. at engine outlet high – alarm	PT 100	

6. Control and monitoring system

Meas. Point	Description	Sensor range	Remarks
2213	Resistance thermometer Cooling water temp. HT at engine outlet high – shut down	PT 100	
2229	Resistance thermometer Cooling water temp. LT at engine inlet high – alarm	PT 100	
5102	Pressure transmitter Fuel oil pressure at engine inlet low – alarm	4-20 mA	
5111	Differential pressure indicator Differential pressure fuel oil filter high – alarm	binary	
5201/5202*	Resistance thermometer 5201 Fuel oil temp. at engine inlet low – alarm *5202 Fuel oil temp. at engine inlet high – alarm	PT 100	1 sensor for 5201 + 5202* * not in use with HFO
5206	Fuel oil temp. after viscomat – DICARE	PT 100	Not mounted on engine
5253	Fuel oil viscosity at viscomat – DICARE	4-20 mA	Not mounted on engine
5301	Level probe/switch unit Leakage oil level at engine high – alarm	binary	
6101	Pressure transmitter Starting air at engine inlet low – alarm	4-20 mA	
6105	Pressure switch Stopping air pressure at engine low – alarm	binary	Alarm delay: 2s
6181	Absolute pressure transmitter Intake air pressure in engine room – DICARE	4-20 mA	
7109	Pressure transmitter Charge air pressure at engine inlet – Indication	4-20 mA	
7201	Resistance thermometer Charge air temp. at engine inlet high – alarm	PT 100	
7206	Resistance thermometer Intake air temp. at turbocharger inlet – DICARE	PT 100	
7301	Level probe/switch unit Condense water in charge air canal	binary	
7307	Differential pressure transmitter Charge air diff. pressure at charge air cooler – DICARE	4-20 mA	
7309	Thermocouple type K Charge air temp. at charge air cooler inlet – DICARE	NiCr-Ni (mV)	
8211.1	Thermocouple type K Exhaust gas temp. after cylinder 1 high high	NiCr-Ni (mV)	Load depended alarm delay: 16s
8211.2	Thermocouple type K Exhaust gas temp. after cylinder 2 high high	NiCr-Ni (mV)	Load depended alarm delay: 16s
8211.3	Thermocouple type K Exhaust gas temp. after cylinder 3 high high	NiCr-Ni (mV)	Load depended alarm delay: 16s

6. Control and monitoring system

Meas. Point	Description	Sensor range	Remarks
8211.4	Thermocouple type K Exhaust gas temp. after cylinder 4 high high	NiCr-Ni (mV)	Load depended alarm delay: 16s
8211.5	Thermocouple type K Exhaust gas temp. after cylinder 5 high high	NiCr-Ni (mV)	Load depended alarm delay: 16s
8211.6	Thermocouple type K Exhaust gas temp. after cylinder 6 high high	NiCr-Ni (mV)	Load depended alarm delay: 16s
8211.7	Thermocouple type K Exhaust gas temp. after cylinder 7 high high	NiCr-Ni (mV)	Load depended alarm delay: 16s
8211.8	Thermocouple type K Exhaust gas temp. after cylinder 8 high high	NiCr-Ni (mV)	Load depended alarm delay: 16s
8211.9	Thermocouple type K Exhaust gas temp. after cylinder 9 high high	NiCr-Ni (mV)	Load depended alarm delay: 16s
8212.1 to 8212.9	Exhaust gas temp. absolute after cyl. 1 to 9 – alarm		Alarm from exhaust gas temp. system, has to be created in the EGTS
8213.1 to 8213.9	Exhaust gas temp. deviation from mean average cyl. 1 to 9 – alarm		Alarm from exhaust gas temp. system, has to be created in the EGTS
8216	Deviation of mean average value reduct alarm cyl. – shut down		Included in meas. Point 8234 from alarm system to (EGTS) LESS
8218	Exhaust gas temp. reduct alarm of each cyl. absolute – shut down		Included in meas. Point 8234 from alarm system to (EGTS) LESS
8221	Thermocouple type K Exhaust gas temp. at turbocharger outlet	NiCr-Ni (mV)	Load depended alarm delay: 16s
8224	Exhaust gas temp. reduction alarm of turbocharger outlet		Included in meas. Point 8234 from alarm system to (EGTS) LESS
8231	Thermocouple type K Exhaust gas temp. at turbocharger inlet – indication	NiCr-Ni (mV)	
8234	Common alarm exhaust gas temp. monitoring load reduction included 8216, 8218, 8224	binary	Common alarm from alarm system to (EGTS) LESS
9404	Relay contact Overspeed – alarm	binary	1.15 x n rated
9401.1	Suppression of alarms	binary	To be created in alarm system; Alarm system received the engine rpm signal via MODbus (plant specific)
9401.2	Fresh water pre-heater switch on / off	binary	Hardwired to CW-preheating control (plant specific)

6. Control and monitoring system

Meas. Point	Description	Sensor range	Remarks
9401.3	Engine is running $n > n_{min}$	binary	Hardwired to PMS (plant specific)
9402	Pre lube oil pump switch on / off	binary	Option Hardwired to yard supplied pumpcontrol (plant specific)
9404	Relay contact Overspeed – shut down	binary	1,15 x n rated
9419	Engine speed signal	4-20 mA	683.3 Hz = 0-1,000 rpm
9419.1	Pick up RPM switching equipment	0-15 KHz	
9419.2	Pick up RPM switching equipment	0-15 KHz	
9419.3	Pick up Electronic governor	0-900 Hz	
9419.4	Pick up Electronic governor	0-15 KHz	
9429	Pick up / transmitter Turbine speed high – alarm* Turbine speed – indication	4-20 mA 0-10 V	* DNV to be created in alarm system
9503	Limit switch Control level at fuel rack – stop position	binary	
9509	Distance sensor / switching device Fuel setting	4-20 mA	
9532.1	Engine fuel rack position	4-20 mA	Hardwired to PMS (plant specific)
9532.2	Engine fuel rack position	4-20 mA	Spare (plant specific)
9532.3	Engine fuel rack position	0-10 V	Option Hardwired to exhaust gas temp. (plant specific)
9561	Limit switch Turbing gear engaged – starting interlock	binary	Start blocking (plant specific)
9602	Relay contact CANbus failure – alarm	binary	
9609	From power management system (PMS) – start interlock		Start blocking
9615	Trouble at electronic speed governor – alarm	binary	Hardwired to alarm system
9616	Trouble at electronic speed governor – shut down		Pick up fault, Actuator wire break
9735	From power management system (PMS) – shut down		Generator protection shut down

6. Control and monitoring system

Meas. Point	Description	Sensor range	Remarks
9836.1	Relay contact Sensor / isolation fault A01.1 – alarm	binary	Hardwired to alarm system
9836.2	Relay contact Sensor / isolation fault A03.1 – alarm	binary	Hardwired to alarm system
9962.1 30108	Relay contact Common alarm A01.1 – alarm	binary	Hardwired to alarm system
9962.2 30008	Relay contact Common alarm A03.1 – alarm	binary	Hardwired to alarm system
9671.1	Relay contact Automatic stop failure – alarm	binary	Hardwired to alarm system
9671.2	Relay contact Overspeed failure – alarm	binary	Hardwired to alarm system
9671.3	Relay contact Emergency stop failure – alarm	binary	Hardwired to alarm system
9674	Relay contact Automatic stop / PLC A01 common – shut down	binary	Hardwired to alarm system
9675	Relay contact Emergency stop – alarm	binary	Hardwired to alarm system
9751.1	Voltage fail at charge air temp. controller – alarm	binary	plant specific
9771	Fresh water preheater voltage failure – alarm	binary	plant specific
9828	Blackout - alarm	binary	plant specific

6. Control and monitoring system

6.5 Local and remote indicators

Local indicators	Remote indicators
Installed at the engine	96 x 96mm (optionally)
Fuel oil temperature at engine inlet	X ²⁾
Fuel oil differential pressure at filter	
Fuel rack position (mean injection pump rack)	
Lube oil temperature at engine inlet	X ²⁾
Lube oil differential pressure at filter	
Fresh water temperature at engine inlet (HT circuit)	
Fresh water temperature at engine outlet (HT circuit)	X ²⁾
Fresh water temperature (LT circuit)	X ²⁾
Fresh water temperature cooler inlet	
Fresh water temperature cooler outlet	
Charge air temperature cooler inlet	
Charge air temperature engine inlet	X ²⁾
Installed at the engine (gauge board)	
Fuel oil pressure	X ²⁾
Lube oil pressure	X ²⁾
Fresh water pressure (HT circuit)	X ²⁾
Fresh water pressure (LT circuit)	X ²⁾
Start air pressure	X ²⁾
Charge air pressure cooler outlet	X ²⁾
Stop air pressure	
Engine speed	X ¹⁾
Turbocharger speed	X
Charge air temperature cooler inlet (digital value)	
Exhaust gas temperature after cylinder (digital value)	
Exhaust gas temperature before/after turbocharger (digital value)	

¹⁾ 144 x 144 mm possible

²⁾ Signal is supplied by the alarm system

6. Control and monitoring system

6.6 LESS: Large Engine Safety System

Engine control boxes include

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

System data

Inputs:

4 fixed automatic shut down + overspeed inputs

4 manual emergency stop inputs

16 configurable inputs for shutdown, load reduce request or start interlock

2 separate override inputs

1 remote reset input

All inputs are wire break- and short circuit monitored.

Outputs:

4 x 2 adjustable speed contacts

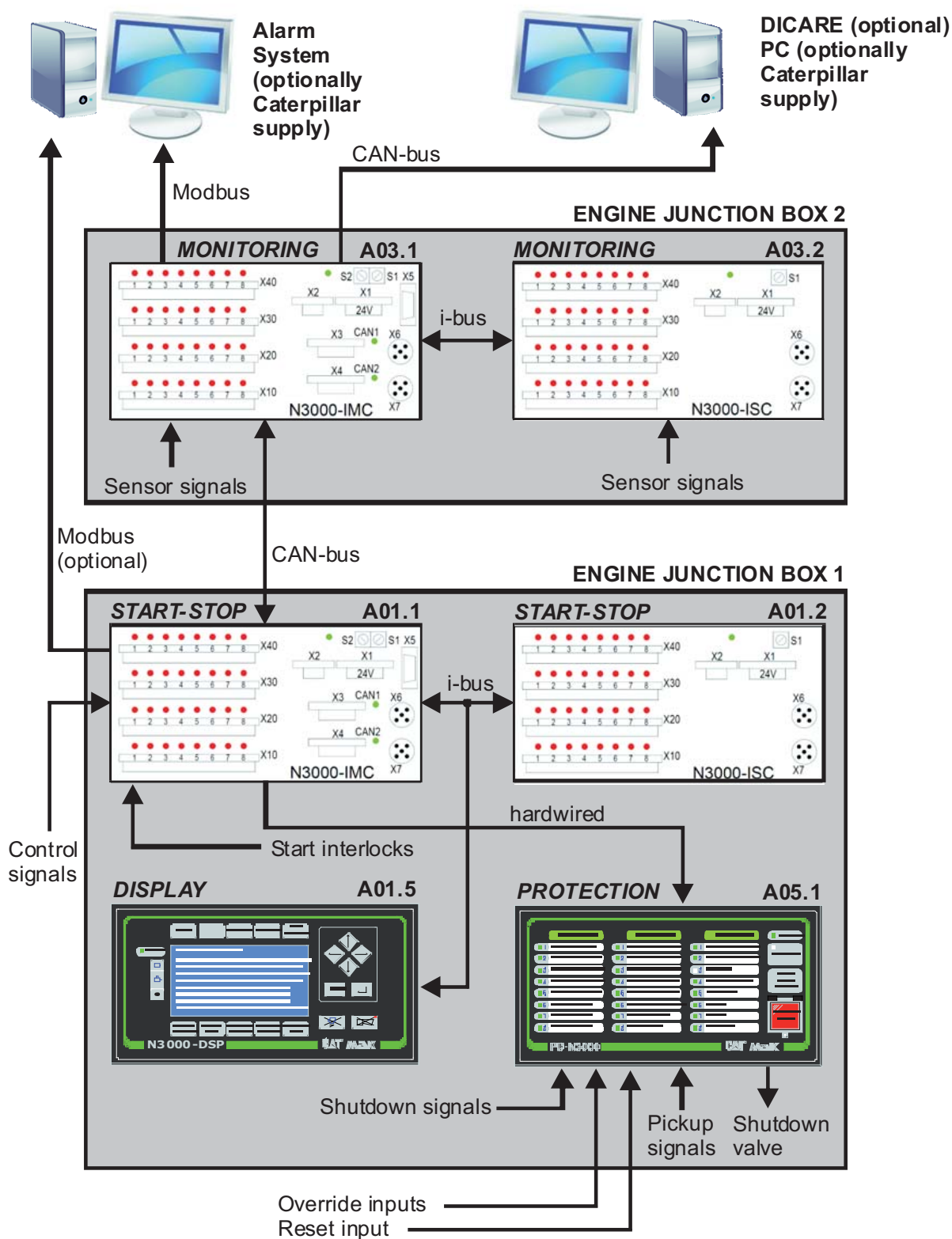
3 fuel setting signals (1 x 0-10V DC, 2 x 4-20 mA)

1 overload contact at rated speed

4 speed signals (1 x pulse, 1 x 0-10V DC, 2 x 4-20 mA or 0-10V DC → configurable)

6. Control and monitoring system

6.6 LESS



7. Diagnostic trending monitoring - DICARE

With MaK DICARE, you can have an expert aboard at all times, ready to serve your needs. The latest, completely revised version combines well-established features with faster signal processing and improved usability, based on common industry standards.

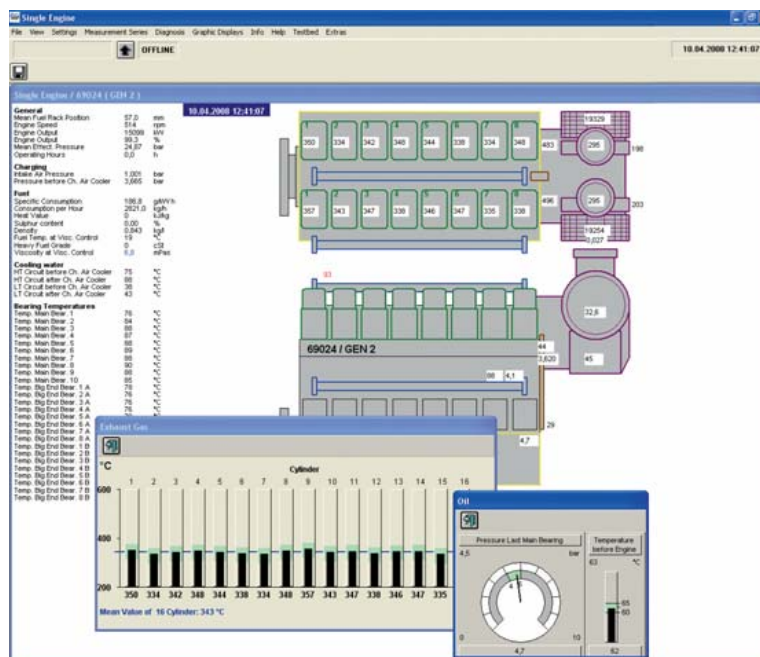
Cat and MaK engines with MaK DICARE remote engine monitoring software provide reliable, condition-specific maintenance suggestions. DICARE continually compares current engine condition to desired state and tells you when maintenance is required. You get the diagnostics you need in easy-to-understand words and graphics so you can take action to keep your engines running strong.

DICARE is only available for medium-speed engines not for high-speed engines.

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

Special attention is placed on monitoring the following criteria:

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



7. Diagnostic trending monitoring - DICARE

Transmitter for DICARE ON-LINE M 43 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:

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 local engine control
- starting trials down to the minimum air pressure
- measurement of crank web deflection (cold/warm condition)

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

9. Engine International Air Pollution Prevention Certificate

The MARPOL Diplomatic Conference has agreed about a limitation of NO_x emissions, referred to as Annex VI to Marpol 73/78.

When testing the engine for NO_x emissions, the reference fuel is Marine Diesel Oil (Distillate) and the test is performed according to ISO 8178 test cycles:

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

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

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

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

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

10. Painting/Preservation

Inside preservation

N 576-3.3

The preservation is sufficient for a period of max. 2 years.
It needs to be removed when the engine is commissioned!

- Main running gear and internal mechanics

Outside preservation

VCI 368 N 576-3.2

Engine outside preservation with Cortec VCI 368 is applicable for Europe and overseas.
It applies for sea and land transportation and storage of the engines in the open, protected from moisture.

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

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

Durability and effect are determined by proper packaging, transportation, and storage, i.e. protected from moisture, stored at a dry place and sufficiently ventilated. Inspections are to be carried out at regular intervals.

Appearance of the engine:

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

N 576-4.1 - Clear Varnish

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

Clear varnish painting is not permissible for:

- Sea transportation of engines
- Storage of engines in the open, even if they are covered with tarpaulin

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

VCI packaging as per N 576-5.2 is generally required!

Durability and effect are determined by proper packaging, transportation, and storage, i.e. the engine is to be protected from moisture, VCI film not ripped or destroyed.

Inspections are to be carried out at regular intervals.

10. Painting/Preservation

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

Appearance of the engine:

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

N 576-4.3 - Painting

The painting is applicable for Europe and overseas.

It applies for sea and land transportation and short-term storage in the open (protected from moisture) up to max. 4 weeks.

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

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

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

Appearance of the engine:

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

N 576-5.2 - VCI packaging

Corrosion protection with VCI packaging applies for:

- Engines with outside preservation VCI 368 as per N 576-3.2
- Engines with clear varnish according to application group N 576-4.1

These engines are always to be delivered with VCI packaging!

Nevertheless, they are not suitable for storage in the open!

- Engines or engine generator sets with painting according to application group N 576-4.3 for shipment to Europe and overseas or storage in the open (protected from moisture).

10. Painting/Preservation

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

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

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

N 576-5.2 Suppl. 1 - Information panel for VCI preservation and inspection

Applies for all engines with VCI packaging as per application group N 576-5.2.

Description:

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

N 576-6.1 - Corrosion Protection Period, Check, and Represervation

There will only be an effective corrosion protection of the engine if the definitions and required work according to factory standard N 576-6.1 are duly complied with.

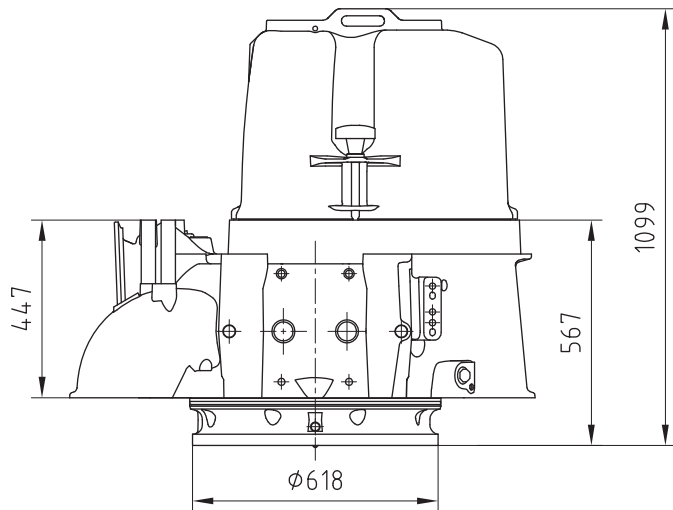
Normally, the applied corrosion protection is effective for a period of max. 2 years if the engines or engine generator sets are protected from moisture. However, depending on the execution of the preservation shorter periods may be applicable.

After 2 years represervation must be carried out.

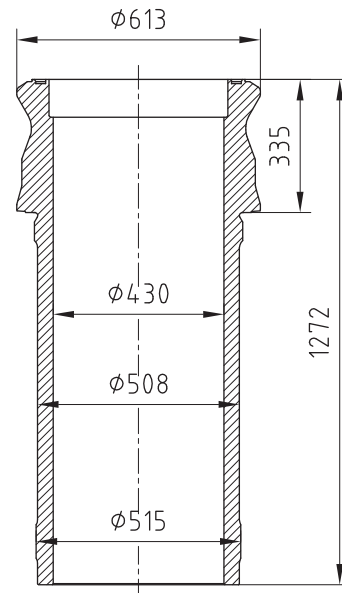
Every 3 months specific inspections are to be carried out the engine or engine generator set at defined inspection points. Any corrosion that is found and existing condensation water are to be removed immediately.

11. Engine parts

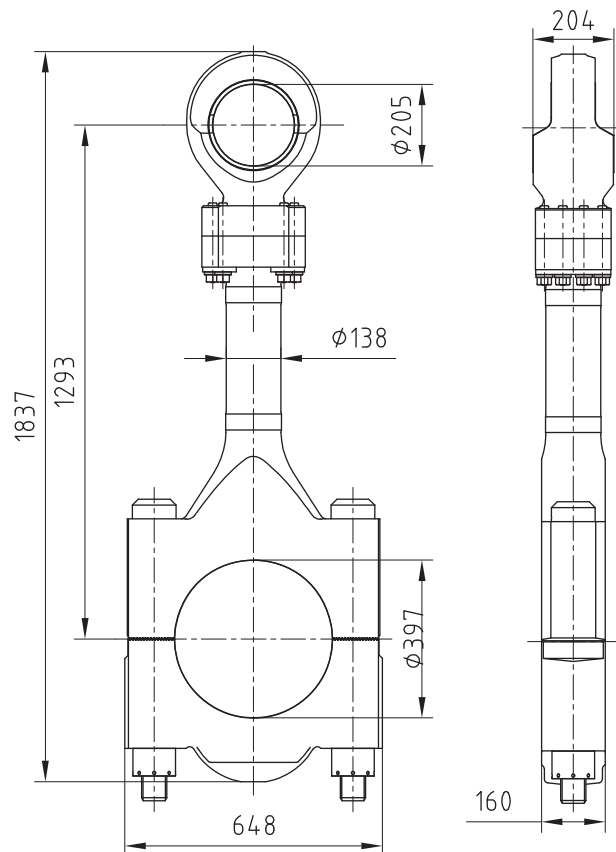
Cylinder head, weight 1,100 kg



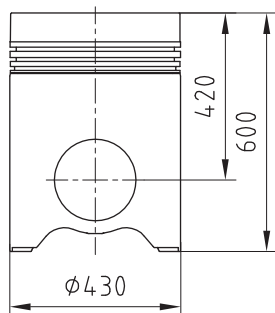
Cylinder liner, weight 674 kg



Connecting rod, weight 558 kg

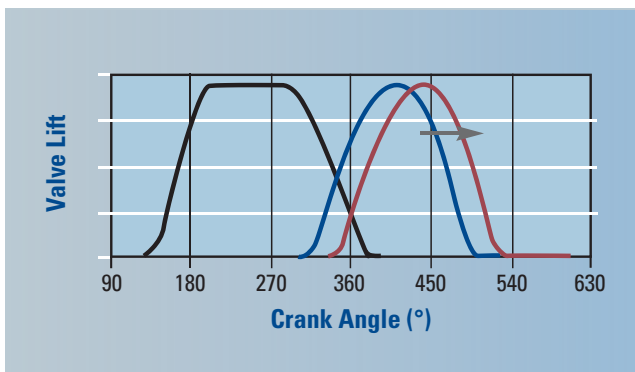


Piston, weight 255 kg

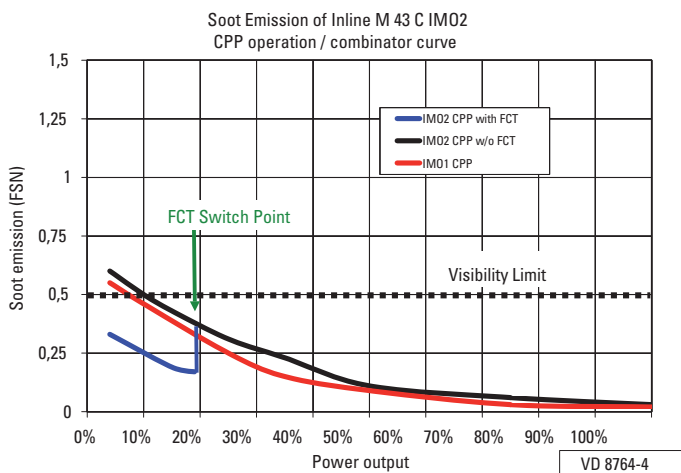
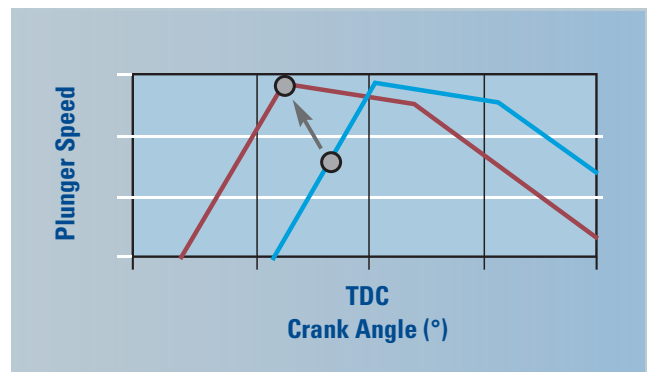


12. Flexible Camshaft Technology - FCT

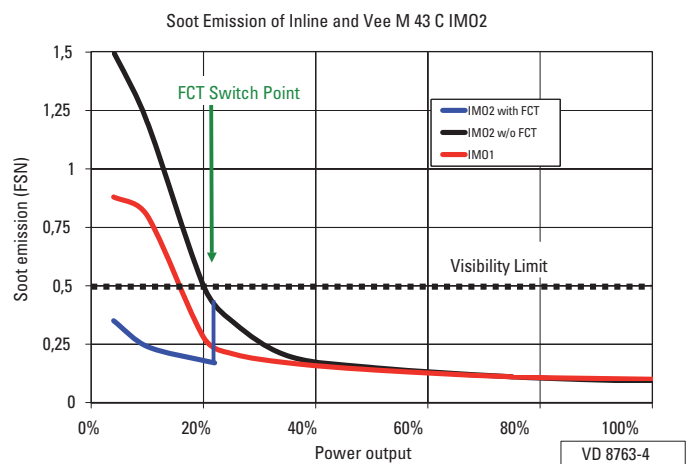
Building upon the Emission Reduction System integration concept, FCT achieves synergy between flexible fuel systems and advanced air systems with maximum utilization of the current engine design. While maintaining high fuel injection pressure over the whole operating range, fuel injection and inlet valve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



schematic diagram



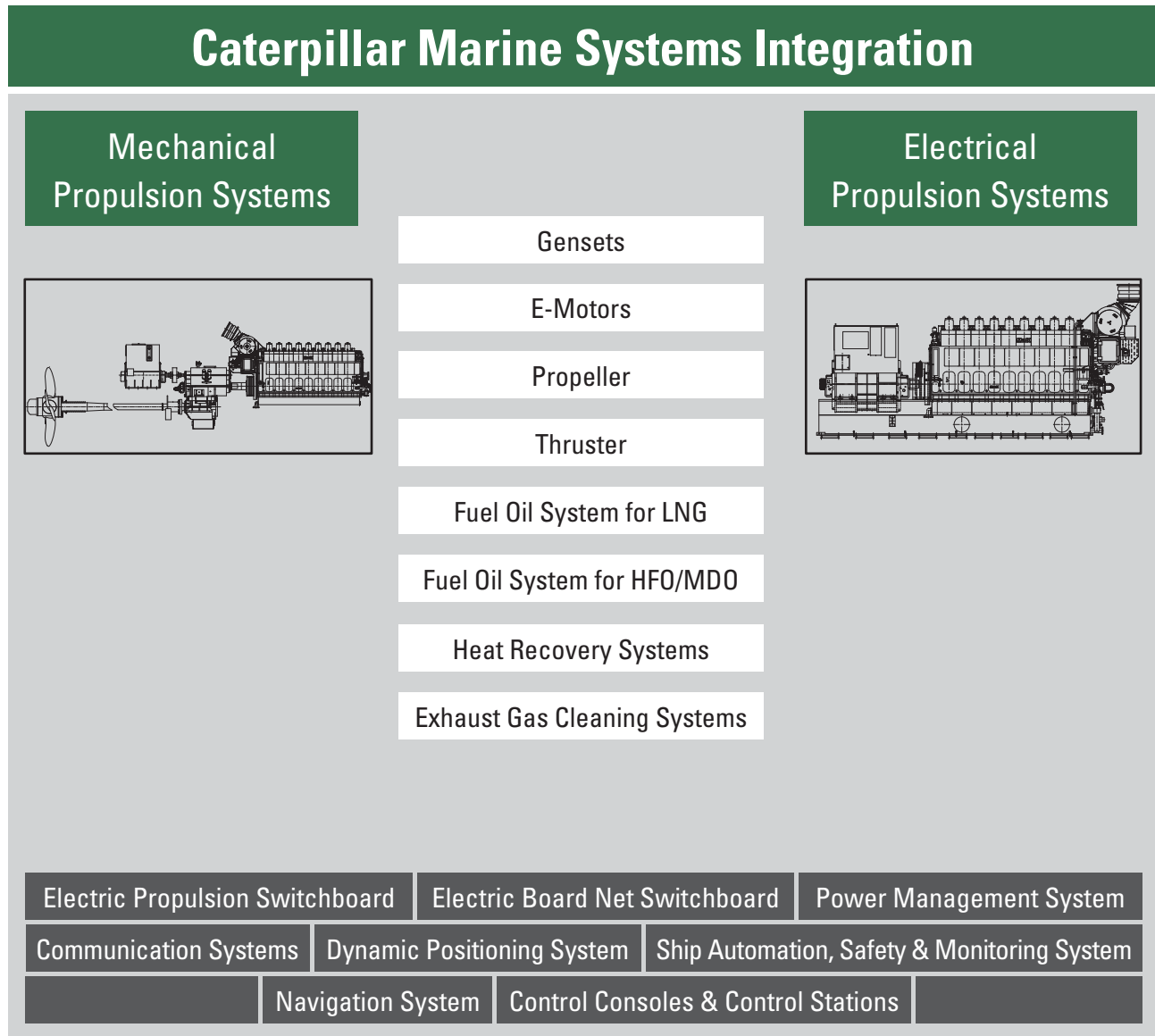
M 43 C constant speed



M 43 C CPP/combinator mode

13. Caterpillar Marine Systems Integration

13.1 The Scope



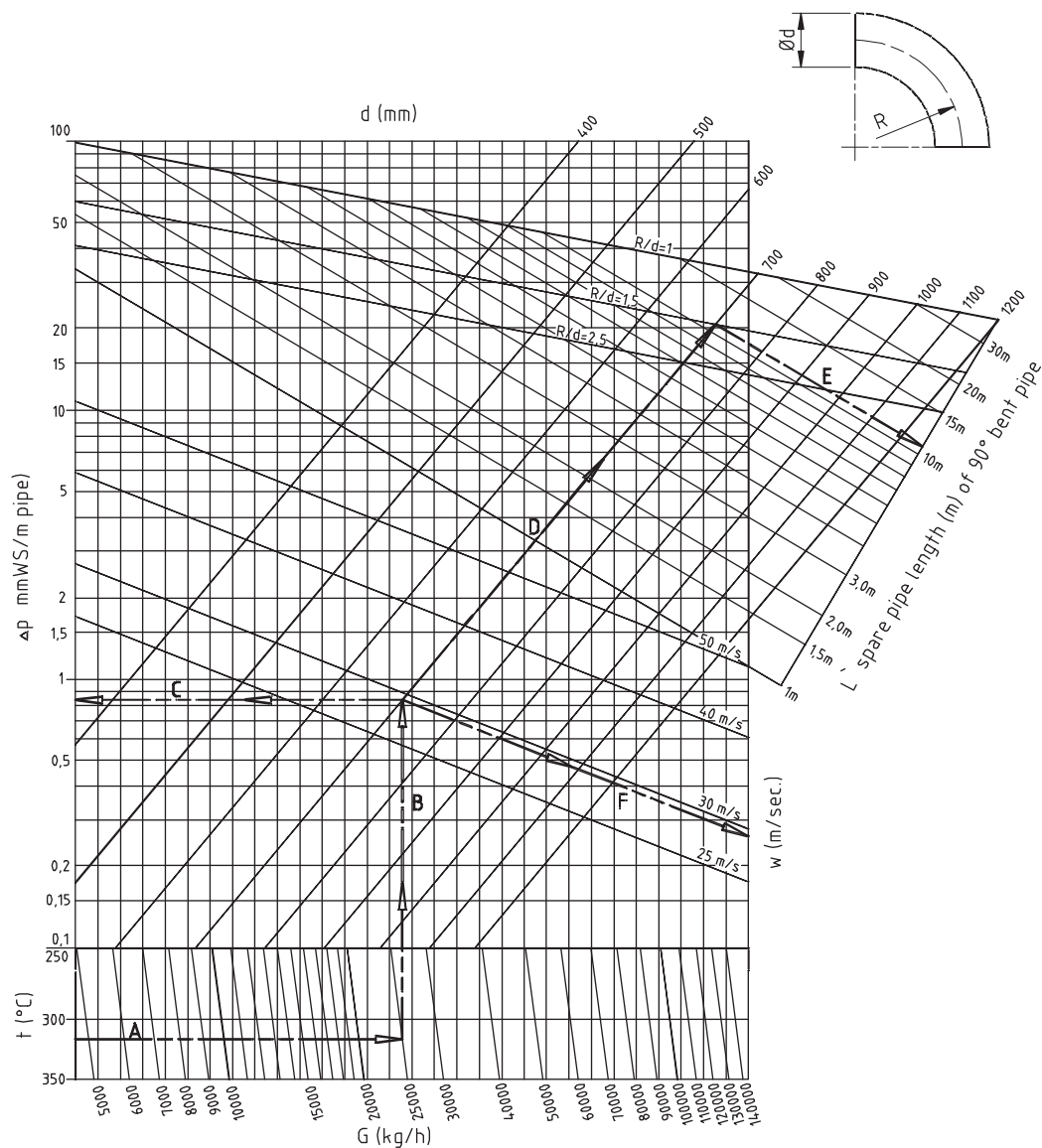
Caterpillar Marine Systems Integration provides:

- System consultancy (feasibility studies)
- Systems integration engineering
- Design and construction drawings

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

Output/cylinder: 1,000 kW
 Tolerance: 5 %
 Atmospheric pressure: 1 bar
 Relative humidity: 60 %
 Constant speed

Intake air temperature: 25 °C

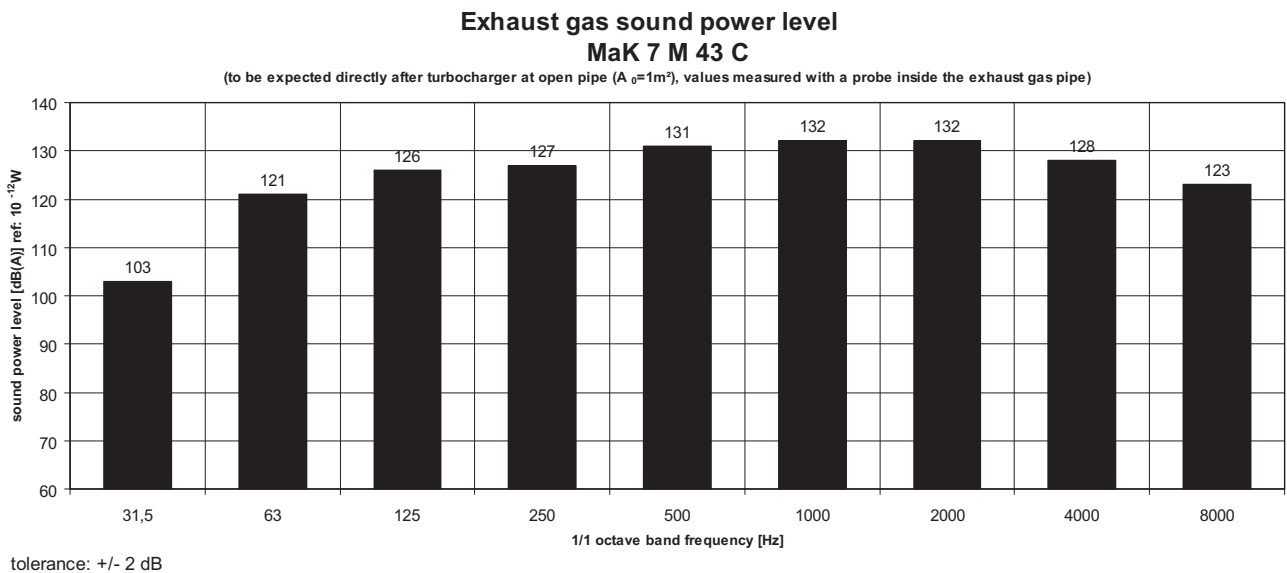
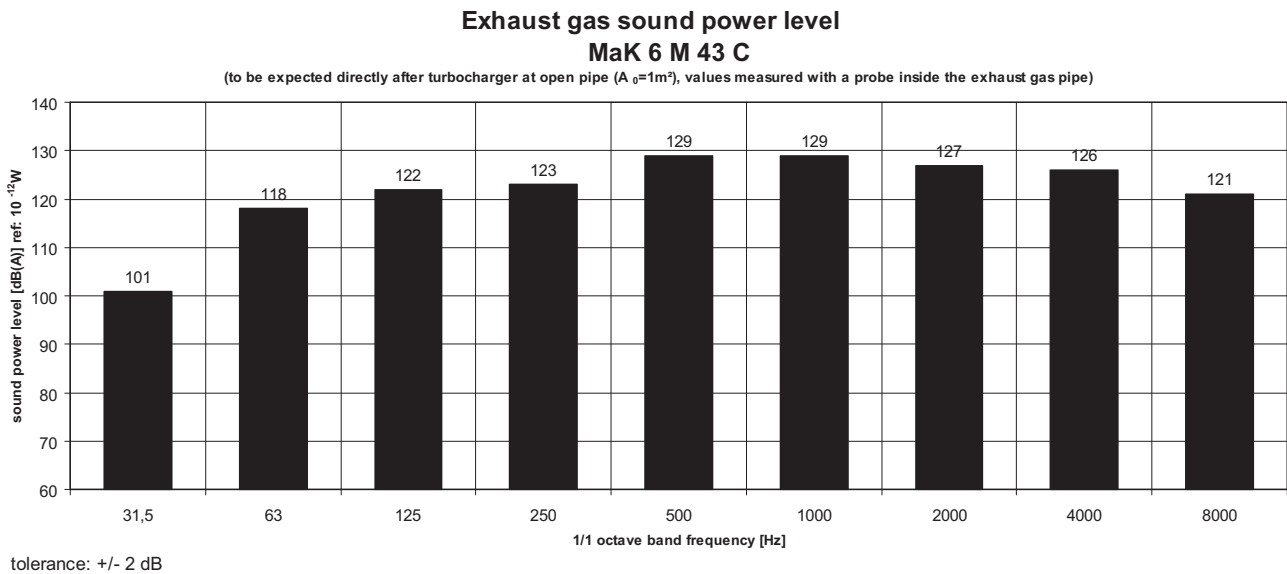
	Output [kW]	• Output % • [kg/h] • [°C]					
		100	90	80	70	60	50
6 M 43 C	6,000	40,920	37,620	34,315	30,025	26,340	22,654
		316	313	310	310	325	345
7 M 43 C	7,000	47,500	44,180	39,430	34,500	27,125	25,610
		312	305	310	312	324	342
8 M 43 C	8,000	54,286	50,491	45,060	39,430	31,000	29,265
		311	303	310	312	324	341
9 M 43 C	9,000	61,075	56,800	50,695	44,360	34,875	32,925
		312	305	311	313	326	342

Intake air temperature: 45 °C

	Output [kW]	• Output % • [kg/h] • [°C]					
		100	90	80	70	60	50
6 M 43 C	6,000	38,465	35,363	32,250	28,225	24,760	21,295
		335	332	329	329	344	366
7 M 43 C	7,000	44,650	41,530	37,065	32,430	25,500	24,075
		331	323	329	331	343	362
8 M 43 C	8,000	51,030	47,460	42,355	37,065	29,140	27,510
		330	321	329	331	343	361
9 M 43 C	9,000	57,410	53,390	47,655	41,700	32,782	30,950
		331	323	330	332	345	362

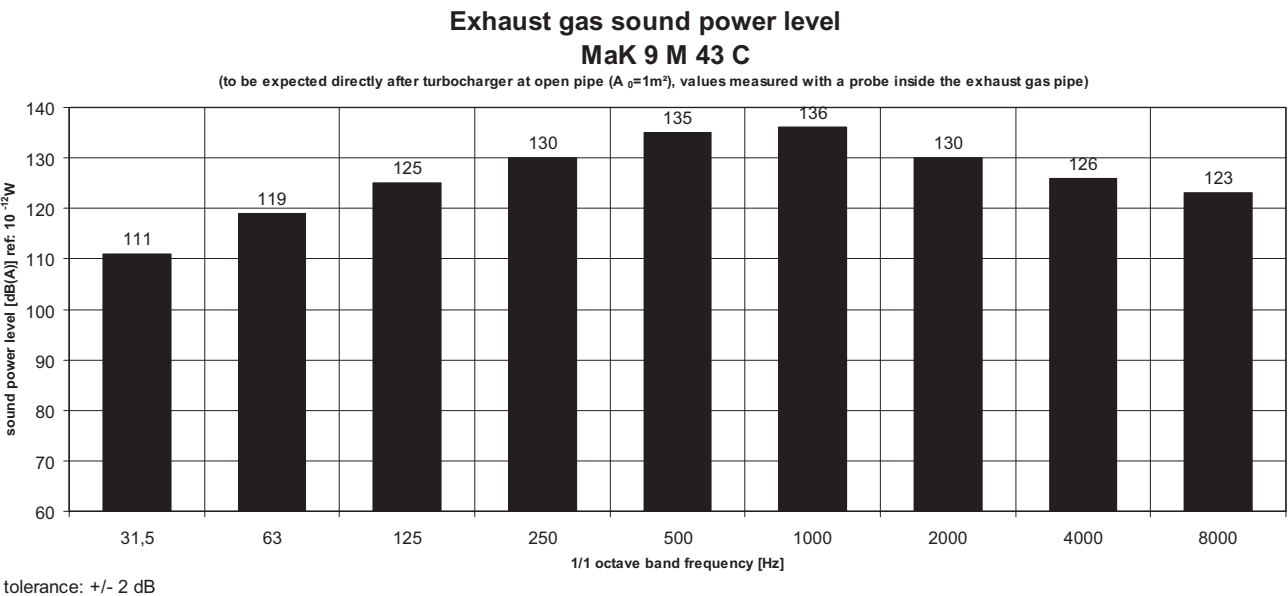
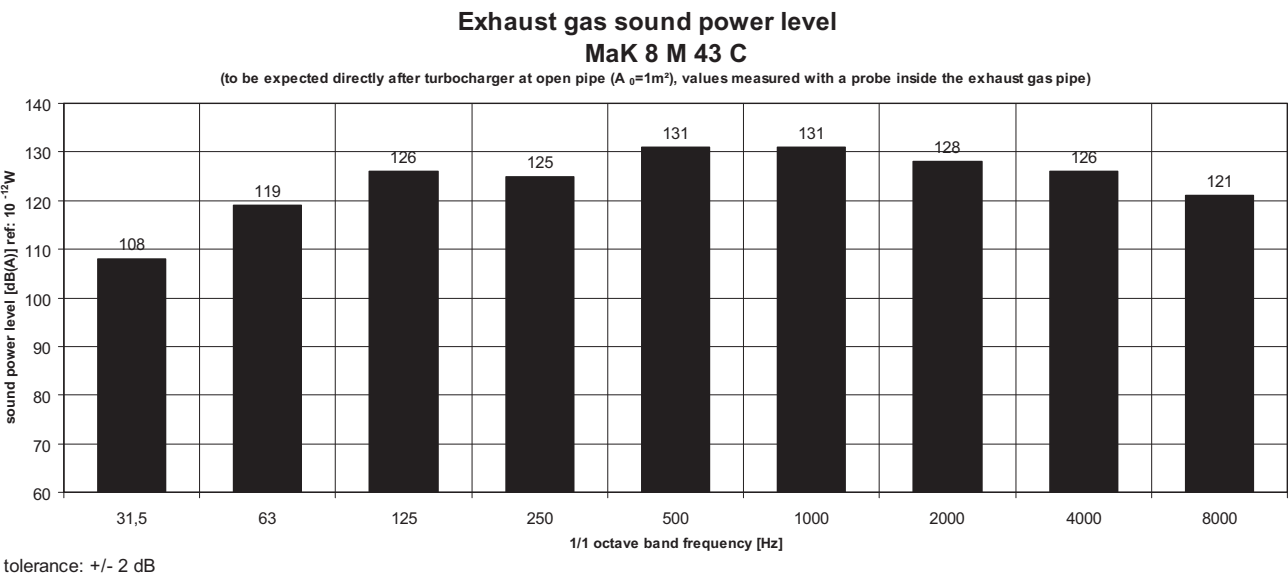
14. Appendix

14.1.3 Exhaust gas sound power level



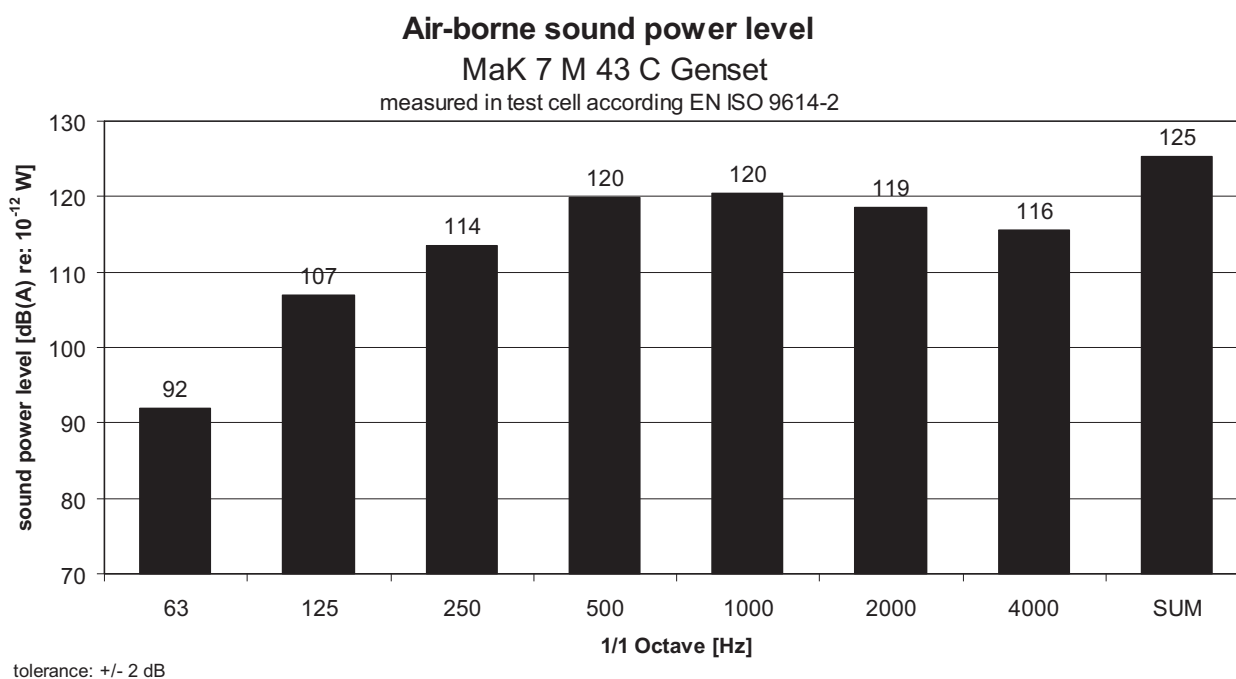
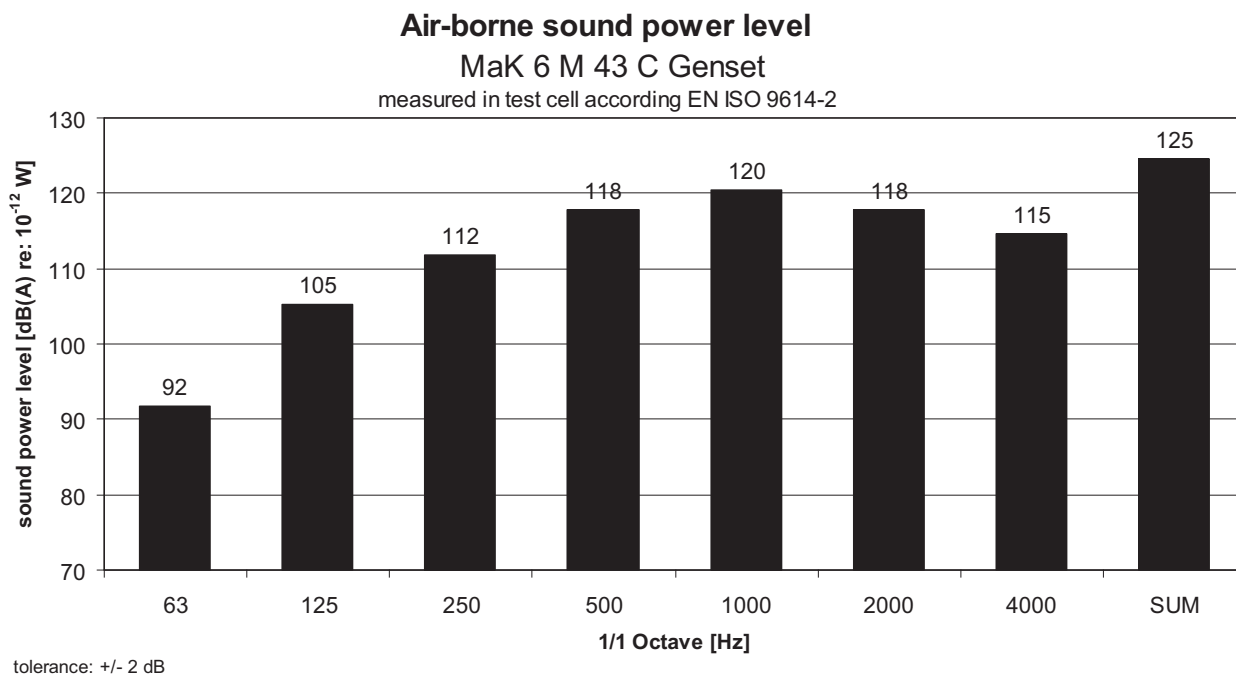
14. Appendix

14.1.3 Exhaust gas sound power level



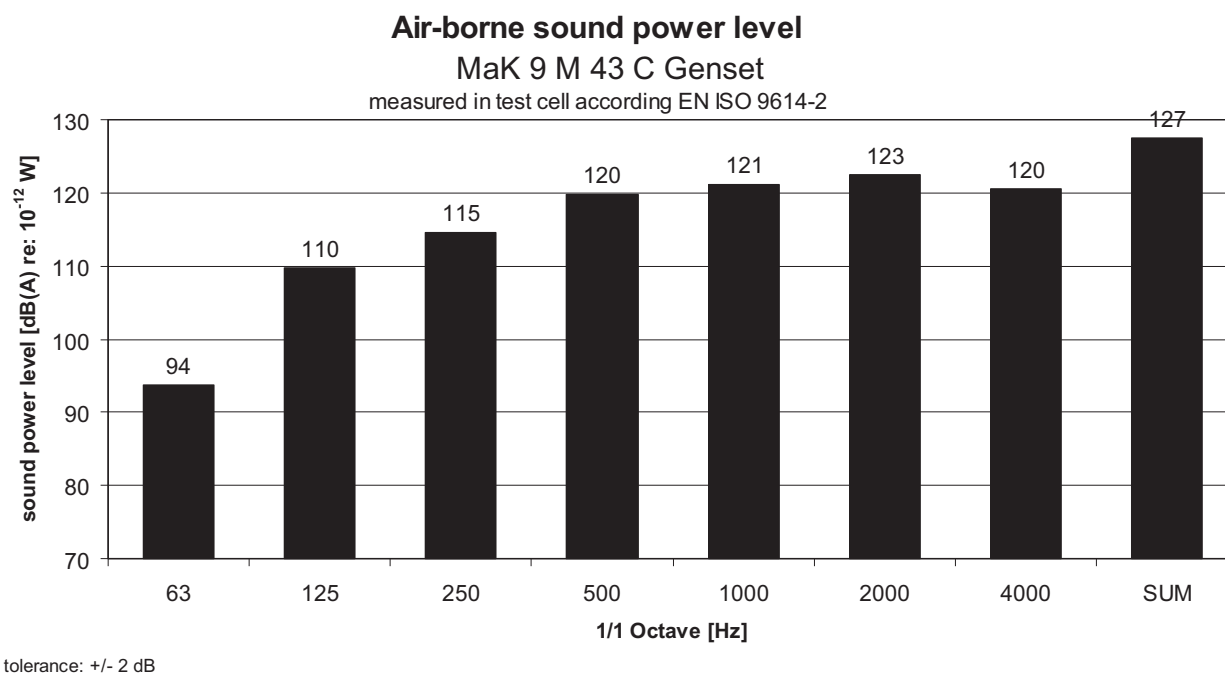
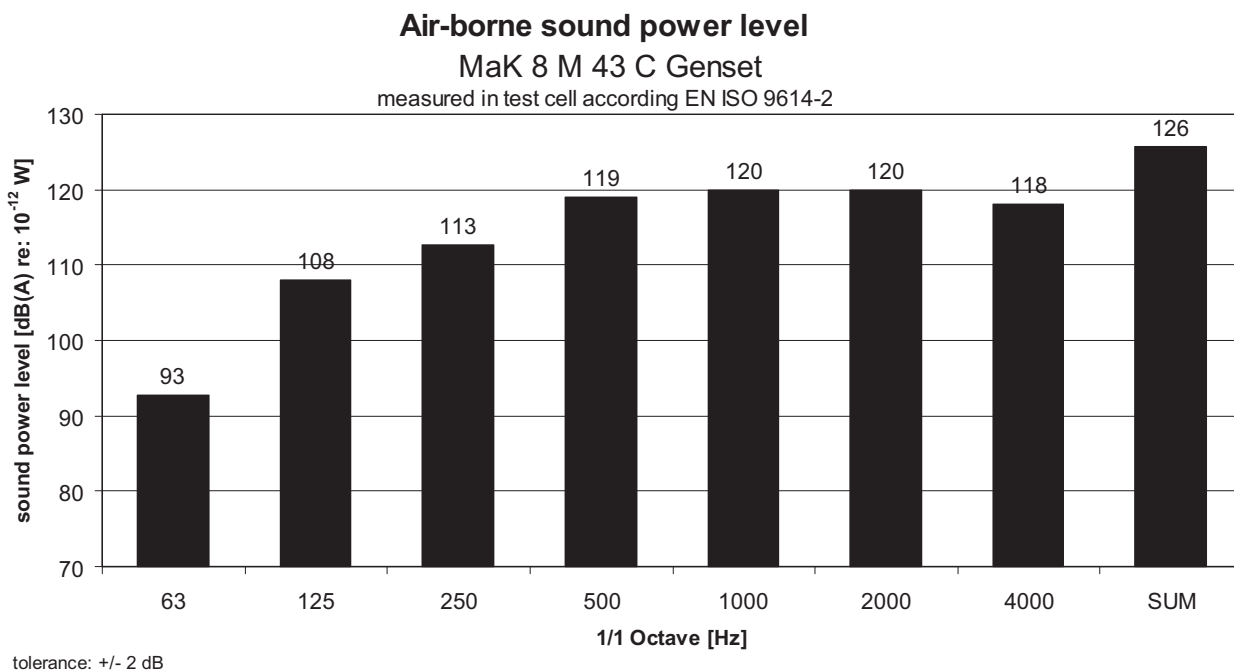
14. Appendix

14.2 Air-borne sound power level



14. Appendix

14.2 Air-borne sound power level



Caterpillar Marine Power Systems

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