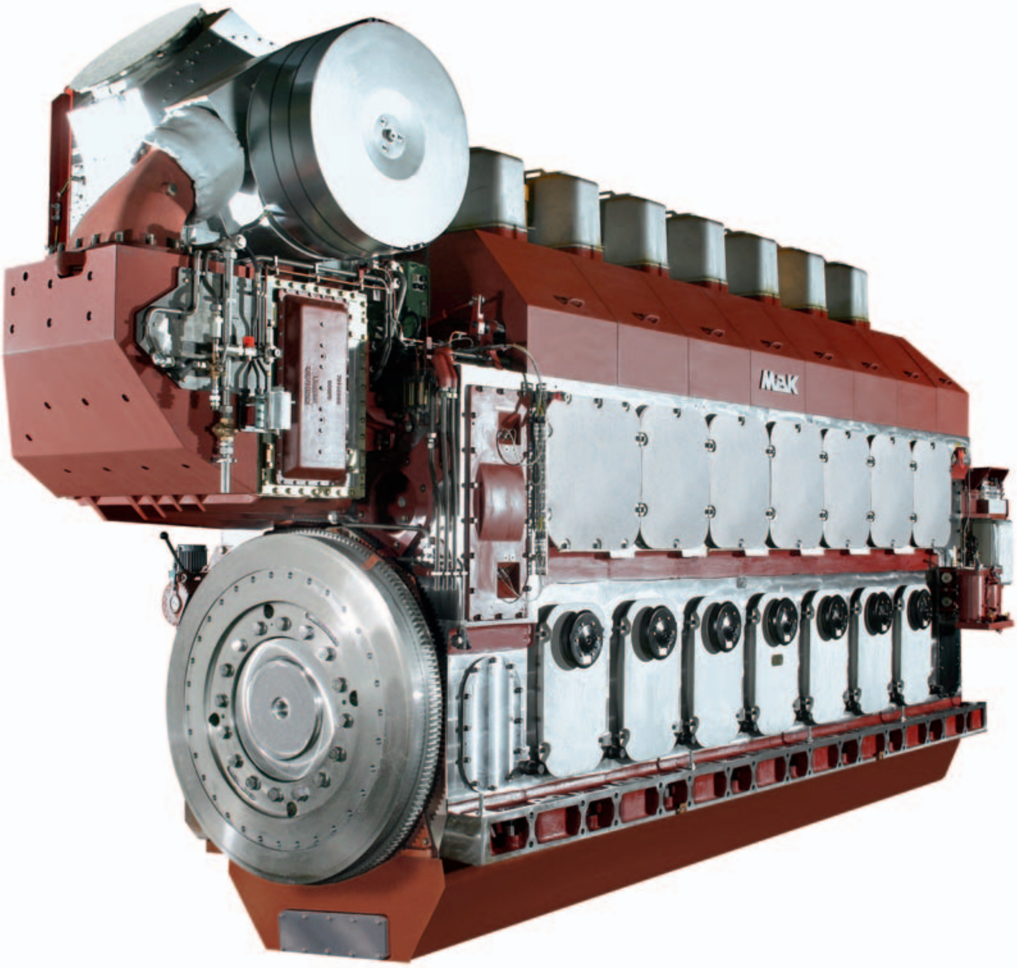
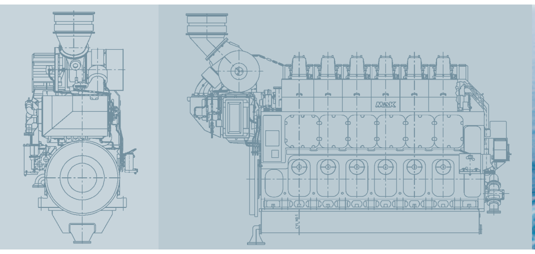
Contents

M 43 C

Project Guide • Propulsion





Introduction

Information for the user of this project guide

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

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

This edition supersedes the previous edition of this project guide.

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Edition August 2012

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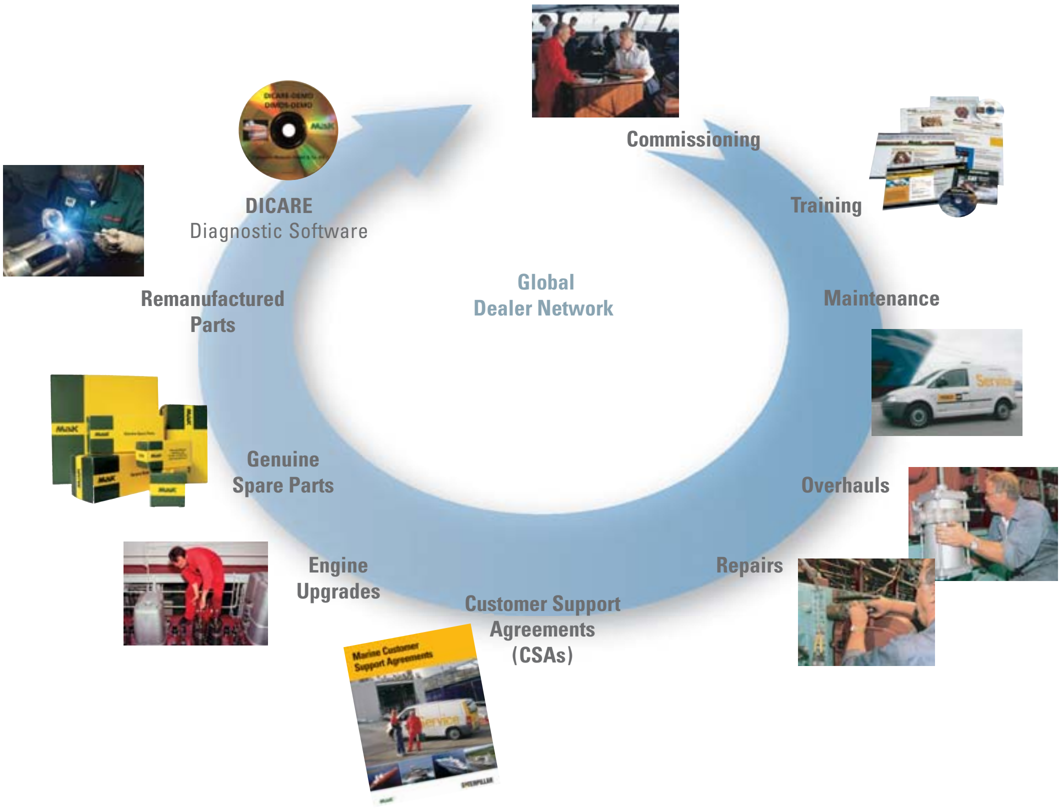

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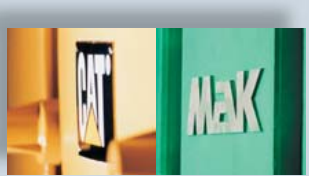

DET NORSKE VERITAS

MANAGEMENT SYSTEM CERTIFICATE

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

This is to certify that

Caterpillar Motoren GmbH & Co. KG

Falckensteiner Str. 2
24159 Kiel - Germany

and the sites

Caterpillar Motoren Rostock GmbH Werftallee 13 18119 Rostock	Caterpillar Power Generation Systems Koboldstraße 2-4 24118 Kiel	Caterpillar Motoren Henstedt-Ulzburg GmbH Rudolf-Diesel Straße 5-9 24558 Henstedt-Ulzburg	Caterpillar Motoren Guangdong Co. Ltd. Shizhou Industrial Estate Chencun Town Shunde District, Foshan City 528341 P. R. China

has been found to conform to the Management System Standard

ISO 9001:2008

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

Initial Certification date:
03.11.2003

This certificate is valid until:
14.11.2013

The audit has been performed under the supervision of

Jürgen Weißbauer
Lead Auditor

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

Place and date:
Essen, 15.11.2010

for the Accredited Unit:
DNV ZERTIFIZIERUNG UND UMWELTGUTACHTER GMBH

Nikolaus Kim
Management Representative

Lack of fulfilment of conditions as set out in the Certification Agreement may render this Certificate invalid.

DNV Zertifizierung und Umweltgutachter GmbH, Schnieringshof 14, 45329 Essen, Tel: +49 201 7296 300 Fax: +49 201 7296 333 - www.dnv.de/zertifizierung

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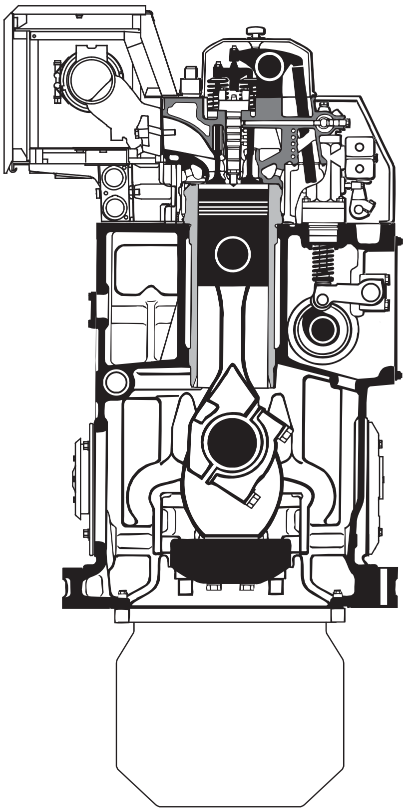
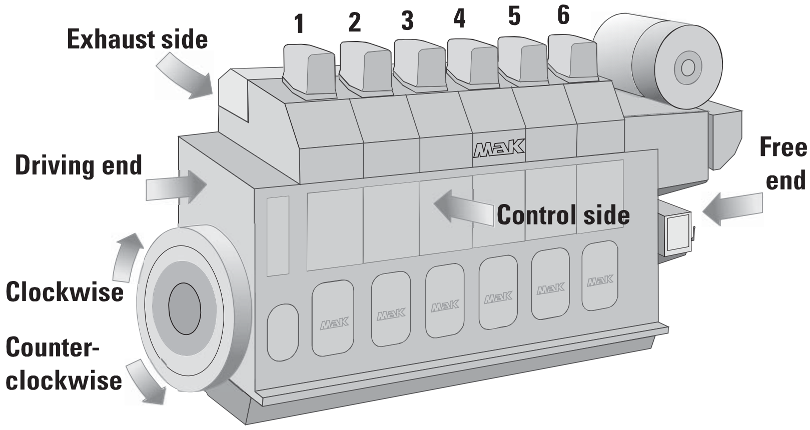
1. Engine description

1.1 Engine description

The M 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. Engine description

1.2 Engine design features

- Designed for heavy fuel operation up to 700 cSt/50°C, fuel grade acc. to CIMAC H55 K55, ISO 8217, 2010 (E), ISO-F-RMH55 RMK55.
- 1-piece dry engine block made of nodular cast iron. It includes the crankshaft bearings, camshaft bearings, charge air duct, vibration damper housing and gear drive housing.
- Underslung crankshaft with corrosion resistant main and big end bearing shells.
- Natural hardened liners, centrifugally cast, with calibration insert.
- Composite type pistons with steel crown and nodular cast iron skirt.
- Piston ring set consisting of 2 chromium plated compression rings, first ring with chromium-ceramic layer 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 made of sections per cylinder allowing a removal of the pieces sideways.
- Turbocharger supplied with integrated plain bearings lubricated by engine lubricating oil system.
- 2-stage freshwater cooling system with 2-stage charge air cooler.
- Nozzle cooling with engine lubricating oil.

2. General data and operation of the engine

Type	1,000 rpm [kW]
6 M 43 C	6,000
7 M 43 C	7,000
8 M 43 C	8,000
9 M 43 C	9,000

The maximum fuel rack position is mechanically limited to 100 % output for CPP and FPP applications. Limitation of 110 % for gensets and DE applications.

2.1 General data and outputs

2.1.1 Output definition

The maximum continuous rating stated by Caterpillar 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)

2. General data and operation of the engine

2.1.2 Fuel consumption

The fuel consumption data refers 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 of the stated consumption data	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 Lube oil consumption

Actual data can be taken from the technical data.

2.1.4 Nitrogen oxide emissions (NO_x values) IMO II

NO_x limit values according to MARPOL 73/78 Annex VI: 10.5 g/kWh

Main engine: Controllable pitch propeller, according to cycle E2: 10.4 g/kWh

2.1.5 Emergency operation without turbocharger

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

Rotor dismantled:	Constant speed 500 rpm, Combinator operation 360 rpm
Rotor blocked:	Constant speed 500 rpm, Combinator operation 350 rpm

2. General data and operation of the engine

2.1.6 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	176
	85%	g/kWh	175	175	175	175
	75%	g/kWh	-/177	-/177	-/177	-/177
	50%	g/kWh	-/184	-/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 TPL71	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
Lubricating 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	8.4	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 engine

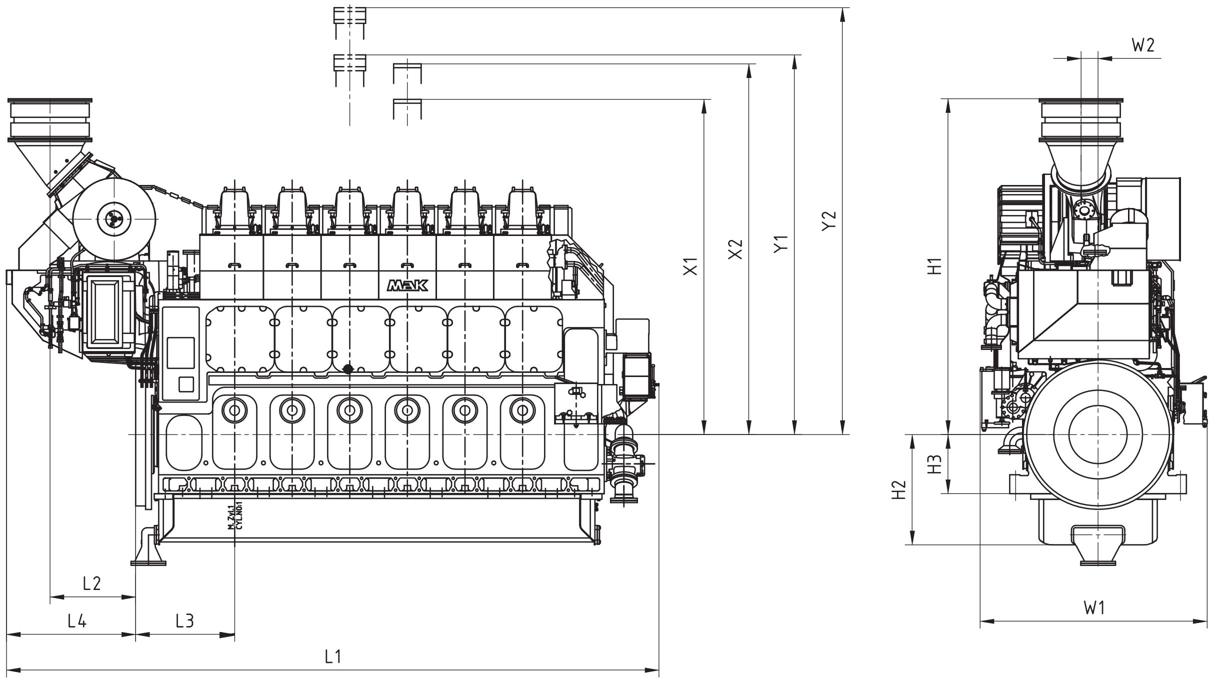
Fresh water cooling	Cylinder	6	7	8	9
Engine content	m³	0.6	0.7	0.8	0.9
Pressure at engine inlet min/max	bar	2.5/6.0	2.5/6.0	2.5/6.0	2.5/6.0
Header tank capacity	m³	0.6	0.6	0.6	0.6
Temperature at engine outlet	°C	80 - 90	80 - 90	80 - 90	80 - 90
Two-circuit system					
Engine driven pump HT	m³/h/bar	—	—	—	—
Independent pump HT	m³/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	m³/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)	kW	447	519	593	667
Heat radiation engine	kW	260	300	330	390
Exhaust gas					
Silencer/spark arrester NB	mm	900	1,000	1,000	1,000
Pipe diameter NB after turbine	mm	900	1,000	1,000	1,000
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
Maximum exhaust gas pressure drop	bar	0.03	0.03	0.03	0.03
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)	Nm³	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 engine

2.2 Engine dimensions

2.2.1 Turbocharger at driving end



Engine type	Dimensions [mm]									Weight
	L1	L2	L3	L4	H1	H2	H3	W1	W2	[t]
6 M 43 C	8,271	1,086	1,255	1,638	4,258	1,399	750	2,878	215	94.0
7 M 43 C	9,068	1,119	1,255	1,704	4,749	1,399	750	2,878	232	107.0
8 M 43 C	9,798	1,119	1,255	1,704	4,749	1,399	750	2,878	232	114.0
9 M 43 C	10,528	1,119	1,255	1,704	4,749	1,399	750	2,878	232	127.0

Removal of:

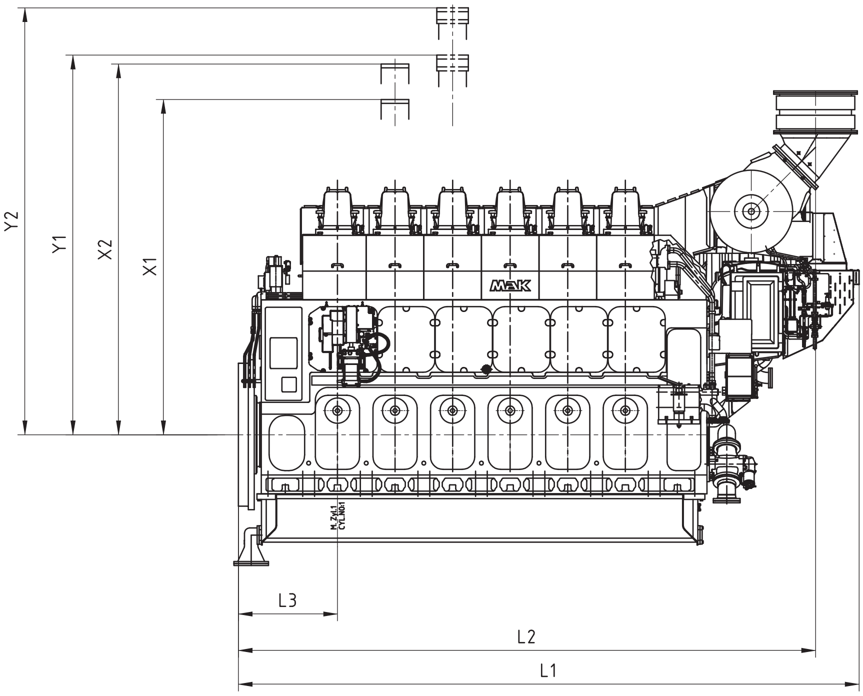
Piston: in transverse direction X1 = 3,530 mm
in longitudinal direction X2 = 3,975 mm

Cylinder liner: in transverse direction Y1 = 4,165 mm
in longitudinal direction Y2 = 4,610 mm
in transverse dir. reduced $Y1_{red.}$ = 3,705 mm

Engine centre distance 6,7,8,9 Cyl. 3,400 mm
(2 engines side by side)

2. General data and operation of the engine

2.2.2 Turbocharger at free end



Engine type	Dimensions [mm]								Weight
	L1	L2	L3	H1	H2	H3	W1	W2	[t]
6 M 43 C	7,867	7,316	1,255	4,358	1,399	750	2,878	215	94.0
7 M 43 C	8,664	8,079	1,255	4,849	1,399	750	2,878	232	107.0
8 M 43 C	9,394	8,809	1,255	4,849	1,399	750	2,878	232	114.0
9 M 43 C	10,124	9,539	1,255	4,849	1,399	750	2,878	232	127.0

Engine centre distance 6,7,8,9 Cyl. 3,400 mm
(2 engines side by side)

2. General data and operation of the engine

2.3 Restrictions for low load operation

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

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

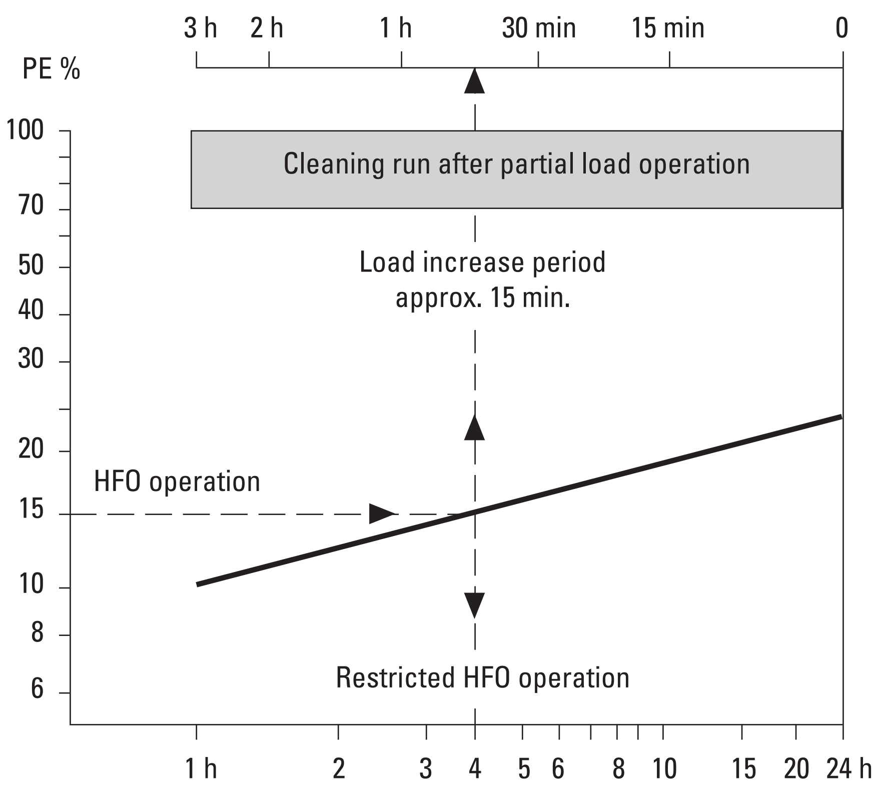
The lube oil treatment system (lube oil separator) remains in operation, the lube oil is separated continuously.

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

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

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

Cleaning run of engine



2. General data and operation of the engine

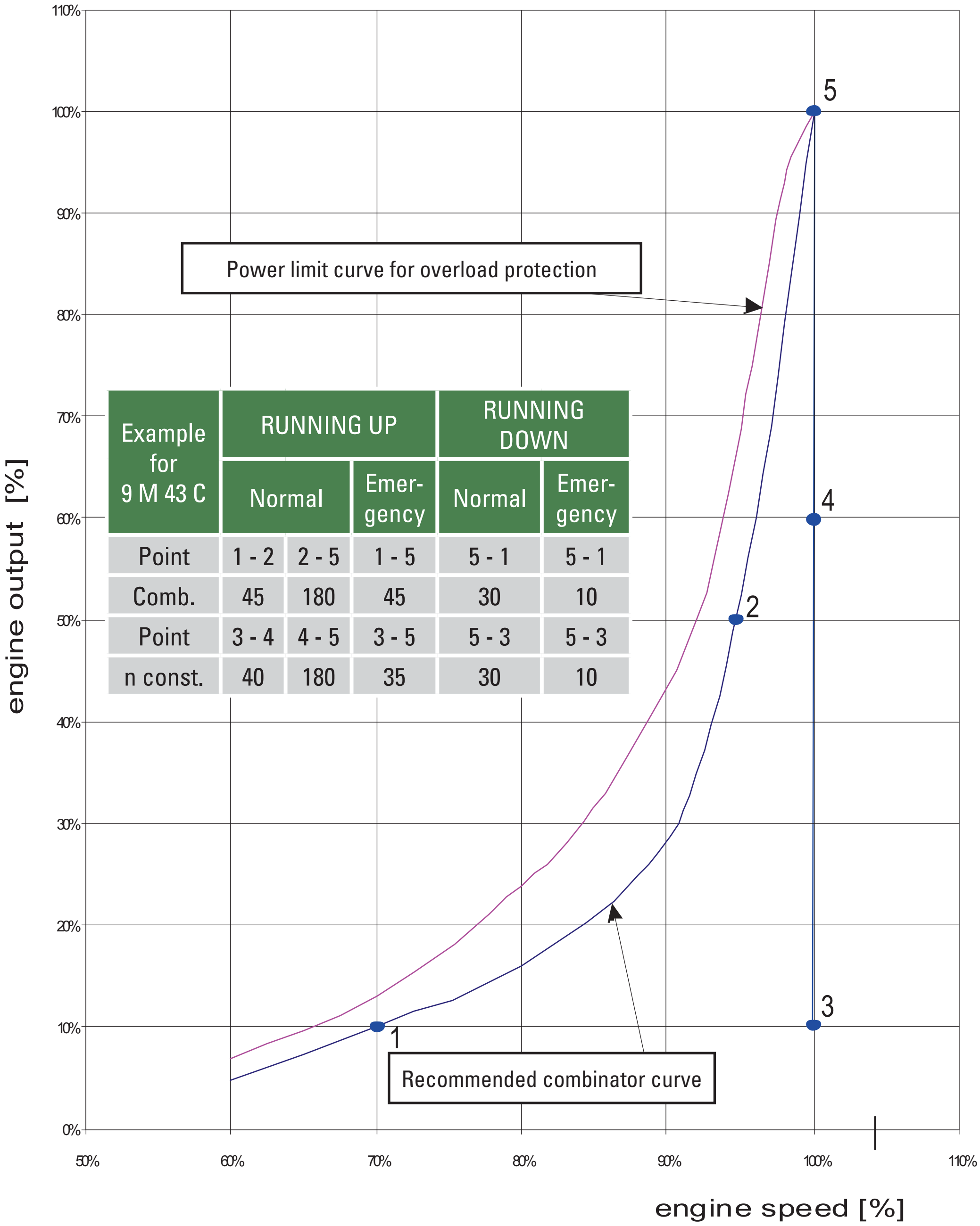
2.4 Controllable pitch propeller operation

The design area for the combinator has to be on the right-hand side of the theoretical propeller curve and may coincide with the theoretical propeller curve in the upper speed range.

A load above the power limit curve is to be avoided by the use of the load control device or overload protection device.

Binding data (depending on the type of vessel, rated output, speed and the turbocharging system) will be established upon order processing.

Standard combinator curve

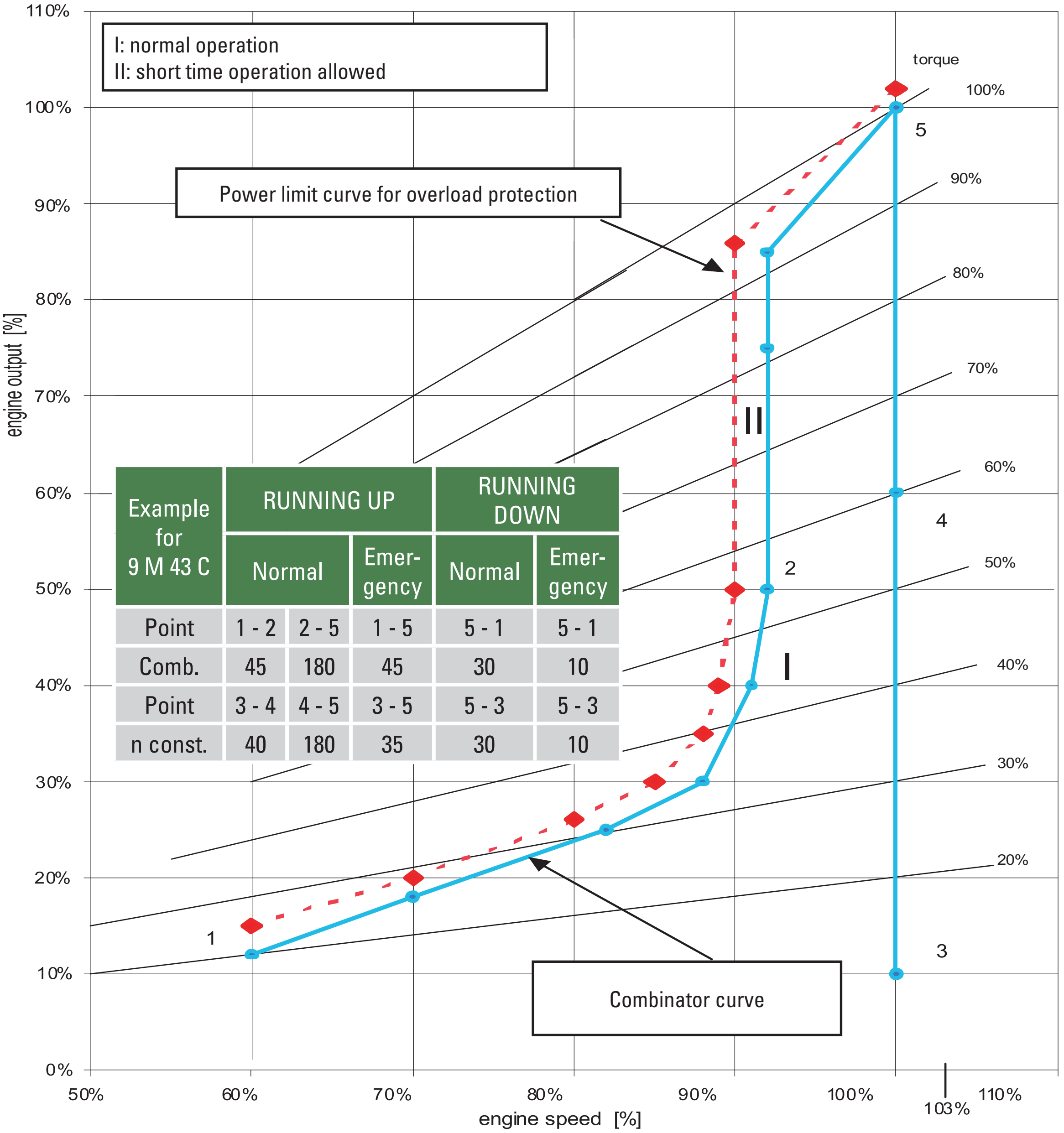


Example for 9 M 43 C	RUNNING UP			RUNNING DOWN	
	Normal		Emer-gency	Normal	Emer-gency
Point	1 - 2	2 - 5	1 - 5	5 - 1	5 - 1
Comb.	45	180	45	30	10
Point	3 - 4	4 - 5	3 - 5	5 - 3	5 - 3
n const.	40	180	35	30	10

2. General data and operation of the engine

2.4.1 Optimized propeller operation

optimized combinator curve with improved fuel consumption, efficiency and torque in part load.



Example for 9 M 43 C	RUNNING UP			RUNNING DOWN	
	Normal		Emer-gency	Normal	Emer-gency
Point	1 - 2	2 - 5	1 - 5	5 - 1	5 - 1
Comb.	45	180	45	30	10
Point	3 - 4	4 - 5	3 - 5	5 - 3	5 - 3
n const.	40	180	35	30	10

The design area for the combinator has to be on the right-hand side of the theoretical propeller curve and may coincide with the theoretical propeller curve in the upper speed range.

A load above the power limit curve is to be avoided by the use of the load control device or overload protection device.

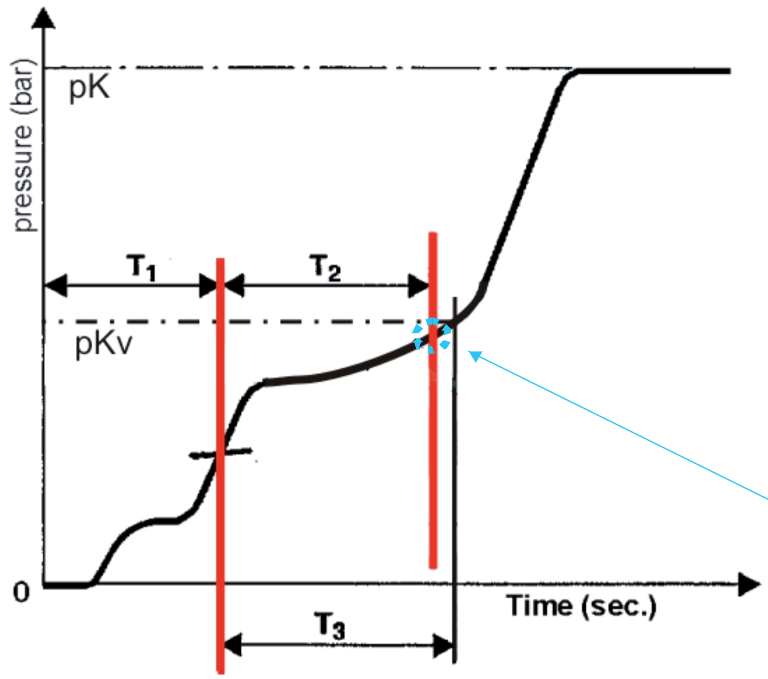
Binding data (depending on the type of vessel, rated output, speed and the turbocharging system) will be established upon order processing.

2. General data and operation of engine

2.5 General clutch procedure

General clutch in procedure for propulsion systems with MaK main engines

The diagram below indicates an example of a typical soft-clutch engagement timeline, required by Caterpillar for marine main engines.
To avoid engine stalling in case of high speed drop, overload of the flexible couplings and visible smoke, the engaging operation has to be smooth and easily controllable.
Important is the time T2, that includes the real slipping time.
This time has to be minimum 3 seconds. (If minimum 3 second adjustment is not possible, consultation is needed.)



pK = Lube oil switching pressure

pKv = Control pre-pressure

T_1 = Filling time

T_2 = Slipping time

T_3 = Pressure holding time

= Point of synchronization

The clutch-in speed of engine should be min. 70 % of rated speed, but could be 60 % depending on torsional vibration calculation (TVC).

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

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

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

Oil content

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

Particle size and density

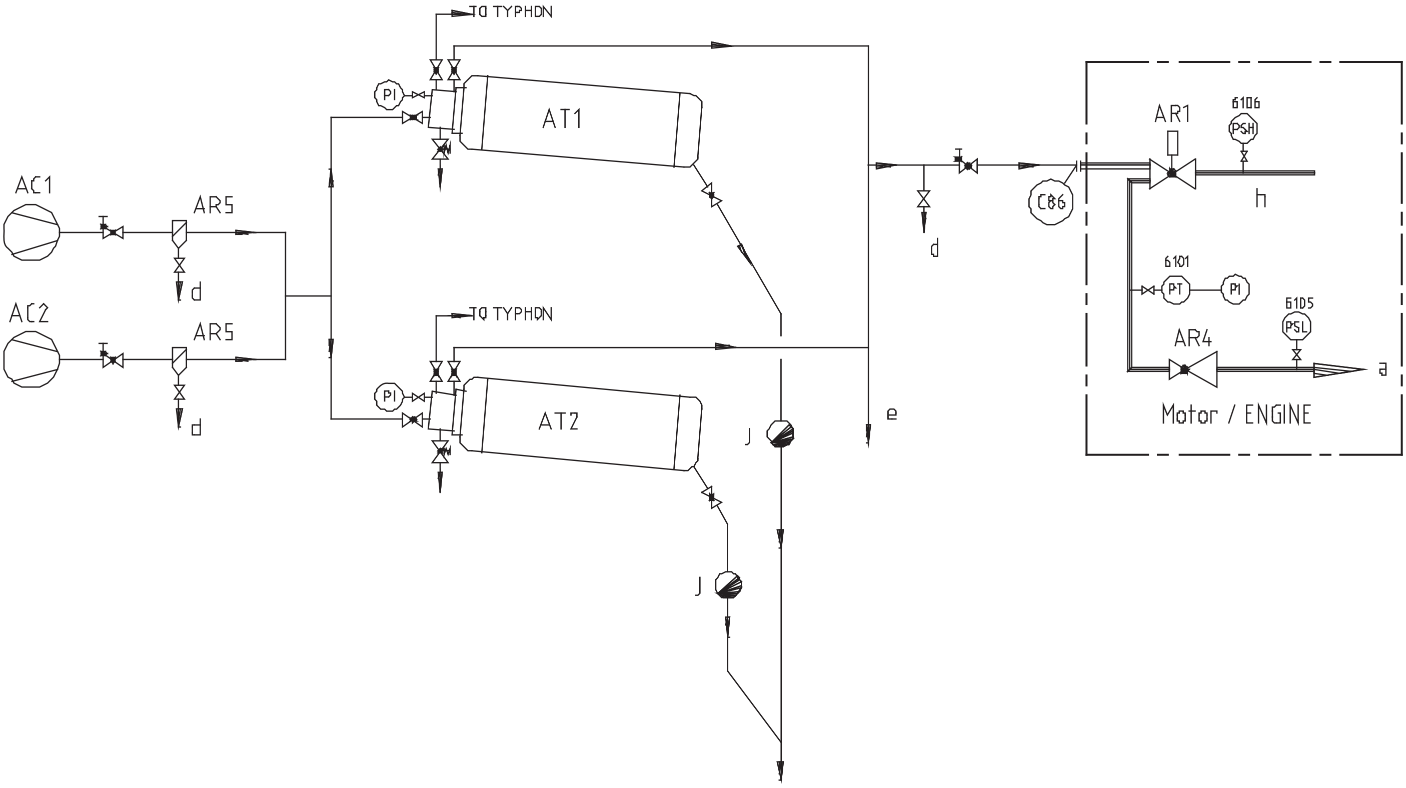
Specification of size and concentration of particles which may still be contained in the compressed air.

Pressure dew point

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

3. Systems

3.2.2 System diagram



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

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

The air receivers are to be drained sufficiently at least once per day.

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

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
AT2	Starting air receiver
PI	Pressure indicator
PSL	Pressure switch low, only for main engine
PSH	Pressure switch high
PT	Pressure transmitter

3. Systems

3.2.3 Starting air system components

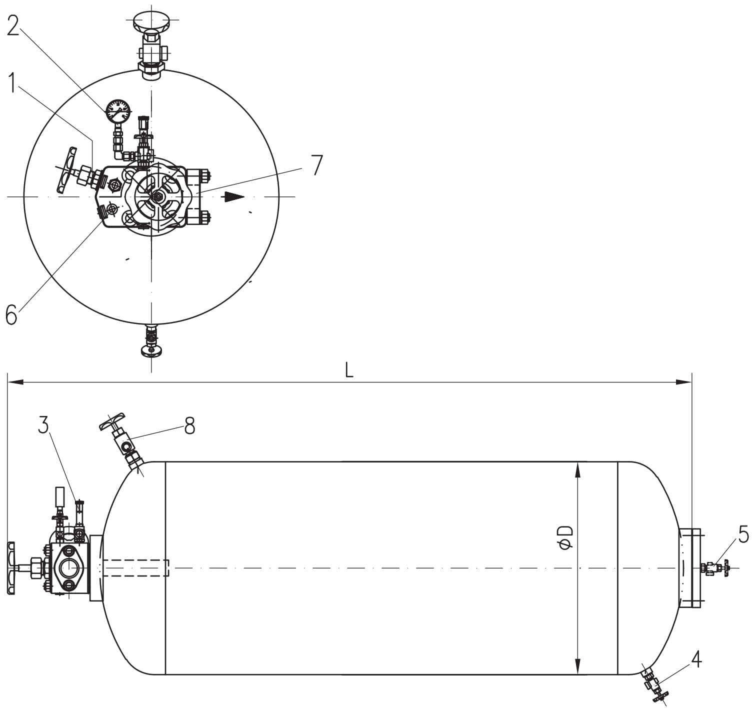
a) Receiver capacity acc. to GL recommendation AT1/AT2

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

Requirement of classification societies (regarding design)

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

3. Systems

b) Compressor AC1/AC2:

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

Capacity

$\dot{V}$ [m³/h] = $\Sigma V_{Rec.} \bullet 30$

$V_{Rec.}$ - Total receiver volume [m³]

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).
Each engine needs an independent exhaust gas routing.

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

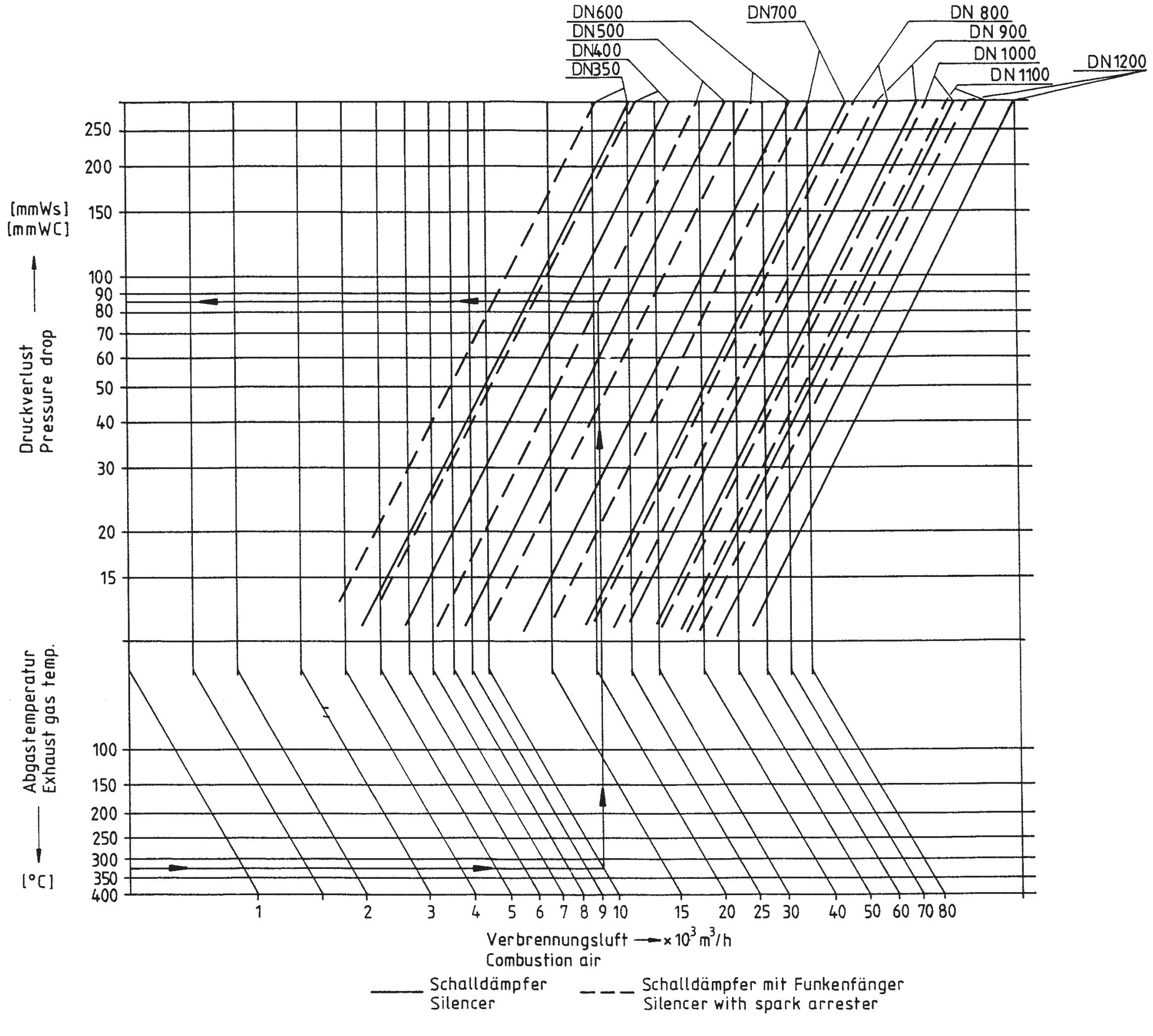
3.3.3 Silencer

Design according to the absorbtion principle with wide-band attenuation over a 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.

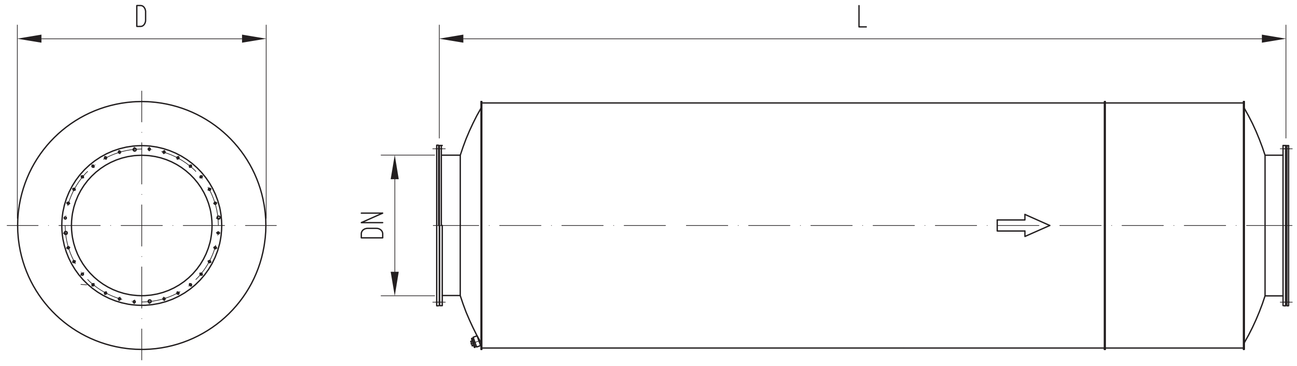


3. Systems

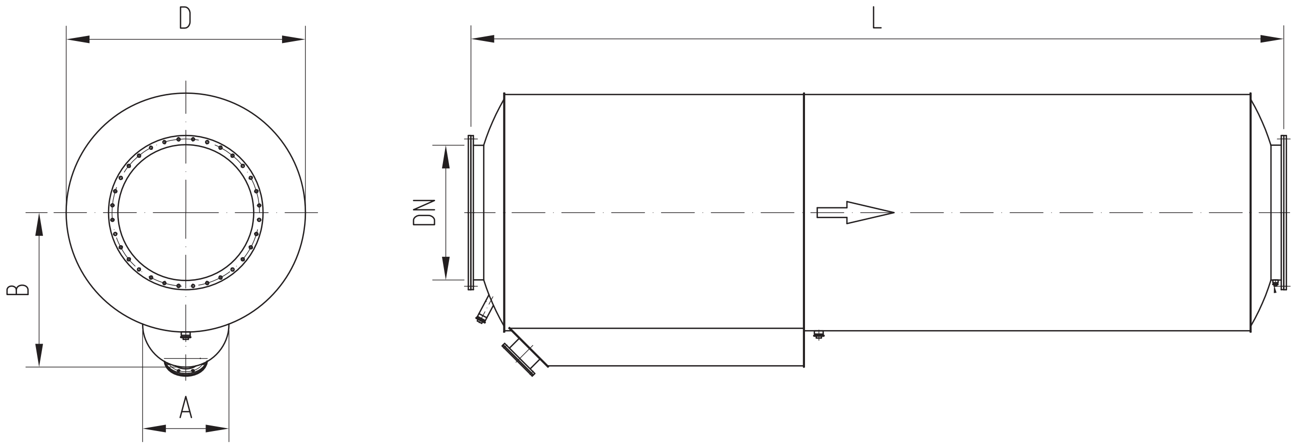
Dimension of silencer/spark arrestor and silencer (in case of Caterpillar supply):

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 needed)

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.

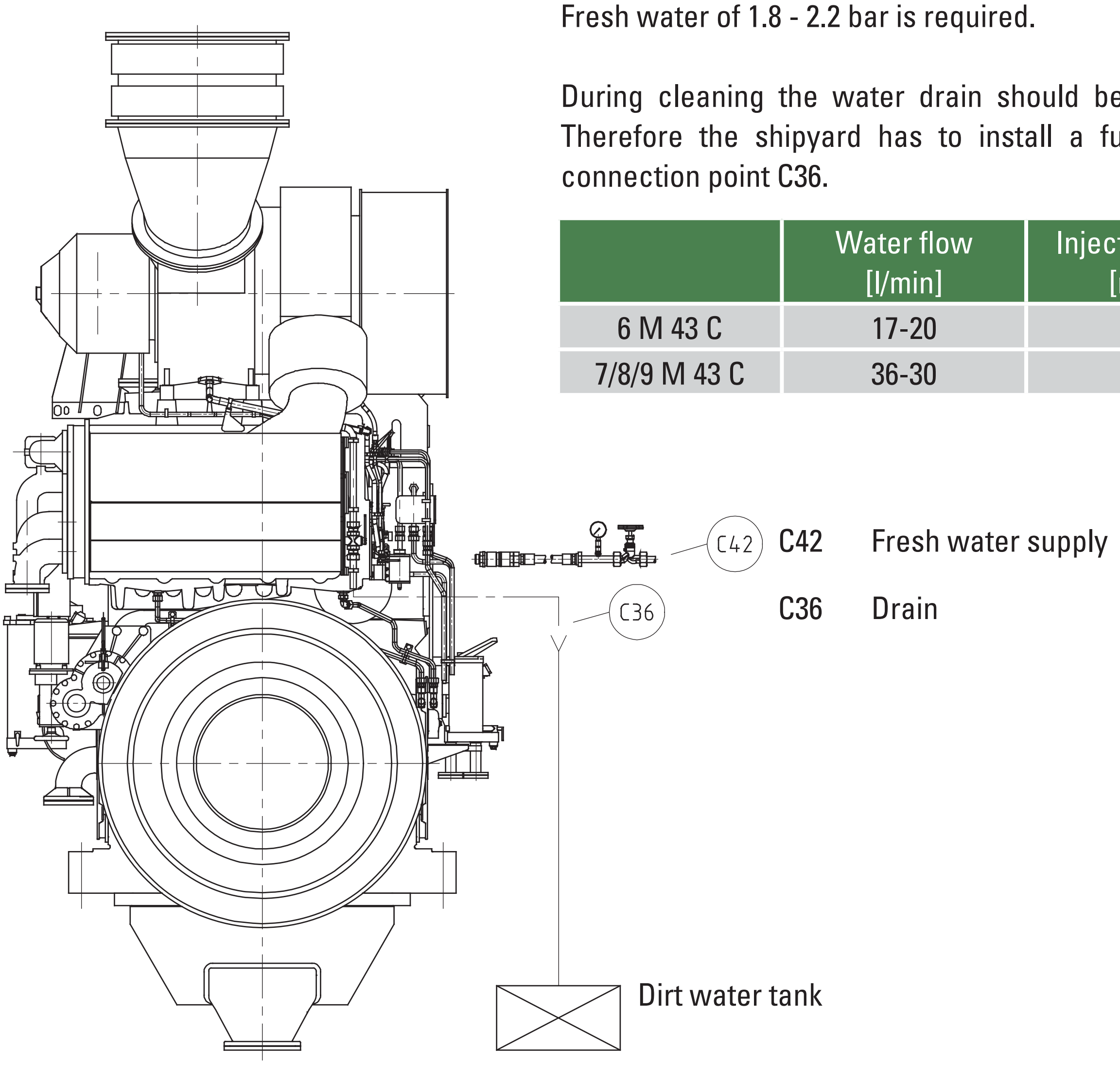
Cleaning the turbine blade and nozzle ring:

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 point 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, that must be carefully selected, treated and controlled. In case of using untreated cooling water corrosion, erosion and cavitation may occur on the walls of the cooling system.

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

Requirements

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

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

Supplementary information

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

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

Treatment before operating the engine for the first time

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

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

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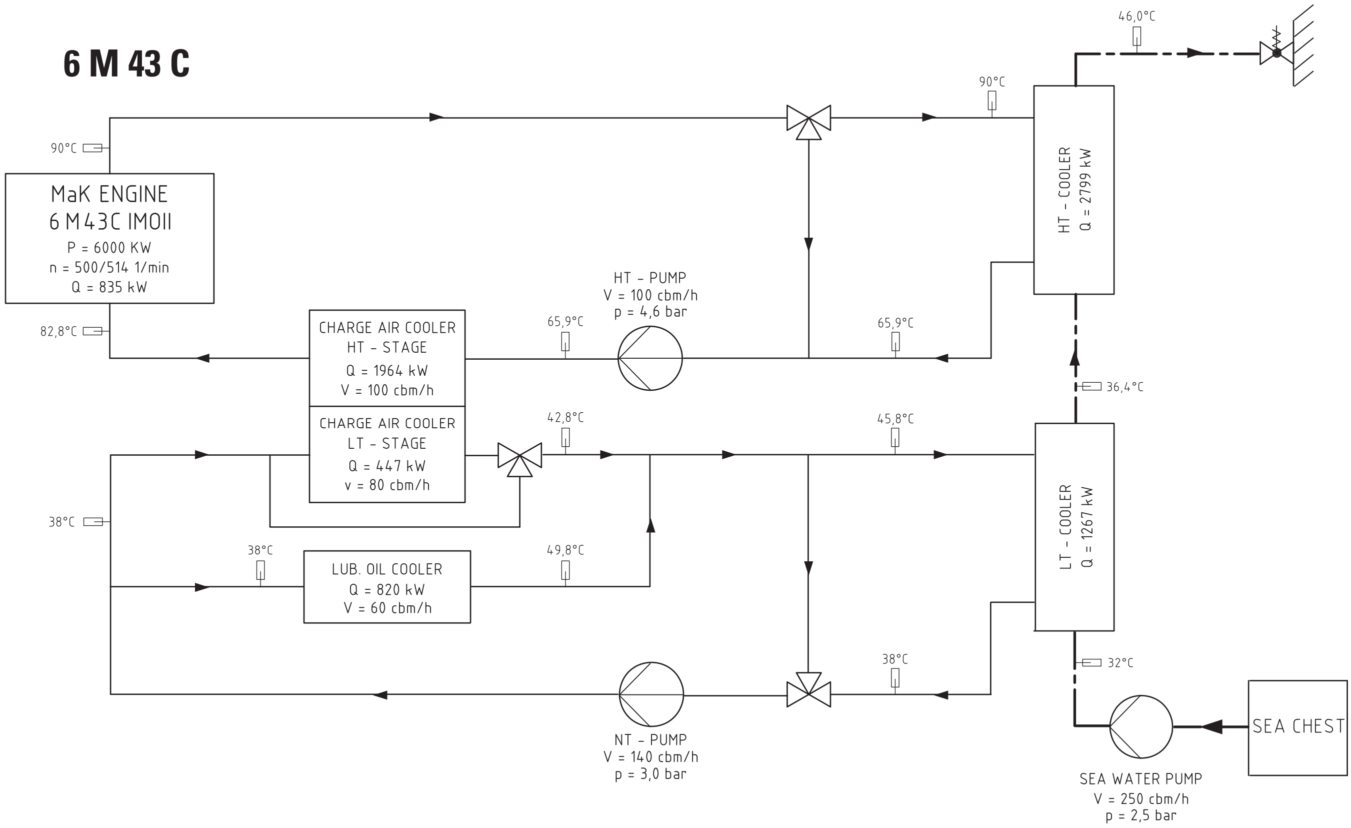
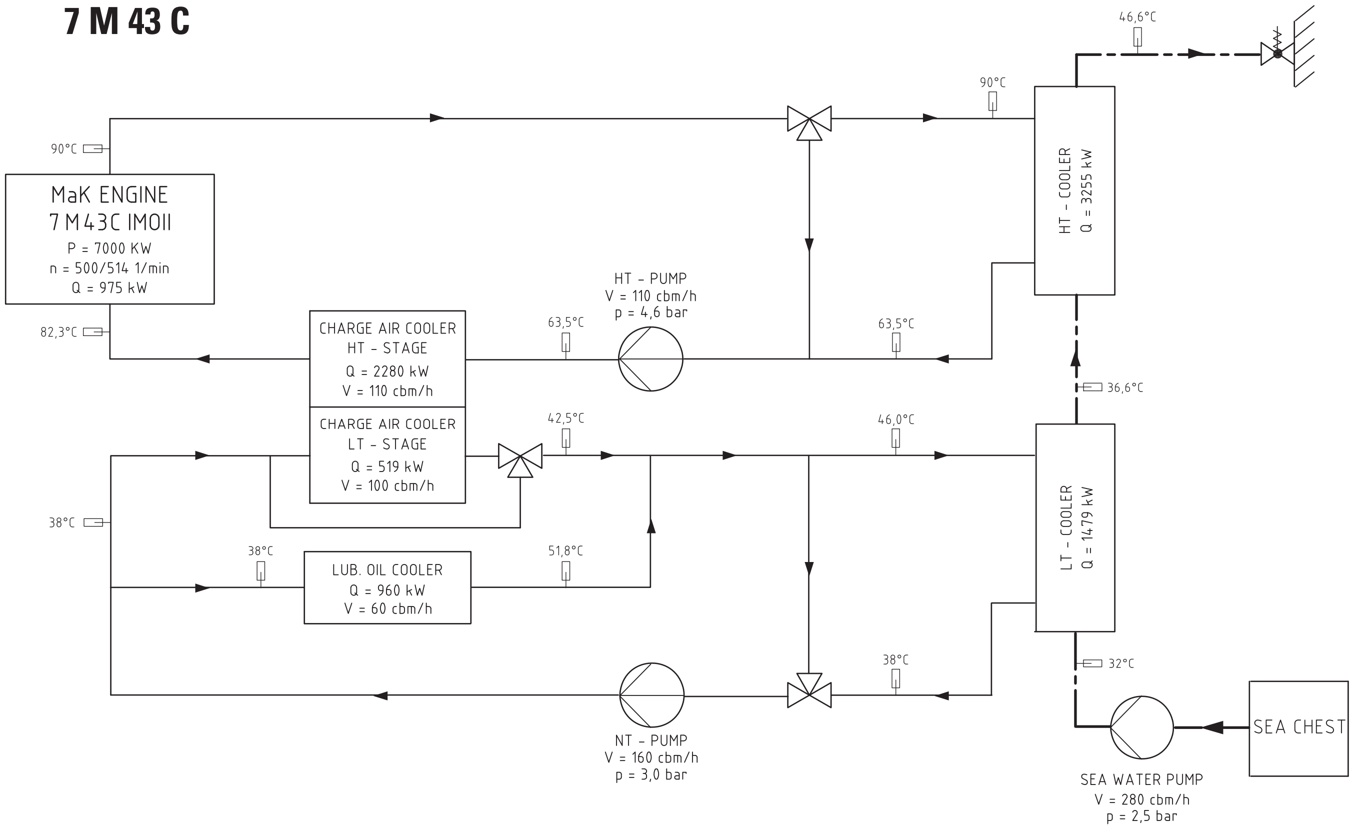
3.4.2 System diagram – Heat balances

6 M 43 C

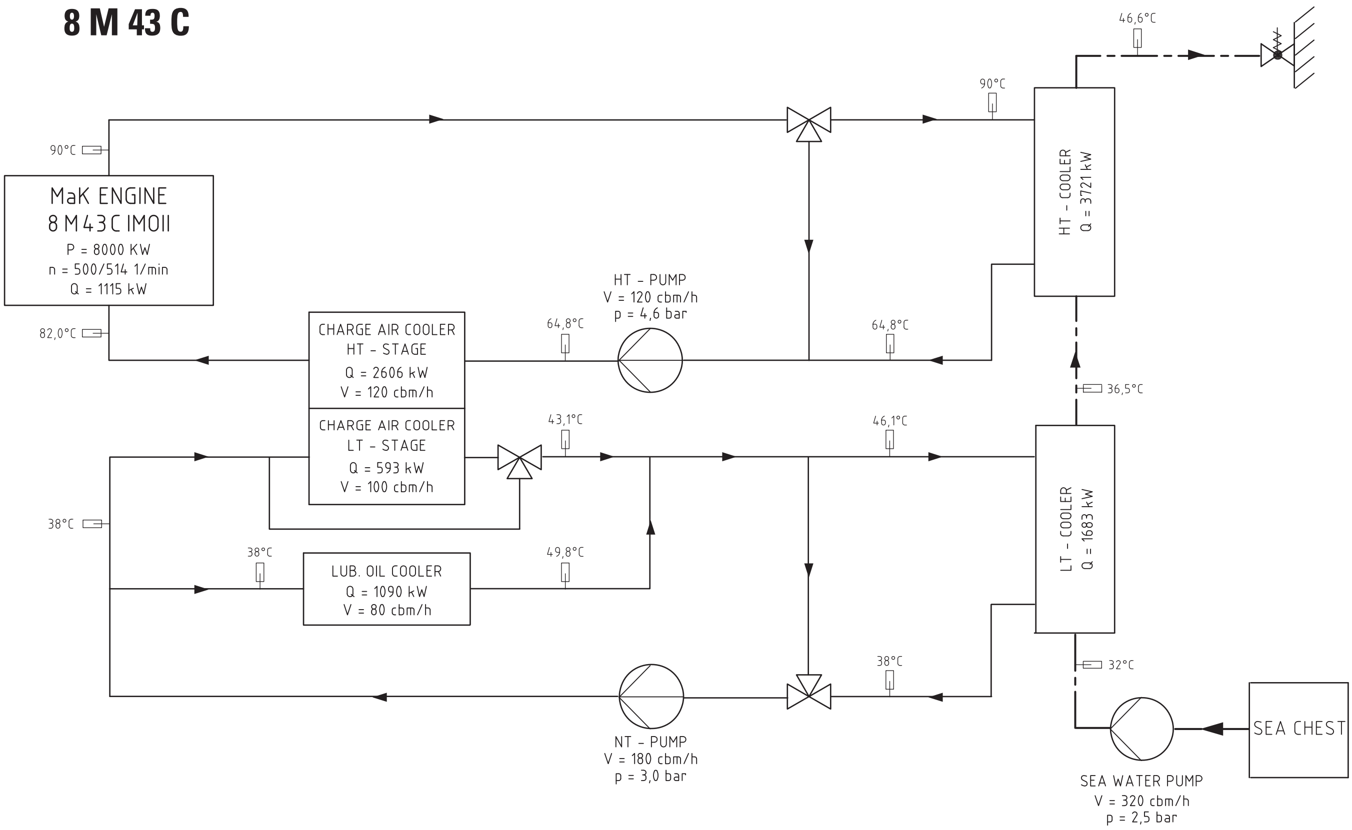


7 M 43 C

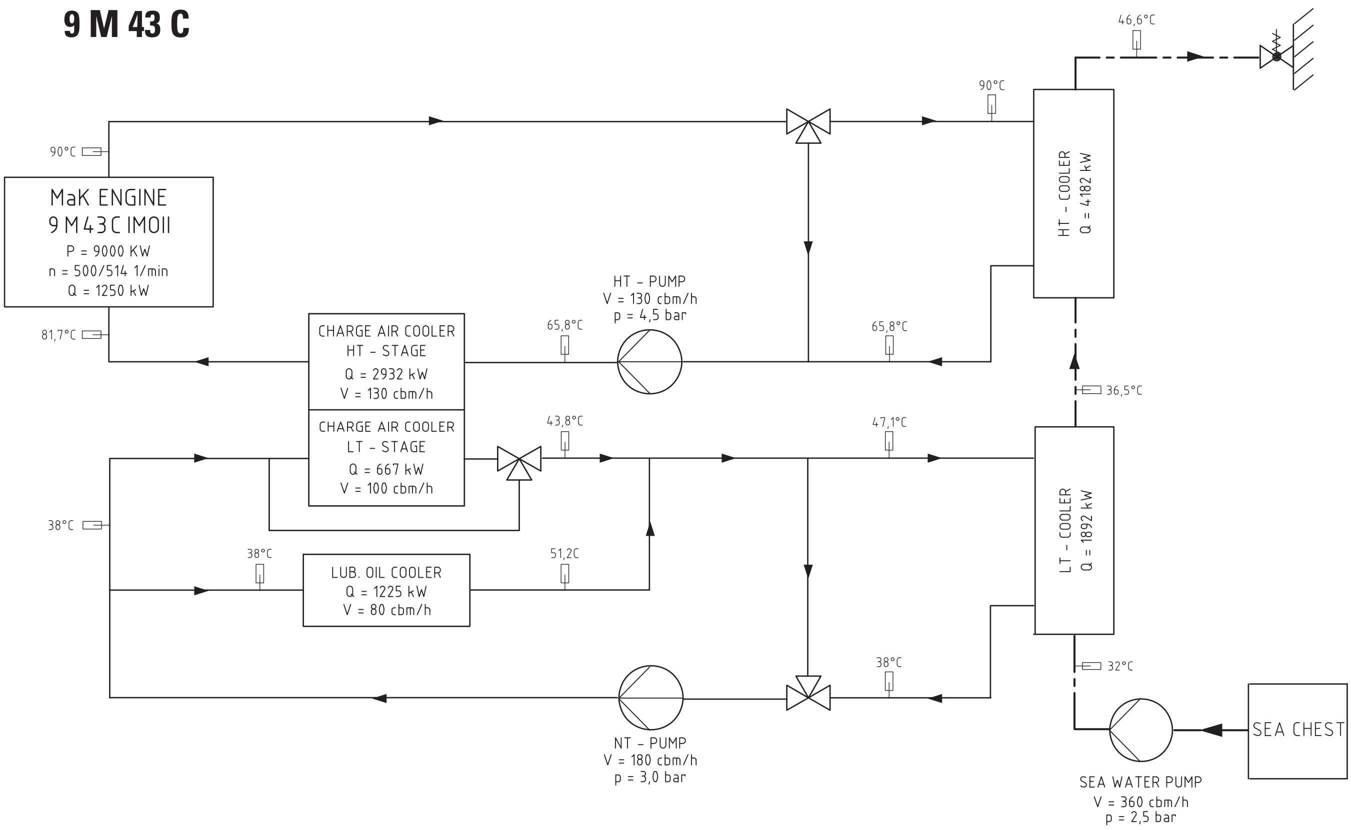


3. Systems

8 M 43 C

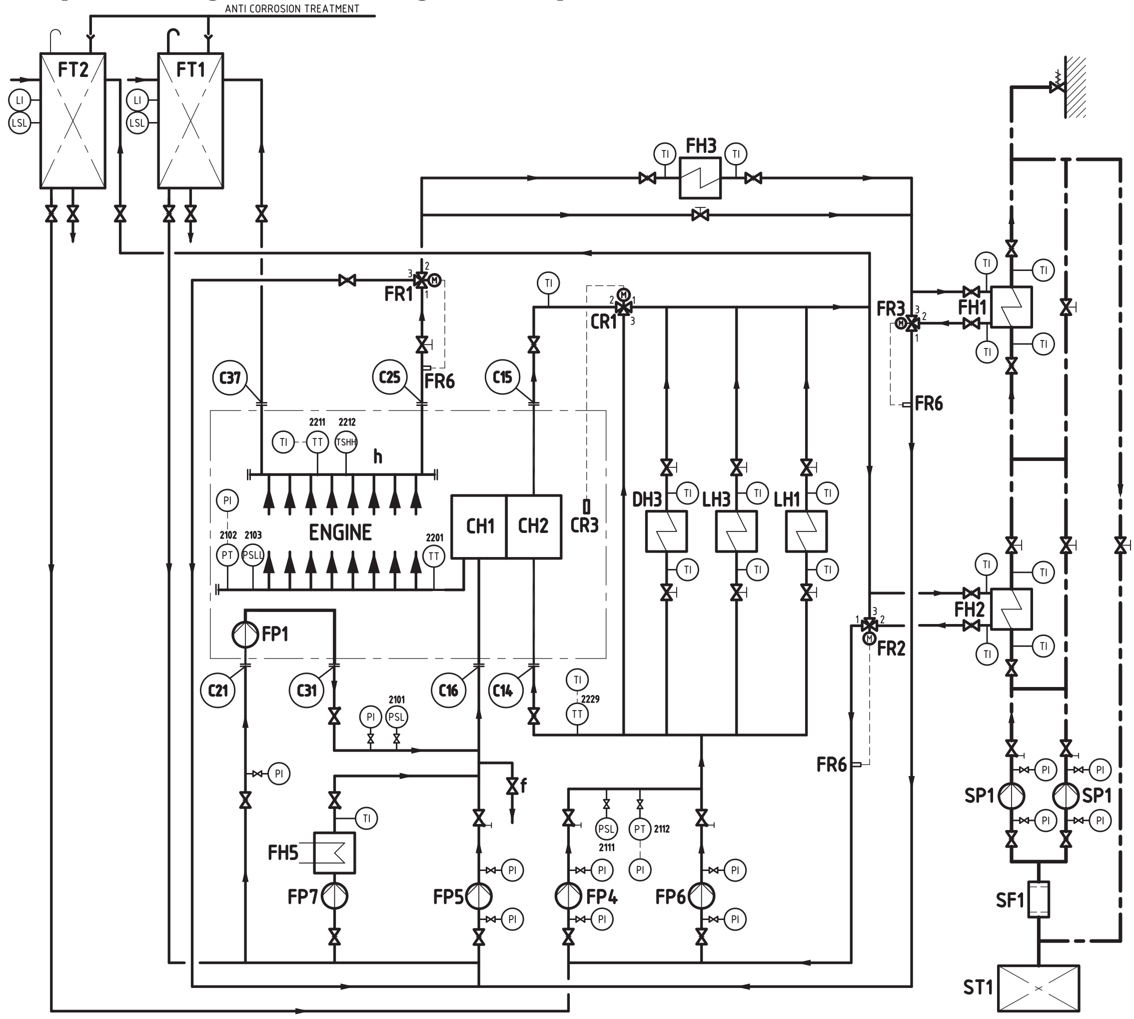


9 M 43 C



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 Charge air thermostat
CR3 Sensor for charge air temp. 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
LH3 Gear lube oil cooler
SF1 Seawater filter
SP1 Seawater pump
SP2 Seawater stand-by pump
ST1 Sea chest
LI Level indicator
LSL Level switch low
PI Pressure indicator
PSL Pressure switch low
PSLL Pressure switch low low
PT Pressure transmitter
TI Temperature indicator
TSHH Temperature switch high high
TT Temperature transmitter (PT 100)

General notes:
f Drain
h Please refer to the measuring points list regarding design of the monitoring devices

Connecting points:
C14 Charge air cooler LT, inlet
C15 Charge air cooler LT, outlet
C16 Charge air cooler HT, inlet
C21 Freshwater pump HT, inlet
C25 Cooling water, engine outlet
C31 Freshwater pump HT, outlet
C37 Vent

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 Caterpillar coolant regulations.

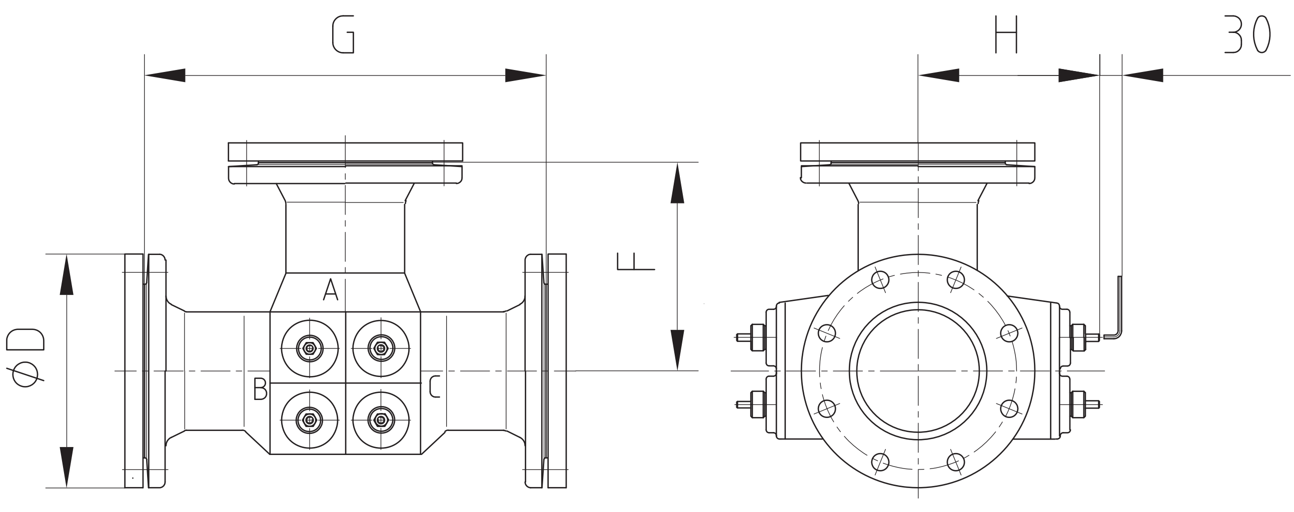
The system components of the LT cooling water circuit are designed for a max. LT cooling water temperature of 38 °C with a corresponding seawater temperature of 32 °C in tropical conditions.

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

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

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

c) HT temperature controller FR1 (separate): P-controller with manual emergency adjustment (basis). Option: PI-controller with electric drive (see Charge air temperature controller CR1)



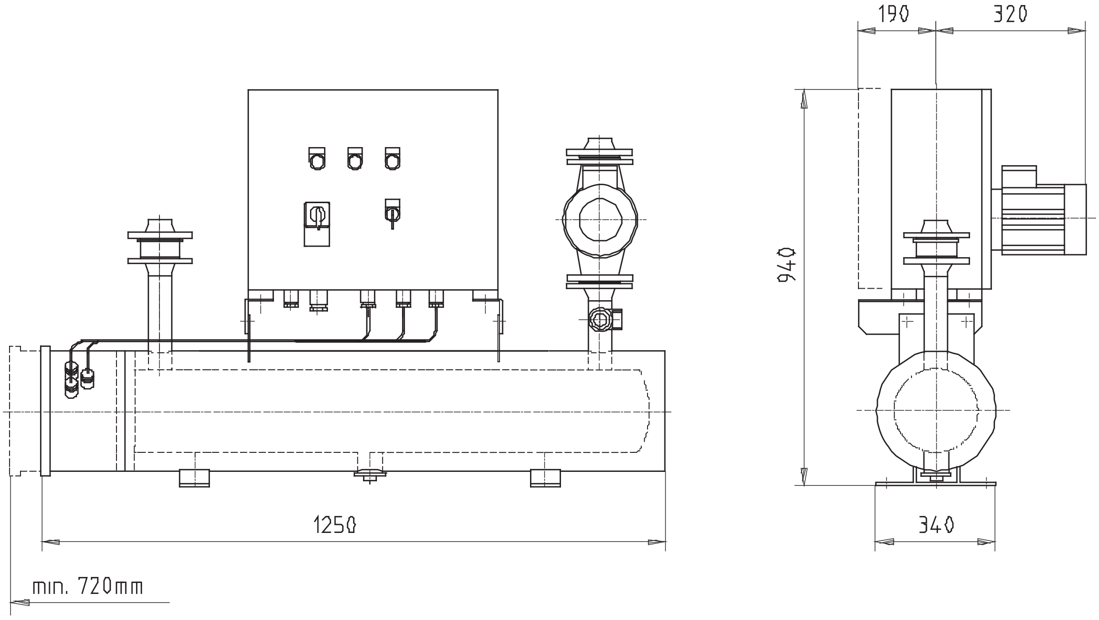
		Dimensions [mm]					Weight [kg]
		DN	D	F	G	H	
6/7 M 43 C	HT	125	250	241	489	200	67
8/9 M 43 C	HT	150	285	254	489	200	80
6/7/8/9 M 43 C	LT	150*	285	254	489	200	80

* Minimum, depending on total cooling water flow

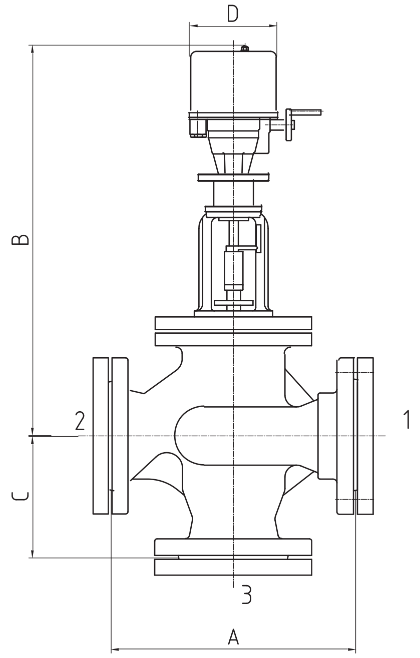
3. Systems

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

e) Preheater FH5/FP7 (separate): 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) Charge air temp. controller CR1 (separate): 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

g) HT cooler FH1 (separate):
Plate type, size depending on the total heat to be dissipated.

h) LT cooler FH2 (separate):
Plate type, size depending on the total heat to be dissipated.

i) Header tank FT1/FT2:
- Arrangement: min. 4 m / max. 16 m above crankshaft centre line (CL).
- Size acc. to technical engine data.
- All continuous vents from engine are to be connected.

3.4.5 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.

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

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

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

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3.5 Fuel oil system, MGO/MDO operation

MaK diesel engines are designed to burn a wide variety of fuels. See the information on fuel requirements in section MDO / MGO and heavy fuel operation or consult the Caterpillar technical product support. For proper operation of MaK engines the minimum Caterpillar 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 No. 2 D	2.4 4.1	No. 2 D No. 4 D	4.1 24.0
DIN	DIN EN 590	8		

Min. injection viscosity 1.5 mm²/s (cSt)
Max. injection viscosity 12 mm²/s (cSt)

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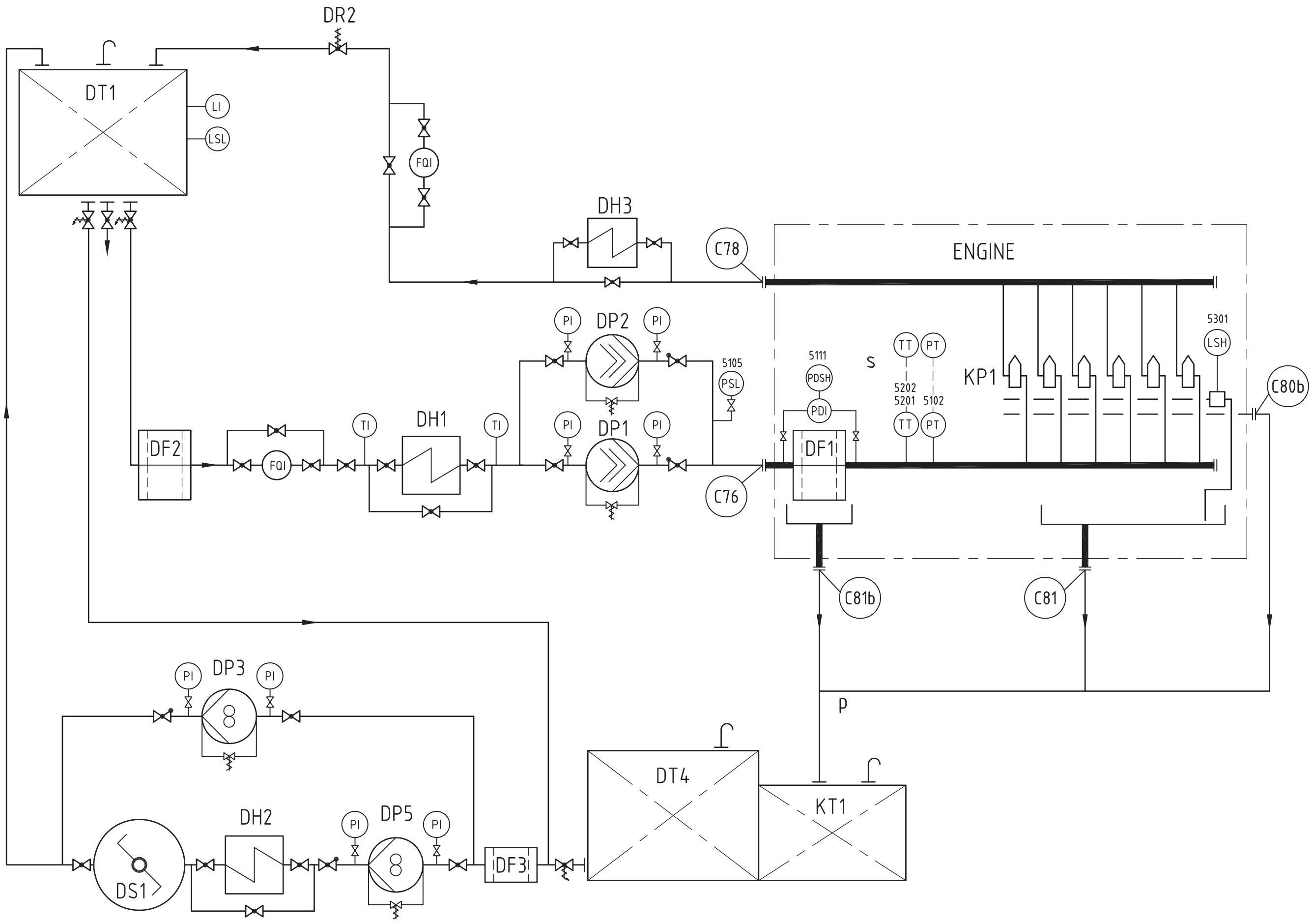
3.5.2 System diagram — Fuel oil system MGO/MDO operation



Accessories and fittings:

DF1 Fuel fine filter (duplex filter)
DF2 Fuel primary filter (duplex filter)
DF3 Fuel coarse filter
DH1 Diesel oil preheater
DH2 Electrical preheater for diesel oil (separator)
DH3 Fuel oil cooler for MDO operation
DP1 Diesel oil feed pump
DP2 Diesel oil stand-by feed pump
DP3 Diesel oil transfer pump (to day tank)
DP5 Diesel oil transfer pump (separator)
DR2 Fuel pressure regulating valve
DS1 Diesel oil separator
DT1 Diesel oil day tank
DT4 Diesel oil storage tank
KP1 Fuel injection pump
KT1 Drip fuel tank

Connecting points:

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

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)

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

3.5.3 MGO/MDO fuel system components

a) Fine filter DF1 (fitted): Duplex filter, mesh size see technical data

b) Strainer DF2 (separate): Mesh size 0.32 mm, dimensions see HFO-system

c) Preheater DH1 (separate): Heating capacity

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

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

d) MGO/MDO cooler DH3: Required to prevent overheating of the day tank

e) Feed pump DP1 (fitted): Capacity see technical data

f) Feed pump DP1 (separate): Capacity see technical data

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g) MGO/MDO service tank DT1:

The classification societies require the installation of at least two service tanks. 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, first of all, be designed to meet the requirements of the diesel generator sets on board.

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

h) Separator DS1:

Recommended for MGO
Required for MDO

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

$\dot{V}_{eff}$ [l/h] = 0.28 • $P_{eng.}$ [kW]

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3.6 Fuel oil system, HFO operation

3.6.1 Requirements for residual fuels for diesel engines (as bunkered)

	Designation		CIMAC A10	CIMAC B10	CIMAC C10	CIMAC D15	CIMAC E25	CIMAC F25	CIMAC G35	CIMAC H35	CIMAC K35	CIMAC H45	CIMAC K45	CIMAC H55	CIMAC K55
	Related to ISO8217 (2010):E-		RMA10	RMB30	RMB30	RMD80	RME180	RMF180	RMG380	RMH380	RMK380	RMH500	RMK500	RMH700	RMK700
Characteristic	Dim.	Limit													
Density at 15°C	kg/m³	max	960 [2]	975 [3]		980 [4]	991		991		1,010	991	1,010	991	1,010
Kin. viscosity at 100°C		max	10			15	25		35			45		55	
	cSt [1]	min	6 [5]				15 [5]								
Flash point	°C	min	60			60	60		60			60		60	
Pour point (winter) (summer)	°C	max	0 6		24	30	30		30			30		30	
Carbon residue (Conradson)	% (m/m)	max	12 [6]		14	14	15	20	18	22		22		22	
Ash	% (m/m)	max	0.10			0.10	0.10	0.15	0.15	0.15		0.15		0.15	
Total sedim, after ageing	% (m/m)	max	0.10			0.10	0.10		0.10			0.10		0.10	
Water	% (V/V)	max	0.3	0.5		0.5	0.5		0.5			0.5		0.5	
Sulphur	% (m/m)	max	3.5			3.5	3.5		3.5			3.5		3.5	
Vanadium	mg/kg	max	50	150		150	200	350	350		450	450		450	
Aluminium + silicon	mg/kg	max	25	40		40	60		60			60		60	
Zinc	mg/kg	max	15			15	15		15			15		15	
Phosphor	mg/kg	max	15			15	15		15			15		15	
Calcium	mg/kg	max	30			30	30		30			30		30	

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

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

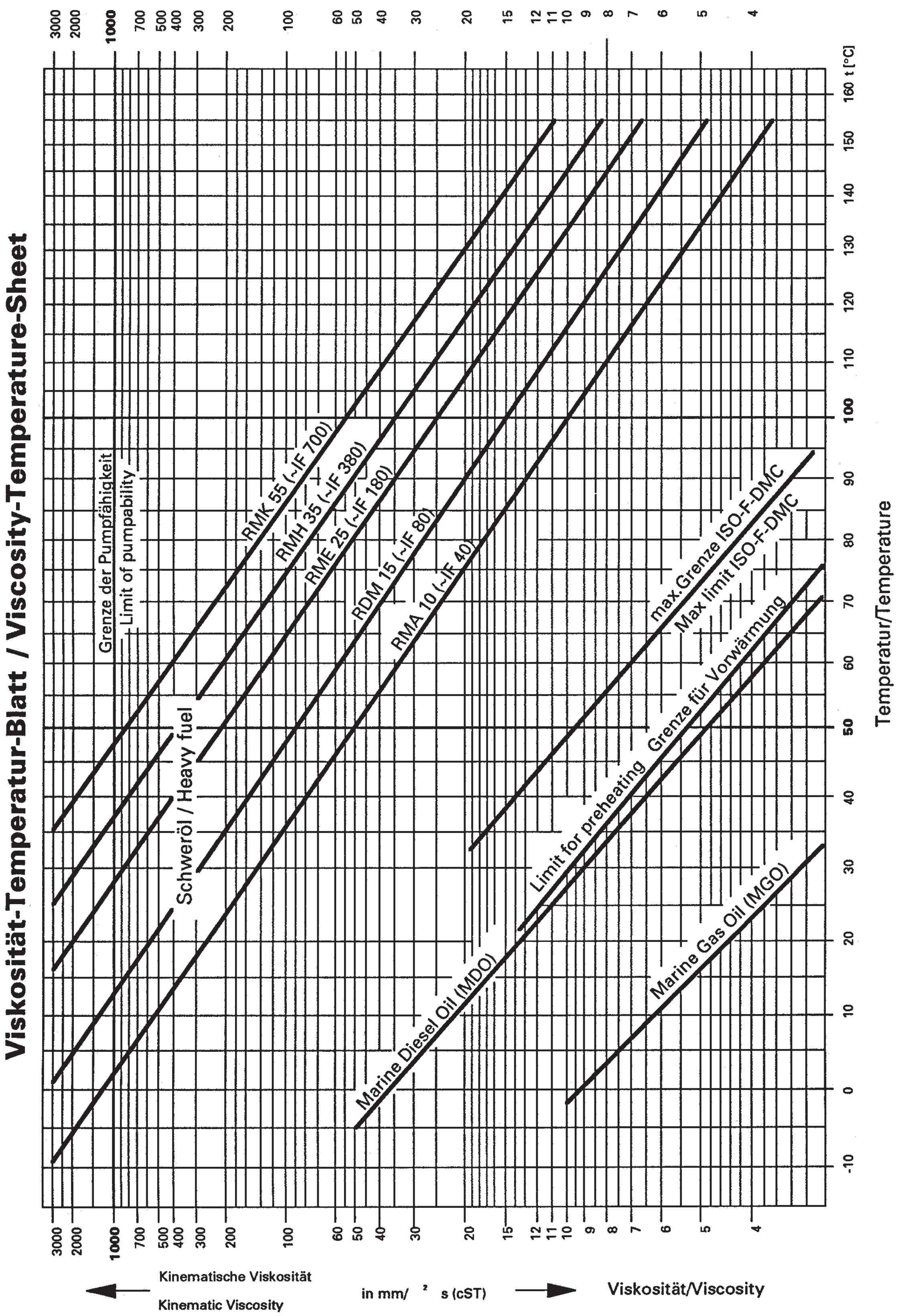
Fuel shall be free of used lubricating oil (ulo)

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

Contents

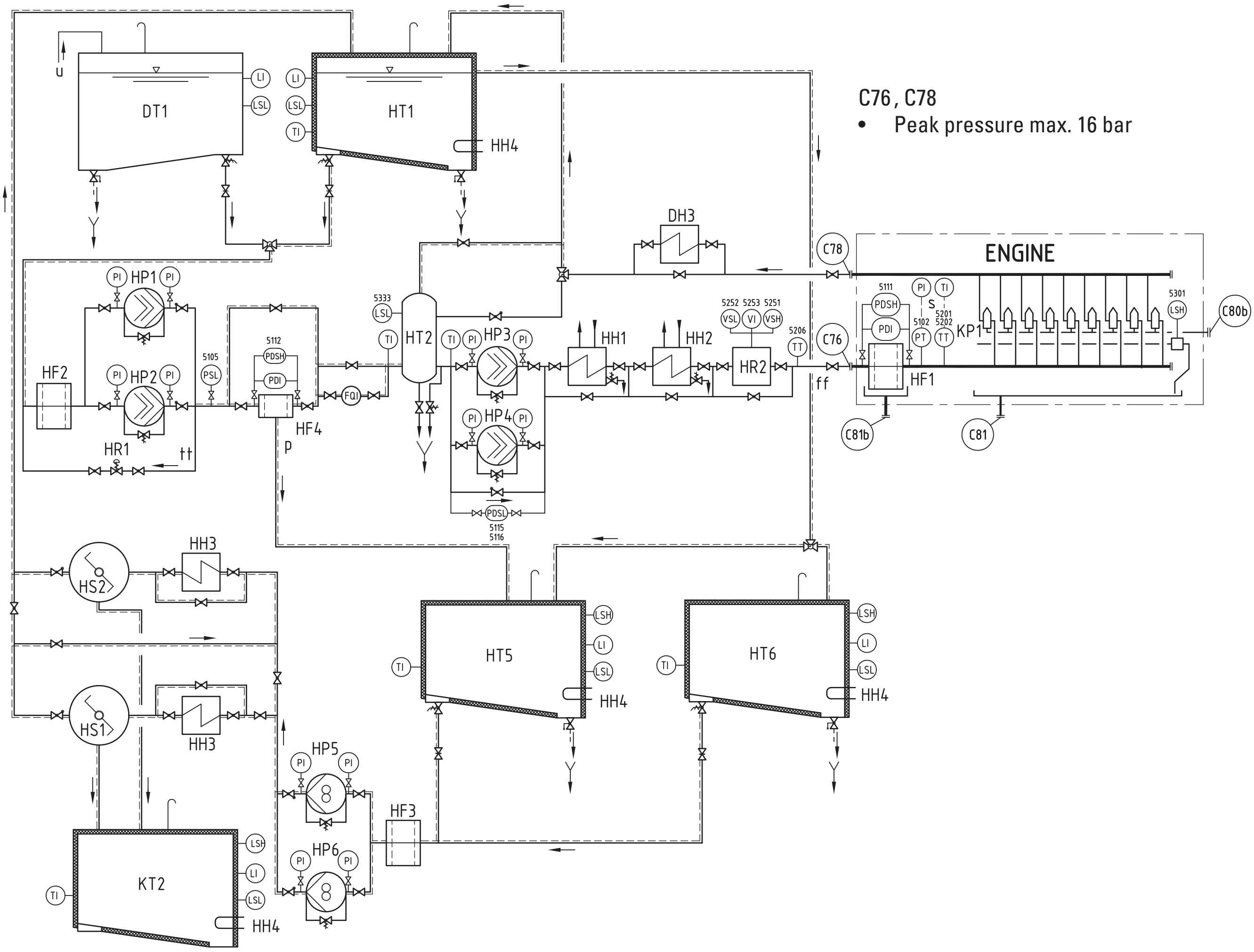
3. Systems

3.6.2 Viscosity / temperature diagram



3. Systems

3.6.3 System diagram – Heavy fuel oil operation



C76, C78
- Peak pressure max. 16 bar

General notes:
For location, dimensions and design (e.g. flexible connection) of the connecting points see engine installation drawing.
Non-return valves have to be spring loaded due to pulsation in the fuel lines.

Accessories and fittings:

DH3	Fuel oil cooler for MDO operation	HT5/HT6	Settling tank
DT1	Diesel oil day tank	HT8	Compensation damping tank
HF1	Fine filter (duplex filter)	KP1	Injection pump
HF2	Primary filter	KT2	Sludge tank
HF3	Coarse filter	FQI	Flow quantity indicator
HF4	Self cleaning fuel filter	LI	Level indicator
HH1	Heavy fuel final preheater	LSH	Level switch high
HH2	Stand-by final preheater	LSL	Level switch low
HH3	Heavy fuel preheater (separator)	PDI	Diff. pressure indicator
HH4	Heating coil	PDSH	Diff. pressure switch high
HP1/HP2	Pressure pump	PDSL	Diff. pressure switch low
HP3/HP4	Circulating pump	PI	Pressure indicator
HP5/HP6	Heavy fuel transfer pump (separator)	PT	Pressure transmitter
HR1	Pressure regulating valve	TI	Temperature indicator
HR2	Viscosimeter	TT	Temperature transmitter (PT 100)
HS1/HS2	Heavy fuel separator	VI	Viscosity indicator
HT1	Heavy fuel day tank	VSH	Viscosity control switch high
HT2	Mixing tank	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 is not insulated nor heated
- u From diesel oil separator or diesel oil transfer pump

All heavy fuel oil pipes must be insulated.
---- heated pipe

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

3.6.4 HFO system components

Supply system:

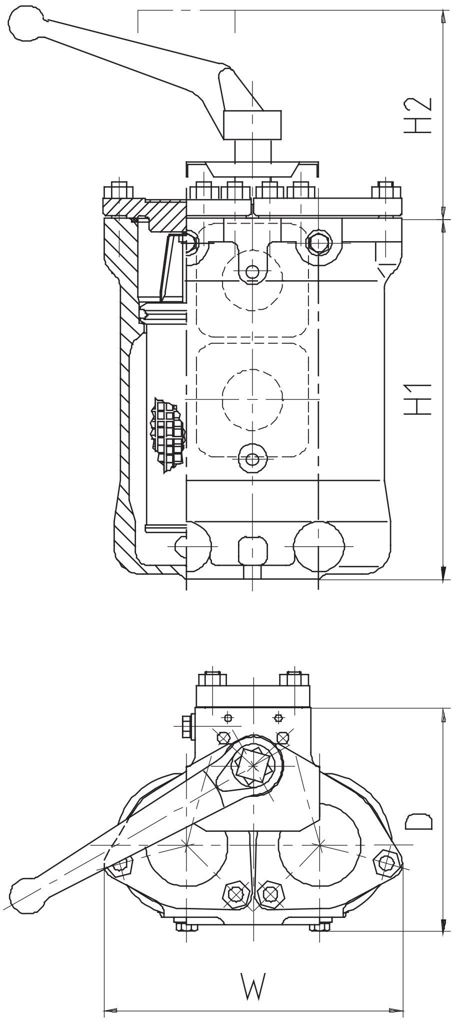
A closed **pressurized system** between day tank and engine is required as well as the installation of an automatic backflushing filter with a mesh size of 10 µm (absolute).

a) Fine filter HF1 (fitted):

- 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

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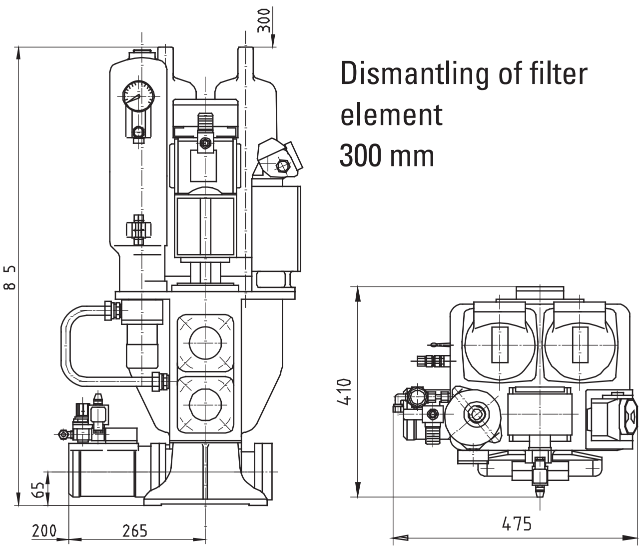
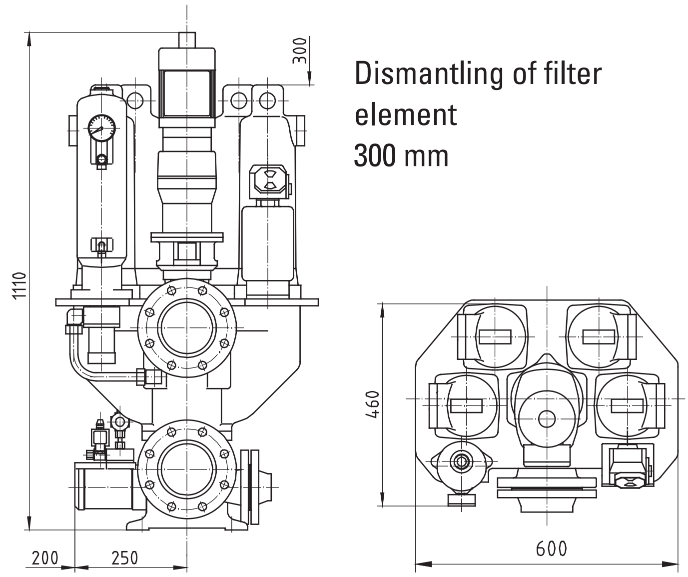
c) Self cleaning filter HF4:

Mesh size 10 µm (absolute).

≤ 8,000 kW, DN 50



> 8,000 kW, DN 100



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.

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

f) Circulating pumps HP3/HP4:

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

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

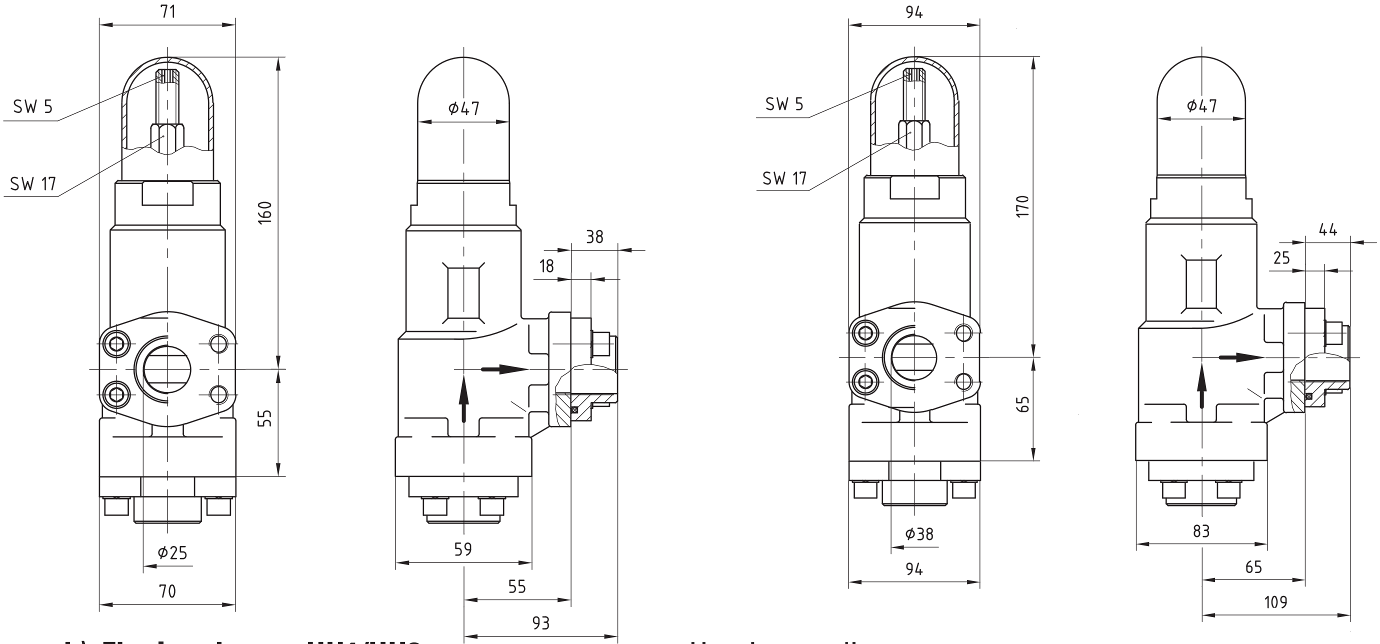
3. Systems

g) Pressure regulating valve HR1:

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

Engine outputs

≤ 8,000 kW | > 8,000 kW



h) Final preheater HH1/HH2:

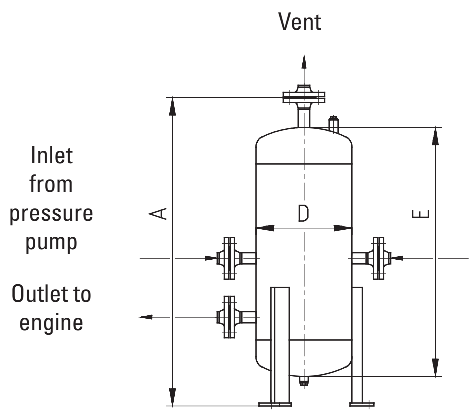
Heating media:

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

Temperature at engine inlet max. 150 °C.

i) Mixing tank HT2:

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



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 day tanks are required. The day tank capacity must cover at least 4 hours/max. 24 hours full load operation of all consumers. An overflow system into the settling tanks and sufficient insulation are required.

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:

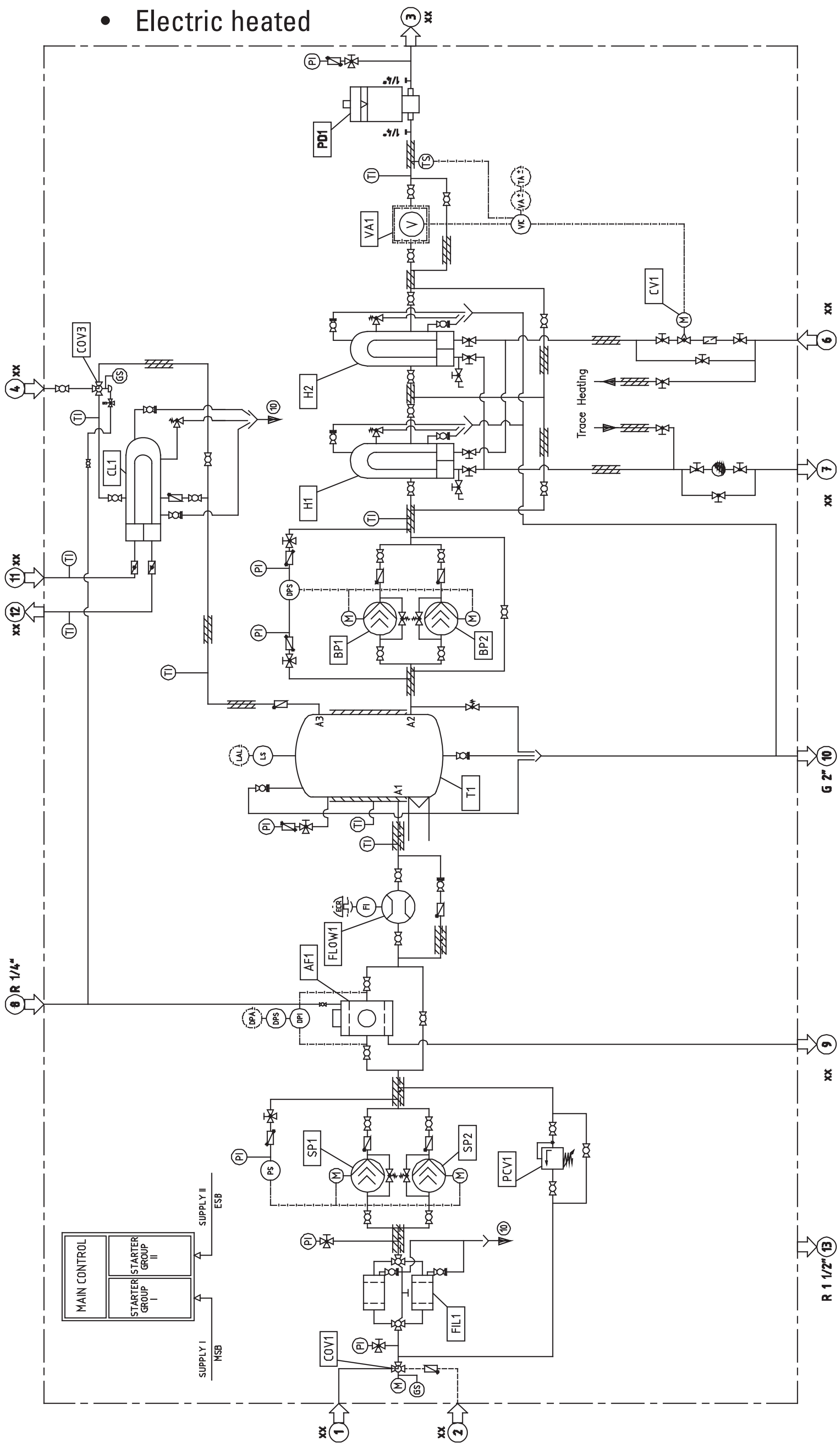
Caterpillar recommends to install two self-cleaning separators. Design parameters as per supplier recommendation. Separating temperature 98 °C. Maker and type are to be advised by Caterpillar.

3. Systems

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 elect. heating

Technical specification of the main components:

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

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

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

d) **Self-cleaning fine filter AF1**
1 pc. automatic self cleaning fine filter 10 microns 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
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, thermaloil or electrical) where necessary.

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

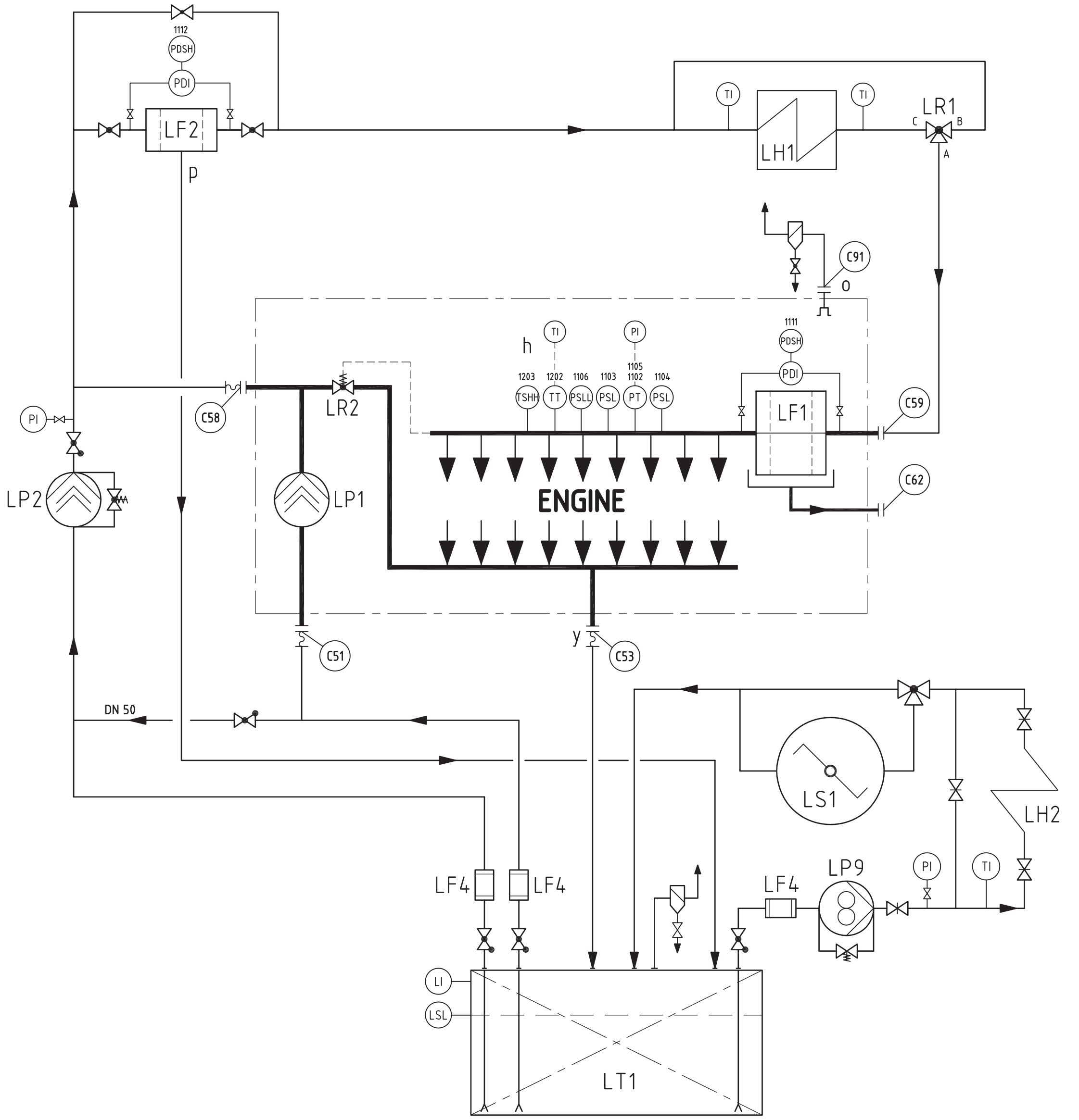
The following oils have been tested and approved by Caterpillar:

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

I Approved in operation
II Permitted for controlled use
When these lube oils are used, Caterpillar must be informed as currently there is insufficient experience available for MaK engines. Otherwise the warranty may be affected.
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



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

Accessories and fittings:

LF1	Duplex lube oil filter	LI	Level indicator
LF2	Lube oil automatic filter	LSL	Level switch low
LF4	Suction strainer	PDI	Diff. pressure indicator
LH1	Lube oil cooler	PDSH	Diff. pressure switch high
LH2	Lube oil preheater	PI	Pressure indicator
LP1	Lube oil force pump	PSL	Pressure switch low
LP2	Lube oil stand-by force pump	PSLL	Pressure switch low low
LP9	Transfer pump (separator)	PT	Pressure transmitter
LR1	Lube oil thermostat valve	TI	Temperature indicator
LR2	Oil pressure regulating valve	TSHH	Temperature switch high high
LS1	Lube oil separator	TT	Temperature transmitter (PT 100)
LT1	Lube oil sump tank		

Notes:

h	Please refer to the measuring point list regarding design of the monitoring devices.
o	See "crankcase ventilation" installation instructions 5.7.
p	Free outlet required.
y	Provide an expansion joint.

Disconnecting points:

C51	Force pump, suction side
C53	Lube oil discharge
C58	Force pump, delivery side
C59	Lube oil inlet, duplex filter
C62	Drip oil, duplex filter
C91	Crankcase ventilation to stack

3. Systems

3.7.3 Lube oil system components

a) Force pump LP1 (fitted): Gear pump

b) Prelubrication pump LP5 (separate): Delivery head 5 bar
For inland waterway vessels and multi engine plants only.
In case of Caterpillar supply vertical design only.

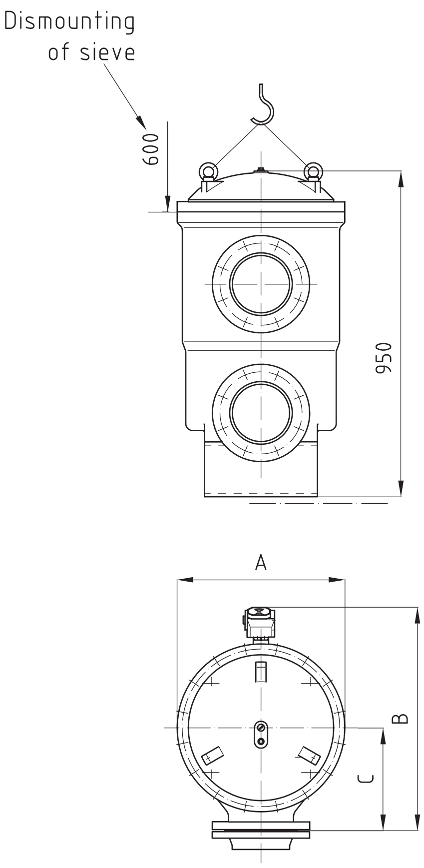
c) Stand-by force pump LP2 (separate):

- Per engine according to classification society requirement
- Screw type/gear type pump

d) Strainer LF4: Mesh size 2 - 3 mm

e) Self cleaning filter LF2 (separate): The self-cleaning filter protects the engine against particles.

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



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 LF1 (fitted):

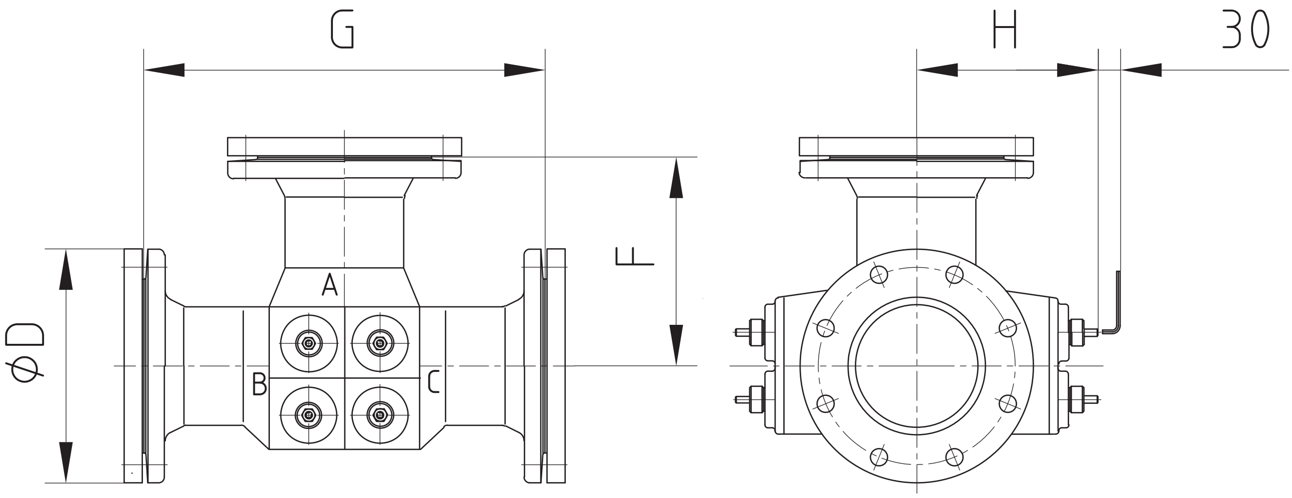
Mesh size 80 µm
Differential pressure indication and alarm contact fitted.

g) Cooler LH1 (separate):

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:

Volume

$$V\,[m^3] = \frac{1.7 \bullet P_{eng.}\,[kW]}{1000}$$

Oil filling approx. 80 % of tank volume.

Discharge to circulation tank:

DN 300 at driving end or free end. Expansion joint required.

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

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

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

3. Systems

3.7.4 Recommendation for lube oil system

For each engine a separate lube oil system is required.

Lube oil quantities/change intervals:

Recommended/circulating quantity:
approx. 1.3 l/kW output with separate tank

The change intervals depend on:

- the 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 cleaning process.

3. Systems

Recommendation of pipe location in the circulating tank (top view)

Expansion joints

Pipe expansion joints are required to compensate piping movement and vibrations. The bellows are designed according to the pressure of the medium.

Lube oil drain

The common connection for the oil drain pipe is located on the driving end of the engine. In case of inclined engine installation another drain pipe connection is available at the free end of the engine.

4. Connecting parts engine

4.1 Power transmission

4.1.1 Coupling between engine and gearbox

For all types of plants the engines will be equipped with flexible flange couplings.

The **guards** for the flexible couplings should be of perforated plate or gratings to ensure an optimum heat dissipation (**yard supply**).

Mass moments of inertia

	Speed [rpm]	Engine * [kgm²]	Flywheel [kgm²]	Total [kgm²]
6 M 43 C	500	1,870	1,430	3,300
7 M 43 C		2,370		3,800
8 M 43 C		2,770		4,200
9 M 43 C		3,350		4,780

Selection of flexible couplings

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

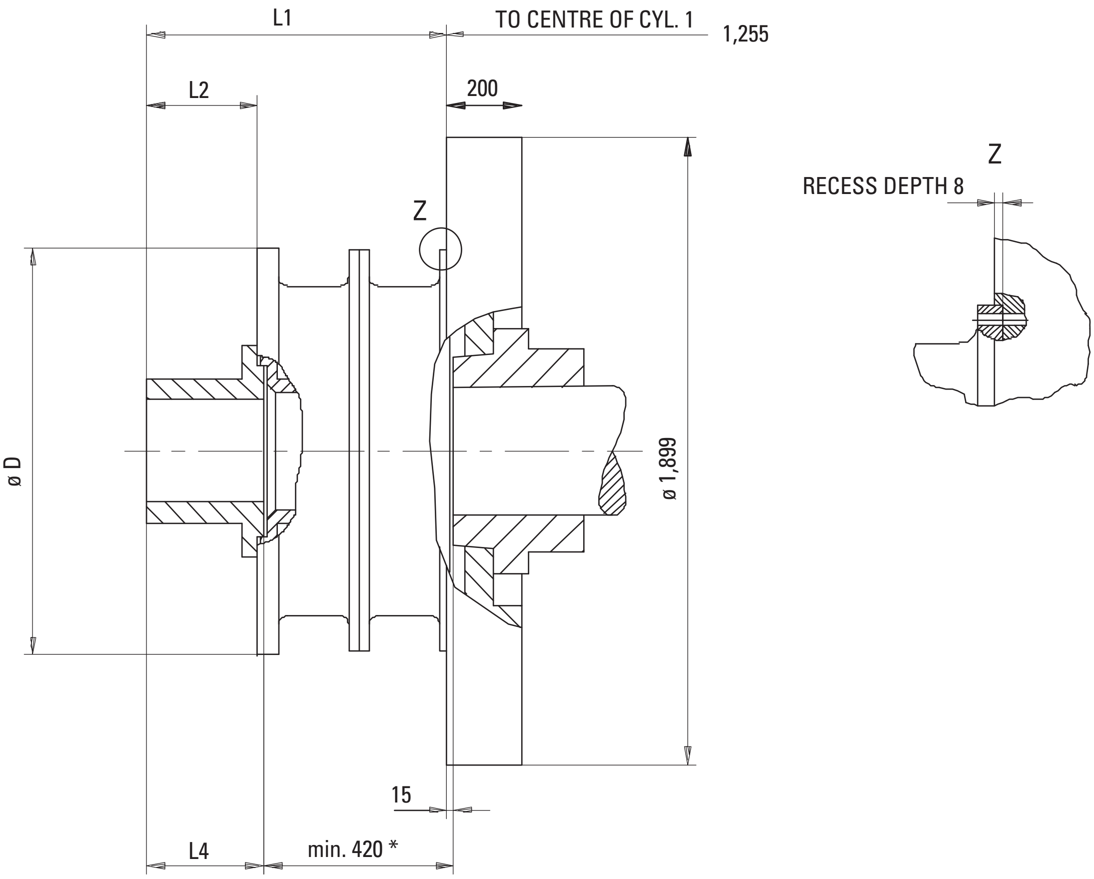
$$T_{KN} \geq \bullet \frac{P_0}{\omega} = \frac{P_0 \bullet 60}{2 \bullet \pi \bullet n_0}$$

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

For installations with a gearbox PTO it is recommended to oversize the PTO coupling by factor 1.5 in order to have sufficient safety margin in the event of misfiring.

4. Connecting parts engine

Flywheel and flexible coupling



* FOR DISMANTLING OF THE FLYWHEEL

	Power	Speed	Nominal torque of coupling	Type Vulkan						Weight	
				Type	D	L1 [1]	L1 [2]	L2	L4 [3]	[1]	[2]
	[kW]	[rpm]	[kNm]	Rato-R	[mm]	[mm]	[mm]	[mm]	[mm]	[kg]	[kg]
6 M 43 C	6,000	500	125	G40KTR	1,250	971	1,021	355	385	1,836	2,204
7 M 43 C	7,000	500	160	G47KWR	1,465	1,136	1,188	442	480	2,869	3,348
8 M 43 C	8,000	500	200	G47KTR	1,465	1,136	1,188	442	480	2,869	3,348
9 M 43 C	9,000	500	200	G47KTR	1,465	1,136	1,188	442	480	2,869	3,348

[1] without torsional limit device
[2] with torsional limit device
[3] length of hub

Space for oil distribution (OD) box to be considered!

4.1.2 Power take-off from the free end

The connection requires a highly flexible coupling. The definite coupling type is subject to confirmation by the torsional vibration calculation.

6 M 43 C	7 M 43 C	8 M 43 C	9 M 43 C
6,000 kW	7,000 kW	3,500 kW	–

4. Connecting parts engine

4.1.3 Data for torsional vibration calculation

Details to be submitted for the torsional vibration calculation

A torsional vibration calculation is made for each installation. For this purpose exact data of all components are required. See table below:

1. Main propulsion

Clutch existing? yes ☐ no ☐
Moments of inertia: Engaged: .... kgm² Disengaged: .... kgm²
Flexible coupling: Make: .... Type: ...... Size: ....
Gearbox: Make: .... Type: ...... Gear ratio: ....
Moments of inertia and dyn. torsional rigidity (Mass elastic system)
Shaft drawings with all dimensions
CPP : D = ... mm Blade No.: ....
Moments of inertia: in air .... kgm²/in water = ...kgm²
Exciting moment in percent of nominal moment = ... %
Operation mode CPP: const. speed ☐ Combinator: ☐
Speed range from: .... -rpm
Normal speed range: CPP = 0.6 Nominal speed

---

2. PTO from gearbox: yes ☐ no ☐

If yes, we need the following information:
Clutch existing? yes ☐ no ☐
Moments of inertia: Engaged: .... kgm² Disengaged: .... kgm²
Flexible coupling: Make: .... Type: ...... Size: ....
Gearbox: Make: .... Type: ...... Gear ratio: ....
Moments of inertia and dyn. torsional rigidity (Mass diagram)
Kind of PTO driven machine: .... Rated output: .... kW
Power characteristics, operation speed range: .... rpm

---

3. PTO from free shaft end: yes ☐ no ☐

If yes, we need the following information:
Clutch existing? yes ☐ no ☐
Moments of inertia: Engaged: .... kgm² Disengaged: .... kgm²
Flexible coupling: Make: .... Type: ...... Size: ....
Gearbox: Make: .... Type: ...... Gear ratio: ....
Moments of inertia and dyn. torsional rigidity (Mass diagram)
Kind of PTO driven machine: .... Rated output: .... kW
Power characteristics, operation speed range: .... rpm

---

4. Explanation

Moments of inertia and dyn. torsional rigidity in absolut dimensions, i.e. not reduced.

4. Connecting parts engine

4.2 Resilient mounting

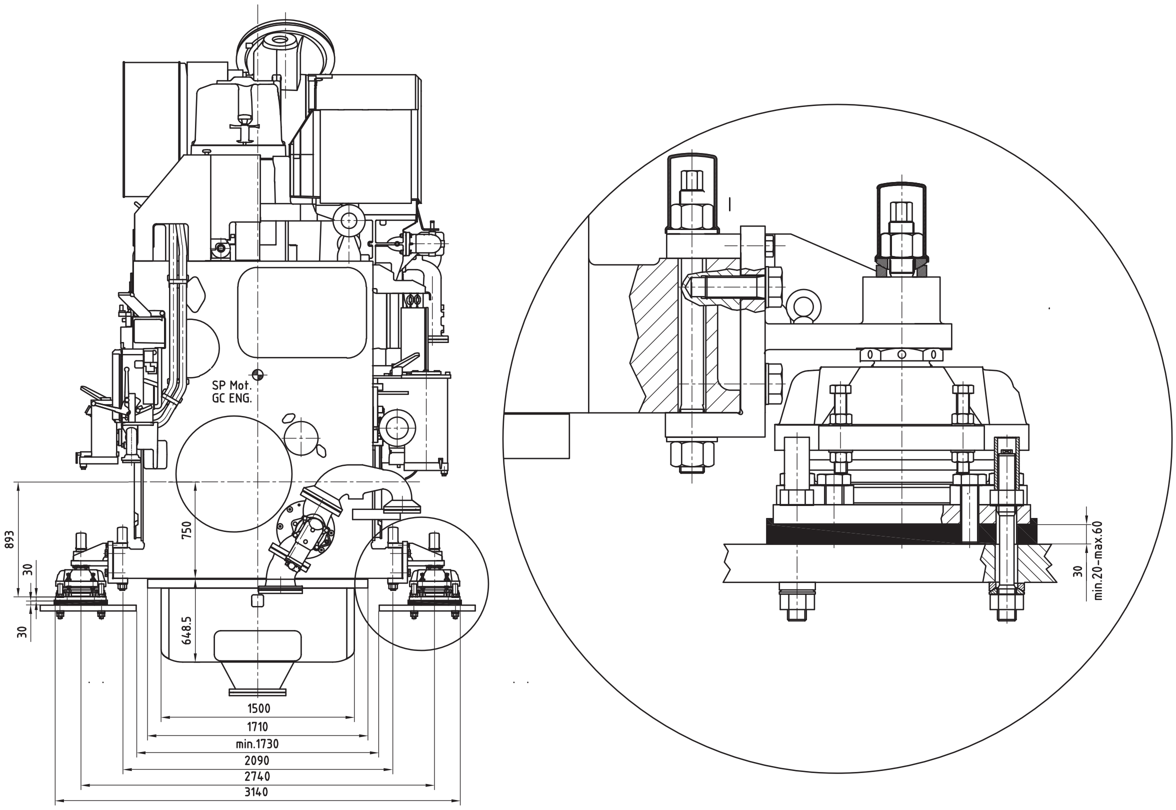
4.2.1 Major components

- Conical rubber elements for insulation of dynamic engine forces and structure-borne noise with integrated stoppers to limit the engine movements.
- Dynamically balanced highly flexible coupling.
- Flexible connections for all media.

Details are shown on binding installation drawings.

No. of elements:

	Conical elements
6 M 43 C	8
7 M 43 C	8
8 M 43 C	10
9 M 43 C	10

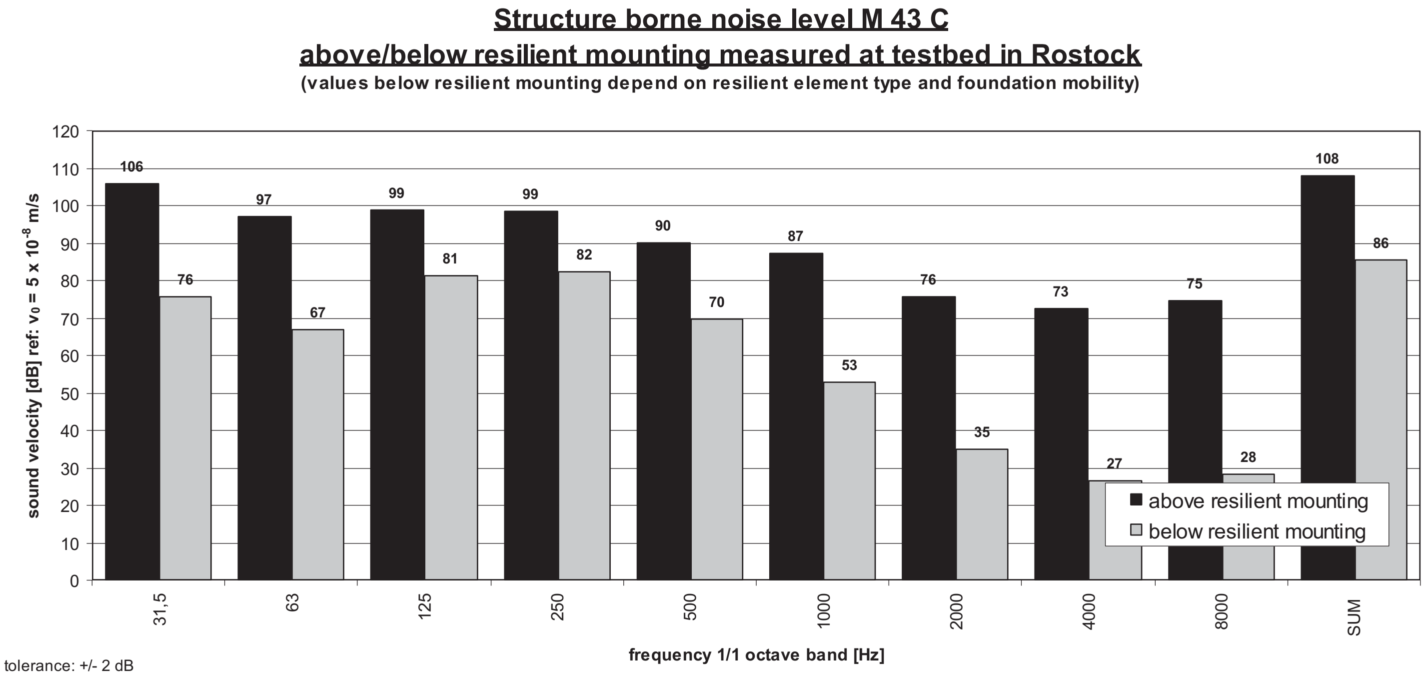


Important note:

- The resilient mounting alone does not provide any garantee for a silent ship operation. Other sources of noise like propeller, gearbox and aux. engines have to be considered as well.
- Radial restoring forces of the flexible coupling (due to seaway) may be of importance for the layout of the reduction gear.

4. Connecting parts engine

4.2.2 Structure-borne noise level L_V, expected (measured in the test cell)



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

Displacement	S_{eff}	< 0.448 mm	f > 2 Hz < 10 Hz
Vibration velocity	V_{eff}	< 28.2 mm/s	f > 10 Hz < 250 Hz
Vibration acceleration	a_{eff}	< 44.2 m/s²	f > 250 Hz < 1000 Hz

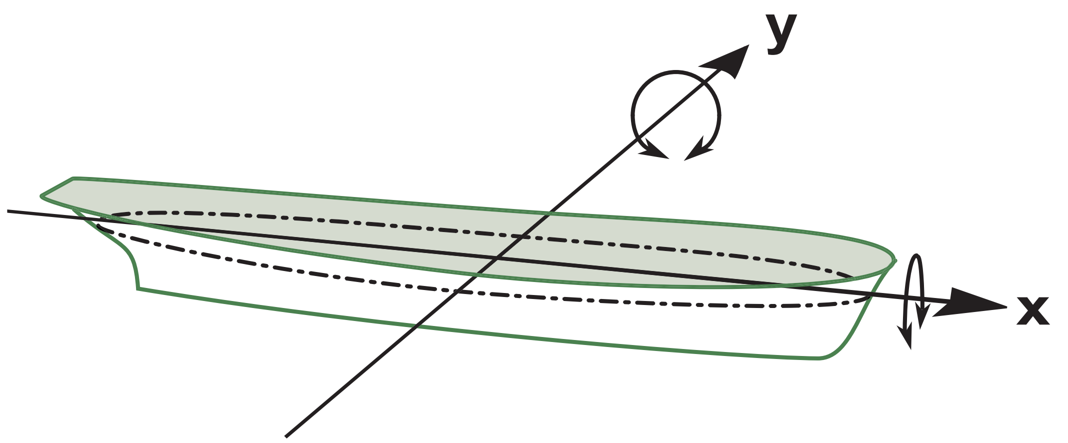
5. Installation and arrangement

5.1 General installation aspect

Max. inclination angles of ships to ensure reliable engine operation:

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

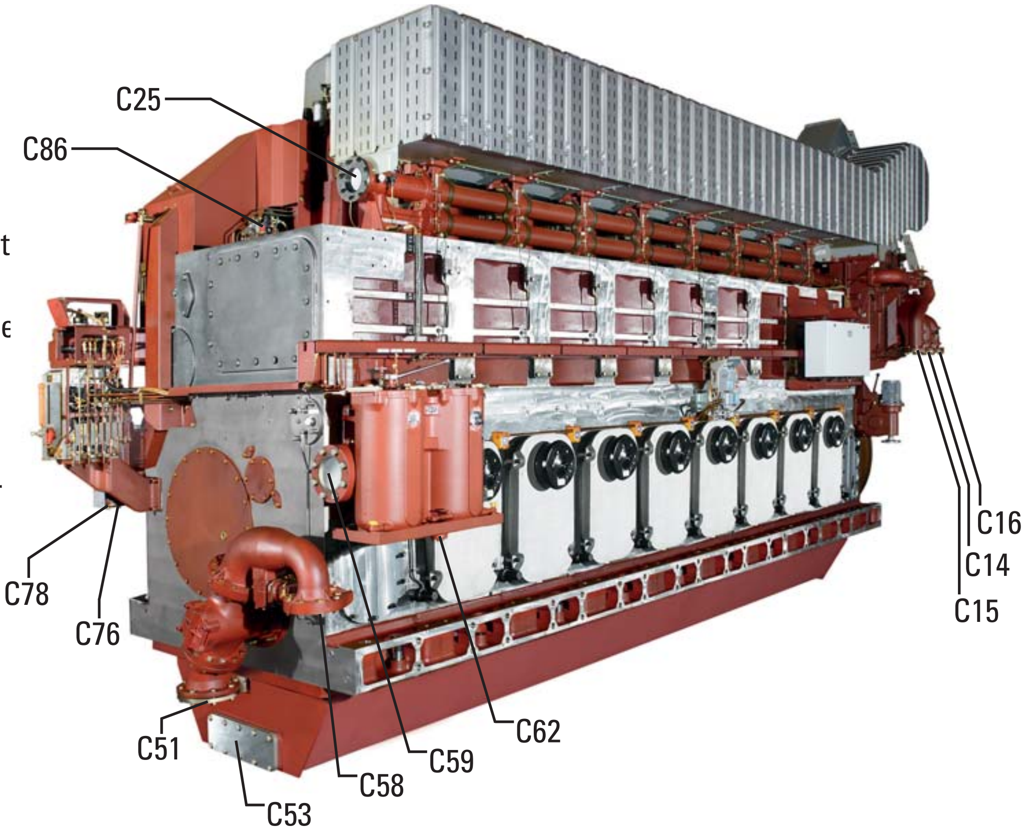
Rotation Y-axis:
Static: trim by head and stern: 5 °
Dynamic: pitching: ± 7.5 °

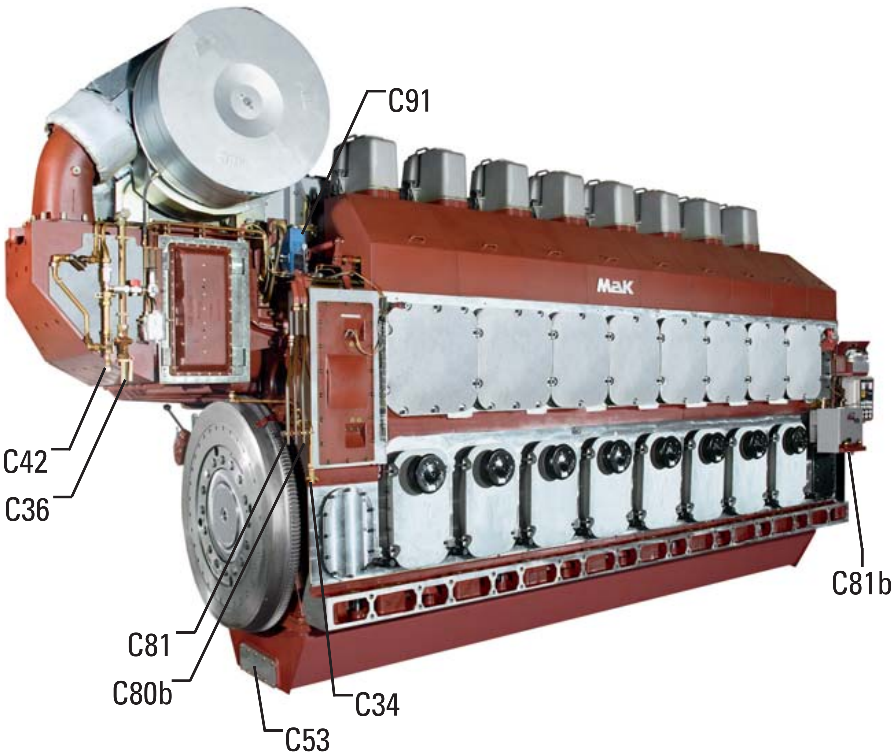


5. Installation and arrangement

5.2 Engine system connections

C14 Charge air cooler LT, inlet
C15 Charge air cooler LT, outlet
C16 Charge air cooler HT, inlet
C25 Cooling water, engine outle
C51 Force pump, suction side
C53 Lube oil discharge
C58 Force pump, delivery side
C59 Lube oil inlet, lube oil filter
C62 Drip oil, pan duplex filter
C76 Inlet, duplex filter
C78 Fuel outlet
C86 Starting air

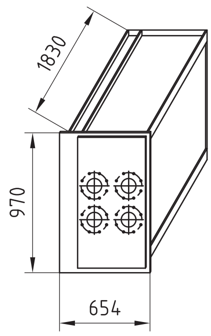


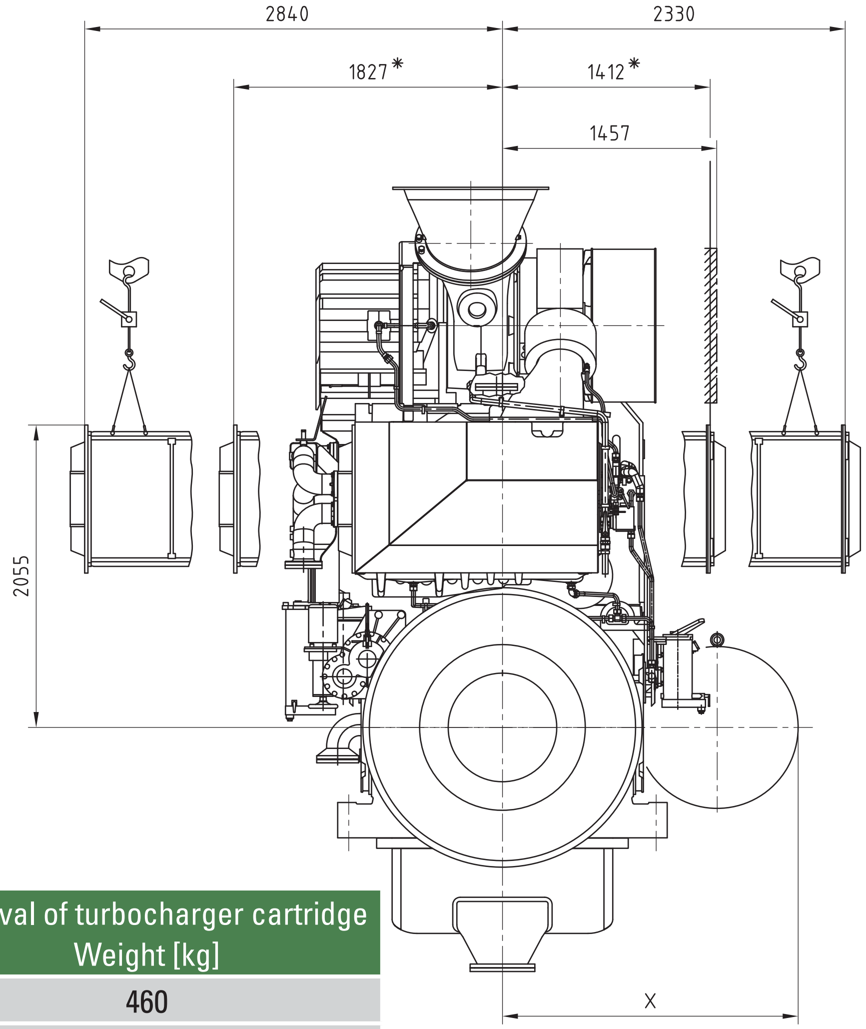


C34 Drain, charge air cooler
C36 Drain, turbocharger washing
C42 Turbine cleaning connection
C80b Drip oil connection injection pump
C81 Drip fuel connection
C81b Drip fuel connection (filter pan)
C91 Crankcase ventilation

5. Installation and arrangement

5.3 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

Engine type		Damper ø	Weight	
	kW	mm	kg	X mm
6 M 43 C	900	1,100	960	2,010
	1,000	1,100	960	2,010
7 M 43 C	900	1,340	1,538	2,250
	1,000	1,340	1,538	2,250
8 M 43 C	900	1,340	1,538	2,250
	1,000	1,480	2,527	2,390
9 M 43 C	900	1,340	1,608	2,250
	1,000	1,480	2,527	2,390

Charge air cooler cleaning

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

Turbocharger removal/maintenance

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

5. Installation and arrangement

5.4 Foundation

5.4.1 External foundation forces and frequencies

The following information is relevant to the foundation design and the aftship structure.

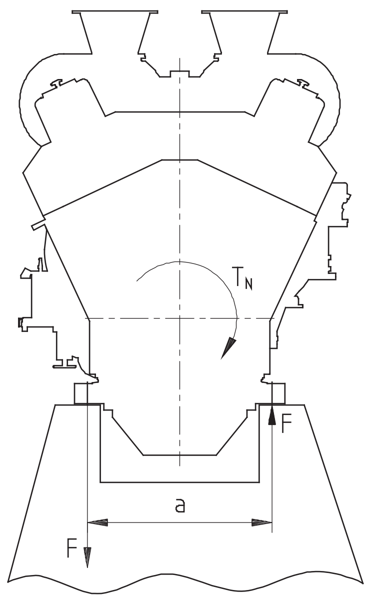
The engine foundation is subjected to both static and dynamic loads.

Static load

The static load results from the engine weight which is distributed over the engine‘s foundation supports and the mean working torque T_N resting on the foundation via the vertical reaction forces. T_N increases the weight on one side and reduces it on the other side by the same amount.

	Output [kW]	Speed [rpm]	T_N [kNm]
6 M 43 C	6,000	500	114.6
7 M 43 C	7,000	500	133.7
8 M 43 C	8,000	500	152.8
9 M 43 C	9,000	500	171.9

Support distance a = 2.090 mm
$F = T_N / a$

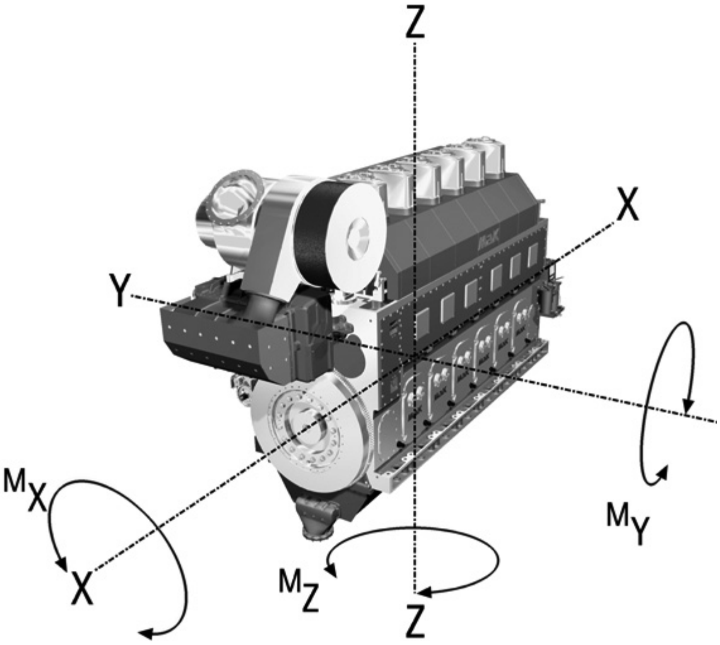


Dynamic load

The dynamic forces and moments are superimposed on the static forces. They result on the one hand from the firing forces causing a pulsating torque and on the other hand from the external mass forces and mass moments.

The tables indicate the dynamic forces and moments as well as the related frequencies.

5. Installation and arrangement



	Output [kW]	Speed [rpm]	Order No.	Frequency [Hz]	M_x [kNm]
6 M 43 C	6,000	500	3.0 6.0	25.0 50.0	97.3 44.1
7 M 43 C	7,000	500	3.5 7.0	29.3 58.3	185.0 28.7
8 M 43 C	8,000	500	4.0 8.0	33.3 66.6	155.0 20.3
9 M 43 C	9,000	500	4.5 9.0	37.5 75.0	143.5 13.1

	Output [kW]	Speed [rpm]	Order No.	Frequency [Hz]	M_y [kNm]	M_z [kNm]
6 M 43 C	6,000	500			–	–
7 M 43 C	7,000	500	2 4	16.6 33.3	59.9 9.5	–
8 M 43 C	8,000	500			–	–
9 M 43 C	9,000	500	1 2	8.3 16.6	30.8 107.6	–

All forces and moments not indicated are irrelevant or do not occur. The effect of these forces and moments on the ship's foundations depends on the type of engine mounting.

5.4.2 Rigid mounting

The vertical reaction forces resulting from the torque variation M_x are the most important disturbances to which the engine foundation is subjected. Regarding dynamic load, the indicated moments M_x only represent the exciting values and can only be compared among each other. The actual forces to which the foundation is subjected depends on the mounting arrangement and the rigidity of the foundation itself.

In order to make sure that there are no local resonant vibrations in the ship's structure, the natural frequencies of important components and partial structures must be at a sufficient distance from the indicated main exitation frequencies.

The dynamic foundation forces can be significantly reduced by means of resilient engine mounting.

General note:

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

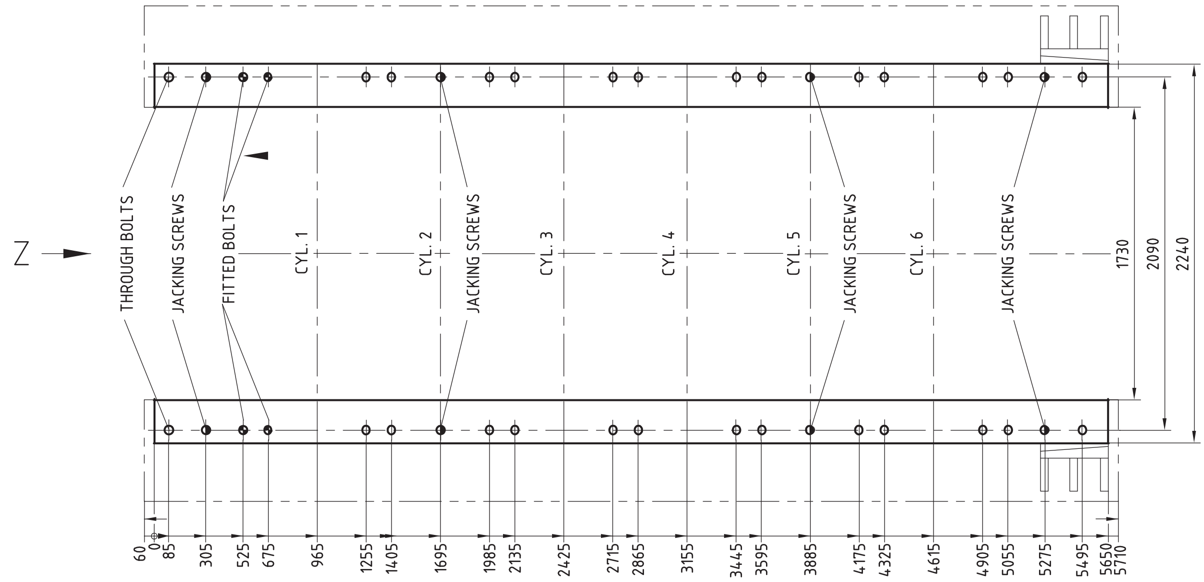
The material can be cast iron or steel.

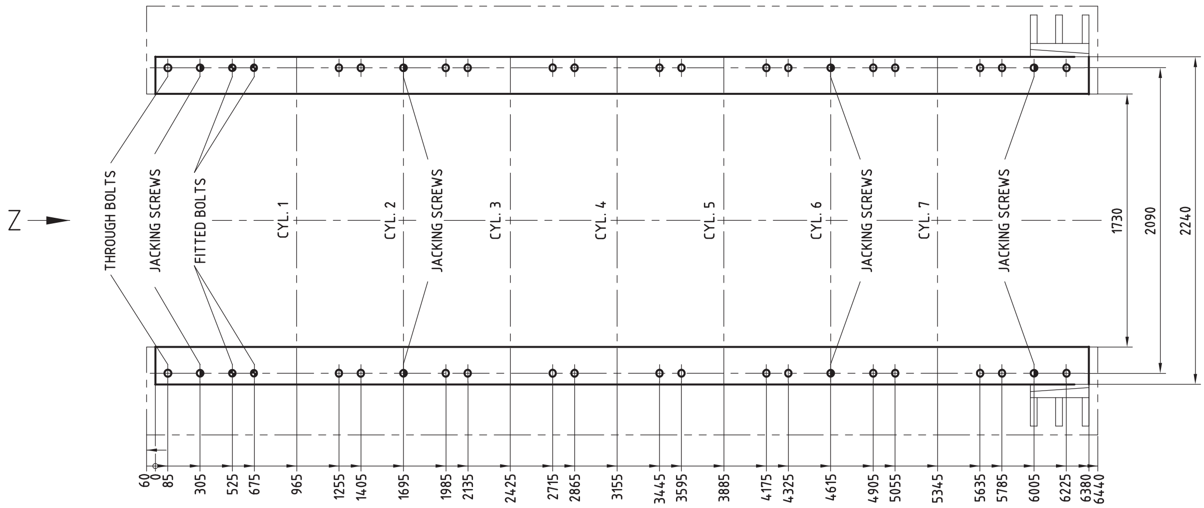
Surface treatment:

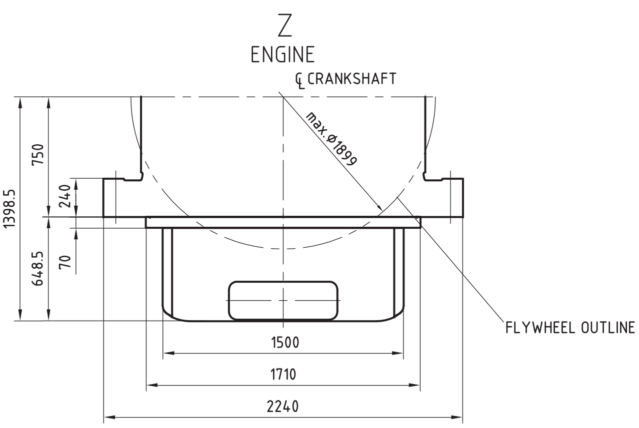
The supporting surface of the top plate has to be milled. When fitting the chocks, a bearing contact of min. 80 % is to be obtained.

5. Installation and arrangement

Rigid mounting







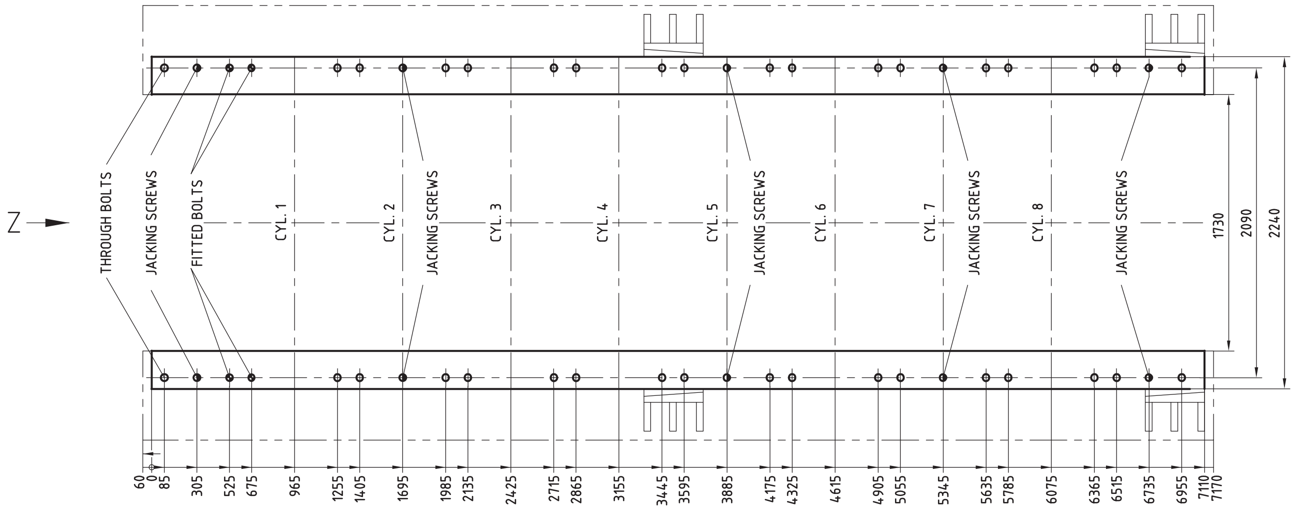
Side stoppers

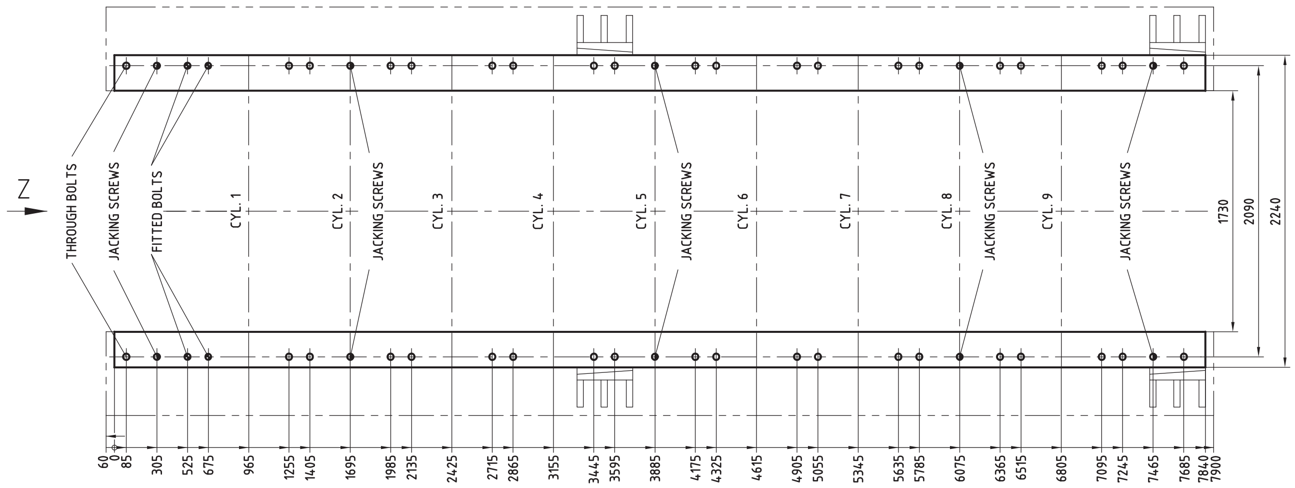
Side stopper to be with 1 wedge (see sketch). Wedge to be placed at operating temperature and secured by welding.
Dimensioning according to classification society and cast resin suppliers requirements.

6/7 M 43 C	8/9 M 43 C
1 pair	2 pairs *

* 1 pair at the end of the cylinder housing and 1 pair between cyl. 4 and cyl. 5.

5. Installation and arrangement





Number of bolts

	Fitted bolts	Foundation bolts
6 M 43 C	4	28
7 M 43 C	4	32
8 M 43 C	4	36
9 M 43 C	4	40

Jacking bolts

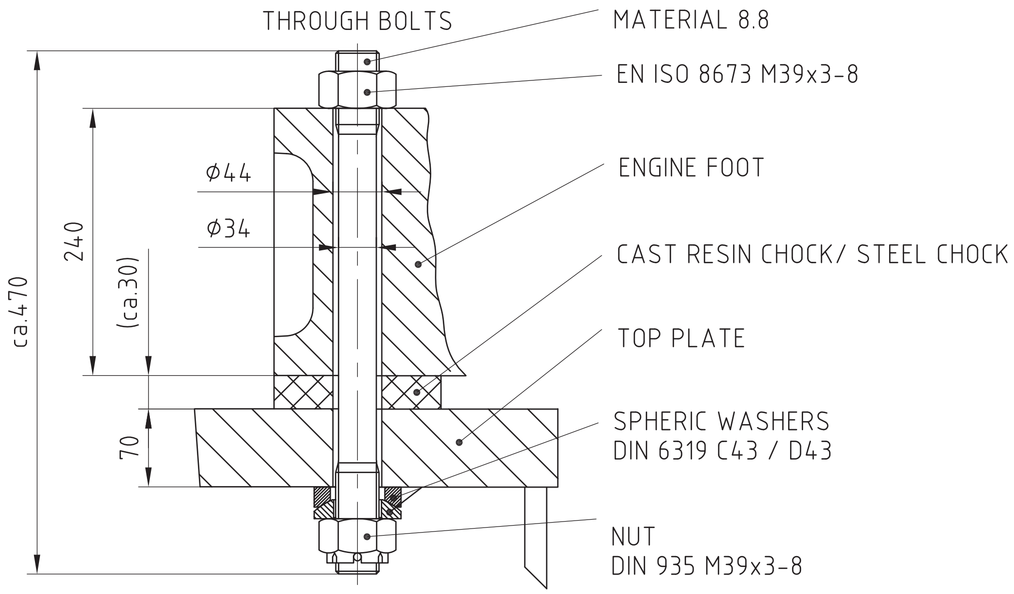
- To be protected against contact/bond with resin
- After setting of resin dismantle the jacking screws completely

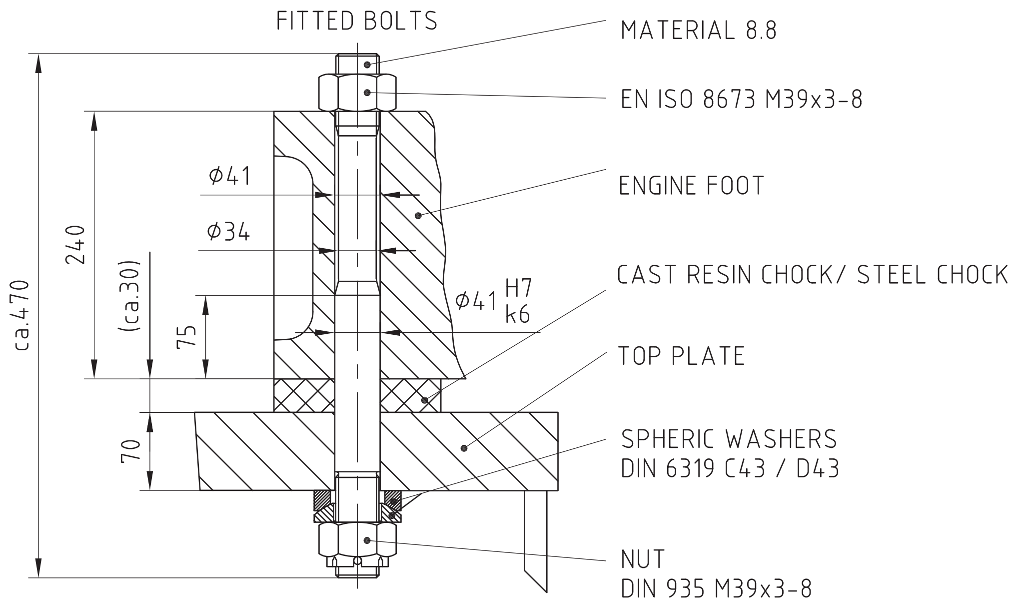
To be supplied by yard:

Foundation bolts, fitted bolts, nuts and tension sleeves, side stoppers, steel chocks, cast resin
The shipyard is solely responsible for adequate design and quality of the foundation.

5. Installation and arrangement

Proposal for rigid mounting





Tightening force M 39		Tightening torque (oil) M 39	
Cast resin / steel		Cast resin / steel	
Through bolts [N]	Fitted bolts [N]	Through bolts M[Nm]	Fitted bolts M [Nm]
max. 340,000	max. 340,000	max. 2,050	max. 2,050

5. Installation and arrangement

5.5 Installation of flexible pipe connections

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

The shipyard's pipe system must be accurately arranged so that 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 usual. The pipes outside the flexible connection must be well fixed and clamped to prevent 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 one individual exhaust gas pipe (a common pipe for several engines is **not permissible).**

During commissioning and maintenance work, checking of the exhaust gas back 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 accessible place.

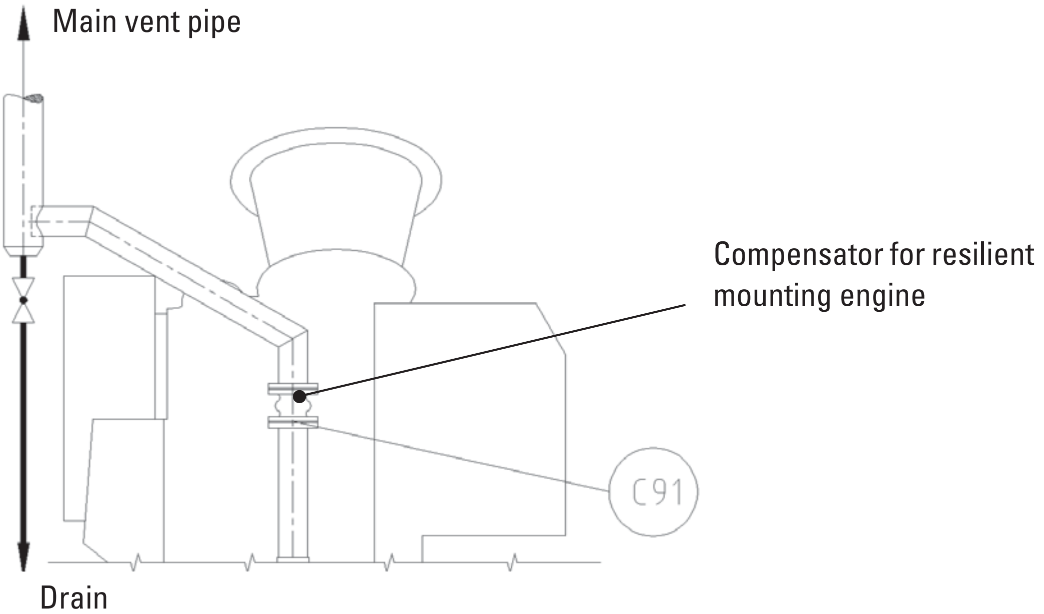
If it should be impossible to use standard transition piece supplied by Caterpillar, the weight of the transition piece manufactured by the shipyard must not exceed the weight of the standard transition piece. A drawing including the weight will then have to be submitted for approval.

5. Installation and arrangement

5.7 Installation of crankcase ventilation on the engine

For the piping of crankcase ventilations please consider the following design criteria:

- 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

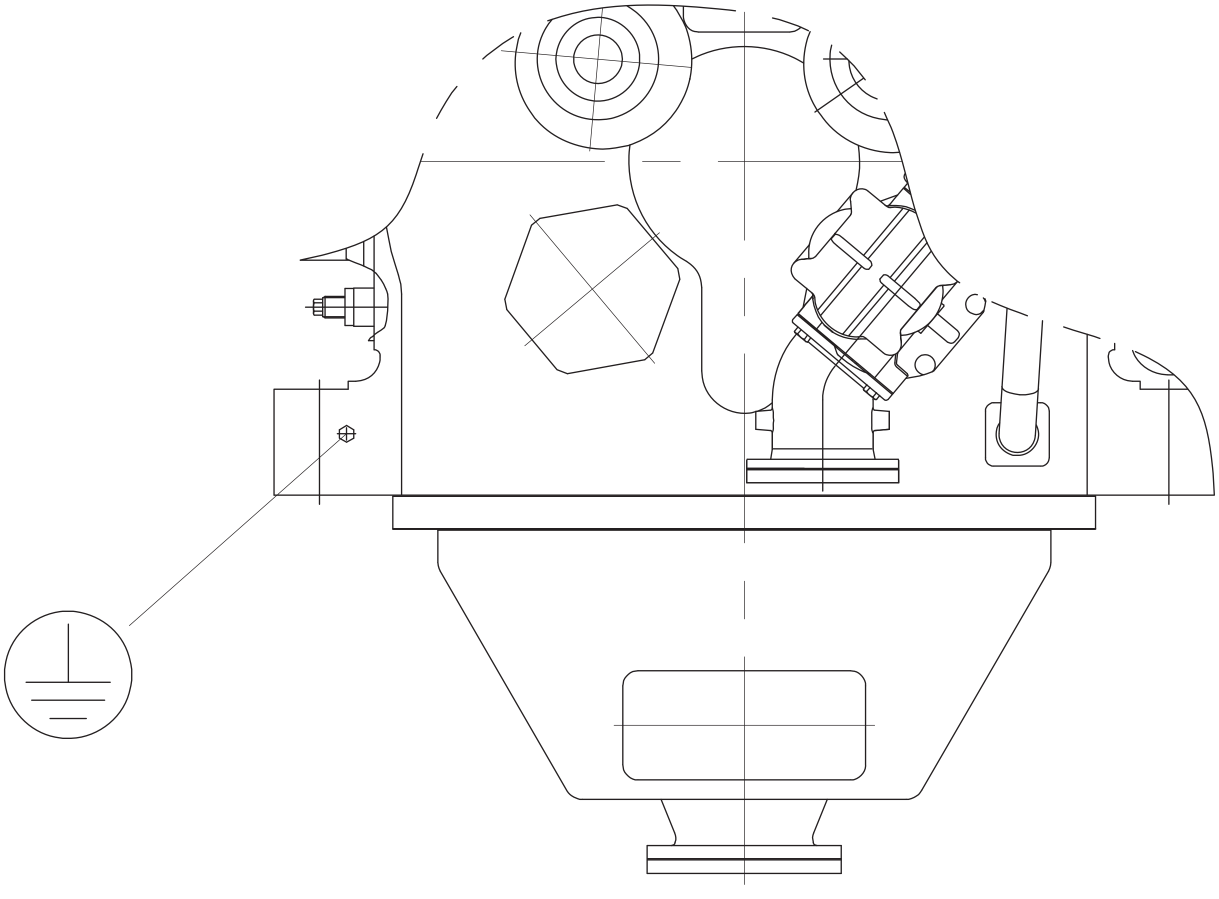
5.8 Earthing of the engine

Information about the execution of the earthing

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

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

Earthing connection on the engine

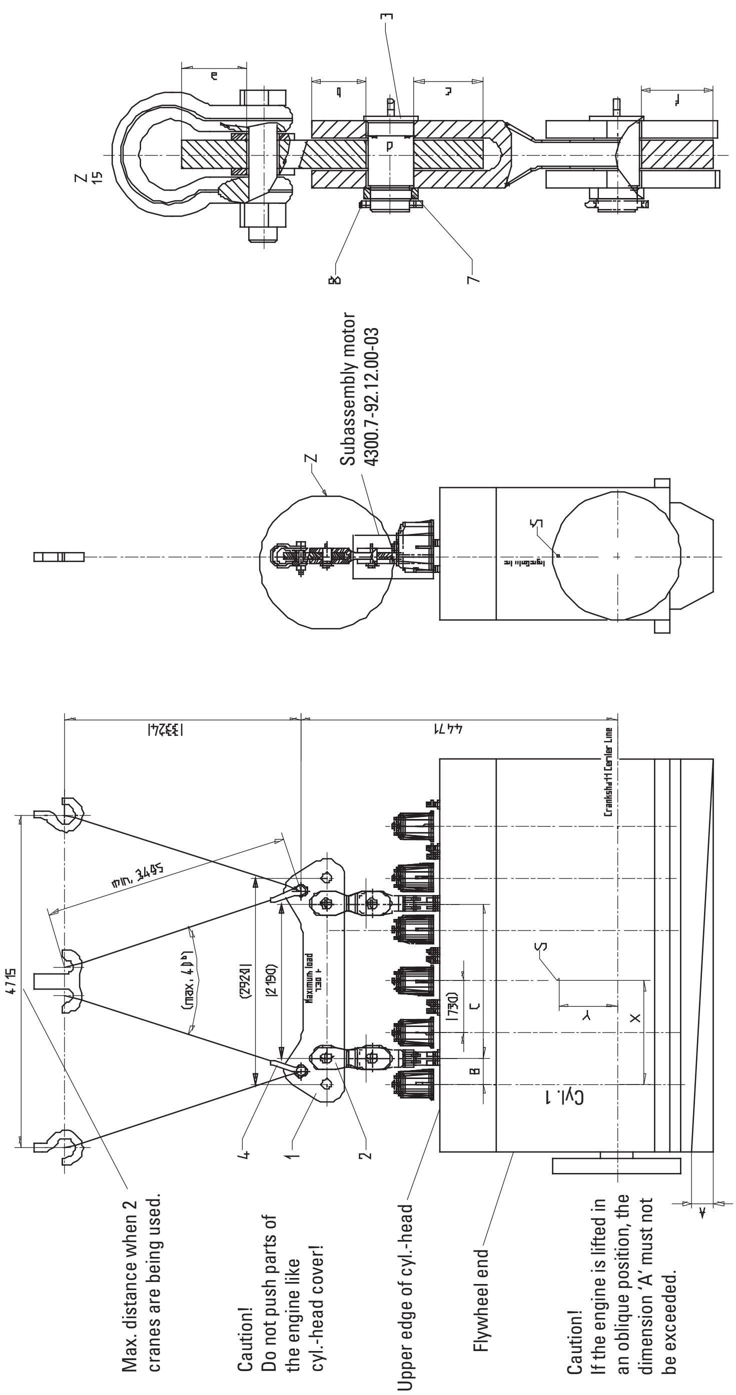


MaK

5. Installation and arrangement

5.9 Lifting of the engine

For the purpose of transport the engine 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.



engine M 43 C No. of cyl.	Turbocharger flywheel end	Turbocharger opposite flywheel end	Weight [t]	Center of gravity* S X [mm]	Center of gravity* S Y [mm]	Mass dimension A [mm]	Mass dimension B [mm]	Mass dimension C [mm]
6	x		91	1,469	828	140	365	2,190
6		x	91	1,864	828	140	365	2,920
7	x		104	1,834	837	160	365	2,920
7		x	104	2,236	837	160	1,095	2,190
8	x		117	2,134	876	180	1,095	2,190
8		x	117	2,669	876	180	1,095	2,920
9	x		130	2,492	893	195	1,095	2,920
9		x	130	3,034	883	195	1,825	2,190

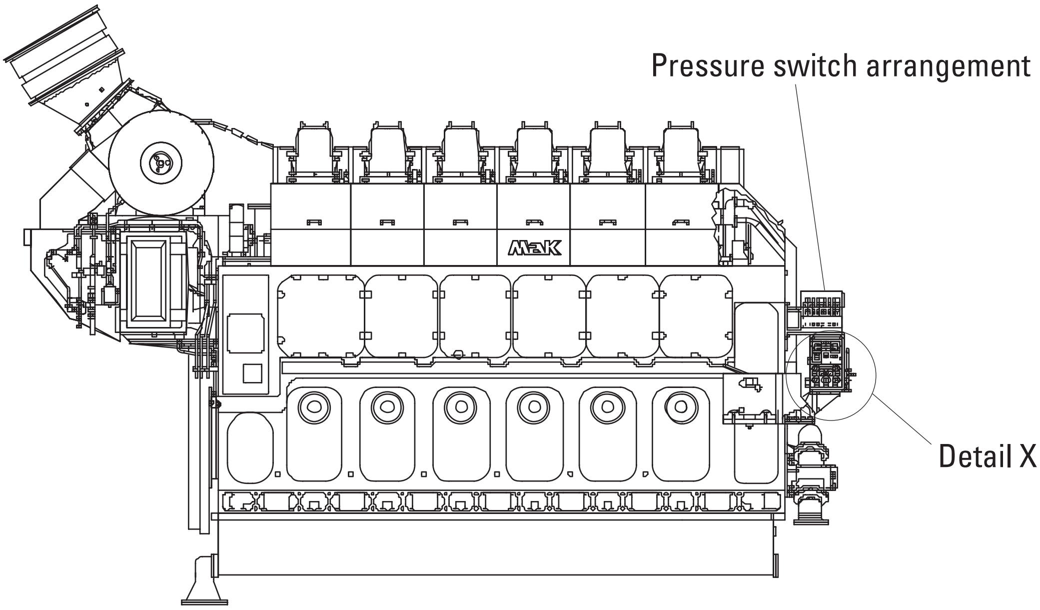
Wear limit [mm] a	b	c	d	f
180	202	187	126	202

Attention!
Device to be used for transport of engine types 6/7/8/9 M 43 C only.
Max. lifting speed: 5m/min.

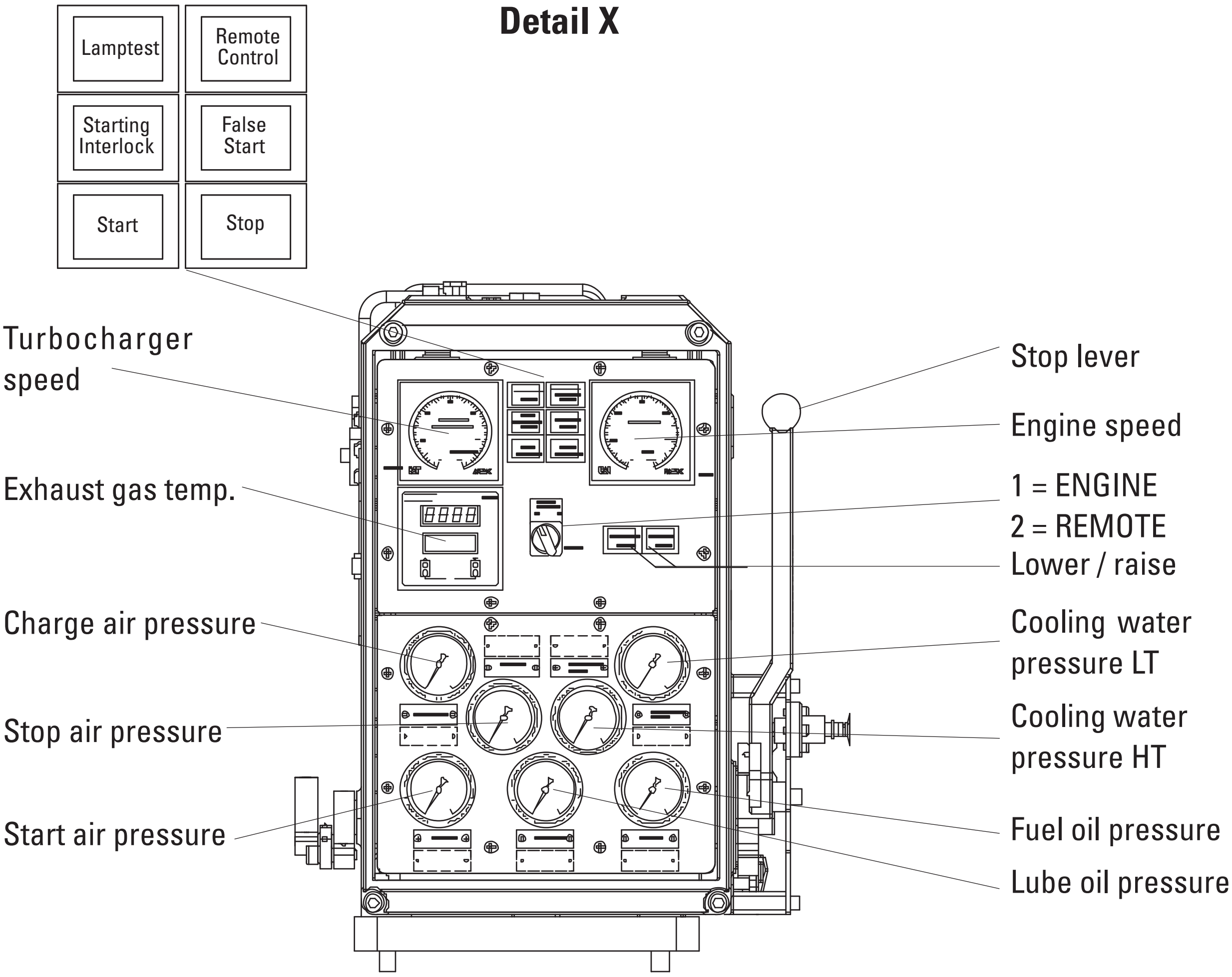
Belonging to this are test sheets of test book for load carrying facilities (cross bars).

6. Control and monitoring system

6.1 Engine control panel

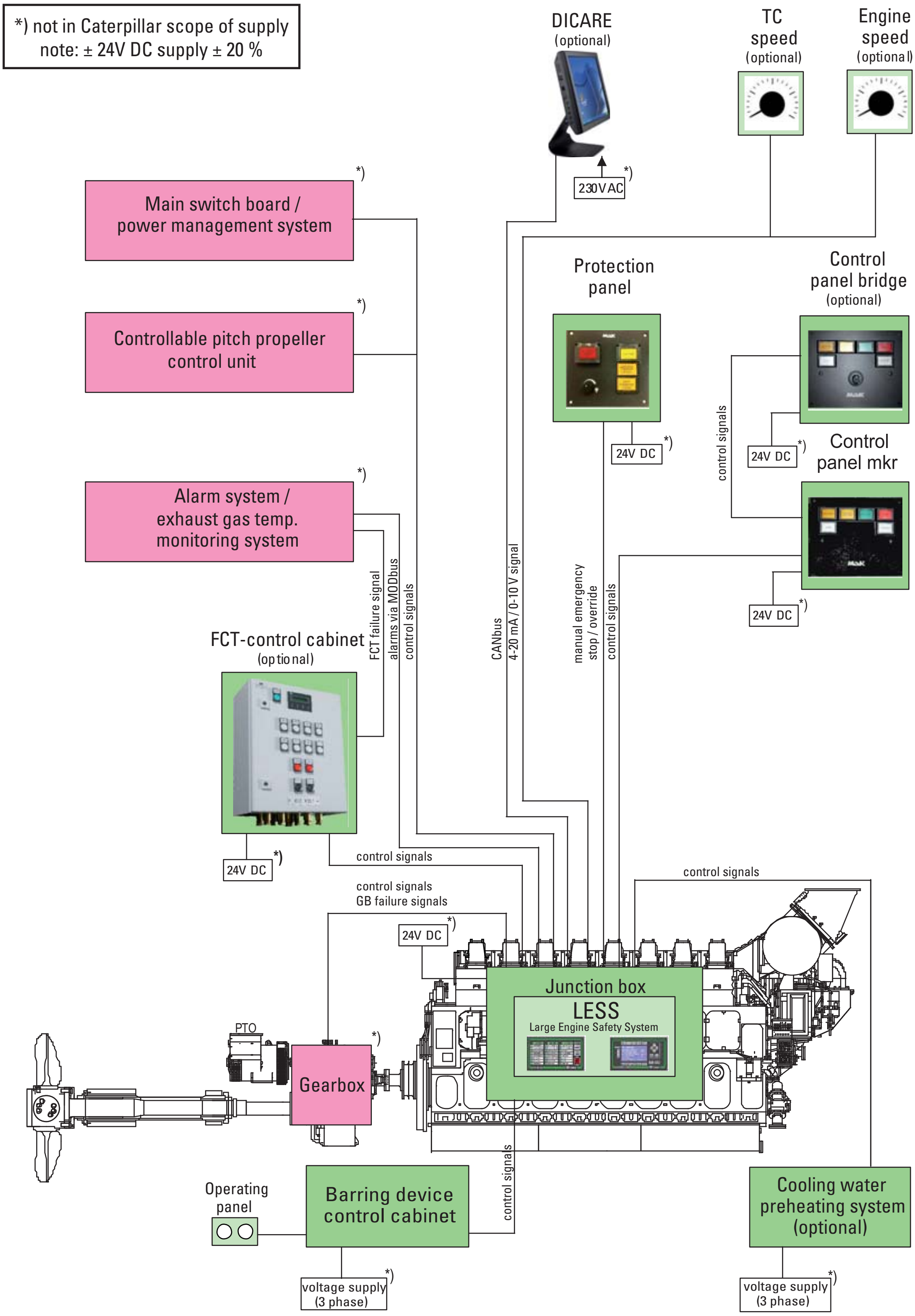


Detail X



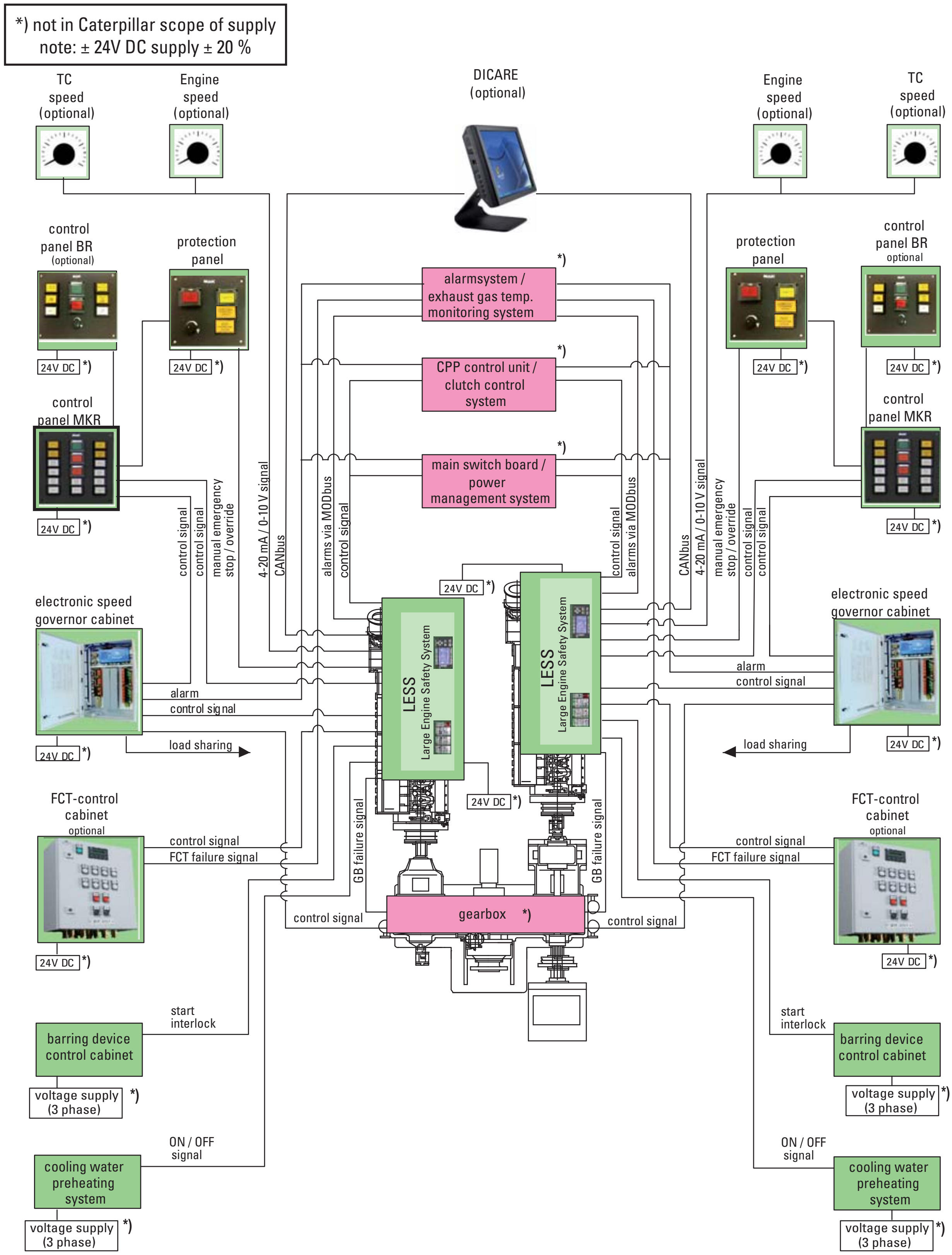
6. Control and monitoring system

6.1.1 Remote control for single-engine plant with one controllable pitch propeller



6. Control and monitoring system

6.1.2 Remote control for twin-engine plant with one controllable pitch propeller



6. Control and monitoring system

6.1.3 LESS: Large Engine Safety System

Engine control boxes include

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

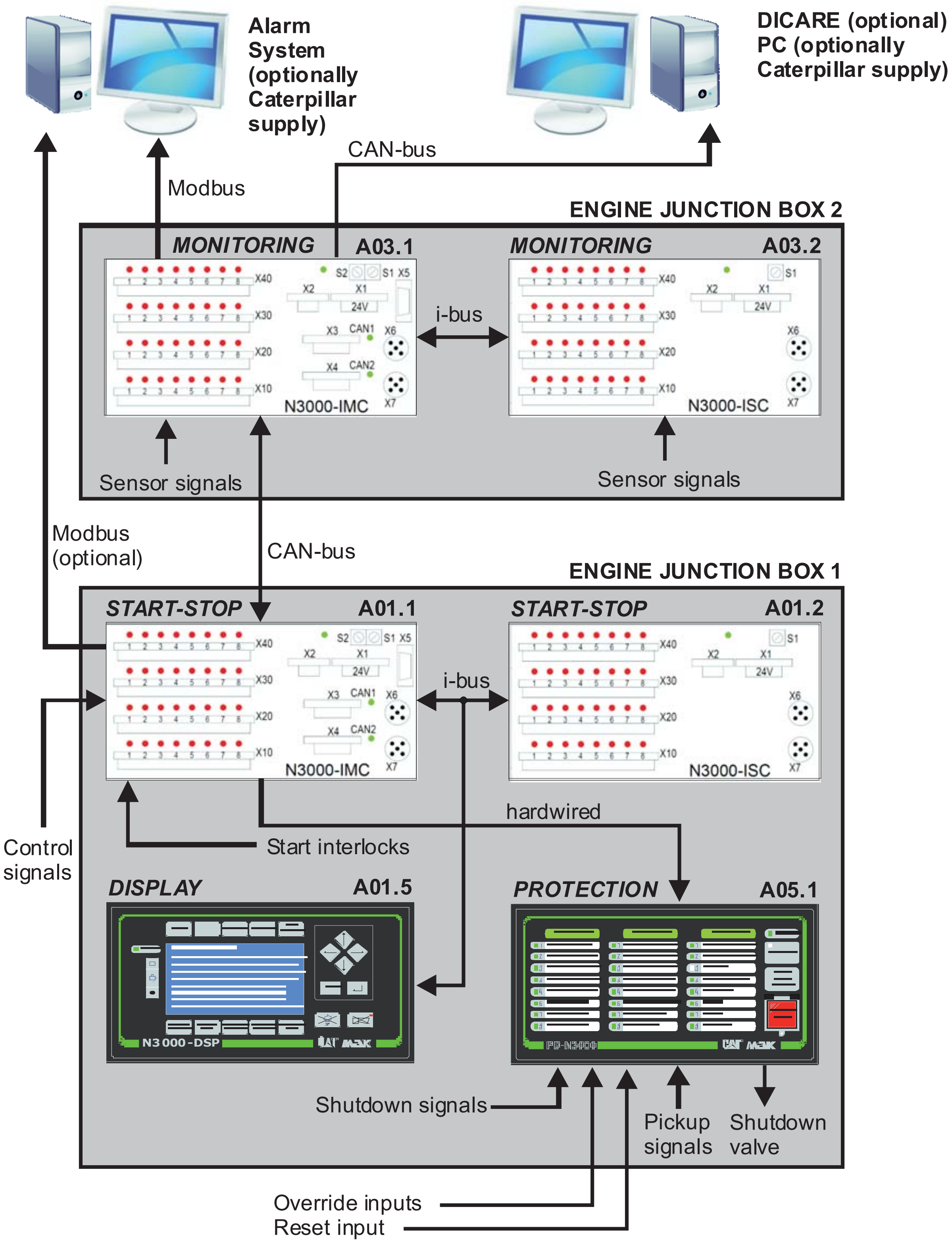
System data

Inputs:
4 fixed automatic shut down + overspeed inputs
4 manual emergency stop inputs
16 configurable inputs for shutdown, load reduce request or starting 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)

Contents

6. Control and monitoring system



6. Control and monitoring system

6.2 Speed control

Main engines are equipped with a mech. / hydr. speed governor (milliampere speed setting) including the following equipment:

- Stepper motor in the top part of the governor for remote speed control
- Separate stepper motor control with adjustable speed range and speed ramp.
  Voltage supply = 24 V DC

The control is fitted easily accessible on the engine in the terminal board box (X1) especially provided for control components.

The set speed value of nmin = 4 mA; nmax = 20 mA is converted into a current required by the stepper motor.

- Speed setting knob (emergency speed setting).
- Shut-down solenoid (24 V DC/100 % duty cycle) for remote stop (not for automatic engine stop).
- Steplessly adjustable droop on the governor from 0 - 10 %.
- Standard setting: 0 %.
- Device for optimization of the governor characteristic.
- Serrated drive shaft (for easy service).
- Start fuel limiter.

Optional:
Electronic governor and actuator with mech. back-up

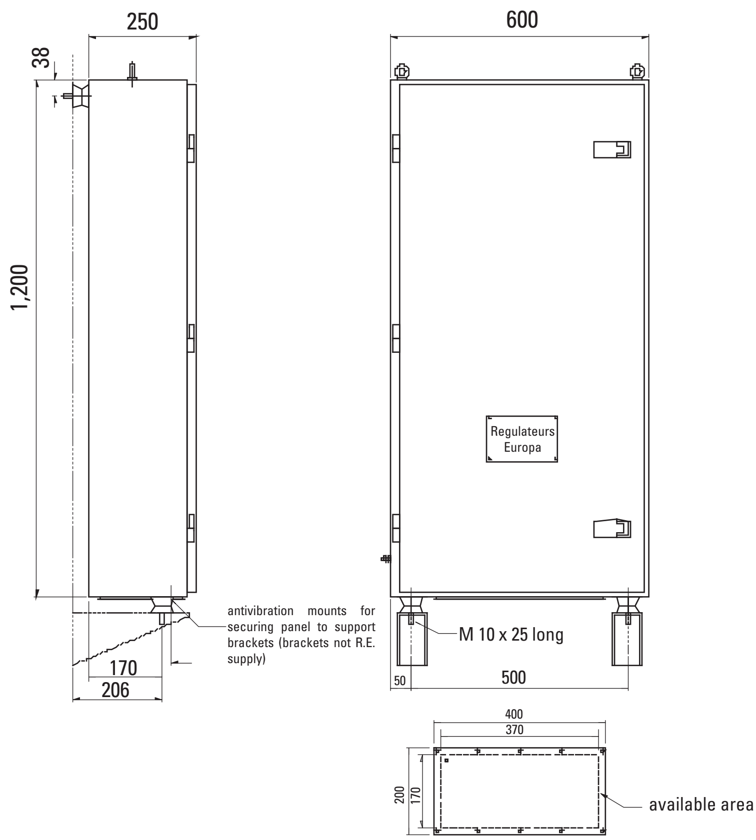
6. Control and monitoring system

6.2 Speed control

Twin engine plant with one controllable pitch propeller: The engines are equipped with an actuator (optional with mech. back-up) and the electronic governors are installed in a separate control cabinet.

The governor comprises the following functions:
- Speed setting range to be entered via parameters
- Adjustable acceleration and deceleration times
- Starting fuel limiter
- Input for stop (not emergency stop)
- 18 - 32 V DC voltage supply
- Alarm output
- Droop operation (primary shaft generator)
- Isochronous load distribution by master/slave principle for twin engine propulsion plants via double-reduction gear

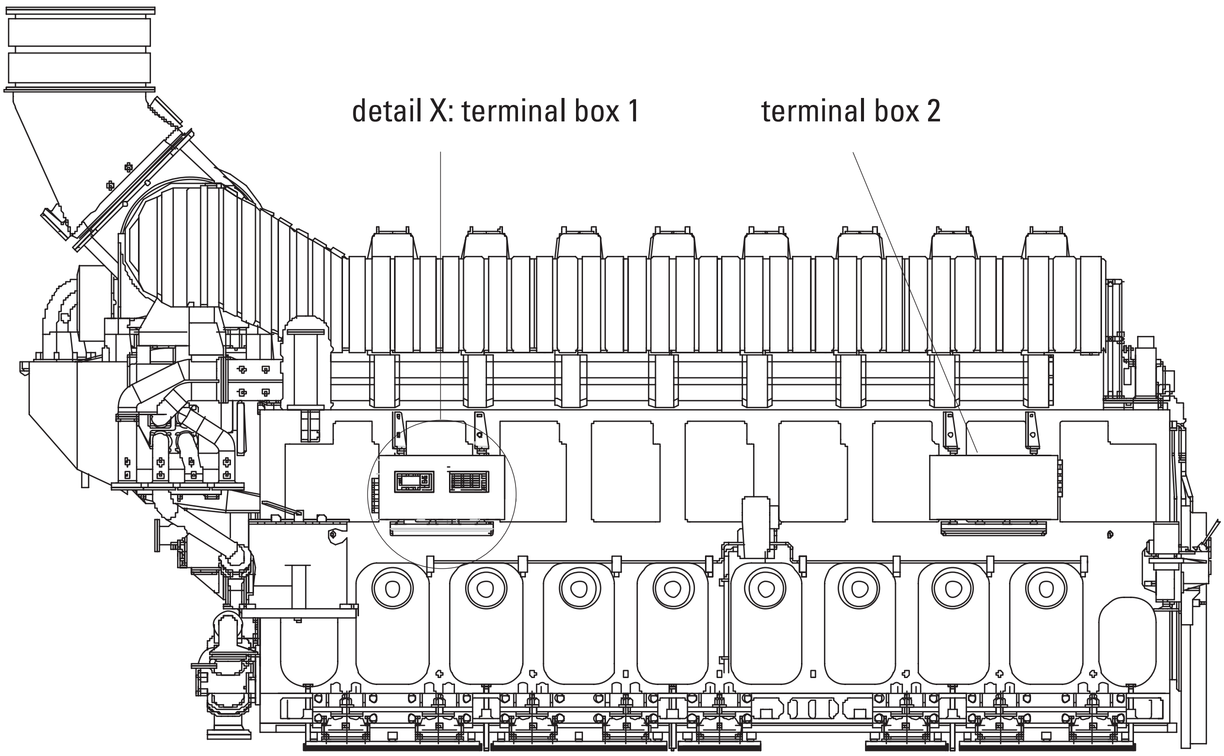
Standard: Regulateurs Europa "Propulsion Panel" with Viking 35 electronic governor (one per engine).



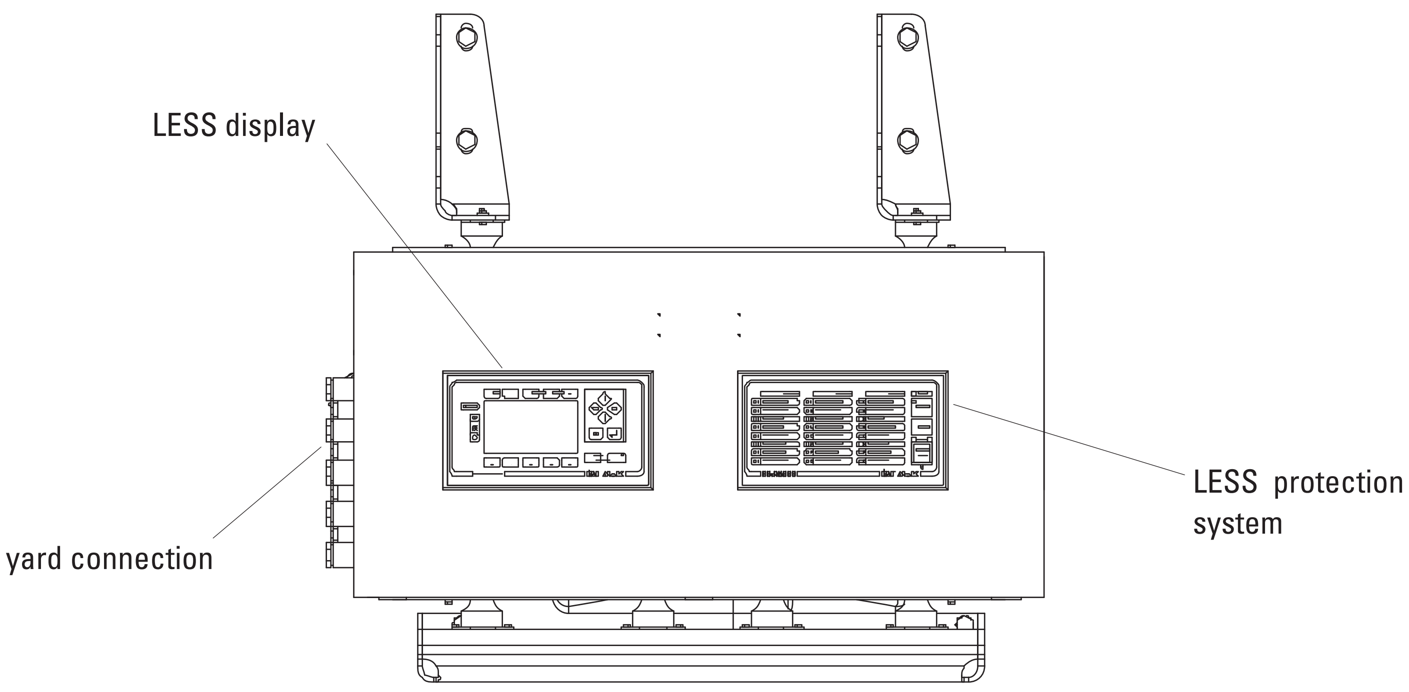
Option: Woodward control twin engine cabinet with Woodward 723+ electronic governor

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	Lube oil pressure low – pre-alarm shutdown	4-20 mA	
1106	Pressure transmitter Lube oil pressure low – pre-alarm shutdown	binary	
1111	Differential pressure lube oil filter high – alarm	binary	Not fitted on engine
1111.1	Differential pressure lube oil filter high – indication	4-20 mA	Depending on glass
1112	Lube oil differential pressure automatic filter – alarm	binary	Not fitted on engine
1112.1	Lube oil differential pressure automatic filter – alarm	4-20 mA	Depending on glass
1202	Resistance thermometer Lube oil temperature at engine inlet high – alarm	PT 100	
1203	NTC/switch unit Lube oil temperature at engine inlet high – load reduction	binary	
1251 **1251.1** **1251.2** **1253** **9631**	**1251** Oil mist concentration in crankcase high – alarm **1251.1** Oil mist concentration in crankcase high – pre-alarm **1251.2** Opacity **1253** Oil mist concentration in crankcase high – shut down **9631** Oil mist detector failure – alarm	**1251:** binary **1251.2:** 4-20 mA **1253:** binary **9631:** binary	1 evaluation unit for **1251, 1253, 9631** **1251.1** (70% from **1251**)
2101	Pressure switch Cooling water pressure HT at engine inlet low – start stand-by pump	binary	20 kPa below operating pressure
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: 20 s
2111	Pressure switch Cooling water pressure LT at engine inlet low – start stand-by pump	binary	20 kPa below operating pressure
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. HT at engine outlet high – alarm	PT 100	

6. Control and monitoring system

Meas. Point	Description	Sensor range	Remarks
2212	NTC / switch unit Cooling water temp. HT at engine outlet high – load reduction	binary	
2229	Resistance thermometer Cooling water temp. LT at engine inlet high – alarm	PT 100	
2321	Oil ingress in fresh water cooler outlet	binary	Option, external sensor
5101	Pressure switch Fuel oil pressure at engine inlet low – start stand-by pump	binary	
5102	Pressure transmitter Fuel oil pressure at engine inlet low – alarm	4-20 mA	
5105	Fuel oil pressure – start stand-by pump by pump control		Option, external sensor
5111	Differential pressure indicator Differential pressure fuel oil filter high – alarm	binary	
5112	Fuel oil differential pressure automatic filter		Option, external sensor
5115	Fuel oil differential pressure – start stand-by pump by pump control		Option, external sensor
5116	Fuel oil differential pressure at circulating pump		Option, external sensor
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 viscosimat – DICARE	PT 100	Not fitted on engine
5251	Fuel oil viscosity at engine inlet (common alarm **5252**)		Option, external sensor
5252	Fuel oil viscosity at engine inlet (common alarm **5251**)		Option, external sensor
5253	Fuel oil viscosity at viscosimat – DICARE	4-20 mA	Not fitted on engine
5301	Level probe / switch unit Leakage oil level at engine high – alarm	binary	
5333	Fuel oil level mixing tank		Option, external sensor
6101	Pressure transmitter Starting air at engine inlet low – alarm	4-20 mA	
6105	Pressure switch Stopping air pressure at engine low – alarm	binary	
6181	Intake air pressure in engine room – DICARE	4-20 mA	
7109	Pressure transmitter Charge air pressure at engine inlet – DICARE, indication	4-20 mA	
7201	Resistance thermometer Charge air temp. at engine inlet high – alarm	PT 100	
7206	Intake air temp. at turbocharger inlet – DICARE	PT 100	
7301	Level probe / switch unit Condense water in charge air canal	binary	
7307	Charge air diff. pressure at charge air cooler – DICARE	4-20 mA	

6. Control and monitoring system

Meas. Point	Description	Sensor range	Remarks
7309	Thermocouple type K Charge air temp. at charge air cooler inlet – indication, DICARE	NiCr-Ni (mV)	
8211.1	Thermocouple type K Exhaust gas temp. after cylinder 1 – load reduction	NiCr-Ni (mV)	
8211.2	Thermocouple type K Exhaust gas temp. after cylinder 2 – load reduction	NiCr-Ni (mV)	
8211.3	Thermocouple type K Exhaust gas temp. after cylinder 3 – load reduction	NiCr-Ni (mV)	
8211.4	Thermocouple type K Exhaust gas temp. after cylinder 4 – load reduction	NiCr-Ni (mV)	
8211.5	Thermocouple type K Exhaust gas temp. after cylinder 5 – load reduction	NiCr-Ni (mV)	
8211.6	Thermocouple type K Exhaust gas temp. after cylinder 6 – load reduction	NiCr-Ni (mV)	
8211.7	Thermocouple type K Exhaust gas temp. after cylinder 7 – load reduction	NiCr-Ni (mV)	
8211.8	Thermocouple type K Exhaust gas temp. after cylinder 8 – load reduction	NiCr-Ni (mV)	
8211.9	Thermocouple type K Exhaust gas temp. after cylinder 9 – load reduction	NiCr-Ni (mV)	
8216	Deviation of mean average value reduct. alarm cyl.		Included in meas. point **8234** load reduction from alarm system to LESS
8218	Exhaust gas temp. reduct alarm of each cyl. absolut		Included in meas. point **8234** load reduction from alarm system to LESS
8221	Thermocouple type K Exhaust gas temp. at turbocharger outlet – load reduction	NiCr-Ni (mV)	
8224	Exhaust gas temp. reduction alarm of turbocharger outlet		Included in meas. point **8234** load reduction from alarm system to LESS
8231	Thermocouple type K Exhaust gas temp. at turbocharger outlet – load reduction	NiCr-Ni (mV)	
8234	Common alarm exhaust gas temp. monitoring load reduction included **8216, 8218, 8224**		Common alarm from alarm system to LESS
9401	Engine speed	binary	Suppression of alarms
9402	Engine speed	binary	Start stand-by pump
9404	Automatic stop alarm	binary	
9406	Switch off lube oil stand-by pump	binary	
9407	Engine speed	binary	n adjustable

6. Control and monitoring system

Meas. Point	Description	Sensor range	Remarks
9419	Engine speed signal From RPM switching equipment – indication, DICARE	4-20 mA	
9419.1	Pick up RPM switching equipment	0-15 KHz	
9419.2	Pick up RPM switching equipment	0-15 KHz	
9429	Pick up / transmitter Turbine speed high – alarm Turbine speed – indication, DICARE	4-20 mA 0-10 V	
9503	Limit switch – control lever at fuel rack – stop position	binary	
9509	Distance sensor / switching device Fuel setting	4-20 mA	
9531	Engine overload at rated speed	binary	
9532	Engine load signal	4-20 mA	
9561	Limit switch Turbing gear engaged – starting interlock	binary	
9602	Relay contact CANbbus failure – alarm	binary	
9614	Failure mechanical governor	binary	
9615	Failure electrical governor – minor alarm	binary	
9616	Failure machannical governor – major alarm	binary	
9671.1	Automatic stop failure – alarm	binary	
9671.2	Overspeed failure – alarm	binary	
9671.3	Emergency failure – alarm	binary	
9674	Overspeed – alarm	binary	
9675	Emergency stop – alarm	binary	
9676	Common alarm load reduction	binary	
9677.1	Override oil mist detector activated	binary	
9677.2	Override load reduction activated	binary	
9717	Relay contact Voltage failure at terminal X3 – alarm	binary	
9751	Voltage failure at charge air temp. controller	binary	
9771	Fresh water preheater voltage failure	binary	
9836.1	Relay contact Sensor / isolation fault A01 – alarm	binary	
9836.2	Relay contact Sensor / isolation fault A02 – alarm	binary	
9962.1	Relay contact Common alarm A01 – alarm	binary	
9962.2	Relay contact Common alarm A02 – alarm	binary	

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 ar 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)	

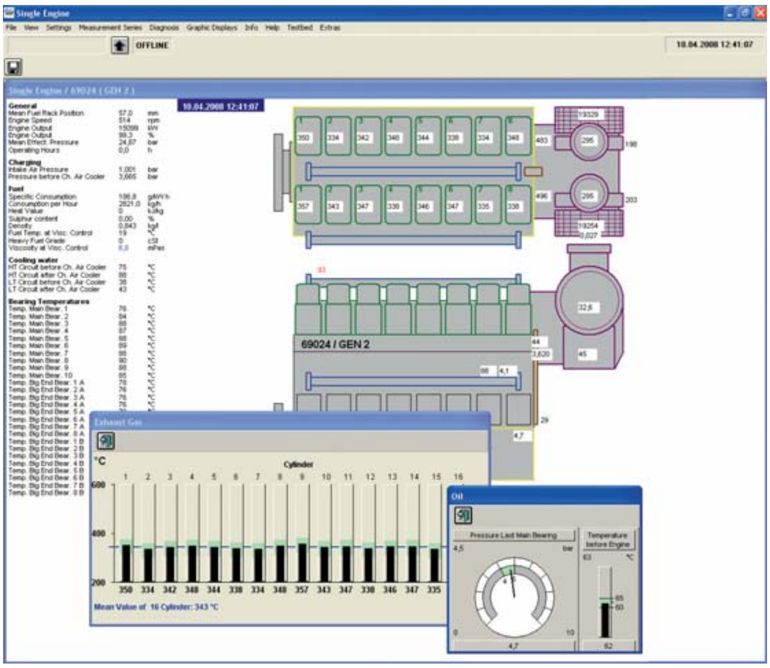
[1] 144 x 144 mm possible
[2] Signal is supplied by the alarm system

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 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 tests 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. 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 determermined 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:
- Castings 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 denpending 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 PVC scotch tape.
  In case of engines delivered without oil pan the overhanging VCI film between engine and transport frame is to be folded back upwards 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 representation

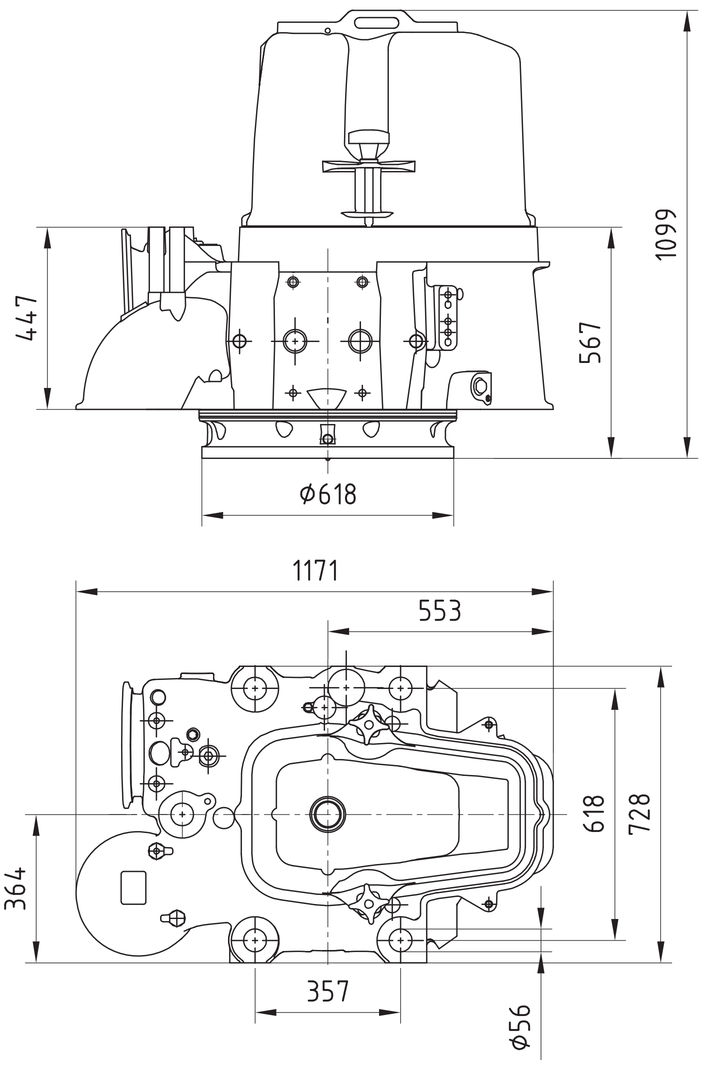
There will only be an effective corrosion protection of the engine if the defintions and required work according to factory standard N 576-6.1 are duly complied with.
In general, the applied corrosion protection is effective for a period of max. 2 years if the engines or engine generator sets are protected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

After 2 years representation must be carried out.

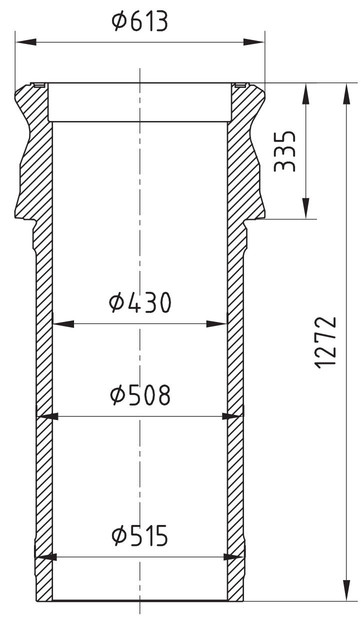
Every 3 months specific inspections are to be carried out at the engine or engine generator set at defined inspection points. Any corrosion and condensation water are to be removed immediately.

11. Engine parts

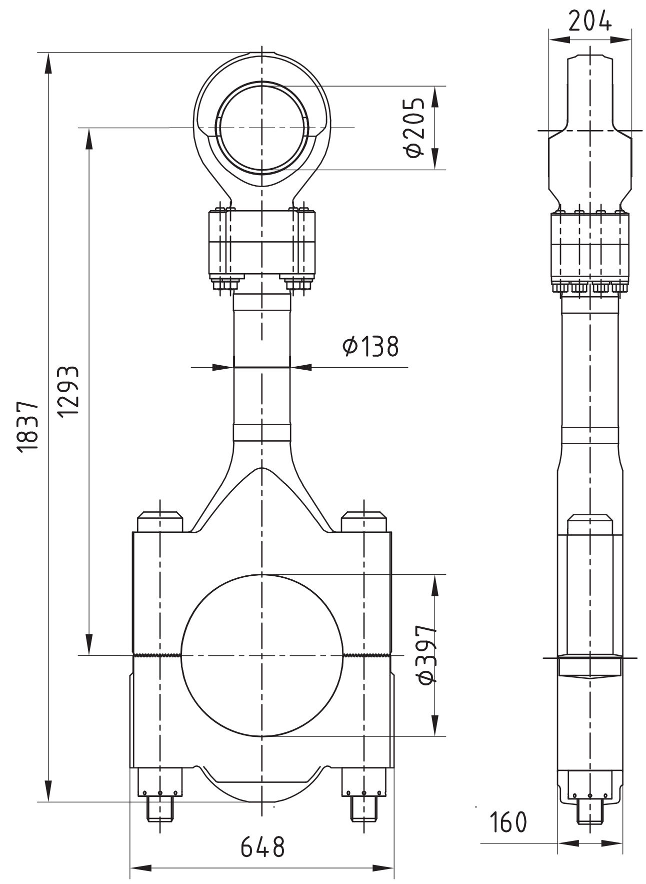
Cylinder head, weight 1,100 kg



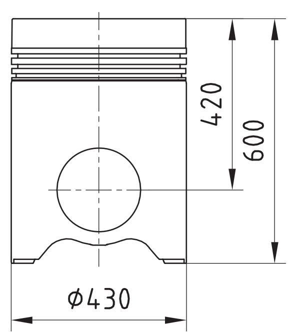
Cylinder liner, weight 674 kg



Connecting rod, weight 558 kg

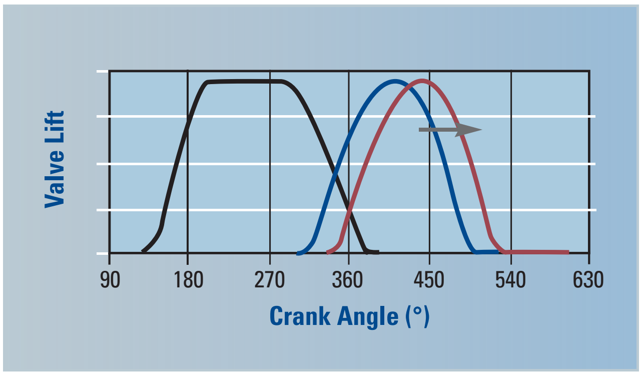


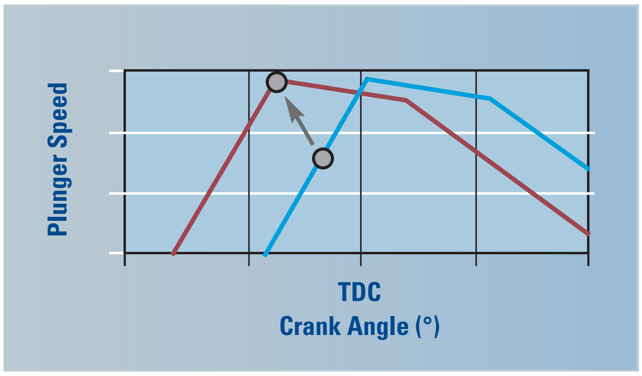
Piston, weight 255 kg



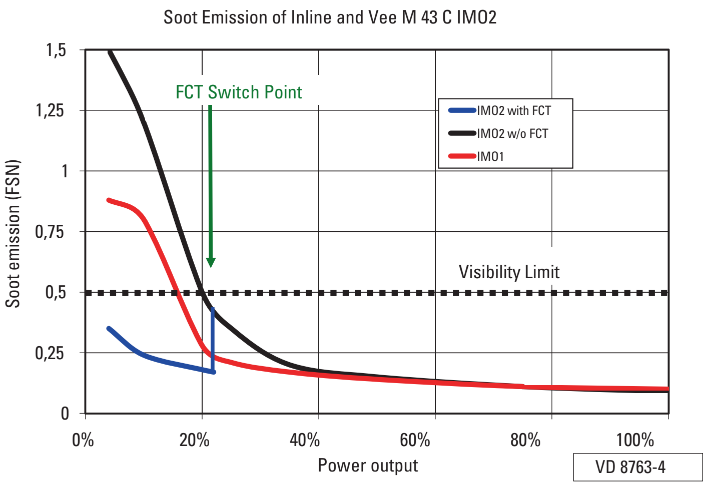
12. Flexible Camshaft Technology – FCT

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.

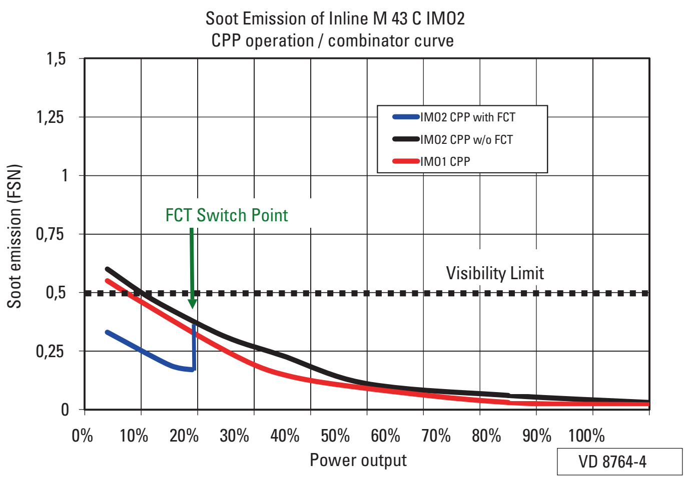




schematic diagram



M 43 C constant speed



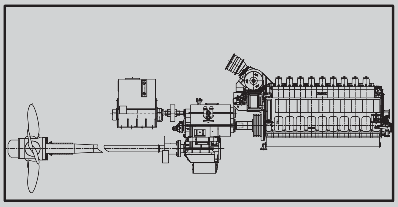
M 43 C CPP/combinator mode

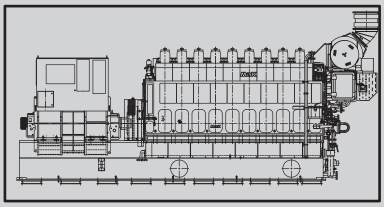
13. Caterpillar Marine Systems Integration

13.1 The Scope

Caterpillar Marine Systems Integration

Mechanical Propulsion Systems		Electrical Propulsion Systems





- Gensets
- E-Motors
- Propeller
- Thruster
- Fuel Oil System for LNG
- Fuel Oil System for HFO/MDO
- Heat Recovery Systems
- Exhaust Gas Cleaning Systems

Electric Propulsion Switchboard	Electric Board Net Switchboard	Power Management System
Communication Systems	Dynamic Positioning System	Ship Automation, Safety & Monitoring System
	Navigation System	Control Consoles & Control Stations

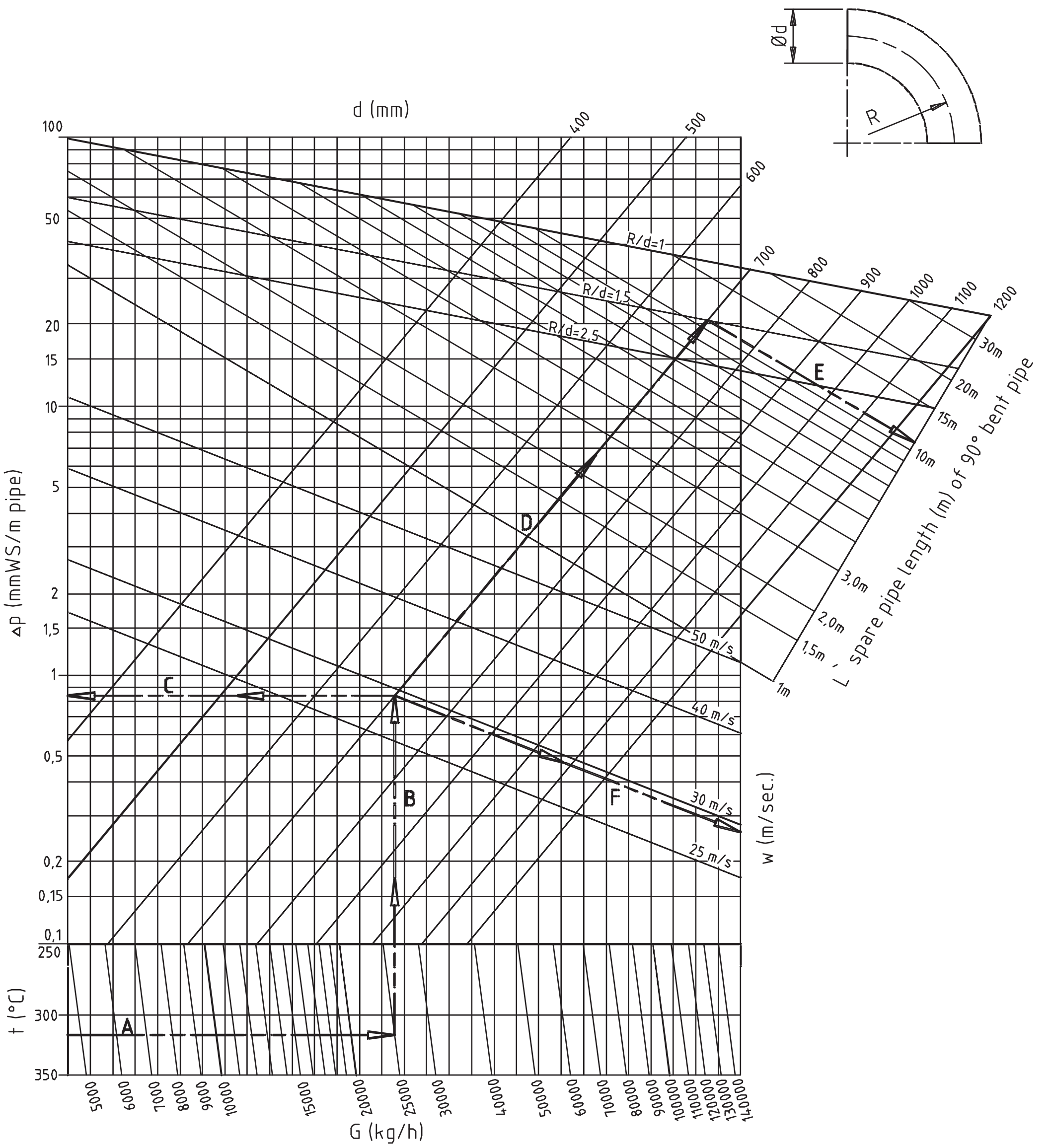
Caterpillar Marine Systems Integration provides:

- 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 pipe length, 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

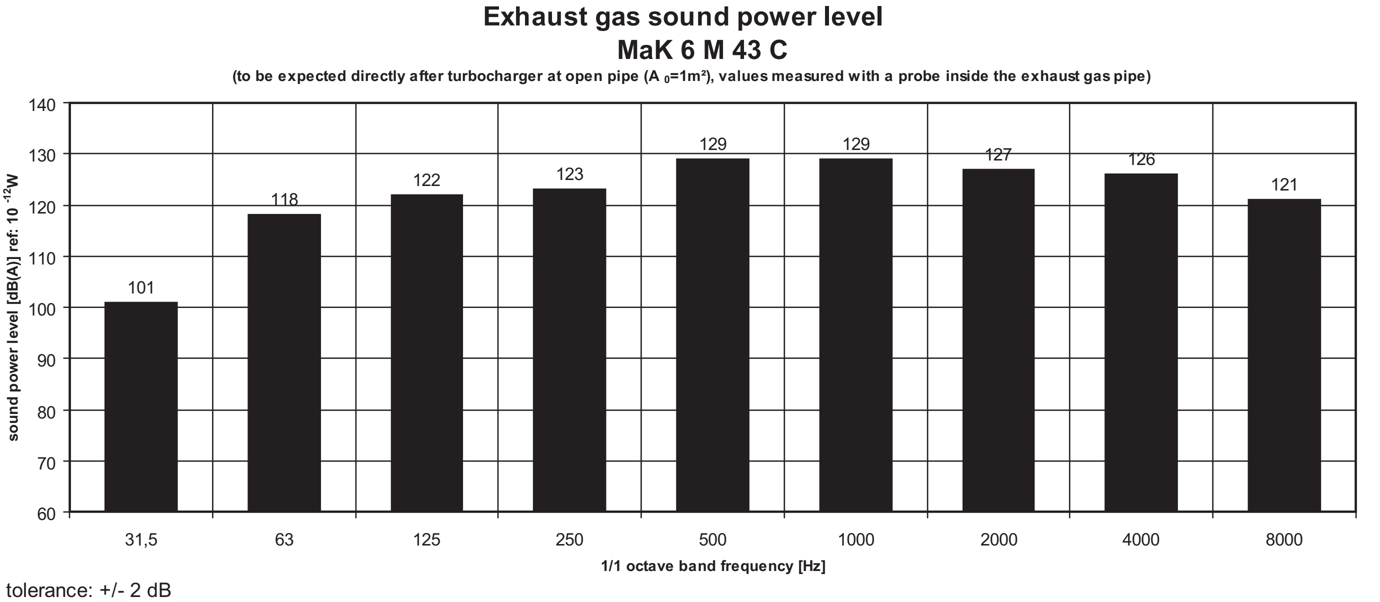
	Output [kW]	• Output % • [kg/h] • [°C]					
		100	90	80	70	60	50
6 M 43 C	6,000	40,920	37,620	34,315	30,025	26,340	22,654
		316	313	310	310	325	345
7 M 43 C	7,000	47,500	44,180	39,430	34,500	27,125	25,610
		312	305	310	312	324	342
8 M 43 C	8,000	54,286	50,491	45,060	39,430	31,000	29,265
		311	303	310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

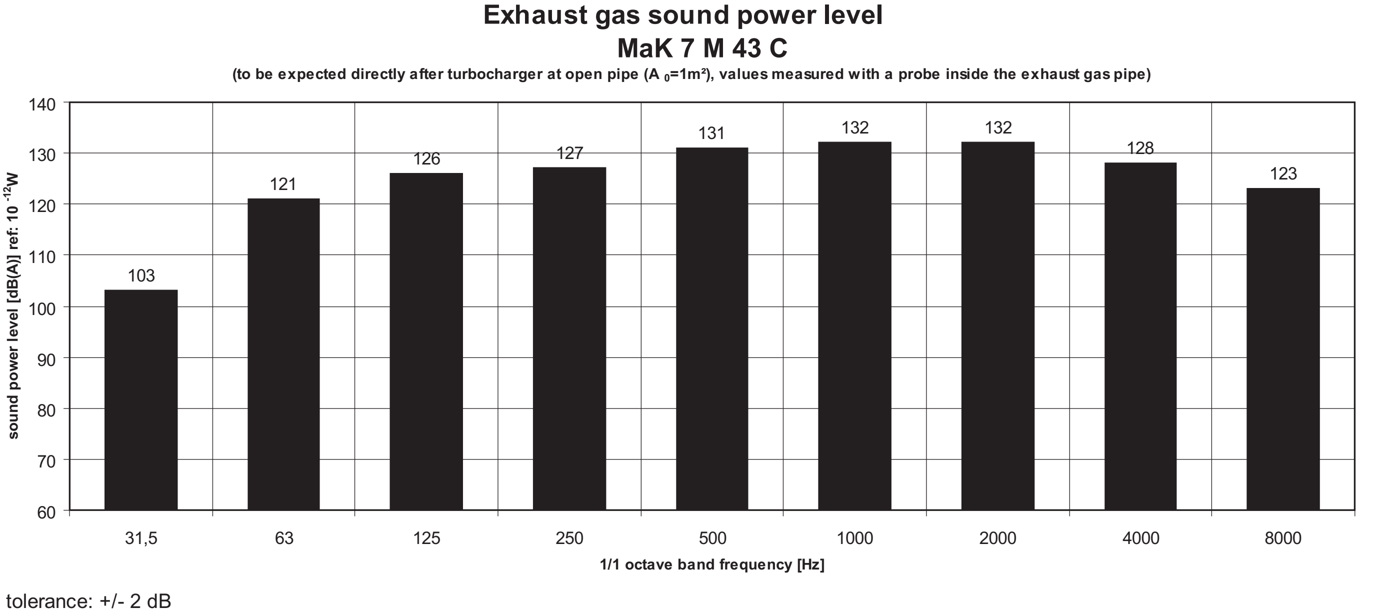
	Output [kW]	• Output % • [kg/h] • [°C]					
		100	90	80	70	60	50
6 M 43 C	6,000	38,465	35,363	32,250	28,225	24,760	21,295
		335	332	329	329	344	366
7 M 43 C	7,000	44,650	41,530	37,065	32,430	25,500	24,075
		331	323	329	331	343	362
8 M 43 C	8,000	51,030	47,460	42,355	37,065	29,140	27,510
		330	321	329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



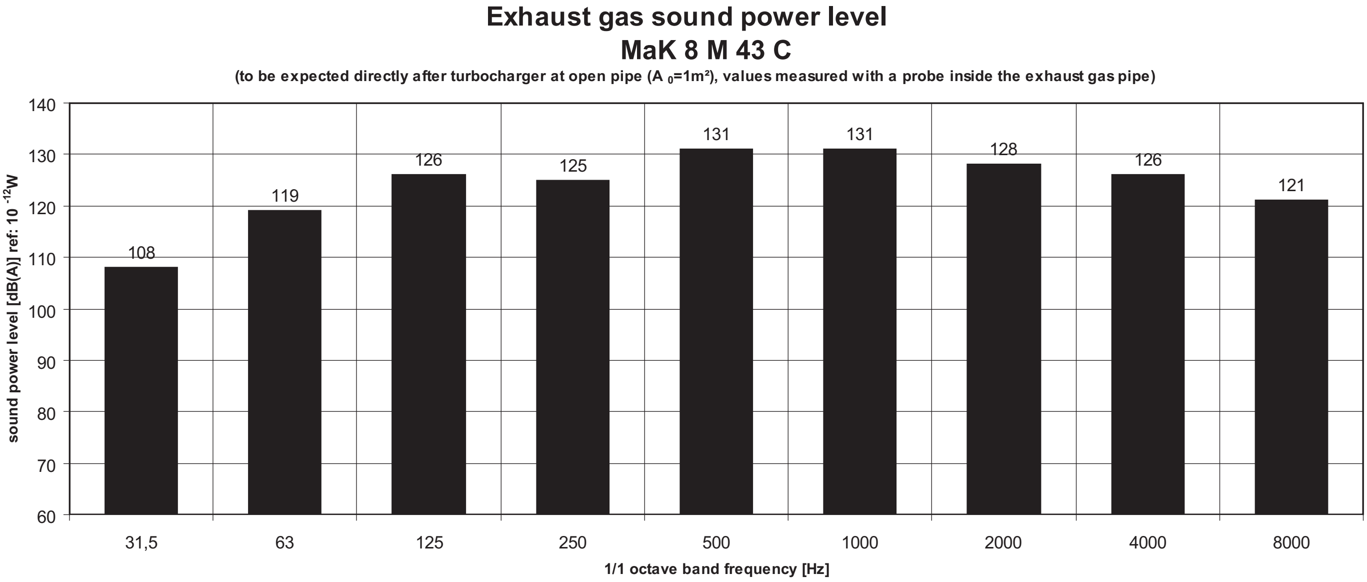
tolerance: +/- 2 dB



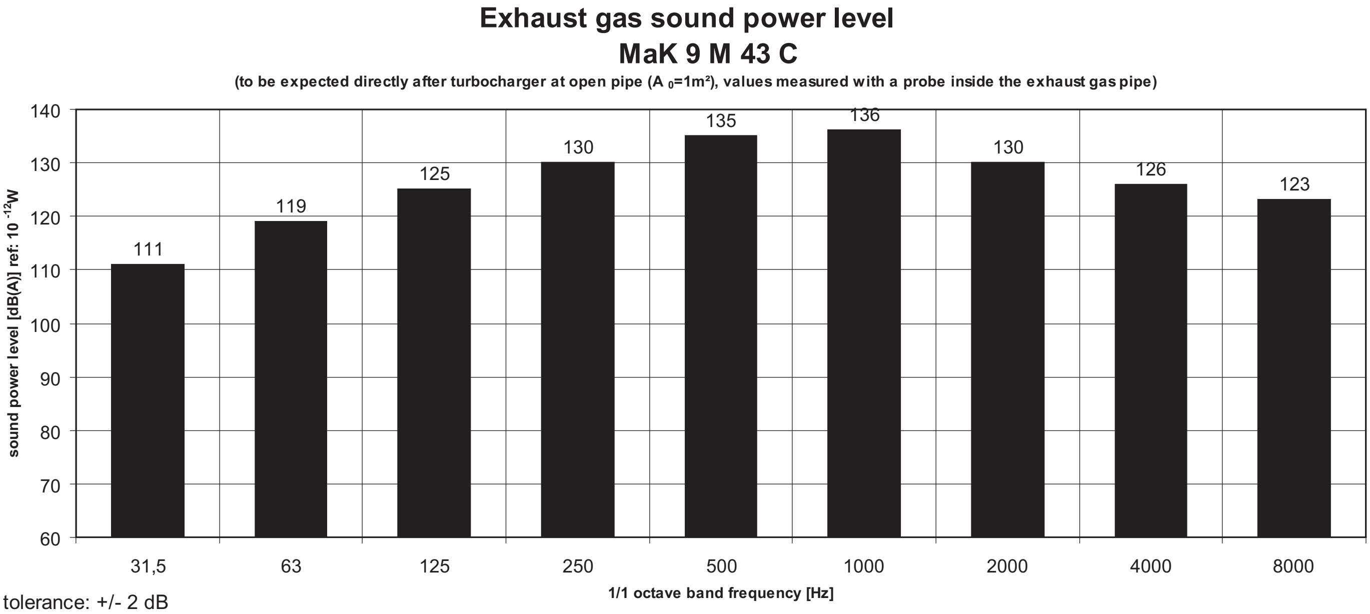
tolerance: +/- 2 dB

14. Appendix

14.1.3 Exhaust gas sound power level



tolerance: +/- 2 dB



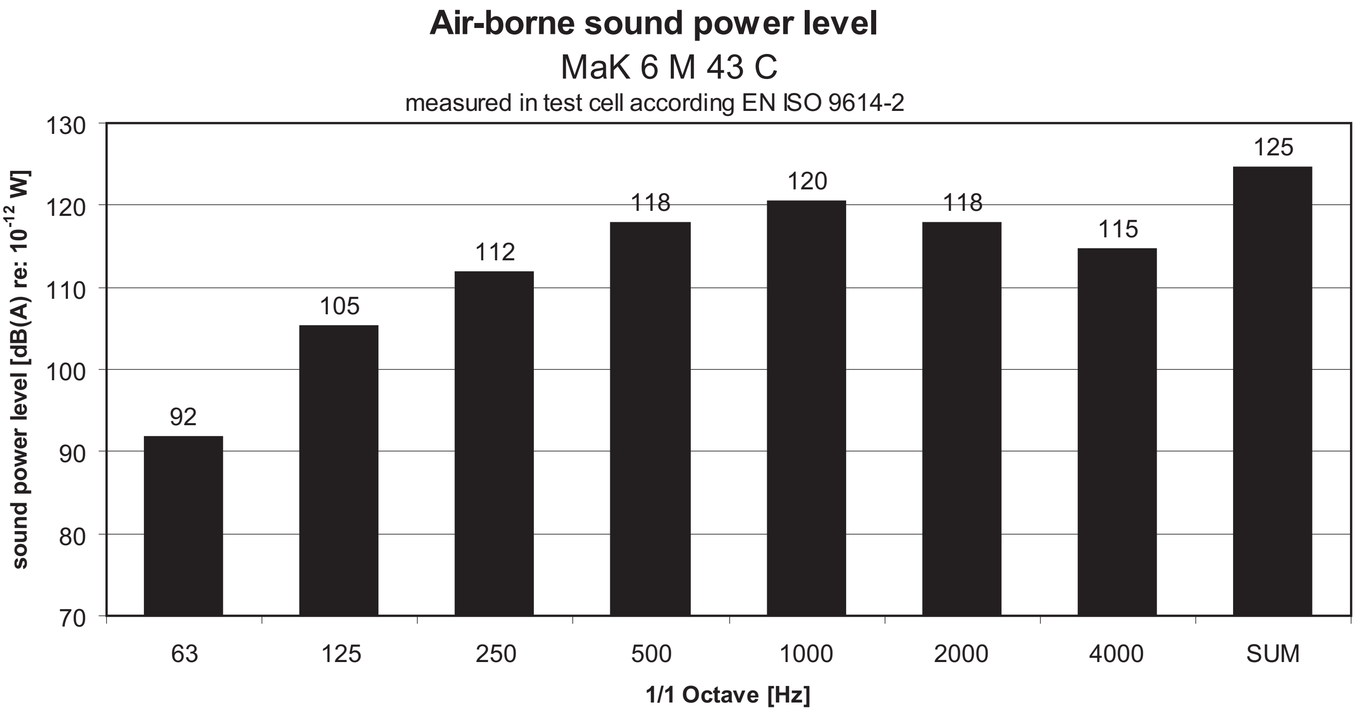
tolerance: +/- 2 dB

14. Appendix

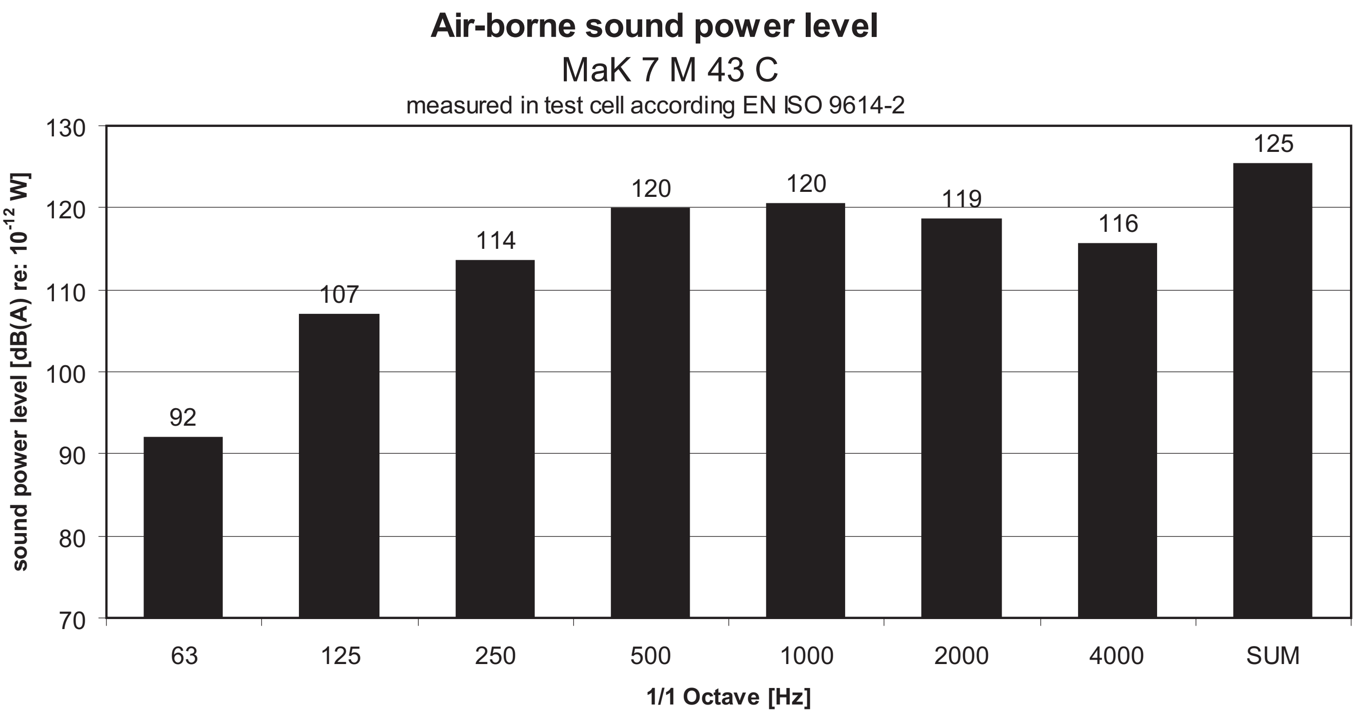
14.2 Air-borne sound power level

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

Noise level for M 43 C engines



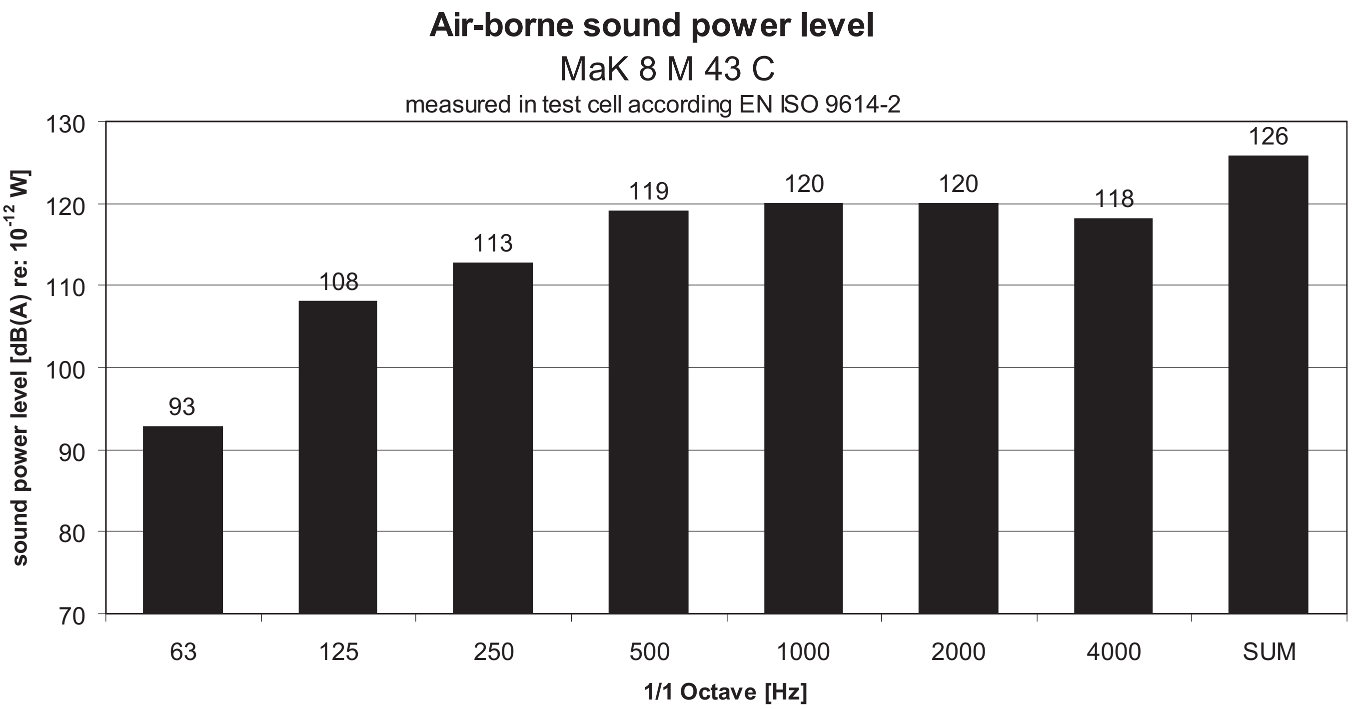
tolerance: +/- 2 dB



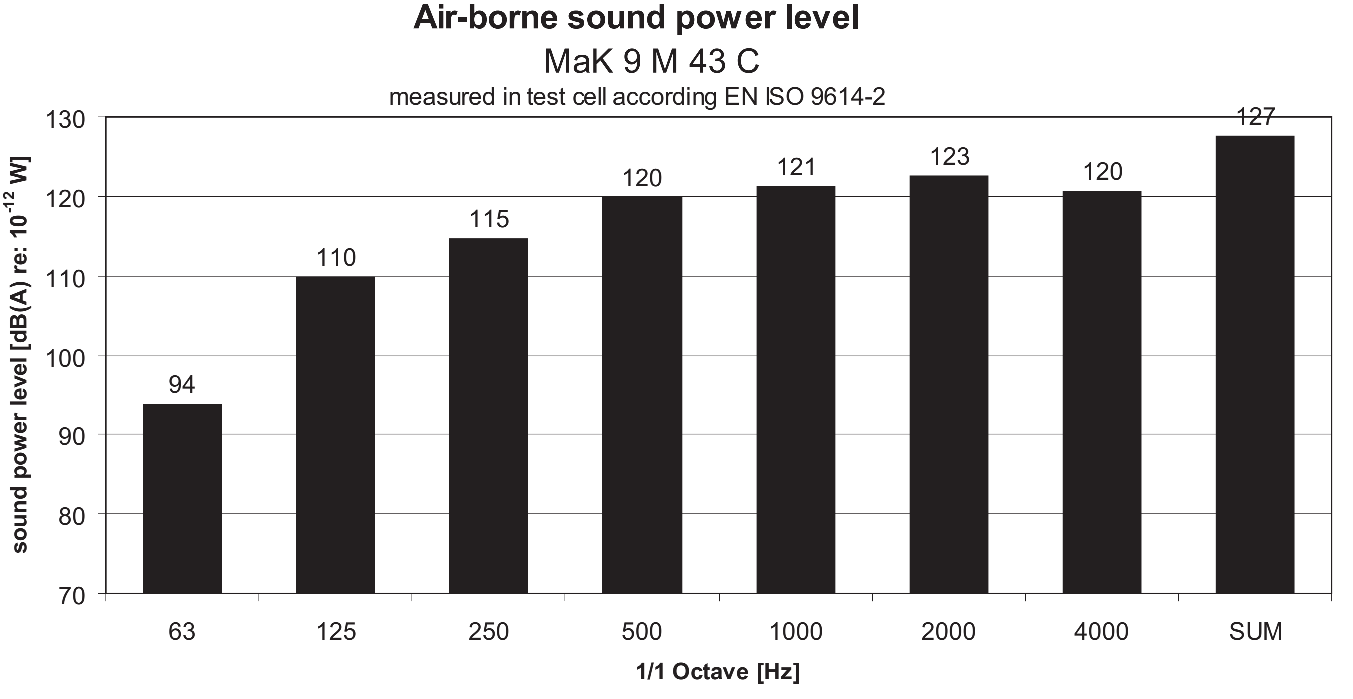
tolerance: +/- 2 dB

14. Appendix

14.2 Airborne sound power level



tolerance: +/- 2 dB



tolerance: +/- 2 dB

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