MAN V28/33D STC

Project Guide – Marine

Four-stroke diesel engine compliant with IMO Tier II

Revision.. **11.2020/7.3**

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1.1 Medium-speed propulsion engine programme

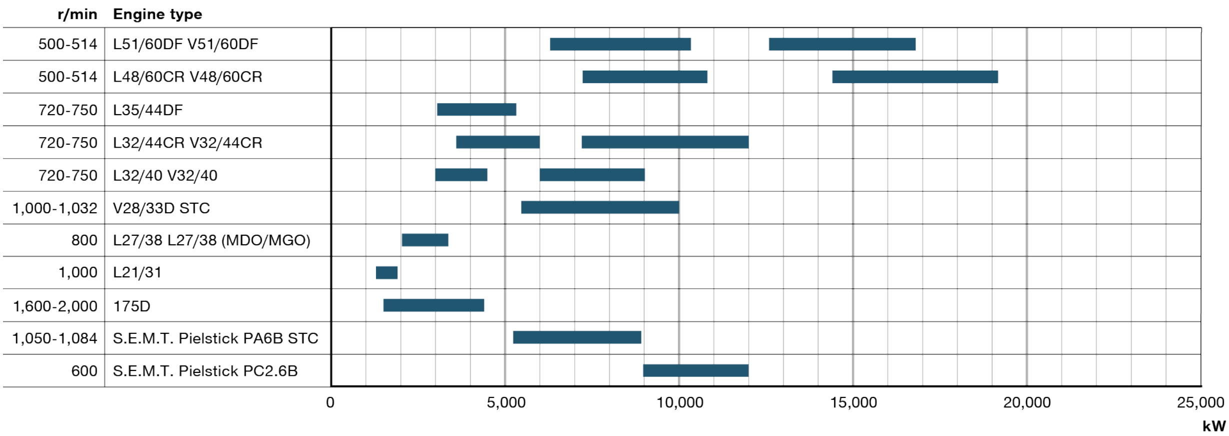

Figure 1: MAN Energy Solutions engine programme

1.2 Engine description MAN V28/33D STC IMO Tier II

Simplicity and functionality

The 280 mm-bore/330 mm-stroke MAN V28/33D STC engine with its simple and functional design is known for:

- High reliability
- Low fuel consumption
- Low operating costs
- High operating efficiency at low and high powers
- Low acoustic and thermal signature characteristics
- Capable of extended operation at low loads without white smoke or maintenance impact
- Optimum power-to-weight and power-to-size ratios
- Ease of installation and maintenance

Crankcase

Machined from a spheroidal graphite iron casting and featuring underslung main bearings which are retained by two vertical studs and two cross-bolts per side for overall engine stiffness. The main bearing caps are secured by hydraulically-tensioned studs to ensure maximum integrity of the crankshaft system.

Oil sump

There are two oil sump designs available, allowing different inclinations. Please contact MAN Energy Solutions for detailed information.

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Cylinder liners

Individual units machined from a centrifugal-spun grey iron casting and incorporating deep flanges that are cooled by a separate cast-aluminium water jacket enabling a dry crankcase. The liners are secured in position in the crankcase by the cylinder heads, and their running surfaces are plateau honed and finished to improve oil retention. A flame ring fitted at the top of the liner prevents the build-up of combustion residues (coke) on the piston crowns and minimises lubricating oil consumption.

Crankshaft

A new strengthened design ensures reduced stresses and improved lubrication via optimised drillings. It is machined from a high tensile NiCrMo continuous grain-flow steel forging and fitted with two bolt-on balance weights per throw. A solid camshaft drive gear is bolted to a flange at the free end that also incorporates a taper to which the vibration damper is fitted.

Main power drive at counter coupling side (100 % PTO, optional)

As a standard the main power drive connection is placed at coupling side. Optionally to provide better customer flexibility in engine arrangement, the main power drive is also available on free end side below turbochargers. This option is available for 12V and 16V engine.

Power take off for auxiliaries at counter coupling side (auxiliary PTO, optional)

If the main power drive connection is placed at coupling side, optionally an auxiliary PTO at counter coupling side can be used, to drive e.g. a fire fighting pump. This option is available for 12V, 16V and 20V engine. Hereby the maximum available output of the engine has to be considered.

Main and connecting rod bearings

Generously dimensioned, precision made, extended life, easily replaceable, thin wall, steel-backed aluminum-tin shells.

Camshafts

Of modular design, comprising one cam element and one bearing journal per engine cylinder, assembled through side access doors and mounted on each side of the engine. Large cam base circles are employed together with large bearings to reduce operating stresses. Housed in the crankcase, the two hollow camshafts incorporate the oil supply gallery to the engine and bearings.

Auxiliary drives

Water pumps and lubricating oil pumps with fuel oil pump are all driven from the flywheel counter side of the engine through the camshaft drive housed in the crankcase.

Pistons

A two-piece design with a lightweight body and alloy steel crown, and a three-ring pack comprising two chrome-ceramic compression rings and an oil control ring. The casehardened gudgeon pin is fully floating and retained by a circlip at each end. Lubricating oil is fed from the connecting rod through drill-

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ings in the gudgeon pin and piston to a cooling chamber in the piston crown. The oil is then discharged through drillings in the underside of the crown back to the sump.

Connecting rods

This straight cut design ensures high reliability, very good engine balancing and low vibrations. It is manufactured from a one-piece alloy steel forging, and the partially grooved lead bronze bearing shell is carried in straight cut big ends with each cap secured by four hydraulically-tensioned studs and nuts. The stepped small end features a steel-backed lead/bronze bush, and all bearing pressures are kept at a minimum.

Cylinder heads

Machined from a spheroidal graphite iron casting with a thick combustion face incorporating coolant drillings. The two inlet and two exhaust valves, the latter with cooled seats, are arranged around the central fuel injector.

Twin inlet ports connect directly to the air manifold, while a single tandem exhaust port exits from the top face for ease of maintenance. Each pair of valves is operated via short pushrods and conventional rockers from the camshaft via followers of the roller bucket tappet type mounted in a separate housing bolted to the crankcase.

Camshaft drive

Located at the free end of the engine and comprising a solid gear bolted to the crankshaft driving a compound idler gear for each cylinder bank, which in turn drive the two camshafts. All gear spindles are supported both sides of the gear by the crankcase.

Air manifolds

This single-element air manifold of symmetrical design is made of GGG40. It is mounted down the vee of the crankcase, and incorporating passages for the lubricating oil and water systems.

Intercooler

A cylindrical two-stage unit contained in a casing that includes part of the inlet ducting; the assembly is mounted directly on top of the air manifold.

Lube oil filter

Mounted at flywheel side of the engine including the lube oil filter and oil cooler.

Duplex filter system: Aluminium design with duplex paper oil filter cartridges allowing switch over during engine operation.

Also an automatic lube oil filter available: Cast iron design with integrated thermostat and a centrifugal oil separator.

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Figure 2: Oil cooler with mounted lube oil duplex filter

Figure 3: Oil cooler with mounted lube oil automatic filter

Turbocharging

Twin axial-flow MAN Energy Solutions turbochargers are mounted on a cast iron bracket at the free end of the engine. Developed specifically for the MAN V28/33D STC engine, the high efficiency and compact MAN TCA33 turbocharger features angled turbine inlet casings designed to match the engine exhaust in terms of interfaces and gas flow optimisation. Each turbocharger uses the same inlet casing, which is simply rephased to the opposite angle.

High efficiency at full and part loads from the turbocharging system yields a substantial charge air surplus and thorough combustion without residues. A requirement for the engine to fit compact machinery rooms resulted in a new turbine outlet casing design. Detailed analysis and design achieved very low pressure losses in the connection itself and in the downstream exhaust duct.

A single turbocharger frame size covers all cylinder configurations, making interfaces common across the engine range; and installation is standardised without compromising performance and efficiency.

Figure 4: Generic illustration of a MAN TCA turbocharger

Sequential turbocharging

The sequentially turbocharging (STC) offers optimised engine-turbocharger matching for high torque at low rpm with reduced fuel consumption, smoke and noise. The system incorporates two identical standard MAN TCA33 turbochargers: One alone supplies sufficient charge air in low and medium speed running modes; the second unit cuts in to boost charging at higher speeds.

A digital control system is programmed to automatically switch off one turbocharger at low rpm, increasing the amount of air reaching the combustion chambers.

An extended torque envelope yielding economical operating modes and improved engine acceleration characteristics from STC versions are particularly valued for naval propulsion applications. High torque at low power is particularly useful when towing another vessel.

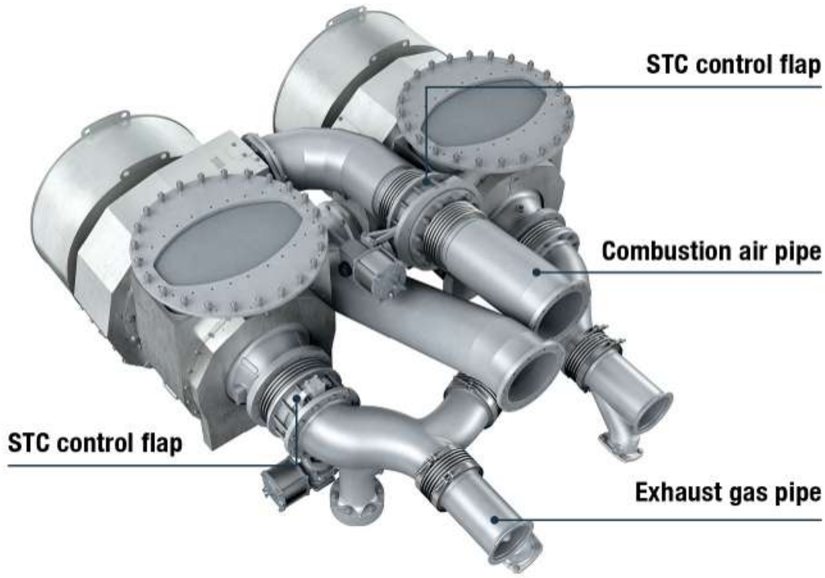

Figure 5: MAN V28/33D STC system

Fuel injection

An advanced microprocessor-managed, solenoid valve-controlled fuel injection system secures flexible and precise control of the injection quantity, rate and timing independent of engine speed.

In combination with the advanced combustion chamber technology the specific fuel consumption is reduced to a very competitive level. The large torque envelope of STC engines reduces fuel consumption by optimising the propeller efficiency.

Extended low-load operation

With STC, the MAN V28/33D STC engine has the capability to operate for extended periods at low-load conditions without visible smoke exhaust emissions or negatively affecting full load performance or maintenance demands.

Electronics – SaCoSone

The MAN V28/33D STC is equipped with the classification society compliant safety and control system SaCoSone. SaCoSone combines all functions of modern engine management into one complete system.

SaCoSone offers:

- Integrated self-diagnosis functions
- Future prove design
- Digital ready
- Maximum reliability and availability
- Simple use and diagnosis
- Quick exchange of modules
- Crankcase monitoring system plus oil mist detection

  As a standard for all our four-stroke medium-speed engines manufactured in Augsburg, these engines will be equipped with a crankcase monitoring system (CCM = splash oil & main bearing temperature) plus OMD (oil mist detection). OMD and CCM are integral part of the MAN Energy Solutions´ safety philosophy and the combination of both will increase the possibility to early detect a possible engine failure and prevent subsequent component damage.

1.3 Engine overview

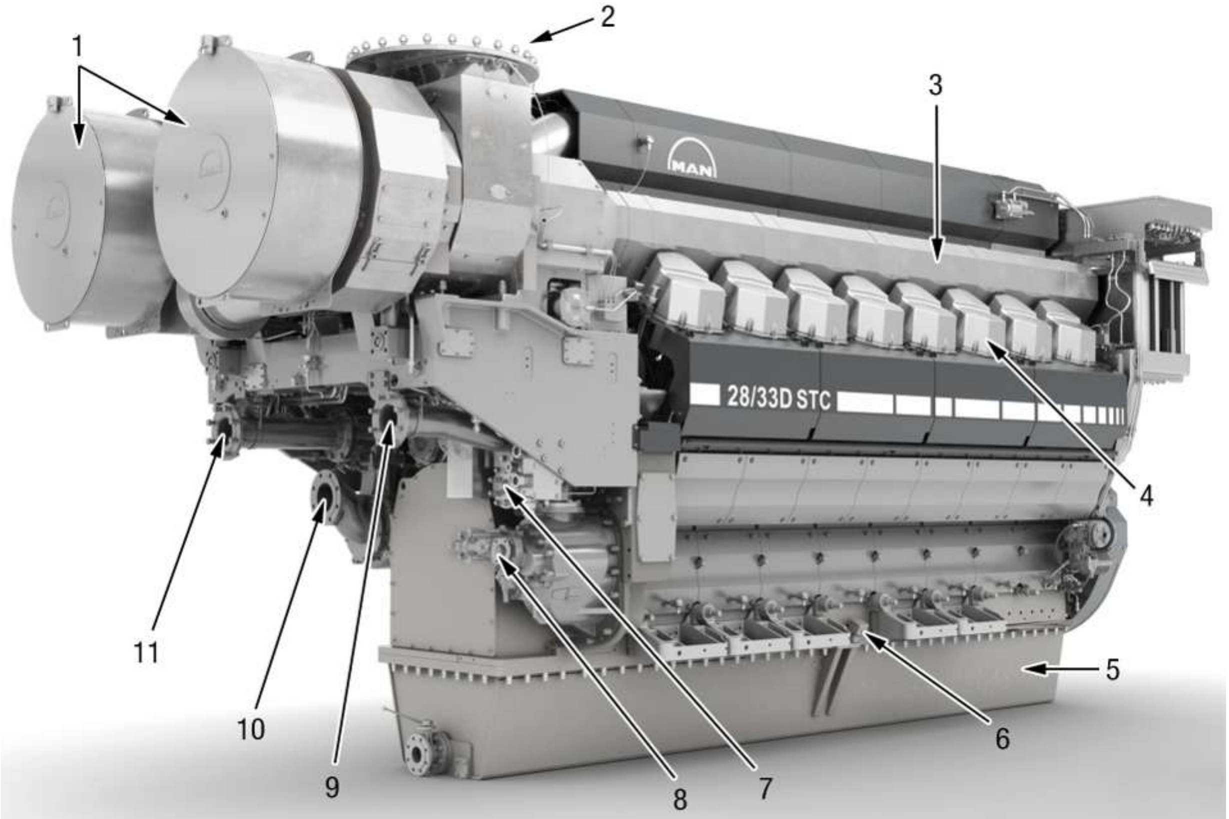

Figure 6: Engine overview, engine view on counter coupling side (CCS)

1	Air filter	7	Lube oil inlet
2	Turbocharger exhaust outlet	8	Fuel supply pump
3	Exhaust heat shield	9	HT water outlet
4	Tappet cover	10	Seawater pump inlet
5	Oil sump	11	Seawater pump outlet
6	Oil level sensor		

Figure 7: Engine overview, lube oil module with automatic filter, engine view on coupling side (CS)

1	Lube oil cooler	2	Lube oil module with automatic filter

Figure 8: Engine overview, lube oil module with duplex filter, engine view on coupling side (CS)

1	Lube oil cooler	2	Lube oil module with duplex filter

1.4 Turbocharger overview

1.4.1 View of a TCA type turbocharger

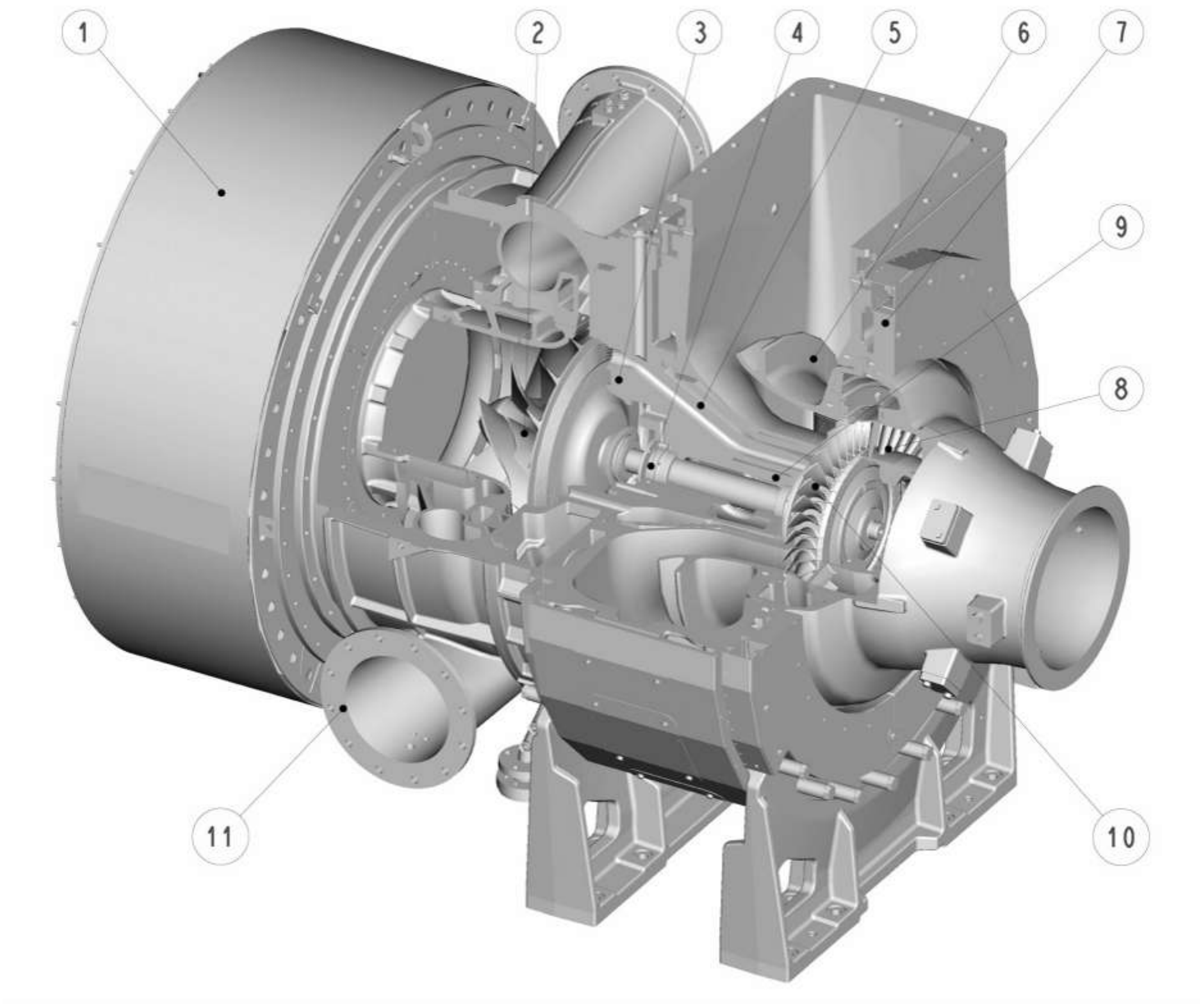

Figure 9: TCA type turbocharger

1	Silencer	7	Burst-proof casing
2	Compressor wheel	8	Nozzle ring
3	Bearing casing	9	Plain bearing
4	Thrust bearing	10	Turbine blades
5	Integrated sealing air system	11	Compressor casing
6	Exhaust diffuser		

The following view indicates the modern design principle of the TCA series:

- Whispering silencer
- Easy-to-service, low-noise compressor wheel
- Optional water-cooled compressor wheel

- Uncooled bearing casing
- Easy access to thrust bearing
- Integrated sealing air, oil pipe and venting systems

1.4.2 Compensator between turbine outlet (engine) and exhaust gas pipe (plant)

All turbocharger casing flanges, with the exception of the turbine outlet, may only be subjected to loads generated by the gas forces, and not to additional external forces or torques.

This necessitates the use of compensators directly at the turbine outlet.

The compensators must be pre-loaded in such a manner that thermal expansion of the pipes and casings does not exert forces or torques in addition to those generated by the air and gas.

- Forces and torques according to API standard 617.
- Operating direction implemented according to MAN Energy Solutions standard.
- Minimising the load as far as possible.
- Characteristic values include gas forces, masses and compensator.

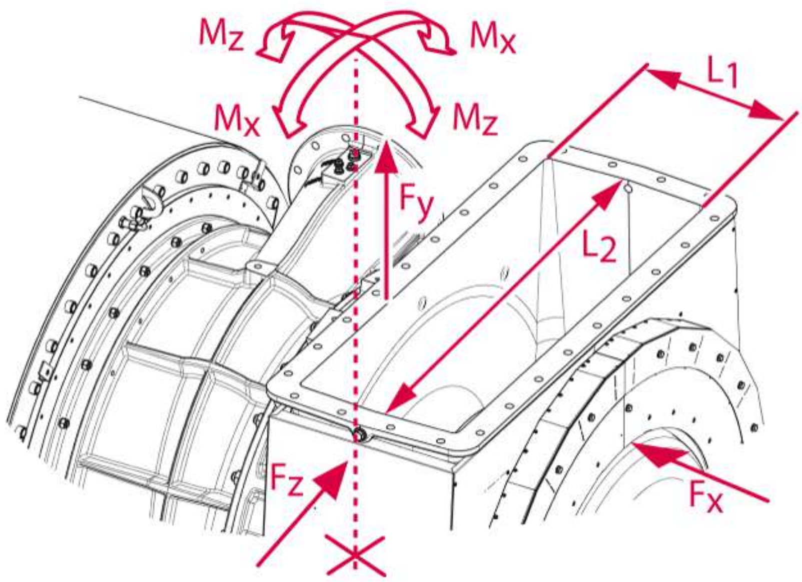

Figure 10: Maximum connection loads on gas outlet casing

Type	F_x [N]	F_y [N]	F_z [N]	M_x [Nm]	M_z [Nm]	L_1 [mm]	L_2 [mm]
TCA33	3,900	7,900	7,900	6,000	3,000	400	690
TCA44	4,200	8,500	8,500	6,400	3,200	340	949
TCA55	4,500	9,100	9,100	6,900	3,400	390	1,080
TCA66	4,900	9,900	9,900	7,500	3,700	463	1,283
TCA77	5,400	10,900	10,900	8,200	4,100	550	1,524
TCA88	5,900	12,000	12,000	9,100	4,500	653	1,810
TCA88-25	6,300	12,700	12,700	9,600	4,800	653	1,812

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Note:

- The layout of the compensator has to consider the possible movement of the engine according its foundation and engine mounting and the movement/extension of the exhaust gas pipe of the plant.
- Recommendations for the layout of the exhaust gas pipe in the section Exhaust gas system, Page 204 have to be considered.

1.4.3 No additional masses allowed

In general no masses are to be fixed to any part of the engine/turbocharger, as these have an impact to the general vibration behaviour of the engine.

Additional loads and changed vibration behaviour can endanger the operational safety of the engine.

Consequently, for any questions in this regard consult MAN Energy Solutions in advance.

2 Engine and operation

2.1 Approved applications and destination/suitability of the engine

Approved applications

The MAN V28/33D STC is designed as multi-purpose drive.

It has been approved by type approval as marine main engine.

As marine main engine[1)] it may be applied for mechanical propulsion drive[2)] for applications as:

- High-speed ferries
- Mega yachts
- Offshore patrol vessels
- Corvettes
- Frigates
- Amphibious ships
- Logistic ships
- Others – to fulfill all customers needs the project requirements have to be defined at an early stage

MAN V28/33D STC to be applied for multi-engine plants only.

Note:
The engine is not designed for operation in hazardous areas. It has to be ensured by the ship's own systems, that the atmosphere of the engine room is monitored and in case of detecting a gas-containing atmosphere the engine will be stopped immediately.

[1)] In line with rules of classifications societies each engine whose driving force may be used for propulsion purpose is stated as main engine.

[2)] See section Engine ratings (output) for different applications, Page 32.

Offshore

For offshore applications it may be applied for mechanical drive for applications as:

- Platforms/offshore supply vessels
- Anchor handling tugs
- General all kinds of service & supply vessels
- Drilling ships

MAN V28/33D STC to be applied for multi-engine plants only.

Due to the wide range of possible requirements such as flag state regulations, fire fighting items, redundancy, inclinations and dynamic positioning modes all project requirements need to be clarified at an early stage.

Note:
The engine is not designed for operation in hazardous areas. It has to be ensured by the ship's own systems, that the atmosphere of the engine room is monitored and in case of detecting a gas-containing atmosphere the engine will be stopped immediately.

Destination/suitability of the engine

Note:
Regardless of their technical capabilities, engines of our design and the respective vessels in which they are installed must at all times be operated in line with the legal requirements, as applicable, including such requirements that may apply in the respective geographical areas in which such engines are actually being operated.

Operation of the engine outside the specified operated range, not in line with the media specifications or under specific emergency situations (e.g. suppressed load reduction or engine stop by active "Override", triggered firefighting system, crash of the vessel, fire or water ingress inside engine room) is declared as not intended use of the engine (for details see engine specific operating manuals). If an operation of the engine occurs outside of the scope of supply of the intended use a thorough check of the engine and its components needs to be performed by supervision of the MAN Energy Solutions service department. These events, the checks and measures need to be documented.

Electric and electronic components attached to the engine – Required engine room temperature

In general our engine components meet the high requirements of the marine classification societies.

The electronic components are suitable for proper operation within an air temperature range from 0 °C to 55 °C. The electrical equipment is designed for operation at least up to 45 °C.

Relevant design criteria for the engine room air temperature:

Minimum air temperature in the area of the engine and its components ≥ 5 °C.

Maximum air temperature in the area of the engine and its components ≤ 45 °C.

Note:
Condensation of the air at engine components must be prevented.

Note:
It can be assumed that the air temperature in the area of the engine and attached components will be 5 – 10 K above the ambient air temperature outside the engine room. If the temperature range is not observed, this can affect or reduce the lifetime of electrical/electronic components at the engine or the functional capability of engine components. Air temperatures at the engine > 55 °C are not permissible.

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2.2 Engine design

2.2.1 Engine cross section

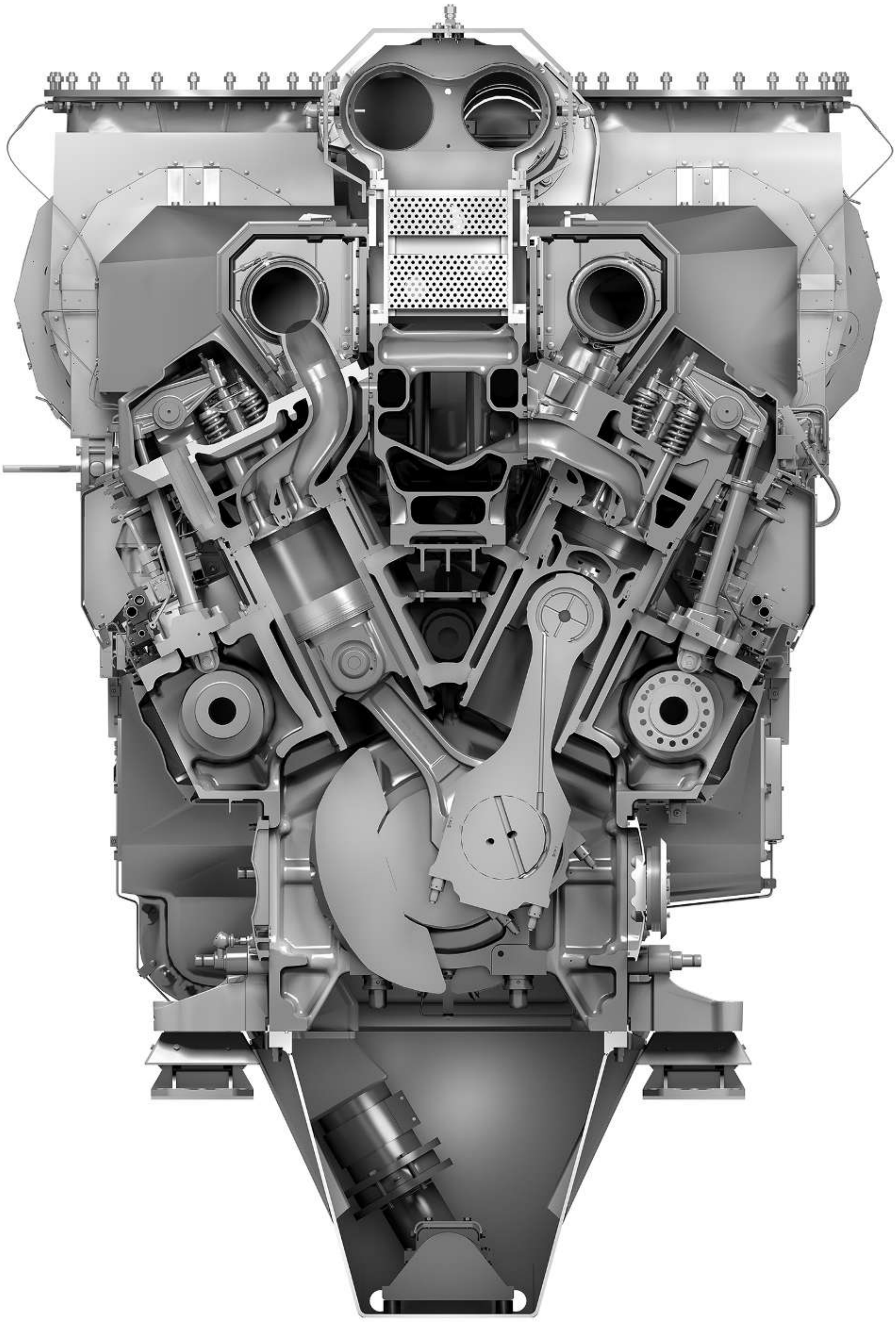
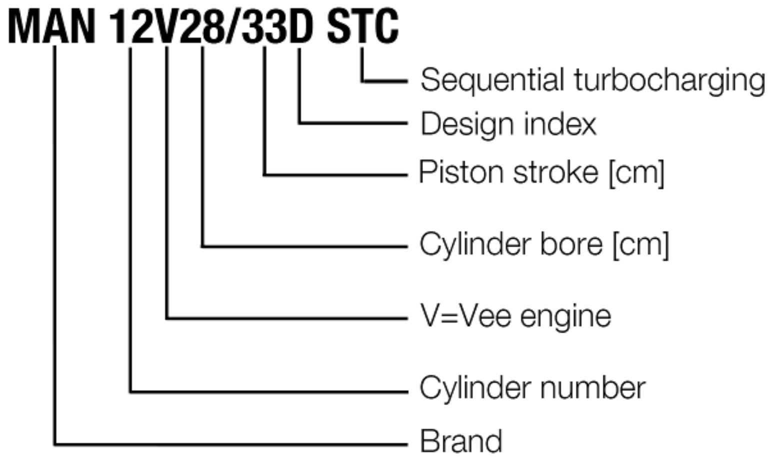


Figure 11: Cross section – MAN V28/33D STC

2.2.2 Engine designations – Design parameters

Example to declare engine designations



Parameter	Value	Unit
Number of cylinders	12, 16, 20	-
Cylinder bore	280	mm
Piston stroke	330	
Displacement per cylinder	20.3	litre
Distance between cylinder centres, vee engine	460	mm
Vee engine, vee angle	52	°
Crankshaft diameter at journal, vee engine	300	mm
Crankshaft diameter at crank pin	240	

Table 1: Design parameters

2.2.3 Turbocharger assignments

No. of cylinders, config.	CPP, FPP
12V	TCA33-42
16V	TCA33-42
20V	TCA33-42

Table 2: Turbocharger assignments

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2.2.4 Engine main dimensions, weights and views

MAN V28/33D STC mechanical propulsion

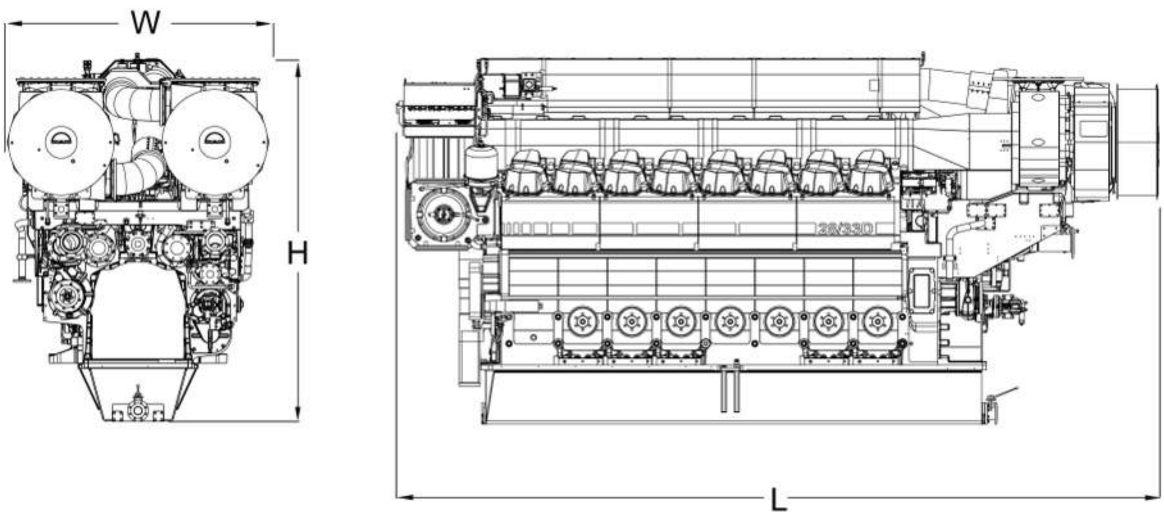


Figure 12: Main dimensions and weights – MAN V28/33D STC mechanical propulsion (lube oil module with automatic filter)

No. of cylinders, config.	W	H (low oil sump)	H (deep oil sump)	L	Weight with flywheel[1]
	mm				t
12V	2,473	3,417	3,682	6,217	36.4
16V				7,137	43.9
20V				8,057	51.6
[1] Tolerance: 5 %. Weight refer to engine with flywheel, TC silencer, attached pumps, oil filter and lube oil cooler (weight given without media filling of engine).					

For Flywheel data, see section Flywheel arrangement, Page 98.

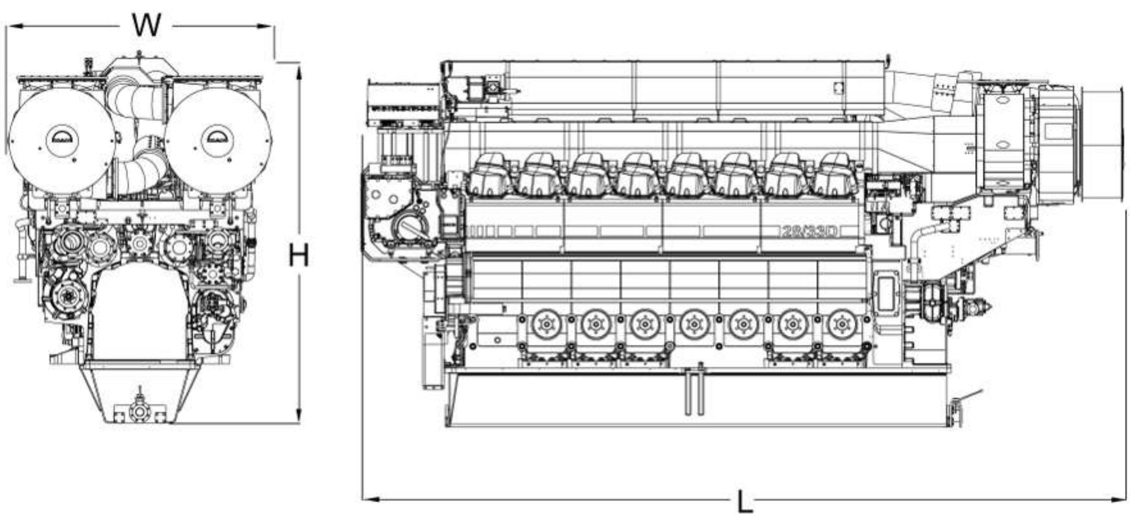
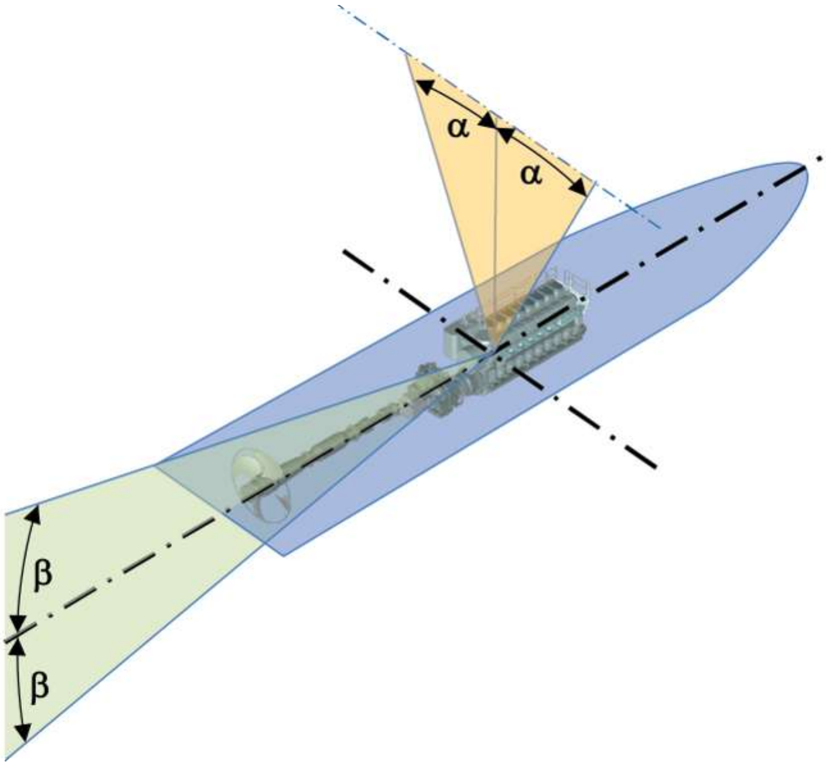


Figure 13: Main dimensions and weights – MAN V28/33D STC mechanical propulsion (lube oil module with duplex filter)

No. of cylinders, config.	W	H (low oil sump)	H (deep oil sump)	L	Weight with flywheel[1]
	mm				t
12V	2,473	3,417	3,682	6,207	36.1
16V				7,127	43.6
20V				8,047	51.3
[1] Tolerance: 5 %. Weight refer to engine with flywheel, TC silencer, attached pumps, oil filter and lube oil cooler (weight given without media filling of engine).					

For Flywheel data, see section Flywheel arrangement, Page 98.

2.2.5 Engine inclination



α Athwartships β Fore and aft

Figure 14: Angle of inclination

Max. permissible angle of inclination [°][1) 2)]					
Application	Athwartships α		Fore and aft β		
	Heel to each side (static)	Rolling to each side (dynamic)	Trim (static)[3]		Pitching (dynamic)
			L < 100 m	L > 100 m	
Main engines	15	22.5	5	500/L	7.5

[1] Athwartships and fore and aft inclinations may occur simultaneously.

[2] While engine may be installed 3° tilted as a maximum in vessels longitudinal direction.

[3] Depending on length L of the ship.

Table 3: Inclinations

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Note:
For higher requirements contact MAN Energy Solutions. Arrange engines always lengthwise of the ship.

2.2.6 Engine equipment for various applications

Device/measure, (figure pos.)	Mechanical propulsion
Charge air blow-off for cylinder pressure limitation	Order-related, required if the intake air ≤ 0 °C[1)]
Charge air by-pass	X
Exhaust flap STC and air flap STC	X
Turbocharger – Compressor cleaning device (wet)	X
Two-stage charge air cooler	X
Oil mist detector	X
Splash oil monitoring	X
Main bearing temperature monitoring	X
Starting system – Compressed air starter	X
Attached HT cooling water pump	X
Attached LT cooling water pump	X
Attached lubrication oil pump	X
Attached seawater pump	X
Attached fuel supply pump	X
HT cooling water temperature control thermostat	X
Lube oil temperature control thermostat	X[2)]
Lube oil cooler	X
Lube oil pressure control valve	X[3)]
Oil sump	X (deep oil sump) O (low oil sump)
Power take off 100 % on counter coupling side	O (12V/16V)
Oil mist eliminator (not attached to the engine)	X
Lube oil filter	X (lube oil duplex filter) O (lube oil automatic filter plus lube oil centrifugal filter)

X = required, O = optional

[1)] MAN Energy Solutions recommends an engine room temperature of +5 °C to avoid freezing wetness on intake air silencer filter mat and electronic equipment.

[2)] Lube oil inlet temperature control by wax thermostat (standard for engines with lube oil duplex filter). For engines with optional lube oil automatic filter: Lube oil outlet temperature control by wax thermostat.

[3)] Integrated in the attached lube oil pump.

Table 4: Engine equipment

Engine equipment for various applications – General description

Charge air blow-off for cylinder pressure limitation (see figure Overview flaps, Page 28)

If engines are operated at full load at low air intake temperature, the high air density leads to the danger of excessive charge air pressure and, consequently, to excessive cylinder pressure. In order to avoid such conditions, part of the charge air is withdrawn upstream (hot blow-off) of the charge air cooler and blown off.

Note:
Hot air withdrawn before charge air cooler has to be blown outside the engine room where it can not harm persons and property or may be used e.g. for intake air preheating.

Charge air by-pass (see figure Overview flaps, Page 28)

The charge air pipe is connected to the exhaust pipe via a reduced diameter pipe and a by-pass flap. The flap is closed in normal operation.

At reduced engine loads and at nominal or reduced speed this charge air by-pass flap is opened to withdraw a part of the charge air and leads it into the exhaust gas pipe upstream the turbine. The increased air flow at the turbine results in a higher charge air pressure of the compressor, which leads to an improved operational behavior of the engine. Additional this flap may be used to avoid surging of the turbocharger.

Exhaust flap STC and air flap STC (see figure Overview flaps, Page 28)

Allows to turn off the second turbocharger at lower loads.

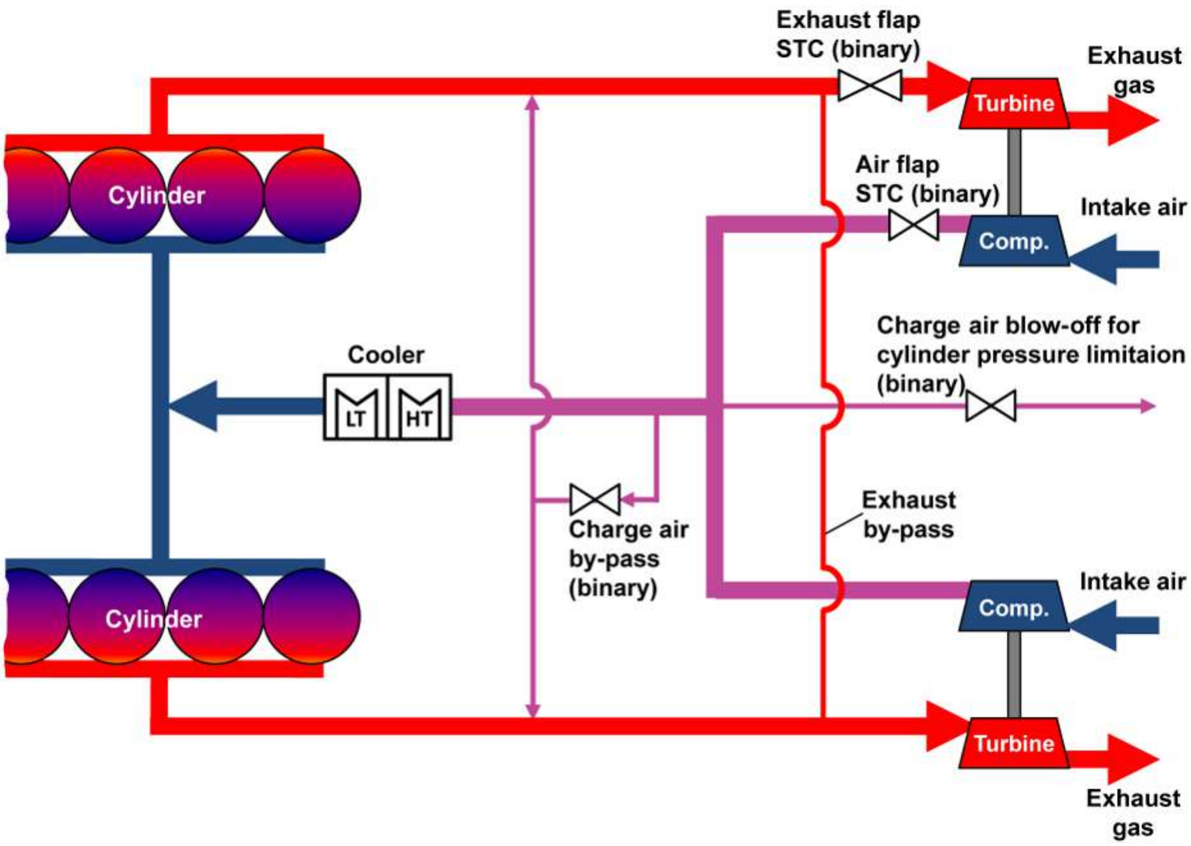

Figure 15: Overview flaps

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Turbocharger – Compressor cleaning device (wet)	Depending on the quality of the intake air, deposits may be formed on the blades of the compressor wheel and diffuser. This contamination reduces the efficiency of the compressor. Cleaning of the compressor is carried out with water during operation at full load with a special compressor cleaning device.
Two-stage charge air cooler	The two-stage charge air cooler consists of two stages which differ in the temperature level of the connected water circuits. The charge air is first cooled by the HT circuit (high temperature stage of the charge air cooler, engine) and then further cooled down by the LT circuit (low temperature stage of the charge air cooler, lube oil cooler).
Oil mist detector	Bearing damage, piston seizure and blow-by in combustion chamber leads to increased oil mist formation. As a part of the safety system the oil mist detector monitors the oil mist concentration in crankcase to indicate these failures at an early stage.
Splash oil monitoring	The splash oil monitoring system is a constituent part of the safety system. Sensors are used to monitor the temperature of each individual drive unit (or pair of drive at V engines) indirectly via splash oil.
Main bearing temperature monitoring	As an important part of the safety system the temperatures of the crankshaft main bearings are measured just underneath the bearing shells in the bearing caps. This is carried out using oil-tight resistance temperature sensors.
Starting system – Compressed air starter	The engine is equipped with compressed air starters, which are attached to the engine. On starting command they will turn the flywheel until a defined speed is reached.

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2.3 Ratings (output) and speeds

2.3.1 General remark

The engine power which is stated on the type plate derives from the following sections and corresponds to $P_{Operating}$ as described in section Derating, definition of P Operating, Page 33.

2.3.2 Standard engine ratings

Engine MAN V28/33D STC propulsion, 455 kW/cyl.

$P_{ISO, standard}$: ISO standard output (as specified in DIN ISO 3046-1)

455 kW/cyl., 1,000 rpm (ICN) [corresponds to 100 % output]

No. of cyl., config.	Engine rating $P_{ISO, standard}$ [1) 2)]					
	455 kW/cyl., 1,000 rpm	Available turning direction	Minimum continuous rating up to a maximum of 12 hours[3)]		Minimum continuous rating up to a maximum of 48 hours[3)]	
	kW	CW/CCW[4) 5)]	FPP at 300 rpm kW	CPP at 400 rpm kW	FPP at 300 rpm kW	CPP at 400 rpm kW
12V	5,460	Yes/Yes	125	165	250	325
16V	7,280	Yes/Yes	165	215	330	430
20V	9,100	Yes/Yes	205	270	410	540

1) $P_{ISO, standard}$ as specified in DIN ISO 3046-1, see paragraph Reference conditions for engine rating, Page 31, according ICN power definition.

2) Engine fuel: Distillate according to ISO 8217, fulfilling the stated quality requirements.

3) See section Low-load operation MAN V28/33D STC, Page 41.

4) For multi-engine arrangement only.

5) CW clockwise; CCW counter clockwise.

Table 5: Engine MAN V28/33D STC propulsion, 455 kW/cyl.

Engine MAN V28/33D STC propulsion, "Navy" (ICFN), 500 kW/cyl.[1]

$P_{ISO, standard}$: ISO standard output (as specified in DIN ISO 3046-1)

500 kW/cyl., 1,032 rpm (ICFN) [corresponds to 100 % output]

No. of cyl., config.	Engine rating $P_{ISO, standard}$ [2) 3)]						
	Fuel stop power ICFN[1)] 500 kW/cyl., 1,032 rpm	MCR 455 kW/cyl., 1,000 rpm	Available turning direction	Minimum continuous rating up to a maximum of 12 hours[4)]		Minimum continuous rating up to a maximum of 48 hours[4)]	
	kW	kW	CW/CCW[5) 6)]	FPP at 300 rpm kW	CPP at 400 rpm kW	FPP at 300 rpm kW	CPP at 400 rpm kW
12V	6,000	5,460	Yes/Yes	125	165	250	325
16V	8,000	7,280	Yes/Yes	165	215	330	430
20V	10,000	9,100	Yes/Yes	205	270	410	540

1) Only available for special class rules or without class approval.

2) $P_{ISO, standard}$ as specified in DIN ISO 3046-1, see paragraph Reference conditions for engine rating, Page 31, according ICFN power definition for application with "Navy" load profile. (F = Fuel stop power, represents highest load also at FAT).

3) Engine fuel: Distillate according to ISO 8217, fulfilling the stated quality requirements.

4) See section Low-load operation MAN V28/33D STC, Page 41.

5) For multi-engine arrangement only.

6) CW clockwise; CCW counter clockwise.

Table 6: Engine MAN V28/33D STC propulsion, "Navy" (ICFN), 500 kW/cyl.

Reference conditions for engine rating

According to ISO 15550; ISO 3046-1

Air temperature before turbocharger t_r	K/°C	298/25
Total atmospheric pressure p_r	kPa	100
Relative humidity Φ_r	%	30
Cooling water temperature inlet charge air cooler (LT stage)	K/°C	298/25

Table 7: Reference conditions for engine rating

2.3.3 Power definition and load profile

Ratings are given according to ISO 3046-1:2002.

According ISO 15550:2002, the power figures in the tables remain valid within a range of ± 3% up to tropical conditions at sea level, i.e.:

- Compressor inlet temperature 45 °C.
- Compressor inlet pressure 1,000 mbar.
- Seawater temperature 32 °C.

For all commercial medium speed propulsion engines the power is defined according ICN[1)] definition (ISO 3046-1:2002 : ISO standard power).

For all navy medium speed propulsion applications the engine rated power is stated as ICFN (ISO standard Continuous Fuel stop Net power), derived from standard ISO 3046-1:2002. It means the engine is capable to deliver power continuously during a period of time corresponding to the application. The engine is operated at stated speed and reference ambient conditions as stated above, while the fuel amount is limited and the fuel stop power cannot be exceeded. The engine rated power is delivered between the maintenance intervals as defined. The ICFN engine power rating description corresponds to 100 % engine power output and cannot be exceeded.

Exemplary load profile: MAN V28/33D STC "Navy" (ICFN), 500 kW/cyl. = 100 % engine output

Typical use: Fast yachts, frigates, corvettes, OPV.

The continuous operating time for loads > 455 kW/cyl. is limited. Therefore the proportion of higher loads in the load profile must not be exceeded.

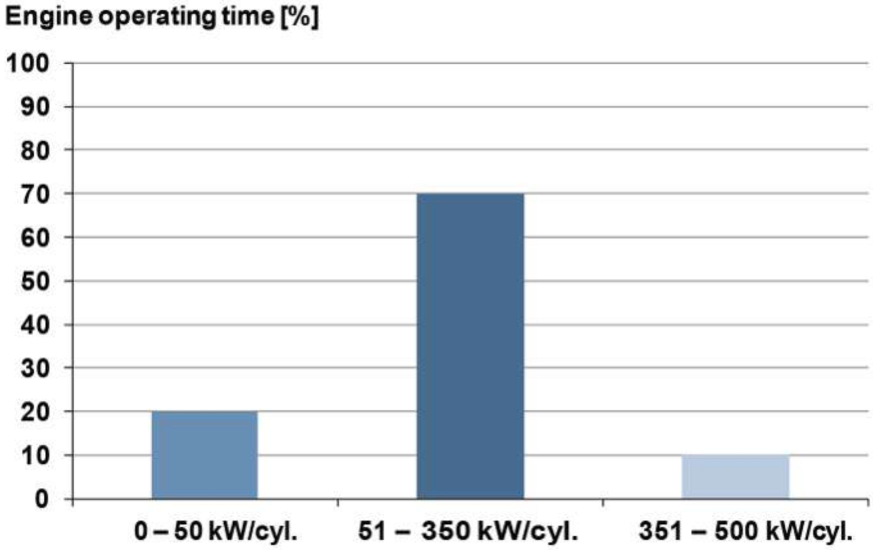

Figure 16: Exemplary load profile: MAN V28/33D STC "Navy" (ICFN), 500 kW/cyl.

[1] IC[F]N according to ISO 3046; I = Power to ISO 3046; C = Continuous power output; [F = Fuel stop power]; N = Net power

2.3.4 Engine ratings (output) for different applications

$P_{Application}$, ISO: Available output under ISO conditions dependent on application

	$P_{Application}$ available output in percentage from ISO standard output	$P_{Application}$ available output	Max. fuel admission (blocking)	Max. permissible speed reduction at maximum torque[1]	Tropic conditions ($t_r/t_{cr}/p_r$=100 kP_a)[2]	Notes
Kind of application	%	kW/cyl.	%	%	°C	
Marine main engines						
Main drive with controllable pitch propeller	100	455 (ICN) 500 (ICFN)[3]	100	-	45/38	[4]

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	$P_{Application}$ available output in percentage from ISO standard output	$P_{Application}$ available output	Max. fuel admission (blocking)	Max. permissible speed reduction at maximum torque[1]	Tropic conditions ($t_r/t_{cr}/p_r$=100 kP_a)[2]	Notes
Kind of application	**%**	**kW/cyl.**	**%**	**%**	**°C**	
Main drive with fixed pitch propeller	100	455 (ICN) 500 (ICFN)[3]	100	10	45/38	[4]
[1] Maximum torque given by available output and nominal speed. [2] t_r = air temperature at compressor inlet of turbocharger; t_{cr} = cooling water temperature before charge air cooler; p_r = atmospheric pressure. [3] For engines with ICFN power definition ("Navy" load profile) as described in section Power definition and load profile, Page 31. [4] According to DIN ISO 3046-1 MAN Energy Solutions has specified a maximum continuous rating for marine engines listed in the column $P_{Application}$.						

Table 8: Available outputs/related reference conditions MAN V28/33D STC

2.3.5 Derating, definition of P Operating

$P_{Operating}$: Available rating (output) under local conditions and dependent on application

Dependent on local conditions or special application demands a further load reduction of $P_{Application, ISO}$ might be required.

1. No derating

No derating necessary, provided that the conditions listed are met:

	No derating up to stated reference conditions (tropic), see 1.
Air temperature before turbocharger T_x	≤ 318 K (45 °C)
Ambient pressure	≥ 100 kPa (1 bar)
Cooling water temperature inlet charge air cooler (LT stage)	≤ 311 K (38 °C)
Intake air pressure before compressor	≥ −2 kPa[1]
Exhaust gas back pressure after turbocharger	≤ 5 kPa[1]
Relative humidity Φ_r	≤ 60 %
[1] Below/above atmospheric pressure.	

Table 9: Derating – Limits of ambient conditions

2. Derating

Contact MAN Energy Solutions:

- If limits of ambient conditions mentioned in the upper table Derating – Limits of ambient conditions, Page 33 are exceeded. A special calculation is necessary.

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- If higher requirements for the emission level exist. For the permissible requirements see section Exhaust gas emission, Page 79.
- If special requirements of the plant for heat recovery exist.
- If special requirements on media temperatures of the engine exist.
- If any requirements of MAN Energy Solutions mentioned in the Project Guide cannot be met.

2.3.6 Engine speeds and related main data

Engine MAN V28/33D STC

Rated speed	rpm	1,000 (1,032)[1]
Permissible range of the speed		[2) 3)]
Clutch[4] Minimum engine speed for activation (FPP) Minimum engine speed for activation (CPP) Maximum engine speed for activation		 400 [5] 400 [5] 1,000 [6]
Highest engine operating speed		1,000 (1,032)[1]
Alarm overspeed		1,070
Auto shutdown overspeed via control module/alarm		1,100

[1] For engines with ICFN power definition (Navy load profile) as described in section Power definition and load profile, Page 31.

[2] According, see section STC operating range for mechanical propulsion (FPP, water jet, CPP), Page 48.

[3] In rare occasions it might be necessary that certain engine speed intervals have to be barred for continuous operation. For FPP applications as well as for applications using resilient mounted engines, the admissible engine speed range has to be confirmed (preferably at an early project phase) by a torsional vibration calculation, by a dimensioning of the resilient mounting, and, if necessary, by an engine operational vibration calculation.

[4] Engagement of clutch needs to be finished latest in 5 minutes, to minimize engine operation time without load at high speed.

[5] Dependent also on clutch in load.

[6] May possibly be restricted by manufacturer of clutch. Nominal speed for activation of clutch only allowed for necessity of switching a 2nd engine to an already driven shaft. After activation of clutch in accordance to Project Guide engine load to be increased instantly for a homogenous load distribution between these engines.

Table 10: Speeds

2.3.7 Speed adjusting range

The following specification represents the standard settings. For special applications, deviating settings may be necessary.

	Drive	Speed droop	Maximum speed at full load	Maximum speed at idle running	Minimum speed
Electronic speed control	1 main engine with controllable pitch propeller and without power take off (PTO)	0 %	100 % (+0.5 %)	100 % (+0.5 %)	40 %

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	Drive	Speed droop	Maximum speed at full load	Maximum speed at idle running	Minimum speed
	1 main engine with controllable pitch propeller and with PTO	0 %	100 % (+0.5 %)	100 % (+0.5 %)	40 %
	Fixed pitch propeller plants	0 %	100 % (+0.5 %)	-	30 %
	Parallel operation of 2 engines driving 1 shaft with/without PTO (CPP):				
	Conventional	5 %	100 % (+0.5 %)	105 % (+0.5 %)	40 %
	or				
	master/slave operation	0 %	100 % (+0.5 %)	100 % (+0.5 %)	40 %
	Fixed pitch propeller plants	0 %	100 % (+0.5 %)	-	30 %

Table 11: Electronic speed control

Note:
For single-engine plants with fixed pitch propeller, the speed droop is of no significance.
Only if several engines drive one shaft with fixed pitch propeller, the speed droop is relevant for the load distribution. In the case of electronic speed control, a speed droop of 0 % is also possible during parallel operation.

2.4 Increased exhaust gas pressure due to exhaust gas after treatment installations

Resulting installation demands

If the recommended exhaust gas back pressure as stated in section Operating/service temperatures and pressures, Page 72 cannot be met due to exhaust gas after treatment installations following limit values need to be considered.

Exhaust gas back pressure after turbocharger	
Operating pressure Δp_{exh}, maximum specified	0 – 50 mbar
Operating pressure Δp_{exh}, range with increase of fuel consumption or possible derating	50 – 80 mbar
Operating pressure Δp_{exh}, where agreement and feedback of MAN Energy Solutions is required	> 80 mbar

Table 12: Exhaust gas back pressure after turbocharger

Intake air pressure before turbocharger	
Operating pressure Δp_{intake}, standard	0 – –20 mbar
Operating pressure Δp_{intake}, range with increase of fuel consumption or possible derating	–20 – –40 mbar
Operating pressure Δp_{intake}, where agreement and feedback of MAN Energy Solutions is required	< –40 mbar

Table 13: Intake air pressure before turbocharger

Sum of the exhaust gas back pressure after turbocharger and the absolute value of the intake air pressure before turbocharger	
Operating pressure Δp_{exh} + Abs(Δp_{intake}), standard	0 – 70 mbar
Operating pressure Δp_{exh} + Abs(Δp_{intake}), range with increase of fuel consumption or possible derating	70 – 120 mbar
Operating pressure Δp_{exh} + Abs(Δp_{intake}), where agreement and feedback of MAN Energy Solutions is required	> 120 mbar

Table 14: Sum of the exhaust gas back pressure after turbocharger and the absolute value of the intake air pressure before turbocharger

Maximum exhaust gas pressure drop – Layout

- Supplier of equipment in exhaust gas line have to ensure that pressure drop Δp_{exh} over entire exhaust gas piping incl. pipe work, scrubber, boiler, silencer, etc. must stay below stated standard operating pressure at all operating conditions.
- It is recommended to consider an additional 10 mbar for consideration of aging and possible fouling/staining of the components over lifetime.
- A proper dimensioning of the entire flow path including all installed components is advised or even the installation of an exhaust gas blower if necessary.
- At the same time the pressure drop Δp_{intake} in the intake air path must be kept below stated standard operating pressure at all operating conditions and including aging over lifetime.
- For significant overruns in pressure losses even a reduction in the rated power output may become necessary.
- On plant side it must be prepared, that pressure sensors directly after turbine outlet and directly before compressor inlet may be installed to verify above stated figures.

By-pass for emergency operation

- Evaluate if the chosen exhaust gas after treatment installation demands a by-pass for emergency operation.
- For scrubber application, a by-pass is recommended to ensure emergency operation in case that the exhaust gas cannot flow through the scrubber freely.
- The by-pass needs to be dimensioned for the same pressure drop as the main installation that is by-passed – otherwise the engine would operated on a differing operating point with negative influence on the performance, e.g. a lower value of the pressure drop may result in too high turbocharger speeds.

Single streaming per engine recommended/multi-streaming to be evaluated project-specific

- In general each engine must be equipped with a separate exhaust gas line as single streaming installation. This will prevent reciprocal influencing of the engine as e.g. exhaust gas backflow into an engine out of operation or within an engine running at very low load (negative pressure drop over the cylinder can cause exhaust gas back flow into intake manifold during valve overlap).
- In case a multi-streaming solution is realised (i.e. only one combined scrubber for multiple engines) this needs to be stated on early project stage. Hereby air/exhaust gas tight flaps need to be provided to safeguard engines out of operation. A specific layout of e.g. sealing air mass flow will be necessary and also a power management may become ne-

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cessary in order to prevent operation of several engines at very high loads while others are running on extremely low load. A detailed analysis as HAZOP study and risk analysis by the yard becomes mandatory.

Engine to be protected from backflow of media out of exhaust gas after treatment installation

- A backflow of e.g. urea, scrubbing water, condensate or even rain from the exhaust gas after treatment installation towards the engine must be prevented under all operating conditions and circumstances, including engine or equipment shutdown and maintenance/repair work.

Turbine cleaning

- Both wet and dry turbine cleaning must be possible without causing malfunctions or performance deterioration of the exhaust system incl. any installed components such as boiler, scrubber, silencer, etc.

White exhaust plume by water condensation

- When a wet scrubber is in operation, a visible exhaust plume has to be expected under certain conditions. This is not harmful for the environment. However, countermeasures like reheating and/or a demister should be considered to prevent condensed water droplets from leaving the funnel, which would increase visibility of the plume.
- The design of the exhaust system including exhaust gas after treatment installation has to make sure that the exhaust flow has sufficient velocity in order not to sink down directly onboard the vessel or near to the plant. At the same time the exhaust pressure drop must not exceed the limit value.

Vibrations

- There must be a sufficient decoupling of vibrations between engine and exhaust gas system incl. exhaust gas after treatment installation, e.g. by compensators.

2.5 Starting

2.5.1 General remarks

Engine and plant installation need to be in accordance to the below stated requirements and the required starting procedure.

Note:
Statements are relevant for non arctic conditions.
For arctic conditions consider relevant sections and clarify undefined details with MAN Energy Solutions.

2.5.2 Type of engine start

Normal start

The standard procedure of a monitored engine start in accordance to MAN Energy Solutions guidelines.

Stand-by start

Shortened starting up procedure of a monitored engine start: Several preconditions and additional plant installations required.

This kind of engine start has to be triggered by an external signal: "Stand-by start required”.

Exceptional start (e.g. blackout start)

A monitored engine start (without monitoring of lube oil pressure) within one hour after stop of an engine that has been faultless in operation or of an engine in stand-by mode.

This kind of engine start has to be triggered by an external signal “Black Start” and may only be used in exceptional cases.

Emergency start

Manual start of the engine at emergency start valve at the engine (if applied), without supervision by the SaCoS engine control. These engine starts will be applied only in emergency cases, in which the customer accepts, that the engine might be harmed.

2.5.3 Requirements on engine and plant installation

As stated in section Engine equipment for various applications, Page 27 the MAN V28/33D STC in general is equipped with attached lubrication pump, HT- and LT cooling water pump, seawater pump and fuel oil supply pump.

Additional plant installation requirements

As a standard and for start-up in normal starting mode (preheated engine) following installations are required:

- Prelubrication pump (free-standing)
- Preheating HT cooling water system (40 – 68 °C)
- Preheating lube oil system in case of stand-by operation and if minimum temperature +20 °C of lube oil can not be kept (40 °C – 55 °C), see accordingly section External lube oil system, Page 167

Additional plant installation requirements for "Stand-by Operation" capability

To enable in addition to the normal starting mode also an engine start from PMS (Power Management System) from stand-by mode with thereby shortened start-up time following installations are required:

- Prelubrication pump (free-standing) with low pressure before engine (0.3 bar < $p_{\text{Oil before engine}}$ < 0.6 bar)
- Preheating HT cooling water system (40 – 68 °C)
- Preheating lube oil system (40 °C – 55 °C), see accordingly section External lube oil system, Page 167
- Power management system with supervision of stand-by times engines

Additional plant installation requirements for "Blackout start" capability

As the MAN V28/33D STC is equipped with all required attached pumps on plant side only following item needs to be considered:

- Regarding "Blackout start" fuel oil conditions, see table Fuel, Page 74.

2.5.4 Starting conditions

Type of engine start:	Blackout start	Stand-by start	Normal start
Explanation:	**After blackout**	**From stand-by mode**	**After stand-still**
Start-up time until load application:	**< 1 minute**	**< 1 minute**	**> 2 minutes**
General notes			
-	Engine start-up only within 1 h after stop of engine that has been faultless in operation or within 1 h after end of stand-by mode.	Maximum stand-by time 7 days[1]. Supervised by power management system plant. Stand-by mode is only possible after engine has been faultless in operation and has been faultless stopped.	Standard
Additional external signal:	Blackout start	Stand-by request	-
[1] If an engine has been in total for 7 days in stand-by mode, no extension of stand-by mode is allowed. The engine needs to be started and operated faultless before the next stand-by mode can be applied.			

Table 15: Starting conditions – General notes

Type of engine start:	Blackout start	Stand-by start	Normal start
General engine status	No start-blocking active	Engine in proper condition No start-blocking active Note: Start-blocking of engine leads to withdraw of "stand-by mode".	Engine in proper condition No start-blocking active
Engine to be turned before start?	No[1]	Yes	Yes
[1] Valid only, if mentioned above conditions (see table Starting conditions – General notes, Page 39) have been considered. Non-observance endangers the engine or its components.			

Table 16: Starting conditions – Required engine conditions

Type of engine start:	Blackout start	Stand-by start	Normal start
Lube oil system			
Prelubrication period	No[1]	Permanent	Yes, previous to engine start
Prelubrication pressure before engine	-	See section Operating/service temperatures and pressures, Page 72 limits according figure "Prelubrication/postlubrication lube oil pressure (duration > 10 min)"	See section Operating/service temperatures and pressures, Page 72 limits according figure "Prelubrication/postlubrication lube oil pressure (duration ≤ 10 min)"
HT cooling water			
HT cooling water to be preheated?	No[1]	Yes	Yes

Type of engine start:	Blackout start	Stand-by start	Normal start
Fuel system			
For MGO operation	No special preparations required	External fuel system in operation or in operation with starting command to engine.	
[1] Valid only, if mentioned above conditions (see table Starting conditions – General notes, Page 39) have been considered. Non-observance endangers the engine or its components.			

Table 17: Starting conditions – Required system conditions MAN V28/33D STC

2.5.5 Start-up – Definitions and requirements

General remark

Prior to the start-up of the engine it must be ensured that the emergency stop of the engine is working properly. Additionally all required supply systems must be in operation or in stand-by operation.

Start-up – Cold engine

If an engine start has to be activated under cold engine conditions, following requirements have to be fullfilled as a minimum:

- Lube oil temperature +5 °C, HT cooling water temperature ≥ 5 °C.
- The engine is prelubricated. Due to the higher viscosity of the lube oil of a cold engine the prelubrication phase needs to be increased.

Before further use of the engine a warming-up phase is required to reach at least the level of the regular preheating temperatures (lube oil temperature > 20 °C, cooling water temperature > 40 °C).

Note:

- It needs to be proven within plant layout, that lube oil circuit is capable to be operated at stated low lube oil temperature with accordingly high viscosity and high pressures.
- If engine cold start is frequently performed, wear could increase in a long-term perspective.
- “Start-Reliability” under stated cold start conditions is reduced and cannot be guaranteed, as the probability of a false start is increased.
- If applicable, warming-up phase can be shortened if engine is operated at lower speed.

Start-up – Preheated engine (Normal start)

For the start-up of the engine it needs to be preheated:

- Lube oil temperature ≥ 20 °C.
- HT cooling water temperature ≥ 40 °C.

Start-up – Engine in stand-by mode (Stand-by start)

For engines in stand-by mode no start preparation is needed and accordingly the engine start will be done just after the start request (if preconditions are fulfilled).

Required conditions media system:

- 0.3 bar < prelubrication pressure before engine < 0.6 bar.
- Lube oil temperature ≥ 40 °C, see accordingly section External lube oil system, Page 167
- HT cooling water temperature ≥ 40 °C

Start-up (Exceptional start)

The engine start will be done just after the start request – but as previously stated without monitoring of lube oil pressure, and therefore this may only be used in exceptional cases.

2.6 Low-load operation

Definition

Basically, the following load conditions are distinguished:

Overload:	> 100 % (MCR) of the engine output (not admitted, see section Engine ratings (output) for different applications, Page 32)
Full load (MCR):	100 % (MCR) of the engine output
Part load:	< 100 % (MCR) of the engine output
Low load:	< 25 % of the engine output

Correlations

The best operating conditions for the engine prevail under even loading in the range of 60 % to 90 % of full load.

During idling or engine operation at a low load, combustion in the combustion chamber is incomplete.

This may result in the forming of deposits in the combustion chamber, which will lead to increased soot emission and to increasing cylinder contamination.

There are no restrictions at loads > 15 % of the full load, provided that the specified engine operating values are not exceeded.

2.6.1 Low-load operation MAN V28/33D STC

Sequential Turbocharging (STC) allows to operate the engine for extended periods in low-load operation.

Figure Time limitation for low-load operation (navy and ferry application), Page 41 shows time-limited areas for low-load operation.

Range II: Operating range which is temporarily admissible e.g. during acceleration and manoeuvring.

After a phase of 12 respectively 48 hours in low-load operation, the load must be increased up to 70 % of full load for 15 to 20 minutes.

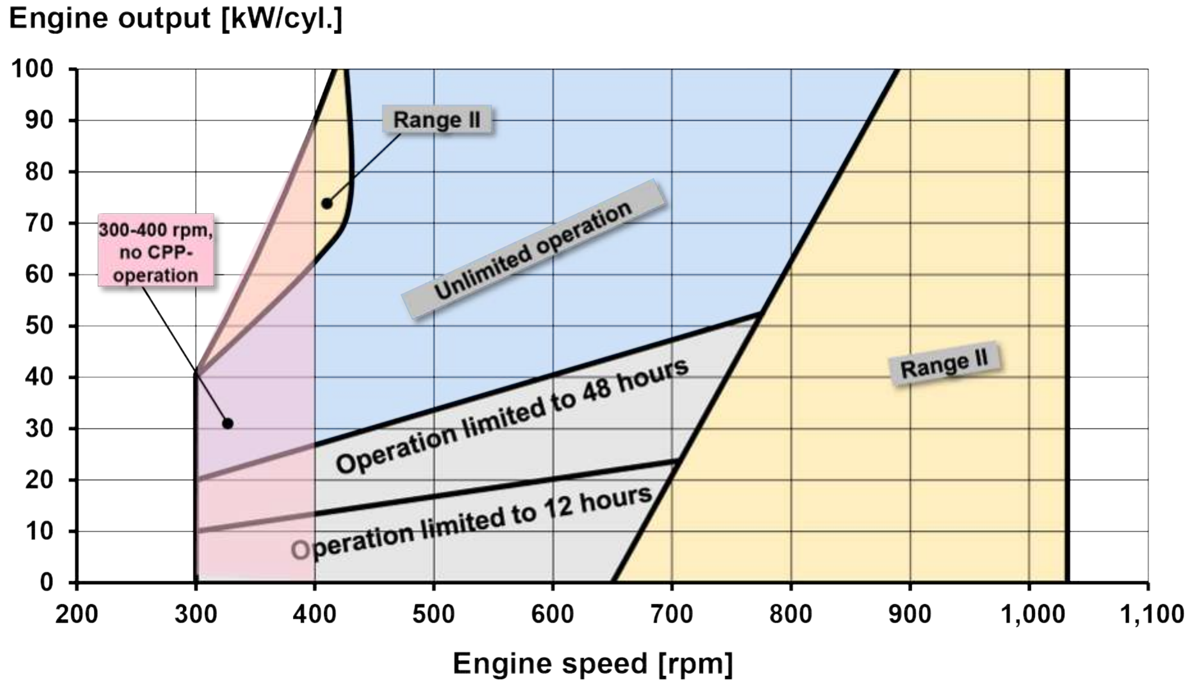

Figure 17: Time limitation for low-load operation (navy and ferry application)

2.7 Engine load reduction as a protective safety measure

Requirements for the power management system/propeller control

In case of a load reduction request due to predefined abnormal engine parameter (e.g. high exhaust gas temperature, high turbine speed, high lube oil temperature) the power output (load) must be ramped down as fast as possible to ≤ 60 % load.

Therefore the power management system/propeller control has to meet the following requirements:

- After a maximum of 5 seconds after occurrence of the load reduction signal, the engine load must be reduced by at least 5 %.
- Then, within the next time period of maximum 30 sec an additional reduction of engine load by at least 35 % needs to be applied.
- The “Prohibited range” shown in figure Engine load reduction as a protective safety measure, Page 43 has to be avoided.

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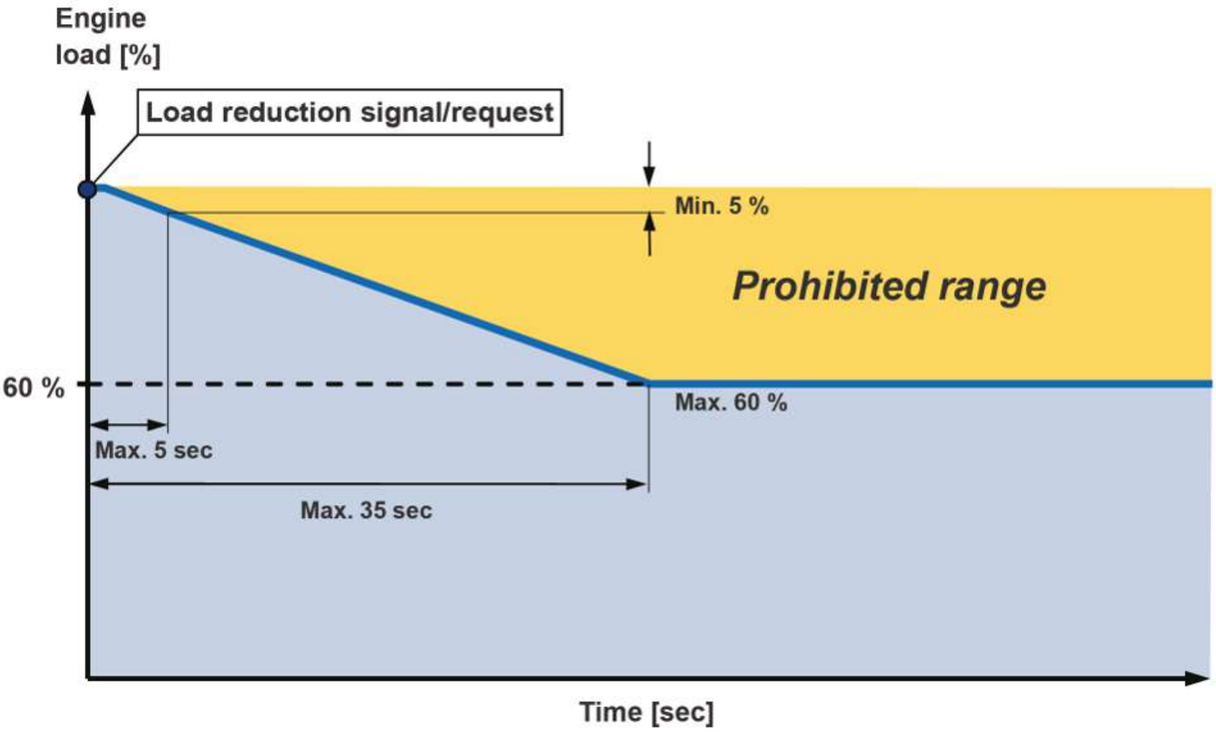

Figure 18: Engine load reduction as a protective safety measure

2.8 Engine operation under arctic conditions

Arctic condition is defined as:

Air intake temperatures of the engine below 0 °C.

If engines operate under arctic conditions (intermittently or permanently), the engine equipment and plant installation have to hold certain design features and meet special requirements. They depend on the possible minimum air intake temperature of the engine and the specification of the fuel used.

Minimum air intake temperature of the engine, t_x:

- Category 1

  0 °C > t_x > –15 °C

- Category 2

  –15 °C ≥ t_x > –50 °C

Special engine design requirements

Special engine equipment required for arctic conditions category 1 and category 2, see section Engine equipment for various applications, Page 27.

Engine equipment

SaCoSone

- SaCoSone equipment is suitable to be stored at minimum ambient temperatures of –15 °C.
- In case these conditions cannot be met, protective measures against climatic influences have to be taken for the following electronic components:
  - EDS Databox APC620

- TFT-touchscreen
- Emergency switch module BD5937

These components have to be stored at places, where the temperature is above −15 °C.

- A minimum operating temperature of ≥ −10 °C has to be ensured. The use of an optional electric heating is recommended.

Plant installation

Engine intake air conditioning

- Cooling down of engine room due to cold ambient air can be avoided by supplying the engine directly from outside with combustion air. For this the combustion air must be filtered (see quality requirements in section Specification of intake air (combustion air), Page 147). Moreover a droplet separator and air intake silencer become necessary, see section Intake air ducting in case of arctic conditions, Page 200. According to classification rules it may be required to install two air inlets from the exterior, one at starboard and one at portside.
- Cold intake air from outside is preheated in front of the cylinders in the charge air cooler. HT water serves as heat source. Depending on load and air temperature additional heat has then to be transferred to the HT circuit by a HT preheating module.
- It is necessary to ensure that the charge air cooler cannot freeze when the engine is out of operation (and the cold air is at the air inlet side). HT cooling water preheating will prevent this. Additionally it is recommended to prepare the combustion air duct upstream of the engine for the installation of a blanking plate, necessary to be installed in case of malfunction on the HT cooling water preheating system.

Category 1

- Charge air blow-off is activated at high engine load with low combustion air temperature. With a blow-off air duct installed in the plant, it can be recirculated in the combustion air duct upstream of the engine. Alternatively, only if blow-off air is deviated downstream of the charge air coolers and is cold (depending on engine type), blow-off air can be directly released in the engine room. Then a blow-off air silencer installed in the plant becomes necessary.
- Alternatively engine combustion air and engine room ventilation air can be supplied together in the engine room, if heated adequately and if accepted by the classification company.

Category 2

- Please contact MAN Energy Solutions.

Instruction for minimum admissible fuel temperature

- In general the minimum viscosity before engine of 1.5 cSt must not be undershoot.
- The fuel specific characteristic values “pour point” and “cold filter plugging point” have to be observed to ensure pumpability respectively filterability of the fuel oil.
- Fuel temperatures of ≤ −10 °C are to be avoided, due to temporarily embrittlement of seals used in the engines fuel oil system. As a result they may suffer a loss of function.

Minimum engine room temperature

- Ventilation of engine room.

  The air of the engine room ventilation must not be too cold (preheating is necessary) to avoid the freezing of the liquids in the engine room systems.
- Minimum power house/engine room temperature for design ≥ +5 °C.

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Coolant and lube oil systems

- Coolant and lube oil system have to be preheated for each individual engine, see section Starting conditions, Page 39.

  See also the specific information regarding special arrangements for arctic conditions, see section Lube oil system, Page 163 and Water systems, Page 176.
- Design requirements for the external preheater of HT cooling water systems according to stated preheater sizes, see figure Required preheater size to avoid heat extraction from HT system, Page 45.
- Maximum permissible antifreeze concentration (ethylene glycol) in the engine cooling water.

  An increasing proportion of antifreeze decreases the specific heat capacity of the engine cooling water, which worsens the heat dissipation from the engine and will lead to higher component temperatures.
- If antifreeze agents must be used, consult MAN Energy Solutions beforehand. Antifreeze agents reduce the capacity of the coolant to absorb heat. In some cases the cooling effect of the coolant may be insufficient.
- For information regarding engine cooling water see section Specification for engine supplies, Page 135.

Insulation

The design of the insulation of the piping systems and other plant parts (tanks, heat exchanger etc.) has to be modified and designed for the special requirements of arctic conditions.

Heat tracing

To support the restart procedures in cold condition (e. g. after unmanned survival mode during winter), it is recommended to install a heat tracing system in the pipelines to the engine.

Note:
A preheating of the lube oil has to be ensured. If the plant is not equipped with a lube oil separator (e.g. plants only operating on MGO) alternative equipment for preheating of the lube oil must be provided.

For plants taken out of operation and cooled down below temperatures of +5 °C additional special measures are needed – in this case please contact MAN Energy Solutions.

Heat extraction HT system and preheater sizes

After engine start, it is necessary to ramp up the engine to the below specified Range II to prevent too high heat loss and resulting risk of engine damage.

Thereby Range I must be passed as quick as possible to reach Range II. Be aware that within Range II low-load operation restrictions may apply.

If operation within Range I is required, the preheater size within the plant must be capable to preheat the intake air to the level, where heat extraction from the HT system is not longer possible.

Example 1:

- Operation at 20 % engine load and –45 °C intake air temperature wanted.
- Preheating of intake air from –45 °C up to minimum –16.5 °C required.
  => According diagram preheater size of 9 kW/cyl. required.
- Ensure that this preheater size is installed, otherwise this operation point is not permissible.

All preheaters need to be operated in parallel to engine operation until minimum engine load is reached.

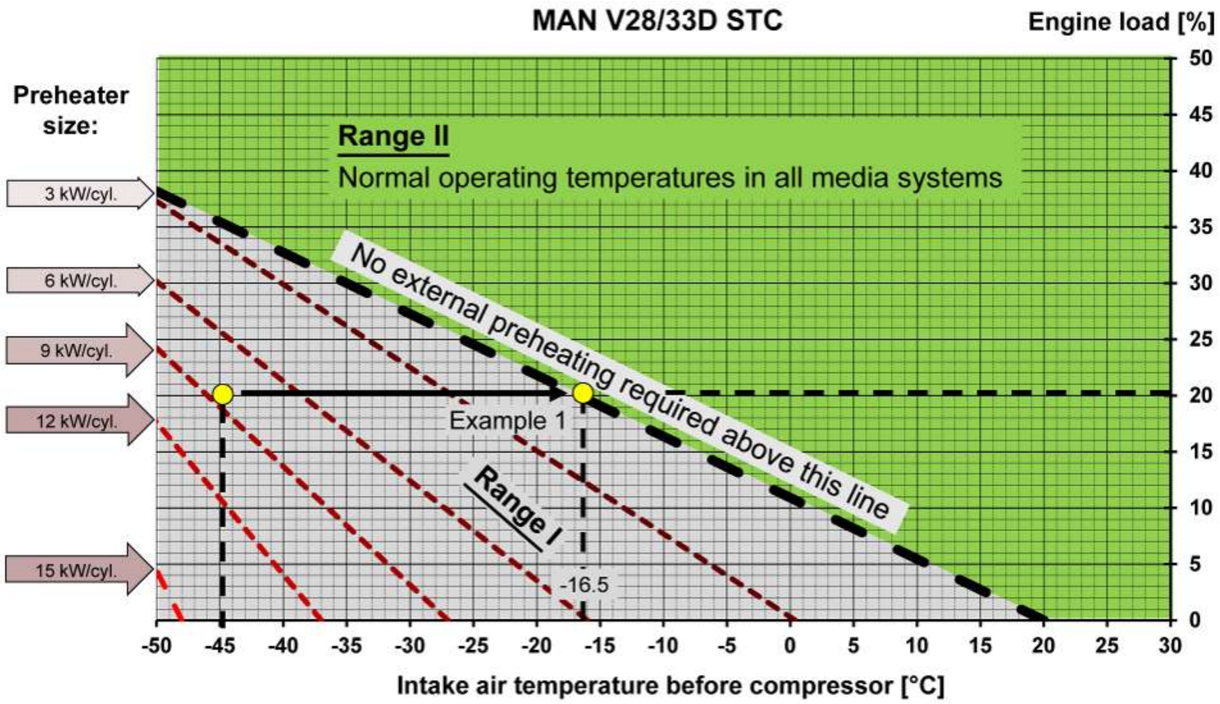

Figure 19: Required preheater size to avoid heat extraction from HT system

2.9 Earthing measures of diesel engines

General

The use of electrical equipment on diesel engines requires precautions to be taken for protection against shock current and for equipotential bonding. These measures not only serve as shock protection but also for functional protection of electric and electronic devices (EMC protection, device protection in case of welding, etc.).

Earthing connections on the engine

Threaded bores M12, 17 mm deep, marked with the earthing symbol are provided in the engine foot on both ends of the engine.

It has to be ensured that earthing is carried out immediately after engine set-up. If this cannot be accomplished any other way, at least provisional earthing is to be effected right after engine set-up.

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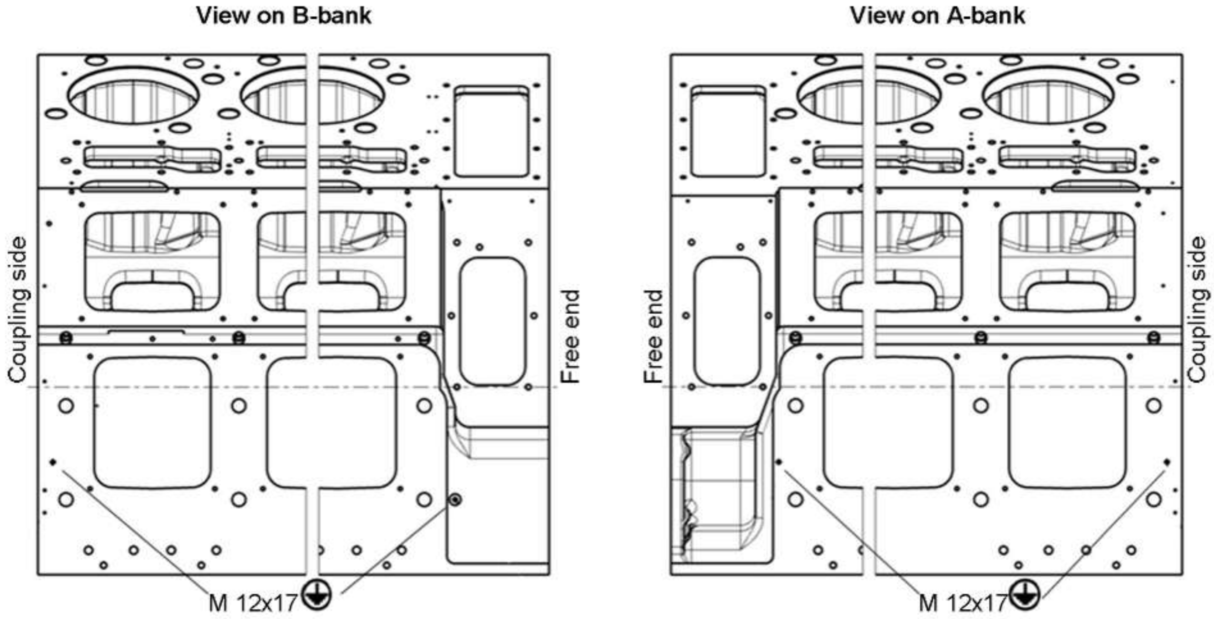

Figure 20: Earthing connection on engine

Earthing conductor

The nominal cross section of the earthing conductor (equipotential bonding conductor) has to be selected in accordance with DIN VDE 0100, part 540 (up to 1 kV) or DIN VDE 0141 (in excess of 1 kV).

Generally, the following applies:

The protective conductor to be assigned to the largest main conductor is to be taken as a basis for sizing the cross sections of the equipotential bonding conductors.

Flexible conductors have to be used for the connection of resiliently mounted engines.

Execution of earthing

The earthing must be executed by the shipyard, since generally it is not scope of supply of MAN Energy Solutions.

Earthing strips are also not included in the MAN Energy Solutions scope of supply.

Additional information regarding the use of welding equipment

In order to prevent damage on electrical components, it is imperative to earth welding equipment close to the welding area, i.e., the distance between the welding electrode and the earthing connection should not exceed 10 m.

2.10 Propeller operation

2.10.1 STC operating range for mechanical propulsion (FPP, water jet, CPP)

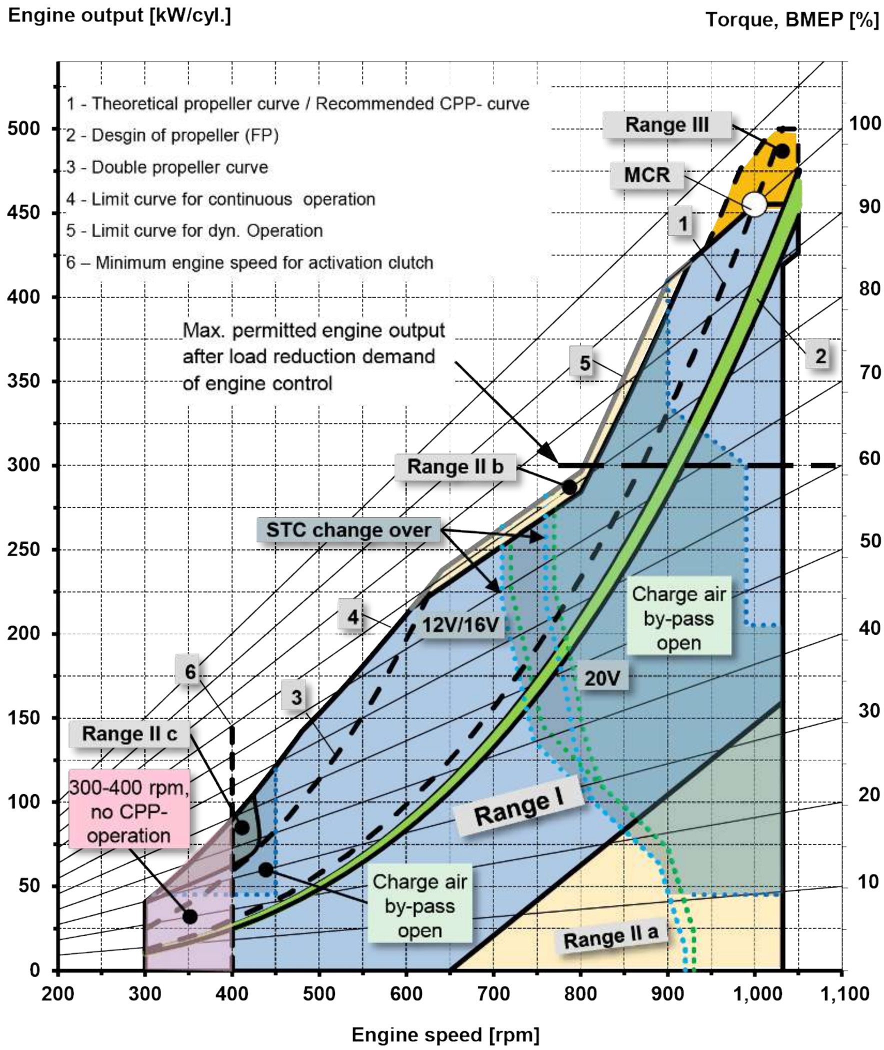

Figure 21: STC operating range for mechanical propulsion (FPP, water jet, CPP)

Note:
In rare occasions it might be necessary that certain engine speed intervals have to be barred for continuous operation.
For FPP applications as well as for applications using resilient mounted engines, the admissible engine speed range has to be confirmed (preferably at an early project phase) by a torsional vibration calculation, by a dimensioning of the resilient mounting, and, if necessary, by an engine operational vibration calculation.

MCR = Maximum continuous rating.

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Operating ranges

Range I: Operating range for continuous operation.

Note:

Operation at higher power or lower speed than limited by the "limit curve for continuous operation" is only permitted for less than 1 minute.

Range II: Operating range which is temporarily (less than 1 minute) admissible e.g. during acceleration and manoeuvring (II a, II b and II c).

Range III: For engines with ICFN power definition ("Navy" load profile) as described in section Power definition and load profile, Page 31.

Recommendation for manoeuvring

- For fast load response during manoeuvring we recommend to use left side of range I, before change from one TC to both TC (300 rpm up to max. 700 rpm)
- For CPP power trains with manoeuvring power requirements up to nominal power we recommend nominal speed operation

Design of propeller (FPP)

A new propeller must be designed to be operated within this range (2). Boundary conditions for the design are clean hull, calm weather, propeller light running inter alia.

The propeller design depends on type and application of the vessel. Therefore the determination of the installed propulsive power in the ship is always the exclusive responsibility of the yard. Determining the engine power: The energy demand or the energy losses from all at the engine additionally attached aggregates has to be considered (e.g. shaft alternators, gearboxes). That means, after deduction of their energy demand from the engine power the remaining engine power must be sufficient for the required propulsion power.

Design of water jet propulsion

A water jet propulsion must be designed such:

- Engine power of 455 kW/cyl. is reached in the range of 1,000 rpm to 1,050 rpm
- When taking into account the water jet propulsion tolerance with respect to rpm at 100 % output, both the minimum and maximum rpm at 100 % output are within the range of 1,000 rpm to 1,050 rpm (e.g. 100 % output is reached at 1,015 rpm, and water jet propulsion tolerance is ±15 rpm, then minimum rpm for 100 % load is 1,000 rpm, maximum is 1,030 rpm)

Preferably, the minimum rpm is 1,000 rpm. This contributes to low SFOC of the engine.

Determining the engine power

The energy demand or the energy losses from all aggregates additionally attached to engine have to be considered (e.g. shaft alternators, gearboxes).

After deduction of their energy demand from the engine power, the remaining engine power must be sufficient for the required propulsion power.

IMO certification for MAN V28/33D STC engines with operating range for fixed pitch propeller (FPP), water jet propulsion

Test cycle type E3 will be applied for the engine´s certification for compliance with the NO_x limits according to NO_x technical code.

IMO certification for MAN V28/33D STC engines with operating range for controllable pitch propeller (CPP)

Test cycle type E2 will be applied for the engine´s certification for compliance with the NO_x limits according to NO_x technical code.

STC

The specific performances of turbocharged diesel engines have been continuously increased, mainly through higher boost air pressures delivered by the turbochargers.

This has been accompanied by increased difficulties to match the turbochargers performance to the reciprocating engine needs at all running conditions between idle and full load. In fact, when the turbochargers are well matched at nominal speed and power, the turbine area becomes too large to make best use of the exhaust gas energy at reduced engine speeds.

Then, the amount of air required to properly burn the fuel is limited, resulting in a poor engine torque ability and degraded combustion with detrimental consequences on fuel consumption, smoke emissions, combustion and exhaust gas temperatures.

This problem can be nicely solved by the use of STC (sequential turbocharging) based on the principle of reducing the number of turbochargers in operation as the engine speed and load are dropped. Thus, the speed of the turbochargers remaining in operation is increased, resulting in significant larger air quantities delivered to the engine.

MAN Energy Solutions has applied this idea to the MAN V28/33D STC engine in a very simple way using only two turbochargers, one of them being switched off at lower engine loads.

The turbocharger arrangement is shown in figure Overview flaps, Page 28.

2.10.2 General requirements for the CPP propulsion control

Pitch control of the propeller plant

General

A distinction between constant-speed operation and combinator-curve operation has to be ensured.

Failure of propeller pitch control:

In order to avoid overloading of the engine upon failure of the propeller pitch control, the propeller pitch must be adjusted to a value, so that the resulting FPP-curve is covered by the allowed area for continuous operation within the operating diagram.

4 – 20 mA load indication from engine control

As a load indication a 4 – 20 mA signal from the engine control is supplied to the propeller control.

Combinator-curve operation:

The 4 – 20 mA signal has to be used for the assignment of the propeller pitch to the respective engine speed. The operation curve of engine speed and propeller pitch (for power range, see section STC operating range for mechanical propulsion (FPP, waterjet, CPP), Page 48) has to be observed also during acceleration/load increase and unloading.

Acceleration/load increase

The engine speed has to be increased prior to increasing the propeller pitch (see figure Example to illustrate the change from one load step to another, Page 52).

When increasing propeller pitch and engine speed synchronously, the speed has to be increased faster than the propeller pitch.

Automatic limitation of the rate of load increase must be implemented in the propulsion control.

Deceleration/unloading the engine

The engine speed has to be reduced later than the propeller pitch (see figure Example to illustrate the change from one load step to another, Page 52).

When decreasing propeller pitch and engine speed synchronously, the propeller pitch has to be decreased faster than the speed.

Example to illustrate the change from one load step to another

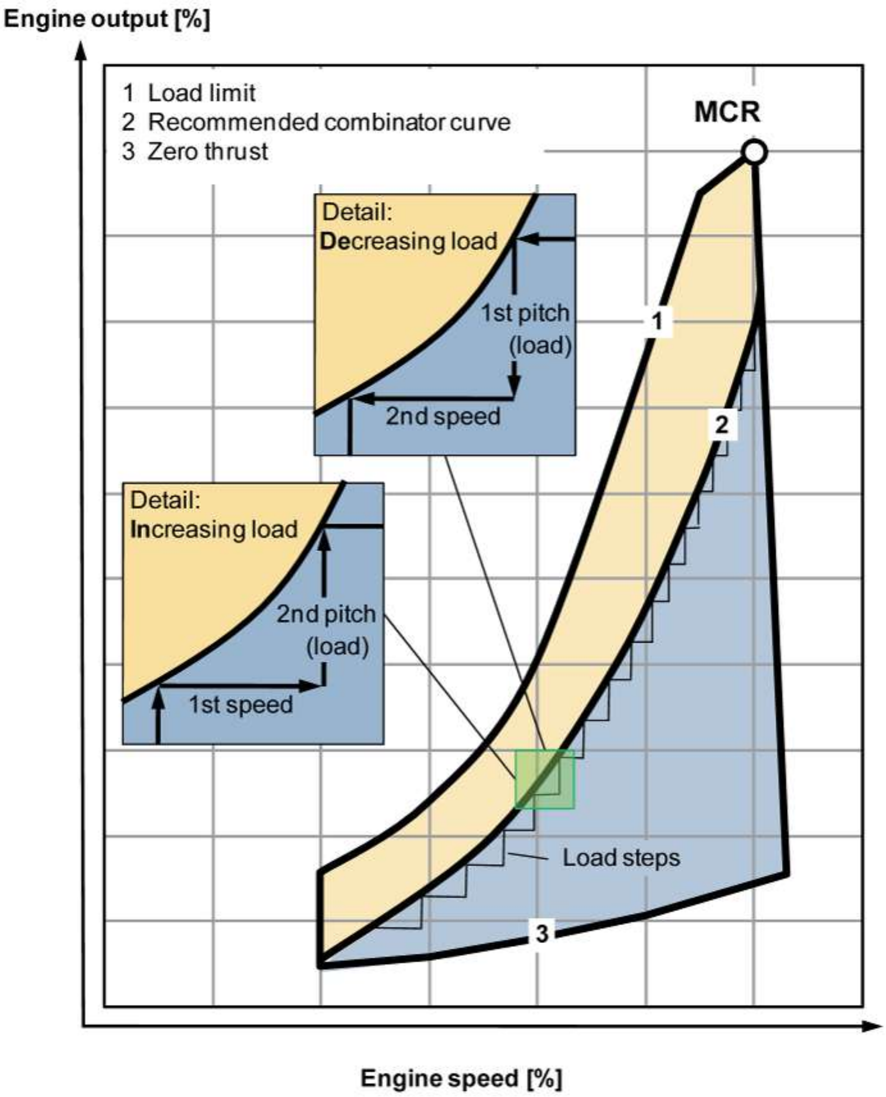

Figure 22: Example to illustrate the change from one load step to another

Windmilling protection

If a stopped engine (fuel admission at zero) is being turned by the propeller, this is called “windmilling”. The permissible period for windmilling is short, because windmilling can cause excessive wear of the engine bearings, due to poor lubrication at low propeller speed.

Single-screw ship

The propeller control has to ensure that the windmilling time is less than 40 sec.

Multiple-screw ship

The propeller control has to ensure that the windmilling time is less than 40 sec. In case of plants without shifting clutch, it has to be ensured that a stopped engine cannot be turned by the propeller.

For maintenance work a shaft interlock has to be provided for each propeller shaft.

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Binary signals from engine control

Overload contact

The overload contact will be activated when the engine's fuel admission reaches the maximum position. At this position, the control system has to stop the increase of the propeller pitch. If this signal remains longer than the predetermined time limit, the propeller pitch has to be decreased.

Contact "Operation close to the limit curve"

This contact is activated when the engine is operated close to a limit curve (torque limiter, charge air pressure limiter, etc.). When the contact is activated, the control system has to stop the increase of the propeller pitch. If this signal remains longer than the predetermined time limit, the propeller pitch has to be decreased.

Propeller pitch reduction contact

This contact is activated when disturbances in engine operation occur, for example too high exhaust gas mean-value deviation. When the contact is activated, the propeller control system has to reduce the propeller pitch to 60 % of the rated engine output, without change in engine speed.

In section Engine load reduction as a protective safety measure, Page 42 the requirements for the response time are stated.

Distinction between normal manoeuvre and emergency manoeuvre

The propeller control system has to be able to distinguish between normal manoeuvre and emergency manoeuvre (i.e., two different acceleration curves are necessary).

MAN Energy Solutions' guidelines concerning acceleration times and power range have to be observed

The power range (see section STC operating range for mechanical propulsion (FPP, waterjet, CPP), Page 48) and the acceleration times (see section Load application for mechanical propulsion (FPP and CPP), Page 54 and figure Control lever setting and corresponding engine specific acceleration times (for guidance), Page 56 have to be observed.

In section Engine load reduction as a protective safety measure, Page 42 the requirements for the response time are stated.

2.10.3 General requirements for the FPP propulsion control

In accordance to IACS “Requirements concerning MACHINERY INSTALLATIONS”, M43, a single control device for each independent propeller has to be provided, with automatic performance preventing overload and prolonged running in critical speed ranges of the propelling machinery.

Operation of the engine according to the stated FPP operating range has to be ensured.

Load control of the propeller plant

As a load indication a 4 – 20 mA signal from the engines safety and control system is supplied to the propeller control system.

Windmilling protection

If a stopped engine (fuel admission at zero) is being turned by the propeller, this is called “windmilling”. The permissible period for windmilling is short, because windmilling can cause, due to poor lubrication at low propeller speed, excessive wear of the engine bearings.

In case of risk that windmilling can appear for a longer period than 40 sec, the engine has to be protected by opening the clutch of the gearbox or/and a shaft breaking system activation at the propeller shaft by the propulsion control system.

For maintenance work a shaft interlock has to be provided for each propeller shaft.

Binary signals from engine control (SaCoS)

Overload contact

The overload contact will be activated when the fuel admission reaches the maximum position.

The propeller control has to reduce the rpm setpoint until contact will be deactivated again.

Reduction contact

This contact is activated when disturbances in engine operation occur, for example too high exhaust gas mean-value deviation. When the contact is activated, the propeller control system has to reduce the output demand to below 60 % of the nominal output of the engine.

In section Engine load reduction as a protective safety measure, Page 42 the requirements for the response time are stated.

Operation close to the limit curves

This contact is activated when the engine is operated close to a limit curve (torque limiter, charge air pressure limiter...). When the contact is activated, the propeller control system has to pause with an increase of a load demand. In case the signal remains longer than the predetermined time limit, the output demand needs to be reduced.

Binary signals to engine control (SaCoS) from ECR or bridge

Override (binary signal by switch)

In case “Override” has been activated, “Stop” or “Reduce” demands of engine safety system will not be excecuted, but printed at the alarm printer.

Binary signals to engine control (SaCoS) from coupling control

Activation of clutch

To enable engine control (SaCoS) to act at the begnning of the clutch-in procedure a binary signal has to be provided.

2.10.4 Load application for mechanical propulsion (FPP and CPP)

Acceleration times for fixed pitch and controllable pitch propeller plants

General remark

Stated acceleration times in the following figure are valid for the engine itself. Depending on the project-specific propulsion train (moments of inertia, vibration calculation etc.) project-specific this may differ. Of course, the acceleration times are not valid for the ship itself, due to the fact, that the time constants for the dynamic behavior of the engine and the vessel may have a ratio of up to 1:100, or even higher (dependent on the type of vessel). The effect on the vessel must be calculated separately.

Propeller control

For remote controlled propeller drives for ships with unmanned or centrally monitored engine room operation in accordance to IACS “Requirements concerning MACHINERY INSTALLATIONS”, M43, a single control device for each independent propeller has to be provided, with automatic performance preventing overload and prolonged running in critical speed ranges of the propelling machinery. Operation of the engine according to the relevant and specific operating range (e.g. Operating range for controllable pitch propeller

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(CPP)) has to be ensured. In case of a manned engine room and manual operation of the propulsion drive, the engine room personnel are responsible for the soft loading sequence, before control is handed over to the bridge.

If the direction of the drive shaft is to be changed during maneuvering (applies in particular to fixed pitch propeller plants) the resulting jolt, the possibility of wind milling and operation in the permitted operating range of the engine needs to be considered. It should be aimed for the lowest possible rotational speed of the propeller shaft, when the rotation direction change is initiated. Already in the project planning and design phase the installation of a shaft brake should be considered.

Load control programme

The lower time limits for normal and emergency manoeuvres are given in our diagrams for application and shedding of load. We strongly recommend that the limits for normal manoeuvring are observed during normal operation. An automatic change-over to a shortened load programme is required for emergency manoeuvres. The final design of the programme should be jointly determined by all the parties involved, considering the demands for manoeuvring and the actual service capacity.

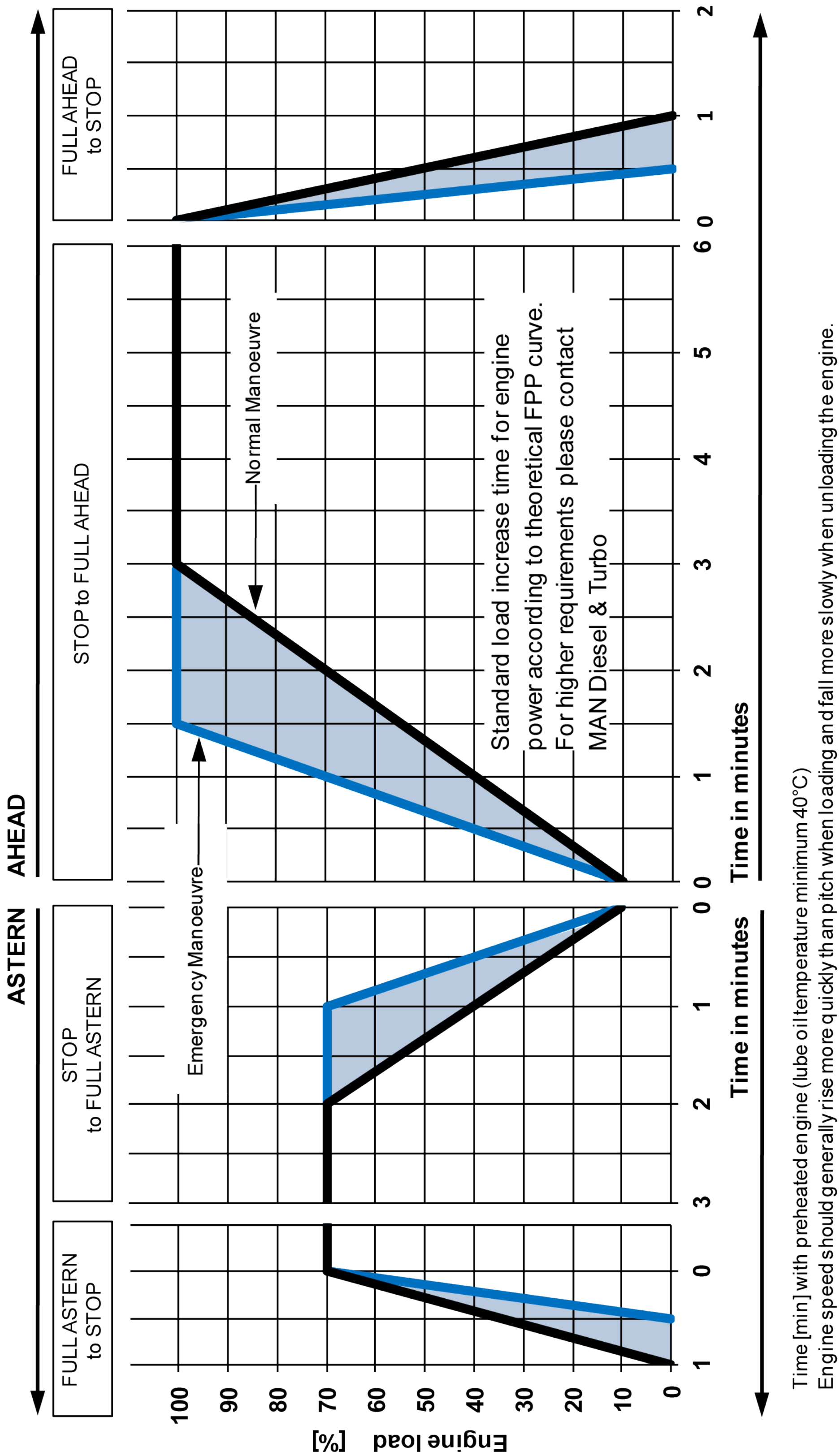

Figure 23: Control lever setting and corresponding engine specific acceleration times (for guidance)

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2.11 Fuel oil, lube oil, starting air and control air consumption

2.11.1 Fuel oil consumption for emission standard: IMO Tier II

Note:

All below stated fuel consumption values are for engines equipped with duplex paper lube oil filter.

Engine MAN V28/33D STC – Mechanical propulsion with controllable pitch propeller (CPP), 455 kW/cyl., (ICN)

455 kW/cyl., 1,000 rpm

% Output	Spec. fuel consumption [g/kWh] with MGO and with all attached pumps[1) 2) 3)]				
	100 [4)]	85	75	50	25
Speed (constant)	1,000 rpm				
MAN 12V28/33D STC	189.0	188.5	195.0	206.0	259.0
MAN 16V/20V28/33D STC	188.0	186.5	193.0	203.0	254.0
Speed (FPP-curve = recommended CPP-curve)	1,000 rpm	947 rpm	910 rpm	800 rpm	630 rpm
MAN 12V28/33D STC	189.0	186.0	187.0	197.0	201.5
MAN 16V/20V28/33D STC	188.0	184.0	185.0	194.0	198.5

1) Tolerance +5 %.

Note: The additions to fuel consumption must be considered before the tolerance for warranty is taken into account.

2) Based on reference conditions, see table Reference conditions for fuel consumption, Page 60.

3) Relevant for engine´s certification for compliance with the NO_x limits according E2 Test cycle.

4) Warranted fuel consumption at 100 % MCR.

Table 18: Fuel consumption – Mechanical propulsion with controllable pitch propeller (CPP)[3)]

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Engine MAN V28/33D STC – Mechanical propulsion with fixed pitch propeller (FPP), 455 kW/cyl., (ICN)

455 kW/cyl., 1,000 rpm

% Output	**Spec. fuel consumption [g/kWh] with MGO and with all attached pumps[1] [2] [3]**				
	100 [4]	**85**	**75**	**50**	**25**
Speed (FPP-curve)	**1,000 rpm**	**947 rpm**	**910 rpm**	**800 rpm**	**630 rpm**
MAN 12V28/33D STC	189.0	186.0	196.0	199.0	201.5
MAN 16V/20V28/33D STC	188.0	183.5	194.0	196.0	198.5

[1] Tolerance +5 %.

Note: The additions to fuel consumption must be considered before the tolerance for warranty is taken into account.

[2] Based on reference conditions, see table Reference conditions for fuel consumption, Page 60.

[3] Relevant for engine´s certification for compliance with the NO_x limits according E3 Test cycle.

[4] Warranted fuel consumption at 100 % MCR.

Table 19: Fuel consumption – Mechanical propulsion with fixed pitch propeller (FPP)[3]

Engine MAN V28/33D STC – Mechanical propulsion with controllable pitch propeller (CPP), "Navy", 500 kW/cyl., (ICFN)

500 kW/cyl., 1,032 rpm (ICFN), constant speed, for test cycle E2

% Output	**Spec. fuel consumption [g/kWh] with MGO and with all attached pumps[1] [2] [3]**			
	100	**75**	**50**	**25**
Output [kW/cyl.][4]	**500 [5]**	**375**	**250**	**125**
Speed [rpm]	**1,032**			
MAN 12V28/33D STC	194.0	198.0	207.0	263.0
MAN 16V/20V28/33D STC	192.0	196.0	204.0	258.0

[1] Tolerance +5 %.

Note: The additions to fuel consumption must be considered before the tolerance for warranty is taken into account.

[2] Based on reference conditions, see table Reference conditions for fuel consumption, Page 60.

[3] Relevant for engine´s certification for compliance with the NO_x limits according E2 Test cycle.

[4] IMO relevant load points.

[5] For engines with ICFN power definition (Navy load profile) as described in section Power definition and load profile, Page 31.

Table 20: Fuel consumption – Mechanical propulsion with controllable pitch propeller (CPP), load profile "Navy"[5], constant speed

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500 kW/cyl., 1,032 rpm (ICFN), FPP curve operation = recommended CPP curve

% Output	Spec. fuel consumption [g/kWh] with MGO and with all attached pumps[1) 2) 3)]					
	100	91 [4)]	85	75	50	25
Output [kW/cyl.]	500 [5)]	455	425	375	250	125
Speed [rpm]	1,032	1,000	978	939	826	650
MAN 12V28/33D STC	194.0	189.0	188.5	189.0	199.0	201.5
MAN 16V/20V28/33D STC	192.0	188.0	186.5	187.0	196.0	198.5

[1)] Tolerance +5 %.

Note: The additions to fuel consumption must be considered before the tolerance for warranty is taken into account.

[2)] Based on reference conditions, see table Reference conditions for fuel consumption, Page 60.

[3)] Relevant for engine´s certification for compliance with the NO_x limits according E2 Test cycle.

[4)] Warranted fuel consumption at MCR, 455 kW/cyl. at 1,000 rpm.

[5)] For engines with ICFN power definition (Navy load profile) as described in section Power definition and load profile, Page 31.

Table 21: Fuel consumption – Mechanical propulsion with controllable pitch propeller (CPP), load profile "Navy"[5)], FPP curve operation = recommended CPP curve

Engine MAN V28/33D STC – Mechanical propulsion with fixed pitch propeller (FPP), "Navy", 500 kW/cyl., (ICFN)

500 kW/cyl., 1,032 rpm (ICFN)

% Output	Spec. fuel consumption [g/kWh] with MGO and with all attached pumps[1) 2) 3)]					
	100	91 [4)]	85	75	50	25
Output [kW/cyl.]	500 [5)]	455	425	375	250	125
Speed [rpm]	1,032	1,000	978	939	826	650
MAN 12V28/33D STC	194.0	189.0	188.5	197.5	201.5	204.0
MAN 16V/20V28/33D STC	192.0	188.0	186.5	195.5	198.5	201.0

[1)] Tolerance +5 %.

Note: The additions to fuel consumption must be considered before the tolerance for warranty is taken into account.

[2)] Based on reference conditions, see table Reference conditions for fuel consumption, Page 60.

[3)] Relevant for engine´s certification for compliance with the NO_x limits according E3 Test cycle.

[4)] Warranted fuel consumption at MCR, 455 kW/cyl. at 1,000 rpm.

[5)] For engines with ICFN power definition (Navy load profile) as described in section Power definition and load profile, Page 31.

Table 22: Fuel consumption – Mechanical propulsion with fixed pitch propeller (FPP), load profile "Navy"[5)]

Additions to fuel consumption (g/kWh)

Additions to fuel consumption (g/kWh)	
For engines equipped with lube oil automatic filter instead of lube oil duplex paper filter	An addition of 0,31 % to be calculated
For engines equipped with PTO	An addition of 0,5 % to be calculated
For exhaust gas back pressure after turbocharger > 50 mbar	Every additional 1 mbar (0.1 kPa) back pressure addition of 0.025 g/kWh to be calculated
In case a charge air blow-off device is installed and activated	Please consult MAN Energy Solutions

Table 23: Additions to fuel consumption

Fuel oil consumption at idle running

Fuel oil consumption at idle running (kg/h)			
No. of cylinders, config.	12V	16V	20V
Speed 400 rpm	21	28	35

Table 24: Fuel oil consumption at idle running

Reference conditions for fuel consumption

According to ISO 15550; ISO 3046-1

Air temperature before turbocharger t_r	K/°C	298/25
Total atmospheric pressure p_r	kPa	100
Relative humidity Φ_r	%	30
Exhaust gas back pressure after turbocharger[1)]	kPa	5
Engine type specific reference charge air temperature before cylinder t_{bar}[2)]	K/°C	313/40
Net calorific value NCV	kJ/kg	42,700

[1)] Measured at 100 % load, accordingly lower for loads < 100 %.

[2)] Specified reference charge air temperature corresponds to a mean value for all cylinder numbers that will be achieved with 25 °C LT cooling water temperature before charge air cooler (according to ISO).

Table 25: Reference conditions for fuel consumption MAN V28/33D STC

IMO Tier II requirements:

For detailed information see section Cooling water system, Page 176.

IMO: International Maritime Organization

MARPOL 73/78; Revised Annex VI-2008, Regulation 13

Tier II: NO_x technical code on control of emission of nitrogen oxides from diesel engines.

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2.11.2 Lube oil consumption

455 kW/cyl. at 1,000 rpm or 500 kW/cyl. at 1,032 rpm

Specific lube oil consumption:

$$0.4\ g/kWh^{1)} \times \frac{100\%}{load\%} \times \frac{455\ kW/cyl.}{nominal\ output\ per\ cyl.}$$

load%	Actual engine load	[%]
nominal output per cyl.	Insert the nominal output per cyl.	[kW/cyl.]

1) The value stated above is without any losses due to cleaning of filter and centrifuge or lube oil charge replacement. Tolerance for warranty +20 %.

Example:

For nominal output 455 kW/cyl. and 100 % actual engine load: 0.40 g/kWh

For nominal output 500 kW/cyl. and 100 % actual engine load: 0.36 g/kWh

2.11.3 Starting air and control air consumption

Starting air consumption

No. of cylinders, config.		12V	16V	20V
Air consumption per start[1)]	Nm^3 [2)]	2.0	2.7	2.7
Reference moment of inertia for stated air consumption figures[1)]	kgm^2	642	856	1,070

1) The stated air consumption values are based on the "Reference moment of inertia" in this table. The air consumption per starting manoeuvre of the unit (e.g. engine plus gear) increases in relation to its total moment of inertia. Please consider also the "Requirement minimum total moments of inertia" as stated within the section Moments of inertia – Crankshaft, damper, flywheel, Page 94.

2) Nm^3 corresponds to one cubic metre of gas at 20 °C and 100.0 kPa abs.

Table 26: Starting air consumption – MAN V28/33D STC

Note:
See also section External compressed air system – Dimensioning starting air receivers, compressors, Page 197.

Control air consumption

	Air consumption [Nm^3][1)]
	Per activation
STC actuators	0.01
Actuator charge air by-pass	0.01
Emergency shut-off valve	0.005

1) Nm^3 corresponds to one cubic metre of gas at 20 °C and 100.0 kPa abs.

Table 27: Control air consumption – MAN V28/33D STC

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2.11.4 Recalculation of fuel consumption dependent on ambient conditions

In accordance to ISO standard ISO 3046-1 "*Reciprocating internal combustion engines – Performance, Part 1: Declarations of power, fuel and lube oil consumptions, and test methods – Additional requirements for engines for general use*" MAN Energy Solutions has specified the method for recalculation of fuel consumption for liquid fuel dependent on ambient conditions for single-stage turbocharged engines as follows:

$\beta = 1 + 0.0006 \times (t_x - t_r) + 0.0004 \times (t_{bax} - t_{bar}) + 0.07 \times (p_r - p_x)$

The formula is valid within the following limits:	
Ambient air temperature	5 °C – 55 °C
Charge air temperature before cylinder	25 °C – 75 °C
Ambient air pressure	0.885 bar – 1.030 bar

Table 28: Limit values for recalculation of liquid fuel consumption

$$b_x = b_r \times \beta \qquad b_r = \frac{b_x}{\beta}$$

β	Fuel consumption factor
t_{bar}	Engine type specific reference charge air temperature before cylinder see table Reference conditions for fuel consumption, Page 60

	Unit	Reference	At test run or at site
Specific fuel consumption	[g/kWh]	b_r	b_x
Ambient air temperature	[°C]	t_r	t_x
Charge air temperature before cylinder	[°C]	t_{bar}	t_{bax}
Ambient air pressure	[bar]	p_r	p_x

Table 29: Recalculation of liquid fuel consumption – Units and references

Example

Reference values:

b_r = 200 g/kWh, t_r = 25 °C, t_{bar} = 40 °C, p_r = 1.0 bar

At site:

t_x = 45 °C, t_{bax} = 50 °C, p_x = 0.9 bar

$\beta = 1 + 0.0006\ (45 - 25) + 0.0004\ (50 - 40) + 0.07\ (1.0 - 0.9) = 1.023$

$b_x = \beta \times b_r = 1.023 \times 200 = 204.6$ g/kWh

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2.11.5 Influence of engine aging on fuel consumption

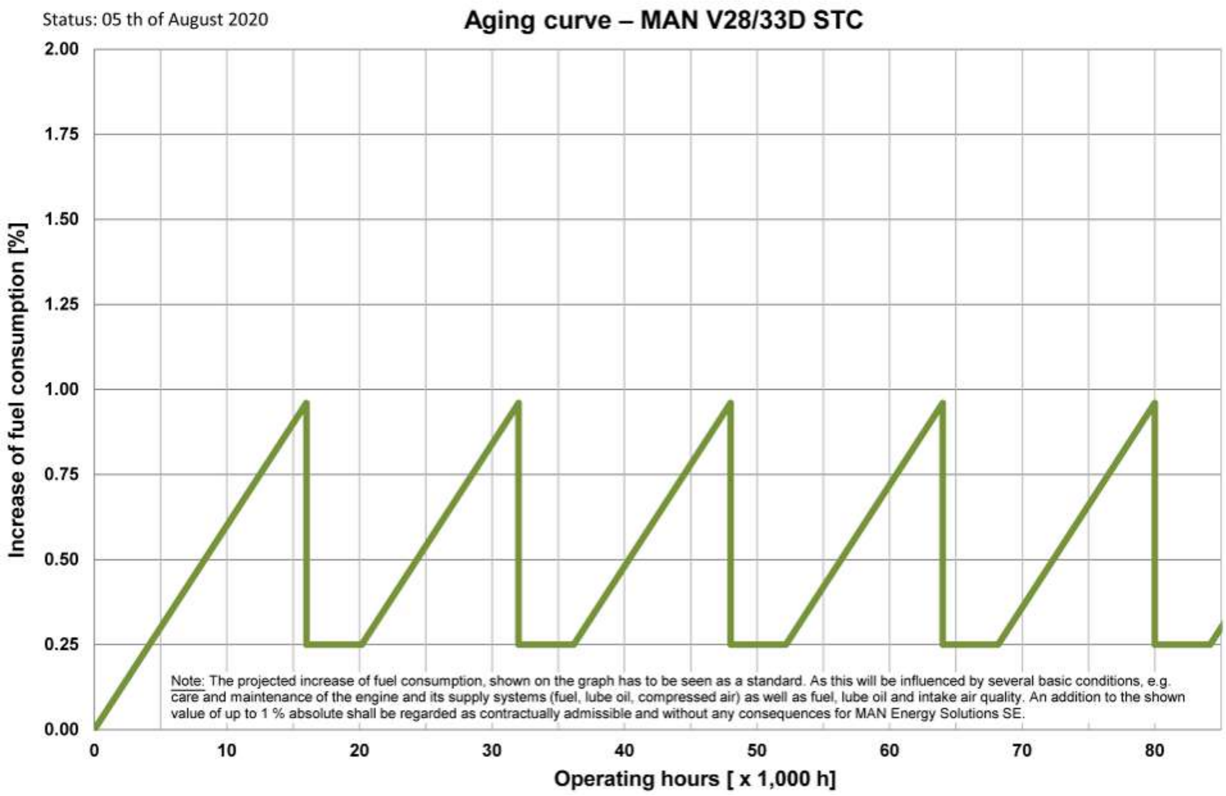

Figure 24: Influence of total engine running time and service intervals on fuel oil consumption

The fuel oil consumption will increase over the running time of the engine. Timely service can reduce or eliminate this increase. For dependencies see figure Influence of total engine running time and service intervals on fuel oil consumption, Page 63.

2.12 Planning data 455 kW/cyl., CPP/FPP, IMO Tier II

2.12.1 Nominal values for cooler specification – 455 kW/cyl., CPP/FPP

MAN V28/33D STC

455 kW/cyl.; 1,000 rpm, mechanical propulsion

Reference conditions: Tropics		
Air temperature	°C	45
Cooling water temp. before charge air cooler (LT stage)		38
Total atmospheric pressure	mbar	1,000
Relative humidity	%	60

Table 30: Reference conditions: Tropics

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No. of cylinders, config.		**12V**	**16V**	**20V**
Engine output	**kW**	**5,460**	**7,280**	**9,100**
Speed	rpm	1,000		
Heat to be dissipated[1]				
HT string: Charge air cooler (HT stage) Jacket cooling	kW	 1,308 919	 1,867 1,221	 2,380 1,513
LT string: Charge air cooler (LT stage) Lube oil cooler		 950 890	 1,164 1,184	 1,474 1,474
Heat radiation (engine, based on engine room temp. 55 °C)		114	152	190
Flow rates[2]				
HT circuit (1. engine/2. charge air cooler HT stage)	m^3/h	130 (130/65)	160 (160/75)	180 (180/75)
LT circuit (1. charge air cooler LT stage/2. lube oil cooler/3. compressor wheel casing cooling)		139 (54/135/4)	184 (108/180/4)	
Lube oil		105	130	155
Seawater		220	290	360
Pumps				
a) Attached pumps				
HT CW service pump at 4 bar, 1,000 rpm	m^3/h	190		
LT CW service pump at 4 bar, 1,000 rpm		190		
Lube oil service pump at 7.5 bar, 1,000 rpm		132	179	220
Fuel supply pump at 6.5 bar, 1,000 rpm		10.8		
Seawater pump at 3.5 bar, 1,000 rpm		300	380	460
b) Free-standing pumps[3]				
HT CW pump (preheating and post-cooling)	m^3/h	15	15	15
Prelubrication pump		16.5 – 19.5	20.5 – 24.5	24.5 – 28.5

[1] Tolerance: +10 % for rating coolers, –15 % for heat recovery.

[2] Basic values for layout of the coolers.

[3] Tolerance of the pump delivery capacities must be considered by the manufacturers.

Table 31: Nominal values for cooler specification – 455 kW/cyl.; 1,000 rpm

Note:
You will find further planning datas for the listed subjects in the corresponding sections.

- Minimal heating power required for preheating HT cooling water see paragraph MOD-004/HT cooling water preheating module, Page 181.

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2.12.2 Temperature basis, nominal air and exhaust gas data – 455 kW/cyl., CPP/FPP

MAN V28/33D STC

455kW/cyl.; 1,000 rpm, mechanic propulsion

Reference conditions: Tropics		
Air temperature	°C	45
Cooling water temp. before charge air cooler (LT stage)		38
Total atmospheric pressure	mbar	1,000
Relative humidity	%	60

Table 32: Reference conditions: Tropics

No. of cylinders, config.		12V	16V	20V
Engine output	**kW**	**5,460**	**7,280**	**9,100**
Speed	rpm	1,000		
Temperature basis				
HT cooling water engine outlet1)	°C	85		
LT cooling water air cooler inlet		38 (setpoint 32 °C)2)		
Lube oil inlet engine		60		
Air data				
Temperature of charge air at charge air cooler outlet	°C	60.8	60.3	59.4
Air flow rate3)	m³/h	32,250	42,900	53,700
	t/h	35.3	47.0	58.8
Charge air pressure (absolute)	bar abs	4.5	4.5	4.5
Air required to dissipate heat radiation (engine) ($t_2 - t_1$ = 10 °C)	m³/h	36,539	48,719	60,899
Exhaust gas data4)				
Volume flow (temperature turbocharger outlet)5)	m³/h	69,600	92,600	115,900
Mass flow	t/h	36.4	48.5	60.7
Temperature at turbine outlet	°C	393	392	392
Heat content (190 °C)	kW	2,233	2,973	3,702
Permissible exhaust gas back pressure	mbar	< 50		

1) HT cooling water flow first through water jacket and cylinder head, then through HT stage charge air cooler.

2) For design see figure External cooling water system diagram, Page 183.

3) Under mentioned above reference conditions.

4) Tolerances: Quantity ±5 %, temperature ±20 °C.

5) Calculated based on stated temperature at turbine outlet and total atmospheric pressure according mentioned above reference conditions.

Table 33: Air and exhaust gas data – 455 kW/cyl.; 1,000 rpm

2.12.3 Load specific values at ISO conditions – 455 kW/cyl., CPP/FPP

MAN V28/33D STC

455 kW/cyl.; 1,000 rpm, mechanical propulsion

Reference conditions: ISO		
Air temperature	°C	25
Cooling water temp. before charge air cooler (LT stage)		25
Total atmospheric pressure	mbar	1,000
Relative humidity	%	30

Table 34: Reference conditions: ISO

Engine output	**%**	**100**	**85**	**75**	**50**
	kW/cyl.	**455**	**387**	**341**	**228**
Speed	rpm	1,000	947	910	800
Heat to be dissipated[1)]					
Cooling water HT (jacket cooling + charge air cooler HT stage)[2)]	kJ/kWh	1,174	1,127	1,188	1,012
Cooling water LT (lube oil cooler + charge air cooler LT stage)[2)]		1,080	1,089	1,145	1,162
Heat radiation		96	109	122	166
Air data					
Temperature of charge air: After compressor At charge air cooler outlet	°C	 224 40.0	 203 40.0	 198 40.0	 143 40.0
Air flow rate	kg/kWh	6.79	7.14	7.72	7.78
Charge air pressure (absolute)	bar abs	4.5	4.0	3.8	2.6
Exhaust gas data[3)]					
Mass flow	kg/kWh	6.99	7.34	7.92	8.00
Temperature at turbine outlet	°C	348	325	329	369
Heat content (190 °C)	kJ/kWh	1,195	1,067	1,185	1,551
Permissible exhaust back pressure	mbar	< 50	-		

[1)] Tolerance: +10 % for rating coolers, –15 % for heat recovery (Tolerance refer to 100 % engine output).

[2)] The values of the particular numbers can differ depending on the charge air cooler specification.

[3)] Tolerances: Quantity ±5 %, temperature ±20 °C (Tolerance refer to 100 % engine output).

Table 35: Load specific values at ISO conditions – 455 kW/cyl.; 1,000 rpm

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2.12.4 Load specific values at tropical conditions – 455 kW/cyl., CPP/FPP

MAN V28/33D STC

455 kW/cyl.; 1,000 rpm, mechanical propulsion

Reference conditions: Tropics		
Air temperature	°C	45
Cooling water temp. before charge air cooler (LT stage)		38
Total atmospheric pressure	mbar	1,000
Relative humidity	%	60

Table 36: Reference conditions: Tropics

Engine output	**%**	**100**	**85**	**75**	**50**
	kW/cyl.	**455**	**387**	**341**	**228**
Speed	rpm	1,000	947	910	800
Heat to be dissipated[1]					
Cooling water HT (jacket cooling + charge air cooler HT stage)[2]	kJ/kWh	1,470	1,408	1,481	1,267
Cooling water LT (lube oil cooler + charge air cooler LT stage)[2]		1,216	1,258	1,330	1,381
Heat radiation		75	85	95	129
Air data					
Temperature of charge air: After compressor At charge air cooler outlet	°C	 256 60.8	 233 57.5	 227 56.2	 166 47.9
Air flow rate	kg/kWh	6.48	6.81	7.36	7.42
Charge air pressure (absolute)	bar abs	4.5	4.0	3.7	2.5
Exhaust gas data[3]					
Mass flow	kg/kWh	6.68	7.01	7.57	7.64
Temperature at turbine outlet	°C	393	366	369	405
Heat content (190 °C)	kJ/kWh	1,475	1,335	1,467	1,792
Permissible exhaust back pressure	mbar	< 50	-		

[1] Tolerance: +10 % for rating coolers, –15 % for heat recovery (Tolerance refers to 100 % engine output).

[2] The values of the particular cylinder numbers can differ depending on the cooler specification.

[3] Tolerances: Quantity ±5 %, temperature ±20 °C (Tolerance refer to 100 % engine output).

Table 37: Load specific values at tropical conditions – 455 kW/cyl.; 1,000 rpm

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2.13 Planning data 500 kW/cyl., CPP/FPP, IMO Tier II

2.13.1 Nominal values for cooler specification – 500 kW/cyl., CPP/FPP

MAN V28/33D STC, load profile "Navy"

500 kW/cyl.; 1,032 rpm, (ICFN), mechanical propulsion

Reference conditions: Tropics		
Air temperature	°C	45
Cooling water temp. before charge air cooler (LT stage)		38
Total atmospheric pressure	mbar	1,000
Relative humidity	%	60

Table 38: Reference conditions: Tropics

No. of cylinders, config.		**12V**	**16V**	**20V**
Engine output	**kW**	**6,000**	**8,000**	**10,000**
Speed	rpm	1,032		
Heat to be dissipated[1)]				
HT string: Charge air cooler (HT stage) Jacket cooling	kW	 1,606 1,094	 2,298 1,452	 2,934 1,800
LT string: Charge air cooler (LT stage) Lube oil cooler		 1,117 951	 1,362 1,266	 1,720 1,576
Heat radiation (engine, based on engine room temp. 55 °C)		113	151	189
Flow rates[2)]				
HT circuit (1. engine/2. charge air cooler HT stage)	m^3/h	134 (134/67)	165 (165/77)	186 (186/77)
LT circuit (1. charge air cooler LT stage/2. lube oil cooler/3. compressor wheel casing cooling)		143 (56/139/4)	190 (112/186/4)	
Lube oil		108	150	200
Seawater		227	300	370
Pumps				
a) Attached pumps				
HT CW service pump at 4 bar, 1,000 rpm	m^3/h	196		
LT CW service pump at 4 bar, 1,000 rpm		196		
Lube oil service pump at 7.5 bar, 1,000 rpm		132	179	220
Fuel supply pump at 6.5 bar		10.8 at 1,000 rpm 11.1 at 1,032 rpm		
Seawater pump at 3.5 bar, 1,000 rpm		300	380	460

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No. of cylinders, config.		12V	16V	20V
Engine output	**kW**	**6,000**	**8,000**	**10,000**
b) Free-standing pumps[3]				
HT CW pump (preheating and post-cooling)	m^3/h	15	15	15
Prelubrication pump		16.5 – 19.5	20.5 – 24.0	24.5 – 28.5
[1] Tolerance: +10 % for rating coolers, –15 % for heat recovery.				
[2] Basic values for layout of the coolers.				
[3] Tolerance of the pump delivery capacities must be considered by the manufacturers.				

Table 39: Nominal values for cooler specification – 500 kW/cyl.; 1,032 rpm

Note:
You will find further planning datas for the listed subjects in the corresponding sections.

- Minimal heating power required for preheating HT cooling water see paragraph MOD-004/HT cooling water preheating module, Page 181.

2.13.2 Temperature basis, nominal air and exhaust gas data – 500 kW/cyl., CPP/FPP

MAN V28/33D STC, load profile "Navy"

500 kW/cyl.; 1,032 rpm (ICFN), mechanic propulsion

Reference conditions: Tropics		
Air temperature	°C	45
Cooling water temp. before charge air cooler (LT stage)		38
Total atmospheric pressure	mbar	1,000
Relative humidity	%	60

Table 40: Reference conditions: Tropics

No. of cylinders, config.		12V	16V	20V
Engine output	**kW**	**6,000**	**8,000**	**10,000**
Speed	rpm	1,032		
Temperature basis				
HT cooling water engine outlet[1]	°C	85		
LT cooling water air cooler inlet		38 (setpoint 32 °C)[2]		
Lube oil inlet engine		60		
Air data				
Temperature of charge air at charge air cooler outlet	°C	64.0	63.5	62.5
Air flow rate[3]	m^3/h	36,050	48,100	60,150
	t/h	39.5	52.7	65.9
Charge air pressure (absolute)	bar abs	4.9	4.9	4.9
Air required to dissipate heat radiation (engine) ($t_2 - t_1$ = 10 °C)	m^3/h	36,539	48,719	60,899
Exhaust gas data[4]				

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No. of cylinders, config.		12V	16V	20V
Engine output	**kW**	**6,000**	**8,000**	**10,000**
Volume flow (temperature turbocharger outlet)[5]	m³/h	77,900	103,850	129,600
Mass flow	t/h	40.8	54.4	68.0
Temperature at turbine outlet	°C	392	392	391
Heat content (190 °C)	kW	2,495	3,318	4,132
Permissible exhaust gas back pressure	mbar	< 50		

[1] HT cooling water flow first through water jacket and cylinder head, then through HT stage charge air cooler.

[2] For design see figure External cooling water system diagram, Page 183.

[3] Under mentioned above reference conditions.

[4] Tolerances: Quantity ±5 %, temperature ±20 °C.

[5] Calculated based on stated temperature at turbine outlet and total atmospheric pressure according mentioned above reference conditions.

Table 41: Air and exhaust gas data – 500 kW/cyl.; 1,032 rpm

2.13.3 Load specific values at ISO conditions – 500 kW/cyl., CPP/FPP

MAN V28/33D STC, load profile "Navy"

500 kW/cyl.; 1,032 rpm (ICFN), mechanical propulsion

Reference conditions: ISO		
Air temperature	°C	25
Cooling water temp. before charge air cooler (LT stage)		25
Total atmospheric pressure	mbar	1,000
Relative humidity	%	30

Table 42: Reference conditions: ISO

Engine output	%		100	85	75	50
	kW/cyl.	**500**	**455**	**387**	**341**	**228**
Speed	rpm	1,032	1,000	947	910	800
Heat to be dissipated[1]						
Cooling water HT (jacket cooling + charge air cooler HT stage)[2]	kJ/kWh	1,292	1,231	1,248	1,232	1,059
Cooling water LT (lube oil cooler + charge air cooler LT stage)[2]		1,141	1,135	1,199	1,192	1,212
Heat radiation		87	97	111	123	168
Air data						
Temperature of charge air: After compressor At charge air cooler outlet	°C	 245 40.0	 230 40.0	 215 40.0	 201 40.0	 145 40.0
Air flow rate	kg/kWh	6.91	7.13	7.90	8.08	8.39
Charge air pressure (absolute)	bar abs	4.9	4.6	4.0	3.9	2.7

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Engine output	%		100	85	75	50
	kW/cyl.	500	455	387	341	228
Exhaust gas data[3]						
Mass flow	kg/kWh	7.11	7.33	8.10	8.29	8.62
Temperature at turbine outlet	°C	345	329	316	318	352
Heat content (190 °C)	kJ/kWh	1,194	1,096	1,093	1,136	1,508
Permissible exhaust back pressure	mbar		< 50	-		
[1] Tolerance: +10 % for rating coolers, −15 % for heat recovery (Tolerance refer to 100 % engine output).						
[2] The values of the particular numbers can differ depending on the charge air cooler specification.						
[3] Tolerances: Quantity ±5 %, temperature ±20 °C (Tolerance refer to 100 % engine output).						

Table 43: Load specific values at ISO conditions – 500 kW/cyl.; 1,032 rpm

2.13.4 Load specific values at tropical conditions – 500 kW/cyl., CPP/FPP

MAN V28/33D STC, load profile "Navy"

500 kW/cyl.; 1,032 rpm (ICFN), mechanical propulsion

Reference conditions: Tropics		
Air temperature	°C	45
Cooling water temp. before charge air cooler (LT stage)		38
Total atmospheric pressure	mbar	1,000
Relative humidity	%	60

Table 44: Reference conditions: Tropics

Engine output	%		100	85	75	50
	kW/cyl.	500	455	387	341	228
Speed	rpm	1,032	1,000	947	910	800
Heat to be dissipated[1]						
Cooling water HT (jacket cooling + charge air cooler HT stage)[2]	kJ/kWh	1,620	1,540	1,561	1,541	1,335
Cooling water LT (lube oil cooler + charge air cooler LT stage)[2]		1,240	1,257	1,350	1,377	1,445
Heat radiation		68	76	86	96	131
Air data						
Temperature of charge air: After compressor At charge air cooler outlet	°C	 279 64.0	 263 62.0	 246 60.0	 230 57.5	 169 49.0
Air flow rate	kg/kWh	6.59	6.79	7.53	7.71	8.01
Charge air pressure (absolute)	bar abs	4.9	4.6	4.3	3.9	2.7

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Engine output	%		100	85	75	50
	kW/cyl.	500	455	387	341	228
Exhaust gas data[3]						
Mass flow	kg/kWh	6.79	7.00	7.74	7.92	8.23
Temperature at turbine outlet	°C	392	373	357	358	388
Heat content (190 °C)	kJ/kWh	1,490	1,382	1,399	1,437	1,771
Permissible exhaust back pressure	mbar	< 50	-			

[1] Tolerance: +10 % for rating coolers, −15 % for heat recovery (Tolerance refer to 100 % engine output).

[2] The values of the particular cylinder numbers can differ depending on the cooler specification.

[3] Tolerances: Quantity ±5 %, temperature ±20 °C (Tolerance refer to 100 % engine output).

Table 45: Load specific values at tropical conditions – 500 kW/cyl.; 1,032 rpm

2.14 Operating/service temperatures and pressures

Intake air (conditions before compressor of turbocharger)

	Min.	Max.
Intake air temperature compressor inlet	0 °C[1]	45 °C[2]
Intake air pressure compressor inlet	−20 mbar	-

[1] Conditions below this temperature are defined as "arctic conditions" – see section Engine operation under arctic conditions, Page 43.

[2] In accordance with power definition. A reduction in power is required at higher temperatures/lower pressures.

Table 46: Intake air (conditions before compressor of turbocharger)

Charge air (conditions within charge air pipe before cylinder)

	Min.	Max.
Charge air temperature at charge air cooler inlet	-	280 °C
Charge air temperature cylinder inlet[1]	15 °C	65 °C
Charge air pressure at charge air cooler inlet	-	5.0 bar (absolute)
Charge air pressure at charge air cooler outlet	-	4.9 bar (absolute)

[1] Aim for a higher value in conditions of high air humidity (to reduce condensate amount).

Table 47: Charge air (conditions within charge air pipe before cylinder)

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HT cooling water – Engine

	Min.	Max.
HT cooling water temperature engine outlet[1]	79 °C	95 °C
HT cooling water temperature at jacket cooling outlet[2]	68 °C	80 °C[3]
HT cooling water temperature engine inlet – Preheated before start	40 °C	68 °C

	Min.	Max.
HT cooling water pressure engine inlet[4]	0.9 bar	5.5 bar
Pressure loss engine (total, for nominal flow rate)	-	1.35 bar
Only for information: + Pressure loss engine (without charge air cooler) + Pressure loss HT piping engine + Pressure loss charge air cooler (HT stage)	 0.3 bar 0.2 bar 0.2 bar	 0.5 bar 0.45 bar 0.4 bar
Pressure rise attached HT cooling water pump (attached as standard)	0.4 bar	5.0 bar
[1] Regulated temperature. [2] SaCoSone measuring point is jacket cooling outlet of the engine. [3] Operation at alarm level. [4] SaCoSone measuring point is jacket cooling inlet.		

Table 48: HT cooling water – Engine

HT cooling water – Plant

	Min.	Max.
Permitted pressure loss of external HT system (plant)	-	1.50 bar
Cooling water expansion tank + Pre-pressure due to expansion tank at suction side of cooling water pump + Pressure loss from expansion tank to suction side of cooling water pump	 0.45 bar -	 0.95 bar 0.1 bar

Table 49: HT cooling water – Plant

LT cooling water – Engine

	Min.	Max.
LT cooling water temperature charge air cooler inlet (LT stage)	32 °C[1]	38 °C[2]
LT cooling water temperature charge air cooler outlet	-	60 °C
LT cooling water pressure charge air cooler inlet (LT stage)	0.8 bar	5.5 bar
Pressure loss charge air cooler (LT stage, for nominal flow rate)	-	0.6 bar
Pressure rise attached LT cooling water pump (attached as standard)	0.4 bar	4.6 bar
[1] Regulated temperature. [2] In accordance with power definition. A reduction in power is required at higher temperatures/lower pressures.		

Table 50: LT cooling water – Engine

LT cooling water – Plant

	Min.	Max.
Permitted pressure loss of external LT system (plant)	-	1.70 bar
Cooling water expansion tank + Pre-pressure due to expansion tank at suction side of cooling water pump + Pressure loss from expansion tank to suction side of cooling water pump	 0.45 bar -	 0.95 bar 0.1 bar

Table 51: LT cooling water – Plant

Seawater

	Min.	Max.
Seawater pressure seawater cooler inlet (if attached)	-	4.0 bar

Table 52: Seawater

Lube oil

	Min.	Max.
Lube oil temperature engine inlet	50 °C	68 °C[1)]
Lube oil temperature engine inlet – Preheated before start[2)]	20 °C	55 °C[3)]
Lube oil temperature engine inlet – Preheated in case of stand-by operation[4)]	40 °C	55 °C[3)]
Lube oil pressure (during engine operation) – Lube oil pump outlet – Engine inlet – Turbocharger inlet	 - 2.0 bar[5)] 1.3 bar	 8.0 bar 6.0 bar 2.2 bar
Prelubrication/postlubrication (duration ≤ 10 min) lube oil pressure – Engine inlet – Turbocharger inlet	 0.3 bar 0.2 bar	 5 bar 2.2 bar
Prelubrication/postlubrication (duration > 10 min) lube oil pressure – Engine inlet – Turbocharger inlet	 0.3 bar 0.2 bar	 0.6 bar 0.6 bar

[1)] Operation at alarm level.

[2)] Preheating required if minimum temperature +5 °C of lube oil can not be kept.

[3)] If a higher temperature of the lube oil will be reached in the system, it is important at an engine start to reduce it as quickly as possible below alarm level to avoid a start failure.

[4)] See accordingly section External lube oil system, Page 167.

[5)] Operation at alarm level at a speed of < 600 rpm.

Table 53: Lube oil

Fuel

	Min.	Max.
Fuel temperature engine inlet – MGO (DMA, DFA) according ISO 8217, DIN EN590 or equivalent fuel	 –10 °C[1)]	 45 °C[2)]
Fuel viscosity engine inlet – MGO (DMA, DFA) according ISO 8217, DIN EN590 or equivalent fuel	 1.5 cSt	 6.0 cSt
Fuel pressure before engine driven supply pump	–0.4 bar	0.5 bar[3)]
Fuel pressure engine inlet	1.9 bar	7.0 bar
Fuel pressure engine inlet in case of black out (only for engine start idling)	0.2 bar	-

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	Min.	Max.
[1)] Maximum viscosity not to be exceeded. “Pour point” and “Cold filter plugging point” have to be observed.		
[2)] Not allowed to fall below minimum viscosity.		
[3)] Pressure loss of piping included.		

Table 54: Fuel

Compressed air in the starting air system

	Min.	Max.
Starting air pressure within vessel/pressure regulating valve inlet 12V	14.0 bar	40.0 bar[1)]
Starting air pressure within vessel/pressure regulating valve inlet 16V	17.0 bar	40.0 bar[1)]
Starting air pressure within vessel/pressure regulating valve inlet 20V	19.0 bar	40.0 bar[1)]
Recommended air pressure	–	39.0 bar
[1)] Valid for current attached 40 bar air starter. For previous version of 30 bar air starter a pressure reducer 40/30 bar is necessary, that has to be installed 5 m before engine connection "starting motor" (7107).		

Table 55: Compressed air in the starting air system

Compressed air in the control air system

	Min.	Max.
Control air pressure engine inlet – Recommended	7.0 bar 8.0 bar	9.0 bar -
Control air pressure for turning gear – Recommended	8.0 bar 8.2 bar	9.0 bar -

Table 56: Compressed air in the control air system

Crankcase pressure (engine)

	Min.	Max.
Pressure within crankcase	–2.5 mbar	0.0 mbar

Table 57: Crankcase pressure (engine)

	Setting
Safety valve attached to the crankcase (opening pressure)	50 – 100 mbar

Table 58: Safety valve

Polar blow-off – Plant

	Min.	Max.
Permitted pressure loss of piping system for blow-off (plant)	-	50.0 mbar[1)]
[1)] 5 % of air flow rate engine to be assumed for blow-off amount.		

Table 59: Charge air blow-off for ignition pressure limitation (plant)

Exhaust gas

	Min.	Max.
Exhaust gas pressure turbine inlet	-	4.0 bar (absolute)

	Min.	Max.
Exhaust gas temperature turbine inlet	-	630 °C
Exhaust gas temperature turbine inlet at alarm level	-	640 °C
Exhaust gas temperature turbine outlet (normal operation under tropic conditions)	-	450 °C
Exhaust gas temperature turbine outlet (emergency operation – STC function out of order at low load)	-	550 °C
Minimum exhaust gas temperature after recooling due to exhaust gas heat utilisation	190 °C[1)]	-
Exhaust gas back pressure after turbocharger (static)	-	50 mbar[2)]

[1)] To avoid sulfur corrosion in the exhaust gas line (plant).

[2)] If this value is exceeded by the total exhaust gas back pressure of the designed exhaust gas line, sections Derating, definition of P_Operating, Page 33 and Increased exhaust gas pressure due to exhaust gas after treatment installations, Page 35 need to be considered.

Table 60: Exhaust gas

Note:
Operating pressures without further specification are below/above atmospheric pressure.

2.15 Leakage rate

Max. leak rate (clean fuel)	Burst leak rate in case of pipe break (for max. 1 min)
l/h per cyl.	l/min
MGO (DMA, DFA)	
8.0	4.0

Table 61: Leakage rate – MAN V28/33D STC

Note:

- A high flow of dirty leakage oil will occur in case of a pipe break, for short time only (< 1 min).
  Engine will run down immediately after a pipe break alarm.
  This leakage can be reused, if the entire fuel treatment of separation and filtration is done.
- The operating leakage (clean) consists out of the operating leakage amount of the high-pressure pumps, plus the operating leakage of the injection valves, which occur during normal operation due to their function.
  This leakage can be reused, if the entire fuel treatment of separation and filtration is done.
- All other leakage amounts (dirt fuel oil from filters or from engine drains) have to be discharged into the sludge tank.

2.16 Filling volumes

Cooling water, fuel oil and oil volume of engine[1]					
No. of cylinders			**12**	**16**	**20**
On engine oil system with deep oil sump, 815 mm	High oil level (eng. running)	litres	1,700	2,050	2,429
	Low oil level (eng. running)		1,510	1,820	2,145
On engine oil system with low oil sump, 550 mm	High oil level (eng. running)		1,460	1,760	2,070
	Low oil level (eng. running)		1,300	1,550	1,806
On engine jacket (HT) water[2]			625	762	899
On engine (LT) water[2]			506	592	678
On engine fuel oil system[2]			12	15	18

[1] The given values are for guidance only and may differ depending on the customer chosen engine specification.

[2] Be aware: This is just the amount inside the engine. By this amount the level in the service or expansion tank will be lowered when media systems are put in operation after first filling.

Table 62: Cooling water, fuel oil and oil volume of engine

Service tanks/expansion tanks	Installation height[1]	Minimum effective capacity		
	m	m³		
No. of cylinders		**12**	**16**	**20**
Expansion tank, cooling water HT circuit	4.5 – 9.5	0.15		
Expansion tank, cooling water LT circuit	4.5 – 9.5	0.15		
Fuel service tank	–4.0 – 6.0	according to classification rules		

[1] Installation height refers to tank bottom and crankshaft centre line.

Table 63: Service tanks/expansion tanks capacities

2.17 Venting amount of crankcase and turbocharger

A ventilation of the engine crankcase and the turbochargers is required, as described in section Crankcase vent, Page 174.

For the layout of the ventilation system guidance is provided below:

Due to normal blow-by of the piston ring package small amounts of combustion chamber gases get into the crankcase and carry along oil dust.

- The amount of crankcase vent gases is approximately 0.1 % of the engine´s air flow rate.
- The temperature of the crankcase vent gases is approximately 5 K higher than the oil temperature at the engine´s oil inlet.
- The density of crankcase vent gases is 1.0 kg/m³ (assumption for calculation).

In addition, the sealing air of the turbocharger needs to be vented.

- The amount of turbocharger sealing air is approximately:
  - For single-stage turbocharged engines 0.2 % of the engine´s air flow rate.
  - For two-stage turbocharged engines 0.4 % of the engine´s air flow rate.
- The temperature of turbocharger sealing air is approximately 5 K higher than the oil temperature at the engine´s oil inlet.

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- The density of turbocharger sealing air is 1.0 kg/m³ (assumption for calculation).

2.18 Exhaust gas emission

2.18.1 Maximum permissible NOx emission limit value IMO Tier II

Engine MAN V28/33D STC[1]

IMO Tier II: Engine in standard version

Rated speed	1,000 rpm	1,032 rpm
NO_x 1) 2) 3) IMO cycle E2/E3	8.98 g/kWh 4)	8.92 g/kWh 4)
Note: The engine´s certification for compliance with the NO_x limits will be carried out during factory acceptance test as a single or a group certification.		
1) Cycle values, operation on DM grade fuel (marine distillate fuel: MGO) according ISO 8217, based on a LT charge air cooling water temperature of max. 32 °C at 25 °C reference seawater temperature. 2) Calculated as NO_2. E2: Test cycle for "constant-speed main propulsion application" including electric propulsion and all controllable pitch propeller installations. E3: Test cycle for "propeller-law-operated main and propeller-law operated auxiliary engine” application. 3) Based on a LT charge air cooling water temperature of max. 32 °C at 25 °C seawater temperature. 4) Maximum permissible NO_x emissions for marine diesel engines according to IMO Tier II: $130 \leq n \leq 2000 \rightarrow 44 * n^{-0.23}$ g/kWh (n = rated engine speed in rpm).		

Table 64: Maximum permissible NO_x emission limit value

[1] Marine engines are guaranteed to meet the revised International Convention for the Prevention of Pollution from Ships, "Revised MARPOL Annex VI (Regulations for the Prevention of Air Pollution from Ships), Regulation 13.4 (Tier II)" as adopted by the International Maritime Organization (IMO).

2.18.2 Exhaust gas components of medium-speed four-stroke diesel engines

The exhaust gas of a medium-speed four-stroke diesel engine is composed of numerous constituents. These are derived from either the combustion air and fuel oil and lube oil used, or they are reaction products, formed during the combustion process see table below. Only some of these are to be considered as harmful substances.

For a typical composition of the exhaust gas of an MAN Energy Solutions four-stroke diesel engine without any exhaust gas treatment devices see table below.

Main exhaust gas constituents	approx. [% by volume]	approx. [g/kWh]
Nitrogen N_2	74.0 – 76.0	5,020 – 5,160

Oxygen O_2	10.0 – 13.5	770 – 1,050
Carbon dioxide CO_2	5.0 – 7.5	540 – 800
Steam H_2O	5.9 – 8.6	260 – 370
Inert gases Ar, Ne, He...	0.9	75
Total	> 99.75	7,000
Additional gaseous exhaust gas constituents considered as pollutants	approx. [% by volume]	approx. [g/kWh]
Sulphur oxides SO_x[1)]	0.03	4.0
Nitrogen oxides NO_x[2)]	0.06 – 0.11	7.0 – 12.0
Carbon monoxide CO[3)]	0.006 – 0.011	0.4 – 0.8
Hydrocarbons HC[4)]	0.1 – 0.3	0.2 – 0.8
Total	< 0.35	26
Additionally suspended exhaust gas constituents, PM[5)]	approx. [mg/Nm^3]	approx. [g/kWh]
	MGO[6)]	
Soot (elemental carbon)[7)]	50	0.3
Fuel ash	4	0.03
Lube oil ash	3	0.02
Note: At rated power and without exhaust gas treatment.		
[1)] SO_x according to ISO-8178 or US EPA method 6C, with a sulphur content in the fuel oil of 1 % by weight. [2)] NO_x according to ISO-8178 or US EPA method 7E, total NO_x emission calculated as NO_2. [3)] CO according to ISO-8178 or US EPA method 10. [4)] HC according to ISO-8178 or US EPA method 25 A. [5)] PM according to VDI-2066, EN-13284, ISO-9096 or US EPA method 17; in-stack filtration. [6)] Marine gas oil DM-A grade with an ash content of the fuel oil of 0.01 % and an ash content of the lube oil of 1.5 %. [7)] Pure soot, without ash or any other particle-borne constituents.		

Table 65: Exhaust gas constituents (only for guidance)

Carbon dioxide CO_2

Carbon dioxide (CO_2) is a product of combustion of all fossil fuels.

Among all internal combustion engines the diesel engine has the lowest specific CO_2 emission based on the same fuel quality, due to its superior efficiency.

Sulphur oxides SO_x

Sulphur oxides (SO_x) are formed by the combustion of the sulphur contained in the fuel.

Among all systems the diesel process results in the lowest specific SO_x emission based on the same fuel quality, due to its superior efficiency.

Nitrogen oxides NO_x ($NO + NO_2$)

The high temperatures prevailing in the combustion chamber of an internal combustion engine cause the chemical reaction of nitrogen (contained in the combustion air as well as in some fuel grades) and oxygen (contained in the combustion air) to nitrogen oxides (NO_x).

Carbon monoxide CO

Carbon monoxide (CO) is formed during incomplete combustion.

In MAN Energy Solutions four-stroke diesel engines, optimisation of mixture formation and turbocharging process successfully reduces the CO content of the exhaust gas to a very low level.

Hydrocarbons HC

The hydrocarbons (HC) contained in the exhaust gas are composed of a multitude of various organic compounds as a result of incomplete combustion.

Due to the efficient combustion process, the HC content of exhaust gas of MAN Energy Solutions four-stroke diesel engines is at a very low level.

Particulate matter PM

Particulate matter (PM) consists of soot (elemental carbon) and ash.

2.18.3 Emission related installation instruction for engines

Position of the exhaust gas sampling points

The sampling position shall be fitted:

- At least 10 times the diameter of the exhaust pipe after the outlet of the engine, turbocharger or last after-treatment device
- In a straight pipe segment:
  - With an inlet path length before sampling position of at least 5 times the diameter of the exhaust pipe after last bending/obstruction/diameter deviation
  - With a path length after sampling position of at least 2 times the diameter of the exhaust pipe
- Aat least 5 times the diameter of the exhaust pipe before end of exhaust pipe
- Sufficiently close to the engine to ensure that the exhaust gas temperature at the sampling position will be minimum 180°C

If this is not attainable, a deviation of these requirements is acceptable if:

- justified by good engineering practice
- an incorrect measurement is not expected

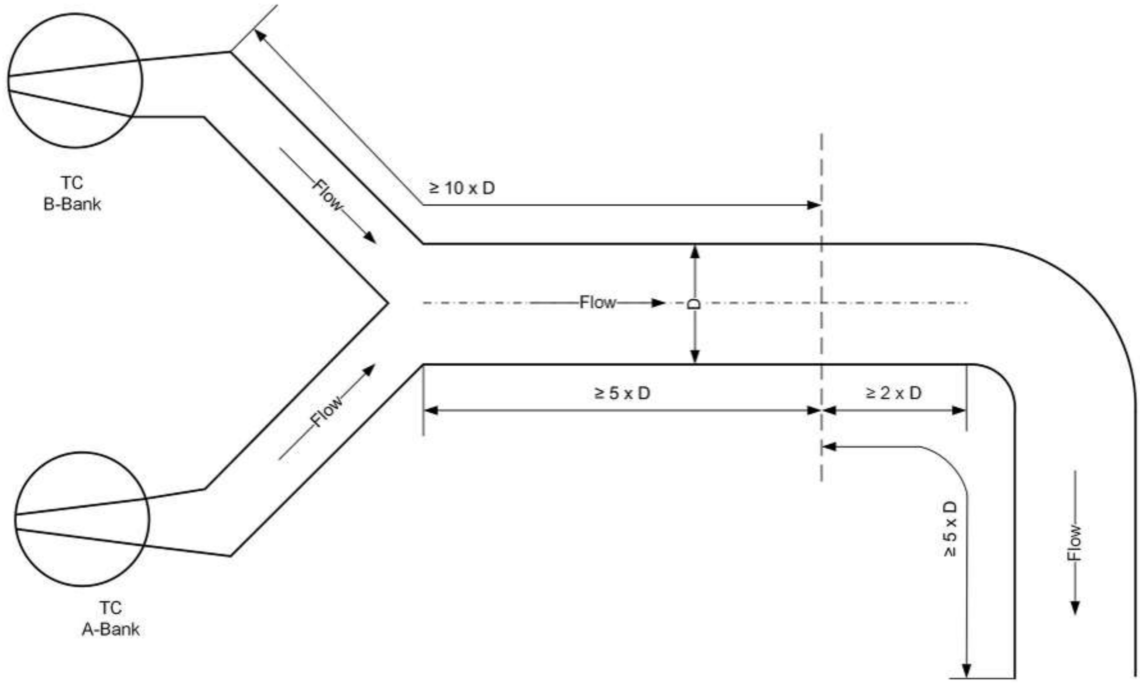


Figure 25: Position of sampling points (exemplary)

In the case an engine has distinct groups of manifolds, it is permissible to acquire a sample from each group individually and calculate an average exhaust emission. In this case each sampling point needs to be designed as mentioned above.

The exhaust gas upstream the sampling point shall be free of any dilution from surrounding air or contamination from other exhaust gas systems.

Accessibility and working area at sampling point

The sampling point shall be accessible in a save way also during engine operation. In case the sampling point is coverd by an insulation, the position shall be clearly visible marked on the insulation. The Insulation shall be designed in a way that it is easy to remove and to install again.

If necessary a step has to be established.

There shall be enough space to place and operate the measurement equipment.

Requirements regarding the working area:

- Minimum space requirements: about 2m width, 2m depth, 2m height
- Sufficient floor load capacity (at least 200 kg per m²)
- Temperature at this working area should be within +5 to + 40°C and well ventilated
- Not subjected to excessive vibrations
- If needed weather protection for personnel and equipment against sun, wind and rain

Depending on the measurement equipment it should to be considered that during the measurements following items are available at the working area:

• Adequate lighting and ventilation

- Power supply
- Pressurized air (instrument quality, oil free)
- Lifting devices for raising and lowering the equipment, if necessary

Exhaust pipe connection

- 1 piece of pipe thread inner diameter G 3” (use for particulate measurements)
- 2 pieces of pipe thread inner diameter G ½" (use for gaseous emission measurements or for smoke number measurement)

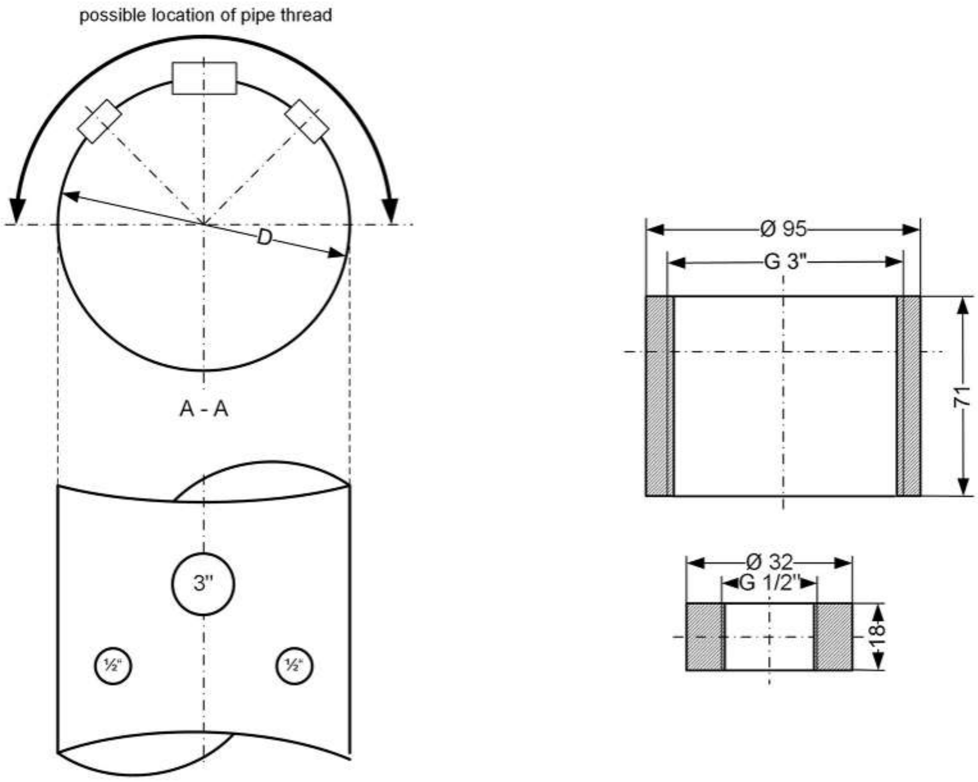


Figure 26: Sampling point, details

Installation of pipe thread G 3'' and G ½”

To establish an airtight connection the pipe threads shall be welded at the exhaust gas pipe. In case of a horizontal orientated exhaust gas pipe the position shall be in the upper half of the exhaust gas pipe in radial direction to the center line (see figure 2) and easy to access.

When the sampling points are not in use, a pipe plug shall close the pipe threads.

2.19 Noise

2.19.1 Airborne noise

Engine MAN V28/33D STC

Sound pressure level Lp

Measurements

Approximately 20 measuring points at 1 metre distance from the engine surface are distributed evenly around the engine according to ISO 6798. The noise at the exhaust outlet is not included, but provided separately in the following sections.

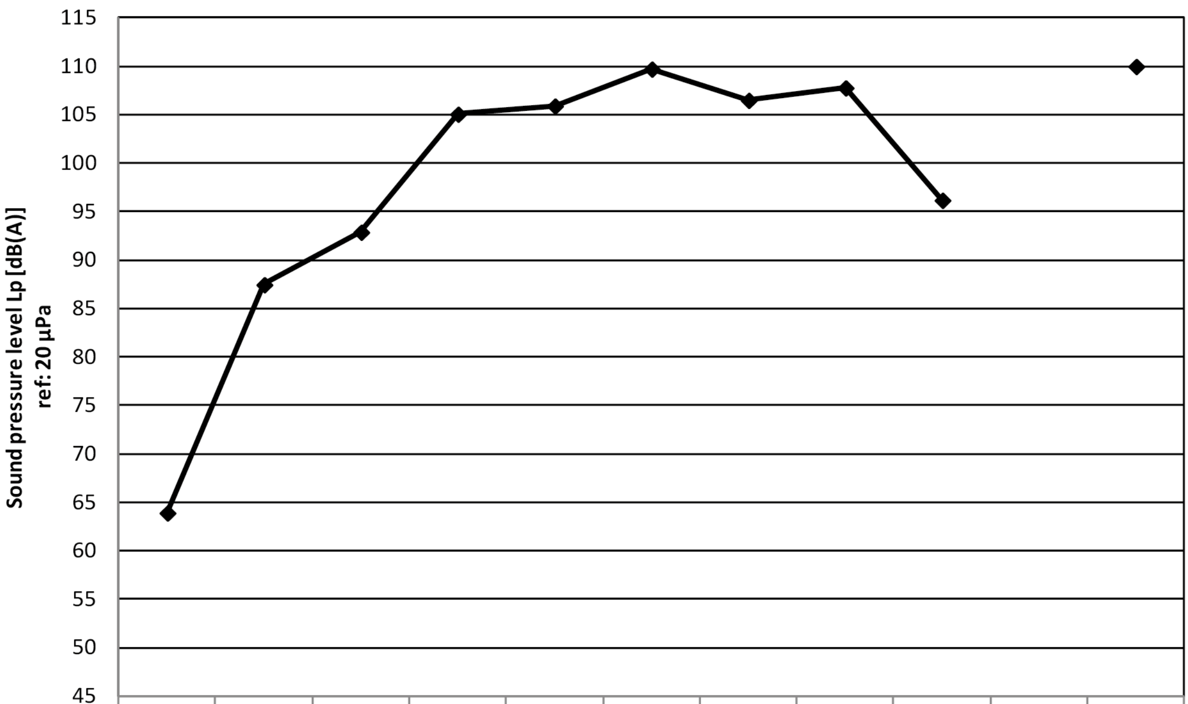
Octave level diagram

The expected sound pressure level Lp is approximately 110 dB(A) at 100 % load.

The octave level diagram below represents an envelope of averaged measured spectra for comparable engines at the testbed and is a conservative spectrum consequently. No room correction is performed. The data will change depending on the acoustical properties of the environment.

Blow-off noise

Blow-off noise is not considered in the measurements, see below.



	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz		Sum
Lp	64	87	93	105	106	110	107	108	96		110

Figure 27: Airborne noise – Sound pressure level Lp – Octave level diagram

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2.19.2 Intake noise

Engine MAN V28/33D STC

Sound power level Lw

Measurements

The (unsilenced) intake air noise is determined based on measurements at the turbocharger test bed and on measurements in the intake duct of typical engines at the test bed.

Octave level diagram

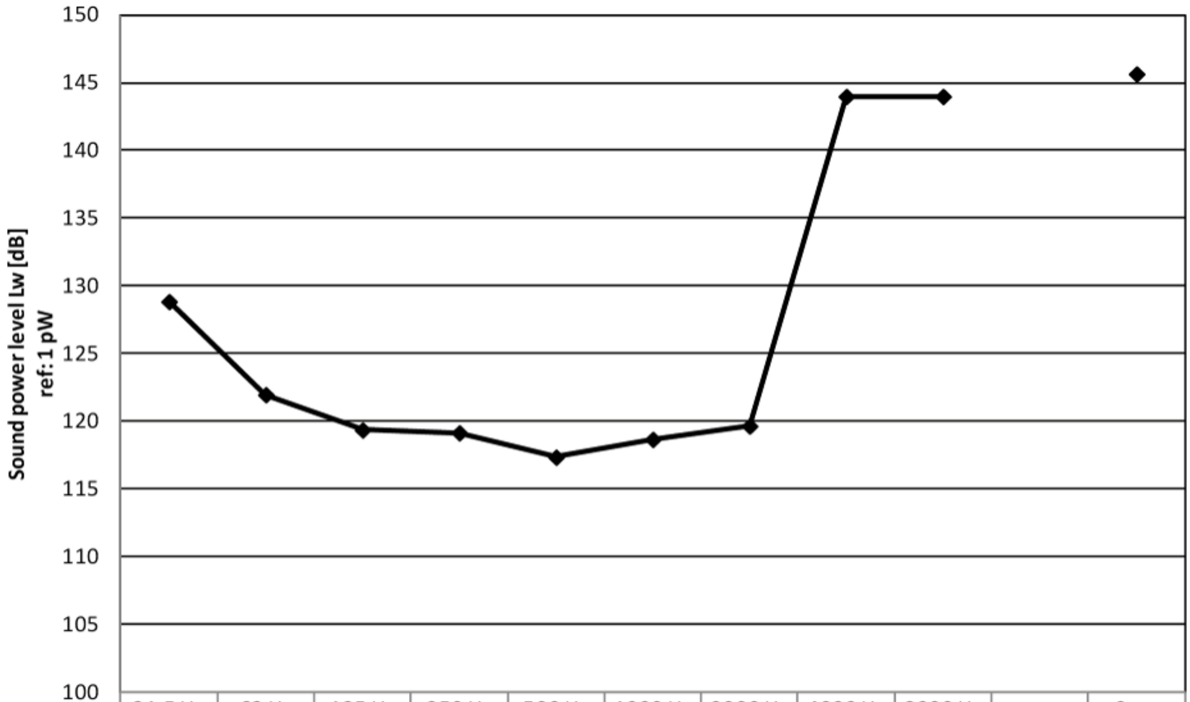
The expected sound power level Lw of the unsilenced intake noise in the intake duct is below 146 dB at 100 % MCR.

The octave level diagram below represents an envelope of averaged measured spectra for comparable engines and is a conservative spectrum consequently. The data will change depending on the acoustical properties of the environment.

Charge air blow-off noise

Charge air blow-off noise is not considered in the measurements, see below.

These data are required and valid only for ducted air intake systems. The data are not valid if the standard air filter silencer is attached to the turbocharger.



	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz		Sum
Lw	129	122	119	119	117	119	120	144	144		146

Figure 28: Unsilenced intake noise – Sound power level Lw – Octave level diagram

2.19.3 Exhaust gas noise

Engine MAN V28/33D STC

Measurements

The (unsilenced) exhaust gas noise is measured according to internal MAN Energy Solutions guidelines at several positions in the exhaust duct.

Octave level diagram

The sound power level Lw of the unsilenced exhaust gas noise in the exhaust pipe is shown at 100 % MCR.

The octave level diagram below represents an envelope of averaged measured spectra for comparable engines and is a conservative spectrum consequently. The data will change depending on the acoustical properties of the environment.

Acoustic design

To ensure an appropriate acoustic design of the exhaust gas system, the yard, MAN Energy Solutions, supplier of silencer and where necessary acoustic consultant have to cooperate.

Blow-off noise

Blow-off noise is not considered in the measurements, see below.

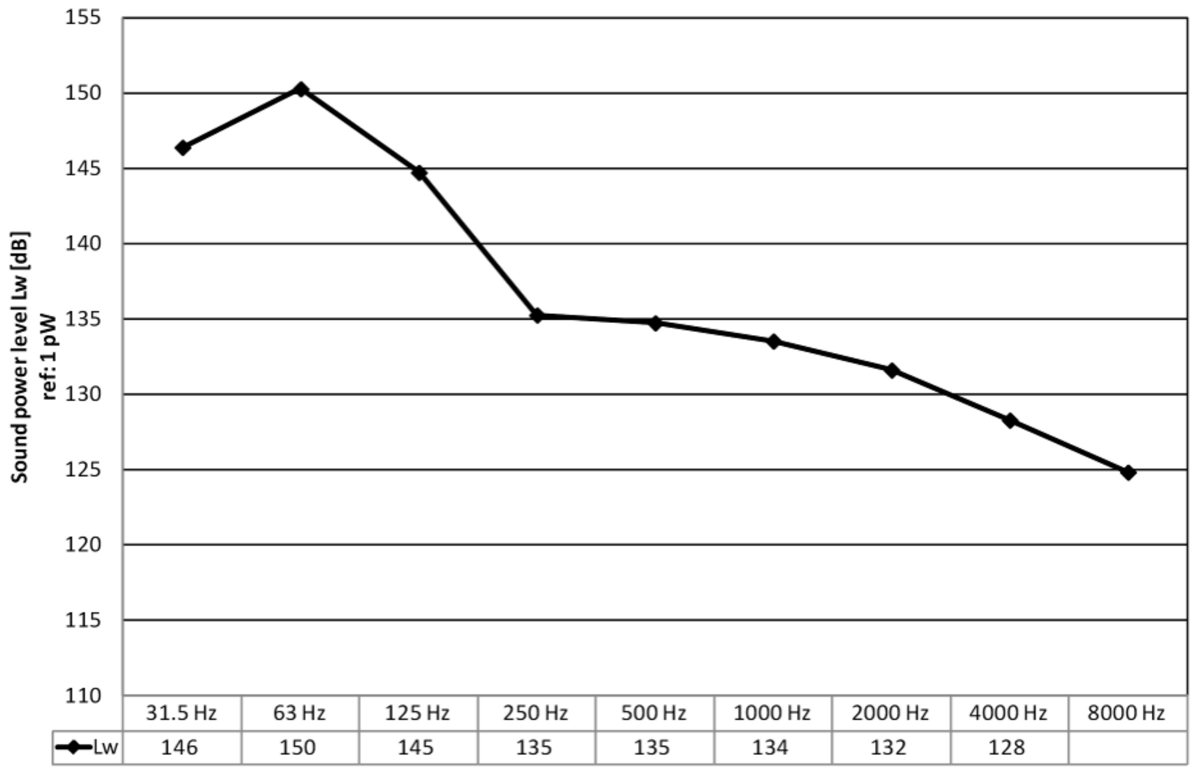


Figure 29: Unsilenced exhaust gas noise – Sound power level Lw – Octave level diagram

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2.19.4 Blow-off noise example

Sound power level Lw

Measurements

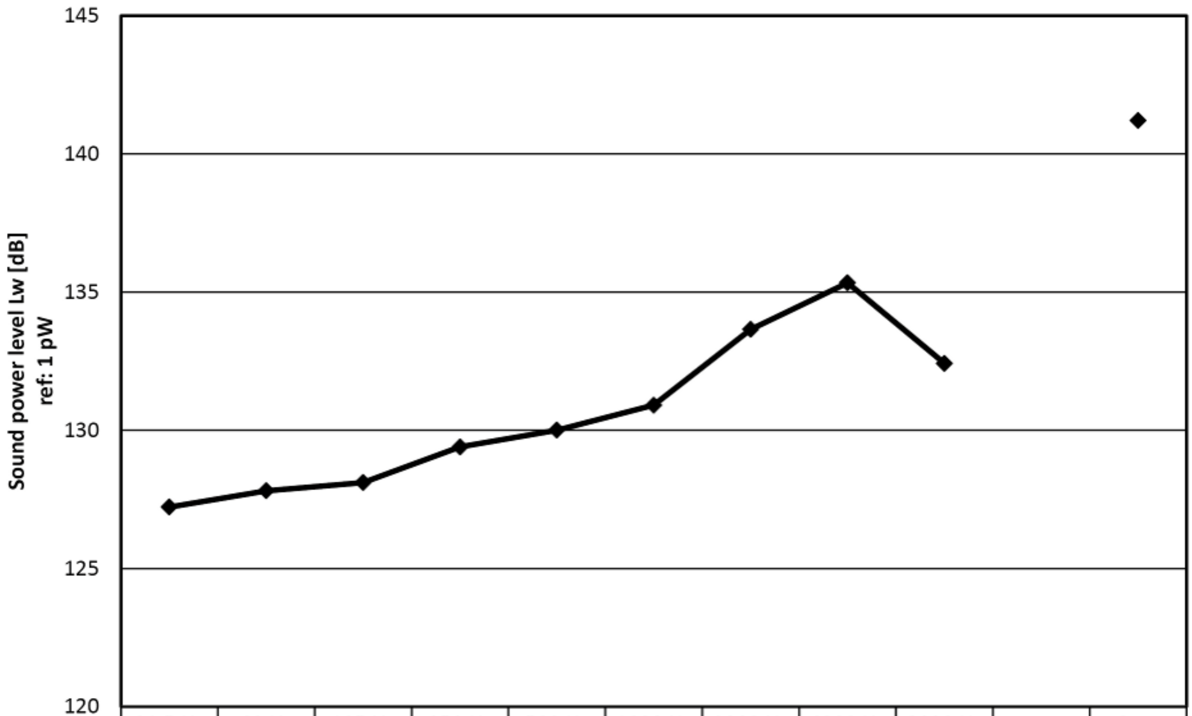
The (unsilenced) charge air blow-off noise is measured according to DIN 45635, part 47 at the orifice of a duct.

Throttle body with bore size 135 mm

Expansion of charge air from 3.4 bar to ambient pressure at 42 °C

Octave level diagram

The sound power level Lw of the unsilenced charge air blow-off noise is approximately 141 dB for the measured operation point.



	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz		Sum
Lw	127	128	128	129	130	131	134	135	132		141

Figure 30: Unsilenced charge air blow-off noise – Sound power level Lw – Octave level diagram

2.19.5 Noise and vibration – Impact on foundation

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Noise and vibration is emitted by the engine to the surrounding (see figure Noise and vibration – Impact on foundation, Page 88). The engine impact transferred through the engine mounting to the foundation is focused subsequently.

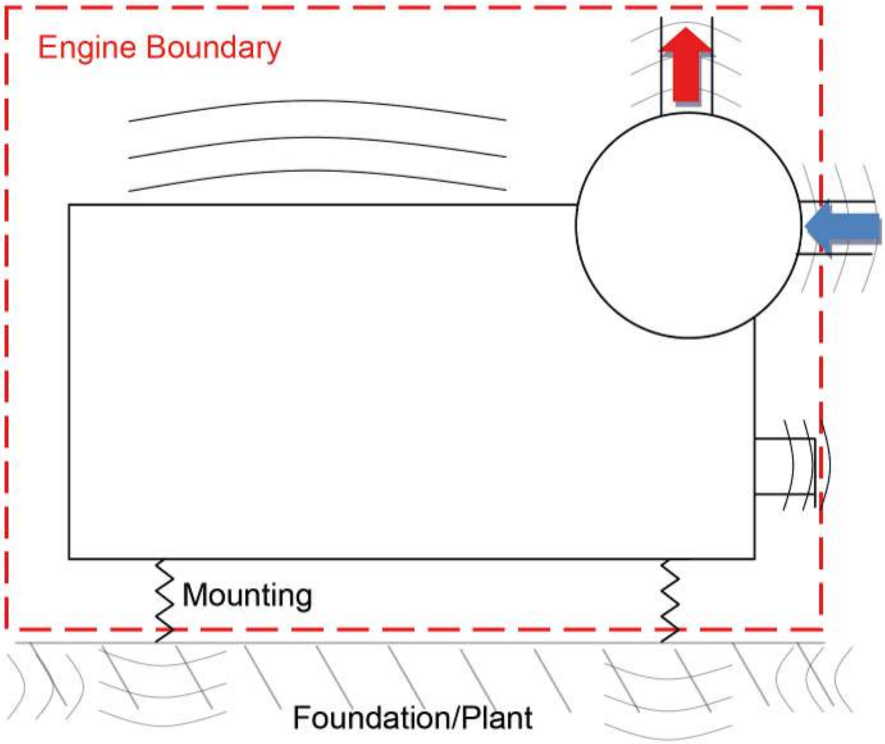

Figure 31: Noise and vibration – Impact on foundation

The foundation is excited to vibrations in a wide frequency range by the engine and by auxiliary equipment (from engine or plant). The engine is vibrating as a rigid body. Additionally, elastic engine vibrations are superimposed. Elastic vibrations are either of global (e.g. complete engine bending) or local (e.g. bending engine foot) character. If the higher frequency range is involved, the term "structure borne noise" is used instead of "vibrations".

Mechanical engine vibrations are mainly caused by mass forces of moved drive train components and by gas forces of the combustion process. For structure borne noise, further excitations are relevant as well, e.g. impacts from piston stroke and valve seating, impulsive gas force components, alternating gear train meshing forces and excitations from pumps.

For the analysis of the engine noise- and vibration-impact on the surrounding, the complete system with engine, engine mounting, foundation and plant has to be considered.

Engine related noise and vibration reduction measures cover e.g. counterbalance weights, balancing, crankshaft design with firing sequence, component design etc. The remaining, inevitable engine excitation is transmitted to the surrounding of the engine – but not completely in case of a resilient engine mounting, which is chosen according to the application-specific requirements. The resilient mounting isolates engine noise and vibration from its surrounding to a large extend. Hence, the transmitted forces are considerably reduced compared with a rigid mounting. Nevertheless, the engine itself is vibrating stronger in the low frequency range in general – especially when driving through mounting resonances.

In order to avoid resonances, it must be ensured that eigenfrequencies of foundation and coupled plant structures have a sufficient safety margin in relation to the engine excitations. Moreover, the foundation has to be designed as stiff as possible in all directions at the connections to the engine. Thus, the foundation mobility (measured according to ISO 7262) has to be as low as possible to ensure low structure borne noise levels. For low frequencies, the global connection of the foundation with the plant is focused for that matter. The dynamic vibration behaviour of the foundation is mostly essential for the mid frequency range. In the high frequency range, the foundation elasticity is mainly influenced by the local design at the engine mounts. E.g. for steel foundations, sufficient wall thicknesses and stiffening ribs at the connection positions shall be provided. The dimensioning of the engine foundation also has to be adjusted to other parts of the plant. For instance, it has to be avoided that engine vibrations are amplified by alternator foundation vibrations. Due to the scope of supply, the foundation design and its connection with the plant is mostly within the responsibility of the costumer. Therefore, the customer is responsible to involve MAN Energy Solutions for consultancy in case of system-related questions with interaction of engine, foundation and plant. The following information is available for MAN Energy Solutions customers, some on special request:

- Residual external forces and couples (Project Guide)

  Resulting from the summation of all mass forces from the moving drive train components. All engine components are considered rigidly in the calculation. The residual external forces and couples are only transferred completely to the foundation in case of a rigid mounting, see above.
- Static torque fluctuation (Project Guide)

  Static torque fluctuations result from the summation of gas and mass forces acting on the crank drive. All components are considered rigidly in the calculation. These couples are acting on the foundation dependent on the applied engine mounting, see above.
- Mounting forces (project-specific)

  The mounting dimensioning calculation is specific to a project and defines details of the engine mounting. Mounting forces acting on the foundation are part of the calculation results. Gas and mass forces are considered for the excitation. The engine is considered as one rigid body with elastic mounts. Thus, elastic engine vibrations are not implemented.
- Reference measurements for engine crankcase vibrations according to ISO 10816-6 (project-specific)
- Reference test bed measurements for structure borne noise (project-specific)

  Measuring points are positioned according to ISO 13332 on the engine feet above and below the mounting elements. Structure borne noise levels above elastic mounts mainly depend on the engine itself. Whereas structure borne noise levels below elastic mounts strongly depend on the foundation design. A direct transfer of the results from the test bed foundation to the plant foundation is not easily possible – even with the consideration of test bed mobilities. The results of test bed foundation mobility measurements according to ISO 7626 are available as a reference on request as well.
- Dynamic transfer stiffness properties of resilient mounts (supplier information, project-specific)

Beside the described interaction of engine, foundation and plant with transfer through the engine mounting to the foundation, additional transfer paths need to be considered. For instance with focus on the elastic coupling of the drive train, the exhaust pipe, other pipes and supports etc. Besides the engine, other sources of noise and vibration need to be considered as well (e.g. auxiliary equipment, propeller, thruster).

2.20 Vibration

2.20.1 Torsional vibrations

Data required for torsional vibration calculation

MAN Energy Solutions calculates the torsional vibrations behaviour for each individual engine plant of their supply to determine the location and severity of resonance points. If necessary, appropriate measures will be taken to avoid excessive stresses due to torsional vibration. These investigations cover the ideal normal operation of the engine (all cylinders are firing equally) as well as the simulated emergency operation (misfiring of the cylinder exerting the greatest influence on vibrations, acting against compression). Besides the natural frequencies and the modes also the dynamic response will be calculated, normally under consideration of the 1^{st} to 24^{th} harmonic of the gas and mass forces of the engine.

Beyond that also further exciting sources such as propeller, pumps etc. can be considered if the respective manufacturer is able to make the corresponding data available to MAN Energy Solutions.

If necessary, a torsional vibration calculation will be worked out which can be submitted for approval to a classification society or a legal authority.

To carry out the torsional vibration calculation following particulars and/or documents are required.

General

- Type of propulsion (mechanical propulsion)
- Arrangement of the wholepropulsion system including all engine-driven equipment
- Definition of the operating modes
- Maximum power consumption of the individual working machines

Engine

- Rated output, rated speed
- Kind of engine load
- Kind of mounting of the engine (can influence the determination of the flexible coupling)

Flexible coupling

- Make, size and type
- Rated torque (Nm)
- Possible application factor
- Maximum speed (rpm)
- Permissible maximum torque for passing through resonance (Nm)
- Permissible shock torque for short-term loads (Nm)
- Permanently permissible alternating torque (Nm) including influencing factors (frequency, temperature, mean torque)
- Permanently permissible power loss (W) including influencing factors (frequency, temperature)

- Dynamic torsional stiffness (Nm/rad) including influencing factors (load, frequency, temperature), if applicable
- Relative damping (ψ) including influencing factors (load, frequency, temperature), if applicable
- Moment of inertia (kgm^2) for all parts of the coupling
- Dynamic stiffness in radial, axial and angular direction
- Permissible relative motions in radial, axial and angular direction, permanent and maximum

Clutch coupling

- Make, size and type
- Rated torque (Nm)
- Permissible maximum torque (Nm)
- Permanently permissible alternating torque (Nm) including influencing factors (frequency, temperature, mean torque)
- Dynamic torsional stiffness (Nm/rad)
- Damping factor
- Moments of inertia for the operation conditions, clutched and declutched
- Course of torque versus time during clutching in
- Permissible slip time (s)
- Slip torque (Nm)
- Maximum permissible engagement speed (rpm)

Gearbox

- Make and type
- Torsional multi mass system including the moments of inertia and the torsional stiffness, preferably related to the individual speed; in case of related figures, specification of the relation speed is required
- Gear ratios (number of teeth, speeds)
- Possible operating conditions (different gear ratios, clutch couplings)
- Permissible alternating torques in the gear meshes

Shaft line

- Drawing including all information about length and diameter of the shaft sections as well as the material
- Alternatively torsional stiffness (Nm/rad)

Propeller

- Kind of propeller (water jet propulsion, fixed pitch or controllable pitch propeller)
- Moment of inertia in air (kgm^2)
- Moment of inertia in water (kgm^2); for controllable pitch propellers also in dependence on pitch; for twin-engine plants separately for single- and twin-engine operation
- Relation between load and pitch
- Number of blades
- Diameter (mm)

- Possible torsional excitation in % of the rated torque for the 1st and the 2nd blade-pass frequency

Pump

- Kind of pump (e.g. dredging pump)
- Drawing of the pump shaft with all lengths and diameters
- Alternatively, torsional stiffness (Nm/rad)
- Moment of inertia in air (kgm^2)
- Moment of inertia in operation (kgm^2) under consideration of the conveyed medium
- Number of blades
- Possible torsional excitation in % of the rated torque for the 1st and the 2nd blade-pass frequency
- Power consumption curve

Water jet propulsion

- Kind of water jet propulsion
- Moment of inertia in air (kgm^2)
- Moment of inertia in water (kgm^2); for twin-engine plants separately for single- and twin-engine operation
- Number of blades
- Diameter (mm)
- Possible torsional excitation in % of the rated torque for the 1st and the 2nd blade-pass frequency

2.21 Requirements for power drive connection (static)

2.21.1 Limit values of masses to be coupled after the engine

Evaluation of permissible theoretical bearing loads

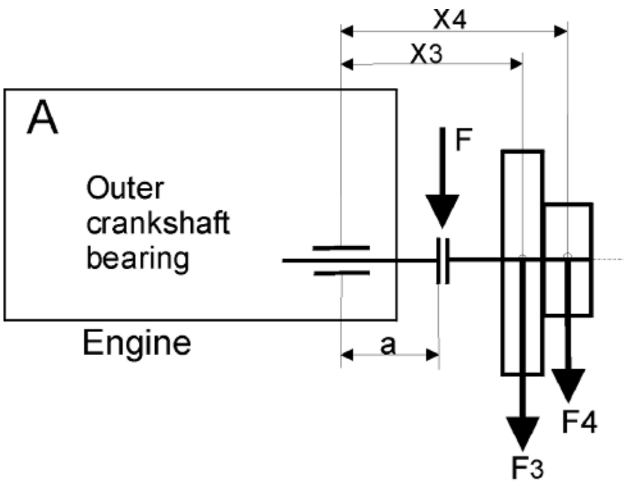

Figure 32: Case A: Overhung arrangement

$M_{max} = F * a = F_3 * x_3 + F_4 * x_4$

F_3	Flywheel weight

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F_4	Coupling weight acting on the engine, including reset forces
a	Distance between end of coupling flange and centre of outer crankshaft bearing

1. Standard engine – Main power drive connection at coupling side

Engine	Distance a	M_{max} = F * a
	mm	kNm
V engine	300	8.2 [1]
[1] Inclusive of couples resulting from restoring forces of the coupling.		

Table 66: Example calculation – Coupling side

2. Optional – Main power drive connection at counter coupling side (100 % PTO)

Engine	Distance a	M_{max} = F * a
	mm	kNm
V engine	592.6	23.2 [1]
[1] Inclusive of couples resulting from restoring forces of the coupling.		

Table 67: Example calculation – Counter coupling side

3. Optional – Auxiliary PTO at counter coupling side (main power drive connection at coupling side)

Engine	Distance a	M_{max} = F * a
	mm	kNm
V engine	810.0	6.0 [1]
[1] Inclusive of couples resulting from restoring forces of the coupling.		

Table 68: Example calculation – For auxiliary PTO on counter coupling side

Note:
For main power drive connection related values see case 1.

Note:
Stated values only for orientation – need to be clarified project specific and may be limited due to the torsional vibration calculation or special service conditions.

Note:
Masses which are connected downstream of the engine in the case of an overhung or rigidly coupled, arrangement result in additional crankshaft bending stress, which is mirrored in a measured web deflection during engine installation.

Provided the limit values for the masses to be coupled downstream of the engine (permissible values for M_{max} and $F_{1\ max}$) are complied with, the permitted web deflections will not be exceeded during assembly.

Observing these values ensures a sufficiently long operating time before a realignment of the crankshaft has to be carried out.

2.21.2 10 % PTO – Maximum torque and requirements screw connection

In case main power drive connection is at coupling side, on counter coupling side a PTO might be used if stated requirements are met.

Screw strength class	8.8	10.9	12.9
Number/standard	12 * DIN 931-M33		
Min. screw-in-depth	25 mm	28 mm	30 mm
Tightening torque	1,400 Nm	2,000 Nm	2,350 Nm
Max. torque at PTO	38 kNm	55 kNm	64 kNm

Note:
Stated values only for orientation – needs to be clarified project specific.

2.22 Requirements for power drive connection (dynamic)

2.22.1 Moments of inertia – Crankshaft, damper, flywheel

Engine MAN V28/33D STC

455 kW/cyl.; 1,000 rpm (ICN), 500 kW/cyl.; 1,032 rpm (ICFN)

Constant speed

a_{mot} = 80 %/sec

Marine main engines				
No. of cylinders, config.	**Engine**			**Required minimum total moment of inertia**[1)]
	Maximum continuous rating	**Moment of inertia crankshaft + damper**	**Moment of inertia flywheel**	
	[kW]	**[kgm²]**	**[kgm²]**	**[kgm²]**
n = 1,000 rpm				
12V	5,460	221	89.5	622
16V	7,280	274	89.5	830
20V	9,100	328	93.0	1,037
n = 1,032 rpm				
12V	6,000	221	89.5	642
16V	8,000	274	89.5	856
20V	10,000	328	93.0	1,070
[1)] Required minimum moment of inertia of engine, flywheel and arrangement after flywheel in total.				

Table 69: Moments of inertia/flywheel – Constant speed

For flywheels dimensions see section Flywheel arrangement, Page 98.

2.22.2 Balancing of masses – Firing order

Certain cylinder numbers have unbalanced forces and couples due to crank diagram. These forces and couples cause dynamic effects on the foundation. Due to a balancing of masses the forces and couples are reduced. In the following tables the remaining forces and couples are displayed.

Engine MAN V28/33D STC

Rotating crank balance 85 %

No. of cylinders, config.	Residual external couples				
	M_{rot} (kNm)	$M_{osc\ 1st\ order}$ (kNm)		$M_{osc\ 2nd\ order}$ (kNm)	
	Engine speed 1,000 rpm				
Direction		vertical	horizontal	vertical	horizontal
12V	0	0		0	
16V					
20V					

Table 70: Residual external couples

For engines of type MAN V28/33D STC the external mass forces are equal to zero.

Firing order: Counted from coupling side

No. of cylinders, config.	Firing interval	Clockwise rotation (viewed from engine coupling side)
12V	68°; 52°	B1-A5-B5-A3-B3-A6-B6-A2-B2-A4-B4-A1
16V	38°; 52°	B1-A5-B5-A2-B2-A6-B6-A8-B8-A4-B4-A7-B7-A3-B3-A1
20V	20°; 52°	B1-A4-B4-A2-B2-A5-B5-A8-B8-A10-B10-A7-B7-A9-B9-A6-B6-A3-B3-A1

Table 71: Firing interval – Clockwise rotation

No. of cylinders, config.	Firing interval	Counterclockwise rotation (viewed from engine coupling side)
12V	68°; 52°	A1-B4-A4-B2-A2-B6-A6-B3-A3-B5-A5-B1
16V	38°; 52°	A1-B3-A3-B7-A7-B4-A4-B8-A8-B6-A6-B2-A2-B5-A5-B1
20V	20°; 52°	A1-B3-A3-B6-A6-B9-A9-B7-A7-B10-A10-B8-A8-B5-A5-B2-A2-B4-A4-B1

Table 72: Firing interval – Counter clockwise rotation

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2.22.3 Static torque fluctuation

General

The static torque fluctuation is the summation of the torques acting at all cranks around the crankshaft axis taking into account the correct phase-angles. These torques are created by the gas and mass forces acting at the crankpins, with the crank radius being used as the lever. An rigid crankshaft is assumed.

The values T_{max} and T_{min} listed in the following table(s) represent a measure for the reaction forces of the engine. The reaction forces generated by the torque fluctuation are dependent on speed and cylinder number and give a contribution to the excitations transmitted into the foundation see figure Static torque fluctuation, Page 96 and the table(s) in this section. According to different mountings these forces are reduced.

In order to avoid local vibration excitations in the vessel, it must be ensured that the natural frequencies of important part structures (e.g. panels, bulkheads, tank walls and decks, equipment and its foundation, pipe systems) have a sufficient safety margin (if possible ±30 %) in relation to all engine excitation frequencies.

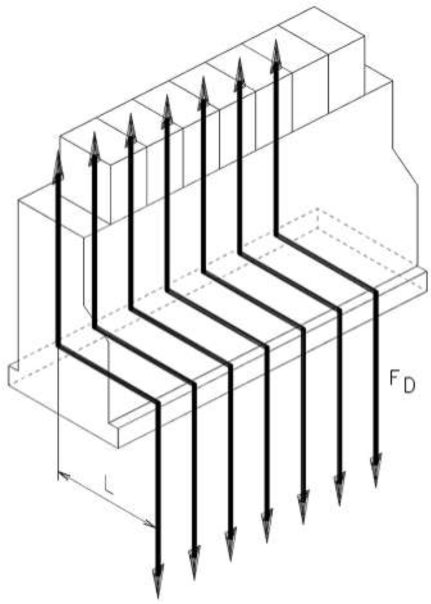

Figure 33: Static torque fluctuation

$$F_D \times L \times z = \frac{T_{max} - T_{min}}{2}$$

L Distance between foundation bolts

z Number of cylinders

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Static torque fluctuation and exciting frequencies

MAN V28/33D STC – Example to declare abbreviations

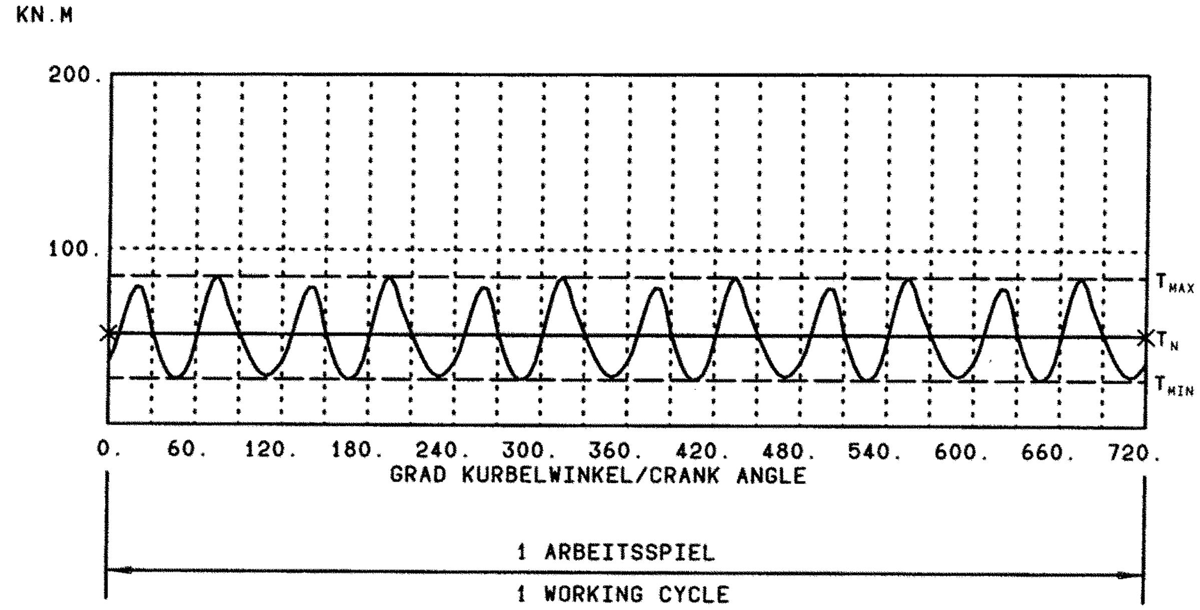

Figure 34: Example to declare abbreviation – MAN V28/33D STC

No. of cylinders, config.	Output	Speed	T_n	T_{max}	T_{min}	Main exciting components		
						Order	Frequency[1]	±T
	kW	rpm	kNm	kNm	kNm	rpm	Hz	kNm
12V	5,460	1,000	52.1	86.4	26.0	3.0	50	8.2
						6.0	100	22.9
16V	7,280		69.5	97.5	40.6	4.0	66.7	18.8
						8.0	133.3	10.2
20V	9,100		86.9	128.2	40.3	5.0	83.3	48.6
						10.0	166.7	0.8
12V	6,000	1,032	55.5	89.6	29.0	3.0	51.6	9.6
						6.0	103.2	24.0
16V	8,000		74.0	100.6	45.0	4.0	68.8	21.4
						8.0	137.6	8.7
20V	10,000		92.5	134.6	45.1	5.0	86.0	49.0
						10.0	172.0	0.6

[1] Exciting frequency of the main harmonic components.

Table 73: Static torque fluctuation and exciting frequencies – MAN V28/33D STC

2.23 Power transmission

2.23.1 Flywheel arrangement

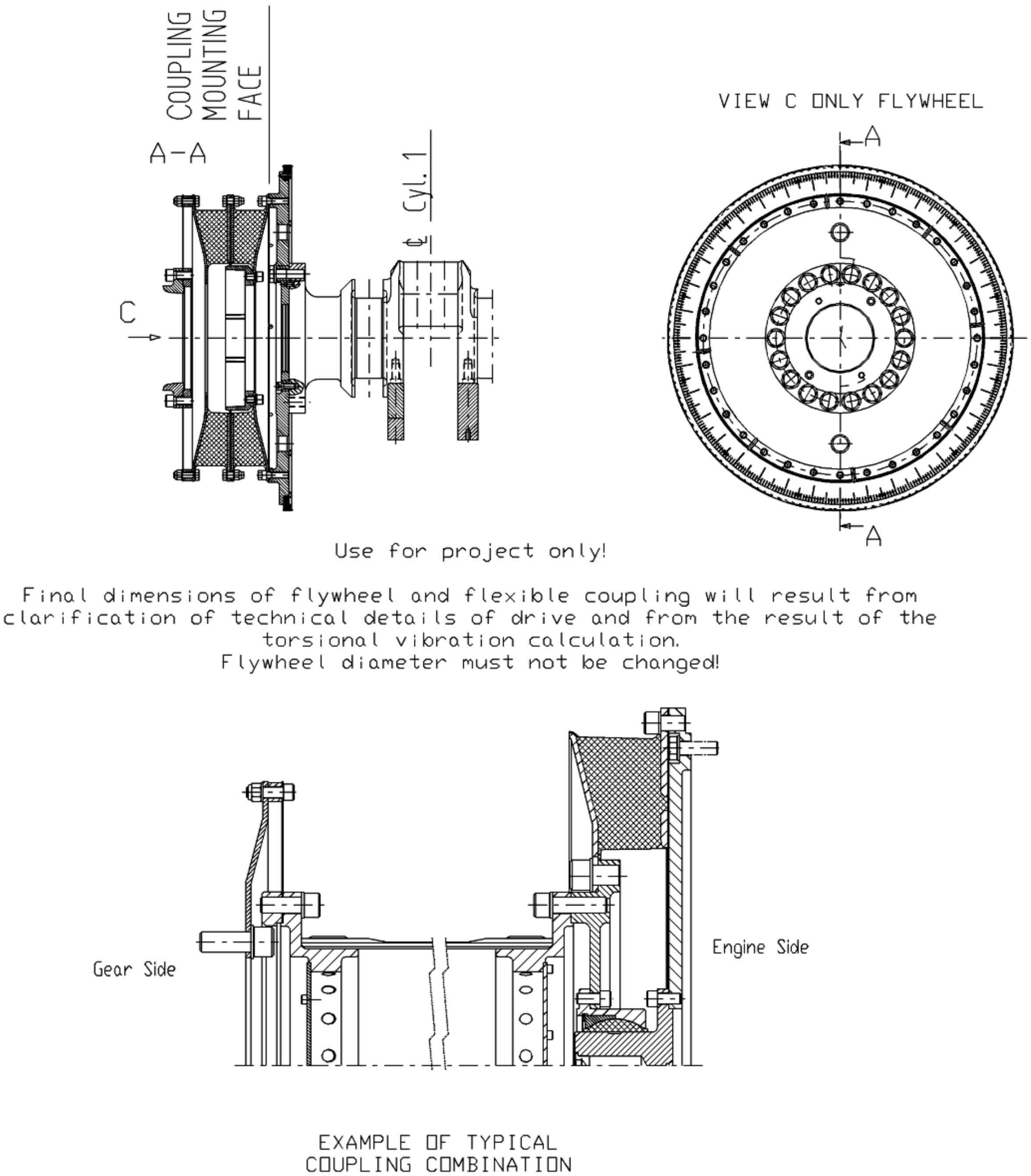

Figure 35: Example of flywheel arrangement with flexible coupling

Note:
The flexible coupling will be part of MAN Energy Solutions supply and thus we will produce a contract specific flywheel/coupling/driven machine arrangement drawing giving all necessary installation dimensions. Final dimensions of fly-

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wheel and flexible coupling will result from clarification of technical details of drive and from the result of the torsional vibration calculation. Flywheel diameter must not be changed.

2.24 Foundation

2.24.1 General requirements for engine foundation

Plate thicknesses

The stated material dimensions are recommendations, calculated for steel plates. Thicknesses smaller than these are not permissible. When using other materials (e.g. aluminium), a sufficient margin has to be added.

Top plates

Before or after having been welded in place, the bearing surfaces should be machined and freed from rolling scale. Surface finish corresponding to Ra 3.2 peak-to-valley roughness in the area of the chocks shall be accomplished.

The thickness given is the finished size after machining.

Downward inclination outwards, not exceeding 0.7 %.

Prior to fitting the chocks, clean the bearing surfaces from dirt and rust that may have formed. After the drilling of the foundation bolt holes, spotface the lower contact face normal to the bolt hole.

Foundation girders

The distance of the inner girders must be observed. We recommend that the distance of the outer girders (only required for larger types) is observed as well.

The girders must be aligned exactly above and underneath the tank top.

Floor plates

No manholes are permitted in the floor plates in the area of the box-shaped foundation. Welding is to be carried out through the manholes in the outer girders.

Top plate supporting

Provide support in the area of the frames from the nearest girder below.

Dynamic foundation requirements

The eigenfrequencies of the foundation and the supporting structures, including GenSet weight (without engine) shall be higher than 20 Hz. Occasionally, even higher foundation eigenfrequencies are required. For further information refer to section Noise and vibration – Impact on foundation, Page 87.

Note:
The requirements of the respective classification society have to be considered in addition.

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2.24.2 Resilient mounting position

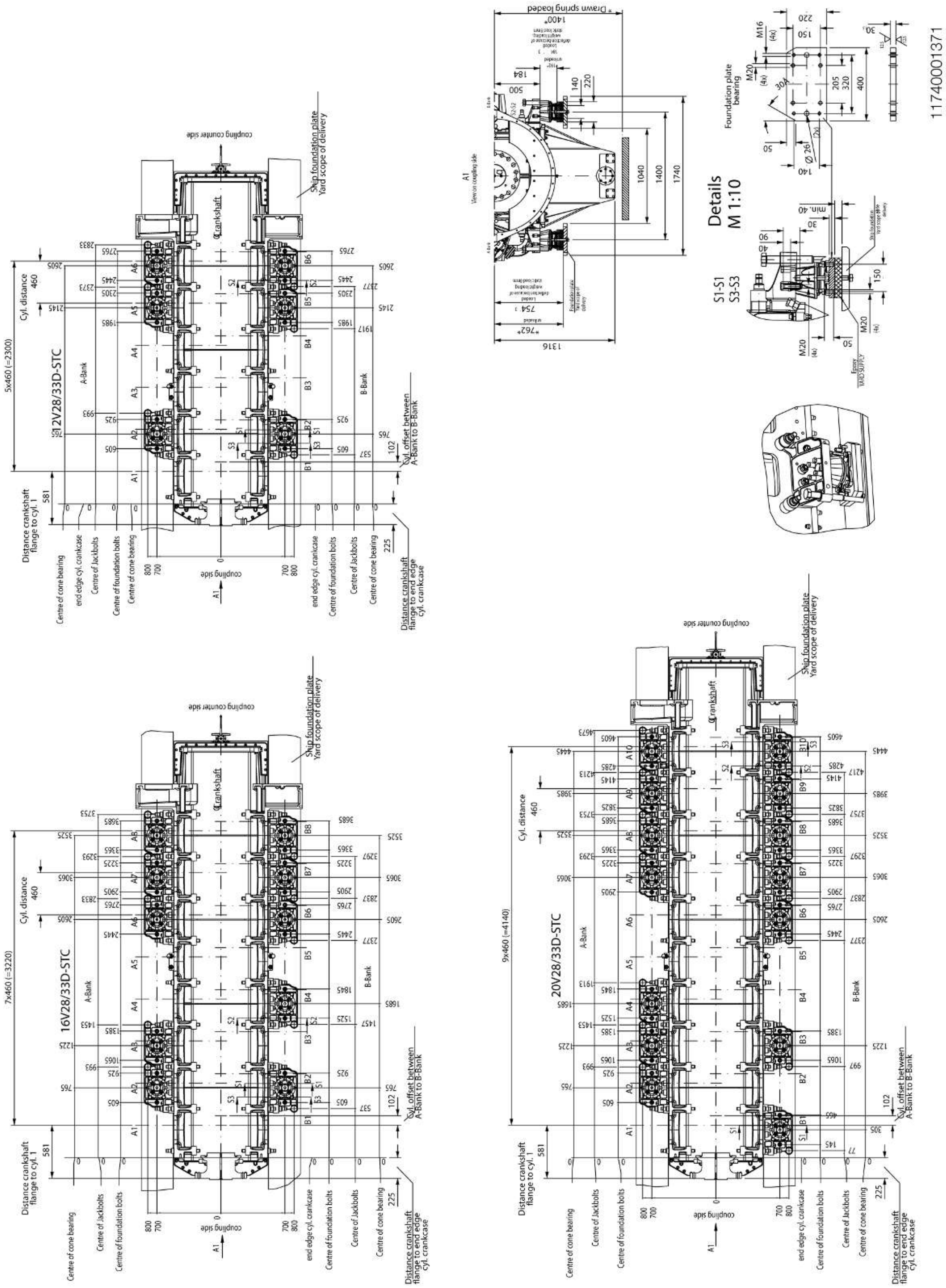

Figure 36: General arrangement

2.24.3 Resilient seating

General

The vibration of the engine causes dynamic effects on the foundation. These effects are attributed to the pulsating reaction forces due to the fluctuating torque. Additionally, in engines with certain cylinder numbers these effects are increased by unbalanced forces and couples brought about by rotating or reciprocating masses which – considering their vector sum – do not equate to zero.

The direct resilient support makes it possible to reduce the dynamic forces acting on the foundation, which are generated by every reciprocating engine and may – under adverse conditions – have harmful effects on the environment of the engine.

With respect to large engines (bore > 400 mm) MAN Energy Solutions offers two different versions of the resilient mounting (one using conical – the other inclined sandwich elements).

The inclined resilient mounting was developed especially for ships with high comfort demands, e.g. passenger ferries and cruise vessels. This mounting system is characterised by natural frequencies of the resiliently supported engine being lower than approximately 7 Hz. The resonances are located away from the excitation frequencies related to operation at nominal speed.

For average demands of comfort, e.g. for merchant ships, and for smaller engines (bore < 400 mm) mountings using conical mounts can be judged as being fully sufficient. Because of the stiffer design of the elements the natural frequencies of the system are significantly higher than in case of the inclined resilient mounting. The natural frequencies of engines mounted with this kind of mounts are lower than approximately 18 Hz. The vibration isolation is thus of lower quality. It is however, still considerably better than a rigid or semi resilient engine support.

The appropriate design of the resilient support will be selected in accordance with the demands of the customer, i.e. it will be adjusted to the special requirements of each plant.

In both versions the supporting elements will be connected directly to the engine feet by special brackets.

The number, rubber hardness and distribution of the supporting elements depend on:

- The weight of the engine
- The centre of gravity of the engine
- The desired natural frequencies

Where resilient mounting is applied, the following has to be taken into consideration when designing a propulsion plant:

- Resilient mountings always feature several resonances resulting from the natural mounting frequencies. In spite of the endeavour to keep resonances as far as possible from nominal speed the lower bound of the speed range free from resonances will rarely be lower than 70 % of nominal speed for mountings using inclined mounts and rarely lower than 85 % for mountings using conical mounts. It must be pointed out that these percentages are only guide values. The speed interval being free from resonances may be larger or smaller. These restrictions in speed will mostly require the deployment of a controllable pitch propeller.

- Between the resiliently mounted engine and the rigidly mounted gearbox or alternator, a flexible coupling with minimum axial and radial elastic forces and large axial and radial displacement capacities should be provided.
- The media connections (compensators) to and from the engine must be highly flexible whereas the fixations of the compensators on the one hand with the engine and on the other hand with the environment must be realised as stiff as possible.
- For the inclined resilient support, provision for stopper elements has to be made because of the sea-state-related movement of the vessel. In the case of conical mounting, these stoppers are integrated in the element.
- In order to achieve a good vibration isolation, the lower brackets used to connect the supporting elements with the ship's foundation are to be fitted at sufficiently rigid points of the foundation. Influences of the foundation's stiffness on the natural frequencies of the resilient support of the engine will not be considered in the mounting design calculation.
- The yard must specify with which inclination related to the plane keel the engine will be installed in the ship. The inclination must be defined and communicated before entering the dimensioning process.

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3 Engine automation

3.1 SaCoSone system overview

The monitoring and safety system SaCoSone is responsible for complete engine operation, control, alarming and safety. All sensors and operating devices are wired to the engine-attached units. The interface to the plant is done by means of an Interface Cabinet.

During engine installation, only the bus connections, the power supply and safety-related signal cables between the units/modules on engine and the cabinets are to be laid, as well as connections to external modules, electrical motors on the engine and parts on site.

The SaCoSone design is based on highly reliable and approved components as well as modules specially designed for installation on medium-speed engines. The used components are harmonised to an homogenous system. The system has already been tested and parameterised in the factory.

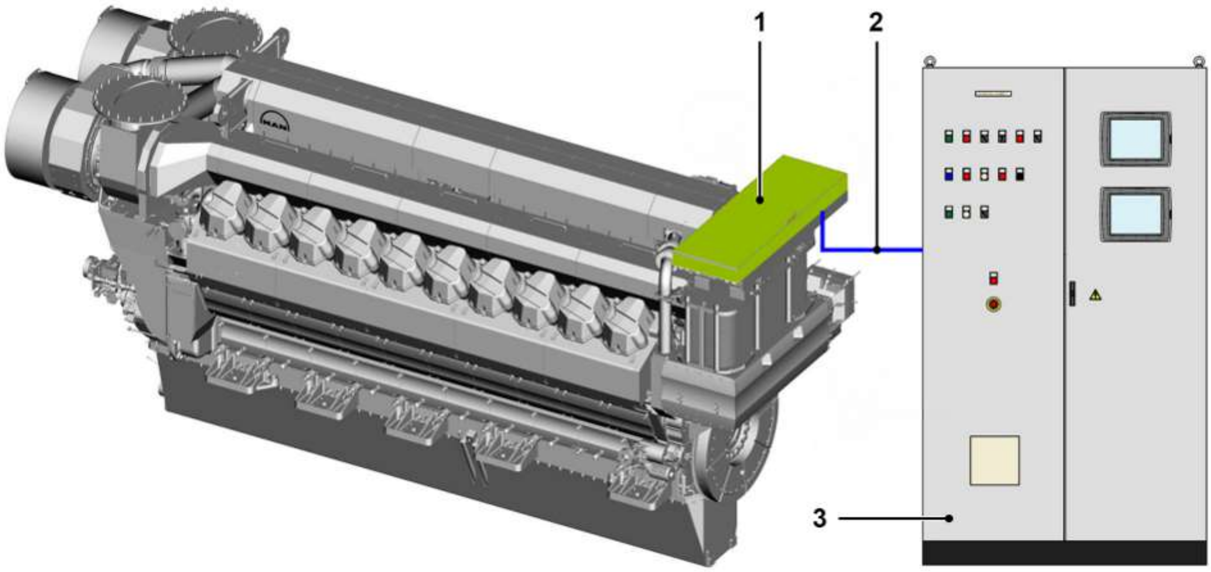

Figure 37: SaCoSone system overview

1	Control and Injection Unit
2	System bus
3	Interface Cabinet with integrated Local Operating Panel
	Remote Operating Panel (optional), not shown
	Turning Gear Control, not shown
	Data Logging Cabinet (optional), not shown

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Control and Injection Unit

The Control and Injection Unit is mounted on the engine cushioned against vibration. It includes the following modules:

- Two identical, highly integrated Control Modules, one for safety functions and the other one for engine control and alarming. The modules work independently of each other and collect engine measuring data by means of separate sensors.
- Two identical, highly integrated injection modules. The first Injection Module is used for speed control and for the actuation of the injection valves. The second one serves as backup and takes over the speed control and the control of the injection valves without interruption in case of an error in the first module.

Figure 38: Control and Injection Unit

Interface Cabinet

The Interface Cabinet is a floor-standing cabinet that optionally will be equipped with an air condition. The Interface Cabinet is the interface between SaCoSone and the plant control and therefore connects the engine safety and control system with the power management, propulsion control and other periphery parts.

It is the central connection for the 400 V AC, 230 V AC and 24 V DC power supply to the engine from the vessel’s power distribution. It includes the starters for the temperature control valves.

The Interface Cabinet is equipped with a Local Operating Panel. This panel provides a TFT display for visualisation of all engine‘s operating and measuring data. At the Local Operating Panel, the engine can be fully operated. Additional hardwired switches are available for relevant functions.

Figure 39: Interface Cabinet

Remote Operating Panel (optional)

The Remote Operating Panel serves for engine operation from a control room. The Remote Operating Panel has the same functions as the Local Operating Panel.

From this operating device it is possible to transfer the engine operation functions to a super-ordinated automation system. In plants with integrated automation systems, this panel can be replaced by IAS.

The panel can be delivered as loose supply for installation in the control room desk.

Figure 40: Remote Operating Panel (optional)

Data Logging Cabinet (optional)

The data logging cabinet is used for the connection to Online Assist. The data logging module is installed in the data logging cabinet.

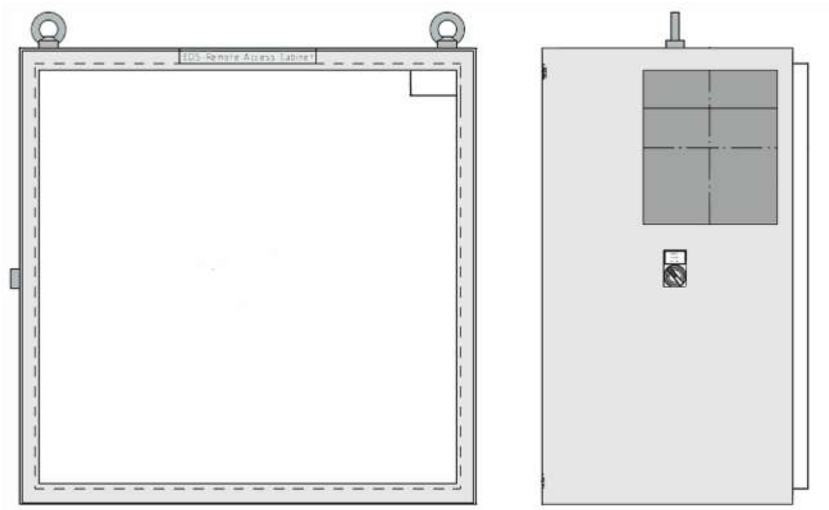

Figure 41: Data Logging Cabinet

Turning Gear Control

The mobile Turning Gear Control contains the control system for turning operation.

The 230 VAC (optional 115 VAC) power supply is fed in via the Interface Cabinet.

The TGC is hard-wired to the Control and Injection Unit.

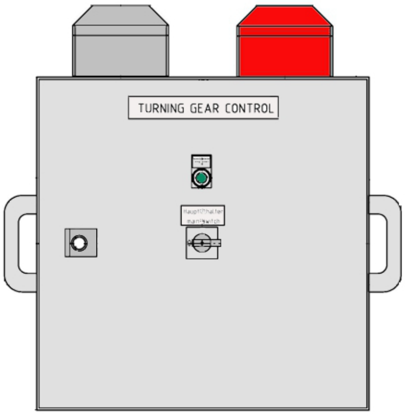

Figure 42: Turning Gear Control

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SaCoSone system bus

The SaCoSone system bus connects all system modules. This redundant field bus system provides the basis of data exchange between the modules and allows the takeover of redundant measuring values from other modules in case of a sensor failure.

SaCoSone is connected to the plant by the Gateway Module. This module is equipped with decentral input and output channels as well as with different interfaces for connection to a super-ordinated automation system, the Remote Operating Panel and the online service.

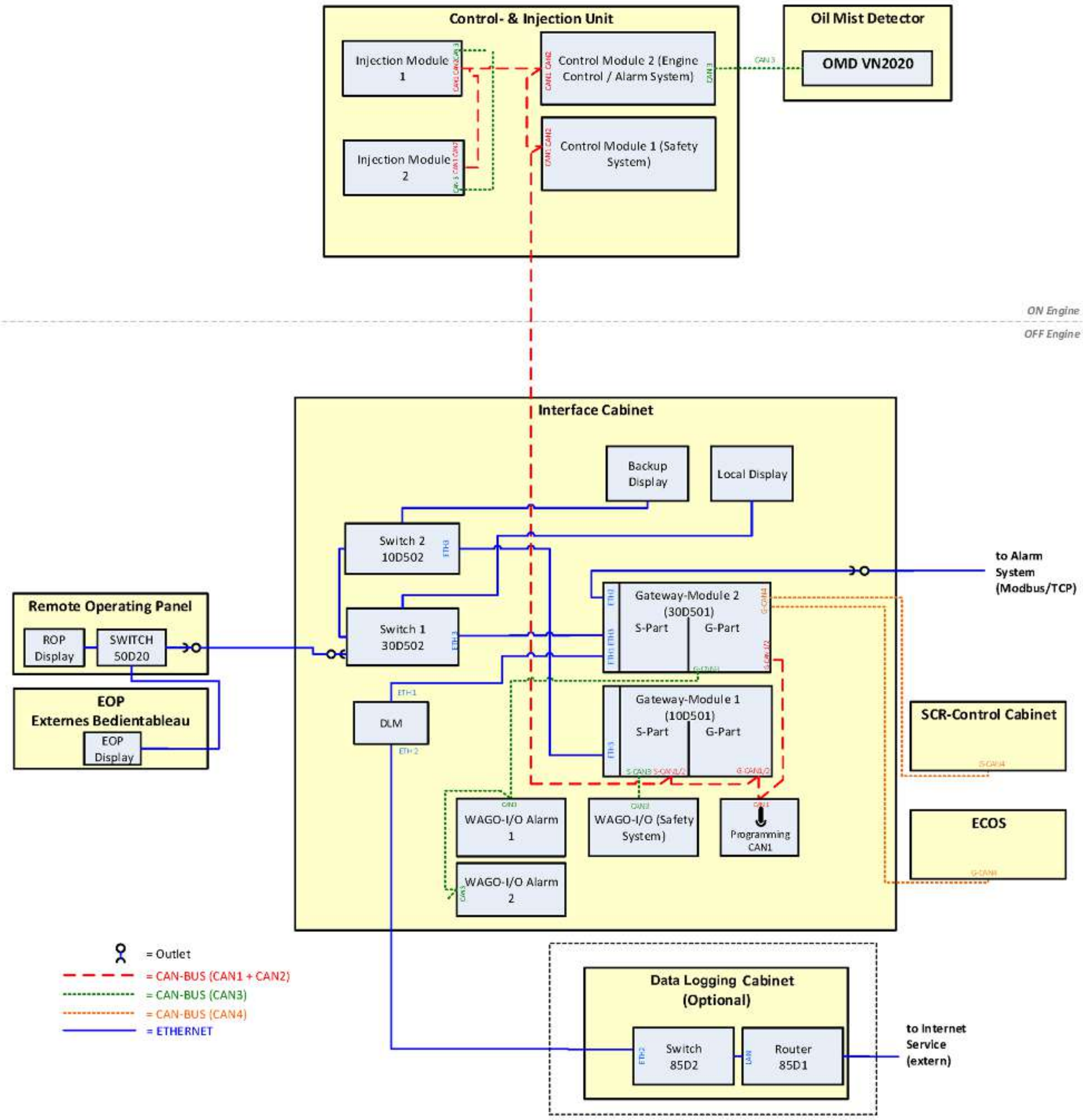

Figure 43: SaCoSone system bus

Monitoring network

The monitoring network interconnects monitoring interface of all available engine controls. This network is the basis of data exchange between monitoring applications, e.g. CoCoS EDS PC or MAN Online Services. Within each en-

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gine control, a component is installed which is responsible for data exchange of TCP/IP level. A firewall is implemented to protect the system which also regulates communication between monitoring network, internet access network and MAN Online Services.

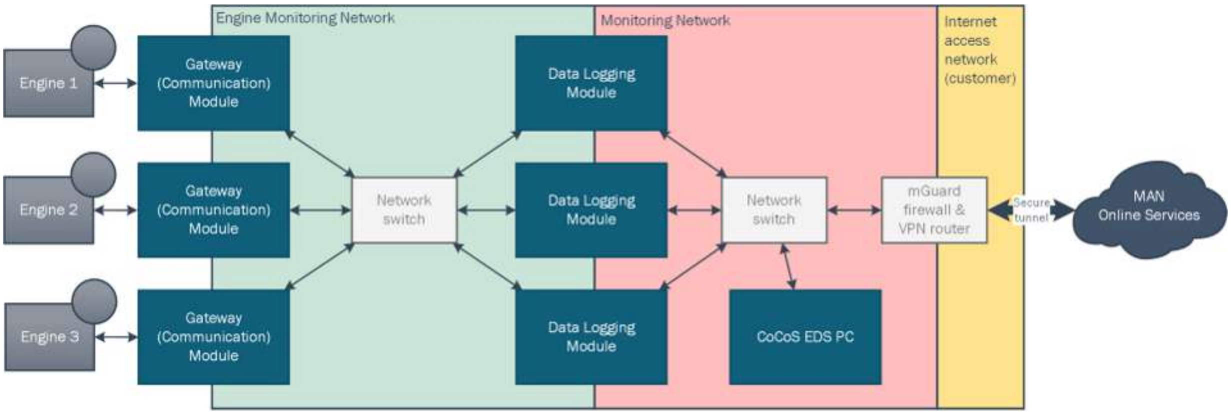

Figure 44: Engine monitoring network, monitoring network, internet access network

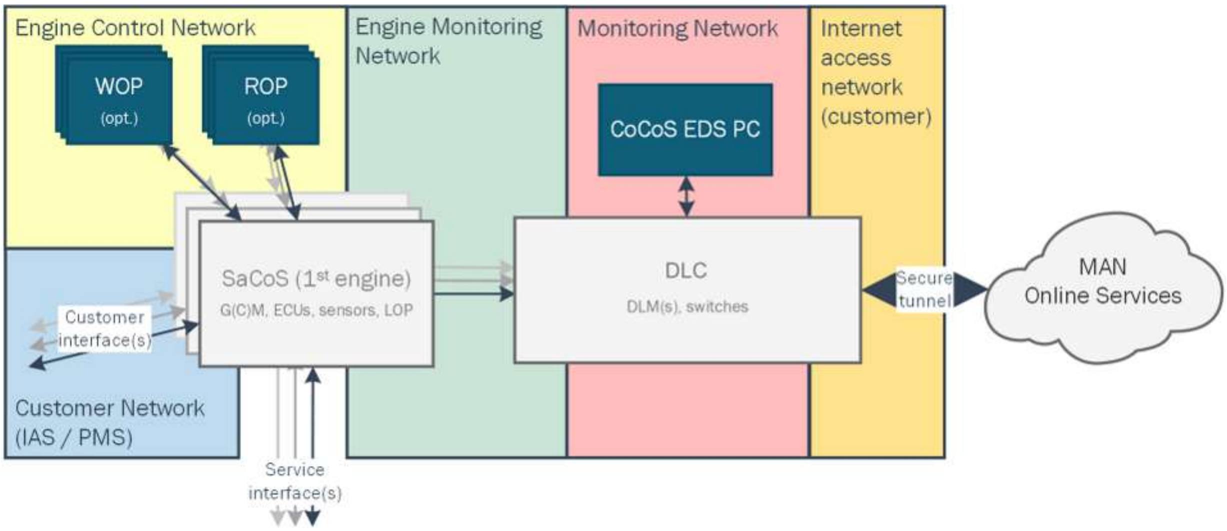

Figure 45: Engine control network, engine monitoring network, monitoring network, internet access network

Cyber security guidelines

The following cyber security guidelines represent a recommendation of protective measures to prevent unauthorized access, among other things. Some recommendations may not be applicable or only partially applicable or achievable, depending on the system.

Assure physical SaCoS security

Due to its design, certain parts and connections of SaCoSone have to be physically protected against access by unauthorized personnel. Only authorized staff must be allowed access, and only after their authentication. Such access should be logged, and the logs kept for future audit purposes. Physical security measures (walls, locked doors, cable routing that makes network and serial cables inaccessible to unauthorized personnel) must be established to prevent attackers from accessing and tampering with SaCoSone hardware, software, cables, and data, disconnecting SaCoSone components from their intended networks, or connecting unauthorized devices to the system.

The level of physical security measures must be assessed by the customer and may be based on but is not limited to system context, intended system use, system location, assumptions about current threats to the customer business, ease of access, and applicable regulations.

Such measures are particularly necessary for the following SaCoSone components and connections associated with safety-critical engine operation and control; depending on the SaCoS variant, those may include but are not limited to the following:

- SaCoSone modules connected via the CAN bus ("Core control network"), including but not limited to Gateway Module, Control Module, Injection Module, WAGO-I/O, VTT frequency converters.
- CAN bus.
- SaCoSone sensors and actuators.
- Network cables connecting operating panels (esp. those placed outside the engine room such as ROP and EOP) to SaCoSone.
- All operating panels incl. LOP, ROP, EOP, and WOP.
  Software update of operating panels can also be performed over USB. It is therefore imperative for the customer to limit and control access to the room(s) where such panels are installed. Only trained MAN service staff is allowed to interact with the USB port of the operating panel, unless the customer is explicitly permitted to do so by MAN Energy Solutions in case of emergency. The customer must not expose the operating panel's USB port on the outside of the panel's enclosure. The enclosure must remain closed except during authorized servicing tasks.
- (Serial or Ethernet) cable(s) connecting the system to external networks (e.g., Customer Network).
- All cables used to connect the SaCoSone Toolbox with the SaCoSone modules, as well as the Toolbox itself.
- Network switches.

Failing to follow those guidelines may result in, but is not limited to the following:

- Catastrophic impact on the safety of the engine, plant, as well as their environment.
- Loss of engine control, potentially to a threat actor.
- Loss of access to (authentic) information on engine and system state (incl. operational and alarm data), potentially to a threat actor.

Devices within Security Zones 1 and higher have limited communication access to devices within Security Zone 0, and thus pose a lower risk of compromising the safety of the engine. However, those devices and their connections may have to be protected against unauthorized access. This may include, but is not limited to the following security measures:

- Communication between the GM and the DLM has to be physically secured against unauthorized access.
- Any network switches installed between the GM and the DLM may not be physically accessed, or connected to.

Failure to follow the outlined guidelines to prevent attack scenarios may result in, but is not limited to the following risk scenarios (Depending on the resources available to the attacker, a targeted attack on SaCoSone may have grave consequences to the engine and its environment. The risk scenarios listed in this document are not exhaustive):

- Loss of engine control, potentially to a threat actor.

- Loss of access to (authentic) information on engine and system state (incl. operational and alarm data), potentially to a threat actor.

Guarantee and verify the security of connection to the Customer Network and operating panels

SaCoSone can be operated remotely using a remote operating panel such as ROP or WOP, as well as by issuing commands from the Customer Network using a serial or Ethernet connection. For that purpose, the SaCoSone Gateway Module (GM) provides an interface that is used by the operating panels and devices within the customer network.

The customer must therefore ensure the following:

- Physical access to network and serial cables connecting SaCoSone with devices on the Customer Network and the operating panels must be restricted.
- Communication with operating panel must not be routed over an already existing network that has other participants or to which other participants can be added in the future without authorization.
- Communication between SaCoSone and devices on the Customer Network must not be exposed to potential aggressors (e.g., potentially compromised or infected devices on the same network).

Failure to follow the outlined guidelines to prevent attack scenarios may result in, but is not limited to the following risk scenarios:

- Loss of engine control, potentially to a threat actor.
- Loss of access to (authentic) information on engine and system state (incl. operational and alarm data), potentially to a threat actor.

Ensure secure access and storage of SaCoS related data

Data that is created by or for SaCoS, including SDIs, parameter sets, or operational data is not protected by the system. It is therefore imperative to store such data securely and protect it against unauthorized access.

Data access and secure storage may be implemented by following the following guidelines:

- Only use separate, dedicated hardware (e.g., SaCoSone Toolbox, dedicated “MAN Energy Solutions Service Stick” USB mass storage devices) for separate, dedicated tasks (e.g., parametrizing SaCoSone, storing SDIs).
- Consider encrypting and/or authenticating SaCoS related data stored outside of SaCoS.
- Never connecting such hardware to devices or networks other than those dedicated to their purpose (e.g., do not connect the MAN Energy Solutions Service Stick used to store SDIs to the DLM).
- Physically secure such hardware by storing it in a secure, access controlled location.
- Do not disclose any authenticators used to access any SaCoS device or system to unauthorized parties. Such authenticators may include the eToken password, LOP passwords, or credentials for devices managed by the customer that connect to SaCoS.
- Data related to servicing the operating panels (e.g., software updates, extracted alarm history) must be stored in a secure, tamper-proof location.

Failing to follow these guidelines may result in, but is not limited to the following scenarios:

- Attacker learns details about system and engine usage, properties, and state.
- Attacker is able to manipulate engine state.

Secure the Customer Network

SaCoS is exposing an unauthenticated network service that the customer can connect to in order to monitor and control the engine. This logical network is referred to as the Customer Network, and must be secured by the customer in order to prevent the loss of engine monitoring and control, potentially to an attacker. Assuring the security of this network is the customer's responsibility.

While the risk of an attacker within the Customer Network being able to threaten the safety of the engine is low, they may gain the ability to control the engine, which may present a safety risk to the overall plant. Therefore, the customer must implement security measures to secure that network that may include, but are not limited to the following:

- Devices on the Customer Network may only communicate with SaCoS via the Eth2 network interface of the GM.
- Limit and protect physical and communication access to the devices on the network that the GM connects to via its Eth2 network interface, as well as all network connections between the GM and any of the devices on the Customer Network.
- Use of wireless technologies is strongly discouraged.
- In addition to the SaCoSone GM, the Customer Network may only contain IAS/PMS devices.
- The "Customer Network" must be segregated from any other customer's networks.
- Do not connect any untrustworthy or vulnerable devices to the Customer Network.
- Do not bridge the Customer Network with public or otherwise untrustworthy networks, or any other plant networks that may have untrusted participants.
- Secure every device on the customer network according to the customer's own risk assessment and CSMS. The measures may include a hardening of the devices, providing them with regular security updates, disabling USB ports, performing antivirus scans, and/or the maintenance of an "air gap" between the Customer Network devices and any other network.
- Avoid running any Modbus services on the Customer Network to avoid incidentally connecting to those services instead of the Modbus service provided by the SaCoSone GM.

Failing to follow the outlined guideline may result in, but is not limited to the following risk scenarios:

- Threat actor may manipulate what is displayed on the operating panels.
- Threat actor may learn operational data reported to the operating panels and to the customer network.
- Threat actor may be able to control engine (within safety constraints).
- Threat actor may be able to execute engine safety test(s) that are usually executing using the operating panel(s).
- Threat actor may be able to deny engine operation and control via the operating panels or via Modbus signals from within the Customer Network.
- Threat actor may be able to disable some of the safety functions implemented by the GM.

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In addition, a compromised SaCoS may pose a threat to the Customer Network, and compromise or infect devices connected to it. While the risk is estimated by MAN Energy Solutions to be very low in the context of a risk assessment performed in the context of Security Level 1 as per IEC 62443, the customer may still want to implement additional security measures in order to protect against this threat. Such measures may include, but are not limited to the following:

- Install a dedicated network security device (e.g., firewall, IPS) that protects the conduit between SaCoS and the Customer Network. Such a device may, e.g., only allow Modbus communication initiated from within the Customer Network and the Modbus responses by the GM, and/or monitor, log, and notify the customer about suspicious or unusual communication activity between SaCoS and the Customer Network.
- Harden devices on the Customer Network under the assumption that SaCoS may act as an aggressor.
- Do not expose any critical assets (e.g., confidential data, other plant control or monitoring functionality) on the Customer Network.

Secure the Operating Panels

The SaCoSone operating panels and their connection to the rest of the system are not hardened or kept up to date, which may allow a potential attacker to compromise them. The customer is therefore advised to ensure the following:

- Physical access to the operating panel must be controlled and restricted to authorized personnel.
- Physical access to the communication ports of the operating panels (including USB and Ethernet ports) must be limited and restricted to authorized MAN Energy Solutions service staff. The customer may not change the connections set up by MAN Energy Solutions, or connect their own devices to the panels except in case of an emergency, and only by following exactly the directions provided by MAN Energy Solutions.
- Software update of an operating panel may only be performed by the customer in case of an emergency, and only if directed by MAN Energy Solutions. USB drive used for transferring the update to the LOP must be wiped prior to its use. Software update files must be obtained directly from MAN Energy Solutions, and only over a secure channel as directed by MAN Energy Solutions, using a secure and trusted device to assure that they have not been tampered with. Customer must make sure that the update they are applying is the version that MAN Energy Solutions directed them to use, and afterwards verify that the installed version is correct.

Failing to follow those guidelines may result in, but is not limited to the following (see also "Secure the Customer Network" section):

- Engine control is lost (to a potential attacker).
- Inauthentic data is shown on the operating panels or reported to devices on the Customer Network.
- Operating panels become inoperable.

Maintain the network segmentation at all times

The network segmentation implemented for SaCoSone is a major part in keeping the system secure against outside threats. Therefore, the network structure that as established during system setup must not be changed. Specifically, the following has to be assured:

- Individual network segments may not be bridged, e.g., by connecting a service device to several network segments at the same time, interconnecting network switches from different network segments, or connecting devices from one segment to devices on other segments.
- No additional devices may be connected to any of the network zones.

Failing to uphold the network segmentation prescribed by MAN Energy Solutions may result in, but is not limited to the full and persistent compromise of SaCoSone and the safety of the engine.

Prepare for security incidents

Following the guidelines outlined in this document helps to minimize the risk of possible system compromise by an attacker, but residual risks will remain. The customer must be prepared for potential compromise scenarios, and be able to respond to a security incident. The customer must prepare an incident response plan that may include, but is not limited to the following steps:

- Purchase spare parts to replace SaCoSone devices that are suspected to have been compromised.
- If making changes to the system (e.g., parameter changes through Toolbox), also remember to take backups of those changes.
- In case a Toolbox is not available, contract specific agreements apply (availability of MAN Energy Solutions service, spare parts, etc.).
- Report the incident to MAN Energy Solutions and follow the instructions of MAN Energy Solutions support service.
- Secure the forensic evidence (including, but not limited to audit and access logs created by SaCoSone and the customer's devices and processes) that may point to potential cause(s) of the incident.
- Analyze the evidence and enact steps to mitigate the vulnerability that led to the incident.

The customer shall also monitor at the best of their abilities the system for indications of a possible security incident. Any of the following indicators may point to the fact that the SaCoS protection measures have been breached:

- Inconsistencies between data displayed on any of the operating panels, and/or reported to devices within the Customer Network are detected.
- Unrealistic or suspicious data is displayed on any or all of the operating panels or the EDS PC, and/or reported to devices within the Customer Network.
- Unusual system behavior is detected that can be attributed to unintended system operation commands.
- Remote engine operation is no longer possible.

To address such a breach, the customer is advised to consider the following mitigations:

- Put the system into a safe state depending on the current situation (e.g., island mode, engine shutdown etc.), inform MAN Energy Solutions service of the suspicious behavior, and continue operation only after the issue has been resolved.
- For the duration of continued operation, switch the system into island mode (i.e. local engine control via LOP) by disconnecting all remote connections to the GM (i.e., network connections to Eth1, Eth2 interfaces of the GM). If this does not resolve the issue, and the current situation allows for it without compromising system safety, also disconnect the network connection to the Eth3 interface of the GM, and operate the system via hardwire.

Failing to follow those guidelines may result in much longer times until an incident has been detected and corrected, leading to potential financial damages, and/or posing a risk to the safety of the system.

Secure disposal / decommissioning

For the purposes of secure device disposal, consider that SaCoS components (including, but not limited to ECUs, Data Logging Modules, EDS PC, eTokens, and the Toolbox) store sensitive information including engine parameters, engine operational data, and cryptographic keys.

Account management

Most SaCoS components do not support interactive access by the customer. Notable exceptions are:

- mGuard configuration account,
- Toolbox account,
- EDS PC account, and
- GM service access using the EXPERT eToken.

mGuard account and EXPERT eToken management is handled by MAN Energy Solutions, whereas SaCoS Toolbox and EDS PC are Windows-based machines to be managed and secured by the customer according to this guideline. For this purpose, the onboard operating system facilities can be utilized.

3.2 Power supply and distribution

The plant has to provide electric power for the automation and monitoring system. In general an uninterrupted 24 V DC power supply is required for SaCoSone.

For marine main engines, an uninterrupted power supply (UPS) is required which must be provided by two individual supply networks. According to classification requirements it must be designed to guarantee the power supply to the connected systems for a sufficiently long period if both supply networks fail.

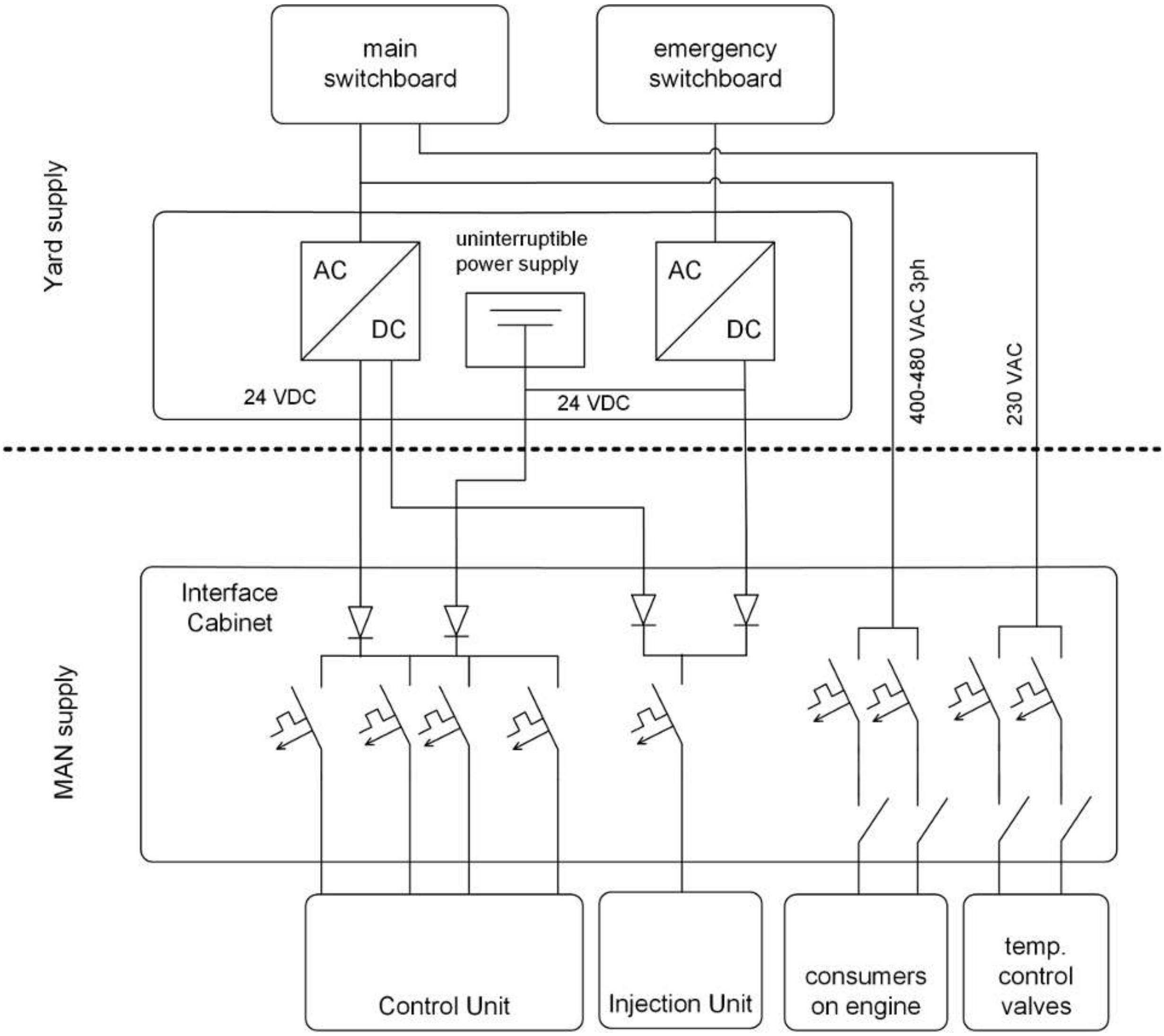

Figure 46: Supply diagram

Voltage	Consumer	Notes:
24 V DC	SaCoSone Interface Cabinet	All SaCoSone components in the Interface Cabinet and on the engine.
230 V 50/60 Hz	SaCoSone Interface Cabinet	Cabinet illumination, socket, anti-condensation heater.
400 – 480 V 50/60 Hz	Crankcase coalescer/extractor fan	Power supply crank case coalescer/ extractor fan.

Table 74: Required power supplies

Emergency conditions

The MAN V28/33D STC engine continues to run as long as the 24 V DC power supply is working and the engine is supplied with fuel.

Therefore, SaCoSone requires an uninterruptible power supply (UPS). This UPS supplies the control system (inclusive electronic speed governor and ROP) via the Interface Cabinet.

That means in case of black ship the engine can still be controlled from remote.

The UPS will supply SaCoSone for approx. 30 minutes until the battery is empty (depending on installed battery capacity).

Furthermore, the fuel supply has to be ensured. The fuel should be provided e.g. via a header tank, for description see section MGO supply system description, Page 186.

Galvanic isolation

It is important that at least one of the two 24 V DC power supplies per engine is foreseen as isolated unit with earth fault monitoring to improve the localisation of possible earth faults. This isolated unit can either be the UPS-buffered 24 V DC power supply or the 24 V DC power supply without UPS.

Example:

The following overviews shows the exemplary layout for a plant consisting of four engines. In this example the 24 V DC power supply without UPS is the isolated unit. The UPS-buffered 24 V DC power supply is used for several engines. In this case there must be the possibility to disconnect the UPS from each engine (e.g. via double-pole circuit breaker) for earth fault detection.

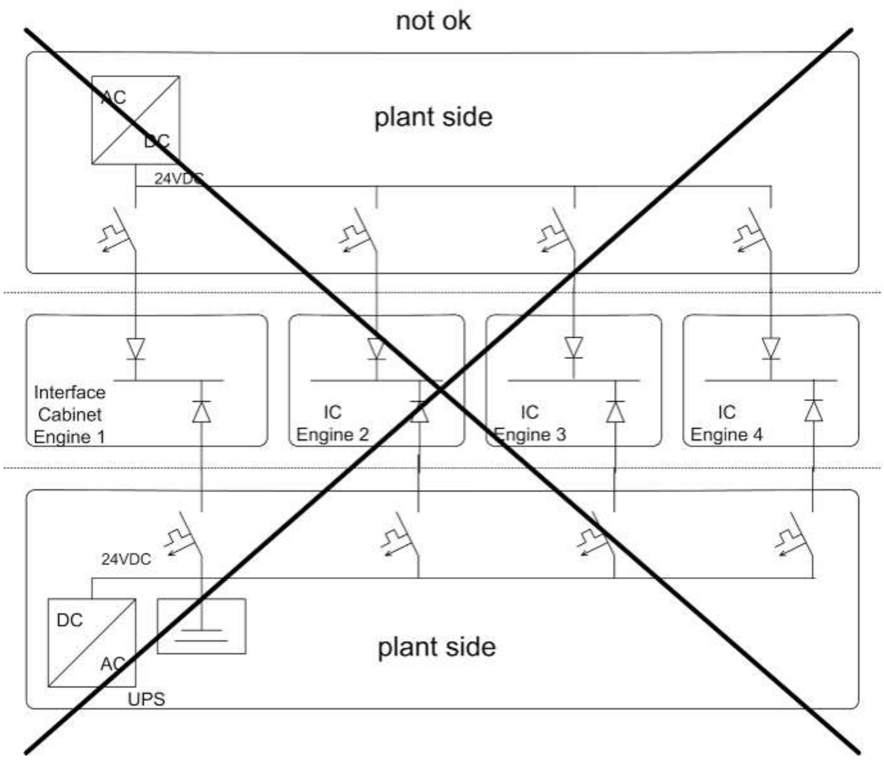

Figure 47: Wrong installation of the 24 V DC power supplies

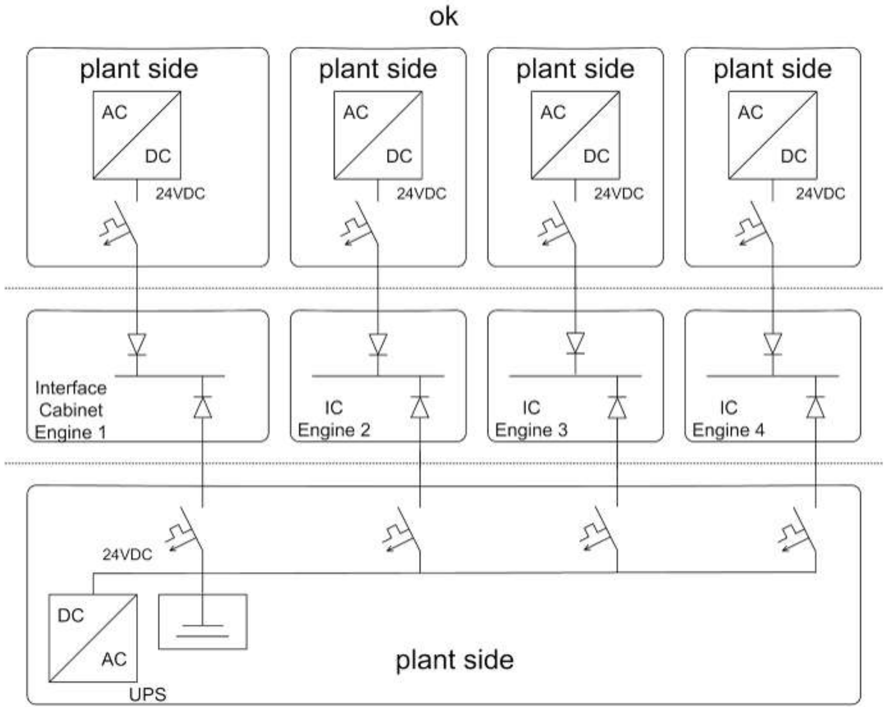

Figure 48: Correct installation of the 24 V DC power supplies

3.3 Safety architecture

Connection of external digital outputs to safety-relevant dual-channel digital inputs of SaCoSone

SaCoS owns a double-channel safety architecture. External emergency stops or automatic shutdowns have to support this architecture to avoid false alarms of the plausibility check. Supporting could be done by having a double-channel architecture too (recommended by MAN Energy Solutions) or by having a single-channel architecture effecting both channels. To support single-channel architectures of marine applications an additional box is necessary, which is effecting both channels and provide a wire break detection (see right figure below).

Note:
A single-channel architecture has a higher probability of failure than a double-channel architecture.

MAN Energy Solutions will not be responsible for any increase of risk, which might be caused by the use of such a single-channel architecture instead of double-channel architecture.

The relais have to be energized on demand of the safety function. The wire-break-monitor will be de-energized at wire-break.

Attention, wire-break-monitoring is not supported for all variants of SaCoS at redundant inputs (because a plausibility check of the two channels, when the safety function is requested, is sufficient to detect errors).

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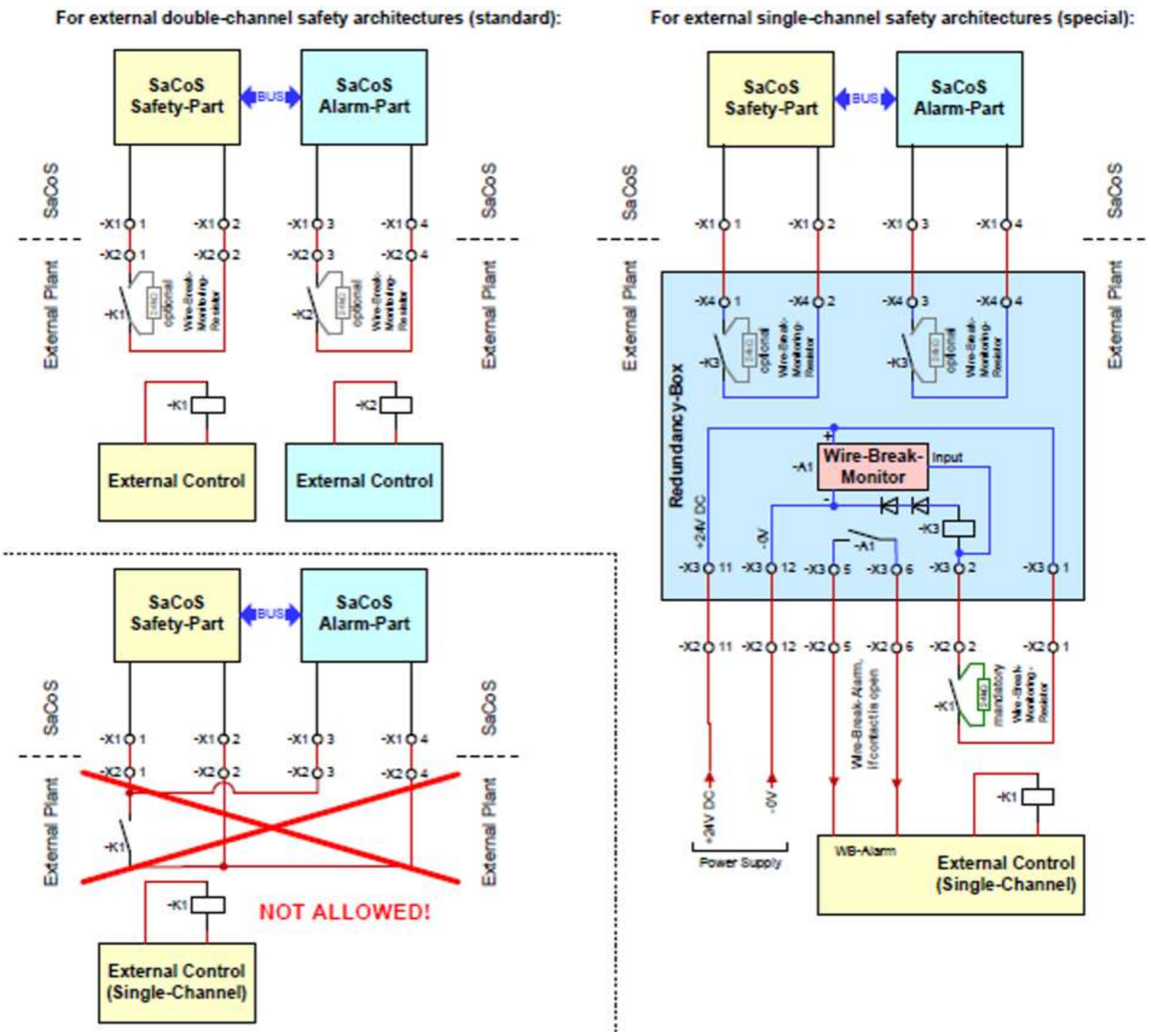


⚠ WARNING It is not allowed to connect both redundant channels of SaCoS direct which each other without redundancy box and connect it then to the external single channel.

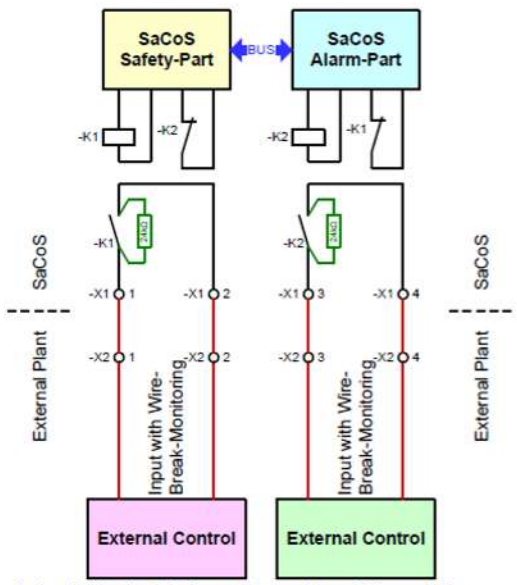
Connection of single-channel digital inputs to safety-relevant dual-channel digital outputs

Where double-channel outputs are provided by MAN Energy Solutions for safety related functions, they have to be connected to a double-channel inputs at site. Where this is not possible, due to the lack of a double-channel architecture in the external controlling system, then a single-channel input can be converted to a double-channel architecture with the circuit proposed in this document.

MAN Energy Solutions will not be responsible for any increase of risk, which might be caused by the use of such a single-channel control.

The relais are deenergized in normal case and energized at failure. The main contacts are open in normal case and closed at failure (the feedback contacts must be complementary). All relays must have forcibly guided contacts.

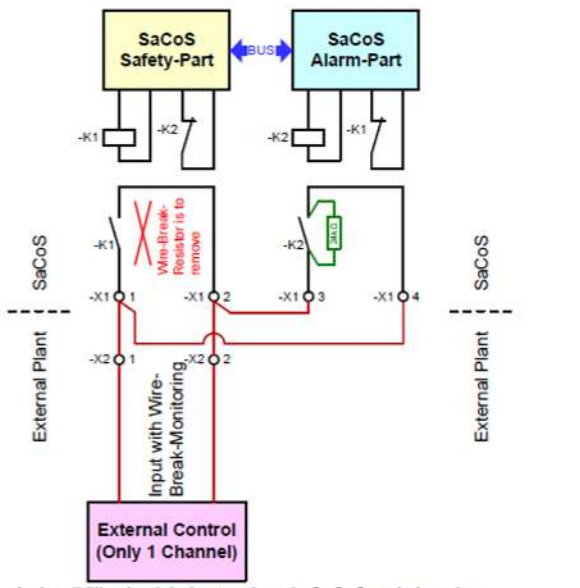
Wiring 2 Digital Inputs To 2 Digital Outputs (Standard):



A plausibility-check between Channel 1 and Channel 2 is necessary at external plant.

A wire-break monitoring is optional at double-channel architectures, if plausibility-check is implemented.

Wiring 1 Digital Input To 2 Digital Outputs (Special Solution):



A plausibility-check between alarm in SaCoS and alarm in external control is necessary.

A wire-break monitoring is mandatory at single-channel architectures.

3.4 Operation

Control station changeover

The operation and control can be done from both operating panels. Selection and activation of the control stations is possible at the Local Operating Panel. On the displays, all the measuring points acquired by means of SaCoSone can be shown in clearly arranged drawings and figures. It is not necessary to install additional speed indicators separately.

The operating rights can be handed over from the Remote Operating Panel to another Remote Operating Panel or to an external automatic system. Therefore a handshake is necessary.

For applications with Integrated Automation Systems (IAS) also the functionality of the Remote Operating Panel can be taken over by the IAS.

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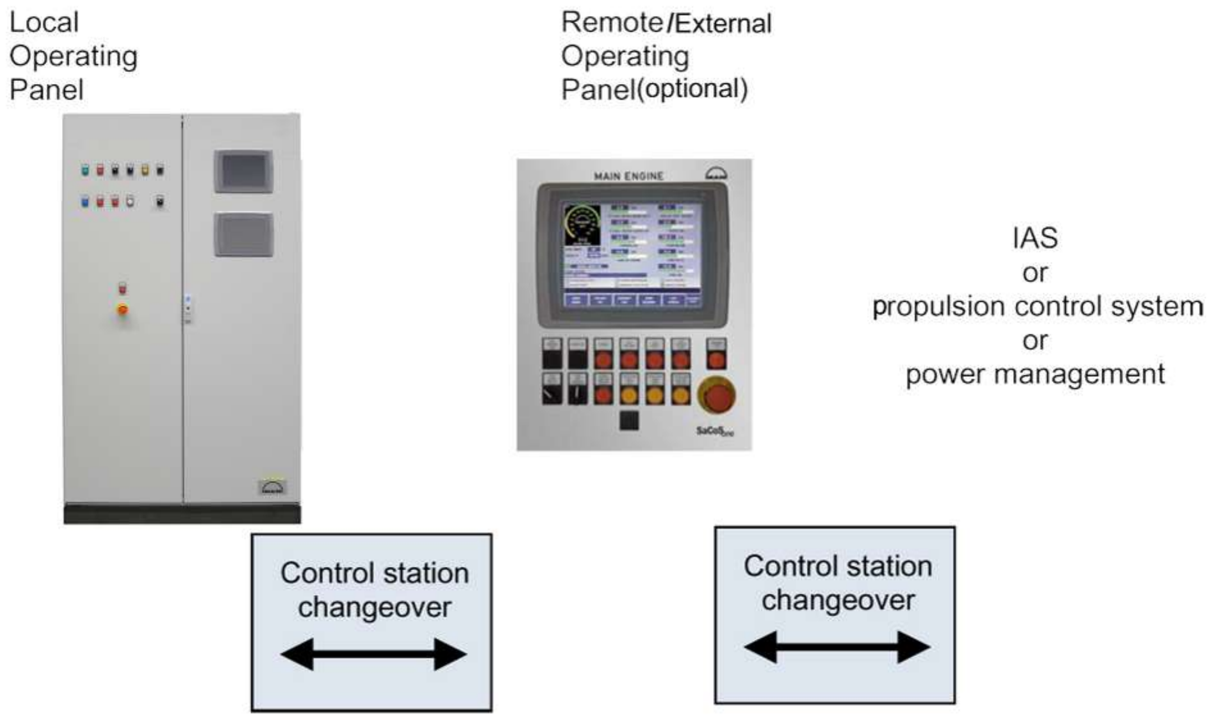

Figure 49: Control station changeover

Speed setting

In case of operating with one of the SaCoSone panels, the engine speed setting is carried out manually by a decrease/increase switch button.
If the operation is controlled by an external system, the speed setting can be done either by means of binary contacts (e.g. for synchronisation) or by an active 4 – 20 mA analogue signal alternatively. The signal type for this is to be defined in the project planning period.

Operating modes

For alternator applications:

- Droop (5-percent speed increase between nominal load and no load)

For propulsion engines:

- Isochronous
- Master/Slave Operation for operation of two engines on one gear box

The operating mode is pre-selected via the SaCoS interface and has to be defined during the application period.

Details regarding special operating modes on request.

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3.5 Functionality

Safety functions

The safety system monitors all operating data of the engine and initiates the required actions, i.e. load reduction or engine shutdown, in case any limit values are exceeded. The safety system is separated into Control Module and

Gateway Module. The Control Module supervises the engine, while the Gateway Module examines all functions relevant for the security of the connected plant components.

The system is designed to ensure that all functions are achieved in accordance with the classification societies' requirements for marine main engines.

The safety system directly influences the emergency shut-down and the speed control.

In addition to the provisions made to permit the internal initiation of demands, binary and analogue channels have been provided for the initiation of safety functions by external systems.

Load reduction

The exceeding of certain parameters requires a load reduction to 60 %. The safety system supervises these parameters and requests a load reduction, if necessary. The load reduction has to be carried out by an external system (IAS, PMS, PCS). For safety reasons, SaCoSone will not reduce the power by itself.

Auto shutdown

Auto shutdown is an engine shutdown initiated by any automatic supervision of either engine internal parameters or mentioned above external control systems. If an engine shutdown is triggered by the safety system, the emergency stop signal has an immediate effect on the emergency shutdown device, and the speed control.

Some auto shutdowns may also be initiated redundantly by the alarm system.

Emergency stop

Emergency stop is an engine shutdown initiated by an operator's manual action by pressing an emergency stop button.

Note:
A manual emergency stop stops the engine, but does not affect the interface signals requesting the auxiliary units. During the integration, the respective integrator must determine how the system reacts. Therefore manual emergency stops are provided to the plant explicit.

Engine shutdown

If an engine shutdown is triggered by the safety system, the shutdown signal is carried out by activating the emergency stop valve and by a pneumatic shut-off of the common rail pilot fuel, the block-and-bleed gas valves and the conventional fuel pumps.

At the same time the emergency stop is triggered, SaCoSone requests to open the generator switch.

Override

During operation, safety actions can be suppressed by the override function for the most parameters. The override has to be activated preventively. The scope of parameters prepared for override are different and depend to the chosen classification society. The availability of the override function depends on the application.

Alarming

The alarm function of SaCoSone supervises all necessary parameters and generates alarms to indicate discrepancies when required.

Self-monitoring

SaCoSone carries out independent self-monitoring functions. Thus, for example the connected sensors are checked constantly for function and wire break. In case of a fault SaCoSone reports the occurred malfunctions in single system components via system alarms.

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Speed control

The engine speed control is realised by software functions of the Control Module/Alarm and the Injection Modules. Engine speed and crankshaft turn angle indication is carried out by means of redundant pick ups at the gear drive.

Load distribution in multi-engine plants

With electronic speed control, the load distribution is carried out by speed droop, isochronously by load sharing lines or master/slave operation.

Load limit curves

- Start fuel limiter
- Charge air pressure dependent fuel limiter
- Torque limiter
- Jump-rate limiter
- External limiter
- Lambda limiter

Note:
In the case of controllable pitch propeller (CPP) units with combinator mode, the combinator curves must be sent to MAN Energy Solutions for assessment in the design stage. If load control systems of the CPP-supplier are used, the load control curve is to be sent to MAN Energy Solutions in order to check whether it is below the load limit curve of the engine.

Shutdown

The engine shutdown, initiated by safety functions and manual emergency stops, is carried out by redundant fast closing valves of the gas valve unit and independent interrupt of power supply of gas admission valves.

Note:
The engine shutdown may have impact on the function of the plant. These effects can be very diverse depending on the overall design of the plant and must already be considered in early phase of the project planning.

Overspeed protection

The engine speed is monitored in both Control Modules independently. In case of overspeed each Control Module actuates the shutdown device by a separate hardware channel. Overspeed is monitored in Ignition Module too to interrupt igntion.

Control

SaCoSone controls all engine-internal functions as well as external components, for example:

Start/stop sequences

- Requests of lube oil and cooling water pumps
- Monitoring of the prelubrication and post-cooling period
- Monitoring of the acceleration period
- Request of start-up air blower

Control station switch-over

Switch-over from local operation in the engine room to remote control from the engine control room.

External control functions

- Electrical lubricating oil pump
- HT preheating unit
- Clutches

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The scope of control functions depends on plant configuration and must be coordinated during the project engineering phase.

Media temperature control

Various media flows must be controlled to ensure trouble-free engine operation.

The temperature controllers are available as software functions inside the Gateway Module of SaCoSone. The temperature controllers are operated by the displays at the operating panels as far as it is necessary. From the Interface Cabinet the relays actuate the control valves.

- The cylinder cooling water (HT) temperature control is equipped with performance-related feed forward control, in order to guarantee the best control accuracy possible (refer also to section Cooling water system, Page 176).
- The low temperature (LT) cooling water temperature control works similarly to the HT cooling water temperature control and can be used if the LT cooling water system is designed as one individual cooling water system per engine.

  In case several engines are operated with a combined LT cooling water system, it is necessary to use an external temperature controller.

  This external controller must be mounted on the engine control room desk and is to be wired to the temperature control valve (refer also to section Cooling water system, Page 176).
- The charge air temperature control is designed similar to the HT cooling water temperature control.

  The cooling water quantity in the LT part of the charge air cooler is regulated by the charge air temperature control valve (refer also to section Cooling water system, Page 176).
- The design of the lube oil temperature control depends on the engine type. It is designed either as a thermostatic valve (waxcartridge type) or as an electric driven control valve with electronic control similar to the HT temperature controller. Refer also to section External lube oil system, Page 167.

Starters

For engine attached pumps and motors the starters are installed in the Interface Cabinet. Starters for external pumps and consumers are not included in the SaCoSone scope of supply in general.

3.6 Interfaces

Data bus interface (machinery alarm system)

This interface serves for data exchange to ship alarm systems or Integrated Automation Systems (IAS).

The interface is actuated with MODBUS protocol and is available as:

- Ethernet interface (MODBUS over TCP) or as
- Serial interface (MODBUS RTU) RS422/RS485, standard 5 wire with electrical isolation (cable length ≤ 100 m)

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Only if the ethernet interface is used, the transfer of data can be handled with timestamps from SaCoSone.

The status messages, alarms and safety actions, which are generated in the system, can be transferred. All measuring values acquired by SaCoSone are available for transfer.

Power management

Hardwired interface, for remote start/stop, load setting, fuel mode selection, etc.

Propulsion control system

Standardised hardwired interface including all signals for control and safety actions between SaCoSone and the propulsion control system.

Others

In addition, interfaces to auxiliary systems are available, such as:

- Nozzle cooling water module (for DF engines)
- HT preheating unit
- Electric driven pumps for lube oil, HT and LT cooling water
- Clutches
- Gearbox
- Propulsion control system

On request additional hard wired interfaces can be provided for special applications.

Cables – Scope of supply

The bus cables between engine and interface are scope of the MAN Energy Solutions supply.

The control cables and power cables are not included in the scope of the MAN Energy Solutions supply. This cabling has to be carried out by the customer.

3.7 Technical data

Cabinet

Design

- Floor-standing cabinets with plinth and fan/air condition
- Cable entries: From below, through cabinet base
- Accessible by front door(s), doors with locks
- Opening angle: 90°
- Standard colour: Light grey (RAL7035)
- Ingress protection: IP54

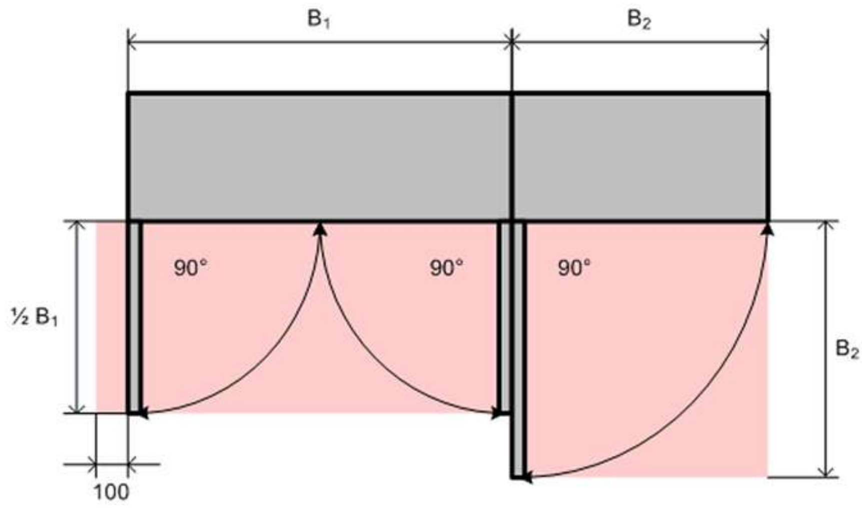
Dimensions and weights of cabinets

Cabinet	Dimensions (mm) including base			Weight
	Width	Height	Depth	
Interface Cabinet, equipped with fan	1,200	2,100	400	300

Cabinet	Dimensions (mm) including base			Weight
	Width	Height	Depth	
Interface Cabinet, equipped with air condition	1,550	2,100	400	360
Data Logging Cabinet (optional)	600	600	350	40

Table 75: Dimensons and weights of cabinets

Door opening area of cabinets



B_1 Width of cabinet 1 B_2 Width of cabinet 2

Figure 50: Exemplary arrangement of control cabinets with door opening areas (top view)

Remote Operating Panel (optional)

Design

- Panel for control desk installation with 3 m cable to terminal bar for installation inside control desk
- Front colour: White aluminium (RAL9006)
- Weight: 15 kg
- Ingress of protection: IP23
- Dimensions: 370 x 480 x 150 mm[1)]

[1)] width x height x depth (including base)

Environmental conditions

Components on engine and wall-mounted cabinets

- Ambient air temperature: +5 °C to +55 °C
- Relative humidity: < 96 %
- Vibrations: < 0.7 g

Floor-standing cabinets

- Ambient air temperature:
  - 0 °C to +45 °C: Floor-standing cabinets will be equipped with a fan
  - Over +45 °C: Floor-standing cabinets will be mandatory equipped with an air condition
- Relative humidity: < 96 %
- Vibrations: < 0.7 g

3.8 Installation requirements

Location

The Interface Cabinet is designed for installation in engine rooms or engine control rooms.

Wall-mounted cabinets and floor-standing cabinets

The cabinet must be installed at a location suitable for service inspection.

Do not install the cabinet close to heat-generating devices.

Floor-standing cabinets

In case of installation at walls, the distance between the floor-standing cabinet and the wall has to be at least 100 mm in order to allow air convection.

The foundation at the installation site must be solid enough to withstand the weight of the floor-standing cabinets.

All floor-standing cabinets have to be fixed to the floor and additionally be secured against tipping over (e.g. by attaching the roof to the wall) with suitable mounting support, proven to withstand at minimum the maximum allowed inclination, see accordingly Engine inclination, Page 26.

Note:
If the restrictions for ambient temperature can not be kept, the floor-standing cabinet must be ordered with an optional air condition system.

Ambient air conditions

For restrictions of ambient conditions, refer to the section Technical data, Page 125.

Cabling

The interconnection cables between the engine and the cabinets have to be installed according to the rules of electromagnetic compatibility. Control cables and power cables have to be routed in separate cable ducts.

The cables for the connection of sensors and actuators which are not mounted on the engine are not included in the scope of MAN Energy Solutions supply. Shielded cables have to be used for the cabling of sensors. For electrical noise protection, an electric ground connection must be made from the cabinet to the ship's hull.

All cabling between the cabinets and the controlled device is scope of customer supply.

The cabinet is equipped with spring loaded terminal clamps. All wiring to external systems should be carried out without conductor sleeves.

The redundant CAN cables are MAN Energy Solutions scope of supply. If the customer provides these cables, the cable must have a characteristic impedance of 120 Ω.

Maximum cable length

Connection	Max. cable length
Cables between engine and Interface Cabinet	≤ 45 m
MODBUS cable between Interface Cabinet and superordinated automation system (only for ethernet)	≤ 100 m

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Connection	Max. cable length
Cable between Interface Cabinet and Remote Operating Panel	≤ 100 m

Table 76: Maximum cable length

Installation works

During the installation period the customer has to protect the cabinet against water, dust and fire. It is not permissible to do any welding near the cabinet. The cabinet has to be fixed to the floor by screws.

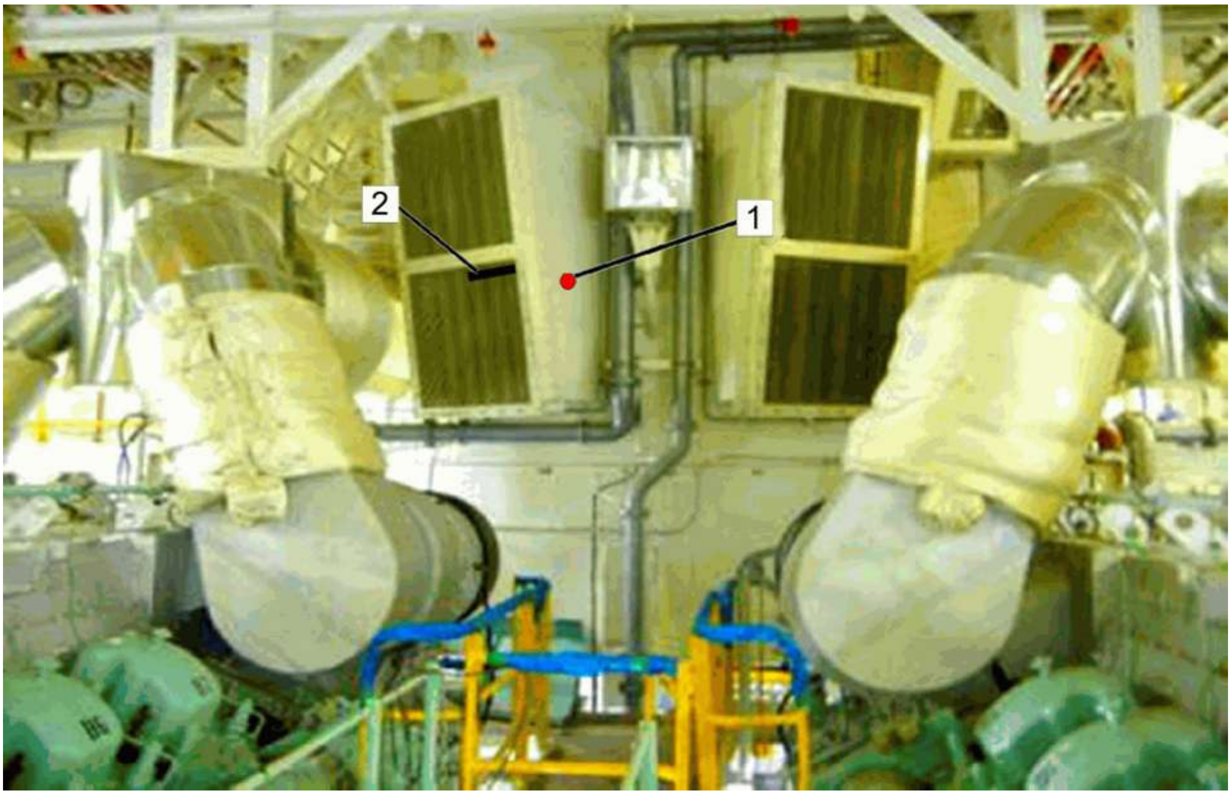
If it is inevitable to do welding near the cabinet, the cabinet and panels have to be protected against heat, electric current and electromagnetic influences. To guarantee protection against current, all of the cabling must be disconnected from the affected components.

The installation of additional components inside the cabinet is only permissible after approval by the responsible project manager of MAN Energy Solutions.

Installation of sensor 1TE6000 „Ambient air temp"

The sensor 1TE6000 "Ambient air temp" (double Pt1000) measures the temperature of the (outdoor) ambient air. The temperature of the ambient air will typically differ from that in the engine room.

The sensor may be installed in the ventilation duct of the fan blowing the (outdoor) ambient air into the engine room. Ensure to keep the sensor away from the influence of heat sources or radiation. The image below shows two options of installing the sensors correctly:



1 Hole drilled into the duct of the engine room ventilation. Sensor measuring the temperature of the airstream.

2 Self-designed holder in front of the duct.

Figure 51: Possible locations for installing the sensor 1TE6000

Note:
The sensor 1TE6100 “intake air temp” is not suitable for this purpose.

3.9 Engine-located measuring and control devices

Exemplary list for project planning

No.	Measuring point	Description	Function	Measuring Range	Location	Connected to	Depending on option
Speed pickups							
1	1SE1004A/B[1)]	speed pickup turbocharger speed	indication, supervision	0–30,000 rpm/ 0–1,000 Hz	turbocharger	Control Module/ Safety	-
2	2SE1004A/B[1)]	speed pickup turbocharger speed	indication, supervision	0–30,000 rpm/ 0–1,000 Hz	turbocharger	Control Module/ Safety	-
3	1SE1005	speed pickup engine speed	camshaft speed and position input for CR	0–1,200 rpm/ 0–2,000 Hz	camshaft drive wheel	Control Module/ Alarm	-
4	2SE1005	speed pickup engine speed	camshaft speed and position input for CR	0–1,200 rpm/ 0–2,000 Hz	camshaft drive wheel	Control Module/ Safety	-
Start and stop of engine							
5	1SSV1011	solenoid valve engine start	actuated during engine start and slowturn	-	engine	Control Module/ Alarm	-
Charge air bypass							
6	1XSV1030	solenoid valve charge air bypass flap	blow by while part-load or low speed	-	engine	Control Module/ Alarm	charge air bypass
Charge air blow-off							
7	1XSV1031	solenoid valve charge air blow off flap A/B	charge air blow off at low suction air temperature	-	engine	Control Module/ Alarm	charge air blow off
Main bearings							
8	xTE1064	double temp sensors main bearings	indication, alarm, engine protection	0–120 °C	engine	Control Modules	main bearing temp monitoring
Turning gear							

No.	Measuring point	Description	Function	Measuring Range	Location	Connected to	Depending on option
9	1GOS1070	limit switch turning gear engaged	indication and start blocking	-	engine	Control Module/ Alarm	-
Lube oil system							
10	1TE2160	temp sensor lube oil temp cooler inlet	indication	0–120 °C	engine	Control Modules	-
11	1PT2165	pressure transmitter lube oil pressure filter inlet	-	0–10 bar	engine	Control Module/ Alarm	-
12	1PT2170	pressure transmitter lube oil pressure engine inlet	alarm at low lube oil pressure	0–10 bar	engine	Control Module/ Alarm	-
13	2PT2170	pressure transmitter lube oil pressure engine inlet	auto shutdown at low pressure	0–10 bar	engine	Control Module/ Safety	-
14	1TE2170	double temp sensor lube oil temp engine inlet	alarm at high temp	0–120 °C	engine	Control Modules	-
15	1QE2170	metal particle detector	-	-	engine	Control Module/ Alarm	-
16	1PT2570A/B[1)]	pressure transmitter lube oil pressure turbocharger inlet	alarm at low lube oil pressure	0–6 bar	engine	Control Module/ Alarm	-
17	2PT2570A/B[1)]	pressure transmitter lube oil pressure turbocharger inlet	auto shutdown at low lube oil pressure	0–6 bar	engine	Control Module/ Safety	-
18	1TE2580A/B[1)]	double temp sensor lube oil temp turbocharger drain	alarm at high temp	0–120 °C	engine	Control Modules	-
Crankcase pressure							
19	1PT2800	pressure transmitter crankcase pressure	input for alarm system	–20 – 0 +20 mbar	engine	Control Module/ Alarm	-
20	2PT2800	pressure transmitter crankcase pressure	input for safety system	–20 – +20 mbar	engine	Control Module/ Safety	-
21	1LS2800	level switch oil level in oil sump	upper level monitoring	-	engine	Control Module/ Alarm	-
22	2LS2800	level switch oil level in oil sump	lower level monitoring	-	engine	Control Module/ Alarm	-
Splash oil							

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No.	Measuring point	Description	Function	Measuring Range	Location	Connected to	Depending on option
23	xTE2880	double temp sensors splash oil temp rod bearings	splash oil supervision	0–120 °C	engine	Control Modules	-
Cooling water systems							
24	1PT3170	pressure transmitter HT cooling water pressure engine inlet	alarm at low pressure	0–6 bar	engine	Control Module/ Alarm	-
25	2PT3170	pressure transmitter HT cooling water pressure engine inlet	detection of low cooling water pressure	0–6 bar	engine	Control Module/ Alarm	-
26	1TE3170	double temp sensor HT cooling water engine inlet	alarm, indication	0–120 °C	engine	Control Modules	-
27	1TE3180A/B[1)]	temp sensor HT cooling water temp engine outlet	-	0–120 °C	engine	Control Modules	-
28	1TE3190	temp sensor HTCW temp before control valve	-	0–120 °C	engine	Control Modules	-
29	1PT4120	pressure transmitter seawater pressure pump outlet	-	0–10 bar	engine	Control Module/ Alarm	-
30	1PT4170	pressure transmitter LT cooling water pressure charge air cooler inlet	alarm at low cooling water pressure	0–6 bar	engine	Control Module/ Alarm	-
31	2PT4170	pressure transmitter LT cooling water pressure charge air cooler inlet	alarm at low cooling water pressure	0–6 bar	engine	Control Unit	-
32	1TE4170	double temp sensor LT cooling water temp charge air cooler inlet	alarm, indication	0–120 °C	LT pipe charge air cooler inlet	Control Modules	-
33	1TE4180	temp sensor LT cooling water temp CA cooler outlet	-	0–120 °C	engine	Control Module/ Alarm	-
34	1TE4185	temp sensor LT cooling water temp after engine	-	0–120 °C	engine	Control Module/ Alarm	-
Fuel system							
35	1PT5070	pressure transmitter fuel pressure engine inlet	remote indication and alarm	0–16 bar	engine	Control Module/ Alarm	-

No.	Measuring point	Description	Function	Measuring Range	Location	Connected to	Depending on option
36	2PT5070	pressure transmitter fuel pressure engine inlet	remote indication and alarm	0–16 bar	engine	Control Module/ Safety	-
37	1TE5070	double temp sensor fuel temp engine inlet	alarm at high temp in MDO-mode and for EDS use	0–200 °C	engine	Control Modules	-
38	xFSV5078A/B[1)]	solenoid valve fuel injection cylinder	fuel injection	-	engine	Injection Module 1/2	-
39	1LS5080	level switch fuel oil injector- and pump leakage	alarm at high level	-	-	Control Module/ Alarm	-
Charge air system							
40	1TE6100A/B[1]	double temp sensor intake air temp	-	0–120 °C	intake air duct after filter	Control Module/ Alarm	-
41	1PT6170A/B[1)]	pressure transmitter charge air pressure before cylinders row A/B	STC control	0–4 bar	engine	Control Modules	STC
42	2PT6170A/B[1)]	pressure transmitter charge air pressure before cylinders row A/B	STC control	0–4 bar	engine	Control Modules	STC
43	1TE6170A/B[1)]	double temp sensor charge air temp charge air cooler A/B inlet	for EDS visualisation	0–300 °C	engine	Control Modules	-
44	1FSV6171A	solenoid valve CA switch-over for STC	bistabile 5/2-way valve to cut off CA pipe of TC A for STC	-	engine	Control Module/ Alarm	STC
45	1PT6180A/B[1)]	pressure transmitter charge air pressure before cylinders row A/B	engine control	0–4 bar	engine	Control Module/ Alarm	-
46	2PT6180A/B[1)]	pressure transmitter charge air pressure before cylinders row A/B	-	0–4 bar	engine	Control Module/ Safety	-
47	1TE6180A/B[1)]	double temp sensor charge air temp after charge air cooler A/B	alarm at high temp	0–120 °C	engine	Control Modules	-

No.	Measuring point	Description	Function	Measuring Range	Location	Connected to	Depending on option
Exhaust gas system							
48	xTE6570A/B[1)]	double thermo-couples exhaust gas temp cylinders A/B	indication, alarm, engine protection	0–800 °C	engine	Control Modules	-
49	1FSV6571A	solenoid valve exhaust gas switch-over for STC	bistabile 5/2-way valve to cut off exhaust pipe of TC A for STC	-	engine	Control Module/ Alarm	STC
50	1TE6575A/B[1)]	double thermo-couples exhaust gas temp before turbocharger A/B	indication, alarm, engine protection	0–800 °C	engine	Control Modules	-
51	1TE6580A/B[1)]	double thermo-couples exhaust gas temp after turbocharger A/B	indication	0–800 °C	engine	Control Modules	-
Control air, start air, stop air							
52	1PT7170	pressure transmitter starting air pressure	engine control, remote indication	0–40 bar	engine	Control Module/ Alarm	-
53	2PT7170	pressure transmitter starting air pressure	engine control, remote indication	0–40 bar	engine	Control Module/ Safety	-
54	1PT7400	pressure transmitter control air pressure	remote indication	0–10 bar	engine	Control Module/ Alarm	-
[1)] A-sensors: Installed on row A; B-sensors: Installed on row B.							

Table 77: List of engine-located measuring and control devices

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4 Specification for engine supplies

4.1 Specification of lubricating oil for operation with DMA/DFA

General

The specific output achieved by modern diesel engines combined with the use of fuels that satisfy the quality requirements more and more frequently increase the demands on the performance of the lubricating oil which must therefore be carefully selected.

Doped lube oils (HD oils) have a proven track record as lubricants for the drive, cylinder, turbocharger, and for cooling the piston. Doped lube oils contain additives that among other things ensure dirt absorption capability, engine cleaning, and neutralisation of acidic combustion products.

Only lube oils that have been approved by MAN Energy Solutions may be used.

Specifications

Base oil

The base oil (doped lubricating oil = base oil + additives) must have a narrow distillation range and be refined using modern methods. If it contains paraffins, they must not impair the thermal stability or oxidation stability.

Compounded lubricating oils (HD oils)

The compounded lubricating oil must have the following properties:

Additives

The additives must be dissolved in the oil and their composition must ensure that as little ash as possible remains after combustion.

The ash must be soft. If this prerequisite is not met, it is likely the rate of deposition in the combustion chamber will be higher, particularly at the outlet valves and at the turbocharger inlet housing. Hard additive ash promotes pitting of the valve seats, and causes valve burn-out, it also increases mechanical wear of the cylinder liners.

Additives must not increase the rate, at which the filter elements in the active or used condition are blocked.

Washing ability

The washing ability must be high enough to prevent the accumulation of tar and coke residue as a result of fuel combustion.

Neutralisation capability

The neutralisation capability (ASTM D2896) must be high enough to neutralise the acidic products produced during combustion. The reaction time of the additive must be harmonised with the process in the combustion chamber.

The base number (BN) should be at least 8.5 mg KOH/g with a fuel sulfur content of 0.2 % or less. At a fuel sulfur content between 0.2 and 1.5 %, the base number should be at least 12 mg KOH/g.

Evaporation tendency

The evaporation tendency must be as low as possible as otherwise the oil consumption will be adversely affected.

Additional requirements

The lubricating oil must not contain viscosity index improver. Fresh oil must not contain water or other contaminants.

The oil must be a SAE40 monograde oil in terms of its viscosity.

Lubricating oil additives

The use of other additives with the lubricating oil, or the mixing of different brands (oils by different manufacturers and different brands of the same manufacturer), is not permitted as this may impair the performance of the existing additives which have been carefully harmonised with each another, and also specially tailored to the base oil.

Military specification

The approved engine oils formally meet the requirements according to NATO O-278.

Other oils with approval according to NATO O-278 may only be used after prior approval from MAN Energy Solutions. A monthly oil analysis by MAN PrimeServLab is also required.

Selection of lubricating oils/ warranty

Most of the oil manufacturers are in close regular contact with engine manufacturers, and can therefore provide information on which oil in their specific product range has been approved by the engine manufacturer for the particular application. Irrespective of the above, the lubricating oil manufacturers are in any case responsible for the quality and characteristics of their products. If you have any questions, we will be happy to provide you with further information.

The list of the currently approved lubricating oils is available at https://corporate.man-es.com/lubrication.

Oil during operation

The intervals between lubricating oil changes are determined by the ageing rate of the oil. The lubricating oil used must comply with the requirements stated in the table entitled Limit values for used engine oil.

Property	Unit	Limit value	Procedure
Viscosity at 40 °C	mm^2/s	100–190 (SAE 40) 80–190 (SAE 10W-40)	ISO 3104, ASTM D445, ASTM D 7042, DIN EN 16896
Viscosity at 100 °C		10.5–19.0 (SAE 40) 10.5–19.0 (SAE10W-40)	
Base number (BN)	%	At least 50 % of fresh oil - BN	ISO 3771
Flash point (PM)	°C	At least 170	ISO 2719
Water content	vol. %	Max. 0.20	DIN 51777, ASTM D6304
Soot content	% (m/m)	Max. 3.0	DIN 51452
Oxidation[1)]	A/cm	Max. 25	DIN 51453
Fuel dilution	% (m/m)	Max. 3.0	DIN 51454
Coolant additive	mg/kg	Free from	DIN 51399-1
TAN	mg KOH/g	+3.5 for fresh oil and BN > TAN	ASTM D664
Metal content (reference values) Iron, chrome, tin, copper, aluminium, lead	ppm	dependent on engine type and operating conditions max. 50 max. 10 max. 15 max. 20	ASTM D5185, DIN 51399-1

[1)] Only possible if there are no ester compounds and no ingress of biofuel.

Table 78: Limit values for engine oil to be used

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A monthly analysis of lube oil samples is mandatory for safe engine operation. We can analyse samples for customers in the MAN Energy Solutions PrimeServLab.

Note:
If operating fluids are improperly handled, this can pose a danger to health, safety and the environment. The relevant safety information by the supplier of operating fluids must be observed.

4.2 Diesel fuel (DMA, DFA) specifications

General information

Diesel fuel is a middle distillate refined from crude oil. It is also referred to as gas oil, marine gas oil (MGO) and diesel oil. It must not contain any residue from crude oil refining. The fuel is permitted to contain synthetic components (e.g. BtL, CtL, GtL, & HVO). In addition, limited quantities of biofuel based on fatty acid methyl ester may be mixed in.

Selection of suitable diesel fuel

Unsuitable or adulterated fuel generally results in a shortening of the service life of engine parts/ components, damage to these and to catastrophic engine failure. It is therefore important to select the fuel with care in terms of its suitability for the engine and the intended application. Through its combustion, the fuel also influences the emissions behaviour of the engine.

Specifications and approvals

Property	Unit		Limit value	Standard[1]
Kinematic viscosity at 40 °C[2]	mm^2/s	Max.	6.000	ISO 3104, ASTM D7042, ASTM D445, DIN EN 16896
		Min.	2.000	
Density at 15 °C	kg/m^3	Max.	890.0	ISO 3675, ISO 12185
		Min.	820.0	
Cetane index & cetane number		Min.	40	ISO 4264 & ISO 5165
Sulfur content[3]	% (m/m)	Max.	1.00	ISO 8754, ISO 14596, ASTM D4294, DIN 51400-10
Flash point[4]	°C	Min.	60.0	ISO 2719
Hydrogen sulfide	mg/kg	Max.	2.00	IP 570
Acid number	mg KOH/g	Max.	0.5	ASTM D664
Corrosion on copper	Class	Max.	1	ISO 2160
Oxidation stability[5]	g/m^3	Max.	25	ISO 12205, EN 15751
	h	Min.	20	
Fatty acid methyl ester (FAME) content[6]	% (V/V)	Max.	7.0	ASTM D7963, IP 579, DIN EN 14078
Carbon residue[7]	%(m/m)	Max.	0.30	ISO 10370
Appearance	–	–	Clear & haze free	visual
Water content	% (m/m)	Max.	0.02	DIN 51777, DIN EN 12937, ASTM D6304
Ash content	% (m/m)	Max.	0.010	ISO 6245

Property	Unit		Limit value	Standard[1)]
Lubricity[8)]	µm	Max.	520	ISO 12156-1, ASTM D6079
Metal content (Na, K, Ca, P, Cu, Zn)	mg/kg	Max.	free from	DIN EN 16476
Particles [9)]	Classes	Max.	18/17/12	ISO 4406

Table 79: Requirements for diesel fuel

Remarks:

1) Always in relation to the currently applicable edition.

2) Specific requirements of the injection system must be taken into account.

3) Independent of the maximum permissible sulfur content, local laws and regulations must be adhered to

4) SOLAS specification. A lower flash point is possible for non-SOLAS-regulated applications.

5) If there is more than 2% (V/V) FAME, an analysis as per DIN EN 15751 must additionally be performed

6) The FAME must either be in accordance with EN 14214 or with ASTM D6751. Applicable laws must be adhered to.

7) Determined at 10% distillation residue

8) Diameter of the corrected wear scar (WSD).

9) Particle distribution in the last tank before engine inlet

The following fuels are approved for use:

- Classes ISO F-DMA & DMZ as per ISO 8217 in the current edition with additional requirement regarding cetane number.
- Class ISO F-DFA & DFZ as per ISO 8217 in the current edition with additional requirements regarding oxidation stability with a correspondingly high FAME content.

In addition, the following fuels can be used:

- Diesel fuel as per EN 590 in the current edition with additional requirement regarding flash point ≥ 60°C in SOLAS regulated areas.
- Diesel fuel no. 2-D as per ASTM D975-15 with additional requirement regarding flash point ≥ 60°C in SOLAS regulated areas.

Viscosity

In order to ensure sufficient lubrication, a minimum level of viscosity must be ensured at the fuel pump. The permissible maximum temperature of the fuel required to maintain minimum viscosity upstream of the injection pump of 1.5 mm^2/s thus depends on the basic viscosity of the fuel. The fuel temperature must be set so that the viscosity does not fall below 1.5 mm^2/s. The temperature of the fuel upstream of the injection pump must under no circumstances be above 45°C, even if the basic viscosity of the fuel would ensure a viscosity of ≥ 1.5 mm^2/s at the injection pump at 45°C. The lubricity requirements of the fuel for the engine are always max. 520 µm WSD as per ISO 12156-1.

Military fuel specification

The fuels of type F-75 or F-76 as per NATO STANAG 1385 can be used if they fully comply with the standards or limit values listed in the table Requirements of the diesel fuel, Page 137 and the minimum permissible viscosity upstream of the injection pump with the corresponding temperature is adhered to.

Cold suitability

The cold suitability of the fuel is determined by the climatic requirements at the place of installation. It is the responsibility of the operating company to choose a fuel with sufficient cold suitability.

The cold suitability of a fuel may be determined and assessed using the following standards:

- Limit of filterability (CFPP) as per EN 116
- Pour point as per ISO 3016
- Cloud point as per EN 23015

To be able to draw a reliable conclusion, it is recommended to perform all three stated procedures.

Bio-fuel admixture

The DFA fuel may contain up to 7.0% of bio-fuel based on fatty acid methyl ester (FAME). The FAME to be added must comply with either EN14214 or ASTM D 6751. Compared to fuels on mineral oil basis only, fuels containing FAME have an increased tendency to oxidise and age and are more vulnerable to microbiological contamination. Furthermore, the fuel may contain an increased quantity of water. This why it is necessary to check the ageing stability at regular intervals when using this type of fuel. In addition, it is important to regularly check the water content of the fuel.

To minimise microbiological contamination, the tanks must be drained on a regular basis. During standstill periods this is required daily, otherwise weekly.

When first using fuels containing bio-diesel, deposits that have accumulated over a longer period of time may become detached. These deposits can block filters or even cause immediate damage.

Using bio-diesel blends in emergency power generators should be avoided. Bio-diesel fuel should be stored in separate reservoirs. Storing fuel containing bio-diesel for more than 6 months is generally not recommended. MAN Energy Solutions is not liable for damage and any possible consequences resulting from the use of fuel containing bio-diesel.

Analyses

Analysis of fuel oil samples is very important for safe engine operation. We can analyse fuel for customers at MAN Energy Solutions laboratory PrimeServLab.

4.3 Specification of engine coolant

Preliminary remarks

An engine coolant is composed as follows: water for heat removal and coolant additive for corrosion protection.

As is also the case with the fuel and lubricating oil, the engine coolant must be carefully selected, handled and checked. If this is not the case, corrosion, erosion and cavitation may occur at the walls of the cooling system in contact with water and deposits may form. Deposits obstruct the transfer of heat and can cause thermal overloading of the cooled parts. The system must be treated with an anticorrosive agent before bringing it into operation for the first time. The concentrations prescribed by the engine manufacturer must always be observed during subsequent operation. The above especially applies if a chemical additive is added.

Requirements

Limit values

The properties of untreated coolant must correspond to the following limit values:

Properties/Characteristic	Properties	Unit
Water type	Distillate or fresh water, free of foreign matter.	–

Properties/Characteristic	Properties	Unit
Total hardness	max. 10	dGH[1)]
pH value	6.5 – 8	–
Chloride ion content	max. 50	mg/l[2)]

Table 80: Properties of coolant that must be complied with

[1)] 1 dGH (German hardness)	≙ 10 mg CaO in 1 litre of water ≙ 17.8 mg $CaCO_3$/l
	≙ 0.357 mval/l ≙ 0.178 mmol/l

[2)] 1 mg/l ≙ 1 ppm

Testing equipment

The MAN Energy Solutions water testing equipment incorporates devices that determine the water properties directly related to the above. The manufacturers of anticorrosive agents also supply user-friendly testing equipment.

For information on monitoring cooling water see section 4.4 Cooling water inspecting.

Additional information

Distillate

If distilled water (from a fresh water generator, for example) or fully desalinated water (from ion exchange or reverse osmosis) is available, this should ideally be used as the engine coolant. These waters are free of lime and salts, which means that deposits that could interfere with the transfer of heat to the coolant, and therefore also reduce the cooling effect, cannot form. However, these waters are more corrosive than normal hard water as the thin film of lime scale that would otherwise provide temporary corrosion protection does not form on the walls. This is why distilled water must be handled particularly carefully and the concentration of the additive must be regularly checked.

Hardness

The total hardness of the water is the combined effect of the temporary and permanent hardness. The proportion of calcium and magnesium salts is of overriding importance. The temporary hardness is determined by the carbonate content of the calcium and magnesium salts. The permanent hardness is determined by the amount of remaining calcium and magnesium salts (sulphates). The temporary (carbonate) hardness is the critical factor that determines the extent of limescale deposit in the cooling system.

Water with a total hardness of > 10°dGH must be mixed with distilled water, or softened.

Damage to the coolant system

Corrosion

Corrosion is an electrochemical process that can widely be avoided by selecting the correct water quality and by carefully handling the water in the engine cooling system.

Flow cavitation

Flow cavitation can occur in areas in which high flow velocities and high turbulence is present. If the steam pressure is reached, steam bubbles form and subsequently collapse in high pressure zones which causes the destruction of materials in constricted areas.

Erosion

Erosion is a mechanical process accompanied by material abrasion and the destruction of protective films by solids that have been drawn in, particularly in areas with high flow velocities or strong turbulence.

Stress corrosion cracking

Stress corrosion cracking is a failure mechanism that occurs as a result of simultaneous dynamic and corrosive stress. This may lead to cracking and rapid crack propagation in water-cooled, mechanically-loaded components if the coolant has not been treated correctly.

Treatment of engine coolant

Formation of a protective film

The purpose of treating the engine coolant using anticorrosive agents is to produce a continuous protective film on the walls of cooling surfaces and therefore prevent the damage referred to above. In order for the anticorrosive agent to be 100 % effective, it is extremely important that untreated water satisfies the requirements in paragraph Requirements, Page 139.

Protective films can be formed by treating the coolant with chemical slushing oil.

Treatment prior to initial commissioning of engine

Treatment with a anticorrosive agent should be carried out before the engine is brought into operation for the first time to prevent irreparable initial damage.

Note:

The engine must not be brought into operation without treating the cooling water first.

Additives for coolants

Only the additives approved by MAN Energy Solutions and listed in the tables under the paragraph entitled Approved cooling water additives may be used.

Required release

A coolant additive may only be permitted for use if tested and approved as per the latest directives of the ICE Research Association (FVV) "Suitability test of internal combustion engine cooling fluid additives." The test report must be obtainable on request. The relevant tests can be carried out on request in Germany at the staatliche Materialprüfanstalt (Federal Institute for Materials Research and Testing), Abteilung Oberflächentechnik (Surface Technology Division), Grafenstraße 2 in D-64283 Darmstadt.

Once the coolant additive has been tested by the FVV, the engine must be tested in a second step before the final approval is granted.

Biocides

If you cannot avoid using a biocide because the coolant has been contaminated by bacteria, observe the following steps:

- You must ensure that the biocide to be used is suitable for the specific application.
- The biocide must be compatible with the sealing materials used in the coolant system and must not react with these.
- The biocide and its decomposition products must not contain corrosion-promoting components. Biocides whose decomposition products contain chloride or sulphate ions are not permitted.
- Biocides that cause foaming of coolant are not permitted.

Antifreeze agents

- If antifreeze agents must be used, consult MAN Energy Solutions beforehand. Antifreeze agents reduce the capacity of the coolant to absorb heat. In some cases the cooling effect of the coolant may be insufficient.

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Prerequisite for effective use of an anticorrosive agent

Clean cooling system

As contamination significantly reduces the effectiveness of the additive, the tanks, pipes, coolers and other parts outside the engine must be free of rust and other deposits before the engine is started up for the first time and after repairs of the pipe system.

The entire system must therefore be cleaned with the engine switched off using a suitable cleaning agent (see table Cleaning agents for removing oil sludge).

Loose solid matter in particular must be removed by flushing the system thoroughly as otherwise erosion may occur in locations where the flow velocity is high.

The cleaning agents must not corrode the seals and materials of the cooling system. In most cases, the supplier of the coolant additive will be able to carry out this work and, if this is not possible, will at least be able to provide suitable products to do this. If this work is carried out by the engine operator, he should use the services of a specialist supplier of cleaning agents. The cooling system must be flushed thoroughly after cleaning. Once this has been done, the engine coolant must be immediately treated with anticorrosive agent. Once the engine has been brought back into operation, the cleaned system must be checked for leaks.

Regular checks of the coolant condition and coolant system

Treated coolant may become contaminated when the engine is in operation, which causes the additive to loose some of its effectiveness. It is therefore advisable to regularly check the cooling system and the coolant condition. To determine leakages in the lube oil system, it is advisable to carry out regular checks of water in the expansion tank. Indications of oil content in water are, e.g. discoloration or a visible oil film on the surface of the water sample.

The additive concentration must be checked at least once a week using the test kits specified by the manufacturer. The results must be documented.

Note:

The chemical additive concentrations must not fall below the minimum concentrations specified in the table entitled Chemical agents.

Excessively low concentrations lead to corrosion and must be avoided. Concentrations that are somewhat higher do not cause damage. Concentrations that are more than twice as high as recommended should be avoided.

Every 2 to 6 months send a cooling water sample to an independent laboratory or to the engine manufacturer for integrated analysis.

If chemical additives or anti-freeze solutions are used, cooling water should be replaced after 3 years at the latest.

If there is a high concentration of solids (rust) in the system, the water must be completely replaced and entire system carefully cleaned.

Deposits in the cooling system may be caused by fluids that enter the coolant, by corrosion in the plant, and by limescale deposits if the water is very hard. If the concentration of chloride ions has increased, this generally indicates that seawater has entered the system. The maximum specified concentration of

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50 mg chloride ions per kg must not be exceeded as otherwise the risk of corrosion is too high. If exhaust gas enters the coolant, this can lead to a sudden drop in the pH value or to an increase in the sulphate content.

Water losses must be compensated for by filling with untreated water that meets the quality requirements specified in the paragraph Requirements, Page 139. The concentration of anticorrosive agent must subsequently be checked and adjusted if necessary.

Subsequent checks of the coolant are especially required if the coolant had to be drained off in order to carry out repairs or maintenance.

Protective measures

Anticorrosive agents contain chemical compounds that can pose a risk to health or the environment if incorrectly used. Comply with the directions in the manufacturer's material safety data sheets.

Avoid prolonged direct contact with the skin. Wash hands thoroughly after use. If larger quantities spray and/or soak into clothing, remove and wash clothing before wearing it again.

If chemicals come into contact with your eyes, rinse them immediately with plenty of water and seek medical advice.

Anticorrosive agents are generally harmful to the water cycle. Observe the relevant statutory requirements for disposal.

Approved coolant additives

A list of currently approved coolant additives and their concentration can be found at https://corporate.man-es.com/lubrication.

4.4 Cooling water inspecting

Summary

Acquire and check typical values of the operating media to prevent or limit damage.

The fresh water used to fill the cooling water circuits must satisfy the specifications. The cooling water in the system must be checked regularly in accordance with the maintenance schedule. The following work/steps is/are necessary:

Acquisition of typical values for the operating fluid, evaluation of the operating fluid and checking the concentration of the anticorrosive agent.

Tools/equipment required

Equipment for checking the fresh water quality

The following equipment can be used:

- The MAN Energy Solutions water testing kit, or similar testing kit, with all necessary instruments and chemicals that determine the water hardness, pH value and chloride content (obtainable from MAN Energy Solutions or Mar-Tec Marine, Hamburg).

Equipment for testing the concentration of additives

Testing equipment according to the recommendations of the supplier. The test kits from the provider normally also include testing equipment which can be used to determine the fresh water quality.

Testing the typical values of water

Short specification

Typical value/property	Water for filling and refilling (without additive)	Circulating water (with additive)
Water type	Fresh water, free of foreign matter	Treated coolant
Total hardness	≤ 10 dGH[1)]	≤ 10 dGH[1)]
pH value	6.5 – 8 at 20 °C	≥ 7.5 at 20 °C
Chloride ion content	≤ 50 mg/l	≤ 50 mg/l[2)]

Table 81: Quality specifications for coolants (short version)

[1)] dGH German hardness

1 dGH = 10 mg/l CaO
= 17.8 mg/l $CaCO_3$
= 0.178 mmol/L

[2)] 1 mg/l = 1 ppm

Testing kit provided by the additive supplier

If the testing kit provided by the additive supplier includes an option for determining the typical values of fresh water, it may be used.

Testing the concentration of chemical additives

The concentration should be tested every week, and/or according to the maintenance schedule, using the testing instruments, reagents and instructions of the relevant supplier.

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Chemical slushing oils can only provide effective protection if the right concentration is precisely maintained. This is why the concentrations recommended by MAN Energy Solutions (see section Specification of engine cooling water, Page 139 must be observed in all cases. These recommended concentrations may not be the same as those specified by the manufacturer.

Regular analysis of coolant is very important for safe engine operation. We can analyse fuel for customers at MAN Energy Solutions laboratory PrimeServLab.

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4.5 Cooling water system cleaning

Summary

Remove contamination/residue from operating fluid systems, ensure/re-establish operating reliability.

Cooling water systems containing deposits or contamination prevent effective cooling of parts. Contamination and deposits must be regularly eliminated.

This comprises the following:

Cleaning the system and, if required, removal of limescale deposits, flushing the system.

Cleaning

The coolant system must be checked for contamination at regular intervals. Cleaning is required if the degree of contamination is high. This work should ideally be carried out by a specialist who can provide the right cleaning agents for the type of deposits and materials in the cooling circuit. The cleaning should only be carried out by the engine operator if this cannot be done by a specialist.

Oil sludge

Oil sludge from lubricating oil that has entered the cooling system or a high concentration of anticorrosive agents can be removed by flushing the system with fresh water to which some cleaning agent has been added. Suitable cleaning agents are listed alphabetically in the table entitled Cleaning agents for removing oil sludge. Products by other manufacturers can be used providing they have similar properties. The manufacturer's instructions for use must be strictly observed.

Manufacturer	Product
Drew	HDE - 777
Nalfleet	Maxi-Clean 2
Unitor	Seaclean, Seaclean Plus

Table 82: Cleaning agents for removing oil sludge

Lime and rust deposits

Lime and rust deposits can form if the water is especially hard or if the concentration of the anticorrosive agent is too low. A thin lime scale layer can be left on the surface as experience has shown that this protects against corrosion. However, limescale deposits with a thickness of more than 0.5 mm obstruct the transfer of heat and cause thermal overloading of the components being cooled.

Rust that has been flushed out may have an abrasive effect on other parts of the system, such as the sealing elements of the water pumps. Together with the elements that are responsible for water hardness, this forms what is known as ferrous sludge which tends to gather in areas where the flow velocity is low.

Products that remove limescale deposits are generally suitable for removing rust. Suitable cleaning agents are listed alphabetically in the table entitled Cleaning agents for removing limescale and rust deposits. Products by other manufacturers can be used providing they have similar properties. The manufacturer's instructions for use must be strictly observed. Prior to cleaning,

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check whether the cleaning agent is suitable for the materials to be cleaned. The products listed in the table entitled Cleaning agents for removing limescale and rust deposits are also suitable for stainless steel.

Manufacturer	Product
Nalfleet	Nalco 8344, 73190
Unitor	Metal Brite
Drew	Ferroclean

Table 83: Cleaning agents for removing lime scale and rust deposits

The carbon dioxide bubbles released when the lime scale layer is dissolved can prevent the cleaning agent from reaching lime scale deposits. It is therefore absolutely necessary to circulate the water with the cleaning agent to flush away the gas bubbles and allow them to escape. The length of the cleaning process depends on the thickness and composition of the deposits.

Following cleaning

The cooling system must be flushed several times once it has been cleaned using cleaning agents. Replace the water during this process. If acids are used to carry out the cleaning, neutralise the cooling system afterwards with suitable chemicals then flush. The system can then be refilled with water that has been prepared accordingly.

Note:

Start the cleaning operation only when the engine has cooled down. Hot engine components must not come into contact with cold water. Open the venting pipes before refilling the cooling water system. Blocked venting pipes prevent air from escaping which can lead to thermal overloading of the engine.

When disposing of cleaning agents or acids, observe the applicable regulations.

Note:

The products to be used can endanger health and may be harmful to the environment. Follow the manufacturer's handling instructions without fail.

4.6 Specification of intake air (combustion air)

General

The quality and condition of intake air (combustion air) have a significant effect on the engine output, wear and emissions of the engine. In this regard, not only are the atmospheric conditions extremely important, but also contamination by solid and gaseous foreign matter.

Mineral dust in the intake air increases wear. Chemicals and gases promote corrosion.

This is why effective cleaning of intake air (combustion air) and regular maintenance of the air filter are required.

When designing the intake air system, the maximum permissible overall pressure drop (filter, silencer, pipe line) of 20 mbar must be taken into consideration.

Exhaust turbochargers for marine engines are equipped with silencers and air filters as a standard.

Requirements

Liquid fuel engines: As minimum, inlet air (combustion air) must be cleaned by an ISO Coarse 45% class filter as per DIN EN ISO 16890, if the combustion air is drawn in from inside (e.g. from the machine room/engine room). If the combustion air is drawn in from outside, in the environment with a risk of higher inlet air contamination (e.g. due to sand storms, due to loading and unloading grain cargo vessels or in the surroundings of cement plants), additional measures must be taken. This includes the use of pre-separators, pulse filter systems and a higher grade of filter efficiency class at least up to ISO ePM10 50% according to DIN EN ISO 16890.

Gas engines and dual-fuel engines: As minimum, inlet air (combustion air) must be cleaned by an ISO COARSE 45% class filter as per DIN EN ISO 16890, if the combustion air is drawn in from inside (e.g. from machine room/engine room). Gas engines or dual-fuel engines must be equipped with a dry filter. Oil bath filters are not permitted because they enrich the inlet air with oil mist. This is not permissible for gas operated engines because this may result in engine knocking. If the combustion air is drawn in from outside, in the environment with a risk of higher inlet air contamination (e.g. due to sand storms, due to loading and unloading grain cargo vessels or in the surroundings of cement plants) additional measures must be taken. This includes the use of pre-separators, pulse filter systems and a higher grade of filter efficiency class at least up to ISO ePM10 50% according to DIN EN ISO 16890.

In general, the following applies:

The inlet air path from air filter to engine shall be designed and implemented airtight so that no false air may be drawn in from the outdoor.

The concentration downstream of the air filter and/or upstream of the turbocharger inlet must not exceed the following limit values.

The air must not contain organic or inorganic silicon compounds.

Properties	**Limit**	**Unit** [1)]
Dust (sand, cement, CaO, Al_2O_3 etc.)	max. 5	mg/Nm^3
Chlorine	max. 1.5	
Sulphur dioxide (SO_2)	max. 1.25	
Hydrogen sulphide (H_2S)	max. 5	
Salt (NaCl)	max. 1	

[1)] One Nm^3 corresponds to one cubic meter of gas at 0 °C and 101.32 kPa.

Table 84: Typical values for intake air (combustion air) that must be complied with

Note:

Intake air shall not contain any flammable gases. Make sure that the combustion air is not explosive and is not drawn in from the ATEX Zone.

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4.7 Specification of compressed air

General

For compressed air quality observe the ISO 8573-1. Compressed air must be free of solid particles and oil (acc. to the specification).

Requirements

Compressed air quality of starting air system

The starting air must fulfil at least the following quality requirements according to ISO 8573-1.

Purity regarding solid particles	Quality class 6
Particle size > 40µm	max. concentration < 5 mg/m^3
Purity regarding moisture	Quality class 7
Residual water content	< 0.5 g/m^3
Purity regarding oil	Quality class X

Additional requirements are:

- The air must not contain organic or inorganic silicon compounds.
- The layout of the starting air system must ensure that no corrosion may occur.
- The starting air system and the starting air receiver must be equipped with condensate drain devices.
- By means of devices provided in the starting air system and via maintenance of the system components, it must be ensured that any hazardous formation of an explosive compressed air/lube oil mixture is prevented in a safe manner.

Compressed air quality in the control air system

Please note that control air will be used for the activation of some safety functions on the engine – therefore, the compressed air quality in this system is very important.

Control air must meet at least the following quality requirements according to ISO 8573-1.

▪ Purity regarding solid particles	Quality class 5
▪ Purity regarding moisture	Quality class 4
▪ Purity regarding oil	Quality class 3

For catalysts

The following specifications are valid unless otherwise defined by any other relevant sources:

Compressed air quality for soot blowing

Compressed air for soot blowing must meet at least the following quality requirements according to ISO 8573-1.

▪ Purity regarding solid particles	Quality class 3
▪ Purity regarding moisture	Quality class 4
▪ Purity regarding oil	Quality class 2

Compressed air quality for reducing agent atomisation

Compressed air for atomisation of the reducing agent must fulfil at least the following quality requirements according to ISO 8573-1.

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▪ Purity regarding solid particles	Quality class 3
▪ Purity regarding moisture	Quality class 4
▪ Purity regarding oil	Quality class 2

Note:

To prevent clogging of catalyst and catalyst lifetime shortening, the compressed air specification must always be observed.

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5 Engine supply systems

5.1 Basic principles for pipe selection

5.1.1 Engine pipe connections and dimensions

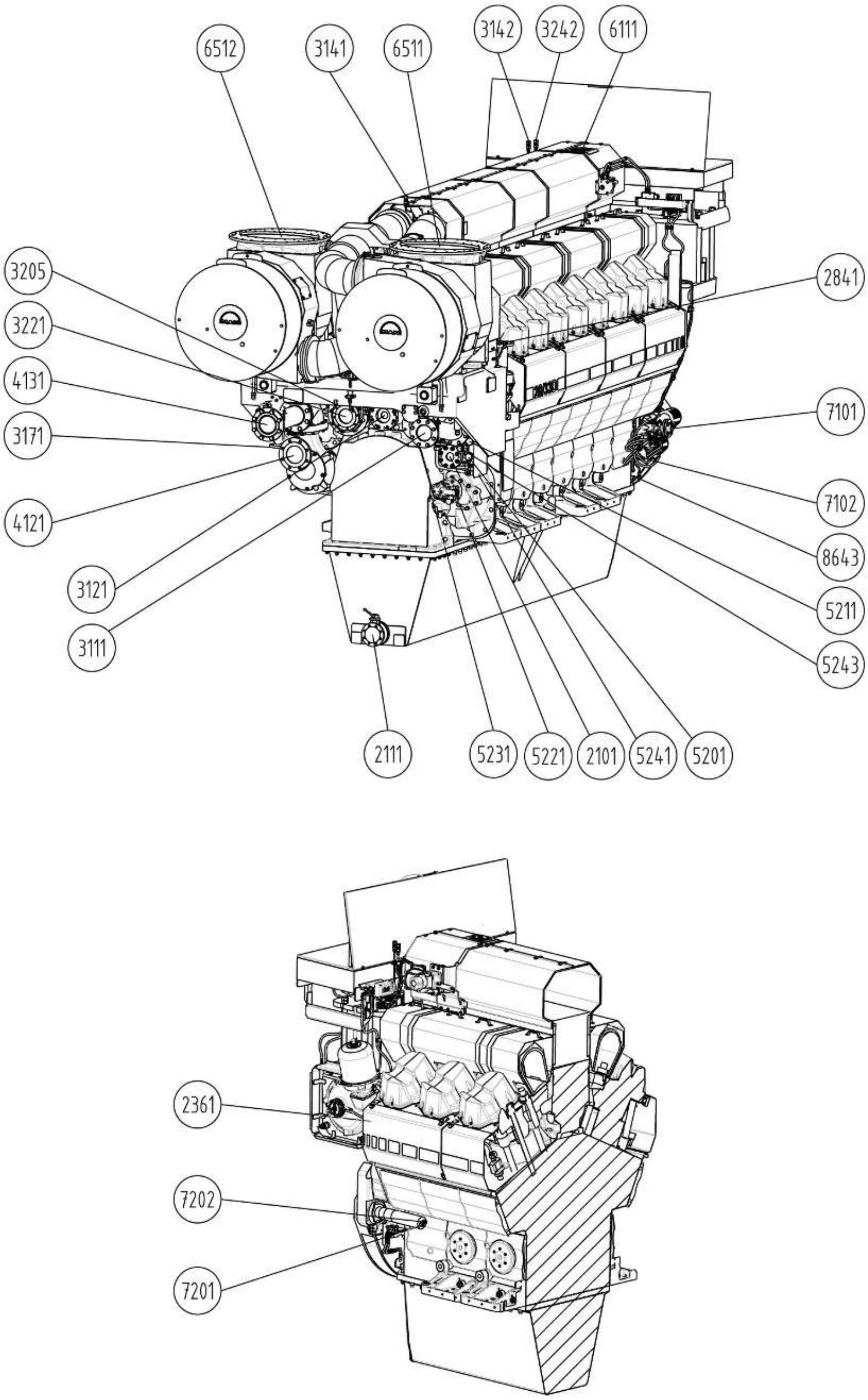

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Figure 52: Engine pipe connections

Anschluss Nr. Connection-No.	Benennung des Rohranschlusses Description of pipe connection	Rohrabmessung Pipe dimension	Bezeichnung des Anschlusst. Code for connection part	Anschlussort Connection location	Flussrichtung Flow direction
2101	Schmieroel lubricating oil	StR 88,9x3,2	EN 1092-1/01 A/DN80/PN16/S235JRG2	Kupplungsgegenseite Coupling counterside	Eintritt Inlet
2111	Ablauf aus der ölwanne Drain from oil pan	StR 88,9x3,2	EN 1092-1/01 A/DN80/PN16/S235JRG2	Kupplungsgegenseite Coupling counterside	Austritt Outlet
2361	Schmieroel Fuelleitung oil tank fill connection	Schlauch/hose EN 857 2SC 25	Schnellkupplung Quick coupling	Kupplungsseite Coupling side	Eintritt Inlet
2841	Kurbelraumentlueftung crankcase venting	StR 88,9x3,2		Kupplungsgegenseite Coupling counterside	Austritt Outlet
3111	HT Kuehlwasser HT cooling water	StR 139,7x4,5	EN 1092-1/01 A/DN125/PN16/S235JRG2	Kupplungsgegenseite Coupling counterside	Austritt Outlet
3121	HT Kuehlwasser HT cooling water	StR 139,7x4,5	EN 1092-1/01 A/DN125/PN16/S235JRG2	Kupplungsgegenseite Coupling counterside	Eintritt Inlet
3141	Entlueftung HT Kuehlwasserleitung 1 air vent HT cooling water pipe 1	StR 16x2	ISO 8434-1 - S16 DIN 3861 - S16-St	Kupplungsgegenseite Coupling counterside	Austritt Outlet
3142	Entlueftung HT Kuehlwasserleitung 2 air vent HT cooling water pipe 2	StR 16x2	ISO 8434-1 - S16 DIN 3861 - S16-St	Kupplungsseite Coupling side	Austritt Outlet
3171	Kuehlwasservorwaermung cooling water preheat	StR 60,3x2,9	EN 1092-1/11 A/DN50/PN16/P265GH+N	Kupplungsgegenseite Coupling counterside	Austritt Outlet
3205	Kuehlwassereintritt f. Verdichternachkuehlung cooling water inlet f. compressor after cooling	StR 22x2	DIN 3911 - L22-St	Kupplungsgegenseite Coupling counterside	Eintritt Inlet
3211	LT Kuehlwasser LT cooling water	StR 139,7x4,5	EN 1092-1/01 A/DN125/PN16/S235JRG2	Kupplungsgegenseite Coupling counterside	Austritt Outlet
3221	NT Kuehlwasser NT cooling water	StR 139,7x4,5	EN 1092-1/01 A/DN125/PN16/S235JRG2	Kupplungsgegenseite Coupling counterside	Eintritt Inlet
3242	Entlueftung NT Kuehlwasserleitung 1 air vent LT cooling water pipe 1	StR 16x2	ISO 8434-1 - S16 DIN 3861 - S16-St	Kupplungsseite Coupling side	Austritt Outlet
4121	Seewasser Pumpe sea water pump	StR 168,3x4,5	EN 1092-1/01 A/DN150/PN16/CuSn7Zn2Pb3	Kupplungsgegenseite Coupling counterside	Eintritt Inlet
4131	Seewasser Pumpe sea water pump	DIN 86019-159x8 CuNi10Fe1.6Mn	EN 1092-1/01 A/DN150/PN16/CuNi10Fe1.6Mn	Kupplungsgegenseite Coupling counterside	Austritt Outlet
5201	Kraftstoff fuel	StR 38x3,5	ISO 8434-1 - S38 DIN 3861 - BS38-ST	Kupplungsgegenseite Coupling counterside	Eintritt Inlet
5211	Kraftstoff fuel	StR 38x3,5	ISO 8434-1 - S38 DIN 3861 - BS38-ST	Kupplungsgegenseite Coupling counterside	Austritt Outlet
5221	Kraftstoff Foerderpumpe fuel supply pump	StR 76,1x2,9		Kupplungsgegenseite Coupling counterside	Eintritt Inlet
5231	Kraftstoff Foerderpumpe fuel supply pump	StR 76,1x2,9		Kupplungsgegenseite Coupling counterside	Austritt Outlet
5241	Leckkraftstoffablauf leakage fuel drain	StR 10x1,5	ISO 8434-1 - S10 DIN 3861 - BS10-ST	Kupplungsgegenseite Coupling counterside	Austritt Outlet
5243	Leckkraftstoffablauf leakage fuel drain	StR 25x2	ISO 8434-1 - S25 DIN 3861 - BS25-ST	Kupplungsgegenseite Coupling counterside	Austritt Outlet
6111	Ladeluftabblaseleitung charge air blow off	StR 60,3x2,9	DRW 11280310218	Kupplungsseite Coupling side	Austritt Outlet
6511	Abgasaustritt exhaust outlet	DN 700	DRW 11289840616	Kupplungsgegenseite Coupling counterside	Austritt Outlet
6512	Abgasaustritt exhaust outlet	DN 700	DRW 11289840616	Kupplungsgegenseite Coupling counterside	Austritt Outlet
7101	Anlassluft starting air	StR 48,3x2,6	EN 1092-1/11 B1/DN40/PN40/P245GH	Kupplungsseite Coupling side	Eintritt Inlet
7102	Steuerluft Eintritt control air inlet	StR 10x1,5	ISO 8434-1 - L10 DIN 3861 - BS10-St	Kupplungsseite Coupling side	Eintritt Inlet
7201	Lufteintritt am Toernmotor Air inlet on turning motor	-	Gewindeanschluss G1/4 thread connection	Kupplungsseite Coupling side	Eintritt Inlet
7202	Lufteintritt am Toernmotor Air inlet on turning motor	-	Gewindeanschluss G1/4 thread connection	Kupplungsseite Coupling side	Eintritt Inlet
8643	Kondenswasserablauf v. Ladeluftleitung condensed water drain f. air manifold	-	kein Anschluss / no connection	Kupplungsseite Coupling side	Austritt Outlet

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Figure 53: Legend to engine pipe connections

5.1.2 Specification of materials for piping

General

- The properties of the piping shall conform to international standards, e.g. DIN EN 10208, DIN EN 10216, DIN EN 10217 or DIN EN 10305, DIN EN 13480-3.
- For piping, black steel pipe should be used; stainless steel shall be used where necessary.
- Outer surface of black steel pipes needs to be primed and painted according to shipyard`s specification.

- The pipes are to be sound, clean and free from all imperfections. The internal surfaces must be thoroughly cleaned and all scale, grit, dirt and sand used in casting or bending has to be removed. No sand is to be used as packing during bending operations.
- In case of pipes with forged bends, care must be taken to ensure that inner surfaces are smooth and that no stray weld metal remains after joining.
- Advices in MAN Energy Solutions work instruction 010.000.001-03. Pipelines cleaning, pickling and preservation. Carry out the pressure test for cleaning of steel pipes before fitting them together should be observed.
- Certain material combinations are sensitive to electro-chemical corrosion, therefore special attention must be paid to the arrangement within a pipe system including all connected components.
- All information given is to be regarded as indication only; the sole responsibility for the functionality and durability of the external piping system lies with the shipyard.

LT-, HT cooling water pipes

Galvanised steel pipe must not be used for the piping of the system as all additives contained in the engine cooling water attack zinc. Moreover, there is the risk of the formation of local electrolytic element couples where the zinc layer has been worn off, and the risk of aeration corrosion where the zinc layer is not properly bonded to the substrate.

Proposed material (EN)

P235GH, E235, X5CrNiMoTi17-12-2

Fuel oil pipes, lube oil pipes

Galvanised steel pipe must not be used for the piping of the system as acid components of the fuel may attack zinc.

Proposed material (EN)

E235, P235GH, X6CrNiMoTi17-12-2

Urea pipes (for SCR only)

Galvanised steel pipe, brass and copper components must not be used for the piping of the system.

Proposed material (EN)

X6CrNiMoTi17-12-2

Compressed air pipes

Galvanised steel pipe must not be used for the piping of the system.

Proposed material (EN)

E235, P235GH, X6CrNiMoTi17-12-2

Seawater pipes

Material depending on required flow speed and mechanical stress.

Proposed material

CuNiFe, glass fiber reinforced plastic, rubber lined steel

5.1.3 Installation of flexible pipe connections

Arrangement of hoses on resiliently mounted engine

Flexible pipe connections become necessary to connect resiliently mounted engines with external piping systems. They are used to compensate the dynamic movements of the engine in relation to the external piping system. For information about the origin of the dynamic engine movements, their direction and identity in principle see tables Static/dynamic movements, Page 154.

Origin of static/ dynamic movements	Engine rotations unit			Coupling displacements unit			Exhaust flange (at the turbocharger)		
	°			mm			mm		
	Axial Rx	Cross direction Ry	Vertical Rz	Axial X	Cross direction Y	Vertical Z	Axial X	Cross direction Y	Vertical Z
Pitching	0.0	±0.07	0.0	±1.4	0.0	±2.6	±3.8	0.0	±2.3
Rolling	±0.36	0.0	0.0	0.0	±4.6	0.2 ±0.2	±0.0	±18.7	±4.6
Engine torque	–0.13 (torque CW)	0.0	0.0	0.0	+0.9	0.0	0.0	+5.7	±1.4 [1)]
Vibration during normal operation	(±0.001)	~0.0	~0.0	0.0	0.0	0.0	±0.03	±0.03	±0.04
Run out resonance	±0.04	0.0	0.0	0.0	±0.4	0.0	0.0	±2.1	±0.5
[1)] TC at bank ‘B’ plus, TC at bank ‘A’ minus.									

Table 85: Static/dynamic movements – MAN 12V28/33D STC

Note:
The above entries are approximate values (±10 %); they are valid for the standard design of the mounting.

Assumed sea way movements: Pitching ±7.5°/rolling ±22.5°.

Origin of static/ dynamic movements	Engine rotations unit			Coupling displacements unit			Exhaust flange (at the turbocharger)		
	°			mm			mm		
	Axial Rx	Cross direction Ry	Vertical Rz	Axial X	Cross direction Y	Vertical Z	Axial X	Cross direction Y	Vertical Z
Pitching	0.0	±0.05	0.0	±1.5	0.0	±2.2	±3.2	0.0	±2.4
Rolling	±0.45	0.0	0.0	0.0	±5.9	0.28 ±0.28	±0.0	±24.9	±6.13
Engine torque	–0.17 (torque CW)	0.0	0.0	0.0	+1.2	0.0	0.0	+7.9	±2.0 [1)]
Vibration during normal operation	(±0.003)	(±0.001)	~0.0	0.0	±0.1	±0.1	±0.01	±0.02	±0.06

Origin of static/ dynamic movements	Engine rotations unit			Coupling displacements unit			Exhaust flange (at the turbocharger)		
	°			mm			mm		
	Axial Rx	Cross direction Ry	Vertical Rz	Axial X	Cross direction Y	Vertical Z	Axial X	Cross direction Y	Vertical Z
Run out resonance	±0.05	0.0	0.0	0.0	±0.5	0.0	±0.5	±2.8	±0.6
[1] TC at bank 'B' plus, TC at bank 'A' minus.									

Table 86: Static/dynamic movements – MAN 16V28/33D STC

Note:
The above entries are approximate values (±10 %); they are valid for the standard design of the mounting.

Assumed sea way movements: Pitching ±7.5°/rolling ±22.5°.

Origin of static/ dynamic movements	Engine rotations unit			Coupling displacements unit			Exhaust flange (at the turbocharger)		
	°			mm			mm		
	Axial Rx	Cross direction Ry	Vertical Rz	Axial X	Cross direction Y	Vertical Z	Axial X	Cross direction Y	Vertical Z
Pitching	0.0	±0.04	0.0	±1.4	0.0	±1.5	±2.5	0.0	±2.0
Rolling	±0.40	0.0	0.0	0.0	±4.7	0.4 ±0.2	±0.0	±22.3	±5.6
Engine torque	–0.17 (torque CW)	0.0	0.0	0.0	+1.1	+0.1	0.0	+7.6	±1.9 [1]
Vibration during normal operation	(±0.014)	~0.0	~0.0	0.0	0.0	0.0	0.0	0.0	0.0
Run out resonance	±0.06	0.0	0.0	±0.05	±0.55	±0.1	±0.03	±3.3	±0.8
[1] TC at bank 'B' plus, TC at bank 'A' minus.									

Table 87: Static/dynamic movements – MAN 20V28/33D STC

Note:
The above entries are approximate values (±10 %); they are valid for the standard design of the mounting.

Assumed sea way movements: Pitching ±7.5°/rolling ±22.5°.

MAN Energy Solutions may be contacted for order specific values when details of engine application have been clarified.

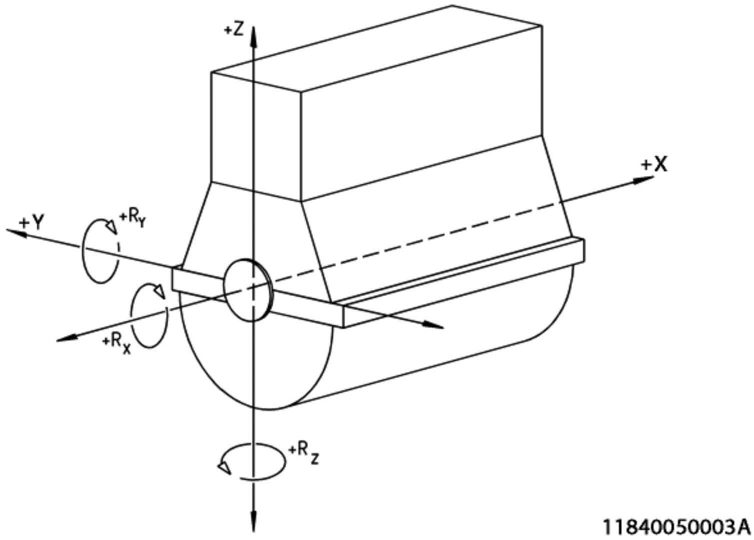

Figure 54: Coordinate system (not applicable for engine installation drawings)

Generally flexible pipes (rubber hoses with steel inlet, metal hoses, PTFE-corrugated hose-lines, rubber bellows with steel inlet, steel bellows, steel compensators) are nearly unable to compensate twisting movements. Therefore the installation direction of flexible pipes must be vertically (in Z-direction) if ever possible. Torsion on flexible pipe connections must be avoided. Flexible pipe connections which are installed in X-direction are particularly at risk. Therefore the installation of flexible pipe connections in this direction should be avoided. Where the installation of flexible pipe connections in X-direction is nevertheless unavoidable, the continuing pipeline on the plant side must be designed in such a way that the torsional forces can be safely absorbed. An installation in horizontal-lateral (Y-direction) is not recommended.

The media connections (compensators) to and from the engine must be highly flexible whereas the fixations of the compensators on the one hand with the engine and on the other hand with the environment must be realised as stiff as possible.

Flange and screw connections

Flexible pipes delivered loose by MAN Energy Solutions are fitted with flange connections from DN32 upwards. Smaller sizes are fitted with screw connections. Each flexible pipe is delivered complete with counter flanges or, those smaller than DN32, with weld-on sockets.

Arrangement of the external piping system

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

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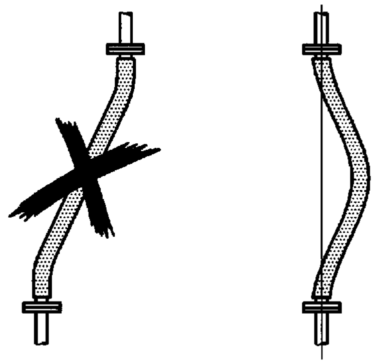

Figure 55: Arrangement of pipes in system

Installation of hoses

In the case of straight-line-vertical installation, a suitable distance between the hose connections has to be chosen, so that the hose is installed with a sag. To satisfy a correct sag in a straight-line-vertically installed hose, the distance between the hose connections (hose installed, engine stopped) has to be approximately 5 % shorter than the same distance of the unconnected hose (without sag). Flexible hoses must not be installed with tensile stress, compression or torsional tension.

In case it is unavoidable (this is not recommended) to connect the hose in lateral-horizontal direction (Y-direction) the hose must preferably be installed with a 90° arc. The minimum bending radii, specified in provided drawings, are to be observed.

Hoses must not be twisted during installation. Turnable lapped flanges on the hoses avoid this.

Where bolted connections are used, hold the hexagon on the hose with a wrench while fitting the nut.

All installation instructions of the hose manufacturer have to be complied with.

Depending on the required application rubber hoses with steel inlet, metal hoses or PTFE-corrugated hose lines are used.

Installation of steel compensators

Steel compensators are used for hot media, e.g. exhaust gas. They can compensate movements in line and transversal to their centre line, but they are absolutely unable to compensate twisting movements. Compensators are very stiff against torsion. For this reason all kind of steel compensators installed on resilient mounted engines are to be installed in vertical direction.

Note:
Exhaust gas compensators are also used to compensate for thermal expansion. Exhaust gas compensators are therefore required for all type of engine mountings, also for semi-resilient or rigid mounted engines. But in these cases the compensators can be shorter, as they are designed only to compensate the thermal expansions and vibrations, but not other dynamic engine movements.

Supports of pipes

Flexible pipes must be installed as close as possible to the engine connection.

On the shipside, directly after the flexible pipe, the pipe is to be fixed with a sturdy pipe anchor of higher than normal quality. This anchor must be capable to absorb the reaction forces of the flexible pipe, the hydraulic force of the fluid and the dynamic force.

Example of the axial force of a compensator to be absorbed by the pipe anchor:

- Hydraulic force

  = (cross section area of the compensator) x (pressure of the fluid inside)
- Reaction force

  = (spring rate of the compensator) x (displacement of the comp.)
- Axial force

  = (hydraulic force) + (reaction force)

Additionally a sufficient margin has to be included to account for pressure peaks and vibrations.

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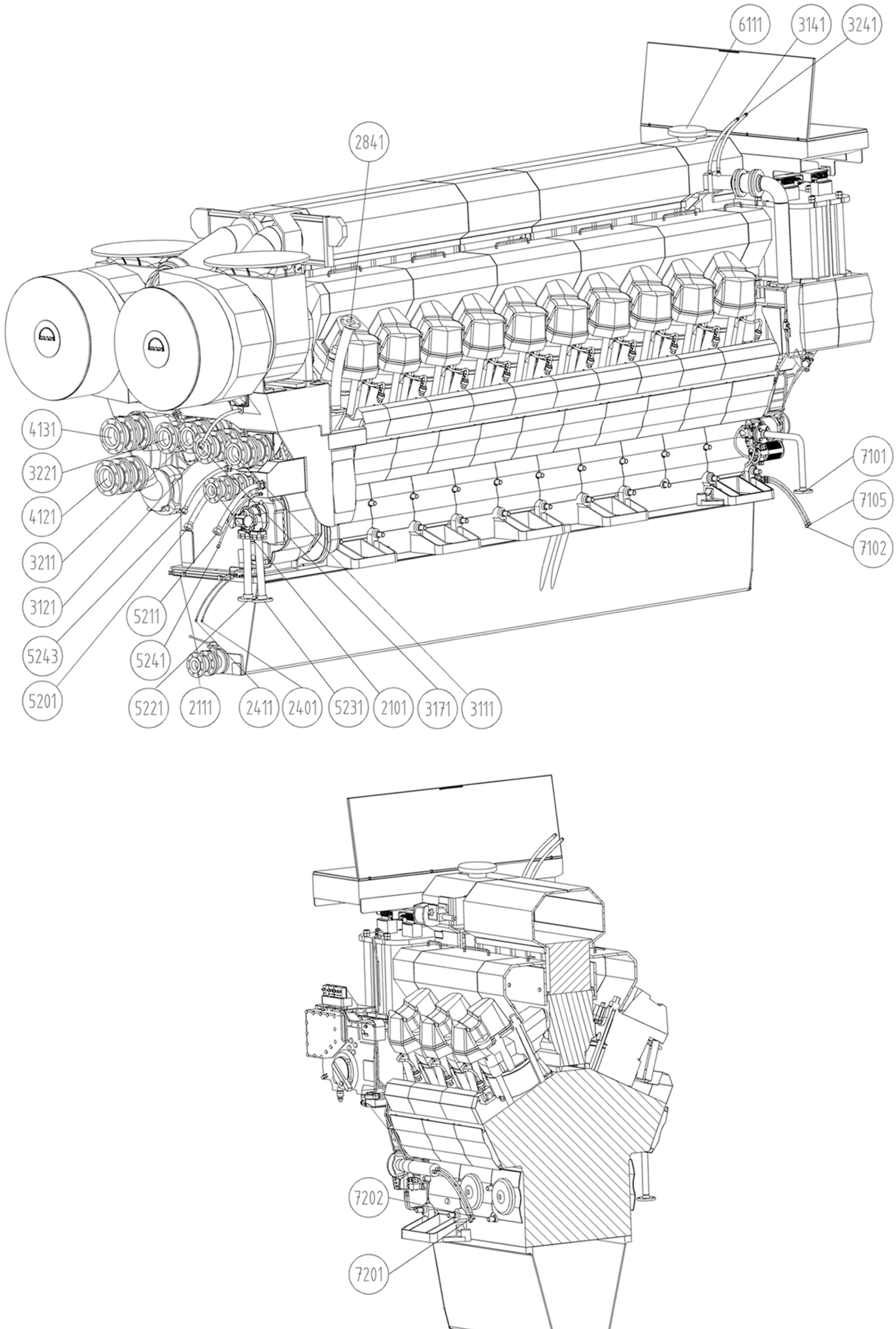

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Figure 56: Example of installation of hoses

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5.1.4 External pipe dimensioning

The external piping systems are to be installed and connected to the engine by the shipyard. Piping systems are to be designed in order to maintain the pressure losses at a reasonable level. To achieve this with justifiable costs, it is recommended to maintain the flow rates as indicated below. Nevertheless, depending on specific conditions of piping systems, it may be necessary in some cases to adopt even lower flow rates. Generally it is not recommended to adopt higher flow rates.

	Recommended velocity (m/s)		
	Suction side	Delivery side	Kind of system
Fresh water (cooling water)	1.5 – 2.5	1.5 – 2.5	Closed
Seawater	1.0 – 1.5	1.5 – 2.5	Open
Lube oil	0.5 – 1.0	1.5 – 2.5	Open
Diesel fuel oil	0.5 – 1.0	1.5 – 2.0	Open
Exhaust gas	40		Open
Intake air (combustion air)	8 – 12		Open

Table 88: Recommended flow rates

5.1.5 Condensate amount in charge air pipes and air vessels

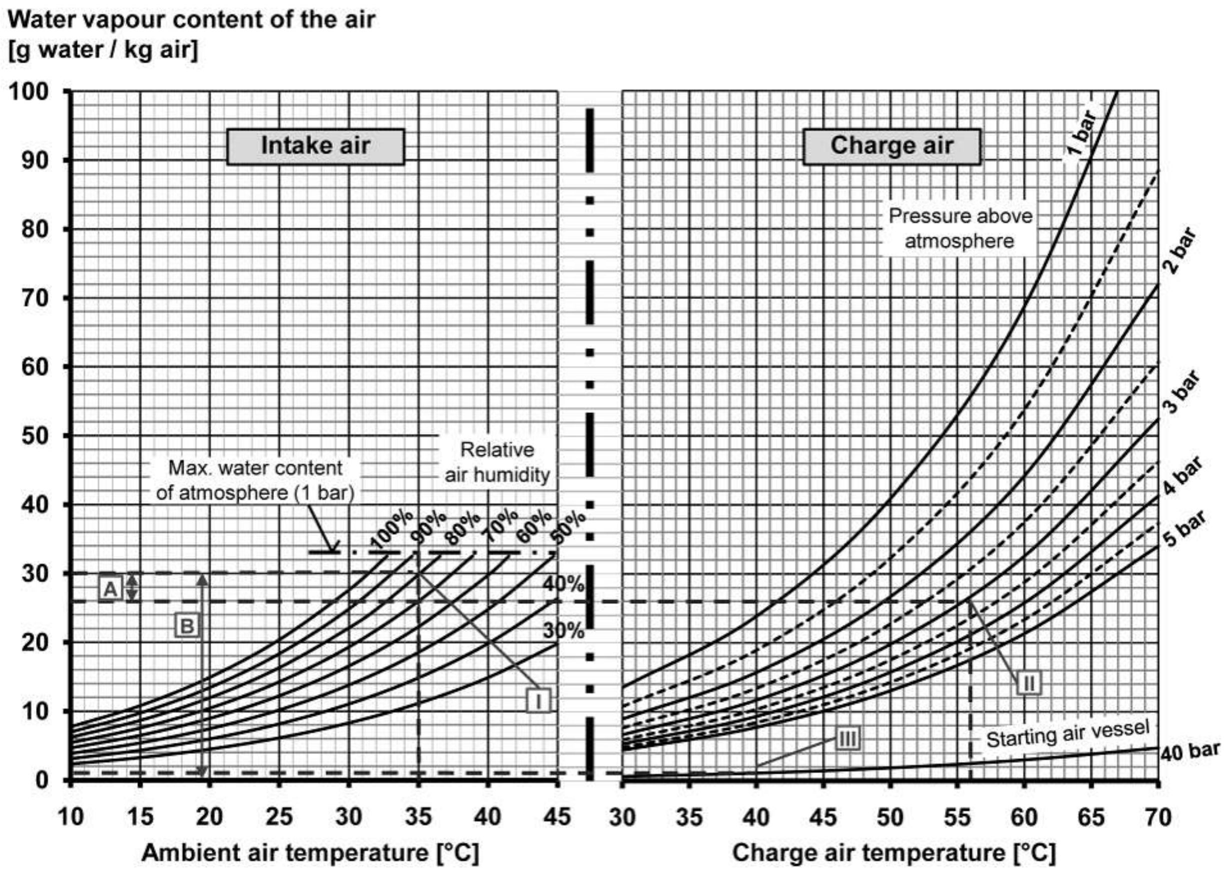

Figure 57: Diagram condensate amount

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The amount of condensate precipitated from the air can be considerablly high, particularly in the tropics. It depends on the condition of the intake air (temperature, relative air humidity) in comparison to the charge air after charge air cooler (pressure, temperature).

It is important, that no condensed water of the intake air/charge air will be led to the compressor of the turbocharger, as this may cause damages.

In addition the condensed water quantity in the engine needs to be minimised. This is achieved by controlling the charge air temperature.

How to determine the amount of condensate:

First determine the point I of intersection in the left side of the diagram (intake air), see figure Diagram condensate amount, Page 160 between the corresponding relative air humidity curve and the ambient air temperature.

Secondly determine the point II of intersection in the right side of the diagram (charge air) between the corresponding charge air pressure curve and the charge air temperature. Note that charge air pressure as mentioned in section Planning data, Page 63 is shown as absolute pressure.

At both points of intersection read out the values [g water/kg air] on the vertically axis.

The intake air water content I minus the charge air water content II is the condensate amount A which will precipitate. If the calculations result is negative no condensate will occur.

For an example see figure Diagram condensate amount, Page 160. Intake air water content 30 g/kg minus 26 g/kg = 4 g of water/kg of air will precipitate.

To calculate the condensate amount during filling of the starting air receiver just use the 40 bar curve (see figure Diagram condensate amount, Page 160) in a similar procedure.

Example how to determine the amount of water accumulating in the charge air pipe

Parameter	Unit	Value
Engine output (P)	kW	9,000
Specific air flow (le)	kg/kWh	6.9
Ambient air condition (I):		
Ambient air temperature	°C	35
Relative air humidity	%	80
Charge air condition (II):		
Charge air temperature after cooler[1)]	°C	56
Charge air pressure (over pressure)[1)]	bar	3.0
Solution according to above diagram		
Water content of air according to point of intersection (I)	kg of water/kg of air	0.030
Maximum water content of air according to point of intersection (II)	kg of water/kg of air	0.026
The difference between (I) and (II) is the condensed water amount (A)		
A = I – II = 0.030 – 0.026 = 0.004 kg of water/kg of air		

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Parameter	Unit	Value
Total amount of condensate Q_A: Q_A = A x le x P Q_A = 0.004 x 6.9 x 9,000 = 248 kg/h		
[1] In case of two-stage turbocharging choose the values of the high-pressure TC and cooler (second stage of turbocharging system) accordingly.		

Table 89: Example how to determine the amount of water accumulating in the charge air pipe

Example how to determine the condensate amount in the starting air receiver

Parameter	Unit	Value
Volumetric capacity of tank (V)	litre m^3	1,500 1.5
Temperature of air in starting air receiver (T)	°C K	40 313
Air pressure in starting air receiver ($p_{\text{above atmosphere}}$) Air pressure in starting air receiver (p_{absolute})	bar bar abs $\frac{N}{m^2}$	40 41 41×10^5
Gas constant for air (R)	$\frac{Nm}{kg \times K}$	287
Ambient air temperature	°C	35
Relative air humidity	%	80
Weight of air in the starting air receiver is calculated as follows: $m = \frac{p \times V}{R \times T} = \frac{41 \times 10^5 \times 1.5}{287 \times 313} = 68.5 \text{ kg}$		
Solution acc. to above diagram:		
Water content of air according to point of intersection (I)	kg of water/kg of air	0.030
Maximum water content of air according to point of intersection (III)	kg of water/kg of air	0.001
The difference between (I) and (III) is the condensed water amount (B) B = I – III B = 0.030 – 0.001 = 0.029 kg of water/kg of air		
Total amount of condensate in the vessel Q_B: Q_B = m x B Q_B = 68.5 x 0.029 = 1.99 kg		

Table 90: Example how to determine the condensate amount in the starting air receiver

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5.2 Lube oil system

5.2.1 Internal lube oil system

To easen the installation of the MAN V28/33D STC all core components of the lube oil system are already integrated in the engine design.

As a standard the engine is equipped with following attached equipment:

- Lube oil pump
- Oil sump for complete lube oil filling (2 different kinds available)
- Lube oil cooler
- Lube oil temperature control valve
- Lube oil duplex filter, optional: Alternatively lube oil automatic filter plus lube oil centrifugal filter

Not attached to the engine, but part of the delivery:

- Oil mist eliminator

Not included:

- Prelubrication pump (electric driven)
- Preheating unit

P-001/Lube oil pump

The MAN V28/33D STC engine is not used for single engine plants. Therefore an electrically driven stand-by lube oil pump with 100 % delivery capacity is not required by classification rules. However, if for any other reason an electrically driven 100 % stand-by lube oil pump becomes necessary, please contact MAN Energy Solutions.

The lube oil service pump draws the lube oil through suction strainers in the engine sump. The engine driven attached lube oil service pump has an integral pressure relief valve to prevent overpressurisation of the system when the oil is more viscous during cold conditions.

A main lube oil pump as spare is required to be on board according to class society. For design data of these lube oil pumps see sections Planning data, Page 63, Operating/service temperatures and pressures, Page 72 and Filling volumes, Page 76.

Note:
Cold starting precautions:

If starting in cold conditions the service pump outlet pressure may exceed the maximum pressure of 8 bar (PT2170). Also, the differential pressure in the lube oil filter may exceed the maximum of 10 bar. Therefore, in cold conditions it is recommended that:

- Before starting the engine, lube oil is circulated by the prelubrication pump in order to absorb heat from the warm, upper part of the engine.
- After starting, the engine is allowed to idle; sensors PT2170 and filter differential pressure are monitored as speed is increased to ensure the maximum pressures are not exceeded.

HE-037/Engine attached lube oil cooler

Oil travels along a passage in the air manifold to the cooler and lube oil filter module mounted at the flywheel end of the engine above the flywheel itself. The cooler is of plate design and mounted horizontally flat on top of the filter module which also incorporates an integral oil thermostat valve.
The cooling medium passing the lube oil cooler is low temperature (LT) cooling water.

Between the main pump and the thermostat a supply is taken from the main feed line to a metal particle detector. This detector provides an additional high level of protection for the engine.

TCV-001/Lube oil temperature control valve

The thermostatic valve is a direct acting, pre-set wax element type, automatic temperature regulator fitted across the inlet and outlet of the cooler. As the oil warms the valve operates to divert more oil through the cooler to maintain it at the correct working temperature at engine inlet.

Filtration of lube oil

As standard the engine is equipped with a lube oil duplex filter. Optional a configuration with automatic filter and centrifuge is available.

FIL-002/Lube oil duplex filter

The duplex filter is equipped with filter elements of 25 µm absolute filter fineness. A changeover valve allows to change the elements in one filter chamber while the engine is running. See also figure External lube oil system diagram including lube oil module with duplex filter (standard), Page 170.

FIL-001/Lube oil automatic filter (optional)

The back washing/flushing of the filter elements is arranged in a way that lube oil flow and pressure will not be affected. The flushing discharge is led to the oil sump. The automatic filter is equipped with an integrated second filtration stage (50 µm absolute filter mesh). This second stage protects the engine from particles which may pass the first stage filter elements (30 µm absolute filter mesh) in case of any malfunction. See also figure External lube oil system diagram including lube oil module with automatic filter (optional), Page 172.

CF-008/Lube oil centrifugal filter (optional)

The engine is equipped with a centrifugal by-pass filter in case an automatic filter is installed to get the contamination out of the system. This filter removes contaminants through centrifugal force. The sludge is collected in the filter fleece which must be cleaned/removed regularly. The cleaned oil returns into to lube oil pan.

Indication and alarm of filters

Lube oil module with duplex filter

The duplex oil filter is equipped with differential pressure transmitters on its inlet and outlet ports. The pressure at these points is transmitted to the control panel and the differential pressure between the two is derived in the control software. An alarm is triggered when the differential pressure reaches 1 bar (rising).

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Lube oil module with automatic filter

The engine mounted automatic filter is equipped with differential pressure gauges, to protect the filter cartridges and to indicate clogging condition of the filter. A high differential pressure is indicated as an alarm. The centrifugal filter has to be cleaned in given intervals. There is no indication at the centrifuge.

For details of the instrumentation, see section SaCoSone system overview, Page 103.

PCV-007/Lube oil pressure relief valve

The pressure relief valve is integrated in the attached lube oil pump. By use of the pressure relief valve, a constant lube oil pressure at engine inlet is adjusted. The pressure relief valve is installed parallel to the attached lube oil pump. The return line of the valve is connected to the suction side of the pump.

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Internal lube oil system – Exemplary

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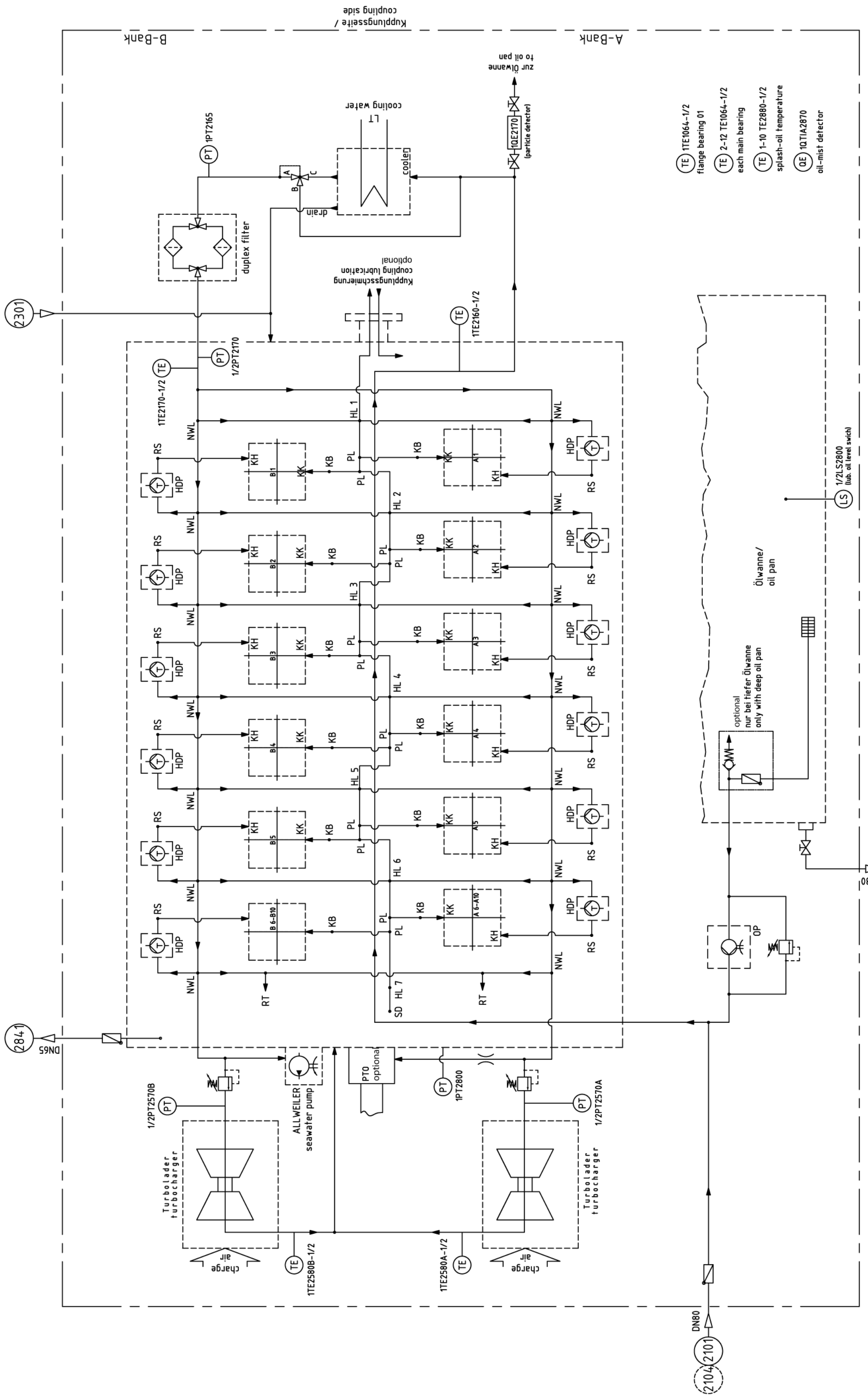

Figure 58: Internal lube oil system – Exemplary for variant with lube oil duplex filter

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Components			
HDP	High pressure fuel pump	NWL	Camshaft bearing
HL	Main bearing	PL	Con-rod bearing
KB	Piston pin	RS	Roller tappet
KH	Rocker lever lubrication	RT	Bearings gear drive
KK	Piston cooling	SD	Vibration damper
KW	Crankshaft	OP	Lube pump
NW	Camshaft		
Major engine connections			
2101	Lube oil inlet to engine	2301	Lube oil filling on engine
2104	Lube oil inlet to engine for provisional lubrication	2841	Venting of crankcase
2111	Lube oil drain from oil pan, counter coupling side 1		

Note:
The drawing shows the basic internal media flow of the engine in general. Project-specific drawings thereof don´t exist.

5.2.2 External lube oil system

P-007/Prelubrication lube oil pump

The MAN V28/33D STC engine is not used for single engine plants. Therefore an electrically driven stand-by lube oil pump with 100 % delivery capacity is not required by classification rules. However, if for any other reason an electrically driven 100 % stand-by lube oil pump becomes necessary, please contact MAN Energy Solutions.

A prelubrication pump P-007 for pre- and postlubrication is necessary. The prelubrication pump draw oil through suction strainers in the engine sump. Dependent on the type of prelubrication pump, an orifice on the discharge side could be necessary to comply with the required differential pressure over the pump, given by the pump manufacturer.

The prelubrication pump is a positive displacement type fitted with a by-pass relief valve to protect the pump and system against overpressure. An interlock is fitted at the engine management (SaCoS) to prevent engine start if the prelubrication oil pressure is not detected or reached. The engine will be fully primed and available to start within 60 seconds of starting the prelubrication pump.

The prelubrication pump must be located as low as possible and close to the lube oil service tank to prevent cavitation. The pressure drop in the piping must not exceed the suction capability of the pump. With adequate diameter, straight lines and short length the pressure drop can be kept low.

For further information according this pump see section Planning data, Page 63 and paragraph Lube oil, Page 74.

After engine stop the postlubrication must be started and must persist for 15 min. This is required to cool down the bearings of the turbocharger and hot inner engine components.

Note:
Cold starting precautions:
If starting in cold conditions the service pump outlet pressure may exceed the maximum pressure of 8 bar (PT2170). Also, the differential pressure in the lube oil filter may exceed the maximum of 10 bar. Therefore, in cold conditions it is recommended that:

- Before starting the engine, lube oil is circulated by the prelubrication pump in order to absorb heat from the warm, upper part of the engine.
- After starting, the engine is allowed to idle; sensors PT2170 and filter differential pressure are monitored as speed is increased to ensure the maximum pressures are not exceeded.

H-025/Lube oil preheater (optional)

For engine room temperatures below 5 °C the HT cooling water preheater can be used to preheat the lube oil by circulating both media simultaneously through the engine. The prelubrication pump can be used for circulation of the lube oil through the engine. For temperatures significantly below 0 °C a more powerful HT cooling water preheater must be provided and also the power of the electric motor and the suction ability of the prelubrication pump has to be adjusted to the highest possible lube oil viscosity. As alternative a separate lube oil preheating unit can be installed.

The same procedure can be used to keep the oil temperature above 40 °C (start requirement) during stand-by operation of the engine.

A separate lube oil preheater or a HT cooling water preheater with higher capacity including a modified prelubrication pump can be supplied by MAN Energy Solutions. Please contact MAN Energy Solutions for technical drawings of auxiliary equipment.

FIL-004/Lube oil suction strainer

The lube oil suction strainer protects the lube oil pumps against larger dirt particles that may have accumulated in the tank. It is recommended to use a cone type strainer with a mesh size of 1.5 mm. Two manometers installed before and after the strainer indicate when manual cleaning of filter becomes necessary, which should preferably be done in port.

BL-007/Fan, crankcase venting

To ensure that a slight vacuum is maintained within the crankcase and to remove the potentially hazardous mix of oil mist and combustion gas a motor driven extractor fan is fitted. The majority of oil mist condenses into droplets in the venting pipe and runs back into the engine, thus the pipework to the fan unit has to have a continuous rise. To ensure prolonged maintenance free operation we recommend that this pipework is installed at a minimum angle of 25 °. If this angle is not achievable for part or all of the installation, manual drain points are to be fitted in the pipework at positions where the oil might collect. The crankcase vacuum is regulated by an extraction fan placed within the engine venting pipe and regulated via a pressure transmitter placed on the crankcase. Distance between engine and venting fan shall be min. 7 metres and max. 10 metres.

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Withdrawal points for oil sampling

A point for drawing lube oil samples is provided – the manual vent for the lube oil filter is used for this purpose. Looking on the flywheel, this vent is positioned on the right hand side of the oil filter casing, just above the manual sump filling point. There is enough room to enable a small sampling bottle to be positioned under the vent tap.

Piping system

As a minimum standard it is recommended to use pipes according to the pressure class PN 10. Lube oil prelubrication connections on the engine are PN 16.

MOD-064/Lube oil replenishing unit

This unit contains a lube oil suction strainer, see paragraph FIL-004/Lube oil suction strainer, Page 168, a lube oil transfer pump and a flexible hose. The lube oil transfer pump P-012 supplies fresh oil from the lube oil storage tank to the operating tank. Starting and stopping of the lube oil transfer pump should preferably be done automatically by float switches fitted in the tank.

Suction pipes

Suction pipes must be installed with a steady slope and dimensioned for the total resistance (incl. pressure drop for suction filter) not exceeding the pump suction head. Before engine starts, venting of suction line must be warranted. Therefore the design of the suction line must be executed accordingly.

Requirements before commissioning of engine

The flushing of the lube oil system in accordance to the MAN Energy Solutions specification (see the relevant working instructions) before commissioning of the engine demands that all installations within the system are in proper operation. Please be aware that special installations for commissioning are required.

Please contact MAN Energy Solutions or licensee if any uncertainties occur.

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External lube oil system diagrams

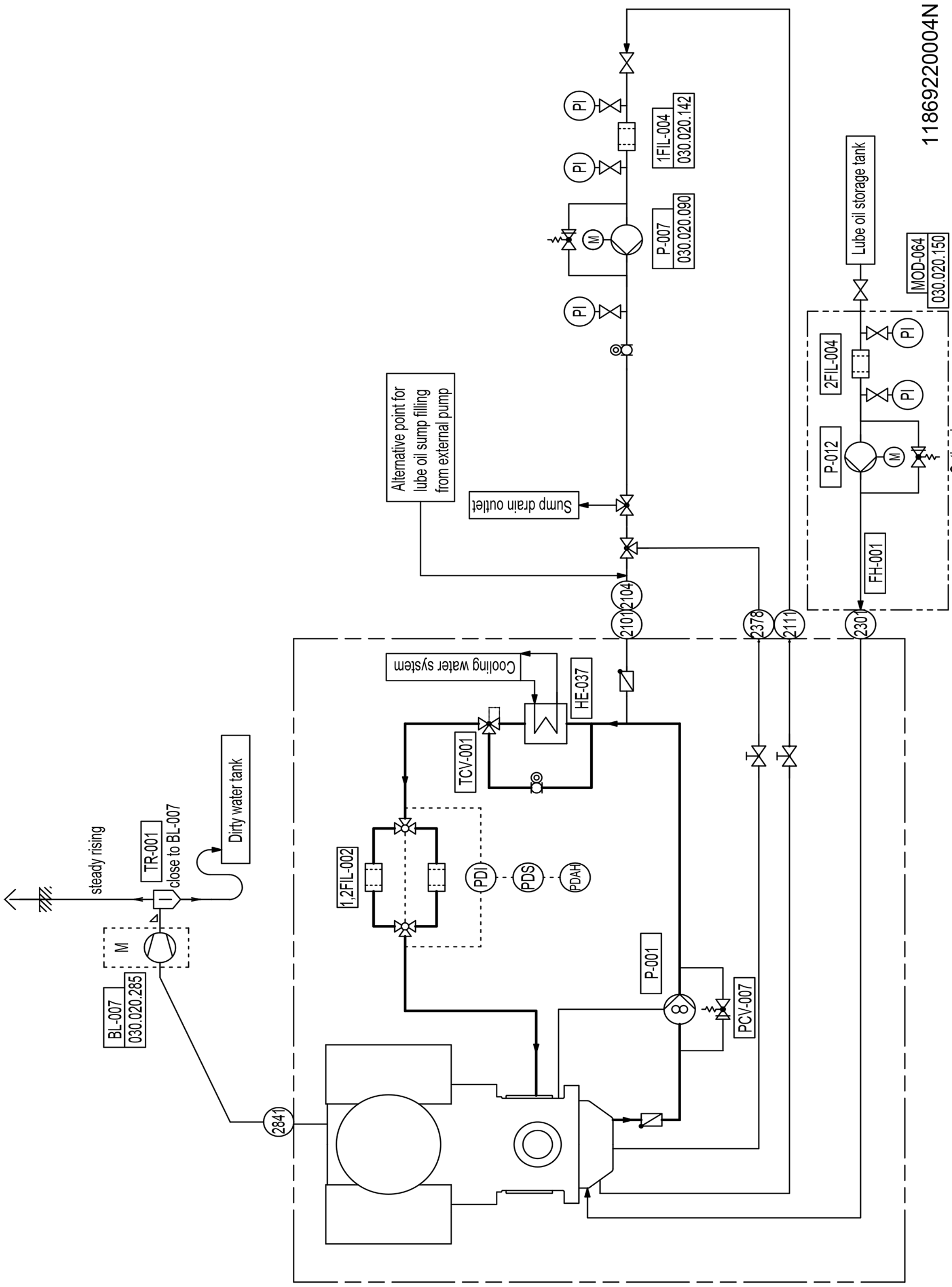

Figure 59: External lube oil system diagram including lube oil module with duplex filter (standard)

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Components			
FH-001	Flexible hose for lube oil replenishing unit	P-007	Prelubrication pump
1,2FIL-002	Lube oil duplex filter	P-012	Lube oil transfer pump
1,2FIL-004	Lube oil suction strainer	PCV-007	Lube oil pressure relief valve
HE-037	Lube oil cooler main engine, attached	T-021	Sludge tank
MOD-064	Lube oil replenishing unit (consists of P-012, 2FIL-004, FH-001)	TCV-001	Lube oil temperature control valve
P-001	Lube oil service pump, attached	TR-010	Oil mist eliminator with extraction fan
Major engine connections			
2101	Lube oil inlet to engine	2301	Lube oil filling connection on base frame tank
2104	Lube oil inlet for provisional lubrication	2378	Lube oil drain from oil pan, coupling side 2
2111	Lube oil drain from oil pan, counter coupling side 1	2841	Venting of crankcase 1

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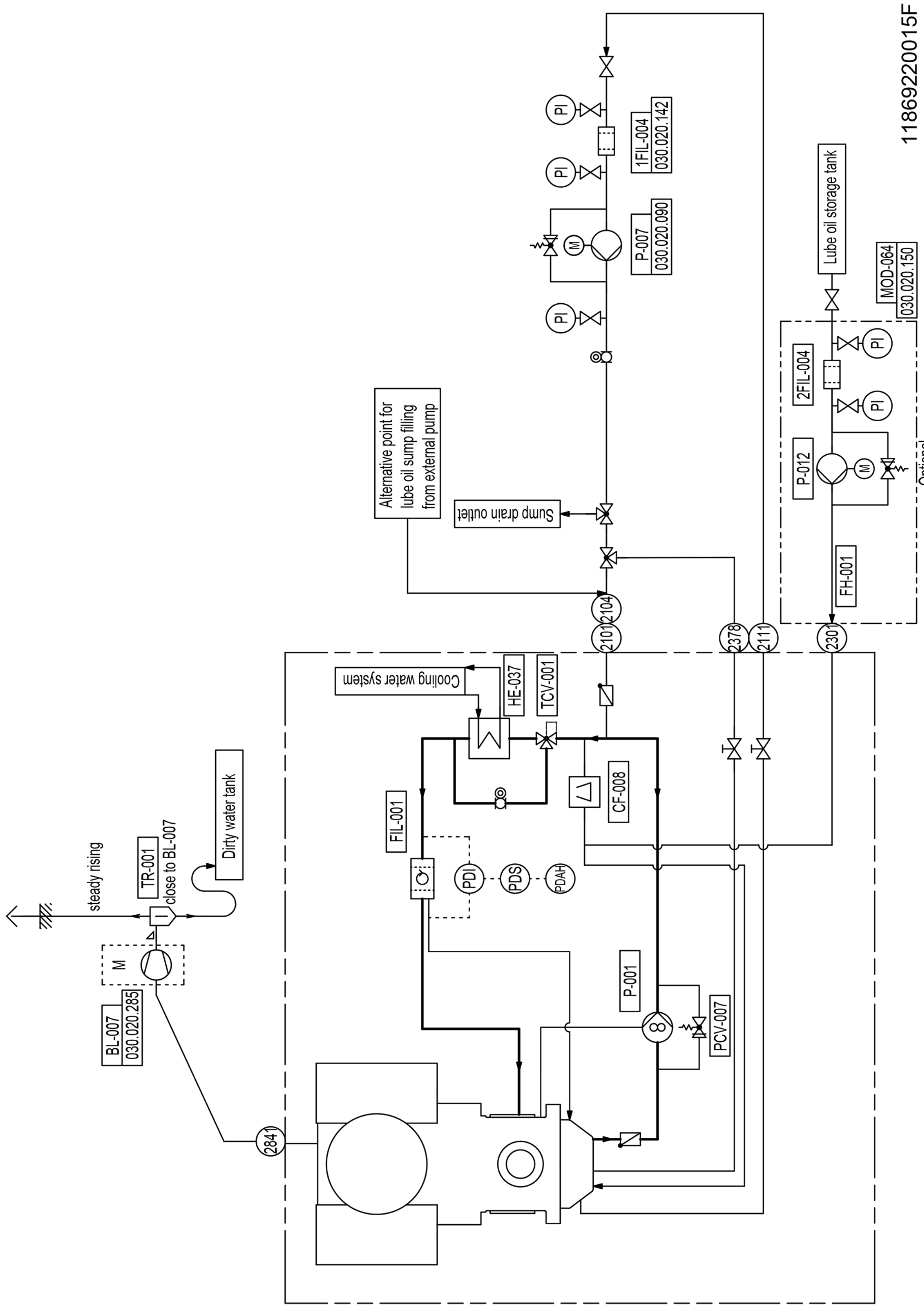

Figure 60: External lube oil system diagram including lube oil module with automatic filter (optional)

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Components			
CF-008	Lube oil centrifugal filter	P-001	Lube oil service pump, attached
FH-001	Flexible hose for lube oil replenishing unit	P-007	Prelubrication pump
FIL-001	Lube oil automatic filter	P-012	Lube oil transfer pump
1,2FIL-004	Lube oil suction strainer	PCV-007	Lube oil pressure relief valve
H-025	Lube oil preheater	BL-007	Fan, crankcase venting
HE-037	Lube oil cooler main engine, attached	TCV-001	Lube oil temperature control valve
MOD-064	Lube oil replenishing unit (consists of P-012, 2FIL-004, FH-001)	TR-001	Condensate trap, lube oil systems
Major engine connections			
2101	Lube oil inlet to engine	2301	Lube oil filling connection on base frame tank
2104	Lube oil inlet for provisional lubrication	2278	Lube oil drain from oil pan, coupling side 2
2111	Lube oil drain from oil pan, counter coupling side 1	2841	Venting of crankcase 1

5.2.3 Prelubrication/postlubrication

Prelubrication

The prelubrication pump must be switched on at least 5 minutes before engine start. The prelubrication pump serves to assist the engine attached main lube oil pump, until this can provide a sufficient flow rate.

For design data of the prelubrication pump see section Planning data, Page 63 and paragraph Lube oil, Page 74.

Postlubrication

The prelubrication pump is also to be used for postlubrication after the engine is turned off.

Postlubrication is effected for a period of 15 minutes.

5.2.4 Lube oil filling and outlets

Lube oil filling

The lube oil system can be manually filled from barrels and hand pump via the filling cap point (2361) situated on the oil filter housing on 'B' bank side, see section Definitions, Page 247. Alternatively filling can be effected by transfer pump from an oil storage tank via the prelubricaton inlet pipe as indicated on the P&I diagram.

Lube oil drain

Assuming a suitable drain or holding tank is installed, the lube oil system can be drained by the installation of lockable three-way valve as indicated on the diagram. Alternatively single valve configurations can be used if it is the shipyard preference. The prelubricaton pump, in manual control, can then be used to empty the system. As a warning, this pump has a high flow rate and will empty a typical oil system on a MAN 12V28/33D STC in less than 3 minutes. Lube oil holding or drain tanks, transfer pumps and associated pipework are all shipyard supply.

5.3 Crankcase vent

Crankcase pressure arising from blow-by of combustion gases past the piston rings is relieved through the crankcase venting, connection 2841. This pressure, if unrelieved, could cause leakage of lubricating oil through the crankshaft oil seals and ultimately crankcase explosion if left unchecked.

Under normal running conditions, the crankcase is filled with warm air laden with oil mist together with relatively small quantities of combustion gases that pass through the venting to the atmosphere.

In the event of a crankcase explosion, the sudden pressure rise is relieved through fast opening disc valves situated on the crankcase doors. The primary pressure wave is followed by a partial vacuum in the crankcase, which closes the valve and thus prevents the in-rush of a charge of air that could cause a secondary and more violent explosion.

Vent pipes

The vent pipe from the engine crankcase is to be arranged according to the following diagram. The required nominal diameter DN of the vent pipe is to be found in the legend following the diagram.

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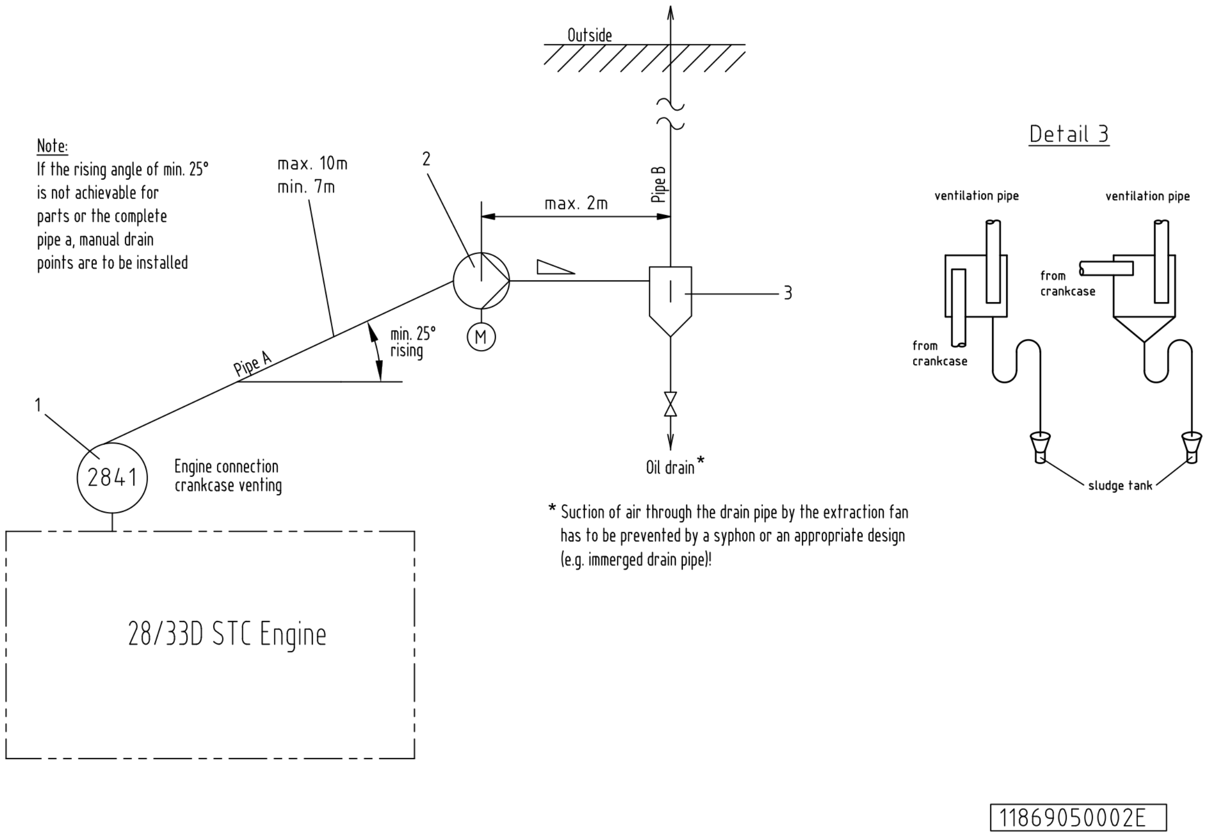

Figure 61: Crankcase vent

1	Connecting crankcase vent	3	Condensate trap
2	Condensate trap		

Pipe	Length	Engine	Diameter
A	7 – 10 m	12V	DN 65
		16V	DN 80
		20V	DN 100
B	See fan curve	12V	DN 100
		16V	
		20V	

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5.4 Water systems

5.4.1 Cooling water system description

Introduction

The following is a description of a MAN V28/33D STC marine cooling system and it is designed to suit the majority of installations. However, should it be absolutely necessary, the cooling water system can be tailored to suit the requirements of individual vessels. In this case MAN Energy Solutions should be consulted.

For the design data of the system components shown in the diagram (figure External cooling water system diagram, Page 183), see section Planning data, Page 63.

The cooling water is to be conditioned using a corrosion inhibitor, see section Specification of engine coolant, Page 139.

LT = low temperature

HT = high temperature

Cooler dimensioning, general

For coolers operated by seawater (not treated water), lube oil or fuel oil on the primary side and treated freshwater on the secondary side, an additional safety margin of 10 % related to the heat transfer coefficient is to be considered. If treated water is applied on both sides, MAN Energy Solutions does not insist on this margin.

- If antifreeze agents must be used, consult MAN Energy Solutions beforehand. Antifreeze agents reduce the thermal heat capacity of the coolant. This can lead in some cases to insufficient cooling effect.

The cooler piping arrangement should include venting and draining facilities for the cooler.

As demanded by modern marine installations, to ensure minimum weight and physical size is attained, the main plate cooler/s are designed with very small margins. In order to achieve maximum cooler efficiency it is important that the design water flow rates within the systems are correct. Also, design flow rates should not be exceeded by more than 15 % to avoid cavitation within the engine and its systems. Therefore, facility for flow restriction, in the form of either adjustable valves or orifice plates and bosses for instrumentation should be installed in the off engine pipework where shown on the P&ID see figure External cooling water system diagram, Page 183.

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Open/closed system

Open system

Characterised by "atmospheric pressure" in the expansion tank. Pre-pressure in the system, at the suction side of the cooling water pump is given by the geodetic height of the expansion tank (standard value 6 – 9 m above crankshaft of engine).

Closed system

In a closed system, the expansion tank is pressurised and has no venting connection to open atmosphere. This system is recommended in case the engine will be operated at cooling water temperatures above 100 °C or an open expansion tank may not be placed at the required geodetic height. Use air separators to ensure proper venting of the system.

Venting

Note:
Insufficient venting of the cooling water system prevents air from escaping which can lead to thermal overloading of the engine.

The cooling water system needs to be vented at the highest point in the cooling system. Additional points with venting lines to be installed in the cooling system according to layout and necessity. In case engines may be operated on gas, all venting pipes have to be routed to open atmosphere.

If LT and HT string are separated, make sure that the venting lines are always routed only to the associated expansion tank. The venting pipe must be connected to the expansion tank below the minimum water level, this prevents oxydation of the cooling water caused by "splashing" from the venting pipe. We recommend to connect the venting pipes at the tank bottom. The expansion tank should be equipped with venting pipe and flange for filling of water and inhibitors.

In case a closed system with pressurised expansion tank is used, air separators have to be installed in the system.

Additional notes regarding venting pipe routing:

- The ventilation pipe should be continuously inclined (min. 5 degrees).
- At the interface to the system (engine connection terminal), the line must be continued directly with an elastic pipe connection (e.g. hose line).
- No additional masses such as shut-off valves, reducers, extensions, etc. may be attached to the engine-side connection terminal, since they represent an additional oscillating mass that can cause the line to break during operation.
- Venting pipes from several engine circuits may only be connected together if there are no longer any pressure differences between the individual pipes.
- It is to be avoided to merge venting pipes from low-temperature (LT) and high-temperature (HT) circuits, as a separate fault detection (e.g. lubricating oil or fuel in the cooling water) is no longer possible.
- No restrictions, no kinks in the ventilation pipes.
- Merging of ventilation pipes only permitted with appropriate cross-sectional enlargement.

Draining

At the lowest point of the cooling system, a drain has to be provided. Additional points for draining to be provided in the cooling system according to layout and necessity, e.g. for components in the system that will be removed for maintenance.

We recommend using lockable valves or locking caps for sample and draining points to avoid opening by mistake.

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5.4.2 Internal LT cooling water system

As a standard the engine is equipped with following attached equipment:

- Two-stage charge air coolers (1,2 HE-008), relevant 2nd stage for LT cooling water
- Lube oil cooler (HE-037)

- LT cooling water pump (P-004)

1,2 HE-008/LT stage of two-stage charge air cooler

To cool down the charge air after compressor of the turbocharger the engine is equipped with a two-stage charge air cooler.

HE-037/Engine mounted lube oil cooler

To cool down the lube oil, the engine is equipped with a plate type heat exchanger.

For the description see section Lube oil system, Page 163. For the heat data, flow rates and tolerances see section Planning data, Page 63. For the principal design criteria for coolers see paragraph Cooler dimensioning, general, Page 176.

P-004/LT cooling water pump

The LT cooling water pump is an engine driven centrifugal pump mounted about the center of the free end of the engine.

The engine driven LT pump circulates the water through the second stage of the charge air cooler and through the engine mounted lubricating oil plate cooler. The water then leaves the engine and is cooled by seawater in the main LT plate cooler. The pump inlet pipework should incorporate a connection to the header tank to ensure a positive pressure at the pump suction. For the LT water pump performance data see paragraph HT and LT fresh water pump, Page 185.

Internal cooling water system (LT and HT) – Exemplary

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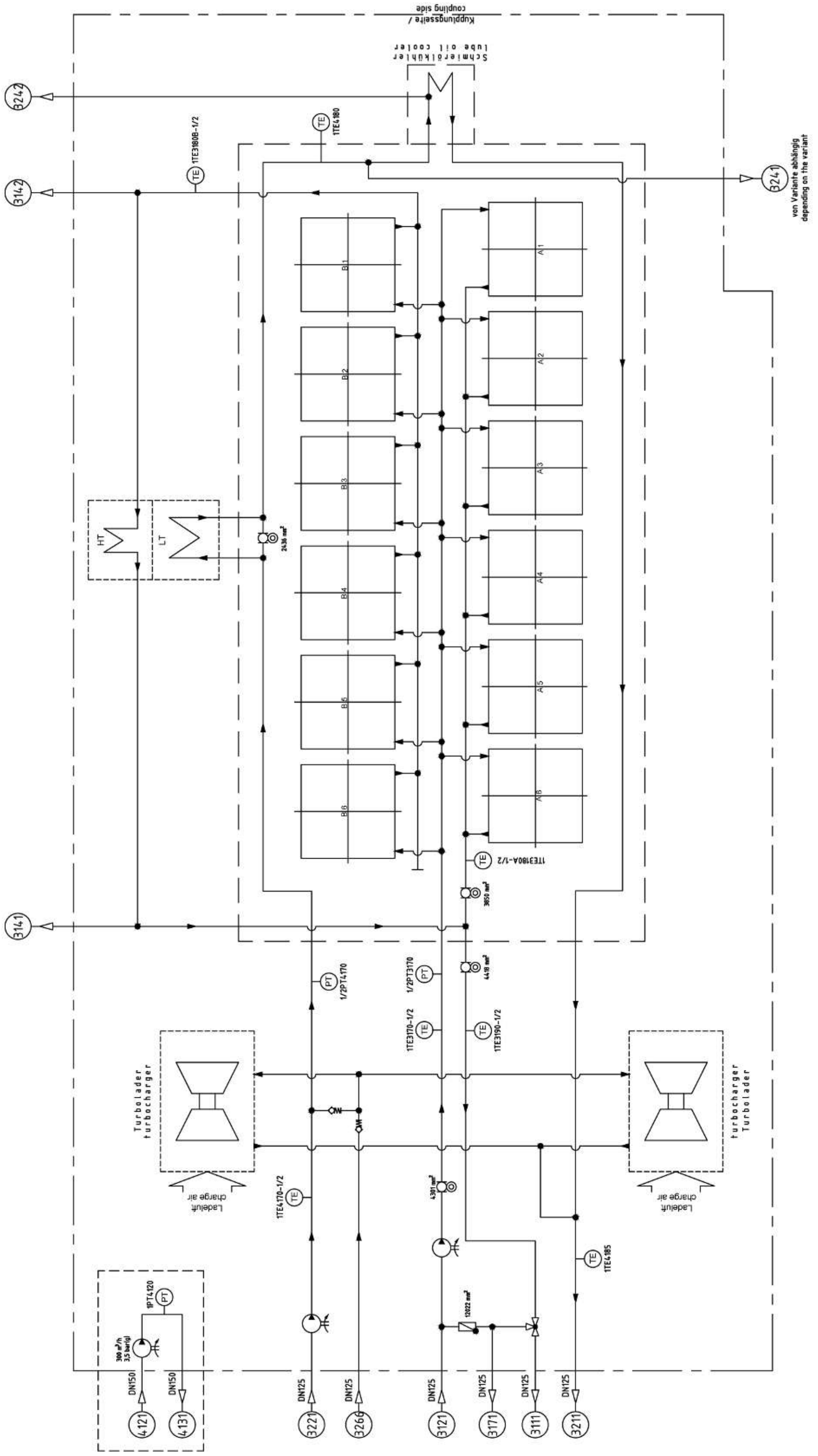

Figure 62: Internal cooling water system (LT and HT) – Exemplary MAN 12V28/33D STC

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Major engine connections			
3111	HT cooling water outlet from engine	3221	LT cooling water inlet to cooling water pump
3121	HT cooling water inlet to cooling water pump	3241	Venting of LT cooling water pipe 1
3141	Venting of HT cooling water pipe 1	3242	Venting of LT cooling water pipe 2
3142	Venting of HT cooling water pipe 2	3266	Cooling water inlet for compressor post cooling
3171	HT cooling water outlet to preheater	4121	Seawater inlet to seawater pump
3211	LT cooling water outlet from engine	4131	Seawater outlet from seawater pump

Note:
The drawing shows the basic internal media flow of the engine in general. Project-specific drawings thereof don´t exist.

5.4.3 External LT cooling water system

TCV-016/LT cooling water temperature control valve

The cooling water temperature in the LT circuit is maintained by a three-way temperature control valve. For the standard configuration of the engine a wax type valve is used.

HE-024/Cooler for LT cooling water

The LT water is recooled by an external plate type heat exchanger. It is possible to either use a single LT cooling water cooler or a combined HT/LT cooling water cooler, see paragraph HE-036/Combined cooler for HT/LT cooling water, Page 182.

For heat data, flow rates and tolerances of the heat sources see section Planning data, Page 63. For the principal design criteria for coolers see paragraph Cooler dimensioning, general, Page 176.

P-092/LT cooling water circulation pump

The pump serves for cooling of the compressor wheel casing of the turbocharger after engine shutdown. It has to be operated during prelubrication and postlubrication and remain in operation for 45 minutes after engine shutdown.

MAN can supply a suitable pump.

1 FIL-021/Strainer for LT cooling water

In order to protect the engine and system components, several commissioning strainers are to be installed during the flushing process. We recommend a mesh size of 1 – 2 mm depending on the pipe diameter. To protect three-way valves and other sensitive components, we recommend to leave at least one strainer remaining in the piping of each system. Please use stainless steel mesh material.

HE-007/Fuel oil cooler

A fuel oil cooler is required to dissipate the heat of the fuel injection pumps during operation, see section Fuel oil system, Page 186 for further details. One cooler is required per engine. In case the fuel oil cooler is recooled by sea water, we recommend to use a double wall type cooler.

T-103/Cooling water expansion tank

The expansion tank compensates changes in system volume and losses due to leakages and temperature changes. It is to be arranged in such a way, that the tank bottom is situated above the highest point of the system at any ship inclination. The expansion pipe should empty into the suction pipe as close to the pump as possible. For the required volume of the tank and the recommended installation height see section Filling volumes, Page 76.

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The fresh water contained within the engine systems will require treatment with an approved corrosion inhibitor additive and depending on location of operation, anti-freeze agent (see section Specification of engine coolant, Page 139).

Venting pipes from engine connections must be led to the expansion tank separately.

Please contact MAN Energy Solutions for details concerning auxiliary equipment.

5.4.4 Internal HT cooling water system

As a standard the engine is equipped with following attached equipment:

- Two-stage charge air coolers (1,2 HE-010), relevant 1st stage for HT cooling water
- HT cooling water temperature control valve (TCV-002)
- HT cooling water pump (P-002)

1,2 HE-010/HT stage of two-stage charge air cooler

To cool down the charge air after compressor of the turbocharger the engine is equipped with a two-stage charge air cooler.

TCV-002/HT cooling water temperature control valve

The cooling water temperature in the HT circuit is maintained by a three way temperature control valve. For the standard configuration of the engine, a wax type valve is used. The HT valve is attached to the engine.

P-002/HT cooling water pump

The HT cooling water pump is an engine driven centrifugal pump mounted at the free end of the engine. The HT cooling water pump circulates the water through the engine (jacket water) and through the first stage of the charge air cooler. The water then leaves the engine and is cooled by seawater in the main HT plate cooler.

The pump inlet pipework should incorporate a connection to the expansion tank to ensure a positive pressure at the pump suction side.

For details concerning the HT water pump performance data see paragraph HT and LT fresh water pump, Page 185.

Note:
See figure Internal cooling water system (LT and HT) – Exemplary MAN 12V28/33D STC, Page 179.

5.4.5 External HT cooling water system

MOD-004/HT cooling water preheating module

The HT circuit also includes a jacket water heater and pump module comprising an in-line thermostatically controlled electrical heater and a centrifugal circulating pump. This unit is operated when the engine is not running and in stand-by mode to maintain the jacket water temperature above 60 °C. The engine has to be preheated to reduce thermal expansion by quick load step up. A temperature above 60 °C also prevents corrosion at the engine that may be caused by condensed water in humid air environments. Required heating power is at least 30 kW. For operation in cold conditions (arctic), a higher heating capacity is required. Please consult MAN Energy Solutions for further information.

Avoid an installation of the preheater in parallel to the engine driven HT pump. In this case, the preheater may not be operated while the engine is running. Preheaters operated on steam or thermal oil may cause alarms since a post-cooling of the heat exchanger is not possible after engine start (preheater pump is blocked by counter pressure of the engine driven pump).

HE-003/Cooler for HT cooling water	For heat data, flow rates and tolerances of the heat sources see section Planning data, Page 63. For the description of the principal design criteria for coolers see paragraph Cooler dimensioning, general, Page 176. It is possible to either use a single HT cooling water cooler or a combined HT/LT cooling water cooler, see paragraph HE-036/Combined cooler for HT/LT cooling water, Page 182.
HE-026/Fresh water generator	The freshwater generator must be switched off automatically when the cooling water temperature at the engine outlet drops below 75 °C continuously. This will prevent operation of the engine at too low temperatures. In case the HT temperature control valve attached to the engine is used, the valve will recirculate hot water and prevent the engine from cooling down.
T-103/Cooling water expansion tank	For information about the shared cooling water expansion tank see paragraph T-103/Cooling water expansion tank, Page 180.
2 FIL-021/Strainer for HT cooling water	In order to protect the engine and system components, several commissioning strainers are to be installed during the flushing process. We recommend a mesh size of 1 – 2 mm depending on the pipe diameter.The suction strainer protects the pump and system against larger dirt particles.

5.4.6 Internal seawater system

P-093/Seawater pump	The seawater pump is an engine driven centrifugal pump mounted at the free end of the engine. The seawater pump serves to draw seawater directly from the ship's seawater chest into the circuit, through a suction strainer and a recommended non-return foot valve (both client supply), delivering the water to the main engine combined cooler for HT/LT cooling water. After removing heat from these circuits, the water is piped to overboard discharge. In case the engine is placed above the seawater line, an electrically driven pump has to be used instead of the attached seawater pump. Please contact MAN Energy Solutions in this case.

5.4.7 External seawater system

HE-036/Combined cooler for HT/LT cooling water	The combined cooler saves weight and installation space compared to solutions by two separate coolers. On the other hand the maintenance of the combined cooler is more time consuming since some pipe connections have to be dismounted to clean the plates.
FIL-019/Seawater inlet filter	The suction strainer protects the pump and system against larger dirt particles. For vessels with only one sea chest a reversible duplex filter is recommended. The mesh size should be in a range of 2 – 4 mm. For vessels operating predominantly in sandy waters, a mesh size of 0.3 – 0.5 mm is recommended.

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5.4.8 External cooling water system diagram

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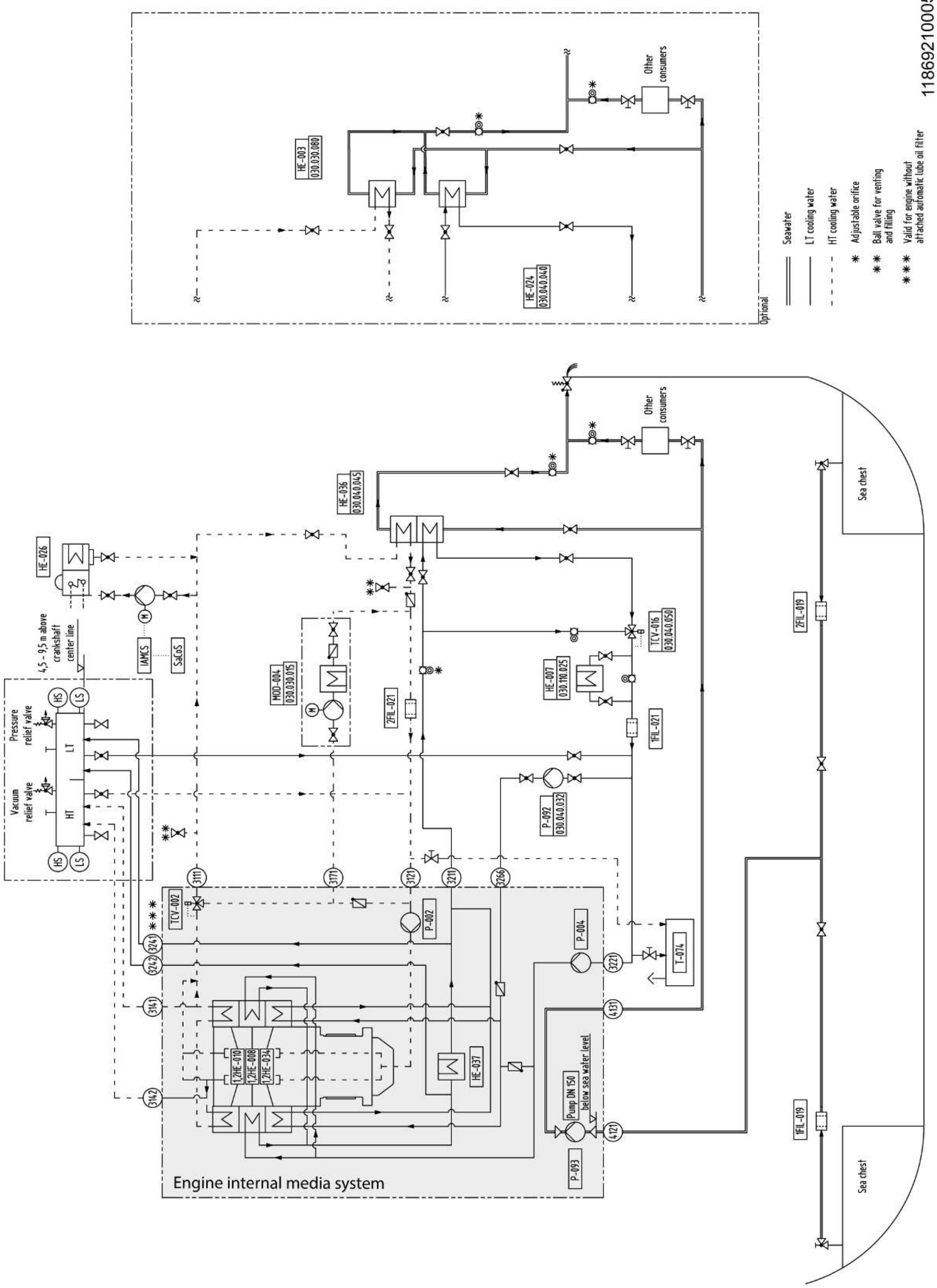

Figure 63: External cooling water system diagram

Components			
1,2FIL-019	Seawater filter	MOD-004	HT cooling water preheating module
1,2FIL-021	Strainer for cooling water	MOV-016	LT cooling water temperature control valve
HE-003	Cooler for HT cooling water	P-002	HT cooling water service pump, attached
HE-007	Fuel oil cooler	P-004	LT cooling water service pump, attached
1,2HE-008	Charge air cooler (stage 2)	P-092	LT cooling water circulation pump
1,2HE-010	Charge air cooler (stage 1)	P-093	Seawater service pump, attached
HE-024	Cooler for LT cooling water	T-074	Fresh water collecting tank
HE-026	Fresh water generator	T-103	HT/LT cooling water expansion tank
1,2HE-034	Compressor wheel casing (water cooled)	TCV-002	HT cooling water temperature control valve
HE-036	Combined cooler for HT/LT cooling water	TCV-016	LT cooling water temperature control valve
HE-037	Lube oil cooler main engine, attached		
Major cooling water engine connections			
3111	HT cooling water outlet from engine	3221	LT cooling water inlet to cooling water pump
3121	HT cooling water inlet to cooling water pump 1	3241	Venting of LT cooling water pipe 1
3141	Venting of HT cooling water pipe 1	3242	Venting of LT cooling water pipe 2
3142	Venting of HT cooling water pipe 2	3266	LT cooling water inlet for compressor post cooling
3171	HT cooling water outlet to preheater	4121	Seawater inlet to seawater pump
3211	LT cooling water outlet from engine 1	4131	Seawater outlet from seawater pump

5.4.9 External cooling water collecting and supply system

T-074/Cooling water collecting tank (not indicated in the diagram)

The tank is to be dimensioned and arranged in such a way that the cooling water content of both the HT and LT water circuits can be drained into it for maintenance purposes.

This is necessary to meet the requirements with regard to environmental protection (water has been treated with chemicals) and corrosion inhibition (re-use of conditioned cooling water).

Volumes for the engine are listed in table Cooling water, fuel oil and oil volume of engine, Page 76.

P-031/Cooling water filling pump

To refill the HT- and LT cooling water system after maintenance, we recommend to install a cooling water filling pump. The pump shall be installed below the cooling water collecting tank with pipe connections to the related systems.

5.4.10 Miscellaneous items

Piping

Coolant additives may attack a zinc layer. It is therefore imperative to avoid using galvanised steel pipes. Treatment of cooling water as specified by MAN Energy Solutions will safely protect the inner pipe walls against corrosion.

Moreover, there is the risk of the formation of local electrolytic element couples where the zinc layer has been worn off, and the risk of aeration corrosion where the zinc layer is not properly bonded to the substrate.

See the working instructions 6682 000.16-01E for cleaning of steel pipes before fitting.

Pipes shall be manufactured and assembled in a way that ensures a proper draining of all segments. Venting is to be provided at each high point of the pipe system and drain openings at each low point. Please make sure to use lockable ball valves or locking caps to prevent hot water leaving the system in case the valves are opened by mistake.

Cooling water pipes are to be designed according to pressure values and flow rates stated in section Planning data, Page 63 and the following sections. The engine cooling water connections have to be designed according to PN10/PN16.

System instrumentation

For details of the instrumentation, see section SaCoSone system overview, Page 103.

5.4.11 Water pump performance

Engine driven water pumps

The engine driven pumps may be delivered with various impeller diameters to adapt the pump capacity to the needs of the plant. Normally HT- and LT-pump are delivered with the same capacity.

Seawater pump

The seawater pump attached to the engine is designed for a wide range of capacity. The standard volume flow required for the seawater cooler is given in section Planning data, Page 63. In case other consumers have to be supplied, the volume flow may be increased. In this case, the increased flow speed at the suction side of the pump can cause some underpressure upstream of the pump. Please consider underpressure and increased NPSH value in the calculation of the system. For further information please contact MAN Energy Solutions.

By use of orifices (yard supply) the delivery capacity of the seawater pump has to be adjusted in order to avoid pump cavitation. For further information please contact MAN Energy Solutions.

HT and LT fresh water pump

Product range	Engine cooling
Branch suction flange	DN 125

Discharge flange	DN 125
Nominal speed	Variable rpm
Specific gravity	1.0
Performance curve based on water.	

5.5 Fuel oil system

5.5.1 MGO supply system description

General

The MAN V28/33D STC engine runs on distillate diesel fuel oil (light fuel oil) only.

The following is a description of a typical MAN V28/33D STC fuel oil system and is designed to suit the majority of installations, refer to figure External MGO supply system diagram, Page 191. Tailored systems are possible for individual vessel requirements as well. To specify those please contact MAN Energy Solutions for assistance.

5.5.2 Internal fuel oil supply system

P-028/Fuel oil supply pump, attached

The diesel fuel oil supply pump is a positive displacement gear type pump. It is mounted and driven by the engine. The supply pump has an integrated pressure relief safety valve.

The day tank and mechanically driven pump arrangement ensures that the engine will remain running or available to start in "black ship" condition. This is assuming 24 V DC is available for the electronic fuel injection and control systems.

The pump increases fuel pressure up to 10 bar.

From the fuel oil pump discharge the fuel oil is piped to an off-engine duplex filter, see section External fuel oil supply system, Page 188.

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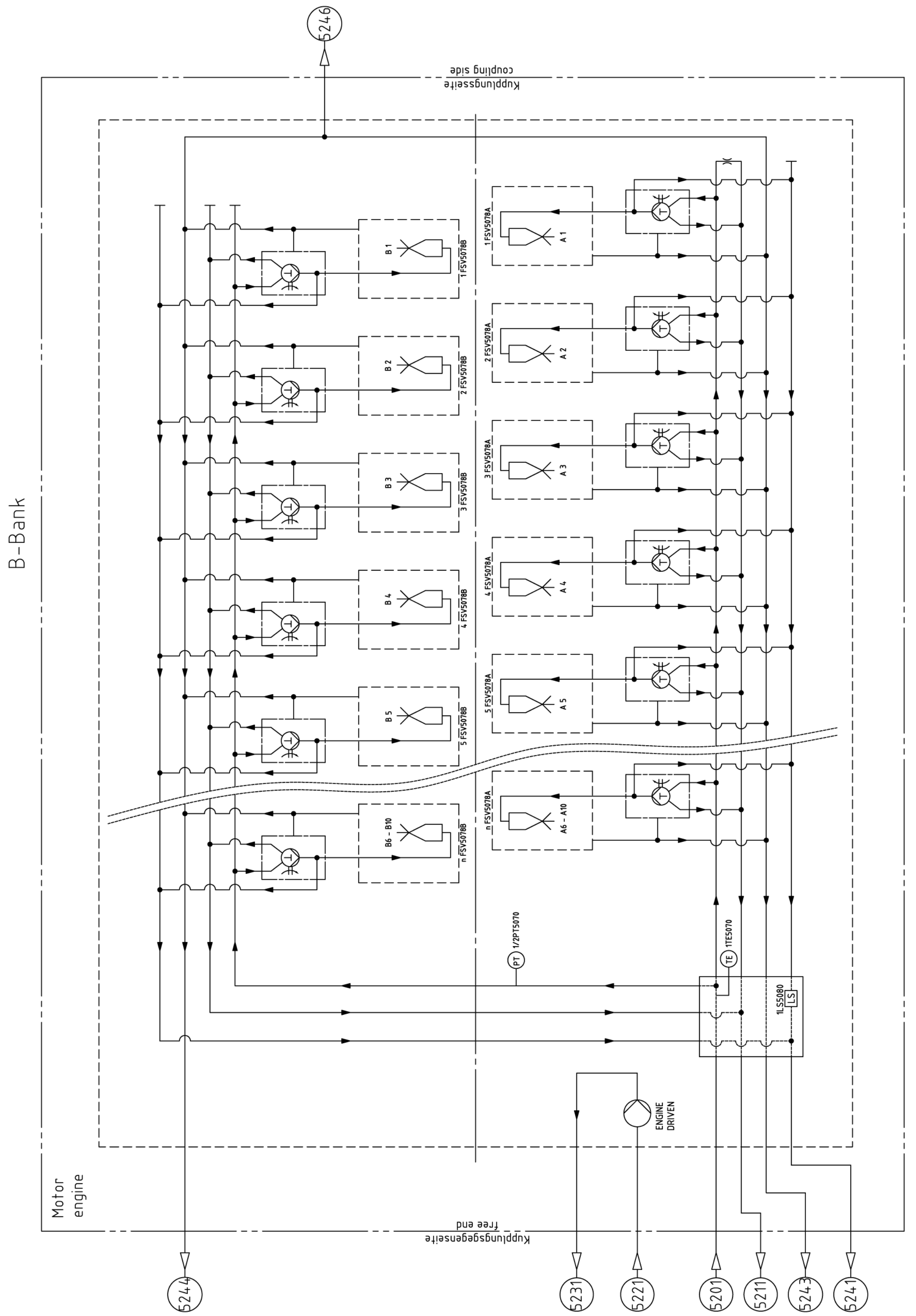

Figure 64: Internal fuel system – Exemplary

Major engine connections			
5201	Fuel oil inlet to engine (main injection system)	5241	Fuel oil break leakage drain
5211	Fuel oil outlet from engine	5243	Fuel oil leakage drain (reusable from pumps and injectors) 1
5221	Fuel oil inlet to fuel oil supply pump	5244	Fuel oil leakage drain (reusable from pumps and injectors) 2
5231	Fuel oil outlet from fuel oil supply pump	5246	Fuel oil leakage drain (reusable from pumps and injectors) 3

Note:
The drawing shows the basic internal media flow of the engine in general. Project-specific drawings thereof don´t exist.

5.5.3 External fuel oil supply system

T-003/Diesel fuel oil service tank

Fuel oil is supplied into the circuit from a service or day tank. The tank is client supply so its dimensions can be customised to fit the vessel's specifications. It is normally a 'standard' header tank design, with float level control valve and fitted with vent and drain pipework. The base of the tank needs to be installed either max. 4 meters beneath or max. 6 meters above the engine crankshaft centreline (pressure loss of supply systems and piping not considered). This is to ensure the required pressure range at the inlet of the engine driven fuel oil pump (engine connection 5221), see table Fuel, Page 74.

P-006/Fuel oil hand pump

The fuel oil hand pump is required to fill up the system for commissioning, after maintenance of the fuel oil supply system and to improve the engine's starting behavior if the fuel oil tank is beneath crankshaft centerline. It is recommended to install the fuel oil hand pump in the supply line close to the tank. The fuel hand pump delivers fuel oil directly in front of the fuel oil supply pump P-028, see section Internal fuel oil supply system, Page 186.

PSV-010/Fuel oil safety valve

During filling up the engine system with the fuel oil hand pump P-006, the fuel oil pressure must not exceed a value of +0.5 bar in front of the engine interface 5221. To protect the system a safety valve parallel to the manual shut-off valve must be installed.

STR-010/Suction strainer

To protect the engine driven fuel oil supply pump, an approximately 0.5 mm gauge (spherepassing mesh) strainer is to be installed at the suction side of the pump.

If a coalescer is installed, the suction strainer is not required.

TR-009/Coalescer

To fulfill the water content requirements in the fuel oil (see table Requirements for diesel fuel, Page 137) a coalescer (water separator) should be installed. The coalescer element mesh width has 30 micron (nominal).

For safety reason the coalescer housing is equipped with a differential pressure transmitter. A certain differential pressure indicates a clogged coalescer element and triggers an alarm, the filter cartridge must be replaced. To allow the replacement of the filter during engine operation it must be switched over to a redundant coalescer element with a manual changeover valve. In the coalescer housing a water sensor is installed. The sensor triggers an alarm if a certain water level inside the coalescer is reached. Following the water has to be drained manually.

FIL-013/Fuel oil duplex filter

The filter unit is a 5 micron (absolute) felt element depth type of duplex construction. It has a manual change over valve to allow filter cartridge change during engine operation to meet classification society requirements.

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The flow through the fuel oil duplex filter is equal to the delivery of the engine driven fuel oil pump, see table Nominal values for cooler specification – 500 kW/cyl.; 1,032 rpm, Page 68.

The fuel oil duplex filter is delivered with a differential pressure indicator.

The emptying port of each filter chamber is to be fitted with a valve and a pipe to the sludge tank. If the filter elements are removed for replacing, the filter chamber must be emptied. This prevents the dirt particles remaining in the filter casing from migrating to the clean oil side of the filter.

After changing the filter cartridge, the reconditioned filter chamber must be vented manually.

From the fuel oil duplex filter the fuel oil is piped back to the engine (connection 5201) and circulated around the engine manifold to the fuel oil injection pumps. Then it exits the engine (connection 5211) before being piped to main pump suction via the fuel oil cooler, and pressure control valve.

HE-007/Fuel oil cooler

The fuel oil cooler is required to cool down the fuel oil, which was heated up while circulating through the injection pumps. The cooler is normally connected to the LT cooling water system and should be dimensioned so that the MGO does not exceed a temperature of max. 45 °C. Only for very light fuel oil types this temperature has to be even lower in order to preserve the minimum admissible fuel oil viscosity on engine inlet, see section Diesel fuel (DMA, DFA) specifications, Page 137.

Engine type	Cooler capacity
V engine	3.0 kW/cyl.
The max. MGO throughput is approximately identical to the engine inlet fuel flow (= delivery quantity of the fuel oil supply pump).	

Table 91: Dimensioning of the fuel oil cooler

The recommended pressure class of the fuel oil cooler is PN16.

PCV-008/Fuel oil pressure retaining valve

In the fuel oil return loop a pressure control valve has to be installed, to ensure a certain fuel oil pressure at engine outlet, see section Operating/service temperatures and pressures, Page 72. It is to be adjusted so that the pressure before engine inlet can be maintained in the required range (see section Operating/service temperatures and pressures, Page 72).

MOD-011/Fuel oil leakage module

The high-pressure fuel oil lines are double skinned and under covers to protect against fuel oil spray in the unlikely event of failure. The outer skin of the line is connected to the alarm system; any fuel oil entering the outer sheath drains to the on-engine leakage tank, below the crankshaft centreline, in which a rise in level will trigger the alarm. The drain connection (connection 5241) should be piped back to the clean leakage fuel oil tank (T-071).

The operating fuel leakage is continuous and depending on engine load (see section Leakage rate, Page 76).
Only the operating fuel leakage can be re-used.
It exits the engine (connection 5243, 5244 and 5246) under gravity, there should be no back pressure imposed on this flow as this will lead to contamination of the engine lube oil with fuel oil. The leak off fuel oil will therefore require collection in a tank and pumping back to bulk tanks should they be sited above the engine.

The function of the fuel oil leakage module is to collect the fuel oil leakage of the diesel engine and to pump the fuel oil back to the fuel storage tank. The module is in operation, when the engine is also in operation. The start and stop of the pump is controlled by a level switch. In case of pump failure there is a second pump installed on the module as stand-by pump.

The leakage fuel flows pressureless (by gravity only) from the engine into this tank, therefore the module has to be installed below the engine connections.

Note that sheath drains (connection 5241) and leak off (connection 5243, 5244 and 5246) should not be connected together and run separately to the collection tank. This prevents backfilling of the sheath drain pipe thus causing false sheath drain alarms.

T-071/Clean leakage fuel oil tank

The clean leakage fuel oil tank is part of the leak-oil module, see paragraph MOD-011/Fuel oil leakage module, Page 189.

FQ-003/Fuel oil flowmeter

The upstream flow rate of the engine should be displayed in the ship automation system. The flowmeter requires a by-pass to ensure a continuous fuel oil flow in case of maintenance or malfunction.

A coriolis type flowmeter is recommended for fuel oil flow measuring. The by-pass of the coriolis type flowmeter needs a shut-off valve.

If a positive displacement type flowmeter is used the by-pass needs to be equipped with a spring loaded overflow valve which opens automatically in case of blocking.

The pressure resistance of the fuel oil flowmeter should be as low as possible and considered during the system design stage.

Instrumentation

For details of the instrumentation, see section SaCoSone system overview, Page 103.

Please contact MAN Energy Solutions for technical drawings of auxiliary equipment.

External fuel oil supply system diagram

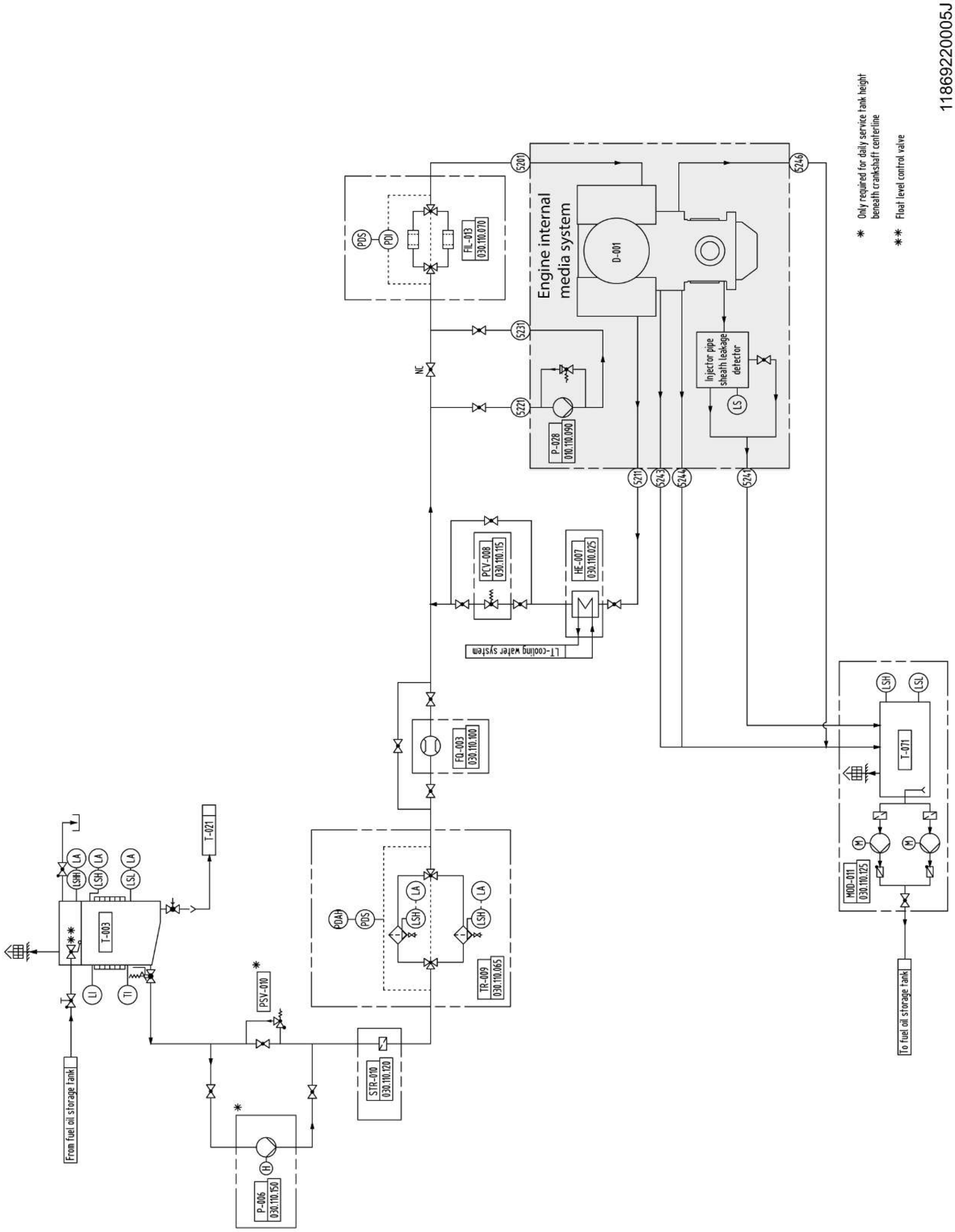

Figure 65: External MGO supply system diagram

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Components			
D-001	Diesel engine	PCV-008	Fuel oil pressure retaining valve
FIL-013	Fuel oil duplex filter	PSV-010	Fuel oil safety valve
FQ-003	Fuel oil flowmeter	STR-010	Fuel oil suction strainer
HE-007	Fuel oil cooler	T-003	Diesel fuel oil service tank
MOD-011	Fuel oil leakage module	T-021	Sludge tank
P-006	Fuel oil hand pump	T-071	Clean leakage fuel oil tank
P-028	Fuel oil supply pump, attached	TR-009	Coalescer (water trap)
Major cooling water engine connections			
5201	Fuel oil inlet to engine	5241	Fuel oil break leakage drain 1
5211	Fuel oil outlet from engine	5243	Fuel oil leakage drain (reusable from pumps and injectors) 1
5221	Fuel oil inlet to fuel oil supply pump	5244	Fuel oil leakage drain (reusable from pumps and injectors) 2
5231	Fuel oil outlet from fuel oil supply pump	5246	Fuel oil leakage drain (reusable from pumps and injectors) 3

5.6 Compressed air system

5.6.1 Compressed air system description

The compressed air supply to the engine plant requires starting air receivers and starting air compressors of a capacity and air delivery rating which will meet the requirements of the relevant classification society.

Piping

The main starting pipe connected to both air receivers, leads via the pressure reducing unit (MOD-088) to the engine attached air starter (engine connection 7101).

Two further 8 bar pressure lines (7102 and 7105) with separate connections to both air receivers 40 bar supply the engine with control air.

A line branches from the aforementioned control air pipe to supply other air-consuming engine accessories (e.g. fuel oil automatic filter) with compressed air.

The pipes to be connected by the shipyard have to be supported immediately behind their connection to the engine. Further supports are required at sufficiently short distance.

Flexible connections for starting air (steel tube type) have to be installed with elastic fixation. The elastic mounting is intended to prevent the hose from oscillating. For detail information please refer to planning and final documentation and manufacturer manual.

Galvanised steel pipes must not be used for the piping of the system.

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Compressed air, at 37 bar for the starting system is supplied from the air receivers/compressors, directly to the engine mounted main air starting motor, engine connection "starting motor" (7101), via an approved flexible connection.

If supplied by MAN Energy Solutions, additional connections on the air receivers are provided for air requirements of the ship, for example the horn. The pipes to be connected by the shipyard have to be supported immediately behind their connection to the engine. Further supports are required at sufficiently short distance.

5.6.2 Internal compressed air system

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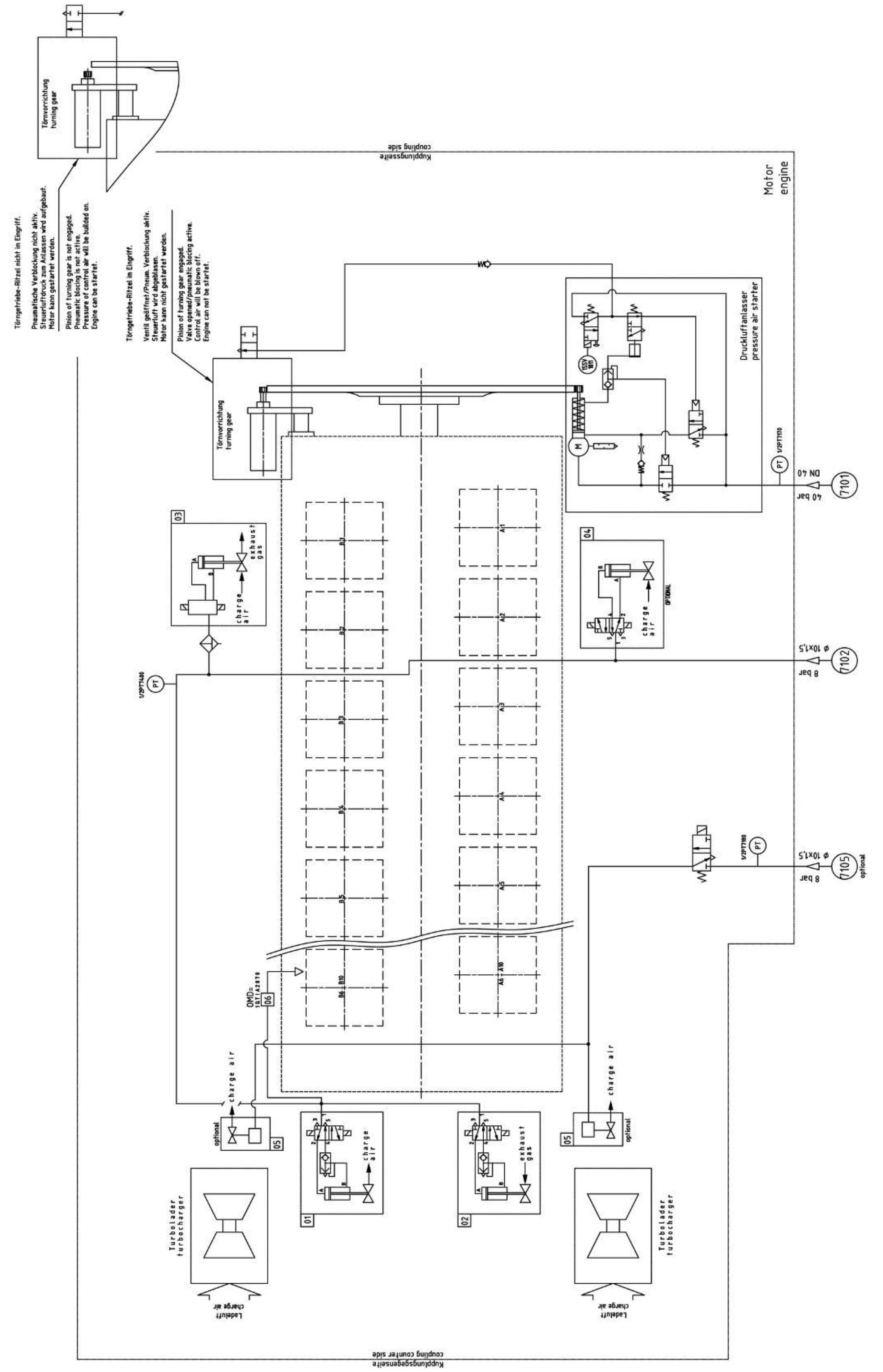

Figure 66: Internal compressed air system – Exemplary

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Components			
01	STC regulating valve, B-bank (charge air pipe)	04	Charge air blow-off valve (optional)
02	STC regulating valve, B-bank (exhaust gas pipe)	05	Emergency shut-off valve (optional)
03	Charge air by-pass	06	Oil mist detector
Major engine connections			
7101	Starting air inlet to engine	7105	Control air inlet to engine 2
7102	Control air inlet to engine 1		

Note:
The drawing shows the basic internal media flow of the engine in general. Project-specific drawings thereof don´t exist.

5.6.3 External compressed air system

1 C-001, 2 C-001/Air compressor

These are multi-stage compressor sets with safety valves, cooler for compressed air and condensate traps.

The operational compressor is switched on by the pressure control at low pressure then switched off when maximum service pressure is attained.

For the MAN V28/33D STC engine an air receiver pressure of 37 bar is required to reduce the physical size of the receiver to a minimum.

The service compressor is electrically driven; the auxiliary compressor may also be driven by a diesel engine. The capacity of both compressors should be identical.

The total capacity of the air compressors has to be capable to charge the air receivers from the atmospheric pressure to full working pressure within one hour.

Air dryer

To ensure the quality requirements of the control air in section Specification of compressed air, Page 149 an air dryer may be required.

Piping

The piping should be as straight and unrestrictive as possible. Pipe diameter DN80 (2 starters).

1 T-007, 2 T-007/Starting air receivers

The installation situation of the air receivers must ensure a good drainage of condensed water. Air receiver must be installed with a downward slope sufficiently to ensure a good drainage of accumulated condensate water.

The installation also has to ensure that during emergency discharging of the safety valve no persons can be compromised.

It is not permissible to weld supports (or other) on the air receivers. The original design must not be altered. Air receivers are to be bedded and fixed by use of external supporting structures.

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The standard design pressure of the starting air receivers is 40 bar.

External starting air system diagram

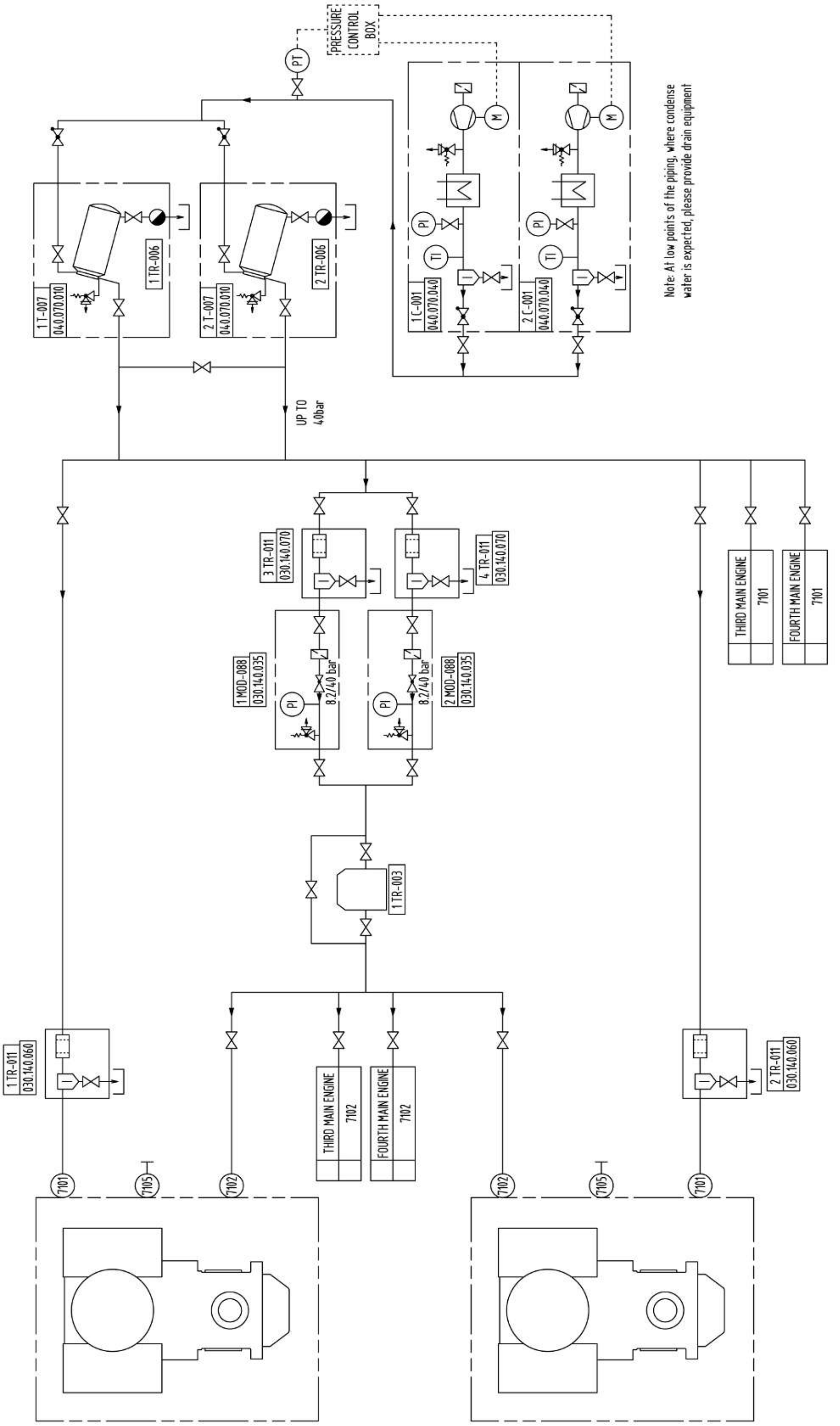

Figure 67: External starting air system diagram

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Components			
1,2 C-001	Air compressor	1 TR-003	Air dryer
1,2 MOD-088	Compressed air pressure reducing unit	1,2 TR-006	Automatic condensate trap
1,2 T-007	Starting air receiver	1,2,3,4 TR-011	Water separator with filter
Connection numbers			
7101	Starting inlet to engine	7105	Control air inlet 2 to emergency shut-off unit (optional)
7102	Control air inlet 1		

5.6.4 Dimensioning starting air receivers, compressors

Emergency case

For safety reasons upstream of engine connection 7105 a small air receiver, with non-return-valve at its inlet, is required.

Starting air receivers

The starting air supply is to be split up into not less than two starting air receivers of nominally the same size, which can be used independently of each another.

The capacity of the air receivers have to be designed so that at least six engine starts without replenishment are possible.

The exact number of required starts depends on the arrangement of the propulsion system and on the special requirements of the classification society.

Before engine connection control air inlet (7102) and "emergency shut-off valve" (7105) an air dryer (10 K below ambient temperature) and a 40 µm filtration has to be installed.

Before engine connections "emergency shut-off valve" (7105) a Vmin = 15 litre shut-off air receiver has to be installed.

Compressors

According to most classification societies, two or more air compressors must be provided. At least one of the air compressors must be driven independently of the main engine and must supply at least 50 % of the required total capacity.

The total capacity of the air compressors has to be capable to charge the receivers from the atmospheric pressure to full pressure of 37 bar within one hour.

The compressor capacities are calculated as follows:

$$P = \frac{V \times 40}{1000}$$

P [m^3/h]	Total volumetric capacity of the compressors

V [litres]	Total volume of the starting air receivers at 37 bar service pressure

As a rule, compressors of identical ratings should be provided. An emergency compressor, if provided, is to be disregarded in this respect.

Diesel-mechanical main engine

In case of diesel-mechanical drive without shifting clutch but with shaft driven alternator please consult MAN Energy Solutions.

Calculation formula for starting air receivers see below:

$$V = \frac{V_{st} \times f_{Drive} \times (z_{st} + z_{safe})}{(p_{max} - p_{min})}$$

V [litre]	Required receiver capacity
V_{st} [litre]	Air consumption per nominal start
f_{Drive}	Factor for drive type (1.0 = diesel-mechanic, 1.5 = alternator drive)
z_{st}	Number of starts required by the classification society
z_{Safe}	Number of starts as safety margin
p_{max} [bar]	Maximum starting air pressure
p_{min} [bar]	Minimum starting air pressure

Other consumers (e.g. auxiliary engines, ship air etc.) are not accounted for in the above formula. If these are connected to the starting air receiver, the capacity of the receiver must be increased accordingly, or an additional separate air receiver has to be installed.

Please contact MAN Energy Solutions for technical drawings of auxiliary equipment.

System instrumentation

For details of the instrumentation, see section SaCoSone system overview, Page 103.

5.7 Engine room ventilation and combustion air

5.7.1 General information

Engine room ventilation system

Its purpose is:

- Supplying the engines and auxiliary boilers with combustion air.
- Carrying off the radiant heat from all installed engines and auxiliaries.

Combustion air

The combustion air must be free from spray water, snow, dust and oil mist.

This is achieved by:

- Louvres, protected against the head wind, with baffles in the back and optimally dimensioned suction space so as to reduce the air flow velocity to 1 – 1.5 m/s.

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- Self-cleaning air filter in the suction space (required for dust-laden air, e.g. cement, ore or grain carrier).
- Sufficient space between the intake point and the openings of exhaust air ducts from the engine and separator room as well as vent pipes from lube oil and fuel oil tanks and the air intake louvres (the influence of winds must be taken into consideration).
- Positioning of engine room doors on the ship's deck so that no oil-laden air and warm engine room air will be drawn in when the doors are open.
- Arranging the separator station at a sufficiently large distance from the turbochargers.

As a standard, the engines are equipped with turbochargers with air intake silencers and the intake air is normally drawn in from the engine room.

In tropical service a sufficient volume of air must be supplied to the turbocharger(s) at outside air temperature. For this purpose there must be an air duct installed for each turbocharger, with the outlet of the duct facing the respective intake air silencer, separated from the latter by a space of approximately 1.5 m (see figure Example: Exhaust gas ducting arrangement, Page 233). No water of condensation from the air duct must be permissible to be drawn in by the turbocharger. The air stream must not be directed onto the exhaust manifold.

If the ship operates at arctic conditions, an air preheater must be applied to maintain the engine room temperature above 5° C. In order to reduce power for air preheating, the engines can be supplied by a separate system directly from outside, see section Intake air ducting in case of arctic conditions, Page 200.

Air fans are to be designed so as to maintain a positive air pressure of 50 Pa (5 mm WC) in the engine room.

Radiant heat

The heat radiated from the main and auxiliary engines, from the exhaust manifolds, waste heat boilers, silencers, alternators, compressors, electrical equipment, steam and condensate pipes, heated tanks and other auxiliaries is absorbed by the engine room air.

The amount of air V required to carry off this radiant heat can be calculated as follows:

$$V = \frac{Q}{\Delta t \times cp \times \rho t}$$

V [m³/h]	Air required
Q [kJ/h]	Heat to be dissipated
Δt [°C]	Air temperature rise in engine room (10 – 12.5)
cp [kJ/kg*k]	Specific heat capacity of air (1.01)
ρt [kg/m³]	Air density at 35 °C (1.15)

Ventilator capacity

The capacity of the air ventilators (without separator room) must be large enough to cover at least the sum of the following tasks:

- The combustion air requirements of all consumers.

- The air required for carrying off the radiant heat.

A rule-of-thumb applicable to plants operating on heavy fuel oil is 20 – 24 m^3/kWh.

Moreover it is recommended to apply variable ventilator speed to regulate the air flow. This prevents excessive energy consumption and cooling down of engines in stand-by.

5.7.2 Intake air ducting in case of arctic conditions

General recommendations for external intake air system of vessels operating in arctic conditions

The design of the intake air system ducting is crucial for reliable operation of the engine. The following points need to be considered:

- Every single engine must be provided with a dedicated intake air system. It is not allowed to combine air intake systems of different engines.
- According to classification rules it may be required to install two air inlets from the exterior, one at starboard and one at portside.
- It must be prevented that exhaust gas and oil dust is sucked into the intake air duct as fast filter blocking might occur.
- Suitable corrosion and low temperature resistant materials should be applied. Stainless steel S316 L might be suitable.
- Inside the duct, there must not be any parts (e.g. bolts, nuts, stiffening, etc.) that could fall off and move towards the engine. Installations, that are absolutely necessary (e.g. light behind filter wall) must be specially secured (self-locking nuts, screwed covers instead of clamped covers etc.).
- Due to the air flow, load changes and other external forces, (especially during ice breaking, if applicable) the intake air pipe is subject to heavy vibrations. Additionally engine and propeller exciting frequencies have to be taken into account. This has to be considered within the overall layout and the intake air duct needs to be reinforced sufficiently.
- Thermal expansion has to be considered for the layout and foundation of the duct (e.g. flexible mounting, additional compensators).
- Suitable drainage arrangements to remove any water from the intake air ducting should be provided. Backflow of air through drains has to be avoided (e.g. by syphons) and regularly checked for proper functioning. Adequate heating is required to prevent icing of drains.
- The air duct and its components need to be insulated properly. Especially a vapor barrier has to be applied to prevent atmospheric moisture freezing in the insulation material.
- An (automatic) shut-off flap should be installed to prevent a chimney effect and cooling down of engine during stand-still (maintenance or stand-by of engine). This flap is to be monitored and engine start should only be allowed in fully-open position. As an alternative, the intake system can be closed by a roller shutter or tarpaulin in front of the filter.
- The overall pressure drop of the intake air system ducting and its components is to be limited to 20 mbar. Moreover the differential pressure of the intake air filter must be monitored to keep this requirement. For additional safety, other components as the droplet separator and the weather hood can be monitored by differential pressure devices. During commissioning and maintenance work, checking of the air intake system back pressure by means of a temporarily connected measuring device may become necessary. For this purpose, a measuring socket is to be provided

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approximately 1 to 2 metres before the turbocharger, in a straight length of pipe at an easily accessible position. Standard pressure measuring devices usually require a measuring socket size of 1/2".

- The turbocharger as a flow machine is dependent on a uniform inflow. Therefore, the ducting must enable an air flow without disturbances or constrictions. For this, multiple deflections with an angle > 45° within the ducting must be avoided.
- The intake air must not flow against the direction of the compressor rotation, otherwise stalling could occur.
- It is recommended to verify the layout of the intake air piping by CFD calculations up to the entry of the compressor of the turbocharger.
- The maximum specified air flow speed of 20 m/s should not be exceeded at any location of the pipe.
- A silencer is recommended to reduce the noise emissions from engine inlet and charge air blow-off. Sound power levels can be found in the relevant section of the Project Guide. Care must be taken, that no insulation material can escape from the silencer, which can fuse into glass spheres in the combustion chamber.

Components of intake air ducting

The whole system and its components must be designed suitably robust to withstand pressure peaks occurring from turbocharger surge. This will not happen during normal operation, but it could occur at fast load changes of the engine. This can happen 2 – 3 times consecutively, until the turbocharger comes back to its normal working range.

The table below shows values at engine inlet connection with a suitable intake air ducting. An unfavorable intake air duct design can also lead to higher values.

Type	Variation	Frequency	Comment
Pressure oscillation	± 40 mbar, 5 – 10 Hz	Permanent	Normal operation/ constant load
Peak pressure (shock wave)	± 300 mbar	Sporadically	Engine emergency stop/ turbocharger surge

The ambient air, which is led to engine by the intake air duct, needs to be conditioned by several components as shown in figure External intake air supply system for arctic conditions, Page 203. It needs to be cleaned according to the requirements in section Specification of intake air (combustion air), Page 147. This could be done by the following components:

- Section for cleaning of intake air (1 – 4)

  A weather hood (1) in combination with a snow trap (2) removes coarse dirt, snow and rain. A heated droplet separator (3) subsequently separates remaining water droplets or snow from the air. An appropriate filter cleans the intake air from particles. (4). As a minimum, inlet air must be cleaned by an ISO coarse 45 % class filter as per DIN EN ISO 16890. If there is a risk of high inlet air contamination, filter efficiency should be at least ISO ePM10 50 % according to DIN EN ISO 16890. See figure External intake air supply system for arctic conditions, Page 203.
- Combustion air silencer (5)

  Noise emissions of engine inlet and charge air blow-off can be reduced by a silencer in the intake air duct. It is recommended to apply a mesh (5a) at the outlet of the silencer to protect the turbocharger against any loose parts (e.g. insulation material of silencer, rust etc.) from the intake air duct.

This mesh is to be applied even if the silencer will not be supplied. A drain close to the turbocharger is required to separate condensate water. See section Noise, Page 84.

- Overpressure flap (6) (optional)

  Depending on the system volume and chosen components it might be necessary to install a overpressure flap between silencer and engine. Peak pressure pulses (e.g. during emergency stop) are conducted into the engine room via this flap, preventing possible damage to the filter and silencer.

- Shut-off flap/blind plate (7)

  It is recommended to install a shut-off flap to prevent cooling down of the engine during longer standstills under arctic conditions. This flap should be monitored by the engine automation system to prevent engine start with closed flap.
  As an alternative, the intake system can be closed by a roller shutter or tarpaulin in front of the filter.

- Compensator (8) and transition piece (9)

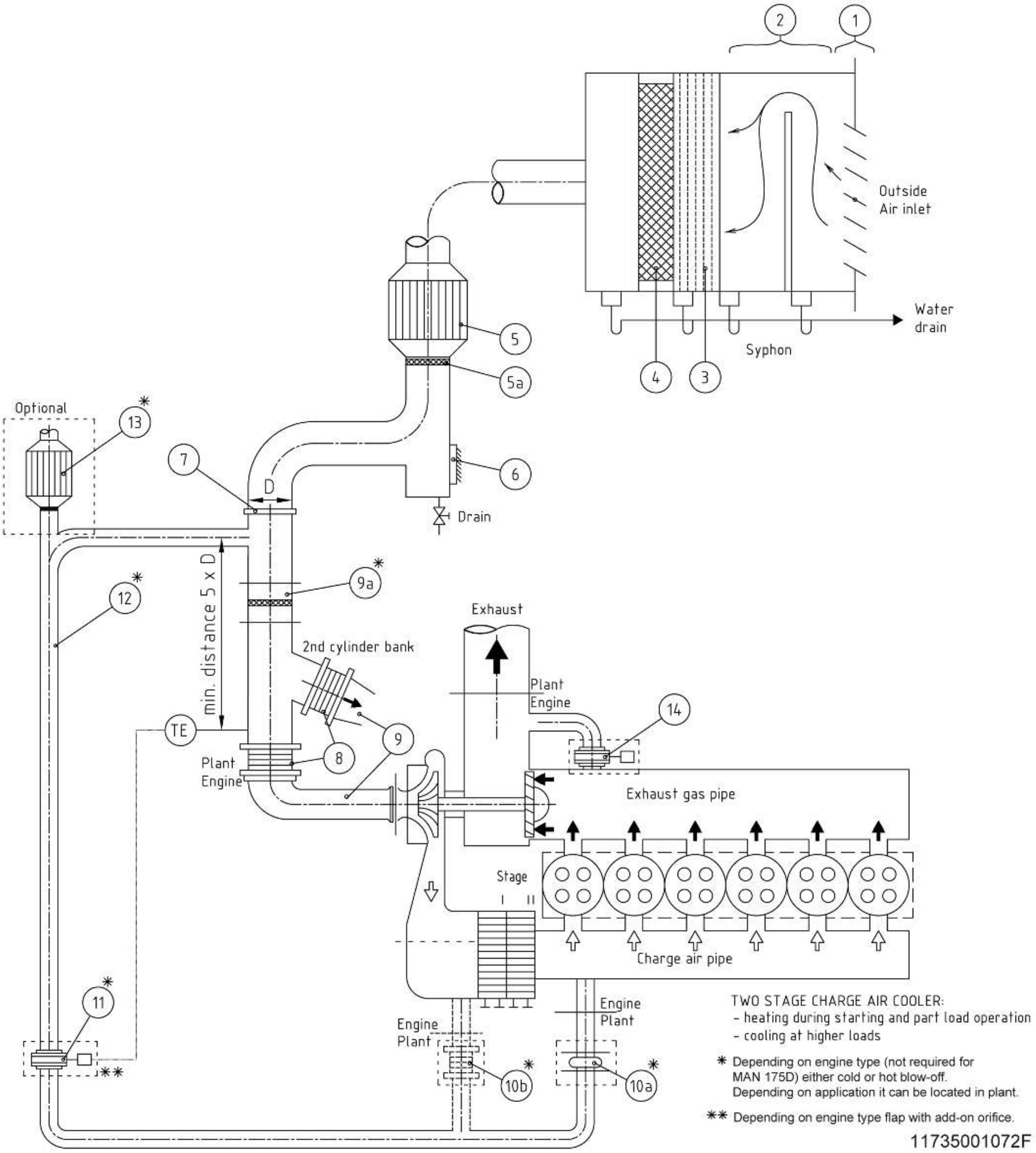
  A steel compensator (rubber might also be considered) has to be installed direct vertically upstream of the 90° transition piece behind turbocharger. A rigid support must be provided as close as possible upstream of the compensator. It has to be noted, that this compensator is solely foreseen to compensate engine-borne movements. Additional compensators might be necessary to cope for thermal expansion.

- Strainer for commissioning phase (9a)

  To prevent residues from installation phase entering the engine during commissioning, it is recommended to install a strainer or protective mesh as close as possible to the turbocharger. After running-in is finished, the strainer must be removed and exchanged by an intermediate pipe.

- Charge air blow-off or recirculation

  For arctic conditions (see section Engine operation under arctic conditions, Page 43) an increased firing pressure, which is caused by higher density of cold air, is prevented by an additional valve, which blows off charge air (11). A compensator (10) connects the engine with the charge air blow-off piping. The blown-off air is taken after (cold blow-off) the charge air cooler or before the charge air cooler (hot blow-off) and is circulated (12) back in the intake air duct or blown out via an additional silencer. A homogenous temperature profile and a correct measurement of intake air temperature in front of compressor has to be achieved. For this a minimum distance of five times the diameter of the intake air duct between inlet of blown-off air and the measuring point must be kept.



TWO STAGE CHARGE AIR COOLER:
- heating during starting and part load operation
- cooling at higher loads

* Depending on engine type (not required for MAN 175D) either cold or hot blow-off. Depending on application it can be located in plant.

** Depending on engine type flap with add-on orifice.

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1 Weather hood
2 Snow trap
3 Heated droplet separator
4 Air intake filter 030.120.010
5 Combustion air silencer 030.130.040
5a Protective mesh
6 Overpressure flap (optional)
7 Blind plate/shut-off flap (for maintenance case)
8 Metal bellow expansion joint combustion air (rubber might be considered)
9 Transition piece
9a (Optional) intermediate pipe with protective grid for running-in phase (to be removed afterwards)
10a Rubber bellow expansion joint – Cold blow-off
10b Metal bellow expansion joint – Hot blow-off
11 Charge air blow-off valve
12 Charge air blow-off pipe
13 Charge air blow-off silencer
14 Waste gate (if required for relevant engine type)

Figure 68: External intake air supply system for arctic conditionsx

5.8 Exhaust gas system

5.8.1 General

Layout

The flow resistance in the exhaust system has a very large influence on the fuel consumption and the thermal load of the engine. The values given in this document are based on an exhaust gas system which flow resistance does not exceed 50 mbar. If the flow resistance of the exhaust gas system is higher than 50 mbar, please contact MAN Energy Solutions for project-specific engine data.

The pipe diameter selection depends on the engine output, the exhaust gas volume and the system back pressure, including silencer and SCR (if fitted). The back pressure also being dependent on the length and arrangement of the piping as well as the number of bends. Sharp bends result in very high flow resistance and should therefore be avoided. If necessary, pipe bends must be provided with guide vanes.

It is recommended not to exceed a maximum exhaust gas velocity of approximately 40 m/s.

Installation

When installing the exhaust system, the following points must be observed:

- The exhaust pipes of two or more engines must not be joined.
- The MAN V28/33D STC has two turbochargers. To avoid interaction of the exhaust gas flows, the exhaust pipe of at least one turbocharger (preferably from Bank A) must have a length of minimum five times of its diameter before beeing joined.
- Because of the high temperatures involved, the exhaust pipes must be able to expand. The expansion joints to be provided for this purpose are to be mounted between fixed-point pipe supports installed in suitable positions. One compensator is required just after the outlet casing of the turbocharger (see section Position of the outlet casing of the turbocharger, Page 234) in order to prevent the transmission of forces to the turbocharger itself. These forces include those resulting from the weight, thermal expansion or lateral displacement of the exhaust piping. For this compensator/expansion joint one sturdy fixed-point support must be provided.

- The exhaust piping should be elastically hung or supported by means of dampers in order to prevent the transmission of sound to other parts of the vessel.
- The exhaust piping is to be provided with water drains, which are to be regularly checked to drain any condensation water or possible leak water from exhaust gas boilers if fitted.
- During commissioning and maintenance work, checking of the exhaust gas system back pressure by means of a temporarily connected measuring device may become necessary. For this purpose, a measuring socket is to be provided approximately 1 to 2 metres after the exhaust gas outlet of the turbocharger, in a straight length of pipe at an easily accessed position. Standard pressure measuring devices usually require a measuring socket size of 1/2". This measuring socket is to be provided to ensure back pressure can be measured without any damage to the exhaust gas pipe insulation.

Exhaust piping insulation

The exhaust gas pipe system has to be insulated to reduce the maximum surface temperature to the level required by both the classification society and SOLAS and to avoid temperatures below the dew point. Therefore the complete exhaust gas system (from outlet of turbocharger, silencer, boiler to outlet stack) should be sufficiently insulated. Also, to avoid temperatures below the dew point, resulting in excessive water formation within the pipe, the exhaust gas piping to the outside, including boiler, if fitted and silencer, should be insulated thus avoiding intensified corrosion and soot deposits on the interior surface of the exhaust gas pipe. When fast engine load changes occur, these deposits might flake off and be entrained by exhaust in the form of soot flakes. The flange connection on the turbocharger outlet, as well as the adjacent round flanges of the adaptor or transition piece, must also be covered with insulating collars, for reasons of safety. Insulation and covering of the compensator must not restrict its freedom of movement. The relevant provisions concerning accident prevention and those of the classification societies and SOLAS requirements must be observed.

Exhaust silencer – Mode of operation

The silencer, normally of client supply, usually operates on the absorption principle, this design being very effective throughout a wide frequency band. The flow path, running through the silencer in a straight line, ensures optimum noise reduction with minimum flow resistance and therefore low back pressure.

Silencer installation

If possible, the silencer should be installed towards the end of the exhaust line; the exact position can be adapted to the space available (from vertical to horizontal). If the silencer has a spark arrester, it must be ensured that the cleaning ports are easily accessible.

Please contact MAN Energy Solutions for technical drawings of auxiliary equipment.

Exhaust gas and charge air system diagram

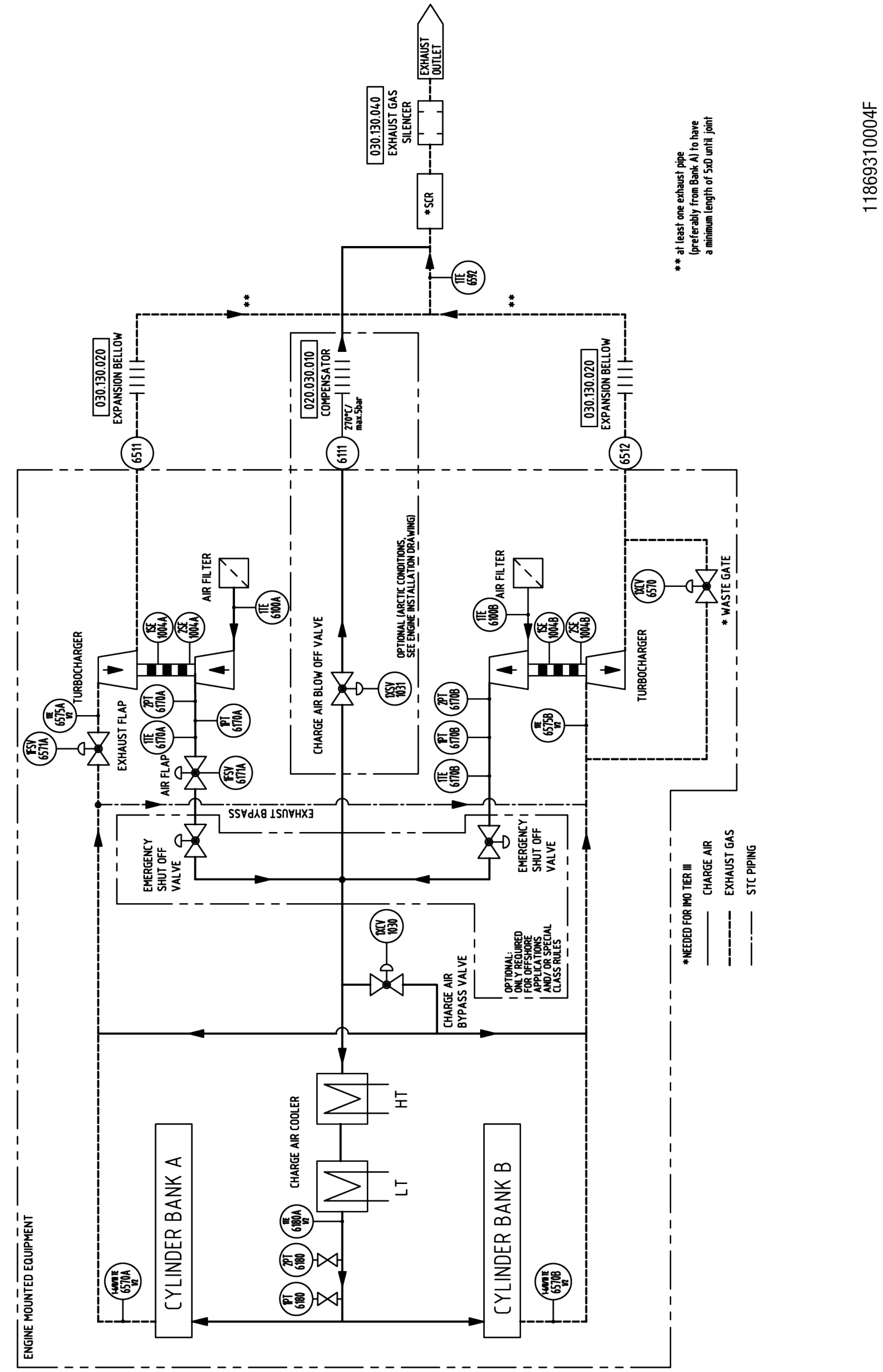

Figure 69: Exhaust gas and charge air system diagram with STC

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6111	OPTIONAL: Charge air blow off	6512	Outlet exhaust gas
6511	Outlet exhaust gas		

5.8.2 Components and assemblies of the exhaust gas system

Exhaust gas silencer and exhaust gas boiler

Mode of operation

The silencer operates on the absorption and resonance principle so it is effective in a wide frequency band. The flow path, which runs through the silencer in a straight line, ensures optimum noise reduction with minimum flow resistance.

A spark arrestor should be provided in the exhaust gas system (e.g. integrated in the silencer).

Note:
Spark arrestors are mandatory for certain ship types.

Installation

If possible, the silencer should be installed towards the end of the exhaust line.

A vertical installation situation is to be preferred in order to avoid formations of gas fuel pockets in the silencer. The cleaning ports of the spark arrestor are to be easily accessible.

Note:
Water entry into the silencer and/or boiler must be avoided, as this can cause damages of the components (e.g. forming of deposits) in the duct.

Exhaust gas boiler

To utilise the thermal energy from the exhaust, an exhaust gas boiler producing steam or hot water may be installed.

Insulation

The exhaust gas system (from outlet of turbocharger, boiler, silencer to the outlet stack) is to be insulated to reduce the external surface temperature to the required level.

The relevant provisions concerning accident prevention and those of the classification societies must be observed.

The insulation is also required to avoid temperatures below the dew point on the interior side. In case of insufficient insulation intensified corrosion and soot deposits on the interior surface are the consequence. During fast load changes, such deposits might flake off and be entrained by exhaust in the form of soot flakes.

Insulation and covering of the compensator must not restrict its free movement.

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6 Engine room planning

6.1 Installation and arrangement

6.1.1 General details

Apart from a functional arrangement of the components, the shipyard is to provide for an engine room layout ensuring good accessibility of the components for servicing.

The cleaning of the cooler tube bundle, the emptying of filter chambers and subsequent cleaning of the strainer elements, and the emptying and cleaning of tanks must be possible without any problem whenever required.

All of the openings for cleaning on the entire unit, including those of the exhaust silencers, must be accessible.

There should be sufficient free space for temporary storage of pistons, camshafts, turbocharger etc. dismounted from the engine. Additional space is required for the maintenance personnel. The panels on the engine sides for inspection of the bearings and removal of components must be accessible without taking up floor plates or disconnecting supply lines and piping. Free space for installation of a torsional vibration meter should be provided at the crankshaft end.

A very important point is that there should be enough room for storing and handling vital spare parts so that replacements can be made without loss of time.

In planning marine installations with two or more engines driving one propeller shaft through a multi-engine transmission gear, provision must be made for a minimum clearance between the engines because the crankcase panels of each engine must be accessible. Moreover, there must be free space on both sides of each engine for removing pistons or cylinder liners.

Note:
MAN Energy Solutions delivered scope of supply is to be arranged and fixed by proven technical experiences as per state of the art. Therefore the technical requirements have to be taken in consideration as described in the following documents subsequential:

- Order related engineering documents.
- Installation documents of our sub-suppliers for vendor specified equipment.
- Operating manuals for diesel engines and auxiliaries.
- Project Guides of MAN Energy Solutions.

Any deviations from the principles specified in the aforementioned documents require a previous approval by MAN Energy Solutions.

Arrangements for fixation and/or supporting of plant related equipment deviating from the scope of supply delivered by MAN Energy Solutions, not described in the aforementioned documents and not agreed with us are not permissible.

For damages due to such arrangements we will not take over any responsibility nor give any warranty.

6.1.2 Installation drawings

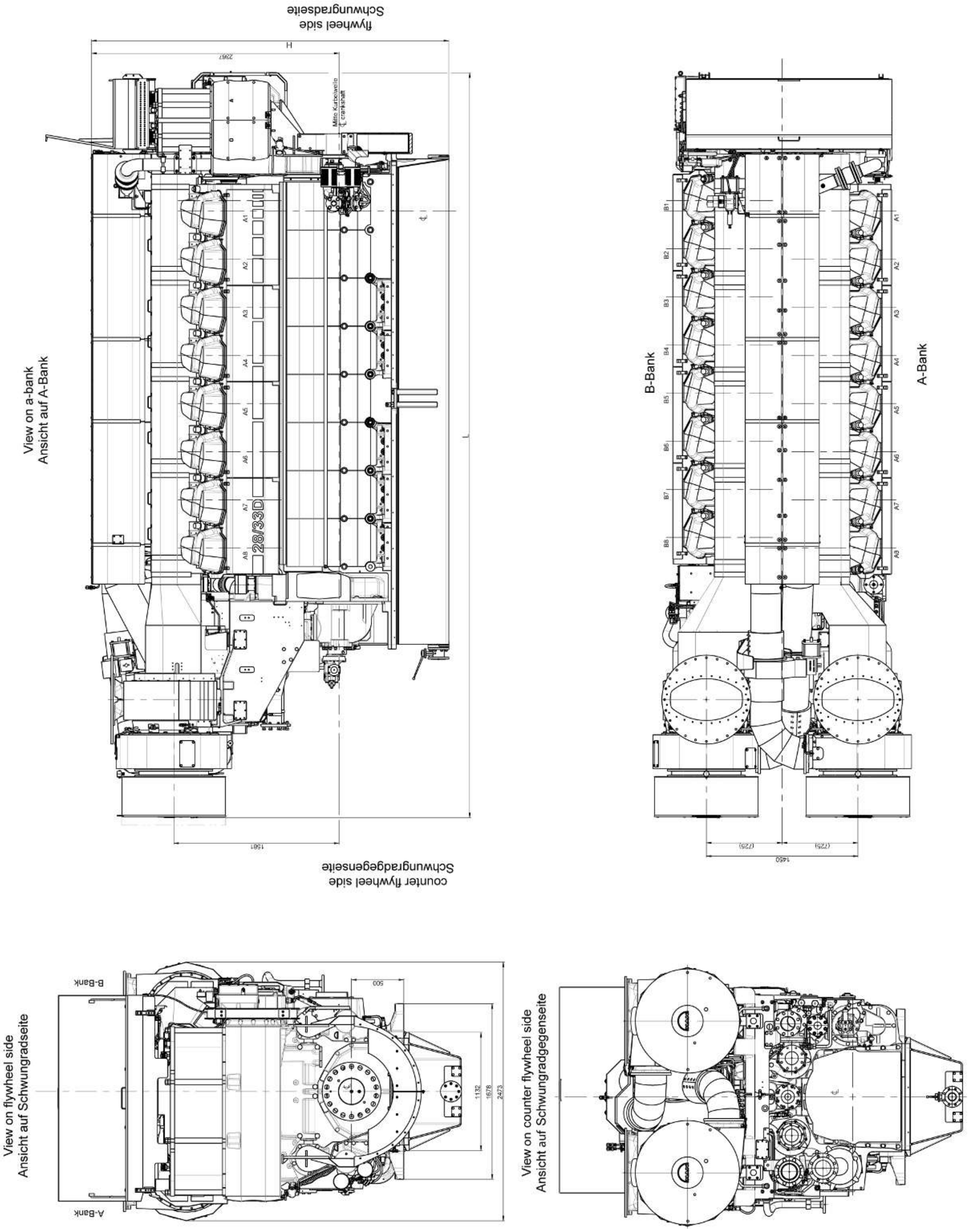

Figure 70: Installation drawing 16V engine with duplex filter (standard) and low oil sump

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No. of cylinders, config.	H (low oil sump)	L
	mm	
12V	3,417	6,217
16V		7,137
20V		8,057
The dimensions are given for guidance only. The figures show a possible design of the engine. The equipment can be combined differently.		

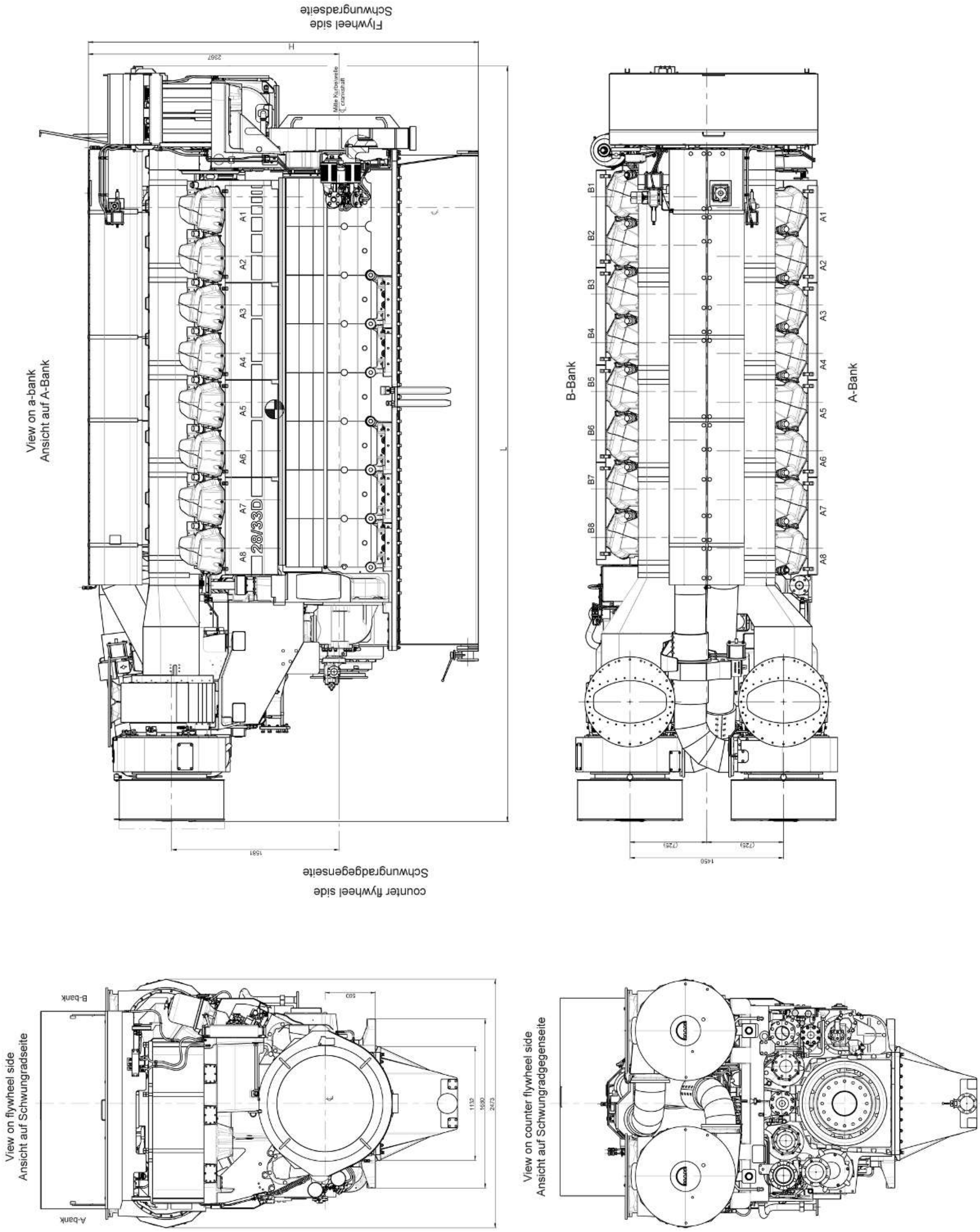

Figure 71: Installation drawing 16V engine with automatic filter (optional), deep oil sump and PTO 100 %

No. of cylinders, config.	H (deep oil sump)	L
	mm	
12V	3,683	6,217
16V		7,137
20V		8,057
The dimensions are given for guidance only. The figures show a possible design of the engine. The equipment can be combined differently.		

6.1.3 Removal dimensions

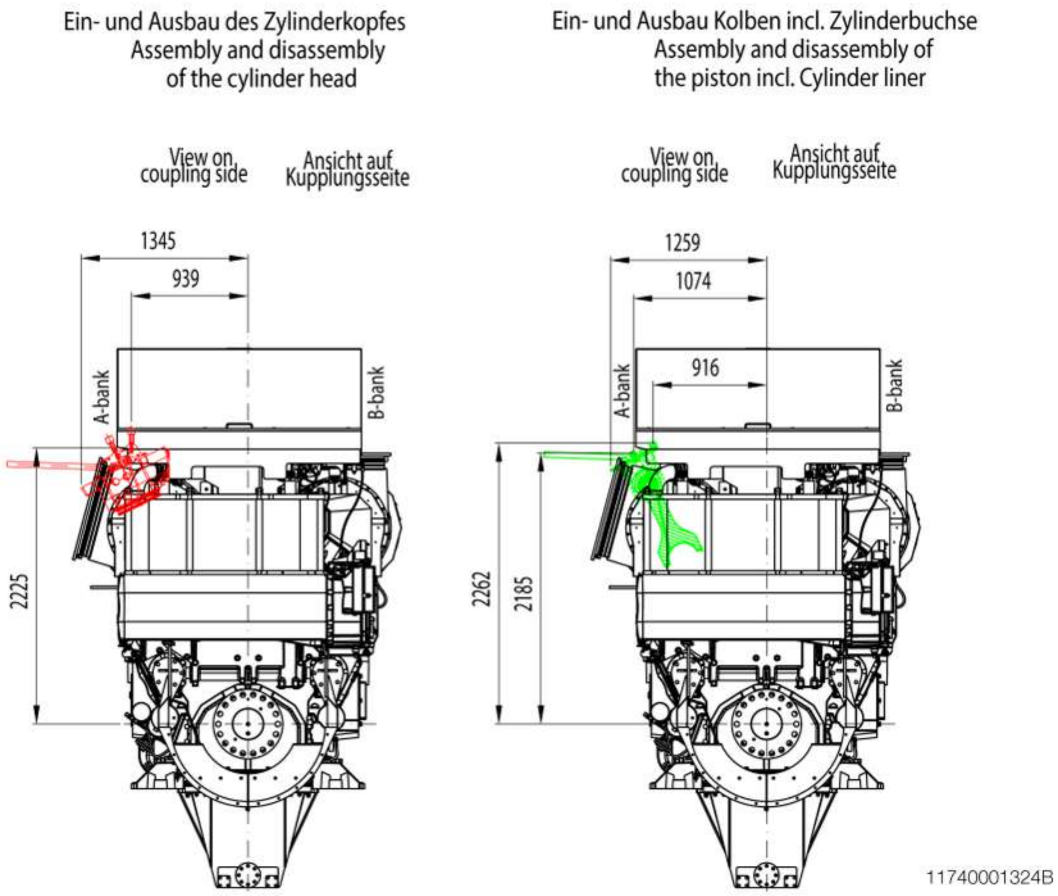

Figure 72: Removal dimensions of cylinder head and piston including cylinder liner

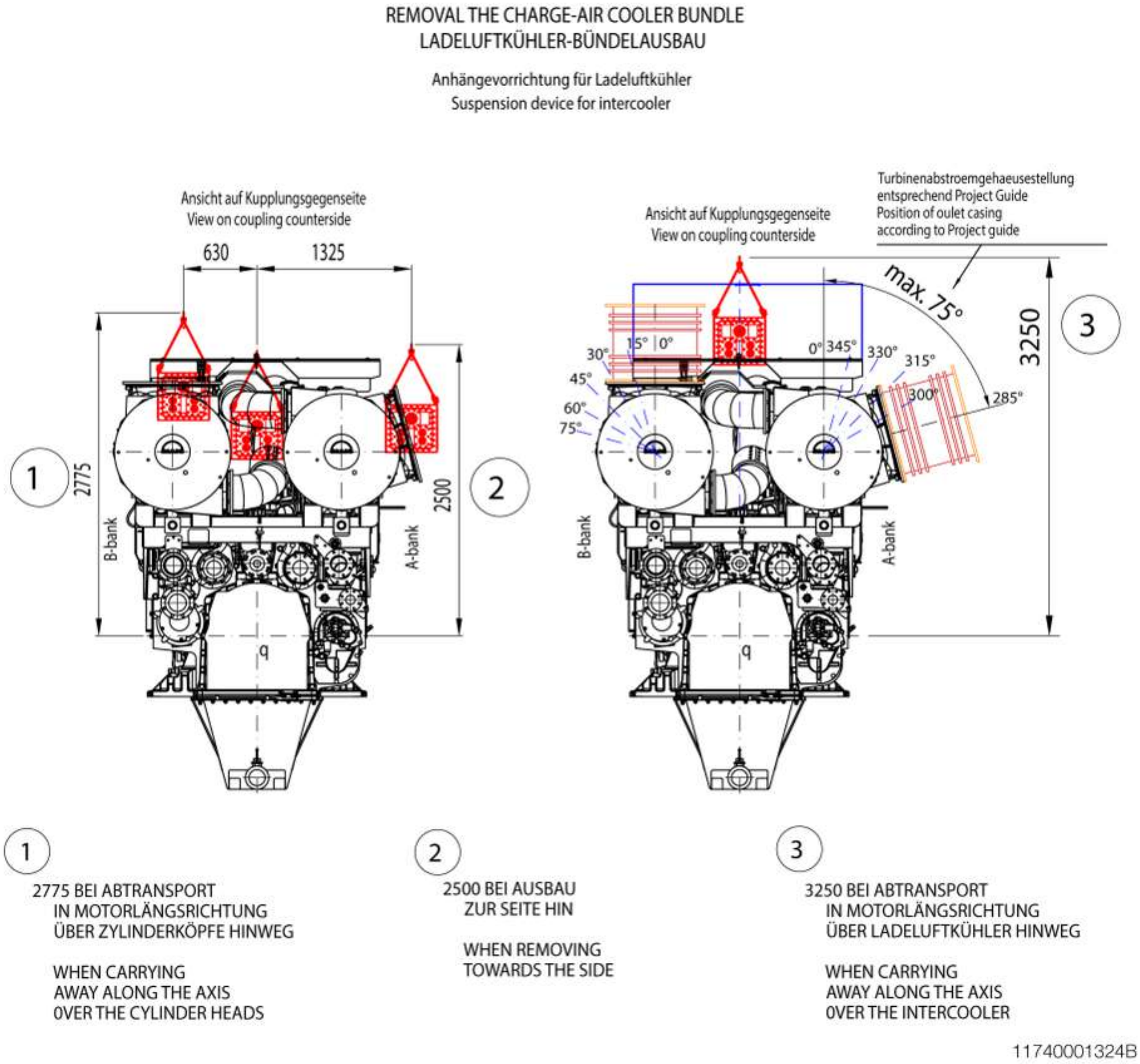

Figure 73: Removal dimensions of charge air cooler bundle

1	When carrying away along the axis over the cylinder heads
2	When removing towards the side
3	When carrying away along the axis over the intercooler
Capacity of suspension device for intercooler: 825 kg	

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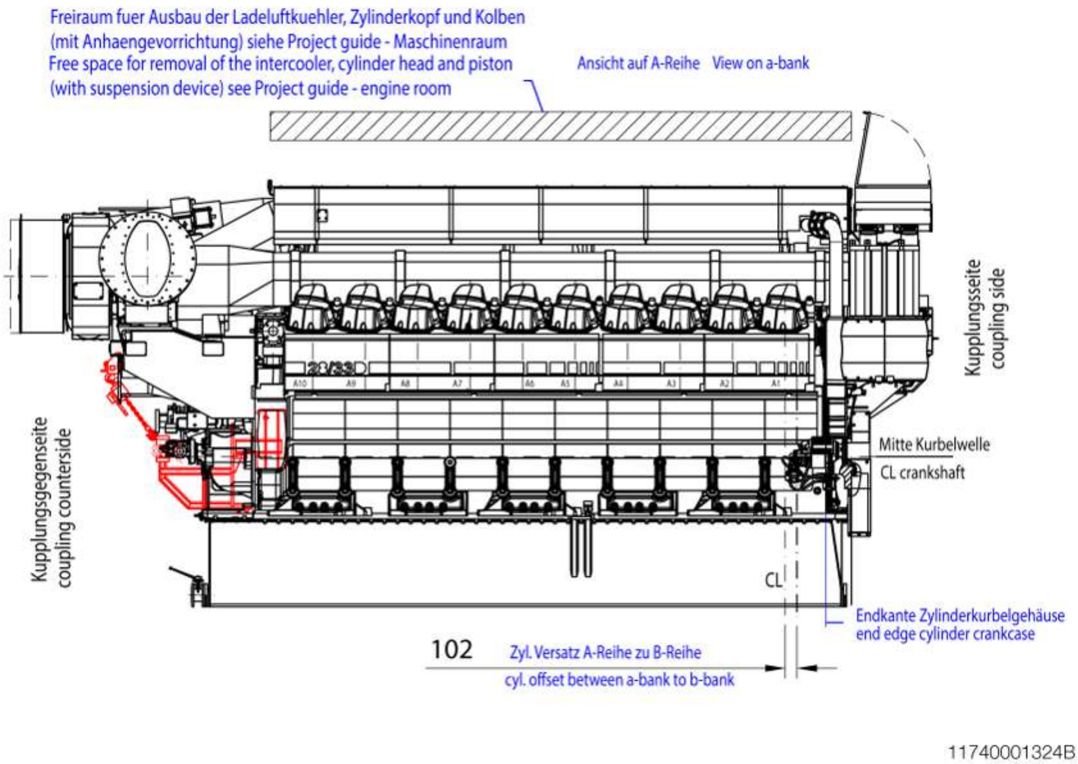

Figure 74: Removal dimensions of lube oil pump and fuel pump

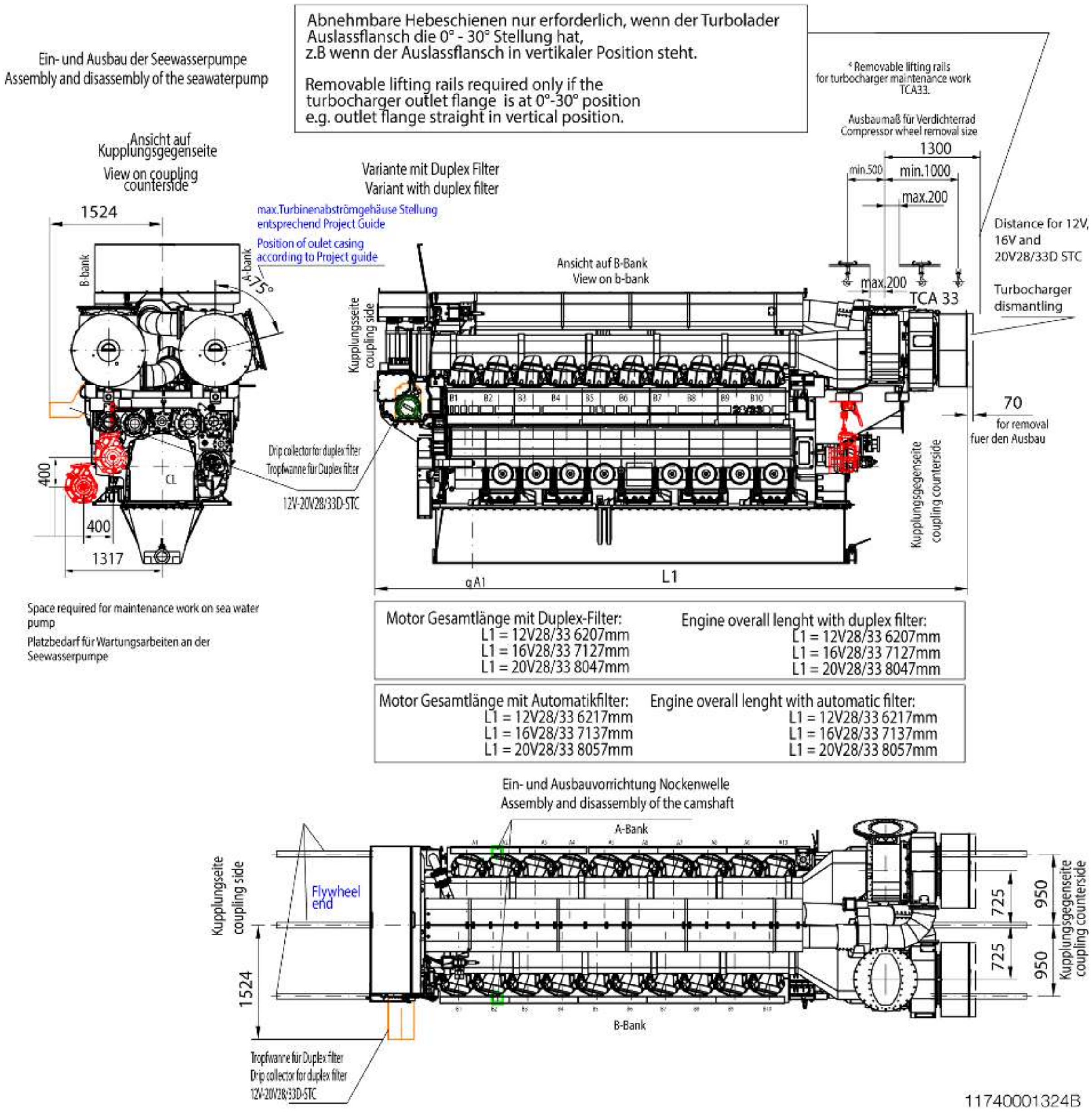

Figure 75: Removal dimensions of lube oil duplex filter, lube oil automatic filter, centrifuge, turbocharger, compressor wheel and seawater pump

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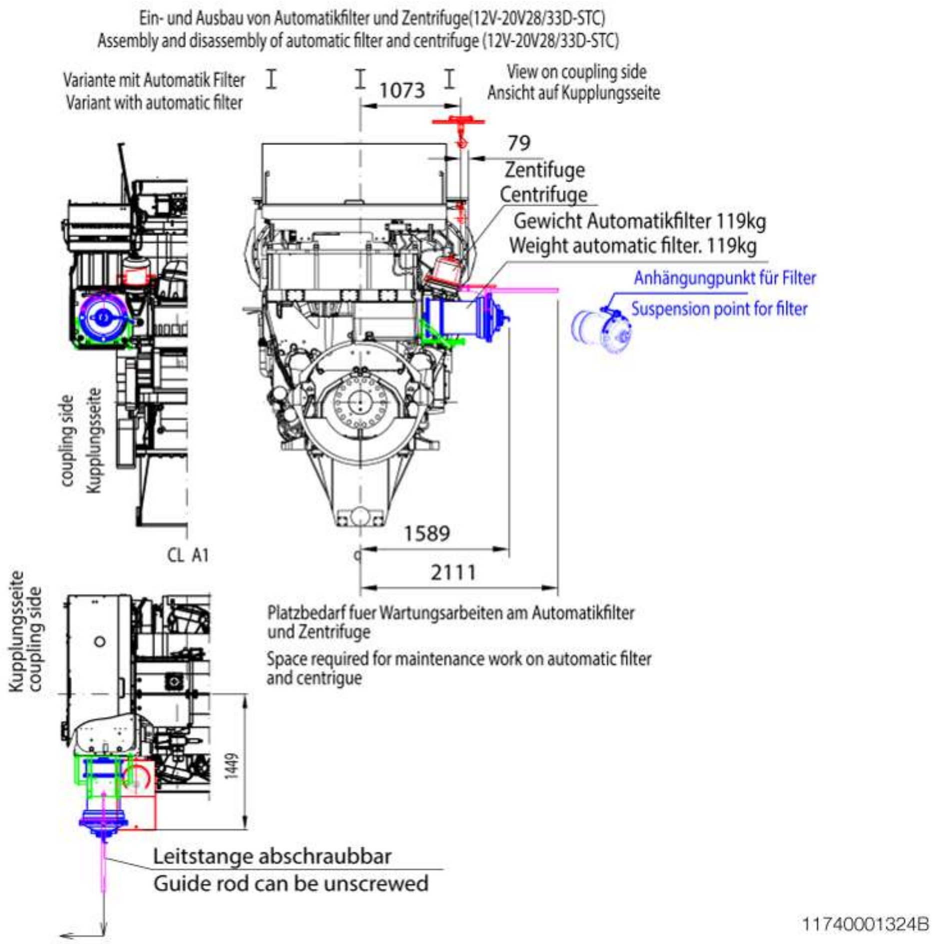

Figure 76: Removal dimensions of seawater pump, lube oil automatic filter, centrifuge, camshaft and turbocharger

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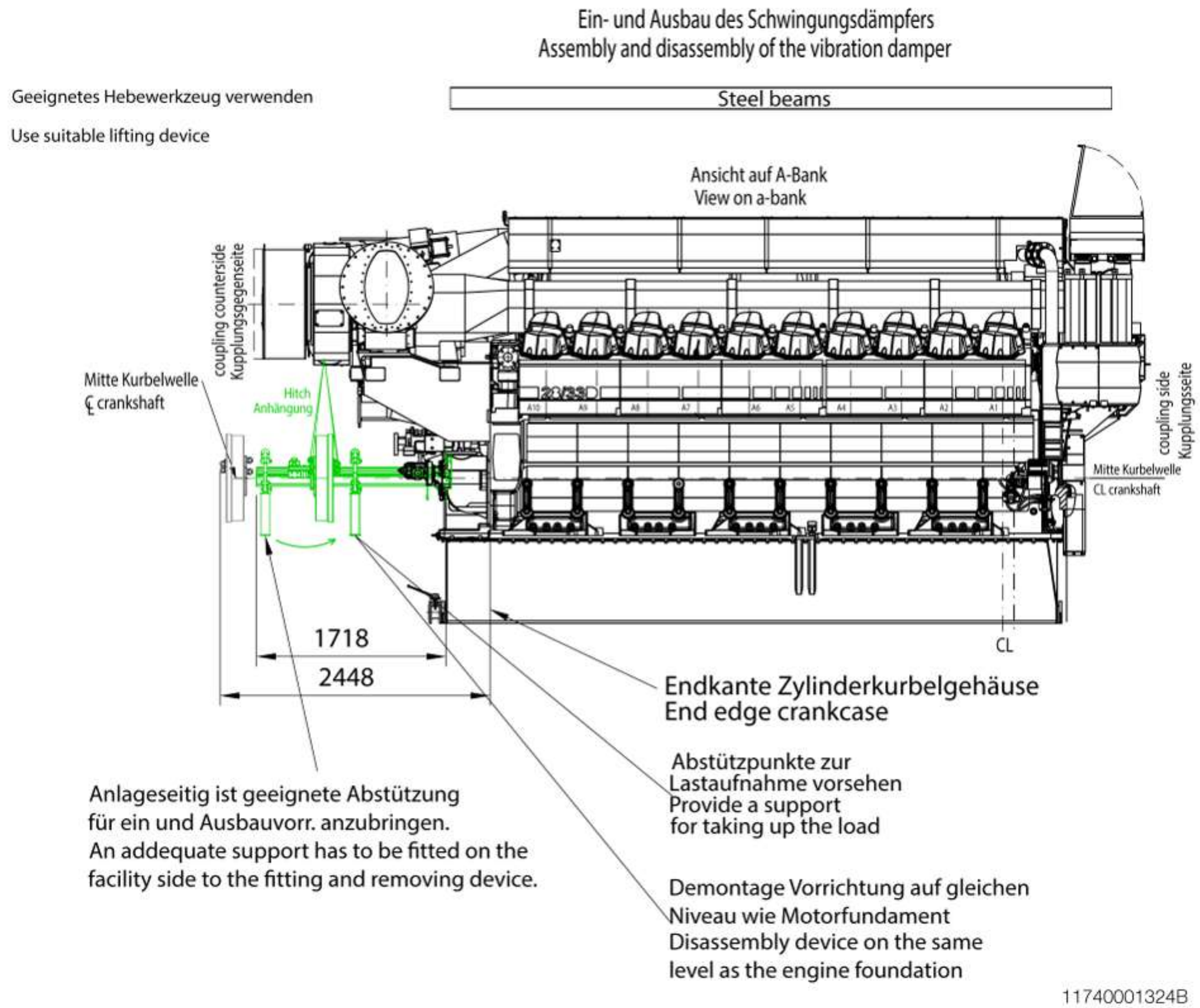

Figure 77: Removal dimensions of vibration damper

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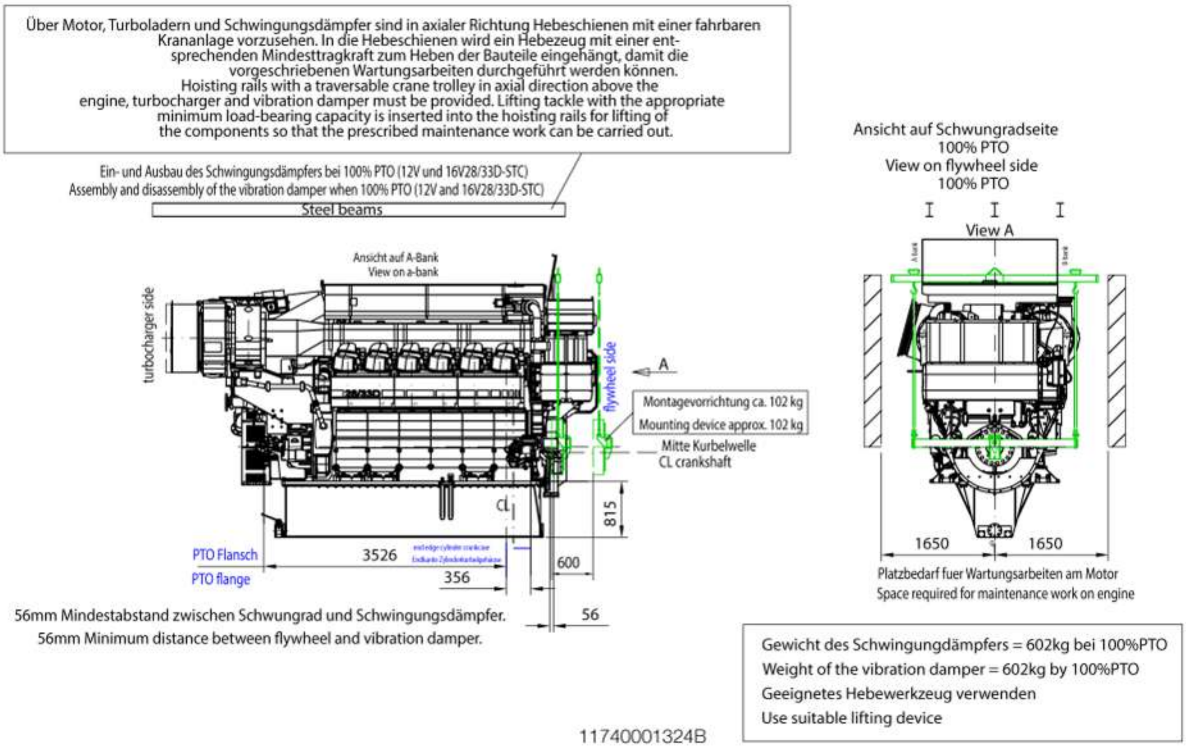

Figure 78: Removal dimensions of vibration damper PTO 100 %

6.1.4 3D Engine Viewer – A support programme to configure the engine room

MAN Energy Solutions offers a free-of-charge online programme for the configuration and provision of installation data required for installation examinations and engine room planning: The 3D Engine Viewer.

Easy-to-handle selection and navigation masks permit configuration of the required engine type, as necessary for virtual installation in your engine room.

In order to be able to use the 3D Engine Viewer, please register on our website under:

https://extranet.mandieselturbo.com/Pages/Dashboard.aspx

After successful registration, the 3D Engine Viewer is available under:

https://extranet.mandieselturbo.com/content/appengineviewer/Pages/Default.aspx

by clicking onto the requested application.

In only three steps, you will obtain professional engine room data for your further planning:

- Selection

  Select the requested output, respectively the requested type.
- Configuration

  Drop-down menus permit individual design of your engine according to your requirements. Each of your configurations will be presented on the basis of isometric models.
- View

The models of the 3D Engine Viewer include all essential geometric and planning-relevant attributes (e.g. connection points, interfering edges, exhaust gas outlets, etc.) required for the integration of the model into your project.

The configuration with the selected engines can now be easily downloaded.

For 2D representation as:

- .pdf
- .dwg
- .dxf

for 3D as:

- .dgn
- .stp
- .sat
- .igs
- 3D-dxf
- and many others

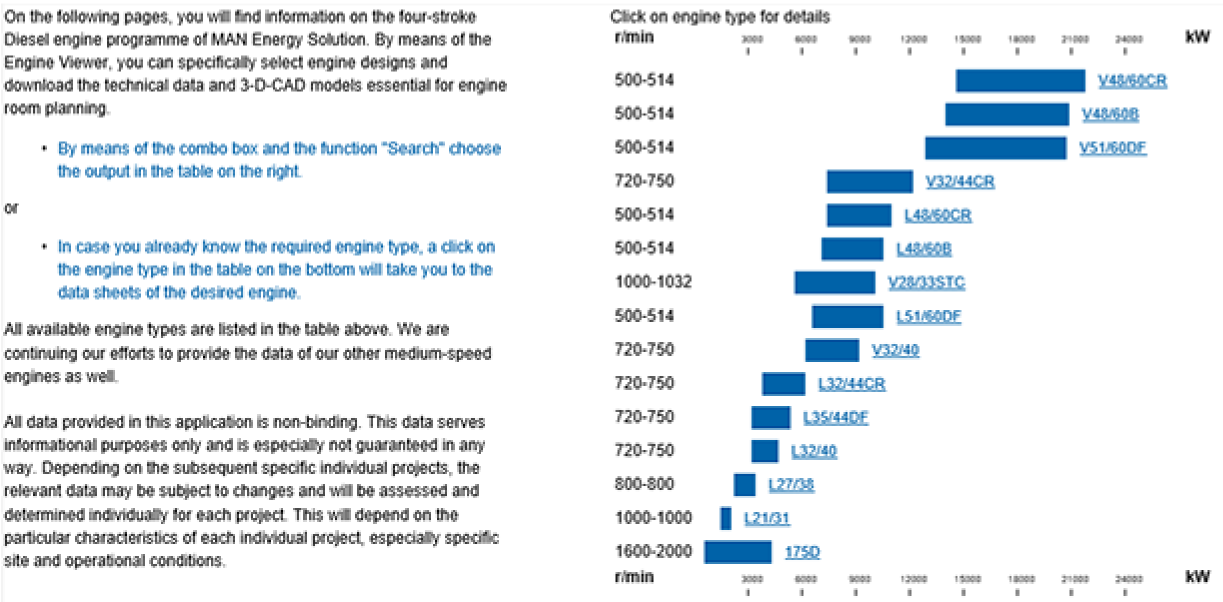

Figure 79: Selection of engine

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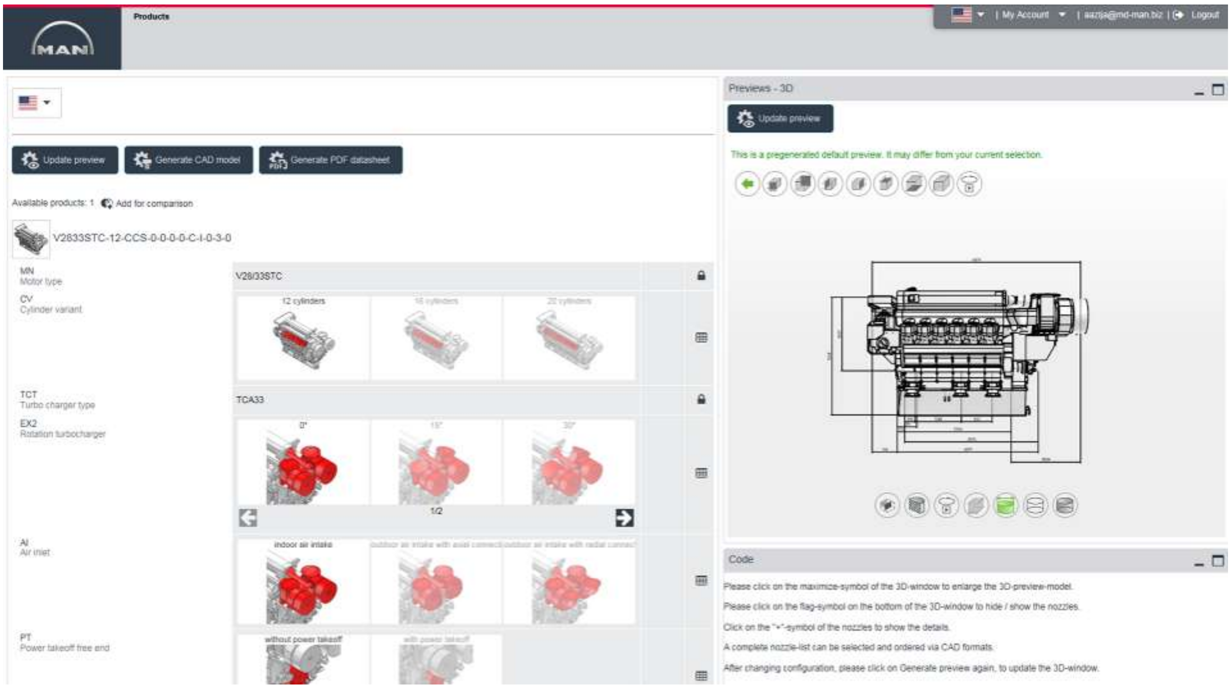

Figure 80: Preselected standard configuration

6.1.5 Lifting device

Lifting gear with varying lifting capacities are to be provided for servicing and repair work on the engine, turbocharger and charge air cooler.

Engine

Component weights

For servicing the engine an overhead traveling crane is required. The lifting capacity shall be sufficient to handle the heaviest component that has to be lifted during servicing of the engine and should foresee extra capacity e.g. to overcome the break loose torque while lifting cylinder heads. The overhead traveling crane can be chosen with the aid of the following table:

Components	Unit	Approximate weights
Cylinder head complete	kg	282
Piston with piston pin, connecting rod (for piston removal) and cylinder liner		320
Charge air cooler		789
Lube oil cooler		1,142

Table 92: Component weights

Crane arrangement

The rails for the crane are to be arranged in such a way, that the crane can cover the whole engine +1,000 mm at both sides. Three rails are required, each one over the cylinders and one over the centre line of the engine.

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The hook position must reach along the engine axis, past the centreline of the first and the last cylinder, so that valves can be dismantled and installed without pulling at an angle. Similarly, the crane must be able to reach the tie rod at the ends of the engine. In cramped conditions, eyelets must be welded under the deck above, to accommodate a lifting pulley.

The required crane capacity is to be determined by the crane supplier.

Crane design

It is necessary that:

- There is an arresting device for securing the crane while hoisting if operating in heavy seas
- There is a two-stage lifting speed

  Precision hoisting approximately = 0.5 m/min

  Normal hoisting approximately = 2 – 4 m/min

Places of storage

In planning the arrangement of the crane, a storage space must be provided in the engine room for the dismantled engine components which can be reached by the crane. It should be capable of holding two rocker arm casings, two cylinder covers and two pistons. If the cleaning and service work is to be carried out here, additional space for cleaning troughs and work surfaces should be planned.

Transport to the workshop

Grinding of valve cones and valve seats is carried out in the workshop or in a neighbouring room.

Transport rails and appropriate lifting tackle are to be provided for the further transport of the complete cylinder cover from the storage space to the workshop. For the necessary deck openings, see following figures and tables.

Turbocharger

Section Turbocharger assignments, Page 24 shows which turbocharger type should be used for which engine variant.

Turbocharger dimensions

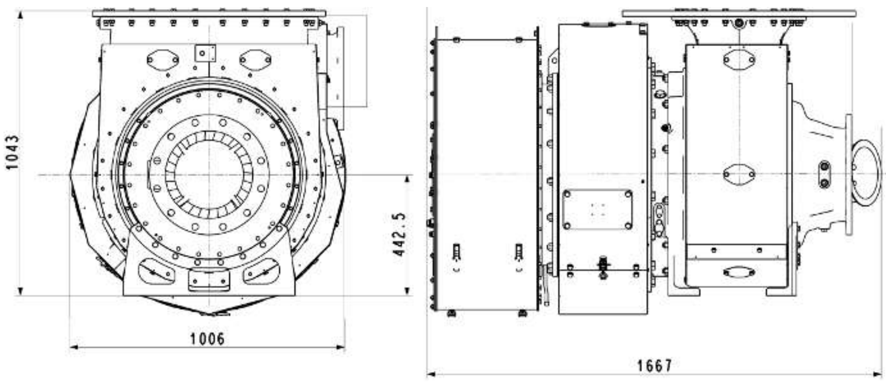

Figure 81: Exemplary illustration of TCA33

Hoisting rail

A hoisting rail with a mobile trolley is to be provided over the centre of the turbocharger running parallel to its axis, into which a lifting tackle is suspended with the relevant lifting power for lifting the parts, which are mentioned in the table(s) below, to carry out the operations according to the maintenance schedule.

Turbocharger		TCA33
Compressor casing single socket	kg	328
Gas admission casing axial		68

Turbocharger		TCA33
Silencer		241
Turbine rotor		54
Space for removal of silencer	mm	156

Table 93: Hoisting rail of the axial turbocharger

Withdrawal space dimensions

The withdrawal space shown in section Removal dimensions, Page 213 and in the table(s) in paragraph Hoisting rail, Page 222 is required for separating the silencer from the turbocharger. The silencer must be shifted axially by this distance before it can be moved laterally.

Minimum distance required for dismantling clearance for the filter silencer is 70 mm, however 500 mm is recommended.

Make sure that the silencer can be removed either downwards or upwards or laterally and set aside, to make the turbocharger accessible for further servicing. Pipes must not be laid in these free spaces.

Fan shafts

The engine combustion air is to be supplied towards the intake silencer in a duct ending at a point 1.5 m away from the silencer inlet. If this duct impedes the maintenance operations, for instance the removal of the silencer, the end section of the duct must be removable. Suitable suspension lugs are to be provided on the deck and duct.

Gallery

If possible the ship deck should reach up to both sides of the turbocharger (clearance 50 mm) to obtain easy access for the maintenance personnel. Where deck levels are unfavourable, suspended galleries are to be provided.

Charge air cooler

One unit is installed on the 12V engine and two units are installed on the 16V and 20V engines.

No. of cylinders, config.	Weight (per unit)	Length (L)	Width (B)	Height (H)
	kg	mm	mm	mm
12V	710	2,338	445	410
16V	420	1,303	445	410
20V	600	1,763	445	410

Table 94: Weights and dimensions of charge air cooler bundle

For further information please contact MAN Energy Solutions.

6.1.6 Space requirement for maintenance

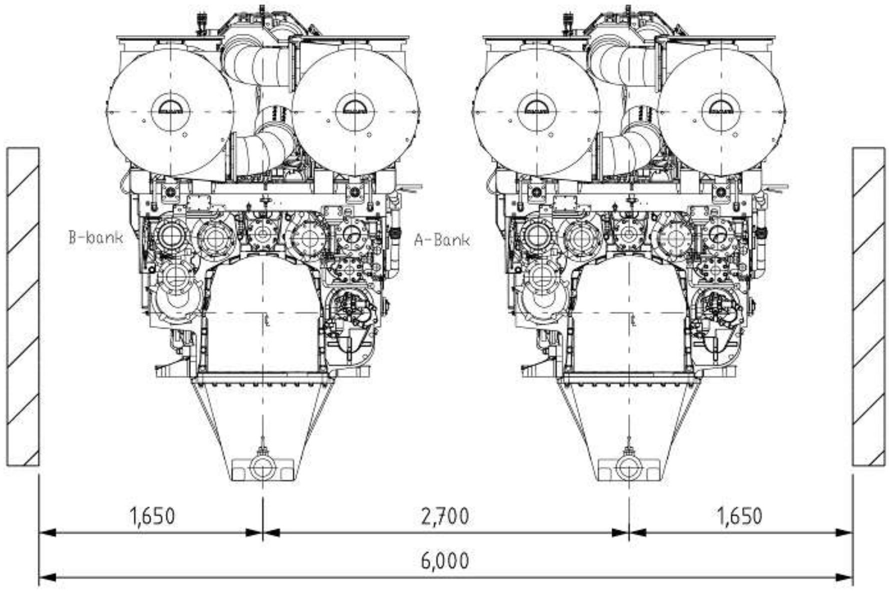

Figure 82: Space requirement for maintenance

6.1.7 Major spare parts

Engine MAN V28/33D STC

In accordance with the rules of the classification society "DNV GL" we only supply those spare parts specified in the following list which refer to original equipment supplied by us. Spare parts for monitoring and remote control equipment are included in the relevant items of the scope of supply.

Note:
Navigation range A = unrestricted range.

Scope of supply for 1 ship

	Quantity	Description
Crankshaft bearing	1	Crankshaft bearing shells, 2-part of each kind, tie-rods and cross pin with nuts
	1	Thrust bearing ring (two part) for 1 locating bearing
Connecting rod and main piston	1	Upper and lower connecting rod bearing shell, with bolts (and nuts where provided)
	1	Piston pin bush
	1	Piston pin
	2	Lock ring for piston pin
	1	Main piston with piston rings, piston pin, connecting rod, bearing shells, bolts and nuts, ready for fitting

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	Quantity	Description
	1	Compression and oil scraper rings for 1 main piston
Cylinder liner and cylinder head	1	Cylinder liner with seals, ready for fitting
	1	Cylinder head with valves and seals
	2	Bolts with nuts, for fixing one cylinder head
Valves in cylinder head	2	Inlet valve with valve guide and valve seat ring
	2	Exhaust valve with valve guide and valve seat ring
	12/16/20	Fuel injection valve (for 1 engine 12V/16V/20V) with injection pipes
Miscellaneous	1	Air start motor
	1	Seals for cylinder liner, support ring[1)], cooling water overflow, valves in cylinder head[1)], between cylinder head and charge-air pipe, between cylinder head and exhaust gas pipe, to push rod jacketing[1)] and to valve protection cap[1)] sufficient for 1 cylinder
	1	Expansion joint for exhaust gas pipe on the engine

[1)] where provided.

Note:
Subject to modification. Consumed spare parts should be replaced immediately.

Table 95: Scope of supply

Turbocharger weight schedule

Turbocharger		TCA33
Silencer	kg	230
Compressor casing		265
Turbine rotor		30
Turbocharger		1,430
Space for removal of silencer	mm	77

Table 96: Hoisting rail for TCA33 turbocharger

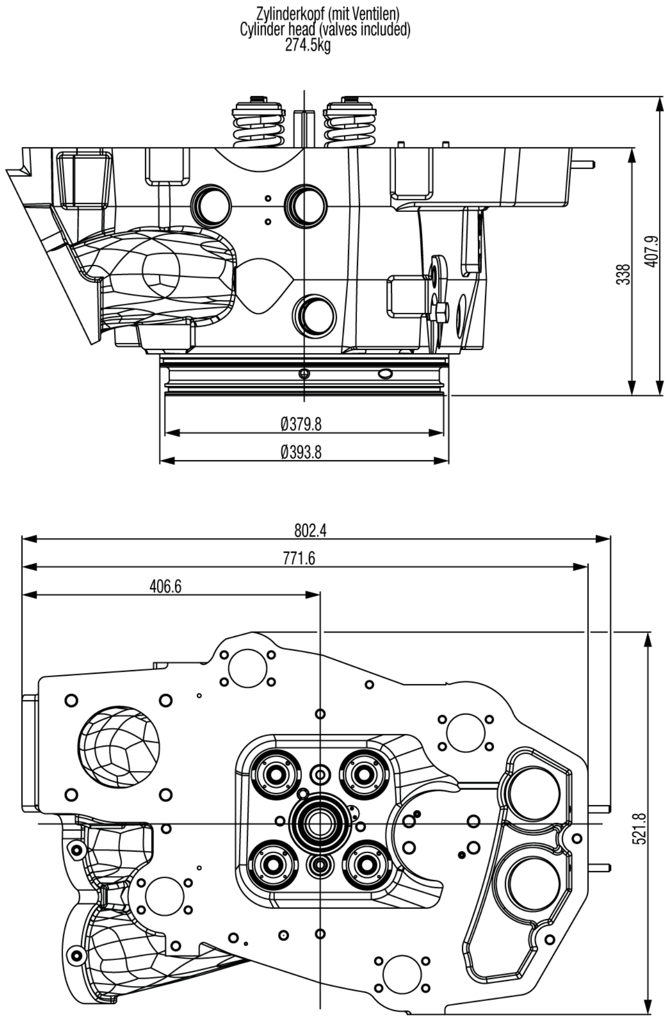
Maintenance items

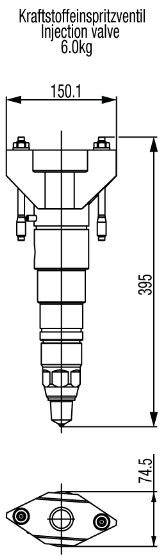
Major spare parts	Weight [kg]
Air by-pass valve	2
Camshaft journals	35
Camshaft gears	65
Camshaft gears – Intermediate	80
Camshaft segment	50
Charge air cooler 12V	754
Charge air cooler 16V	870 (2 x 435)
Charge air cooler 20V	1,220 (2 x 610)
Connecting rod – Complete with bush, bearing and bolts	91
Crankshaft gear	32

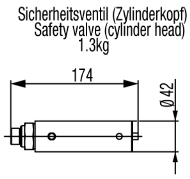
Major spare parts	Weight [kg]
Cylinder head covers (main)	7
Cylinder head with valves (less covers and valve gear)	275
Cylinder liner without cutting ring	133
Explosion relief valve and door	12
Fuel filter element (off engine)	8
Fuel injection pump	9
Fuel injector	6.5
Fuel circulating pump	12
Main bearing (lower + upper)	3
Main bearing caps	72
Oil filter element	8
Lube oil pump with attached fuel pump	285
Piston with piston pin	70
Compressed air starter motor	30
Tappet housing assembly	55
Turbocharger	1,430
Vibration damper 12V, 16V	579
Vibration damper 20V	595
Water pump – High temperature	90
Water pump – Jacket water	90
Water pump – Seawater	250
All weights quoted are for guidance only.	

Table 97: Maintenance items

6.1.8 Major spare parts – Main dimensions







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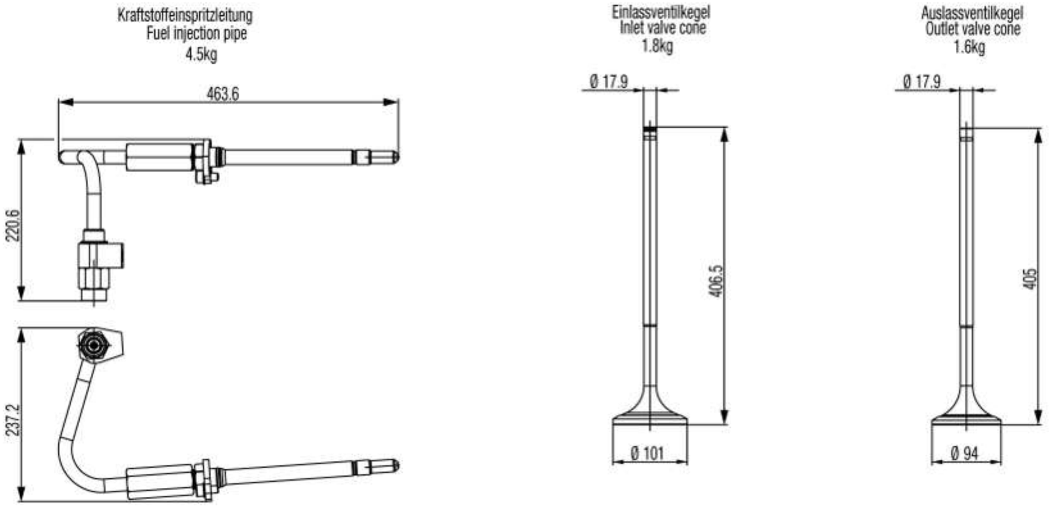

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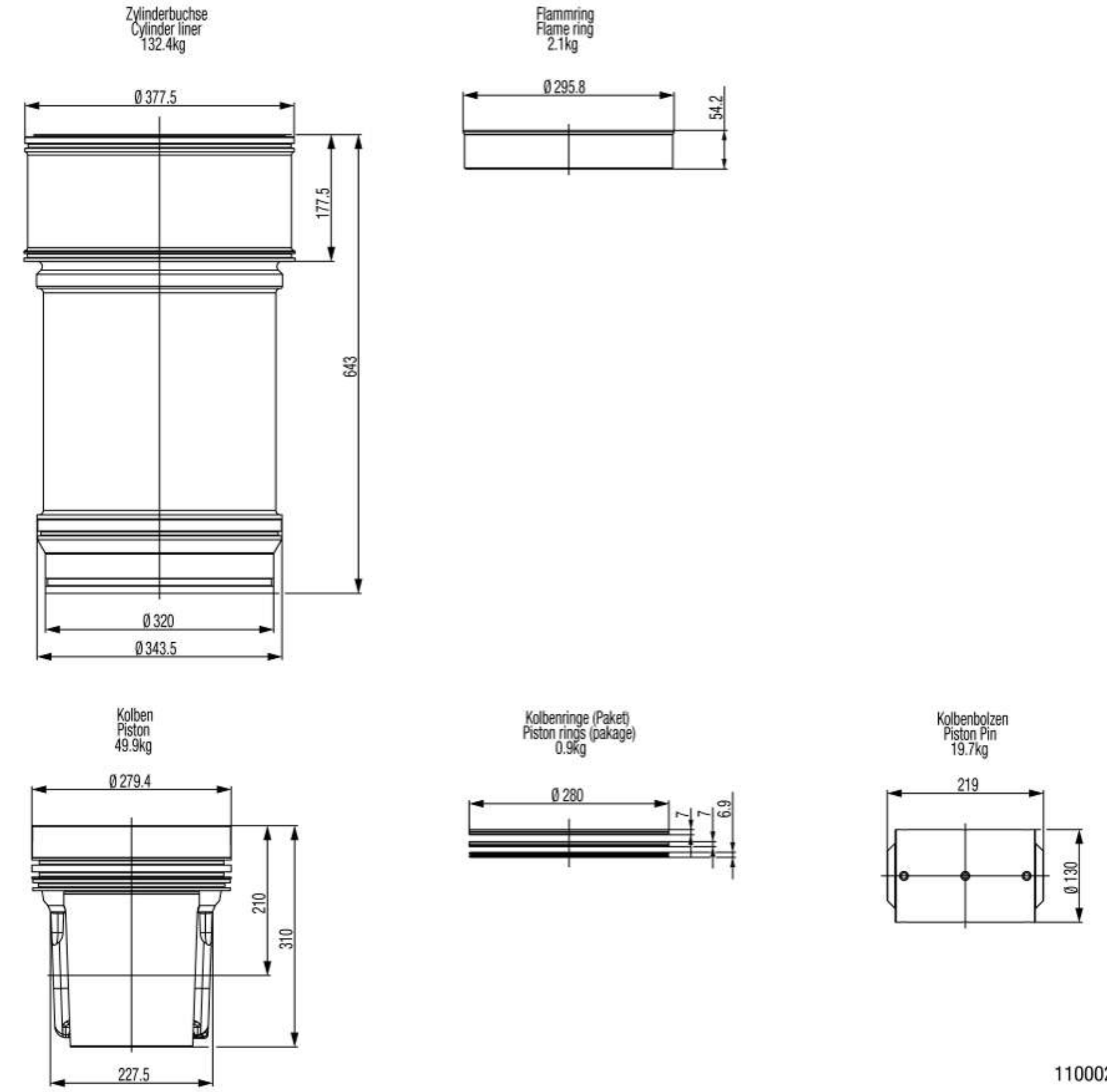

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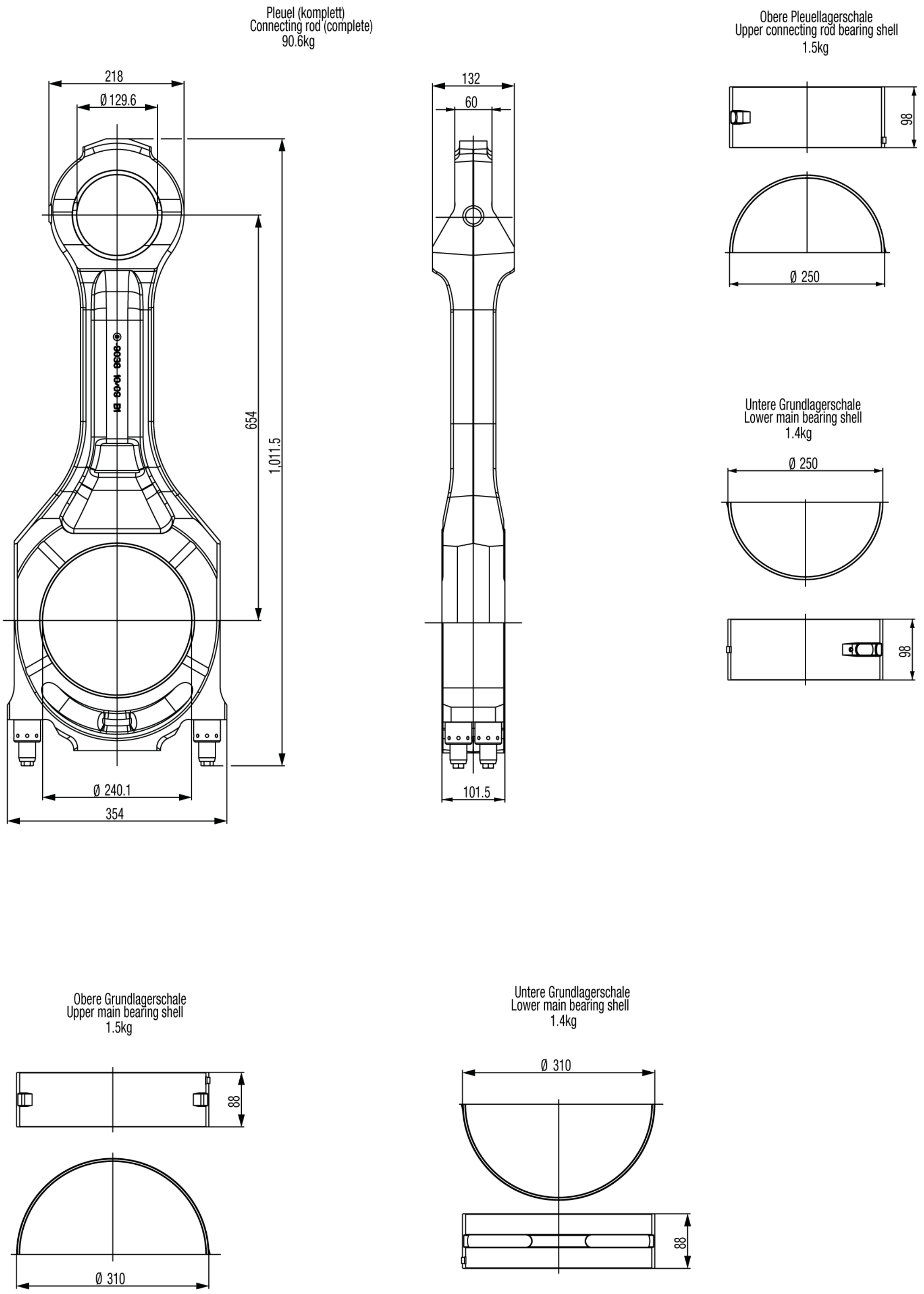

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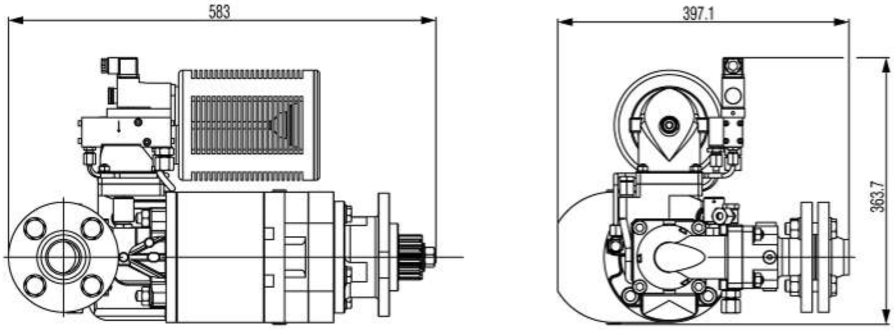
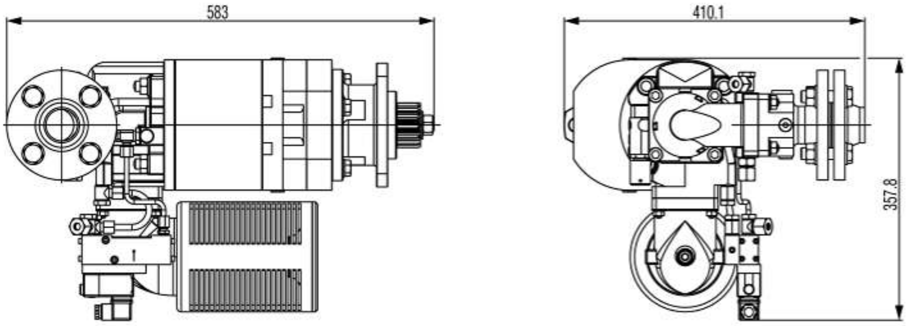
Druckluftanlasserfür Motorrechtslauf
Compressed air starter for engine clockwise rotation
39.5kg



Druckluftanlasserfür Motorlinkslauf
Compressed air starter for engine counter clockwise rotation
39.5kg



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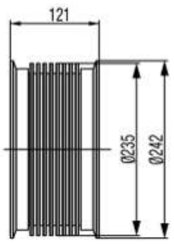
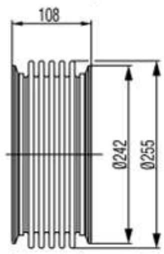
Abgaskompensator (Zwischen Leitungsteilstücken)
Exhaust gas expansion joint (between pipes)
5.0kg



Abgaskompensator (für STC-Leitung)
Exhaust gas expansion joint (in STC-pipe)
4.3kg



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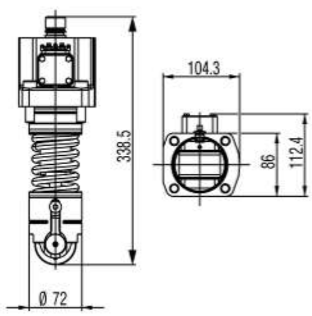
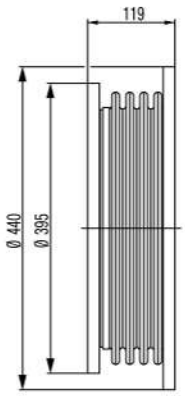
Hochdruckpumpe
High pressure pump
9.2kg



Abgaskompensator (vor Turbolader)
Exhaust gas expansion joint (before turbo charger)
31.8kg



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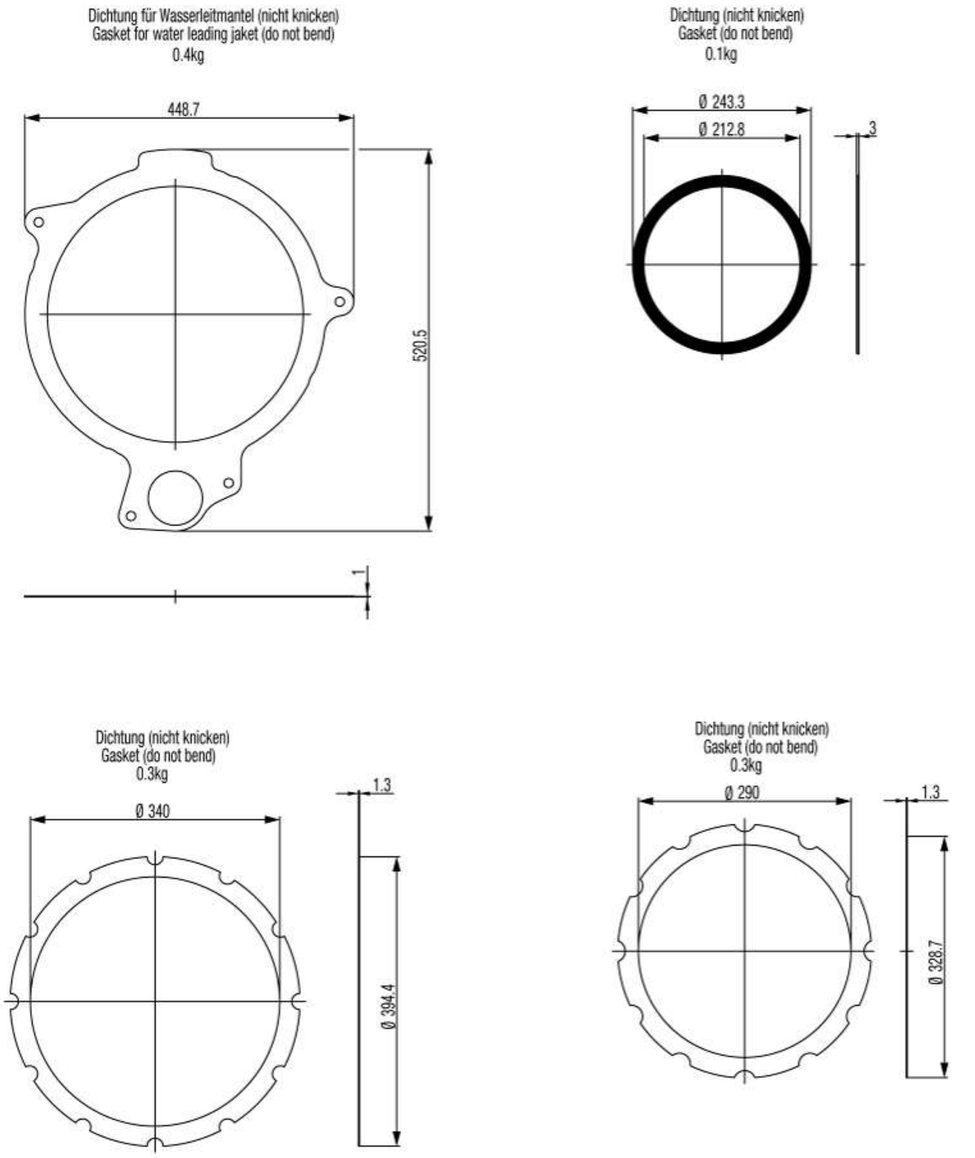

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6.1.9 Mechanical propulsion system arrangement

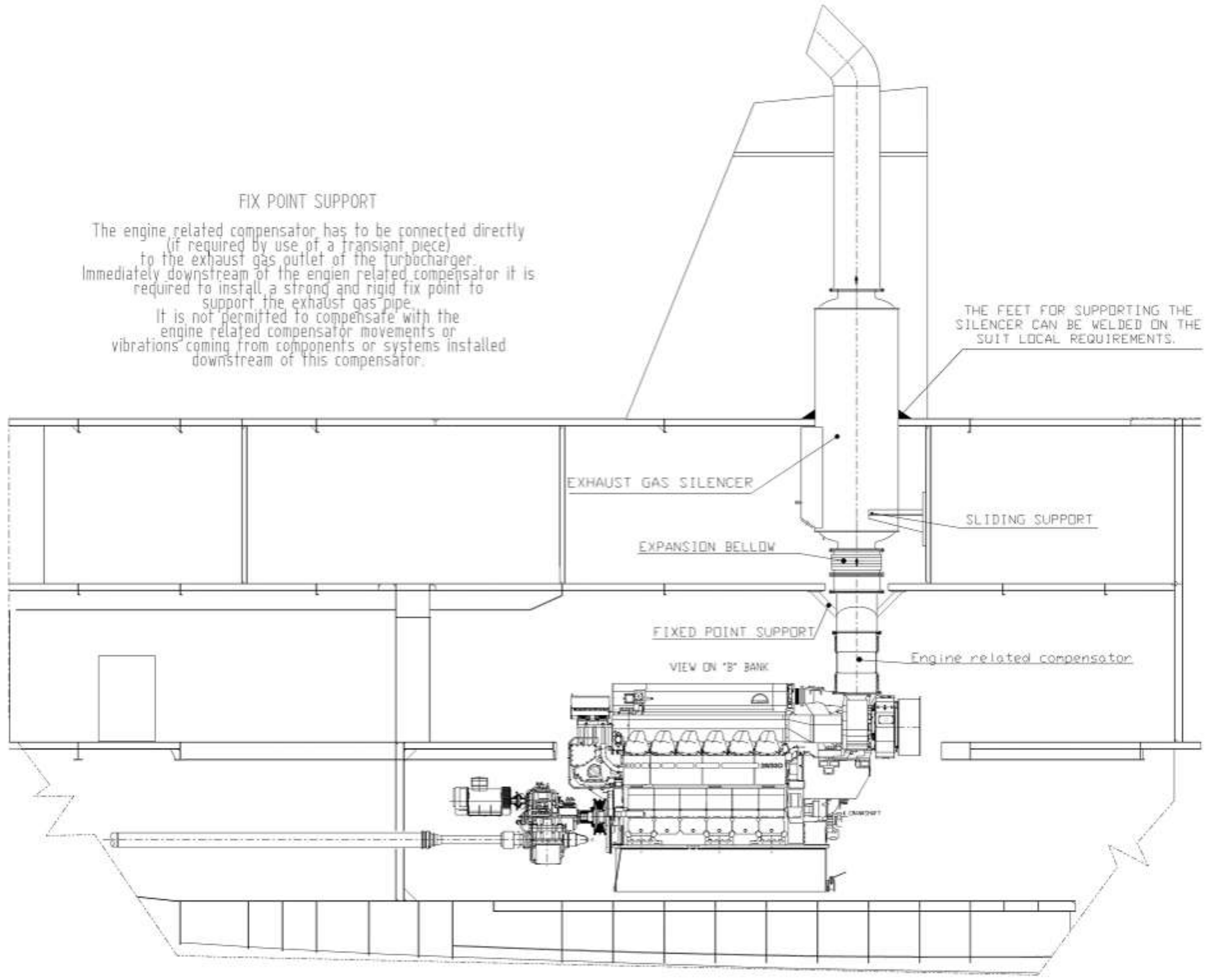

Figure 83: Example: Mechanical propulsion system arrangement – Exhaust gas section

Fix point support

The engine related compensator has to be connected directly to the exhaust gas outlet of the turbocharger (installation of compensator vertically or max. 45° position after turbocharger).

In case that the compensator cannot be directly connected to the exhaust gas outlet of the turbocharger, please contact MAN Energy Solutions.

Immediately downstream of the engine related compensator it is required to install a strong and rigid fix point to support the exhaust gas pipe.

It is not permitted to compensate with the engine related compensator movements or vibrations coming from components or systems installed downstream of this compensator.

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6.2 Exhaust gas ducting

6.2.1 Example: Ducting arrangement

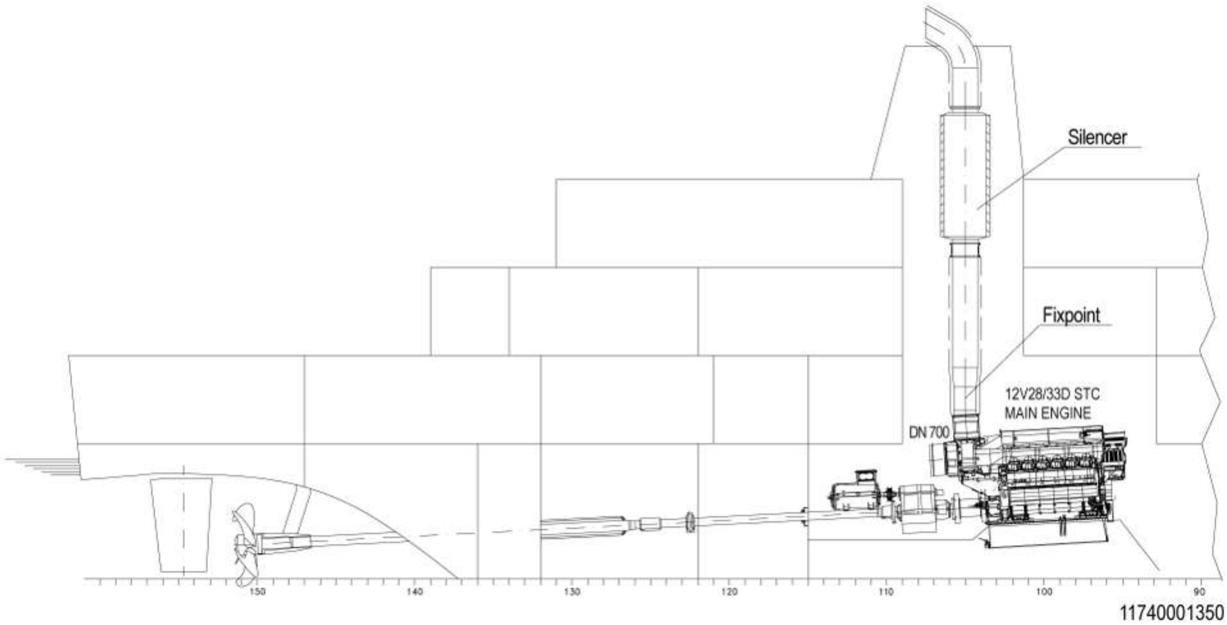

Figure 84: Example: Exhaust gas ducting arrangement

Fix point support

The engine related compensator has to be connected directly to the exhaust gas outlet of the turbocharger (installation of compensator vertically or max. 45° position after turbocharger). In case that the compensator cannot be directly connected to the exhaust gas outlet of the turbocharger, contact MAN Energy Solutions. Immediately downstream of the engine related compensator, it is required to install a strong and rigid fix point to support the exhaust gas pipe. It is not permitted to compensate with the engine related compensator movements or vibrations coming from components or systems installed downstream of this compensator.

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6.2.2 Position of the outlet casing of the turbocharger

Resiliently mounted engine

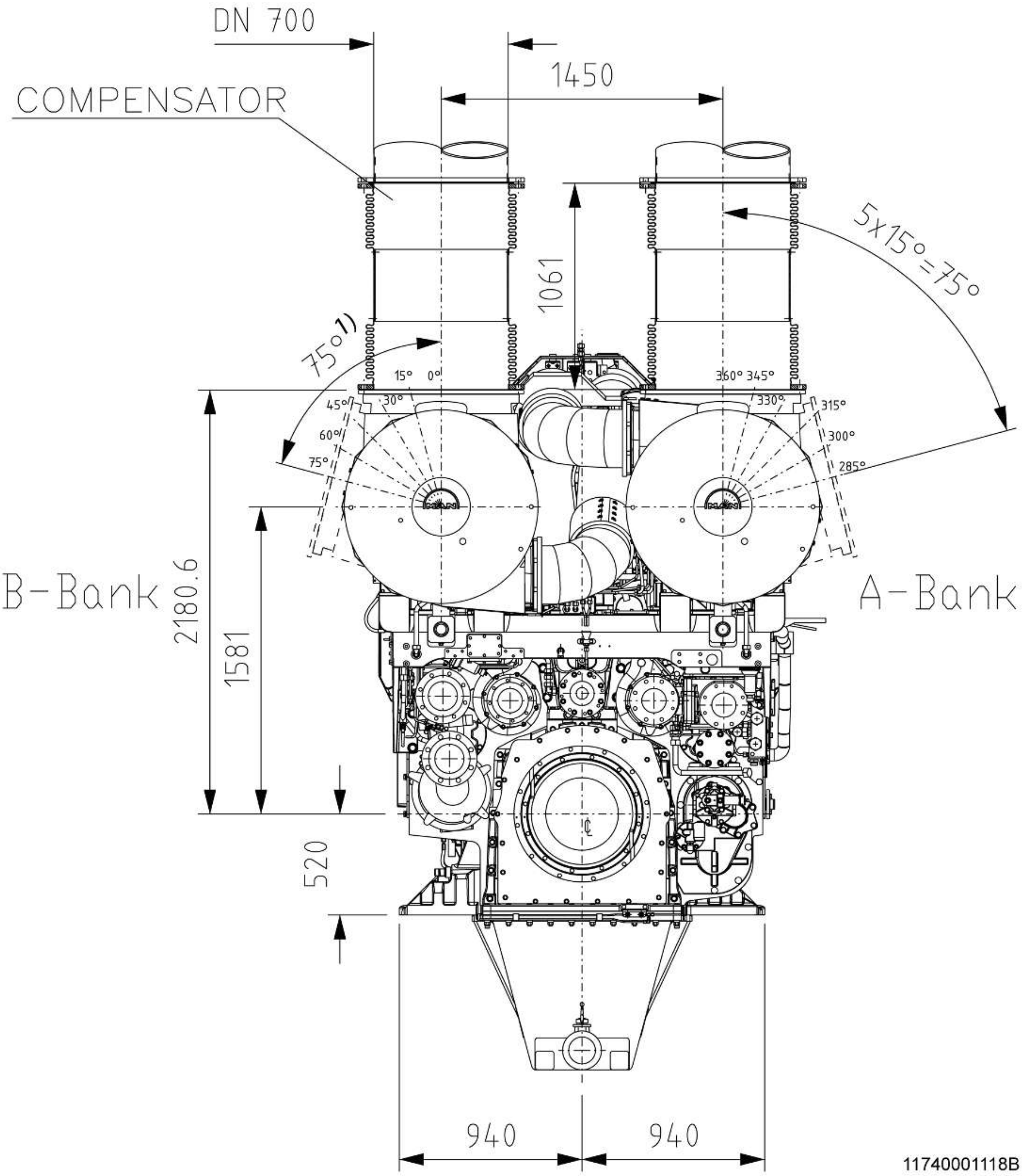

Figure 85: Possible positions of the outlet casing of the turbocharger – View on counter coupling side

Note:
1) In case of attached wastegate (valid for all Tier III applications) the position of the outlet casing of the turbocharger on B-Bank needs to be "0°".

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7 Annex

7.1 Safety instructions and necessary safety measures

The following list of basic safety instructions, in combination with further engine documentation like user manual and working instructions, should ensure a safe handling of the engine. Due to variations between specific plants, this list does not claim to be complete and may vary with regard to project-specific requirements.

7.1.1 General

There are risks at the interfaces of the engine, which have to be eliminated or minimised in the context of integrating the engine into the plant system. Responsible for this is the legal person which is responsible for the integration of the engine.

Following prerequisites need to be fulfilled:

- Layout, calculation, design and execution of the plant have to be state of the art.
- All relevant classification rules, regulations and laws are considered, evaluated and are included in the system planning.
- The project-specific requirements of MAN Energy Solutions regarding the engine and its connection to the plant are implemented.
- In principle, the more stringent requirements of a specific document is applied if its relevance is given for the plant.

7.1.2 Safety equipment and measures provided by plant-side

- Proper execution of the work

  Generally, it is necessary to ensure that all work is properly done according to the task trained and qualified personnel.

  All tools and equipment must be provided to ensure adequate accesible and safe execution of works in all life cycles of the plant.

  Special attention must be paid to the execution of the electrical equipment. By selection of suitable specialised companies and personnel, it has to be ensured that a faulty feeding of media, electric voltage and electric currents will be avoided.

- Fire protection

  A fire protection concept for the plant needs to be executed. All from safety considerations resulting necessary measures must be implemented. The specific remaining risks, e.g. the escape of flammable media from leaking connections, must be considered.

  Generally, any ignition sources, such as smoking or open fire in the maintenance and protection area of the engine is prohibited.

  Smoke detection systems and fire alarm systems have to be installed and in operation.

- Electrical safety

  Standards and legislations for electrical safety have to be followed. Suitable measures must be taken to avoid electrical short circuit, lethal electric shocks and plant specific topics as static charging of the piping through the media flow itself.

- Noise and vibration protection

  The noise emission of the engine must be considered early in the planning and design phase. A soundproofing or noise encapsulation could be necessary. The foundation must be suitable to withstand the engine vibration and torque fluctuations. The engine vibration may also have an impact on installations in the surrounding of the engine, as galleries for maintenance next to the engine. Vibrations act on the human body and may dependent on strength, frequency and duration harm health.
- Thermal hazards

  In workspaces and traffic areas hot surfaces must be isolated or covered, so that the surface temperatures comply with the limits by standards or legislations.
- Composition of the ground

  The ground, workspace, transport/traffic routes and storage areas have to be designed according to the physical and chemical characteristics of the excipients and supplies used in the plant.

  Safe work for maintenance and operational staff must always be possible.
- Adequate lighting

  Light sources for an adequate and sufficient lighting must be provided by plant-side. The current guidelines should be followed (100 Lux is recommended, see also DIN EN 1679-1).
- Working platforms/scaffolds

  For work on the engine working platforms/scaffolds must be provided and further safety precautions must be taken into consideration. Among other things, it must be possible to work secured by safety belts. Corresponding lifting points/devices have to be provided.
- Setting up storage areas

  Throughout the plant, suitable storage areas have to be determined for stabling of components and tools.

  It is important to ensure stability, carrying capacity and accessibility. The quality structure of the ground has to be considered (slip resistance, resistance against residual liquids of the stored components, consideration of the transport and traffic routes).
- Engine room ventilation

  An effective ventilation system has to be provided in the engine room to avoid endangering by contact or by inhalation of fluids, gases, vapours and dusts which could have harmful, toxic, corrosive and/or acid effects.
- Venting of crankcase and turbocharger

  The gases/vapours originating from crankcase and turbocharger are ignitable. It must be ensured that the gases/vapours will not be ignited by external sources. For multi-engine plants, each engine has to be ventilated separately. The engine ventilation of different engines must not be connected.

  In case of an installed suction system, it has to be ensured that it will not be stopped until at least 20 minutes after engine shutdown.
- Intake air filtering

  In case air intake is realised through piping and not by means of the turbocharger´s intake silencer, appropriate measures for air filtering must be provided. It must be ensured that particles exceeding 5 μm will be restrained by an air filtration system.

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- Quality of the intake air

  It has to be ensured that combustible media will not be sucked in by the engine.

  Intake air quality according to the section Specification of intake air (combustion air), Page 147 has to be guaranteed.
- Emergency stop system

  The emergency stop system requires special care during planning, realisation, commissioning and testing at site to avoid dangerous operating conditions. The assessment of the effects on other system components caused by an emergency stop of the engine must be carried out by plant-side.
- Fail-safe 24 V power supply

  Because engine control, alarm system and safety system are connected to a 24 V power supply this part of the plant has to be designed fail-safe to ensure a regular engine operation.
- Hazards by rotating parts/shafts

  Contact with rotating parts must be excluded by plant-side (e.g. free shaft end, flywheel, coupling).
- Safeguarding of the surrounding area of the flywheel

  The entire area of the flywheel has to be safeguarded by plant-side.

  Special care must be taken, inter alia, to prevent from: Ejection of parts, contact with moving machine parts and falling into the flywheel area.
- Securing of the engine´s turning gear

  The turning gear has to be equipped with an optical and acoustic warning device. When the turning gear is first activated, there has to be a certain delay between the emission of the warning device's signals and the start of the turning gear. The gear wheel of the turning gear has to be covered. The turning gear should be equipped with a remote control, allowing optimal positioning of the operator, overlooking the entire hazard area (a cable of approximately 20 m length is recommended). Unintentional engagement or start of the turning gear must be prevented reliably.

  It has to be prescribed in the form of a working instruction that:

  - The turning gear has to be operated by at least two persons.
  - The work area must be secured against unauthorised entry.
  - Only trained personnel is permissible to operate the turning gear.
- Securing of the starting air pipe

  To secure against unintentional restarting of the engine during maintenance work, a disconnection and depressurisation of the engine´s starting air system must be possible. A lockable starting air stop valve must be provided in the starting air pipe to the engine.
- Securing of the turbocharger rotor

  To secure against unintentional turning of the turbocharger rotor while maintenance work, it must be possible to prevent draught in the exhaust gas duct and, if necessary, to secure the rotor against rotation.
- Consideration of the blow-off zone of the crankcase cover´s relief valves

  During crankcase explosions, the resulting hot gases will be blown out of the crankcase through the relief valves. This must be considered in the overall planning.

- Installation of flexible connections

  For installation of flexible connections follow strictly the information given in the planning and final documentation and the manufacturer manual.

  Flexible connections may be sensitive to corrosive media. For cleaning only adequate cleaning agents must be used (see manufacturer manual). Substances containing chlorine or other halogens are generally not permissible.

  Flexible connections have to be checked regularly and replaced after any damage or lifetime given in manufacturer manual.

- Connection of exhaust port of the turbocharger to the exhaust gas system of the plant

  The connection between the exhaust port of the turbocharger and the exhaust gas system of the plant has to be executed gas tight and must be equipped with a fire proof insulation.

  The surface temperature of the fire insulation must not exceed 220 °C.

  In workspaces and traffic areas, a suitable contact protection has to be provided whose surface temperature must not exceed 60 °C.

  The connection has to be equipped with compensators for longitudinal expansion and axis displacement in consideration of the occurring vibrations (the flange of the turbocharger reaches temperatures of up to 450 °C).

- Media systems

  The stated media system pressures must be complied. It must be possible to close off each plant-side media system from the engine and to depressurise these closed off pipings at the engine. Safety devices in case of system over pressure must be provided.

- Drainable supplies and excipients

  Supply system and excipient system must be drainable and must be secured against unintentional recommissioning (EN 1037). Sufficient ventilation at the filling, emptying and ventilation points must be ensured. The residual quantities which must be emptied have to be collected and disposed of properly.

- Spray guard has to be ensured for liquids possibly leaking from the flanges of the plant´s piping system. The emerging media must be drained off and collected safely.

- Charge air blow-off (if applied)

  The piping must be executed by plant-side and must be suitably isolated. In workspaces and traffic areas, a suitable contact protection has to be provided whose surface temperature must not exceed 60 °C.

  The compressed air is blown-off either outside the vessel or into the engine room. In both cases, installing a silencer after blow-off valve is recommended. If the blow-off valve is located upstream of the charge air cooler, air temperature can rise up to 200 °C. It is recommended to blow-off hot air outside the plant.

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- Signs
  - Following figure shows exemplarily the risks in the area of a combustion engine. This may vary slightly for the specific engine.

    This warning sign has to be mounted clearly visibly at the engine as well as at all entrances to the engine room.

Figure 86: Warning sign E11.48991-1108

  - Prohibited area signs.

    Depending on the application, it is possible that specific operating ranges of the engine must be prohibited.

    In these cases, the signs will be delivered together with the engine, which have to be mounted clearly visibly on places at the engine which allow intervention of the engine operation.

- Optical and acoustic warning device

  Communication in the engine room may be impaired by noise. Acoustic warning signals might not be heard. Therefore it is necessary to check where at the plant optical warning signals (e.g. flash lamp) should be provided.

  In any case, optical and acoustic warning devices are necessary while using the turning gear and while starting/stopping the engine.

7.2 Programme for Factory Acceptance Test (FAT)

Please see overleaf!

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According to MAN ES instruction I0189EN

<table>
<tr><th rowspan="2"></th><th rowspan="2">Test points</th><th colspan="4">Factory Acceptance Test (FAT)</th></tr>
<tr><th colspan="2">Pre- Tests</th><th colspan="2">Demonstration tests</th></tr>
<tr><td rowspan="8">Diesel engines</td><td>100 %</td><td colspan="2">-</td><td colspan="2">60min*</td></tr>
<tr><td>110 %</td><td colspan="2">-</td><td colspan="2">M</td></tr>
<tr><td>85% (nominal continuous cruise power)**</td><td colspan="2">-</td><td colspan="2">M</td></tr>
<tr><td>Minimum speed at full constant torque - (mechanical pump drive only)</td><td colspan="2">-</td><td colspan="2">M</td></tr>
<tr><td>75%</td><td colspan="2">M</td><td colspan="2">-</td></tr>
<tr><td>50%</td><td colspan="2">M</td><td colspan="2">-</td></tr>
<tr><td>25%</td><td colspan="2">M</td><td colspan="2">-</td></tr>
<tr><td>Idle*** (only engines driving generators)</td><td colspan="2">M</td><td colspan="2">-</td></tr>
<tr><td rowspan="8">Dual Fuel (DF-) engines</td><td></td><td>Gas mode</td><td>Diesel mode</td><td>Gas mode</td><td>Diesel mode</td></tr>
<tr><td>100%</td><td>-</td><td>-</td><td>30min*</td><td>30min*</td></tr>
<tr><td>110%</td><td>-</td><td>-</td><td>M</td><td>M</td></tr>
<tr><td>85% (nominal continuous cruise power)**</td><td>-</td><td>-</td><td>M</td><td>M</td></tr>
<tr><td>75%</td><td>M</td><td>M</td><td>-</td><td>-</td></tr>
<tr><td>50%</td><td>M</td><td>M</td><td>-</td><td>-</td></tr>
<tr><td>25%</td><td>-</td><td>M</td><td>-</td><td>-</td></tr>
<tr><td>Idle*** (only engines driving generators)</td><td>-</td><td>M</td><td>-</td><td>-</td></tr>
<tr><td colspan="6">* 2 readings have to be done at an interval of 30 min. On DF-engines only one reading in Diesel and one in Gas-mode.
** Replaces the 90% load point of classification rules.
M = Minimum 15 minutes and steady-state conditions reached (acc. Instruction conducting a measurement of MAN-ES)
Idle*** Nominal engine speed</td></tr>
</table>

Figure 87: Engine performance check – Table 1

Content of MAN ES instruction I0189EN

1 Purpose

This instruction specifies tests and checks at Factory Acceptance Test (FAT) of marine engines produced by MAN ES. The following tests and checks are based on the rules and regulations of the classification societies as well as the ISO standard 3046 and 15550 in its version when this instruction has been published and have to be done to fulfill the requirements of a standard FAT.

2 Scope

This instruction is valid for all employees of companies and business units mentioned below, and is binding for all employees, which are affected by this instruction within the scope of their duties. The superior has to ensure that the employees know and observe the determinations of this instruction. It is valid for Marine application of Medium-, and high speed engines with nominal speed up to 1000rpm from MAN ES

Valid for the following companies: MAN Energy Solutions SE

Valid for the following locations: Augsburg; Frederikshavn; Saint-Nazaire; Aurangabad

Valid for the following business units: SBU E

Valid for the following departments: PEAA; PECFS; IN-ES; FR-EE

3 Terms and definitions

Term	Definition
FAT	Factory Acceptance Test
CPP	Controllable Pitch Propeller
FPP	Fixed Pitch Propeller
IACS	International Association of Classification Societies

4 Engine testing

The complete test of a medium speed engine on test bed needs several days. Therefore, the test is separated in two periods, the pre-test and the demonstration test. The pre-test is an internal test, which is partially to be done in presence of the classification society if required. The classification society has to be informed about pre-test date in time. The demonstration test is to prove the engine quality and observance of contracts in presence of classification society and customer. For each engine, the FAT procedure for the demonstration test has to be generated based on the tests and checks under point 4.2 of this instruction and contractual agreement with the customer. Additional test requests of classification society have to be considered in the FAT Procedure. Under the following points the standard scope of pre- test and demonstration test is specified.

4.1 Pre- Tests (internal tests)

The pre-test is divided in tests and checks to be done prior first engine start and checks during engine operation. Main focus is to detect and fix quality issues and adjusting the engine before starting the demonstration tests.

4.1.1 Main tests and checks before first engine fire

- check crank web deflection after alignment of the engine (results to be stated in FAT protocol)
- flushing of all media systems (lube oil, fuel oil, water)

Figure 88: Engine performance check – Part 1

- visual check of engine including cam- and crank shaft housing (before first engine start and after running in procedure)
- test of alarm and safety system. The requirements of classification society and engine manufacturer specification (check of safety functions F0387EN) have to be fulfilled. The test results have to be stated in the FAT protocol.

4.1.2 Function- and performance check

Limits and requirements for each test can be found in project guides, rules of classification societies and internal specifications of MAN-ES. The internal testing of engines is generally specified in the guideline for engine testing of MAN ES (F0387EN). The following points represent the minimum of tests to be done to ensure the functionality and performance of the engine.

- Starting tests and calculation of start air consumption in gas and diesel operation. To be done at least once per shipset for each accordingly engine type. The results have to be stated in each FAT protocol for reference.
- Thermographic inspection (according working instruction W0202EN - Surface temperature examination on engines and components for marine application) of engine insulation for confirmation of SOLAS surface temperature requirements (only one engine per ship set). Results to be stated in FAT-protocol only by request of classification society
- Noise level and vibration measurement according ISO 10816-6 and manufacturer Guidelines (only by contractual agreement). Results have to be stated in FAT protocol
- Integration test on one engine per ship test. Test program is engine type specific and appointed before engine test. Results to be stated in FAT protocol
- Performance Check: The engine performance is to be tested on the load points listed in table 1. Further information can be found under point 4.3 of this instruction. Performance readings have to be stated in FAT protocol
- Governor test (load drop). Rapid load drop from full load to zero load. Results have to be stated in FAT protocol
- Check of engine attached flaps and valves (blow off, blow by, waste gate, jet assist)
- Visual check for leakages on fuel oil, lube oil and water systems on the engine (check of connecting flanges, screw connections and inspection drillings)
- Surge test of turbocharger on new engine configurations during the turbocharger-matching process. Results not to be stated in FAT protocol.

4.2 Demonstration tests

The demonstration test is a final quality approval of the engine before its delivery in presence of the classification and the customer by request. The demonstration test has to be done according to the engine specific FAT-procedure (demonstration test), which has to be sent out to customer and classification society one week prior demonstration test date. The scope of the FAT-procedure (demonstration test) is based on the following points:

1) One change over from diesel to gas operation and from gas to diesel operation at lowest and highest possible load (only on Dual Fuel engines)

2) One gas start (only on Dual fuel engines with gas start functionality)

3) Performance Check: The engine performance is to be tested on the load points listed in table 1. Further information can be found under point 4.3 of this instruction

4) Visual check for leakages on fuel oil, lube oil and water systems on the engine (check of connecting flanges, screw connections and inspection drillings)

5) Visual check of crank case, camshaft, rollers and gear drive after engine stop

6) Additional inspections only by contractual agreement with customer, request of classification society or by indication of irregularities of the operating values.

Figure 89: Engine performance check – Part 2

7) Cylinder liner inspection (only engines ≥ 32cm liner diameter) of one cylinder liner per engine by borescope. In case of additional inspection (e.g. dismantling of piston) the borescope inspection is omitted. Evaluation of the cylinder liner surface according Q10.09121-3325 “Visual test Cylinder liner inspection after running-in”.

Optional tests and inspections only by request of classification society, contractual agreement with customer or by indication of irregularities.

4.3 Engine Performance Check

The engine performance check has to be done on all load points listed in table 1. Engines for generator application (incl. diesel-electric dredger), diesel-mechanic dredger appl. with propulsion function and CPP-application have to be tested on constant speed curve. Engines for diesel-mechanic propulsion application with fixed pitch propeller, mechanical pump drive only (dredger) and water jet application have to be tested on recommended FPP-curve of MAN-ES. Engines with ECOMAP function to be tested on standard full load map only. Additional mappings can be tested according contractual agreement with customer. Between pre-tests and demonstration tests minor adjustments for engine optimization are allowed. These adjustments must not lead to an excess of the engine specifications in any load point and have to be stated in the FAT-protocol. The performance parameter to be measured are specified in ISO 15550. For all measurement devices the calibration tolerances of this standard are to be fulfilled and the given calibration intervals of the specific manufacturers have to be considered. All performance data of the engines have to be within the specification limits (Documents: Quality criteria of engine) of the engine manufacturer. The performance readings have to be conducted according to the specified instructions of the engine manufacturer (Instruction I0158: Guideline for conducting a measurement at the test beds).

See Table 1: Engine Performance check

4.4 After engine operation

After finishing the test program, the engine has to be conserved according to working instruction W0176EN. The fuel delivery system has to be adjusted that overload power cannot be delivered on board on diesel-mechanic drives. Engines driving electrical generators have to be adjusted that 110% rated power is capable.

4.5 FAT - protocol

All operations, events, findings, measures and agreements have to be documented in one engine specific FAT protocol of MAN-ES. The final FAT-protocol has to be reviewed by the surveyor of the classification society and a copy has to be handed out to the customer. The FAT protocol contains the following informations:

- Cover sheet
- List of contents
- Signature sheet with representatives
- Operating record for all engine operation points
- Fuel oil analysis
- Line records for governor test or load jump tests
- Check of safety functions of engine and test bed before first start of the engine
- Visual inspection sheet with conducted checks and documentation of engine conditions
- Additional remarks
- Crank web deflection measurement results
- Software versions of engine control and safety system and emission relevant identification number
- Information about engine equipment

Figure 90: Engine performance check – Part 3

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- Starting test incl. air consumption calculation of reference engine
- NOx- emission trend line of reference engine
- Characteristic NOx emission Map (only for variable speed)
- Information about firing pressure indication measurement
- Operating data sheet to estimate the engine output
- Calibration reports of fuel oil and fuel gas measurement devices and power/torque measurement device

Figure 91: Engine performance check – Part 4

7.3 Engine running-in

Prerequisites

Engines require a running-in period in case one of the following conditions applies:

- When put into operation on site, if
  - after test run the pistons or bearings were dismantled for inspection or
  - the engine was partially or fully dismantled for transport.
- After fitting new drive train components, such as cylinder liners, pistons, piston rings, crankshaft bearings, big-end bearings and piston pin bearings.
- After the fitting of used bearing shells.
- After long-term low-load operation (> 500 operating hours).

Supplementary information

Operating Instructions

During the running-in procedure the unevenness of the piston-ring surfaces and cylinder contact surfaces is removed. The running-in period is completed once the first piston ring perfectly seals the combustion chamber. i.e. the first piston ring should show an evenly worn contact surface. If the engine is subjected to higher loads, prior to having been running-in, then the hot exhaust gases will pass between the piston rings and the contact surfaces of the cylinder. The oil film will be destroyed in such locations. The result is material damage (e.g. burn marks) on the contact surface of the piston rings and the cylinder liner. Later, this may result in increased engine wear and high lube oil consumption.

The time until the running-in procedure is completed is determined by the properties and quality of the surfaces of the cylinder liner, the quality of the fuel and lube oil, as well as by the load of the engine and speed. The running-in periods indicated in following figures may therefore only be regarded as approximate values.

Operating media

The running-in period may be carried out preferably using MGO (DMA, DFA).

The fuel used must meet the quality standards see section Specification for engine supplies, Page 135 and the design of the fuel system.

For the running-in of gas four-stroke engines it is best to use the gas which is to be used later in operation.

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Dual fuel engines are run in using liquid fuel mode with the fuel intended as the pilot fuel.

Lube oil

The running-in lube oil must match the quality standards, with regard to the fuel quality.

Engine running-in

Cylinder lubrication (optional)

The cylinder lubrication must be switched to "Running In" mode during completion of the running-in procedure. This is done at the control cabinet or at the control panel (under "Manual Operation"). This ensures that the cylinder lubrication is already activated over the whole load range when the engine starts. The running-in process of the piston rings and pistons benefits from the increased supply of oil. Cylinder lubrication must be returned to "Normal Mode" once the running-in period has been completed.

Checks

Inspections of the bearing temperature and crankcase must be conducted during the running-in period:

- The first inspection must take place after 10 minutes of operation at minimum speed.
- An inspection must take place after operation at full load respectively after operational output level has been reached.

The bearing temperatures (camshaft bearings, big-end and main bearings) must be determined in comparison with adjoining bearings. For this purpose an electrical sensor thermometer may be used as a measuring device.

At 85 % load and at 100 % load with nominal speed, the operating data (ignition pressures, exhaust gas temperatures, charge air pressures, etc.) must be measured and compared with the acceptance report.

Standard running-in programme

Dependent on the application the running-in programme can be derived from the figures in paragraph Diagram(s) of standard running-in, Page 246. During the entire running-in period, the engine output has to be within the marked output range. Critical speed ranges are thus avoided.

Running-in during commissioning on site

Most four-stroke engines are subjected to a test run at the manufacturer´s premises. As such, the engine has usually been run in. Nonetheless, after installation in the final location, another running-in period is required if the pistons or bearings were disassembled for inspection after the test run, or if the engine was partially or fully disassembled for transport.

Running-in after fitting new drive train components

If during revision work the cylinder liners, pistons, or piston rings are replaced, a new running-in period is required. A running-in period is also required if the piston rings are replaced in only one piston. The running-in period must be conducted according to following figures or according to the associated explanations.

The cylinder liner may be re-honed according to working instructions 050.05, if it is not replaced. A transportable honing machine may be requested from one of our service and support locations.

Running-in after refitting used or new bearing shells (crankshaft, connecting rod and piston pin bearings)

When used bearing shells are reused, or when new bearing shells are installed, these bearings have to be run in. The running-in period should be 3 to 5 hours under progressive loads, applied in stages. The instructions in the preceding text segments, particularly the ones regarding the "Inspections", and following figures must be observed.

Idling at higher speeds for long periods of operation should be avoided if at all possible.

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Running-in after low-load operation

Continuous operation in the low-load range may result in substantial internal pollution of the engine. Residue from fuel and lube oil combustion may cause deposits on the top-land ring of the piston exposed to combustion, in the piston ring channels as well as in the inlet channels. Moreover, it is possible that the charge air and exhaust pipes, the charge air cooler, the turbocharger and the exhaust gas tank may be polluted with oil.

Since the piston rings have adapted themselves to the cylinder liner according to the running load, increased wear resulting from quick acceleration and possibly with other engine trouble (leaking piston rings, piston wear) should be expected.

Therefore, after a longer period of low-load operation (≥ 500 hours of operation) a running-in period should be performed again, depending on the power, according to following figures.

Also for instruction see section Low-load operation, Page 41.

Note:
For further information, you may contact the MAN Energy Solutions customer service or the customer service of the licensee.

Diagram of standard running-in

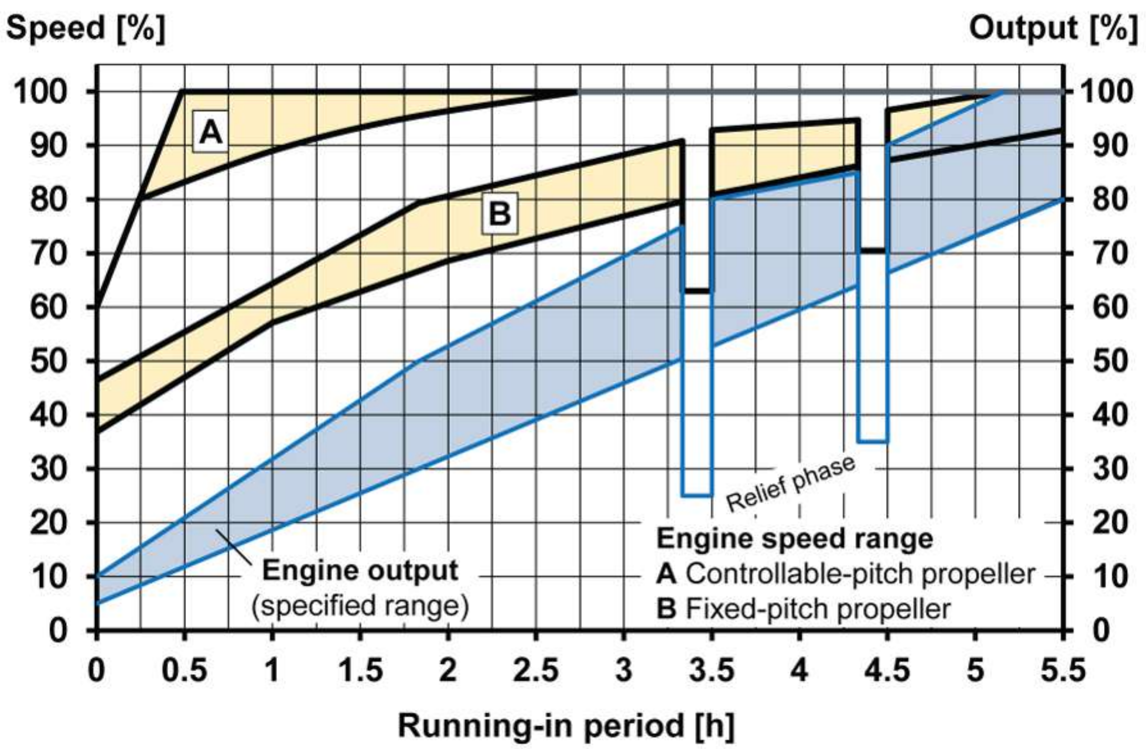

Figure 92: Standard running-in programme for marine engines (variable speed)

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7.4 Definitions

Auxiliary GenSet/auxiliary generator operation

A generator is driven by the engine, hereby the engine is operated at constant speed. The generator supplies the electrical power not for the main drive, but for supply systems of the vessel.

Load profile with focus between 40 % and 80 % load.

Engine´s certification for compliance with the NO_x limits according D2 Test cycle. See within section Engine ratings (output) for different applications, Page 32 if the engine is released for this kind of application and the corresponding available output $P_{Application}$.

Blackout

The classification societies define blackout on board ships as a loss of the main source of electrical power resulting in the main and auxiliary machinery to be out of operation and at the same time all necessary alternative energies (e.g. start air, battery electricity) for starting the engines are available.

Dead ship condition

The classification societies define dead ship condition as follows:

- The main propulsion plant, boilers and auxiliary machinery are not in operation due to the loss of the main source of electrical power.
- In restoring propulsion, the stored energy for starting the propulsion plant, the main source of electrical power and other essential auxiliary machinery is assumed not to be available.
- It is assumed that means are available to start the emergency generators at all times. These are used to restore the propulsion.

Designation of engine sides

- Coupling side, CS

  The coupling side is the main engine output side and is the side to which the propeller, the alternator or other working machine is coupled.
- Free engine end/counter coupling side, CCS

  The free engine end is the front face of the engine opposite the coupling side.

Designation of cylinders

The cylinders are numbered in sequence, from the coupling side, 1, 2, 3 etc. In V engines, looking on the coupling side, the left hand bank of cylinders is designated A, and the right hand bank is designated B. Accordingly, the cylinders are referred to as A1-A2-A3 or B1-B2-B3, etc.

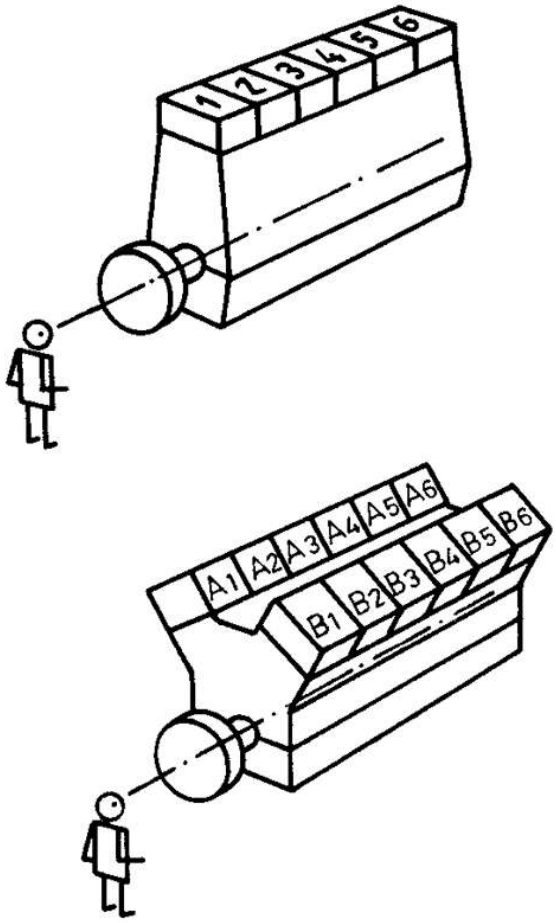

Figure 93: Designation of cylinders

Direction of rotation

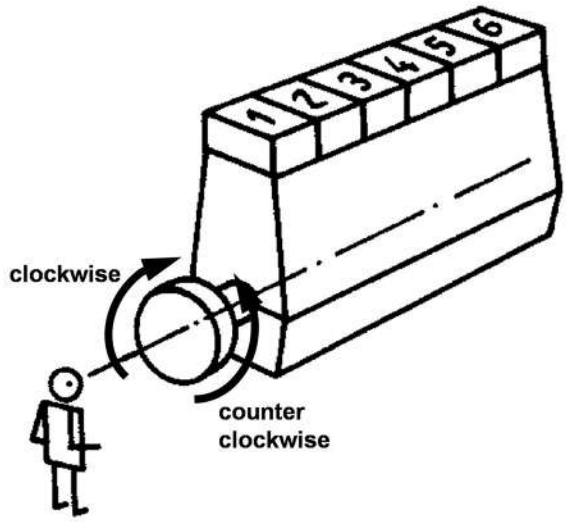

Figure 94: Designation: Direction of rotation seen from flywheel end

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Electric propulsion

The generator being driven by the engine supplies electrical power to drive an electric motor. The power of the electric motor is used to drive a controllable pitch or fixed pitch propeller, pods, thrusters, etc.

Load profile with focus between 80 % and 95 % load.

Engine´s certification for compliance with the NO_x limits according E2 Test cycle. See within section Engine ratings (output) for different applications, Page 32 if the engine is released for this kind of application and the corresponding available output $P_{Application}$.

GenSet

The term "GenSet" is used, if engine and electrical alternator are mounted together on a common base frame and form a single piece of equipment.

Gross calorific value (GCV)

This value supposes that the water of combustion is entirely condensed and that the heat contained in the water vapor is recovered.

Mechanical propulsion with controllable pitch propeller (CPP)

A propeller with adjustable blades is driven by the engine.

The CPP´s pitch can be adjusted to absorb all the power that the engine is capable of producing at nearly any rotational speed.

Load profile with focus between 80 % and 95 % load.

Engine´s certification for compliance with the NO_x limits according E2 Test cycle. See within section Engine ratings (output) for different applications, Page 32 if the engine is released for this kind of application and the corresponding available output $P_{Application}$.

Mechanical propulsion with fixed pitch propeller (FPP)

A fixed pitch propeller is driven by the engine. The FPP is always working very close to the theoretical propeller curve (power input ~ n^3). A higher torque in comparison to the CPP even at low rotational speed is present.

Load profile with focus between 80 % and 95 % load.

Engine´s certification for compliance with the NO_x limits according E3 Test cycle. See within section Engine ratings (output) for different applications, Page 32 if the engine is released for this kind of application and the corresponding available output $P_{Application}$.

Multi-engine propulsion plant

In a multi-engine propulsion plant at least two or more engines are available for propulsion.

Net calorific value (NCV)

This value supposes that the products of combustion contain the water vapor and that the heat in the water vapor is not recovered.

Offshore application

Offshore construction and offshore drilling place high requirements regarding the engine´s acceleration and load application behaviour. Higher requirements exist also regarding the permissible engine´s inclination.

Due to the wide range of possible requirements such as flag state regulations, fire fighting items, redundancy, inclinations and dynamic positioning modes all project requirements need to be clarified at an early stage.

Output

- ISO standard output (as specified in DIN ISO 3046-1)

  Maximum continuous rating of the engine at nominal speed under ISO conditions, provided that maintenance is carried out as specified.
- Operating-standard-output (as specified in DIN ISO 3046-1)

  Maximum continuous rating of the engine at nominal speed taking in account the kind of application and the local ambient conditions, provided that maintenance is carried out as specified. For marine applications this is stated on the type plate of the engine.
- Fuel stop power (as specified in DIN ISO 3046-1)

  Fuel stop power defines the maximum rating of the engine theoretical possible, if the maximum possible fuel amount is used (blocking limit).
- Rated power (in accordance to rules of DNV)

  Maximum possible continuous power at rated speed and at defined ambient conditions, provided that maintenances carried out as specified.
- Output explanation

  Power of the engine at distinct speed and distinct torque.
- 100 % output

  100 % output is equal to the rated power only at rated speed. 100 % output of the engine can be reached at lower speed also if the torque is increased.
- Nominal output

  = rated power.
- MCR

  Maximum continuous rating.
- ECR

  Economic continuous rating = output of the engine with the lowest fuel consumption.

Overload power (at FAT or SAT/sea trial)

Only if required by rules of classification societies, it is admitted to operate the engine at 110 % of rated power for a maximum of 1 h in total as part of the FAT or SAT/sea trial and in addition a maximum of 1 h in total as part of the comissioning of the plant. Engine operation has to be done under supervision of trained MAN Energy Solutions personal.

Single-engine propulsion plant

In a single-engine propulsion plant only one single-engine is available for propulsion.

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Suction dredger application (mechanical drive of pumps)

For direct drive of a suction dredger pump by the engine via gear box the engine speed is directly influenced by the load on the suction pump.

The power demand of the dredge pump needs to be adapted to the operating range of the engine, particularly while start-up operation. Load profile with focus between 80 % and 100 % load.

Engine´s certification for compliance with the NO_x limits according C1 Test cycle. See within section Engine ratings (output) for different applications, Page 32 if the engine is released for this kind of application and the corresponding available output $P_{Application}$.

Water jet application

A marine propulsion system that creates a jet of water that propels the vessel. The water jet propulsion is always working close to the theoretical propeller curve (power input ~ n^3). With regard to its requirements the water jet propulsion is identical to the mechanical propulsion with FPP.

Load profile with focus between 80 % and 95 % load.

Engine´s certification for compliance with the NO_x limits according E3 Test cycle. See within section Engine ratings (output) for different applications, Page 32 if the engine is released for this kind of application and the corresponding available output $P_{Application}$.

Weight definitions for SCR

- Handling weight (reactor only):

  This is the "net weight" of the reactor without catalysts, relevant for transport, logistics, etc.
- Operational weight (with catalysts):

  That's the weight of the reactor in operation, that is equipped with a layer of catalyst and the second layer empty – as reserve.
- Maximum weight structurally:

  This is relevant for the static planning purposes maximum weight, that is equipped with two layers catalysts.

7.5 Abbreviations

Abbreviation	Explanation
BN	Base number
CBM	Condition based maintenance
CCM	Crankcase monitoring system
CCS	Counter coupling side
CS	Coupling side
ECR	Economic continuous rating
EDS	Engine diagnostics system
GCV	Gross calorific value
GVU	Gas Valve Unit
HFO	Heavy fuel oil
HT CW	High temperature cooling water
LT CW	Low temperature cooling water
MCR	Maximum continuous rating
MDO	Marine diesel oil
MGO	Marine gas oil
MN	Methane number
NCV	Net calorific value
OMD	Oil mist detection
SaCoS	Safety and control system
SAT	Site acceptance test
SECA	Sulphur emission control area
SP	Sealed plunger
STC	Sequential turbocharging
TAN	Total acid number
TBO	Time between overhaul
TC	Turbocharger
TC	Temperature controller
ULSHFO	Ultra low sulphur heavy fuel oil

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7.6 Symbols

Note:
The symbols shown should only be seen as examples and can differ from the symbols in the diagrams.

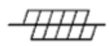
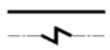
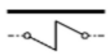
DESIGNATION	SYMBOL	CODE	DESIGNATION	SYMBOL	CODE
MAIN CIRCUIT (FLOW DIRECTION SHOWN)			FLEXIBLE PIPE CONNECTION		EH
SECONDARY CIRCUIT			EXPANSION BELLOWS (STEEL)		EB
CONTROL AIR PIPE, PULSE LINE, ELECTRICAL LINE	-------		2/2 (TWO-PORT, TWO-POSITION) DIRECTIONAL CONTROL SOLENOID-OPERATED VALVE		
CAPILLARY TUBE (WITH THERMOSTATIC REGULATORS)	—x—x—x—		3/2 (THREE-PORT, TWO-POSITION) DIRECTIONAL CONTROL VALVE		
LAGGED PIPE			GENERAL SHUT-OFF VALVE		V
STEAM HEATED PIPE (HEAVY FUEL OIL OPERATION, MAIN CIRCUIT)			GATE VALVE		GV
ELECTRICALLY HEATED PIPE (HEAVY FUEL OIL OPERATION, MAIN CIRCUIT)			STRAIGHT-WAY VALVE		V

Figure 95: Symbols used in functional and pipeline diagrams 1

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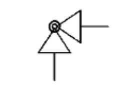
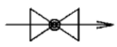
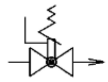
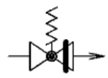
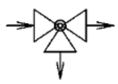
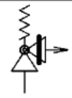
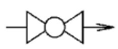
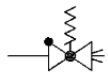
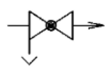
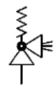
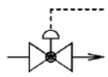
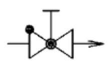
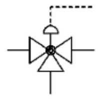
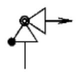
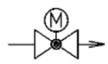
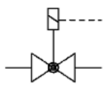
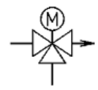
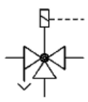
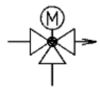
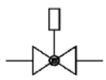
DESIGNATION	SYMBOL	CODE	DESIGNATION	SYMBOL	CODE
ANGLE VALVE		V	GENERAL SHUT-OFF VALVE, MOTOR DRIVEN		MOV
VALVE WITH MINIMUM FLOW		V	QUICK ACTING SHUT-OFF VALVE		V
GENERAL THREE-WAY VALVE		CK	SAFETY VALVE (STRAIGHT WAY)		PSV
THREE-WAY VALVE		V	SAFETY VALVE (ANGLE)		PSV
COCK		CK	BACK PRESSURE VALVE (STRAIGHT WAY)		BPV
SHUT-OFF VALVE WITH VENTILATION		V	BACK PRESSURE VALVE (ANGLE)		BPV
NON-RETURN VALVE		NRV	DIAPHRAGM VALVE (PNEUMATICALLY-OPERATED)		DV
NON-RETURN VALVE (CAN BE SHUT OFF)		NRV	DIAPHRAGM SHUTTLE VALVE		DV
ANGLE NON-RETURN VALVE		NRV	MOTORISED VALVE		MOV
SOLENOID-OPERATED VALVE		SOV	GENERAL THREE-WAY VALVE, MOTOR DRIVEN		MOV
SOLENOID-OPERATED VALVE (AUTOMATIC VENT)		SOV	MOTORISED SHUTTLE VALVE		MOV
GENERAL SHUT-OFF VALVE, GENERAL DRIVE		V	GENERAL SHUT-OFF VALVE WITH TRANSATORY MOTON VALVE		V

Figure 96: Symbols used in functional and pipeline diagrams 2

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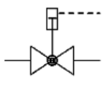
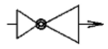
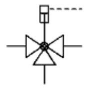
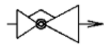
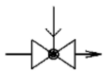
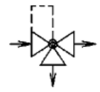
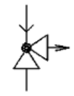
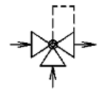
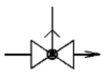
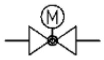
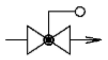
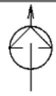
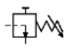
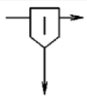
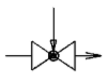
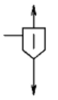
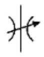
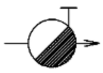
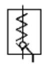
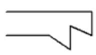
DESIGNATION	SYMBOL	CODE	DESIGNATION	SYMBOL	CODE
PISTON-OPERATED VALVE		POV	PRESSURE REDUCING VALVE		PCV
SHUTTLE VALVE WITH DRIVE PISTON		POV	PRESSURE CONTROL VALVE		PCV
SELF-CLOSING VALVE (STRAIGHT WAY)		QV	TEMPERATURE REGULATOR (SELF-ACTUATING DISTRIBUTION VALVE)		TCV
SELF-CLOSING VALVE (ANGLE)		QV	TEMPERATURE REGULATOR (SELF-ACTUIATING MIXING VALVE)		TCV
AUTOMATIC OPENING VALVE		V	TEMPERATURE CONTROL VALVE, ELECTRICALLY CONTROLLED		TCV
FLOAT VALVE		LOV	VANE HAND PUMP		P
SPRING-LOADED ADJUSTABLE PRESSURE LIMITING VALVE		PCV	WATER TRAP		TR
SAFETY VALVE		PSV	OIL TRAP		TR
FLOW-CONTROL VALVE, ADJUSTABLE			CONDENSATE TRAP, CAN BE SHUT OFF		TR
NON-RETURN VALVE, UNIDIRECTIONAL FLOW			ACCUMULATOR, GAS CYLINDER		
NON-RETURN VALVE WITH SPRING, NORMALLY CLOSED			OILER		
PILOTED NON-RETURN VALVE WITH SPRING, FLOW IN BOTH DIRECTIONS POSSIBLE DUE TO CONTROL PRESSURE			HEATING COIL (STEAM OR WATER)		H

Figure 97: Symbols used in functional and pipeline diagrams 3

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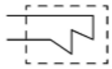
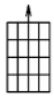
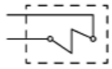
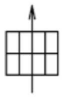
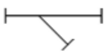
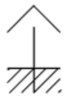
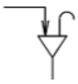
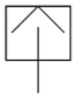
DESIGNATION	SYMBOL	CODE	DESIGNATION	SYMBOL	CODE
PLUG-IN HEATER (STEAM OR WATER)		H	SUCTION STRAINER		STR
PLUG-IN HEATER (ELECTRIC)		H	SUCTION BELL		SB
BACKFLOW PREVENTER (DISCOTYP)		NRV	FLAME TRAP		GS
NON-RETURN FLAP		NRF	VENT		
STRAINER		STR	VENT WITH FLAME TRAP		
FUNNEL (OPEN)		FU	VENT, OUTBOARD ABOVE DECK		
FUNNEL (CLOSED)		FU	VENT CAP		
OVERFLOW CHECK TANK, DISCHARGE FUNNEL		FU	Withdrawal point for fuel oil sample		

Figure 98: Symbols used in functional and pipeline diagrams 4

7.7 Preservation, packaging, storage

7.7.1 General

Introduction

Engines are internally and externally treated with preservation agent before delivery. The type of preservation and packaging must be adjusted to:

- Means of transport
- Type and period of storage

Improper storage may cause severe damage to the product.

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Packaging and preservation of engine

The type of packaging depends on:

- The requirements imposed with transport and storage period
- Climatic and environmental effects
- Which preservative agents are used

As standard, the preservation and packaging of an engine is designed for a storage period of 12 month and for sea transport.

Note:
The packaging must be protected against damage. It must only be removed when:

- A follow-up preservation is required
- The packaged material is to be used
- Shortly before operating the engine

The condition of the packaging must be checked regularly and repaired in case of damage. Especially a VCI packaging can only provide a proper corrosion protection if it is intact and completely closed.

In addition, the engine interiors are protected by vapour phase corrosion protection. Inner compartments must not be opened while transportation and storage. Otherwise, a re-preservation of the opened compartment will be required. The inner corrosion protection can remain inside the engine.

If bare metal surfaces get exposed for example, by disassembly of the coupling device, the unprotected metal must be treated with agent "f" according to the list of recommended anti-corrosion agents (https://www.man-es.com/documentation-/corrosion-protection).

This especially applies to the tie rod where the lifting device has been mounted.

In case of an installed intake air filter there is a steel plate cover or similar around the filter fleece, which has to be used during transportation and storage.

Note:
During storage and in case of a follow-up preservation the crankshaft must not be turned. If the crankshaft is turned, usually for the first time after preservation this will be done during commissioning, the preservation is partially removed. If the engine is to be stored again for a period thereafter, then adequate re-preservation is required.

Preservation and packaging of loose equipment

Unless stated otherwise in the customer specification, the preservation and packaging of loose equipment and engine parts which are dismantled for transport, must be carried out such that:

- The preservation and packaging of loose equipment and engine parts will not be damaged during transport
- The corrosion protection remains fully intact for at least 12 months when stored in a roofed dry room

Transport

Transport and packaging of the engine, loose equipment and engine parts must be coordinated.

After transportation, any damage to the corrosion protection and packaging must be rectified, and/or MAN Energy Solutions must be notified immediately.

7.7.2 Storage location and duration

Storage location

Storage location of engine

As standard, the engine is packaged and preserved for outdoor storage.

The storage location must meet the following requirements:

- Engine is stored on firm and dry ground.
- Packaging material does not absorb any moisture from the ground.
- Engine is accessible for visual checks.

Storage location of loose equipment

Loose equipment must always be stored in a roofed dry room.

The storage location must meet the following requirements:

- Parts are protected against environmental effects and the elements.
- The room must be well ventilated.
- Parts are stored on firm and dry ground.
- Packaging material does not absorb any moisture from the ground.
- Parts cannot be damaged.
- Parts are accessible for visual inspection.
- An allocation of loose equipment to the order or requisition must be possible at all times.

Note:
Packaging made of or including VCI paper or VCI film must not be opened or must be closed immediately after opening.

Storage conditions

In general the following requirements must be met:

- Minimum ambient temperature: –10 °C
- Maximum ambient temperature: +60 °C
- Relative humidity: < 60 %

In case these conditions cannot be met, contact MAN Energy Solutions for clarification.

Storage period

The permissible storage period of 12 months must not be exceeded.

Before the maximum storage period is reached:

- Check the condition of the stored engine and loose equipment.
- Renew the preservation or install the engine or components at their intended location.

7.7.3 Follow-up preservation when preservation period is exceeded

A follow-up preservation must be performed before the maximum storage period has elapsed, i.e. generally after 12 months.

Request assistance by authorised personnel of MAN Energy Solutions.

7.7.4 Removal of corrosion protection

Packaging, corrosion protection and silica gel must only be removed from the engine immediately before commissioning the engine in its installation location.

Remove outer protective layers, any foreign body from engine or component (VCI packs, blanking covers, etc.), check engine and components for damage and corrosion, perform corrective measures, if required.

The preservation agents sprayed inside the engine do not require any special attention. They will be washed off by engine oil during subsequent engine operation.

Contact MAN Energy Solutions if you have any questions.

7.8 Engine colour

Engine standard colour according RAL colour table is RAL 7040 Window grey. Other colours on request.

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