49/60

Project Guide – Marine

Four-stroke diesel engine

compliant with IMO Tier II

Revision..... **12.2025/3.0**

2025-12-03 - 3.0

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Four-stroke diesel engine

49/60 IMO Tier II Project Guide – Marine

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1 Introduction

1.1 Medium-speed propulsion engine programme

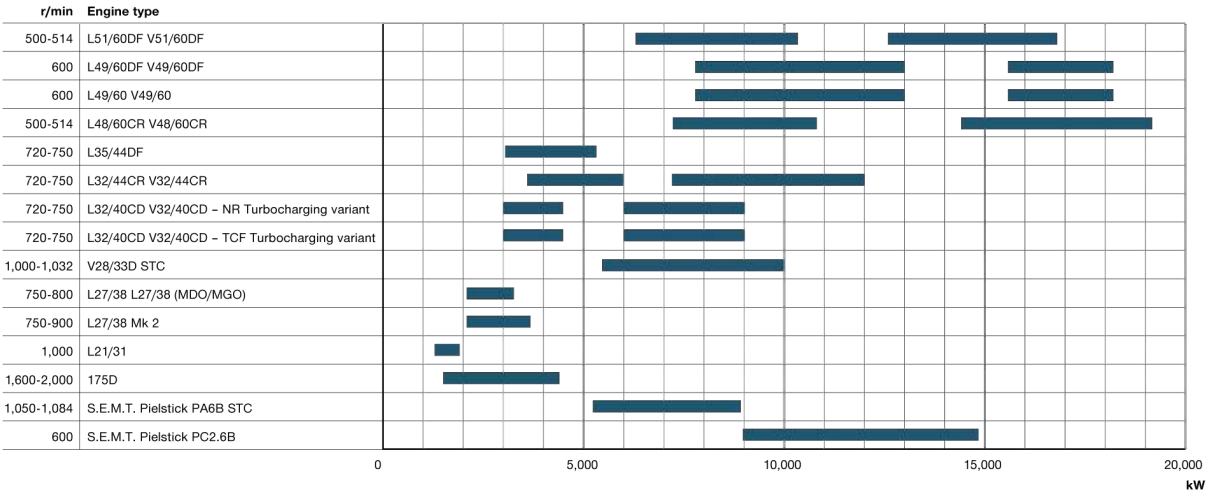


Figure 1: Everllence engine programme

1.2 Engine description IMO Tier II

General

The four-stroke medium-speed 49/60 engine represents the latest state-of-the-art product of Everllence.

- 600 rpm nominal speed for a wide range of applications
- 1,300 kW/cyl. nominal output makes this the most powerful engine in the segment

To reach the highest power output at the lowest fuel oil consumption and to comply with the latest exhaust emission regulations, the engine combines the most advanced technologies:

- Next generation of common rail main injection system
- Compact, high-efficient two-stage turbocharging system
- 3-position VVT
- SaCoS 5000 for improved engine control, including cyber security

Fuels

The 49/60 can be operated with DMA (Marine Gas Oil), DMB (Marine Diesel Oil) and, depending on the configuration with residual fuel (HFO) up to a viscosity of 700 mm^2/s (cSt) at 50°C. The fuel system is designed for fuel temperatures up to 150°C and starting and stopping the engine during HFO operation. Note the special sections concerning synthetic fuels, FAME and residual marine fuels containing FAME.

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Operation with FAME - transesterified biofuel (optional)

In case of intended use of FAME fuels according to EN-14214 or ASTM D6751 and according to the additional requirements of Everllence (see paragraph FAME (fatty acid methyl ester) additive of 0.5 to 100% (DFA), Page 248 in section Diesel fuel (DMA, DFA) specification, Page 245).

- Special considerations for fuel handling, storage and fuel preparation to be considered
- To be clarified, if special equipment on engine or within plant is needed
- Change of engine performance to be clarified

Contact Everllence if this option is needed.

Operation with synthetic fuels (optional)

Synthetic fuels such as HVO, BTL, CTL, GTL according to DIN EN 15940 differ in the procedure of production, but are identical in their fuel properties and need to comply to the requirements of Everllence (see paragraph "Synthetic fuels (DIN EN 15940)" in section Diesel fuel (DMA, DFA) specification, Page 245).

In case of intended use of these synthetic diesel fuels:

- Special considerations for fuel handling, storage and fuel preparation have to be considered
- To be clarified, if special equipment on engine or within plant is needed
- Change of engine performance to be clarified

Due to the lower volumetric heat value than DMA in case of fixed engine setting a minor increase of the specific fuel consumption ($\Delta be_{42700,ISO}$ <+1,5%, and a slight decrease of NO_X-emissions is expected.

Contact Everllence if this option is needed.

Fuels for pilot fuel system

The pilot fuel system has been designed for operation with marine gas oil (DMA, DFA) as specified in section Specifications of diesel fuel used as pilot oil, Page 245.

Note the special sections concerning synthetic fuels, FAME and pilot fuels containing FAME.

NO_x emission with liquid fuels - IMO 2008 versus IMO 2028[1)]

The 49/60 complies with IMO Tier II NO_X emission limits and in connection with an appropriate Everllence SCR exhaust gas aftertreatment system also with IMO Tier III NO_X limitations prescribed for ECA´s.

Parent engines certified before January 1st 2028 and member engines of such groups built before January 1st 2030 have to be in line with IMO 2008 regulations.

Engines that are certified or manufactured[1)] after these dates must comply with the requirements of the IMO NO_X Technical Code 2028. Among other changes, this updated regulation introduces more stringent limits on NO_X emissions compared to previous standards. As a result, engine setting is adapted accordingly.

[1)] Decisive is the issue date of the EIAPP certificate.

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Soot

Soot emissions during operation on liquid fuel are in range > 10% load well below the limit of visibility.

Common rail injection

The 49/60 injection system uses the latest Everllence` common rail technology which allows different settings of injection timing, duration and pressure. This technical advantage allows to achieve favourable CO_2 and emissions results of the 49/60 on its operating profile. Due to constant development of our safety concept, the redundant high-pressure pumps guarantee limited continued operation of the engine even if there is high-pressure pump malfunction.

Boost injection (liquid fuel operation)

A special, patented feature for common rail engines, called boost injection, is integrated in the control system. It is able to detect a load increase at the engine at early stage and to improve the load response of the engine significantly by activation of a boost injection in the common rail control.

Common rail pilot fuel injection system

The 49/60 employs advanced pilot fuel injection strategy, creating new degrees of freedom in terms of engine adaptation flexibility.

Safety concept of common rail system

The common rail system comprises an intelligent designed safety concept:

- All high-pressure pipes are screened or have a double wall design.
- Flow limiting valves at each cylinder prevent uncontrolled injection.
- Redundant high-pressure pumps guarantee continued operation of the engine even in the event of high-pressure pump malfunction.
- Redundant twin type pressure sensors and speed sensors assure that the engine stays operational even in the event of failure of one of these elements. In case of single-engine plants the ECUs (Electronic Control Units) are in double type as well.

Two-stage turbocharging

For two-stage turbocharging, two different types of Everllence´ most efficient turbochargers are placed upstream from the engine and these are connected in series. The result: The engine is supplied with a significantly higher charge air pressure while turbocharger efficiency is considerably increased. The higher pressure ratio also improves the efficient application of Miller valve timing.

Miller valve timing

To reduce the temperature peaks which promote the formation of NO_x, early closure of the inlet valve causes the charge air to expand and cool before start of compression. The resulting reduction in combustion temperature reduces NO_x emissions.

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VVT – Variable valve timing with 3 positions

Variable valve timing enables variations in the opening and closing of the inlet valves. VVT is an enabling technology of variable Miller valve timing. A strong Miller effect under high load operation results in an improvement in the NO_x-SFOC trade-off. At low load the Miller valve timings are reduced to attain higher combustion temperatures and thus lower soot emissions.

A patented design has been invented for 3 possible VVT positions.

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 L engines.

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 for example, a fire fighting pump. This option is available for L engines. Hereby the maximum available output of the engine has to be considered.

Electronics – SaCoS 5000

The 49/60 is equipped with the classification society compliant safety and control system SaCoS 5000. SaCoS 5000 combines all functions of modern engine management into one complete system.

SaCoS 5000 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 Everllence´ safety philosophy and the combination of both will increase the possibility to early detect a possible engine failure and prevent subsequent component damage.
- Propulsion Optimisation Interface

  The Propulsion Optimisation Interface serves with engine parameters and at an early stage gives information about upcoming limitation. This allows a smooth and look ahead control of the CPP propulsion system.

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Cyber security

The marine certified safety and control system SaCoS 5000 is compliant to the IACS UR E27 requirements for cyber resilience on-board equipment, which will get mandatory for ships contracted for construction or after 1st July 2024. A confirmation of compliance will be given by the main classification societies, ensuring the utmost benefit for our customers.

PrimeServ Assist - CEON (optional feature)

Everllence PrimeServ Assist is our solution to support our customers in monitoring and assessing the condition of their equipment. Equipment connected to our Everllence CEON cloud platform is monitored by Everllence's advanced analytics running in the Everllence CEON platform to detect degradations and optimisation potentials. Everllence experts analyse root causes and define mitigating actions based on this data.

Benefits:

- Availability: Ensuring 24/7 engine availability by monitoring operating values and pro-actively advising on operating tasks.
- Efficiency: Optimize equipment performance and reduce fuel consumption and emissions by detecting degradations of performance influencing parameters over time.
- Maintenance: Reduce maintenance cost by evaluating aging of individual components over time and pro-active advising counter measures.

Core technologies in-house

As well as its expertise in engine design, development and manufacture, Everllence is also a leader in the engineering and manufacturing of the key technologies which determine the economic and ecological performance of a diesel engine and constitute the best offer for our customers:

- High-efficiency turbochargers
- Advanced-electronic fuel injection equipment
- Electronic hardware and software for engine control, monitoring and diagnosis
- High-performance exhaust gas after treatment systems

Our impressive array of computer aided design tools and one of the engine industry’s largest, best-equipped foundries allow us to decisively shorten product development and application engineering processes. Our mastery of these engine technologies is the firm foundation for:

- Low emissions
- Low-operating costs
- Low-life cycle costs
- Long-service life

Everllence total system competence

As the leading engine builder in the marine sector, Everllence has unrestricted access to the know-how required to design and execute highly efficient SCR systems for both new engines and retrofit applications on engines already in the field.

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In Everllence´ case, this clear “Advantage” over other supplier of SCR systems is further multiplied by our status as a global leader in the design and manufacture of turbochargers and fuel injection systems for large engines. Everllence and its PrimeServ after-sales organisation is ideally placed to supply and service the optimum SCR system for your engine.

1.3 Engine overview

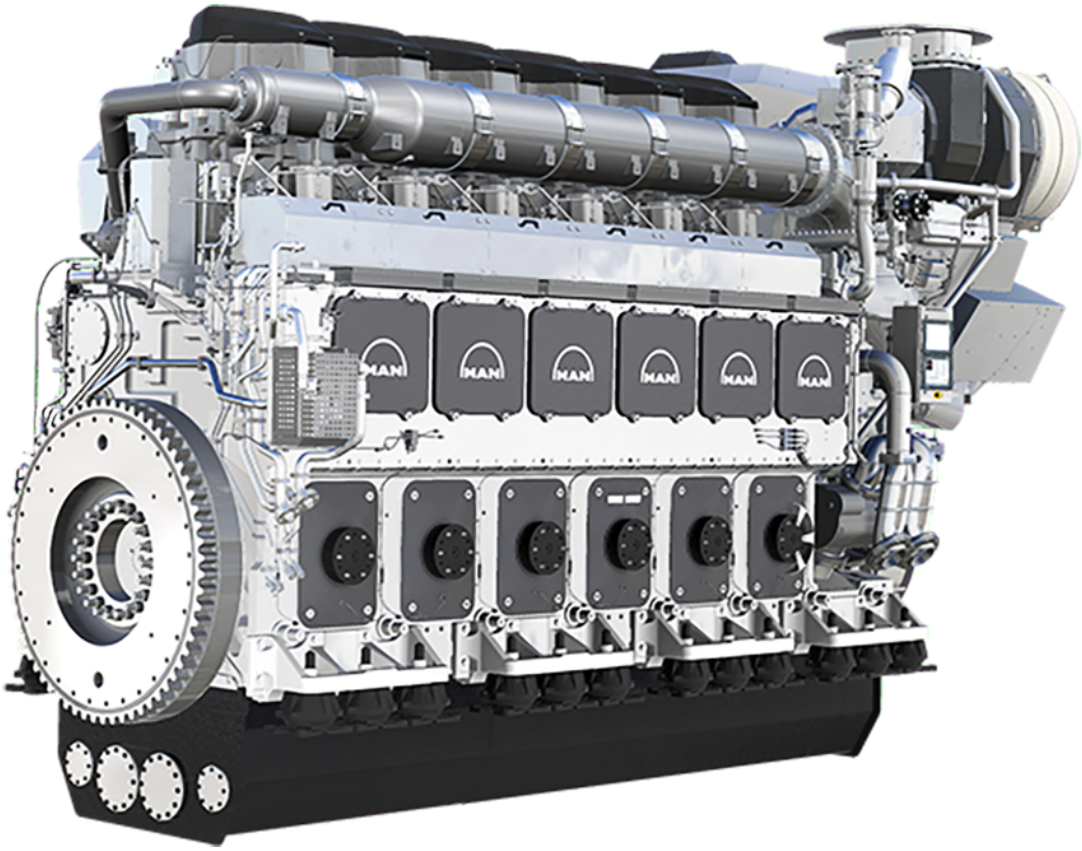


Figure 2: Engine overview, L engine perspective left front view

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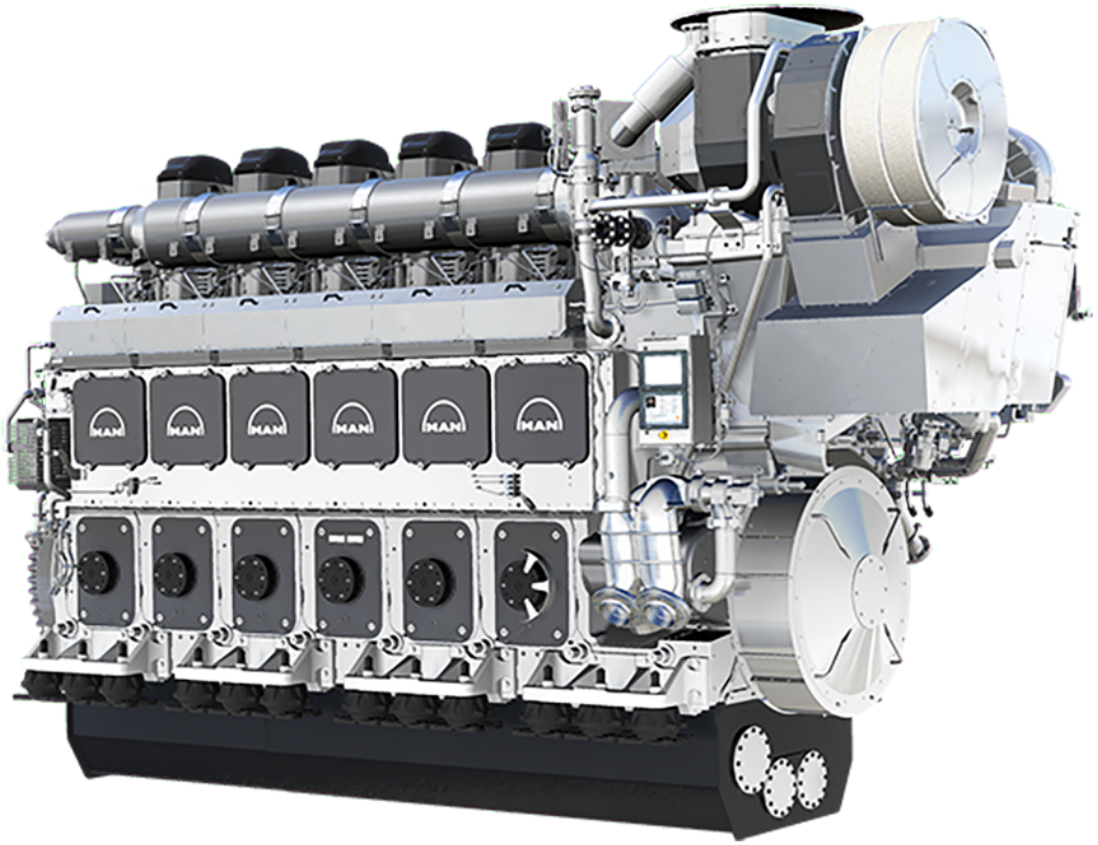


Figure 3: Engine overview, L engine perspective left rear view

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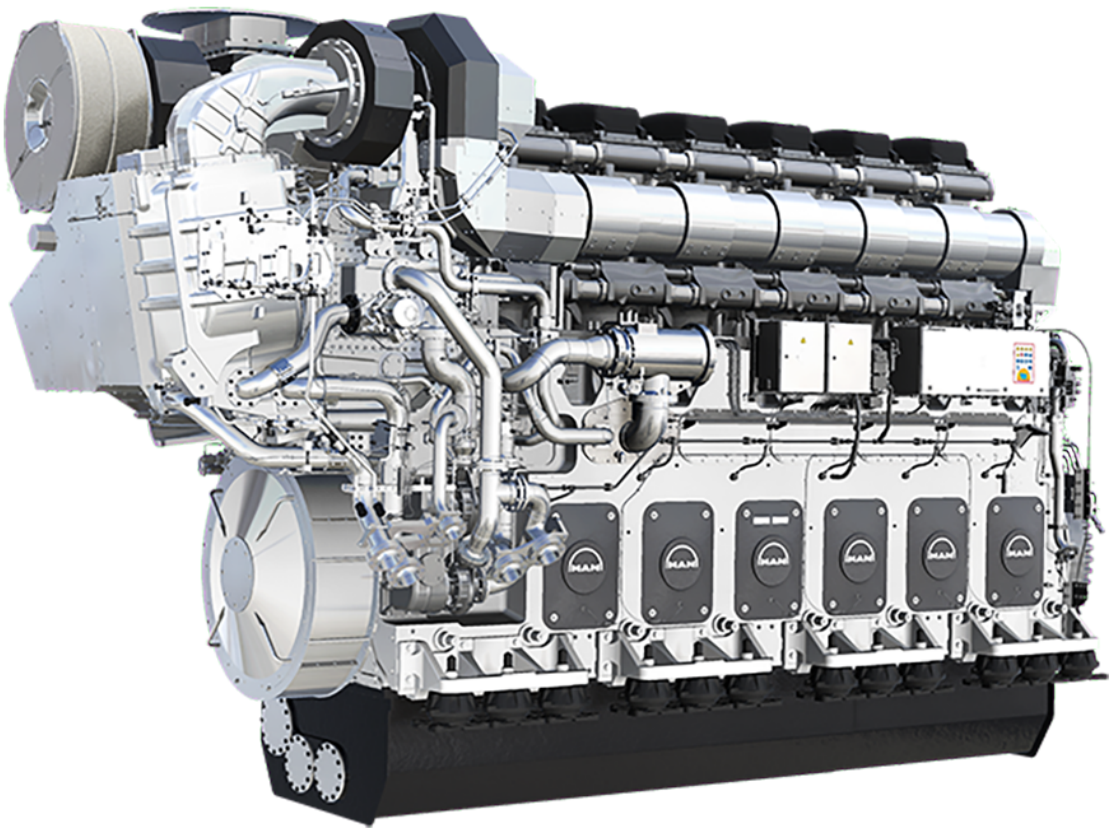


Figure 4: Engine overview, L engine perspective right rear view

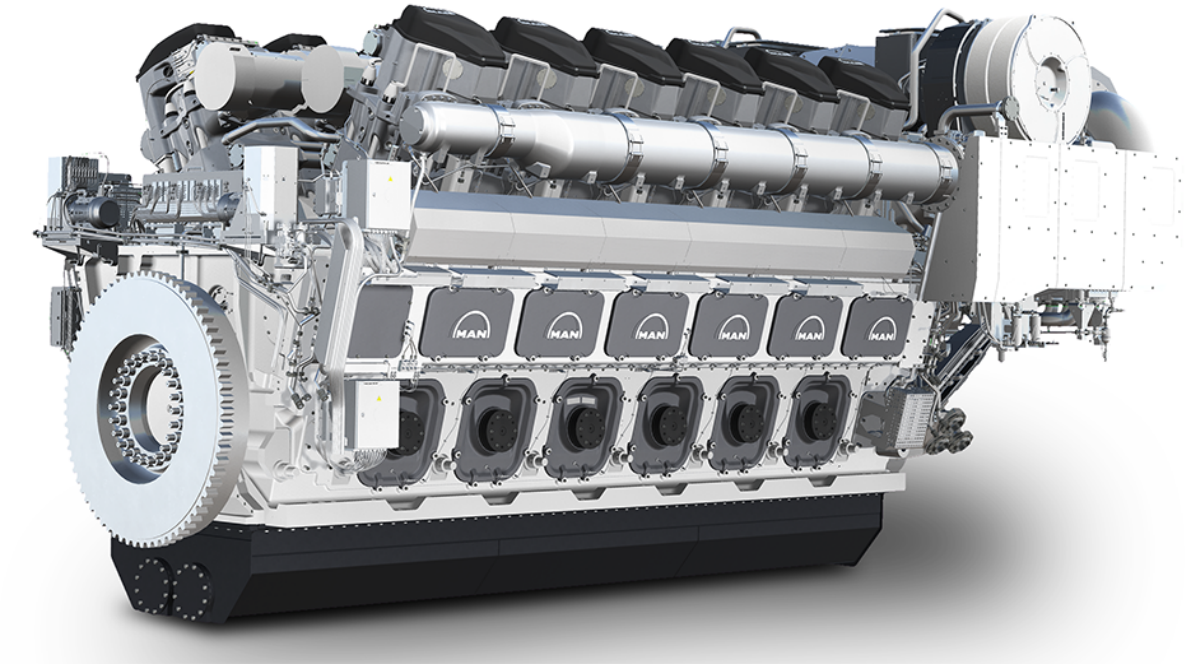


Figure 5: Engine overview, V engine perspective left front view

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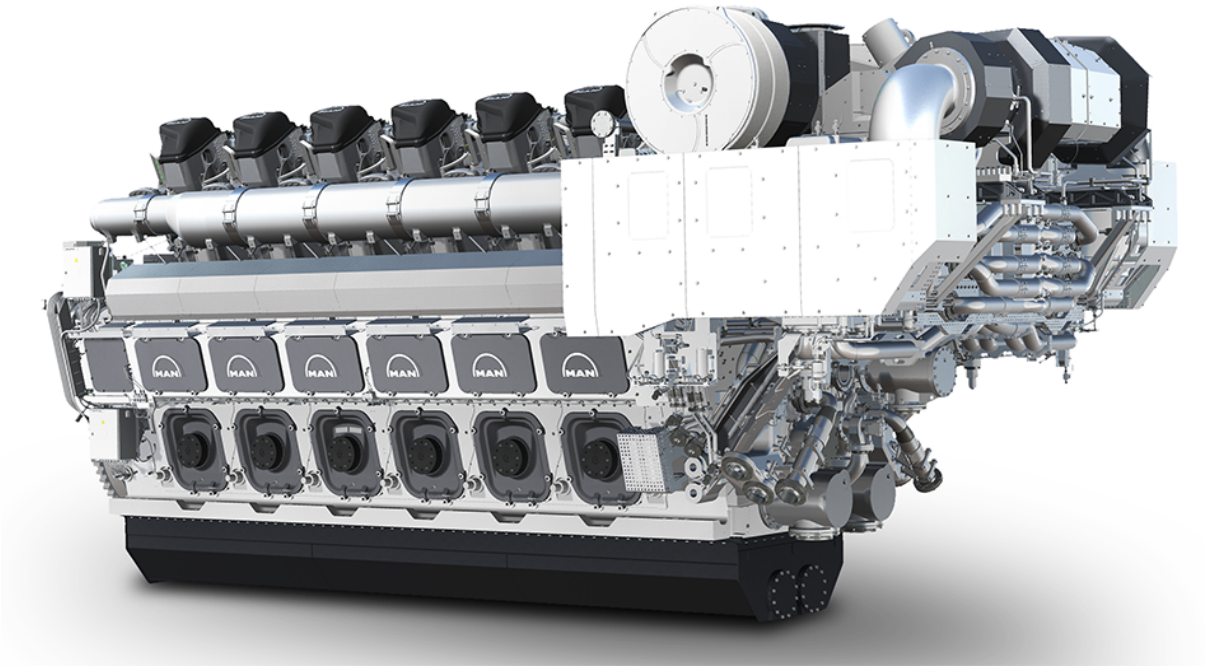


Figure 6: Engine overview, V engine perspective left rear view

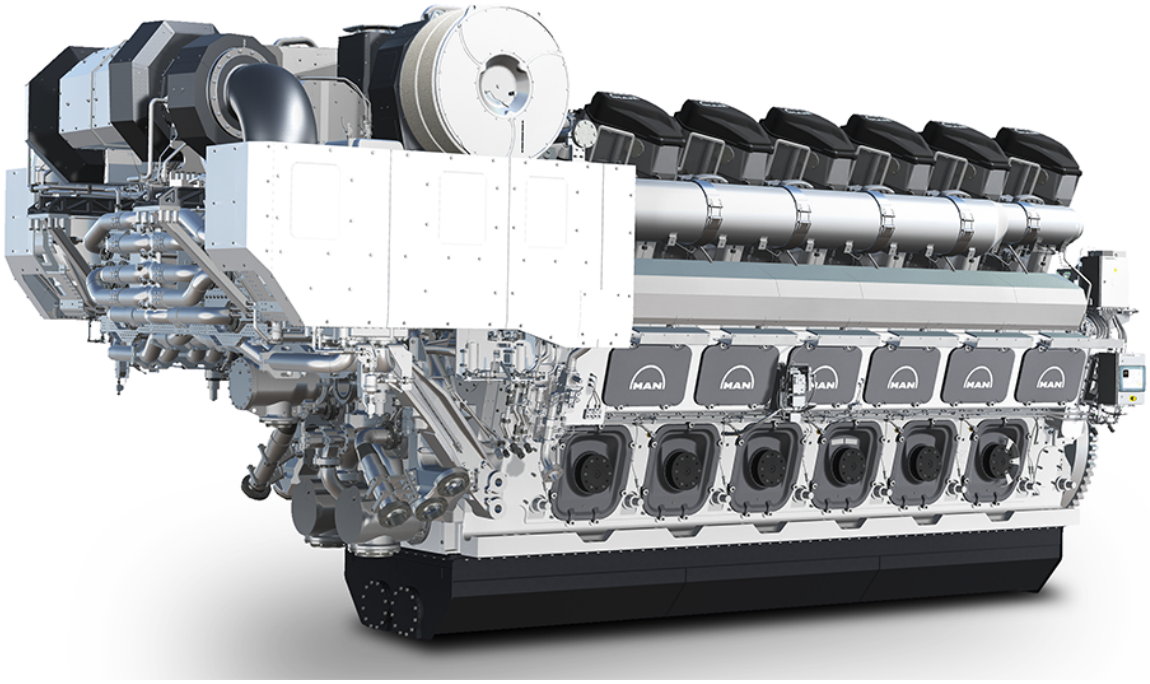
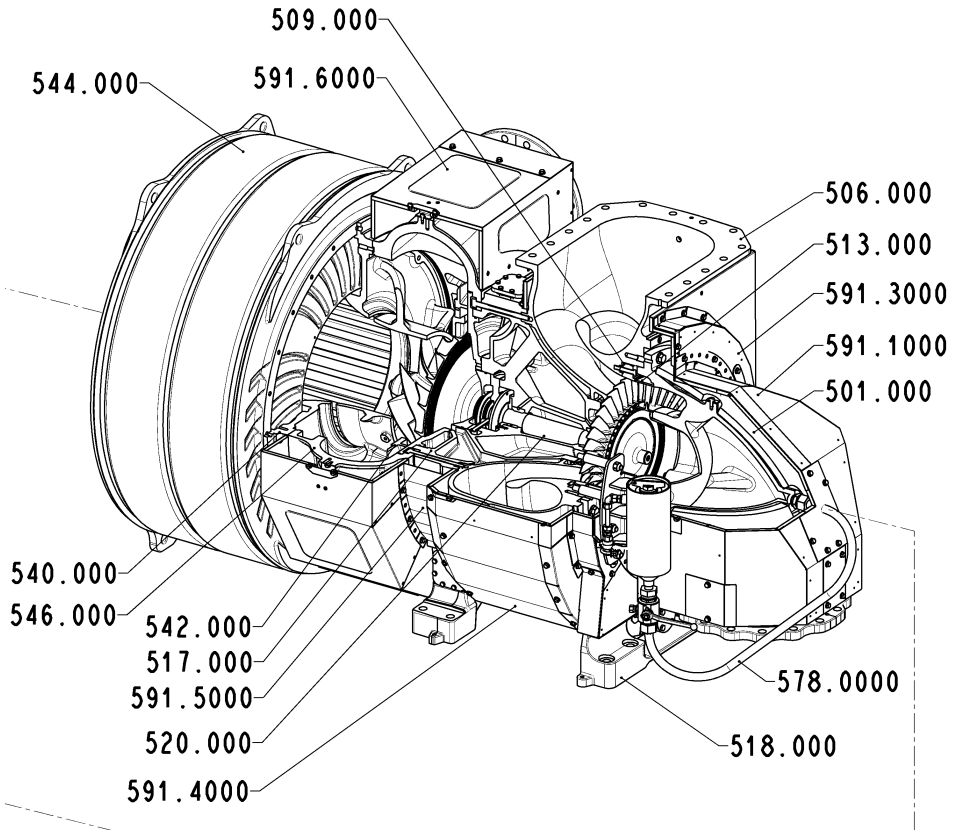


Figure 7: Engine overview, V engine perspective right rear view

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1.4 Turbocharger overview

1.4.1 View of a TCT type turbocharger



506.000 Turbine outlet casing
509.000 Cover ring
513.000 Nozzle ring
517.000 Bearing casing
518.000 Casing foot
520.000 Rotor assembly

540.000 Insert piece
542.000 Diffuser ring

544.000 Silencer
546.000 Compressor casing
578.0000 Turbine cleaning, dry
591.1000 Turbine inlet casing cladding
591.3000 Ring cladding
591.4000 Covering for the turbine outlet casing
591.5000 Covering for the bearing casing
591.6000 Covering for the compressor casing

Figure 8: TCT type turbocharger

1.4.2 TCT turbocharger for the 1st stage of the two-stage turbocharging - Remarks concerning exhaust gas pipe (plant)

For the 49/60, all turbochargers are attached to the engine. For connection of the exhaust gas pipe to the turbine outlet of the TCT-turbocharger, note the general remarks:

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.

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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 Everllence standard.
- Minimising the load as far as possible.
- Characteristic values include gas forces, masses and compensator.

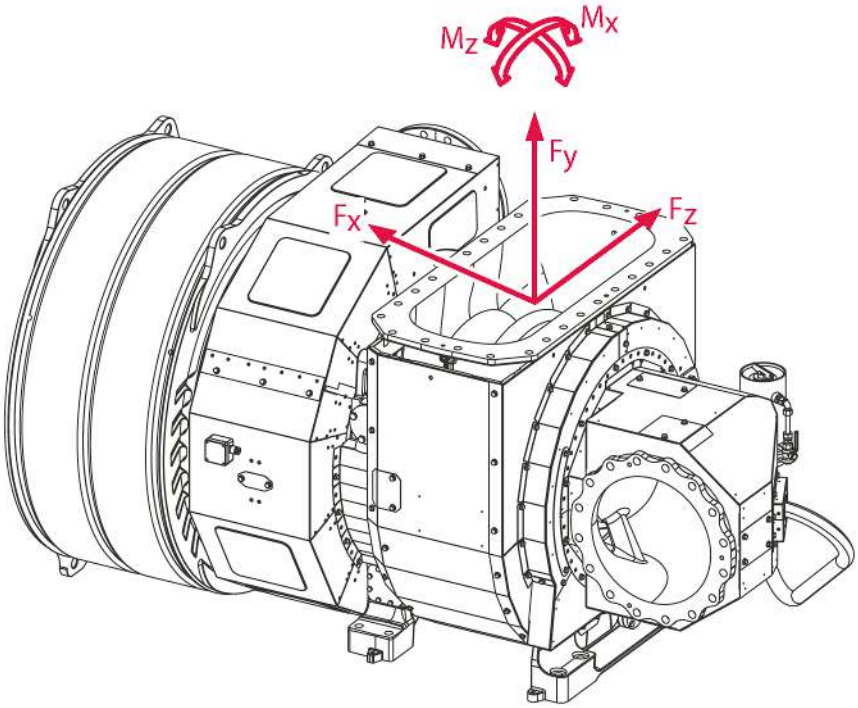


Figure 9: Maximum connection loads, turbine outlet casing

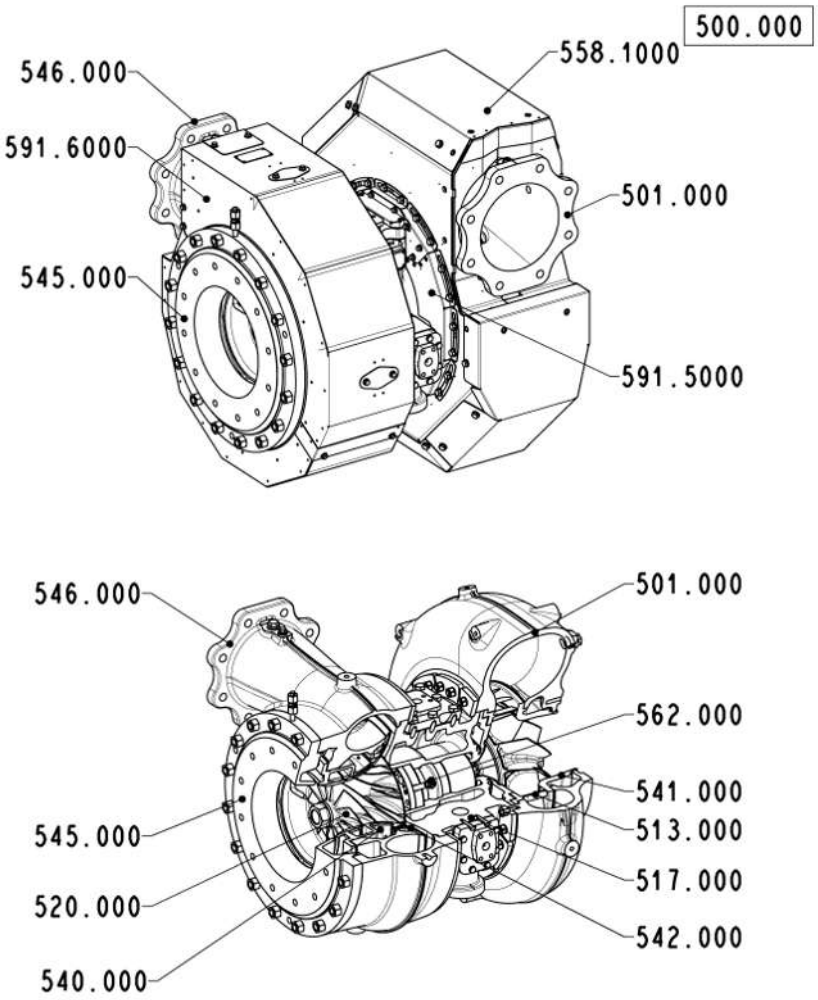
Model	TCT30	TCT40	TCT50	TCT60	TCT70	TCT80
F_X [N]	4,500	5,000	5,600	6,300	7,100	8,000
F_Y [N]	4,500	5,000	5,600	6,300	7,100	8,000
F_Z [N]	8,900	10,000	11,300	12,600	14,200	15,900
M_X [Nm]	5,800	6,500	7,300	8,200	9,200	10,400
M_Y [Nm]	2,900	3,300	3,700	4,200	4,700	5,300
M_Z [Nm]	2,900	3,300	3,700	4,200	4,700	5,300

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 414 have to be considered.

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1.4.3 View of a TCX type turbocharger



500.000	TCX, complete	545.000	Intermediate piece[1) 2)]
501.000	Turbine inlet casing	546.000	Compressor casing
513.000	Turbine nozzle ring	558.1000	Burst protection
517.000	Bearing casing	562.000	Speed measuring device
520.000	Rotor assembly	578.000	Turbine washing device (wet and dry)[1) 3)]
540.000	Insert piece, compressor side	579.000	Compressor cleaning device[1) 3)]
541.000	Insert piece, turbine side	591.5000	Covering for the bearing casing
542.000	Diffuser, bladeless	591.6000	Sound insulation

[1)] Optional, depending on design version.
[2)] Currently not available on TCX23.
[3)] Not shown.

Figure 10: TCX type turbocharger

1.4.4 TCX type turbocharger - No additional installation to be done

The TCX turbocharger for the 2nd stage of the two-stage turbocharger is part of the engine and completely piped.

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1.4.5 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 Everllence in advance.

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2 Engine and operation

2.1 Approved applications and destination/suitability of the engine

Approved applications

The 49/60 is designed as multi-purpose drive. It has been approved by type approval as marine main engine (L-type engines only) by a large number of classification societies (ABS, BV, CCS, ClassNK, CR, CRS, DNV, KR, LR, RINA).

As marine main engine[1] (L-type engines only), it may be applied for mechanical or electric propulsion[2] for applications as:

- Bulker, container vessel and general cargo vessel
- Ferry and cruise liner
- Tanker
- Dredger and tugs – in line with project requirements regarding required high-torque performance engine will be adapted
- Others – to fulfill all customers needs the project requirements have to be defined at an early stage

For the applications named above the 49/60 can be applied for single- (L-type engines only) and for multi-engine plants.

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 40.

Offshore

For offshore applications it may be applied as electric propulsion[3] for:

- FPSO (Floating Production Storage and Offloading Unit)

For the applications named above the 49/60 can be applied for single- (L-type engines only) and for multi-engine plants.

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.

[3] See section Engine ratings (output) for different applications, Page 40.

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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 Everllence 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.

Relevant design criteria for the engine room air temperature:

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

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

The electronic components are suitable for proper operation within an air temperature range from 5°C to 55°C.

For further information see also section Engine automation, Technical data, envirionmental conditions, Page 223.

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

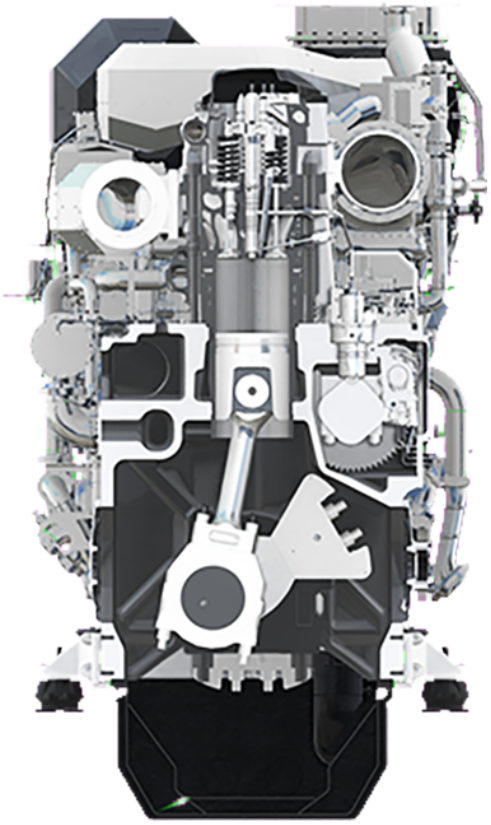


Figure 11: Engine cross section L engine

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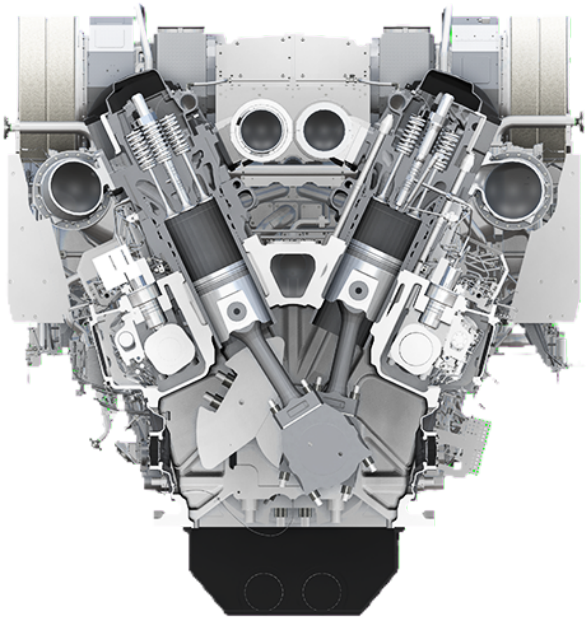


Figure 12: Engine cross section V engine

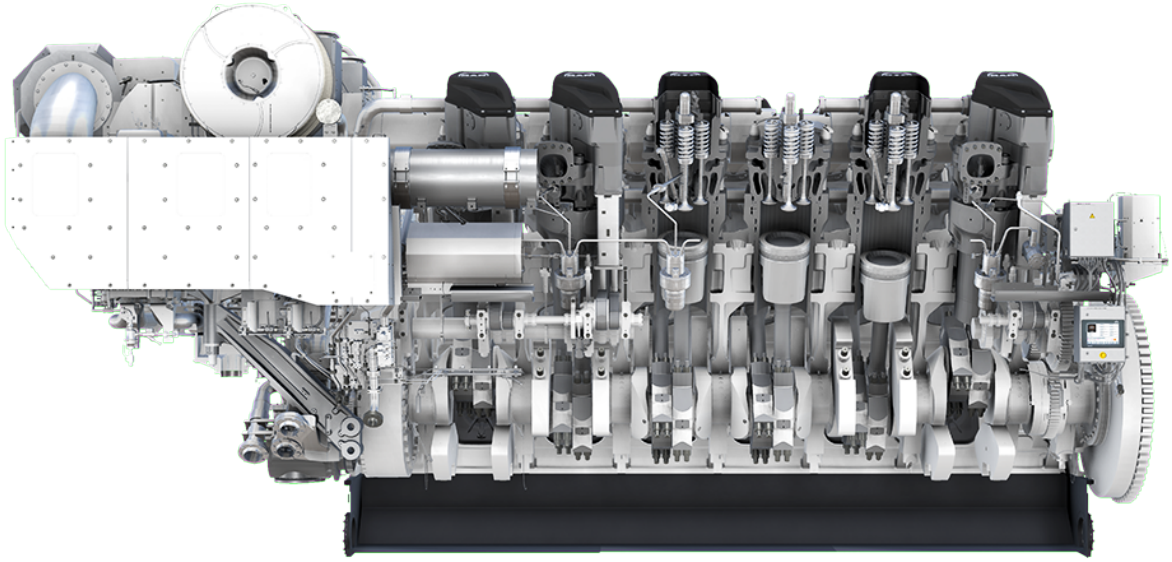


Figure 13: Engine longitudinal section V engine

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2.2.2 Engine designations – Design parameters

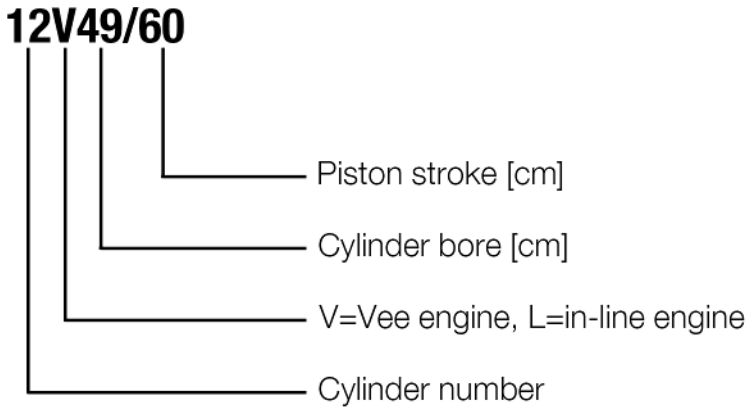


Figure 14: Example to declare engine designations

Parameter	Value	Unit
Number of cylinders	6, 7, 8, 9, 10 12, 14	-
Cylinder bore	490	mm
Piston stroke	600	
Displacement per cylinder	113	litre
Distance between cylinder centres, in-line engine	820	mm
Distance between cylinder centres, vee engine	980	
Vee engine, vee angle	50	°
Crankshaft diameter at journal, in-line engine	430	mm
Crankshaft diameter at journal, vee engine	500	
Crankshaft diameter at crank pin	430	

Table 1: Design parameters

2.2.3 Turbocharger assignments

49/60	
No. of cylinders, config.	**Mechanical propulsion with CPP/electric propulsion**
	1,300 kW/cyl., 600 rpm
6L–8L	1 x TCT40 (LP), 1x TCX21 (HP)
9L–10L	1 x TCT50 (LP), 1 x TCX23 (HP)
12V, 14V	2 x TCT40 (LP), 2 x TCX21 (HP)

Table 2: Turbocharger assignments

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Turbocharger assignments mentioned above are for guidance only and may vary due to project-specific reasons. Consider the relevant turbocharger Project Guides for additional information.

2.2.4 Engine main dimensions, weights and views

L engine – TC on counter coupling side

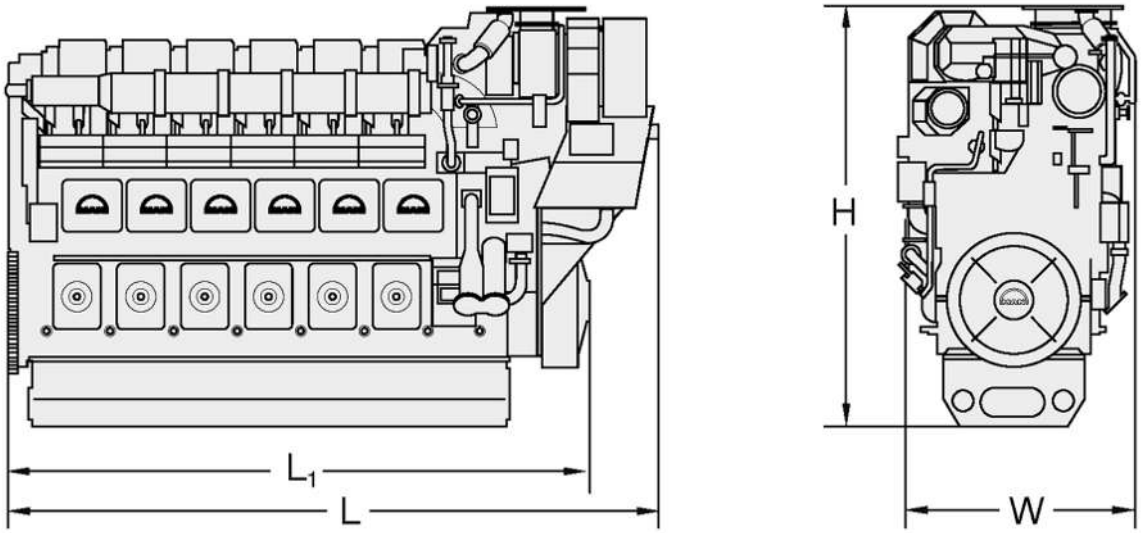


Figure 15: Main dimensions and weights – L engine, TC on counter coupling side

No. of cylinders, config.	L*	L_1	W	H	Weight without flywheel
	mm				t
6L	8,518	7,238	3,134	5,426	130
7L	9,338	8,058	3,134	5,426	145
8L	10,399	8,878	3,134	5,426	165
9L	11,219	9,698	3,154	5,582	180
10L	12,039	10,518	3,154	5,582	195
The dimensions and weights are given for guidance only (weight given without media filling of engine). * Flywheel/coupling on gear drive counter side (GDCS), TC always on gear drive side (GDS).					

Minimum distance between centre of engines: 3,700 mm.

Flywheel data, see section Flywheel arrangement, Page 170.

Dimensions turbocharger on counter coupling side, see section Installation drawings, Page 423.

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L engine – TC on coupling side

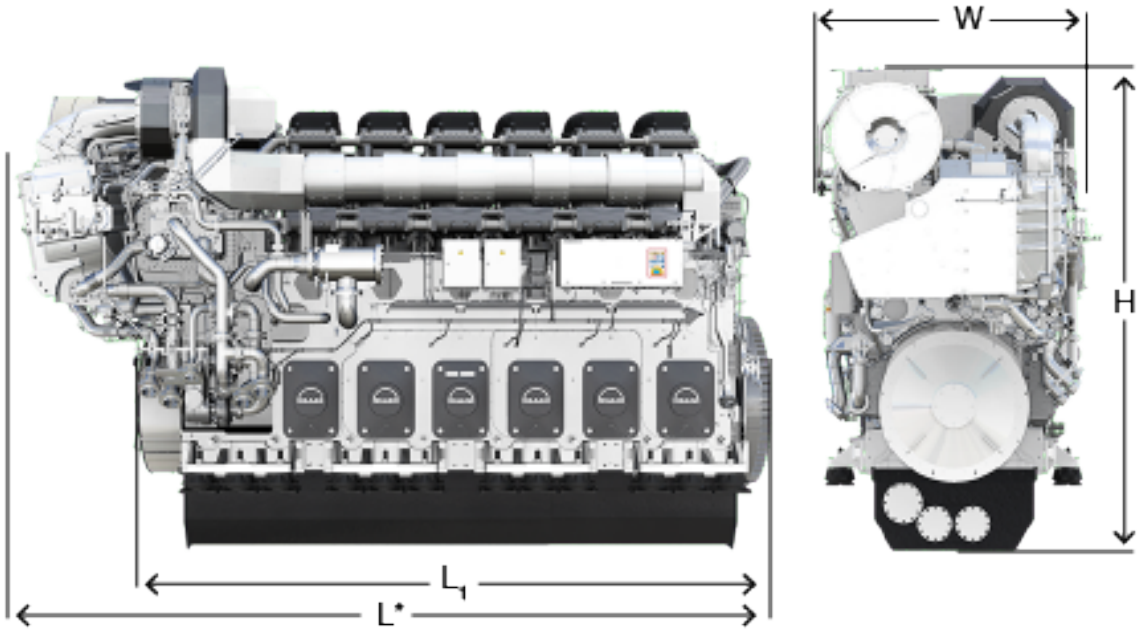


Figure 16: Main dimensions and weights – L engine, TC on coupling side

No. of cylinders, config.	L*	L_1	W	H	Weight without flywheel
	mm				t
6L	8,760	7,238	3,134	5,426	130
7L	9,580	8,058	3,134	5,426	145
8L	10,400	8,878	3,134	5,426	165
9L	11,441	9,698	3,154	5,582	180
10L	12,261	10,518	3,154	5,582	195
The dimensions and weights are given for guidance only (weight given without media filling of engine).					
* Flywheel/coupling on gear drive side (GDS), TC always on gear drive side (GDS).					

Minimum distance between centre of engines: 3,700 mm.

Flywheel data, see section Flywheel arrangement, Page 170.

Dimensions turbocharger on counter coupling side, see section Installation drawings, Page 423.

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V engine

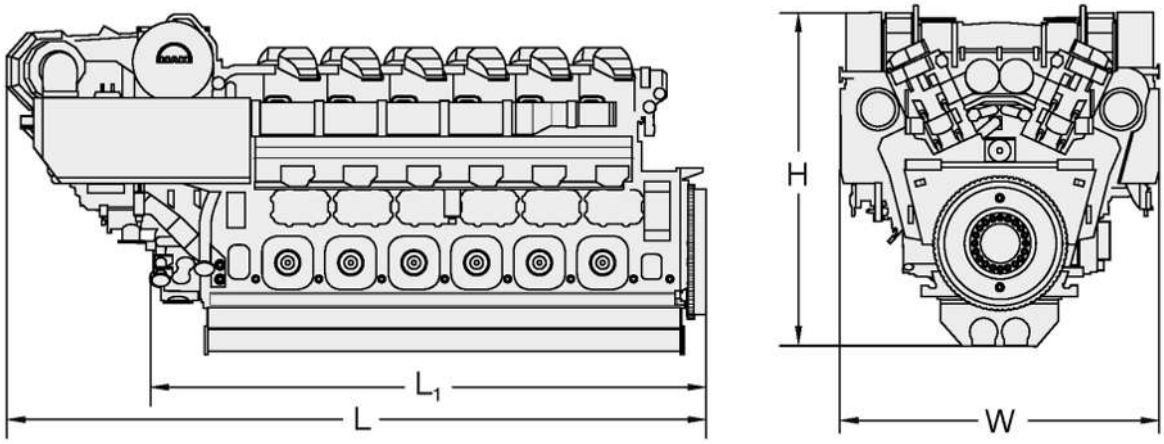


Figure 17: Main dimensions and weights – V engine

No. of cylinders, config.	L	L_1	W	H	Weight without flywheel
	mm				t
12V	10,898	9,350	5,019	5,681	217
14V	11,878	10,330	5,019	5,681	245
The dimensions and weights are given for guidance only (weight given without media filling of engine).					

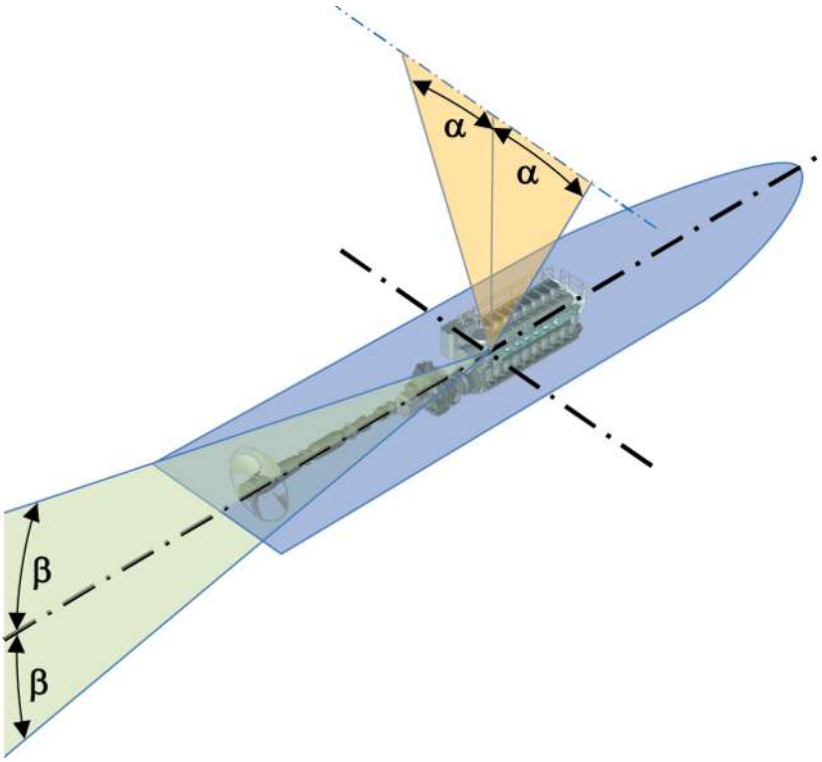
Minimum distance between centre of engines: 5,750 mm.

Flywheel data, see section Flywheel arrangement, Page 170.

Dimensions turbocharger on counter coupling side, see section Installation drawings, Page 423.

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2.2.5 Engine inclination



α Athwartships β Fore and aft

Figure 18: Angle of inclination

Max. permissible angle of inclination [°][1]					
Application	**Athwartships α**		**Fore and aft β**		
	Heel to each side (static)	**Rolling to each side (dynamic)**	**Trim (static)[2]**		**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] Depending on length L of the ship.

Table 3: Inclinations

Note:
For higher requirements contact Everllence. Arrange engines always lengthwise of the ship.

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2.2.6 Engine equipment for various applications

Device/measure, (figure pos.)	Ship			
	Suction dredger/ pumps (mech. drive)	Mechanical propulsion	EPROX-AC	Electric propulsion
Charge air blow-off (cold) for cylinder pressure limitation by continuous adjustable flap	Order related, required if intake air ≤ 0°C [1)2)]			
Charge air by-pass	X	X	X	–
Waste gate for lambda control and temperature after turbine control	X	X	X	X
Two-stage turbocharging with attached turbocharger module	X	X	X	X
LP turbocharger – Compressor cleaning device (wet)	–[3)]	–[3)]	–[3)]	–[3)]
LP turbocharger – Turbine cleaning device (dry)	X	X	X	X
HP turbocharger – Compressor cleaning device (wet)	–[3)]	–[3)]	–[3)]	–[3)]
HP turbocharger – Turbine cleaning device (dry)	X	X	X	X
HP turbocharger – Turbine cleaning device (wet)	X	X	X	X
Compressor and turbine cooling of TCX turbocharger	X	X	X	X
Jet assist	O[4)]	O[4)]	O[5)]	O[5)]
Two-stage charge air cooler	X	X	X	X
ChATCo Pro	X	X	X	X
Dynamic VVT	X	X	X	X
Adaptive combustion control (ACC 2.0)	X	X	X	X
Oil mist detector	X	X	X	X
Splash oil monitoring	X	X	X	X
Main bearing temperature monitoring	X	X	X	X
Starting system – Starting air valves within cylinder head	X	X	X	X
Slow Turn	X	X	X	X
Attached lube oil pump	X	X	X	X
Attached HT cooling water pump	X	X	X	X
Attached LT cooling water pump	O	O	O	O
Lube oil pressure control valve	X	X	X	X
Power take off 100% on counter coupling side	O[6)]	O[6)]	O[6)]	O[6)]
Power take off for auxiliaries counter coupling side	O[6) 7)]	O[6) 7)]	O[6) 7)]	O[6) 7)]

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Device/measure, (figure pos.)	Ship			
	Suction dredger/ pumps (mech. drive)	Mechanical propulsion	EPROX-AC	Electric propulsion
X = required, O = optional, – = not required				
[1] Required in case of operation under arctic conditions.				
[2] Everllence recommends an engine room temperature of +5°C, to avoid freezing wetness on intake air silencer filter mat and electronic equipment.				
[3] Specification of intake air (combustion air), Page 274 must be fulfilled, therefore no compressor cleaning device needed.				
[4] Jet assist needed, if a shaft generator with an output higher than 25% of the nominal engine output is attached to the gear/engine.				
[5] Jet assist required, if classification society demand load application from 0% to 100% within 3 load steps. Check section Start-up and load application and the plant requirements for the additionally necessity of jet assist.				
[6] Available for L engine.				
[7] Hereby the maximum available output of the engine must not be exceeded.				

Table 4: Engine equipment

Engine equipment for various applications – General description

Cylinder pressure limitation by hot charge air blow-off (binary) (see figure Overview flaps, Page 36)

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 downstream) of the charge air cooler and blown off (hot charge air blow-off).

Hot charge air by-pass (variable) (see figure Overview flaps, Page 36)

A part of the hot charge air after compressor will be withdrawn into the exhaust gas pipe. The flap is closed in normal operation.
In some areas of the operating map of the engine, this charge air by-pass will be opened and 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.
In addition, this flap may be used to avoid surging of the turbocharger.

Waste gate for lambda control and temperature after turbine control (see figure Overview flaps, Page 36)

The waste gate is used to by-pass the turbine of the turbocharger with a part of the exhaust gas. This leads to a charge air pressure reduction and the temperature after turbine is increased. As well it allows to adapt the air-flow precise, stepless and continuous to the respective engine operating conditions.

For plants with an SCR catalyst, downstream of the turbine, a minimum exhaust gas temperature upstream the SCR catalyst is necessary in order to ensure its proper performance.

In case the temperature downstream the turbine falls below the set minimum exhaust gas temperature value, the waste gate is opened gradually in order to blow-off exhaust gas upstream of the turbine until the exhaust gas temperature downstream of the turbine (and thus upstream of the SCR catalyst) has reached the required level.

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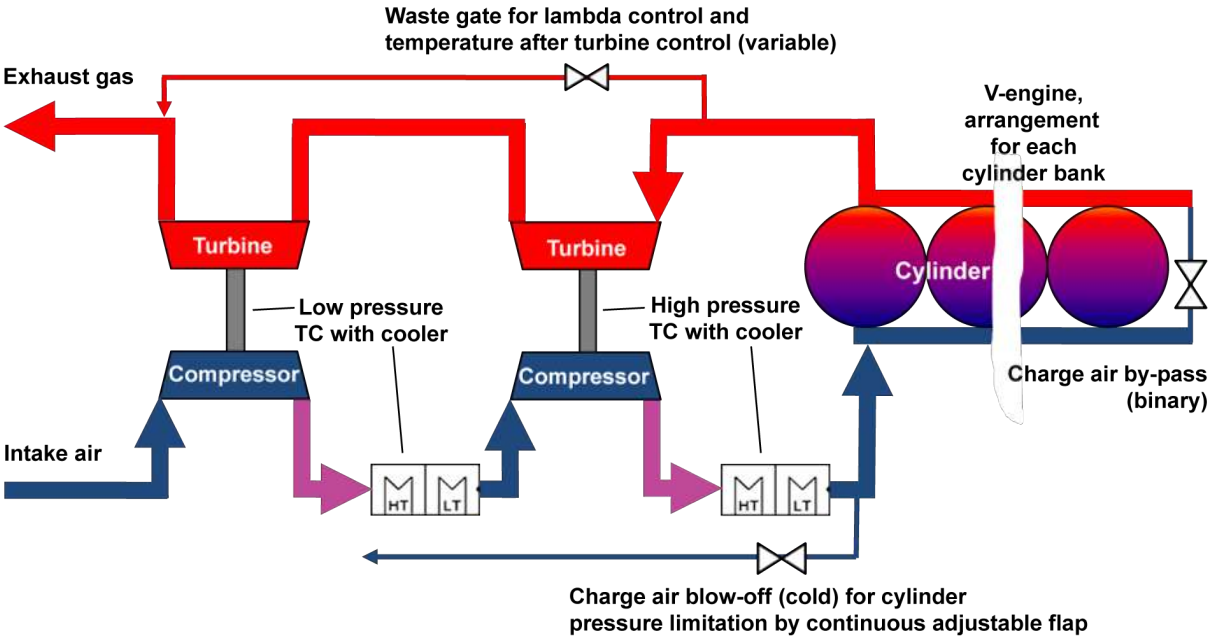


Figure 19: Overview flaps

Two-stage turbocharging

At two-stage turbocharging, the engine deploys two different turbochargers in sequence. Both turbochargers together increase the pressure ratio and the efficiency of the overall turbocharger system significantly, as it would not be possible by using only one single turbocharger.

The high charge air pressure can be used for enhanced Miller Cycling, delivering considerable fuel savings and further reducing NO_x emissions. Alternatively, the excess combustion air can be used to increase the engine's power output.

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.

Turbocharger – Turbine cleaning device (dry)

The turbochargers of engines operated with residual fuel (HFO), diesel oil (DMB), or gas oil (DMA) must be cleaned prior to initial operation and at regular intervals to remove combustion residue from the blades of the turbine rotor and nozzle ring.

Dry cleaning of the turbine should also be applied, in case of operation with inferior gas quality. Dry cleaning of the turbine is particularly suitable for cleaning the turbine rotor (turbine blades). Therefore, a special cleaning device to be used.

Turbocharger – Turbine cleaning device (wet)

The turbochargers of engines operated with residual fuel (HFO), diesel oil (DMB), or gas oil (DMA) must be cleaned prior to initial operation and at regular intervals to remove combustion residue from the blades of the turbine rotor and nozzle ring. Wet cleaning of the turbine is particularly suitable for cleaning the nozzle ring. Wet cleaning is carried out during operation at greatly reduced engine load in order to avoid overstressing the turbine materials (thermal shock). Therefore, a special cleaning device to be used.

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Compressor and turbine cooling of TCX-turbocharger

The TCX-turbocharger as a standard is equipped with a cooling system of the compressor and of the turbine side. Herefore HT-water is used and it is integrated into the internal cooling water circuit of the engine.

Jet assist

Jet assist is used to improve the dynamic behavior of the engine to load steps and ramps. By means of nozzles in the turbocharger, compressed air is directed onto the compressor wheel to accelerate it. This results in a quicker adaption of the turbocharger to the new load condition. Jet assist is generally working with a compressed air pressure between 18 bar and 30 bar at the engine connection. However, it works most efficiently with a pressure of 27 bar.

Therefore, the pressure difference from the compressed air tanks to the engine connections should, in any case, not be higher than 3 bar.

Jet assist activating time: 3 seconds to 10 seconds (5 seconds on average).

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).

ChATCo Pro

ChATCo Pro (charge air temperature control professional) controls the charge air temperature dependent on:

- The point of operation of the engine in its specified operating range
- The kind of fuel
- Ambient conditions and media temperatures
- The focus for optimisation (e.g. prevention of condensed water in the charge air pipe or e.g. an increased charge air temperature for stabile combustion)

Dynamic VVT

The dynamic VVT (variable valve timing) is a patented advanced version of the previous one, enabling 3 different positions of the opening and closing timing of the inlet valves.

At low load operation it is used to attain higher combustion temperatures and thus lower soot emissions.

At higher loads it is used to attain low combustion temperatures and thus lower NO_x emissions (Miller Valve Timing). Now by a intermediate position a even better tuning of the engine can be achieved.

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 – Starting air valves within cylinder head

The engine is equipped with starting air valves within some of the cylinder heads. On starting command, compressed air will be led in a special sequence into the cylinder and will push down the piston and turn thereby the crankshaft untill a defined speed is reached.

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Slow turn

Engines, which are equipped with slow turn, are automatically turned prior to engine start with the turning process being monitored by the engine control. If the engine does not reach the expected number of crankshaft revolutions (2.5 revolutions) within a specified period of time, or in case the slow turn time is shorter than the programmed minimum slow turn time, an error message is issued. This error message serves as an indication that there is liquid (oil, water, fuel) in the combustion chamber. If the slow turn manoeuvre is completed successfully, the engine is started automatically.

Slow turn is always required for plants with power management system (PMS) demanding automatic engine start.

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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 41.

2.3.2 Standard engine ratings

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

No. of cylinders, config.	Available turning direction CW/CCW[3]	Engine rating, $P_{ISO, standard}$ [1) 2)]	
		Electric propulsion/EPROX-AC, mechanical propulsion with CPP 1,300 kW/cyl., 600 rpm	Suction dredger/pumps (mech. drive) 1,300 kW/cyl., 600 rpm
6L	Yes/Yes	7,800	7,800
7L	Yes/Yes	9,100	9,100
8L	Yes/Yes	10,400	10,400
9L	Yes/Yes	11,700	11,700
10L	Yes/Yes	13,000	13,000
12V	Yes/Yes	15,600	not available
14V	Yes/Yes	18,200	not available

[1)] $P_{ISO, standard}$ as specified in DIN ISO 3046-1, see paragraph Reference conditions for engine rating, Page 39.

[2)] Engine fuel: Distillate according to ISO 8217 or RM-grade fuel, fulfilling the stated quality requirements. Contents of FAME or synthetic fuels are not considered for this reference, as they affect the volumetric heat value.

[3)] CW = clockwise; CCW = counter clockwise.

Table 5: Engine ratings

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 6: Reference conditions for engine rating

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2.3.3 Engine ratings (output) for different applications

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

	$P_{Application}$ Available output in percentage of ISO standard output	Max. fuel admission (blocking)	Max. permissible speed reduction at maximum torque[1)]	Tropic conditions ($t_r/t_{cr}/p_r$=100kP_a)[2)]	Notes	Optional power take-off in percentage of ISO standard output
Kind of application	**%**	**%**	**%**	**°C**		**%**
Marine main engines with mechanical or electric propulsion						
Main drive with electric propulsion/ EPROX-AC	100	110	-	45/38	[3)]	-
Main drive with controllable pitch propeller	100	100	-	45/38	-	-
Suction dredger/pumps (mechanical drive)						
Main drive for suction dredger/pumps	100	100	-	45/38	[3)]	-

[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)] In accordance with DIN ISO 3046-1 and for further clarification of relevant sections within DIN ISO 8528-1, the following is specified:
- The maximum output (MCR) has to be observed by the power management system of the plant.
- The range of 100 % up to 110 % fuel admission may only be used for a short time for governing purposes (e.g. transient load conditions and suddenly applied load).

Table 7: Available outputs/related reference conditions

Note:
Power fluctuations in the electrical grid.
It is an intrinsic property of the powertrain of a generating set that it acts as a torsional vibration system. This complex system consists of the engine, coupling and generator (within or outside Everllence scope of supply) and the electric plant. Such electric power plant can be consisting of further power sources as well as consumers (such as electric motors), transformers, frequency converters, energy storage systems, bus bars or circuit breakers and the entire distribution system (within or outside Everllence scope of supply). The reciprocating engine, as well as the electric power distribution or the other consumers and power sources excite the system. As a consequence, the active power at the generator terminals is not completely constant over time and some additional power oscillations so-called power fluctuations occur. These power fluctuations do not affect the operational safety of the generating set, as long as the stability requirements of the electric system in regards to frequency and voltage meet the class requirements. In addition, this behavior is in accordance with ISO 8528-5 [1] and does as per Everllence experience not affect power system stability in an unacceptable range. Gas operated engines

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tend to show greater power fluctuations than engines operated with liquid fuels. This belongs to the typical cyclical fluctuations of the Otto combustion process that uses a premixed combustion. Note that Everllence quotations do not consider any specific limitations regarding power fluctuations. On request by the purchaser, Everllence provides support or further analysis of the overall system behavior, where the GenSets as well as the electric distribution and consumers should be included in the analysis.

[1] Reciprocating internal combustion engine driven alternating current generating sets – Part 5: Generating sets.

2.3.4 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 8: Derating – Limits of ambient conditions

2. Derating

Contact Everllence:

- If limits of ambient conditions mentioned in the upper table Derating – Limits of ambient conditions, Page 41 are exceeded. A special calculation is necessary.
- If higher requirements for the emission level exist. For the permissible requirements see section Exhaust gas emission, Page 144.
- If special requirements of the plant for heat recovery exist.
- If special requirements on media temperatures of the engine exist.
- If any requirements of Everllence mentioned in the Project Guide cannot be met.

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2.3.5 Engine speeds and related main data

Rated speed	rpm	600	
Permissible range of speed		[1]	
Alarm overspeed (110% of nominal speed)		660	
Auto shutdown overspeed (115% of nominal speed)		690	
Speed adjusting range		See section Speed adjusting range, Page 42	
Alternator frequency	Hz	50	60
Number of pole pairs	-	5	6
Note: Power take-off on engine free end up to 100% of rated output.			
[1] According to section Operating range for generator operation/electric propulsion, Page 69, Operating range for EPROX-AC, Page 70, Operating range for controllable pitch propeller (CPP), Page 79 and figure Permissible frequency deviations and corresponding max. output, Page 73.			

Table 9: Engine speeds and related main data

2.3.6 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 operation	Maximum speed at no-load operation	Minimum speed
Electronic speed control	1 main engine with controllable pitch propeller and without PTO	0%	100% (+0.5%)	100% (+0.5%)	60%
	1 main engine with controllable pitch propeller and with PTO	0%	100% (+0.5%)	100% (+0.5%)	60%
	Parallel operation of 2 engines driving 1 shaft with/ without PTO: Load sharing via speed droop or master/slave operation	5% 0%	100% (+0.5%) 100% (+0.5%)	105% (+0.5%) 100% (+0.5%)	60% 60%
	GenSets/electric propulsion plants: With load sharing via speed droop or isochronous operation	5% 0%	100% (+0.5%) 100% (+0.5%)	105% (+0.5%) 100% (+0.5%)	100%[1] 100%[1]
[1] Speed after start of the engine, before synchronisation.					

Table 10: Electronic speed control

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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 133 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 Everllence is required	> 80 mbar

Table 11: Exhaust gas back pressure after turbocharger

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

Table 12: 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 Everllence is required	> 120 mbar

Table 13: 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.

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- 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 necessary 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

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

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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 Everllence.

2.5.2 Type of engine start

Normal start

The standard procedure of a monitored engine start in accordance to Everllence guidelines.

For details and requirements see section Starting conditions, Page 48.

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".

For details and requirements see section Starting conditions, Page 48.

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.

For details and requirements see section Starting conditions, Page 48.

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

General requirements on engine and plant installation

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

Engine
Plant

- Lube oil service pump (attached)
- Prelubrication pump (free-standing)
- Preheating HT cooling water system (60–90°C)

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- Preheating lube oil system (> 40°C). For maximum admissible value see table Lube oil, Page 137

Requirements on engine and plant installation 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:

Engine
- Lube oil service pump (attached).

Plant
- Prelubrication pump (free-standing) with low pressure before engine (0.3 bar < $p_{Oil\ before\ engine}$ < 0.6 bar)
- Preheating HT cooling water system (60–90°C)
- Preheating lube oil system (> 40°C). For maximum admissible value see table Lube oil, Page 137
- Power management system with supervision of stand-by times engines

Additional requirements on engine and plant installation for "Blackout start" capability

Following **additional** installations to the above stated ones are required to enable in addition a "Blackout start":

Engine
- HT CW service pump (attached) recommended
- LT CW service pump (attached) recommended
- Attached fuel oil supply pump recommended (if applicable)

Plant
- Regarding "Blackout start" fuel oil conditions, see table Fuel, Page 138

If fuel oil supply pump is not attached to the engine:

- Air driven fuel oil supply pump or fuel oil service tanks at sufficient height or pressurised fuel oil tank

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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.

Prior to next stand-by mode, engine needs to be operated at minimum 50% output for ≥ 30 min.

Table 14: 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	No	Yes[1]
Engine to be preheated and prelubricated?	No[2]	Yes	Yes

[1] It is recommended to install Slow Turn. Otherwise the engine has to be turned by turning gear.

[2] Valid only, if mentioned above conditions (see table Starting conditions – General notes, Page 48) have been considered. Non-observance endangers the engine or its components.

Table 15: Starting conditions – Required engine conditions

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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 133 limits according figure "Prelubrication/postlubrication lube oil pressure (duration > 10 min)"	See section Operating/service temperatures and pressures, Page 133 limits according figure "Prelubrication/postlubrication lube oil pressure (duration ≤ 10 min)"
Lube oil to be preheated?	No[1)]	Yes	Yes
HT cooling water			
HT cooling water to be preheated?	No[1)]	Yes	Yes
Fuel system			
For DMA/DMB operation	Sufficient fuel oil pressure at engine inlet required.	Supply pumps in operation or with starting command to engine.	
For operation with residual fuel (HFO)[2)]	Sufficient fuel oil pressure at engine inlet required. Emergency fuel supply pumps in DMA/DMB mode always.	Supply and booster pumps in operation, fuel preheated to operating viscosity. In case of permanent stand-by of liquid fuel engines or during operation of an DF engine in gas mode a periodical exchange of the circulating HFO has to be ensured to avoid cracking of the fuel. This can be done by releasing a certain amount of circulating HFO into the day tank and substituting it with "fresh" fuel from the tank.	

[1)] Valid only, if mentioned above conditions (see table Starting conditions – General notes, Page 48) have been considered. Non-observance endangers the engine or its components.

[2)] Only with 600 kW variant.

Table 16: Starting conditions – Required system conditions

Additional remark regarding "Blackout start"

If additional requirements on engine and plant installation for "Blackout start" capability are fullfilled, it is possible to start up the engine in shorter time. But untill all media systems are back in normal operation the engine can only be operated according to the settings of alarm and safety system.

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2.6 Start-up and load application

2.6.1 General remarks

To limit the effort regarding regulating the media circuits, also to ensure an uniform heat input it always should be aimed for longer load application times by taking into account the realistic requirements of the specific plant.

All questions regarding the dynamic behaviour should be clarified in close co-operation between the customer and Everllence at an early project stage.

Requirements for plant design:

- The load application behaviour must be considered in the electrical system design of the plant.
- The system operation must be safe in case of graduated load application.
- The load application conditions (E-balance) must be approved during the planning and examination phase.
- The possible failure of one engine must be considered, see section Generator operation/electric propulsion – Power management, Page 73.

2.6.2 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 > 20°C, HT cooling water temperature > 20°C.
- Distillate fuel must be used until warming up phase is completed.
- 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 > 40°C, cooling water temperature > 60°C).

The duration of the warming-up phase depends on the system layout and the media volumes in the system and is therefore project-specific.

See diagrams in section Load application – Continuous loading, Page 51.

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 ≥ 40°C.
- HT cooling water temperature ≥ 60°C.

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The required start-up time in normal starting mode (preheated engine), with the required time for starting-up the lube oil system and prelubrication of the engine is shown in the diagrams in section Load application – Continuous loading, Page 51 in connection with the information in figure(s) Duration of the load application – Continuous loading, Page 53.

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 Lube oil system, Page 294
- HT cooling water temperature ≥ 60°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.

Speed ramp-up

The standard speed ramp-up serves for all engine conditions and ensures a low opacity level of the exhaust gas.

A "fast speed ramp-up", that is near to the maximum capability of the engine, may be used in exceptional cases.

For liquid fuel engines:

- Exhaust gas will be visible (opacity > 60%).
- External signal from plant to be provided for request to SaCoS 5000.

Load ramp-up

The time needed for load ramp-up is in high extent dependent on the engine conditions:

- Cold

  (If applicable see "Start-up – Cold engine" for remarks and temperatures)
- Warm (= preheated)
  - Lube oil temperature ≥ 40°C.
  - HT cooling water temperature ≥ 60°C.
- Hot (= previously been in operation)
  - Lube oil temperature ≥ 40°C.
  - HT cooling water temperature ≥ 60°C.
  - Exhaust gas pipe engine and turbocharger > 320°C (within 1 h after engine stop).

Note:
Load application handled within plant automation:
The compliance of the load application with the specifications of Everllence has to be handled within the plant automation.
The SaCoS engine control will not interfere in the load ramp-up or load ramp-down initiated by the plant control.

2.6.3 Load application – Continuous loading

The start procedure after "Starting request" is structured into following phases:

Start preparation (consists of phase 1, 2 and 3)

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- Phase 1:
  Pressure formation in the lube oil system to gain specified lube oil pressure before engine.
- Phase 2:
  Prelubrication and pre-processing of the engine for specified time.
- Phase 3:
  "Slow Turn" function activated, if required.

Start process and running-up to minimum speed (consists of phase 4 and 5)

- Phase 4:
  Activation of starting system engine till engine is running.
- Phase 5:
  Increase of engine speed till specified minimum speed is reached.

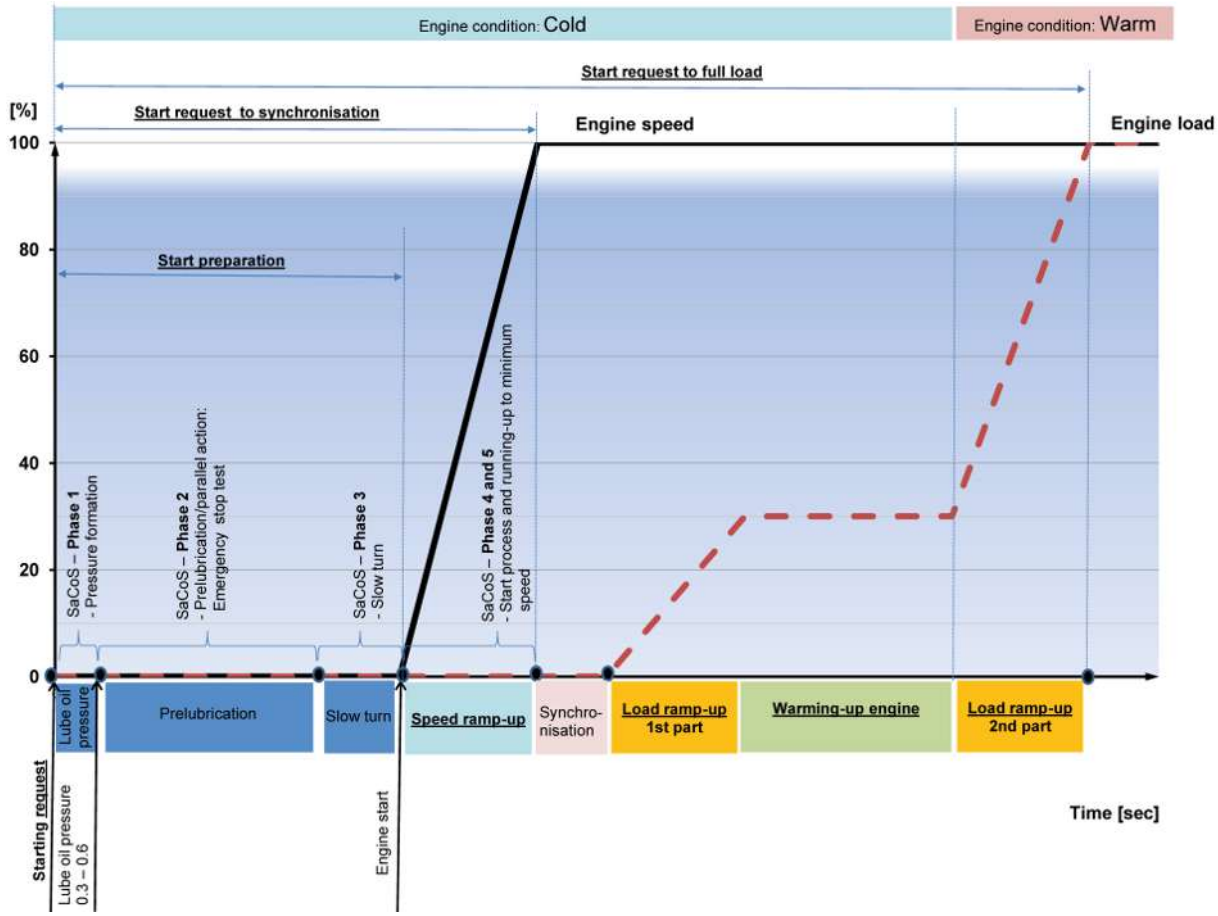


Figure 20: Start-up and load ramp-up for cold engine condition (emergency case)

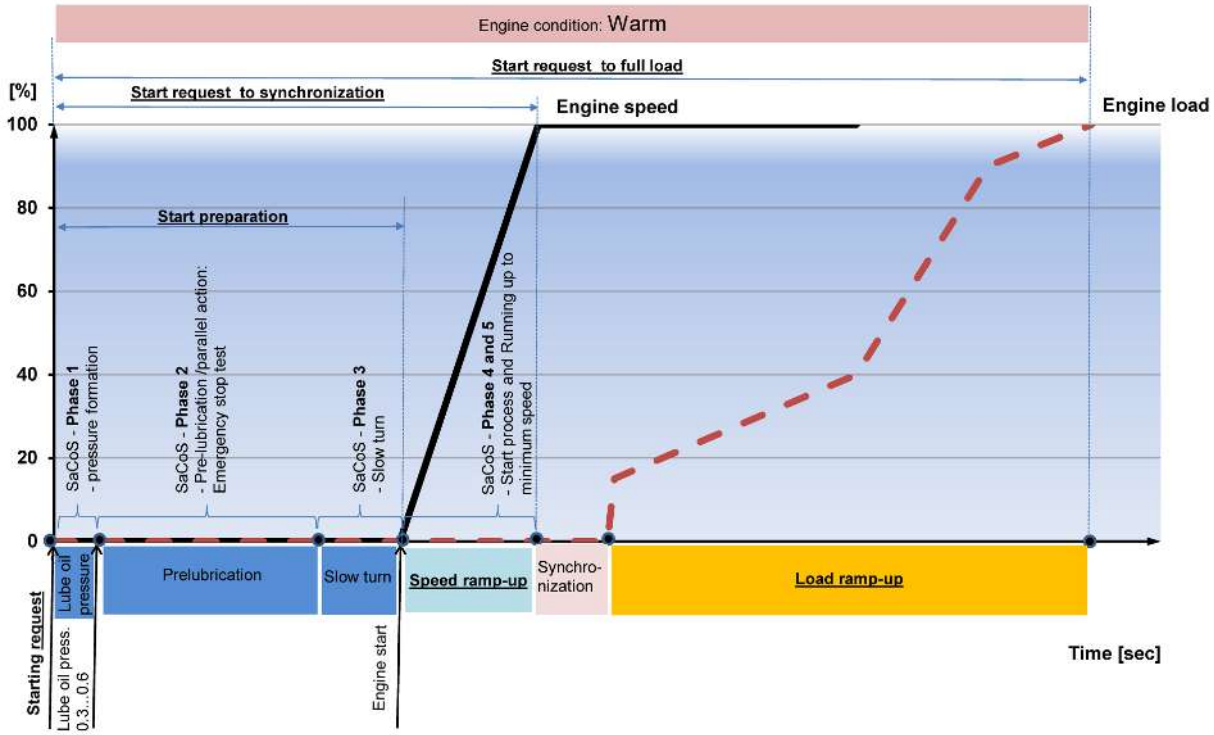


Figure 21: Start-up and load ramp-up for warm/hot engine condition

Find in the table below the relevant durations for the phases in above given diagrams.

Note:

- For "Phase 3" the engine needs to be equipped with "Slow Turn".
- Jet assist as engine equipment is recommended.
- If "fast speed ramp-up" is needed, the possibility of this has to be clarified on a project-specific basis.
- For "stand-by" special plant equipment is required.

Special note for EPROX-AC:

- Load ramps are valid for speed range 80% up to 100%.
- Speed has to be ramped up with 1%/s of nominal speed in parallel to load ramp.

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Engine condition / (recommended time)	Start preparation [sec]			Speed ramp-up [sec]		Synchronisation [sec]	Load ramp-up [sec] liquid fuel: () exceptional ramp up with Jet-Assist 1)		Total [sec] Start request to 100 % load liquid fuel: () exceptional ramp up time 1)	
	Phase 1	Phase 2	Phase 3	Phase 4 and 5 () in liquid fuel operation: exceptional speed ramp-up 1)						
Cold	10	300	30	50		10	0 - 30%: 360 at 30%: 600 30% - 100%: 320 ∑ 1280 s		1680	
Warm and Stand-by	0	0	0	50	(18)	10	70	(30)	130	(58)
Hot and Stand-by	0	0	0	50	(18)	10	45	(20)	105	(48)

1) Exceptional ramp up with clearly visible smoke.

Figure 22: Duration of the load application, engine equipped with jet assist – Continuous loading (extract)

For further information or deviating engine condition/equipment contact Everllence.

2.6.4 Load application – Load steps (for electric propulsion)

Minimum requirements of classification societies and ISO rule

The specification of the IACS (Unified Requirement M3) contains first of all guidelines for suddenly applied load steps. Originally two load steps, each 50%, were described. In view of the technical progress regarding increasing mean effective pressures, the requirements were adapted. According to IACS and ISO 8528-5 a diagram is used to define – based on the mean effective pressure of the respective engine – the number of load steps for a load application from 0% load to 100% load. This diagram serves as a guideline for four-stroke diesel engines in general and is reflected in the rules of the classification societies.

Be aware, that for marine engines load application requirements must be clarified with the respective classification society as well as with the shipyard and the owner.

Accordingly Everllence has specified the following table.

Declared power mean effective pressure of the engine (p_{me})	**Number of load steps**
> 13.5 bar up to 18 bar	3
> 18 bar up to 22.5 bar	4
> 22.5 bar up to 27 bar	5
> 27 bar	6
The size of each load step to be calculated as: 100% load divided by "Number of load steps". For example: 100% load / "4" = 25% load increase per load step.	

Table 17: Number of load steps dependent on the p_{me} of the engine according IACS M3 Rev.6, four-stroke diesel engines

Boundary conditions for load steps according table above:

- Engine and media systems faultless in operation
- Engine as a minimum preheated

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- Before an additional load step will be applied, at least 20 seconds waiting time after initiation of the previous load step needs to be considered

Performance according IACS M3 Rev.6 for Everllence GenSets as a standard will be fullfilled

As a standard, Everllence Gensets fulfill the requirements of the performance according IACS M3 Rev.6. (as stated in table below). Clarify any higher project-specific requirements at an early project stage with Everllence. They must be part of the contract.

	IACS M3 Rev.6
Auto shutdown overspeed	at 115% of nominal speed
Alarm overspeed	at 110% of nominal speed
Frequency drop (Max. remaining speed deviation in the whole load range)	≤ 5% of nominal frequency
Steady-state frequency band (Deviation at recent frequency at constant load)	≤ 1.0% of recent frequency
In case of power increase	
Transient frequency deviation related to rated frequency (Dynamic speed drop)	≤ -10% of nominal frequency
Only for gas engines	-
Frequency recovery time (till frequency is within steady-state frequency band of new frequency)	≤ 5 sec
In case of 100% load drop	
Transient frequency deviation related to rated frequency (Dynamic speed increase)	≤ +10% of nominal frequency
Frequency recovery time (till frequency is within steady-state frequency band of new frequency)	≤ 5 sec

Table 18: Requirements according IACS M3 Rev.6

Engine specific load steps – Maximum load step dependent on base load

Boundary conditions:

- Engine and media systems faultless in operation
- Engine condition hot
- Engine in steady state for minimum 5 min

If above stated boundary conditions are fulfilled, the maximum load step which can be applied as a function of the currently driven base load can be derived out of the below stated diagram(s).

EPROX-AC

After synchronisation within the operating range of EPROX-AC as setting for a change in speed, it is recommended: 1% of nominal speed per sec.

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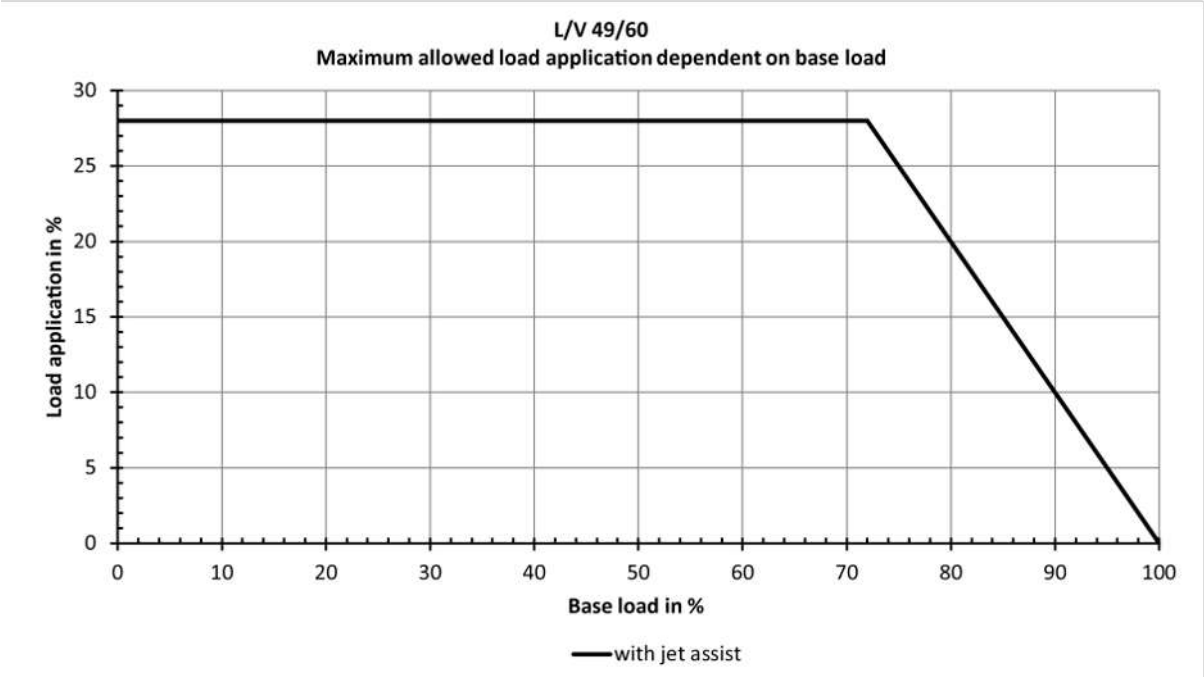


Figure 23: Load application dependent on base load (engine condition hot) - 49/60, performance according IACS M3 Rev.6

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2.6.5 Load application for mechanical propulsion (CPP)

Acceleration times for 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 (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.

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.

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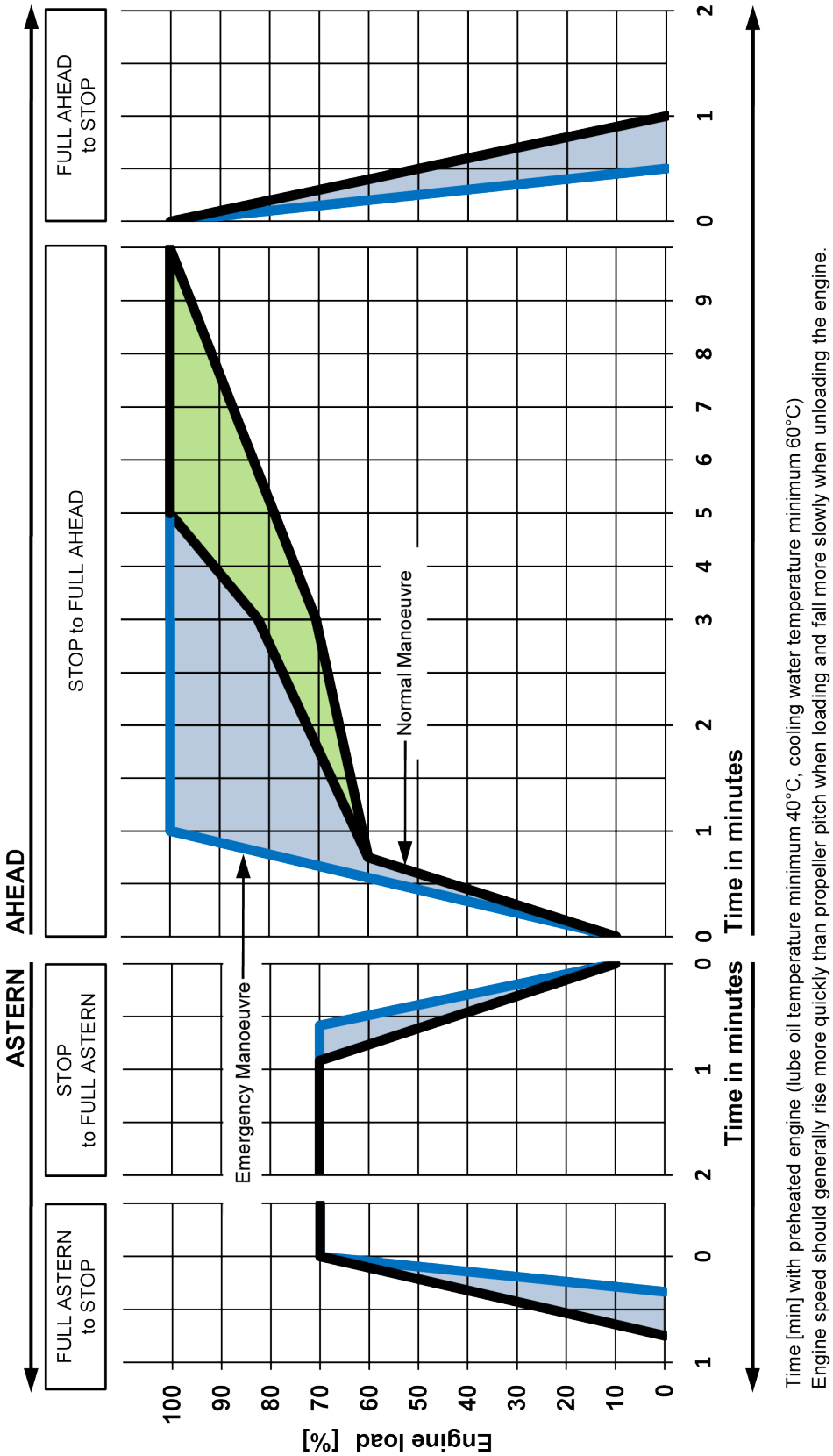


Figure 24: Control lever setting and corresponding engine specific acceleration times (for guidance)

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2.7 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 40)
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 idle or no-load operation, 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.

This process is more acute in low-load operation and during manoeuvring when the cooling water temperatures are not kept at the required level, and are decreasing too rapidly. This may result in too low charge air and combustion chamber temperatures, deteriorating the combustion at low loads especially in residual fuel oil operation (HFO operation).

Operation with residual fuel oil (HFO) or with marine gas oil (DMA, DFA) or marine diesel oil (DMB, DFB)

Based on the above, the low-load operation in the range of < 25 % of the full load is subjected to specific limitations. According to figure Time limitation for low-load operation (left), duration of "relieving operation" (right), Page 59 immediately after a phase of low-load operation the engine must be operated at > 70 % of the full load for some time in order to reduce the deposits in the cylinders and the exhaust gas turbocharger again.

- Provided that the specified engine operating values are observed, there are no restrictions at loads > 25 % of the full load.
- Continuous operation at < 25 % of the full load should be avoided whenever possible.
- No-load operation, particularly at nominal speed (alternator operation) is only permissible for one hour maximum.

After 500 hours of continuous operation with liquid fuel, at a low load in the range of 20 % to 25 % of the full load, the engine must be run-in again.

See section Engine running in, Page 481.

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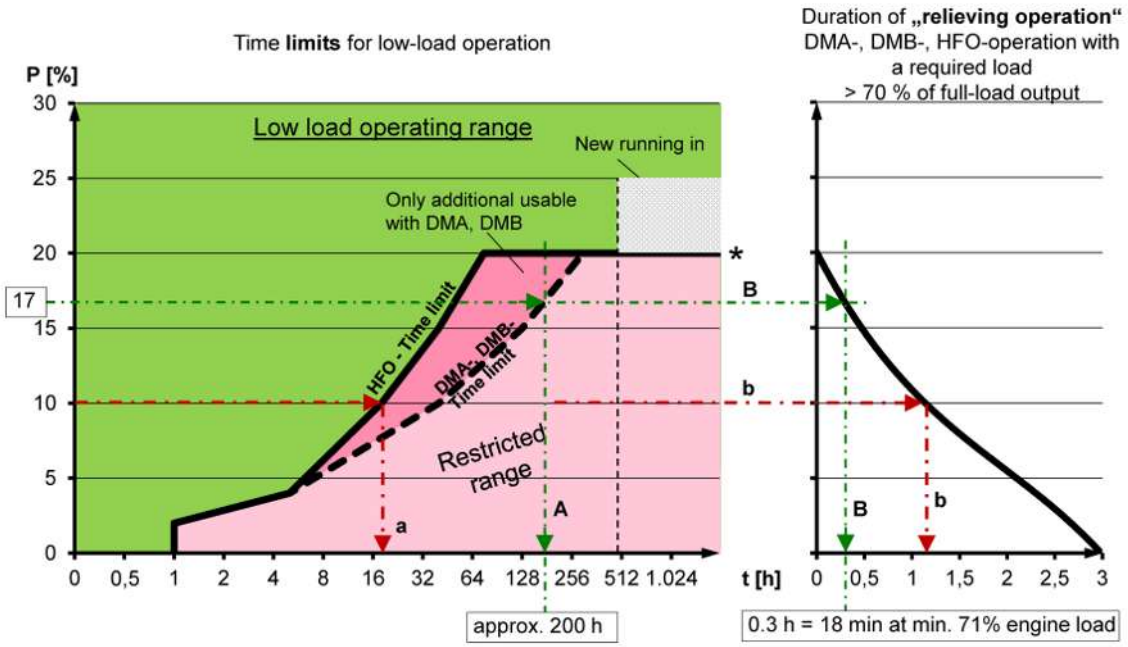


Figure 25: Time limitation for low-load operation (left), duration of "relieving operation" (right)

P % of the full load

t Operating time in hours (h)

* Generally, the time limits in residual fuel oil operation (HFO operation) apply to all HFO grades according to the designated fuel specification. In certain rare cases, when HFO grades with a high ignition delay together with a high coke residues content are used, it may be necessary to raise the total level of the limiting curve for HFO from 20% up to 30%.

Example for residual fuel oil (HFO, if applicable)

Line a — Time limits for low-load operation with residual fuel oil (HFO):

At 10% of the full load, operation on residual fuel oil (HFO) is allowable for 19 hours maximum.

Line b — Duration of "relieving operation":

Let the engine run at a load >70% of the full load appr. within 1.2 hours to burn the deposits formed.

Note:
The acceleration time from the actual load up to 70% of the full load must be at least 15 minutes.

Example for marine gas oil (DMA, DFA), marine diesel oil (DMB, DFB)

Line A — Time limits for low-load operation with DMA/DMB:

At 17% of the full load, operation on DMA/DMB is allowable appr. for 200 hours maximum.

Line B — Duration of "relieving operation":

Let the engine run at a load >70% of the full load appr. within 18 minutes to burn the deposits formed.

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Note:
The acceleration time from the actual load up to 70% of the full load must be at least 15 minutes.

2.8 Engine load reduction and engine stop

Sudden load shedding

For the sudden load shedding from 100% to 0% engine load, several requirements of the classification societies regarding the dynamic and permanent change of engine speed have to be fulfilled.

In case of a sudden load shedding and related compressor surging, check the proper function of the turbocharger silencer filter mat.

Recommended load reduction/stopping the engine

Figure Engine ramping down, generally, Page 62 shows the shortest possible times for continuously ramping down the engine.

Even with the stated shortest possible times for continuously ramping down (Phase 1 and Phase 2) the requirements of ISO 8528-5 G2 will be fulfilled.

To limit the effort regarding regulating the media circuits and also to ensure an uniform heat dissipation it always should be aimed for longer ramping down times by taking into account the realistic requirements of the specific plant.

Before final engine stop, the engine has to be operated for a minimum of 1 minute in no-load operation.

Run-down cooling

In order to dissipate the residual engine heat, the system circuits should be kept in operation after final engine stop.

	Minimum operation time after final engine stop
Lube oil circuit	15 min.
HT circuit[1) 2)]	30 min.
LT circuit[3)]	15 min.

[1)] Also serves for compressor wheel cooling.

[2)] See accordingly for the layout of the HT cooling water pump: Table Minimum flow rate during preheating and post-cooling, Page 329.

[3)] See accordingly for the layout of the LT cooling water pump section LT cooling water system, Page 325.

Table 19: System circuit operation time after engine stop

If for any reason the HT cooling water stand-by pump is not in function, the engine has to be operated for 15 minutes at 0% to 10% load before final stop, so that with the engine driven HT cooling water pump the heat will be dissipated.

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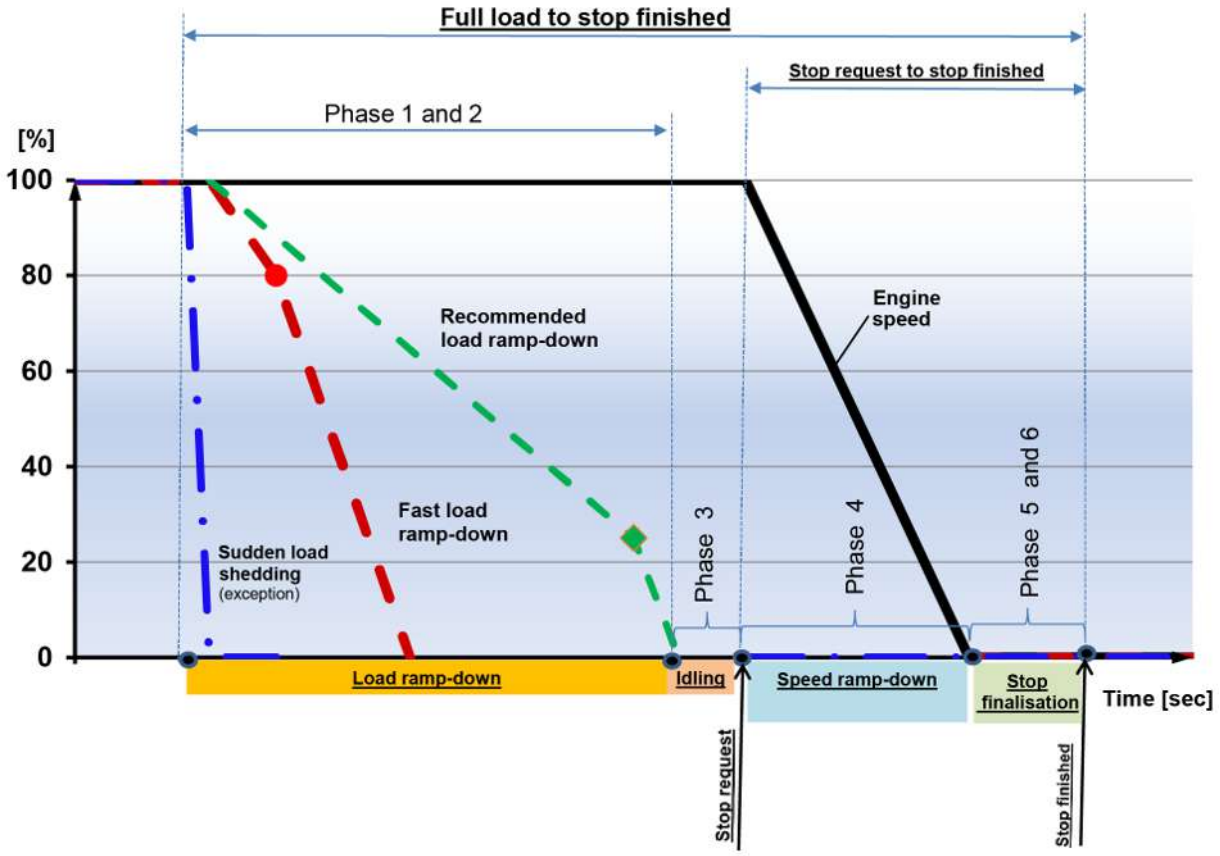


Figure 26: Engine ramping down, generally

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Duration "Full load to stop finished"						
Phase	1	2	3	4	5 + 6	-
Designation	Load ramp-down	Load ramp-down	Idling	Speed ramp-down	5) SaCoS stop process finalisation	Total duration ≥
					6) Run down cooling and lubrication[1)]	
Fast stop						
Speed [%]	100	100	100	100–0	0	-
Load [%]	100–80	80–0	0	0	0	-
Time [sec]	15	25	60	120	5) In case of active stand-by 60 sec otherwise: > 300 sec	490
					6) max. 1,800 sec.[1)]	1,990
Recommended stop						
Speed [%]	100	100	100	100–0	0	-
Load [%]	100–25	25–0	0	0	0	-
Time [sec]	115	5	10	120	5) In case of active stand-by 60 sec otherwise: > 300 sec	550
					6) max. 1,800 sec.[1)]	2,050
[1)] Run down cooling, for details see table System circuit operation time after engine stop, Page 61.						

Table 20: Recommended load reduction/stopping the engine

2.9 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.

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- The “Prohibited range” shown in figure Engine load reduction as a protective safety measure, Page 64 has to be avoided.

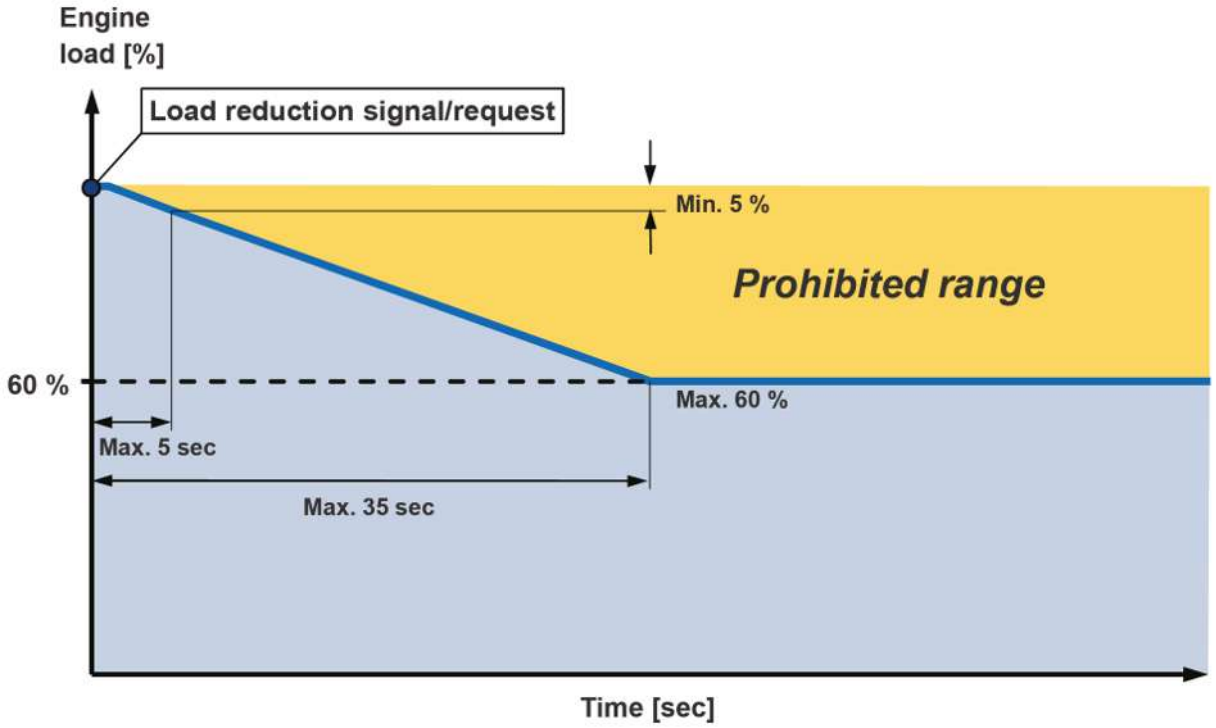


Figure 27: Engine load reduction as a protective safety measure

2.10 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
  $-15°C \geq t_x > -50°C$

Special engine design requirements

Special engine equipment required for arctic conditions category 1 and category 2, see section Engine equipment for various applications, Page 34.

Engine equipment

SaCoS 5000

- SaCoS 5000 equipment is suitable to be stored at minimum ambient temperatures of –15°C.

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- In case these conditions cannot be met, protective measures against climatic influences have to be taken for the following electronic components:
  - EDS Data box
  - TFT-touchscreen
  - Emergency switch module

  These components have to be stored at places, where the temperature is above –15°C.
- A minimum operating temperature of ≥ 0°C has to be ensured. The use of an optional electric heating is recommended.

See environmental conditions in section Technical data – Environmental conditions, Page 223.

Alternators

Alternator operation is possible according to suppliers specification.

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 274). Moreover a droplet separator and air intake silencer become necessary, see section Intake air ducting in case of arctic conditions, Page 406. 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

- Contact Everllence.

Piping for charge air blow-off

To ensure a correct operation of the charge air blow-off, the following need to be considered:

- Charge air blow-off flap installed at plant
- Diameter of piping > DN100

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- Admissible pressure loss in piping between engine and flap: < 500 mbar
- Admissible pressure loss in piping after flap: < 1,000 mbar

Hereby as additional information, the expected charge air blow-off amount (per cylinder) and temperature is stated, dependent on the intake air temperature before compressor.

Charge air blow-off amount quantity									
Intake air temperature before compressor [°C]	**-55**	**-45**	**-35**	**-25**	**-20**	**-15**	**-10**	**-5**	**0**
Max. blow-off mass flow per cylinder (100% load) [kg/s]	0.29	0.24	0.19	0.14	0.12	0.10	0.07	0.05	0.02
Max. blow-off temperature [°C][1] Cold blow-off	50								
Tolerances: ±5°C for temperature, ±4% for flow quantity.									
[1] Temperatures specified for insulation design are max. blow-off temperatures at 0°C intake air temperature.									

Table 21: Charge air blow-off amount

Instruction for minimum admissible fuel temperature

- In general the minimum viscosity before engine of 1.9 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.

Coolant and lube oil systems

- Coolant and lube oil system have to be preheated for each individual engine, see section Starting conditions, Page 48.

  See also the specific information regarding special arrangements for arctic conditions, see section Lube oil system, Page 294 and Cooling water system, Page 318.
- 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 67.
- 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.

  Therefore, an antifreeze concentration of 40% glycol of the engine cooling water systems (HT and LT) within the engine room, respectively power house is recommended. A list of currently approved coolant additives and their concentration can be found at Lubrication.
- If a concentration of anti-freezing agents of > 50% in the cooling water systems is required, contact Everllence for approval.
- For information regarding engine cooling water, see section Specification for engine supplies, Page 239.

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Insulation

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

Heat tracing

To support the restart procedures in cold condition (for example, 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. For plants taken out of operation and cooled down below temperatures of +5°C additional special measures are required. In this case contact Everllence.

Heat extraction HT system and preheater sizes

Start-up of an engine at arctic conditions (air intake temperatures of the engine below +0°C) has to be done with a preheated engine (normal start). See section Start-up and load application, Page 50.

Engine operation under arctic conditions and at low load carries the risk of heat loss in the cooling water systems and resulting risk of engine operation problems or even damage.

Therefore 3 cases are given:

Case1

Preheating of the intake air of the engine to a minimum of 0°C.

Case 2

Installation of adequate HT preheater, that operates in parallel to engine operation to compensate HT energy losses.

If operation within Range I is required,

a)

the preheater size within the plant must be capable to compensate any heat losses within the cooling water system and to keep these on the required temperature level.

b)

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

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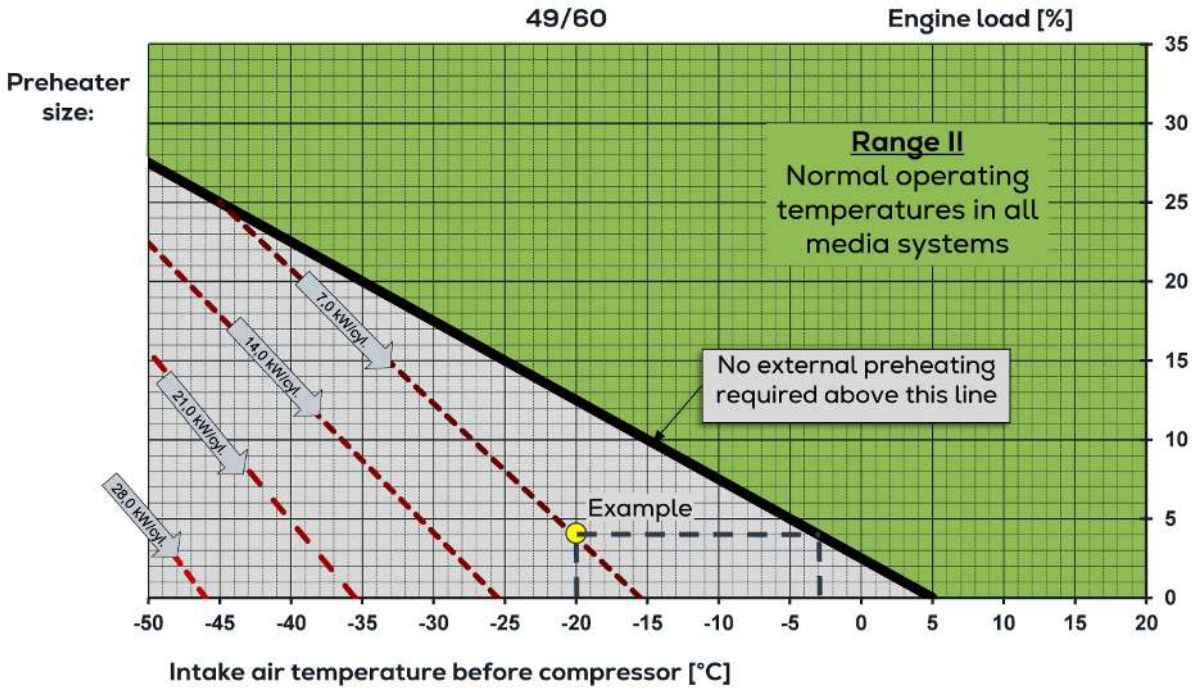


Figure 28: Required preheater size to avoid heat extraction from HT system, 49/60

Example:

- Operation at 4% engine load and -20°C intake air temperature wanted.
- According diagram preheater size of 7.0 kW/cyl. required.
- Ensure that this preheater size is installed, otherwise this operation point is not permissible.

Case 3

Start up and fast passage through the area with HT energy loss.

In case operation within Range I is not required and the needed additional preheater capacity will not be applied, than following needs to be noticed:

- For any start up of the engine with <0°C.
  - Engine must be preheated.
  - Start up and load up to a minimum of the stated engine load, where no external preheating is not longer required, must be done within ≤ 5 min. Within this 5 min the stored heat of the preheated media systems can overcome the possible heat loss, without the risk of operation problems of the engine.
- Operation in Range I must be avoided.
- For operation within Range I without the needed additional preheater capacity, no guarantee can be given for a stable, trouble free engine operation.

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2.11 Generator operation

2.11.1 Operating range for generator operation/electric propulsion

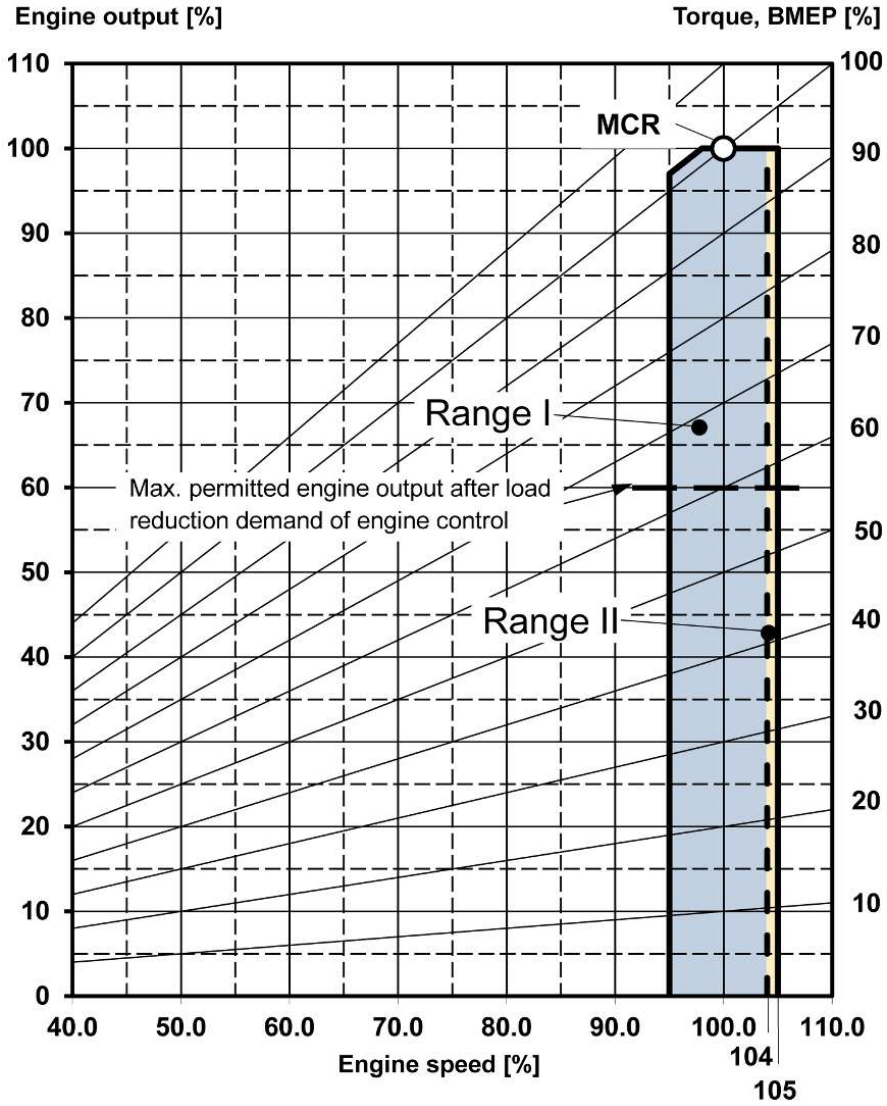


Figure 29: Operating range for generator operation/electric propulsion

- MCR[1]
  Maximum continuous rating.
- Range I
  Operating range for continuous service.
- Range II
  No continuous operation permissible.
  Maximum operating time less than 2 minutes.

[1] In accordance with DIN ISO 3046-1 and for further clarification of relevant sections within DIN ISO 8528-1, the following is specified:

- The maximum output (MCR) has to be observed by the power management system of the plant.

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- The range of 100% up to 110% fuel admission may only be used for a short time for governing purposes (for example, transient load conditions and suddenly applied load).

IMO certification for engines with operating range for electric propulsion

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.

2.11.2 Operating range for EPROX-AC

EPROX-AC is an electric propulsion system based on an AC net and allowing the system frequency to vary. The generators operate with variable speed between 80% and 100% of nominal speed.

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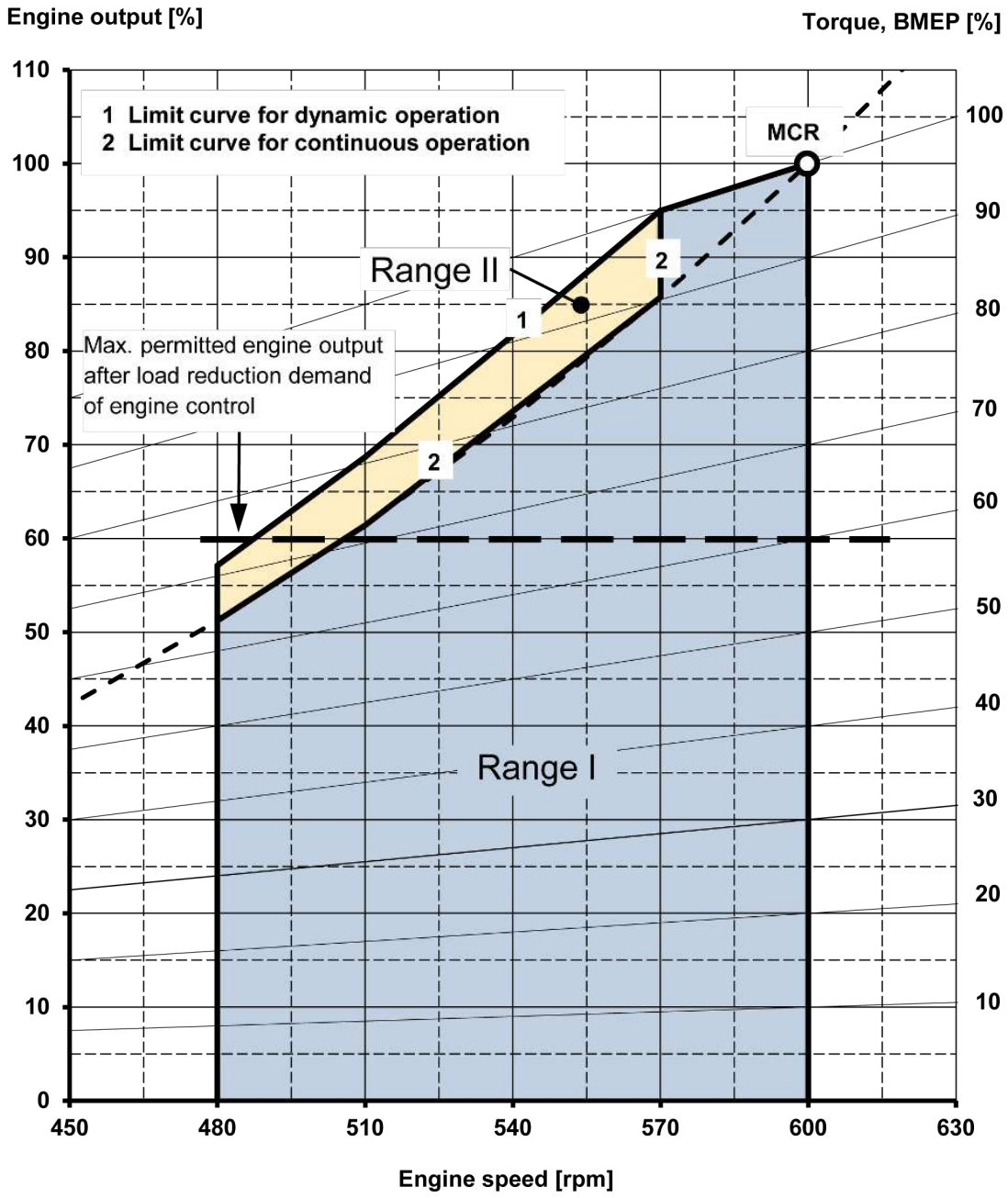


Figure 30: Operating range for EPROX-AC

Note:
In rare occasions it might be necessary that certain engine speed intervals have to be barred for continuous operation.
For applications using resiliently 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

Range I: Operating range for continuous operation.

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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.

Limit curves 49/60, EPROX-AC		
Engine speed [rpm]	Engine output [%]	
	Continuous operation	Dynamic operation
480	0	51.2
480	51.2	57.1
510	61.4	68.7
540	72.9	81.7
570	85.7	95
570	95	-
600	100	-
600	0	-

Table 22: Limit curves values 49/60, EPROX-AC

IMO certification for engines with operating range for EPROX-AC

Test cycle type E2 and D2 will be applied for the engine´s certification for compliance with the NO_X limits according to NO_X technical code 2008.

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 2028 (double certifications will no longer be required).

2.11.3 Available outputs and permissible frequency deviations

General

Generating sets, which are integrated in an electricity supply system, are subjected to the frequency fluctuations of the mains. Depending on the severity of the frequency fluctuations, output and operation respectively have to be restricted.

Frequency adjustment range

According to DIN ISO 8528-5, operating limits of > 2.5% are specified for the lower and upper frequency adjustment range.

Operating range

Depending on the prevailing local ambient conditions, a certain maximum continuous rating will be available.

In the output/speed and frequency diagrams, a range has specifically been marked with “No continuous operation permissible in this area”. Operation in this range is only permissible for a short period of time, for example, for less than 2 minutes. In special cases, a continuous rating is permissible if the standard frequency is exceeded by more than 4%.

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Limiting parameters

Max. torque

In case the frequency decreases, the available output is limited by the maximum permissible torque of the generating set.

Max. speed for continuous rating

An increase in frequency, resulting in a speed that is higher than the maximum speed admissible for continuous operation, is only permissible for a short period of time, that is, for less than 2 minutes.

For engine-specific information see section Ratings (output) and speeds, Page 39 of the specific engine.

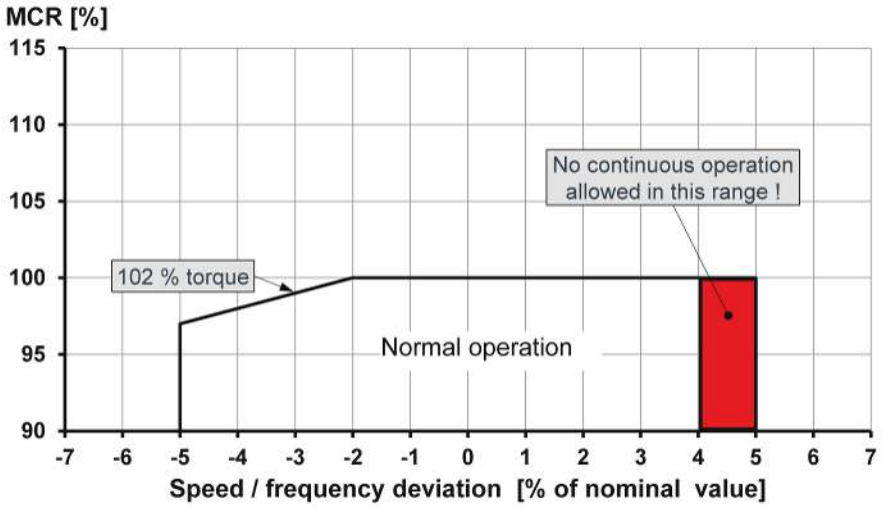


Figure 31: Permissible frequency deviations and corresponding max. output

2.11.4 Generator operation/electric propulsion – Power management

Operation of vessels with electric propulsion is defined as parallel operation of main engines with generators forming a closed system.

The power supply of the plant as a standard is done by auxilliary GenSets also forming a closed system.

In the design/layout of the plant a possible failure of one engine has to be considered in order to avoid overloading and under-frequency of the remaining engines with the risk of an electrical blackout.

Therefore we recommend to install a power management system. This ensures uninterrupted operation in the maximum output range and in case one engine fails the power management system reduces the propulsive output or switches off less important energy consumers in order to avoid under-frequency.

According to the operating conditions it is the responsibility of the ship's operator to set priorities and to decide which energy consumer has to be switched off.

The base load should be chosen as high as possible to achieve an optimum engine operation and lowest soot emissions.

The optimum operating range and the permissible part loads are to be observed (see section Low-load operation, Page 59).

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Load application in case one engine fails

In case one engine fails, its output has to be made up for by the remaining engines in the system and/or the load has to be decreased by reducing the propulsive output and/or by switching off electrical consumers.

The immediate load transfer to one engine does not always correspond with the load reserve that the particular engine has available at the respective moment. That depends on the engine's base load.

Be aware that the following section only serves as an example and is definitely not valid for this engine type. For the engine specific capability see figure(s) Load application dependent on base load (engine condition hot), Page 55.

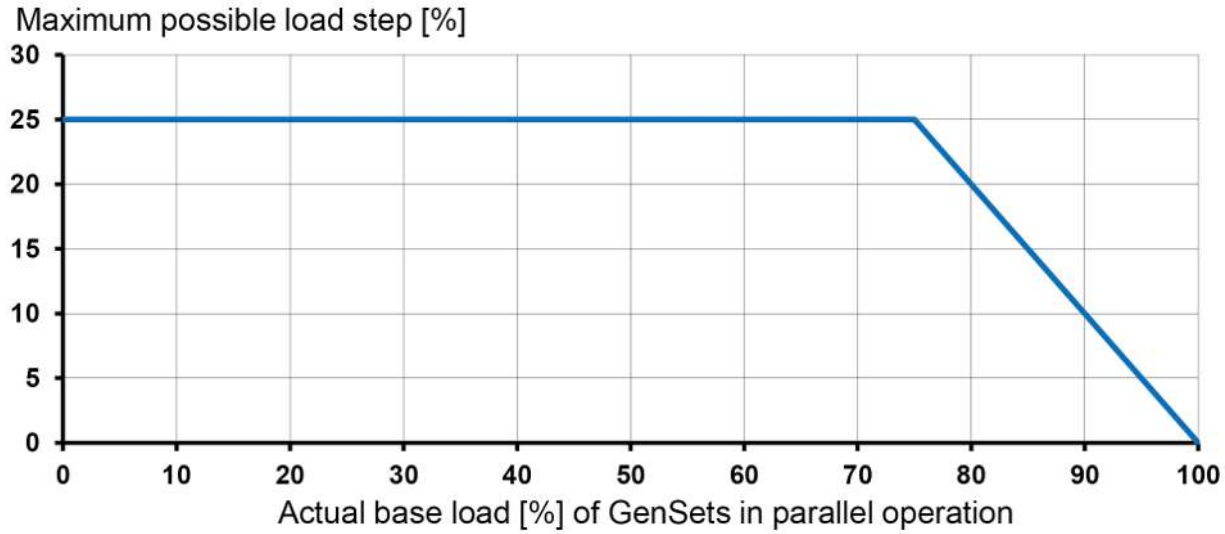


Figure 32: Maximum load step depending on base load (example may not be valid for this engine type)

Based on the above stated exemplary figure and on the total number of engines in operation the recommended maxium load of these engines can be derived. Observing this limiting maximum load ensures that the load from one failed engine can be transferred to the remaining engines in operation without power reduction.

Number of engines in parallel operation	3	4	5	6	7	8	9	10
Recommended maximum load in (%) of P_{max}	50	75	80	83	86	87.5	89	90

Table 23: Exemplary – Recommended maximum load in (%) of P_{max} dependend on number of engines in parallel operation

2.11.5 Alternator – Reverse power protection

Definition of reverse power

If an alternator, coupled to a combustion engine, is no longer driven by this engine, but is supplied with propulsive power by the connected electric grid and operates as an electric motor instead of working as an alternator, this is called reverse power. The speed of a reverse power driven engine is accordingly to the grid frequency and the rated engine speed.

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Demand for reverse power protection

For each alternator (arranged for parallel operation) a reverse power protection device has to be provided because if a stopped combustion engine (fuel admission at zero) is being turned it can cause, due to poor lubrication, excessive wear on the engine´s bearings. This is also a classifications` requirement.

Examples for possible reverse power occurences

- Due to lack of fuel the combustion engine no longer drives the alternator, which is still connected to the mains.
- Stopping of the combustion engine while the driven alternator is still connected to the electric grid.
- On ships with electric drive the propeller can also drive the electric traction motor and this in turn drives the alternator and the alternator drives the connected combustion engine.
- Sudden frequency increase, for example, because of a load decrease in an isolated electrical system -> if the combustion engine is operated at low load (for example, just after synchronising).

Adjusting the reverse power protection relay

The necessary power to drive an unfired diesel or gas engine at nominal speed cannot exceed the power which is necessary to overcome the internal friction of the engine. This power is called motoring power. The setting of the reverse-power relay should be, as stated in the classification rules, 50% of the motoring power. To avoid false tripping of the alternator circuit breaker a time delay has to be implemented. A reverse power >> 6% mostly indicates serious disturbances in the generator operation.

The following table Adjusting the reverse power relay, Page 75 provides a summary.

Admissible reverse power P_{el} [%]	Time delay for tripping the alternator circuit breaker [sec]
$P_{el} < 3$	30
$3 \leq P_{el} < 8$	3 to 10
$P_{el} \geq 8$	1.5

Table 24: Adjusting the reverse power relay

2.11.6 Earthing measures of diesel engines and bearing insulation on alternators

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, 20 mm deep, marked with the earthing symbol are provided in the engine foot on both ends of the engine.

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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.

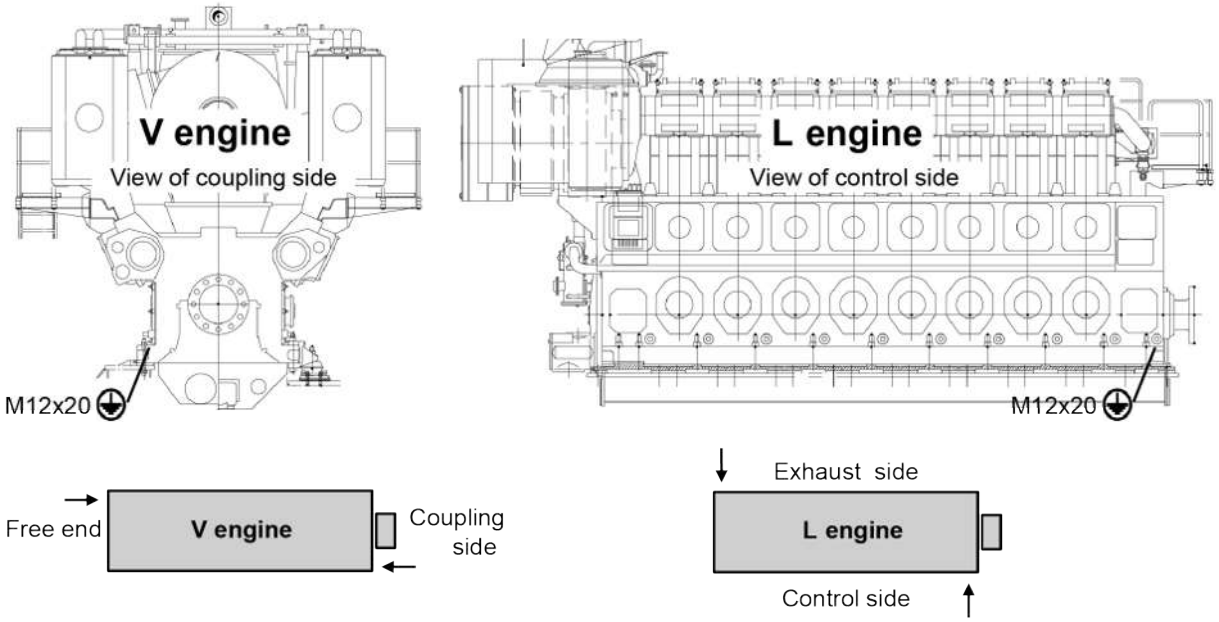


Figure 33: Earthing connection on engine (are arranged diagonally opposite each other) – Exemplary

Measures to be taken on the alternator

Shaft voltages, for example, voltages between the two shaft ends, are generated in electrical machines because of slight magnetic unbalances and ring excitations. In the case of considerable shaft voltages (for example, > 0.3 V), there is the risk that bearing damage occurs due to current transfers. For this reason, at least the bearing that is not located on the drive end is insulated (valid for alternators > 1 MW output). For verification, the voltage available at the shaft (shaft voltage) is measured while the alternator is running and excited. With proper insulation, a voltage can be measured. In order to protect the prime mover and to divert electrostatic charging, an earthing brush is often fitted on the coupling side.

Observation of the required measures is the alternator manufacturer's responsibility.

Consequences of inadequate bearing insulation on the alternator and insulation check

In case the bearing insulation is inadequate, for example, if the bearing insulation was short-circuited by a measuring lead (PT100, vibration sensor), leakage currents may occur, which result in the destruction of the bearings. One possibility to check the insulation with the alternator at standstill (prior to coupling the alternator to the engine; this, however, is only possible in the case of single-bearing alternators) would be:

- Raise the alternator rotor (insulated, in the crane) on the coupling side.
- Measure the insulation by the megger test against earth.

Note:
Hereby the max. voltage permitted by the alternator manufacturer is to be observed.

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If the shaft voltage of the alternator at rated speed and rated voltage is known (for example, from the test record of the alternator acceptance test), it is also possible to carry out a comparative measurement.

If the measured shaft voltage is lower than the result of the “earlier measurement” (test record), the alternator manufacturer should be consulted.

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.

Earthing conductors have to be provided at two diagonally opposite points of engine.

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 Everllence.

Earthing strips are also not included in the Everllence 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, that is, the distance between the welding electrode and the earthing connection should not exceed 10 m.

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2.12 Propeller operation

2.12.1 General remark for operating ranges

Be advised that engines with several operational demands, always the stricter limitations need to be applied and is valid for all operational tasks.

E.g. mechanical dredger applications need to be classified in following manner:

- Engine only dredge pump drive.

  Operating range for pump drive valid.
- Engine driving dredge pump and on counter side a fixed pitch propeller.

  Operating range for fixed pitch propeller valid.
- Engine driving dredge pump and on counter side a controllable pitch propeller.

  Operating range for pump drive valid.
- Engine driving dredge pump and on counter side a controllable pitch propeller and a small generator.

  Operating range for pump drive valid.

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2.12.2 Operating range for controllable pitch propeller (CPP)

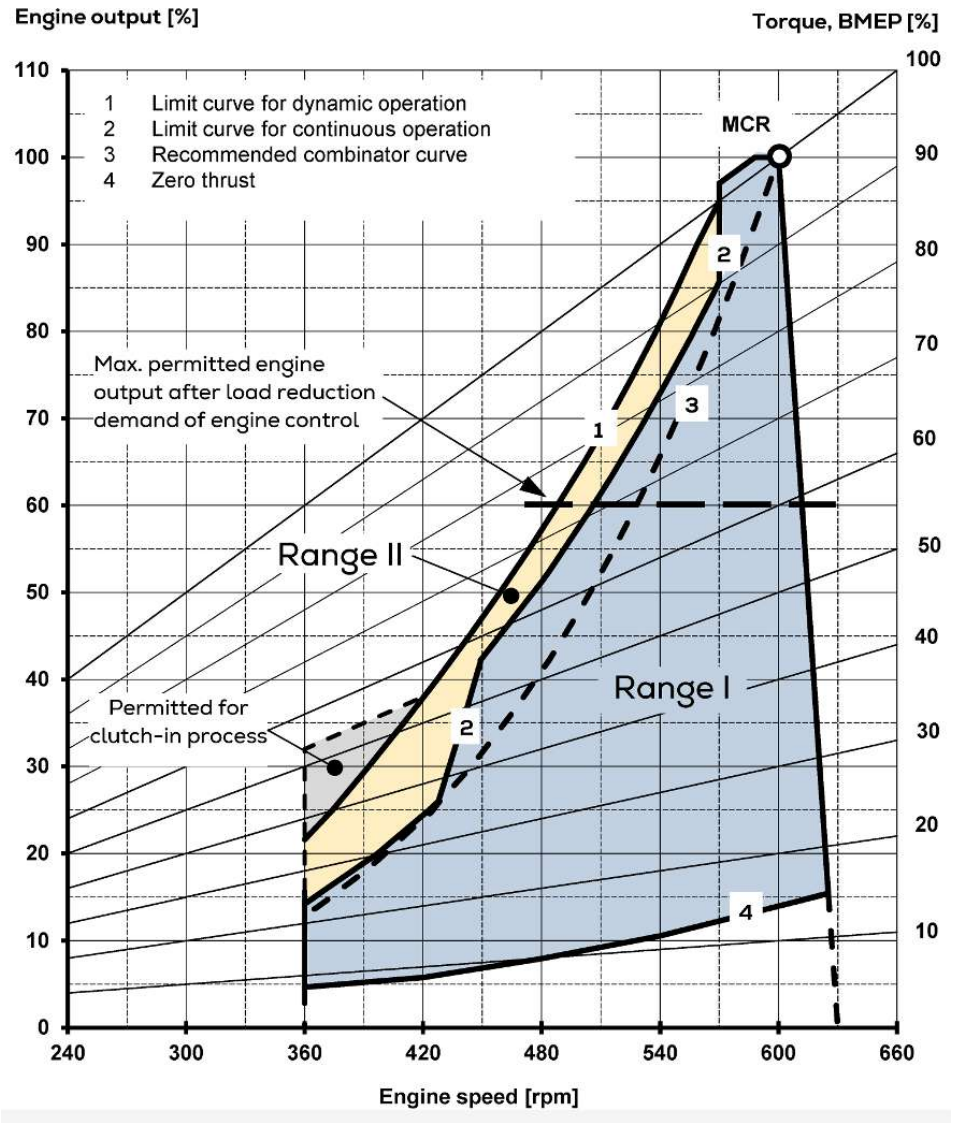


Figure 34: Operating range for controllable pitch propeller

Note:
operating range CPP valid for IMO 2008.

Note:
In rare occasions it might be necessary that certain engine speed intervals have to be barred for continuous operation.
For applications using resiliently 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

Range I: Operating range for continuous operation.

Note:

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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.

The combinator curve must be placed at a sufficient distance to the load limit curve. For overload protection, a load control has to be provided.

Transmission losses (e.g. by gearboxes and shaft power) and additional power requirements (e.g. by PTO) must be taken into account.

IMO certification for 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.

Engine speed [rpm]	Limit curve dynamic operation	Limit curve continuous operation	Recommended combinator curve
	Engine output [%]		
360	21.6	14.2	13
366	23	15	13.8
372	24.4	16.1	14.8
390	29.3	18.9	17.9
397	31.3	20	19.2
420	37.9	24.4	24
424	38.8	25	24.7
428	40	26	26
440	44	35	28.9
446	45.8	39.6	30.5
466	52.4	47.1	36.4
484	58.5	52.5	42.3
500	64.4	57.9	48.2
505	66.4	59.6	50.2
515	70.2	63.2	54.3
530	76.5	68.9	60.9
543	82	74.1	67.1
556	88.6	79.5	73.7
558	89.7	80.4	74.8
568	94.1	84.8	80.3
570	95	85.7	81.5
570	97	97	81.5
576	98	98	84.9
579	98.5	98.5	86.7

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Engine speed [rpm]	Limit curve dynamic operation	Limit curve continuous operation	Recommended combinator curve
	Engine output [%]		
590	100	100	93.5
600	100	100	100

Table 25: Limit curve values, recommended combinator curve 49/60

2.12.3 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 < 60 % of the maximum possible pitch.

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 Operating range for controllable pitch propeller (CPP), Page 79) 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 82).

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

The engine should not be operated in the area above the combinator curve (Range II in figure Operating range for controllable pitch propeller, Page 79).

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 82).

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

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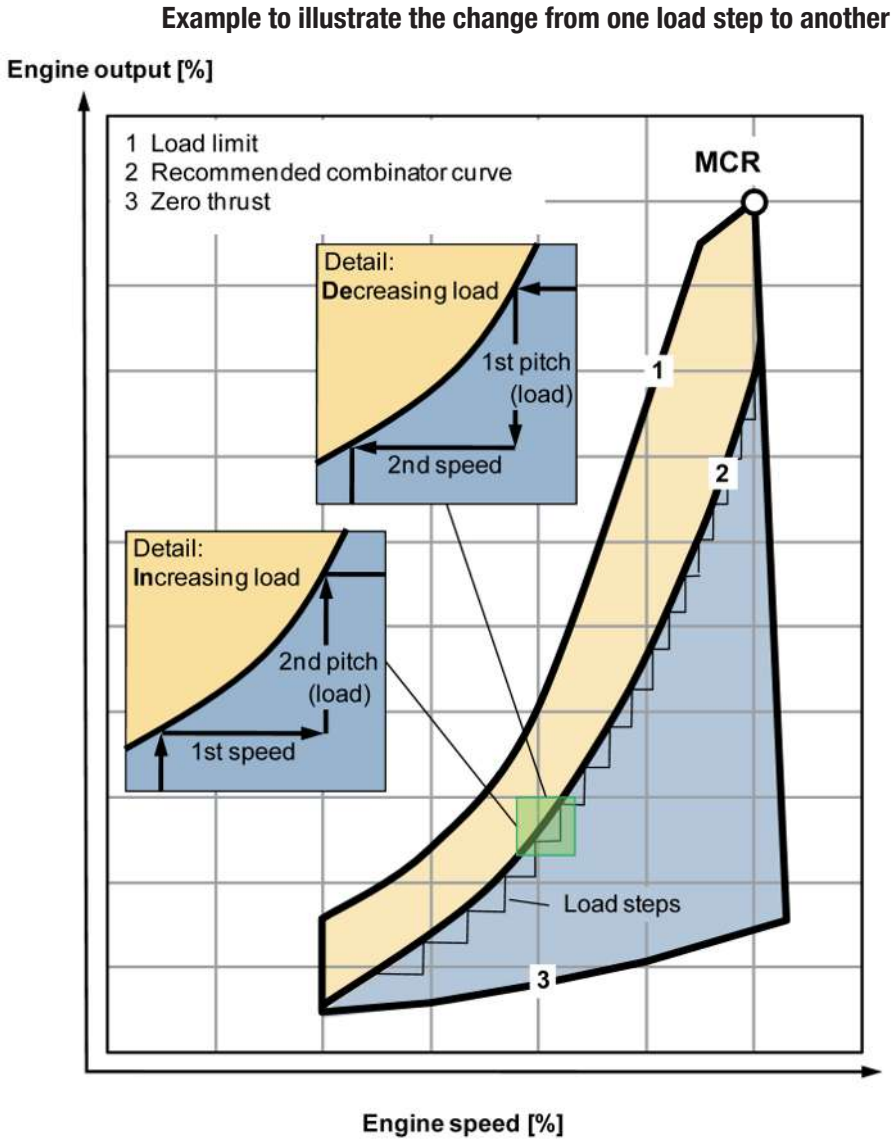


Figure 35: Example to illustrate the change from one load step to another

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 seconds.

Multiple-screw ship

The propeller control has to ensure that the windmilling time is less than 40 seconds. 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 63 the requirements for the response time are stated.

Additional signals from the Propulsion Optimisation Interface are available

In addition, binary and analogue signals from the Propulsion Optimisation Interface are available that allow an optimsed data exchange between the engine and a smooth and look ahead control of the CPP propulsion system. Clarify details at an early stage of the project.

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).

Everllence' guidelines concerning acceleration times and power range have to be observed

The power range (see section Operating range for controllable pitch propeller (CPP), Page 79) and the acceleration times (see paragraph Acceleration times, Page 57) have to be observed. In section Engine load reduction as a protective safety measure, Page 63 the requirements for the response time are stated.

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2.12.4 Operating range for mechanical pump drive

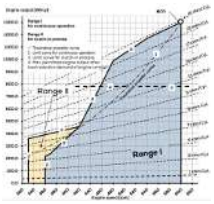


Figure 36: Operating range for mechanical pump drive

- MCR

  Maximum continuous rating, fuel stop power
- Range I

  Operating range for continuous operation
- Range II

  Operating range which is temporarily admissible e.g. during acceleration.
- For dredge applications with dredge pumps directly mechanically driven by the engines there is a requirement for full constant torque operation between 80% and 100% of nominal engine speed. This specific operating range results in a reduced output of the engine according to table Available outputs/related reference conditions, Page 40.

IMO certification for engines with operating range for mechanical pump drive

Test cycle type C1 for auxiliary engine application will be applied for the engine´s certification for compliance with the NO_X limits according to NO_X technical code.

Limit curves mechanical pump drive 49/60

Engine speed [rpm]	Limit curve dynamic operation [3]	Limit curve continuous operation [2]
	Engine output [%]	
330	0	0
330	130	0
330	325	0
330	358.3	0
360	390.9	0
360	390.9	130
360	390.9	215.8
370	401.7	240.5
380	412.6	287.3
388.9	422.3	325
390	423.5	329.5
400	434.3	371.7

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Engine speed [rpm]	Limit curve dynamic operation [3]	Limit curve continuous operation [2]
	Engine output [%]	
420	456	456
423		481.9
428		525.1
440		628.7
442.5		650
450		715
468		878.8
478.6		975
480		988
518.6		1,105
540		1,170
570		1,235
570		1,235
600		1,300
600		0

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

2.13.1 Fuel oil consumption for emission standard: IMO Tier II

49/60 – Electric propulsion (speed = constant) compliant with IMO NO_x Tech. Code 2008

1,300 kW/cyl., 600 rpm

% Output			100	85 [1]	75	50	25
Spec. fuel consumption with DMA or DMB, HFO without attached pumps[2] [3] [4]							
DMA or DMB	g/kWh	6, 7, 9L, 12, 14V	175.5	170.5	177	187	213
		8, 10L:	176.5	171	177.5	187	213
HFO		6, 7, 9L, 12, 14V	177	172	178.5	188.5	214.5
		8, 10L:	178	172.5	179	188.5	214.5
Pilot fuel consumption included in above stated values (approximately)	g/kWh	L,V:	1.8	2.1	2.4	3.5	7.8

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% Output	100	85 [1]	75	50	25

[1] Warranted fuel consumption at 85% MCR.

[2] Based on reference conditions, see table Reference conditions for fuel consumption, Page 94.

[3] Tolerance +5%.

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

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

Table 26: Fuel consumption 49/60 – Electric propulsion (speed = constant) compliant with IMO NO_x Tech. Code 2008

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49/60 – Electric propulsion (speed = constant) compliant with IMO NO_x Tech. Code 2028

1,300 kW/cyl., 600 rpm

% Output			100	85 [1]	75	50	25
Spec. fuel consumption with DMA or DMB, HFO without attached pumps[2] [3] [4]							
DMA or DMB	g/kWh	6, 7, 9L, 12, 14V	175.5	174.5	177	187	213
		8, 10L:	176.5	175	177.5	187	213
HFO		6, 7, 9L, 12, 14V	177	176	178.5	188.5	214.5
		8, 10L:	178	176.5	179	188.5	214.5
Pilot fuel consumption included in above stated values (approximately)	g/kWh	L,V:	1.8	2.1	2.4	3.5	7.8

[1] Warranted fuel consumption at 85% MCR.

[2] Based on reference conditions, see table Reference conditions for fuel consumption, Page 94.

[3] Tolerance +5%.

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

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

Table 27: Fuel consumption 49/60 – Electric propulsion (speed = constant) compliant with IMO NO_x Tech. Code 2028

2025-12-03 - 3.0

49/60 – EPROX-AC compliant with IMO NO_x Tech. Code 2008

1,300 kW/cyl., 600 rpm

% Output			100	85 [1]	75	50	25
Speed			Constant = 600 rpm				
Spec. fuel consumption with DMA or DMB, HFO without attached pumps[2] [3] [4]							
DMA or DMB	g/kWh	6, 7, 9L, 12, 14V	175.5	170.5	177	187	213
		8, 10L:	176.5	171	177.5	187	213
HFO		6, 7, 9L, 12, 14V	177	172	178.5	188.5	214.5
		8, 10L:	178	172.5	179	188.5	214.5
Pilot fuel consumption included in above stated values (approximately)	g/kWh	L,V:	1.8	2.1	2.4	3.5	7.8
Speed (left limit of EPROX AC-operanting range I)			600 rpm	570 rpm	545 rpm	480 rpm	480 rpm
Spec. fuel consumption with DMA or DMB, HFO without attached pumps[2] [3] [4]							
DMA or DMB	g/kWh	6, 7, 9L, 12, 14V	175.5	169	171	175.5	196
		8, 10L:	176.5	169	171	175.5	196
HFO		6, 7, 9L, 12, 14V	177	170.5	172.5	177	197.5
		8, 10L:	178	170.5	172.5	177	197.5
Pilot fuel consumption included in above stated values (approximately)	g/kWh	L,V:	1.8	2.1	2.4	3.5	7.8

[1] Warranted fuel consumption at 85% MCR.

[2] Based on reference conditions, see table Reference conditions for fuel consumption, Page 94.

[3] Tolerance +5%.

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

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

Table 28: Fuel consumption 49/60 – EPROX-AC compliant with IMO NO_x Tech. Code 2008

2025-12-03 - 3.0

49/60 – EPROX-AC compliant with IMO NO_x Tech. Code 2028

1,300 kW/cyl., 600 rpm

% Output			100	85 [1]	75	50	25
Speed			Constant = 600 rpm				
Spec. fuel consumption with DMA or DMB, HFO without attached pumps [2] [3] [4]							
DMA or DMB	g/kWh	6, 7, 9L, 12, 14V	175.5	175	177	187	213
		8, 10L:	176.5	175.5	177.5	187	213
HFO		6, 7, 9L, 12, 14V	177	176	178.5	188.5	214.5
		8, 10L:	178	176.5	179	188.5	214.5
Pilot fuel consumption included in above stated values (approximately)	g/kWh	L,V:	1.8	2.1	2.4	3.5	7.8
Speed (left limit of EPROX AC-operanting range I)			600 rpm	570 rpm	545 rpm	480 rpm	480 rpm
Spec. fuel consumption with DMA or DMB, HFO without attached pumps [2] [3] [4]							
DMA or DMB	g/kWh	6, 7, 9L, 12, 14V	175.5	171	171	177.5	196
		8, 10L:	176.5	171	171	177.5	196
HFO		6, 7, 9L, 12, 14V	177	170.5	172.5	177	197.5
		8, 10L:	178	170.5	172.5	177	197.5
Pilot fuel consumption included in above stated values (approximately)	g/kWh	L,V:	1.8	2.1	2.4	3.5	7.8

[1] Warranted fuel consumption at 85% MCR.

[2] Based on reference conditions, see table Reference conditions for fuel consumption, Page 94.

[3] Tolerance +5%.

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

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

Table 29: Fuel consumption 49/60 – EPROX-AC compliant with IMO NO_x Tech. Code 2028

2025-12-03 - 3.0

49/60 – Mechanical propulsion with CPP compliant with IMO NO_x Tech. Code 2008

1,300 kW/cyl., 600 rpm

% Output			100	85 [1]	75	50	25
Speed			Constant = 600 rpm				
Spec. fuel consumption with DMA or DMB, HFO without attached pumps[2] [3] [4]							
DMA or DMB	g/kWh	6, 7, 9L, 12, 14V	175.5	170.5	177	187	213
		8, 10L:	176.5	171	177.5	187	213
HFO		6, 7, 9L, 12, 14V	177	172	178.5	188.5	214.5
		8, 10L:	178	172.5	179	188.5	214.5
Pilot fuel consumption included in above stated values (approximately)	g/kWh	L,V:	1.8	2.1	2.4	3.5	7.8
Speed on recommended combinator curve			600 rpm	576 rpm	558 rpm	505 rpm	424rpm
Spec. fuel consumption with DMA or DMB, HFO without attached pumps[2] [3] [4]							
DMA or DMB	g/kWh	6, 7, 9L, 12, 14V	175.5	169.5	172	176	193
		8, 10L:	176.5	170	172	176	193
HFO		6, 7, 9L, 12, 14V	177	171.5	173.5	177.5	194.5
		8, 10L:	178	171.5	173.5	177.5	194.5
Pilot fuel consumption included in above stated values (approximately)	g/kWh	L,V:	1.8	2.1	2.4	3.5	7.8

[1] Warranted fuel consumption at 85% MCR.

[2] Based on reference conditions, see table Reference conditions for fuel consumption, Page 94.

[3] Tolerance +5%.

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

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

Table 30: Fuel consumption 49/60 – Mechanical propulsion with CPP and standard compression ratio compliant with IMO NO_x Tech. Code 2008

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49/60 – Mechanical propulsion with CPP compliant with IMO NO_x Tech. Code 2028

1,300 kW/cyl., 600 rpm

% Output			100	85 [1]	75	50	25
Speed			Constant = 600 rpm				
Spec. fuel consumption with DMA or DMB, HFO without attached pumps[2] [3] [4]							
DMA or DMB	g/kWh	6, 7, 9L, 12, 14V	tbd	tbd	tbd	tbd	tbd
		8, 10L:	tbd	tbd	tbd	tbd	tbd
HFO		6, 7, 9L, 12, 14V	tbd	tbd	tbd	tbd	tbd
		8, 10L:	tbd	tbd	tbd	tbd	tbd
Pilot fuel consumption included in above stated values (approximately)	g/kWh	L,V:	1.8	2.1	2.4	3.5	7.8
Speed on recommended combinator curve			600 rpm	576 rpm	558 rpm	505 rpm	424rpm
Spec. fuel consumption with DMA or DMB, HFO without attached pumps[2] [3] [4]							
DMA or DMB	g/kWh	6, 7, 9L, 12, 14V	tbd	tbd	tbd	tbd	tbd
		8, 10L:	tbd	tbd	tbd	tbd	tbd
HFO		6, 7, 9L, 12, 14V	tbd	tbd	tbd	tbd	tbd
		8, 10L:	tbd	tbd	tbd	tbd	tbd
Pilot fuel consumption included in above stated values (approximately)	g/kWh	L,V:	1.8	2.1	2.4	3.5	7.8

[1] Warranted fuel consumption at 85% MCR.

[2] Based on reference conditions, see table Reference conditions for fuel consumption, Page 94.

[3] Tolerance +5%.

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

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

Table 31: Fuel consumption 49/60 – Mechanical propulsion with CPP and standard compression ratio compliant with IMO NO_x Tech. Code 2028

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L49/60 – Mechanical pump drive (speed = constant) compliant with IMO NO_x Tech. Code 2008

1,300 kW/cyl., 600 rpm

% Output			100	85 [1]	75	50	25
Speed			Constant = 600 rpm				
Spec. fuel consumption with DMA or DMB, HFO without attached pumps[2] [3] [4]							
DMA or DMB	g/kWh	6, 7, 9L:	176	172.5	178	189	213
		8, 10L:	177	173	178.5	189	213
HFO		6, 7, 9L:	177.5	174	179.5	190.5	214.5
		8, 10L:	178.5	174.5	180	190.5	214.5
Pilot fuel consumption included in above stated values (approximately)	g/kWh	L:	1.8	2.1	2.4	3.5	7.8

[1] Warranted fuel consumption at 85% MCR.

[2] Based on reference conditions, see table Reference conditions for fuel consumption, Page 94.

[3] Tolerance +5%.

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

[4] Relevant for engine´s certification for compliance with the NO_x limits according C1 test cycle.

Table 32: Fuel consumption L49/60– Mechanical pump drive compliant with IMO NO_x Tech. Code 2008

Additions to fuel consumption

1. Engine driven pumps increase the fuel consumption by:

$$be_{ISO\ with\ pumps} = be_{ISO\ without\ pumps} \times (1 + f_{pumps})$$

$$f_{pumps} = (f_{HT\ pumps} + f_{LT\ pumps} + f_{LO\ pumps}) \times \frac{1{,}300\ kW/cyl.}{Nominal\ output\ per\ cyl.}$$

For HT CW service pump (attached)

6L-8L:

$$f_{HT\ pumps} = i_{HT\ pumps} \times 0.0025 \times \frac{100\%}{load\%} \times \left(\frac{n_x}{n_n}\right)^3$$

9L, 10L, 12V:

$$f_{HT\ pumps} = i_{HT\ pumps} \times 0.0020 \times \frac{100\%}{load\%} \times \left(\frac{n_x}{n_n}\right)^3$$

14V:

$$f_{HT\ pumps} = i_{HT\ pumps} \times 0.0022 \times \frac{100\%}{load\%} \times \left(\frac{n_x}{n_n}\right)^3$$

For LT CW service pump (attached)

6L-10L, 12V:

$$f_{LT\ pumps} = i_{LT\ pumps} \times 0.0026 \times a \times \frac{100\%}{load\%} \times \left(\frac{n_x}{n_n}\right)^3$$

14V:

$$f_{LT\ pumps} = i_{LT\ pumps} \times 0.0035 \times a \times \frac{100\%}{load\%} \times \left(\frac{n_x}{n_n}\right)^3$$

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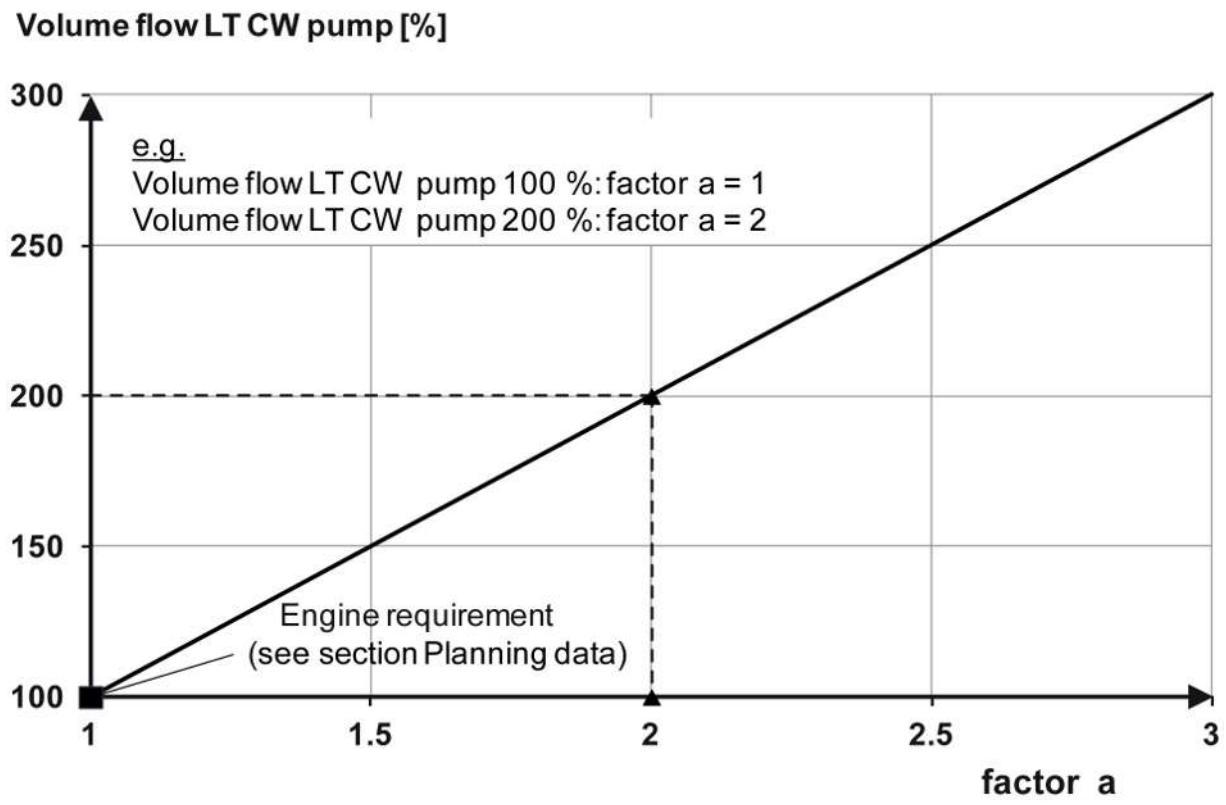


Figure 37: Derivation of factor a

For all lube oil service pumps (attached)

GenSet, electric propulsion:

6L-8L:

$$f_{LO\ pumps} = 0.0088 \times \frac{100\%}{load\%} \times \left(\frac{n_x}{n_n}\right)^1$$

9L, 10L, 12V:

$$f_{LO\ pumps} = 0.0079 \times \frac{100\%}{load\%} \times \left(\frac{n_x}{n_n}\right)^1$$

14V:

$$f_{LO\ pumps} = 0.0068 \times \frac{100\%}{load\%} \times \left(\frac{n_x}{n_n}\right)^1$$

Mechanical propulsion CPP:

6L-8L:

$$f_{LO\ pumps} = 0.0088 \times \frac{100\%}{load\%} \times \left(\frac{n_x}{n_n}\right)^1$$

9L, 10L, 12V:

$$f_{LO\ pumps} = 0.0079 \times \frac{100\%}{load\%} \times \left(\frac{n_x}{n_n}\right)^1$$

14V:

$$f_{LO\ pumps} = 0.0068 \times \frac{100\%}{load\%} \times \left(\frac{n_x}{n_n}\right)^1$$

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Mechanical pump drive (dredger):

6L-8L:

$$f_{LO\ pumps} = 0.0088 \times \frac{100\%}{load\%} \times \left(\frac{n_x}{n_n}\right)^1$$

9L, 10L:

$$f_{LO\ pumps} = 0.0082 \times \frac{100\%}{load\%} \times \left(\frac{n_x}{n_n}\right)^1$$

f_{pumps}	Actual factor for impact of attached pumps	[-]
$i_{HT\ pumps}$	Number of attached HT cooling water service pumps	[-]
$i_{LT\ pumps}$	Number of attached LT cooling water service pumps	[-]
n_x	Actual engine speed	[rpm]
n_n	Nominal engine speed	[rpm]
load%	Actual engine load	[%]
Nominal output per cylinder	Insert the nominal output per cylinder	[kW/cyl.]

2. For exhaust gas back pressure after turbine > 50 mbar

Every additional 1 mbar (0.1 kPa) back pressure addition of 0.015 g/kWh has to be calculated.

3. For exhaust gas temperature control by adjustable waste gate

For every increase of the exhaust gas temperature by 1°C, due to activation of adjustable waste gate, an addition of 0.03 g/kWh to be calculated.

4. For engines equipped with PTO an addition of 0.5% has to be calculated.

5. For gas with low Wobbe Index Wi

For gas with a Wobbe Index Wi < 44 MJ/Nm^3 an increased spec. energy consumption needs to be considered - to be defined project-specific.

Fuel oil consumption at idle running

No. of cylinders, config.	6L	7L	8L	9L	10L	12V	14V
	kg/h						
Liquid fuel operation at 600 rpm, based on DMA (42,700 kJ/kg)	135	160	180	200	225	270	315

Table 33: 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 high pressure TC t_{ba1r}[2)]	K/°C	316/43

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Engine type specific reference charge air temperature before cylinder t_{ba2r} [2]	K/°C	323/50
Liquid fuel: Main fuel[3], pilot fuel[4] NCV	kJ/kg	42,700
Pilot fuel cetane number (CN)	-	55 ≤ CN ≤ 60
Open crankcase ventilation (OCV) installed	-	-

[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).

[3] Main fuel: Stated figures for DMA, DMB or HFO valid for fuel type fulfilling the stated quality requirements and without contents of FAME or synthetic fuels, that may result in low volumetric heat values.

[4] Pilot fuel: Stated figures for DMA valid for fuel type fulfilling the stated quality requirements.

Table 34: Reference conditions for fuel consumption 49/60 (DMA, DMB)

IMO Tier II requirements:

For detailed information see section Cooling water system, Page 318.

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.

2.13.2 Lube oil consumption

Specific lube oil consumption:

$$0.38\ \text{g/kWh}^{1)} \times \frac{100\%}{\text{load\%}} \times \frac{1{,}300\ \text{kW/cyl.}}{\text{nominal output per cyl.}}$$

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 1,300 kW/cyl. and 100% actual engine load: 0.38 g/kWh

The lube oil quality needs to be checked regularly. An oil change is required, if the oil quality no longer matches the specification.

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2.13.3 Starting air and control air consumption

No. of cylinders, config.		6L	7L	8L	9L	10L	12V	14V
Control air consumption	Nm^3/h [1]	2.5						
Air consumption at minimum moment of inertia [2]								
Air consumption per start	Nm^3 [1]	3.6	4.5	4	4	5	4.8	7.2
Air consumption per slow turn **without** subsequent start [3]	Nm^3 [1]	3.6	4.5	4	4	5	7.5	7.2
Reference moment of inertia for stated air consumption figures	kgm^2	5,767	6,218	6,846	6,825	7,168	9,500	9,922
Air consumption at high moment of inertia [2]								
Air consumption per start	Nm^3 [1]	4.7	5.8	5	5.2	6.6	6.5	9.2
Air consumption per slow turn **without** subsequent start [3]	Nm^3 [1]	4.7	5.8	5	5.2	6.6	10.2	9.2
Reference moment of inertia for stated air consumption figures [2]	kgm^2	11,000	11,500	12,000	12,500	13,000	18,000	21,000
Starting system active in case of start [4]	sec	5						
Starting system active in case of slow turn **without** subsequent start [4]	sec	15						
Air consumption per jet assist activation [5]	Nm^3 [1]	2.5	2.5	2.5	3.3	3.3	4.85	4.85
Air consumption jet assist in case of emergency loading [6]	Nm^3 [1]	To be considered: 20 jet assist activations during loading from 0% to 100% load						

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No. of cylinders, config.	6L	7L	8L	9L	10L	12V	14V

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

[2] The air consumption per starting manoeuvre/slow turn of the unit (e.g. engine plus alternator) increases in relation to its total moment of inertia. Linear interpolation must be carried out between the stated figures to gain the relevant air consumption figures for the unit within the plant based on its total moment of inertia at start. Consider also the "Required minimum total moments of inertia" as stated within table Moments of inertia for marine main engines – Crankshaft, damper, flywheel, Page 163.

[3] Required for plants with power management system demanding automatic engine start. Slow turn will be activated only after a long period of engine standstill. This value states the air consumption for slow turn manoeuvre only, without the air consumption for the automatically activated engine start after the end of the slow turn manoeuvre.

[4] Stated time duration for activated starting system **only relevant for layout** of starting air system.
For layout of the starting air system, note:

- Starting air pressure stated within section Operating/service temperatures and pressures, Page 133.
- Maximum velocity (m/s) see section External pipe dimensioning, Page 278.
- Consider multiple start of engines and the temporal distribution of events, if needed.
- See section External compressed air system – Dimensioning starting air receivers, compressors, Page 397.

[5] The mentioned above air consumption per jet assist activation is valid for a jet duration of 5 seconds. The jet duration may vary between 3 sec and 10 sec, depending on the loading (average jet duration 5 sec). See section External compressed air system – Jet assist, Page 399 for the different applications and accordingly needed consideration for the layout.
Note: In the period of the "Normal Start", jet assist **will not** be activated.

[6] See accordingly figure Duration of the load application, engine equipped with jet assist – Continuous loading (extract), Page 53.

Table 35: Starting air and control air consumption

2.13.4 Recalculation of liquid 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*" Everllence has specified the method for recalculation of fuel consumption for liquid fuel dependent on ambient conditions for single-stage turbocharged engines as follows:

$$\beta = 1 + 0.00055 \times (t_x - t_r) + 0.0002 \times (t_{ba1x} - t_{ba1r}) + 0 \times (t_{ba2x} - t_{ba2r}) + 0.060 \times (p_r - p_x)$$

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 36: 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

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t_{bar}	Engine type specific reference charge air temperature before cylinder see table Reference conditions for fuel consumption, Page 94

	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 HP TC	[°C]	t_{ba1r}	t_{ba1x}
Charge air temperature before cylinder	[°C]	t_{ba2r}	t_{ba2x}
Ambient air pressure	[bar]	p_r	p_x

Table 37: Recalculation of liquid fuel consumption – Units and references

Example

Reference values:

b_r = 172 g/kWh, t_r = 25 °C, t_{ba1r} = 37 °C, t_{ba2r} = 43 °C, p_r = 1.0 bar

At site:

t_x = 45 °C, t_{ba1x} = 47 °C, t_{ba2x} = 53 °C, p_x = 0.9 bar

$\beta = 1 + 0.00055 \times (45 - 25) + 0.0002 \times (47 - 37) + 0 \times (53 - 43) + 0.060 \times (1 - 0.9) = 1.019$

$b_x = \beta \times b_r = 1.019 \times 172$ g/kWh = 175.3 g/kWh

2.13.5 Influence of engine aging on fuel 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 following figures.

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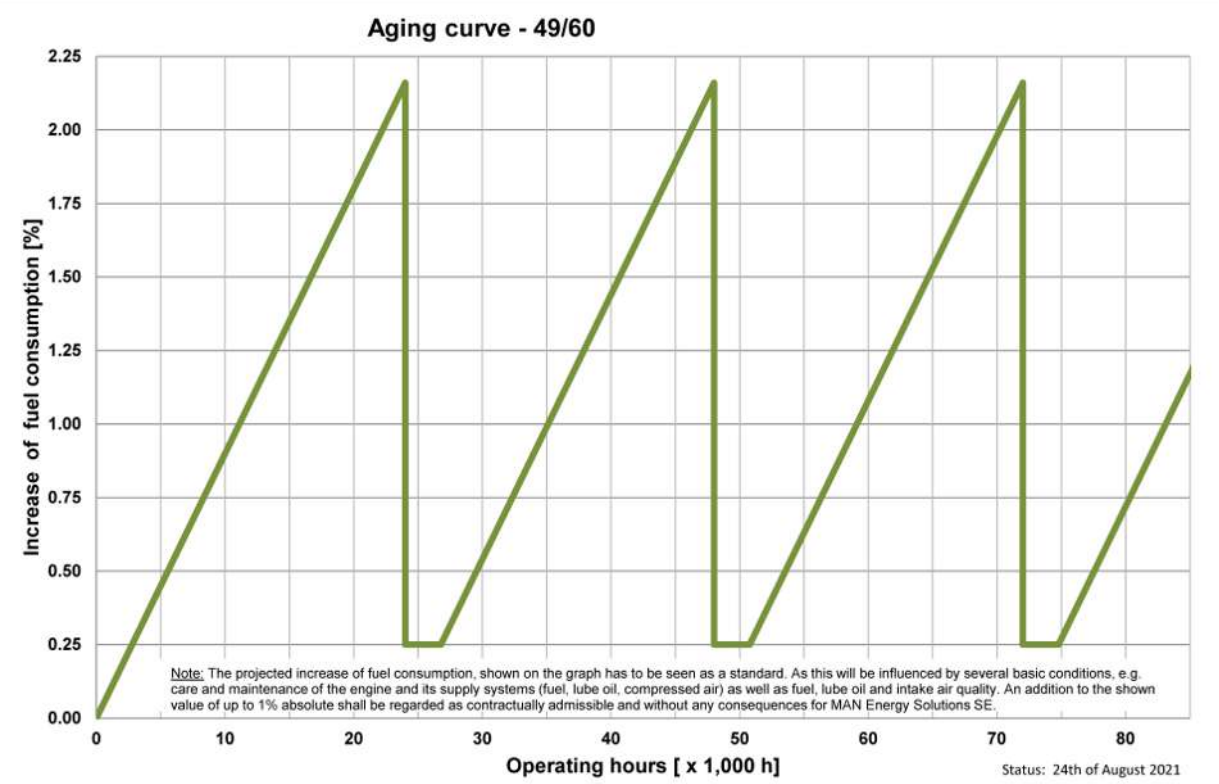


Figure 38: Influence of total engine running time and service intervals on fuel oil consumption

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2.14 Planning data for emission standard: IMO Tier II, Electric propulsion/EPROX-AC

2.14.1 Nominal values for cooler specification – L49/60 IMO Tier II, – Electric propulsion/ EPROX-AC

1,300 kW/cyl., 600 rpm – Electric propulsion/EPROX-AC

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.		**6L**	**7L**	**8L**	**9L**	**10L**
Engine output	kW	7,800	9,100	10,400	11,700	13,000
Speed	rpm	600				
Heat to be dissipated[1]						
HT circuit: + Charge air cooler LP and HP HT stage + Jacket cooling + Turbocharger cooling SUM:	kW	 2,190 863 29 3,082	 2,469 1,078 33 3,580	 3,140 1,226 38 4,404	 3,312 1,385 43 4,740	 3,548 1,539 48 5,135
LT circuit (charge air cooler LP and HP LT stage)		1,265	1,564	1,705	1,864	2,163
Lube oil cooler[2]		863	1,007	1,151	1,294	1,437
Nozzle cooling		25	29	33	37	41
Heat radiation engine (based on engine room temperature 55°C)		124	145	166	185	207
Flow rates[3]						
HT circuit (charge air cooler LP and HP HT stage, jacket cooling and turbocharger cooling)	m^3/h	93.4	107.9	122.4	139.5	154
LT circuit (charge air cooler LP and HP LT stage)		108	126	144	162	180
Lube oil		169	192	215	235	256
Nozzle cooling		2	2.3	2.6	2.9	3.2
Pumps						
a) Attached						
HT CW service pump	m^3/h	93.4	107.9	122.4	139.5	154
LT CW service pump	m^3/h	108	126	144	162	180

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No. of cylinders, config.		6L	7L	8L	9L	10L
Lube oil service pump		210	224	260	260	295
b) Free-standing[4]						
HT CW stand-by pump	m^3/h	93.4	107.9	122.4	139.5	154
LT CW stand-by pump		Depending on plant design				
Lube oil stand-by pump		177+z	202+z	226+z	247+z	269+z
Prelubrication pump		35-41 +0.5z	39-45.5 +0.5z	43.5-50.5 +0.5z	47-55+0.5 z	51-59.5 +0.5z
Nozzle CW pump		2	2.3	2.6	2.9	3.2
DMA/DMB supply pump		5.5	6.4	7.3	8.2	9.2
HFO supply pump		2.9	3.4	3.9	4.4	4.9
HFO circulating pump		5.5	6.4	7.3	8.2	9.2

[1] Tolerance: +8% for rating coolers and heat radiation, +6% for central cooler (HT-, LT- and lube oil system), -12% for heat recovery from HT- or LT- or lube oil system.

[2] Lube oil cooler not within engine system, therefore only heat amount to be considered. Addition required for separator heat (e.g. 30 kJ/kWh).

[3] Basic values for layout design of the coolers.

[4] Tolerances of the pumps delivery capacities must be considered by the pump manufacturer.

z = flushing oil of the automatic filter.

Table 39: Nominal values for cooler specification – L49/60 – Electric propulsion/EPROX-AC

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

- Minimal heating power required for preheating HT cooling water see paragraph HT cooling water preheating module (MOD-004), Page 328.
- Minimal heating power required for preheating lube oil see paragraph H-002/Lube oil preheater, Page 298.
- Capacities of preheating pumps see paragraph HT cooling water preheating module (MOD-004), Page 328.

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2.14.2 Nominal values for cooler specification – V49/60 IMO Tier II – Electric propulsion/ EPROX-AC

1,300 kW/cyl., 600 rpm – Electric propulsion/EPROX-AC

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**	**14V**
Engine output	kW	15,600	18,200
Speed	rpm	600	
Heat to be dissipated[1]			
HT circuit: + Charge air cooler LP and HP HT stage + Jacket cooling + Turbocharger cooling SUM:	kW	 4,442 1,847 57 6,346	 5,022 2,154 67 7,243
LT circuit (charge air cooler LP and HP LT stage)		2,459	3,029
Lube oil cooler[2]		1,725	2,012
Nozzle cooling		50	67
Heat radiation engine (based on engine room temp. 55°C)		249	290
Flow rates[3]			
HT circuit (charge air cooler LP and HP HT stage, jacket cooling and turbocharger cooling)	m^3/h	186.8	215.8
LT circuit (charge air cooler LP and HP LT stage)		214	250
Lube oil		283	319
Nozzle cooling		3.8	4.5
Pumps			
a) Attached			
HT CW service pump	m^3/h	186.8	215.8
LT CW service pump		214	250
Lube oil service pump		376	376
b) Free-standing[4]			
HT CW stand-by pump	m^3/h	186.8	215.8
LT CW stand-by pump		Depending on plant design	
Lube oil stand-by pump		297+z	355+z
Prelubrication pump		56-65.5+0.5z	62.5-73+0.5z

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No. of cylinders, config.		12V	14V
Nozzle CW pump		3.8	4.5
DMA/DMB supply pump		5.8	6.8
HFO supply pump		10.9	12.8
HFO circulating pump		5.8	6.8

[1] Tolerance: +8% for rating coolers and heat radiation, +6% for central cooler (HT-, LT- and lube oil system), -12% for heat recovery from HT- or LT- or lube oil system.

[2] Lube oil cooler not within engine system, therefore only heat amount to be considered. Addition required for separator heat (e.g. 30 kJ/kWh).

[3] Basic values for layout design of the coolers.

[4] Tolerances of the pumps delivery capacities must be considered by the pump manufacturer.

z = flushing oil of the automatic filter.

Table 41: Nominal values for cooler specification – V49/60 – Electric propulsion/EPROX-AC

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

- Minimal heating power required for preheating HT cooling water see paragraph HT cooling water preheating module (MOD-004), Page 328.
- Minimal heating power required for preheating lube oil see paragraph H-002/Lube oil preheater, Page 298.
- Capacities of preheating pumps see paragraph HT cooling water preheating module (MOD-004), Page 328.

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2.14.3 Flow scheme for cooler specification – 49/60 – Electric propulsion/EPROX-AC

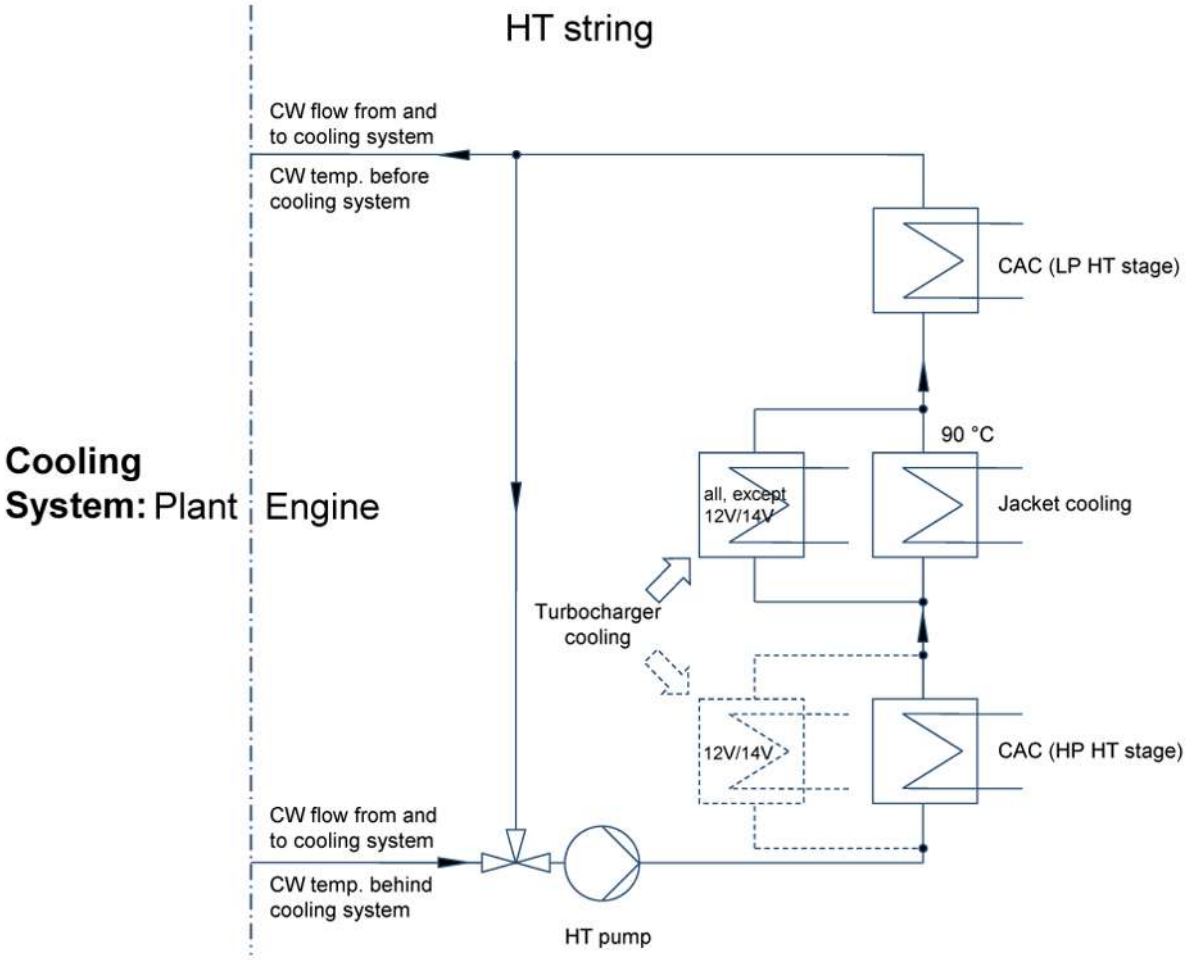


Figure 39: Flow scheme HT string - 49/60

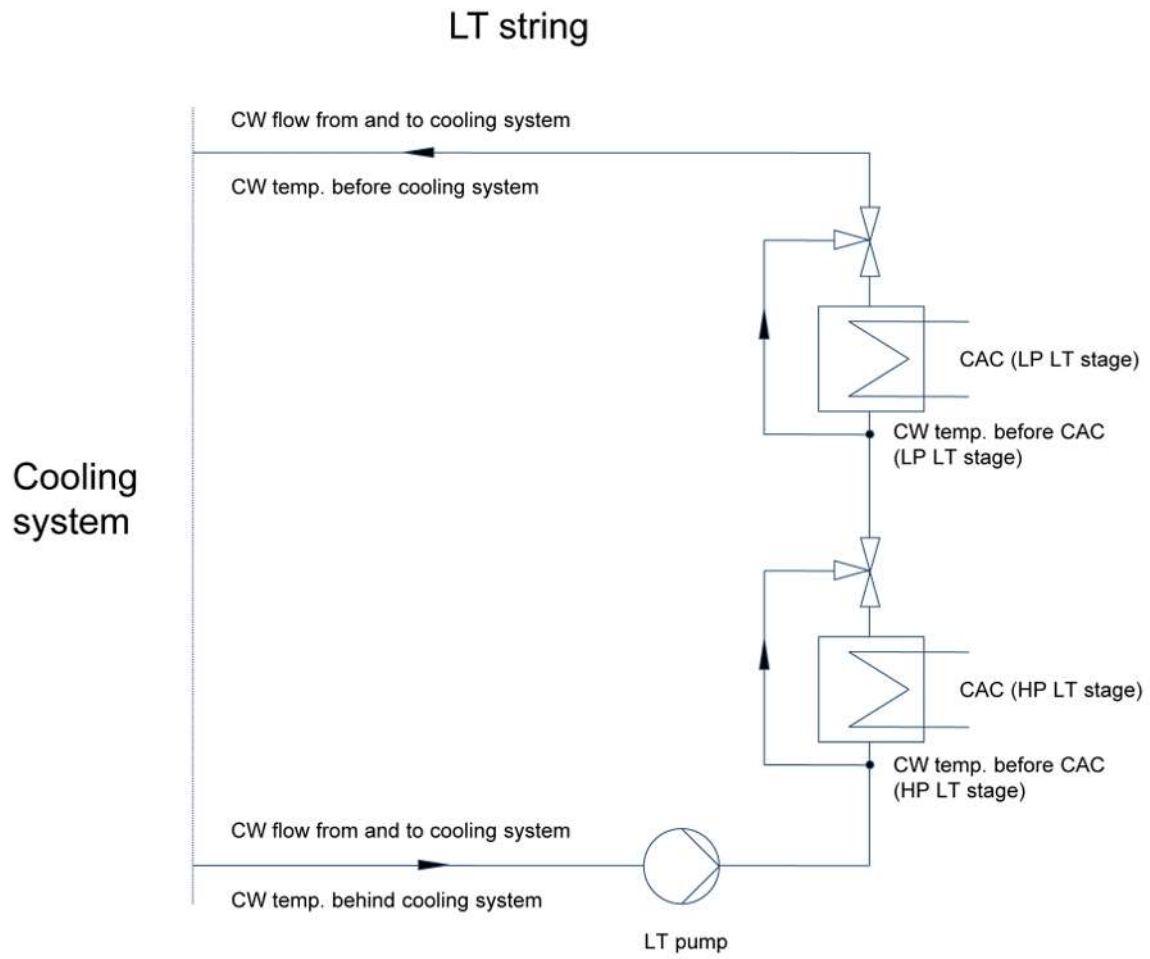


Figure 40: Flow scheme LT string - 49/60

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2.14.4 Temperature basis, nominal air and exhaust gas data – L49/60 IMO Tier II – Electric propulsion/EPROX-AC

1,300 kW/cyl.; 600 rpm – Electric propulsion/EPROX-AC

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 42: Reference conditions: Tropics

No. of cylinders, config.		**6L**	**7L**	**8L**	**9L**	**10L**
Engine output	kW	7,800	9,100	10,400	11,700	13,000
Speed	rpm	600				
Temperature basis						
HT cooling water temperature at HP TC charge air cooler outlet	°C	80				
HT cooling water at jacket cooling outlet[1)]		90[2)]				
HT cooling water temperature at LP TC charge air cooler outlet (= last charge air cooler)		104[3)]				
LT cooling water air cooler inlet		38 (setpoint 32°C)[4)]				
Lube oil engine inlet	°C	65				
Nozzle cooling water engine inlet		60				
Air data						
Temperature of charge air at charge air cooler outlet HP	°C	70				
Air flow rate[5)]	m^3/h	45,262	52,807	60,925	67,823	77,862
Mass flow	t/h	49.5	57.8	66.7	74.2	85.2
Charge air pressure (absolute)	bar abs	6.64	6.64	6.51	6.64	6.42
Air required to dissipate heat radiation (engine) ($t_2 - t_1 = 10°C$)	m^3/h	39,942	45,599	53,256	59,883	66,537
Exhaust gas data[6)]						
Volume flow (temperature turbocharger outlet)[7)]	m^3/h	87,530	102,116	116,868	131,154	151,622
Mass flow	t/h	51	59.5	68.7	76.5	87.7
Exhaust gas temperature at LP turbine outlet	°C	324	324	319	324	329
Heat content (190°C)	kW	2,044	2,385	2,653	3,063	3,635
Permissible exhaust gas back pressure after turbocharger	mbar	≤ 50				

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No. of cylinders, config.	6L	7L	8L	9L	10L
[1] HT cooling water flow through: 1. HP HT stage charge air cooler 2. Jacket cooling 3. LP HT stage charge air cooler.					
[2] Regulated temperature.					
[3] Relevant for plant system.					
[4] For design see figure Cooling water system diagram, Page 333.					
[5] Under mentioned above reference conditions.					
[6] All exhaust gas data values relevant for HFO operation. Tolerances: ±15°C for temperature at turbine outlet, ±4% for flow quantity.					
[7] Calculated based on stated temperature at turbine outlet and total atmospheric pressure according mentioned above reference conditions.					

Table 43: Temperature basis, nominal air and exhaust gas data – L49/60 – Electric propulsion/EPROX-AC

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2.14.5 Temperature basis, nominal air and exhaust gas data – V49/60 IMO Tier II – Electric propulsion/EPROX-AC

1,300 kW/cyl.; 600 rpm – Electric propulsion/EPROX-AC

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

No. of cylinders, config.		**12V**	**14V**
Engine output	kW	15,600	18,200
Speed	rpm	600	
Temperature basis			
HT cooling water temperature at HP TC charge air cooler outlet	°C	80	
HT cooling water at jacket cooling outlet[1)]		90[2)]	
HT cooling water temperature at LP TC charge air cooler outlet (= last charge air cooler)		104[3)]	
LT cooling water air cooler inlet		38 (setpoint 32°C)[4)]	
Lube oil engine inlet		65	
Nozzle cooling water engine inlet		60	
Air data			
Temperature of charge air at charge air cooler outlet HP	°C	70	
Air flow rate[5)]	m^3/h	90,432	105,505
Mass flow	t/h	99	115.5
Charge air pressure (absolute)	bar abs	6.64	
Air required to dissipate heat radiation (engine) ($t_2 - t_1 = 10°C$)	m^3/h	79,844	93,152
Exhaust gas data[6)]			
Volume flow (temperature turbocharger outlet)[7)]	m^3/h	174,873	93,152
Mass flow	t/h	101.9	118.9
Exhaust gas temperature at LP turbine outlet	°C	324	
Heat content (190°C)	kW	4,084	4,765
Permissible exhaust gas back pressure after turbocharger	mbar	≤ 50	

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No. of cylinders, config.	12V	14V
[1] HT cooling water flow through: 1. HP HT stage charge air cooler 2. Jacket cooling 3. LP HT stage charge air cooler. [2] Regulated temperature. [3] Relevant for plant system. [4] For design see figure Cooling water system diagram, Page 333. [5] Under mentioned above reference conditions. [6] All exhaust gas data values relevant for HFO operation. Tolerances: ±15°C for temperature at turbine outlet, ±4% for flow quantity. [7] Calculated based on stated temperature at turbine outlet and total atmospheric pressure according mentioned above reference conditions.		

Table 45: Temperature basis, nominal air and exhaust gas data – V49/60 – Electric propulsion/EPROX-AC

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2.14.6 Load specific values at ISO conditions – L/V49/60 IMO Tier II – Electric propulsion/ EPROX-AC

1,300 kW/cyl.; 600 rpm – Electric propulsion/EPROX-AC

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 46: Reference conditions: ISO

Engine output	**%**	**100**	**85 IMO 2008**	**85 IMO 2028**	**75**	**50**
Speed	**rpm**	**600**				
Heat to be dissipated[1]						
HT circuit: + Charge air cooler LP and HP HT stage + Jacket cooling + Turbocharger cooling SUM:	kJ/kWh	 849 362 13 1,224	 710 356 13 1,079	 778 372 13 1,163	 722 391 13 1,126	 487 493 13 993
LT circuit (charge air cooler LP and HP LT stage)		722	663	702	676	730
Lube oil cooler[3]		371	439	439	487	658
Nozzle cooling		11	13	13	15	20
Heat radiation engine (based on engine room temp. 35°C)		74	82	82	88	113
Air data						
Temperature of charge air at: Charge air cooler outlet HP	°C	 50	 50	 50	 50	 50
Air flow rate	kg/kWh	6.83	6.79	7.06	7.11	8.36
Charge air pressure (absolute)	bar abs	6.73	5.43	5.67	5.07	3.41
Exhaust gas data[4]						
Mass flow	kg/kWh	7.02	6.97	7.25	7.3	8.57
Exhaust gas temperature at LP turbine outlet	°C	278	273	273	279	287
Heat content (190°C)	kJ/kWh	656	617	642	694	887
Permissible exhaust gas back pressure after turbocharger	mbar	≤ 50	-			
Tolerances refer to 100% load.						

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Engine output	%	100	85 IMO 2008	85 IMO 2028	75	50
Speed	rpm	600				

[1] Tolerance: +8% for rating coolers and heat radiation, +6% for central cooler (HT-, LT- and lube oil system), -12% for heat recovery from HT- or LT- or lube oil system.

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

[3] Addition required for separator heat (e.g. 30 kJ/kWh).

[4] Tolerances: ±15°C for temperature at turbine outlet, ±4% for flow quantity.

Table 47: Load specific values at ISO conditions – L/V49/60 – Electric propulsion/EPROX-AC

2.14.7 Load specific values at tropical conditions – L/V49/60 IMO Tier II – Electric propulsion/EPROX-AC

1,300 kW/cyl.; 600 rpm – Electric propulsion/EPROX-AC

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 48: Reference conditions: Tropics

Engine output	%	100	85 IMO 2008	85 IMO 2028	75	50
Speed	rpm	600				
Heat to be dissipated[1]						
HT circuit: + Charge air cooler LP and HP HT stage + Jacket cooling + Turbocharger cooling SUM:	kJ/kWh	 1,087 424 13 1,524	 945 423 13 1,381	 1,027 436 13 1,476	 957 454 13 1,424	 715 556 13 1,284
LT circuit (charge air cooler LP and HP LT stage)		590	423	455	430	558
Lube oil cooler[3]		398	472	472	523	703
Nozzle cooling		11	13	13	15	20
Heat radiation engine (based on engine room temp. 55°C)		57	64	64	69	87
Air data						
Temperature of charge air at: Charge air cooler outlet HP	°C	 70	 70	 70	 69.4	 60.5
Air flow rate	kg/kWh	6.41	6.37	6.62	6.67	7.89
Charge air pressure (absolute)	bar abs	6.51	5.24	5.47	4.88	3.25
Exhaust gas data[4]						
Mass flow	kg/kWh	6.6	6.56	6.81	6.87	8.09

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Engine output	**%**	**100**	**85 IMO 2008**	**85 IMO 2028**	**75**	**50**
Speed	**rpm**	**600**				
Exhaust gas temperature at LP turbine outlet	°C	319	314	315	320	324
Heat content (190°C)	kJ/kWh	918	875	911	962	1,158
Permissible exhaust gas back pressure after turbocharger	mbar	≤ 50	-			
Tolerances refer to 100% load.						
[1] Tolerance: +8% for rating coolers and heat radiation, +6% for central cooler (HT-, LT- and lube oil system), -12% for heat recovery from HT- or LT- or lube oil system. [2] The values of the particular cylinder numbers can differ depending on the charge air cooler specification. [3] Addition required for separator heat (e.g. 30 kJ/kWh). [4] Tolerances: ±15°C for temperature at turbine outlet, ±4% for flow quantity.						

Table 49: Load specific values at tropical conditions – L/V49/60 – Electric propulsion/EPROX-AC

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2.15 Planning data for emission standard: IMO Tier II, Mechanical propulsion with CPP

Planning data is valid for engine variant with standard compression ratio. Planning data is valid for IMO 2008 regulations. Values for IMO 2028 to be defined.

2.15.1 Nominal values for cooler specification – L49/60 IMO Tier II – Mechanical propulsion with CPP

1,300 kW/cyl., 600 rpm – Mechanical propulsion with CPP

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 50: Reference conditions: Tropics

No. of cylinders, config.		**6L**	**7L**	**8L**	**9L**	**10L**
Engine output	kW	7,800	9,100	10,400	11,700	13,000
Speed	rpm	600				
Heat to be dissipated[1)]						
HT circuit: + Charge air cooler LP and HP HT stage + Jacket cooling + Turbocharger cooling SUM:	kW	 2,190 863 29 3,082	 2,469 1,078 33 3,580	 3,140 1,226 38 4,404	 3,312 1,385 43 4,740	 3,548 1,539 48 5,135
LT circuit (charge air cooler LP and HP LT stage)		1,265	1,564	1,705	1,864	2,163
Lube oil cooler[2)]		863	1,007	1,151	1,294	1,437
Nozzle cooling		25	29	33	37	41
Heat radiation engine (based on engine room temperature 55°C)		124	145	166	185	207
Flow rates[3)]						
HT circuit (charge air cooler LP and HP HT stage, jacket cooling and turbocharger cooling)	m^3/h	93.4	107.9	122.4	139.5	154
LT circuit (charge air cooler LP and HP LT stage)		108	126	144	162	180
Lube oil		169	192	215	235	256
Nozzle cooling		2	2.3	2.6	2.9	3.2
Pumps						
a) Attached						

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No. of cylinders, config.		6L	7L	8L	9L	10L
HT CW service pump	m^3/h	93.4	107.9	122.4	139.5	154
LT CW service pump	m^3/h	108	126	144	162	180
Lube oil service pump		210	224	260	260	295
b) Free-standing[4]						
HT CW stand-by pump	m^3/h	93.4	107.9	122.4	139.5	154
LT CW stand-by pump		Depending on plant design				
Lube oil stand-by pump		178+z	202+z	226+z	247+z	269+z
Prelubrication pump		35-41 +0.5z	39-45.5 +0.5z	43.5-50.5 +0.5z	47-55+0.5 z	51-59.5 +0.5z
Nozzle CW pump		2	2.3	2.6	2.9	3.2
DMA/DMB supply pump		5.5	6.4	7.3	8.2	9.2
HFO supply pump		2.9	3.4	3.9	4.4	4.9
HFO circulating pump		5.5	6.4	7.3	8.2	9.2

[1] Tolerance: +8% for rating coolers and heat radiation, +6% for central cooler (HT-, LT- and lube oil system), -12% for heat recovery from HT- or LT- or lube oil system.

[2] Lube oil cooler not within engine system, therefore only heat amount to be considered. Addition required for separator heat (e.g. 30 kJ/kWh).

[3] Basic values for layout design of the coolers.

[4] Tolerances of the pumps delivery capacities must be considered by the pump manufacturer.

z = flushing oil of the automatic filter.

Table 51: Nominal values for cooler specification – L49/60 – Mechanical propulsion with CPP

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

- Minimal heating power required for preheating HT cooling water see paragraph HT cooling water preheating module (MOD-004), Page 328.
- Minimal heating power required for preheating lube oil see paragraph H-002/Lube oil preheater, Page 298.
- Capacities of preheating pumps see paragraph HT cooling water preheating module (MOD-004), Page 328.

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2.15.2 Nominal values for cooler specification – V49/60 IMO Tier II – Mechanical propulsion with CPP

1,300 kW/cyl., 600 rpm – Mechanical propulsion with CPP

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 52: Reference conditions: Tropics

No. of cylinders, config.		**12V**	**14V**
Engine output	kW	15,600	18,200
Speed	rpm	600	
Heat to be dissipated[1]			
HT circuit: + Charge air cooler LP and HP HT stage + Jacket cooling + Turbocharger cooling SUM:	kW	 4,442 1,847 57 6,346	 5,022 2,154 67 7,243
LT circuit (charge air cooler LP and HP LT stage)		2,459	3,029
Lube oil cooler[2]		1,725	2,012
Nozzle cooling		50	58
Heat radiation engine (based on engine room temp. 55°C)		249	290
Flow rates[3]			
HT circuit (charge air cooler LP and HP HT stage, jacket cooling and turbocharger cooling)	m^3/h	186.8	215.8
LT circuit (charge air cooler LP and HP LT stage)		214	250
Lube oil		283	319
Nozzle cooling		3.8	4.5
Pumps			
a) Attached			
HT CW service pump	m^3/h	186.8	215.8
LT CW service pump		214	250
Lube oil service pump		376	376
b) Free-standing[4]			
HT CW stand-by pump	m^3/h	186.8	215.8
LT CW stand-by pump		Depending on plant design	
Lube oil stand-by pump		297+z	355+z

No. of cylinders, config.		12V	14V
Prelubrication pump		56-65.5 +0.5z	62.5-73 +0.5z
Nozzle CW pump		3.8	4.5
DMA/DMB supply pump		10.9	12.8
HFO supply pump		5.8	6.8
HFO circulating pump	m^3/h	10.9	12.8

[1] Tolerance: +8% for rating coolers and heat radiation, +6% for central cooler (HT-, LT- and lube oil system), -12% for heat recovery from HT- or LT- or lube oil system.

[2] Lube oil cooler not within engine system, therefore only heat amount to be considered. Addition required for separator heat (e.g. 30 kJ/kWh).

[3] Basic values for layout design of the coolers.

[4] Tolerances of the pumps delivery capacities must be considered by the pump manufacturer.

z = flushing oil of the automatic filter.

Table 53: Nominal values for cooler specification – V49/60 – Mechanical propulsion with CPP

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

- Minimal heating power required for preheating HT cooling water see paragraph HT cooling water preheating module (MOD-004), Page 328.
- Minimal heating power required for preheating lube oil see paragraph H-002/Lube oil preheater, Page 298.
- Capacities of preheating pumps see paragraph HT cooling water preheating module (MOD-004), Page 328.

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2.15.3 Flow scheme for cooler specification – 49/60 – Mechanical propulsion with CPP

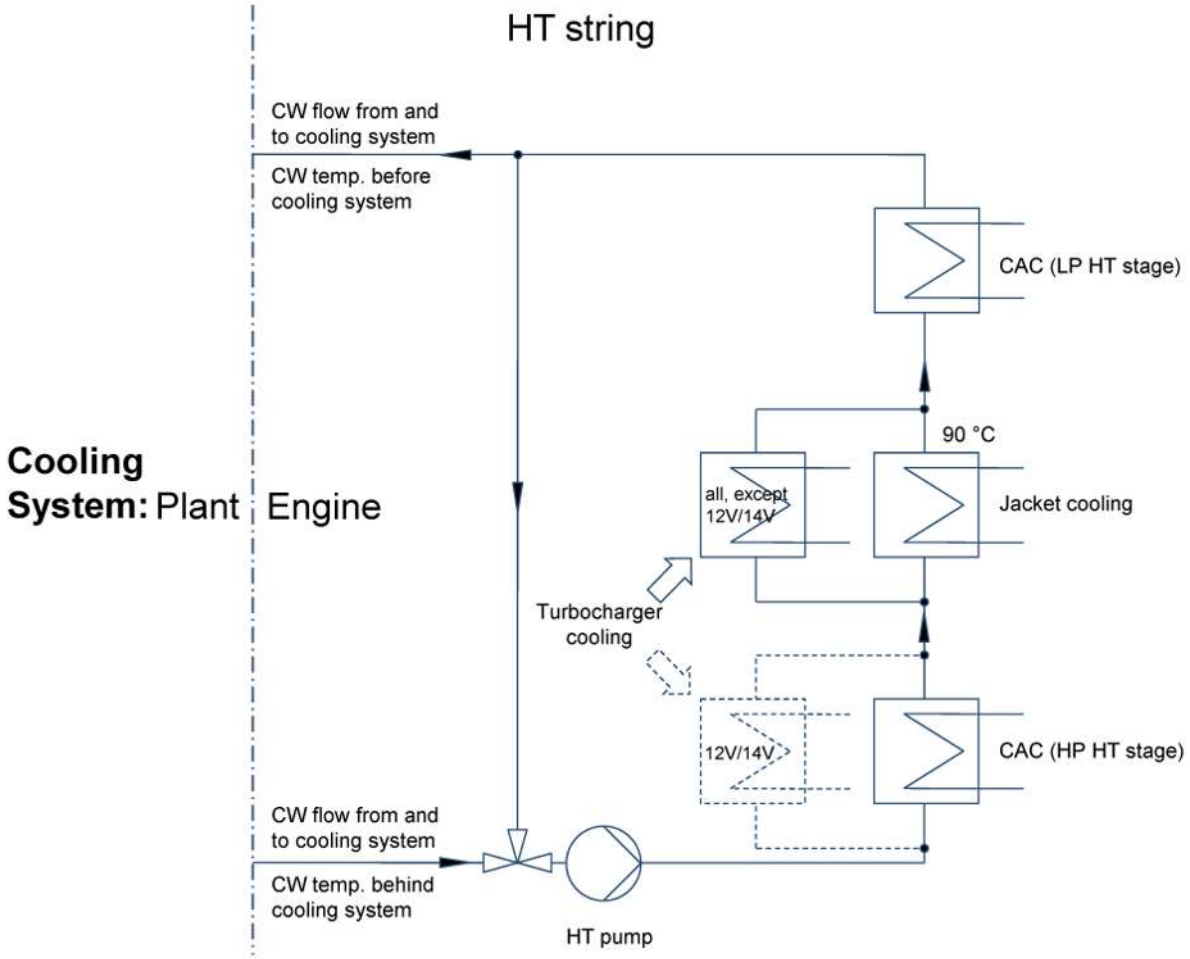


Figure 41: Flow scheme HT string - 49/60

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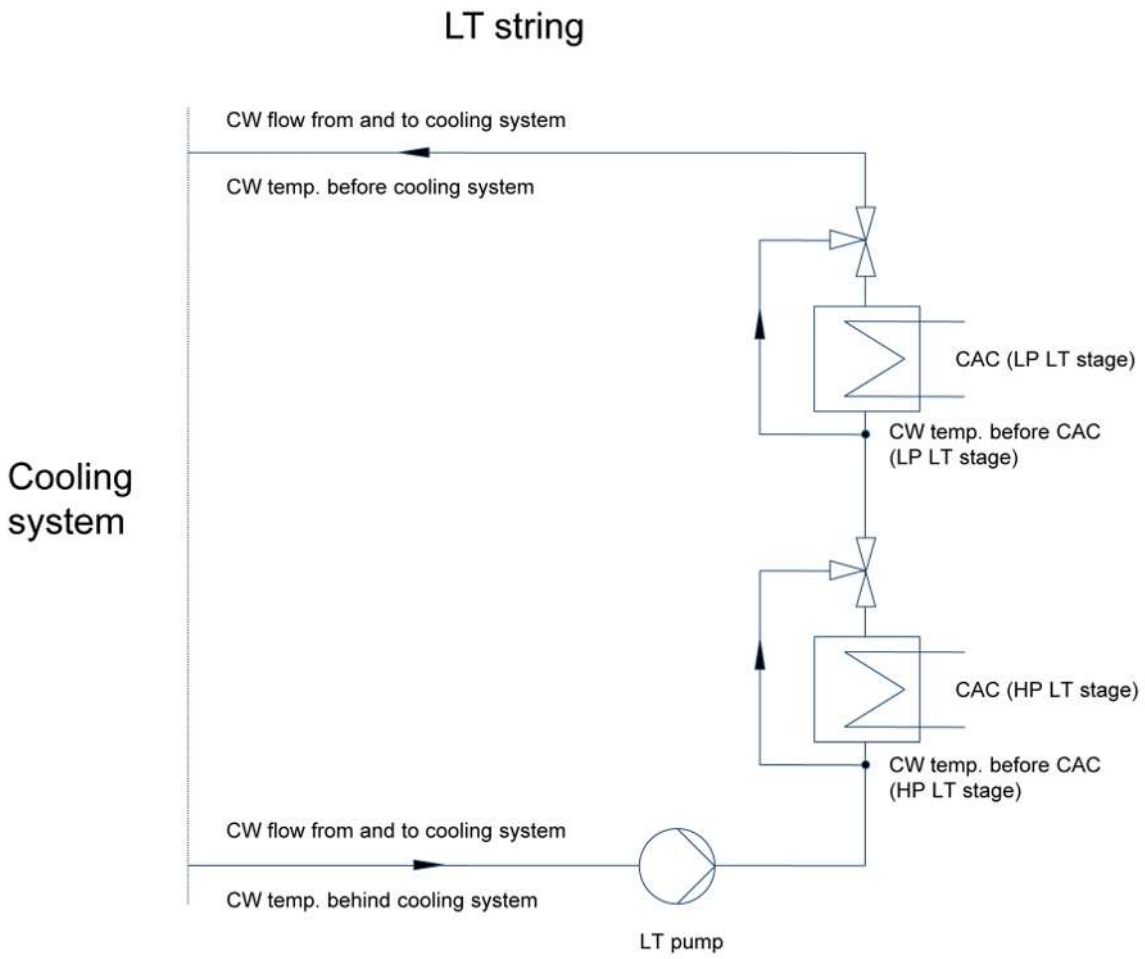


Figure 42: Flow scheme LT string - 49/60

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2.15.4 Temperature basis, nominal air and exhaust gas data – L49/60 IMO Tier II – Mechanical propulsion with CPP

1,300 kW/cyl.; 600 rpm – Mechanical propulsion with CPP

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 54: Reference conditions: Tropics

No. of cylinders, config.		**6L**	**7L**	**8L**	**9L**	**10L**
Engine output	kW	7,800	9,100	10,400	11,700	13,000
Speed	rpm	600				
Temperature basis						
HT cooling water temperature at HP TC charge air cooler outlet	°C	80				
HT cooling water at jacket cooling outlet[1)]		90[2)]				
HT cooling water temperature at LP TC charge air cooler outlet (= last charge air cooler)		104[3)]				
LT cooling water air cooler inlet		38 (setpoint 32°C)[4)]				
Lube oil engine inlet	°C	65				
Nozzle cooling water engine inlet		60				
Air data						
Temperature of charge air at charge air cooler outlet HP	°C	70				
Air flow rate[5)]	m^3/h	45,262	52,807	60,925	67,823	77,862
Mass flow	t/h	49.5	57.8	66.7	74.2	85.2
Charge air pressure (absolute)	bar abs	6.64	6.64	6.51	6.64	6.42
Air required to dissipate heat radiation (engine) ($t_2 - t_1 = 10°C$)	m^3/h	39,942	45,599	53,256	59,883	66,537
Exhaust gas data[6)]						
Volume flow (temperature turbocharger outlet)[7)]	m^3/h	87,530	102,116	116,868	131,154	151,622
Mass flow	t/h	51	59.5	68.7	76.5	87.7
Exhaust gas temperature at LP turbine outlet	°C	324	324	319	324	329
Heat content (190°C)	kW	2,044	2,385	2,653	3,063	3,635
Permissible exhaust gas back pressure after turbocharger	mbar	≤ 50				

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No. of cylinders, config.	6L	7L	8L	9L	10L
[1] HT cooling water flow through: 1. HP HT stage charge air cooler 2. Jacket cooling 3. LP HT stage charge air cooler.					
[2] Regulated temperature.					
[3] Relevant for plant system.					
[4] For design see figure Cooling water system diagram, Page 333.					
[5] Under mentioned above reference conditions.					
[6] All exhaust gas data values relevant for HFO operation. Tolerances: ±15°C for temperature at turbine outlet, ±4% for flow quantity.					
[7] Calculated based on stated temperature at turbine outlet and total atmospheric pressure according mentioned above reference conditions.					

Table 55: Temperature basis, nominal air and exhaust gas data – L49/60 – Mechanical propulsion with CPP

2.15.5 Temperature basis, nominal air and exhaust gas data – V49/60 IMO Tier II – Mechanical propulsion with CPP

1,300 kW/cyl.; 600 rpm – Mechanical propulsion with CPP

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 56: Reference conditions: Tropics

No. of cylinders, config.		**12V**	**14V**
Engine output	kW	15,600	18,200
Speed	rpm	600	
Temperature basis			
HT cooling water temperature at HP TC charge air cooler outlet	°C	80	
HT cooling water at jacket cooling outlet[1)]		90[2)]	
HT cooling water temperature at LP TC charge air cooler outlet (= last charge air cooler)		104[3)]	
LT cooling water air cooler inlet		38 (setpoint 32°C)[4)]	
Lube oil engine inlet		65	
Nozzle cooling water engine inlet		60	
Air data			
Temperature of charge air at charge air cooler outlet HP	°C	70	
Air flow rate[5)]	m^3/h	90,432	105,505
Mass flow	t/h	99	115.5
Charge air pressure (absolute)	bar abs	6.64	
Air required to dissipate heat radiation (engine) ($t_2 - t_1 = 10°C$)	m^3/h	79,844	93,152
Exhaust gas data[6)]			
Volume flow (temperature turbocharger outlet)[7)]	m^3/h	174,873	93,152
Mass flow	t/h	101.9	118.9
Exhaust gas temperature at LP turbine outlet	°C	324	
Heat content (190°C)	kW	4,084	4,765
Permissible exhaust gas back pressure after turbocharger	mbar	≤ 50	

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No. of cylinders, config.	12V	14V
[1] HT cooling water flow through: 1. HP HT stage charge air cooler 2. Jacket cooling 3. LP HT stage charge air cooler.		
[2] Regulated temperature.		
[3] Relevant for plant system.		
[4] For design see figure Cooling water system diagram, Page 333.		
[5] Under mentioned above reference conditions.		
[6] All exhaust gas data values relevant for HFO operation. Tolerances: ±15°C for temperature at turbine outlet, ±4% for flow quantity.		
[7] Calculated based on stated temperature at turbine outlet and total atmospheric pressure according mentioned above reference conditions.		

Table 57: Temperature basis, nominal air and exhaust gas data – V49/60 – Mechanical propulsion with CPP (minimum MN 70-95)

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2.15.6 Load specific values at ISO conditions – L/V49/60 IMO Tier II – Mechanical propulsion with CPP

1,300 kW/cyl.; 600 rpm – Mechanical propulsion with CPP

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 58: Reference conditions: ISO

Engine output	**%**	**100**	**85 IMO 2008**	**75**	**50**
Speed	**rpm**	**600**			
Heat to be dissipated[1]					
HT circuit: + Charge air cooler LP and HP HT stage + Jacket cooling + Turbocharger cooling SUM:	kJ/kWh	 849 362 13 1,224	 710 356 13 1,079	 722 391 13 1,126	 487 493 13 993
LT circuit (charge air cooler LP and HP LT stage)		722	663	676	730
Lube oil cooler[3]		371	439	487	658
Nozzle cooling		11	13	15	20
Heat radiation engine (based on engine room temp. 35 °C)		74	82	88	112
Air data					
Temperature of charge air at charge air cooler outlet HP	°C	50	50	50	50
Air flow rate	kg/kWh	6.83	6.79	7.11	8.36
Charge air pressure (absolute)	bar abs	6.73	5.43	5.07	3.41
Exhaust gas data[4]					
Mass flow	kg/kWh	7.02	6.97	7.3	8.57
Exhaust gas temperature at LP turbine outlet	°C	278	273	279	287
Heat content (190°C)	kJ/kWh	656	617	694	887
Permissible exhaust gas back pressure after turbocharger	mbar	≤ 50	-		
Tolerances refer to 100% load.					

[1] Tolerance: +8% for rating coolers and heat radiation, +6% for central cooler (HT-, LT- and lube oil system), -12% for heat recovery from HT- or LT- or lube oil system.

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

[3] Addition required for separator heat (e.g. 30 kJ/kWh).

[4] Tolerances: ±15°C for temperature at turbine outlet, ±4% for flow quantity.

Table 59: Load specific values at ISO conditions – L/V49/60 – Mechanical propulsion with CPP

2.15.7 Load specific values at tropical conditions – L/V49/60 IMO Tier II – Mechanical propulsion with CPP

1,300 kW/cyl.; 600 rpm – Mechanical propulsion with CPP

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 60: Reference conditions: Tropics

Engine output	**%**	**100**	**85**	**75**	**50**
Speed	**rpm**	**600**			
Heat to be dissipated[1]					
HT circuit: + Charge air cooler LP and HP HT stage + Jacket cooling + Turbocharger cooling SUM:	kJ/kWh	 1,087 424 13 1,524	 945 423 13 1,381	 957 454 13 1,424	 715 556 13 1,284
LT circuit (charge air cooler LP and HP LT stage)		590	423	430	558
Lube oil cooler[3]		398	472	523	703
Nozzle cooling		11	13	15	20
Heat radiation engine (based on engine room temp. 55°C)		57	64	69	87
Air data					
Temperature of charge air at charge air cooler outlet HP	°C	70	70	69.4	60.5
Air flow rate	kg/kWh	6.41	6.37	6.67	7.89
Charge air pressure (absolute)	bar abs	6.51	5.24	4.88	3.25
Exhaust gas data[4]					
Mass flow	kg/kWh	6.6	6.56	6.87	8.09
Exhaust gas temperature at LP turbine outlet	°C	319	314	320	324
Heat content (190°C)	kJ/kWh	918	875	962	1,158
Permissible exhaust gas back pressure after turbocharger	mbar	≤ 50	-		
Tolerances refer to 100% load.					

[1] Tolerance: +8% for rating coolers and heat radiation, +6% for central cooler (HT-, LT- and lube oil system), -12% for heat recovery from HT- or LT- or lube oil system.

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

[3] Addition required for separator heat (e.g. 30 kJ/kWh).

[4] Tolerances: ±15°C for temperature at turbine outlet, ±4% for flow quantity.

Table 61: Load specific values at tropical conditions – L/V49/60 – Mechanical propulsion with CPP

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2.16 Planning data for emission standard: IMO Tier II, Suction dredger/pumps (mechanical drive)

Planning data is valid for engine variant with standard compression ratio. Planning data is valid for IMO 2008 regulations. Values for IMO 2028 to be defined.

2.16.1 Nominal values for cooler specification – L49/60 IMO Tier II – Suction dredger/pumps (mechanical drive)

1,300 kW/cyl., 600 rpm – Suction dredger/pumps (mechanical drive)

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 62: Reference conditions: Tropics

No. of cylinders, config.		**6L**	**7L**	**8L**	**9L**	**10L**
Engine output	kW	7,800	9,100	10,400	11,700	13,000
Speed	rpm	600				
Heat to be dissipated[1)]						
HT circuit: + Charge air cooler LP and HP HT stage + Jacket cooling + Turbocharger cooling SUM:	kW	2,414 1,004 29 3,447	2,721 1,172 33 3,926	3,452 1,332 38 4,822	3,639 1,505 43 5,187	3,829 1,672 48 5,549
LT circuit (charge air cooler LP and HP LT stage)		1,433	1,768	1,922	1,433	2,381
Lube oil cooler[2)]		880	1,026	1,173	1,318	1,464
Nozzle cooling		25	29	33	37	48
Heat radiation engine (based on engine room temperature 55°C)		124	145	166	185	207
Flow rates[3)]						
HT circuit (charge air cooler LP and HP HT stage, jacket cooling and turbocharger cooling)	m^3/h	93.4	107.9	122.4	139.5	154
LT circuit (charge air cooler LP and HP LT stage)		108	126	144	162	180
Lube oil		169	192	215	235	256
Nozzle cooling		2	2.3	2.6	2.9	3.2
Pum^ps						

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No. of cylinders, config.		6L	7L	8L	9L	10L
a) Attached						
HT CW service pump	m^3/h	93.4	107.9	122.4	139.5	154
LT CW service pump	m^3/h	108	126	144	162	180
Lube oil service pump		210	224	260	295	295
b) Free-standing[4]						
HT CW stand-by pump	m^3/h	93.4	107.9	122.4	139.5	154
LT CW stand-by pump		Depending on plant design				
Lube oil stand-by pump		177+z	202+z	226+z	247+z	269+z
Prelubrication pump		35-41 +0.5z	39-45.5 +0.5z	43.5-50.5 +0.5z	47-55 +0.5z	51-59.5 +0.5z
Nozzle CW pump		2	2.3	2.6	2.9	3.2
DMA/DMB supply pump		5.5	6.4	7.4	8.2	9.2
HFO supply pump		2.9	3.4	4	4.4	4.9
HFO circulating pump		5.5	6.4	7.4	8.2	9.2

[1] Tolerance: +15 for rating coolers and heat radiation, -20% for heat recovery from HT- or LT- or lube oil system.

[2] Lube oil cooler not within engine system, therefore only heat amount to be considered. Addition required for separator heat (e.g. 30 kJ/kWh).

[3] Basic values for layout design of the coolers.

[4] Tolerances of the pumps delivery capacities must be considered by the pump manufacturer.

z = flushing oil of the automatic filter.

Table 63: Nominal values for cooler specification – L49/60 – Suction dredger/pumps (mechanical drive)

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

- Minimal heating power required for preheating HT cooling water see paragraph HT cooling water preheating module (MOD-004), Page 328.
- Minimal heating power required for preheating lube oil see paragraph H-002/Lube oil preheater, Page 298.
- Capacities of preheating pumps see paragraph HT cooling water preheating module (MOD-004), Page 328.

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2.16.2 Flow scheme for cooler specification – 49/60 – Mechanical propulsion with CPP

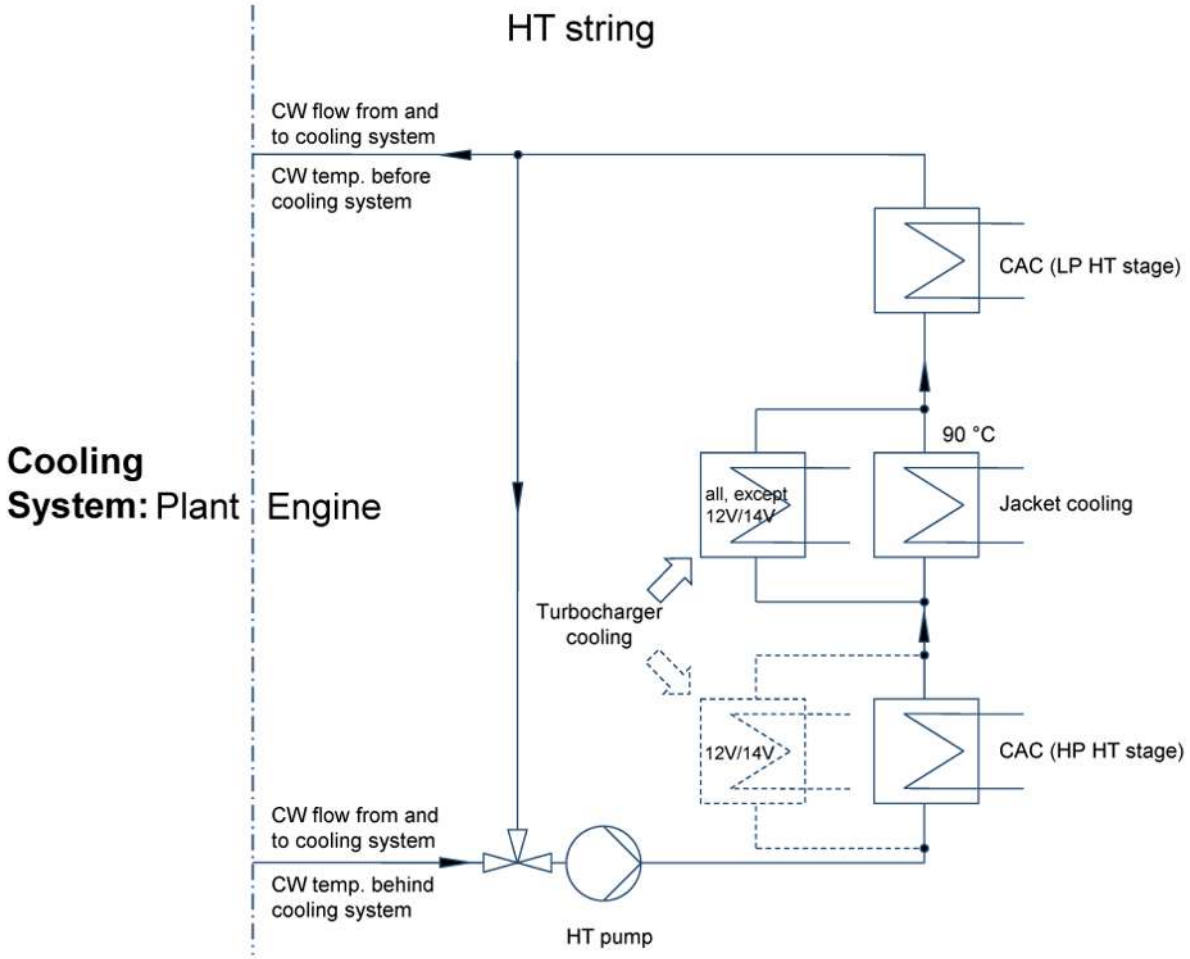


Figure 43: Flow scheme HT string - 49/60

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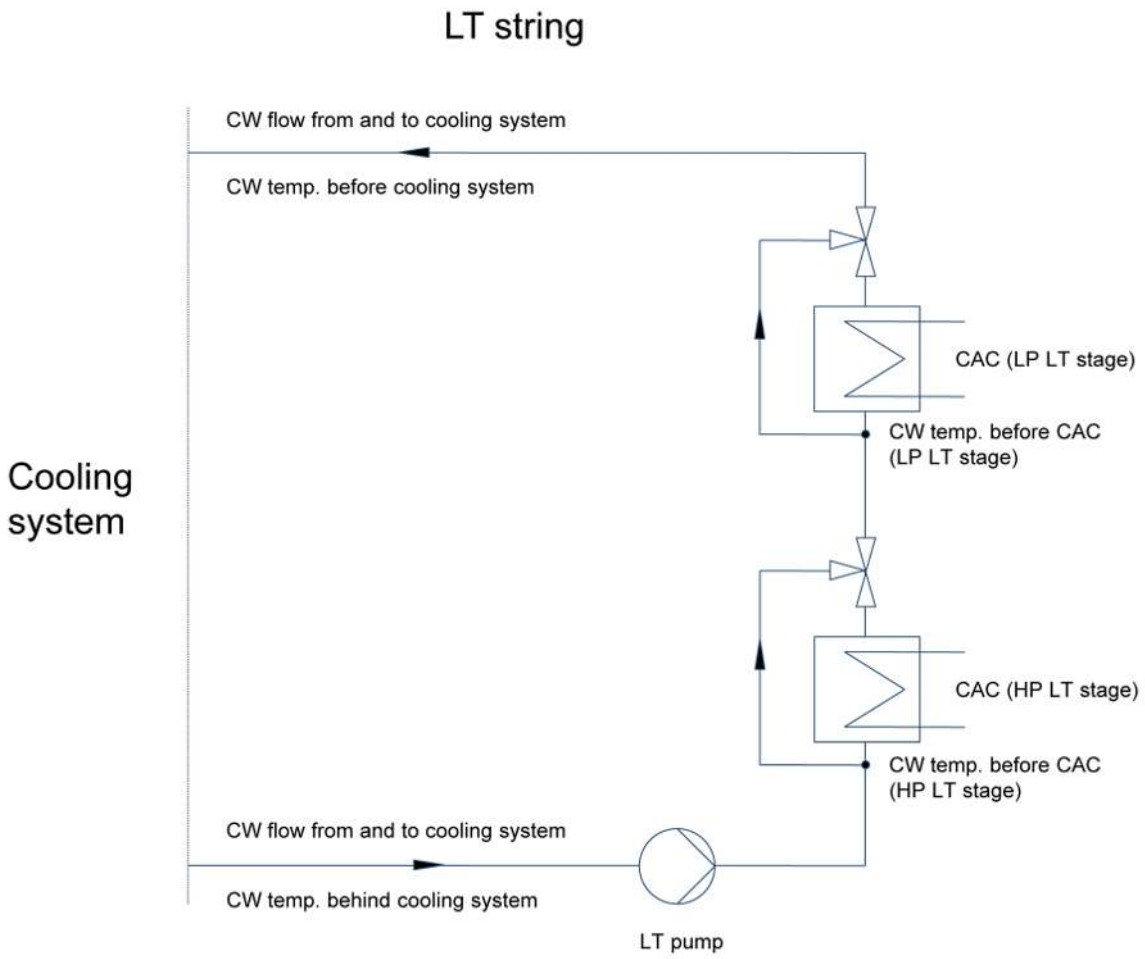


Figure 44: Flow scheme LT string - 49/60

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2.16.3 Temperature basis, nominal air and exhaust gas data – L49/60 IMO Tier II – Suction dredger/pumps (mechanical drive)

1,300 kW/cyl.; 600 rpm – Suction dredger/pumps (mechanical drive)

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 64: Reference conditions: Tropics

No. of cylinders, config.		**6L**	**7L**	**8L**	**9L**	**10L**
Engine output	kW	7,800	9,100	10,400	11,700	13,000
Speed	rpm	600				
Temperature basis						
HT cooling water temperature at HP TC charge air cooler outlet	°C	80				
HT cooling water at jacket cooling outlet[1)]		90[2)]				
HT cooling water temperature at LP TC charge air cooler outlet (= last charge air cooler)		104[3)]				
LT cooling water air cooler inlet		38 (setpoint 32°C)[4)]				
Lube oil engine inlet	°C	65				
Nozzle cooling water engine inlet		60				
Air data						
Temperature of charge air at charge air cooler outlet HP	°C	70				
Air flow rate[5)]	m^3/h	47,955	55,948	64,551	71,846	82,328
Mass flow	t/h	52.5	61.2	70.6	78.6	90.1
Charge air pressure (absolute)	bar abs	7	7	6.8	7	6.69
Air required to dissipate heat radiation (engine) ($t_2 - t_1 = 10°C$)	m^3/h	39,954	46,614	53,273	59,902	66,558
Exhaust gas data[6)]						
Volume flow (temperature turbocharger outlet)[7)]	m^3/h	89,107	103,955	118,979	133,495	154,109
Mass flow	t/h	54	63	72.7	80.9	92.6
Exhaust gas temperature at LP turbine outlet	°C	302	302	297	302	305
Heat content (190°C)	kW	1,793	2,091	2,312	2,686	3,134
Permissible exhaust gas back pressure after turbocharger	mbar	≤ 50				

No. of cylinders, config.	6L	7L	8L	9L	10L
[1] HT cooling water flow through: 1. HP HT stage charge air cooler 2. Jacket cooling 3. LP HT stage charge air cooler.					
[2] Regulated temperature.					
[3] Relevant for plant system.					
[4] For design see figure Cooling water system diagram, Page 333.					
[5] Under mentioned above reference conditions.					
[6] All exhaust gas data values relevant for HFO operation. Tolerances: ±15°C for temperature at turbine outlet, ±4% for flow quantity.					
[7] Calculated based on stated temperature at turbine outlet and total atmospheric pressure according mentioned above reference conditions.					

Table 65: Temperature basis, nominal air and exhaust gas data – L49/60 – Suction dredger/pumps (mechanical drive)

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2.16.4 Load specific values at ISO conditions – L/V49/60 IMO Tier II – Suction dredger/ pumps (mechanical drive)

1,300 kW/cyl.; 600 rpm – Suction dredger/pumps (mechanical drive)

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 66: Reference conditions: ISO

Engine output	**%**	**100**	**85**	**75**	**50**
Speed	**rpm**	**600**			
Heat to be dissipated[1)]					
HT circuit: + Charge air cooler LP and HP HT stage + Jacket cooling + Turbocharger cooling SUM:	kJ/kWh	 936 393 13 1,342	 800 397 13 1,210	 813 441 13 1,267	 709 562 13 1,284
LT circuit (charge air cooler LP and HP LT stage)		788	724	760	847
Lube oil cooler[3)]		378	451	519	726
Nozzle cooling		11	13	15	20
Heat radiation engine (based on engine room temp. 35°C)		74	82	88	112
Air data					
Temperature of charge air at charge air cooler outlet HP	°C	50	50	50	50
Air flow rate	kg/kWh	7.24	7.24	7.8	9.42
Charge air pressure (absolute)	bar abs	7.04	5.83	5.45	3.84
Exhaust gas data[4)]					
Mass flow	kg/kWh	7.43	7.24	7.80	9.43
Exhaust gas temperature at LP turbine outlet	°C	256	251	253	252
Heat content (190°C)	kJ/kWh	526	482	533	632
Permissible exhaust gas back pressure after turbocharger	mbar	≤ 50	-		
Tolerances refer to 100% load.					
[1)] Tolerance: +15% for rating coolers and heat radiation, -20% for heat recovery from HT- or LT- or lube oil system. [2)] The values of the particular cylinder numbers can differ depending on the charge air cooler specification. [3)] Addition required for separator heat (e.g. 30 kJ/kWh). [4)] Tolerances: ±15°C for temperature at turbine outlet, ±4% for flow quantity.					

Table 67: Load specific values at ISO conditions – L/V49/60 – Suction dredger/pumps (mechanical drive)

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2.16.5 Load specific values at tropical conditions – L/V49/60 IMO Tier II – Suction dredger/ pumps (mechanical drive)

1,300 kW/cyl.; 600 rpm – Suction dredger/pumps (mechanical drive)

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 68: Reference conditions: Tropics

Engine output	**%**	**100**	**85**	**75**	**50**
Speed	**rpm**	**600**			
Heat to be dissipated[1]					
HT circuit: + Charge air cooler LP and HP HT stage + Jacket cooling + Turbocharger cooling SUM:	kJ/kWh	 1,195 461 13 1,669	 1,059 466 13 1,538	 1,090 517 13 1,620	 994 641 13 1,648
LT circuit (charge air cooler LP and HP LT stage)		665	484	478	608
Lube oil cooler[3]		406	485	558	777
Nozzle cooling		11	13	15	20
Heat radiation engine (based on engine room temp. 55°C)		57	64	69	87
Air data					
Temperature of charge air at charge air cooler outlet HP	°C	70	70	70	63.5
Air flow rate	kg/kWh	6.79	6.79	7.31	8.87
Charge air pressure (absolute)	bar abs	6.8	5.61	5.25	3.68
Exhaust gas data[4]					
Mass flow	kg/kWh	6.99	6.98	7.51	9.08
Exhaust gas temperature at LP turbine outlet	°C	297	291	293	288
Heat content (190°C)	kJ/kWh	800	754	825	946
Permissible exhaust gas back pressure after turbocharger	mbar	≤ 50	-		
Tolerances refer to 100% load.					

[1] Tolerance: +15% for rating coolers and heat radiation, -20% for heat recovery from HT- or LT- or lube oil system.

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

[3] Addition required for separator heat (e.g. 30 kJ/kWh).

[4] Tolerances: ±15°C for temperature at turbine outlet, ±4% for flow quantity.

Table 69: Load specific values at tropical conditions – L/V49/60 – Suction dredger/pumps (mechanical drive)

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2.17 Operating/service temperatures and pressures

Ambient air

	Min.	Max.
Ambient air temperature (outside vessel)	0°C[1)]	45°C[2)]
[1)] Conditions below this temperature are defined as "arctic conditions" – see section Engine operation under arctic conditions, Page 64. [2)] In accordance with power definition. A reduction in power is required at higher temperatures.		

Table 70: Ambient air

Engine room air

	Min.	Max.
Engine room air temperature	0°C recommended: 5°C[1)]	55°C[2)]
[1)] Recommendation given to avoid any possibility for ice formation. In general 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. [2)] Air temperatures at the engine > 55°C are not permissible.		

Table 71: Engine room air

Intake air (conditions before compressor of turbocharger)

	Connection number internal media schemata "Charge air and exhaust gas diagram"	Min.	Max.
Intake air temperature compressor inlet	TE6100	0°C[1)]	45 °C[2)]
Intake air pressure compressor inlet	PT6100	–20 mbar	-
[1)] Conditions below this temperature are defined as "arctic conditions" – see section Engine operation under arctic conditions, Page 64. External intake air supply to be applied in this case. [2)] In accordance with power definition. A reduction in power is required at higher temperatures/lower pressures.			

Table 72: Intake air (conditions before compressor of turbocharger)

Charge air (conditions within charge air pipe before cylinder)

	Connection number internal media schemata "Charge air and exhaust gas diagram"	Min.	Max.
Charge air temperature cylinder inlet[1)]	TE6180	50°C	60°C
[1)] Aim for a higher value in conditions of high air humidity (to reduce condensate amount).			

Table 73: Charge air (conditions within charge air pipe before cylinder)

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HT cooling water – Engine

	Connection number internal media schemata "Cooling water system"	Min.	Max.
HT cooling water temperature at attached HT cooling water pump inlet (optional) and at HP TC charge air cooler inlet	3121 (3102), TE3145	60°C	80°C
HT cooling water temperature at HP TC charge air cooler outlet	TE3170	60°C	92°C
HT cooling water temperature at jacket cooling outlet[1)]	TE3180	90°C nominal[2)]	-
HT cooling water temperature at LP TC charge air cooler outlet (= last charge air cooler)	3111, TE3190	-	100°C[3)]
HT cooling water temperature engine inlet – Preheated before start	3121 (3102), TE3145	60°C	80°C
HT cooling water pressure engine inlet at nominal speed; nominal value 4 bar	PT3145	3 bar	8 bar
Pressure loss engine (total, for nominal flow rate)	-	6L, 8L: 1.1 bar 7L, 9L: 1.2 bar 10L: 1.4 bar 12V: 1.5 bar 14V: 1.7 bar	-
Pressure rise attached HT cooling water pump (at nominal speed)	-	6L: 3.6 bar 7L, 8L: 3.5 bar 9L: 3.4 bar 10L: 3.3 bar 12V: 3.9 bar 14V: 4.4 bar	-

[1)] HT cooling water flow through: 1. HP HT stage charge air cooler 2. Jacket cooling 3. LP HT stage charge air cooler.

[2)] Regulated temperature, set point will be lowered by SaCoS funtion if needed, to avoid exceeding of the maximum temperature at engine outlet.

[3)] Operation at alarm level.

Table 74: HT cooling water – Engine

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HT cooling water – Plant

	Connection number internal media schemata "Cooling water system"	Min.	Max.
Permitted pressure loss of external HT system (plant)	-	2.5 bar	-
Minimum required pressure rise of free-standing HT cooling water stand-by pump (plant)	-	6L: 3.6 bar 7L, 8L: 3.5 bar 9L: 3.4 bar 10L: 3.3 bar 12V: 3.9 bar 14V: 4.4 bar	-
Cooling water expansion tank			
Pre-pressure due to expansion tank at suction side of cooling water pump	-	0.6 bar	2.5 bar
Pressure loss from expansion tank to suction side of cooling water pump	-	-	0.1 bar

Table 75: HT cooling water – Plant

LT cooling water – Engine

	Connection number internal media schemata "Cooling water system"	Min.	Max.
LT cooling water temperature at attached HT cooling water pump inlet (optional) and at charge air cooler inlet (LT-stage LP TC)	3221 (3202), TE4145	25°C[1)]	38°C[2)]
LT cooling water pressure charge air cooler inlet (LT stage) at nominal speed; nominal value 4 bar	PT4145	2 bar	8 bar
Pressure loss charge air cooler (LT stage, for nominal flow rate)	-	6L: 0.7 bar 7L: 0.9 bar 8L: 1.0 bar 9L: 1.2 bar 10L: 1.4 bar 12V: 2.0 bar 14V: 2.6 bar	-
Pressure rise attached LT cooling water pump (at nominal speed)	-	6L: 3.6 bar 7L: 3.5 bar 8L: 3.3 bar 9L: 3.9 bar 10L: 3.8 bar 12V: 4.3 bar 14V: 4.9 bar	-

[1)] Regulated temperature.

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

Table 76: LT cooling water – Engine

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LT cooling water – Plant

	Connection number internal media schemata "Cooling water system"	Min.	Max.
Permitted pressure loss of external LT system (plant)			
6L-10L	-	-	2.5 bar
12V, 14V	-	-	2.0 bar
Minimum required pressure rise of free-standing LT cooling water stand-by pump (plant)	-	6L: 3.6 bar 7L: 3.5 bar 8L: 3.3 bar 9L: 3.9 bar 10L: 3.8 bar 12V: 4.3 bar 14V: 4.9 bar	-
Cooling water expansion tank			
Pre-pressure due to expansion tank at suction side of cooling water pump	-	0.8 bar	2.5 bar
Pressure loss from expansion tank to suction side of cooling water pump	-	-	0.1 bar

Table 77: LT cooling water – Plant

Nozzle cooling water

	Connection number internal media schemata "Cooling water system"	Min.	Max.
Nozzle cooling water temperature engine inlet	3401, TE3470	55°C[1)]	70°C[1)]
Nozzle cooling water pressure engine inlet Open system Closed system	 3401, PT3470 3401, PT3470	 2 bar 3 bar	 3 bar 5 bar
Pressure loss engine (fuel nozzles, for nominal flow rate)	-	-	1.5 bar
[1)] Standard setting 60°C, alarm low at 52°C, alarm high at 75°C.			

Table 78: Nozzle cooling water

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Lube oil

	Connection number internal media schemata "Lubricating oil diagram"	Min.	Max.
Lube oil temperature engine inlet – valid for SAE 40	2101, TE2170	65°C[1]	70°C[2]
Lube oil temperature engine inlet – Preheated before start	2101, TE2170	40°C	65°C[3]
Lube oil pressure at nominal speed (during engine operation)			
Engine inlet	2101, TE2170	3.5 bar	4.5 bar
Turbocharger inlet	PT2570	1.3 bar	2.2 bar
Prelubrication/postlubrication (duration ≤ 10 min) lube oil pressure			
Engine inlet	2101, PT2170	2.0 bar	4.5 bar
Prelubrication/postlubrication (duration > 10 min) lube oil pressure			
Engine inlet	2101, PT2170	0.3 bar[4]	0.6 bar
Lube oil pump (attached, free-standing)			
Design pressure	-	5.0 bar	8.0 bar
Opening pressure safety valve	-	-	8 bar

[1] Regulated temperature.

[2] Operation at alarm level.

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

[4] Note: Oil pressure > 0.3 bar must be ensured also for lube oil temperatures up to 70°C.

Table 79: Lube oil

Fuel – Main injection system

	Connection number internal media schemata "Fuel system"	Min.	Max.
Fuel temperature engine inlet DMA, DFA and DMB, DFB according ISO 8217 HFO according ISO 8217	 5101, TE5070 5101, TE5070	 –10°C[1)] -	 45°C[2)] 150°C[2)]
Fuel viscosity engine inlet DMA, DFA and DMB, DFB according ISO 8217 HFO according ISO 8217, recommended viscosity	 - -	 1.9 cSt 1.9 cSt	 14.0 cSt 14.0 cSt
Fuel pressure engine inlet Nominal pressure Permitted pressure range	 5101, PT5070 5101, PT5070	 11 bar 9 bar	 11 bar 12 bar
Fuel pressure engine inlet in case of black out (to start one engine to idle. Start main fuel supply system before adding load)	5101, PT5070	5 bar	-
Differential pressure (engine inlet/engine outlet)	-	5 bar	-
Pressure variation at engine inlet Nominal pressure variation Maximum pressure variation	 5101, PT5070 5101, PT5070	 - -	 ±0.5 bar ±1.5 bar
HFO supply system Minimum required pressure rise of free-standing HFO supply pump (plant) Minimum required pressure rise of free-standing HFO circulating pump (booster pumps, plant) Required minimum absolute design pressure free-standing HFO circulating pump (booster pumps, plant)	 - - -	 8 bar 10 bar 14 bar	 - - -
DMA/DMB supply system Minimum required pressure rise of free-standing DMA/DMB supply pump (plant)	-	14 bar	-
Fuel temperature within HFO day tank (preheating)	-	-[3)]	90°C[4)]

[1)] Maximum viscosity not to be exceeded. “Pour point” and “Cold filter plugging point” have to be observed.

[2)] Not permissible to fall below minimum viscosity.

[3)] Minimum temperature to be considered for an optimum transfer by pumps to attached tanks.

[4)] If flash point is below 100°C, than the limit is: 10 degree distance to the flash point.

Table 80: Fuel

	Connection number internal media schemata "Fuel system"	Setting
Safety valve/pressure limiting valve in CR system	-	2,450 bar + 200 bar

Table 81: Pressure limiting valve CR system

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Fuel – Pilot fuel system

	Connection number internal media schemata "Fuel system"	Min.	Max.
Fuel temperature engine inlet – DMA, DFA	5201, TE5275	–10°C[1]	70°C[2]
Fuel viscosity engine inlet – DMA, DFA	-	1.3 cSt	6.0 cSt
Pilot fuel pressure engine inlet	5201, PT5275	3.5 bar	5.0 bar
Pilot fuel return, fuel pressure engine outlet	-	0.0 bar	0.2 bar

[1] Maximum viscosity not to be exceeded. “Pour point” and “Cold filter plugging point” have to be observed.

[2] Not permissible to fall below minimum viscosity.

Table 82: Fuel – Pilot fuel system

Compressed air in the starting air system

	Connection number internal media schemata "Pressure air system"	Min.	Max.
Starting air pressure	7171, PT7170	15.0 bar[1]	30.0 bar[2] [3]
Alarm emergency stop air pressure	PT7180	10.0 bar[4]	-
Jet assist pressure engine inlet	7177	18.0 bar[5]	30.0 bar
Operating temperature	-	5°C	65°C

[1] Operation at alarm level. Engine start possible down to "Alarm emergency stop air pressure".

[2] Nominal value.

[3] For layout of the starting air system, note:

- Starting air consumption and start duration stated within section Starting air and control air consumption, Page 96.
- Maximum velocity (m/s) see section External pipe dimensioning, Page 278 - consider multiple start of engines, if needed.

[4] Within calculation of starting air vessels this value must not be undershot.

[5] Below this value jet assist will be deactivated.

Table 83: Compressed air in the starting air system

Compressed air in the control air system

	Connection number internal media schemata "Pressure air system"	Min.	Max.
Control air pressure engine inlet	7102, PT7400	5.5 bar[1]	7 bar
Operating temperature	-	5°C	65°C

[1] Operation at alarm level.

Table 84: Compressed air in the control air system

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Crankcase pressure (engine)

	Connection number internal media schemata "Lubricating oil diagram"	Min.	Max.
Pressure within crankcase	2841, PT2800	–2.5 mbar	3 mbar

Table 85: Crankcase pressure (engine)

	Connection number internal media schemata "Lubricating oil diagram"	Setting
Safety valve attached to the crankcase (opening pressure)	-	50-70 mbar

Table 86: Safety valve

Exhaust gas

	Connection number internal media schemata "Charge air and exhaust gas diagram"	Min.	Max.
Exhaust gas temperature turbine outlet (normal operation under tropic conditions)	6511, TE6592	-	415°C
Exhaust gas temperature turbine outlet	6511, TE6592	360°C	415°C
Exhaust gas temperature turbine outlet (emergency operation – According classification rules – One failure of TC)	6511, TE6592	-	589°C
Recommended design exhaust gas temperature turbine outlet for layout of exhaust gas line (plant)	6511, TE6592	450°C[1)]	-
Minimum exhaust gas temperature after recooling due to exhaust gas heat utilisation	6511, TE6592	190°C[2)]	-
Exhaust gas back pressure after turbocharger (static)	6511	-	50.0 mbar[3)]

[1)] Project-specific evaluation required, figure given as minimum value for guidance only.

[2)] To avoid sulphur corrosion in exhaust gas line (plant).

[3)] 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 41 and Increased exhaust gas pressure due to exhaust gas after treatment installations, Page 43 need to be considered.

Table 87: Exhaust gas

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

2.18 Leakage rate

No. of cylinders, config.	Operating leakage (clean fuel)		Burst leak rate in case of pipe break (for max. 1 min)
	l/h		l/min per cylinder bank
	HFO	DMA/DMB	HFO/DO
6L	10.5	60	65

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No. of cylinders, config.	Operating leakage (clean fuel)		Burst leak rate in case of pipe break (for max. 1 min)
	l/h		l/min per cylinder bank
	HFO	DMA/DMB	HFO/DO
7L	12.6	72	78
8L	12.6	72	78
9L	14.7	84	91
10L	16.8	96	104
12V	21	120	130
14V	25.2	144	156

Table 88: Leakage rate of CR main injection system

Note:

- The values given in this table are average values; there may be deviations in individual measurements, e.g. due to fuel temperature, fuel inlet pressure, wear condition of the high-pressure pump, etc.
- High flow rates of dirty leakage oil will only occur in case of a pipe break and should occur for short time only. An alarm will be activated (< 1 min) and the operator must take actions. Special considerations have to be taken for the layout of single engine plants. 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 injector, 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.

No. of cylinders, config.	Number of high-pressure pumps	Needed minimum pilot fuel oil supply [l/h] at engine connection 5201	Operating leakage DMA/DMZ [l/h] at engine connection 5211	Burst leak rate in case of pipe break [l/min] (for max. 1 min) at engine connection 5211
6L	1	205	145	3.7
7L		205	135	
8L		205	125	
9L		210	120	
10L		220	125	
12V	2	405	285	7.4
14V		405	265	

Table 89: Leakage rate of CR pilot fuel injection system

Note:

- The values given in this table are average values; there may be deviations in individual measurements, e.g. due to fuel temperature, fuel inlet pressure, wear condition of the high-pressure pump, etc.

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- High flow rates of dirty leakage oil will only occur in case of a pipe break and should occur for short time only. An alarm will be activated (< 1 min) and the operator must take actions. Special considerations have to be taken for the layout of single engine plants. This leakage can be reused, if the entire fuel treatment of separation and filtration is done.
- The operating leakage (clean) of the pilot fuel system (CR injection) includes the leakage amount of the high-pressure pumps, injection valves and valve groups, 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.

2.19 Filling volumes

Cooling water and oil volume of engine[1]								
No. of cylinders		**6L**	**7L**	**8L**	**9L**	**10L**	**12V**	**14V**
LT cooling water approximately	litres	275	275	298	298	298	988	988
HT cooling water approximately		886	990	1,117	1,221	1,325	2,294	2,539
Lube oil		808	902	1,002	1,097	1,191	1,136	1,291
[1] 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.								

Table 90: Cooling water and oil volume of engine

Service tanks	Installation height[1]	Minimum effective capacity						
	m	m^3						
No. of cylinders		**6L**	**7L**	**8L**	**9L**	**10L**	**12V**	**14V**
Cooling water expansion tank	6 – 9	1.0					1.5	
Required diameter for expansion pipeline	-	≥ DN50					≥ DN65	
Lube oil in lube oil service tank[2]	litres	7,800	9,100	10,400	11,700	13,000	15,600	18,200
[1] Installation height refers to tank bottom and crankshaft centre line.								
[2] The minimum quantity of lube oil for the engine in the lube oil service tank is 1.0 litr/kW.								

Table 91: Service tanks capacities

2.20 Venting amount of crankcase and turbocharger

A ventilation of the engine crankcase and the turbochargers is required, as described in section Crankcase vent and tank vent, Page 316.

Crankcase and turbocharger ventilation are connected together and be discharged via connection number 2841, see figure Internal lube oil system – Exemplary, Page 294.

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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 mist.

- The amount of crankcase blow-by air is approximately 0.1% of the engine´s air flow rate.

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

- The amount of turbocharger blow-by air is approximately:
  - For single-stage turbocharged engines 0.2% of the engine´s air flow rate. (Accordingly see Planning data, Page 100).
  - For two-stage turbocharged engines 0.4% of the engine´s air flow rate. (Accordingly see Planning data, Page 100).
- The temperature of the crankcase and turbocharger blow-by air is approximately 15 K higher than the oil temperature at the engine´s oil inlet.
- The density of the crankcase and turbocharger blow-by air is 1.0 kg/m³ at the condition of approximately 70°C (343 K) and 1,013 mbar (assumption for calculation).

2.21 Crankcase ventilation

OCV (Standard)

An open crankcase ventilation system (OCV) for the 49/60 engine is the preferred application for the crankcase ventilation depending on class approval. The Crankcase gases are vented by a fan through an oil separator towards the funnel. The collected oil in the oil separator drains back via a syphon and pipes into the lube oil sump tank.

Note:
It is mandatory to eliminate most of the lube oil/lube oil dust within the crankcase vent, before feeding it into the air inlet of the turbocharger compressor. This is needed to avoid a negative impact on the compressor TBO.

CCV (Option)

For layout of the oil separator must be considered:

Lube oil content of raw crankcase vent

- Above stated venting amount.
- Lube oil content of the crankcase vent of max. 350 mg per m³ venting air.
- After lube oil separator, a maximum lube oil concentration of 0.5 mg/m³ at the compressor inlet must be ensured.

Layout of the blower:

Equipped with a 2-stage filter to separate the lube oil from the airstream.

The lube oil will then be fed back to the lube oil tank.

The blower is controlled by a frequency converter.

After engine start crankcase pressure controlled to minimum -2.5 mbar. (In general the setting will be done for -1,6 mbar).

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2.22 Exhaust gas emission

2.22.1 Maximum permissible NOx emission limit value IMO Tier II

IMO Tier III: Engine in standard version[1]

Rated speed	600 rpm
NO_x [1) 2)]	
IMO Tier II cycle D2/E2	10.1 g/kWh[3)]
IMO Tier III cycle D2/E2	2.5 g/kWh[3)]
Note: The engine´s certification for compliance with the NO_x limits will be carried out during factory acceptance test according engine group concept.	
[1)] Cycle values , operation on DM grade fuel (marine distillate fuel: DMA or DMB) according ISO 8217, based on a LT charge air cooling water temperature of 32°C at 25°C reference seawater temperature. [2)] Calculated as NO_2. D2: Test cycle for constant speed aux. engine application. E2: Test cycle for "constant speed main propulsion application" (including electric propulsion and all controllable pitch propeller installations). [3)] Maximum permissible NO_x emissions for marine diesel engines according to IMO Tier II: 130 ≤ n ≤ 2,000 → 44 * $n^{-0.23}$ g/kWh (n = rated engine speed in rpm) IMO Tier III: 130 ≤ n ≤ 2,000 → 9 * $n^{-0.2}$ g/kWh (n = rated engine speed in rpm).	

Table 92: Maximum permissible NO_x emission limit value

[1] Marine engines are guaranteed to meet the requirements of MARPOL Annex VI, regulations for the prevention of air pollution from ships, as amended.

2.22.2 Smoke emission index (FSN)

Valid for normal engine operation.

Engine load	Smoke emission index (FSN)[1)]	
Fuel	DMA, DMB	HFO
100%	0.2+0.1	0.2+0.1
75%		
50%		0.2+0.2
25%		0.35+0.2
10%		0.35+0.3
[1)] Valid for distillate fuel according to ISO 8217 or RM-grade fuel, fulfilling the stated quality requirements.		

Table 93: Smoke emission index IMO Tier II (FSN)

Limit of visibility is 0.4 FSN.

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2.22.3 Exhaust gas – possible components and visibility

The exhaust gas of reciprocating internal combustion engines is composed of numerous constituents. These are derived from either the combustion air and fuel and lube oil used, or they are reaction products, formed during the combustion process. Only some of these are to be considered as harmful substances.

The following listed exhaust gas components need to be seen as a general overview – the presence and amount of the singular component depends in large extends on the engine type, combustion process and fuel type.

Nitrogen N_2

Nitrogen (N_2) is with approximately 73–75 vol-% the main constituent of the exhaust gas.

Oxygen O_2

Approximately 21 vol-% of the ambient air is Oxygen (O_2).

Carbon dioxide CO_2

Carbon dioxide (CO_2) is a product of combustion.

Water vapour H_2O

The water in the exhaust comes from the combustion of the fuel and, to a lesser extent, from the moisture in the intake air. In diesel operation, the water vapour content is approximately 6 vol-%, in gas operation approximately 10 vol-%.

Inert gases Ar, Ne, He, etc.

Inert gases, such as Ar, Ne, He, etc., are constituents of the ambient air with a volume fraction of approximately 0.9 vol-%.

Sulphur oxides SO_x

Sulphur oxides (SO_x) are formed by the combustion of the sulphur contained in the fuel. The sulphur content in the fuel determines the SO_2 content in the exhaust gas.

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 types of fuel) and oxygen (contained in the combustion air) to form nitrogen oxides (NO_x).

Carbon monoxide CO

Carbon monoxide (CO) is formed during incomplete combustion.

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.

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Particulate matter PM

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

Methanol CH_3OH

Methanol only might occur in methanol operation as result of incomplete combustion.

Formaldehyde CH_2O

Formaldehyde (CH_2O) is a gas known by its pungent smell. Its proportion in the exhaust gas depends on the fuel and the degree of combustion. If the proportion of formaldehyde (CH_2O) is high, it can be removed by an oxidation catalyst – this is only necessary for gas or methanol operation.

Nitrous oxide N_2O

Nitrous oxide (N_2O) is a gas that only might occur in relevant quantity in ammonia (NH_3) operation.

Visibility of the exhaust gas

The visibility of exhaust gas highly depends on ambient conditions and the observer's line of sight to the exhaust gas, background and the sun. The exhaust gas can either be seen or not depending on the ambient temperature, wind velocity, diameter and height of the chimney and the colouring of the background. It can be black, blue, brown, yellow or white depending on the components present in the exhaust gas. Black or gray exhaust gas is mainly due to the presence of carbon particles. A blue appearance is usually due to droplets resulting from the incomplete combustion of fuel or lubricating oil. A yellow or brown appearance can be caused by the presence of NO_2 in the exhaust gas. White exhaust gas may be caused by condensed water and/or liquid fuel.

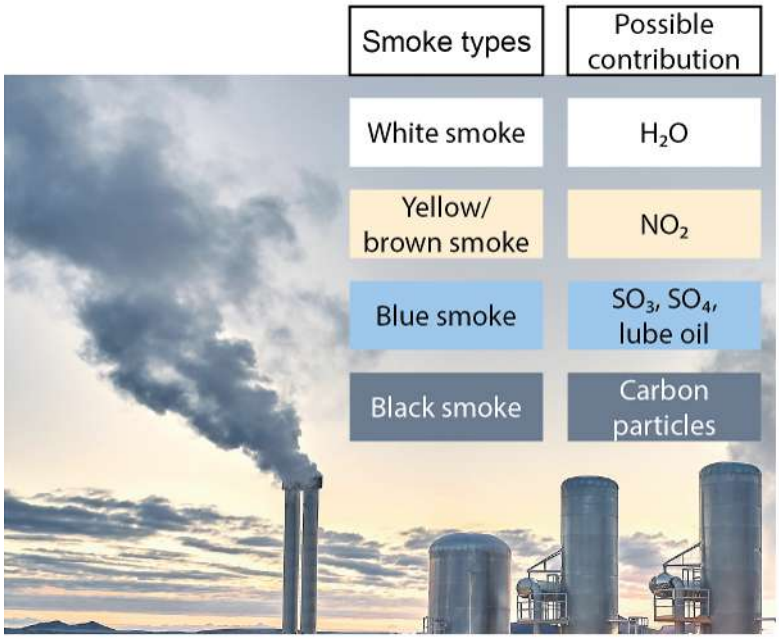


Figure 45: Possible components of the exhaust gas – Visibility

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2.22.4 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
- At 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

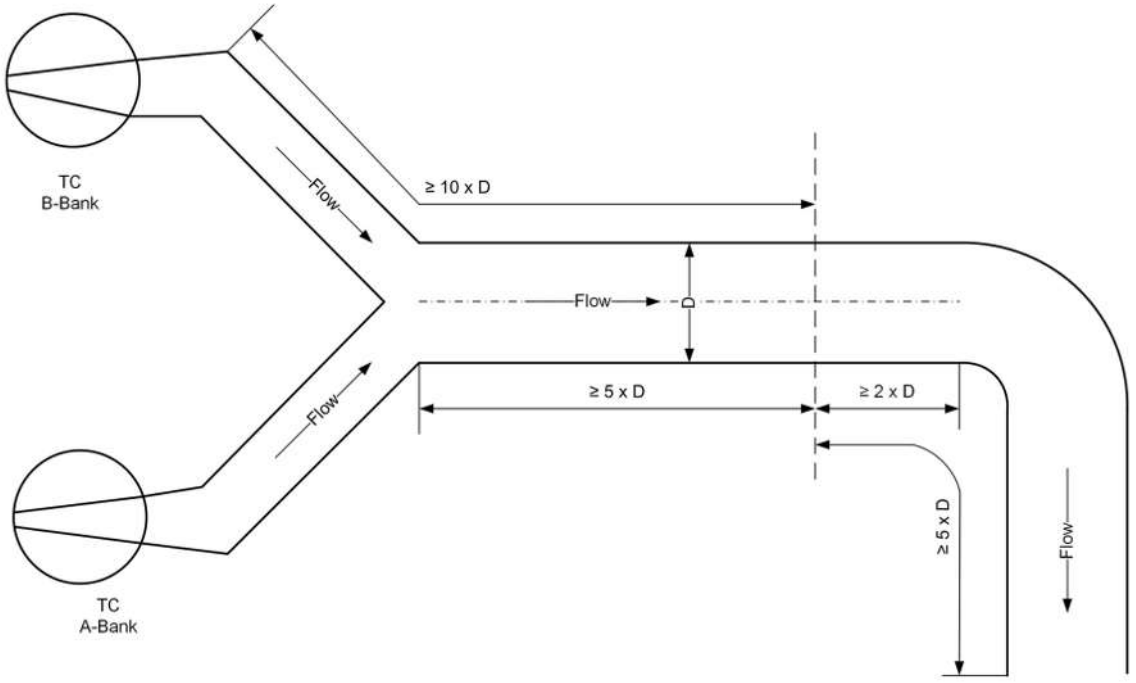


Figure 46: Position of sampling points (exemplary)

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 must 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.

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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 covered 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 2-m width, 2-m depth, 2-m height
- Sufficient floor load capacity (at least 200 kg per m^2)
- Temperature at this working area should be within +5°C 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 be considered that during the measurements following items are available at the working area:

- Adequate lighting and ventilation
- Power supply
- Pressurised 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)

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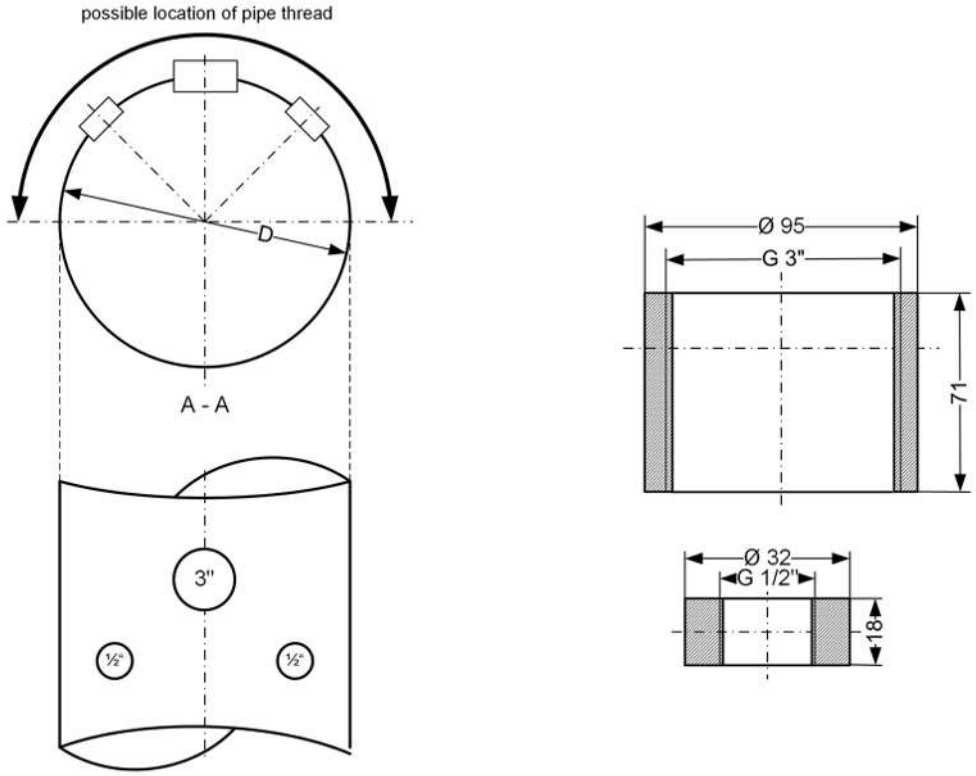


Figure 47: Sampling point, details

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 centre line and easy to access.

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

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2.23 Noise

2.23.1 Airborne noise

L engine

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 octave level diagram below shows the maximum expected octave levels at 100% MCR for L engines. No room correction is performed. The data will change depending on the acoustical properties of the environment and the specific application.

Blow-off noise

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



	31,5Hz	63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	8kHz
Lp [dB(A)]	72	82	98	98	103	103	102	96	89

Figure 48: Airborne noise spectrum from L engine - Sound pressure level Lp - octave level diagram

V engine

Sound pressure level Lp

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Measurements

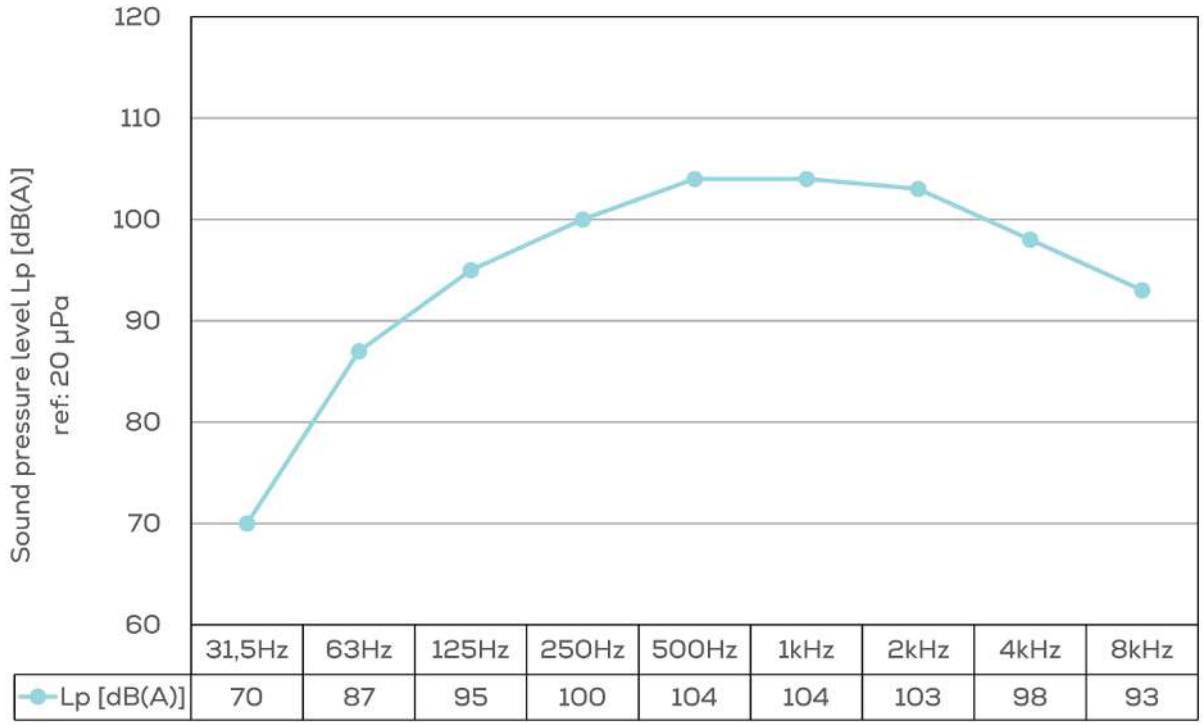
Approximately 20 measuring points at 1 metre distance from the engine surface are distributed evenly around the engine according to ISO 6798. The noise at the exhaust outlet is not included, but provided separately in the following sections.

Octave level diagram

The octave level diagram below shows the maximum expected octave levels at 100% MCR for V engines. No room correction is performed. The data will change depending on the acoustical properties of the environment and the specific application.

Blow-off noise

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



	31,5Hz	63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	8kHz
Lp [dB(A)]	70	87	95	100	104	104	103	98	93

Figure 49: Airborne noise spectrum from V engine - Sound pressure level Lp - octave level diagram

2.23.2 Intake noise

L engine

Sound power level Lw

Measurements

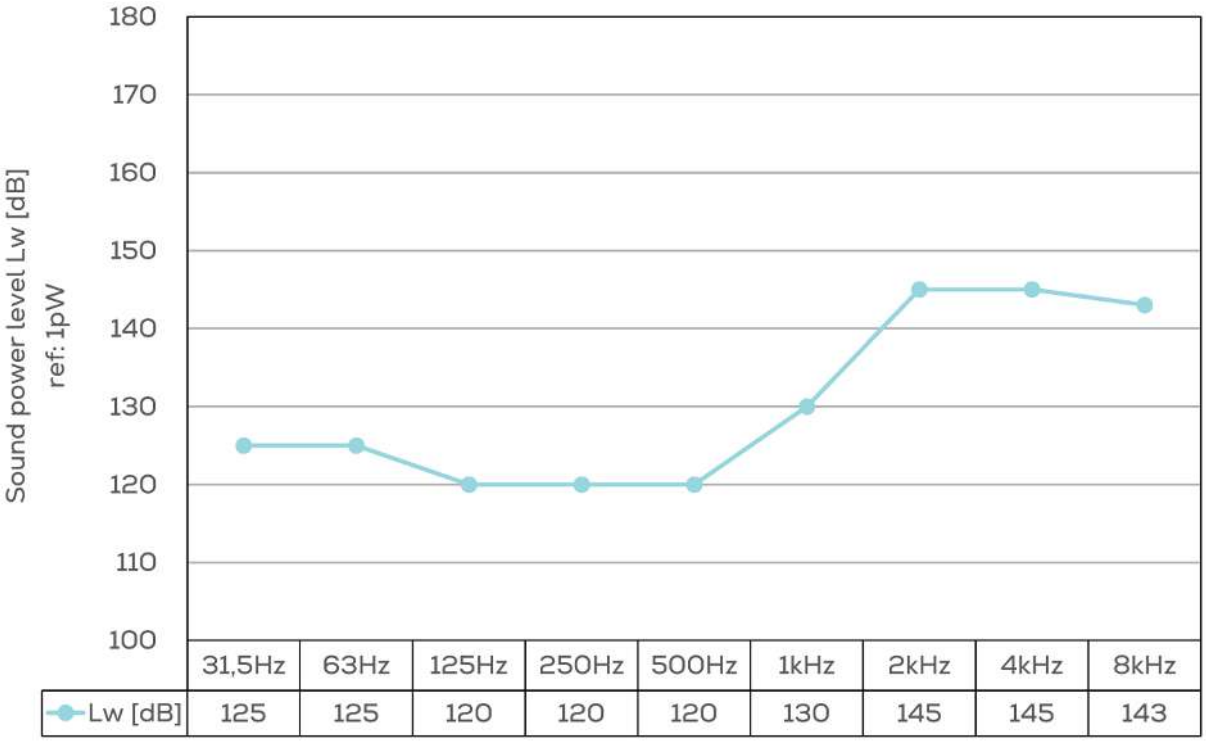
The unsilenced intake noise is measured at multiple points in the intake air pipe before the turbocharger.

Octave level diagram

The maximum expected octave sound power levels Lw of the unsilenced intake noise in the intake pipe is shown at 100% MCR for L engines. The data will change depending on the acoustical properties of the environment.

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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.



	31,5Hz	63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	8kHz
Lw [dB]	125	125	120	120	120	130	145	145	143

Figure 50: Intake noise spectrum from L engine - Sound power level Lw - octave level diagram

V engine

Sound power level Lw

Measurements

The unsilenced intake noise is measured at multiple points in the intake air pipe before the turbocharger.

Octave level diagram

The maximum expected octave sound power levels Lw of the unsilenced intake noise in the intake pipe is shown at 100% MCR for V engines. The data will change depending on the acoustical properties of the environment.

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.

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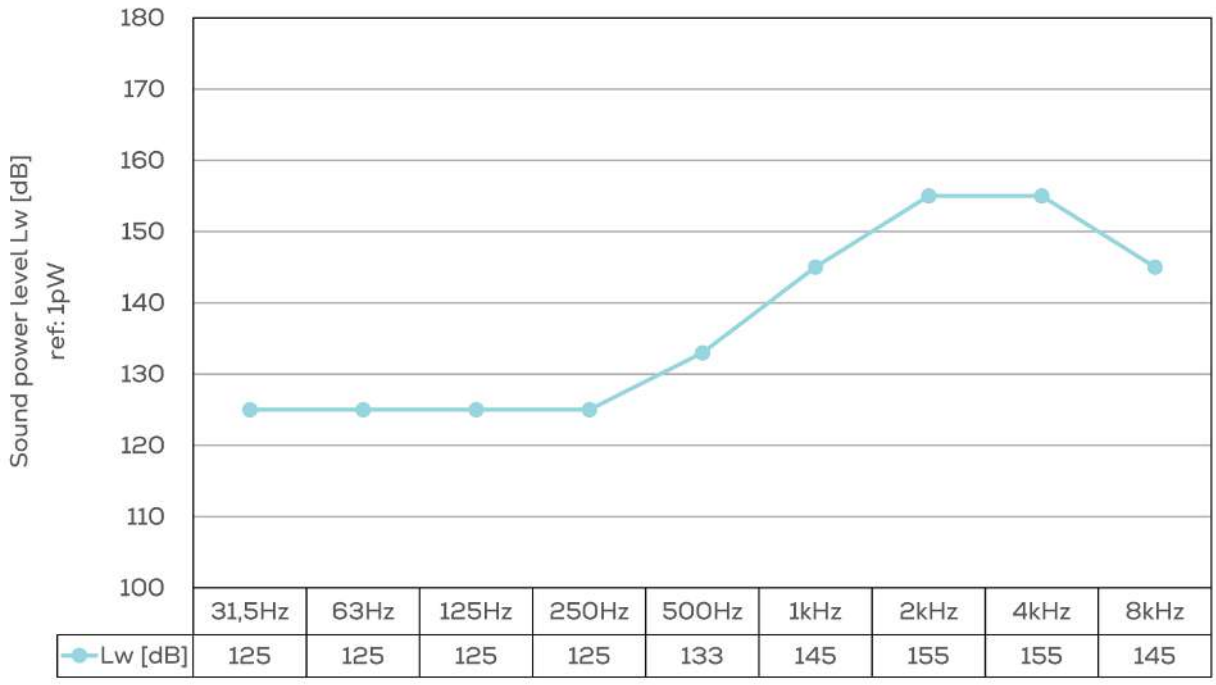


Figure 51: Intake noise spectrum from V engine - Sound power level Lw - octave level diagram

2.23.3 Exhaust gas noise

L engine

Sound power level Lw

Measurements

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

Octave level diagram

The maximum expected octave sound power levels Lw of the unsilenced exhaust gas noise in the exhaust gas pipe is shown at 100% MCR for L engines. 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, Everllence, supplier of silencer and where necessary acoustic consultant have to cooperate.

Waste gate blow-off noise

Waste gate blow-off noise is not considered in the measurements, see below.

2025-12-03 - 3.0

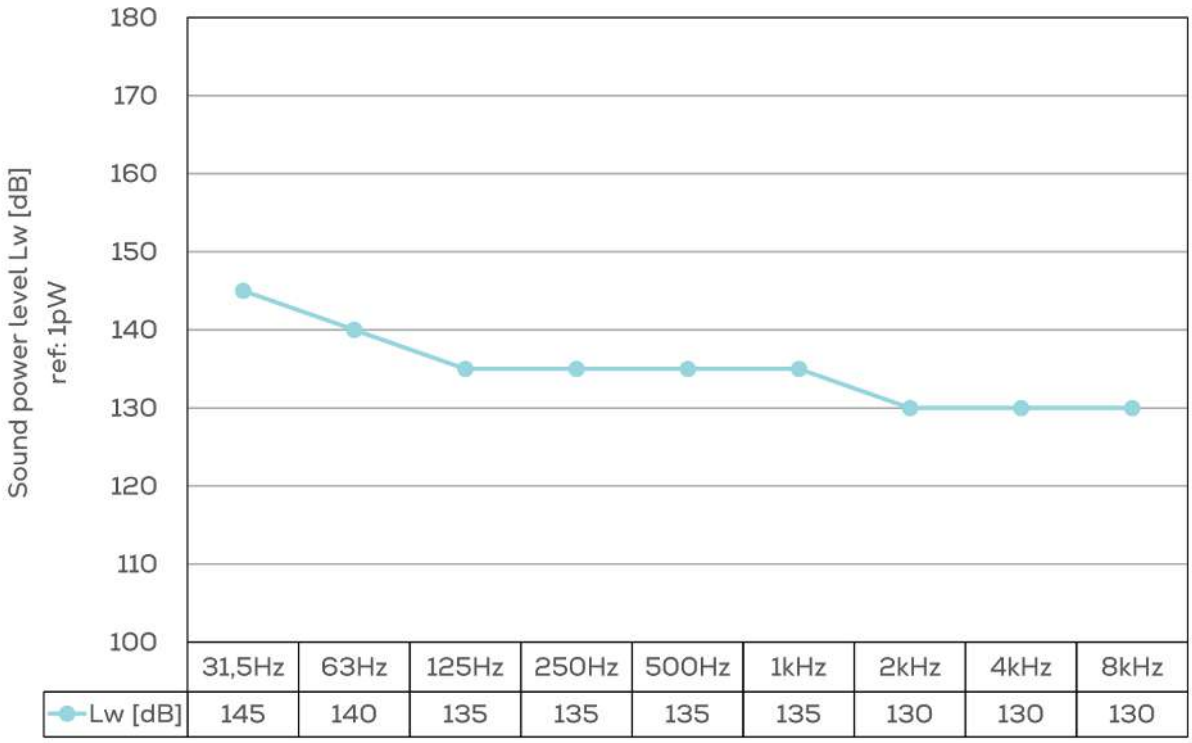


Figure 52: Exhaust gas noise spectrum from L engine - Sound power level Lw - octave level diagram

V engine

Sound power level Lw at 100% MCR

Measurements

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

Octave level diagram

The maximum expected octave sound power levels Lw of the unsilenced exhaust gas noise in the exhaust gas pipe is shown at 100% MCR for V engines. 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, Everllence, supplier of silencer and where necessary acoustic consultant have to cooperate.

Waste gate blow-off noise

Waste gate blow-off noise is not considered in the measurements, see below.

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Figure 53: Exhaust gas noise spectrum from V engine - Sound power level Lw - octave level diagram

2.23.4 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

2025-12-03 - 3.0

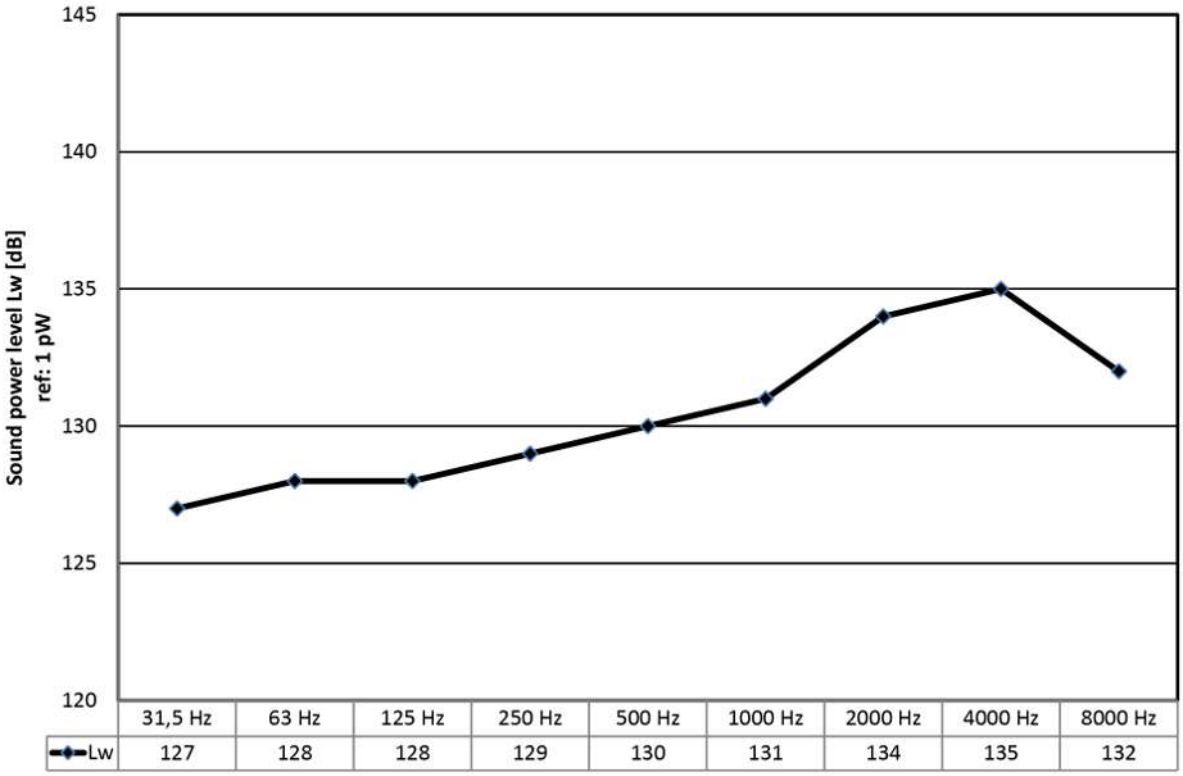


Figure 54: Unsilenced charge air blow-off noise – Sound power level Lw – Octave level diagram

2.23.5 Noise and vibration – Impact on foundation

Noise and vibration is emitted by the engine to the surrounding (see figure Noise and vibration – Impact on foundation, Page 157). The engine impact transferred through the engine mounting to the foundation is focused subsequently.

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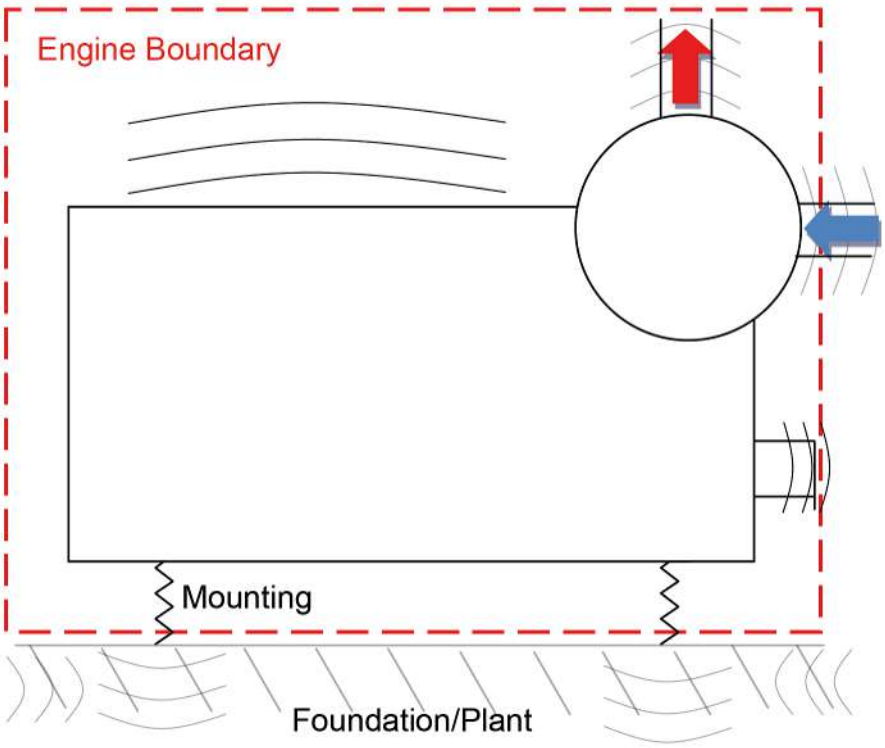


Figure 55: Noise and vibration – Impact on foundation

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

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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 Everllence for consultancy in case of system-related questions with interaction of engine, foundation and plant. The following information is available for Everllence 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).

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2.24 Vibration

2.24.1 Torsional vibrations

Data required for torsional vibration calculation

Everllence 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 1st to 24th harmonic of the gas and mass forces of the engine.

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 (GenSet, mechanical or electric propulsion)
- Arrangement of the whole 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 (fixed pitch propeller, controllable pitch propeller, combinator curve, operation with reduced speed at excessive load)
- Kind of mounting of the engine (can influence the determination of the flexible coupling)
- Operational speed range

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

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- 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

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 (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

Alternator for electric propulsion plants

- Drawing of the alternator shaft with all lengths and diameters
- Alternatively, torsional stiffness (Nm/rad)
- Moment of inertia of the parts mounted to the shaft (kgm^2)
- Electrical output (kVA) including power factor cos φ and efficiency
- Or mechanical output (kW)
- Complex synchronizing coefficients for no-load and full load in dependence on frequency, reference torque
- Island or parallel mode
- Load profile (e.g. load steps)
- Frequency fluctuation of the net

Alternator for mechanical propulsion plants (e.g. PTO/PTH)

- Drawing of the alternator shaft with all lengths and diameters
- Torsional stiffness, if available

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- Moment of inertia of the parts mounted to the shaft (kgm²)
- Electrical output (kVA) including power factor cos φ and efficiency
- Or mechanical output (kW)
- Complex synchronizing coefficients for no-load and full load in dependence on frequency, reference torque

2.25 Requirements for power drive connection (static)

Limit values of masses to be coupled after the engine

Evaluation of permissible theoretical bearing loads

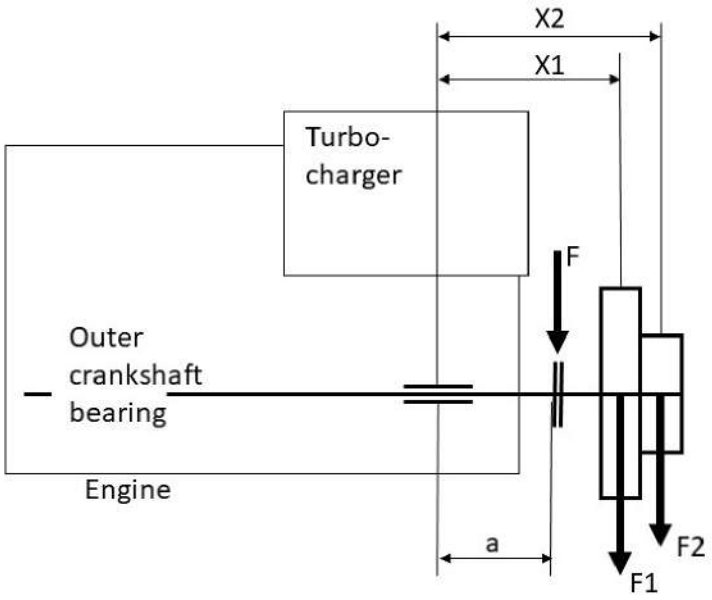


Figure 56: Case A1: Overhung arrangement, turbocharger on coupling side

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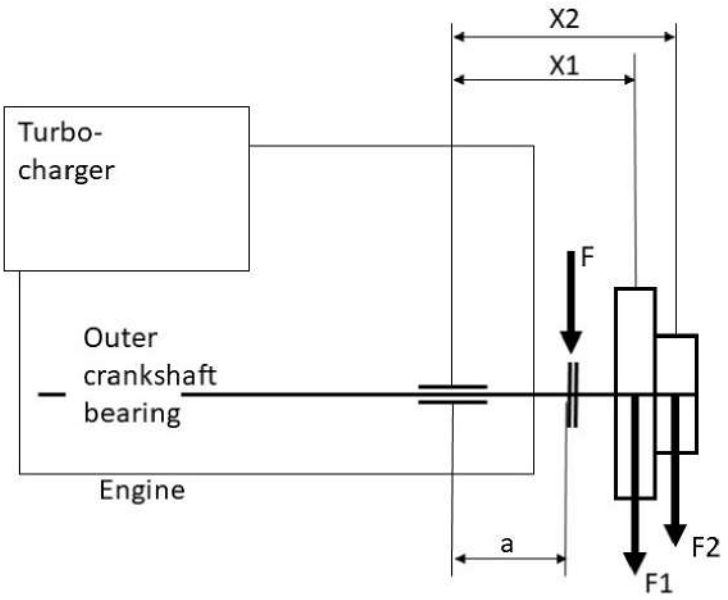


Figure 57: Case A2: Overhung arrangement, turbocharger on counter coupling side

$M_{max} = F * a = F_1 * x_1 + F_2 * x_2$

F_1	Flywheel weight
F_2	Coupling weight acting on the engine, including reset forces
a	Distance between end of coupling flange and centre of outer crankshaft bearing

Engine	Distance a	Case A
		$M_{max} = F * a$
	mm	kNm
L engine TC on coupling side, case A1	400	111 [1]
L engine TC on counter coupling side, case A2	255	59 [1]
V engine	267.7	119
[1] Inclusive of couples resulting from restoring forces of the coupling.		

Table 94: Example calculation case A

Distance between engine seating surface and crankshaft centre line:

- L engine: 700 mm
- V engine: 830 mm

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.

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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.

2.26 Requirements for power drive connection (dynamic)

2.26.1 Moments of inertia – Crankshaft, damper, flywheel

Engine 49/60

Operation with variable speed

Marine main engines						
Engine					Required minimum total moment of inertia[1] $J_{Total\ min}$	Plant
No. of cylinders, config.	Maximum continuous rating	Moment of inertia crankshaft + damper J_1	Moment of inertia flywheel J_2	Mass of flywheel		Required minimum additional moment of inertia after flywheel[2]
	[kW]	[kgm²]	[kgm²]	[kg]	[kgm²]	[kgm²]
n = 600 rpm						
6L	7,800	3,195	2,572	4,760	2,470	-
7L	9,100	3,646			2,882	
8L	10,400	4,274			3,293	
9L	11,700	4,253			3,705	
10L	13,000	4,596			4,117	
12V	15,600	6,565	2,935	4,835	4,940	-
14V	18,200	6,987			5,763	

[1] Required minimum moment of inertia of engine, flywheel and arrangement after flywheel in total.

[2] Required additional moment of inertia after flywheel to achieve the required minimum total moment of inertia.

Table 95: Moments of inertia/flywheels for marine main engines – 49/60

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Constant speed

Marine main engines							
Engine						Required minimum total moment of inertia[1] $J_{Total\ min}$	Plant
No. of cylinders, config.	Maximum continuous rating	Moment of inertia crankshaft + damper J_1	Moment of inertia flywheel J_2	Mass of flywheel	Cyclic irregularity		Required minimum additional moment of inertia after flywheel[2]
	[kW]	[kgm²]	[kgm²]	[kg]		[kgm²]	[kgm²]
n = 600 rpm							
6L	7,800	3,195	2,572	4,760	1/88	5,812	-
7L	9,100	3,646			1/70	6,780	563
8L	10,400	4,274			1/50	7,749	903
9L	11,700	4,253			1/62	8,718	1,893
10L	13,000	4,596			1/74	9,686	2,518
12V	15,600	6,565	2,935	4,835	1/67	11,624	2,124
14V	18,200	6,987	2,935	4,835	1/131	13,561	3,638

[1] Required minimum moment of inertia of engine, flywheel and arrangement after flywheel in total.

[2] Required additional moment of inertia after flywheel to achieve the required minimum total moment of inertia.

Table 96: Moments of inertia/flywheels for electric propulsion plants – 49/60

For flywheels dimensions see section Power transmission, Page 169.

2.26.2 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.

L engine

Rotating crank balance: 100%

No. of cylinders, config.	Firing order	Residual external couples		
		M_{rot} (kNm) + ½ $M_{osc\ 1st\ order}$ (kNm)		$M_{osc\ 2nd\ order}$ (kNm)
Directiion		vertical	horizontal	vertical
Engine speed		600 rpm		
6L	A	0	0	0
7L	C	2.2	0	119.5
8L	B	0	0	0
9L	B	37.3	37.3	202.2
10L	B	0	0	0

Table 97: Residual external couples – L engine

The external mass forces are equal to zero.

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M_{rot} is eliminated by means of balancing weights on resiliently mounted engines.

Firing order: Counted from gear drive side

No. of cylinders, config.	Firing order	Clockwise rotation	Counter clockwise rotation
6L	A	1-3-5-6-4-2	1-2-4-6-5-3
7L	C[1)]	1-2-4-6-7-5-3	1-3-5-7-6-4-2
8L	B	1-4-7-6-8-5-2-3	1-3-2-5-8-6-7-4
9L	B	1-6-3-2-8-7-4-9-5	1-5-9-4-7-8-2-3-6
10L	B	1-4-3-2-6-10-7-8-9-5	1-5-9-8-7-10-6-2-3-4

[1)] Irregular firing order.

Table 98: Firing order – L engine

V engine

Rotating crank balance: 115%

No. of cylinders, config.	Firing order	Residual external couples			
		M_{rot} (kNm)+ $M_{osc\ 1st\ order}$ (kNm)		$M_{osc\ 2nd\ order}$ (kNm)	
Direction		vertical	horizontal	vertical	horizontal
Engine speed		600 rpm			
12V	See table below	0	0	0	0
14V		0	0	70.5	39.2

Table 99: Residual external couples – V engine

No. of cylinders, config.	Firing order	Residual external forces			
		F_{rot} (kNm)+ $F_{osc\ 1st\ order}$ (kN)		$F_{osc\ 2nd\ order}$ (kN)	
Direction		vertical	horizontal	vertical	horizontal
Engine speed		600 rpm			
12V	See table below	0	0	0	0
14V		0	0	80	44

Table 100: Residual external forces – V engine

The external mass forces are equal to zero.

M_{rot} is eliminated by means of balancing weights on resiliently mounted engines.

Firing order: Counted from coupling side

No. of cylinders, config.	Clockwise rotation	Counter clockwise rotation
12V	A1-B1-A3-B4-A5-B5-A6-B6-A4-B3-A2-B2	B1-A1-B2-A2-B3-A4-B6-A6-B5-A5-B4-A3
14V	A1-B1-A2-B2-A4-B4-A6-B6-A7-B7-A5-B5-A3-B3	A1-B3-A3-B5-A5-B7-A7-B6-A6-B4-A4-B2-A2-B1

Table 101: Firing order – V engine

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2.26.3 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 166 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.

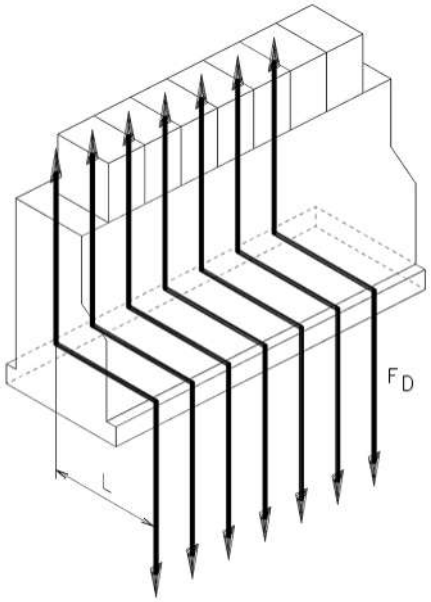


Figure 58: Static torque fluctuation

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

L Distance between foundation bolts

z Number of cylinders

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Static torque fluctuation and exciting frequencies

L engine – Example to declare abbreviations

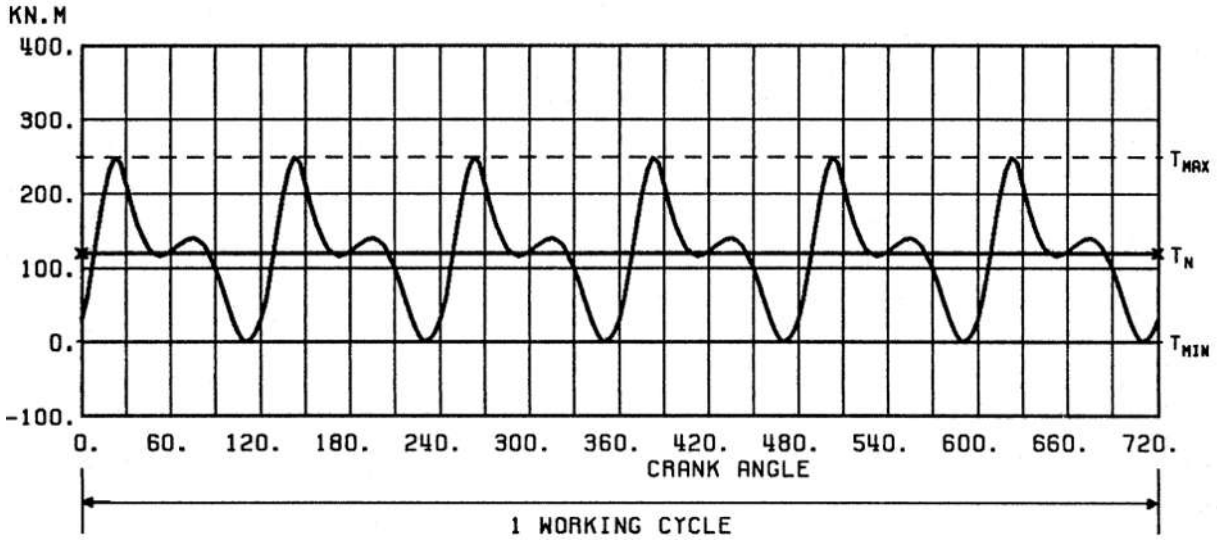


Figure 59: Example to declare abbreviations – L engine

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
6L	7,800	600	124	248	–16	3.0 6.0	30 60	62 77
7L	9,100		145	457	–118	3.5 7.0	35 70	259 55
8L	10,400		166	408	–46	4.0 8.0	40 80	221 42
9L	11,700		186	418	–24	4.5 9.0	45 90	218 31
10L	13,000		207	424	15	5.0 10.0	50 100	201 23

[1)] Exciting frequency of the main harmonic components.

Table 102: Static torque fluctuation and exciting frequencies – L engine

V engine – Example to declare abbreviations

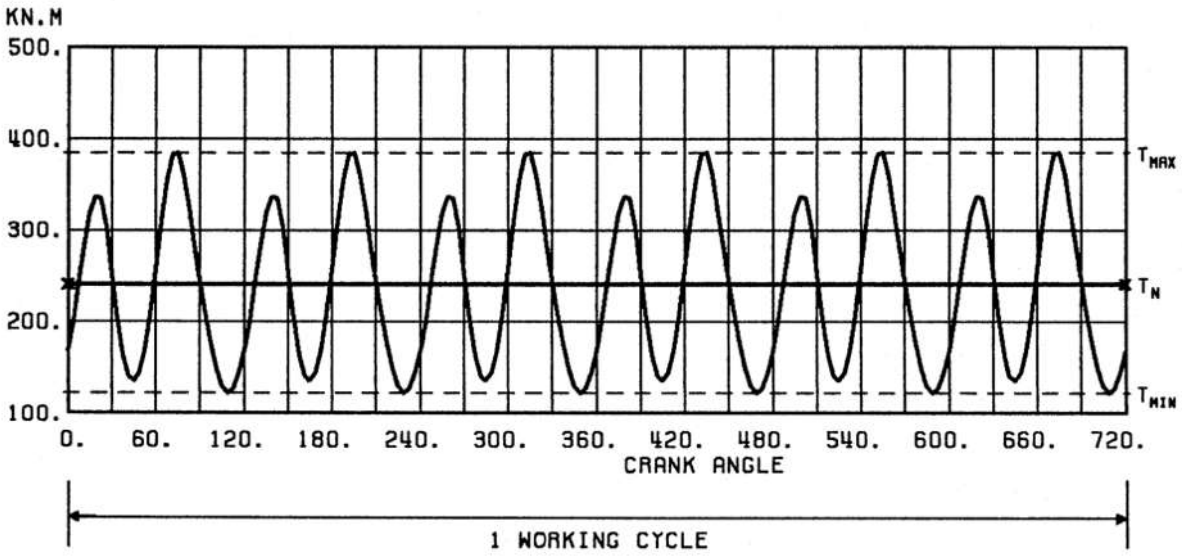


Figure 60: Example to declare abbreviation – V engine

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	15,600	600	248	409	105	3.0 6.0	30 60	32 134
14V	18,200		290	481	103	3.5 7.0	35 70	22 108
[1)] Exciting frequency of the main harmonic components.								

Table 103: Static torque fluctuation and exciting frequencies – V engine

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2.27 Power transmission

See overleaf

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2.27.1 Flywheel arrangement

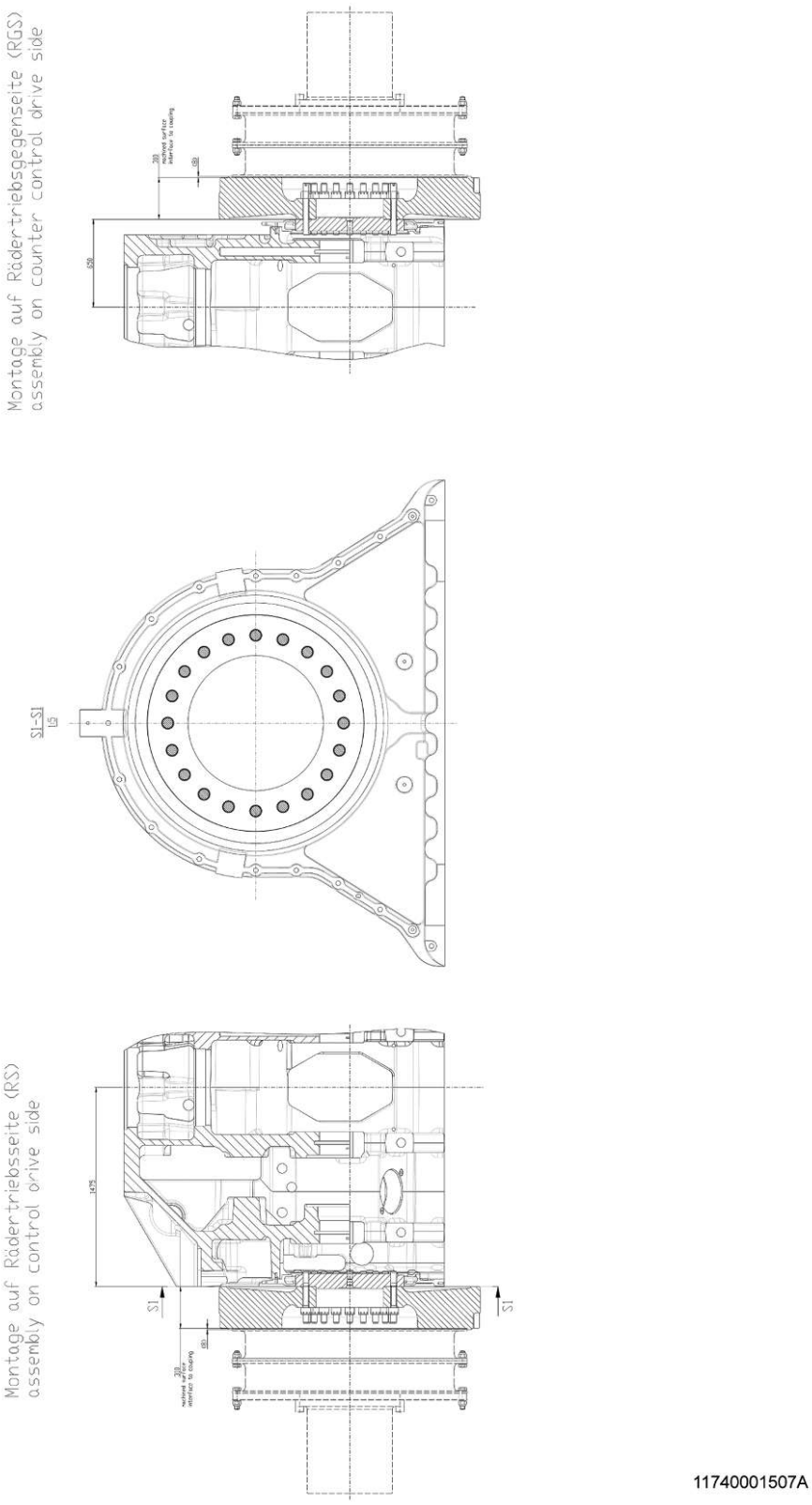


Figure 61: Flywheel with flexible coupling

Note:
Final dimensions of flywheel 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.

For mass of flywheel see section Moments of inertia – Crankshaft, damper, flywheel, Page 163.

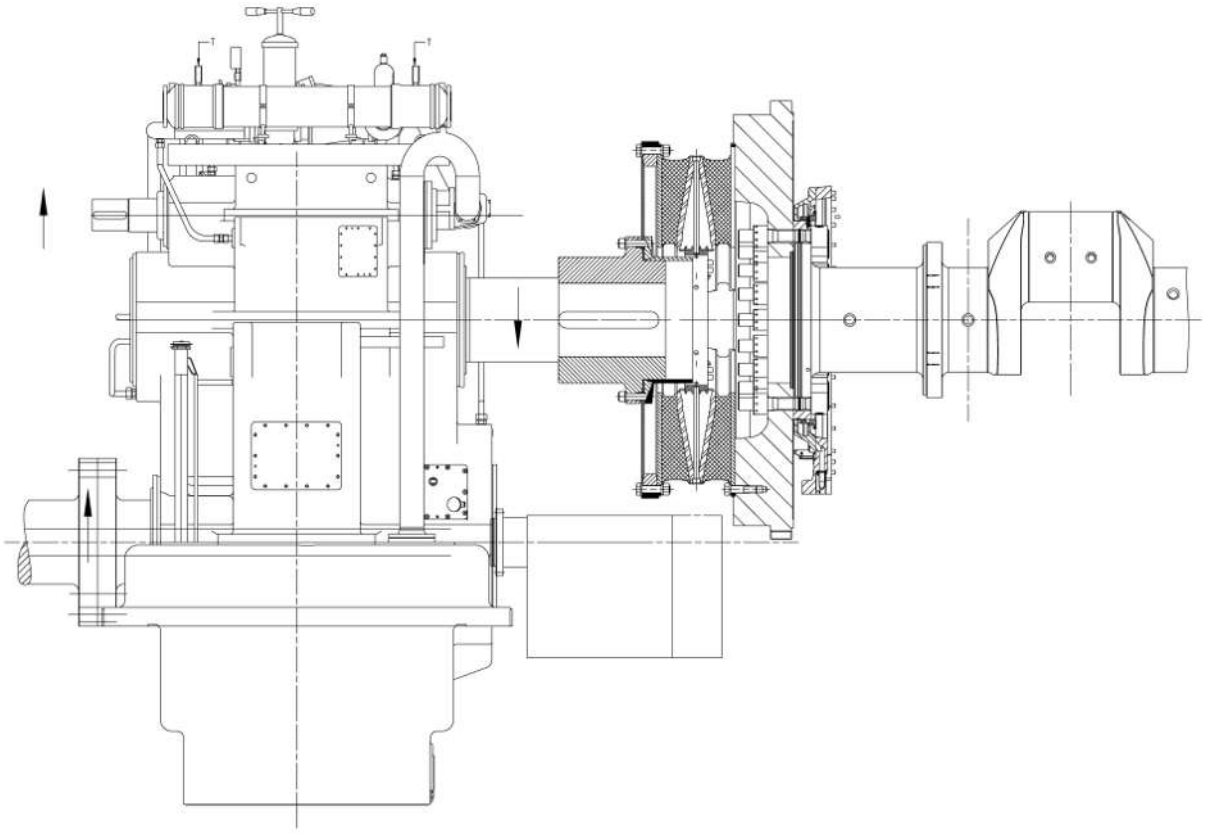


Figure 62: Example for an arrangement of flywheel, coupling and gearbox

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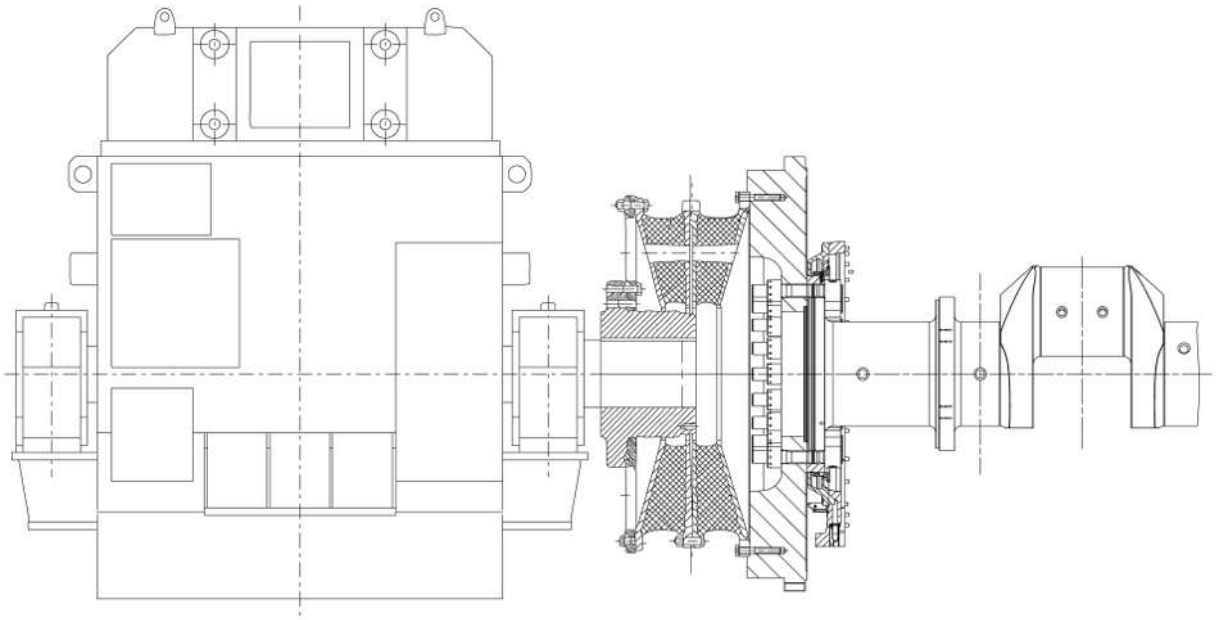


Figure 63: Example for an arrangement of flywheel, coupling and alternator

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

2.27.2 Main PTO

The power take-off on engine free end is up to 100% of rated output. The clutch has a specific size depending on the maximum power output at the PTO. Three different interfaces are available for this purpose. The PTO is only available for L engines.

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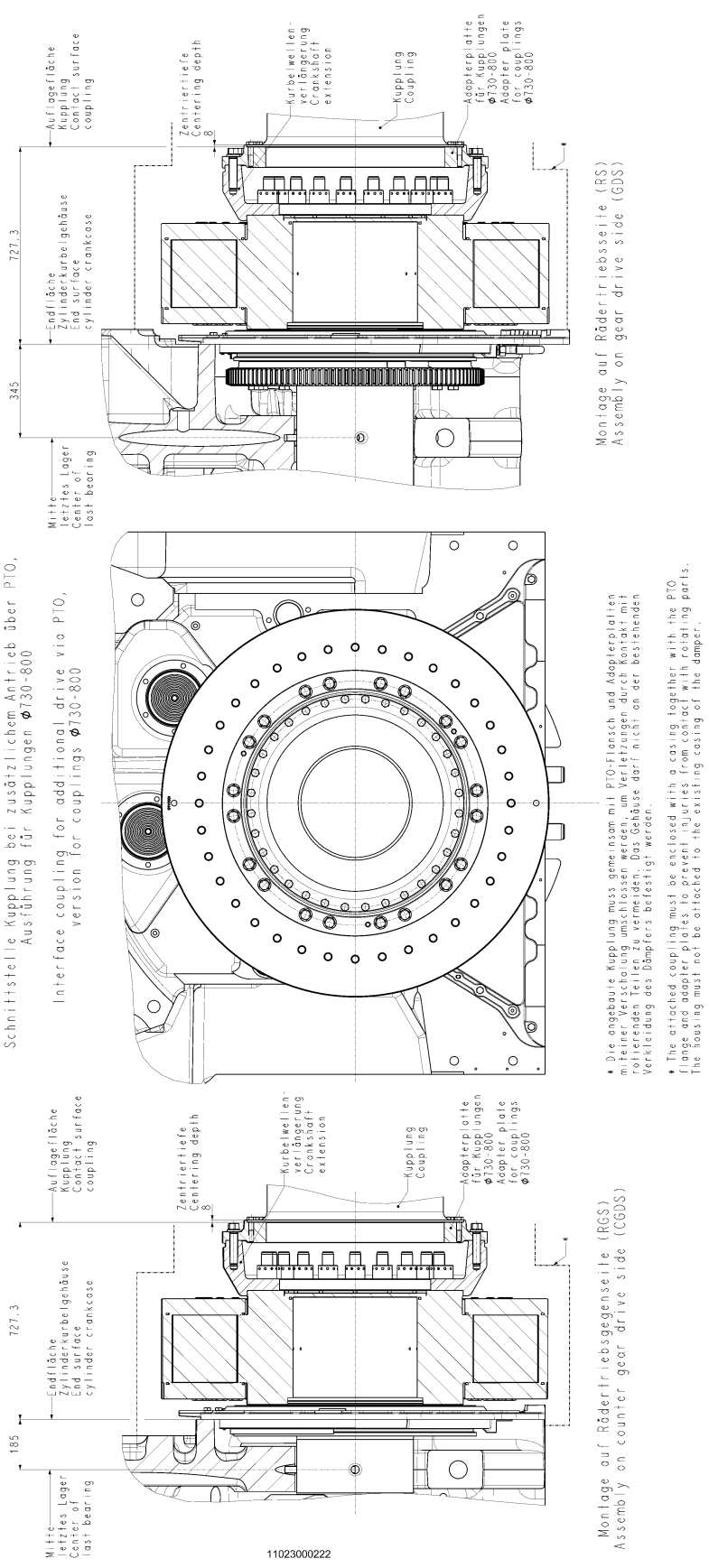


Figure 64: PTO on engine free end – version for couplings Ø730-800 mm

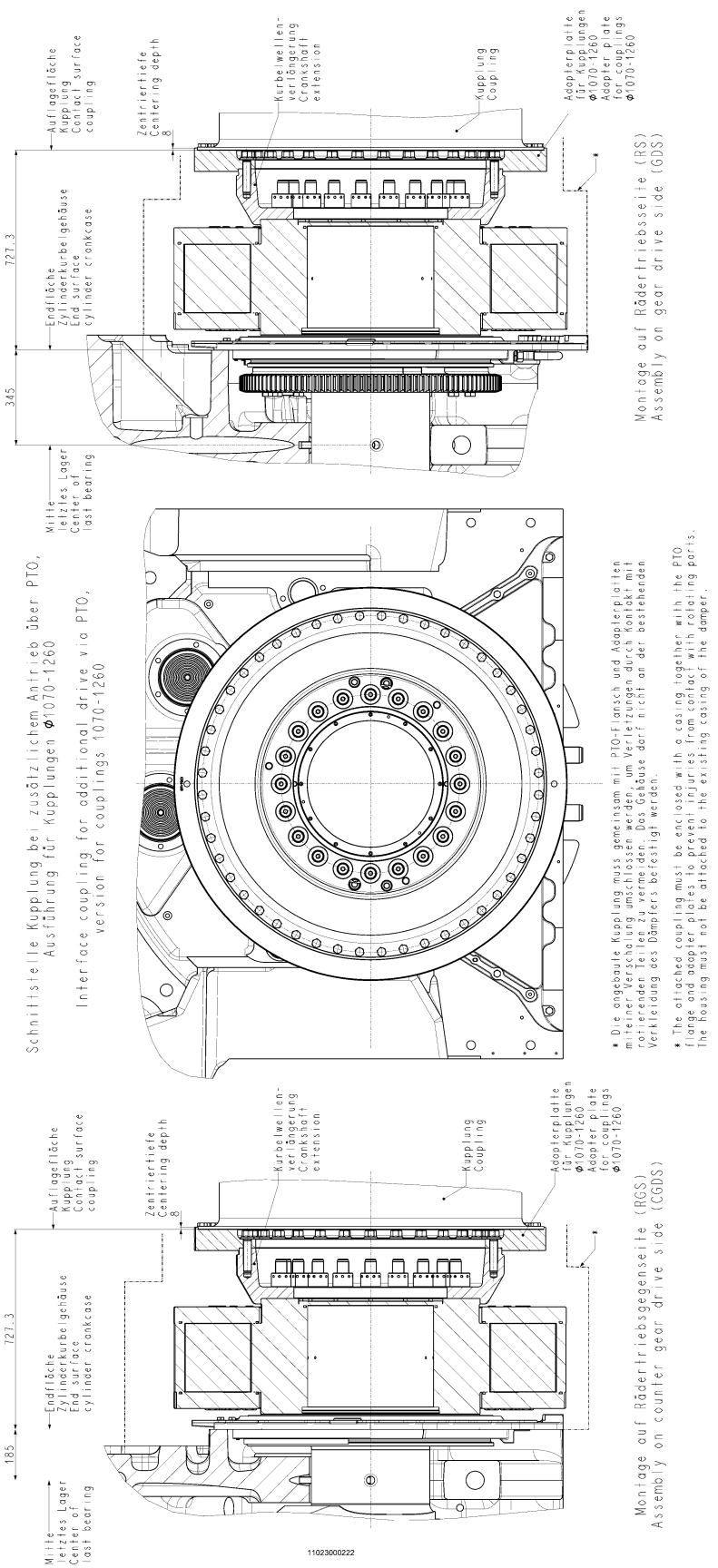


Figure 65: PTO on engine free end – version for couplings Ø1,070-1,260 mm

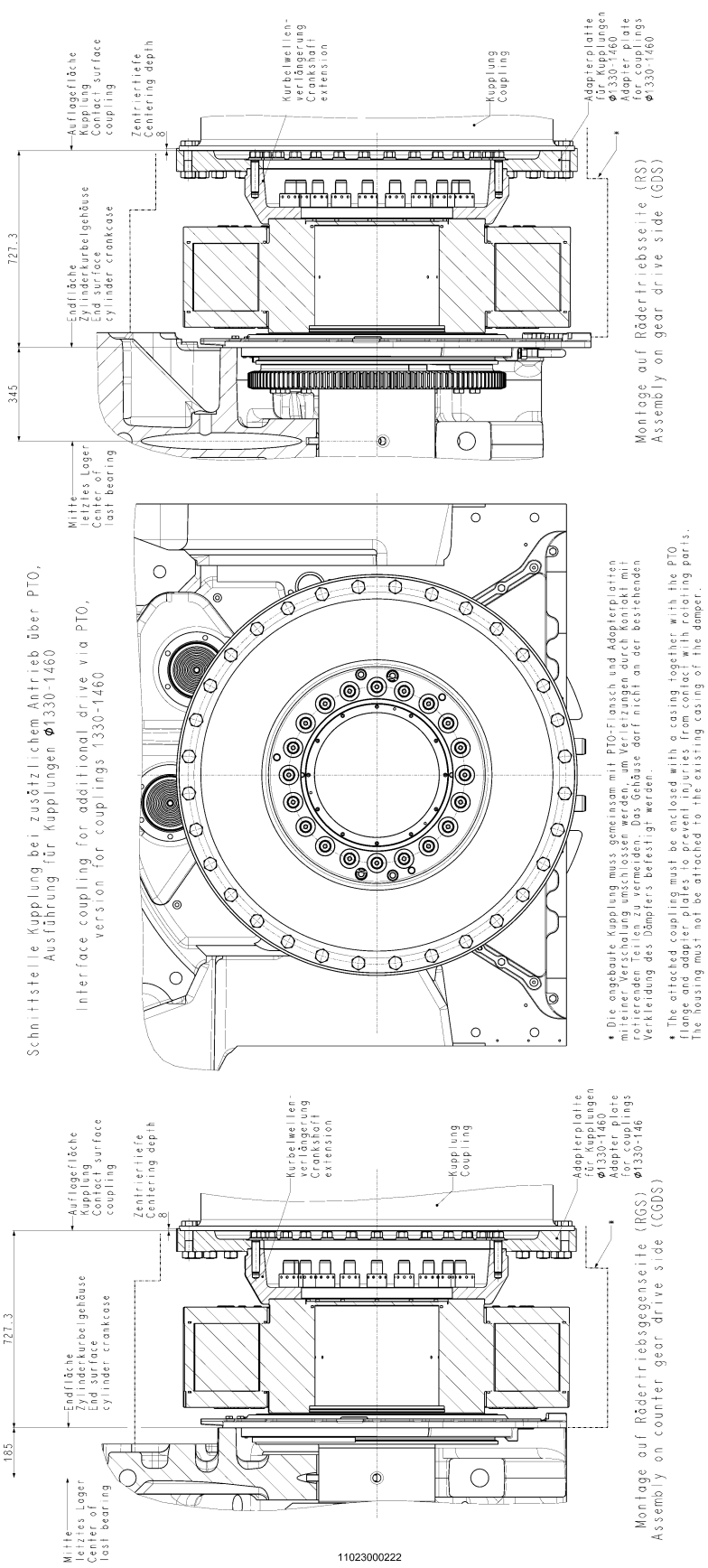


Figure 66: PTO on engine free end – version for couplings Ø1,330-1,460 mm

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2.28 Foundation

2.28.1 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 156.

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

2.28.2 Rigid seating

Remark:

V engine: Rigid seating not available

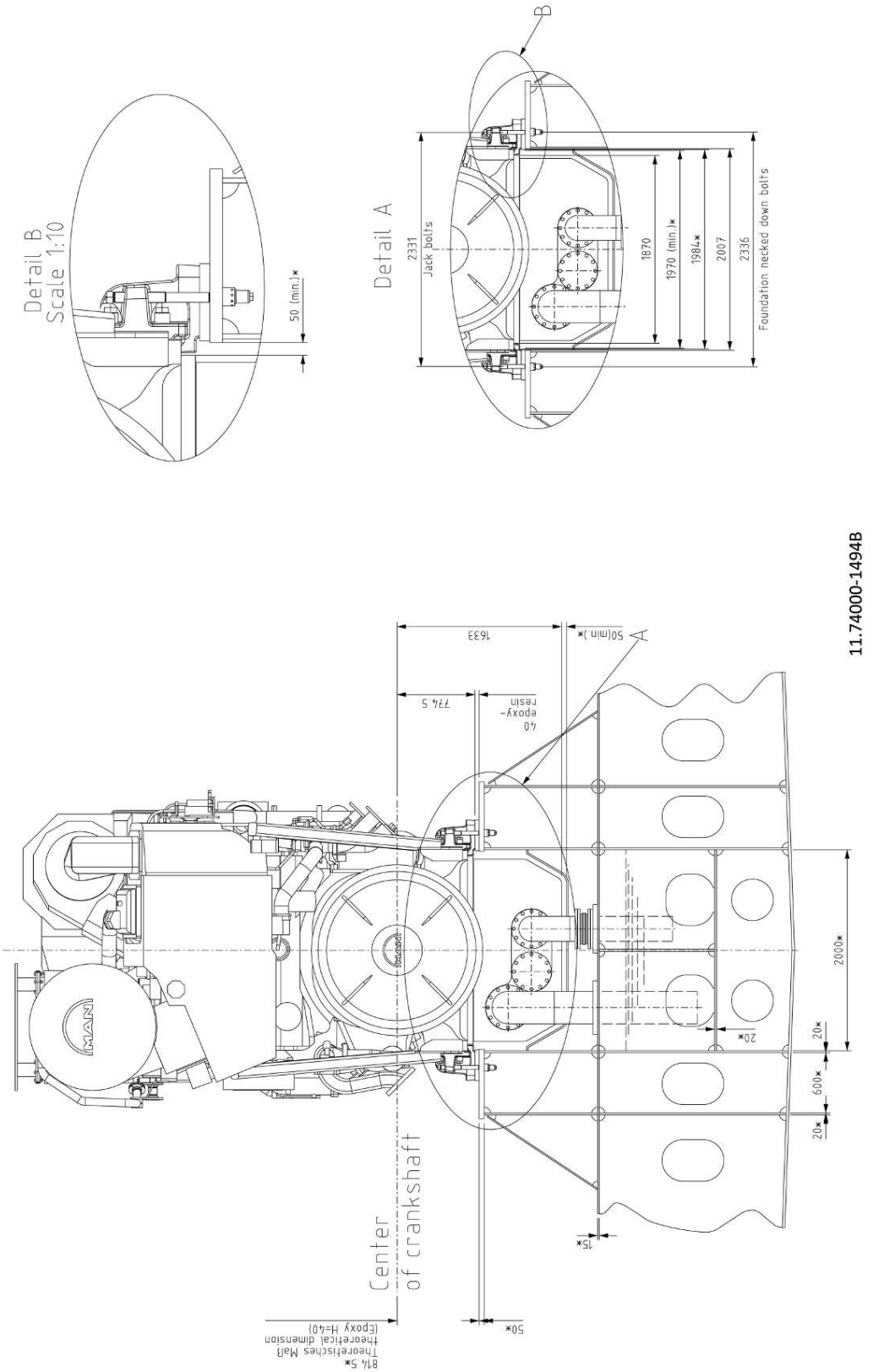
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L engine:

- Rigid seating available for 6L engine
- Rigid seating not available for 7L and 8L engine
- Rigid seating only available for constant speed at 9L and 10L engine

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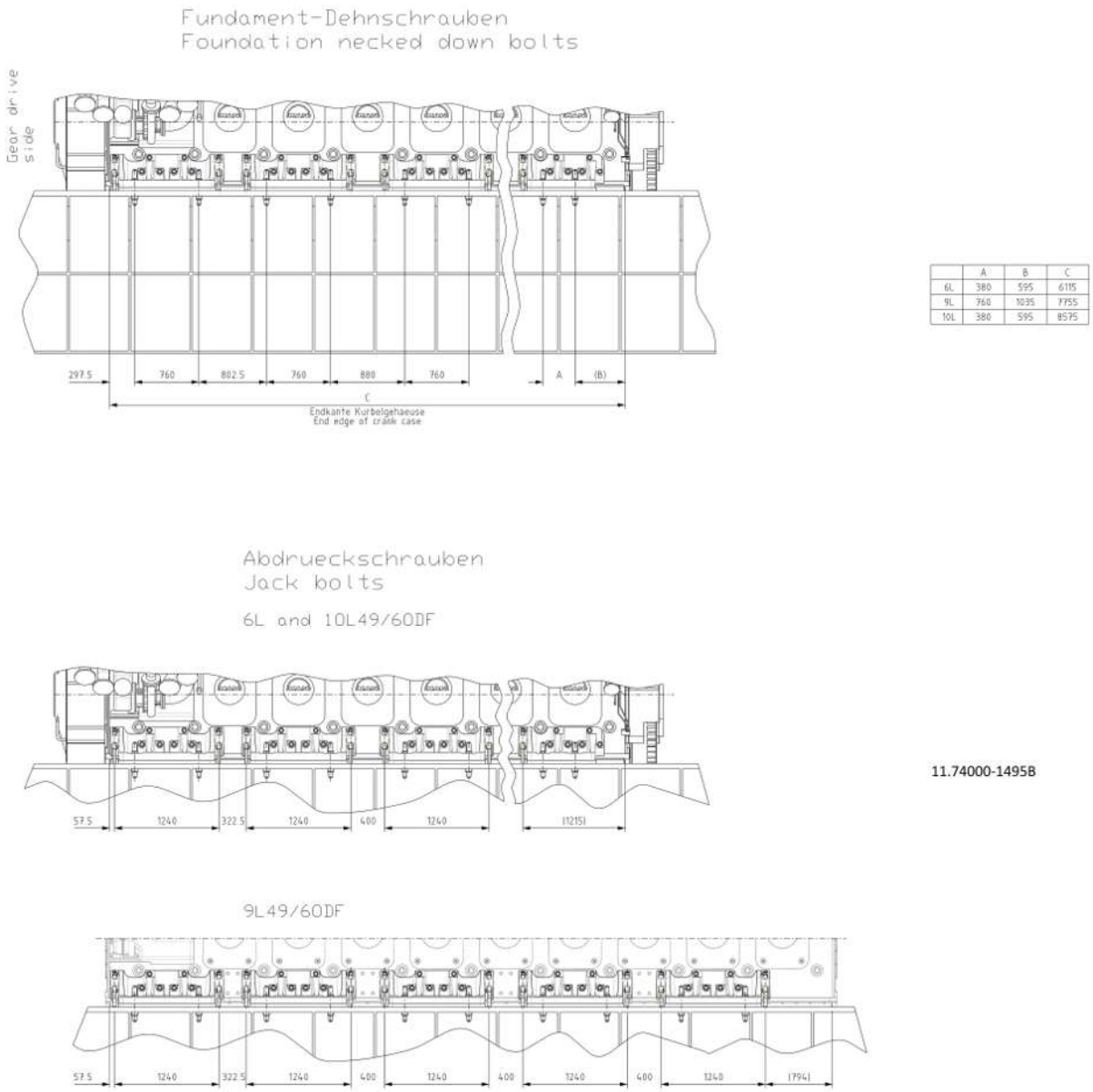
Recommended configuration of foundation – L engine



* Dimensions and distances shown on the drawing are exemplarily only. The final dimensions have to be designed by the shipyard acc. to the static and dynamic requirements of the vessel. The weight and forces on the foundation depend on the engine type, number of cylinders and engine speed.

Figure 67: Recommended configuration of foundation L engine

Recommended configuration of foundation – Number of bolts

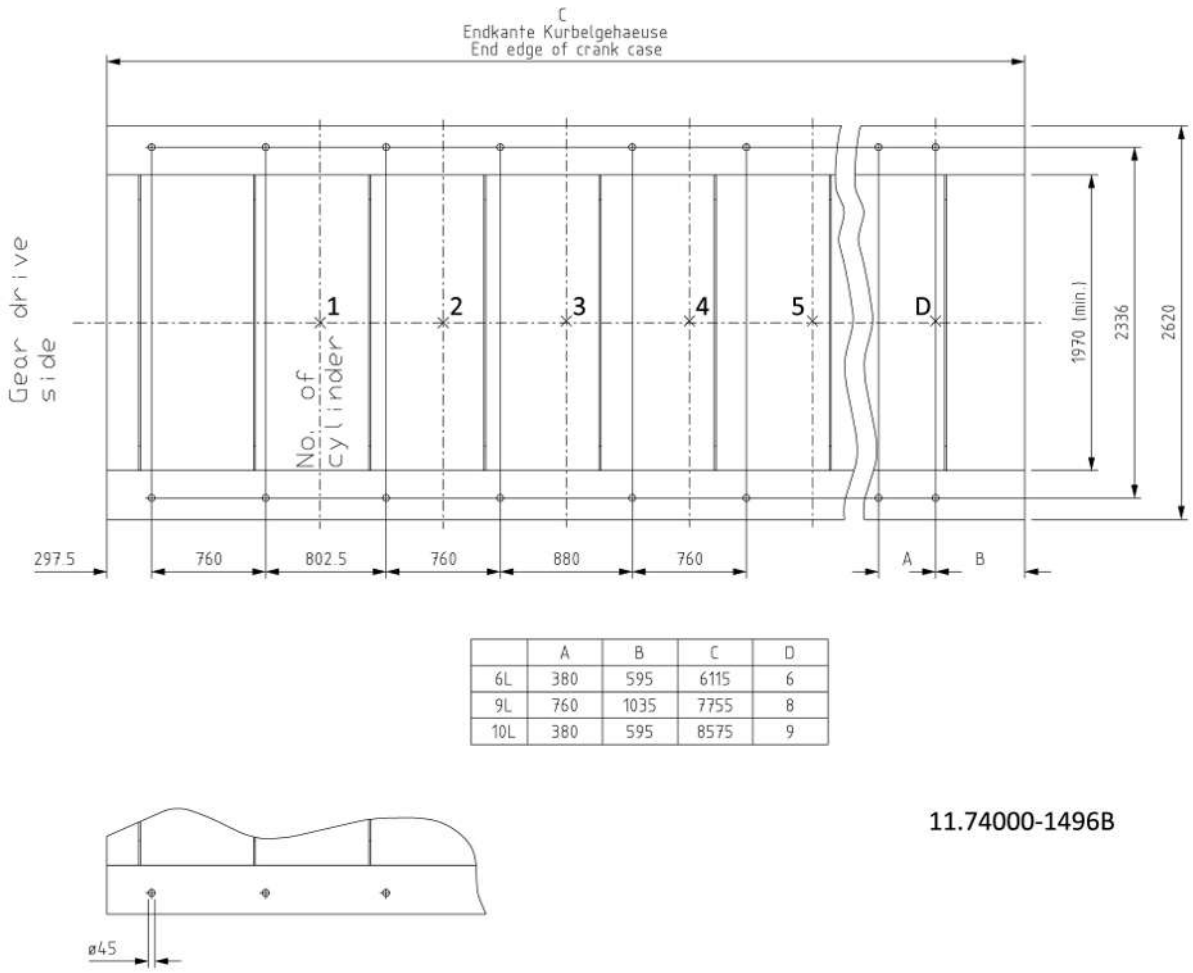


	A	B	C
6L	380	595	6115
9L	760	1035	7755
10L	380	595	8575

11.74000-1495B

Figure 68: Recommended configuration of foundation – Number of bolts

Arrangement of foundation bolt holes



	A	B	C	D
6L	380	595	6115	6
9L	760	1035	7755	8
10L	380	595	8575	9

Figure 69: Arrangement of foundation bolt holes

Two **fitted bolts** have to be provided either on starboard side or portside.

In any case they have to be positioned on the coupling side.

Number and position of the **stoppers** have to be provided according to the figure above.

2.28.3 Chocking with synthetic resin

Most classification societies permit the use of the following synthetic resins for chocking diesel engines:

- Chockfast Orange
  (Philadelphia Resins Corp. U.S.A)
- Epocast 36
  (H.A. Springer, Kiel)

Everllence accepts engines being chocked with synthetic resin provided:

- If processing is done by authorised agents of the above companies.
- If the classification society responsible has approved the synthetic resin to be used for a unit pressure (engine weight + foundation bolt preloading) of 450 N/cm^2 and a chock temperature of at least 80 °C.

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The loaded area of the chocks must be dimensioned in a way, that the pressure effected by the engines dead weight does not exceed 70 N/cm^2 (requirement of some classification societies).

The pretensioning force of the foundation bolts was chosen so that the permissible total surface area load of 450 N/cm^2 is not exceeded. This will ensure that the horizontal thrust resulting from the mass forces is safely transmitted by the chocks.

The shipyard is responsible for the execution and must also grant the warranty.

Tightening of the foundation bolts only permissible with hydraulic tensioning device. Nuts definitely must not be tightened with hook spanner and hammer, even for later inspections.

Tightening of foundation bolts

The tensioning tools with tensioning nut and pressure sleeve are included in the standard scope of supply of tools for the engine.

Dedicated installation values (e.g. pre-tensioning forces) will be given in the customer documentation specific to each project.

2.28.4 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) Everllence 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.

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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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2.28.5 Recommended configuration of foundation

Engine mounting using inclined sandwich elements

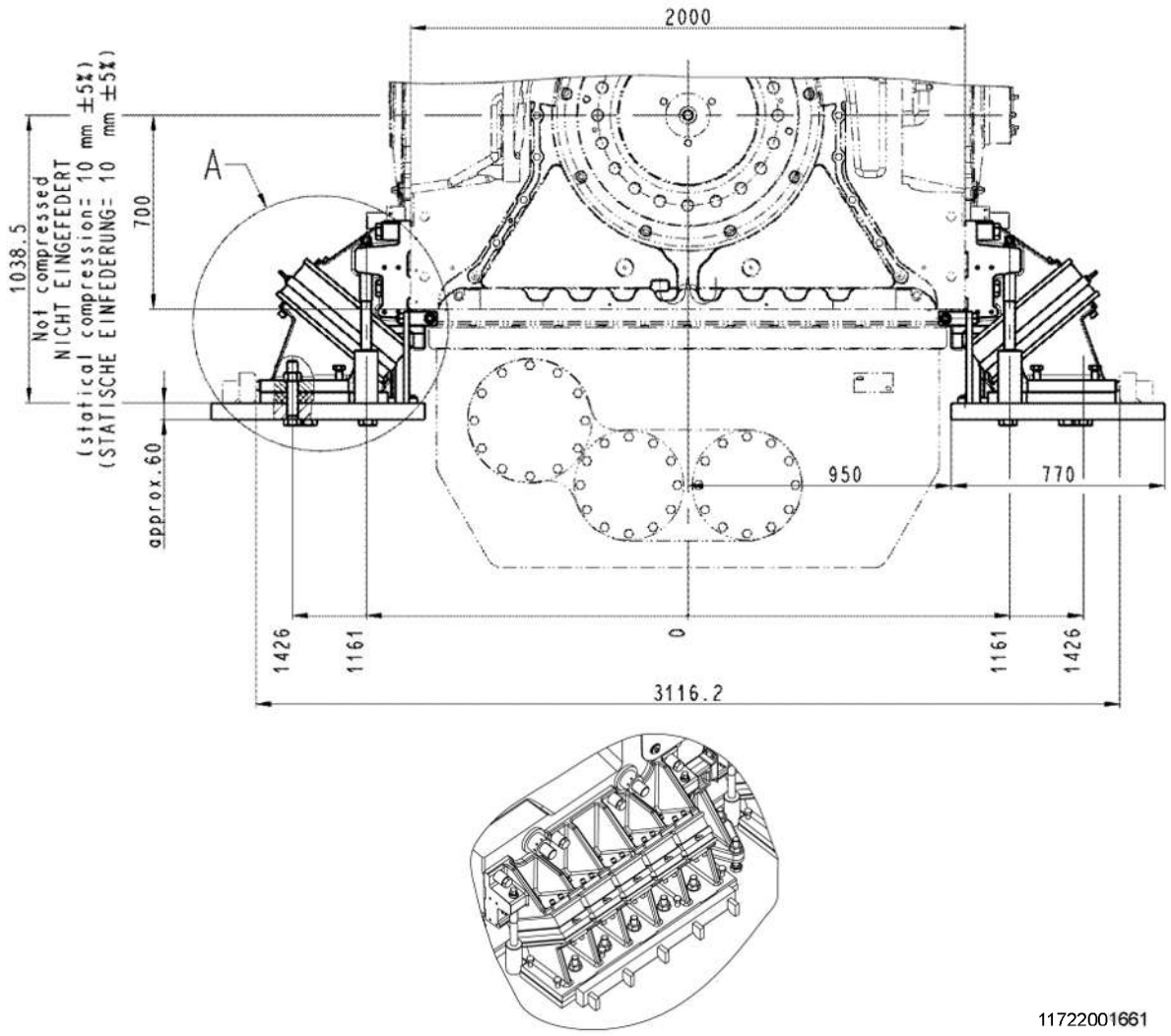


Figure 70: Recommended configuration of foundation – L engine, inclined resilient seating, picture 1 of 3

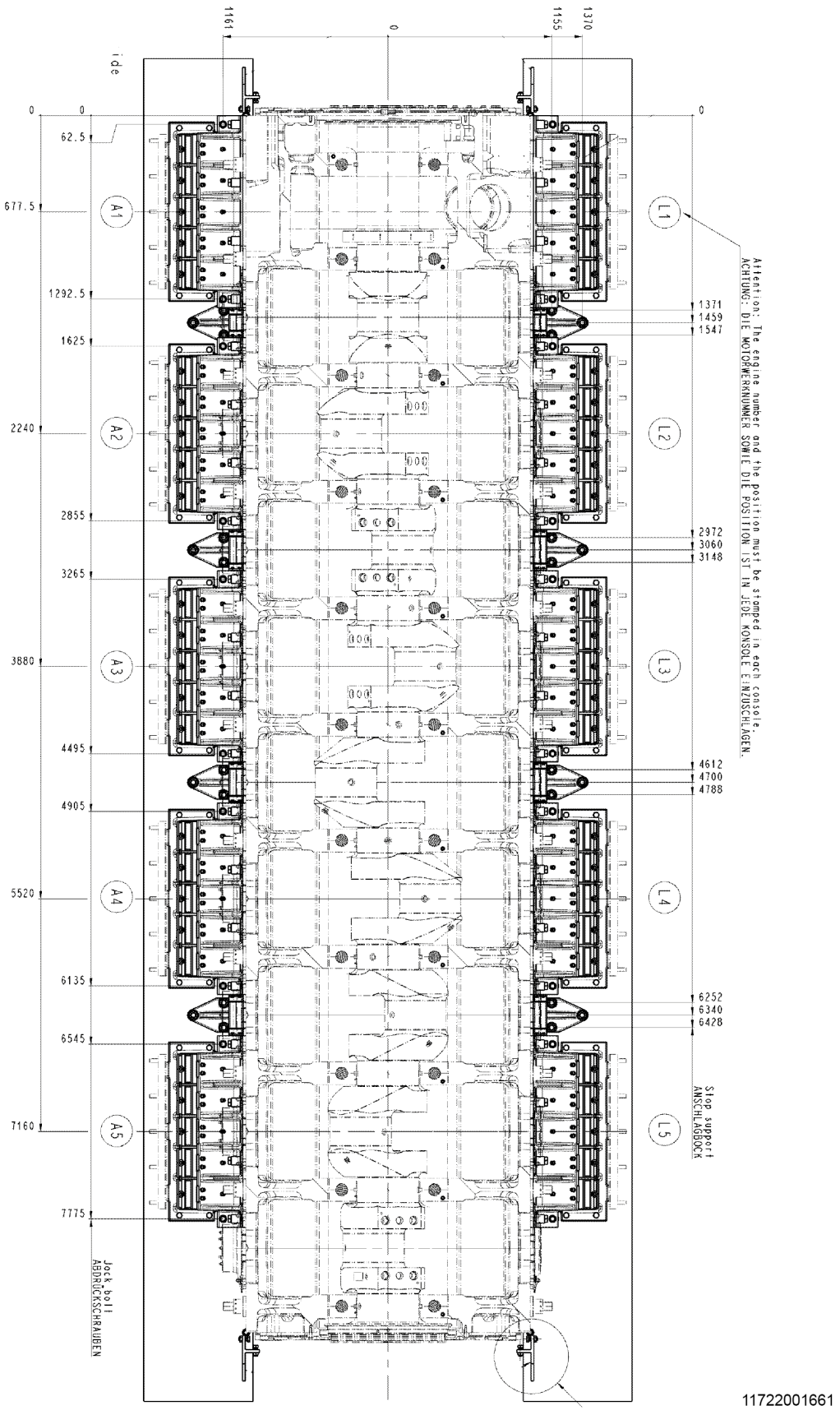


Figure 71: Recommended configuration of foundation – L engine, inclined resilient seating, picture 2 of 3

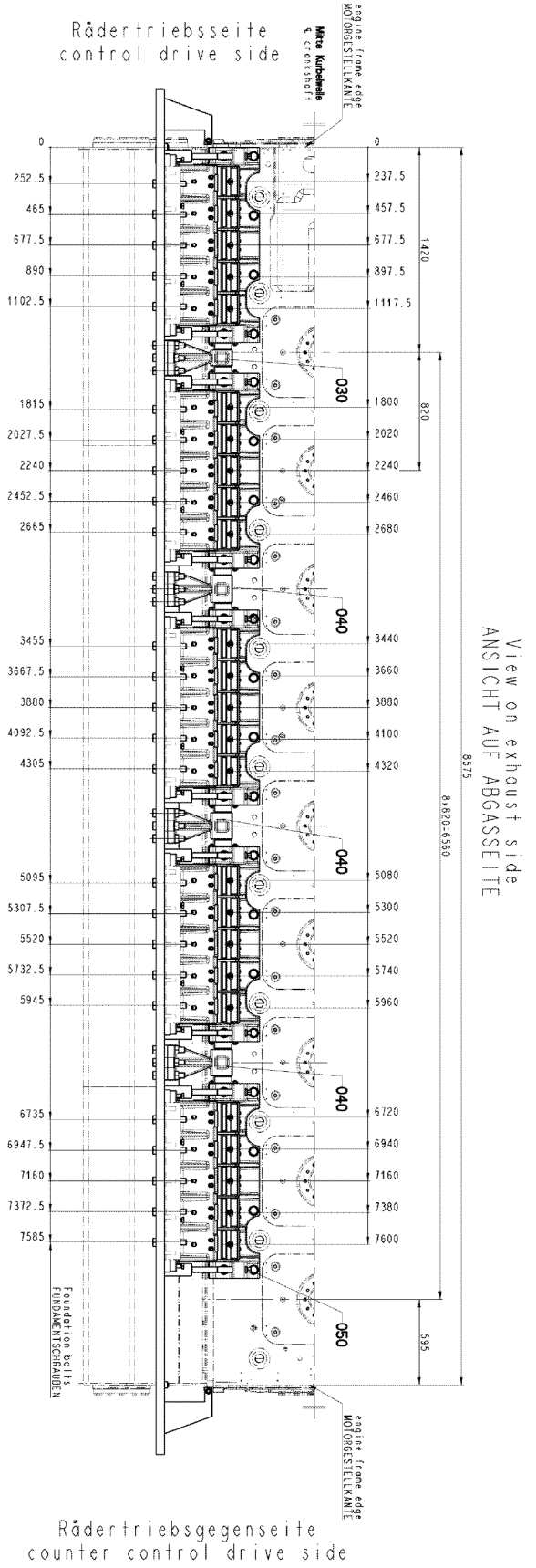
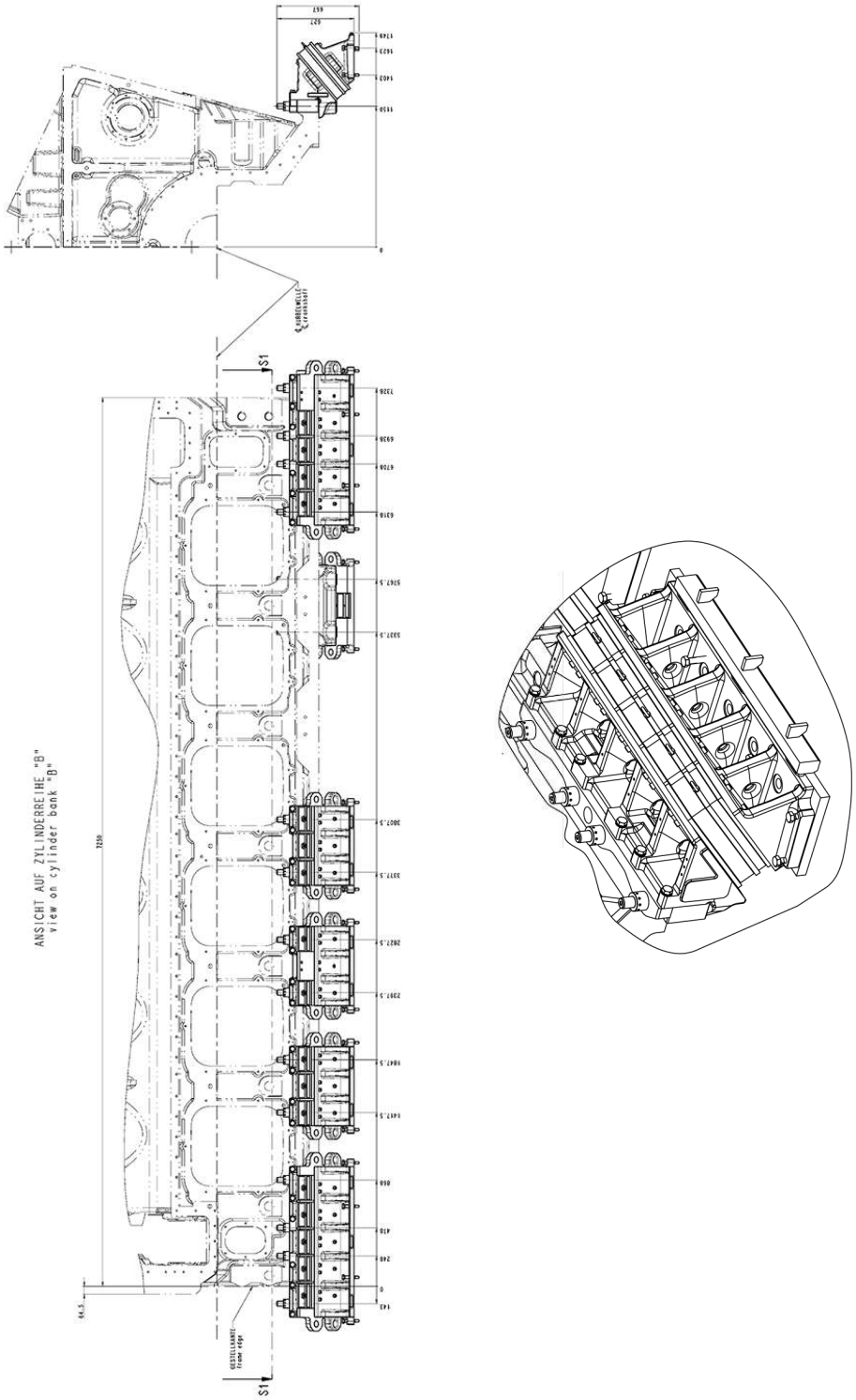


Figure 72: Recommended configuration of foundation – L engine, inclined resilient seating, picture 3 of 3

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12V, 14V engine (exemplary)



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Figure 73: Recommended configuration of foundation, view on B-bank – V engine, resilient seating, picture 1 of 2 (preliminary, valid installation drawings will be given based on project specific demands)

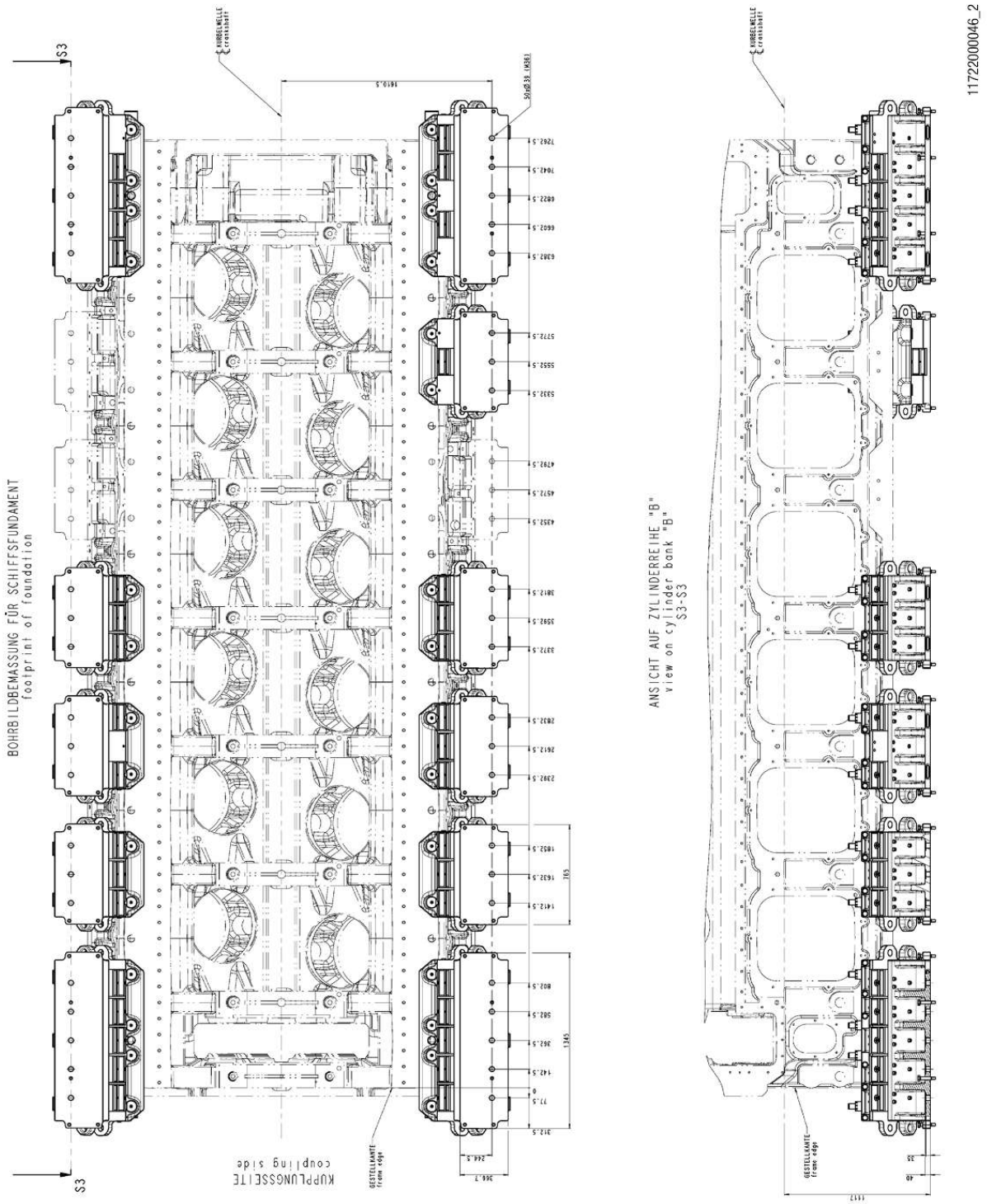
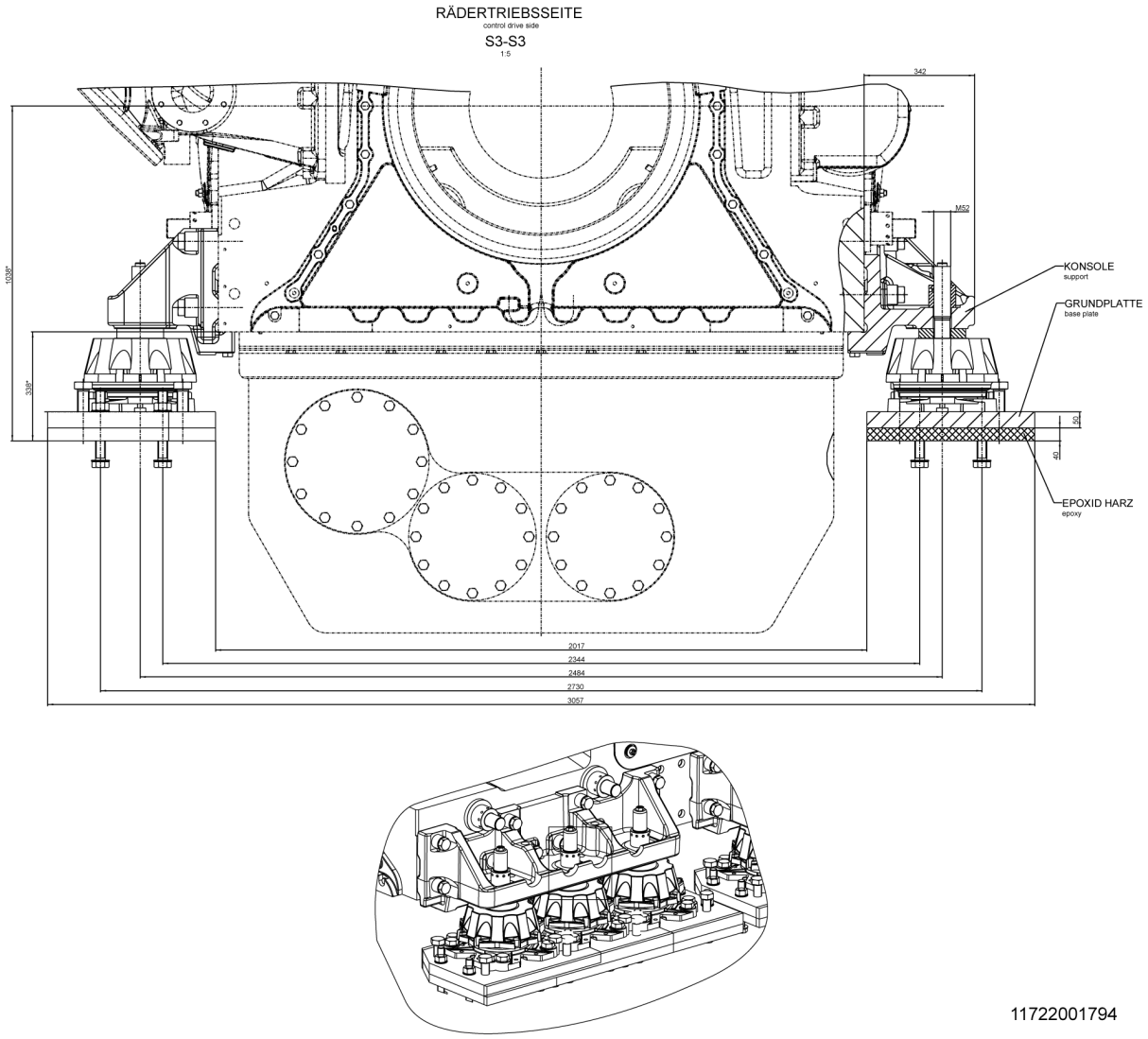


Figure 74: Recommended configuration of foundation, view on B-bank – V engine, resilient seating, picture 2 of 2 (preliminary, valid installation drawings will be given based on project specific demands)

Engine mounting using conical mounts



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Figure 75: Recommended configuration of foundation – L engine, conical resilient seating, picture 1 of 3 (preliminary, valid installation drawings will be given based on project specific demands)

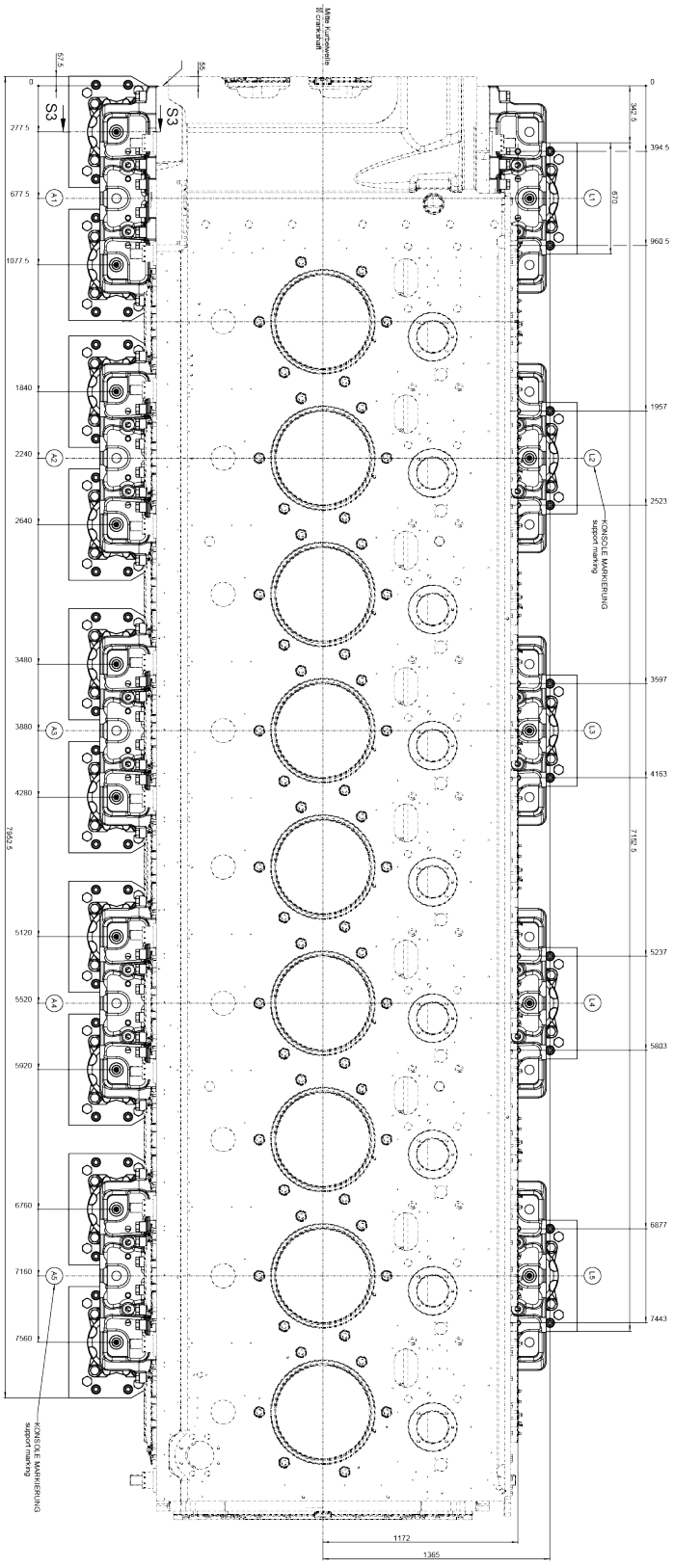
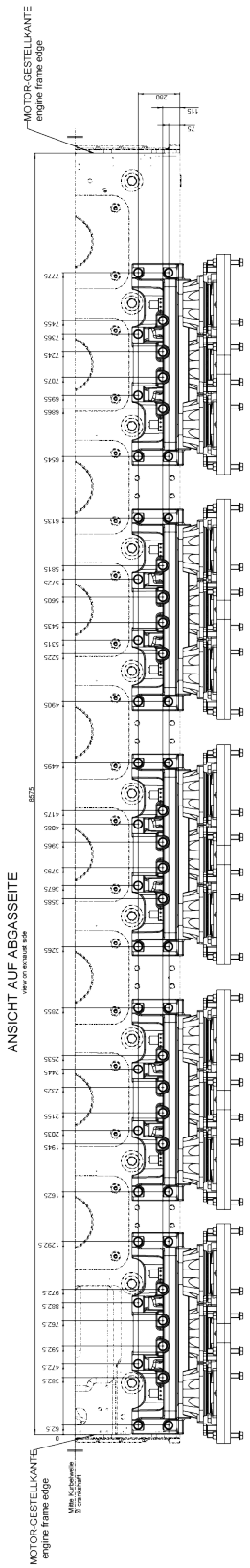


Figure 76: Recommended configuration of foundation – L engine, conical resilient seating, picture 2 of 3 (preliminary, valid installation drawings will be given based on project specific demands)

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Figure 77: Recommended configuration of foundation – L engine, conical resilient seating, picture 3 of 3 (preliminary, valid installation drawings will be given based on project specific demands)

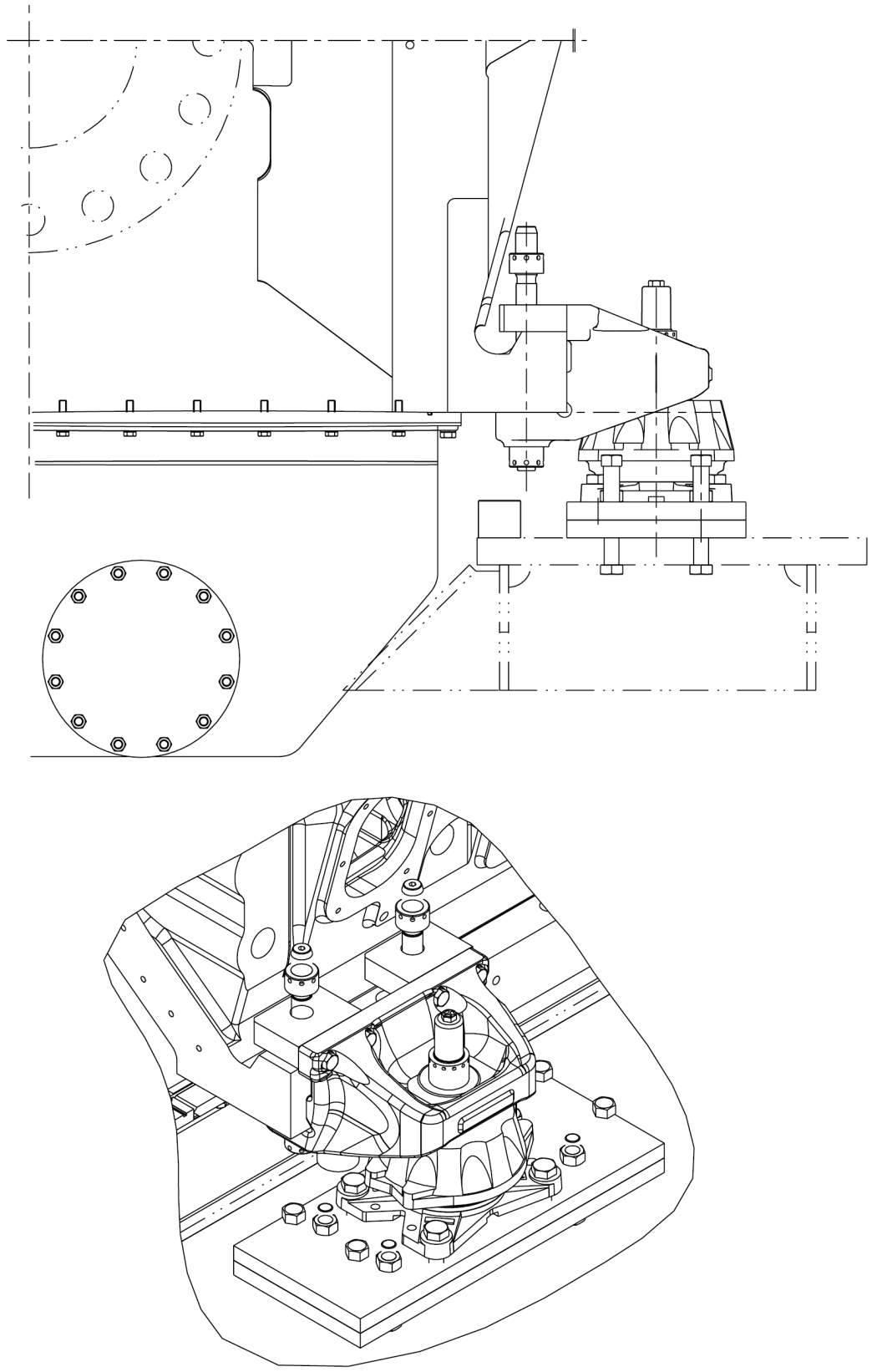


Figure 78: Resilient mounting conical mounts – V engine, picture 1 of 2 (preliminary, valid installation drawings will be given based on project specific demands)

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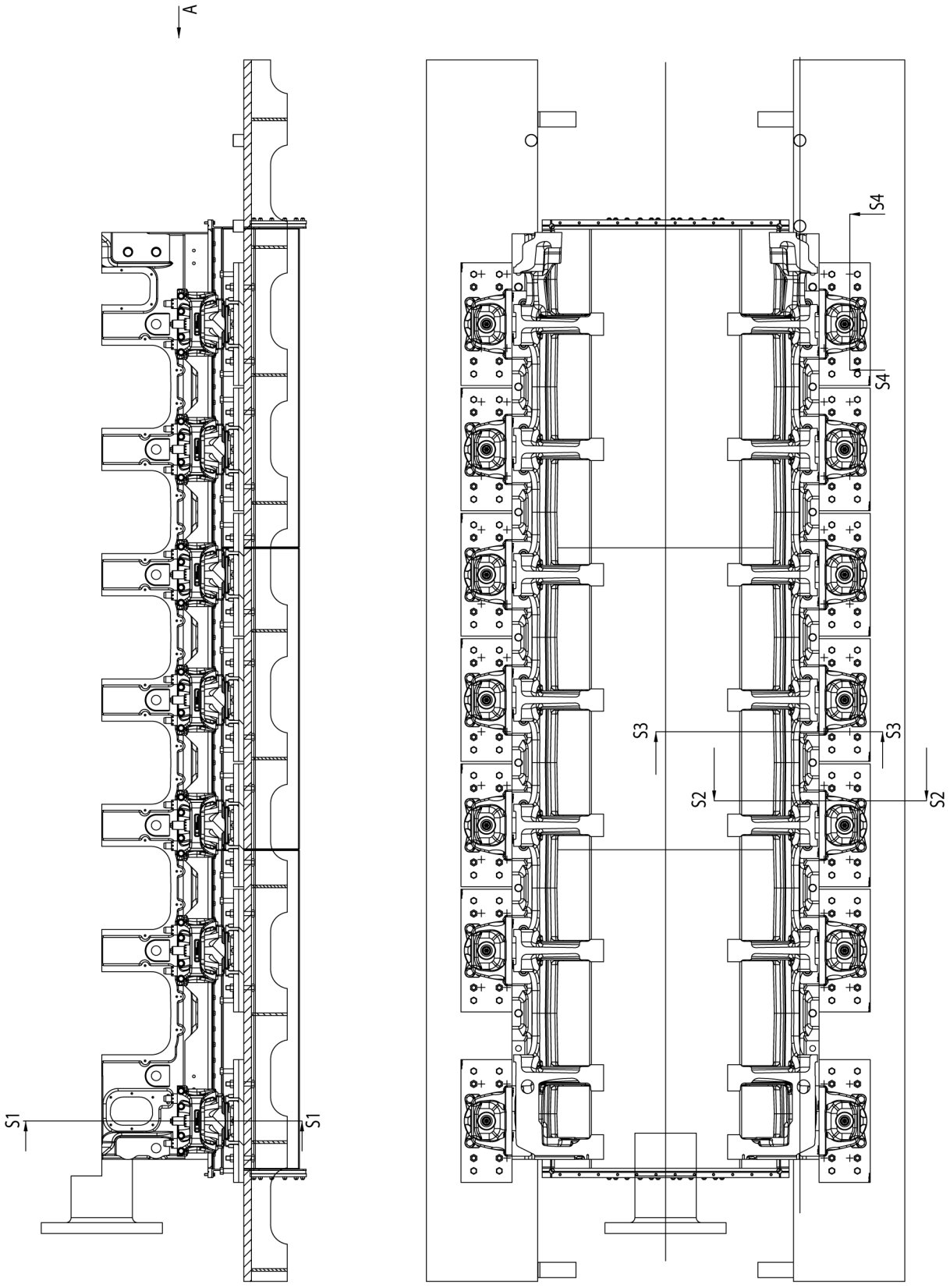


Figure 79: Resilient mounting conical mounts – V engine, picture 2 of 2 (preliminary, valid installation drawings will be given based on project specific demands)

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2.28.6 Engine alignment

The alignment of the engine to the attached power train is crucial for trouble-free operation.

Dependent on the plant installation influencing factors on the alignment might be:

- Thermal expansion of the foundations
- Thermal expansion of the engine, alternator or the gearbox
- Thermal expansion of the rubber elements in the case of resilient mounting
- The settling behaviour of the resilient mounting
- Shaft misalignment under pressure
- Necessary axial pre-tensioning of the flex-coupling

Therefore take care that a special alignment calculation, resulting in alignment tolerance limits will be carried out.

Follow the relevant working instructions of this specific engine type. Alignment tolerance limits must not be exceeded.

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3 Engine automation

3.1 SaCoS 5000 system overview

The engine is equipped with the latest generation of Everllence' engine control- and safety system SaCoS 5000 (Safety and Control System) for four-stroke diesel- and gas engines. The engine control- and safety system is responsible for complete engine operation, control, alarming and safety. All sensors and actuators are wired to the engine-attached units. The whole system design has a modular and flexible topology. The interface to the plant is done by means of an Interface Cabinet. The SaCoS 5000 design is based on highly reliable and approved components as well as modules specially designed for installation on 4-stroke medium speed engines. The used components are harmonised to an homogenous system. The system has already been tested and parameterised in the factory, the final parameterisation takes place at the customer. 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 Control Modules are integrated in the Control Unit, the LOP and in the Interface Cabinet, the Injection Modules are integrated in the Injection Unit, the Cylinder Pressure Module is mounted on engine. The Display Modules are integrated in the LOP, the LOP has an ingress protection of IP55. The Gateway Communication Module is integrated in the Interface Cabinet, the Interface Cabinet has an ingress protection of IP54.

Abbreviation	Name	Function
DML	Display Module L	The 12.1"-touchscreen is used for operation of the engine and the visualisation of all operating values.
GCM	Gateway Communication Module	Provides the communication interface to an external system.
IM	Injection Module	Provides the complete fuel injection control functionality.
CM	Control Module	Offers a variety of different input/output functionalities to achieve basic control functionalities, e.g. as engine control.
CPM	Cylinder Pressure Module	Records the maximum cylinder pressure via the pressure transmitters.

Table 104: SaCoS module types

System bus

The system bus connects all the modules together and forms the basis of the data exchange between the SaCoS 5000 modules. Data communication is guaranteed at all times as the connection is made redundant. In this way, modules can access the redundant measured values from other modules if their own sensor should fail. I/O extensions are connected to modules via a non-redundant bus.

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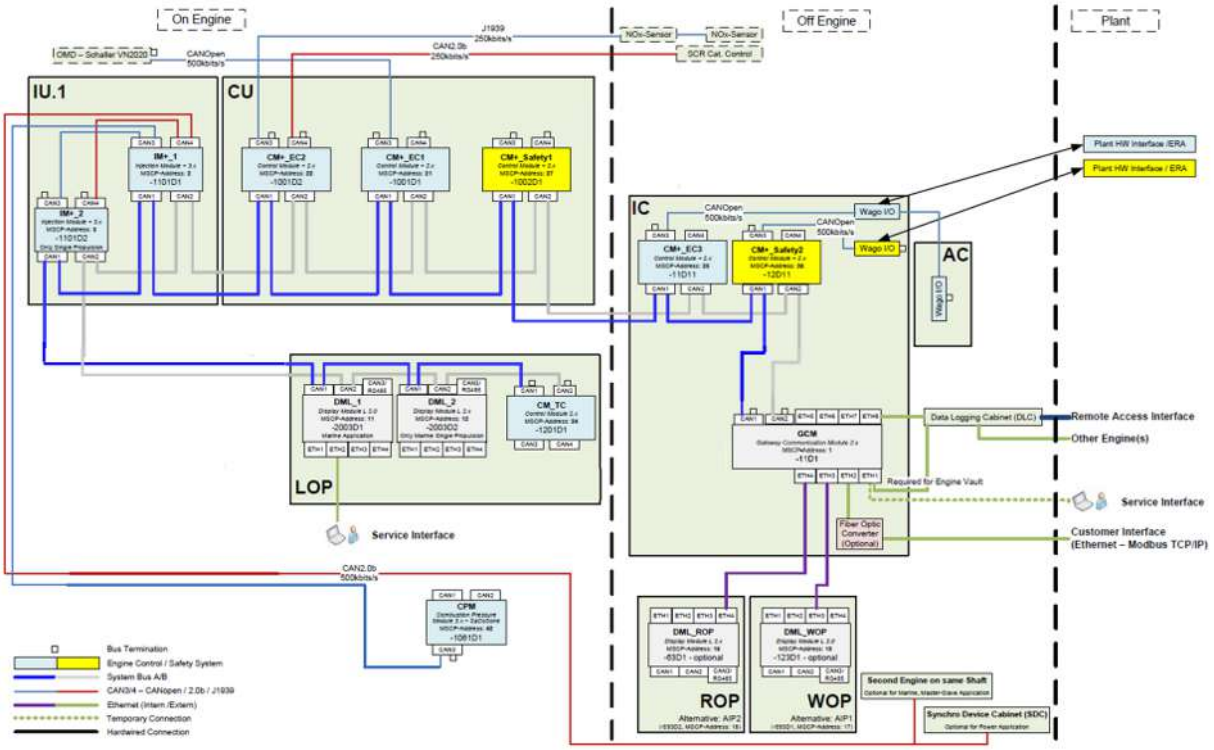


Figure 80: System bus

3.1.1 Cybersecurity guidelines

3.1.1.1 Terms, abbreviations and definitions

Term, abbreviation	Definition
G(C)M	Gateway (Communication) Module
DM	Display module
LOP	Local operating panel
ROP	Remote operating panel (see also WOP, wheel operating panel)
SCR	Selective catalytic reduction
IAS	Integrated alarm system (see also “customer network”)
PMS	Power management system
SDI	SaCoSone device image
EXPERT	Everllence tool for SaCoS parameterisation
Toolbox	(Virtual) device for parameterisation and backup/restore of SaCoS
RDP	Remote desktop protocol
CEON	Everllence service for recording engine data
DLC	Data logging cabinet
ER	Engine room
ECR	Engine control room
SaCoS	Safety and Control System
SL	SCR Single Line system (medium speed)
ML	SCR Multi Line system (high speed / 175D)
ROC	Remote operation centre
WBM	Web-based management
IC	Interface cabinet
eToken	SaCoS 5000 security token SaCoSone security token (Thales Group eToken 5110+)

Table 105: Terms, abbreviations, and definitions

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3.1.1.2 System Overview

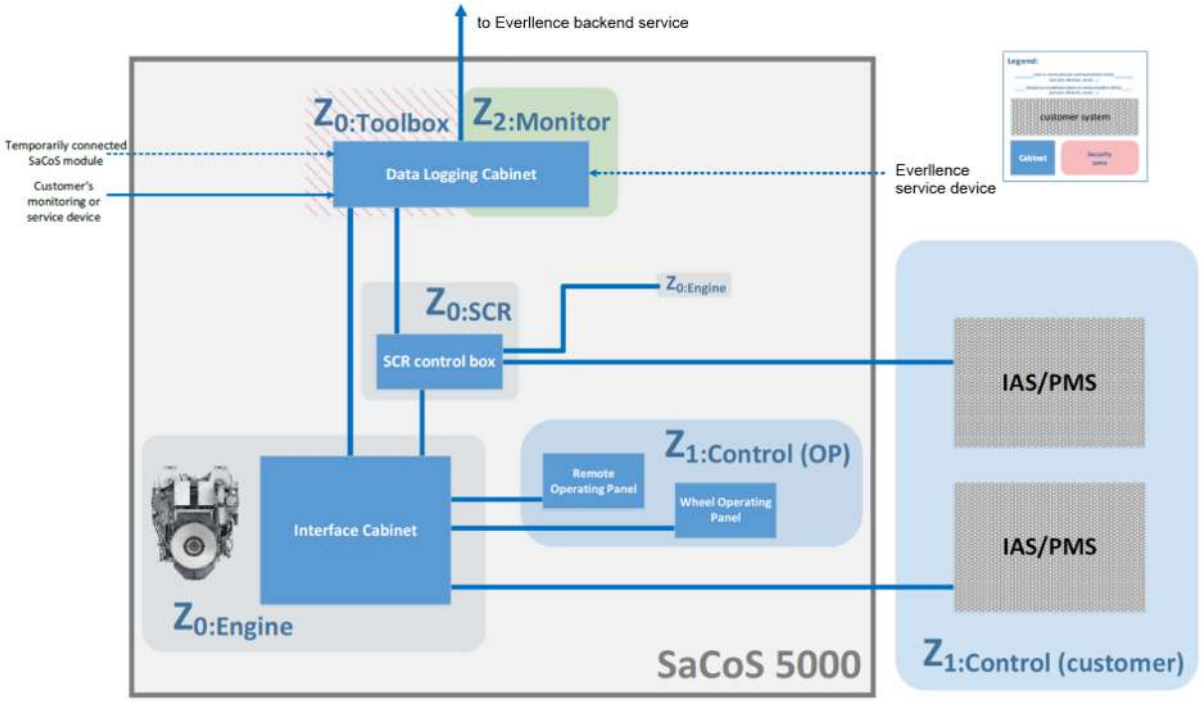


Figure 81: SaCoS 5000 Largebore with SCR and EngineVault: Zones and connections (simplified)

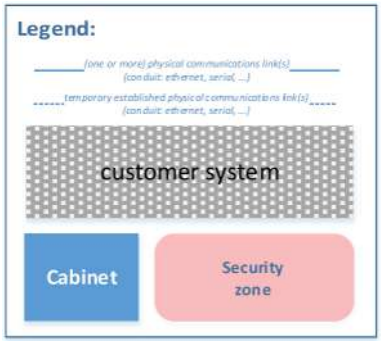


Figure 82: SaCoS 5000 Largebore with SCR and EngineVault: Zones and connections (simplified) – Legend

Fig. *SaCoS 5000 Largebore with SCR and EngineVault: Zones and connections (simplified)*:
Shows a simplified overview of the SaCoS 5000 system (Largebore version with SCR and EngineVault), and some of the relevant zones and connections.

Fig. *SaCoS 5000 Largebore with SCR and EngineVault: Zones and connections (simplified) – Legend*:
Shows the legend for the simplified overview of the SaCoS 5000 system (Largebore version with SCR and EngineVault).

The system is divided into the following main security zones:

- $Z_{0:Engine}$: Devices in this zone implement the main functionality of the engine control system.
- $Z_{0:SCR}$: Devices in this zone implement the SCR functionality and enable local monitoring and control of the SCR system.

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- $Z_{1:Control\ (OP)}$: This zone contains the control panels (including, for example, the ROP and WOP) that enable local monitoring and control of the engine control system.
- $Z_{1:Control\ (customer)}$: This zone contains the ship's integrated alarm and/or power management system(s) (IAS/PMS).
- $Z_{2:Monitor}$ and $Z_{0:Toolbox}$: These zones (not included in all SaCoS variants) include virtualised and physical devices that implement local/remote monitoring and logging of control system data, and enable local/remote system parameterisation, including restoring system backups to SaCoS modules that are temporarily connected to the data logging cabinet (DLC) for this purpose. To obtain limited, secure and interactive access to the Jumphost (also called *Engine Vault PC* in SaCoS) in the DLC and to use the described functionality, the user can connect to the system with their own device via the network connection provided for this purpose in the DLC.

The majority of the devices making up the control system are installed in locked control cabinets or units. These must be set up in restricted locations such as engine rooms (ER) and engine control rooms (ECR).

3.1.1.3 Physical security of SaCoS

Due to their design, some SaCoS devices and communication links must be physically protected against unauthorised access at all times (i.e., including during commissioning). Only authorised and authenticated personnel may have access to these devices and connections. Such access must be logged.

The security of these protections should be assessed by the customer, taking into account the system context, system purpose, system location, assumptions about current and future threats to the customer's business, and applicable regulations.

3.1.1.4 Secure access and storage of SaCoS data

It is necessary to keep the data created by or for SaCoS secure and protected against access by third parties.

3.1.1.5 Secure use of the Engine Vault PC in the DLC

It is the customer’s responsibility to use the Engine Vault PC securely in accordance with the guidelines in the operating instructions.

3.1.1.6 Securing Z1:Control(Customer)

$Z_{1:Control(Customer)}$ must be a trusted network in the sense of IACS UR E27.

A compromised SaCoS can also pose a threat to customer networks and devices, and infect or compromise the customer systems within them. The operator/integrator can implement additional measures such as installing additional network security devices to protect against this threat.

3.1.1.7 Maintaining network segmentation

Network segmentation is one of SaCoS’s key protection measures. Therefore, the network structure set up by Everllence must not be changed.

Specifically, the following guidelines should be adhered to:

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- Individual network segments must not be bridged (e.g. by connecting a device to several segments at the same time, connecting network switches from different segments to each other, or connecting devices from one segment to other segments).
- No additional devices may be connected to the SaCoS network segments.
- The physical switches on the DLC that enable and disable the remote network connection of Everllence service staff to the Engine Vault PC for remote maintenance (designation on the cabinet), as well as the Engine Vault PC's network access to the Gateway and Display Modules (designation on the cabinet) for parameterisation, must normally be in the "disabled" position. Access should only be activated temporarily, only when required, only by authorised staff, and should be switched off again as soon as possible after completion of the work. Remote access (remote) to Engine Vault PC may only be enabled upon explicit and authenticated request from Everllence. Only those physical switches that are necessary for the functionality or activity actually required should be activated.

3.1.1.8 Preparation for security incidents

Residual risks may remain even if the present guidelines are followed. The customer should prepare for possible security incidents in order to be able to react to them quickly. This includes the creation of an *incident response plan*, which should address the following points, among others:

- Obtain spare parts to replace SaCoS modules that have failed or been compromised due to an attack.
- If changes are made to the system (e.g. parameterisation of the system), these changes should be saved accordingly.
- Report the security incident to Everllence via a secure channel and follow the instructions.
- Save all data relevant to the cause (may require assistance from the engine manufacturer’s 1st level support). This includes, but is not limited to, the access logs and general audit logs generated by the customer, customer devices, and the plant.
- Analyse the data and take steps to address the vulnerability that led to the incident.

The customer is also instructed to monitor the system for indications of a possible security incident to the extent possible.

3.1.1.9 Safe disposal

The customer is responsible for the security of potentially sensitive data when disposing of the devices.

3.1.1.10 User account management

The operator and service personnel are responsible for managing the access data for SaCoS devices.

3.1.1.11 Security Incident Report

The security incidents concerning SaCoS should be reported to Everllence PrimeServ.

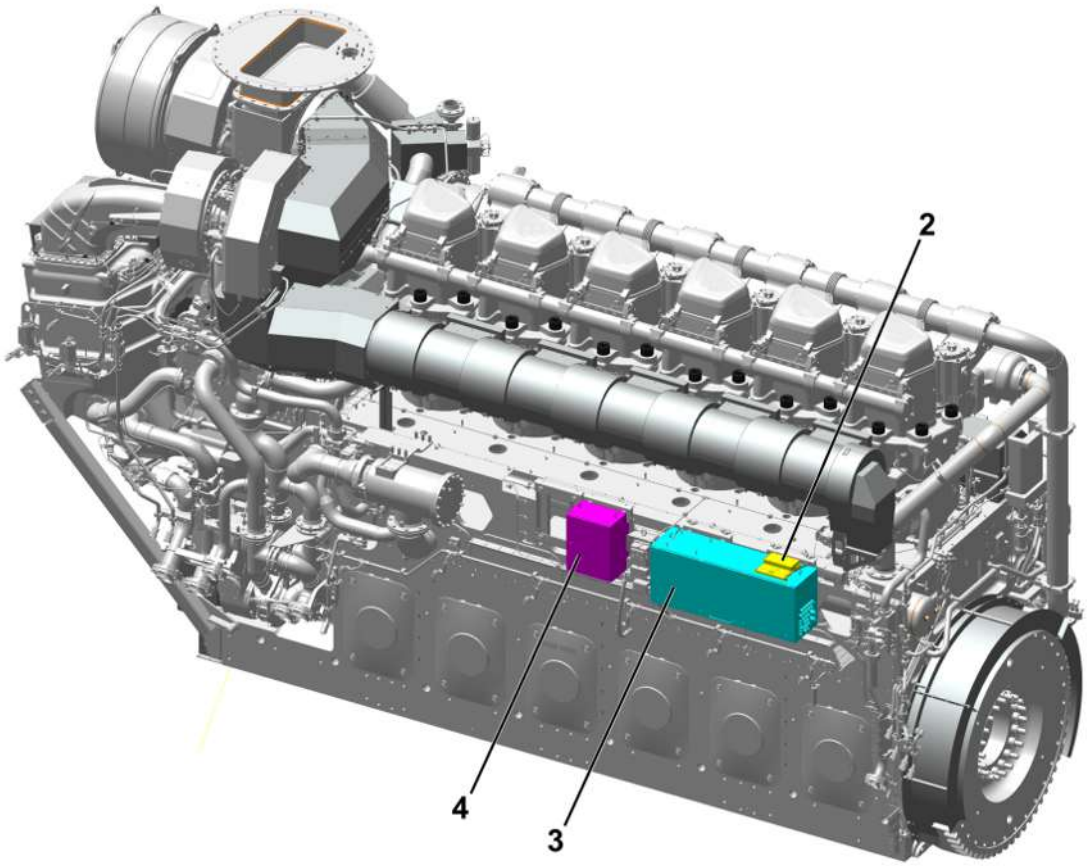
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3.1.2 Equipment on engine

Components mounted on engine (exemplary representation)

Example L engine

Exhaust side

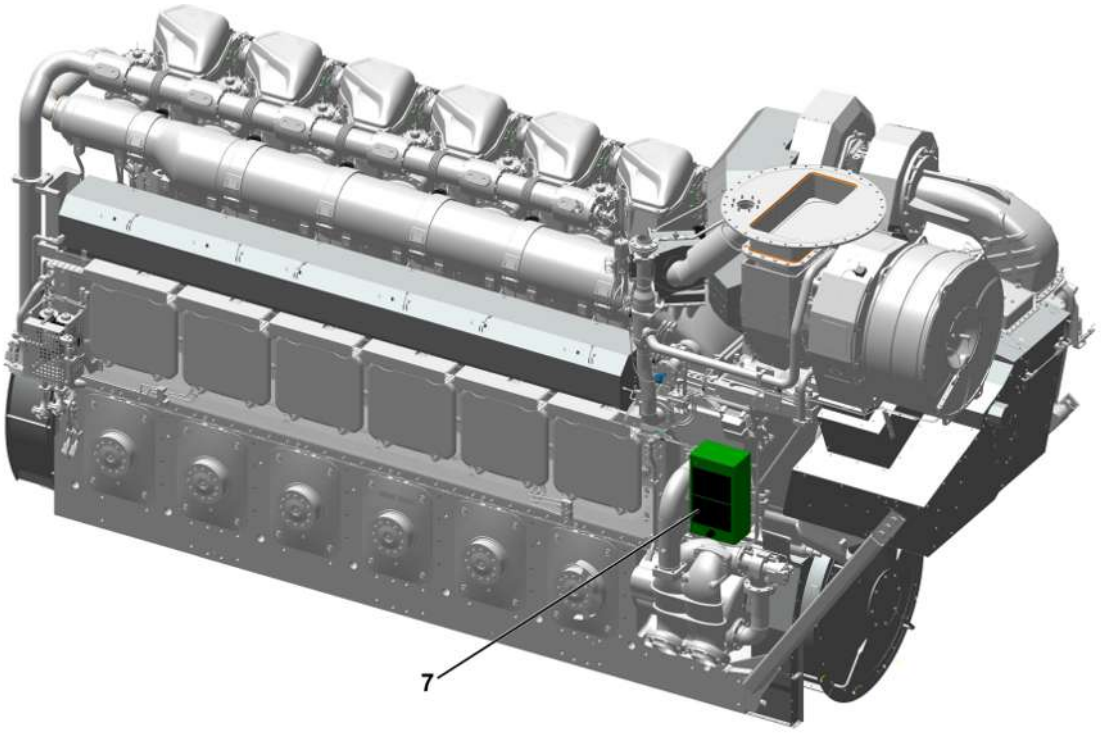


2 Cylinder Pressure Module
3 Control Unit
4 Injection Unit 1

Figure 83: Components mounted on L engine (exhaust side)

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Charge air side



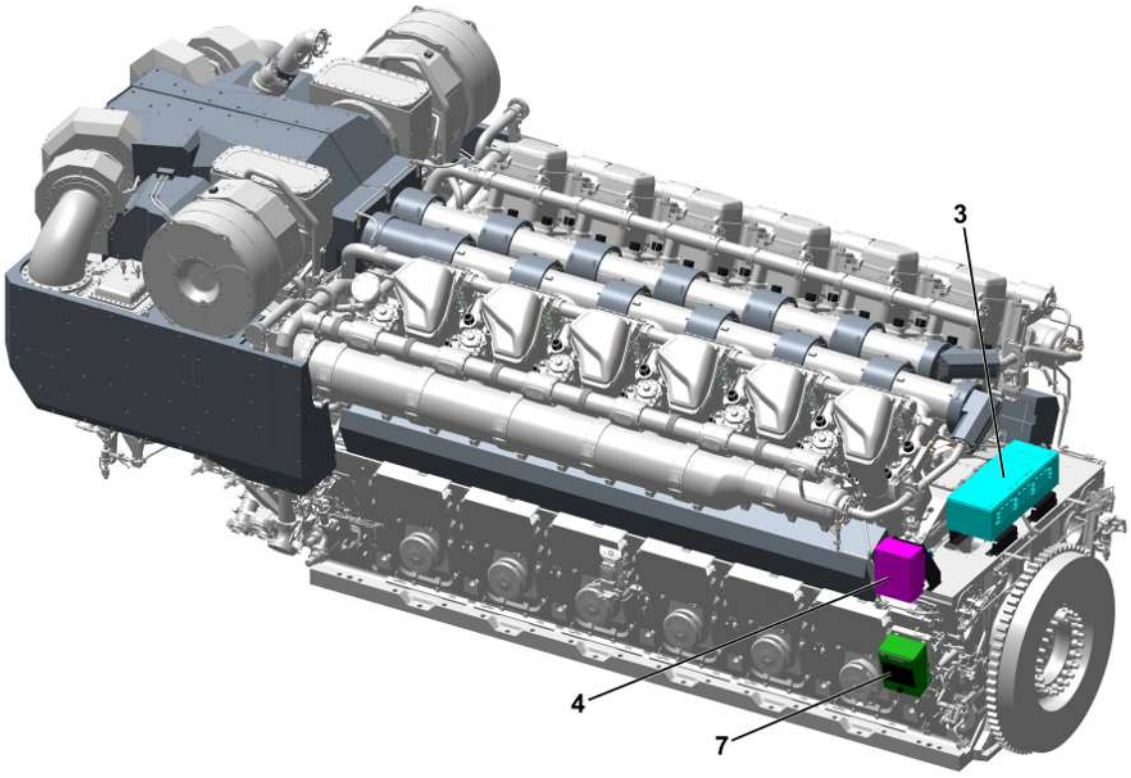
7 Local Operating Panel

Figure 84: Components mounted on L engine (charge air side)

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Example V engine

Bank A

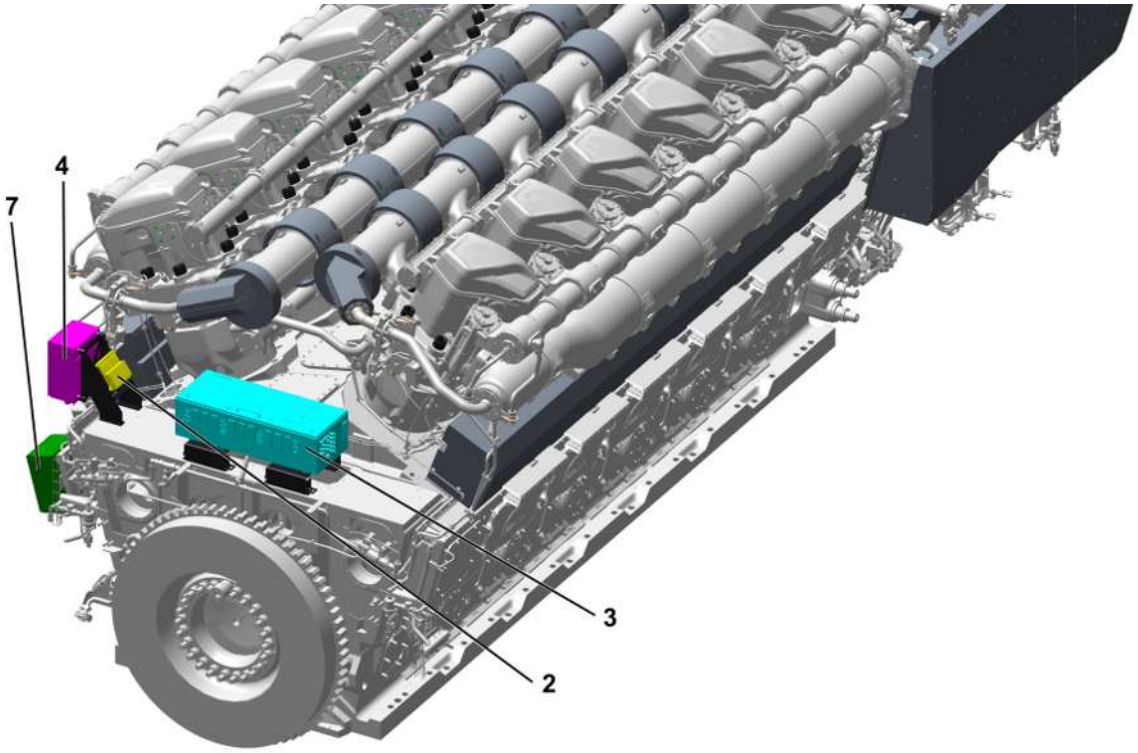


3 Control Unit
4 Injection Unit 1
7 Local Operating Panel

Figure 85: Components mounted on V engine (cylinder bank A)

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Bank B



2 Cylinder Pressure Module
3 Control Unit
4 Injection Unit 1
7 Local Operating Panel

Figure 86: Components mounted on V engine (cylinder bank B)

Control Unit (3)

The Control Unit is mounted on the engine cushioned against any vibration. It includes three identical, highly integrated Control Modules: One for safety functions and the other two for engine control and alarming.

The modules work independently of each other and collect engine measuring data by means of separate sensors.

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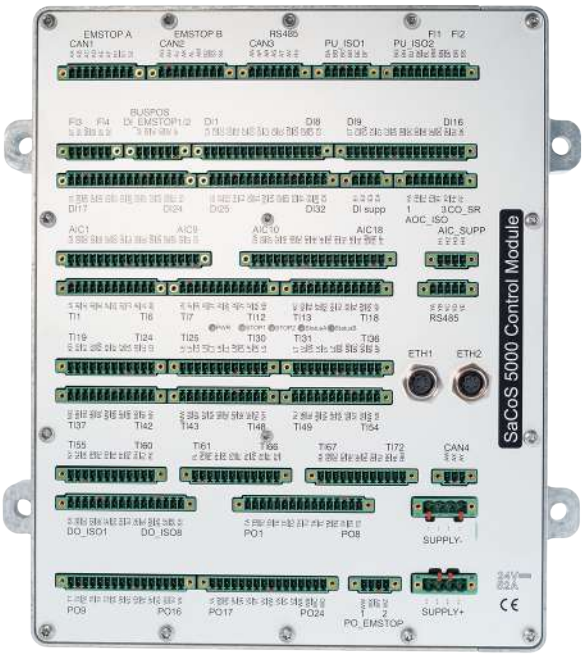


Figure 87: Control Module

Injection Unit (4)

The Injection Unit is mounted on the engine. The Injection Unit includes highly integrated Injection Modules. These Injection Modules are responsible for speed control and the actuation of the gas injection.

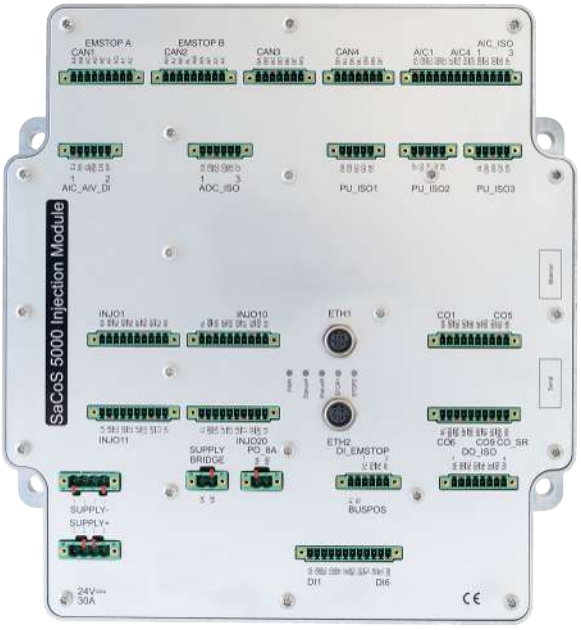


Figure 88: Injection Module

Cylinder Pressure Module (2)

The Cylinder Pressure Module takes over the task of monitoring the pressure of all cylinders for all combustion types via special inside pressure sensors.

It ensures a correct injection control in order to avoid any overload and damage of a specific cylinder.



Figure 89: Cylinder Pressure Module

Local Operating Panel (LOP) (7)

The Local Operating Panel is mounted on the engine and allows to fully control the engine. For the manual emergency stop, the LOP provides an additional emergency stop button. The LOP can be implemented with or without a backup display; the variant depends on the requirements of the ship classification societies.

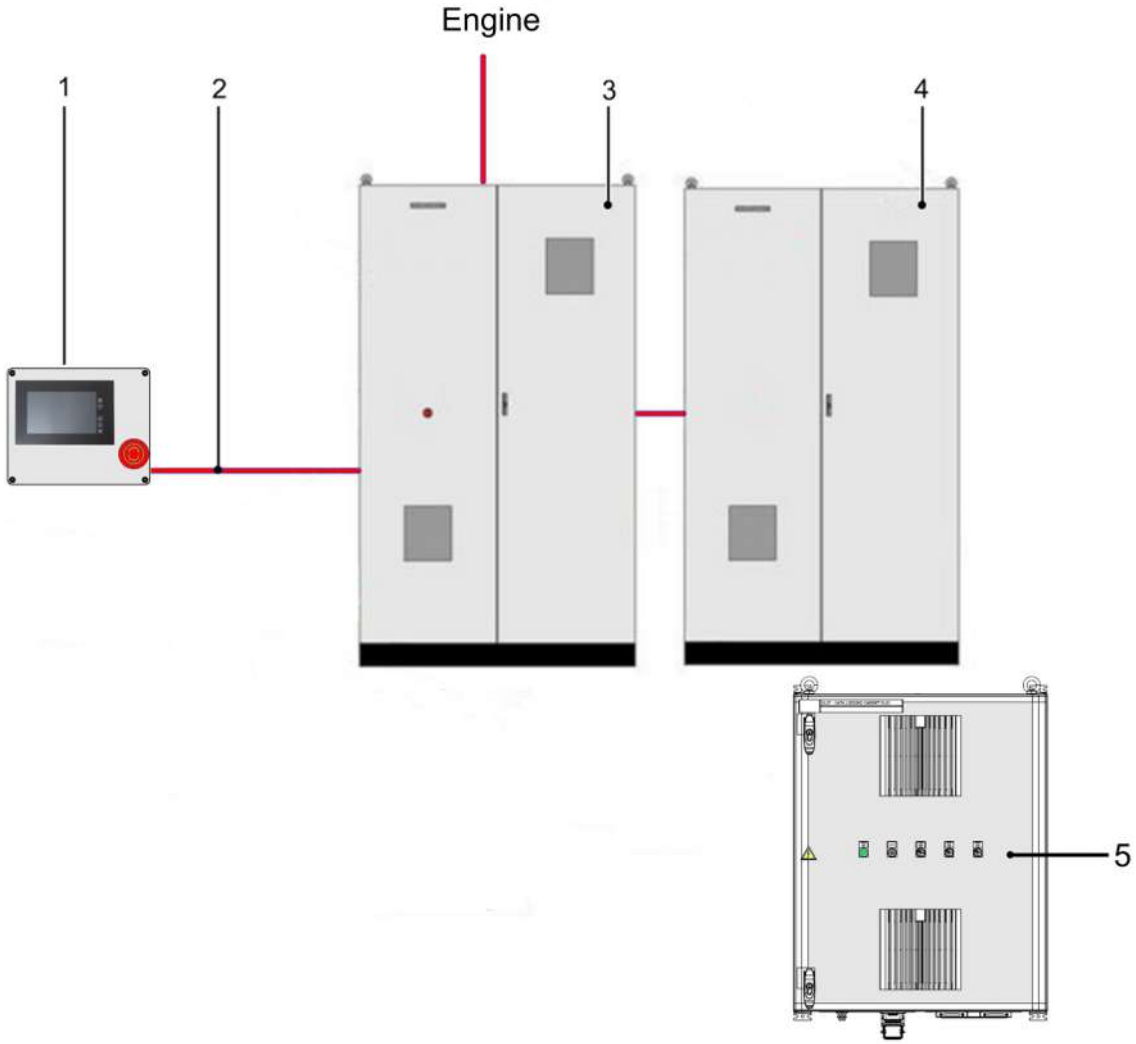
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Figure 90: Local Operating Panel

3.1.3 Equipment off engine

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1 ROP/WOP, optional
2 System bus
3 Interface Cabinet
4 Auxiliary Cabinet
5 Data Logging Cabinet see section Data Logging Solutions
6 Power Supply Cabinet, optional (not shown)

Figure 91: System Overview

In the MeOH retrofit case 49/60 => 49/60DF-M, an FVTC Cabinet is required for monitoring and controlling the FVT.

Auxiliary Cabinet

The Auxiliary Cabinet is a floor-standing cabinet, that optionally will be equipped with an air condition. The Auxiliary Cabinet houses the power units of the loads attached to the engine (such as starters for pumps, etc., depending upon engine type), as well as the infeed of 400 V AC voltage supply for loads on the engine.

The 230 V AC supply voltage for cabinet lighting/cabinet heating/cabinet ventilation and cabinet air conditioning is fed into the Auxiliary Cabinet and has to be provided for each Auxiliary Cabinet separately by the customer

In the Auxiliary Cabinet 24 V DC voltage is distributed to all other control cabinets.

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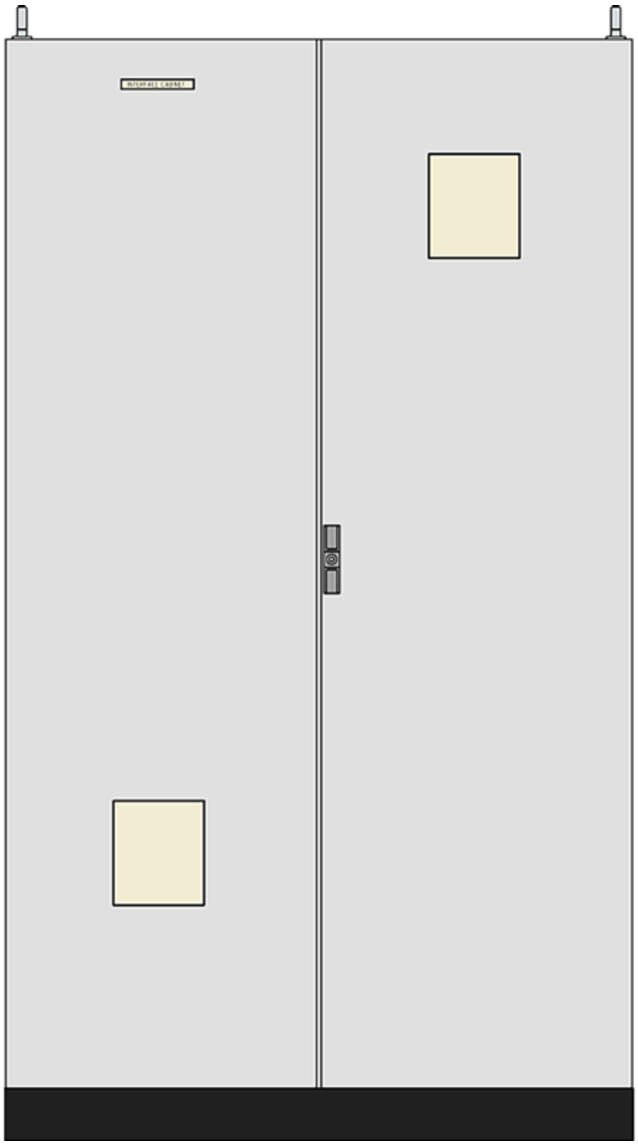


Figure 92: Auxiliary Cabinet

Interface Cabinet

The Interface Cabinet is a floor-standing cabinet, that optionally will be equipped with an air condition. The Interface Cabinet represents the communication interface between SaCoS 5000, the respective master system control and the system's supply systems, such as lubricant or coolant modules. For this purpose, the Interface Cabinet features a Gateway Communication Module with input and output channels as well as various interfaces to the system or vessel automation systems, Remote Operating Panel and Digital Services and two Control Modules.

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Figure 93: Gateway Communication Module

The 230 V AC supply voltage for cabinet lighting/cabinet heating/cabinet ventilation and cabinet air conditioning is fed into the Interface Cabinet and has to be provided for each Interface Cabinet separately by the customer. The 24 V DC power supply is ensured via the Auxiliary Cabinet.

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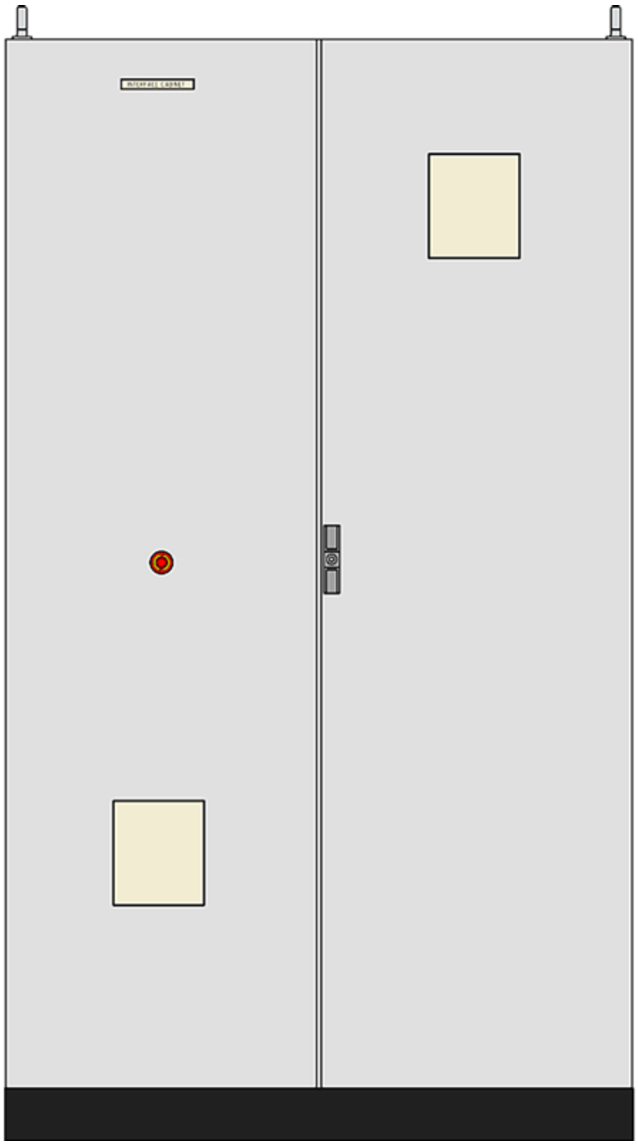


Figure 94: Interface Cabinet

Remote Operating Panel/Wheelhouse Operating Panel (optional)

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

The ROP/WOP is also equipped with an emergency stop button and a buzzer. In addition, the WOP is equipped with an override button.

From this operating device it is possible to transfer the engine operation functions to a superordinated automation system.

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

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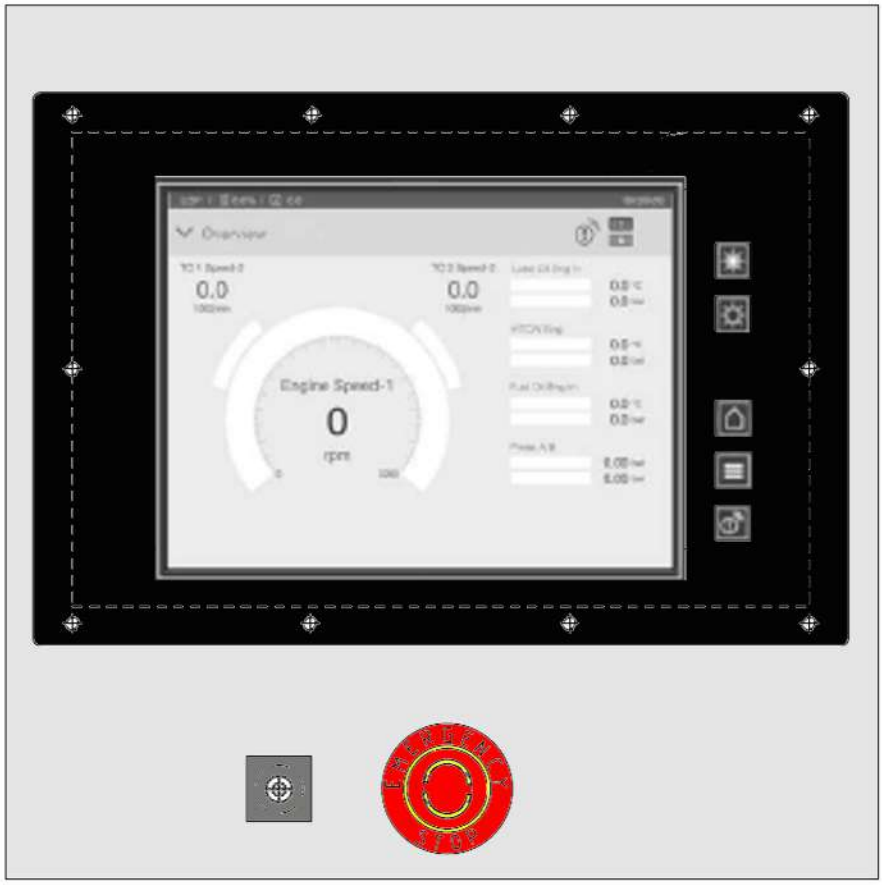


Figure 95: Remote Operating Panel

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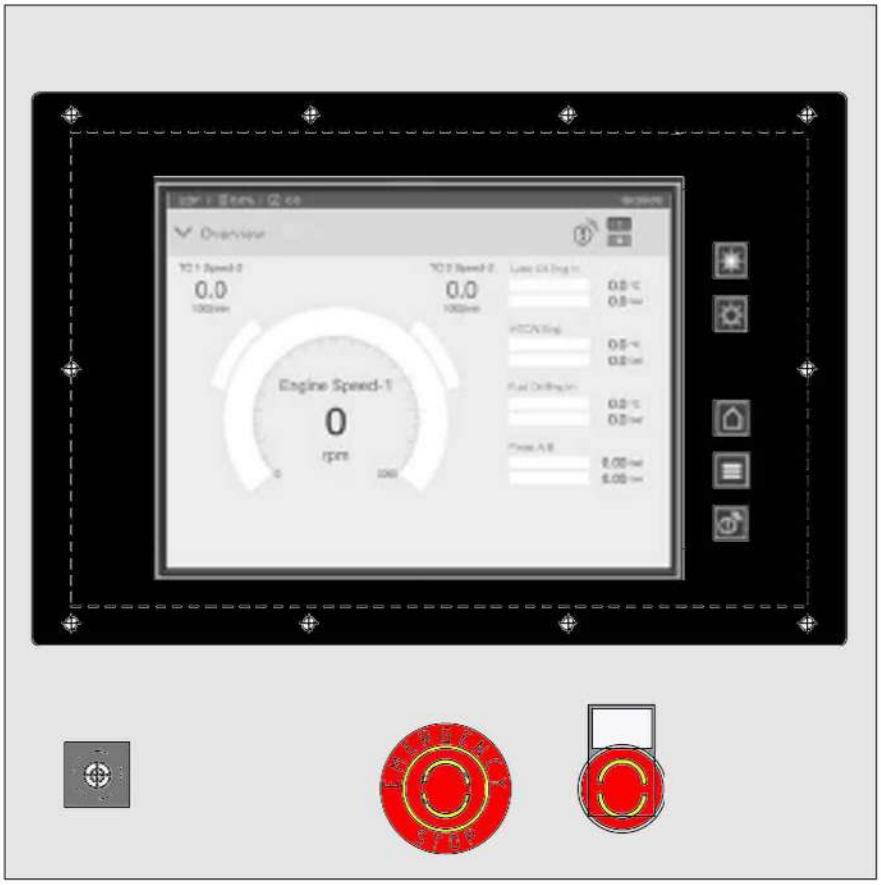


Figure 96: Wheelhouse Operating Panel

Power Supply Cabinet (optional)

For the 24 V DC power supply Everllence offers a Power Supply Cabinet with uninterrupted power supply or without uninterrupted power supply.

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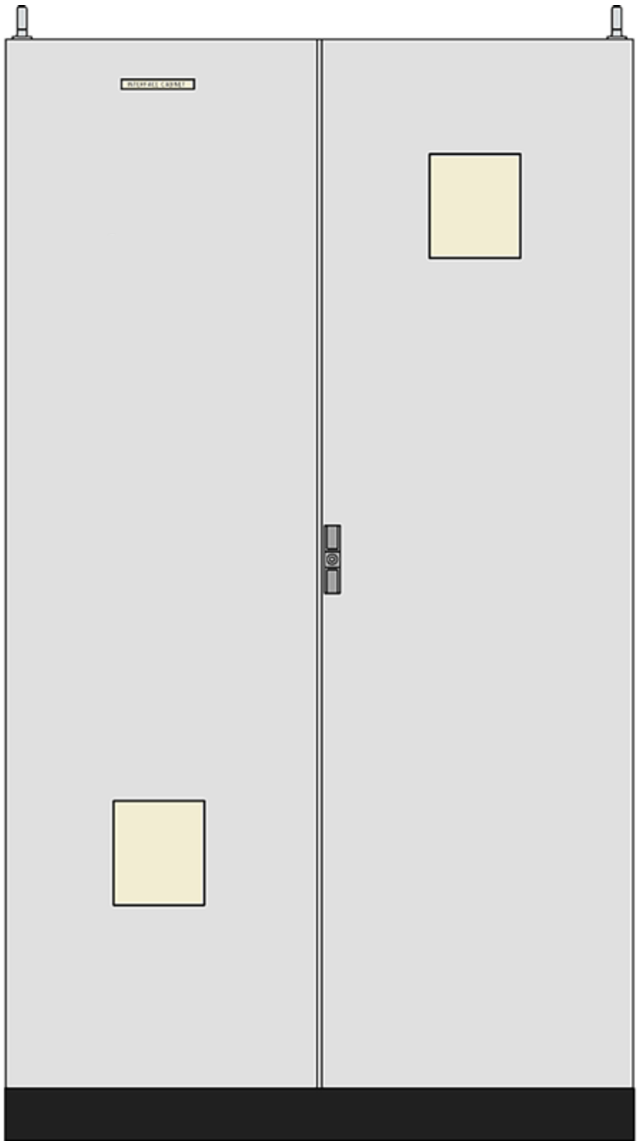


Figure 97: Power Supply Cabinet

3.2 Power supply and distribution

The plant has to provide electric power for SaCoS 5000. An uninterrupted 24 V DC power supply is required for SaCoS 5000.

For marine main engines, a redundant power supply is required which must be provided by two individual supply networks:

- At least one of the power supplies must be uninterruptable (UPS).
- Both feeds must be decoupled from each other (e.g. with power diodes or MOSFETs) in the positive line so that they cannot interfere with each other.
- The minus conductors must be connected to each other to prevent voltage doubling in the event of a double earth fault (see DIN EN 50156-1).

If the Power Supply Cabinet from Everllence is used, the Power Supply Cabinet will handle this requirements.

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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.

For the power supply Everllence offers a Power Supply Cabinet with uninterrupted power supply or without uninterrupted power supply.

If the Power Supply Cabinet is not used, the customer's infeed must take over the tasks of the Power Supply Cabinet. The following must also be noted:

- The back-up fuses specified in the circuit diagram must be provided for the SaCoS 5000 components (nominal current and tripping characteristics must be observed).
- The short-circuit breaking capacity of the back-up fuses must be sufficiently large.

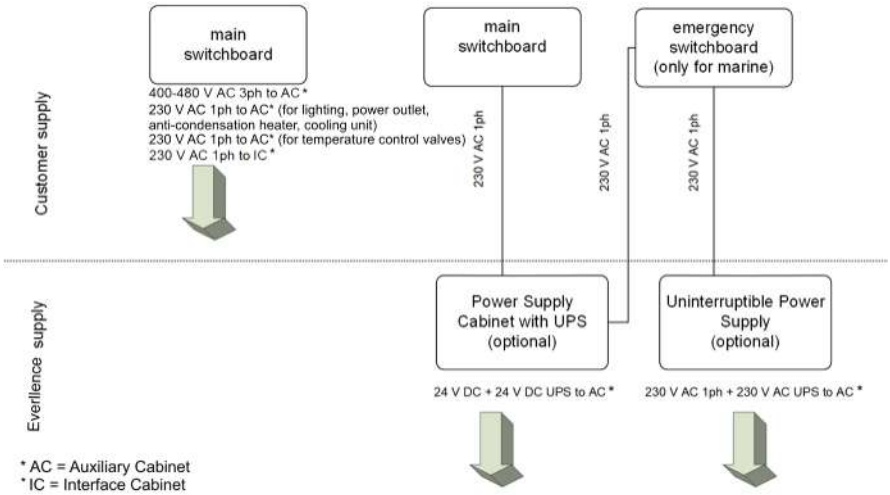


Figure 98: Supply diagram with Power Supply Cabinet and UPS

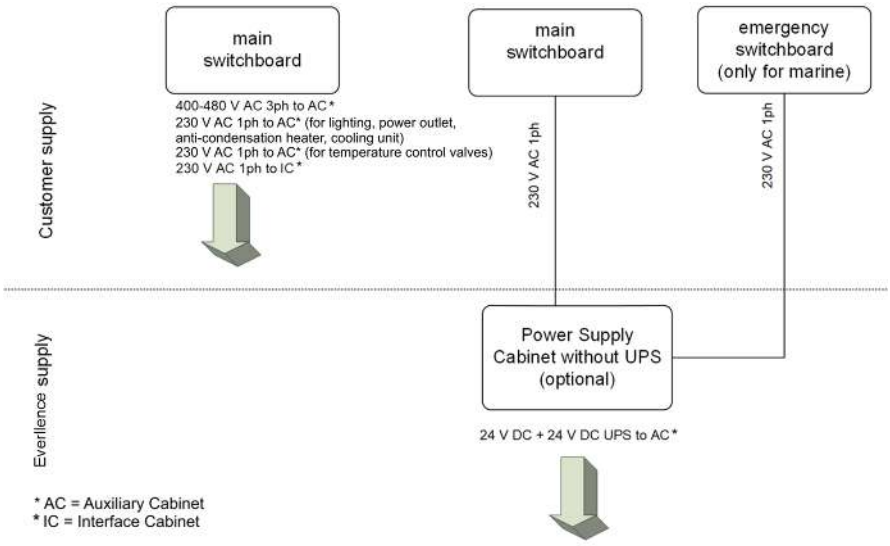


Figure 99: Supply diagram with Power Supply Cabinet

Required power supplies

Consumer	Voltage	Notes
Interface Cabinet	230 V 50/60 Hz	Light/socket, cooling device, heater
Auxiliary Cabinet	24 V DC	All SaCoS components in the Auxiliary Cabinet and on the engine (for marine additional UPS buffered)
	230 V 50/60 Hz	Light/socket, cooling device, heater
	400–480 V 50/60 Hz	Power supply for consumers on engine (e.g. cylinder lubricator)
Data Logging Cabinet	230 V 50/60 Hz	All SaCoS components in the Data Logging Cabinet

Table 106: Required power supplies

Galvanic isolation

A fault in an IT mains (see IEC 60364-1) affects the entire galvanic island formed by the IT network. If different engines are fed from galvanically connected power supplies, then a fault in one of the engines can also affect all other engines. It is therefore the subject of the system risk assessment to determine whether engines may be galvanically connected to each other. It is strongly recommended not to supply multiple engines from galvanically connected power supplies in order to limit the impact of errors and facilitate troubleshooting. For the same reason, the power supplies of the engines must be galvanically isolated from the power supplies for other parts of the system.

3.3 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 SaCoS 5000 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.

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

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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.

Speed setting

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.

3.4 Functionality

Safety functions

The safety system monitors all operating data of the engine and initiates safety actions, e.g. load reduction request or engine shutdown, in case any limit values are exceeded.

Safety stop category	Properties	To external	
		Man Em Stop	
Manual Emergency Stop *ManEmStop*	• Source: Manually • Safety Chain: Hard- and Soft-wired • Processing: Redundant • Override-able: No • EmStop Actuators: all	SaCoS Safety Stop*	Overall Safety Stop*
Internal Automatic Emergency Stop *IntAutoEmStop*	• Source: Automatically • Safety Chain: Hardwired • Processing: Redundant • Override-able: No • EmStop Actuators: all		
Internal Automatic Shutdown *IntAutoSD*	• Source: Automatically • Safety Chain: Cloud-based • Processing: Single or redundant • Override-able: Yes • EmStop Actuators: Individually		
External Emergency Stop *ExtEmStop*	• Source: Unknown • Safety Chain: Hard- and Soft-wired • Override-able: No • Processing: Redundant • EmStop Actuators: all		
External Automatic Shutdown *ExtAutoSD*	• Source: Unknown • Safety Chain: Cloud-based • Override-able: Yes • Processing: Redundant • EmStop Actuators: Individually		

Figure 100: Safety Functions

Note:
The automatic emergency stop and automatic shutdown may have impact on the function of the plant. These effects can differ widely depending on the overall design of plant and must already be considered in an early phase of the project planning.

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.

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Load reduction

The safety system supervises requests a load reduction to 60%.The load reduction has to be carried out by an external system (PMS, PCS, etc.). For safety reasons, SaCoS 5000 will not reduce the load by itself. The load reduction can be also be requested via an external system.

Override

With the Override switch on the bridge or in the engine control room, the safety system function can be restricted to the issuing of alarms and messages. With the Override active, the engine is not automatically shutdown by the safety system and neither a load reduction will occur.

Exceptions are:

- External emergency stop
- Internal automatic emergency stop
- Manual emergency stop

Further exceptions depend on the specifications of the respective classification society.

Alarm functions

The alarm functions supervise all necessary limit values and generate alarms to indicate discrepancies. The alarm functions are processed in an area completely independent of the safety system area in all redundant modules.

Self-monitoring

SaCoS 5000 carries out independent self-monitoring functions. Thus, for example the connected sensors are checked constantly for function and wire break. SaCoS 5000 reports all occurred malfunctions via alarm messages.

Speed control

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

Load limit curves

SaCoS 5000 features the following load limit curves:

- Start fuel limiter
- Maximum fuel limiter
- Charge air pressure dependent fuel limiter
- Torque limiter
- Rail pressure limiter
- Jump-rate limiter

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 independently from each other in the alarm system and safety system. In case engine overspeed is detected each system actuates the shutdown device via a separate hardware channel.

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Control

SaCoS 5000 controls all engine-internal functions as well as external components in the plant.

Start/stop sequence

SaCoS 5000 controls all steps of the start/stop sequence:

- Slow turn
- Start air/stop air pressure monitoring
- Requests of lube oil and cooling water pumps
- Monitoring of the prelubrication and post-cooling period
- Monitoring of the acceleration period

Control station switch-over

SaCoS 5000 controls the switch-over between the different operating panels and the switch-over to an external control system.

External functions

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

- Electrical lube oil pump
- Electrical driven HT cooling water pump
- Electrical driven LT cooling water pump
- Nozzle cooling water module
- HT preheating unit
- Clutches

Media temperature control

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

The temperature controllers are available as software functions. The temperature controllers are operated by the displays at the operating panels as far as it is necessary. From the Auxiliary 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 systems, Page 318).
- 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 systems, Page 318).
- The charge air temperature control is designed identically 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 systems, Page 318).

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- 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 298.

3.5 Interfaces

Data bus interface (machinery alarm system)

This interface serves for data exchange to the ship alarm system. The interface is actuated with MODBUS protocol and is available as:

- Ethernet interface (MODBUS over TCP (Transmission Control Protocol))

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

Alternator control

Hardwired interface, used for example for synchronisation, load indication, etc.

Power Management System

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

Propulsion Optimization Interface

Standardised hardwired interface including all signals for control and safety actions between SaCoS 5000 and the propulsion control system.

This includes the following signals:

- Overload
- Operation close to the limit curve
- Propeller pitch reduction
- Engine speed
- Engine torque
- Distance to active limiter
- Derating factor (for DF engines)

This signals allow an optimized data exchange between engine and a smooth and look ahead control of the CCP propulsion system.

Clarify details at early stage of project.

Others

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

- Nozzle cooling water module
- HT preheating unit
- Electric driven pump for lube oil
- Clutches
- Gearbox

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Alternator electric power (active power) signal

To keep, despite natural long-term deterioration effects, engine operation within its optimum range Everllence' engine safety and control system SaCoS 5000 must be provided with an alternator electric power (active power) signal. Interface and signal shall comply with the following requirements:

1. The electric power of the generator (active power) shall be measured with the following components:
   - Current transformer with accuracy class: cl. 0.2 s
   - Voltage transformer with accuracy class: cl. 0.2
   - Measuring transducer with accuracy class: cl. 1
2. Measuring transducer shall provide the current active power as 4 – 20 mA signal and shall provide 0 – 90 % of measured value with response time ≤ 300 ms (EN 60688). The maximum response time of the 4 – 20 mA signal shall not exceed 350 ms.
3. The 4 – 20 mA generator power signal shall be hard-wired with shielded cable. The analogue value of 4 mA shall be approximately equivalent to 0 % nominal generator power, the value of 20 mA shall be approximately equivalent to 110 % nominal generator power. A proper scaling shall be determined during project execution.

Furthermore the signal for “Generator CB is closed” from Power Management System to SaCoS 5000 Interface Cabinet shall be provide.

3.6 Data Logging

Details on data logging, such as:

- Description of what data is logged
- Description of access rights
- Analysis of data
- Description of which tools are required

etc., see document "Data Logging Cabinet SaCoS Engine Vault PC – Operating Instructions”.

3.7 Data Logging

Details on data logging, such as:

- Description of what data is logged
- Description of access rights
- Analysis of data
- Description of which tools are required

etc., see document "Data Logging Cabinet SaCoS Engine Vault PC – Operating Instructions”.

3.8 Technical data

Cabinet

Design

- Floor-standing cabinets with plinth and fan/air condition
- Cable entries: From below, through cabinet base

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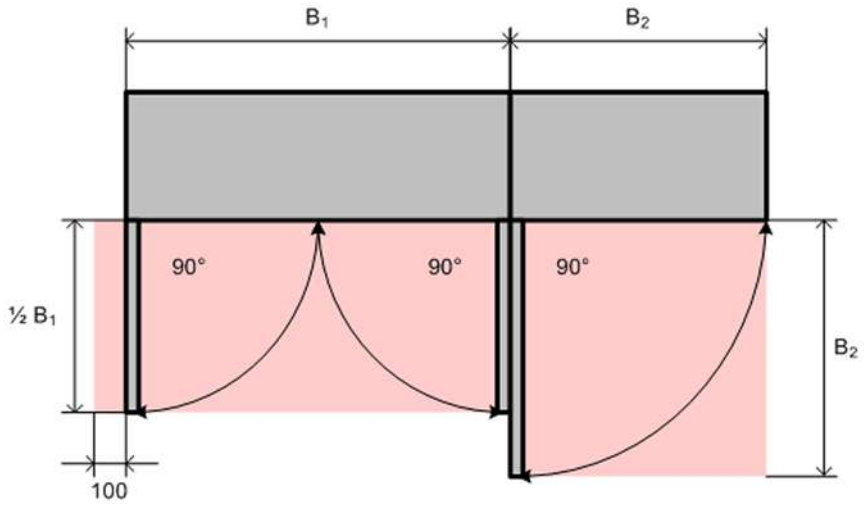
- Accessible by front door(s), doors with locks
- Opening angle: 90°
- Standard colour: Light grey (RAL7035)
- Ingress protection: IP54

Dimensions and weights of cabinets

Cabinet	Dimensions (mm) including base			Approx. weight (kg)
	Width	Height	Depth	
Interface Cabinet, equipped with fan	1,200	2,100	400	300
Interface Cabinet, equipped with air condition	1,550	2,100	400	360
Auxiliary Cabinet, equipped with fan	1,200	2,100	400	300
Auxiliary Cabinet, equipped with air condition	1,550	2,100	400	360
Power Supply Cabinet, equipped with fan	1,200	2,100	400	300
Power Supply Cabinet, equipped with air condition	1,550	2,100	400	360
* Fuel Valve Train Cabinet	600	1,000	250	40
Data Logging Cabinet	800	1,000	400	60
Remote Operating Panel	400	400	-	5
Wheelhouse Operating Panel	400	400	-	5
* In the MeOH retrofit case 49/60LO => 49/60DF-M, an FVTC Cabinet is required for monitoring and controlling the FVT. The space requirement for the other cabinets does not change in the MeOH retrofit case.				

Table 107: Dimensions and weights of cabinets

Door opening area of cabinets



B_1 Width of cabinet 1 B_2 Width of cabinet 2

Figure 101: Exemplary arrangement of control cabinets with door opening areas (top view)

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Environmental conditions

Components on engine and wall-mounted cabinets

- Ambient air temperature: +5 °C to +55 °C (Exception: an ambient air temperature of +5 °C to +45 °C applies to the Data Logging Cabinet, SCR Cabinet, Gas Valve Unit Cabinet and Fuel Valve Train Cabinet)
- 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

3.9 Installation requirements

Location

- The cabinets are designed for installation in engine rooms or engine control rooms.
- The cabinets must be installed at a location suitable for service inspection.
- Do not install the cabinets close to heat-generating devices.

Wall-mounted cabinets and floor-standing cabinets

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

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

Floor-standing cabinets

In case of installation at walls, the distance between the floor-standing cabinets and the wall has to be at least 100 mm 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. Also they have to be secured against tipping over (for example, by attaching the roof to the wall) with suitable mounting support, proven to withstand at minimum the maximum allowed inclination, see accordingly section Engine inclination, Page 33.

Note:
If the restrictions for ambient temperature cannot 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 221.

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.

Cabling

- The interconnection cables between the engine and cabinets have to be installed according to the rules of electromagnetic compatibility (for example, IEC 60446). Control cables and power cables have to be routed in separate cable ducts.

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- The cables for the connection of sensors and actuators which are **not mounted on the engine** are not included in the scope of supply of Everllence. Shielded cables have to be used for the cabling of sensors. For electrical noise protection, an electric ground connection must be made from the cabinets to the ship´s hull.
- All cabling between the cabinets and the controlled device is scope of customer supply.
- The cabinets are equipped with spring loaded terminal clamps. All wiring to external systems should be carried out without conductor sleeves.
- The redundant CAN cables are Everllence scope of supply.

Maximum cable lengths

Connection	Max. cable length
Cables between engine and Interface Cabinet	≤ 45 m
MODBUS cable between Interface Cabinet and superordinate automation system (only for Ethernet)	≤ 100 m
Cable between Interface Cabinet and Remote Operating Panel	≤ 100 m

Installation works

- During the installation period, the customer has to protect the cabinets against water, dust, and fire. It is not permissible to do any welding near the cabinets. The cabinets to be fixed to the floor by screws.
- If it is inevitable to do welding near the cabinets, the cabinets and panels have to be protected against heat, electric current, and electromagnetic influences. To guarantee protection against current, the cabling must be disconnected from the affected components.
- The installation of other components inside the cabinets is only permissible after approval by the responsible project manager of Everllence.

Sensors

The sensor 1TE3165 “HTCW Temp After Mixing Point” (double PT1000) measures the HT-CW temperature after the mixing point.

The sensor 1TE4165 “LTCW Temp After Control Valve” (double PT000) measures the LT-CW temperature after the control valve.

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.

Installation of sensor 1TE6000 „Ambient Air Temp”

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:

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Figure 102: Possible locations for installing the sensor 1TE6000

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.

Note:
The sensor 1TE6100 “Intake Air Temp” is not suitable for this purpose.

3.10 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	speed pickup HP-TC speed	indication, supervision	-	turbocharger	safety system	-
2	1SE1005	speed pickup engine speed	camshaft speed and position input for CR	0–700 rpm/ 0–1,400 Hz	camshaft drive wheel	engine control system	-
3	2SE1005	speed pickup engine speed	camshaft speed and position input for CR	0–700 rpm/ 0–1,400 Hz	camshaft drive wheel	safety system	-
4	1SE1006A/B	speed pickup LP-TC speed	TC speed monitoring	-	turbocharger	safety system	-
Start and stop of engine							

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No.	Measuring point	Description	Function	Measuring Range	Location	Connected to	Depending on option
5	1SSV1011	solenoid valve engine start	actuated during engine start and slow turn	-	engine	engine control system	-
6	1HZ1012	push button manual emergency stop from LOP	emergency stop from local control station	-	local operating panel	safety system	-
7	2HZ1012	push button manual emergency stop from ROP	emergency stop from remote control station	-	remote operating panel	safety system	-
8	3HZ1012	push button manual emergency stop from WOP	emergency stop from wheelhouse control station	-	wheelhouse operating panel	safety system	-
9	4HZ1012	push button manual emergency stop from IC	emergency stop from interface cabinet	-	interface cabinet	safety system	-
10	2HOS1013	push button override from Wheelhouse	override button for related safety actions	-	wheelhouse operating panel	safety system	-
11	4HOS1013	push button override crankcase monitoring from Wheelhouse	separate override button for crankcase related safety actions	-	wheelhouse operating panel	safety system	-
12	1XSV1015	solenoid valve enable rail flushing	3/2-way valve to switch between emergency stop and rail flushing	-	engine	engine control system	-
13	1SSV1017	solenoid valve engine start lock valve	3/2-way valve M371/1, blocking of manual emergency start	-	engine	engine control system	-

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No.	Measuring point	Description	Function	Measuring Range	Location	Connected to	Depending on option
Engine torque							
14	1WT1023	torque transmitter engine torque	-	4 ... 20mA	engine	injection system	optional, depended of plant configuration-
Variable Valve Timing							
15	1PT1024	pressure transmitter VVT part load hydraulic pressure	feedback VVT part load position reached	-	engine	engine control system	VVT
16	2PT1024	pressure transmitter VVT full load hydraulic pressure	feedback VVT full load position reached	-	engine	engine control system	VVT
17	1PSV1024	solenoid valve VVT full load	switch between part load and full/intermediate load position	-	engine	engine control system	VVT
18	2PT1025	pressure transmitter VVT full load hydraulic pressure-2	feedback VVT full load position reached	-	engine	engine control system	VVT
19	1PT1026	pressure transmitter VVT intermediate load hydraulic pressure	feedback VVT intermediate load position reached	-	engine	engine control system	VVT
20	1PSV1026	solenoid valve VVT intermediate load	switch between intermediate load and full load position	-	engine	engine control system	VVT
Charge air bypass							
21	1XCV1030A/B	control valve engine bypass row A/B	blow by while part load or low speed	-	engine	engine control system	charge air bypass

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No.	Measuring point	Description	Function	Measuring Range	Location	Connected to	Depending on option
22	1ET1030A/B	analogue output signal engine bypass row A/B position setpoint	desired value output to bypass flap A/B	-	TC on/off engine	engine control system	-
23	1GT1030A/B	analogue input signal charge air bypass row A/B position feedback	actual value input from bypass flap A/B	4 ... 20mA	TC on/off engine	engine control system	-
Charge air blow-off							
24	1XCV1031A/B	control valve charge air blow-off flap row A/B	charge air blow-off at low suction air temperature	-	engine	engine control system	charge air blow-off
25	1ET1031A/B	analogue output signal charge air blow-off flap row A/B position setpoint	desired value output to blow-off flap A/B	-	TC on/off engine	alarm system	-
26	1GT1031A/B	analogue input signal charge air blow-off flap row A/B position feedback	actual value input from blow-off flap A/B	4 ... 20mA	TC on/off engine	alarm system	-
Flange bearings							
27	xTE1063x	double temp sensors main bearings	indication, alarm, engine protection	0–120 C	engine	engine control system & safety system	main bearing temp monitoring
Main bearings							
28	xTE1064x	double temp sensors main bearings	indication, alarm, engine protection	0–120 C	engine	engine control system & safety system	main bearing temp monitoring
Turning gear							
29	1GOS1070	limit switch turning gear engaged	indication and start blocking	-	engine	engine control system	turning gear
30	1SSV1070	pneumatic valve turning gear engaged	3/2-way valve M306, start blocking while turning gear engaged	-	engine	-	turning gear

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No.	Measuring point	Description	Function	Measuring Range	Location	Connected to	Depending on option
Slow turn							
31	1SSV1075	solenoid valve slow turn	3/2-way valve M329/3, slow turn	-	engine	engine control system	slow turn
Jet assist							
32	1SSV1080	solenoid valve jet assist	2/2-way valve, jet assist	-	engine	engine control system	jet assist
Knock control							
33	xES1200	binary input signal knock control ready	-	-	KCM	-	-
34	xXE1200A/B	Knock sensor knocking intensity cyl. x	-	-	engine	-	-
35	xXS1200	binary input signal heavy knocking	-	-	KCM	-	-
Combustion pressure							
36	xPT1300A/B	pressure transmitter combustion max. pressure cyl. x	-	0 ... 280 bar	engine	-	-
37	xXS1300	binary input signal misfire detected	-	-	CPM	-	-
Lube oil system							
38	4EM2100	electric motor engine pre-lubrication pump	engine lubrication during start/stop procedure or standby operation	-	engine	-	-
39	1TCV2170	temp control valve lube oil temp control valve	indication of lube oil temperature	0–2 bar	engine	engine control system	-
40	1PT2170	pressure transmitter lube oil pressure engine inlet	alarm at low lube oil pressure	0–10 bar	engine	engine control system	-
41	2PT2170	pressure transmitter lube oil pressure engine inlet	auto shutdown at low pressure	0–10 bar	engine	engine control system	-
42	1TE2170	double temp sensor lube oil temp engine inlet	alarm at high temp	0–120 C	engine	engine control system & safety system	-

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No.	Measuring point	Description	Function	Measuring Range	Location	Connected to	Depending on option
43	1ESV2310	solenoid valve lube oil frame tank re-fill	-	-	-	engine control system	base frame = yes
44	1PT2310	pressure transmitter lube oil pressure frame tank-1	alarm at low lube oil pressure	0–100 mbar	engine	engine control system	-
45	2PT2310	pressure transmitter lube oil pressure frame tank-2	alarm at low lube oil pressure	0–100 mbar	engine	engine control system	-
46	xLS2320	level switch lube oil service tank CS/CCS level low	alarm at low lube oil level	-	engine	engine control system	-
47	1PT2550A/B	pressure transmitter lube oil pressure LP-TC A inlet	-	0–6 bar	TC on/off engine	engine control system	-
48	1TE2560A/B	temp sensor lube oil temp LP-TC A/B outlet	-	0–120°C	TC on/off engine	-	-
49	1PT2570A/B	pressure transmitter lube oil pressure HP turbocharger inlet	alarm at low lube oil pressure	0–6 bar	engine	engine control system	-
50	1TE2580A/B	double temp sensor lube oil temp HP turbocharger drain	alarm at high temp	0–120 C	engine	engine control system	-
Crankcase pressure							
51	1PT2800	pressure transmitter crankcase pressure	-	−20 – +20 mbar	engine	engine control system	-
Oil mist detection							
52	1QTIA2870	oil mist detector oil mist concentration in crankcase	oil mist supervision	-	engine	-	oil mist detection
53	1QS2870	opacity switch oil mist in crankcase	integrated in 1QTIA2870	-	engine	engine control system	OMD = VN115
54	2QS2870	opacity switch oil mist in crankcase	integrated in 1QTIA2870	-	engine	safety system	OMD = VN115
Splash oil							
55	xTE2880x	double temp sensor splash oil temp rod bearings	splash oil supervision	0–120 C	engine	engine control system & safety system	-
Cooling water systems							

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No.	Measuring point	Description	Function	Measuring Range	Location	Connected to	Depending on option
56	1TE3145	temp sensor HTCW temp. after service pump	-	0–120 °C	engine	engine control system	-
57	1PT3145	pressure transmitter HTCW press. after service pump	-	0–10 bar	engine	engine control system	-
58	2PT3145	pressure transmitter HTCW press. after service pump	-	0–10 bar	engine	safety system	-
59	1TE3165	double temp sensor, HT water temp after mixing point	-	0–120 C	engine	engine control system	-
60	1TE3170	double temp sensor HTCW temp cylinder cooling outlet	alarm, indication	0–120 C	engine	engine control system & safety system	-
61	1TE3180	double temp sensor HTCW temp cylinder cooling inlet	alarm, indication	0–120 C	engine	engine control system & safety system	-
62	1GT3180	analogue output signal HTCW temp control valve position set-point	-	-	-	-	-
63	1ET3180	analogue input signal HTCW temp control valve position feed-back	-	-	-	-	-
64	1PT3190	pressure transmitter HTCW pressure LP-CA cooler outlet	-	0–10 bar	TC on/off engine	-	-
65	1TE3190	temp sensor HTCW temp LP-CA cooler outlet	-	0–120 C	TC on/off engine	-	-
66	1PT3470	pressure transmitter nozzle cooling water pressure engine inlet	alarm at low cooling water pressure	0–10 bar	engine	engine control system	-
67	1TE3470	double temp sensor nozzle cooling water temp engine inlet	alarm at high cooling water temp	0–120°C	engine	engine control system & safety system	-
68	1TE4145	temp sensor LTCW temp. service pump outlet	-	0–120 C	TC on/off engine	engine control system	-

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No.	Measuring point	Description	Function	Measuring Range	Location	Connected to	Depending on option
69	1PT4145	pressure transmitter LTCW press. service pump outlet	-	0–10 bar	TC on/off engine	engine control system	-
70	1TE4165	double temp sensor, LT water temp after control valve	-	0–120°C	engine	engine control system	-
71	1GT4170	analogue output signal LTCW temp control valve position set-point	-	-	-	-	-
72	1ET4170	analogue input signal LTCW temp control valve position feed-back	-	-	-	-	-
Fuel system							
73	1PT5070	pressure transmitter fuel pressure engine inlet	remote indication and alarm	0–40 bar	engine	engine control system	-
74	1PDS5070	differential pressure switch fuel oil indicator filter	filter contamination monitoring	0–2 bar	engine	engine control system	-
75	1TE5070	double temp sensor fuel temp engine inlet	alarm at high temp in DMB-mode and for EDS use	0–200°C	engine	engine control system	-
76	xFCV5075A/B	suction throttle valves row A/B	volume control of low pressure fuel	-	engine	injection system	-
77	xTE5076A/B	temp sensor fuel oil temp. HP pump 1 leakage pipe	temp. control fuel oil pipes	0–200°C	-	-	-
78	1PT5076A/B	pressure transmitter fuel oil rail pressure row A/B	-	0–3,000 bar	engine	injection system	-
79	2PT5076A/B	pressure transmitter fuel oil rail pressure row A/B	-	0–3,000 bar	engine	injection system	-
80	xFSV5078A/B	valve group for fuel injection	fuel injection	-	engine	injection system	-
81	1TE5080A/B	double temp sensor fuel temp after flushing valve, row A/B	remote indication and alarm	0–200°C	engine	-	-

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No.	Measuring point	Description	Function	Measuring Range	Location	Connected to	Depending on option
82	1LS5080A/B	level switch fuel oil injector- and pump leakage row A/B	alarm at high level	-	leakage fuel oil monitoring tank FSH-001	engine control system	-
83	2LS5080A/B	level switch dirty oil leakage pump bank GDS row A/B	alarm at high level	-	pump bank leakage monitoring GDS	engine control system	-
84	3LS5080A/B	level switch dirty oil leakage pump bank CGDS row A/B	alarm at high level	-	pump bank leakage monitoring CGDS	engine control system	-
85	1PT5080	pressure transmitter fuel oil pressure engine outlet	-	0–40 bar	engine	engine control system	-
86	1FSV5080A/B	flushing valve	unloading of common rail high pressure fuel system A	-	engine	-	-
87	1TE5081A/B	double temp sensor fuel temp after common rail PLV, row A/B	remote indication and alarm	0–200°C	engine	engine control system	-
88	1PZV5081	pressure limiting valve fuel oil rail row A/B	mechanical limitation of rail pressure	-	engine	-	-
89	1TE5082	temp sensor fuel oil temp after common rail press reducing valve	indication and alarm	-	engine	-	-
90	1FSV5082	3/2-way valve fuel oil common rail press reducing valve	common rail press	-	engine	-	-
91	1TE5275	temp sensor pilot fuel oil temp engine inlet	indication and alarm	-	engine	-	-
92	xPT5275	pressure transmitter pilot fuel oil supply press	pilot fuel oil low pressure system	-	engine	-	-

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No.	Measuring point	Description	Function	Measuring Range	Location	Connected to	Depending on option
93	1PDS5275	differential pressure switch pilot fuel oil fine filter diff press high	fine filter contamination monitoring	-	engine	-	-
94	1FCV5275	suction throttle valve pilot fuel high press pump	pilot fuel quantity control	-	engine	-	-
95	xPT5276	pressure transmitter pilot fuel oil common rail press	pilot fuel common rail press	-	engine	-	-
96	1LS5276	Level switch pilot fuel oil leakage switch high-press pump	alarm at low fuel oil level	-	engine	-	-
97	1EM5276	electric motor pilot fuel high-press pump	-	-	engine	-	-
98	1LS5277	Level switch pilot fuel oil common rail leakage switch segment 1	indication and alarm	-	engine	-	-
99	xFSV5278	injection valve pilot fuel oil injection cyl. x	-	-	engine	-	-
100	1TE5281	temp sensor pilot fuel oil temp after PLV	indication and alarm	-	engine	-	-
101	1PZV5281	pressure limiting valve pilot fuel oil rail press limiting valve	-	-	engine	-	-
102	xTE5860	temp sensor fuel gas temp GVU inlet	indication and alarm	-	GVU	-	-
103	xPT5862	pressure transmitter fuel gas press GVU inlet	indication and alarm	-	GVU	-	-
104	1PDS5862	differential press switch fuel gas filter GVU diff press high	indication and alarm	-	GVU	-	-
105	1TE5862	analogue output signal fuel gas press set-point	desired value output to GVU	-	GVU	-	-

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No.	Measuring point	Description	Function	Measuring Range	Location	Connected to	Depending on option
106	1PV5863	solenoid valve fuel gas line venting valve before gas locks	gas line venting	-	GVU	-	-
107	1PV5864	electro-pneumatic valve fuel gas lock valve 1	blocking of gas supply	-	GVU	-	-
108	1PV5865	electro-pneumatic valve fuel gas lock valve 2	blocking of gas supply	-	GVU	-	-
109	2PV5864	solenoid valve fuel gas line venting valve between gas locks	gas line venting	-	GVU	-	-
110	1PT5865	pressure transmitter fuel gas press GVU outlet-1	indication and alarm	-	GVU	-	-
111	2PV5865	electro-pneumatic valve fuel gas venting valve 1 after gas locks	gas line venting	-	GVU	-	-
112	3PV5865	electro-pneumatic valve fuel gas venting valve 2 after gas locks	gas line venting	-	GVU	-	-
113	1PT5884	pressure transmitter fuel gas press engine inlet-1	indication and alarm	-	engine	-	-
114	2PT5884	pressure transmitter fuel gas press engine inlet-2	indication and alarm	-	engine	-	-
115	xFSV5885	injection valve main gas injection cyl. x	-	-	engine	-	-
116	1PT5887	pressure transmitter gas line purge gas press after inlet valve 1	non-return valve leak-age monit-oring	-	engine	-	-
117	1FSV5888	solenoid valve gas line purge gas in-let valve	-	-	engine	-	-
118	1PT5889	pressure transmitter gas line purge gas supply press 1	inert gas availability monitoring	-	engine	-	-
Charge air system							

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No.	Measuring point	Description	Function	Measuring Range	Location	Connected to	Depending on option
119	1TE6000	temp sensor ambient air temp	-	-	-	-	-
120	1PT6100A/B	pressure transmitter intake air pressure row A/B	-	–20 – +20 mbar	intake air duct after filter	engine control system	-
121	1TE6100A/B	double temp sensor intake air temp row A/B	-	–50 – +80 C	intake air duct after filter	engine control system	-
122	1PDT6155A/B	differential pressure transmitter charge air differential pressure LP-CA cooler A/B	-	0–100 mbar	TC on/off engine	engine control system	optional
123	1PT6160	pressure transmitter charge air pressure LP-CA cooler A/B outlet	-	0–6 bar	TC on/off engine	engine control system	-
124	1TE6160	temp sensor charge air temp LP-CA cooler A/B outlet	-	0–120°C	TC on/off engine	engine control system	-
125	1TCV6160	temp control valve LP-charge air temp	control of LTCW temp for LP-CA cooler stage 2	-	TC on/off engine	engine control system	-
126	1ET6160	analogue output signal LP charge air temp control valve position setpoint	desired value output to 1TCV6160 A	-	TC on/off engine	engine control system	-
127	1GT6160	analogue input signal LP charge air temp control valve row A/B position feedback	actual value input from 1TCV6160 A	-	TC on/off engine	engine control system	-
128	1PDT6175A/B	differential pressure transmitter charge air differential pressure HP-CA cooler A/B	-	0–100 mbar	TC on/off engine	engine control system	optional, depended of plant configuration
129	1PT6180	pressure transmitter charge air pressure before cylinders row A/B	engine control	0–10 bar	engine	engine control system	-

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No.	Measuring point	Description	Function	Measuring Range	Location	Connected to	Depending on option
130	2PT6180	pressure transmitter charge air pressure before cylinders row A/B	-	0–10 bar	engine	safety system	-
131	3PT6180	pressure transmitter charge air pressure row A/B	-	0–10 bar	engine	safety system	-
132	1TE6180	double temp sensor charge air temp after charge air cooler A/B	alarm at high temp	0–120 C	engine	engine control system & safety system	-
133	1TCV6180	temp control valve HP-charge air temp	control of LTCW temp for HP-CA cooler stage 2	-	TC on/off engine	engine control system	-
134	1ET6180	analogue input signal HP charge air temp control valve position setpoint	desired value output to 1TCV6180 A	-	TC on/off engine	engine control system	-
135	1GT6180	analogue input signal HP charge air temp control valve position feedback	actual value input from 1TCV6180 A	-	TC on/off engine	engine control system	-
Exhaust gas system							
136	xTE6570A/B	double temp sensor exhaust gas temp cylinders A/B	indication, alarm, engine protection	0–800°C	engine	engine control system & safety system	-
137	1XCV6570A/B	variable flap waste gate A/B	-	-	TC on/off engine	-	-
138	1ET6570A/B	analog output signal waste gate row A/B position setpoint	desired value output to waste gate position controller	-	TC on/off engine	engine control system	-
139	1GT6570A/B	analog input signal waste gate row A/B position feedback	actual value input from waste gate position controller	-	TC on/off engine	engine control system	-
140	1TE6575A/B	double temp sensors exhaust gas temp before turbocharger A/B	indication, alarm, engine protection	0–800 C	engine	engine control system & safety system	-

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No.	Measuring point	Description	Function	Measuring Range	Location	Connected to	Depending on option
141	1TE6580	temp sensor exhaust gas temp HP-TC outlet	indication, alarm, engine protection	-	TC on/off engine	engine control system	-
142	1TT6582	temperature transmitter exhaust gas venting purge air temp	leakage monitoring of 1FSV6582	-	-	-	-
143	2TT6582	temperature transmitter exhaust gas venting purge air temp	leakage monitoring of 1FSV6582	-	-	-	-
144	1PT6582	pressure transmitter exhaust gas venting purge air press.	venting fan function monitoring	-	-	-	-
145	1FSV6582	solenoid valve exhaust gas venting valve	exhaust system venting	-	-	-	-
146	1FSV6583	solenoid valve exhaust gas venting valve	exhaust system venting	-	-	-	-
147	1TE6592	temp sensor exhaust gas temp. after waste gate inflow	-	0–800°C	plant	-	-
148	xPZV6599	Rupture disc exhaust pipe rupture disc x	overpressure relief	-	-	-	-
Control air, start air, stop air							
149	1PT7170	pressure transmitter starting air pressure	engine control, remote indication	0–40 bar	engine	engine control system	-
150	1PT7400	pressure transmitter control air pressure	remote indication	0–10 bar	engine	engine control system	-
151	1PT7460	Pressure transmitter control air pressure GVU	remote indication	0–10 bar	GVU	engine control system	-

Table 108: List of engine-located and plant-located measuring and control devices

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4 Specification for engine supplies

4.1 Explanatory notes for operating supplies – Diesel engines

4.1.1 Lube oil

Selection of the lube oil must be in accordance with the relevant sections.

The lube oil must always match the worst fuel oil quality.

A base number (BN) that is too low is critical due to the risk of corrosion.

A base number that is too high, could lead to deposits/sedimentation.

4.1.2 Fuel

The quality of the fuel specified in the relevant sections must be ensured.

Engine operation with DM-grade fuel according to ISO 8217, viscosity ≥ 2 cSt at 40°C

A) Short-term operation, max. 72 hours

Engines that are normally operated with residual fuel, can also be operated with DM-grade fuel for short periods.

Boundary conditions:

- DM-grade fuel in accordance with stated specifications and a viscosity of ≥ 2 cSt at 40°C.
- DMA-operation maximum 72 hours within a two-week period (cumulative with distribution as required).
- Fuel oil cooler switched on and fuel oil temperature before engine ≤ 45°C. In general, the minimum viscosity before engine of 1.9 cSt must not be undershoot!

B) Long-term (> 72 h) or continuous operation

For long-term (> 72 h) or continuous operation with DM-grade fuel special engine- and plant-related planning prerequisites must be set and special actions are necessary during operation.

Following features are required on engine side:

- Valve seat lubrication with possibility to be turned off and on manually.

Following features are required on plant side:

- Layout of fuel system to be adapted for low-viscosity fuel (capacity and design of fuel supply and booster pump).
- Cooler layout in fuel system for a fuel oil temperature before engine of ≤ 45 °C (min. permissible viscosity before engine 1.9 cSt).
- Nozzle cooling system with possibility to be turned off and on during engine operation.

Boundary conditions for operation:

- Fuel in accordance with DMA, DFA and a viscosity of ≥ 2 cSt at 40°C.
- Fuel oil cooler activated and fuel oil temperature before engine ≤ 45°C. In general the minimum viscosity before engine of 1.9 cSt must not be undershoot!

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- Valve seat lubrication turned on.
- Nozzle cooling system.

Continuous operation with DMA, DFA:

- Lube oil for diesel operation (BN10-BN16) has to be used.

Operation with residual fuel (HFO) of a sulphur content of < 1.5%

Previous experience with stationary engines using residual fuel (HFO) of a low sulphur content does not show any restriction in the utilisation of these fuels, provided that the combustion properties are not affected negatively.

This may well change if in the future new methods are developed to produce low sulphur-containing residual fuels.

If it is intended to run continuously with low sulphur-containing residual fuel, lube oil with a low BN (BN30) has to be used. This is required, in spite of experiences that engines have been proven to be very robust with regard to the continuous usage of the standard lube oil (BN40) for this purpose.

Instruction for minimum admissible fuel temperature

- In general the minimum viscosity before engine of 1.9 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 approximately minus 10 °C and less have to be avoided, due to temporarily embrittlement of seals used in the engines fuel oil system and as a result their possibly loss of function.

Operation with FAME (fatty acid methyl ester) additives 7% to 100% or with operation with synthetic fuels (DIN EN 15940)

Note the specifications and special remarks in paragraphs Synthetic fuels (DIN EN 15940), Page 247, FAME (fatty acid methyl ester) additive of 0.5 to 100%, Page 248 and FAME (fatty acid methyl ester) additive up to max. 7%, Page 253.

4.1.3 Nozzle cooling

The quality of the engine cooling water required in relevant section has to be ensured.

Nozzle cooling system activation	
Kind of fuel	**Activated**
DMA, DFA	No, see section Fuel system, Page 348
DMB, DFB	No
HFO	Yes

Table 109: Nozzle cooling system activation

4.1.4 Intake air

The quality of the intake air as stated in the relevant sections has to be ensured.

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4.2 Specification of lubricating oil (SAE 40) for operation with DMA/DMB, DFA, DFB

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.

Lubricating oils contain additives that, amongst other things, ensure dirt absorption capability, cleaning of the engine and the neutralisation of acidic combustion products.

Only lubricating oils that have been approved by Everllence may be used. These are listed under Lubrication.

Specifications

Doped lube oils (HD oils)

The base oil which has been mixed with additives (doped lube oil) must have the following properties:

Neutralization capacity

The neutralization capacity (DIN ISO 3771) must be so high that the acidic products produced during combustion are neutralized. The reaction time of the additives must be matched to the process in the combustion chamber.

Additional requirements

Fresh oil must not contain water or other contaminants.

Lubricating oil selection

Engine	SAE class
16/24, 21/31, 27/38, 23/30, 28/32, 32/40, 32/44CR, 35/44DF, 48/60CR, 49/60, 49/60DF, 51/60DF, 51/60R, 51/60R-DF-M	40

Table 110: Viscosity (SAE class) of lubricating oils

Oil quality

Only lubricating oils approved by Everllence may be used. Lubricating oils of military specification O-278 can be used if they are listed under Lubrication in the list of currently approved lubricating oils.

The operating conditions of the engine and the quality of the fuel determine the additive fractions the lube oil should contain. If marine diesel oil with a high sulphur content of 1.0 up to 1.5 weight % is used, a base number (BN) of approx. 20 should be selected. However, the operating results that ensure the most efficient engine operation ultimately determine the additive content.

Oil for mechanical/hydraulic speed governors

Multigrade oil 5W40 should ideally be used in mechanical-hydraulic controllers with a separate oil sump, unless the technical documentation for the speed governor specifies otherwise. If this oil is not available when filling, 15W40 oil may be used instead in exceptional cases. In this case, it makes no difference whether synthetic or mineral-based oils are used.

The military specification applied for these oils is NATO O-236.

Experience with the drive engine L27/38 has shown that the operating temperature of the Woodward controller UG10MAS and corresponding actuator for UG723+ can reach temperatures higher than 93 °C. In these cases, we recommend using synthetic oil such as Castrol Alphasyn HG150.

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Lubricating oil additives

The use of other additives in conjunction with the lubricating oil or the mixing of different brands (oils from different manufacturers and different brands from the same manufacturer) is not permitted, as this can affect the performance of existing additives, which have been carefully matched to each other and have also been specially adapted to the base oil.

Selection of lubricating oils/ warranty

Most oil manufacturers have close and constant contacts with engine manufacturers and can therefore specify which oil from their own product line is approved by the engine manufacturer for the application. Regardless of this information, lubricating oil manufacturers are always liable for the quality and properties 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 Lubrication.

Oil during operation

There are no prescribed oil change intervals for Everllence medium speed engines. The oil properties must be analysed monthly. The oil must therefore be suitable for the intended purpose and meet the defined limit values as per the table. If this is the case, the oil can continue to be used. See table Limit values for used lube oil, Page 242.

The quality can only be maintained if it is purified via a separator or an otherwise suitable device.

Tests

A monthly analysis of lube oil samples is mandatory for safe engine operation. We can analyse samples for customers in the Everllence 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.

Note:
Everllence does not assume liability for problems that occur when using these oils.

	Limit value	Procedure
Viscosity at 40 °C	110–220 mm²/s	ASTM D7042, ASTM D445, DIN EN 16896 or ISO 3104
Base number (BN)	at least 50 % of fresh oil	ISO 3771
Flash point (PM)	at least 185 °C	ISO 2719
Water content	max. 0.2 % (max. 0.5 % for brief periods)	DIN 51777 or ASTM D6304
n-heptane insoluble	max. 1.5 %	DIN 51592 or IP 316
Metal content	dependent on engine type and operating conditions	–
Guide value only Fe Cr Cu Pb Sn Al	 max. 50 ppm max. 10 ppm max. 15 ppm max. 20 ppm max. 10 ppm max. 20 ppm	ASTM D5185 or DIN 51399-1

Table 111: Limit values for used lube oil

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4.3 Specification of lubricating oil (SAE 40) for residual fuel operation (HFO)

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.

Medium alkalinity lubricating oils have a proven track record as lubricants for the moving parts and turbocharger cylinder and for cooling the pistons. Lubricating oils of medium alkalinity contain additives that, in addition to other properties, ensure a higher neutralization reserve than with fully compounded engine oils (HD oils).

International specifications do not exist for medium alkalinity lubricating oils. A test operation is therefore necessary for a corresponding long period in accordance with the manufacturer's instructions.

Only lubricating oils that have been approved by Everllence may be used.

The list of the currently approved lubricating oils is available at Lubrication.

Specifications

Additional requirements

Fresh oil must not contain water or other contaminants.

Lube oil selection

Engine	SAE class
16/24, 21/31, 27/38, 23/30, 28/32, 32/40, 32/44CR, 35/44DF, 48/60CR, 49/60, 49/60DF, 51/60DF, 51/60R, 51/60R-DF-M	40

Table 112: Viscosity (SAE class) of lubricating oils

Neutralisation properties (BN)

At the present level of knowledge, an interrelation between the expected operating conditions and the BN number can be established. However, the operating results are still the overriding factor in determining which BN number provides the most efficient engine operation.

Table Base number to be used for various operating conditions, Page 243 indicates the relationship between the anticipated operating conditions and the BN number.

Approx. BN of fresh oil (mg KOH/g oil)	Engines/operating conditions
20	Marine diesel oil (DMB) of a lower quality and with a high sulphur content or residual fuel with a sulphur content of less than 0.50%
30	Generally 16/24, 21/31, 23/30, 28/32 under normal operating conditions. For engines 27/38, 32/40, 32/44CR, 35/44DF, 48/60CR, 49/60, 49/60DF (marine application) and 51/60DF operating with 100% residual fuel with a sulphur content < 1.5% only.
40	Under unfavourable operating conditions and where the corresponding requirements for the oil service life and cleaning capacity exist, 16/24, 21/31, 23/30 and 28/32. In general 27/38, 32/40, 32/44CR, 35/44DF, 48/60CR, 49/60, 49/60DF (marine application) and 51/60DF for operation with residual fuel, provided the sulphur content is over 1.5%.

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Approx. BN of fresh oil (mg KOH/g oil)	Engines/operating conditions
50	32/40, 32/44CR and 48/60CR, if the oil service life or engine cleanliness is insufficient with a BN number of 40 (high sulphur content of fuel, extremely low lubricating oil consumption).

Table 113: Base number to be used for various operating conditions

Operation with low-sulphur fuel

To comply with the emissions regulations, the sulphur content of fuels used nowadays varies. Fuels with low-sulphur content must be used in environmentally-sensitive areas (e.g. SECA). Fuels with higher sulphur content may be used outside SECA zones. In this case, the BN number of the lube oil selected must satisfy the requirements for operation using fuel with high-sulphur content. A lube oil with low BN number may only be selected if fuel with a low sulphur content is used exclusively during operation.
However, the practical results demonstrate that the most efficient engine operation is the factor ultimately determining the permitted additive content.

Oil for mechanical/hydraulic speed governors

Multigrade oil 5W40 should ideally be used in mechanical-hydraulic controllers with a separate oil sump, unless the technical documentation for the speed governor specifies otherwise. If this oil is not available when filling, 15W40 oil may be used instead in exceptional cases. In this case, it makes no difference whether synthetic or mineral-based oils are used.

The military specification applied for these oils is NATO O-236.

Experience with the drive engine L27/38 has shown that the operating temperature of the Woodward controller UG10MAS and corresponding actuator for UG723+ can reach temperatures higher than 93 °C. In these cases, we recommend using synthetic oil such as Castrol Alphasyn HG150.

Hydraulic oil for engines with VVT controller

Hydraulic oil HLP 46 (DIN 51502) or ISO VG 46 (DIN 51519) must be used according to the specification DIN 51524-2. Mixing hydraulic oils from different manufacturers is not permitted.

Lubricating oil additives

The use of other additives in conjunction with the lubricating oil or the mixing of different brands (oils from different manufacturers and different brands from the same manufacturer) is not permitted, as this can affect the performance of existing additives, which have been carefully matched to each other and have also been specially adapted to the base oil.

Oil during operation

There are no prescribed oil change intervals for Everllence medium speed engines. The oil properties must be analysed monthly. The oil must therefore be suitable for the intended purpose and meet the defined limit values as per the table. If this is the case, the oil can continue to be used. See table Limit values for used lube oil, Page 245.

The quality can only be maintained if it is purified via a separator or an otherwise suitable device.

Temporary operation with distillate fuel

Due to current and future emissions regulations, the use of residual fuel in designated areas is not possible. Instead of this, a low-sulphur diesel fuel must be used in these areas.

If the duration of the operation with low-sulphur diesel fuel is limited to less than 1,000 h, a lubricating oil that is intended for residual fuel operation (BN 30–55 mg KOH/g) can continue to be used during this time.

If the temporary operation with low-sulphur diesel fuel lasts longer than 1,000 h and is then operated with residual fuel again after that, a lubricating oil with a BN of 20 must be used. If the BN 20 lubricating oil is from the same

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brand as the lubricating oil used in the HFO operation with high BN (40 or 50), no oil change is required for the switch. It is sufficient to use BN 20 oil to top up the used lubricating oil.

If you want to use residual fuel again, you must switch back in good time to a lubricating oil with a higher BN (30–55). If the lubricating oil with the higher BN is from the same brand as the BN 20, the switch can also be made without changing oil. To do this, approx. 2 weeks before operating again with residual fuel, use the lubricating oil with the higher BN (30–55) to top up the consumed lubricating oil.

	Limit value	Procedure
Viscosity at 40 °C	110–220 mm²/s	ASTM D7042, ASTM D445, DIN EN 16896 or ISO 3104
Base number (BN)	at least 50 % of fresh oil	ISO 3771
Flash point (PM)	at least 185 °C	ISO 2719
Water content	max. 0.2 % (max. 0.5 % for brief periods)	DIN 51777 or ASTM D6304
n-heptane insoluble	max. 1.5 %	DIN 51592 or IP 316
Metal content	dependent on engine type and operating conditions	–
Guide value only Fe Cr Cu Pb Sn Al	 max. 50 ppm max. 10 ppm max. 15 ppm max. 20 ppm max. 10 ppm max. 20 ppm	ASTM D5185 or DIN 51399-1

Table 114: Limit values for used lube oil

Tests

A monthly analysis of lube oil samples is mandatory for safe engine operation. We can analyse samples for customers in the Everllence PrimeServLab.

Note:
Everllence does not assume liability for problems that occur when using these oils.

4.4 Diesel fuel (DMA, DFA) specification

General information

Diesel fuel is a middle distillate refined from crude oil. It is also referred to as: gas oil, marine gas oil (DMA), DFA, diesel oil. It should not contain any residue from crude oil refining.

Selection of suitable 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 influences the emissions behaviour of the engine.

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Specifications and approvals (DMA)

The fuel quality varies regionally and depends on climatic conditions. All requirements from ISO 8217:2024 apply

The following values must be maintained at the engine inlet:

Property	Unit		Limit value[1)]	Standard[2)]
Appearance	-	-	Clear, bright and free from visible contamination	visual
Kinematic viscosity at 40° C[3)]	mm^2/s	Max. Min.	6.0 2.0	ISO 3104, ASTM D7042, ASTM D445, DIN EN 16896
Density at 15°C	kg/m^3	Max. Min.	890.0 820.0	ISO 3675, ISO 12185
Water content	% (m/m)	Max.	0.02	DIN 51777, DIN EN 12937, ASTM D6304
Cetane number		Min.	40	EN ISO 5165, IP541, EN 15195, EN 16715, EN 17155
Sulphur content[4)]	% (m/m)	Max.	1.0	ISO 8754, ISO 14596, ASTM D4294, DIN 51400-10
Flashpoint[5)]	°C	Min.	60.0	ISO 2719
Acid number	mg KOH/g	Max.	0.5	ASTM D664
Carbon residue[6)]	% (m/m)	Max.	0.30	ISO 10370
Ash content	% (m/m)	Max.	0.010	ISO 6245
Lubricity (WSD)	µm	Max.	520	ISO 12156-1, ASTM D6079
Corrosion effect on copper	Class	Max.	1	EN ISO 2160
Hydrogen sulphide	mg/kg	Max.	2.0	IP 570
FAME[7)]-content	% (V/V)	Max.	0.5	ASTM D7963, IP 579, DIN EN 14078
Oxidation stability	g/m^3	Min.	25	EN ISO 12205
Sediment content[8)]	% (m/m)	Max.	0.01	ISO 10307-1
CFPP	°C		10°C below the lowest temperature in the fuel system	DIN EN 116, IP 309, IP 612
Pour Point[9)] winter grade	°C	Max.	-6	ISO 3016
Pour Point[9)] summer grade	°C	Max.	0	ISO 3016
Na, K, Ca, P, Cu, Zn, Si	mg/kg	Max.	free from	DIN EN 16476

Table 115: Requirements for diesel fuel (DMA)

Remarks:

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[1] The fuel must be suitable for the intended application. It must not contain any substance in a concentration that causes additional air pollution, is harmful for personnel, jeopardises ship safety and/or has an adverse effect on machine performance. The fuel must be free from non-ferrous metals according to DIN EN 16476. The fuel must not contain any waste oil.

[2] Always refer to the currently applicable edition.

[3] Specific requirements of the injection system must be taken into account

[4] Independent of the maximum permissible sulphur content, local laws and regulations must be adhered to

[5] Additional requirements (e.g. SOLAS) must be observed. Applicable laws must be adhered to.

[6] Determined at 10% distillation residue

[7] The FAME must either be in accordance with EN 14214 or with ASTM D6751 as well as with increased oxidation stability of at least 8 hours (EN 15751). For information on the use of fuels with more than 0.5% FAME see section Diesel fuel (DMA, DFA) specification, Page 248

[8] If the sample is not clear and bright, complete sedimentation through hot filtration and the determination of water content is required

[9] 10°C below the lowest temperature in the fuel system

The following fuels are approved for use if the fuel complies with table Requirements for diesel fuel (DMA), Page 246:

- Classes ISO F-DMA & DMZ according to ISO 8217:2024
- Diesel fuel as per EN 590:2022 with additional requirement regarding flashpoint > 60 °C in SOLAS regulated areas
- Diesel fuel no. 2-D as per ASTM D975-21 with additional requirement regarding flashpoint > 60 °C in SOLAS regulated areas

Please submit enquiries to Everllence for all fuels which do not meet the abovementioned standards.

Viscosity

In order to ensure sufficient lubrication, a minimum level of viscosity must be ensured at the fuel injection pump. The specified maximum temperature required to maintain a viscosity of more than 1.9 mm^2/s upstream of the fuel injection pump depends on the fuel viscosity. The temperature of the fuel upstream of the fuel injection pump must not exceed 45 °C in any case. The lubricity requirement for the fuel upstream of the engine is a maximum of 520 µm WSD in each case according to 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 for diesel fuel (DMA), Page 246 pursuant to ISO 8217:2024 and the minimum permissible viscosity upstream of the injection pump with the corresponding temperature is adhered to.

Synthetic fuels (DIN EN 15940)

When using synthetic fuels according to DIN EN 15940 with a density of less than 820 kg/m^2 at 15 °C, prior consultation with Everllence is required.

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Synthetic fuels such as HVO, BTL, CTL, GTL according to DIN EN 15940, can be produced from renewable electrical energy and CO_2 or from the same basic material such as FAME fuels (vegetable oil, cooking oil, animal fat) but in a completely different procedure. Synthetic fuels are produced by means of hydrogen treatment, with a fuel being generated which has a very similar chemical structure to high-performance diesel fuel and consists of paraffinic hydrocarbons. In contrast to fossil diesel fuel, synthetic fuel barely contains any aromatic components, which causes very good combustion properties.

Although the energy content (per mass unit) is higher in comparison with fossil diesel fuel, the volumetric energy content is lower due to the lower density (typically approx. 780 kg/m³ at 15°C). This may lead to deviations in the specified engine output, operating behaviour, load application and emissions as well as deviations in the specific fuel consumption.

The lubricity of synthetic fuels is relatively low. In order to meet fuel specifications (requirements on diesel fuel) and guarantee sufficient lubricity of the fuel, the fuel supplier needs to add a lubricity additive or FAME.

The lower flashpoint limit is too low at a minimum of 55°C. The additional requirement relating to flashpoint min. 60 °C in SOLAS regulated areas must be observed.

We strongly advise against using a mixture of HFO and synthetic fuel (in accordance with EN 15940). The reason is that the HFO contains asphaltenes, which are held in solution by the aromatics contained in HFO. Synthetic fuel is purely paraffinic (does not contain any aromatics) and therefore cannot hold asphaltenes in solution. This means that when synthetic fuel is added to HFO, these asphaltenes precipitate, deposits form or fuel filters become clogged or, in the worst case scenario, the injection system fails.

FAME (fatty acid methyl ester) additive of 0.5 to 100% (DFA)

The following values must be maintained at the engine inlet:

Property	Unit		Limit value[1)]	Standard[2)]
Appearance	-	-	Clear, bright and free from visible contamination	visually
Kinematic viscosity at 40° C[3)]	mm^2/s	Max. Min.	6.0 2.0	ISO 3104, ASTM D7042, ASTM D445, DIN EN 16896
Density at 15°C	kg/m^3	Max. Min.	890.0 820.0	ISO 3675, ISO 12185
Water content	% (m/m)	Max.	0.02	DIN 51777, DIN EN 12937, ASTM D6304
Cetane number		Min.	40	EN ISO 5165, IP541, EN 15195, EN 16715, EN 17155
Sulphur content[4)]	% (m/m)	Max.	1.0	ISO 8754, ISO 14596, ASTM D4294, DIN 51400-10
Flashpoint[5)]	°C	Min.	60.0	ISO 2719
Acid number	mg KOH/g	Max.	0.5	ASTM D664
Carbon residue[6)]	% (m/m)	Max.	0.30	ISO 10370
Ash content	% (m/m)	Max.	0.010	ISO 6245

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Property	Unit		Limit value[1)]	Standard[2)]
Lubricity (WSD)	µm	Max.	520	ISO 12156-1, ASTM D6079
Corrosion effect on copper	Class	Max.	1	EN ISO 2160
Hydrogen sulphide	mg/kg	Max.	2.0	IP 570
FAME[7)]-content	% (V/V)	Min.	0.5	ASTM D7963, IP 579, DIN EN 14078
Oxidation stability	h	Min.	8	EN 15751
Sediment content[8)]	% (m/m)	Max.	0.01	ISO 10307-1
CFPP	°C		10°C below the lowest temperature in the fuel system	DIN EN 116, IP 309, IP 612)
Pour Point[9)] winter grade	°C	Max.	-6	ISO 3016
Pour Point[9)] summer grade	°C	Max.	0	ISO 3016
Na, K, Ca, P, Cu, Zn, Si	mg/kg	Max.	free from	DIN EN 16476

Table 116: Requirements for diesel fuel (DMA)

Remarks:

[1)] The fuel must be suitable for the intended application. It must not contain any substance in a concentration that causes additional air pollution, is harmful for personnel, jeopardises ship safety and/or has an adverse effect on machine performance. The fuel must be free from non-ferrous metals according to DIN EN 16476. The fuel must not contain any waste oil.

[2)] Always refer to the currently applicable edition.

[3)] Specific requirements of the injection system must be taken into account

[4)] Independent of the maximum permissible sulphur content, local laws and regulations must be adhered to

[5)] Additional requirements (e.g. SOLAS) must be observed. Applicable laws must be adhered to.

[6)] Determined at 10% distillation residue

[7)] The FAME must either be in accordance with EN 14214 or with ASTM D6751 as well as with increased oxidation stability of at least 8 hours (EN 15751).

[8)] If the sample is not clear and bright, complete sedimentation through hot filtration and the determination of water content is required

[9)] 10°C below the lowest temperature in the fuel system

When using DFA (FAME according to EN 14214 or ASTM D6751* or their mixtures with DMA), prior consultation with Everllence is required. In addition, the following should be observed:

- Due to the typically lower calorific value or energy content of FAME fuels and their mixtures with DMA (DFA), it may result in deviations to the specified engine output, operating behaviour, load application, specific fuel consumption and emissions.
- The sealing materials used must be suitable for DFA. NBR seals are not suitable and must not be used.

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- DFA tends to attract water. The risk of microbial growth is therefore increased. For this reason, the water content needs to be kept as low as possible. The maximum water content must not be exceeded. Everllence recommends draining water from the fuel tank every day.
- Long standstill periods (e.g. emergency power units) must be avoided due to microbial growth. To prevent damage, it is recommendable to only operate applications with fuel which is free of FAME (DMA).
- The fuel reacts to air and this may lead to microbial growth. Ensure that the atmospheric oxygen ventilation is kept to a minimum. A nitrogen buffer is ideally installed in the fuel tank.
- The entire fuel system must be purged with fuel which is free of FAME (DMA) prior to longer standstill periods.
- If DFA is to be used with other fuels and mixing cannot be avoided, contact your fuel supplier to ensure the compatibility of these fuels.
- It is recommended that wherever possible a heat tracing system is installed in the fuel supply system, in order to prevent deposits or blockage of the lines.
- As DFA have a higher evaporation temperature than standard DMA qualities, these are enriched in lubricating oil. Regular analysis of all the lubricating oil is highly recommended. The lubricating oil needs to be replaced if a FAME content of 12% is reached.
- DFA may cause a layer to form, such a phenomenon leads to increased consumption of lubricating oil. If such an increase in lubricating oil consumption values is detected, please contact your Everllence PrimeServ department.
- Fuels may cause harmful reactions with metals such as zinc or copper. We highly recommend getting in contact with your tank and heating oil system supplier.
- After switching to DFA, pay attention to the delta pressure indicators/ alarms of the filters, as the residues dissolved by DFA can clog the filters.
- In any case, it is the responsibility of the operating company to adhere to the legal requirements (e.g. SOLAS) and agree on these with the relevant authorities.

* as well as with increased oxidation stability of at least 8 hours (EN 15751)

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.

Analyses

The examination of fuel samples is essential for safe engine operation. Examinations can be carried out in the Everllence PrimeServLab laboratory for our customers.

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To guarantee the safety of the crew and to obtain a representative sample, sampling must take place in accordance with valid Everllence operating instructions.

4.5 Marine diesel oil (DMB, DFB) specification

General information

Marine diesel oil as a heavy distillate is available for marine applications only. Another names are: Marine diesel oil (MDO), DMB, DFB. It is made from crude oil and may contain synthetic components (e.g. BtL, CtL, GtL and HVO). The fuel is treated the same as residual fuel in the supply chain. This means that it is possible for the fuel to be blended with high-viscosity residual fuel residue, e.g. in a bunker vessel, and it might therefore contain residue from crude oil processing. This can affect the properties of the fuel.

Selection of suitable 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 influences the emissions behaviour of the engine.

Specifications and approvals

The fuel quality varies regionally and depends on climatic conditions. All requirements from ISO 8217:2024 apply.

The following values must be maintained at the engine inlet:

Property	Unit		Limit value[1)]	Standard[2)]
Appearance[3)]	–	–	Free from contamination	visually
Kinematic viscosity at 40 °C[4)]	mm^2/s	Max. Min.	11.0 2.0	ISO 3104, ASTM D7042, ASTM D445, DIN EN 16896
Density at 15°C	kg/m^3	Max. Min.	900.0 820.0	ISO 3675, ISO 12185
Water content	% (m/m)	Max.	0.02	DIN 51777, DIN EN 12937, ASTM D6304
Cetane number		Min.	35	EN ISO 5165, IP541, EN 15195, EN 16715, EN 17155
Sulphur content[5)]	% (m/m)	Max.	1.50	EN ISO 8754, EN ISO 14596, ASTM D4294, DIN 51400-10
Flashpoint[6)]	°C	Min.	60.0	ISO 2719
Acid number	mg KOH/g	Max.	0.5	ASTM D664
Carbon residue	% (m/m)	Max.	0.30	ISO 10370
Ash content	% (m/m)	Max.	0.010	ISO 6245
Lubricity (WSD)	µm	Max.	520	ISO 12156-1, ASTM D6079
Corrosion effect on copper	Class	Max.	1	ISO 2160

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Property	Unit		Limit value[1)]	Standard[2)]
Hydrogen sulphide	mg/kg	Max.	2.0	IP 570
FAME[7)]-content DMB	% (V/V)	Max.	0.5	ASTM D7963, IP 579, DIN EN 14078
FAME[7)]-content DFB	% (V/V)	Max.	7.0	ASTM D7963, IP 579, DIN EN 14078
Oxidation stability DMB	g/m^3	Min.	25	ISO 10307-1
Oxidation stability[8)] DFB	h	Min.	8.0	ISO 10370
Na, K, Ca, P, Cu, Zn, Si	mg/kg	Max.	free from	DIN EN 16476

Table 117: Requirements for diesel fuel (DMB/DFB)

Remarks:

[1)] The fuel must be suitable for the intended application. It must not contain any substance in a concentration that causes additional air pollution, is harmful for personnel, jeopardises ship safety and/or has an adverse effect on machine performance. The fuel must be free from non-ferrous metals according to DIN EN 16476. The fuel must not contain any waste oil.

[2)] Always in relation to the currently applicable edition.

[3)] Only possible with clear samples. If the sample is not clear or contains visible contamination, the check must be completed mandatorily for the entire sediment.

[4)] Specific requirements of the injection system must be taken into account

[5)] Local laws and regulations must be observed independently of the maximum possible sulphur content.

[6)] Additional requirements (e.g. SOLAS) must be observed. Applicable laws must be adhered to.

[7)] The FAME must either be in accordance with EN 14214 or with ASTM D6751 as well as with increased oxidation stability of at least 8 hours (EN 15751).

[8)] If there is more than 2% (V/V) FAME, an analysis as per EN15751 must additionally be carried out.

Approved fuels

The following fuels are approved for use if the fuel complies with table Requirements for diesel fuel (DMB/DFB), Page 251:

- Class ISO F-DMB according to ISO 8217:2024
- Class ISO F-DFB according to ISO 8217:2024 with additional requirement regarding oxidation stability

Please submit enquiries to Everllence for all fuels which do not meet the abovementioned standards.

Viscosity

In order to ensure sufficient lubrication, a minimum level of viscosity must be ensured at the fuel injection pump. The specified maximum temperature required to maintain a viscosity of more than 1.9 mm^2/s upstream of the fuel injection pump depends on the fuel viscosity. The temperature of the fuel upstream of the fuel injection pump must not exceed 45 °C in any case. The lubricity requirement for the fuel upstream of the engine is a maximum of 520 µm WSD in each case according to ISO 12156-1.

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Contamination

We recommend installing a separator upstream of the fuel filter. Separation temperature 40–50°C. Most solid particles (sand, corrosion and catalytic converter fragments) and water can thus be removed and the cleaning intervals for the filter elements can be significantly extended.

FAME (fatty acid methyl ester) additive up to max. 7%

Using fuels with biofuel admixture based on fatty acid methyl ester (FAME) of max. 7 vol. % is possible.
The FAME must comply with the requirements stipulated in EN 14214 or ASTM D6751.*

It is the responsibility of the operating company that the fuel always complies with all requirements in table Requirements for diesel fuel (DMB/DFB), Page 251.

Applications with longer standstill periods (e.g. emergency power units) can be affected by fuel ageing. To prevent damage, it is recommendable to only operate these applications with fuel which is free of FAME or to purge the entire fuel system with fuel which is free of biodiesel prior to longer standstill periods.

FAME blends typically contain a higher water content. This higher water content must be reduced by appropriate means in order to adhere to the maximum permissible water content at the engine inlet.

In any case, it is the responsibility of the operating company to adhere to the legal requirements (e.g. SOLAS).

Everllence is not liable for damage caused to the engine or subsequent damage resulting from this caused by FAME fuel blends.

* as well as with increased oxidation stability of at least 8 hours (EN 15751)

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.

Analyses

The examination of fuel samples is essential for safe engine operation. Examinations can be carried out in the Everllence PrimeServLab laboratory for our customers.

To guarantee the safety of the crew and to obtain a representative sample, sampling must take place in accordance with valid Everllence operating instructions.

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4.6 Specifications of diesel fuel used as pilot oil

General information

Diesel fuel is a middle distillate refined from crude oil. It is also referred to as: gas oil, marine gas oil (DMA), DFA, diesel oil. It should not contain any residue from crude oil refining.

Selection of suitable 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 influences the emissions behaviour of the engine.

Specifications and approvals

If synthetic diesel oil (according to DIN EN 15940) or DFA (FAME according to EN 14214 or ASTM D6751 and their mixtures with DMA) is used, prior consultation with Everllence is required. For information on the use of these fuels, see Synthetic fuels, Page 247 and FAME (fatty acid methyl ester) additive of 0.5 to 100% (DFA), Page 248.

The fuel quality varies regionally and depends on climatic conditions. All requirements from ISO 8217:2024 apply

The following values must be maintained at the engine inlet:

Property	Unit		Limit value[1)]	Standard[2)]
Appearance			Clear, bright and free from visible contamination	visually
Kinematic viscosity at 40° C [3)]	mm^2/s	Max. Min.	6.0 2.0	ISO 3104, ASTM D7042, ASTM D445, DIN EN 16896
Density at 15°C	kg/m^3	Max. Min.	890.0 820.0	ISO 3675, ISO 12185
Water content	% (m/m)	Max.	0.02	DIN 51777, DIN EN 12937, ASTM D6304
Cetane number		Min. Max.	40 60	EN ISO 5165, IP541, EN 15195, EN 16715, EN 17155
Sulphur content[4)]	% (m/m)	Max.	1.0	ISO 8754, ISO 14596, ASTM D4294, DIN 51400-10
Flashpoint[5)]	°C	Min.	60.0	ISO 2719
Acid number	mg KOH/g	Max.	0.5	ASTM D664
Carbon residue[6)]	% (m/m)	Max.	0.30	ISO 10370
Ash content	% (m/m)	Max.	0.010	ISO 6245
Lubricity (WSD)	µm	Max.	520	ISO 12156-1, ASTM D6079
Corrosion effect on copper	Class	Max.	1	EN ISO 2160

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Property	Unit		Limit value[1)]	Standard[2)]
Hydrogen sulphide	mg/kg	Max.	2.0	IP 570
FAME[7)]-content DMA	% (V/V)	Max.	0.5	ASTM D7963, IP 579, DIN EN 14078
FAME[7)]-content DFA	% (V/V)	Max.	40.0	ASTM D7963, IP 579, DIN EN 14078
Oxidation stability DMA	g/m^3	Min.	25	EN ISO 12205
Oxidation stability[8)] DFA	h	Min.	8	EN 15751
Sediment content[9)]	% (m/m)	Max.	0.01	ISO 10307-1
Total aromatic content	% (m/m)	Max.	45	DIN EN 12916
CFPP	°C		10°C below the lowest temperature in the fuel system	DIN EN 116, IP 309, IP 612)
Pour Point[10)] Winter quality	°C	Max.	-6	ISO 3016
Pour Point[10)] Summer quality	°C	Max.	0	ISO 3016
Na, K, Ca, P, Cu, Zn, Si	mg/kg	Max.	free from	DIN EN 16476
Polycyclic aromatic hydrocarbons	% (m/m)	Max.	20	DIN EN 12916

Table 118: Requirements for diesel fuel

Remarks:

[1)] The fuel must be suitable for the intended application. It must not contain any substance in a concentration that causes additional air pollution, is harmful for personnel, jeopardises ship safety and/or has an adverse effect on machine performance. The fuel must be free from non-ferrous metals according to DIN EN 16476. The fuel must not contain any waste oil.

[2)] Always refer to the currently applicable edition.

[3)] Specific requirements of the injection system must be taken into account

[4)] Independent of the maximum permissible sulphur content, local laws and regulations must be adhered to

[5)] Additional requirements (e.g. SOLAS) must be observed. Applicable laws must be adhered to.

[6)] Determined at 10% distillation residue

[7)] The FAME must either be in accordance with EN 14214 or with ASTM D6751 as well as with increased oxidation stability of at least 8 hours (EN 15751).

[8)] If there is more than 2% (V/V) FAME, an analysis as per EN 15751 must additionally be carried out

[9)] If the sample is not clear and bright, complete sedimentation through hot filtration and the determination of water content is required

[10)] 10 °C below the lowest temperature in the fuel system

The following fuels are approved for use if the fuel complies with table Requirements for diesel fuel, Page 254:

- Classes ISO F-DMA & DMZ according to ISO 8217:2024
- Class ISO F-DFA & DFZ according to ISO 8217:2024
- Diesel fuel according to EN 590:2022
- Diesel fuel no. 2-D as per ASTM D975-21 with additional requirement regarding flashpoint ≥ 60°C in SOLAS regulated areas.

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Viscosity

In order to ensure sufficient lubrication, a minimum level of viscosity must be ensured at the fuel injection pump. The specified maximum temperature required to maintain a viscosity of more than 1.9 mm^2/s upstream of the fuel injection pump depends on the fuel viscosity. The temperature of the fuel upstream of the fuel injection pump must not exceed 50°C in any case. The lubricity requirement for the fuel upstream of the engine is a maximum of 520 µm WSD in each case according to ISO 12156-1.

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.

Analyses

The examination of fuel samples is essential for safe engine operation. Examinations can be carried out in the Everllence PrimeServLab laboratory for our customers.

To guarantee the safety of the crew and to obtain a representative sample, sampling must take place in accordance with valid Everllence operating instructions.

4.7 Residual fuel (HFO) specification

General information

Four-stroke diesel engines from Everllence can be powered with any residual fuel recovered from crude oil that fulfils the requirements specified in the table Residual fuel requirements, Page 257, provided that the engine and the fuel management system are designed accordingly. It is also referred to as: Residual fuels (RM), FAME Residual fuels (RF). In order to ensure a favourable ratio between fuel costs, spare parts and also repair and servicing expenditure, we recommend observing the following points.

Selection of suitable 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 influences the emissions behaviour of the engine.

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Specifications and approvals

The fuel quality varies regionally and depends on climatic conditions. All requirements from ISO 8217:2024 apply

The following values must be maintained at the engine inlet:

Property	Unit		Limit value[1)]	Standard[2)]
Kin. viscosity at 50° C[3)]	mm/s	Max. Min.	700 1.9	EN ISO 3104, ASTM D7042, ASTM D445, DIN EN 16896
Kin. viscosity at 100°C[3)]	mm/s	Max.	55	EN ISO 3104, ASTM D7042, ASTM D445, DIN EN 16896
Density at 15°C	kg/m^3	Max.	1010	ISO 3675, ISO 12185
Water content[4)]	% (m/m)	Max.	0.20	DIN 51777, ASTM D6304, DIN ISO 3733
Sulphur content[5)]	% (m/m)	Max.	5.0	ISO 8754, ISO 14596, ASTM D4294
Flashpoint[6)]	°C	Min.	60.0	ISO 2719
Acid number	mg KOH/g	Max.	2.5	ASTM D664
Carbon residue (CCR)	% (m/m)	Max.	20.0	EN ISO 10370
Ash content	% (m/m)	Max.	0.150	ISO 6245
Hydrogen sulphide	mg/kg	Max.	2.0	IP 570
Total sediment (aged)	% (m/m)	Max.	0.10	ISO 10307-2
Asphaltene content	% (m/m)	Max.	2/3 x CCR	Factory standard, DIN 51595
Fatty acid methyl ester content[7)]	% (m/m)		Report	ASTM D7963, IP 631, DIN EN 14078, DIN EN 14103
Pour point[8)]	°C	Max.	30	ISO 3016
Vanadium	mg/kg	Max.	450	IP 501, IP 470, ISO 14597, DIN EN 15944 DIN 51790-6
Sodium	mg/kg	Max.	100 and 1/3 x vanadium	IP 501, IP 470
Aluminium and silicone[9)]	mg/kg	Max.	15	IP 501, IP 470, DIN ISO 10478
Calcium Zinc	mg/kg mg/kg	Max. Max.	30 15	IP 501, IP 470
Calcium Phosphorus	mg/kg mg/kg	Max. Max.	30 15	IP 501, IP 470, IP 500
CCAI[10)]		Max.	870	

Table 119: Residual fuel requirements

Remarks:

[1)] Engine inlet requirement: Additional parameters defined for ISO 8217. The entire ISO 8217:2024 document is mandatory. The fuel mixture at the engine inlet must be homogeneous. The fuel mixture is homogeneous if the p-value according to ASTM D7060 is at min. 1.20. Other processes (e.g. ASTM D7112 or ASTM D7157) can also be used to check the homogeneity of the fuel mixture. Furthermore, the fuel must be

fit for use and must not contain substances in a concentration that contributes to further contamination of the air and/or may impair the safety of personnel or the performance of the machine.

[2] Always reference the latest edition.

[3] If FAME is present in the HFO (RF), the max. viscosity is limited to 500 mm2/s at 50°C.
Specific requirements of the injection system must be taken into account.

[4] According to ISO 8217:2024, the bunker product (before purification) may contain max. 0.50% water.

[5] Local laws and regulations must be observed independently of the maximum possible sulphur content.

[6] Additional requirements (e.g. SOLAS) must be observed. Applicable laws must be adhered to.

[7] When using RF (FAME according to EN 14214 or ASTM D6751* and their mixtures with HFO), prior consultation with Everllence is required.
The FAME must either be in accordance with EN 14214 or with ASTM D6751 as well as with increased oxidation stability of at least 8 hours (EN 15751). For additional information see FAME mixtures, Page 264.

[8] The pour point must be suitably selected by the operating company in accordance with the design of the fuel system and on the basis of the requirements at the place of use.

[9] The bunker product (prior to purification) may contain max. 60 mg/kg Al and Si.

[10] This method is only applicable to 'straight run' residual oils. The increasing complexity of refinery processes means that the CCAI method does not correctly reproduce the ignition behaviour for all residual oils. A test device (fuel combustion analyser; FCA) based on the constant volume combustion method measures the ignition delay to determine the ignition quality of a fuel and this measurement is converted into the cetane number (ECN: Estimated Cetane Number). It was discovered that residual fuels with a low ECN number cause malfunctions and can even lead to engine damage. An ECN > 20 can be considered acceptable.

Please submit enquiries to Everllence for all fuels which do not meet the abovementioned standards.

Residual fuel (HFO)

Origin/refinery process

The quality of the residual fuel depends to a large extent on the quality of the crude oil and the refining process used. For this reason, residual fuels of the same viscosity can have significantly different properties depending on the bunker spaces. Residual fuel can consist of a mixture of residual oil, distillates and FAME. Residual oils and distillates generally originate from modern refining processes, such as CatCracker or Visbreaker. These processes can have an adverse affect on the stability of the fuel and on the ignition and combustion properties. These factors also have a considerable effect on the preparation of the residual fuel and the operating results of the engine.

The engine operator is responsible for selecting the corresponding residual fuels.

Important

The fuel properties in the table Residual fuel requirements, Page 257, even if they meet the requirements mentioned there, may not be sufficient to determine the ignition and combustion properties and stability of the fuel. This means that the operational performance of the engine may depend on properties that

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are not defined in the specification. This particularly applies to the oil property that causes formation of deposits in the combustion chamber, injection system, gas pipes and exhaust system. A number of fuels have a tendency towards incompatibility with lubricating oil which leads to deposits being formed in the fuel injection pump that can cause a blockage of the pumps. It may therefore be necessary to exclude specific fuels that could cause problems.

Blends

The addition of engine oils (old lubricating oil, ULO – used lubricating oil) and additives that are not manufactured from mineral oils, (coal-tar oil, for example), and residual products of chemical or other processes such as solvents (polymers or chemical waste) is not permitted. Some of the reasons for this are as follows: abrasive and corrosive effects, unfavourable combustion characteristics, poor compatibility with mineral oils and, last but not least, adverse effects on the environment. The order for the fuel must expressly state what is not permitted as the fuel specifications that generally apply do not include this limitation.

If engine oils (old lubricating oil, ULO – used lubricating oil) are added to fuel, this poses a particular danger as the additives in the lubricating oil act as emulsifiers that cause dirt, water and catfines to be transported as fine suspension. They therefore prevent the necessary cleaning of the fuel. In our experience (and this has also been the experience of other manufacturers), this can severely damage the engine and turbocharger components.

The addition of chemical waste products (solvents, for example) to the fuel is prohibited for environmental protection reasons according to the resolution of the IMO Marine Environment Protection Committee passed on 1st January 1992.

Leak oil collector

Leak oil collectors that act as receptacles for leak oil, and also return and overflow pipes in the lube oil system, must not be connected to the fuel tank. Leak oil lines should be emptied into sludge tanks.

Please submit enquiries to Everllence for all fuels which do not meet the abovementioned standards.

Additional information

The following information will clarify the correlation between the quality of the residual fuel, fuel preparation, engine operation and the operating results.

Viscosity/injection viscosity

Residual fuels with higher viscosity can be of lower quality. The maximum permissible viscosity depends on the available pre-heating equipment and the capacity (flow rate) of the separator.

The prescribed injection viscosity of 12-14 mm^2/s and the corresponding fuel temperature upstream of the engine must be complied with. Only in this way can a suitable atomisation and mixture formation be ensured and therefore low-residue combustion. This also prevents mechanical overload of the injection system at the same time. The prescribed injection viscosity and/or the required fuel oil temperature upstream of the engine can be found in the viscosity temperature diagram.

Residual fuel preparation

Fault-free engine operation depends to a considerable extent on the care with which the residual fuel was prepared. Particular attention should be paid to ensuring that inorganic foreign matter with a strongly abrasive effect (catalyst particles, rust, sand) are effectively separated. It has been shown in practice that wear as a result of abrasion in the engine increases considerably if the aluminium and silicon content is higher than 15 mg/kg.

Viscosity and density have an influence on the cleaning effect. This must be taken into account when designing and installing the cleaning system.

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Vanadium/Sodium	If the vanadium/sodium ratio is unfavourable, the melting point of the ash may fall in the operating area of the exhaust valve which can lead to high-temperature corrosion. Most of the water and water-soluble sodium compounds it contains can be removed by pre-treating the residual fuel in the settling tank and in the separators. The risk of high-temperature corrosion is low if the sodium content is one third of the vanadium content or less. It must also be ensured that sodium does not enter the engine in the form of seawater in the intake air. If the sodium content is higher than 100 mg/kg, this is likely to result in a higher quantity of salt deposits in the combustion chamber and exhaust-gas system. This will impair the function of the engine (including the suction function of the turbocharger). Under certain conditions, high-temperature corrosion can be prevented using a fuel additive that increases the melting point of residual fuel ash (see also Residual fuel (HFO) specification, Page 263).
Ash	Fuel ash consists for the greater part of vanadium oxide and nickel sulphate (see above chapter for more information). Residual fuel containing a high proportion of ash in the form of foreign matter, e.g. sand, corrosion compounds and catalyst particles, accelerates the mechanical wear in the engine. Catalyst particles produced as a result of the catalytic cracking process may be present in the residual fuel. In most cases, these catalyst particles are aluminium silicates causing a high degree of wear in the injection system and the engine.
Flashpoint	National and international regulations for transport and storage involving the use of fuel must be considered in regard to the flashpoint. In general, a flashpoint of above 60 °C is specified for fuels of diesel engines.
Low-temperature performance	The pour point is the temperature at which the fuel can no longer flow (but can be pumped). Since many residual fuels with low viscosity have a pour point above 0°C, the bunker facility must also be pre-heated. The entire fuel system must be designed in such a way that the residual fuel can be pre-heated to around 10°C above the pour point.
Pump properties	If the viscosity of the fuel is higher than 700 mm^2/s (cSt), or the temperature is not at least 10°C above the pour point, pump problems will occur. For more information, also refer to section Low-temperature behaviour.
Combustion properties	If the proportion of asphaltene is more than two thirds of the coke residue (Conradson), combustion may be delayed which in turn may increase the formation of combustion residues, leading to such as deposits on and in the injection nozzles, large amounts of smoke, low output, increased fuel consumption and a rapid rise in ignition pressure as well as combustion close to the cylinder wall (thermal overloading of lubricating oil film). If the ratio of asphaltenes to coke residues reaches the limit 0.66, and if the asphaltene content exceeds 8%, the risk of deposits forming in the combustion chamber and injection system is higher. These problems can also occur when using unstable residual fuels, or if incompatible residual fuels are blended. This would lead to an increased separation of asphalt (see section Compatibility, Page 263).
Ignition quality	Nowadays, to achieve the prescribed reference viscosity, cracking-process products are used as the low viscosity ingredients of residual fuels although the ignition characteristics of these may also be poor. The cetane number of these compounds should be > 35. If the proportion of aromatic hydrocarbons is high (more than 35%), this also adversely affects the ignition quality.

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The ignition delay in residual fuels with poor ignition characteristics is longer, the combustion is also delayed which can lead to thermal overloading of the oil film at the cylinder liner and also high cylinder pressures. The ignition delay and accompanying increase in pressure in the cylinder are also influenced by the end temperature and compression pressure, i.e. by the compression ratio, the charge-air pressure and charge-air temperature.

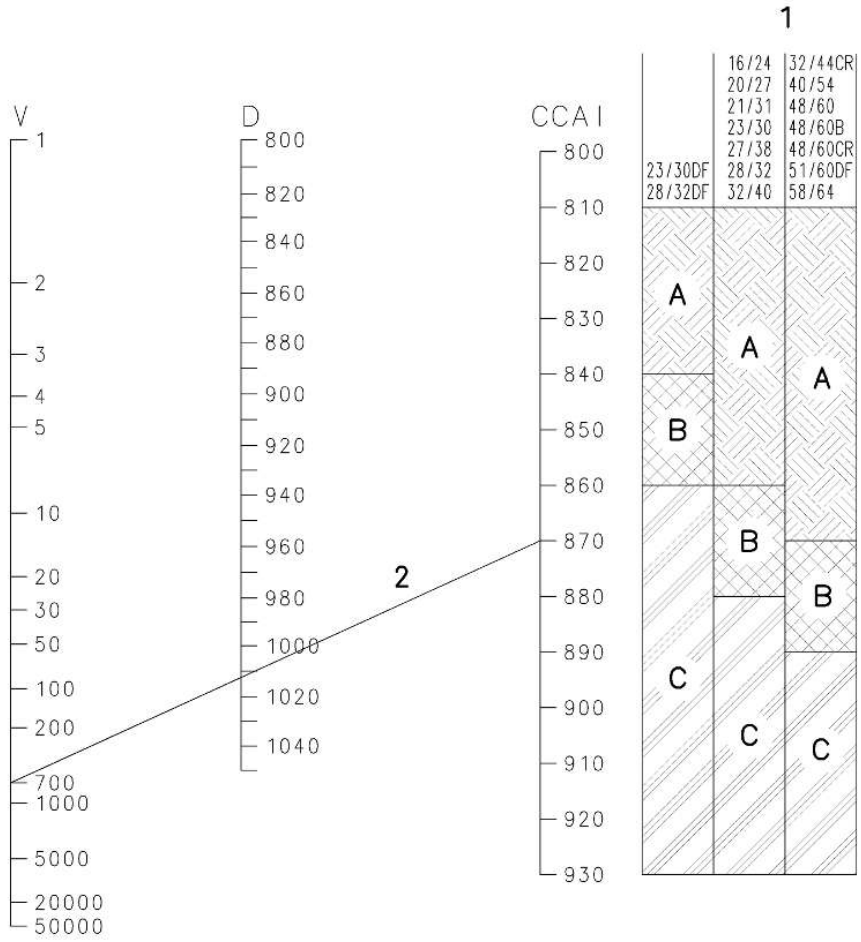
The disadvantages of using fuels with poor ignition characteristics can be limited by pre-heating the charge air in partial load operation and reducing the output for a limited period. However, a more effective solution is a high compression ratio and operational adjustment of the injection system to the ignition characteristics of the fuel used, as is the case with Everllence.

The ignition quality is one of the most important properties of the fuel. This value appears as CCAI in ISO 8217. This method is only applicable to 'straight run' residual oils. The increasing complexity of refinery processes has the effect that the CCAI method does not correctly reflect the ignition behaviour for all residual oils.

A test instrument based on the Fuel Combustion Analyser (FCA) method has been developed, which is used in some fuel testing laboratories (FCA according to IP 541).
The ignition quality of a fuel is determined as the ignition delay in the instrument and converted into an instrument-dependent cetane number (ECN: Estimated Cetane Number). It has been determined that residual fuels with a low ECN number cause operating problems and may even lead to damage to the engine. An ECN > 20 can be considered acceptable.

As the liquid components of the residual fuel have a decisive influence on the ignition quality, and flow properties determine the combustion quality, the system operator is responsible for obtaining a fuel that is suitable for the diesel engine. Also see illustration entitled Nomogram for determining the CCAI – assigning the CCAI ranges to engine types, Page 262.

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V Viscosity in mm^2/s (cSt) at 50°C

D Density [in kg/m^3] at 15°C

CCAI **C**alculated **C**arbon **A**romaticity **I**ndex

1 Engine type

A Normal operating conditions

B The ignition characteristics can be poor and require an adjustment to the engine or the operating conditions.

C Any problems identified can even lead to engine damage after a short operating period.

2 The CCAI is calculated from the density and viscosity of the residual fuel.

The CCAI can be calculated with the help of the following formula:

$$CCAI = D - 141 \log \log (V+0.85) - 81$$

Figure 103: Nomogram for determining the CCAI and assigning the CCAI ranges to engine types

Sulphuric acid corrosion

The engine should be operated at the coolant temperatures prescribed in the operating handbook for the relevant load. If the temperature of the components that are exposed to acidic combustion products is below the acid dew point, acid corrosion can no longer be effectively prevented, even if alkaline lube oil is used.

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Stability

The fuel must be a homogeneous mixture when entering the engine. Precipitation of any fuel components is not permissible! Experience has shown that stability decreases with continued storage and the given conditions. It is hence of great interest to the operator that the fuel has the maximum possible stability reserve so that it can provide a homogeneous fuel mixture at all times when entering the engine (see table Residual fuel requirements).

Compatibility

The supplier must guarantee that the residual fuel is homogeneous and remains stable even after the usual storage time. If different bunker oils are mixed, this may lead to separation that is connected with sludge build-up in the fuel system and where large quantities of sludge can be deposited in the separator, clog up the filter, prevent atomisation and lead to residue-rich combustion.

Cases like this can be traced back to incompatibility or instability. The fuel storage tanks should therefore be drained as much as possible before they can be bunkered again, in order to avoid incompatibilities.

Contamination

The fuel must not contain any substances that can lead to instability or deposits, otherwise engine operation may be impaired or engine damage may occur. With the help of an analysis according to ASTM D7845 (GC-MS), such substances can be partially detected and analysed. The fuel should be free of all substances listed in ASTM D7845, or their concentration should be below the limit of quantification noted therein. Proportions above the limit of quantification of all substances listed in ASTM D7845 can cause problems in engine operation. The combination of different substances could also cause problems with the engine even in a small amount.

Mixing residue fuels

If residual fuel for the main engine is blended with distillate fuel (e.g. DMA, FAME) or other residual fuels, to obtain the required quality, it is essential that the components are compatible (see section Compatibility, Page 263). The compatibility of the resulting mixture must be tested over the entire mixing range. Reduced long-term stability due to consumption of the stability reserve can be a result. If a mixture of different fuels is planned or unavoidable, the stability reserve of the fuel must be sufficient to ensure that non-homogeneous fuels are not produced when blending.

Mixture with synthetic fuel

We strongly advise against using a mixture of HFO and synthetic fuel (in accordance with EN 15940). The reason is that the HFO contains asphaltenes, which are held in solution by the aromatics contained in HFO. Synthetic fuel is purely paraffinic (does not contain any aromatics) and therefore cannot hold asphaltenes in solution. This means that when synthetic fuel is added to HFO, these aromatics precipitate, deposits form or fuel filters become clogged or, in the worst case scenario, the injection system fails.

Additives for residual fuels

Everllence-Engines can also be economically operated without additives. It is up to the customer to decide whether or not the use of additives is beneficial. The supplier of the additive must guarantee that the engine operation will not be impaired by using the product.

As a rule, the use of fuel additives during the warranty period must be avoided.

If the lubrication oil quality and the engine cooling system fulfil the specified requirements, the BN values stated in section 010.005 Engine – Operating Instructions 010.000.023-11 are sufficient.

Residual fuels with low sulphur content

From the perspective of an engine manufacturer, there is no lower threshold for the sulphur content of residual fuel. We have not identified any issues that can be traced to the sulphur content with the low-sulphur residual fuels that are currently commercially available.

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If the engine is not constantly operated with low-sulphur residual fuel, the lubricating oil must be selected accordingly for the highest sulphur content of the utilised fuels.

FAME mixtures

FAME admixtures (RF20 to RF500)

When using RF (FAME according to EN 14214 or ASTM D6751* and their mixtures with HFO), prior consultation with Everllence is required. In addition, the following should be observed:

- The fuel mixture at the engine inlet must be homogeneous. The fuel mixture is homogeneous if the p-value according to ASTM D7060 is at least 1.20. Other processes (e.g. ASTM D7112 or ASTM D7157) can also be used to check the homogeneity of the fuel mixture. Furthermore, the fuel must be fit for use and must not contain substances in a concentration that contribute to further contamination of the air and/or may impair the safety of personnel or the performance of the machine.
- If RF is to be used with other fuels and blending cannot be avoided, contact your fuel supplier to ensure the compatibility of these fuels.
- After switching to RF, pay attention to the delta pressure indicators/alarms of the filters, as they can become clogged by residues dissolved by RF.
- Heating is installed and active in the fuel supply system to prevent deposits or blockages to the pipes.
- The temperature resistance of the fuel must be guaranteed up to 150°C.
- Storage and leakage handling of FAME fuels, FAME mixtures with residual fuels and distillate fuels must be separated from each other in order to avoid incompatibility reactions due to the mixing of larger amounts of different fuels.
- Due to the typically lower calorific value or energy content of RF, it may result in deviations to the specified engine output, operating behaviour, load application, specific fuel consumption and emissions.
- Fuels may cause harmful reactions with metals such as zinc or copper. We highly recommend getting in contact with your tank and heating oil system supplier.
- The sealing materials used must be suitable for RF. NBR seals are not suitable and must not be used.
- RF reacts to air and this may lead to microbial growth. Ensure that the atmospheric oxygen ventilation is kept to a minimum. A nitrogen buffer is ideally installed in the fuel tank.
- RF tends to attract water. This increases the risk of microbial growth. Correctly adjust the separator to the new fuel type.
- If free water appears in the fuel tanks, it is important to drain this water immediately.
- Long standstill periods (e.g. emergency power units) must be avoided due to microbial growth. To prevent damage, it is recommendable to only operate applications with fuel which is free of FAME.
- The entire fuel system must be purged with fuel which is free of FAME prior to longer standstill periods.
- Since FAME has a higher evaporation temperature, it accumulates in the lubricating oil. Regular analysis of all the lubricating oil is highly recommended. The lubricating oil needs to be replaced if a FAME content of 12% is reached.

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- RF may cause a layer to form, such a phenomenon leads to increased consumption of lubricating oil. If such an increase in lubricating oil consumption values is detected, please contact your Everllence PrimeServ department.

In any case, it is the responsibility of the operating company to adhere to the legal requirements (e.g. SOLAS) and agree on these with the relevant authorities.

* as well as with increased oxidation stability of at least 8 hours (EN 15751).

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 standard:

- Pour point as per ISO 3016

Analyses

To ensure sufficient cleaning of the fuel via the separator, perform regular functional check by sampling up- and downstream of the separator.

The examination of fuel samples is essential for safe engine operation. Examinations can be carried out in the Everllence PrimeServLab laboratory for our customers.

To guarantee the safety of the crew and to obtain a representative sample, sampling must take place in accordance with valid Everllence operating instructions.

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4.8 Viscosity-temperature diagram (VT diagram)

Explanations of viscosity-temperature diagram

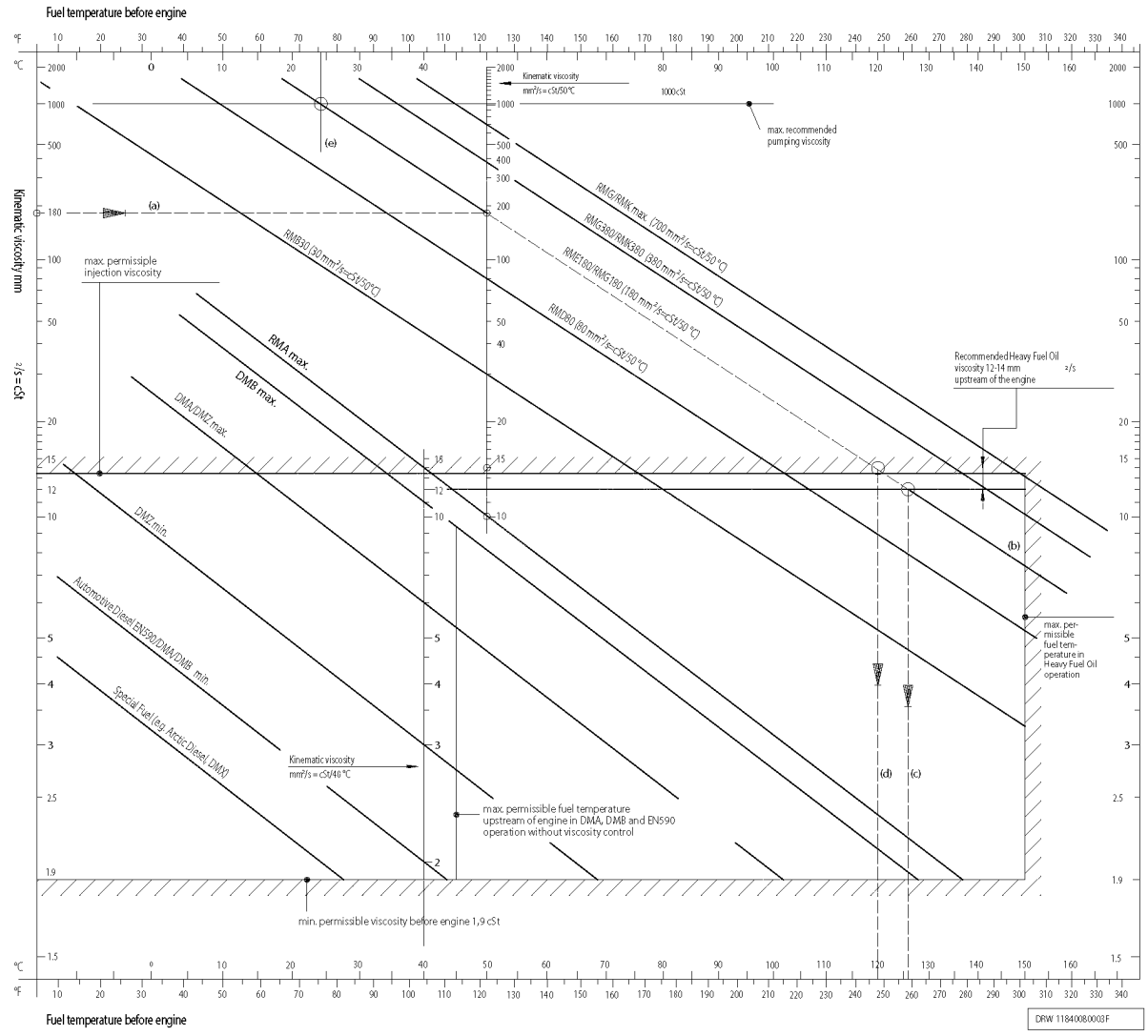


Figure 104: Viscosity-temperature diagram (VT diagram)

In the diagram, the fuel temperatures are shown on the horizontal axis and the viscosity is shown on the vertical axis.

The diagonal lines correspond to viscosity-temperature curves of fuels with different reference viscosities. The vertical viscosity axis in mm^2/s (cSt) applies for 40, 50 or 100 °C.

Determining the viscosity-temperature curve and the required preheating temperature

Example: resudual fuel with 180 mm^2/s at 50 °C

Prescribed injection viscosity in mm^2/s	Required fuel temperature at the engine inlet[1)] in °C
≥ 12	126 (line c)
≤ 14	119 (line d)

Prescribed injection viscosity in mm²/s	Required fuel temperature at the engine inlet[1] in °C
[1] For these figures, the temperature drop from the last pre-heating device to the fuel injection pump is not taken into account.	

Table 120: Determining the viscosity temperature trend and the required pre-heating temperature

Residual fuel with a viscosity of 180 mm^2/s at 50 °C can reach a viscosity of 1,000 mm^2/s at 24 °C (line e) – this is the maximum permissible viscosity of fuel that the pump can deliver.

A residual fuel discharge temperature of 152 °C is reached when using a recent state-of-the-art preheating device with 8 bar saturated steam. At higher temperatures there is a risk of residues forming in the preheating system – this leads to a reduction in heating output and thermal overloading of the residual fuel. Asphalt is also formed in this case, i.e. quality deterioration.

The residual fuel lines between the outlet of the last preheating system and the injection valve must be suitably insulated to limit the maximum drop in temperature to 4 °C. This is the only way to achieve the necessary injection viscosity of 14 mm^2/s for residual fuels with a reference viscosity of 700 mm^2/s at 50 °C (the maximum viscosity as defined in the international specifications such as ISO CIMAC or British Standard). If residual fuel with a low reference viscosity is used, the injection viscosity should ideally be 12 mm^2/s in order to achieve more effective atomisation to reduce the combustion residue.

The delivery pump must be designed for residual fuel with a viscosity of up to 1,000 mm^2/s. The pour point also determines whether the pump is capable of transporting the residual fuel. The bunker facility must be designed so as to allow the residual fuel to be heated to roughly 10 °C above the pour point.

Note:

The viscosity of gas oil or diesel oil (marine diesel oil) upstream of the engine must be at least 1.9 mm^2/s. If the viscosity is too low, this may cause seizing of the pump plunger or nozzle needle valves as a result of insufficient lubrication.

This can be avoided by monitoring the temperature of the fuel. Although the maximum permissible temperature depends on the viscosity of the fuel, it must never exceed the following values:

- 45 °C at the most with DMA and DMB

A fuel cooler must therefore be installed.

If the viscosity of the fuel is < 2 cSt at 40 °C, consult the technical service of Everllence in Augsburg.

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4.9 Specification of engine coolant

Preliminary remarks

The composition of the engine coolant is as follows: water to dissipate the heat and a coolant additive as corrosion protection.

Engine coolant, like fuel and lubricating oil, is a medium that must be carefully selected, treated and controlled. Otherwise, corrosion, erosion and cavitation can occur on the walls of the cooling system which are in contact with water and deposits can form. Deposits impede heat transfer and can lead to thermal overload of the parts to be cooled. Treatment with a corrosion inhib-

itor must be carried out before the initial commissioning of the system. During subsequent operation, the concentrations prescribed by the engine manufacturer must always be observed. This applies in particular when 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.	–
Total hardness	max. 10	dGH[1)]
pH value	6.5 – 8	–
Chloride ion content	max. 50	mg/l[2)]

Table 121: 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 manufacturers of anticorrosive agents supply user-friendly testing equipment.

For information on monitoring cooling water, see section Coolant inspecting, Page 272.

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. Subsequent hardening of extremely soft water is only necessary to prevent foaming if emulsifiable slushing oils are used.

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Damage to the cooling water 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 an anticorrosive agent to be 100 % effective, it is extremely important that untreated water satisfies the requirements in the paragraph Requirements, Page 268.

A list of currently approved coolant additives and their concentration can be found at Lubrication.

Additives for coolants

Only additives that have been approved by Everllence and are listed in the section Permitted coolant additives, Page 272 may be used.

In closed circuits only

Additives may only be used in closed circuits where no significant consumption occurs, apart from leaks or evaporation losses. Observe the applicable environmental protection regulations when disposing of coolant containing additives. For more information, consult the additive supplier.

Chemical additives

Sodium nitrite and sodium borate based additives etc. have a proven track record. Galvanised iron pipes or zinc sacrificial anodes must not be used in cooling systems. This corrosion protection is not required due to the prescribed coolant treatment and electrochemical potential reversal that may occur due to the coolant temperatures which are usual in engines nowadays. If necessary, the pipes must be deplated.

Slushing oil

The use of anti-corrosion oils in the cooling water circuit is not permitted for Everllence engines.

Antifreeze agents

If temperatures below the freezing point of water in the engine cannot be excluded, an antifreeze agent that also prevents corrosion must be added to the cooling system or corresponding parts. Otherwise, the entire system must be heated.

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Sufficient corrosion protection is achieved by adding the antifreeze additives listed under Permitted coolant additives, Page 272, whereby the prescribed minimum concentration must be observed. This concentration prevents freezing at temperatures as low as -22°C and ensures adequate corrosion protection. However, the amount of antifreeze actually required always depends on the lowest temperatures to be expected at the place of use.

Antifreezes are generally based on ethylene glycol. A suitable chemical corrosion inhibitor must be added if the concentration of antifreeze prescribed by the user for a particular application is not sufficient to achieve adequate corrosion protection or if a lower concentration of antifreeze is used than would be required for adequate corrosion protection due to less stringent antifreeze requirements. As the antifreeze agents listed under Permitted coolant additives, Page 272 also contain corrosion inhibitors that are not generally compatible with other anti-corrosion agents, only pure glycol may be used as antifreeze in these cases.

Simultaneous use of a nitrite-free coolant additive with glycol is not permitted, as it is no longer possible to monitor the concentration of the corrosion inhibitor in such a mixture.

Antifreeze reduces the ability of the coolant to absorb heat. In some cases, the cooling effect of the coolant is not sufficient for certain operating conditions. Everllence's standard configuration is not based on the use of antifreeze. If antifreeze is to be used, consult Everllence beforehand.

The cooling system must be thoroughly cleaned before antifreeze is used.

If the coolant contains emulsifiable slushing oil, antifreeze agent may not be added as otherwise the emulsion would break up and oil sludge would form in the cooling system.

Biocides

If the use of a biocide is unavoidable because the coolant has been contaminated by bacteria, the following steps must be observed:

- It must be ensured that a biocide suitable for the specific application is used
- The biocide is compatible with the sealing materials used in the coolant system and does not corrode them
- Neither the biocide nor its degradation products contain any corrosive components. Biocides whose decomposition products contain chloride or sulphate ions are not permitted
- Biocides that cause the coolant to foam are not permitted
- Biocides should not be used constantly, but only in a pulse dose

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 section Cooling water system cleaning).

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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 system

Treated coolant can become contaminated during operation and the additive can lose some of its effectiveness. It is therefore advisable to check the cooling system and the condition of the coolant regularly. To detect leaks in the lubricating oil system, regular checking of the water in the expansion tank is recommended. Signs of oil in the water include discoloration or a visible oil film on the surface of the water sample.

Check the additive concentration using the test kits provided by the additive manufacturer at least once per week. The results must be recorded.

Note:

The chemical additive concentrations shall not be less than the minimum concentrations specified. See paragraph Permitted coolant additives, Page 272.

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, a coolant sample must be sent to an independent laboratory or to the engine manufacturer for an integrated analysis.

If chemical additives or antifreeze agents are used, coolant should be replaced after 3 years at the latest.

If there are high concentrations of solids (rust), the water must be completely changed and the entire system must be carefully cleaned.

Deposits in the cooling system can be caused by liquids penetrating the coolant, the emulsion breaking up, corrosion in the system, and limescale deposits due to high water hardness. An increase in the content of chloride ions is generally an indication of seawater ingress. The specified maximum of 50 mg chloride ions per kg must not be exceeded, otherwise the risk of corrosion is too high. Exhaust gases entering the coolant can lead to a sudden drop in pH or an increase in sulphate content.

Water losses must be replenished using untreated water that meets the quality standards specified in the Requirements, Page 268 section. The corrosion inhibitor's concentration must then be checked and corrected if necessary.

Coolant checks are particularly necessary after repairs or maintenance work during which the coolant had to be drained.

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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.

Auxiliary engines

If the same cooling water system used in a Everllence two-stroke main engine is used in a marine engine of type 16/24, 21/ 31, 23/30H, 27/38 or 28/32H, the cooling water recommendations for the main engine must be observed.

Analyses

Everllence can carry out coolant analyses for our customers in the PrimeServLab chemical laboratory. A sample of 0.25 l is required for testing.

Permitted coolant additives

A list of currently approved coolant additives and their concentration can be found at Lubrication.

4.10 Coolant inspecting

Summary

Acquire and check typical values of the operating media to prevent or limit damage.

The freshwater 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

Devices for testing fresh water quality

The following can be used:

- The water test kit with all the necessary instruments and chemicals for determining water hardness, pH value and chloride content (available from Mar-Tec Marine, Hamburg).

Equipment for testing the concentration of additives

When using chemical additives:

- Testing equipment in accordance with the supplier's recommendations. Testing kits from the supplier also include equipment that can be used to determine the fresh water quality.

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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 122: 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 the concentration of rust inhibitors

Short specification

Anticorrosive agent	Concentration
Chemical additives	According to the quality specification, see section Specification of engine coolant, Page 267.
Anti-freeze agents	

Table 123: Concentration of coolant additives

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.

Chemical anti-corrosion agents can only provide effective protection if the concentration is precisely maintained. Respectively, the concentrations recommended by Everllence (quality specifications in section Specification of engine coolant, Page 267) must be maintained under all circumstances. These recommended concentrations may deviate from those specified by the manufacturer.

Testing the concentration of anti-freeze agents

The concentration must be checked in accordance with the manufacturer's instructions or the test can be outsourced to a suitable laboratory. If in doubt, consult Everllence.

Regular water samplings

Small quantities of lube oil in coolant can be found by visual check during regular water sampling from the expansion tank.

Testing

Regular analysis of coolant is very important for safe engine operation. We can analyse cooling water, fuel and lube oil for our customers at Everllence laboratory Everllence PrimeServLab.

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4.11 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	

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Properties	Limit	Unit [1]
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 124: 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.

4.12 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

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- 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.

- 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 room and application planning

5.1 3D Engine Viewer – A support programme to configure the engine room

Everllence 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 and the GenSet 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, respectively GenSet Viewer, register on our website under:

Everllence Extranet

After successful registration, the 3D Engine Viewer and the GenSet Viewer are available under:

3D Engine Viewer

3D GenSet Viewer

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 and the GenSet 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

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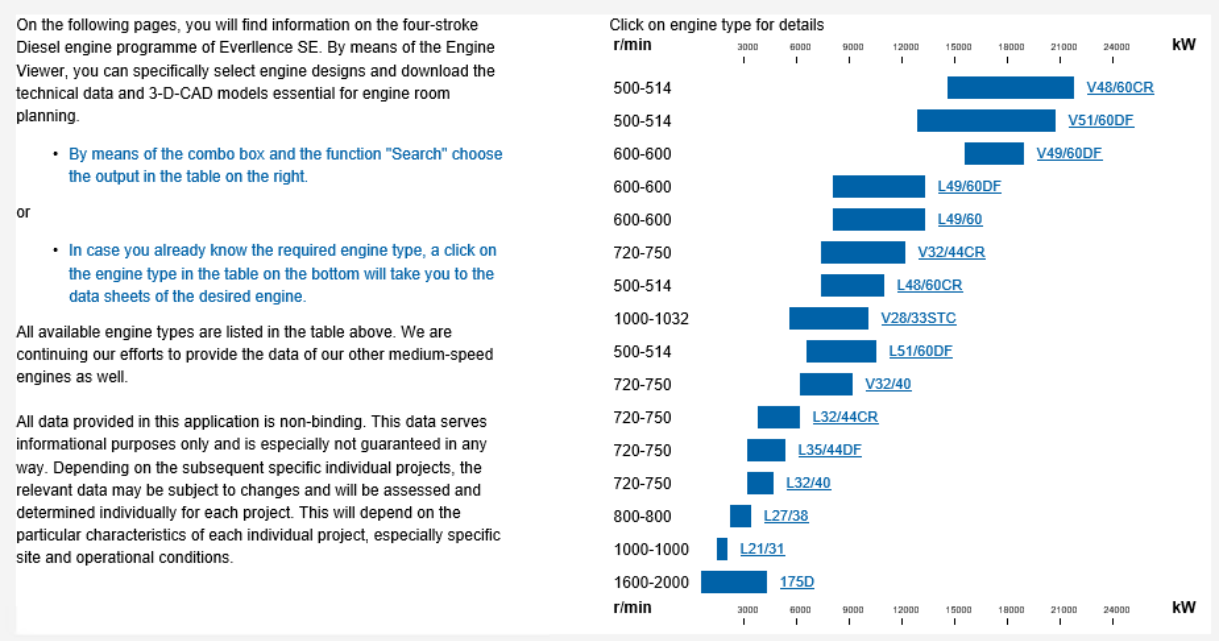


Figure 105: Selection of engine

5.2 Basic principles for pipe selection

5.2.1 External pipe dimensioning

The external piping systems are to be dimensioned, designed, installed and connected to the engine by the shipyard. The pipe systems should to be designed in such a way that the pressure losses are kept within reasonable limits. To achieve this at justifiable cost, 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 use higher flow rates.

For small pipes a low flow speed has to calculated, for bigger pipes (> DN 125) the higher values may be chosen.

	Recommended flow rates (m/s)	
	Suction side	Delivery side
Fresh water (cooling water)	1.0–2.0	1.5–3.0
Lube oil	0.5–1.0	1.5–2.5
Seawater	1.0–1.5	1.5–2.5
Diesel fuel	0.5–1.0	1.5–2.0
Residual fuel	0.3–0.8	1.0–1.8
Compressed air for control air system	-	2–10
Compressed air for starting air system	-	25–30 [1)]
Intake air	20–25	
Exhaust gas	40	

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	Recommended flow rates (m/s)	
	Suction side	Delivery side
[1] During engine start higher velocities acceptable, depends on total pressure loss of supply system.		

Table 125: Recommended flow rates

In addition to obtaining certain flow rates it is recommended to achieve an uniform inflow towards pumps. If disturbances in front of the pump cannot be avoided on the system side, the inflow musts be made uniform to a permissible level. This can be achieved, amongst other things, by a sufficiently long straight pipe section (approx. 5 to 8 times the nominal diameter DN between the pump and the point of interference), bends with a large radius of curvature, as well as other measures.

Bends have to be carried out using radius 1.5 x DN or higher. Sharp angles or other installations that may cause cavitation are to be avoided.

5.2.2 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, carbon steel pipe should be used; stainless steel shall be used where necessary.
- Outer surface of carbon 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 Everllence 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- and nozzle 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

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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

5.2.3 Installation of flexible pipe connections

Arrangement of hoses on engine

Flexible pipe connections are 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.

The engine´s movement on its foundation is caused by the engine´s rotation and torque itself as well as by rolling and pitching of the ship. Based on roll angles of +/- 22.5° and pitching of +/- 7.5° (according to prescriptive rules of classification societies) the excursions at the exhaust gas outlet can be up to 5 mm in X-, 25 mm in Y- and 6 mm in Z-direction. As the exhaust gas outlet is at the highest point of the engine the excursions at lower positions are smaller respectively. In order to obtain exact data on excursions at certain points, a project-specific calculation of the elastic engine mount is required.

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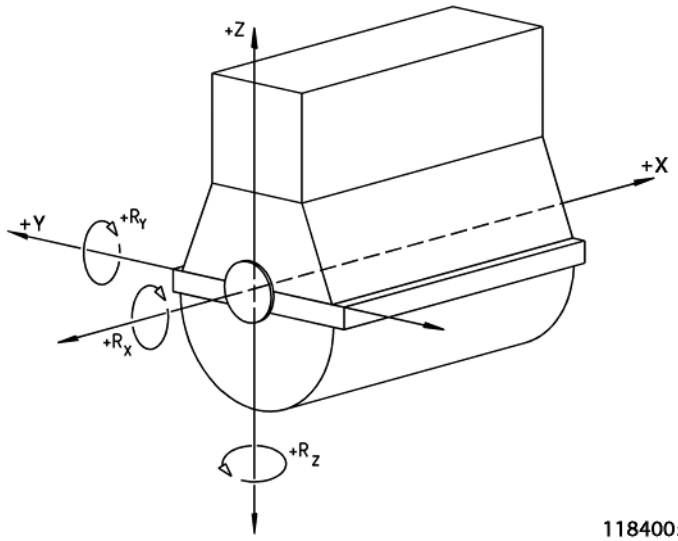


Figure 106: Coordinate system

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 Everllence 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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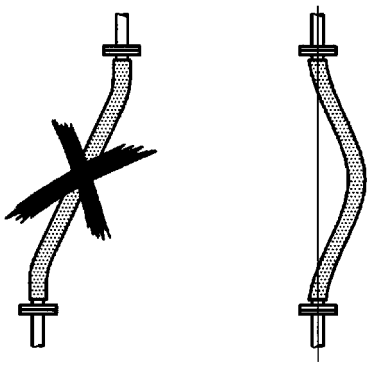


Figure 107: Arrangement of pipes in system

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.

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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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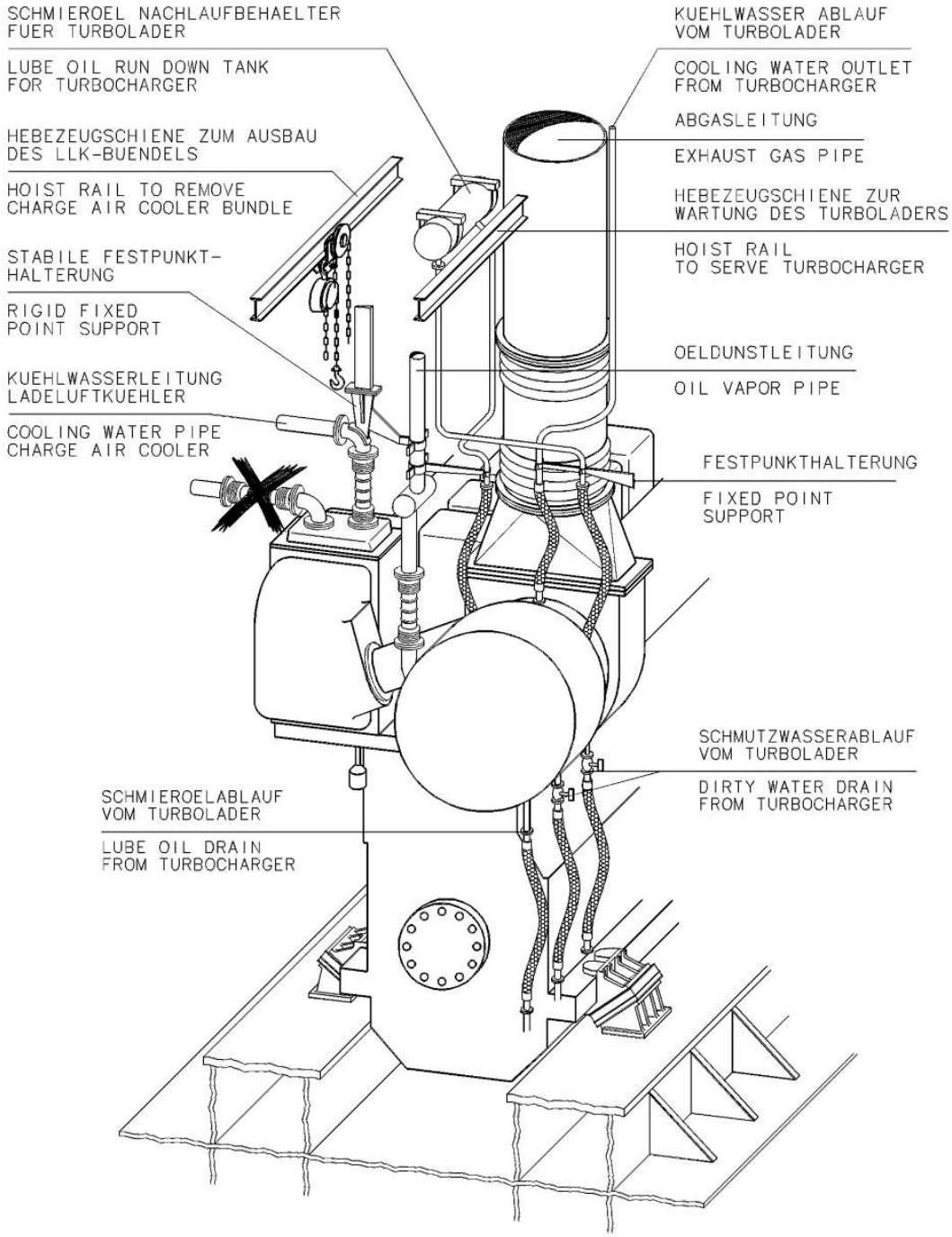


Figure 108: Installation of hoses

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5.2.4 Condensate amount in charge air pipes and air vessels

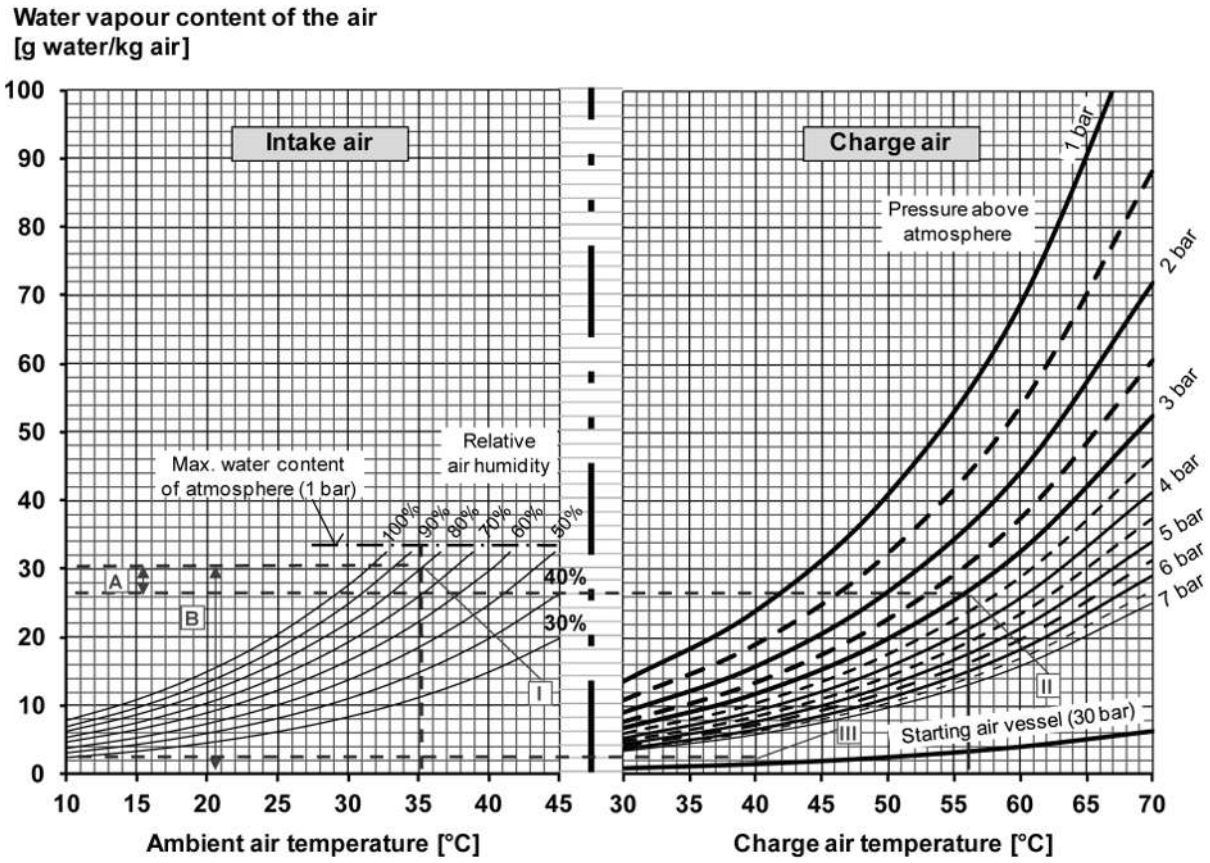


Figure 109: Diagram condensate amount

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 285 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 100 is shown as absolute pressure.

At both points of intersection read out the values [g water/kg air] on the vertically axis.

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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 285. 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 30 bar curve (see figure Diagram condensate amount, Page 285) 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		
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 126: Example how to determine the amount of water accumulating in the charge air pipe

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Example how to determine the condensate amount in the starting air receiver

Parameter	Unit	Value
Volumetric capacity of tank (V)	litre m^3	3,500 3.5
Temperature of air in starting air receiver (T)	°C K	40 313
Air pressure in starting air receiver ($p_{above\ atmosphere}$) Air pressure in starting air receiver ($p_{absolute}$)	bar bar abs $\frac{N}{m^2}$	30 31 31×10^5
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: $m = \frac{p \times V}{R \times T} = \frac{31 \times 10^5 \times 3.5}{287 \times 313} = 121\,kg$		
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 (III)	kg of water/kg of air	0.002
The difference between (I) and (III) is the condensed water amount (B) B = I – III B = 0.030 – 0.002 = 0.028 kg of water/kg of air		
Total amount of condensate in the vessel (Q_B) Q_B = m x B Q_B = 121 x 0.028 = 3.39 kg		

Table 127: Example how to determine the condensate amount in the starting air receiver

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5.3 Media interfaces

The following presentation of the media connection numbers is for orientation only.

Final drawings will follow as part of the project-specific execution.

Be aware that distinct media connection numbers are linked to optional engine features only.

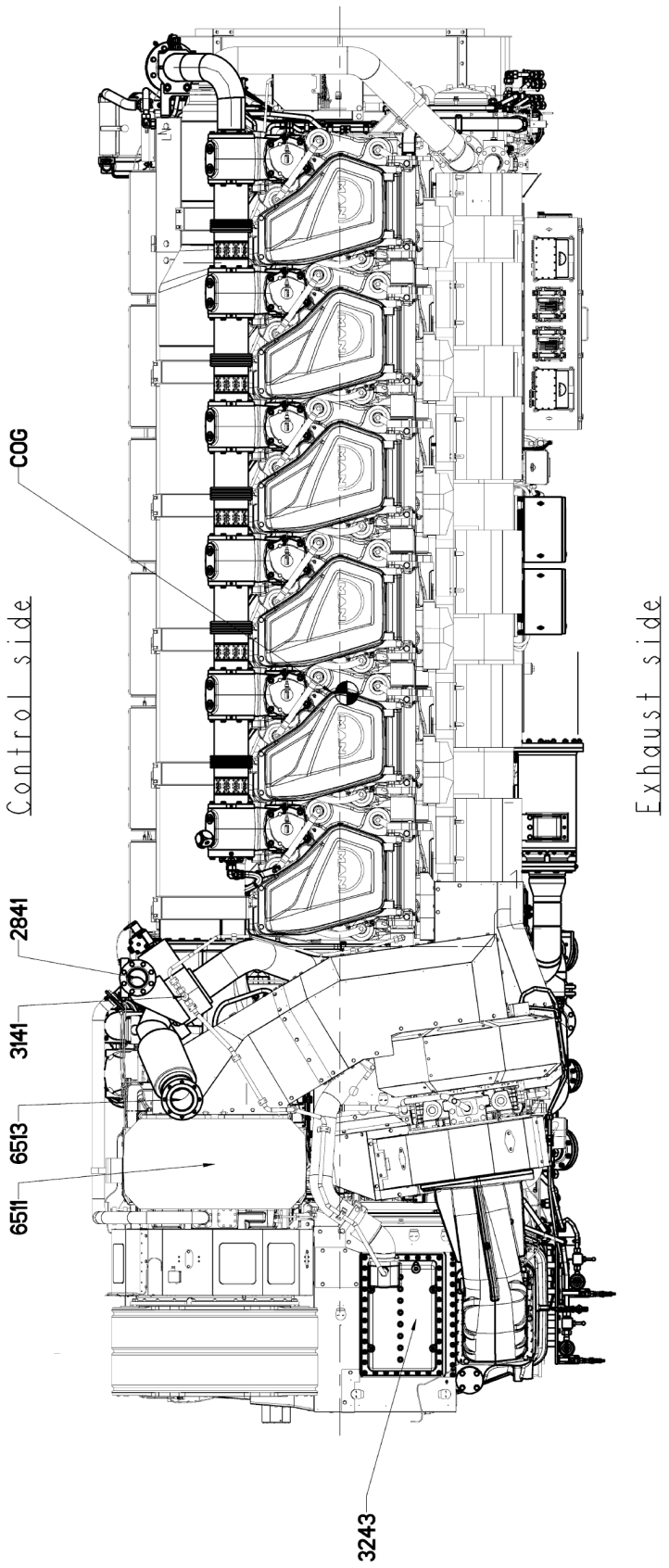


Figure 110: Media interfaces exemplary, top view

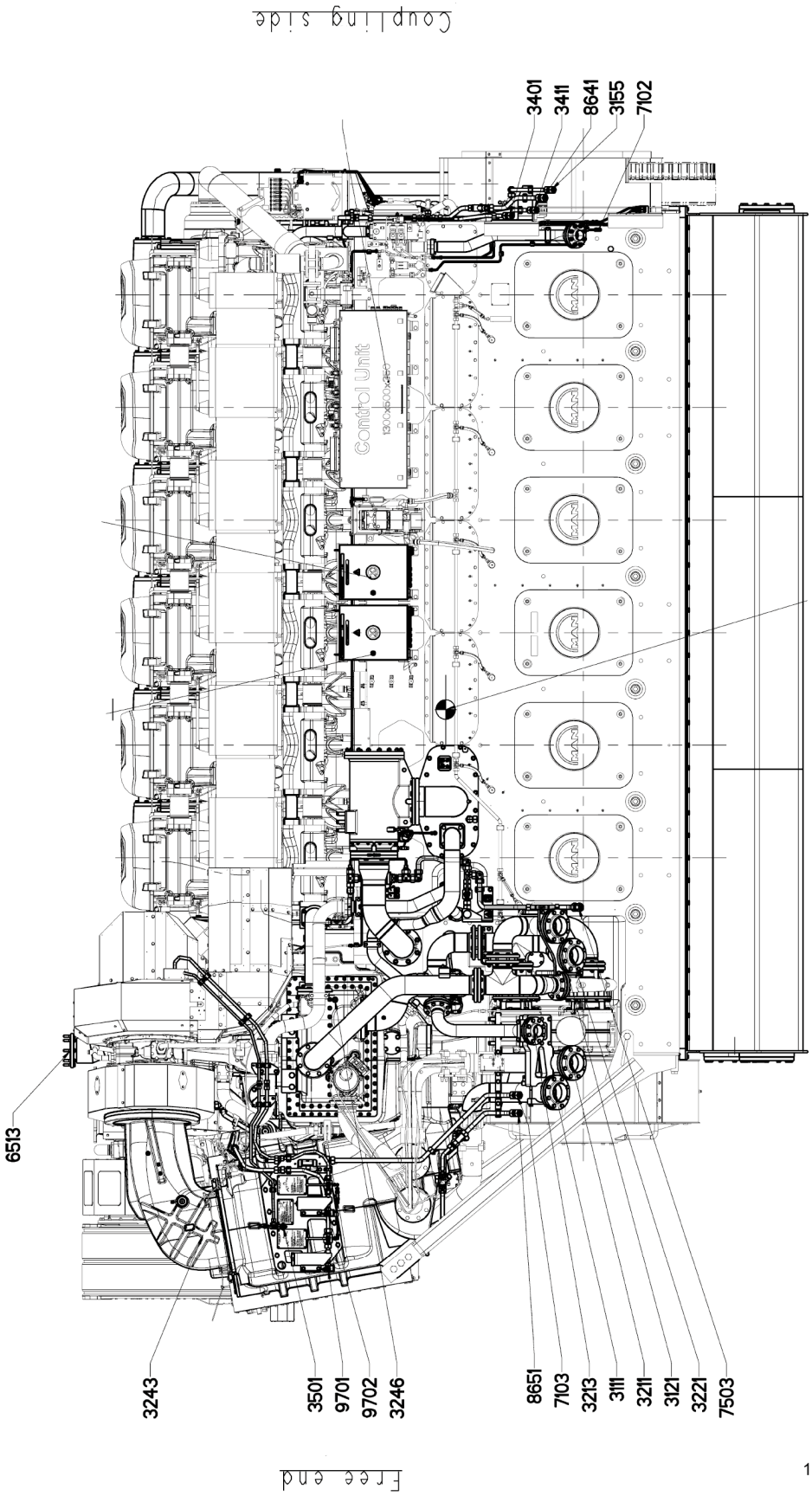


Figure 111: Media interfaces exemplary, exhaust side

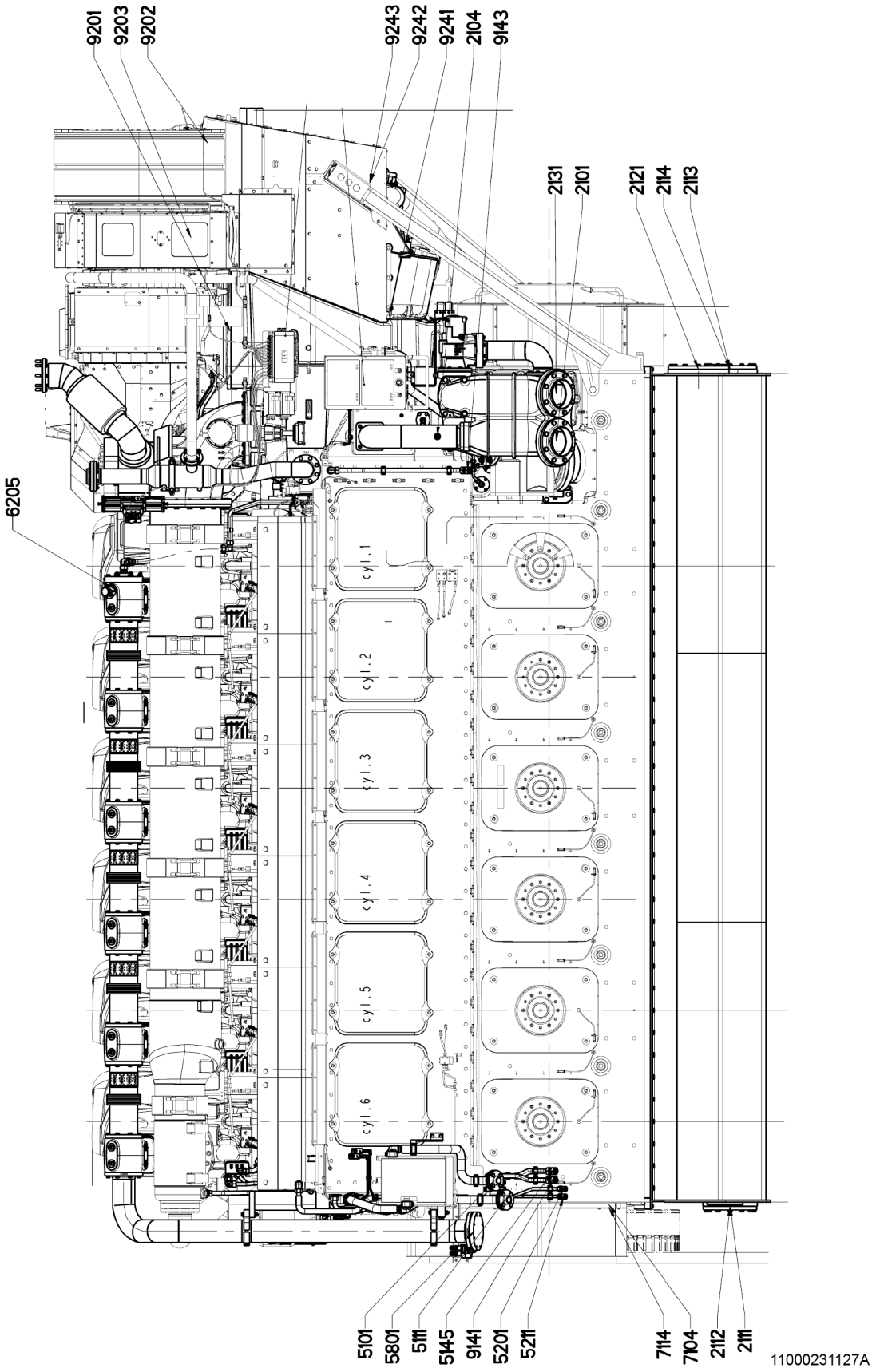


Figure 112: Media interfaces exemplary, control side

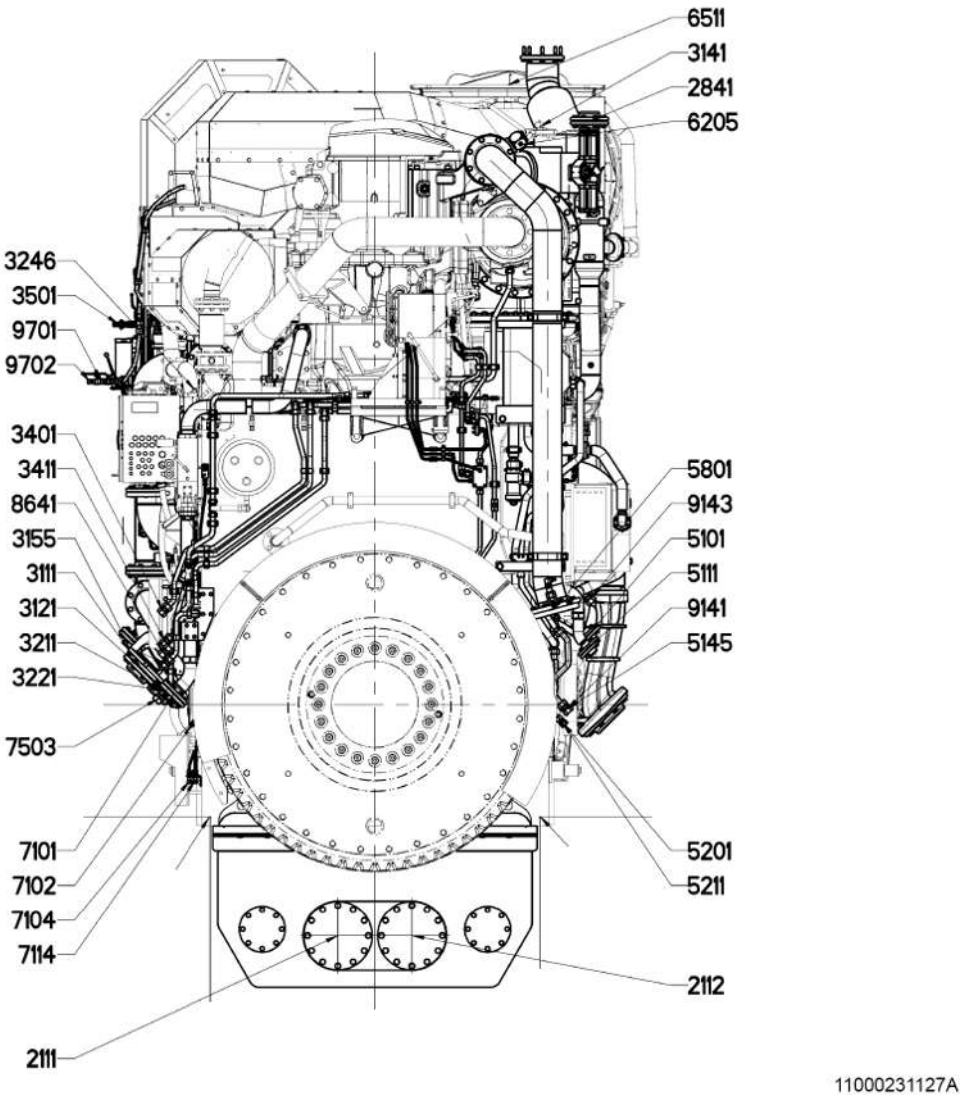


Figure 113: Media interfaces exemplary, coupling side

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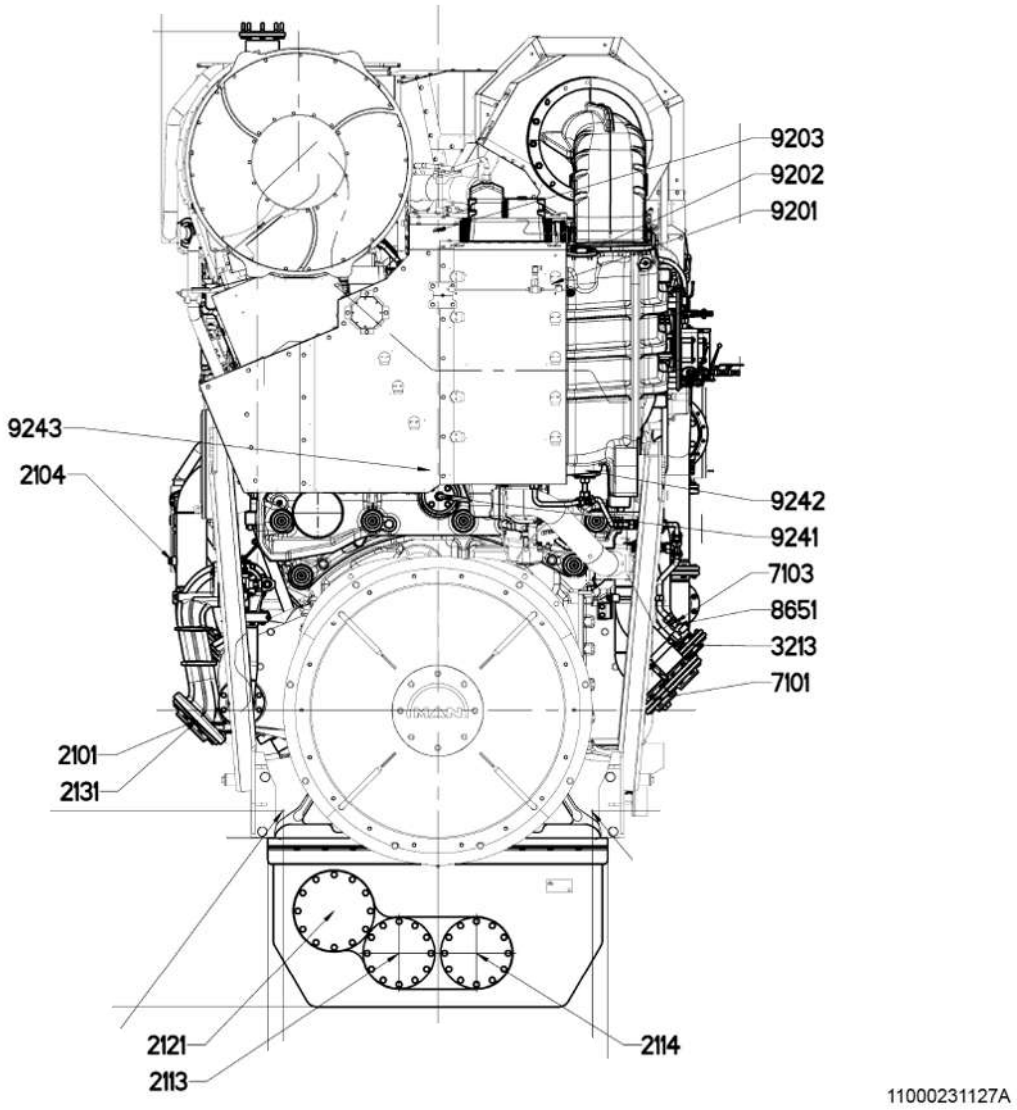


Figure 114: Media interfaces exemplary, coupling side (above), free end

Figure 115: Connections

Werftanschluesse am Motor shipyard connections on engine										
Anschluss Nr. connection no.	X	Y	Z	Benennung description	Anschlussteil am Motor connection part on engine	Anschlussteil zur Anlage connection part on plant	Rohrabmessung pipe dimension	Flussrichtung flow direction	Anschlussseite Connection side	Kommentar Comment
2101	-1320	-50	918	Schmieröleintritt in Motor lube oil inlet to engine	DIN EN 1092-1 11 B1/DN200/PN10 EN-GJS-400-15	DIN EN 1092-1 11 B1/DN200/PN10 St	DIN EN 10220 Ø219.1x6.3	Eintritt Inlet	Kupplungsgegenseite free end	
2104	-1463	824	955	Schmieröleintritt in Motor für provisorische Vorschmierung lube oil inlet to engine for provisional lubrication	R575 AG 1 St	DIN 910 G1 A (Screw plug) St		Eintritt Inlet	Kupplungsgegenseite free end	Connected not piped
2111	213	-1335	-4725	Schmierölaustritt aus Ölwanne, Rädertriebgegenseite 1 lube oil drain from oil pan, gear drive counter side 1	DIN EN 1092-1 05 A/DN250/PN10 S235JR+AR	DIN EN 1092-1 05 A/DN250/PN10 S235JRG2+N		Austritt Outlet	Kupplungsseite coupling side	
2112	-213	-1335	-4725	Schmierölaustritt aus Ölwanne, Rädertriebgegenseite 2 lube oil drain from oil pan, gear drive counter side 2	DIN EN 1092-1 05 A/DN250/PN10 S235JR+AR	DIN EN 1092-1 05 A/DN250/PN10 S235JRG2+N		Austritt Outlet	Kupplungsseite coupling side	
2113	-213	-1335	1450	Schmierölaustritt aus Ölwanne, Rädertriebseite 1 lube oil drain from oil pan, gear drive side 1	DIN EN 1092-1 05 A/DN250/PN10 S235JR+AR	DIN EN 1092-1 05 A/DN250/PN10 S235JRG2+N		Austritt Outlet	Kupplungsgegenseite free end	
2114	213	-1335	1450	Schmierölaustritt aus Ölwanne, Rädertriebseite 2 lube oil drain from oil pan, gear drive side 2	DIN EN 1092-1 05 A/DN250/PN10 S235JR+AR	DIN EN 1092-1 05 A/DN250/PN10 S235JRG2+N		Austritt Outlet	Kupplungsgegenseite free end	
2121	-570	-1103	1450	Schmieröleintritt in Schmierölpumpe 1 lube oil inlet to lube oil pump 1	DIN EN 1092-1 05 A/DN300/PN10 S235JR+AR	DIN EN 1092-1 05 A/DN300/PN10 S235JRG2+N		Eintritt Inlet	Kupplungsgegenseite free end	
2131	-1320	-50	1268	Schmierölaustritt aus Schmierölpumpe 1 lube oil outlet from lube oil pump 1	DIN EN 1092-1 11 B1/DN200/PN10 EN-GJS-400-15	DIN EN 1092-1 11 B1/DN200/PN10 St	DIN EN 10220 Ø219.1x6.3	Austritt Outlet	Kupplungsgegenseite free end	
2841	-1236	3360	661	Entlüftung Kurbelraum 1 venting of crankcase 1	DIN EN 1092-1 11 B1/DN100/PN16 St	DIN EN 1092-1 11 B1/DN100/PN16 St	DIN EN 10220 Ø114.3x3.6 St	Austritt Outlet	Kupplungsgegenseite free end	
3111	1348	205	1710	HT Kühlwasseraustritt aus Motor HT cooling water outlet from engine	DIN EN 1092-1 11 B1/DN125/PN16 St	DIN EN 1092-1 11 B1/DN125/PN16 St	DIN EN 10220 Ø139.7x4.0 St	Austritt Outlet	Kupplungsgegenseite free end	
3121	1348	205	498	HT Kühlwassereintritt in Kühlwasserpumpe 1 HT cooling water inlet to cooling water pump 1	DIN EN 1092-1 11 B1/DN125/PN16 St	DIN EN 1092-1 11 B1/DN125/PN16 St	DIN EN 10220 Ø139.7x4.0 St	Eintritt Inlet	Kupplungsgegenseite free end	
3141	-948	3327	775	Entlüftung HT Kühlwasserleitung 1 venting of HT cooling water pipe 1	ISO 8434-1 TC - S25 St	ISO 8434-1 N – S25 ; ISO 8434-1 CR – S25 St	DIN EN 10305 Ø25x2 St	Austritt Outlet	Kupplungsgegenseite free end	
3155	1211	233	-4866	Entlüftung Stützring (HT) 1 drain of support ring (HT) 1	ISO 8434-1 SC - S25 St	ISO 8434-1 N – S25 ; ISO 8434-1 CR – S25 St	DIN EN 10305-1 Ø25x2 St	Austritt Outlet	Kupplungsgegenseite coupling side	
3211	1227	84	1495	NT Kühlwasseraustritt aus Motor 1 LT cooling water outlet from engine 1	DIN EN 1092-1 11 B1/DN125/PN16 St	DIN EN 1092-1 11 B1/DN125/PN16 St	DIN EN 10220 Ø139.7x4.0 St	Austritt Outlet	Kupplungsgegenseite free end	
3213	1393	363	1261	NT Kühlwasseraustritt aus Motor 2 LT cooling water outlet from engine 2	DIN EN 1092-1 11 B1/DN80/PN16 St	DIN EN 1092-1 11 B1/DN80/PN16 St	DIN EN 10220 Ø88.9x3.2 St	Austritt Outlet	Kupplungsgegenseite free end	
3221	1227	84	713	NT Kühlwassereintritt in Kühlwasserpumpe LT cooling water inlet to cooling water pump	DIN EN 1092-1 11 B1/DN125/PN16 St	DIN EN 1092-1 11 B1/DN125/PN16 St	DIN EN 10220 Ø139.7x4.0 St	Eintritt Inlet	Kupplungsgegenseite free end	
3243	465	2773	2746	Entlüftung des NT-Niederdruck-Ladeluftkühlers 1 venting of LT low pressure charge air cooler 1	DIN 910 M22x1.5 (Screw plug)			Austritt Outlet	Kupplungsgegenseite free end	Connection not piped
3246	1039	1812	1035	Entlüftung des NT-Hochdruck-Ladeluftkühlers 1 venting of LT high pressure charge air cooler 1	DIN 910 M22x1.5 (Screw plug) St		DIN EN 10305-1 Ø18x2 St	Austritt Outlet	Kupplungsgegenseite free end	
3401	1223	537	-4678	Düsenkühlwassereintritt in Motor nozzle cooling water inlet to engine	ISO 8434-1 SC - S25 St	ISO 8434-1 N – S25 ; ISO 8434-1 CR – S25 St	DIN EN 10305-1 Ø25x2 St	Eintritt Inlet	Kupplungsgegenseite coupling side	
3411	1211	357	-4718	Düsenkühlwasseraustritt aus Motor nozzle cooling water outlet from engine	ISO 8434-1 SC - S25 St	ISO 8434-1 N – S25 ; ISO 8434-1 CR – S25 St	DIN EN 10305-1 Ø25x2 St	Austritt Outlet	Kupplungsgegenseite coupling side	
3501	1478	2189	2688	Waschwassereintritt für Turbine 1 washing water inlet for turbine 1	Geka LW25-1" V		DIN EN 10305 Ø16x2 V	Eintritt Inlet	Kupplungsgegenseite free end	Only connected during cleaning
5101	-1234	403	-4536	Kraftstoffeintritt in Motor fuel oil inlet to engine	DIN EN 1092-1 11 C/DN40/PN40 St	DIN EN 1092-1 11 D/DN40/PN40 St	DIN EN 10216-2 Ø48.3x2.6 St	Eintritt Inlet	Kupplungsseite coupling side	
5111	-1234	328	-4678	Kraftstoffaustritt aus Motor fuel oil outlet from engine	DIN EN 1092-1 11 C/DN40/PN40 St	DIN EN 1092-1 11 D/DN40/PN40 St	DIN EN 10216-2 Ø48.3x2.6 St	Austritt Outlet	Kupplungsseite coupling side	
5145	-1087	-9	-4466	Kraftstoffleckageablauf (wiederverwendbar von Pumpen und Injektoren) 3 fuel oil leckage drain (reusable from pumps and injectors) 3	ISO 8434-1 SC - S30 V	ISO 8434-1 N – S30 ; ISO 8434-1 CR – S30 V	DIN EN 10305 Ø30x2 St	Austritt Outlet	Kupplungsseite coupling side	
5201	-1083	-105	-4599	Kraftstoffeintritt in Motor fuel oil inlet to engine	ISO 8434-1 SC - S20 St	ISO 8434-1 N – S20 ; ISO 8434-1 CR – S20 St	DIN EN 10305 Ø20x2 St	Eintritt Inlet	Kupplungsseite coupling side	
5211	-1083	-105	-4654	Kraftstoffaustritt aus Motor fuel oil outlet from engine	ISO 8434-1 SC - S20 St	ISO 8434-1 N – S20 ; ISO 8434-1 CR – S20 St	DIN EN 10305 Ø20x2 St	Austritt Outlet	Kupplungsseite coupling side	
5801	-1035	552	-4909	Brenngaseintritt in Motor 1 fuel gas inlet to engine 1	DRW 1123484O258 X2CrNiMo17-12-2+AT	DRW 1123484O271 X2CrNiMo17-12-2+AT	DIN EN 10217-7 Ø139.7x4/Ø168.3x4.5 (Double wall) X2CrNiMo17-12-2+AT	Eintritt Inlet	Kupplungsseite coupling side	
6205	-843	3226	-161	Belüftungsanschluss Doppelwandigkeit der Gasleitung 1 inlet for ventilation of gas pipe jacket 1	ISO 8434-1 S38		DIN EN 10216-5 Ø38x2.6 V	Eintritt Inlet	Kupplungsseite coupling side	
6511	-765	3567	1800	Abgasaustritt aus Turbolader 1 exhaust gas outlet from turbocharger 1				Austritt Outlet	Kupplungsgegenseite free end	
6513	-965	3739	1405	Abgasaustritt aus Abgasabblaseeinrichtung 1 exhaust gas outlet from waste gate 1	DIN EN 1092-1 11 B1/DN125/PN16 St			Austritt Outlet	Kupplungsgegenseite free end	
7101	1163	60	-4535	Anlasslufteintritt in Motor starting air inlet to engine	DIN EN 1092-1 11 C/DN65/PN40 St	DIN EN 1092-1 11 D/DN65/PN40 St	DIN EN 10305 Ø76.1x2.9 St	Eintritt Inlet	Kupplungsseite coupling side	
7102	1053	-113	-4575	Steuerlufteintritt in Motor 1 control air inlet to engine 1	ISO 8434-1 SC - S10 St	ISO 8434-1 N – S10 ; ISO 8434-1 CR – S10 St	DIN EN 10305 Ø10x1.5 St	Eintritt Inlet	Kupplungsseite coupling side	
7103	1299	481	1730	Lufteintritt in Motor für Jet Assist air inlet to engine for jet assist	ISO 8434-1 SC - S30 St	ISO 8434-1 N – S30 ; ISO 8434-1 CR – S30 St	DIN EN 10305 Ø30x2 St	Eintritt Inlet	Kupplungsgegenseite free end	
7104	1070	-439	-4713	Steuerlufteintritt in Motor aus Törnmaschinenverblockung control air inlet to engine from turning gear blocking	ISO 8434-1 BHC - S10 St	ISO 8434-1 N - S10 ; ISO 8434-1 CR - S10 St	DIN EN 10305-4 Ø10x1.5 St	Eintritt Inlet	Kupplungsseite coupling side	
7114	1035	-439	-4733	Steuerlaustritt aus Motor in Törnmaschinenverblockung control air outlet from engine to turning gear blocking	ISO 8434-1 BHC - S10 St	ISO 8434-1 N - S10 ; ISO 8434-1 CR - S10 St	DIN EN 10305-4 Ø10x1.5 St	Austritt Outlet	Kupplungsseite coupling side	
7503	1250	35	361	Inertgaseintritt in Hauptbrennstrang 1 inert gas inlet to main fuel gas pipe 1	ISO 8434-1 S - S30 V	ISO 8434-1 N – S30 ; ISO 8434-1 CR – S30 V	DIN EN 10216-5 Ø30x2 D3 T3 X5CrNi18-10+AT	Eintritt Inlet	Kupplungsgegenseite free end	
8641	1220	294	-4807	Kondenswasserablauf aus Ladeluftleitung, Rädertriebgegenseite 1 condensate water drain from charge air manifold, gear drive counter side 1	ISO 8434-1 SC - S30 V	ISO 8434-1 N - S30 ; ISO 8434-1 CR - S30 V	DIN EN 10305-1 Ø30x2 V	Austritt Outlet	Kupplungsseite coupling side	
8651	1308	471	1860	Kondenswasserablauf aus Ladeluftkühler 1 condensate water drain from charge air cooler 1	ISO 8434-1 SC - S30 V	ISO 8434-1 N – S30 ; ISO 8434-1 CR – S30 V	DIN EN ISO 1127 Ø30x2 V	Austritt Outlet	Kupplungsgegenseite free end	
9141	-1087	-9	-4533	Schmutzölablauf von Pumpenbank, Rädertriebgegenseite 1 dirty oil drain from pump bank, gear drive counter side 1	ISO 8434-1 SC - S30 V	ISO 8434-1 N – S30 ; ISO 8434-1 CR – S30 V	DIN EN 10305-1 Ø30x2 St	Austritt Outlet	Kupplungsseite coupling side	
9143	-1237	603	705	Schmutzölablauf von Pumpenbank, Rädertriebseite 1 dirty oil drain from pump bank, gear drive side 1	ISO 8434-1 SC - S30 V	ISO 8434-1 N – S30 ; ISO 8434-1 CR – S30 V	DIN EN 10305-1 Ø30x2 St	Austritt Outlet	Kupplungsgegenseite free end	
9201	625	2351	1732	LLK-Reinigungsflüssigkeit Eintritt 1 charge air cooler cleaning agent inlet 1		DIN EN 1092-1 01 A/DN50/PN16 St	DIN EN 10220 Ø60.3x2.9 St	Eintritt Inlet	Kupplungsgegenseite free end	Only connected during cleaning
9202	793	2516	3119	LLK-Reinigungsflüssigkeit Eintritt 2 charge air cooler cleaning agent inlet 2		DIN EN 1092-1 01 A/DN50/PN16 St	DIN EN 10220 Ø60.3x2.9 St	Eintritt Inlet	Kupplungsgegenseite free end	Only connected during cleaning
9203	-28	2640	2421	LLK-Reinigungsflüssigkeit Eintritt 3 (ND bei 2 Stufen) charge air cooler cleaning agent inlet 3		DIN EN 1092-1 01 A/DN50/PN16 St	DIN EN 10220 Ø60.3x2.9 St	Eintritt Inlet	Kupplungsgegenseite free end	Only connected during cleaning
9241	10	1180	1841	LLK-Reinigungsflüssigkeit Ablauf 1 charge air cooler cleaning agent drain 1		DIN EN 1092-1 01 A/DN50/PN16 St	DIN EN 10220 Ø60.3x2.9 St	Austritt Outlet	Kupplungsgegenseite free end	Only connected during cleaning
9242	810	1323	2824	LLK-Reinigungsflüssigkeit Ablauf 2 charge air cooler cleaning agent drain 2		DIN EN 1092-1 01 A/DN50/PN16 St	DIN EN 10220 Ø60.3x2.9 St	Austritt Outlet	Kupplungsgegenseite free end	Only connected during cleaning
9243	-40	1323	2824	LLK-Reinigungsflüssigkeit Ablauf 3 (ND bei 2 Stufen) charge air cooler cleaning agent drain 3		DIN EN 1092-1 01 A/DN50/PN16 St	DIN EN 10220 Ø60.3x2.9 St	Austritt Outlet	Kupplungsgegenseite free end	Only connected during cleaning
9701	1581	1862	3002	Drucklufteintritt für Turbolader-Trockenreinigung 1 compressed air inlet for turbocharger dry cleaning 1	ISO 8434-1 SDSC - S12 x G1/2 V	ISO 8434-1 N – S12 ; ISO 8434-1 CR – S12 V	DIN EN 10305 Ø12x1.5 V	Eintritt Inlet	Kupplungsgegenseite free end	Only connected during cleaning
9702	1646	1860	2595	Drucklufteintritt für Turbolader-Trockenreinigung 2 compressed air inlet for turbocharger dry cleaning 2	ISO 8434-1 SDSC - S12 x G1/2 V	ISO 8434-1 N – S12 ; ISO 8434-1 CR – S12 V	DIN EN 10305 Ø12x1.5 V	Eintritt Inlet	Kupplungsgegenseite free end	Only connected during cleaning
COG	-42	1002	-1080	Schwerpunkt Center of Gravity				COG COG	Kupplungsseite coupling side	point of gravity dry

Connection-no. Anschluss Nr.	Typ of medium Art des Mediums
21..	lube oil main system Schmieröl-Hauptsystem
28..	oil mist (crankcase ventilation) Ölduns (Kurbelraumentlüftung)
31..	engine cooling water (high temperture) Motorkühlwasser (Hochtemperatur)
32..	charge air cooling water (low temperature) Ladeluftkühlwasser (Niedertemperatur)
34..	nozzel cooling water Düsenkühlwasser
35..	water mins, turbocharger washing water Netzwasser, Turbolader-Waschwasser
41..	sea water (general)(not on engine) Seewasser (allgmein) (nicht am Motor)
51..	fuel system heavy fuel capable (not heated) Kraftstoffsystem schwerölfähig (nicht beheizt)
52..	fuel system diesel oil operation Kraftstoffsystem Diesel/ölbetrieb
58..	gas (low pressure) Gas (Niederdruck)
62..	intake air and charge air Ansaug- und Ladeluft
65..	exhaust gas Abgas
71..	starting air Ansaugluft
72..	control air Steuerluft
75..	inert gas Inertgas
86..	condensate inside engine room Kondensat im Maschinenraum
91..	bilge drainage, dirty oil drainage Bilge-Drainage, Schmutzölablauf
97..	dry cleaning of turbocharger Turbolader-Trockenreinigung

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5.4 Lube oil system

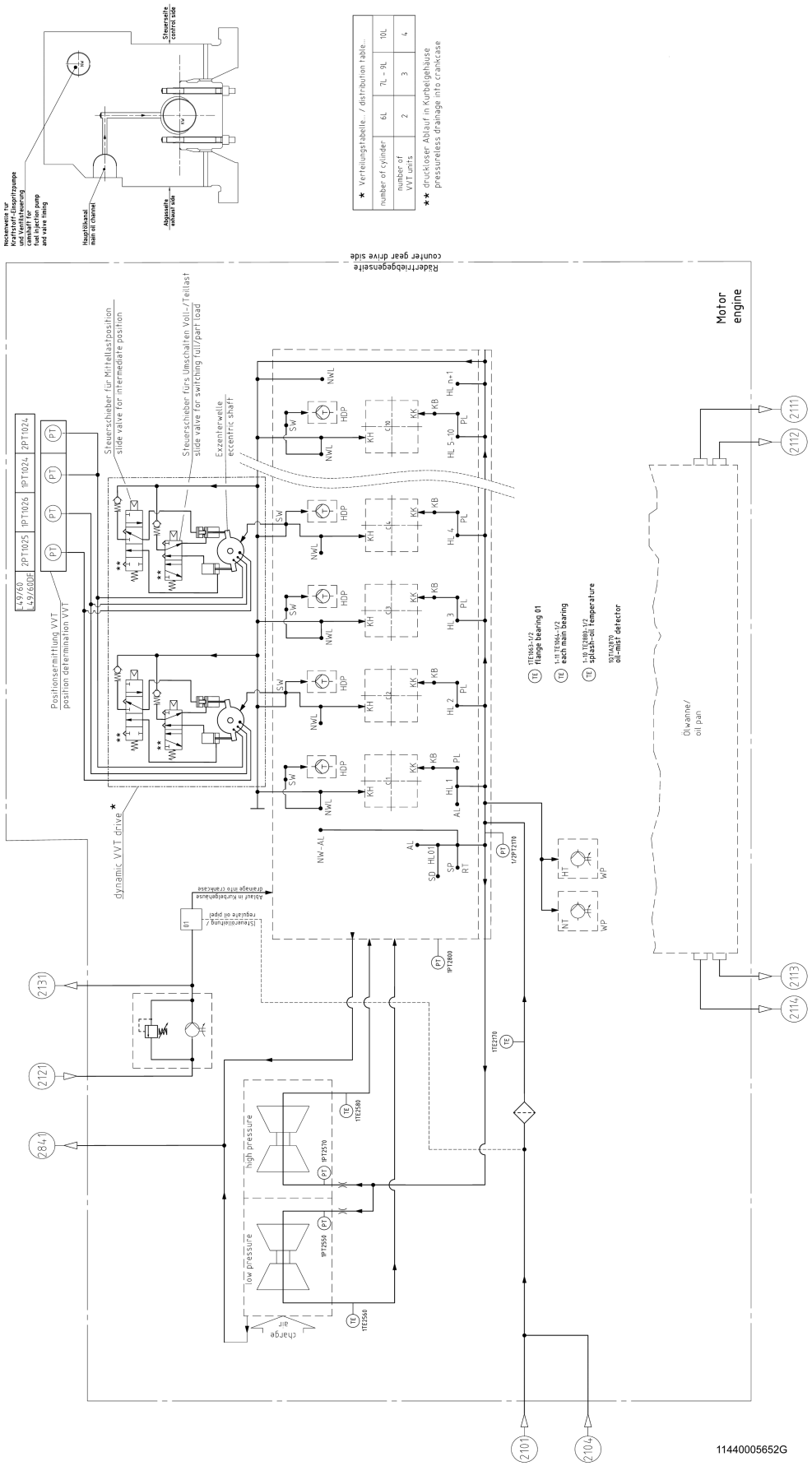
5.4.1 Internal lube oil system

As a standard:

- Engine equipment with attached lube oil pump

See overleaf

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Nockenwelle für Kraftstoff-Einspritzpumpe und Ventilsteuerung
camshaft for fuel injection pump and valve timing
Hauptölkanal main oil channel
Abgasseite exhaust side
Steuerseite control side
★ Verteilungstabelle... / distribution table...
number of cylinder
6L
7L – 9L
10L
number of VVT units
2
3
4
★★ druckloser Ablauf in Kurbelgehäuse
pressureless drainage into crankcase
Rädertriebgegenseite
counter gear drive side
Motor
engine
Steuerschieber für Mittellastposition
slide valve for intermediate position
Steuerschieber fürs Umschalten Voll-/Teillast
slide valve for switching full/part load
Exzenterwelle
eccentric shaft
L49/60
L49/60DF
2PT025
1PT026
1PT024
2PT024
Positionsermittlung VVT
position determination VVT
dynamic VVT drive
Ölwanne/
oil pan
1TE1063-1/2
flange bearing 01
1-11 TE1064-1/2
each main bearing
1-10 TE2880-1/2
splash-oil temperature
1QTA2870
oil-mist detector
1PT2070
1TE2170
1PT2880
1TE2580
1PT2570
1PT2550
1TE2560
high pressure
low pressure
charge air
Ablauf in Kurbelgehäuse
drainage into crankcase
Steuerölleitung /
regulate oil pipe
11440005652G

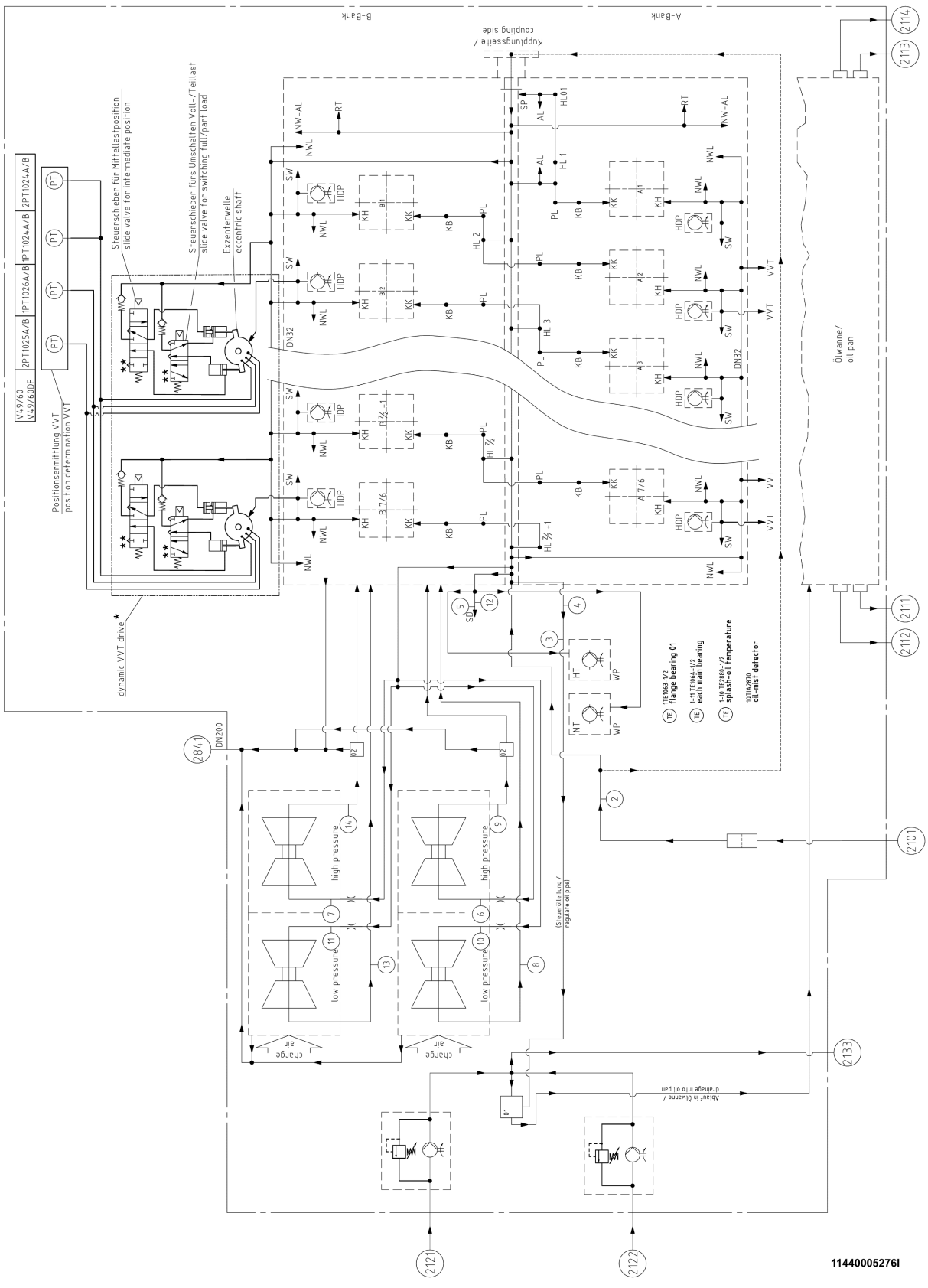
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Connection numbers

2101 Lube oil inlet to engine
2104 Lube oil inlet to engine for provisional lubrication
2111 Lube oil drain from oil pan, gear drive counter side 1
2112 Lube oil drain from oil pan, gear drive counter side 2
2113 Lube oil drain from oil pan, gear drive side 1
2114 Lube oil drain from oil pan, gear drive side 2
2121 Lube oil inlet to lube oil pump
2131 Lube oil outlet from lube oil pump
2841 Venting of crankcase

Figure 116: Internal lube oil system L engine – Exemplary

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B-Bank
A-Bank
Kupplungsseite / coupling side
Steuerschieber für Mittellastposition
slide valve for intermediate position
Steuerschieber fürs Umschalten Voll-/Teillast
slide valve for switching full/part load
Exzenterwelle
eccentric shaft
V49/60
V49/60DF
2PT1025A/B
1PT1026A/B
1PT1024A/B
2PT1024A/B
Positionsermittlung VVT
position determination VVT
dynamic VVT drive *
Ölwanne/
oil pan
DN32
DN200
high pressure
low pressure
charge air
Abluft in Ölwanne / drainage into oil pan
(Steuerölleitung / regulate oil pipe)
1TE1063-1/2
flange bearing 01
1-11 TE1064-1/2
each main bearing
1-10 TE2886-1/2
splash-oil temperature
1QT1A2870
OIL-MIST detector
11440005276I

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Connection numbers			
2101	Oil inlet on the engine	2121	Oil pump inlet
2111	Oil drain from oil pan 1 (counter coupling side)	2122	Oil pump inlet
2112	Oil drain from oil pan 2 (counter coupling side)	2133	Oil pumps combined outlet
2113	Oil drain from oil pan 1 (coupling side)	2841	Crankcase venting
2114	Oil drain from oil pan 2 (coupling side)		

Figure 117: Internal lube oil system V engine – Exemplary

5.4.2 External lube oil system – Description

The following description refers to the figure(s) Lube oil system diagram(s), Page 239, which represent the standard design of external lube oil service system.

The internal lubrication of the engine and the turbocharger is provided with a force-feed lubrication system.

In multi-engine plants, for each engine a separate lube oil system is required.

According to the required lube oil quality, see table Main fuel/lube oil type.

Requirements before commissioning of engine

The flushing of the lube oil system in accordance to the Everllence specification (see the relevant working instructions) demands before commissioning of the engine, that all installations within the system are in proper operation. Be aware that special installations for commissioning are required and the lube oil separator must be in operation from the very first phase of commissioning.

Contact Everllence or licensee if any uncertainties occur.

T-001/Lube oil service tank

The main purpose of the lube oil service tank is to separate air and particles from the lube oil, before pumping the lube oil to the engine. For the design of the service tank the class requirements have to be taken in consideration. For design requirements of Everllence see section External lube oil system – Lube oil service tank, Page 311.

H-002/Lube oil preheater

To fulfill the starting conditions (see section Starting conditions, Page 48) preheating of the lube oil in the lube oil frame tank is necessary. Therefore the preheater of the separator is often used. The preheater must be enlarged in size if necessary, so that it can heat up the content of the service tank to ≥ 40 °C, within 4 hours. If engines have to be kept in stand-by mode, the lube oil of the corresponding engines always has to be in the temperature range of starting conditions. Means that also the maximum lube oil temperature limit should not be exceeded during engine start.

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.

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PSV-004/Lube oil non-return flap with integrated safety valve

A non-return flap must be installed close to the lube oil tank to prevent lube oil back flow when the engine has been shut off. This non-return flap must be by-passed by a safety valve to protect the pump against high pressure caused by momentary counter-rotation of the engine during shutdown. Everllence solution for these two requirements is a special non-return flap with integrated safety valve. If there is used a normal return flap, the line of the external safety valve should lead back into the lube oil tank submerged. The required opening pressure of the safety valve is approximately 0.4 bar.

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.

P-001/P-007/P-074/Lube oil pumps

For ships with more than one main engine additionally to the service pump a prelubrication pump P-007 for pre- and postlubrication is necessary. 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. For further information according that pump see section Planning data, Page 100 and paragraph Lube oil, Page 137. A main lube oil pump as spare is required to be on board according to class society.

For ships with a single main engine drive it is preferable to design the lube oil system with a combination of an engine driven lube oil service pump (attached) P-001 and a lube oil stand-by pump (free-standing) P-074 (100% capacity).

Additionally a prelubrication pump is recommended. If nevertheless the stand-by pump is used for pre- and postlubrication Everllence has to be consulted as there are necessary modifications in the engine automation.

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.

Using the stand-by pump for continuous prelubrication is not permissible.

As long as the installed stand-by pump provides 100% capacity of the operating pump, the class requirement to have a spare part operating pump on board, is fulfilled. Both pumps 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 design data of these lube oil pumps see section Planning data, Page 100 and the following.

In case of unintended engine stop (e.g. blackout) the postlubrication must be started as soon as possible (latest within 20 min) after the engine has stopped and must persist according to table System circuit operation time after engine stop, Page 61.

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This is required to cool down the bearings of turbocharger and hot inner engine components.

Application	Necessary pumps referred to respective application(s)			
	For operation		For pre- and postlubrication	To keep engine in stand-by
Single main engine	Lube oil service pump (attached) P-001	Lube oil stand-by pump P-074 (100 %)	Prelubrication pump P-007 recommended. If stand-by pump P-074 should be used for pre- and postlubrication, Everllence has to be consulted.	Prelubrication pump P-007 is required
Ships with more than one main engine	Lube oil service pump (attached) P-001	Lube oil stand-by pump P-074 recommended for increased availability (safety). Otherwise pump as spare is requested to be on board according to class requirement.	Prelubrication pump P-007 recommended. If stand-by pump P-074 should be used for pre- and postlubrication, Everllence has to be consulted.	Prelubrication pump P-007 is required

Table 128: Lube oil pumps

HE-002/Lube oil cooler

Dimensioning

Heat data, flow rates and tolerances are indicated in section Planning data, Page 100 and the following.

For the separator a heat-intake of 30 kJ/kWh was estimated.

On the lube oil side, the pressure drop shall not exceed 1.1 bar.

Design/Outfitting

The cooler installation must be designed for easy venting and draining.

TCV-001/Lube oil temperature control valve

The lube oil temperature control valve regulates the inlet oil temperature of the engine. The control valve is executed by wax-type thermostats.

Lube oil treatment

The treatment of the circulating lube oil can be divided into two major functions:

- Removal of contaminations to keep up the lube oil performance.
- Retention of dirt to protect the engine.

The removal of combustion residues, water and other mechanical contaminations is the major task of separators/centrifuges (CF-001) installed in by-pass to the main lube oil service system of the engine. The installation of a lube oil separator per engine is recommended to ensure a continuous separation during engine operation.

The lube oil filters integrated in the system protect the diesel engine in the main circuit retaining all residues which may cause a harm to the engine.

Depending on the filter design, the collected residues are to be removed from the filter mesh by automatic back flushing, manual cleaning or changing the filter cartridge. The retention capacity of the installed filter should be as high as possible.

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When selecting an appropriate filter arrangement, the customer request for operation and maintenance, as well as the class requirements, have to be taken in consideration.

Instead of a separator an adequate filtration system (FIL-027) can be used for lube oil treatment. This is only valid for engines which operate with liquid fuels of DM- or DF-class (acc. ISO 8217) exclusively (gas also for dual fuel engines, no residual fuel). By using a filtration system, the used lube oil must be suitable for filtration. A separate heater to preheat the lube oil before engine start has to be foreseen. The filtration system must be approved by Everllence.

FIL-001/FIL-002 Arrangement principles for lube oil filters

Depending on engine type, the number of installed main engines in one plant and on the safety standard demanded by the customer, different arrangement principles for the filters FIL-001/FIL-002 are possible:

	Option 1		Option 2	
	FIL-001 automatic filter continous flushing	**FIL-002 duplex filter as indicator filter**	**FIL-001 automatic filter intermittent flushing**	**FIL-002 duplex filter as indicator filter**
FIL-001 includes second filter stage	Yes	-	No	-
Location	Engine room installed close to engine	Installed upstream of FIL-001	Engine room installed close to engine	Installed upstream of FIL-001
Requirement by-pass	Internal by-pass	-	Required	-
Requirement of FIL-002	To fulfill higher safety concept (optional)		Required	
Mesh width	34 µm first filter stage 80 µm second filter stage	60 µm	34 µm	60 µm
It is always recommended to install one separator in partial flow of each engine. Filter design has to be approved by Everllence.				

Table 129: Arrangement principles for lube oil filters

FIL-001/Lube oil automatic filter

The lube oil automatic filter is an automatic back washing filter installed as a main filter. The back washing/flushing of the filter elements has to be arranged in a way that lube oil flow and pressure will not be affected. The flushing discharge (oil sludge mixture) is led to the lube oil service tank. The oil will be permanently by-pass cleaned via suction line into a separator. This provides an efficient final removal of deposits (see section External lube oil system – Lube oil service tank, Page 311).

As state-of-the-art, lube oil automatic filter types are recommended to be equipped with an integrated second filtration stage. This second stage protects the engine from particles which may pass the first stage filter elements in case of any malfunction. If the lube oil system is equipped with a two-stage automatic filter, additional lube oil duplex filter FIL-002 can be avoided. As far as the automatic filter is installed without any additional filters downstream before the engine inlet, the filter has to be installed as close as possible to the engine (see table Arrangement principles for lube oil filters, Page 301). In that

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case the pipe section between filter and engine inlet must be closely inspected before installation. This pipe section must be divided and flanges have to be fitted so that all bends and welding seams can be inspected and cleaned prior to final installation.

Differential pressure gauges have to be installed to protect the filter cartridges and to indicate clogging condition of the filter. A high differential pressure has to be indicated as an alarm.

In case filter stage 1 is not working sufficiently, the engine can run in emergency operation for maximum 72 hours with the second filter stage, but has to be stopped after. This measure ensures that disturbances in backwashing do not result in a complete failure of filtering and that the main stream filter can be cleaned without interrupting filtration.

FIL-002/Lube oil duplex filter as indicator filter

The lube oil duplex filter has the function of an indicator filter and must be cleaned manually. It must be installed downstream of the lube oil automatic filter, as close as possible to the engine. The pipe section between filter and engine inlet must be closely inspected before installation. This pipe section must be divided and flanges have to be fitted so that all bends and welding seams can be inspected and cleaned prior to final installation. In case of a two-stage automatic filter, the installation of a duplex filter can be avoided. Customers who want to fulfil a higher safety level, are free to mount an additional duplex filter close to the engine.

The lube oil duplex filter protects the engine also in case of malfunctions of the lube oil automatic filter. The monitoring system of the automatic filter generates an alarm signal to alert the operating personnel. A maintenance of the automatic filter becomes necessary. For this purpose the lube oil flow through the automatic filter has to be stopped. Single-main engine plants may continue to stay in operation by by-passing the automatic filter. Lube oil can still be filtrated sufficiently in this situation by only using the duplex filter.

In multi-engine plants, where it is not possible to by-pass the lube oil automatic filter without loss of lube oil filtration, the affected engine has to be stopped in this situation.

The design of the lube oil duplex filter must ensure that no parts of the filter can become loose and enter the engine.

The drain connections equipped with shut-off fittings in the two chambers of the lube oil duplex filter returns into the leakage oil collecting tank (T-006). Draining will remove the dirt accumulated in the casing and prevents contamination of the clean oil side of the filter. Check also table Arrangement principles for lube oil filters, Page 301.

Indication and alarm of filters

The lube oil automatic filter FIL-001 and the lube oil duplex filter FIL-002 are equipped with local visual differential pressure indicators and additionally with differential pressure switches. The switches are used for pre-alarm and main alarm.

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Differential pressure between filter inlet and outlet (dp)	Lube oil automatic filter FIL-001		Lube oil duplex filter FIL-002
	Intermittent flushing	Continuous flushing	
dp switch with lower set point is active	This dp switch has to be installed twice if an intermittent flushing filter is used. The first switch is used for the filter control; it will start the automatic flushing procedure. The second switch is adjusted at the identical set point as the first. Once the second switch is activated, and after a time delay of approximately 3 minutes, the dp pre-alarm "filter is polluted" is generated. The time delay becomes necessary to effect the automatic flushing procedure before and to evaluate its effect.	The dp pre-alarm: "Filter is polluted" is generated immediately	
dp switch with higher set point is active	The dp main alarm "filter failure" is generated immediately. If the main alarm is still active after 30 min, the engine output power will be reduced automatically.		

Table 130: Indication and alarm of filters

BL-007/Fan, crankcase venting

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. This will be achieved by producing a vacuum in the crankcase using a speed controlled venting fan placed within the engine ventilation 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.

The pressure loss of the piping (including all installed components in the piping) after the fan should not exceed 6 mbar.

CF-001/Lube oil separator

The lube oil is intensively cleaned by separation in the by-pass thus relieving the filters and allowing an economical design.

The lube oil separator should be of the self-cleaning type. The design is to be based on a lube oil quantity of 1.0 l/kW. This lube oil quantity should be cleaned within 24 hours at:

- HFO-operation 6–7 times
- DMB-operation 4–5 times

The formula for determining the separator flow rate (Q) is:

$$Q = \frac{1.0 \times P \times n}{24}$$

Q [l/h]	Separator flow rate
P [kW]	Total engine output
n	5 for DMA/DMB 5 for gas (+ DMA/DMB for ignition only)

With the evaluated flow rate the size of separator has to be selected according to the evaluation table of the manufacturer. The separator rating stated by the manufacturer should be higher than the flow rate (Q) calculated according to the formula above.

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Separator equipment

The lube oil preheater H-002 must be able to heat the oil to 95°C and the size is to be selected accordingly. In addition to a PI-temperature control, which avoids a thermal overloading of the oil, silting of the preheater must be prevented by high turbulence of the oil in the preheater.

Control accuracy ±1°C.

Cruise ships operating in arctic waters require larger lube oil preheaters. In this case the size of the preheater must be calculated with a Δt of 60 K.

The freshwater supplied must be treated as specified by the separator supplier.

The supply pumps shall be of the free-standing type, i.e. not mounted on the separator and are to be installed in the immediate vicinity of the lube oil service tank.

This arrangement has three advantages:

- Suction of lube oil without causing cavitation.
- The lube oil separator does not need to be installed in the vicinity of the service tank but can be mounted in the separator room together with the fuel oil separators.
- Better matching of the capacity to the required separator throughput.

As a reserve for the lube oil separator, the use of the diesel fuel oil separator is admissible. For reserve operation the diesel fuel oil separator must be converted accordingly. This includes the pipe connection to the lube oil system which must not be implemented with valves or spectacle flanges. The connection is to be executed by removable change-over joints that will definitely prevent DMB from getting into the lube oil circuit. See also rules and regulations of classification societies.

FIL-027/Lube oil fine filter

The lube oil is intensively cleaned by fine filtration in the by-pass thus relieving the main filters and allowing an economical design.

The lube oil fine filter is not of self-cleaning type, therefore the filter elements need to be replaced. The design is to be based on a lube oil quantity of 1.0 l/kW. This lube oil quantity should be cleaned within 24 hours at:

- Liquid fuels of DM- and DF-class operation 4 – 5 times
- Dual fuel engines operating on gas (+DMA/DMB for ignition only) 4 – 5 times

The formula for determining the fine filter flow rate (Q) is:

$$Q = \frac{1.0 \times P \times n}{24}$$

Q [l/h]	Fine filter flow rate
P [kW]	Total engine output
n	5 for DMA/DMB 5 for gas (+ DMA/DMB for ignition only)

With the evaluated flow rate and the lube oil volume of the engine, the number of filter elements of the fine filter has to be selected according to the evaluation table of the maker. The table per maker is based on a fixed filter life time

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stated in the table (filter lifetime in engine operating hours). This has to be considered carefully. For a longer filter exchange interval, the number of filter elements has to be increased.

The information regarding released manufacturers and filter types for lube oil fine filters can be found here: Lube-oil-treatment.

Fine filter equipment

Depending on the size of the fine filter, a lifting possibility above the filter housing can be necessary for filter exchange.

The supply pump shall be of freestanding type, that is not mounted on the same frame as the fine filter. It is to be installed in the immediate vicinity of the lube oil service tank.

This arrangement has three advantages:

- Suction of lube oil without causing cavitation.
- The lube oil fine filter does not need to be installed near of the service tank. It can be mounted in one room together with the fuel oil filters or separators.
- Better accessibility of lube oil fine filter for filter exchange.

As a reserve for the lube oil fine filter, the use of the diesel fuel oil separator is admissible. For reserve operation, the diesel fuel oil separator must be converted accordingly. This includes the pipe connection to the lube oil system which must not be implemented with valves or spectacle flanges. The connection is to be executed by removable changeover joints that will definitely prevent DMB from getting into the lube oil circuit. See also rules and regulations of classification societies.

PCV-007/Pressure relief valve

By use of the pressure relief valve, a constant lube oil pressure before the engine is adjusted.

The pressure relief valve is installed upstream of the lube oil cooler. By spilling off exceeding lube oil quantities upstream of the major components these components can be sized smaller. The return pipe (spilling pipe) from the pressure relief valve returns into the lube oil service tank.

The control line of the pressure relief valve has to be connected to the engine inlet. In this way the pressure losses of filters, pipes and cooler are compensated.

TR-001/Condensate trap

See section Crankcase vent and lube oil tank vent, Page 316.

T-006/Leakage oil collecting tank

See section External fuel system – Residual fuel (HFO) supply system, Page 372.

Withdrawal points for samples

Points for drawing lube oil samples are to be provided upstream and downstream of the filters and the separator, to verify the effectiveness of these system components.

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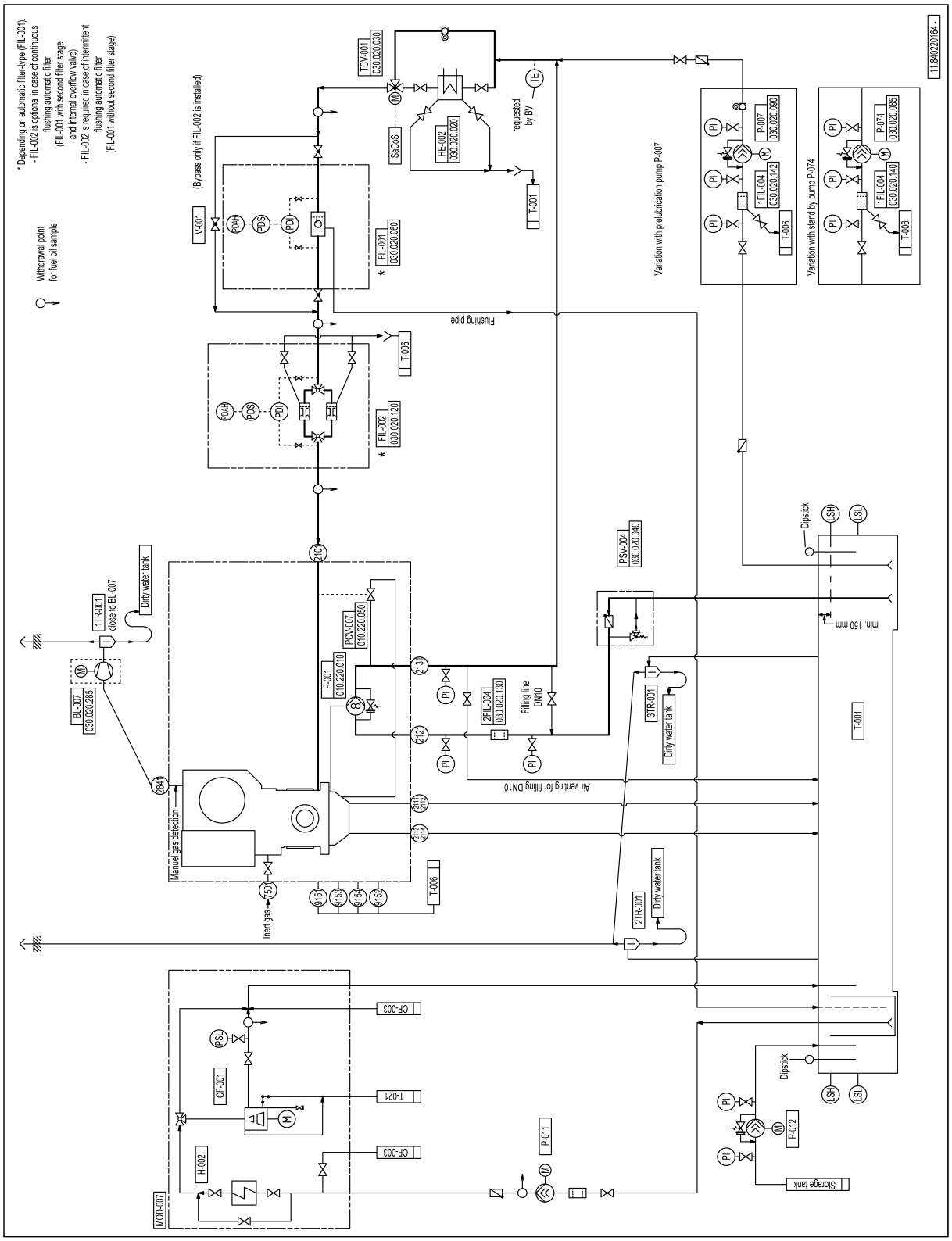
Piping system

It is recommended to use pipes according to the pressure class PN16.

P-012/Lube oil transfer pump

The lube oil transfer pump 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.

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* Depending on automatic filter-type (FIL-001):
- FIL-002 is optional in case of continuous flushing automatic filter (FIL-001 with second filter stage and internal overflow valve)
- FIL-002 is required in case of intermittent flushing automatic filter (FIL-001 without second filter stage)
Withdrawal point for fuel oil sample
(Bypass only if FIL-002 is installed)
V-001
FIL-001 030.020.060
FIL-002 030.020.120
TCV-001 030.020.030
HE-002 030.020.020
SaCoS
requested by BV
T-001
Flushing pipe
T-006
Variation with prelubrication pump P-007
P-007 030.020.090
1FIL-004 030.020.142
Variation with stand by pump P-074
P-074 030.020.085
1FIL-004 030.020.140
PSV-004 030.020.040
Dipstick
min. 150 mm
1TR-001 close to BL-007
Dirty water tank
BL-007 030.020.285
P-001 010.220.010
PCV-007 010.220.055
2FIL-004 030.020.130
Filling line DN10
3TR-001
Air venting for filling DN10
Manuel gas detection
Inert gas
2TR-001
MOD-007
H-002
CF-001
CF-003
T-021
P-011
P-012
Storage tank

Components

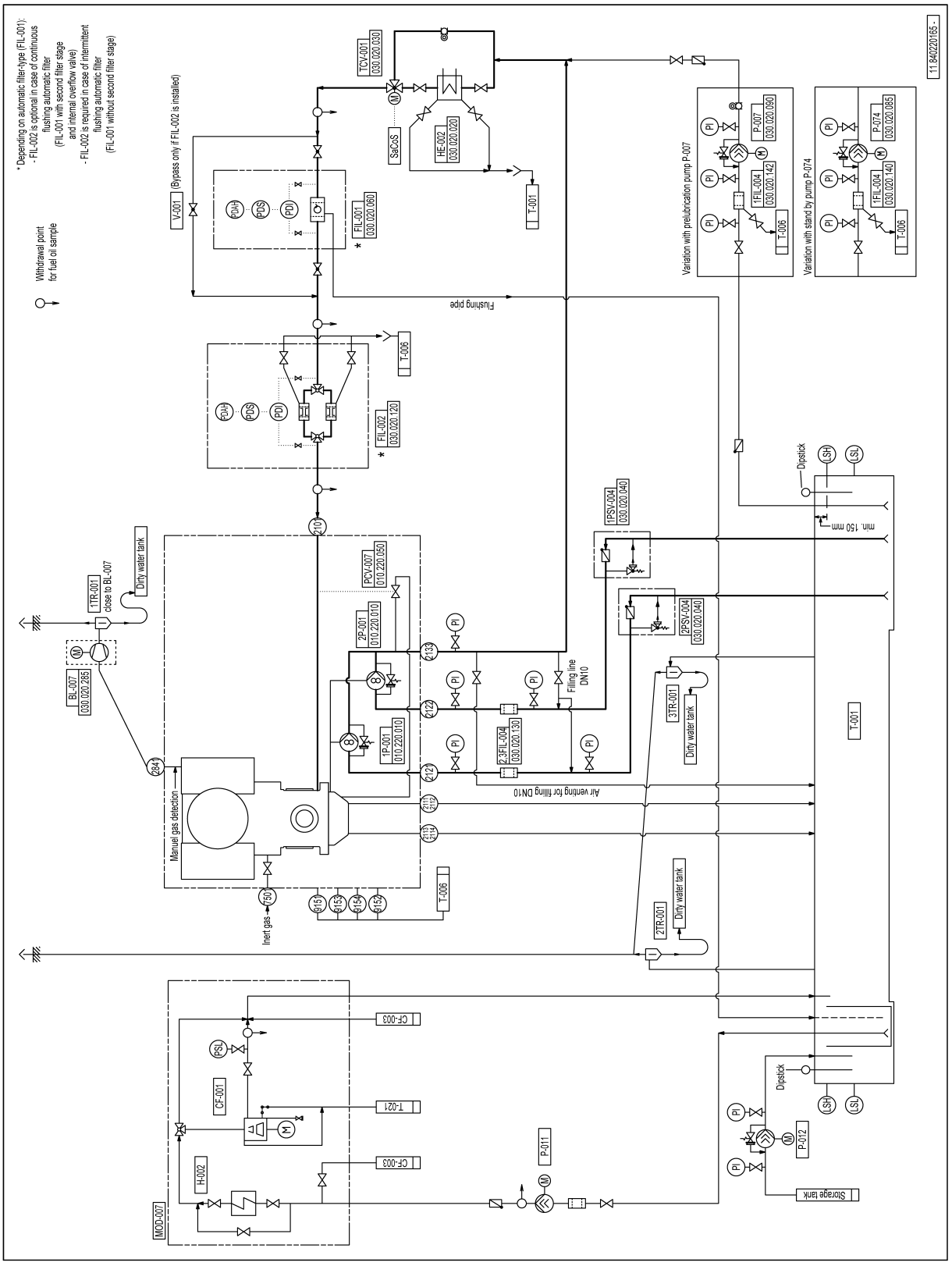
BL-007	Fan, crankcase venting
CF-001	Lube oil separator
CF-003	Diesel fuel oil separator
FIL-001	Lube oil automatic filter
FIL-002	Lube oil duplex filter
1,2 FIL-004	Lube oil suction strainer
H-002	Lube oil preheating unit
HE-002	Lube oil cooler
MOD-007	Lube oil separator module
NRF-001	Lube oil non return flap
P-001	Lube oil service pump, attached
P-007	Prelubrication pump
P-011	Lube oil feed pump separator
P-012	Lube oil transfer pump
P-074	Lube oil stand-by pump, free-standing
PCV-007	Lube oil pressure relief valve
PSV-004	Lube oil non return flap with integrated safety valve
T-001	Lube oil service tank
T-006	Leakage oil collecting tank
T-021	Sludge tank
TCV-001	Lube oil temperature control valve
1,2,3 TR-001	Condensate trap, lube oil system
V-001	Lead sealed globe valve, by-pass to lube oil main filter

Connection numbers

2101	Lube oil inlet to engine
2111/2112	Lube oil drain from oil pan, counter coupling side 1
2113/2114	Lube oil drain from oil pan, coupling side 1
2121	Lube oil inlet to lube oil pump 1
2131	Lube oil outlet from lube oil pump 1
2841	Venting of crankcase 1
7501	Inert gas inlet to crankcase 1
9151	Dirty oil drain on free end 1 (from crankcase foot)
9152	Dirty oil drain on free end 2 (from crankcase foot)
9153	Dirty oil drain on coupling side 1 (from crankcase foot)
9154	Dirty oil drain on coupling side 2 (from crankcase foot)

Figure 118: Lube oil system diagram – L engine

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* Depending on automatic filter-type (FIL-001):
- FIL-002 is optional in case of continuous flushing automatic filter (FIL-001 with second filter stage and internal overflow valve)
- FIL-002 is required in case of intermittent flushing automatic filter (FIL-001 without second filter stage)
Withdrawal point for fuel oil sample
V-001 (Bypass only if FIL-002 is installed)
TCV-001 030.020.030
SeCoS
HE-002 030.020.020
T-001
FIL-001 030.020.060
FIL-002 030.020.120
T-006
Flushing pipe
Variation with prelubrication pump P-007
P-007 030.020.090
1FIL-004 030.020.142
Variation with stand by pump P-074
P-074 030.020.085
1FIL-004 030.020.140
1PSV-004 030.020.040
2PSV-004 030.020.040
PCV-007 010.220.050
2P-001 010.220.010
1P-001 010.220.010
2.3FIL-004 030.020.130
Filling line DN10
Air venting for filling DN10
1TR-001 close to BL-007
Dirty water tank
BL-007 030.020.285
Manuel gas detection
Inert gas
2TR-001
3TR-001
Dipstick
min. 150 mm
CF-001
H-002
MOD-007
P-011
P-012
Storage tank
11.840220165 -

	Components
BL-007	Fan, crankcase venting
CF-001	Lube oil separator
CF-003	Diesel fuel oil separator
FIL-001	Lube oil automatic filter
FIL-002	Lube oil duplex filter
1,2,3 FIL-004	Lube oil suction strainer
H-002	Lube oil preheating unit
HE-002	Lube oil cooler
MOD-007	Lube oil separator module
NRF-001	Lube oil non return flap
1,2 P-001	Lube oil service pump, attached
P-007	Prelubrication pump
	Connection numbers
2101	Lube oil inlet to engine
2111/2112	Lube oil drain from oil pan, counter coupling side 1
2113/2114	Lube oil drain from oil pan, coupling side 1
2121/2122	Lube oil inlet to lube oil pump
P-011	Lube oil feed pump separator
P-012	Lube oil transfer pump
P-074	Lube oil stand-by pump, free-standing
PCV-007	Lube oil pressure relief valve
1,2 PSV-004	Lube oil non return flap with integrated safety valve
T-001	Lube oil service tank
T-006	Leakage oil collecting tank
T-021	Sludge tank
TCV-001	Lube oil temperature control valve
1,2,3 TR-001	Condensate trap, lube oil system
V-001	Lead sealed globe valve, bypass to lube oil main filter
2133	Lube oil outlet from lube oil pump 1
2841	Venting of crankcase 1
7501	Inert gas inlet to crankcase 1

Figure 119: Lube oil system diagram – V engine

5.4.3 External lube oil system – 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 100 and paragraph Lube oil, Page 137.

During the starting process, the maximal temperature mentioned in section Starting conditions, Page 48 must not be exceeded at engine inlet. Therefore, a small LT cooling waterpump can be necessary if the lube oil cooler is served only by an attached LT pump.

Postlubrication

The prelubrication pump is also to be used for postlubrication after the engine is turned off.

See table System circuit operation time after engine stop, Page 61 for the required operation time.

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5.4.4 External lube oil system – Lube oil outlets

Lube oil drain

Two connections for oil drain pipes are located on both ends of the engine oil sump, except for L engine with flexible engine mounting – with one drain arranged in the middle of each side.

For an engine installed in the horizontal position, two oil drain pipes are required, one at the coupling end and one at the free end.

If the engine is installed in an inclined position, three oil drain pipes are required, two at the lower end and one at the higher end of the engine oil sump.

The drain pipes must be kept short. The slanted pipe ends must be immersed in the oil, so as to create a liquid seal between crankcase and tank.

Expansion joints

At the connection of the oil drain pipes to the lube oil service tank, expansion joints are required.

Shut-off butterfly valves

If for lack of space, no cofferdam can be provided underneath the lube oil service tank, it is necessary to install shut-off butterfly valves in the drain pipes. If the ship should touch ground, these butterfly valves can be shut via linkages to prevent the ingress of seawater through the engine.

Drain pipes, shut-off butterfly valves with linkages, expansion joints, etc. are not supplied by the engine builder.

Lube oil outlets – Drawings

See figure Example: Lube oil service tank, Page 313 and Example: Details lube oil service tank, Page 314.

5.4.5 External lube oil system – Lube oil service tank

The lube oil service tank is to be arranged over the entire area below the engine. To ensure uniform vertical thermal expansion of the whole engine foundation.

To provide for adequate degassing, a minimum distance of 150 mm is required between tank top and the highest operating level (high-level alarm). The low oil level (low-level alarm) shall still permit the lube oil to be drawn in free of air, if the ship is moving maximum according to the classification society rules (pitching and rolling).

Depending on the design of the lube oil service tank, a well or a central suction is the preferred solution.

The minimum quantity for a proper engine operation is 1.0 l/kW (quantity of lube oil circulation). This is a theoretical factor for permanent lube oil quality control. It is the decisive factor for the design of the by-pass cleaning. The lube oil quantity, which is required during operation, depends on the tank geometry and the volume of the system (piping, system components), and may exceed the theoretical quantity of 1.0 l/kW to be topped up. The low-

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level alarm in the service tank is to be adjusted to a height, which ensures that the pumps can draw in oil, free of air, at the inclinations according to the classification society but min. 0.7 l/kW.

To ensure an adequate degassing of air out of the lube oil, the arrangement of the suction pipes to the engine and the drain pipes extending from the engine oil sump are to be selected in a way that the oil will remain for the longest possible time in the lube oil service tank. The maximum flow rates must be considered.

The manholes in the floor plates inside the service tank are to be arranged so as to ensure sufficient flow to the suction pipe of the pump also at low lube oil service level.

The tank has to be vented both ends, according to section Crankcase vent and tank vent, Page 316.

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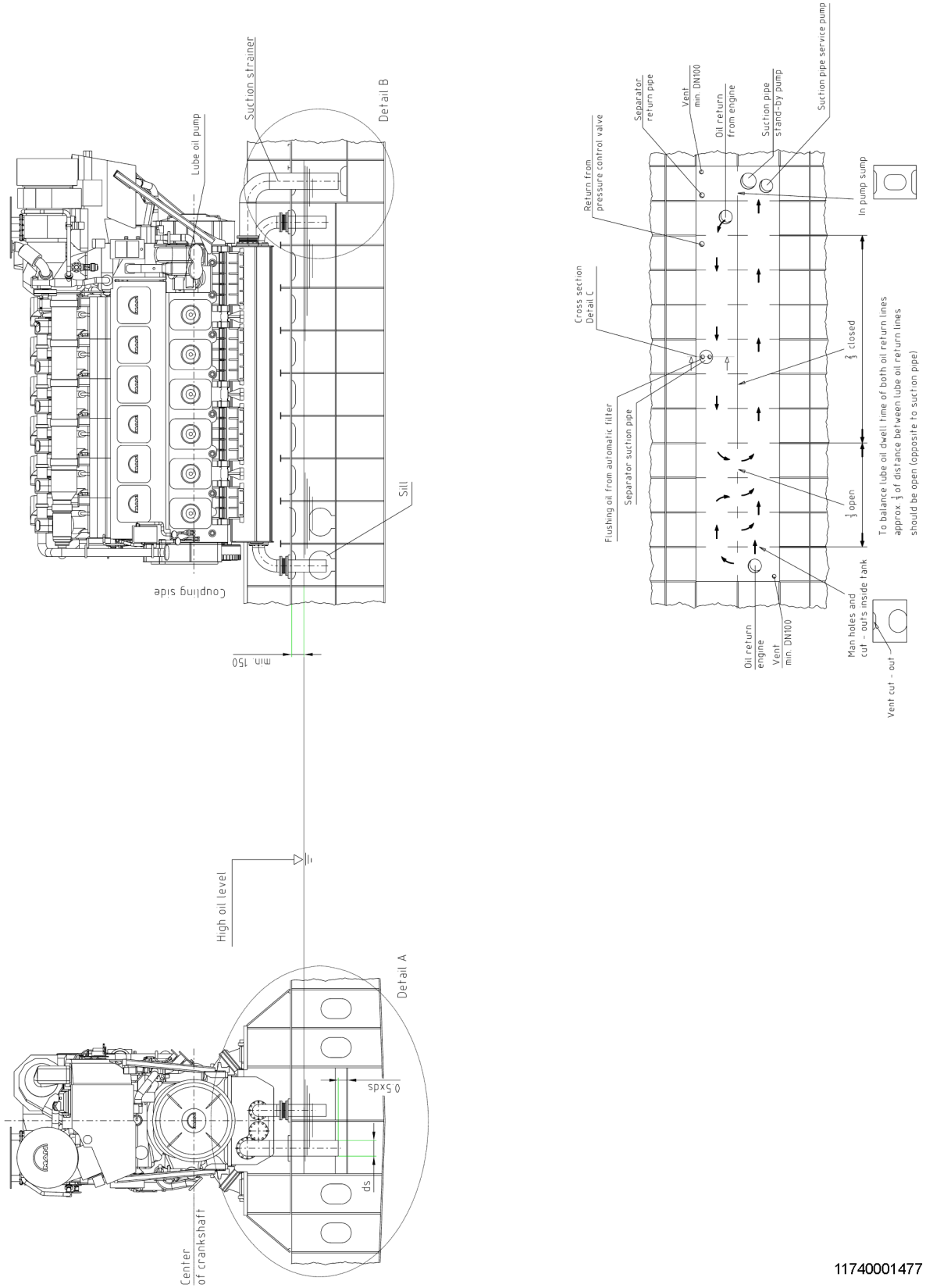


Figure 120: Example: Lube oil service tank

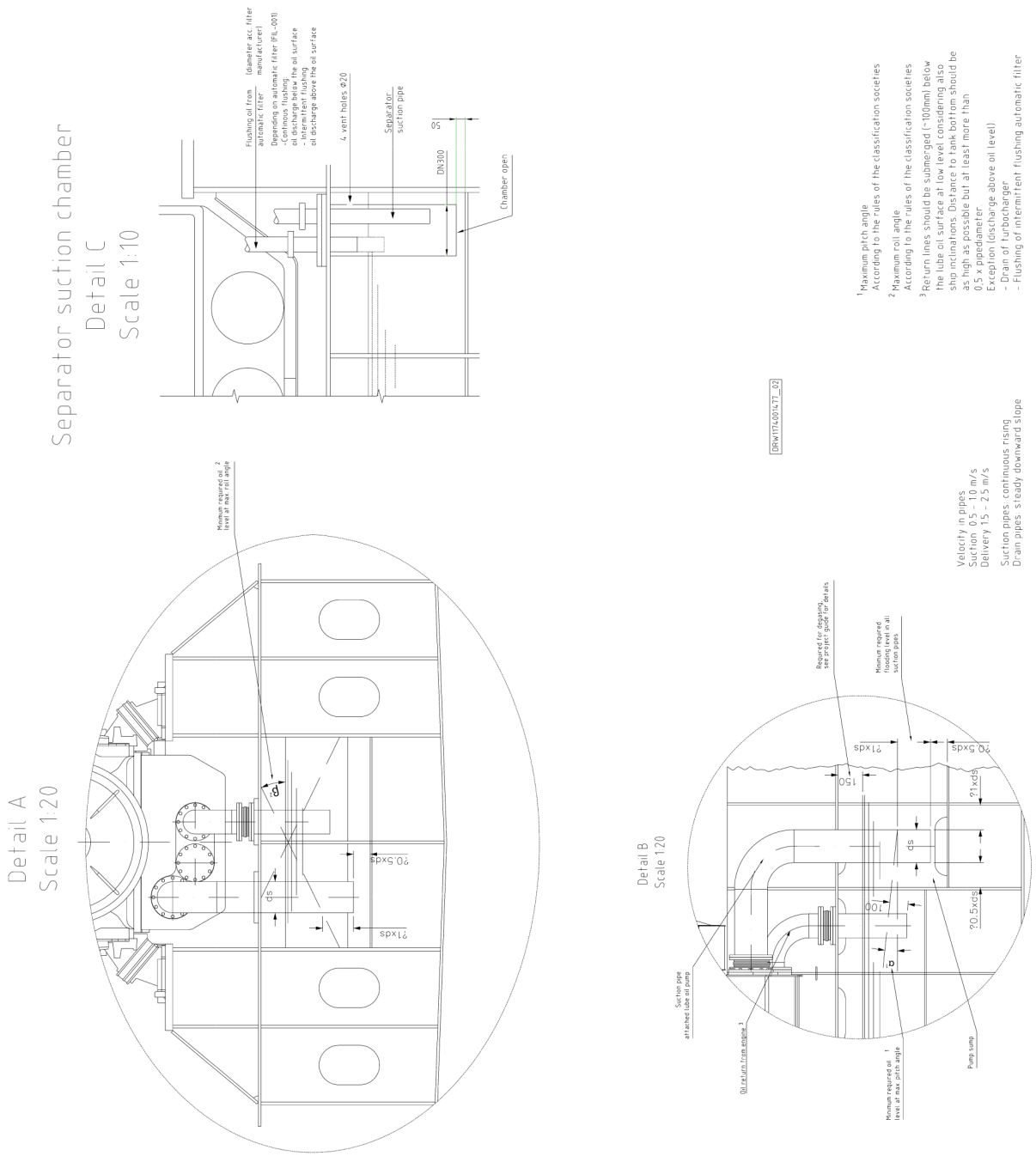


Figure 121: Example: Details lube oil service tank

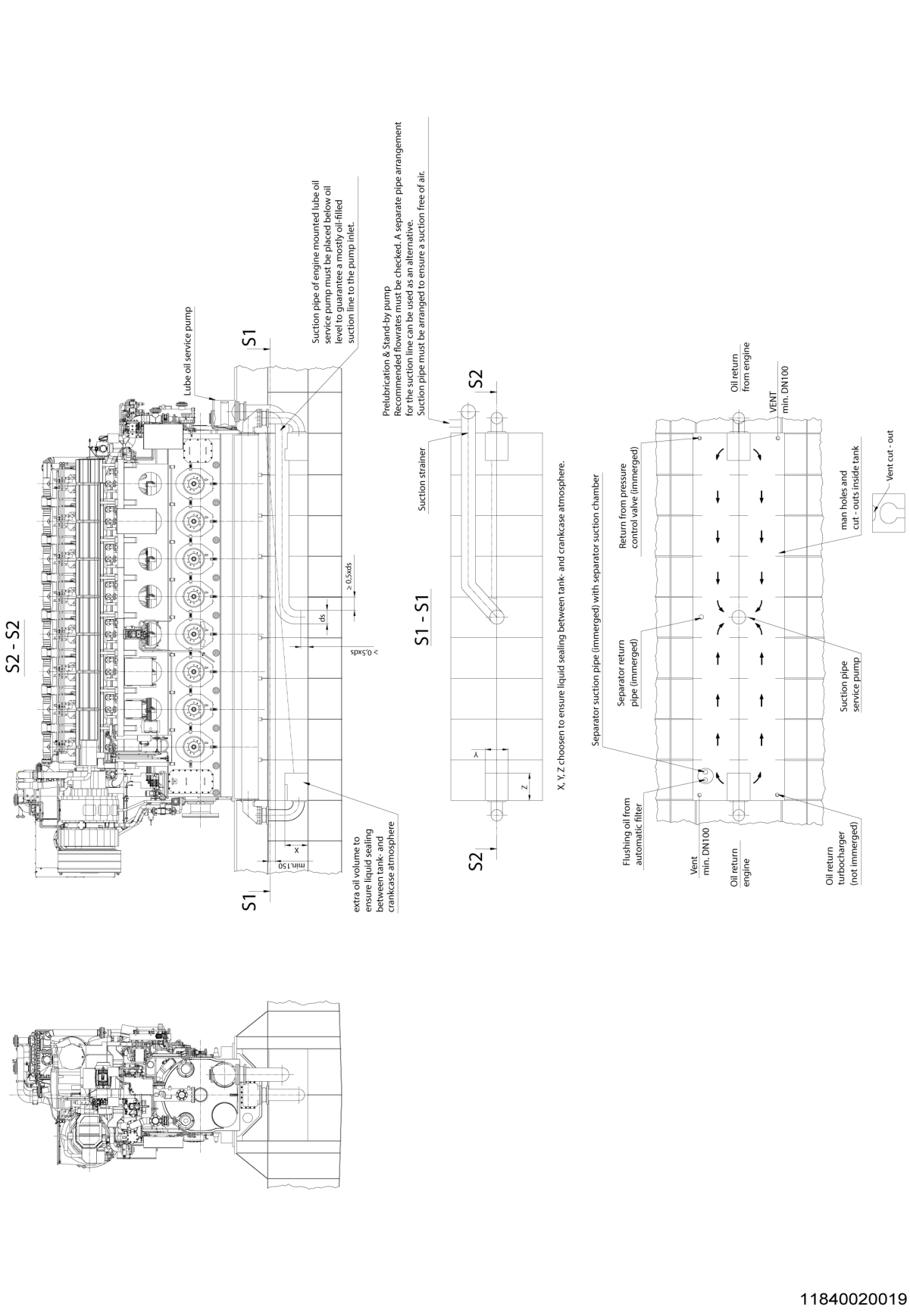


Figure 122: Example: Lube oil service tank with central suction

5.5 Crankcase vent and lube oil tank vent

Open crankcase ventilation

An open crankcase ventilation system (OCV) is installed for the 49/60 engine, crankcase gases are vented by a fan through a oil separator to the ambient air. The collected oil in the oil separator drains back via a siphon and piping into the lube oil sump tank.

Vent pipes

The vent pipes from engine crankcase and lube oil service tank are to be arranged according to the sketch. The engine is equipped with a ventilation opening for crankcase, which shall be equipped with a ventilation pipe built steadily ascending to outside. The required nominal diameters ND are stated in the chart following the diagram.

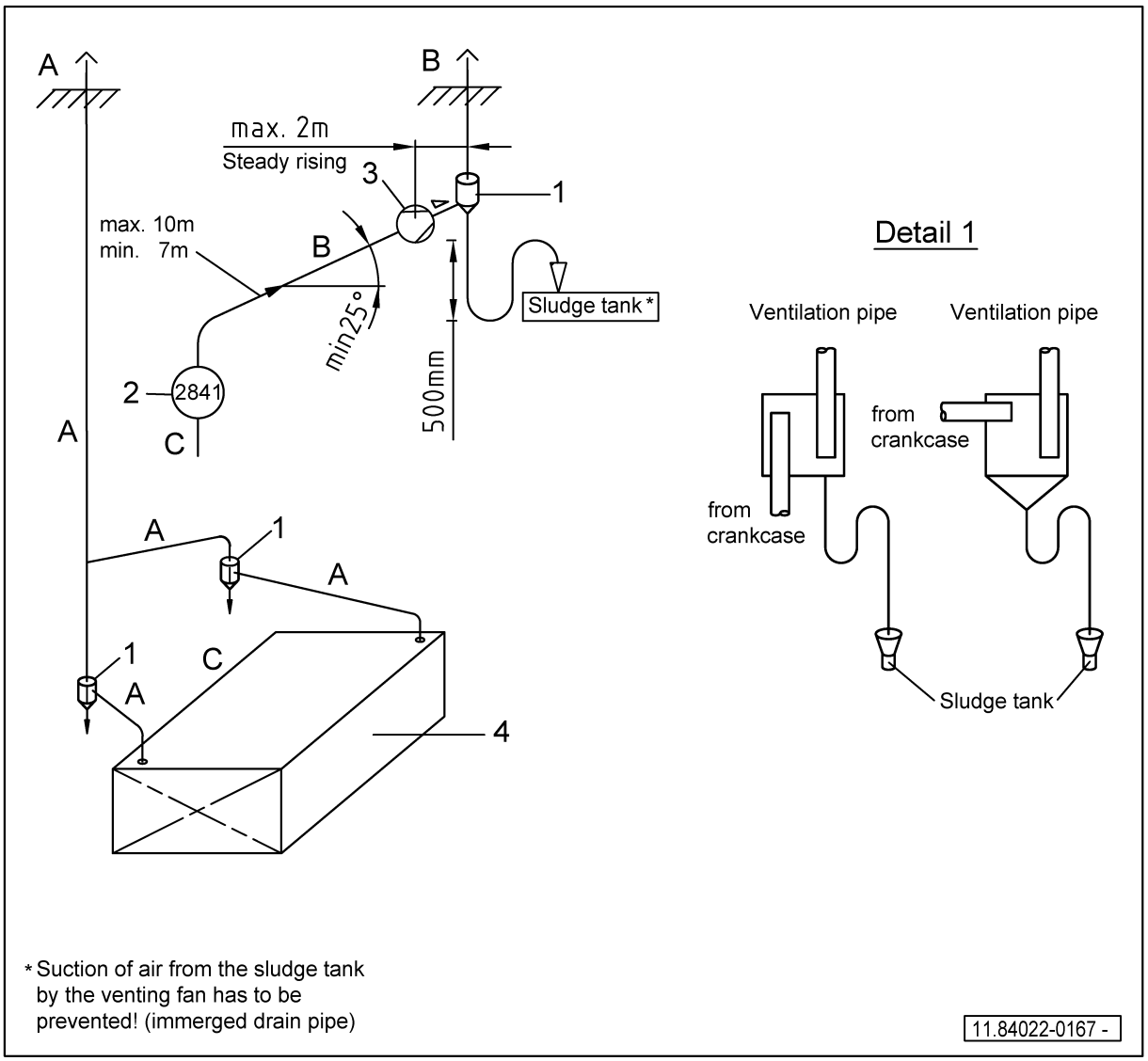
Regarding the venting fan see also paragraph BL-007/Fan, crankcase venting, Page 302. Depending of the relevant environmental legislation a filter has to be installed in this pipe to prevent oil mist emissions to the atmosphere. In this case an additional by-pass has to be installed to prevent an overpressure in the crankcase.

The crankcase ventilation pipe shall lead to a safe location outside the engine room, remote from any source of ignition. The crankcase ventilation pipe may not be connected with any other ventilation pipes.

Note:

- In case of multi-engine plants the venting pipework has to be kept separately.
- All venting openings as well as open pipe ends are to be equipped with flame breakers and shall lead to a safe location outside the engine room remote from any source of ignition.
- Condensate trap overflows are to be connected via siphon to drain pipe.
- Specific requirements of the classification societies are to be strictly observed.
- The maximum pressure loss of the arrangement (piping, condensate trap and flame arrester) after the crankcase venting fan depends on the fan type and must not be exceeded to ensure proper and safe engine operation.

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1 Condensate trap, continuously open
2 Connection crankcase vent
3 Venting fan
4 Lubricating oil service tank

Figure 123: Crankcase vent and tank vent

Engine	Nominal diameter ND (mm)		
	A	B	C
L	100	150	100
V	100	150	150

Table 131: Nominal diameter ND (mm)

5.6 Cooling water system

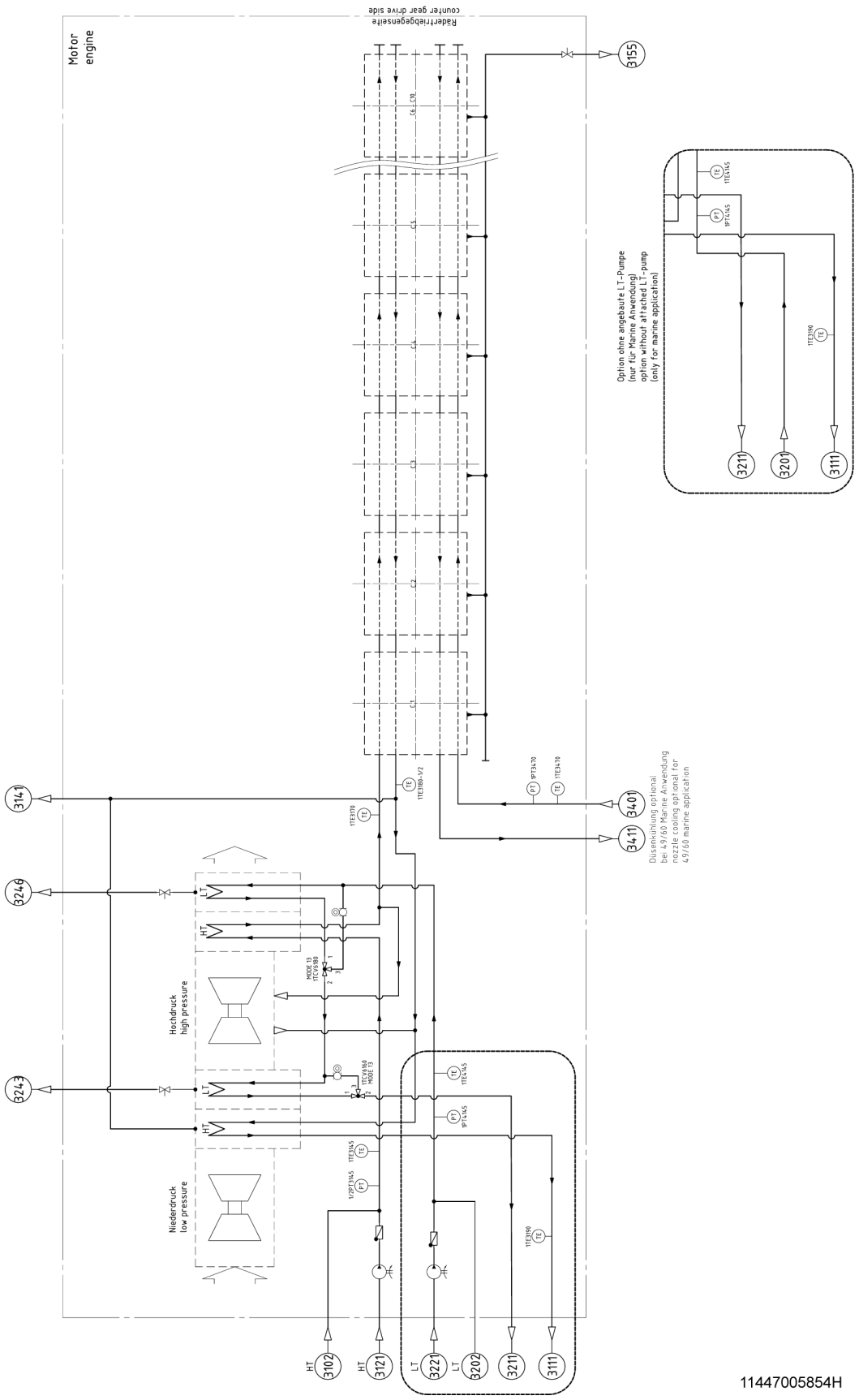
5.6.1 Internal cooling water system

As a standard:

- Engine equipment with attached HT cooling water pump

See overleaf

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Motor engine
Rädertriebgegenseite
counter gear drive side
3155
C6 | C10
C5
C4
C3
C2
C1
Option ohne angebaute LT-Pumpe
(nur für Marine Anwendung)
option without attached LT-pump
(only for marine application)
1TE445
1PT445
1TE390
3211
3201
3111
1TE378
1TE398-172
1PT370
1TE370
3140
3411
Düsenkühlung optional
bei 49/60 Marine Anwendung
nozzle cooling optional for
49/60 marine application
3141
3246
3243
LT
HT
MODE 13
1TCV6980
1TCV6960
MODE 13
Hochdruck
high pressure
Niederdruck
low pressure
1TE445
1PT445
1TE345
1/2PT345
1TE390
HT 3102
HT 3121
LT 3221
LT 3202
3211
3111
11447005854H

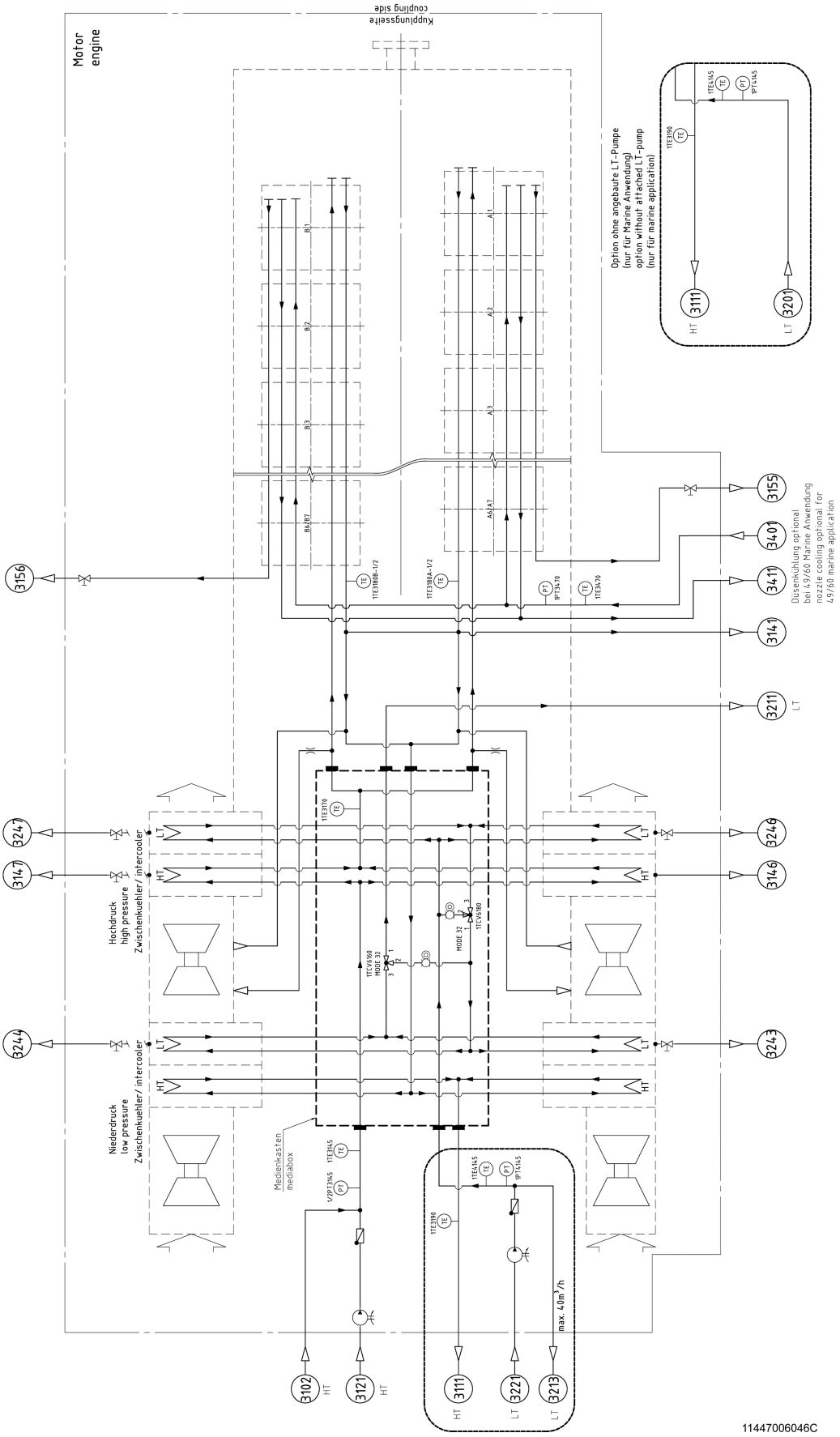
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Connection numbers

3102 HT cooling water inlet to engine (reserve connection)
3111 HT cooling water outlet from engine
3121 HT cooling water inlet to cooling water pump 1
3141 Venting of HT cooling water pipe 1
3155 Drain of support ring 1 (HT)
3201 LT cooling water inlet to engine
3202 LT cooling water inlet to engine (reserve connection)
3211 LT cooling water outlet from engine 1
3221 LT cooling water inlet to cooling water pump
3243 Venting of LT low pressure charge air cooler 1
3246 Venting of LT high pressure charge air cooler 1
3401 Nozzle cooling water inlet to engine
3411 Nozzle cooling water outlet from engine

Figure 124: Internal cooling water system L engine – Exemplary

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Motor
engine
Kupplungsseite
coupling side
Option ohne angebaute LT-Pumpe
(nur für Marine Anwendung)
option without attached LT-pump
(nur für marine application)
Düsenkühlung optional
bei 49/60 Marine Anwendung
nozzle cooling optional for
49/60 marine application
Hochdruck
high pressure
Zwischenkuehler/ intercooler
Niederdruck
low pressure
Zwischenkuehler/ intercooler
Medienkasten
mediabox
max. 40m³/h
11447006046C

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Connection numbers

3102	HT cooling water inlet to engine (reserve connection)	3211	LT cooling water outlet from engine 1
3111	HT cooling water outlet from engine	3213	LT cooling water outlet from engine 2
3121	HT cooling water inlet to cooling water pump 1	3221	LT cooling water inlet to cooling water pump
3141	Venting of HT cooling water pipe 1	3243	Venting of LT low pressure charge air cooler 1
3143	Venting of CAC 1 (HT LP stage)	3244	Venting of LT low pressure charge air cooler 2
3146	Venting of CAC 1 (HT HP stage)	3246	Venting of LT high pressure charge air cooler 1
3155	Drain of support ring 1 (HT)	3247	Venting of LT high pressure charge air cooler 2
3156	Drain of support ring 2 (HT)	3401	Nozzle cooling water inlet to engine
3201	LT cooling water inlet to engine	3411	Nozzle cooling water outlet from engine

Figure 125: Internal cooling water system V engine – Exemplary

5.6.2 External cooling water system – Description

The diagrams showing cooling water systems for main engines comprising the possibility of heat utilisation in a fresh water generator and equipment for preheating of the charge air in a two-stage charge air cooler during part load operation.

Note:
The arrangement of the cooling water system shown here is only one of many possible solutions. It is recommended to inform Everllence in advance in case other arrangements should be desired. In any case two seawater coolers have to be installed to ensure continuous operation while one cooler is shut off (e.g. for cleaning).

For special applications, e.g. GenSets or dual fuel engines, supplements will explain specific necessities and deviations.

For the design data of the system components shown in the diagram see section Planning data, Page 100 and following sections.

There are many possible concepts for the arrangement of cooling water systems and the best solution always depends on the specific application of the engine and ship. The table below shows the main characteristics and schemes of two main concepts. For further information contact Everllence.

Concept	Mixing CW system	Conventional CW system
Arrangement	Physically and thermodynamically connected LT and HT circuit	Physically and thermodynamically separated LT and HT circuit
Features	One central seawater cooler sufficient Reduced piping	No transfer of pressure peaks and pollutants between LT and HT circuits Central cooler possible with HT-cooler recooled by LT-cooling water

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Concept	Mixing CW system	Conventional CW system
Application	Economic solution for vessels with limited space Not recommended for multi-engine plants with attached cooling water pumps or variable engine speed Not recommended for plants with combustion air intake from outside the vessel or plants with high requirements on capacity of waste heat recovery from HT-cooling water.	Vessels which require convenient commissioning and maintenance as well as robust temperature control

Table 132: Characteristics of cooling water concepts

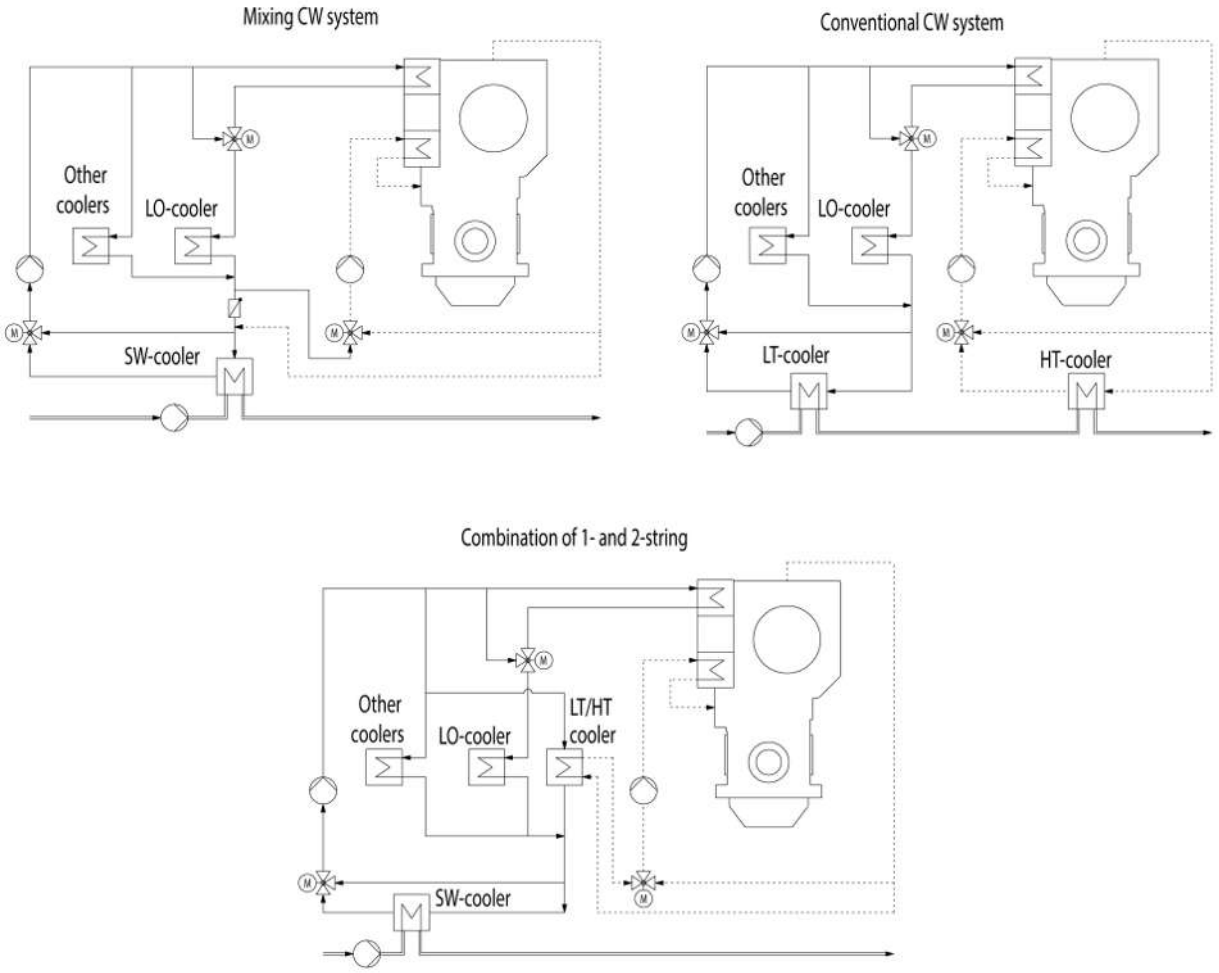


Figure 126: Basic schemes of cooling water concepts

The cooling water is to be conditioned by using a corrosion inhibitor, see section Specification of engine coolant, Page 267.

Cooling water that is not treated properly may cause serious corrosion during storage or operation of the engine.

LT = Low temperature

HT = High temperature

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Cooler dimensioning, general

For coolers operated by seawater (not treated water), lube oil or DMA/DMB 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, Everllence does not insist on this margin.

In case antifreeze is added to the cooling water, the corresponding lower heat transfer is to be taken into consideration.

The cooler piping arrangement should include venting and draining facilities for the cooler. In case coolers for lube oil, fuel oil or other environmental hazardous fluids are operated by seawater, we strongly recommend to use double wall plate type coolers. These coolers allow to detect leakage and prevent the seawater from pollution by hazardous fluids.

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. Make sure that a minimum flow rate of 1% of the HT-cooling water flow given in section 2 is led from the engine HT-venting connection to the expansion tank at maximum engine speed.

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 or low flashpoint fuels like methanol, 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.

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.

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- 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.
- In case the engine HT cooling water may be cooled down in part load operation, a throttle valve has to be installed in the HT venting pipe to adjust the flow towards the expansion tank. The valve is recommended for plants with mixing systems, combustion air intake from outside the vessel, operation under arctic conditions or other special applications. In these cases, contact Everllence.

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.

LT cooling water system

In general the LT cooling water passes through the following components:

- Stage 2 of the two-stage charge air coolers (HE-040/041)
- Lube oil cooler, free-standing (HE-002)
- Nozzle cooling water cooler (HE-005)
- Fuel oil cooler (HE-007)
- Gearbox lube oil cooler (HE-023) (or e.g. alternator cooling in case of an electric propulsion plant)
- Cooler for LT cooling water (HE-024)
- Fuel oil cooler, supply circuit (HE-025) (if applicable, see section External fuel system – Residual fuel (HFO) supply system, Page 372)
- Other components, for example, auxiliary engines (GenSets)

LT cooling water pumps can be either of engine driven or electrically driven type.

In case an engine driven LT pump is used and no electric driven pump (LT main pump) is installed in the LT circuit, an LT circulation pump has to be installed. We recommend an electric driven pump with a capacity of approximately 8 m³/h for L engines, 12 m³/h for V engines at 1.5 bar pressure head. The pump has to be operated simultaneously to the prelubrication pump. Make sure to keep the pump running after stop of the engine to cool down all connected system components. See table System circuit operation time after engine stop, Page 61 for the required operation time. In case a 100% lube oil stand-by pump is installed, the circulation pump has to be increased to the size of a 100% LT stand-by pump to ensure cooling down the lube oil in the cooler during prelubrication before engine start. The system has to be designed, so that the temperatures for lube oil and cooling water, which are given in section Operating/service temperatures and pressures, Page 133, are adhered during operation and stand-by of the engine. For shutdown of the engine the information in section Engine load reduction, Page 61 must be observed. In case no electric stand-by pump will be installed, the engine and lube oil tank have to be cooled down by operating the engine at low load

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(< 15% MCR) for at least 4 minutes before shut down. The shipyard has to make sure, that lube oil separators will not cause overheating of the oil during standstill of the engine. For max. permissible temperatures, see section Starting conditions, Page 48. For details contact Everllence.

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

However, the capacity of the cooler for LT cooling water (HE-024) is determined by the temperature difference between seawater and LT cooling water. Due to this correlation, an LT freshwater temperature of 32°C can be ensured at a seawater temperature of 25°C.

To meet the IMO Tier I/IMO Tier II regulations the set point of the LT cooling water temperature control valve (MOV-016) is to be adjusted to 32°C. However this temperature will fluctuate and reach at most 38°C with a seawater temperature of 32°C (tropical conditions). In case other temperatures are required in the LT system, the engine setting has to be adapted accordingly. For details contact Everllence.

The charge air coolers stage 2 and the lube oil cooler (HE-002) are installed in series to obtain a low delivery rate of the LT cooling water pump (P-004 or P-076).

P-004 or P-076/LT cooling water pump

The delivery rates of the service and stand-by pump are mainly determined by the cooling water required for the charge air cooler stage 2 and the other coolers.

For operating auxiliary engines (GenSets) in port, the installation of an additional smaller pump is recommendable.

MOV-040 and 041/Charge air temperature control valves CHATCO PRO

The three way valves are mounted at the engine.

They serve two purposes:

1. In engine part load operation, depending on the ambient temperature, the charge air coolers stage 2 (HE-040/041) are partially or completely by-passed, so that a higher charge air temperature is maintained.
2. The valve reduces the accumulation of condensed water during engine operation under tropical conditions by regulation of the charge air temperature. Below a certain intake air temperature the charge air temperature is kept constant. When the intake temperature rises, the charge air temperature will be increased accordingly.

The valves are engine mounted and controlled by the SaCoS system.

HE-002/Lube oil cooler, free-standing

For the description see section External lube oil system, Page 298. For heat data, flow rates and tolerances see section Planning data, Page 100 and the following. For the description of the principal design criteria see paragraph Cooler dimensioning, general, Page 324.

HE-024/Cooler for LT cooling water

For heat data, flow rates and tolerances of the heat sources see section Planning data, Page 100 and the following. For the description of the principal design criteria for coolers see paragraph Cooler dimensioning, general, Page 324.

MOV-016/LT cooling water temperature control valve

This is a motor-actuated three-way regulating valve with a linear characteristic. It is to be installed as a mixing valve. It maintains the LT cooling water at set point temperature (32°C standard).

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The three-way valve is to be designed for a pressure loss of 0.3–0.6 bar. It is to be equipped with an actuator with low positioning speed. For adjustment of the valve follow instructions given in Everllence planning documentation. The actuator must permit manual emergency adjustment.

The actual LT flow temperature is measured by a temperature sensor, directly downstream of the three-way mixing valve in the supply pipe to charge air cooler stage 1.

This sensor has to be installed by the shipyard. To ensure instantaneous measurement of the mixing temperature of the three-way mixing valve, the distance to the valve should be 10 to 15 times the pipe diameter.

For single engine plants, the control function may be taken over by the SaCoS control unit.

For multi engine plants, Everllence can supply a suitable external controller.

Note:
For engine operation with reduced NO_x emission, according to IMO Tier I/IMO Tier II requirement, at 100% engine load and a seawater temperature of 25°C (IMO Tier I/IMO Tier II reference temperature), an LT cooling water temperature of 32°C before charge air cooler stage 2 (HE-008) is to be maintained. For other temperatures, the engine setting has to be adapted. For further details contact Everllence.

FIL-021/Strainer for cooling water

In order to protect the engine and system components, several strainers are to be provided at the places marked in the diagram. We recommend to install Y-type strainers with magnetic inserts and a mesh size of 1–2 mm depending on the pipe diameter.

The strainers have to be installed in horizontal pipes or pipes with flow direction downwards.

We recommend to install shut off-flaps upstream and downstream of the strainer.

HE-005/Nozzle cooling water cooler

The nozzle cooling water system is a separate and closed cooling circuit. It is cooled down by LT cooling water via the nozzle cooling water cooler (HE-005).

Heat data, flow rates and tolerances are indicated in section Planning data, Page 100 and the following. The principal design criteria for coolers has been described before in paragraph Cooler dimensioning, general, Page 324. For plants with two main engines only one nozzle cooling water cooler (HE-005) is required. As an option a compact nozzle cooling water module (MOD-005) can be delivered, see section Nozzle cooling water module, Page 339.

HE-007/Fuel oil cooler

This cooler is required to dissipate the heat of the fuel injection pumps during DMA/DMB operation. For the description of the principal design criteria for coolers see paragraph Cooler dimensioning, general, Page 324. For plants with more than one engine, connected to the same fuel oil system, only one DMA/DMB cooler is required. In case the fuel oil cooler is recooled by seawater, we recommend to use a double-wall type cooler.

In case fuels with very low viscosity are used (for example, arctic diesel or military fuels), a chiller system may be necessary to meet the minimum required fuel viscosity (see section Fuel system). Contact Everllence in that case.

HE-025/Fuel oil cooler, supply circuit

See section Heavy fuel oil (HFO) supply system, Page 372.

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T-075/LT cooling water expansion tank

The effective tank capacity should be high enough to keep approximately 2/3 of the tank content of HT cooling water expansion tank T-002. In case of twin-engine plants with a common cooling water system, the tank capacity should be by approximately 50% higher. The tanks T-075 and T-002 should be arranged side by side to facilitate installation. For plants with combustion air intake from outside, or high demands of waste heat energy, we recommend to separate HT- and LT- tanks from each other (no common tank).

In case HT/LT switchover (charge air preheating) is applied, the tank has to be placed at the same height as the HT expansion tank and a compensating line has to be installed.

In any case the tank bottom must be installed above the highest point of the LT system at any ship inclination.

For the recommended installation height and the diameter of the connecting pipe, see table Service tanks capacities, Page 142.

HT cooling water circuit

General

The HT cooling water system consists of the following coolers and heat exchangers:

- Charge air coolers stage 1 (HE-038/039)
- Cylinder cooling
- Cooler for HT cooling water (HE-003)
- Heat utilisation, e.g. fresh water generator (HE-026)
- HT cooling water preheating module (MOD-004)

The HT cooling water pumps can be either of engine-driven or electrically-driven type. The outlet temperature of the cylinder cooling water at the engine varies between 88°C and 100°C, depending on the engine load and intake air temperature.

The maximum outlet temperature is limited to 100°C for standard applications. It may be released to max. 106°C for waste heat recovery use.

For HT cooling water systems, where more than one main engine is integrated, each engine should be provided with an individual engine driven HT cooling water pump. Alternatively electrically-driven HT cooling water pumps may be used for all engines. However, an individual HT temperature control valve is required for each engine. The total cooler and pump capacities are to be adapted accordingly.

The shipyard is responsible for the correct cooling water distribution, ensuring that each engine will be supplied with cooling water at the flow rates required by the individual engines, under all operating conditions. To meet this requirement, orifices, flow regulation valves, by-pass systems etc. are to be installed where necessary. Check total pressure loss in HT circuit. The delivery height of the attached pump must not be exceeded.

HT cooling water preheating module (MOD-004)

Before starting a cold engine, it is necessary to preheat the water jacket up to min. 60°C at engine outlet.

For the total heating power required for preheating the HT cooling water from 10°C to 60°C within 4 hours see table Heating power, Page 328.

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Engine type	L/V engine
Min. heating power (kW/cylinder)	14

Table 133: Heating power

These values include the radiation heat losses from the outer surface of the engine. Also a margin of 20 % for heat losses of the cooling system has been considered.

To prevent a too quick and uneven heating of the engine, the preheating temperature of the HT cooling water must remain mandatory below 90°C at engine inlet and the circulation amount may not exceed 30% of the nominal flow. The maximum heating power has to be calculated accordingly.

A secondary function of the preheater is to provide heat capacity in the HT cooling water system during engine part load operation. This is required for marine propulsion plants with a high freshwater requirement, e.g. on passenger vessels, where frequent load changes are common.

For engines operated in arctic conditions or with charge air from outside the vessel, the capacity of the preheater has to be increased. In this case contact Everllence.

It is also required for arrangements with an additional charge air preheating by deviation of HT cooling water to the charge air cooler stage 2 (HE-008). In this case the heat output of the preheater is to be increased by approximately 50%.

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 counterpressure of the engine driven pump).

An electrically driven pump becomes necessary to circulate the HT cooling water during preheating. For the required minimum flow rate see table below.

No. of cylinders, config.	Minimum flow rate required during preheating and post-cooling
	m^3/h
6L	14 – 21
7L	16 – 24
8L	18 – 27
9L	20 – 30
10L	22 – 33
12V	28 – 42
14V	32 – 48

Table 134: Minimum flow rate during preheating and post-cooling

The preheating of the main engine with cooling water from auxiliary engines is also possible, provided that the cooling water is treated in the same way. In that case, the expansion tanks of the two cooling systems have to be installed at the same level. Furthermore, it must be checked whether the available heat is sufficient to pre-heat the main engine. This depends on the number of auxil-

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iary engines in operation and their load. It is recommended to install a separate preheater for the main engine, as the available heat from the auxiliary engines may be insufficient during operation in port.

As an option Everllence can supply a compact HT cooling water preheating module (MOD-004). One module for each main engine is recommended. Depending on the plant layout, also two engines can be heated by one module.

Contact Everllence to check the hydraulic circuit and electric connections.

The preheater has to be designed to meet explosion protection requirements, in case gas may accumulate in some components of the module.

HE-003/Cooler for HT cooling water

For heat data, flow rates and tolerances of the heat sources see section Planning data, Page 100 and following sections. For the description of the principal design criteria for coolers see paragraph Cooler dimensioning, general, Page 324.

HE-026/Fresh water generator

The fresh water generator must be switched off automatically when the cooling water temperature at the engine outlet drops below 90°C continuously.

A binary contact (SaCoS) for the heat consumer release can be used for activation of the fresh water generator. The heat consumer must then be switched off accordingly.

This will prevent operation of the engine at too low temperatures. For vessels with very high demands of fresh water, a separate control system is needed to keep the HT-temperature within the required limits. Contact Everllence for further information.

HT temperature control

The HT temperature control system consists of the following components:

- 1 electrically activated three-way mixing valve with linear characteristic curve (MOV-002).
- 1 temperature sensor TE, directly downstream of the three-way mixing valve in the supply pipe to charge air cooler stage 1 (for EDS visualisation and control of preheater valve).

  This sensor will be delivered by Everllence and has to be installed by the shipyard.
- 1 temperature sensor TE, directly downstream of the engine outlet.

  This sensor is already installed at the engine by Everllence.

The temperature controllers are available as software functions inside the Gateway Communication Module of SaCoS 5000. 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.

It serves to maintain the cylinder cooling water temperature between 90 and 100 °C at the engine outlet – even in case of frequent load changes – and to protect the engine from excessive thermal load.

For adjusting the outlet water temperature (between 90 and 100°C) to engine load and speed, the cooling water inlet temperature is controlled. The electronic water temperature controller recognises deviations by means of the sensor at the engine outlet and afterwards corrects the reference value accordingly.

- The electronic temperature controller is installed in the switch cabinet of the engine room.

For a stable control mode, the following boundary conditions must be observed when designing the HT freshwater system:

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- The temperature sensor is to be installed in the supply pipe to stage 1 of the charge air cooler. To ensure instantaneous measurement of the mixing temperature of the three-way mixing valve, the distance to the valve should be 10 to 15 times the pipe diameter.
- The three-way valve (MOV-002) is to be installed as a mixing valve. It is to be designed for a pressure loss of 0.3–0.6 bar. It is to be equipped with an actuator of high positioning speed. For adjustment of the valve follow instructions given in Everllence planning documentation. The actuator must permit manual emergency adjustment.
- The pipes within the system are to be kept as short as possible in order to reduce the dead times of the system, especially the pipes between the three-way mixing valve and the inlet of the charge air cooler stage 1 which are critical for the control.

The same system is required for each engine, also for multi-engine installations with a common HT fresh water system.

In case of a deviating system layout, Everllence is to be consulted.

P-002/HT cooling water service pump, attached

The engine is normally equipped with a HT cooling water service pump, attached (default solution).

For technical data of the pumps see table HT cooling water – Engine, Page 133.

P-079/HT cooling water stand-by pump, free-standing

The HT cooling water stand-by pump (free-standing) has to be of the electrically driven type.

It is required to cool down the engine after shut-down. See table System circuit operation time after engine stop, Page 61 for the required cool down time. In case that neither an electrically driven HT cooling water pump nor an electrically driven stand-by pump is installed (for example, multi-engine plants with engine driven HT cooling water pump without electrically driven HT stand-by pump, if applicable by the classification rules), it is possible to cool down the engine by a separate small preheating pump, see table Minimum flow rate during preheating and post-cooling, Page 329. If the optional HT cooling water preheating module (MOD-004) with integrated circulation pump is installed, it is also possible to cool down the engine with this small pump. However, the pump used to cool down the engine, has to be electrically driven and started automatically after engine shut-down.

None of the cooling water pumps is a self-priming centrifugal pump.

Design flow rates should not be exceeded by more than 15% to avoid cavitation in the engine and its systems. A throttling orifice is fitted at the engine for adjusting the specified operating point.

T-002/HT cooling water expansion tank

The HT cooling water expansion tank compensates changes in system volume and losses due to leakages. 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 shall connect the tank with the suction side of the pump(s), as close as possible. It is to be installed in a steady rise to the expansion tank, without any air pockets. The minimum required diameter for the pipe is given, see table Service tanks capacities, Page 142 depending on engine size. In case more than one engine is connected to the same tank, the pipe has to be extended accordingly.

For the recommended volume of the tank and the recommended installation height, see table Service tanks capacities, Page 142.

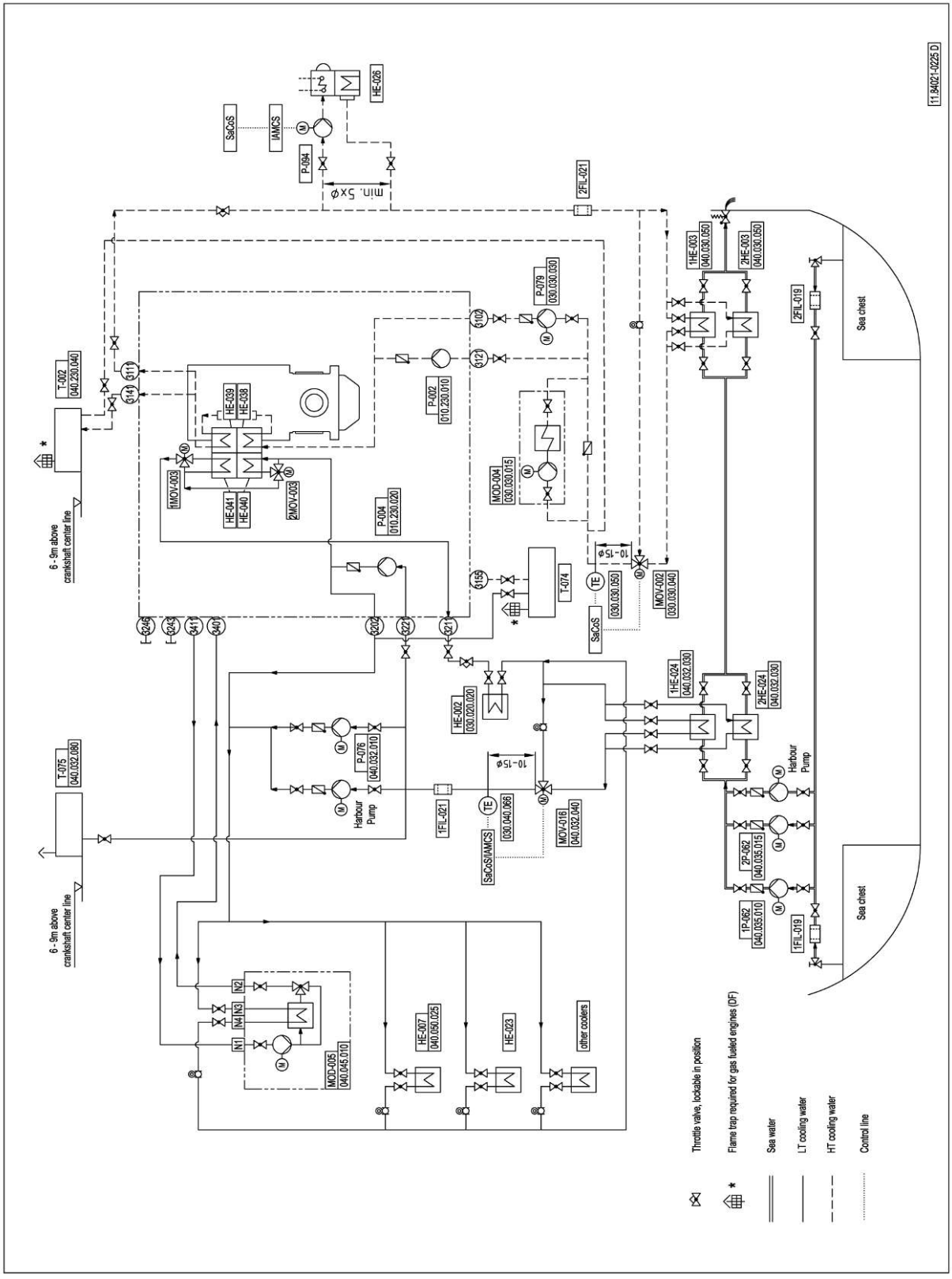
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The tank may be designed to a smaller volume if necessary. In that case make sure, that proper air venting is ensured even in heavy seas at max. ship inclinations. We recommend a minimum volume of 15% of the total HT cooling water amount in the plant.

Tank equipment:

- Sight glass for level monitoring or other suitable device for continuous level monitoring
- Low-level alarm switch
- Overflow and filling connection
- Inlet for corrosion inhibitor

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11.84021-0025 D
T-002 040.230.040
6 - 9m above crankshaft center line
HE-039
HE-038
HE-041
HE-040
1MOV-009
2MOV-009
P-004 010.230.020
P-002 010.230.010
P-079 030.030.030
MOD-004 030.030.015
T-074
SaCoS
030.030.050
MOV-002 030.030.040
10-15ø
HE-002 030.020.020
T-075 040.032.080
P-076 040.032.010
Harbour Pump
1FIL-021
SaCoS/IAMCS
030.040.066
MOV-016 040.032.040
1HE-024 040.032.030
2HE-024 040.032.030
1HE-003 040.030.050
2HE-003 040.030.050
2FIL-021
2FIL-019
Sea chest
2P-062 040.035.015
1P-062 040.035.010
1FIL-019
HE-026
P-084
IAMCS
SaCoS
min. 5xø
MOD-005 040.045.010
HE-007 040.060.025
HE-023
other coolers
Throttle valve, lockable in position
Flame trap required for gas fuelled engines (DF)
Sea water
LT cooling water
HT cooling water
Control line

Components

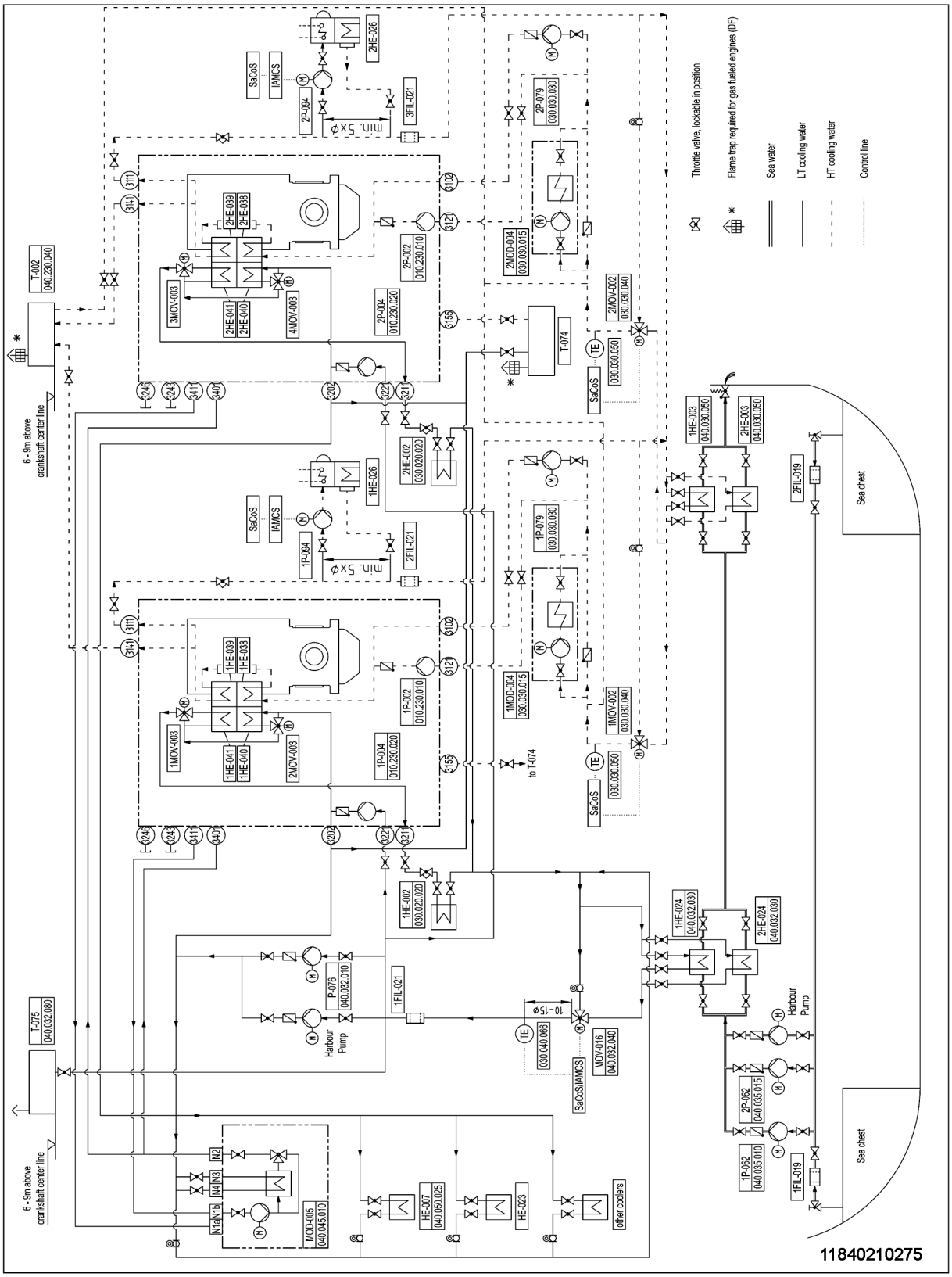
1,2 FIL-019	Seawater filter
1,2 FIL-021	Strainer for cooling water
HE-002	Lube oil cooler
1,2 HE-003	Cooler for HT cooling water
HE-007	Fuel oil cooler
HE-023	Gearbox lube oil cooler
1,2 HE-024	Cooler for LT cooling water
HE-026	Fresh water generator
HE-038	HP HT charge air cooler
HE-039	LP HT charge air cooler
HE-040	HP LT charge air cooler
HE-041	LP LT charge air cooler
MOD-004	HT cooling water preheating module
MOD-005	Nozzle cooling water module
MOV-002	HT cooling water temperature control valve
1 MOV-003	HP alumatic temperature control valve
2 MOV-003	LP alumatic temperature control valve
MOV-016	LT cooling water temperature control valve
P-002	HT cooling water service pump, attached
P-004	LT cooling water service pump, attached
1,2 P-062	Seawater pump, free-standing
P-076	LT cooling water pump, free-standing
P-079	HT cooling water pump, free-standing
P-094	HT cooling water pump WHR
T-002	HT cooling water expansion tank
T-074	Fresh water collecting tank
T-075	LT cooling water expansion tank

Major cooling water engine connections

3102	HT cooling water inlet to engine 2
3111	HT cooling water outlet from engine
3121	HT cooling water inlet to cooling water pump 1
3141	Venting of HT cooling water pipe 1
3155	Drain of support ring (HT) 1
3202	LT cooling inlet to engine 2
3211	LT cooling water outlet from engine 1
3221	LT cooling water inlet to cooling water pump
3243	Venting of LT low pressure charge air cooler
3246	Venting of LT high pressure charge air cooler
3401	Nozzle cooling water inlet to engine
3411	Nozzle cooling water outlet from engine

Figure 127: Cooling water system diagram – Single engine plant

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Throttle valve, lockable in position
Flame trap required for gas fueled engines (DF)
Sea water
LT cooling water
HT cooling water
Control line
6 - 9m above crankshaft center line
Sea chest
Harbour Pump
other coolers
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Components

1,2 FIL-019	Seawater filter
1,2,3 FIL-021	Strainer for cooling water
1,2 HE-002	Lube oil cooler
1,2 HE-003	Cooler for HT cooling water
HE-007	Fuel oil cooler
HE-023	Gearbox lube oil cooler
1,2 HE-024	Cooler for LT cooling water
1,2 HE-026	Fresh water generator
1,2 HE-038	HP HT charge air cooler
1,2 HE-039	LP HT charge air cooler
1,2 HE-040	HP LT charge air cooler
1,2 HE-041	LP LT charge air cooler
1,2 MOD-004	HT cooling water preheating module
MOD-005	Nozzle cooling water module
1,2 MOV-002	HT cooling water temperature control valve
1,3 MOV-003	LP alumatic temperature control valve
2,4 MOV-003	HP alumatic temperature control valve
MOV-016	LT cooling water temperature control valve
1,2 P-002	HT cooling water service pump, attached
1,2 P-004	LT cooling water service pump, attached
1,2 P-062	Seawater pump, free-standing
P-076	LT cooling water pump, free-standing
1,2 P-079	HT cooling water pump, free-standing
1,2 P-094	HT cooling water pump WHR
T-002	HT cooling water expansion tank
T-074	Fresh water collecting tank
T-075	LT cooling water expansion tank

Major cooling water engine connections

3102	HT cooling water inlet to engine (reserve connection)
3111	HT cooling water outlet from engine
3121	HT cooling water inlet to cooling water pump 1
3141	Venting of HT cooling water pipe 1
3155	Drain of support ring (HT) 1
3202	LT cooling water inlet to engine 2 (reserve connection)
3211	LT cooling water outlet from engine 1
3221	LT cooling water inlet to cooling water pump
3243	Venting of LT low pressure charge air cooler (manual)
3246	Venting of LT high pressure charge air cooler (manual)
3401	Nozzle cooling water inlet to engine
3411	Nozzle cooling water outlet from engine

Figure 128: Cooling water system diagram – Twin engine plant

5.6.3 External cooling water system – Collection and supply system

T-074/Cooling water collecting tank

The tank is to be dimensioned and arranged in such a way that the cooling water content of the circuits of the cylinder, turbocharger and nozzle cooling systems 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 (reuse of conditioned cooling water).

Volumes for the engine are listed in table Cooling water and oil volume of engine, Page 142.

Tank equipment:

- Sight glass for level monitoring or other suitable device for continuous level monitoring
- Low-level alarm switch

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- Overflow and filling connection
- Inlet for corrosion inhibitor

P-031/Cooling water filling pump (not indicated in the diagram)

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.

5.6.4 External cooling water system – 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 Everllence 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. 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 100 and the following sections. Consider the maximal possible pressure level, that can be produced by the pumps (zero delivery head) integrated in the system and static pressure by expansion tanks or other equipment. The engine cooling water connections have to be designed according to PN10/PN16.

5.6.5 External cooling water system – Nozzle cooling system

General

In HFO operation, the nozzles of the fuel injection valves are cooled by freshwater circulation, therefore a nozzle cooling water system is required. It is a separate and closed system re-cooled by the LT cooling water system, but not directly in contact with the LT cooling water. The separate nozzle cooling water system ensures easy detection of damages at the nozzles. Even small fuel leakages are visible via the sight glass. The closed system also prevents the engine and other parts of the cooling water system from pollution by fuel oil. Cleaning of the system is quite easy and only a small amount of contaminated water has to be discharged to the sludge tank. In case the nozzle cooling water is not contaminated, it may be drained to the cooling water collecting tank. The nozzle cooling water is to be treated with corrosion inhibitor according to Everllence specification. For further information see section Specification of engine coolant, Page 267.

Note:
In diesel engines designed to operate prevalently on HFO the injection valves are to be cooled during operation on HFO. In the case of DMA or DMB operation exceeding 72 h, the nozzle cooling is to be switched off and the supply

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line is to be closed. The return pipe has to remain open. In diesel engines designed to operate exclusively on DMA or DMB (no HFO operation possible), nozzle cooling is not required. The nozzle cooling system is omitted.

For reliable engine operation with HFO incl. stand-by and starting, a nozzle cooling water temperature of at least 55°C must always be ensured.

For operation on HFO, the nozzle cooling system has to be activated.

For reliable engine operation with HFO incl. standby and starting, a nozzle cooling water temperature of at least 55°C must always be ensured.

P-005/Nozzle cooling water pump

The centrifugal (non self-priming) pump discharges cooling water via the nozzle cooling water cooler (HE-005) and the strainer for cooling water (FIL-021) to the header pipe on the engine and then to the individual injection valves.

From here, it is pumped through a manifold into the nozzle cooling water service tank from where it returns to the pump.

One system can be installed for up to three engines.

T-076/Nozzle cooling water service tank

The nozzle cooling water service tank (T-076) is used for deaeration of the nozzle cooling water.

HE-005/Nozzle cooling water cooler

The nozzle cooling water cooler is to be connected in the LT cooling water circuit according to schematic diagram. Cooling of the nozzle cooling water is effected by the LT cooling water.

If an antifreeze is added to the cooling water, the resulting lower heat transfer rate must be taken into consideration. The cooler is to be provided with venting and draining facilities.

TCV-005/Nozzle cooling water temperature control valve

The nozzle cooling water temperature control valve with thermal-expansion elements regulates the flow through the cooler to reach the required inlet temperature of the nozzle cooling water. It has a regulating range from approximately 55°C (valve begins to open the pipe from the cooler) to 65°C (pipe from the cooler completely open).

For reliable engine operation with HFO incl. stand-by and starting, a nozzle cooling water temperature of at least 55°C must always be ensured.

FIL-021/Strainer for cooling water

To protect the nozzles for the first commissioning of the engine a strainer for cooling water has to be provided.

We recommend to install Y-type strainers with magnetic inserts. For further operation of the engine, we recommend to use a cartridge with mesh size of about 1 mm to catch particles.

The strainers have to be installed in horizontal pipes or pipes with flow direction downwards.

We recommend to install ball valves upstream and downstream of the strainer.

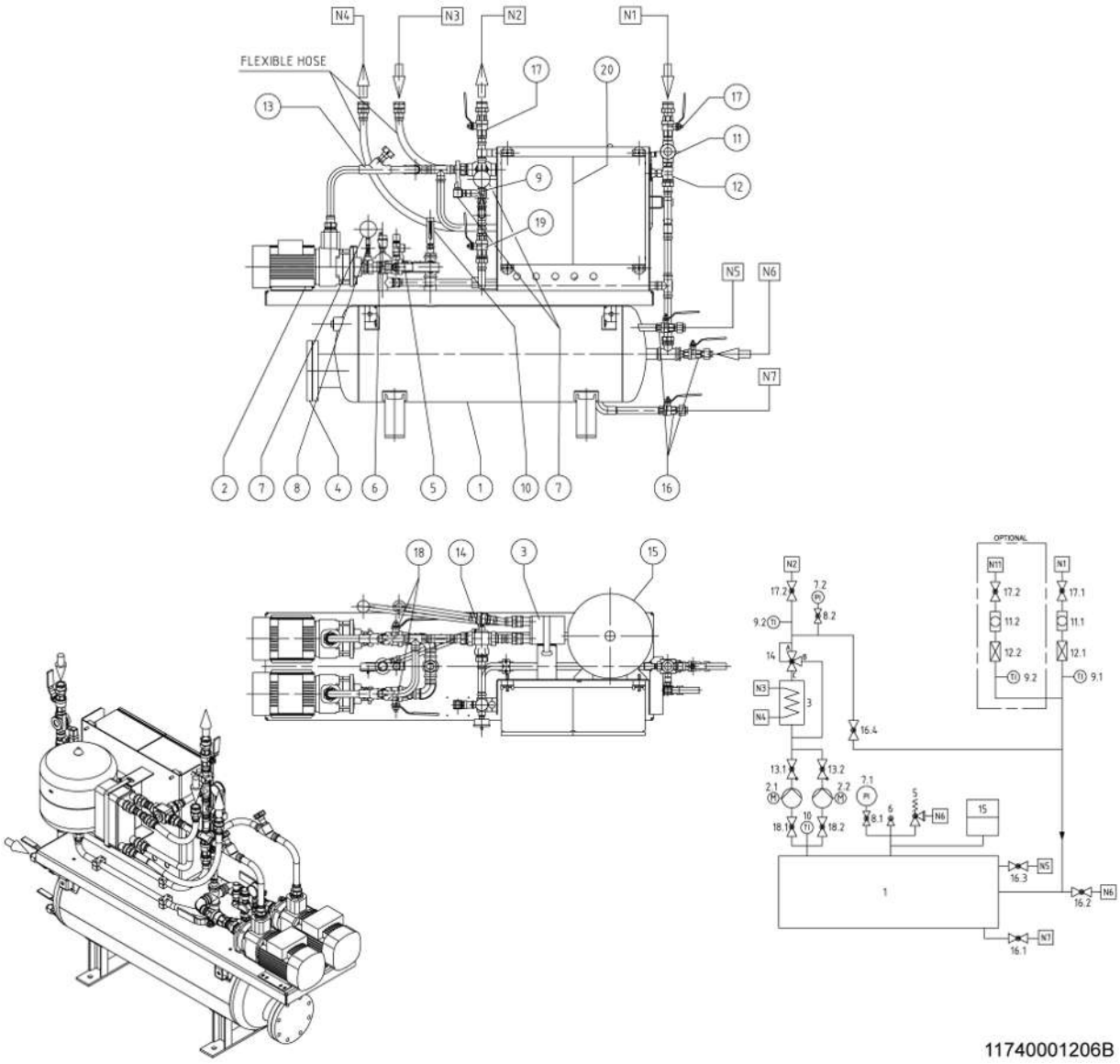
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5.6.6 External cooling water system – Nozzle cooling water module

Design

The nozzle cooling water module consists of a storage tank, on which all components required for nozzle cooling are mounted.

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Part list

1 Tank
2 Circulation pump
3 Plate heat exchanger
4 Inspection hatch
5 Safety valve
6 Automatic venting
7 Pressure gauge
8 Valve
9 Thermometer
10 Thermometer

Connections to the nozzle cooling module

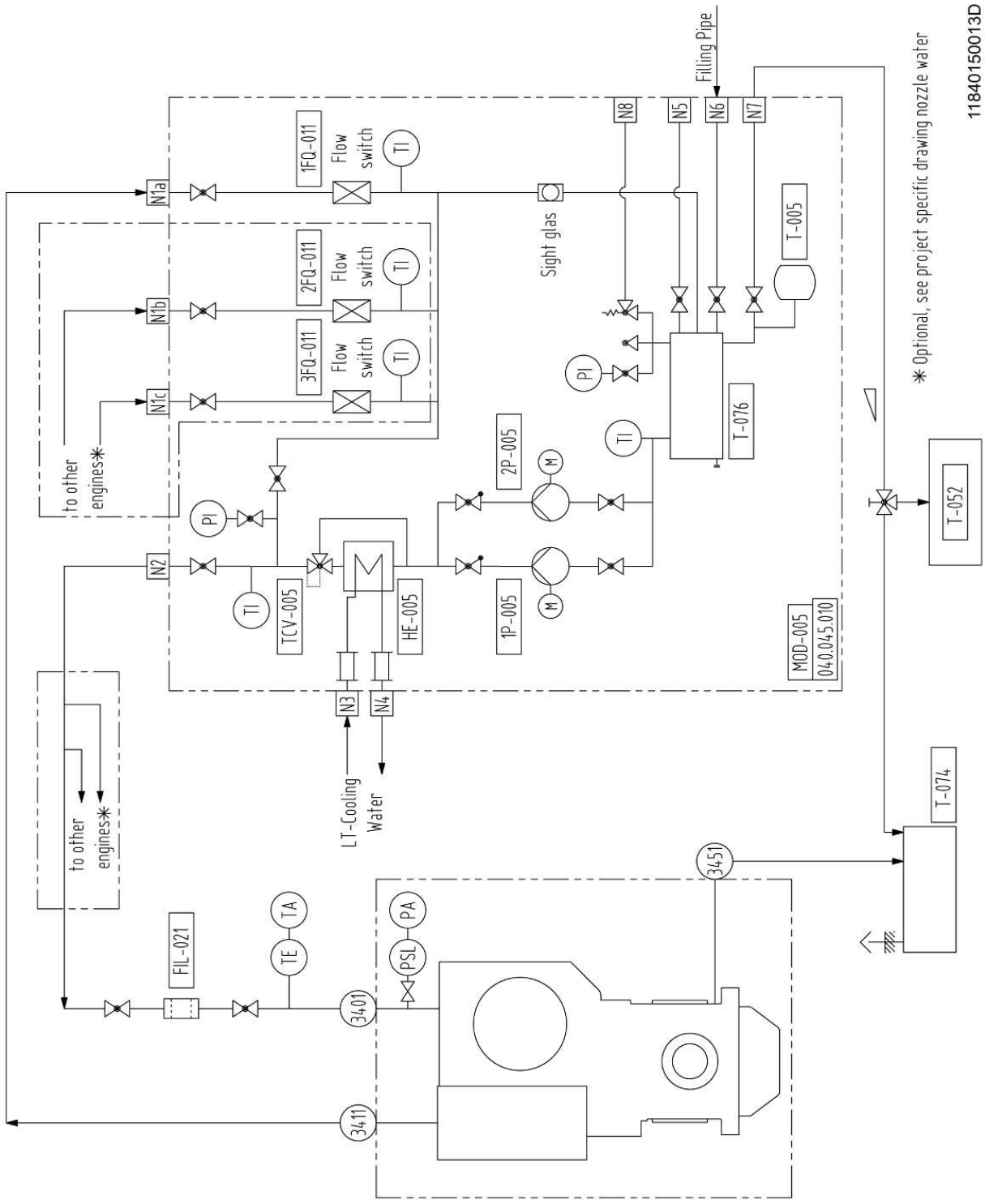
N1 Nozzle cooling water return from engine
N2 Nozzle cooling water outlet to engine
N3 Cooling water inlet
N4 Cooling water outlet

11 Sight glass
12 Flow switch set point
13 Valve with non-return
14 Temperature regulating valve
15 Expansion pot
16 Ball type cock
17 Ball type cock
18 Ball type cock
19 Ball type cock
20 Switch cabinet

N5 Check for "oil in water"
N6 Filling connection
N7 Discharge

Figure 129: Example: Compact nozzle cooling water module

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11840150013D
Filling Pipe
N8
N5
N6
N7
N1a
N1b
N1c
1FQ-011
2FQ-011
3FQ-011
Flow switch
TI
Sight glas
T-005
T-076
PI
2P-005
1P-005
M
to other engines*
N2
TCV-005
HE-005
MOD-005
040.045.010
T-052
* Optional, see project specific drawing nozzle water
N3
N4
LT-Cooling Water
T-074
3451
3401
3411
FIL-021
TA
TE
PA
PSL

Components

FIL-021	Strainer for cooling water
1,2,3 FQ-011	Flow switch
HE-005	Nozzle cooling water cooler
MOD-005	Nozzle cooling water module
1,2 P-005	Nozzle cooling water pump
T-005	Nozzle cooling water expansion tank
T-052	Sludge tank
T-074	Fresh water collecting tank
T-076	Nozzle cooling water service tank
TCV-005	Nozzle cooling water temperature control valve

Connection numbers

3401	Nozzle cooling water inlet to engine
3411	Nozzle cooling water outlet from engine
3451	Drain of nozzle cooling water pipe

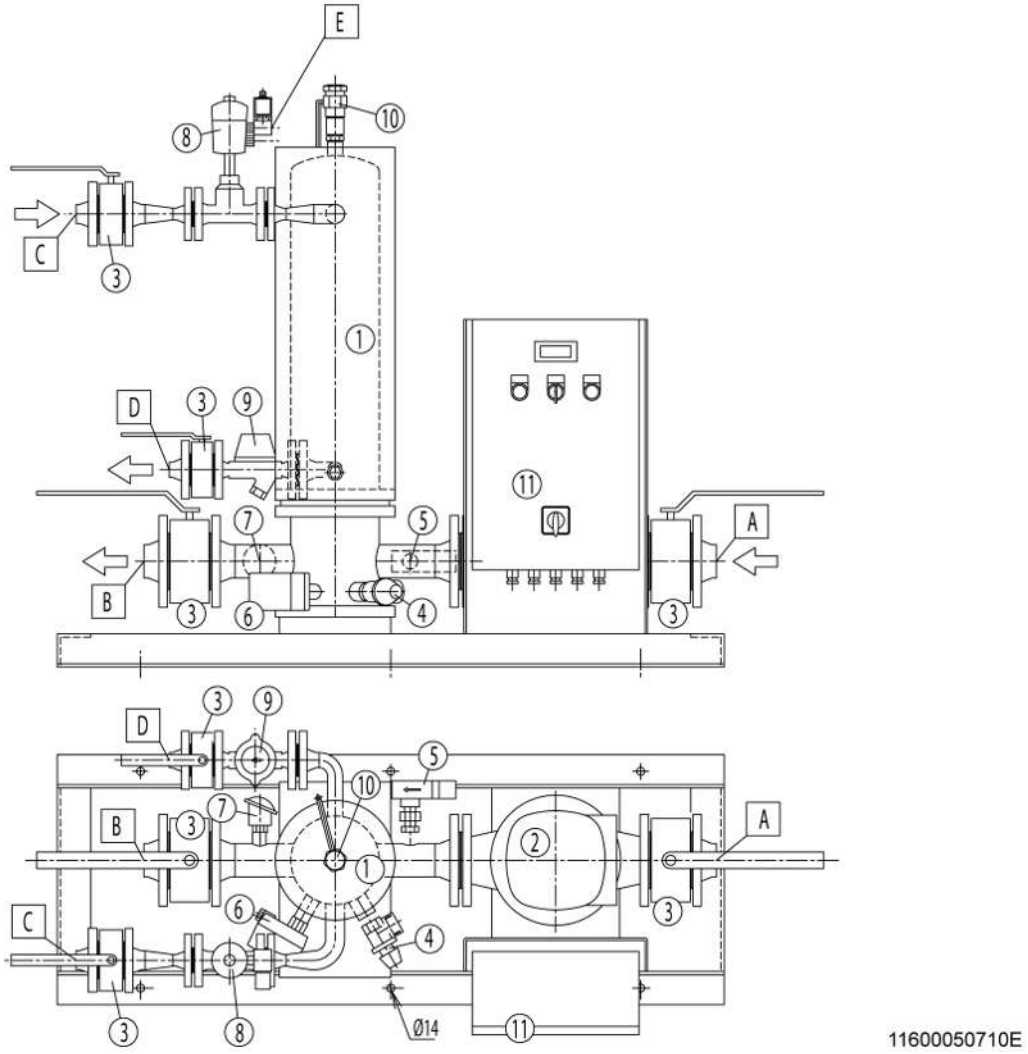
Connection to the nozzle cooling water module

N1a	Nozzle cooling water inlet a
N1b	Nozzle cooling water inlet b
N1c	Nozzle cooling water inlet c
N2	Nozzle cooling water outlet
N3	LT cooling water inlet
N4	LT cooling water outlet
N5	Sample point for "oil in water"
N6	Filling connection
N7	Drain connection
N8	Connection safety valve, route to safe area

Figure 130: Nozzle cooling water module diagram

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5.6.7 External cooling water system – HT cooling water preheating module



Components

1 Preheater
2 Circulating pump
3 Valve
4 Safety valve
5 Flow switch
6 Temp. limiter
7 Temp. sensor
8 Pneumatic valve
9 Condensate water discharger
10 Automatic ventilation
11 Switch cabinet

Connections

A Cooling water inlet, PN16/40
B Cooling water outlet, PN16/40
C Steam inlet, PN40
D Condensate outlet PN40
E Pilot solenoid valve

Figure 131: Example – Compact HT cooling water preheating module

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5.7 Bilge water/oily water

5.7.1 Introduction

For operation and maintenance of the engine, several pipes and tanks for supply of fresh water and disposal of bilge/oily water are to be provided.

A water cleaning system for bilge water in accordance with MARPOL requirements and rules of classification societies and local authorities must be installed. Oily water or water treated with chemical additives must not be discharged into the sea.

5.7.2 Turbocharger washing equipment

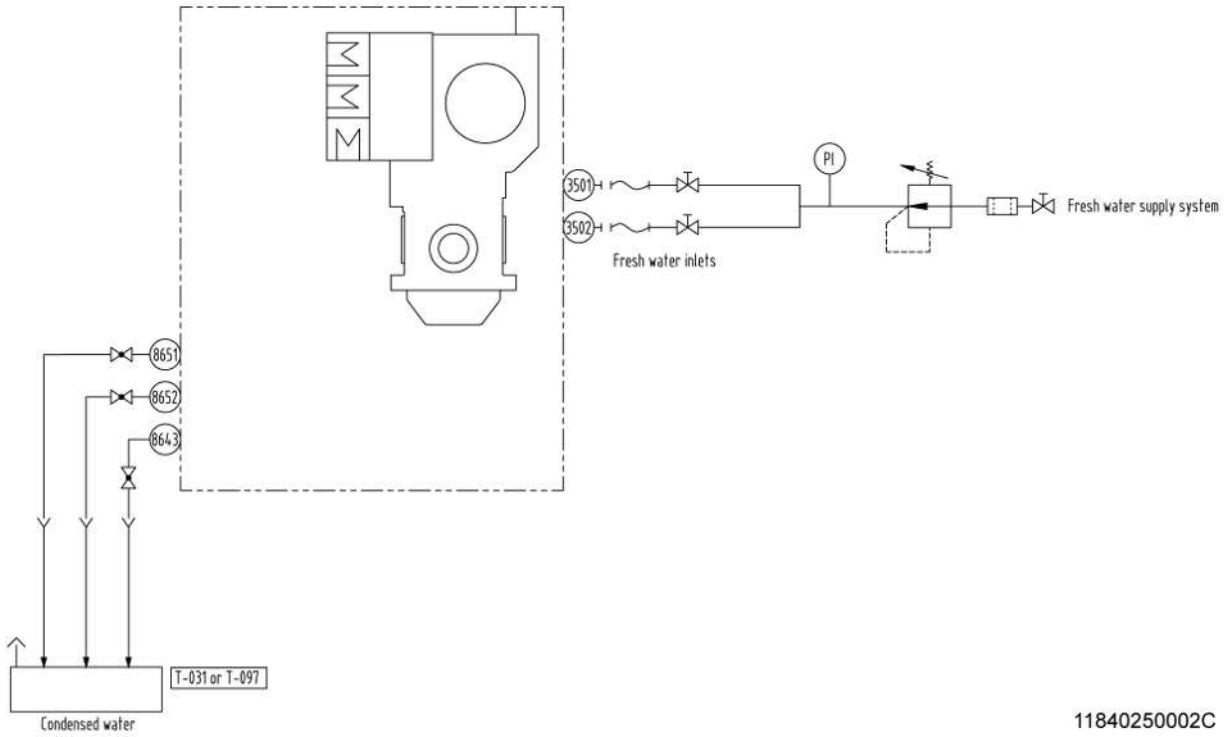
The turbocharger of engines operating on residual fuel or DMB must be cleaned at regular intervals. This requires the installation of a freshwater supply line from the sanitary fresh water system to the turbine washing equipment and dirty-water drain pipes via a funnel (for visual inspection) to the bilge system. A fresh water connection DN 25 with shut-off valve, pressure reducing device (2–4 bar) with integrated filter and pressure gauge (0–6 bar) is to be provided.

The water lance must be removed after every washing process. This is a precautionary measure, which serves to prevent an inadvertent admission of water to the turbocharger.

The turbocharger washing equipment is completely mounted on the turbocharger.

For further information contact Everllence.

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Components

T-031 Condensate collecting tank

T-097 Bilge

Sanitary water engine connections

3501 Inlet connection for turbine cleaning device wet

3502 Inlet connection for turbine cleaning device wet

Condensed water engine connections

8643 Condensed water drain from charge air manifold

8652 Condensed water drain

8651 Condensed water drain

Figure 132: P&ID washing water/condensed water

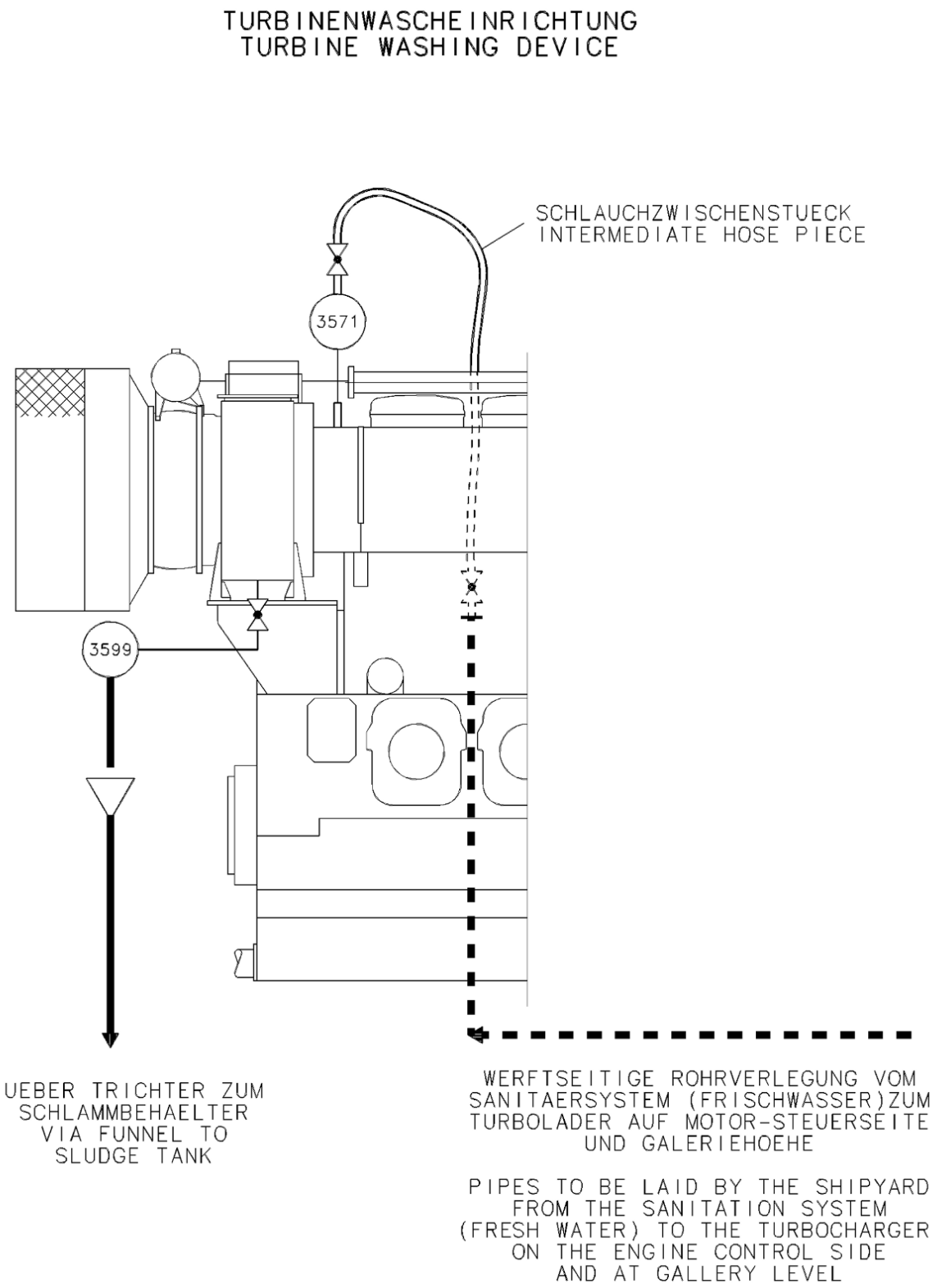


Figure 133: Cleaning turbine

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5.7.3 Cleaning of charge air cooler

The cooler bundle can be cleaned without being removed. Prior to filling with cleaning solvent, the charge air cooler and its adjacent housings must be separated from the turbocharger and charge air pipe using blind flanges.

- The casing must be filled and drained with a firehose with shut-off valve.
- If the cooler bundle is contaminated with oil, the charge air cooler casing is to be filled with freshwater and a liquid detergent additive.
- Insert the ultrasonic cleaning device after addition of the cleaning agent in default dosing portion.
- Flush with freshwater at least two times.

The contaminated water must be removed after every sequence and drained into the bilge or an oily/dirty water tank.

Recommended cleaning medium:

"PrimeServClean C 0186"

Note:
When using cleaning agents:
The instructions of the manufacturers must be observed. In particular the data sheets with safety relevance must be followed. The temperature of these products has (due to the fact that some of them are inflammable) to be at least 10 °C lower than the respective flash point. The waste disposal instructions of the manufacturers must be observed. All terms and conditions of the classification societies as well as MARPOL requirements must be fulfilled.

To be defined

Figure 134: Principle layout

5.7.4 Condensate monitoring tank drain

The condensate deposition in the charge air cooler is drained via the condensate monitoring tank. The condensate can be drained to the bilge.

If sailing mainly in tropical areas with high amount of condensate, the installation of a separate condensate holding tank might be useful to avoid the unnecessary use of an oily water separator. This condensate might be directly discharged to the sea. Nevertheless, oil monitoring of the condensate is mandatory.

5.7.5 Nozzle cooling water drain

It might occur, that the nozzle cooling water becomes contaminated with fuel oil due to a nozzle failure.

For such an event, a draining possibility to the sludge tank should be provided. As the cooling water volume is quite low, the draining can be done manually (e.g. with a bucket or a temporary hose).

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5.7.6 Condensate drain starting air system

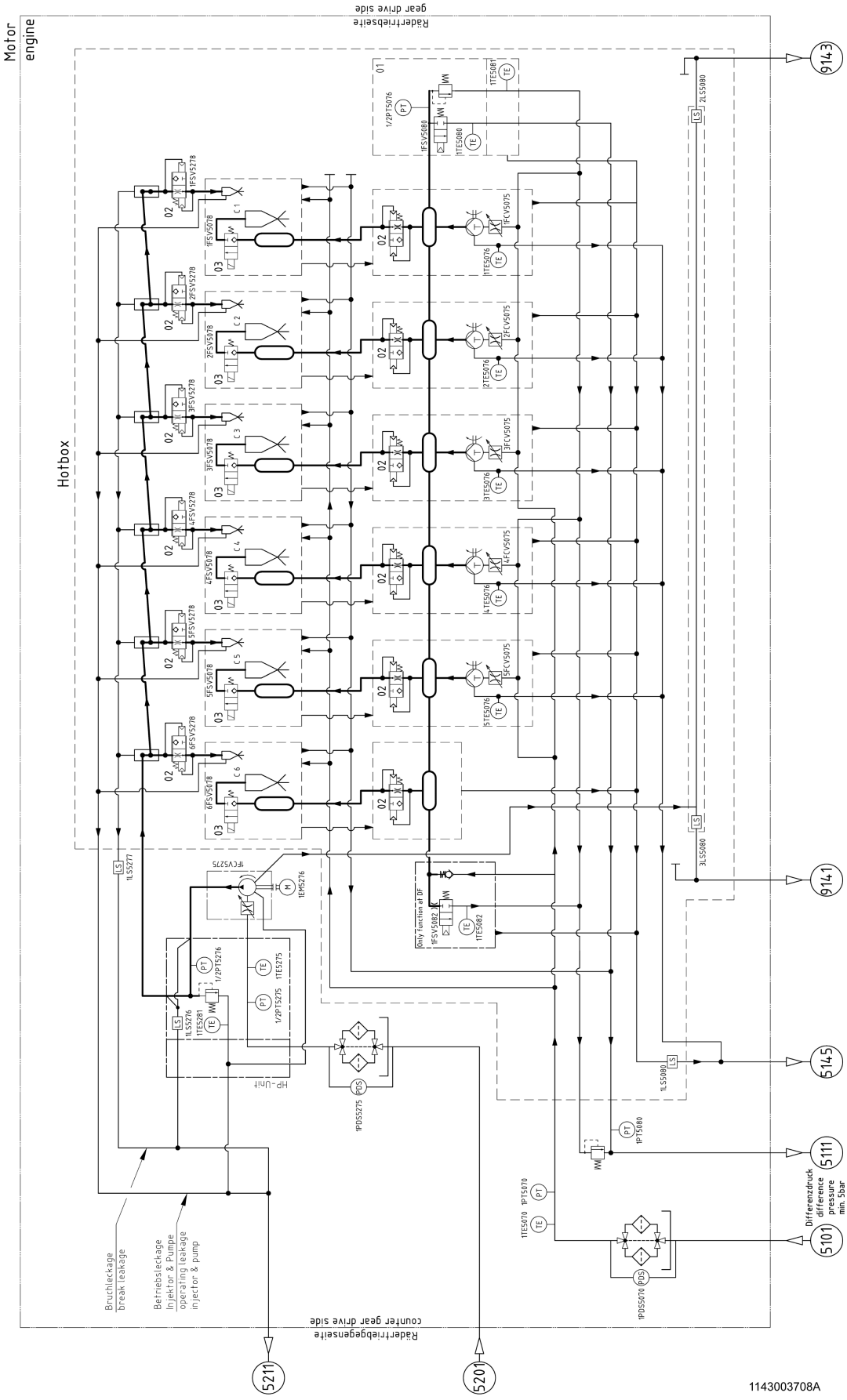
The condensed water from condensate traps related to the starting air system may be led to the bilge. The function of the drains should be monitorable (e.g. via funnels, sight glasses or other devices).

5.8 Fuel system

5.8.1 Internal fuel system

See overleaf

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Motor
engine
Hotbox
Rädertriebseite
gear drive side
Rädertriebgegenseite
counter gear drive side
Bruchleckage
break leakage
Betriebsleckage
Injektor & Pumpe
operating leakage
injector & pump
Differenzdruck
difference
pressure
min. 5bar
only function at DF
HP-Unit
9143
9141
5145
5111
5101
5211
5201
1143003708A

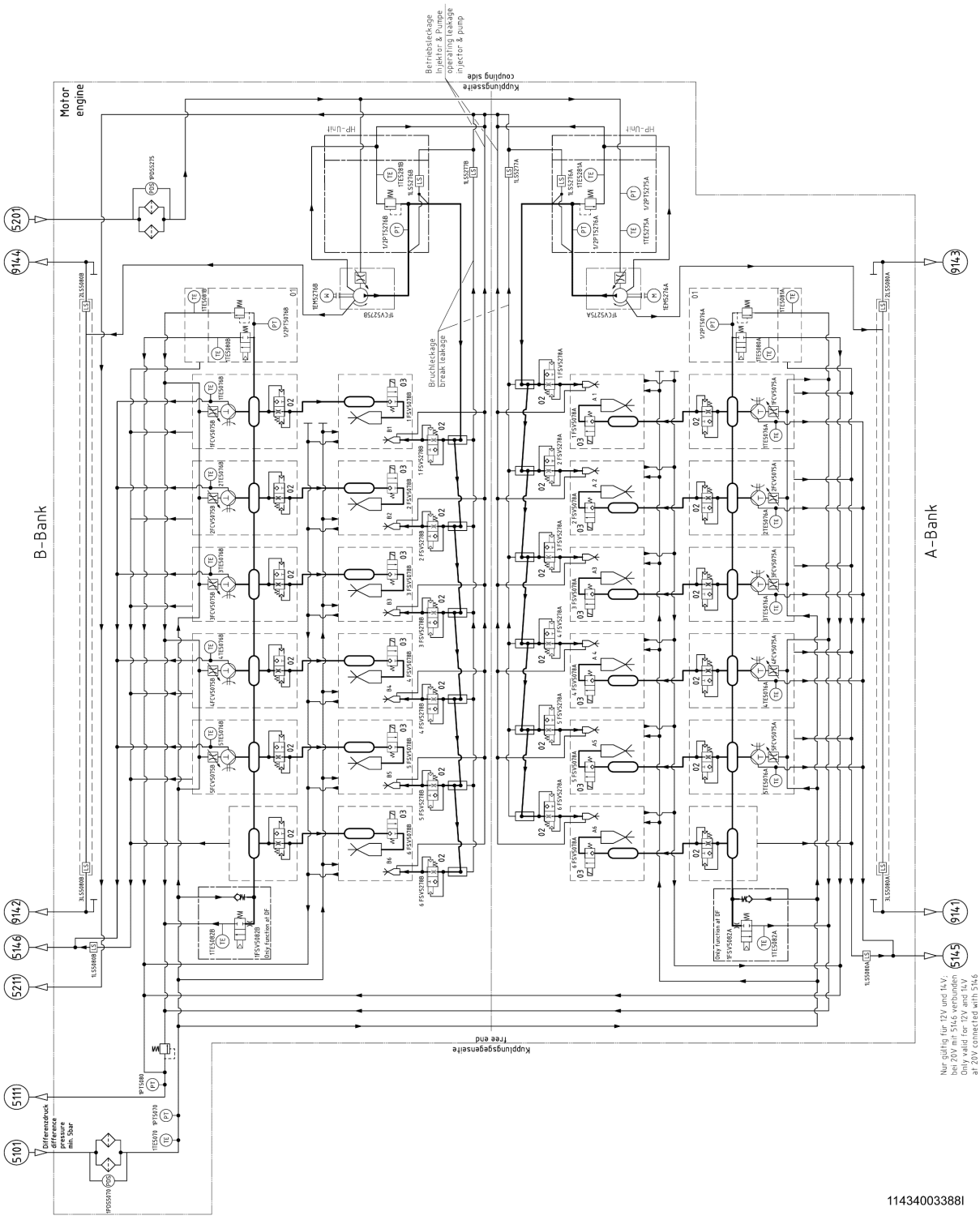
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Connection numbers

5101 Fuel oil inlet to engine (main injection system)
5111 Fuel oil outlet from engine
5145 Fuel oil leakage drain (reusable)
5201 Fuel oil inlet to engine (pilot injection system)
5211 Fuel oil outlet from engine
9141 Dirty oil drain from pump bank, gear drive counter side
9143 Dirty oil drain from pump bank, gear drive side

Figure 135: Internal fuel system L engine – Exemplary

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Motor engine
B-Bank
A-Bank
Betriebsleckage Injektor & Pumpe
operating leakage injector & pump
Kupplungsseite coupling side
Kupplungsgegenseite free end
Bruchleckage break leakage
Differenzdruck difference pressure min. 5bar
Only function at DF
Nur gültig für 12V und 14V; bei 20V mit 5146 verbunden
Only valid for 12V and 14V at 20V connected with 5146
114340033881

Connection numbers

5101	Fuel oil inlet to engine (main injection system)	5211	Fuel oil outlet from engine
5111	Fuel oil outlet from engine	9141	Dirty oil drain from pump bank, counter coupling side 1
5145	Fuel oil leakage drain (reusable) 1	9142	Dirty oil drain from pump bank, counter coupling side 2
5146	Fuel oil leakage drain (reusable) 2	9143	Dirty oil drain from pump bank, coupling side 1
5201	Pilot fuel oil inlet to engine (pilot injection system)	9144	Dirty oil drain from pump bank, coupling side 2

Figure 136: Internal fuel system V engine – Exemplary

5.8.2 External fuel system – DMB (Marine diesel oil) treatment system

A prerequisite for safe and reliable engine operation with a minimum of servicing is a properly designed and well-functioning fuel oil treatment system.

The schematic diagram, see figure DMB treatment system diagram, Page 354 shows the system components required for fuel oil treatment for marine diesel oil (DMB).

T-015/Diesel fuel oil storage tank

The minimum effective capacity of the tank should be sufficient for the operation of the propulsion plant, as well as for the operation of the auxiliary diesels for the maximum duration of voyage including the resulting sediments and water. Regarding the tank design, the requirements of the respective classification society are to be observed.

Tank heating

The tank heater must be designed so that the DMB in it is at a temperature of at least 10°C minimum above the pour point. The supply of the heating medium must be automatically controlled as a function of the DMB temperature.

Fuel with biodiesel

In case fuel oils with up to 100% of biodiesel (FAME) are used, there is an increased risk of degradation especially due to microbial activity which can threaten engine performance. In order to minimise this risk, long storage periods of this fuel have to be avoided. Furthermore all distillate tanks are to be supplied with a drainage system to prevent bacterial growth by water accumulation. To increase the water separation, a coalescer unit could be installed as a parallel installation on the most critical tanks (not indicated in the diagram).

Tank venting

In case of longer storage of diesel fuel oil, a technical device (for example, air dryer) should be installed to prevent condensation of water in the fuel oil tanks due to humidity.

T-021/Sludge tank

If disposal by an incinerator plant is not planned, the tank has to be dimensioned so that it is capable of absorbing all residues which accumulate during the operation in the course of a maximum duration of voyage. The content of this tank must not be added to the engine fuel oil. In order to enable the emptying of the tank, it must be heated.

The heating is to be dimensioned so that the content of the tank can be heated to approximately 40 °C.

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P-073/Diesel fuel oil separator feed pump

The diesel fuel oil separator feed pump should always be electrically driven, i.e. not mounted on the separator, as the delivery volume can be matched better to the required throughput.

H-019/Fuel oil preheater

In order to achieve the separating temperature, a separator adapted to suit the fuel oil viscosity should be fitted.

The preheater must be able to heat the diesel oil up to 40 °C and the size must be selected according to the maximum throughput. However the medium temperature prescribed in the separator manual must be observed and adjusted.

CF-003/Diesel fuel oil separator

A self-cleaning separator must be provided. The diesel fuel oil separator is dimensioned in accordance with the separator manufacturers' guidelines.

The required flow rate (Q) can be roughly determined by the following equation:

$$Q = \frac{P \times b_e}{\rho}$$

Q [l/h]	Separator flow rate
P [kW]	Total engine output
b_e [g/kWh]	Fuel oil consumption
ρ [g/l]	Density at separating temp approximately 870 kg/m^3 = [g/l]

With the evaluated flow rate, the size of the separator has to be selected according to the evaluation table of the manufacturer. The separator rating stated by the manufacturer should be higher than the flow rate (Q) calculated according to the above formula.

For the first estimation of the maximum fuel oil consumption (b_e), increase the specific table value by 15%, see section Planning data, Page 100.

For project-specific values contact Everllence.

In the following, characteristics affecting the fuel oil consumption are listed exemplary:

- Tropical conditions
- The engine-mounted pumps
- Fluctuations of the calorific value (Especially when using biofuels and synthetic fuels)
- The consumption tolerance

Regarding required limits on water and particles in the fuel after separation refer to table Requirements for diesel fuel.

Note:
If a homogeniser is used, it must never be installed between the settling tank and separator as otherwise it will not be possible to ensure satisfactory separation of harmful contaminants, particularly seawater.

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FIL-039/DMA fuel oil filter treatment module

Instead of a diesel fuel oil separator CF-003 an adequate filtration system (FIL-039) can be used for fuel oil treatment. This is only valid for engines which operate with marine gas oil (DMA).

The fuel oil is intensively cleaned by fine filtration in the by-pass thus relieving the main filters and allowing an economical design The fuel oil fine filter is not of self-cleaning type, therefore the filter elements need to be replaced regularly.

The formula for determining the fine filter flow rate (Q) is:

$$Q = \frac{P \times b_e}{p}$$

Q [l/h]	Separator flow rate
P [kW]	Total engine output
b_e [g/kWh]	Fuel consumption
p	Density at separating temperature – Approx. 830 kg/m^3 = g/dm^3

With the evaluated flow rate the size of the fine filter module has to be selected according to the evaluation table of the maker.

The information regarding released manufacturers and filter types for fuel oil fine filters can be found here: Fuel oil fine filter selection for Everllence marine engines.

Withdrawal points for samples

Fuel oil sampling points are to be provided upstream and downstream of each separator, to verify the effectiveness of these system components.

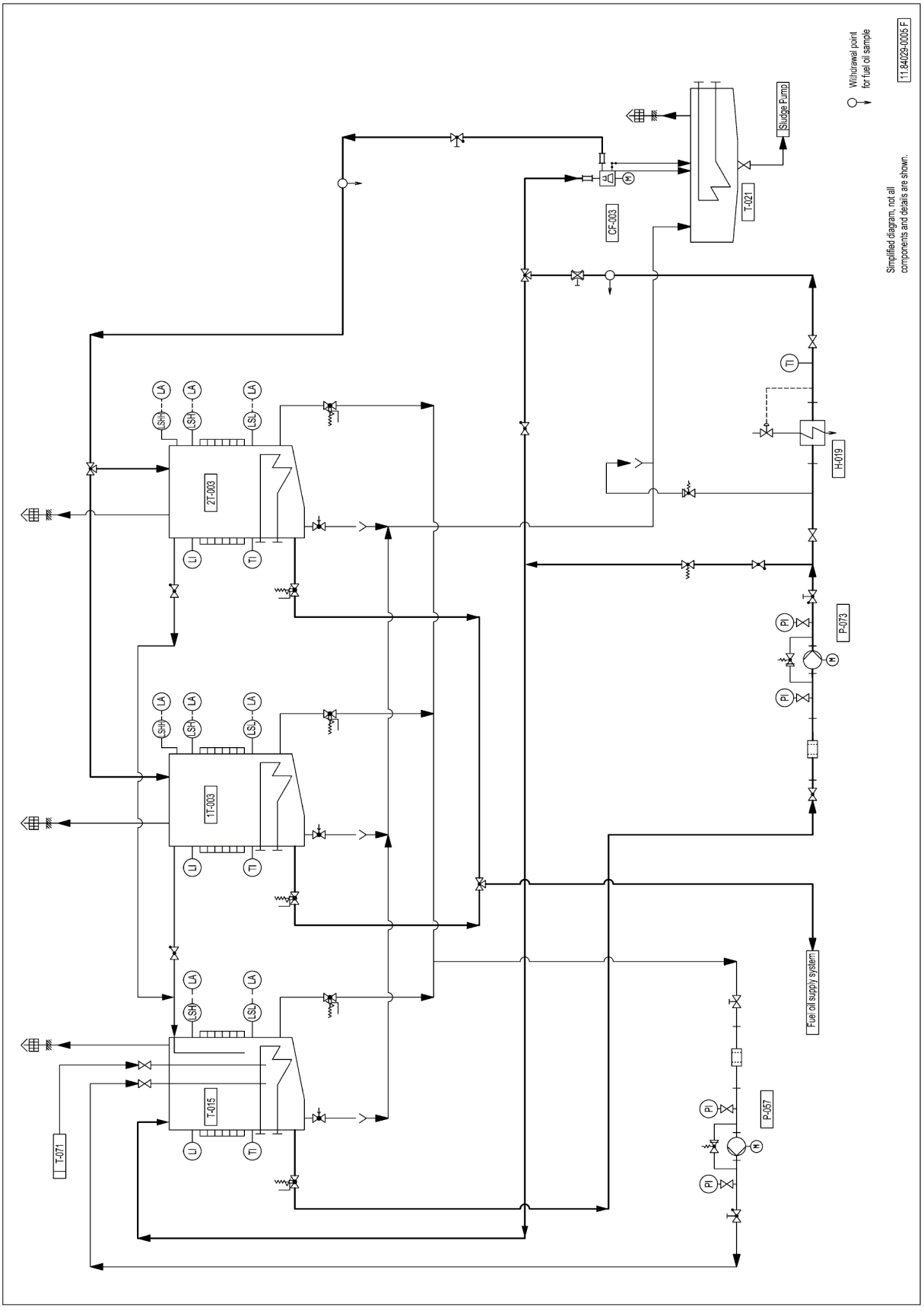
T-003/Diesel fuel oil service tank

See description in section Marine diesel oil (DMB) supply system for diesel engines, Page 358.

T-071/Clean leakage fuel oil tank

See description in section External fuel system – DMB (Marine diesel oil) supply system, Page 358.

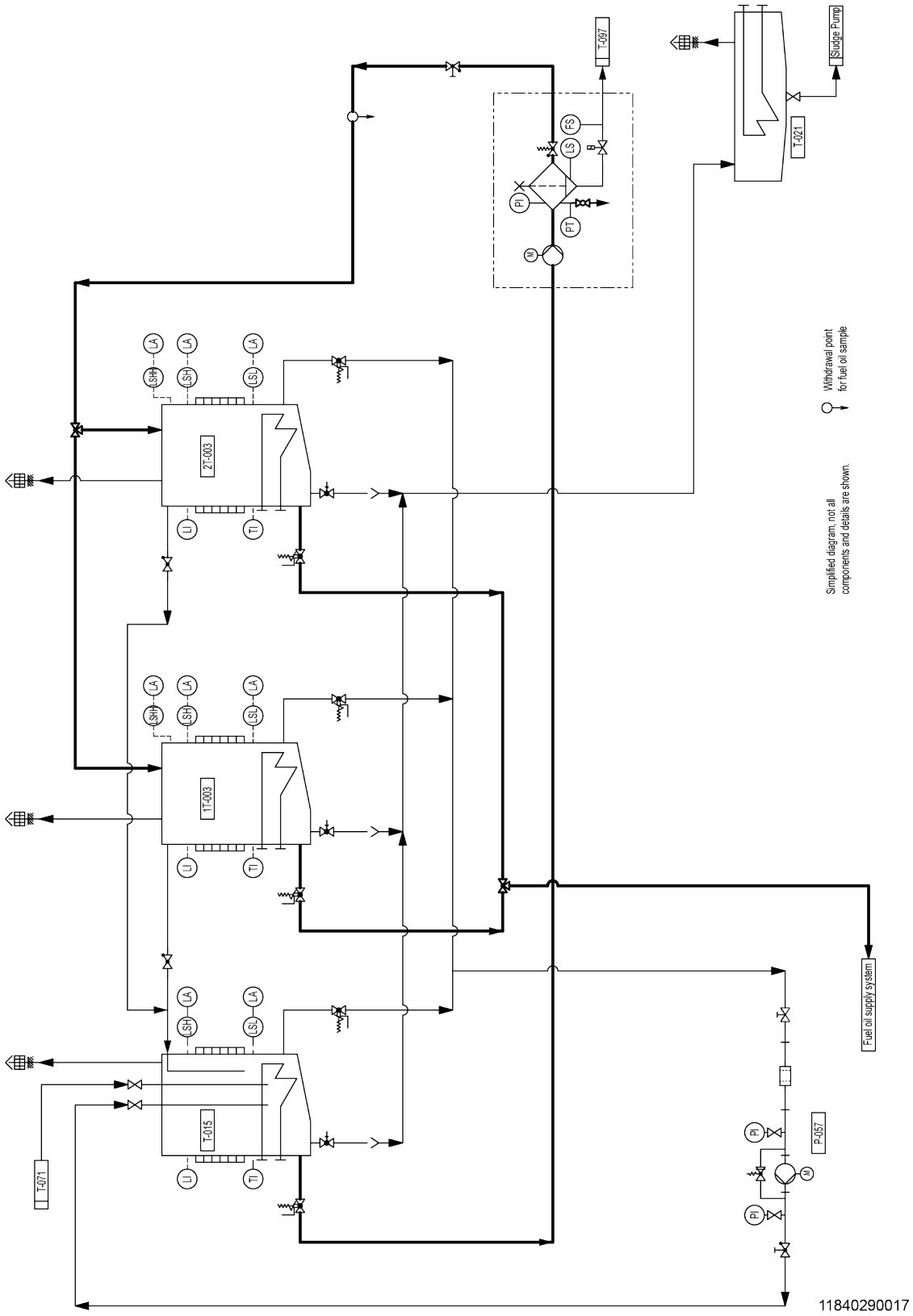
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Withdrawal point for fuel oil sample
11.84029-0005 F
Simplified diagram, not all components and details are shown.
Sludge Pump
T-021
CF-003
H-019
P-073
2T-003
1T-003
T-015
T-071
P-057
Fuel oil supply system

	Components		
CF-003	Diesel fuel oil separator	T-015	Diesel fuel oil storage tank
H-019	Fuel oil preheater	T-021	Sludge tank
P-057	Diesel fuel oil transfer pump	1,2 T-003	Diesel fuel oil service tank
P-073	Diesel fuel oil separator feed pump	T-071	Clean leakage fuel oil tank

Figure 137: Fuel oil treatment with separator CF-003

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T-097
Sludge Pump
T-021
FS
LS
PI
PT
M
LA
SH
SL
2T-003
1T-003
T-015
LI
TI
T-071
Withdrawal point for fuel oil sample
Simplified diagram; not all components and details are shown.
Fuel oil supply system
P-057
11840290017

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	Components		
CF-003	Diesel fuel oil separator	T-071	Clean leakage fuel oil tank
H-019	Fuel oil preheater	T-097	Oily water or bilge water tank
1,2 T-003	Diesel fuel oil service tank	P-057	Diesel fuel oil transfer pump
T-015	Diesel fuel oil storage tank	P-073	Diesel fuel oil separator feed pump
T-021	Sludge tank		

Figure 138: Fuel oil treatment with fuel oil treatment module FIL-039 (only DMA)

5.8.3 External fuel system – Marine diesel oil (DMB) supply system for diesel engines

General

The DMB supply system is an open system with open deaeration service tank. Usually one or two main engines are connected to one fuel system. If required auxiliary engines can be connected to the same fuel system as well (not indicated in the diagram).

DMB fuel oil viscosity

DMB and FAME with a max. nominal viscosity of 11 cSt (at 40°C), or lighter DMB qualities, can be used.

At engine inlet the fuel oil viscosity should be 11 cSt or less. The fuel temperature has to be adapted accordingly. It is also to ensure, that the DMB fuel temperature of max. 45°C at engine inlet (for all DMB qualities) is not exceeded. Therefore, a tank heating and a cooler in the fuel return pipe are required.

T-003/Diesel fuel oil service tank

The classification societies specify that at least two service tanks are to be installed on board. The minimum tank capacity of each tank should, in addition to the DMB consumption of other consumers, enable a full load operation of min. 8 operating hours for all engines under all conditions.

The tank should be provided with a sludge space with a tank bottom inclination of preferably 10° and sludge drain valves at the lowest point. An overflow pipe from the diesel fuel oil service tank T-003 to the diesel fuel oil storage tank T-015 including heating coils and insulation is to be installed.

If DMB and FAME fuel with 11 cSt (at 40°C) is used, the tank heating is to be designed to keep the tank temperature at min. 40°C.

For lighter types of fuel oil it is recommended to adjust the tank temperature in order to ensure a fuel oil viscosity of 11 cSt or less. Rules and regulations for tanks issued by the classification societies must be observed.

The required minimum DMB capacity of each service tank is:

$V_{DMBST} = (Q_p \times t_o \times M_s)/(3 \times 1{,}000\ l/m^3)$		
Required min. volume of one diesel fuel oil service tank	V_{DMBST}	m^3
Required supply pump capacity, DMB 45°C See paragraph P-008/Diesel fuel oil supply pump, Page 359	Q_p	l/h
Operating time t_o = 8 h	t_o	h

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Margin for sludge M_s = 1.05	M_s	-

Table 135: Required minimum DMB capacity

In case more than one engine or different engines are connected to the same fuel oil system, the service tank capacity has to be increased accordingly.

STR-010/Suction strainer

To protect the fuel oil supply pumps, an approximately 0.5 mm gauge (sphere-passing mesh) strainer is to be installed at the suction side of each supply pump.

P-008/Diesel fuel oil supply pump

To cool the engine mounted high pressure pumps, the capacity of the supply pumps must be at least 300% of the maximum fuel oil consumption.

$Q_P = (P \times (br_{ISO} / 1{,}000) \times f \times S) / \rho$		
Required booster pump delivery capacity	Q_P	m^3/h
Engine output at 100% MCR	P	kW
Specific engine fuel oil consumption (ISO) at 100% MCR	br_{ISO}	g/kWh
Factor for pump dimensioning	f = 3	-
Safety factor for consideration of attached pumps and tropical conditions	S = 1.1	-
Min. fuel density @ 15°C	ρ	kg/m^3
Note: The fuel density shall be chosen according the fuel with the lowest density, for which the system is designed for (in general DMA, min. density 820 kg/m^3 @ 15°C). In case more than one engine is connected to the same fuel oil system, the pump capacity has to be increased accordingly.		

Table 136: Simplified fuel oil booster pump dimensioning

PSV-010/Fuel oil system safety valve

The fuel oil system design pressure is PN16. The system is to be protected from higher pressure levels by corresponding safety valves. Because of the high pressure range of the diesel fuel oil supply pumps, it is recommended to install a separate safety valve after these pumps (outlined with code PSV-010 in the fuel oil supply diagram).

FIL-003/Fuel oil automatic filter, supply circuit

The automatic filter should be a type that causes no significant pressure drop during flushing sequence. As a reference an acceptable value for a pressure decrease during back flushing is 0.3 – 0.5 bar. The filter mesh size shall be 0.010 mm (absolute) for common rail injection and 0.034 mm (absolute) for conventional injection.

The automatic filter must be equipped with differential pressure indication and switches.

The design criterion relies on the filter surface load, specified by the filter manufacturer.

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A by-pass pipe in parallel to the automatic filter is required. A stand-by filter in the by-pass is not required. In case of maintenance on the automatic filter, the by-pass is to be opened; the fuel is then filtered by the fuel oil duplex filter FIL-013.

FIL-013/Fuel oil duplex filter

See description in paragraph FIL-013/Fuel oil duplex filter, Page 377.

FQ-003/Fuel oil flowmeter

For a fuel oil consumption measurement (not mentioned in the diagram), flowmeters have to be installed upstream and downstream of the engine. The measured difference of these flows equals the consumption.

The upstream flow rate of each engine should be displayed in the ship automation and SaCoS system. Each 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.

FBV-010/Flow balancing valve

DMB supply system for only one main engine and without auxiliary engines

The flow balancing valve FBV-010 is not required.

DMB supply system for more than one main engine or/and additional auxiliary engines

The flow balancing valve (1,2 FBV-010) is required at the fuel outlet of each engine. It is used to adjust the individual fuel flow for each engine. It will compensate the influence (flow distribution due to pressure losses) of the piping system. Once these valves are adjusted, they have to be blocked and must not be manipulated later.

PCV-011/Fuel oil spill valve

DMB supply systems for only one main engine and without auxiliary engines

Fuel oil spill valve PCV-011 is not required.

DMB supply systems for more than one main engine or/and additional auxiliary engines

In case two engines are operated with one fuel module, it has to be possible to separate one engine at a time from the fuel circuit for maintenance purposes. In order to avoid a pressure increase in the pressurised system, the fuel, which cannot circulate through the shut-off engine, has to be rerouted via this valve into the return pipe.

This valve is to be adjusted so that rerouting is effected only when the pressure, in comparison to normal operation (multi-engine operation), is exceeded. This valve should be designed as a pressure relief valve, not as a safety valve.

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V-002/Shut-off cock

DMB supply systems for only one main engine and without auxiliary engines

Shut-off cock V-002 is not required.

DMB supply systems for more than one main engine or/and additional auxiliary engines

The shut-off cock is closed during normal operation (multi-engine operation). When one engine is separated from the fuel circuit for maintenance purposes, this cock has to be opened manually.

HE-007/Fuel oil cooler

The fuel oil cooler is required to cool down the fuel, 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 DMB does not exceed a temperature of max. 45 °C.

Only for very light DMB fuel types this temperature has to be even lower in order to preserve the minimum admissible fuel oil viscosity on engine inlet.

Depending on the fuel oil type a chiller unit might be required to decrease the fuel oil temperature to reach the required injection system operation viscosity, see section Viscosity-temperature diagram (VT diagram), Page 266.

Engine type	Cooler capacity
L/V engine	7.0 kW/cyl.
The max. DMA/DMB throughput is approximately identical to the engine inlet fuel flow (=delivery quantity of the installed diesel fuel oil supply pump).	

Table 137: Dimensioning of the fuel oil cooler

The recommended pressure class of the fuel oil cooler is PN16.

PCV-008/Pressure retaining valve

In open fuel oil supply systems (fuel loop with circulation through the diesel fuel oil service tank; service tank under atmospheric pressure) this pressure-retaining valve is required to keep the system pressure to a certain value against the diesel fuel oil service tank. 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 133).

FSH-001/Leakage fuel oil monitoring tank

High pressure pump overflow and escaping fuel oil from burst control pipes is carried to the monitoring tanks from which it is drained into the clean leakage fuel oil collecting tank. The engine interface connection of the monitoring tank is a pressureless drain. Leakage fuel oil flows by gravity only from these tank into collecting tanks (to be installed below the engine connections). To prevent pressure resistance at the engine interface connection the pipework to the collecting tank has to have a sufficient downward slope. The float switch mounted in the tanks must be connected to the alarm system. The classification societies require the installation of monitoring tanks for unmanned engine rooms. Lloyd's Register specifies tank monitoring for manned engine rooms as well.

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T-006/Leakage oil collecting tank

Dirty leak fuel and leak oil are collected in the leakage oil collecting tank. It must be emptied into the sludge tank. The content of the leakage oil collecting tank T-006 must not be added to the engine fuel. It can be burned for instance in a waste oil boiler.

The leakage oil collecting tank T-006 is only necessary if the leakages can not flow directly into the sludge tank T-021 by gravity.

T-071/Clean leakage fuel oil tank

When only DMB is used, the high pressure pump overflow and other, clean fuel oil that escapes from the common rail injection system is lead pressureless (by gravity only) to an extra clean leakage fuel oil collecting tank. From there it can be emptied into the diesel fuel oil storage tank. Clean leakage fuel oil from T-071 can be used again after passing the separator. For additional information see description in section External fuel system – Heavy fuel oil (HFO) supply system, Page 372.

Withdrawal points for samples

Fuel oil sampling points are to be provided upstream and downstream of each filter, to verify the effectiveness of these system components.

T-015/Diesel fuel oil storage tank

See description in paragraph T-015/Diesel fuel oil storage tank, Page 352.

T-021/Sludge tank

See description in paragraph T-021/Sludge tank, Page 352.

CF-003/Diesel fuel oil separator

See description in paragraph CF-003/Diesel fuel oil separator, Page 353.

CV-004/Pilot fuel oil service tank filling valve

See description in section External fuel system – Pilot fuel supply system, Page 387.

T-101/Pilot fuel oil service tank

See description in section External fuel system – Pilot fuel supply system, Page 387.

FIL-033/Pilot fuel oil duplex filter

See description in section External fuel system – Pilot fuel supply system, Page 387.

Piping

The fuel oil system design pressure is PN16 (see section External pipe dimensioning, Page 278). The system is to be protected from higher pressure levels by corresponding safety valves. Additional safety valves, not displayed in the P&ID, might become necessary depending on the actual fuel oil system design.

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Material

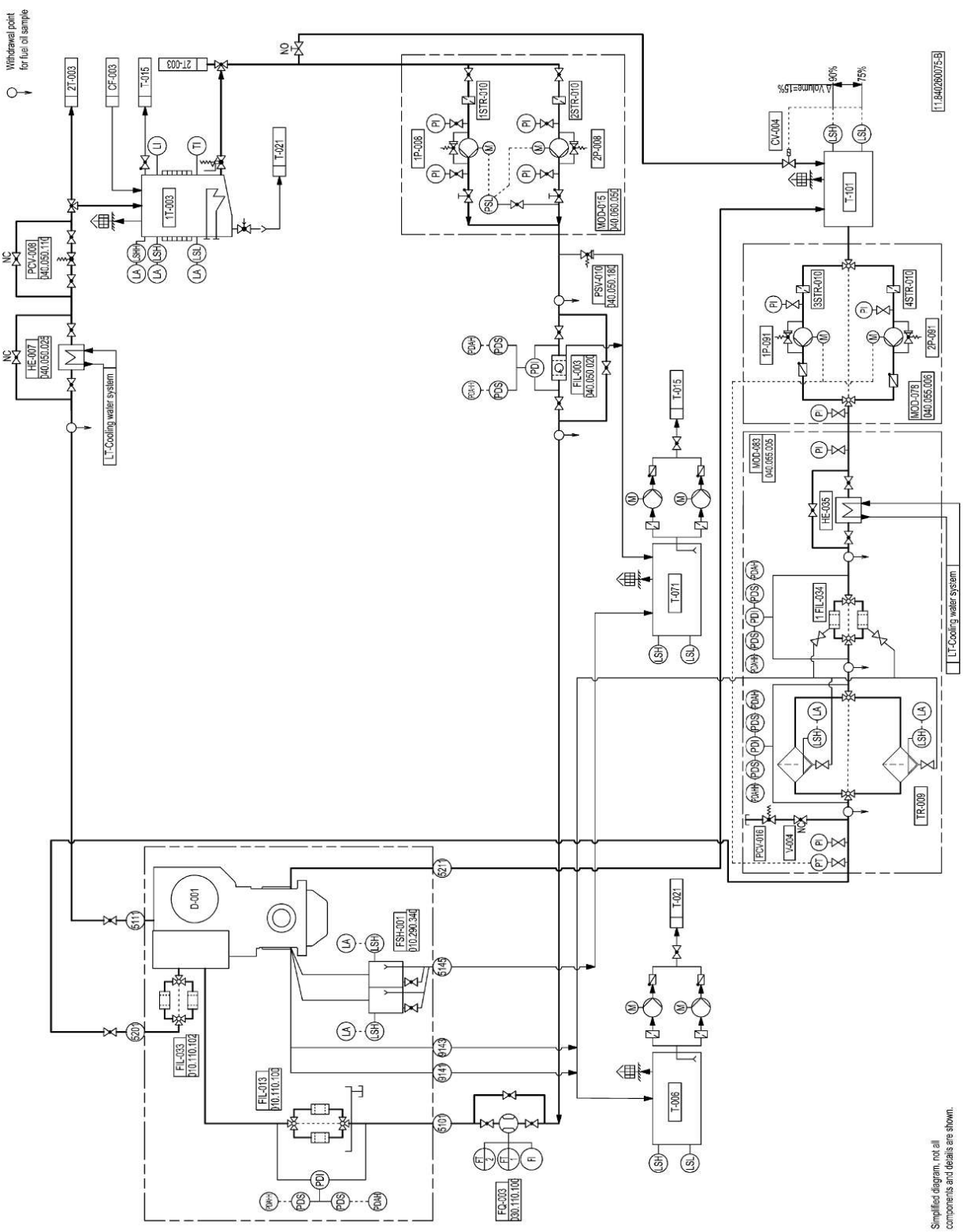
The casing material of pumps and filters should be EN-GJS (nodular cast iron), in accordance to the requirements of the classification societies.

General notes

The arrangement of the final fuel filter directly upstream of the engine inlet (depending on the plant design the final filter could be either the fuel oil duplex filter FIL-013 or the fuel oil automatic filter (supply circuit) FIL-003) has to ensure that no parts of the filter itself can be loosen.

The pipe between the final filter and the engine inlet has to be done as short as possible and is to be cleaned and treated with particular care to prevent damages (loosen objects/parts) to the engine. Valves or components shall not be installed in this pipe. It is required to dismantle this pipe completely in presents of our commissioning personnel for a complete visual inspection of all internal parts before the first engine start. Therefore, flange pairs have to be provided on eventually installed bends.

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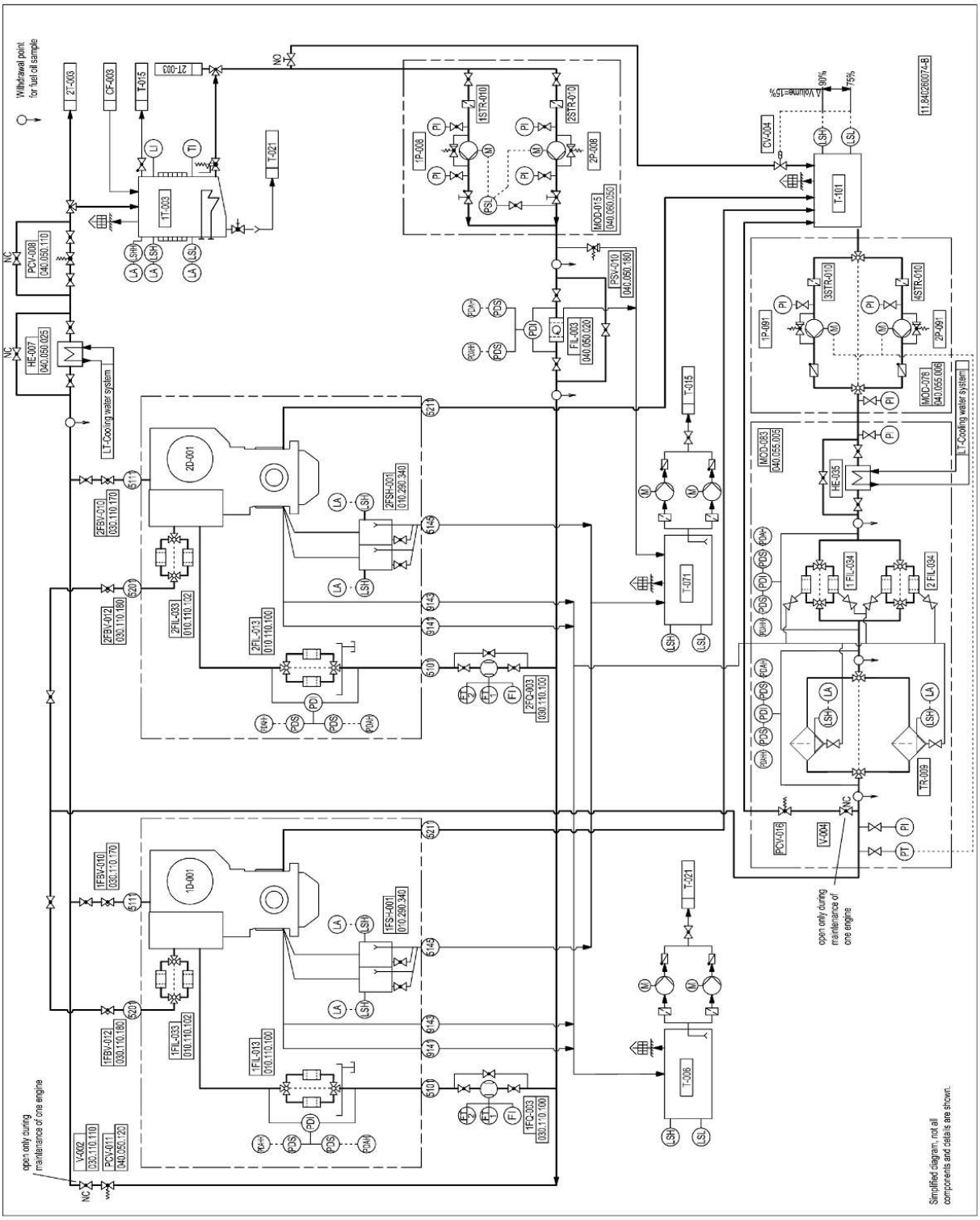

Withdrawal point for fuel oil sample
2T-003
CF-003
T-015
2T-003
T-021
1T-003
PCV-006 040.050.114
HE-007 040.050.025
LT-Cooling water system
NO
1P-008
1STR-010
2STR-010
2P-008
MOD-075 040.060.056
PSV-010 040.050.184
FIL-003 040.050.024
T-015
T-071
T-021
T-006
D-001
FSH-001 010.290.348
FIL-033 010.110.102
FIL-013 010.110.100
FQ-003 200.110.100
CV-004
T-101
3STR-010
4STR-010
1P-091
2P-091
MOD-078 040.055.006
MOD-083 040.065.035
HE-035
1 FIL-034
LT-Cooling water system
PCV-016
V-004
TR-009
Δ Volume=15%
90%
75%
11.840260075-B
Simplified diagram, not all components and details are shown.

2025-12-03 - 3.0

	Components		
CF-003	Diesel fuel oil separator	1,2 P-008	Diesel fuel oil supply pump
CV-004	Pilot fuel oil service tank filling valve	1,2 P-091	Pilot fuel oil supply pump
D-001	Diesel engine	PCV-008	Pressure retaining valve
FIL-003	Fuel oil automatic filter, supply circuit	PCV-016	Pilot fuel oil spill valve
FIL-013	Fuel oil duplex filter	PSV-010	Fuel oil safety valve
FIL-033	Pilot fuel oil duplex filter	1,2,3,4 STR-010	Suction strainer
FIL-034	Pilot fuel oil duplex filter	1,2 T-003	Diesel fuel oil service tank
FQ-003	Fuel oil flowmeter	T-006	Leakage oil collecting tank
FSH-001	Leakage fuel oil monitoring tank	T-015	Diesel fuel oil storage tank
HE-007	Fuel oil cooler	T-021	Sludge tank
HE-035	Pilot fuel oil cooler	T-071	Clean leakage fuel oil tank
MOD-015	Fuel oil supply pump unit	T-101	Pilot fuel oil service tank
MOD-078	Pilot fuel oil supply pump module	TR-009	Coalescer (water trap)
MOD-083	Pilot fuel oil filter module	V-004	Shut-off cock
	Major engine connections		
5101	Fuel oil inlet to engine	5211	Pilot fuel oil outlet from engine
5111	Fuel oil outlet from engine	9141	Dirty oil drain from pump bank, counter coupling side 1
5145	Fuel oil leakage drain (reusable from pumps and injectors) 1	9143	Dirty oil drain from pump bank, coupling side 1
5201	Pilot fuel oil inlet to engine		

Figure 139: DMB supply system diagram – Single engine plant

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Withdrawal point for fuel oil sample
LT-Cooling water system
open only during maintenance of one engine
Simplified diagram, not all components and details are shown.

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	Components
CF-003	Diesel fuel oil separator
CV-004	Pilot fuel oil service tank filling valve
1,2 D-001	Diesel engine
1,2 FBV-010	Flow balancing valve
1,2 FBV-012	Pilot fuel oil flow balancing valve
FIL-003	Fuel oil automatic filter
1,2 FIL-013	Fuel oil duplex filter
1,2 FIL-033	Pilot fuel oil duplex filter
FIL-034	Pilot fuel oil duplex filter
1,2 FQ-003	Fuel oil flowmeter
1,2 FSH-001	Leakage fuel oil monitoring tank
HE-007	Fuel oil cooler
HE-035	Pilot fuel oil cooler
MOD-015	Fuel oil supply pump unit
MOD-078	Pilot fuel oil supply pump module
MOD-083	Pilot fuel oil filter module
	Major engine connections
5101	Fuel oil inlet to engine
5111	Fuel oil outlet from engine
5145	Fuel oil leakage drain (reusable from pumps and injectors) 1
5201	Pilot fuel oil inlet to engine
1,2 P-008	Diesel fuel oil supply pump
1,2 P-091	Pilot fuel oil supply pump
PCV-008	Pressure retaining valve
PCV-011	Fuel oil spill valve
PCV-016	Pilot fuel oil spill valve
PSV-010	Fuel oil safety valve
1,2,3,4 STR-010	Suction strainer
1,2 T-003	Diesel fuel oil service tank
T-006	Leakage oil collecting tank
T-015	Diesel fuel oil storage tank
T-021	Sludge tank
T-071	Clean leakage fuel oil tank
T-101	Pilot fuel oil service tank
TR-009	Coalescer (water trap)
V-002	Shut-off cock
V-004	Shut-off cock
5211	Pilot fuel oil outlet from engine
9141	Dirty oil drain from pump bank, counter coupling side 1
9143	Dirty oil drain from pump bank, coupling side 1

Figure 140: DMB supply system diagram – Twin engine plant

5.8.4 External fuel system – Residual fuel (HFO) treatment system

A prerequisite for safe and reliable engine operation with a minimum of servicing is a properly designed and well-functioning fuel oil treatment system.

The schematic diagram, see figure Residual fuel (HFO) treatment system diagram, Page 370 shows the system components required for fuel treatment of residual fuel oil (HFO).

Bunker fuel oil

Fuel compatibility problems are avoidable if mixing of newly bunkered fuel oil with remaining fuel oil can be prevented by a suitable number of bunkers. Moreover the overall fuel oil system (all fuel oil tanks, piping and so on) must be designed to limit mixing of different bunker batches to an absolute minimum. Heating coils in bunkers must be designed so that the HFO in it is at a temperature of at least 10°C minimum above the pour point.

P-038/HFO transfer pump

The HFO transfer pump discharges fuel from the bunkers into the HFO settling tanks. Being a screw pump, it handles the fuel oil gently, thus prevent water being emulsified in the fuel oil. Its capacity must be sized to fill the complete HFO settling tank within ≤ 2 hours.

T-016/Residual fuel (HFO) settling tank

Two HFO settling tanks should be installed, in order to obtain thorough precleaning and to allow fuels of different origin to be kept separate. When using RM-fuels we recommend two HFO settling tanks for each fuel type (high sulphur HFO, low sulphur HFO).

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Size

Pre-cleaning by settling is the more effective the longer the solid material is given time to settle. The storage capacity of the HFO settling tank should be designed to hold at least a 24-hour supply of fuel oil at full load operation, including sediments and water the fuel oil contains.

The minimum volume (V) to be provided is:

$$V = \frac{5.7 \times P}{1{,}000}$$

V [m^3]	Minimum volume
P [kW]	Engine rating

Tank heating

The heating surfaces should be dimensioned that the HFO settling tank content can be evenly heated to 75°C within 6 to 8 hours. The heating should be automatically controlled, depending on the fuel oil temperature.

In order to avoid:

- Agitation of the sludge due to heating, the heating coils should be arranged at a sufficient distance from the tank bottom.
- The formation of asphaltene, the fuel oil temperature should not be permissible to exceed 75°C.
- The formation of carbon deposits on the heating surfaces, the heat transferred per unit surface must not exceed 1.1 W/cm^2.

Design

The HFO settling tank is to be fitted with baffle plates in longitudinal and transverse direction in order to reduce agitation of the fuel oil in the tank in rough seas as far as possible. The suction pipe of the HFO separator must not reach into the sludge space. One or more sludge drain valves, depending on the slant of the tank bottom (preferably 10°), are to be provided at the lowest point. The HFO settling tank is to be insulated against thermal losses.

Sludge must be removed from the HFO settling tank before the separators draw fuel oil from it.

T-021/Sludge tank

If disposal by an incinerator plant is not planned, the tank has to be dimensioned so that it is capable of absorbing all residues which accumulate during the operation in the course of a maximum duration of voyage. The content of this tank must not be added to the engine fuel oil. In order to enable the emptying of the tank, it must be heated.

The heating is to be dimensioned so that the content of the tank can be heated to approximately 60°C.

P-015/HFO separator feed pump

The HFO separator feed pump should preferably be of the free-standing type, that is, not mounted on the HFO separator, as the delivery volume can be matched better to the required throughput.

H-008/HFO preheater

To reach the separating temperature, a HFO preheater matched to the fuel oil viscosity has to be installed.

CF-002/Residual fuel (HFO) separator

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As a rule, poor quality, high viscosity fuel oil is used. Two new generation separators must therefore be installed.

The separators shall be capable to separate water from HFO with a density of 1,010 kg/m³ at 15°C.

HFO separators must always be provided in sets of 2 of the same type:

- 1 service separator
- 1 stand-by separator

Of self-cleaning type.

As a matter of principle, all separators are to be equipped with an automatic programme control for continuous desludging and monitoring.

Mode of operation

The stand-by separator is always to be put into service, to achieve the best possible fuel oil cleaning effect with the separator plant as installed.

The piping of both HFO separators is to be arranged in accordance with the manufacturer´s advice, preferably for both parallel and series operation.

The discharge flow of the free-standing dirty oil pump is to be split up equally between the two separators in parallel operation.

The freshwater supplied must be treated as specified by the separator supplier.

Size

The HFO separators are dimensioned in accordance with the separator manufacturers' guidelines. The required design flow rate (Q) can be roughly determined by the following equation:

$$Q = \frac{P \times b_e}{\rho}$$

Q [l/h]	Separator flow rate
P [kW]	Total engine output
b_e [g/kWh]	Fuel oil consumption
ρ [g/l]	Density at separating temp approximately 930 kg/m³ = [g/l]

With the evaluated flow rate, the size of the separator has to be selected according to the evaluation table of the manufacturer. The separator rating stated by the manufacturer should be higher than the flow rate (Q) calculated according to the above formula.

For the first estimation of the maximum fuel oil consumption (b_e), increase the specific table value by 15%, see section Planning data, Page 100.

For project-specific values contact Everllence.

In the following, characteristics affecting the fuel oil consumption are listed exemplary:

- Tropical conditions
- The engine-mounted pumps
- Fluctuations of the calorific value (Especially when using biofuels and synthetic fuels)
- The consumption tolerance

Regarding required limits on water and particles in the fuel after separation refer to table Requirements for diesel fuel.

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Note:
If a homogeniser is used, it must never be installed between the settling tank and separator as otherwise it will not be possible to ensure satisfactory separation of harmful contaminants, particularly seawater.

Withdrawal points for samples

Fuel oil sampling points are to be provided upstream and downstream of each separator, to verify the effectiveness of these system components.

MOD-008/Fuel oil module

See description in figure(s) HFO supply system diagram(s).

T-022/Residual fuel (HFO) service tank

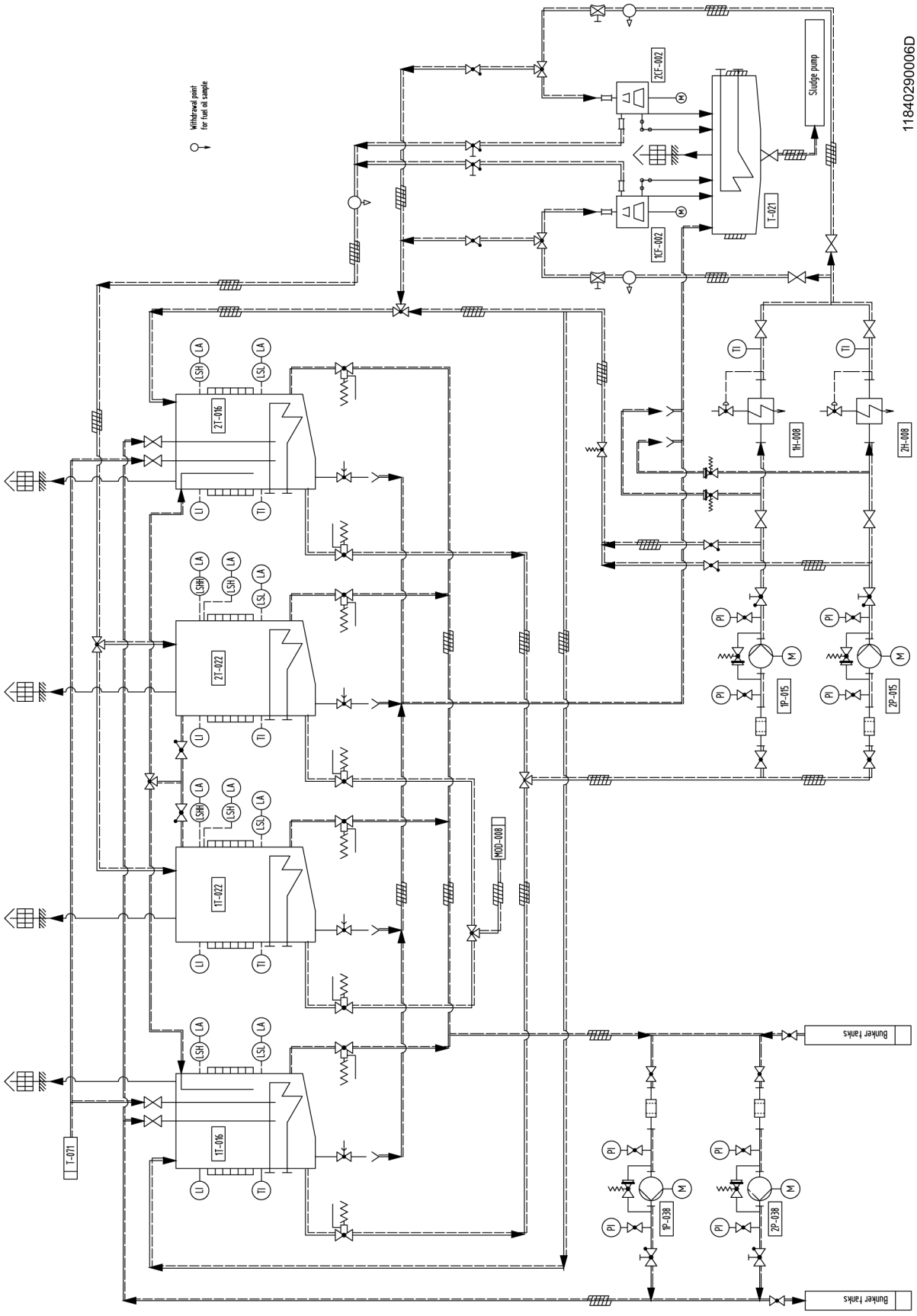
See description in paragraph T-022/Residual fuel (HFO) service tank, Page 372.

T-071/Clean leakage fuel oil tank

See description in paragraph T-071/Clean leakage fuel oil tank, Page 380.

Residual fuel (HFO) treatment system diagram

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11840290006D
Withdrawal point for fuel oil sample
Sludge pump
2CF-002
1CF-002
1T-021
2T-016
2T-022
1T-022
1T-016
1T-011
1H-008
2H-008
1P-015
2P-015
1P-038
2P-038
MOD-008
Bunker tanks
Bunker tanks

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	Components		
1,2 CF-002	HFO separator	1,2 T-016	HFO settling tank
1,2 H-008	HFO preheater	T-021	Sludge tank
MOD-008	Fuel oil module	1,2 T-022	HFO service tank
1,2 P-015	HFO separator feed pump	T-071	Clean leakage fuel oil tank
1,2 P-038	HFO transfer pump		

Figure 141: Residual fuel (HFO) treatment system diagram

5.8.5 External fuel system – Residual fuel (HFO) supply system

General

The HFO supply system is a pressurised closed loop system. Normally one or two main engines are connected to one fuel system. If required, auxiliary engines can be connected to the same fuel system as well (not indicated in the diagram).

To ensure that high-viscosity fuel oils achieve the specified injection viscosity, high operation temperature is necessary, which may cause degassing problems in conventional, pressureless systems.

A remedial measure is adopting a pressurised system in which the required system pressure is 1 bar above the evaporation pressure of water.

Fuel	Injection viscosity[1)]	Temperature after final heater HFO	Evaporation pressure	Min. required system pressure
mm²/50°C	mm²/s	°C	bar	bar
180	12	126	1.4	2.4
320	12	138	2.4	3.4
380	12	142	2.7	3.7
420	12	144	2.9	3.9
500	14	141	2.7	3.7
700	14	147	3.2	4.2

[1)] For fuel oil viscosity depending on fuel temperature see section Viscosity-temperature diagram (VT diagram), Page 266.

Table 138: Injection viscosity and temperature after final heater residual fuel (HFO)

The indicated pressures are minimum requirements due to the fuel characteristic. Nevertheless, to meet the required fuel pressure at the engine inlet (see section Planning data, Page 100 and the following), the pressure in the fuel oil mixing tank and booster circuit becomes significant higher than indicated in this table.

T-022/HFO service tank

The HFO cleaned in the residual fuel separator is passed to the service tank, and as the separators are in continuous operation, the tank is always kept filled.

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To fulfil this requirement it is necessary to fit the HFO service tank T-022 with overflow pipes, which are connected with the HFO settling tanks T-016. The tank capacity is to be designed for at least eight-hours' fuel supply at full load so as to provide for a sufficient period of time for separator maintenance.

The tank should have a sludge space with a tank bottom inclination of preferably 10° with sludge drain valves at the lowest point and it is to be equipped with heating coils.

The sludge must be drained from the service tank at regular intervals.

The heating coils are to be designed for a tank temperature of 75°C.

The rules and regulations for tanks issued by the classification societies must be observed.

HFO with high and low sulphur content must be stored in separate service tanks.

T-003/Diesel fuel oil service tank

The classification societies specify that at least two service tanks are to be installed on board. The minimum volume of each tank should, in addition to the DMA/DMB consumption of the generating sets, enable an eight-hour full load operation of the main engine.

Cleaning of the DMA/DMB by an additional separator should, in the first place, be designed to meet the requirements of the diesel alternator sets on board. Just like the HFO service tank, the diesel fuel oil service tank is to be provided with a sludge space with sludge drain valve, and with an overflow pipe from the diesel fuel oil service tank T-003, to the diesel fuel oil storage tank T-015. For more detailed information see section External fuel system – Marine diesel oil (DMB) supply system, Page 358.

CK-002/Three-way valve for fuel oil changeover

This valve is used for changing over from DMA/DMB operation to HFO operation and vice versa. This valve could be operated manually or automatically. It is equipped with two limit switches for remote indication and suppression of alarms from the viscosity measuring and control system, during DMA/DMB operation.

STR-010/Suction strainer

To protect the fuel oil supply pumps, an approximately 0.5 mm gauge (sphere-passing mesh) strainer is to be installed at the suction side of each supply pump.

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P-018/Fuel oil supply pump

The capacity of the supply pump must be at least 160% of the maximum fuel oil consumption.

$Q_P = (P \times (br_{ISO} / 1{,}000) \times f \times S) / \rho$		
Required supply pump delivery capacity	Q_P	m^3/h
Engine output at 100% MCR	P_1	kW
Specific engine fuel oil consumption (ISO) at 100% MCR	br_{ISO}	g/kWh
Factor for pump dimensioning	f = 1.6	-
Safety factor for consideration of attached pumps and tropical conditions	S = 1.1	-
Min. fuel density at 15°C	ρ	kg/m^3
Note: **The fuel density shall be chosen according the fuel with the lowest density, for which the system is designed for (in general DMA, min. density 820 kg/m^3 at 15°C).** **In case more than one engine is connected to the same fuel oil system, the pump capacity has to be increased accordingly.**		

Table 139: Simplified fuel oil supply pump dimensioning

The delivery height of the fuel oil supply pump shall be selected according to the required system pressure (see table Injection viscosity and temperature after final heater heavy fuel oil, Page 372), the required pressure in the mixing tank and the resistance of the piping system.

		Injection system
		bar
Positive pressure at the fuel module inlet due to tank level above fuel module level	–	0.10
Pressure loss of the pipes between fuel module inlet and mixing tank inlet	+	0.20
Pressure in the mixing tank	+	≤ 6.70
Operating delivery height of the supply pump	=	6.80

Table 140: Example for the determination of the expected operating delivery height of the fuel oil supply pump

It is recommended to install fuel oil supply pumps designed for the following pressures:

Engines with conventional fuel oil injection system: Design delivery height 7.0 bar, design output pressure 7.0 bar.

Engines with common rail injection system: Design delivery height 8.0 bar, design output pressure 8.0 bar.

HE-025/Fuel oil cooler, supply circuit

If no fuel is consumed in the system while the pump is in operation, the finned-tube cooler prevents excessive heating of the fuel. Its cooling surface must be adequate to dissipate the heat that is produced by the pump to the ambient air.

In case of continuos DMA/DMB operation, a water cooled fuel oil cooler is required to keep the fuel oil temperature below 45°C.

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PCV-009/Pressure limiting valve

This valve is used for setting the required system pressure and keeping it constant. It returns in the case of

- engine shutdown 100%, and of
- engine full load 37.5% of the quantity delivered by the fuel oil supply pump back to the pump suction side.

T-011/Fuel oil mixing tank

The mixing tank compensates pressure surges which occur in the pressurised part of the fuel system.

For this purpose, there has to be an air cushion in the tank. As this air cushion is exhausted during operation, compressed air (max. 10 bar) has to be refilled via the control air connection from time to time.

Before prolonged shutdowns the system is changed over to DMA/DMB operation.

The tank volume shall be designed keep the engine running at 50% load for 5 minutes. At 50% load the fuel oil consumption is approx. 1/2 x fuel oil consumption at full load.

The tank shall be designed for the maximum possible service pressure, usually approximately 10 bar and is to be accepted by the classification society in question.

The expected operating pressure in the fuel oil mixing tank depends on the required fuel oil pressure at the inlet (see section Planning data, Page 100) and the pressure losses of the installed components and pipes.

		Injection system
		bar
Required max. fuel oil pressure at engine inlet	+	12.00
Pressure difference between fuel oil inlet and outlet engine	–	≥ 5.00
Pressure loss of the fuel oil return pipe between engine outlet and mixing tank inlet, e.g.	–	0.30
Pressure loss of the flow balancing valve (to be installed in multi-engine plants, pressure loss approximately 0.5 bar)	–	0.00
Operating pressure in the fuel oil mixing tank	=	≤ 6.70

Table 141: Example for the determination of the expected operating pressure of the fuel oil mixing tank

This example demonstrates, that the calculated operating pressure in the fuel oil mixing tank is (for all HFO viscosities) higher than the min. required fuel oil pressure (see table Injection viscosity and temperature after final heater heavy fuel oil, Page 372).

P-003/Fuel oil booster pump

To cool the engine mounted high pressure pumps, the capacity of the booster pump must be at least 300% of the maximum fuel oil consumption.

$Q_P = (P \times (br_{ISO} / 1{,}000) \times f \times S) / \rho$		
Required booster pump delivery capacity	Q_P	m^3/h
Engine output at 100% MCR	P	kW
Specific engine fuel oil consumption (ISO) at 100% MCR	br_{ISO}	g/kWh

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Factor for pump dimensioning	f = 3	-
Safety factor for consideration of attached pumps and tropical conditions	S = 1.1	-
Min. fuel density at 15°C	ρ	kg/m^3
Note: The fuel density shall be chosen according the fuel with the lowest density, for which the system is designed for (in general DMA, min. density 820 kg/m^3 at 15°C). In case more than one engine is connected to the same fuel oil system, the pump capacity has to be increased accordingly.		

Table 142: Simplified fuel oil booster pump dimensioning

The delivery height of the fuel oil booster pump is to be adjusted to the total resistance of the booster system.

		Injection system
		bar
Pressure difference between fuel inlet and outlet engine	+	≥ 5.00
Pressure loss of the flow balancing valve (to be installed only in multi-engine plants, pressure loss approximately 0.5 bar)	+	0
Pressure loss of the pipes, mixing tank – Engine mixing tank, e.g.	+	0.5
Pressure loss of the final heater residual fuel max.	+	0.8
Pressure loss of the automatic filter	+	0.5
Pressure loss of the indicator filter	+	0.8
Operating delivery height of the booster pump	=	≥ 7.60

Table 143: Example for the determination of the expected operating delivery height of the fuel oil booster pump

It is recommended to install booster pumps designed for the following pressures:

Engines with conventional fuel oil injection system: Design delivery height 7.0 bar, design output pressure 10.0 bar.

Engines common rail injection system: Design delivery height 10.0 bar, design output pressure 14.0 bar.

VI-001/Viscosimeter

This device regulates automatically the heating of the final heater HFO depending on the viscosity of the circulating fuel oil, to reach the viscosity required for injection.

H-004/Final heater HFO

The capacity of the final heater shall be determined on the basis of the injection temperature at the nozzle, to which at least 4 K must be added to compensate for heat losses in the piping. The piping for both heaters shall be arranged for single and series operation.

Parallel operation with half the throughput must be avoided due to the risk of sludge deposits.

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FIL-030/Automatic filter

The automatic filter should be a type that causes no significant pressure drop during flushing sequence. As a reference an acceptable value for a pressure decrease during back flushing is 0.3 – 0.5 bar. The filter mesh size has to be 0.010 mm (absolute) for common rail injection. The used sealing material has to resist the operation condition defined in table Fuel, Page 138. Long term operation has to be confirmed by the filter manufacturer.

The automatic filter must be equipped with differential pressure indication and switches.

Design criterion is the filter area load specified by the filter manufacturer. The automatic filter has to be installed in the plant (is not attached on the engine).

	Common rail injection system
Filter mesh width (mm)	0.010
Design pressure	PN16
Design temperature	≥ 150 °C

Table 144: Required filter mesh width (sphere passing mesh) – Common rail injection system

T-008/Fuel oil damper tank

The injection nozzles cause pressure peaks in the pressurised part of the fuel oil system. In order to protect the viscosity measuring and control unit, these pressure peaks have to be equalised by a compensation tank. The volume of the pressure peaks compensation tank is 20 l.

Alternatively a metal bellow damper can be used in combination with an air cushion in the fuel oil mixing tank.

FQ-003/Fuel oil flowmeter

For a fuel oil consumption measurement (not mentioned in the diagram), flowmeters have to be installed upstream and downstream of the engine. The measured difference of these flows equals the consumption.

The upstream flow rate of each engine should be displayed in the ship automation and SaCoS system. Each 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.

FIL-013/Fuel oil duplex filter

This filter is attached on the engine.

The emptying port of each filter chamber should be fitted with a valve and a pipe to the sludge tank. If the filter elements are removed for cleaning, 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.

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Design criterion is the filter area load specified by the filter manufacturer.

	Injection system
Filter mesh width (mm)	0.025
Design pressure	PN16

Table 145: Required filter mesh width (sphere passing mesh) – Injection system

FSH-001/Leakage fuel oil monitoring tank

High pressure pump overflow and escaping fuel oil from burst control pipes is carried to the monitoring tanks from which it is drained into the clean leakage fuel oil collecting tank. The engine interface connection of the monitoring tank is a pressureless drain. Leakage fuel oil flows by gravity only from these tank into collecting tanks (to be installed below the engine connections). To prevent pressure resistance at the engine interface connection the pipework to the collecting tank has to have a sufficient downward slope. The float switch mounted in the tanks must be connected to the alarm system. The classification societies require the installation of monitoring tanks for unmanned engine rooms. Lloyd's Register specifies tank monitoring for manned engine rooms as well.

FBV-010/Flow balancing valve

Residual fuel supply system for only one main engine, without auxiliary engines

The flow balancing valve FBV-010 is not required.

Residual fuel supply system for more than one main engine or/and additional auxiliary engines

The flow balancing valve at engine outlet is to be installed only (one per engine) in multi-engine arrangements connected to the same fuel system. It is used to balance the fuel flow through the engines. Each engine has to be fed with its correct, individual fuel flow.

CV-003/Cooling water control valve for fuel oil cooler

The purpose of this valve is to allow a smooth temperature/viscosity adaption to avoid sludge formation due to a harsh temperature change during a fuel oil change over. This is achieved by controlling the cooling water flow through the fuel oil cooler.

HE-007/Fuel oil cooler
CK-003/Three-way valve (fuel oil cooler/by-pass)

The propose of the fuel oil cooler is to ensure that the viscosity of DMA/DMB will not become too fluid in engine inlet.

With the three-way valve (fuel oil cooler/by-pass) CK-003, the fuel oil cooler HE-007 has to be opened when the engine is switched from HFO to DMA/DMB operation.

That way, the DMA/DMB, which was heated while circulating via the injection pumps, is re-cooled before it is returned to the fuel oil mixing tank T-011. Switching on the fuel oil cooler may be effected only after flushing the pipes with DMA/DMB.

The cooler is cooled by LT cooling water.

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Depending on the fuel oil type a chiller unit might be required to decrease the fuel oil temperature to reach the required injection system operation viscosity, see section Viscosity-temperature diagram (VT diagram), Page 266.

The thermal design of the cooler is based on the following data:

$P_c = P_1 \times br_{ISO} \times f_1$		
$Q_c = P_1 \times br_{ISO} \times f_2$		
Cooler outlet temperature DMA/DMB[1] T_{out} = 45°C	T_{out}	°C
Dissipated heat of the cooler	P_c	kW
DMB flow for thermal dimensioning of the cooler[2]	Q_c	l/h
Engine output power at 100% MCR	P_1	kW
Specific engine fuel oil consumption (ISO) at 100% MCR	br_{ISO}	g/kWh
Factor for heat dissipation: f_1 = 2.68 x 10^{-5}	f_1	kWh/g
Factor for DMA/DMB flow: f_2 = 2.80 x 10^{-3}	f_2	l/g
Note: **In case more than one engine, or different engines are connected to the same fuel system, the cooler capacity has to be increased accordingly.**		
[1] This temperature has to be normally maximum 45°C. Only for very light DMA fuel types this temperature has to be even lower in order to preserve the minimum admissible fuel oil viscosity in engine inlet (see section Viscosity-temperature diagram (VT diagram), Page 266). [2] The maximum DMA/DMB throughput is identical to the delivery quantity of the installed fuel oil booster pump.		

Table 146: Simplified fuel oil cooler dimensioning for engines with common rail injection

The recommended pressure class of the fuel oil cooler is PN16.

FBV-013/Minimum flow valve

The minimum flow valve has to be installed in the plant. This valve is used to adjust the flushing flow to exchange the HFO supply system with fresh HFO every 12 hours.

It becomes necessary to avoid circulation of the same HFO content for a long period. Therefore the external main fuel oil system must be designed to ensure that the HFO content of the fuel system is completely exchanged with "fresh" HFO every 12 hours. This can be done by a return pipe from the booster system into the residual fuel (HFO) service tank.

In case the fuel supply system is filled with DMA, no fuel exchange is required. For that the manual valve prior the FBV-013 can be closed.

V-002/Shut-off cock

HFO supply system for only one main engine, without auxiliary engines

Shut-off cock V-002 is not required.

HFO supply system for more than one main engine or/and additional auxiliary engines

The stop cock is closed during normal operation (multi-engine operation). When one engine is separated from the fuel oil circuit for maintenance purposes, this cock has to be opened manually.

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HFO supply system for only one main engine, without auxiliary engines

PCV-011/Fuel oil spill valve

Fuel oil spill valve PCV-011 is not required.

HFO supply system for more than one main engine or/and additional auxiliary engines

In case two engines are operated with one fuel oil module, it has to be possible to separate one engine at a time from the fuel oil circuit for maintenance purposes. In order to avoid a pressure increase in the pressurised system, the fuel oil, which cannot circulate through the shut-off engine, has to be rerouted via this valve into the return pipe. This valve is to be adjusted so that rerouting is effected only when the pressure, in comparison to normal operation (multi-engine operation), is exceeded. This valve should be designed as a pressure relief valve, not as a safety valve.

MOV-017/Leakage fuel oil switch-over valve

Depending on the supplied fuel oil type, the operation leakage of the high-pressure injection system can be drained into the HFO or distillate clean leakage fuel oil tank by switching over this valve.

Note:
It must be ensured that no HFO contamination is led into the distillate clean leakage fuel oil tank.

T-071/Clean leakage fuel oil tank

High pressure pump overflow and other clean fuel oil that escapes from the injection system is led to the clean leakage fuel oil tanks.

From there the content of the distillate clean leakage fuel oil tank (1 T-071) must be emptied into the diesel fuel oil storage tank (T-015). The content of the HFO clean leakage fuel oil tank (2 T-071) must be emptied into the residual fuel (HFO) settling tank (T-016). The installation of these two clean leakage fuel oil tanks enables an effective separation of different fuel oil types.

The amount of clean operation leakage differs in a broad range, depending on the wear of the high pressure pumps, the type of fuel oil and the operating temperatures.

For data regarding the leak rate, see table(s) Leakage rate, Page 140.

A high flow of leakage fuel oil will occur in case of a pipe break, for short time only (< 1 min). Engine will give an alarm after a pipe break alarm.

Clean leakage fuel oil from the clean leakage fuel oil tanks 1,2 T-071 can be used again after passing the fuel oil separator.

Leakage fuel oil flows pressureless (by gravity only) from the engine into these tanks (to be installed below the engine connections). Pipe clogging must be avoided by trace heating and by a sufficient downward slope.

It must be ensured that the leakage fuel oil is well diluted with fresh fuel before entering the engine again. Nevertheless, leakage oil collecting tank T-006 is still required to collect lube oil leakages from lube oil drains (and other).

In case the described clean leakage fuel oil tank T-071 is installed, leakages from the following engine connections are to be conducted into this tank:

Engine type	Connection
L engine	5145

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Engine type	Connection
V engine	5145, 5146

Table 147: Connections clean leakage fuel oil tank

Withdrawal points for samples

Fuel oil sampling points are to be provided upstream and downstream of each filter, to verify the effectiveness of these system components.

T-006/Leakage oil collecting tank

Dirty leak fuel and leak oil are collected in the leakage oil collecting tank. It must be emptied into the sludge tank. The content of the leakage oil collecting tank T-006 must not be added to the engine fuel. It can be burned for instance in a waste oil boiler.

The leakage oil collecting tank T-006 is only necessary if the leakages can not flow directly into the sludge tank T-021 by gravity.

CF-002/Residual fuel (HFO) separator

See description in paragraph CF-002/Residual fuel (HFO) separator, Page 368.

CF-003/Diesel fuel oil separator

See description in paragraph CF-003/Diesel fuel oil separator, Page 353.

T-015/Diesel fuel oil storage tank

See description in paragraph T-015/Diesel fuel oil storage tank, Page 352.

T-016/Residual fuel (HFO) settling tank

See description in paragraph T-016/Residual fuel (HFO) settling tank, Page 367.

T-021/Sludge tank

See description in paragraph T-021/Sludge tank, Page 368.

CV-004/Pilot fuel oil service tank filling valve

See description in section External fuel system – Pilot fuel supply system, Page 387.

T-101/Pilot fuel oil service tank

See description in section External fuel system – Pilot fuel supply system, Page 387.

FIL-033/Pilot fuel oil duplex filter

See description in section External fuel system – Pilot fuel supply system, Page 387.

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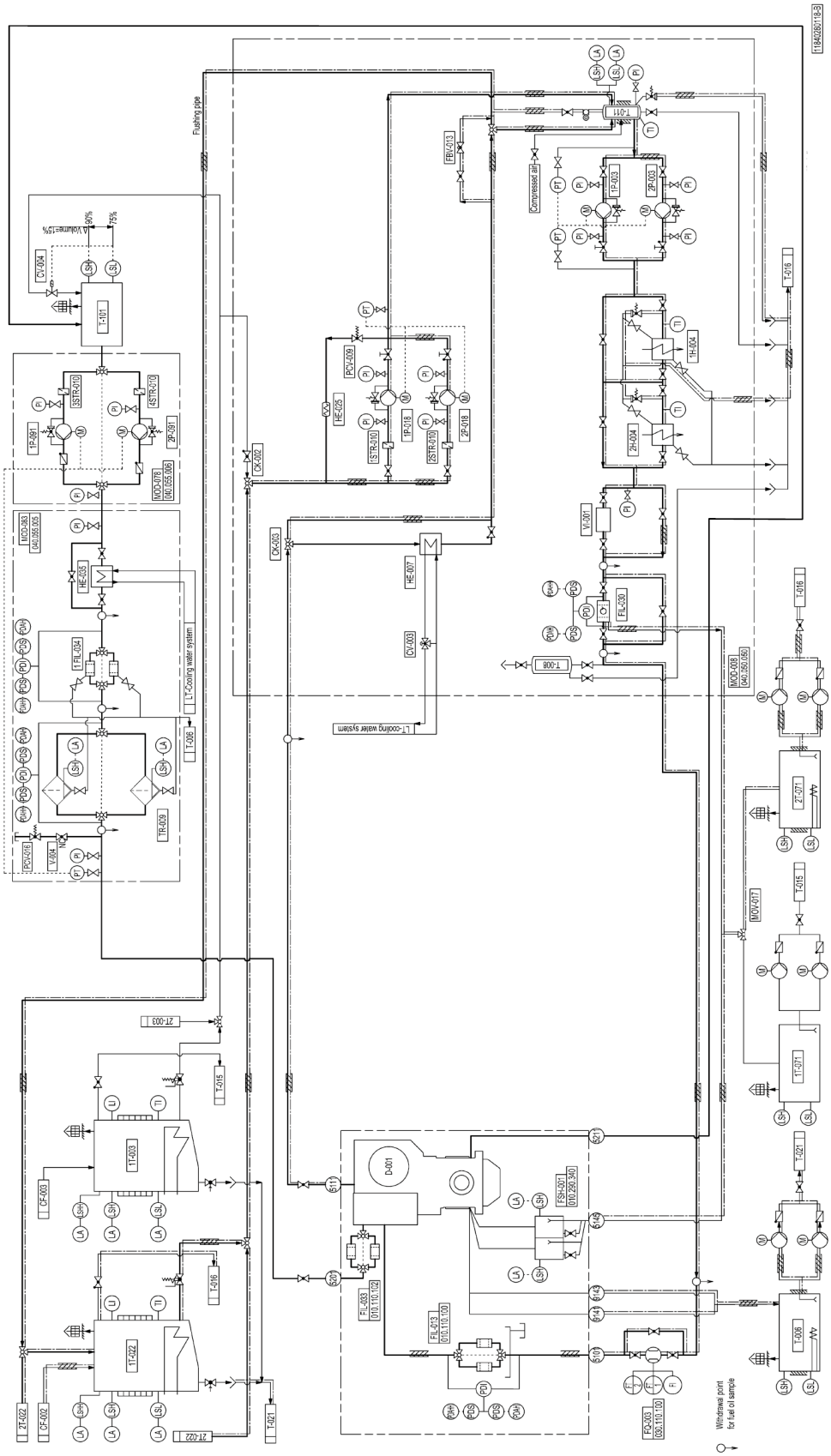
Piping

The fuel oil system design pressure is PN16 (see section External pipe dimensioning, Page 278). The system is to be protected from higher pressure levels by corresponding safety valves. Additional safety valves, not displayed in the P&ID, might become necessary depending on the actual fuel oil system design.

Material

The casing material of pumps and filters should be EN-GJS (nodular cast iron), in accordance to the requirements of the classification societies.

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Flushing pipe
LT-cooling water system
Compressed air
Withdrawal point for fuel oil sample
D-001
T-011
T-008
T-006
T-015
T-016
T-021
T-022
MOV-017
MOD-008 040.050.056
MOD-078 040.055.006
MOD-083 040.055.005
1184028011/0-3

Components

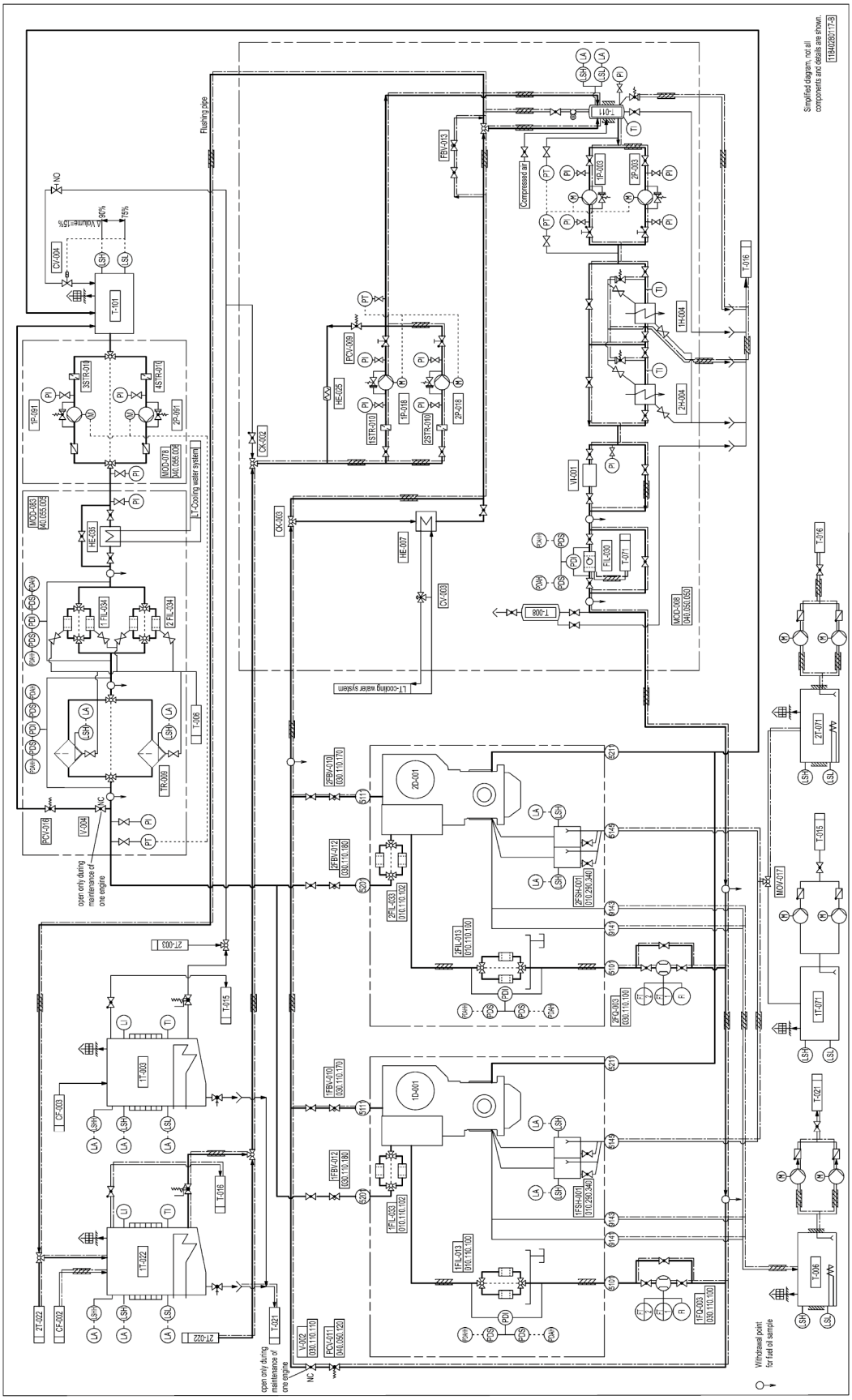
CF-002	Heavy fuel oil separator
CF-003	Diesel fuel oil separator
CK-002	Three-way valve for fuel oil changeover
CK-003	Three-way valve (for oil cooler/ by-pass)
CV-003	Cooling water control valve for fuel oil cooler
CV-004	Pilot fuel oil service tank filling valve
D-001	Diesel engine
FBV-013	Minimum flow valve
FIL-013	Fuel oil duplex filter
FIL-030	Fuel oil automatic filter, booster circuit
FIL-033	Pilot fuel duplex filter
FIL-034	Pilot fuel duplex filter
FQ-003	Fuel oil flowmeter
FSH-001	Leakage fuel oil monitoring tank
1,2 H-004	Final heater heavy fuel oil
HE-007	Fuel oil cooler
HE-025	Fuel oil cooler, supply circuit
HE-035	Pilot fuel oil cooler
MOD-008	Fuel oil module
MOD-078	Pilot fuel oil supply pump module
MOD-083	Pilot fuel oil filter module
MOV-017	Leakage fuel oil switch-over valve
1,2 P-003	Fuel oil booster pump
1,2 P-018	Fuel oil supply pump
1,2 P-091	Pilot fuel oil supply pump
PCV-009	Pressure limiting valve
PCV-016	Pilot fuel oil spill valve
PSV-010	Fuel oil safety valve
1,2,3,4 STR-010	Fuel oil function strainer
1,2 T-003	Diesel fuel oil service tank
T-006	Leakage oil collecting tank
T-008	Fuel oil damper tank
T-011	Fuel oil mixing tank
T-015	Diesel fuel oil storage tank
T-016	HFO settling tank
T-021	Sludge tank
1,2 T-022	HFO service tank
1,2 T-071	Clean leakage fuel oil tank
T-101	Pilot fuel oil service tank
TR-009	Coalescer (water trap)
V-004	Shut-off cock
VI-001	Viscosimeter

Major engine connections

5101	Fuel oil inlet to engine
5111	Fuel oil outlet from engine
5145	Fuel oil leakage drain (reusable from pumps and injectors) 1
5201	Pilot fuel oil inlet to engine
5211	Pilot fuel oil outlet from engine
9141	Dirty oil drain from pump bank, counter coupling side 1
9143	Dirty oil drain from pump bank, coupling side 1

Figure 142: HFO supply system diagram – Single engine plant

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Simplified diagram, not all components and details are shown.
Flushing pipe
LT-Cooling water system
open only during maintenance of one engine
Withdrawal point for fuel oil sample

Components

CF-002	Heavy fuel oil separator
CF-003	Diesel fuel oil separator
CK-002	Three-way valve for fuel oil changeover
CK-003	Three-way valve (for oil cooler/ by-pass)
CV-003	Cooling water control valve for fuel oil cooler
CV-004	Pilot fuel oil service tank filling valve
1,2 D-001	Diesel engine
1,2 FBV-010	Flow balancing valve
1,2 FBV-012	Flow balancing valve pilot fuel
FBV-013	Minimum flow valve
1,2 FIL-013	Fuel oil duplex filter
FIL-030	Fuel oil automatic filter, booster circuit
1,2 FIL-033	Pilot fuel duplex filter
FIL-034	Pilot fuel duplex filter
1,2 FQ-003	Fuel oil flowmeter
1,2 FSH-001	Leakage fuel oil monitoring tank
1,2 H-004	Final heater HFO
HE-007	Fuel oil cooler
HE-025	Fuel oil cooler, supply circuit
HE-035	Pilot fuel oil cooler
MOD-008	Fuel oil module
MOD-078	Pilot fuel oil supply pump module
MOD-083	Pilot fuel oil filter module
MOV-017	Leakage fuel oil switch-over valve
1,2 P-003	Fuel oil booster pump
1,2 P-018	Fuel oil supply pump
1,2 P-091	Pilot fuel oil supply pump
PCV-009	Pressure limiting valve
PCV-011	Fuel oil spill valve
PCV-016	Pilot fuel oil spill valve
1,2,3,4 STR-010	Fuel oil function strainer
1,2 T-003	Diesel fuel oil service tank
T-006	Leakage oil collecting tank
T-008	Fuel oil damper tank
T-011	Fuel oil mixing tank
T-015	Diesel fuel oil storage tank
T-016	HFO settling tank
T-021	Sludge tank
1,2 T-022	HFO service tank
1,2 T-071	Clean leakage fuel oil tank
T-101	Pilot fuel oil service tank
TR-009	Coalescer (water trap)
V-002	Fuel oil shut-off cock
V-004	Shut-off cock
VI-001	Viscosimeter

Major engine connections

5101	Fuel oil inlet to engine
5111	Fuel oil outlet from engine
5145	Fuel oil leakage drain (reusable from pumps and injectors) 1
5201	Pilot fuel oil inlet to engine
5211	Pilot fuel oil outlet from engine
9141	Dirty oil drain from pump bank, counter coupling side 1
9143	Dirty oil drain from pump bank, coupling side 1

Figure 143: HFO supply system diagram – Twin engine plant

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5.8.6 External fuel system – Pilot fuel supply system

General

The pilot fuel oil supply system is an open system with open deaeration pilot fuel oil service tank. Usually one or two engines are connected to one pilot fuel oil supply system, see figure(s) HFO supply system diagram(s). Each cylinder of the engine is equipped with two injection nozzles, the pilot fuel oil nozzle and the main fuel oil nozzle.

Diesel fuel oil viscosity

As pilot fuel oil only DMA, DFA according to ISO 8217 with a max. nominal viscosity range of 2–6 cSt at 40°C is permissible (see table Fuel – Pilot fuel system).

Pilot fuel oil

The pilot fuel oil nozzles are part of the pilot fuel oil common rail system. Pilot fuel oil nozzles are designed to operate with very small fuel oil quantities in order to minimise the pilot fuel oil consumption. This enigne type is equipped with a pilot fuel oil system for all applications. In liquid fuel oil mode, pilot fuel oil DMA, DFA is injected for cooling the nozzles of the pilot fuel oil injectors.

Without further pilot fuel oil injection, cooling of the pilot fuel oil nozzles is missing. With the low pilot fuel oil pressure, there is a danger that the combustion pressure could flow back into the injector. In both cases the injector will be damaged after a few operating hours.

The engine has two pilot fuel oil connections, the pressurised pilot fuel oil inlet and the pressureless pilot fuel oil outlet. Non-burned fuel oil and leakage fuel oil from the pilot fuel oil nozzles is circulated via the pilot fuel oil outlet connection to the pilot fuel oil service tank.

The leakage fuel oil flows pressure less (by gravity only) from the engine into the pilot fuel oil service tank (to be installed below the engine connections). Pipe resistance and clogging must be avoided by a sufficient downward slope.

T-101/Pilot fuel oil service tank

The pilot fuel oil service tank, installed on the pilot fuel oil return pipe, has to be designed for a content of min. 300 l for each connected engine. At the engine outlet, the pilot fuel oil is pressureless. Therefore the pilot fuel oil return pipe between the engine and the pilot fuel oil collecting tank has to be installed with a downward slope. Filling of the tank is to be governed by fuel level switches. A difference of 15% of the total tank volume between filling start and stop is to be established. The filling of the pilot fuel oil service tank should be done with well-separated fuel from the diesel fuel oil service tank. The tank is filled by hydrostatic pressure of the diesel fuel oil service tank or a supply pump.

CV-004/Pilot fuel oil service tank filling valve

The valve is installed if hydrostatic filling of the pilot fuel oil service tank is applied. The valve must be operated automatically depending on the filling level of the pilot fuel oil service tank.

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STR-010/Suction strainer

To protect the fuel supply pumps, an approximately 0.25 mm gauge (sphere-passing mesh) strainer is to be installed at the suction side of each supply pump.

P-091/Pilot fuel oil supply pump

The pilot fuel oil supply pump shall keep sufficient fuel pressure before the engine mounted pilot fuel oil high pressure pump.

The pilot fuel oil supply pump has to be designed for a flow of 220 l/h for each connected L engine and 400 l/h for each connected V engine. For at least one engine supplied by one pilot fuel oil supply pump an increased flow has to be considered to cover the failure case of an open pressure safety valve (PSV) on the pilot fuel oil high-pressure pump of one engine. This increases the necessary flow for one engine to 220 l/h for a L engine and 440 l/h for a V engine. If the failure case of an open PSV is considered in the design of the pump, enough margin in normal operation is considered for:

- Tropical conditions
- Realistic heating value
- Tolerance

For required flow of the supply pump on different engine configurations with max. 3 engines supplied per pump see following table.

	0xV49/60	1xV49/60	2xV49/60	3xV49/60
0xL49/60	-	440 l/h	840 l/h	1,240 l/h
1xL49/60	220 l/h	660 l/h	1,060 l/h	-
2xL49/60	440 l/h	880 l/h	-	-
3xL49/60	660 l/h	-	-	-

Table 148: Required flow of the supply pump on different engine configurations

The delivery height shall be selected with reference to the system losses and the pressure required before the engine (see section Planning data, Page 100). Normally the required delivery height is 10 bar.

The pilot fuel oil pumps have to be installed on the same level as the pilot oil service tank T-101. Furthermore the pumps shall be installed as close as possible to the pilot oil service tank T-101.

HE-035/Pilot fuel oil cooler

The pilot fuel oil cooler is required to cool down the fuel oil, which was heated up while circulating through the high pressure pilot fuel oil injection system. The pilot fuel oil cooler is normally connected to the LT cooling water system and should be dimensioned so that the DMA does not exceed a temperature of max. 45°C.

The thermal design of the pilot fuel oil cooler is based on the following data:

Pilot fuel outlet temperature out of cooler	≤ 45°C
Dissipated heat of the pilot fuel oil cooler	
Standard operation	min. 0.07 kW/cyl.

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Only in case of an open pressure limiting valve of the pilot fuel system during engine operation	2.6 kW per cylinder bank

Table 149: Dimensioning of the pilot fuel oil cooler

The max. DMA volume flow is identical to the delivery quantity of the installed pilot fuel oil supply pump P-091. The recommended pressure class of the pilot fuel oil cooler is PN16.

FIL-034/Pilot fuel oil duplex filter

To ensure high fuel oil quality (see section Pilot fuel) this filter has to be designed as a depth filter. The pilot fuel oil duplex filter is to be installed upstream of the engine, the emptying port of each filter chamber is to be fitted with a valve and a pipe to the leakage oil collecting tank (T-006).

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. Design criterion is the filter area load specified by the filter manufacturer.

Filter mesh width (mm)	0.010
Design pressure	PN16

Table 150: Required filter mesh width (sphere passing mesh)

For single engine plants, one duplex filter is installed. For multi-engine plants, two duplex filters in parallel are installed.

TR-009/Coalescer and fine filter stage

The coalescer is equipped with a water level sensor. If the water reaches a certain level an alarm will be triggered and the coalescer can be emptied to the leakage oil collecting tank T-006 by switching to the redundant coalescer and opening the manual drain valve.

The coalescer is equipped with a fine filter stage. To ensure a high fuel quality at the engine inlet the filter is designed as a depth filter. Before changing the filter element, the housing has to be drained analog the water draining.

Filter mesh width (mm)	0.001
Design pressure	PN16

Table 151: Required filter mesh width (sphere passing mesh)

V-004/Shut-off cock

Pilot fuel oil supply system for only one engine

Shut-off cock V-002 is not required.

Pilot fuel oil supply system for more than one engine

The stop cock is closed during normal operation (multi-engine operation). When one engine is separated from the pilot fuel oil circuit for maintenance purposes, this cock has to be opened manually.

PCV-016/Pilot fuel oil spill valve

This valve is used for setting the required pressure before the pilot fuel oil high pressure pump. It should be designed as a pressure relief valve, not as a safety valve.

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FIL-033/Pilot fuel oil duplex filter

This filter (designed as a depth filter) is attached on the engine. 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. Design criterion is the filter area load specified by the filter manufacturer.

Filter mesh width (mm)	0.001
Design pressure	PN40

Table 152: Required filter mesh width (sphere passing mesh)

Piping

The fuel oil system design pressure is PN16 (see section External pipe dimensioning, Page 278). The system is to be protected from higher pressure levels by corresponding safety valves. Additional safety valves, not displayed in the P&ID, might become necessary depending on the actual fuel oil system design.

Material

The casing material of pumps and filters should be EN-GJS (nodular cast iron), in accordance to the requirements of the classification societies.

5.8.7 External fuel system – Fuel oil supply at blackout conditions

As the main electrical grid is not available during a blackout, an alternative energy source has to guarantee fuel oil supply. If a sufficient uninterruptible power supply (UPS) system is available, it can be connected to the regular fuel oil supply pumps and run them in spite of blackout.

Alternatively an additional pneumatic pump can be installed. If this pump is connected to a working air system, it must be ensured that this system can always deliver sufficient compressed air required to outlast the blackout operation.

Also the starting air system can be used, if the additional air is considered for design of starting air receivers and the adequate control of the blackout pump is implemented in the ship automation system. Background is that the amount of compressed air required by class societies for engine starts must not be affected. Everllence can design a suitable pneumatic pump and calculate its compressed air consumption.

Duration of blackout operation

Duration of the blackout pump operation should last till the regular fuel supply is recovered:

- Duration of the emergency GenSet for connecting to the main electrical grid
- Start-up time of the fuel oil module after main grid is restored
- Buffer time

On the other hand, the duration of the blackout pump operation should be limited by the ship automation system due to:

- Reduction of UPS or compressed air consumption

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- Consideration of engine related systems without power supply (e.g. cooling water system might overheat)

Depending on engine load it can be advisable to schedule blackout operation to maximum 90 seconds.

Integration in fuel oil system

In a diesel fuel oil supply system it is recommended to integrate the blackout pump parallel to the regular fuel oil supply pumps. In order to reduce compressed air consumption, it is possible to choose a downsized pump and operate the engine in part load.

For a residual fuel supply system a pneumatic pump delivers fuel oil from DMB service tank into the mixing tank to guarantee low load operation. For high-load operation contact Everllence.

Note:
A fuel oil supply with cold DMA/DMB shortly after HFO operation will lead to temperature shocks in the injection system and has to be avoided under any circumstances.

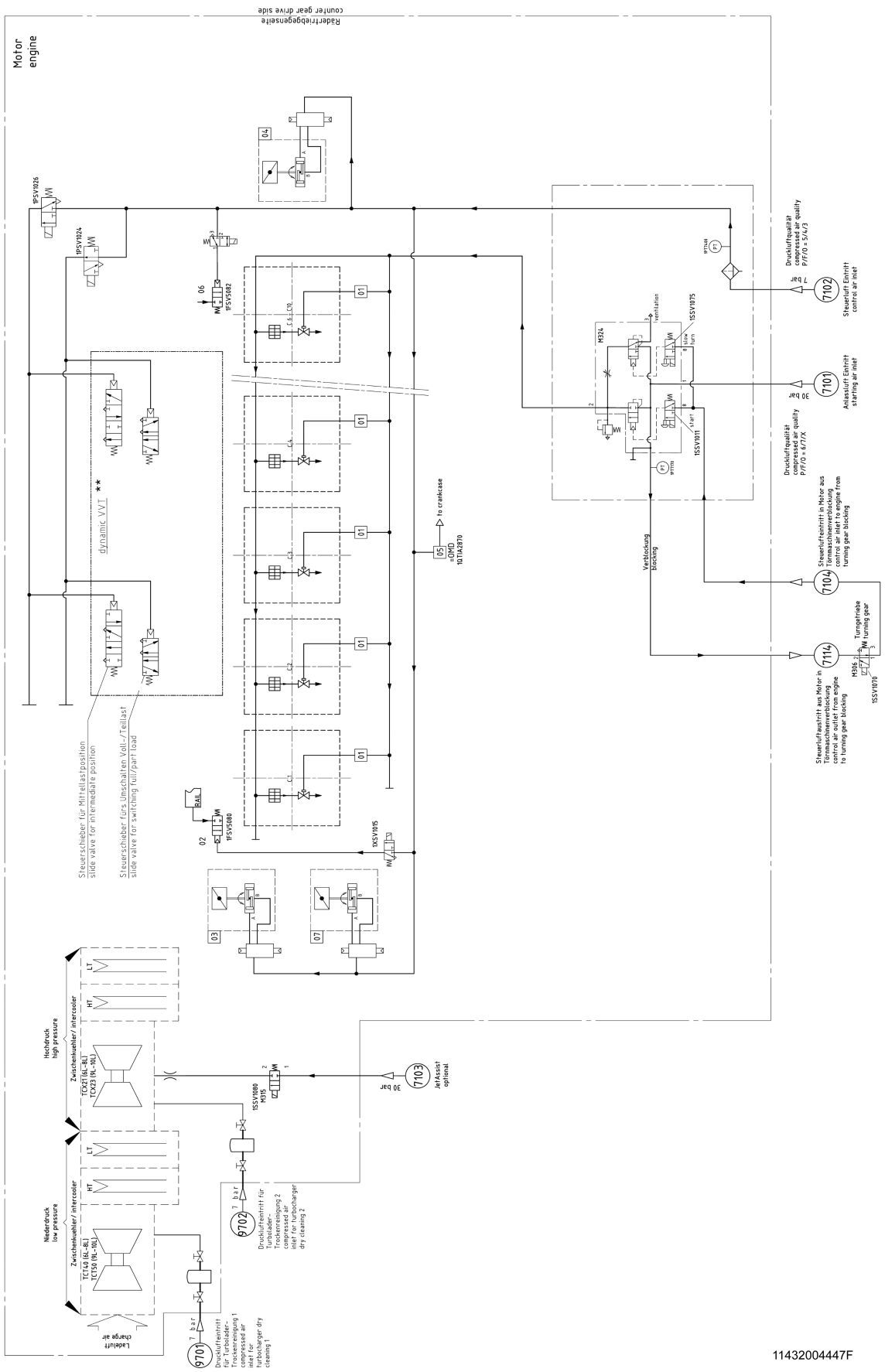
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5.9 Compressed air system

5.9.1 Internal compressed air system

See overleaf

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Motor
engine
Rädertriebgegenseite
counter gear drive side
dynamic VVT **
Steuerschieber für Mittellastposition
slide valve for intermediate position
Steuerschieber fürs Umschalten Voll-/Teillast
slide valve for switching full/part load
to crankcase
Verblockung
blocking
Druckluftqualität
compressed air quality
P/F/O = 5/4/3
Steuerluft Eintritt
control air inlet
Druckluftqualität
compressed air quality
P/F/O = 6/7/X
Anlassluft Eintritt
starting air inlet
Steuerluftaustritt in Motor aus
Turmaschinenverblockung
control air inlet to engine from
turning gear blocking
Steuerluftaustritt aus Motor in
Turmaschinenverblockung
control air outlet from engine
to turning gear blocking
Turngetriebe
turning gear
Hochdruck
high pressure
Niederdruck
low pressure
Zwischenkühler/ intercooler
Ladeluft
charge air
Druckluftaustritt
für Turbolader-
Trockenreinigung 1
compressed air
outlet for
turbocharger dry
cleaning 1
Druckluftaustritt für
Turbolader-
Trockenreinigung 2
compressed air
outlet for turbocharger
dry cleaning 2
JetAssist
optional
11432004447F

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Figure 144: Internal compressed air system L engine – Exemplary

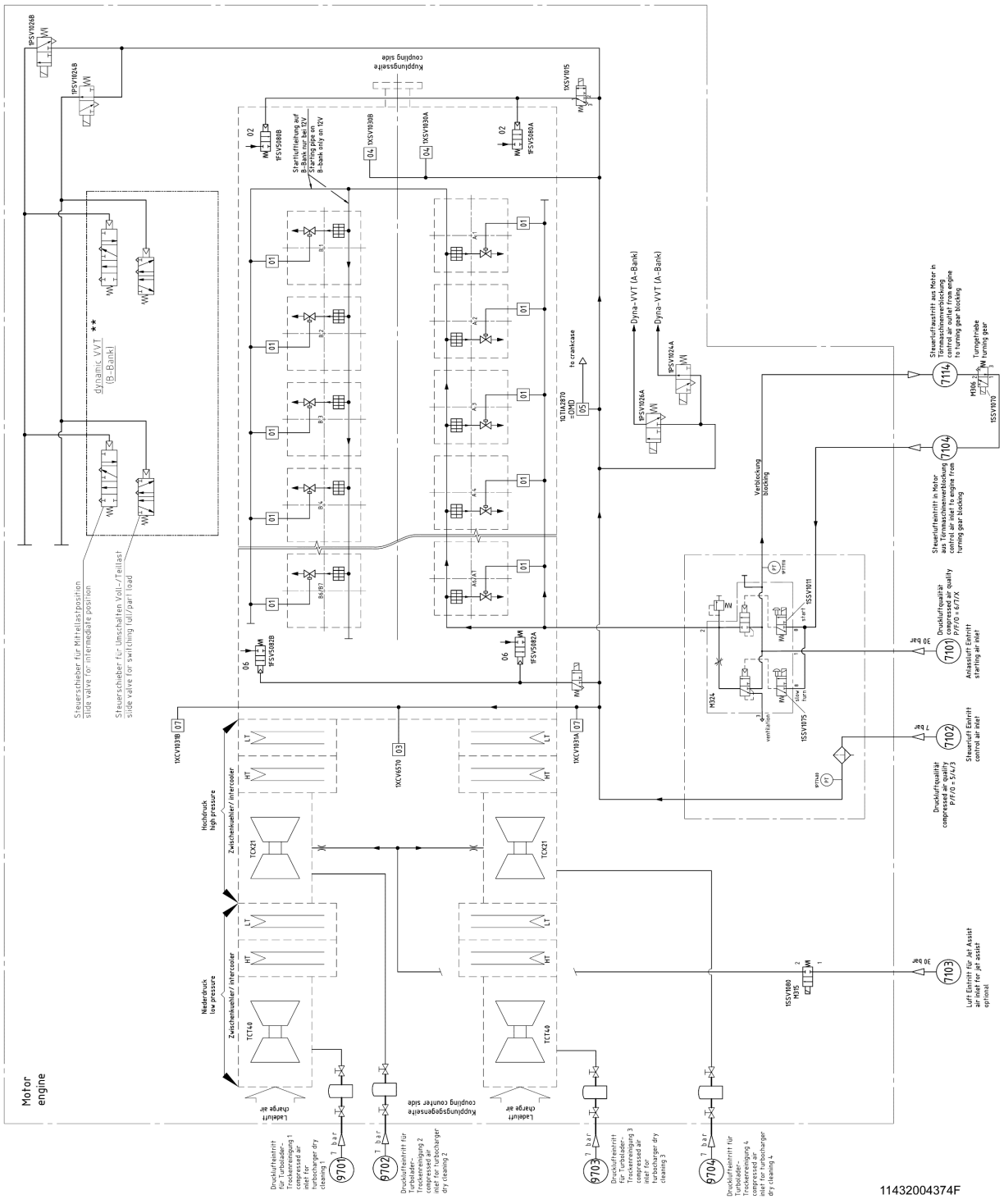


Figure 145: Internal compressed air system V engine – Exemplary

5.9.2 External 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 (engine connection 7101), connected to both air receivers, leads to the main starting valve (MSV-001) of the engine.

A second pressure line for control air (engine connection 7102) is realised by a redundant compressed air reducing unit (1,2 MOD-088) and a air dryer (TR-003) to provide a sufficient air quality.

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.

A third 30 bar pipe is required for engines with jet assist (engine connection 7103). Depending on the air receiver arrangement, this pipe can be branched off from the starting air pipe near engine or must be connected separately to the air receiver for jet assist.

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 refer to planning and final documentation and manufacturer manual.

Galvanised steel pipes must not be used for the piping of the system.

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.

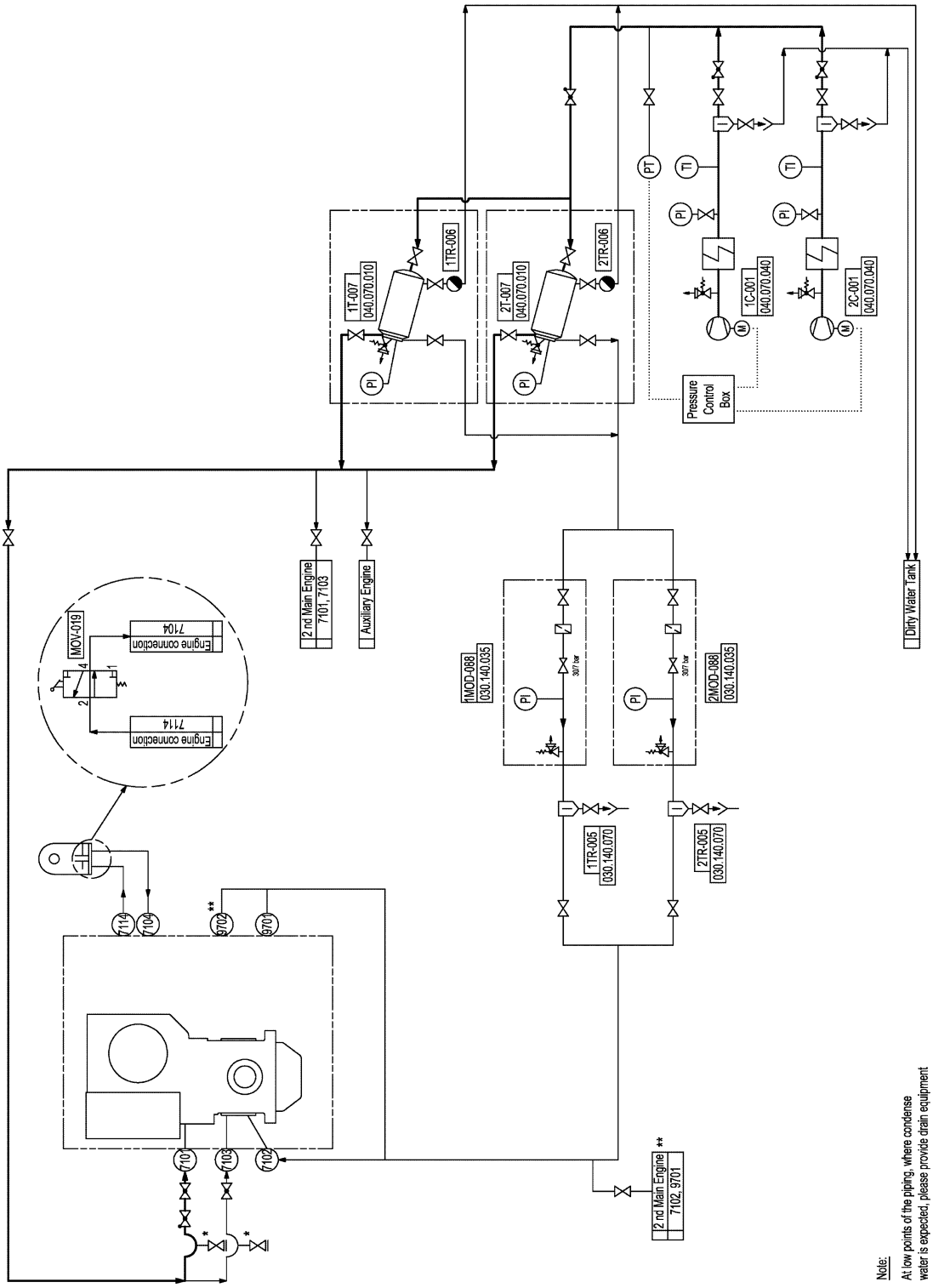
A max. service pressure of 30 bar is required. The standard design pressure of the starting air receivers is 30 bar and the design temperature is 50 °C.

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.

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Note:

* At low points of the piping, where condense water is expected, please provide drain equipment

** If applicable

Simplified diagram, not all components and details are shown.

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	Components
1,2 C-001	Air compressor
M-019	Valve for engine interlocking device
1,2 T-007	Starting air receiver

	Connection numbers
7101	Air inlet on main starting valve
7102	Control air inlet
7103	Air inlet for jet assist
7104	Control air outlet from engine to turning gear blocking
1,2 TR-005	Water trap, compressed air system
1,2 TR-006	Automatic condensate trap
1,2 MOD-088	Compressed air reducing unit
7114	Control air inlet from turning gear blocking to engine
9701	Compressed air for turbocharger dry cleaning
** 9702	Compressed air for turbocharger dry cleaning

Figure 146: Starting air system diagram

5.9.3 External compressed air system – Dimensioning starting air receivers, compressors

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 engine requires compressed air for starting, if the standard pneumatic starter is supplied. The design of the pressure air receiver directly depends on the air consumption and the requirements of the classification societies.

For dimensioning the air receivers according to the classification rules, the air consumption of the liquid fuel mode start is used as standard. The air receivers will get larger, if the increased air consumption of the gas start is demanded (e.g. by classification society).

In case of mechanical-propulsion drive without shifting clutch but with shaft driven alternator, consult Everllence.

For more information concerning jet assist see section External compressed air system – Jet assist, Page 399.

For air consumption see section Starting air and control air consumption, Page 96.

The air consumption per starting manoeuver and per Slow Turn activation depends on the inertia moment of the unit.

Within the table Starting air and control air consumption, Page 96 two different values for starting air and slow turn air consumption are stated, one at minimum and one at high moment of inertia. Accordingly the valid starting air consumption V_{Start} and $V_{Slow\ Turn}$ for the unit need to be interpolated between the two figures stated in the table based on the relevant total moment of inertia J_{Total} for the unit.

Hereby relevant is the moment of inertia, that needs to be accelerated by the engine's starting air system and can not be separated from the engine by a clutch during starting-up.

First the moment of inertia of the plant J_{Total} needs to be calculated:

$J_{Total} = J_1 + J_2 + J_{Plant\ attached\ to\ flywheel}$

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For moment of inertia Θ_1 and Θ_2 of the engine see section Moments of inertia – Crankshaft, damper, flywheel, Page 163.

Calculation for starting air receiver of engines without jet assist and Slow Turn:

$$V = \frac{\left(V_{Start} * \left(Z_{St} + Z_{Safe}\right)\right) * p_{amb}}{\left(p_{max} - p_{min}\right)}$$

Calculation for starting air receiver of engines with jet assist and Slow Turn:

$$V = \frac{\left(V_{Start} * \left(Z_{St} + Z_{Safe}\right) + \frac{V_{Jet}}{5\,sec} * Z_{Jet} * t_{Jet} + V_{Slowturn} * Z_{SL}\right) * p_{amb}}{\left(p_{max} - p_{min}\right)}$$

V [litre]	Required receiver capacity
V_{Start}[litre]	Interpolated air consumption per start and valid for the unit, to be recalculated from Nm^3 to litre
J_1	Moment of inertia of crankshaft and damper of the engine[2)]
J_2	Moment of inertia of flywheel of the engine[2)]
$J_{Plant\ attached\ to\ the\ flywheel}$	Plant specific moment of inertia attached to the flywheel, that needs to be accelerated by the engine's starting air system and can not be separated from the engine by a clutch during starting-up
J_{Total}	Total moment of inertia of engine and plant, that needs to be accelerated by the engine's starting air system
z_{st}	Number of starts required by the classification society
z_{Safe}	Number of starts as safety margin
V_{Jet} [litre]	Assist air consumption per jet assist[1)], to be recalculated from Nm^3 to litre
z_{Jet}	Number of jet assist procedures[3)]
t_{Jet} [sec]	Duration of jet assist procedures
$V_{Slow\ Turn}$	Interpolated air consumption per slow turn and valid for the unit, to be recalculated from Nm^3 to litre
z_{sl}	Number of Slow Turn manoeuvres
p_{amb}	Ambient pressure
p_{max} [bar]	Maximum starting air pressure (normally 30 bar)
p_{min} [bar]	Minimum starting air pressure (15 bar)

[1)] Tabulated values see section Starting air and control air consumption, Page 96.

[2)] Tabulated values see section Moments of inertia – Crankshaft, damper, flywheel, Page 163.

[3)] The required number of jet manoeuvres has to be checked with yard or ship owner. To make a decision, consider the information in section External compressed air system – Jet assist, Page 399.

If other consumers (i.e. auxiliary engines, ship air etc.) which are not listed in the formula are connected to the starting air receiver, the capacity of starting air receiver must be increased accordingly, or an additional separate air receiver has to be installed.

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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 30 bar within one hour.

The compressor capacities are calculated as follows:

$$P = \frac{V \times 30}{1000}$$

P [Nm^3/h]	Total volumetric delivery capacity of the compressors
V [litres]	Total volume of the starting air receivers at 30 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.

5.9.4 External compressed air system – Jet assist

General

Air consumption

The air consumption for jet assist is, to a great extent, dependent on the load profile of the ship. In case of frequently and quickly changing load steps, jet assist will be actuated more often than this will be the case during long routes at largely constant load.

Layout of starting air vessels and compressor – Guiding values for consideration of jet assist manoeuvres

For the layout of starting air vessels and compressor add to the air consumption of the considered starts and slow turns also the air consumption of these jet assist manoeuvres.

The data in following table is not binding. The required number of jet manoeuvres has to be checked with yard or ship owner. For decision see also section Start-up and load application, Page 50.

The values shown in the following table are based on diesel oil mode.

Application	Recommended no. of jet assist with average duration	
	Per hour	In rapid succession
General drive	None[1)]	None[1)]
Diesel-mechanical drive without shifting clutch	None[1)]	None[1)]
Diesel-mechanical drive with shifting clutch	3 x 5 sec	2 x 5 sec
Diesel-mechanical drive with shaft-driven alternator (> 50 % MCR)	5 x 5 sec	3 x 5 sec
Electric propulsion	10 x 5 sec	5 x 5 sec

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Application	Recommended no. of jet assist with average duration	
	Per hour	In rapid succession
Electric propulsion offshore applications – Semisub production/drilling applications and drillships[2)]	(20 x 5 sec)	(10 x 5 sec)
Ships with frequent load changes (e.g. ferries)	10 x 5 sec	5 x 5 sec

[1)] According the necessity of the application "jet assist" check figures Load application dependent on base load (engine condition hot), Page 55. If the curve "without jet assist" is sufficient, jet assist can be omitted.

[2)] For these applications contact Everllence for a project specific estimation.

Table 153: Guiding values for the number of jet assist manoeuvres dependent on application

Dynamic positioning for drilling vessels, cable-laying vessels, off-shore applications

When applying dynamic positioning, pulsating load application of > 25 % may occur frequently, up to 30 times per hour. In these cases, the possibility of a specially adapted, separate compressed air system has always to be checked.

Air supply

Generally, larger air receivers are to be provided for the air supply of the jet assist.

For the design of the jet assist air supply the temporal distribution of events needs to be considered, if there might be an accumulation of events.

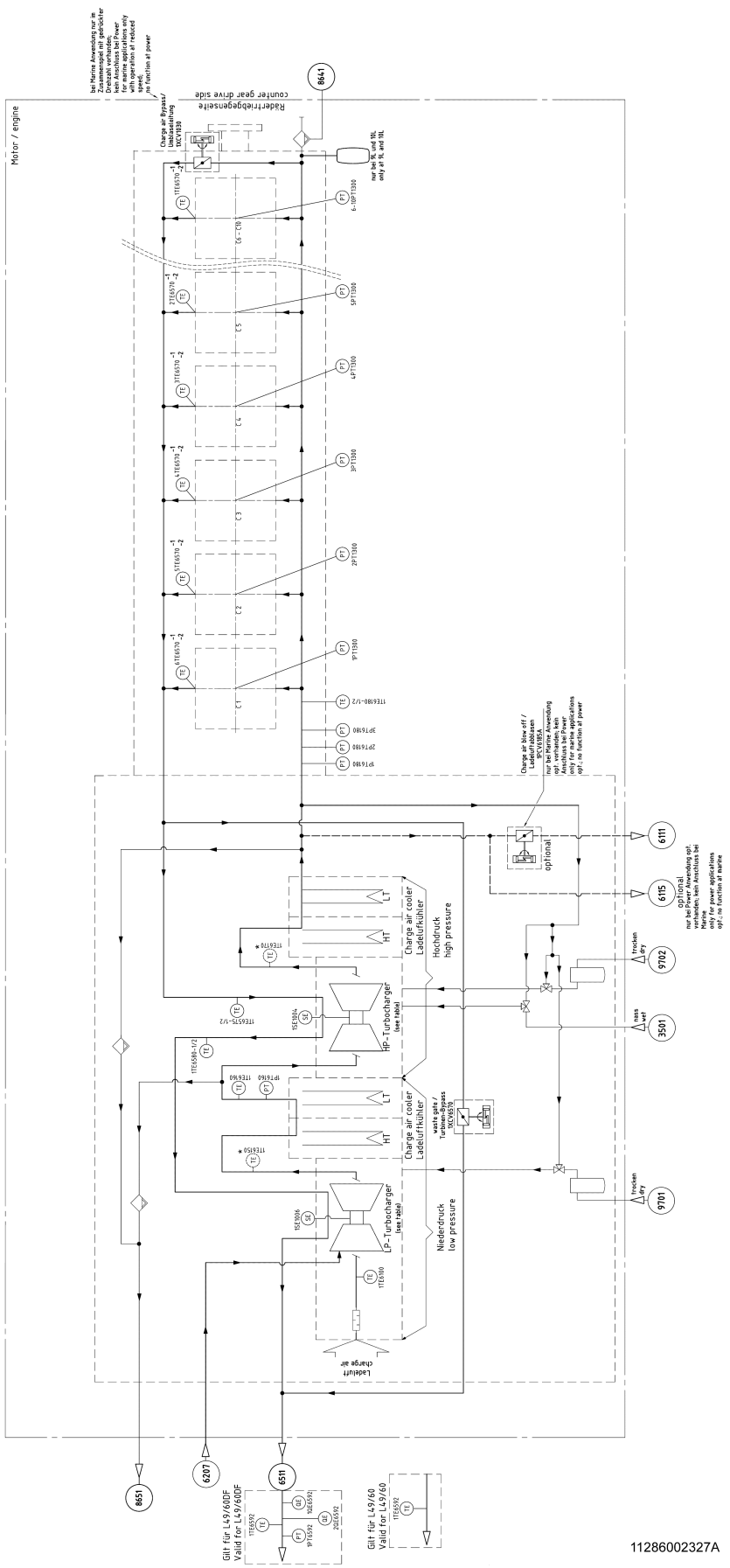
In each case the delivery capacity of the compressors is to be adapted to the expected jet assist requirement per unit of time.

5.10 Engine room ventilation and intake air

5.10.1 Internal engine intake air

See overleaf

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Motor / engine
Radtriebgegenseite
counter gear drive side
8641
Charge air Bypass/
Ladeluftumführung
LVCV1830
nur bei 9L und 10L
only at 9L and 10L
Charge air shut off /
Ladeluftabsperrklappe
LVCV1840
optional
6111
6115
optional
trocken
dry
9702
nass
wet
3501
9701
HP-Turbocharger
(see table)
LP-Turbocharger
(see table)
Charge air cooler
Ladeluftkühler
LT
HT
Hochdruck
high pressure
Niederdruck
low pressure
Ladeluft
charge air
waste gate /
turbine by-pass
LVCV6570
8651
6207
6511
Gilt für L49/60DF
Valid for L49/60DF
Gilt für L49/60
Valid for L49/60
11286002327A

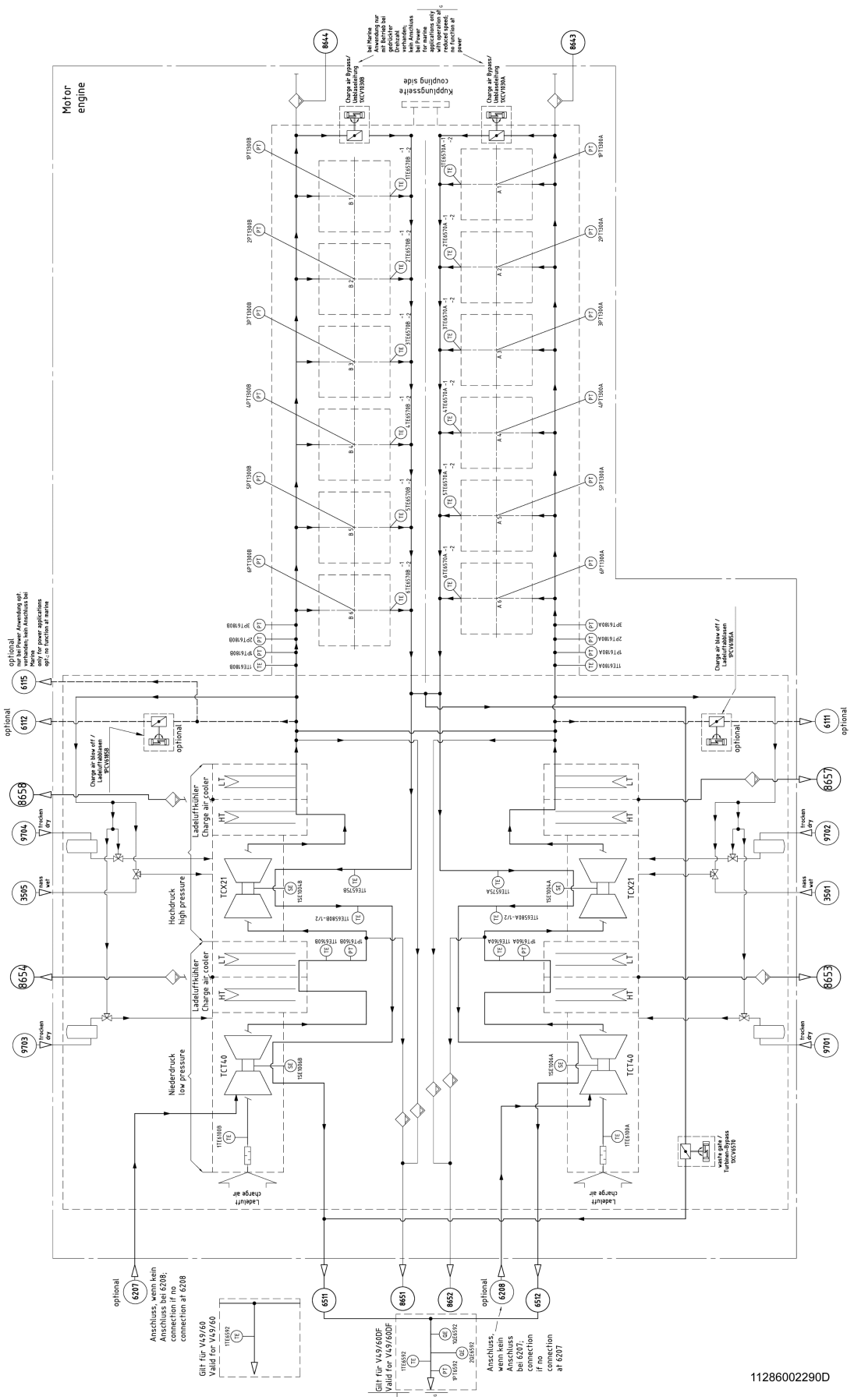
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Connection numbers

3501 Washing water inlet for turbine 1
6111 Charge air outlet from blow-off piping 1
6115 Charge air outlet for urea atomisation air after CAC HP (opt.)
6207 Closed crankcase ventilation inlet to compressor 1
6511 Exhaust gas outlet from turbocharger
8641 Condensate water drain from charge air manifold, gear drive counter side
8651 Condensate water drain from charge air cooler
9701 Compressed air inlet for turbocharger dry cleaning 1
9702 Compressed air inlet for turbocharger dry cleaning 2

Figure 147: Charge air and exhaust gas diagram L engine

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Motor
engine
Kupplungsseite
coupling side
Charge air Bypass/
Ladeluftabblasen
YCV1938B
YCV1938A
8644
8643
6115
6112
6111
8658
8657
9704
9702
3505
3501
8654
8653
9703
9701
6207
6511
8651
8652
6208
6512
TCX21
TCT40
Hochdruck
high pressure
Niederdruck
low pressure
Ladeluft
Charge air
Ladeluft Charge air cooler
Charge air blow off /
Ladeluftablassen
PCV1885A
Gilt für V49/60
Valid for V49/60
Gilt für V49/60DF
Valid for V49/60DF
Anschluss, wenn kein
Anschluss bei 6208;
connection if no
connection at 6208
Anschluss,
wenn kein
Anschluss
bei 6207;
connection
if no
connection
at 6207
11286002290D

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Connection numbers

3501 Washing water inlet for turbine 1
3505 Washing water inlet for turbine 3
6111 Charge air outlet from blow-off piping 1 (optional)
6112 Charge air outlet from blow-off piping 2 (optional)
6115 Charge air outlet for urea atomisation air after CAC HP (opt.)
6207 Closed crankcase ventilation inlet to compressor 1 (optional)
6208 Closed crankcase ventilation inlet to compressor 2 (optional)
6511 Exhaust gas outlet from turbocharger 1
6512 Exhaust gas outlet from turbocharger 2
8643 Condensate water drain from charge air manifold, coupling side 1
8644 Condensate water drain from charge air manifold, coupling side 2
8651 Condensate water drain from charge air cooler 1
8652 Condensate water drain from charge air cooler 2
8653 Condensate water drain from charge air cooler 3
8654 Condensate water drain from charge air cooler 4
8657 Condensate water drain from charge air cooler 5
8658 Condensate water drain from charge air cooler 6
9701 Compressed air inlet for turbocharger dry cleaning 1
9702 Compressed air inlet for turbocharger dry cleaning 2
9703 Compressed air inlet for turbocharger dry cleaning 3
9704 Compressed air inlet for turbocharger dry cleaning 4

Figure 148: Charge air and exhaust gas diagram V engine

5.10.2 External 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.

Intake air engine

The intake air of the engine 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.
- 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.

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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 416). 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 406.

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 [m^3/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/m^3]	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 residual fuel 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.

Maximum engine room temperature

The engine room ventilation must ensure a maximum engine room temperature, with following boundary conditions:

- Maximum air temperature in the area of the engine and its components ≤ 45°C.
- Maximum air temperature at least 5 K below the flash point of any liquids, that is present within the engine room.

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5.10.3 External air supply with or without arctic conditions

General recommendations for external intake air system of vessels

The design of the intake air system ducting is crucial for reliable operation of the engine. The following points need to be considered:

(1) Every single engine must be provided with a dedicated intake air system. It is not allowed to combine air intake systems of different engines.

(2) According to classification rules, it may be required for arctic operation to install two air inlets from the exterior, one at starboard and one at portside.

(3) It must be prevented that exhaust gas and oil dust is sucked into the intake air duct as fast filter blocking might occur.

(4) In case of arctic operation, suitable corrosion and low temperature resistant materials should be applied. Stainless steel S316 L might be suitable. For non-arctic operation, a steel duct with C5-M-coating acc. DIN EN ISO 12944 might be sufficient.

(5) 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.).

(6) 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.

(7) Thermal expansion has to be considered for the layout and foundation of the duct (e.g. flexible mounting, additional compensators).

(8) 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.

(9) 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.

(10) 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.

(11) 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 fulfill 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 approximately 1–2 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".

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(12) The turbocharger as a flow machine requires a uniform inflow. Therefore, the ducting must enable an air flow without disturbances or constrictions. To prevent non-uniform compressor inlet flow conditions, the duct design should consider the following:

- Avoid or minimise the number of elbows.
- Avoid multiple/repetitive deflections with a flow turn angle > 45°.
- Avoid combinations of flow turns in multiple planes.
- For engines with two turbochargers it must be ensured, that both turbochargers have identical conditions for the air supply, otherwise this would result in decreasing the surge stability.

(13) To prevent stalling, any intake air flow that exhibits a swirl counterrotating against the compressor wheel rotation must be avoided.

(14) 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.

(15) The maximum specified air flow speed of 20-25 m/s should not be exceeded at any location of the pipe.

(16) 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, Page 409. It needs to be cleaned according to the requirements in section Specification of intake air (combustion air), Page 274. 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). A metal grid (e.g. 10x10 mm) after filter wall at intake air room is necessary to avoid filter elements or lost parts getting into air intake system. 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

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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, Page 409.

- 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 150.

- Overpressure flap (6) (optional)

  Depending on the system volume and chosen components, it might be necessary to install an 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 starting with a 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 directly vertically upstream of the 90° transition piece behind the 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)

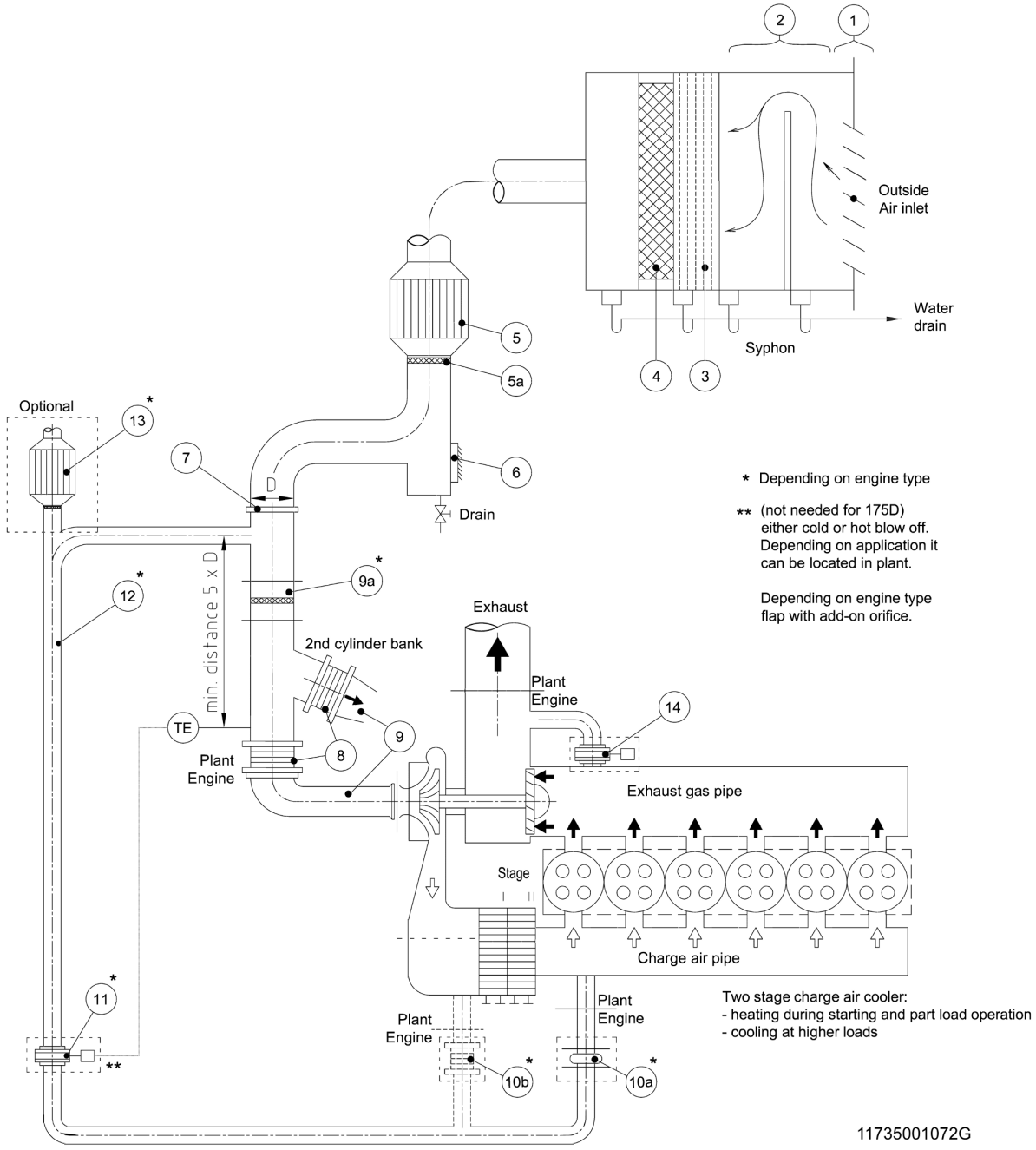
  To prevent residues from installation phase entering the engine during commissioning, a strainer or protective mesh must be installed as close as possible to the turbocharger. After the running-in is finished, the strainer must be removed and exchanged by an intermediate pipe. Final performance measurement and engine setting shall be done without an intake air strainer.

- Charge air blow-off or recirculation

  For arctic conditions, 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.

Within section Engine operation under arctic conditions, Page 64 additional information is given and boundary conditions for the layout of the piping are stated.

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2
1
Outside
Air inlet
Water
drain
Syphon
4
3
5
5a
6
Drain
Optional
*
13
7
D
12
*
9a
*
min. distance 5 x D
2nd cylinder bank
Exhaust
Plant
Engine
14
TE
9
8
Plant
Engine
Exhaust gas pipe
Stage
Charge air pipe
11
*
**
Plant
Engine
Plant
Engine
10b
*
10a
*
* Depending on engine type
** (not needed for 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.
Two stage charge air cooler:
- heating during starting and part load operation
- cooling at higher loads
11735001072G

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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 Intermediate pipe with strainer for running-in phase (to be removed afterwards) 030.120.190
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)

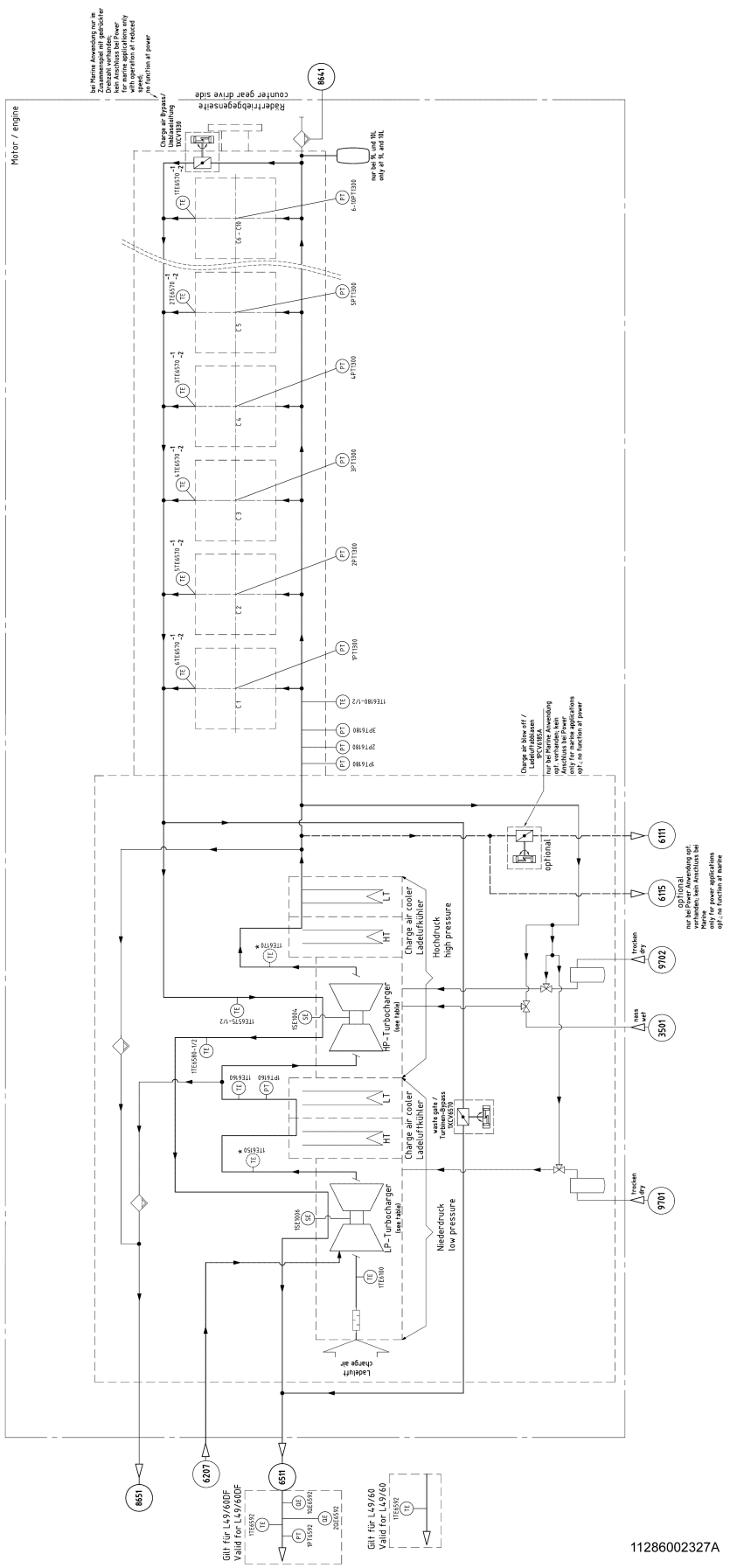
Figure 149: External intake air supply system

5.11 Exhaust gas system

5.11.1 Internal engine exhaust gas system

See overleaf

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Motor / engine
Radertriebgegenseite
counter gear drive side
8641
Charge air Bypass/
Ladeluftumführung
bei Marine Anwendung nur in Zusammenhang mit geschlossener Drehzahl verbunden
kein Anschluss bei Power Generation Anwendungen
for marine applications only with operation at reduced speed
no function at power
nur bei 9L und 10L
only at 9L and 10L
Charge air shut off /
Ladeluftabsperrklappe
nur bei Marine Anwendung
opt. vorhanden, kein Anschluss bei Power Generation
only for marine applications
opt., no function at power
optional
6111
6115
optional
nur bei Power Generation Anwendungen opt. vorhanden, kein Anschluss bei Marine
only for power applications
opt., no function at marine
Charge air cooler
Ladeluftkühler
HT
LT
Hochdruck
high pressure
HP-Turbocharger
(see table)
Niederdruck
low pressure
LP-Turbocharger
(see table)
waste gate /
turbine shut off
trocken
dry
nass
wet
9702
3501
9701
Ladeluft
charge air
8651
6207
6511
Gilt für L49/60DF
Valid for L49/60DF
Gilt für L49/60
Valid for L49/60
11286002327A

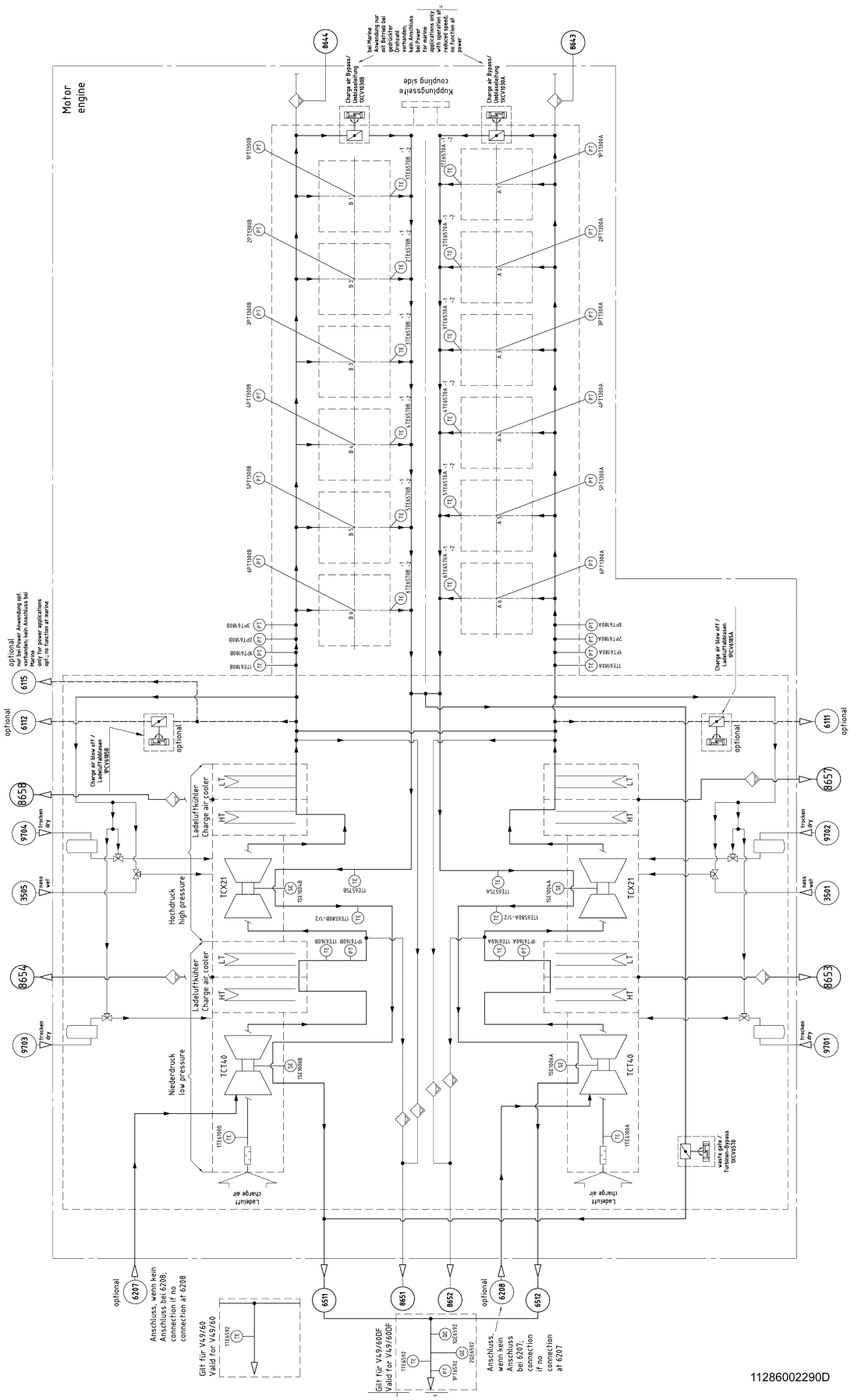
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Connection numbers

3501 Washing water inlet for turbine 1
6111 Charge air outlet from blow-off piping 1
6115 Charge air outlet for urea atomisation air after CAC HP (opt.)
6207 Closed crankcase ventilation inlet to compressor 1
6511 Exhaust gas outlet from turbocharger
8641 Condensate water drain from charge air manifold, gear drive counter side
8651 Condensate water drain from charge air cooler
9701 Compressed air inlet for turbocharger dry cleaning 1
9702 Compressed air inlet for turbocharger dry cleaning 2

Figure 150: Charge air and exhaust gas diagram L engine

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Motor
engine
Kupplungsseite
coupling side
Charge air Bypass/
Ladeluftabblasen
Ladeluft
charge air
Ladeluft-Kühler
Charge air cooler
Hochdruck
high pressure
Niederdruck
low pressure
TCX21
TCT40
trocken
dry
nass
wet
optional
Gilt für V49/60
Valid for V49/60
Gilt für V49/60DF
Valid for V49/60DF
Anschluss, wenn kein Anschluss bei 6207; connection if no connection at 6207
Anschluss, wenn kein Anschluss bei 6207; connection if no connection at 6207
11286002290D

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Connection numbers

3501 Washing water inlet for turbine 1
3505 Washing water inlet for turbine 3
6111 Charge air outlet from blow-off piping 1 (optional)
6112 Charge air outlet from blow-off piping 2 (optional)
6115 Charge air outlet for urea atomisation air after CAC HP (opt.)
6207 Closed crankcase ventilation inlet to compressor 1 (optional)
6208 Closed crankcase ventilation inlet to compressor 2 (optional)
6511 Exhaust gas outlet from turbocharger 1
6512 Exhaust gas outlet from turbocharger 2
8643 Condensate water drain from charge air manifold, coupling side 1
8644 Condensate water drain from charge air manifold, coupling side 2
8651 Condensate water drain from charge air cooler 1
8652 Condensate water drain from charge air cooler 2
8653 Condensate water drain from charge air cooler 3
8654 Condensate water drain from charge air cooler 4
8657 Condensate water drain from charge air cooler 5
8658 Condensate water drain from charge air cooler 6
9701 Compressed air inlet for turbocharger dry cleaning 1
9702 Compressed air inlet for turbocharger dry cleaning 2
9703 Compressed air inlet for turbocharger dry cleaning 3
9704 Compressed air inlet for turbocharger dry cleaning 4

Figure 151: Charge air and exhaust gas diagram V engine

5.11.2 External exhaust gas system – General information

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, contact Everllence for project-specific engine data.

Note:
20 mbar resistance for the Everllence SCR-LPC or 37 mbar for the Everllence SCR-LPS as part of the total resistance have to be considered.

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, at stack outlet 35 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.
- 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 418) 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.

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- 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, two measuring sockets need 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.

5.11.3 External 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, silencer, catalyst, boiler to the outlet stack) is to be insulated to reduce the external surface temperature and airborne noise to the required level.

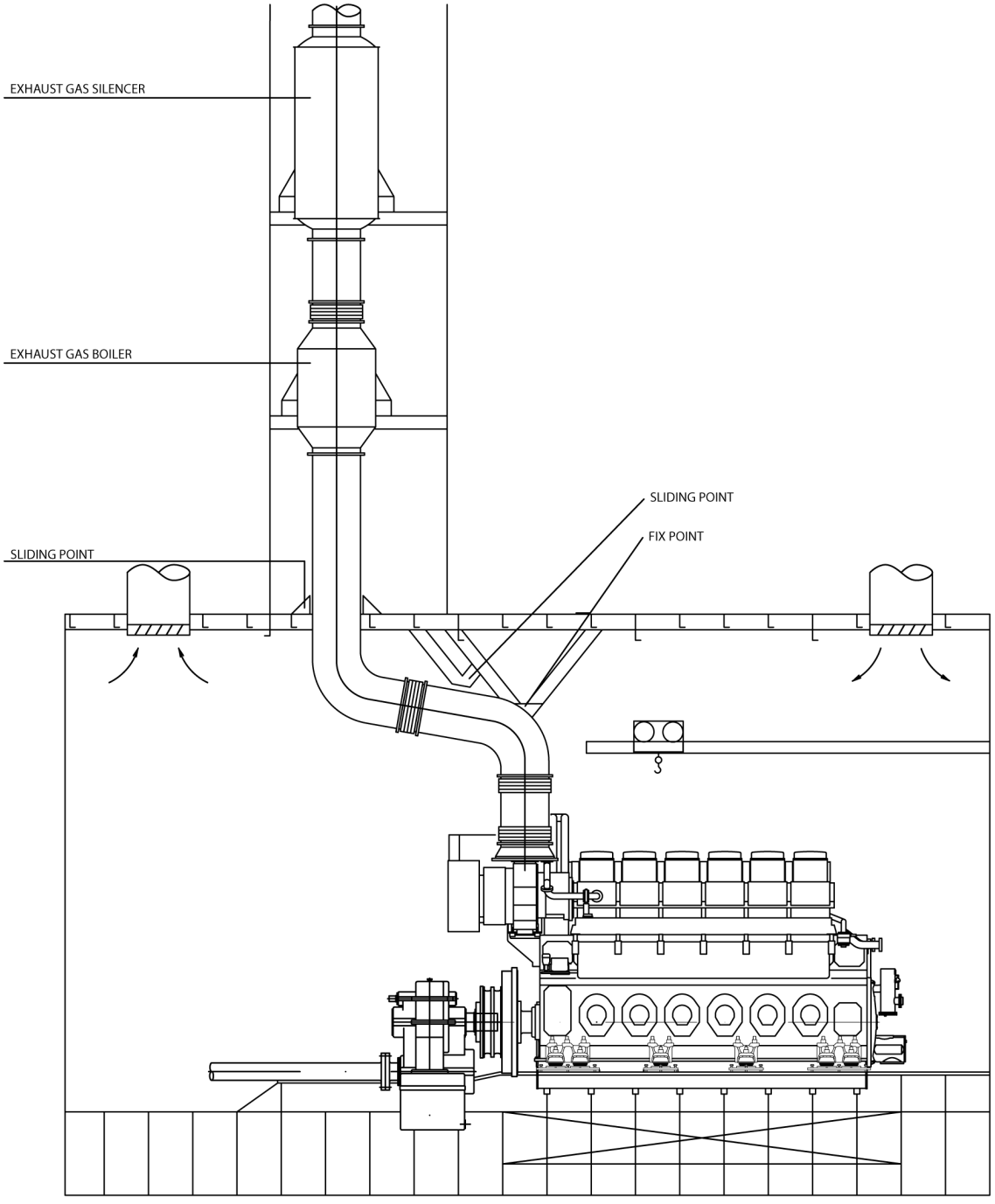
The relevant provisions concerning accident prevention and those of the classification societies must be observed.

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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5.11.4 External example: Ducting arrangement



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Figure 152: Example: Exhaust gas ducting arrangement

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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 Everllence. 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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5.11.5 Position of the outlet casing of the turbocharger

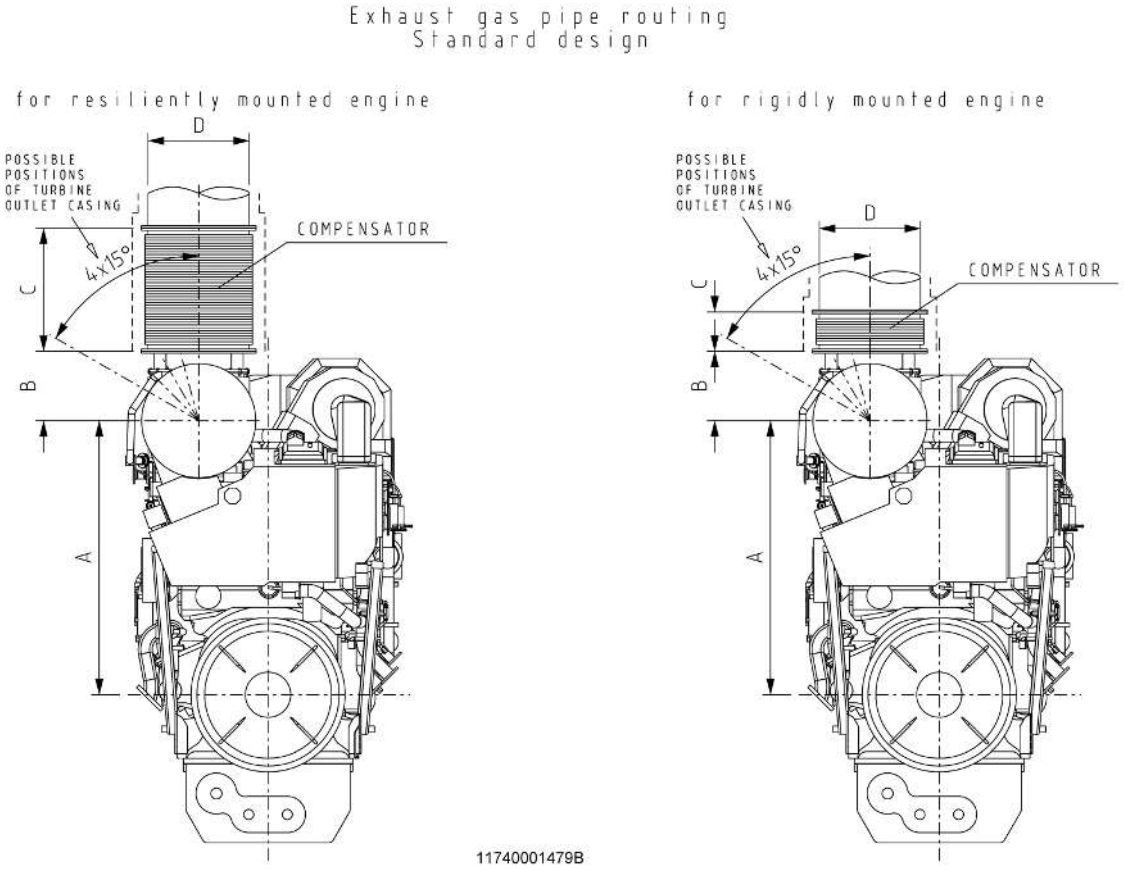


Figure 153: Exhaust gas pipe routing – L engine

No. of cylinders, config.		6L	7L	8L	9L	10L
Turbocharger type		TCT40/TCX21			TCT50/TCX23	
A[1]	mm	3,023			2,990	
B		770			839	
C x[2]		432				
C xx[3]		1,356			1,421	
D		DN 1,100			DN 1,200	

[1] Incl. seals and transition piece.

[2] x = for rigidly mounted engines.

[3] xx = for resiliently mounted engines.

Table 154: Position of exhaust outlet casing L engine – Standard design

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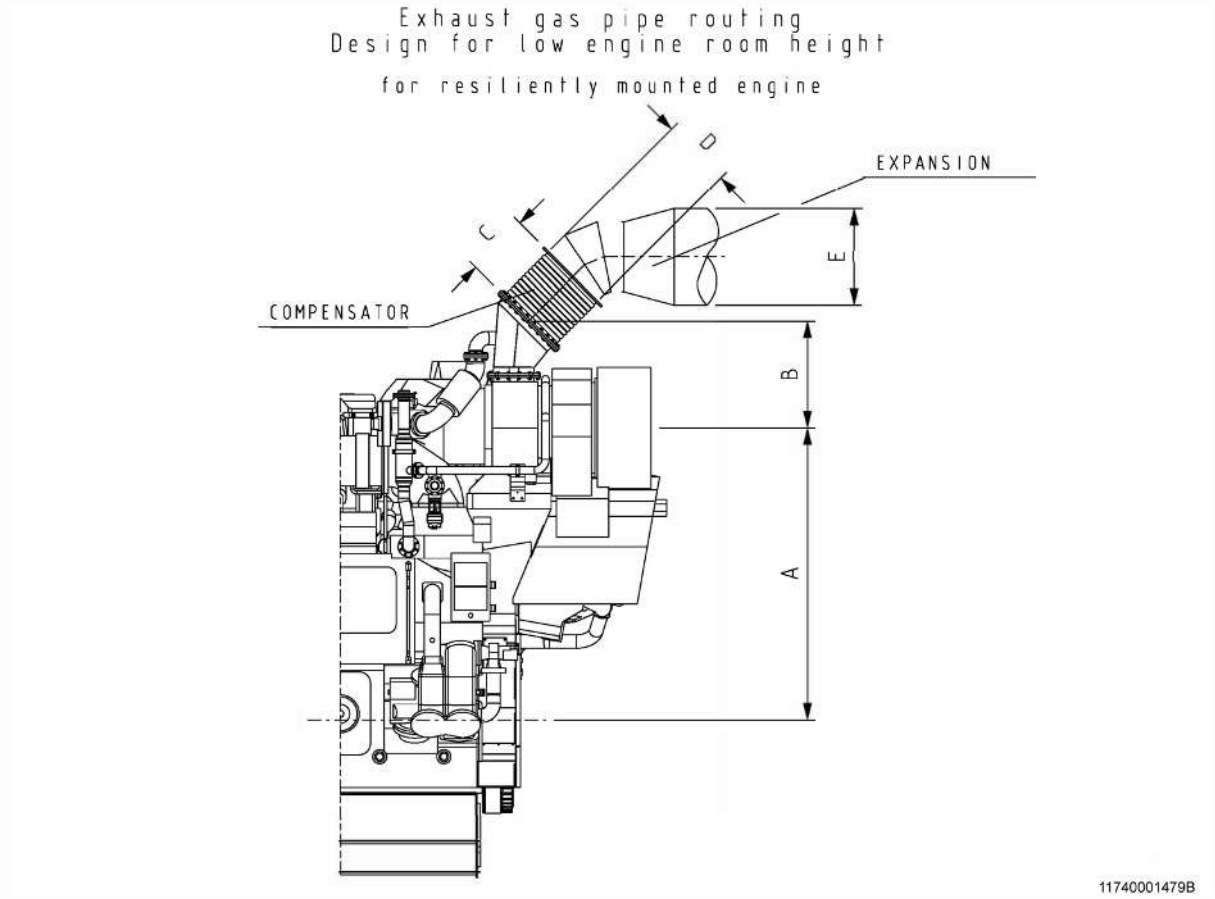


Figure 154: Exhaust gas pipe routing – L engine, design for low engine room height

No. of cylinders, config.		6L	7L	8L	9L	10L
Turbocharger type		**TCT40/TCX21**			**TCT50/TCX23**	
A[1]	mm	3,023			2,990	
B		1,108			1,177	
C x[2]		tbd				
C xx[3]		650			900	
D		DN 700			DN 800	
E		DN 900	DN 1,000	DN 1,100	DN 1,100	DN 1,200

[1] Incl. seals and transition piece.

[2] x = for rigidly mounted engines.

[3] xx = for resiliently mounted engines.

Table 155: Position of exhaust outlet casing L engine – Standard design

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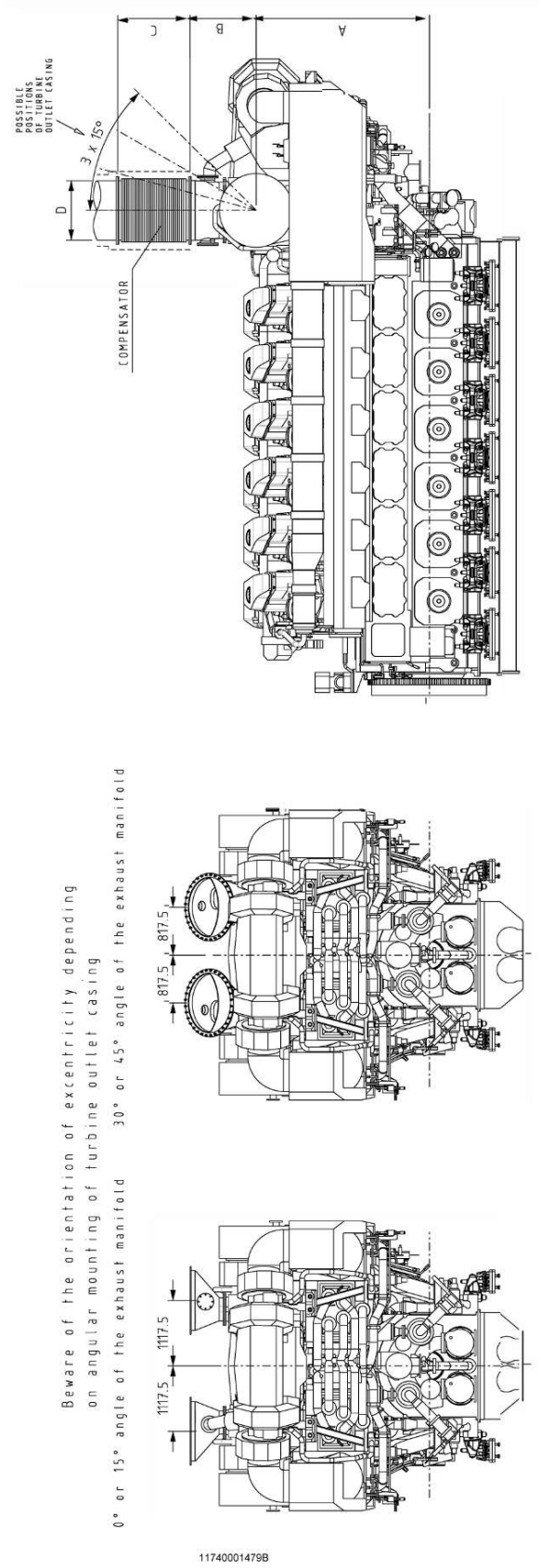


Figure 155: Exhaust gas pipe routing – V engine

No. of cylinders, config.		12V	14V
Turbocharger type		**TCT40/TCX21**	
A[1)]	mm	2,954	
B		1,130	
C		1,357	
D		DN 1,000	
[1)] Incl. seals and transition piece.			

Table 156: Position of exhaust outlet casing V engine – Standard design

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5.12 Maintenance space and requirements

5.12.1 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:
Everllence 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 Everllence.

Any deviations from the principles specified in the aforementioned documents require a previous approval by Everllence.

Arrangements for fixation and/or supporting of plant related equipment deviating from the scope of supply delivered by Everllence, 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.

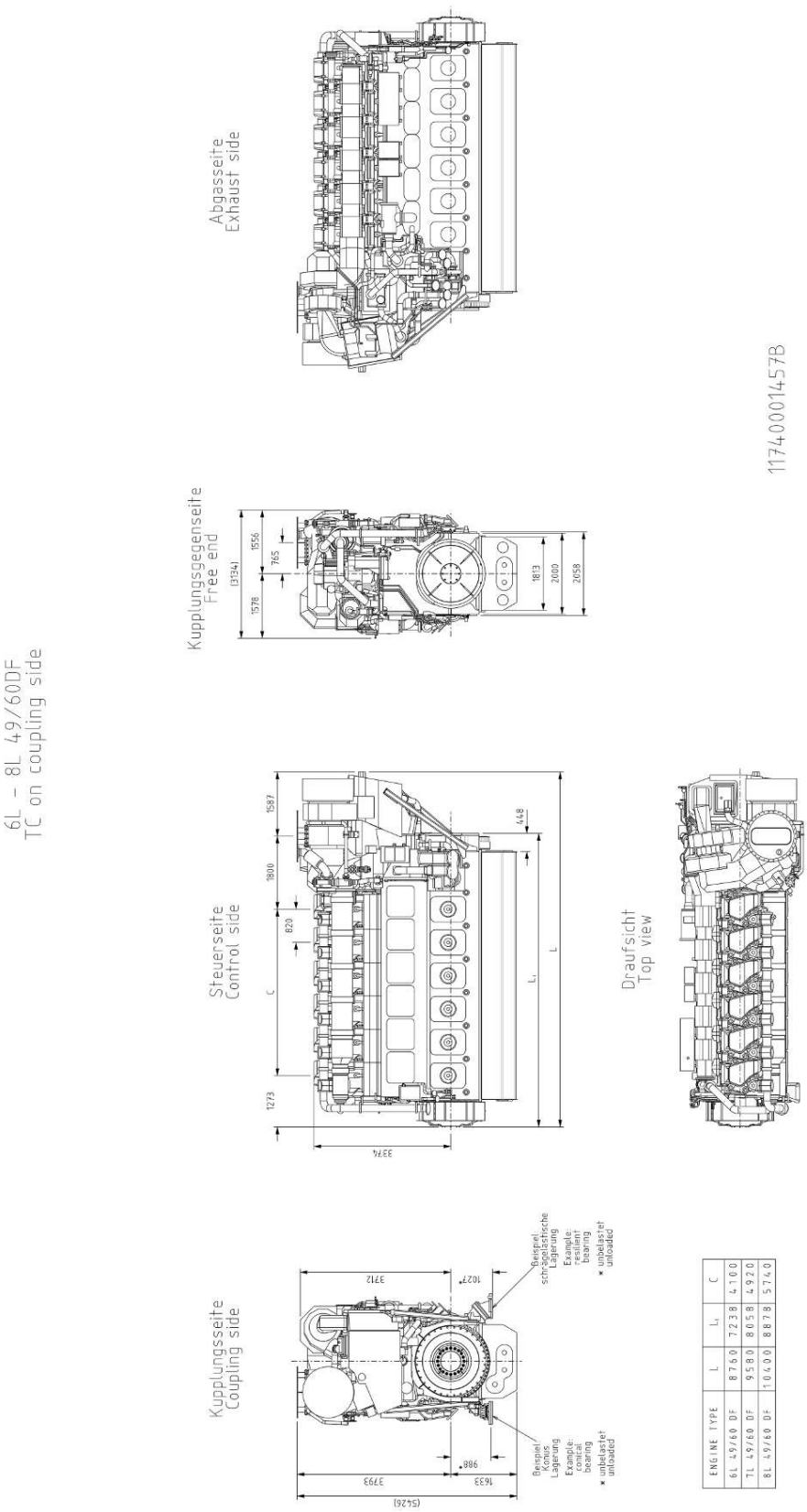
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5.12.2 Installation drawings

Note:
Specific requirements to the passageway e.g. of the classification societies or flag state authority may result in a higher space demand.

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6L, 7L, 8L engine



ENGINE TYPE	L	L_1	C
6L 49/60 DF	8760	7238	4100
7L 49/60 DF	9580	8058	4920
8L 49/60 DF	10400	8878	5740

Figure 156: Installation drawing 6L, 7L, 8L engine – Turbocharger on coupling side

9L, 10L engine

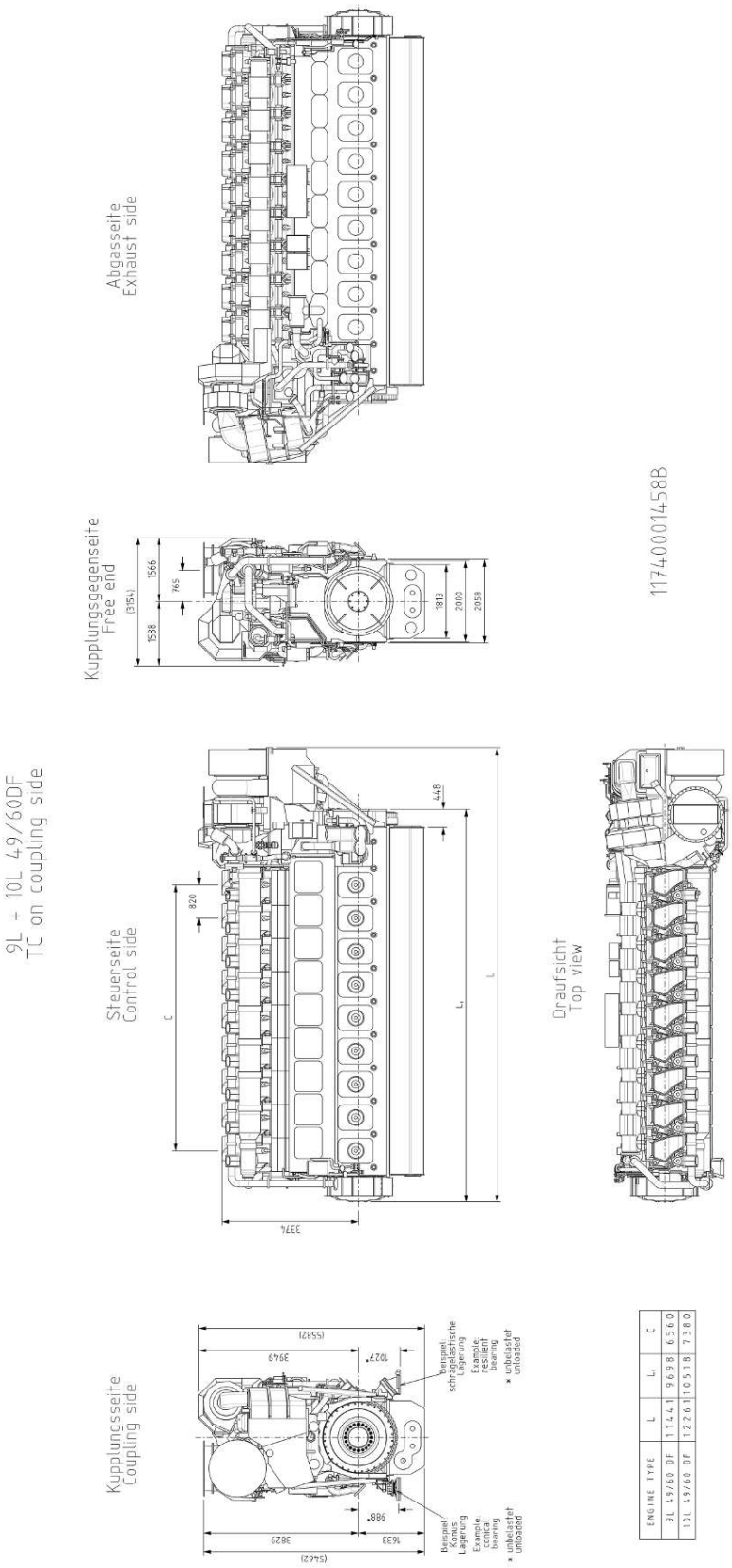


Figure 157: Installation drawing 9L, 10L engine – Turbocharger on coupling side

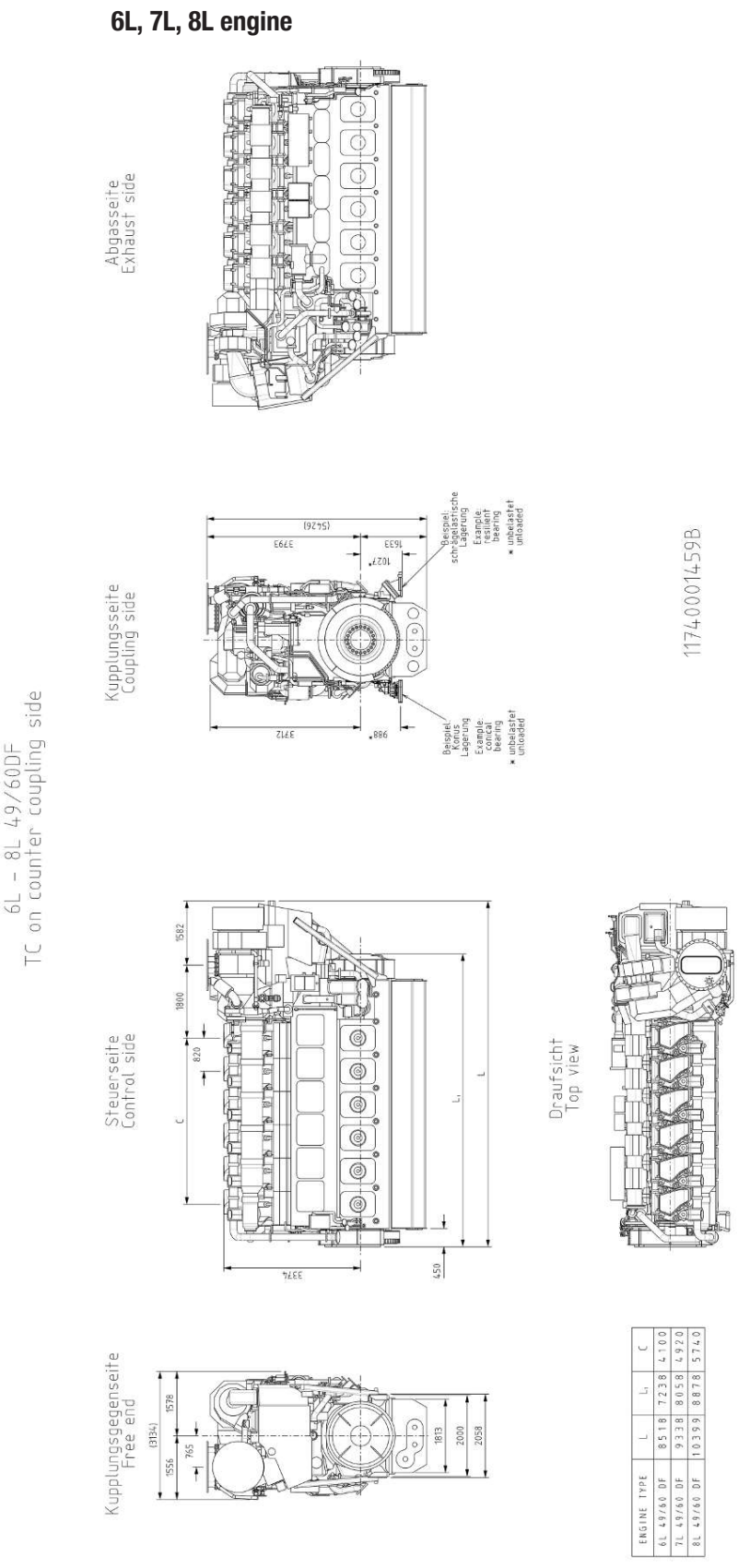


Figure 158: Installation drawing 6L, 7L, 8L engine – Turbocharger on counter coupling side

9L, 10L engine

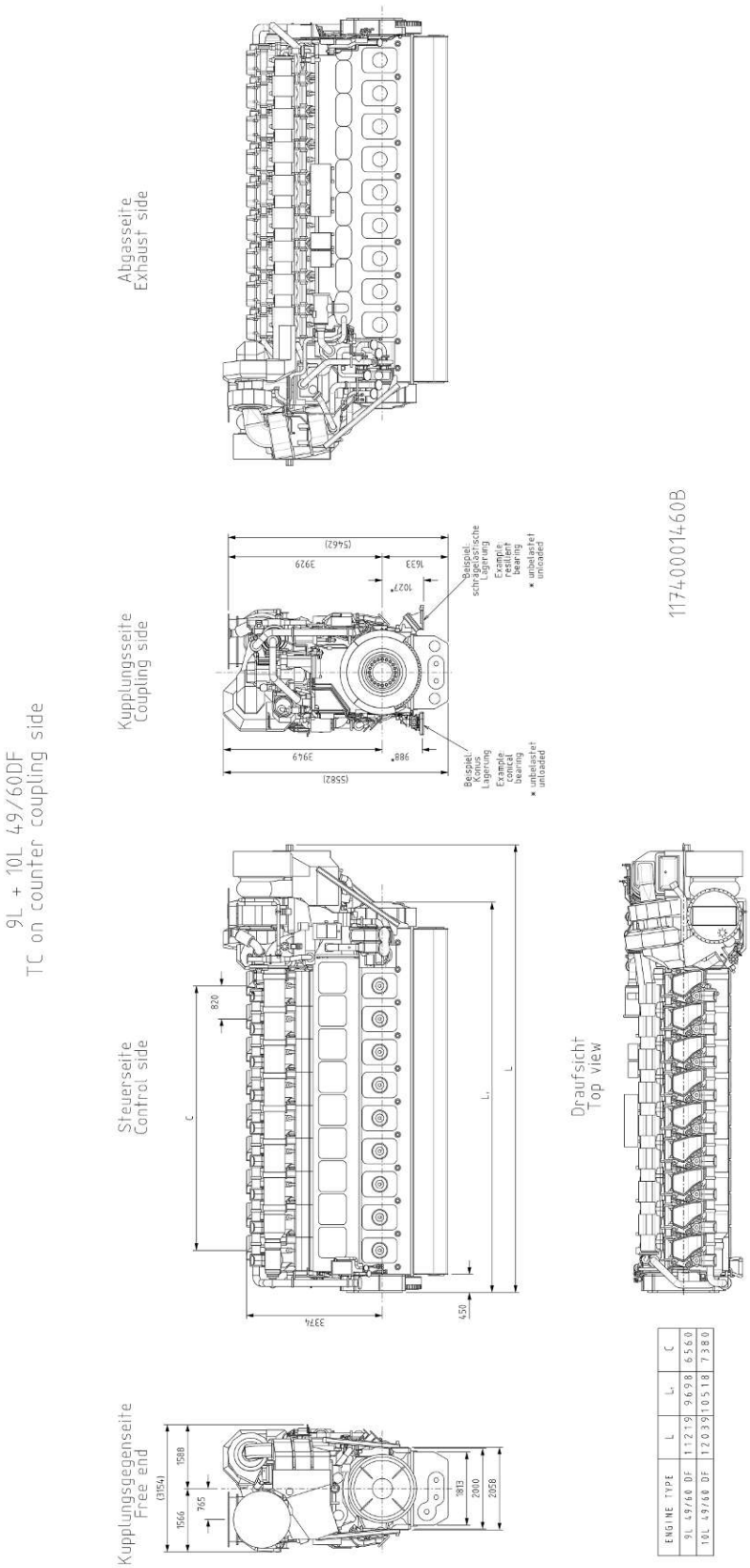


Figure 159: Installation drawing 9L, 10L engine – Turbocharger on counter coupling side

5.12.3 Removal dimensions of piston and cylinder liner

See overleaf

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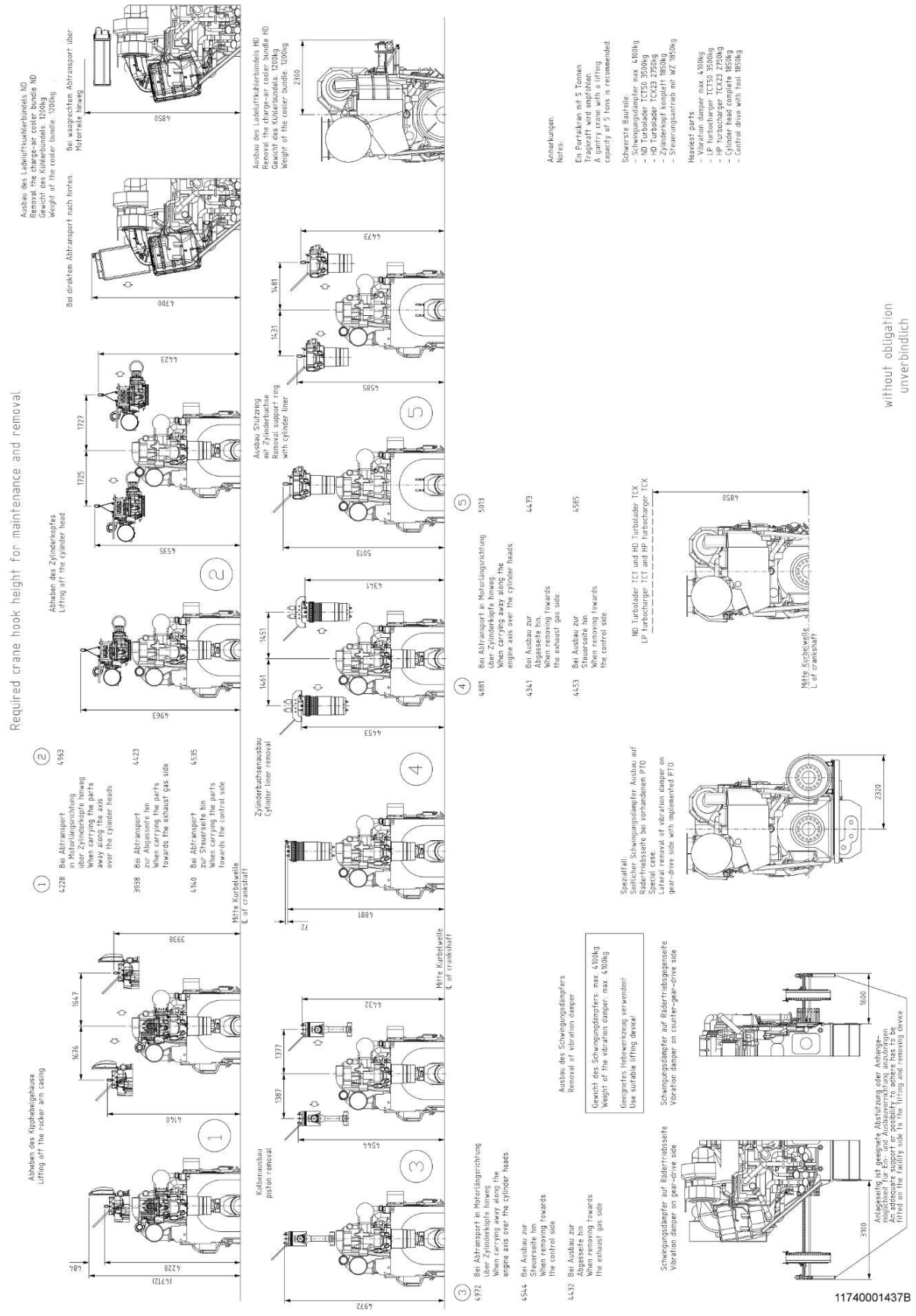


Figure 160: Removal dimensions of piston and cylinder liner – L engine

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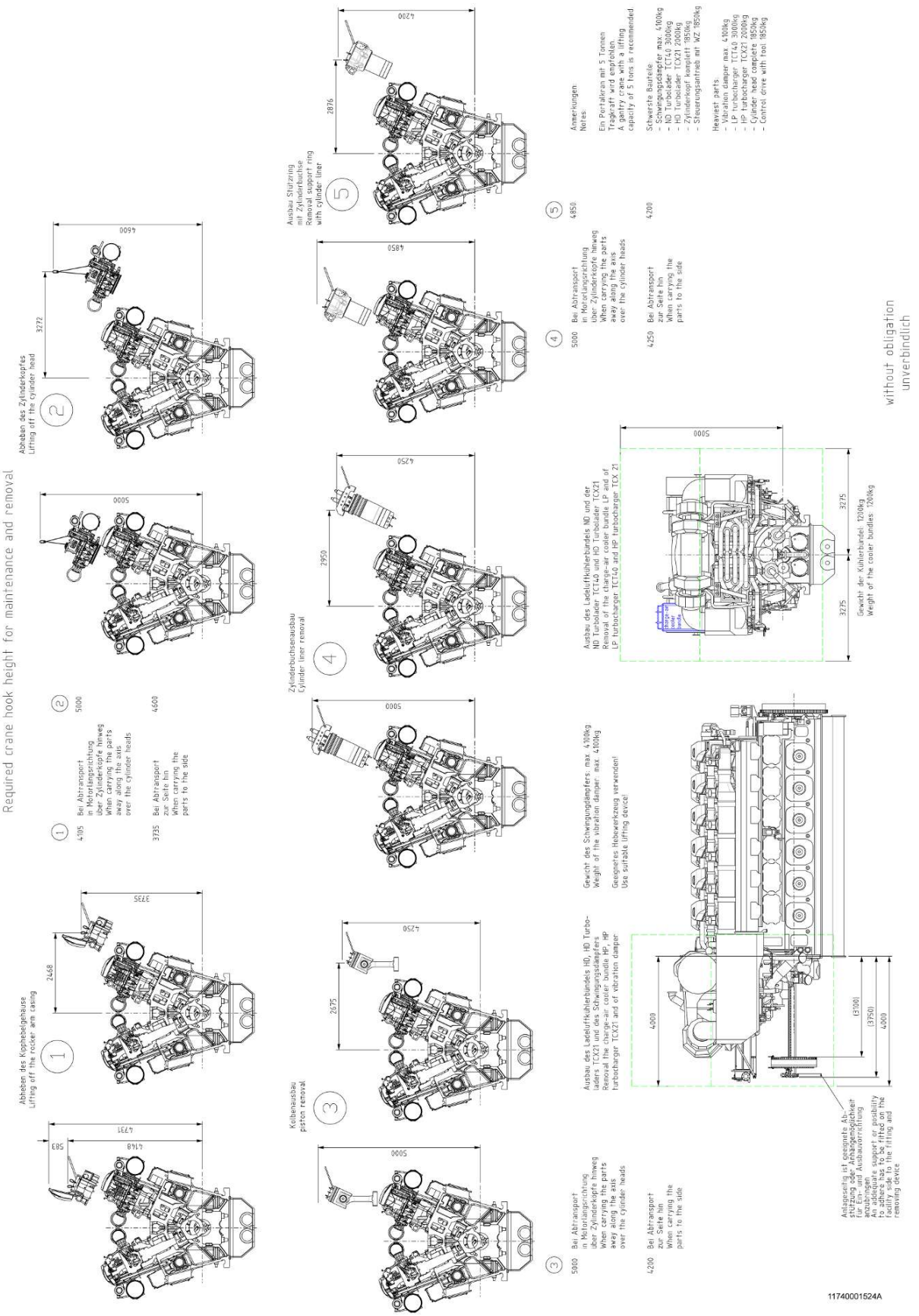


Figure 161: Removal dimensions of piston and cylinder liner – V engine

5.12.4 Engine arrangements

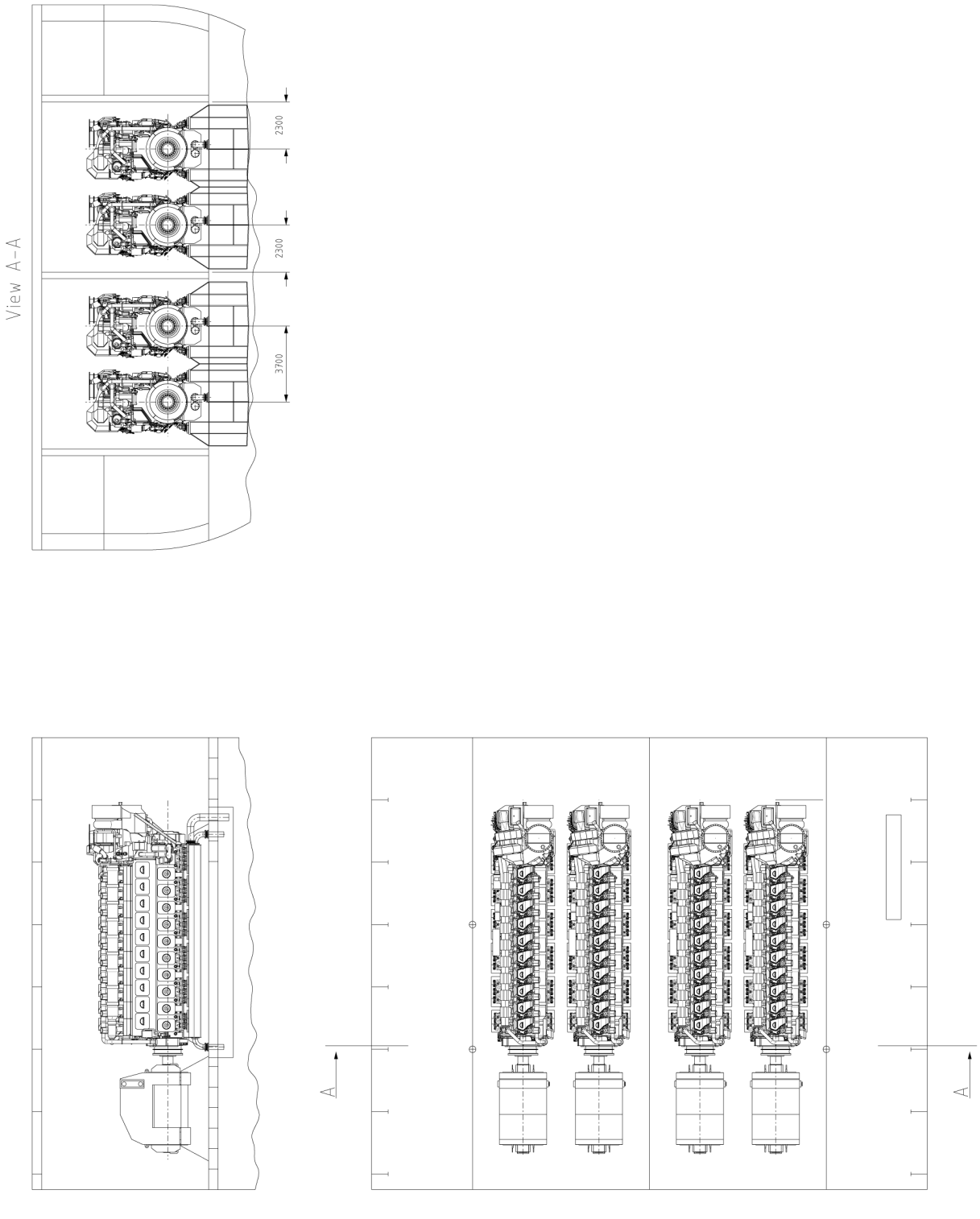


Figure 162: Example: Arrangement with L49/60DF engine

5.12.5 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	1,500
Cylinder head complete with attachments		1,900
Piston with piston pin and connecting rod (for piston removal)		700
Rocker arm casing		400
Cylinder liner		650
Charge air cooler		See table Weight and dimensions of charge air cooler bundle, Page 436

Table 157: Component weights

Crane arrangement

The rails for the crane are to be arranged in such a way that the crane can cover the whole of the engine beginning at the exhaust pipe.

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.

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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 29 shows which turbocharger type should be used for which engine variant.

TCX turbocharger

The drawing of the turbocharger connection dimensions provides a complete overview of all dimensions. Different casing models can be installed depending on the engine type.

In case of questions contact Everllence.

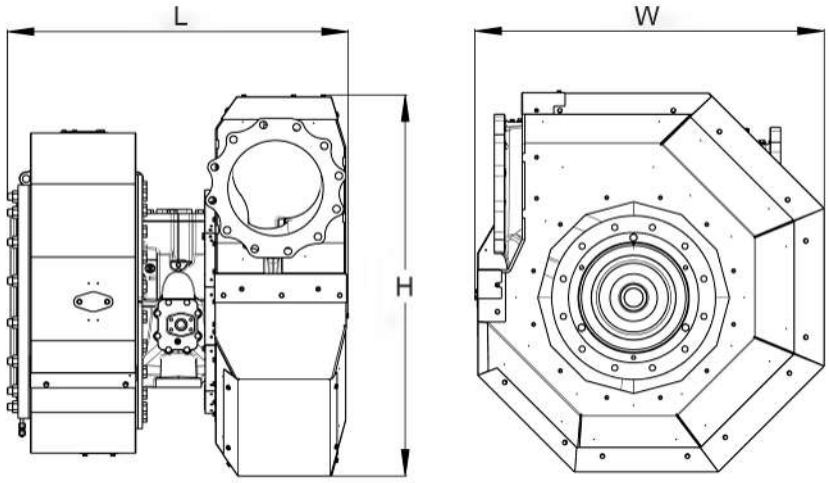


Figure 163: Main dimensions of the TCX turbocharger with the casing at 0°

Dimensions in mm		TCX21	TCX23
L	Length	1,004	1,203
W	Width	1,046	1,239
H	Height	1,131	1,336

Table 158: Main dimensions of TCX turbocharger

TCT turbocharger

In case of questions contact Everllence.

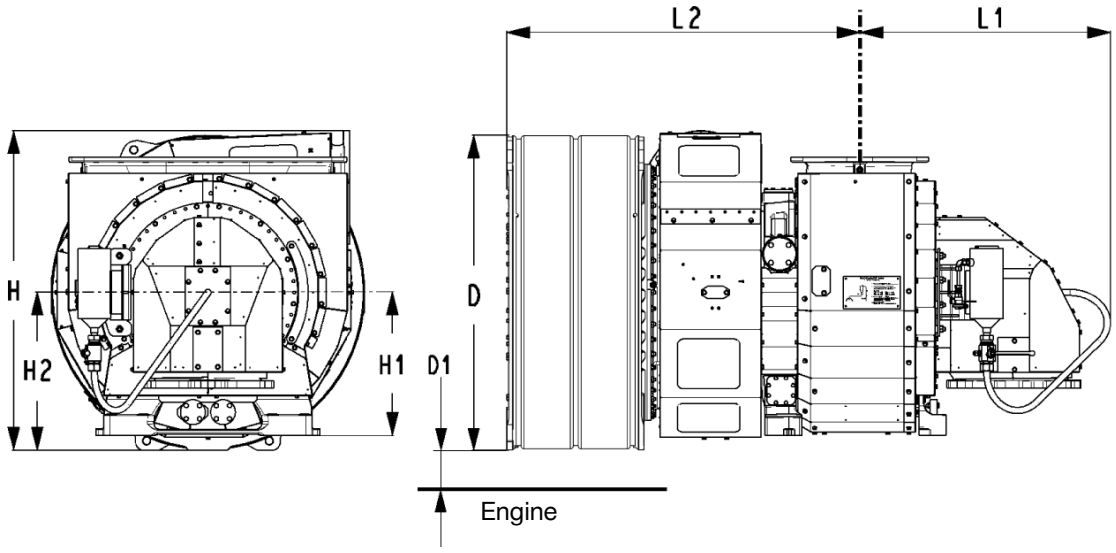


Figure 164: Dimensions of the TCT turbocharger

Dimensions [mm]	TCT40	TCT50
L1	1,048[1)] 568[2)] 1,048[3)]	1,123[1)] 639[2)] 1,123[3)]
L2	1,422[4)] 1,759[5)] 1,073[6)]	1,600[4)] 1,987[5)] 1,208[6)]
H	1,284	1,447
H1	575	645
H2	634	714
D	1,264	1,421
D1[7)]	100 mm	

[1)] Turbocharger with turbine inlet casing 90°.

[2)] Turbocharger with axial turbine inlet casing.

[3)] Turbocharger with turbine inlet casing 60°.

[4)] Turbocharger with silencer.

[5)] Turbocharger with air intake casing 90°.

[6)] Turbocharger with axial air intake casing.

[7)] Circumferential clearance around the silencer.

Table 159: TCT turbocharger dimensions

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.

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TCX

Turbocharger		TCX21	TCX23
Turbine rotor	kg	68-73	115-122
Bearing casing		326	538
Compressor casing		284-291	471-481
Turbine inlet casing		368	610
Silencer		-	-

Table 160: Hoisting rail of the axial turbocharger

TCT

Turbocharger		TCT40	TCT50
Turbine rotor	kg	95	136
Bearing casing		509	731
Compressor casing		310	443
Turbine inlet casing		146-171	206-231
Silencer		296	413

Table 161: Hoisting rail of the axial turbocharger

Withdrawal space dimensions

The withdrawal space shown in section Removal dimensions, Page 428 and in the table(s) in paragraph Hoisting rail, Page 434 is required for separating the silencer from the turbocharger. The silencer must be shifted axially by this distance before it can be moved laterally.

In addition to this measure, another 100 mm are required for assembly clearance.

This is the minimum distance between silencer and bulkhead or tween-deck. We recommend to plan additional 300 – 400 mm as working space.

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

For cleaning of the charge air cooler bundle, it must be possible to lift it vertically out of the cooler casing and lay it in a cleaning bath.

Exception 32/40CD: The cooler bundle of this engine is drawn out at the end. Similarly, transport onto land must be possible.

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For lifting and transportation of the bundle, a lifting rail is to be provided which runs in transverse or longitudinal direction to the engine (according to the available storage place), over the centreline of the charge air cooler, from which a trolley with hoisting tackle can be suspended.

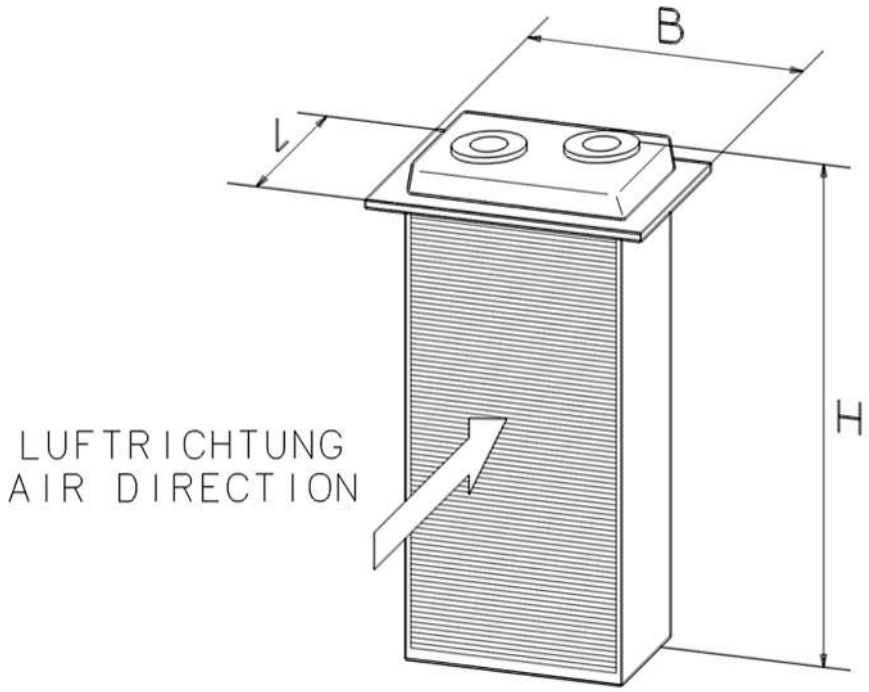


Figure 165: Air direction

Engine type	Weight	Length (L)	Width (B)	Height (H)
	kg	mm	mm	mm
6L, 7L HP stage	1,050	638	1,015	1,425
6L, 7L LP stage	1,000	532	800	1,530
8L – 10L HP stage	1,200	638	1,015	1,425
8L – 10L LP stage	1,150	568	940	1,730
12V, 14V HP stage	800	635	1,000	1,157
12V, 14V LP stage	750	622	812	1,385
20V (1st intercooler stage)	770	372	1,015	2,308
20V (2nd intercooler stage)	910	442	1,015	2,308

Table 162: Weight and dimensions of charge air cooler bundle

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5.12.6 Space requirement for maintenance

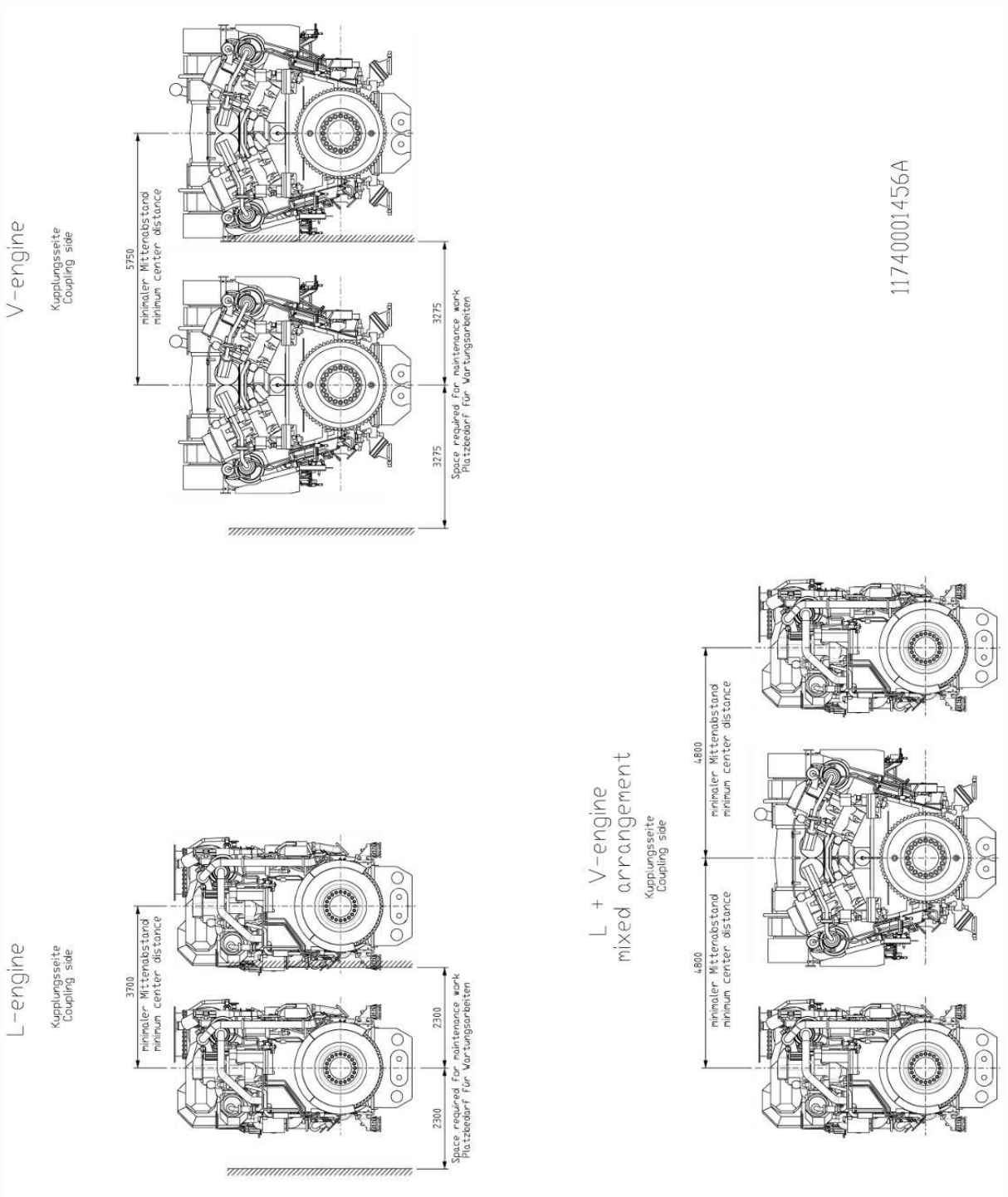
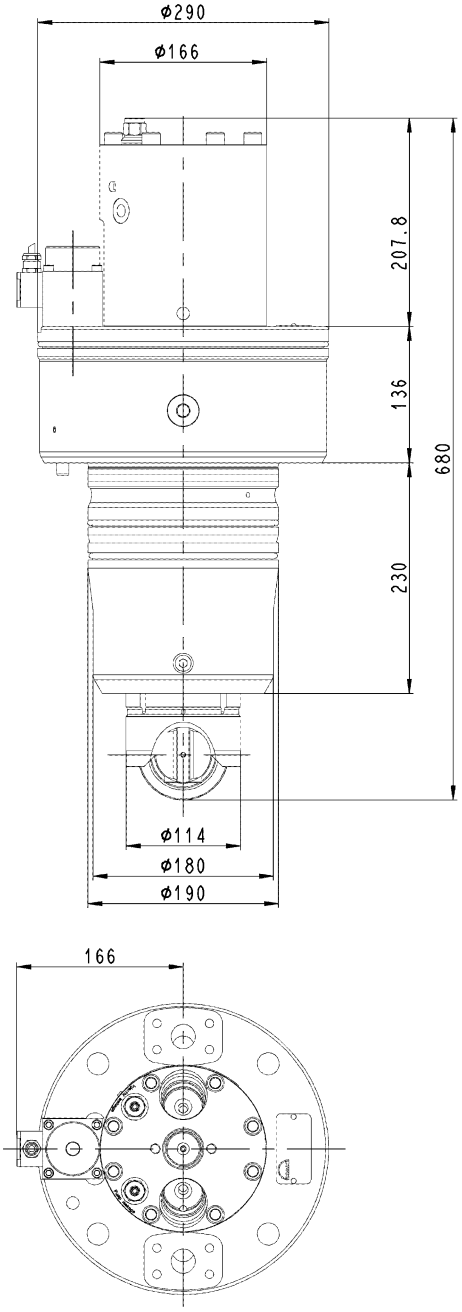


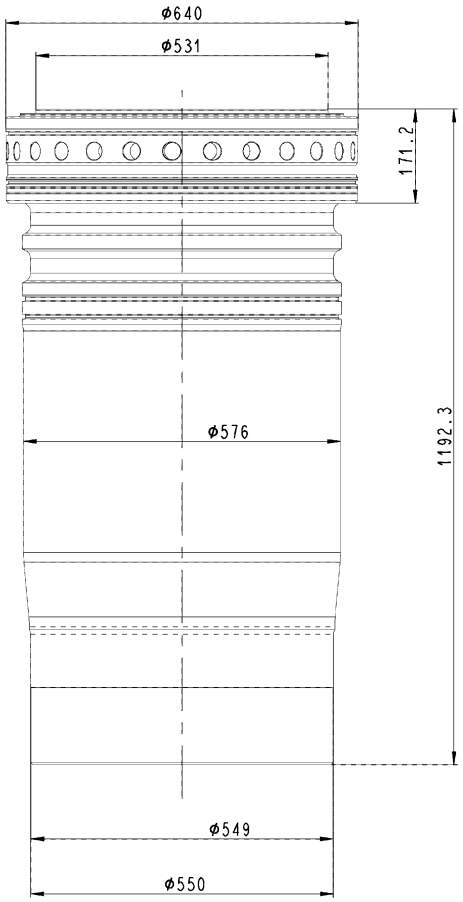
Figure 166: Space requirement for maintenance

5.12.7 Major spare parts

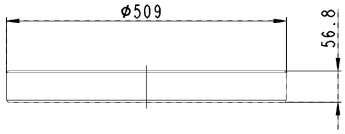
High pressure pump
124 kg
L+V49/60DF
L+V49/60



Cylinder liner
572 kg

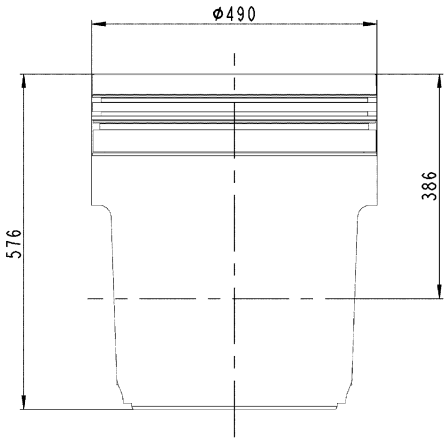


Fire band
6 kg

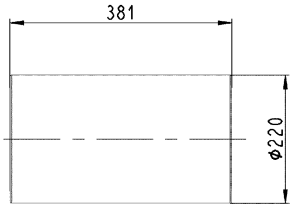


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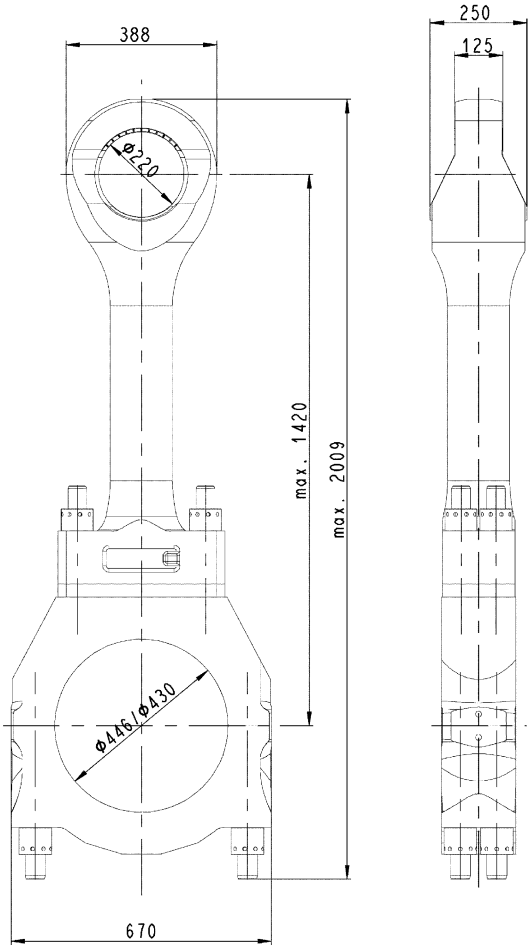
Piston complete with piston pin 389 kg



Piston pin 105.5 kg

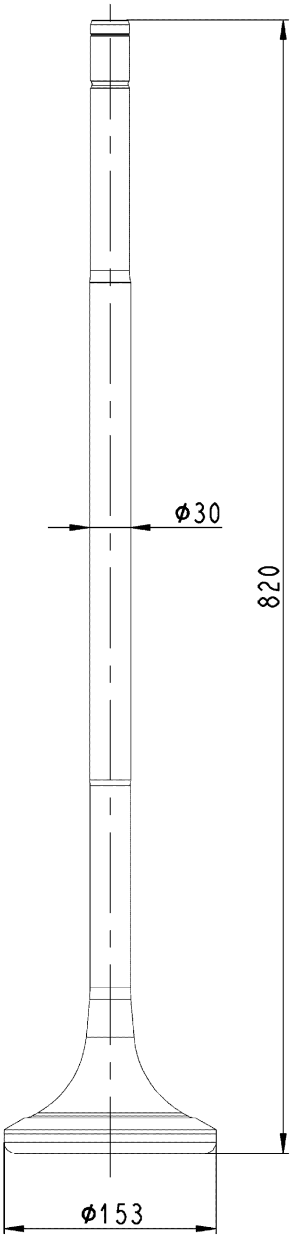


Connecting rod max. 702 kg

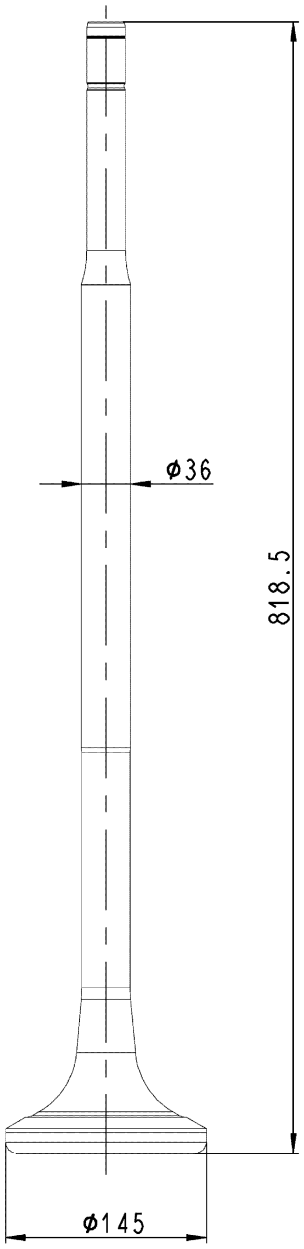


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Inlet valve
8.7 kg

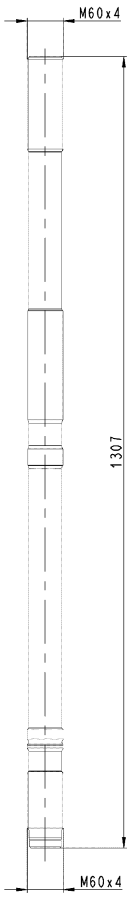


Exhaust valve
9.4 kg

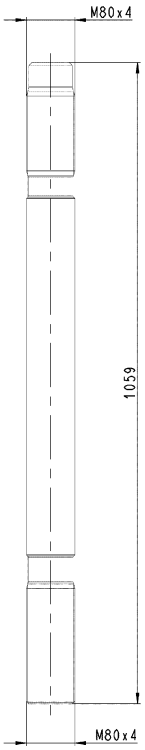


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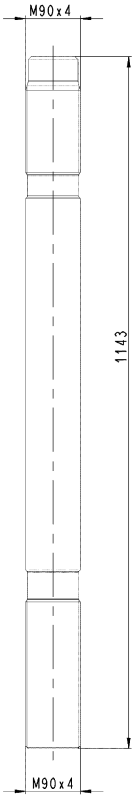
Tierod cylinder head
6L-10L
12V-20V
25.2 kg



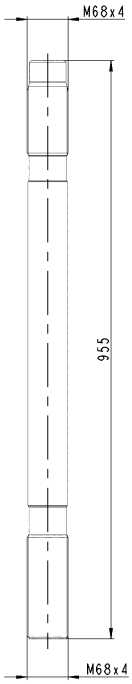
Tierod
6L-10L
40.4 kg



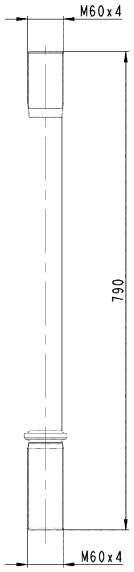
Tierod
6L-10L
12V-20V
55.5 kg



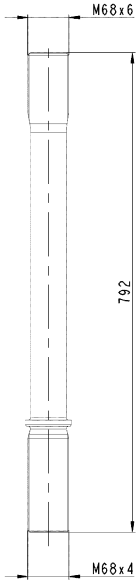
Tierod
6L-10L
12V-20V
25 kg



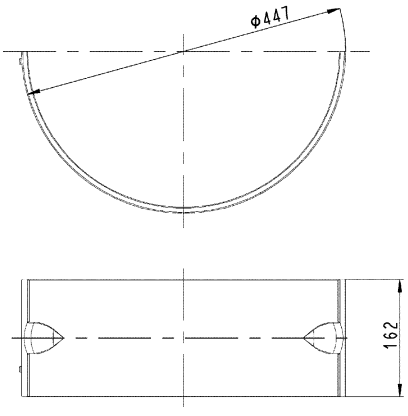
Cross tierod
6L-10L
15.3 kg



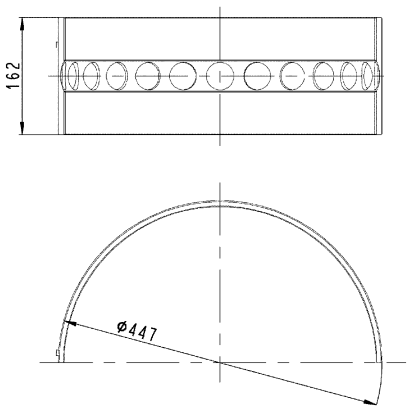
Cross tierod
6L-10L
12V-20V
18.9 kg



Lower bearing shell
6L-10L
7.1 kg

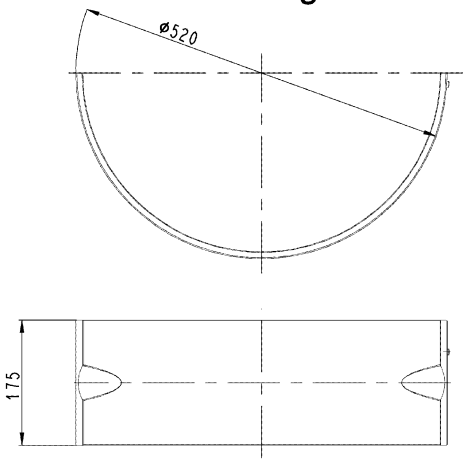


Upper bearing shell
6L-10L
6.1 kg

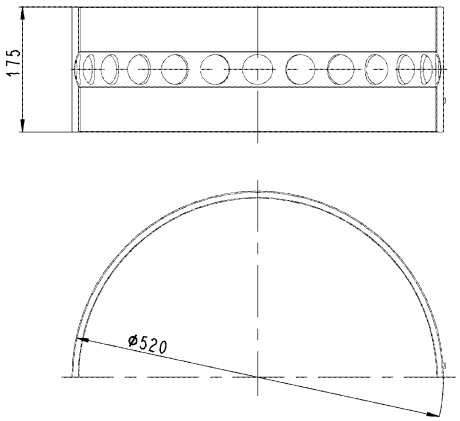


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Lower bearing shell
12V-20V
10.5 kg

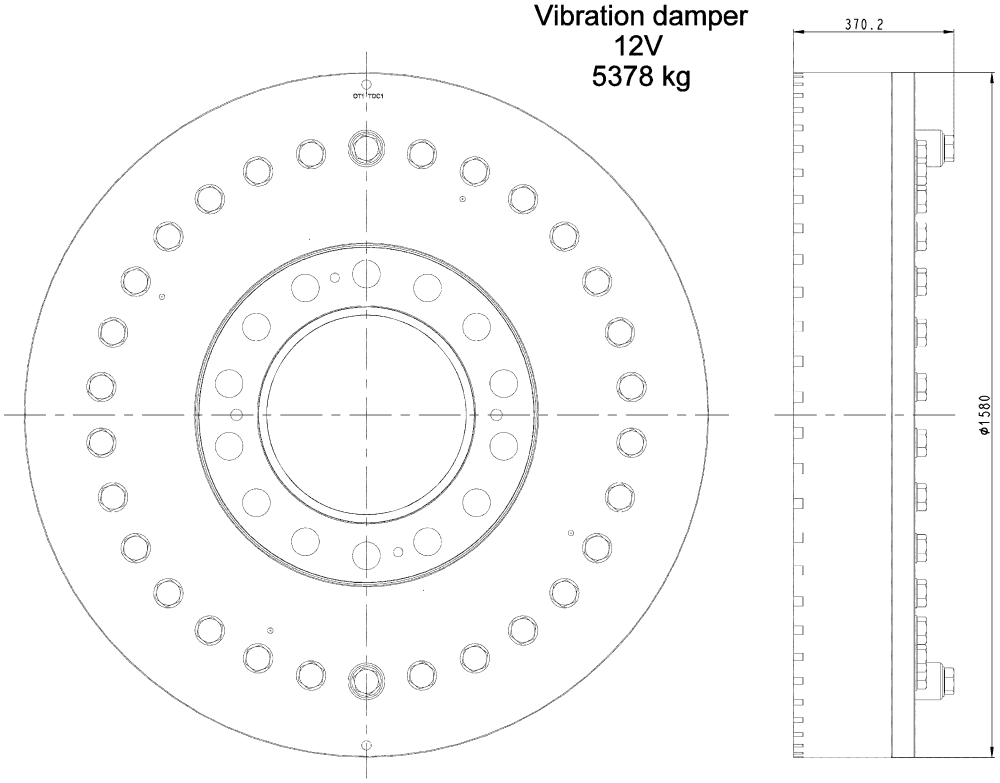


Upper bearing shell
12V-20V
9 kg

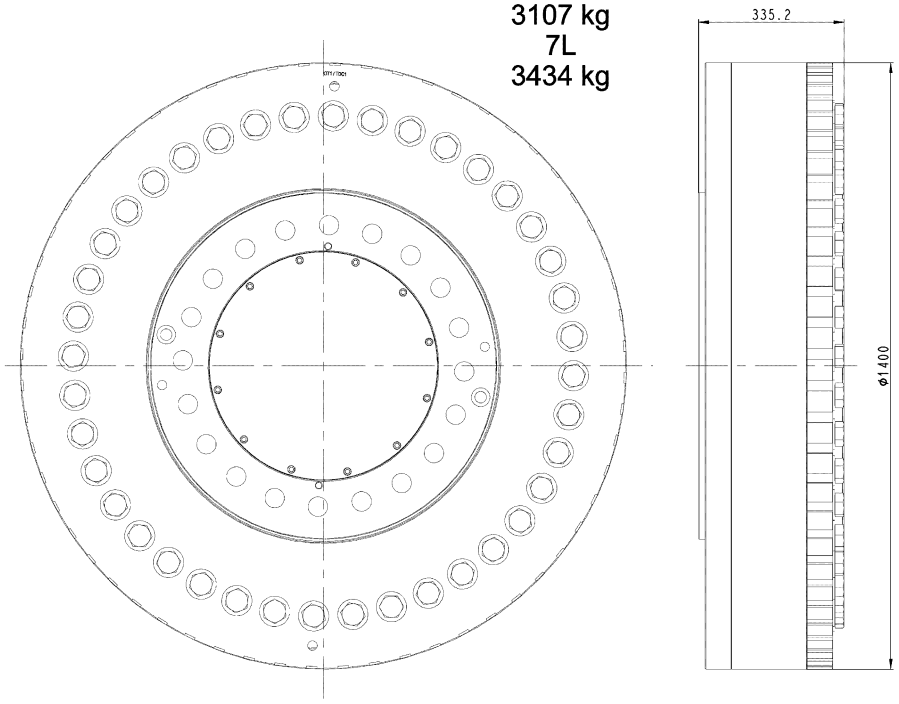


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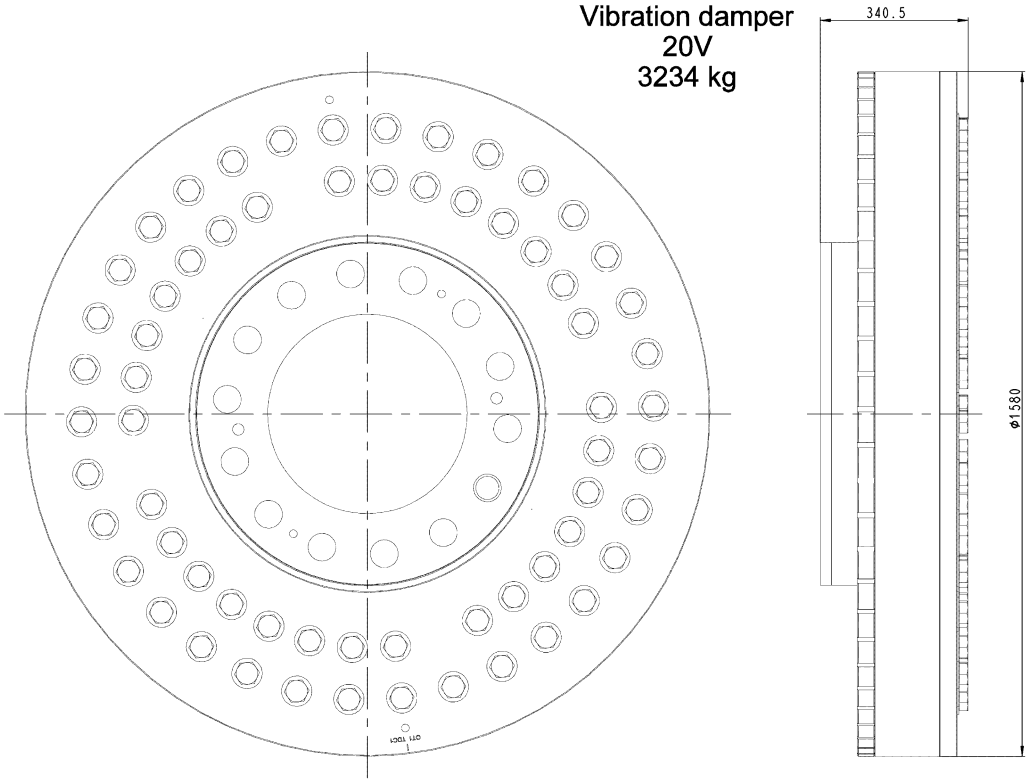
Vibration damper
12V
5378 kg



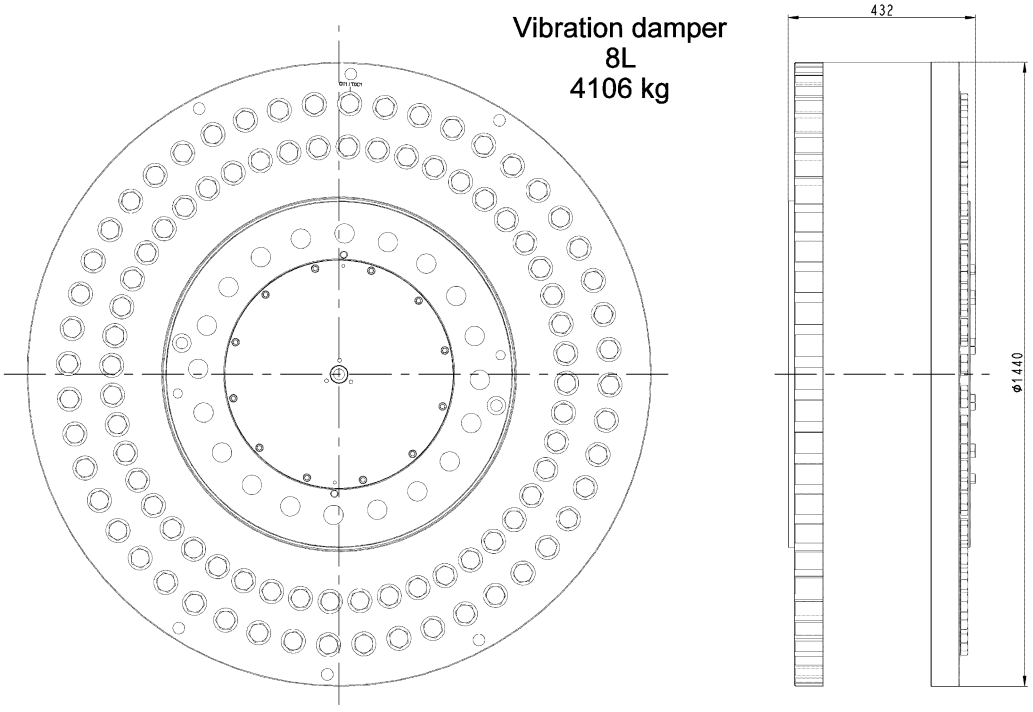
Vibration damper
6L, 9L, 10L
3107 kg
7L
3434 kg



Vibration damper
20V
3234 kg

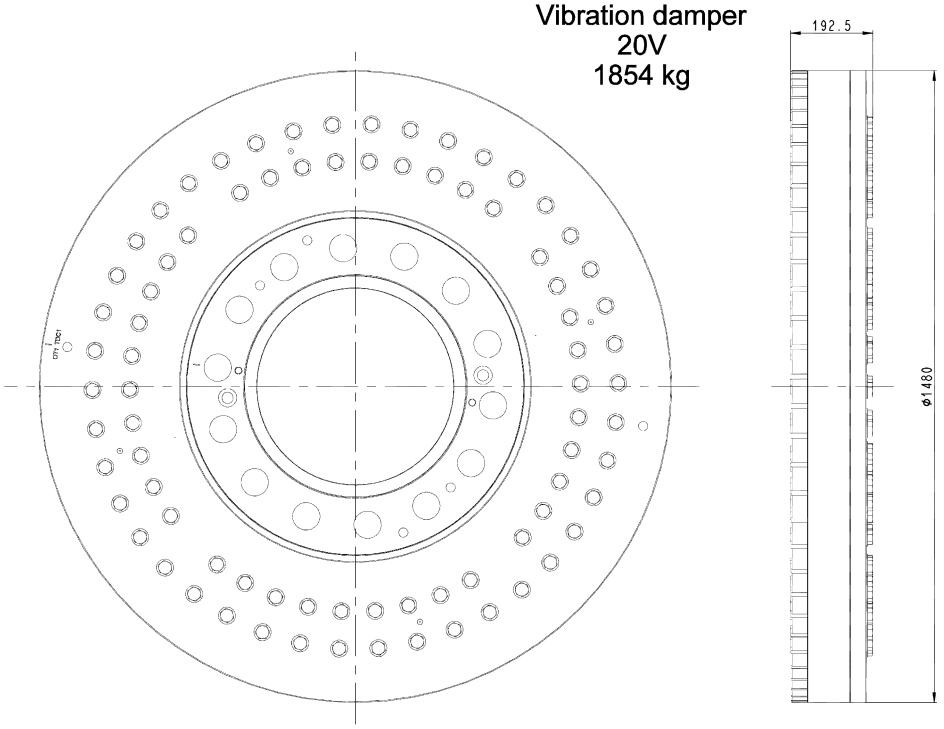


Vibration damper
8L
4106 kg

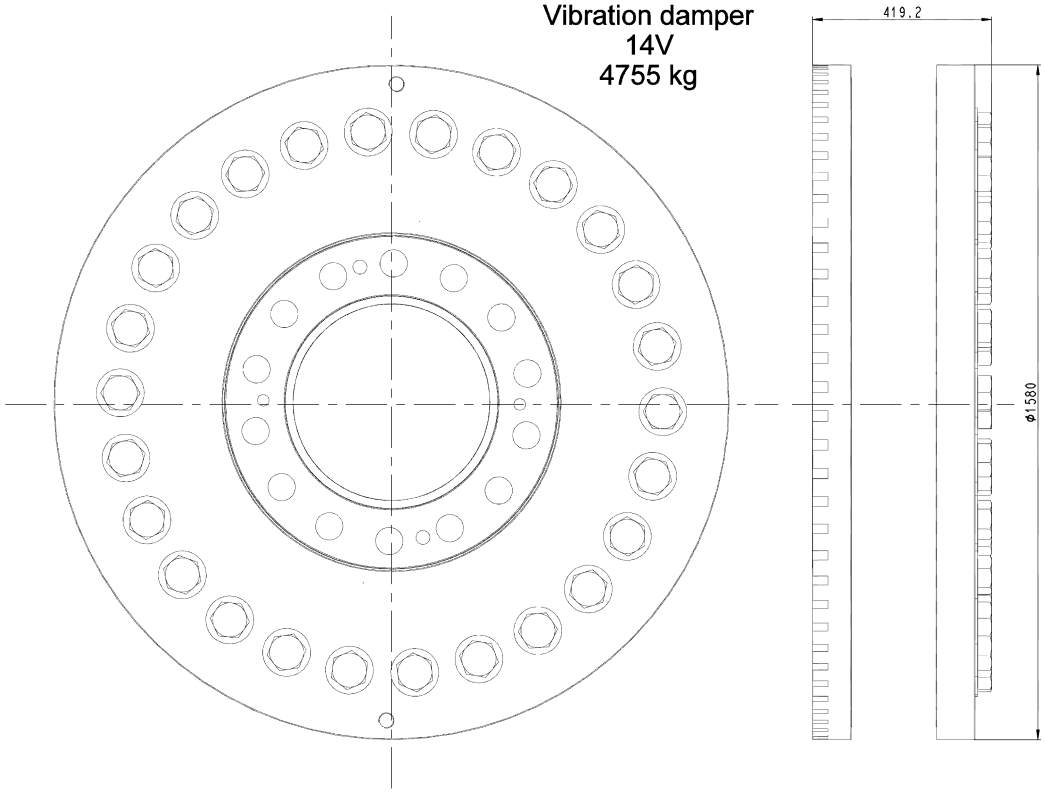


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Vibration damper
20V
1854 kg



Vibration damper
14V
4755 kg



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5.12.8 Mechanical propulsion system arrangement

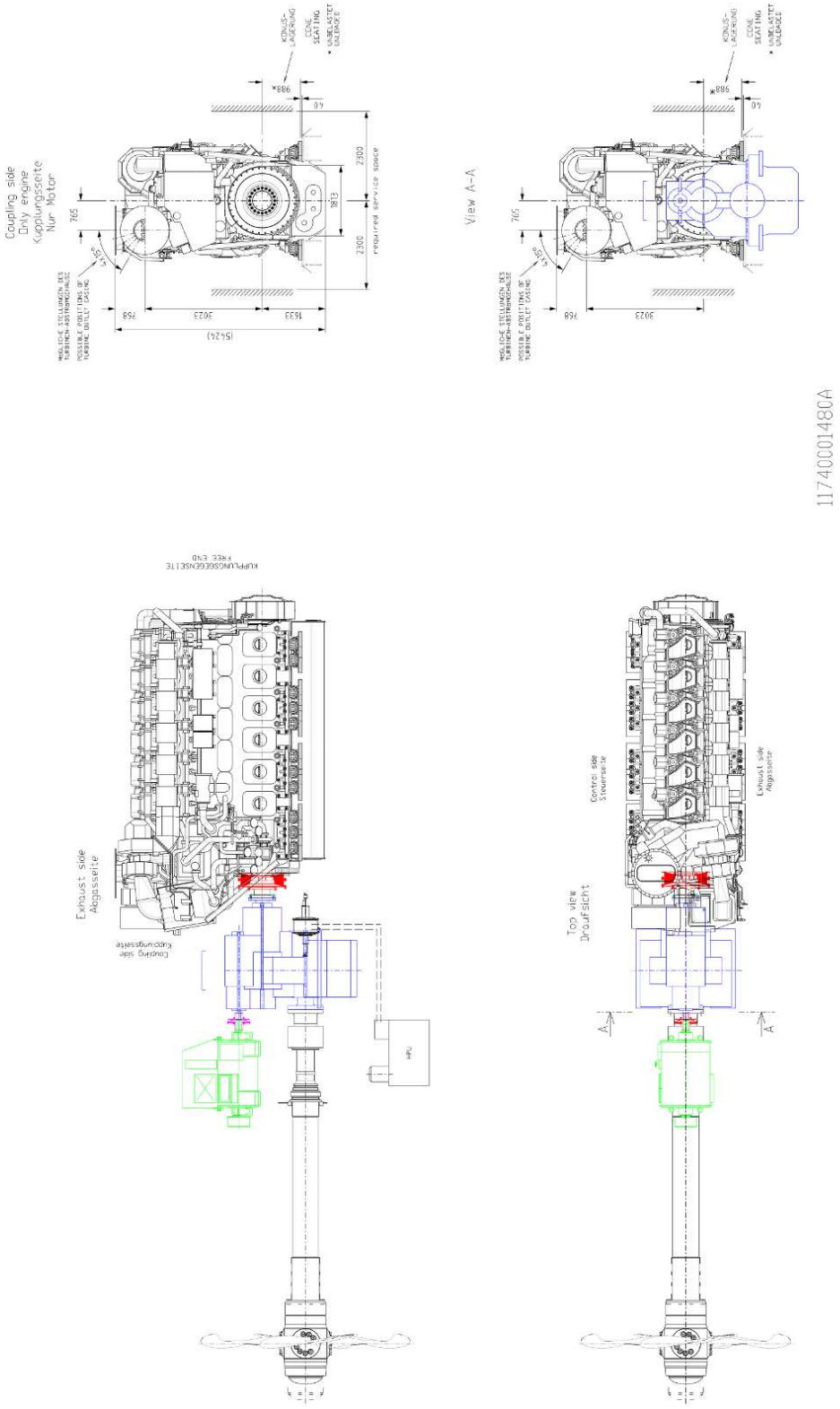


Figure 167: Example: Propulsion system arrangement L49/60DF

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6 Propulsion packages

6.1 General

Everllence standard propulsion packages

The Everllence standard propulsion packages are optimised at 90% MCR, 100% rpm and 96.5% of the ship speed. The propeller is calculated with the class notation "No Ice" and high skew propeller blade design. These propulsion packages are examples of different combinations of engines, gearboxes, propellers and shaft lines according to the design parameters above. Due to different and individual aft ship body designs and operational profiles your inquiry and order will be carefully reviewed and all given parameters will be considered in an individual calculation. The result of this calculation can differ from the standard propulsion packages by the assumption of e.g. a higher Ice Class or different design parameters.

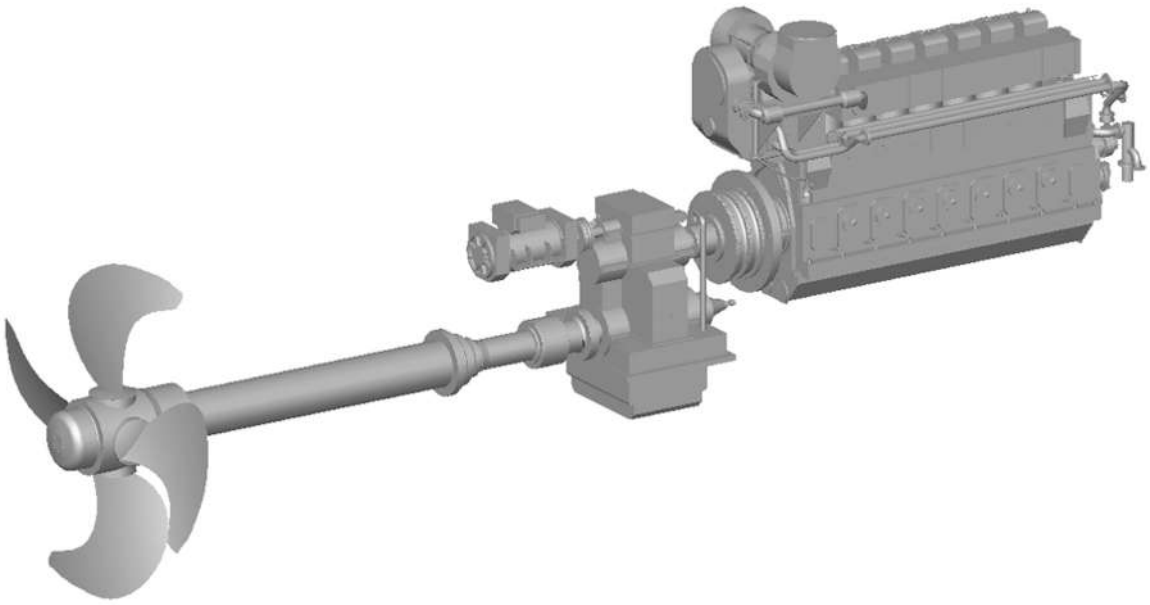


Figure 168: Everllence standard propulsion package with engine 7L32/40 (example)

6.2 Propeller layout data

To find out which of our propeller fits you, fill in the propeller layout data sheet which you find here Project guide supplements and send it via e-mail to our sales department. The e-mail address is located under contacts on the web page.

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6.3 Propeller clearance

To reduce the emitted pressure impulses and vibrations from the propeller to the hull, Everllence recommends a minimum tip clearance see section Recommended configuration of foundation, Page 183.

For ships with slender aft body and favourable inflow conditions the lower values can be used whereas full after body and large variations in wake field causes the upper values to be used.

In twin-screw ships the blade tip may protrude below the base line.

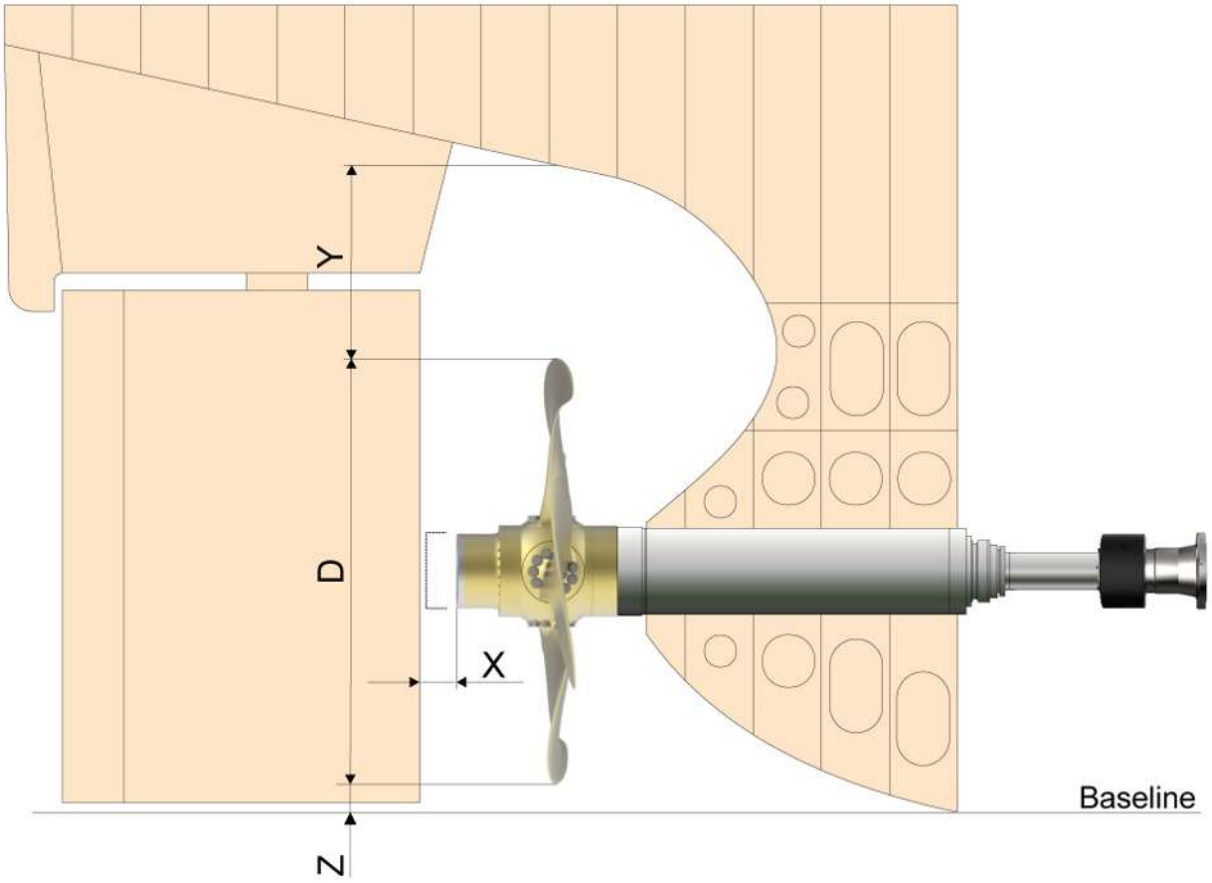


Figure 169: Recommended tip clearance

Hub	Dismantling of hub cylinder	High skew propeller	Non-skew propeller	Baseline clearance
	X min.	Y	Y	Z
Type	[mm]	[mm]	[mm]	[mm]
VBS1020	150	15 – 20 % of D	20 – 25 % of D	Minimum 50 – 100
VBS1100	160			
VBS1180	170			
VBS1260	175			
VBS1350	190			
VBS1450	200			
VBS1550	215			

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Hub	Dismantling of hub cylinder	High skew propeller	Non-skew propeller	Baseline clearance
	X min.	Y	Y	Z
Type	[mm]	[mm]	[mm]	[mm]
VBS1640	230			
VBS1730	395 [1]			
VBS1810	405			

[1] Dimension is not finally fixed.

6.4 Alphatronic 3000 propulsion control system

Alphatronic 3000 is Everllence´ propulsion control system for marine engines and propulsion system solutions. The following brief description is for controlling controllable pitch propeller (CPP) propulsion systems powered by four-stroke medium-speed engines with a standardised interface to the SaCoS 5000 control and safety system.

Alphatronic 3000 provides:

- Safe control of the propulsion plant and reliable maneuvering of the ship.
- Economic operation thanks to optimised engine/propeller load control.
- Quick system response and efficient CPP maneuverability.
- User-friendly operator functions due to logic and ergonomic design of control panels, handles and displays.

The system offers three levels of propulsion control:

- Normal control with automatic load control.
- Backup control from bridge and engine control room.
- Independent telegraph system for communication from bridge to machinery space.

The Alphatronic 3000 system is based on a modular panel design concept to elegantly fit any ship console layout. Configurable touch screens in the propulsion control panels meet a wide range of customer specific functions.

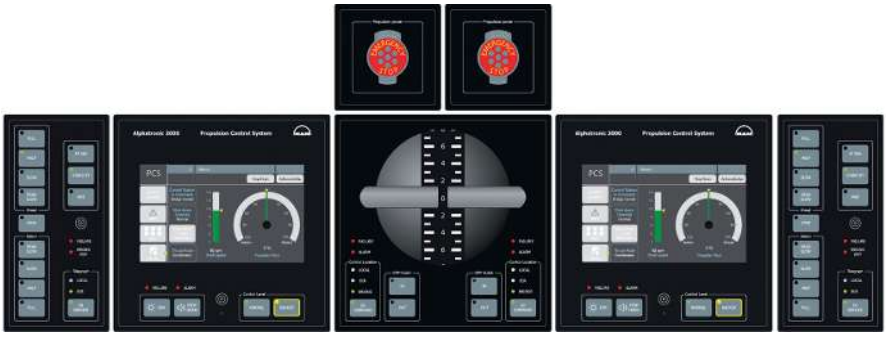


Figure 170: Control station layout for a twin CP propeller plant

A number of tailored features and functions can be provided by Alphatronic 3000 – as for example the speed pilot. The optional speed pilot feature is available with connection to the ship‘s GPS system for ‘speed over ground’ (SOG) input. The speed pilot optimises the voyage planning and operational speeds e.g. for pulling, steaming and convoy sailing – with fuel saving potentials of up to 4%.

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For a more extensive description of the Alphatronic 3000 propulsion control system, functions, system architecture, interfaces, panels and displays, be referred to our 40-page product information "Alphatronic 3000".



Figure 171: Manoeuvre handle panels

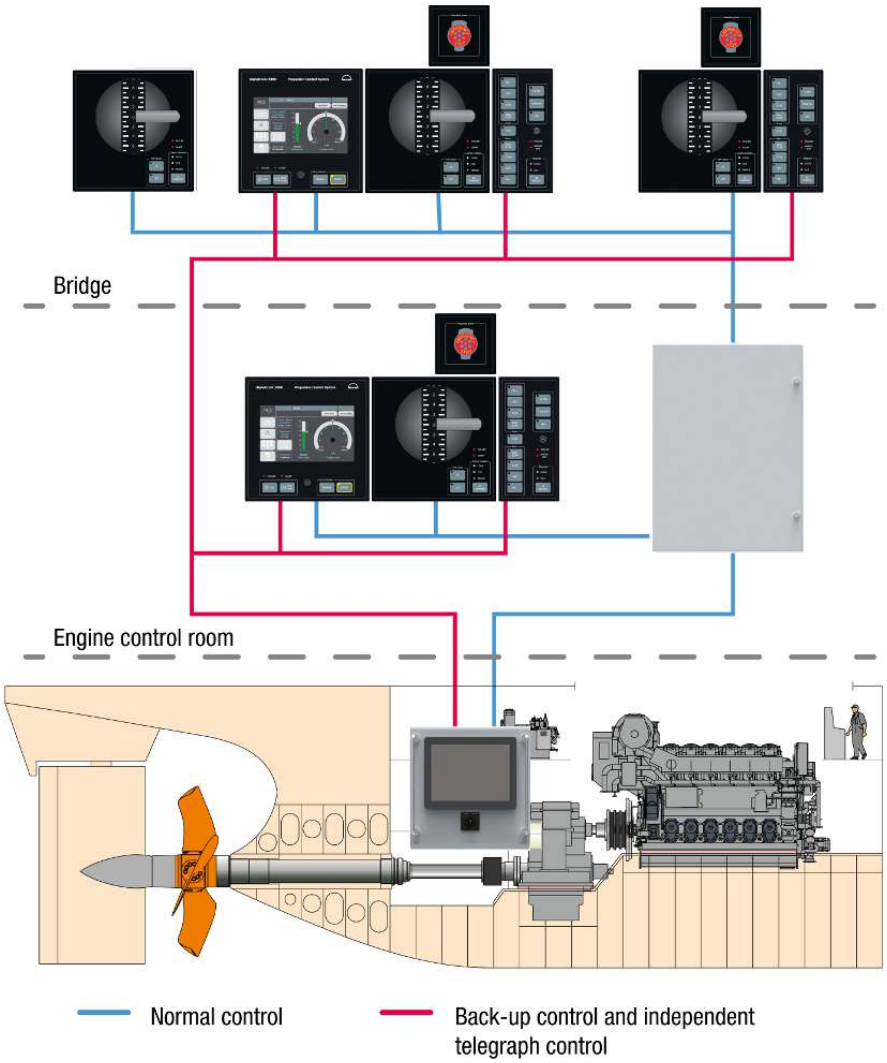


Figure 172: Simple control system architecture – Single CP propeller four-stroke propulsion example

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7 Electric propulsion plants

7.1 Advantages of electric propulsion

Due to different and individual types, purposes and operational profiles of electric propulsion driven vessels the design of an electric propulsion plant differs a lot and has to be evaluated case by case. All the following is for information purpose only and without obligation.

In general the advantages of electric propulsion can be summarized as follows:

- Lower fuel consumption and emissions due to the possibility to optimise the loading of diesel engines/GenSets. The GenSets in operation can run on high loads with high efficiency. This applies especially to vessels which have a large variation in power demand, for example for an offshore supply vessel.
- High reliability, due to multiple engine redundancy. Even if an engine/GenSet malfunctions, there will be sufficient power to operate the vessel safely. Reduced vulnerability to single point of failure providing the basis to fulfill high redundancy requirements.
- Reduced life cycle cost, resulting from lower operational and maintenance costs.
- Improved manoeuvrability and station-keeping ability, by deploying special propulsors such as azimuth thrusters or pods. Precise control of the electric propulsion motors controlled by frequency converters.
- Increased payload, as electric propulsion plants take less engine room space.
- More flexibility in location of diesel engine/GenSets and propulsors. The propulsors are supplied with electric power through cables. They do not need to be adjacent to the diesel engines/GenSets.
- Low propulsion noise and reduced vibrations. For example, a slow speed E-motor allows to avoid a gearbox and propulsors like pods keep most of the structure bore noise outside of the hull.
- Efficient performance and high motor torques, as the system can provide maximum torque also at slow propeller speeds, which gives advantages for example in icy conditions.

7.2 Losses in electric propulsion plants

An electric propulsion plant consists of standard electrical components. The following losses are typical:

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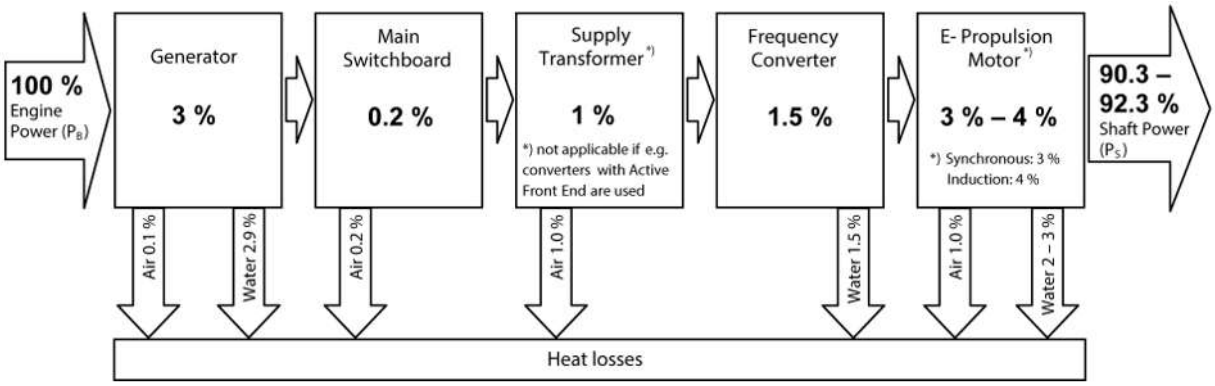
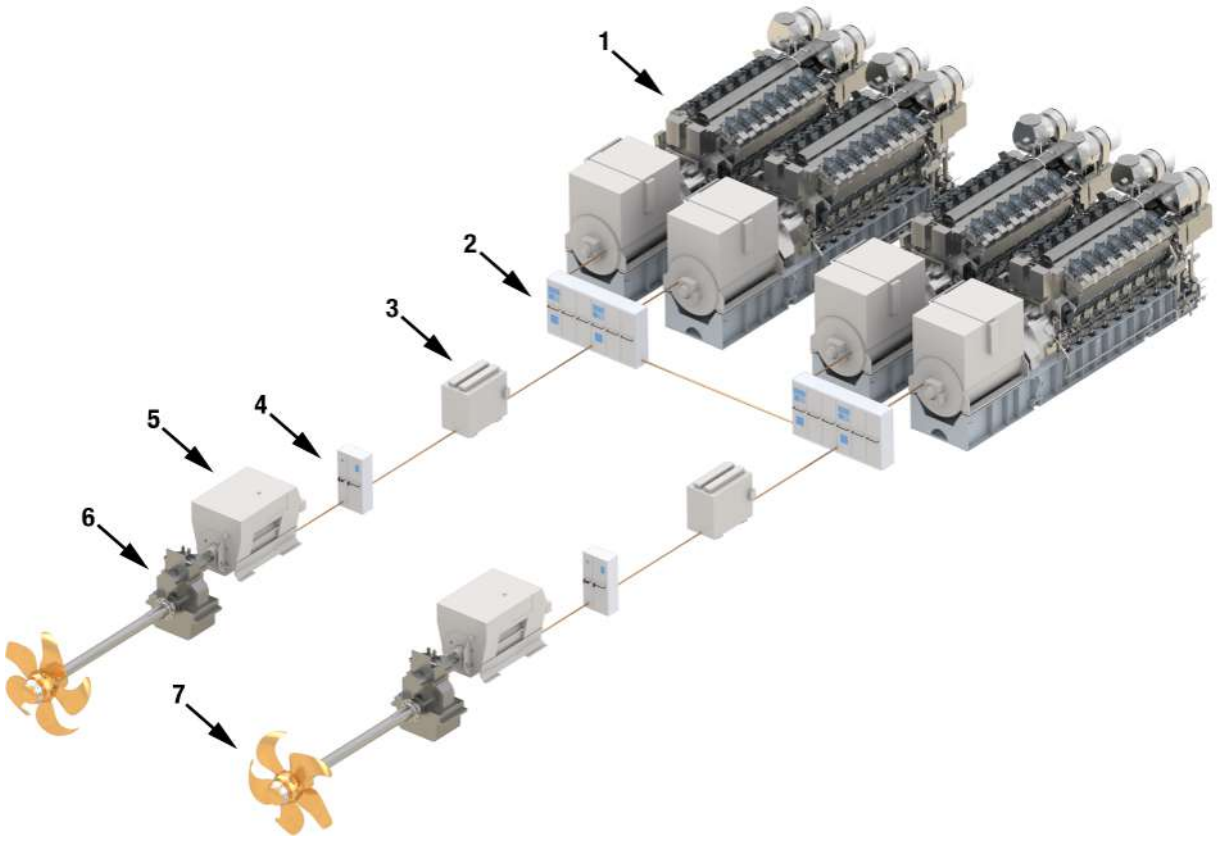


Figure 173: Typical losses of electric propulsion plants

7.3 Components of an electric propulsion plant



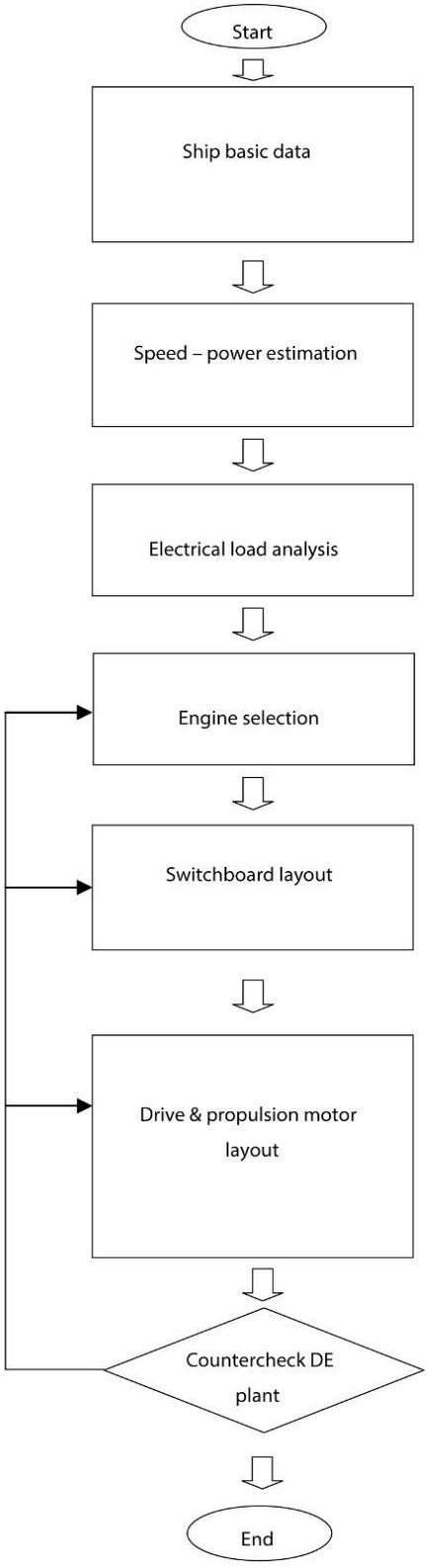
1 GenSets: Diesel engines and alternators
2 Main switchboards
3 Supply transformers: Dependent on the type of the converter. Not required in case of the use of frequency converters with six pulses, an active front end or a sinusoidal drive.
4 Frequency converters
5 Electric propulsion motors
6 Gearboxes (optional): Dependent on the speed of the E-propulsion motor
7 Propellers/propulsion

Figure 174: Example: Electric propulsion plant

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7.4 Electric propulsion plant design

Generic workflow how to design an electric propulsion plant:



- Type of vessel
- Propulsion type: Shaft line, thruster, pod, …
- Propeller type: FPP, CPP
- Operational profile
- Class notation: Propulsion redundancy, ice class, …

- Ship design points
- Propulsion power: At sea, maneuvering, at port, …
- Sea margin

- Electrical power: At sea, maneuvering, at port, …
- Efficiency of DE plant: Typically = 91 %
- Efficiency of alternators: Typically = 96 % – 97 %

- Number and type of engines/gensets: Installed power
- Max. allowed loading of engines: % of MCR
- Maintenance of engines: At sea operation, at port, …

- Frequency choice: 50/60 Hz
- Voltage choice: Low voltage, medium voltage
- Number of switchboard sections
- Alternator parameters: cos φ, xd"

- Selection of converter type: PWM, LCI, AFE, Sinusoidal, …
- Selection of pulse number: 6p, 12p, 24p
- Selection of supply transformer: Investigate transformer less configuration (e.g. "Active Front End")
- Selection of E-propulsion motor type and no. of windings
- THD mitigation method

- Check I_{sc}: "Increase voltage, optimize xd", …
- Check availability of reactive power: Change number/type of alternators, cos φ, …
- Check THD limits: Increase pulse number, add filters, …

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The requirements of a project will be considered in an application specific design, taking into account the technical and economical feasibility and later operation of the vessel. In order to provide you with appropriate data, fill the form "Diesel-electric propulsion plants: Questionnaire" you find here Project guide supplements and return it to your sales representative.

7.5 Engine selection

The engines for an electric propulsion plant have to be selected accordingly to the power demand at all the design points. For a concept evaluation the rating, the capability and the loading of engines can be calculated like this:

Example: Offshore supply vessel (at operation mode with the highest expected total load)

- Total propulsion power demand (at E-motor shaft) 10,000 kW (incl. sea margin)
- Max. electrical consumer load: 1,000 kW

No.	Item	Unit	
1.1	Shaft power on propulsion motors Electrical transmission efficiency	P_S [kW]	10,000 0.91
1.2	Engine brake power for propulsion	P_{B1} [kW]	10,989
2.1	Electric power for ship (E-load) Alternator efficiency	[kW]	1,000 0.965
2.2	Engine brake power for electric consumers	P_{B2} [kW]	1,036
2.3	Total engine brake power demand (= 1.2 + 2.2)	P_B [kW]	12,025
3.1	Diesel engine selection	Type	6L32/44CR
3.2	Rated power (MCR) running on DMB	[kW]	3,600
3.3	Number of engines	-	4
3.4	Total engine brake power installed	P_B [kW]	14,400
4.1	Loading of engines (= 2.3/3.4)	% of MCR	83.5
5.1	Check: Maximum permissible loading of engines	% of MCR	90.0

Table 163: Selection of the engines for an electric propulsion plant

For the detailed selection of the type and number of engines furthermore the operational profile of the vessel, the maintenance strategy of the engines and the boundary conditions given by the general arrangement have to be considered. For the optimal cylinder configuration of the engines often the power conditions in port are decisive.

7.6 E-plant, switchboard and alternator design

The configuration and layout of an electric propulsion plant, the main switchboard and the alternators follows some basic design principles. For a concept evaluation the following items should be considered:

- A main switchboard which is divided in symmetrical sections is very reliable and redundancy requirements are easy to be met.
- An even number of GenSets/alternators ensures the symmetrical loading of the bus bar sections.

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- Electric consumers should be arranged symmetrically on the bus bar sections.
- The switchboard design is mainly determined by the level of the short circuit currents which have to be withstand and by the breaking capacity of the circuit breakers (CB).
- The voltage choice for the main switchboard depends on several factors. On board of a vessel it is usually handier to use low voltage. Due to short circuit restrictions the following table can be used for voltage choice as a rule of thumb:

Total installed alternator power	Voltage	Breaking capacity of CB
< 10 – 12 MW (and: Single propulsion motor < 3.5 MW)	440 V	100 kA
< 13 – 15 MW (and: Single propulsion motor < 4.5 MW)	690 V	100 kA
< 48 MW	6,600 V	30 kA
< 130 MW	11,000 V	50 kA

Table 164: Rule of thumb for the voltage choice

- The design of the alternators and the electric plant always has to be balanced between voltage choice, availability of reactive power, short circuit level and permissible total harmonic distortion (THD).
- On the one hand side a small xd" of an alternator increases the short circuit current I_{sc}", which also increases the forces the switchboard has to withstand ($F \sim I_{sc}$" ^ 2). This may lead to the need of a higher voltage. On the other side a small xd" gives a lower THD but a higher weight and a bigger size of the alternator. As a rule of thumb a xd"=16 % is a good figure for low voltage alternators and a xd"=14 % is good for medium voltage alternators.
- For a rough estimation of the short circuit currents the following formulas can be used:

	Short circuit level [kA] (rough)	Legend
Alternators	$n * P_r / (\sqrt{3} * U_r * xd" * \cos \varphi_{Grid})$	n: No. of alternators connected P_r: Rated power of alternator [kWe] U_r: Rated voltage [V] xd": Subtransient reactance [%] cos φ: Power factor of the vessel´s network (typically = 0.9)
Motors	$n * 6 * P_r / (\sqrt{3} * U_r * xd" * \cos \varphi_{Motor})$	n: No. of motors (directly) connected P_r: Rated power of motor [kWe] U_r: Rated voltage [V] xd": Subtransient reactance [%] cos φ: Power factor of the motor (typically = 0.85 – 0.90 for an induction motor)

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	Short circuit level [kA] (rough)	Legend
Converters	Frequency converters do not contribute to the I_{sc}"	-

Table 165: Formulas for a rough estimation of the short circuit currents

- The dimensioning of the cubicles in the main switchboard is usually done accordingly to the rated current for each incoming and outgoing panel. For a concept evaluation the following formulas can be used:

Type of switchboard cubicle	Rated current [kA]	Legend
Alternator incoming	$P_r / (\sqrt{3} * U_r * \cos \varphi_{Grid})$	P_r: Rated power of alternator [kWe] U_r: Rated voltage [V] cos φ: Power factor of the network (typically = 0.9)
Transformer outgoing	$S_r / (\sqrt{3} * U_r)$	S_r: Apparent power of transformer [kVA] U_r: Rated voltage [V]
Motor outgoing (induction motor controlled by a PWM-converter)	$P_r / (\sqrt{3} * U_r * \cos \varphi_{Converter} * \eta_{Motor} * \eta_{Converter})$	P_r: Rated power of motor [kWe] U_r: Rated voltage [V] cos φ: Power factor converter (typically = 0.95) η_{Motor}: Typically = 0.96 $\eta_{Converterr}$: Typically = 0.97
Motor outgoing (induction motor started: DoL, Y/△, soft-starter)	$P_r / (\sqrt{3} * U_r * \cos \varphi_{Motor} * \eta_{Motor})$	P_r: Rated power of motor [kWe] U_r: Rated voltage [V] cos φ: Power factor motor (typically = 0.85 – 0.90) η_{Motor}: Typically = 0.96

Table 166: Formulas to calculate the rated currents of switchboard panel

- The choice of the type of the E-motor depends on the application. Usually induction motors are used up to a power of 7 MW (η_{Motor}: Typically = 0.96). If it comes to applications above 7 MW per E-motor often synchronous machines are used. Also in applications with slow speed E-motors (without a reduction gearbox), for ice going or pod-driven vessels often synchronous E-motors (η_{Motor}: Typically = 0.97) are used.
- In plants with frequency converters based on VSI-technology (PWM type) the converter itself can deliver reactive power to the E-motor. So often a power factor cos φ = 0.9 is a good figure to design the alternator rating. Nevertheless there has to be sufficient reactive power for the ship consumers, so that a lack in reactive power does not lead to unnecessary starts of (stand-by) alternators.
- The harmonics can be improved (if necessary) by using supply transformers for the frequency converters with a 30 ° phase shift between the two secondary windings, which cancel the dominant 5^{th} and 7^{th} harmonic currents. Also an increase in the pulse number leads to lower THD. Using a 12-pulse configuration with a PWM type of converter the resulting harmonic distortion will normally be below the limits defined by the classification societies. When using a transformer less solution with a converter

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with an Active Front End (Sinusoidal input rectifier) or in a 6-pulse configuration usually THD-filters are necessary to mitigate the THD on the sub-distributions.

The final layout of the electrical plant and the components has always to be based on a detailed analysis and a calculation of the short circuit levels, the load flows and the THD levels as well as on an economical evaluation.

7.7 Over-torque capability

In electric propulsion plants, which are operating with a fix pitch propeller, the dimensioning of the electric propulsion motor has to be done accurately, in order to have sufficient propulsion power available. For dimensioning the electric motor it has to be investigated what amount of over-torque, which directly defines the motor´s cost, weight and space demand, is required to operate the propeller with sufficient power also in situations, where additional power is required (for example because of heavy weather or icy conditions).

Usually a constant power range of 5 % – 10 % is applied on the propulsion (Field weakening range), where constant E-motor power is available.

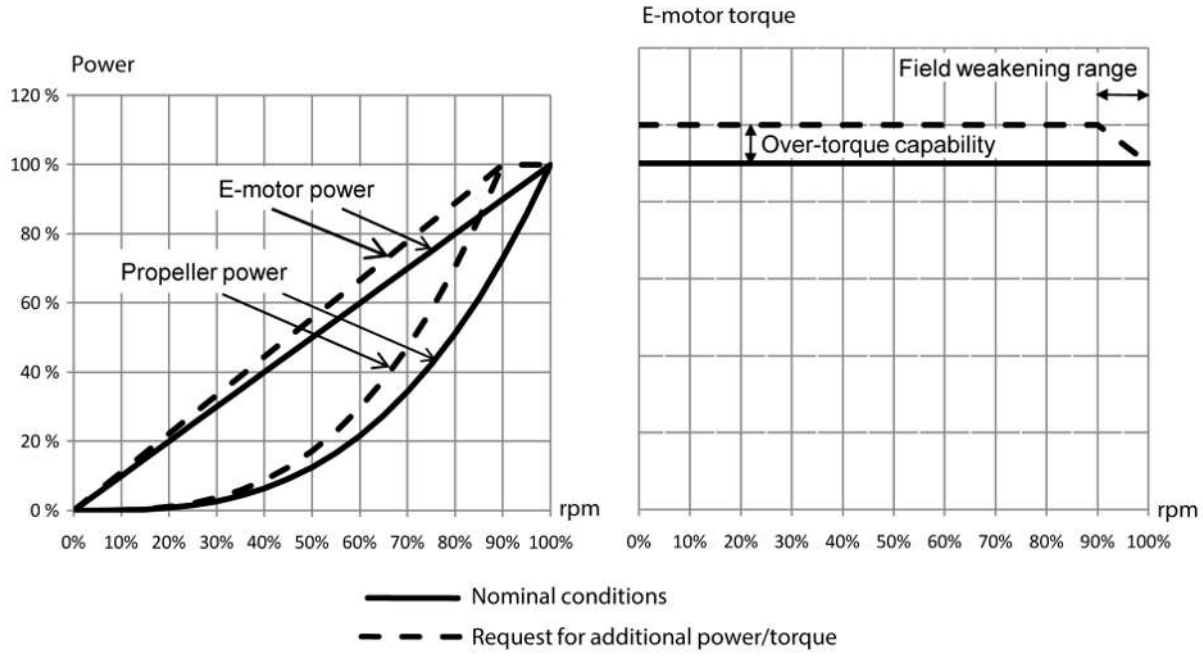


Figure 175: Example: Over-torque capability of an E-propulsion train for a FPP-driven vessel

7.8 Power management

Power management system

The following main functions are typical for a power management system (PMS):

- Automatic load dependent start/stop of GenSets/alternators
- Manual starting/stopping of GenSets/alternators
- Fault dependent start/stop of stand-by GenSets/alternators in cases of under-frequency and/or under-voltage
- Start of GenSets/alternators in case of a blackout (black-start capability)

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- Determining and selection of the starting/stopping sequence of GenSets/ alternators
- Start and supervise the automatic synchronization of alternators and bus tie breakers
- Balanced and unbalanced load application and sharing between GenSets/alternators. Often an emergency programme for quickest possible load acceptance is necessary
- Regulation of the network frequency (with static droop or constant frequency)
- Distribution of active load between alternators
- Distribution of reactive load between alternators
- Handling and blocking of heavy consumers
- Automatic load shedding
- Tripping of non-essential consumers
- Bus tie and breaker monitoring and control

All questions regarding the interfaces from/to the power management system have to be clarified with Everllence at an early project stage.

7.9 Example configurations of electric propulsion plants

Offshore Support Vessels

The term “Offshore Service & Supply Vessel” includes a large class of vessel types, such as platform supply vessels (PSV), anchor handling/tug/supply (AHTS), offshore construction vessel (OCV), diving support vessel (DSV), multipurpose vessel (MPV), etc.

Electric propulsion is the norm in ships which frequently require dynamic positioning and station keeping capability. Initially these vessels mainly used variable speed motor drives and fixed pitch propellers. Now they mostly deploy variable speed thrusters and they are also often equipped with hybrid propulsion systems.

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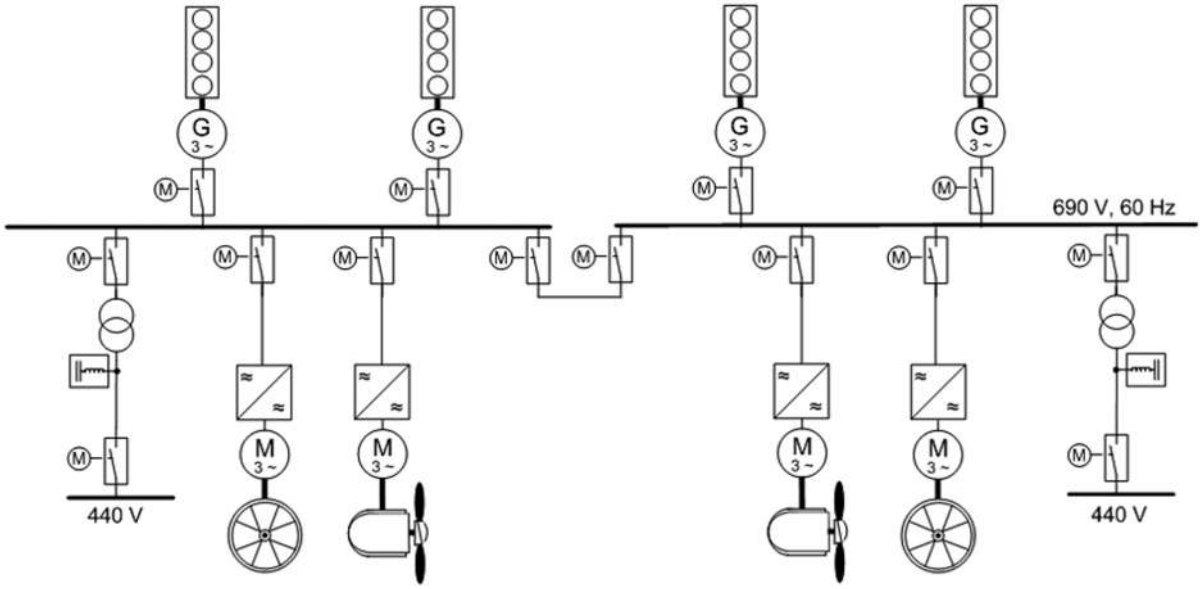


Figure 176: Example: Electric propulsion configuration of a PSV

In offshore applications often frequency converters with a 6-pulse configuration or with an active front end are used, which give specific benefits in the space consumption of the electric plant, as it is possible to get rid of the heavy and bulky supply transformers.

Type of converter/drive	Supply transformer	Type of E-motor	Pros & cons
6 pulse drive or active front end	-	Induction	+ Transformer less solution + Less space and weight – THD filters to be considered

Table 167: Main DE-components for offshore applications

LNG Carriers

A propulsion configuration with two E-motors (e.g. 600 rpm or 720 rpm) and a reduction gearbox (twin-in-single-out) is a typical configuration, which is used at LNG carriers where the installed alternator power is in the range of about 40 MW. The electric plant fulfils high redundancy requirements. Due to the high propulsion power, which is required and higher efficiencies, mainly synchronous E-motors are used.

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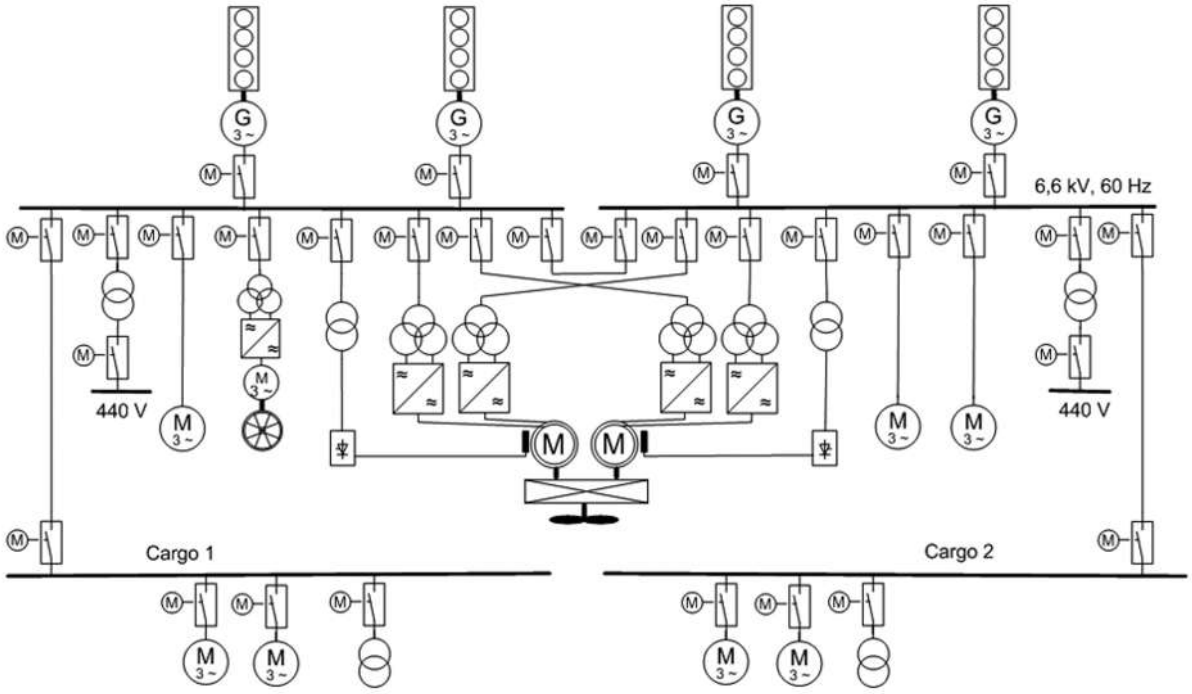


Figure 177: Example: Electric propulsion configuration of a LNG carrier with geared transmission, single screw and fixed pitch propeller

Type of converter/drive	Supply transformer	Type of E-motor	Pros & cons
VSI with PWM	24 pulse	Synchronous	+ High propulsion power + High drive & motor efficiency + Low harmonics – Complex E-plant configuration

Table 168: Main DE-components for a LNG carrier

For ice going carriers and tankers also podded propulsion is a robust solution, which has been applied in several vessels.

Cruise ships and ferries

Passenger vessels – cruise ships and ferries – are an important application field for electric propulsion. Safety and comfort are paramount. New regulations, as “Safe Return to Port”, require a high reliable and redundant electric propulsion plant and also onboard comfort is of high priority, allowing only low levels of noise and vibration from the ship´s machinery.

A typical electric propulsion plant is shown in the example below.

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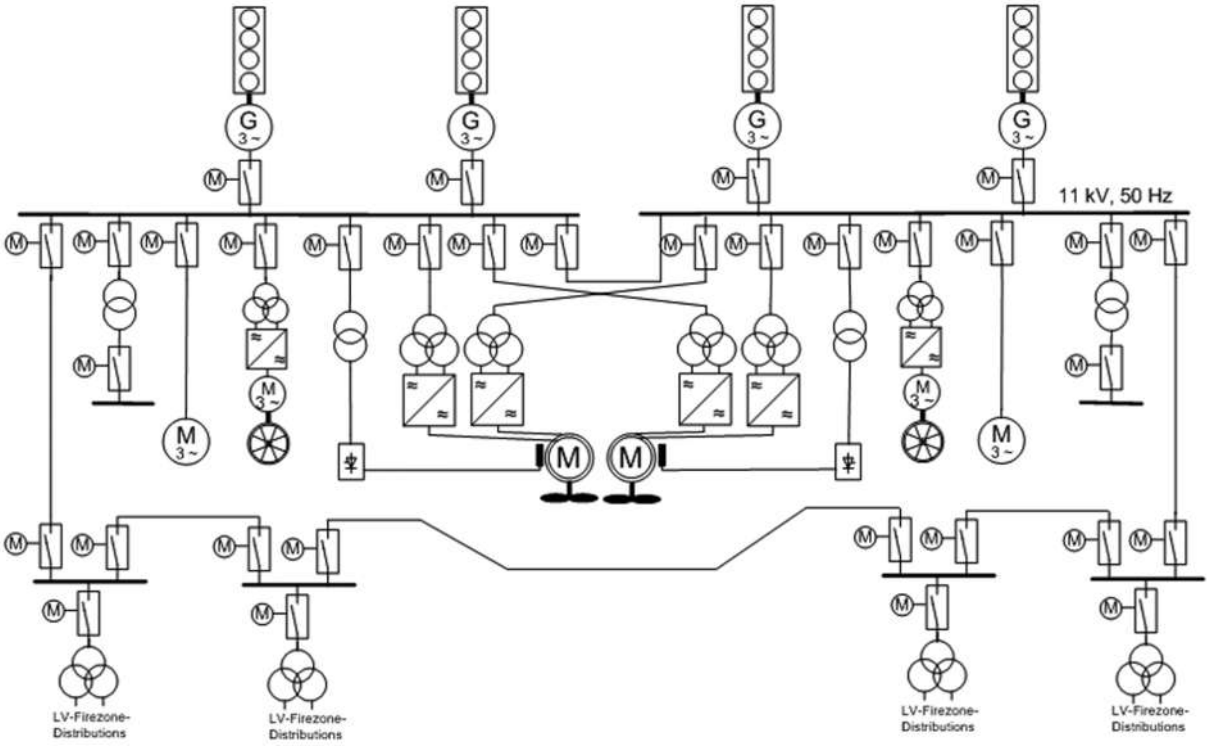


Figure 178: Example: Electric propulsion configuration of a cruise liner, twin screw, gear less

Type of converter/drive	Supply transformer	Type of E-motor	Pros & cons
VSI with PWM	24 pulse	Synchronous (e.g. slow speed 150 rpm)	+ Highly redundant & reliable + High drive & motor efficiency + Low noise & vibration – Complex E-plant configuration

Table 169: Main DE-components for a cruise liner

For cruise liners often also geared transmission is applied as well as pods.

For a RoPax ferry almost the same requirements are valid as for a cruise liner.

The figure below shows an electric propulsion plant with a “classical” configuration, consisting of E-motors (e.g. 1,200 rpm), geared transmission, frequency converters and supply transformers.

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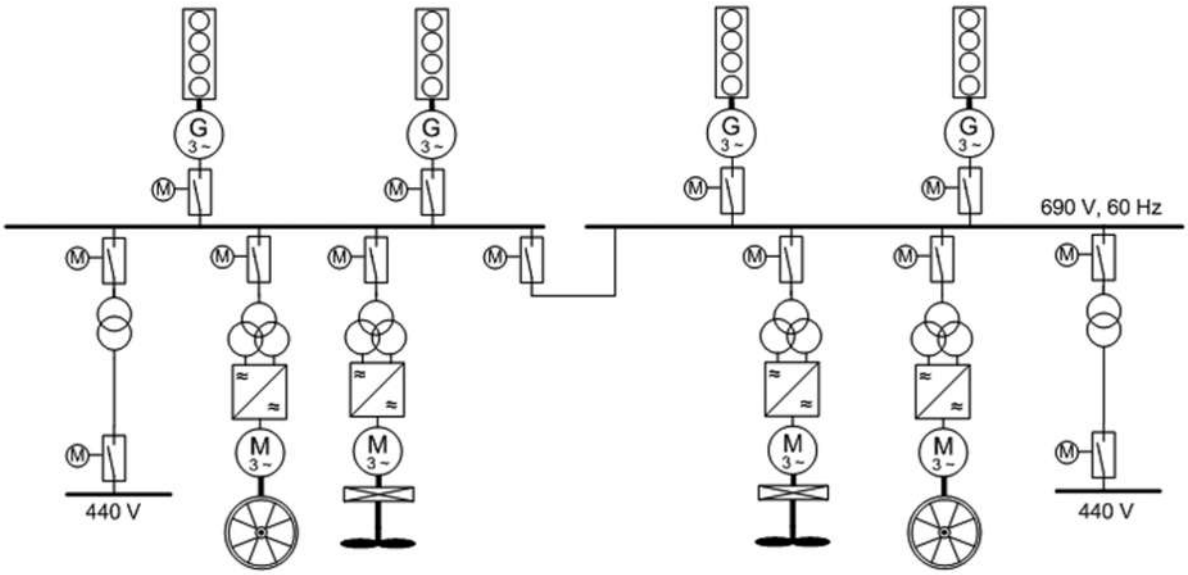


Figure 179: Example: Electric propulsion configuration of a RoPax ferry, twin screw, geared transmission

Type of converter/drive	Supply transformer	Type of E-motor	Pros & cons
VSI-type (with PWM technology)	12 pulse, two secondary windings, 30° phase shift	Induction	+ Robust & reliable technology + No seperate THD filters – More space & weight (compared to transformer less solution)

Table 170: Main DE-components for a RoPax ferry

Low loss applications

As Everllence works together with different suppliers for electric propulsion plants an optimal matched solution can be designed for each application, using the most efficient components from the market. The following example shows a low loss solution, patented by STADT AS (Norway).

In many cases a combination of an E-propulsion motor, running on two constants speeds (medium, high) and a controllable pitch propeller (CPP) gives a high reliable and compact solution.

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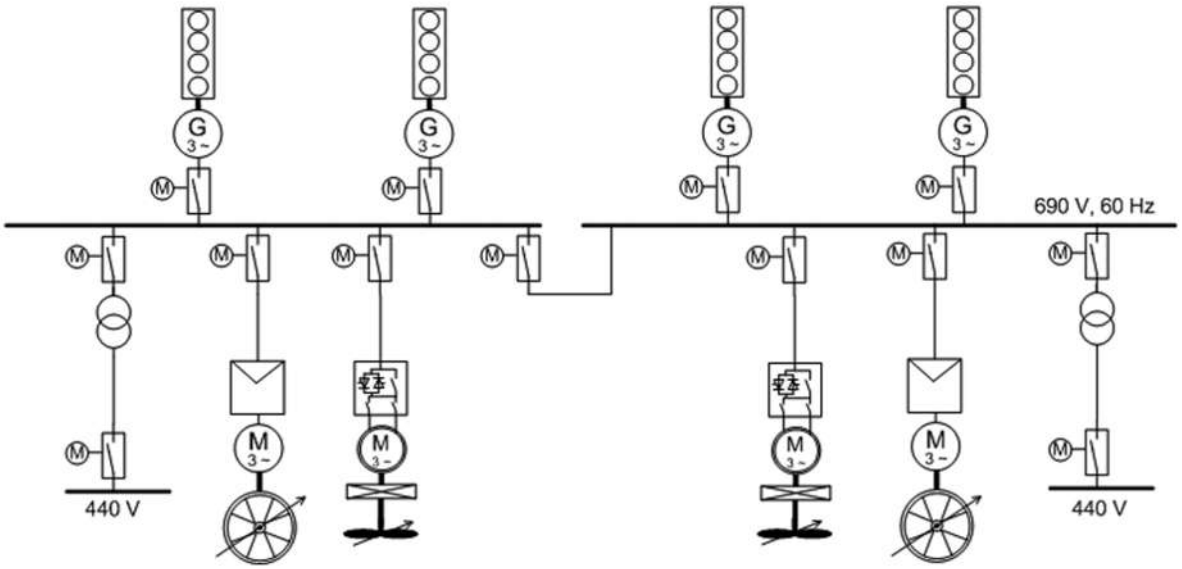


Figure 180: Example: Electric propulsion configuration of a RoRo, twin screw, geared transmission

Type of converter/drive	Supply transformer	Type of E-motor	Pros & cons
Sinusoidal drive (patented by STADT AS)	-	Induction (two speeds)	+ Highly reliable & compact + Very low losses + Transformer less solution + Low THD (no THD filters required) – Only applicable with a CP propeller

Table 171: Main DE-components of a low loss application (patented by STADT AS)

7.10 High-efficient electric propulsion plants with variable speed GenSets (EPROX-AC)

Variable speed power generation can provide significant fuel savings with electric propulsion when the operational profile of the vessel has a lot of variation in speed and power demand. Recent developments in the electric plant show solutions for adjusting the rotational speed of the main diesel engines, which allow the system frequency to vary within a range of 48 – 60 Hz. The main power system of the ship is specially engineered for variable frequency. Distribution for the auxiliary and hotel loads is provided by frequency convert especially when the total power demand is in range, where a medium voltage solution is required such a system concept can be applied.

The shift from constant speed to variable speed diesel engine operation results in a high fuel-oil efficiency at each system load. Such a solution enables a decoupled operation of diesel engines, propulsion drives and the consumers, as the power sources and hotel loads can be controlled and optimised independently.

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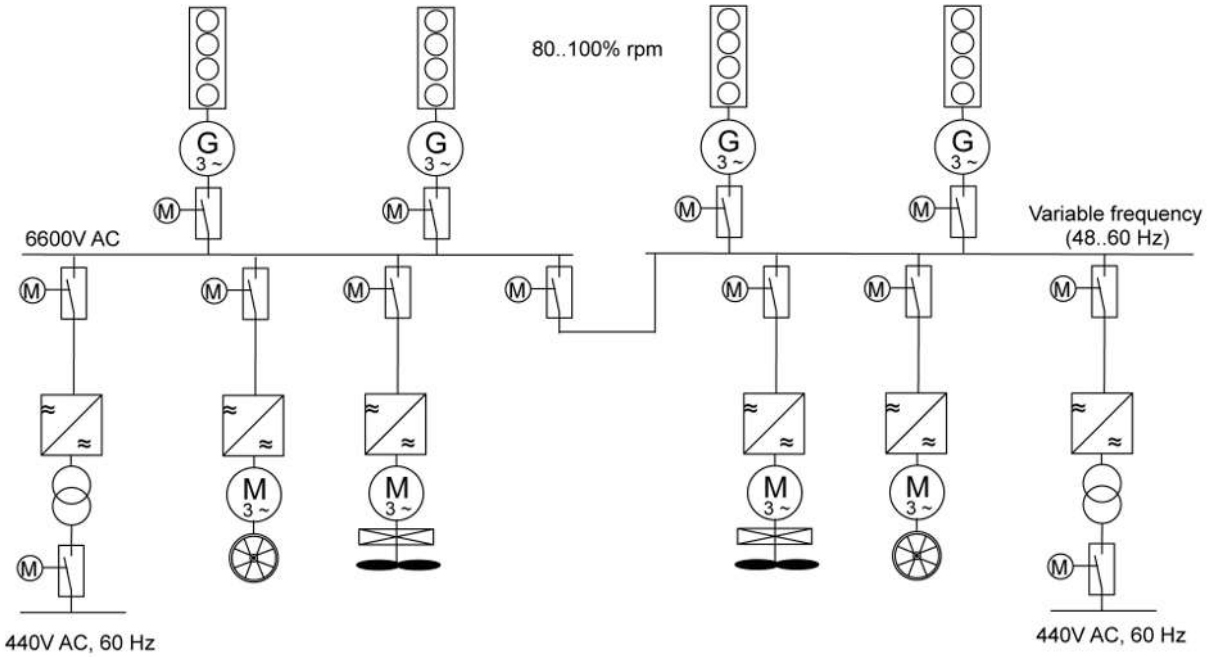


Figure 181: Example: High-efficient electric propulsion plant based on a main switchboard operated with variable frequency

Constant speed operation for the GenSets is no longer a constraint. When the main engines run at constant rpm, fuel efficiency is compromised. Utilising an enlarged engine operation map with a speed range of 80 % to 100 % paves the way to a high potential in fuel oil saving. According to the total system load all diesel engines can operate at a common floating speed set point.

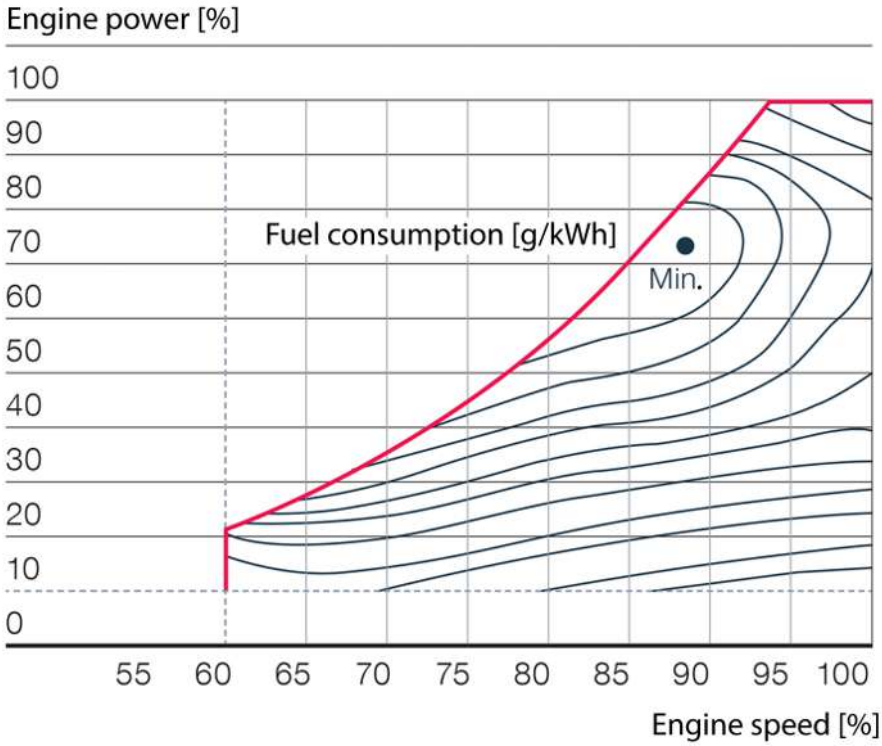


Figure 182: Typical SFOC map for a four-stroke medium-speed diesel engine (for illustration purpose only)

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The efficiency of the system can be even increased when energy storage devices, like batteries, are integrated. They can reduce the transient loads on the engines, improve the dynamic system response and the maneuverability of the propulsion system and absorb rapid power fluctuations from the vessel ´s grid. Fast load applications are removed from the engines and peak loads are shaved.

It is also beneficial to run the engines always on high loads, where the specific fuel oil consumption is lowest. This degree of freedom can be utilised and surplus power can charge the batteries. If less power is required, one engine can be shut down, with the remaining ones running still with a high loading, supported by power of the batteries.

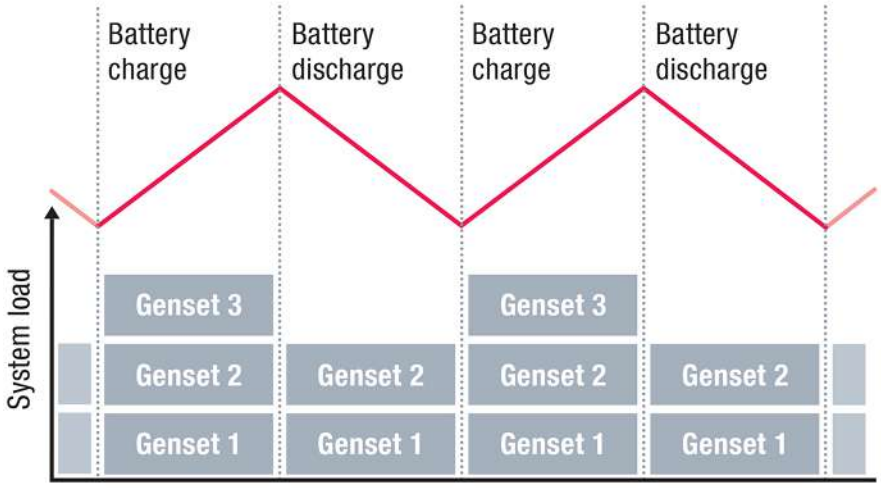


Figure 183: Batteries enable the diesel engines to operate at a high loading respectively with low specific fuel oil consumption

7.11 Fuel-saving hybrid propulsion system (HyProp ECO)

For many applications a hybrid propulsion system is a good choice, especially when flexibility, performance and efficiency are required. With HyProp ECO a system solution has been developed, which combines a diesel engine and an electric machine in a smart manner.

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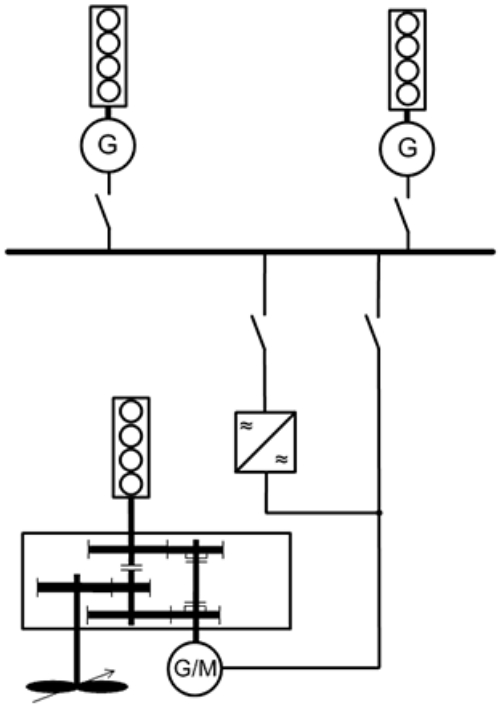


Figure 184: Principal layout of a HyProp ECO propulsion system

Beside the main diesel engine, the auxiliary GenSets, a 2-step reduction gearbox and the CP propeller a reversible electric machine, a frequency converter and a by-pass are the key components of the system. With this many operation modes can be achieved. When operating the system via the by-pass the normal PTO and PTI-boosting modes can be applied without any losses in the transmission line to/from the main switchboard. Utilising the frequency converter is done for two different purposes. Either it is used for starting-up the electric machine as emergency propulsion motor (PTH) in case the main engine is off. Usually the 2nd step in the gearbox is then used. Or the converter is of a bi-directional type and the propeller can be operated very efficiently at combinator mode with the PTO running in parallel with the auxiliary GenSets with a constant voltage and frequency towards the main switchboard. In this mode the converter can also be used for electric propulsion as variable speed drive for the propeller.

The major advantage of HyProp ECO is that costly components, like the frequency converter can be designed small. A typical figure for its size is 30 % of the installed alternator/motor power as for almost all modes, where the converter is involved, the required power is much lower compared to a design for pure PTO/PTI purposes. Therefore HyProp ECO combines lowest investment with optimised performance.

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8 Annex

8.1 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.

8.1.1 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 Everllence 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.

8.1.2 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.

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- 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.

  The engine room ventilation must ensure a maximum engine room temperature, with following boundary conditions:

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

  – Maximum air temperature at least 5 K below the flash point of any liquids, that is present within the engine room.

- Venting of crankcase and turbocharger

  With crankcase ventilation the gases/vapours originating from crankcase and turbocharger are not ignitable. 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

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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.

- 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 274 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

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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.

- 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.

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Figure 185: 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.

8.2 Programme for Factory Acceptance Test (FAT)

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1 Purpose

This instruction specifies the standard of tests and checks to be carried out during Factory Acceptance Tests (FAT) of marine engines. The following tests and checks are based on the rules and regulations of the classification societies as well as the ISO standards 3046 and 15550 in their versions at the time when this instruction is published and which have to be conducted 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 respective manager has to ensure that the employees know and observe this instruction. It is valid for marine applications of medium-, and high speed engines with a nominal speed up to 1000rpm and engine driving generators.

Valid for the following locations: Augsburg; Aurangabad; Saint-Nazaire

Valid for the following business units: SBU E

Valid for the following departments: FR-EE; RM-IN-PE; PEAA

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 a test bed requires several days. Therefore, the test is separated into 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 demonstration test is to verify the engine quality and observance of contractually agreed terms and conditions in presence of classification society and customer. For each engine, an engine specific procedure for the demonstration test has to be generated based on the tests and checks of point 4.2 of this instruction and contractual agreements with the customer. Additional test requests by the classification society have to be considered in the test 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 into tests and checks to be carried out prior to the first engine start and subsequent checks during engine operation. The main focus is to detect and fix technical issues and adjust the engine before starting the demonstration tests. Some checks of the pre-tests are required by classification rules. Before conducting these tests the corresponding surveyor of the classification society has to be informed about the pre-test date in time.

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Figure 186: Programme for Factory Acceptance Test (FAT) – Part 1

4.1.1 Main tests and check before first engine start

a) check crank web deflection after alignment of the engine (results to be stated in FAT protocol)
b) flushing of all media systems (lube oil, fuel oil, water)
c) visual check of engine including cam shaft and crank shaft housing (before first engine start and subsequently during operation)
d) test of alarm and safety system. The requirements of the classification society and engine manufacturer specification (check of safety functions F0387EN) must be fulfilled. The test results must 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 the engine manufacturer. The internal testing of engines is generally specified in the Guideline “F0387EN” of the engine manufacturer. The following points represent the minimum of tests to be conducted to ensure the functionality and performance of the engine.

a. Start of tests and calculation of start air consumption in gas and diesel operation. To be done at least once per shipset for each engine type. The results have to be stated in each FAT protocol for reference.
b. Thermographic inspection (according to working instruction W0202EN - Surface Temperature Examination on Engines and Components for Marine Application) of engine insulation for confirmation of SOLAS surface temperature requirements.
c. Noise level and vibration measurements according to ISO 10816-6 and manufacturer guidelines (only to be carried out and stated in the FAT protocol if there is a contractual obligation).
d. Integration tests to be conducted on each engine, except if the tests have already been conducted on an identical engine of the same vessel or a sister vessel (same yard, same shipping company, same type of vessel). The scope of the tests has to be agreed upon with the classification society for selected cases based on the FMEA required in UR M44/M78 of IACS. For the alarm and safety system, an engine-independent test is carried out in advance and witnessed by the classification society. In the case of the FAT, only engine-related tests, such as the injection module failures, are additionally witnessed.
e. Performance Check: The engine performance is to be tested at the load points listed in table 1. Further information can be found under point 4.3 of this instruction. Performance readings must be stated in the FAT protocol. The specific fuel consumption has to be recorded an calculated to ISO-conditions in all load points, except in idle operation.
f. Governor test (load drop): Sudden load drop from full load to zero load. Results must be stated in the FAT protocol.
g. Check of attached engine flaps and valves (blow off, blow by, waste gate, jet assist).
h. Visual check for leakages on fuel oil, lube oil and water systems of the engine (check of connecting flanges, screw connections and inspection drillings).
i. Surge test of turbocharger on new engine configurations during the turbocharger-matching process. Results not to be stated in the FAT protocol.
j. Cylinder liner inspection (only engines ≥ 32cm liner diameter) of one cylinder liner per engine by borescope. Evaluation of the cylinder liner surface according to Q10.09121-3325 “Visual Test Cylinder Liner Inspection after Running-In”. In case of additional inspections (e.g. dismantling of piston) during demonstration tests the borescope inspection is omitted.)

Figure 187: Programme for Factory Acceptance Test (FAT) – Part 2

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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. The demonstration test has to be done according to the engine-specific test procedure (demonstration test), confirmed by the classification society and customer. The test procedure has to be sent to the classification society and customer one-week prior to the demonstration test at the latest. The scope of the FAT-procedure (demonstration test) is based on the following standards:

a. Switch from liquid to gas operation and back at minimum and nominal load.
b. One gas start (only on dual fuel engines with gas start functionality)
c. Performance Check: The engine performance has to be tested on the load points listed in table 1. Further information can be found under point 4.3 of this instruction.
d. Visual check of crank case, camshaft, rollers and gear drive after engine stop.

Optional tests and inspections only by request of the 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) have to be tested on the generator curve. Engines for CPP-application and diesel-mechanic dredger application with propulsion function have to be tested on the recommend combinator curve of the engine manufacturer. Engines for diesel-mechanic propulsion application with fixed pitch propeller (exclusively mechanical pump drive) and water jet application have to be tested on the recommended FPP-curve of MAN-ES. Engines with ECOMAP function have to be tested on the standard full load map only. Additional mappings can be tested according to a contractual agreement with the 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. The calibrations have to fulfil the requirements given by the QM-system and the documentation of the calibration have to be available at any time . All performance data of the engines have to be within the specification limits (documents: List of measuring and control devices, quality criteria of engine) of the engine manufacturer. The performance readings have to be conducted according to the specified instructions of the engine manufacturer.

Figure 188: Programme for Factory Acceptance Test (FAT) – Part 3

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	Test points	Factory Acceptance Test (FAT)			
		Pre- Tests		Demonstration tests	
Diesel engines	100 %	-		60min*	
	110 %	-		M	
	85% (nominal continuous cruise power)**	-		M	
	Minimum speed at full constant torque - (mechanical pump drive only)	-		M	
	75%	M		-	
	50%	M		-	
	25%	M		-	
	Idle*** (only engines driving generators)	M		-	
Dual Fuel (DF-) engines		Gas mode	Diesel mode	Gas mode	Diesel mode
	100%	-	-	60min*	60min*
	110%	-	-	-	M
	85% (nominal continuous cruise power)**	-	-	M	M
	75%	M	M	-	-
	50%	M	M	-	-
	25%	M	M	-	-
	Idle*** (only engines driving generators)	-	M	-	-

* 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

For all trial conditions provision should be made for time needed by the Surveyor to carry out visual inspections

Table 1: Engine performance check

Figure 189: Programme for Factory Acceptance Test (FAT) – Part 4

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4.4 Handling of quality issues

A major purpose of the engine test run is to find and to fix potential quality issues during the pre-tests of the engine (before FAT). All quality issues are generally to be handled according to the official process for quality assurance of the engine manufacturer. With the beginning of the engine FAT all quality issues should have been solved. In case of any open issues, customer and classification society have to be informed prior the beginning of the FAT. Existing and upcoming quality issues during FAT have to be documented in the FAT protocol. Measures to fix these quality issues have to be defined by the manufacturer with agreement of customer and classification society.

During FAT the quality of the product (engine, Genset) has to be inspected as a final step before delivery. The goal is to conduct the engine operation without any unexpected alarm, shut down or load reduction. It has to be ensured that the engine functionality is given as expected and applicable regulations (class rules, emission rules) and contractual agreements are fulfilled. Any abnormalities which might led to functional impact during further engine operation on board have to be eliminated before the engine is handed over to the customer.

In case of any changes needed after delivery of the engines (e.g. change of components, software), this must be implemented latest during commissioning. These changes and elimination of the failure has to be ensured and documented by the commissioning staff of the engine manufacturer.

4.5 After engine operation

After finishing the test program, the engine has to be preserved according to working instruction W0176EN. The fuel delivery system of diesel-mechanic drives has to be adjusted so that overload power cannot be delivered during engine operation on board. Engines driving electrical generators have to be adjusted so that 110% rated power is possible.

4.6 FAT – protocol

All operations, events, findings, further measures and agreements have to be documented in one and the same 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 information:

- Cover sheet
- Signature sheet with representatives
- Operating record for all engine operation points
- Information about the fuel oil characteristics
- 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
- Crank web deflection measurement for cold condition (check of alignment on test bed)
- Emission-relevant identification numbers, software version numbers
- Firing pressure comparison
- Starting test incl. air consumption calculation of reference engine
- Characteristic NOx emission Map (only for variable speed engines and parent engine protocols)
- Operating data sheet to estimate the engine output
- Calibration informations about fuel oil, fuel gas and torque measurement devices

Figure 190: Programme for Factory Acceptance Test (FAT) – Part 5

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5 References - applicable documents always refer to the current version unless stated otherwise.

- IACS-regulations and regulations of classification societies
- ISO 15550, ISO 3046, ISO 10816-6
- F0387EN Checklist for Rigging Up, Connecting, Commissioning, Performing the Test Run and Performing the Customer Acceptance Test for a Combustion Engine on the Test Bed
- W0202EN - Surface Temperature Examination on Engines and Components for Marine Application
- W0176EN Preserving Internal Engine Compartments of Medium-Speed Four-Stroke Diesel Engines after Test Run
- W0221EN Sampling of Fuel Oil
- Instruction I0158 - Guideline for Conducting a Measurement at the Test Beds (only for use of EDS-System)
- Q10.09054-0005 - Fuel Oil Consumption Measurement of Diesel Engines on Test Bed
- Q10.09121-3325 - Visual Test Cylinder Liner Inspection after Running-In

6 Annexes

The annexes always refer to the current version unless not stated otherwise.

- Annex 1 example of engine performance reading

Figure 191: Programme for Factory Acceptance Test (FAT) – Part 6

8.3 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 dam-

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age (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

Liquid fuel engines

The running-in period may be carried out preferably using DMA or DMB.

The fuel used must meet the quality standards see section Specification for engine supplies, Page 239 and the design of the fuel system.

Dual fuel engines

Dual fuel engines are run in using liquid fuel mode with the fuel intended as the pilot fuel.

Gas fuel engines

For the running-in of gas four-stroke engines it is best to use the gas which is to be used later in operation.

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 483. 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.

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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 or no-load operation at higher speeds for long periods should be avoided if at all possible.

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 59.

Note:
For further information, you may contact the Everllence customer service or the customer service of the licensee.

Diagrams of standard running-in

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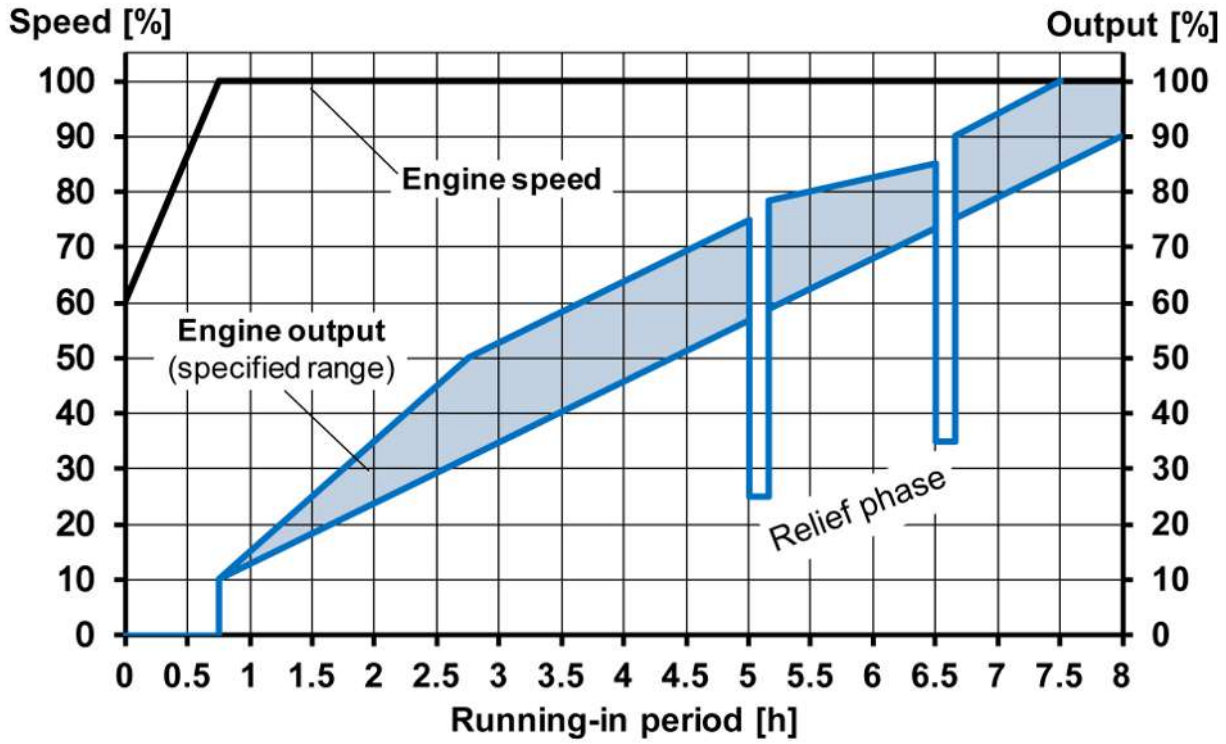


Figure 192: Standard running-in programme for engines operated with constant speed

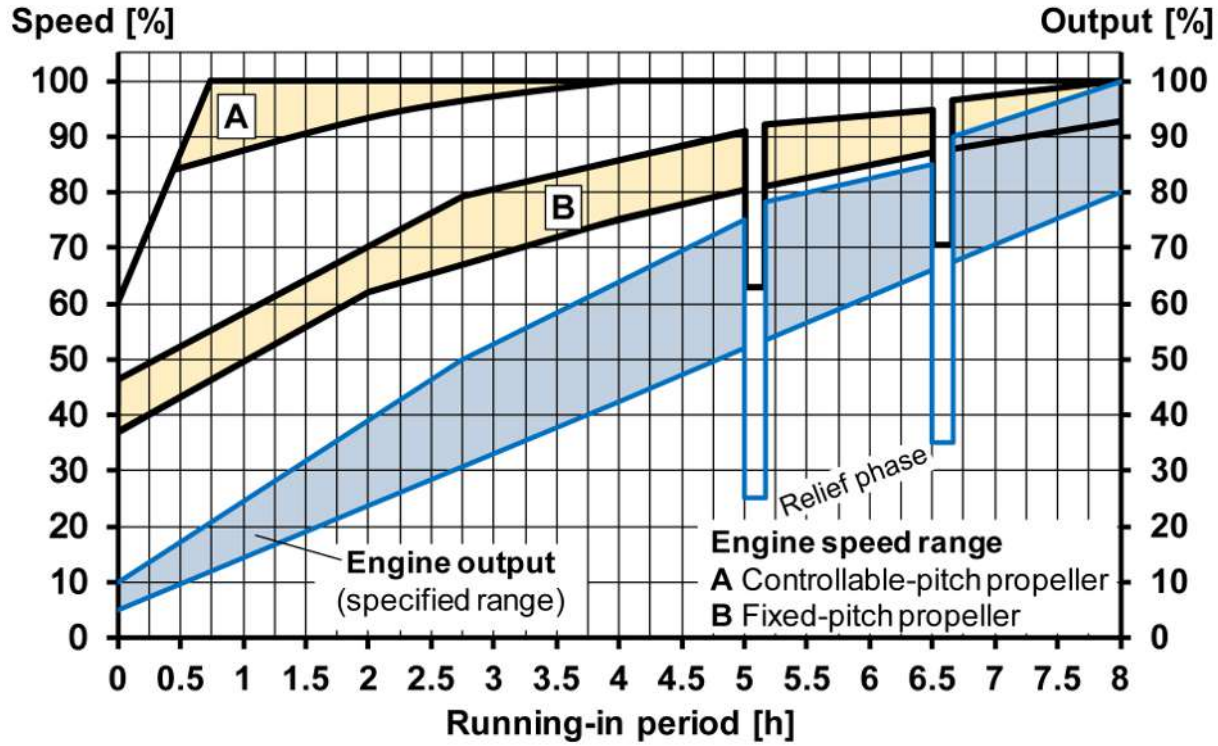


Figure 193: Standard running-in programme for marine engines (variable speed)

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8.4 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 40 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.

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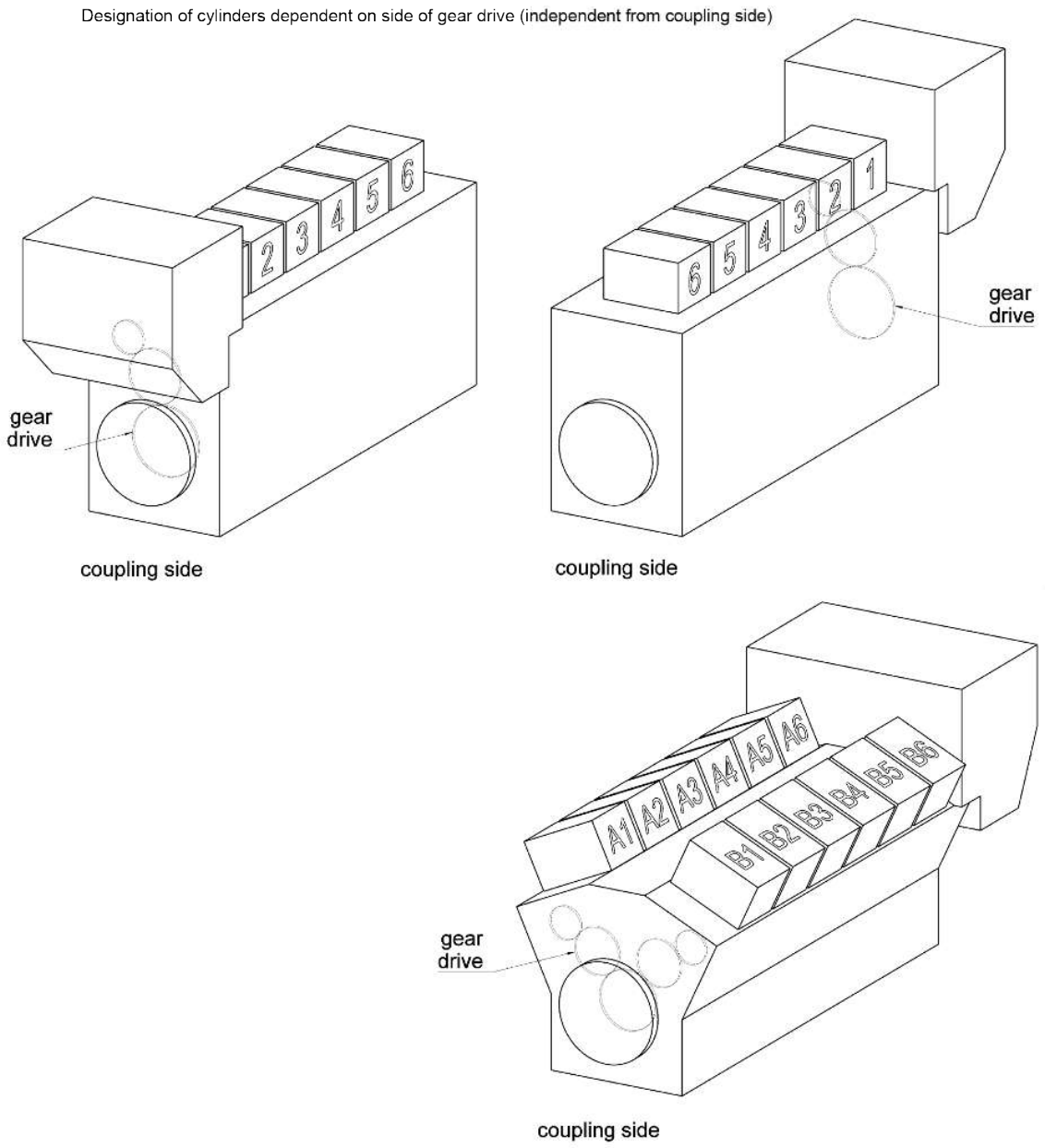


Figure 194: Designation of cylinders

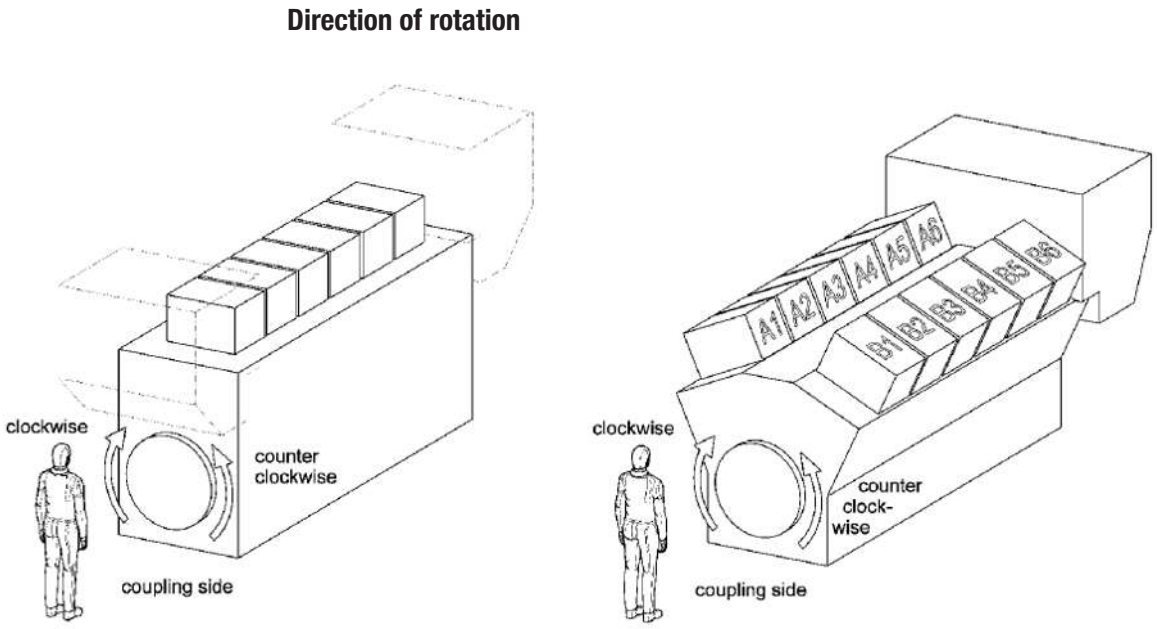


Figure 195: Designation - Direction of rotation

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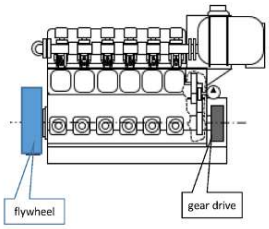
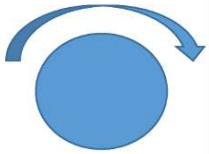
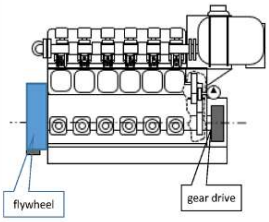
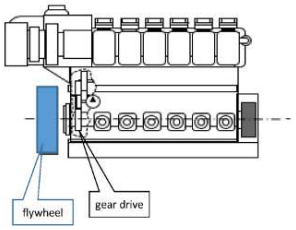
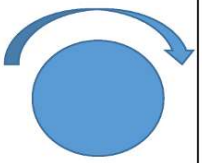
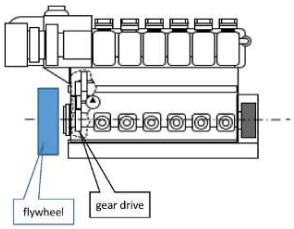
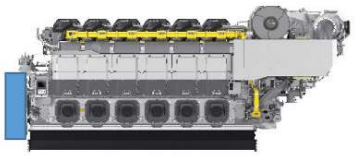
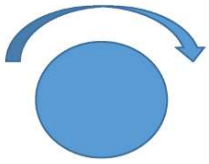
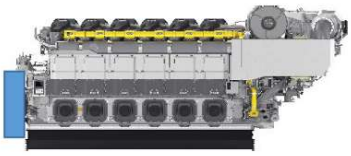
Engine Type	Type	Sideview of engine	View on Flywheel	Description
L-type	A			TC on CCS, turning clockwise
L-type	B			TC on CCS, turning counter-clockwise
L-type	C			TC on CS, turning clockwise
L-type	D			TC on CS, turning counter-clockwise
V-Type	A			TC on CCS, turning clockwise
V-Type	B			TC on CCS, turning counter-clockwise

Figure 196: Direction of rotation for different engine types

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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 40 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.

Idling operation

Idling/Idling operation refers to operation:

- Before the engine is coupled to the propulsion system or to the mechanical dredge pump
- Of the GenSet with open Genoswitch

A distinction is made between:

- Idling at minimum speed and
- Idling at rated speed

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 40 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 40 if the engine is released for this kind of application and the corresponding available output $P_{Application}$.

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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.

No-load operation

As soon as the engine has been coupled, or a GenSet with closed Geno switch has been connected to electrical grid and no load has yet been delivered, this is named as no-load operation.

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.

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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 Everllence personal.

Single-engine propulsion plant

In a single-engine propulsion plant only one single-engine is available for propulsion.

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 40 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 40 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.

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8.5 Abbreviations

Abbreviation	Explanation
BN	Base number
CBM	Condition based maintenance
CCM	Crankcase monitoring system
CCS	Counter coupling side
CS	Coupling side
DLC	Data Logging Cabinet
DMA	Gas oil
DMB	Diesel oil
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
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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8.6 Symbols

Note:
The symbols shown should only be seen as examples and can differ from the symbols in the diagrams.

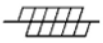
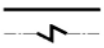
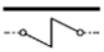
DESIGNATION	SYMBOL	CODE	DESIGNATION	SYMBOL	CODE
MAIN CIRCUIT (FLOW DIRECTION SHOWN)			FLEXIBLE PIPE CONNECTION		EH
SECONDARY CIRCUIT			EXPANSION BELLOWS (STEEL)		EB
CONTROL AIR PIPE, PULSE LINE, ELECTRICAL LINE			2/2 (TWO-PORT, TWO-POSITION) DIRECTIONAL CONTROL SOLENOID-OPERATED VALVE		
CAPILLARY TUBE (WITH THERMOSTATIC REGULATORS)			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 197: Symbols used in functional and pipeline diagrams 1

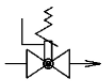
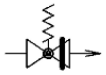
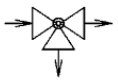
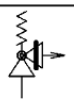
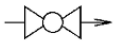
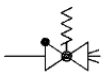
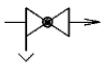
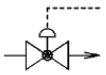
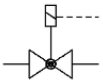
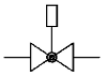
DESIGNATION	SYMBOL	CODE	DESIGNATION	SYMBOL	CODE
ANGLE VALVE		V	GENERAL SHUT-OFF VALVE, MOTOR DRIVEN		MOV
VALVE WITH MINIMUM FLOW		V	QUICK ACTING SHUT-OFF VALVE		V
GENERAL THREE-WAY VALVE		CK	SAFETY VALVE (STRAIGHT WAY)		PSV
THREE-WAY VALVE		V	SAFETY VALVE (ANGLE)		PSV
COCK		CK	BACK PRESSURE VALVE (STRAIGHT 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 198: Symbols used in functional and pipeline diagrams 2

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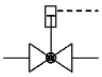
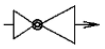
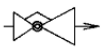
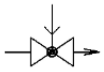
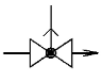
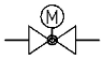
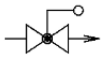
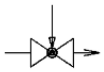
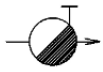
DESIGNATION	SYMBOL	CODE	DESIGNATION	SYMBOL	CODE
PISTON-OPERATED VALVE		POV	PRESSURE REDUCING VALVE		PCV
SHUTTLE VALVE WITH DRIVE PISTON		POV	PRESSURE CONTROL VALVE		PCV
SELF-CLOSING VALVE (STRAIGHT WAY)		QV	TEMPERATURE REGULATOR (SELF-ACTUATING DISTRIBUTION VALVE)		TCV
SELF-CLOSING VALVE (ANGLE)		QV	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 199: Symbols used in functional and pipeline diagrams 3

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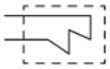
DESIGNATION	SYMBOL	CODE	DESIGNATION	SYMBOL	CODE
PLUG-IN HEATER (STEAM OR WATER)		H	SUCTION STRAINER		STR
PLUG-IN HEATER (ELECTRIC)		H	SUCTION BELL		SB
BACKFLOW PREVENTER (DISCOTYP)		NRV	FLAME TRAP		GS
NON-RETURN FLAP		NRF	VENT		
STRAINER		STR	VENT WITH FLAME TRAP		
FUNNEL (OPEN)		FU	VENT, OUTBOARD ABOVE DECK		
FUNNEL (CLOSED)		FU	VENT CAP		
OVERFLOW CHECK TANK, DISCHARGE FUNNEL		FU	Withdrawal point for fuel oil sample		

Figure 200: Symbols used in functional and pipeline diagrams 4

8.7 Preservation, packaging, storage

8.7.1 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.

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

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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 (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 Everllence must be notified immediately.

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8.7.2 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 Everllence 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.

8.7.3 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 Everllence.

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8.7.4 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 Everllence if you have any questions.

8.8 Engine colour

Engine standard colour according RAL colour table is RAL 7040 Window grey. Other colours on request.

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