WÄRTSILÄ Engines

Wärtsilä 32

PRODUCT GUIDE

Introduction

This Product Guide provides data and system proposals for the early design phase of marine engine installations. For contracted projects specific instructions for planning the installation are always delivered. Any data and information herein is subject to revision without notice. This 1/2023 issue replaces all previous issues of the Wärtsilä 32 Project Guides.

Issue	Published	Updates
1/2023	02.06.2023	Chapter Automation updated, other minor updates throughout the guide.
2/2021	27.5.2021	Lubricating oil and automation updated, InfoBoard download function enabled.
2/2021	10.5.2021	Lubricating oil and automation updated
1/2021	15.03.2021	Technical data updated. Other minor updates throughout the guide.
1/2019	12.12.2019	Technical data updated. Other minor updates throughout the guide.
1/2018	14.03.2018	Technical data updated. Other minor updates throughout the guide.
1/2017	05.01.2017	Technical data updated. Other minor updates throughout the guide.
3/2016	16.12.2016	Engines with output 480 and 500 kW/cylinder removed. Technical data updated. Arctic material for cooling water system added.
2/2016	07.09.2016	Technical data updated
1/2016	06.09.2016	Technical data updated
2/2015	11.09.2015	Information for operating in arctic conditions updated.
1/2015	25.02.2015	Material for air assist and operation in Arctic conditions added. Other updates throughout the product guide.

Wärtsilä, Marine Business

Vaasa, May 2023

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1. Main Data and Outputs

The Wärtsilä 32 is a 4-stroke, non-reversible, turbocharged and intercooled diesel engine with direct fuel injection.

Cylinder bore .... 320 mm

Stroke .... 400 mm

Piston displacement .... 32.2 l/cylinder

Number of valves .... 2 inlet valves
2 exhaust valves

Cylinder configuration .... 6, 7, 8 and 9 in-line
12 and 16 in V-form

V-angle .... 55°

Direction of rotation .... Clockwise, counterclockwise on request

Speed .... 720, 750 rpm

Mean piston speed .... 9.6, 10.0 m/s

1.1 Maximum continuous output

Table 1-1 Rating table for Wärtsilä 32

Cylinder configuration	Main engines	Generating sets				Dredger
	750 rpm	720 rpm		750 rpm		750/ 775 rpm
	Engine [kW]	Engine [kW]	Generator [kVA]	Engine [kW]	Generator [kVA]	Engine [kW]
W 6L32	3480	3360	4030	3480	4180	3120
W 7L32	4060	3920	4700	4060	4870	3640
W 8L32	4640	4480	5380	4640	5570	4160
W 9L32	5220	5040	6050	5220	6260	4680
W 12V32	6960	6720	8060	6960	8350	6240
W 16V32	9280	8960	10750	9280	11140	8320

The mean effective pressure Pe can be calculated as follows:

$$P_e = \frac{P \times c \times 1.2 \times 10^9}{D^2 \times L \times n \times \pi}$$

where:

Pe = mean effective pressure [bar]

P = output per cylinder [kW]

n = engine speed [r/min]

D = cylinder diameter [mm]

L = length of piston stroke [mm]

(continued)

c = operating cycle (4)

1.2 Reference conditions

The output is available up to an air temperature of max. 45°C.

For higher temperatures, the output has to be reduced according to the formula stated in ISO 3046-1:2002 (E).

The specific fuel oil consumption is available by using *Engine Online Configurator* available at Wärtsilä.com. The stated specific fuel oil consumption applies to engines with engine driven pumps, operating in ambient conditions according to ISO 15550:2016 (E). The ISO standard reference conditions are:

total barometric pressure	100 kPa
air temperature	25 °C
relative humidity	30 %

Correction factors for the fuel oil consumption in other ambient conditions are given in standard ISO 15550:2016 (E).

1.3 Operation in inclined position

The engine is designed to ensure proper engine operation at inclination positions. The starting point was the minimum requirements of the IACS M46.2 (1982) (Rev.1 June 2002) - Main and auxiliary machinery.

Max. inclination angles at which the engine will operate satisfactorily:

Table 1-2 Inclination with Normal Oil Sump

• Permanent athwart ship inclinations (list)	15°
• Temporary athwart ship inclinations (roll)	22.5°
• Permanent fore and aft inclinations (trim)	10°
• Temporary fore and aft inclinations (pitch)	10°

Table 1-3 Inclination with Deep Oil Sump

• Permanent athwart ship inclinations (list)	25°
• Temporary athwart ship inclinations (roll)	25°
• Permanent fore and aft inclinations (trim)	25°
• Temporary fore and aft inclinations (pitch)	25°

NOTE
- Athwartships and fore-end-aft inclinations may occur simultaneously - Inclination angles are applicable ONLY to marine main and auxiliary machinery engines. Emergency power installations are not currently available - If inclination exceeds some of the above mentioned IACS requirements, a special arrangement might be needed. Please fill in a NSR (Non-standard request)

1.4 Arctic package description

When a vessel is operating in cold ambient air conditions and the combustion air to the engine is taken directly from the outside air, the combustion air temperature and thus also the density is outside the normal range specified for the engine operation. Special arrangements are needed to ensure correct engine operation both at high and at low engine loading conditions. Read more about the special arrangements in chapters *Combustion air system design in arctic conditions*, *Cooling water system for arctic conditions* and *Lubricating oil system in arctic conditions*.

1.5 Dimensions and weights

1.5.1 Main engines

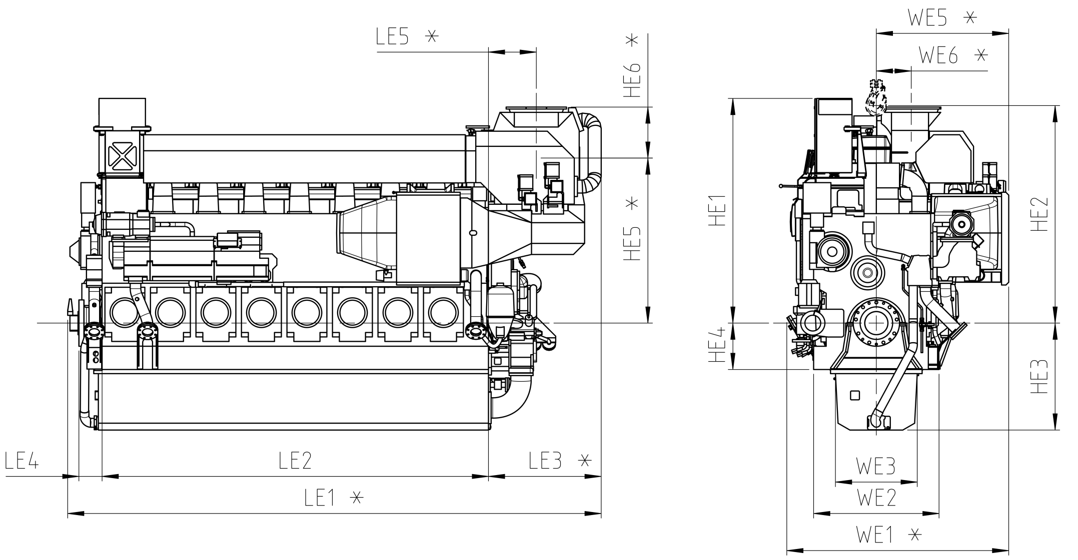


Fig 1-1 In-line engines (DAAF061578B)

Engine	LE1	LE2	LE3	LE4	LE5	HE1	HE2	HE3	HE4	HE5
W 6L32	5255	3670	1214	250	515	2423	2345	1153	500	1780
W 7L32	5745	4160	1214	250	515	2423	2345	1153	500	1780
W 8L32	6235	4650	1214	250	515	2423	2345	1153	500	1780
W 9L32	5725	5140	1214	250	515	2423	2345	1153	500	1780

Engine	HE6	WE1	WE2	WE3	WE5	WE6	Weight
W 6L32	550	2389	1350	880	1425	325	35.4
W 7L32	550	2389	1350	880	1425	325	39.7
W 8L32	550	2389	1350	880	1425	325	44.6
W 9L32	550	2389	1350	880	1425	325	48.7

* Turbocharger at flywheel end.Depending on engine configuration and selection of turbo charger

All dimensions in mm. Weight in metric tons with liquids (wet oil sump) but without flywheel.

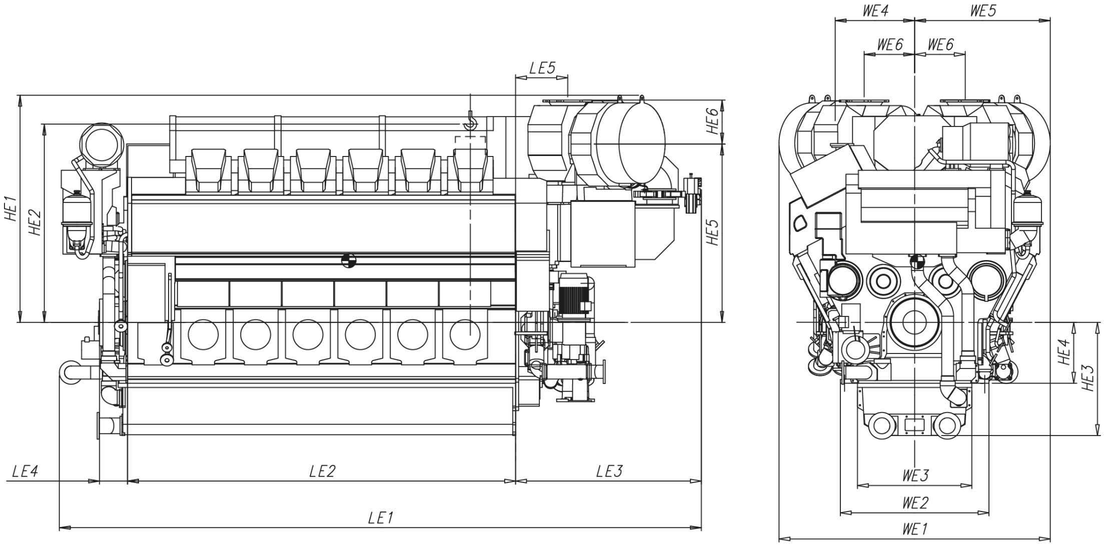


Fig 1-2 V-engines (DAAF062155)

Engine	LE1	HE1	WE1	HE2	HE4	HE3	LE2	LE4	WE3	WE2
W 12V32	6865	2430	2900	2120	650	1210	4150	300	1225	1590
W 16V32	7905	2595	3325	2120	650	1210	5270	300	1225	1590

Engine	WE5	LE3	WE4	HE5	HE6	WE6	LE5	Weight
W 12V32	1450	1985	850	1905	470	540	555	56.9
W 16V32	1665	1925	850	2020	550	575	560	71.1

* Turbocharger at flywheel end.

All dimensions in mm. Weight in metric tons with liquids (wet sump) but without flywheel.

Most current 2D drawings and 3D models of Engines and Gensets are available at www.wartsila.com and all dimensions and weights shown above are for reference only.

1.5.2 Generating sets

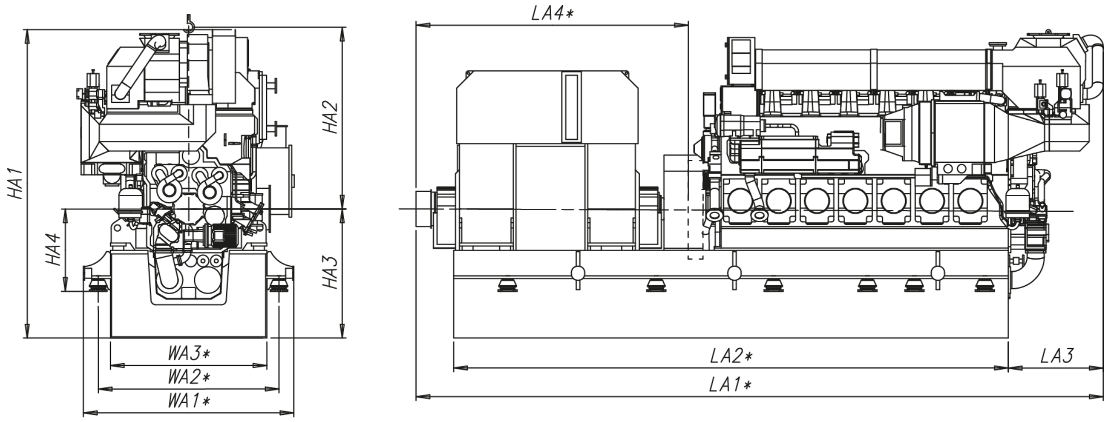


Fig 1-3 In-line engines (DAAF061592)

Engine	LA1*	LA3	LA2*	LA4*	WA1*	WA2*	WA3*	HA4	HA3	HA2	HA1	Weight**
W 6L32	8345	1215	6875	3265	2490	2110	1800	1046	1450	2345	3745	56.985
W 7L32	9927	1214	8100	3500	3120	2510	2200	1085	1780	2422	4202	65.10
W 8L32	10410	1285	8555	3710	2690	2310	2000	1046	1630	2345	4010	75.760
W 9L32	10505	1285	8870	3825	2890	2510	2200	1046	1630	2345	4010	85.650

* Dependent on generator and flexible coupling.

All dimensions in mm. Weight in metric tons with liquids.

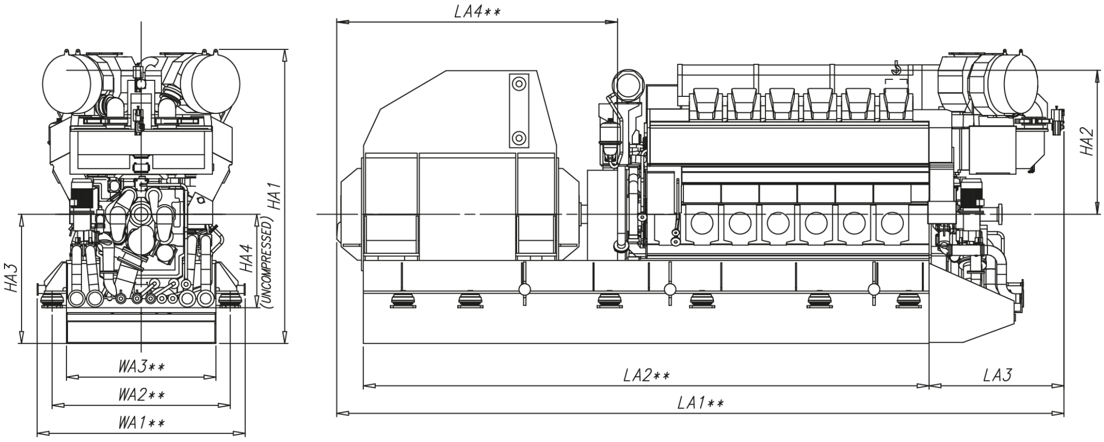


Fig 1-4 V-engines (DAAF061875)

Engine	LA1**	LA3	LA2**	LA4**	WA1	WA2	WA3	HA4	HA3	HA2	HA1	Weight**
W 12V32	10700	1985	8325	4130	3060	2620	2200	1375	1700	2120	4130	100.1
W 16V32	11465	1925	9130	4245	3360	2920	2500	1375	1850	2120	4445	127.3

** Dependent on generator and flexible coupling.

All dimensions in mm. Weight in metric tons with liquids.

Most current *2D* drawings and *3D* models of Engines and Gensets are available at www.wartsila.com and all dimensions and weights shown above are for reference only.

2. Operating Ranges

2.1 Engine operating modes

If the engine is configured for Selective Catalytic Reduction (SCR) use then it can be operated in two modes; IMO Tier 2 mode and SCR mode. The mode can be selected by an input signal to the engine automation system.

In SCR mode the exhaust gas temperatures after the turbocharger are actively monitored and adjusted to stay within the operating temperature window of the SCR.

2.2 Engine operating range

Running below nominal speed the load must be limited according to the diagrams in this chapter in order to maintain engine operating parameters within acceptable limits. Minimum speed is indicated in the diagram, but project specific limitations may apply.

2.2.1 Controllable pitch propellers

An automatic load control system is required to protect the engine from overload. The load control reduces the propeller pitch automatically, when a pre-programmed load versus speed curve (“engine limit curve”) is exceeded, overriding the combinator curve if necessary. The engine load is derived from fuel rack position and actual engine speed (not speed demand).

The propeller efficiency is highest at design pitch. It is common practice to dimension the propeller so that the specified ship speed is attained with design pitch, nominal engine speed and 85% output in the specified loading condition. The power demand from a possible shaft generator or PTO must be taken into account. The 15% margin is a provision for weather conditions and fouling of hull and propeller. An additional engine margin can be applied for most economical operation of the engine, or to have reserve power.

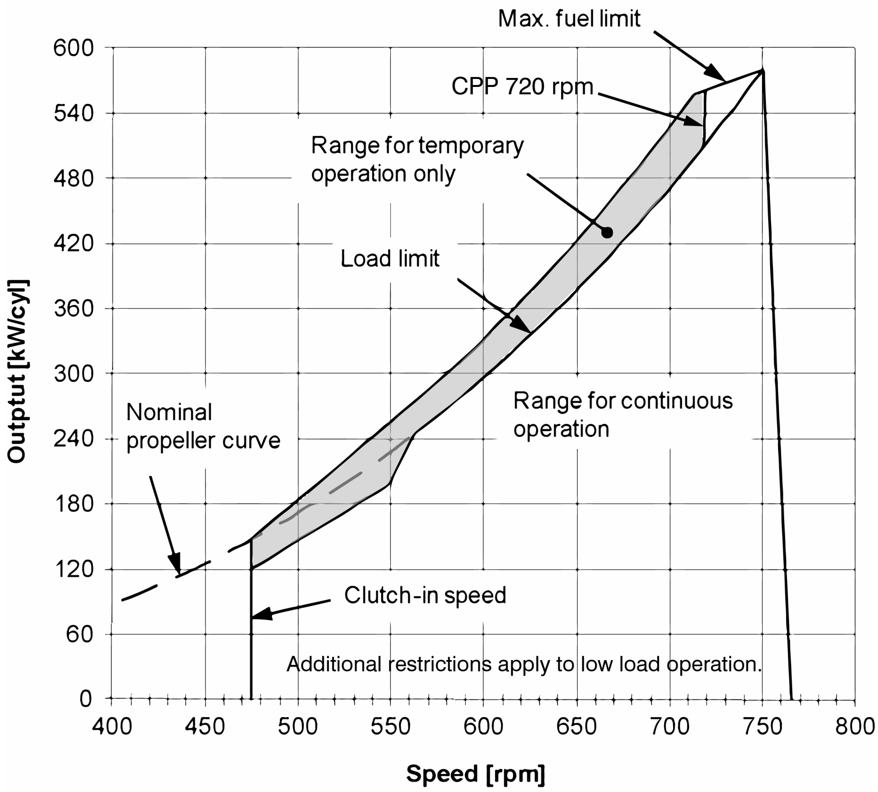
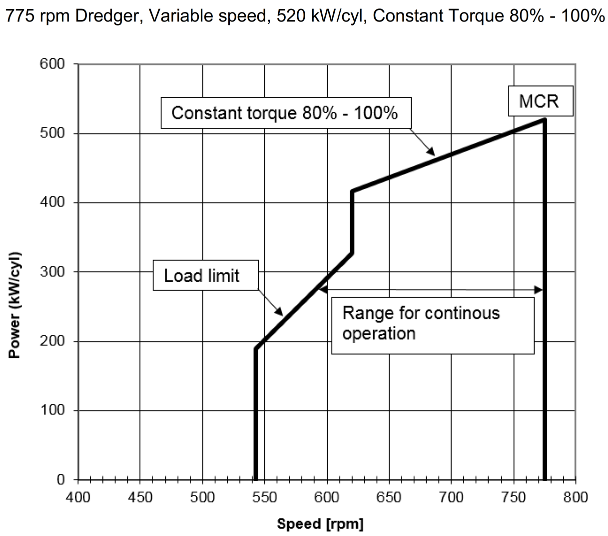
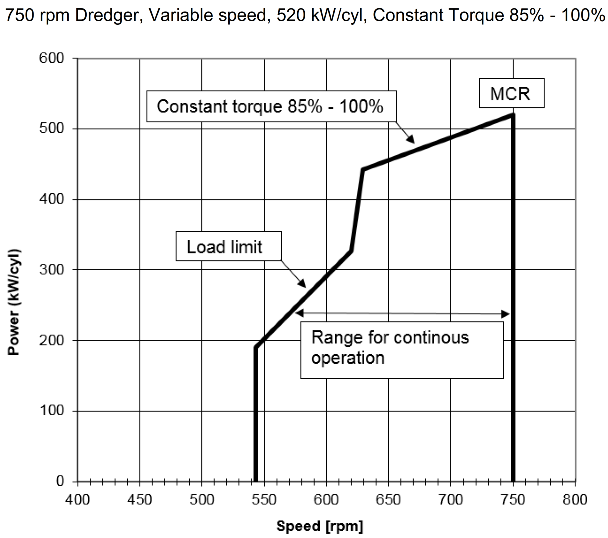


Fig 2-1 Operating field for CP Propeller, 580 kW/cyl, 750 rpm (DAAF023096B)

2.2.2 Dredgers

Mechanically driven dredging pumps typically require a capability to operate with full torque down to 80% of nominal engine speed. This requirement results in significant de-rating of the engine.





Output = Nominal cylinder output 520 kW at 100%
MCR = Maximum Continuous Rating

Fig 2-2 Operating field for Dredgers (DAAF362377)

2.3 Loading capacity

Controlled load increase is essential for highly supercharged diesel engines, because the turbocharger needs time to accelerate before it can deliver the required amount of air. A slower loading ramp than the maximum capability of the engine permits a more even temperature distribution in engine components during transients.

The engine can be loaded immediately after start, provided that the engine is pre-heated to a HT-water temperature of 70ºC, and the lubricating oil temperature is min. 40 ºC.

The ramp for normal loading applies to engines that have reached normal operating temperature.

2.3.1 Mechanical propulsion

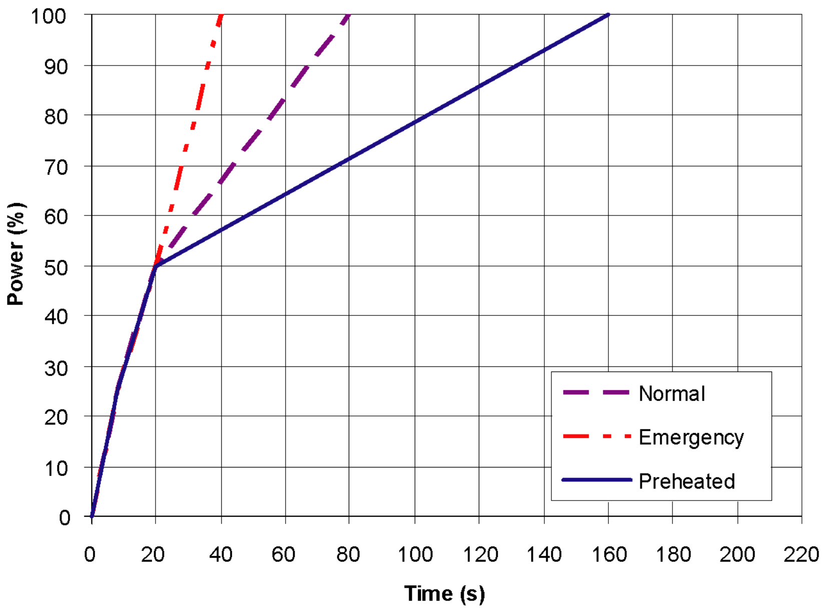


Fig 2-3 Maximum recommended load increase rates for variable speed engines

The propulsion control must include automatic limitation of the load increase rate. If the control system has only one load increase ramp, then the ramp for a preheated engine should be used. In tug applications the engines have usually reached normal operating temperature before the tug starts assisting. The “emergency” curve is close to the maximum capability of the engine.

If minimum smoke during load increase is a major priority, slower loading rate than in the diagram can be necessary below 50% load.

Large load reductions from high load should also be performed gradually. In normal operation the load should not be reduced from 100% to 0% in less than 15 seconds. When absolutely necessary, the load can be reduced as fast as the pitch setting system can react (overspeed due to windmilling must be considered for high speed ships).

2.3.2 Diesel electric propulsion and auxiliary engines

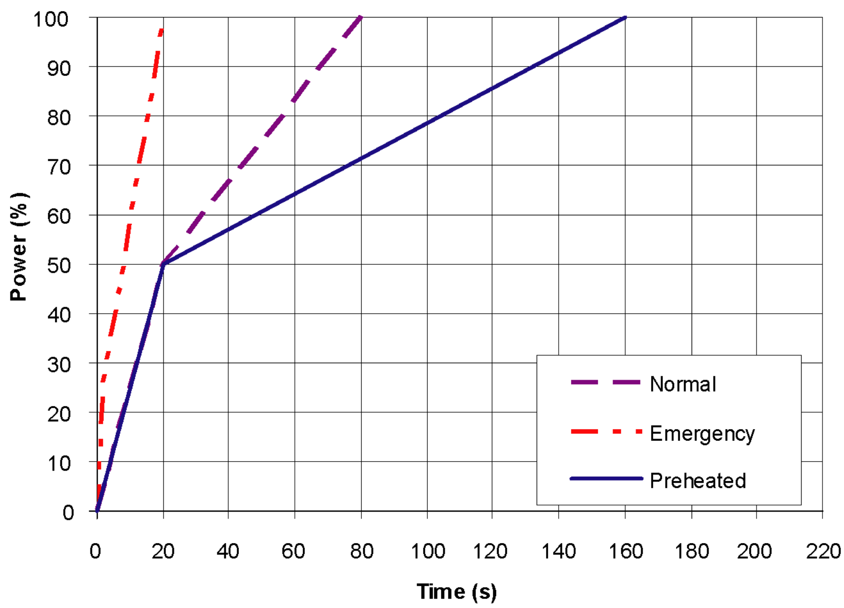


Fig 2-4 Maximum recommended load increase rates for engines operating at nominal speed

In diesel electric installations loading ramps are implemented both in the propulsion control and in the power management system, or in the engine speed control in case isochronous load sharing is applied. If a ramp without knee-point is used, it should not achieve 100% load in shorter time than the ramp in the figure. When the load sharing is based on speed droop, the load increase rate of a recently connected generator is the sum of the load transfer performed by the power management system and the load increase performed by the propulsion control.

The “emergency” curve is close to the maximum capability of the engine and it shall not be used as the normal limit. In dynamic positioning applications loading ramps corresponding to 20-30 seconds from zero to full load are however normal. If the vessel has also other operating modes, a slower loading ramp is recommended for these operating modes.

In typical auxiliary engine applications there is usually no single consumer being decisive for the loading rate. It is recommended to group electrical equipment so that the load is increased in small increments, and the resulting loading rate roughly corresponds to the “normal” curve.

NOTE
According to classification rules, all engines driving generators must be able to take 110% load, 110% output can be utilised for as long as it takes to bring the system back to a safe state with a power demand below 100%. Overload may never be used on a routine basis, or planned for in the operation of the plant. It is a power reserve for extreme situations.

In normal operation the load should not be reduced from 100% to 0% in less than 15 seconds. If the application requires frequent unloading at a significantly faster rate, special arrangements can be necessary on the engine. In an emergency situation the full load can be thrown off instantly.

2.3.2.1 Maximum instant load steps

The electrical system must be designed so that tripping of breakers can be safely handled. This requires that the engines are protected from load steps exceeding their maximum load acceptance capability. The maximum load steps are 0-28-60-100% MCR without air assist. Engines driving generators are prepared for air assist, please refer to technical data which can be found by accessing *Engine Online Configurator* available through Wärtsilä's website and, Chapter Exhaust gas system for details. Sudden load steps equal to 33% MCR can be absorbed also at low load if air assist is used. If air assist is used, the arrangement of the air supply must be approved by the classification society.

When electrical power is restored after a black-out, consumers are reconnected in groups, which may cause significant load steps. The engine must be allowed to recover for at least 10 seconds before applying the following load step, if the load is applied in maximum steps.

2.3.2.2 Start-up

A diesel generator typically reaches nominal speed quickly after the start signal. The acceleration is limited by the speed control to minimise smoke during start-up. If requested faster starting times can be arranged.

2.4 Low load operation

Engine running with low load is limited as follows:

- Low load operation — 10 – 20% of rated power
- Maximum time — 30 hours

High load running (minimum 70%) is to be followed for minimum 60 minutes to clean up the engine.

NOTE
Engine can be operated through SCR at all loads. SCR is activated at 25% and higher loads.

NOTE
Operating restrictions on SCR applications in low load operation to be observed.

2.5 SCR Operation

SCR operation on sustained low load or idling might need special attention from the operator. Please contact Wärtsilä for further details.

2.6 Low air temperature

In standard conditions the following minimum inlet air temperatures apply:

- Starting + 5ºC (when running)
- Idling and highload - 5ºC

For lower suction air temperatures engines shall be configured for arctic operation.

For further guidelines, see chapter *Combustion air system design*.

3. Technical Data

3.1 Introduction

Real-time product information including all technical data can be found by using *Engine Online Configurator* available through Wärtsilä's website. Please check online for the most up to date technical data.

NOTE
Fuel consumptions in SCR operation guaranteed only when using Wärtsilä SCR unit.

NOTE
For proper operation of the Wärtsilä Nitrogen Oxide Reducer (NOR) systems, the exhaust temperature after the engine needs to be kept within a certain temperature window. Please consult your sales contact at Wärtsilä for more information about SCR Operation.

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4. Description of the Engine

4.1 Definitions

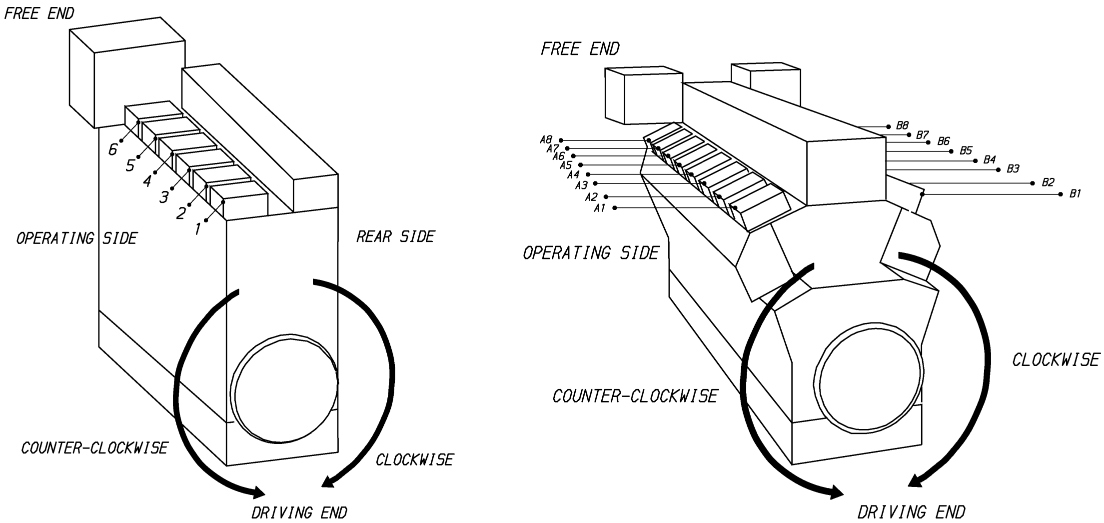


Fig 4-1 In-line engine and V-engine definitions (1V93C0029 / 1V93C0028)

4.2 Main components and systems

The dimensions and weights of engines are shown in section *1.5 Dimensions and weights* .

4.2.1 Engine block

The engine block, made of nodular cast iron, is cast in one piece for all cylinder numbers. It incorporates the camshaft bearing housings and the charge air receiver. In V-engines the charge air receiver is located between the cylinder banks.

The main bearing caps, made of nodular cast iron, are fixed from below by two hydraulically tensioned screws. These are guided sideways by the engine block at the top as well as at the bottom. Hydraulically tightened horizontal side screws at the lower guiding provide a very rigid crankshaft bearing.

A hydraulic jack, supported in the oil sump, offers the possibility to lower and lift the main bearing caps, e.g. when inspecting the bearings. Lubricating oil is led to the bearings and piston trough this jack. A combined flywheel/trust bearing is located at the driving end of the engine.

The oil sump, a light welded design, is mounted on the engine block from below and sealed by O-rings. The oil sump is available in two alternative designs, wet or dry sump, depending on the type of application. The wet oil sump comprises, in addition to a suction pipe to the lube oil pump, also the main distributing pipe for lube oil as well as suction pipes and a return connection for the separator. The dry sump is drained at either end (free choice) to a separate system oil tank.

4.2.2 Crankshaft

The crankshaft is forged in one piece and mounted on the engine block in an under-slung way.

The connecting rods, at the same crank in the V-engine, are arranged side-by-side in order to achieve standardisation between the in-line and V-engines.

The crankshaft is fully balanced to counteract bearing loads from eccentric masses. If necessary, it is provided with a torsional vibration damper at the free end of the engine.

4.2.3 Connecting rod

The connecting rod is of forged alloy steel. All connecting rod studs are hydraulically tightened. Oil is led to the gudgeon pin bearing and piston through a bore in the connecting rod.

The connecting rod is of a three-piece design, which gives a minimum dismantling height and enables the piston to be dismounted without opening the big end bearing.

4.2.4 Main bearings and big end bearings

The main bearings and the big end bearings are of tri-metal design with steel back, lead-bronze lining and a soft running layer. The bearings are covered all over with Sn-flash of 0.5-1 μm thickness for corrosion protection. Even minor form deviations become visible on the bearing surface in the running in phase. This has no negative influence on the bearing function.

4.2.5 Cylinder liner

The cylinder liners are centrifugally cast of a special grey cast iron alloy developed for good wear resistance and high strength. Cooling water is distributed around upper part of the liners with water distribution rings. The lower part of liner is dry. To eliminate the risk of bore polishing the liner is equipped with an anti-polishing ring.

4.2.6 Piston

The piston is of composite design with nodular cast iron skirt and steel crown. The piston skirt is pressure lubricated, which ensures a well-controlled lubrication oil flow to the cylinder liner during all operating conditions. Oil is fed through the connecting rod to the cooling spaces of the piston. The piston cooling operates according to the cocktail shaker principle. The piston ring grooves in the piston top are hardened for better wear resistance.

4.2.7 Piston rings

The piston ring set are located in the piston crown and consists of two directional compression rings and one spring-loaded conformable oil scraper ring. Running face of compression rings are chromium-ceramic-plated.

4.2.8 Cylinder head

The cylinder head is made of grey cast iron. The thermally loaded flame plate is cooled efficiently by cooling water led from the periphery radially towards the centre of the head. The bridges between the valves cooling channels are drilled to provide the best possible heat transfer.

The mechanical load is absorbed by a strong intermediate deck, which together with the upper deck and the side walls form a box section in the four corners of which the hydraulically tightened cylinder head bolts are situated. The exhaust valve seats are directly water-cooled.

The valve seat rings are made of specially alloyed cast iron with good wear resistance. The inlet valves as well as, in case of LFO installation, the exhaust valves have stellite-plated seat faces and chromium-plated stems. Engines for HFO operation have Nimonic exhaust valves.

All valves are equipped with valve rotators.

A “multi-duct” casting is fitted to the cylinder head. It connects the following media with the cylinder head:

- charge air from the air receiver
- exhaust gas to exhaust system
- cooling water from cylinder head to the return pipe

4.2.9 Camshaft and valve mechanism

The cams are integrated in the drop forged shaft material. The bearing journals are made in separate pieces, which are fitted, to the camshaft pieces by flange connections. The camshaft bearing housings are integrated in the engine block casting and are thus completely closed. The bearings are installed and removed by means of a hydraulic tool. The camshaft covers, one for each cylinder, seal against the engine block with a closed O-ring profile.

The valve tappets are of piston type with self-adjustment of roller against cam to give an even distribution of the contact pressure. The valve springs make the valve mechanism dynamically stable.

Variable Inlet valve Closure (VIC), which is available on IMO Tier 2 engines, offers flexibility to apply early inlet valve closure at high load for lowest NOx levels, while good part-load performance is ensured by adjusting the advance to zero at low load. The inlet valve closure can be adjusted up to 30° crank angle.

4.2.10 Camshaft drive

The camshafts are driven by the crankshaft through a gear train.

4.2.11 Turbocharging and charge air cooling

The SPEX (Single Pipe Exhaust) turbocharging system is designed to combine the good part load performance of a pulse charging system with the simplicity and good high load efficiency of a constant pressure system. In order to further enhance part load performance and prevent excessive charge air pressure at high load, all engines are equipped with a wastegate on the exhaust side. The wastegate arrangement permits a part of the exhaust gas to discharge after the turbine in the turbocharger at high engine load.

In addition there is a by-pass valve on main engines to increase the flow through the turbocharger at low engine speed and low engine load. Part of the charge air is conducted directly into the exhaust gas manifold (without passing through the engine), which increases the speed of the turbocharger. The net effect is increased charge air pressure at low engine speed and low engine load, despite the apparent waste of air.

All engines are provided with devices for water cleaning of the turbine and the compressor. The cleaning is performed during operation of the engine.

In-line engines have one turbocharger and V-engines have one turbocharger per cylinder bank. The turbocharger(s) can be placed either at the driving end or at the free end.

The turbocharger is supplied with inboard plain bearings, which offers easy maintenance of the cartridge from the compressor side. The turbocharger is lubricated by engine lubricating oil with integrated connections.

A two-stage charge air cooler is standard. Heat is absorbed with high temperature (HT) cooling water in the first stage, while low temperature (LT) cooling water is used for the final air cooling in the second stage. The engine has two separate cooling water circuits. The flow of LT cooling water through the charge air cooler is controlled to maintain a constant charge air temperature.

4.2.12 Fuel injection equipment

The fuel injection equipment and system piping are located in a hotbox, providing maximum reliability and safety when using preheated heavy fuels. The fuel oil feed pipes are mounted directly to the injection pumps, using a specially designed connecting piece. The return pipe is integrated in the tappet housing.

Cooling of the nozzles by means of lubricating oil is standard for HFO-installations, while the nozzles for LFO-installations are non-cooled.

There is one fuel injection pump per cylinder with shielded high-pressure pipe to the injector. The injection pumps, which are of the flow-through type, ensure good performance with all types of fuel. The pumps are completely sealed off from the camshaft compartment.

Setting the fuel rack to zero position stops the fuel injection. For emergencies the fuel rack of each injection pump is fitted with a stop cylinder. The fuel pump and pump bracket are adjusted in manufacturing to tight tolerances. This means that adjustments are not necessary after initial assembly.

The fuel injection pump design is a reliable mono-element type designed for injection pressures up to 2000 bar. The constant pressure relief valve system provides for optimum injection, which guarantees long intervals between overhauls. The injector holder is designed for easy maintenance.

4.2.13 Lubricating oil system

The engine internal lubricating oil system include the engine driven lubricating oil pump, the electrically driven prelubricating oil pump, thermostatic valve, filters and lubricating oil cooler. The lubricating oil pumps are located in the free end of the engine, while the automatic filter, cooler and thermostatic valve are integrated into one module.

4.2.14 Cooling water system

The fresh water cooling system is divided into a high temperature (HT) and a low temperature (LT) circuit.

The HT-water cools cylinder liners, cylinder heads and the first stage of the charge air cooler. The LT-water cools the second stage of the charge air cooler and the lubricating oil.

4.2.15 Exhaust pipes

The exhaust manifold pipes are made of special heat resistant nodular cast iron alloy.

The complete exhaust gas system is enclosed in an insulating box consisting of easily removable panels. Mineral wool is used as insulating material.

4.2.16 Automation system

Wärtsilä 32 is equipped with a modular embedded automation system, Wärtsilä Unified Controls - UNIC, which is available in two different versions. The basic functionality is the same in both versions, but the functionality can be easily expanded to cover different applications.

All versions have en engine safety module and a local control panel mounted on the engine. The engine safety module handles fundamental safety, for example overspeed and low lubricating oil pressure shutdown. The safety module also performs fault detection on critical signals and alerts the alarm system about detected failures. The local control panel has push buttons for local start/stop and shutdown reset, as well as a display showing the most important operating parameters. Speed control is included in the automation system on the engine (all versions).

Conventional heavy duty cables are used on the engine and the number of connectors are minimised. Power supply, bus communication and safety-critical functions are doubled on the engine. All cables to/from external systems are connected to terminals in the main cabinet on the engine.

4.3 Cross section of the engine

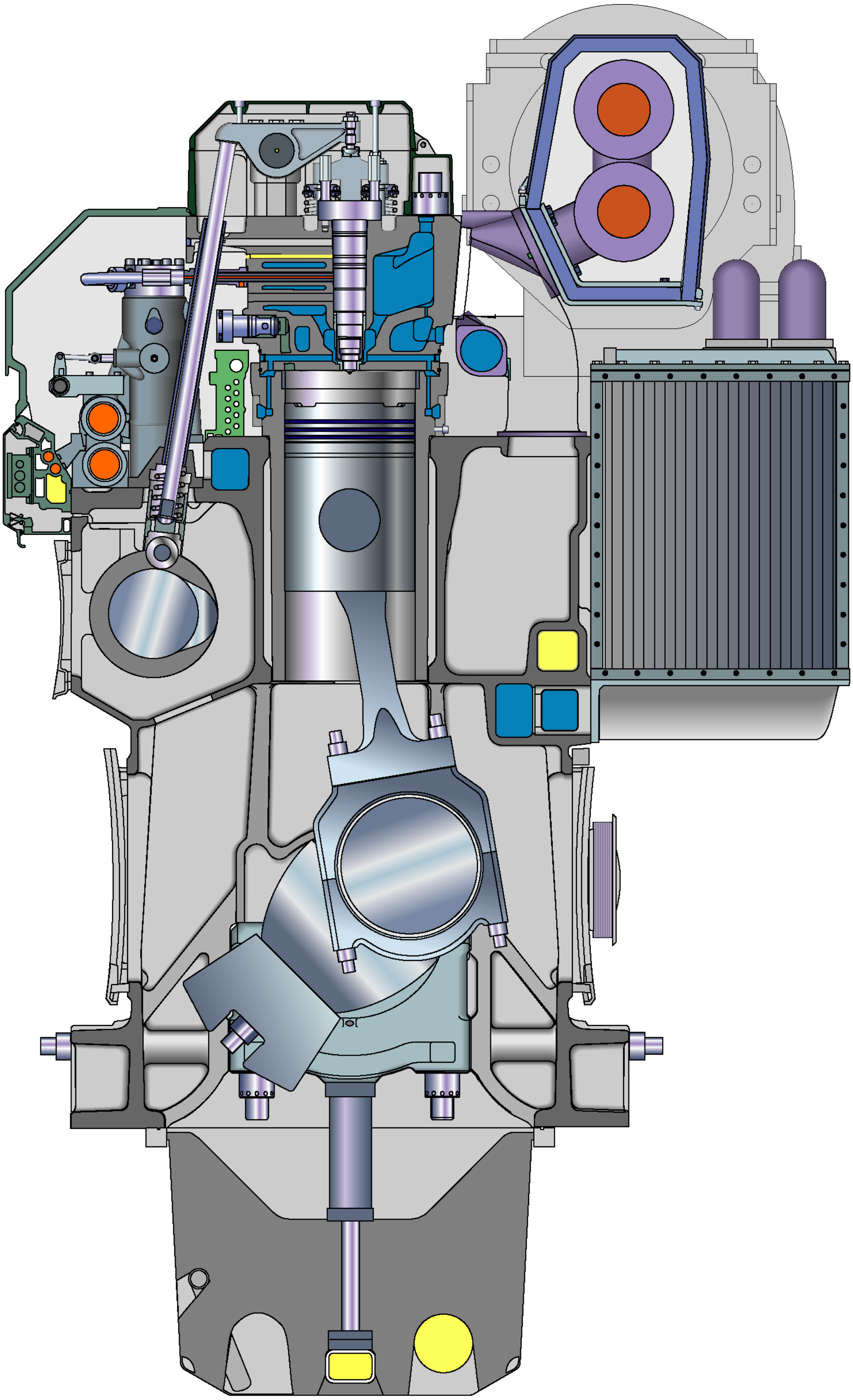


Fig 4-2 Cross section of the in-line engine

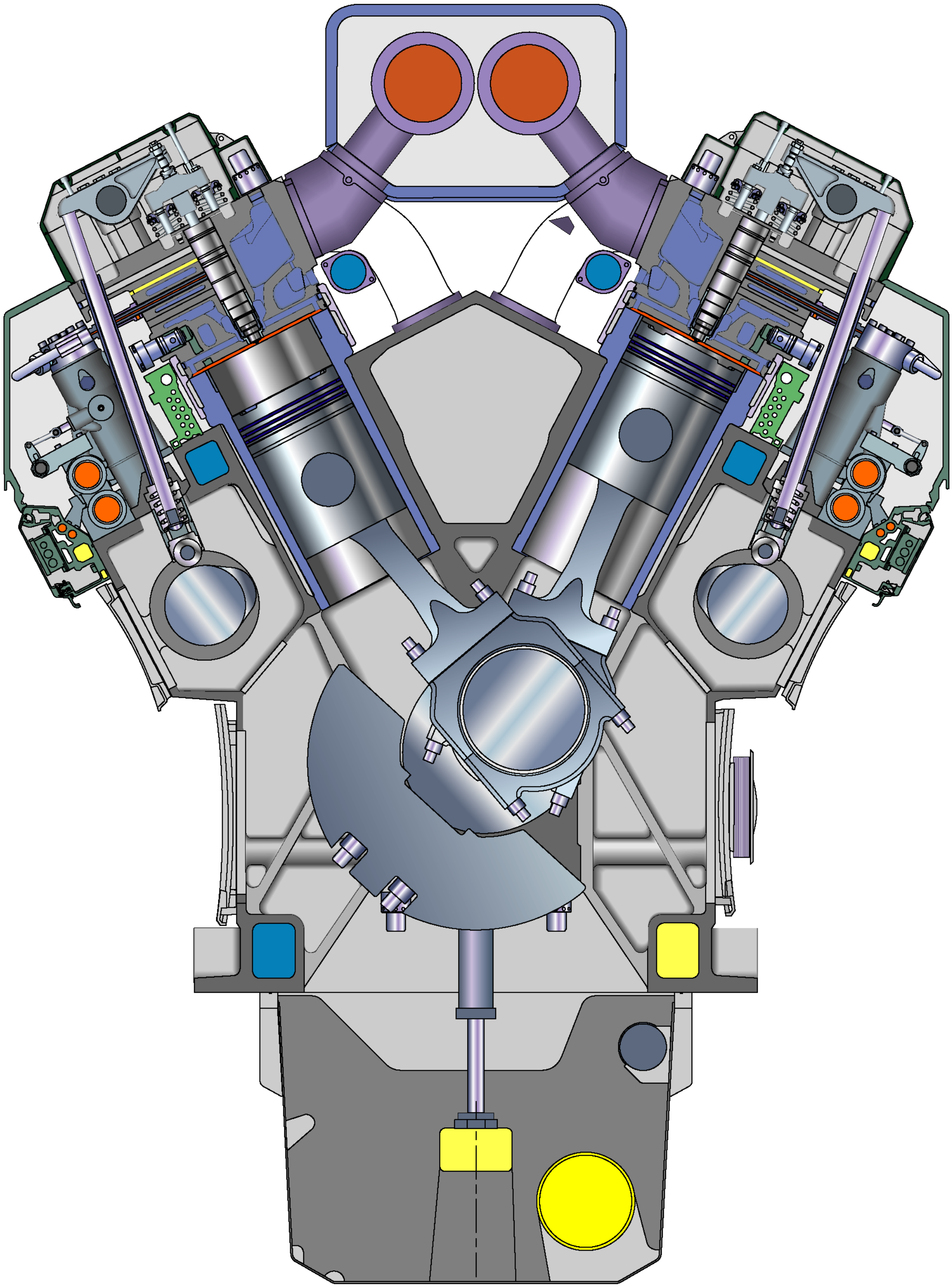


Fig 4-3 Cross section of the V-engine

4.4 Expected Technical Life Time

NOTE

- Service actions are combined to certain overhaul packages and intervals. Overhaul intervals are typically based on components, which has shortest technical lifetime. Certain components are also such a type that they need to be replaced every time, when they are removed from the engine. For these reasons components recommended overhaul times can be shorter than technical life time, which is maximum expected lifetime of the component.
- Time Between Overhaul data can be found in Services Engine Operation and Maintenance Manual (O&MM)
- Achieved life times very much depend on the operating conditions, average loading of the engine, fuel quality used, fuel handling systems, performance of maintenance etc. I.e. values given in optimal conditions where Wärtsilä´s all recommendations are followed.
- Expected lifetime is different depending on HFO1 or HFO2 used. For detailed information of HFO1 and HFO2 qualities, please see *6.1.4.1*.

4.4.1 Time between inspection & Expected Life Time

Table 4-1 Time Between Overhaul and Expected Life Time

Component	Time between inspection or overhaul (h)		Expected life time (h)	
	HFO operation	LFO	HFO operation	LFO
Piston	20000	24000	84000	120000
Piston rings	20000	24000	20000	36000
Cylinder liner	20000	24000	96000	180000
Cylinder head	20000	24000	96000	96000
Inlet valve	20000	24000	40000	48000
Exhaust valve	20000	24000	32000	40000
Injection valve nozzle	2000		6000	6000
Injection pump	12000		-	-
Injection pump element	-		24000	24000
Main bearing	32000	32000	48000	48000
Big end bearing	20000	24000	24000	36000

Table 4-2 Dredger TC exchange interval

	Cutter (h)	Hopper (h)
TC Option#1		
6L	10,000	25,000
8L / 9L / 16V	25,000	25,000

Table 4-2 Dredger TC exchange interval (continued)

	Cutter (h)	Hopper (h)
TC Option#2		
6L / 7L / 12V	12,500	12,500
8L / 16V	12,500	12,500

4.5 Engine storage

At delivery the engine is provided with VCI coating and a tarpaulin. For storage longer than 3 months please contact Wärtsilä.

5. Piping Design, Treatment and Installation

This chapter provides general guidelines for the design, construction and planning of piping systems, however, not excluding other solutions of at least equal standard. Installation related instructions are included in the project specific instructions delivered for each installation.

Fuel, lubricating oil, fresh water and compressed air piping is usually made in seamless carbon steel (DIN 2448) and seamless precision tubes in carbon or stainless steel (DIN 2391), exhaust gas piping in welded pipes of corten or carbon steel (DIN 2458). Sea-water piping should be in Cunifer or hot dip galvanized steel.

NOTICE
The pipes in the freshwater side of the cooling water system must not be galvanized.

NOTICE
The external fuel system must not contaminate the engine's fuel with zinc. For example, galvanized surfaces or surfaces painted with paints containing zinc must not be in contact with the engine fuel. Zinc in the fuel system could lead to e.g. clogged injectors and operational problems.

Attention must be paid to fire risk aspects. Fuel supply and return lines shall be designed so that they can be fitted without tension. Flexible hoses must have an approval from the classification society. If flexible hoses are used in the compressed air system, a purge valve shall be fitted in front of the hose(s).

It is recommended to make a fitting order plan prior to construction.

The following aspects shall be taken into consideration:

- Pockets shall be avoided. When not possible, drain plugs and air vents shall be installed
- Leak fuel drain pipes shall have continuous slope
- Vent pipes shall be continuously rising
- Flanged connections shall be used, cutting ring joints for precision tubes

Maintenance access and dismounting space of valves, coolers and other devices shall be taken into consideration. Flange connections and other joints shall be located so that dismounting of the equipment can be made with reasonable effort.

5.1 Pipe dimensions

When selecting the pipe dimensions, take into account:

- The pipe material and its resistance to corrosion/erosion.
- Allowed pressure loss in the circuit vs delivery head of the pump.
- Required net positive suction head (NPSH) for pumps (suction lines).
- In small pipe sizes the max acceptable velocity is usually somewhat lower than in large pipes of equal length.
- The flow velocity should not be below 1 m/s in sea water piping due to increased risk of fouling and pitting.
- In open circuits the velocity in the suction pipe is typically about 2/3 of the velocity in the delivery pipe.

Table 5-1 Recommended maximum velocities on pump delivery side for guidance

Piping	Pipe material	Max velocity [m/s]
Fuel oil piping	Black steel	1.0
Lubricating oil piping	Black steel	1.5
Fresh water piping	Black steel	2.5
Sea water piping	Galvanized steel	2.5
	Aluminum brass	2.5
	10/90 copper-nickel-iron	3.0
	70/30 copper-nickel	4.5
	Rubber lined pipes	4.5

Compressed air pipe sizing has to be calculated project specifically. The pipe sizes may be chosen on the basis of air velocity or pressure drop. In each pipeline case it is advised to check the pipe sizes using both methods, this to ensure that the alternative limits are not being exceeded.

Pipeline sizing on air velocity: For dry air, practical experience shows that reasonable velocities are 25...30 m/s, but these should be regarded as the maximum above which noise and erosion will take place, particularly if air is not dry. Even these velocities can be high in terms of their effect on pressure drop. In longer supply lines, it is often necessary to restrict velocities to 15 m/s to limit the pressure drop.

Pipeline sizing on pressure drop: As a rule of thumb the pressure drop from the starting air vessel to the inlet of the engine should be max. 0.1 MPa (1 bar) when the bottle pressure is 3 MPa (30 bar).

It is essential that the instrument air pressure, feeding to some critical control instrumentation, is not allowed to fall below the nominal pressure stated in chapter "*Compressed air system*" due to pressure drop in the pipeline.

5.2 Trace heating

The following pipes shall be equipped with trace heating (steam, thermal oil or electrical). It shall be possible to shut off the trace heating.

- All heavy fuel pipes
- All leak fuel and filter flushing pipes carrying heavy fuel

5.3 Pressure class

The pressure class of the piping should be higher than or equal to the design pressure, which should be higher than or equal to the highest operating (working) pressure. The highest operating (working) pressure is equal to the setting of the safety valve in a system.

The pressure in the system can:

- Originate from a positive displacement pump
- Be a combination of the static pressure and the pressure on the highest point of the pump curve for a centrifugal pump
- Rise in an isolated system if the liquid is heated

Within this publication there are tables attached to drawings, which specify pressure classes of connections. The pressure class of a connection can be higher than the pressure class required for the pipe.

Example 1:

The fuel pressure before the engine should be 0.7 MPa (7 bar). The safety filter in dirty condition may cause a pressure loss of 0.1 MPa (1.0 bar). The viscosimeter, automatic filter, preheater and piping may cause a pressure loss of 0.25 MPa (2.5 bar). Consequently the discharge pressure of the circulating pumps may rise to 1.05 MPa (10.5 bar), and the safety valve of the pump shall thus be adjusted e.g. to 1.2 MPa (12 bar).

- A design pressure of not less than 1.2 MPa (12 bar) has to be selected.
- The nearest pipe class to be selected is PN16.
- Piping test pressure is normally 1.5 x the design pressure = 1.8 MPa (18 bar).

Example 2:

The pressure on the suction side of the cooling water pump is 0.1 MPa (1 bar). The delivery head of the pump is 0.3 MPa (3 bar), leading to a discharge pressure of 0.4 MPa (4 bar). The highest point of the pump curve (at or near zero flow) is 0.1 MPa (1 bar) higher than the nominal point, and consequently the discharge pressure may rise to 0.5 MPa (5 bar) (with closed or throttled valves).

- Consequently a design pressure of not less than 0.5 MPa (5 bar) shall be selected.
- The nearest pipe class to be selected is PN6.
- Piping test pressure is normally 1.5 x the design pressure = 0.75 MPa (7.5 bar).

Standard pressure classes are PN4, PN6, PN10, PN16, PN25, PN40, etc.

5.4 Pipe class

Classification societies categorize piping systems in different classes (DNV) or groups (ABS) depending on pressure, temperature and media. The pipe class can determine:

- Type of connections to be used
- Heat treatment
- Welding procedure
- Test method

Systems with high design pressures and temperatures and hazardous media belong to class I (or group I), others to II or III as applicable. Quality requirements are highest on class I.

Examples of classes of piping systems as per DNV rules are presented in the table below.

Table 5-2 Classes of piping systems as per DNV rules

Media	Class I		Class II		Class III	
	MPa (bar)	°C	MPa (bar)	°C	MPa (bar)	°C
Steam	> 1.6 (16)	or > 300	< 1.6 (16)	and < 300	< 0.7 (7)	and < 170
Flammable fluid	> 1.6 (16)	or > 150	< 1.6 (16)	and < 150	< 0.7 (7)	and < 60
Other media	> 4 (40)	or > 300	< 4 (40)	and < 300	< 1.6 (16)	and < 200

5.5 Insulation

The following pipes shall be insulated:

- All trace heated pipes
- Exhaust gas pipes
- Exposed parts of pipes with temperature > 60°C

Insulation is also recommended for:

- Pipes between engine or system oil tank and lubricating oil separator
- Pipes between engine and jacket water preheater

5.6 Local gauges

Local thermometers should be installed wherever a new temperature occurs, i.e. before and after heat exchangers, etc.

Pressure gauges should be installed on the suction and discharge side of each pump.

5.7 Cleaning procedures

Instructions shall be given at an early stage to manufacturers and fitters how different piping systems shall be treated, cleaned and protected.

5.7.1 Cleanliness during pipe installation

All piping must be verified to be clean before lifting it onboard for installation. During the construction time uncompleted piping systems shall be maintained clean. Open pipe ends should be temporarily closed. Possible debris shall be removed with a suitable method. All tanks must be inspected and found clean before filling up with fuel, oil or water.

Piping cleaning methods are summarised in table below:

Table 5-3 Pipe cleaning

System	Methods
Fuel oil	A,B,C,D,F
Lubricating oil	A,B,C,D,F
Starting air	A,B,C
Cooling water	A,B,C
Exhaust gas	A,B,C
Charge air	A,B,C

[1]) In case of carbon steel pipes

Methods applied during prefabrication of pipe spools

A = Washing with alkaline solution in hot water at 80°C for degreasing (only if pipes have been greased)

B = Removal of rust and scale with steel brush (not required for seamless precision tubes)

D = Pickling (not required for seamless precision tubes)

(continued)

Methods applied after installation onboard

C = Purging with compressed air

F = Flushing

5.7.2 Fuel oil pipes

Before start up of the engines, all the external piping between the day tanks and the engines must be flushed in order to remove any foreign particles such as welding slag.

Disconnect all the fuel pipes at the engine inlet and outlet. Install a temporary pipe or hose to connect the supply line to the return line, bypassing the engine. The pump used for flushing should have high enough capacity to ensure highly turbulent flow, minimum same as the max nominal flow. Heaters, automatic filters and the viscosimeter should be bypassed to prevent damage caused by debris in the piping. The automatic fuel filter must not be used as flushing filter.

The pump used should be protected by a suction strainer. During this time the welds in the fuel piping should be gently knocked at with a hammer to release slag and the filter inspected and carefully cleaned at regular intervals.

The cleanliness should be minimum ISO 4406 © 20/18/15, or NAS 1638 code 9. A measurement certificate shows required cleanliness has been reached there is still risk that impurities may occur after a time of operation.

NOTICE
The engine must not be connected during flushing.

5.7.3 Lubricating oil pipes

Flushing of the piping and equipment built on the engine is not required and flushing oil shall not be pumped through the engine oil system (which is flushed and clean from the factory).

It is however acceptable to circulate the flushing oil via the external oil sump/tank or via engine sump if this is advantageous. Cleanliness of the oil sump shall be verified after completed flushing and is acceptable when the cleanliness has reached a level in accordance with ISO 4406 © 21/19/15, or NAS 1638 code 10. All pipes connected to the engine, the engine wet sump or to the external engine wise oil tank shall be flushed. Oil used for filling shall have a cleanliness of ISO 4406 © 21/19/15, or NAS 1638 code 10.

NOTICE
The engine must not be connected during flushing.

5.7.4 Pickling

Prefabricated pipe spools are pickled before installation onboard.

Pipes are pickled in an acid solution of 10% hydrochloric acid and 10% formaline inhibitor for 4-5 hours, rinsed with hot water and blown dry with compressed air.

After acid treatment the pipes are treated with a neutralizing solution of 10% caustic soda and 50 grams of trisodiumphosphate per litre of water for 20 minutes at 40...50°C, rinsed with hot water and blown dry with compressed air.

Great cleanliness shall be validated in all work phases after completed pickling.

5.8 Flexible pipe connections

All external pipes must be precisely aligned to the fitting or the flange of the engine to minimize causing external forces to the engine connection.

Adding adapter pieces to the connection between the flexible pipe and engine, which are not validated by Wärtsilä are forbidden. Observe that the pipe clamp for the pipe outside the flexible connection must be very rigid and welded to the steel structure of the foundation to prevent vibrations and external forces to the connection, which could damage the flexible connections and transmit noise. The support must be close to the flexible connection. Most problems with bursting of the flexible connection originate from poor clamping.

Proper installation of pipe connections between engines and ship's piping to be ensured.

- Flexible pipe connections must not be twisted
- Installation length of flexible pipe connections must be correct
- Minimum bending radius must be respected
- Piping must be concentrically aligned
- When specified, the flow direction must be observed
- Mating flanges shall be clean from rust, burrs and anticorrosion coatings
- If not otherwise instructed, bolts are to be tightened crosswise in several stages
- Painting of flexible elements is not allowed
- Rubber bellows must be kept clean from oil and fuel
- The piping must be rigidly supported close to the flexible piping connections.

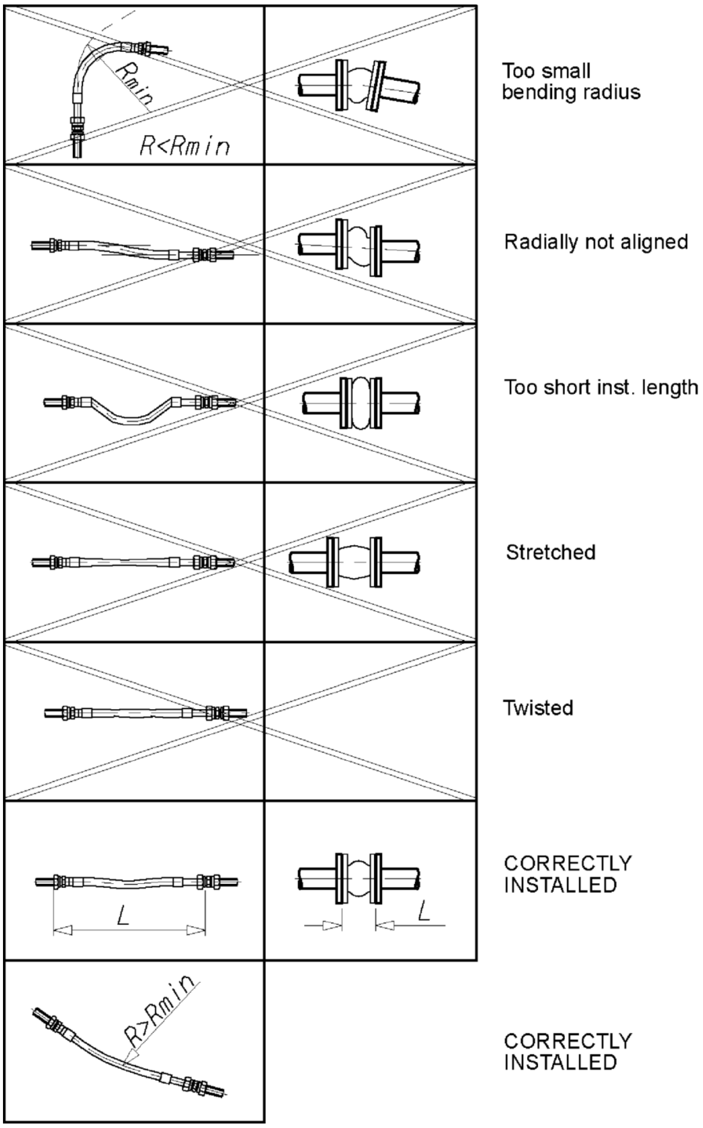


Fig 5-1 Flexible hoses

NOTICE
Pressurized flexible connections carrying flammable fluids or compressed air have to be type approved.

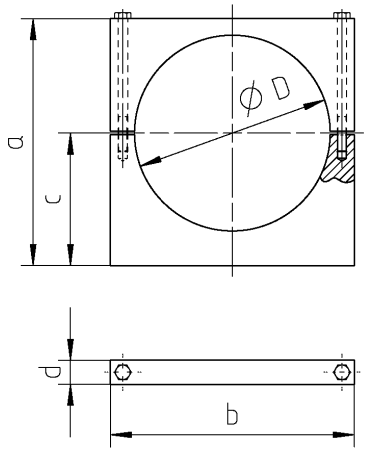
5.9 Clamping of pipes

It is very important to fix the pipes to rigid structures next to flexible pipe connections in order to prevent damage caused by vibration. The following guidelines should be applied:

- Pipe clamps and supports next to the engine must be very rigid and welded to the steel structure of the foundation.
- The first support should be located as close as possible to the flexible connection. Next support should be 0.3-0.5 m from the first support.
- First three supports closest to the engine or generating set should be fixed supports. Where necessary, sliding supports can be used after these three fixed supports to allow thermal expansion of the pipe.
- Supports should never be welded directly to the pipe. Either pipe clamps or flange supports should be used for flexible connection.

A typical pipe clamp for a fixed support is shown in Figure 5-2. Pipe clamps must be made of steel; plastic clamps or similar may not be used.

SUPPORTS AFTER FLEXIBLE BELLOW (FIXED) DN 25-300)



	DN	d_u mm	D mm	a mm	b mm	c mm	d mm	BOLTS
	25	33.7	35	150	80	120	25	M10x50
	32	42.4	43	150	75	120	25	M10x50
	40	48.3	48	154.5	100	115	25	M12x60
	50	60.3	61	185	100	145	25	M12x60
	65	76.1	76.5	191	115	145	25	M12x70
	80	88.9	90	220	140	150	30	M12x90
	100	114.3	114.5	196	170	121	25	M12x100
	125	139.7	140	217	200	132	30	M16x120
	150	168.3	170	237	240	132	30	M16x140
	200	219.1	220	295	290	160	30	M16x160
	250	273.0	274	355	350	190	30	M16x200
A	300	323.9	325	410	405	220	40	M16x220

d_u= Pipe outer diameter

Fig 5-2 Pipe clamp for fixed support (V61H0842A)

6. Fuel Oil System

6.1 Acceptable fuel characteristics

The fuel specifications are based on the ISO 8217:2017 (E) standard. Observe that a few additional properties not included in the standard are listed in the tables.

For maximum fuel temperature before the engine, please refer to technical data which can be found by accessing *Engine Online Configurator* available through Wärtsilä's website.

The fuel shall not contain any added substances or chemical waste, which jeopardizes the safety of installations or adversely affects the performance of the engines or is harmful to personnel or contributes overall to air pollution.

6.1.1 Light Fuel Oil (LFO)

The fuel specification is based on the ISO 8217:2017(E) standard and covers the fuel grades ISO-F-DMX, DMA, DFA, DMZ, DFZ, DMB and DFB. These fuel grades are referred to as Light Fuel Oil (LFO).

The distillate grades mentioned above can be described as follows:

- DMX: A fuel quality which is suitable for use at ambient temperatures down to –15 °C without heating the fuel. Especially in merchant marine applications its use is restricted to lifeboat engines and certain emergency equipment due to reduced flash point. The low flash point which is not meeting the SOLAS requirement can also prevent the use in other marine applications, unless the fuel system is built according to special requirements. Also the low viscosity (min. 1.4 cSt) can prevent the use in engines unless the fuel can be cooled down enough to meet the min. injection viscosity limit of the engine.
- DMA: A high quality distillate, generally designated MGO (Marine Gas Oil) in the marine field.
- DFA: A similar quality distillate fuel compared to DMA category fuels but a presence of max. 7,0% v/v of Fatty acid methyl ester (FAME) is allowed.
- DMZ: A high quality distillate, generally designated MGO (Marine Gas Oil) in the marine field. An alternative fuel grade for engines requiring a higher fuel viscosity than specified for DMA grade fuel.
- DFZ: A similar quality distillate fuel compared to DMZ category fuels but a presence of max. 7,0% v/v of Fatty acid methyl ester (FAME) is allowed.
- DMB: A general purpose fuel which may contain trace amounts of residual fuel and is intended for engines not specifically designed to burn residual fuels.
- DFB: A similar quality distillate fuel compared to DMB category fuels but a presence of max. 7,0% v/v of Fatty acid methyl ester (FAME) is allowed.

6.1.1.1 Table Light fuel oils

Table 6-1 Distillate fuel specifications

Characteristics	Unit	Limit	Category ISO-F							Test method(s) and references
			DMX	DMA	DFA	DMZ	DFZ	DMB	DFB	
Kinematic viscosity at 40 °C [j]	mm^2/s [a]	Max	5,500	6,000		6,000		11,00		ISO 3104
		Min	1,400 [i]	2,000		3,000		2,000		

Table 6-1 Distillate fuel specifications (continued)

<table>
<tr><th colspan="2" rowspan="2">Characteristics</th><th rowspan="2">Unit</th><th rowspan="2">Limit</th><th colspan="7">Category ISO-F</th><th rowspan="2">Test method(s) and references</th></tr>
<tr><th>DMX</th><th>DMA</th><th>DFA</th><th>DMZ</th><th>DFZ</th><th>DMB</th><th>DFB</th></tr>
<tr><td colspan="2">Density at 15 °C</td><td>kg/m³</td><td>Max</td><td>-</td><td colspan="2">890,0</td><td colspan="2">890,0</td><td colspan="2">900,0</td><td>ISO 3675 or ISO 12185</td></tr>
<tr><td colspan="2">Cetane index</td><td></td><td>Min</td><td>45</td><td colspan="2">40</td><td colspan="2">40</td><td colspan="2">35</td><td>ISO 4264</td></tr>
<tr><td colspan="2">Sulphur b, k)</td><td>% m/m</td><td>Max</td><td>1,00</td><td colspan="2">1,00</td><td colspan="2">1,00</td><td colspan="2">1,50</td><td>ISO 8754 or ISO 14596, ASTM D4294</td></tr>
<tr><td colspan="2">Flash point</td><td>°C</td><td>Min</td><td>43,0 l)</td><td colspan="2">60,0</td><td colspan="2">60,0</td><td colspan="2">60,0</td><td>ISO 2719</td></tr>
<tr><td colspan="2">Hydrogen sulfide</td><td>mg/kg</td><td>Max</td><td>2,00</td><td colspan="2">2,00</td><td colspan="2">2,00</td><td colspan="2">2,00</td><td>IP 570</td></tr>
<tr><td colspan="2">Acid number</td><td>mg KOH/g</td><td>Max</td><td>0,5</td><td colspan="2">0,5</td><td colspan="2">0,5</td><td colspan="2">0,5</td><td>ASTM D664</td></tr>
<tr><td colspan="2">Total sediment by hot filtration</td><td>% m/m</td><td>Max</td><td>-</td><td colspan="2">-</td><td colspan="2">-</td><td colspan="2">0,10 c)</td><td>ISO 10307-1</td></tr>
<tr><td colspan="2">Oxidation stability</td><td>g/m³</td><td>Max</td><td>25</td><td colspan="2">25</td><td colspan="2">25</td><td colspan="2">25 d)</td><td>ISO 12205</td></tr>
<tr><td colspan="2">Fatty acid methyl ester (FAME) e)</td><td>% v/v</td><td>Max</td><td>-</td><td>-</td><td>7,0</td><td>-</td><td>7,0</td><td>-</td><td>7,0</td><td>ASTM D7963 or IP 579</td></tr>
<tr><td colspan="2">Carbon residue - Micro method on 10% distillation residue</td><td>% m/m</td><td>Max</td><td>0,30</td><td colspan="2">0,30</td><td colspan="2">0,30</td><td colspan="2">-</td><td>ISO 10370</td></tr>
<tr><td colspan="2">Carbon residue - Micro method</td><td>% m/m</td><td>Max</td><td>-</td><td colspan="2">-</td><td colspan="2">-</td><td colspan="2">0,30</td><td>ISO 10370</td></tr>
<tr><td rowspan="2">Cloud point f)</td><td>winter</td><td rowspan="2">°C</td><td rowspan="2">Max</td><td>-16</td><td colspan="2">Report</td><td colspan="2">Report</td><td colspan="2">-</td><td rowspan="2">ISO 3015</td></tr>
<tr><td>summer</td><td>-16</td><td colspan="2">-</td><td colspan="2">-</td><td colspan="2">-</td></tr>
<tr><td rowspan="2">Cold filter plugging point f)</td><td>winter</td><td rowspan="2">°C</td><td rowspan="2">Max</td><td>-</td><td colspan="2">Report</td><td colspan="2">Report</td><td colspan="2">-</td><td rowspan="2">IP 309 or IP 612</td></tr>
<tr><td>summer</td><td>-</td><td colspan="2">-</td><td colspan="2">-</td><td colspan="2">-</td></tr>
<tr><td rowspan="2">Pour point f)</td><td>winter</td><td rowspan="2">°C</td><td rowspan="2">Max</td><td>-</td><td colspan="2">-6</td><td colspan="2">-6</td><td colspan="2">0</td><td rowspan="2">ISO 3016</td></tr>
<tr><td>summer</td><td>-</td><td colspan="2">0</td><td colspan="2">0</td><td colspan="2">6</td></tr>
<tr><td colspan="2">Appearance</td><td></td><td>-</td><td colspan="5">Clear and bright g)</td><td colspan="2">c)</td><td>-</td></tr>
<tr><td colspan="2">Water</td><td>% v/v</td><td>Max</td><td>-</td><td colspan="2">-</td><td colspan="2">-</td><td colspan="2">0,30 c)</td><td>ISO 3733 or ASTM D6304-C m)</td></tr>
<tr><td colspan="2">Ash</td><td>% m/m</td><td>Max</td><td>0,010</td><td colspan="2">0,010</td><td colspan="2">0,010</td><td colspan="2">0,010</td><td>ISO 6245</td></tr>
<tr><td colspan="2">Lubricity, corr. wear scar diam. h)</td><td>µm</td><td>Max</td><td>520</td><td colspan="2">520</td><td colspan="2">520</td><td colspan="2">520 d)</td><td>ISO 12156-1</td></tr>
</table>

NOTICE

a) 1 mm²/s = 1 cSt.

b) Notwithstanding the limits given, the purchaser shall define the maximum sulphur content in accordance with relevant statutory limitations.

c) If the sample is not clear and bright, the total sediment by hot filtration and water tests shall be required.

d) If the sample is not clear and bright, the Oxidation stability and Lubricity tests cannot be undertaken and therefore, compliance with this limit cannot be shown.

e) See ISO 8217:2017(E) standard for details.

f) Pour point cannot guarantee operability for all ships in all climates. The purchaser should confirm that the cold flow characteristics (pour point, cloud point, cold filter clogging point) are suitable for ship's design and intended voyage.

g) If the sample is dyed and not transparent, see ISO 8217:2017(E) standard for details related to water analysis limits and test methods.

h) The requirement is applicable to fuels with a sulphur content below 500 mg/kg (0,050 % m/m).

Additional notes not included in the ISO 8217:2017(E) standard:

i) Low min. viscosity of 1,400 mm²/s can prevent the use ISO-F-DMX category fuels in Wärtsilä® 4-stroke engines unless a fuel can be cooled down enough to meet the specified min. injection viscosity limit.

j) Allowed kinematic viscosity before the injection pumps for this engine type is 2,0 - 24 mm²/s. If the W32 engine is equipped with low viscosity injection pumps, the allowed min. kinematic viscosity before the injection pumps is 1,5 mm²/s.

k) There doesn't exist any minimum sulphur content limit for Wärtsilä® 4-stroke diesel engines and also the use of Ultra Low Sulphur Diesel (ULSD) is allowed provided that the fuel quality fulfils other specified properties.

l) Low flash point of min. 43 °C can prevent the use ISO-F-DMX category fuels in Wärtsilä® engines in marine applications unless the ship's fuel system is built according to special requirements allowing the use or that the fuel supplier is able to guarantee that flash point of the delivered fuel batch is above 60 °C being a requirement of SOLAS and classification societies.

m) Alternative test method.

6.1.2 Operation on 0,10 % m/m residual sulphur fuels (ULSFO RM) for SECA areas

Due to the tightened sulphur emission legislation being valid since 01.01.2015 in the specified SECA areas many new max. 0,10 % m/m sulphur content fuels have entered the market. Some of these fuels are not pure distillate fuels, but contain new refinery streams, like hydrocracker bottoms or can also be blends of distillate and residual fuels. The new 0,10 % m/m sulphur fuels are also called as Ultra Low Sulphur Fuel Oils (ULSFO) or "hybrid" fuels, since those can contain properties of both distillate and residual fuels. In the existing ISO 8217:2017(E) standard the fuels are classed as RMA 10, RMB 30 or RMD 80, if not fulling the DM grade category requirements, though from their properties point of view this is generally not an optimum approach.

These fuels can be used in the Wärtsilä 32 engine type, but special attention shall be paid to optimum operating conditions. See also Services Instruction WS02Q312.

Characteristics	Unit	RMA 10	RMB 30	RMD 80	Test method reference
Kinematic viscosity bef. inj. pumps c)	mm^2/s a)	2,0 - 24	2,0 - 24	2,0 - 24	-
Kinematic viscosity at 50 °C, max.	mm^2/s a)	10,00	30,00	80,00	ISO 3104
Density at 15 °C, max.	kg/m^3	920,0	960,0	975,0	ISO 3675 or ISO 12185
CCAI, max. e)	-	850	860	860	ISO 8217, Annex F
Sulphur, max. b)	% m/m	0,10	0,10	0,10	ISO 8574 or ISO 14596
Flash point, min.	°C	60,0	60,0	60,0	ISO 2719
Hydrogen sulfide, max.	mg/kg	2,00	2,00	2,00	IP 570
Acid number, max.	mg KOH/g	2,5	2,5	2,5	ASTM D664
Total sediment existent, max.	% m/m	0,10	0,10	0,10	ISO 10307-2
Carbon residue, micro method, max.	% m/m	2,50	10,00	14,00	ISO 10370
Asphaltenes, max. c)	% m/m	1,5	6,0	8,0	ASTM D3279
Pour point (upper), max., winter quality d)	°C	0	0	30	ISO 3016
Pour point (upper), max., summer quality d)	°C	6	6	30	ISO 3016
Water max.	% v/v	0,30	0,50	0,50	ISO 3733 or ASTM D6304-C c)
Water bef. engine, max. c)	% v/v	0,30	0,30	0,30	ISO 3733 or ASTM D6304-C c)
Ash, max.	% m/m	0,040	0,070	0,070	ISO 6245 or LP1001 c, h)
Vanadium, max. f)	mg/kg	50	150	150	IP 501, IP 470 or ISO 14597
Sodium, max. f)	mg/kg	50	100	100	IP 501 or IP 470
Sodium bef. engine, max. c, f)	mg/kg	30	30	30	IP 501 or IP 470

(continued)

Characteristics	Unit	RMA 10	RMB 30	RMD 80	Test method reference
Aluminium + Silicon, max.	mg/kg	25	40	40	IP 501, IP 470 or ISO 10478
Aluminium + Silicon bef. engine, max.[c)]	mg/kg	15	15	15	IP 501, IP 470 or ISO 10478
Used lubricating oil: [g)] - Calcium, max. - Zinc, max. - Phosphorus, max.	mg/kg mg/kg mg/kg	30 15 15	30 15 15	30 15 15	IP 501 or IP 470 IP 501 or IP 470 IP 501 or IP 500

NOTE

a) 1 mm²/s = 1 cSt.

b) The purchaser shall define the maximum sulphur content in accordance with relevant statutory limitations.

c) Additional properties specified by the engine manufacturer, which are not included in the ISO 8217:2017(E) standard.

d) Purchasers shall ensure that this pour point is suitable for the equipment on board / at the plant, especially if the ship operates / plant is located in cold climates.

e) Straight run residues show CCAI values in the 770 to 840 range and are very good ignitors. Cracked residues delivered as bunkers may range from 840 to – in exceptional cases – above 900. Most bunkers remain in the max. 850 to 870 range at the moment. CCAI value cannot always be considered as an accurate tool to determine fuels' ignition properties, especially concerning fuels originating from modern and more complex refinery processes.

f) Sodium contributes to hot corrosion on exhaust valves when combined with high sulphur and vanadium contents. Sodium also strongly contributes to fouling of the exhaust gas turbine blading at high loads. The aggressiveness of the fuel depends on its proportions of sodium and vanadium, but also on the total amount of ash. Hot corrosion and deposit formation are, however, also influenced by other ash constituents. It is therefore difficult to set strict limits based only on the sodium and vanadium content of the fuel. Also a fuel with lower sodium and vanadium contents than specified above, can cause hot corrosion on engine components.

g) The fuel shall be free from used lubricating oil (ULO). A fuel shall be considered to contain ULO when either one of the following conditions is met:

- Calcium > 30 mg/kg and zinc > 15 mg/kg OR
- Calcium > 30 mg/kg and phosphorus > 15 mg/kg

h) Ashing temperatures can vary when different test methods are used having an influence on the test result.

6.1.3 Operation on 0,50 % m/m sulphur residual fuels (VLSFO RM)

In addition to the 0,10 % m/m sulphur ULSFOs also another new fuel category has entered the marine market after the global fuel sulphur content limit of max. 0,50 % m/m became valid on the 01.01.2020. These Very Low Sulphur Fuel Oils (VLSFO RM) have to be used outside of SECA areas unless the engines are equipped with exhaust gas cleaning system (scrubber). There doesn't exist own fuel categories for VLSFO RM products, but the existing RM categories included in the ISO 8217:2017(E) standard are valid.

Properties of the VLSFO RM category products can vary significantly and only the max. 0,50 % m/m sulphur content is a common requirement for those. Some of the fuels are low viscosity products like the ULSFO RM products described in chapter "Operation on 0,10% m/m residual sulphur fuels" while some others are more viscous fuels which shall anyway fulfil either the “HFO 1” or “HFO 2” quality requirements included in the below chapter, “Heavy fuel oil”. See also Services Instruction WS02Q312.

6.1.4 Heavy Fuel Oil (HFO)

Residual fuel grades are referred to as HFO (Heavy Fuel Oil). The fuel specification HFO 2 is based on the ISO 8217:2017(E) standard and covers the categories ISO-F-RMA 10 to RMK 700. Fuels fulfilling the specification HFO 1 permit longer overhaul intervals of specific engine components than HFO 2.

6.1.4.1 Table Heavy fuel oils

Table 6-2 Residual fuel specifications

Characteristics	Unit	Limit HFO 1	Limit HFO 2	Test method reference
Kinematic viscosity bef. inj. pumps [d]	mm^2/s [b]	20 ± 4	20 ± 4	-
Kinematic viscosity at 50 °C, max.	mm^2/s [b]	700,0	700,0	ISO 3104
Density at 15 °C, max.	kg/m^3	991,0 / 1010,0 [a]	991,0 / 1010,0 [a]	ISO 3675 or ISO 12185
CCAI, max. [f]	-	850	870	ISO 8217, Annex F
Sulphur, max. [c, g]	%m/m	Statutory requirements or max. 3,50 % m/m [c]		ISO 8754 or ISO 14596
Flash point, min.	°C	60,0	60,0	ISO 2719
Hydrogen sulfide, max.	mg/kg	2,00	2,00	IP 570
Acid number, max.	mg KOH/g	2,5	2,5	ASTM D664
Total sediment aged, max.	%m/m	0,10	0,10	ISO 10307-2
Carbon residue, micro method, max.	%m/m	15,00	20,00	ISO 10370
Asphaltenes, max. [d]	%m/m	8,0	14,0	ASTM D3279
Pour point (upper), max. [e]	°C	30	30	ISO 3016
Water, max. [d]	%V/V	0,50	0,50	ISO 3733 or ASTM D6304-C [d]
Water before engine, max. [d]	%V/V	0,30	0,30	ISO 3733 or ASTM D6304-C [d]
Ash, max.	%m/m	0,050	0,150	ISO 6245 or LP1001 [d, i]

Table 6-2 Residual fuel specifications (continued)

Characteristics	Unit	Limit HFO 1	Limit HFO 2	Test method reference
Vanadium, max. [g)]	mg/kg	100	450	IP 501, IP 470 or ISO 14597
Sodium, max. [g)]	mg/kg	50	100	IP 501 or IP 470
Sodium before engine, max. [d, g)]	mg/kg	30	30	IP 501 or IP 470
Aluminium + Silicon, max. [d)]	mg/kg	30	60	IP 501, IP 470 or ISO 10478
Aluminium + Silicon before engine, max. [d)]	mg/kg	15	15	IP 501, IP 470 or ISO 10478
Used lubricating oil [h)] - Calcium, max. - Zinc, max. - Phosphorus, max.	 mg/kg mg/kg mg/kg	 30 15 15	 30 15 15	 IP 501 or IP 470 IP 501 or IP 470 IP 501 or IP 500

NOTICE

a) Max. 1010 kg/m³ at 15 °C, provided the fuel treatment system can reduce water and solids (sediment, sodium, aluminium, silicon) before engine to the specified levels.

b) 1 mm²/s = 1 cSt.

c) The purchaser shall define the maximum sulphur content in accordance with relevant statutory limitations. However, the use of fuels with sulphur content higher than 3,50 % m/m is also possible. Please contact Wärtsilä for further evaluation.

d) Additional properties specified by the engine manufacturer, which are not included in the ISO 8217:2017(E) standard.

e) Purchasers shall ensure that this pour point is suitable for the equipment on board / at the plant, especially if the ship operates / plant is located in cold climates.

f) Straight run residues show CCAI values in the 770 to 840 range and are very good ignitors. Cracked residues delivered as bunkers may range from 840 to – in exceptional cases – above 900. Most bunkers remain in the max. 850 to 870 range at the moment. CCAI value cannot always be considered as an accurate tool to determine fuels' ignition properties, especially concerning fuels originating from modern and more complex refinery processes.

g) Sodium contributes to hot corrosion on exhaust valves when combined with high sulphur and vanadium contents. Sodium also strongly contributes to fouling of the exhaust gas turbine blading at high loads. The aggressiveness of the fuel depends on its proportions of sodium and vanadium, but also on the total amount of ash. Hot corrosion and deposit formation are, however, also influenced by other ash constituents. It is therefore difficult to set strict limits based only on the sodium and vanadium content of the fuel. Also a fuel with lower sodium and vanadium contents than specified above, can cause hot corrosion on engine components.

h) The fuel shall be free from used lubricating oil (ULO). A fuel shall be considered to contain ULO when either one of the following conditions is met:

- Calcium > 30 mg/kg and zinc > 15 mg/kg OR
- Calcium > 30 mg/kg and phosphorus > 15 mg/kg

i) The ashing temperatures can vary when different test methods are used having an influence on the test result.

6.1.5 Biofuel oils

Liquid biofuel characteristics and specifications

The Wärtsilä engines are designed and developed for continuous operation on liquid biofuel (LBF) qualities with the properties included in the Tables SVO and PVO, FAME, B10 table, B20 table and B30 table and Paraffinic diesel fuels from synthesis and hydrotreatment. For the Straight Vegetable Oils (SVO) and Pure Vegetable Oils (PVO) operation included in Table SVO and PVO dedicated kits are required.

Liquid biofuels included in the Tables SVO and PVO, FAME, have typically lower heating value (LHV) than fossil fuels, while the capacity of fuel injection system influencing on guaranteed engine output must be checked case by case. Concerning biodiesel blends included in tables B10 table, B20 table and B30 table the influence of LHV is however not significant.

NOTICE
Liquid biofuels included in the Table Paraffinic diesel fuels from synthesis and hydrotreatment have a low density, why the capacity of fuel injection system influencing on guaranteed engine output must be checked case by case. Their flash point can based on specifications be also lower than 60 °C required for marine applications by SOLAS and Classification societies, which may prevent the use.

NOTICE
The use of liquid bio fuels qualities included in the table SVO and PVO, FAME, B10 table, B20 table and B30 table needs to be validated by contacting Wärtsilä.

Acceptable storage period for liquid biofuels excluding products which belong to the category being presented in Paraffinic diesel fuels from synthesis and hydrotreatment can be significantly shorter than storage period specified for fossil fuels. Some biodiesel manufacturers are referring to max. one month storage period. After that acidity starts to increase leading to faster oxidation rate of the fuel.

<u>Blending of different fuel qualities:</u>

Straight Vegetable Oils (SVO) and Pure Vegetable Oils (PVO) (table SVO and PVO) must not be mixed with fossil fuels, but have to be used as such.

Mixing of Straight Vegetable Oils (SVO) and Pure Vegetable Oils (PVO) (table SVO and PVO) and distillate fuel will increase the risk of cavitation in the fuel system, since the required fuel temperature before engine is normally 80 - 90 °C. At this temperature light fractions of distillate fuel have already started to evaporate.

The use of residual fuel requires much higher operating temperature than the use of Straight Vegetable Oils (SVO) and Pure Vegetable Oils (PVO), i.e. normally above 100 °C in order to achieve a proper fuel injection viscosity. Thus mixing of Straight Vegetable Oils (SVO) and Pure Vegetable Oils (PVO) (table SVO and PVO) with residual fuel will increase the risk of biofuel component polymerization due to elevated temperature.

Liquid biofuel qualities presented in the table FAME, and table Paraffinic diesel fuels from synthesis and hydrotreatment can be mixed with fossil distillate fuel and residual fuel with various ratios. Fossil fuel being used as a blending component has to fulfil Wärtsilä's distillate and residual fuel specification based on the ISO 8217:2017(E) standard. Depending on the bio component type its quality has to meet either the EN 14214:2012 standard included in the table FAME, or the EN 15940:2016 standard included in the table Paraffinic diesel fuels from synthesis and hydrotreatment. For biodiesel blend B10 there also exists an EN 16734 standard and for B20 & B30 blends an EN 16709 standard respectively. Biodiesel blend quality has to fulfil the requirements included in those two standards

<u>Required fuel temperatures:</u>

Straight Vegetable Oils (SVO) and Pure Vegetable Oils (PVO) (table SVO and PVO) temperature before an engine is an utmost important operating parameter. Too low temperature will cause solidification of fatty acids leading to clogging of filters, plug formation in the fuel system and even to fuel injection equipment component breakdowns. Too high fuel temperature will increase the risk of polymerization and formation of gummy deposits, especially in the presence of oxygen.

When operating on Straight Vegetable Oils (SVO) and Pure Vegetable Oils (PVO) (table SVO and PVO), it is utmost important to maintain a proper fuel temperature before fuel injection pumps in order to ensure safe operation of the engine and fuel system. The recommended fuel operating temperature depends on both the liquid biofuel quality and the degree of processing. E.g. many palm oil qualities require ~ 80 - 90 °C fuel temperature in order to achieve an expected lifetime of fuel injection equipment and to avoid fuel filter clogging. Some refined palm oil qualities are however behaving acceptably also at lower, ~ 70 - 75 °C operating temperature. For other types of Straight Vegetable Oils (SVO) and Pure Vegetable Oils (PVO) the temperature requirement can be slightly different and must be confirmed before the use.

For fuel qualities included in the table FAME, B10 table, B20 table and B30 table and Paraffinic diesel fuels from synthesis and hydrotreatment, fuel temperature before fuel injection pumps is limited to max. 45 °C. If residual fuel is used as a blending component together with HVO or biodiesel, fuel injection viscosity and injection temperature requirements being valid for residual fuels have to be followed.

6.1.5.1 Straight Vegetable Oils (SVO) and Pure Vegetable Oils (PVO)

The specification included in the table below is valid for crude and refined liquid biofuels, like palm oil, coconut oil, copra oil, rape seed oil, jatropha oil, fish oil, etc.

Table 6-3 Liquid biofuel specification for Straight Vegetable Oils (SVO) and Pure Vegetable Oils (PVO) (residual fuel substitutes)

Property	Unit	Limit	Test method reference
Viscosity, max.	mm^2/s @ 50 °C mm^2/s @ 80 °C	70 [1)] 15 [1)]	ISO 3104
Injection viscosity, min.	mm^2/s	2.0 [2)]	ISO 3104
Injection viscosity, max.	mm^2/s	24	ISO 3104
Density, max.	kg/m^3 @ 15 °C	940	ISO 3675 or ISO 12185
Ignition properties [3)]		[3)]	FIA-100 FCA test
Sulphur, max.	% m/m	0.05	ISO 8754
Total sediment existent, max.	% m/m	0.05	ISO 10307-1
Water, max. before engine	% v/v	0.20	ISO 3733
Micro carbon residue, max.	% m/m	0.50	ISO 10370
Ash, max.	% m/m	0.05	ISO 6245 / LP1001 [4)]
Phosphorus, max.	mg/kg	100	ISO 10478
Silicon, max.	mg/kg	15	ISO 10478
Alkali content (Na+K), max.	mg/kg	30	ISO 10478
Flash point (PMCC), min.	°C	60	ISO 2719

Table 6-3 Liquid biofuel specification for Straight Vegetable Oils (SVO) and Pure Vegetable Oils (PVO) (residual fuel substitutes) (continued)

Property	Unit	Limit	Test method reference
Cloud point, max.	°C	5)	ISO 3015
Cold filter plugging point, max.	°C	5)	IP 309
Copper strip corrosion (3 hrs @ 50 °C), max.	Rating	1b	ASTM D130
Steel corrosion (24 / 72 hours @ 20, 60 and 120 °C), max.	Rating	No signs of corrosion	LP 2902
Oxidation stability @ 110 °C, min.	h	17.0 6)	EN 14112
Acid number, max.	mg KOH/g	15.0	ASTM D664
Strong acid number, max.	mg KOH/g	0.0	ASTM D664
Iodine number, max.	g iodine /100 g	120 7)	ISO 3961
Synthetic polymers	% m/m	Report 8)	LP 2501

NOTICE

1) If injection viscosity of max. 24 cSt cannot be achieved with an unheated fuel, fuel system has to be equipped with a heater (mm²/s = cSt).

2) Min. viscosity limit at engine inlet in running conditions (mm²/s = cSt).

3) Ignition properties have to be equal to or better than the requirements for fossil fuels, i.e., CI min. 35 for LFO and CCAI max. 870 for HFO.

4) Ashing temperatures can vary when different test methods are used having an influence on the test result.

5) Cloud point and cold filter plugging point have to be at least 10 °C below fuel injection temperature and the temperature in the whole fuel system has to be min. 10 – 15 °C higher than cloud point and cold filter plugging point.

6) A lower oxidation stability value down to min. 10 hours can be considered acceptable if other fuel properties, like cloud point, cold filter plugging point and viscosity support that. This needs to be decided case-by-case.

7) Iodine number of soybean oil is somewhat higher, up to ~ 140, which is acceptable for specific that biofuel quality.

8) Biofuels originating from food industry can contain synthetic polymers, like e.g. styrene, propene and ethylene used in packing material. Such compounds can cause filter clogging and shall thus not be present in biofuels.

NOTICE

If Selective Catalyst Reduction or oxidation catalyst needs to be used the specification included in the table above does not apply, but the fuel quality requirements have to be discussed separately. The specification does not take into consideration Particulate Matter emission limits.

NOTICE
When analysing the energy content (Higher and Lower Heating Value) of Straight Vegetable Oils (SVO) and Pure Vegetable Oils (PVO) the calculation method included in the ISO 8217 standard can't be used, but the analysis has to be made by following the ASTM D240 standard.

NOTICE
The use of liquid biofuel oils fulfilling the table above requirements always require a NSR to be made.

6.1.5.2 Fatty acid methyl ester (FAME) / Biodiesel

Renewable refined liquid biofuels which are manufactured by using transesterification processes, can contain both vegetable and / or animal based feedstock and do normally show out very good physical and chemical properties. These fuels can be used provided that the specification included in the table below is fulfilled. International standards ASTM D 6751-20 or EN 14214:2012 (E) are typically used for specifying biodiesel quality. Further, for biodiesel blend B10 there exists an EN 16734 standard and for B20 & B30 blends an EN 16709 standard respectively. Biodiesel blend quality has to fulfil the requirements included in those two standards. The requirements of B10, B20 and B30 are included in the Table B10 table, B20 table and B30 table.

Table 6-4 Fatty acid methyl ester (FAME) / Biodiesel specification based on the EN 14214:2012 standard

Property	Unit	Limit	Test method reference
Viscosity, min. - max.	mm^2/s @ 40 °C	3.5 - 5.0	EN ISO 3104
Injection viscosity, min.	mm^2/s	2.0 [1)]	EN ISO 3104
Density, min. - max.	kg/m^3 @ 15 °C	860 - 900	EN ISO 3675 / 12185
Cetane number, min.	-	51.0	EN ISO 5165
Sulphur content, max.	mg/kg	10.0	EN ISO 20846 / 20884 / 13032
Sulphated ash content, max.	% m/m	0.02	ISO 3987
Total contamination, max.	mg/kg	24	EN 12662
Water content, max.	mg/kg	500	EN ISO 12937
Phosphorus content, max.	mg/kg	4.0	EN 14107
Group I metals (Na + K) content, max.	mg/kg	5.0	EN 14108 / EN 14109 / 14538
Group II metals (Ca + Mg) content, max.	mg/kg	5.0	EN 14538
Flash point, min.	°C	101	EN ISO 2719A / 3679
Cold filter plugging point, max. (climate dependent requirement)	°C	-20 → +5 [2)]	EN 116
Oxidation stability @ 110 °C, min.	h	8.0	EN 14112
Copper strip corrosion (3 hrs @ 50 °C), max.	Rating	Class 1	EN ISO 2160
Acid value, max.	mg KOH/g	0.50	EN 14104

Table 6-4 Fatty acid methyl ester (FAME) / Biodiesel specification based on the EN 14214:2012 standard (continued)

Property	Unit	Limit	Test method reference
Iodine value, max.	g iodine/100 g	120	EN 14111 / 16300
FAME content, min.	% m/m	96.5	EN 14103
Linolenic acid methyl ester, max.	% m/m	12.0	EN 14103
Polyunsaturated (≥ 4 double bonds) methyl esters, max.	% m/m	1.00	EN 15779
Methanol content, max.	% m/m	0.20	EN 14110
Monoglyceride content, max.	% m/m	0.70	EN 14105
Diglyceride content, max.	% m/m	0.20	EN 14105
Triglyceride content, max.	% m/m	0.20	EN 14105
Free glycerol, max.	% m/m	0.02	EN 14105 / EN 14106
Total glycerol, max.	% m/m	0.25	EN 14105

NOTICE

1) Min. limit at engine inlet in running conditions (mm^2/s = cSt).

2) Cold flow properties of renewable biodiesel can vary based on the geographical location and also based on the feedstock properties, which issues must be taken into account when designing the fuel system. For arctic climates even lower CFPP values down to -44 °C are specified.

NOTICE

When analysing the energy content (Higher and Lower Heating Value) of Biodiesel the calculation method included in the ISO 8217 standard can't be used, but the analysis has to be made by following the ASTM D240 standard.

NOTICE

The use of liquid biofuel oils fulfilling the table above requirements always require a NSR to be made.

6.1.5.3 Automotive B10 diesel fuel

Table 6-5 Automotive B10 diesel fuel – Requirements and test methods based on the EN 16734:2016 standard

Property	Unit	Limit	Test method reference
Viscosity, min - max.	mm^2/s @ 40 °C	2.000 - 4.500	EN ISO 3104
Injection viscosity, min.	mm^2/s	2.0 1)	EN ISO 3104
Density, min - max.	kg/m^3 @ 15 °C	820 - 845	EN ISO 3675

Table 6-5 Automotive B10 diesel fuel – Requirements and test methods based on the EN 16734:2016 standard (continued)

Property	Unit	Limit	Test method reference
Sulphur content, max.	mg/kg	10.0	EN ISO 20846 / 20884 / 13032
Ash content, max.	% m/m	0.01	EN ISO 6245
Total contamination, max.	mg/kg	24	EN 12662
Water content, max.	% m/m	0.02	EN ISO 12937
Manganese content, max.	mg/l	2.0	EN 16576
Cold filter plugging point, max. (climate dependent requirement)	°C	-20 -> +5 2)	EN 116 / 16329
Flash point, min.	°C	55 3)	EN ISO 2719
Oxidation stability, min.	h	20.0	EN 15751
Oxidation stability, max.	g/m3	25	EN 12205
Polycyclic aromatic hydrocarbons, max.	% m/m	8.0	EN 12916
Carbon residue (on 10% distillation residue), max.	% m/m	0.3	EN ISO 10370
Copper strip corrosion (3 hrs @ 50 °C), max.	Rating	Class 1	EN ISO 2160
Lubricity, wear scar diameter at 60 oC, max.	um	460	EN ISO 12156-1
Distillation			EN ISO 3405 / 3924
- % v/v recovered at 250 °C, max.	% v/v	< 65	
- % v/v recovered at 350°C, min	% v/v	85	
- 95% v/v recovered at, max.	°C	360	
FAME content, min.	% v/v	10.0	EN 14078

NOTICE

1) Min. limit at engine inlet in running conditions (mm^2/s = cSt).

2) Cold flow properties of renewable biodiesel can vary based on the geographical location and also based on the feedstock properties, which issues must be taken into account when designing the fuel system. For arctic climates even lower CFPP values down to -44 °C are specified.

3) The use in marine applications is allowed provided that a fuel supplier can guarantee min. flash point of 60 °C.

NOTICE

The use of liquid biofuel oils fulfilling the table above requirements always require a NSR to be made.

6.1.5.4 High FAME diesel fuel (B20)

Table 6-6 High FAME diesel fuel (B20) – Requirements and test methods based on the EN 16709:2015 standard

Property	Unit	Limit	Test method reference
Viscosity, min - max.	mm^2/s @ 40 °C	2.000 - 4.620	EN ISO 3104
Injection viscosity, min.	mm^2/s	2.0 1)	EN ISO 3104
Density, min - max.	kg/m^3 @ 15 °C	820 - 860	EN ISO 3675
Cetane number, min.	-	51.0	EN ISO 5165, EN 15195 / 16144 / 16715 / 16906
Sulphur content, max.	mg/kg	10.0	EN ISO 20846 / 20884 / 13032
Ash content, max.	% m/m	0.01	EN ISO 6245
Total contamination, max.	mg/kg	24	EN 12662
Water content, max.	% m/m	0.026	EN ISO 12937
Manganese content, max.	mg/l	2.0	EN 16576
Cold filter plugging point, max. (climate dependent requirement)	°C	-20 -> +5 2)	EN 116 / 16329
Flash point, min.	°C	55 3)	EN ISO 2719
Oxidation stability, min.	h	20.0	EN 15751
Polycyclic aromatic hydrocarbons, max.	% m/m	8.0	EN 12916
FAME content, min.	% v/v	14.0 - 20.0	EN 14078
Distillation			EN ISO 3405 / 3924
- % v/v recovered at 250 °C, max.	% v/v	< 65	
- % v/v recovered at 350°C, min	% v/v	85	
- 95% v/v recovered at, max.	°C	360	

NOTICE

1) Min. limit at engine inlet in running conditions (mm^2/s = cSt).

2) Cold flow properties of renewable biodiesel can vary based on the geographical location and also based on the feedstock properties, which issues must be taken into account when designing the fuel system. For arctic climates even lower CFPP values down to -44 °C are specified.

3) The use in marine applications is allowed provided that a fuel supplier can guarantee min. flash point of 60 °C.

NOTICE

The use of liquid biofuel oils fulfilling the table above requirements always require a NSR to be made.

6.1.5.5 High FAME diesel fuel (B30)

Table 6-7 High FAME diesel fuel (B30) – Requirements and test methods based on the EN 16709:2015 standard

Property	Unit	Limit	Test method reference
Viscosity, min - max.	mm^2/s @ 40 °C	2.000 - 4.620	EN ISO 3104
Injection viscosity, min.	mm^2/s	2.0 1)	EN ISO 3104
Density, min - max.	kg/m^3 @ 15 °C	825 - 865	EN ISO 3675
Cetane number, min.	-	51.0	EN ISO 5165, EN 15195 / 16144 / 16715 / 16906
Sulphur content, max.	mg/kg	10.0	EN ISO 20846 / 20884 / 13032
Ash content, max.	% m/m	0.01	EN ISO 6245
Total contamination, max.	mg/kg	24	EN 12662
Water content, max.	% m/m	0.029	EN ISO 12937
Manganese content, max.	mg/l	2.0	EN 16576
Cold filter plugging point, max. (climate dependent requirement)	°C	-20 -> +5 2)	EN 116 / 16329
Flash point, min.	°C	55 3)	EN ISO 2719
Oxidation stability, min.	h	20.0	EN 15751
Polycyclic aromatic hydrocarbons, max.	% m/m	8.0	EN 12916
FAME content, min. - max.	% v/v	24.0 - 30.0	EN 14078
Distillation			EN ISO 3405 / 3924
- % v/v recovered at 250 °C, max.	% v/v	< 65	
- % v/v recovered at 350°C, min	% v/v	85	
- 95% v/v recovered at, max.	°C	360	

NOTICE

1) Min. limit at engine inlet in running conditions (mm²/s = cSt).

2) Cold flow properties of renewable biodiesel can vary based on the geographical location and also based on the feedstock properties, which issues must be taken into account when designing the fuel system. For arctic climates even lower CFPP values down to -44 °C are specified.

3) The use in marine applications is allowed provided that a fuel supplier can guarantee min. flash point of 60 °C.

NOTICE

The use of liquid biofuel oils fulfilling the table above requirements always require a NSR to be made.

6.1.5.6 Paraffinic diesel fuels from synthesis and hydrotreatment

Paraffinic renewable distillate fuels originating from synthesis or hydrotreatment are high quality distillate fuels and their composition and physical & chemical properties do differ from transesterified biodiesel. The quality of paraffinic diesel shall meet the EN 15940:2016 Class A requirements included in the table below. For arctic or severe winter climates additional or more stringent requirements are set concerning cold filter plugging point, cloud point, viscosity and distillation properties.

Table 6-8 Requirements for paraffinic diesel from synthesis or hydrotreatment based on the EN 15940:2016 standard

Property	Unit	Limit	Test method reference
Viscosity, min. - max.	mm^2/s @ 40 °C	2.0 - 4.5	EN ISO 3104
Injection viscosity, min.	mm^2/s	2.0 1)	EN ISO 3104
Density, min. - max.	kg/m^3 @ 15 °C	765 - 800 2)	EN ISO 3675 / 12185
Cetane number, min.	-	70.0	EN 15195 / EN ISO 5165
Sulphur content, max.	mg/kg	5.0	EN ISO 20846 / 20884
Ash content, max.	% m/m	0.010	EN ISO 6245
Total contamination, max.	mg/kg	24	EN 12662
Water content, max.	mg/kg	200	EN ISO 12937
Total aromatics, max.	% m/m	1.1	EN 12916
Carbon residue on 10% distillation residue, max.	% m/m	0.30	EN ISO 10370
Lubricity, max.	µm	460	EN ISO 12156-1
Flash point, min.	°C	55 3)	EN ISO 2719
Cold filter plugging point, max. (climate dependent requirement)	°C	-20 → +5 4)	EN 116 / 16329
Oxidation stability, max. Oxidation stability, min.	g/m^3 h	25 20 5)	EN ISO 12205 EN 15751
Copper strip corrosion (3 hrs @ 50 °C), max.	Rating	Class 1	EN ISO 2160
Distillation			EN ISO 3405 / 3924
% v/v recovered @ 250 °C, max.	% v/v	65	
% v/v recovered @ 350 °C, min.	% v/v	85	
95 % v/v recovered at, max.	°C	360	
Distillation % v/v recovered @ 250 °C, max. % v/v recovered @ 350 °C, min. 95 % v/v recovered at, max.	% v/v % v/v °C	65 85 360	EN ISO 3405 / 3924
FAME content, max.	% v/v	7.0	EN 14078

NOTICE
1) Min. limit at engine inlet in running conditions (mm^2/s = cSt). **2)** Due to low density the guaranteed engine output of pure hydrotreated fuel / GTL has to be confirmed case by case. **3)** The use in marine applications is allowed provided that a fuel supplier can guarantee min. flash point of 60 °C. **4)** Cold flow properties of renewable biodiesel can vary based on the geographical location and also based on the feedstock properties, which issues must be taken into account when designing the fuel system. For arctic or severe winter climates even lower CFPP values down to -44 °C are specified. **5)** Additional requirement if the fuel contains > 2.0 % v/v of FAME.

NOTICE
When analysing the energy content (Higher and Lower Heating Value) of paraffinic diesel the calculation method included in the ISO 8217 standard can't be used, but the analysis has to be made by following the ASTM D240 standard.

6.2 External fuel oil system

The design of the external fuel system may vary from installation to installation but every system shall be designed to provide the engine with fuel oil of correct flow, pressure, viscosity and degree of purity. Temperature control is required to maintain stable and correct viscosity of the fuel before the injection pumps (please refer to *Engine Online Configurator* available through Wärtsilä website for details). Sufficient circulation through every engine connected to the same circuit must be ensured in all operating conditions.

The fuel treatment system should comprise at least one settling tank and two separators. Correct dimensioning of HFO separators is of greatest importance, and therefore the recommendations of the separator manufacturer must be closely followed. Poorly centrifuged fuel is harmful to the engine and a high content of water may also damage the fuel feed system.

The external fuel system must not contaminate the engine's fuel with zinc. For example, galvanized surfaces or surfaces painted with paints containing zinc must not be in contact with engine fuel. Zinc in the fuel system could lead to e.g. clogged injectors and operational problems.

Injection pumps generate pressure pulses into the fuel feed and return piping.

The fuel pipes between the feed unit and the engine must be properly clamped to rigid structures. The distance between the fixing points should be at close distance next to the engine. See chapter *Piping design, treatment and installation*.

A connection for compressed air should be provided before the engine, together with a drain from the fuel return line to the clean leakage fuel or overflow tank. With this arrangement it is possible to blow out fuel from the engine prior to maintenance work, to avoid spilling.

NOTICE
In multiple engine installations, where several engines are connected to the same fuel feed circuit, it must be possible to close the fuel supply and return lines connected to the engine individually. This is a SOLAS requirement. It is further stipulated that the means of isolation shall not affect the operation of the other engines, and it shall be possible to close the fuel lines from a position that is not rendered inaccessible due to fire on any of the engines.

6.2.1 Definitions Filtration term used

● **Beta value $ß_{xx}$ ISO 16889, and Efficiency εxx**: scientific measurement of filter effectiveness. Numerical result on a given filter variates, depending on test method used, and on dust size distribution used during measurements.

- **Beta value $ß_{xx}$ = YY** : ISO name with ISO 16889 internationally standardised test method. Scientific repeatability below 25 micron $ß_{xx}$ =75, but weaker repeatability for filter mesh bigger than 25..45 microns. Example: $ß_{20}$ = 75 means "ultipass test, with standardised dust (ISO MTD dust): every 75 particles 20 micron ISO dust sent, one passes."
- **Efficiency εxx = YY %** : Old terminology, mathematically same meaning as Betavalue, but not any ISO standardised test method, and not necessarily with ISO MTD dust. Hence sometimes used for particles larger than 25..45 micron. Example: ε20 = 98,7% means "ndefined test method, undefined dust: every 75 particles 20 micron non-ISO dust sent, one passes, which is 98,7% stopped."

● **mesh size**: opening of the mesh (surface filtration), and often used as commercial name at purchase. Only approximately related to Efficiency and Beta-value. Insufficient to compare two filters from two suppliers. Good to compare two meshes of same filter model from same supplier. Totally different than micron absolute, that is always much bigger size in micron.

e.g. a real example: 30 micron mesh size = approx. 50 micron $ß_{50}$ = 75

● **abs. mesh (sphere passing mesh)**: it is a more accurate mesh size definition than above. It also specifies the measurement method (with spherical particles, passing /not passing through). On a given filter, it can have a different micron value than the commercial "mesh size"

● **XX micron, absolute**: it defines the real grade of filtration only when it is followed by Betavalue or Efficiency. Example: many suppliers intend it as $ß_{xx}$ = 75 ISO 16889 similar to old efficiency εxx = 98,7%, or as $ß_{xx}$ = 200 ISO 16889 (was εxx = 99,9%), but some suppliers intend it as $ß_{xx}$ = 2 ISO 16889 (was εxx = 50%)

● **XX micron, nominal**: commercial name of that mesh, at purchase. Not really related to filtration capability, especially when comparing different suppliers. Typically, a totally different value than XX micron, absolute e.g. a real example: 10 micron nominal (ε10 = 60%) = approx. 60 micron absolute $ß_{60}$ = 75 ISO 16889

6.2.2 Fuel heating requirements HFO

Heating is required for:

- Bunker tanks, settling tanks, day tanks
- Pipes (trace heating)
- Separators
- Fuel feeder/booster units

To enable pumping the temperature of bunker tanks must always be maintained 5...10°C above the pour point, typically at 40...50°C. The heating coils can be designed for a temperature of 60°C.

The tank heating capacity is determined by the heat loss from the bunker tank and the desired temperature increase rate.

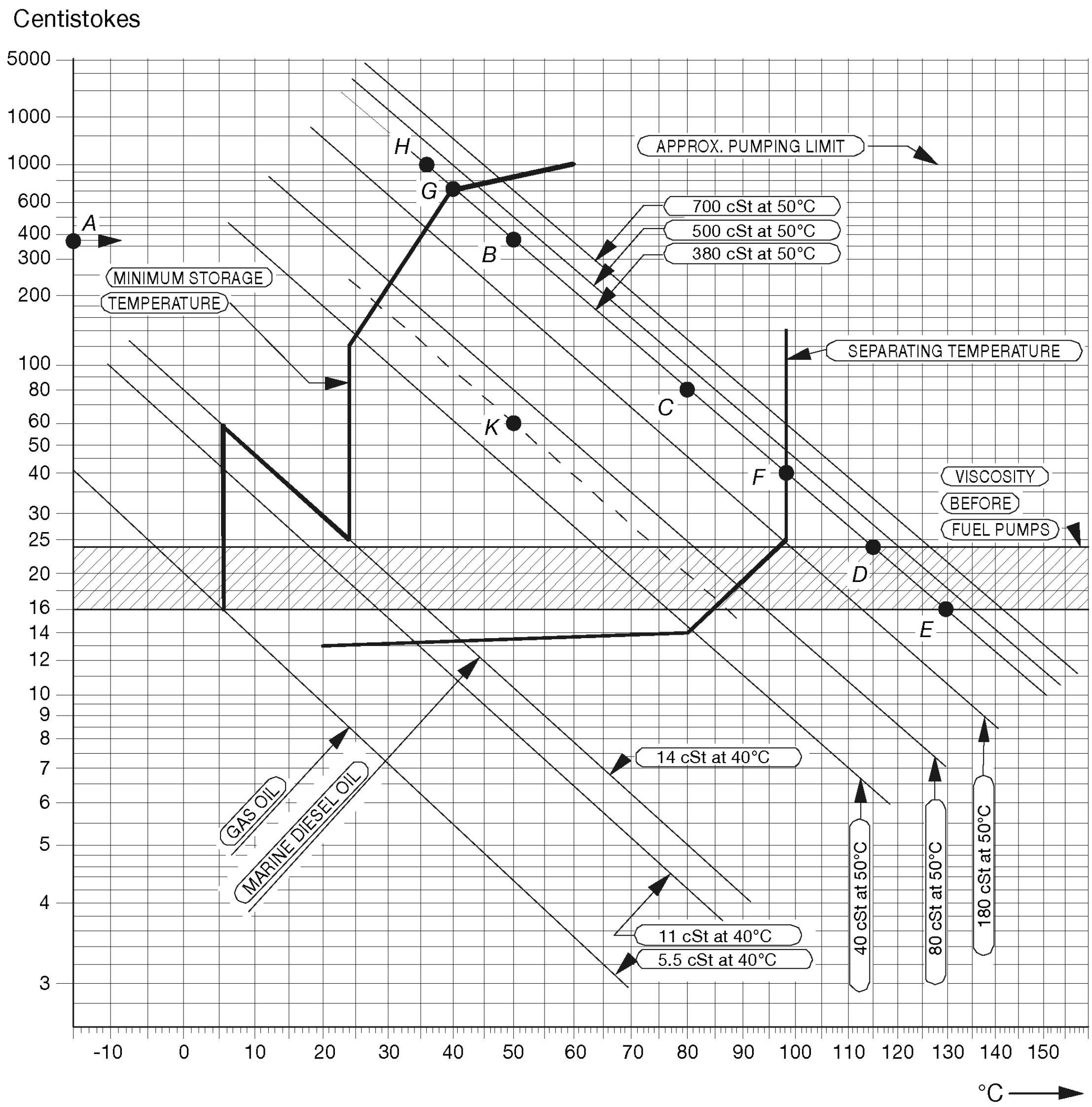


Fig 6-1 **Fuel oil viscosity-temperature diagram for determining the pre-heating temperatures of fuel oils (V92G0071b)**

Example 1: A fuel oil with a viscosity of 380 cSt (A) at 50°C (B) or 80 cSt at 80°C (C) must be pre-heated to 115 - 130°C (D-E) before the fuel injection pumps, to 98°C (F) at the separator and to minimum 40°C (G) in the bunker tanks. The fuel oil may not be pumpable below 36°C (H).

To obtain temperatures for intermediate viscosities, draw a line from the known viscosity/temperature point in parallel to the nearest viscosity/temperature line in the diagram.

Example 2: Known viscosity 60 cSt at 50°C (K). The following can be read along the dotted line: viscosity at 80°C = 20 cSt, temperature at fuel injection pumps 74 - 87°C, separating temperature 86°C, minimum bunker tank temperature 28°C.

6.2.3 Fuel tanks

The fuel oil is first transferred from the bunker tanks to settling tanks for initial separation of sludge and water. After centrifuging the fuel oil is transferred to day tanks, from which fuel is supplied to the engines.

6.2.3.1 Settling tank, HFO (1T02) and LFO (1T10)

Separate settling tanks for HFO and LFO are recommended.

To ensure sufficient time for settling (water and sediment separation), the capacity of each tank should be sufficient for min. 24 hours operation at maximum fuel consumption. The tanks should be provided with internal baffles to achieve efficient settling and have a sloped bottom for proper draining. The temperature in HFO settling tanks should be maintained between 50°C and 70°C, which requires heating coils and insulation of the tank. Usually LFO settling tanks do not need heating or insulation, but the tank temperature should be in the range 20...40°C.

6.2.3.2 Day tank, HFO (1T03) and LFO (1T06)

Two day tanks for HFO are to be provided, each with a capacity sufficient for at least 8 hours operation at maximum fuel consumption. A separate tank is to be provided for LFO. The capacity of the LFO tank should ensure fuel supply for 8 hours. Settling tanks may not be used instead of day tanks.

The day tank must be designed so that accumulation of sludge near the suction pipe is prevented and the bottom of the tank should be sloped to ensure efficient draining. HFO day tanks shall be provided with heating coils and insulation. It is recommended that the viscosity is kept below 140 cSt in the day tanks. Due to risk of wax formation, fuels with a viscosity lower than 50 cSt at 50°C must be kept at a temperature higher than the viscosity would require. Continuous separation is nowadays common practice, which means that the HFO day tank temperature normally remains above 90°C. The temperature in the LFO day tank should be in the range 20...40°C. The level of the tank must ensure a positive static pressure on the suction side of the fuel feed pumps.

If black-out starting with LFO from a gravity tank is foreseen, then the tank must be located at least 15 m above the engine crankshaft.

6.2.3.3 Leak fuel tank, clean fuel (1T04)

Clean leak fuel is drained by gravity from the engine. The fuel should be collected in a separate clean leak fuel tank, from where it can be pumped to the day tank and reused without separation. The pipes from the engine to the clean leak fuel tank should be arranged continuosly sloping.

The tank and the pipes must be heated and insulated, unless the installation is designed for operation on LFO only.

In HFO installations the change over valve for leak fuel (1V13) is needed to avoid mixing of the LFO and HFO clean leak fuel. When operating the engines in LFO, the clean LFO leak fuel shall be directed to the LFO clean leak fuel tank. Thereby the LFO can be pumped back to the LFO day tank (1T06).

When switching over from HFO to LFO the valve 1V13 shall direct the fuel to the HFO leak fuel tank long time enough to ensure that no HFO is entering the LFO clean leak fuel tank.

Refer to section "*Fuel feed system - HFO installations*" for an example of the external HFO fuel oil system.

The leak fuel piping should be fully closed to prevent dirt from entering the system.

6.2.3.4 Leak fuel tank, dirty fuel (1T07)

In normal operation no fuel should leak out from the components of the fuel system. In connection with maintenance, or due to unforeseen leaks, fuel or water may spill in the hot box of the engine. The spilled liquids are collected and drained by gravity from the engine through the dirty fuel connection.

Dirty leak fuel shall be led to a sludge tank.

The tank and the pipes must be heated and insulated, unless the installation is designed for operation exclusively on LFO.

6.2.4 Fuel treatment

6.2.4.1 Separation

Heavy fuel (residual, and mixtures of residuals and distillates) must be cleaned in an efficient centrifugal separator before it is transferred to the day tank.

Classification rules require the separator arrangement to be redundant so that required capacity is maintained with any one unit out of operation.

All recommendations from the separator manufacturer must be closely followed.

Centrifugal disc stack separators are recommended also for installations operating on LFO only, to remove water and possible contaminants. The capacity of LFO separators should be sufficient to ensure the fuel supply at maximum fuel consumption. Would a centrifugal separator be considered too expensive for a LFO installation, then it can be accepted to use coalescing type filters instead. A coalescing filter is usually installed on the suction side of the circulation pump in the fuel feed system. The filter must have a low pressure drop to avoid pump cavitation.

Separator mode of operation

The best separation efficiency is achieved when also the stand-by separator is in operation all the time, and the throughput is reduced according to actual consumption.

Separators with monitoring of cleaned fuel (without gravity disc) operating on a continuous basis can handle fuels with densities exceeding 991 kg/m3 at 15°C. In this case the main and stand-by separators should be run in parallel.

When separators with gravity disc are used, then each stand-by separator should be operated in series with another separator, so that the first separator acts as a purifier and the second as clarifier. This arrangement can be used for fuels with a density of max. 991 kg/m3 at 15°C. The separators must be of the same size.

Separation efficiency

The term Certified Flow Rate (CFR) has been introduced to express the performance of separators according to a common standard. CFR is defined as the flow rate in l/h, 30 minutes after sludge discharge, at which the separation efficiency of the separator is 85%, when using defined test oils and test particles. CFR is defined for equivalent fuel oil viscosities of 380 cSt and 700 cSt at 50°C. More information can be found in the CEN (European Committee for Standardisation) document CWA 15375:2005 (E).

The separation efficiency is measure of the separator's capability to remove specified test particles. The separation efficiency is defined as follows:

$$n = 100 \times \left(1 - \frac{C_{out}}{C_{in}}\right)$$

where:

n = separation efficiency [%]

C_{out} = number of test particles in cleaned test oil

C_{in} = number of test particles in test oil before separator

6.2.4.2 Separator unit (1N02/1N05)

Separators are usually supplied as pre-assembled units designed by the separator manufacturer.

Typically separator modules are equipped with:

- Suction strainer (1F02)
- Feed pump (1P02)
- Pre-heater (1E01)
- Sludge tank (1T05)
- Separator (1S01/1S02)
- Sludge pump
- Control cabinets including motor starters and monitoring

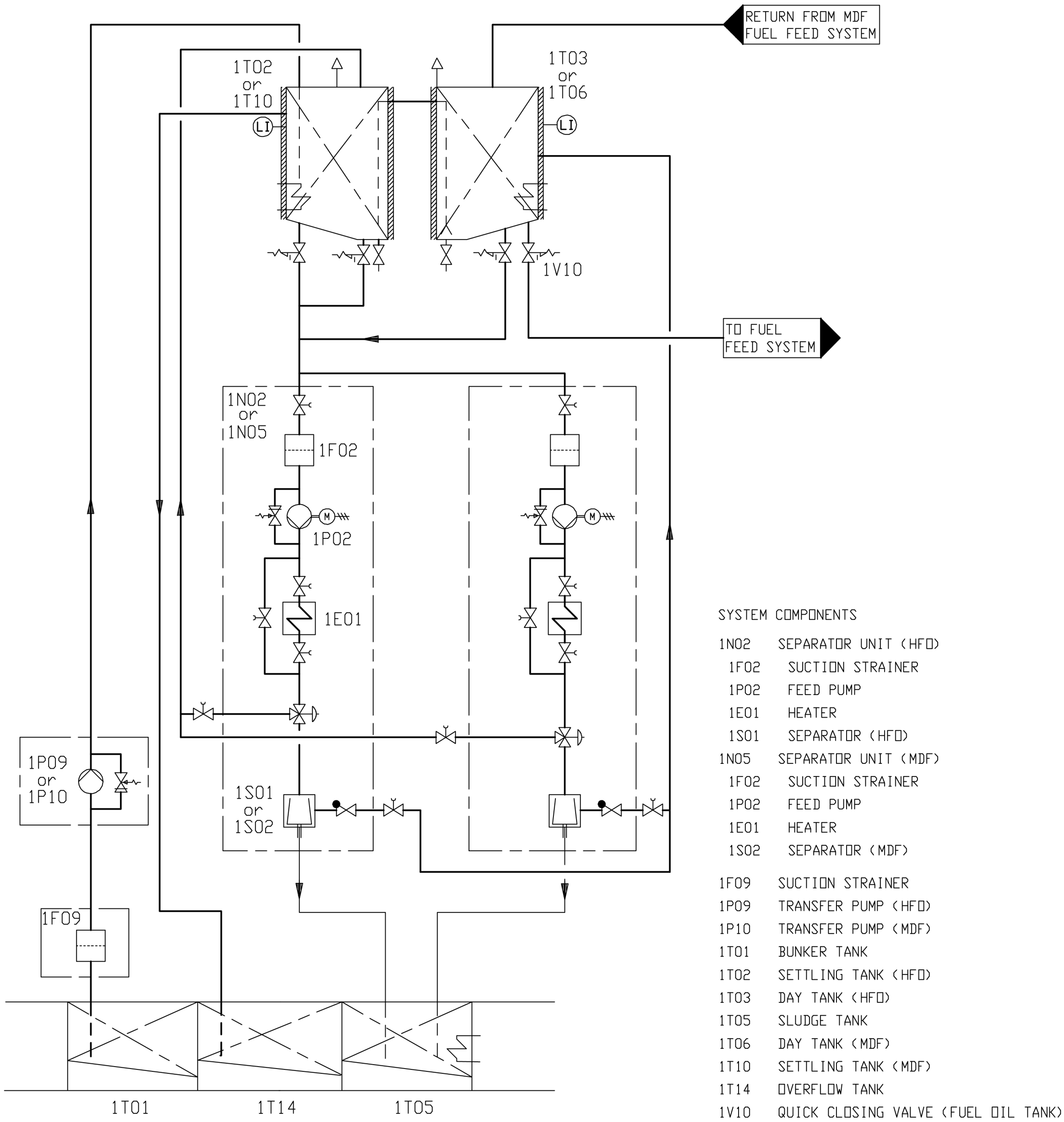


Fig 6-2 Fuel transfer and separating system (V76F6626G)

6.2.4.3 Separator feed pumps (1P02)

Feed pumps should be dimensioned for the actual fuel quality and recommended throughput of the separator. The pump should be protected by a suction strainer (mesh size about 0.5 mm)

An approved system for control of the fuel feed rate to the separator is required.

Design data:	HFO	LFO

(continued)

Design pressure	0.5 MPa (5 bar)	0.5 MPa (5 bar)
Design temperature	100°C	50°C
Viscosity for dimensioning electric motor	1000 cSt	100 cSt

6.2.4.4 Separator pre-heater (1E01)

The pre-heater is dimensioned according to the feed pump capacity and a given settling tank temperature.

The surface temperature in the heater must not be too high in order to avoid cracking of the fuel. The temperature control must be able to maintain the fuel temperature within ± 2°C.

Recommended fuel temperature after the heater depends on the viscosity, but it is typically 98°C for HFO and 20...40°C for LFO. The optimum operating temperature is defined by the sperarator manufacturer.

The required minimum capacity of the heater is:

$$P = \frac{Q \times \Delta T}{1700}$$

where:

P = heater capacity [kW]

Q = capacity of the separator feed pump [l/h]

ΔT = temperature rise in heater [°C]

For heavy fuels ΔT = 48°C can be used, i.e. a settling tank temperature of 50°C. Fuels having a viscosity higher than 5 cSt at 50°C require pre-heating before the separator.

The heaters to be provided with safety valves and drain pipes to a leakage tank (so that the possible leakage can be detected).

6.2.4.5 Separator (1S01/1S02)

Based on a separation time of 23 or 23.5 h/day, the service throughput Q [l/h] of the separator can be estimated with the formula:

$$Q = \frac{P \times b \times 24[h]}{\rho \times t}$$

where:

P = max. continuous rating of the diesel engine(s) [kW]

b = specific fuel consumption + 15% safety margin [g/kWh]

ρ = density of the fuel [kg/m^3]

t = daily separating time for self cleaning separator [h] (usually = 23 h or 23.5 h)

The flow rates recommended for the separator and the grade of fuel must not be exceeded. The lower the flow rate the better the separation efficiency.

Sample valves must be placed before and after the separator.

6.2.4.6 LFO separator in HFO installations (1S02)

A separator for LFO is recommended also for installations operating primarily on HFO. The LFO separator can be a smaller size dedicated LFO separator, or a stand-by HFO separator used for LFO.

6.2.4.7 Sludge tank (1T05)

The sludge tank should be located directly beneath the separators, or as close as possible below the separators, unless it is integrated in the separator unit. The sludge pipe must be continuously falling.

6.2.5 Fuel feed system - LFO installations

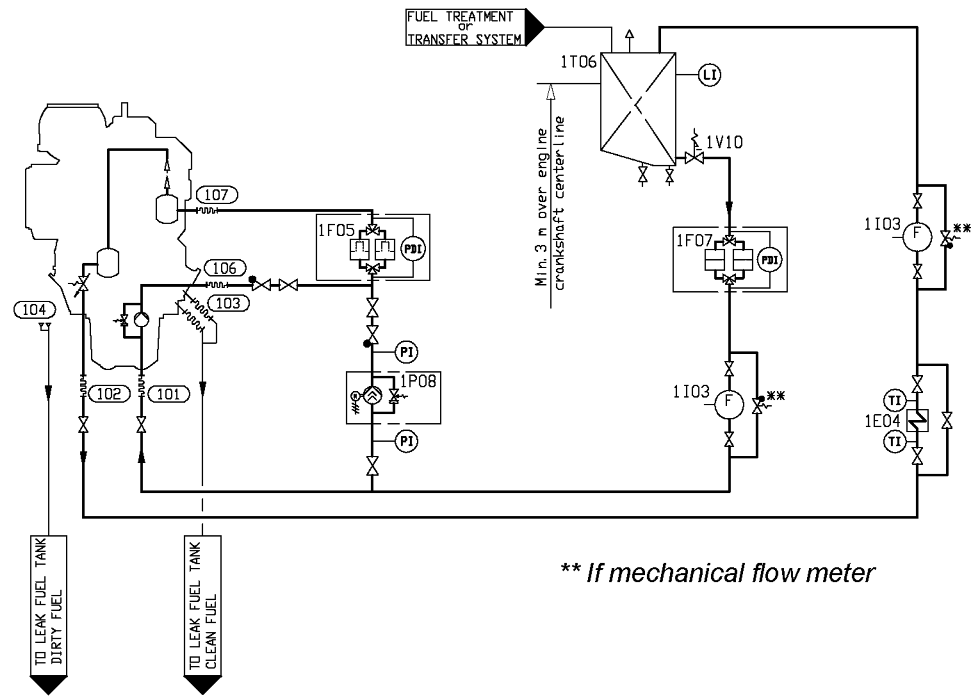


Fig 6-3 Typical example of fuel oil system (LFO) with engine driven pump (V76F6629G)

System components		Pipe connections	
1E04	Cooler (LFO)	101	Fuel inlet
1F05	Fine filter or Safety filter (LFO)	102	Fuel outlet
1F07	Suction strainer (LFO)	103	Leak fuel drain, clean fuel
1I03	Flow meter (LFO)	104	Leak fuel drain, dirty fuel
1P08	Stand-by pump (LFO)	106	Fuel to external filter
1T06	Day tank (LFO)	107	Fuel from external filter
1V10	Quick closing valve (fuel oil tank)		

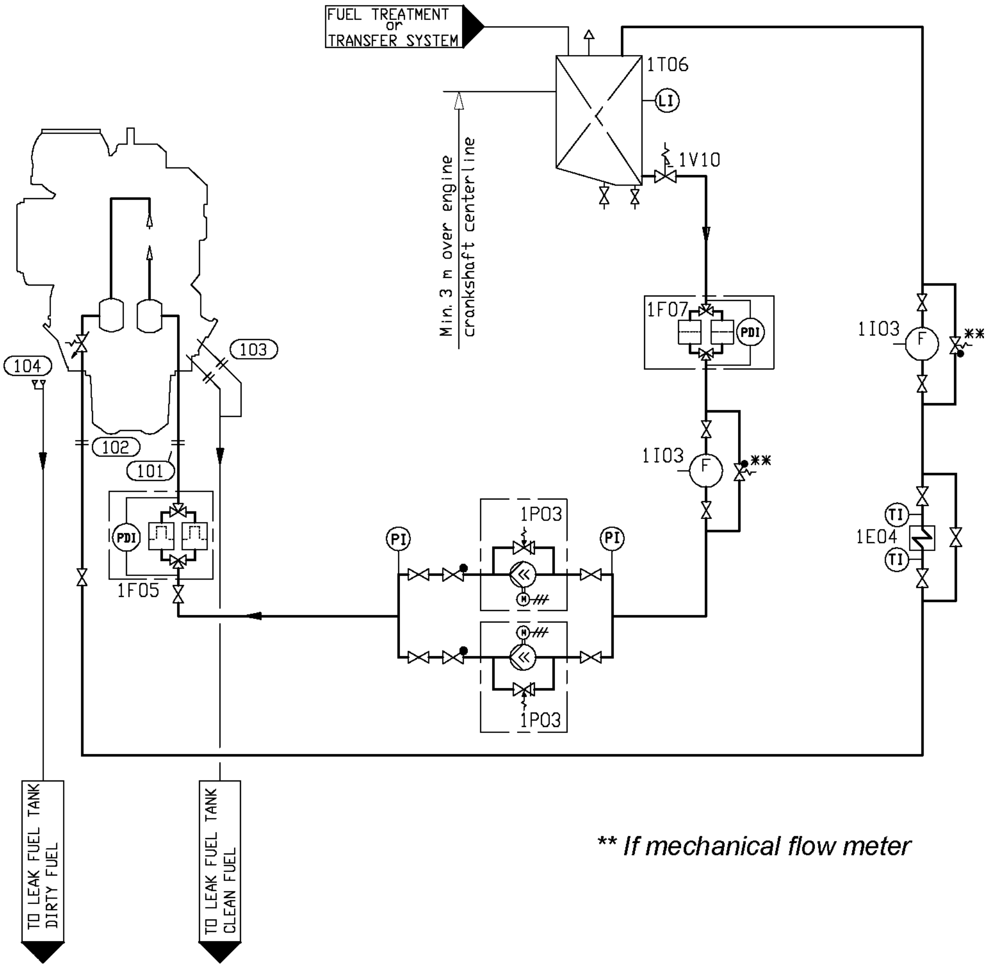


Fig 6-4 **Typical example of fuel oil system (LFO) without engine driven pump (V76F6116E)**

System components		Pipe connections	
1E04	Cooler (LFO)	101	Fuel inlet
1F05	Fine filter or Safety filter (LFO)	102	Fuel outlet
1F07	Suction strainer (LFO)	1031	Leak fuel drain, clean fuel
1I03	Flowmeter (LFO)	1032	Leak fuel drain, clean fuel
1P03	Circulation pump (LFO)	1033	Leak fuel drain, clean fuel
1T06	Day tank (LFO)	1034	Leak fuel drain, clean fuel
1V10	Quick closing valve (fuel oil tank)	1041	Leak fuel drain, dirty fuel
		1042	Leak fuel drain, dirty fuel
		1043	Leak fuel drain, dirty fuel
		1044	Leak fuel drain, dirty fuel

If the engines are to be operated on LFO only, heating of the fuel is normally not necessary. In such case it is sufficient to install the equipment listed below. Some of the equipment listed below is also to be installed in the LFO part of a HFO fuel oil system.

6.2.5.1 Circulation pump, LFO (1P03)

The circulation pump maintains the pressure at the injection pumps and circulates the fuel in the system. It is recommended to use a screw pump as circulation pump. A suction strainer with a fineness of 0.5 mm should be installed before each pump. There must be a positive static pressure of about 30 kPa on the suction side of the pump.

Design data:

Capacity without circulation pumps (1P12)	please refer to *Engine Online Configurator* available through Wärtsilä website
Capacity with circulation pumps (1P12)	15% more than total capacity of all 1P12 circulation pumps
Design pressure	1.6 MPa (16 bar)
Max. total pressure (safety valve)	1.0 MPa (10 bar)
Nominal pressure	please refer to *Engine Online Configurator* available through Wärtsilä website
Design temperature	50°C
Viscosity for dimensioning of electric motor	90 cSt

6.2.5.2 Stand-by pump, LFO (1P08)

The stand-by pump is required in case of a single main engine equipped with an engine driven pump. It is recommended to use a screw pump as stand-by pump. The pump should be placed so that a positive static pressure of about 30 kPa is obtained on the suction side of the pump.

Design data:

Capacity	5 x the total consumption of the connected engine
Design pressure	1.6 MPa (16 bar)
Max. total pressure (safety valve)	1.2 MPa (12 bar)
Design temperature	50°C
Viscosity for dimensioning of electric motor	90 cSt

6.2.5.3 Flow meter, LFO (1I03)

If the return fuel from the engine is conducted to a return fuel tank instead of the day tank, one consumption meter is sufficient for monitoring of the fuel consumption, provided that the meter is installed in the feed line from the day tank (before the return fuel tank). A fuel oil cooler is usually required with a return fuel tank.

The total resistance of the flow meter and the suction strainer must be small enough to ensure a positive static pressure of about 30 kPa on the suction side of the circulation pump.

6.2.5.4 Fine filter or Safety filter, LFO (1F05)

The fuel oil fine filter (safety filter) is a full flow duplex type filter with steel net. This filter must be installed as near the engine as possible.

The diameter of the pipe between the fine filter (safety filter) and the engine should be the same as the diameter before the filters.

Design data:	
Fuel viscosity	according to fuel specifications
Design temperature	50°C
Design flow	Larger than feed/circulation pump capacity
Design pressure	1.6 MPa (16 bar)
Fineness	34 µm (absolute mesh size) ($ß_{34}$ = 2, $ß_{50}$ = 75, ISO16889)

Maximum permitted pressure drops at 14 cSt:	
- clean filter	20 kPa (0.2 bar)
- alarm	80 kPa (0.8 bar)

6.2.5.5 LFO cooler (1E04)

The fuel viscosity may not drop below the minimum value stated in *Engine Online Configurator* available through Wärtsilä website. When operating on LFO, the practical consequence is that the fuel oil inlet temperature must be kept below 45°C. Very light fuel grades may require even lower temperature.

Sustained operation on LFO usually requires a fuel oil cooler. The cooler is to be installed in the return line after the engine(s). LT-water is normally used as cooling medium.

If LFO viscosity in day tank drops below stated minimum viscosity limit then it is recommended to install a LFO cooler into the engine fuel supply line in order to have reliable viscosity control.

Design data:	
Heat to be dissipated	2.5 kW/cyl
Max. pressure drop, fuel oil	80 kPa (0.8 bar)
Max. pressure drop, water	60 kPa (0.6 bar)
Margin (heat rate, fouling)	min. 15%
Design temperature LFO/HFO installation	50/150°C

6.2.5.6 Return fuel tank (1T13)

The return fuel tank shall be equipped with a vent valve needed for the vent pipe to the LFO day tank. The volume of the return fuel tank should be at least 100 l.

6.2.5.7 Black out start

Diesel generators serving as the main source of electrical power must be able to resume their operation in a black out situation by means of stored energy. Depending on system design and classification regulations, it may in some cases be permissible to use the emergency generator. Engines without engine driven fuel feed pump can reach sufficient fuel pressure to enable black out start by means of:

- A gravity tank located min. 15 m above the crankshaft
- A pneumatically driven fuel feed pump (1P11)
- An electrically driven fuel feed pump (1P11) powered by an emergency power source

6.2.6 Fuel feed system - HFO installations

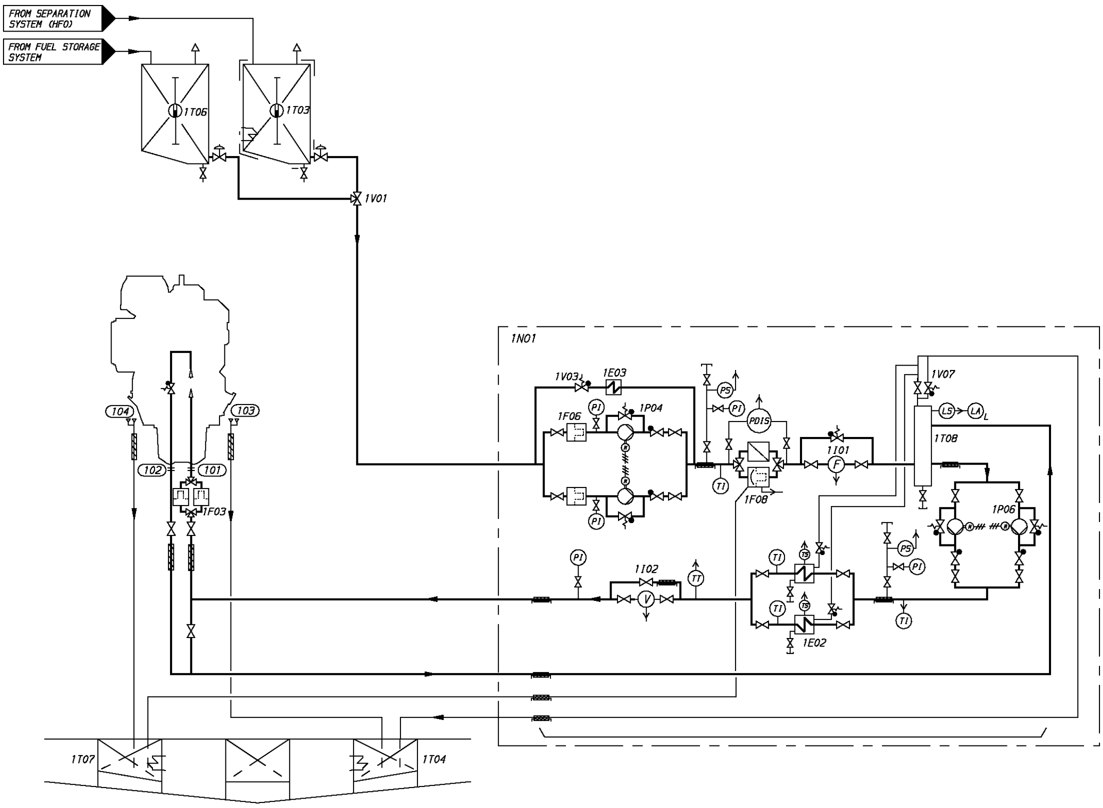


Fig 6-5 Example of fuel oil system (HFO) single engine installation (V76F6627D)

System components:			
1E02	Heater (booster unit)	1P04	Fuel feed pump (booster unit)
1E03	Cooler (booster unit)	1P06	Circulation pump (booster unit)
1E04	Cooler (LFO)	1T03	Day tank (HFO)
1F03	Safety filter (HFO)	1T06	Day tank (LFO)
1F06	Suction filter (booster unit)	1T08	De-aeration tank (booster unit)
1F08	Automatic filter (booster unit)	1V01	Changeover valve
1I01	Flow meter (booster unit)	1V03	Pressure control valve (booster unit)
1I02	Viscosity meter (booster unit)	1V07	Venting valve (booster unit)
1N01	Feeder/booster unit	1V10	Quick closing valve (fuel oil tank)

Pipe connections:		L32	V32
101	Fuel inlet	DN32	
102	Fuel outlet	DN32	
1031	Leak fuel drain, clean fuel	OD28	
1032	Leak fuel drain, clean fuel	-	OD28
1033	Leak fuel drain, clean fuel	OD28	DN20
1034	Leak fuel drain, clean fuel	-	DN20
1041	Leak fuel drain, dirty fuel	OD18	
1042	Leak fuel drain, dirty fuel	-	OD18
1043	Leak fuel drain, dirty fuel	OD28	DN32

(continued)

Pipe connections:		L32	V32
1044	Leak fuel drain, dirty fuel	-	DN32

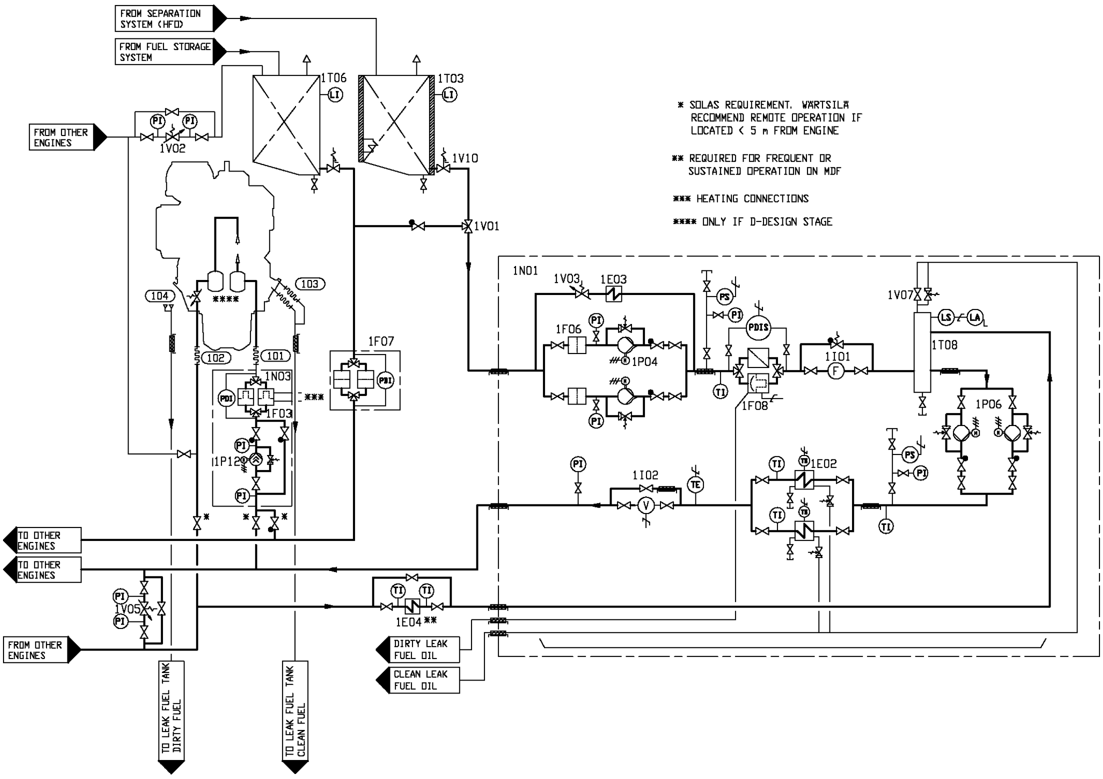


Fig 6-6 **Example of fuel oil system (HFO) multiple engine installation (V76F6628F)**

System components:			
1E02	Heater (booster unit)	1P06	Circulation pump (booster unit)
1E03	Cooler (booster unit)	1P12	Circulation pump (HFO/LFO)
1E04	Cooler (LFO)	1T03	Day tank (HFO)
1F03	Safety filter (HFO)	1T06	Day tank (LFO)
1F06	Suction filter (booster unit)	1T08	De-aeration tank (booster unit)
1F07	Suction strainer (LFO)	1V01	Changeover valve
1F08	Automatic filter (booster unit)	1V02	Pressure control valve (LFO)
1I01	Flow meter (booster unit)	1V03	Pressure control valve (booster unit)
1N01	Feeder/booster unit	1V05	Overflow valve (HFO/LFO)
1N03	Pump and filter unit (HFO/LFO)	1V07	Venting valve (booster unit)
1P04	Fuel feed pump (booster unit)	1V10	Quick closing valve (fuel oil tank)

Pipe connections:		L32	V32
101	Fuel inlet	DN32	
102	Fuel outlet	DN32	
1031	Leak fuel drain, clean fuel	OD28	
1032	Leak fuel drain, clean fuel	-	OD28
1033	Leak fuel drain, clean fuel	OD28	DN20
1034	Leak fuel drain, clean fuel	-	DN20
1041	Leak fuel drain, dirty fuel	OD18	
1042	Leak fuel drain, dirty fuel	-	OD18
1043	Leak fuel drain, dirty fuel	OD28	DN32
1044	Leak fuel drain, dirty fuel	-	DN32

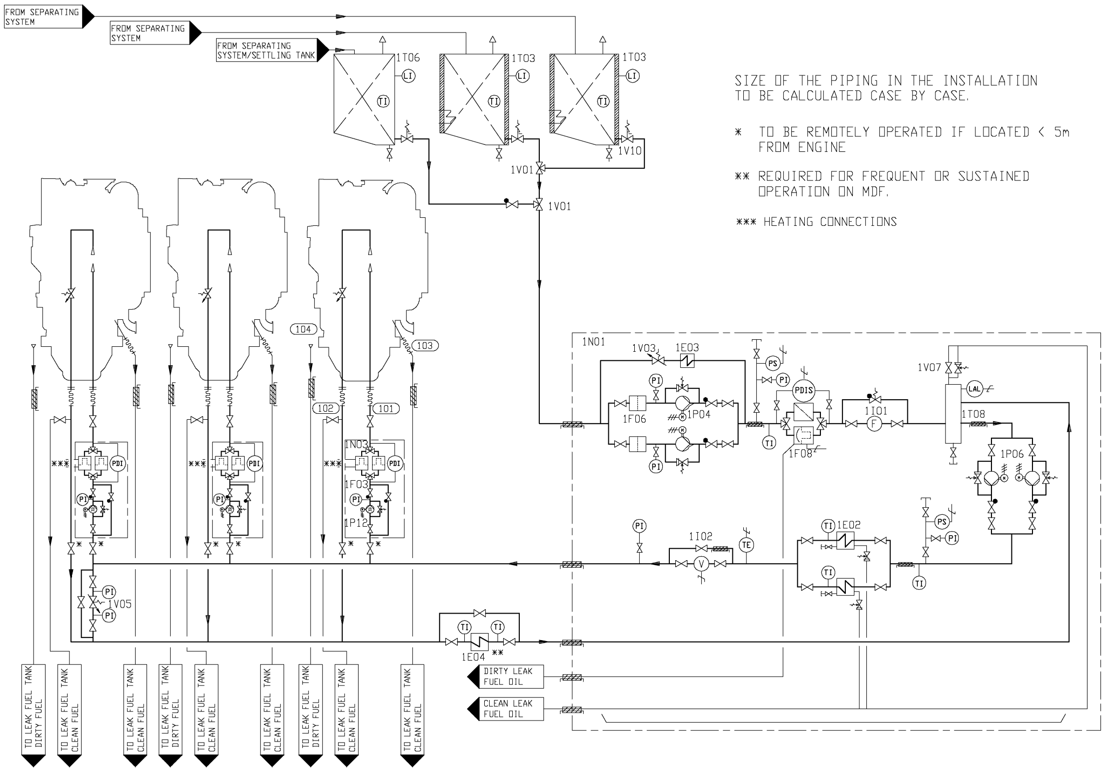


Fig 6-7 Example of fuel oil system (HFO) multiple engine installation (DAAE057999D)

System components:			
1E02	Heater (booster unit)	1P06	Circulation pump (booster unit)
1E03	Cooler (booster unit)	1P12	Circulation pump (HFO/LFO)
1E04	Cooler (LFO)	1T03	Day tank (HFO)
1F03	Safety filter (HFO)	1T06	Day tank (LFO)
1F06	Suction filter (booster unit)	1T08	De-aeration tank (booster unit)
1F08	Automatic filter (booster unit)	1V01	Changeover valve
1I01	Flow meter (booster unit)	1V03	Pressure control valve (booster unit)
1I02	Viscosity meter (booster unit)	1V05	Overflow valve (HFO/LFO)
1N01	Feeder/booster unit	1V07	Venting valve (booster unit)
1N03	Pump and filter unit (HFO/LFO)	1V10	Quick closing valve (fuel oil tank)
1P04	Fuel feed pump (booster unit)		

Pipe connections:		L32	V32
101 / 102	Fuel inlet / outlet	DN25	DN32
1031	Leak fuel drain, clean fuel	OD28	
1032	Leak fuel drain, clean fuel	-	OD28
1033	Leak fuel drain, clean fuel	OD28	DN20
1034	Leak fuel drain, clean fuel	-	DN20
1041	Leak fuel drain, dirty fuel	OD18	
1042	Leak fuel drain, dirty fuel	-	OD18
1043	Leak fuel drain, dirty fuel	OD28	-
1044	Leak fuel drain, dirty fuel	-	DN32

HFO pipes shall be properly insulated. If the viscosity of the fuel is 180 cSt/50°C or higher, the pipes must be equipped with trace heating. It shall be possible to shut off the heating of the pipes when operating on LFO (trace heating to be grouped logically).

6.2.6.1 Starting and stopping

The engine can be started and stopped on HFO provided that the engine and the fuel system are pre-heated to operating temperature. The fuel must be continuously circulated also through a stopped engine in order to maintain the operating temperature. Changeover to LFO for start and stop is not required.

Prior to overhaul or shutdown of the external system the engine fuel system shall be flushed and filled with LFO.

6.2.6.2 Changeover from HFO to LFO

The control sequence and the equipment for changing fuel during operation must ensure a smooth change in fuel temperature and viscosity. When LFO is fed through the HFO feeder/booster unit, the volume in the system is sufficient to ensure a reasonably smooth transfer.

When there are separate circulating pumps for LFO, then the fuel change should be performed with the HFO feeder/booster unit before switching over to the LFO circulating pumps. As mentioned earlier, sustained operation on LFO usually requires a fuel oil cooler. The viscosity at the engine shall not drop below the minimum limit stated in *Engine Online Configurator* available through Wärtsilä website.

6.2.6.3 Number of engines in the same system

When the fuel feed unit serves Wärtsilä 32 engines only, maximum one engine should be connected to the same fuel feed circuit, unless individual circulating pumps before each engine are installed.

Main engines and auxiliary engines should preferably have separate fuel feed units. Individual circulating pumps or other special arrangements are often required to have main engines and auxiliary engines in the same fuel feed circuit. Regardless of special arrangements it is not recommended to supply more than maximum two main engines and two auxiliary engines, or one main engine and three auxiliary engines from the same fuel feed unit.

In addition the following guidelines apply:

- Twin screw vessels with two engines should have a separate fuel feed circuit for each propeller shaft.
- Twin screw vessels with four engines should have the engines on the same shaft connected to different fuel feed circuits. One engine from each shaft can be connected to the same circuit.

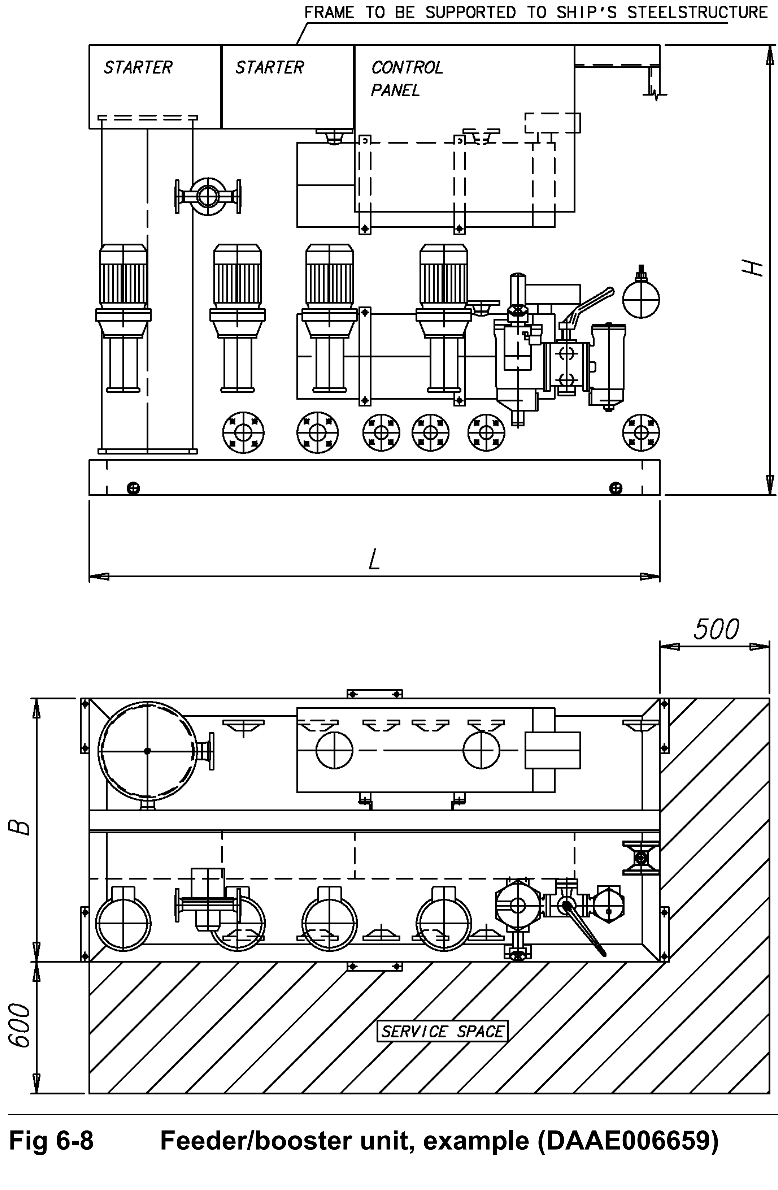
6.2.6.4 Feeder/booster unit (1N01)

A completely assembled feeder/booster unit can be supplied. This unit comprises the following equipment:

- Two suction strainers
- Two fuel feed pumps of screw type, equipped with built-on safety valves and electric motors
- One pressure control/overflow valve
- One pressurized de-aeration tank, equipped with a level switch operated vent valve
- Two circulating pumps, same type as the fuel feed pumps
- Two heaters, steam, electric or thermal oil (one heater in operation, the other as spare)
- One automatic back-flushing filter with stand-by filter

- One viscosimeter for control of the heaters
- One control valve for steam or thermal oil heaters, a control cabinet for electric heaters
- One temperature sensor for emergency control of the heaters
- One control cabinet including starters for pumps
- One alarm panel

The above equipment is built on a steel frame, which can be welded or bolted to its foundation in the ship. The unit has all internal wiring and piping fully assembled. All HFO pipes are insulated and provided with trace heating.



	H	L	B
STEAM	1800	2500	1100
ELECTRICAL	2050	2600	1200

All dimensions in mm.

Fig 6-8 Feeder/booster unit, example (DAAE006659)

Fuel feed pump, booster unit (1P04)

The feed pump maintains the pressure in the fuel feed system. It is recommended to use a screw pump as feed pump. The capacity of the feed pump must be sufficient to prevent pressure drop during flushing of the automatic filter.

A suction strainer with a fineness of 0.5 mm should be installed before each pump. There must be a positive static pressure of about 30 kPa on the suction side of the pump.

Design data:

(continued)

Capacity	Total consumption of the connected engines added with the flush quantity of the automatic filter (1F08) and 15% margin.
Design pressure	1.6 MPa (16 bar)
Max. total pressure (safety valve)	0.7 MPa (7 bar)
Design temperature	100°C
Viscosity for dimensioning of electric motor	1000 cSt

Pressure control valve, booster unit (1V03)

The pressure control valve in the feeder/booster unit maintains the pressure in the de-aeration tank by directing the surplus flow to the suction side of the feed pump.

Design data:	
Capacity	Equal to feed pump
Design pressure	1.6 MPa (16 bar)
Design temperature	100°C
Set-point	0.3...0.5 MPa (3...5 bar)

Automatic filter, booster unit (1F08)

It is recommended to select an automatic filter with a manually cleaned filter in the stand-by line. The automatic filter must be installed before the heater, between the feed pump and the de-aeration tank, and it should be equipped with a heating jacket. Overheating (temperature exceeding 100°C) is however to be prevented, and it must be possible to switch off the heating for operation on LFO.

Design data:	
Fuel viscosity	According to fuel specification
Design temperature	100°C
Preheating	If fuel viscosity is higher than 25 cSt/100°C
Design flow	Equal to feed pump capacity
Design pressure	1.6 MPa (16 bar)
Fineness:	
- automatic filter (or fuel main filter)	34 µm absolute ($ß_{34}$ = 2, $ß_{50}$ = 75, ISO 16889)
- stand-by filter	34 µm absolute ($ß_{34}$ = 2, $ß_{50}$ = 75, ISO 16889)
Maximum permitted pressure drops at 14 cSt:	
- clean filter	20 kPa (0.2 bar)
- alarm	80 kPa (0.8 bar)

Flow meter, booster unit (1I01)

If a fuel consumption meter is required, it should be fitted between the feed pumps and the de-aeration tank. When it is desired to monitor the fuel consumption of individual engines in a multiple engine installation, two flow meters per engine are to be installed: one in the feed line and one in the return line of each engine.

There should be a by-pass line around the consumption meter, which opens automatically in case of excessive pressure drop.

If the consumption meter is provided with a prefilter, an alarm for high pressure difference across the filter is recommended.

De-aeration tank, booster unit (1T08)

It shall be equipped with a low level alarm switch and a vent valve. The vent pipe should, if possible, be led downwards, e.g. to the overflow tank. The tank must be insulated and equipped with a heating coil. The volume of the tank should be at least 100 l.

Circulation pump, booster unit (1P06)

The purpose of this pump is to circulate the fuel in the system and to maintain the required pressure at the injection pumps, which is stated in *Engine Online Configurator* available through Wärtsilä website. By circulating the fuel in the system it also maintains correct viscosity, and keeps the piping and the injection pumps at operating temperature. When more than one engine is connected to the same feeder/booster unit, individual circulation pumps (1P12) must be installed before each engine.

When more than one engine is connected to the same feeder/booster unit, individual circulation pumps (1P12) must be installed before each engine.

Design data:	
Capacity:	
- without circulation pumps (1P12)	5 x the total consumption of the connected engines
- with circulation pumps (1P12)	15% more than total capacity of all circulation pumps
Design pressure	1.6 MPa (16 bar)
Max. total pressure (safety valve)	1.0 MPa (10 bar)
Design temperature	150°C
Viscosity for dimensioning of electric motor	500 cSt

Heater, booster unit (1E02)

The heater must be able to maintain a fuel viscosity of 14 cSt at maximum fuel consumption, with fuel of the specified grade and a given day tank temperature (required viscosity at injection pumps stated in *Engine Online Configurator available through Wärtsilä website*). When operating on high viscosity fuels, the fuel temperature at the engine inlet may not exceed 135°C however.

The power of the heater is to be controlled by a viscosimeter. The set-point of the viscosimeter shall be somewhat lower than the required viscosity at the injection pumps to compensate for heat losses in the pipes. A thermostat should be fitted as a backup to the viscosity control.

To avoid cracking of the fuel the surface temperature in the heater must not be too high. The heat transfer rate in relation to the surface area must not exceed 1.5 W/cm^2.

The required heater capacity can be estimated with the following formula:

$$P = \frac{Q \times \Delta T}{1700}$$

where:

P = heater capacity (kW)

Q = total fuel consumption at full output + 15% margin [l/h]

ΔT = temperature rise in heater [°C]

Viscosimeter, booster unit (1I02)

The heater is to be controlled by a viscosimeter. The viscosimeter should be of a design that can withstand the pressure peaks caused by the injection pumps of the diesel engine.

Design data:

Operating range	0...50 cSt
Design temperature	180°C
Design pressure	4 MPa (40 bar)

6.2.6.5 Pump and filter unit (1N03)

When more than one engine is connected to the same feeder/booster unit, a circulation pump (1P12) must be installed before each engine. The circulation pump (1P12) and the safety filter (1F03) can be combined in a pump and filter unit (1N03). A safety filter is always required.

There must be a by-pass line over the pump to permit circulation of fuel through the engine also in case the pump is stopped. The diameter of the pipe between the filter and the engine should be the same size as between the feeder/booster unit and the pump and filter unit.

Circulation pump (1P12)

The purpose of the circulation pump is to ensure equal circulation through all engines. With a common circulation pump for several engines, the fuel flow will be divided according to the pressure distribution in the system (which also tends to change over time) and the control valve on the engine has a very flat pressure versus flow curve.

In installations where LFO is fed directly from the LFO tank (1T06) to the circulation pump, a suction strainer (1F07) with a fineness of 0.5 mm shall be installed to protect the circulation pump. The suction strainer can be common for all circulation pumps.

Design data:

Capacity	please refer to *Engine Online Configurator* available through Wärtsilä website
Design pressure	1.6 MPa (16 bar)
Max. total pressure (safety valve)	1.0 MPa (10 bar)
Design temperature	150°C
Pressure for dimensioning of electric motor (ΔP):	
- if LFO is fed directly from day tank	0.7 MPa (7 bar)

(continued)

- if all fuel is fed through feeder/booster unit	0.3 MPa (3 bar)
Viscosity for dimensioning of electric motor	500 cSt

Safety filter (1F03)

The safety filter is a full flow duplex type filter with steel net. The filter should be equipped with a heating jacket. The safety filter or pump and filter unit shall be installed as close as possible to the engine.

Design data:	
Fuel viscosity	according to fuel specification
Design temperature	150°C
Design flow	Equal to circulation pump capacity
Design pressure	1.6 MPa (16 bar)
Filter fineness	34 µm (absolute mesh size) ($ß_{34}$ = 2, $ß_{50}$ = 75, ISO16889)
Maximum permitted pressure drops at 14 cSt:	
- clean filter	20 kPa (0.2 bar)
- alarm	80 kPa (0.8 bar)

6.2.6.6 Overflow valve, HFO (1V05)

When several engines are connected to the same feeder/booster unit an overflow valve is needed between the feed line and the return line. The overflow valve limits the maximum pressure in the feed line, when the fuel lines to a parallel engine are closed for maintenance purposes.

The overflow valve should be dimensioned to secure a stable pressure over the whole operating range.

Design data:	
Capacity	Equal to circulation pump (1P06)
Design pressure	1.6 MPa (16 bar)
Design temperature	150°C
Set-point (Δp)	0.2...0.7 MPa (2...7 bar)

6.2.7 Flushing

The external piping system must be thoroughly flushed before the engines are connected and fuel is circulated through the engines. The piping system must have provisions for installation of a temporary flushing filter.

The fuel pipes at the engine (connections 101 and 102) are disconnected and the supply and return lines are connected with a temporary pipe or hose on the installation side. All filter inserts are removed, except in the flushing filter of course. The automatic filter and the viscosimeter should be bypassed to prevent damage.

The fineness of the flushing filter should be 35 μm or finer.

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7. Lubricating Oil System

7.1 Lubricating oil requirements

7.1.1 Engine lubricating oil

The lubricating oil must be of viscosity class SAE 40 and have a viscosity index (VI) of minimum 95. The lubricating oil alkalinity (BN) is tied to the fuel grade, the required lubricating oil alkalinity in distillate fuel / liquid bio fuel operation is tied to the fuel quality as stated in the table hereafter. BN is an abbreviation of Base Number. The value indicates milligrams KOH per gram of oil.

Table 7-1 Fuel standards and lubricating oil requirements

Category	Fuel standard		Lubricating oil BN	Fuel S content [% m/m]
A	ASTM D 975-01, ISO 8217:2017(E)	GRADE NO. 1-D, 2-D, 4-D ISO-F-DMX -> DMB, DFA -> DFB	10 - 20 21 – 30 *)	< 0,40
B	ASTM D 975-17 ISO 8217:2017(E)	GRADE NO. 1-D, 2-D, 4-D ISO-F-DMX -> DMB, DFA -> DFB	15 – 20 (10 – 14) **) (21 – 30) *)	0,40 – 1,50
C	ASTM D 975-17, ASTM D 396-17, ISO 8217:2017(E)	GRADE NO. 4-D GRADE NO. 5-6 RMA 10 - RMK 700 (incl. also max. 0,50 % m/m S VLSFO RM)	30 - 55	≤ 3,50 or statutory requirements ***)
D	ISO 8217:2017(E)	RMA 10 - RMK 700 (ULSFO RM)	20	≤ 0,10
E	CRUDE OIL (CRO)		30 - 55	≤ 4,50
F	LIQUID BIO FUEL (LBF)		10 - 20	≤ 0,05

*) Though the use of BN 21 – 30 lubricating oils is allowed in distillate fuel operation, there is no technical reason for that but a lower BN level shown in the above table is well enough.

**) BN 10 – 14 lubricating oils cannot be recommended in the first place when operating on > 0,40 % m/m sulphur distillate fuels due to shortened oil change interval resulting from BN depletion.

***) Sulphur content can be also higher than 3,50 % m/m.

In case a low sulphur (S max. 0,4 % m/m) distillate fuel is used, it’s recommended to use a lubricating oil with BN of 10 – 15.

It is recommended to use in the first place BN 50 - 55 lubricants when operating on residual fuel. This recommendation is valid especially for engines having wet lubricating oil sump and using residual fuel with sulphur content above 2,0 % mass. BN 40 lubricants can be used when operating on residual fuel as well if experience shows that the lubricating oil BN equilibrium remains at an acceptable level.

In residual fuel operation BN 30 lubricants are recommended to be used only in special cases, like e.g. such as installations equipped with an SCR catalyst. Lower BN products eventually have a positive influence on cleanliness of the SCR catalyst. With BN 30 oils lubricating oil change intervals may be rather short, but lower total operating costs may be achieved because of better plant availability provided that the maintenance intervals of the SCR catalyst can be increased.

BN 30 oils are also a recommended alternative when operating on crude oil having low sulphur content. Though crude oils many times have low sulphur content, those can contain other acid compounds and thus an adequate alkali reserve is important. With crude oils having higher sulphur content BN 40 – 55 lubricating oils should be used.

If both distillate fuel and high sulphur (> 0,50 m/m S) residual fuel are used in turn as fuel, lubricating oil quality has to be chosen according to instructions being valid for residual fuel operation, i.e. BN 30 is the minimum. Optimum BN in this kind of operation depends on the length of operating periods on both fuel qualities as well as of sulphur content of fuels in question. Thus in particular cases BN 40 or even higher BN lubricating oils should be used.

If Ultra Low Sulphur Fuel Oil (max. 0,10 % m/m S ULSFO RM) classed as residual fuel is used, the lubricating oil BN requirement is min. 20. In Very Low Sulphur Fuel Oil (max. 0,50 % m/m S VLSFO RM) operation with fuels classed as residual fuels the use of min. BN 30 lubricating oils is required.

Different oil brands may not be blended, unless it is approved by the oil suppliers. Blending of different oils must also be validated by Wärtsilä, if the engine is still under warranty.

An updated list of validated lubricating oils is supplied for every installation. Please refer to Service Bulletin WS15S475.

Different oil brands may not be blended, unless it is approved by the oil suppliers. Blending of different oils must also be validated by Wärtsilä, if the engine is still under warranty.

An updated list of validated lubricating oils is supplied for every installation.

7.1.2 Oil in speed governor or actuator

An oil of viscosity class SAE 30 or SAE 40 is suitable and usually the same oil can be used as in the engine. Turbocharger oil can also be used in the governor. At cold ambient conditions it may be necessary to use a multigrade oil (e.g. SAE 5W-40) for better governor response during start-up. Oil change interval: 2000 service hours.

NOTICE
Monograde engine oils, multigrade oils or turbocharger oils etc. are not compatible with each other and shall not be mixed. Thus it’s important to drain and flush with the new oil both the governor and booster properly if changing the oil quality.

7.1.3 Oil in turning device

Based on the turning device manufacturer’s instructions EP-gear oils *) having viscosity of 414 - 506 mm²/s (cSt) at 40 °C = ISO VG 460 **) are normally considered as suitable lubricating oils for turning device. The following products are fulfilling the requirements:

*) EP = Extreme pressure

**) ISO VG = Viscosity Grade categorisation specified by International Organization for Standardization

An updated list of approved oils is supplied for every installation.

7.1.4 Lubricating oil system in arctic conditions

The recommended minimum lubricating oil temperature for the prelubricating oil pump is 25°C and the recommended minimum lubricating oil temperature for the engine starting and loading is 40°C. The heating of the lubricating oil is typically done with the heater of the lubricating oil separator. If no lubricating oil separator is installed onboard, then other means of heating the lubricating oil are required.

7.2 External lubricating oil system

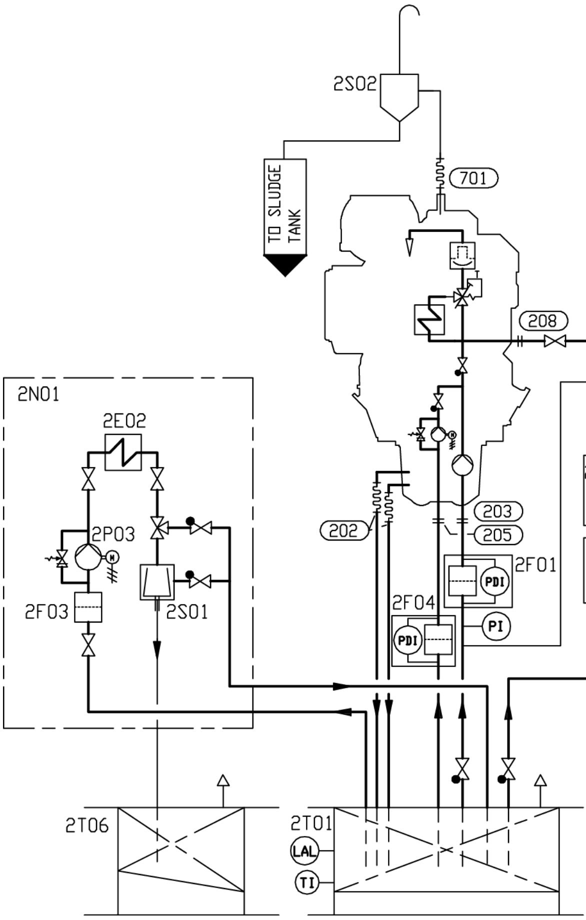


Fig 7-1 Lubricating oil system, main engines (V76E4562D)

System components:			
2E02	Heater (separator unit)	2P03	Separator pump (separator unit)
2F01	Suction strainer (main lubricating oil pump)	2P04	Stand-by pump
2F03	Suction filter (separator unit)	2S01	Separator
2F04	Suction strainer (Prelubricating oil pump)	2S02	Condensate trap
2F06	Suction strainer (stand-by pump)	2T01	System oil tank
2N01	Separator unit	2T06	Sludge tank

Pipe connections:		Size L32	Size V32
202	Lubricating oil outlet	DN150	DN150
203	Lubricating oil to engine driven pump	DN200	DN250
205	Lubricating oil to priming pump	DN80	DN125
208	Lubricating oil from electric driven pump	DN100	DN125
701	Crankcase air vent	DN100	DN125

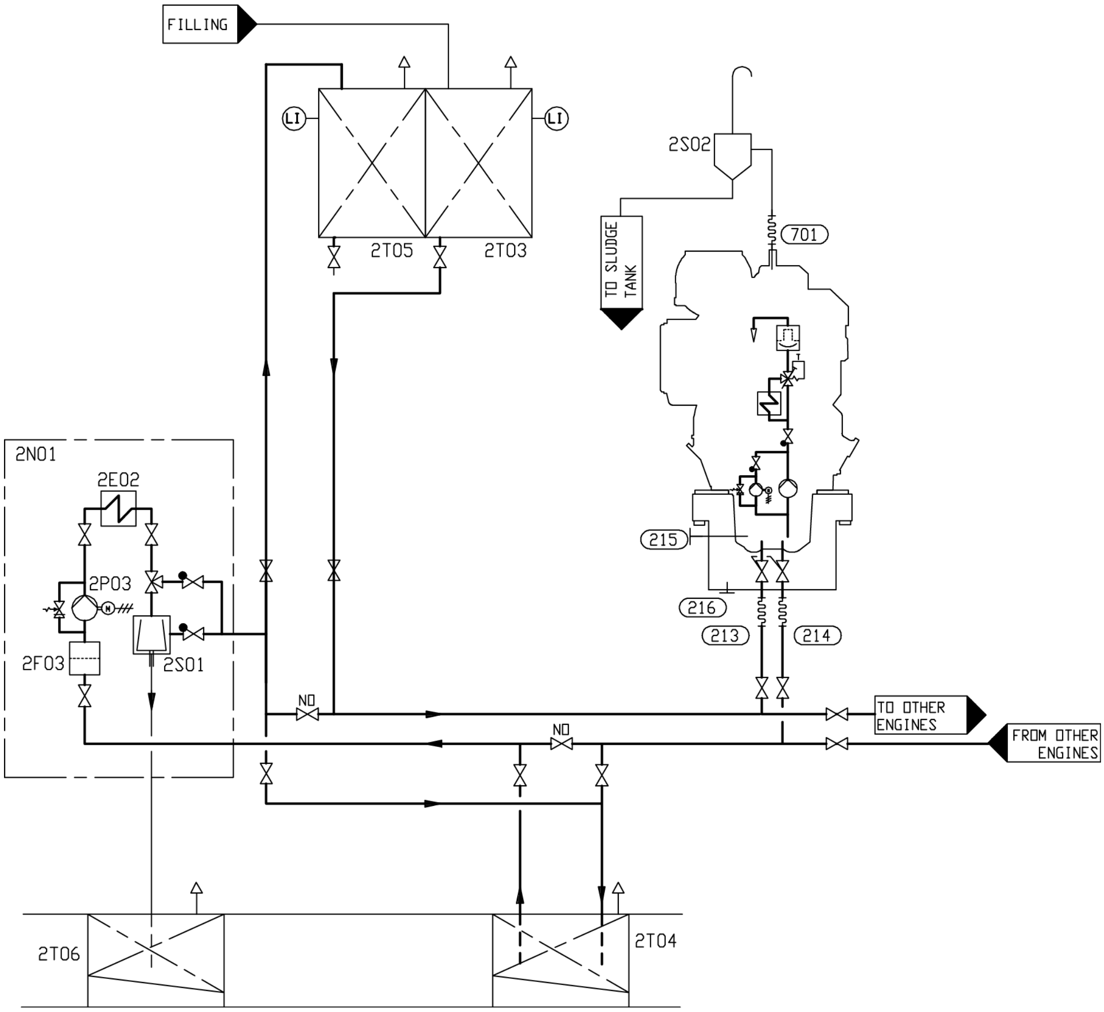


Fig 7-2 Lubricating oil system, auxiliary engines (3V76E4563C)

System components:			
2E02	Heater (separator unit)	2S02	Condensate trap
2F03	Suction filter (separator unit)	2T03	New oil tank
2N01	Separator unit	2T04	Renovating oil tank
2P03	Separator pump (separator unit)	2T05	Renovated oil tank
2S01	Separator	2T06	Sludge tank

Pipe connections:		Size L32	Size V32
213	Lubricating oil from separator and filling	DN40	DN40
214	Lubricating oil to separator and drain	DN40	DN40
215	Lubricating oil filling	DN40	DN40
216	Lubricating oil drain	M22*1.5	M22*1.5
701	Crankcase air vent	DN100	DN125

7.2.1 Separation system

7.2.1.1 Separator unit (2N01)

For engines that can operate on liquid fuels (Diesel, DF), an external lube oil by-pass treatment device (e.g. separator, filter/coalescer type) is required to remove dirt, particles and possible water from the engine oil. Sufficient oil temperature for starting the engine to be ensured by a heater installed together with the lube oil by-pass treatment.

A lube oil separator is required, as an oil by-pass treatment device, for engines running on fuels classified as lower grade than ISO-F-DMB. For ISO-F-DMB fuels or higher grade, other alternative as oil by-pass treatment is allowed as long as the oil quality and cleanliness can be maintained. Specific conditions for oil temperature during starting to be considered if lube oil by-pass treatment is used in case it is not including heater.

General Separator requirements:

- The separator should be dimensioned for continuous centrifuging
- Each lubricating oil system should have its own individual separator
- Rate of circulation of the entire volume per 24h: approx. 5 times
- Centrifuging temperature: 95 °C

Separators are usually supplied as pre-assembled units.

Typically lubricating oil separator units are equipped with:

- Feed pump with suction strainer and safety valve
- Preheater
- Separator
- Control cabinet

The lubricating oil separator unit may also be equipped with an intermediate sludge tank and a sludge pump, which offers flexibility in placement of the separator since it is not necessary to have a sludge tank directly beneath the separator.

Separator feed pump (2P03)

The feed pump must be selected to match the recommended throughput of the separator. Normally the pump is supplied and matched to the separator by the separator manufacturer.

The lowest foreseen temperature in the system oil tank (after a long stop) must be taken into account when dimensioning the electric motor.

Separator preheater (2E02)

The preheater is to be dimensioned according to the feed pump capacity and the temperature in the system oil tank. When the engine is running, the temperature in the system oil tank located in the ship's bottom is normally 65...75°C. To enable separation with a stopped engine the heater capacity must be sufficient to maintain the required temperature without heat supply from the engine.

Recommended oil temperature after the heater is 95°C.

It shall be considered that, while the engine is stopped in stand-by mode without LT water circulation, the separator unit may be heating up the total amount of lubricating oil in the oil tank to a value higher than the nominal one required at engine inlet, after lube oil cooler (please refer to *Engine Online Configurator* available through Wärtsilä website). Higher oil temperatures at engine inlet than the nominal, may be creating higher component wear and in worst conditions damages to the equipment and generate alarm signal at engine start, or even a load reduction request to PMS.

The surface temperature of the heater must not exceed 150°C in order to avoid cooking of the oil.

The heaters should be provided with safety valves and drain pipes to a leakage tank (so that possible leakage can be detected).

Separator (2S01)

The separators should preferably be of a type with controlled discharge of the bowl to minimize the lubricating oil losses.

The service throughput *Q* [*l/h*] of the separator can be estimated with the formula:

$$Q = \frac{1.35 \times P \times n}{t}$$

where:

Q = volume flow [l/h]

P = engine output [kW]

n = 5 for HFO, 4 for LFO

t = operating time [h/day]: 24 for continuous separator operation, 23 for normal dimensioning

Sludge tank (2T06)

The sludge tank should be located directly beneath the separators, or as close as possible below the separators, unless it is integrated in the separator unit. The sludge pipe must be continuously falling.

7.2.1.2 Renovating oil tank (2T04)

In case of wet sump engines the oil sump content can be drained to this tank prior to separation.

7.2.1.3 Renovated oil tank (2T05)

This tank contains renovated oil ready to be used as a replacement of the oil drained for separation.

7.2.2 System oil tank (2T01)

Recommended oil tank volume is stated in *Engine Online Configurator* available through Wärtsilä website.

The system oil tank is usually located beneath the engine foundation. The tank may not protrude under the reduction gear or generator, and it must also be symmetrical in transverse direction under the engine. The location must further be such that the lubricating oil is not cooled down below normal operating temperature. Suction height is especially important with engine driven lubricating oil pump. Losses in strainers etc. add to the geometric suction height. Maximum suction ability of the pump is stated in *Engine Online Configurator* available through Wärtsilä website.

The pipe connection between the engine oil sump and the system oil tank must be flexible to prevent damages due to thermal expansion. The return pipes from the engine oil sump must end beneath the minimum oil level in the tank. Further on the return pipes must not be located in the same corner of the tank as the suction pipe of the pump.

The suction pipe of the pump should have a trumpet shaped or conical inlet to minimise the pressure loss. For the same reason the suction pipe shall be as short and straight as possible and have a sufficient diameter. A pressure gauge shall be installed close to the inlet of the lubricating oil pump. The suction pipe shall further be equipped with a non-return valve of flap type without spring. The non-return valve is particularly important with engine driven pump and it must be installed in such a position that self-closing is ensured.

Suction and return pipes of the separator must not be located close to each other in the tank.

The ventilation pipe from the system oil tank may not be combined with crankcase ventilation pipes.

It must be possible to raise the oil temperature in the tank after a long stop. In cold conditions it can be necessary to have heating coils in the oil tank in order to ensure pumpability. The separator heater can normally be used to raise the oil temperature once the oil is pumpable. Further heat can be transferred to the oil from the preheated engine, provided that the oil viscosity and thus the power consumption of the pre-lubricating oil pump does not exceed the capacity of the electric motor.

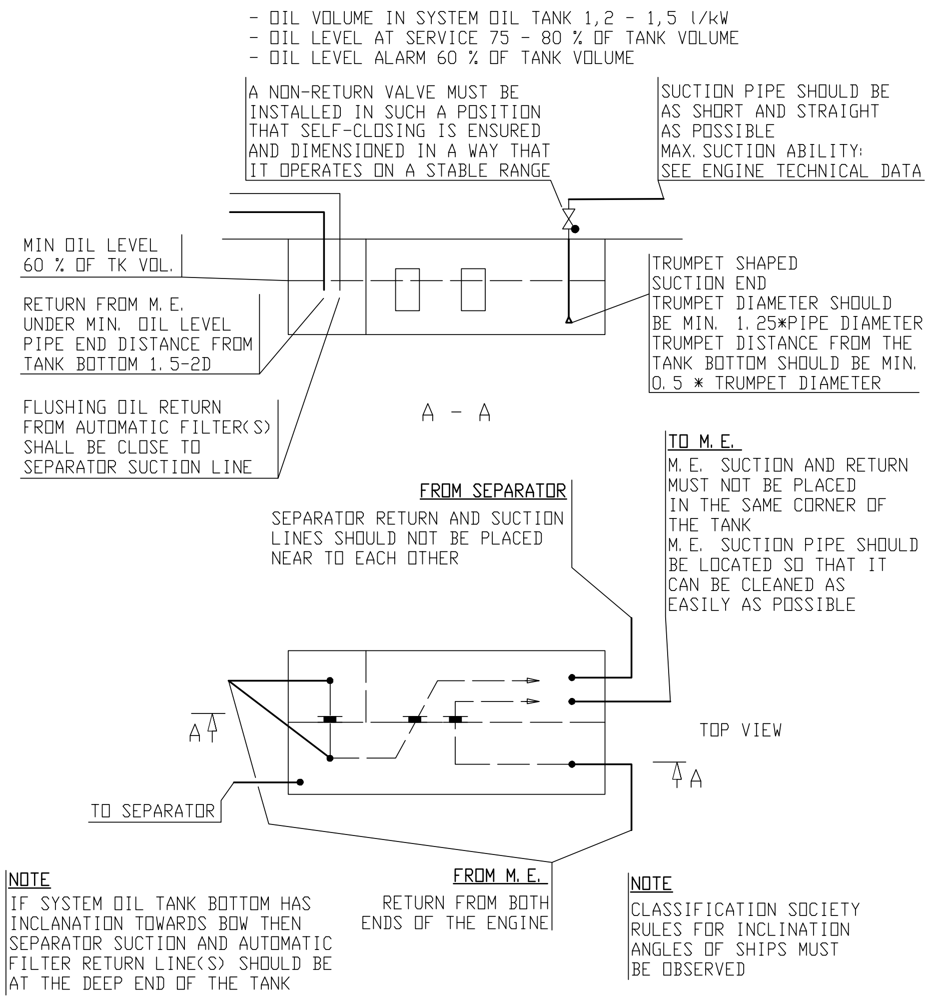


Fig 7-3 Example of system oil tank arrangement (DAAE007020G)

7.2.3 New oil tank (2T03)

In engines with wet sump, the lubricating oil may be filled into the engine, using a hose or an oil can, through the crankcase cover or through the separator pipe. The system should be arranged so that it is possible to measure the filled oil volume.

7.2.4 Suction strainers (2F01, 2F04, 2F06)

It is recommended to install a suction strainer before each pump to protect the pump from damage. The suction strainer and the suction pipe must be amply dimensioned to minimize pressure losses. The suction strainer should always be provided with alarm for high differential pressure.

Design data:	
Fineness	0.5...1.0 mm

7.2.5 Lubricating oil pump, stand-by (2P04)

The stand-by lubricating oil pump is normally of screw type and should be provided with an safety valve.

Design data:	
Capacity	please refer to *Engine Online Configurator* available through Wärtsilä website
Design pressure, max	0.8 MPa (8 bar)
Design temperature, max.	100°C
Lubricating oil viscosity	SAE 40
Viscosity for dimensioning the electric motor	500 mm^2/s (cSt)

7.3 Crankcase ventilation system

The purpose of the crankcase ventilation is to evacuate gases from the crankcase in order to keep the pressure in the crankcase within acceptable limits.

Each engine must have its own vent pipe into open air. The crankcase ventilation pipes may not be combined with other ventilation pipes, e.g. vent pipes from the system oil tank.

The diameter of the pipe shall be large enough to avoid excessive back pressure. Other possible equipment in the piping must also be designed and dimensioned to avoid excessive flow resistance.

A condensate trap and a drain must be provided for the vent pipe near the engine.

The connection between engine and pipe is to be flexible. It is very important that the crankcase ventilation pipe is properly fixed to a support rigid in all directions directly after the flexible hose from crankcase ventilation outlet, extra mass on the oil mist detector must be avoided. There should be a fixing point on both sides of the pipe at the support. Absolutely rigid mounting between the pipe and the support is recommended. The supporting must allow thermal expansion and ship's structural deflections.

Design data:	
Flow	please refer to *Engine Online Configurator* available through Wärtsilä website
Crankcase pressure, max.	please refer to *Engine Online Configurator* available through Wärtsilä website
Temperature	80°C

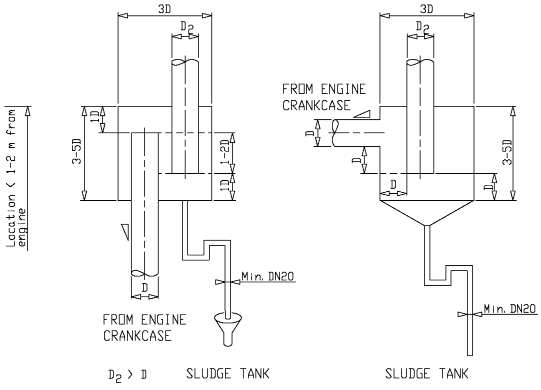


Fig 7-4 Condensate trap (DAAE032780B)

The size of the ventilation pipe (D2) out from the condensate trap should be bigger than the ventilation pipe (D) coming from the engine.
For more information about ventilation pipe (D) size, see the external lubricating oil system drawing.

The max. back-pressure must also be considered when selecting the ventilation pipe size.

7.4 Flushing instructions

Flushing instructions in this Product Guide are for guidance only. For contracted projects, please refer to Installation Planning Instructions (IPI) for the fineness of the flushing filter and other project specific instructions.

7.4.1 Piping and equipment built on the engine

Flushing of the piping and equipment built on the engine is not required and flushing oil shall not be pumped through the engine oil system (which is flushed and clean from the factory). Cleanliness of the external system shall be verified after completed flushing and is acceptable when the cleanliness has reached a level in accordance with ISO 4406 © 21/19/15, or NAS 1638 code 10. All pipes connected to the engine, the engine wet sump or to the external engine wise oil tank shall be flushed. Oil used for filling shall have a cleanliness of ISO 4406 © 21/19/15, or NAS 1638 code 10.

NOTICE
The engine must not be connected during flushing.

7.4.2 External oil system

Refer to the system diagram(s) in section *External lubricating oil system* for location/description of the components mentioned below.

If the engine is equipped with a wet oil sump the external oil tanks, new oil tank (2T03), renovating oil tank (2T04) and renovated oil tank (2T05) shall be verified to be clean before bunkering oil. Especially pipes leading from the separator unit (2N01) directly to the engine shall be ensured to be clean for instance by disconnecting from engine and blowing with compressed air.

If the engine is equipped with a dry oil sump the external oil tanks, new oil tank and the system oil tank (2T01) shall be verified to be clean before bunkering oil.

Operate the separator unit continuously during the flushing (not less than 24 hours). Leave the separator running also after the flushing procedure, this to ensure that any remaining contaminants are removed.

If an electric motor driven stand-by pump (2P04) is installed then piping shall be flushed running the pump circulating engine oil through a temporary external oil filter (recommended mesh 34 microns) into the engine oil sump through a hose and a crankcase door. The pump shall be protected by a suction strainer (2F06).

Whenever possible the separator unit shall be in operation during the flushing to remove dirt. The separator unit is to be left running also after the flushing procedure, this to ensure that any remaining contaminants are removed.

7.4.3 Type of flushing oil

7.4.3.1 Viscosity

In order for the flushing oil to be able to remove dirt and transport it with the flow, ideal viscosity is 10...50 cSt. The correct viscosity can be achieved by heating engine oil to about 85°C or by using a separate flushing oil which has an ideal viscosity in ambient temperature.

7.4.3.2 Flushing with engine oil

The ideal is to use engine oil for flushing. This requires a heater or that the separator unit is in operation to heat the oil. Engine oil used for flushing can be reused as engine oil provided that no debris or other contamination is present in the oil at the end of flushing.

7.4.3.3 Flushing with low viscosity flushing oil

If no separator heating is available during the flushing procedure it is possible to use a low viscosity flushing oil instead of engine oil. In such a case the low viscosity flushing oil must be disposed of after completed flushing. Great care must be taken to drain all flushing oil from pockets and bottom of tanks so that flushing oil remaining in the system will not compromise the viscosity of the actual engine oil.

7.4.3.4 Lubricating oil sample

To verify the cleanliness a LO sample shall be taken by the shipyard after the flushing is completed. The properties to be analyzed are Viscosity, BN, AN, Insolubles, Fe and Particle Count.

Commissioning procedures shall in the meantime be continued without interruption unless the commissioning engineer believes the oil is contaminated.

8. Compressed Air System

Compressed air is used to start engines and to provide actuating energy for safety and control devices. The use of starting air for other purposes is limited by the classification regulations.

To ensure the functionality of the components in the compressed air system, the compressed air has to be free from solid particles and oil.

8.1 Instrument air quality

The quality of instrument air, from the ships instrument air system, for safety and control devices must fulfill the following requirements.

Instrument air specification:	
Design pressure	1 MPa (10 bar)
Nominal pressure	0.7 MPa (7 bar)
Dew point temperature	+3°C
Max. oil content	1 mg/m^3
Max. particle size	3 µm
Consumption per valve	2.5 Nm^3/h
Instrument air quality at engine connection	ISO 8573-1:2010 [5:5:3]

8.2 External compressed air system

The design of the starting air system is partly determined by classification regulations. Most classification societies require that the total capacity is divided into two equally sized starting air receivers and starting air compressors. The requirements concerning multiple engine installations can be subject to special consideration by the classification society.

The starting air pipes should always be slightly inclined and equipped with manual or automatic draining at the lowest points.

Instrument air to safety and control devices must be treated in an air dryer.

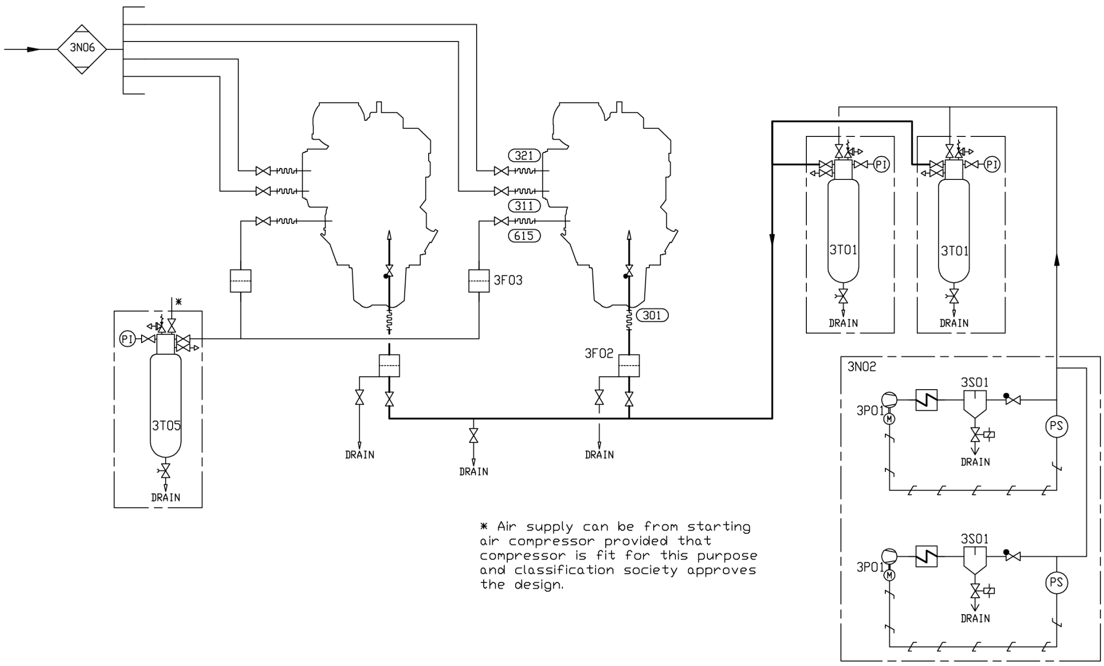


Fig 8-1 External starting air system (3V76H4142F)

System components:		Pipe connections:		Size L32	Size V32
3F02	Air filter (starting air inlet)	301	Starting air inlet	DN32	
3F03	Air filter (air assist inlet)	311	Control air to wastegate valve	OD08	OD10
3N02	Starting air compressor unit	321	Control air for pressure reducing device	OD08	OD10
3N06	Air dryer unit	615	Air inlet to air assist system	OD28	
3P01	Compressor (starting air compressor unit)				
3S01	Separator (starting air compressor unit)				
3T01	Starting air vessel				
3T05	Air bottle				

8.2.1 Starting air compressor unit (3N02)

At least two starting air compressors must be installed. It is recommended that the compressors are capable of filling the starting air vessel from minimum (1.8 MPa) to maximum pressure in 15...30 minutes. For exact determination of the minimum capacity, the rules of the classification societies must be followed. If the system is designed so that air assist will be used, bigger compressors are needed.

8.2.2 Oil and water separator (3S01)

An oil and water separator should always be installed in the pipe between the compressor and the air vessel. Depending on the operation conditions of the installation, an oil and water separator may be needed in the pipe between the air vessel and the engine.

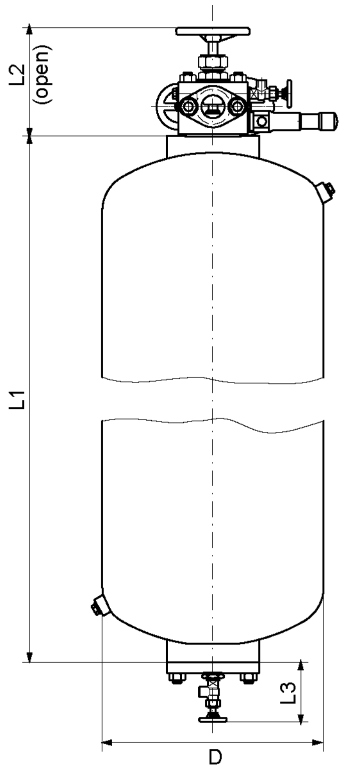
8.2.3 Air vessels (3T01 & 3T05)

The air vessels should be dimensioned for a nominal pressure of 3 MPa.

The number and the capacity of the air vessels for propulsion engines depend on the requirements of the classification societies and the type of installation.

It is recommended to use a minimum air pressure of 1.8 MPa, when calculating the required volume of the vessels.

The air vessels are to be equipped with at least a manual valve for condensate drain. If the air vessels are mounted horizontally, there must be an inclination of 3...5° towards the drain valve to ensure efficient draining.



Size [Litres]	Dimensions [mm]				Weight [kg]
	L1	L2 [1)]	L3 [1)]	D	
250	1767	243	110	480	274
500	3204	243	133	480	450
710	2740	255	133	650	625
1000	3560	255	133	650	810
1250	2930	255	133	800	980

[1)] Dimensions are approximate.

Fig 8-2 Air vessel

8.2.3.1 Starting air vessel (3T01)

The starting air consumption stated in technical data is for a successful start. During start the main starting valve is kept open until the engine starts, or until the max. time for the starting attempt has elapsed. A failed start can consume two times the air volume stated in technical data. If the ship has a class notation for unattended machinery spaces, then the starts are to be demonstrated.

NOTICE

Please refer to technical data which can be found by accessing *Engine Online Configurator* available through Wärtsilä's website.

The required total air vessel volume can be calculated using the formula:

$$V_R = \frac{p_E \times V_E \times n}{p_{Rmax} - p_{Rmin}}$$

where:

V_R = total starting air vessel volume [m^3]

p_E = normal barometric pressure (NTP condition) = 0.1 MPa

V_E = air consumption per start [Nm^3], please refer to technical data which can be found by accessing *Engine Online Configurator* available through Wärtsilä's website.

n = required number of starts according to the classification society

p_{Rmax} = maximum starting air pressure = 3 MPa

p_{Rmin} = minimum starting air pressure = 1.8 MPa

8.2.3.2 Air assist vessel (3T05)

The required total air assist air vessel volume can be calculated using the formula:

Table 8-1

$$V_R = \frac{V_A \times n_1}{p_{Rmax} - p_{Rmin}} \quad (^*$$

* if air assist supply is taken from starting air vessels it is a subject to class approval.

where:

V_R = total air vessel volume [m^3]

V_A = Air consumption per activation, please refer to technical data which can be found by accessing *Engine Online Configurator* available through Wärtsilä's website.

n_1 = Number of activations

p_{Rmax} = maximum air pressure = please refer to technical data which can be found by accessing *Engine Online Configurator* available through Wärtsilä's website.

p_{Rmin} = minimum air pressure = please refer to technical data which can be found by accessing *Engine Online Configurator* available through Wärtsilä's website.

NOTICE
The total vessel volume shall be divided into at least two equally sized starting air vessels.

8.2.4 Air filter, starting air inlet (3F02)

Condense formation after the water separator (between starting air compressor and starting air vessels) create and loosen abrasive rust from the piping, fittings and receivers. Therefore it is recommended to install a filter before the starting air inlet on the engine to prevent particles to enter the starting air equipment.

An Y-type strainer can be used with a stainless steel screen and mesh size 40 µm. The pressure drop should not exceed 20 kPa (0.2 bar) for the engine specific starting air consumption under a time span of 4 seconds.

8.2.5 Air filter, air assist inlet (3F03)

Condense formation after the water separator (between starting air compressor and air vessels) create and loosen abrasive rust from the piping, fittings and receivers. Therefore it is recommended to install a filter before the starting air inlet on the engine to prevent particles to enter the starting air equipment.

An Y-type strainer can be used with a stainless steel screen and mesh size 400 µm. The pressure drop should not exceed 20 kPa (0.2 bar) for the engine specific air assist consumption.

8.2.6 Air assist

A receiver air injections system (air assist) is installed on all auxiliary and diesel electric applications. If the first load step of 0-33% is required then air assist is to be connected and used. If the system is designed for 0-28-60-100% load steps, the air assist do not have to be connected or used.

The air assist is controlled by UNIC. The consumption for one air assist activation can be found in Technical Data, which can be found by accessing *Engine Online Configurator* available through Wärtsilä's website.

The air supply to the air assist is to be arranged from a separate air vessel or alternatively from the starting air vessels. Air supply from the starting air vessels must be approved by classification society, this must be checked on a project specific basis.

Air assist consumption is depending on the operation profile of the vessel, it is only activated when initial load is below ~15%.

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9. Cooling Water System

9.1 Water quality

Raw water quality to be used in the closed cooling water circuits of engines has to meet the following specification.

Property	Unit	Limits for chemical use
pH 1)	-	6,5 – 8,5
Hardness	°dH	max. 10
Chlorides as Cl 1)	mg/l	max. 80
Sulphates as SO4	mg/l	max. 150
Silica as SiO2	mg/l	max. 100

Use of raw water produced with an evaporator as well as a good quality tap water will normally ensure that an acceptable raw water quality requirement is fulfilled, but e.g. sea water and rain water are unsuitable raw water qualities.

1) If a Reverse Osmosis (RO) process is used, min. limit for pH is 6,0 based on the RO process operational principle. The use of water originating from RO process further presumes that a max. content of 80 mg/l for chloride content is achieved.

9.1.1 Corrosion inhibitors

The use of validated cooling water additives is mandatory, failing to follow this requirement will void any agreed engine warranty. An updated list of validated products is supplied for every installation and it can also be found in the Instruction manual of the engine, together with dosage and further instructions.

9.1.2 Validated cooling water additives

Manufacturer	Additive name	Additive type
Alm International S.A.	Diaprosim RD11 (RD11M)	Sodium nitrite + borate
S.A. Arteco N.V.	Havoline XLI	Organic Acid Technology
Drew Marine	Liquidewt Maxigard	Sodium nitrite + borate Sodium nitrite + borate
Chevron (Texaco + Caltex)	Delo XLI Corrosion Inhibitor Concentrate (supersedes Hav-oline XLI) XL Corrosion Inhibitor Concentrate	Organic Acid Technology Organic Acid Technology
Korves Oy	Pekar J	Organic Acid Technology
Kuwait Petroleum (Danmark) AS	Q8 Corrosion Inhibitor Long-Life	Organic Acid Technology
Marine Care B.V.	Caretreat 2 Diesel	Sodium nitrite + borate
Maritech AB	Marisol CW	Sodium nitrite + borate

(continued)

Manufacturer	Additive name	Additive type
Motul	HD Cool Power Ultra	Organic Acid Technology
Nalco Chemical Company	TRAC102 TRAC118 Nalcool 2000	Sodium nitrite + borate Sodium nitrite + borate Sodium nitrite + borate
Shell	Shipcare Cooling Water Treat	Sodium nitrite + borate
Solenis	Drewgard 4109	Sodium nitrite + borate
Suez Water Technologies & Solutions	CorrShield NT4293 CorrShield NT4200	CorrShield NT4293 CorrShield NT4200
Total	WT Supra	Organic Acid Technology
Vecom Marine Alliance B.V.	Cool Treat NCLT	Sodium nitrite + borate
Wilhelmsen Chemicals AS	Dieselguard NB Rocor NB liquid Cooltreat AL Engine Water Treatment 9-108 Nalfleet 2000	Sodium nitrite + borate Sodium nitrite + borate Organic Acid Technology Sodium nitrite + borate Sodium nitrite + borate

In order to prevent corrosion in the cooling water system, the instructions of right dosage and concentration of active corrosion inhibitors should always be followed. Please contact Wärtsilä for details.

9.1.3 Glycol

If a freezing risk exists, glycol needs to be added to cooling water. However, in case there is no freezing risk, the use of glycol in cooling water shall be avoided due to its detrimental effect on heat transfer. Since glycol alone does not protect the engine and cooling water system against corrosion, additionally a validated cooling water additive must always be used. All validated cooling water additives are compatible with glycol.

Ready-to-use mixtures of commercial coolant brands containing both glycol and corrosion inhibitors are not allowed to use. Those are typically designed to be used as strong (~ 30 –) 50% / 50 (~ 70) % mixtures. However, in Wärtsilä engines normally a much lower glycol amount is adequate to protect the cooling water system against freezing. The outcome of decreasing the glycol amount is that simultaneously also the concentration of corrosion inhibitors will decrease to too low level resulting in an increased risk of corrosion.

The amount of glycol in closed cooling water system shall always be minimized since heat transfer of water containing glycol has deteriorated significantly. The engine may therefore be subject to additional output derating when using glycol in the cooling water, please contact Wärtsilä for details.

Instead of ready-to-use glycol-corrosion inhibitor mixtures a pure commercially available monopropylene glycol (MPG) or monoethyleneglycol (MEG) has to be used when a freezing risk exists. So called industrial quality of both glycol types is allowed to use, but MPG is considered to be a more environmentally friendly alternative.

9.1.4 Wärtsilä Water Conditioner Unit (WWCU)

As an alternative to the validated cooling water additives, Wärtsilä Water Conditioner Unit (WWCU) can also be used to treat cooling water of engines' closed water circuits. WWCU is based on the Enwamatic EMM cooling water treatment system, but it includes a number of new features based on Wärtsilä design. The WWCU protects an engine from corrosion without a need to use any chemicals. It acts as a side stream filtration and water treatment unit and includes the following functions:

- corrosion protection
- scale control
- filtration
- control of bacterial growth and air separation

The WWCU can be a sensible alternative for the installations in which environmentally friendly solutions are appreciated or even required by authorities.

The WWCU cannot be used if simultaneously ready-to-use mixtures of commercial coolant brands containing both glycol and corrosion inhibitors are used in the cooling water system. If protection against freezing is needed, the equipment can on the other hand be used together with pure monopropylene glycol (MPG) or monoethylene glycol (MEG). The WWCU must be installed so that the cooling water inlet temperature to the unit does not exceed 109 °C and that the inlet pressure does not exceed 10 bar (abs.).

Due to a severe corrosion risk WWCU can´t be used in the cooling water systems containing aluminium or aluminium alloys as a construction material. The reason for the above mentioned ban is that in the cooling water systems equipped with the WWCU pH of cooling water can be above 9 and at that pH range corrosion rate of aluminium / aluminium alloys starts to increase significantly.

One WWCU unit has to be installed to each separate cooling water circuit and the right type must be chosen according to the water volume of each cooling water system.

The WWCU must be backflushed regularly in order to remove deposits from the bottom of the unit. In case of new installation even daily backflushing is needed, but the backflush interval can be extended when a stable situation in the cooling water system is achieved.

A typical backflush interval in a stabilized cooling water system is estimated to be from one week to one month depending on water quality and added make-up water amount. Further, it is important to follow continuously functioning of the WWCU. Frequent operation of an engine will intensify the circulation rate of cooling water through the WWCU.

If WWCU is installed to the engines having already been in service and in which chemical cooling water treatment has been used, the cooling water system has to be drained and possible deposits (grease, rust, other impurities) need to be removed from the system prior to the start of using WWCU. If flushing of the cooling water system does not result in an adequate cleanliness, additionally a chemical cleaning has to be done. Major cooling water additive suppliers are able to offer suitable cleaning chemicals.

If an engine will not be in service for longer periods, water circulation in the closed cooling water circuit will be slow and a special attention has to be paid to that corrosion of the system will not occur.

The list of the WWCU types along with the specified cooling water system volumes are included in the table below.

WWCU type	Specified water system volume (m^3)
WWCU F1	0 - 7
WWCU F2	0 - 20
WWCU F3	0 - 40

The use of pipes having galvanized inner surfaces is not allowed in the cooling water system.

9.2 External cooling water system

It is recommended to divide the engines into several circuits in multi-engine installations. One reason is of course redundancy, but it is also easier to tune the individual flows in a smaller system. Malfunction due to entrained gases, or loss of cooling water in case of large leaks can also be limited. In some installations it can be desirable to separate the HT circuit from the LT circuit with a heat exchanger.

The external system shall be designed so that flows, pressures and temperatures are close to the nominal values in Technical Data, which can be found by accessing *Engine Online Configurator* available through Wärtsilä's website. And the cooling water must be properly de-aerated.

Pipes with galvanized inner surfaces are not allowed in the fresh water cooling system. Some cooling water additives react with zinc, forming harmful sludge. Zinc also becomes nobler than iron at elevated temperatures, which causes severe corrosion of engine components.

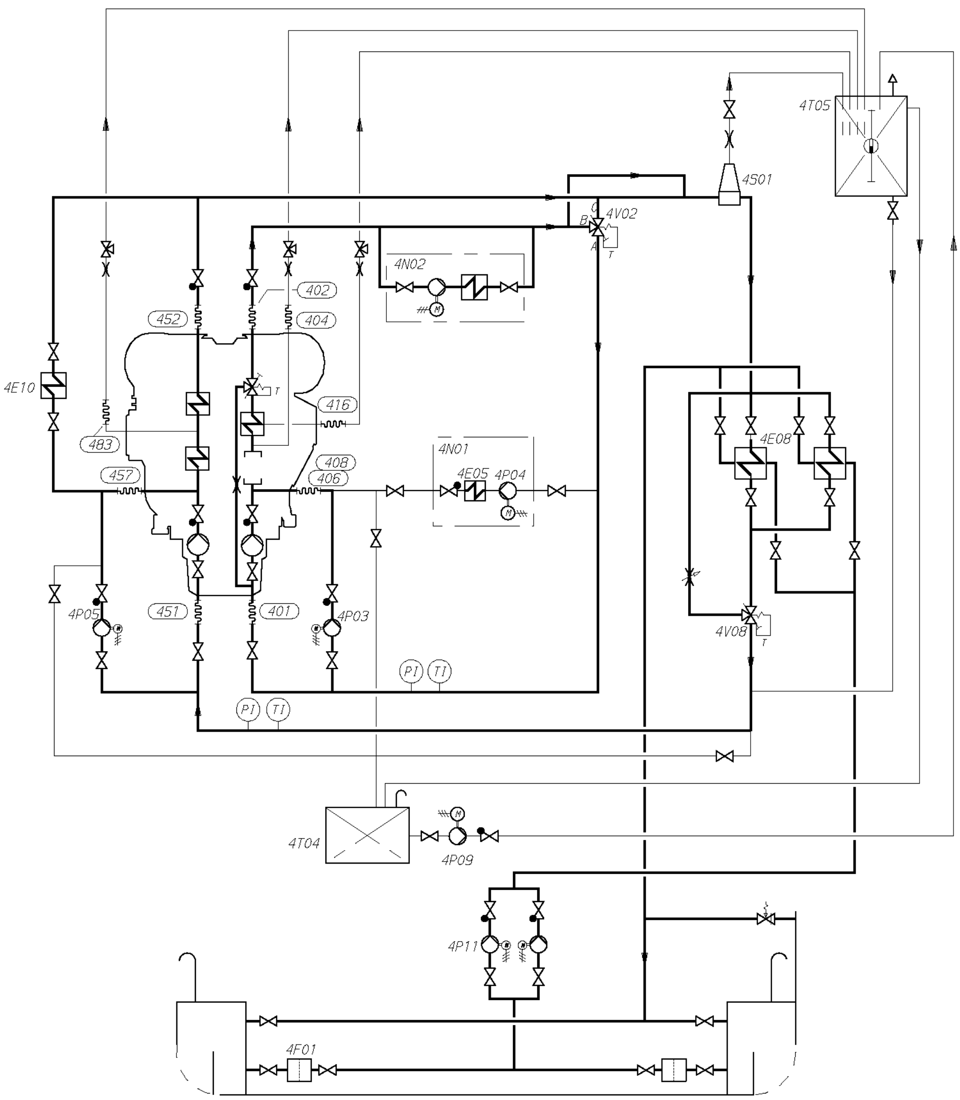

Fig 9-1 Example diagram for single main engine (LFO) (V76C5775C)

System components:					
4E05	Heater (preheating unit)	4P03	Stand-by pump (HT)	4T04	Drain tank
4E08	Central cooler	4P04	Circulating pump (preheater)	4T05	Expansion tank

(continued)

System components:					
4E10	Cooler (reduction gear)	4P05	Stand-by pump (LT)	4V02	Temp. control valve (heat recovery)
4F01	Suction strainer (sea water)	4P09	Transfer pump		
4N01	Preheating unit	4P11	Circulating pump (sea water)	4V08	Temp. control valve (central cooler)
4N02	Evaporator unit	4S01	Air venting		

Pipe connections:			
401	HT-water inlet	416	HT-water airvent from air cooler
402	HT-water	451	LT-water inlet
404	HT-water air vent	452	LT-water outlet
406	Water from preheater to HT-circuit	457	LT-water from stand-by pump
408	HT-water from stand-by pump	483	LT-water air vent

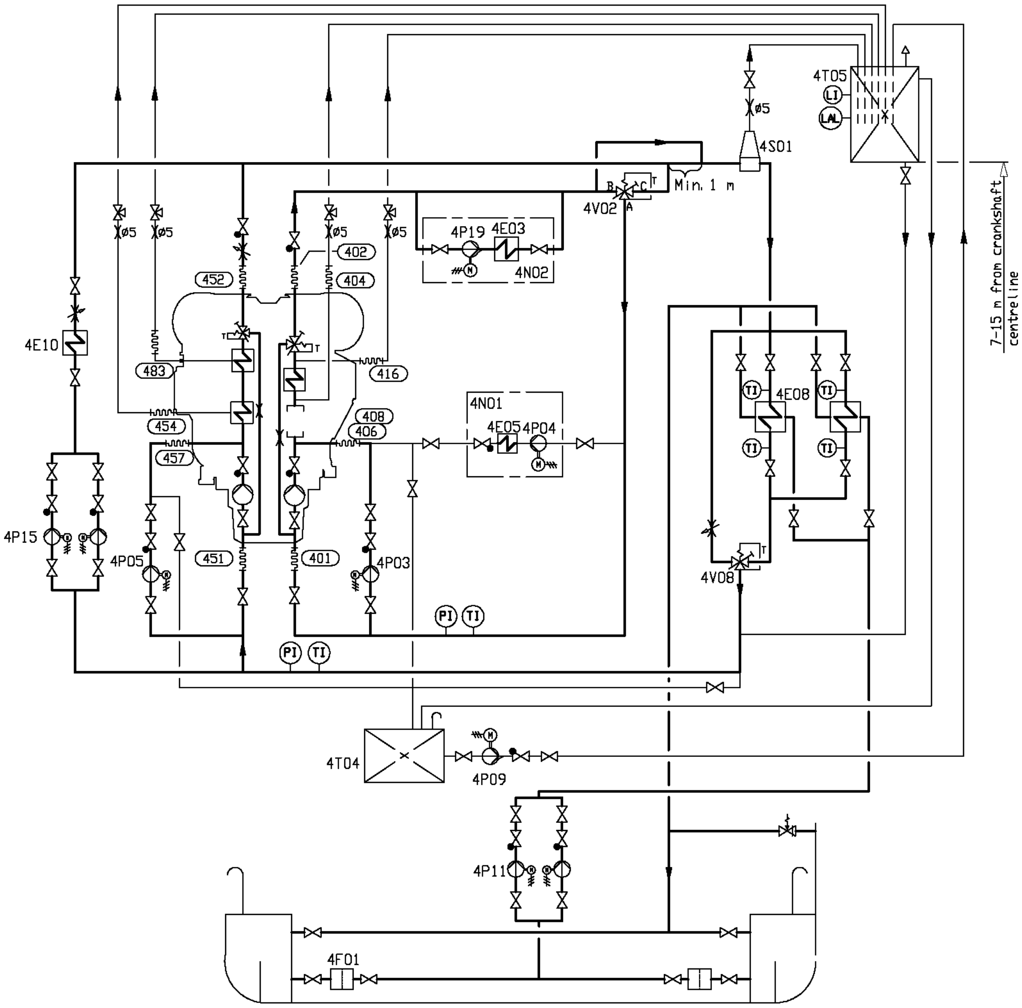

Fig 9-2 Example diagram for single main engine (HFO), reduction gear fresh water cooled (V76C5262C)

System components:			
4E03	Heat recovery (evaporator)	4P09	Transfer pump
4E05	Heater (preheating unit)	4P11	Circulating pump (sea water)
4E08	Central cooler	4P15	Circulating pump (LT)
4E10	Cooler (reduction gear)	4P19	Circulating pump (evaporator)
4F01	Suction strainer (sea water)	4S01	Air venting
4N01	Preheating unit	4T04	Drain tank
4N02	Evaporator unit	4T05	Expansion tank
4P03	Stand-by pump (HT)	4V02	Temperature control valve (heat recovery)
4P04	Circulating pump (preheater)	4V08	Temperature control valve (central cooler)
4P05	Stand-by pump (LT)		

Pipe connections:					
401	HT-water inlet	DN125	451	LT-water inlet	DN125
402	HT-water outlet	DN125	452	LT-water outlet	DN125
404	HT-water air vent	OD12	454	LT-water air vent from air cooler	OD12
406	Water from preheater to HT-circuit	DN32	457	LT-water from stand-by pump	DN125
408	HT-water from stand-by pump	DN125	483	LT-water air vent	OD12

(continued)

Pipe connections:					
416	HT-water airvent from air cooler	OD12			

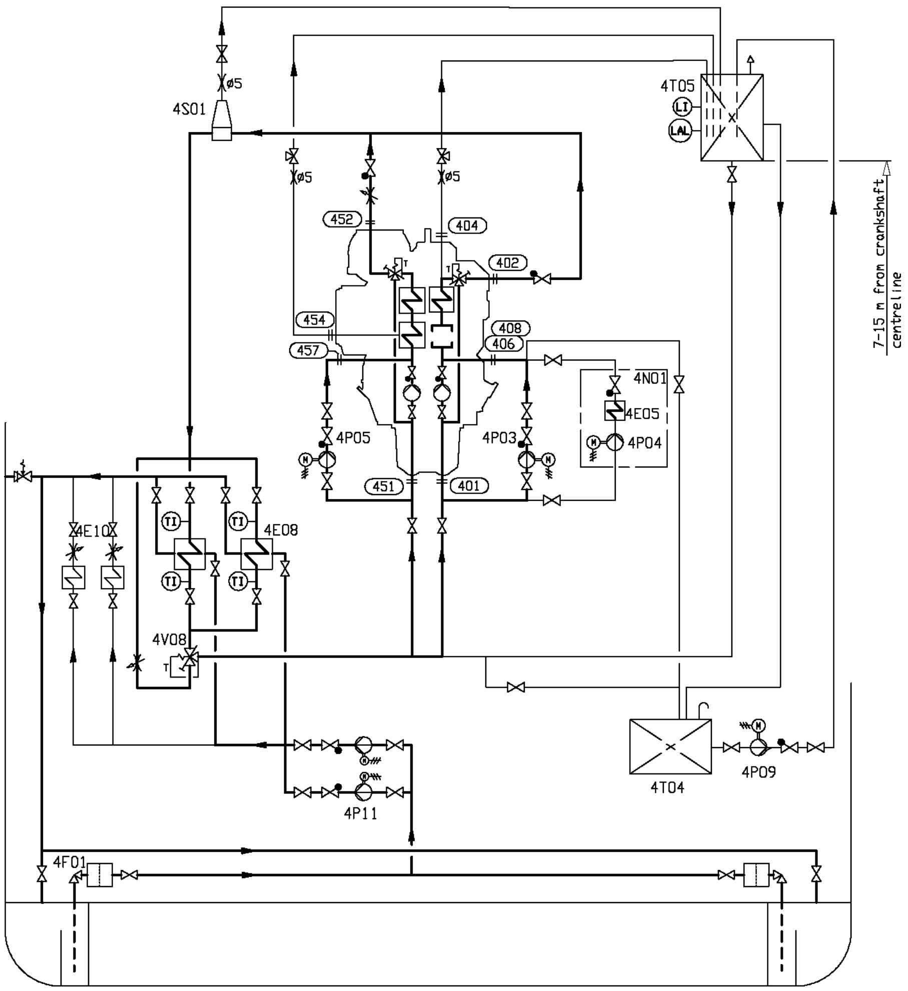

Fig 9-3 Example diagram for single main engine (HFO) reduction gear sea water cooled (V76C5791B)

System components:			
4E05	Heater (preheater)	4P05	Stand-by pump (LT)
4E08	Central cooler	4P09	Transfer pump
4E10	Cooler (reduction gear)	4P11	Circulating pump (sea water)
4F01	Suction strainer (sea water)	4S01	Air venting
4N01	Preheating unit	4T04	Drain tank
4P03	Stand-by pump (HT)	4T05	Expansion tank
4P04	Circulating pump (preheater)	4V08	Temp control valve (central cooler)

Pipe connections:					
401	HT-water inlet	DN100	451	LT-water inlet	DN100
402	HT-water outlet	DN100	452	LT-water outlet	DN100
404	HT-water air vent	OD12	454	LT-water air venting from air cooler	OD12
406	Water from preheater to HT-circuit	OD28	457	LT-water from stand-by pump	DN100
408	HT-water from stand-by pump	DN100			

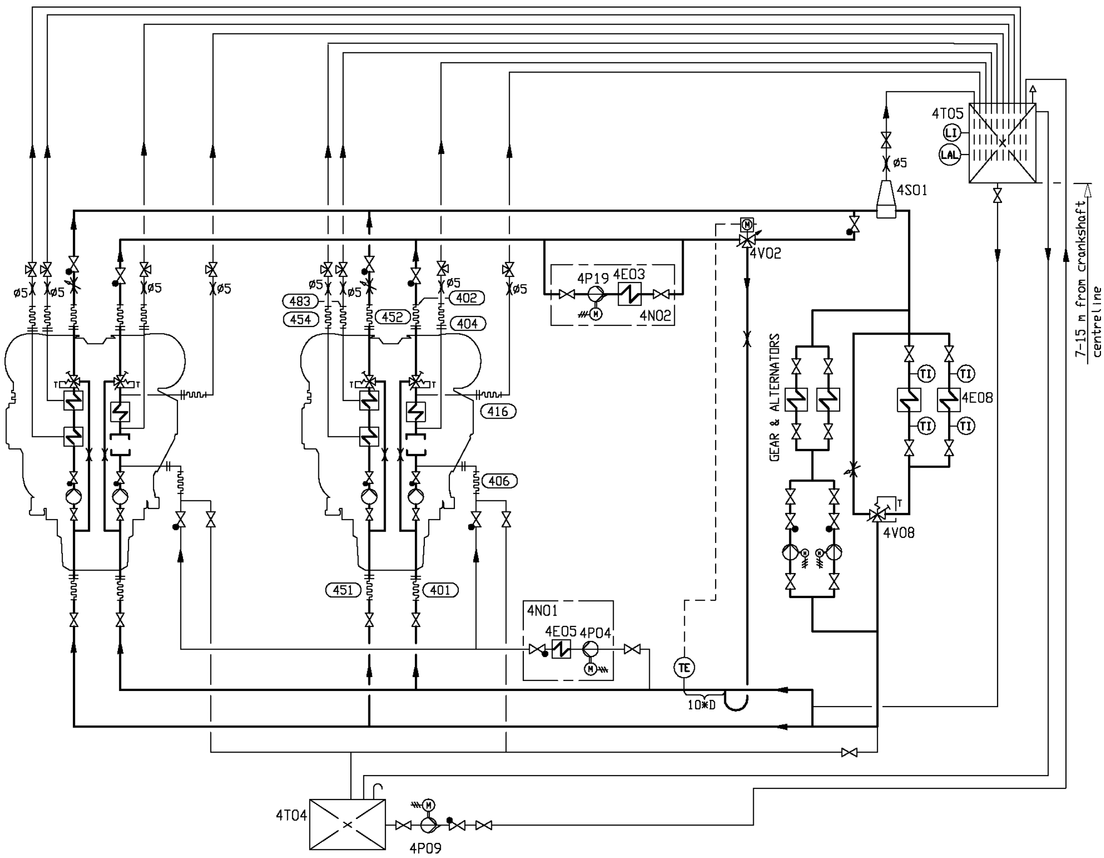

Fig 9-4 Example diagram for multiple main engines (V76C5263C)

System components:			
4E03	Heat recovery (evaporator)	4P19	Circulating pump (evaporator)
4E05	Heater (preheater)	4S01	Air venting
4E08	Central cooler	4T04	Drain tank
4N01	Preheating unit	4T05	Expansion tank
4N02	Evaporator unit	4V02	Temperature control valve (heat recovery)
4P04	Circulating pump (preheater)	4V08	Temperature control valve (central cooler)
4P09	Transfer pump		

Pipe connections:					
401	HT-water inlet	DN125	451	LT-water inlet	DN125
402	HT-water outlet	DN125	452	LT-water outlet	DN125
404	HT-water air vent	OD12	454	LT-water air vent from air cooler	DN125
406	Water from preheater to HT-circuit	DN32	483	LT-water air vent	OD12
416	HT-water airvent from air cooler	OD12			

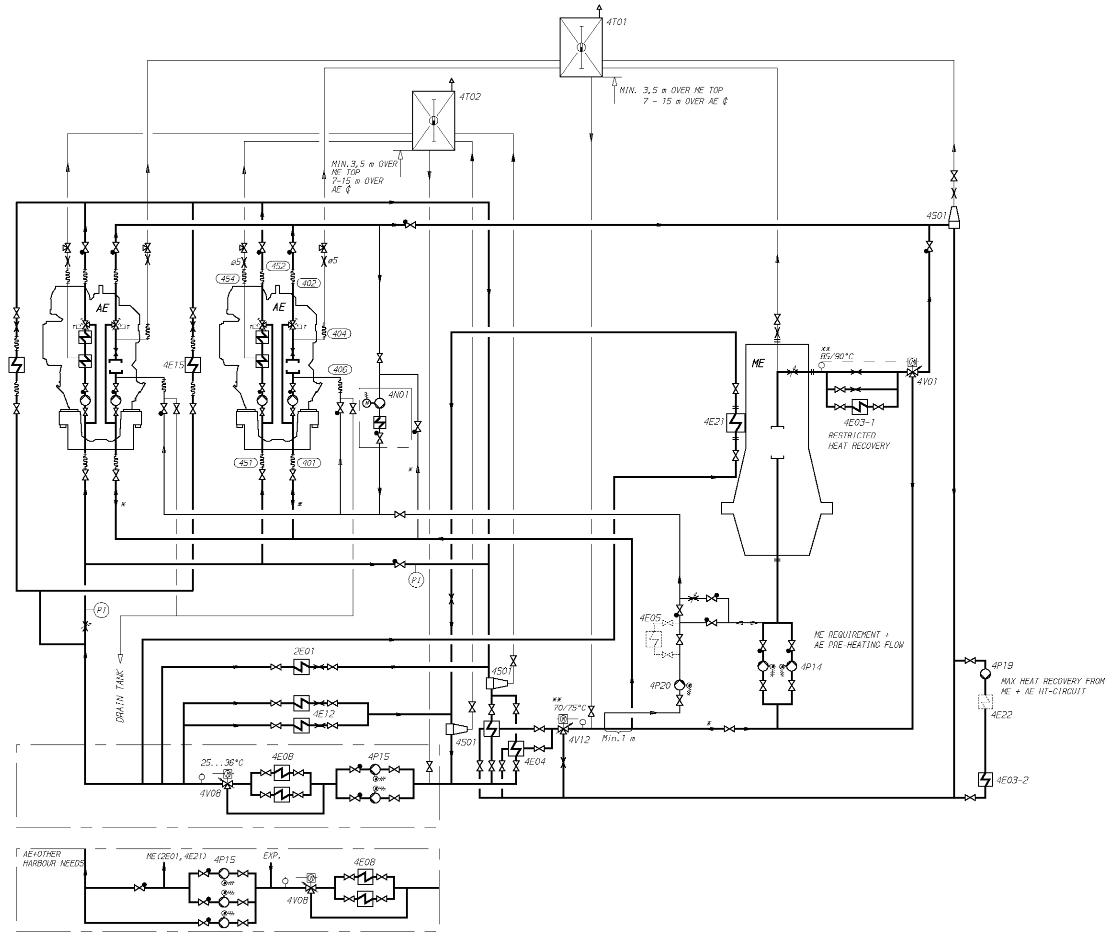

Fig 9-5 Example diagram for common auxiliary engines and a low speed main engine with split LT and HT circuit (DAAE026913A)

Notes:

* Preheating

** Depending of Main engine type

The preheating unit (4N01) is needed for preheating before start of first auxiliary engine AE, if the heater (4E05) is not installed.

The pump (4P04) is used for preheating of stopped main engine and auxiliary engine with heat from running auxiliary engine.

The pump (4P14) preheats stopped auxiliary engine when main engine is running.

The heater (4E05) is only needed if the heat from the running auxiliary engine is not sufficient for preheating the main engine, e.g. in extreme winter conditions

It is not necessary to open/close valve when switching on the preheating of main engine or auxiliary engine.

The LT-circulating pump 4P15 can alternatively be mounted after the central coolers 4E08 and thermostatic valve 4V08 which gives possibility to use a smaller pump in harbour without clousing valves to main engine.

System components:			
2E01	Lubricating oil cooler	4P14	Circulating pump (HT)
4E03-1	Heat recovery (evaporator) ME	4P15	Circulating pump (LT)
4E03-2	Heat recovery (evaporator) ME + AE	4P19	Circulating pump (evaporator)
4E04	Raw water cooler (HT)	4P20	Circulating pump (preheating HT)
4E05	Heater (preheater), optional	4S01	Air venting
4E08	Central cooler	4T01	Expansion tank (HT)
4E12	Cooler (installation parts)	4T02	Expansion tank (LT)
4E15	Cooler (generator), optional	4V01	Temperature control valve (HT)

(continued)

System components:			
4E21	Cooler (scavenge air)	4V03	Temperature control valve (LT)
4E22	Heater (booster), optional	4V12	Temperature control valve (heat recovery and preheating)
4N01	Preheating unit		

Pipe connections:			
401	HT-water inlet	451	LT-water inlet
402	HT-water outlet	452	LT-water outlet
404	HT-water air vent	454	LT-water air vent from air cooler
406	Water from preheater to HT-circuit		

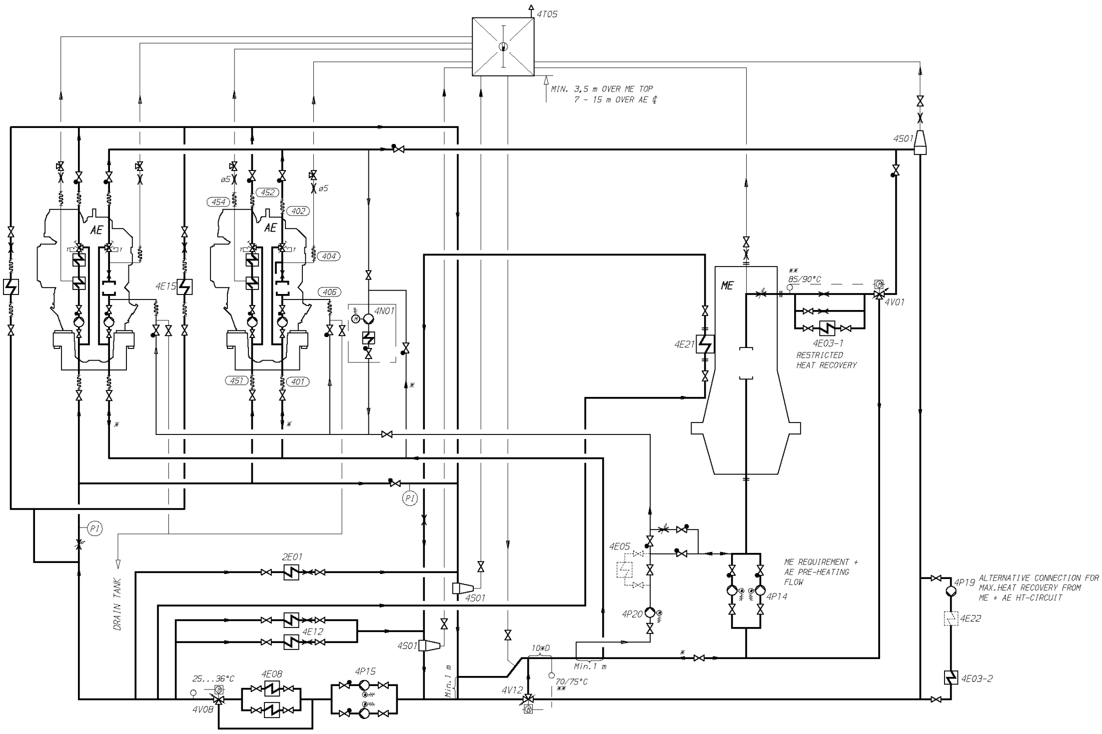

Fig 9-6 Example diagram for common auxiliary engines and a low speed main engine with mixed LT and HT circuit (DAAE026912A)

Notes:

* Preheating flow

** Depending of ME type

The preheating unit (4N01) is needed for preheating before start of first auxiliary engine AE, if heater (4E05) is not installed.

The pump (4P04) is used for preheating of stopped main engine ME and auxiliary engine AE with heat from running auxiliary engine.

The pump (4P14) preheats the stopped auxiliary engine AE when main engine ME is running.

The heater (4E05) is only needed if the heat from the running auxiliary engine is not sufficient for preheating the main engine, e.g. in extreme winter conditions

It is not necessary to open/close valve when switching on the preheating of main engine or auxiliary engine.

System components:			
2E01	Lubriating oil cooler	4P14	Circulating pump (HT)
4E03-1	Heat recovery (evaporator) ME	4P15	Circulating pump (LT)
4E03-2	Heat recovery (evaporator) ME + AE	4P19	Circulating pump (evaporator)
4E05	Heater (preheater), optional	4P20	Circulating pump (preheating HT)
4E08	Central cooler	4S01	Air venting
4E12	Cooler (installation parts)	4T05	Expansion tank
4E15	Cooler (generator)	4V01	Temperature control valve (HT)
4E21	Cooler (scavenge air)	4V08	Temperature control valve (central cooler)
4E22	Heater (booster), optional	4V12	Temperature control valve (heat recovery and preheating)
4N01	Preheating unit		

Pipe connections:					
401	HT-water inlet	406	Water from preheater to HT-circuit	452	LT-water outlet

(continued)

Pipe connections:					
402	HT-water outlet	451	LT-water inlet	454	LT-water air vent from air cooler
404	HT-water air vent				

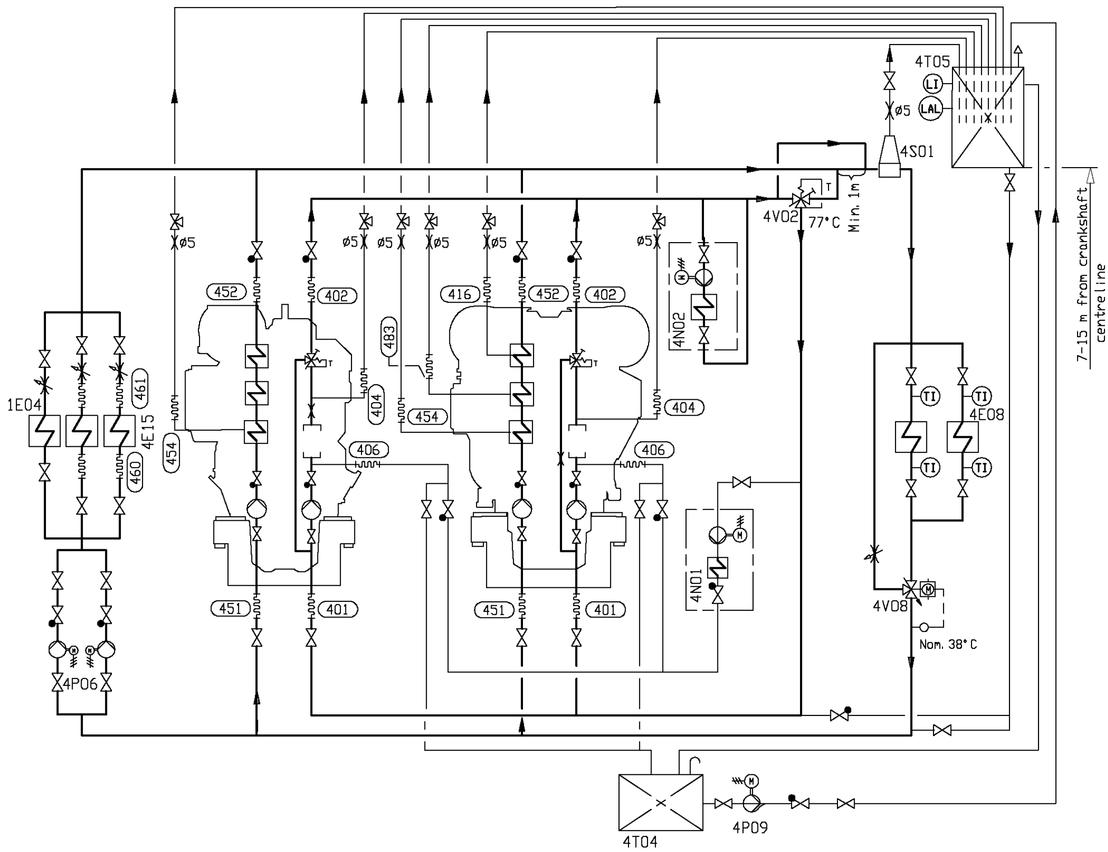

Fig 9-7 Example diagram for arctic conditions (DAAF301175)

System components:			
1E04	Cooler (LFO)	4P09	Transfer pump
4E08	Central cooler	4S01	Air venting
4E15	Cooler (generator)	4T04	Drain tank
4N01	Preheating unit	4T05	Expansion tank
4N02	Evaporator unit	4V02	Temperature control valve (heat recovery)
4P06	Circulating pump	4V08	Temperature control valve (central cooler)

Pipe connections:		V32	L32
401	HT-water inlet	DN125	DN100
402	HT-water outlet	DN125	DN100
404	HT-water air vent	OD12	OD12
406	Water from preheater to HT-circuit	DN32	OD28
416	HT-water air vent from air cooler	OD12	-
451	LT-water inlet	DN125	DN100
452	LT-water outlet	DN125	DN100
454	LT-water air vent from air cooler	OD12	OD12
460	LT-water to generator	-	-
461	LT-water from generator	-	-
483	LT-water air vent	OD12	-

9.2.1 Cooling water system for arctic conditions

At low engine loads the combustion air is below zero degrees Celsius after the compressor stage, it cools down the cooling water and the engine instead of releasing heat to the cooling water in the charge air cooler. If the combustion air temperature reaching the cylinders is too cold, it can cause uneven burning of the fuel in the cylinder and possible misfires. Additionally overcooling the engine jacket can cause cold corrosion of the cylinder liners or even a stuck piston.

Maintaining nominal charge air receiver and HT-water inlet temperature are important factors when designing the cooling water system for arctic conditions. To manage this the HT-charge air cooler is replaced with a double-stage cooler on the engine LT-water cooling water system. With this setup the LT thermostatic valve have to be placed in the external system.

9.2.1.1 The arctic sea water cooling system

In arctic conditions, the hot sea water from the central cooler outlet is typically returned back to the sea chest in order to prevent ice slush from blocking the sea water filters. An example flow diagram of the arctic sea water system is shown below.

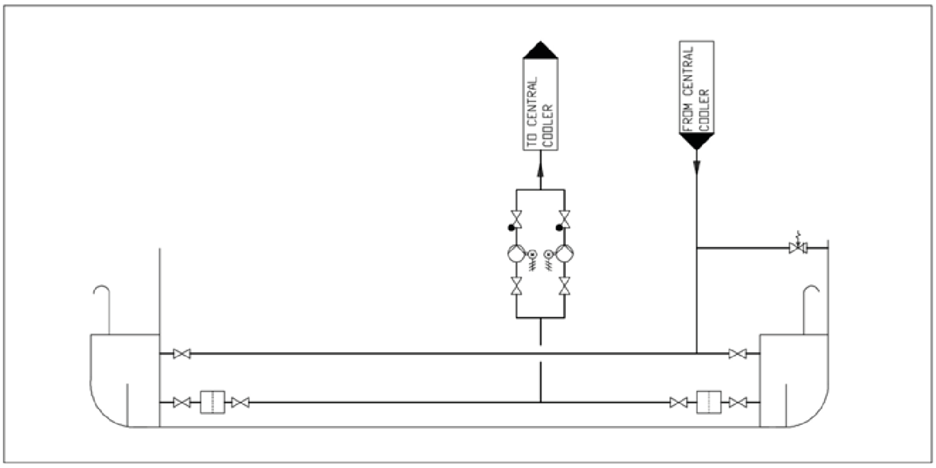

Fig 9-8 Example flow diagram of arctic sea water system

Ships (with ice class) designed for cold sea-water should have provisions for recirculation back to the sea chest from the central cooler:

- For melting of ice and slush, to avoid clogging of the sea water strainer
- To enhance the temperature control of the LT water, by increasing the seawater temperature

9.2.2 Stand-by circulation pumps (4P03, 4P05)

Stand-by pumps should be of centrifugal type and electrically driven. Required capacities and delivery pressures can be found in *Engine Online Configurator available through Wärtsilä website* .

NOTICE
Stand-by pumps may be considered as backup rather than actual spare pumps.

9.2.3 Sea water pump (4P11)

The sea water pumps are always separate from the engine and electrically driven.

The capacity of the pumps is determined by the type of coolers and the amount of heat to be dissipated.

Significant energy savings can be achieved in most installations with frequency control of the sea water pumps. Minimum flow velocity (fouling) and maximum sea water temperature (salt deposits) are however issues to consider.

9.2.4 Temperature control valve, HT-system (4V01)

External HT temperature control valve is an option for V-engines.

The temperature control valve is installed directly after the engine. It controls the temperature of the water out from the engine, by circulating some water back to the HT pump. The control valve can be either self-actuated or electrically actuated. Each engine must have a dedicated temperature control valve.

Set point	96°C

9.2.5 Temperature control valve for central cooler (4V08)

When it is desired to utilize the engine driven LT-pump for cooling of external equipment, e.g. a reduction or a generator, there must be a common LT temperature control valve in the external system, instead of an individual valve for each engine. The common LT temperature control valve is installed after the central cooler and controls the temperature of the water before the engine and the external equipment, by partly bypassing the central cooler. The valve can be either direct acting or electrically actuated.

The set-point of the temperature control valve 4V08 is 38 ºC in the type of system described above.

Engines operating on HFO must have individual LT temperature control valves. A separate pump is required for the external equipment in such case, and the set-point of 4V08 can be lower than 38 ºC if necessary.

9.2.6 Temperature control valve for heat recovery (4V02)

The temperature control valve after the heat recovery controls the maximum temperature of the water that is mixed with HT water from the engine outlet before the HT pump. The control valve can be either self-actuated or electrically actuated.

Especially in installations with dynamic positioning (DP) feature, installation of valve 4V02 is strongly recommended in order to avoid HT temperature fluctuations during low load operation.

The set-point is usually up to 75 ºC.

9.2.7 Coolers for other equipment and LFO coolers

The engine driven LT circulating pump can supply cooling water to one or two small coolers installed in parallel to the engine, for example a LFO cooler or a reduction gear cooler. This is only possible for engines operating on LFO, because the LT temperature control valve cannot be built on the engine to control the temperature after the engine. Separate circulating pumps are required for larger flows.

Design guidelines for the LFO cooler are given in chapter *Fuel system*.

9.2.8 Fresh water central cooler (4E08)

The fresh water cooler can be of either plate, tube or box cooler type. Plate coolers are most common. Several engines can share the same cooler.

It can be necessary to compensate a high flow resistance in the circuit with a smaller pressure drop over the central cooler.

The flow to the fresh water cooler must be calculated case by case based on how the circuit is designed.

In case the fresh water central cooler is used for combined LT and HT water flows in a parallel system the total flow can be calculated with the following formula:

$$q = q_{LT} + \frac{3.6 \times \Phi}{4.15 \times (T_{OUT} - T_{IN})}$$

where:

q = total fresh water flow [m³/h]

q_{LT} = nominal LT pump capacity[m³/h]

Φ = heat dissipated to HT water [kW]

T_{out} = HT water temperature after engine (96°C)

T_{in} = HT water temperature after cooler (38°C)

Design data:

Fresh water flow	please refer to *Engine Online Configurator* available through Wärtsilä website
Heat to be dissipated	please refer to *Engine Online Configurator* available through Wärtsilä website
Pressure drop on fresh water side	max. 60 kPa (0.6 bar)
Sea-water flow	acc. to cooler manufacturer, normally 1.2 - 1.5 x the fresh water flow
Pressure drop on sea-water side, norm.	acc. to pump head, normally 80 - 140 kPa (0.8 - 1.4 bar)
Fresh water temperature after LT cooler	max. 38 °C
Fresh water temperature after HT cooler	max. 77 °C
Margin (heat rate, fouling)	15%

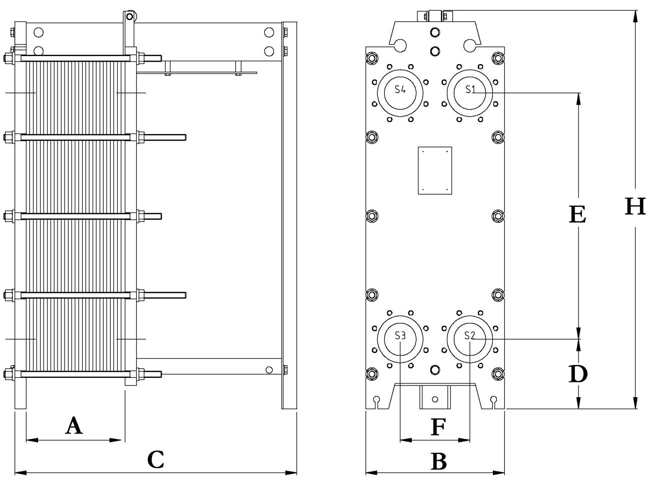

Fig 9-9 Main dimensions of the central cooler.

NOTE
The sizes are for guidance only. These central coolers are dimensioned to exchange the heat of the engine only, other equipment such as CPP, gearbox etc. is not taken into account.

Engine type	P [kW]	Weight [kg]	Dimension [mm]						
			A	B	C	D	E	F	H
1 x 6L32	1641	820	193	690	817	330	1057	380	1675
1 x 7L32	1914	830	227	690	817	330	1057	380	1675
1 x 8L32	2189	860	262	690	817	330	1057	380	1675
1 x 9L32	2462	880	296	690	817	330	1057	380	1675
1 x 12V32	3170	890	331	690	817	330	1057	380	1675
1 x 16V32	4227	960	448	690	817	330	1057	380	1675
1 x 18V32	4755	1000	524	690	817	330	1057	380	1730

As an alternative for the central coolers of the plate or of the tube type a box cooler can be installed. The principle of box cooling is very simple. Cooling water is forced through a U-tube-bundle, which is placed in a sea-chest having inlet- and outlet-grids. Cooling effect is reached by natural circulation of the surrounding water. The outboard water is warmed up and rises by its lower density, thus causing a natural upward circulation flow which removes the heat.

Box cooling has the advantage that no raw water system is needed, and box coolers are less sensitive for fouling and therefore well suited for shallow or muddy waters.

9.2.9 Waste heat recovery

The waste heat in the HT cooling water can be used for hot water consumers, absorption chillers, potable water production, AC system heating, stand-by engines preheating and generating electricity through e.g., an ORC (Organic Rankine Cycle). The system should in such case be provided with a temperature control valve to avoid unnecessary cooling, as shown in the example diagrams. With this arrangement the HT water flow through the heat recovery can be increased.

The heat available from HT cooling water is affected by ambient conditions. It should also be taken into account that the recoverable heat is reduced by circulation to the expansion tank, radiation from piping and leakages in temperature control valves.

To maximize heat recovery and functionality, it is recommended for all valves installed on the LT and HT line, to have max 0.5% volumetric leakage. For electrical actuated valves, full stroke speed must be max. 65 seconds and dead band max. 1%.

9.2.10 Air venting

Air may be entrained in the system after an overhaul, or a leak may continuously add air or gas into the system. The engine is equipped with vent pipes to evacuate air from the cooling water circuits. The vent pipes should be drawn separately to the expansion tank from each connection on the engine, except for the vent pipes from the charge air cooler on V-engines, which may be connected to the corresponding line on the opposite cylinder bank.

Venting pipes to the expansion tank are to be installed at all high points in the piping system, where air or gas can accumulate.

The vent pipes must be continuously rising.

9.2.11 Expansion tank (4T05)

The expansion tank compensates for thermal expansion of the coolant, serves for venting of the circuits and provides a sufficient static pressure for the circulating pumps.

Design data:

Pressure from the expansion tank at pump inlet	70 - 150 kPa (0.7...1.5 bar)
Volume	min. 10% of the total system volume

NOTICE

The maximum pressure at the engine must not be exceeded in case an electrically driven pump is installed significantly higher than the engine.

Concerning the water volume in the engine, please refer to *Engine Online Configurator* available through Wärtsilä website.

The expansion tank should be equipped with an inspection hatch, a level gauge, a low level alarm and necessary means for dosing of cooling water additives.

The vent pipes should enter the tank below the water level. The vent pipes must be drawn separately to the tank (see air venting) and the pipes should be provided with labels at the expansion tank.

The balance pipe down from the expansion tank must be dimensioned for a flow velocity not exceeding 1.0...1.5 m/s in order to ensure the required pressure at the pump inlet with engines running. The flow through the pipe depends on the number of vent pipes to the tank and the size of the orifices in the vent pipes. The table below can be used for guidance.

Table 9-1 Minimum diameter of balance pipe

Nominal pipe size	Max. flow velocity (m/s)	Max. number of vent pipes with ø 5 mm orifice
DN 32	1.1	3
DN 40	1.2	6
DN 50	1.3	10
DN 65	1.4	17

9.2.12 Drain tank (4T04)

It is recommended to collect the cooling water with additives in a drain tank, when the system has to be drained for maintenance work. A pump should be provided so that the cooling water can be pumped back into the system and reused.

Concerning the water volume in the engine, please refer to *Engine Online Configurator* available through Wärtsilä website. The water volume in the LT circuit of the engine is small.

9.2.13 HT preheating

The cooling water circulating through the cylinders must be preheated to at least 50 ºC, preferably 70 ºC.

This is an absolute requirement for installations that are designed to operate on heavy fuel, but strongly recommended also for engines that operate exclusively on marine diesel fuel.

The energy required for preheating of the HT cooling water can be supplied by a separate source or by a running engine, often a combination of both. In all cases a separate circulating pump must be used. It is common to use the heat from running auxiliary engines for preheating of main engines. In installations with several main engines the capacity of the separate heat source can be dimensioned for preheating of two engines, provided that this is acceptable for the operation of the ship. If the cooling water circuits are separated from each other, the energy is transferred over a heat exchanger.

9.2.13.1 HT heater (4E05)

The energy source of the heater can be electric power, steam or thermal oil.

It is recommended to heat the HT water to a temperature near the normal operating temperature. The heating power determines the required time to heat up the engine from cold condition.

The minimum required heating power is 5 kW/cyl, which makes it possible to warm up the engine from 20 ºC to 60...70 ºC in 10-15 hours. The required heating power for shorter heating time can be estimated with the formula below. About 2 kW/cyl is required to keep a hot engine warm.

Design data:	
Preheating temperature	min. 50°C for starts at LFO
Required heating power	5 kW/cyl
Heating power to keep hot engine warm	2 kW/cyl

Required heating power to heat up the engine, see formula below:

$$P = \frac{(T_1 - T_0)(m_{eng} \times 0.14 + V_{LO} \times 0.48 + V_{FW} \times 1.16)}{t} + k_{eng} \times n_{cyl}$$

where:

P = Preheater output [kW]

T_1 = Preheating temperature = 60...70 °C

T_0 = Ambient temperature [°C]

m_{eng} = Engine weight [tonne]

V_{LO} = Lubricating oil volume [m^3] (wet sump engines only)

V_{FW} = HT water volume [m^3]

t = Preheating time [h]

k_{eng} = Engine specific coefficient = 1 kW

n_{cyl} = Number of cylinders

The formula above should not be used for $P < 3.5$ kW/cyl

9.2.13.2 Circulation pump for HT preheater (4P04)

Design data:	
Capacity	0.4 m^3/h per cylinder
Delivery pressure	80...100 kPa (0.8...1.0 bar)

9.2.13.3 Preheating unit (4N01)

A complete preheating unit can be supplied. The unit comprises:

- Electric or steam heaters
- Circulating pump
- Control cabinet for heaters and pump
- Set of thermometers
- Non-return valve
- Safety valve

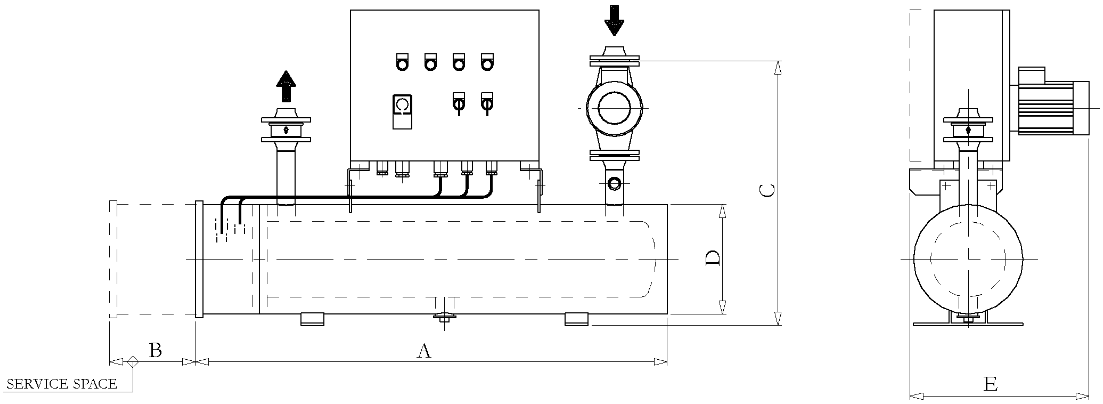

Fig 9-10 Preheating unit, electric (V60L0562C)

Heater capacity [kW]	Pump capacity [m³/h]		Weight [kg]	Pipe conn.	Dimensions [mm]				
	50 Hz	60 HZ		In/outlet	A	B	C	D	E
18	11	13	95	DN40	1250	900	660	240	460
22.5	11	13	100	DN40	1050	720	700	290	480
27	12	13	103	DN40	1250	900	700	290	480
30	12	13	105	DN40	1050	720	700	290	480
36	12	13	125	DN40	1250	900	700	290	480
45	12	13	145	DN40	1250	720	755	350	510
54	12	13	150	DN40	1250	900	755	350	510
72	12	13	187	DN40	1260	900	805	400	550
81	12	13	190	DN40	1260	900	805	400	550
108	12	13	215	DN40	1260	900	855	450	575

9.2.14 Throttles

Throttles (orifices) are to be installed in all by-pass lines to ensure balanced operating conditions for temperature control valves. Throttles must also be installed wherever it is necessary to balance the waterflow between alternate flow paths.

9.2.15 Thermometers and pressure gauges

Local thermometers should be installed wherever there is a temperature change, i.e. before and after heat exchangers etc. in external system.

Local pressure gauges should be installed on the suction and discharge side of each pump.

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10. Combustion Air System

10.1 Engine room ventilation

To maintain acceptable operating conditions for the engines and to ensure trouble free operation of all equipment, attention shall be paid to the engine room ventilation and the supply of combustion air.

The air intakes to the engine room must be located and designed so that water spray, rain water, dust and exhaust gases cannot enter the ventilation ducts and the engine room.

The dimensioning of blowers and extractors should ensure that an overpressure of about 50 Pa is maintained in the engine room in all running conditions.

For the minimum requirements concerning the engine room ventilation and more details, see applicable standards, such as ISO 8861.

The amount of air required for ventilation is calculated from the total heat emission Φ to evacuate. To determine Φ, all heat sources shall be considered, e.g.:

- Main and auxiliary diesel engines
- Exhaust gas piping
- Generators
- Electric appliances and lighting
- Boilers
- Steam and condensate piping
- Tanks

It is recommended to consider an outside air temperature of no less than 35°C and a temperature rise of 11°C for the ventilation air.

The amount of air required for ventilation is then calculated using the formula:

$$q_V = \frac{\Phi}{\rho \times c \times \Delta T}$$

where:

q_v = air flow [m³/s]

Φ = total heat emission to be evacuated [kW]

ρ = air density 1.13 kg/m³

c = specific heat capacity of the ventilation air 1.01 kJ/kgK

ΔT = temperature rise in the engine room [°C]

The heat emitted by the engine is listed in *Engine Online Configurator* available through Wärtsilä website.

The engine room ventilation air has to be provided by separate ventilation fans. These fans should preferably have two-speed electric motors (or variable speed). The ventilation can then be reduced according to outside air temperature and heat generation in the engine room, for example during overhaul of the main engine when it is not preheated (and therefore not heating the room).

The ventilation air is to be equally distributed in the engine room considering air flows from points of delivery towards the exits. This is usually done so that the funnel serves as exit for most of the air. To avoid stagnant air, extractors can be used.

It is good practice to provide areas with significant heat sources, such as separator rooms with their own air supply and extractors.

Under-cooling of the engine room should be avoided during all conditions (service conditions, slow steaming and in port). Cold draft in the engine room should also be avoided, especially in areas of frequent maintenance activities. For very cold conditions a pre-heater in the system should be considered. Suitable media could be thermal oil or water/glycol to avoid the risk for freezing. If steam is specified as heating medium for the ship, the pre-heater should be in a secondary circuit.

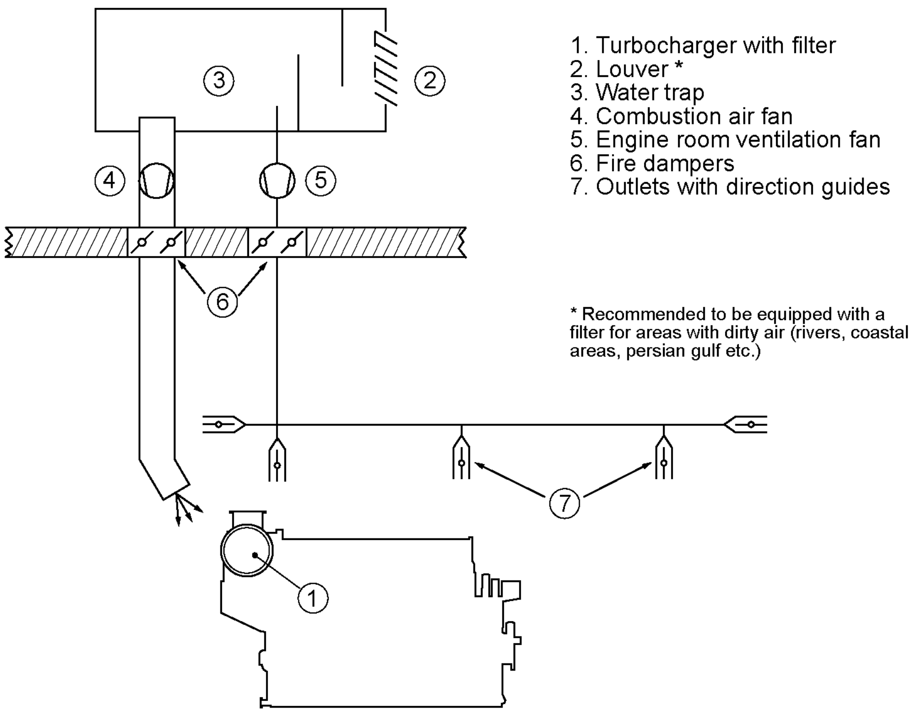

Fig 10-1 Engine room ventilation, turbocharger with air filter (DAAE092651)

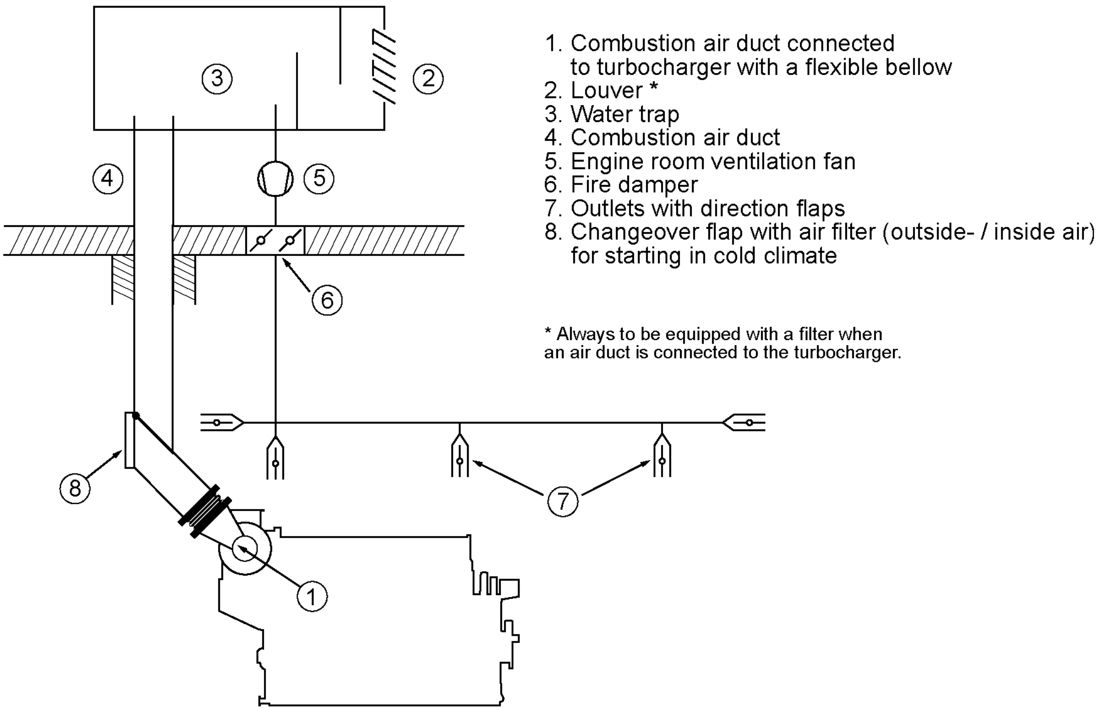

Fig 10-2 Engine room ventilation, air duct connected to the turbocharger (DAAE092652A)

10.2 Combustion air system design

Usually, the combustion air is taken from the engine room through a filter on the turbocharger. This reduces the risk for too low temperatures and contamination of the combustion air. It is important that the combustion air is free from sea water, dust, fumes, etc.

For the required amount of combustion air, please refer to *Engine Online Configurator* available through Wärtsilä website.

The combustion air shall be supplied by separate combustion air fans, with a capacity slightly higher than the maximum air consumption. The combustion air mass flow stated in *Engine Online Configurator* available through Wärtsilä website is defined for an ambient air temperature of 25°C. Calculate with an air density corresponding to 30°C or more when translating the mass flow into volume flow. The expression below can be used to calculate the volume flow.

$$q_c = \frac{m'}{\rho}$$

where:

q_c = combustion air volume flow [m³/s]

m' = combustion air mass flow [kg/s]

ρ = air density 1.15 kg/m³

The fans should preferably have two-speed electric motors (or variable speed) for enhanced flexibility. In addition to manual control, the fan speed can be controlled by engine load.

In multi-engine installations each main engine should preferably have its own combustion air fan. Thus the air flow can be adapted to the number of engines in operation.

The combustion air should be delivered through a dedicated duct close to the turbocharger, directed towards the turbocharger air intake. The outlet of the duct should be equipped with a flap for controlling the direction and amount of air. Also other combustion air consumers, for example other engines, gas turbines and boilers shall be served by dedicated combustion air ducts.

If necessary, the combustion air duct can be connected directly to the turbocharger with a flexible connection piece. With this arrangement an external filter must be installed in the duct to protect the turbocharger and prevent fouling of the charge air cooler. The permissible total pressure drop in the duct is max. 2 kPa. The duct should be provided with a step-less change-over flap to take the air from the engine room or from outside depending on engine load and air temperature.

For very cold conditions heating of the supply air must be arranged. The combustion air fan is stopped during start of the engine and the necessary combustion air is drawn from the engine room. After start either the ventilation air supply, or the combustion air supply, or both in combination must be able to maintain the minimum required combustion air temperature. The air supply from the combustion air fan is to be directed away from the engine, when the intake air is cold, so that the air is allowed to heat up in the engine room.

10.2.1 Charge air shut-off valve (optional)

In installations where it is possible that the combustion air includes combustible gas or vapour the engines can be equipped with charge air shut-off valve. This is regulated mandatory where ingestion of flammable gas or fume is possible.

10.2.2 Condensation in charge air coolers

Air humidity may condense in the charge air cooler and in the engine block air receiver. Especially in tropical conditions amount of condense water can be remarkable. To remove the condense water from the charge air system, engines are equipped with two water drain holes. One at the bottom of charge air cooler and another one at the engine block air receiver. To reduce engine room noise level, these drain holes are equipped with silencers. Possible clogging of these drains / silencers needs to be monitored every second day or after every 50 running hours. Replace silencer(s) when needed.

The amount of condensed water can be estimated with the diagram below.

Example, according to the diagram:

At an ambient air temperature of 35°C and a relative humidity of 80%, the content of water in the air is 0.029 kg water/ kg dry air. If the air manifold pressure (receiver pressure) under these conditions is 2.5 bar (= 3.5 bar absolute), the dew point will be 55°C. If the air temperature in the air manifold is only 45°C, the air can only contain 0.018 kg/kg. The difference, 0.011 kg/kg (0.029 - 0.018) will appear as condensed water.

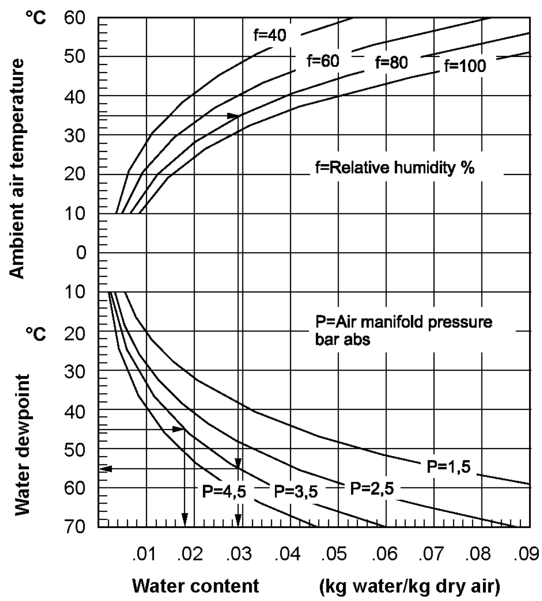

Fig 10-3 Condensation in charge air coolers

10.2.3 Drain Pipe of Charge Air Cooler

According to IMO Resolution MSC.337(91) and SOLAS, Chapter II-1, Regulations 3-12.3 and 3-12.4, drain pipes of charge air cooler must be routed away from engine in order to reduce sound pressure levels down to 110 dB in machinery space. In addition, charge air condensate drain must be checked regularly to ensure that no clogging occurs and condensate flows freely.

Please refer to an example design of drain pipes below for Marine Business applications.

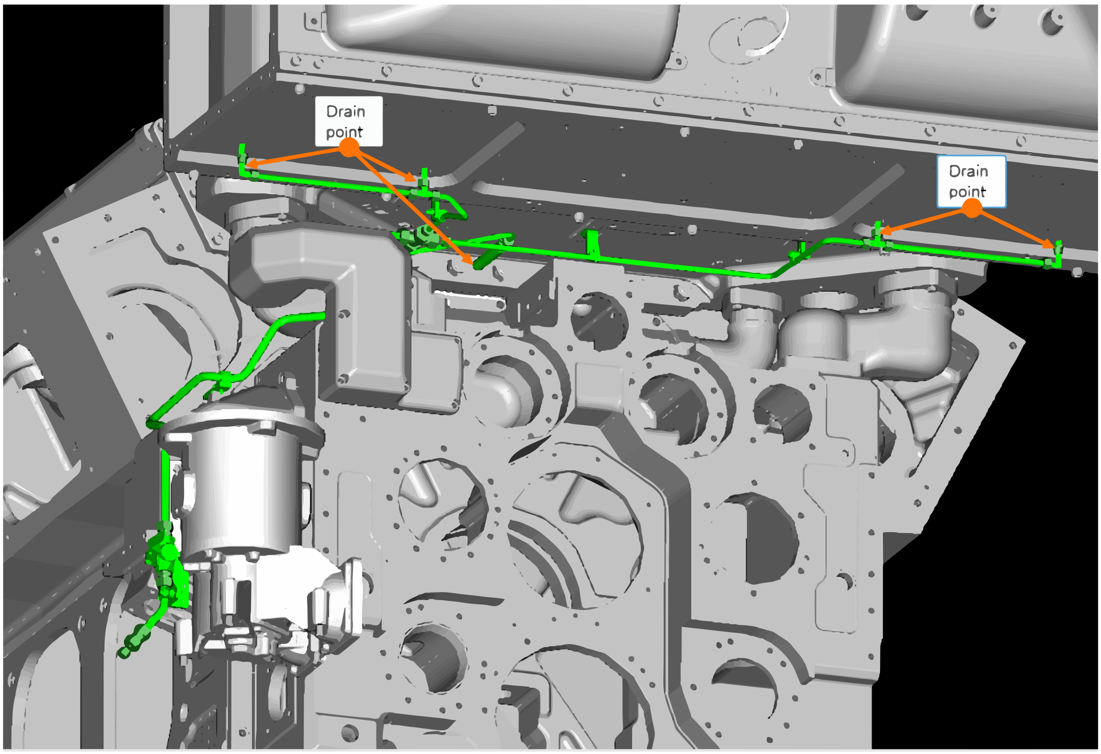

Fig 10-4 Drain Pipe of Charge Air Cooler (an example view from free end)

10.2.4 Combustion air system design in arctic conditions

At high engine loads, the cold air has a higher density and the compressor is working more efficiently thus increasing the flow of combustion air. The cylinder peak firing pressure increases and there is also a risk of compressor surging as the compressor is out of the specified operation area.

At low engine loads and during engine starting, the combustion air is still below zero degrees Celsius after the compressor and it cools down the engine. There is a risk of overcooling the engine as a result.

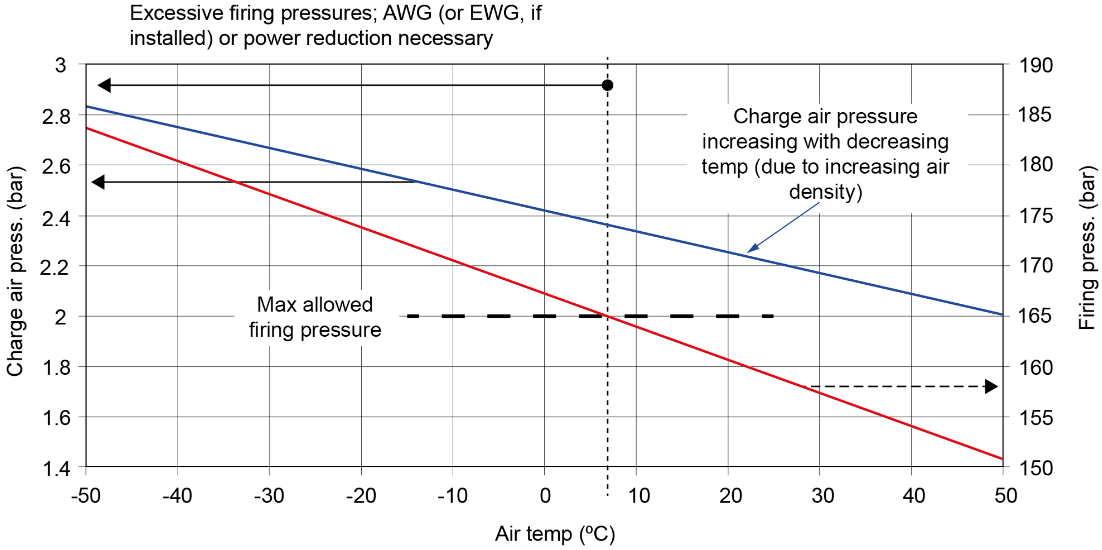

Fig 10-5 **Example of influence of suction air temp on charge air pressure & firing pressure at 100% load**

10.2.4.1 Ensuring correct compressor performance

The cylinder peak firing pressure can be limited by using waste gates on the engine. Exhaust gas waste gate (EWG) is used to reduce the turbocharger speed by bypassing the turbine stage and thus reducing the charge air pressure in the charge air receiver.

Similarly air waste gate (AWG) is used to reduce the charge air pressure by bleeding air from the charge air receiver. The air from the air waste gate is blown out either to outside of the vessel or into the engine room. In both cases installing a silencer after the air waste gate is recommended. If the air waste gate is located before the charge air cooler, the air must be blown outside of the vessel via a separate air duct as the air temperature right after the compressor can rise up to 200°C. An example scheme of air waste gate and exhaust gas waste gate arrangement is shown below.

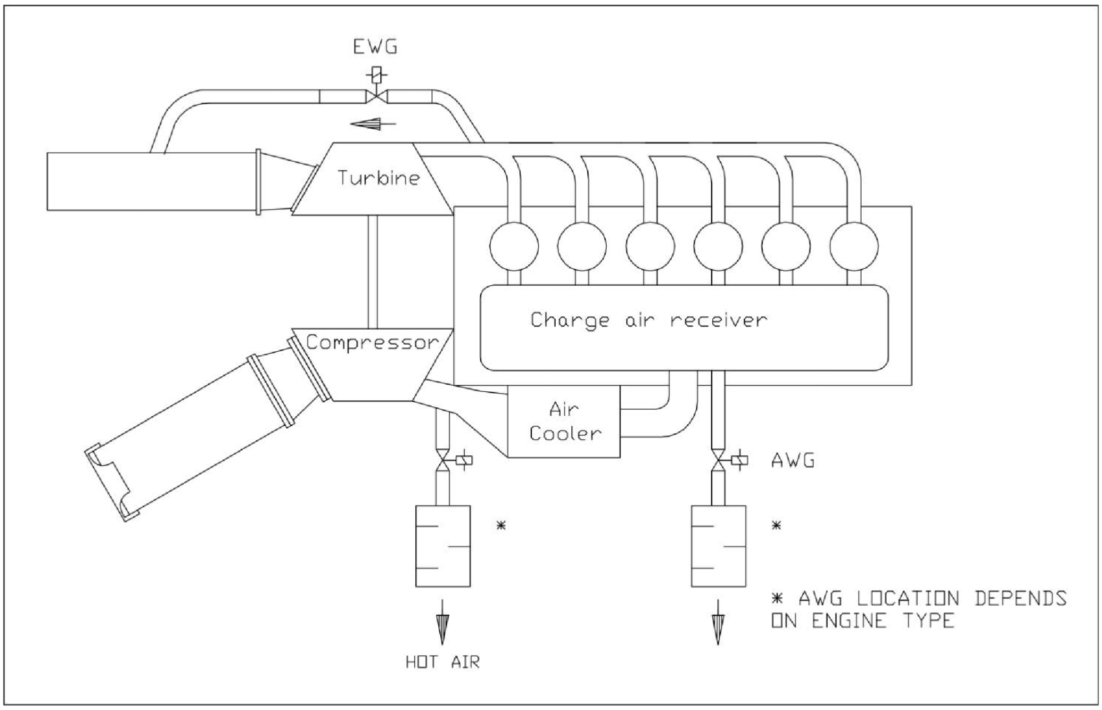

Fig 10-6 **Example scheme of air and exhaust waste gate arrangement**

In addition to limiting the cylinder peak firing pressure, the waste gates are also used to ensure correct compressor performance. In cold conditions, the compressor can run in an area of unstable delivery, which occurs at high pressure versus flow ratios. In such operation conditions a stall occurs at some locations in the compressor due to a high degree of flow separation. This compressor “surge” means a temporary interruption in the air flow and can be recognized as a sound bang.

To reliably operate in all conditions, the actual operating line of the compressor needs a sufficient margin to the “surge line”. The charge air pressure can be reduced with the waste gates and thus moving the compressor operating point away from the “surge line”.

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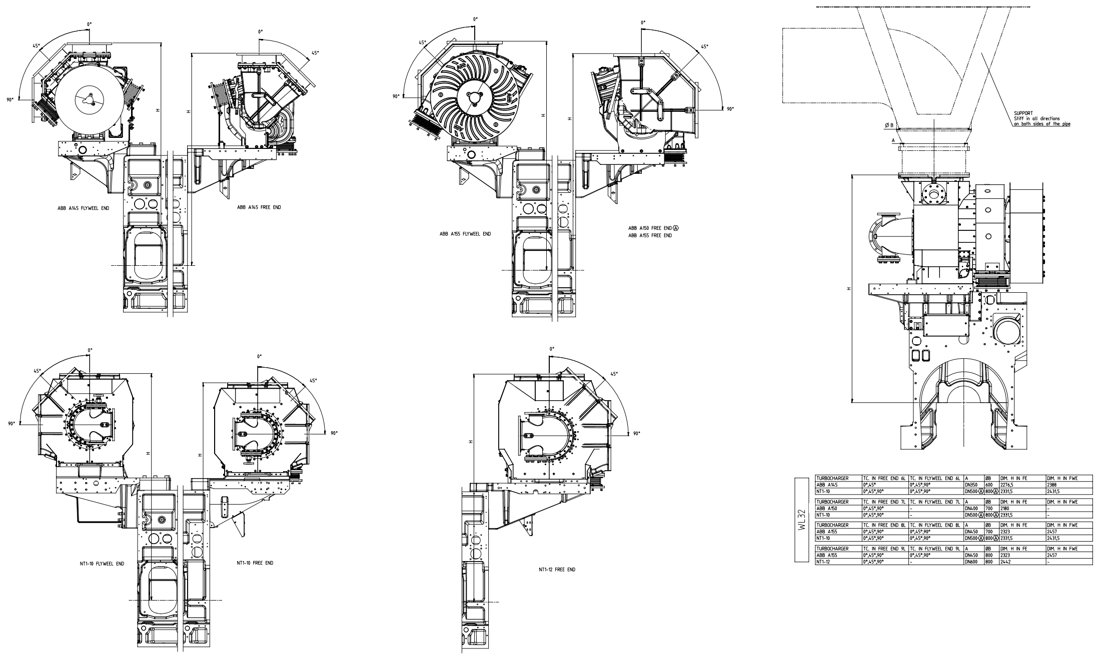
11. Exhaust Gas System

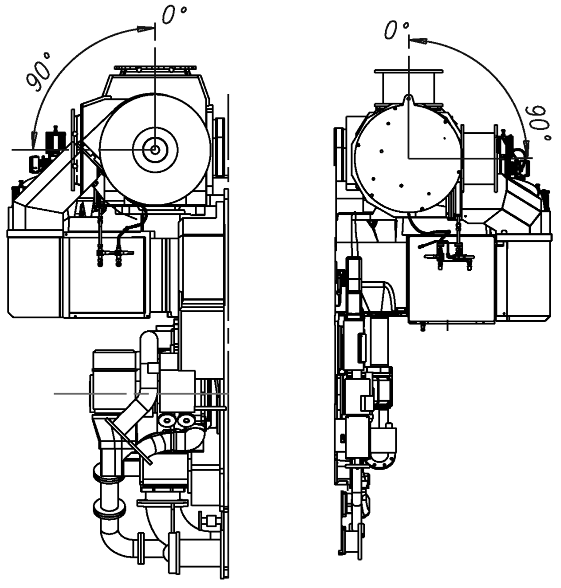
11.1 Exhaust gas outlet



TURBOCHARGER	TC. IN FREE END 6L	TC. IN FLYWEEL END 6L	A	ØB	DIM. H IN FE	DIM. H IN FWE
ABB A145	0°,45°	0°,45°,90°	DN350	600	2276,5	2388
NT1-10	0°,45°,90°	0°,45°,90°	DN500 (A)	800 (A)	2331,5	2431,5
TURBOCHARGER	TC. IN FREE END 7L	TC. IN FLYWEEL END 7L	A	ØB	DIM. H IN FE	DIM. H IN FWE
ABB A150	0°,45°,90°	-	DN400	700	2180	-
NT1-10	0°,45°,90°	-	DN500 (A)	800 (A)	2331,5	-
TURBOCHARGER	TC. IN FREE END 8L	TC. IN FLYWEEL END 8L	A	ØB	DIM. H IN FE	DIM. H IN FWE
ABB A155	0°,45°,90°	0°,45°,90°	DN450	700	2323	2457
NT1-10	0°,45°,90°	0°,45°,90°	DN500 (A)	800 (A)	2331,5	2431,5
TURBOCHARGER	TC. IN FREE END 9L	TC. IN FLYWEEL END 9L	A	ØB	DIM. H IN FE	DIM. H IN FWE
ABB A155	0°,45°,90°	0°,45°,90°	DN450	800	2323	2457
NT1-12	0°,45°,90°	-	DN600	800	2442	-

Fig 11-1 Exhaust pipe diameters and directions, Inline engines (DAAF434204A)

V-engine



TC at free end   TC at flywheel end

Engine	TC type	TC location	
		Free end	Driving end
W 12V32	NT-10	0°	0°
W 16V32	A155 NT1-10	0° 0°	- 0°

Fig 11-2 Exhaust pipe connections (DAAE059232C)

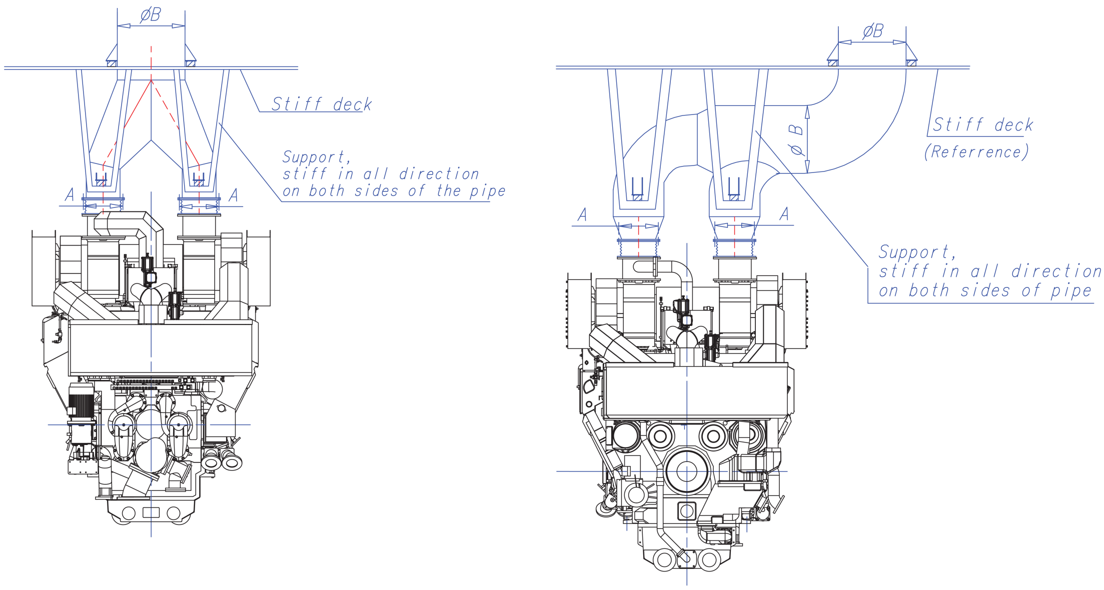


Fig 11-3 Exhaust pipe, diameters and support (DAAE057873F, DAAE057874F)

Engine	TC type	A [mm]	ØB [mm]
W 12V32	NT1-10	DN500	900

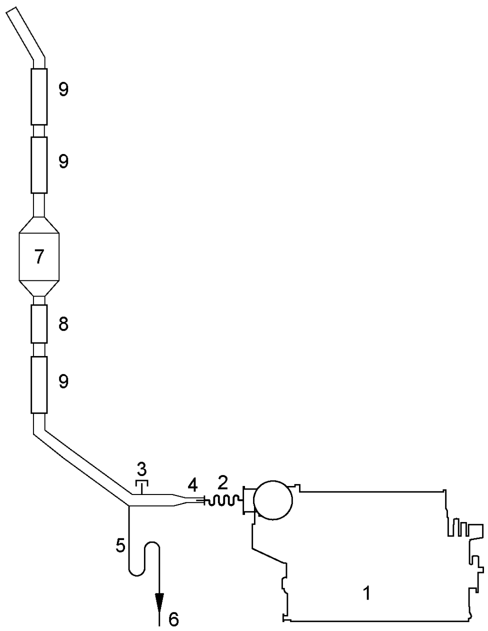
(continued)

Engine	TC type	A [mm]	ØB [mm]
W 16V32	A155	DN500	1000
	NT1-10	DN500	1000

11.2 External exhaust gas system

Each engine should have its own exhaust pipe into open air. Backpressure, thermal expansion and supporting are some of the decisive design factors.

Flexible bellows must be installed directly on the turbocharger outlet, to compensate for thermal expansion and prevent damages to the turbocharger due to vibrations.



1 Diesel engine
2 Exhaust gas bellows
3 Connection for measurement of back pressure
4 Transition piece
5 Drain with water trap, continuously open
6 Bilge
7 SCR
8 Urea injection unit (SCR)
9 CSS silencer element

Fig 11-4 External exhaust gas system

11.2.1 Piping

The piping should be as short and straight as possible. Pipe bends and expansions should be smooth to minimise the backpressure. The diameter of the exhaust pipe should be increased directly after the bellows on the turbocharger. Pipe bends should be made with the largest possible bending radius; the bending radius should not be smaller than 1.5 x D.

The recommended flow velocity in the pipe is maximum 35…40 m/s at full output. If there are many resistance factors in the piping, or the pipe is very long, then the flow velocity needs to be lower. The exhaust gas mass flow given in *Engine Online Configurator* available through Wärtsilä website can be translated to velocity using the formula:

$$v = \frac{4 \times m'}{1.3 \times \left(\frac{273}{273 + T}\right) \times \pi \times D^2}$$

where:

v = gas velocity [m/s]

m' = exhaust gas mass flow [kg/s]

T = exhaust gas temperature [°C]

D = exhaust gas pipe diameter [m]

The exhaust pipe must be insulated with insulation material approved for concerned operation conditions, minimum thickness 30 mm considering the shape of engine mounted insulation. Insulation has to be continuous and protected by a covering plate or similar to keep the insulation intact.

Closest to the turbocharger the insulation should consist of a hook on padding to facilitate maintenance. It is especially important to prevent the airstream to the turbocharger from detaching insulation, which will clog the filters.

After the insulation work has been finished, it has to be verified that it fulfils SOLAS-regulations. Surface temperatures must be below 220°C on whole engine operating range.

11.2.2 Supporting

It is very important that the exhaust pipe is properly fixed to a support that is rigid in all directions directly after the bellows on the turbocharger. There should be a fixing point on both sides of the pipe at the support. The bellows on the turbocharger may not be used to absorb thermal expansion from the exhaust pipe. The first fixing point must direct the thermal expansion away from the engine. The following support must prevent the pipe from pivoting around the first fixing point.

Absolutely rigid mounting between the pipe and the support is recommended at the first fixing point after the turbocharger. Resilient mounts can be accepted for resiliently mounted engines with “double” variant bellows (bellow capable of handling the additional movement), provided that the mounts are self-captive; maximum deflection at total failure being less than 2 mm radial and 4 mm axial with regards to the bellows. The natural frequencies of the mounting should be on a safe distance from the running speed, the firing frequency of the engine and the blade passing frequency of the propeller. The resilient mounts can be rubber mounts of conical type, or high damping stainless steel wire pads. Adequate thermal insulation must be provided to protect rubber mounts from high temperatures. When using resilient mounting, the alignment of the exhaust bellows must be checked on a regular basis and corrected when necessary.

After the first fixing point resilient mounts are recommended. The mounting supports should be positioned at stiffened locations within the ship’s structure, e.g. deck levels, frame webs or specially constructed supports.

The supporting must allow thermal expansion and ship’s structural deflections.

11.2.3 Back pressure

The maximum permissible exhaust gas back pressure is stated in *Engine Online Configurator* available through Wärtsilä website. The back pressure in the system must be calculated by the shipyard based on the actual piping design and the resistance of the components in the exhaust system. The exhaust gas mass flow and temperature given in *Engine Online Configurator* available through Wärtsilä website may be used for the calculation.

Each exhaust pipe should be provided with a connection for measurement of the back pressure. The back pressure must be measured by the shipyard during the sea trial.

11.2.4 Exhaust gas bellows (5H01, 5H03)

Bellows must be used in the exhaust gas piping where thermal expansion or ship's structural deflections have to be segregated. The flexible bellows mounted directly on the turbocharger outlet serves to minimise the external forces on the turbocharger and thus prevent excessive vibrations and possible damage. All exhaust gas bellows must be of an approved type.

11.2.5 SCR-unit (11N14)

The SCR-unit requires special arrangement on the engine in order to keep the exhaust gas temperature and backpressure into SCR-unit working range. The exhaust gas piping must be straight at least 3...5 meters in front of the SCR unit. If both an exhaust gas boiler and a SCR unit will be installed, then the exhaust gas boiler shall be installed after the SCR. Arrangements must be made to ensure that water cannot spill down into the SCR, when the exhaust boiler is cleaned with water.

More information about the SCR-unit can be found in the *Wärtsilä Environmental Product Guide.*

11.2.6 Exhaust gas boiler

If exhaust gas boilers are installed, each engine should have a separate exhaust gas boiler. Alternatively, a common boiler with separate gas sections for each engine is acceptable.

For dimensioning the boiler, the exhaust gas quantities and temperatures given in *Engine Online Configurator* available through Wärtsilä website.

11.2.7 Exhaust gas silencers

The exhaust gas silencing can be accomplished either by the patented Compact Silencer System (CSS) technology or by the conventional exhaust gas silencer.

11.2.7.1 Exhaust noise

The unattenuated exhaust noise is typically measured in the exhaust duct. The in-duct measurement is transformed into free field sound power through a number of correction factors.

The spectrum of the required attenuation in the exhaust system is achieved when the free field sound power (A) is transferred into sound pressure (B) at a certain point and compared with the allowable sound pressure level (C).

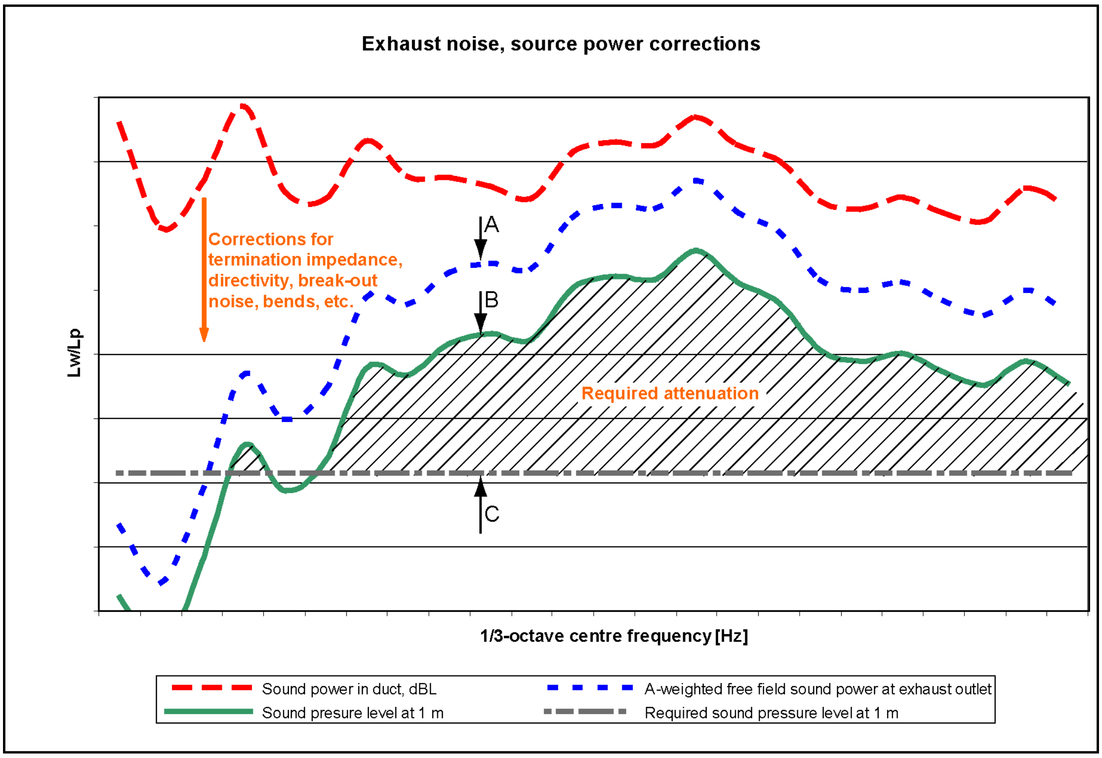


Fig 11-5 Exhaust noise, source power corrections

The conventional silencer is able to reduce the sound level in a certain area of the frequency spectrum. CSS is designed to cover the whole frequency spectrum.

11.2.7.2 Silencer system comparison

With a conventional silencer system, the design of the noise reduction system usually starts from the engine. With the CSS, the design is reversed, meaning that the noise level acceptability at a certain distance from the ship's exhaust gas pipe outlet, is used to dimension the noise reduction system.

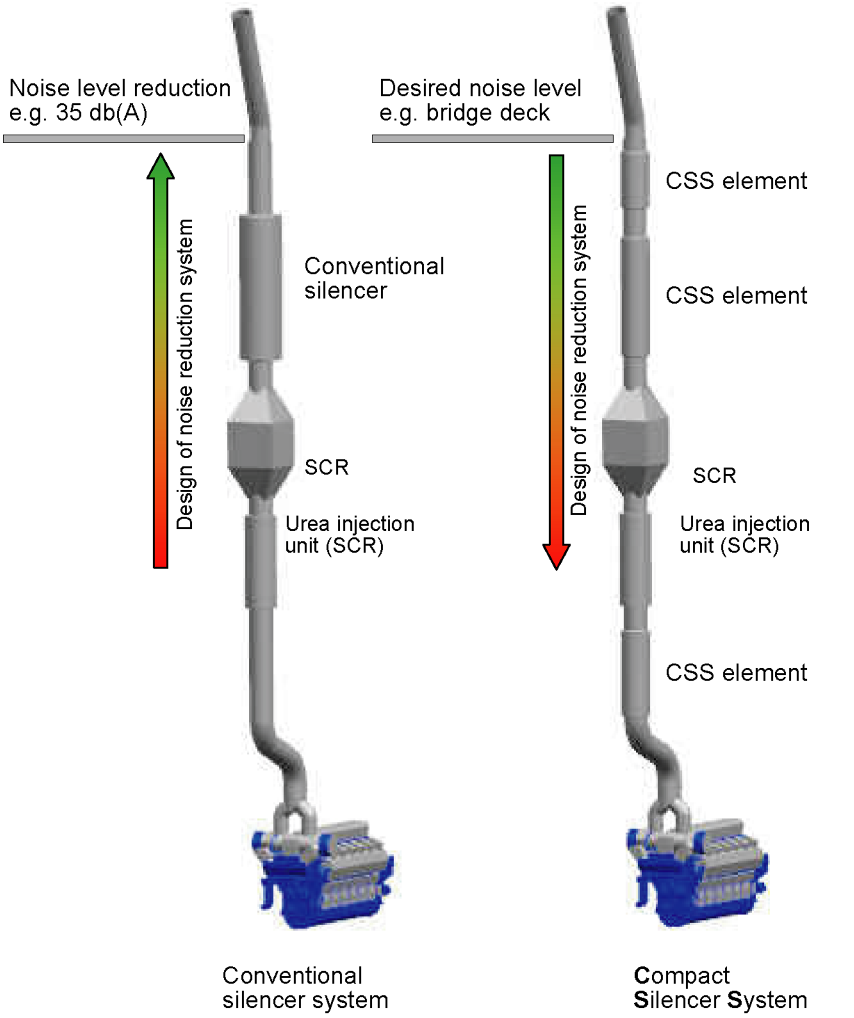


Fig 11-6 Silencer system comparison

11.2.7.3 Compact silencer system (5N02)

The CSS system is optimized for each installation as a complete exhaust gas system. The optimization is made according to the engine characteristics, to the sound level requirements and to other equipment installed in the exhaust gas system, like SCR, exhaust gas boiler or scrubbers.

The CSS system is built up of three different CSS elements; resistive, reactive and composite elements. The combination-, amount- and length of the elements are always installation specific. The diameter of the CSS element is 1.4 times the exhaust gas pipe diameter.

The noise attenuation is valid up to a exhaust gas flow velocity of max 40 m/s. The pressure drop of a CSS element is lower compared to a conventional exhaust gas silencer (5R02).

11.2.7.4 Conventional exhaust gas silencer (5R02)

Yard/designer should take into account that unfavourable layout of the exhaust system (length of straight parts in the exhaust system) might cause amplification of the exhaust noise between engine outlet and the silencer. Hence the attenuation of the silencer does not give any absolute guarantee for the noise level after the silencer.

When included in the scope of supply, the standard silencer is of the absorption type, equipped with a spark arrester. It is also provided with a soot collector and a condense drain, but it comes without mounting brackets and insulation. The silencer can be mounted either horizontally or vertically.

The noise attenuation of the standard silencer is either 25 or 35 dB(A). This attenuation is valid up to a flow velocity of max. 40 m/s.

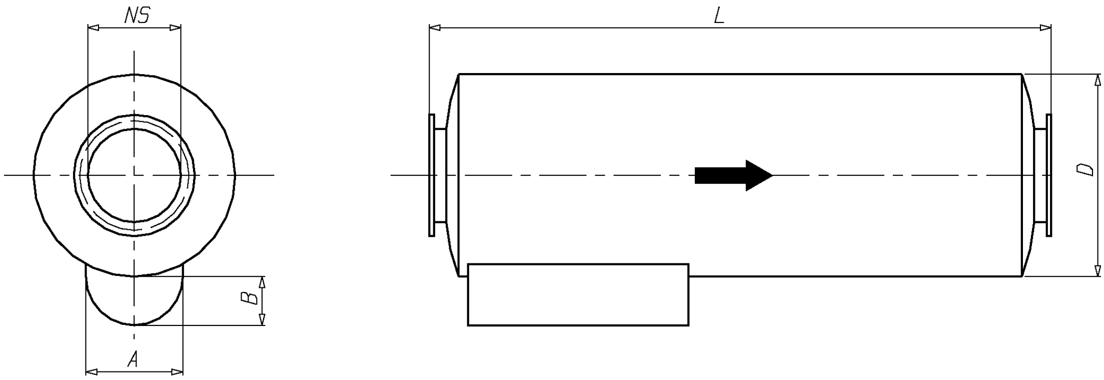


Fig 11-7 Exhaust gas silencer (V49E0142C)

Table 11-1 Typical dimensions of exhaust gas silencers

NS	D	A	B	Attenuation: 25 dB(A)		Attenuation: 35 dB(A)	
				L	Weight [kg]	L	Weight [kg]
600	1300	635	260	4010	980	5260	1310
700	1500	745	270	4550	1470	6050	1910
800	1700	840	280	4840	1930	6340	2490
900	1800	860	290	5360	2295	6870	2900
1000	1900	870	330	5880	2900	7620	3730
Flanges: DIN 2501							

12. Turbocharger Cleaning

Regular water cleaning of the turbine and the compressor reduces the formation of deposits and extends the time between overhauls. Fresh water is injected into the turbocharger during operation. Additives, solvents or salt water must not be used and the cleaning instructions, as outlined in the Engine Operation & Maintenance Manual, must be carefully followed.

12.1 Turbine cleaning system

A dosing unit consisting of a flow meter and an adjustable throttle valve is delivered for each installation. The dosing unit is installed in the engine room and connected to the engine with a detachable rubber hose. The rubber hose is connected with quick couplings and the length of the hose is normally 10 m. One dosing unit can be used for several engines.

Water supply:	
Fresh water	
Min. pressure	0.3 MPa (3 bar)
Max. pressure	2 MPa (20 bar)
Max. temperature	80 °C
Flow	15-30 l/min (depending on cylinder configuration)

The turbocharges are cleaned one at a time on V-engines.

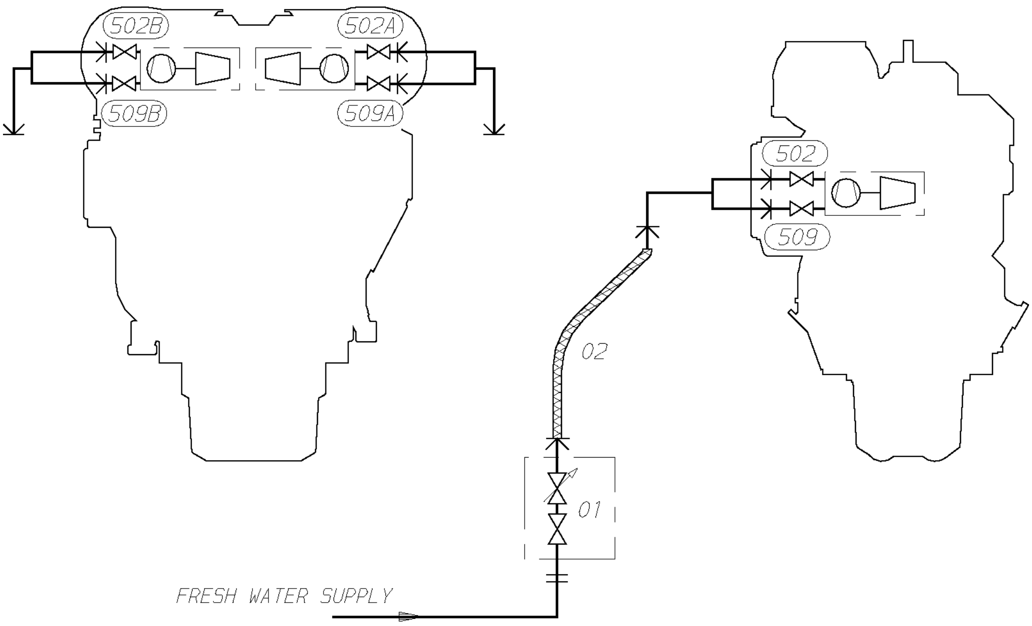


Fig 12-1 Turbocharger cleaning system (V76A2937A)

System components		Pipe connections		Size
01	Dosing unit with shut-off valve	502	Cleaning water to turbine	OD18
02	Rubber hose	509	Cleaning water to compressor	OD18

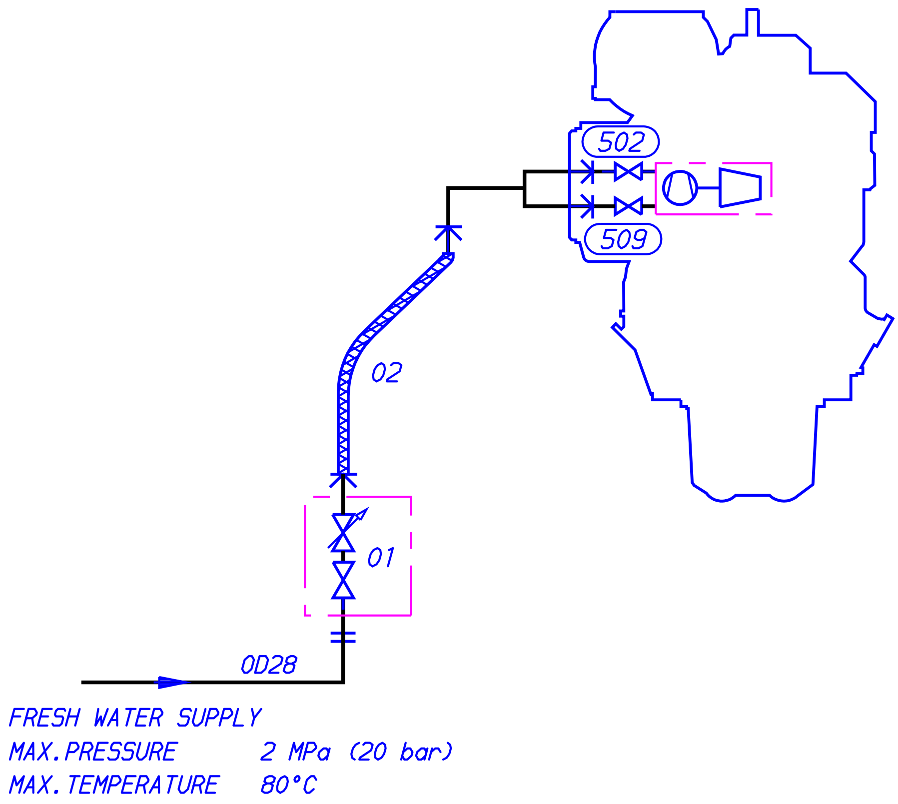


Fig 12-2 Turbocharger cleaning system (V76A2937A)

System components		Pipe connections		Size
01	Dosing unit with shut-off valve	502	Cleaning water to turbine	OD18
02	Rubber hose	509	Cleaning water to compressor	OD18

12.2 Compressor cleaning

The compressor side of the turbocharger is cleaned with the same equipment as the turbine.

12.2.1 Compressor cleaning

A dosing unit consisting of a flow meter and an adjustable throttle valve is delivered for each installation. The dosing unit is installed in the engine room and connected to the engine with a detachable rubber hose. The rubber hose is connected with quick couplings and the length of the hose is normally 10 m. One dosing unit can be used for several engines.

Water supply:	
Fresh water	
Min. pressure	0.3 MPa (3 bar)
Max. pressure	2 MPa (20 bar)
Max. temperature	80 °C
Flow	15-30 l/min (depending on cylinder configuration)

The turbocharges are cleaned one at a time on V-engines.

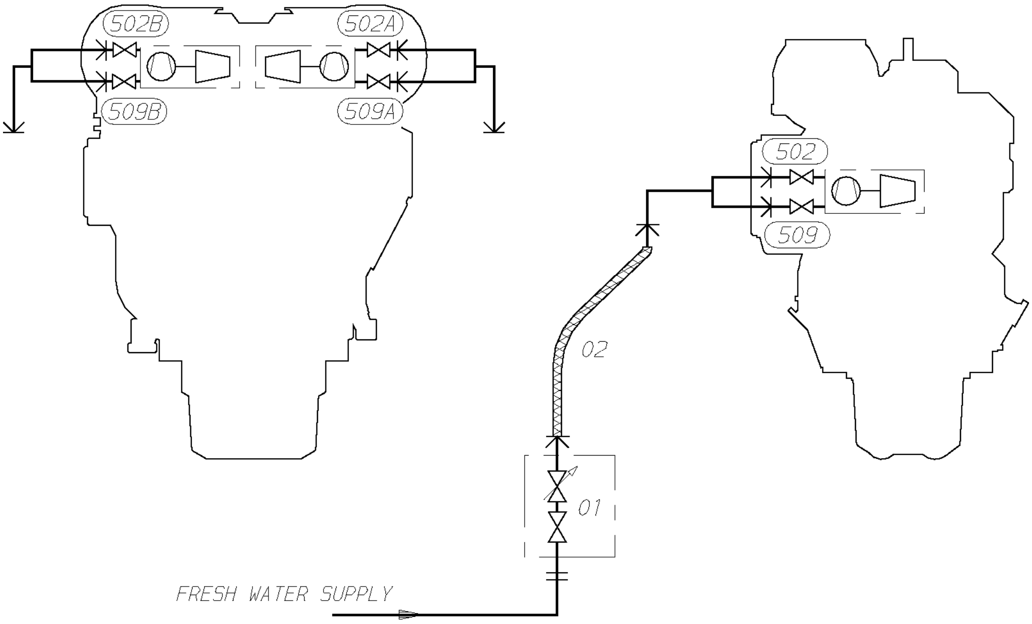


Fig 12-3 Turbocharger cleaning system (V76A2937A)

System components		Pipe connections		Size
01	Dosing unit with shut-off valve	502	Cleaning water to turbine	OD18
02	Rubber hose	509	Cleaning water to compressor	OD18

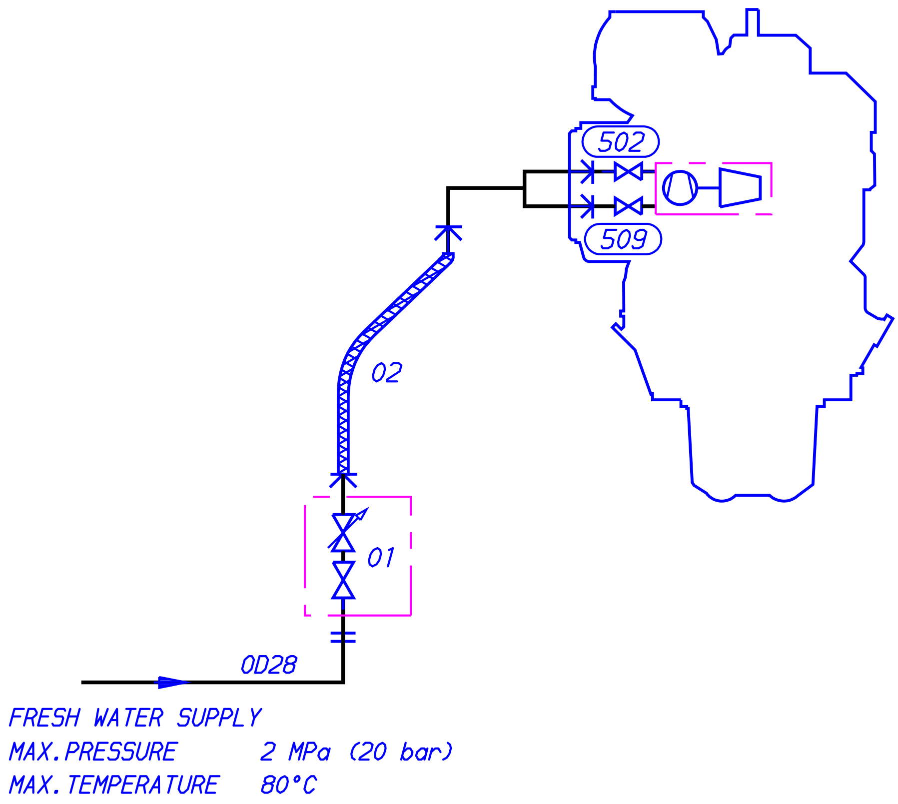


Fig 12-4 Turbocharger cleaning system (V76A2937A)

System components		Pipe connections		Size
01	Dosing unit with shut-off valve	502	Cleaning water to turbine	OD18
02	Rubber hose	509	Cleaning water to compressor	OD18

13. Exhaust Emissions

Exhaust emissions from the diesel engine mainly consist of nitrogen, oxygen and combustion products like carbon dioxide (CO_2), water vapour and minor quantities of carbon monoxide (CO), sulphur oxides (SO_x), nitrogen oxides (NO_x), partially reacted and non-combusted hydrocarbons (HC) and particulate matter (PM).

There are different emission control methods depending on the aimed pollutant. These are mainly divided in two categories; primary methods that are applied on the engine itself and secondary methods that are applied on the exhaust gas stream.

13.1 Diesel engine exhaust components

The nitrogen and oxygen in the exhaust gas are the main components of the intake air which don't take part in the combustion process.

CO_2 and water are the main combustion products. Secondary combustion products are carbon monoxide, hydrocarbons, nitrogen oxides, sulphur oxides, soot and particulate matters.

In a diesel engine the emission of carbon monoxide and hydrocarbons are low compared to other internal combustion engines, thanks to the high air/fuel ratio in the combustion process. The air excess allows an almost complete combustion of the HC and oxidation of the CO to CO_2, hence their quantity in the exhaust gas stream are very low.

13.1.1 Nitrogen oxides (NO_x)

The combustion process gives secondary products as Nitrogen oxides. At high temperature the nitrogen, usually inert, react with oxygen to form Nitric oxide (NO) and Nitrogen dioxide (NO_2), which are usually grouped together as NO_x emissions. Their amount is strictly related to the combustion temperature.

NO can also be formed through oxidation of the nitrogen in fuel and through chemical reactions with fuel radicals. NO in the exhaust gas flow is in a high temperature and high oxygen concentration environment, hence oxidizes rapidly to NO_2. The amount of NO_2 emissions is approximately 5 % of total NOx emissions.

13.1.2 Sulphur Oxides (SO_x)

Sulphur oxides (SO_x) are direct result of the sulphur content of the fuel oil. During the combustion process the fuel bound sulphur is rapidly oxidized to sulphur dioxide (SO_2). A small fraction of SO_2 may be further oxidized to sulphur trioxide (SO_3).

13.1.3 Particulate Matter (PM)

The particulate fraction of the exhaust emissions represents a complex mixture of inorganic and organic substances mainly comprising soot (elemental carbon), fuel oil ash (together with sulphates and associated water), nitrates, carbonates and a variety of non or partially combusted hydrocarbon components of the fuel and lubricating oil.

13.1.4 Smoke

Although smoke is usually the visible indication of particulates in the exhaust, the correlations between particulate emissions and smoke is not fixed. The lighter and more volatile hydrocarbons will not be visible nor will the particulates emitted from a well maintained and operated diesel engine.

Smoke can be black, blue, white, yellow or brown in appearance. Black smoke is mainly comprised of carbon particulates (soot). Blue smoke indicates the presence of the products of the incomplete combustion of the fuel or lubricating oil. White smoke is usually condensed water vapour. Yellow smoke is caused by NO_x emissions. When the exhaust gas is cooled significantly prior to discharge to the atmosphere, the condensed NO_2 component can have a brown appearance.

13.2 Marine exhaust emissions legislation

13.2.1 International Maritime Organization (IMO)

The increasing concern over the air pollution has resulted in the introduction of exhaust emission controls to the marine industry. To avoid the growth of uncoordinated regulations, the IMO (International Maritime Organization) has developed the Annex VI of MARPOL 73/78, which represents the first set of regulations on the marine exhaust emissions.

The IMO Tier 3 NOx emission standard has entered into force from year 2016. It applies for new marine diesel engines that:

- Are > 130 kW
- Installed in ships which keel laying date is 1.1.2016 or later
- Operating inside the North American ECA and the US Caribbean Sea ECA

From 1.1.2021 onwards Baltic sea and North sea will be included in to IMO Tier 3 NOx requirements.

13.2.2 Other Legislations

There are also other local legislations in force in particular regions.

13.3 Methods to reduce exhaust emissions

All standard Wärtsilä engines meet the NOx emission level set by the IMO (International Maritime Organisation) and most of the local emission levels without any modifications. Wärtsilä has also developed solutions to significantly reduce NOx emissions when this is required.

Diesel engine exhaust emissions can be reduced either with primary or secondary methods. The primary methods limit the formation of specific emissions during the combustion process. The secondary methods reduce emission components after formation as they pass through the exhaust gas system.

14. Automation System

Wärtsilä Unified Controls - UNIC is a fully embedded and distributed engine management system, which handles all control functions on the engine.

The distributed modules communicate over an internal communication bus.

The power supply to each module is physically doubled on the engine for full redundancy.

Control signals to/from external systems are hardwired to the terminals in the main cabinet on the engine. Process data for alarm and monitoring are communicated over a Modbus TCP connection to external systems.

14.1 Technical data and system overview

14.1.1 Ingress protection

The ingress protection class of the system is IP54.

14.1.2 Ambient temp for automation system

The automation system on the engine allows for an ambient engine room temperature up to 55°C.

Single components such as electronic modules have a temperature rating not less than 70°C.

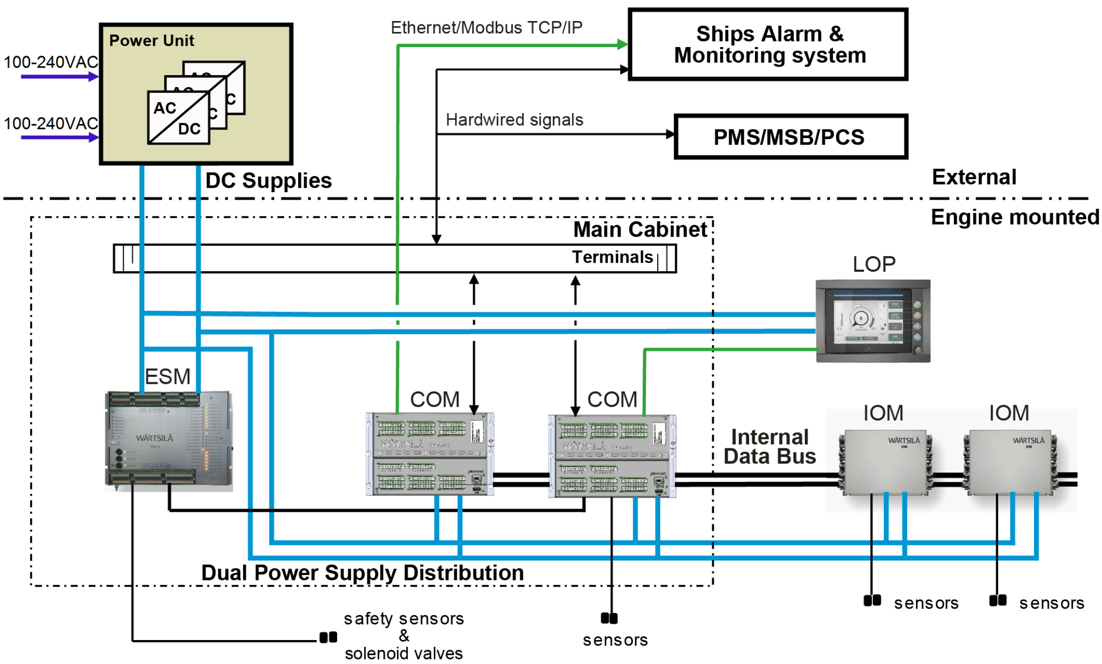


Fig 14-1 Architecture of UNIC

Short explanation of the modules used in the system:

COM Communication Module. Handles strategic control functions (such as start/stop sequencing and speed/load control, i.e. "speed governing") of the engine.
The communication modules handle engine internal and external communication, as well as hardwired external interfaces.

(continued)

LOP	The LOP (local operator panel) shows all engine measurements (e.g. temperatures and pressures) and provides various engine status indications as well as an event history.
IOM	Input/Output Module handles measurements and limited control functions in a specific area on the engine.
ESM	Engine Safety Module handles fundamental engine safety, for example shutdown due to overspeed or low lubricating oil pressure.

The above equipment and instrumentation are prewired on the engine.

14.1.3 Local operator panel

The Local operator panel (LOP) consist of a display unit (LDU) with touch screen as well as an emergency stop button built on the engine.

The local operator panel shows all engine measurements (e.g. temperatures and pressures) and provides various engine status indications as well as an event history

The following control functions are available:

- Local/remote control selection
- Local start & stop
- Shutdown reset
- Local emergency speed setting (mechanical propulsion)
- Local emergency stop

Fig 14-2 Local operator panel

14.1.4 Engine safety system

The engine safety module handles fundamental safety functions, for example overspeed protection.

Main features:

- Redundant design for power supply, speed inputs and stop solenoid control
- Fault detection on sensors, solenoids and wires
- Led indication of status and detected faults
- Digital status outputs
- Shutdown latching and reset
- Shutdown pre-warning
- Shutdown override (configuration depending on application)

14.1.5 Power unit

A power unit is delivered with each engine. The power unit supplies DC power to the automation system on the engine and provides isolation from other DC systems onboard. A firewall/ router for communication between engine and ship automation system is integrated in the power unit. The cabinet is designed for bulkhead mounting, protection degree IP44, max. ambient temperature 50°C.

The power unit contains redundant power converters, each converter dimensioned for 100% load. At least one of the two incoming supplies must be connected to a UPS. The power unit supplies the automation system on the engine with necessary DC voltages.

Power supply from ship's system:

- Supply 1: 230 VAC / abt. 250 W
- Supply 2: 230 VAC, alternatively 24 VDC / abt. 250 W

14.1.6 Cabling and system overview

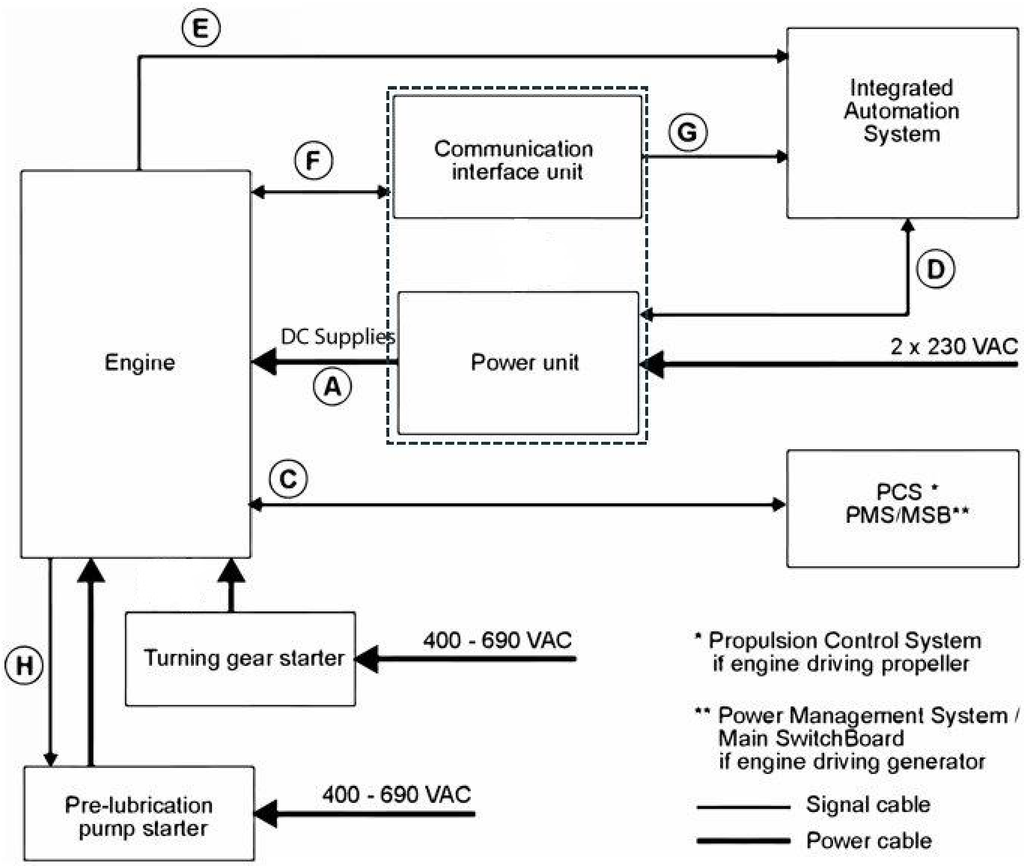


Fig 14-3 UNIC overview

Table 14-1 Typical amount of cables

Cable	From <=> To	Cable types (typical)
A	Engine <=> Power Unit	2 x 4 mm^2 (power supply) * 2 x 4 mm^2 (power supply) * 2 x 4 mm^2 (power supply) * 2 x 4 mm^2 (power supply) * 2 x 4 mm^2 (power supply) * 2 x 4 mm^2 (power supply) * 2 x 4 mm^2 (power supply) * 2 x 4 mm^2 (power supply) *
C	Engine <=> Propulsion Control System Engine <=> Power Management System / Main Switch-board	1 x 2 x 0.75 mm^2 1 x 2 x 0.75 mm^2 1 x 2 x 0.75 mm^2 24 x 0.75 mm^2 24 x 0.75 mm^2
D	Power unit <=> Integrated Automation System	2 x 0.75 mm^2
E	Engine <=> Integrated Automation System	3 x 2 x 0.75 mm^2
F	Engine => Power Unit	1 x Ethernet CAT 5
G	Power Unit => Integrated automation system	1 x Ethernet CAT 5

Table 14-1 Typical amount of cables (continued)

Cable	From <=> To	Cable types (typical)
H	Engine => Pre-lubrication pump starter	2 x 0.75 mm^2

NOTICE
Cable types and grouping of signals in different cables will differ depending on installation. * Dimension of the power supply cables depends on the cable length.

Power supply requirements are specified in section *Power unit*.

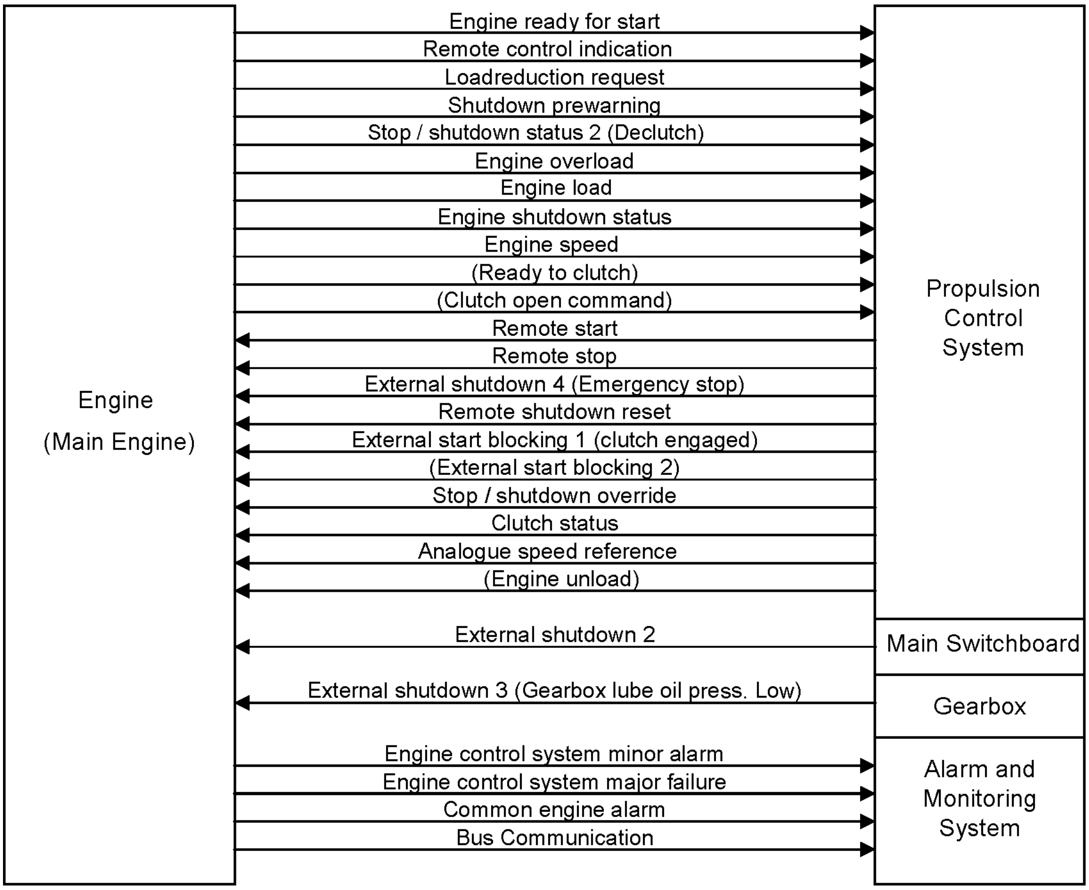


Fig 14-4 Typical signal overview (Main engine)

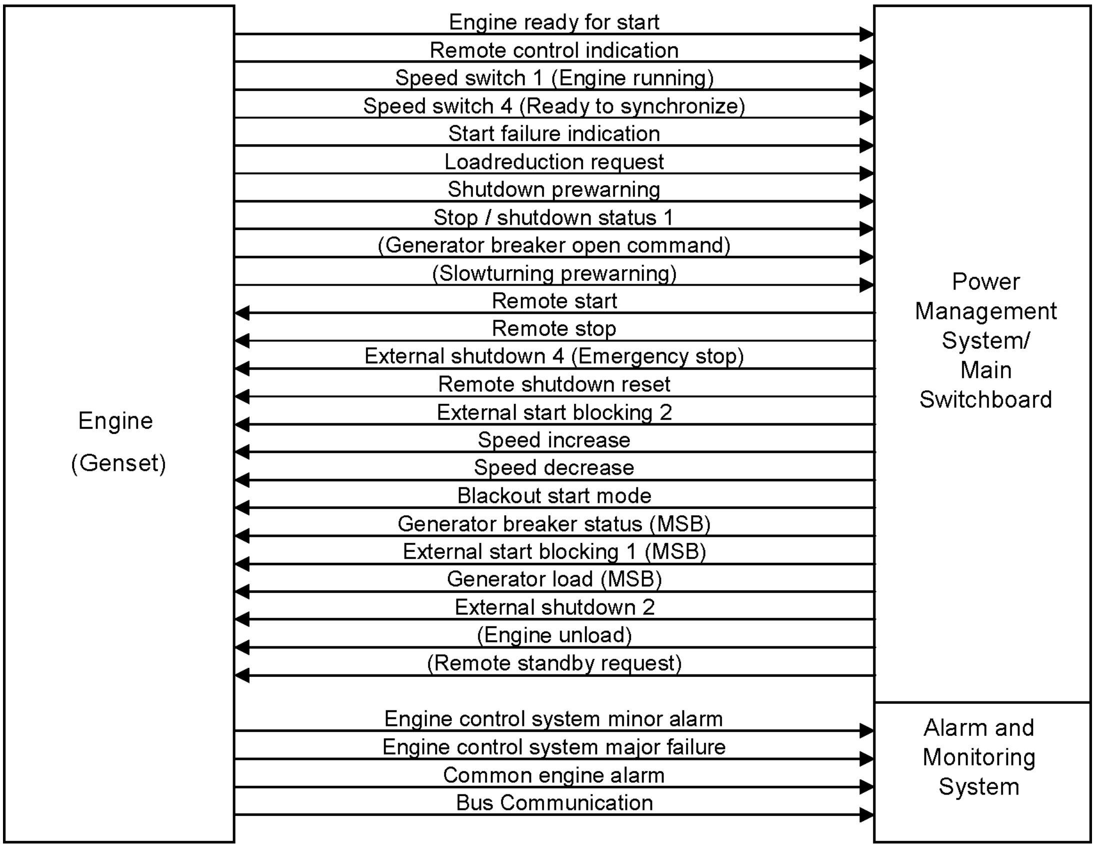


Fig 14-5 Typical signal overview (Generating set)

14.2 Functions

14.2.1 Start

The engine is started by injecting compressed air directly into the cylinders.

The engine can be started locally, or remotely if applicable for the installation e.g. from the power management system or control room. In an emergency situation it is also possible to operate the starting air valve manually.

Starting is blocked both pneumatically and electrically when the turning gear is engaged.

The engine is equipped with a slow turning system, which rotates the engine without fuel injection for a few turns before start. Slow turning is performed automatically at predefined intervals, if the engine has been selected as stand-by.

For generating sets, possible need for hydrostatic lifting device (jack-up pump) should be checked with generator maker.

14.2.1.1 Start blocking

Starting is inhibited by the following functions:

- Turning device engaged
- Pre-lubricating pressure low (override if black-out input is high and within last 30 minutes after the pressure has dropped below the set point)
- Stop signal to engine active (safety shut-down, emergency stop, normal stop)
- External start blocking active
-

14.2.2 Stop, shutdown and emergency stop

14.2.2.1 Stop mode

Before stopping the engine, the control system shall first unload the engine slowly (if the engine is loaded), and after that open the generator breaker and send a stop signal to the engine.

Immediately after the engine stop signal is activated in gas operating mode, the GVU performs gas shut-off and ventilation. The pilot injection is active during the first part of the deceleration in order to ensure that all gas remaining in engine is burned.

In case the engine has been running on gas within two minutes prior to the stop the exhaust gas system is ventilated to discharge any unburned gas.

14.2.2.2 Shutdown mode

Shutdown mode is initiated automatically as a response to abnormal measurement signals.

In shutdown mode the clutch/generator breaker is opened immediately without unloading. The actions following a shutdown are similar to normal engine stop.

Shutdown mode must be reset by the operator and the reason for shutdown must be investigated and corrected before re-start.

14.2.2.3 Emergency stop mode

The sequence of engine stopping in emergency stop mode is similar to shutdown mode, except that also the pilot fuel injection is de-activated immediately upon stop signal.

Emergency stop is the fastest way of manually shutting down the engine. In case the emergency stop push-button is pressed, the button is automatically locked in pressed position.

To return to normal operation the push button must be pulled out and alarms acknowledged by pushing reset either locally or remotely.

14.2.3 Speed control

14.2.3.1 Main engines (mechanical propulsion)

The electronic speed control is integrated in the engine automation system.

The remote speed setting from the propulsion control is an analogue 4-20 mA signal. It is also possible to select an operating mode in which the speed reference can be adjusted with increase/decrease signals.

The electronic speed control handles load sharing between parallel engines, fuel limiters, and various other control functions (e.g. ready to open/close clutch, speed filtering). Overload protection and control of the load increase rate must however be included in the propulsion control as described in the chapter *Operating Ranges*.

14.2.3.2 Generating sets

The electronic speed control is integrated in the engine automation system.

The load sharing can be based on traditional speed droop, or handled independently by the speed control units without speed droop. The later load sharing principle is commonly referred to as isochronous load sharing. With isochronous load sharing there is no need for load balancing, frequency adjustment, or generator loading/unloading control in the external control system.

In a speed droop system each individual speed control unit decreases its internal speed reference when it senses increased load on the generator. Decreased network frequency with higher system load causes all generators to take on a proportional share of the increased total load. Engines with the same speed droop and speed reference will share load equally. Loading and unloading of a generator is accomplished by adjusting the speed reference of the individual speed control unit. The speed droop is typically 4%, which means that the difference in frequency between zero load and maximum load is 4%.

In isochronous mode the speed reference remains constant regardless of load level. Both isochronous load sharing and traditional speed droop are standard features in the speed control and either mode can be easily selected. If the ship has several switchboard sections with tie breakers between the different sections, then the status of each tie breaker is required for control of the load sharing in isochronous mode.

14.3 Alarm and monitoring signals

Regarding sensors on the engine, the actual configuration of signals and the alarm levels are found in the project specific documentation supplied for all contracted projects.

14.4 Electrical consumers

14.4.1 Motor starters and operation of electrically driven pumps

Motor starters are not part of the control system supplied with the engine, but available as loose supplied items.

14.4.1.1 Engine turning device (9N15)

The crankshaft can be slowly rotated with the turning device for maintenance purposes. The motor starter must be designed for reversible control of the motor. The electric motor ratings are listed in the table below.

Table 14-2 Electric motor ratings for engine turning device

Engine type	Voltage [V]	Frequency [Hz]	Power [kW]	Current [A]
Wärtsilä 32	3 x 208 - 690	50/ 60	2.2 - 3.5	2.5 - 9.2

14.4.1.2 Pre-lubricating oil pump

The pre-lubricating oil pump must always be running when the engine is stopped. The engine control system handles start/stop of the pump automatically via a motor starter.

It is recommended to arrange a back-up power supply from an emergency power source. Diesel generators serving as the main source of electrical power must be able to resume their operation in a black out situation by means of stored energy. Depending on system design and classification regulations, it may be permissible to use the emergency generator.

Electric motor ratings are listed in the table below.

Table 14-3 Electric motor ratings for pre-lubricating pump

Engine type	Voltage [V]	Frequency [Hz]	Power [kW]	Current [A]
Wärtsilä 32	3 x 380 - 690	50 / 60	7.5 - 15	7.5 - 42.9

14.4.1.3 Stand-by pump, lubricating oil (if applicable) (2P04)

The engine control system starts the pump automatically via a motor starter, if the lubricating oil pressure drops below a preset level when the engine is running.

The pump must not be running when the engine is stopped, nor may it be used for pre-lubricating purposes. Neither should it be operated in parallel with the main pump, when the main pump is in order.

14.4.1.4 Stand-by pump, HT cooling water (if applicable) (4P03)

The engine control system starts the pump automatically via a motor starter, if the cooling water pressure drops below a preset level when the engine is running.

14.4.1.5 Stand-by pump, LT cooling water (if applicable) (4P05)

The engine control system starts the pump automatically via a motor starter, if the cooling water pressure drops below a preset level when the engine is running.

14.4.1.6 Circulating pump for preheater (4P04)

The preheater pump shall start when the engine stops (to ensure water circulation through the hot engine) and stop when the engine starts. The engine control system handles start/stop of the pump automatically.

14.5 System requirements and guidelines for diesel-electric propulsion

Typical features to be incorporated in the propulsion control and power management systems in a diesel-electric ship:

1. The load increase program must limit the load increase rate during ship acceleration and load transfer between gensets according to the curves in chapter *Loading Capacity*.

If the control system has only one load increase ramp, then the ramp for a preheated engine is to be used.

The load increase rate of a recently connected generator is the sum of the load transfer performed by the power management system and the load increase performed by the propulsion control.

2. Rapid loading according to the “emergency" curve in chapter *Loading Capacity* may only be possible by activating an emergency function, which generates visual and audible alarms in the control room and on the bridge.

3. The propulsion control should be able to control the propulsion power according to the load increase rate at the gensets. Controlled load increase with different number of generators connected and in different operating conditions is difficult to achieve with only time ramps for the propeller speed.

4. The load reduction rate should also be limited in normal operation. Crash stop can be recognised by for example a large lever movement from ahead to astern.

5. Some propulsion systems can generate power back into the network. The gensets can absorb max. 5% reverse power.

6. The power management system performs loading and unloading of generators in a speed droop system, and it usually also corrects the system frequency to compensate for the droop offset, by adjusting the speed setting of the individual speed control units. The speed reference is adjusted by sending an increase/decrease pulse of a certain length to the speed control unit. The power management should determine the length of the increase/decrease pulse based on the size of the desired correction and then wait for 30 seconds or more before performing a new correction, in particular when performing small corrections.

The relation between duration of increase/decrease signal and change in speed reference is usually 0.1 Hz per second. The actual speed and/or load will change at a slower rate.

7. In speed droop mode all generators take an equal share of increased system load, regardless of any difference in initial load. The control system (Power Management System) should monitor the generator load and reduce the system load, if the generator load exceeds 100%.

8. The system should monitor the network frequency and reduce the load, if the network frequency tends to drop excessively.

15. Foundation

Engines can be either rigidly mounted on chocks, or resiliently mounted on rubber elements. If resilient mounting is considered, Wärtsilä must be informed about existing excitations such as propeller blade passing frequency. Dynamic forces caused by the engine are listed in the chapter *Vibration and noise*.

15.1 Steel structure design

The system oil tank may not extend under the reduction gear, if the engine is of dry sump type and the oil tank is located beneath the engine foundation. Neither should the tank extend under the support bearing, in case there is a PTO arrangement in the free end. The oil tank must also be symmetrically located in transverse direction under the engine.

The foundation and the double bottom should be as stiff as possible in all directions to absorb the dynamic forces caused by the engine, reduction gear and thrust bearing. The foundation should be dimensioned and designed so that harmful deformations are avoided.

The foundation of the driven equipment must be integrated with the engine foundation.

15.2 Mounting of main engines

15.2.1 Rigid mounting

Main engines can be rigidly mounted to the foundation either on steel chocks or resin chocks.

The holding down bolts are through-bolts with a lock nut at the lower end and a hydraulically tightened nut at the upper end. The tool included in the standard set of engine tools is used for hydraulic tightening of the holding down bolts. Two of the holding down bolts are fitted bolts and the rest are clearance bolts. The two Ø43H7/n6 fitted bolts are located closest to the flywheel, one on each side of the engine.

A distance sleeve should be used together with the fitted bolts. The distance sleeve must be mounted between the seating top plate and the lower nut in order to provide a sufficient guiding length for the fitted bolt in the seating top plate. The guiding length in the seating top plate should be at least equal to the bolt diameter.

The design of the holding down bolts is shown in the foundation drawings. It is recommended that the bolts are made from a high-strength steel, e.g. 42CrMo4 or similar. A high strength material makes it possible to use a higher bolt tension, which results in a larger bolt elongation (strain). A large bolt elongation improves the safety against loosening of the nuts.

To avoid sticking during installation and gradual reduction of tightening tension due to unevenness in threads, the threads should be machined to a finer tolerance than normal threads. The bolt thread must fulfil tolerance 6g and the nut thread must fulfil tolerance 6H. In order to avoid bending stress in the bolts and to ensure proper fastening, the contact face of the nut underneath the seating top plate should be counterbored.

Lateral supports must be installed for all engines. One pair of supports should be located at flywheel end and one pair (at least) near the middle of the engine. The lateral supports are to be welded to the seating top plate before fitting the chocks. The wedges in the supports are to be installed without clearance, when the engine has reached normal operating temperature. The wedges are then to be secured in position with welds. An acceptable contact surface must be obtained on the wedges of the supports.

15.2.1.1 Resin chocks

The recommended dimensions of resin chocks are 150 x 400 mm. The total surface pressure on the resin must not exceed the maximum permissible value, which is determined by the type of resin and the requirements of the classification society. It is recommended to select a resin type that is approved by the relevant classification society for a total surface pressure of 5 N/mm^2. (A typical conservative value is Ptot 3.5 N/mm^2).

During normal conditions, the support face of the engine feet has a maximum temperature of about 75°C, which should be considered when selecting the type of resin.

The bolts must be made as tensile bolts with a reduced shank diameter to ensure a sufficient elongation since the bolt force is limited by the permissible surface pressure on the resin. For a given bolt diameter the permissible bolt tension is limited either by the strength of the bolt material (max. stress 80% of the yield strength), or by the maximum permissible surface pressure on the resin.

15.2.1.2 Steel chocks

The top plates of the foundation girders are to be inclined outwards with regard to the centre line of the engine. The inclination of the supporting surface should be 1/100 and it should be machined so that a contact surface of at least 75% is obtained against the chocks.

Recommended chock dimensions are 250 x 200 mm and the chocks must have an inclination of 1:100, inwards with regard to the engine centre line. The cut-out in the chocks for the clearance bolts shall be 44 mm (M42 bolts), while the hole in the chocks for the fitted bolts shall be drilled and reamed to the correct size (Ø43H7) when the engine is finally aligned to the reduction gear.

The design of the holding down bolts is shown the foundation drawings. The bolts are designed as tensile bolts with a reduced shank diameter to achieve a large elongation, which improves the safety against loosening of the nuts.

15.2.1.3 Steel chocks with adjustable height

As an alternative to resin chocks or conventional steel chocks it is also permitted to install the engine on adjustable steel chocks. The chock height is adjustable between 45 mm and 65 mm for the approved type of chock. There must be a chock of adequate size at the position of each holding down bolt.

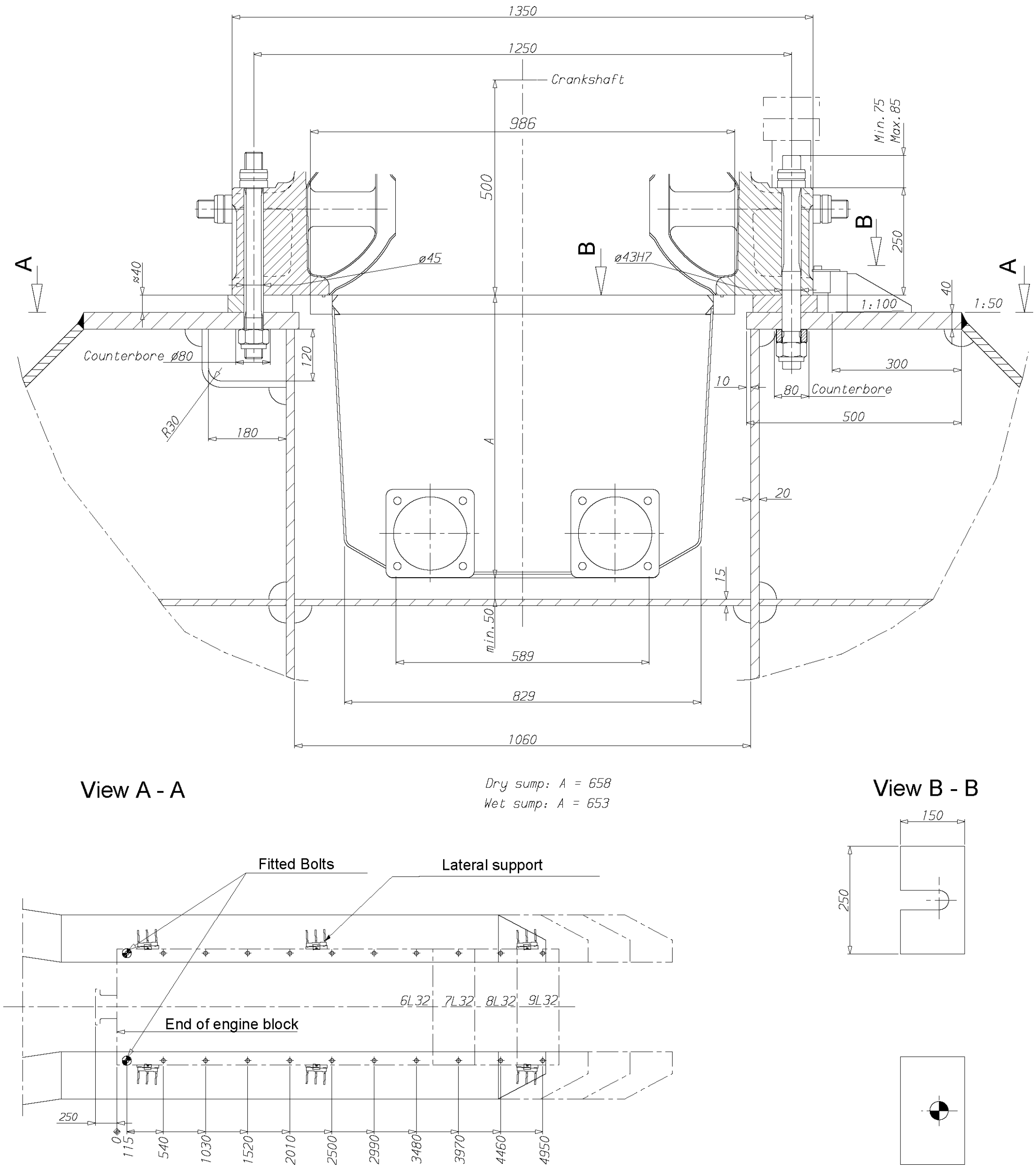
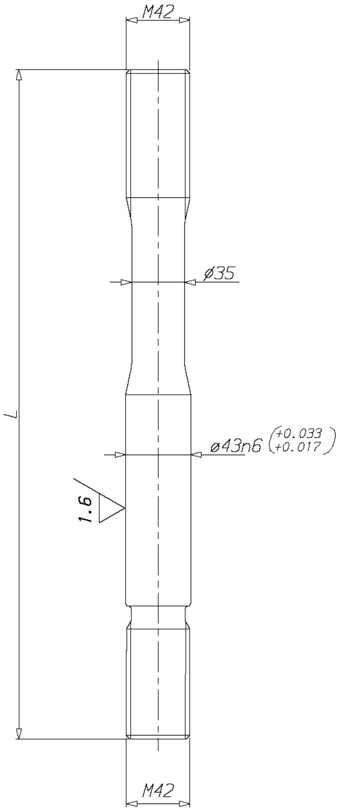
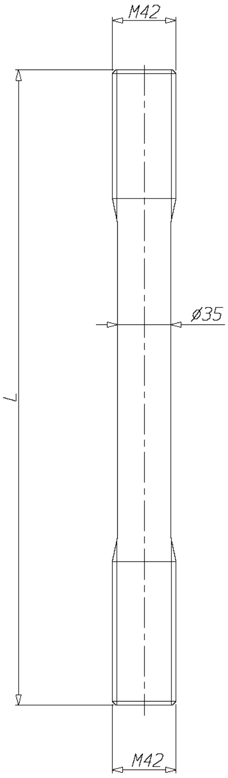


Fig 15-1 Main engine seating and fastening, in-line engines, steel chocks (V69A0144G)

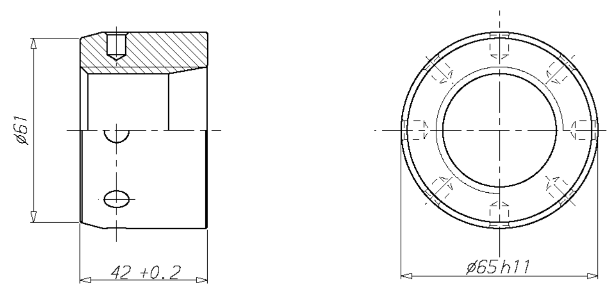
Fitted bolt
(Steel chocks)



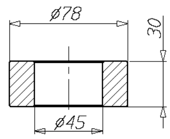
Clearance Bolt
(Steel chocks)



Round Nut



Distance Sleeve



Number of pieces per engine				
	W 6L32	**W 7L32**	**W 8L32**	**W 9L32**
Fitted bolt	2	2	2	2
Clearance bolt	14	16	18	20
Round nut	16	18	20	22
Lock nut	16	18	20	22
Distance sleeve	2	2	2	2
Lateral support	4	4	4	6
Chocks	16	18	20	22

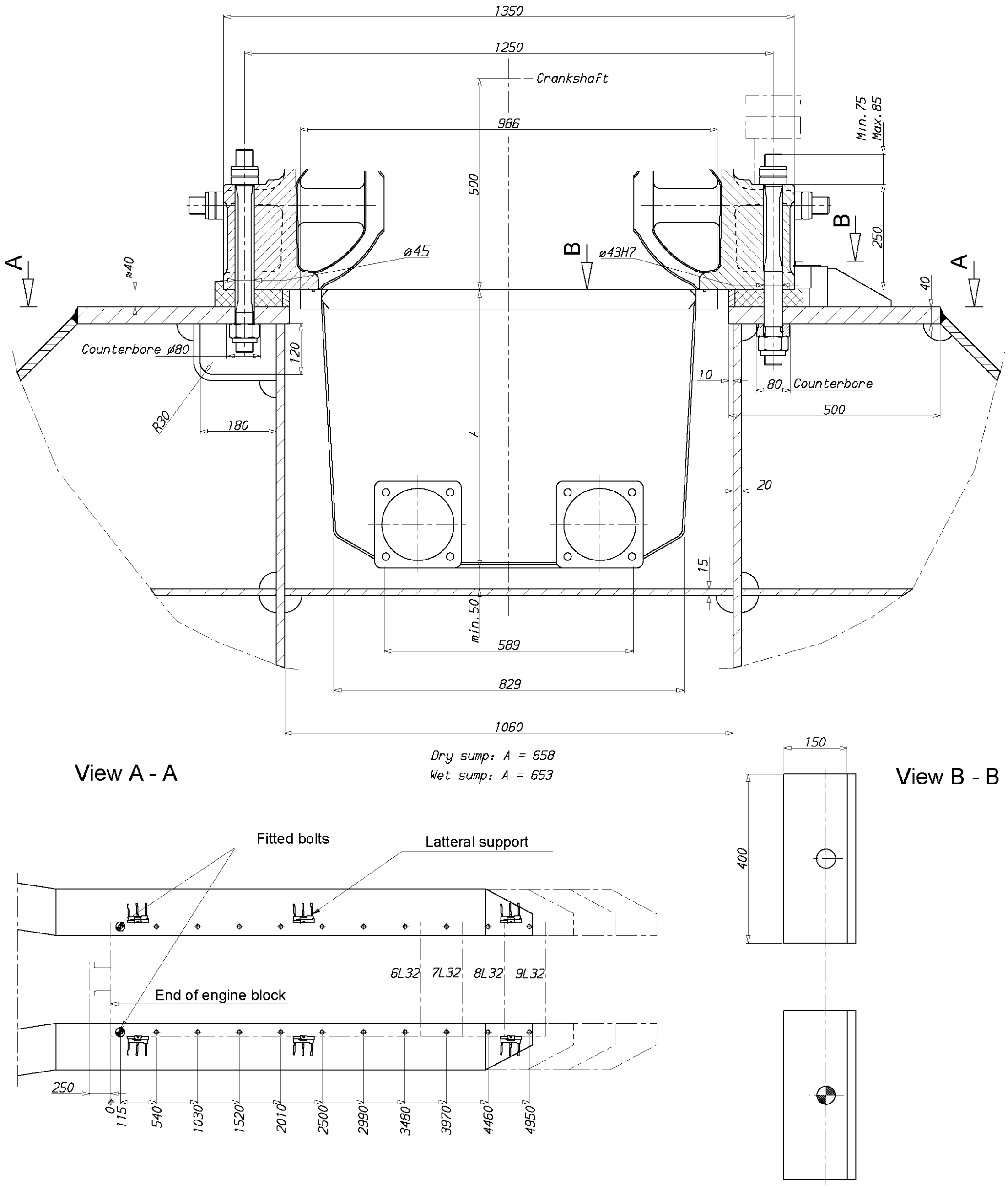
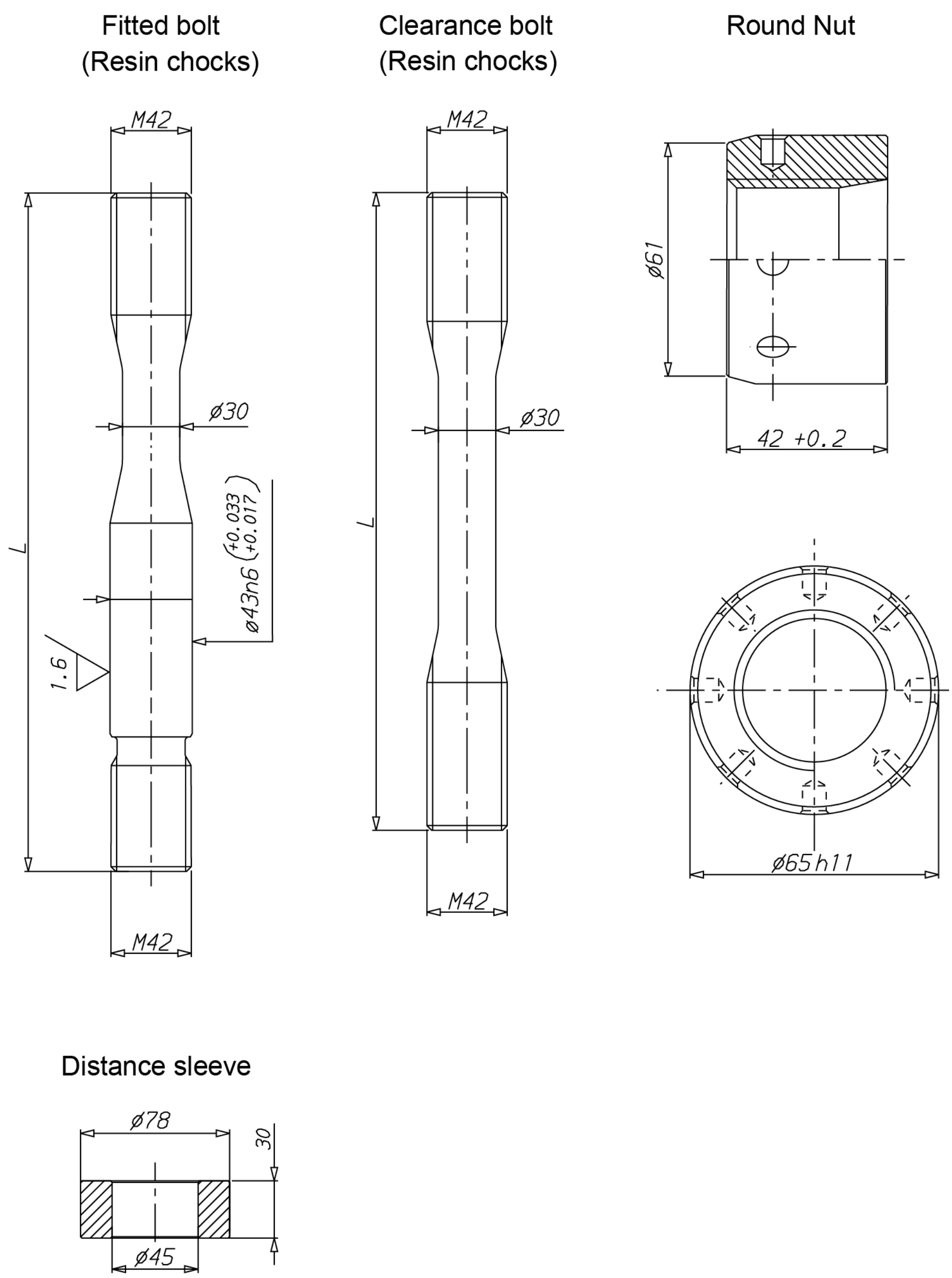


Fig 15-2 Main engine seating and fastening, in-line engines, resin chocks (V69A0140G)



Number of pieces per engine				
	W 6L32	W 7L32	W 8L32	W 9L32
Fitted bolt	2	2	2	2
Clearance bolt	14	16	18	20
Round nut	16	18	20	22
Lock nut	16	18	20	22
Distance sleeve	2	2	2	2
Lateral support	4	4	4	6
Chocks	16	18	20	22

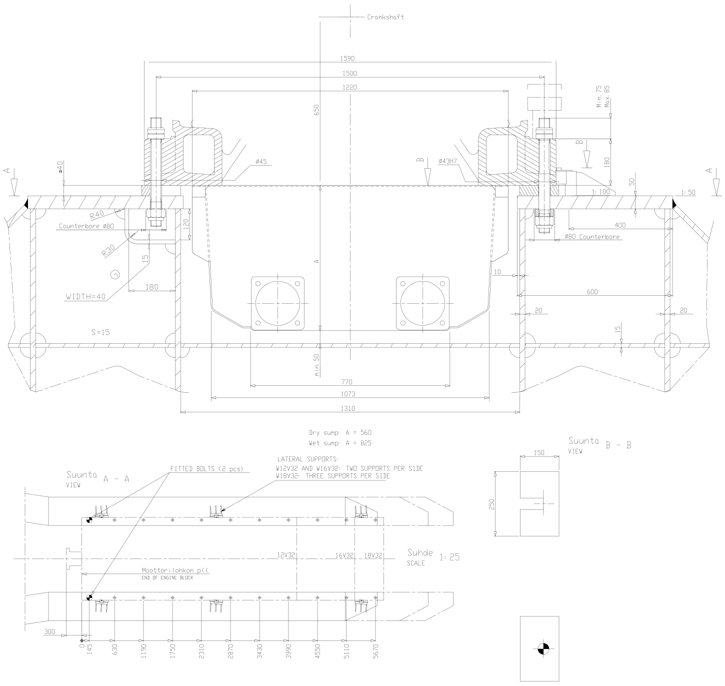
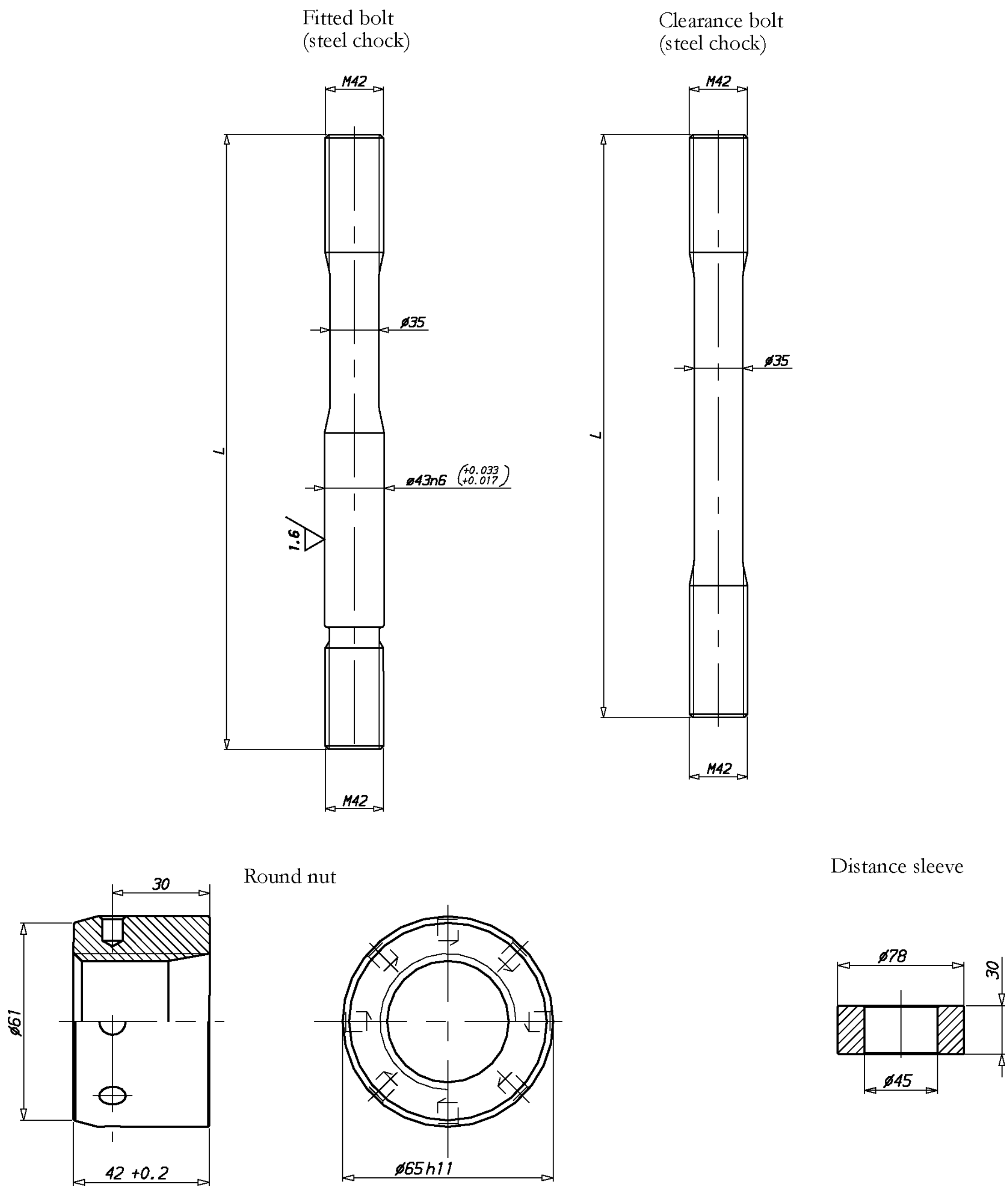


Fig 15-3 Main engine seating and fastening, V-engines, steel chocks (V69A0145I)



Number of pieces per engine			
	W 12V32	W 16V32	W 18V32
Fitted bolt	2	2	2
Clearance bolt	14	18	20
Round nut	16	20	22
Lock nut	16	20	22
Distance sleeve	2	2	2
Lateral support	4	4	6
Chocks	16	20	22

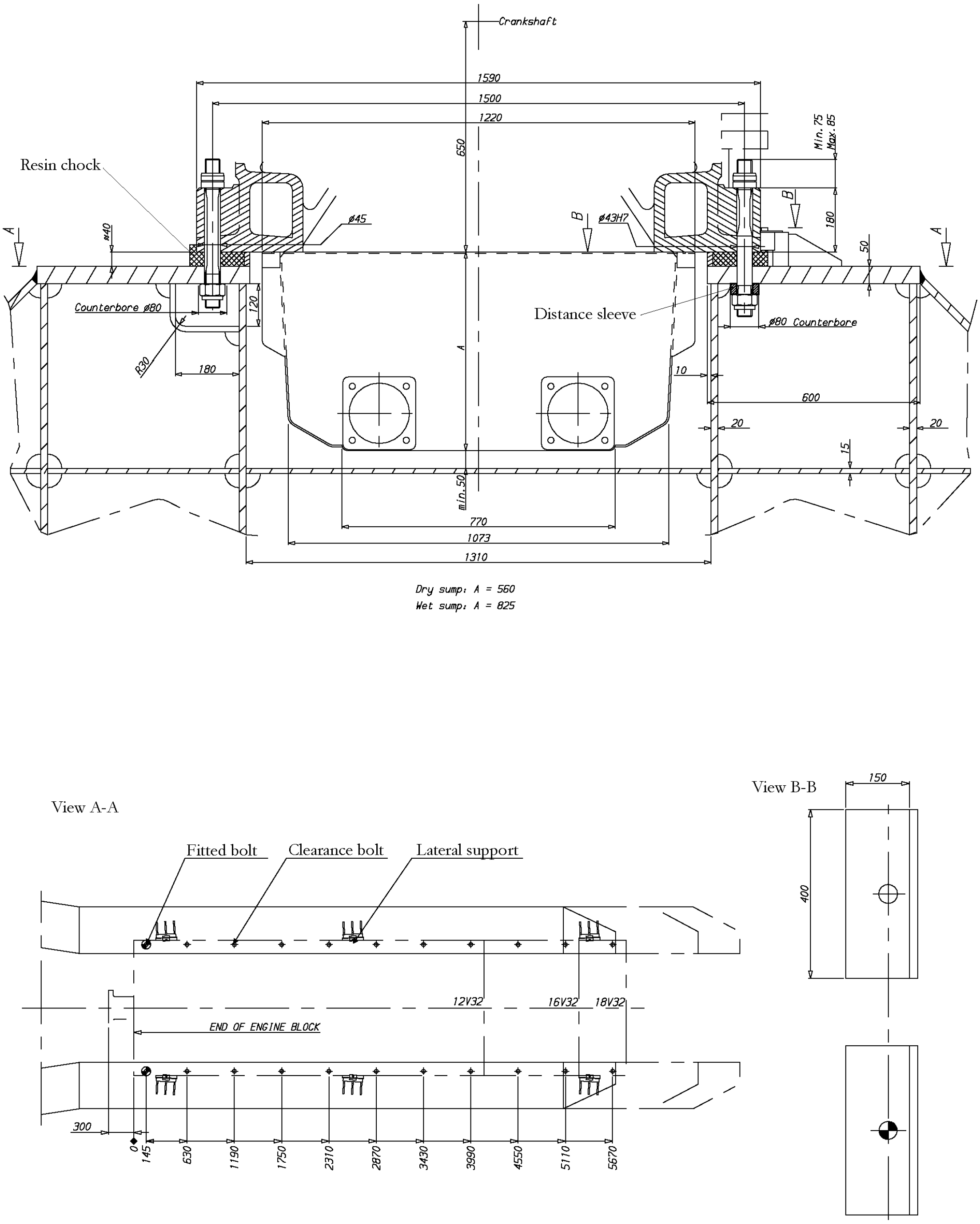
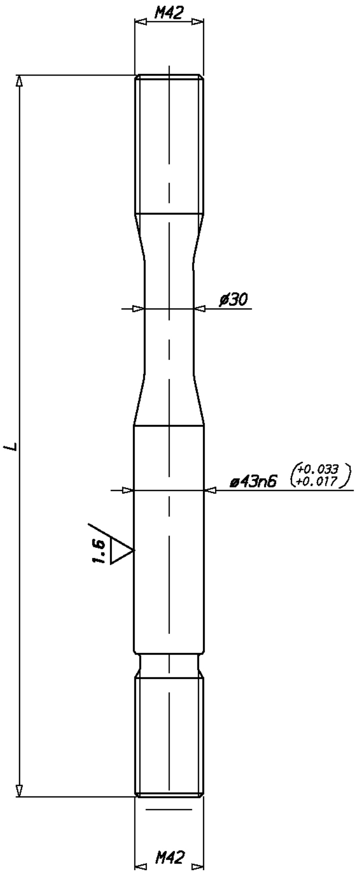
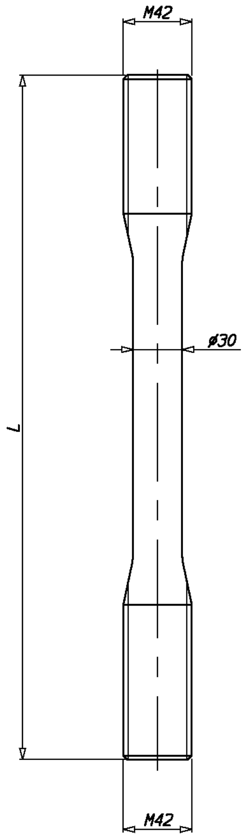


Fig 15-4 Main engine seating and fastening, V engines, resin chocks (V69A0146G)

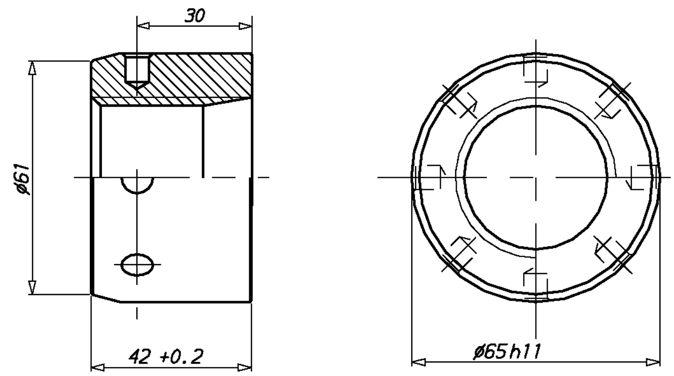
Fitted bolt
(resin chock)



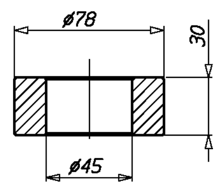
Clearance bolt
(resin chock)



Round nut



Distance sleeve



Number of pieces per engine			
	W 12V32	W 16V32	W 18V32
Fitted bolt	2	2	2
Clearance bolt	14	18	20
Round nut	16	20	22
Lock nut	16	20	22
Distance sleeve	2	2	2
Lateral support	4	4	6
Chocks	16	20	22

15.2.2 Resilient mounting

In order to reduce vibrations and structure borne noise, main engines can be resiliently mounted on rubber elements. The transmission of forces emitted by the engine is 10-20% when using resilient mounting. For resiliently mounted engines a speed range of 500-750 rpm is generally available, but cylinder configuration 18V is limited to constant speed operation (750 rpm) and resilient mounting is not available for 7L32.

Two different mounting arrangements are applied. Cylinder configurations 6L, 8L, 12V and 16V are mounted on conical rubber mounts, which are similar to the mounts used under generating sets. The mounts are fastened directly to the engine feet with a hydraulically tightened bolt. To enable drilling of holes in the foundation after final alignment adjustments the mount is fastened to an intermediate steel plate, which is fixed to the foundation with one bolt. The hole in the foundation for this bolt can be drilled through the engine foot. A resin chock is cast under the intermediate steel plate.

Cylinder configurations 9L and 18V are mounted on cylindrical rubber elements. These rubber elements are mounted to steel plates in groups, forming eight units. These units, or resilient elements, each consist of an upper steel plate that is fastened directly to the engine feet, rubber elements and a lower steel plate that is fastened to the foundation. The holes in the foundation for the fastening bolts can be drilled through the holes in the engine feet, when the engine is finally aligned to the reduction gear. The resilient elements are compressed to the calculated height under load by using M30 bolts through the engine feet and distance pieces between the two steel plates. Resin chocks are then cast under the resilient elements. Shims are provided for installation between the engine feet and the resilient elements to facilitate alignment adjustments in vertical direction. Steel chocks must be used under the side and end buffers located at each corner if the engine.

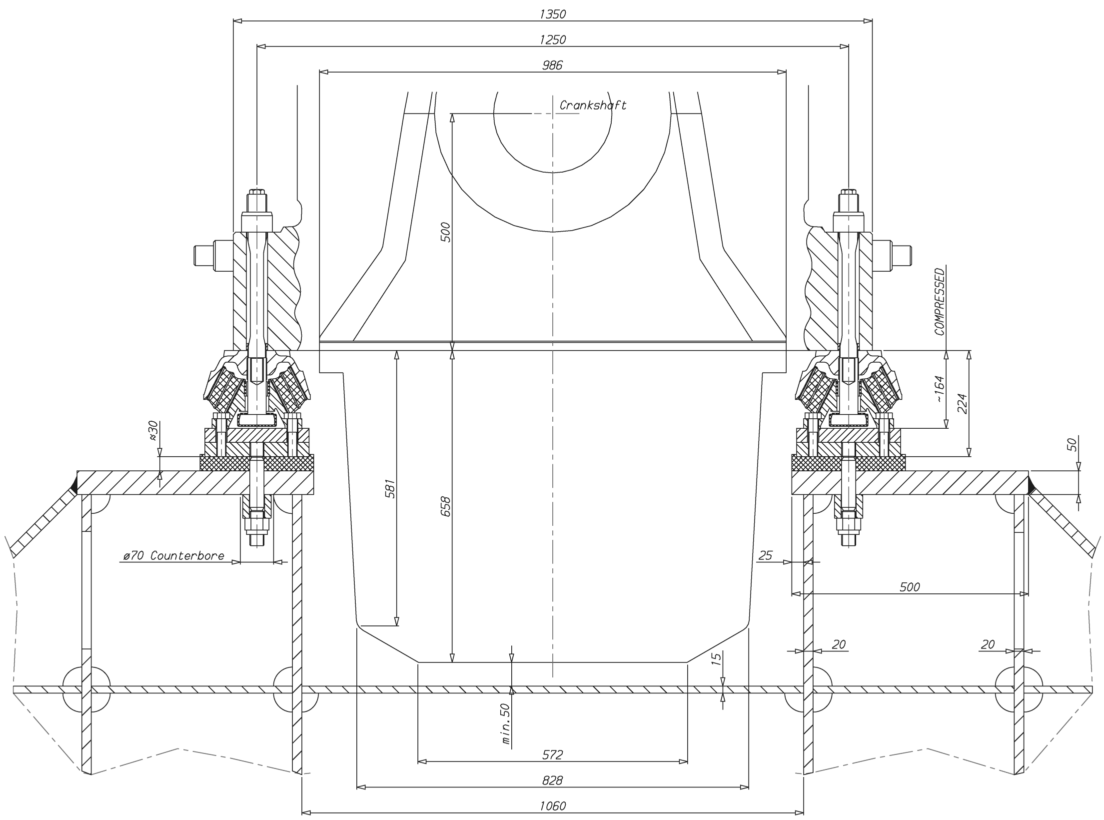


Fig 15-5 Principle of resilient mounting, W6L32 and W8L32 (DAAE048811)

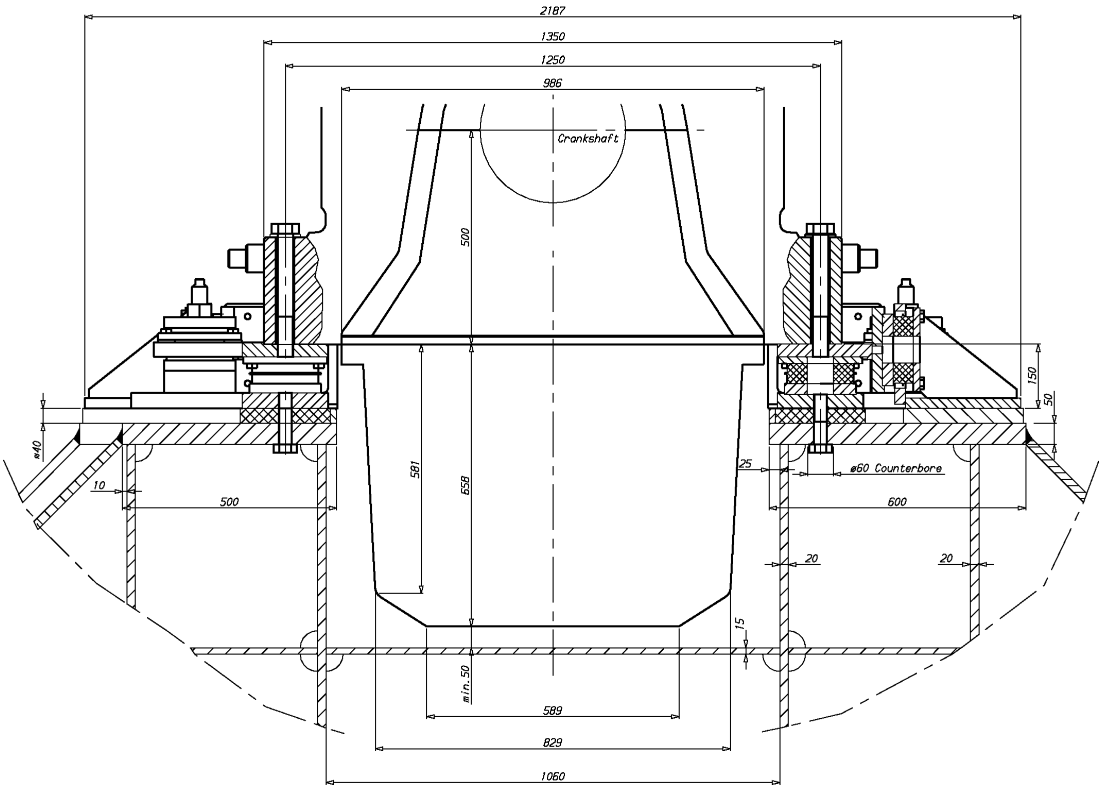


Fig 15-6 Principle of resilient mounting, W9L32 (V69A0247A)

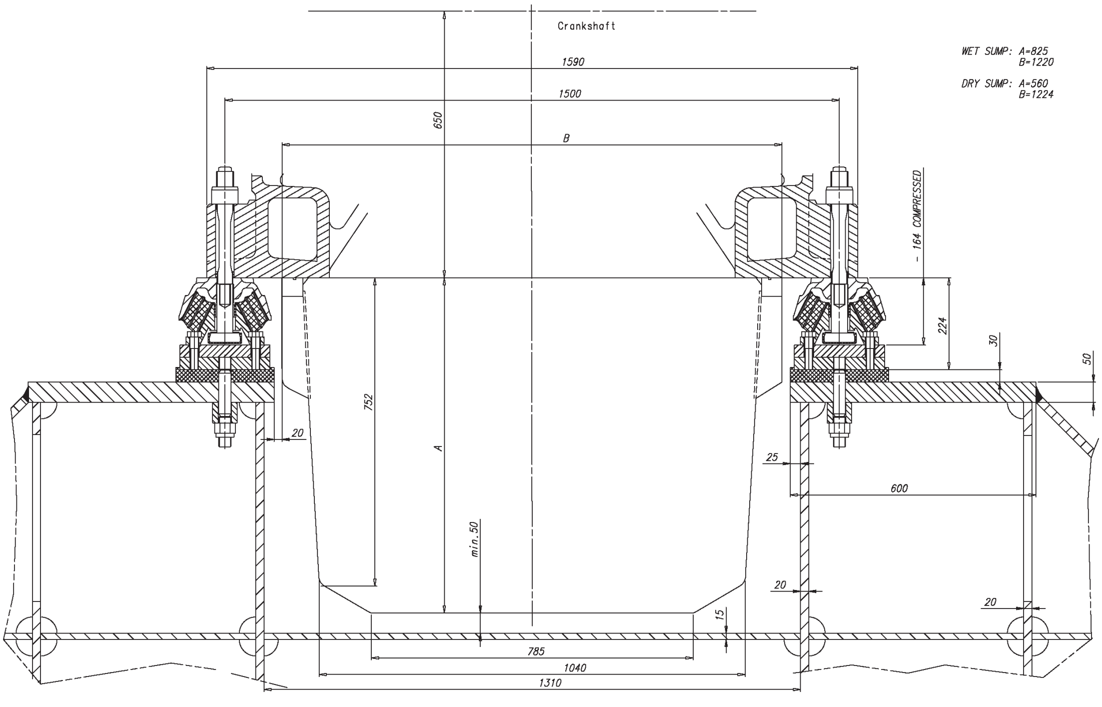


Fig 15-7 Principle of resilient mounting, W12V32 and W16V32 (DAAE041111A)

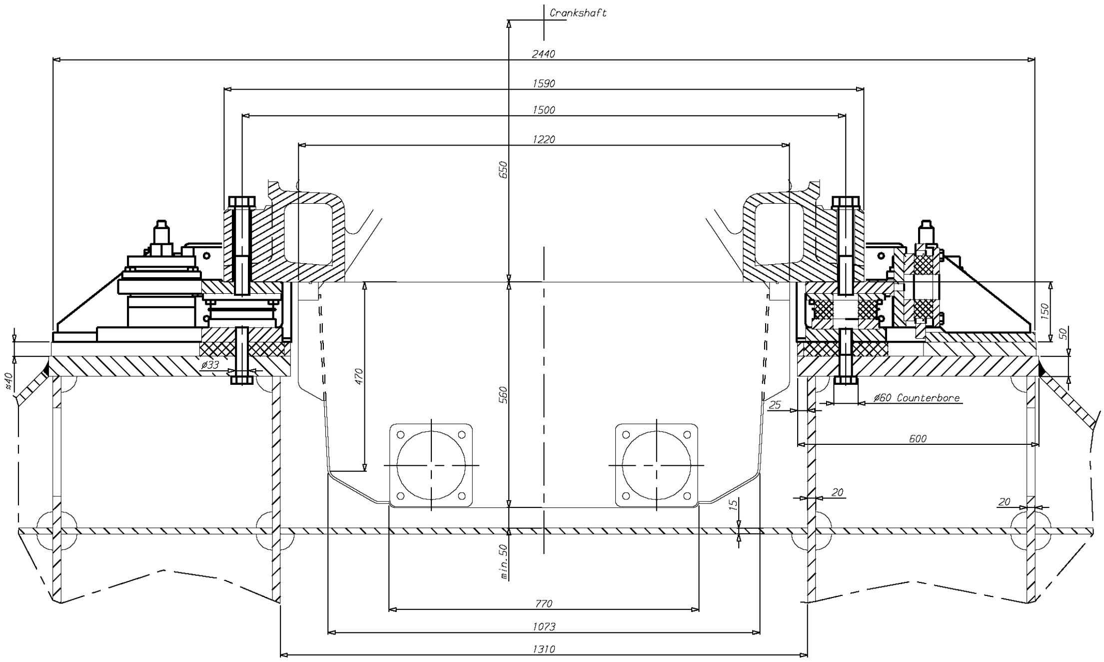


Fig 15-8 Principle of resilient mounting, W18V32 (V69A0248A)

15.3 Mounting of generating sets

15.3.1 Generator feet design

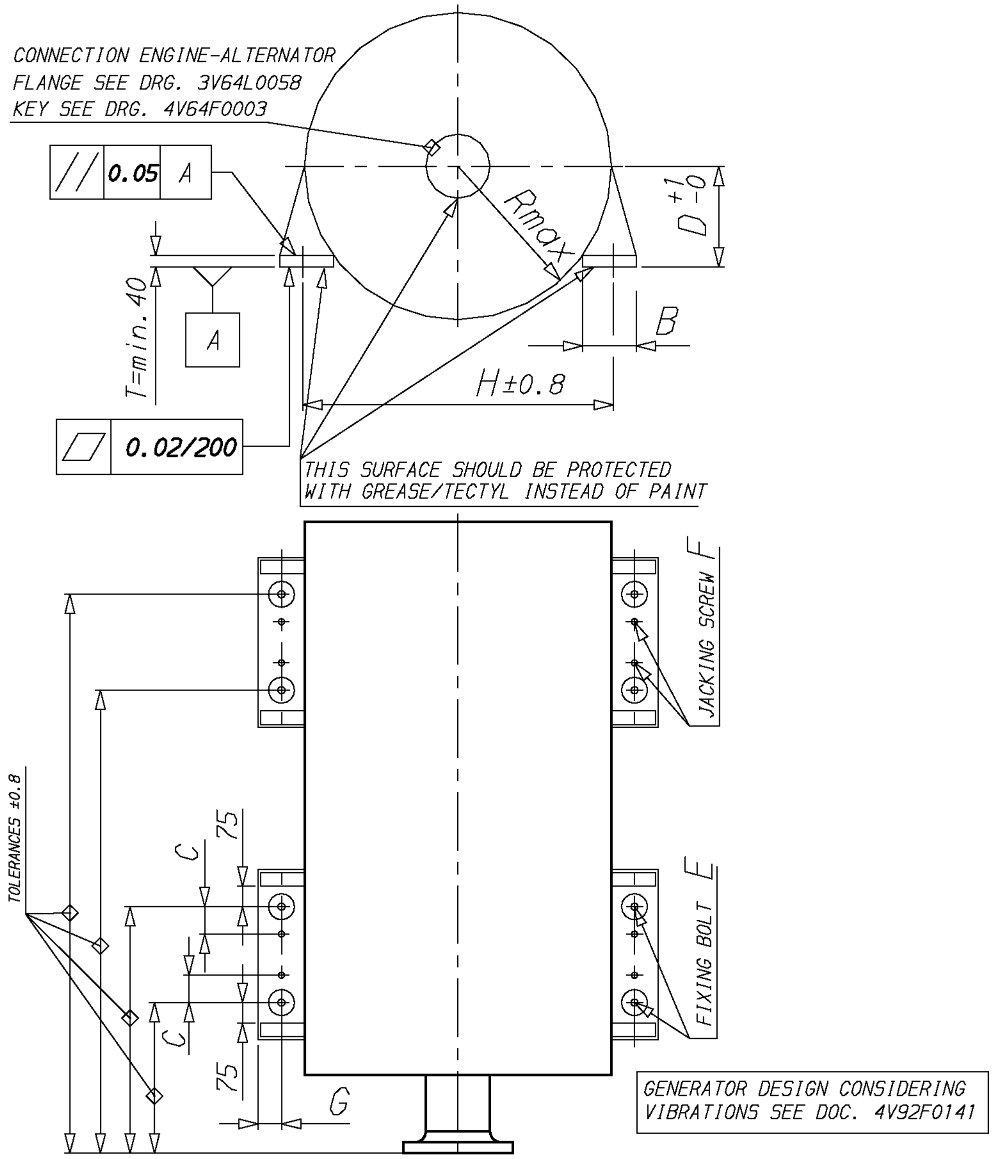


Fig 15-9 Distance between fixing bolts on generator (V92F0143b)

H [mm]	W 6L32 Rmax [mm]	W 7L32 Rmax [mm]	W 8L32 Rmax [mm]	W 9L32 Rmax [mm]	W 12V32 Rmax [mm]	W 16V32 Rmax [mm]	W 18V32 Rmax [mm]
1400	715	-	-	-	-	-	-
1600	810	810	810	810	-	-	-
1800	-	905	905	905	985	985	985
1950	-	980	980	980	1045	1045	1045
2200	-	-	-	1090	-	-	1155

Engine	G [mm]	F	E [mm]	D [mm]	C [mm]	B [mm]
W L32	85	M24 or M27	Ø35	475	100	170
W V32	100	M30	Ø48	615	130	200

15.3.2 Resilient mounting

Generating sets, comprising engine and generator mounted on a common base frame, are usually installed on resilient mounts on the foundation in the ship.

The resilient mounts reduce the structure borne noise transmitted to the ship and also serve to protect the generating set bearings from possible fretting caused by hull vibration.

The number of mounts and their location is calculated to avoid resonance with excitations from the generating set engine, the main engine and the propeller.

NOTICE
To avoid induced oscillation of the generating set, the following data must be sent by the shipyard to Wärtsilä at the design stage:

- main engine speed [RPM] and number of cylinders
- propeller shaft speed [RPM] and number of propeller blades

The selected number of mounts and their final position is shown in the generating set drawing.

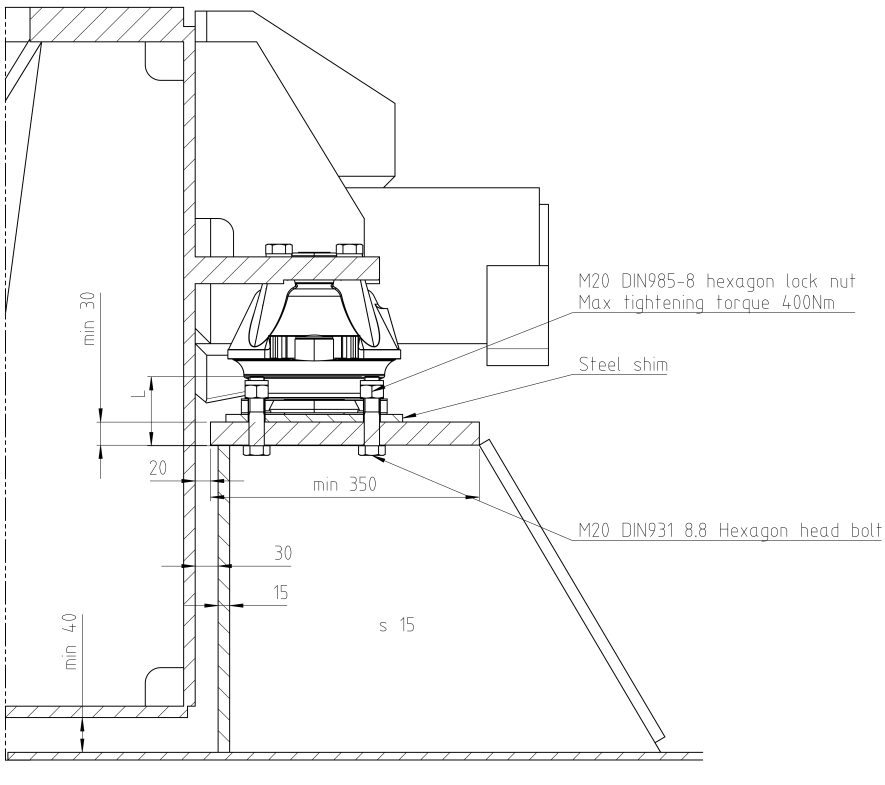


Fig 15-10 Recommended design of the generating set seating, Inline engines (V46L0295E)

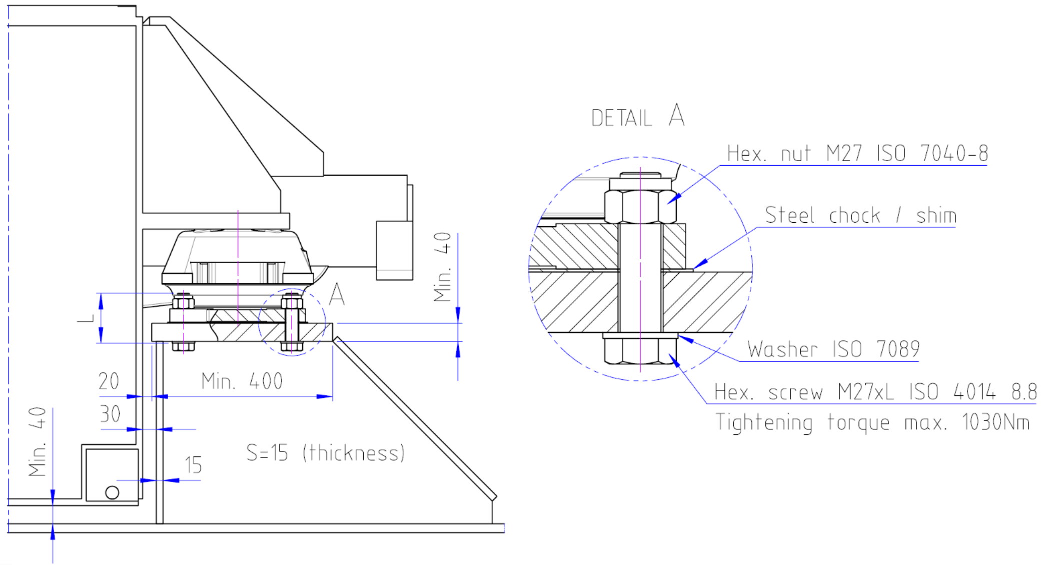


Fig 15-11 **Recommended design of the generating set seating, V engines (DAAE020067C)**

15.3.2.1 Rubber mounts

The generating set is mounted on conical resilient mounts, which are designed to withstand both compression and shear loads. In addition the mounts are equipped with an internal buffer to limit the movements of the generating set due to ship motions. Hence, no additional side or end buffers are required.

The rubber in the mounts is natural rubber and it must therefore be protected from oil, oily water and fuel.

The mounts should be evenly loaded, when the generating set is resting on the mounts. The maximum permissible variation in compression between mounts is 2.0 mm. If necessary, chocks or shims should be used to compensate for local tolerances. Only one shim is permitted under each mount.

The transmission of forces emitted by the engine is 10 -20% when using conical mounts. For the foundation design, see drawing 3V46L0295 (in-line engines) and 3V46L0294 (V-engines).

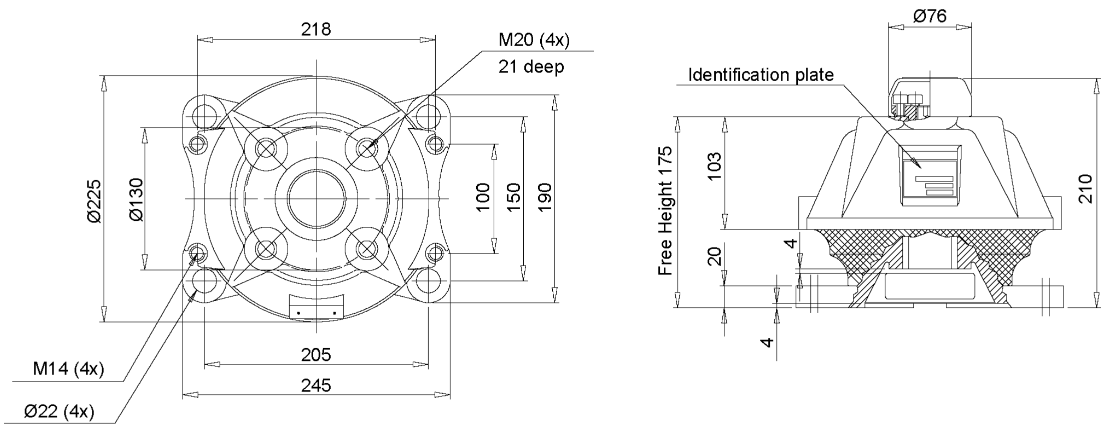


Fig 15-12 **Rubber mount, In-line engines (DAAE004230C)**

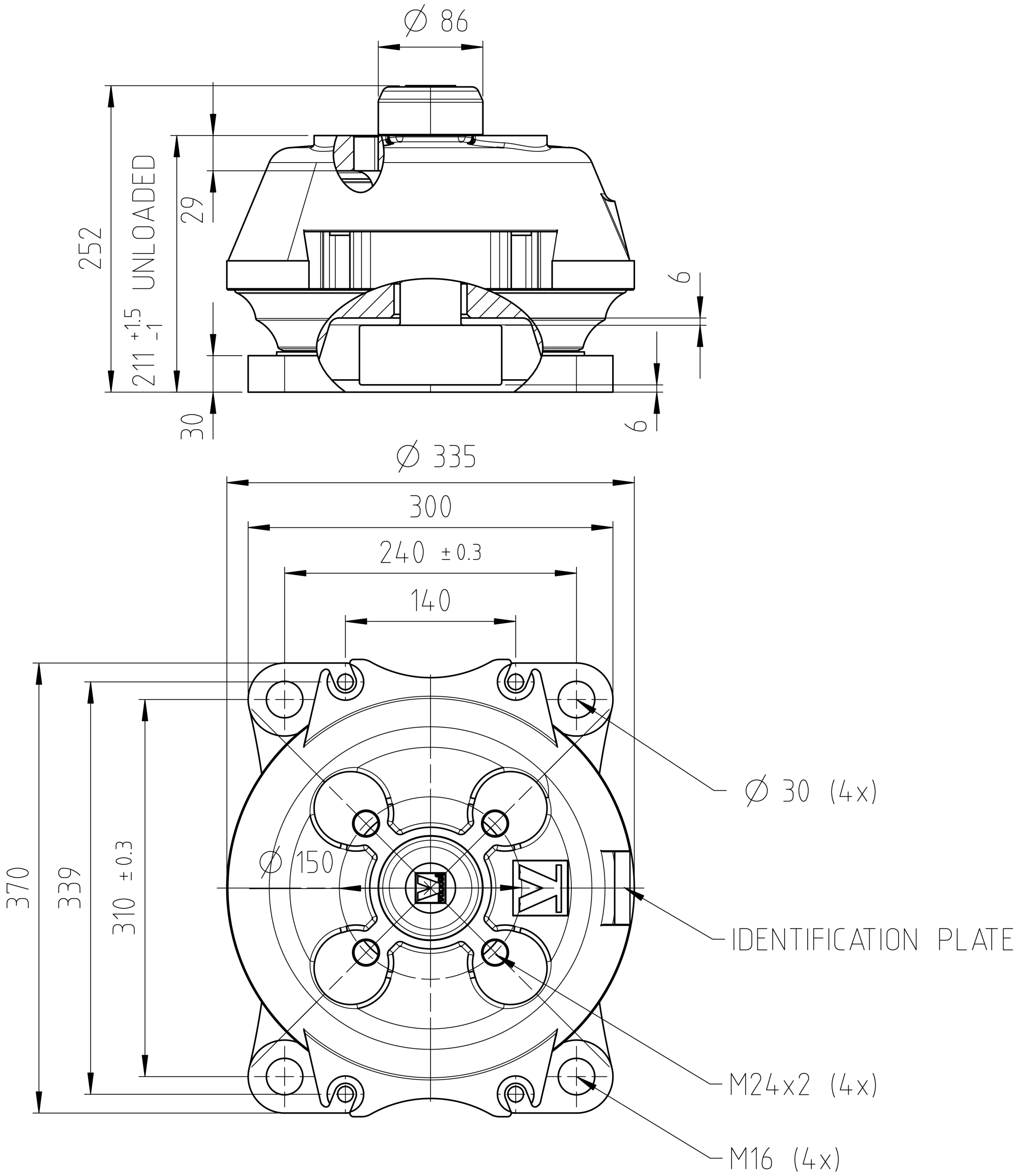


Fig 15-13 Rubber mount, V-engines (DAAE018766C)

15.4 Flexible pipe connections

When the engine or generating set is resiliently installed, all connections must be flexible and no grating nor ladders may be fixed to the engine or generating set. When installing the flexible pipe connections, unnecessary bending or stretching should be avoided. The external pipe must be precisely aligned to the fitting or flange on the engine. It is very important that the pipe clamps for the pipe outside the flexible connection must be very rigid and welded to the steel structure of the foundation to prevent vibrations, which could damage the flexible connection.

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16. Vibration and Noise

Generating sets comply with vibration levels according to ISO 8528-9. Main engines comply with vibration levels according to ISO 10816-6 Class 5.

16.1 External forces & couples

Some cylinder configurations produce external forces and couples. These are listed in the tables below.

The ship designer should avoid natural frequencies of decks, bulkheads and superstructures close to the excitation frequencies. The double bottom should be stiff enough to avoid resonances especially with the rolling frequencies.

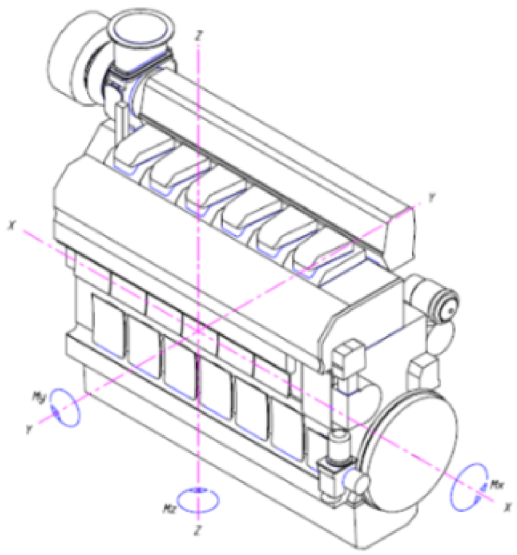

Fig 16-1 External forces, couples and torque variations

Table 16-1 External forces

Engine	Speed [rpm]	Freq. [Hz]	F_Y [kN]	F_Z [kN]	Freq. [Hz]	F_Y [kN]	F_Z [kN]	Freq. [Hz]	F_Y [kN]	F_Z [kN]
6L	720 750	12 12.5	--- ---	--- ---	24 25	--- ---	--- ---	48 50	--- ---	--- ---
7L	720 750	12 12.5	--- ---	--- ---	24 25	--- ---	--- ---	48 50	--- ---	--- ---
8L	720 750	12 12.5	--- ---	--- ---	24 25	--- ---	--- ---	48 50	--- ---	5 6
9L	720 750	12 12.5	--- ---	--- ---	24 25	--- ---	--- ---	48 50	--- ---	--- ---
12V	720 750	12 12.5	--- ---	--- ---	24 25	--- ---	--- ---	48 50	--- ---	--- ---
16V	720 750	12 12.5	--- ---	--- ---	24 25	--- ---	--- ---	48 50	5 5	3 3

--- couples and forces = zero or insignificant.

Table 16-2 External couples

Engine	Speed [rpm]	Freq. [Hz]	M_Y [kNm]	M_Z [kNm]	Freq. [Hz]	M_Y [kNm]	M_Z [kNm]	Freq. [Hz]	M_Y [kNm]	M_Z [kNm]
6L	720 750	12 12.5	--- ---	--- ---	24 25	--- ---	--- ---	48 50	--- ---	--- ---
7L	720 750	12 12.5	12 13	12 13	24 25	22 24	--- ---	48 50	3 3	--- ---
8L	720 750	12 12.5	--- ---	--- ---	24 25	--- ---	--- ---	48 50	--- ---	--- ---
9L	720 750	12 12.5	43 46	43 46	24 25	25 27	--- ---	48 50	2 2	--- ---
12V	720 750	12 12.5	--- ---	--- ---	24 25	--- ---	--- ---	48 50	--- ---	--- ---
16V	720 750	12 12.5	--- ---	--- ---	24 25	--- ---	--- ---	48 50	--- ---	--- ---

--- couples and forces = zero or insignificant.

Table 16-3 Torque variations

Engine	Speed [rpm]	Freq. [Hz]	M_X [kNm]	Freq. [Hz]	M_X [kNm]	Freq. [Hz]	M_X [kNm]	Freq. [Hz]	M_X [kNm]
6L	720 750	36 37.5	44 41	72 75	21 21	108 112.5	4 4	144 150	1 1
7L	720 750	42 43.8	81 81	84 87.5	15 15	126 131.3	2 2	168 175	0 0
8L	720 750	48 50	71 71	96 100	10 10	144 150	1 1	192 200	0 0
9L	720 750	54 56.25	66 66	108 113	6 6	162 169	1 1	216 225	0 0
12V	720 750	36 38	11 11	72 75	41 41	108 113	3 3	144 150	1 1
16V	720 750	48 50	49 49	96 100	15 15	144 150	1 1	192 200	0 0

16.2 Mass moments of inertia

The mass-moments of inertia of the main engines (including flywheel) are typically as follows:

Engine	J [kg m²]
W 6L32	430 - 540
W 7L32	550 - 630
W 8L32	540 - 700
W 9L32	640 - 780
W 12V32	620 - 920

(continued)

Engine	J [kg m²]
W 16V32	740 - 1030

16.3 Air borne noise

The airborne noise of the engines is measured as sound power level based on ISO 9614-2. The results represent typical engine A-weighted sound power level at full load and nominal speed.

A-weighted sound power level in octave frequency band [dB, ref. 1pW]								
[Hz]	125	250	500	1000	2000	4000	8000	Total
6L	97	107	117	116	114	115	111	122
7L	97	107	116	117	114	117	107	122
8L	99	111	116	119	117	121	115	125
9L	99	107	117	119	116	116	109	124
12V	103	113	120	122	117	114	112	126
16V	103	110	120	121	116	114	112	125

16.4 Exhaust noise

The results represent typical exhaust sound power level measured after turbocharger outlet in duct line with 1m diameter and exhaust temperature approximately 360 Celsius at engine full load and nominal speed.

Exhaust Gas Sound Power Level in Octave Frequency Band [dB, ref. 1pW]									
[Hz]	32	63	125	250	500	1000	2000	4000	Total
6L	147	148	141	134	119	110	107	106	151
7L	147	149	138	133	127	120	113	101	151
8L	150	153	146	137	125	111	104	106	156
9L	155	147	143	139	129	114	107	110	156
12V	148	150	141	135	126	111	102	103	152
16V	146	149	143	131	123	108	102	105	152

16.5 Air inlet noise

The results represent typical unsilenced air inlet A-weighted sound power level at turbocharger inlet at engine full load and nominal speed.

A-weighted Air Inlet Sound Power Level in Octave Frequency Band [dB, ref. 1pW]									
[Hz]	63	125	250	500	1000	2000	4000	8000	Total
6L	90	98	106	119	124	127	140	136	142
7L	84	92	102	114	119	121	141	134	142
8L	85	98	104	121	125	129	145	138	146
9L	81	97	105	119	125	128	141	137	143
12V	84	97	107	120	127	130	141	135	143
16V	85	94	107	120	124	130	146	138	147

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17. Power Transmission

17.1 Flexible coupling

The power transmission of propulsion engines is accomplished through a flexible coupling or a combined flexible coupling and clutch mounted on the flywheel. The crankshaft is equipped with an additional main bearing at the flywheel end. Therefore also a rather heavy coupling can be mounted on the flywheel without intermediate bearings.

The type of flexible coupling to be used has to be decided separately in each case on the basis of the torsional vibration calculations.

In case of two bearing type generator installations a flexible coupling between the engine and the generator is required.

17.1.1 Connection to generator

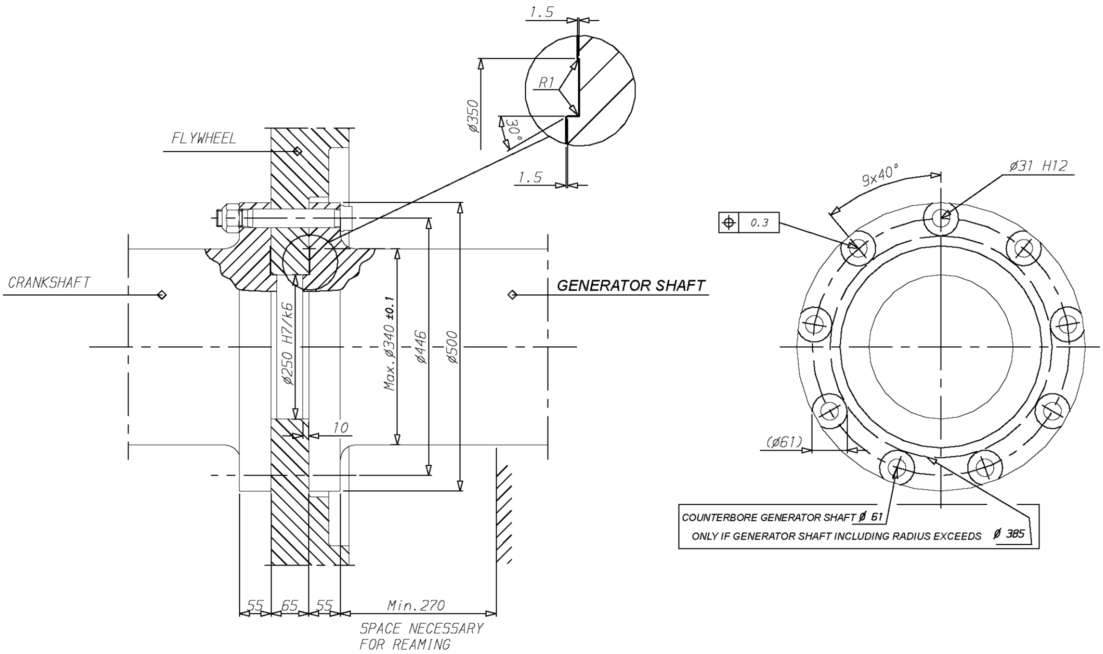
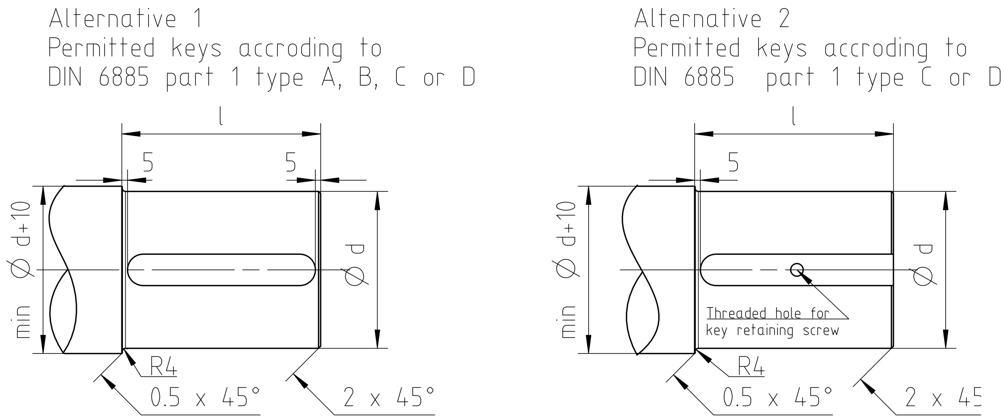


Fig 17-1 Connection engine-generator (V64L0058C)



Alternator manufacturer supplies the key

Engine	Shaft length l [mm]	Shaft diameter d [mm]
6L32	280	200
7L32	280	220
8L32	280	255
9L32	280	255
12V32	310	275
16V32	310	275

Fig 17-2 Directives for generator end design (V64F0003B)

17.2 Clutch

In many installations the propeller shaft can be separated from the diesel engine using a clutch. The use of multiple plate hydraulically actuated clutches built into the reduction gear is recommended.

A clutch is required when two or more engines are connected to the same driven machinery such as a reduction gear.

To permit maintenance of a stopped engine clutches must be installed in twin screw vessels which can operate on one shaft line only.

17.3 Shaft locking device

To permit maintenance of a stopped engine clutches must be installed in twin screw vessels which can operate on one shaft line only. A shaft locking device should also be fitted to be able to secure the propeller shaft in position so that wind milling is avoided. This is necessary because even an open hydraulic clutch can transmit some torque. Wind milling at a low propeller speed (<10 rpm) can due to poor lubrication cause excessive wear of the bearings.

The shaft locking device can be either a bracket and key or an easier to use brake disc with calipers. In both cases a stiff and strong support to the ship's construction must be provided.

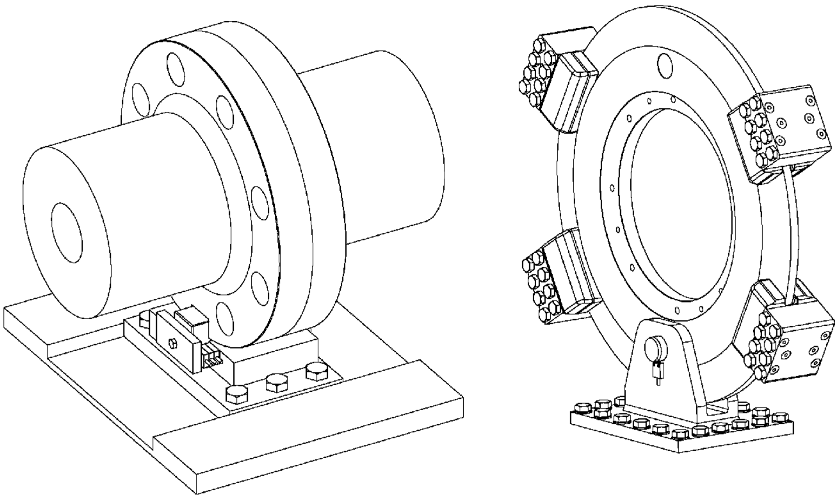


Fig 17-3 Shaft locking device and brake disc with calipers

17.4 Power-take-off from the free end

The engine power can be taken from both ends of the engine. For in-line engines full engine power is also available at the free end of the engine. On V-engines the engine power at free end must be verified according to the torsional vibration calculations.

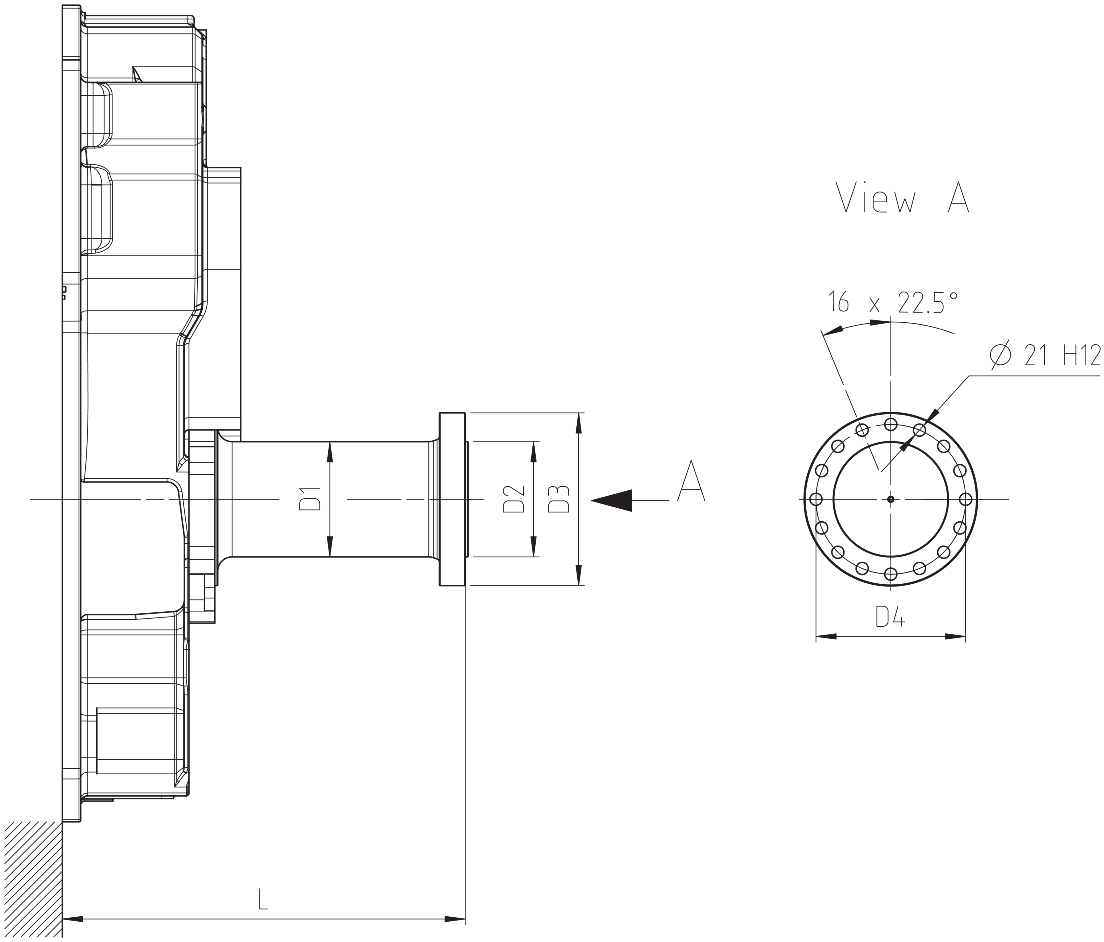


Fig 17-4 Power take off at free end (4V62L1260D)

Engine	Rating [1)] [kW]	D1 [mm]	D2 [mm]	D3 [mm]	D4 [mm]	L [mm]	PTO shaft connected to
In-line engines	5000	200	200	300	260	650	Extension shaft with support bearing
	5000	200	200	300	260	775	Coupling, max weight at distance L = 800 kg
V-engines	5000	200	200	300	260	800	Extension shaft with support bearing
	3500	200	200	300	260	1070	Coupling, max weight at distance L = 390 kg

1) PTO shaft design rating, engine output may be lower

17.5 Input data for Torsional Vibration Calculation

The torsional vibration calculation (TVC) is performed for each installation according to classification requirements. For this purpose, the following project specific exact data of all components included in the shaft system are required.

General and operational data

- Classification society (leading class, in case of dual class)
- Class notations (especially in case of Ice, Polar, Redundant Propulsion)
- List of all operating modes (including for navigation in ice, if applicable)

- Power distribution between the different consumers for every operating mode
- Power Vs Speed curve for every consumer
- GA drawing or layout illustrating propulsion machinery arrangements

Gearbox

- Mass elastic diagram showing:
  - All clutching possibilities (especially in case of multiple clutches)
  - Dimensions of all shafts
  - Mass moment of inertia of all rotating parts including shafts and flanges
  - Torsional stiffness of shafts between rotating masses
  - Gear ratios
  - Drawing number (including revision)
- GA drawing or other type of drawing showing:
  - Input and output interface details (type/dimensions details, material and yield strength, surface roughness)
    - In case of cylindrical shaft interface: fillet radius at step diameter and keyway standard
  - Material of shafts including minimum tensile strength
  - Drawing number (including revision)

Propeller and shafting

- Mass-elastic diagram or propeller shaft drawing showing:
  - Mass moment of inertia of all rotating parts including the rotating part of the OD-box, SKF couplings and rotating parts of the bearings
  - Mass moment of inertia of the propeller in water for all operating modes (as minimum full/zero pitch)
  - Torsional stiffness or dimensions of the shafts
  - Drawing number (including revision)
- Drawing or data sheet with:
  - Propeller power consumption for all operating modes (as minimum full/zero pitch)
  - Number of propeller blades
  - Material of the shafts including minimum tensile strength
  - In case of Ice class notation: propeller outer diameter, outer diameter of the propeller hub, propeller pitch at bollard pull condition
  - In case of cardan shafts: joint inclination angle and mass moment of inertia of every single part (joints and shaft)
  - Drawing number (including revision)

Shaft generator or main generator

- Technical data sheet with at least:
  - Nominal power and speed
  - Information if variable or constant speed operation
  - In case of variable speed, Power Vs Speed curve
  - Number of pole pairs
  - Bearing external load capabilities (axial and radial)
- Outline drawing with:

    - input interface details (type/dimensions details, material and yield strength, surface roughness)
        - In case of cylindrical shaft interface: fillet radius at step diameter and keyway standard
    - Bearing axial clearance (minimum and maximum values)
    - Drawing number (including revision)
- Mass-elastic diagram or the generator shaft drawing showing:
    - Mass moment of inertia of all rotating parts and total inertia value of the rotor, including the shaft
    - Torsional stiffness or dimensions of the shaft
    - Material of the shaft including minimum tensile strength
    - Drawing number of the diagram or drawing
- For shaft generator (connected to gearbox)
    - In case of PTI function, Power Vs Speed curve
    - In case of booster function, Power Vs Speed curve
- For main generator (connected to engine)
    - Electrical data: reactances and time constants

Flexible coupling/clutch

- Customer preferred coupling brand, if any
- Brand selection restrictions due to possible international export regulations
- Specific dimensional requirements (for example length)
- If coupling is in customer scope of supply, the following data of it must be informed:
    - Mass moment of inertia of all parts of the coupling
    - Number of flexible elements
    - Torsional stiffness per element
    - Dynamic magnification or relative damping
    - Nominal torque, permissible vibratory torque and permissible power loss
    - Drawing of the coupling showing interface details, maker, type and drawing number

Other components:

- In case of electric motor
    - Nominal power and speed
    - Power Vs Speed curve
    - Outline drawing with:
        - input interface details (type/dimensions details, material and yield strength, surface roughness)
            - In case of cylindrical shaft interface: fillet radius at step diameter and keyway standard
        - Drawing number (including revision)
    - Mass-elastic diagram or the motor shaft drawing showing:
        - Mass moment of inertia of all rotating parts and total inertia value of the rotor, including the shaft
        - Torsional stiffness or dimensions of the shaft
        - Material of the shaft including minimum tensile strength

    - Drawing number of the diagram or drawing
- In case of pump:
  - Nominal power and speed
  - Power Vs Speed curve
  - Information if variable or constant speed operation
  - Outline drawing with:
    - input interface details (type/dimensions details, material and yield strength, surface roughness)
      - In case of cylindrical shaft interface: fillet radius at step diameter and keyway standard
    - Drawing number (including revision)
  - Mass-elastic diagram or the impeller shaft drawing showing:
    - Mass moment of inertia of all rotating parts and total inertia value of the impeller, including the shaft
    - Torsional stiffness or dimensions of the shaft
    - Material of the shaft including minimum tensile strength
    - Drawing number of the diagram or drawing
  - Number of impeller blades
  - Torsional excitations (especially in case of dredging pump)

17.6 Turning gear

The engine is equipped with an electrical driven turning gear, capable of turning the flywheel and crankshaft.

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18. Engine Room Layout

18.1 Crankshaft distances

Minimum crankshaft distances are to be arranged in order to provide sufficient space between engines for maintenance and operation.

18.1.1 Main engines

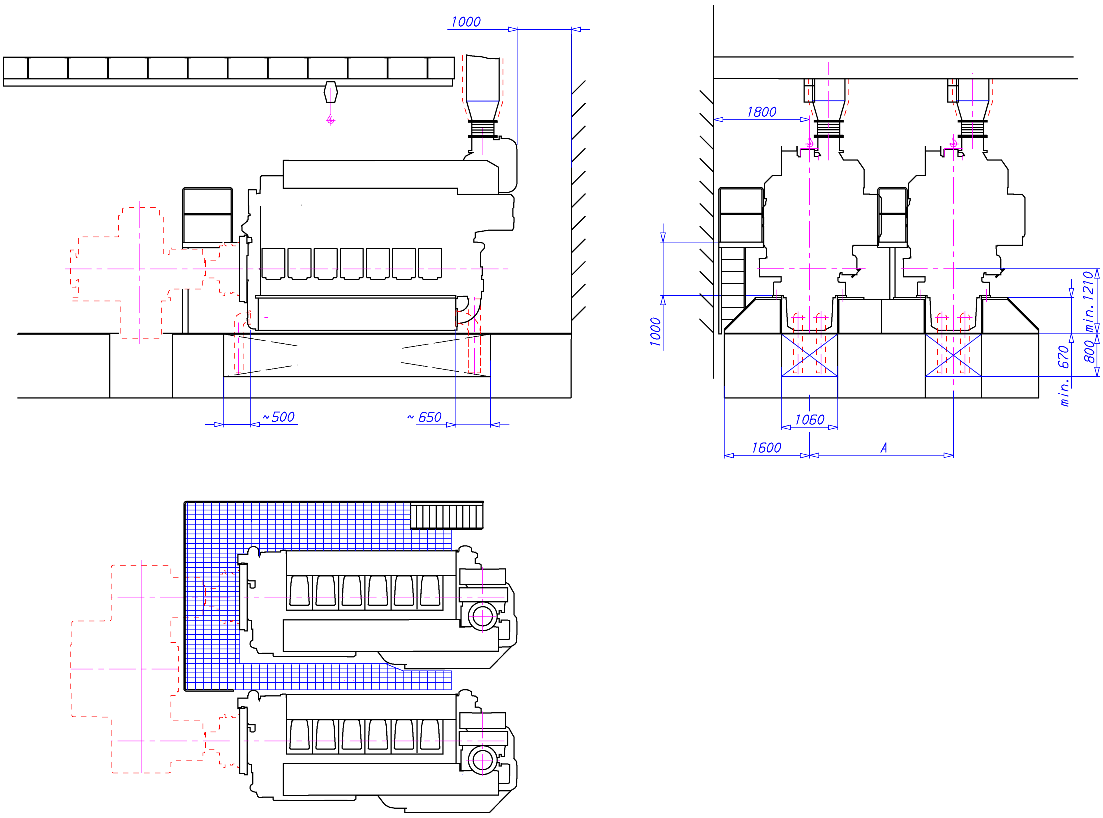


Fig 18-1 In-line engines, turbocharger in free end (DAAE041961)

Engine	A
W 6L32	2700
W 7L32	2700
W 8L32	2700
W 9L32	2700

All dimensions in mm.

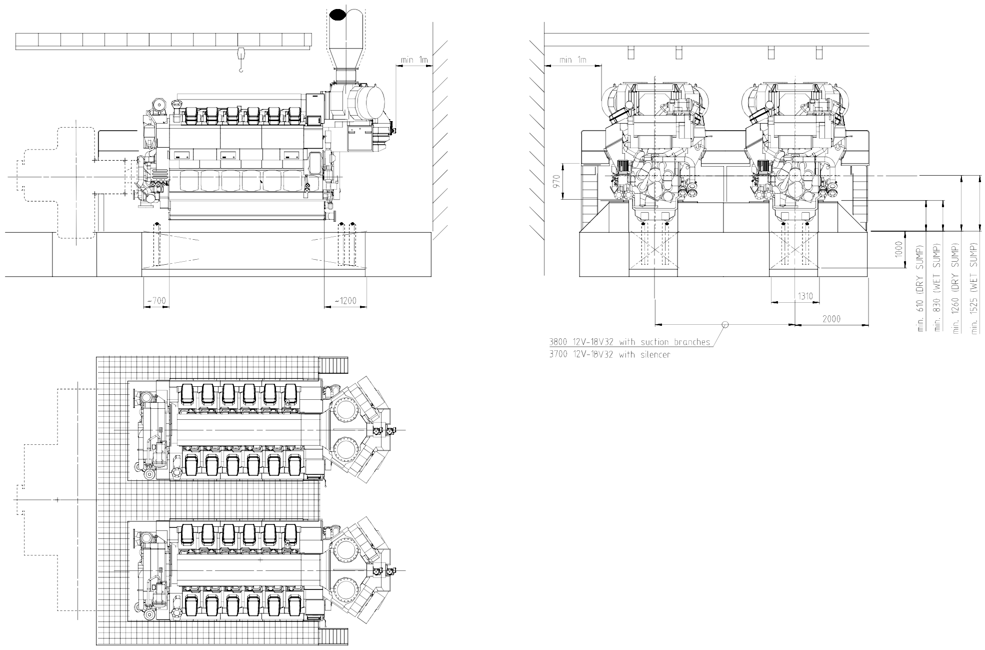


Fig 18-2 V engines, turbocharger in free end (DAAE042488C)

Engine	A
V-engine with filter/ silencer on turbocharger	3700
V-engine with suction branches	3800

All dimensions in mm.

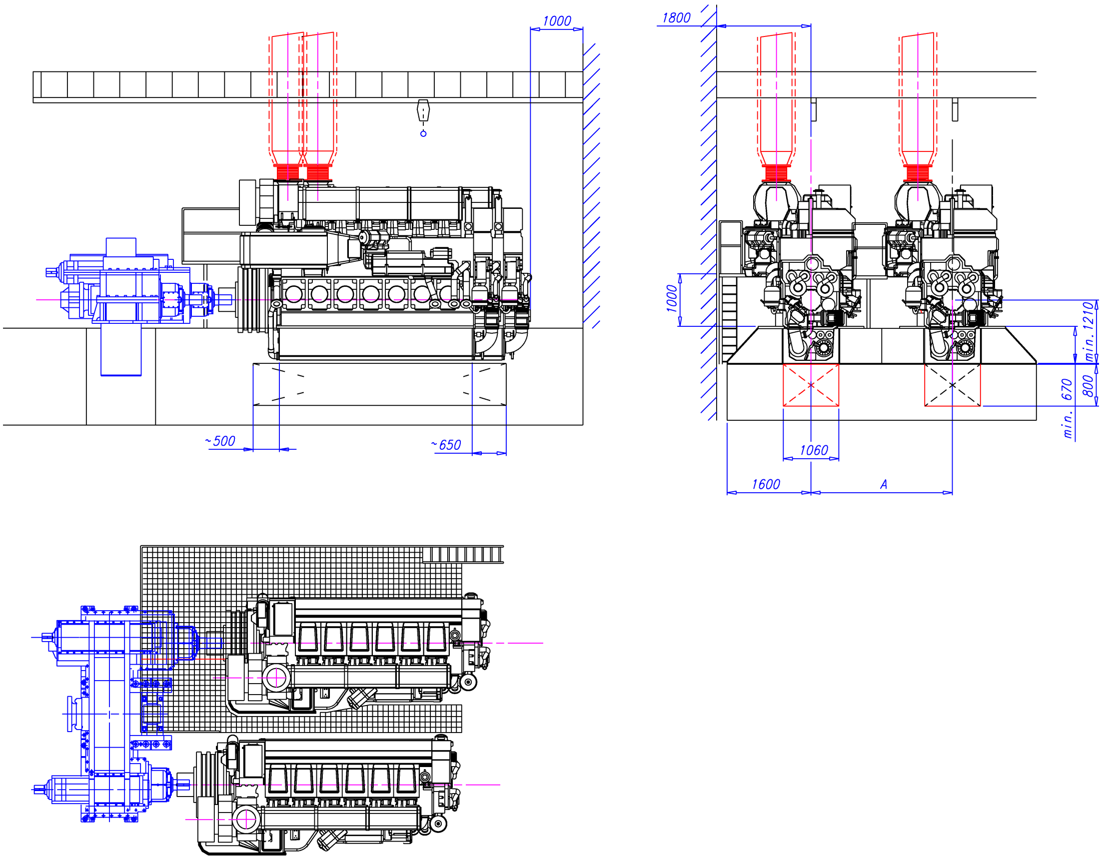


Fig 18-3 In-line engines, turbocharger in driving end (DAAE030105a)

Engine	A
W 6L32	2700
W 7L32	2700
W 8L32	2700
W 9L32	2700

All dimensions in mm.

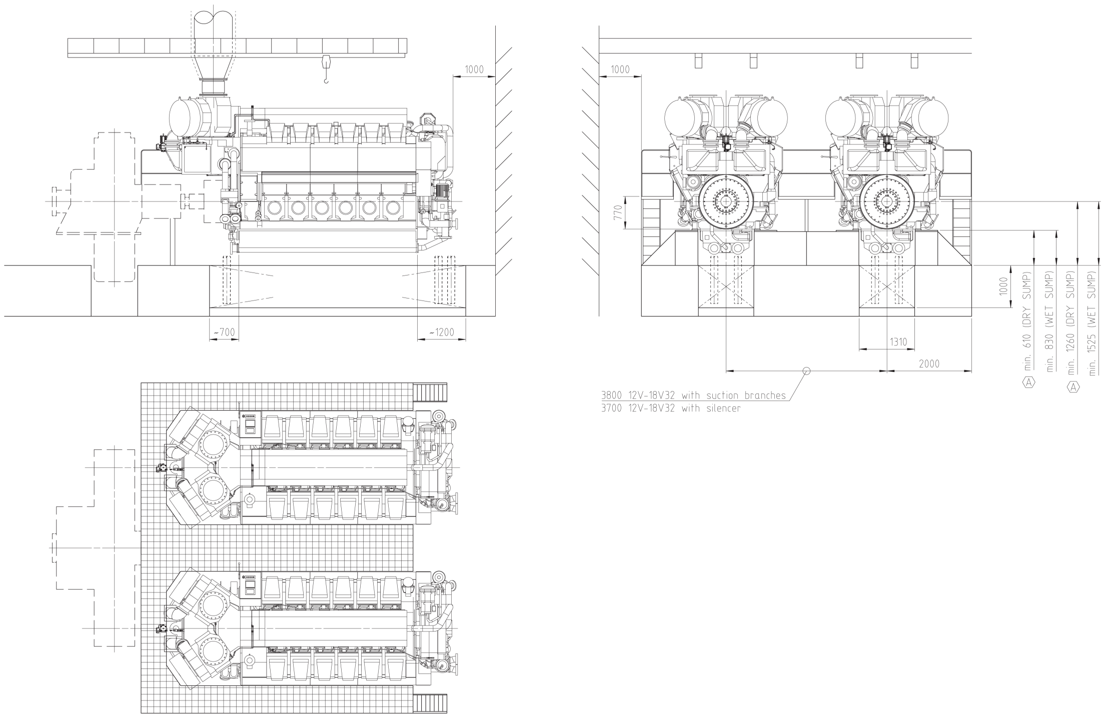


Fig 18-4 V engines, turbocharger in driving end (DAAE053931A)

Engine	A
V-engine with filter/ silencer on turbocharger	3700
V-engine with suction branches	3800

All dimensions in mm.

18.1.2 Generating sets

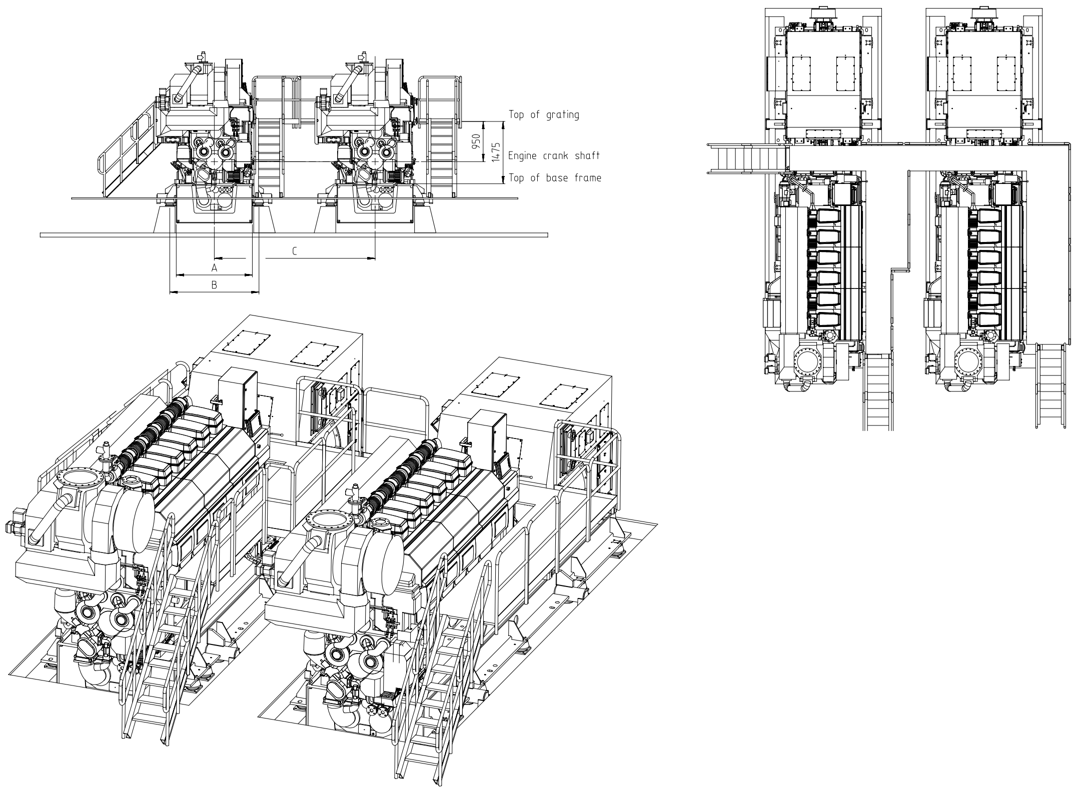
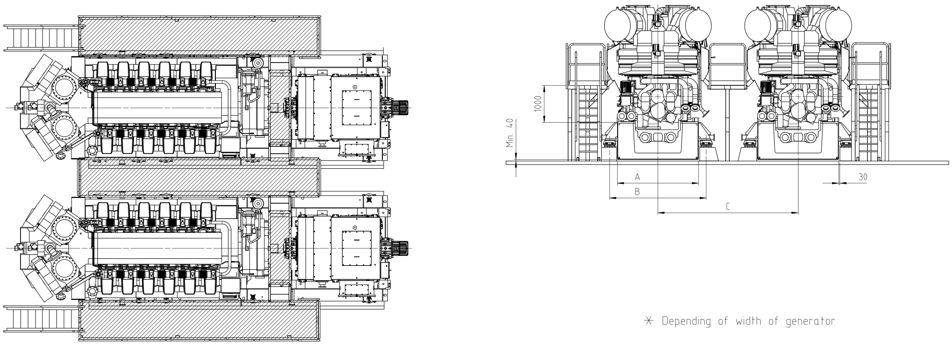


Fig 18-5 In-line engines, turbocharger in free end (DAAE082973C)

Engine	* A	* B	* C
W 6L32	1800	2110	Min. 3800
W 7L32	1800	2110	Min. 3800
W 8L32	1800	2110	Min. 3800
W 9L32	2000	2310	Min. 3800

All dimensions in mm.

*** Dependent on generator type.



✳ Depending of width of generator

ENGINE	✳A	✳B	✳C
12V	2200	2620	Min. 3800
16V	2200	2620	Min. 3800

Fig 18-6 V-engines, turbocharger in free end (DAAF073293A)

All dimensions in mm.

18.1.3 Father-and-son arrangement

When connecting two engines of different type and/or size to the same reduction gear the minimum crankshaft distance has to be evaluated case by case. However, some general guidelines can be given:

- It is essential to check that all engine components can be dismounted. The most critical are usually turbochargers and charge air coolers.
- When using a combination of in-line and v-engine, the operating side of in-line engine should face the v-engine in order to minimise the distance between crankshafts.
- Special care has to be taken checking the maintenance platform elevation between the engines to avoid structures that obstruct maintenance.

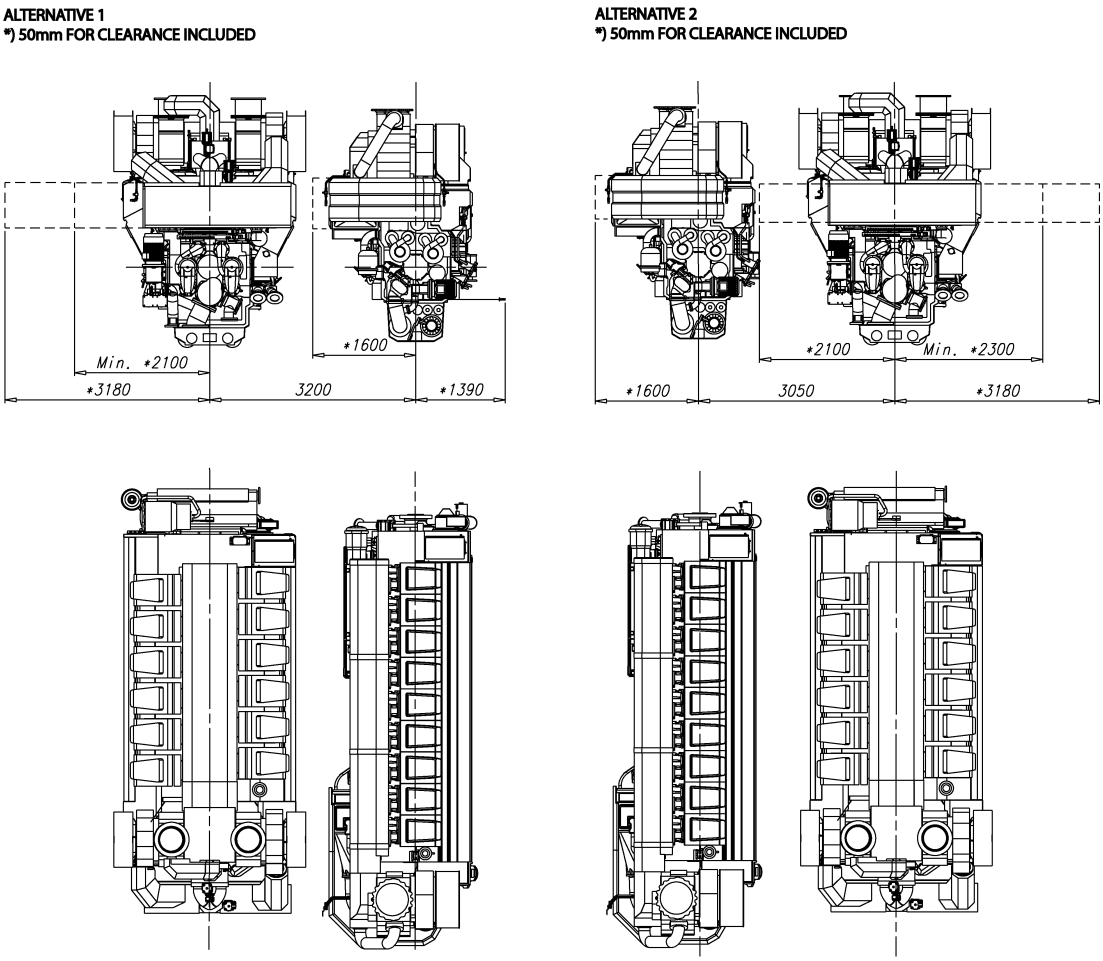


Fig 18-7 Example of father-and-son arrangement, 9L32 + 12V32, TC in free end (DAAE040264a)

All dimensions in mm.

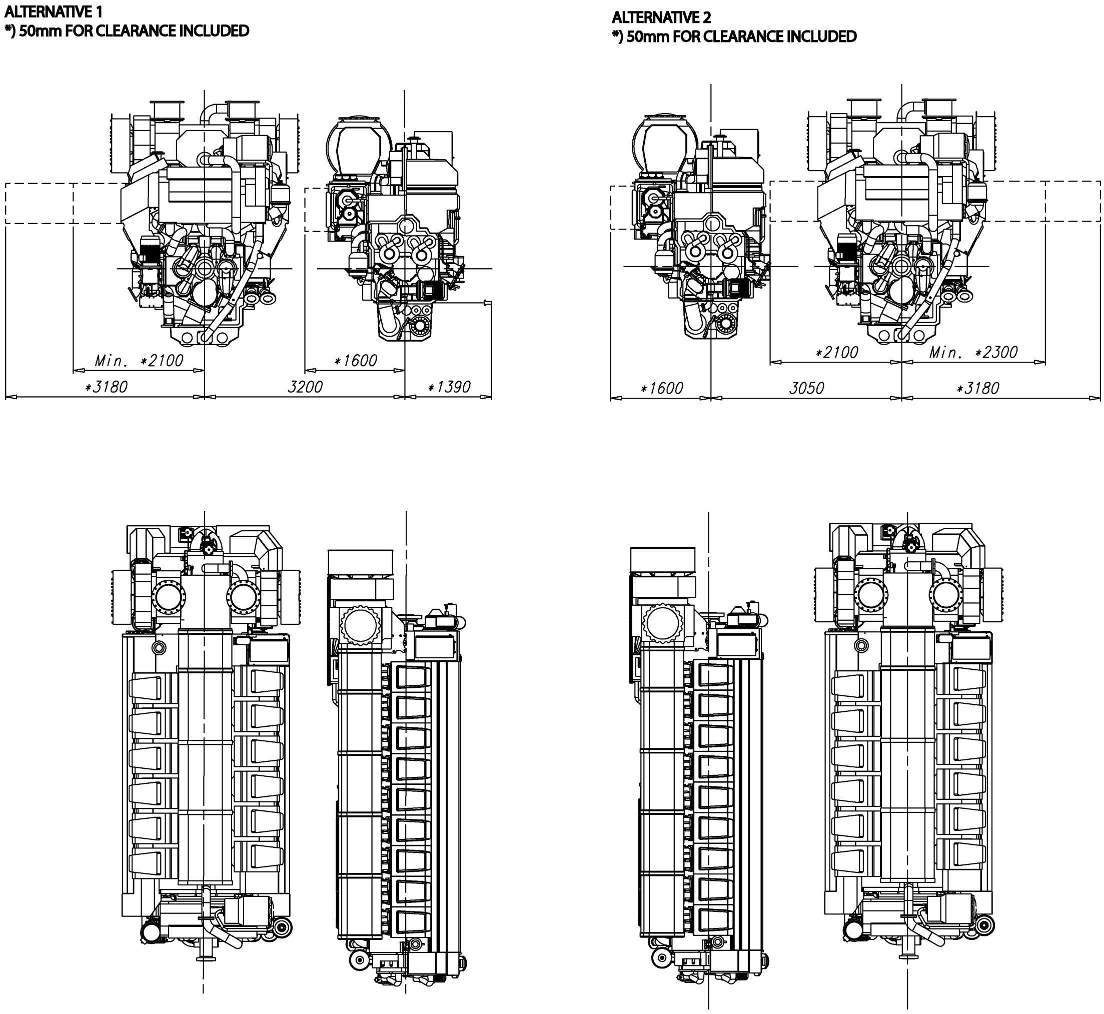


Fig 18-8 Example of father-and-son arrangement, 9L32 + 12V32, TC in flywheel end (DAAE057212)

All dimensions in mm.

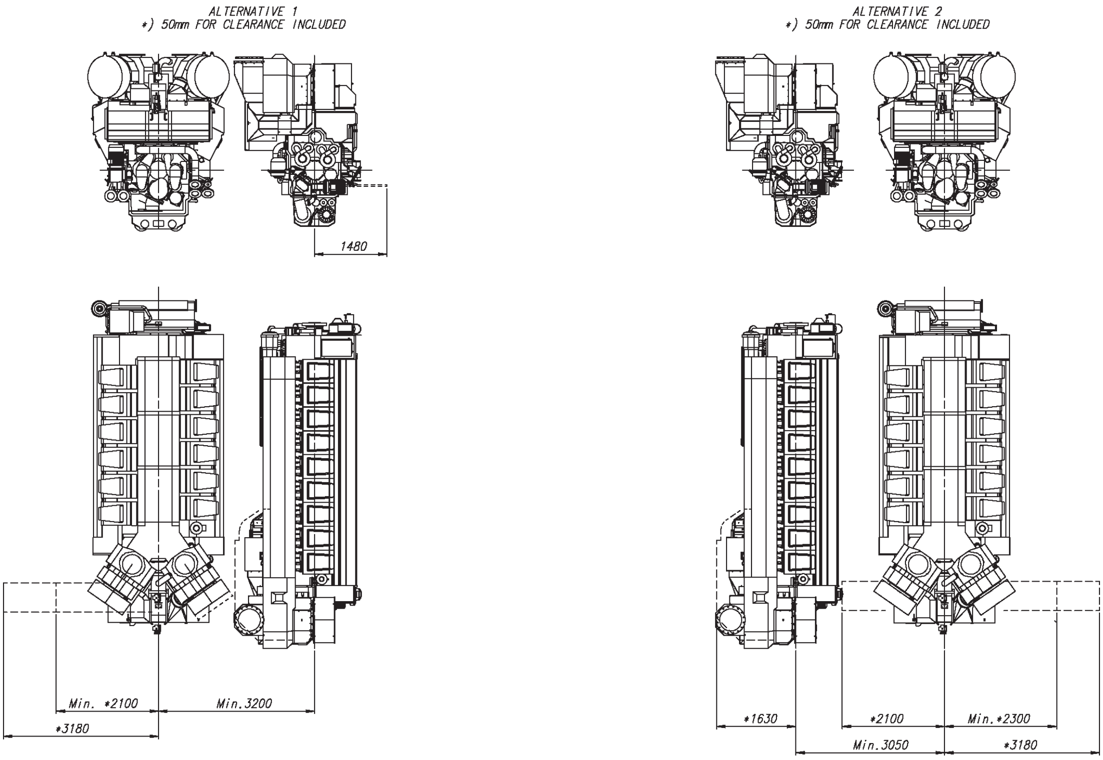


Fig 18-9 Example of father-and-son arrangement, 9L32 + 12V32, TC in free end (DAAF033143)

All dimensions in mm.

18.1.4 Distance from adjacent intermediate/propeller shaft

Some machinery arrangements feature an intermediate shaft or propeller shaft running adjacent to engine. To allow adequate space for engine inspections and maintenance there has to be sufficient free space between the intermediate/propeller shaft and the engine. To enable safe working conditions the shaft has to be covered. It must be noticed that also dimensions of this cover have to be taken into account when determining the shaft distances in order to fulfil the requirement for minimum free space between the shaft and the engine.

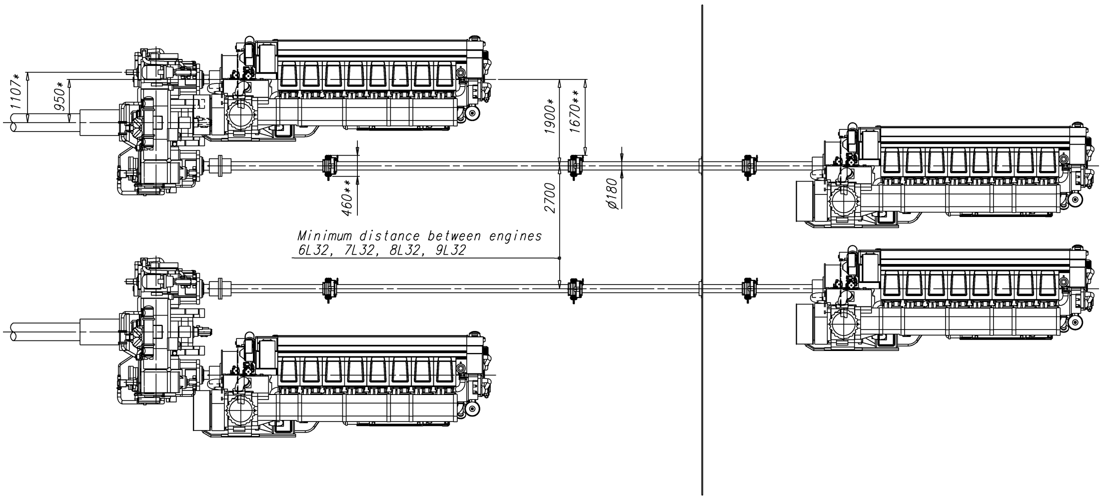


Fig 18-10 Main engine arrangement, in-line engines (DAAE059183)

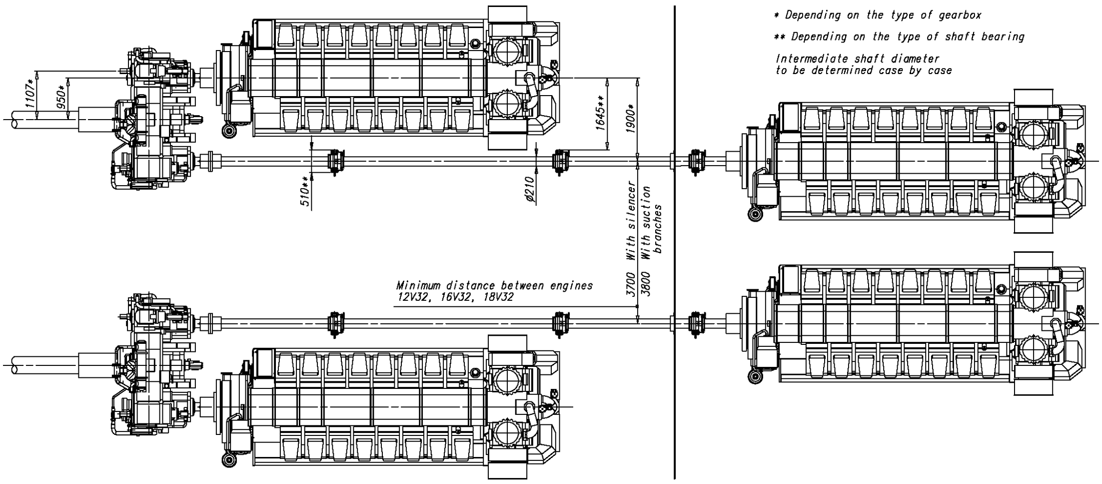


Fig 18-11 Main engine arrangement, V-engines (DAAE059181A)

Notes:
All dimensions in mm.
Intermediate shaft diameter to be determined case by case
* Depending on type of gearbox
** Depending on type of shaft bearing

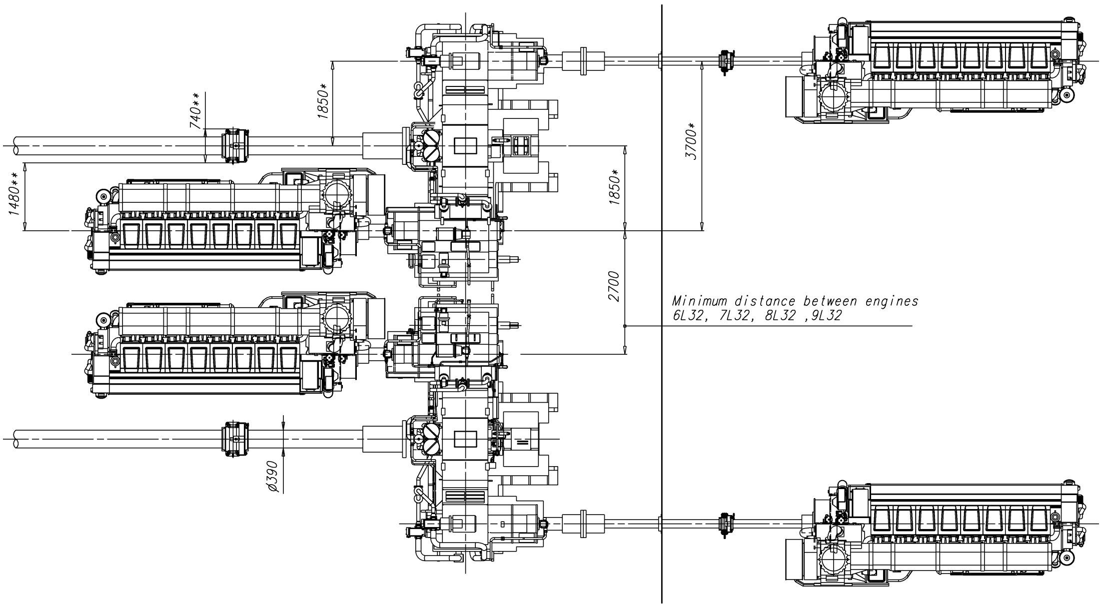


Fig 18-12 Main engine arrangement, in-line engines (DAAE059178)

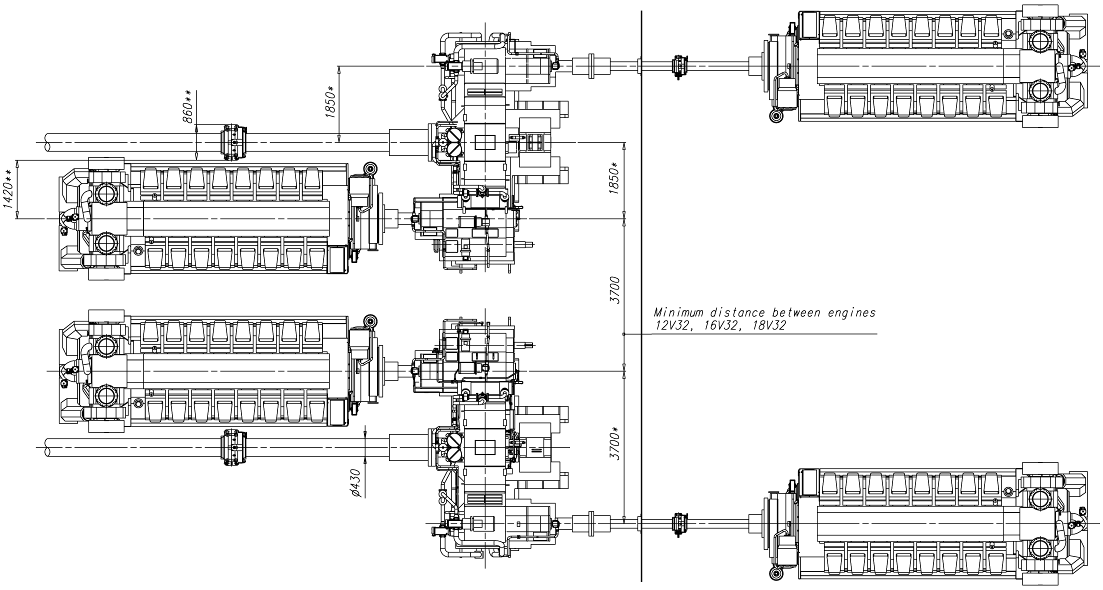


Fig 18-13 Main engine arrangement, V-engines (DAAE059176)

Notes:
All dimensions in mm.
Intermediate shaft diameter to be determined case by case
* Depending on type of gearbox
** Depending on type of shaft bearing

18.2 Space requirements for maintenance

18.2.1 Working space around the engine

The required working space around the engine is mainly determined by the dismounting dimensions of engine components, and space requirement of some special tools. It is especially important that no obstructive structures are built next to engine driven pumps, as well as camshaft and crankcase doors.

However, also at locations where no space is required for dismounting of engine parts, a minimum of 1000 mm free space is recommended for maintenance operations everywhere around the engine.

18.2.2 Engine room height and lifting equipment

The required engine room height is determined by the transportation routes for engine parts. If there is sufficient space in transverse and longitudinal direction, there is no need to transport engine parts over the rocker arm covers or over the exhaust pipe and in such case the necessary height is minimized.

Separate lifting arrangements are usually required for overhaul of the turbocharger since the crane travel is limited by the exhaust pipe. A chain block on a rail located over the turbocharger axis is recommended.

18.2.3 Maintenance platforms

In order to enable efficient maintenance work on the engine, it is advised to build the maintenance platforms on recommended elevations. The width of the platforms should be at minimum 800 mm to allow adequate working space. The surface of maintenance platforms should be of non-slippery material (grating or chequer plate).

NOTE
Working Platforms should be designed and positioned to prevent personnel slipping, tripping or falling on or between the walkways and the engine

18.3 Transportation and storage of spare parts and tools

Transportation arrangement from engine room to storage and workshop has to be prepared for heavy engine components. This can be done with several chain blocks on rails or alternatively utilising pallet truck or trolley. If transportation must be carried out using several lifting equipment, coverage areas of adjacent cranes should be as close as possible to each other.

Engine room maintenance hatch has to be large enough to allow transportation of main components to/from engine room.

It is recommended to store heavy engine components on slightly elevated adaptable surface e.g. wooden pallets. All engine spare parts should be protected from corrosion and excessive vibration.

On single main engine installations it is important to store heavy engine parts close to the engine to make overhaul as quick as possible in an emergency situation.

18.4 Required deck area for service work

During engine overhaul some deck area is required for cleaning and storing dismantled components. Size of the service area is dependent of the overhauling strategy chosen, e.g. one cylinder at time, one bank at time or the whole engine at time. Service area should be plain steel deck dimensioned to carry the weight of engine parts.

18.4.1 Service space requirement for the in-line engine

18.4.1.1 Service space requirement, turbocharger in free end

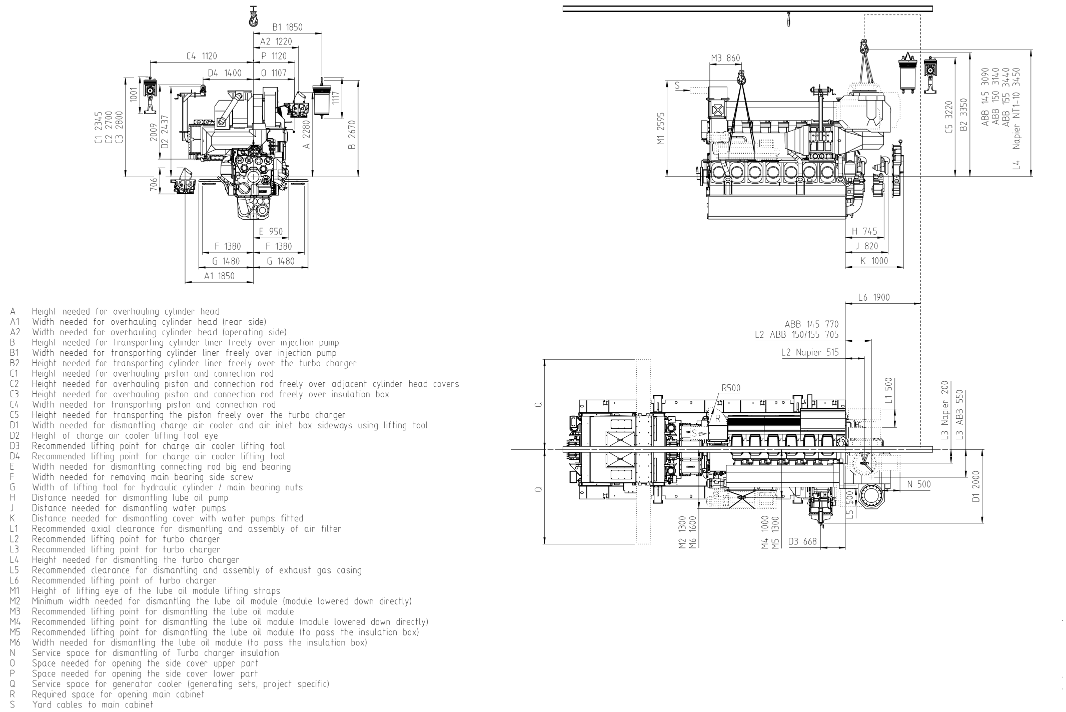


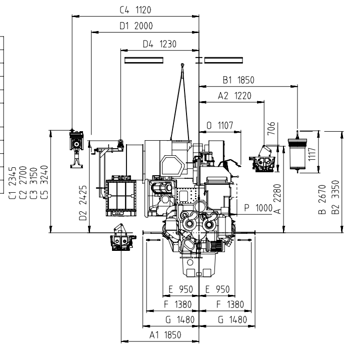
Fig 18-14 Service space requirement, turbocharger in free end (DAAF023936F)

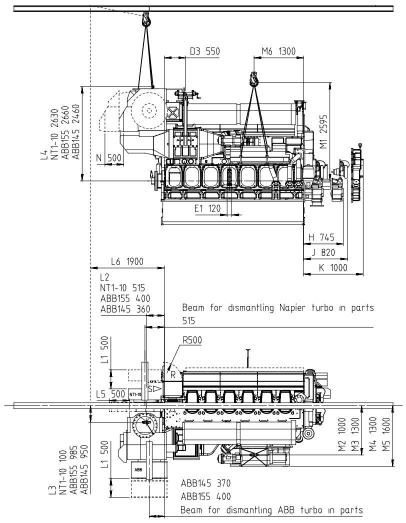
** Actual dimensions might vary based on power output and turbocharger maker.*

18.4.1.2 Service space requirement, turbocharger in driving end

Approximate engine component weights [kg]

Complete turbo charger ABB145 (6L)	850
(air inlet, compressor, cartride can be individually removed)	
Complete turbo charger ABB155 (8L, 9L)	1 800
(lifted in parts; casing 500kg, cartridge 360kg, compressor 280kg)	
Complete turbo charger Napier NT1-10 (6L-9L)	1 250
(lifted in parts; outlet casing 350kg, main casing 350kg, compressor casing 300kg)	
Charge air cooler + lifting tool	900+150
Lube oil module (lifted in parts, main housing 320kg)	700
Cylinder head	400
Cylinder liner	300
Piston + connecting rod	200





Above: Example of monorail crane beam arrangement
For maintenance convenience a versatile overhead crane min 2T is recommended

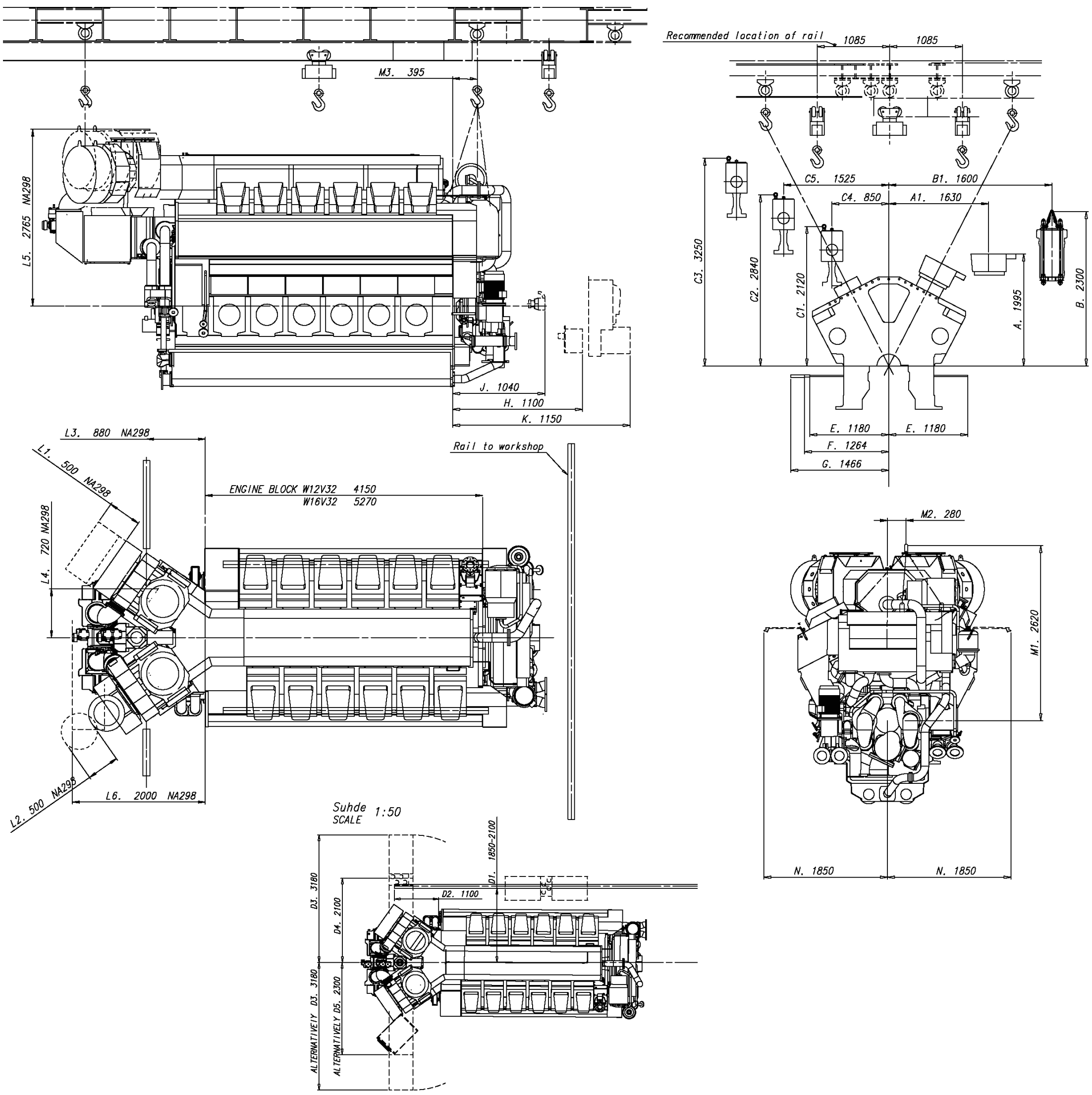
Service space drawing information subject to project specific consideration

- A Height needed for overhauling cylinder head
- A1 Width needed for overhauling cylinder head (rear side)
- A2 Width needed for overhauling cylinder head (operating side)
- B Height needed for transporting cylinder liner freely over injection pump
- B1 Width needed for transporting cylinder liner freely over injection pump
- B2 Height needed for transporting cylinder liner freely over the turbo charger
- C1 Height needed for overhauling piston and connection rod
- C2 Height needed for overhauling piston and connection rod freely over adjacent cylinder head covers
- C3 Height needed for overhauling piston and connection rod freely over gas manifold
- C4 Width needed for transporting piston and connection rod
- C5 Height needed for transporting the piston freely over the turbo charger
- D1 Width needed for dismantling charge air cooler and air inlet box sideways using lifting tool
- D2 Height of charge air cooler lifting tool eye
- D3 Recommended lifting point for charge air cooler lifting tool
- D4 Recommended lifting point for charge air cooler lifting tool
- E Width needed for dismantling connecting rod big end bearing
- E1 Width of big end bearing mounting slide
- F Width needed for removing main bearing side screw
- G Width of lifting tool for hydraulic cylinder / main bearing nuts
- H Distance needed for dismantling lube oil pump
- J Distance needed for dismantling water pumps
- K Distance needed for dismantling cover with water pumps fitted
- L1 Recommended axial clearance for dismantling and assembly of air filter
- L2 Recommended lifting point for complete turbo charger
- L3 Recommended lifting point for complete turbo charger
- L4 Height needed for dismantling the turbo charger
- L5 Recommended clearance for dismantling and assembly of exhaust gas casing
- L6 Recommended lifting point of turbo charger
- M1 Height of lifting eye of the lube oil module lifting straps
- M2 Recommended lifting point for dismantling the lube oil module (module lowered down directly)
- M3 Minimum width needed for dismantling the lube oil module (module lowered down directly)
- M4 Recommended lifting point for lifting the lube oil module (to pass the insulation box)
- M5 Minimum width needed for lifting the lube oil module (to pass the insulation box)
- M6 Recommended lifting point for lube oil module
- N Service space for dismantling of Turbo charger insulation
- O Space needed for opening the side cover upper part
- P Space needed for access to electrical rquipment
- R Required space for opening main cabinet
- S Yard cables to main cabinet

Fig 18-15 Service space requirement, turbocharger in driving end (DAAF484922A)

18.4.2 Service space requirement for the V-engine

18.4.2.1 Service space requirement, turbocharger in driving end



A. Hight needed for overhauling cylinder head
A1. Width needed for overhauling cylinder head
B. Hight needed for overhauling cylinder liner
B1. Width needed for overhauling cylinder liner
C1. Height needed for overhauling piston and connecting rod
C2. Height needed for transporting piston and connecting rod freely over adjacent cylinder head covers
C3. Height needed for transporting piston and connecting rod freely over exaust gas insulation box
C4-5. Width needed for transporting piston and connecting rod
D1. Recommended location of rail for removing the CAC either on A- or B-bank.
D2. Recommended location of starting point for rails.
D3. Width needed for dismantling the whole CAC either from A-bank or B-bank. (Advantage: CAC can be pressure tested before assembly)
D4. Minimum width needed for dismantling CAC from B-bank when CAC is divided into 3 parts before turning 90°. (Pressure test in place)
D5. Minimum width needed for dismantling CAC from A-bank when CAC is divided into 3 parts before turning. (Pressure test in place)
E. Width needed for removing main bearing side screw
F. Width needed for dismantling connecting rod big end bearing
G. Width of lifting tool for hydraulic cylinder/main bearing nuts
H. Distance needed to dismantle lube oil pump
J. Distance needed to dismantle water pumps
K. Distance needed to dismantle pump cover with fitted pumps
L1. The recommended axial clearance for dismantling and assembling of silencer is 500mm, minimum clearance is 120mm for NA298 The given dimension for L1 includes the minimum maintenance space.
L2. The recommended axial clearance for dismantling and assembling of suction branches is 500mm, minimum clearance is 120mm for NA298 The given dimension for L2 includes the minimum maintenance space .
L3. Recommended lifting point for the turbocharger
L4. Recommended lifting point sideways for the turbocharger
L5. Height needed for dismantling the turbocharger
L6. Recommended space needed to dismantle insulation, (CAC overhaul)
M1. Height of lube oil module lifting tool eye
M2. Width of lube oil module lifting tool eye
M3. Width of lube oil module lifting tool eye
N. Space necessary for opening the side cover

Ⓐ

Fig 18-16 Service space requirement, turbocharger in driving end (DAAF059974A)

18.4.2.2 Service space requirement, turbocharger in free end

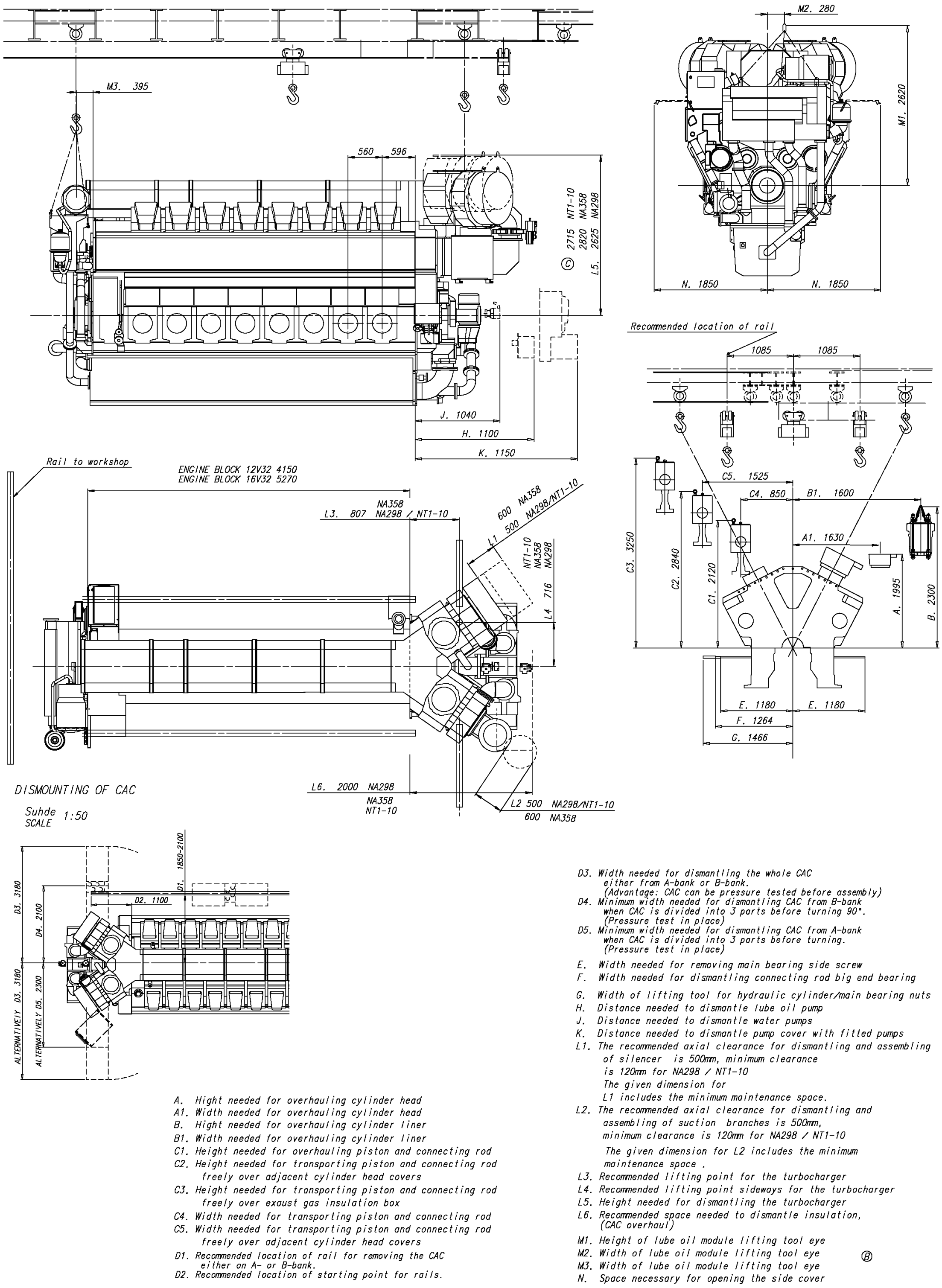


Fig 18-17 Service space requirement, turbocharger in free end (DAAF064757C)

18.4.2.3 Service space requirement, genset

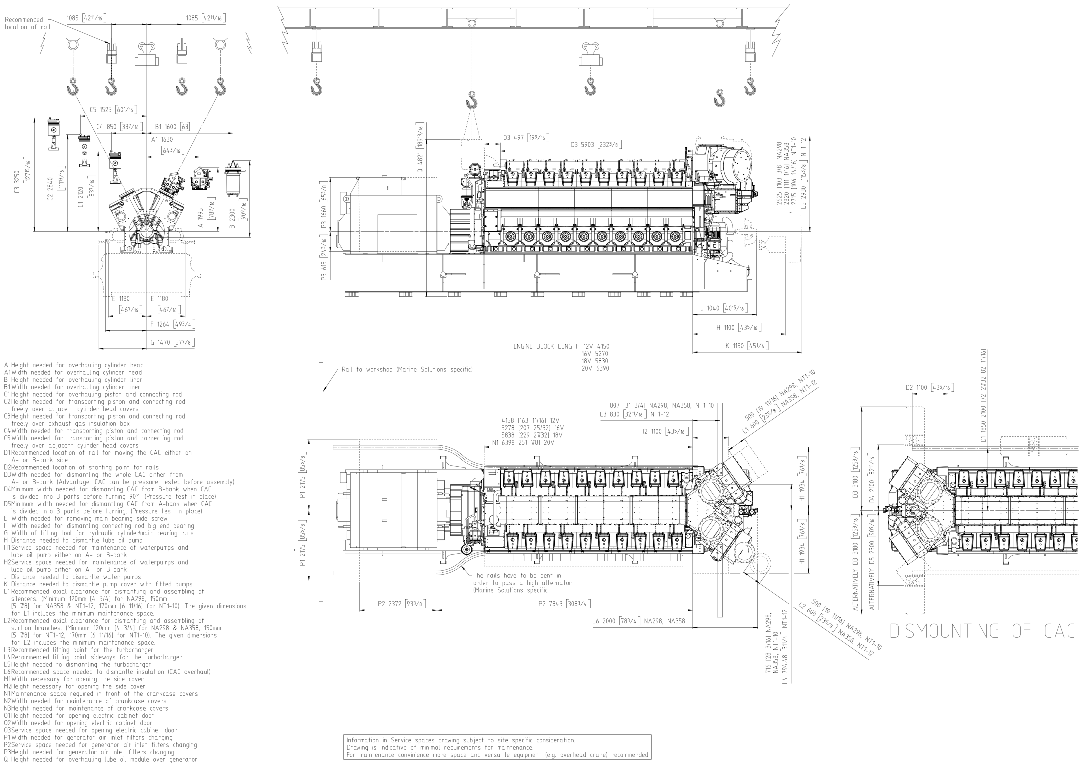


Fig 18-18 Service space requirement, genset (DAAF032607G)

** Actual dimensions might vary based on power output and turbocharger maker.*

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19. Transport Dimensions and Weights

19.1 Lifting of main engines

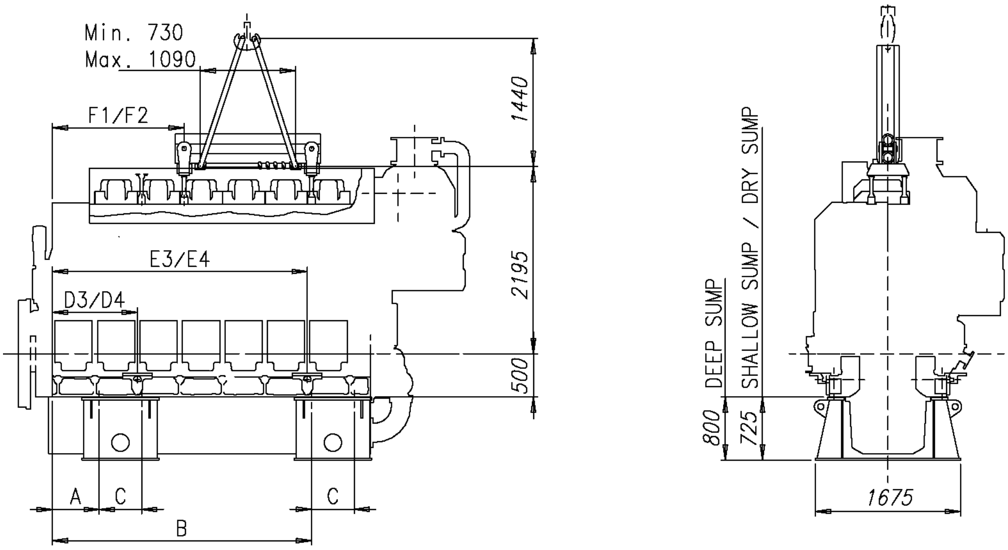

Fig 19-1 Lifting of main engines, in-line engines (2V83D0253F)

All dimensions in mm.

Transport bracket weight = 890 kg.

Engine	A	B	C	F1*	F2*	D3*	D4*	E3*	E4*
W 6L32	540	2990	490	1520	1030	980	980	2940	2940
W 7L32	540	3480	490	1520	1520	490	980	2940	3430
W 8L32	540	3970	490	2010	1520	490	980	3430	3920
W 9L32	540	4460	490	2010	1520	490	980	3920	4410

* 1 = Turbocharger in free end

2 = Turbocharger in driving end

3 = Rear side (B-bank)

4 = Operating side (A-bank)

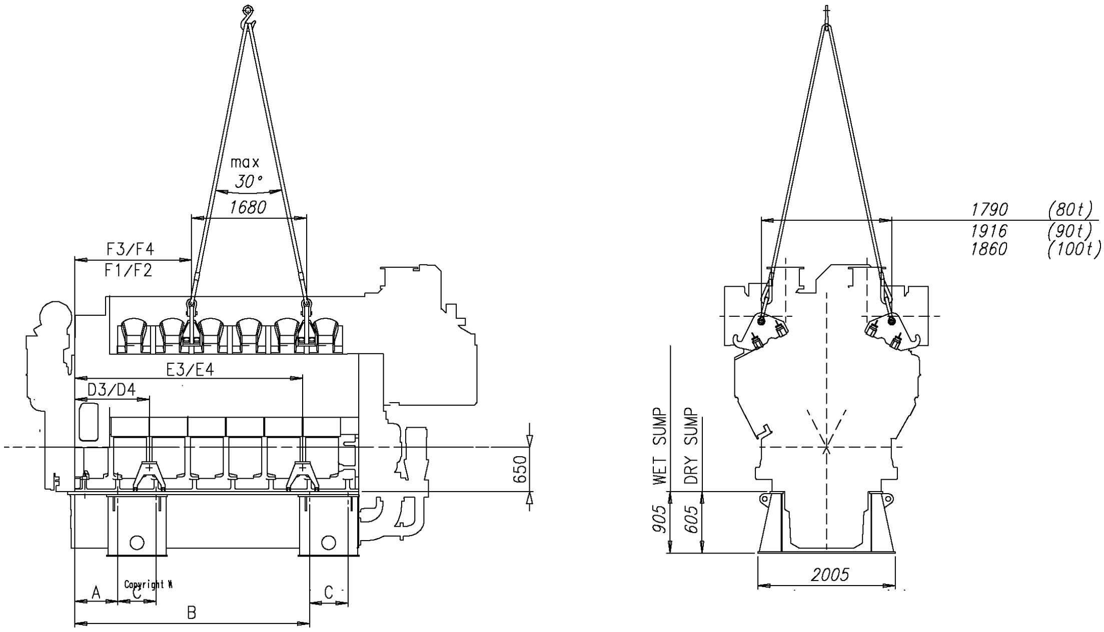

Fig 19-2 Lifting of main engines, V-engines (2V83D0253F)

All dimensions in mm.

Transport bracket weight = 935 kg.

Engine	A	B	C	D3	D4	E3, E4	F1, F4	F1, F3	F2, F4	F2, F3
W 12V32	630	3430	560	1090	530	3330	1594	1706	1034	1146
W 16V32	630	4550	560	1090	530	4450	2154	2266	1594	1706

* 1 = Turbocharger in free end

2 = Turbocharger in driving end

3 = Rear side (B-bank)

4 = Operating side (A-bank)

19.2 Lifting of generating sets

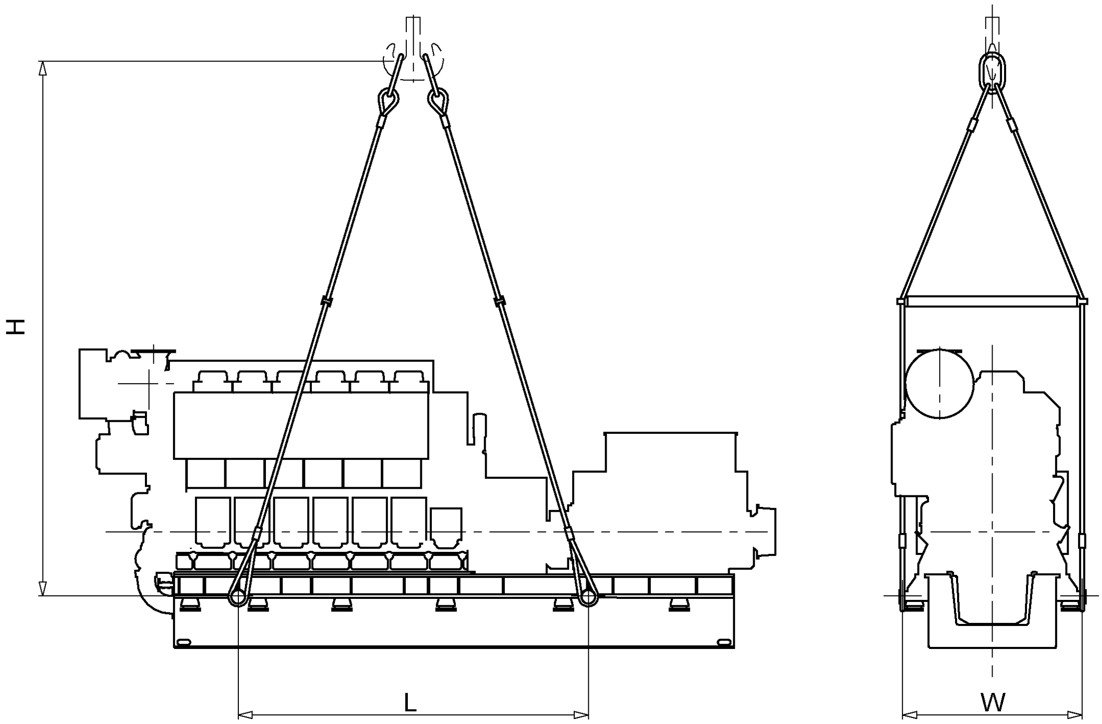

Fig 19-3 Lifting of generating sets (3V83D0251C, -252B)

Engine	H [mm]	L [mm]	W [mm]
W L32	6595...6685	4380...6000	2240...2645
W V32	6900...9400	5500...9400	2940...3275

19.3 Engine components

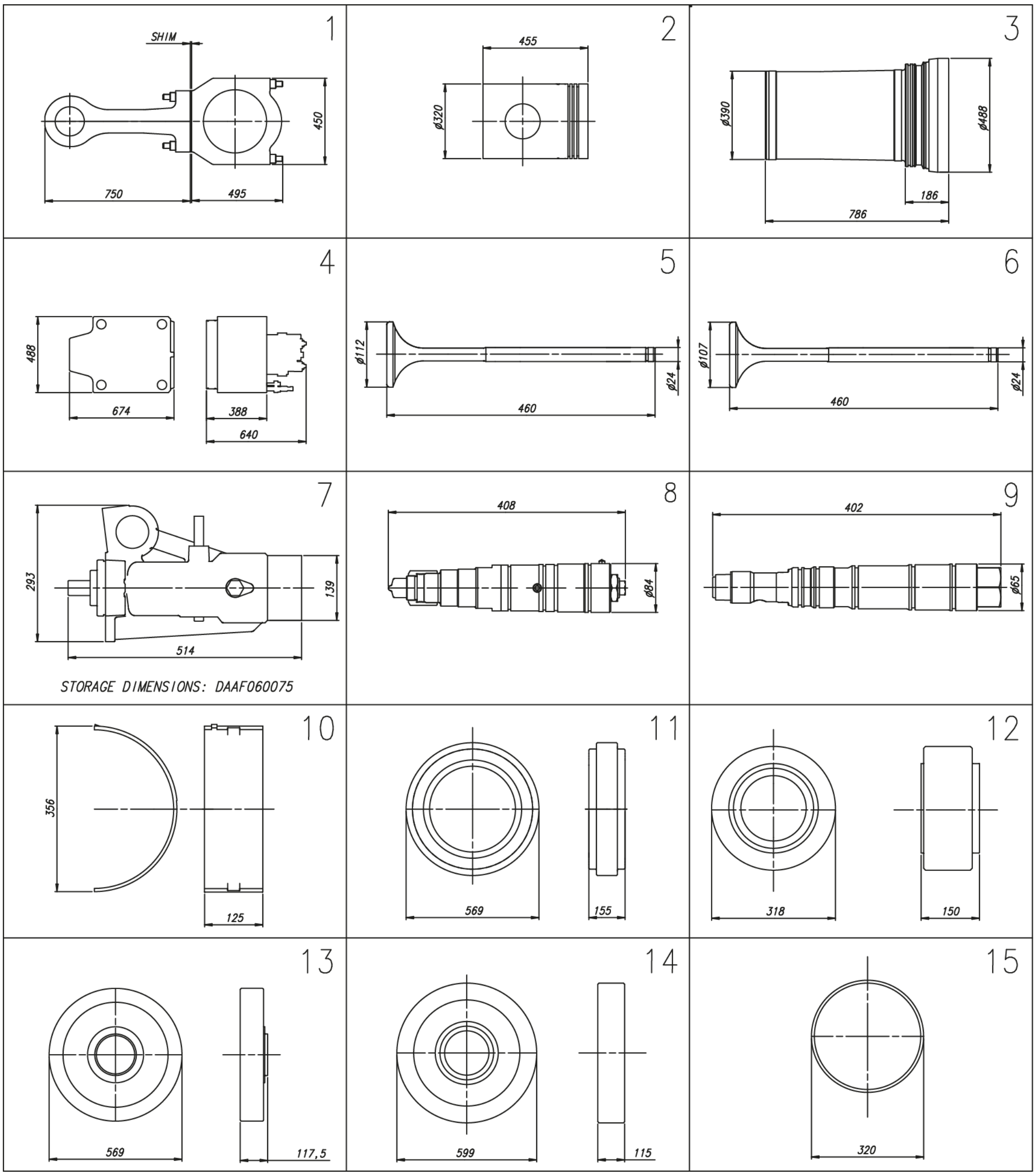

Fig 19-4 Major spare parts, (DAAF049715A)

Table 19-1 Weights for DAAF049715A

Item no	Description	Weight [kg]	Item No	Description	Weight [kg]
1	Connecting rod	157.0	9	Starting valve	6.4
2	Piston	82.0	10	Main bearing shell	7.3
3	Cylinder liner	300	11	Split gear wheel	121.0
4	Cylinder head	400	12	Small intermediate gear	49.0
5	Inlet valve	3.0	13	Large intermediate gear	113.0
6	Exhaust valve	3.0	14	Camshaft gear wheel	132.0

Table 19-1 Weights for DAAF049715A (continued)

Item no	Description	Weight [kg]	Item No	Description	Weight [kg]
7	Injection pump	50.0	15	Piston ring set	1.5
8	Injection valve	9.4			

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20. Product Guide Attachments

This and all other product guides can be accessed on the internet, at www.wartsila.com. Product guides are available both in web and PDF format. Engine outline drawings are available not only in *2D* drawings (in PDF, DXF format), but also in *3D* models. Please consult your sales contact at Wärtsilä for more information.

Engine outline drawings are not available in the printed version of this product guide.

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21. ANNEX

21.1 Unit conversion tables

The tables below will help you to convert units used in this product guide to other units. Where the conversion factor is not accurate a suitable number of decimals have been used.

Length conversion factors

Convert from	To	Multiply by
mm	in	0.0394
mm	ft	0.00328

Mass conversion factors

Convert from	To	Multiply by
kg	lb	2.205
kg	oz	35.274

Pressure conversion factors

Convert from	To	Multiply by
kPa	psi (lbf/in^2)	0.145
kPa	lbf/ft^2	20.885
kPa	inch H_2O	4.015
kPa	foot H_2O	0.335
kPa	mm H_2O	101.972
kPa	bar	0.01

Volume conversion factors

Convert from	To	Multiply by
m^3	in^3	61023.744
m^3	ft^3	35.315
m^3	Imperial gallon	219.969
m^3	US gallon	264.172
m^3	l (litre)	1000

Power conversion

Convert from	To	Multiply by
kW	hp (metric)	1.360
kW	US hp	1.341

Moment of inertia and torque conversion factors

Convert from	To	Multiply by
kgm^2	lbft^2	23.730
kNm	lbf ft	737.562

Fuel consumption conversion factors

Convert from	To	Multiply by
g/kWh	g/hph	0.736
g/kWh	lb/hph	0.00162

Flow conversion factors

Convert from	To	Multiply by
m^3/h (liquid)	US gallon/min	4.403
m^3/h (gas)	ft^3/min	0.586

Temperature conversion factors

Convert from	To	Multiply by
°C	F	F = 9/5 *C + 32
°C	K	K = C + 273.15

Density conversion factors

Convert from	To	Multiply by
kg/m^3	lb/US gallon	0.00834
kg/m^3	lb/Imperial gallon	0.01002
kg/m^3	lb/ft^3	0.0624

21.1.1 Prefix

Table 21-1 The most common prefix multipliers

Name	Symbol	Factor	Name	Symbol	Factor	Name	Symbol	Factor
tera	T	10^{12}	kilo	k	10^{3}	nano	n	10^{-9}
giga	G	10^{9}	milli	m	10^{-3}			
mega	M	10^{6}	micro	μ	10^{-6}			

21.2 Collection of drawing symbols used in drawings

INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
1 2101		Valve (general)
2 X8068		Valve, globe type
3 X8071		Valve, ball type
4 X8074		Valve, gate type
5 X8075		Valve, butterfly type (Form 1)
6 X8075		Valve, butterfly type (Form 2)
7 X8076		Valve, needle type
8 X8087		Valve, control type, continuously operated
9 X8077		Check valve (general), (Two-way non-return valve; flow from left to right)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
10 X2113		Check valve globe type
11 X8078		Swing check valve (Form 1)
12 X8165		Swing check valve (Form 2)
13 X2124		Safety valve, spring loaded, globe type
14 X1021		Manual operation of valve
15 X2001		Weight-loaded safety valve detained in open position after operation
16 X2134		Float-operated control valve

INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
17 X2131		Control valve with electric motor actuator
18 X2103		Two-way valve with solenoid actuator
19		Two-way valve with double-acting cylinder actuator (pneumatic)
20 X2104		Two-way valve with electric motor actuator
21 X2101		Two-way valve with diaphragm actuator (pneumatic)
22		Two-way control valve with diaphragm actuator (pneumatic)
23 X2002		Spring-loaded safety two-way valve with automatic return after operation

Fig 21-1 List of symbols (DAAF406507A - 1)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
24		Manually operated control valve
25 X2112		Combinated non-return valve and manually actuated stop valve. Flow from left to right
26		Spring-loaded non-return valve. Flow from left to right
27 X2133		Self-operating pressure reducing control valve
28		Pressure control valve (spring loaded)
29		Pressure control valve (remote pressure sensing)
30		Pneumatically actuated valve, apring-loaded cylinder actuator
31		Quick-closing valve
32 2103		Valve, three way type (general)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
33 X8070		Valve, three way globe type
34 X8073		Valve, three way ball type
35		Three-way control valve with electrical motor actuator
36 X2103		Three-way valve with solenoid actuator
37 X2107		Three-way valve with double-acting cylinder actuator (pneumatic)
38		Three-way valve with electric motor actuator
39 X2102		Three-way valve with diaphragm actuator

INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
40		Three-way control valve with diaphragm actuator
41		Self-operating pressure reducing three-way control valve
42		Self-operating thermostatic three-way control valve
43		Self-contained thermostat valve
44 2102		Valve, angle type (general)
45 X8069		Valve, angle globe type

Fig 21-2 List of symbols (DAAF406507A - 2)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
46 X8072		Valve, angle ball type
47 X2125		Safety valve, spring loaded, globe angle type
48		Weight loaded angled valve detained in open position after operation
49		Spring-loaded safety angled valve with automatic return after operation
50		Non-return angled two-way valve. Flow from left to right
51		Non-return angled two-way valve hand operating. Flow from left to right
52 2181		Self-operating release valve (steam trap)
53 X2212		Adjustable restrictor (valve)
54 2031		Restrictor
55 772		Orifice plate
56 X2182		Shuttle valve with "AND-function"
57		Valve 2/2 Pneum/Pneum
58		Valve 2/2 Pneum/Spring
59		Valve 2/2 Solenoid/Spring
60		Valve 2/2 Lever/Spring
61		Valve 2/2 Manual/Spring
62		Valve 3/2 Pneum/Pneum
63		Valve 3/2 Pneum/Spring
64		Valve 3/2 Solenoid/Spring
65		Valve 3/2 Lever/Spring
66		Valve 3/2 Manual/Spring
67		Valve 4/2 Pneum/Pneum

Fig 21-3 List of symbols (DAAF406507A - 3)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
68		Valve 4/2 Pneum/Spring
69		Valve 4/2 Solenoid/Spring
70		Valve 4/2 Lever/Spring
71		Valve 4/2 Manual/Spring
72		Turbogenerator
73		Turbogenerator with gear transmission
74		Turbocharger
75 C0082		Electric motor (general)
76		Electrically driven pump
77		Electrically driven compressor
78 2302		Compressor, vacuum pump (general)
79 2301		Pump, liquid type (general)
80 2401		Hydraulic pump
81		Manual hydraulic pump
82 X2071		Boiler feedwater vessel with deaerator
83 2501		Heating or cooling coil
84 X8079		Heat exchanger (general), condenser
85 X2674		Pneumatic-air lubricator
86 X8111		Cooling tower, dry with induced draught
87 2521		Cooling tower (general) (Deaerator)
88 2040		Funnel
89		Trough or drip tray with drain funnel

Fig 21-4 List of symbols (DAAF406507A - 4)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617

POS Reg. No.	SYMBOL	DESCRIPTION
90 517		Flanged dummy cover (Blind flange pair)
91 511		Flanged connection
92 518		End cap
93 514		Screwed joint
94 516		Reducer
95		Joint with change of pipe dimension, pipe reducer eccentric
96 565		Quick-release coupling element which fits into another coupling element of the same type
97 567		Quick-release coupling element of female type with automatic closing when decoupled
98 566		Quick-release coupling element of male type with automatic closing when decoupled

INTERNATIONAL STANDARD ISO 10628 and ISO 14617

POS Reg. No.	SYMBOL	DESCRIPTION
99 564		Quick-release coupling element of female type
100 563		Quick-release coupling element of male type
101 X411		Hose
102 532		Expansion sleeve
103 533		Compensator (Expansion bellows)
104 2038		Siphon
105 2039		Vent (outlet to the atmosphere for steam/gas)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617

POS Reg. No.	SYMBOL	DESCRIPTION
106		Air vent + flame arrestor
107 2036		Flame arrestor
108 X322		Pipeline with thermal insulation
109 X8174		Piping, heated or cooled and insulated
110 X2619		High speed centrifuge (Separator)
111 X2614		Centrifuge with perforated shell (Centrifugal filter)

Fig 21-5 List of symbols (DAAF406507A - 5)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617

POS Reg. No.	SYMBOL	DESCRIPTION
112 X8116		Liquid filter (general)
113 X8117		Liquid filter, bag, candle or cartridge type
114		Automatic filter with by-pass filter
115 X8019		Suction filter
116 X8119		Liquid rotary filter, drum or disc type
117		Duplex filter
118		Candle filter with rotaing drum with by-pass
119 X8122		Gas filter (general)
120 X8022		Gas filter, bag, candle or cartridge type

INTERNATIONAL STANDARD ISO 10628 and ISO 14617

POS Reg. No.	SYMBOL	DESCRIPTION
121 X8123		Screening device, sieve, strainer, general
122 X8031		Gravity separator, settling chamber
123 X2618		Separator, cyclone type
124 X8090		Strainer
125 2073		Pressure vessel with diaphragm, for example expansion vessel
126 2062		Pressure or vacuum vessel
127 301		Tank, vessel

INTERNATIONAL STANDARD ISO 10628 and ISO 14617

POS Reg. No.	SYMBOL	DESCRIPTION
128 X2069		Vessel with dished ends and heating / cooling jacket
129 2033		Silencer
130 2034		Viewing glass
131		Receiver, pulse damper
132		Indicating measuring instrument P = Pressure 1066 T = Temperature 1070 V = Viscosity 1072 F = Flow rate 1056
133		Local instrument

Fig 21-6 List of symbols (DAAF406507A - 6)

INTERNATIONAL STANDARD
ISO 10628 and ISO 14617

POS Reg. No.	SYMBOL	DESCRIPTION
134		Local panel
135		Signal to control board
136		TI = Temperature indicator TE = Temperature sensor TEZ = Temperature sensor shut-down PI = Pressure indicator PS = Pressure switch PT = Pressure transmitter PSZ = Pressure switch shut-down PDIS = Differential pressure indicator and alarm LS = Level switch QS = Flow switch TSZ = Temperature switch
137 X2122		Overflow safety valve
138 X1048	FI	Flow rate indication
139 X1056	FRQ FT	Recording of flow rate with summation of volume
140 X1036		Automatic operation of valve with infinite number of stable positions

INTERNATIONAL STANDARD
ISO 10628 and ISO 14617

POS Reg. No.	SYMBOL	DESCRIPTION
141 X1032		Automatic operation of valve with two stable positions open and close
142 2006		Bearing
143 X8080		Rupture disc
144 513		Clamped flange coupling
145 C0100		Coupling
146 X2231		Spring-loaded non-return valve
147 X2232		Pilot-operated non-return valve, closed by pilot pressure

INTERNATIONAL STANDARD
ISO 10628 and ISO 14617

POS Reg. No.	SYMBOL	DESCRIPTION
148 X2233		Pilot-operated non-return valve, opened by pilot pressure against return spring
149 X2192		Single-stage pressure-relief valve
150 X2199		Pressure-reducing valve
151 X2180		Shuttle valve with OR-function 1
152 X2180		Shuttle valve with OR-function 2

Fig 21-7 List of symbols (DAAF406507A - 7)

INTERNATIONAL STANDARD
ISO 10628 and ISO 14617

POS Reg. No.	SYMBOL	DESCRIPTION
153 2113		L-bore in a three-way valve
154 2114		T-bore in a three-way valve
155 2104		Four-way valve
156		four-way valve globe type
157		four-way valve ball type
158		L-bore in a four-way valve
159		T-bore in a four-way valve
160 2115		Double L-bore in a four-way valve
161 2127		Piston type; plunger type

INTERNATIONAL STANDARD
ISO 10628 and ISO 14617

POS Reg. No.	SYMBOL	DESCRIPTION
162 2126		Valve disc or butterfly type
163 X2114		Swing-type non-return valve
164 X2115		Spring-loaded ball-type non-return valve
165		Spring-loaded globe-type non-return valve
166 X2121		Safety valve which opens when pressure p higher than set value
167 X2121		Pipe break valve which closes when flow rate q is higher than set value
168 X2124		Globe type spring-loaded safety valve operating when pressure p higher than set value

INTERNATIONAL STANDARD
ISO 10628 and ISO 14617

POS Reg. No.	SYMBOL	DESCRIPTION
169 X2125		Angled, globe-type, spring-loaded vacuum valve operating when pressure p lower than set value
170		Angled, globe-type, spring-loaded vacuum valve operating when pressure p higher than set value
171 2123		Valve Plug type
172		Manual operation of Three-way valve

Fig 21-8 List of symbols (DAAF406507A - 8)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
173		Valve body 2 position 2-3-4 port
174		Valve body 2 position 5 port
175		Valve body 3 position 2-3-4 port
176		Valve body 3 position 5 port
177		Valve body 4 position 2-3-4 port
178		Valve body 4 position 5 port
179		2-2 Valve arrow up
180		2-2 Valve arrow down
181		2-2 Valve both arrows

INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
182		3-2 Valve 1
183		3-2 Valve 2
184		4-2 Valve 1
185		4-2 Valve 2
186		5-2 Valve 1
187		5-2 Valve 2
188		4-3 Valve open 1

INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
189		4-3 Valve open 2
190		4-3 Valve empty 1
191		4-3 Valve empty 2
192		5-3 Valve open 1
193		5-3 Valve open 2
194		5-3 Valve empty 1
195		5-3 Valve empty 2

Fig 21-9 List of symbols (DAAF406507A - 9)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
196		2-port closed
197		2-port single arrow
198		2-port double arrow
199		3-port single arrow
200		3-port double arrow
201		3-port crossover single arrow
202		3-port crossover double arrow
203		4-port
204		4-port closed

INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
205		4-port crossed
206		4-port tandem single arrow
207		4-port tandem double arrow
208		4-port crossover single arrow
209		4-port crossover double arrow
210		4-port open
211		4-port semi-connected

INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
212		5-port closed
213		5-port arrows same direction
214		5-port arrows opposite direction
215		5-port crossover arrows same
216		5-port crossover opposite arrows
217		5-port crossover arrows same up

Fig 21-10 List of symbols (DAAF406507A - 10)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
218		Spring for valve
219		Spring for valve variable
220 711		Plunger for valve
221		Plunger for valve variable
222		Roller for valve
223		Roller for valve variable
224		Manual override for valve
225		Pull / push button for valve
226		Lever for valve

INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
227		Pedal for valve
228		Electrical actuation for valve
229		Electrical actuation for valve variable
230		Pilot operation for valve
231		Exhaust port for valve
232 723		Single acting cylinder
233		Double ended cylinder

INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
234		Single acting cylinder with spring (1)
235		Single acting cylinder with spring (2)
236 724		Double acting cylinder

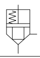
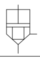
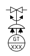
Fig 21-11 List of symbols (DAAF406507A - 11)

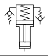
Wärtsilä specific symbols for P&I diagrams		
POS Reg. No.	SYMBOL	DESCRIPTION
238		Cam profile 1
239		Flywheel
240		Gear wheel
241		Spray nozzle
242		Leak collector
243		Oil sump
244		Dipstick 1
245		Dipstick 2
246		Cylinder

Wärtsilä specific symbols for P&I diagrams		
POS Reg. No.	SYMBOL	DESCRIPTION
247		Water tank
248		Description arrow for flow in one direction
249		Description arrow for flow in both directions
250		Line jump
251		Arrow for flow
252		Starting air distributor
253		Starting air distributor 2

Wärtsilä specific symbols for P&I diagrams		
POS Reg. No.	SYMBOL	DESCRIPTION
254		Bearing upper and lower
255		L-engine
256		V-engine
257		square heat exchanger
258		Starting air valve for cylinder head
259	XXX	External connection
260		Automatic filter

Fig 21-12 List of symbols (DAAF406507A - 12)

Wärtsilä specific symbols for P&I diagrams		
POS Reg. No.	SYMBOL	DESCRIPTION
261		Separator
262		Separator with filter
263		Filter
264		Flexible double wall pipe
265		Cartridge valve with spring
266		Cartridge valve
267		Revision mark
268		PT sensor with gauge valve
269		Hydraulic wastegate valve

Wärtsilä specific symbols for P&I diagrams		
POS Reg. No.	SYMBOL	DESCRIPTION
270		Booster for valve mechanism
271		
272		
273		
274		
275		
276		

Wärtsilä specific symbols for P&I diagrams		
POS Reg. No.	SYMBOL	DESCRIPTION
277		
278		
279		
280		
281		
282		

Fig 21-13 List of symbols (DAAF406507A - 13)

Wärtsilä is a global leader in complete lifecycle power solutions for the marine and energy markets. By emphasising technological innovation and total efficiency, Wärtsilä maximises the environmental and economic performance of the vessels and power plants of its customers.

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