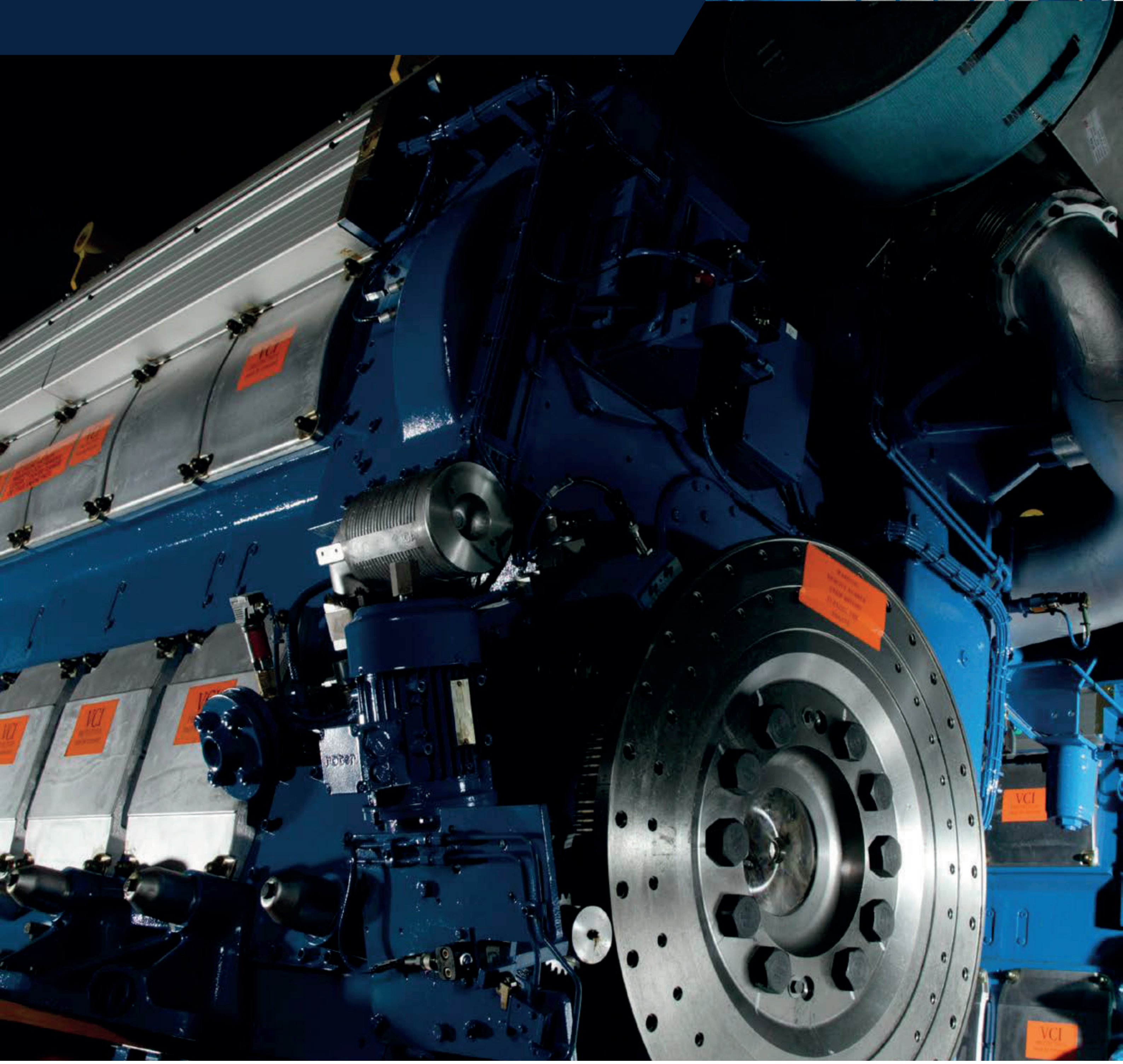
WÄRTSILÄ **Engines**

Wärtsilä 26

PRODUCT GUIDE



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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 1/2022 issue replaces all previous issues of the Wärtsilä 26 Project Guides.

Issue	Published	Updates
1/2022	08.03.2018	Technical data updated. Other updates throughout the Product Guide
1/2018	19.09.2018	Technical data updated. Other updates throughout the Product Guide
1/2017	30.11.2017	Technical data updated. Other updates throughout the Product Guide.
2/2016	27.09.2016	Technical data updated
1/2016	07.09.2016	Technical data section updated
1/2015	18.06.2015	Updates throughout the product guide

Wärtsilä, Marine Business

Vaasa, March 2022

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1. Main Data and Outputs

The Wärtsilä 26 is a 4-stroke, non-reversible, turbocharged and intercooled diesel engine with direct fuel injection.

Cylinder bore	260 mm
Stroke	320 mm
Piston displacement	17,0 l/cyl
Number of valves	2 inlet valves and 2 exhaust valves
Cylinder configuration	6, 8 and 9 in-line; 12 and 16 in V-form
V angle	55°
Direction of rotation	clockwise, counter-clockwise on request
Speed	900, 1000 rpm
Mean piston speed	9.6, 10.7 m/s

1.1 Maximum continuous output

Table 1-1 Rating table for Wärtsilä 26

Cylinder configuration	Main engines		Generating sets			
	900 rpm	1000 rpm	900 rpm		1000 rpm	
	[kW]	[kW]	[KVA]	[kWe]	[KVA]	[kWe]
6L26	1950	2040	2352	1882	2461	1969
8L26	2600	2720	3136	2509	3281	2625
9L26	2925	3060	3528	2823	3691	2953
12V26	3900	4080	4704	3764	4922	3937
16V26	5200	5440	6273	5018	6562	5250

The generator outputs are calculated for an efficiency of 96.5% and a power factor of 0.8. The maximum fuel rack position is mechanically limited to 110% of the continuous output for engines driving generators.

The mean effective pressure p_e 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:

P_e = mean effective pressure [bar]

P = output per cylinder [kW]

n = engine speed [rpm]

D = Cylinder diameter [mm]

L = length of piston stroke [mm]

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 through Wärtsilä website (an online tool called *Engine Online Configurator*). The stated specific fuel oil consumption applies to engines with engine driven pumps, operating in ambient conditions according to ISO 15550:2002 (E). The ISO standard reference conditions are:

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

Correction factors for the fuel oil consumption in other ambient conditions are given in standard ISO 15550:2002 (E).

1.3 Operation in inclined position

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

● Permanent athwart ship inclinations	15.0°
● Temporary athwart ship inclinations	22.5°
● Permanent fore-and-after inclinations	5.0°
● Temporary fore-and-after inclinations	7.5°

The inclination package option (deep wet sump design) gives the possibility to reach higher degree of inclination for W26 engines.

The inclinations that can be reached are here below summarized:

STATIC	TRIM Longitudinal	15°
	LIST Transversal	22.5°
DYNAMIC	PITCHING Longitudinal	15°
	ROLLING Transversal	22.5°

Larger angles are possible with special arrangements.

1.4 Dimensions and weights

1.4.1 Main engines

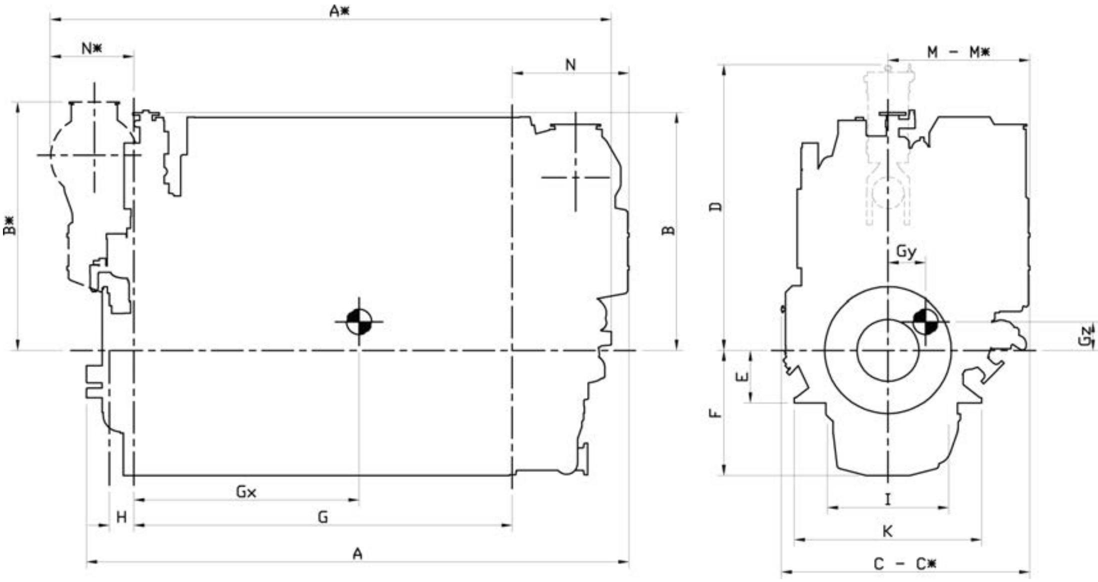


Fig 1-1 In-line engines (DAAE034755B)

Engine	A*	A	B*	B	C*	C	D	E	F_{wet}	F_{dry}	G
W 6L26	4387	4130	1882	1833	1960	2020	2430	400	950	818	2866
W 8L26	5302	5059	2023	1868	2010	2107	2430	400	950	818	3646
W 9L26	5691	5449	2023	1868	2016	2107	2430	400	950	818	4036

Engine	H	I	K	M*	M	N*	N	Weight	
								dry sump	wet sump
W 6L26	186	920	1420	1103	1171	669	904	17.0	17.2
W 8L26	186	920	1420	1167	1258	794	1054	21.6	21.9
W 9L26	186	920	1420	1167	1258	794	1054	23.3	23.6

Engine	Wet sump						Dry sump					
	Gx *	Gy *	Gz *	Gx	Gy	Gz	Gx *	Gy *	Gz *	Gx	Gy	Gz
W 6L26	1551	90	450	1300	90	450	1551	90	458	1300	90	458
W 8L26	2002	78	457	1704	78	457	2002	78	465	1704	78	465
W 9L26	2204	74	454	1921	74	454	2204	74	462	1921	74	462

* Turbocharger at flywheel end.

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

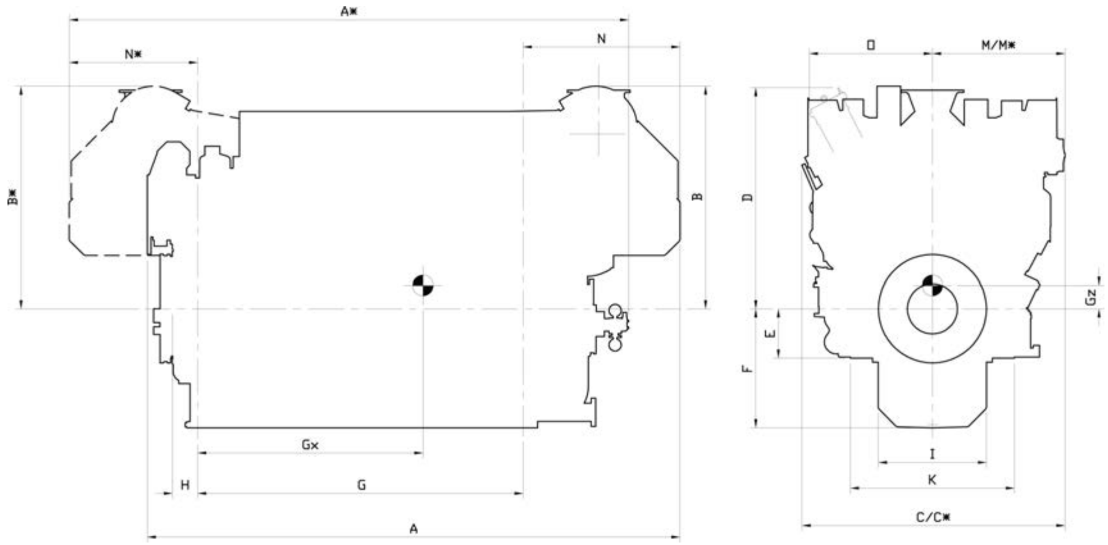


Fig 1-2 V-engines (DAAE034757B)

Engine	A*	A	B*	B	C*	C	D	E	F_{wet}	F_{dry}	G
W 12V26	5442	5314	2034	2034	2552	2602	2060	460	1110	800	3035
W 16V26	6223	6025	2151	2190	2489	2763	2060	460	1110	800	3875

Engine	H	I	K	M *	M	N *	N	O	Weight	
									dry sump	wet sump
W 12V26	235	1010	1530	1364	1238	1433	1698	1148	28.7	29.0
W 16V26	235	1010	1530	1248	1248	1363	1626	1160	36.1	37.9

Engine	Wet sump				Dry sump			
	Gx *	Gz *	Gx	Gz	Gx *	Gz *	Gx	Gz
W 12V26	1224	413	1811	413	1224	470	1811	470
W 16V26	1852	548	2258	548	1852	568	2258	568

* Turbocharger at flywheel end.

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

1.4.2 Generating sets

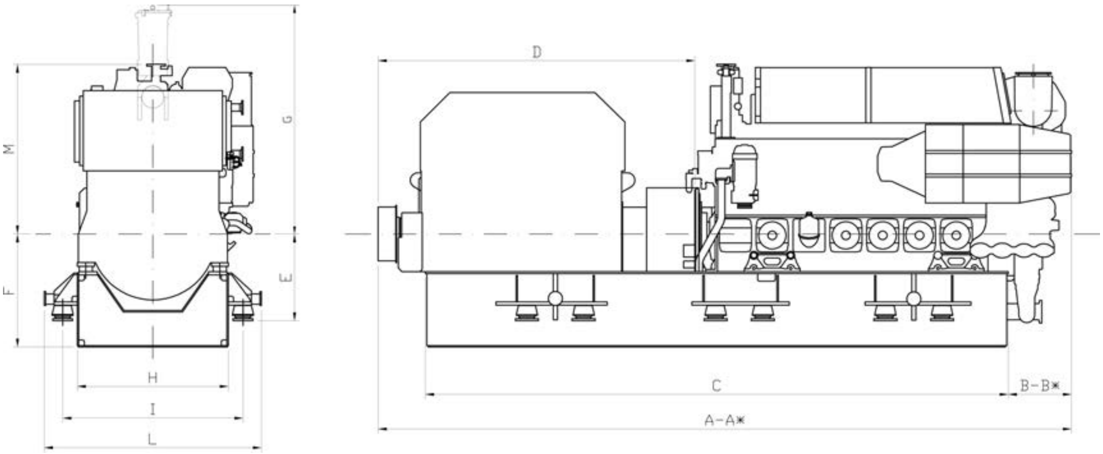


Fig 1-3 Generating sets (DAAE034758B)

Engine	A	A*	B	B*	C	D	E	F	G	H	I	L	M	Weight
W 6L26	7500	7500	835	702	6000	3200	921	1200	2430	1600	1910	2300	1833	35
W 8L26	8000	8000	835	702	7000	3300	921	1200	2430	1600	1910	2300	1868	45
W 9L26	8500	8500	835	702	7500	3400	921	1300	2430	1600	1910	2300	1868	50
W 12V26	8400	-	1263	-	6700	3600	981	1560	2765	2000	2310	2700	2126**	60
W 16V26	9700	-	1400	-	7730	4000	981	1560	2765	2000	2310	2700	2156**	70

* Turbocharger at flywheel end. ** TC inclination 30°

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

NOTE

Generating set dimensions are for indication only, based on low voltage generators. Final generating set dimensions and weights depend on selection of generator and flexible coupling.

2. Operating Ranges

2.1 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.

2.1.1 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.

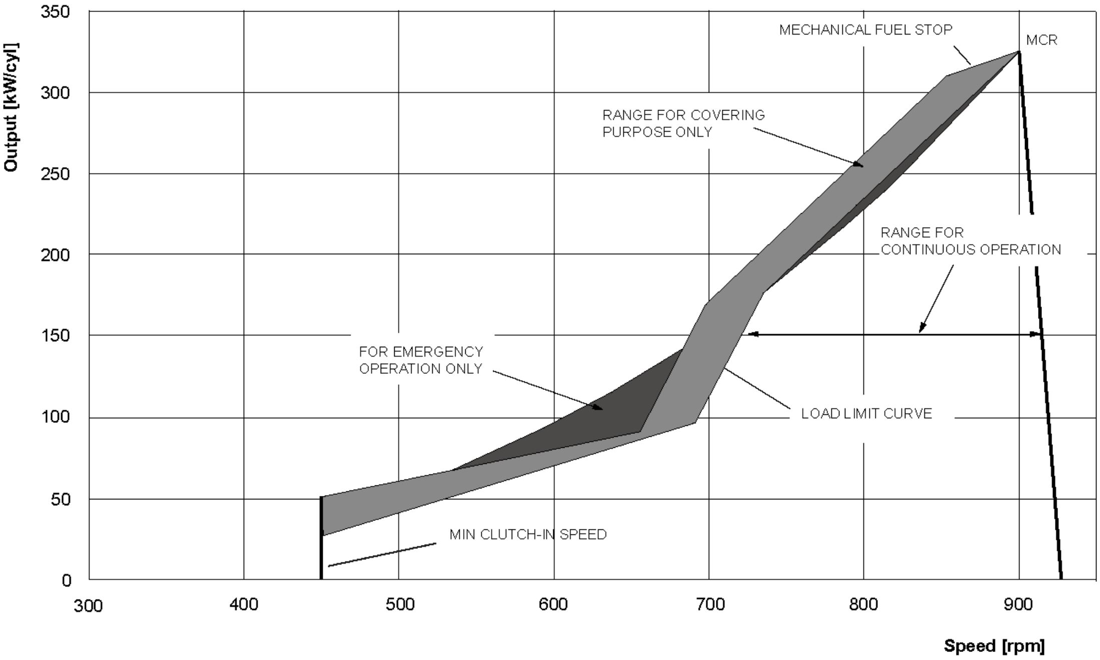


Fig 2-1 Operating field for CP propeller 900rpm

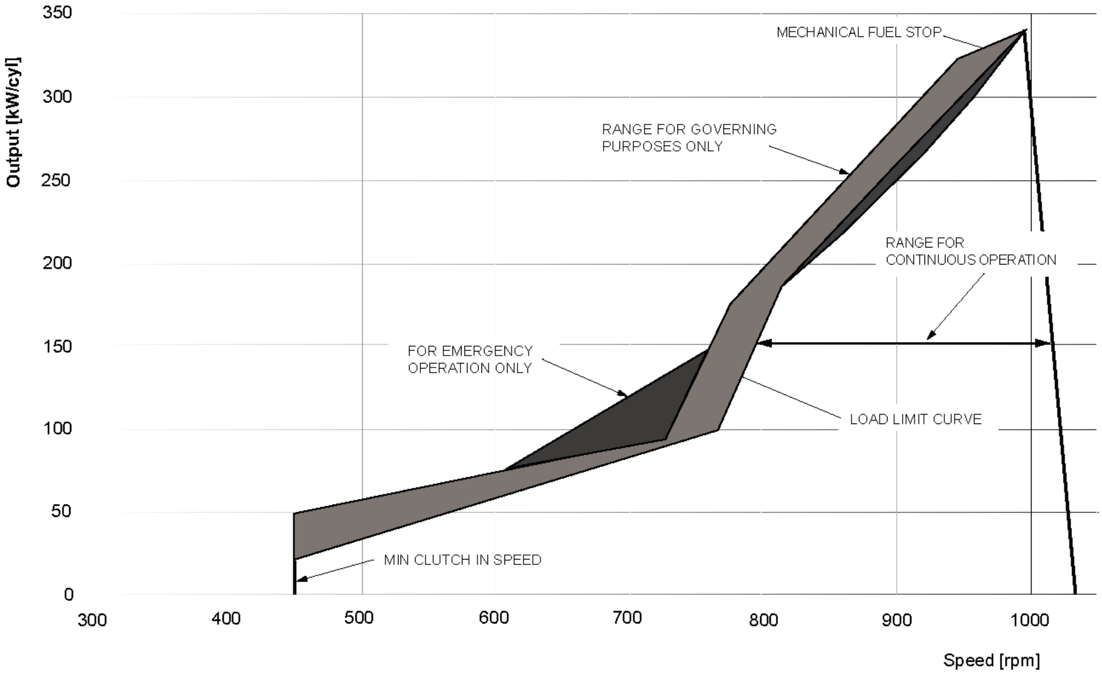


Fig 2-2 **Operating field for CP propeller 1000rpm**

2.1.2 Fixed pitch propellers

The thrust and power absorption of a given fixed pitch propeller is determined by the relation between ship speed and propeller revolution speed. The power absorption during acceleration, manoeuvring or towing is considerably higher than during free sailing for the same revolution speed. Increased ship resistance, for reason or another, reduces the ship speed, which increases the power absorption of the propeller over the whole operating range.

Loading conditions, weather conditions, ice conditions, fouling of hull, shallow water, and manoeuvring requirements must be carefully considered, when matching a fixed pitch propeller to the engine. The nominal propeller curve shown in the diagram must not be exceeded in service, except temporarily during acceleration and manoeuvring. A fixed pitch propeller for a free sailing ship is therefore dimensioned so that it absorbs max. 85% of the engine output at nominal engine speed during trial with loaded ship. Typically this corresponds to about 82% for the propeller itself.

If the vessel is intended for towing, the propeller is dimensioned to absorb 95% of the engine power at nominal engine speed in bollard pull or towing condition. It is allowed to increase the engine speed to 101.7% in order to reach 100% MCR during bollard pull.

A shaft brake should be used to enable faster reversing and shorter stopping distance (crash stop). The ship speed at which the propeller can be engaged in reverse direction is still limited by the windmilling torque of the propeller and the torque capability of the engine at low revolution speed.

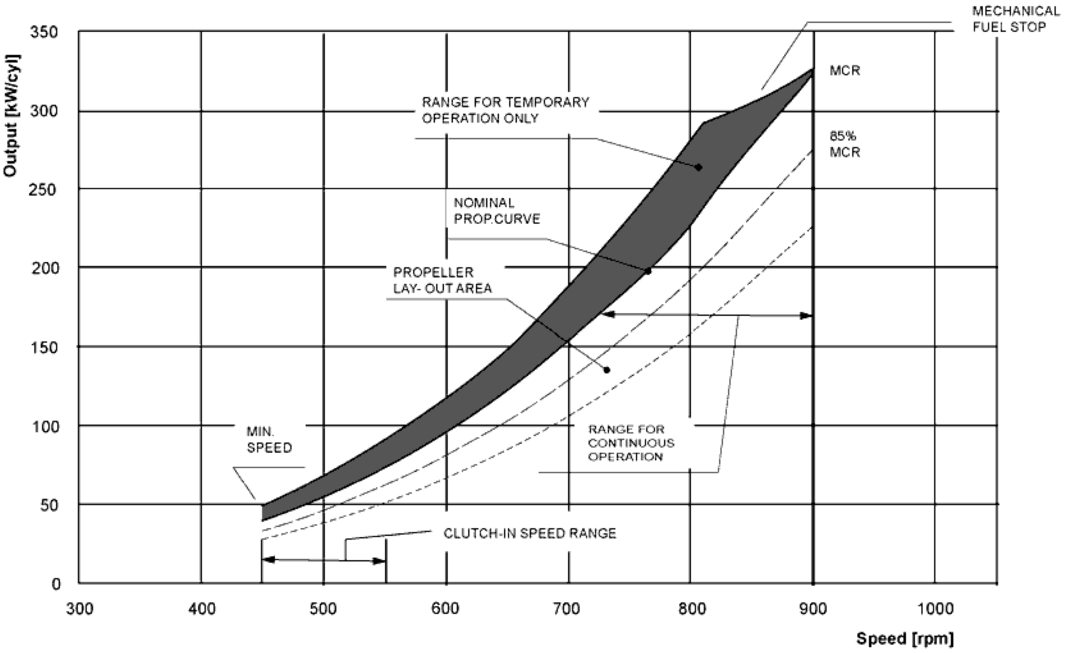


Fig 2-3 Operating field for FP Propeller 900rpm

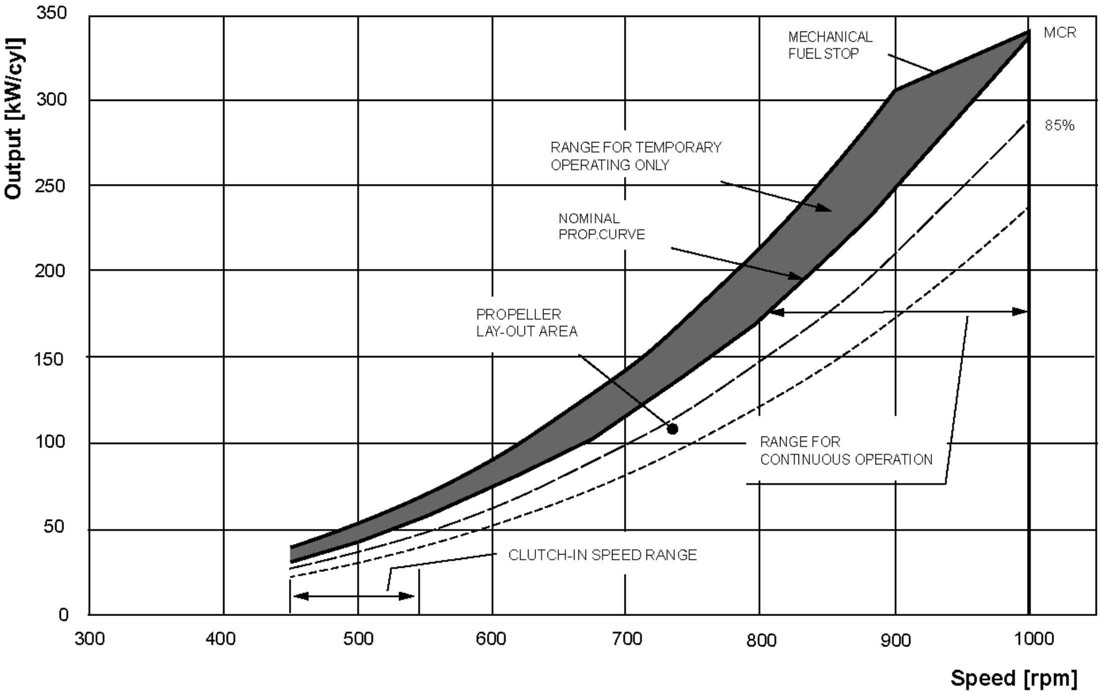


Fig 2-4 Operating field for FP Propeller 1000rpm

2.1.2.1 FP propellers in twin screw vessels

Requirements regarding manoeuvring response and acceleration, as well as overload with one engine out of operation must be very carefully evaluated if the vessel is designed for free sailing, in particular if open propellers are applied. If the bollard pull curve significantly exceeds the maximum overload limit, acceleration and manoeuvring response can be very slow. Nozzle propellers are less problematic in this respect.

2.1.3 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.

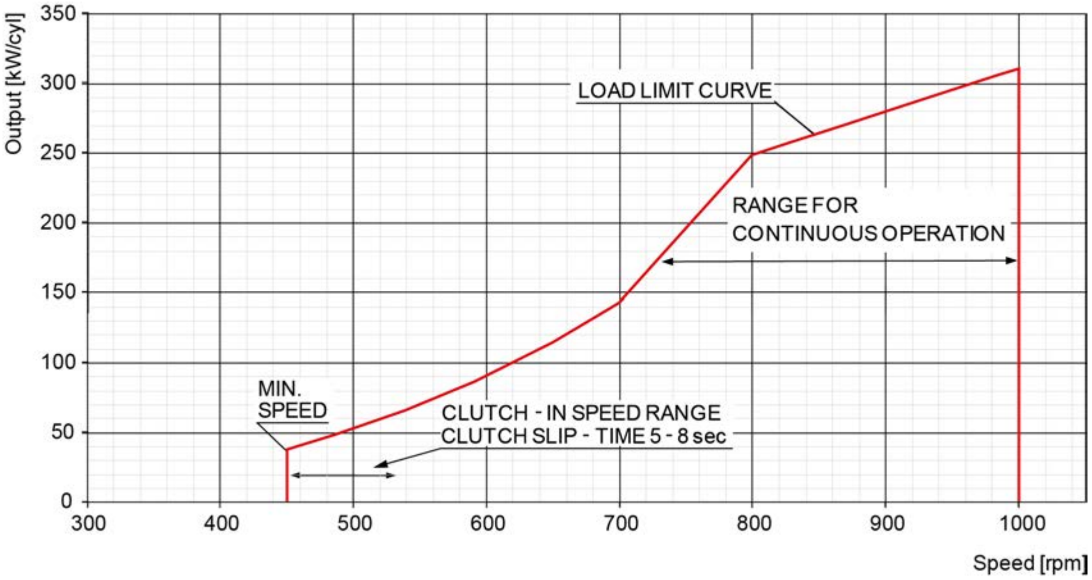


Fig 2-5 **Operating field for Dredgers**

2.2 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 60…70ºC, and the lubricating oil temperature is min. 40 ºC.

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

2.2.1 Mechanical propulsion

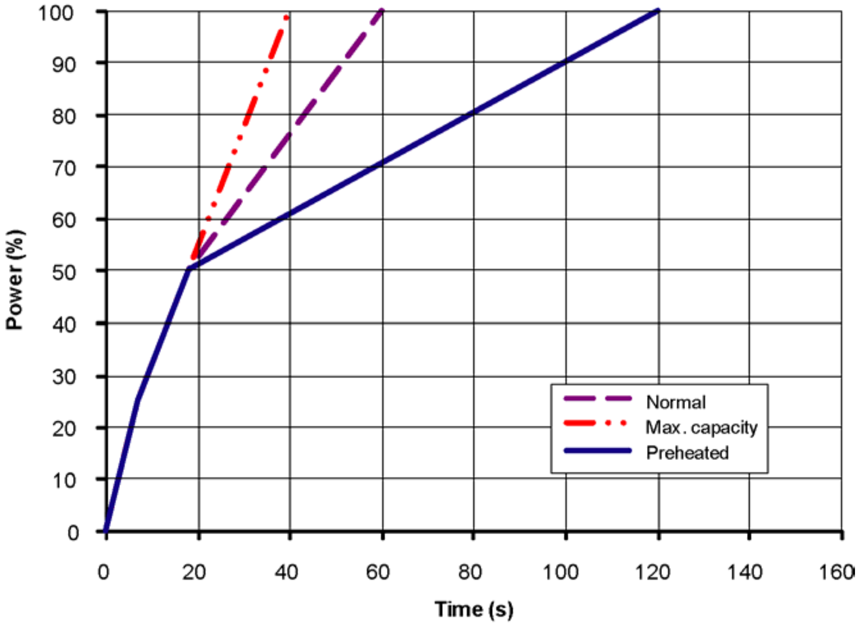


Fig 2-6 **Maximum recommended load increase rates for variable speed engines**

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).

2.2.2 Diesel electric propulsion and auxiliary engines

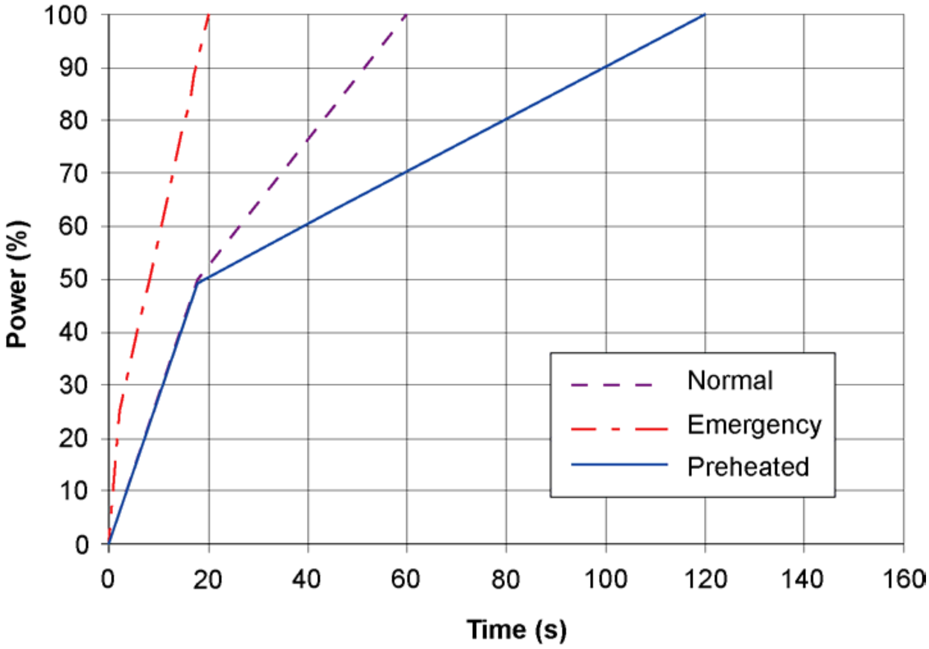


Fig 2-7 **Maximum recommended load increase rates for engines operating at nominal speed**

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.

2.2.2.1 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 permissible load step is 33% MCR. The resulting speed drop is less than 10% and the recovery time to within 1% of the steady state speed at the new load level is max. 5 seconds.

When electrical power is restored after a black-out, consumers are reconnected in groups, which may cause significant load steps. The engine can be loaded in three steps up to 100% load, provided that the steps are 0-33-66-100. The engine must be allowed to recover for at least 7 seconds before applying the following load step, if the load is applied in maximum steps.

2.2.2.2 Start-up

A diesel generator typically reaches nominal speed in about 20...25 seconds after the start signal. The acceleration is limited by the speed control to minimise smoke during start-up.

2.3 Low load operation

The engine can be started, stopped and operated on gas, heavy and light fuel oil with the following limits for low load operations:

Absolute idling (declutched main engine, disconnected generator)

- Maximum 10 minutes if the engine is to be stopped after the idling.

- Maximum 8 hours if the engine is to be loaded after the idling.

Operation below 20 % load

- Maximum 100 hours continuous operation. At intervals of 100 operating hours the engine must be loaded to minimum 70 % of the rated output.

Operation above 20% load

- No restrictions.

2.4 SCR Operation

SCR operations on sustained low load or idling might need special attention from the operator. For further details please contact Wärtsilä.

2.5 Low air temperature

In standard conditions the following minimum inlet air temperatures apply:

- Starting + 5ºC
- Idling - 5ºC $^{*)}$
- High load - 10ºC $^{*)}$
- Artic package -10°C / -30°C

Depending on the setup down to -45ºC.

If the engine is equipped with a two-stage charge air cooler, sustained operation between 0 and 40% load can require special provisions in cold conditions to prevent too low engine temperature.

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. Minimum target temperature are 320°C or 340°C (with liquid fuel) depending of sulphur content. Please consult your sales contact at Wärtsilä for more information about SCR Operation.

4. Description of the Engine

4.1 Definitions

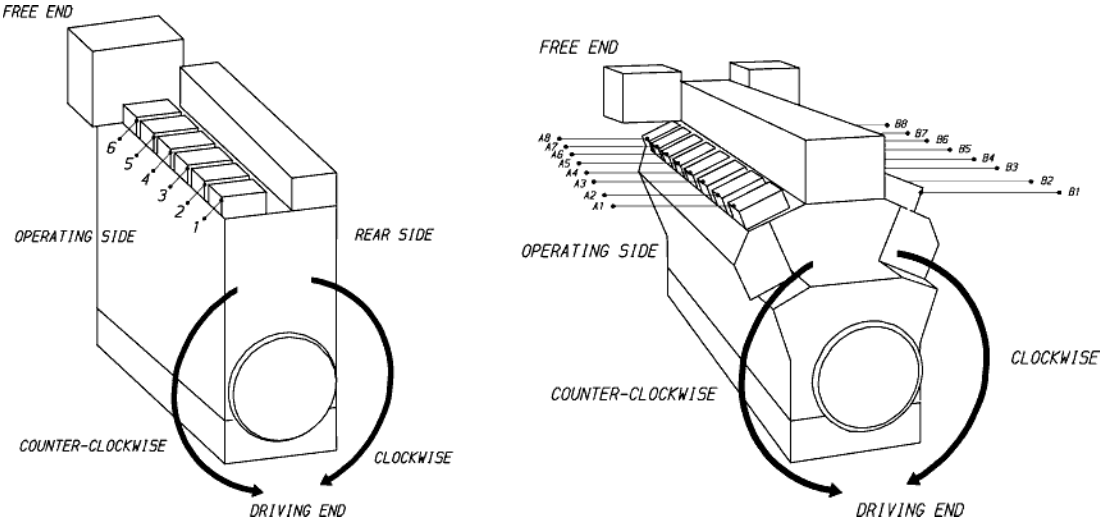


Fig 4-1 **In-line engine and V-engine definitions (1V93C0029 / 1V93C0028)**

4.2 Main engine components

Main dimensions and weights are presented in chapter *Main Data and Outputs*.

4.2.1 Engine block

The engine block is a one piece nodular cast iron component. The engine block is of stiff and durable design to absorb internal forces. The engine can be resiliently mounted without requiring any intermediate foundations.

The engine block carries the under-slung crankshaft.

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

For ease of mounting the engine feet (nodular cast iron) can be mounted in a number of positions along the engine block. This minimises modifications to existing foundation and makes various mounting configurations easy to implement.

Engine–driven cooling water pumps and a lubricating oil pump are mounted on a multi functional cast iron housing (pump module) which is fitted at the free end of the engine.

4.2.2 Crankshaft

The crankshaft is forged in one piece and is underslung in the engine block. The crankshaft design satisfies the requirements of all classification societies.

The crankshaft design features a very short cylinder distance with a maximum bearing length resulting in a short engine. The crankshaft is forged from one piece of high tensile steel.

Counterweights are fitted on the crankshaft webs. The high degree of balancing results in an even and thick oil film for all bearings. The gear on the crankshaft is fitted by a flange connection.

Depending on the outcome of the torsional vibration calculation, vibration dampers will be fit at the free end of the engine. If required full output can be taken from either end of the engine.

4.2.3 Connecting rod

The connecting rod is of forged alloy steel. All connecting rod studs are hydraulically tightened.

The connecting rod has a horizontal split at the crankpin bearing. The advantages of this type of connecting rod are:

- Shorter length
- High rigidity (stiffness)
- Low mass (results in smaller bearing load)

For overhaul the piston and connecting rod are removed together with the cylinder liner as one unit. The oil supply for the piston cooling, gudgeon pin bush and piston skirt lubrication takes place through a single drilling in the connecting rod.

4.2.4 Main bearings and big end bearings

The main bearings and the crankpin bearings are of the bi–metal type with a steel backing and a soft running layer with excellent corrosion resistance.

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. They are of wet type, sealed against the engine block by means of a gasket at the upper part and by O-rings at the lower part. To eliminate the risk of bore polishing the liner is equipped with an anti-polishing ring.

Cooling around the liner is divided into two parts: the greater volume in the lower part for uniform cooling water distribution and a smaller volume at the top of the jacket to facilitate an efficient cooling due to a high flow velocity.

4.2.6 Piston

The piston is of composite design with nodular cast iron skirt and steel crown. The piston skirt and cylinder liner are lubricated by a unique lubricating system utilizing lubricating nozzles in the piston skirt. This system ensures excellent running behaviour and constant low lubrication oil consumption 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 consists of two directional compression rings and one spring-loaded conformable oil scraper ring. All rings are chromium-plated and located in the piston crown. The two compression rings are asymmetrically profiled.

4.2.8 Cylinder head

The cylinder head is made of spheroidal or grey lamellar cast iron. The thermally loaded flame plate is cooled efficiently by cooling water led from the periphery radially towards the centre of the head. Cooling channels are drilled in the bridges between valves, 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.

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 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 completely hardened camshaft material. To provide the required rigidity to deal with the high transmission forces involved, the fuel cam is located very close to the bearing.

The bearing journals are made in separate pieces which are fitted to the camshaft sections by means of flanged connections. This design allows lateral dismantling of the camshaft sections.

The camshaft bearings are located in integrated bores in the engine block casting. The built–on valve tappet unit bolted to the engine block makes maintenance easy.

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 camshaft is driven from the crankshaft through a fully integrated gear train.

Camshaft gear is shrunk on camshaft. Adjusting of timing is possible by means of oil pressure on the gear wheel.

4.2.11 Turbocharging and charge air cooling

The charge air module for the V–engine is a casting in which the charge air cooler is accommodated and which supports the turbochargers.

For the in–line engine the turbocharger support and the charge air housing are different modules. Connections between turbocharger, charge air cooler and scavenging air duct as well as the connections to the cooling water systems and turbocharger housing(s) are integrated. This construction eliminates the conventional piping outside the engine.

The selected turbocharger offers the ideal combination of high-pressure ratios and good efficiency at full and part load.

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.

The turbocharger(s) is (are) as standard located at the driving end, but can also be mounted on the free end.

The charge air cooler is of the one-stage type for in-line engines and of the two–stage type, consisting of HT and LT cooling water sections, for V-engines. Treated fresh water is used in both sections. The charge air cooler is an insert type element and can easily be removed for cleaning the air side.

The water side is accessible through removal of the cooler end covers.

4.2.12 Fuel injection equipment

The high injection pressure and bore to stroke ratio ensure low NOx emission and low fuel oil consumption. The fuel injection equipment and system piping are located in a hot box, providing maximum reliability and safety when using pre-heated heavy fuel oils. The fuel oil circulation lines are mounted directly in the fuel injection pump tappet housing. Particular design attention has been made to significantly reduce pressure pulses in the system.

The HP fuel pumps are individual per cylinder with shielded high pressure pipes. The HP fuel pumps are of the flow through type to ensure good performance with all fuel oil types. The pumps are completely isolated from the camshaft compartment preventing fuel contamination of the lubricating oil.

The nozzles of the fuel injector are cooled with lubricating oil.

The HP fuel pump is a reliable mono–element type designed for injection pressures up to 1500 bar. The engine is stopped through activation of the individual stop cylinders on each HP fuel pump.

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 on V engines. The LT-water cools the second stage of the charge air cooler and the lubricating oil.

4.2.15 Exhaust pipes

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

4.2.16 Pump module

The pump module is a cast iron housing fitted at the free end of the engine which supports the cooling water pumps, the lubricating oil pump(s) and the fuel oil circulating pump (for distillate fuel oil only). The module contains the liquid channels between the pumps and the corresponding channels in the engine block, the charge air module, the lubricating oil module and the engine sump. Also the thermostatic valves of the cooling water systems for V engines are mounted in the pump module.

4.2.17 Automation system

Wärtsilä 26 is equipped with a modular embedded automation system, Wärtsilä Unified Controls - UNIC which has a hardwired interface for control functions and a bus communication interface for alarm and monitoring.

UNIC has an 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.

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

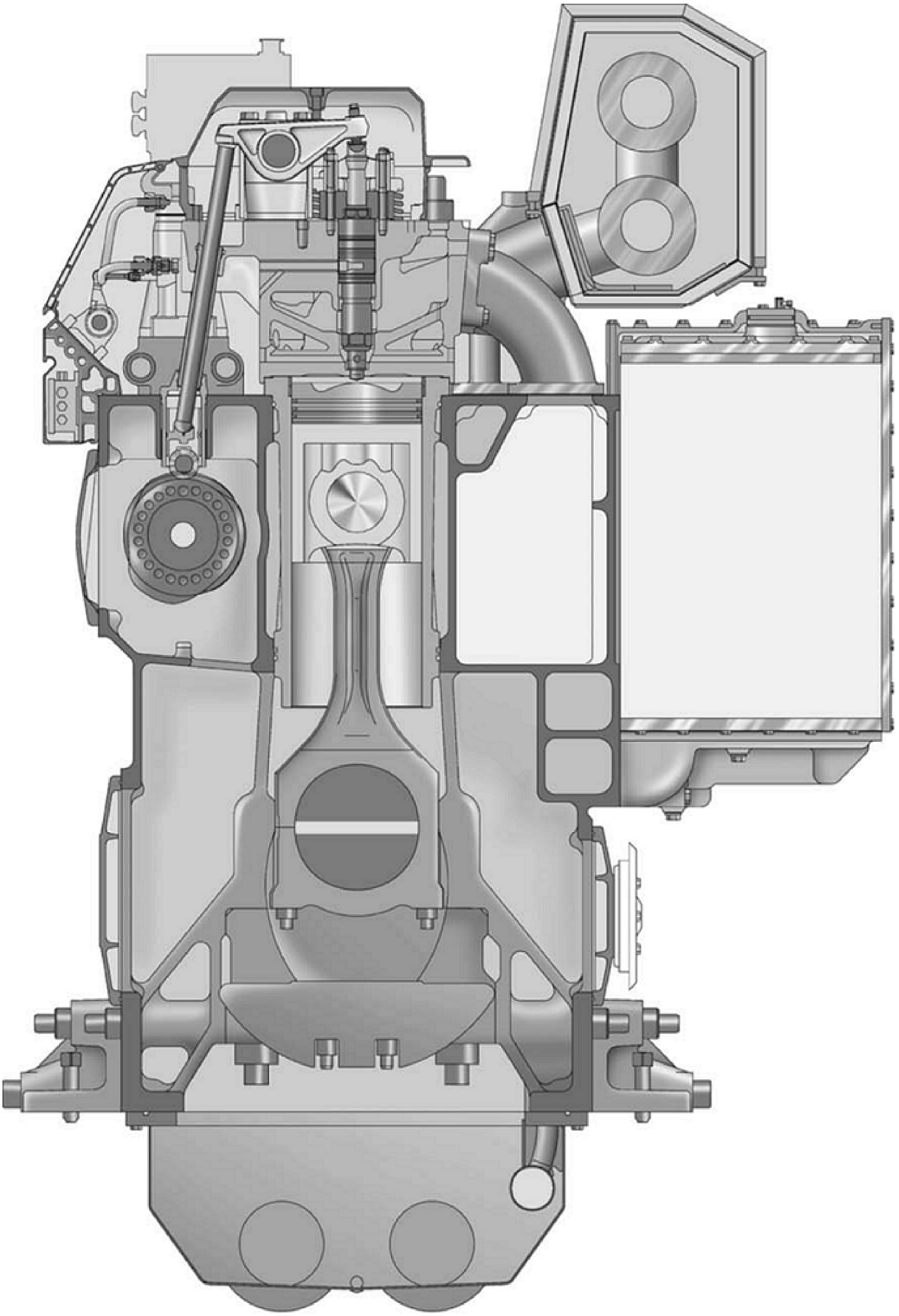


Fig 4-2 Cross section of in-line engine

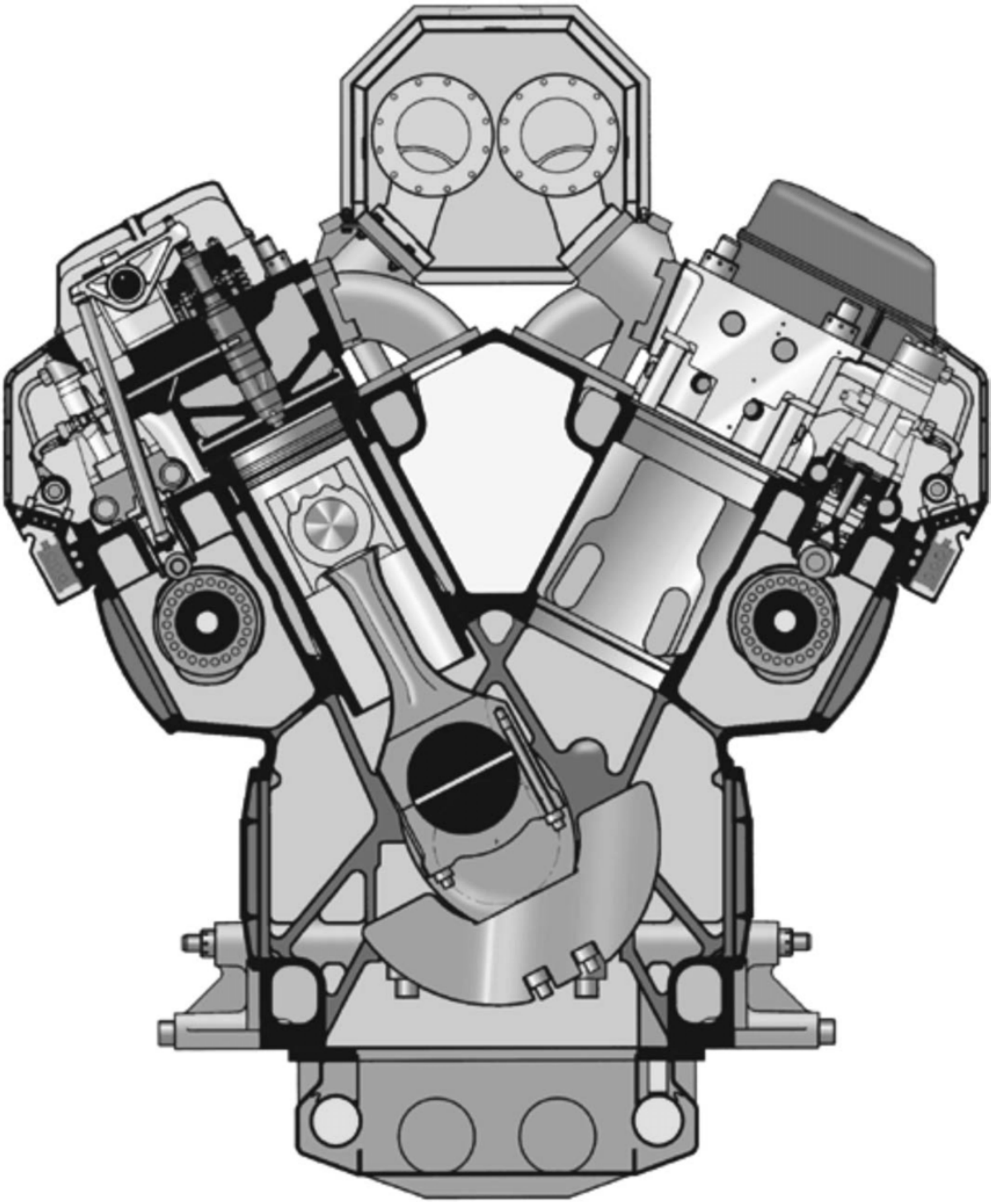


Fig 4-3 Cross section of V-engine

4.4 Overhaul intervals and expected life times

The following overhaul intervals and lifetimes are for guidance only. Actual figures will be different depending on service conditions. Expected component lifetimes have been adjusted to match overhaul intervals.

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.

Table 4-1 Time between overhauls and expected lifetimes

Component	MDF	HFO	MDF	HFO
	Time between overhauls [h]		**Expected component lifetimes [h]**	
Piston	24 000	12 000	72 000	48 000
Piston rings	-	-	24 000	12 000
Cylinder liner	24 000	12 000	72 000	36 000
Cylinder head	24 000	12 000	-	-
Inlet valve	24 000	12 000	48 000	36 000
Exhaust valve	24 000	12 000	24 000	24 000
Injection valve	4000	4 000	-	-
Injection valve nozzle	-	-	4 000	4 000
Injection pump	24 000	24 000	-	-
Injection pump element	-	-	24 000	24 000
Main bearing	-	-	36 000	24 000
Turbocharger	-	-	12 000	24 000
	8 000	8 000	48 000 1)	48 000
Intermediate bearing	-	-	48 000	36 000

NOTE
Lifetime for rotating parts.

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 Finland Oy.

5. Piping Design, Treatment and Installation

This chapter provides general guidelines for the design, construction and installation of piping systems, however, not excluding other solutions of at least equal standard.

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).

Pipes on the freshwater side of the cooling water system must not be galvanized. Sea-water piping should be made in hot dip galvanised steel, aluminium brass, cunifer or with rubber lined pipes.

NOTE
The pipes in the freshwater side of the cooling water system must not be galvanized!

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).

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.
- Recommended maximum fluid velocities on the delivery side of pumps are given as guidance in table *5-1*.

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

Piping	Pipe material	Max velocity [m/s]
Fuel piping (MDF and HFO)	Black steel	1.0
Lubricating oil piping	Black steel	1.5

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

NOTE

The diameter of gas fuel piping depends only on the allowed pressure loss in the piping, which has to be calculated project specifically.

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 Operating and design pressure

The pressure class of the piping shall be equal to or higher than the maximum operating pressure, which can be significantly higher than the normal operating pressure.

A design pressure is defined for components that are not categorized according to pressure class, and this pressure is also used to determine test pressure. The design pressure shall also be equal to or higher than the maximum pressure.

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 Product Guide 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 1.0 MPa (10 bar). The safety filter in dirty condition may cause a pressure loss of 0.1 MPa (1 bar). The viscosimeter, heater and piping may cause a pressure loss of 0.2 MPa (2 bar). Consequently the discharge pressure of the circulating pumps may rise to 1.3 MPa (13 bar), and the safety valve of the pump shall thus be adjusted e.g. to 1.4 MPa (14 bar).

- The minimum design pressure is 1.4 MPa (14 bar).
- The nearest pipe class to be selected is PN16.
- Piping test pressure is normally 1.5 x the design pressure = 2.1 MPa (21 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).

- The minimum design pressure is 0.5 MPa (5 bar).
- The nearest pressure 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 in 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)

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 (c) 20/18/15, NAS9. A measurement certificate shows required cleanliness has been reached there is still risk that impurities may occur after a time of operation.

Note! 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 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 (c) 21/19/15, NAS10. 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 (c) 21/19/15, NAS10.

Note! 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 approved 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 approved 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.

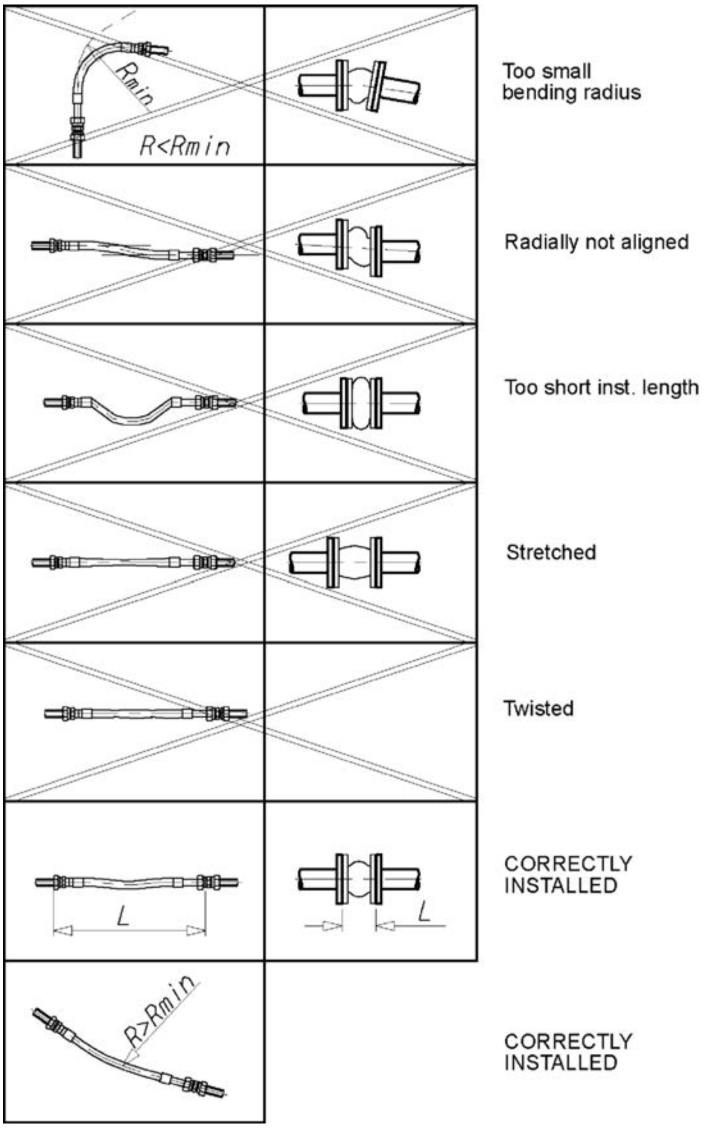


Fig 5-1 Flexible hoses

NOTE

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

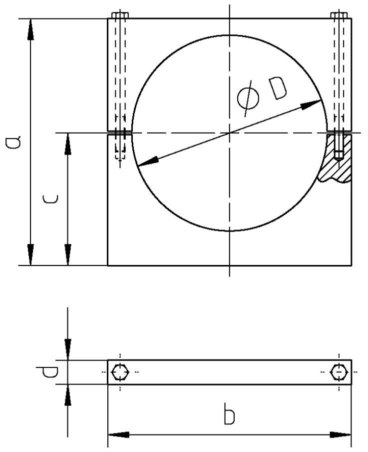
5.9 Clamping of pipes

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
Ⓐ 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 Marine Diesel Fuel (MDF)

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 MDF (Marine Diesel Fuel).

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. It is generally designated MDO (Marine Diesel Oil) in the marine field.
- 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		

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

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.

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 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.

6.1.2.1 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)
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.

6.2 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.

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.

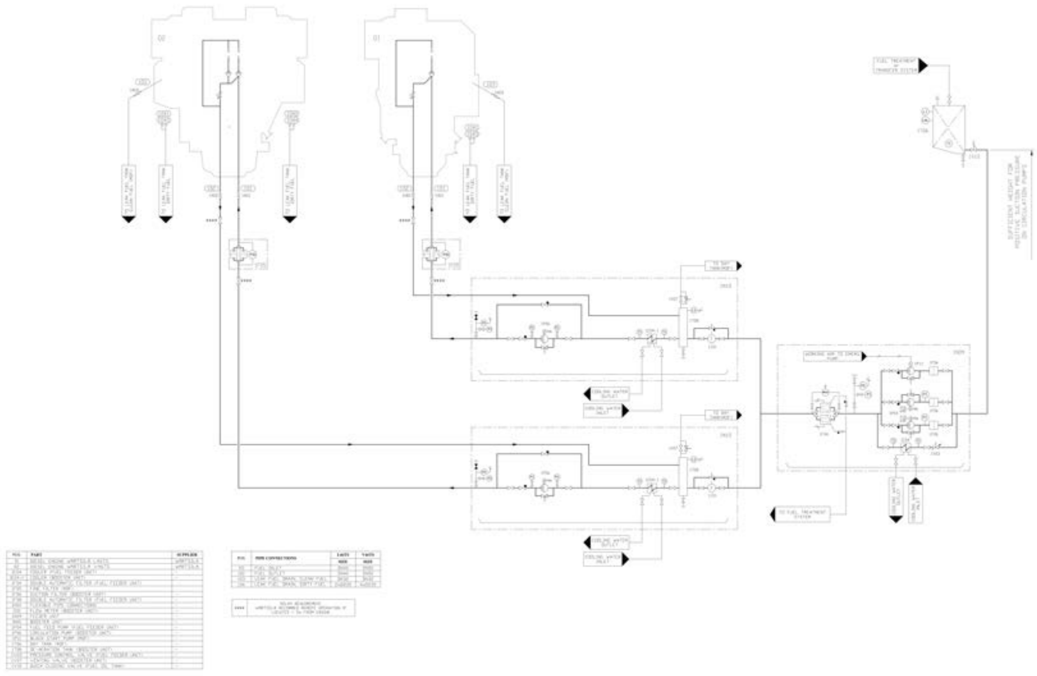


Fig 6-1 **Fuel oil system MDF Multiple engine installation (DAAF426282)**

NOTE
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.

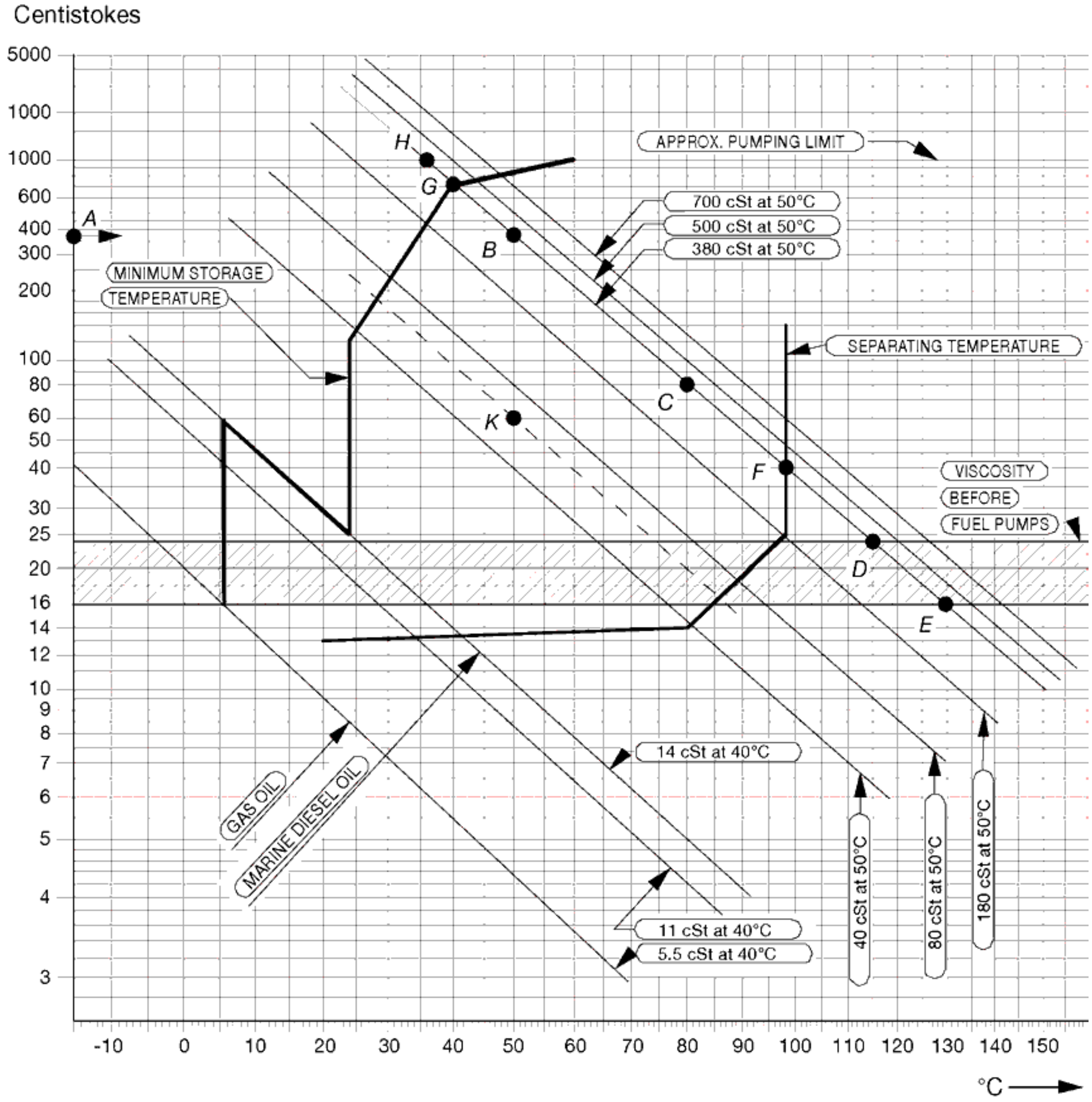


Fig 6-2 **Fuel oil viscosity-temperature diagram for determining the pre-heating temperatures of fuel oils (4V92G0071b)**

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 MDF (1T10)

Separate settling tanks for HFO and MDF 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 MDF 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 MDF (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 MDF. The capacity of the MDF 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 MDF 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 MDF from a gravity tank is foreseen, then the tank must be located at least 15 m above the engine crankshaft.

6.2.3.3 Starting tank, MDF (1T09)

The starting tank is needed when the engine is equipped with the engine driven fuel feed pump and when the MDF day tank (1T06) cannot be located high enough, i.e. less than 2 meters above the engine crankshaft.

The purpose of the starting tank is to ensure that fuel oil is supplied to the engine during starting. The starting tank shall be located at least 2 meters above the engine crankshaft. The volume of the starting tank should be approx. 60 l.

6.2.3.4 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 MDF only.

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

6.2.3.5 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 MDF.

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 MDF only, to remove water and possible contaminants. The capacity of MDF separators should be sufficient to ensure the fuel supply at maximum fuel consumption. Would a centrifugal separator be considered too expensive for a MDF 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

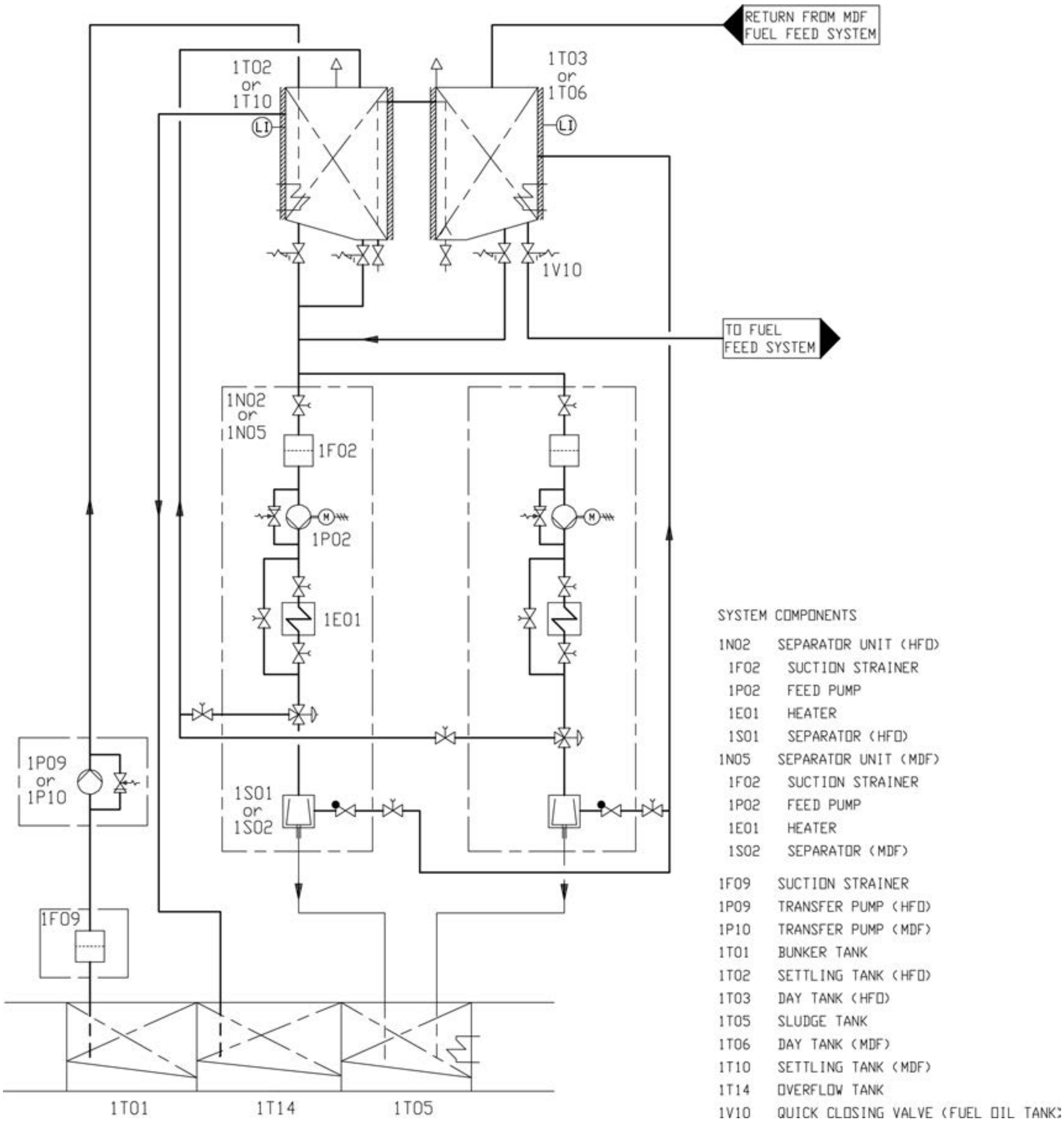


Fig 6-3 Fuel transfer and separating system (V76F6626G)

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	MDF

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 MDF. 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 $\Delta T = 48°C$ 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 MDF separator in HFO installations (1S02)

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

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 - MDF installations

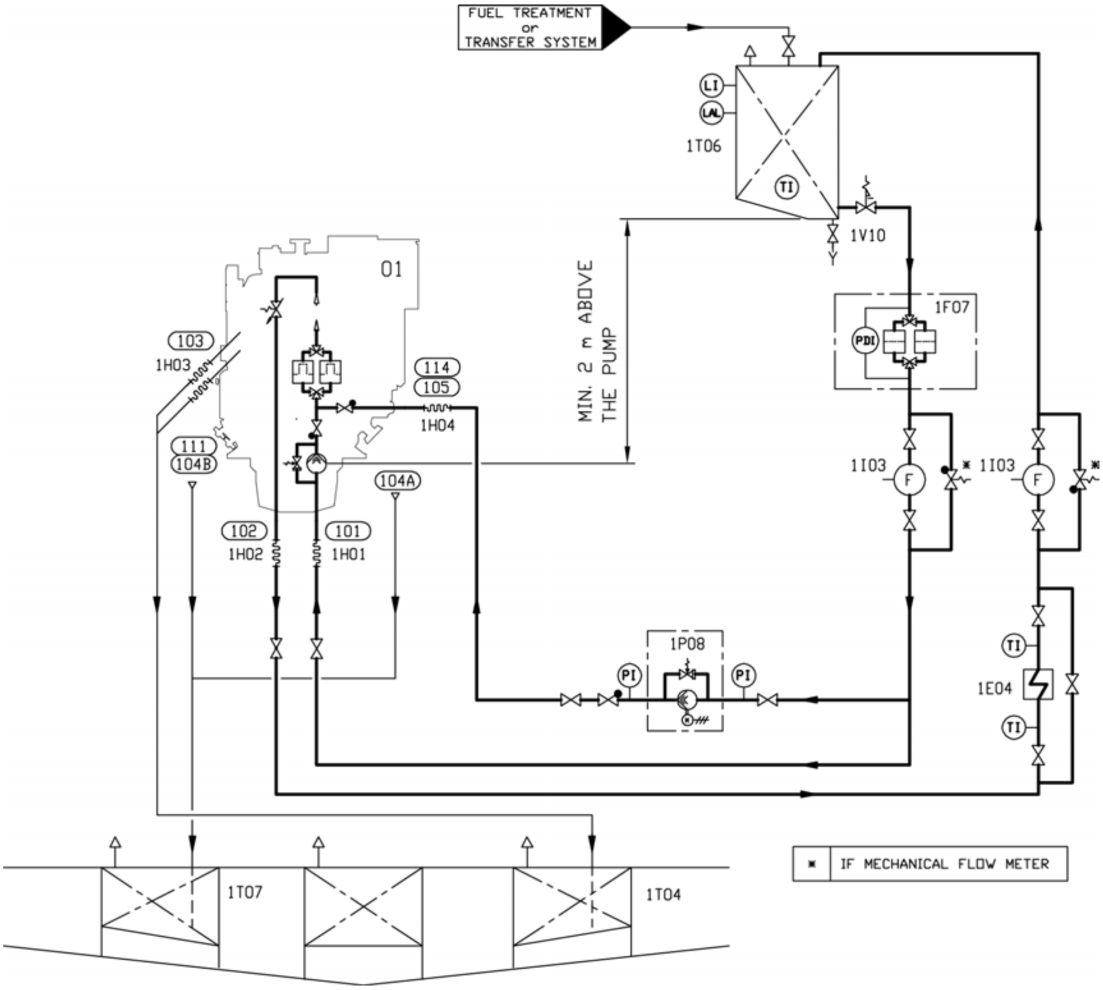


Fig 6-4 Fuel feed system for inline engine (DAAF078369A)

System components			
01	Diesel engine Wärtsilä L26	1P08	Stand-by pump, MDF
1E04	Cooler (MDF)	1T04	Leak fuel tank, clean fuel
1F07	Suction strainer, MDF	1T06	Day tank, MDF
1H0X	Flexible pipe connection	1T07	Leak fuel tank, dirty fuel
1I03	Flow meter	1V10	Quick closing valve (fuel oil tank)

Pos	Pipe connections	Size
101	Fuel inlet	DN32
102	Fuel outlet	DN32
103	Leak fuel drain, clean fuel	2 * OD22
104A	Leak fuel drain, dirty fuel	OD22
104B	Leak fuel drain, dirty fuel	OD22
105	Fuel stand-by connection	DN32
111	Drain fuel from fuel filter drip tray	OD22
114	Fuel from starting/day tank	DN32

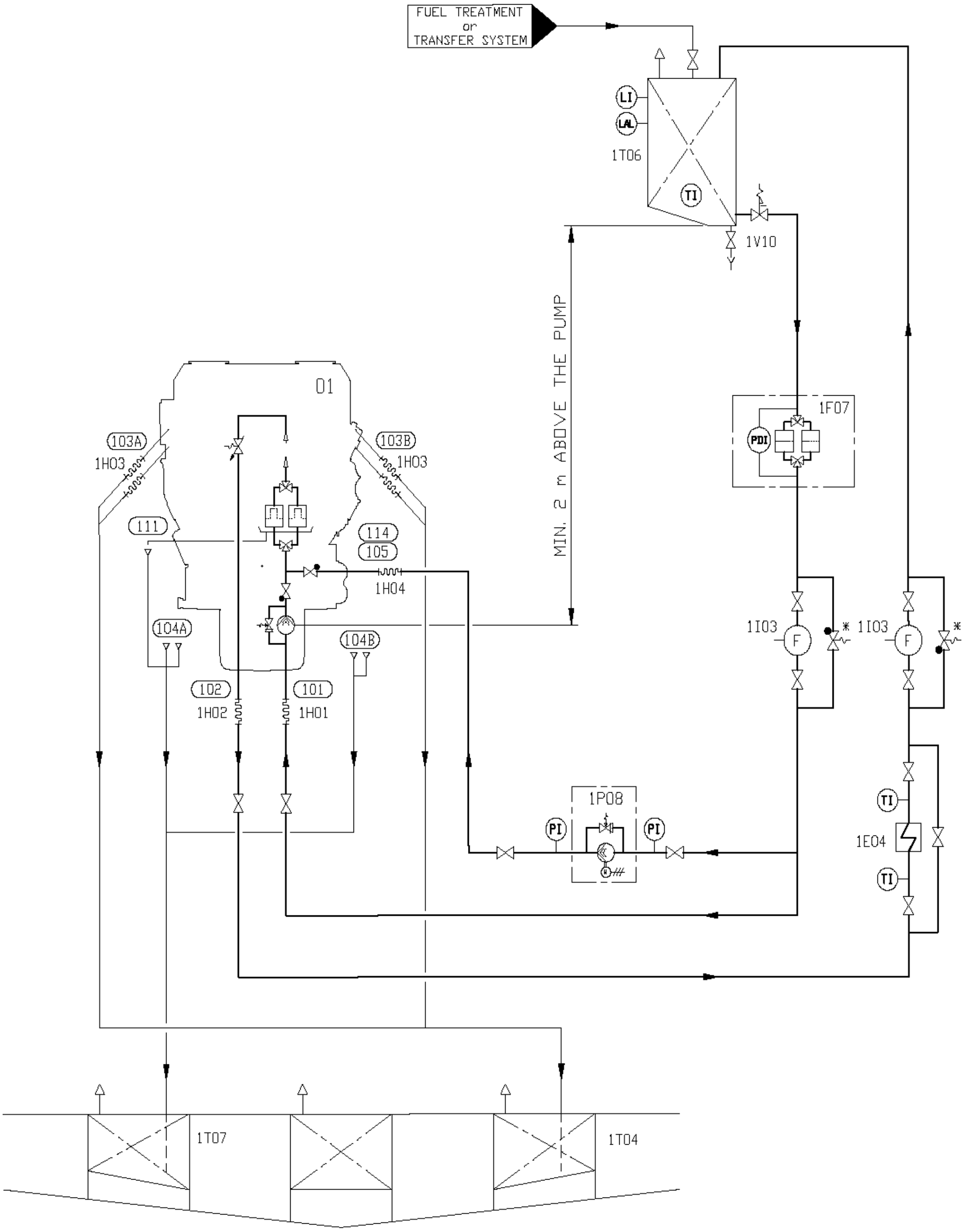


Fig 6-5 Fuel feed system for V-engine (DAAF078370A)

System components			
01	Diesel engine Wärtsilä V26	1P08	Stand-by pump, MDF
1E04	Cooler (MDF)	1T04	Leak fuel tank, clean fuel
1F07	Suction strainer, MDF	1T06	Day tank, MDF
1H0X	Flexible pipe connection	1T07	Leak fuel tank, dirty fuel
1I03	Flow meter	1V10	Quick closing valve (fuel oil tank)

Pos	Pipe connections	Size
101	Fuel inlet	DN32

Pos	Pipe connections	Size
102	Fuel outlet	DN25
103	Leak fuel drain, clean fuel	4 * OD22
104	Leak fuel drain, dirty fuel	4 * OD22
105	Fuel stand-by connection	DN25
111	Drain fuel from fuel filter drip tray	OD22
114	Fuel from starting/day tank	DN25

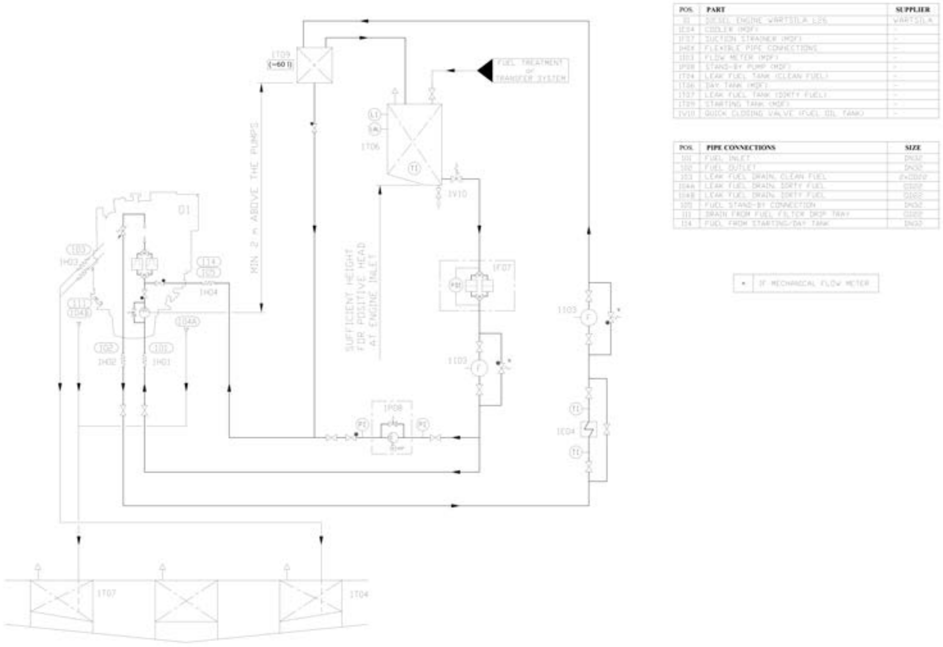


Fig 6-6 **Typical example of external fuel system for Single Main Engine with Starting Tank (DAAF078371B)**

Pos	Pipe connections	Size
101	Fuel inlet	DN32
102	Fuel outlet	DN32
103	Leak fuel drain, clean fuel	2 * OD22
104A	Leak fuel drain, dirty fuel	OD22
104B	Leak fuel drain, dirty fuel	OD22
105	Fuel stand-by connection	DN32
111	Drain fuel from fuel filter drip tray	OD22
114	Fuel from starting/day tank	DN32

*If mechanical flow meter

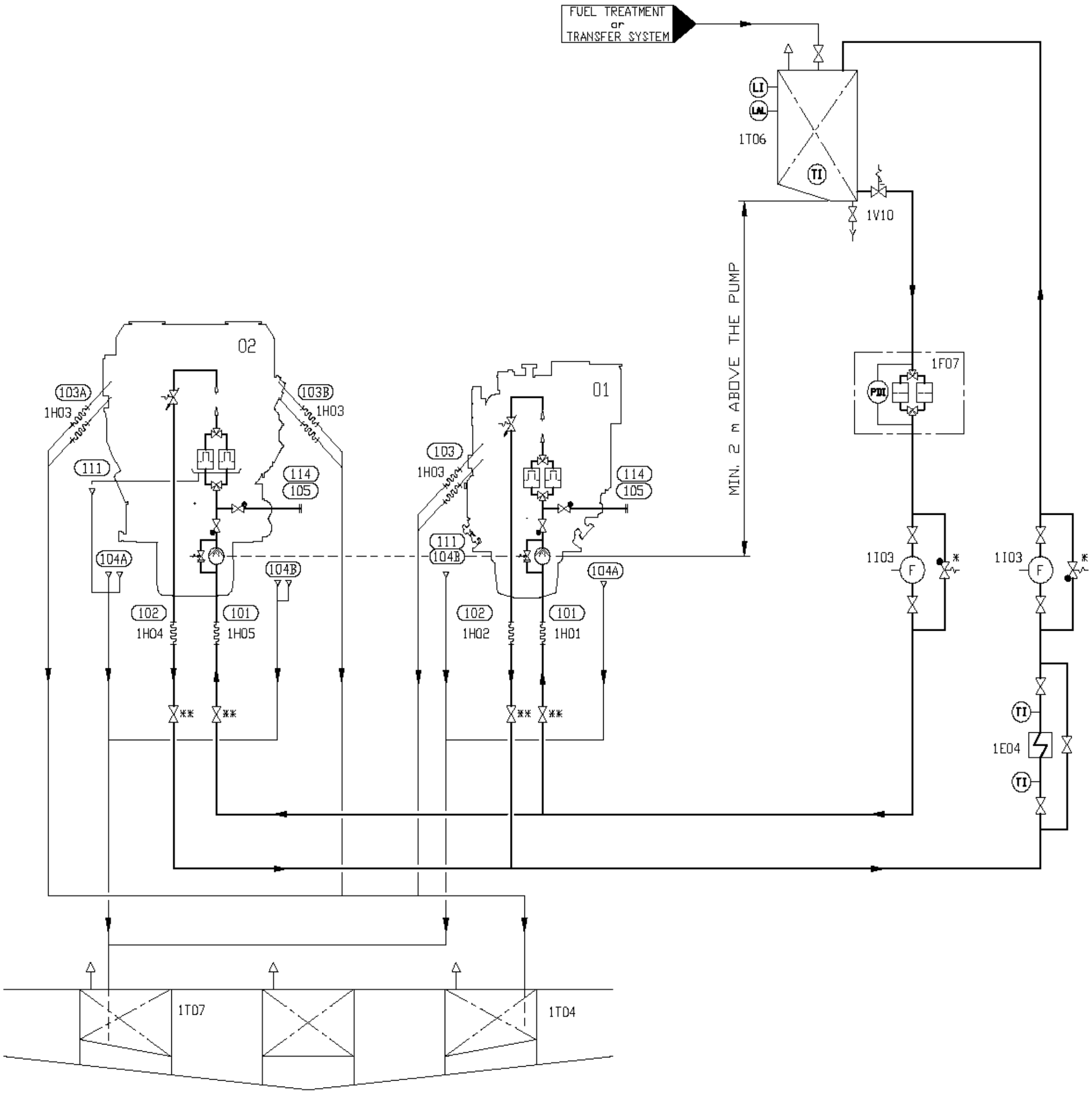


Fig 6-7 **Typical example of external fuel system for multiple engine installation (DAAF078372A)**

System components			
01	Diesel engine Wärtsilä L26	1T04	Leak fuel tank, clean fuel
02	Diesel engine Wärtsilä V26	1T06	Day tank, MDF
1E04	Cooler (MDF)	1T07	Leak fuel tank, dirty fuel
1F07	Suction strainer, MDF	1V10	Quick closing valve (fuel oil tank)
1H0X	Flexible pipe connection		
1I03	Flow meter (MDF)		

Pos	Pipe connections	L26	V26
101	Fuel inlet	DN32	
102	Fuel outlet	DN32	DN25
103	Leak fuel drain, clean fuel	2 * OD22	4 * OD22
104A	Leak fuel drain, dirty fuel	OD22	2 * OD22
104B	Leak fuel drain, dirty fuel	OD22	2 * OD22
105	Fuel stand-by connection	DN32	DN25
111	Drain fuel from fuel filter drip tray	OD22	

Pos	Pipe connections	L26	V26
114	Fuel from starting/day tank	DN32	DN35

If the engines are to be operated on MDF 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 MDF part of a HFO fuel oil system.

6.2.5.1 Circulation pump, MDF (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, MDF (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	6 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, MDF (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, MDF (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 MDF cooler (1E04)

The fuel viscosity may not drop below the minimum value stated in *Engine Online Configurator* available through Wärtsilä website. When operating on MDF, 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 MDF 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 MDF viscosity in day tank drops below stated minimum viscosity limit then it is recommended to install an MDF cooler into the engine fuel supply line in order to have reliable viscosity control.

Design data:	
Heat to be dissipated	2 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 MDF/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 MDF 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. HFO 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

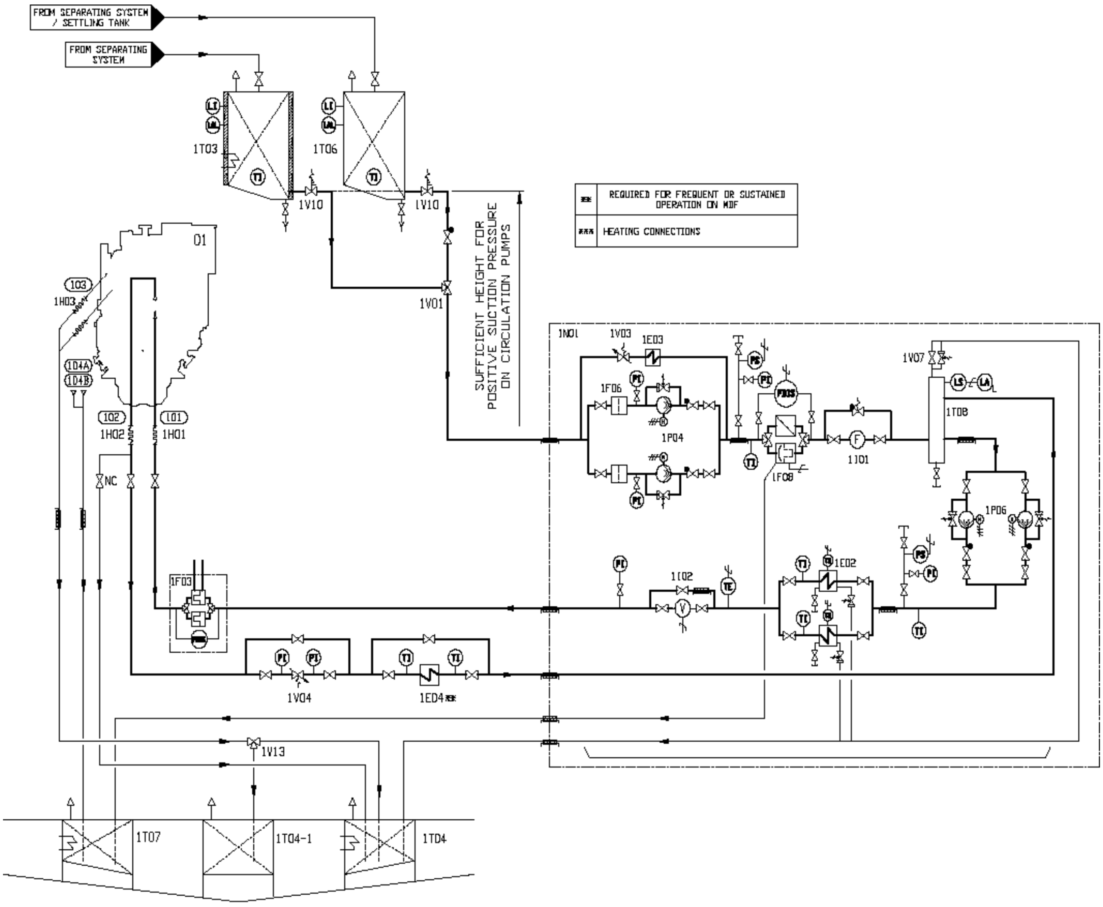


Fig 6-8 Example of fuel oil system (HFO), (DAAF078373A)

System components:			
01	Diesel engine Wärtsilä 26	1T03	Day tank (HFO)
1E02	Heater (booster unit)	1T04	Leak fuel tank (clean fuel) - HFO
1E03	Cooler (booster unit)	1T04-1	Leak fuel tank (clean fuel) - MDF
1E04	Cooler (MDF)	1T06	Day tank (MDF)
1F03	Safety filter (HFO)	1T07	Leak fuel tank (dirty fuel)
1F06	Suction filter (booster unit)	1T08	De-aeration tank (booster unit)
1F08	Automatic filter (booster unit)	1V01	Change over valve
1H0X	Flexible pipe connections	1V03	Pressure control valve (booster unit)
1I01	Flow meter (booster unit)	1V04	Pressure control valve (HFO)
1I02	Viscosity meter (booster unit)	1V07	Venting valve (booster unit)
1N01	Feeder/booster unit	1V10	Quick closing valve (fuel oil tank)
1P04	Fuel feed pump (booster unit)	1V13	Change over valve for leak fuel
1P06	Circulation pump (booster unit)		

Pos.	Pipe connections	L26	V26
101	Fuel inlet	DN32	DN25
102	Fuel outlet	DN32	DN25
103	Leak fuel drain, clean fuel	2 * OD22	4 * OD22
104A	Leak fuel drain, dirty fuel	OD22	2 * OD22

Pos.	Pipe connections	L26	V26
104B	Leak fuel drain, dirty fuel	OD22	2 * OD22

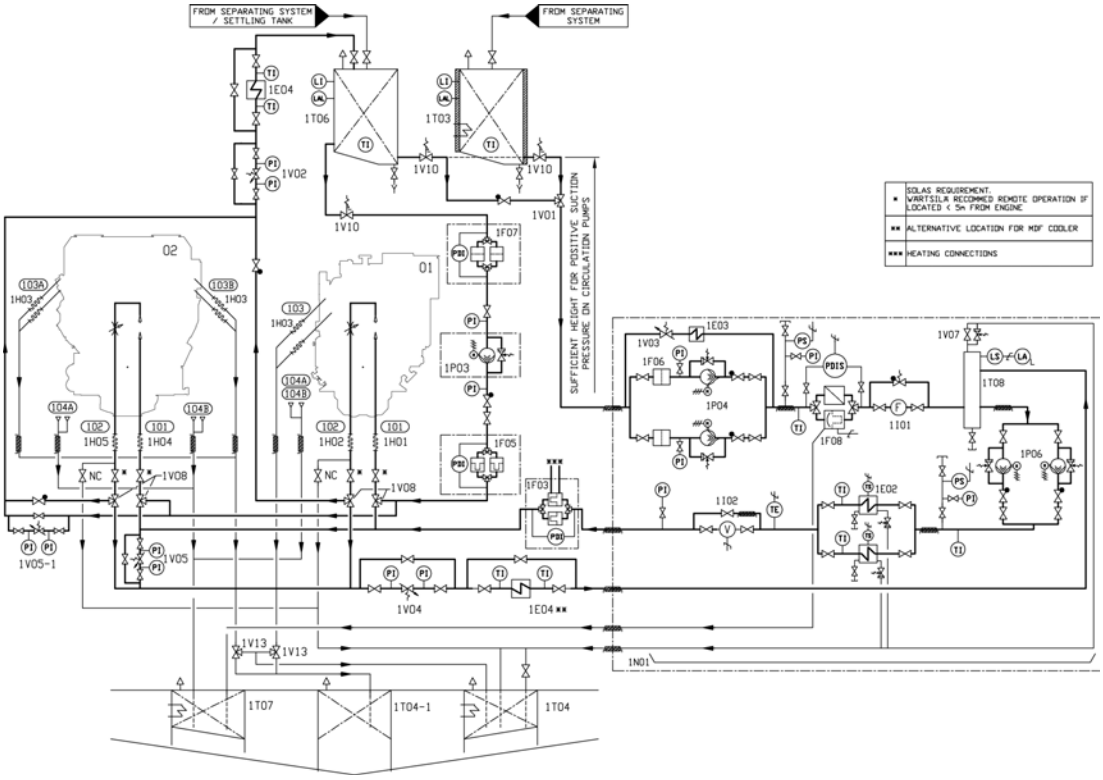


Fig 6-9 Example of fuel oil system (HFO), multiple engine installation, (DAAF078374A)

System components:			
01	Diesel engine Wärtsilä L26	1T03	Day tank (HFO)
02	Diesel engine Wärtsilä V26	1T04	Leak fuel tank (clean fuel) - HFO
1E02	Heater (booster unit)	1T04-1	Leak fuel tank (clean fuel) - MDF
1E03	Cooler (booster unit)	1T06	Day tank (MDF)
1E04	Cooler (MDF)	1T07	Leak fuel tank (dirty fuel)
1F03	Safety filter (HFO)	1T08	De-aeration tank (booster unit)
1F05	Fine filter (MDF)	1V01	Change over valve
1F06	Suction filter (booster unit)	1V02	Pressure control valve (MDF)
1F07	Suction strainer (MDF)	1V03	Pressure control valve (booster unit)
1F08	Automatic filter (booster unit)	1V04	Pressure control valve (HFO)
1H0X	Flexible pipe connections	1V05	Overflow valve (HFO/MDF)
1I01	Flow meter (booster unit)	1V05-1	Overflow valve (HFO/MDF)
1I02	Viscocity meter (booster unit)	1V07	Venting valve (booster unit)
1N01	Feeder / booster unit	1V08	Changeover valve
1P03	Circulation pump (MDF)	1V10	Quick closing valve (fuel oil tank)
1P04	Fuel feed pump (booster unit)	1V13	Change over valve for leak fuel
1P06	Circulation pump (booster unit)		

Pos.	Pipe connections	L26	V26
101	Fuel inlet	DN32	DN25
102	Fuel outlet	DN32	DN25
103	Leak fuel drain, clean fuel	2 * OD22	4 * OD22
104A	Leak fuel drain, dirty fuel	OD22	2 * OD22
104B	Leak fuel drain, dirty fuel	OD22	2 * OD22

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 MDF (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 MDF 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 MDF.

6.2.6.2 Changeover from HFO to MDF

The control sequence and the equipment for changing fuel during operation must ensure a smooth change in fuel temperature and viscosity. When MDF 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 MDF, then the fuel change should be performed with the HFO feeder/booster unit before switching over to the MDF circulating pumps. As mentioned earlier, sustained operation on MDF 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 26 engines only, maximum two engines 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.

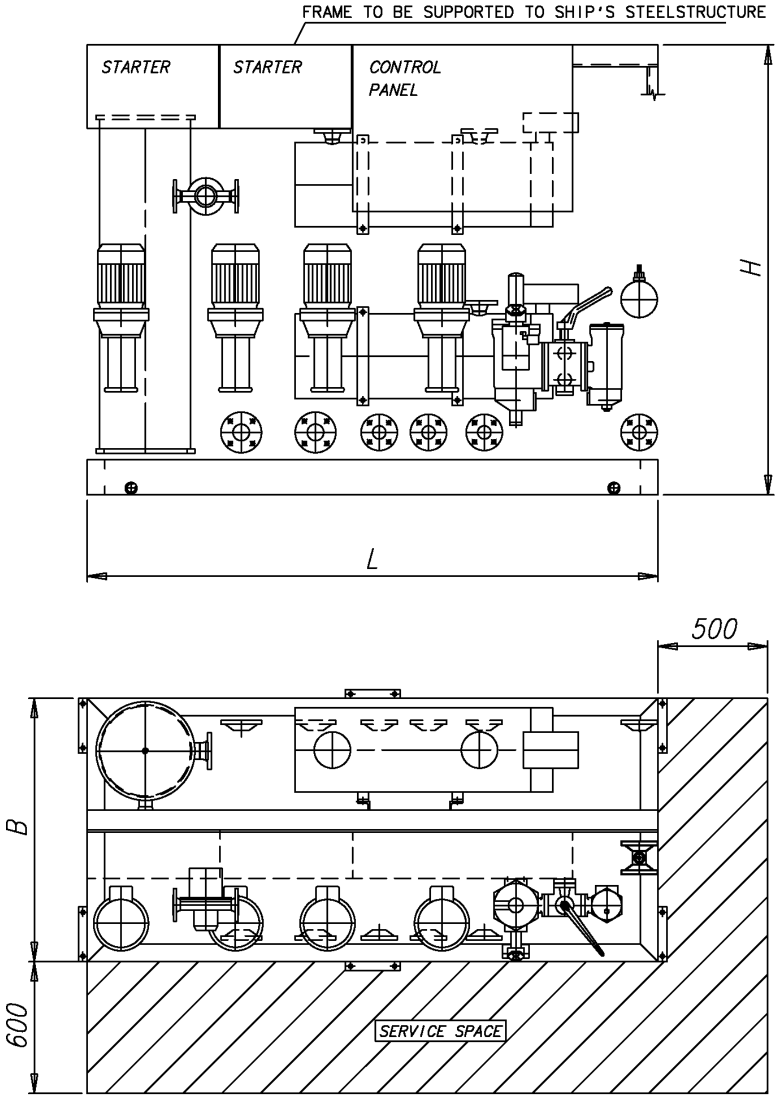
6.2.6.4 Feeder/booster unit (1N01)

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 6-10 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:

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 MDF.

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 two engines are connected to the same feeder/booster unit, individual circulation pumps (1P12) must be installed before each engine.

Design data:

Capacity:	
- without circulation pumps (1P12)	6 x the total consumption of the connected engine
- 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 two engines are 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 MDF is fed directly from the MDF 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 MDF is fed directly from day tank	0.7 MPa (7 bar)
- 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)
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.

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, as shown in the table below. 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
A	ASTM D 975-01, BS MA 100: 1996 CIMAC 2003 ISO 8217:2017(E)	GRADE NO. 1-D, 2-D, 4-D DMX, DMA, DMB DX, DA, DB ISO-F-DMX, DMB	10...30
B	ASTM D 975-01 BS MA 100: 1996 CIMAC 2003 ISO 8217:2017(E)	GRADE NO. 1-D, 2-D, 4-D DMX, DMA, DMB DX, DA, DB ISO-F-DMX - DMB	15...30
C	ASTM D 975-01, ASTM D 396-04, BS MA 100: 1996 CIMAC 2003 ISO 8217:2017(E)	GRADE NO. 4-D GRADE NO. 5-6 DMC, RMA10-RMK55 DC, A30-K700 RMA10-RMK 700	30...55

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.

If both distillate fuel and 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 Oils (ULSFO) with sulphur content of max. 0,10 % m/m being classed as residual fuels are used, the use of BN 20 lubricating oil is allowed.

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 acceptable in normal operating conditions. Usually the same oil as in the engine can be used. At low ambient temperatures it may be necessary to use a multigrade oil (e.g. SAE 5W-40) to ensure proper operation during start-up with cold oil.

7.1.3 Oil in turning device

It is recommended to use EP-gear oils, viscosity 400-500 cSt at 40°C = ISO VG 460.

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

7.2 External lubricating oil system

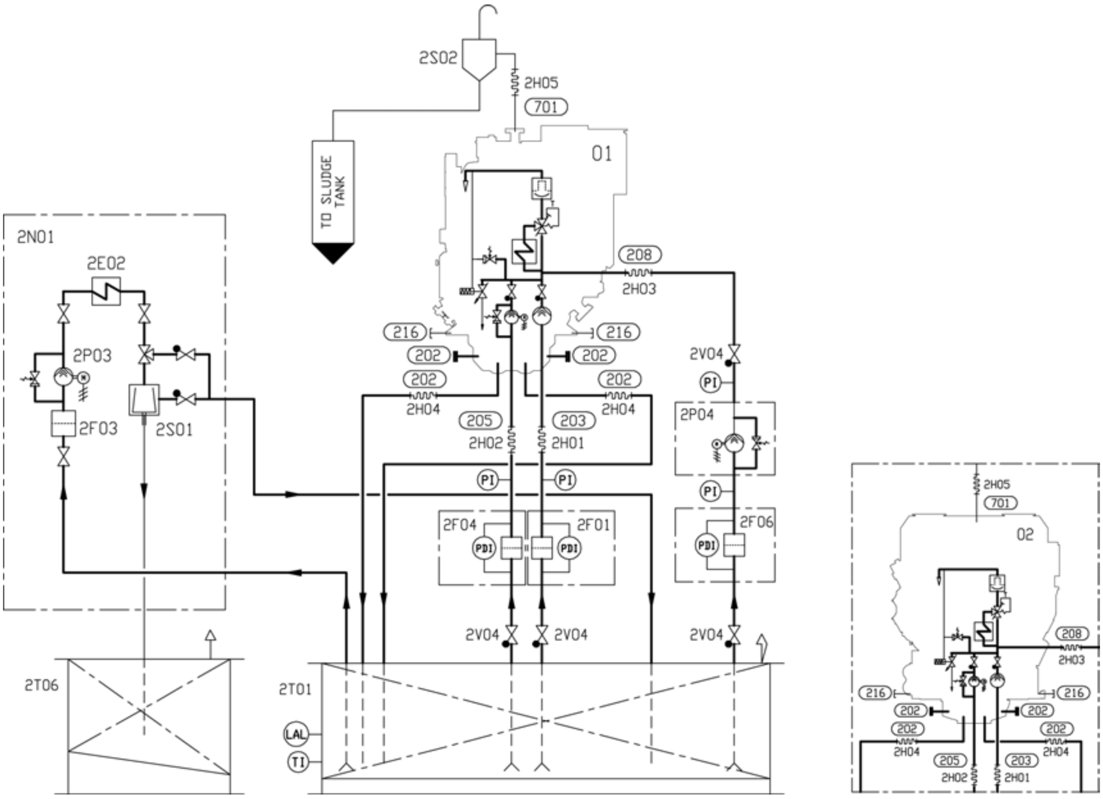


Fig 7-1 Typical example of an external lubricating oil system for a single main engine with a dry sump (DAAF078375A)

System components:			
01	Diesel engine Wärtsilä L26	2N01	Separator unit
02	Diesel engine Wärtsilä V26	2P03	Separator pump (separator unit)
2E02	Heater (separator unit)	2P04	Stand-by pump
2F01	Suction strainer (main LO pump)	2S01	Separator (separator unit)
2F03	Suction filter (separator unit)	2S02	Condensate trap
2F04	Suction strainer (pre lubricating oil pump)	2T01	System oil tank
2F06	Suction strainer (stand-by pump)	2T06	Sludge tank
2H0X	Flexible pipe connections	2V04	Non-return valve

Pos	Pipe connections	L26	V26
202	Lube oil outlet (from oil sump)	4 * DN150	
203	Lube oil to engine driven pump	DN200	DN150
205	Lube oil to priming pump	DN65	
208	Lube oil from el. driven pump	DN80	DN100
216	Lube oil drain	2 * plug G 3/4"	
701	Crankcase air vent	DN80	DN100

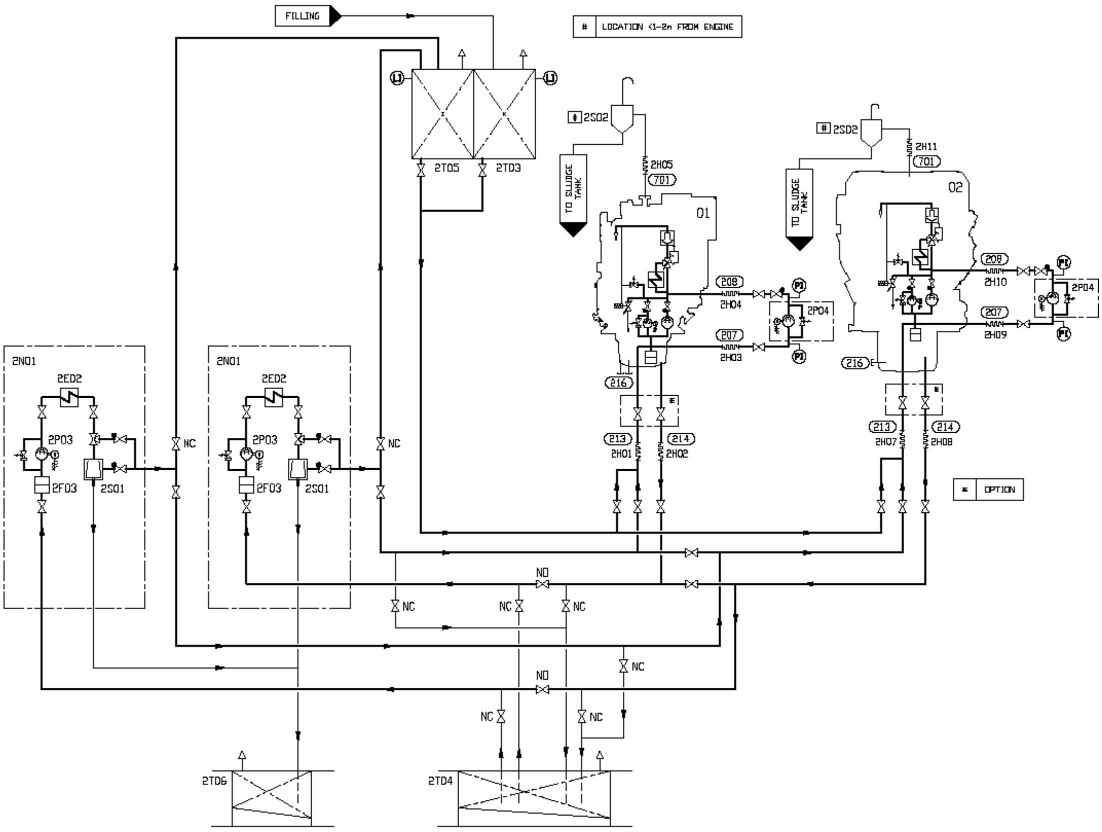


Fig 7-2 **Typical example of an external lubricating oil system for a single main engine with a wet sump (DAAF078378A)**

System components:			
01	Diesel engine Wärtsilä L26	2P04	Stand-by pump
02	Diesel engine Wärtsilä V26	2S01	Separator (separator unit)
2E02	Heater (separator unit)	2S02	Condensate trap
2F03	Suction filter (separator unit)	2T03	New oil tank
2H0X	Flexible pipe connections	2T04	Renovating oil tank
2N01	Separator unit	2T05	Renovated oil tank
2P03	Separator pump (separator unit)	2T06	Sludge tank

Pos	Pipe connections	L26	V26
207	Lube oil to el. driven pump	DN125	DN150
208	Lube oil from el. driven pump	DN80	DN100
213	Lube oil from separator and filling	DN40(*) or plug G1 1/2"	
214	Lube oil to separator and drain	DN40(*) or plug G1 1/2"	
216	Lube oil drain	2 * plug G1 1/2"	
701	Crankcase air vent	DN80	DN100

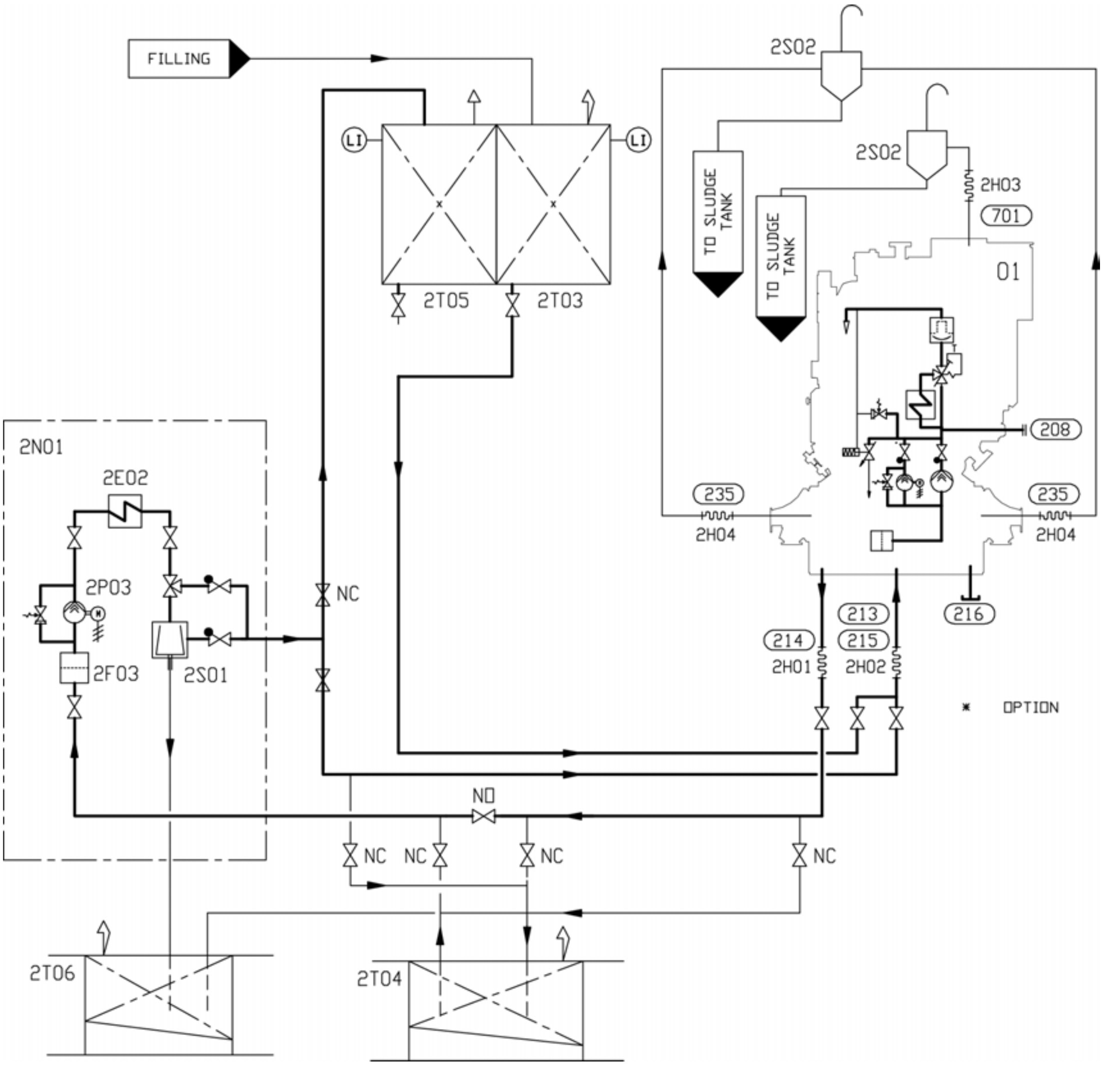


Fig 7-3 Typical example of an external lubricating oil system for a genset with wet CBF (DAAF078377A)

System components:			
01	Diesel engine Wärtsilä 26	2S01	Separator (separator unit)
2E02	Heater (separator unit)	2S02	Condensate trap
2F03	Suction filter (separator unit)	2T03	New oil tank
2H0X	Flexible pipe connections	2T04	Renovating oil tank
2N01	Separator unit	2T05	Renovated oil tank
2P03	Separator pump (separator unit)	2T06	Sludge tank

Pos	Pipe connections	L26	V26
208	Lube oil from el. driven pump	DN80	DN100
213	Lube oil from separator and filling	DN40	
214	Lube oil to separator and drain	DN40(*) or plug G 2"	
215	Lube oil filling	DN40	
216	Lube oil drain	2 * plug G 2"	
235	Lube oil tank air vent	2 * DN80	
701	Crankcase air vent	DN80	DN100

7.2.1 Separation system

7.2.1.1 Separator unit (2N01)

As a method of external lubricating oil treatment, the requirement depends on fuel type. Engines operating on HFO should have dedicated lubricating oil separator and the separators shall be dimensioned for continuous separating. If the installation is designed to operate on MDF only, the use of lubricating oil separator or similar device maintaining oil cleanliness is recommended.

A lube oil separator is required, as oil by-pass treatment device, for engines running on fuels classified as worse than ISO-F-DMB.

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 MDF

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.

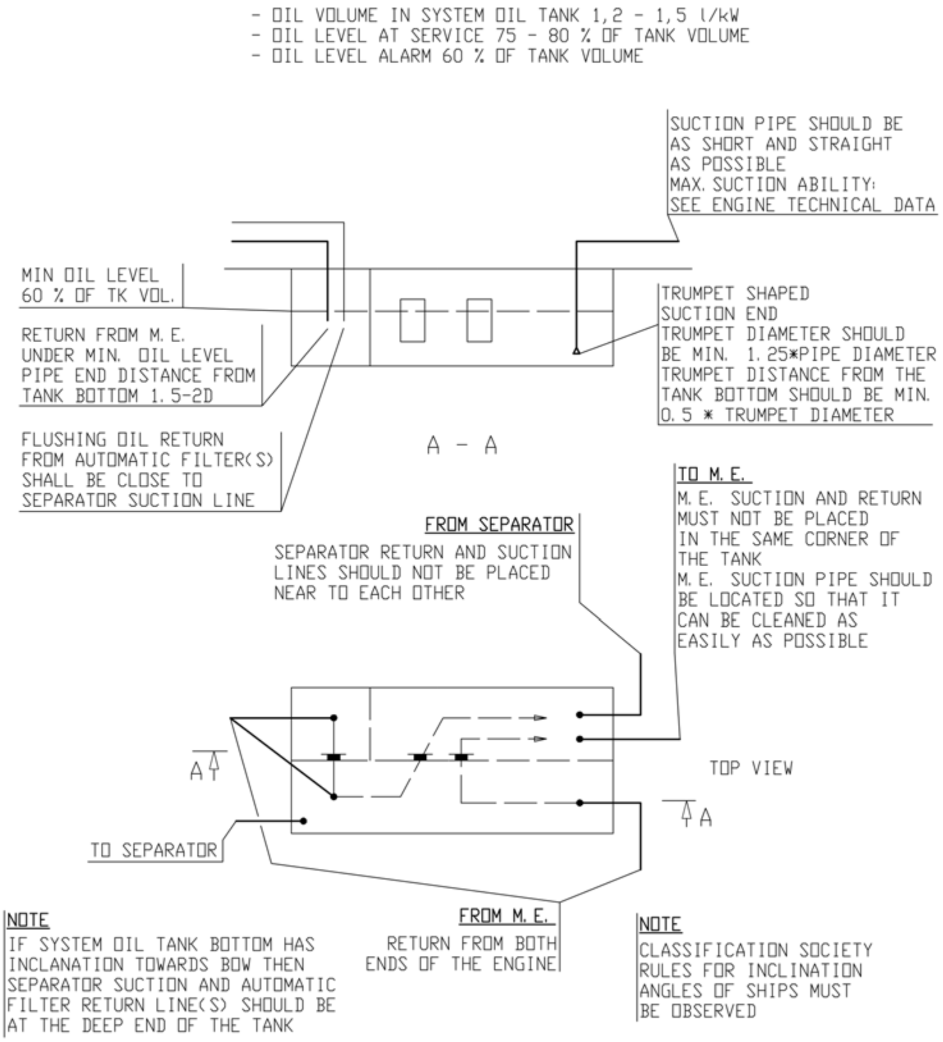


Fig 7-4 **Example of system oil tank arrangement (DAAE007020F)**

Design data:

Oil tank volume	1.2...1.5 l/kW, please refer to *Engine Online Configurator* available through Wärtsilä website

Oil level at service	75...80% of tank volume
Oil level alarm	60% of tank volume

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

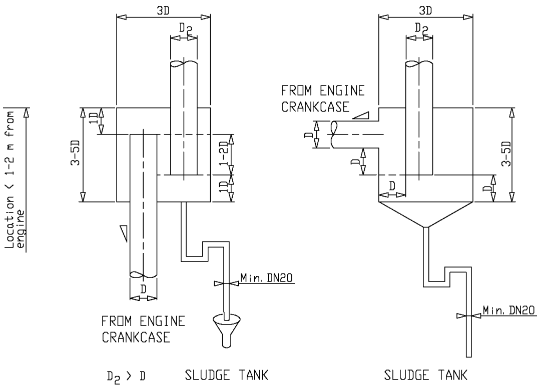


Fig 7-5 **Condensate trap (DAAE032780B)**

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). It is however acceptable to circulate the flushing oil via the engine sump if this is advantageous. Cleanliness of the oil sump shall be verified after completed 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 65°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 however 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 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.

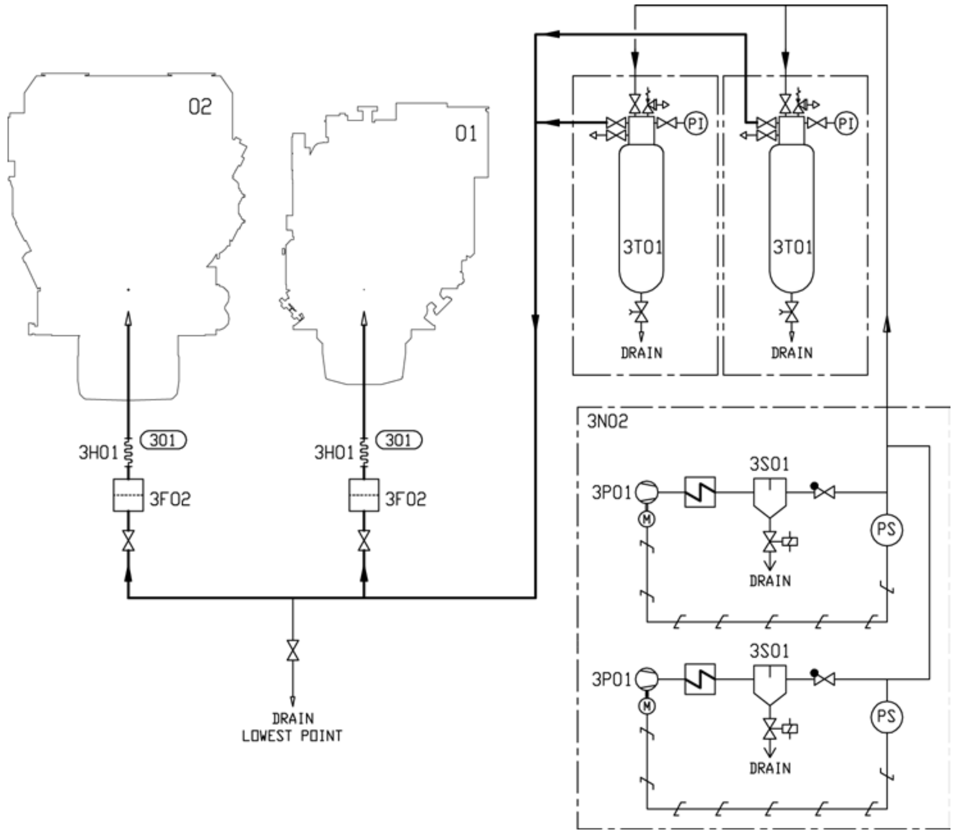


Fig 8-1 **Example of external compressed air system (DAAF078379A)**

System components			
01	Diesel engine Wärtsilä L26	3N02	Starting air compressor unit
02	Diesel engine Wärtsilä V26	3P01	Compressor (starting air compressor unit)
3H01	Flexible pipe connection	3S01	Separator (starting air compressor unit)
3F02	Air filter (starting air inlet)	3T01	Staring air vessel

Pos	Pipe connections	Size
301	Staring air inlet	DN40

8.1.1 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.

8.1.2 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.

8.1.3 Starting air vessel (3T01)

The starting 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 starting 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.

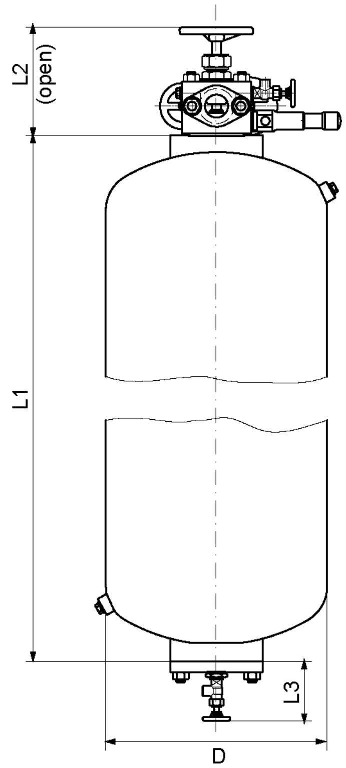


Fig 8-2 **Starting air vessel**

Size [Litres]	Dimensions [mm]				Weight [kg]
	L1	L2 1)	L3 1)	D	
125	1807	243	110	324	170
180	1217	243	110	480	200
250	1767	243	110	480	274
500	3204	243	133	480	450
710	2740	255	133	650	625
1000	3560	255	133	650	810

1) Dimensions are approximate.

The starting air consumption stated in *Engine Online Configurator* (available through Wärtsilä website) 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 take twice the air consumption of a successful start. If the ship has a class notation for unattended machinery spaces, then the starts are to be demonstrated.

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

$$V_R = \frac{p_E \times V_E \times n}{p_{R\max} - p_{R\min}}$$

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 *Engine Online Configurator* available through Wärtsilä 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 = please refer to *Engine Online Configurator* available through Wärtsilä website

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

8.1.4 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.

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. 10
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. 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 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.

Starting from 20% glycol the engine is to be de-rated 0.23 % per 1% glycol in the water. Max. 60% glycol is permitted.

Corrosion inhibitors shall be used regardless of glycol in the cooling water.

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 using *Engine Online Configurator* available through Wärtsilä's website.and that

the cooling water is 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.

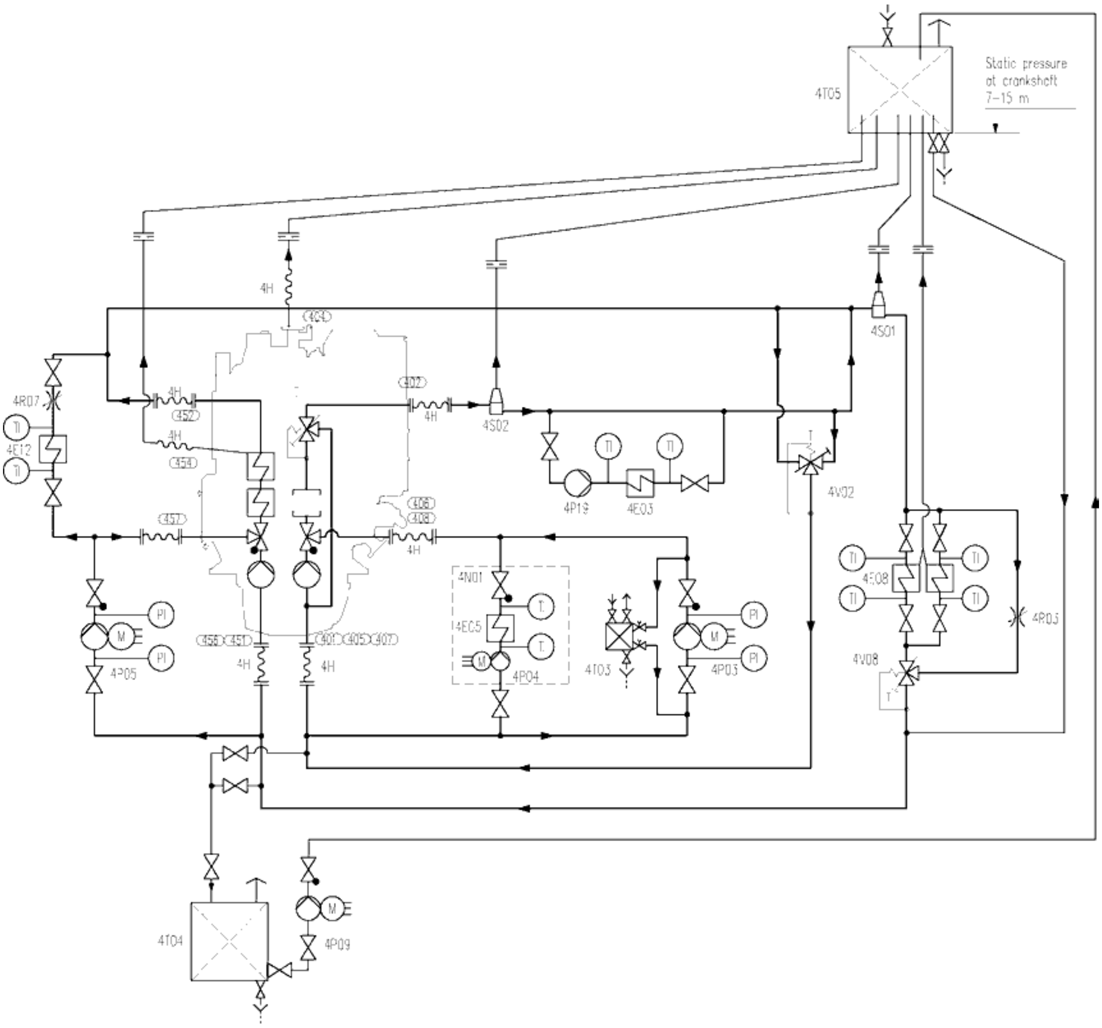


Fig 9-1 External cooling water system example, only for MDF (DAAE038900C)

System components:			
4E03	Heat recovery (evaporator)	4P19	Circulating pump (evaporator)
4E05	Heater (preheater)	4R03	Adjustable throttle valve (LT cooler)
4E08	Central cooler	4R07	Adjustable throttle valve (LT water)
4E12	Cooler (installation parts)	4S02	Air deaerator (HT)
4N01	Preheating unit	4T03	Additive dosing tank

System components:			
4P03	Stand-by pump (HT)	4T04	Drain tank
4P04	Circulating pump (preheater)	4T05	Expansion tank
4P05	Stand-by pump (LT)	4V02	Temperature control valve (heat recovery)
4P09	Transfer pump	4V08	Temperature control valve (central cooler)
*Pipe connections are listed below the internal cooling water system diagram*s			

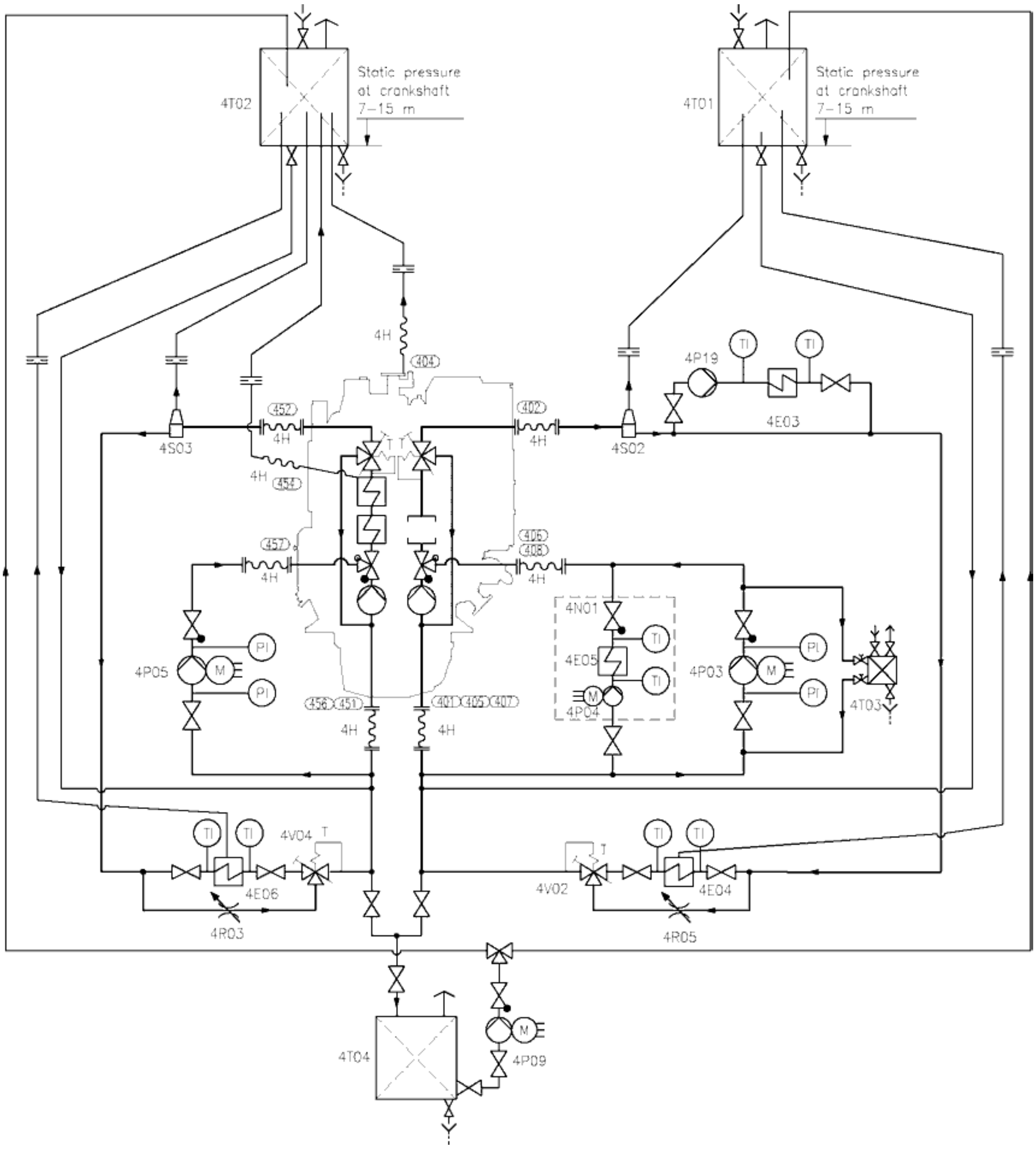


Fig 9-2 External cooling water system example (DAAE038901C)

System components:			
4E03	Heat recovery (evaporator)	4R03	Adjustable throttle valve (LT cooler)
4E04	Raw water cooler (HT)	4R05	Adjustable throttle valve (HT valve)
4E05	Heater (preheater)	4S02	Air deaerator (HT)
4E06	Raw water cooler (LT)	4S03	Air deaerator (LT)
4N01	Preheating unit	4T03	Additive dosing tank
4P03	Stand-by pump (HT)	4T04	Drain tank
4P04	Circulating pump (preheater)	4T05	Expansion tank
4P05	Stand-by pump (LT)	4V02	Temperature control valve (heat recovery)
4P19	Circulating pump (evaporator)	4V08	Temperature control valve (central cooler)
4P09	Transfer pump		
*Pipe connections are listed below the internal cooling water system diagram*s			

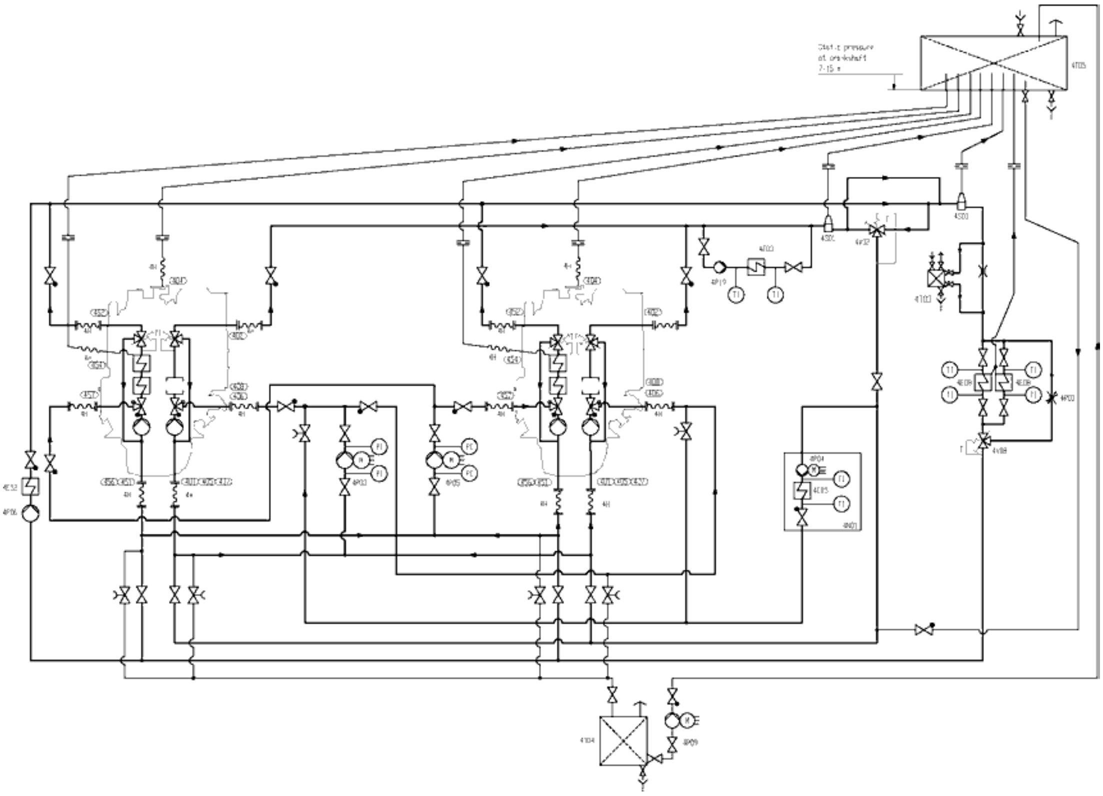
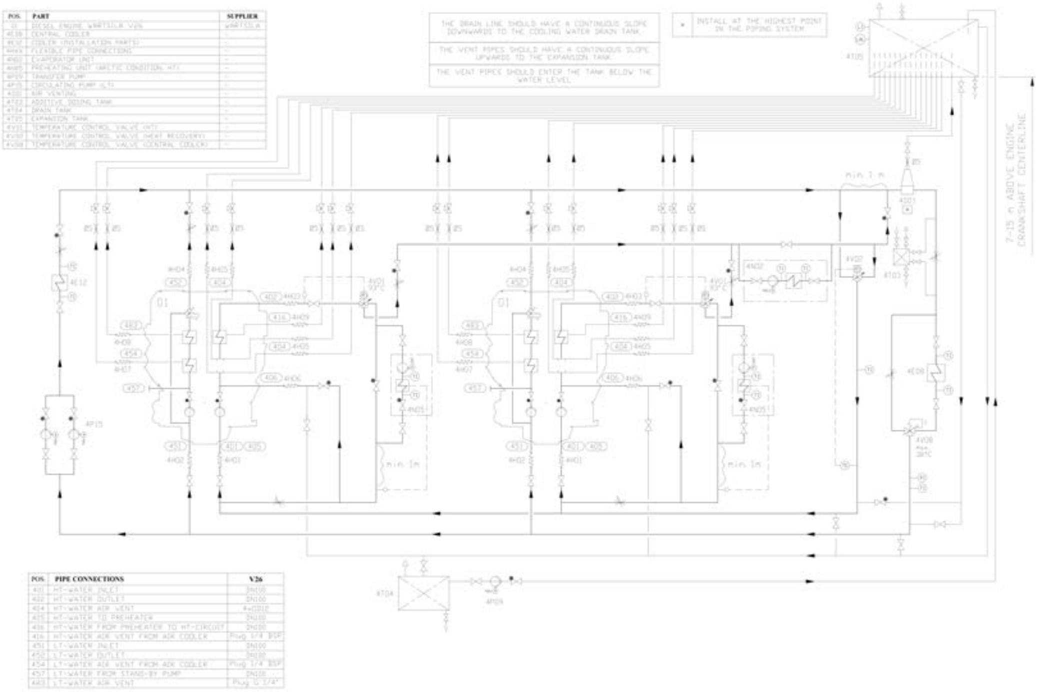


Fig 9-3 External cooling water system example (DAAE038902C)

System components:			
4E03	Heat recovery (evaporator)	4P09	Transfer pump
4E05	Heater (preheater)	4P19	Circulating pump (evaporator)
4E08	Central cooler	4R03	Adjustable throttle valve (LT cooler)
4E12	Cooler (installation parts)	4S01	Air venting
4N01	Preheating unit	4T03	Additive dosing tank
4P03	Stand-by pump (HT)	4T04	Drain tank
4P04	Circulating pump (preheater)	4T05	Expansion tank
4P05	Stand-by pump (LT)	4V02	Temperature control valve (heat recovery)
4P06	Circulating pump	4V08	Temperature control valve (central cooler)
*Pipe connections are listed below the internal cooling water system diagram*s			



POS.	PART	SUPPLIER
01	DIESEL ENGINE WÄRTSILÄ V26	WÄRTSILÄ
4E08	CENTRAL COOLER	-
4E12	COOLER (INSTALLATION PARTS)	-
4HXX	FLEXIBLE PIPE CONNECTIONS	-
4N02	EVAPORATOR UNIT	-
4N05	PREHEATING UNIT (ARCTIC CONDITION, HT)	-
4P09	TRANSFER PUMP	-
4P15	CIRCULATING PUMP (LT)	-
4S01	AIR VENTING	-
4T03	ADDITIVE DOSING TANK	-
4T04	DRAIN TANK	-
4T05	EXPANSION TANK	-
4V01	TEMPERATURE CONTROL VALVE (HT)	-
4V02	TEMPERATURE CONTROL VALVE (HEAT RECOVERY)	-
4V08	TEMPERATURE CONTROL VALVE (CENTRAL COOLER)	-

THE DRAIN LINE SHOULD HAVE A CONTINUOUS SLOPE DOWNWARDS TO THE COOLING WATER DRAIN TANK.

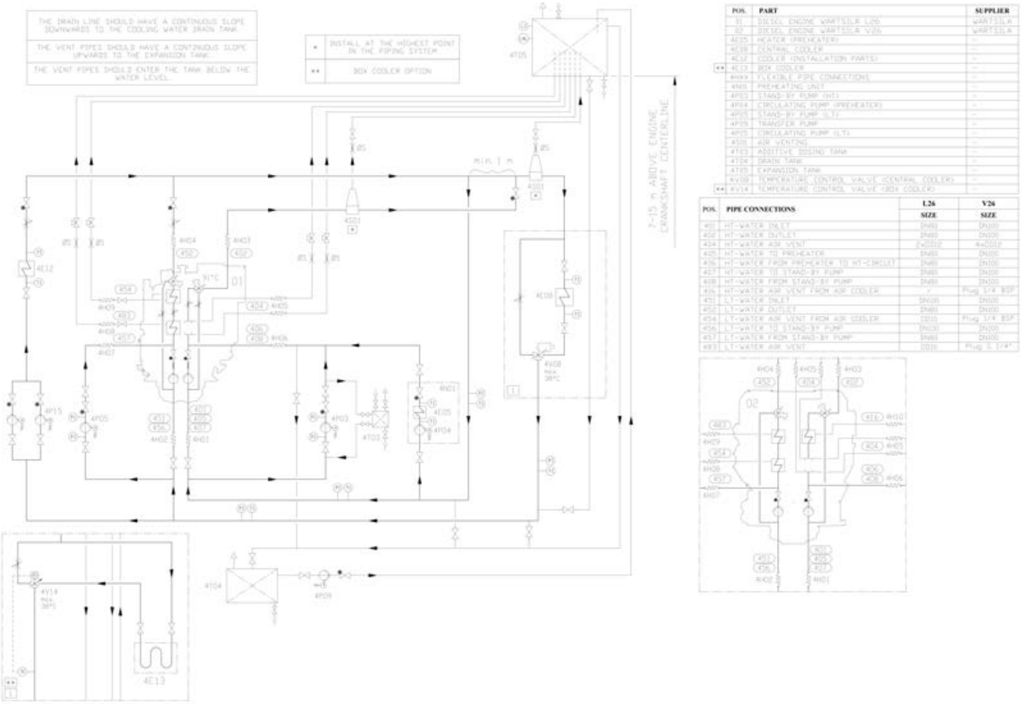
THE VENT PIPES SHOULD HAVE A CONTINUOUS SLOPE UPWARDS TO THE EXPANSION TANK.

THE VENT PIPES SHOULD ENTER THE TANK BELOW THE WATER LEVEL.

*	INSTALL AT THE HIGHEST POINT IN THE PIPING SYSTEM

POS.	PIPE CONNECTIONS	V26
401	HT-WATER INLET	DN100
402	HT-WATER OUTLET	DN100
404	HT-WATER AIR VENT	4xOD12
405	HT-WATER TO PREHEATER	DN100
406	HT-WATER FROM PREHEATER TO HT-CIRCUIT	DN100
416	HT-WATER AIR VENT FROM AIR COOLER	Plug 1/4 BSP
451	LT-WATER INLET	DN100
452	LT-WATER OUTLET	DN100
454	LT-WATER AIR VENT FROM AIR COOLER	Plug 1/4 BSP
457	LT-WATER FROM STAND-BY PUMP	DN100
483	LT-WATER AIR VENT	Plug G 1/4"

Fig 9-4 External cooling water system example - for arctic conditions V engine (DAAF089179B)



THE DRAIN LINE SHOULD HAVE A CONTINUOUS SLOPE DOWNWARDS TO THE COOLING WATER DRAIN TANK.

THE VENT PIPES SHOULD HAVE A CONTINUOUS SLOPE UPWARDS TO THE EXPANSION TANK.

THE VENT PIPES SHOULD ENTER THE TANK BELOW THE WATER LEVEL.

*	INSTALL AT THE HIGHEST POINT IN THE PIPING SYSTEM
**	BOX COOLER OPTION

	POS.	PART	SUPPLIER
	01	DIESEL ENGINE WÄRTSILÄ L26	WÄRTSILÄ
	02	DIESEL ENGINE WÄRTSILÄ V26	WÄRTSILÄ
	4E05	HEATER (PREHEATER)	-
	4E08	CENTRAL COOLER	-
	4E12	COOLER (INSTALLATION PARTS)	-
**	4E13	BOX COOLER	-
	4HXX	FLEXIBLE PIPE CONNECTIONS	-
	4N01	PREHEATING UNIT	-
	4P03	STAND-BY PUMP (HT)	-
	4P04	CIRCULATING PUMP (PREHEATER)	-
	4P05	STAND-BY PUMP (LT)	-
	4P09	TRANSFER PUMP	-
	4P15	CIRCULATING PUMP (LT)	-
	4S01	AIR VENTING	-
	4T03	ADDITIVE DOSING TANK	-
	4T04	DRAIN TANK	-
	4T05	EXPANSION TANK	-
	4V08	TEMPERATURE CONTROL VALVE (CENTRAL COOLER)	-
**	4V14	TEMPERATURE CONTROL VALVE (BOX COOLER)	-

POS.	PIPE CONNECTIONS	L26	V26
		SIZE	SIZE
401	HT-WATER INLET	DN80	DN100
402	HT-WATER OUTLET	DN80	DN100
404	HT-WATER AIR VENT	2xOD12	4xOD12
405	HT-WATER TO PREHEATER	DN80	DN100
406	HT-WATER FROM PREHEATER TO HT-CIRCUIT	DN80	DN100
407	HT-WATER TO STAND-BY PUMP	DN80	DN100
408	HT-WATER FROM STAND-BY PUMP	DN80	DN100
416	HT-WATER AIR VENT FROM AIR COOLER	-	Plug 1/4 BSP
451	LT-WATER INLET	DN100	DN100
452	LT-WATER OUTLET	DN80	DN100
454	LT-WATER AIR VENT FROM AIR COOLER	OD10	Plug 1/4 BSP
456	LT-WATER TO STAND-BY PUMP	DN100	DN100
457	LT-WATER FROM STAND-BY PUMP	DN80	DN100
483	LT-WATER AIR VENT	OD10	Plug G 1/4"

Fig 9-5 External cooling water system example - combined LT/HT (DAAF078380B)

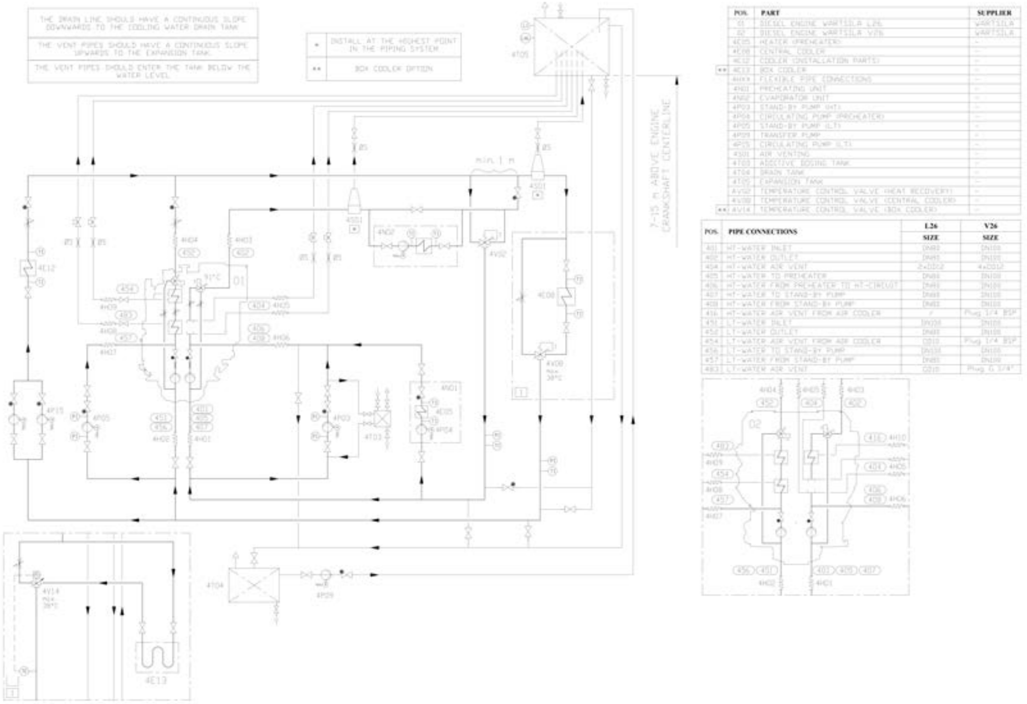


Fig 9-6 External cooling water system example - combined LT/HT with heat recovery (DAAF088988B)

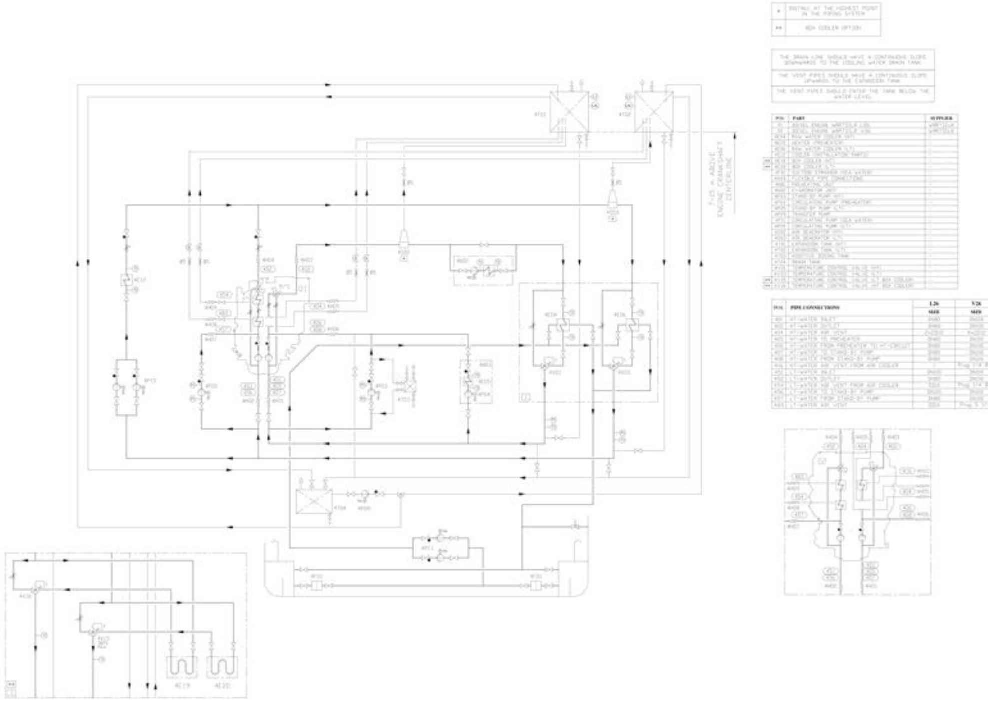
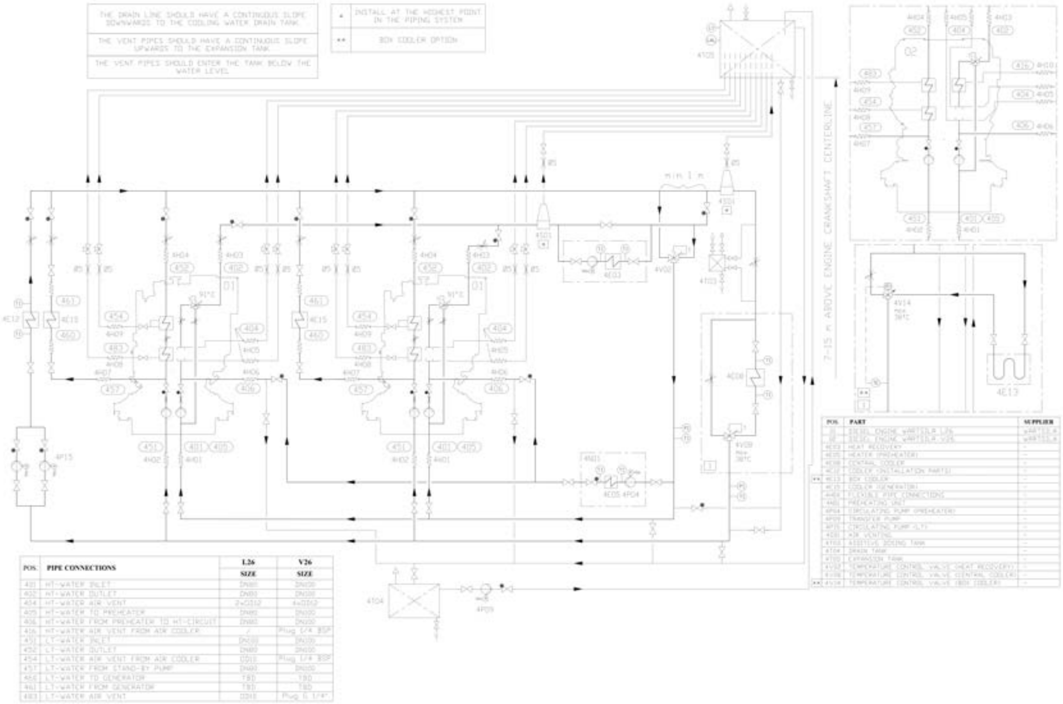


Fig 9-7 External cooling water system example - separate LT/HT (DAAF088989B)



THE DRAIN LINE SHOULD HAVE A CONTINUOUS SLOPE DOWNWARDS TO THE COOLING WATER DRAIN TANK

THE VENT PIPES SHOULD HAVE A CONTINUOUS SLOPE UPWARDS TO THE EXPANSION TANK

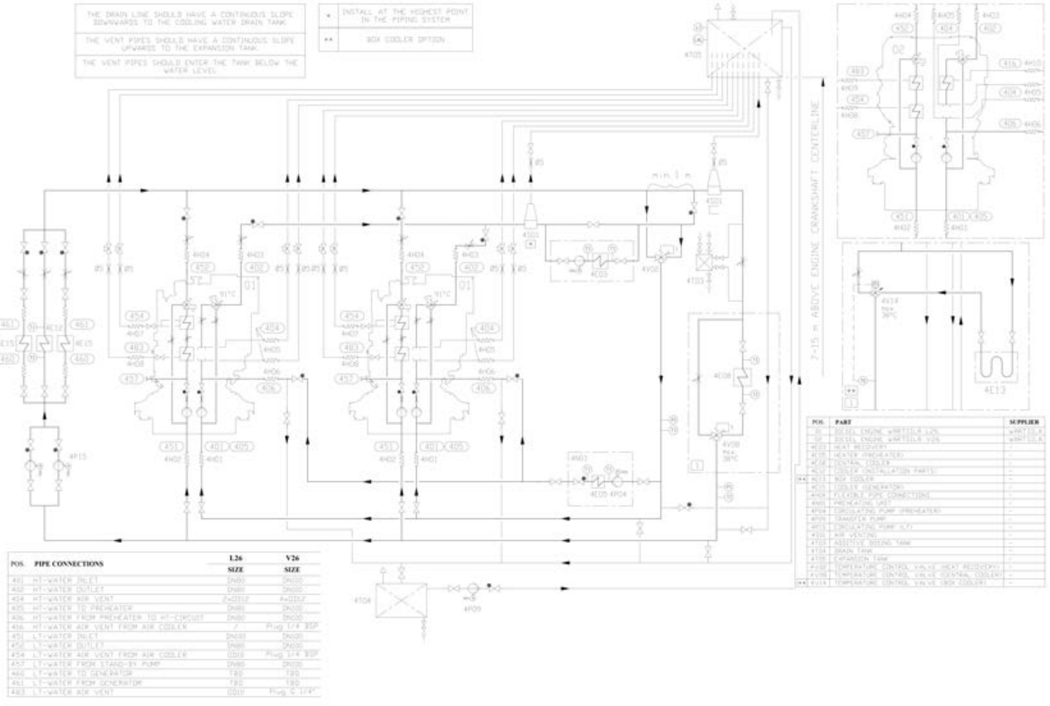
THE VENT PIPES SHOULD ENTER THE TANK BELOW THE WATER LEVEL

*	INSTALL AT THE HIGHEST POINT IN THE PIPING SYSTEM
**	BOX COOLER OPTION

POS.	PIPE CONNECTIONS	L26	V26
		SIZE	SIZE
401	HT-WATER INLET	DN80	DN100
402	HT-WATER OUTLET	DN80	DN100
404	HT-WATER AIR VENT	2xOD12	4xOD12
405	HT-WATER TO PREHEATER	DN80	DN100
406	HT-WATER FROM PREHEATER TO HT-CIRCUIT	DN80	DN100
416	HT-WATER AIR VENT FROM AIR COOLER	/	Plug 1/4 BSP
451	LT-WATER INLET	DN100	DN100
452	LT-WATER OUTLET	DN80	DN100
454	LT-WATER AIR VENT FROM AIR COOLER	OD10	Plug 1/4 BSP
457	LT-WATER FROM STAND-BY PUMP	DN80	DN100
460	LT-WATER TO GENERATOR	TBD	TBD
461	LT-WATER FROM GENERATOR	TBD	TBD
483	LT-WATER AIR VENT	OD10	Plug G 1/4"

	POS.	PART	SUPPLIER
	01	DIESEL ENGINE WÄRTSILÄ L26	WÄRTSILÄ
	02	DIESEL ENGINE WÄRTSILÄ V26	WÄRTSILÄ
	4E03	HEAT RECOVERY	-
	4E05	HEATER (PREHEATER)	-
	4E08	CENTRAL COOLER	-
	4E12	COOLER (INSTALLATION PARTS)	-
**	4E13	BOX COOLER	-
	4E15	COOLER (GENERATOR)	-
	4H0X	FLEXIBLE PIPE CONNECTIONS	-
	4N01	PREHEATING UNIT	-
	4P04	CIRCULATING PUMP (PREHEATER)	-
	4P09	TRANSFER PUMP	-
	4P15	CIRCULATING PUMP (LT)	-
	4S01	AIR VENTING	-
	4T03	ADDITIVE DOSING TANK	-
	4T04	DRAIN TANK	-
	4T05	EXPANSION TANK	-
	4V02	TEMPERATURE CONTROL VALVE (HEAT RECOVERY)	-
	4V08	TEMPERATURE CONTROL VALVE (CENTRAL COOLER)	-
**	4V14	TEMPERATURE CONTROL VALVE (BOX COOLER)	-

Fig 9-8 External cooling water system example - Genset (DAAF088991B)



THE DRAIN LINE SHOULD HAVE A CONTINUOUS SLOPE DOWNWARDS TO THE COOLING WATER DRAIN TANK

THE VENT PIPES SHOULD HAVE A CONTINUOUS SLOPE UPWARDS TO THE EXPANSION TANK

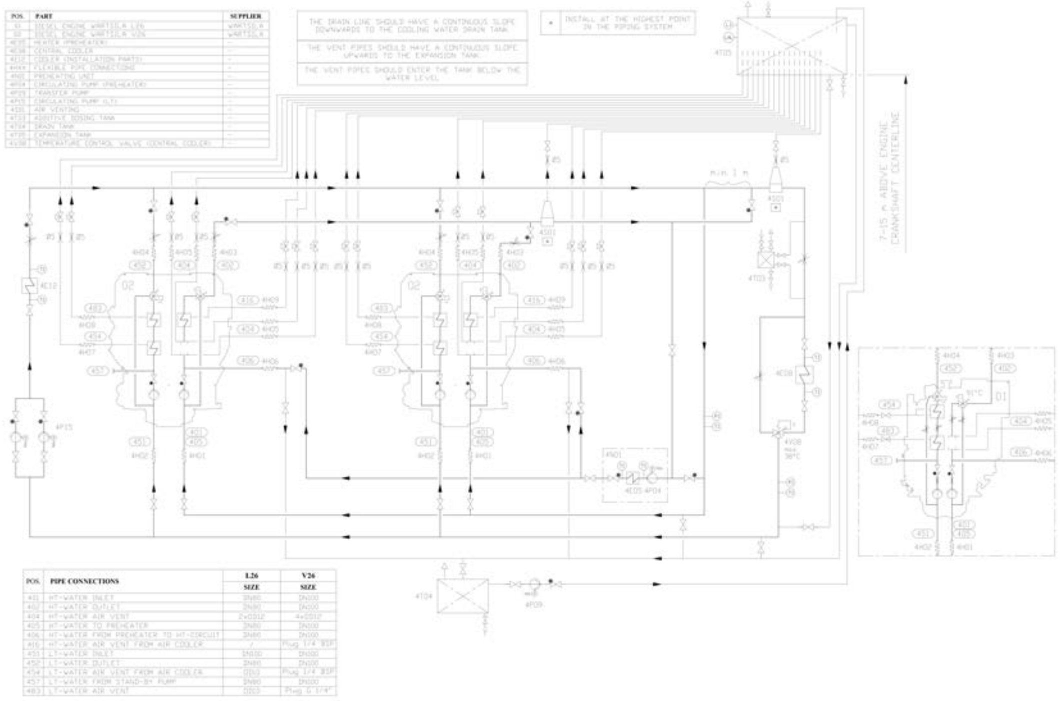
THE VENT PIPES SHOULD ENTER THE TANK BELOW THE WATER LEVEL

*	INSTALL AT THE HIGHEST POINT IN THE PIPING SYSTEM
**	BOX COOLER OPTION

POS.	PIPE CONNECTIONS	L26	V26
		SIZE	SIZE
401	HT-WATER INLET	DN80	DN100
402	HT-WATER OUTLET	DN80	DN100
404	HT-WATER AIR VENT	2xOD12	4xOD12
405	HT-WATER TO PREHEATER	DN80	DN100
406	HT-WATER FROM PREHEATER TO HT-CIRCUIT	DN80	DN100
416	HT-WATER AIR VENT FROM AIR COOLER	/	Plug 1/4 BSP
451	LT-WATER INLET	DN100	DN100
452	LT-WATER OUTLET	DN80	DN100
454	LT-WATER AIR VENT FROM AIR COOLER	OD10	Plug 1/4 BSP
457	LT-WATER FROM STAND-BY PUMP	DN80	DN100
460	LT-WATER TO GENERATOR	TBD	TBD
461	LT-WATER FROM GENERATOR	TBD	TBD
483	LT-WATER AIR VENT	OD10	Plug G 1/4"

	POS.	PART	SUPPLIER
	01	DIESEL ENGINE WÄRTSILÄ L26	WÄRTSILÄ
	02	DIESEL ENGINE WÄRTSILÄ V26	WÄRTSILÄ
	4E03	HEAT RECOVERY	-
	4E05	HEATER (PREHEATER)	-
	4E08	CENTRAL COOLER	-
	4E12	COOLER (INSTALLATION PARTS)	-
**	4E13	BOX COOLER	-
	4E15	COOLER (GENERATOR)	-
	4H0X	FLEXIBLE PIPE CONNECTIONS	-
	4N01	PREHEATING UNIT	-
	4P04	CIRCULATING PUMP (PREHEATER)	-
	4P09	TRANSFER PUMP	-
	4P15	CIRCULATING PUMP (LT)	-
	4S01	AIR VENTING	-
	4T03	ADDITIVE DOSING TANK	-
	4T04	DRAIN TANK	-
	4T05	EXPANSION TANK	-
	4V02	TEMPERATURE CONTROL VALVE (HEAT RECOVERY)	-
	4V08	TEMPERATURE CONTROL VALVE (CENTRAL COOLER)	-
**	4V14	TEMPERATURE CONTROL VALVE (BOX COOLER)	-

Fig 9-9 External cooling water system example - Genset (DAAF088992B)



POS.	PART	SUPPLIER
01	DIESEL ENGINE WÄRTSILÄ L26	WÄRTSILÄ
02	DIESEL ENGINE WÄRTSILÄ V26	WÄRTSILÄ
4E05	HEATER (PREHEATER)	-
4E08	CENTRAL COOLER	-
4E12	COOLER (INSTALLATION PARTS)	-
4Hxx	FLEXIBLE PIPE CONNECTIONS	-
4N01	PREHEATING UNIT	-
4P04	CIRCULATING PUMP (PREHEATER)	-
4P09	TRANSFER PUMP	-
4P15	CIRCULATING PUMP (LT)	-
4S01	AIR VENTING	-
4T03	ADDITIVE DOSING TANK	-
4T04	DRAIN TANK	-
4T05	EXPANSION TANK	-
4V08	TEMPERATURE CONTROL VALVE (CENTRAL COOLER)	-

POS.	PIPE CONNECTIONS	L26	V26
		SIZE	SIZE
401	HT-WATER INLET	DN80	DN100
402	HT-WATER OUTLET	DN80	DN100
404	HT-WATER AIR VENT	2xOD12	4xOD12
405	HT-WATER TO PREHEATER	DN80	DN100
406	HT-WATER FROM PREHEATER TO HT-CIRCUIT	DN80	DN100
416	HT-WATER AIR VENT FROM AIR COOLER	/	Plug 1/4 BSP
451	LT-WATER INLET	DN100	DN200
452	LT-WATER OUTLET	DN80	DN100
454	LT-WATER AIR VENT FROM AIR COOLER	OD10	Plug 1/4 BSP
457	LT-WATER FROM STAND-BY PUMP	DN80	DN100
483	LT-WATER AIR VENT	OD10	Plug G 1/4"

Fig 9-10 External cooling water system example - combined LT/HT (DAAF088993B)

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

9.2.1 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* .

NOTE
Some classification societies require that spare pumps are carried onboard even though the ship has multiple engines. Stand-by pumps can in such case be worth considering also for this type of application.

9.2.2 Sea water pump (4P11)

The capacity of electrically driven sea water 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 electrically driven sea water pumps. Minimum flow velocity (fouling) and maximum sea water temperature (salt deposits) are however issues to consider.

9.2.3 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.

When there is no temperature control valve in the seawater system (4V07, see figure 9.16), it is advised to install a temperature control valve over the central cooler(s) in order to maintain the temperature before engine at a constant value.

9.2.4 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.

The set-point is usually somewhere close to 75 ºC.

The arrangement shown in the example system diagrams also results in a smaller flow through the central cooler, compared to a system where the HT and LT circuits are connected in parallel to the cooler.

9.2.5 Coolers for other equipment and MDF 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 MDF cooler or a reduction gear cooler. This is only possible for engines operating on MDF, 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 MDF cooler are given in chapter *Fuel system*.

9.2.6 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.

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 therefor well suited for shallow or muddy waters.

9.2.7 Waste heat recovery

The waste heat in the HT cooling water can be used for fresh water production, central heating, tank heating etc. 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.

9.2.8 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.

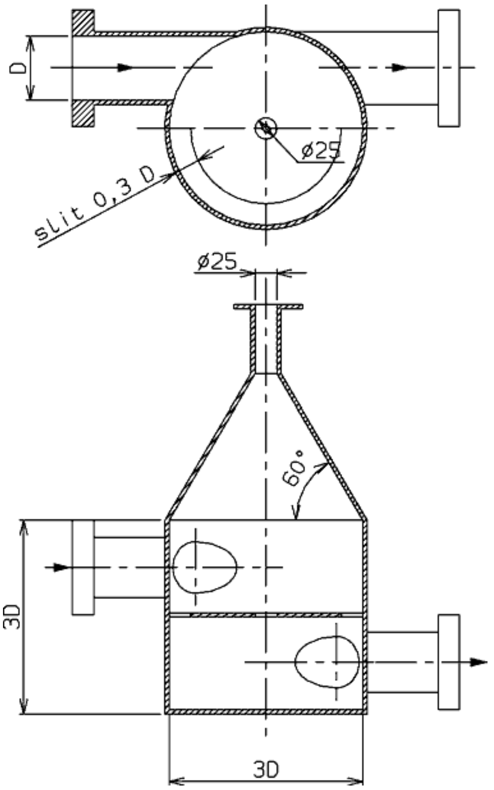


Fig 9-11 Automatic de-aerator (9811MR102).

The water flow is forced in a circular movement in the air separator. Air and gas collect in the centre of the separator due to the higher centrifugal force on water.

9.2.9 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

NOTE

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

9.2.10 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.

9.2.11 Additive dosing tank (4T03)

It is also recommended to provide a separate additive dosing tank, especially when water treatment products are added in solid form. The design must be such that the major part of the water flow is circulating through the engine when treatment products are added.

The tank should be connected to the HT cooling water circuit as shown in the example system diagrams.

9.2.12 Preheating

The cooling water circulating through the cylinders must be preheated to at least 60 ºC, preferably 70 ºC. Presence of preheating is is an absolute requirement for installations that are designed to operate on heavy fuel and 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.

9.2.12.1 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 3 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 1.5 kW/cyl is required to keep a hot engine warm.

Desig data:

Preheating temperature	min. 60°C
Required heating power	3 kW/cyl

Heating power to keep hot engine warm	1.5 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 [ton]

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 = 0.75 kW

n_{cyl} = Number of cylinders

The formula above should not be used for $P < 2.5$ kW/cyl

9.2.12.2 Circulation pump for preheater (4P04)

Design data:

Capacity	0.45 m^3/h per cylinder
Delivery pressure	80...100 kPa (0.8...1.0 bar)

9.2.12.3 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

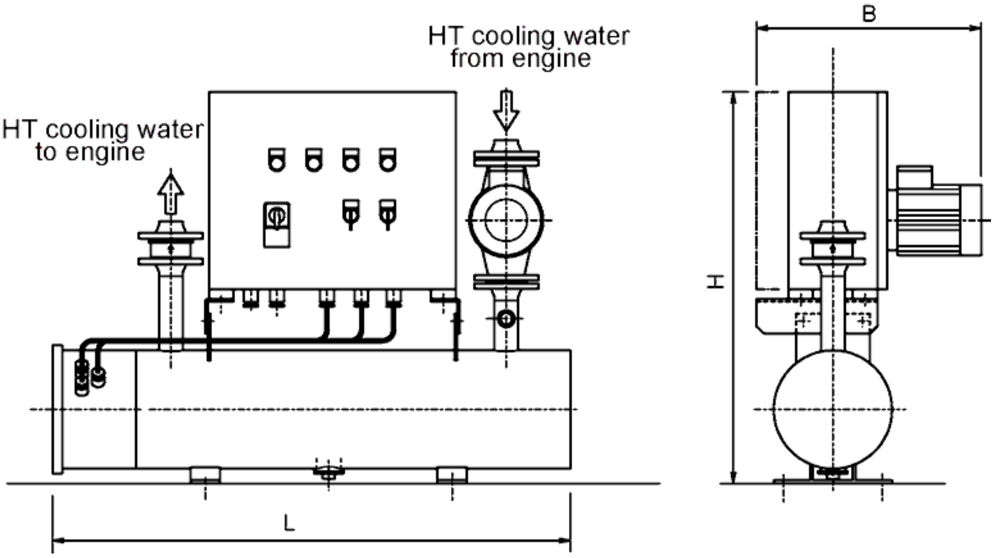


Fig 9-12 Electric pre-heating unit, main dimensions

Heating power [kW]*	L [mm]	H [mm]	B [mm]	Mass [kg] (wet)
12 (16)	1050	800	460	93
16 (21)	1250	800	460	95
18 (24)	1250	800	460	95
24 (32)	1250	840	480	103
32 (42)	1250	840	480	125

9.2.13 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.

9.2.14 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.

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]

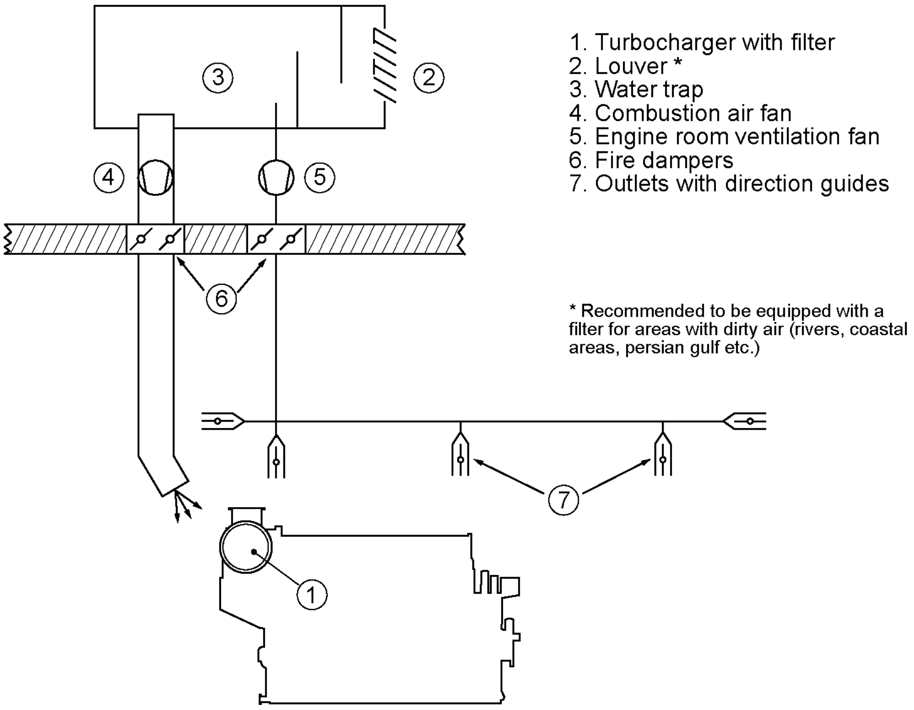
The heat emitted by the engine is listed in *Engine Online Configurator* available through Wärtsilä website.

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.

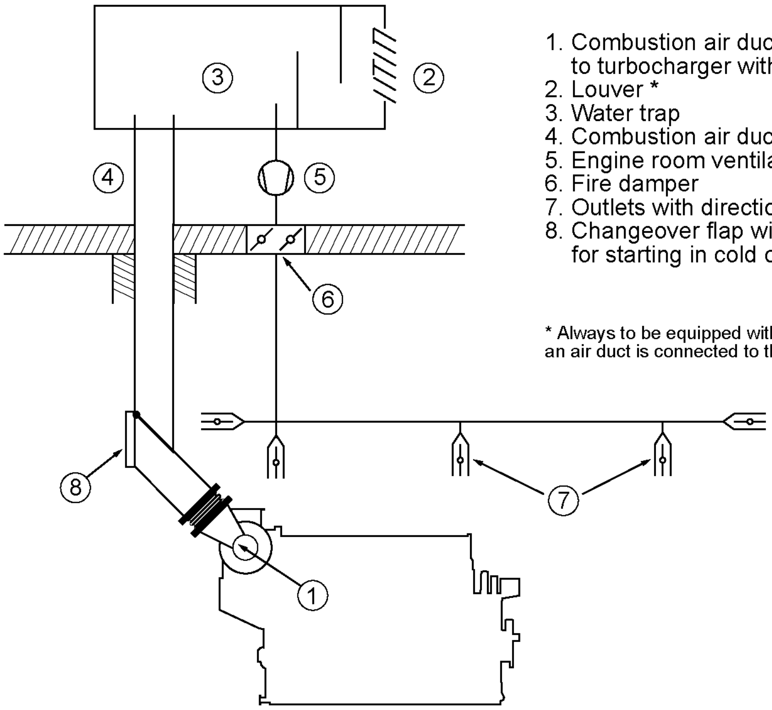
Under-cooling of the engine room should be avoided during all conditions (service conditions, slow steaming and in port). Cold draft in the engine room should also be avoided, especially in areas of frequent maintenance activities. For very cold conditions a pre-heater in the system should be considered. 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.



1. Turbocharger with filter
2. Louver *
3. Water trap
4. Combustion air fan
5. Engine room ventilation fan
6. Fire dampers
7. Outlets with direction guides

* Recommended to be equipped with a filter for areas with dirty air (rivers, coastal areas, persian gulf etc.)

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



1. Combustion air duct connected to turbocharger with a flexible bellow
2. Louver *
3. Water trap
4. Combustion air duct
5. Engine room ventilation fan
6. Fire damper
7. Outlets with direction flaps
8. Changeover flap with air filter (outside- / inside air) for starting in cold climate

* Always to be equipped with a filter when an air duct is connected to the turbocharger.

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. 1.5 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 arctic setup is to be used. 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.

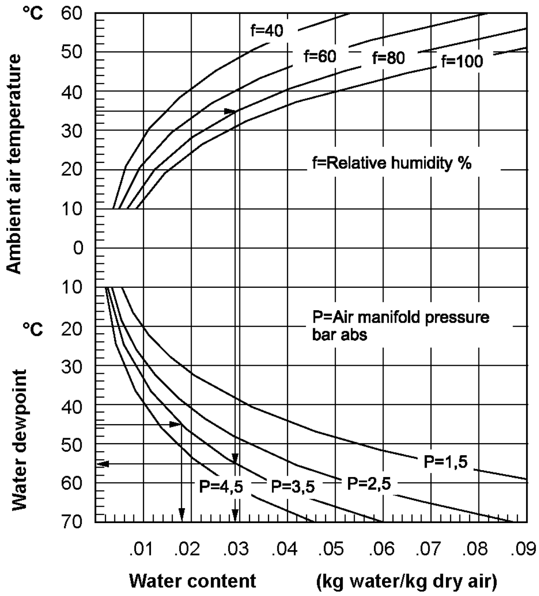


Fig 10-3 Condensation in charge air coolers

11. Exhaust Gas System

11.1 Exhaust gas outlet

The exhaust gas outlet from the turbocharger can be inclined into several positions. The possibilities depend on the cylinder configuration as shown in figures of this section. The turbocharger can be located at both ends, the figure shows only free end solutions. A flexible bellow has to be mounted directly on the turbine outlet to protect the turbocharger from external forces.

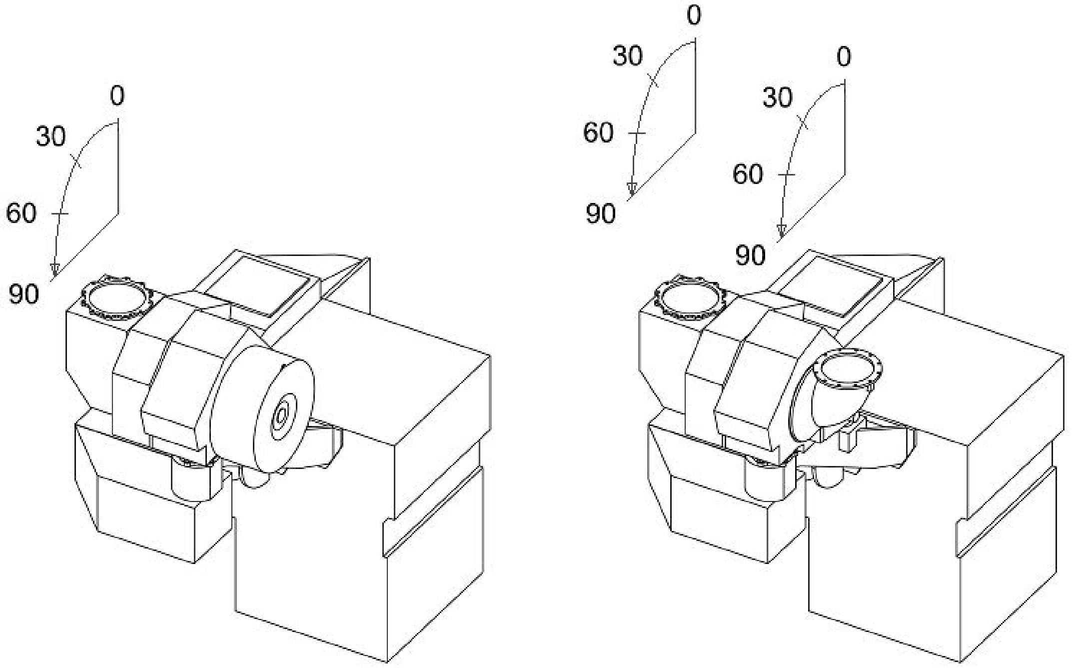


Fig 11-1 Exhaust outlet possibilities, in-line engines

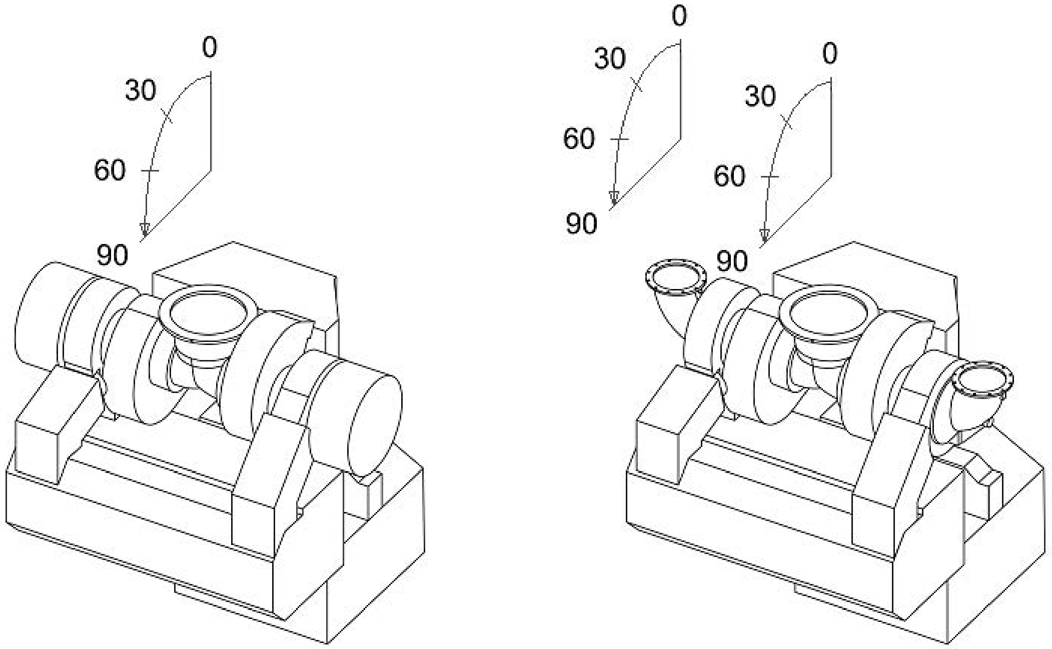


Fig 11-2 Exhaust outlet possibilities, 12V-engine

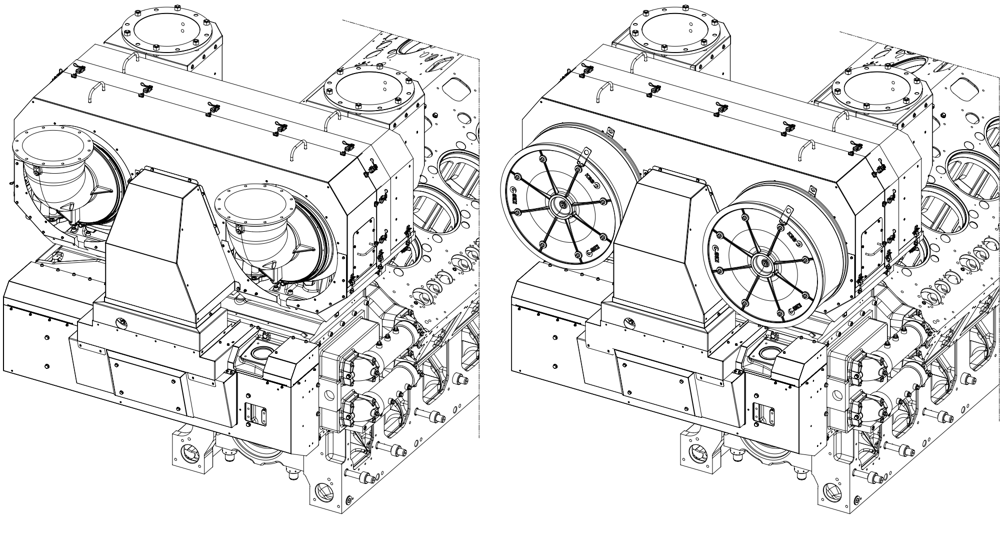


Fig 11-3 Exhaust outlet possibilities, 16V-engine

Engine	TC in free end	TC in driving end
W 6L26	0°,30°,45°,60°,90°	0°,30°,45°,60°,90°
W 8/9L26	0°,30°,45°,60°,90°	0°,30°,45°,60°,90°
W 12V26	0°,30°,60°	0°,30°,60°

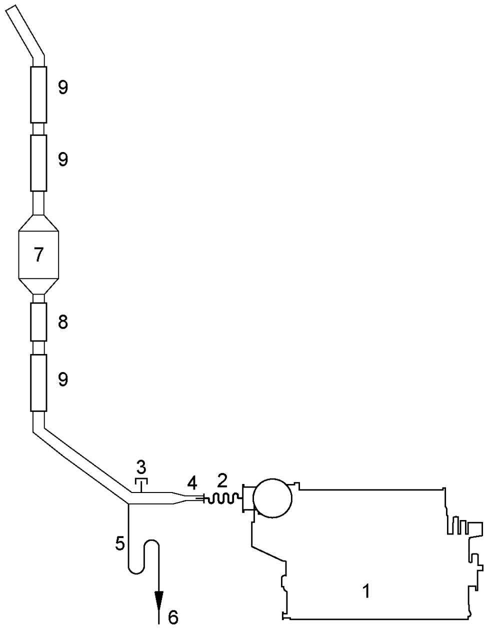
Engine	TC in free end	TC in driving end
W 16V26*	0°	0°

*ABB,KBB

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).

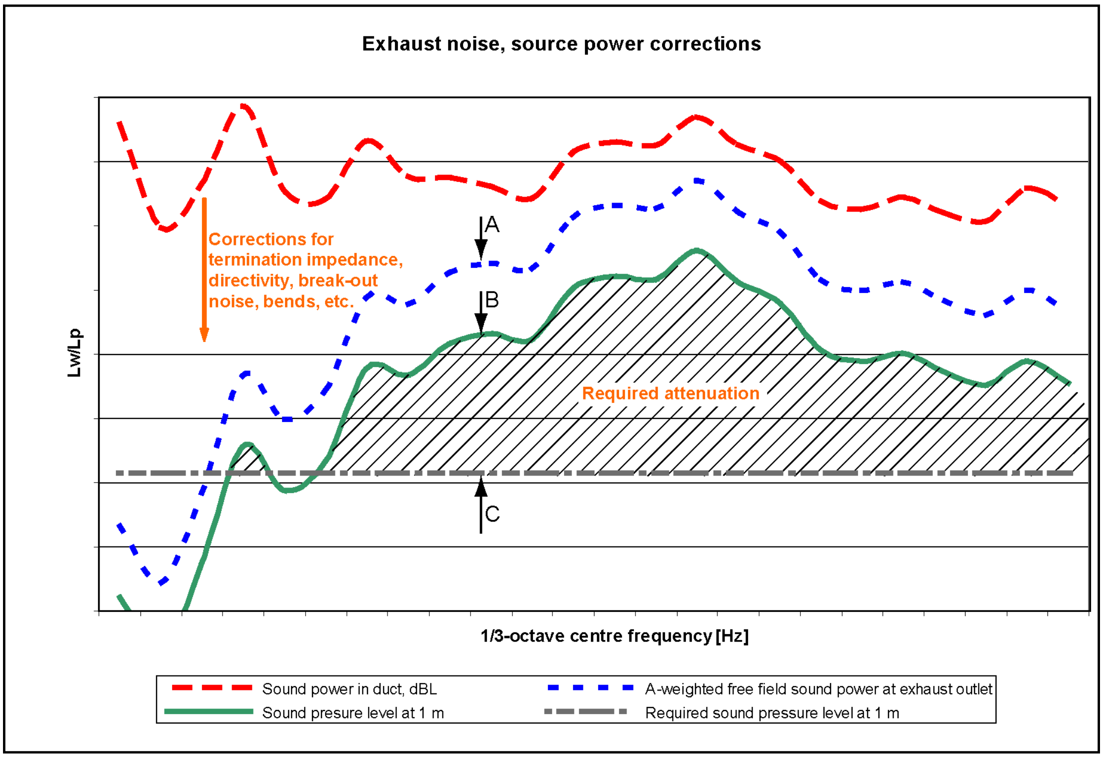


Fig 11-5 **Exhaust noise, source power corrections**

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.

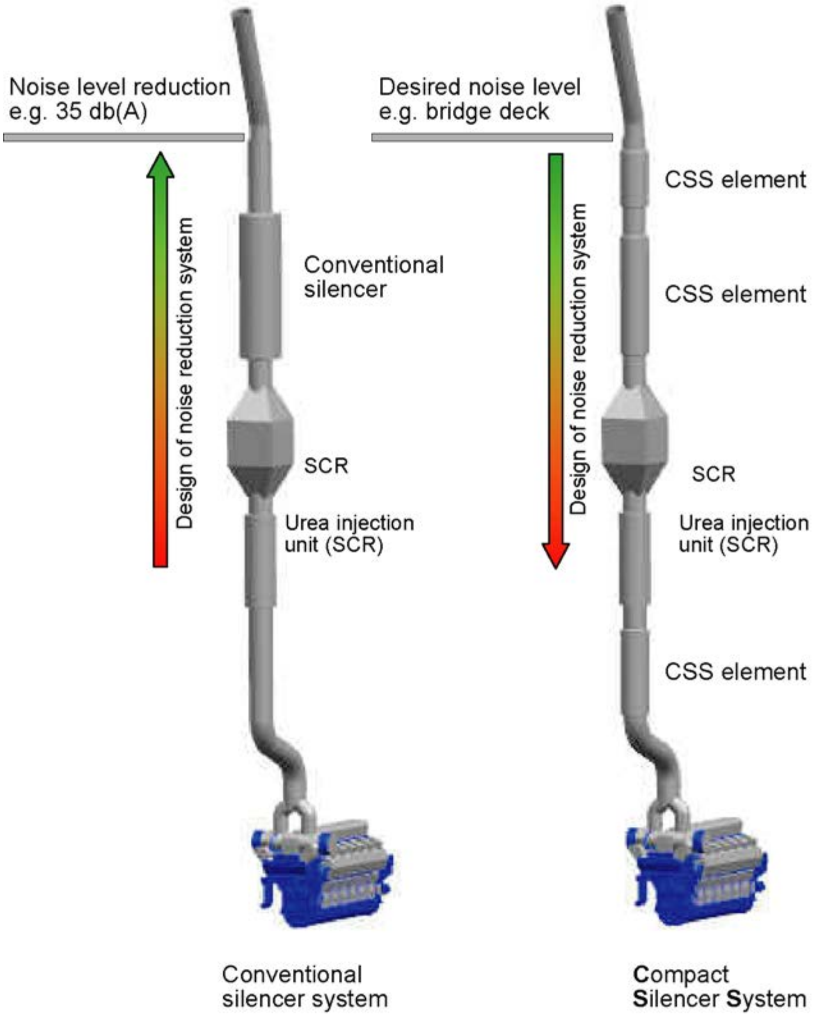


Fig 11-6 Silencer system comparison

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.

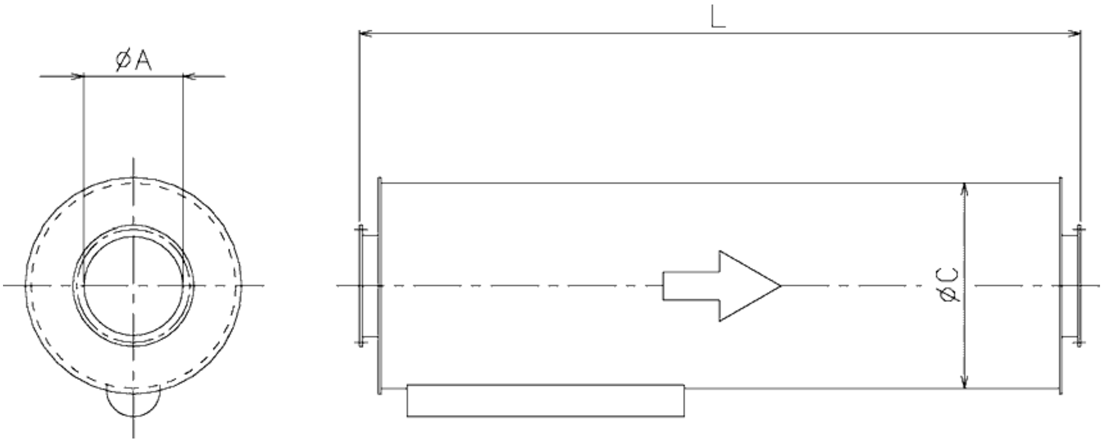


Fig 11-7 Exhaust gas silencer (9855MR366)

Table 11-1 Typical dimensions of the exhaust gas silencer

Engine type	A [mm]	C [mm]	Attenuation: 25 dB(A)		Attenuation: 35 dB(A)	
			L [mm]	Weight [kg]	L [mm]	Weight [kg]
6L26	500	1200	3430	690	4280	860
8L26	600	1300	4010	980	5260	1310
9L26	600	1300	4010	980	5260	1310
12V26	700	1500	4550	1470	6050	1910
16V26	800	1700	4840	1930	6340	2490
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.

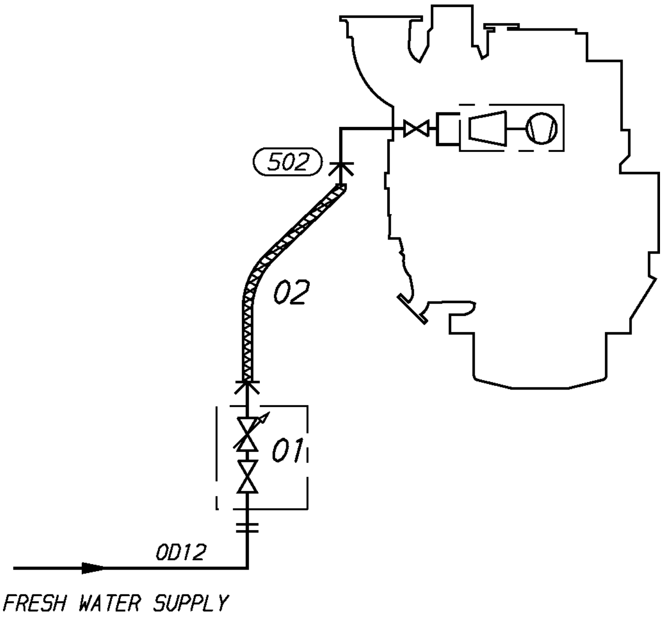


Fig 12-1 Turbine cleaning system (DAAE003884)

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

12.2 Compressor cleaning system

The compressor side of the turbocharger is cleaned using a separate dosing vessel mounted on the engine.

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; for example start sequencing, start blocking, fuel injection, cylinder balancing, speed control, load sharing, normal stops and safety shutdowns.

14.1 General Description

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. Alternatively Modbus RTU serial line RS-485 is also available.

UNIC is specifically designed for the demanding environment on engines, thus special attention has been paid to temperature and vibration endurance. This allows the system to be mounted directly on engine that provides a very compact design and reduces cabling on and around the engine.

14.2 UNIC Hardware

14.2.1 Mechanical design

The UNIC system is designed to meet very high targets on reliability. This includes special measures for redundancy, fault tolerance as well as mechanical and electrical design. The sensors and actuators are designed to be reliable, easy to service and to calibrate. Flying lead design is introduced to avoid failure prone connectors. Only cables suitable for the demanding engine environment are used on the engines. The well protected point-to-point cables provide the most reliable solution, as they ensure good protection against electrical disturbances, high mechanical strength as well as good protection against chemicals and temperature. The UNIC modules which are distributed on the engine, are mounted in specially designed terminal boxes (WTB). These enclosures are used to facilitate all interconnections on the engine.

14.2.2 Power supply

The required power supply domains are sourced from an off-engine power unit and routed to engine’s main cabinet. From there the power supplies are distributed to correct consumers at the engine automation system.

14.2.3 UNIC modules

14.2.3.1 Local display module

The Local Display Unit (LDU) act as interface for engine control and monitoring.

14.2.3.2 Communication module

The Communication Module (COM) is designed to primarily act as the interface of UNIC. The module also measures the engine speed and position. External control systems can be connected to UNIC system via the COM module. For control and monitoring purposes it is also possible to connect a number of discrete and/or analogue signals to the configurable in and output channels.

14.2.3.3 Input and output module

The Input and Output Module (IOM) is used for data acquisition of analogue/binary/ frequency signals, and also for control, such as waste-gate valve control, by-pass valve control and LT/HT water thermostat valve control.

14.2.4 Engine safety module

The Engine Safety Module (ESM) is an electronic control unit specifically designed for the purpose of fundamental safety on Wärtsilä engines.

14.2.5 Communication

The system utilizes modern communication bus technologies for safe and fast transmission of measurements and control signals.

UNIC modules are connected to HSR (High-availability Seamless Redundancy) bus.

The HSR communication ensures measurement and control redundancy of UNIC engine control system.

In addition to HSR the UNIC modules also support CAN protocol to enable communication with devices not supporting HSR, such as the ESM and wastegate actuators.

14.3 UNIC Machinery protection

Most sensors connected to UNIC have some machinery protection specified. Depending on how critical an abnormal measurement is for the engine, different levels of protective actions are configured. UNIC machinery protection is divided in the following classes:

- Alarm
- Start blocking
- Load reduction request
- Shutdown
- Emergency stop

14.3.1 Alarm

When a monitored engine signal exceeds its pre-defined set-point, an alarm is activated. The alarm is presented in the external alarm system and in the local display. All alarms trigger the "common alarm" signal, which toggles off and on again each time a new alarm triggers it.

14.3.2 Start blocking

Engine starting is blocked when a start block is active. It is not allowed to by-pass a start blocking since it may cause a serious hazard either for the engine and its surrounding or for associated systems.

14.3.3 Load reduction request

Load reduction request is an automatic safety measure initiated by UNIC engine control system. During certain abnormal situations on engine UNIC can request an external system to reduce the maximum engine load output. The maximum available load output can be different depending on the type of abnormality.

14.3.4 Shutdown and emergency stop

An engine shutdown or an emergency stop can be initiated by UNIC or by a protective safety system. Wärtsilä has an internal standard that defines engine shutdowns, unavoidable shutdowns and emergency stops which are managed by the UNIC control system.

15. Foundation

Engines can be either rigidly mounted on chocks, or resiliently mounted on rubber elements. If resilient mounting is considered, Wärtsilä should 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

When main engines are rigid mounted normally either adjustable steel chocks or resin chocks are used. The chocking arrangement shall be sent to the classification society and Wärtsilä for approval.

The bolt closest to the flywheel at either side of the engine shall be made as a Ø34H7/m6 fitted bolt. All other bolts are clearance bolts.

The clearance bolts shall be through bolts with lock nuts. Ø33 holes can be drilled into the seating through the holes in the mounting brackets.

The design of the foundation bolts is shown in the foundation drawings. When these dimensions are followed, standard bolts can be used for the clearance bolts in order to fulfill the requirements of the classification societies. For the fitting bolts is recommended to use a high strength steel, e.g. 42CrMo4 TQ+T 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 ensure sufficient elongation distance sleeves according to the bolt drawings shall be used.

In order to avoid bending stresses in the foundation bolts the nuts underneath the top-plate must be provided with spherical washers which can compensate for an inclined surface. Alternatively the contact face of the nut/bolthead underneath the top plate should be counter bored perpendicular to the orientation of the bolt.

When tightening the bolts with a torque wrench, the equivalent stress in the bolts is allowed to be max. 90% of the material yield strength.

Side supports should be fitted to all engine feet where no fitting bolts are used. In addition end supports should be fitted at the free end of the engines in case fitting bolts are omitted. Side supports are to be welded to the top plate before aligning the engine and fitting the chocks. If resin shocks are used an additional pair of lateral supports shall be fitted at the flywheel end of the engine. The clearance hole in the chock and top plate should have a diameter about 2 mm larger than the bolt diameter for all clearance bolts.

15.2.1.1 Resin chocks

Installation of main engines on resin chocks is possible provided that the requirements of the classification societies are fulfilled.

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.

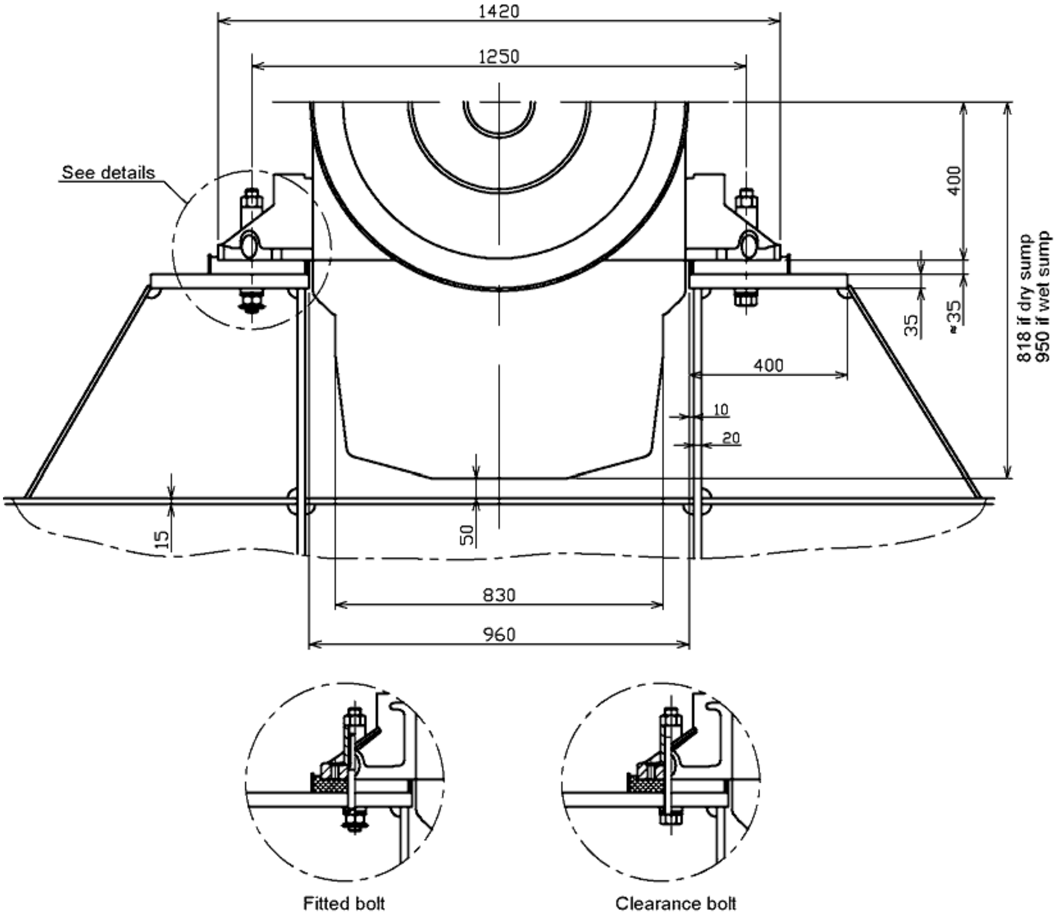
The total surface pressure on the resin must not exceed the maximum value, which is determined by the type of resin and the requirements of the classification society. It is recommended to select a resin type, which has a type approval from the relevant classification society for a total surface pressure of 5 N/mm² (typical conservative value is $p_{tot} < 3.5$ N/mm²).

When installing an engine on resin chocks the following issues are important:

- Sufficient elongation of the foundation bolts
- Maximum allowed surface pressure on the resin $p_{tot} = p_{static} + p_{bolt}$
- Correct tightening torque of the foundation bolts

15.2.1.2 Adjustable steel chocks

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.



Fitted bolt

Clearance bolt

Fig 15-1 **Seating and fastening, rigidly mounted in-line engine on resin chocks (DAAE077678A/DAAE077679A)**

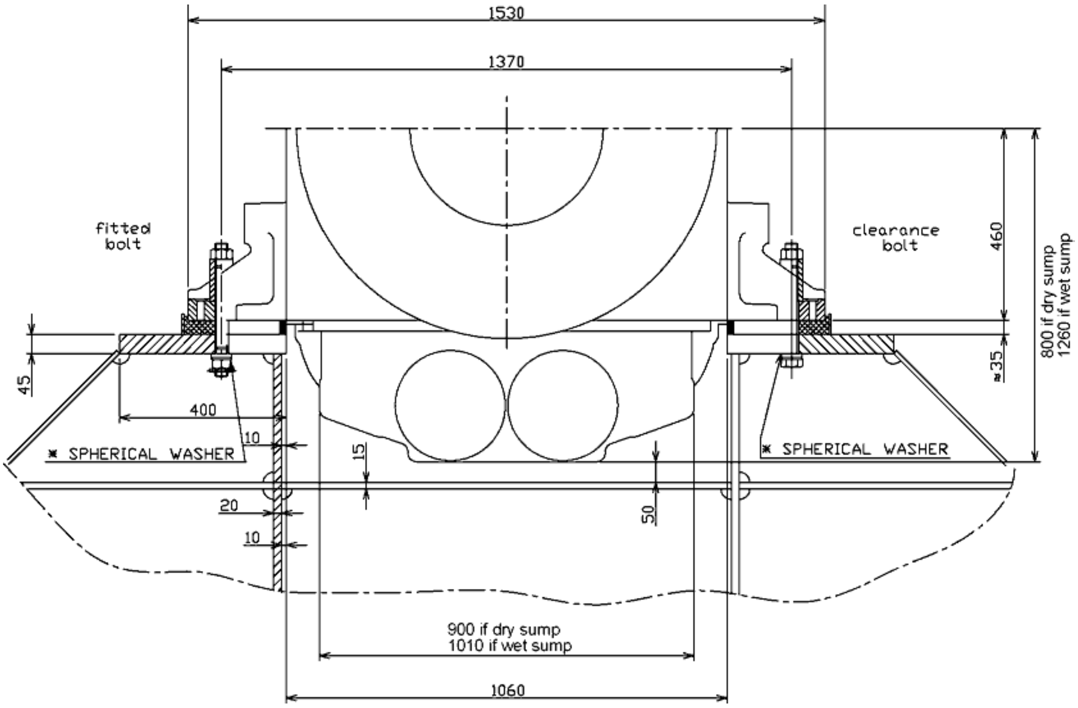
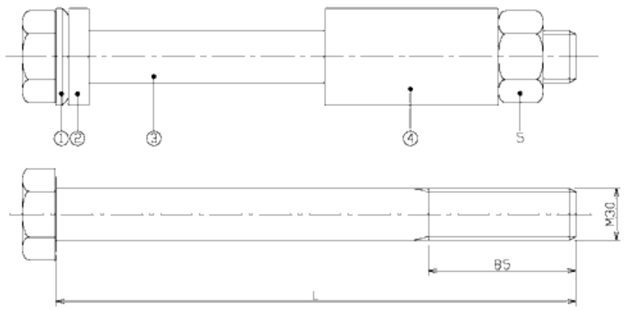


Fig 15-2 **Seating and fastening, rigidly mounted V-engines on resin chocks (9813ZT114/9813ZT117)**

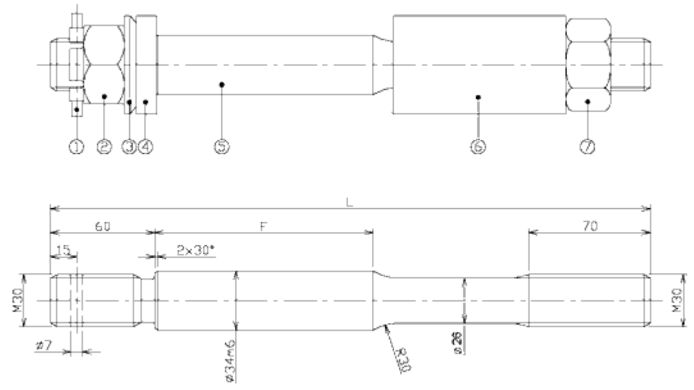
Clearance bolt



1. Spherical washer
2. Concial seat
3. Clearance bolt
4. Distance bush
5. Hexagon nut

L: W L26 = top plate + filling + 210 mm
W V26 = top plate + filling + 220 mm

Fitted bolt



1. Split pen
2. Castle nut
3. Spherical washer
4. Conical seat
5. Fitted bolt
6. Distance bush
7. Hexagon nut

L: W L26 = top plate + filling + 245 mm
W V26 = top plate + filling + 255 mm

F: W L26 = top plate + filling + 25 mm
W V26 = top plate + filling + 35 mm

Distance bush

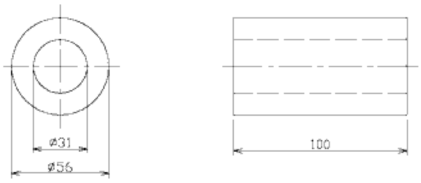


Fig 15-3 Clearance bolt (9813ZT122) / Fitted bolt (9813ZT121)

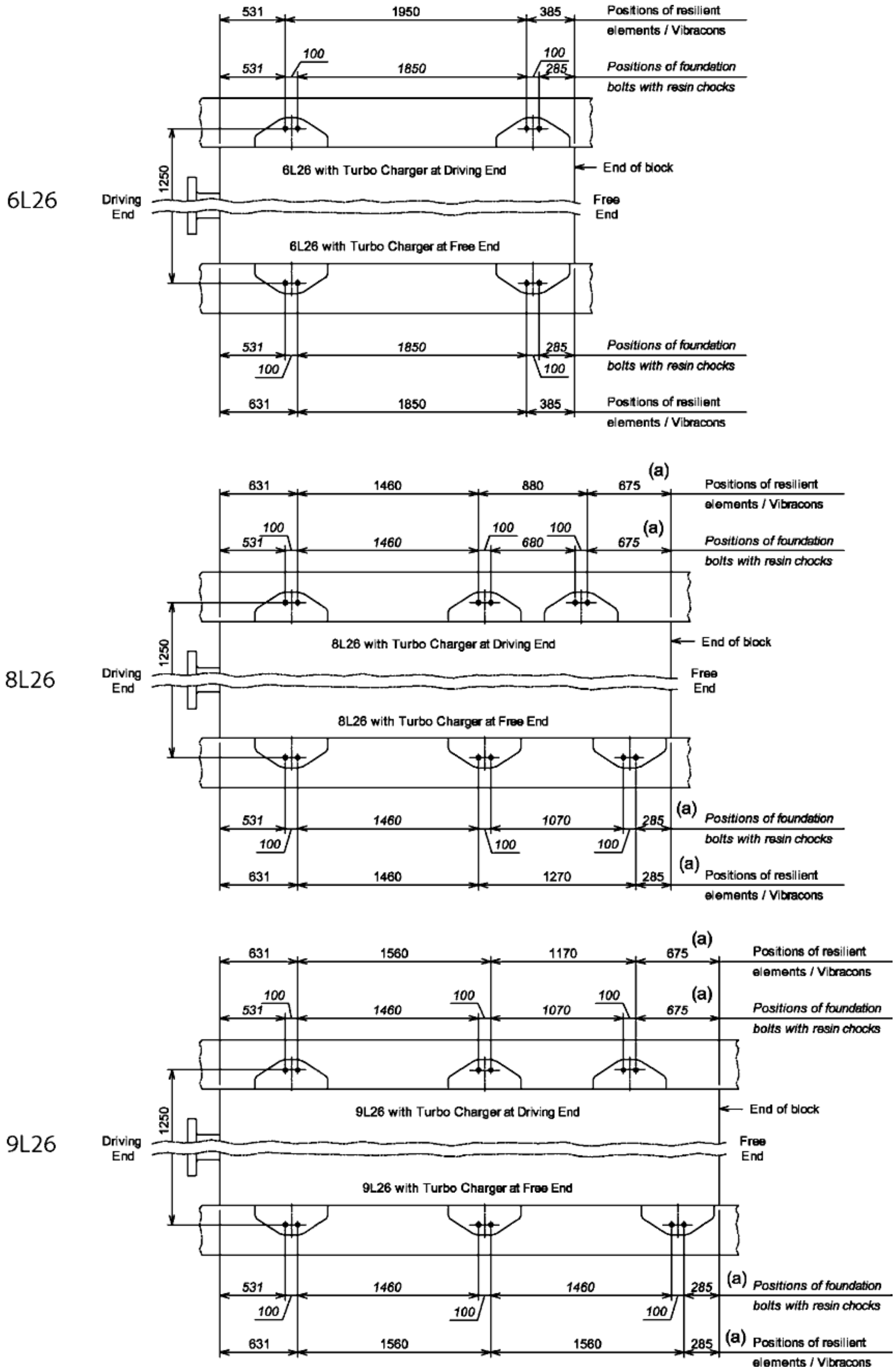


Fig 15-4 **Foundation top-view and drilling plan, in-line engines (9813ZT110A)**

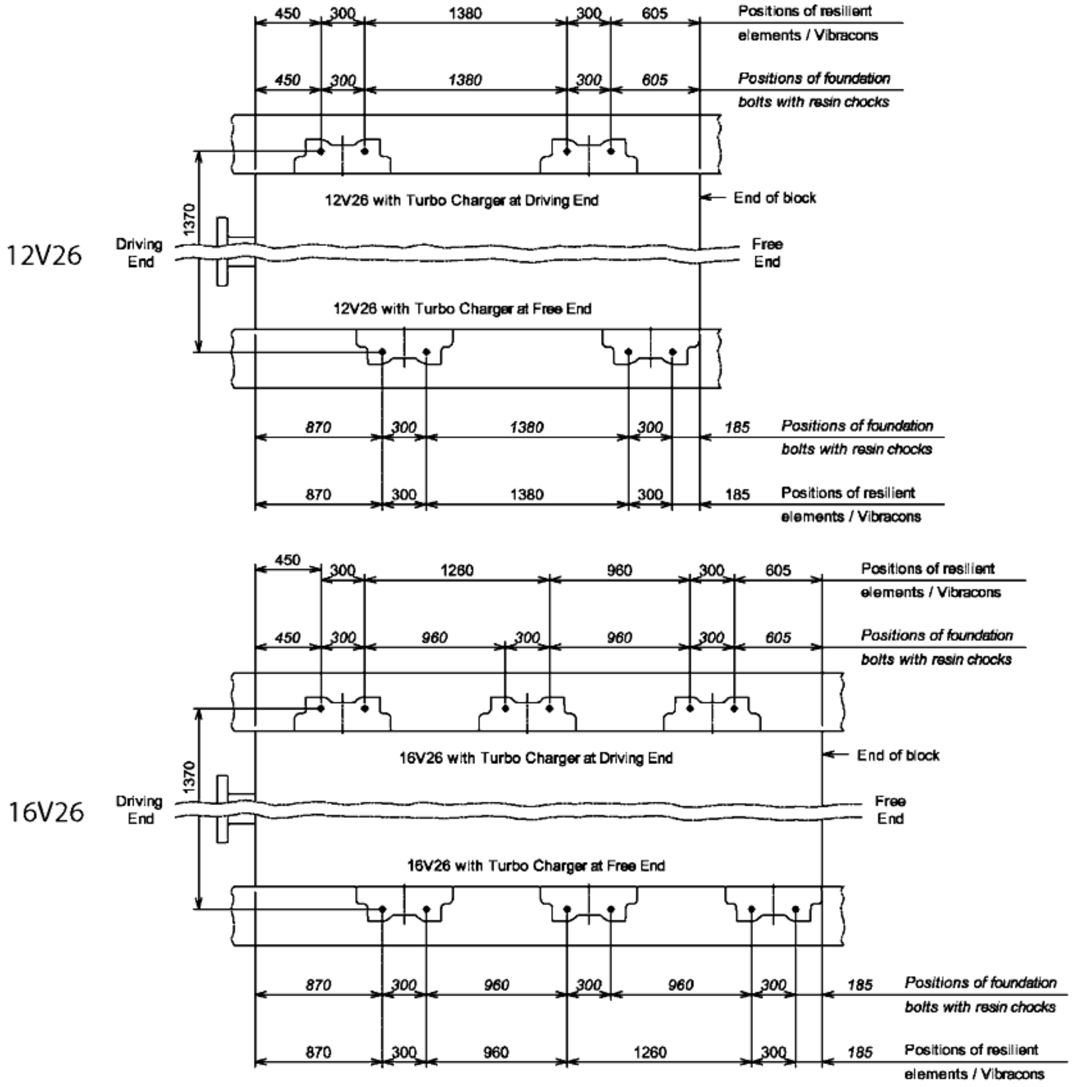


Fig 15-5 Foundation top-view and drilling plan, V-engines (9813ZT112A)

15.2.2 Resilient mounting

Engines driving gearboxes, generators, pumps etc. can be resiliently mounted in order to reduce vibrations and structure borne noise, while the driven equipment is fixed to a solid foundation. The engine block is rigid, therefore no intermediate base-frame is necessary. The resiliently elements are bolted to the engine feet directly.

The transmission of forces emitted by the engine is 10...30% when comparing resiliently mounting with rigid mounting.

Note! For resiliently mounted 9L engines the available speed range is limited. Please contact Wärtsilä for further information.

The standard engine mountings are of conical type. With conical mounting the rubber rubber element is loaded by both compression and shear. The mounts are equipped with an internal central buffer. Hence no additional side or end supports are required to limit the movements of the engine due to ships motions. The material of the mountings is rubber, which has superior vibration technical properties. Unfortunately natural rubber is prone to damage by mineral oil, therefore such elements should not be installed directly on the tank top, where they might come into contact with oily water. The rubber elements are protected against dripping and splashing from above by means of covers.

The number of resilient elements and their location is calculated to avoid resonance with excitations from the engine and the propeller.

When installing and aligning the engine on resilient elements it should be aimed at getting the same force on each rubber element. This means that the compression of all elements is equal. Due to creep of the resilient elements the alignment needs to be checked at regular intervals and corrected when necessary. To facilitate the alignment and re-alignment resilient elements of the height adjustable type are used for resiliently mounted engines.

Due to the soft mounting the engine will move when passing resonance speeds at start and stop. Also due to heavy seas engines will move. Typical amplitudes are ±3.5 mm at the crankshaft centre and ± 17 mm at top of the engine (the figures are calculated for a 22.5° roll angle). The torque reaction (at 1000 rpm and 100% load) will cause a displacement of the engine of up to 1 mm at the crankshaft centre and 5 mm at the turbocharger outlet. The coupling between engine and driven equipment should be flexible enough to be able to cope with these displacements.

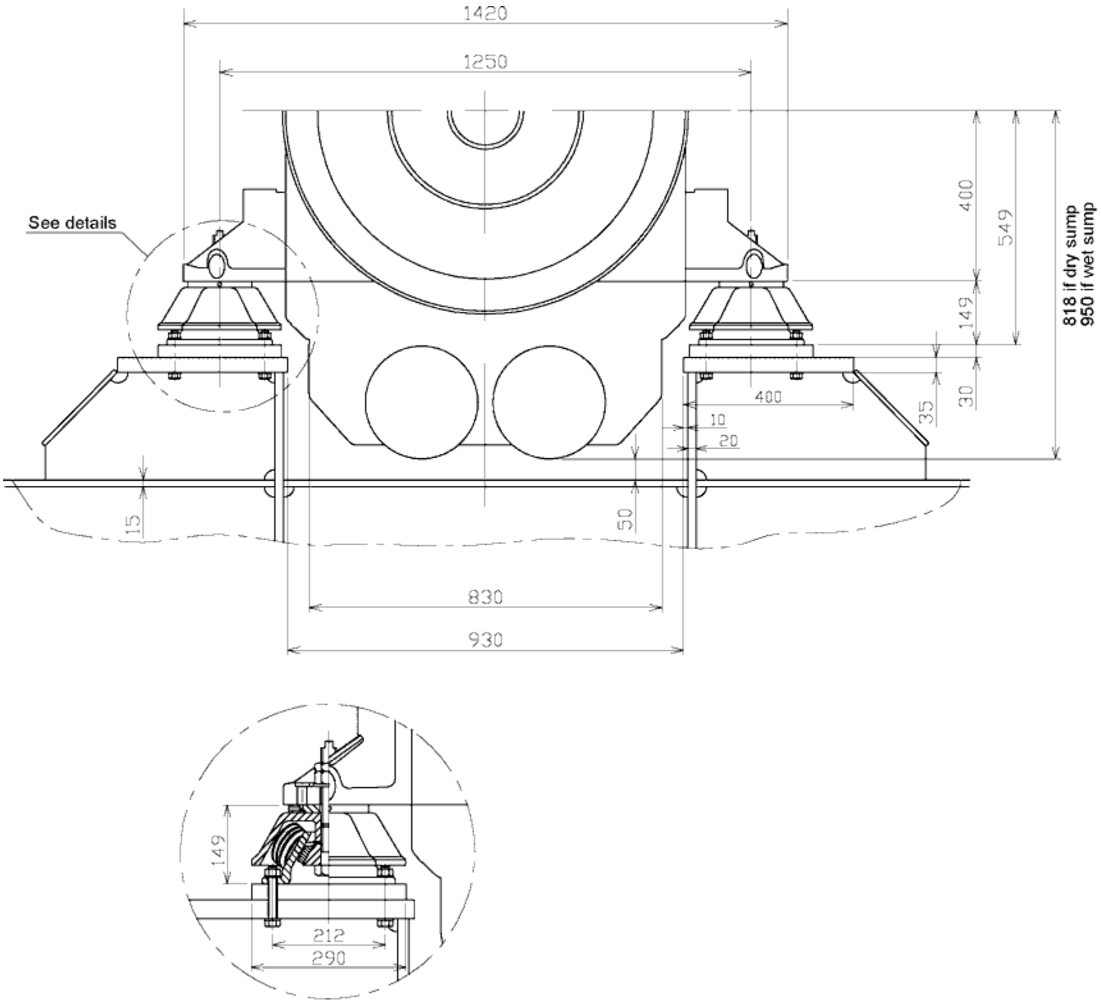
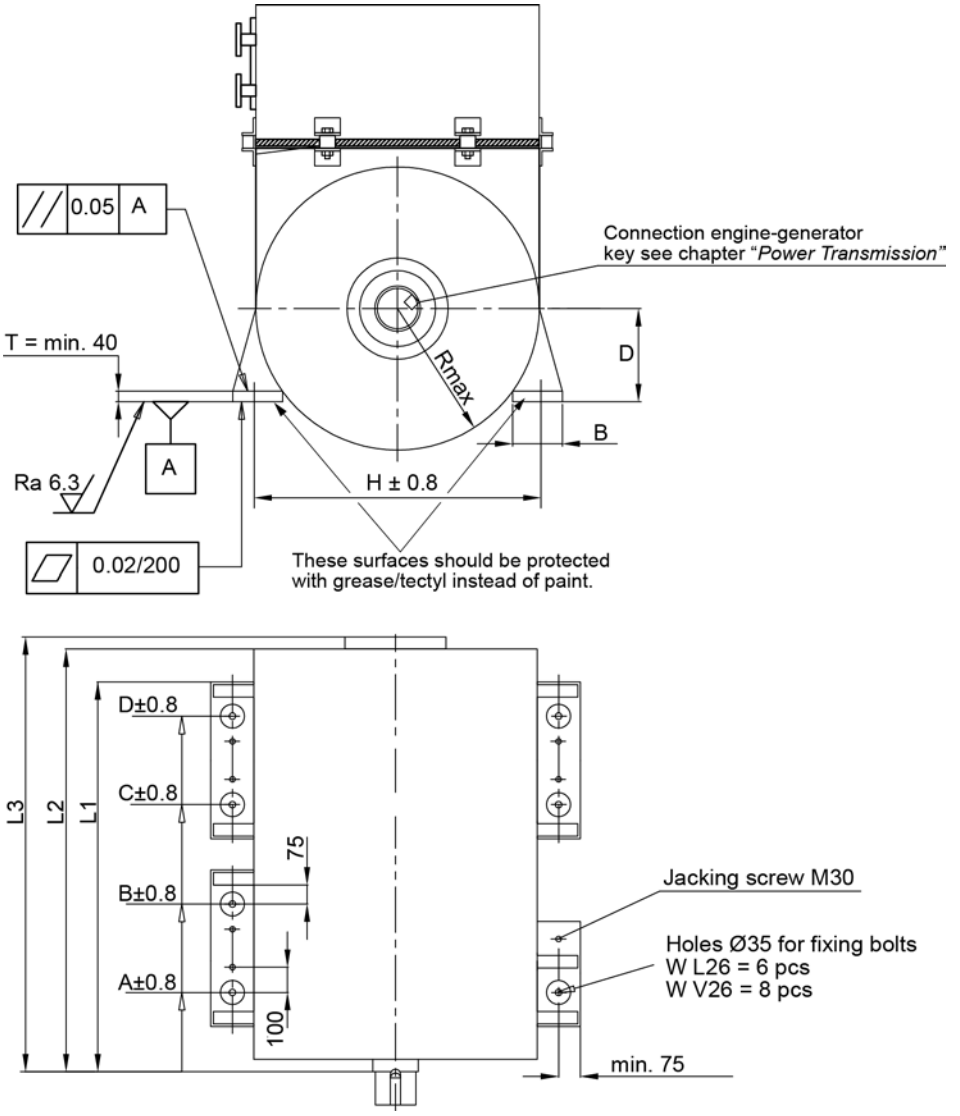


Fig 15-6 Principle of resilient mounting, in-line engines (DAAE077680 / DAAE077681)

15.3 Mounting of generating sets

15.3.1 Generator feet design



Connection engine-generator key see chapter "*Power Transmission*"

These surfaces should be protected with grease/tectyl instead of paint.

Jacking screw M30

Holes Ø35 for fixing bolts
W L26 = 6 pcs
W V26 = 8 pcs

Fig 15-7 Distance between fixing bolts on generator (9506ZT733B)

H [mm]	Rmax [mm]
1250	560
1340	650
1420	700
1540	750
1620	780
1800	850
1950	925
2200	1000

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 vibrations.

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.

NOTE

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 and number of cylinders
- Propeller shaft speed and number of propeller blades

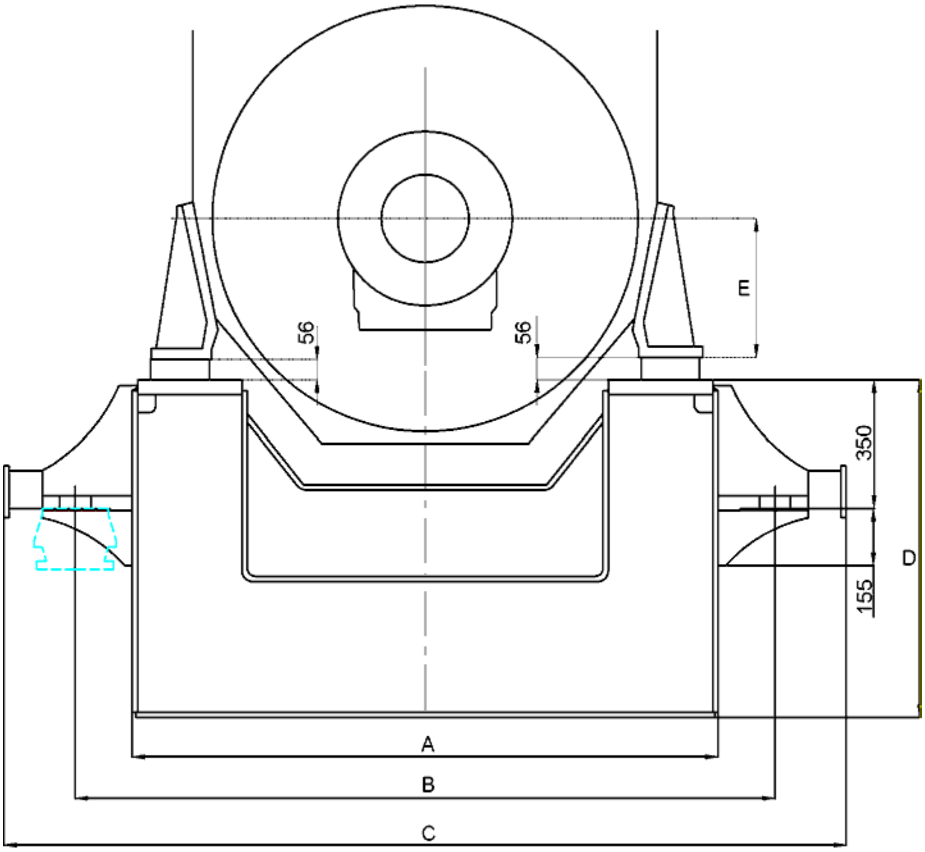


Fig 15-8 **Standard generator dimensions and common base frame arrangement (9506ZT732)**

Engine	Dimensions [mm]				
	A	B	C	D	E
W 6L26	1600	1910	2300	800	344
W 8L26	1600	1910	2300	800	344
W 9L26	1600	1910	2300	900	344
W 12V26	2000	2310	2700	1100	404
W 16V26	2000	2310	2700	1100	404

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.

16. Vibration and Noise

Wärtsilä 26 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 and 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.

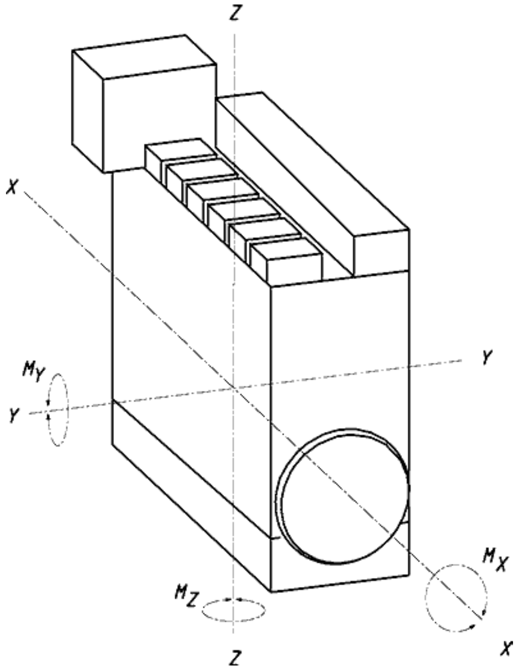


Fig 16-1 Coordinate system

Table 16-1 External forces and couples

Engine	Speed [rpm]	Frequency [hz]	F_Y [kN]	F_Z [kN]	Frequency [hz]	M_Y [kNm]	M_Z [kNm]	Frequency [hz]	M_Y [kNm]	M_Z [kNm]
W 6L26	900 1000	15 16.7	5.0 6.1	5.0 6.1	15 16.7	3.5 4.3	3.5 4.3	30 33.3	0.5 0.6	- -
W 8L26	900 1000	15 16.7	5.0 6.1	5.0 6.1	15 16.7	4.5 5.5	4.5 5.5	30 33.3	0.5 0.6	- -
W 9L26	900 1000	15 16.7	3.1 3.8	3.1 3.8	15 16.7	29 35	21 25	30 33.3	15 19	- -
W 12V26	900 1000	15 16.7	5.0 6.1	5.0 6.1	15 16.7	4.0 5.0	4.0 5.0	30 33.3	0.2 0.3	0.2 0.3
W 16V26	900 1000	15 16.7	5.0 6.1	5.0 6.1	15 16.7	6.0 7.4	6.0 7.4	30 33.3	0.3 0.4	0.4 0.5

- couples are zero or insignificant

16.2 Torque variations

Table 16-2 Torque variation at 100% load

Engine	Speed [rpm]	Frequency [hz]	M_X [kNm]	Frequency [hz]	M_X [kNm]
W 6L26	900 1000	45 50	15.4 12.0	90 100	10.2 10.2
W 8L26	900 1000	60 66.7	31.4 31.8	120 133.3	4.7 4.3
W 9L26	900 1000	67.5 75	30.7 31.6	135 150	3.0 2.6
W 12V26	900 1000	45 50	4.0 3.1	90 100	19.6 19.6
W 16V26	900 1000	60 66.7	21.5 21.8	120 133.3	7.2 6.7

16.3 Mass moments of inertia

The mass-moments of inertia of the main engines (including flywheel) are typically as follows:

Engine	Inertia [kgm^2]
W 6L26	121
W 8L26	136
W 9L26	183
W 12V26	236
W 16V26	279

16.4 Air borne noise

The airborne noise of the engine is measured as a sound power level according to ISO 9614-2. The results are presented with A-weighing in octave bands, reference level 1 pW. Two values are given; a minimum value and a 90% value. The minimum value is the lowest measured noise level. The 90% value indicates that 90% of all measured noise levels are below this value.

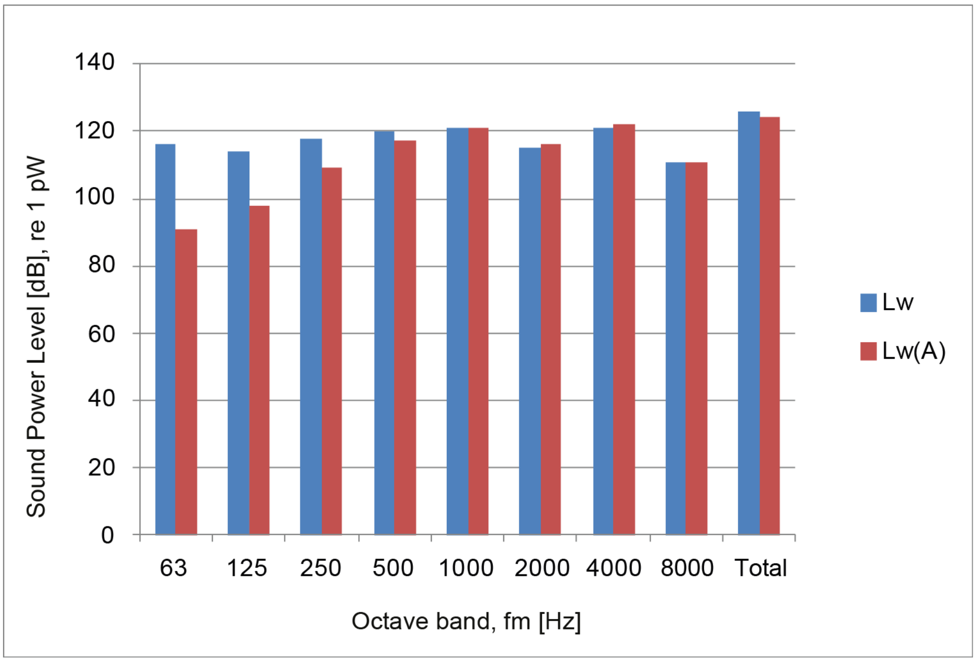


Fig 16-2 Typical sound power level for engine noise, W L26

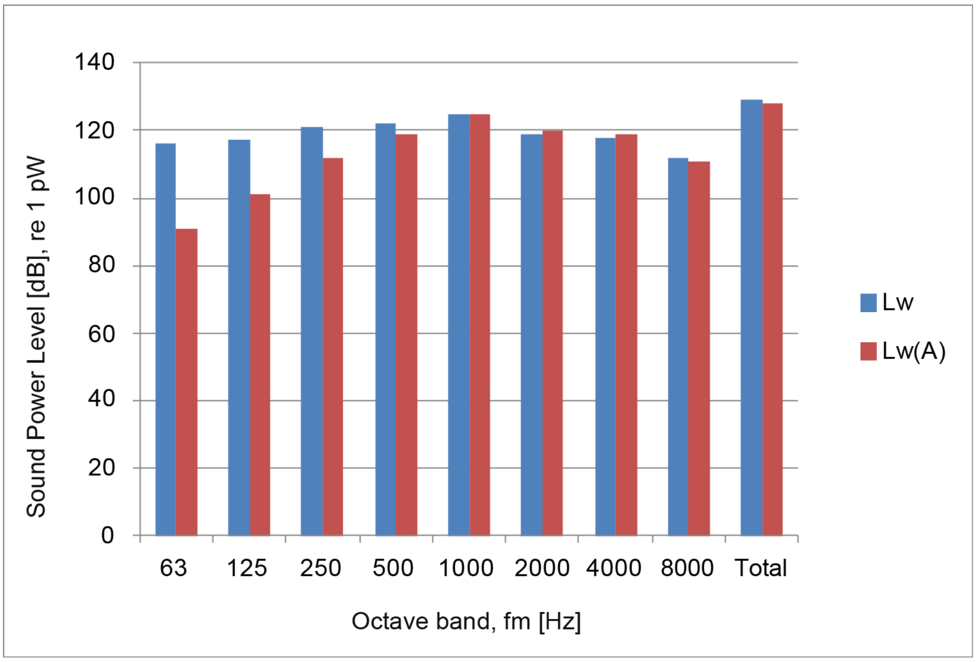


Fig 16-3 Typical sound power level for engine noise, W V26

16.5 Exhaust noise

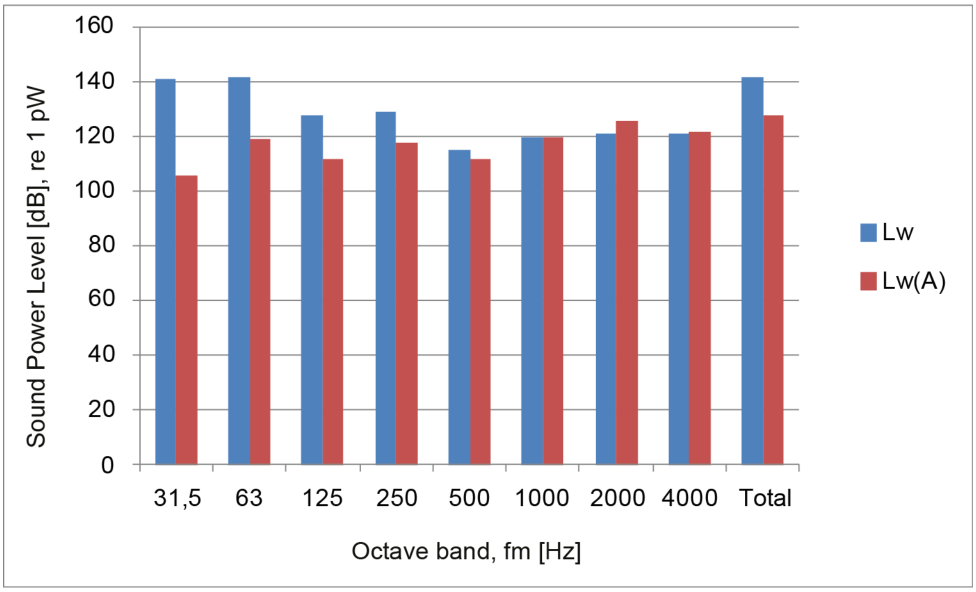


Fig 16-4 Typical sound power level for exhaust noise, W L26

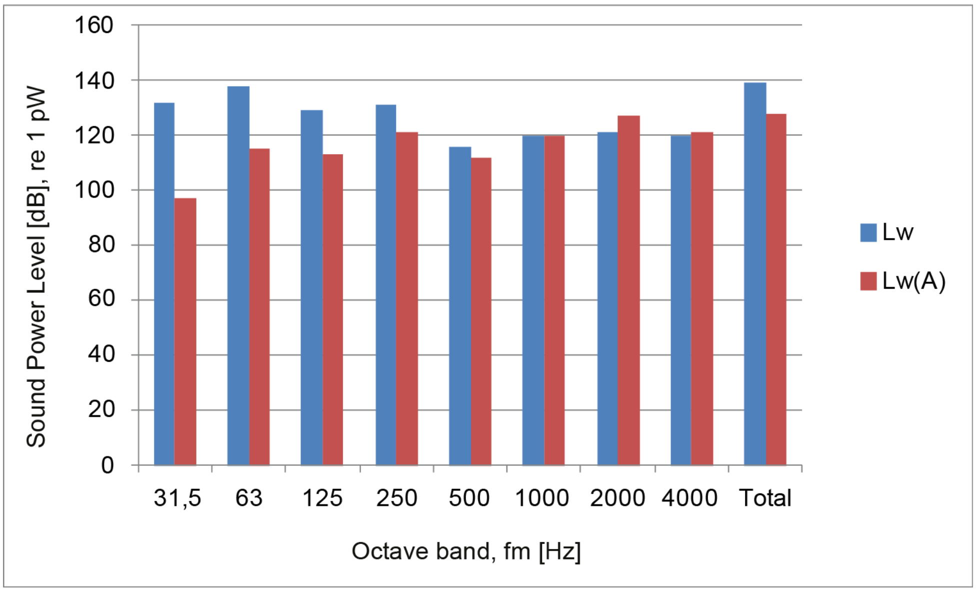


Fig 16-5 Typical sound power level for exhaust noise, W V26

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.

The following figure gives an indication of flywheel-coupling length based on engine nominal torque. Changes are possible due to constant development.

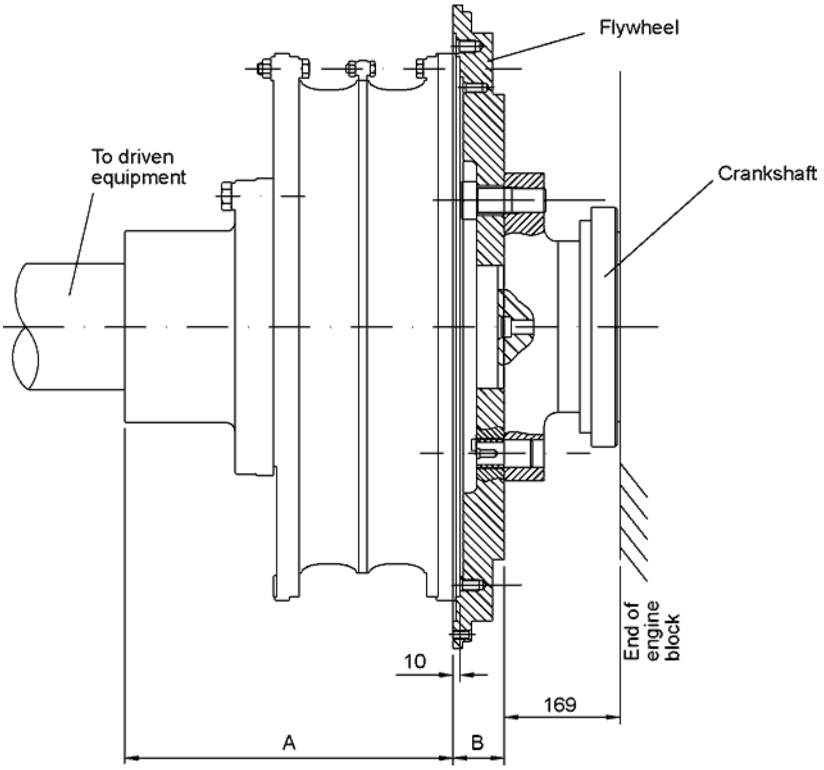


Fig 17-1 Connection engine/driven equipment (DAAE026899C)

Engine	A [mm]			B [mm]
	Main engine rigid mounting 1)	Main engine resilient mounting 2)	Generating set	
W 6L26	440	470	355	75
W 8L26	475	500	355	75
W 9L26	475	530	370	75

1) single row coupling

2) two row coupling

Classification rules usually require a fail safe device for single main engines. The fail safe device permits restricted operation in case the flexible parts of the coupling would fail.

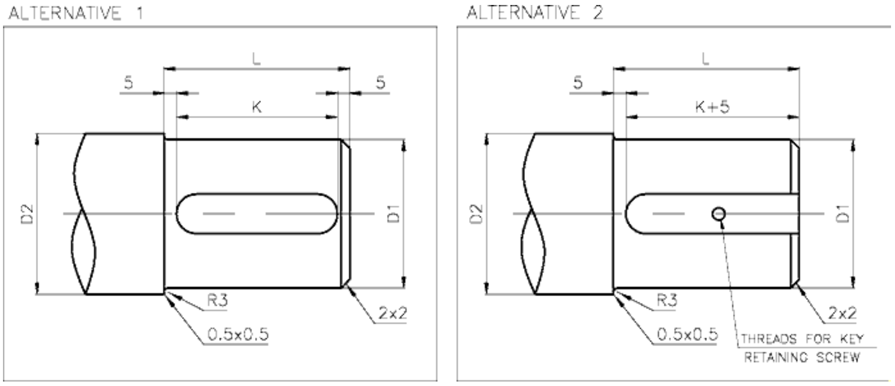


Fig 17-2 **Directives for generator end design (9506ZT734)**

Alternative 1: Permitted keys are according to DIN 6685, Part 1: Type A, B, C or D.

Alternative 2: Permitted keys are according to DIN 6685, Part 1: Type C or D.

Engine	D1 [mm]	L [mm]	K [mm]	min. D2 [mm]
W 6L26	160	250	240	175
W 8L26	160	250	240	175
W 9L26	160	250	240	175
W 12V26	210	250	240	225
W 16V26	220	280	270	235

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.

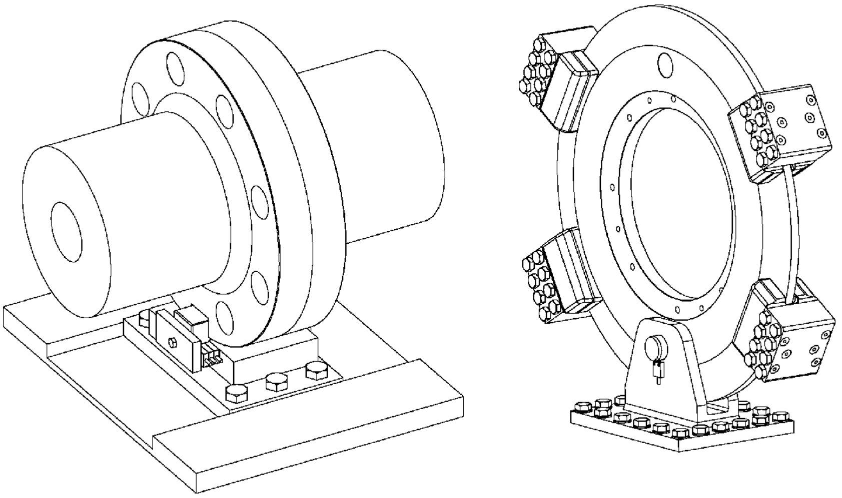


Fig 17-3 Shaft locking device and brake disc with calipers

17.4 Power-take-off from the free end

At the free end a shaft connection as a power take off can be provided. If required full output can be taken from the PTO shaft.

The arrangement of the standard PTO shaft is shown in this section. The maximum allowable bending moments on the PTO shaft depend on several criteria. As a guidance the values as mentioned in table below can be used for the maximum allowed bending moments and radial forces. When these values are exceeded, an extra support bearing is needed.

In the figures an indication is given how an extra support bearing could be arranged externally. Such a support bearing is only possible when engine and support bearing are rigidly mounted on the same base. This can be the ship's foundation but this can also be a flexible mounted common base frame.

Table 17-1 Maximum allowable loading crankshaft flanges (can be applied simultaneously) (9910ZT161f)

	Radial Force [kN]	Moments [kNm]		Axial Force [kN]
		L	V	
Driving end	100	13	9	10
Free end (PTO)	100	6.5	4.5	7

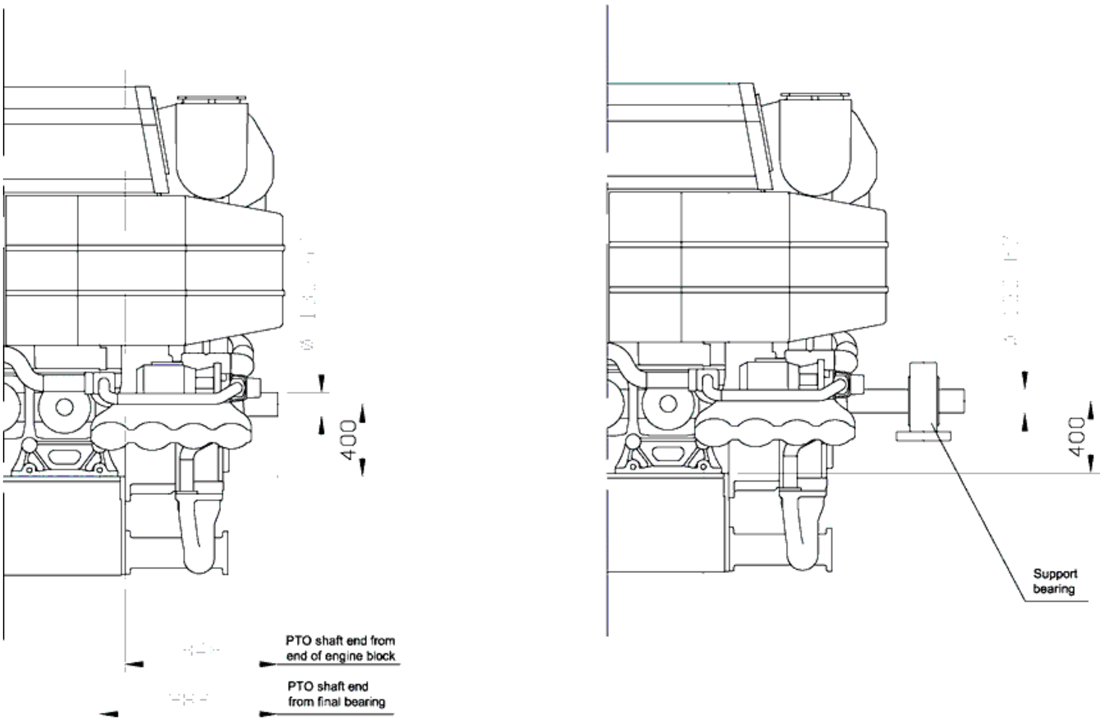


Fig 17-4 PTO-shaft arrangement of standard PTO shaft and with external support bearing for in-line engines

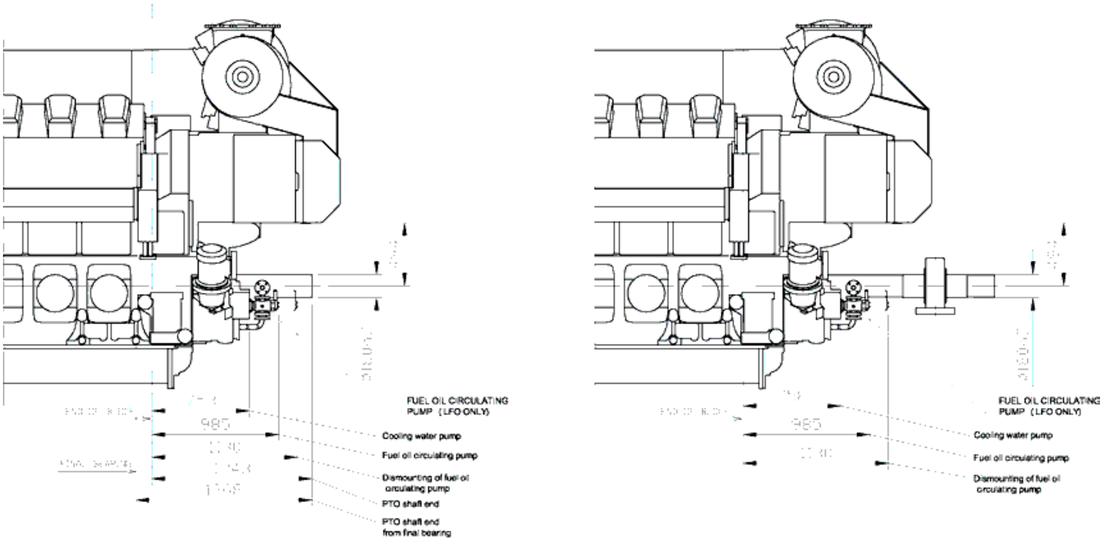


Fig 17-5 PTO-shaft arrangement of standard PTO shaft and with external support bearing for V engines

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 for turning the engine. The electrical motor is equipped with a hand wheel for manual turning.

18. Engine Room Layout

18.1 Crankshaft distances

Minimum crankshaft distances have to be followed in order to provide sufficient space between engines for maintenance and operation.

18.1.1 In-line engines

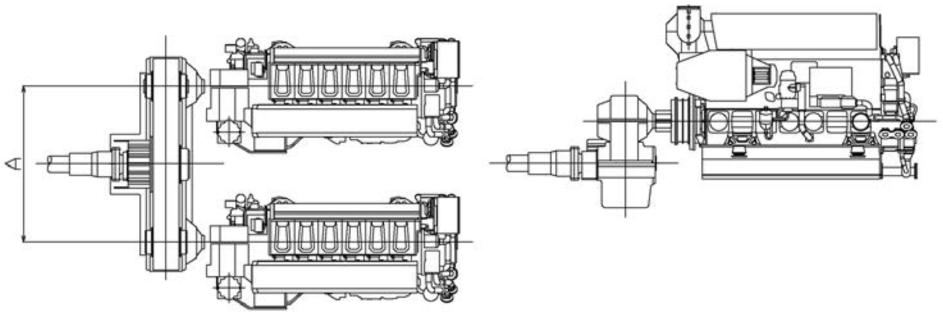


Fig 18-1 Crankshaft centre distances, in-line engines (DAAE026895A)

Engine type	A[1] [mm]	A[2] [mm]
W 6L26	2500	2300
W 8L26	2500	2400
W 9L26	2500	2400

1) Maintenance charge air cooler with standard service tool

2) Maintenance charge air cooler without standard service tool

18.1.2 V-engines

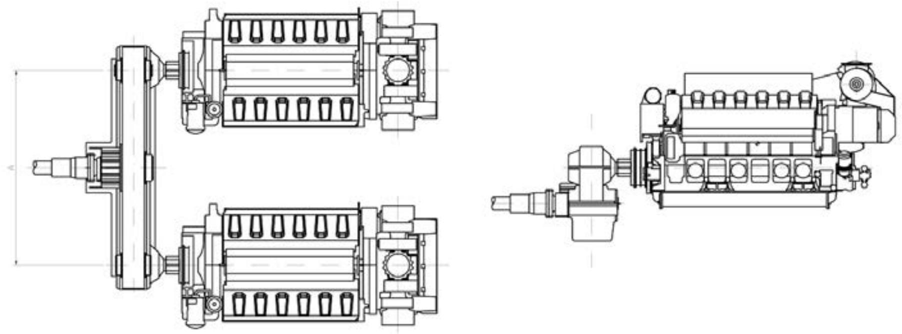


Fig 18-2 Crankshaft centre distances, V-engines (DAAE034187B)

Engine type	A [mm]
W 12V26	3150
W 16V26	3150

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

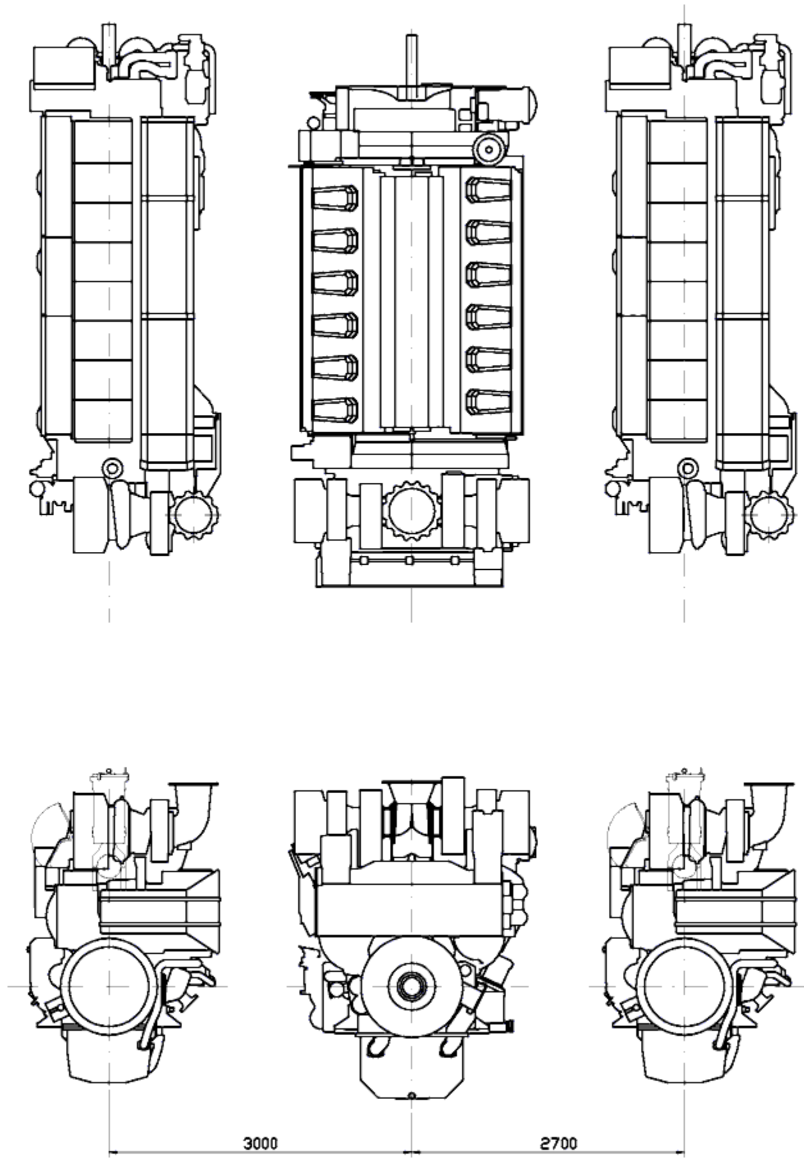


Fig 18-3 **Main engine arrangement with two in-line engine and one V-engine (DAAE033711)**

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.

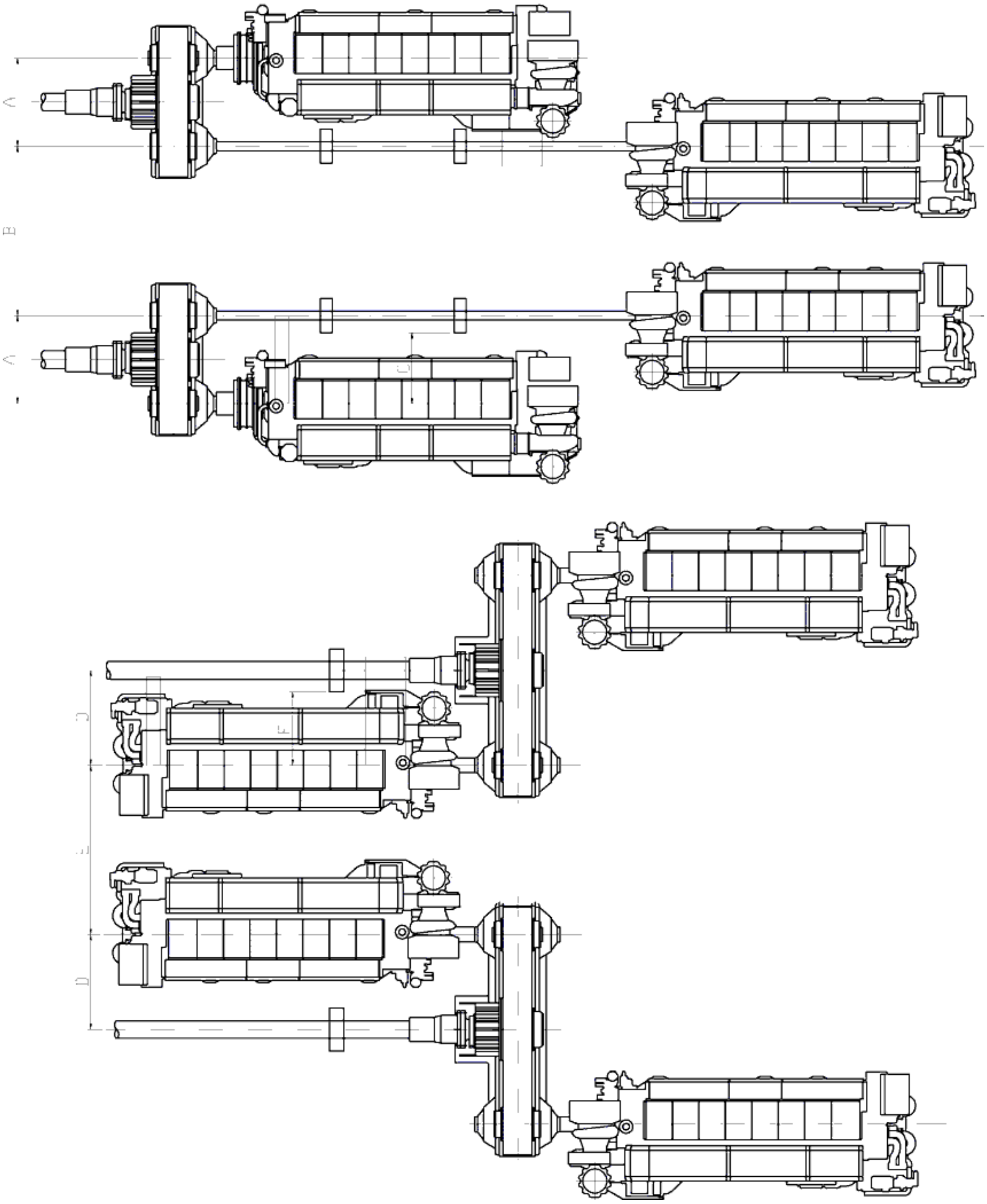


Fig 18-4 Main engines arrangement, 4 engines (DAAE033712)

Engine	A	B	C	D	E	F
W L26	1500	2500	1172	1500	2500	1172
W V26	1900	3000	1633	2100	3000	1782

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 some engine components, as well as 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 any engine part dismounting, a minimum of 1000 mm free space everywhere around the engine is recommended to be reserved for maintenance operations.

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

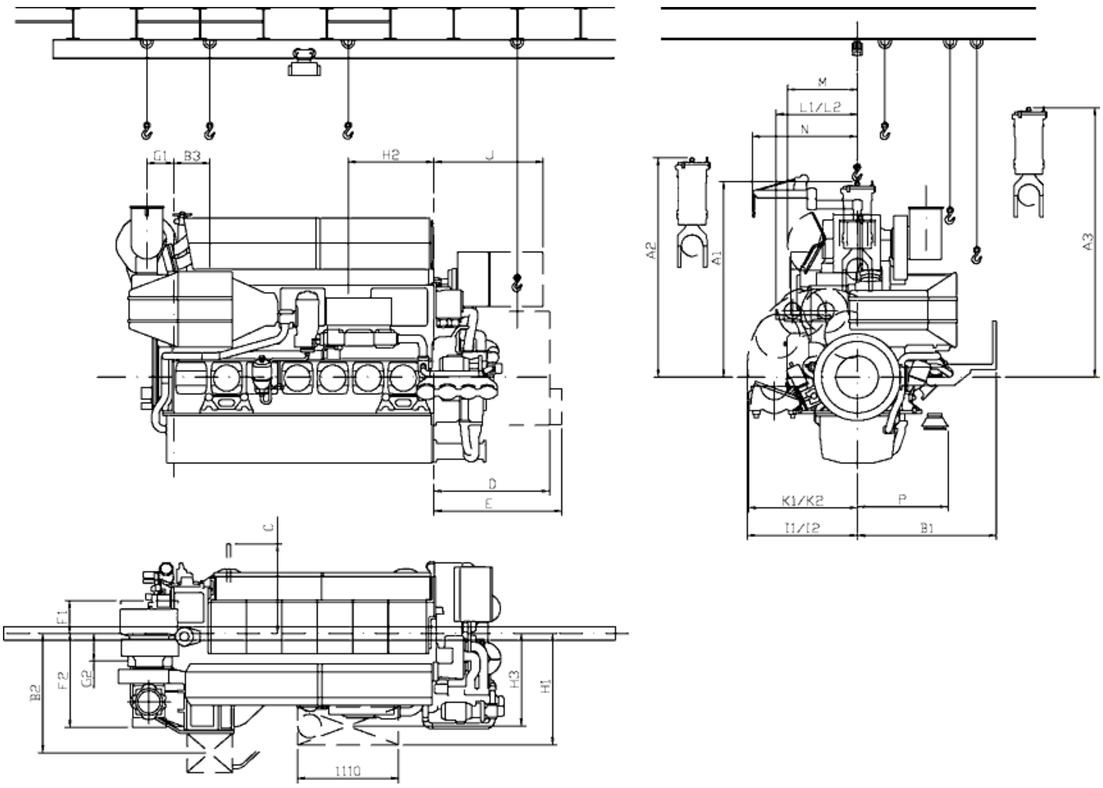


Fig 18-5 Service space requirements for in-line engines, turbocharger in driving end (DAAE026452C)

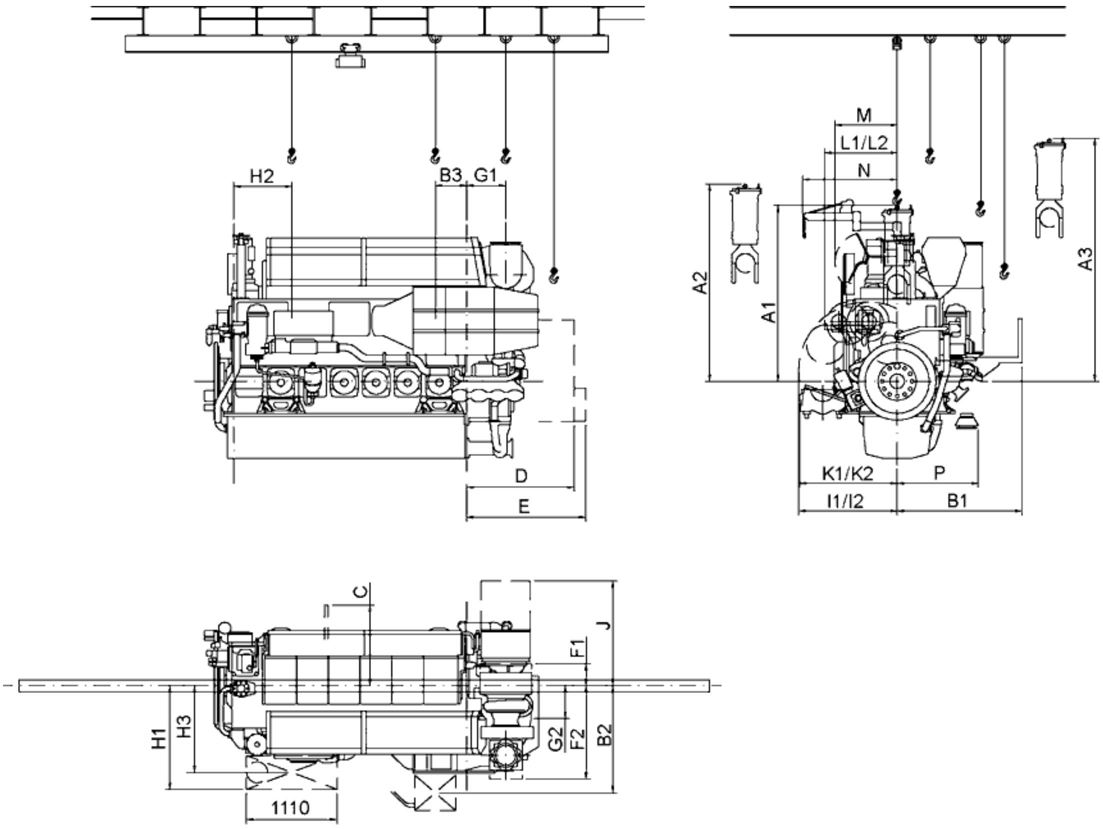


Fig 18-6 Service space requirements for in-line engines, turbocharger in free end (DAAE030871B)

Description		TC at driving end			TC at free end		
		6L	8L	9L	6L	8L	9L
A1	Height to lift the power unit out of cylinder head studs	2164			2164		
A2	Height for transporting the power unit sidewards over hotbox profile	2430			2430		
A3	Height for transporting the power unit sidewards over isolating box	3000			3000		
B1	Length for dismantling charge air cooler insert	1600			1600		
B2	Recommended lifting point for charge air cooler insert	1318			1318		
B3	Recommended lifting point for charge air cooler insert	395			395		
C	Removal of main bearing side screw (to both side)	987			987		
D	Distance for dismantling of engine driven pumps	1100			1100		
E	Distance for dismantling and lifting pump cover with fitted pumps (min)	1250			1510		
F1	Minimum axial clearance for dismantling and assembly of silencers	364	450	450	264	361	361
F2	Minimum axial clearance for dismantling and assembly of exhaust gas outlet elbow (recommended +400 mm)	1038	1178	1178	1146	1270	1270
G1	Lifting point for turbocharger	275	369	369	481	526	526
G2	Lifting point for turbocharger	305	298	298	405	390	390
H1	Width for dismantling lubricating oil module and/or plate cooler	1300			1300		
H2	Recommended lifting point for dismantling lubricating oil module and/or plate cooler	969			715		
H3	Recommended lifting point for dismantling lubricating oil module and/or plate cooler	1003			1027		
I1	Dismounting space camshaft gearwheel	1300			1300		
I2	Dismounting space intermediate gearwheel	1250			1250		
J	Space necessary for access to the connection box	1350			1350		
K1	Dismounting space main bearing caps (to either side)	1200			1200		
K2	Dismounting space big end bearing caps (to either side)	1172			1172		
L1	Dismounting space camshaft journal	808			808		
L2	Dismounting space camshaft section	895			895		
M	Hotbox opening space	850			850		
N	Dismounting space for high pressure fuel pumps with standard tool	1160			1160		
P	Dismounting space for resilient element (metalastic)	1000			1000		

18.4.2 Service space requirement for the V-engine

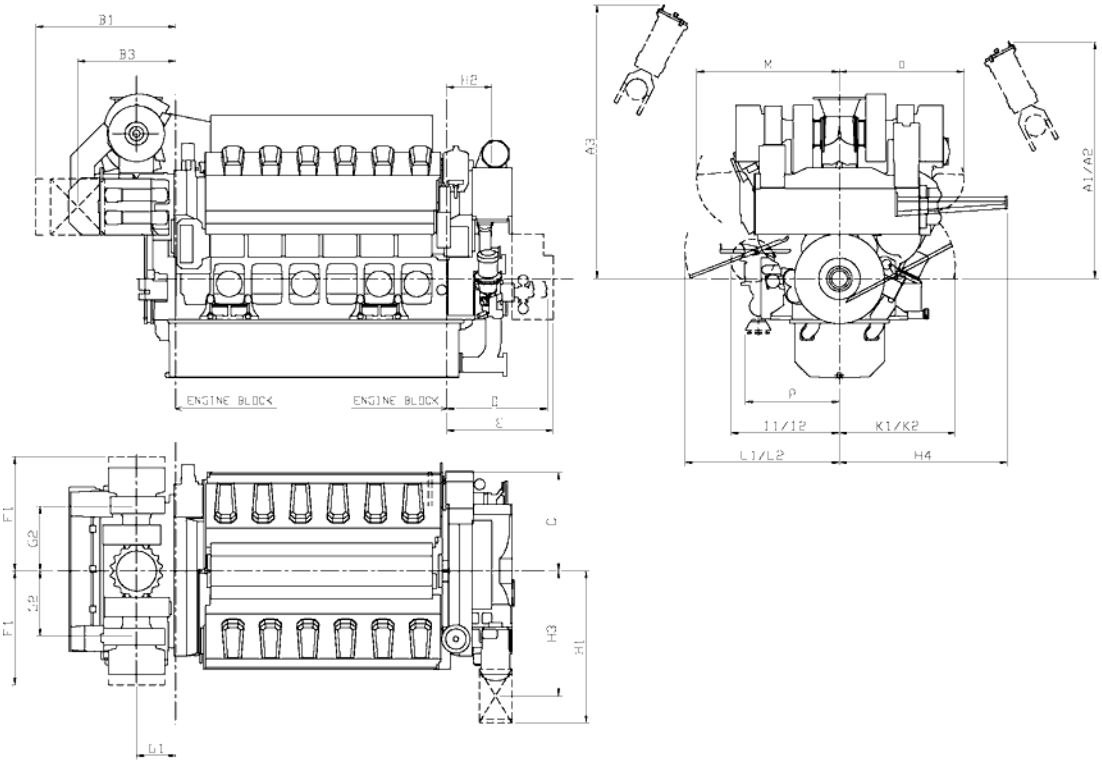


Fig 18-7 Service space requirements for V-engines, turbocharger in driving end (DAAE033190A)

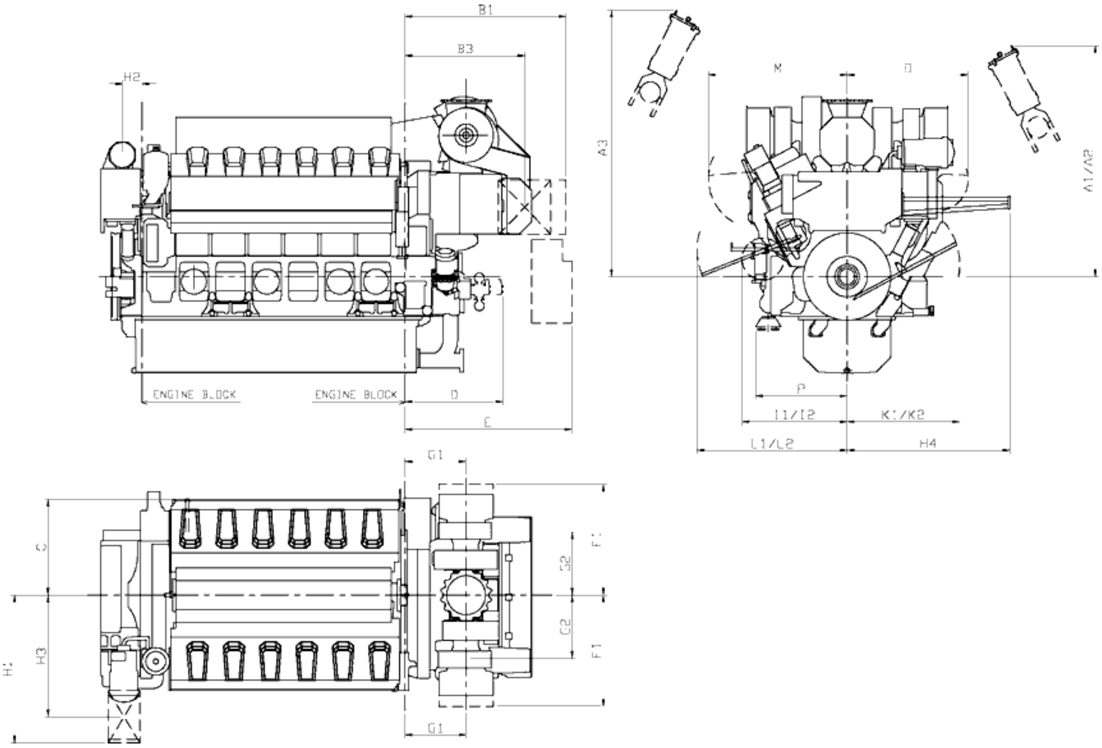


Fig 18-8 Service space requirements for V-engines, turbocharger in free end (DAAE033191A)

Description		TC in flywheel end		TC in free end	
		12V	16V	12V	16V
A1	Height to lift the power unit out of cylinder head studs	2220		2220	
A2	Height for transporting the power unit sidewards over hotbox profile	2765		2765	
A3	Height for transporting the power unit sidewards over isolating box	3170		3170	
B1	Length for dismantling charge air cooler insert	1670		1955	
B3	Recommended lifting point for charge air cooler insert	1100		1382	
C	Removal of main bearing side screw (to both side)	1210		1210	
D	Distance for dismantling and lifting of engine driven pumps	1230		1230	
E	Distance for dismantling pump cover with fitted pumps (min)	1295		2025	2170
F1	Minimum axial clearance for dismantling and assembly of silencers (recommended +400)	1380		1380	
G1	Lifting point for turbocharger	440	576	705	842
G2	Lifting point for turbocharger	730	573	730	573
H1	Width for dismantling lubricating oil cooler	1800		1800	
H2	Recommended lifting point for dismantling lubricating oil cooler	509		225	
H3	Recommended lifting point for dismantling lubricating oil cooler	1400		1400	
H4	Dismounting tool for lubricating oil cooler	1900		1900	
I1	Dismounting space camshaft gearwheel	1315		1315	
I2	Dismounting space intermediate gearwheel	1350		1350	
K1	Dismounting space main bearing caps (to either sides)	1045		1045	
K2	Dismounting space big end bearing caps (to either sides)	1400		1400	
L1	Dismounting space camshaft journal	1210		1210	
L2	Dismounting space camshaft section	1830		1830	
M	WECS opening space	1700		1700	
O	Hotbox opening space	1500		1500	
P	Dismounting space for resilient element (metalastic)	1155		1155	

19. Transport Dimensions and Weights

19.1 Lifting of main engines

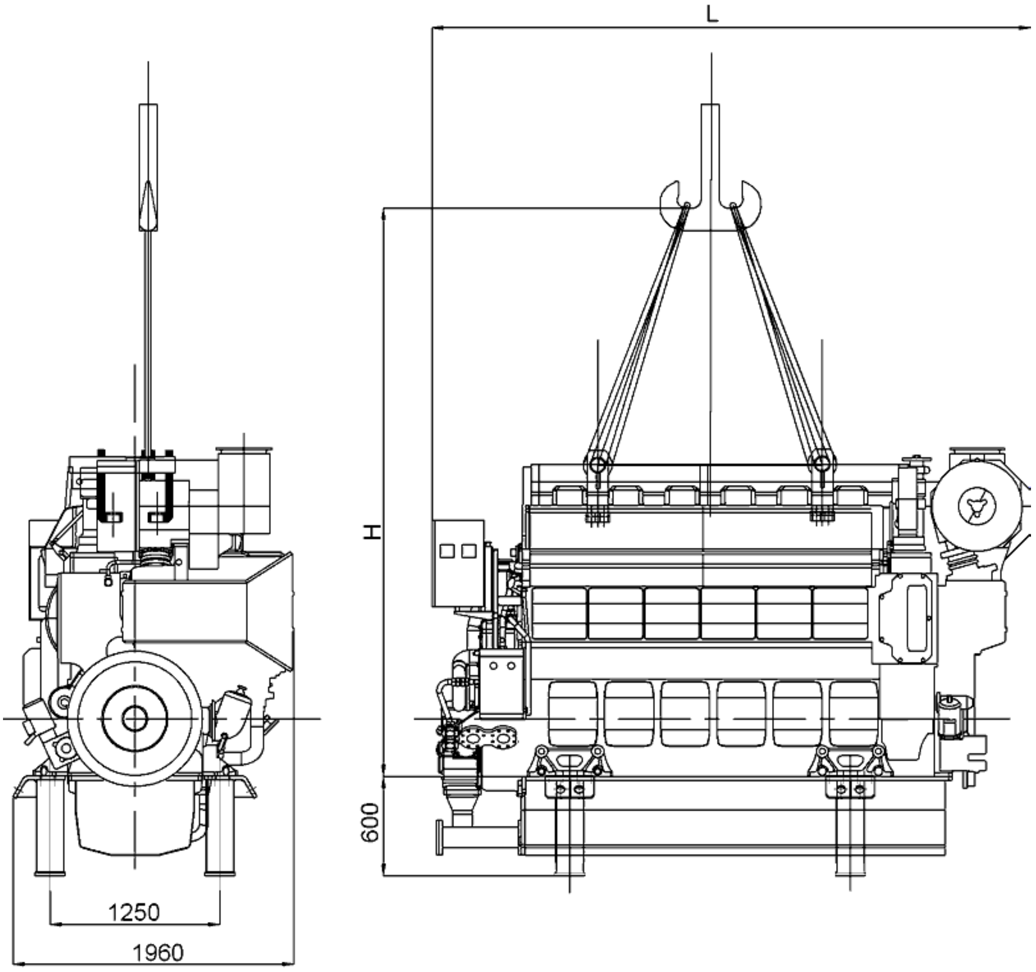


Fig 19-1 Lifting of main engines, in-line engines (DAAE026602A)

Engine	L	H
W 6L26	4387	3435
W 8L26	5302	3494
W 9L26	5691	3494

All dimensions in mm.

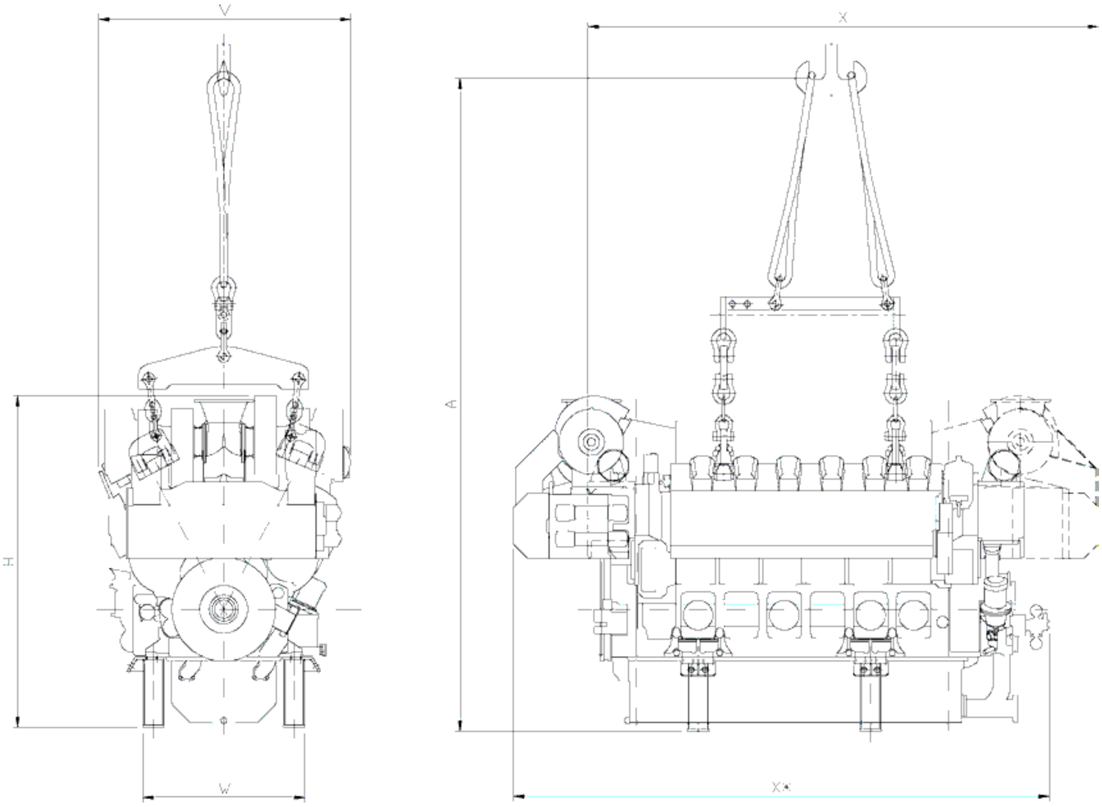


Fig 19-2 Lifting of main engines, V-engines (9610ZT128C)

Engine	A	V	W	X*	H*	X	H	Weight **
W 12V26	6355	2453	1580	5218	3224	4968	3224	31.2
W 16V26	6355	2473	1580	6220	3224	5981	3224	37.4

*) Turbocharger in driving end

**) Weight [ton] for wet sump engines including hoisting tool and transport support

All dimensions in mm.

19.2 Lifting of generating sets

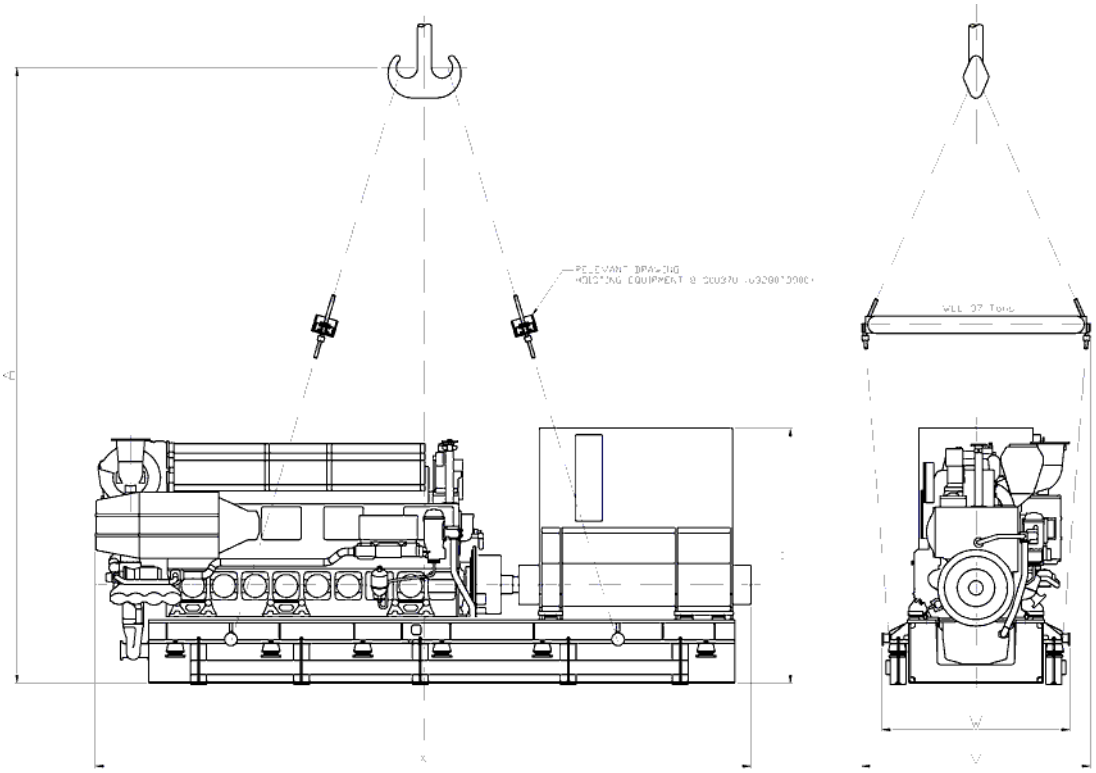


Fig 19-3 Lifting of generating sets (9610ZT129a)

Engine	Dimensions [mm]							Weights [ton]		
	A	X*	H*	X	H	V	W	Generating set	Hoisting tool	Transport support
W 6L26	6546	7100	3100	7345	3100	2780	2300	37.7	1.7	0.5
W 8L26	8167	8180	3160	8243	3160	2780	2300	42.9	1.7	0.5
W 9L26	8731	8570	3160	8853	3160	2780	2300	47.5	1.7	0.5
W 12V26	-	-	-	8353	3660	2780	2700	59.3	1.7	0.5
W 16V26	-	-	-	9772	3660	2780	2700	68.8	1.7	0.5

*) Turbocharger in driving end

The dimensions X, H and the weight of the generating set depends on the generator.

19.3 Engine components

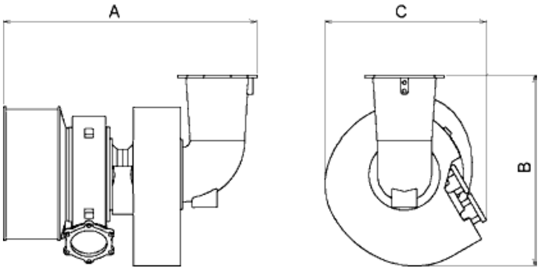


Fig 19-4 Turbocharger

Engine	A [mm]	B [mm]	C [mm]	Weight [kg]
W 6L26	1217	804	660	335
W 8L26	1428	879	831	570
W 9L26	1428	879	831	570
W 12V26	1217	804	660	2*335
W 16V26	1185	830	978	2*775

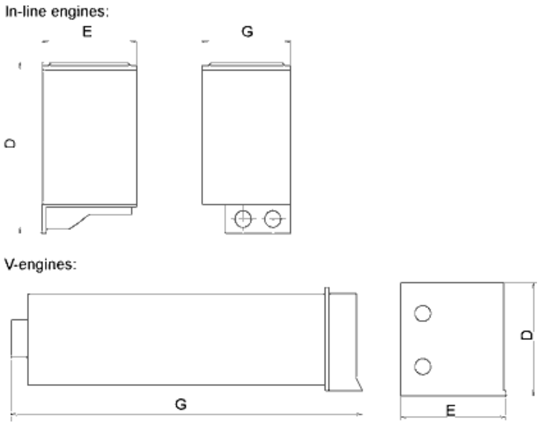
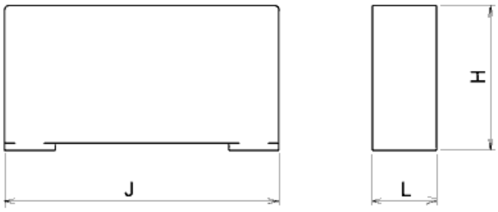


Fig 19-5 Charge Air Cooler

Engine	D [mm]	E [mm]	G [mm]	Weight [kg]
W 6L26	965	534	500	440
W 8L26	965	534	500	530
W 9L26	965	534	500	530
W 12V26	625	590	1900	680
W 16V26	625	590	1900	725

In-line engines



V-engines

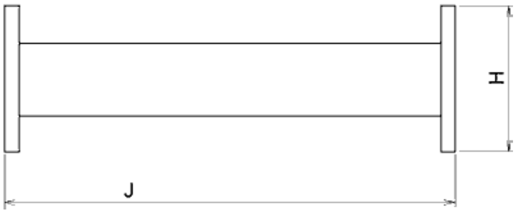


Fig 19-6 Lubricating oil cooler

Engine	H [mm]	J [mm]	L [mm]	Weight [kg]
W 6L26	291	694	304	100
W 8L26	379	694	304	120
W 9L26	412	694	304	128
W 12V26	370	1300	-	145/165*
W 16V26	370	1300	-	145/165*

*) in case of increased cooler capacity

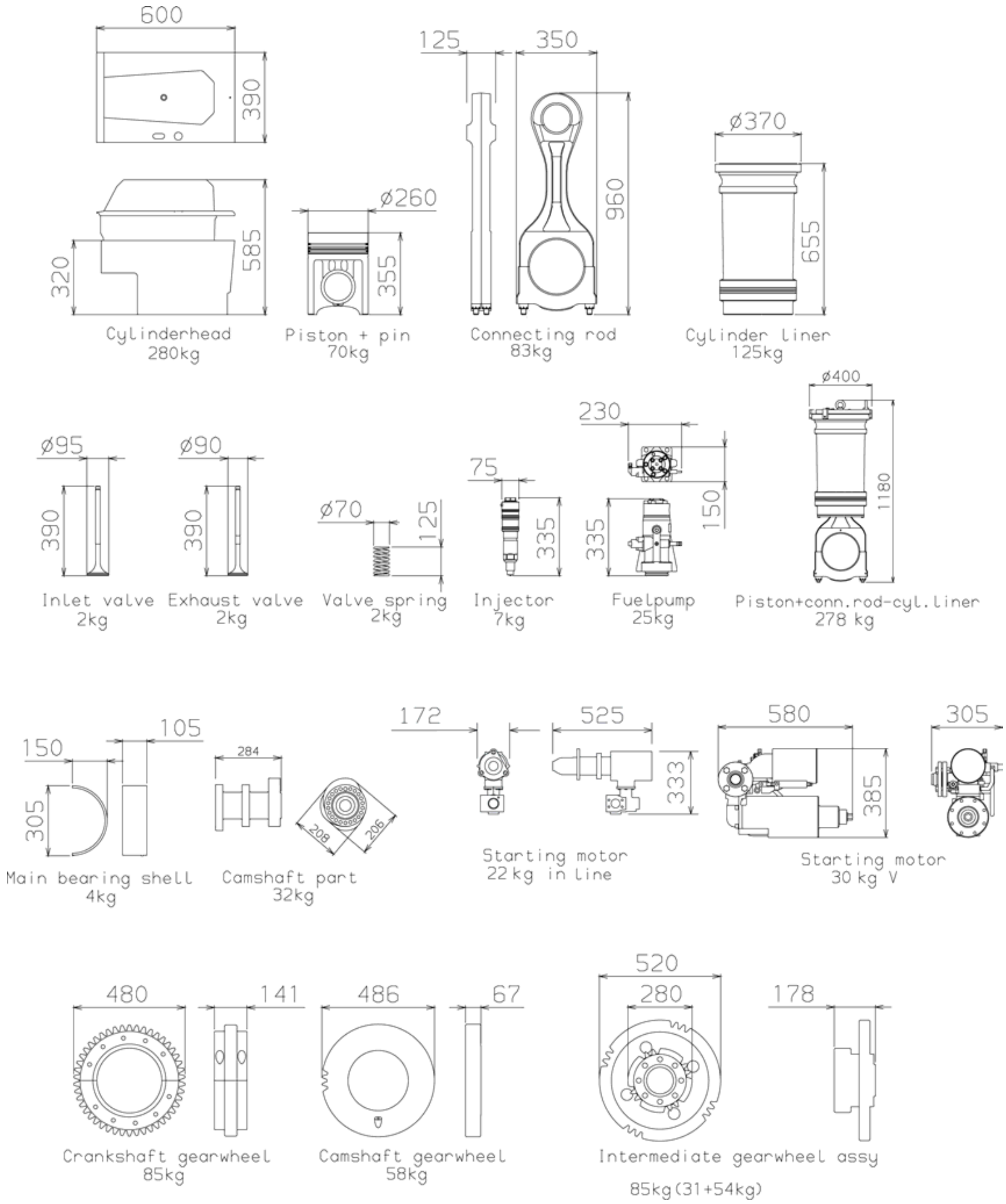


Fig 19-7 Major spare parts

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 in near future. Please consult your sales contact at Wärtsilä for more information.

Engine outline drawings are not available in the printed version of this product guide.

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

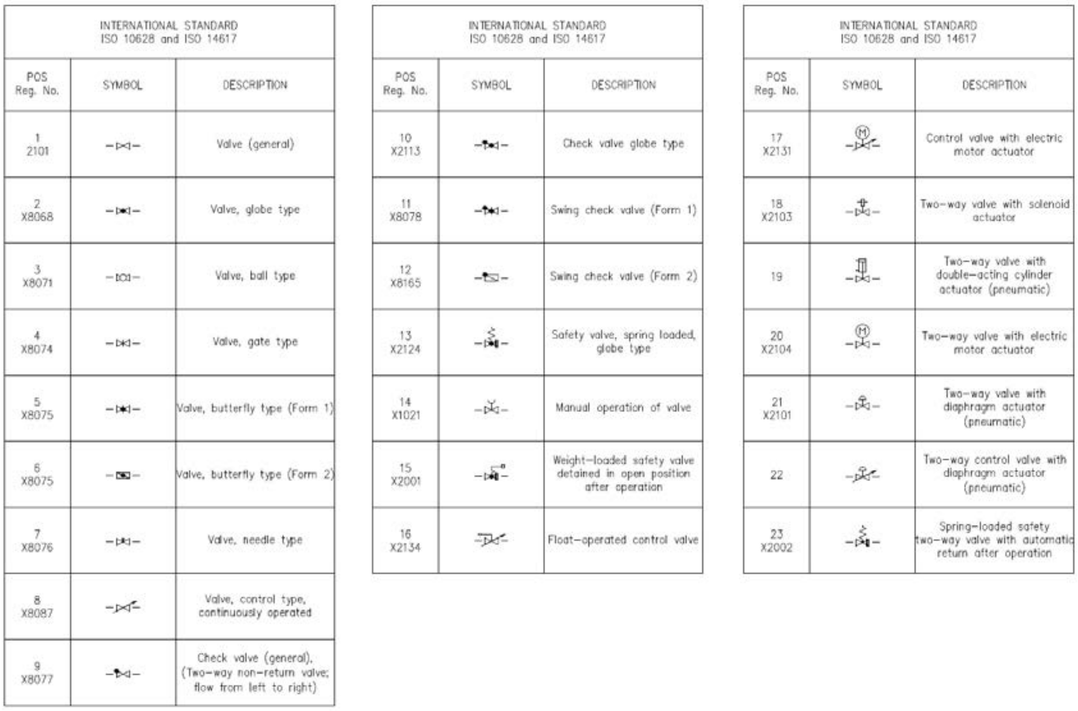
Convert from	To	Multiply by
kg/m^3	lb/US gallon	0.00834
kg/m^3	lb/Imperial gallon	0.01002
kg/m^3	lb/ft^3	0.0624

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)

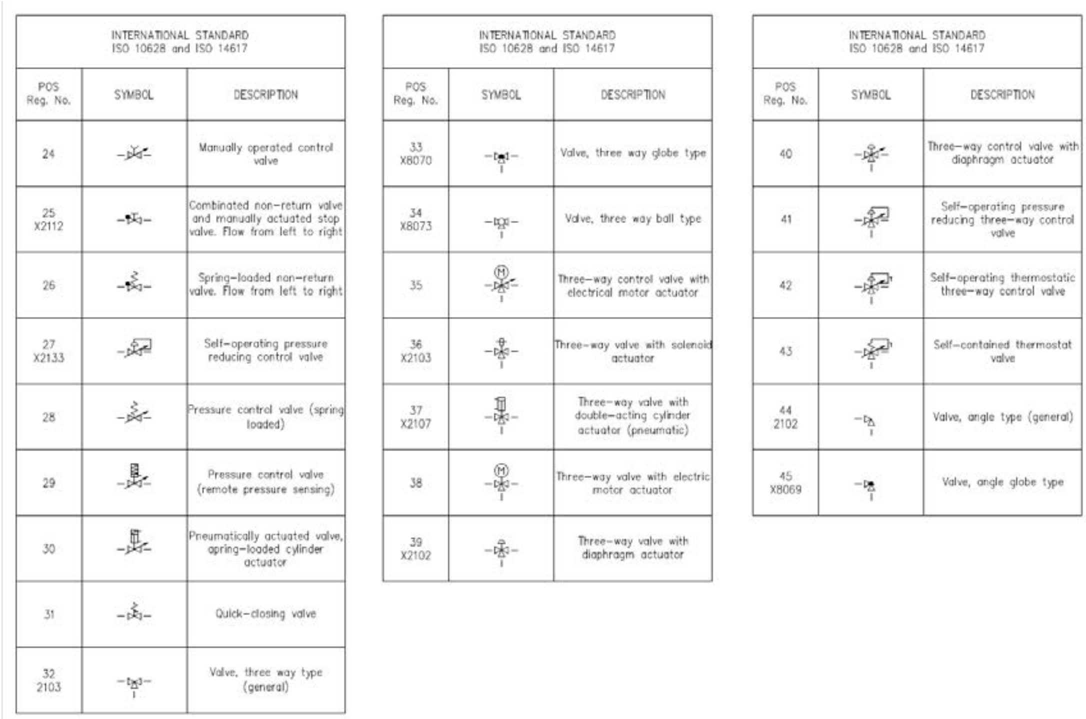
INTERNATIONAL STANDARD ISO 10628 and ISO 14617

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 (DAAF406507 - 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, spring-loaded cylinder actuator
31		Quick-closing valve
32 2103		Valve, three way type (general)

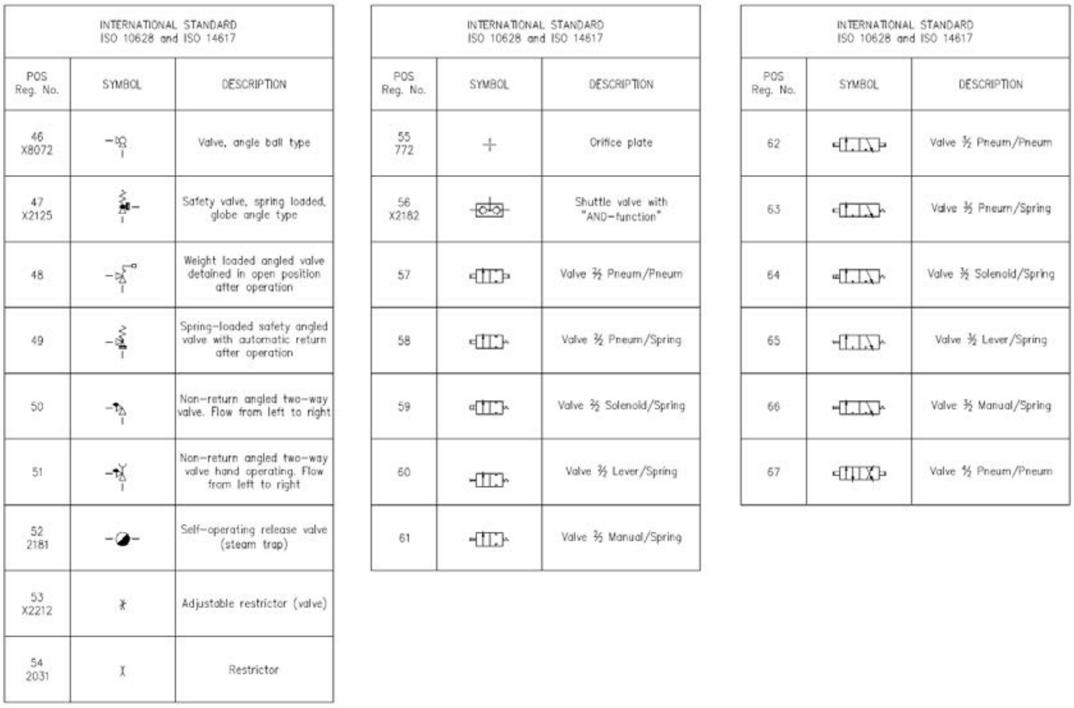
INTERNATIONAL STANDARD ISO 10628 and ISO 14617

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 (DAAF406507 - 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

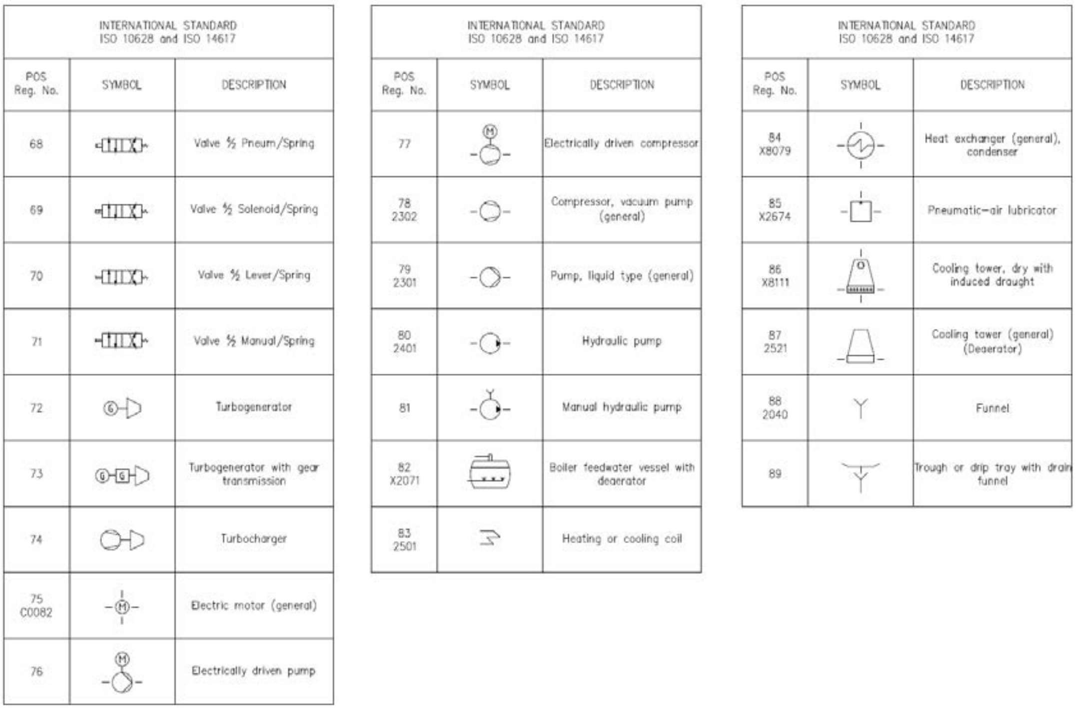
INTERNATIONAL STANDARD
ISO 10628 and ISO 14617

POS Reg. No.	SYMBOL	DESCRIPTION
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

INTERNATIONAL STANDARD
ISO 10628 and ISO 14617

POS Reg. No.	SYMBOL	DESCRIPTION
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 (DAAF406507 - 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

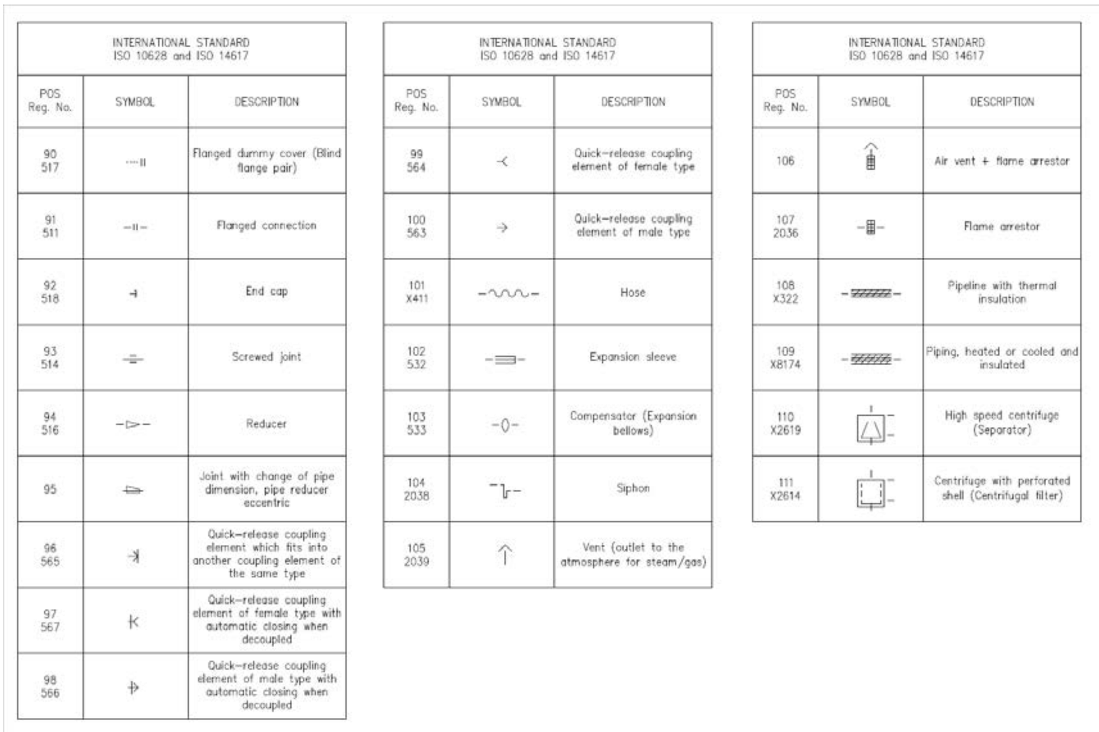
INTERNATIONAL STANDARD
ISO 10628 and ISO 14617

POS Reg. No.	SYMBOL	DESCRIPTION
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

INTERNATIONAL STANDARD
ISO 10628 and ISO 14617

POS Reg. No.	SYMBOL	DESCRIPTION
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 (DAAF406507 - 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

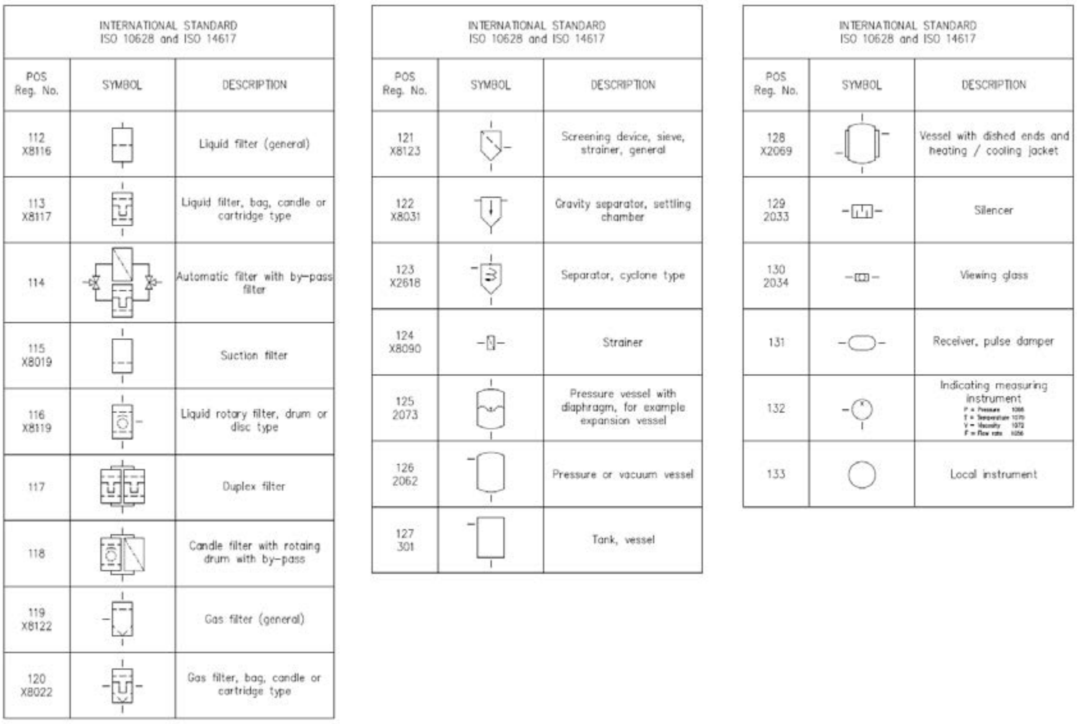
INTERNATIONAL STANDARD
ISO 10628 and ISO 14617

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 (DAAF406507 - 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

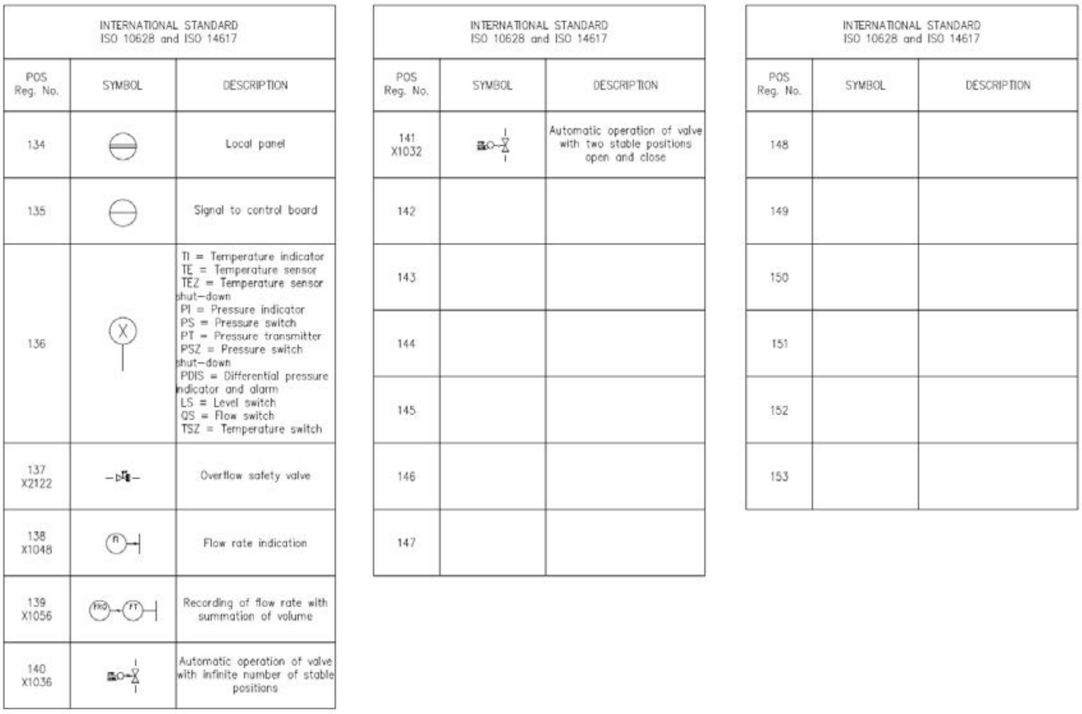
INTERNATIONAL STANDARD
ISO 10628 and ISO 14617

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 (DAAF406507 - 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		Flow rate indication
139 X1056		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		
143		
144		
145		
146		
147		

INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
148		
149		
150		
151		
152		
153		

Fig 21-7 List of symbols (DAAF406507 - 7)

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