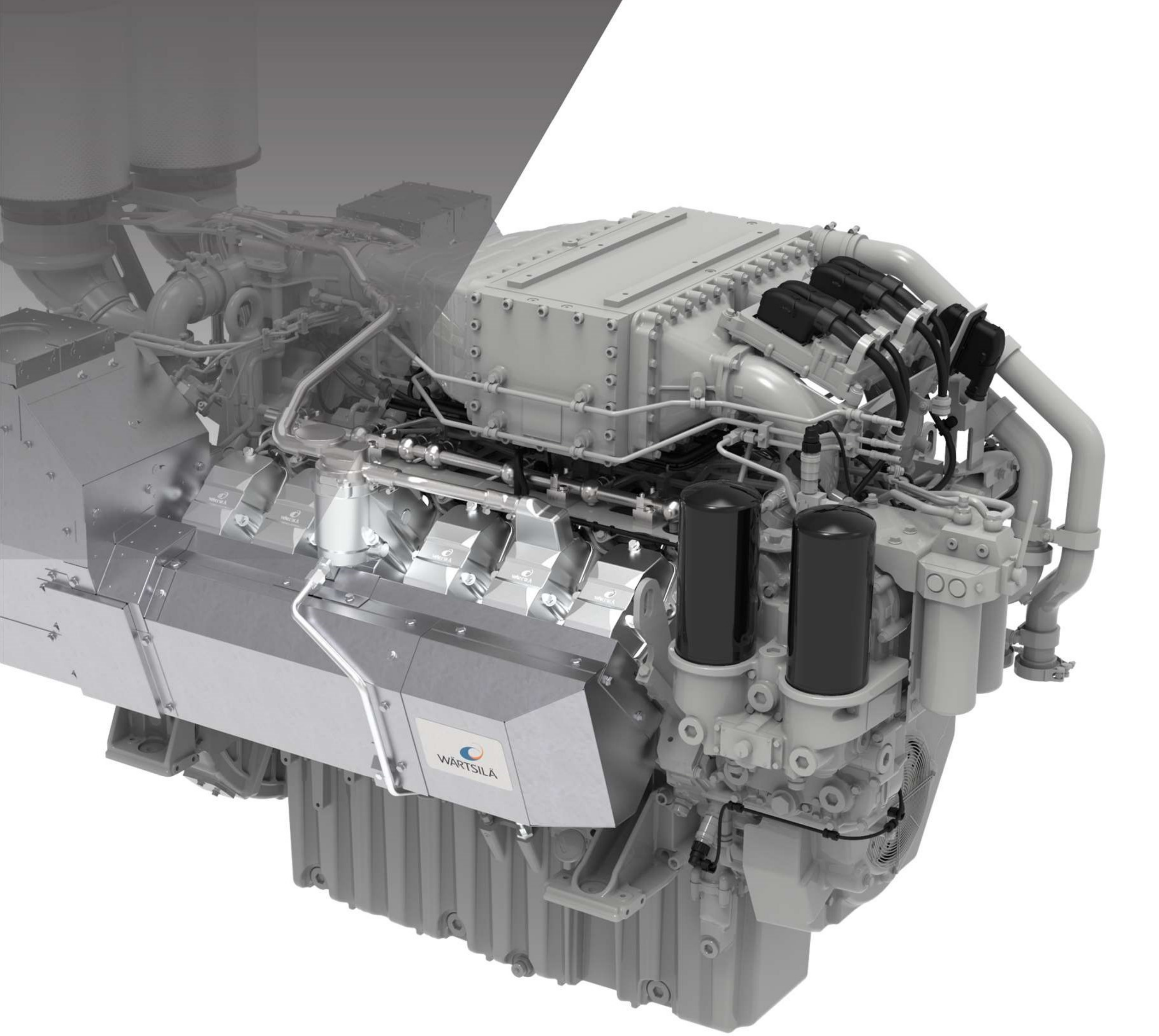
Product Guide

WÄRTSILÄ 14



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 14 Project Guides.

Issue	Published	Updates
1/2022	22.04.2022	Automation System and other updates throughout the Product Guide
2/2021	2.07.2021	3rd version published
1/2021	29.01.2021	2nd version published
1/2019	18.12.2019	first version published

Wärtsilä, Marine Business

Vaasa, April 2022

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1. Main Data and Outputs

1.1 Technical Main Data

The Wärtsilä 14 is a 4-stroke, non-reversible, turbocharged and intercooled diesel engine with direct injection of fuel.

Cylinder bore	135mm
Stroke	157mm
Piston displacement	2,25 l/cyl
Engine displacement	12V - 27L
	16V - 36L
Number of valves	2 inlet valves and 2 exhaust valves
Cylinder configuration	12 and 16, V-engine
Direction of rotation	Counter clockwise
Speed	1500rpm, 1600rpm, 1800rpm, 1900 rpm
Mean piston speed	(7,6 m/s), (8,4 m/s), (9,4 m/s); (9,9 m/s)

1.2 Maximum continuous output

1.2.1 Rated output

Wärtsilä 14 engine is produced in 12- and 16-cylinder configurations and the nominal speed from 1500 to 1900 rpm. Power output for mechanical propulsion between 749 and 1340 kWm and for auxiliary generating set and diesel-electric propulsion applications between 675 and 1155 kWe.

CYLINDER CONFIGURATION	12V	16V
Nominal Power (kWm)	749 - 1005	1005 - 1340
Nominal Power (kWe)	675 - 865	900 - 1155
Nominal Speed	1500 - 1900	1500 - 1900

A Rating - Continuous Duty

This rating is an ISO 15550 rating. Intended for continuous use in applications requiring uninterrupted service at full power. For vessels operating at rated load and rated speed up to 100% of the time without interruption or load cycling (80 to 100% load factor). Typical operation ranges from 5000 to 8000 hours per year.

B Rating - Heavy Duty

This rating is an ISO 15550 rating. Intended for continuous use in variable load applications where full power is limited to a period of 10 out of every 12 operating hours (83% of the time) with some load cycling. Overall load factor is between 40 – 80%. Typical operation ranges from 3000 to 5000 hours per year.

C Rating - Medium Continuous Duty

This rating is an ISO 15550 rating. Intended for continuous use in variable load applications where full power is limited to a period of 6 out of every 12 operating hours (50% of the time) with cyclical loading and speed. Overall load factor is between 20 – 80%. Typical operation ranges from 2000 to 4000 hours per year.

D Rating - Intermittent Duty

This rating is an ISO 15550 rating. Intended for continuous use in variable load applications where full power is limited to a period of 3 out of every 12 operating hours (25% of the time) with some load cycling. Overall load factor is maximum 50%. Typical operation ranges from 2000 to 4000 hours per year.

E Rating: Prime Power

Diesel electric propulsion and Auxiliary generating sets shall follow the Prime Power rating definition in accordance to ISO8528-1:

- Annual Hours of Operation: Unlimited

- Overall Load Factor <70%

1.2.1.1 Mechanical propulsion

Table 1-1 W12V14 Output tables (kW)

Rating	Nominal Power kWm	Nominal Power bhp	Nominal Speed rpm
A	749 810	1004 1086	1600 1800
B	790 850	1059 1139	1600 1800
C	890 920	1193 1233	1800 1900
D	970 1005	1300 1347	1800 1900

Table 1-2 W16V14 Output tables (kW)

Rating	Nominal Power kWm	Nominal Power bhp	Nominal Speed rpm
A	1005 1080	1347 1448	1600 1800
B	1055 1135	1414 1522	1600 1800
C	1185 1225	1589 1642	1800 1900
D	1295 1340	1736 1796	1800 1900

1.2.1.2 Diesel electric propulsion, constant speed

Table 1-3 Output tables (kW)

50Hz W12V14 Rating	Nominal Power kWm	Nominal Power kWe	Nominal Speed rpm
E.1	710	675	1500
E.2	790	750	1500

60Hz W12V14 Rating	Nominal Power kWm	Nominal Power kWe	Nominal Speed rpm
E.1	710	675	1800
E.2	790	750	1800
E.3	910	865	1800

50Hz W16V14 Rating	Nominal Power kWm	Nominal Power kWe	Nominal Speed rpm
E.1	945	900	1500
E.2	1055	1000	1500

60Hz W16V14 Rating	Nominal Power kWm	Nominal Power kWe	Nominal Speed rpm
E.1	945	900	1800
E.2	1055	1000	1800
E.3	1215	1155	1800

1.2.2 Rated output - Auxiliary Engines

Table 1-4 Output tables (kW)

50Hz W12V14 Rating	Nominal Power kWm	Nominal Power kWe	Nominal Speed rpm
E.1	710	675	1500
E.2	790	750	1500

60Hz W12V14 Rating	Nominal Power kWm	Nominal Power kWe	Nominal Speed rpm
E.1	710	675	1800
E.2	790	750	1800
E.3	910	865	1800

50Hz W16V14 Rating	Nominal Power kWm	Nominal Power kWe	Nominal Speed rpm
E.1	945	900	1800
E.2	1055	1000	1800

60Hz W16V14 Rating	Nominal Power kWm	Nominal Power kWe	Nominal Speed rpm
E.1 E.2 E.3	945 1055 1215	900 1000 1155	1800 1800 1800

1.3 Reference Conditions

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

For higher temperatures, please contact Wärtsilä.

The specific fuel oil consumption can be found by accessing *Engine Online Configurator* available through Wärtsilä's website. 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).

1.4 Operation in inclined position

The engine is designed to ensure proper engine operation at inclination positions, specified under IACS M46.2 (1982) (Rev.1 June 2002) - Main and auxiliary machinery.

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

- Permanent athwart ship inclination (list) +/ 15° dynamic in any direction
- Temporary athwart ship inclinations (roll) +/ 22,5° dynamic in any direction
- Permanent fore-and-aft inclinations (trim) +/ 5° dynamic in any direction
- Temporary fore and aft inclinations (pitch) +/ 7,5° dynamic in any direction

1.5 Principal dimensions and weights

1.5.1 W14 Engine Outline Drawings

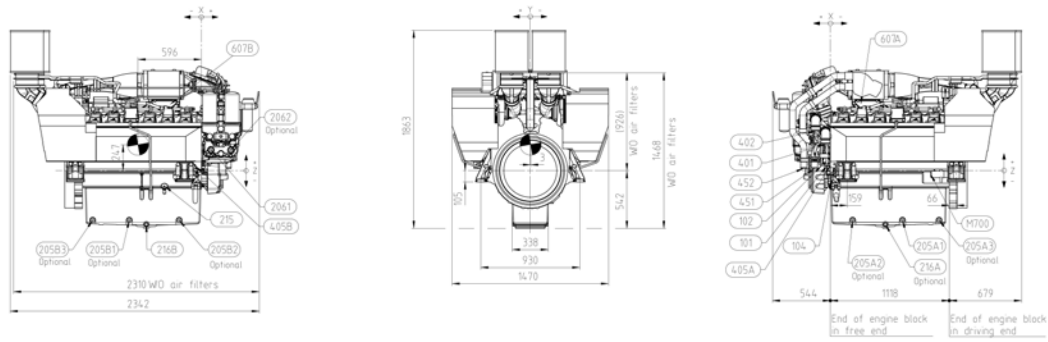

Fig 1-1 W12V14 Engine outline drawing (DAAF443744E)

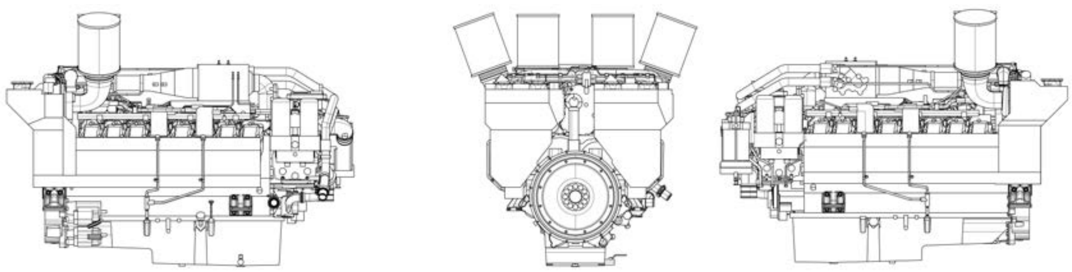

Fig 1-2 W16V14 Engine outline drawing (DAAF460820D)

	Wärtsilä 12V14	Wärtsilä 16V14
Engine Length (mm)	2342	2601
Engine Width (mm)	1470	1825
Engine Height (mm)	1863	1906
Engine Weight without oil, without water (kg)	2850	3789

1.5.2 W14 Genset Outline Drawings

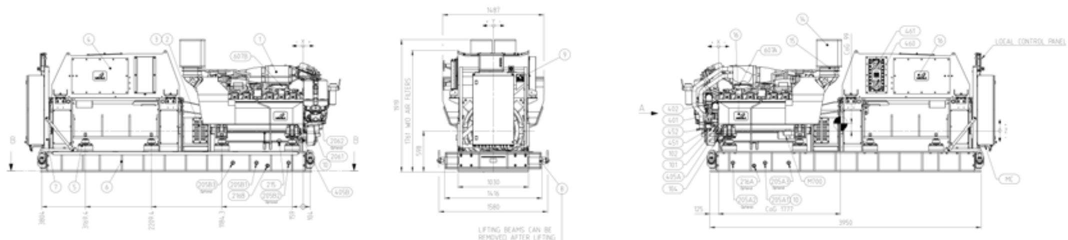

Fig 1-3 W12V14 Genset outline drawing (DAAF491140C)

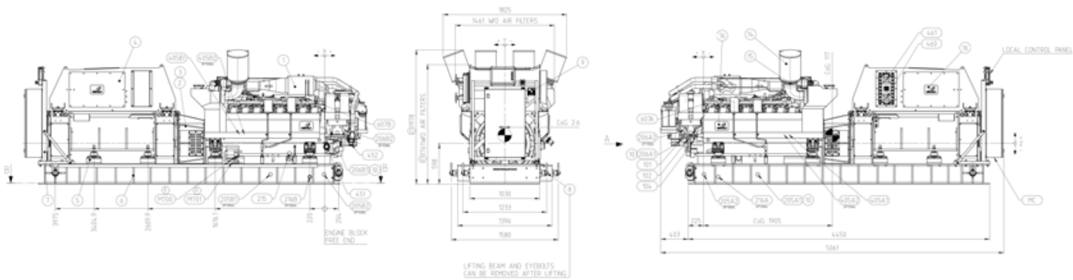

Fig 1-4 W16V14 Genset outline drawing (DAAF500353G)

	Wärtsilä 12V14	Wärtsilä 16V14
Generating set Length (mm)*	4577	5061
Generating set Width (mm)*	1580	1825
Generating set Height (mm)*	1919	1978
Generating set Weight (kg)*	7840	9110

* Dependent on generator type and size, without liquids

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.

If further questions concerning other operating ranges than the typical operating fields specified below, please contact Wärtsilä.

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 demand quantity and actual engine speed (not speed demand).

The propeller efficiency is highest at desigh pitch. The power demand from a possible shaft generator or PTO must be taken into account.

The propulsion control must also include automatic limitation of the load increase rate. Maximum loading rates can be found later in this chapter.

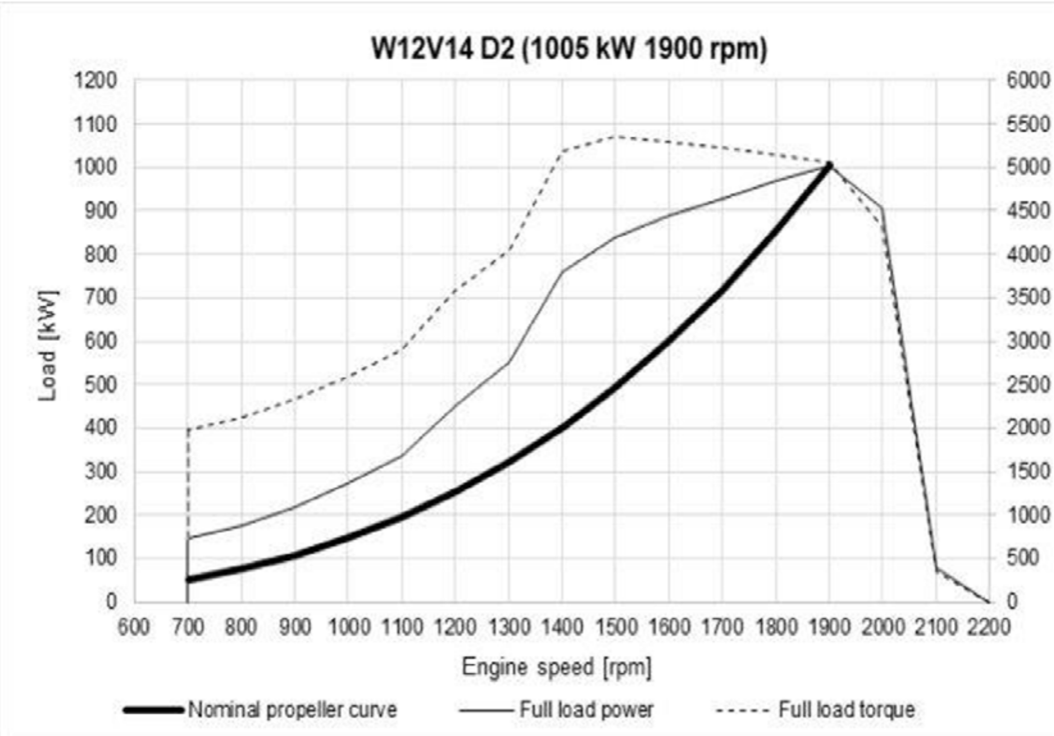

Fig 2-1 Typical Operating Field W12V14 (DMTA00035729A)

NOTE
1. Minimum engine speed 700 rpm
2. Minimum clutch-in speed 700 rpm
3. Additional restrictions apply to low load operation
4. Additional restrictions may apply from the aftertreatment systems

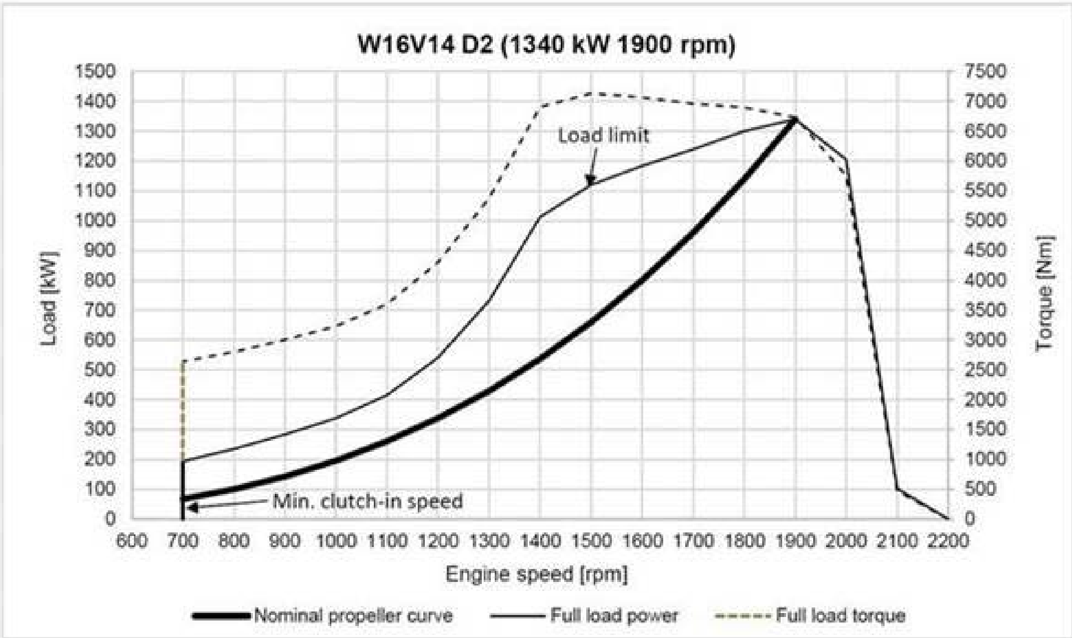

Fig 2-2 Typical Operating Field W16V14 (DMTA00035964A)

NOTE
1. Minimum engine speed 700 rpm
2. Minimum clutch-in speed 700 rpm
3. Additional restrictions apply to low load operation
4. Additional restrictions may apply from the aftertreatment systems

NOTE
D2 is an engine output rating, which refers to Intermittent Duty according to ISO 15550, and it’s intended for continuous use in variable load applications.

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.

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.

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.

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

2.2.1 Mechanical Propulsion

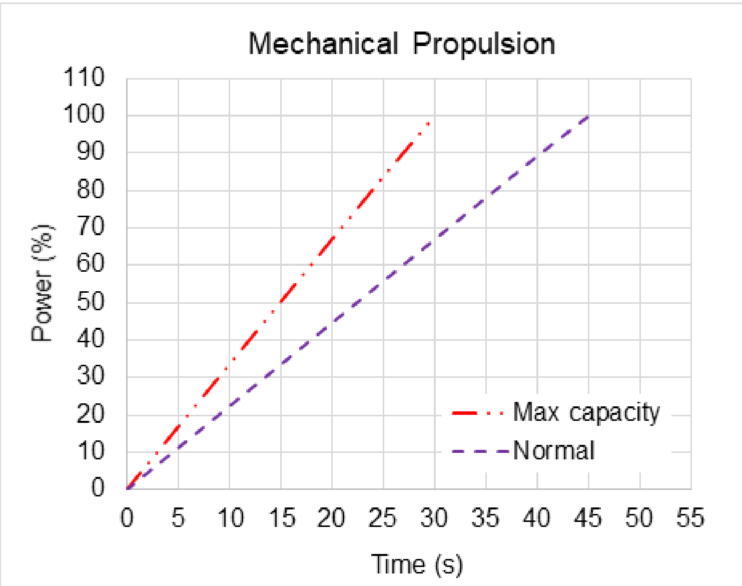

Fig 2-3 Maximum recommended load increase rates for variable speed engines

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

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

Large load reductions from high load should also be performed gradually. In normal operation the load should not be reduced from 100% to 0% in less than 10 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

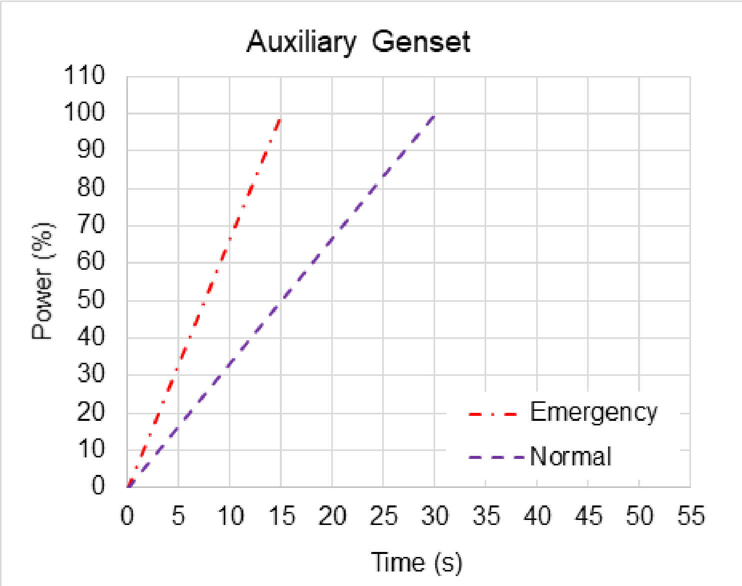

Fig 2-4 Maximum recommended load increase rates for constant speed engines

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. 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.

In normal operation the load should not be reduced from 100% to 0% in less than 15 seconds. In an emergency situation the full load can be thrown off instantly.

2.2.3 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 permissable 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 or in a fast sequence with few generators on the busbar, which may cause significant load steps. 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.

Maximum load steps, DME and AUX engines

Instant Load Application	Engine unloading
• Maximum load step according to figure below (0 – 33 – 66 – 100 %) • Maximum transient speed decrease of 10 % of rated speed • Steady-state frequency band ± 1.0 % • Steady-state recovery time ≤ 5 sec. • Time between load steps ≥ 5 sec., however the max. load limit specified in the graph below should not be exceeded	• Instant load rejection 100 % - 0 % • Maximum transient speed increase of 10 % of the rated speed • Steady-state frequency band ± 1.0 % • Steady-state recovery time ≤ 5 sec.

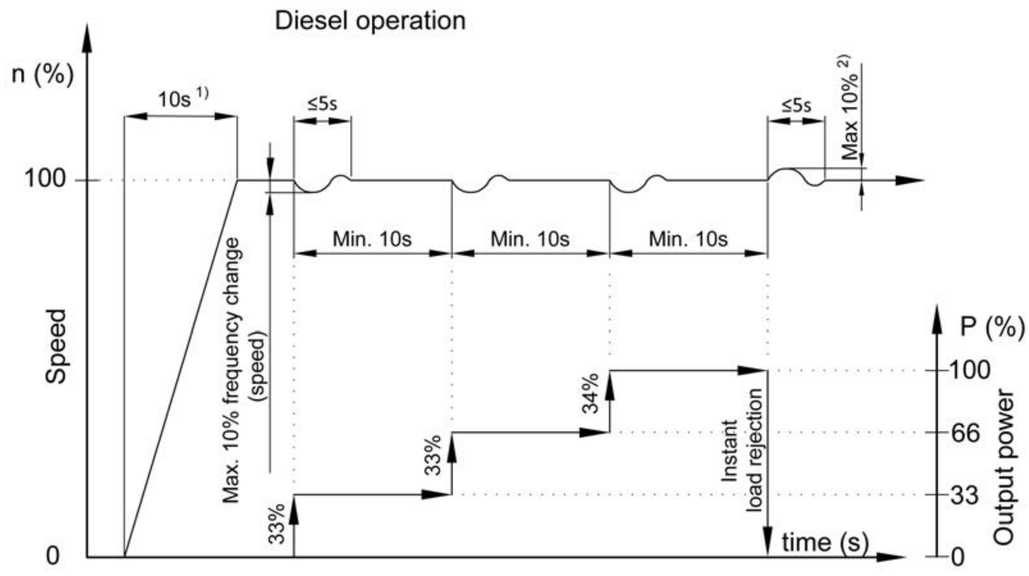

Fig 2-5 Diesel Operation

NOTE
1) Engine in normal operating condition
2) Speed increase is not allowed to caue the intervention of the over speed device according to *Engine Online Configurator*

2.2.4 Start-up time

A diesel generator typically reaches nominal speed in about 10...15 seconds after the start signal. The acceleration is limited by the speed control to minimise smoke during start-up.

2.3 Low load operation

Operation below 1100rpm AND below 96kW (8kW/cyl):

Maximum 6 hours if the engine is to be stopped after the period

Maximum 12 hours if the engine is to be loaded after the period. At intervals of 12 operating hours the engine must be loaded to minimum 70 % of the rated output.

Operation at or above 1100rpm AND below 96kW (8kW/cyl)

Maximum 300 hours continuous operation. At intervals of 300 operating hours the engine must be loaded to minimum 70 % of the rated output.

Operation at or above 96kW (8kW/cyl)

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:

- +5 ºC

For further guidelines, see chapter *Combustion Air System* design.

NOTE
Please contact Wärtsilä in case minimum inlet air temperature is lower than above mentioned.

3. Technical Data

3.1 Introduction

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

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

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

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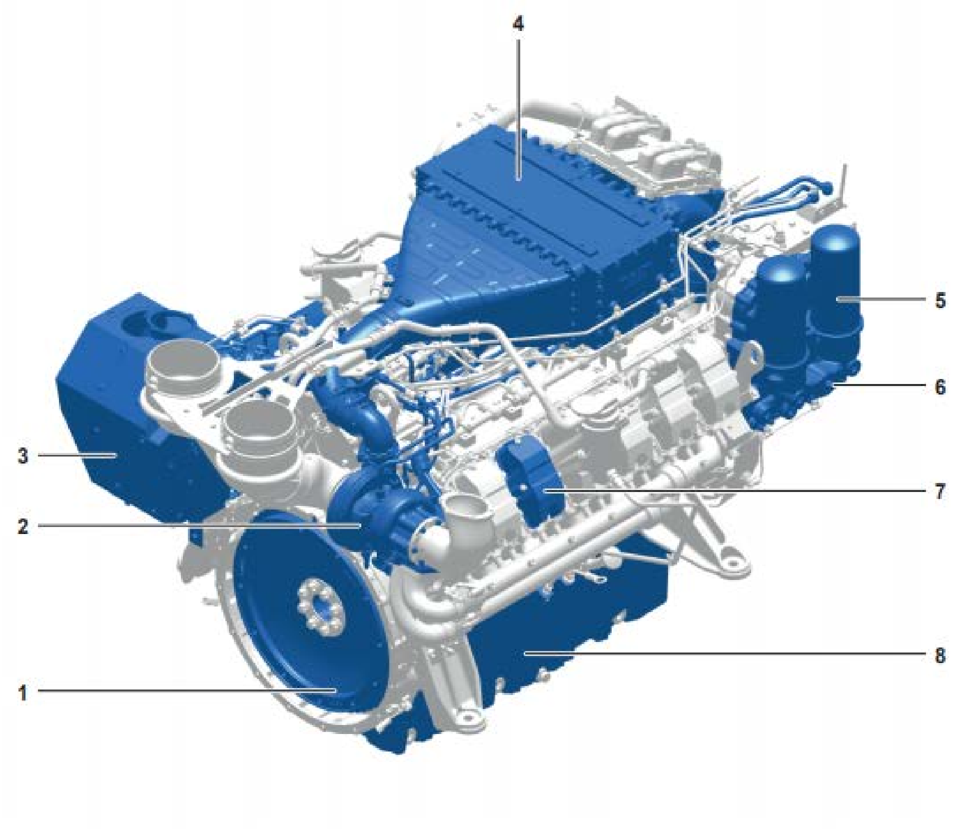
4. Description of the Engine

4.1 Definitions



1 Flywheel
2 Exhaust gas turbocharger
3 Exhaust manifold heat protection (multipiece)
4 Charge air cooler
5 Oil filter
6 Oil cooler with switching
7 Cylinder head cover
8 Oil pan

Fig 4-1 System description

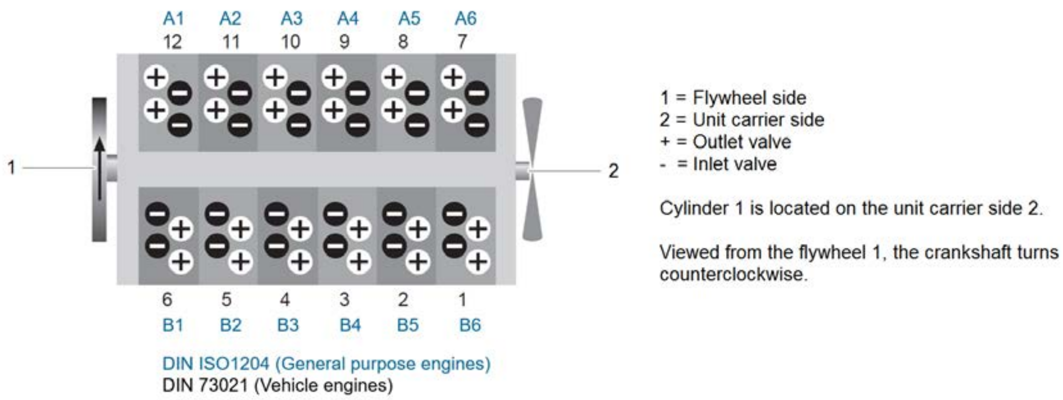


Fig 4-2 Cylinder designation

4.2 Main components and system

4.2.1 Engine block

The engine block is a one piece nodular cast iron component with integrated channels for lubricating oil and cooling water.

On V12 the crankshaft is fixed on the block by a Bed-plate with screws installed from the bottom with 42 screws.

On V16 the main bearing caps are fixed from below by two screws per bearing cap. They are guided sideways by the engine block at the top as well as at the bottom. Four horizontal side screws per bearing cap at the lower guiding provide a very rigid crankshaft bearing.

4.2.2 Crankshaft

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

4.2.3 Connecting rod

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

4.2.4 Main bearings and big end bearings

The main bearings and the big end bearings are of steel blacked leaded bronze trimetal bearing with Sputter overlay for loaded shell and steel blacked leaded bronze trimetal with synthetic coating for the low loaded shell.

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 metallically at the upper part and by O-rings at the lower part.

4.2.6 Piston

The piston is of mono-block design and the piston ring grooves in the top of piston.

4.2.7 Piston rings

The piston ring set consists of two compression rings and one spring-loaded oil scraper ring.

4.2.8 Cylinder head

The cross flow cylinder head is made of cast iron. The mechanical load is absorbed by a flame plate, which together with the upper deck and the side walls form a rigid box section. There are six cylinder head bolts. The exhaust valves seat rings and the flame deck are efficiently water-cooled. The valve seat rings are made of alloyed steel, for wear resistance. All valves and valve guides are and equipped with valve springs.

Following components are connected to the cylinder head:

- Charged and cooled air flow from intake system
- Exhaust gas pipe of exhaust system
- Cooling water circuit
- High Pressure circuit (HP) fuel pipe connections
- Oil circuit through cylinder head for rocker arm

4.2.9 Camshaft and valve mechanism

The camshaft is made of one piece. The camshaft bearing housings are integrated in the engine block casting.

The valve tappets are of piston type with roller against the cam. The valve springs ensure that the valve mechanism is dynamically stable.

4.2.10 Camshaft drive

The camshaft is driven by the crankshaft through a gear train.

4.2.11 Fuel injection equipment

Common Rail System:

High pressure system consist on:

- LP pump mounted with same shaft as HP pump (two pistons)

- Two rails, injection pipes, two rail feeding pipes, High pressure connectors, injectors, volume and pressure valves (VCV and PCV).

The injection valve is centrally located in the cylinder head and the fuel is admitted sideways through a high pressure connection piece.

4.2.12 Turbocharging and charge air cooling

The turbo chargers and wastegate valves offers the ideal combination of high-pressure ratios and good efficiency.

The charge air cooler is single stage type and cooled by water.

4.2.13 Exhaust pipes

The complete exhaust gas system is enclosed in an insulated box consisting of easily removable panels. Ceramic and glass fibers are used as insulating material.

4.2.14 Engine Automation system

The engine automation system is an embedded engine management system. The automation system has a hardwired interface for control functions and a bus communication interface for alarm and monitoring. For more information, see chapter Automation System.

4.3 Overhaul intervals and expected lifetimes

4.3.1 Expected Life Time

4.3.1.1 Time between Overhaul and Maintenance Schedules

Overhauls and engine life time definitions

Engine life time: The nominal engine life for W14 marine engine shall be 20,000 hours in accordance to the ratings and operating profiles.

4.4 Engine storage

At delivery the engine is provided with VCI bag and the genset is provided with VCI coating and a tarpaulin. For storage longer than 6 months please contact Wärtsilä Finland Oy.

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5. Piping Design, Treatment and Installation

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

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

NOTE
The pipes in the freshwaterside 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.

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

The following aspects shall be taken into consideration:

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

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

5.1 Pipe dimension

When selecting the pipe dimensions, take into account:

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

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

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

5.2 Pressure class

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

The pressure in the system can:

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

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

5.3 Pipe class

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

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

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

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

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

5.4 Insulation

The following pipes shall be insulated:

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

Insulation is also recommended for:

- Pipes between engine and jacket water preheater

5.5 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.

5.6 Cleaning procedures

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

5.6.1 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 5-2 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

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

5.6.2 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.

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 7 µm absolute mesh size ($ß_7$ = 100). 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.

5.6.3 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).

5.6.4 Pickling

Prefabricated pipe spools are pickled before installation onboard.

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

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

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

5.7 Flexible pipe connections

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

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

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

- Flexible pipe connections must not be twisted
- Installation length of flexible pipe connections must be correct
- Minimum bending radius must be respected
- Piping must be concentrically aligned
- When specified, the flow direction must be observed
- Mating flanges shall be clean from rust, burrs and anticorrosion coatings
- If not otherwise instructed, bolts are to be tightened crosswise in several stages

- Painting of flexible elements is not allowed
- Rubber bellows must be kept clean from oil and fuel
- The piping must be rigidly supported close to the flexible piping connections.

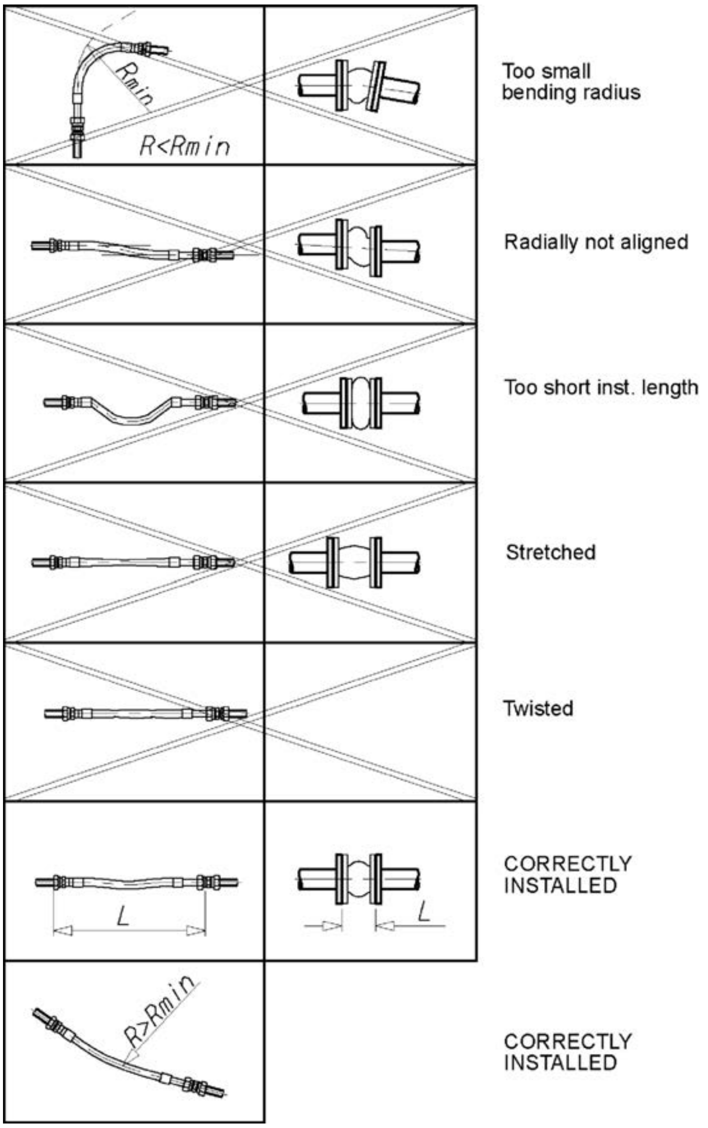


Fig 5-1 Flexible hoses

5.8 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. Connection information available in engine drawings.

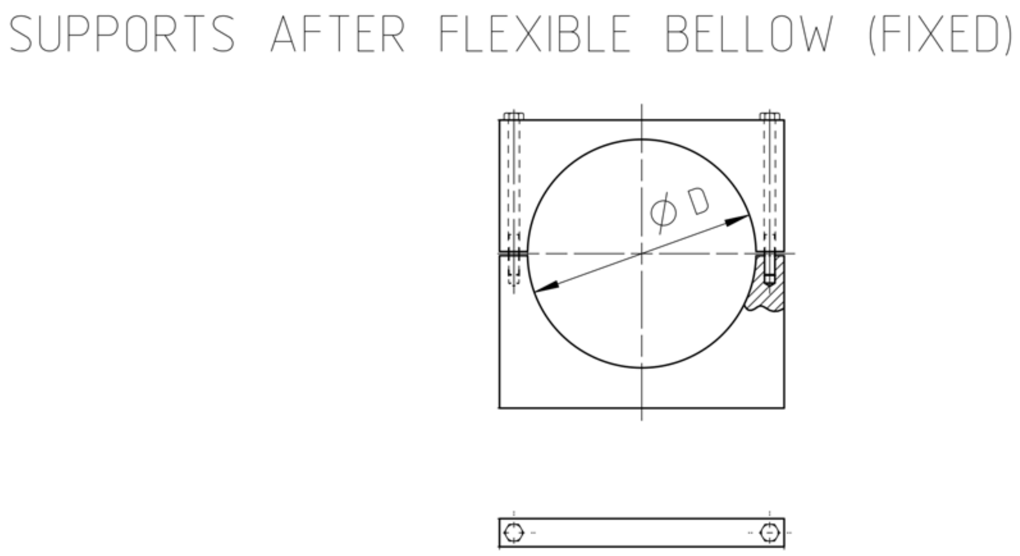


Fig 5-2 Pipe clamp for fixed support

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.

The equipment is specified for fuel according to ISO 8217:2017 (E) for Marine distillate fuels with maximum Sulphur content of 0,5% (5'000ppm).

Please contact Wärtsilä in case DMB category fuels or other fuel types are planned to be used which are not included in this document.

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, DMZ. 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. 1.3 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.
- **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.

6.1.1.1 Table Light fuel oils

Characteristics		Unit	Limit	Category ISO-F			Test method(s) and references
				DMX	DMA	DMZ	
Kinematic viscosity at 40 °C j)		mm2/s a)	Max	5,500	6,000	6,000	ISO 3104
			MIn	1,400 i)	2,000	3,000	
Density at 15 °C		kg/m³	Max	-	890,0	890,0	ISO 3675 or ISO 12185
Cetane Index			Min	45	40	40	ISO 4264
Sulphur b,k)		% m/m	Max	0,5			ISO 8754 or ISO 14596, ASTM D4294
Flash point		°C	Min	43,0 l)	60	60,0	ISO 2719

Hydrogen sulfide		mg/kg	Max	2,00	2,00	2,00	IP 570
Acid number		mg/KOH /g	Max	0,5	0,5	0,5	ASTM D664
Total sediment by hot filtration		% m/m	Max	-	-	-	ISO 10307 - 1
Oxidation stability		g/ m³	Max	25	25	25	ISO 12205
Fatty acid methylester (FAME) e)		% v/v	Max	-	-	-	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	-	-	-	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	ISO 3016
	summer			-	0	0	
Appearance			-	Clear and bright g)			-
Water		% v/v	Max	-	-	-	ISO 3733
							or ASTM D6304-C m)
Ash		% m/m	Max	0,010	0,010	0,010	ISO 6245
Lubricity, corr. wear scar diam. h)		µm	Max	520	520	520	ISO 12156

NOTE

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) Lower than min. viscosity of 1,400 mm²/s can prevent the use ISO-F-DMX category fuels in W14 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 1,3 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 EN 590 Standard

EN 590 is a standard published by European Committee for Standardization. Based on 98/70/EG it allows the blending of up to 7% fatty acid methyl ester biodiesel with 'conventional' diesel - a 7:93 mix.

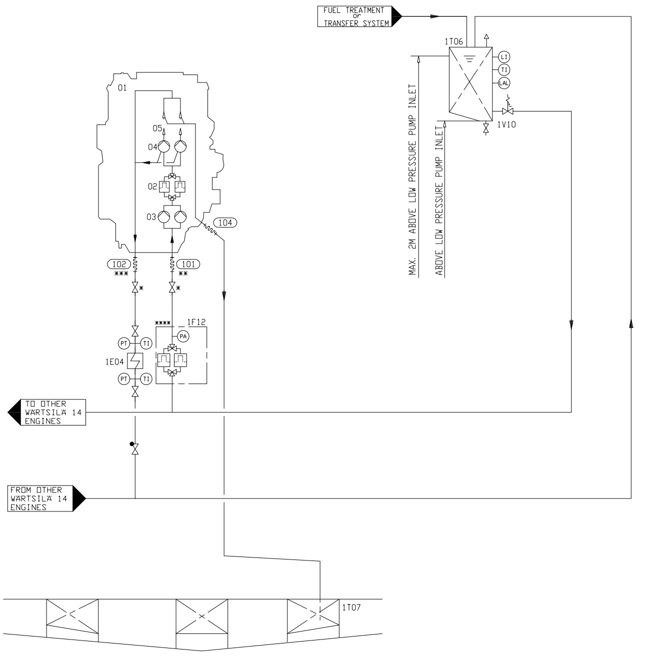
6.1.2.1 Table EN 590

Property	Unit	Limits		Test method
		minimum	maximum	
Cetane number		**51,0**	-	EN ISO 5165 EN 15195 EN 16144
Cetane index		46,0	-	EN ISO 4264
Density at 15 °C	**kg/m³**	820,0	**845,0**	EN ISO 3675 EN ISO 12185
Polycyclic aromatic hydrocarbons	**% (m/m)**	-	**8,0**	EN 12916

Sulfur content	**mg/kg**	-	**10,0**	EN ISO 20846 EN ISO 20884 EN ISO 13032
Manganese content	**mg/l**	-	**2,0**	prEN 16576
Flash point	°C	Above 55,0	-	EN ISO 2719
Carbon residue (on 10% distillation residue)	% (m/m)	-	0,30	EN ISO 10370
Ash content	% (m/m)	-	0,010	EN ISO 6245
Water content	mg/kg	-	200	EN ISO 12937
Total contamination	mg/kg	-	24	EN 12662
Copper strip corrosion (3 h at 50 °C)	rating	class 1		EN ISO 2160
Fatty acid methyl ester (FAME) content	**% (V/V)**	-	**7,0**	EN 14078
Oxidation stability	g/m^3 h	- 20	25 -	EN ISO 12205 EN 15751
Lubricity, corrected wear scar diameter (wsd 1,4) at 60 °C	µm	-	460	EN ISO 12156-1
Viscosity at 40 °C	mm^2/s	2,000	4,500	EN ISO 3104
Distillation % (V/V) recovered at 250 °C % (V/V) recovered at 350 °C **95 % (V/V) recovered at**	. % (V/V) % (V/V) **°C**	. . 85	. < 65 . **360**	EN ISO 3405 EN ISO 3924
NOTE Requirments in bold refer to the European Fuels Directive 98/70/EC [1].				

NOTE
Detail information of EN590 can be found in standard.

6.2 External fuel oil system

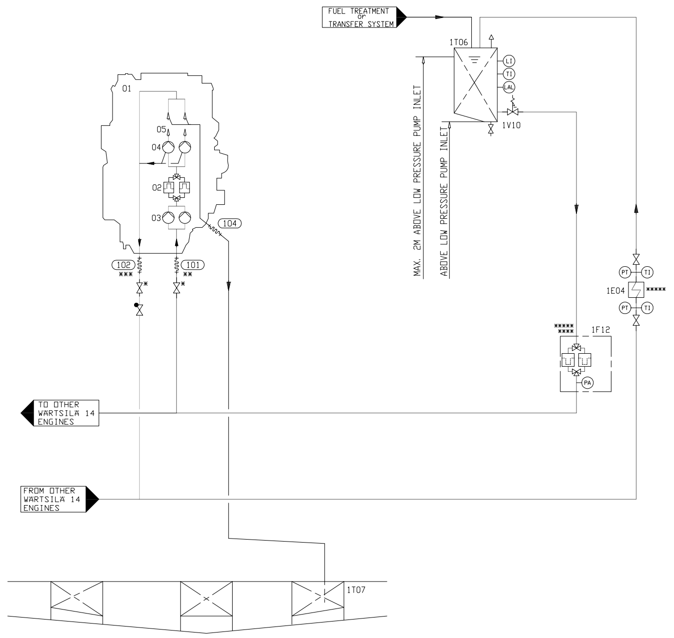


POS.	PART	SUPPLIER
01	DIESEL ENGINE WÄRTSILÄ 14	WÄRTSILÄ
02	FINE FILTER (HIGH PRESSURE PUMP INLET)	WÄRTSILÄ
03	LOW PRESSURE PUMP	WÄRTSILÄ
04	HIGH PRESSURE PUMP	WÄRTSILÄ
05	HP RAIL AND INJECTORS	WÄRTSILÄ
1E04	COOLER (MDF)	-
1F12	WATER COALESCING FILTER (MDF)	WÄRTSILÄ
1T06	DAY TANK (MDF)	-
1T07	LEAK FUEL TANK (DIRTY FUEL)	-
1V10	QUICK CLOSING VALVE (FUEL OIL TANK)	-

POS.	PIPE CONNECTIONS	12V	16V
		SIZE	SIZE
101	FUEL INLET	M26x1.5	M30x2
102	FUEL OUTLET	M22x1.5	M22x1.5
104	LEAK FUEL DRAIN, DIRTY FUEL	M16x1.5	M16x1.5

* SOLAS REQUIREMENT. WÄRTSILÄ RECOMMEND REMOTE OPERATION IF LOCATED < 5 m FROM ENGINE.
** FUEL INLET PRESSURE (101): see technical data section.
*** FUEL OUTLET PRESSURE (102): see technical data section.
**** 2xWATER IN FUEL SENSORS IN PRE-FILTER
- QS1401 WATER IN FUEL 1
- QS1402 WATER IN FUEL 2

Fig 6-1 External Fuel Oil System (W12V14 & W16V14 DAAF478921D)



POS.	PART	SUPPLIER
01	DIESEL ENGINE WÄRTSILÄ 14	WÄRTSILÄ
02	FINE FILTER (HIGH PRESSURE PUMP INLET)	WÄRTSILÄ
03	LOW PRESSURE PUMP	WÄRTSILÄ
04	HIGH PRESSURE PUMP	WÄRTSILÄ
05	HP RAIL AND INJECTORS	WÄRTSILÄ
1E04	COOLER (MDF)	******
1F12	WATER COALESCING FILTER (MDF)	******
1T06	DAY TANK (MDF)	YARD
1T07	LEAK FUEL TANK (DIRTY FUEL)	YARD
1V10	QUICK CLOSING VALVE (FUEL OIL TANK)	YARD

POS.	PIPE CONNECTIONS	12V	16V
		SIZE	SIZE
101	FUEL INLET	M26x1.5	M30x2
102	FUEL OUTLET	M22x1.5	M22x1.5
104	LEAK FUEL DRAIN, DIRTY FUEL	M16x1.5	M16x1.5

* SOLAS REQUIREMENT. WÄRTSILÄ RECOMMEND REMOTE OPERATION IF LOCATED < 5 M FROM ENGINE.
** FUEL INLET PRESSURE (101): see technical data section.
*** FUEL OUTLET PRESSURE (102): see technical data section.
**** 2xWATER IN FUEL SENSORS IN PRE-FILTER
- QS1401 WATER IN FUEL 1
- QS1402 WATER IN FUEL 2
***** ALTERNATIVELY PARTS 1F12 AND/OR 1E04 CAN BE INDIVIDUAL FOR EACH ENGINE
****** FOR PARTS IN WÄRTSILÄ SCOPE OF SUPPLY, SEE INSTALLATION PLANNING INSTRUCTIONS

Fig 6-2 External Fuel Oil System with Common Fine Filter & MDF Cooler (W12V14 & W16V14 DAAF478922E)

The design of the external fuel system may vary from ship to ship, but every system should provide well cleaned fuel of correct viscosity and pressure to each engine. Temperature control is required to maintain stable and correct viscosity of the fuel before the injection pumps (please refer to technical data which can be found by accessing *Engine Online Configurator* available through Wärtsilä's website). 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 duplex type suction prefilter with water sensors.

The fuel pipes between the engine and ship piping 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.

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

- **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 ß50 = 75
- **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.
- **XX micron, absolute**: intended here as ßxx = 75 ISO 16889 (similar to old εxx = 98,7%)

  - Beta value ßxx = YY : ISO name with ISO 16889 standardised test method. Weak repeatability for dust bigger than 25..45 microns.

  - Example: ß20 = 75 means “every 75 particles 20 micron ISO dust sent, one passes”.

  - Efficiency εxx = YY % : same meaning as Beta-value, but not any ISO standardised test method, hence sometimes used for particles larger than 25..45 micron.

  - Example: ε20 = 98,7% means “every 75 particles 20 micron non-ISO dust sent, one passes, which is 98,7% stopped.”

6.2.2 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.

6.2.2.1 Settling tank, MDF (1T10)

Separate settling tanks for MDF are recommended.

In case intention is to operate on low sulphur fuel it is beneficial to install double settling tanks to avoid incompatibility problems.

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. Usually MDF settling tanks do not need heating or insulation, but the tank temperature should be in the range 20...40°C.

6.2.2.2 Day tank, MDF (1T06)

The capacity of the MDF tank should ensure fuel supply for 8 hours. Settling tanks may not be used instead of day tanks.

In case intention is to operate on different fuel qualities (low sulphur fuel) it is beneficial to install double day tanks to avoid incapability problems.

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.

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.

6.2.2.3 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.

6.2.3 Fuel treatment

6.2.3.1 Separation

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, 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.

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.

6.2.3.2 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

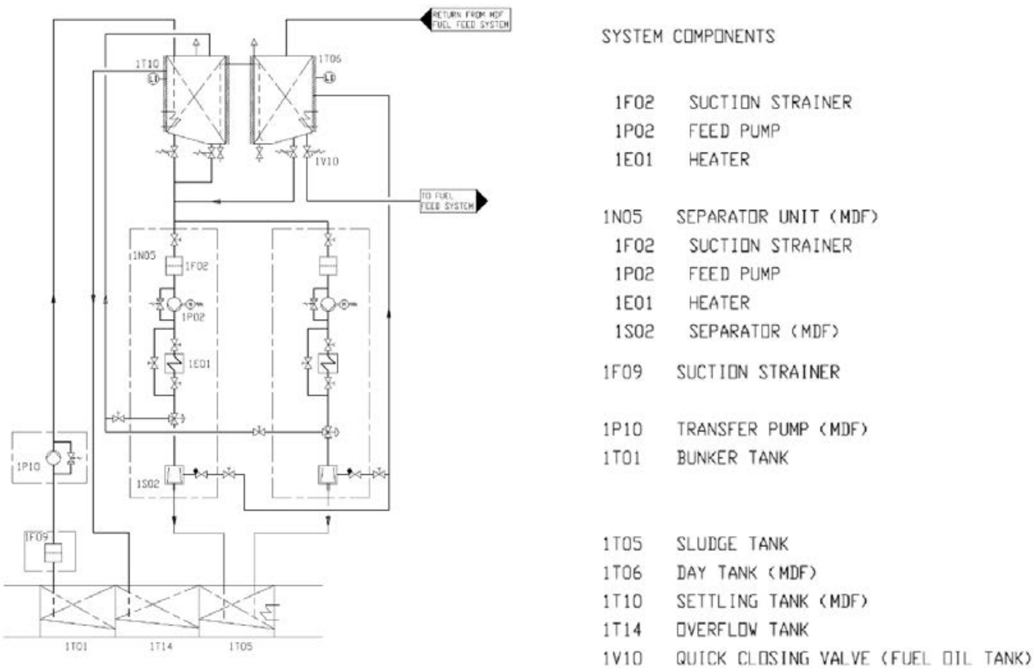


Fig 6-3 Fuel transfer and separating system (W14)

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

6.2.3.4 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 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]

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).

6.2.3.5 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.

6.2.3.6 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.

6.2.3.7 Water coalescing filter, MDF (1F12)

The fuel oil filter is a full flow duplex type filter with coalescing filter element and water sensor. This filter must be installed as near the engine as possible.

The diameter of the pipe between the 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	According to engine technical data which can be found by accessing *Engine Online Configurator* available through Wärtsilä's website
Fineness	7 µm (absolute mesh size) ($ß_7$ = 100)
Water separation efficiency	η> 98%
Pressure drop over filter	Minimum pressure at engine inlet to be ensured during filter lifetime

6.2.3.8 MDF cooler (1E04)

The fuel viscosity may not drop below the minimum value stated in technical data which can be found by accessing *Engine Online Configurator* available through Wärtsilä's 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.

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	1.4 kW/engine

6.2.4 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 cleanliness should be minimum 7 µm absolute mesh size ($ß_7$ = 100), (Fineness of flushing filter to be equal or finer than the water colescer filter (1F12)).

7. Lubricating Oil system

7.1 Lubricating Oil Requirements

Engine lubricating oil

The lubricating oil must be of viscosity class SAE 30 or 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	Fuel S content, [% m/m]
A	ASTM D 975-01	GRADE NO. 1-D, 2-D, 4-D		
	ISO 8217:2017(E)	ISO-F-DMX -> DMB, DFA -> DFB	10-13	< 0.50
	EN590			

When the solution includes a particulate filter aftertreatment unit (DPF) then low SAPS lubricating oil quality is required (lubricating oil ash content < 1.0%).

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.

7.2 External lubricating oil system

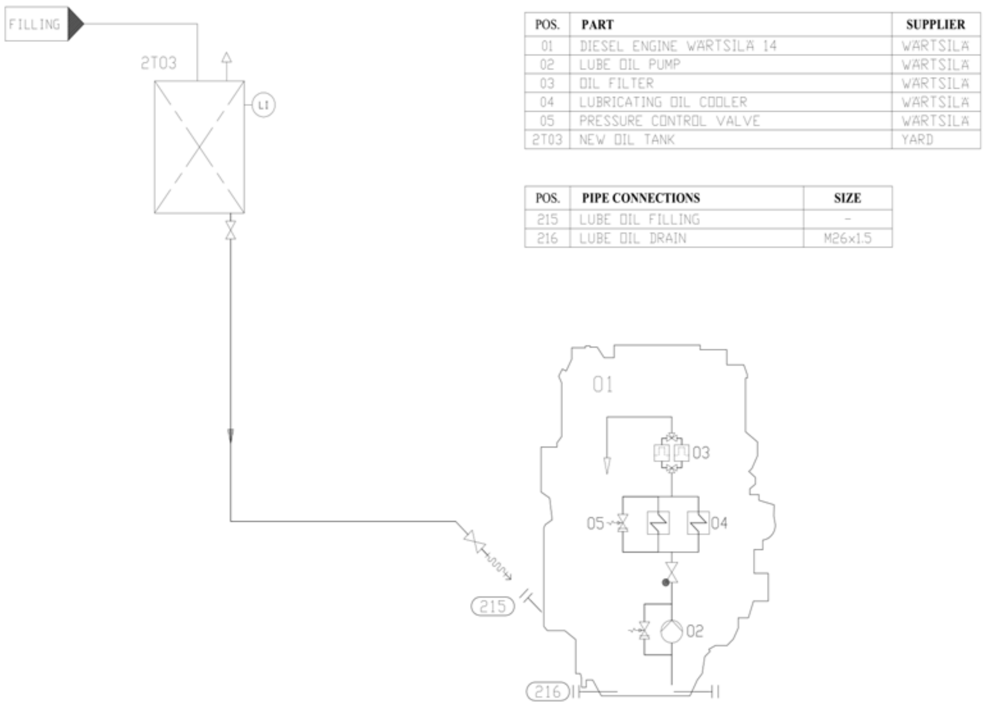


Fig 7-1 External Lub Oil System (DAAF478924B)

7.2.1 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 dedicated lubricating oil filling connection (215). The system should be arranged so that it is possible to measure the filled oil volume.

7.3 Crankcase ventilation system

Crankcase ventilation system is designed to control the balance of air pressure between the engine crankcase and the atmospheric pressure while processing the accompanying fumes.

The system is a closed blow-by system. Oil is separated from the blow by gases in the filter element and the gas returns to the inlet through the pressure regulating valve. The oil flows back to the oil sump via the return line, thus no additional emissions goes to in the atmosphere.

7.4 Flushing instructions

7.4.1 Piping and equipment built on the engine

Flushing of the piping and equipment built on the engine is not required. The engine oil system is flushed and clean from the factory.

8. Cooling Water System

8.1 Water Quality

The fresh water in the cooling water system of the engine must fulfil the following requirements:

pH .... min. 6.5...8.5

Hardness 0-3,5 mmol/dm3

Chlorides .... max. 80 mg/l

Sulphates .... max. 100 mg/l

8.1.1 Corrosion inhibitors

The use of a validated cooling water additive 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.

8.2 Engine driven circulating pumps

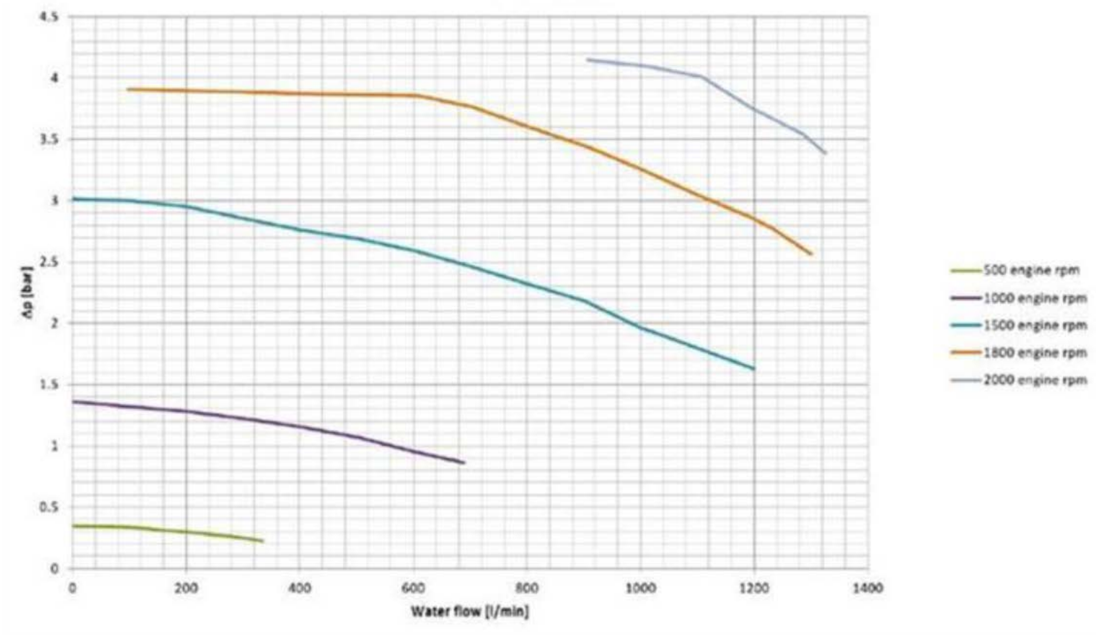


Fig 8-1 W12V14 Engine Driven HT-Water Pump Performance

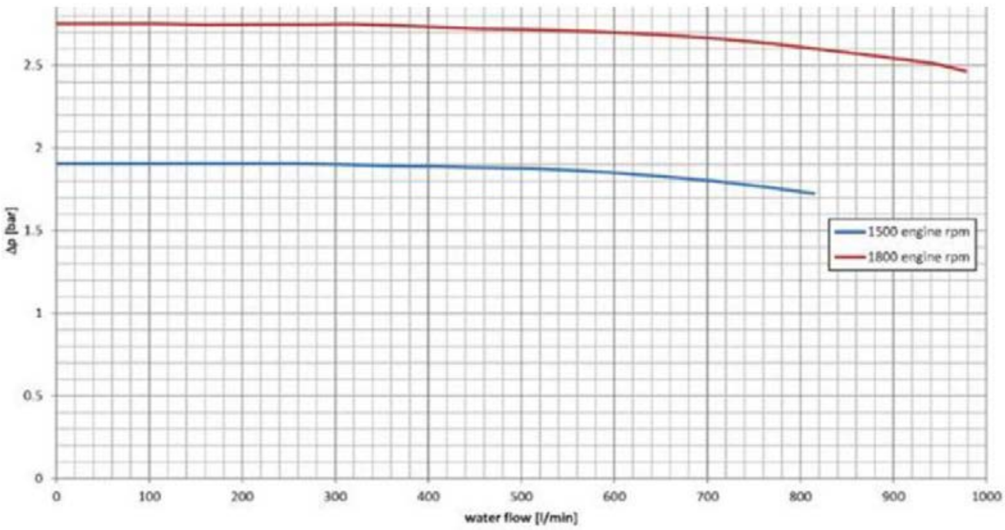


Fig 8-2 W16V14 Engine Driven HT-Water Pump Performance

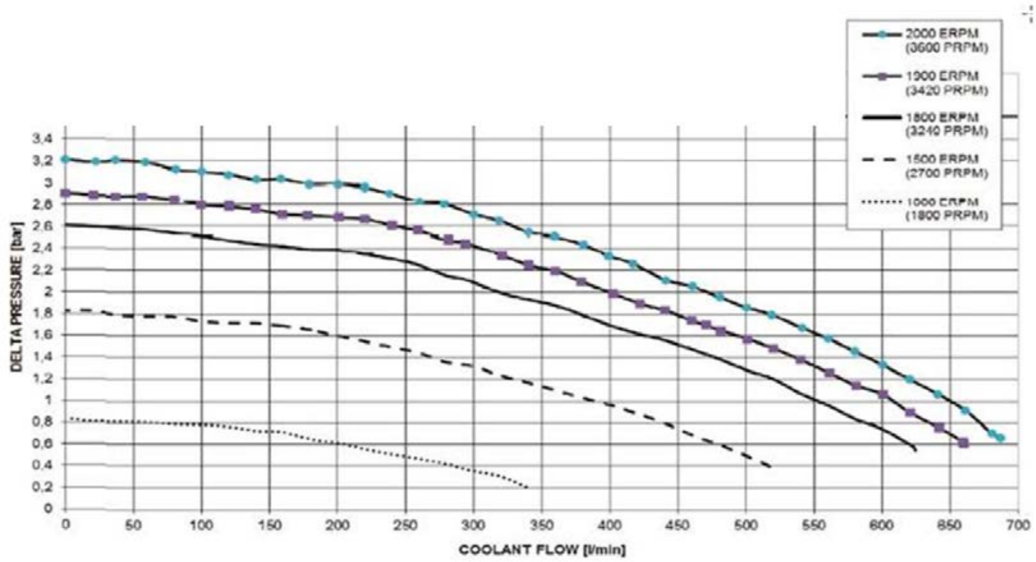
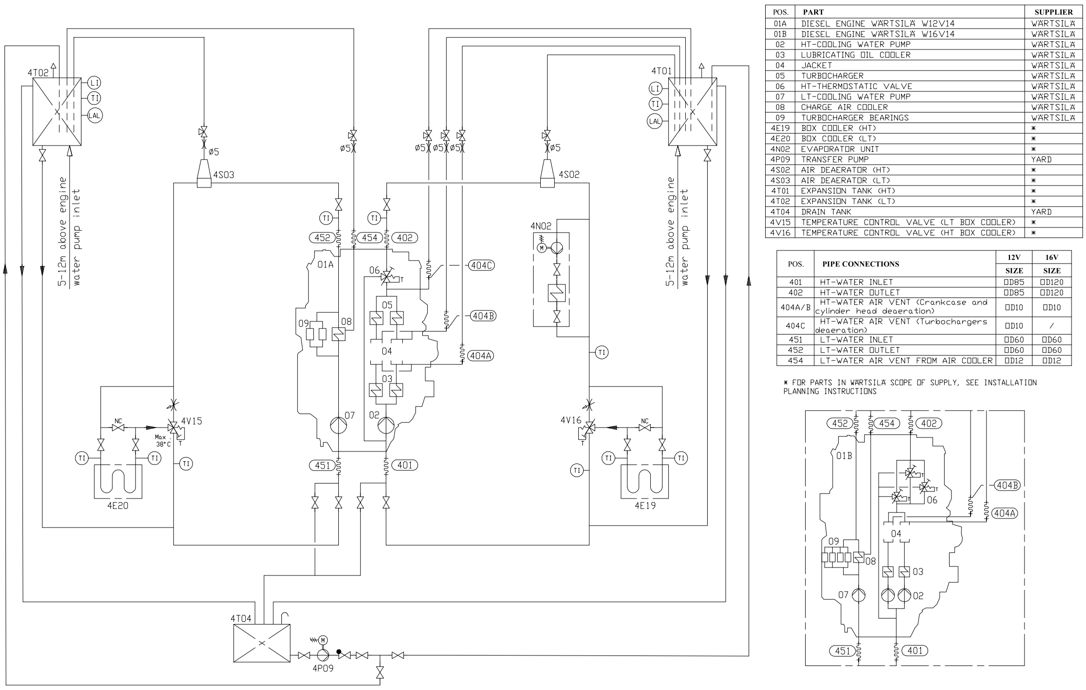


Fig 8-3 W12V14 & W16V14 Engine Driven LT-Water Pump Performance

8.3 External cooling water system

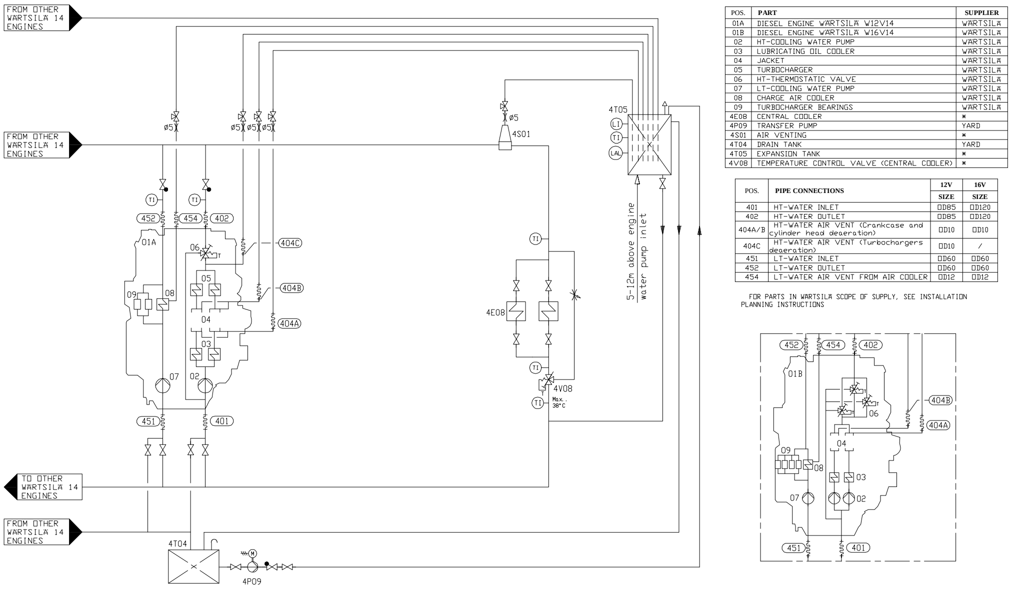


POS.	PART	SUPPLIER
01A	DIESEL ENGINE WÄRTSILÄ W12V14	WÄRTSILÄ
01B	DIESEL ENGINE WÄRTSILÄ W16V14	WÄRTSILÄ
02	HT-COOLING WATER PUMP	WÄRTSILÄ
03	LUBRICATING OIL COOLER	WÄRTSILÄ
04	JACKET	WÄRTSILÄ
05	TURBOCHARGER	WÄRTSILÄ
06	HT-THERMOSTATIC VALVE	WÄRTSILÄ
07	LT-COOLING WATER PUMP	WÄRTSILÄ
08	CHARGE AIR COOLER	WÄRTSILÄ
09	TURBOCHARGER BEARINGS	WÄRTSILÄ
4E19	BOX COOLER (HT)	*
4E20	BOX COOLER (LT)	*
4N02	EVAPORATOR UNIT	*
4P09	TRANSFER PUMP	YARD
4S02	AIR DEAERATOR (HT)	*
4S03	AIR DEAERATOR (LT)	*
4T01	EXPANSION TANK (HT)	*
4T02	EXPANSION TANK (LT)	*
4T04	DRAIN TANK	YARD
4V15	TEMPERATURE CONTROL VALVE (LT BOX COOLER)	*
4V16	TEMPERATURE CONTROL VALVE (HT BOX COOLER)	*

POS.	PIPE CONNECTIONS	12V	16V
		SIZE	SIZE
401	HT-WATER INLET	OD85	OD120
402	HT-WATER OUTLET	OD85	OD120
404A/B	HT-WATER AIR VENT (Crankcase and cylinder head deaeration)	OD10	OD10
404C	HT-WATER AIR VENT (Turbochargers deaeration)	OD10	/
451	LT-WATER INLET	OD60	OD60
452	LT-WATER OUTLET	OD60	OD60
454	LT-WATER AIR VENT FROM AIR COOLER	OD12	OD12

* FOR PARTS IN WÄRTSILÄ SCOPE OF SUPPLY, SEE INSTALLATION PLANNING INSTRUCTIONS

Fig 8-4 External Cooling Water Circuits (W12V14, Separated LT & HT DAAF478927C)

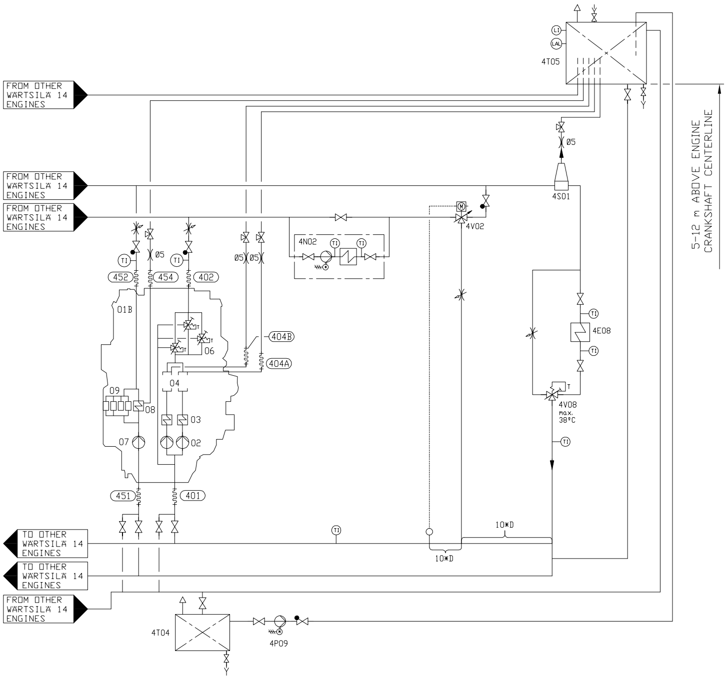


POS.	PART	SUPPLIER
01A	DIESEL ENGINE WÄRTSILÄ W12V14	WÄRTSILÄ
01B	DIESEL ENGINE WÄRTSILÄ W16V14	WÄRTSILÄ
02	HT-COOLING WATER PUMP	WÄRTSILÄ
03	LUBRICATING OIL COOLER	WÄRTSILÄ
04	JACKET	WÄRTSILÄ
05	TURBOCHARGER	WÄRTSILÄ
06	HT-THERMOSTATIC VALVE	WÄRTSILÄ
07	LT-COOLING WATER PUMP	WÄRTSILÄ
08	CHARGE AIR COOLER	WÄRTSILÄ
09	TURBOCHARGER BEARINGS	WÄRTSILÄ
4E08	CENTRAL COOLER	*
4P09	TRANSFER PUMP	YARD
4S01	AIR VENTING	*
4T04	DRAIN TANK	YARD
4T05	EXPANSION TANK	*
4V08	TEMPERATURE CONTROL VALVE (CENTRAL COOLER)	*

POS.	PIPE CONNECTIONS	12V	16V
		SIZE	SIZE
401	HT-WATER INLET	OD85	OD120
402	HT-WATER OUTLET	OD85	OD120
404A/B	HT-WATER AIR VENT (Crankcase and cylinder head deaeration)	OD10	OD10
404C	HT-WATER AIR VENT (Turbochargers deaeration)	OD10	/
451	LT-WATER INLET	OD60	OD60
452	LT-WATER OUTLET	OD60	OD60
454	LT-WATER AIR VENT FROM AIR COOLER	OD12	OD12

FOR PARTS IN WÄRTSILÄ SCOPE OF SUPPLY, SEE INSTALLATION PLANNING INSTRUCTIONS

Fig 8-5 External Cooling Water Circuits (W12V14, Combined LT & HT DAAF478926C)



POS.	PART	SUPPLIER
01A	DIESEL ENGINE WÄRTSILÄ W12V14	WÄRTSILÄ
01B	DIESEL ENGINE WÄRTSILÄ W16V14	WÄRTSILÄ
02	HT-COOLING WATER PUMP	WÄRTSILÄ
03	LUBRICATING OIL COOLER	WÄRTSILÄ
04	JACKET	WÄRTSILÄ
05	TURBOCHARGER	WÄRTSILÄ
06	HT-THERMOSTATIC VALVE	WÄRTSILÄ
07	LT-COOLING WATER PUMP	WÄRTSILÄ
08	CHARGE AIR COOLER	WÄRTSILÄ
09	TURBOCHARGER BEARINGS	WÄRTSILÄ
4E08	CENTRAL COOLER	*
4N02	EVAPORATOR UNIT	*
4P09	TRANSFER PUMP	YARD
4S01	AIR VENTING	*
4T04	DRAIN TANK	YARD
4T05	EXPANSION TANK	*
4V02	TEMPERATURE CONTROL VALVE (HEAT RECOVERY)	*
4V08	TEMPERATURE CONTROL VALVE (CENTRAL COOLER)	*

POS.	PIPE CONNECTIONS	12V	16V
		SIZE	SIZE
401	HT-WATER INLET	OD85	OD120
402	HT-WATER OUTLET	OD85	OD120
404A/B	HT-WATER AIR VENT (Crankcase and cylinder head deaeration)	OD10	OD10
404C	HT-WATER AIR VENT (Turbochargers deaeration)	OD10	/
451	LT-WATER INLET	OD60	OD60
452	LT-WATER OUTLET	OD60	OD60
454	LT-WATER AIR VENT FROM AIR COOLER	OD12	OD12

* FOR PARTS IN WÄRTSILÄ SCOPE OF SUPPLY, SEE INSTALLATION PLANNING INSTRUCTIONS

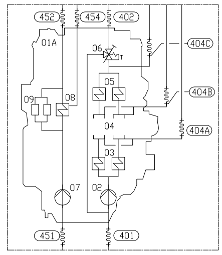


Fig 8-6 External Cooling Water System (W16V14, with Heat Recovery DAAF511552B)

The external system shall be designed so that flows, pressures and temperatures are close to the nominal values in technical data which can be found by accessing *Engine Online Configurator* available through Wärtsilä's website, and the cooling water 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.

8.3.1 Sea water pump

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.

8.3.2 Temperature control valve for LT - circuit (4V08, 4V15)

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 4V08/4V15 is 38 ºC in the type of system described above.

8.3.3 Temperature control valve for HT- circuit (4V02, 4V16)

The HT temperature control valve is installed in the high temperature external system in case the HT-circuit has a dedicated cooler, either a plate heat exchanger or a box cooler connected to the sea water.

The waste heat in the HT cooling water can be also 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.

The set-point is usually up to 80 ºC.

8.3.4 Fresh water central cooler (4E08)

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

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

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

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

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

where:

q = total fresh water flow [m³/h]

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

Φ = heat dissipated to HT water [kW]

T_{out} = HT water temperature after engine (92 °C)

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

Design data:

Fresh water flow	please refer to Engine Online Configurator available through Wärtsilä website
Heat to be dissipated	please refer to Engine Online Configurator available through Wärtsilä website
Pressure drop on fresh water side	max. 40 kPa (0.4 bar)
Sea-water flow	acc. to cooler manufacturer, normally 1.2 - 1.5 x the fresh water flow
Pressure drop on sea-water side, norm.	acc. to pump head, normally 80 - 140 kPa (0.8 - 1.4 bar)
Fresh water temperature after LT cooler	max. 38 °C
Fresh water temperature after HT cooler	max. 82 °C
Margin (heat rate, fouling)	15%

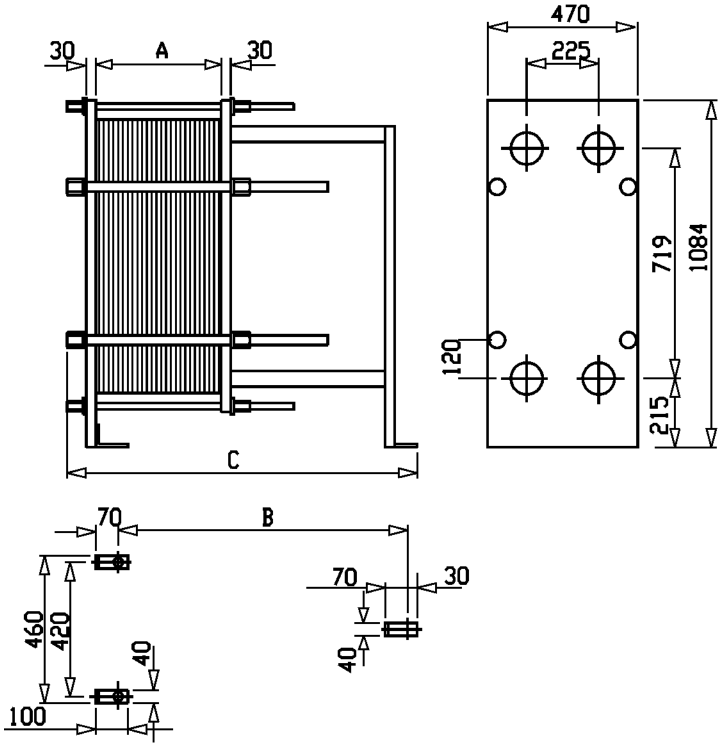


Fig 8-7 Central cooler, main dimensions (V47E0188b)

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.

8.3.5 Evaporator unit (4N02)

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.

8.3.6 Air deaerator (4S02 (HT), 4S03 (LT))

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.

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.

8.3.7 Expansion tank (4T05 (LT & HT), 4T02 (LT), 4T01 (HT))

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	50 - 120 kPa (0.5...1.2 bar)
Volume	min. 10% of the total system volume.

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 8-1 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

8.3.8 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.

8.3.9 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.

8.3.10 Thermometers and pressure gauges

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

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

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9. Combustion Air System

9.1 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. During normal operating conditions the air temperature at the turbocharger inlet should be kept between 5ºC and 45ºC. For the minimum requirements concerning the engine room ventilation and more details, see applicable standards.

The amount of air required for ventilation is calculated from the total heat emission Φto 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
- Other auxiliary equipment

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:

qv = 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.

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

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

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

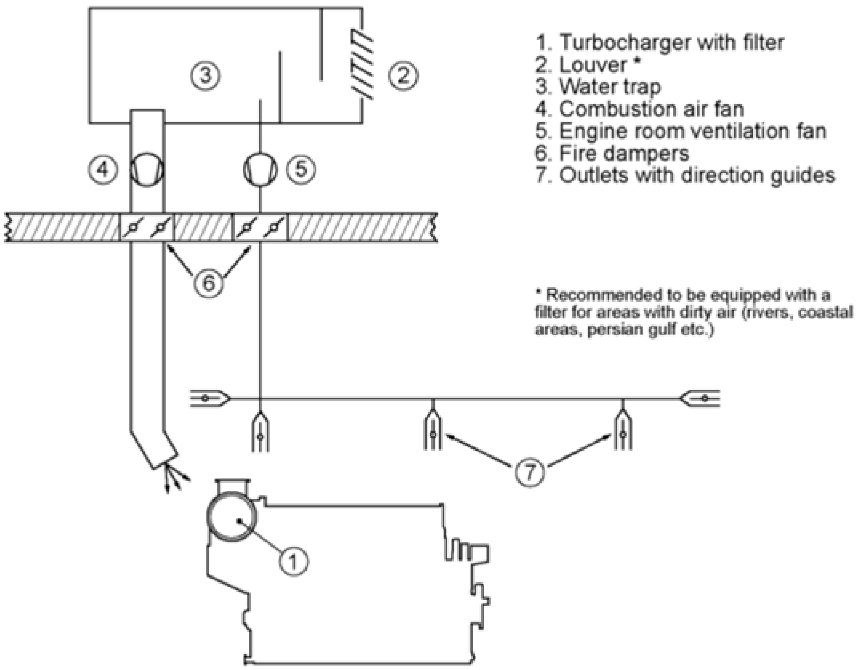

Fig 9-1 Engine room ventilation, turbocharger with air filter (DAAE092651)

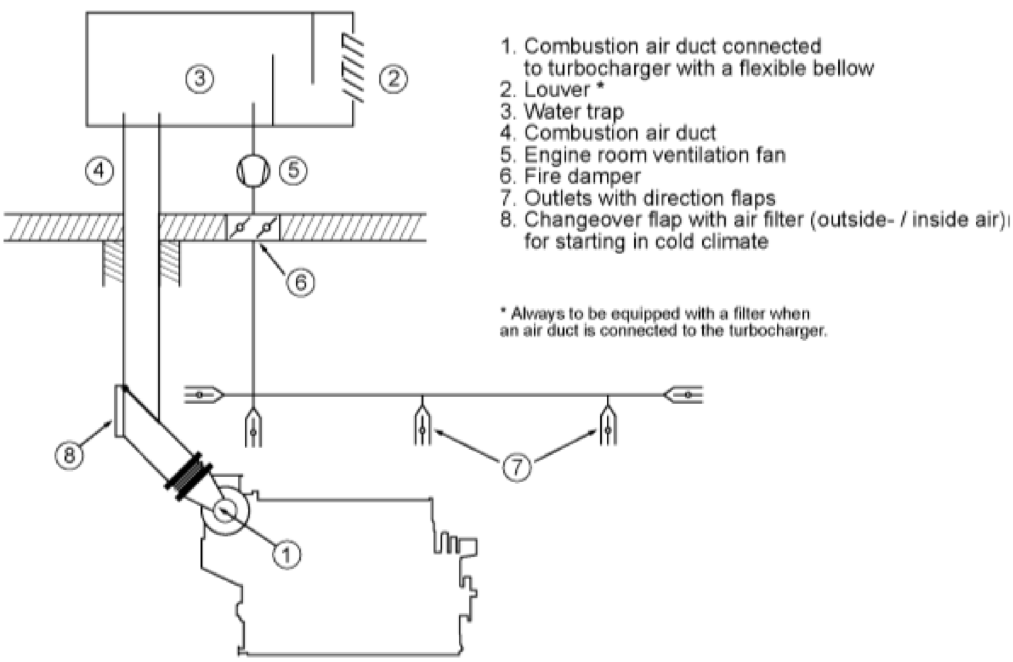

Fig 9-2 Engine room ventilation, air duct connected to the turbocharger

9.2 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.

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 technical data, which can be found by accessing *Engine Online Configurator* available through Wärtsilä's 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:

qc = 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.

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.

9.2.1 Condensation in charge air coolers

Air humidity may condense in the charge air cooler, especially in tropical conditions. The engine equipped with a small drain pipe from the charge air cooler for condensed water.

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.

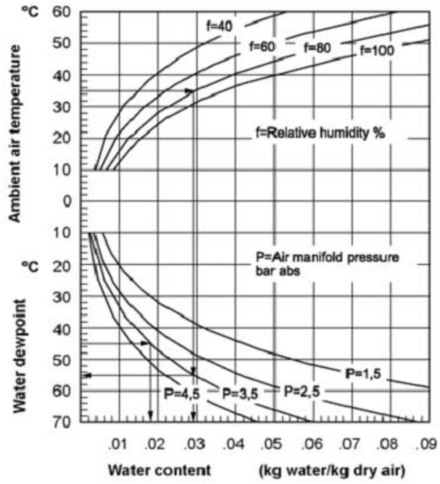

Fig 9-3 Condensation in charge air coolers

10. Exhaust Gas System

10.1 Temperature sensor location after Turbocharger

For measuring the exhaust gases after the turbocharger, the engine is delivered with temperature sensor TE537.

The sensor shall be installed after the exhaust gas branch pipe. The sensor is delivered with engine. Measuring results from this sensor is used to alarm / trigger load reduction, if exhaust gasses are abnormal high.

10.2 Exhaust gas outlet

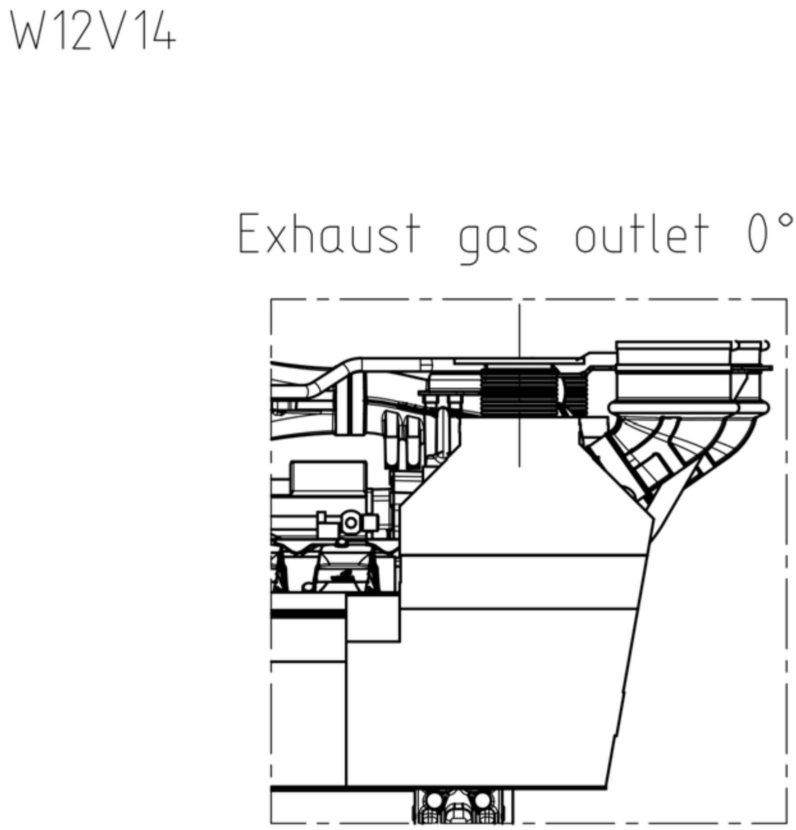

Fig 10-1 Exhaust pipe connections, W12V14 (DAAF508138A)

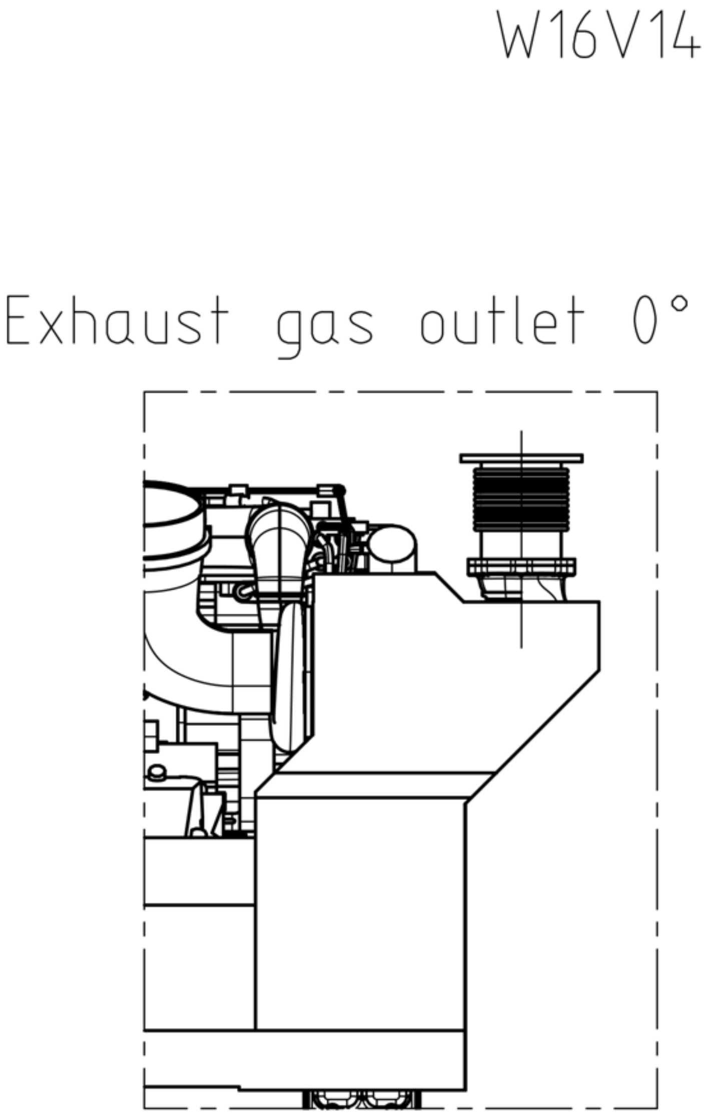

Fig 10-2 Exhaust pipe connections, W16V14 (DAAF508138A)

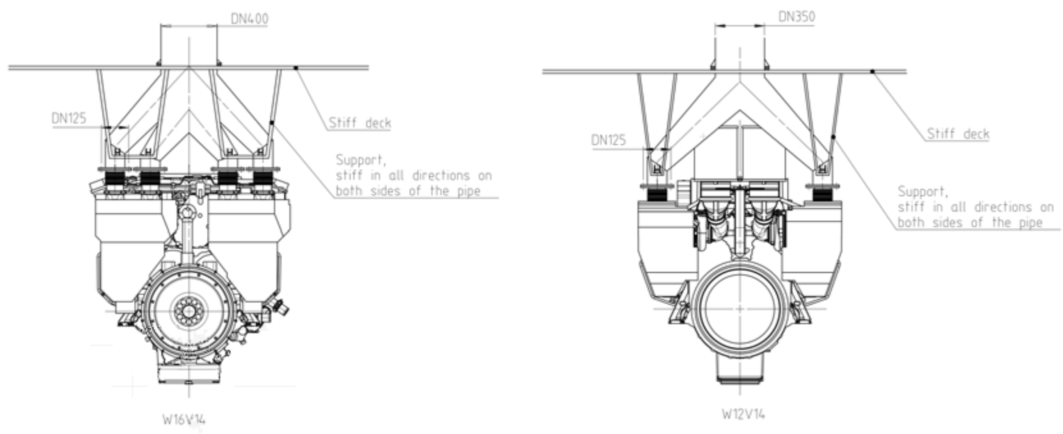

Fig 10-3 Exhaust pipe, diameters and support (DAAF508138A)

10.3 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.

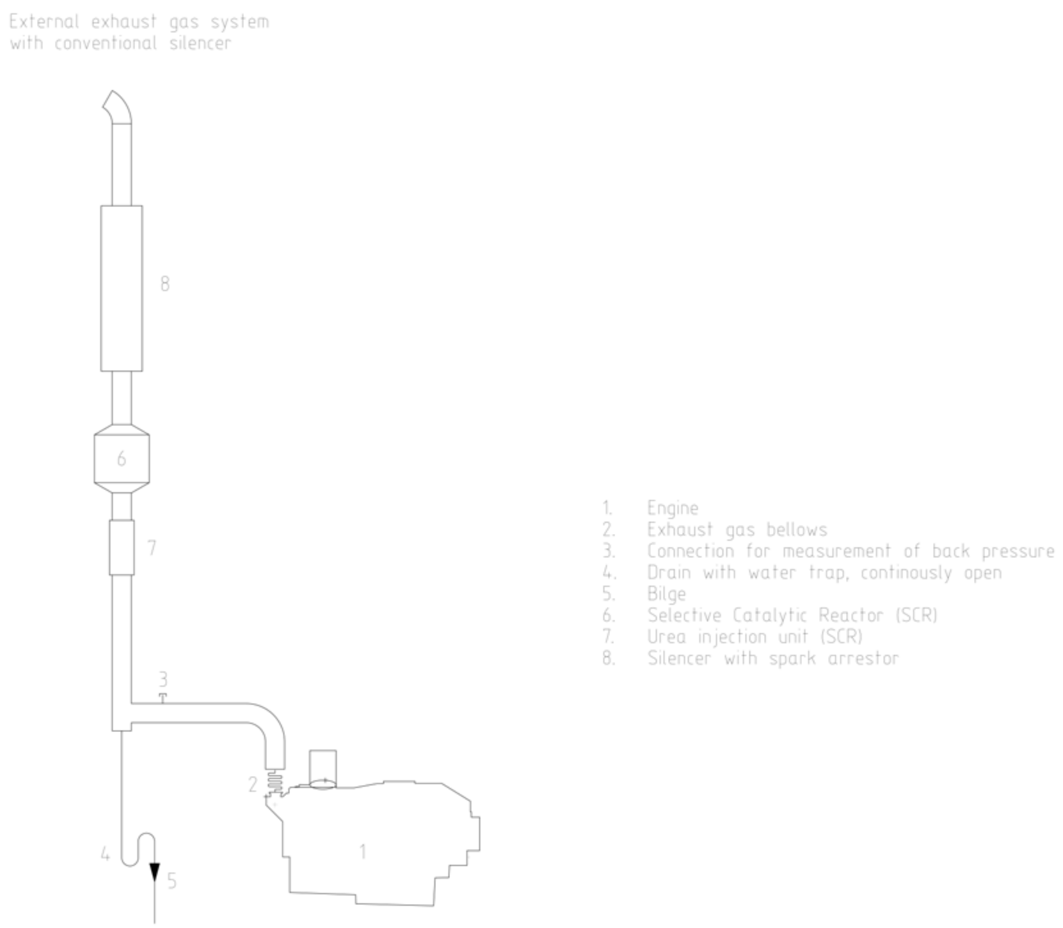

Fig 10-4 External exhaust gas system with conventional silencer (DAAF526752)

10.3.1 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 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.

10.3.2 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. 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.

10.3.3 Back pressure

The maximum permissible exhaust gas back pressure, exhaust gas mass flow and temperature are stated in *Engine Online Configurator*, which is 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.

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.

10.3.4 Exhaust gas bellows (5H01)

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.

10.3.5 SCR-unit (11N14)

SCR unit is needed in case engine must comply with IMO TIER III or EU Stage V emission regulations. In case engine is equipped with both, SCR and DPF, DPF is typically located upstream compared to SCR. 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.

For more information regarding the exhaust aftertreatment system, please contact Wärtsilä.

10.3.6 Diesel Particulate Filter (DPF)

Diesel particulate filter can be added after engine, to achieve particle emission level down to EU Stage V level. In case of EU Stage V certification, both DPF and SCR units are needed. DPF is typically located upstream compared to SCR.

10.3.7 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.

10.3.8 Exhaust gas silencers

If the exhaust system is installed with a SCR and DPF, exhaust gas silencer could be left out depending on the acoustic properties of the SCR and DPF.

10.3.8.1 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 35 dB(A). This attenuation is valid up to a flow velocity of max. 40 m/s.

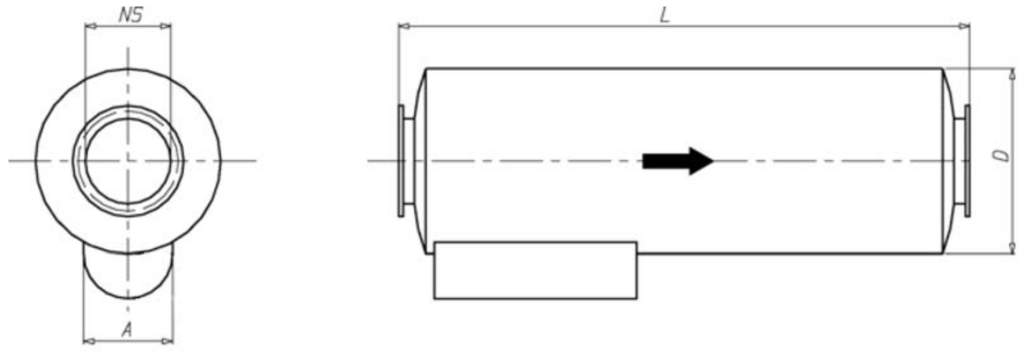

Fig 10-5 Exhaust gas silencer

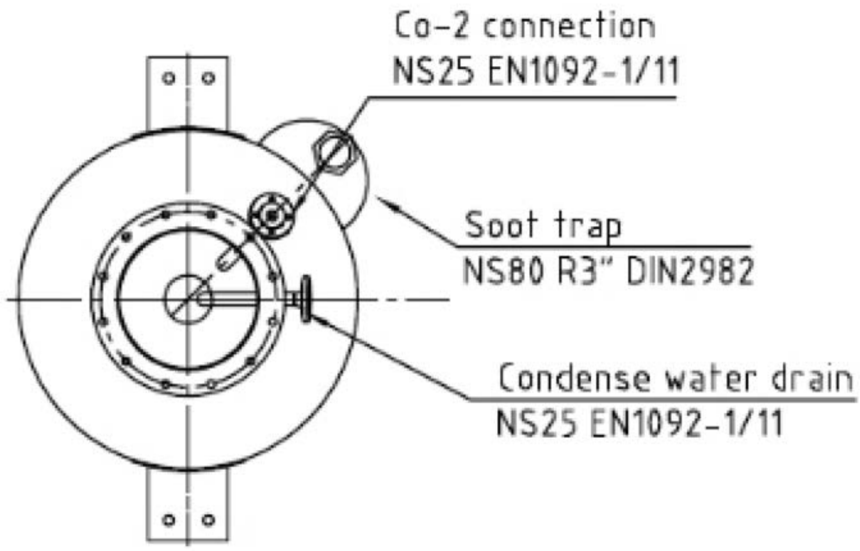

Fig 10-6 Silencer with feet

Table 10-1 Typical dimensions of exhaust gas silencers

Engine config.	NS	D	A	Attenuation: 35 dB(A) L	Weight [kg]	Feet
12V	350	860	305	3780	720	without
16V	400	1060	420	4280	995	without
12V	350	860	305	3780	750	with
16V	400	1060	420	4280	1035	with

10.3.8.2 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).

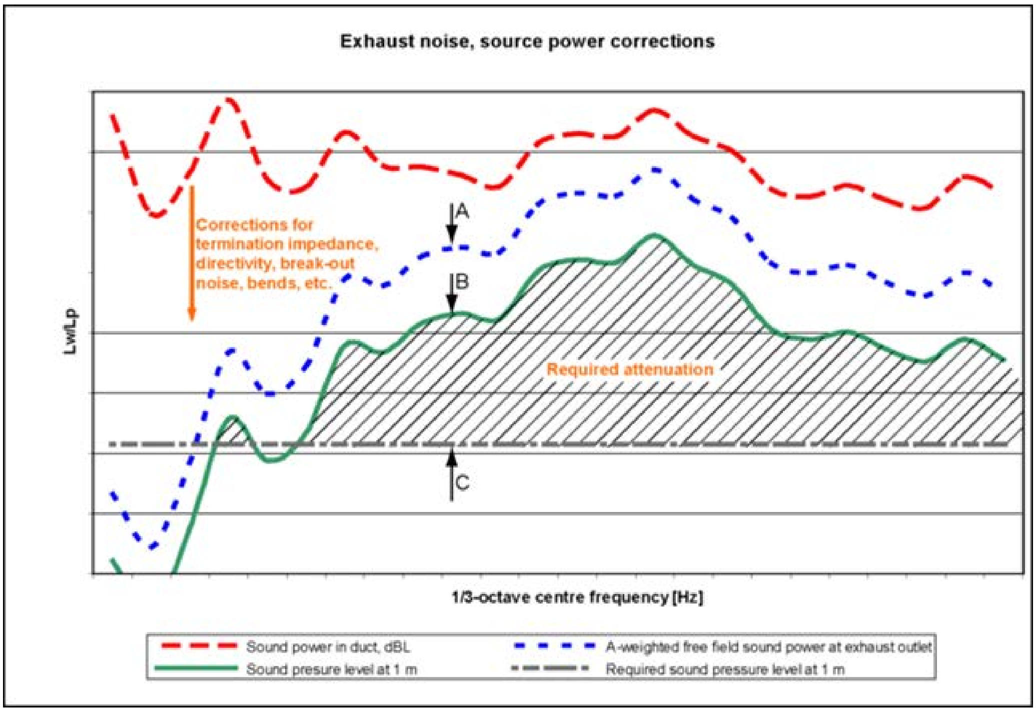

Fig 10-7 Exhaust noise, source power corrections

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

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11. Exhaust Emissions

Exhaust emissions from the diesel engine mainly consist of nitrogen, oxygen and combustion products like carbon dioxide (CO2), water vapour and minor quantities of carbon monoxide (CO), sulphur oxides (SOx), nitrogen oxides (NOx), 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.

11.1 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.

11.1.1 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.

11.1.2 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).

11.1.3 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.

11.1.4 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.

12. Electrical and Automation System

12.1 Starting System

All engines are equipped with an electric starting motor. The starting motor drives a gear rim at the flywheel. Electric starting motor is powered by batteries.

Table 12-1 Starting motor

Engine	Starter
W12V14	24 VDC, 7.8 kW
W16V14	24 VDC, 2 x 8.4 kW

12.2 Generator

The W14 generating set is standardized with the generator. There are many generator variants available with different voltage and power ranges, please refer to the list below. The generator is always equipped with double bearing and requires bellhousing between the engine and generator.

- Air cooled IP23
- Water cooled IP44
- Double bearing
- Voltage range 50Hz 400 VAC
- Voltage range 60Hz 440, 450, 690 VAC
- Power range 50 Hz 841 – 1265 kVA
- Power range 60 Hz 839 – 1453 kVA

12.3 Engines with SCR and DPF

The SCR automation power supply shall be arranged from an external system (ship system).

The minimum length from engine to first after- treatment device is one pipe diameter from the point where pipes from individual turbochargers are combined. The max. allowable length is 15 meters, insulated piping (length of piping between engine to DPF plus the length of piping between DPF to SCR)

The needed power for SCR automation is: 230 VAC, 0.2 kW.

The DPF automation power supply shall be arranged from an external system (ship system).

The DPF is first in line (before SCR). The minimum length from engine is one pipe diameter from the point where pipes from individual turbochargers are combined. The max. allowable length is not relevant for DPF.

The needed power for DPF is as follows:

- Air blower 3 kW, 400 VAC
- Fuel pump 140 W, 24 VDC
- Controller 660 W, 400 VAC

12.4 Automation System

The engine automation system is an embedded engine management system. The system has a modular design, and some parts and functions in the configuration are optional depending on application. The system 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 which provides a compact design. The number of inputs and outputs are determined to optimally suit this system arrangement, and the galvanic signal isolation is also made to match these needs. The automation system handles all tasks related to start/stop management, engine safety, fuel management and speed/load control, as well as charge air, cooling, and combustion. The system utilizes modern bus technologies for safe transmission of sensor- and other signals. The automation system can be accessed with a software- based maintenance tools, which is used for tuning parameters, troubleshooting and for software installation.

Control signals to/from external systems are hardwired to the modules in the UNIC cabinet. Process data for alarm and monitoring are communicated to external systems over a Modbus TCP.

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

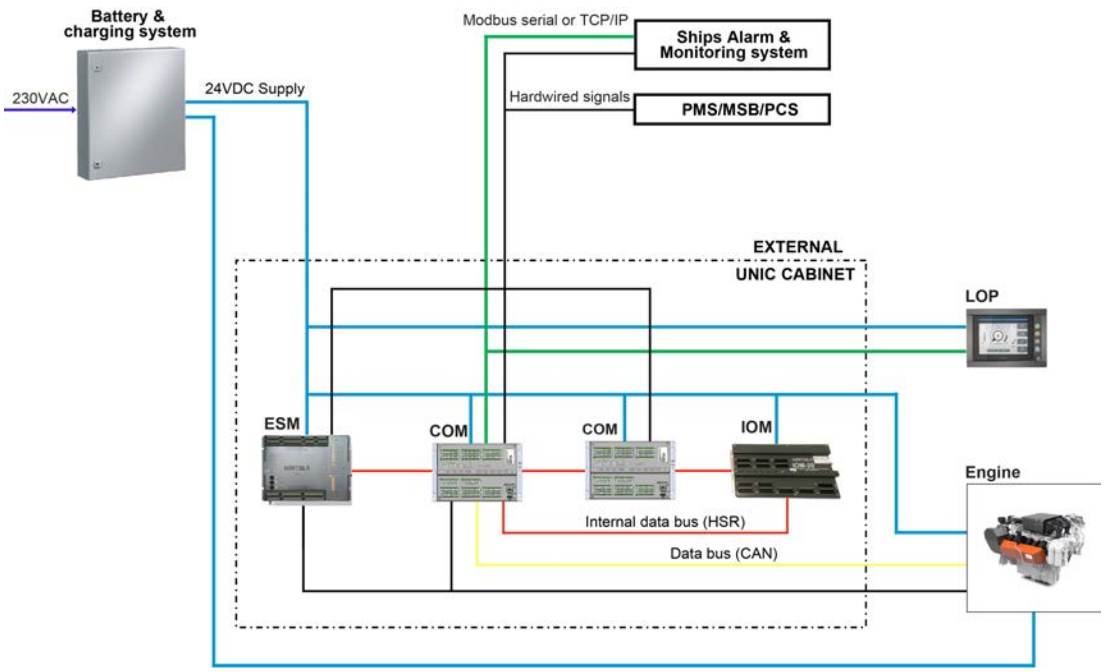


Fig 12-1 Architecture of Engine Automation System

Short explanation of the modules used in the system:

Engine Safety module, ESM: The engine safety module handles the most fundamental engine safety functions related to engine over-speed protection, low lube oil pressure and other safety functions required by classification societies. The ESM is able to shutdown the engine without relaying on any other system functions.

Local Operator Panel, LOP: The unit contains push buttons for local engine control, and a graphical display for local reading of the most important engine parameters. Main use of the buttons are engine start, stop, shutdown reset and local/remote control selection with protection degree of IP66.

Input/Output module, IOM: When placed inside the main cabinet the IOM module extends the number of input/output channels in UNIC for the on-engine measurements.

Comunication Module, COM: The Communication Module is designed to primarily act as the interface of UNIC. 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.

The above equipment (ESM, IOM, COM) and instrumentation are prewired on the engine and installed inside UNIC cabinet.The UNIC cabinet ingress protection class is IP54 and the ingress protection class of the engine ECU is IPP66.

12.4.1 Local operator panel

The local operator panel (LOP) act as interface for engine control and monitoring.

LOP is provided with a status LED bar for monitoring the engine status. A more detailed engine information can be checked from the LOP touch-screen. Mechanical push buttons are used locally for starting, stopping or taking local control of the engine. The LED on the left side of the engine status LED bar indicates the LOP status. The USB port is used for uploading LOP screenshots or uploading log file about system events (e.g. engine alarms, shutdowns, stops).

The LOP has a touchscreen for activation of various pages. Information shown on the LOP pages includes:

• General system layout

• Engine status information (for example, engine running mode)

• Sensor names

• Process values and signal values (abnormal values highlighted)

12.4.2 Engine safety system

The engine safety module handles fundamental safety functions, for example overspeed protection. It is also the interface to the shutdown devices on the engine for all other parts of the control system.

Main features:

- Redundant design for power supply, speed inputs and stop solenoid control
- Fault detection on sensors, solenoids and wires
- Led indication of status and detected faults
- Digital status outputs
- Shutdown latching and reset
- Shutdown pre-warning
- Shutdown override (configuration depending on application)
- Analogue output for engine speed
- Adjustable speed switches

12.4.3 Battery and charging system

Battery & charging system gives the power supply for the engine starter and engine automation. The battery and charging system can be Wärtsilä scope of supply, or in yard scope of supply. The system shall be capable to start the engine 6 times (non-reversible engine) within 30 minutes without recharging).

If the battery and charging system is in yard scope of supply the consumers are:

- 1 starter on 12V (7,8 kW)

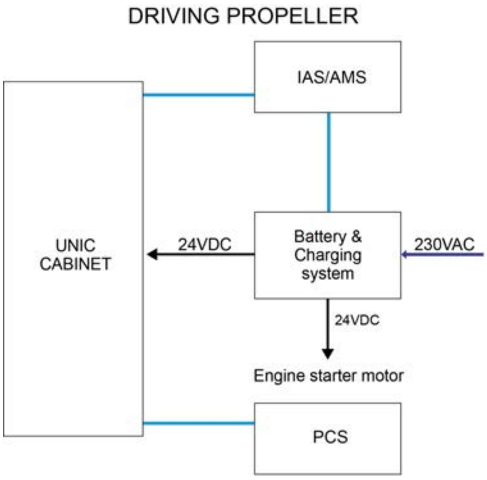
- 2 starters on 16V (2x8,4 kW)

- Engine automation system 0,3 kW

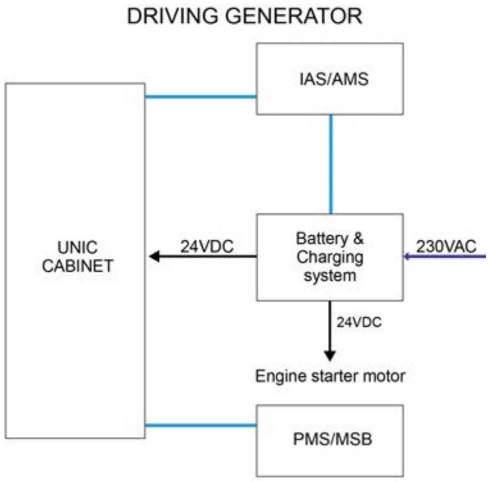
12.4.4 Communication from engine to external system

An Ethernet communication unit is delivered in case Modbus TCP is selected as communication protocol. The Ethernet communication unit contains a firewall which is used to prevent unauthorized access and ensure the cyber security of the engine control system.

12.4.5 Cabling and system overview



From	To	Cable types (typical)
Power supply	Battery & charging system	3 x 1.5mm²
Battery & charging system	Engine / starter motor	2 x 95mm² 2 x 95mm² (If 16V engine)
Battery & charging system	UNIC cabinet	2 x 4.0mm²
Battery & charging system	IAS/AMS	2 x 0.75mm²
UNIC cabinet	IAS/AMS	6 x 0.75mm² 1 x 2 x 0.5mm² (Modbus RS485)
UNIC cabinet	PCS	16 x 0.75mm² 16 x 0.75mm² 1 x 2 x 0.75mm² 2 x 2 x 0.75mm²



From	To	Cable types (typical)
Power supply	Battery & charging system	3 x 1.5mm²
Battery & charging system	Engine / starter motor	2 x 95mm² 2 x 95mm² (If 16V engine)
Battery & charging system	UNIC cabinet	2 x 4.0mm²
Battery & charging system	IAS/AMS	2 x 0.75mm²
UNIC cabinet	IAS/AMS	6 x 0.75mm² 1 x 2 x 0.5mm² (Modbus RS485)
UNIC cabinet	PMS/MSB	16 x 0.75mm² 16 x 0.75mm² 1 x 2 x 0.75mm² 12 x 0.75mm² (If isoch. Mode is used) 2 x 0.75mm² (If isoch. Mode is used) 2 x 0.75mm² (If isoch. Mode is used)
UNIC cabinet	Next engine UNIC cabinet	CAN cable (If isoch. Mode is used)

Fig 12-2 Overview

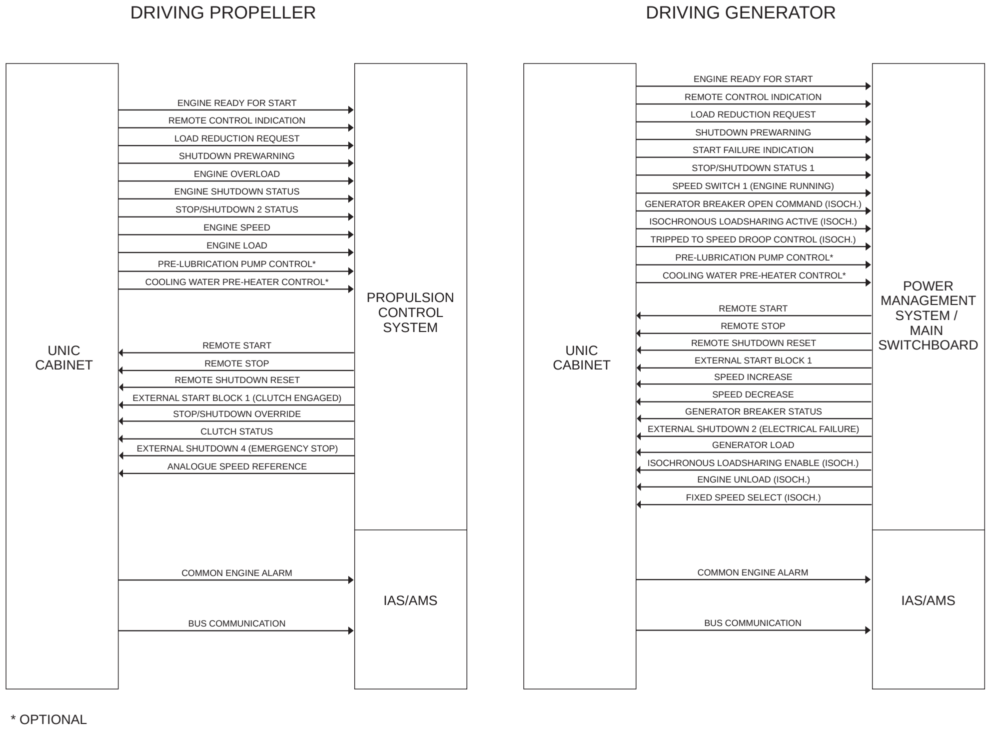


Fig 12-3 Signal overview

12.4.6 Function

12.4.6.1 Engine Mode Control

The engine automation system can initiate some required actions as blocking a start, initiating an alarm, or to shutting down the engine. Depending on whether the engine is in standstill, starting or running the required action can vary. That is why UNIC has a number of engine modes. Different modes have different priority, and the mode transitions can occur only according to the pre-defined rules.

Stop mode

Stop mode is entered from stand-by mode, shutdown mode or emergency stop mode. When the engine automation system is powered up, the default mode is always stop mode. The engine is always standstill in stop mode. If no start blocking is active, the mode automatically transfers to stand-by mode. In shutdown mode a manual reset must be performed before the engine enters stop mode.

Start mode

Start mode is entered from stand-by mode.

After the engine start is requested there are only two possible outcomes:

- Engine accelerates and successfully enters a run mode.
- Engine enters shut-down mode or emergency stop mode based on start failure conditions

The manual stop, shutdown or emergency stop request will also interrupt the ongoing start sequence.

In blackout situations it is possible to start the engine with a faster start sequence. The blackout start is activated with a dedicated blackout start input before requesting the start mode.

Run mode

Run mode is entered from start mode if no stop, shutdown or emergency stop requests are active. The transition from start mode to run mode happens when the engine rotational speed is above a pre-set run mode speed limit.

Engine remains in run mode until the manual stop, shutdown or emergency stop request become active.

Shutdown mode

Shutdown mode can be entered from stop mode, stand-by mode, start mode or run mode.

In shutdown mode engine is in standstill or under deceleration. Engine enters this mode when engine external shutdown input is active or UNIC detected abnormal engine condition. This mode is also temporarily entered from a manual stop request.

In shutdown mode UNIC sets fuel demand to zero that ensures that the main fuel injections are not performed. If the shutdown request came from an abnormal engine condition, the engine will remain in shutdown mode until the reset input is activated.

Emergency stop mode

Emergency stop mode has the highest priority and can be entered from any other mode.

In emergency stop engine is in standstill or under deceleration. Emergency stop mode is entered in case of activation of the local emergency stop button, but also from an emergency stop request from an abnormal engine condition detected by a measurement or an internal engine automation system failure condition.

In emergency stop mode, the engine will be automatically and instantly stopped by setting all fuel demand to zero. The engine will remain in emergency stop mode until the issue which caused the emergency stop is resolved, and reset input is activated.

12.4.6.2 Engine speed and position measurement

Speed sensors mounted close to the flywheel measure the engine speed, and a cam sensor mounted close to the camshaft that measures the engine phase. The precise crank position is calculated from the engine crank and cam signals.

The engine crank position is used for combustion control and measurement. The engine speed is additionally used for the internal speed controller, engine speed-dependent control maps and overspeed protection.

12.4.6.3 Speed reference control

The speed reference is calculated based on inputs and controls and used in the closedloop speed controller.

There are three speed control modes:

- CB open mode
- Speed droop mode
- Isochronous load sharing mode

Depending on the selected mode, speed dependent control parameters are used.

Loading sharing

Load sharing is done to divide the load between engines.

Load sharing is performed when two or more engines are operating in parallel. Each engine will contribute equally to the total power demand, and load changes are absorbed evenly by the engines in operation.

There are different ways to perform load sharing depending on the installation and selected speed load mode.

Speed/load modes

The automation system has three different speed load control modes: CB open control, speed droop control and load sharing and isochronous control.

CB open control

CB open control is active during engine start, and in run mode until the generator breaker or the clutch has been closed. Start fuel limiter is used in this mode. Binary/ analogue inputs are enabled for synchronisation purpose. The PID parameters are engine speed dependent.

Speed drop control and load sharing

Speed droop control and load sharing become active after the closure of the generator breaker or the clutch. Load sharing is based on a built-in droop curve, which means that the internal engine speed reference will decrease proportionally to the load increase. After a major load increase, the internal speed reference may need to be increased by the power management system (PMS) to ensure that the bus frequency is kept within a certain window regardless of the net load level. Control of the speed reference from a plant management system is necessary. The PID parameters are dependent on the engine speed and load.

Isochronous control and load sharing

Isochronous control and load sharing become active after closure of the generator breaker or the clutch when isochronous load sharing has been selected. In this control mode the load sharing is provided over load sharing CAN. The engine speed remains unaffected by a droop slope at all load levels without speed reference adjustments from a plant management system. The PID parameters are dependent on the engine speed and load.

12.4.6.4 Speed control

The engine speed controller controls the engine speed by managing the fuel injection quantity in order to reach a desired setpoint managed by UNIC speed reference control

Engine speed controller

Based on the current engine speed and on the current speed setpoint a PID controller is used to ensure that the current engine speed reaches the speed setpoint. The output magnitude of the controller is a fuel demand.

The speed request calculation functionality selects and calculates the correct speed request coming from the speed reference control.

The proportional, integral and derivative parameters of the PID controller can be adjusted with map parameters. The effective injection quantity and the actual engine speed define the working point of the maps.

12.4.7 Alarm and monitoring signals

Regarding sensors on the engine, please see the internal P&I diagrams in this product guide. The actual configuration of signals and the alarm levels are found in the project specific documentation supplied for all contracted projects.

13. Foundation

Engines can be either rigidly mounted on chocks, or resiliently mounted on rubber elements. If resilient mounting is considered, Wärtsilä must be informed about existing excitations such as propeller blade passing frequency.

13.1 Steel structure design

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.

13.2 Mounting of main engines

13.2.1 Rigid mounting

Main engines can be rigidly mounted to the foundation either on steel chocks or resin chocks.

Prior to installation the shipyard must send detailed plans and calculations of the chocking arrangement to the classification society and to Wärtsilä for approval.

The engine has four feet integrated to the engine block. There are two Ø21 mm holes for M20 holding down bolts and a threaded M16 hole for jacking a bracket in each foot. The Ø21 holes in the seating top plate for the holding down bolts can be drilled though the holes in the engine feet. In order to avoid bending stress in the bolts and to ensure proper fastening, the contact face underneath the seating top plate should be counterbored. Alternatively spherical washers can be used.

Holding down bolts are through-bolts with lock nuts. Selflocking nuts are acceptable, but hot dip galvanized bolts should not be used together with selflocking (nyloc) nuts. Two of the holding down bolts are fitted bolts and the rest are clearance (fixing) bolts. The fixing bolts are M20 8.8 bolts according DIN 931, or equivalent. The guiding length in the seating top plate should be at least equal to the bolt diameter.

The tensile stress in the bolts is allowed to be max. 80% of the material yield strength.

Lateral supports must be installed for all engines. One pair of supports should be located at the free end and one pair (at least) near the middle of the engine. The lateral supports are to be welded to the seating top plate before fitting the chocks. The wedges in the supports are to be installed without clearance, when the engine has reached normal operating temperature. The wedges are then to be secured in position with welds. An acceptable contact surface must be obtained on the wedges of the supports.

13.2.2 Resilient mounting

In order to reduce vibrations and structure borne noise, main engines can be resiliently mounted on rubber mounts. The transmission of forces emitted by a resiliently mounted engine is 10-20% compared to a rigidly mounted engine.

Conical rubber mounts are used in the normal mounting arrangement and additional buffers are thus not required. A different mounting arrangement can be required for wider speed ranges (e.g. FPP installations).

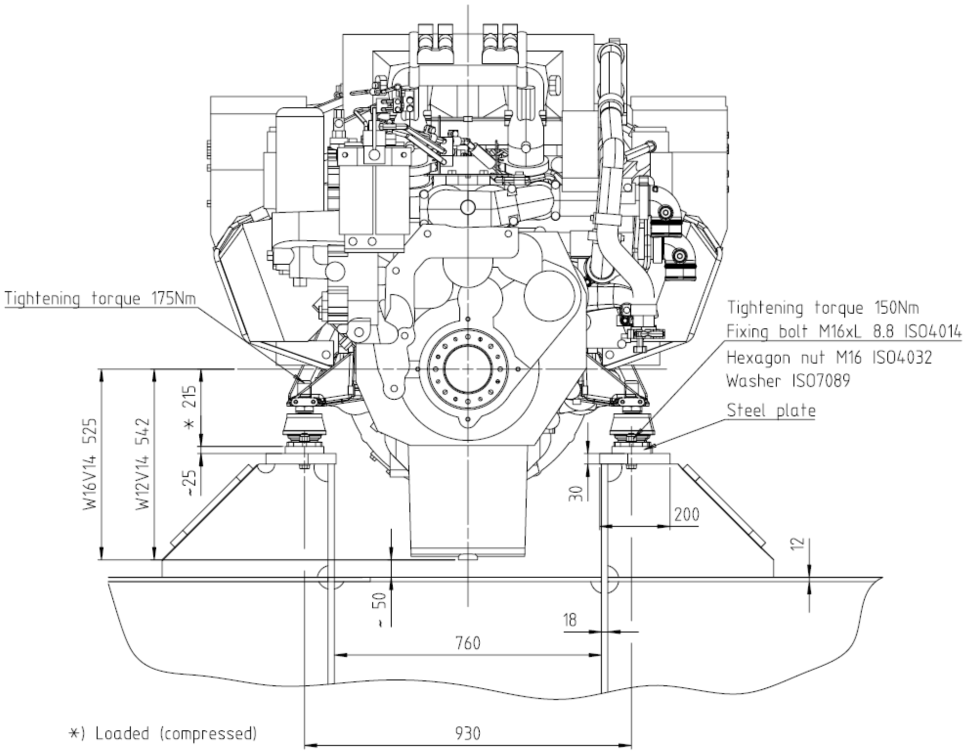


Fig 13-1 Resilient Mounting (DAAF490760A)

13.3 Mounting of generating sets

13.3.1 Installation

Engine and generator are mounted on the common base frame with flexible mounts. Generating set is rigidly mounted to the foundation.

13.3.2 Mounting

Generating set, comprising engine and generator resiliently mounted on a common base frame is to be installed rigidly on the foundation of the ship

The resilient mounts reduce the structure borne noise transmitted to the ship and also serve to protect the generating set bearings from possible fretting caused by hull vibration.

The number of mounts and their location is calculated to avoid resonance with excitations from the generating set engine, the main engine and the propeller.

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 [rpm] and number of cylinders ● propeller shaft speed [rpm] and number of propeller blades

The selected number of mounts and their final position is shown in the generating set drawing.

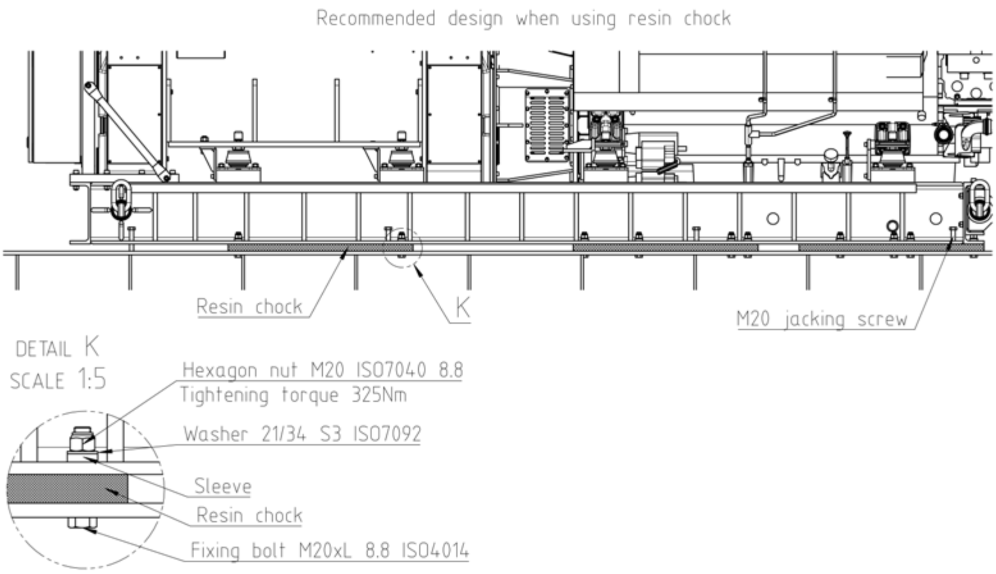


Fig 13-2 Recommended design of the generating set seating (DAAF495116B-1)

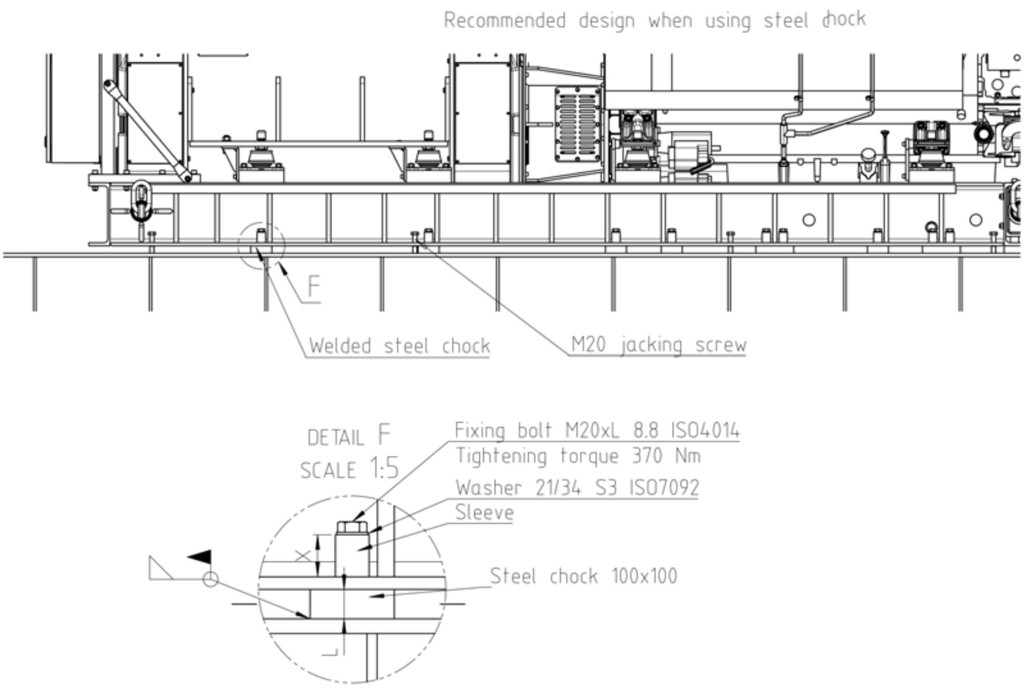


Fig 13-3 Recommended design of the generating set seating (DAAF495116B-2)

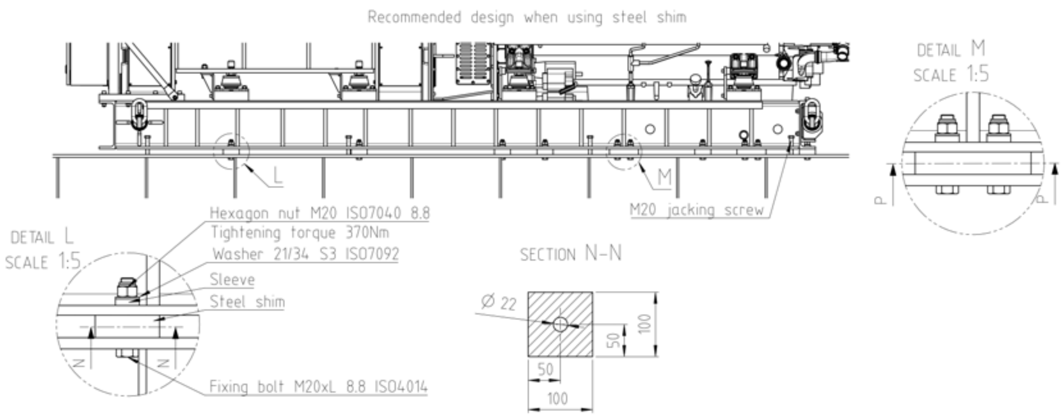


Fig 13-4 Recommended design of the generating set seating (DAAF495116B-3)

13.3.3 Rubber mounts

The engine and generator are mounted on conical resilient mounts, which are designed to withstand both compression and shear loads. In addition the mounts are equipped with an internal buffer to limit movements of the generating set due to ship motions. Hence, no additional side or end buffers are required.

The rubber in the mounts is to be protected from oil, oily water and fuel.

The transmission of forces emitted by the engine is 10-20% when using conical mounts.

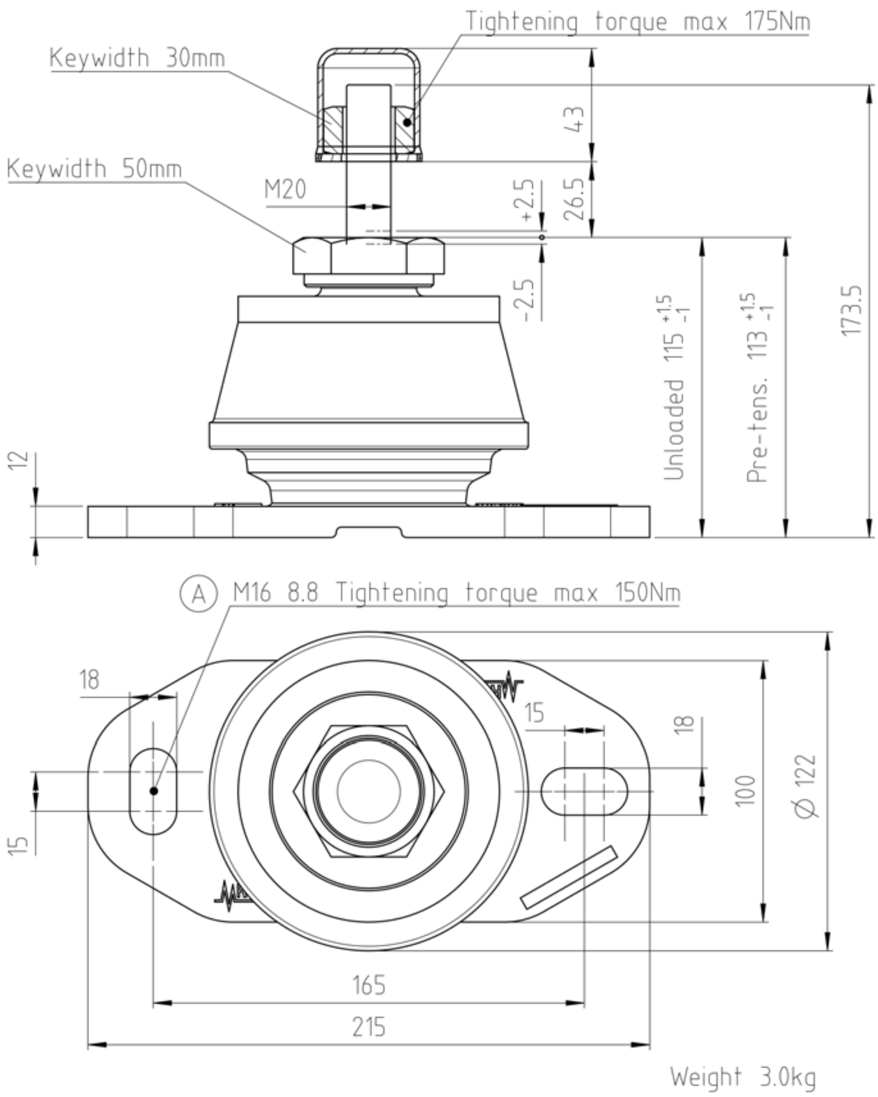


Fig 13-5 Rubber mounts (DAAF504777A)

13.4 Flexible pipe connections

When the engine is resiliently installed, all connections must be flexible and no grating nor ladders may be fixed to the generating set. When installing the flexible pipe connections, unnecessary bending or stretching should be avoided. Flexible hoses are to be installed with a certain bend to minimize strain on the hose. 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.

14. Vibration and Noise

Generating sets comply with vibration levels according to ISO 8528-9.

Main engines comply with vibration levels according to ISO 10816-6 Class 5.

14.1 Mass moments of inertia

The mass-moments of inertia of the propulsion engines (including flywheel, coupling outer part and damper) are typically as follows:

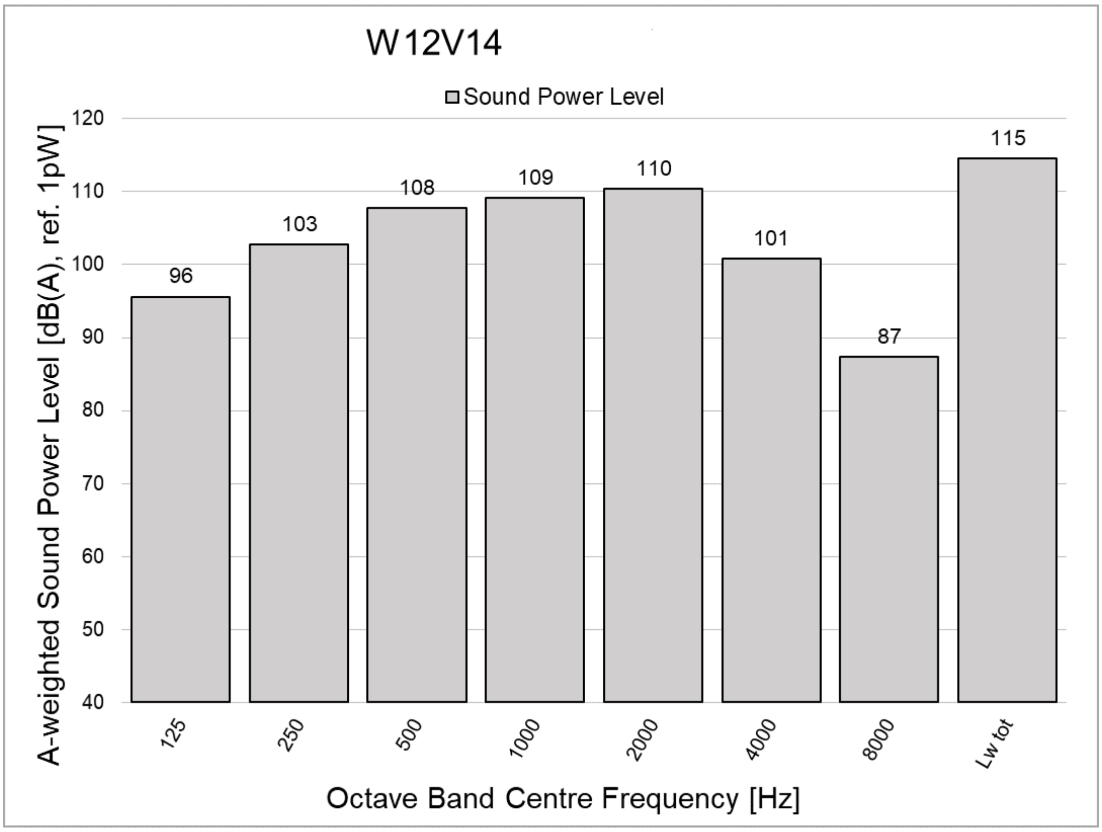
Engine	J [kgm²]
W 12V14	7…10
W 16V14	8…11

14.2 Airborne Noise

The results represent typical airborne noise Sound Power Level. Results are presented in terms of Octave Band Spectrum.

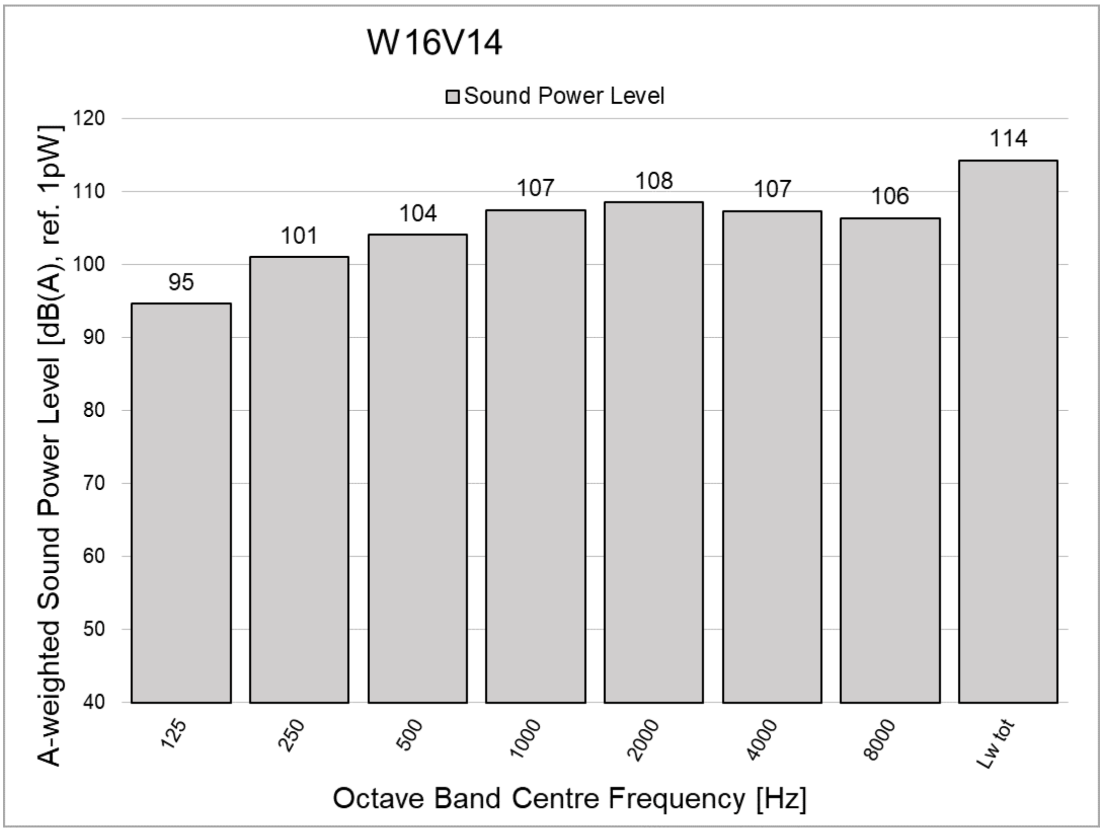
Reported data are, according to Wärtsilä internal method [3], based on ISO 9614 – Part 1 [2].

For customer related project, please contact Wärtsilä.



W12V14 ABN A-weighted in Octave Frequency Band [dB(A), ref. 1pW]								
f (Hz)	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**Lw tot**
SWL (dB)	96	103	108	109	110	101	87	115

Fig 14-1 Octave band ABN SWL of W12V14 engine



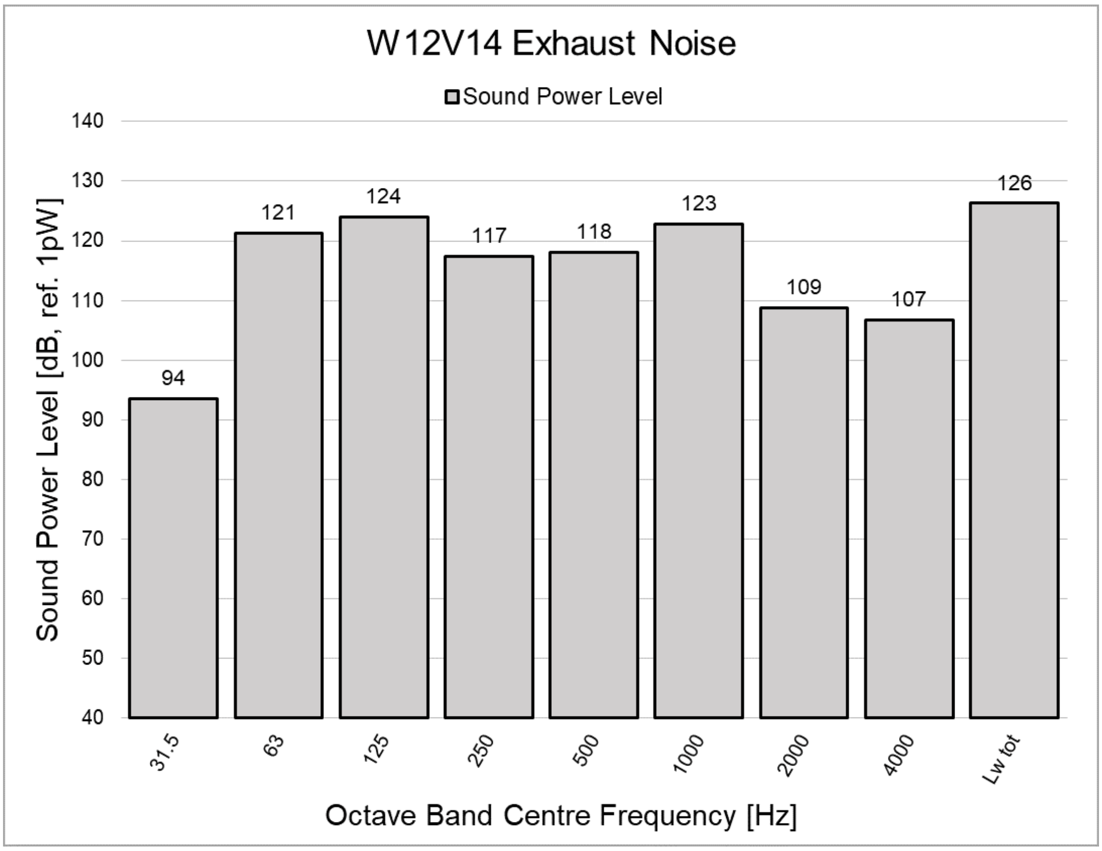
W16V14 ABN A-weighted in Octave Frequency Band [dB(A), ref. 1pW]								
f (Hz)	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**Lw tot**
SWL (dB)	95	101	104	107	108	107	106	114

Fig 14-2 Octave band ABN SWL of W16V14 engine

14.3 Exhaust Noise

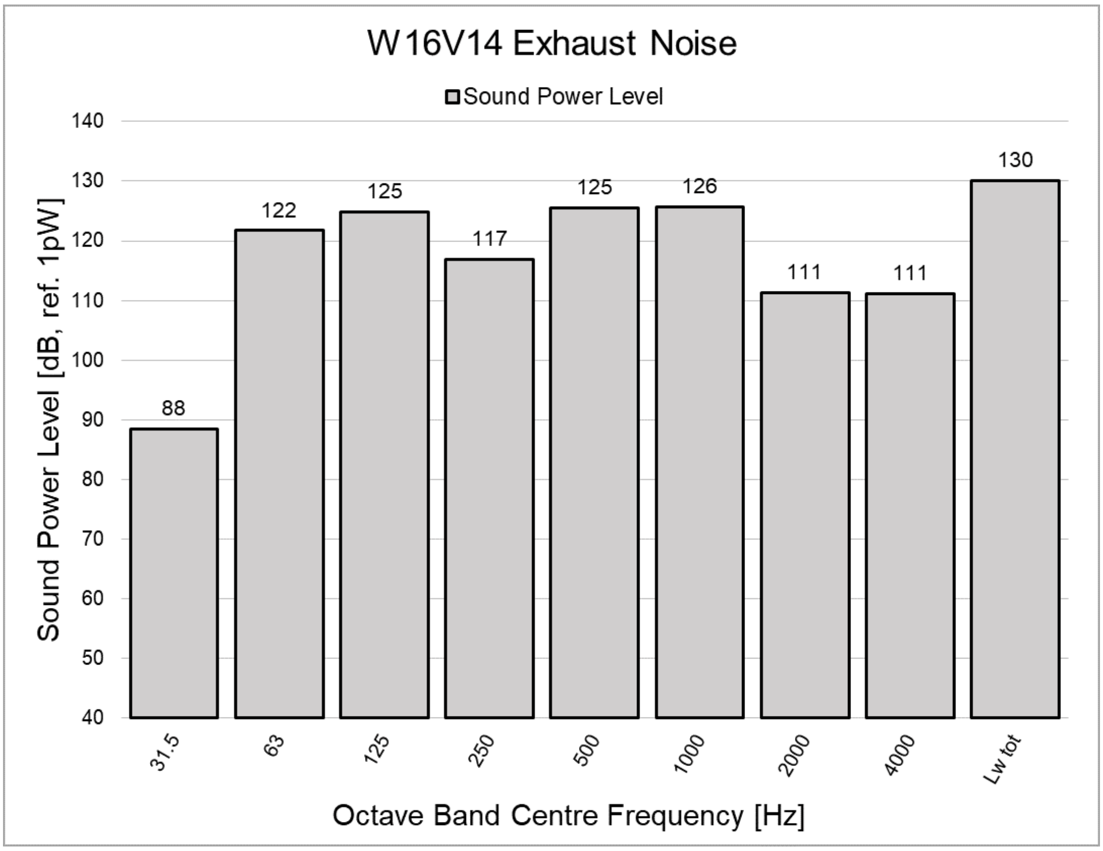
The results represent typical exhaust sound power level emitted from turbocharger outlet to free field at engine full load and nominal speed. Reported data are based on Wärtsilä internal method.

For customer related project, please contact Wärtsilä.



W12V14 EGN in Octave Frequency Band [dB, ref. 1pW]									
f (Hz)	31.5	63	125	250	500	1000	2000	4000	Lw tot
SWL (dB)	94	121	124	117	118	123	109	107	126

Fig 14-3 Octave band EGN SWL of W12V14 engine



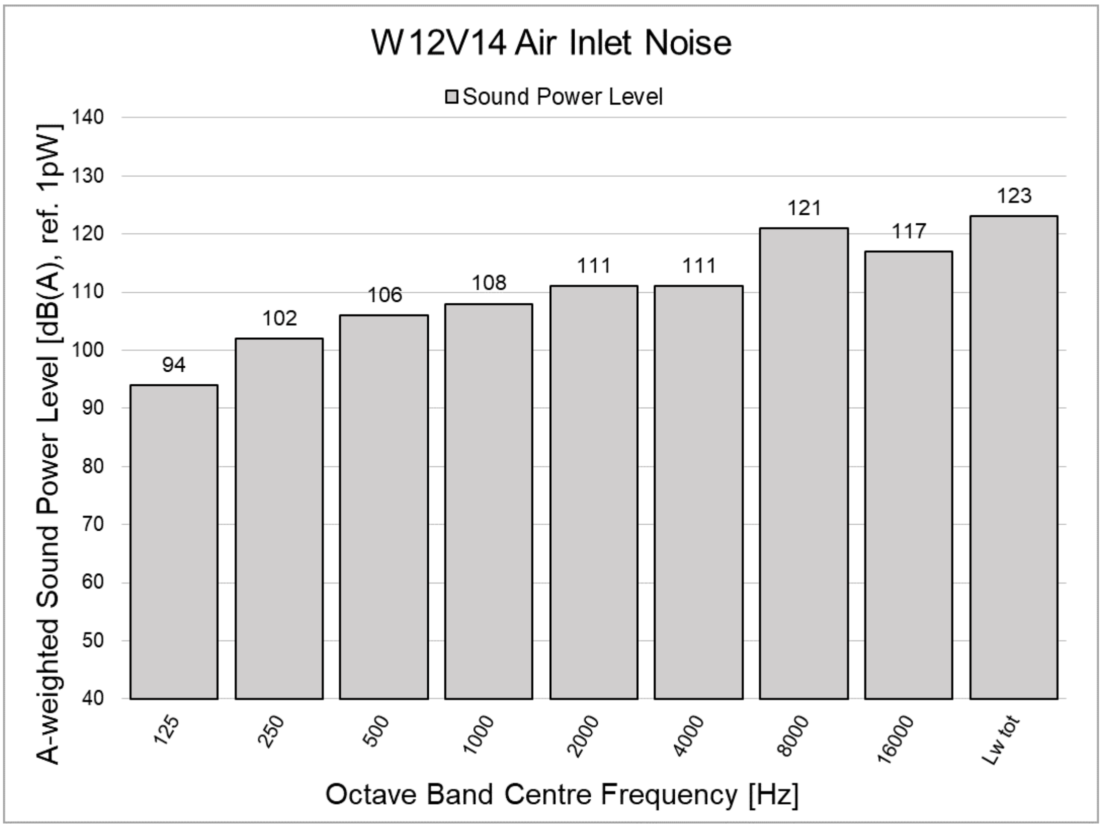
W16V14 EGN in Octave Frequency Band [dB, ref. 1pW]									
f (Hz)	**31.5**	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**Lw tot**
SWL (dB)	88	122	125	117	125	126	111	111	130

Fig 14-4 Octave band EGN SWL of W16V14 engine

14.4 Air Inlet Noise

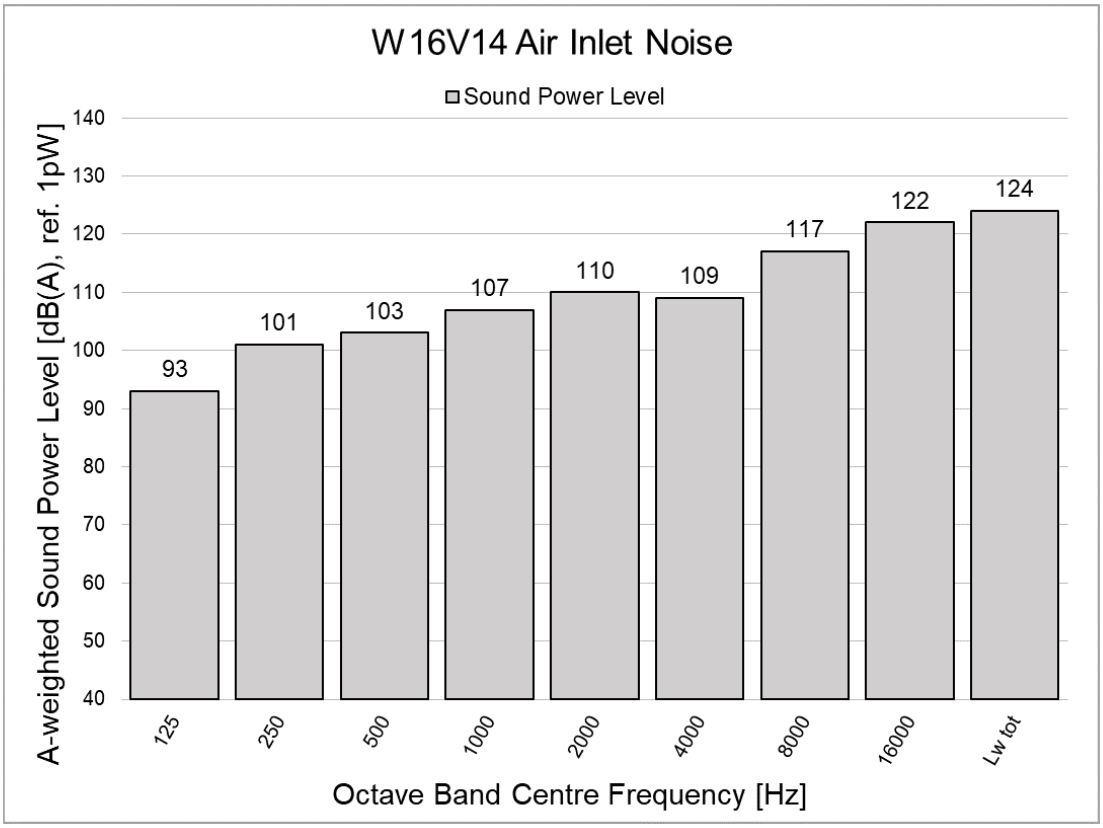
The results represent typical unsilenced air inlet A-weighted sound power level at turbocharger inlet at engine full load and nominal speed using a Wärtsilä internal method based on ISO 3740 series.

For customer related project, please contact Wärtsilä.



W12V14 AIN A-weighted in Octave Frequency Band [dB(A), ref. 1pW]									
f [Hz]	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**16000**	**Lw tot**
SWL [dB(A)]	94	102	106	108	111	111	121	117	123

Fig 14-5 Octave band AIN SWL of W12V14 engine



W16V14 AI N A-weighted in Octave Frequency Band [dB(A), ref. 1pW]									
f [Hz]	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**16000**	**Lw tot**
SWL [dB(A)]	93	101	103	107	110	109	117	122	124

Fig 14-6 Octave band AIN SWL of W16V14 engine

15. Power Transmission

15.1 Flexible coupling

The power transmission of propulsion engines is accomplished through a flexible coupling mounted on the flywheel.

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.

15.2 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.

15.3 Shaft locking device

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.

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.

15.4 Power-take-off from the free end

At the free end a shaft connection as a power take off can be provided.

15.5 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)

16. Engine Room Layout

16.1 Crankshaft distances

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

16.1.1 Main engines

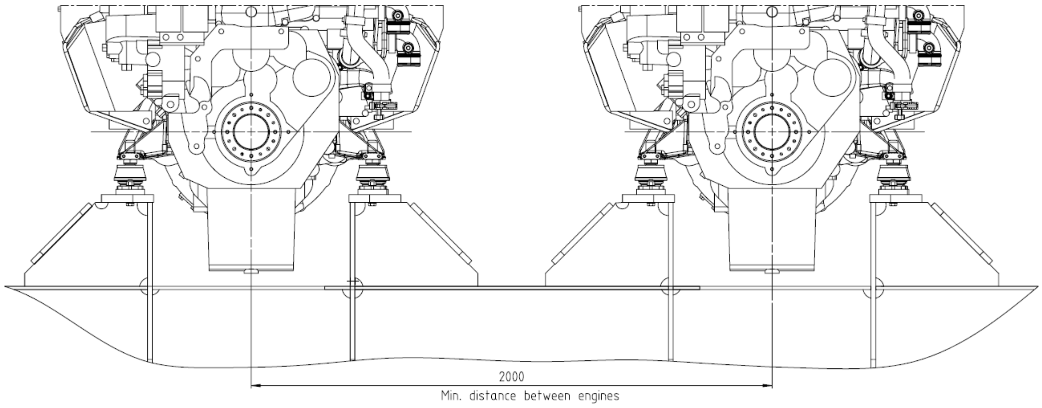


Fig 16-1 **Crankshaft distances main engines (DAAF490760A)**

16.1.2 Generating Sets

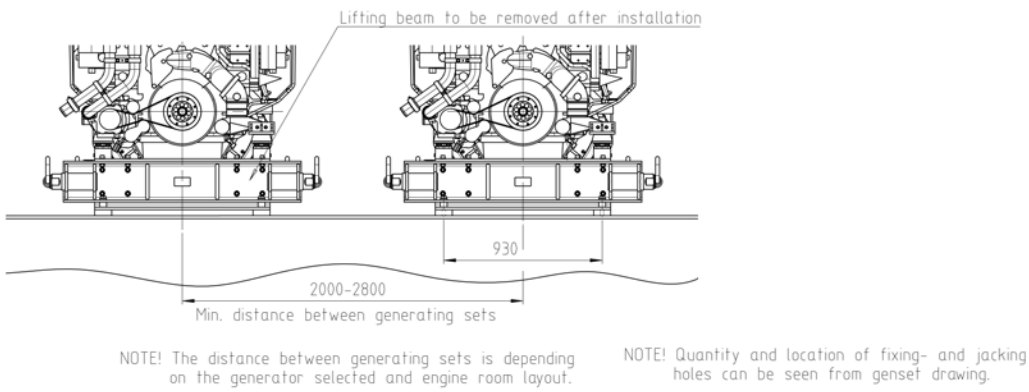


Fig 16-2 **Crankshaft distances generating sets (DAAF495116B)**

16.2 Space requirements for maintenance

16.2.1 Working space reservation

It is recommended to reserve about one meter of free working space.

No obstructions should be built in way of:

- Camshaft withdrawal space

- Engine driven pump service space
- Charge air cooler withdrawal space
- Piston overhauling height
- Turbocharger maintenance space

Free route for hauling parts to and from engine to be foreseen.

See chapter Transport Dimensions and Weights for dimensions of maintenance items.

16.3 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.

All engine spare parts should be protected from corrosion and excessive vibration.

16.4 Required deck area for service work

During engine maintenance some deck area is required for cleaning and storing dismantled components.

Service area should be plain steel deck dimensioned to carry the weight of engine parts.

16.4.1 Service space requirement

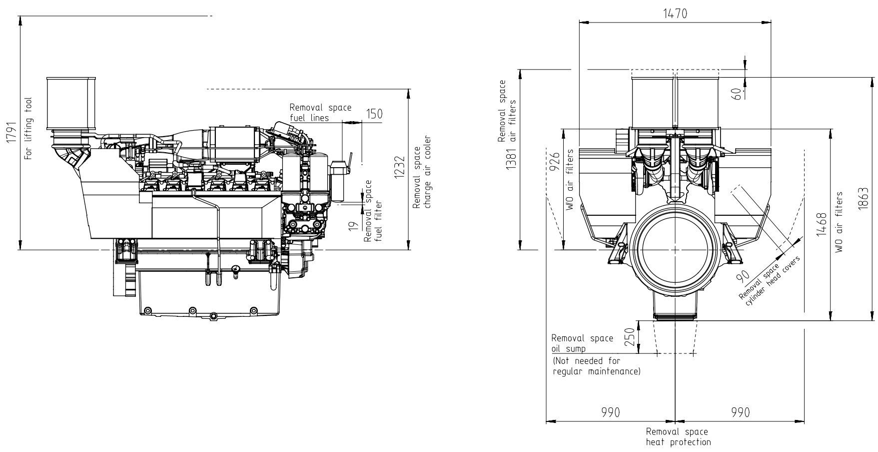


Fig 16-3 Service space for main engine W12V14 (DAAF508677B)

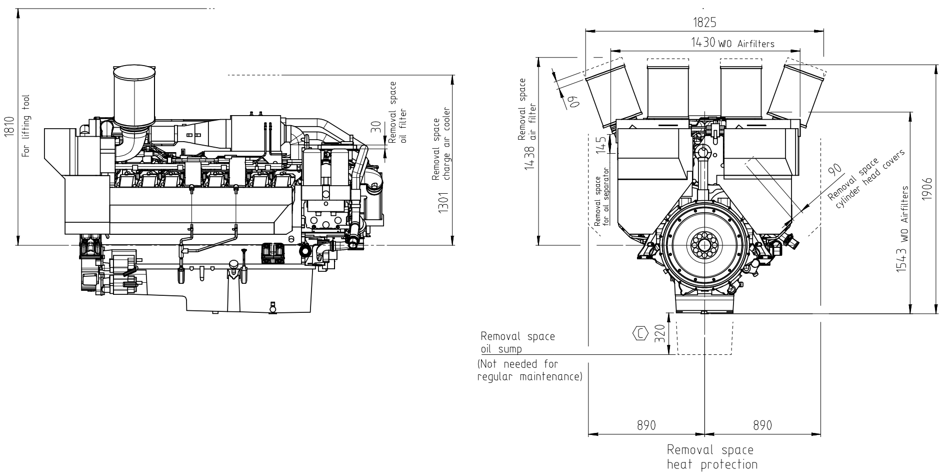


Fig 16-4 Service space for main engine W16V14 (DAAF508567C)

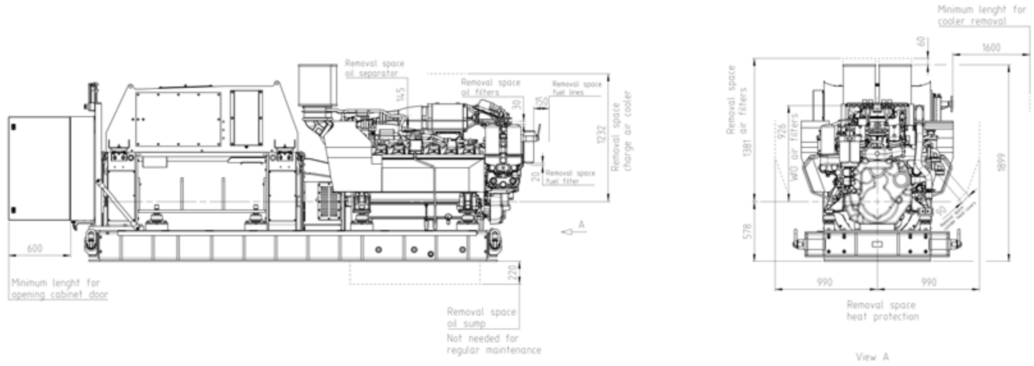


Fig 16-5 Service space for genset W12V14 (DAAF518400)

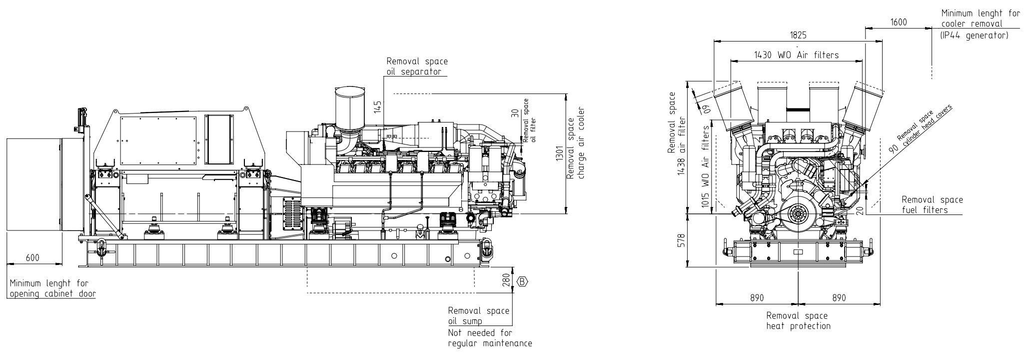


Fig 16-6 Service space for genset W16V14 (DAAF518448B)

17. Transports Dimensions and Weights

17.1 Lifting equipment

It is essential for efficient and safe working conditions that the lifting equipment are applicable for the job and they are correctly dimensioned and located.

The required engine room height depends on space reservation of the lifting equipment and also on the lifting and transportation arrangement. The minimum engine room height can be achieved if there is enough transversal and longitudinal space, so that there is no need to transport parts over insulation box or rocker covers.

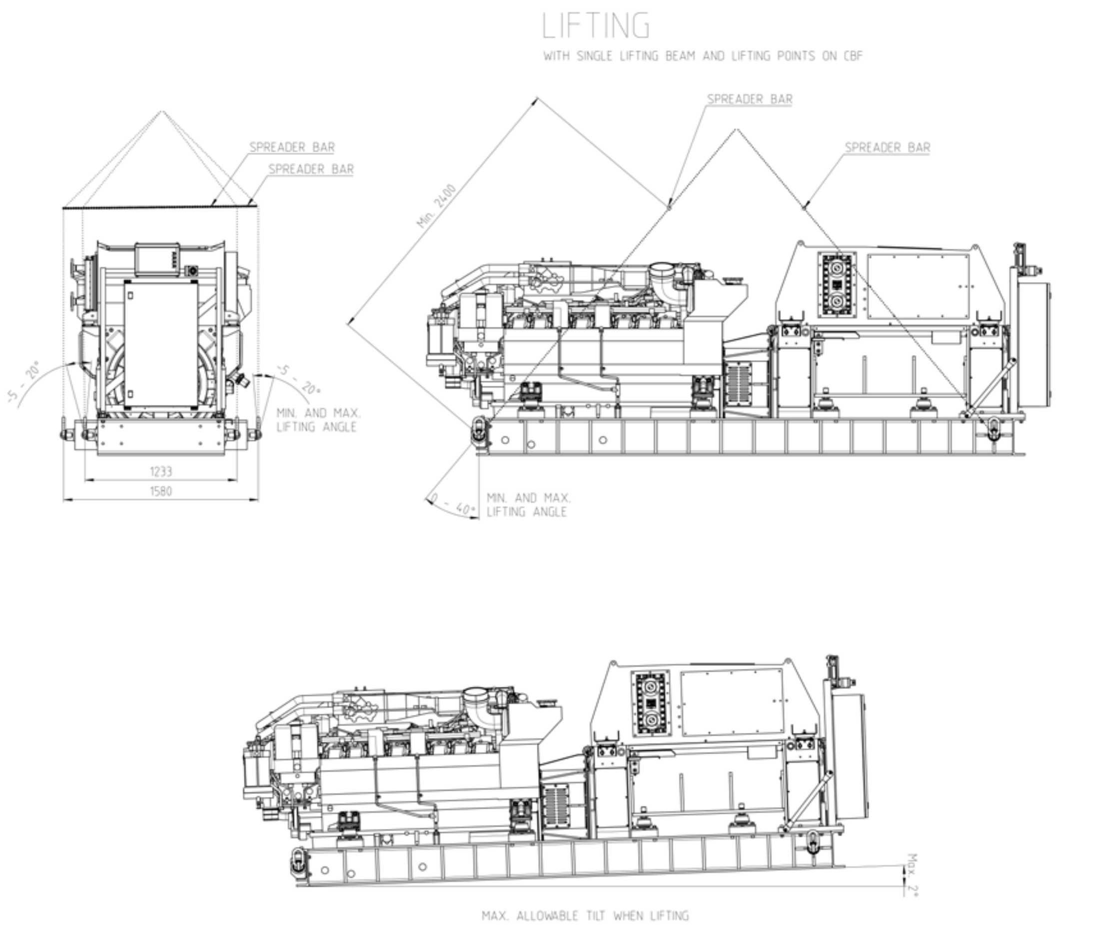
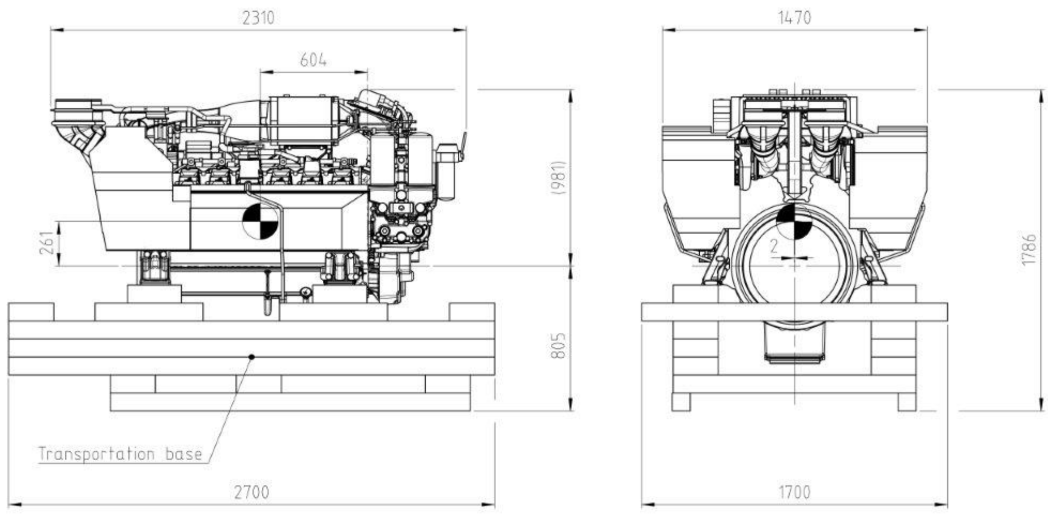


Fig 17-1 Lifting equipment W14 Genset (DAAF500570A)

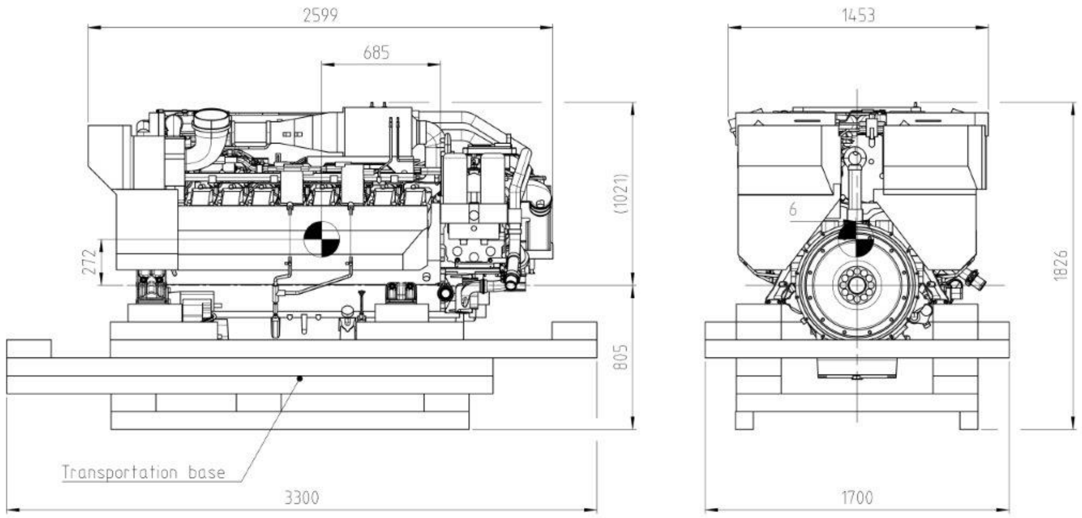
17.2 Lifting of the engines



Weights Tol. ±2.5%

Engine without oil & water	2850	Kg
Transporation base	270	Kg
Total weight	3120	Kg

Fig 17-2 Lifting drawing W12V14 DAAF554406



Weights Tol. ±2.5%

Engine without oil & water	3790	Kg
Transporation base	320	Kg
Total weight	4110	Kg

Fig 17-3 Lifting drawing W16V14 DAAF554784

18. 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.

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19. ANNEX

19.1 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

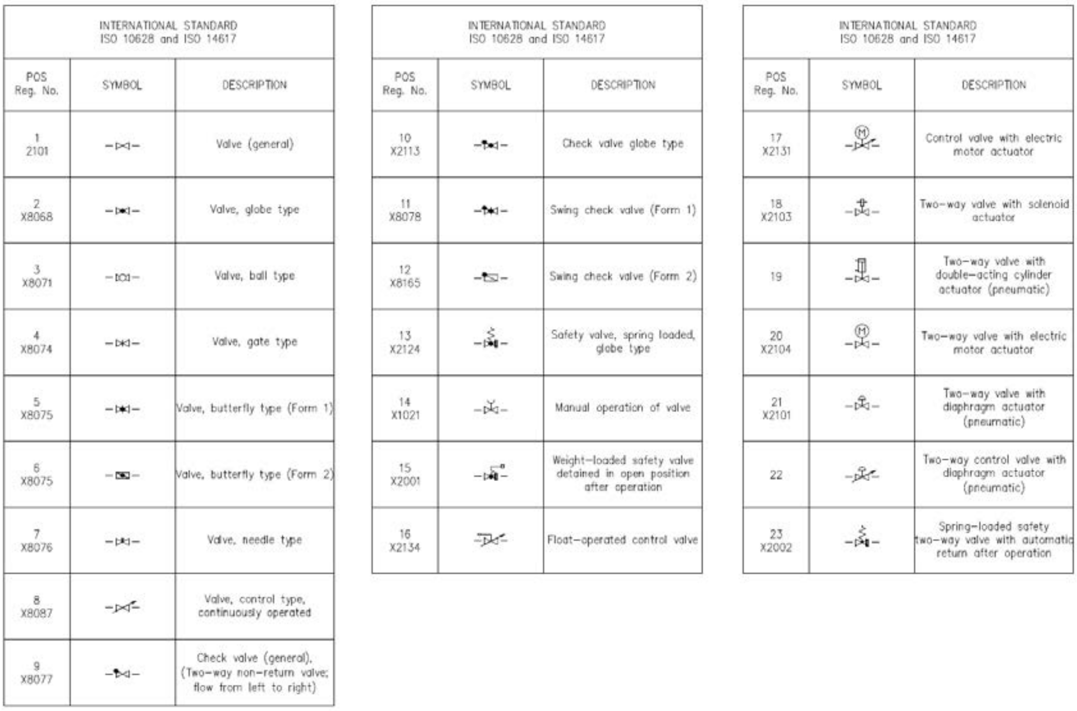
Convert from	To	Multiply by
kg/m^3	lb/US gallon	0.00834
kg/m^3	lb/Imperial gallon	0.01002
kg/m^3	lb/ft^3	0.0624

19.1.1 Prefix

Table 19-1 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}			

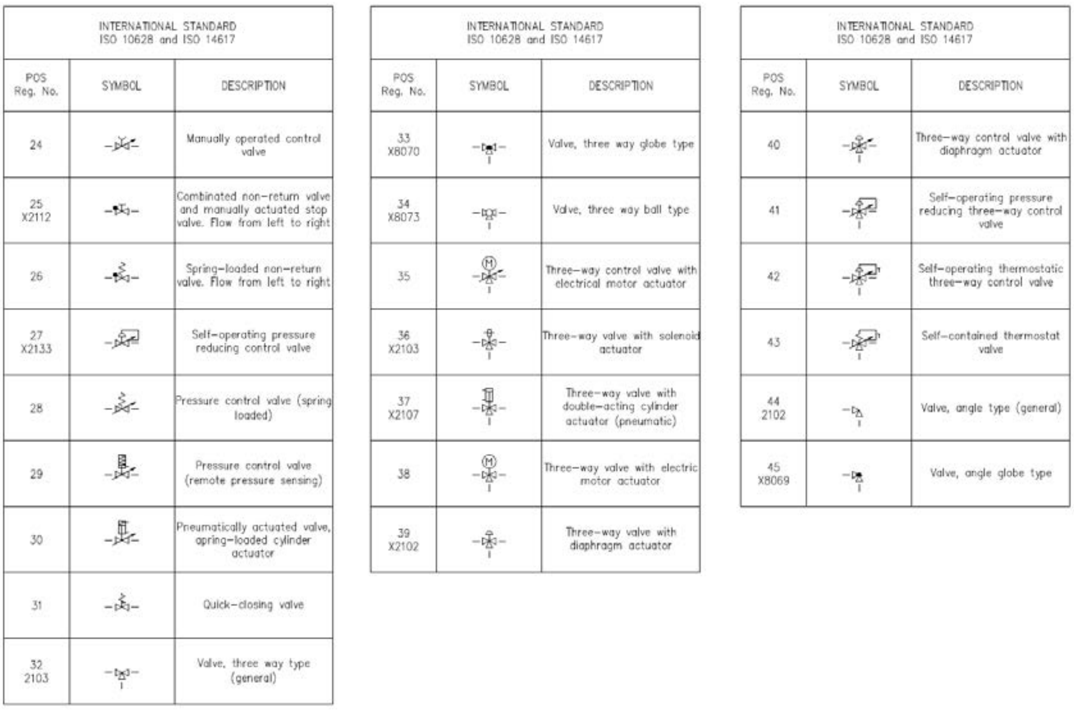
19.2 Collection of drawing symbols used in drawings



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)
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
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 19-1 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)
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
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 19-2 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 3/2 Pneum/Pneum
58		Valve 3/2 Pneum/Spring
59		Valve 3/2 Solenoid/Spring
60		Valve 3/2 Lever/Spring
61		Valve 3/2 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 5/2 Pneum/Pneum

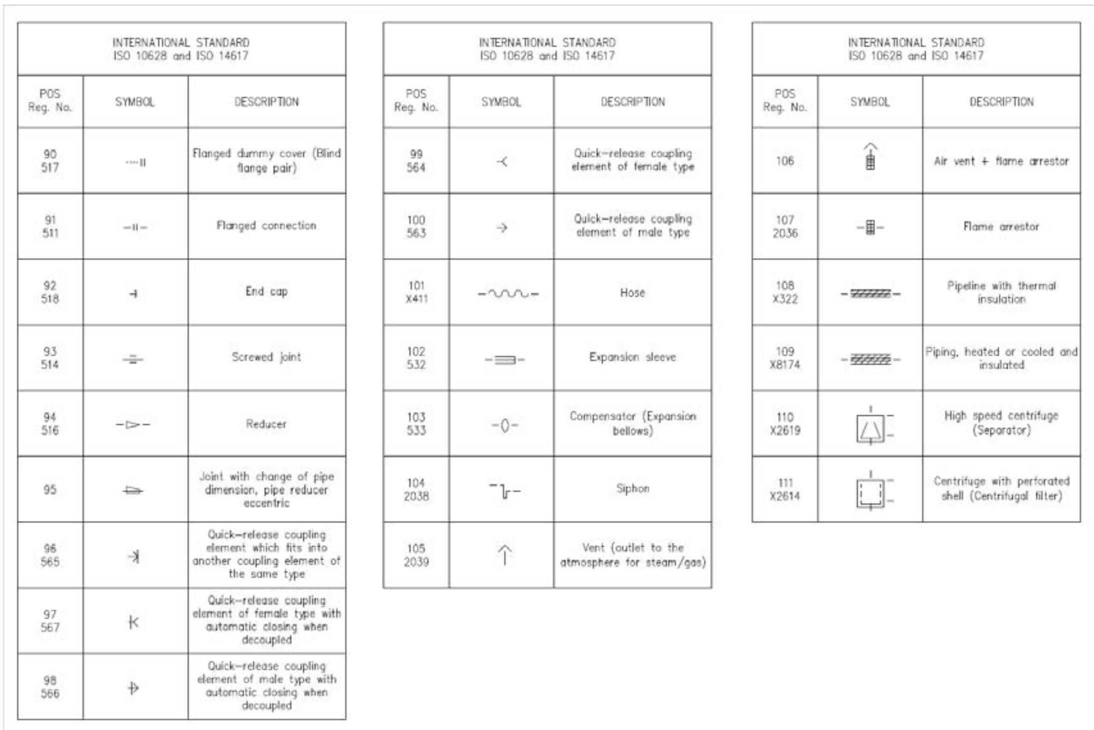
Fig 19-3 List of symbols (DAAF406507 - 3)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
68		Valve 5/2 Pneum/Spring
69		Valve 5/2 Solenoid/Spring
70		Valve 5/2 Lever/Spring
71		Valve 5/2 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

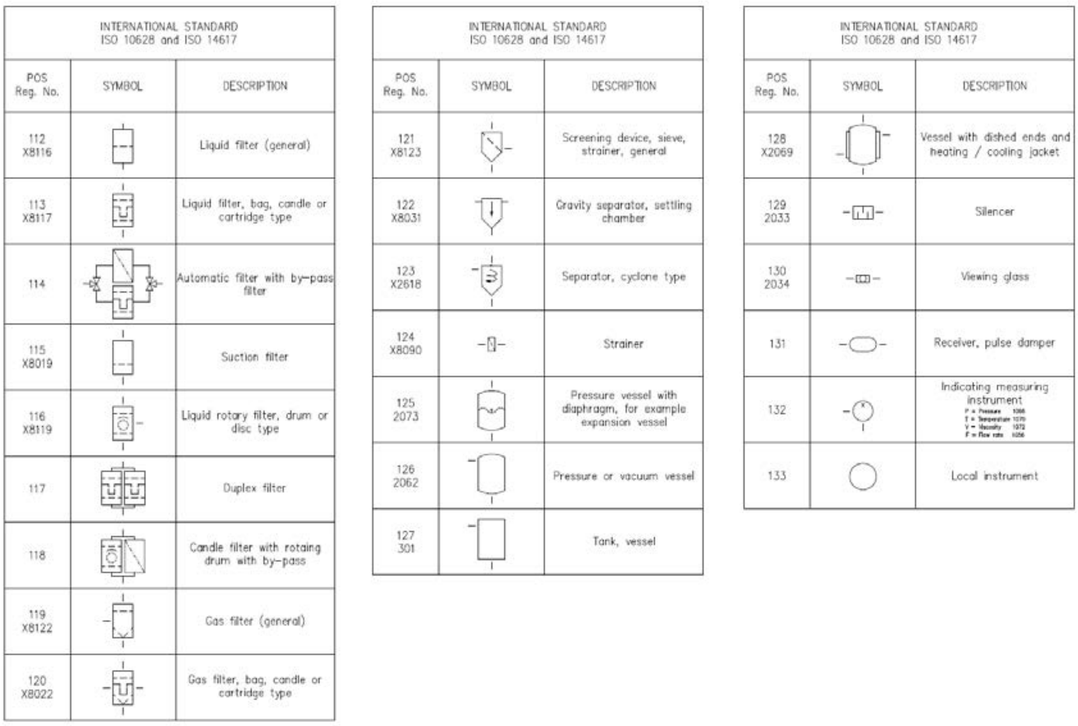
Fig 19-4 List of symbols (DAAF406507 - 4)



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
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)
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)

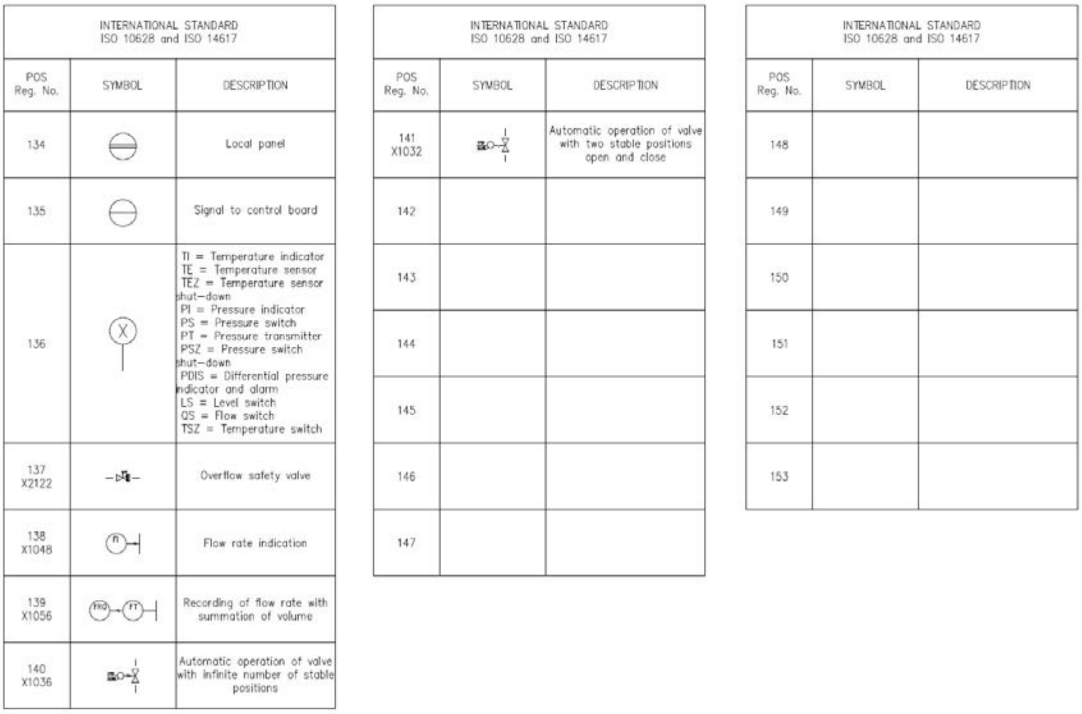
Fig 19-5 List of symbols (DAAF406507 - 5)



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
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
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
133		Local instrument

Fig 19-6 List of symbols (DAAF406507 - 6)

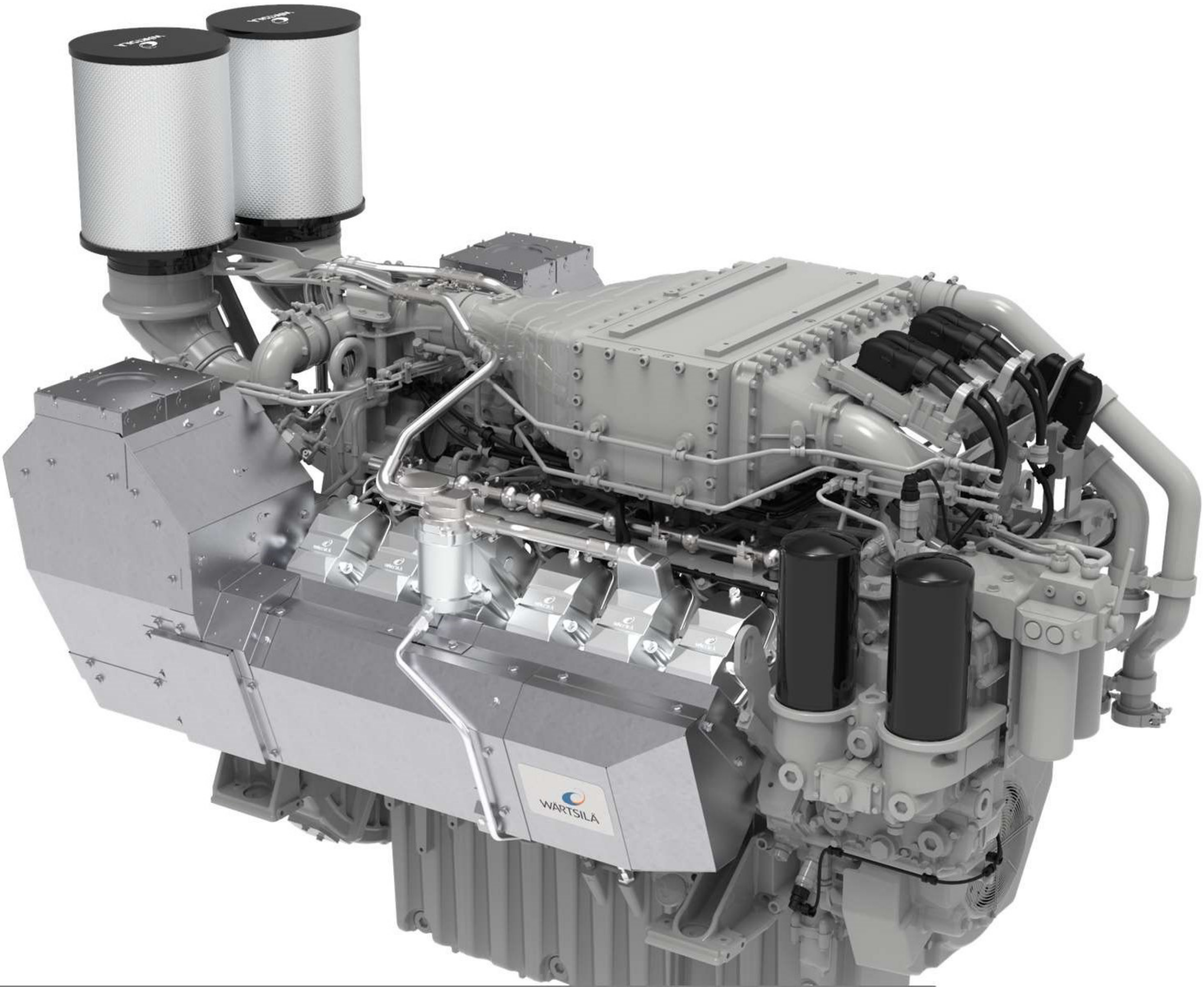


INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
134		Local panel
135		Signal to control board
136		TI = Temperature indicator TE = Temperature sensor TEZ = Temperature sensor shut-down PI = Pressure indicator PS = Pressure switch PT = Pressure transmitter PSZ = Pressure 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 19-7 List of symbols (DAAF406507 - 7)



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