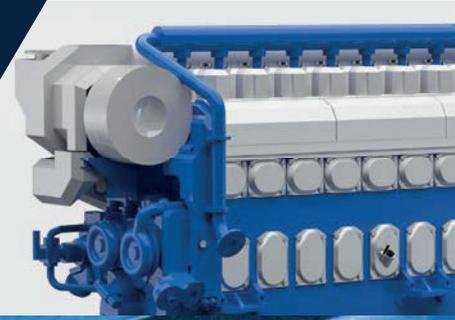


# Wärtsilä 20DF

PRODUCT GUIDE



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# Introduction

This Product Guide provides data and system proposals for the early design phase of marine engine installations. For contracted projects specific instructions for planning the installation are always delivered. Any data and information herein is subject to revision without notice. This 1/2024 issue replaces all previous issues of the Wärtsilä 20DF Product Guides.

<b>Issue</b>	<b>Published</b>	<b>Updates</b>
1/2024	19.03.2024	Chapter Automation updated. Other minor updates throughout the product guide.
1/2022	01.02.2022	1200 rpm and other updates.
2/2021	08.07.2021	MN min. changed to 70, and other updates.
1/2021	02.07.2021	900 rpm added, output and other updates.
1/2020	01.08.2020	Chapter Automation System updated, other minor updates.
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2/2018	21.12.2018	Technical data section updated. Other minor updates.
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3/2016	13.09.2016	Technical data updated
2/2016	20.05.2016	Cetane index for pilot fuel oils added
1/2016	18.03.2016	Performance data update. Other minor updates.
1/2015	27.02.2015	Updates throughout the product guide
1/2013	19.12.2013	Information for W20DF engines with cylinder output 185kW added

Wärtsilä, Marine Business

Vaasa, March 2024

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# 1. Main Data and Outputs

## 1.1 Technical main data

The Wärtsilä 20DF is a 4-stroke, non-reversible, turbocharged and inter-cooled dual fuel engine with direct injection of liquid fuel and indirect injection of gas fuel. The engine can be operated in gas mode or in diesel mode.

Cylinder bore .....	200 mm
Stroke .....	280 mm
Piston displacement .....	8.8 l/cyl
Number of valves .....	2 inlet valves and 2 exhaust valves
Cylinder configuration .....	6, 8 and 9 in-line
Direction of rotation .....	clockwise, counterclockwise on request
Speed .....	900, 1000, 1200 rpm
Mean piston speed .....	8.4 – 11.2 m/s

## 1.2 Maximum continuous output

**Table 1-1 Rating table for Wärtsilä 20DF**

Engine type	Main Engines	
	1200 rpm	
	kW	BHP
Wärtsilä 6L20DF	1110	1510
Wärtsilä 8L20DF	1480	2010
Wärtsilä 9L20DF	1665	2260

**Table 1-2 Rating table for Wärtsilä 20DF**

Engine type	Generating sets					
	900 rpm		1000 rpm		1200 rpm	
	Engine [kW]	Generator [kVA]	Engine [kW]	Generator [kVA]	Engine [kW]	Generator [kVA]
Wärtsilä 6L20DF	870	1040	960	1150	1170	1400
Wärtsilä 8L20DF	1160	1390	1280	1540	1560	1870
Wärtsilä 9L20DF	1305	1570	1440	1730	1755	2110

### NOTE

Formula  $KW_m \times 0.96$  (generator efficiency) / 0.8 (cos phi) is used for kVA calculation.

The mean effective pressure  $P_e$  can be calculated using the following formula:

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

where:

$P_e$  = mean effective pressure [bar]

$P$  = output per cylinder [kW]

$n$  = engine speed [r/min]

$D$  = cylinder diameter [mm]

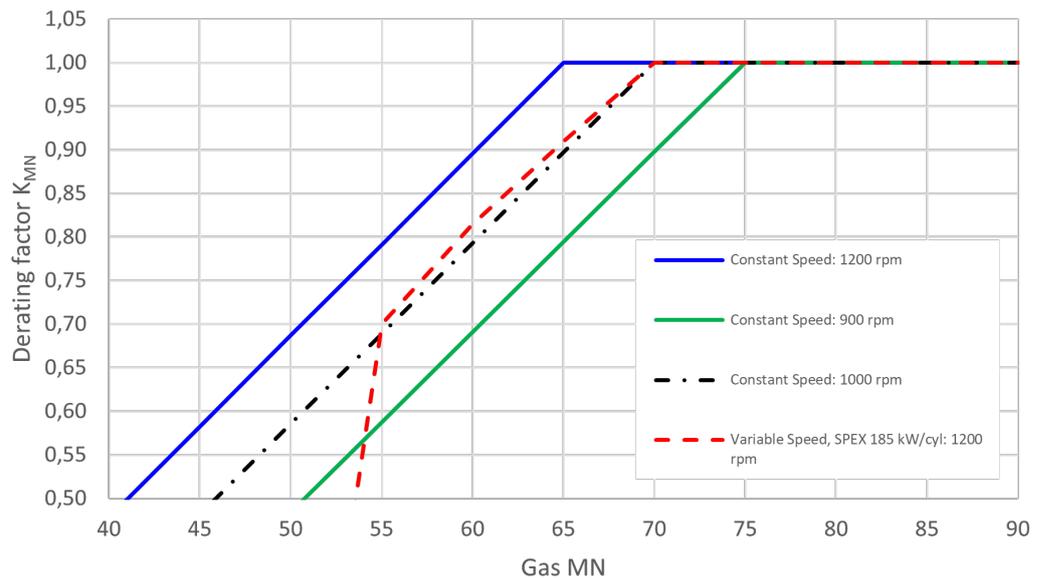
$L$  = length of piston stroke [mm]

$c$  = operating cycle (4)

## 1.3 Output limitations in gas mode

### 1.3.1 Output limitations due to methane number

Derating factor ( $K_{\text{KNOCK}}$ )



Methane Number, [MN]

#### NOTICE

\* Variable speed is available for genset and CPP applications with full 195 kW/cyl output, with limited operating field. Please contact Wärtsilä for further details.

#### Notes:

For the engine to be able to run 100% load in gas the methane number must be 80 or above, it is however possible to run the engine on gases with lower methane number at a reduced output, the maximum output that can be taken out of the engine when running on lower methane number gas is according to above curve. Going above this curve will lead knocking and trip to diesel mode, so if gas mode to be insured when operating on lower methane gas, the above is to be considered in the vessels PMS system.

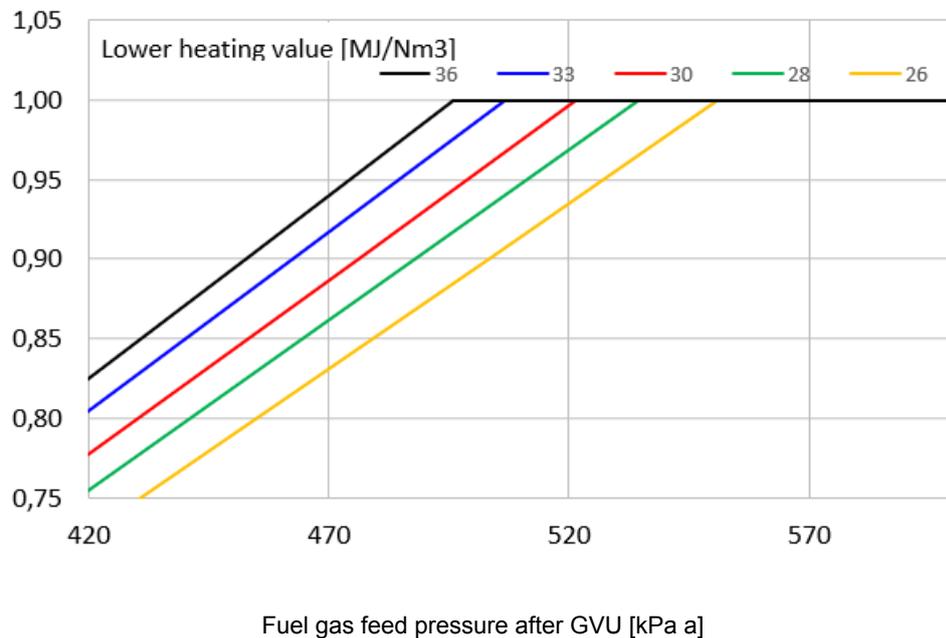
The dew point shall be calculated for the specific site conditions. The minimum charge air temperature shall be above the dew point, otherwise condensation will occur in the charge air cooler. Minimum charge air receiver +45°C is recommended.

The charge air temperature is approximately 5 °C higher than the charge air coolant temperature at rated load.

Glycol usage in cooling water according to chapter 9 "Cooling Water System".

## 1.3.2 Output limitations due to gas feed pressure and lower heating value

Derating factor ( $K_{GAS}$ )



### Notes:

The above given values for gas feed pressure are at engine inlet i.e. after the gas regulating unit..

No compensation (uprating) of the engine output is allowed, neither for gas feed pressure higher than required in the graph above nor lower heating value above 36.9 MJ/Nm<sup>3</sup>.

LHV below 35 MJ/Nm<sup>3</sup> can have a negative impact to step loading capability, the engine loading performance in gas mode is tested with LNG which LHV equals to 36.9 MJ/Nm<sup>3</sup>.

Values are given in Nm<sup>3</sup> is at 0 °C and 101.3 kPa.

If the gas pressure is lower than required, a pressure booster unit can be installed before the gas valve unit to ensure adequate gas pressure. If pressure arise is not possible the engine output has to be adjusted according to above.

For de-rating of output for gas temperature above 5°C, contact Wärtsilä.

The graph shows the minimum Gas feed pressure at different LHV [MJ/Nm<sup>3</sup>] needed to put the engine in operation. The efficiency and BSEC figures reported in the heat balance table are guaranteed with min Gas feed pressure of 550kPa a for all the allowed LHV values.

## 1.4 Reference conditions

The output is available within a range of ambient conditions and coolant temperatures, which are available through Wärtsilä website. The required fuel quality for maximum output is specified in the section [Fuel Characteristics](#). For ambient conditions or fuel qualities outside the specification, the output may have to be reduced.

The specific fuel consumption is available through Wärtsilä website at [Engine Online Configurator](#). The statement applies to engines operating in ambient conditions according to ISO 15550:2016 (E).

total barometric pressure	100 kPa
air temperature	25 °C
relative humidity	30 %
charge air coolant temperature	25 °C ~ 38 °C

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

## 1.5 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), (Rev.2 Dec 2018) - Main and auxiliary machinery.

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

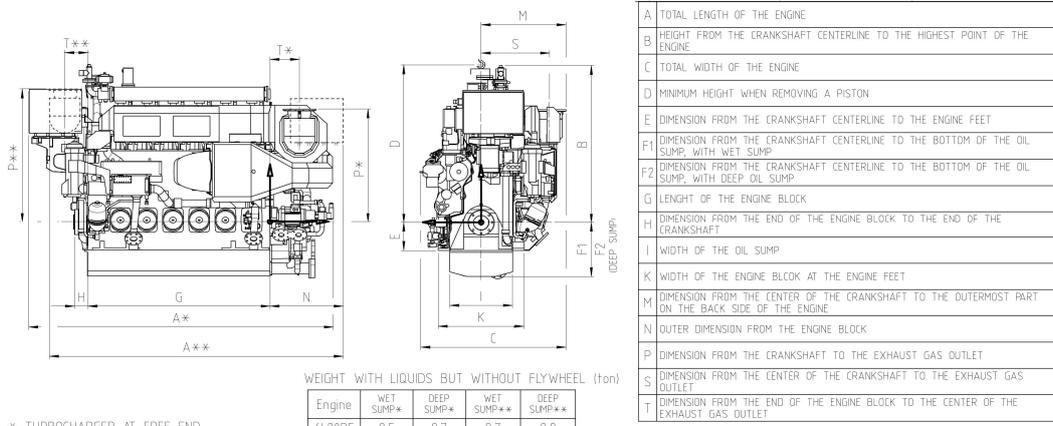
- Permanent athwart ship inclinations (list) 15°
- Temporary athwart ship inclinations (roll) 22.5°
- Permanent fore-and-aft inclinations (trim) 5°
- Temporary fore and aft inclinations (pitch) 7.5°

Inclination in all directions requires special arrangements.

<b>NOTE</b>
- Athwartships and fore-end-aft inclinations may occur simultaneously
- Inclination angles are applicable <b>ONLY</b> to marine main and auxiliary machinery engines. Emergency power installations are not currently available
- If inclination exceeds some of the above mentioned IACS requirements, a special arrangement might be needed.

# 1.6 Principal dimensions and weights

## 1.6.1 Main engines



WEIGHT WITH LIQUIDS BUT WITHOUT FLYWHEEL (ton)

Engine	WET SUMP*	DEEP SUMP*	WET SUMP**	DEEP SUMP**
6L20DF	9.5	9.7	9.7	9.9
8L20DF	11.8	12.0	-	-
9L20DF	12.8	13.0	13.4	13.6

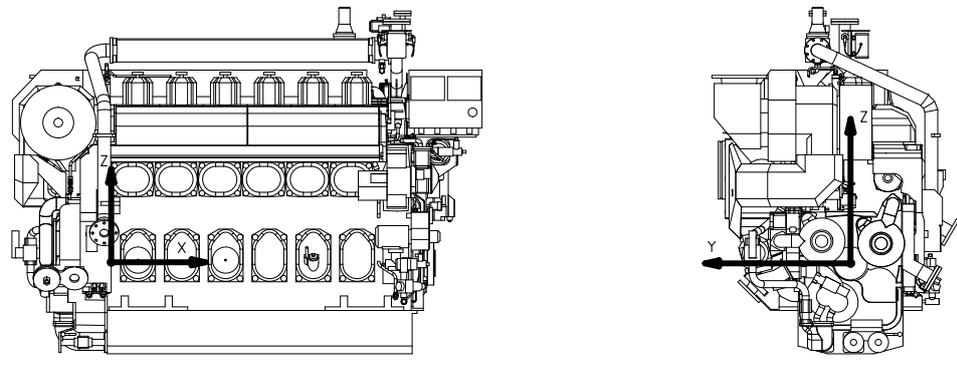
\* TURBOCHARGER AT FREE END  
 \*\* TURBOCHARGER AT FLYWHEEL END

Engine	A*	A**	B	C*	C**	D	E	F1	F2	G	H	I	K	M*	M**	N*	N**
6L20DF	3480	3499	1806	1659	1640	1800	325	624	824	2080	155	722	980	970	950	723	829
8L20DF	4080	4210	1806	1773	1817	1800	325	624	824	2680	155	722	980	1084	1127	723	829
9L20DF	4380	4510	1806	1773	1817	1800	325	624	824	2980	155	722	980	1084	1127	723	829

Engine	P*	P**	S*	S**	T*	T**
6L20DF	1297	1528	781	763	336	266
8L20DF	1390	1614	863	907	339	329
9L20DF	1390	1614	863	907	339	329

Fig 1-1 Main engines (DAAF014777B)



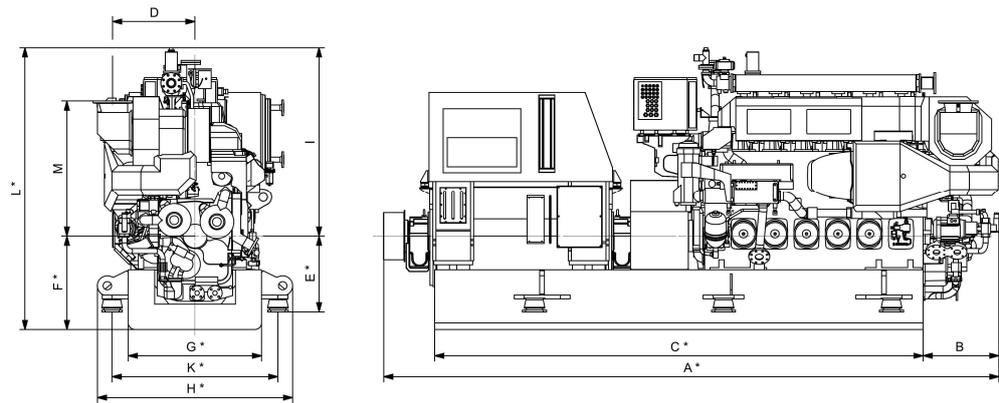
W20DF  
1000 / 1200 RPM

Moottori- tyyppi ENGINE TYPE	Turboahminen sijainti TURBOCHARGER LOCATION	Käivapaino DRY WEIGHT ilman vauhtipyörää WITHOUT FLYWHEEL kg (average)	Nesteiden massa WEIGHT OF LIQUIDS Öljy + jäähdytysvesi OIL + COOLING WATER kg (approx.)	Massakeskipiste CENTRE OF GRAVITY			
				X (mm)	Y (mm)	Z (mm)	
6L20LF	Free end	8850	With dry sump, running condition Wet sump	115 465	912	87	341
6L20LD	Driving end	9050	Deep sump	645	982	72	-
8L20LF	Free end	11000	With dry sump, running condition Wet sump	145 585	1178	80	341
8L20LD	-	-	Deep sump	825	-	-	-
9L20LF	Free end	11900	With dry sump, running condition Wet sump	165 660	1336	78	341
9L20LD	Driving end	12500	Deep sump	925	1437	85	-

Weights are approx. and should be used only for guidance. Weights may vary due i.e. following reasons:  
 • Turbocharger type / brand  
 • Turbocharger with silencer or suction air pipe  
 • Oil sump type => wet or deep  
 • Gas inlet pipe type => pipe to down, straight from gas manifold, 90° connection  
 • Pre-lubrication pump electric motor type  
 • With / without engine driven fuel pump  
 • Casting variations  
 Estimated tolerance for the weight: +2.5%

Fig 1-2 Main engine weight and center of gravity (DAAF405604)

## 1.6.2 Generating sets



ENGINE TYPE	A*	B	C*	D*	E*	F*	G*	H*	I	K*	L*	M	WEIGHT (ton)*
6L20DF	5600	723	4600	781	725	895	1270 1420	1960 2090	1806	1580 1730	2661	1297	18,0
8L20DF	6500	723	5300	863	725	1025	1420 1570	2010 2110	1806	1730 1880	2831	1390	22,0
9L20DF	6700	723	5700	863	725	1025 1125	1420 1570	2010 2110	1806	1730 1880	2831 2931	1390	25,0

\* DEPENDENT ON GENERATOR TYPE AND SIZE:  
 -WIDTH  
 -LENGTH  
 -HEIGHT  
 -WEIGHT (air or water cooled)

**Fig 1-3 Generating sets (DAAF014947C)**



Most current [2D](#) drawings and [3D](#) models of Engines and Gensets are available at [www.wartsila.com](http://www.wartsila.com) and all dimensions and weights shown above are for reference only.

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## 2. Operating Ranges

### 2.1 Engine operating modes

The engine is designed and developed for continuous operation on natural gas as well as on liquid fuels.

It has three operating modes;

Operating mode	Fuel	Type of mode
Gas mode	Pilot diesel + Gas	Normal operating mode
Diesel mode	Pilot diesel + Back-up diesel	Normal operating mode
Back-up Mode	Back-up diesel	Emergency mode

#### IMPORTANT NOTE:

The back-up mode should be seen as an emergency mode with limited maximum output. When engine trips to back-up mode, engine automation (UNIC) sends load reduction request to external power managements system (PMS). If the PMS confirms that other engines in same power grid can cover the required total power demand, engine output is limited to max. 70% of MCR.

The fuel transfer from gas mode to diesel mode can be performed at any load but the transfer from diesel mode to gas mode has to be done below 80% load (Transfer from Back-up mode to Gas or Diesel mode is not possible until engine is stopped and pilot system diagnostic check is done).

#### **NOTICE**

- No planned overload is allowed in gas operation, only for load transients. Prolonged overload will trip the engine to diesel.
- In liquid fuel operation overload is permitted as follows (according to classification societies' rules):
  - **Marine Main engines:** maximum output limited at 100% load. 110% load is allowed only for testing purposes.
  - **Marine Auxiliary engines:** maximum output limited at 110% load.

**NOTICE**

According to classification rules, all engines driving generators must be able to take 110 % load. 110% output can be utilised for as long as it takes to bring the system back to a safe state with a power demand below 100%.

Overload may never be used on a routine basis, or planned for in the operation of the plant. It is a power reserve for extreme situations.

## 2.2 Engine operating range

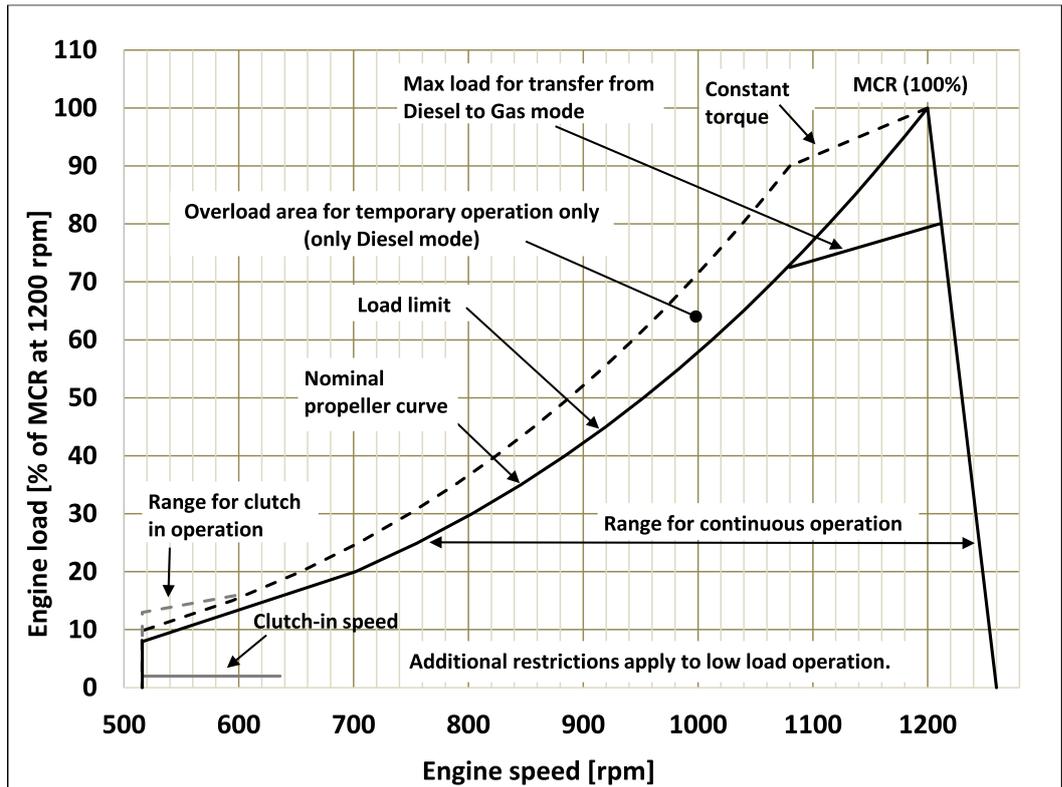
Running below nominal speed the load must be limited according to the diagrams in this chapter in order to maintain engine operating parameters within acceptable limits. Minimum speed is indicated in the diagram, but project specific limitations may apply.

### 2.2.1 Controllable pitch propellers

An automatic load control system is required to protect the engine from overload. The load control reduces the propeller pitch automatically, when a pre-programmed load versus speed curve (engine limit curve) is exceeded, overriding the combinator curve if necessary. Engine load is determined from measured shaft power and actual engine speed. The shaft power meter is supplied by Wärtsilä.

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

CPP Application Operating Field DAAF526055



**NOTE**

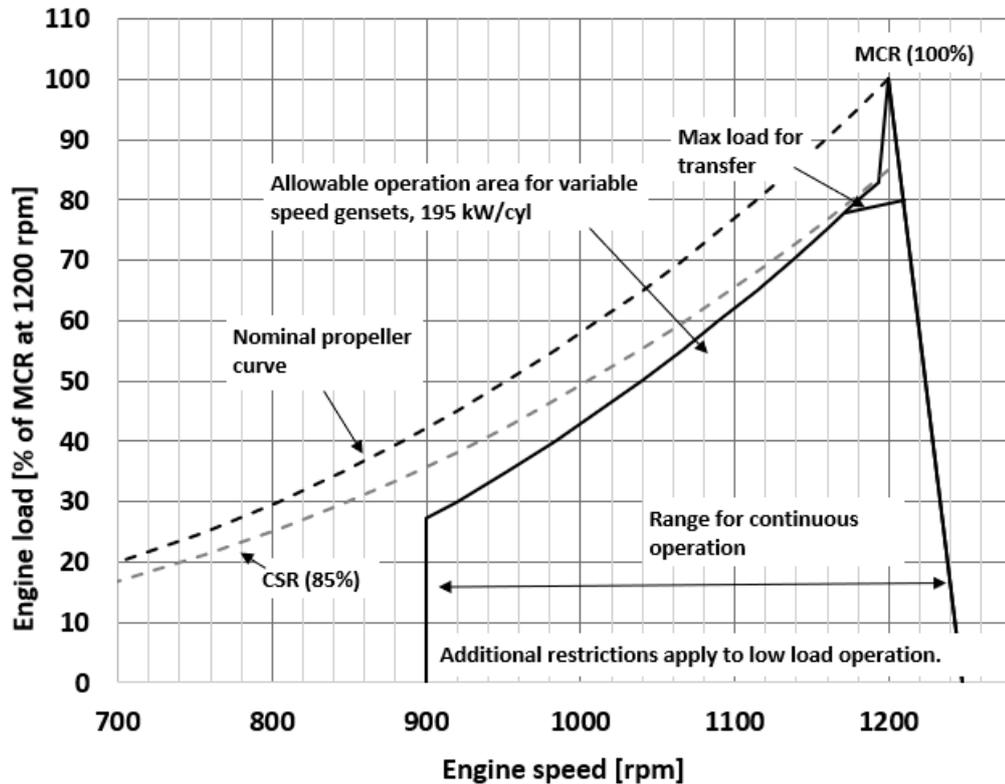
- Rated output = 185 kW/cyl at 1200 rpm
- MCR = Maximum Continuous Rating
- Actual minimum speed in variable speed applications is installation dependent. It is defined by TVC calculation when overall propulsion system is known (flywheel, clutch, transmission, propeller etc.)
- For reliable output measurement, torque flange is mandatory on mechanical propulsions
- Valid for both gas operation and diesel operation

**Remarks:** The maximum output may have to be reduced depending on gas properties and gas pressure. The permissible output will in such case be reduced with same percentage at all revolution speeds.

Restrictions for low load operation to be observed.

**2.2.2 1200 rpm Genset**

## Variable speed 1200 rpm genset, 195kW/cyl DAAF550317



- MCR = Maximum Continuous Rating. The maximum continuous rated power output as specified on the nameplate and in the Technical File of the marine engine.
- CSR = Continuous Service Rating.
- Valid for both gas operation and diesel operation
- Additional restrictions apply to low load operation.
- The chart is presenting engine performance capability only. The vibration behaviour of genset depends from common base frame design and it depends from generator type and its dimensions / masses. As every project does have different generator and common base frame, each project does have also different vibration behaviour. To be able to ensure that genset vibration levels are according to ISO 8528-9, actual minimum operating speed needs to be evaluated case by case and verified during the FAT. Typical preliminary speed range for 1200rpm engine is 1050-1200rpm.

## 2.3 Loading capacity

Controlled load increase is essential for highly supercharged engines, because the turbocharger needs time to accelerate before it can deliver the required amount of air. Sufficient time to achieve even temperature distribution in engine components must also be ensured. Dual fuel engines operating in gas mode require precise control of the air/fuel ratio, which makes controlled load increase absolutely decisive for proper operation on gas fuel.

The loading ramp Normal operating temperature (see figures) indicates maximum load rate for an engine that has reached normal operation temperature. See [below chapter](#). When transferring from diesel to gas mode, fast load changes must be avoided.

Emergency loading ramp indicates the maximum load rate of the engine in diesel mode for an engine that has reached normal operating temperature. This can be used in critical situations e.g. when recovering from a fault condition to regain sufficient propulsion and steering as fast as possible. Emergency load ramp causes undesired thermal stress of the engine and repeated use should be avoided.

The loading ramp pre-heated indicates the maximum capability in diesel mode of an engine which has not reached the normal operating temperature yet. See [below chapter](#). Loading the engine in gas mode is not possible before reaching the normal operating temperature.

Electric generators must be capable of 10% overload. The maximum engine output is 110% in diesel mode and 100% in gas mode. Transfer to diesel mode takes place automatically in case of overload. Lower than specified methane number may result in automatic transfer to diesel when operating close to 100% output. Load taking ability also suffers from low methane number, [see chart](#). Expected variations in gas fuel quality must be taken into account to ensure that gas operation can be maintained in normal operation.

NOTE
In case of Main or Auxiliary generator applications, 110% output can be utilised for as long as it takes to bring the system back to a safe state with a power demand below 100%.
Overload may never be used on a routine basis, or planned for in the operation of the plant. It is a power reserve for extreme situations.

## 2.3.1 Successive Loading & Unloading

### NOTICE

Important notes:

- 1) Continuous unloading greater than Gas Nominal unloading line/steps can cause trip to diesel due to too high gas delta pressure.
- 2) Loading rates given for CS and VS engines are given for MN  $\geq$  70 gas unless otherwise mentioned
- 3) The stated loading times apply for a running engine and does not include the time taken for gas leakage test, engine acceleration and generator synchronisation / clutching-in.
- 4) Engine is at preheated temperature when HT-cooling water temperature after cylinders is min. 70°C and lubricating oil temperature is min. 40°C.
- 5) Engine is at normal operating temperature when HT-cooling water temperature after the engine is min. 85°C, lube oil temperature is min. 60°C and in gas mode also charge air receiver temperature is ~55°C @0%, ~50°C @50%, or min. 45°C@100%. For indication only, this is typically reached after operating the engine continuously for 30 minutes at  $\geq$  75% load.
- 6) Emergency loading indicates the maximum capacity of the engine in diesel operation. This load ramp causes undesired thermal stress of the engine and repeated use should be avoided.
- 7) Gas mode operation 1200 rpm MN  $\geq$  70, 1000 rpm MN  $\geq$  70 and 900 rpm MN  $\geq$  75. The loading ramp indicates the maximum capacity in gas operation. Faster loading may result in alarms, knock and undesired trips to diesel.

### 2.3.1.1 Constant speed applications

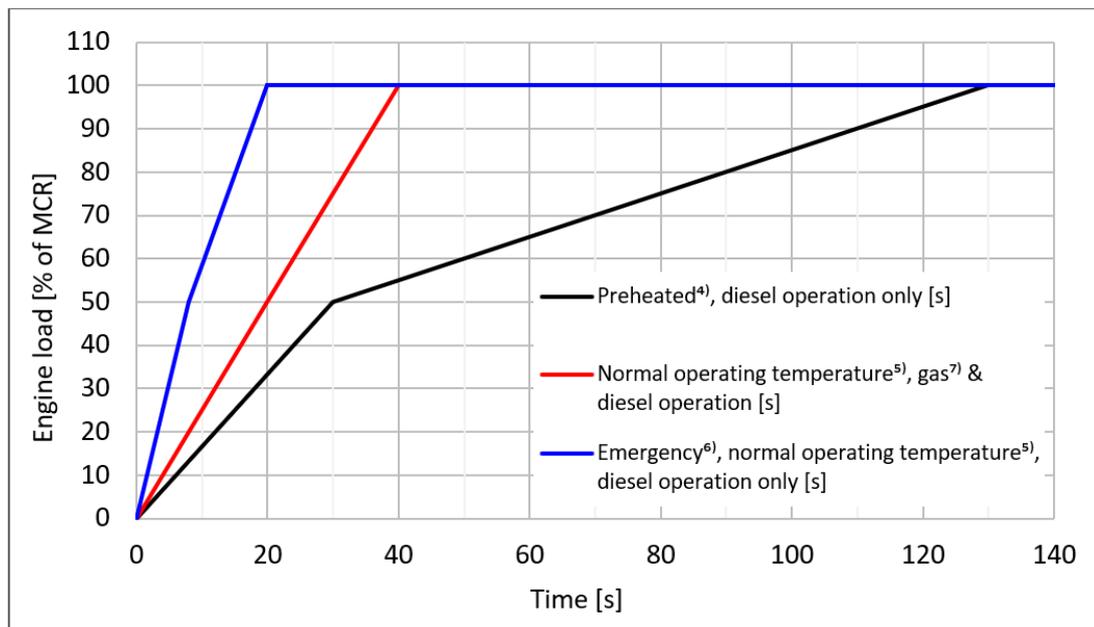
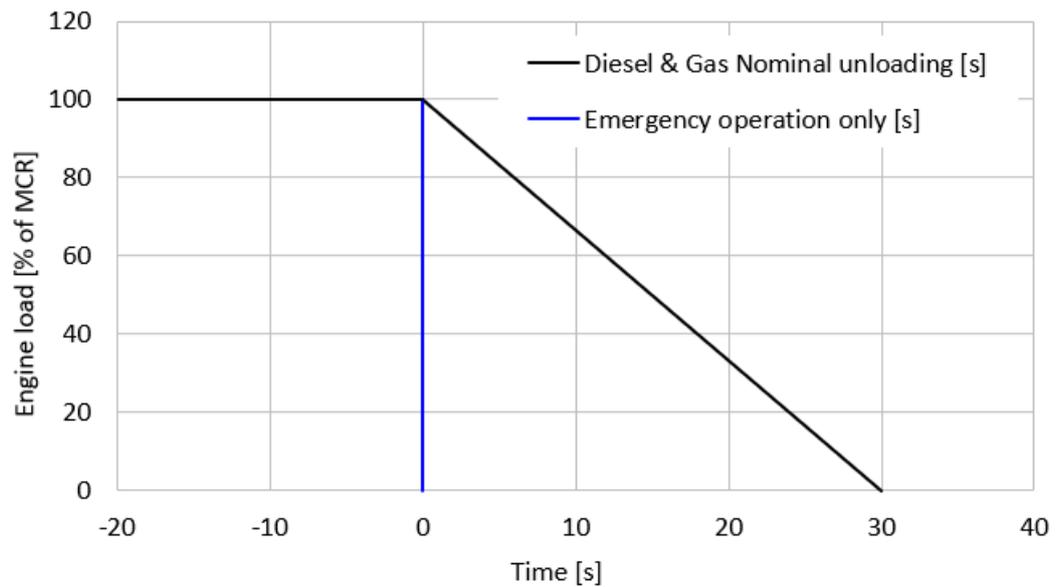


Fig 2-1 Normal Loading rate, CS 1200, 1000 and 900 rpm

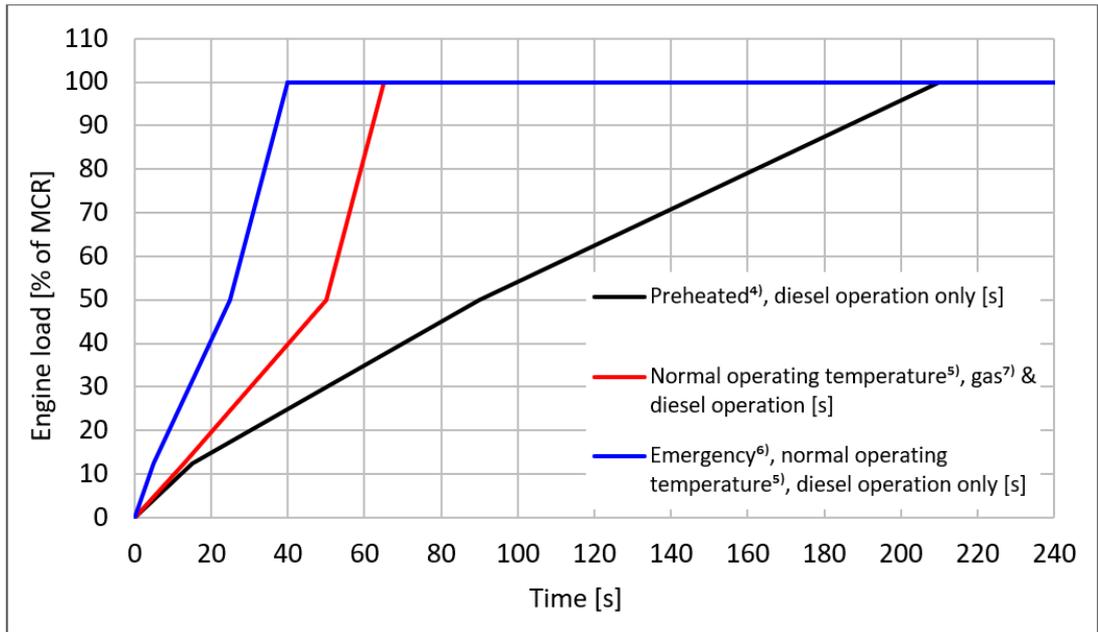


**Fig 2-2 Unloading rate, CS 1200 , 1000 and 900 rpm**

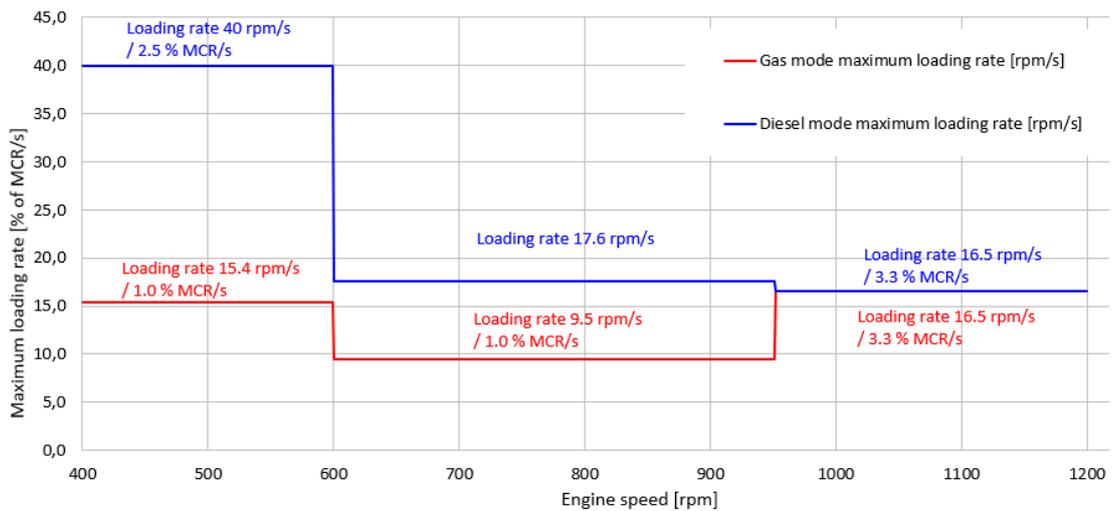
The propulsion control and the power management system must not permit faster load reduction than 15 s from 100% to 0% without automatic transfer to diesel first.

In electric propulsion applications 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, it must be taken into account that the load increase rate of a recently connected generator is the sum of the load transfer performed by the power management system and the load increase performed by the propulsion control.

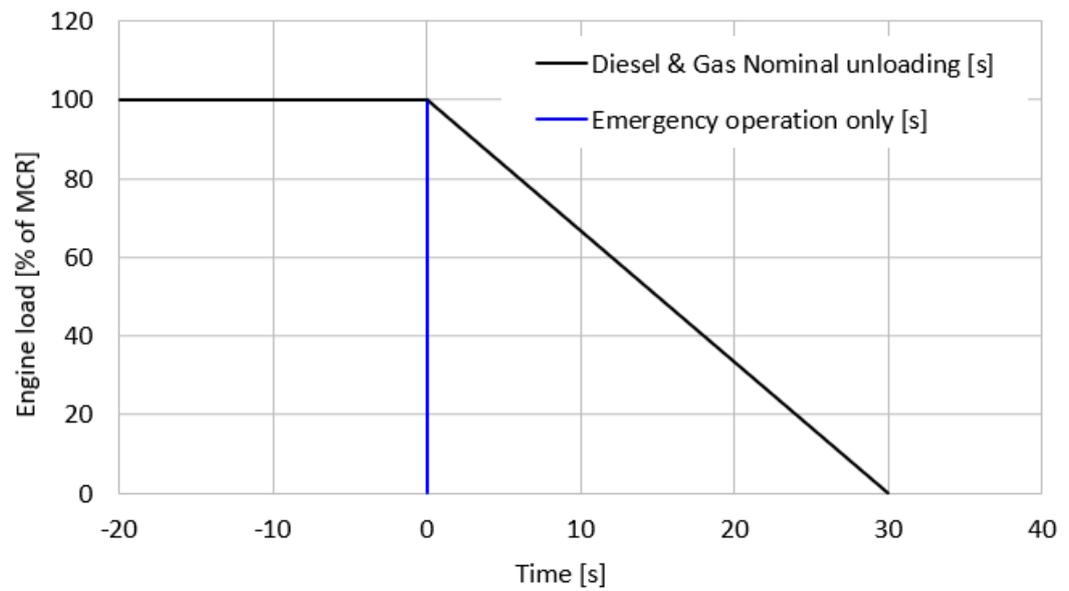
### 2.3.1.2 Mechanical propulsion, variable speed, controllable pitch propeller (CPP)



**Fig 2-3 Normal Loading rate, VS 1200 rpm**



**Fig 2-4 Maximum Loading rate, VS 1200 rpm**



**Fig 2-5 Unloading rate, VS 1200 rpm**

The propulsion control must not permit faster load reduction than 15 s from 100% to 0% without automatic transfer to diesel first.

### 2.3.2 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. If fast load shedding is complicated to implement or undesired, the instant load step capacity can be increased with a fast acting signal that requests transfer to diesel mode.

The maximum permissible load step which may be applied at any given load can be read from the figure below. The values are valid for engines operating in island mode (speed control). Furthermore the stated values are limited to a running engine that has reached nominal operating temperatures, or for an engine which has been operated at above 30% load within the last 30 minutes.

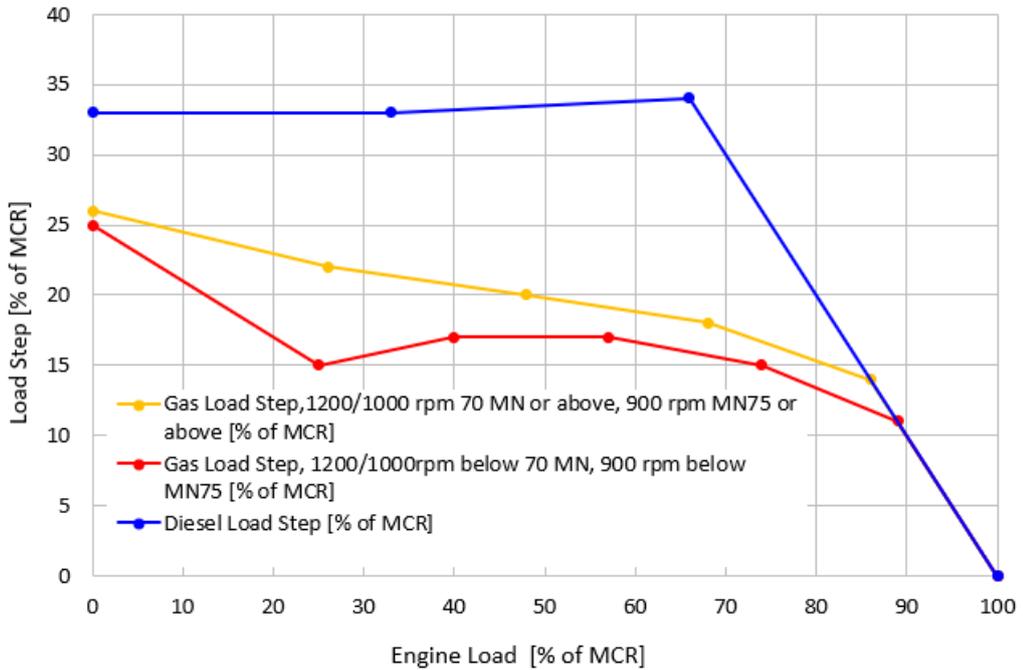


Fig 2-6 Load Steps, CS 1200, 1000 and 900 rpm

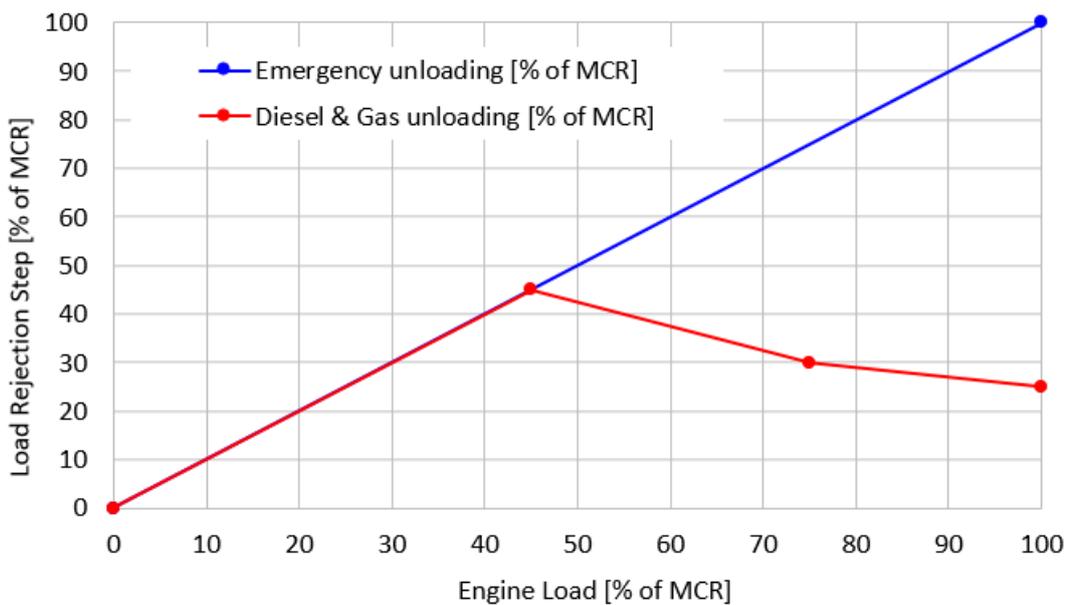


Fig 2-7 Unloading Steps, CS 1200, 1000 and 900 rpm

### 2.3.2.1 Gas mode

- Maximum step-wise load increases according to the figure shown above
  - Steady-state frequency band  $\leq 1.0$  %
  - Maximum speed drop 10 %
- Steady-state recovery time  $\leq 5$  sec.
- Time between load steps of maximum size  $\geq 10$  s
- Maximum step-wise load reductions: 100-75-45-0%

### 2.3.2.2 Diesel mode

- Maximum step-wise load increase 33% of MCR (for engines without SCR, it's 25% for engines with SCR)
  - Steady-state frequency band  $\leq 1.0$  %
  - Maximum speed drop 10 %
  - Steady-state recovery time  $\leq 5$  s
- Time between load steps of maximum size  $\geq 10$  s
- Maximum step-wise load reductions: 100 - 0%

### 2.3.3 Start-up

A stand-by generator reaches nominal speed in 50-70 seconds after the start signal (check of pilot fuel injection is always performed during a normal start).

With black-out start active nominal speed is reached in about 25 s (pilot fuel injection disabled).

The engine can be started with gas mode selected. It will then start using gas fuel as soon as the pilot check is completed and the gas supply system is ready.

The engine can be started, stopped and operated on gas, heavy and light fuel oil under all operating conditions.

## 2.4 Low load operation

### 2.4.1 Operation at low load and idling

<b>NOTE</b>
The below information is valid when the engine is running without a SCR.

The below information is valid when the engine is running without a SCR.

Operating and stopping the engine in gas or diesel operation with the following limits for low load operations:

**Absolute idling (declutched main engine, disconnected generator):**

- Maximum 10 minutes if the engine is to be stopped after the idling. 3 minutes idling before stop is recommended.
- Maximum 6 hours if the engine is to be loaded after the idling.

**Operation below 39 kW/cyl <sup>1)</sup> load on HFO or below 19.5 kW/cyl <sup>2)</sup> load on LFO or gas:**

- Maximum 100 hours continuous operation. At intervals of 100 operating hours the engine must be loaded to minimum 70 % of the rated output for one hours before continuing with low-load operation or shutting down

Operation **at or above 39 kW/cyl** <sup>1)</sup> load on HFO or **at or above 19.5 kW/cyl** <sup>2)</sup> load on LFO or gas:

- No restrictions

1) 20 % from 195 kW/cyl

2) 10 % from 195 kW/cyl

NOTE
The engine can be started and stopped on HFO provided that the engine and the fuel system are pre-heated to operating temperature.

## 2.5 SCR Operation

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

## 2.6 Skip Firing

Skip firing may come into effect in low load operation e.g. at 10% or 25% load for both emissions and loading performance. Please contact Wärtsilä for further information.

## 2.7 Low air temperature

The operating range with Arctic and/or Tropical ambient conditions of Wärtsilä 20DF engine is from -45°C up to +55°C . If these conditions are exceeded, please contact Wärtsilä.

For further guidelines, see chapter [Combustion air system design](#).

## 3. Technical Data

### 3.1 Introduction

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

<b>NOTE</b>
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Fuel consumptions in SCR operation guaranteed only when using Wärtsilä SCR unit.
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<b>NOTE</b>
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For proper operation of the Wärtsilä Nitrogen Oxide Reducer (NOR) systems, the exhaust temperature after the engine needs to be kept within a certain temperature window. Please consult your sales contact at Wärtsilä for more information about SCR Operation.
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## 4. Description of the Engine

### 4.1 Definitions

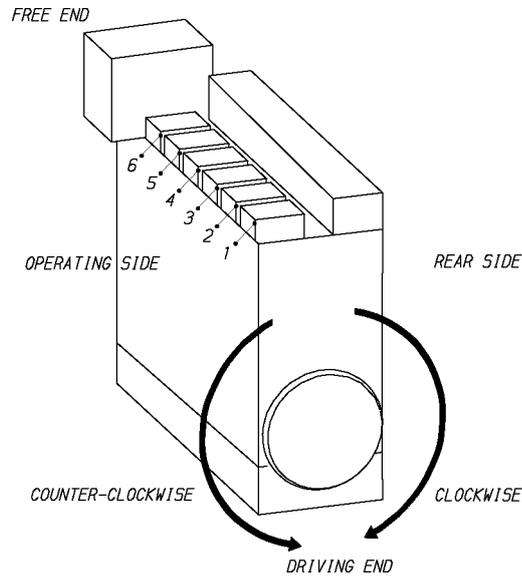


Fig 4-1 In-line engine definitions (V93C0029)

## 4.2 Main components and systems

The dimensions and weights of engines are shown in section [1.6](#).

### 4.2.1 Engine Block

The engine block, made of nodular cast iron, is cast in one piece for all cylinder numbers. It has a stiff and durable design to absorb internal forces and enable the engine to be resiliently mounted without any intermediate foundations.

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

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

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

### 4.2.2 Crankshaft

The crankshaft design is based on a reliability philosophy with very low bearing loads. High axial and torsional rigidity is achieved by a moderate bore to stroke ratio. The crankshaft satisfies the requirements of all classification societies.

The crankshaft is forged in one piece and mounted on the engine block in an under-slung way. The journals are of same size regardless of number of cylinders.

The crankshaft is fully balanced to counteract bearing loads from eccentric masses by fitting counterweights in every crank web. This results in an even and thick oil film for all bearings. If necessary, the crankshaft is provided with a torsional vibration damper.

### 4.2.3 Connection rod

The connecting rods are of three-piece design, which makes it possible to pull a piston without opening the big end bearing. Extensive research and development has been made to develop a connecting rod in which the combustion forces are distributed to a maximum area of the big end bearing.

The connecting rod of alloy steel is forged and has a fully machined shank. The lower end is split horizontally to allow removal of piston and connecting rod through the cylinder liner. All connecting rod bolts are hydraulically tightened. The gudgeon pin bearing is solid aluminium bronze.

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

### 4.2.5 Cylinder liner

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

### 4.2.6 Piston

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

### 4.2.7 Piston rings

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

### 4.2.8 Cylinder head

The cylinder head is made of grey cast iron, the main design criteria being high reliability and easy maintenance. The mechanical load is absorbed by a strong intermediate deck, which together with the upper deck and the side walls form a box section in the four corners of which the hydraulically tightened cylinder head bolts are situated.

The cylinder head features two inlet and two exhaust valves per cylinder. All valves are equipped with valve rotators. No valve cages are used, which results in very good flow dynamics. The basic criterion for the exhaust valve design is correct temperature by carefully controlled water cooling of the exhaust valve seat. The thermally loaded flame plate is cooled efficiently by cooling water led from the periphery radially towards the centre of the head. The bridges between the valves cooling channels are drilled to provide the best possible heat transfer.

## 4.2.9 Camshaft and valve mechanism

There is one cam piece for each cylinder with separate bearing pieces in between. The cam and bearing pieces are held together with flange connections. This solution allows removing of the camshaft pieces sideways. The drop forged completely hardened camshaft pieces have fixed cams. The camshaft bearing housings are integrated in the engine block casting and are thus completely closed. The bearings are installed and removed by means of a hydraulic tool. The camshaft covers, one for each cylinder, seal against the engine block with a closed O-ring profile. The valve mechanism guide block is integrated into the cylinder block. The valve tappets are of piston type with self-adjustment of roller against cam to give an even distribution of the contact pressure. Double valve springs make the valve mechanism dynamically stable.

## 4.2.10 Camshaft drive

The camshafts are driven by the crankshaft through a gear train. The driving gear is fixed to the crankshaft by means of flange connection. The intermediate gear wheels are fixed together by means of a hydraulically tightened central bolt.

## 4.2.11 Fuel system

The Wärtsilä 20DF engine is designed for continuous operation on fuel gas (natural gas) or Marine Diesel Fuel (LFO). It is also possible to operate the engine on Heavy Fuel Oil (HFO). Dual fuel operation requires external gas feed system and fuel oil feed system. For more details about the fuel system see chapter [Fuel System](#).

### 4.2.11.1 Fuel gas system

The fuel gas system on the engine comprises the following built-on equipment:

- Low-pressure fuel gas common rail pipe
- Gas admission valve for each cylinder
- Safety filters at each gas admission valve
- Common rail pipe venting valve
- Double wall gas piping

The gas common rail pipe delivers fuel gas to each admission valve. The common rail pipe is a fully welded double wall pipe, with a large diameter, also acting as a pressure accumulator. Feed pipes distribute the fuel gas from the common rail pipe to the gas admission valves located at each cylinder.

The gas admission valves (one per cylinder) are electronically controlled and actuated to feed each individual cylinder with the correct amount of gas. The gas admission valves are controlled by the engine control system to regulate engine speed and power. The valves are located on the intake duct of the cylinder head. The gas admission valve is a direct actuated solenoid valve. The valve is closed by a spring (positive sealing) when there is no electrical signal. With the engine control system it is possible to adjust the amount of gas fed to each individual cylinder for load balancing of the engine, while the engine is running. The gas admission valves also include safety filters (80 µm).

The venting valve of the gas common rail pipe is used to release the gas from the common rail pipe when the engine is transferred from gas operating mode to diesel operating mode. The valve is pneumatically actuated and controlled by the engine control system.

### 4.2.11.2 Main fuel oil injection system

The main fuel oil injection system is in use when the engine is operating in diesel mode. When the engine is operating in gas mode, fuel flows through the main fuel oil injection system at all times enabling an instant transfer to diesel mode.

The engine internal main fuel oil injection system comprises the following main equipment for each cylinder:

- Fuel injection pump
- High pressure pipe
- Double fuel injection valve (for main and pilot injection)

The fuel injection pump design is of the mono-element type designed for injection pressures up to 150 MPa. The injection pumps have built-in roller tappets, and are also equipped with pneumatic stop cylinders, which are connected to overspeed protection system.

The high-pressure injection pipe runs between the injection pump and the injection valve. The pipe is of double wall shielded type and well protected inside the engine hot box.

The injection valve consist of a main fuel injection valve and a separate pilot fuel injection valve. The main fuel injection valve is centrally located in the cylinder head. The pilot fuel valve is located at the side.

The hotbox encloses all main fuel injection equipment and system piping, providing maximum reliability and safety. The high pressure side of the main injection system is thus completely separated from the exhaust gas side and the engine lubricating oil spaces. Any leakage in the hot box is collected to prevent fuel from mixing with lubricating oil. For the same reason the injection pumps are also completely sealed off from the camshaft compartment.

### 4.2.11.3 Pilot fuel injection system

The pilot fuel injection system is used to ignite the air-gas mixture in the cylinder when operating the engine in gas mode. The pilot fuel system comprises the following built-on equipment:

- Pilot fuel oil filter
- Common rail high pressure pump
- Common rail piping
- Pilot fuel oil injection valve for each cylinder

The pilot fuel filter is a full flow duplex unit preventing impurities entering the pilot fuel system. The filtration degree is  $\beta_{4,5} = 1000$ , ISO16889.

The high pressure pilot fuel pump is an engine-driven pump located at the driving end of the engine. The fuel oil pressure is elevated by the pilot pump to required level. The engine control system monitors and controls the pressure level during engine run.

Pressurized pilot fuel is delivered from the pump unit into a small diameter common rail pipe. The common rail pipe delivers pilot fuel to each injection valve and acts as a pressure accumulator against pressure pulses. The high pressure piping is of double wall shielded type and well protected inside the hot box. The feed pipes distribute the pilot fuel from the common rail to the injection valves.

The pilot fuel oil injection valve needle is actuated by a solenoid, which is controlled by the engine control system. The pilot diesel fuel is admitted through a high pressure connection screwed in the nozzle holder. When the engine runs in diesel mode the pilot fuel injection is also in operation to keep the needle clean.

## 4.2.12 Exhaust pipes

The exhaust pipes are made of special heat resistant nodular cast iron alloy. The complete exhaust system is enclosed in an insulating box made of insulated sandwich steel sheets, easily removable. Mineral wool is used as insulating material.

## 4.2.13 Lubricating oil system

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

## 4.2.14 Cooling system

The fresh water cooling system is divided into a high temperature (HT) and a low temperature (LT) circuit. The HT-water cools cylinder liners, cylinder heads. The LT-water cools the charge air cooler and the lubricating oil.

## 4.2.15 Turbocharging and charge air cooling

The 185kW engine version is equipped with SPEX (Single Pipe Exhaust system) turbocharging system, which combines the advantages of both pulse and constant pressure systems. The complete exhaust gas manifold is enclosed by a heat insulation box to ensure low surface temperatures.

The turbocharger is installed transversely and is located in the free end of the engine as standard. As option, the turbocharger can be located in the driving end of the engine. Vertical, longitudinally inclined, and horizontal exhaust gas outlets are available.

In order to optimize the turbocharging system for both high and low load performance, as well as diesel and gas mode operation, a pressure relief valve system "air waste gate (AWG)" is installed in the charge air circuit. The AWG reduce the charge air pressure by bleeding air from the charge air system. The air is simply blown out into the atmosphere / engine room through the silencer unit.

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

For cleaning of the turbocharger during operation there is, as standard, a water-washing device for the air side as well as the exhaust gas side.

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

## 4.2.16 Automation system

Wärtsilä 20DF is equipped with a modular embedded automation system, Wärtsilä Unified Controls - UNIC.

The UNIC system have hardwired interface for control functions and a bus communication interface for alarm and monitoring. A engine safety module and a local control panel are mounted on the engine. The engine safety module handles fundamental safety, for example overspeed and low lubricating oil pressure shutdown. The safety module also performs fault detection on critical signals and alerts the alarm system about detected failures. The local control panel has push buttons for local start/stop and shutdown reset, as well as a display showing the most important operating parameters. Speed control is included in the automation system on the engine.

All necessary engine control functions are handled by the equipment on the engine, bus communication to external systems, a more comprehensive local display unit, and fuel injection control.

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

## 4.3 Cross section of the engine

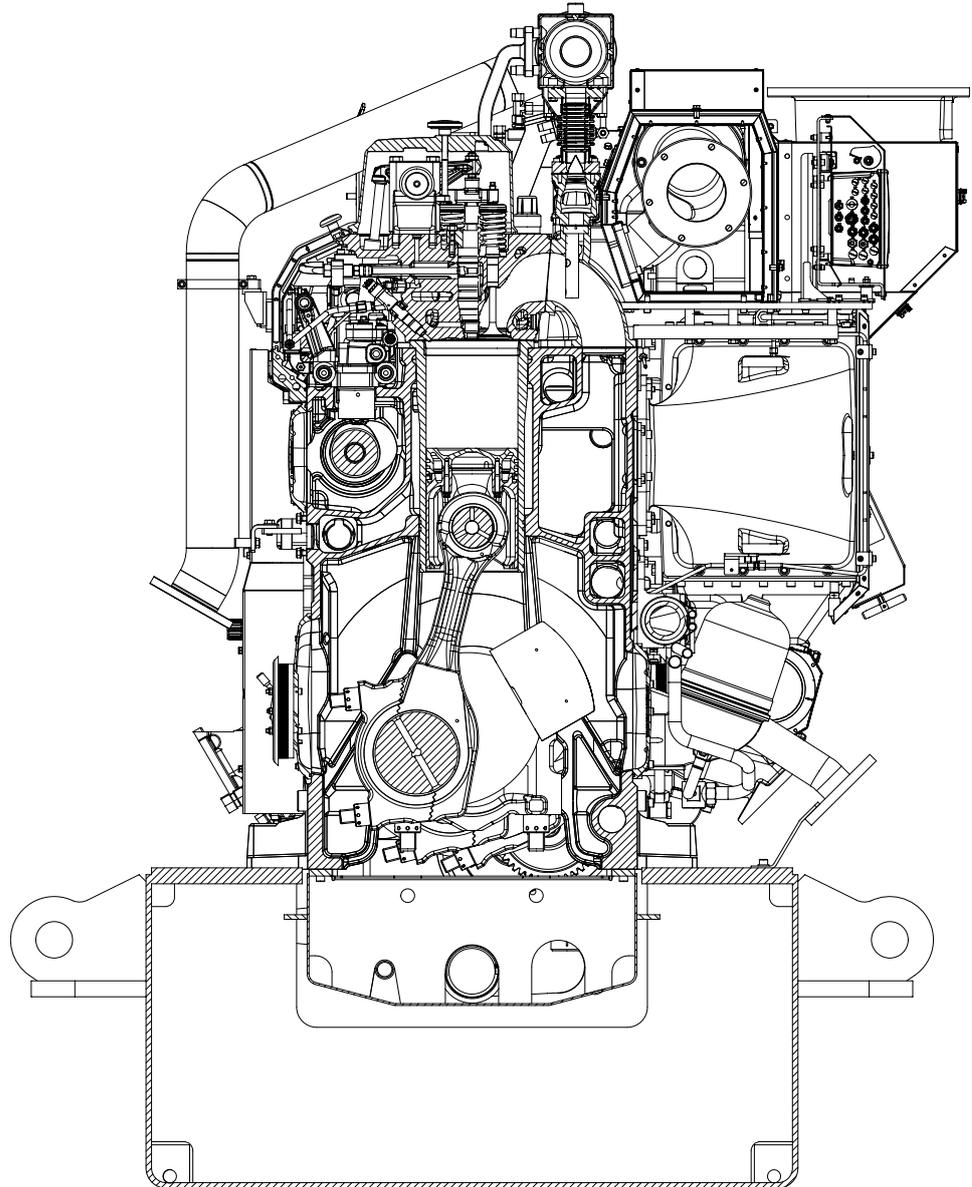


Fig 4-2 Cross sections of the engine (DAAF509337)

## 4.4 Time between inspection or Overhaul & Expected Life Time

<b>NOTE</b>	
<ul style="list-style-type: none"> <li>Achieved life times very much depend on the operating conditions, average loading of the engine, fuel quality used, fuel handling systems, performance of maintenance etc</li> <li>Expected lifetime is different depending on HFO1 or HFO2 used. For detailed information of HFO1 and HFO2 qualities, please see <a href="#">Heavy Fuel Oil</a>.</li> </ul>	

**Table 4-1 Time Between Overhaul and Expected Life Time**

Component	Time between inspection or overhaul (h)		Expected life time (h)	
	HFO1/ HFO2 <sup>1)</sup>	LFO/ GAS	HFO1/ HFO2 <sup>1)</sup>	LFO/ GAS
Piston	14000/ 10000	20000	48000/ 42000	60000
Piston rings	14000/ 10000	20000	14000/ 10000	20000
Cylinder liner	14000/ 10000	20000	60000/ 48000	80000
Cylinder head	14000/ 10000	20000	56000/ 50000	60000
Inlet valve	10000	10000	42000/ 30000	48000
Exhaust valve	10000	10000	28000 / 20000	40000
Main bearing	14000/ 10000	20000	48000/ 42000	60000
Big end bearing	14000/ 10000	20000	20000/ 20000	20000
Injection valve nozzle	2000	2000	4000/ 4000	4000
Injection pump element	14000/ 10000	20000	28000/ 20000	28000
Pilot injection valve	8000	8000	-	10000
Pilot fuel pump	8000	8000	-	12000
Main gas admission valve	-	10000	-	10000

<b>NOTE</b>	
1) For detailed information of HFO1 and HFO2 qualities, please see <a href="#">Heavy Fuel Oil</a> .	
2) If engine is operated with ultra-low sulphur fuel oil or gas fuel, Nimonic Exhaust valves lifetime is limited to 12000h.	

<b>NOTE</b>	
Turbocharger lifetime for W20DF Dredger applications are 25000 hours for Constant Speed engines and 50000 hours for Constant Torque engines.	

**NOTE**

Inspection of one cylinder head after 10000 running hours.

## 4.5 Engine storage

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

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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 project specific instructions delivered for each installation.

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

Gas piping between Gas Valve Unit and the engine is to be made of stainless steel.

### **NOTICE**

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

### **NOTICE**

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

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

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

#### **The following aspects shall be taken into consideration:**

- Pockets shall be avoided. When not possible, drain plugs and air vents shall be installed
- Leak fuel drain pipes shall have continuous slope
- Vent pipes shall be continuously rising
- Flanged connections shall be used, cutting ring joints for precision tubes
- Flanged connections shall be used in fuel oil, lubricating oil, compressed air and fresh water piping
- Welded connections (TIG) must be used in gas fuel piping as far as practicable, but flanged connections can be used where deemed necessary

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

### 5.1 Pipe dimensions

#### **When selecting the pipe dimensions, take into account:**

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

- In open circuits the velocity in the suction pipe is typically about  $2/3$  of the velocity in the delivery pipe.

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

Piping	Pipe material	Max velocity [m/s]
LNG piping	Stainless steel	3
Fuel gas piping	Stainless steel / Carbon steel	20
Fuel oil piping	Black steel	1.0
Lubricating oil piping	Black steel	1.5
Fresh water piping	Black steel	2.5
Sea water piping	Galvanized steel	2.5
	Aluminum brass	2.5
	10/90 copper-nickel-iron	3.0
	70/30 copper-nickel	4.5
	Rubber lined pipes	4.5

**NOTICE**

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

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

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

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

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

## 5.2 Trace heating

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

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

## 5.3 Pressure class

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

**The pressure in the system can:**

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

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

**Example 1:**

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

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

**Example 2:**

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

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

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

## 5.4 Pipe class

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

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

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

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

Gas piping is to be designed, manufactured and documented according to the rules of the relevant classification society.

In the absence of specific rules or if less stringent than those of DNV, the application of DNV rules is recommended.

Relevant DNV rules:

- Ship Rules Part 4 Chapter 6, Piping Systems
- Ship Rules Part 5 Chapter 5, Liquefied Gas Carriers

- Ship Rules Part 6 Chapter 13, Gas Fuelled Engine Installations

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

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

## 5.5 Insulation

The following pipes shall be insulated:

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

Insulation is also recommended for:

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

## 5.6 Local gauges

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

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

## 5.7 Cleaning procedures

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

### 5.7.1 Cleanliness during pipe installation

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

Piping cleaning methods are summarised in table below:

**Table 5-3 Pipe cleaning**

System	Methods
Fuel gas	A,B,C D,F <sup>1)</sup>
Fuel oil	A,B,C,D,F
Lubricating oil	A,B,C,D,F

**Table 5-3 Pipe cleaning (continued)**

System	Methods
Starting air	A,B,C
Cooling water	A,B,C
Exhaust gas	A,B,C
Charge air	A,B,C

1) In case of carbon steel pipes

**Methods applied during prefabrication of pipe spools**

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

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

*D = Pickling (not required for seamless precision tubes)*

**Methods applied after installation onboard**

*C = Purging with compressed air*

*F = Flushing*

## 5.7.2 Fuel oil pipes

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

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

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

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

**NOTICE**

The engine must not be connected during flushing.

## 5.7.3 Lubricating oil pipes

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

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

sump or to the external engine wise oil tank shall be flushed. Oil used for filling shall have a cleanliness of ISO 4406 © 21/19/15, or NAS 1638 code 10.

<b>NOTICE</b>
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The engine must not be connected during flushing.
---

### 5.7.4 Pickling

Prefabricated pipe spools are pickled before installation onboard.

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

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

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

## 5.8 Flexible pipe connections

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

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

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

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

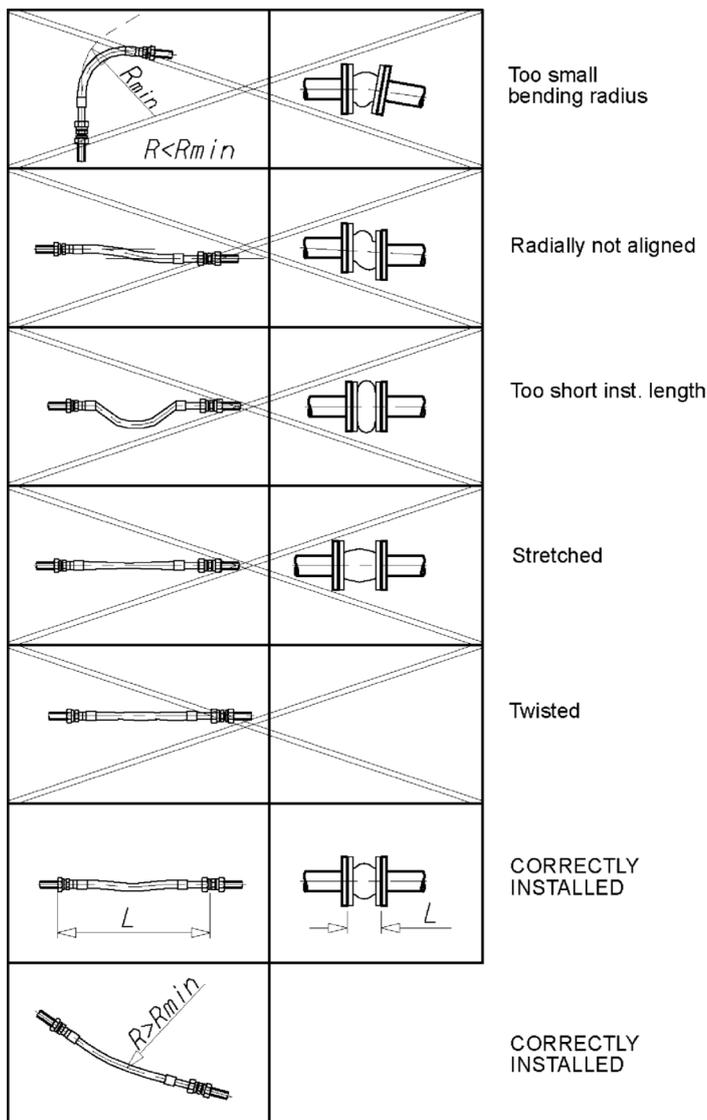


Fig 5-1 Flexible hoses

**NOTICE**

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

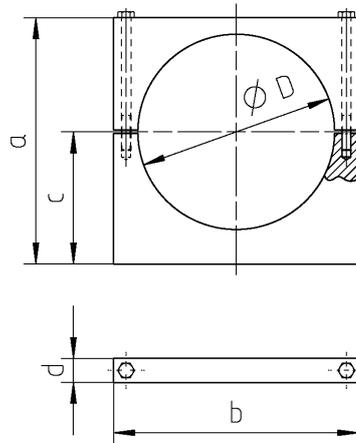
## 5.9 Clamping of pipes

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

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

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

SUPPORTS AFTER FLEXIBLE BELLOW (FIXED) DN 25–300



DN	$d_u$ mm	D mm	a mm	b mm	c mm	d mm	BOLTS
25	33.7	35	150	80	120	25	M10x50
32	42.4	43	150	75	120	25	M10x50
40	48.3	48	154.5	100	115	25	M12x60
50	60.3	61	185	100	145	25	M12x60
65	76.1	76.5	191	115	145	25	M12x70
80	88.9	90	220	140	150	30	M12x90
100	114.3	114.5	196	170	121	25	M12x100
125	139.7	140	217	200	132	30	M16x120
150	168.3	170	237	240	132	30	M16x140
200	219.1	220	295	290	160	30	M16x160
250	273.0	274	355	350	190	30	M16x200
① 300	323.9	325	410	405	220	40	M16x220

$d_u$  = Pipe outer diameter

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

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## 6. Fuel System

### 6.1 Acceptable fuel characteristics

#### 6.1.1 Gas fuel specification

As a dual fuel engine, the Wärtsilä 20DF engine is designed for continuous operation in gas operating mode or diesel operating mode. For continuous operation in the rated output, the gas used as main fuel in gas operating mode has to fulfill the below mentioned quality requirements.

##### 6.1.1.1 Gas Fuel

###### Limit values for gas characteristics

The engine is designed and developed for continuous operation on natural gas, without reduction in the rated output, on gas qualities according to following specification:

Property	Unit	Limit	Test method reference
Lower Heating Value (LHV <sub>V</sub> ), min. <sup>a)</sup>	MJ/m <sup>3</sup> N <sup>b)</sup>	26	ISO 6976
Methane Number (MN), min. <sup>*)</sup>		Please refer to <a href="#">Output limitations due to methane number</a>	
Methane (CH <sub>4</sub> ) content, min. <sup>c)</sup>	% v/v	70	ISO 6974
Hydrogen sulphide (H <sub>2</sub> S) content, max.	% v/v	0.05	ISO 19739
Hydrogen (H <sub>2</sub> ) content, max. <sup>d)</sup>	% v/v	3.0	ASTM D7833 mod.
Liquid phase water and hydrocarbon condensate bef. engine, max. <sup>e)</sup>	% v/v	Not allowed	
Oil content	mg/m <sup>3</sup> N	2.0	
Ammonia content, max.	mg/m <sup>3</sup> N	25	Honeywell SPX Flex Gas Detector
Chlorine + Fluorine content, max.	mg/m <sup>3</sup> N	50	UOP 1001, ASTM D 7359 mod.
Particles or solids content in engine inlet, max.	mg/m <sup>3</sup> N	50	ISO 4406 mod., IP 565 mod.
Particles or solids size in engine inlet, max.	µm	5	ISO 4406 mod., IP 565 mod.
Gas inlet temperature	°C	0...60	

**NOTICE**

Note a The required gas feed pressure is depending on the Lower Heating Value (LHV) of the gas.

Note b Values for volume (m<sup>3</sup>N) are given at 0 °C and 101,3 kPa

Note c Instead of fossil methane gas is also allowed to contain biomethane and / or synthetic methane provided that the gas specification is still fulfilled and the gas quality is not deteriorated. The use of untreated biogas containing harmful compounds like e.g. silicates is however not allowed.

Note d If the hydrogen (H<sub>2</sub>) content of gas is higher than 3,0 % v/v but less than 15% v/v, please contact Wärtsilä for further evaluation. If hydrogen (H<sub>2</sub>) is added to gas, it has to be taken into account that Methane Number (MN) derating rules do still apply.

Note e In the specified operating conditions (temperature and pressure) dew point of natural gas has to be low enough in order to prevent any formation of condensate.

There is available an international ISO 23306:2020 standard: "Specification of liquefied natural gas as a fuel for marine applications" and though Wärtsilä gas specification is not identical with the standard content, the standard anyway offers useful information about LNG properties, sampling, MN calculation, ageing of gas, bunkering chain and gas contamination.

Engine output is depending on the Methane Number.

Methane Number (MN) can be assigned to any gaseous fuel indicating the percentage by volume of methane in blend with hydrogen that exactly matches the knock intensity of the unknown gas mixture under specified operating conditions in a knock testing engine. The Methane Number (MN) gives a scale for evaluation of the resistance to knock of gaseous fuels.

\*) Given Methane Number limits are valid for charge air temperature of 45 °C. See MN limit related details in the above mentioned documents.

To define the Methane Number (MN) of the gas, the method included in the EN 16726-2015 standard shall be used. Additionally, Wärtsilä has developed an internal MN calculator which is based on the Propane Knock Index (PKI) calculator included in the ISO 23306:2020 standard.

Depending on the gas composition, the MN results obtained with those two methods can differ from each other, and therefore it is recommended to calculate MN also with the Wärtsilä method. If the difference of MN for a specific gas quality calculated with the two above mentioned methods is bigger than 3 units, please contact Wärtsilä for further evaluation.

Additionally, if the total concentration of the heavier hydrocarbons than butane (C<sub>4</sub>), i.e. pentane (C<sub>5</sub>), hexane (C<sub>6</sub>), heptane (C<sub>7</sub>), etc. exceeds 1,0 % v/v, please contact Wärtsilä for further evaluation.

## 6.1.2 Liquid fuel specification

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 shown below.

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.

### 6.1.2.1 Pilot fuel oil

The optimum engine performance is achieved with fuel fulfilling the requirements in [table](#) below. However, normal operation of the engine is fully possible with a fuel according to the ISO 8217:2017(E) with a possible impact on the engine efficiency. In case of questions regarding the engine performance please contact Wärtsilä.

**Table 6-1 Pilot fuel oil**

Property	Unit	ISO-F-DMA	ISO-F-DMZ	ISO-F-DMB	Test method ref.
Cetane index, min.	-	50	50	50	ISO 4264

### 6.1.2.2 Light fuel oil operation

The fuel specification is based on the ISO 8217:2017(E) standard and covers the fuel grades ISO-F-DMX, DMA, DFA, DMZ, DFZ, DMB and DFB.

The distillate grades mentioned above can be described as follows:

- **DMX:** A fuel quality which is suitable for use at ambient temperatures down to  $-15\text{ °C}$  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.
- **DMA:** A high quality distillate, generally designated MGO (Marine Gas Oil) in the marine field.
- **DFA:** A similar quality distillate fuel compared to DMA category fuels but a presence of max. 7,0% v/v of Fatty acid methyl ester (FAME) is allowed.
- **DMZ:** A high quality distillate, generally designated MGO (Marine Gas Oil) in the marine field. An alternative fuel grade for engines requiring a higher fuel viscosity than specified for DMA grade fuel.
- **DFZ:** A similar quality distillate fuel compared to DMZ category fuels but a presence of max. 7,0% v/v of Fatty acid methyl ester (FAME) is allowed.
- **DMB:** A general purpose fuel which may contain trace amounts of residual fuel and is intended for engines not specifically designed to burn residual fuels. It is generally designated MDO (Marine Diesel Oil) in the marine field.
- **DFB:** A similar quality distillate fuel compared to DMB category fuels but a presence of max. 7,0% v/v of Fatty acid methyl ester (FAME) is allowed.

For maximum fuel temperature before the engine, please refer to [Engine Online Configurator](#) available through Wärtsilä website.

**Table 6-2 Light fuel oils**

Characteristics	Unit	Limit	Category ISO-F						Test method(s) and references
			DMX	DMA	DFA	DMZ	DFZ	DMB	
Kinematic viscosity at 40 °C <sup>i)</sup>	mm <sup>2</sup> /s <sup>a)</sup>	Max	5,500	6,000	6,000	11,00			ISO 3104
		Min	1,400 <sup>i)</sup>	2,000	3,000	2,000			
Density at 15 °C	kg/m <sup>3</sup>	Max	-	890,0	890,0	900,0			ISO 3675 or ISO 12185
Cetane index <sup>j)</sup>		Min	45	40	40	35			ISO 4264
Sulphur <sup>b, k)</sup>	% m/m	Max	0,50	0,50	0,50	0,50			ISO 8754 or ISO 14596, ASTM D4294
Flash point	°C	Min	43,0 <sup>l)</sup>	60,0	60,0	60,0			ISO 2719
Hydrogen sulfide	mg/kg	Max	2,00	2,00	2,00	2,00			IP 570

**Table 6-2 Light fuel oils (continued)**

Characteristics	Unit	Limit	Category ISO-F						Test method(s) and references
			DMX	DMA	DFA	DMZ	DFZ	DMB	
Acid number	mg KOH/g	Max	0,5	0,5	0,5	0,5	0,5	ASTM D664	
Total sediment by hot filtration	% m/m	Max	-	-	-	0,10 <sup>c)</sup>	ISO 10307-1		
Oxidation stability	g/m <sup>3</sup>	Max	25	25	25	25 <sup>d)</sup>	ISO 12205		
Fatty acid methyl ester (FAME) <sup>e)</sup>	% v/v	Max	-	-	7,0	-	7,0	ASTM D7963 or IP 579	
Carbon residue – Micro method on 10% distillation residue	% m/m	Max	0,30	0,30	0,30	-	ISO 10370		
Carbon residue – Micro method	% m/m	Max	-	-	-	0,30	ISO 10370		
Cloud point <sup>f)</sup>	winter	°C	Max	-16	Report	Report	-	ISO 3015	
	summer			-16	-	-	-		
Cold filter plugging point <sup>f)</sup>	winter	°C	Max	-	Report	Report	-	IP 309 or IP 612	
	summer			-	-	-	-		
Pour point <sup>f)</sup>	winter	°C	Max	-	-6	-6	0	ISO 3016	
	summer			-	0	0	6		
Appearance			Clear and bright <sup>g)</sup>				c)	-	
Water	% v/v	Max	-	-	-	0,30 <sup>c)</sup>	ISO 3733, ASTM D6304-C <sup>m)</sup>		
Ash	% m/m	Max	0,010	0,010	0,010	0,010	ISO 6245		
Lubricity, corr. wear scar diam. <sup>h)</sup>	µm	Max	520	520	520	520 <sup>d)</sup>	ISO 12156-1		

**NOTICE**

- a) 1 mm<sup>2</sup>/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 plugging point) are suitable for ship's design and intended voyage.
- g) If the sample is dyed and not transparent, see ISO 8217:2017(E) standard for details related to water analysis limits and test methods.
- h) The requirement is applicable to fuels with a sulphur content below 500 mg/kg (0,050 % m/m).

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

- i) Low min. viscosity of 1,400 mm<sup>2</sup>/s can prevent the use of ISO-F-DMX category fuels in Wärtsilä® engines unless a fuel can be cooled down enough to meet the min. injection viscosity limits stated in table "Kinematic viscosity before fuel pumps" below.
- j) -
- k) There doesn't exist any minimum sulphur content limit for Wärtsilä® DF 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 of 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.

**Pilot fuel quality in GAS operation**

In order to provide the engine efficiency in GAS operation stated in this document while also complying to IMO Tier III NO<sub>x</sub> legislation when running in GAS operation, the pilot fuel shall fulfil the characteristics specified in table 6-2, except that the following additional requirements are valid for Cetane Index related to ISO 8217:2017(E) fuel categories DMX, DMA, DFA, DMZ, DFZ, DMB and DFB.

The optimum engine performance is achieved with fuel fulfilling the requirements in table below.

**NOTICE**

Engine efficiency is depending on Cetane Index of pilot fuel and an optimum efficiency is not achieved if using a fuel quality having Cetane Index at a min. limit stated in the table above. In case of questions regarding the engine performance please contact Wärtsilä.

**Table 6-3 Pilot fuel oils**

Characteristics	Unit	Limit	Test method reference
Cetane index, min.	-	50	ISO 4264

### Minimum injection viscosity and temperature limits before pilot and main fuel injection pumps

The limit values below are valid for distillate fuels categories DMX, DMA, DFA, DMZ, DFZ, DMB and DFB included in the ISO 8217:2017(E) fuel standard:

**Table 6-4 Kinematic viscosity before fuel pumps**

Characteristics	Unit	Limit
<ul style="list-style-type: none"> <li>Kinematic viscosity before pilot fuel pump, min.</li> <li>Kinematic viscosity before pilot fuel pump, max.</li> </ul>	mm <sup>2</sup> /s <sup>a)</sup>	<ul style="list-style-type: none"> <li>1,8</li> <li>11,0</li> </ul>
<ul style="list-style-type: none"> <li>Kinematic viscosity before standard main fuel pump, min.</li> <li>Kinematic viscosity before standard main fuel pump, max.</li> </ul>	mm <sup>2</sup> /s <sup>a)</sup>	<ul style="list-style-type: none"> <li>1,8</li> <li>24,0</li> </ul>

#### NOTE

a) 1 mm<sup>2</sup>/s = 1 cSt.

Fuel temperature before pilot fuel pump is allowed to be min. +5 °C and max. +50 °C.

### 6.1.2.3

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

Due to the tightened sulphur emission legislation being valid since 01.01.2015 in the specified Sulphur Emission Control Areas (SECA) areas many new max. 0,10% m/m sulphur content fuels have entered the market. Some of these fuels are not pure distillate fuels, but they contain new refinery streams, like hydrocracker bottoms or are blends of distillate and residual fuels.

The new 0,10% m/m sulphur fuels are called as Ultra Low Sulphur Fuel Oils (ULSFO RM) or sometimes also as “hybrid fuels”, since those can contain properties of both distillate and residual fuels. In the existing ISO 8217:2017(E) standard the fuels are classed as RMA 10, RMB 30 or RMD 80, etc., if not fulfilling the DM grade category requirements, though from their properties point of view this is generally not an optimum approach. These fuels can be used in back-up and diesel mode, but special attention shall be paid to optimum operating conditions.

The ULSFO RM category fuels are not allowed to be used as a pilot fuel, but only distillate fuel qualities specified in chapter "Distillate fuel oil operation" are allowed. The table below shows the RMA 10 – RMD 80 categories, to which the most of these fuels belong, though some may also have higher viscosity.

See also Services Instruction WS02Q312.

Characteristics	Unit	RMA 10	RMB 30	RMD 80	Test method reference
Kinematic viscosity bef. injection pumps <sup>c)</sup>	mm <sup>2</sup> /s <sup>a)</sup>	6,0 - 24	6,0 - 24	6,0 - 24	-
Kinematic viscosity at 50 °C, max.	mm <sup>2</sup> /s <sup>a)</sup>	10,00	30,00	80,00	ISO 3104
Density at 15 °C, max.	kg/m <sup>3</sup>	920,0	960,0	975,0	ISO 3675 or ISO 12185
CCAI, max. <sup>e)</sup>	-	850	860	860	ISO 8217, Annex F
Sulphur, max. <sup>b)</sup>	% m/m	0,10	0,10	0,10	ISO 8574 or ISO 14596

(continued)

Characteristics	Unit	RMA 10	RMB 30	RMD 80	Test method reference
Flash point, min.	°C	60,0	60,0	60,0	ISO 2719
Hydrogen sulfide, max.	mg/kg	2,00	2,00	2,00	IP 570
Acid number, max.	mg KOH/g	2,5	2,5	2,5	ASTM D664
Total sediment aged, max.	% m/m	0,10	0,10	0,10	ISO 10307-2
Carbon residue, micro method, max.	% m/m	2,50	10,00	14,00	ISO 10370
Asphaltenes, max. c)	% m/m	1,5	6,0	8,0	ASTM D3279
Pour point (upper), max., winter quality d)	°C	0	0	30	ISO 3016
Pour point (upper), max., summer quality d)	°C	6	6	30	ISO 3016
Water max.	% v/v	0,30	0,50	0,50	ISO 3733 or ASTM D6304-C c)
Water bef. engine, max. c)	% v/v	0,30	0,30	0,30	ISO 3733 or ASTM D6304-C c)
Ash, max.	% m/m	0,040	0,070	0,070	ISO 6245 or LP1001 c, h)
Vanadium, max. f)	mg/kg	50	150	150	IP 501, IP 470 or ISO 14597
Sodium, max. f)	mg/kg	50	100	100	IP 501 or IP 470
Sodium bef. engine, max. c, f)	mg/kg	30	30	30	IP 501 or IP 470
Aluminium + Silicon, max.	mg/kg	25	40	40	IP 501, IP 470 or ISO 10478
Aluminium + Silicon bef. engine, max. c)	mg/kg	15	15	15	IP 501, IP 470 or ISO 10478
Used lubricating oil: g) - Calcium, max. - Zinc, max. - Phosphorus, max.	mg/kg mg/kg mg/kg	30 15 15	30 15 15	30 15 15	IP 501 or IP 470 IP 501 or IP 470 IP 501 or IP 500

**NOTICE**

- a)** 1 mm<sup>2</sup>/s = 1 cSt.
- b)** The purchaser shall define the maximum sulphur content in accordance with relevant statutory limitations.
- c)** Additional properties specified by the engine manufacturer, which are not included in the ISO 8217:2017(E) standard.
- d)** Purchasers shall ensure that this pour point is suitable for the equipment on board / at the plant, especially if the ship operates / plant is located in cold climates.
- e)** Straight run residues show CCAI values in the 770 to 840 range and are very good ignitors. Cracked residues delivered as bunkers may range from 840 to – in exceptional cases – above 900. Most bunkers remain in the max. 850 to 870 range at the moment. CCAI value cannot always be considered as an accurate tool to determine fuels' ignition properties, especially concerning fuels originating from modern and more complex refinery processes.
- f)** Sodium contributes to hot corrosion on exhaust valves when combined with high sulphur and vanadium contents. Sodium also strongly contributes to fouling of the exhaust gas turbine blading at high loads. The aggressiveness of the fuel depends on its proportions of sodium and vanadium, but also on the total amount of ash. Hot corrosion and deposit formation are, however, also influenced by other ash constituents. It is therefore difficult to set strict limits based only on the sodium and vanadium content of the fuel. Also a fuel with lower sodium and vanadium contents than specified above, can cause hot corrosion on engine components.
- g)** The fuel shall be free from used lubricating oil (ULO). A fuel shall be considered to contain ULO when either one of the following conditions is met:
- Calcium > 30 mg/kg and zinc > 15 mg/kg OR
  - Calcium > 30 mg/kg and phosphorus > 15 mg/kg
- h)** Ashing temperatures can vary when different test methods are used having an influence on the test result.

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

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

Properties of the VLSFO RM category products can vary significantly and only the max. 0,50 % m/m sulphur content is a common requirement for those. Some of the fuels are low viscosity products like the ULSFO RM products described in chapter "Operation on 0,10 % m/m residual sulphur fuels (ULSFO RM) for SECA areas" while some others are more viscous fuels which shall anyway fulfil either the "HFO 1" or "HFO 2" quality requirements included in the chapter "High sulphur residual operation". These fuels can be used in the Wärtsilä DF engine types in back-up and diesel mode, but special attention shall be paid to optimum operating conditions. See also Services Instruction WS02Q312.

### 6.1.2.5 High sulphur residual fuel operation:

The fuel specification “HFO 2” is based on the ISO 8217:2017(E) standard and covers the fuel categories ISO-F-RMA 10 – RMK 700. Additionally, the engine manufacturer has specified the fuel specification “HFO 1”. This tighter specification is an alternative and by using a fuel fulfilling this specification, longer overhaul intervals of specific engine components are guaranteed (See the Engine Manual of a specific engine type).

HFO is accepted only when operating the engines in back-up or diesel mode. Use of HFO as a pilot fuel in gas mode is not possible. A LFO fuel fulfilling the distillate fuel specification included in section [Light fuel oil operation](#) has to be used.

**Table 6-5 Heavy fuel oils**

Characteristics	Unit	Limit HFO 1	Limit HFO 2	Test method reference
Kinematic viscosity before main injection pumps <sup>d)</sup>	mm <sup>2</sup> /s <sup>b)</sup>	20 ± 4	20 ± 4	-
Kinematic viscosity at 50 °C, max.	mm <sup>2</sup> /s <sup>b)</sup>	700,0	700,0	ISO 3104
Density at 15 °C, max.	kg/m <sup>3</sup>	991,0 / 1010,0 <sup>a)</sup>	991,0 / 1010,0 <sup>a)</sup>	ISO 3675 or ISO 12185
CCAI, max. <sup>f)</sup>	-	850	870	ISO 8217, Annex F
Sulphur, max. <sup>c, g)</sup>	% m/m	Statutory requirements, or max. 1,50 <sup>c)</sup>	3,50	ISO 8754 or ISO 14596
Flash point, min.	°C	60,0	60,0	ISO 2719
Hydrogen sulfide, max.	mg/kg	2,00	2,00	IP 570
Acid number, max.	mg KOH/g	2,5	2,5	ASTM D664
Total sediment aged, max.	% m/m	0,10	0,10	ISO 10307-2
Carbon residue, micro method, max.	% m/m	15,00	20,00	ISO 10370
Asphaltenes, max. <sup>d)</sup>	% m/m	8,0	14,0	ASTM D3279
Pour point (upper), max. <sup>e)</sup>	°C	30	30	ISO 3016
Water, max.	% V/V	0,50	0,50	ISO 3733 or ASTM D6304-C <sup>d)</sup>
Water before engine, max. <sup>d)</sup>	% V/V	0,30	0,30	ISO 3733 or ASTM D6304-C <sup>d)</sup>
Ash, max.	% m/m	0,050	0,150	ISO 6245 or LP1001 <sup>d, i)</sup>
Vanadium, max. <sup>g)</sup>	mg/kg	100	450	IP 501, IP 470 or ISO 14597
Sodium, max. <sup>g)</sup>	mg/kg	50	100	IP 501 or IP 470
Sodium before engine, max. <sup>d, g)</sup>	mg/kg	30	30	IP 501 or IP 470
Aluminium + Silicon, max.	mg/kg	30	60	IP 501, IP 470 or ISO 10478
Aluminium + Silicon before engine, max. <sup>d)</sup>	mg/kg	15	15	IP 501, IP 470 or ISO 10478

**Table 6-5 Heavy fuel oils (continued)**

Characteristics	Unit	Limit HFO 1	Limit HFO 2	Test method reference
Used lubricating oil: <sup>h)</sup>	mg/kg	30	30	IP 501 or IP 470
- Calcium, max. <sup>h)</sup>	mg/kg	15	15	IP 501 or IP 470
- Zinc, max. <sup>h)</sup>	mg/kg	15	15	IP 501 or IP 500
- Phosphorus, max. <sup>h)</sup>	mg/kg	15	15	IP 501 or IP 500

**NOTICE**

**a)** Max. 1010 kg/m<sup>3</sup> at 15 °C, provided the fuel treatment system can reduce water and solids (sediment, sodium, aluminium, silicon) before engine to the specified levels.

**b)** 1 mm<sup>2</sup>/s = 1 cSt.

**c)** The purchaser shall define the maximum sulphur content in accordance with relevant statutory limitations. The global sulphur content in marine applications is max. 0,50 % m/m unless an exhaust gas scrubber is used.

**d)** Additional properties specified by the engine manufacturer, which are not included in the ISO 8217:2017(E) standard. Injection viscosity of high sulphur fuels belonging to RMA 10 – RMD 80 categories can be lower than specified in the table above, i.e. 6 – 16 cSt.

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

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

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

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

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

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

### 6.1.3 Biofuel oils

#### Liquid biofuel characteristics and specifications

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

**NOTICE**

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

**NOTICE**

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

**NOTICE**

Fuel injection system is not validated for Straight and Pure Vegetable oils ([SVO and PVO](#)) qualities. Wärtsilä have to cover possible FIE warranty cost. Depending on FIE equipment, field follow up / validation may be required.

**NOTICE**

If a liquid biofuel is used as a pilot fuel in the DF engine types, only the products fulfilling the specification included in the table [FAME](#), [B10 table](#), [B20 table](#) and [B30 table](#) and table [Paraffinic diesel fuels from synthesis and hydrotreatment](#) are allowed to use.

**NOTICE**

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

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

**Blending of different fuel qualities:**

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

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

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

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

B20 & B30 blends an EN 16709 standard respectively. Biodiesel blend quality has to fulfil the requirements included in those two standards

#### Required fuel temperatures:

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

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

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

### 6.1.3.1 Straight Vegetable Oils (SVO) and Pure Vegetable Oils (PVO)

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

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

Property	Unit	Limit	Test method reference
Viscosity, max.	mm <sup>2</sup> /s @ 50 °C mm <sup>2</sup> /s @ 80 °C	70 <sup>1)</sup> 15 <sup>1)</sup>	ISO 3104
Injection viscosity, max.	mm <sup>2</sup> /s	24	ISO 3104
Density, max.	kg/m <sup>3</sup> @ 15 °C	940	ISO 3675 or ISO 12185
Ignition properties <sup>3)</sup>		<sup>3)</sup>	FIA-100 FCA test
Sulphur, max.	% m/m	0.05	ISO 8754
Total sediment existent, max.	% m/m	0.05	ISO 10307-1
Water, max. before engine	% v/v	0.20	ISO 3733
Micro carbon residue, max.	% m/m	0.50	ISO 10370
Ash, max.	% m/m	0.05	ISO 6245 / LP1001 <sup>4)</sup>
Phosphorus, max.	mg/kg	100	ISO 10478
Silicon, max.	mg/kg	15	ISO 10478

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

Property	Unit	Limit	Test method reference
Alkali content (Na+K), max.	mg/kg	30	ISO 10478
Flash point (PMCC), min.	°C	60	ISO 2719
Cloud point, max.	°C	5)	ISO 3015
Cold filter plugging point, max.	°C	5)	IP 309
Copper strip corrosion (3 hrs @ 50 °C), max.	Rating	1b	ASTM D130
Steel corrosion (24 / 72 hours @ 20, 60 and 120 °C), max.	Rating	No signs of corrosion	LP 2902
Oxidation stability @ 110 °C, min.	h	17.0 6)	EN 14112
Acid number, max.	mg KOH/g	15.0	ASTM D664
Strong acid number, max.	mg KOH/g	0.0	ASTM D664
Iodine number, max.	g iodine /100 g	120 7)	ISO 3961
Synthetic polymers	% m/m	Report 8)	LP 2501

**NOTICE**

- 1) If injection viscosity of max. 24 cSt cannot be achieved with an unheated fuel, fuel system has to be equipped with a heater ( $\text{mm}^2/\text{s} = \text{cSt}$ ).
- 2) Min. viscosity limit at engine inlet in running conditions ( $\text{mm}^2/\text{s} = \text{cSt}$ ).
- 3) Ignition properties have to be equal to or better than the requirements for fossil fuels, i.e., CI min. 35 for LFO and CCAI max. 870 for HFO.
- 4) Ashing temperatures can vary when different test methods are used having an influence on the test result.
- 5) Cloud point and cold filter plugging point have to be at least 10 °C below fuel injection temperature and the temperature in the whole fuel system has to be min. 10 – 15 °C higher than cloud point and cold filter plugging point.
- 6) A lower oxidation stability value down to min. 10 hours can be considered acceptable if other fuel properties, like cloud point, cold filter plugging point and viscosity support that. This needs to be decided case-by-case.
- 7) Iodine number of soybean oil is somewhat higher, up to ~ 140, which is acceptable for specific that biofuel quality.
- 8) Biofuels originating from food industry can contain synthetic polymers, like e.g. styrene, propene and ethylene used in packing material. Such compounds can cause filter clogging and shall thus not be present in biofuels.

**NOTICE**

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

**NOTICE**

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

**6.1.3.2 Fatty acid methyl ester (FAME) / Biodiesel**

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

**Table 6-7 Fatty acid methyl ester (FAME) / Biodiesel specification based on the EN 14214:2012 standard**

Property	Unit	Limit	Test method reference
Viscosity, min. - max.	mm <sup>2</sup> /s @ 40 °C	3.5 - 5.0	EN ISO 3104
Density, min. - max.	kg/m <sup>3</sup> @ 15 °C	860 - 900	EN ISO 3675 / 12185
Cetane number, min.	-	51.0	EN ISO 5165
Sulphur content, max.	mg/kg	10.0	EN ISO 20846 / 20884 / 13032
Sulphated ash content, max.	% m/m	0.02	ISO 3987
Total contamination, max.	mg/kg	24	EN 12662
Water content, max.	mg/kg	500	EN ISO 12937
Phosphorus content, max.	mg/kg	4.0	EN 14107
Group I metals (Na + K) content, max.	mg/kg	5.0	EN 14108 / EN 14109 / 14538
Group II metals (Ca + Mg) content, max.	mg/kg	5.0	EN 14538
Flash point, min.	°C	101	EN ISO 2719A / 3679
Cold filter plugging point, max. (climate dependent requirement)	°C	-20 → +5 <sup>2)</sup>	EN 116
Oxidation stability @ 110 °C, min.	h	8.0	EN 14112
Copper strip corrosion (3 hrs @ 50 °C), max.	Rating	Class 1	EN ISO 2160
Acid value, max.	mg KOH/g	0.50	EN 14104
Iodine value, max.	g iodine/100 g	120	EN 14111 / 16300
FAME content, min.	% m/m	96.5	EN 14103
Linolenic acid methyl ester, max.	% m/m	12.0	EN 14103
Polyunsaturated ( ≥ 4 double bonds) methyl esters, max.	% m/m	1.00	EN 15779

**Table 6-7 Fatty acid methyl ester (FAME) / Biodiesel specification based on the EN 14214:2012 standard (continued)**

Property	Unit	Limit	Test method reference
Methanol content, max.	% m/m	0.20	EN 14110
Monoglyceride content, max.	% m/m	0.70	EN 14105
Diglyceride content, max.	% m/m	0.20	EN 14105
Triglyceride content, max.	% m/m	0.20	EN 14105
Free glycerol, max.	% m/m	0.02	EN 14105 / EN 14106
Total glycerol, max.	% m/m	0.25	EN 14105

**NOTICE**

1) Min. limit at engine inlet in running conditions ( $\text{mm}^2/\text{s} = \text{cSt}$ ).

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

**NOTICE**

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

**6.1.3.3****Automotive B10 diesel fuel****Table 6-8 Automotive B10 diesel fuel – Requirements and test methods based on the EN 16734:2016 standard**

Property	Unit	Limit	Test method reference
Viscosity, min - max.	$\text{mm}^2/\text{s}$ @ $40\text{ }^\circ\text{C}$	2,000 – 4,500	EN ISO 3104
Density, min - max.	$\text{kg}/\text{m}^3$ @ $15\text{ }^\circ\text{C}$	820 - 845	EN ISO 3675
Sulphur content, max.	mg/kg	10.0	EN ISO 20846 / 20884 / 13032
Ash content, max.	% m/m	0.01	EN ISO 6245
Total contamination, max.	mg/kg	24	EN 12662
Water content, max.	% m/m	0.02	EN ISO 12937
Manganese content, max.	mg/l	2.0	EN 16576
Cold filter plugging point, max. (climate dependent requirement)	$^\circ\text{C}$	$-20 \rightarrow +5$ <sup>2)</sup>	EN 116 / 16329
Flash point, min.	$^\circ\text{C}$	55 <sup>3)</sup>	EN ISO 2719
Oxidation stability, min.	h	20.0	EN 15751
Oxidation stability, max.	$\text{g}/\text{m}^3$	25	EN 12205

**Table 6-8 Automotive B10 diesel fuel – Requirements and test methods based on the EN 16734:2016 standard (continued)**

Property	Unit	Limit	Test method reference
Polycyclic aromatic hydrocarbons, max.	% m/m	8.0	EN 12916
Carbon residue (on 10% distillation residue), max.	% m/m	0.3	EN ISO 10370
Copper strip corrosion (3 hrs @ 50 °C), max.	Rating	Class 1	EN ISO 2160
Lubricity, wear scar diameter at 60 oC, max.	um	460	EN ISO 12156-1
Distillation			EN ISO 3405 / 3924
- % v/v recovered at 250 °C, max.	% v/v	< 65	
- % v/v recovered at 350°C, min	% v/v	85	
- 95% recovered at, max.	°C	360	
FAME content, min.	% v/v	10.0	EN 14078

**NOTICE**

- 1) Min. limit at engine inlet in running conditions ( $\text{mm}^2/\text{s} = \text{cSt}$ ).
- 2) Cold flow properties of renewable biodiesel can vary based on the geographical location and also based on the feedstock properties, which issues must be taken into account when designing the fuel system. For arctic climates even lower CFPP values down to  $-44\text{ °C}$  are specified.
- 3) The use in marine applications is allowed provided that a fuel supplier can guarantee min. flash point of  $60\text{ °C}$ .

**6.1.3.4 High FAME diesel fuel (B20)****Table 6-9 High FAME diesel fuel (B20) – Requirements and test methods based on the EN 16709:2015 standard**

Property	Unit	Limit	Test method reference
Viscosity, min - max.	$\text{mm}^2/\text{s}$ @ 40 °C	2,000 – 4,620	EN ISO 3104
Density, min - max.	$\text{kg}/\text{m}^3$ @ 15 °C	820 - 860	EN ISO 3675
Cetane number, min.	-	51.0	EN ISO 5165, EN 15195 / 16144 / 16715 / 16906
Sulphur content, max.	mg/kg	10.0	EN ISO 20846 / 20884 / 13032
Ash content, max.	% m/m	0.01	EN ISO 6245
Total contamination, max.	mg/kg	24	EN 12662
Water content, max.	% m/m	0.026	EN ISO 12937
Manganese content, max.	mg/l	2.0	EN 16576

**Table 6-9 High FAME diesel fuel (B20) – Requirements and test methods based on the EN 16709:2015 standard (continued)**

Property	Unit	Limit	Test method reference
Cold filter plugging point, max. (climate dependent requirement)	°C	-20 -> +5 <sup>2)</sup>	EN 116 / 16329
Flash point, min.	°C	55 <sup>3)</sup>	EN ISO 2719
Oxidation stability, min.	h	20.0	EN 15751
Polycyclic aromatic hydrocarbons, max.	% m/m	8.0	EN 12916
FAME content, min.	% v/v	14.0 - 20.0	EN 14078
Distillation			EN ISO 3405 / 3924
- % v/v recovered at 250 °C, max.	% v/v	< 65	
- % v/v recovered at 350°C, min	% v/v	85	
- 95% recovered at, max.	°C	360	

**NOTICE**

- 1) Min. limit at engine inlet in running conditions ( $\text{mm}^2/\text{s} = \text{cSt}$ ).
- 2) Cold flow properties of renewable biodiesel can vary based on the geographical location and also based on the feedstock properties, which issues must be taken into account when designing the fuel system. For arctic climates even lower CFPP values down to -44 °C are specified.
- 3) The use in marine applications is allowed provided that a fuel supplier can guarantee min. flash point of 60 °C.

**6.1.3.5 High FAME diesel fuel (B30)****Table 6-10 High FAME diesel fuel (B30) – Requirements and test methods based on the EN 16709:2015 standard**

Property	Unit	Limit	Test method reference
Viscosity, min - max.	$\text{mm}^2/\text{s} @ 40$ °C	2,000 – 4,620	EN ISO 3104
Density, min - max.	$\text{kg}/\text{m}^3 @ 15$ °C	825 - 865	EN ISO 3675
Cetane number, min.	-	51.0	EN ISO 5165, EN 15195 / 16144 / 16715 / 16906
Sulphur content, max.	mg/kg	10.0	EN ISO 20846 / 20884 / 13032
Ash content, max.	% m/m	0.01	EN ISO 6245
Total contamination, max.	mg/kg	24	EN 12662
Water content, max.	% m/m	0.029	EN ISO 12937
Manganese content, max.	mg/l	2.0	EN 16576

**Table 6-10 High FAME diesel fuel (B30) – Requirements and test methods based on the EN 16709:2015 standard (continued)**

Property	Unit	Limit	Test method reference
Cold filter plugging point, max. (climate dependent requirement)	°C	-20 -> +5 <sup>2)</sup>	EN 116 / 16329
Flash point, min.	°C	55 <sup>3)</sup>	EN ISO 2719
Oxidation stability, min.	h	20.0	EN 15751
Polycyclic aromatic hydrocarbons, max.	% m/m	8.0	EN 12916
FAME content, min. - max.	% v/v	24.0 - 30.0	EN 14078
Distillation			EN ISO 3405 / 3924
- % v/v recovered at 250 °C, max.	% v/v	< 65	
- % v/v recovered at 350°C, min	% v/v	85	
- 95% recovered at, max.	°C	360	

**NOTICE**

**1)** Min. limit at engine inlet in running conditions ( $\text{mm}^2/\text{s} = \text{cSt}$ ).

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

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

**6.1.3.6 Paraffinic diesel fuels from synthesis and hydrotreatment**

Paraffinic renewable distillate fuels originating from synthesis or hydrotreatment are high quality distillate fuels and their composition and physical & chemical properties do differ from transesterified biodiesel. The quality of paraffinic diesel shall meet the EN 15940:2016 Class A requirements included in the table below.

For arctic or severe winter climates additional or more stringent requirements are set concerning cold filter plugging point, cloud point, viscosity and distillation properties.

**Table 6-11 Requirements for paraffinic diesel from synthesis or hydrotreatment based on the EN 15940:2016 standard**

Property	Unit	Limit	Test method reference
Viscosity, min. - max.	$\text{mm}^2/\text{s} @ 40$ °C	2,000 – 4,500	EN ISO 3104
Density, min. - max.	$\text{kg}/\text{m}^3 @ 15$ °C	765 - 800 <sup>2)</sup>	EN ISO 3675 / 12185
Cetane number, min.	-	70.0	EN 15195 / EN ISO 5165
Sulphur content, max.	mg/kg	5.0	EN ISO 20846 / 20884

**Table 6-11 Requirements for paraffinic diesel from synthesis or hydrotreatment based on the EN 15940:2016 standard (continued)**

Property	Unit	Limit	Test method reference
Ash content, max.	% m/m	0.010	EN ISO 6245
Total contamination, max.	mg/kg	24	EN 12662
Water content, max.	mg/kg	200	EN ISO 12937
Total aromatics, max.	% m/m	1.1	EN 12916
Carbon residue on 10% distillation residue, max.	% m/m	0.30	EN ISO 10370
Lubricity, max.	µm	460	EN ISO 12156-1
Flash point, min.	°C	55 <sup>3)</sup>	EN ISO 2719
Cold filter plugging point, max. (climate dependent requirement)	°C	-20 → +5 <sup>4)</sup>	EN 116 / 16329
Oxidation stability, max. Oxidation stability, min.	g/m <sup>3</sup> h	25 20 <sup>5)</sup>	EN ISO 12205 EN 15751
Copper strip corrosion (3 hrs @ 50 °C), max.	Rating	Class 1	EN ISO 2160
Distillation % v/v recovered @ 250 °C, max. % v/v recovered @ 350 °C, min. 95 % recovered at, max.	% v/v % v/v °C	65 85 360	EN ISO 3405 / 3924
FAME content, max.	% v/v	7.0	EN 14078

**NOTICE**

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

**NOTICE**

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

## 6.2 Operating principles

Wärtsilä 20DF engines are usually installed for dual fuel operation meaning the engine can be run either in gas or diesel operating mode. The operating mode can be changed while the

engine is running, within certain limits, without interruption of power generation. If the gas supply would fail, the engine will automatically transfer to diesel mode operation (LFO).

### 6.2.1 Gas mode operation

In gas operating mode the main fuel is gas which is fed to the engine at a low pressure. The gas is ignited by injecting a small amount of pilot diesel fuel (LFO). Gas and pilot fuel injection are solenoid operated and electronically controlled common rail systems.

### 6.2.2 Diesel mode operation

In diesel operating mode the engine operates only on liquid fuel oil. LFO or HFO is used as fuel with a conventional fuel injection system. The LFO pilot injection is always active.

### 6.2.3 Backup mode operation

The engine control and safety system or the blackout detection system can in some situations transfer the engine to backup mode operation. In this mode the LFO pilot injection system is not active and operation longer than 30 minutes (with HFO) or 5 hours (with LFO) may cause clogging of the pilot fuel injection nozzles.

Engine load must also be kept below 70%.

<b>NOTE</b>
Please contact Wärtsilä for fuel and operating mode change details.

## 6.3 Fuel gas system

### 6.3.1 External fuel gas system

#### 6.3.1.1 Fuel gas system, with open type GVU

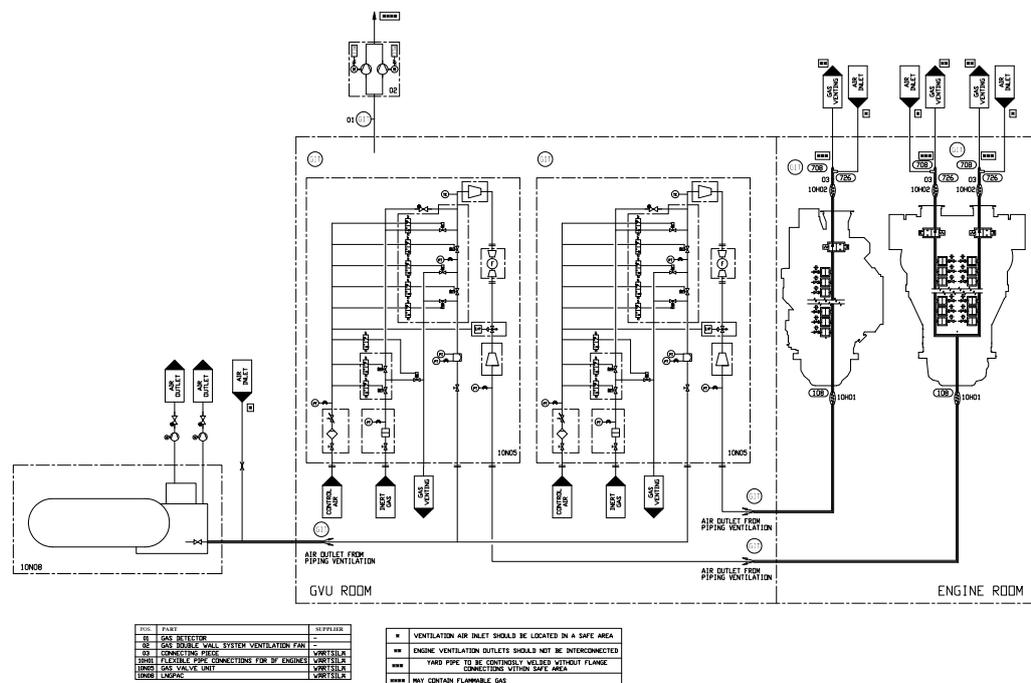


Fig 6-1 Example of fuel gas operation with open type GVU (DAAF022750J)

POS.	PIPE CONNECTIONS	W20DF SIZE
108	GAS INLET	DN65/ 100
708	GAS SYSTEM VENT	OD33.7
726	AIR INERT TO DOUBLE WALL GAS SYSTEM	OD60.3

### 6.3.1.2 Fuel gas system, with enclosed GVU

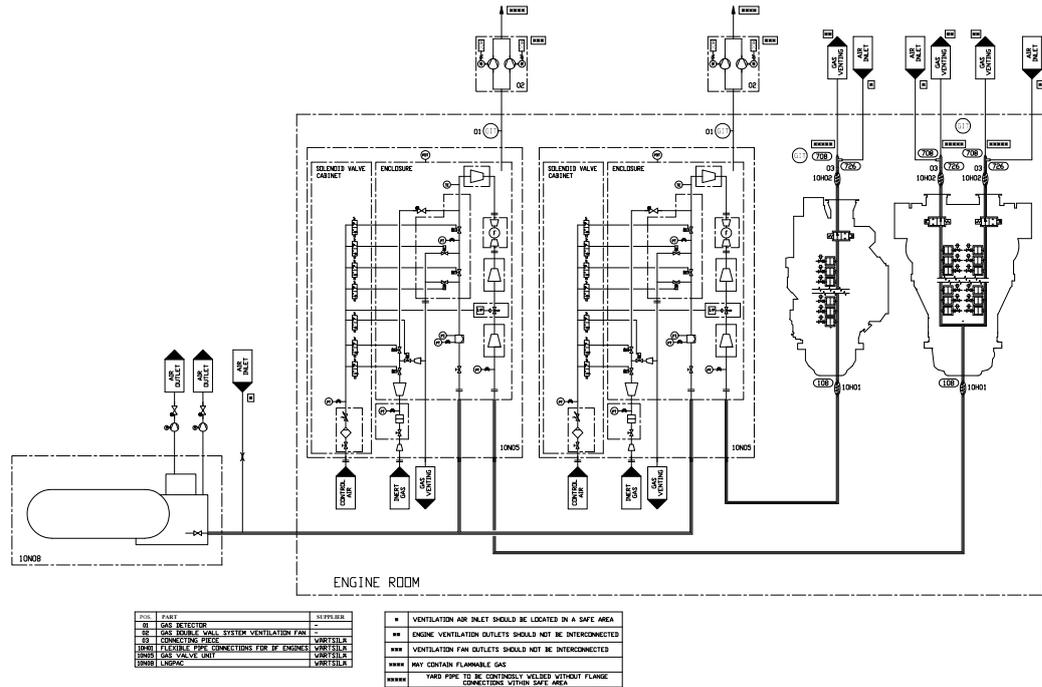


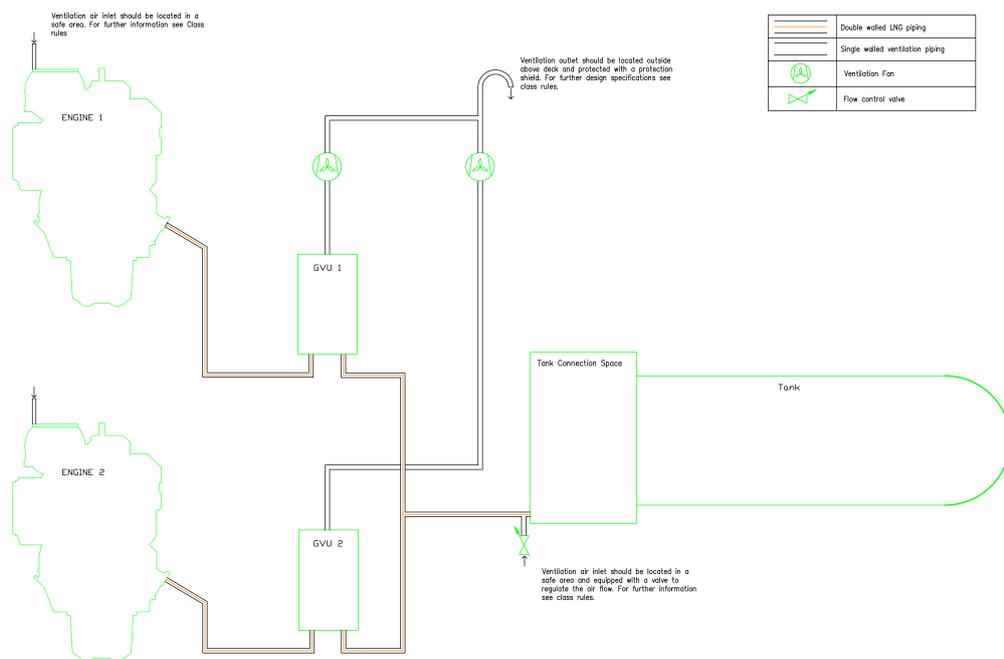
Fig 6-2 Example of fuel gas system with enclosed GVU (DAAF077105F)

POS.	PIPE CONNECTIONS	W20DF SIZE
108	GAS INLET	DN65/ 100
708	GAS SYSTEM VENT	OD33.7
726	AIR INERT TO DOUBLE WALL GAS SYSTEM	OD60.3

The fuel gas can typically be contained as CNG, LNG at atmospheric pressure, or pressurized LNG. The design of the external fuel gas feed system may vary, but every system should provide natural gas with the correct temperature and pressure to each engine.

### 6.3.1.3 Double wall gas piping and the ventilation of the piping

The annular space in double wall piping is ventilated artificially by underpressure created by ventilation fans. The first ventilation air inlet to the annular space is located at the engine. The ventilation air is recommended to be taken from a location outside the engine room, through dedicated piping. The second ventilation air inlet is located at the outside of the tank connection space at the end of the double wall piping. To balance the air intake of the two air intakes a flow restrictor is required at the air inlet close to the tank connection space. The ventilation air is taken from both inlets and lead through the annular space of the double wall pipe to the GUV room or to the enclosure of the gas valve unit. From the enclosure of the gas valve unit a dedicated ventilation pipe is connected to the ventilation fans and from the fans the pipe continues to the safe area. The 1,5 meter hazardous area will be formed at the ventilation air inlet and outlet and is to be taken in consideration when the ventilation piping is designed. According to classification societies minimum ventilation capacity has to be at least 30 air changes per hour. With enclosed GUV this 30 air changes per hour normally correspond to -20 mbar inside the GUV enclosure according to experience from existing installations. However, in some cases required pressure in the ventilation might be slightly higher than -20 mbar and can be accepted based on case analysis and measurements.



**Fig 6-3 Example arrangement drawing of ventilation in double wall piping system with enclosed GVUs (DAAF500224)**

### 6.3.1.4 Gas valve unit (10N05)

Before the gas is supplied to the engine it passes through a Gas Valve Unit (GVU). The GVU include a gas pressure control valve and a series of block and bleed valves to ensure reliable and safe operation on gas.

The unit includes a manual shut-off valve, inerting connection, filter, fuel gas pressure control valve, shut-off valves, ventilating valves, pressure transmitters/gauges, a gas temperature transmitter and control cabinets.

The filter is a full flow unit preventing impurities from entering the engine fuel gas system. The fineness of the filter is 5 µm absolute mesh size. The pressure drop over the filter is monitored and an alarm is activated when pressure drop is above permitted value due to dirty filter.

The fuel gas pressure control valve adjusts the gas feed pressure to the engine according to engine load. The pressure control valve is controlled by the engine control system. The system is designed to get the correct fuel gas pressure to the engine common rail pipe at all times.

Readings from sensors on the GVU as well as opening and closing of valves on the gas valve unit are electronically or electro-pneumatically controlled by the GVU control system. All readings from sensors and valve statuses can be read from Local Display Unit (LDU). The LDU is mounted below control cabinet of the GVU of enclosed design type. With GVU open design LDU is delivered as loose supply.

The two shut-off valves together with gas ventilating valve (between the shut-off valves) form a double-block-and-bleed function. The block valves in the double-block-and-bleed function effectively close off gas supply to the engine on request. The solenoid operated venting valve in the double-block-and-bleed function will relieve the pressure trapped between the block valves after closing of the block valves. The block valves V03 and V05 and inert gas valve V07 are operated as fail-to-close, i.e. they will close on current failure. Venting valves V02 and V04 are fail-to-open, they will open on current failure. There is a connection for inerting the fuel gas pipe with nitrogen, see figure "*Gas valve unit P&I diagram*". The inerting of the fuel gas pipe before double block and bleed valves in the GVU is done from gas storage system. Gas is blown downstream the fuel gas pipe and out via vent valve V02 on the GVU when inerting from gas storage system.

During a stop sequence of DF-engine gas operation (i.e. upon gas trip, pilot trip, stop, emergency stop or shutdown in gas operating mode, or transfer to diesel operating mode) the GVU performs a gas shut-off and ventilation sequence. Both block valves (V03 and V05) on the gas valve unit are closed and ventilation valve V04 between block valves is opened. Additionally on emergency stop ventilation valve V02 will open and on certain alarm situations the V07 will inert the gas pipe between GVU and the engine.

The gas valve unit will perform a leak test procedure before engine starts operating on gas. This is a safety precaution to ensure the tightness of valves and the proper function of components.

One GVU is required for each engine. The GVU has to be located close to the engine to ensure engine response to transient conditions. The maximum length of fuel gas pipe between the GVU and the engine gas inlet is 30 m.

Inert gas and compressed air are to be dry and clean. Inert gas pressure max 0.9 MPa (9 bar). The requirements for compressed air quality are presented in [chapter Compressed air system](#).



Maximum inert gas pressure mentioned above is for guidance only. For contracted projects, please refer to Installation Planning Instructions (IPI).

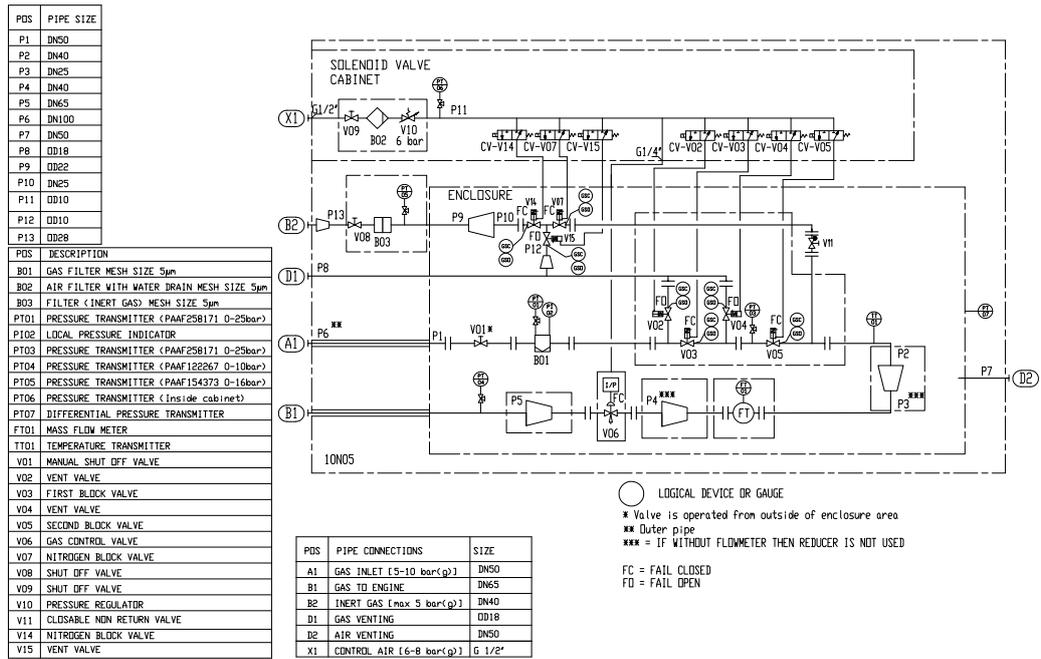


Fig 6-4 GVU-ED flow diagram DN50 (DAAF513569A)

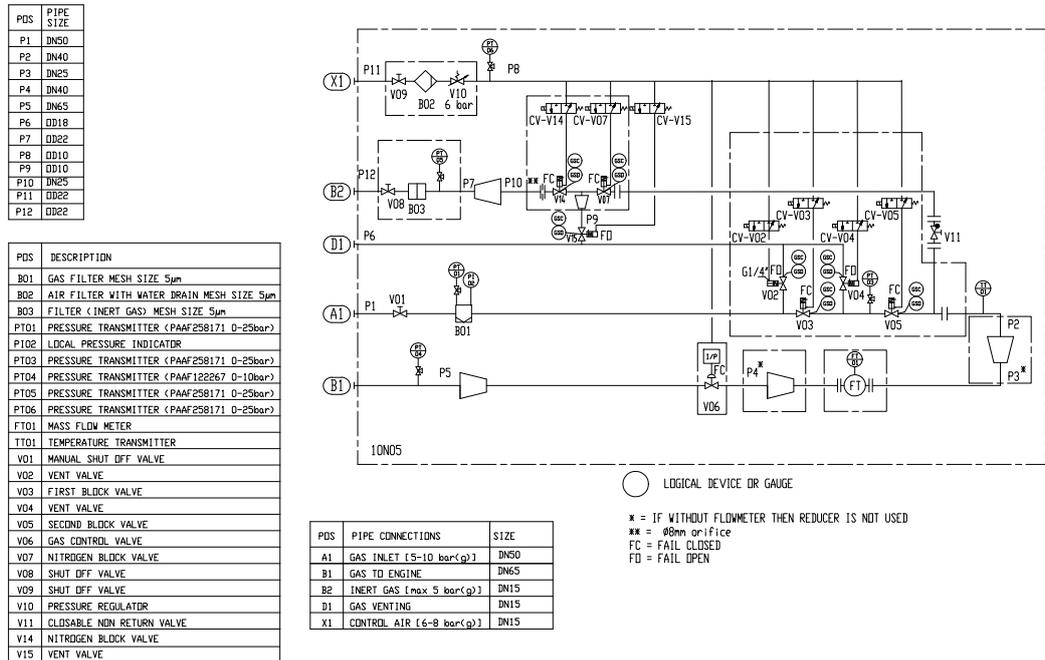


Fig 6-5 GVU-OD flow diagram DN50 (DAAF513568A)

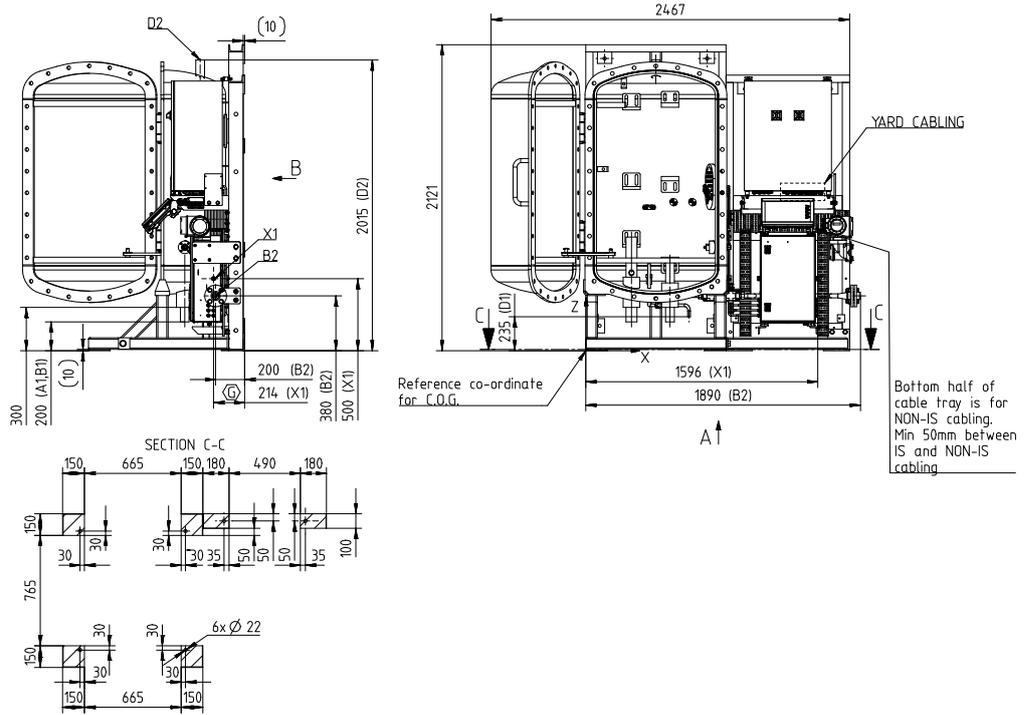


Fig 6-6 Main dimensions of the GVU (DAAF470665G)

### 6.3.1.5 Master fuel gas valve

IMO IGC code and IGF code requires a master gas fuel valve to be installed in the fuel gas feed system. At least one master gas fuel valve is required, but it is recommended to apply one valve for each engine compartment using fuel gas to enable independent operation.

It is always recommended to have one main shut-off valve directly outside the engine room and valve room in any kind of installation.

### 6.3.1.6 Fuel gas venting

In certain situations during normal operation of a DF-engine, as well as due to possible faults, there is a need to safely ventilate the fuel gas piping. During a stop sequence of a DF-engine gas operation the GVU and DF-engine gas venting valves performs a ventilation sequence to relieve pressure from gas piping. Additionally in emergency stop V02 will relief pressure from gas piping upstream from the GVU.

This small amount of gas can be ventilated outside into the atmosphere, to a place where there are no sources of ignition.

Alternatively to ventilating outside into the atmosphere, other means of disposal (e.g. a suitable furnace) can also be considered. However, this kind of arrangement has to be accepted by classification society on a case by case basis.

#### **NOTICE**

All breathing and ventilation pipes that may contain fuel gas must always be built sloping upwards, so that there is no possibility of fuel gas accumulating inside the piping.

In case the DF-engine is stopped in gas operating mode, the ventilation valves will open automatically and quickly reduce the gas pipe pressure to atmospheric pressure.

The pressure drop in the venting lines are to be kept at a minimum.

To prevent gas ventilation to another engine during maintenance vent lines from gas supply or GVU of different engines cannot be interconnected. However, vent lines from the same

engine can be interconnected to a common header, which shall be lead to the atmosphere. Connecting the engine or GVU venting lines to the LNGPac venting mast is not allowed, due to risk for backflow of gas into the engine room when LNGPac gas is vented!

### 6.3.1.7 Purging by inert gas

Before beginning maintenance work, the fuel gas piping system has to be de-pressurized and inerted with an inert gas. If maintenance work is done after the GVU and the enclosure of the GVU hasn't been opened, it is enough to inert the fuel gas pipe between the GVU and engine by triggering the starting sequence from the GVU control cabinet.

If maintenance work is done on the GVU and the enclosure of the GVU need to be opened, the fuel gas pipes before and after the GVU need to be inerted. Downstream from the GVU including the engine built gas piping, inerting is performed by triggering the inerting sequence from the GVU control cabinet. Regarding the engine crankcase inerting, a separate inert gas connection exist located on the engine. Upstream from the GVU double-block-and-bleed-valves, the inerting is performed from the gas storage system by feeding inert gas downstream the fuel gas pipe and out from the GVU gas ventilation pipe.

In addition to maintenance, during certain alarm and emergency situations (e.g. annular space ventilation failure and/or gas leak detection), the fuel gas piping is to be flushed with inert gas.

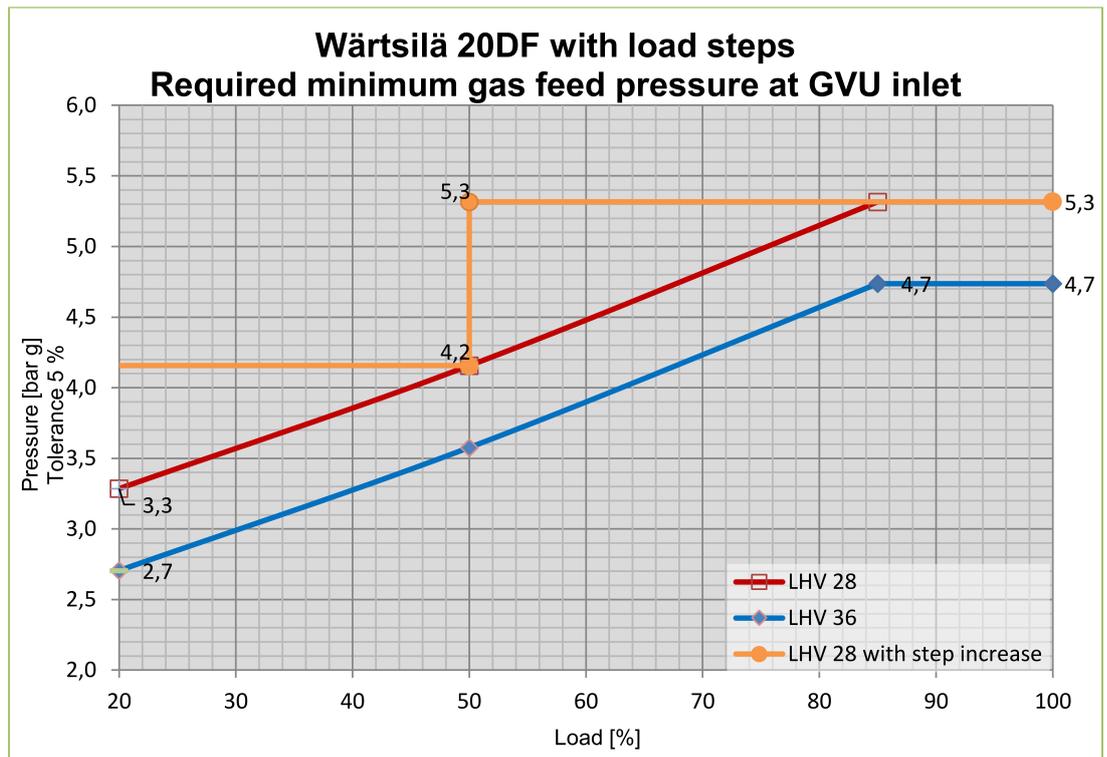
The following guidelines apply for flushing the engine crankcase with inert gas:

- 1 Flow rate with 2 mm orifice and 5 bar pressure [l/min]: 144
- 2 A sniffer is recommended to be installed in the crankcase breather pipe in order to indicate when the crankcase have been flushed from toxic gases.
- 3 Crankcase size: 0.22m<sup>3</sup>/crank

### 6.3.1.8 Gas feed pressure

The required fuel gas feed pressure depends on the expected minimum lower heating value (LHV) of the fuel gas, as well as the pressure losses in the feed system to the engine. The LHV of the fuel gas has to be above 28 MJ/m<sup>3</sup> at 0°C and 101.3 kPa. For pressure requirements, please refer to [Engine Online Configurator](#) available through Wärtsilä's website and chapter "[1.3.2 Output limitations due to gas feed pressure and lower heating value](#)".

- The pressure losses in the gas feed system to engine has to be added to get the required gas pressure.
- A pressure drop of 120 kPa over the GVU is a typical value that can be used as guidance.
- The required gas pressure to the engine depends on the engine load. This is regulated by the GVU.



**Fig 6-7 Gas feed pressure recommendation for engines including load steps (DBAC394653 rev. b)**

## 6.4 Fuel oil system

### 6.4.1 External fuel oil system

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

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

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

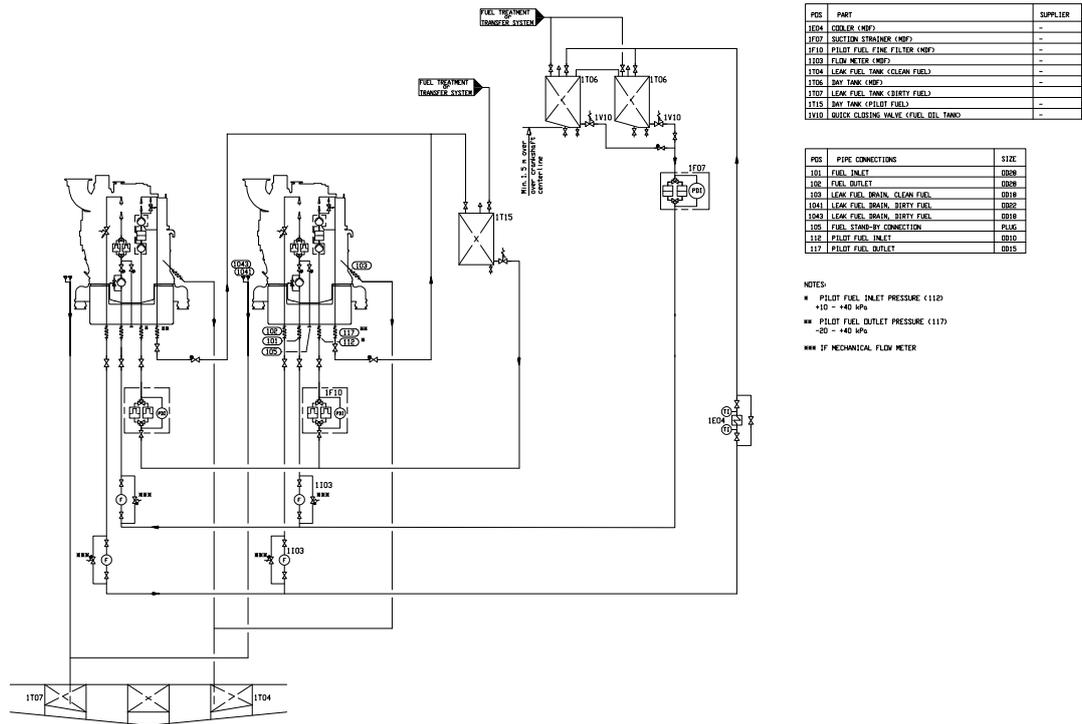
Injection pumps generate pressure pulses into the fuel feed and return piping.

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

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

## 6.4.1.1

## Fuel oil system (LFO), multiple engines, with engine driven pump



**Fig 6-8 Example of fuel oil system (LFO), multiple engines with engine driven pump (DAAF624746)**

### NOTICE

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

### NOTE

- Recommended maximum number of engines connected in parallel to the same fuel feed system is three
- Separate fuel feed circuits are recommended for each propeller shaft (two engine installations); in four engine installations so that one engine from each shaft is fed from the same circuit
- Main and auxiliary engines are recommended to be connected to separate circuits

## 6.4.1.2

## Definitions Filtration term used

- **Beta value  $\beta_{xx}$  ISO 16889, and Efficiency  $\epsilon_{xx}$** : scientific measurement of filter effectiveness. Numerical result on a given filter variates, depending on test method used, and on dust size distribution used during measurements.
- **Beta value  $\beta_{xx} = YY$** : ISO name with ISO 16889 internationally standardised test method. Scientific repeatability below 25 micron  $\beta_{xx} = 75$ , but weaker repeatability for filter mesh bigger than 25.45 microns. Example:  $\beta_{20} = 75$  means "ultrapass test, with standardised dust (ISO MTD dust): every 75 particles 20 micron ISO dust sent, one passes."

- **Efficiency  $\epsilon_{xx} = YY\%$**  : Old terminology, mathematically same meaning as Betavalue, but not any ISO standardised test method, and not necessarily with ISO MTD dust. Hence sometimes used for particles larger than 25..45 micron. Example:  $\epsilon_{20} = 98,7\%$  means “undefined test method, undefined dust: every 75 particles 20 micron non-ISO dust sent, one passes, which is 98,7% stopped.”
- **mesh size**: opening of the mesh (surface filtration), and often used as commercial name at purchase. Only approximately related to Efficiency and Beta-value. Insufficient to compare two filters from two suppliers. Good to compare two meshes of same filter model from same supplier. Totally different than micron absolute, that is always much bigger size in micron.  
e.g. a real example: 30 micron mesh size = approx. 50 micron  $\beta_{50} = 75$
- **abs. mesh (sphere passing mesh)**: it is a more accurate mesh size definition than above. It also specifies the measurement method (with spherical particles, passing /not passing through). On a given filter, it can have a different micron value than the commercial “mesh size”
- **XX micron, absolute**: it defines the real grade of filtration only when it is followed by Betavalue or Efficiency. Example: many suppliers intend it as  $\beta_{xx} = 75$  ISO 16889 similar to old efficiency  $\epsilon_{xx} = 98,7\%$ , or as  $\beta_{xx} = 200$  ISO 16889 (was  $\epsilon_{xx} = 99,9\%$ ), but some suppliers intend it as  $\beta_{xx} = 2$  ISO 16889 (was  $\epsilon_{xx} = 50\%$ )
- **XX micron, nominal**: commercial name of that mesh, at purchase. Not really related to filtration capability, especially when comparing different suppliers. Typically, a totally different value than XX micron, absolute e.g. a real example: 10 micron nominal ( $\epsilon_{10} = 60\%$ ) = approx. 60 micron absolute  $\beta_{60} = 75$  ISO 16889

### 6.4.1.3 Fuel heating requirements HFO

Heating is required for:

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

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

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



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

### **Day tank, HFO (1T03) and LFO (1T06)**

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

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

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

### **Leak fuel tank, clean fuel (1T04)**

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

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

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

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

Refer to section "[Fuel feed system - HFO installations](#)" for an example of the external HFO fuel oil system.

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

### **Leak fuel tank, dirty fuel (1T07)**

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

Dirty leak fuel shall be led to a sludge tank.

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

### **Pilot fuel day tank, LFO (1T15)**

The pilot fuel is used to ignite the air-gas mixture in the cylinder when operating the engine is in gas mode. The pilot fuel should be of type LFO and stored in a pilot fuel tank. The pilot fuel tank temperature should be max 45°C and the capacity sufficient for at least 8 hours operation.

Pilot pump has very limited inlet pressure (112) range as well as backflow outlet pressure (117) and therefore special attention to be paid on day tank positioning. To make deaeration of the pilot fuel line possible, minimum fuel level in the day tank should be slightly higher than pilot pump at engine.

Alternatively, as described in the recommended external system drawings, a common fuel oil system (for main and pilot fuel oil) can be applied. In such installation, no separate pilot fuel oil tank is needed.

#### NOTE

In case pilot fuel level (in pilot fuel day tank) is below centerline of pilot gear pump, de-aeration needs to be arranged.

### 6.4.1.5 Fuel treatment

#### Separation

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

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

All recommendations from the separator manufacturer must be closely followed.

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

#### Separator mode of operation

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

Separators with monitoring of cleaned fuel (without gravity disc) operating on a continuous basis can handle fuels with densities exceeding 991 kg/m<sup>3</sup> 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/m<sup>3</sup> at 15°C. The separators must be of the same size.

#### Separation efficiency

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

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

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

where:

(continued)

$n$  = separation efficiency [%]

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

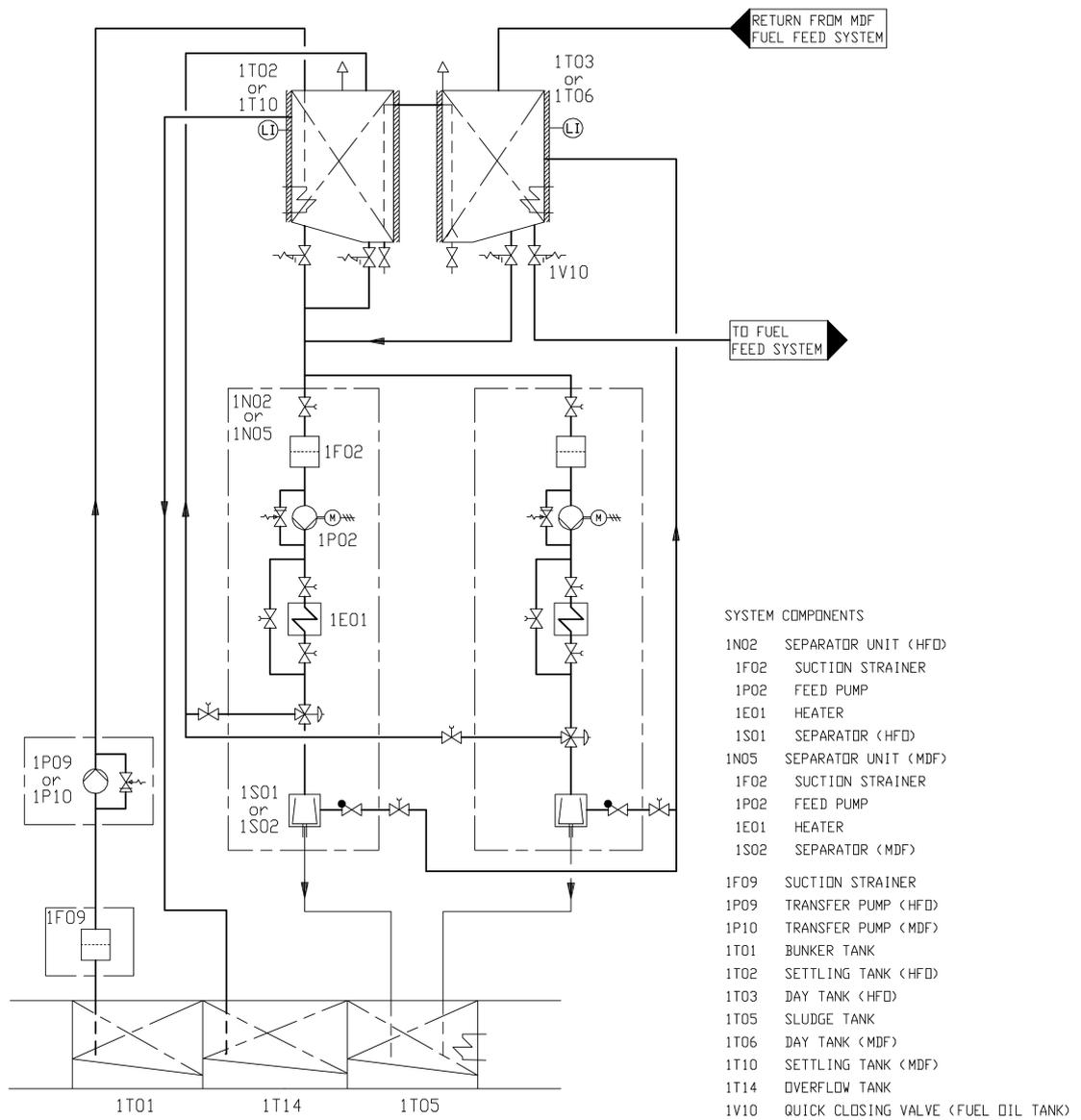
$C_{in}$  = number of test particles in test oil before separator

### **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 6-10 Fuel transfer and separating system (V76F6626G)**

### 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 approx. 0.5 mm)

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

#### Design data:

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

### 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  $\pm 2^{\circ}\text{C}$ .

Recommended fuel temperature after the heater depends on the viscosity, but it is typically  $98^{\circ}\text{C}$  for HFO and  $20\text{...}40^{\circ}\text{C}$  for LFO. The optimum operating temperature is defined by the separator 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]

$\Delta T$  = temperature rise in heater [ $^{\circ}\text{C}$ ]

For heavy fuels  $\Delta T = 48^{\circ}\text{C}$  can be used, i.e. a settling tank temperature of  $50^{\circ}\text{C}$ . Fuels having a viscosity higher than 5 cSt at  $50^{\circ}\text{C}$  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).

### 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:

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

**where:**

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

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

$\rho$  = density of the fuel [ $\text{kg}/\text{m}^3$ ]

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.

### LFO separator in HFO installations (1S02)

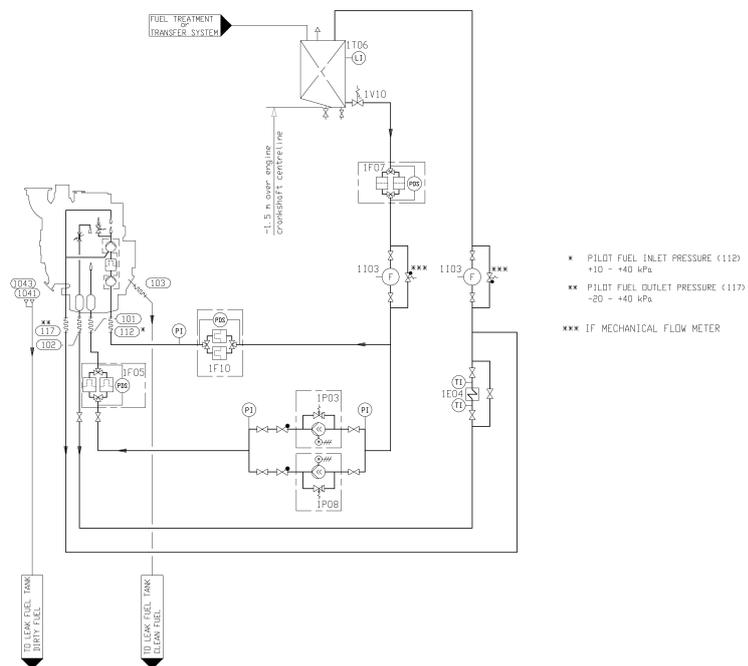
A separator for LFO is recommended also for installations operating primarily on HFO. The LFO separator can be a smaller size dedicated LFO separator, or a stand-by HFO separator used for LFO.

### 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.

## 6.4.1.6 Fuel feed system - LFO installations

### Fuel oil system (LFO), single engine installation



**Fig 6-11 Example of fuel oil system (LFO), single engine installation with electric fuel circulation pump (DAAF013948G)**

System components	
1E04	Cooler (LFO)
1F05	Fine Filter (LFO)
1F07	Suction Strainer (LFO)
1F10	Pilot Fuel Fine Filter or Pilot Fuel Pre-filter (LFO)
1I03	Flow Meter (LFO)
1P03	Circulation Pump (LFO)
1P08	Stand-by Pump (LFO)
1T06	Day Tank (LFO)
1V02	Pressure Control Valve (LFO)
1V10	Quick Closing Valve (Fuel Oil Tank)

Pipe Connections		Size
101	Fuel Inlet	OD18
102	Fuel Outlet	OD18
103	Leak Fuel Drain, Clean Fuel	OD18
1041	Leak Fuel Drain, Dirty Fuel	OD22
1043	Leak Fuel Drain, Dirty Fuel	OD18
112	Pilot Fuel Inlet	OD10
117	Pilot Fuel Outlet	OD15

Fuel oil system (LFO), with black start unit

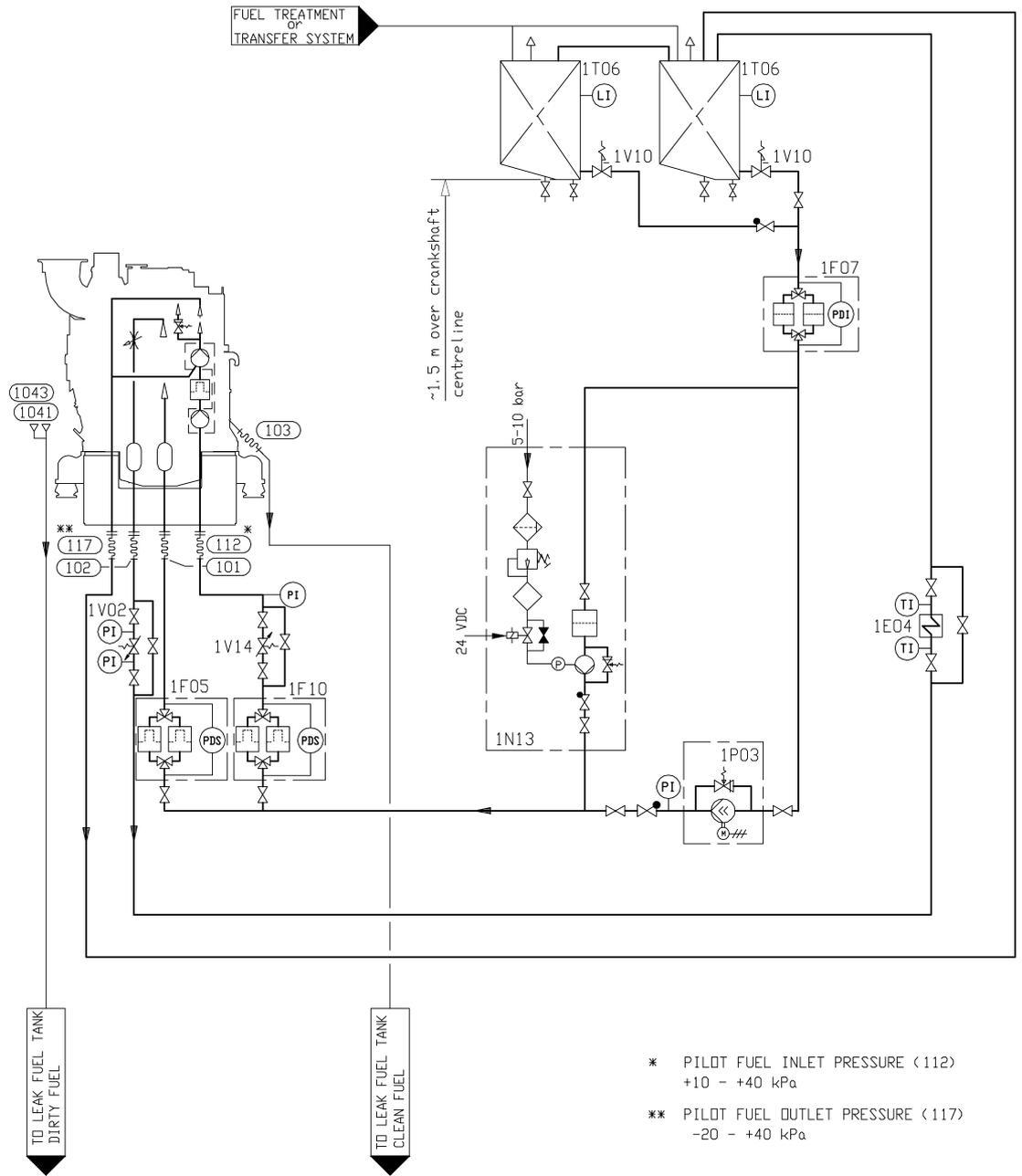
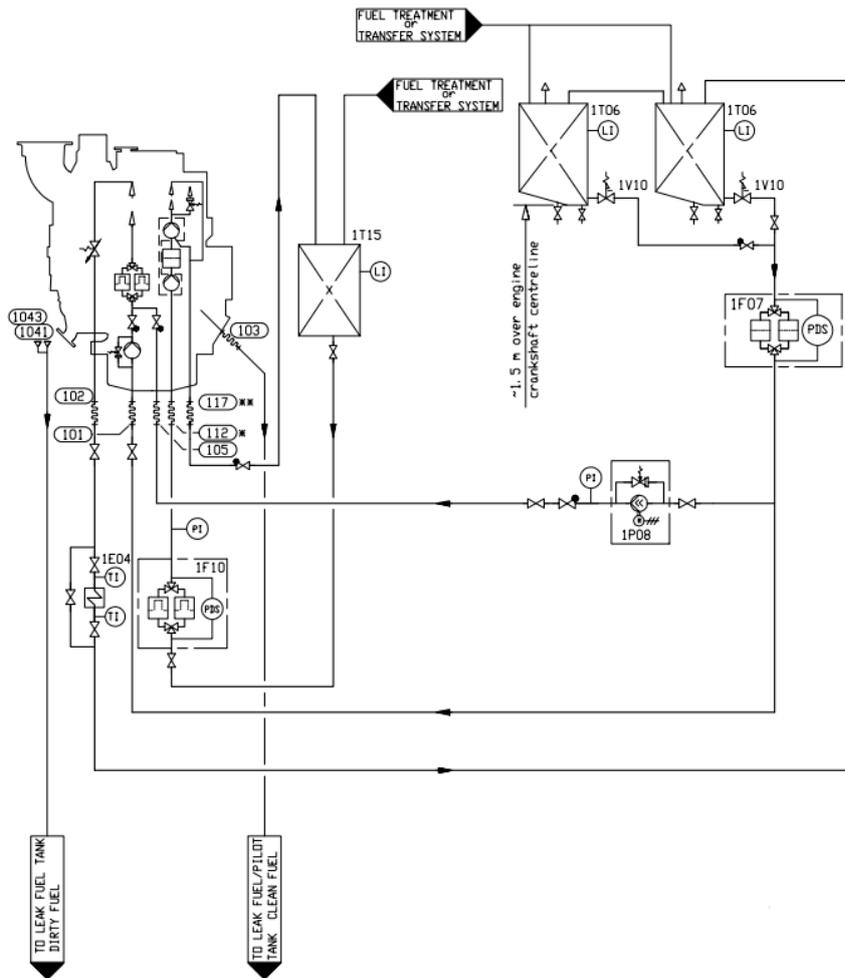


Fig 6-12 Example of fuel oil system (LFO), with black start unit (DAAF056783D)

System components		Pipe connections	
1E04	Cooler (LFO)	101	Fuel inlet - OD18
1F05	Fine filter (LFO)	102	Fuel outlet - OD18
1F07	Suction strainer (LFO)	103	Leak fuel drain, clean fuel - OD18
1F10	Pilot Fuel Fine Filter or Pilot Fuel Pre-filter (LFO)	1041	Leak fuel drain, dirty fuel - OD22
1P03	Circulation pump (LFO)	1043	Leak fuel drain, dirty fuel - OD18
1N13	Black start fuel oil pump unit	112	Pilot fuel inlet - OD10
1T06	Day tank (LFO)	117	Pilot fuel outlet - OD15
1V02	Pressure control valve (LFO)		
1V10	Quick closing valve (fuel oil tank)		
1V14	Pilot fuel pressure reduction valve (LFO)		

Fuel oil system (LFO), single main engine installation



**NOTE**

\* Pilot Fuel Inlet Pressure (112) +10 - +40 kPa

\*\*Pilot Fuel Outlet Pressure (117) -20 - +40 kPa

**Fig 6-13 Example of fuel oil system (LFO), single main engine installation with engine driven fuel pump (DAAF013949G)**

System components		Pipe connections	
1E04	Cooler (LFO)	101	Fuel inlet - OD28
1F07	Suction strainer (LFO)	102	Fuel outlet - OD28
1F10	Pilot Fuel Fine Filter or Pilot Fuel Pre-filter(LFO)	103	Leak fuel drain, clean fuel - OD18
1P08	Stand-by pump (LFO)	1041	Leak fuel drain, dirty fuel - OD22
1T06	Day tank (LFO)	1043	Leak fuel drain, dirty fuel - OD18
1T15	Day tank (pilot fuel)	105	Fuel stand-by connection - OD22
1V10	Quick closing valve (fuel oil tank)	112	Pilot fuel inlet - OD10
		117	Pilot fuel outlet - OD15

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

### Circulation pump, LFO (1P03)

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

#### Design data:

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

### Flow meter, LFO (1I03)

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

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

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

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

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

#### Design data:

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

Maximum permitted pressure drops at 14 cSt:

- clean filter	20 kPa (0.2 bar)
----------------	------------------

(continued)

- alarm 80 kPa (0.8 bar)

### Pilot Fuel Fine Filter or Pilot Fuel Pre-filter, LFO (1F10)

The pilot fuel oil fine filter (or sometimes called pilot fuel pre-filter) is a full flow duplex type filter with steel net. This filter must be installed as near the engine as possible.

The diameter of the pipe between the fine filter 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	acc to max pilot fuel flow 160kg/h (192L/h)
Design pressure	1.6 MPa (16 bar)
Fineness	$\beta_5 = 75$ , ISO16889

Maximum permitted pressure drops at 14 cSt:

- clean filter	20 kPa (0.2 bar)
- alarm	50 kPa (0.5 bar)*

### **NOTICE**

\* The high alarm may differ depending on the type of filter used.

### LFO cooler (1E04)

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

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

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

#### Design data:

Heat to be dissipated	1 kW/cyl
Max. pressure drop, fuel oil	80 kPa (0.8 bar)
Max. pressure drop, water	60 kPa (0.6 bar)
Margin (heat rate, fouling)	min. 15%
Design temperature LFO/HFO installation	50/150°C

### Return fuel tank (1T13)

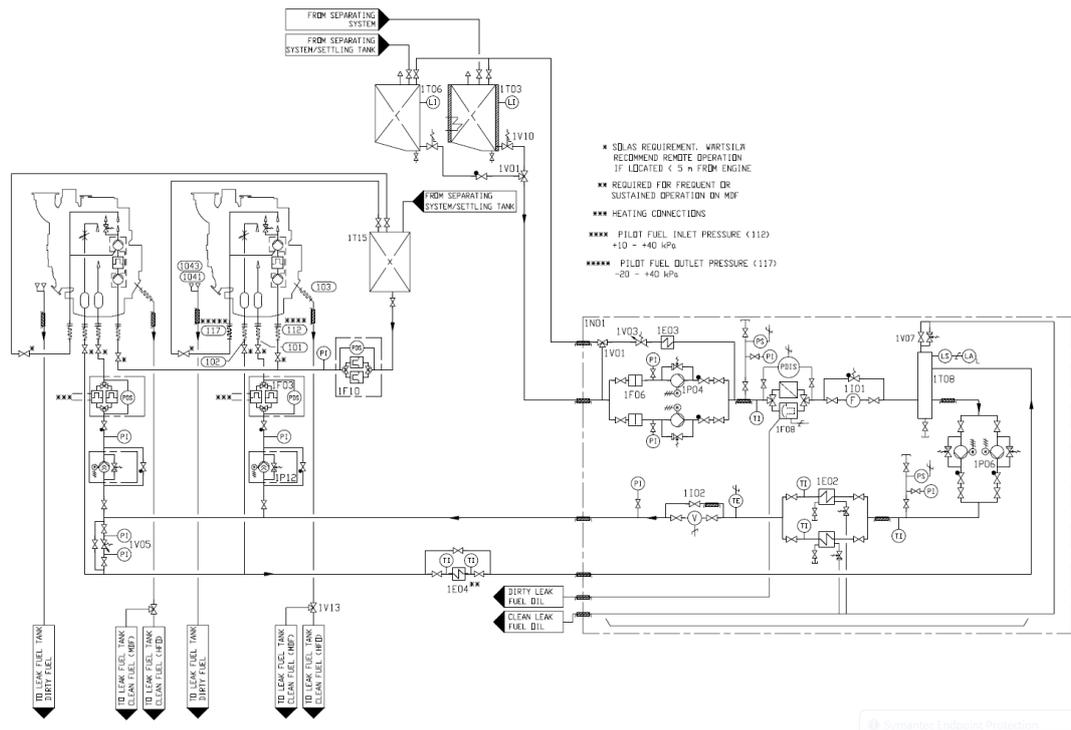
The return fuel tank shall be equipped with a vent valve needed for the vent pipe to the LFO day tank. The volume of the return fuel tank should be at least 100 l.

**Black out start**

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

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

### 6.4.1.7 Fuel feed system - HFO installations



**Fig 6-14 Example of fuel oil system (HFO), multiple engine installation (DAAF013950H)**

**System components:**

1E02	Heater (booster unit)	1P06	Circulation pump (booster unit)
1E03	Cooler (booster unit)	IP12	Circulation pump (HFO/LFO)
1E04	Cooler (LFO)	1T03	Day tank (HFO)
1F03	Safety filter (HFO)	1T06	Day tank (LFO)
1F06	Suction filter (booster unit)	1T08	De-aeration tank (booster unit)
1F08	Automatic filter (booster unit)	1T15	Day tank (pilot fuel)
1F10	Pilot Fuel Fine Filter or Pilot Fuel Pre-filter (LFO)	1V01	Changeover valve
1I01	Flow meter (booster unit)	1V03	Pressure control valve (booster unit)
1I02	Viscosity meter (booster unit)	1V05	Overflow valve (HFO/LFO)
1N01	Feeder / Booster unit	1V07	Venting valve (booster unit)
1P04	Fuel feed pump (booster unit)	1V10	Quick closing valve (fuel oil tank)

**Pipe connections:**

101	Fuel inlet	OD18	1043	Leak fuel drain, dirty fuel	OD18
102	Fuel outlet	OD18	112	Pilot fuel inlet	OD10
103	Leak fuel drain, clean fuel	OD18	117	Pilot fuel outlet	OD15
1041	Leak fuel drain, dirty fuel	OD22			

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

## Starting and stopping

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

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

## Changeover from HFO to LFO

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

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

## Number of engines in the same system

When the fuel feed unit serves Wärtsilä 20DF engines only, maximum two engines should be connected to the same fuel feed circuit, unless individual circulating pumps before each engine are installed.

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

### In addition the following guidelines apply:

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

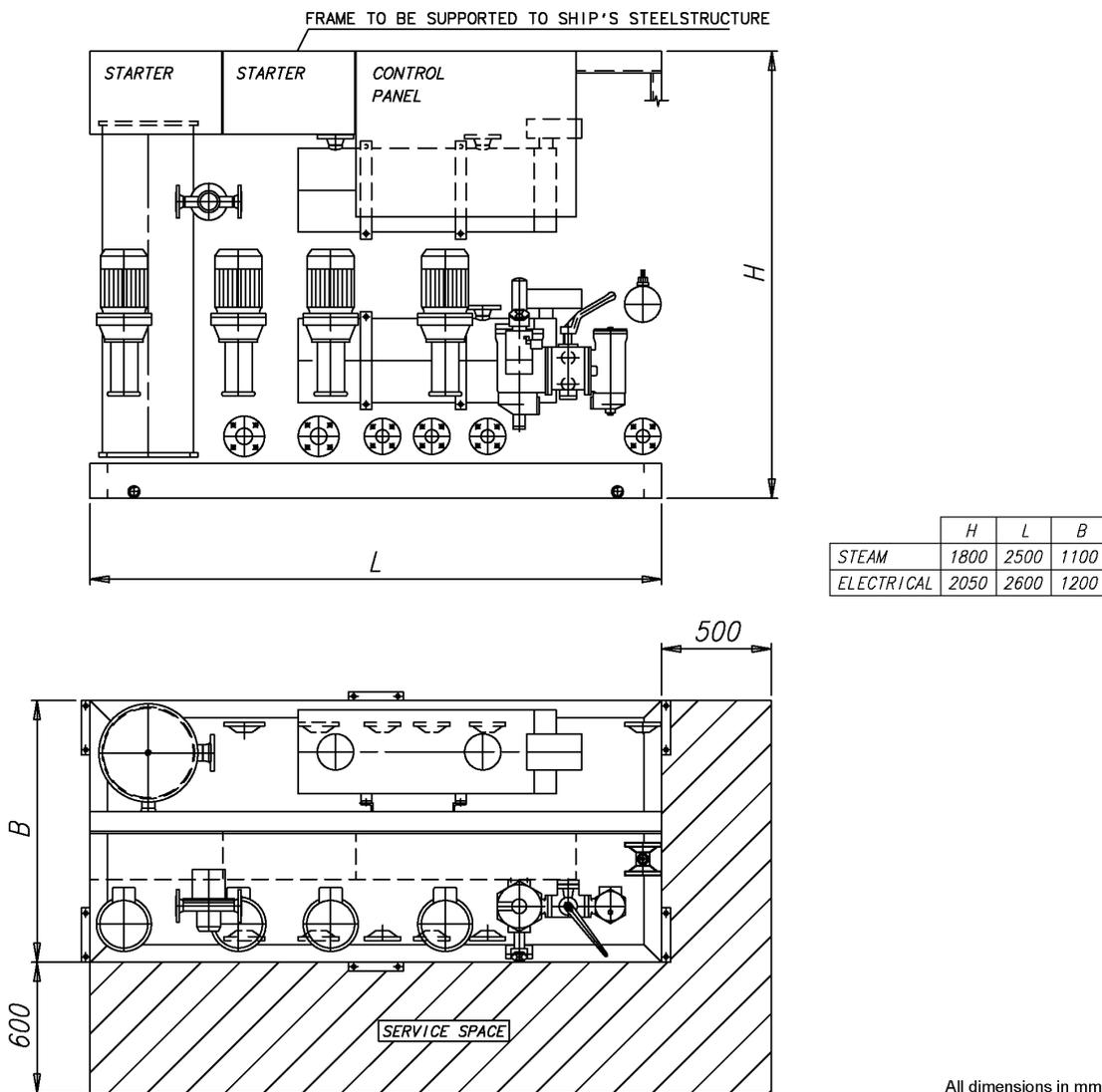
## Feeder/booster unit (1N01)

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

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

- One alarm panel

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



**Fig 6-15 Feeder/booster unit, example (DAAE006659)**

### Fuel feed pump, booster unit (1P04)

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

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

#### Design data:

Capacity	Total consumption of the connected engines added with the flush quantity of the automatic filter (1F08) and 15% margin.
Design pressure	1.6 MPa (16 bar)
Max. total pressure (safety valve)	0.7 MPa (7 bar)

(continued)

Design temperature	100°C
Viscosity for dimensioning of electric motor	1000 cSt

### Pressure control valve, booster unit (1V03)

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

#### Design data:

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

### Automatic filter, booster unit (1F08)

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

#### Design data:

Fuel viscosity	According to fuel specification
Design temperature	100°C
Preheating	If fuel viscosity is higher than 25 cSt/100°C
Design flow	Equal to feed pump capacity
Design pressure	1.6 MPa (16 bar)
Fineness:	
- automatic filter (or fuel main filter)	34 µm absolute ( $\beta_{34} = 2$ , $\beta_{50} = 75$ , ISO 16889)
- stand-by filter	34 µm absolute ( $\beta_{34} = 2$ , $\beta_{50} = 75$ , ISO 16889)

Maximum permitted pressure drops at 14 cSt:

- clean filter	20 kPa (0.2 bar)
- alarm	80 kPa (0.8 bar)

### Flow meter, booster unit (1I01)

If a fuel consumption meter is required, it should be fitted between the feed pumps and the de-aeration tank. When it is desired to monitor the fuel consumption of individual engines in a

multiple engine installation, two flow meters per engine are to be installed: one in the feed line and one in the return line of each engine.

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

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

### De-aeration tank, booster unit (1T08)

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

### Circulation pump, booster unit (1P06)

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

#### Design data:

Capacity without circulation pumps (1P12)	please refer to <a href="#">Engine Online Configurator</a> available through Wärtsilä website
Capacity with circulation pumps (1P12)	15% more than total capacity of all 1P12 circulation pumps
Design pressure	1.6 MPa (16 bar)
Max. total pressure (safety valve)	1.0 MPa (10 bar)
Design temperature	150°C
Viscosity for dimensioning of electric motor	500 cSt

### Heater, booster unit (1E02)

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

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

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

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

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

#### where:

P = heater capacity (kW)

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

(continued)

$\Delta T$  = temperature rise in heater [°C]

### Viscosimeter, booster unit (1I02)

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

#### Design data:

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

### Pump and filter unit (1N03)

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

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

### Circulation pump (1P12)

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

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

#### Design data:

Capacity	please refer to <a href="#">Engine Online Configurator</a> available through Wärtsilä website
Design pressure	1.6 MPa (16 bar)
Max. total pressure (safety valve)	1.0 MPa (10 bar)
Design temperature	150°C
Pressure for dimensioning of electric motor ( $\Delta P$ ):	
- if LFO is fed directly from day tank	0.7 MPa (7 bar)
- if all fuel is fed through feeder/booster unit	0.3 MPa (3 bar)
Viscosity for dimensioning of electric motor	500 cSt

### Safety filter (1F03)

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

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

### Overflow valve, HFO (1V05)

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

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

#### Design data:

Capacity	Equal to circulation pump (1P06)
Design pressure	1.6 MPa (16 bar)
Design temperature	150°C
Set-point ( $\Delta p$ )	0.1...0.2 MPa (1...2 bar)

### Pressure control valve (1V04)

The pressure control valve increases the pressure in the return line so that the required pressure at the engine is achieved. This valve is needed in installations where the engine is equipped with an adjustable throttle valve in the return fuel line of the engine.

The adjustment of the adjustable throttle valve on the engine should be carried out after the pressure control valve (1V04) has been adjusted. The adjustment must be tested in different loading situations including the cases with one or more of the engines being in stand-by mode. If the main engine is connected to the same feeder/booster unit the circulation/temperatures must also be checked with and without the main engine being in operation.

## 6.4.1.8

### Flushing

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

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

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

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## 7. Lubricating Oil System

### 7.1 Lubricating oil requirements

#### 7.1.1 Engine lubricating oil

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

**Table 7-1 Fuel standards and lubricating oil requirements, gas, LFO and LBF operation**

Category	Fuel standard		Lubricating oil BN	Fuel S content, [% m/m]
A	ASTM D 975-17 ISO 8217:2017(E)	GRADE 1-D, 2-D, 4-D ISO-F-DMX - DMB DFA -> DFB	10...15	< 0.4
B	ASTM D 975-17 ISO 8217:2017(E)	GRADE 1-D, 2-D, 4-D ISO-F-DMX - DMB DFA -> DFB	15...20	0.4 - 1.5

If gas oil or LFO is continuously used as fuel, lubricating oil with a BN of 10-20 is recommended to be used. In periodic operation with natural gas and LFO, lubricating oil with a BN of 10-15 is recommended.

The required lubricating oil alkalinity in HFO operation is tied to the fuel specified for the engine, which is shown in the following table.

**Table 7-2 Fuel standards and lubricating oil requirements, HFO operation**

Category	Fuel standard		Lubricating oil BN	Fuel S content, [% m/m]
C	ASTM D 975-17 ASTM D 396-17, ISO 8217:2017(E)	GRADE NO. 4D GRADE NO. 5-6 RMA10-RMK700 (incl. also max. 0,50 % m/m S VLSFO RM)	30...55	≤ 4.5

In installation where engines are running periodically with different fuel qualities, i.e. natural gas, LFO and HFO, lubricating oil quality must be chosen based on HFO requirements. BN 50-55 lubricants are to be selected in the first place for operation on HFO. BN 40 lubricants can also be used with HFO provided that the sulphur content of the fuel is relatively low, and the BN remains above the condemning limit for acceptable oil change intervals. BN 30 lubricating oils should be used together with HFO only in special cases; for example in SCR (Selective Catalytic Reduction) installations, if better total economy can be achieved despite shorter oil change intervals. Lower BN may have a positive influence on the lifetime of the SCR catalyst.

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

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

### Engine oil selection

For the recommendation considering the lubrication oil BN, please refer to the table below. Recommendation is for engines running mainly in gas mode.

**Table 7-3 Engine oil selection**

Fuel	Recommended Oil BN
Mainly gas / occasionally LFO	BN 4–7
Mainly gas / occasionally HFO	BN 20

## 7.1.2 Oil in speed governor or actuator

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

### **NOTICE**

1. Monograde engine oils, multigrade oils or turbocharger oils etc. are not compatible with each other and shall not be mixed. Thus it's important to drain and flush with the new oil both the governor and booster properly if changing the oil quality.
2. Considering the existence of various governor/actuator types, it is advisable to assess the lubricating oil requirement on a case-by-case basis, as some types may not require it.

### **NOTICE**

No oil in digital electric actuator, please contact Wärtsilä for further details.

## 7.1.3 Pilot fuel pump

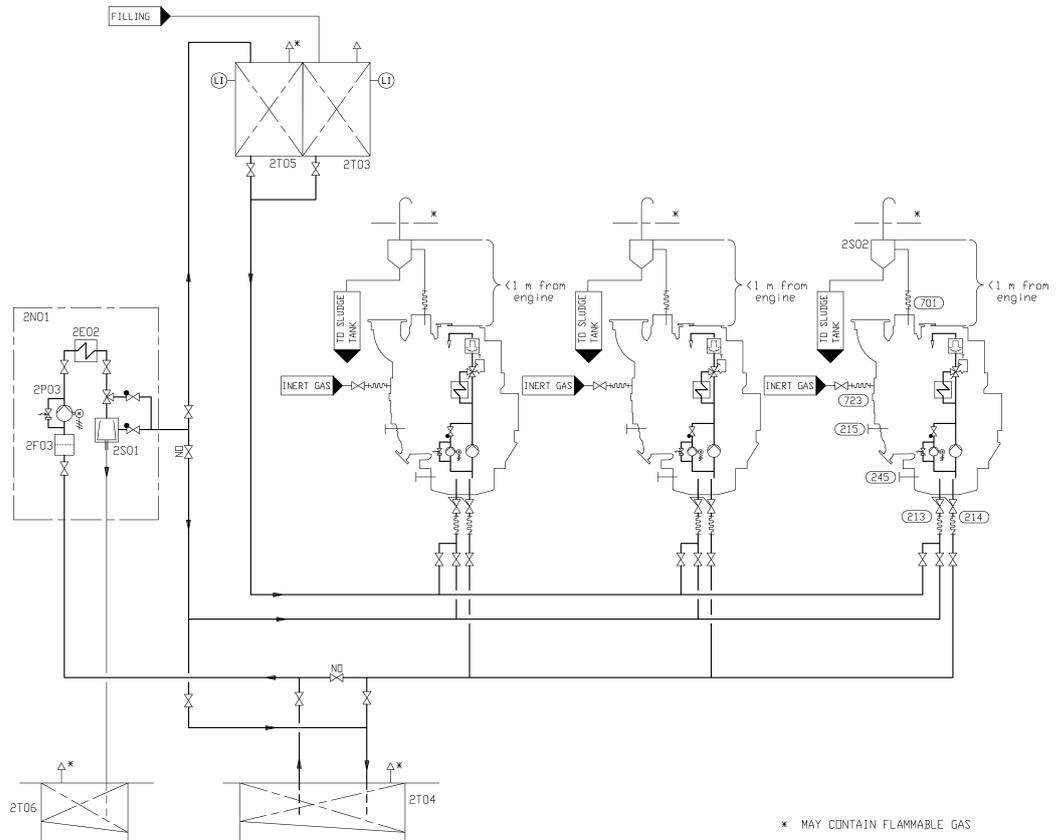
It is recommended to use lithium soap based EP-greases having a penetration of 300...350 when measured according to ASTM D 217 standard and being classed as NLGI Grade 1 at 30...70°C operating temperature.

An updated list of validated oils is supplied for every installation. The oils are valid for pumps with electrical motor only.

Pilot fuel pump is deactivated only when engine is operated at backup mode.

## 7.2 External lubricating oil system

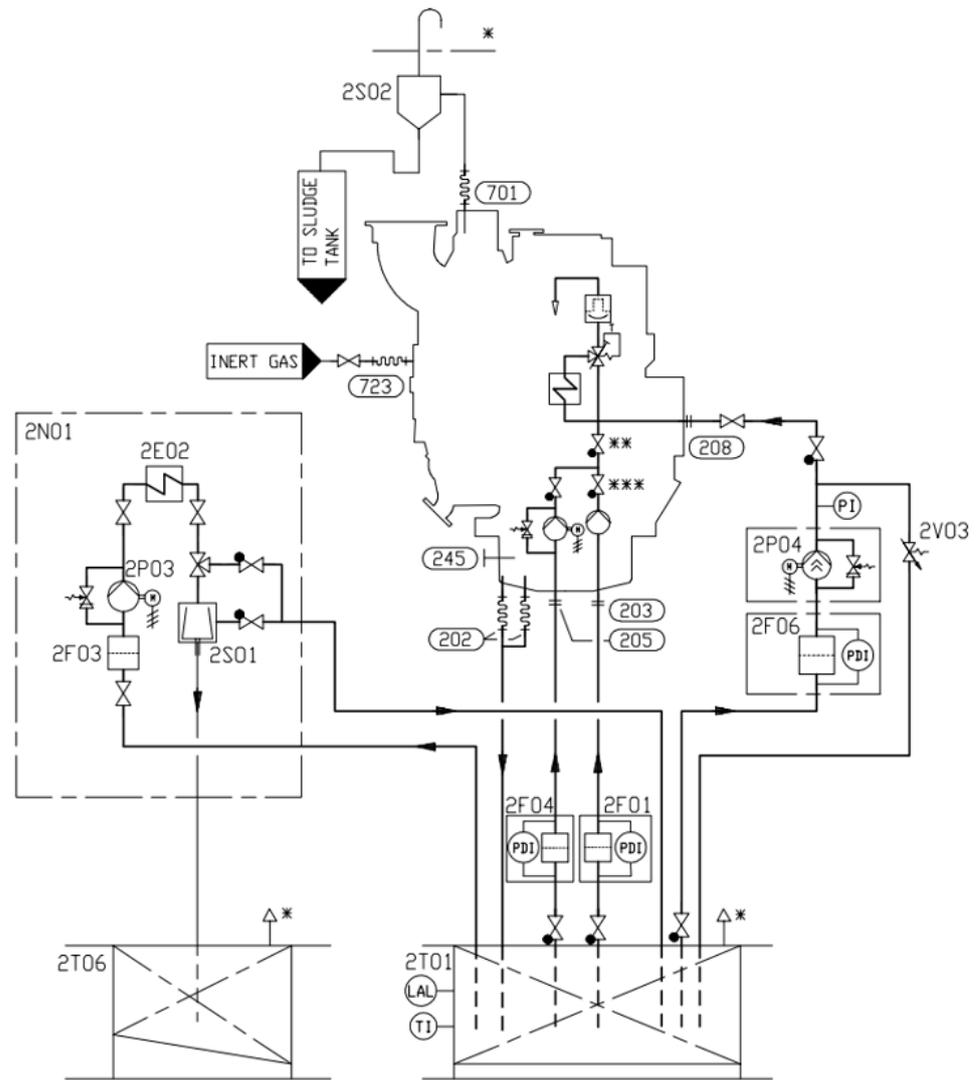
### 7.2.1 Lubricating oil system, wet oil sump



**Fig 7-1 Example of lubricating oil system, auxiliary engine with wet oil sump (DAAF013952F)**

System components		Pipe connections		Size
2E02	Heater (separator unit)	213	Lubricating oil from separator and filling	DN32
2F03	Suction filter (separator unit)	214	Lubricating oil to separator and drain	DN32
2N01	Separator unit	215	Lube oil filling	M48*2
2P03	Separator pump (separator unit)	245	Priming pump lubrication drain	M12
2S01	Separator	701	Crankcase air vent	DN65
2S02	Condensate trap	723	Inert gas inlet	OD12
2T03	New oil tank			
2T04	Renovating oil tank			
2T05	Renovated oil tank			
2T06	Sludge tank			

## 7.2.2 Lubricating oil system, dry oil sump



- \* MAY CONTAIN FLAMMABLE GAS
- \*\* IF STAND-BY PUMP, ENGINE WITH TC IN FLYWHEEL END
- \*\*\* IF STAND-BY PUMP, ENGINE WITH TC IN FREE END

**Fig 7-2 Example of lubricating oil system, single main engine with dry oil sump (DAAF013953E)**

System components		Pipe connections		Size
2E02	Heater (separator unit)	202	Lube oil outlet (from oil sump)	DN100
2F01	Suction strainer (main lube oil pump)	203	Lube oil to engine driven pump	DN100
2F03	Suction filter (separator unit)	205	Lube oil to priming pump	DN32
2F04	Suction strainer (prelubricating oil pump)	208	Lube oil from electric driven pump	DN80
2F06	Suction strainer (stand-by pump)	245	Priming pump lubrication drain	M12
2N01	Separator unit	701	Crankcase air vent	DN65
2P03	Separator pump (separator unit)	723	Inert gas inlet	OD12
2P04	Stand-by pump			

(continued)

System components		Pipe connections		Size
2S01	Separator			
2S02	Condensate trap			
2T01	System oil tank			
2T06	Sludge tank			
2V03	Pressure control valve			

## 7.2.3 Separation system

### 7.2.3.1 Separator unit (2N01)

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

Separators are usually supplied as pre-assembled units.

#### Typically lubricating oil separator units are equipped with:

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

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

#### Separator feed pump (2P03)

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

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

#### Separator preheater (2E02)

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

Recommended oil temperature after the heater is 95°C.

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

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

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

#### Separator (2S01)

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

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

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

where:

Q = volume flow [l/h]

P = engine output [kW]

n = 5 for HFO, 4 for LFO

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

### Sludge tank (2T06)

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

### 7.2.3.2 Renovating oil tank (2T04)

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

### 7.2.3.3 Renovated oil tank (2T05)

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

### 7.2.4 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). Alternatively, through the crankcase cover or through the separator pipe. The system should be arranged so that it is possible to measure the filled oil volume.

### 7.2.5 Suction strainers (2F01, 2F04, 2F06)

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

#### Design data:

Fineness	0.5...1.0 mm
----------	--------------

### 7.2.6 Lubricating oil pump, stand-by (2P04)

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

#### Design data:

Capacity	please refer to <a href="#">Engine Online Configuration</a> or available through Wärtsilä website
Design pressure, max	0.8 MPa (8 bar)
Design temperature, max.	100°C
Lubricating oil viscosity	SAE 40

(continued)

Viscosity for dimensioning the electric motor 500 mm<sup>2</sup>/s (cSt)

## 7.3 Crankcase ventilation system

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

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

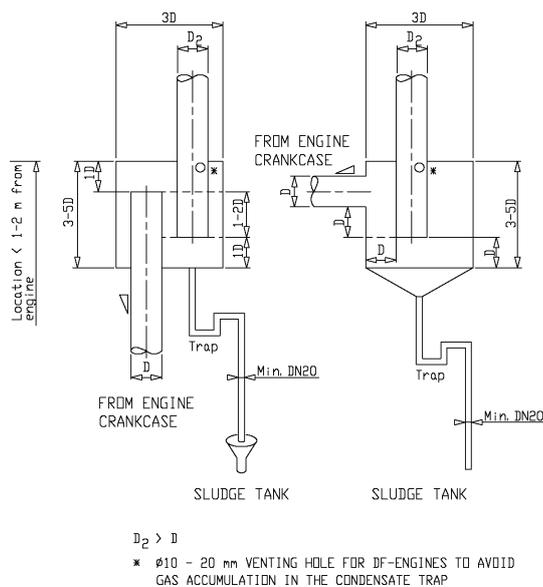
The diameter of the pipe shall be large enough to avoid excessive back pressure. Other possible equipment in the piping must also be designed and dimensioned to avoid excessive flow resistance.

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

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

### Design data:

Flow	please refer to <a href="#">Engine Online Configurator</a> available through Wärtsilä website
Crankcase pressure, max.	please refer to <a href="#">Engine Online Configurator</a> available through Wärtsilä website
Temperature	80°C



The size of the ventilation pipe (D2) out from the condensate trap should be bigger than the ventilation pipe (D) coming from the engine.

For more information about ventilation pipe (D) size, see the external lubricating oil system drawing.

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

**Fig 7-3 Condensate trap (DAAF369903)**

All Wärtsilä dual fuel engines are equipped with oil mist detector (QU700) and crankcase pressure monitoring sensor (PT700). According to the latest classification rules, crankcase pressure must be measured by a separate sensor and not integrated to oil mist detector. High crankcase pressure leads to alarm. Some classification societies may also require engine shutdown due to high crankcase pressure. If high crankcase pressure alarm is triggered during gas operation, engine trips to diesel mode.

All breathing and ventilation pipes that may contain fuel gas must always be built sloping upwards to avoid fuel gas accumulating inside the piping. The free end of the ventilation pipes is to be protected by a flame arrester (usu. provided by yard) and it must be positioned so that winds do not prevent free ventilation.

In installations without constant crankcase gas concentration monitoring, crankcase gas concentration sampling point for manual measurement from running engine should be arranged into the crankcase ventilation piping outside of engine. Usually this is to be built by yard.

<b>NOTICE</b>
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Purging of the crankcase with inert gas is recommended before maintenance interventions. Purging is not required, if engine has been running in diesel mode for at least 15 minutes before shutting down.
---

## 7.4 Flushing instructions

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

### 7.4.1 Piping and equipment built on the engine

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

<b>NOTICE</b>
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The engine must not be connected during flushing.
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### 7.4.2 External oil system

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

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

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

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

If an electric motor driven stand-by pump (2P04) is installed then piping shall be flushed running the pump circulating engine oil through a temporary external oil filter (recommended mesh 34

microns) into the engine oil sump through a hose and a crankcase door. The pump shall be protected by a suction strainer (2F06).

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

## **7.4.3 Type of flushing oil**

### **7.4.3.1 Viscosity**

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

### **7.4.3.2 Flushing with engine oil**

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

### **7.4.3.3 Flushing with low viscosity flushing oil**

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

### **7.4.3.4 Lubricating oil sample**

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

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

## 8. Compressed Air System

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

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

### 8.1 Instrument air quality

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

Instrument air specification:	
Design pressure	1 MPa (10 bar)
Nominal pressure	0.7 MPa (7 bar)
Dew point temperature	+3°C
Max. oil content	1 mg/m <sup>3</sup>
Max. particle size	5 µm
Consumption	Approx. 5,5 Nm <sup>3</sup> /h (running engine) Approx. 5,0 Nm <sup>3</sup> /h (engine not in operation)
Instrument air quality at engine connection	ISO 8573-1:2010 [5:5:3]

The instrument air system is used for controlling the gas venting valve and charge air shut-off valve. The air pressure for controlling the valves is about 600-700 kPa. The instrument air needs to be clean, dry and oil free to secure the function of the components.

Instrument air is filtered air. The instrument air quality should be according to "Quality Standard for Instrument Air" ISA-S7.0.01-1996 except for the max. particle size that should be less than 5 microns instead of max. 40 microns.

## 8.2 External compressed air system

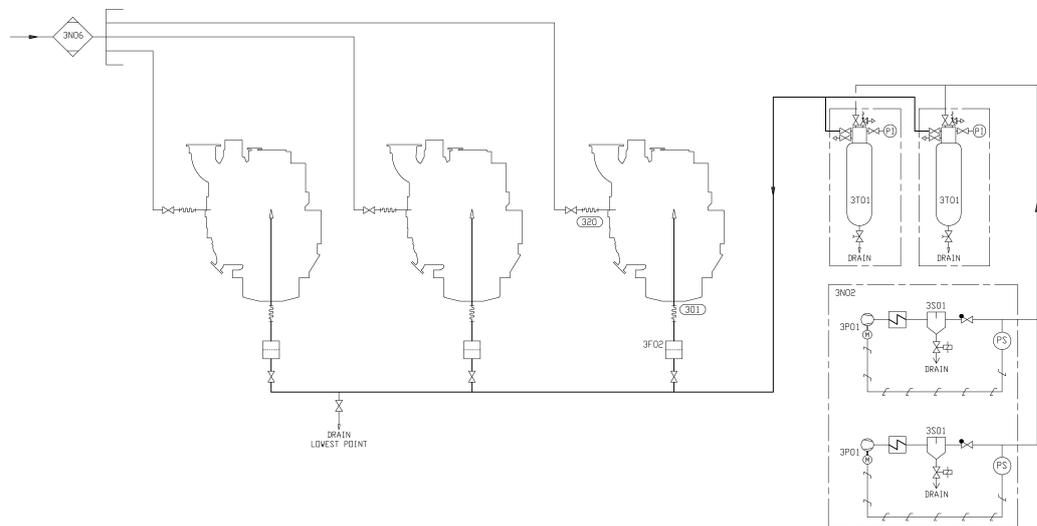
The design of the starting air system is partly determined by classification regulations. Most classification societies require that the total capacity is divided into two equally sized starting air receivers and starting air compressors. The requirements concerning multiple engine installations can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

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

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

### NOTICE

To ensure the fast and reliable start of the engine, the pressure drop during the starting sequence from the starting air vessel to the inlet of the engine must not exceed 100–200 kPa when the vessel pressure is in the middle of the operating range. This pressure drop have to be remarked for sizing of the air feed pipe to the engine. Other requirements and clarifications to meet fast and reliable start such as inertia connected to engine, please contact Wärtsilä for further details.



**Fig 8-1 Example of external compressed air system (DAAF013955E)**

System components		Pipe connections	
3F02	Air filter (starting air inlet)	301	Starting air inlet - OD28
3N02	Starting air compressor unit	320	Instrument air inlet - OD12
3N06	Air dryer unit		
3P01	Compressor (starting air compressor unit)		
3S01	Separator (starting air compressor unit)		
3T01	Starting air vessel		

### 8.2.1 Starting air compressor unit (3N02)

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

### 8.2.2 Oil and water separator (3S01)

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

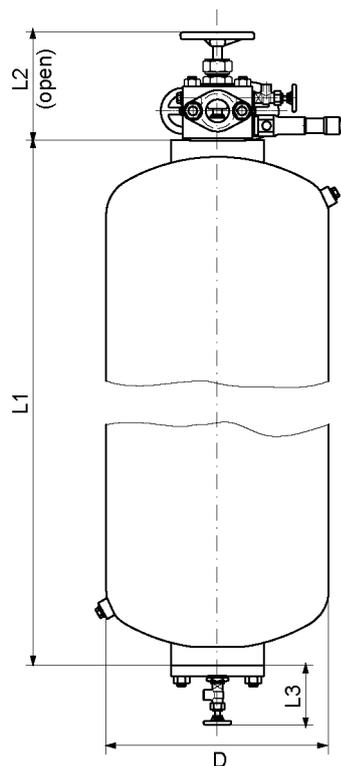
### 8.2.3 Starting air vessel (3T01)

The starting air vessels should be dimensioned for a nominal pressure of 3000 kPa (g).

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

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

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



Size [Litres]	Dimensions [mm]				Weight [kg]
	L1	L2 1)	L3 1)	D	
125	1807	243	110	324	170
180	1217	243	110	480	200
250	1767	243	110	480	274
500	3204	243	133	480	450

1) Dimensions are approximate.

Fig 8-2 Starting air vessel

The starting air consumption stated in [Engine Online Configurator](#) (available through Wärtsilä website) is for a successful start. During start the main starting valve is kept open until the engine starts, or until the max. time for the starting attempt has elapsed. A failed start can take

twice the air consumption of a successful start. If the ship has a class notation for unattended machinery spaces, then the starts are to be demonstrated.

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

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

**where:**

$V_R$  = total starting air vessel volume [m<sup>3</sup>]

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

$V_E$  = air consumption per start [Nm<sup>3</sup>] please refer to [Engine Online Configurator](#) available through Wärtsilä website

$n$  = required number of starts according to the classification society

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

$p_{Rmin}$  = minimum starting air pressure = please refer to [Engine Online Configurator](#) available through Wärtsilä website

<b>NOTICE</b>
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The total vessel volume shall be divided into at least two equally sized starting air vessels.
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## 8.2.4 Air filter, starting air inlet (3F02)

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

An Y-type strainer can be used with a stainless steel screen and mesh size 200 (75 µm). The pressure drop should not exceed 20 kPa (0.2 bar) for the engine specific starting air consumption under a time span of 4 seconds.

The starting air filter is mandatory for Wärtsilä 20DF engines.

## 9. Cooling Water System

### 9.1 Water quality

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

Property .....	Unit	Limits for chemical use
pH <sup>1)</sup> .....	-	6,5 – 8,5
Hardness .....	°dH	max. 10
Chlorides as Cl <sup>1)</sup> .....	mg/l	max. 80
Sulphates as SO <sub>4</sub> .....	mg/l	max. 150
Silica as SiO <sub>2</sub> .....	mg/l	max. 100

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

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

#### 9.1.1 Corrosion inhibitors

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

#### 9.1.2 Validated cooling water additives

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

(continued)

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

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

### 9.1.3 Glycol

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

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

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

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

### 9.1.4 Wärtsilä Water Conditioner Unit (WWCU)

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

- corrosion protection

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

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

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

Due to a severe corrosion risk WWCU can't be used in the cooling water systems containing aluminium or aluminium alloys as a construction material. The reason for the above mentioned ban is that in the cooling water systems equipped with the WWCU pH of cooling water can be above 9 and at that pH range corrosion rate of aluminium / aluminium alloys starts to increase significantly.

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

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

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

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

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

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

WWCU type	Specified water system volume (m <sup>3</sup> )
WWCU F1	0 - 7
WWCU F2	0 - 20
WWCU F3	0 - 40

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

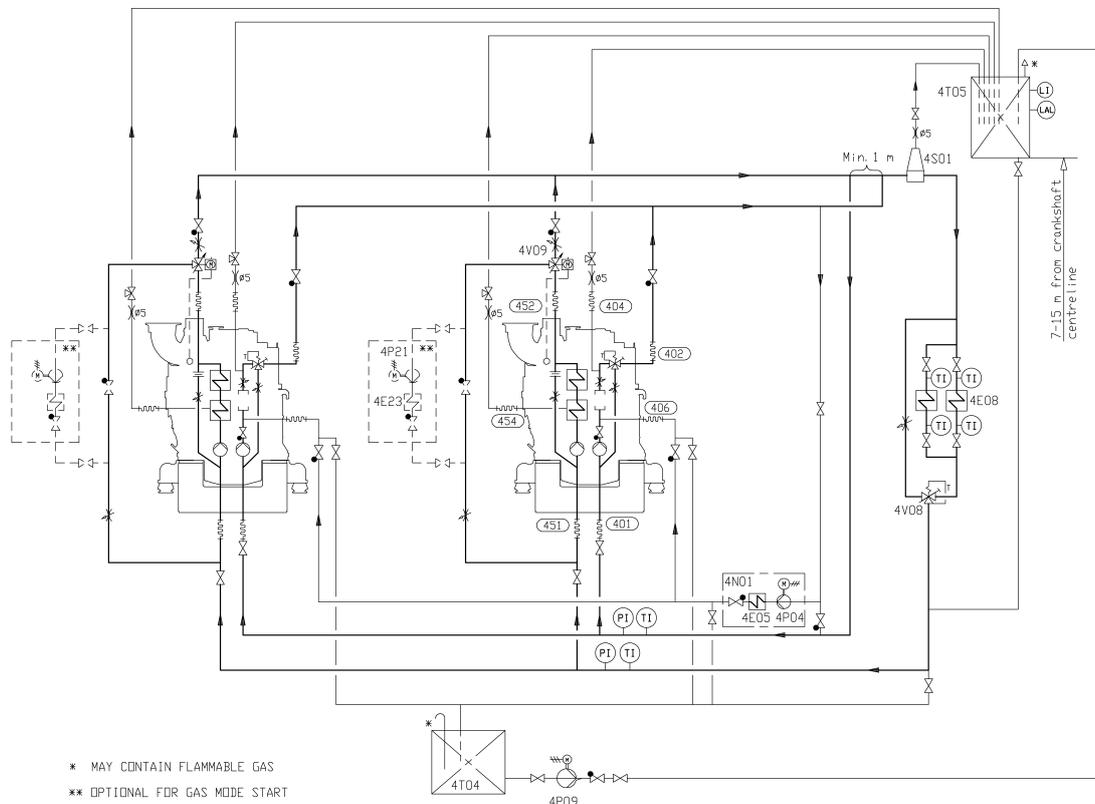
## 9.2 External cooling water system

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

The external system shall be designed so that flows, pressures and temperatures are close to the nominal values specified in [Engine Online Configurator](#) available through Wärtsilä 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.

### 9.2.1 External cooling water system, multiple engines without heat recovery



**Fig 9-1 External cooling water system, multiple engines without heat recovery (DAAF013957F)**

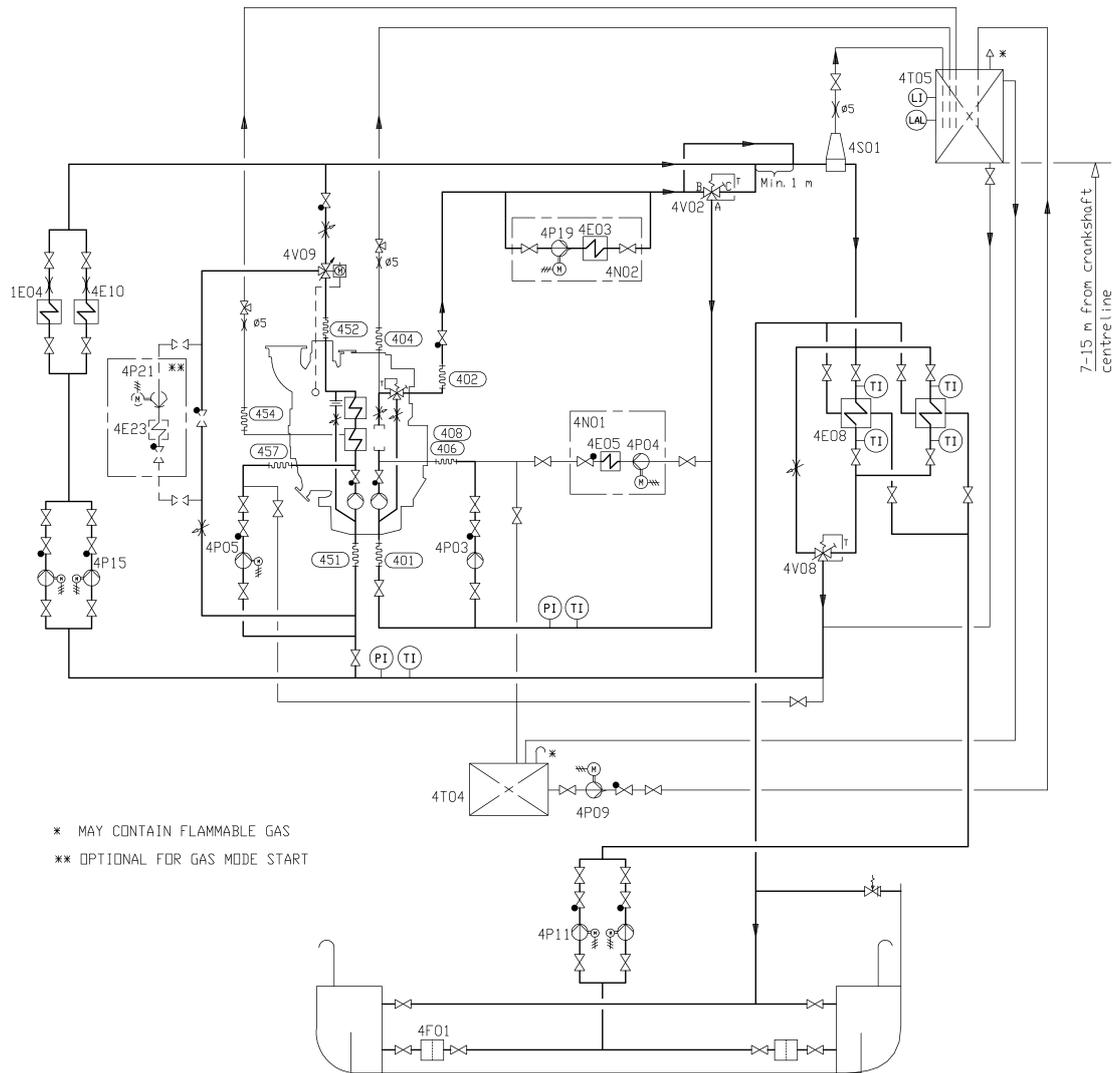
System components:			
4E05	Heater (preheater)	4P21	Circulating pump (preheating LT)
4E08	Central cooler	4S01	Air venting
4E23	Heater (LT)	4T04	Drain tank

(continued)

<b>System components:</b>			
4N01	Preheating unit	4T05	Expansion tank
4P04	Circulating pump (preheater)	4V08	Temperature control valve (central cooler)
4P09	Transfer pump	4V09	Temperature control valve (charge air)

<b>Pipe connections:</b>					
401	HT-water inlet	DN65	451	LT-water inlet	DN80
402	HT-water outlet	DN65	452	LT-water outlet	DN80
404	HT-water air vent	OD12	454	LT-water air vent from air cooler	OD12
406	Water from preheater to HT-circuit	OD28			

## 9.2.2 External cooling water system, single main engine with heat recovery



**Fig 9-2 External cooling water system, single main engine with heat recovery (DAAF013958E)**

System components:			
1E04	Cooler (LFO)	4P09	Transfer pump
4E03	Heat recovery (evaporator)	4P11	Circulating pump (sea water)
4E05	Heater (preheater)	4P15	Circulating pump (LT)
4E08	Central cooler	4P19	Circulating pump (evaporator)
4E10	Cooler (reduction gear)	4P21	Circulating pump (preheating LT)
4E23	Heater (LT)	4S01	Air venting
4F01	Suction strainer (sea water)	4T04	Drain tank
4N01	Preheating unit	4T05	Expansion tank
4N02	Evaporator unit	4V02	Temperature control valve (heat recovery)
4P03	Stand-by pump (HT)	4V08	Temperature control valve (central cooler)
4P04	Circulating pump (preheater)	4V09	Temperature control valve (charge air)
4P05	Stand-by pump (LT)		

Pipe connections:					
401	HT-water inlet	DN65	451	LT-water inlet	DN80
402	HT-water outlet	DN65	452	LT-water outlet	DN80
404	HT-water air vent	OD12	454	LT-water air vent from air cooler	OD12
406	Water from preheater to HT-circuit	DN65	457	LT-water from stand-by pump	DN80
408	HT-water from stand-by pump	DN65			

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

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

### 9.2.3 Stand-by circulation pumps (4P03, 4P05)

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

<b>NOTICE</b>
Stand-by pumps may be considered as backup rather than actual spare pumps.

### 9.2.4 Sea water pump (4P11)

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

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

### 9.2.5 Temperature control valve for central cooler (4V08)

When external equipment (e.g. a reduction gear, generator or LFO cooler) are installed in the same cooling water circuit, there must be a common LT temperature control valve and separate pump 4P15 in the external system. 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 recommended set-point of the temperature control valve 4V08 is 35 °C.

<b>NOTE</b>
Max LT cooling water temperature before engine is 38 °C.

### 9.2.6 Charge air temperature control valve (4V09)

The temperature of the charge air is maintained on desired level with an electrically actuated temperature control valve in the external LT circuit. The control valve regulates the water flow through the LT-stage of the charge air cooler according to the measured temperature in the charge air receiver.

The charge air temperature is controlled according to engine load and fuel mode.

### 9.2.7 Temperature control valve for heat recovery (4V02)

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

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

The set-point is usually up to 75 °C.

## 9.2.8 Coolers for other equipment and LFO coolers

As engine specific LT thermostatic valve is mandatory for DF engines, the engine driven LT pump cannot be used for cooling of external equipment. Instead, separate cooling water pumps must be installed for coolers installed in parallel to the engine.

Design guidelines for the LFO cooler are given in chapter [Fuel system](#).

## 9.2.9 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 [m<sup>3</sup>/h]

$q_{LT}$  = nominal LT pump capacity [m<sup>3</sup>/h]

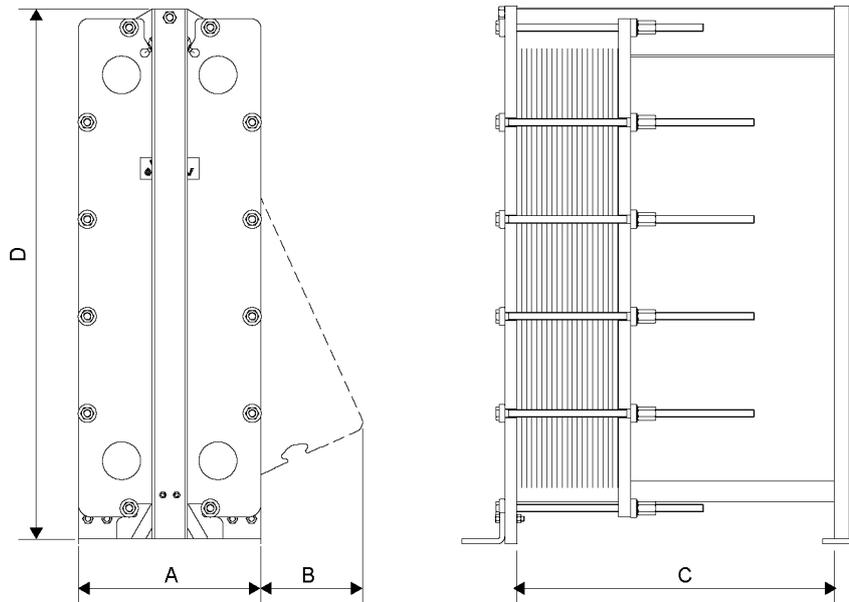
$\Phi$  = heat dissipated to HT water [kW]

$T_{out}$  = HT water temperature after engine (91°C)

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

### Design data:

Fresh water flow	please refer to <a href="#">Engine Online Configurator</a> available through Wärtsilä website
Heat to be dissipated	please refer to <a href="#">Engine Online Configurator</a> available through Wärtsilä website
Pressure drop on fresh water side	max. 60 kPa (0.6 bar)
Sea-water flow	acc. to cooler manufacturer, normally 1.2 - 1.5 x the fresh water flow
Pressure drop on sea-water side, norm.	acc. to pump head, normally 80 - 140 kPa (0.8 - 1.4 bar)
Fresh water temperature after LT cooler	max. 38 °C
Fresh water temperature after HT cooler	max. 83 °C
Margin (heat rate, fouling)	15%



**Fig 9-3 Central cooler main dimensions. Example for guidance only**

Engine type	rpm	A [mm]	C [mm]	D [mm]	Weight [kg]
W 6L20DF	1000	578	425	1133	290
	1200	578	425	1133	310
W 8L20DF	1000	578	425	1133	310
	1200	446	587	1082	330
W 9L20DF	1000	578	675	1133	340
	1200	589	960	1760	470

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

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

## 9.2.10 Waste heat recovery

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

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

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

## 9.2.11 Air venting

Air may be entrained in the system after an overhaul, or a leak may continuously add air or gas into the system. The engine is equipped with vent pipes to evacuate air from the cooling water circuits. The vent pipes should be drawn separately to the expansion tank from each connection on the engine.

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

The vent pipes must be continuously rising.

## 9.2.12 Expansion tank (4T05)

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

### Design data:

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

### **NOTICE**

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

Concerning the water volume in the engine, please refer to [Engine Online Configurator](#) available through Wärtsilä website.

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

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

Small amounts of fuel gas may enter the DF-engine cooling water system. The gas (just like air) is separated in the cooling water system and will finally be released in the cooling water expansion tank. Therefore, the cooling water expansion tank has to be of closed-top type, to prevent release of gas into open air.

For proper deaeration the expansion vessel low level anyhow to be clearly the cooling water systems highest point. Static connection from vessel to pipe before engine pump inlet recommended DN50 size.

The DF-engine cooling water expansion tank breathing has to be treated similarly to the gas pipe ventilation. Openings into open air from the cooling water expansion tank other than the breather pipe have to be normally either closed or of type that does not allow fuel gas to exit the tank (e.g. overflow pipe arrangement with water lock). The cooling water expansion tank breathing pipes of engines located in same engine room can be combined.

The structure and arrangement of cooling water expansion tank may need to be approved by Classification Society project-specifically.

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

**Table 9-1 Minimum diameter of balance pipe**

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

### 9.2.13 Drain tank (4T04)

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

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

### 9.2.14 HT preheating

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

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

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

#### 9.2.14.1 HT heater (4E05)

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

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

The minimum required heating power is 2 kW/cyl, which makes it possible to warm up the engine from 20 °C to 60...70 °C in 10-15 hours. The required heating power for shorter heating time can be estimated with the formula below. About 1 kW/cyl is required to keep a hot engine warm.

**Design data:**

Preheating temperature	min. 50°C for starts at LFO or gas; min 70°C for startings at HFO
Required heating power	2 kW/cyl
Heating power to keep hot engine warm	1 kW/cyl

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

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

where:

- P = Preheater output [kW]
- T<sub>1</sub> = Preheating temperature = 60...70 °C
- T<sub>0</sub> = Ambient temperature [°C]
- m<sub>eng</sub> = Engine weight [tonne]
- V<sub>LO</sub> = Lubricating oil volume [m<sup>3</sup>] (wet sump engines only)
- V<sub>FW</sub> = HT water volume [m<sup>3</sup>]
- t = Preheating time [h]
- k<sub>eng</sub> = Engine specific coefficient = 0.5 kW
- n<sub>cyl</sub> = Number of cylinders

### 9.2.14.2 Circulation pump for HT preheater (4P04)

Design data:

- Capacity 0.3 m<sup>3</sup>/h per cylinder
- Delivery pressure 80...100 kPa (0.8...1.0 bar)

### 9.2.14.3 Preheating unit (4N01)

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

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

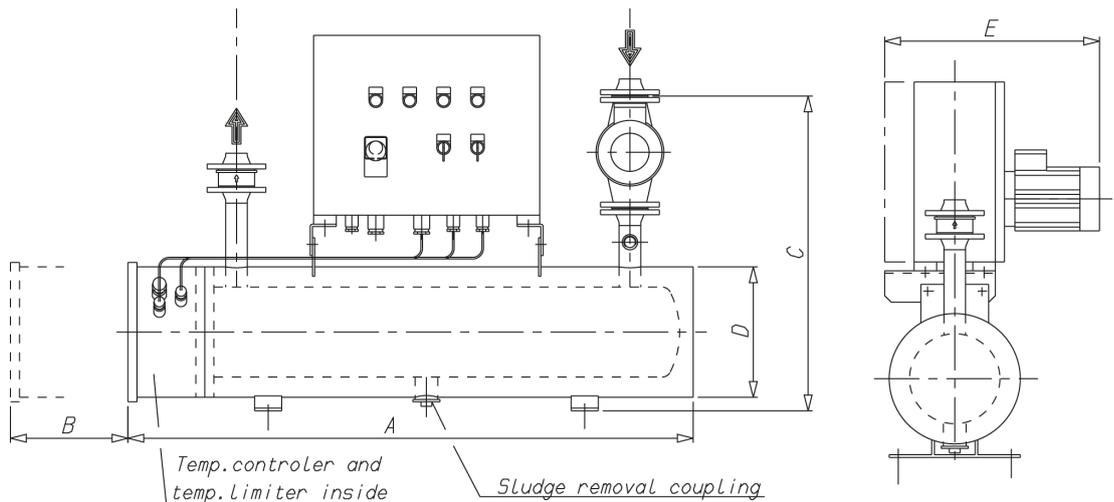


Fig 9-4 Preheating unit, electric (V60L0653A)

Heater capacity	Pump capacity	Weight	Pipe connections	Dimensions				
				kW	m <sup>3</sup> / h	kg	Inlet / Outlet	A
7.5	3	75	DN40	1050	720	610	190	425

(continued)

Heater capacity	Pump capacity	Weight	Pipe connections	Dimensions				
kW	m <sup>3</sup> / h	kg	Inlet / Outlet	A	B	C	D	E
12	3	93	DN40	1050	550	660	240	450
15	3	93	DN40	1050	720	660	240	450
18	3	95	DN40	1250	900	660	240	450
22.5	8	100	DN40	1050	720	700	290	475
27	8	103	DN40	1250	900	700	290	475
30	8	105	DN40	1050	720	700	290	475
36	8	125	DN40	1250	900	700	290	475
45	8	145	DN40	1250	720	755	350	505
54	8	150	DN40	1250	900	755	350	505

### 9.2.15 LT preheater (4E23)

If loading in gas mode directly after start is desired, LT preheating is to be arranged to ensure charge air receiver temperature of 45 °C. Required heating power of the LT cooling water is 4 kW per cylinder.

### 9.2.16 Throttles

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

### 9.2.17 Thermometers and pressure gauges

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

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

## 10. Combustion Air System

### 10.1 Engine room ventilation

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

The air intakes to the engine room must be located and designed so that water spray, rain water, dust and exhaust gases cannot enter the ventilation ducts and the engine room. For the minimum requirements concerning the engine room ventilation and more details, see the Dual Fuel Safety Concept and applicable standards.

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

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

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

The amount of air required for ventilation (note also that the earlier mentioned demand on 30 air exchanges/hour has to be fulfilled) is then calculated using the formula:

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

**where:**

$Q_v$  = air flow [m<sup>3</sup>/s]

$\Phi$  = total heat emission to be evacuated [kW]

$\rho$  = air density 1.13 kg/m<sup>3</sup>

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

$\Delta T$  = temperature rise in the engine room [°C]

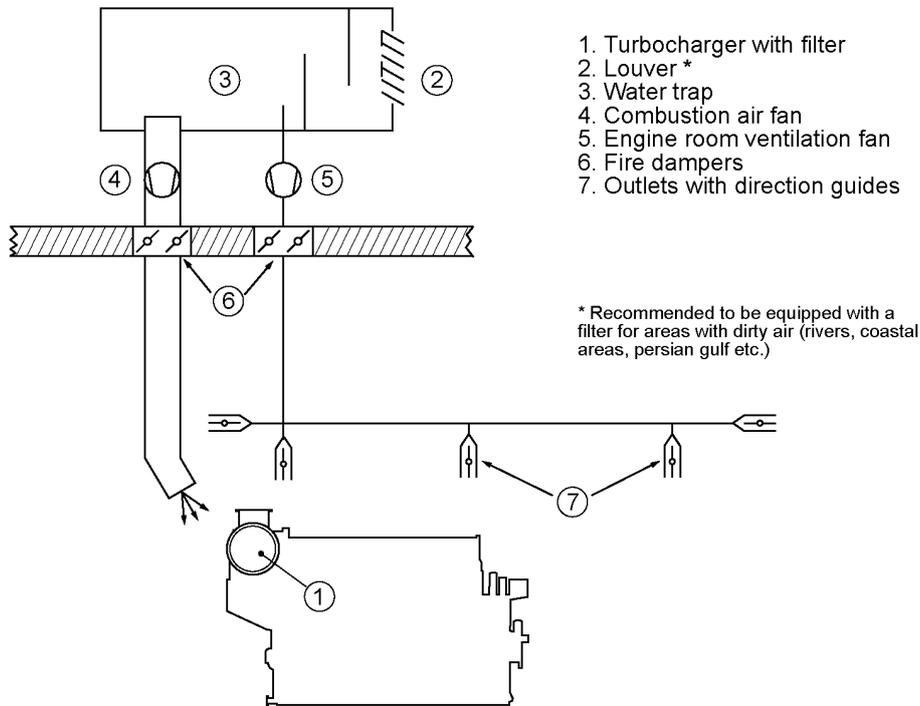
The heat emitted by the engine is listed in [Engine Online Configurator](#) available through Wärtsilä website.

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

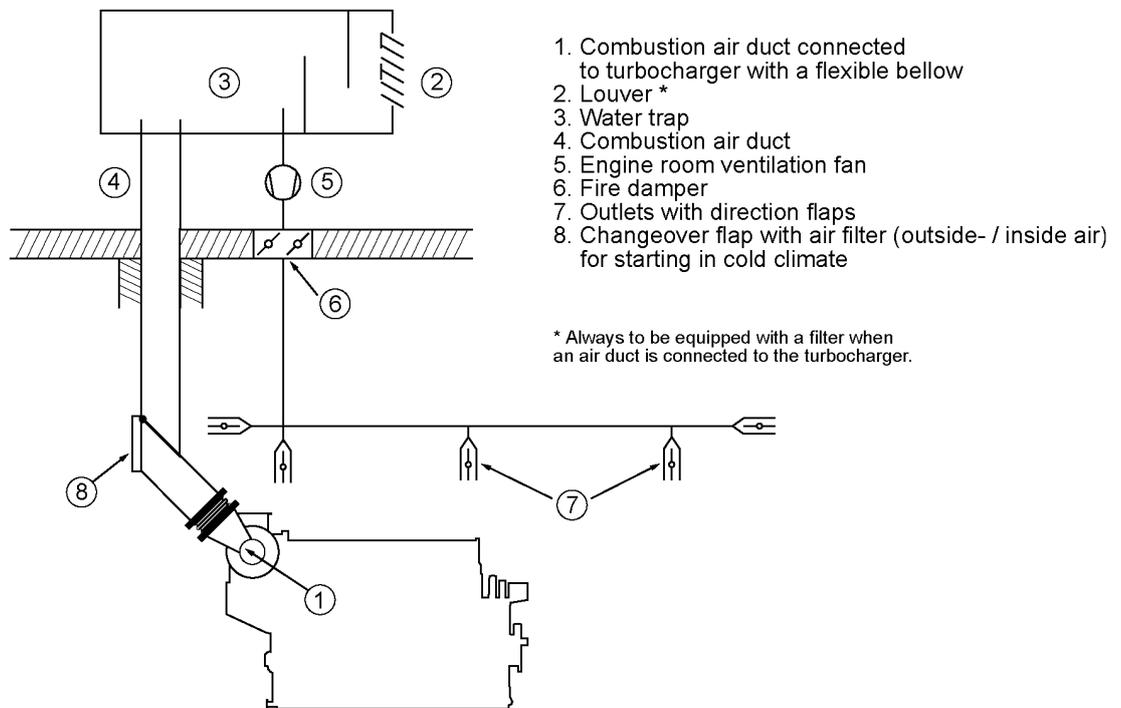
The ventilation air is to be equally distributed in the engine room considering air flows from points of delivery towards the exits. This is usually done so that the funnel serves as exit for most of the air. To avoid stagnant air, extractors can be used.

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

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



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



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

## 10.2 Combustion air system design

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

For the required amount of combustion air, please refer to [Engine Online Configurator](#) available through Wärtsilä website.

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

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

where:

$q_c$  = combustion air volume flow [m<sup>3</sup>/s]

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

$\rho$  = air density 1.15 kg/m<sup>3</sup>

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

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

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

If necessary, the combustion air duct can be connected directly to the turbocharger with a flexible connection piece. With this arrangement an external filter must be installed in the duct to protect the turbocharger and prevent fouling of the charge air cooler. The permissible total pressure drop in the duct is max. 1.5 kPa. The duct should be provided with a step-less change-over flap to take the air from the engine room or from outside depending on engine load and air temperature.

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

### 10.2.1 Charge air shut-off valve (optional)

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

## 10.2.2 Condensation in charge air coolers

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

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

### Example, according to the diagram:

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

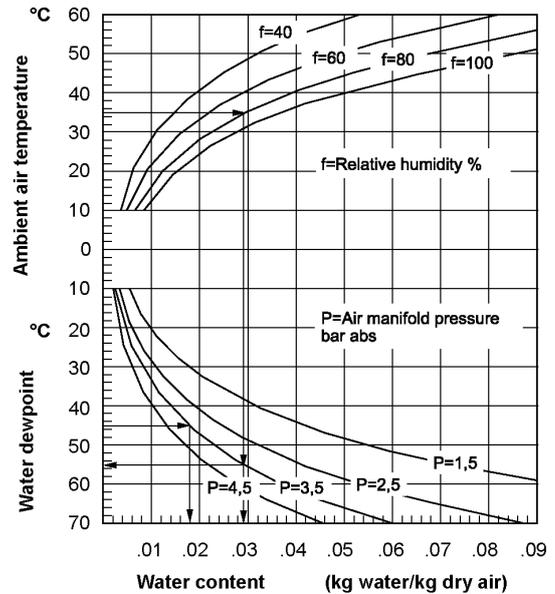


Fig 10-3 Condensation in charge air coolers

## 11. Exhaust Gas System

### 11.1 Temperature sensor location after Turbocharger

For measuring the exhaust gases after the turbocharger, the engine is delivered with temperature sensor TE517. The sensor is located at the exhaust gas bend, which is mounted on the turbocharger. Measuring results from this sensor is used to alarm / trigger load reduction, if exhaust gasses are abnormal high. It is also used in exhaust gas temperature (t6) control functionality in the SCR installations.

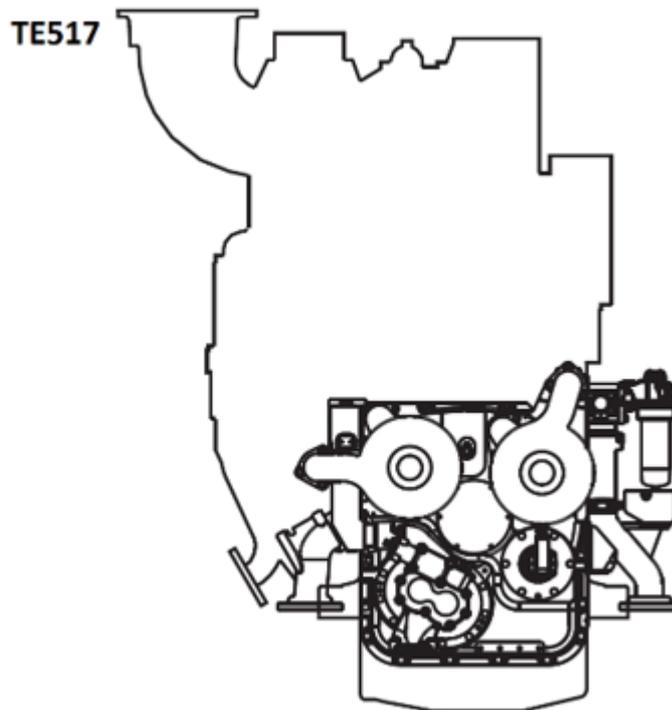


Fig 11-1 TE517 sensor location on turbocharger bend curve

#### To be noted in SCR installations

When urea injection is activated, urea water liquid and compressed air, which are colder than exhaust gasses, are mixed into the hot exhaust gasses in the mixing and injection unit. This endothermic reaction, which happens before SCR reactor, drops the exhaust gas temperature from the engine t6 set point with approx. 5-10 °C. This means that exhaust gas temperature just before the SCR reactor inlet is approx. 5-10 °C lower than temperature at TE517. Temperature drop is load and exhaust gas flow dependent. Largest temperature drop affect can therefore be seen on low engine loads, where urea injection ratio is higher compared to the decreased exhaust gas flow.

The exothermic chemical reaction that is taking place inside the SCR reactor, increases the exhaust gas temperature with approx. 10 °C. The exhaust gas temperature at SCR outlet is therefore approx. the same as at TE517 sensor location.

When urea is not injected, its cooling affect before catalyst elements is not seen. This means that SCR inlet and outlet temperatures should be even.

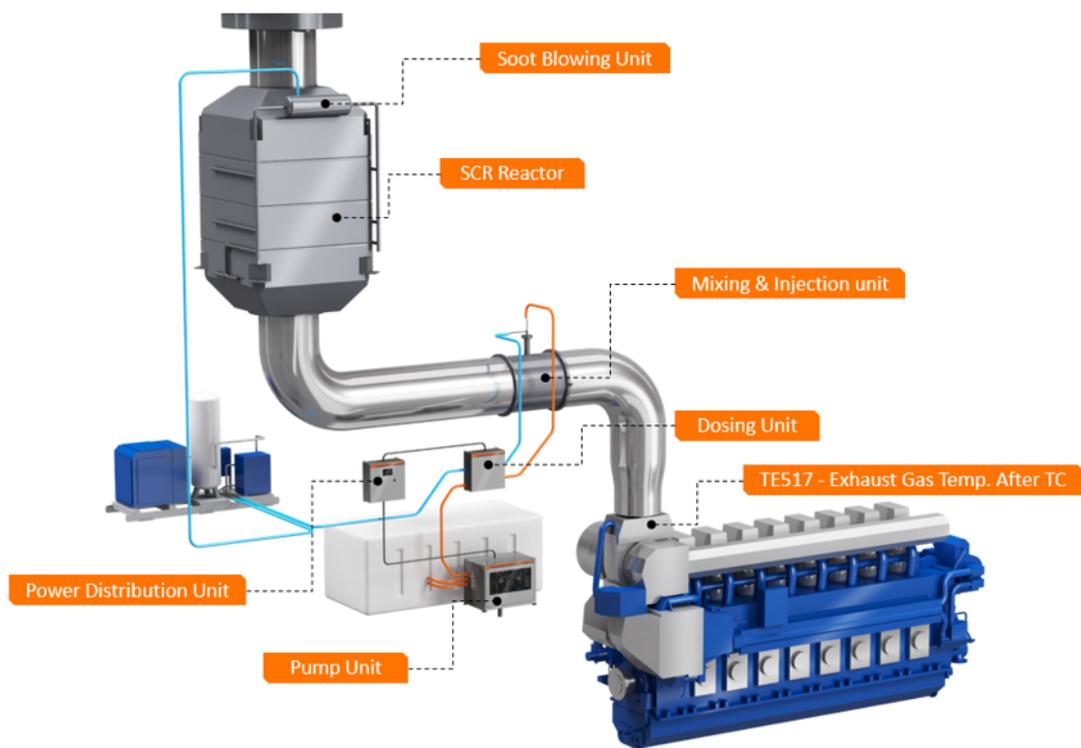
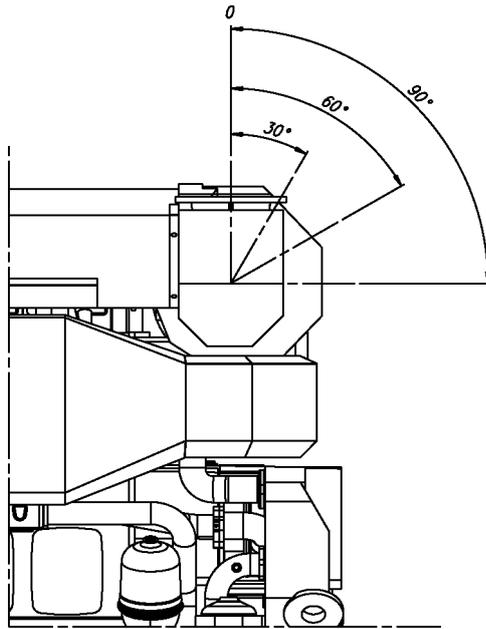


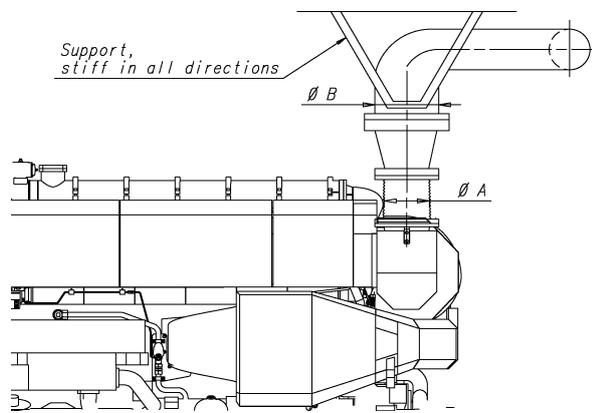
Fig 11-2 Principle layout of SCR (Wärtsilä NOR)

## 11.2 Exhaust gas outlet



Engine	TC in free end and/or TC in drive end
W 6L20DF	0°, 30°, 60°, 90°
W 8L20DF	0°, 30°, 60°, 90°
W 9L20DF	0°, 30°, 60°, 90°

**Fig 11-3 Exhaust pipe connections (DAAE066842)**



Engine	$\varnothing A$ [mm]	$\varnothing B$ [mm]
W 6L20DF	250	300-350
W 8L20DF	300	350-450
W 9L20DF	300	350-450

**Fig 11-4 Exhaust pipe, diameters and support (DAAF014083)**

## 11.3 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.

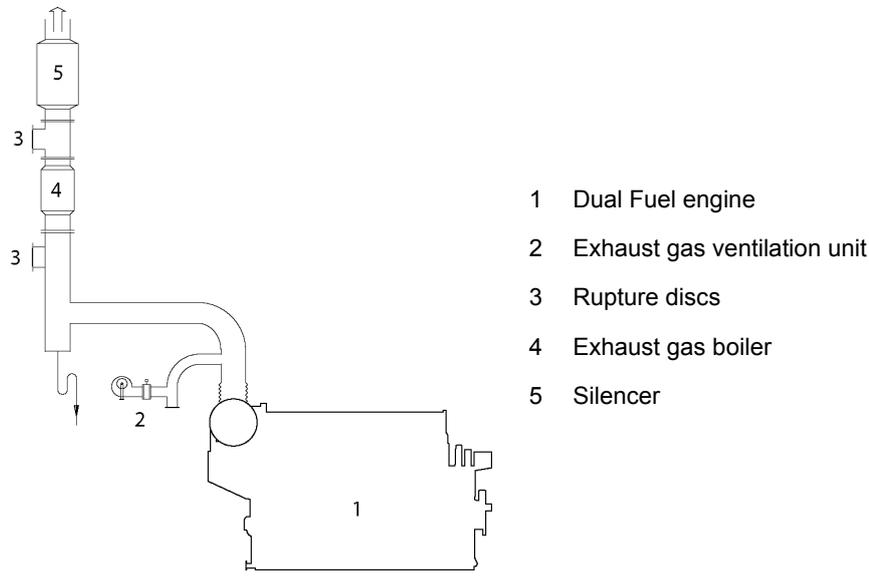


Fig 11-5 External exhaust gas system

### 11.3.1 System design - safety aspects

Natural gas may enter the exhaust system if a malfunction occurs during gas operation. The gas may accumulate in the exhaust piping and it could be ignited in case a source of ignition (such as a spark) appears in the system. The external exhaust system must therefore be designed so that the pressure build-up in case of an explosion does not exceed the maximum permissible pressure for any of the components in the system. The engine can tolerate a pressure of at least 200 kPa. Other components in the system might have a lower maximum pressure limit. The consequences of a possible gas explosion can be minimized with proper design of the exhaust system; the engine will not be damaged and the explosion gases will be safely directed through predefined routes. The following guidelines should be observed, when designing the external exhaust system:

- The piping and all other components in the exhaust system should have a constant upward slope to prevent gas from accumulating in the system. If horizontal pipe sections cannot be completely avoided, their length should be kept to a minimum. The length of a single horizontal pipe section should not exceed five times the diameter of the pipe. Silencers and exhaust boilers etc. must be designed so that gas cannot accumulate inside.
- The exhaust system must be equipped with explosion relief devices, such as rupture discs, in order to ensure safe discharge of explosion pressure. The outlets from explosion relief devices must be in locations where the pressure can be safely released.

In addition the control and automation systems include the following safety functions:

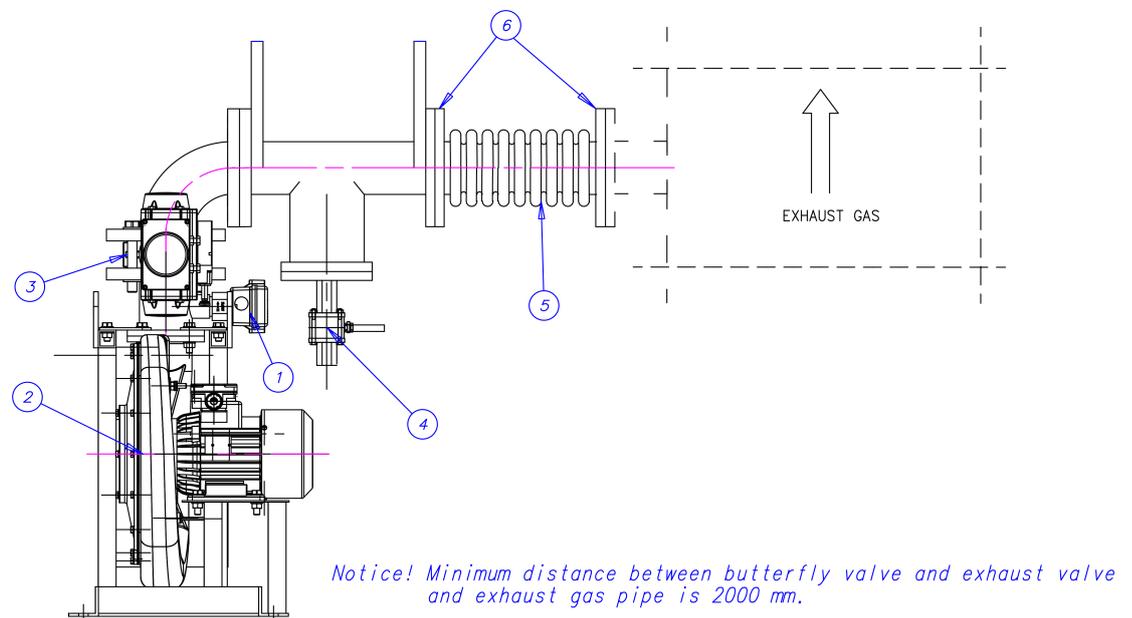
- Before start the engine is automatically ventilated, i.e. rotated without injecting any fuel.

- During the start sequence, before activating the gas admission to the engine, an automatic combustion check is performed to ensure that the pilot fuel injection system is working correctly.
- The combustion in all cylinders is continuously monitored and should it be detected that all cylinders are not firing reliably, then the engine will automatically trip to diesel mode.
- The exhaust gas system is ventilated by a fan after the engine has stopped, if the engine was operating in gas mode prior to the stop.

### 11.3.2 Exhaust gas ventilation unit (5N01)

An exhaust gas ventilation system is required to purge the exhaust piping after the engine has been stopped in gas mode. The exhaust gas ventilation system is a class requirement. The ventilation unit is to consist of a centrifugal fan, a flow switch and a butterfly valve with position feedback. The butterfly valve has to be of gas-tight design and able to withstand the maximum temperature of the exhaust system at the location of installation.

The fan can be located inside or outside the engine room as close to the turbocharger as possible. The exhaust gas ventilation sequence is automatically controlled by the GVU.



**Fig 11-6 Exhaust gas ventilation arrangement (DAAF315146A)**

Unit components			
1	Switch	4	Drain
2	Fan	5	Bellow
3	Butterfly valve	6	Flange

### 11.3.3 Relief devices - rupture discs

Explosion relief devices such as rupture discs are to be installed in the exhaust system. Outlets are to discharge to a safe place remote from any source of ignition. The number and location of explosion relief devices shall be such that the pressure rise caused by a possible explosion cannot cause any damage to the structure of the exhaust system.

This has to be verified with calculation or simulation. Explosion relief devices that are located indoors must have ducted outlets from the machinery space to a location where the pressure

can be safely released. The ducts shall be at least the same size as the rupture disc. The ducts shall be as straight as possible to minimize the back-pressure in case of an explosion.

For under-deck installation the rupture disc outlets may discharge into the exhaust casing, provided that the location of the outlets and the volume of the casing are suitable for handling the explosion pressure pulse safely. The outlets shall be positioned so that personnel are not present during normal operation, and the proximity of the outlet should be clearly marked as a hazardous area.

### 11.3.4 Piping

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

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

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

**where:**

v = gas velocity [m/s]

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

T = exhaust gas temperature [°C]

D = exhaust gas pipe diameter [m]

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

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

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

### 11.3.5 Supporting

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

Absolutely rigid mounting between the pipe and the support is recommended at the first fixing point after the turbocharger. Resilient mounts can be accepted for resiliently mounted engines with "double" variant bellows (bellow capable of handling the additional movement), provided that the mounts are self-captive; maximum deflection at total failure being less than 2 mm radial and 4 mm axial with regards to the bellows. The natural frequencies of the mounting should

be on a safe distance from the running speed, the firing frequency of the engine and the blade passing frequency of the propeller. The resilient mounts can be rubber mounts of conical type, or high damping stainless steel wire pads. Adequate thermal insulation must be provided to protect rubber mounts from high temperatures. When using resilient mounting, the alignment of the exhaust bellows must be checked on a regular basis and corrected when necessary.

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

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

### 11.3.6 Back pressure

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

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

### 11.3.7 Exhaust gas bellows (5H01, 5H03)

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

### 11.3.8 SCR-unit (11N14)

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

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

### 11.3.9 Exhaust gas boiler

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

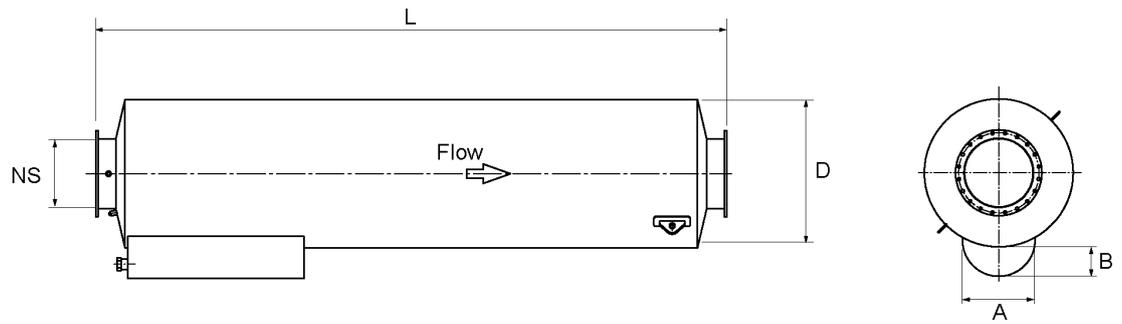
For dimensioning the boiler, the exhaust gas quantities and temperatures given in [Engine Online Configurator](#) available through Wärtsilä website.

### 11.3.10 Exhaust gas silencer (5R09)

The yard/designer should take into account that unfavorable 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 should be mounted vertically.

The noise attenuation of the standard silencer is either 25 or 35 dB(A).



**Fig 11-7 Exhaust gas silencer (DAAE087980)**

**Table 11-1 Typical dimensions of exhaust gas silencers, Attenuation 35 dB (A)**

NS	L [mm]	D [mm]	A [mm]	B [mm]	Weight [kg]
300	3530	860	305	150	455
350	3780	950	346	115	580
400	4280	1060	420	150	710
450	4280	1200	470	180	855

**Flanges: DIN 2501**

# 12. Turbocharger Cleaning

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

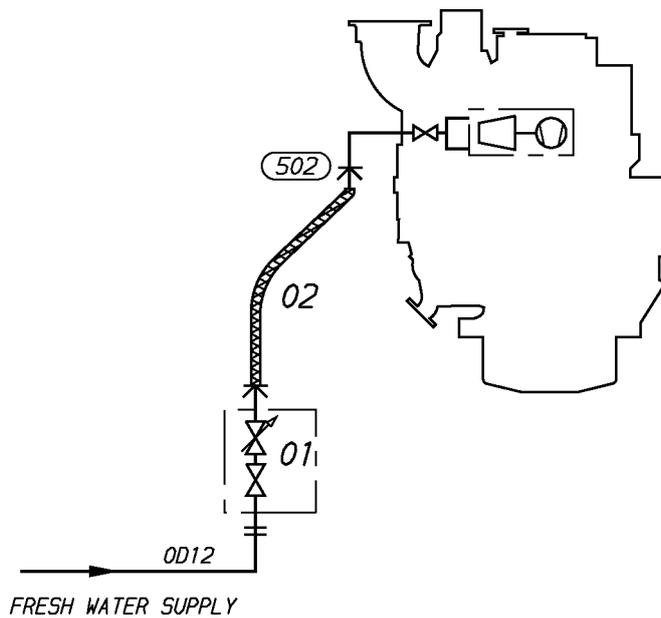
Regular cleaning of the turbine is not necessary when operating on gas.

## 12.1 Turbine cleaning system

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

**Water supply:**

- Fresh water
- Min. pressure                      0.3 MPa (3 bar)
- Max. pressure                      2 MPa (20 bar)
- Max. temperature                80 °C
- Flow                                    6-10 l/min (depending on cylinder configuration)



**Fig 12-1 Turbine cleaning system (DAAE003884)**

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

## 12.2 Compressor cleaning

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

## 13. Exhaust Emissions

Exhaust emissions from the dual fuel engine mainly consist of nitrogen, carbon dioxide (CO<sub>2</sub>) and water vapour with smaller quantities of carbon monoxide (CO), sulphur oxides (SO<sub>x</sub>) and nitrogen oxides (NO<sub>x</sub>), partially reacted and non-combusted hydrocarbons and particulates.

### 13.1 Dual fuel engine exhaust components

Due to the high efficiency and the clean fuel used in a dual fuel engine in gas mode, the exhaust gas emissions when running on gas are extremely low. In a dual fuel engine, the air-fuel ratio is very high, and uniform throughout the cylinders. Maximum temperatures and subsequent NO<sub>x</sub> formation are therefore low, since the same specific heat quantity released to combustion is used to heat up a large mass of air. Benefitting from this unique feature of the lean-burn principle, the NO<sub>x</sub> emissions from the Wärtsilä 20DF are very low, complying with most existing legislation. In gas mode most stringent emissions of IMO and SECA are met, while in diesel mode the dual fuel engine is a normal diesel engine.

To reach low emissions in gas operation, it is essential that the amount of injected diesel fuel is very small. The Wärtsilä DF engines therefore use a "micro-pilot" with less than 1% diesel fuel injected at nominal load. Thus the emissions of SO<sub>x</sub> from the dual fuel engine are negligible. When the engine is in diesel operating mode, the emissions are in the same range as for any ordinary diesel engine, and the engine will be delivered with an EIAPP certificate to show compliance with the MARPOL Annex VI.

### 13.2 Marine exhaust emissions legislation

#### 13.2.1 International Maritime Organization (IMO)

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

The IMO Tier 3 NO<sub>x</sub> emission standard has entered into force from year 2016. It applies for new marine diesel engines that:

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

From 1.1.2021 onwards Baltic sea and North sea will be included in to IMO Tier 3 NO<sub>x</sub> requirements.

#### 13.2.2 Other Legislations

There are also other local legislations in force in particular regions.

### 13.3 Methods to reduce exhaust emissions

All standard Wärtsilä engines meet the NO<sub>x</sub> emission level set by the IMO (International Maritime Organisation) and most of the local emission levels without any modifications. Wärtsilä has also developed solutions to significantly reduce NO<sub>x</sub> emissions when this is required.

Diesel engine exhaust emissions can be reduced either with primary or secondary methods. The primary methods limit the formation of specific emissions during the combustion process. The secondary methods reduce emission components after formation as they pass through the exhaust gas system.

For dual fuel engines same methods as mentioned above can be used to reduce exhaust emissions when running in diesel mode. In gas mode there is no need for scrubber or SCR.



As a result of optimization of combustion chamber geometry and operating conditions (including but not limited to optimized compression ratio,  $P_{max}$ , best-in-class engine components, advanced automation controls etc.), THC (Total Hydrogen Carbon) is reduced significantly in current engine design.

Refer to the "*Wärtsilä Environmental Product Guide*" for information about exhaust gas emission control systems.

# 14. Automation System

## 14.1 UNIC

Wärtsilä Unified Controls - UNIC is a fully embedded and distributed engine management system, which handles all control functions on the engine.

The distributed modules communicate over an internal communication bus.

The power supply to each module is physically doubled on the engine for full redundancy.

Control signals to/from external systems are hardwired to the terminals in the main cabinet on the engine. Process data for alarm and monitoring are communicated over a Modbus TCP connection to external systems.

### 14.1.1 Technical data and system overview

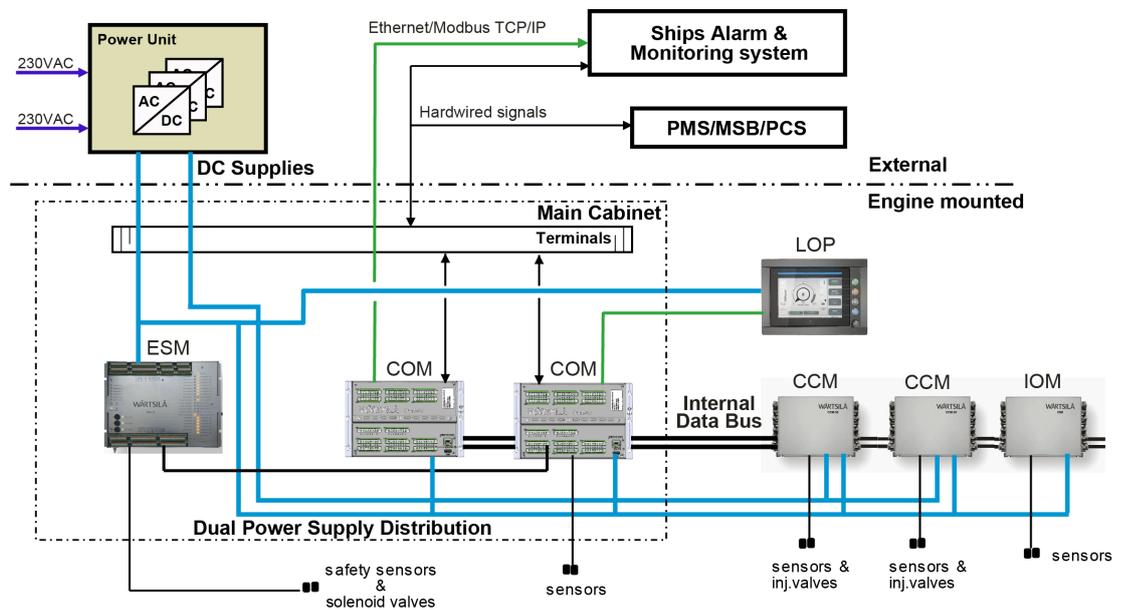
#### 14.1.1.1 Ingress protection

The ingress protection class of the system is IP54.

#### 14.1.1.2 Ambient temp for automation system

The automation system on the engine allows for an ambient engine room temperature up to 55°C.

Single components such as electronic modules have a temperature rating not less than 70°C.



**Fig 14-1 Architecture of UNIC**

Short explanation of the modules used in the system:

**COM** Communication Module. Handles strategic control functions (such as start/stop sequencing and speed/load control, i.e. "speed governing") of the engine. The communication modules handle engine internal and external communication, as well as hardwired external interfaces.

**LOP** The LOP (local operator panel) shows all engine measurements (e.g. temperatures and pressures) and provides various engine status indications as well as an event history.

(continued)

<b>IOM</b>	Input/Output Module handles measurements and limited control functions in a specific area on the engine.
<b>CCM</b>	Cylinder Control Module handles fuel injection control and local measurements for the cylinders.
<b>ESM</b>	Engine Safety Module handles fundamental engine safety, for example shutdown due to overspeed or low lubricating oil pressure.

The above equipment and instrumentation are prewired on the engine.

### 14.1.1.3 Local operator panel

The Local operator panel (LOP) consist of a display unit (LDU) with touch screen as well as an emergency stop button built on the engine.

The local operator panel shows all engine measurements (e.g. temperatures and pressures) and provides various engine status indications as well as an event history

The following control functions are available:

- Local/remote control selection
- Local start & stop
- Trip & Shutdown reset
- Local emergency speed setting (mechanical propulsion)
- Local emergency stop



Fig 14-2 Local operator panel

### 14.1.1.4 Engine safety system

The engine safety module handles fundamental safety functions, for example overspeed protection.

Main features:

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

### 14.1.1.5 Power unit

A power unit is delivered with each engine. The power unit supplies DC power to the automation system on the engine and provides isolation from other DC systems onboard. A firewall/ router for communication between engine and ship automation system is integrated in the power unit. The cabinet is designed for bulkhead mounting, protection degree IP44, max. ambient temperature 50°C.

The power unit contains redundant power converters, each converter dimensioned for 100% load. At least one of the two incoming supplies must be connected to a UPS. The power unit supplies the automation system on the engine with necessary DC voltages.

Power supply from ship's system:

- Supply 1: 230 VAC / abt. 750 W
- Supply 2: 230 VAC / abt. 750 W

### 14.1.1.6 Cabling and system overview

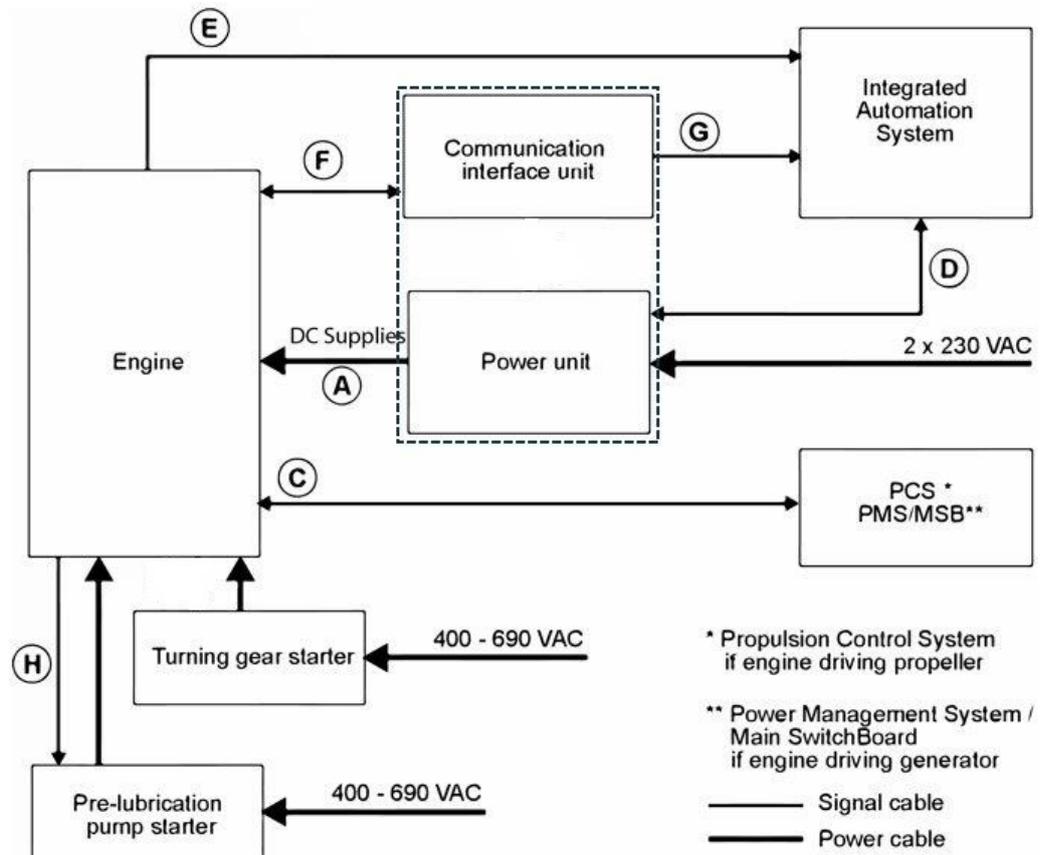


Fig 14-3 UNIC overview

**Table 14-1 Typical amount of cables**

Cable	From <=> To	Cable types (typical)
A	Engine <=> Power Unit	2 x 4 mm <sup>2</sup> (power supply) * 2 x 4 mm <sup>2</sup> (power supply) *
C	Engine <=> Propulsion Control System Engine <=> Power Management System / Main Switch-board	1 x 2 x 0.75 mm <sup>2</sup> 1 x 2 x 0.75 mm <sup>2</sup> 1 x 2 x 0.75 mm <sup>2</sup> 24 x 0.75 mm <sup>2</sup> 24 x 0.75 mm <sup>2</sup>
D	Power unit <=> Integrated Automation System	2 x 0.75 mm <sup>2</sup>
E	Engine <=> Integrated Automation System	3 x 2 x 0.75 mm <sup>2</sup>
F	Engine => Power Unit	1 x Ethernet CAT 5
G	Power Unit => Integrated automation system	1 x Ethernet CAT 5
H	Engine => Pre-lubrication pump starter	2 x 0.75 mm <sup>2</sup>
I	Gas Valve Unit <=> Integrated Automation System	2 x 2 x 0.75 mm <sup>2</sup> 1 x Ethernet CAT5
I	Engine <=> Gas Valve Unit	4 x 2 x 0.75 mm <sup>2</sup> 2 x 2 x 0.75 mm <sup>2</sup> 3 x 2 x 0.75 mm <sup>2</sup>
I	Gas Valve Unit <=> Fuel gas supply system	4 x 2 x 0.75 mm <sup>2</sup>
I	Gas Valve Unit <=> Gas detection system	1 x 2 x 0.75 mm <sup>2</sup>
I	Power unit <=> Gas Valve Unit	2 x 4 mm <sup>2</sup> (power supply) * 2 x 4 mm <sup>2</sup> (power supply) * 3 x 2 x 0.75 mm <sup>2</sup>
I	Gas Valve Unit <=> Exhaust gas fan and pre-lube starter	3 x 2 x 0.75 mm <sup>2</sup> 2 x 5 x 0.75 mm <sup>2</sup>

**NOTICE**

Cable types and grouping of signals in different cables will differ depending on installation.

\* Dimension of the power supply cables depends on the cable length.

Power supply requirements are specified in section *Power unit*.

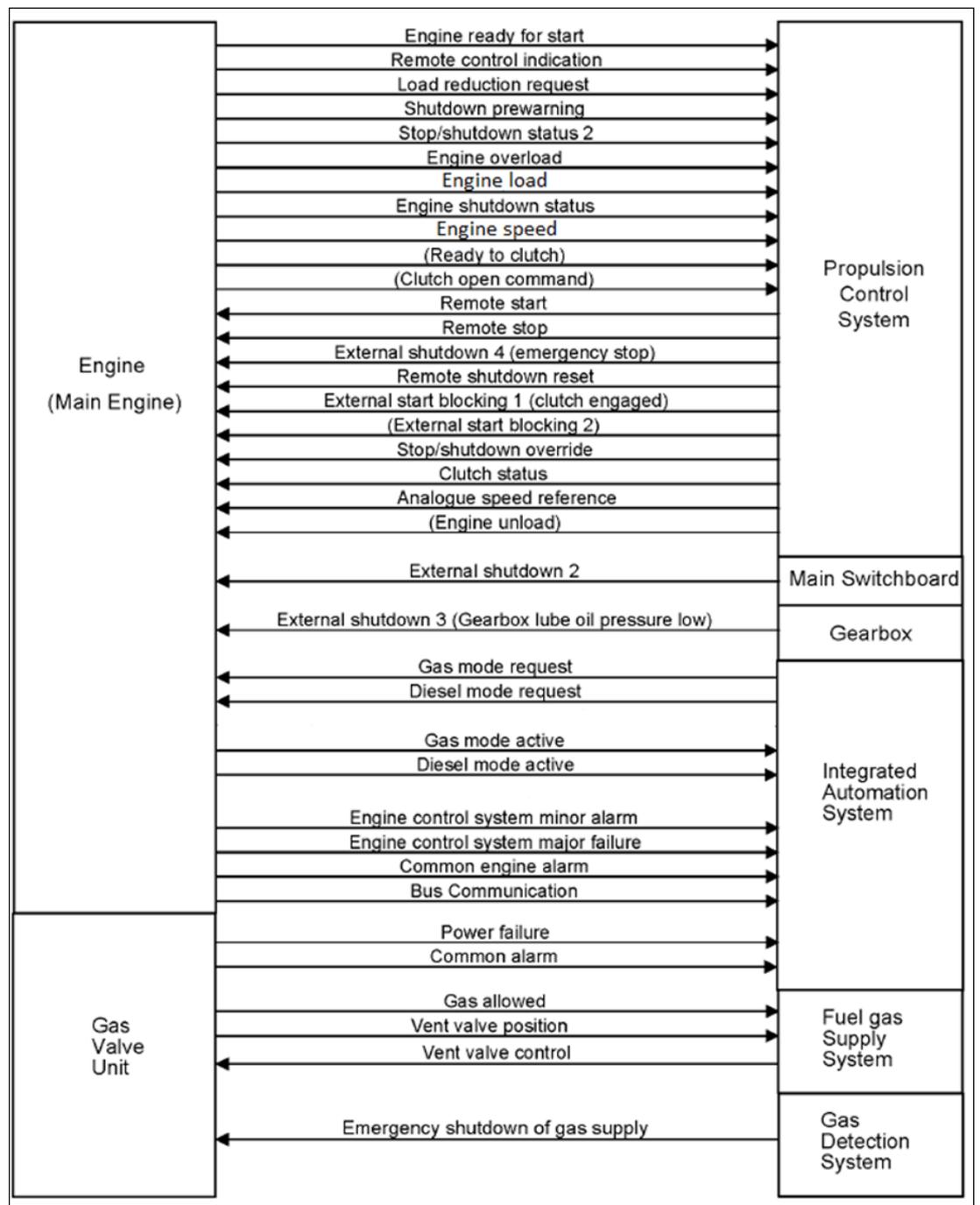


Fig 14-4 Typical signal overview (Main engine)

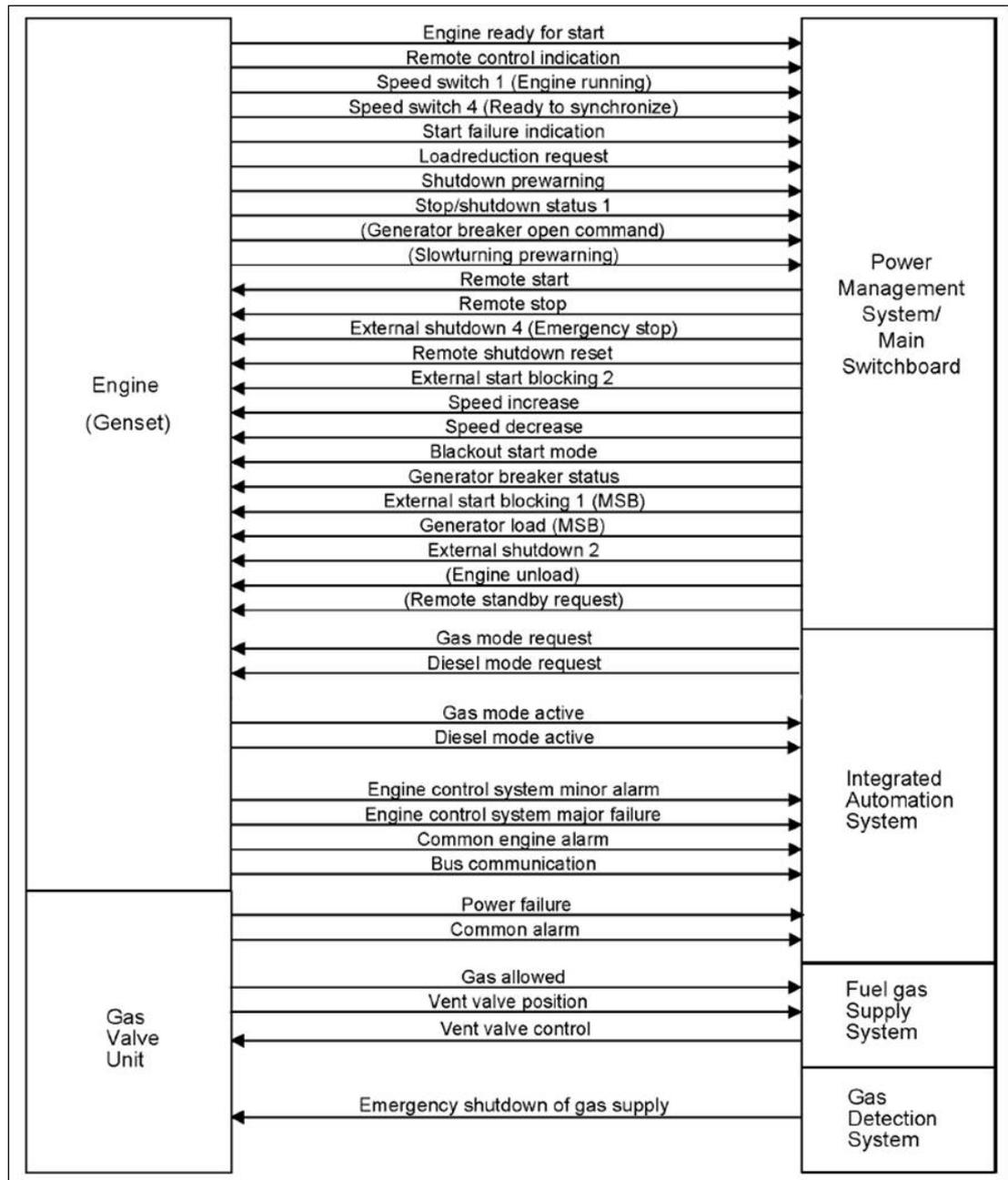


Fig 14-5 Typical signal overview (Generating set)

## 14.1.2 Functions

### 14.1.2.1 Engine operating modes

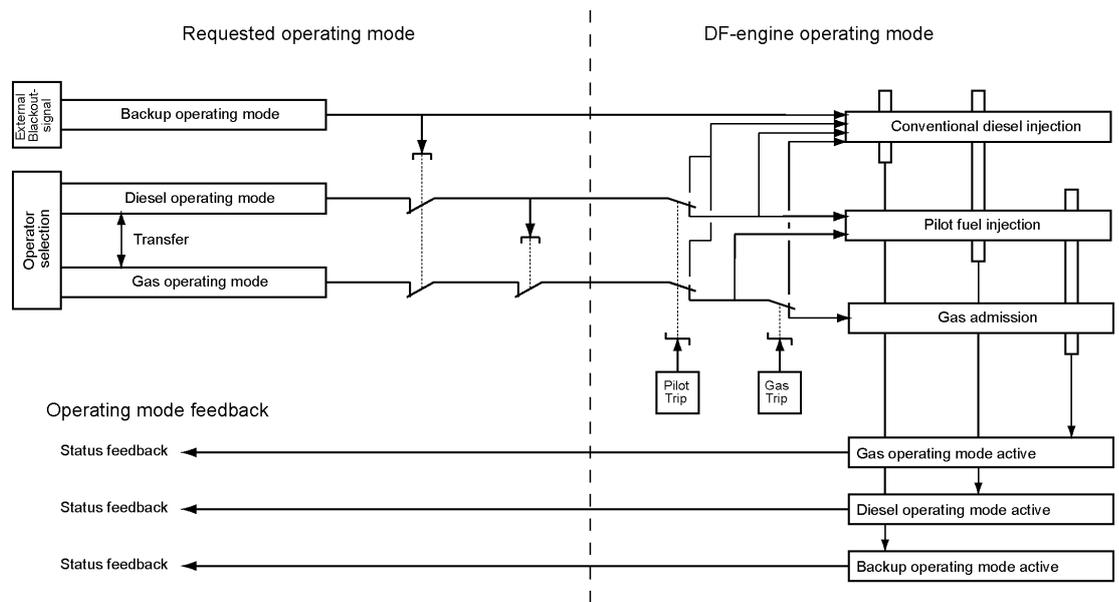
The operator can select two different fuel operating modes:

- Gas operating mode (gas fuel + pilot fuel injection)
- Diesel operating mode (conventional diesel fuel injection + pilot fuel injection)

Below a certain load limit the engine can be transferred from diesel- into gas operating mode. The engine will automatically trip from gas- into diesel operating mode (gas trip) in several alarm situations. In addition, the blackout detection system can force the engine to start in diesel operating mode.

The engine control system automatically forces the engine to backup operating mode (regardless of operator choice of operating mode) in two cases:

- Pilot fuel injection system related fault is detected (pilot trip)
- Engine is started while the blackout start mode signal (from external source) is active



**Fig 14-6 Principle of engine operating modes**

### 14.1.2.2 Start

The engine is started by compressed air driven turbine motor.

The engine can be started locally, or remotely if applicable for the installation e.g. from the power management system or control room. In an emergency situation it is also possible to operate the starting air valve manually.

Starting is blocked both pneumatically and electrically when the turning gear is engaged.

#### Start blocking

Starting is inhibited by the following functions:

- Turning device engaged
- Pre-lubricating pressure low (override if black-out input is high and within last 30 minutes after the pressure has dropped below the set point)
- Stop signal to engine active (safety shut-down, emergency stop, normal stop)
- External start blocking active
- Exhaust gas ventilation not performed

#### Start in gas operating mode

If the engine is ready to start in gas operating mode the output signals "engine ready for gas operation" (no gas trips are active) and "engine ready for start" (no start blockings are active) are activated. In gas operating mode the following tasks are performed automatically:

- The starting air is activated
- Pilot fuel injection and pilot fuel pressure control is enabled
- A combustion check using liquid fuel only (verify that all cylinders are firing)
- A GUV gas leakage test
- Gas admission is started (gas is now the main fuel, ignited by a small amount of liquid fuel)

The start mode is interrupted in case of abnormalities during the start sequence. The start sequence takes about 1.5 minutes to complete.

### Start in diesel operating mode

When starting an engine in diesel operating mode the GVU check is omitted. The combustion check is performed to ensure correct functioning of the pilot fuel injection in order to enable later transfer into gas operating mode. The start sequence takes about one minute to complete.

### Start in blackout mode

When the blackout signal is active, the engine will be started by using the diesel fuel only. The start is performed similarly to a diesel engine, i.e. after receiving start signal the engine will start and ramp up to speed setpoint using only the diesel fuel system. The blackout signal disables some of the start blocks to get the engine running as quickly as possible.



If engine is equipped with slow-turning device, the slow-turning sequence is by-passed during blackout start.

## 14.1.2.3 Gas/diesel transfer control

### Transfer from gas- to diesel-operating mode

The engine will transfer from gas to diesel operating mode at any load within 1s. This can be initiated in three different ways: manually, by the engine control system or by the gas safety system (gas operation mode blocked).

### Transfer from diesel- to gas-operating mode

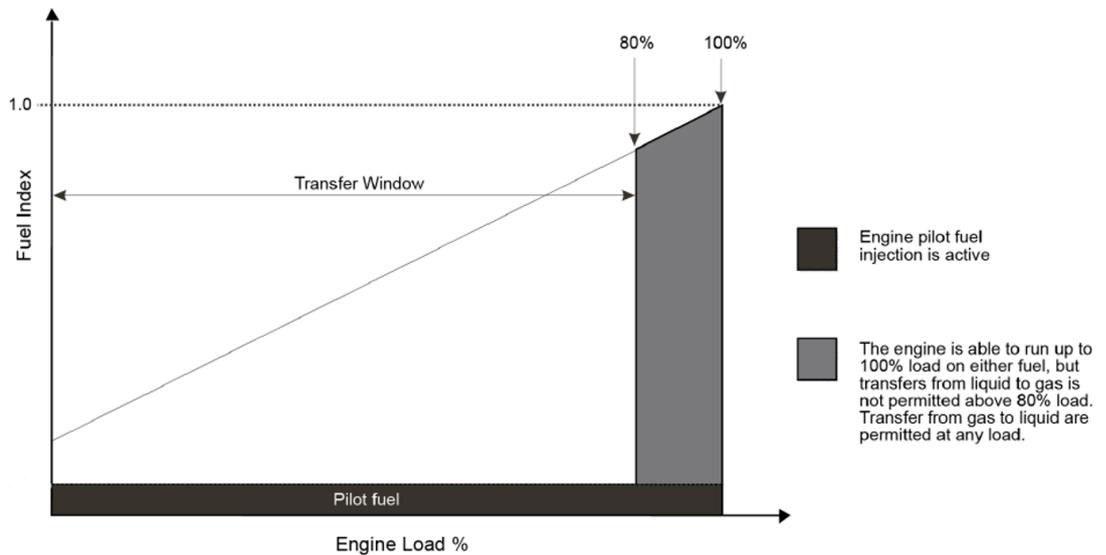
The engine can be transferred to gas mode at engine load below 80%.

Fuel transfers to gas usually takes about 2 minutes to complete, in order to minimize disturbances to the gas fuel supply systems.

The engine can run in backup operating mode in case the engine has been started with the blackout start input active or a pilot trip has occurred. A transfer to gas operating mode can only be done after a combustion check, which is initiated by a diesel mode request.

A leakage test for the GVU is automatically done before each gas transfer. GVU leakage test takes about 1 minute before the actual engine fuel mode transfer taking place

NOTE
Transfer sequence from liquid to gas mode passes through LFO operation to ensure back-up fuel system is flushed clean of HFO. HFO to LFO transfer time is depend on the design of external fuel system and HFO viscosity. Usually HFO to LFO transfer takes about 30 minutes.



**Fig 14-7 Operating modes are load dependent**

### Points for consideration when selecting fuels

When selecting the fuel operating mode for the engine, or before transferring between operating modes, the operator should consider the following:

- To prevent an overload of the gas supply system, transfer one engine at a time to gas operating mode
- Before a transfer command to gas operating mode is given to an engine, the PMS or operator must ensure that the other engines have enough 'spinning reserve' during the transfers. This because the engine may need to be unloaded below the upper transfer limit before transferring
- If engine load is within the transfer window, the engine will be able to switch fuels without unloading
- Whilst an engine is transferring, the starting and stopping of heavy electric consumers should be avoided

## 14.1.2.4 Stop, shutdown and emergency stop

### Stop mode

Before stopping the engine, the control system shall first unload the engine slowly (if the engine is loaded), and after that open the generator breaker and send a stop signal to the engine.

Immediately after the engine stop signal is activated in gas operating mode, the GUV performs gas shut-off and ventilation. The pilot injection is active during the first part of the deceleration in order to ensure that all gas remaining in engine is burned.

In case the engine has been running on gas within two minutes prior to the stop the exhaust gas system is ventilated to discharge any unburned gas.

### Shutdown mode

Shutdown mode is initiated automatically as a response to abnormal measurement signals.

In shutdown mode the clutch/generator breaker is opened immediately without unloading. The actions following a shutdown are similar to normal engine stop.

Shutdown mode must be reset by the operator and the reason for shutdown must be investigated and corrected before re-start.

### **Emergency stop mode**

The sequence of engine stopping in emergency stop mode is similar to shutdown mode, except that also the pilot fuel injection is de-activated immediately upon stop signal.

Emergency stop is the fastest way of manually shutting down the engine. In case the emergency stop push-button is pressed, the button is automatically locked in pressed position.

To return to normal operation the push button must be pulled out and alarms acknowledged by pushing reset either locally or remotely.

## **14.1.2.5 Speed control**

### **Main engines (mechanical propulsion)**

The electronic speed control is integrated in the engine automation system.

The remote speed setting from the propulsion control is an analogue 4-20 mA signal. It is also possible to select an operating mode in which the speed reference can be adjusted with increase/decrease signals.

The electronic speed control handles load sharing between parallel engines, fuel limiters, and various other control functions (e.g. ready to open/close clutch, speed filtering). Overload protection and control of the load increase rate must however be included in the propulsion control as described in the chapter [Operating Ranges](#).

### **Generating sets**

The electronic speed control is integrated in the engine automation system.

The load sharing can be based on traditional speed droop, or handled independently by the speed control units without speed droop. The latter load sharing principle is commonly referred to as isochronous load sharing. With isochronous load sharing there is no need for load balancing, frequency adjustment, or generator loading/unloading control in the external control system.

In a speed droop system each individual speed control unit decreases its internal speed reference when it senses increased load on the generator. Decreased network frequency with higher system load causes all generators to take on a proportional share of the increased total load. Engines with the same speed droop and speed reference will share load equally. Loading and unloading of a generator is accomplished by adjusting the speed reference of the individual speed control unit. The speed droop is typically 4%, which means that the difference in frequency between zero load and maximum load is 4%.

In isochronous mode the speed reference remains constant regardless of load level. Both isochronous load sharing and traditional speed droop are standard features in the speed control and either mode can be easily selected. If the ship has several switchboard sections with tie breakers between the different sections, then the status of each tie breaker is required for control of the load sharing in isochronous mode.

## **14.1.3 Alarm and monitoring signals**

Regarding sensors on the engine, the actual configuration of signals and the alarm levels are found in the project specific documentation supplied for all contracted projects.

## **14.1.4 Electrical consumers**

### **14.1.4.1 Motor starters and operation of electrically driven pumps**

Motor starters are not part of the control system supplied with the engine, but available as loose supplied items.

### Pre-lubricating oil pump

The pre-lubricating oil pump must always be running when the engine is stopped. The engine control system handles start/stop of the pump automatically via a motor starter.

It is recommended to arrange a back-up power supply from an emergency power source. Diesel generators serving as the main source of electrical power must be able to resume their operation in a black out situation by means of stored energy. Depending on system design and classification regulations, it may be permissible to use the emergency generator.

Electric motor ratings are listed in the table below.

**Table 14-2 Electric motor ratings for pre-lubricating pump**

Engine type	Voltage [V]	Frequency [Hz]	Power [kW]	Current [A]
Wärtsilä 20DF	3 x 208 - 690	50 / 60	2.9 - 3.7	3 - 11.3

### Exhaust gas ventilation unit

The exhaust gas ventilating unit is engine specific and includes an electric driven fan, flow switch and closing valve. For further information, see chapter *Exhaust gas system*.

### Stand-by pump, lubricating oil (if applicable) (2P04)

The engine control system starts the pump automatically via a motor starter, if the lubricating oil pressure drops below a preset level when the engine is running.

The pump must not be running when the engine is stopped, nor may it be used for pre-lubricating purposes. Neither should it be operated in parallel with the main pump, when the main pump is in order.

### Stand-by pump, HT cooling water (if applicable) (4P03)

The engine control system starts the pump automatically via a motor starter, if the cooling water pressure drops below a preset level when the engine is running.

### Stand-by pump, LT cooling water (if applicable) (4P05)

The engine control system starts the pump automatically via a motor starter, if the cooling water pressure drops below a preset level when the engine is running.

### Circulating pump for preheater (4P04)

The preheater pump shall start when the engine stops (to ensure water circulation through the hot engine) and stop when the engine starts. The engine control system handles start/stop of the pump automatically.

## 14.1.5 System requirements and guidelines for diesel-electric propulsion

Typical features to be incorporated in the propulsion control and power management systems in a diesel-electric ship:

1. The load increase program must limit the load increase rate during ship acceleration and load transfer between gensets according to the curves in chapter [Loading Capacity](#).

If the control system has only one load increase ramp, then the ramp for a preheated engine is to be used.

The load increase rate of a recently connected generator is the sum of the load transfer performed by the power management system and the load increase performed by the propulsion control.

2. Rapid loading according to the "emergency" curve in chapter [Loading Capacity](#) may only be possible by activating an emergency function, which generates visual and audible alarms in the control room and on the bridge.

3. The propulsion control should be able to control the propulsion power according to the load increase rate at the gensets. Controlled load increase with different number of generators connected and in different operating conditions is difficult to achieve with only time ramps for the propeller speed.

4. The load reduction rate should also be limited in normal operation. Crash stop can be recognised by for example a large lever movement from ahead to astern.

5. Some propulsion systems can generate power back into the network. The gensets can absorb max. 5% reverse power.

6. The power management system performs loading and unloading of generators in a speed droop system, and it usually also corrects the system frequency to compensate for the droop offset, by adjusting the speed setting of the individual speed control units. The speed reference is adjusted by sending an increase/decrease pulse of a certain length to the speed control unit. The power management should determine the length of the increase/decrease pulse based on the size of the desired correction and then wait for 30 seconds or more before performing a new correction, in particular when performing small corrections.

The relation between duration of increase/decrease signal and change in speed reference is usually 0.1 Hz per second. The actual speed and/or load will change at a slower rate.

7. In speed droop mode all generators take an equal share of increased system load, regardless of any difference in initial load. The control system (Power Management System) should monitor the generator load and reduce the system load, if the generator load exceeds 100%.

8. The system should monitor the network frequency and reduce the load, if the network frequency tends to drop excessively.

## 15. Foundation

Engines can be either rigidly mounted on chocks, or resiliently mounted on rubber elements. If resilient mounting is considered, Wärtsilä must be informed about existing excitations such as propeller blade passing frequency. Dynamic forces caused by the engine are listed in the chapter *Vibration and noise*.

### 15.1 Steel structure design

The system oil tank may not extend under the reduction gear, if the engine is of dry sump type and the oil tank is located beneath the engine foundation. Neither should the tank extend under the support bearing, in case there is a PTO arrangement in the free end. The oil tank must also be symmetrically located in transverse direction under the engine.

The foundation and the double bottom should be as stiff as possible in all directions to absorb the dynamic forces caused by the engine, reduction gear and thrust bearing. The foundation should be dimensioned and designed so that harmful deformations are avoided.

The foundation of the driven equipment must be integrated with the engine foundation.

### 15.2 Mounting of main engines

#### 15.2.1 Rigid mounting

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

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 Ø22 mm holes for M20 holding down bolts and a threaded M16 hole for a jacking screw in each foot. The Ø22 holes in the seating top plate for the holding down bolts can be drilled through 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.

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 two Ø23 H7/m6 fitted bolts are located closest to the flywheel, one on each side of the engine. The fitted bolts must be designed and installed so that a sufficient guiding length in the seating top plate is achieved, if necessary by installing a distance sleeve between the seating top plate and the lower nut. The guiding length in the seating top plate should be at least equal to the bolt diameter. The fitted bolts should be made from a high strength steel, e.g. 42CrMo4 or similar and the bolt should have a reduced shank diameter above the guiding part in order to ensure a proper elongation. The recommended shank diameter for the fitted bolts is 17 mm.

The tensile stress in the bolts is allowed to be max. 80% of the material yield strength and the equivalent stress during tightening should not exceed 90% of the 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.

### 15.2.1.1 Resin chocks

The recommended dimensions of resin chocks are 150 x 400 mm. The total surface pressure on the resin must not exceed the maximum value, which is determined by the type of resin and the requirements of the classification society. It is recommended to select a resin that has a type approval from the relevant classification society for a total surface pressure of 5 N/mm<sup>2</sup>. (A typical conservative value is  $p_{\text{tot}}$  3.5 N/mm<sup>2</sup>).

During normal conditions, the support face of the engine feet has a maximum temperature of about 75°C, which should be considered when selecting the type of resin.

The bolts must be made as tensile bolts with a reduced shank diameter to ensure sufficient elongation since the bolt force is limited by the permissible surface pressure on the resin. For a given bolt diameter the permissible bolt tension is limited either by the strength of the bolt material (max. stress 80% of the yield strength), or by the maximum permissible surface pressure on the resin.

### 15.2.1.2 Steel chocks

The top plates of the foundation girders are to be inclined outwards with regard to the centre line of the engine. The inclination of the supporting surface should be 1/100 and it should be machined so that a contact surface of at least 75% is obtained against the chocks.

Recommended size of the chocks are 115 x 170 mm at the position of the fitted bolts (2 pieces) and 115 x 190 mm at the position of the fixing bolts (6 pieces). The design should be such that the chocks can be removed, when the lateral supports are welded to the foundation and the engine is supported by the jacking screws. The chocks should have an inclination of 1:100 (inwards with regard to the engine centre line). The cut out in the chocks for the fixing bolts shall be 24...26 mm (M20 bolts), while the hole in the chocks for the fitted bolts shall be drilled and reamed to the correct size (ø23 H7) when the engine is finally aligned to the reduction gear.

The design of the holding down bolts is shown in figure [Chocking of main engines \(V69A0238C\)](#). The bolts are designed as tensile bolts with a reduced shank diameter to achieve a large elongation, which improves the safety against loosening of the nuts.

### 15.2.1.3 Steel chocks with adjustable height

As an alternative to resin chocks or conventional steel chocks it is also permitted to install the engine on adjustable steel chocks. The chock height is adjustable between 30...50 mm for the approved type of chock. There must be a chock of adequate size at the position of each holding down bolt.

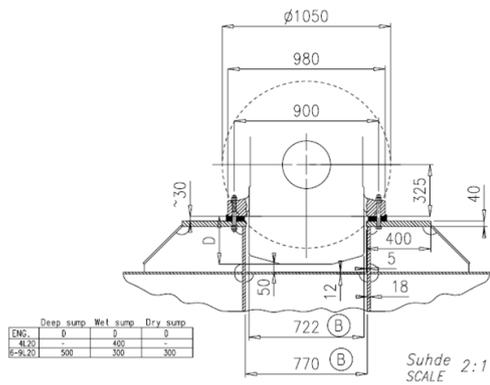
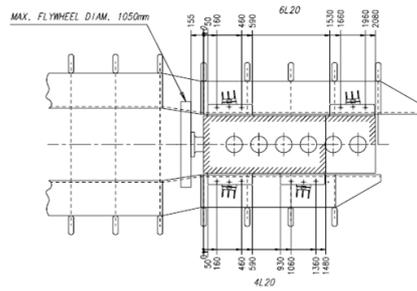
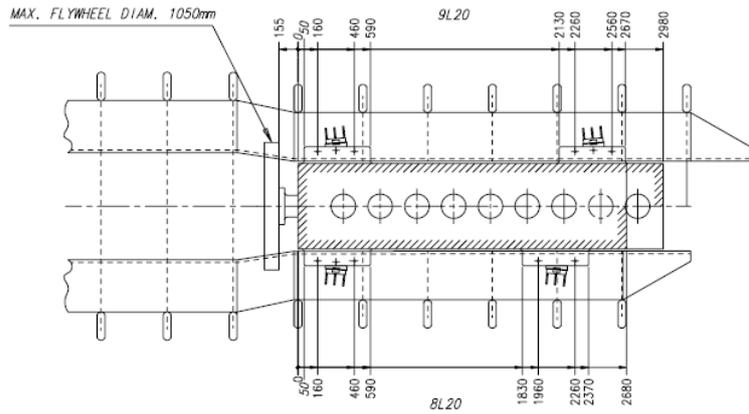
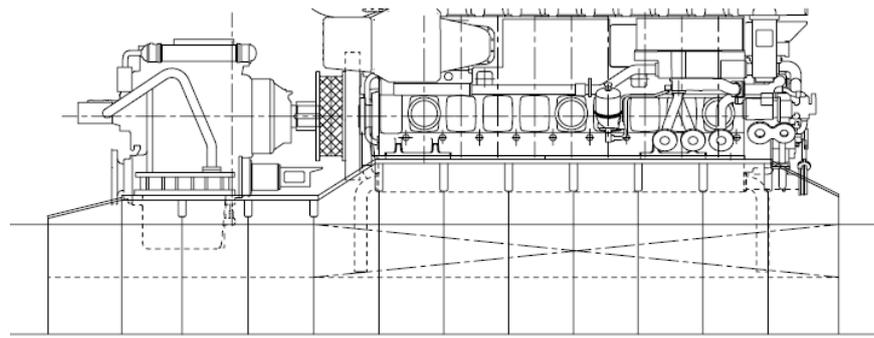


Fig 15-1 Main engine seating, view from above (DAAE017514B)

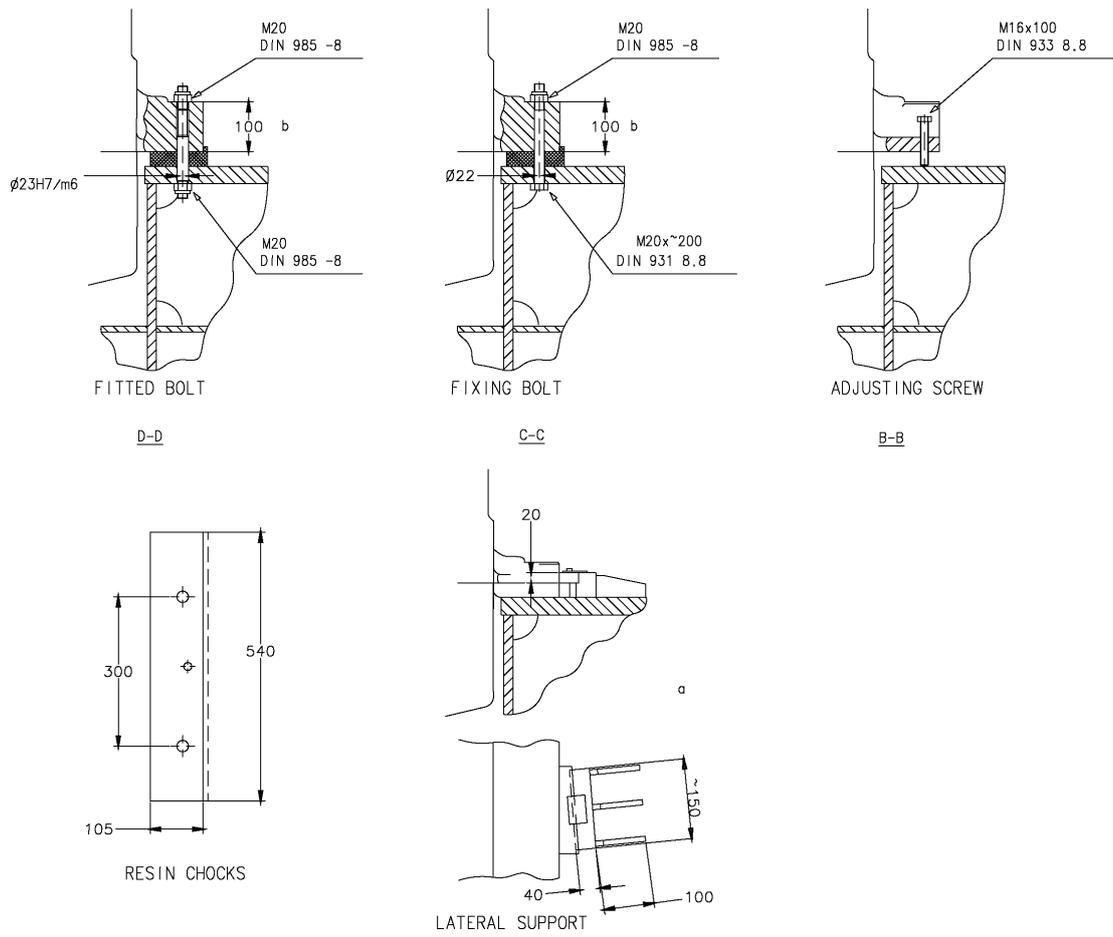
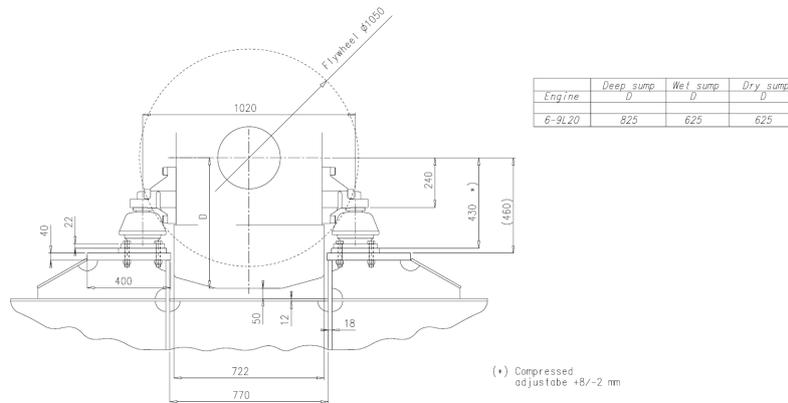


Fig 15-2 Chocking of main engines (V69A0238C)

## 15.2.2 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.



**Fig 15-3 Resilient mounting (DAAE003263B)**

## 15.3 Mounting of generating sets

### 15.3.1 Generator feet design

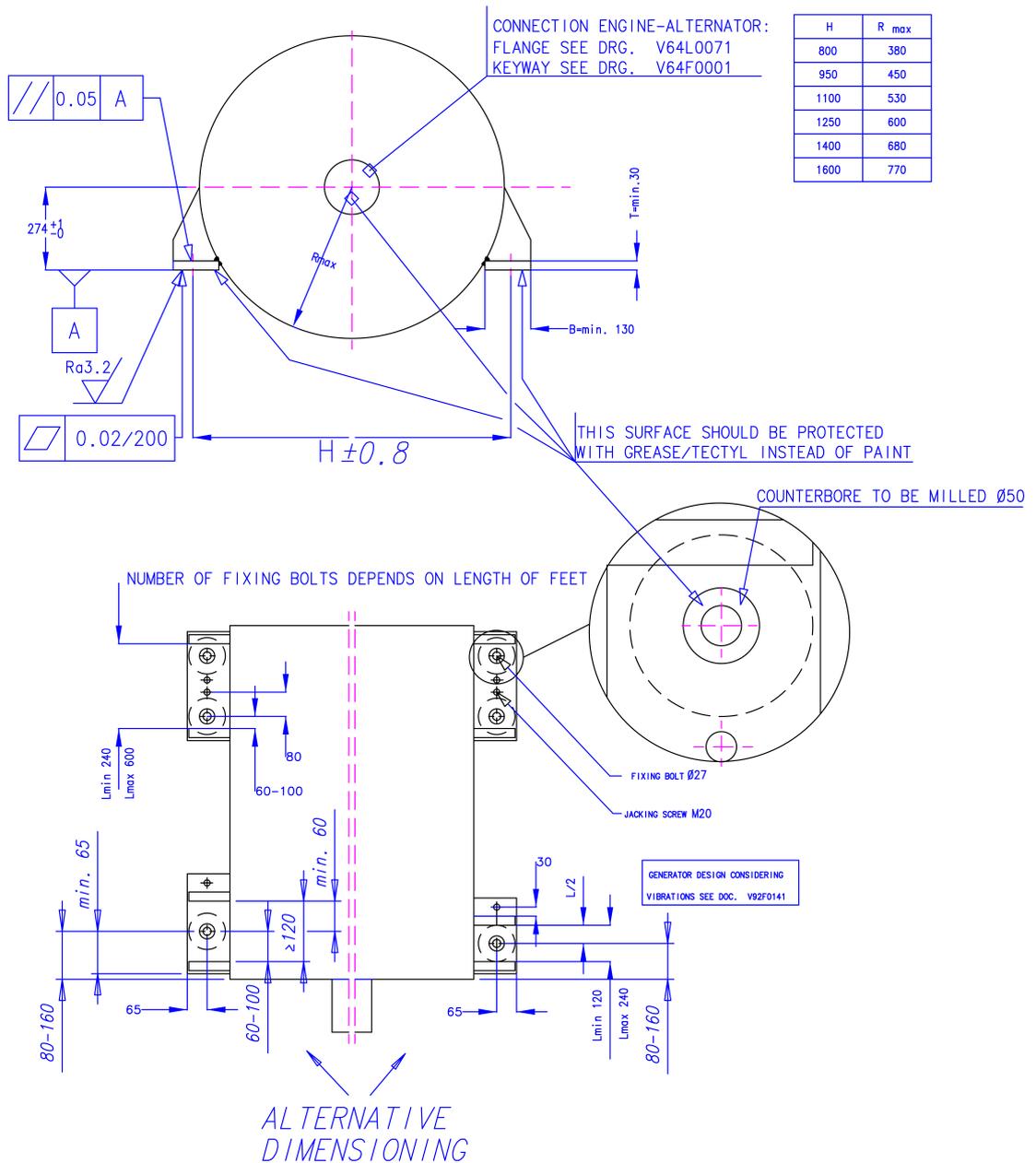


Fig 15-4 Instructions for designing the feet of the generator and the distance between its holding down bolt (V92F0134E)

### 15.3.2 Resilient mounting

Generating sets, comprising engine and generator mounted on a common base frame, are usually installed on resilient mounts on the foundation in the ship.

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

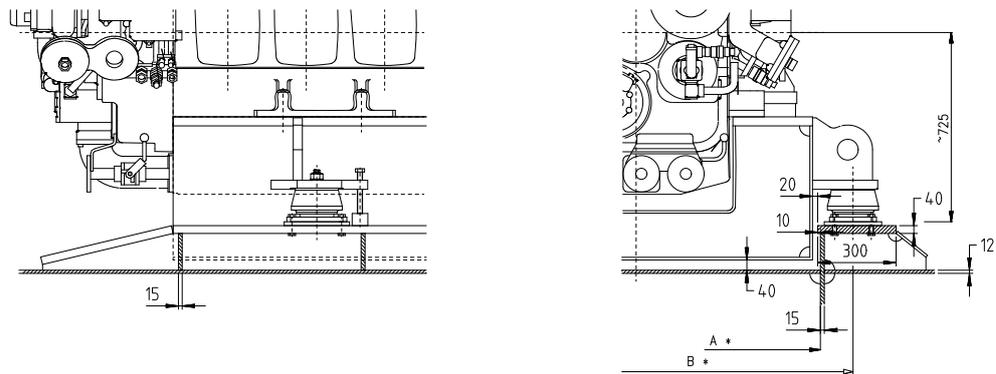
The number of mounts and their location is calculated to avoid resonance with excitations from the generating set engine, the main engine and the propeller.

**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 15-5 Recommended design of the generating set seating (V46L0720H)**

Engine type	A*	B*
6L	1330 / 1480	1580 / 1730
8L	1480 / 1630	1730 / 1880
9L	1480 / 1630 / 1860	1730 / 1880 / 2110

\* *Dependent on generator width*

### 15.3.3 Rubber mounts

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

The rubber in the mounts is natural rubber and it must therefore be protected from oil, oily water and fuel.

The mounts should be evenly loaded, when the generating set is resting on the mounts. The maximum permissible variation in compression between mounts is 2.0 mm. If necessary, chocks or shims should be used to compensate for local tolerances. Only one shim is permitted under each mount.

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

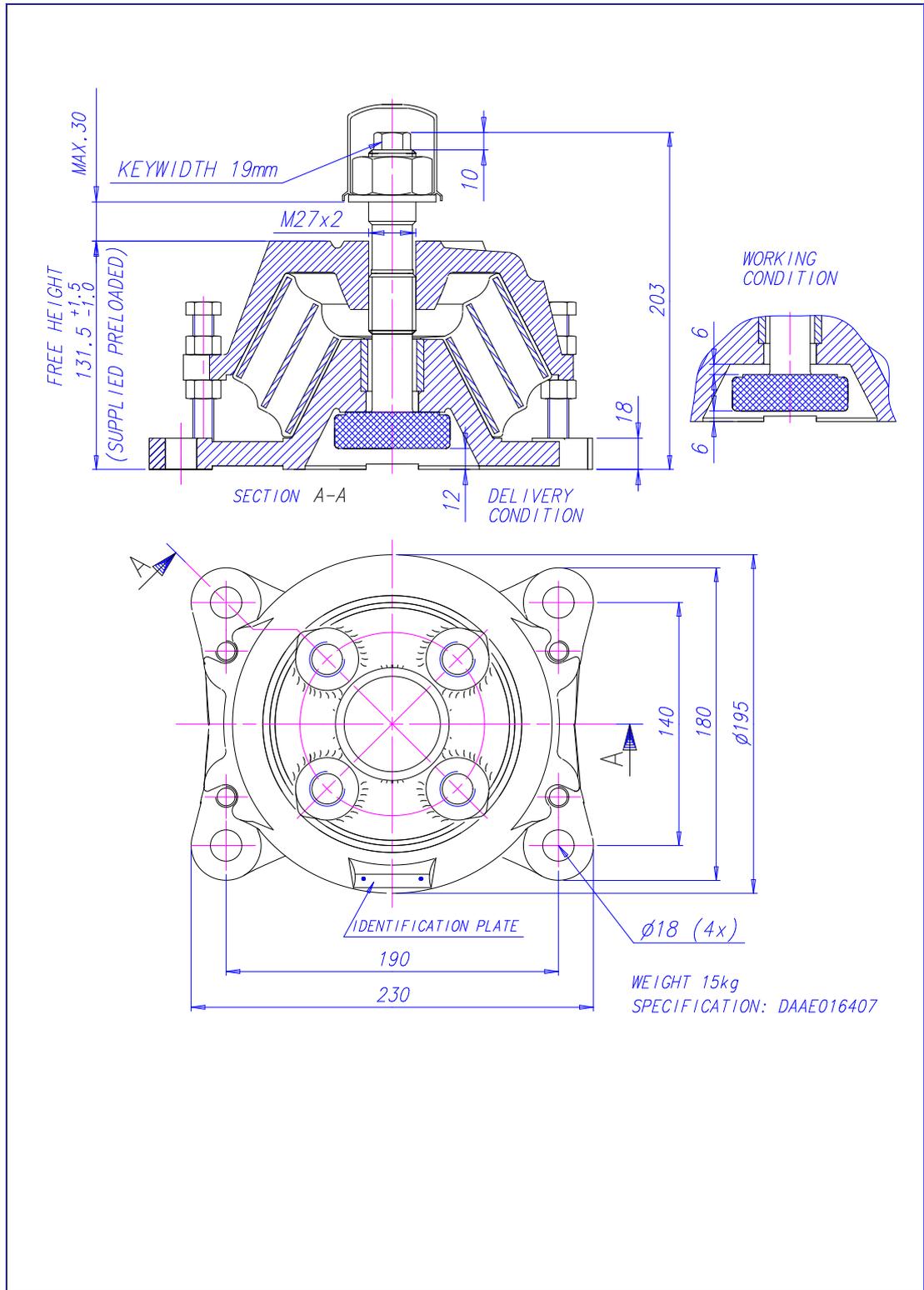


Fig 15-6 Rubber mounts (DAAE016408C)

## 15.4 Flexible pipe connections

When the engine or the generating set 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. The external pipe must be precisely aligned to the fitting or flange on the engine. It is very important that the pipe clamps for the pipe outside the flexible connection must be very rigid and welded to the steel structure of the foundation to prevent vibrations, which could damage the flexible connection.

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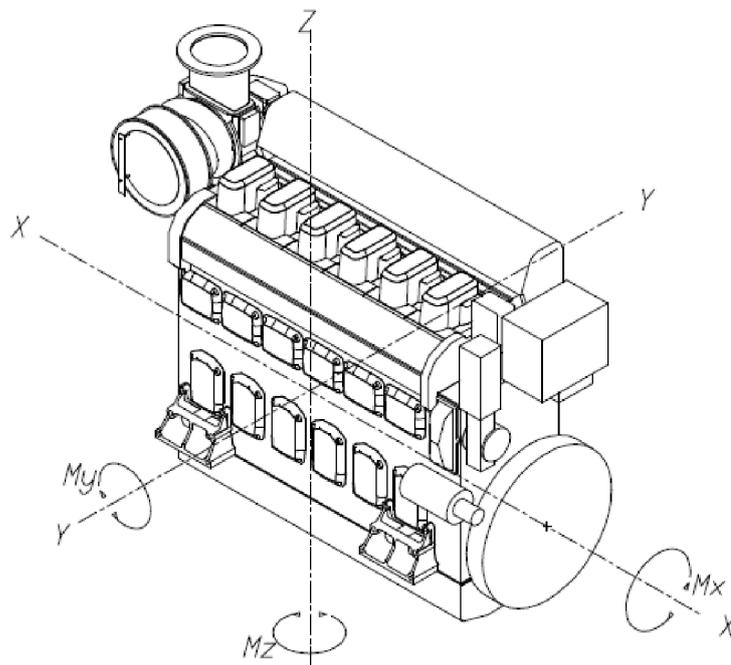
## 16. Vibration and Noise

Generating sets comply with vibration levels according to ISO 8528-9. Main engines comply with vibration levels according to ISO 10816-6 Class 5.

### 16.1 External forces, couples & torque variations

Some cylinder configurations produce external forces and couples. These are listed in the tables below.

The ship designer should avoid natural frequencies of decks, bulkheads and superstructures close to the excitation frequencies. The double bottom should be stiff enough to avoid resonances especially with the rolling frequencies.



**Fig 16-1 External forces, couples and torque variations**

#### External forces

$F_z = 0$ ,  $F_y = 0$  for all others than 8 cylinder engines.

**Table 16-1 External forces**

Engine	Speed [rpm]	Freq. [Hz]	$F_y$ [kN]	$F_z$ [kN]
8L20DF	900	60	–	2
	1000	67	–	3
	1200	80	–	4

– forces = zero or insignificant.

**External couples**

$M_z = 0$ ,  $M_y = 0$  for all others than 9 cylinder engines.

**Table 16-2 External couples**

Engine	Speed [rpm]	Freq. [Hz]	$M_y$ [kNm]	$M_z$ [kNm]	Freq. [Hz]	$M_y$ [kNm]	$M_z$ [kNm]	Freq. [Hz]	$M_y$ [kNm]	$M_z$ [kNm]
9L20DF	900	15	7	7	30	5	–	60	–	–
	1000	17	9	9	33	6	–	67	1	–
	1200	20	12	12	40	9	–	60	1	–

– couples = zero or insignificant.

**Torque variations****Table 16-3 Torque variations at 100% load - Diesel**

Engine	Speed [rpm]	Freq. [Hz]	M <sub>x</sub> [kNm]	Freq. [Hz]	M <sub>x</sub> [kNm]	Freq. [Hz]	M <sub>x</sub> [kNm]
6L20DF	900	45	8	90	4	135	–
	1000	50	6	100	4	150	–
	1200	60	3	120	4	180	1
8L20DF	900	60	14	120	1	–	–
	1000	67	13	133	1	–	–
	1200	80	13	160	1	–	–
9L20DF	900	67,5	12	135	1	–	–
	1000	75	12	150	1	–	–
	1200	90	13	180	1	–	–

**Table 16-4 Torque variations at 100% load - Gas**

Engine	Speed [rpm]	Freq. [Hz]	M <sub>x</sub> [kNm]	Freq. [Hz]	M <sub>x</sub> [kNm]	Freq. [Hz]	M <sub>x</sub> [kNm]
6L20DF	900	45	7	90	4	135	1
	1000	50	5	100	4	150	1
	1200	60	3	120	4	180	1
8L20DF	900	60	13	120	3	–	–
	1000	67	13	133	2	–	–
	1200	80	12	160	2	–	–
9L20DF	900	67,5	13	135	2	–	–
	1000	75	12	150	2	–	–
	1200	90	12	180	1	–	–

– torque variations = zero or insignificant.

**Table 16-5 Torque variations at 0% load**

Engine	Speed [rpm]	Freq. [Hz]	M <sub>x</sub> [kNm]	Freq. [Hz]	M <sub>x</sub> [kNm]	Freq. [Hz]	M <sub>x</sub> [kNm]
6L20DF	900	45	5	90	1	135	–
	1000	50	7	100	1	150	–
	1200	60	12	120	1	180	–
8L20DF	900	60	3	120	1	–	–
	1000	67	3	133	1	–	–
	1200	80	2	160	1	–	–
9L20DF	900	67,5	4	135	1	–	–
	1000	75	4	150	1	–	–
	1200	90	4	180	1	–	–

– torque variations = zero or insignificant.

**NOTICE**

External forces, couples and torque variations for W20DF 900 rpm engine will be added when available.

## 16.2 Mass moments of inertia

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

Engine	J [kgm <sup>2</sup> ]
W 6L20DF	90...150
W 8L20DF	110...160
W 9L20DF	100...170

## 16.3 Air borne noise

The airborne noise of the engines is measured as sound power level based on ISO 9614-2. The results represent typical engine A-weighted sound power level at full load and nominal speed.

**Table 16-6 A-weighted Sound Power Level (Diesel Mode) in Octave Frequency Band [dB, ref. 1pW]**

[Hz]	125	250	500	1000	2000	4000	8000	Total
6L	94	101	106	112	112	106	105	116
8L	100	103	108	114	114	111	110	119
9L	98	104	112	115	113	111	107	119

**Table 16-7 A-weighted Sound Power Level (Gas Mode) in Octave Frequency Band [dB, ref. 1pW]**

[Hz]	125	250	500	1000	2000	4000	8000	Total
6L	95	101	105	109	108	103	103	114
8L	100	103	108	111	111	107	107	117
9L	100	105	109	114	114	111	110	119

## 16.4 Exhaust noise

The results represent typical exhaust sound power level measured after turbocharger outlet in duct line with 0,5m diameter and exhaust temperature approximately 370 Celsius for gas and 320 Celsius for diesel at engine full load and nominal speed.

**Table 16-8 Exhaust Gas Sound Power Level in Octave Frequency Band [dB, ref. 1pW]**

[Hz]	32	63	125	250	500	1000	2000	4000	Total
6L	131	142	137	135	132	128	120	112	145
8L	127	142	139	138	132	124	109	101	145
9L	134	148	141	129	122	111	105	101	149

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# 17. Power Transmission

## 17.1 Flexible coupling

The power transmission of propulsion engines is accomplished through a flexible coupling or a combined flexible coupling and clutch mounted on the flywheel. The crankshaft is equipped with an additional main bearing at the flywheel end. Therefore also a rather heavy coupling can be mounted on the flywheel without intermediate bearings.

The type of flexible coupling to be used has to be decided separately in each case on the basis of the torsional vibration calculations.

In case of two bearing type generator installations a flexible coupling between the engine and the generator is required.

### 17.1.1 Connection to generator

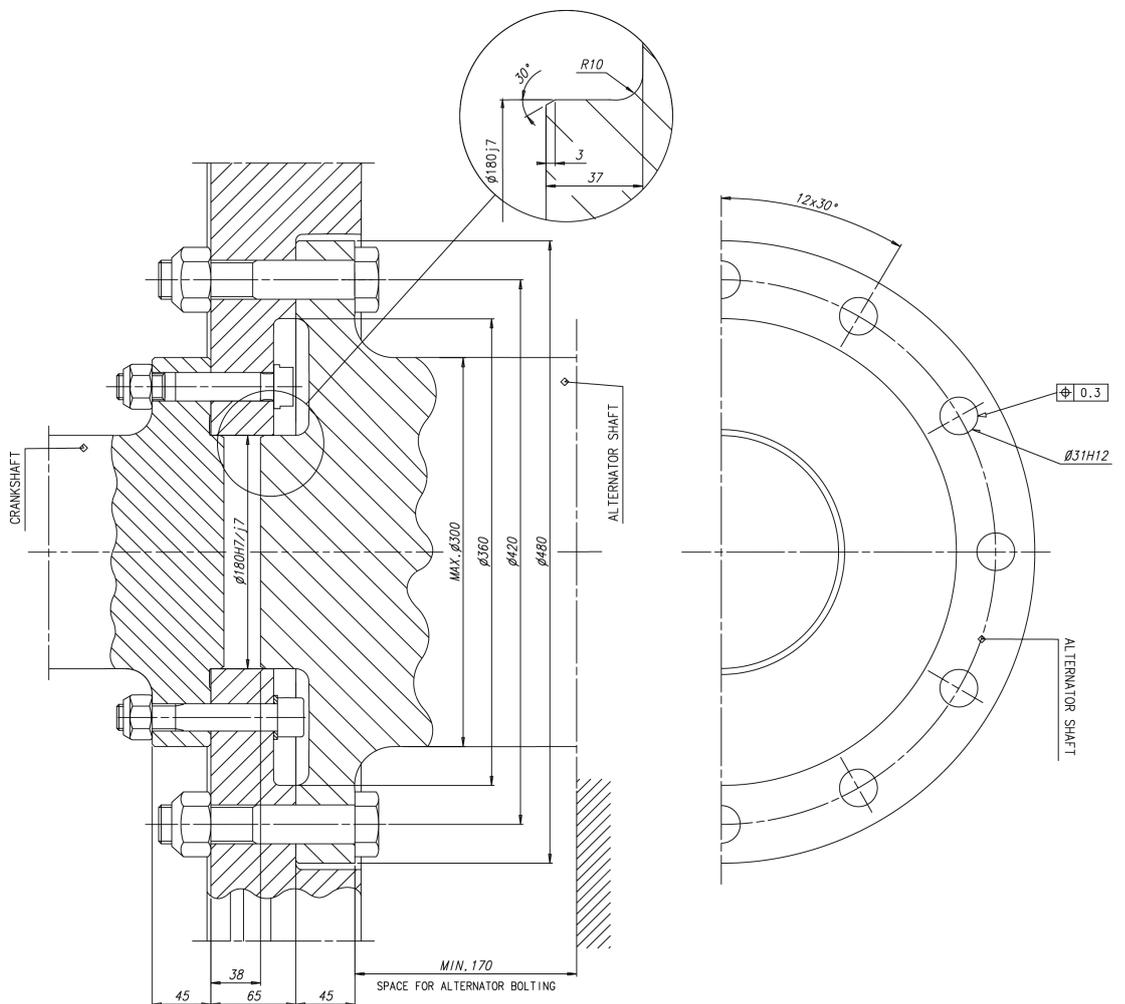
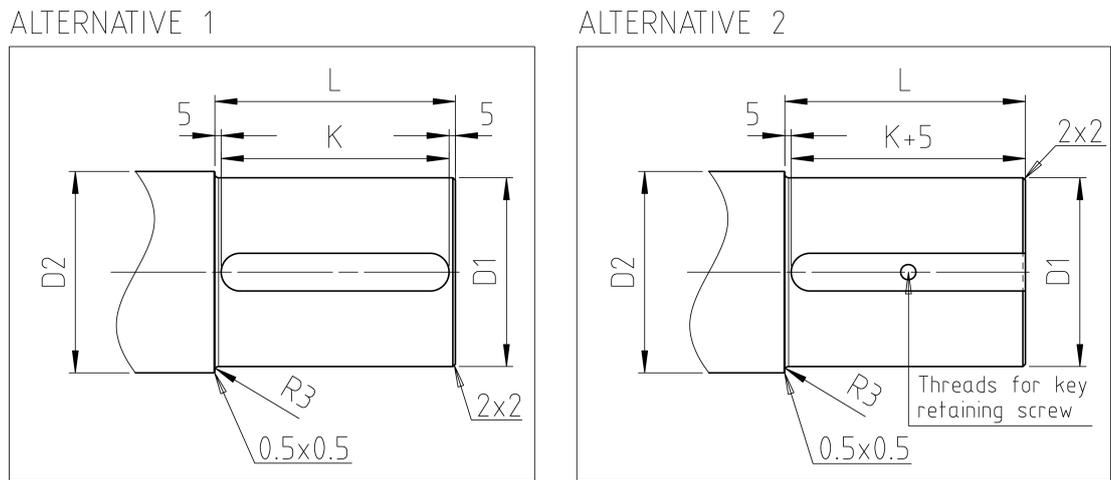


Fig 17-1 Connection engine/single bearing generator (V64L0071B)



**Fig 17-2 Connection engine/two-bearing generator (V64F0001C)**

Engine	Dimensions [mm]			
	D <sub>1</sub>	L	K	min D
W 6L20DF	150	190	180	160
W 8L20DF	150	190	180	160
W 9L20DF	150	190	180	160

## 17.2 Torque flange

In mechanical propulsion applications, as well as in the presence of a PTO shaft, it is necessary to install a torque meter on each output shaft to accurately measure the absorbed power. The torque flange, which has a standardized installation length of 160 mm for all cylinder configurations, should be installed after the flexible coupling.

## 17.3 Clutch

In many installations the propeller shaft can be separated from the engine using a clutch. The use of multiple plate hydraulically actuated clutches built into the reduction gear is recommended.

A clutch is required when two or more engines are connected to the same driven machinery such as a reduction gear.

To permit maintenance of a stopped engine clutches must be installed in twin screw vessels which can operate on one shaft line only.

## 17.4 Shaft locking device

A shaft locking device should be fitted to be able to secure the propeller shaft in position so that wind milling is avoided. This is necessary because even an open hydraulic clutch can transmit some torque. Wind milling at a low propeller speed (<10 rpm) can due to poor lubrication cause excessive wear of the bearings.

The shaft locking device can be either a bracket and key or an easier to use brake disc with calipers. In both cases a stiff and strong support to the ship's construction must be provided.

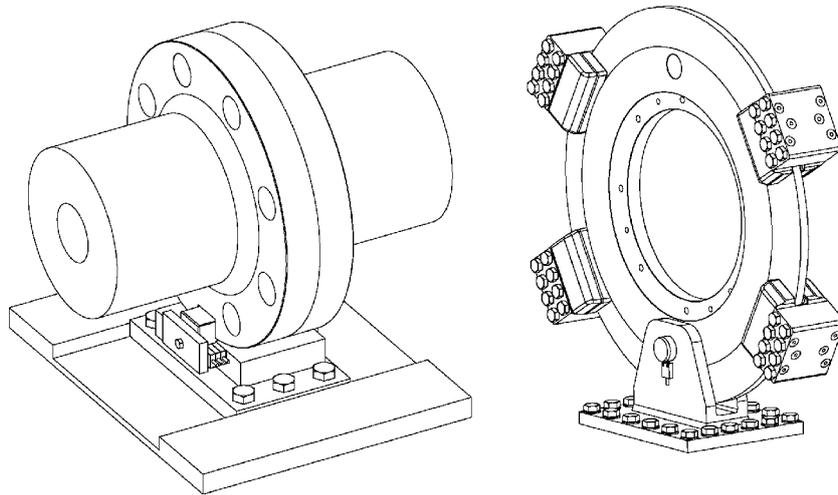


Fig 17-3 Shaft locking device and brake disc with calipers

## 17.5 Power-take-off from the free end

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

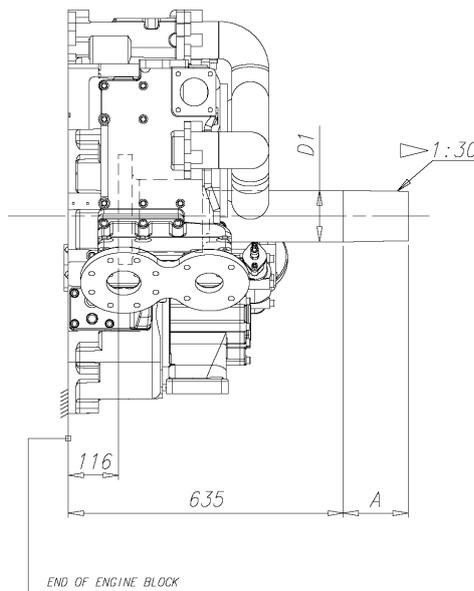


Fig 17-4 PTO alternative 1 (DAAE079074A)

Rating [kW]	Dimensions [mm]	
	D1	A
700 <sup>1)</sup>	80	105
2300 <sup>1)</sup>	120	150

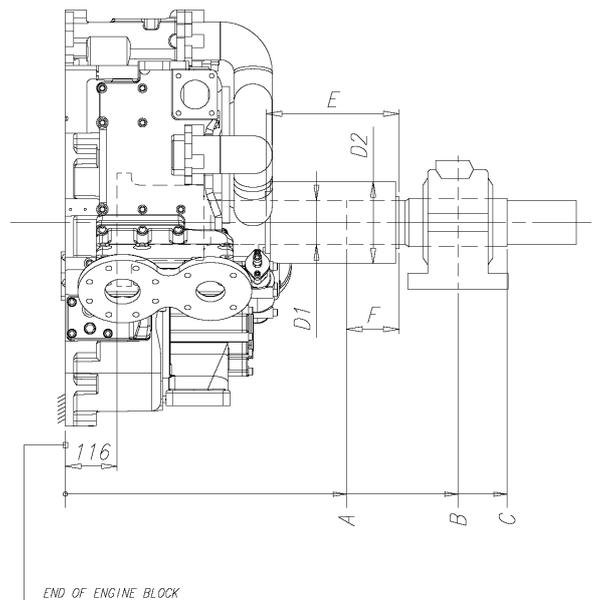


Fig 17-5 PTO alternative 2 (DAAE079045)

Rating [kW] <sup>1)</sup>	Dimensions [mm]						
	D1	D2	A	B	C	E	F
1700 <sup>1)</sup>	100	170	610	860	970	280	108
2200 <sup>1)</sup>	110	185	630	880	990	300	118

Rating is dependent on coupling hub. Max. output may also be restricted due to max coupling weight 135 kg. 1320 kW always accepted.

External support bearing is not possible for resiliently mounted engines.

<sup>1)</sup> PTO shaft design rating, engine output may be lower

## 17.6 Input data for Torsional Vibration Calculation

The torsional vibration calculation (TVC) is performed for each installation according to classification requirements. For this purpose, the following project specific exact data of all components included in the shaft system are required.

### General and operational data

- Classification society (leading class, in case of dual class)
- Class notations (especially in case of Ice, Polar, Redundant Propulsion)
- List of all operating modes (including for navigation in ice, if applicable)
- Power distribution between the different consumers for every operating mode
- Power Vs Speed curve for every consumer
- GA drawing or layout illustrating propulsion machinery arrangements

### Gearbox

- Mass elastic diagram showing:
  - All clutching possibilities (especially in case of multiple clutches)
  - Dimensions of all shafts
  - Mass moment of inertia of all rotating parts including shafts and flanges
  - Torsional stiffness of shafts between rotating masses
  - Gear ratios
  - Drawing number (including revision)
- GA drawing or other type of drawing showing:
  - Input and output interface details (type/dimensions details, material and yield strength, surface roughness)
    - In case of cylindrical shaft interface: fillet radius at step diameter and keyway standard
  - Material of shafts including minimum tensile strength
  - Drawing number (including revision)

### Propeller and shafting

- Mass-elastic diagram or propeller shaft drawing showing:
  - Mass moment of inertia of all rotating parts including the rotating part of the OD-box, SKF couplings and rotating parts of the bearings
  - Mass moment of inertia of the propeller in water for all operating modes (as minimum full/zero pitch)
  - Torsional stiffness or dimensions of the shafts
  - Drawing number (including revision)
- Drawing or data sheet with:
  - Propeller power consumption for all operating modes (as minimum full/zero pitch)
  - Number of propeller blades
  - Material of the shafts including minimum tensile strength
  - In case of Ice class notation: propeller outer diameter, outer diameter of the propeller hub, propeller pitch at bollard pull condition

- In case of cardan shafts: joint inclination angle and mass moment of inertia of every single part (joints and shaft)
- Drawing number (including revision)

#### **Shaft generator or main generator**

- Technical data sheet with at least:
  - Nominal power and speed
  - Information if variable or constant speed operation
  - In case of variable speed, Power Vs Speed curve
  - Number of pole pairs
  - Bearing external load capabilities (axial and radial)
- Outline drawing with:
  - input interface details (type/dimensions details, material and yield strength, surface roughness)
    - In case of cylindrical shaft interface: fillet radius at step diameter and keyway standard
  - Bearing axial clearance (minimum and maximum values)
  - Drawing number (including revision)
- Mass-elastic diagram or the generator shaft drawing showing:
  - Mass moment of inertia of all rotating parts and total inertia value of the rotor, including the shaft
  - Torsional stiffness or dimensions of the shaft
  - Material of the shaft including minimum tensile strength
  - Drawing number of the diagram or drawing
- For shaft generator (connected to gearbox)
  - In case of PTI function, Power Vs Speed curve
  - In case of booster function, Power Vs Speed curve
- For main generator (connected to engine)
  - Electrical data: reactances and time constants

#### **Flexible coupling/clutch**

- Customer preferred coupling brand, if any
- Brand selection restrictions due to possible international export regulations
- Specific dimensional requirements (for example length)
- If coupling is in customer scope of supply, the following data of it must be informed:
  - Mass moment of inertia of all parts of the coupling
  - Number of flexible elements
  - Torsional stiffness per element
  - Dynamic magnification or relative damping
  - Nominal torque, permissible vibratory torque and permissible power loss
  - Drawing of the coupling showing interface details, maker, type and drawing number

#### **Other components:**

- In case of electric motor
  - Nominal power and speed
  - Power Vs Speed curve

- Outline drawing with:
  - input interface details (type/dimensions details, material and yield strength, surface roughness)
    - In case of cylindrical shaft interface: fillet radius at step diameter and keyway standard
  - Drawing number (including revision)
- Mass-elastic diagram or the motor shaft drawing showing:
  - Mass moment of inertia of all rotating parts and total inertia value of the rotor, including the shaft
  - Torsional stiffness or dimensions of the shaft
  - Material of the shaft including minimum tensile strength
  - Drawing number of the diagram or drawing
- In case of pump:
  - Nominal power and speed
  - Power Vs Speed curve
  - Information if variable or constant speed operation
  - Outline drawing with:
    - input interface details (type/dimensions details, material and yield strength, surface roughness)
      - In case of cylindrical shaft interface: fillet radius at step diameter and keyway standard
    - Drawing number (including revision)
  - Mass-elastic diagram or the impeller shaft drawing showing:
    - Mass moment of inertia of all rotating parts and total inertia value of the impeller, including the shaft
    - Torsional stiffness or dimensions of the shaft
    - Material of the shaft including minimum tensile strength
    - Drawing number of the diagram or drawing
  - Number of impeller blades
  - Torsional excitations (especially in case of dredging pump)

## 17.7 Turning gear

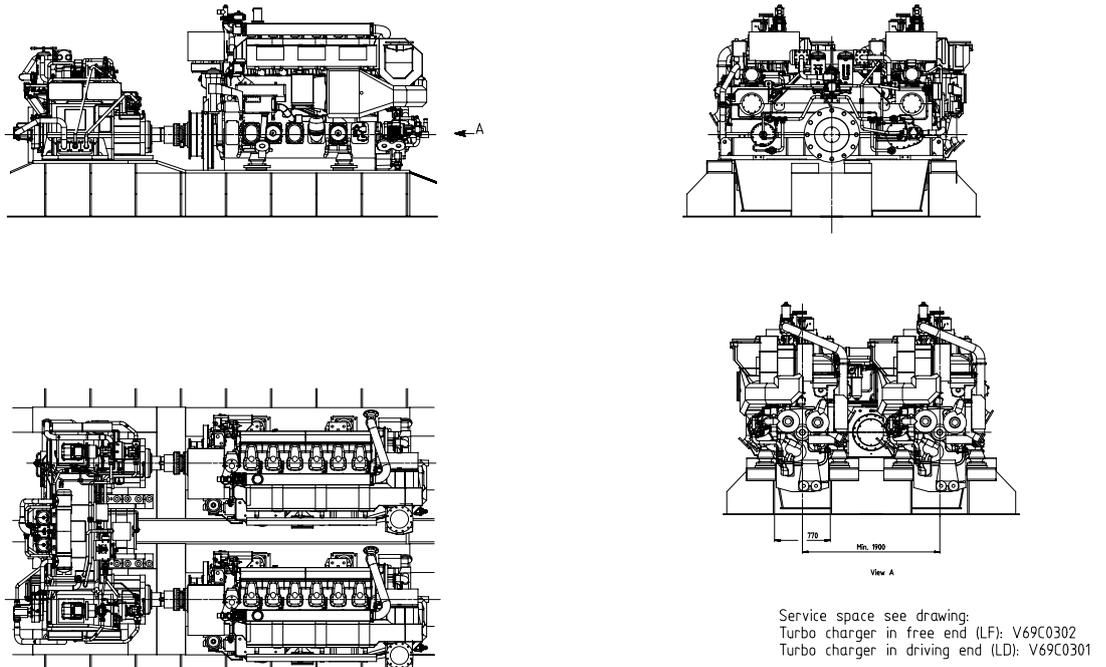
The engine can be turned with a manual ratchet tool after engaging a gear wheel on the flywheel gear rim. The ratchet tool is provided with the engine.

# 18. Engine Room Layout

## 18.1 Crankshaft distances

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

### 18.1.1 Main engines

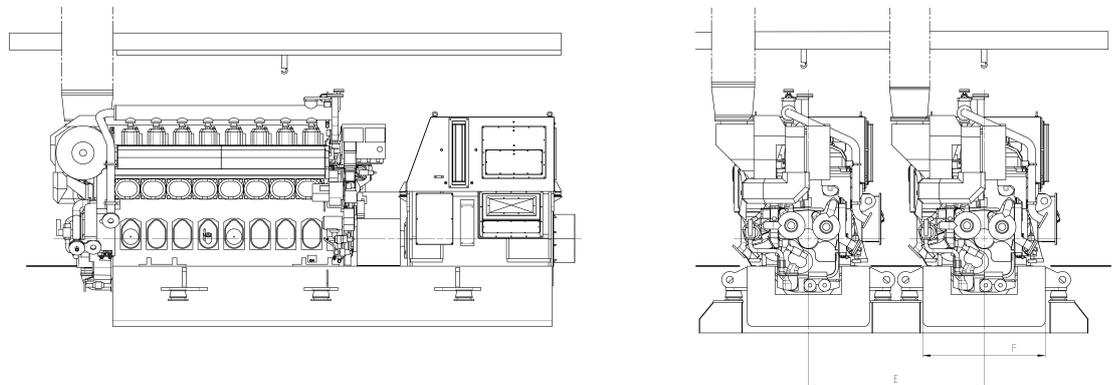


**Fig 18-1 Crankshaft distances main engines (DAAF017589A)**

**NOTE**

Please refer to [Service Space Requirement](#) for details.

### 18.1.2 Generating sets



**Fig 18-2 Crankshaft distances generating sets (DAAE007434D)**

**Table 18-1 Standard genset**

Engine type	E*	F
W 6L20DF	1970 / 2040 / 2170	1270 / 1420 / 1570
W 8L20DF	2040 / 2170 / 2250	1420 / 1570 / 1700
W 9L20DF	2040 / 2200 / 2400	1420 / 1570 / 1700

**Table 18-2 Double flexible installed genset**

Engine type	E*	F
W 6L20DF	2450	1350
W 8L20DF	2450	1350
W 9L20DF	2450	1350

E = MIN. DISTANCE BETWEEN ENGINES DEPENDENT ON COMMON BASE PLATE

F = WIDTH OF THE COMMON BASE PLATE DEPENDENT ON WIDTH OF THE ALTERNATOR

\* In case of extra wide lifting lugs needed, 230mm should be added to dimension E. Depending on final generator selection

\* Dimension E should be checked at all times with each project specific configuration due to generator service space

All dimensions in mm.

## 18.2 Space requirements for maintenance

### 18.2.1 Working space reservation

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

No obstructions should be built in way of:

- Crankcase and camshaft covers
- Camshaft withdrawal space
- Engine driven pump service space
- Charge air cooler withdrawal space
- Piston overhauling height
- Turbocharger maintenance space
- Electrical junction box door

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

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

### 18.2.2 Engine room height and 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.

Separate lifting arrangement for overhauling turbocharger is required (unless overhead travelling crane, which also covers the turbocharger is used). Turbocharger lifting arrangement is usually best handled with a chain block on a rail located above the turbocharger axis.

### 18.2.3 Maintenance platforms

In order to enable efficient maintenance work on the engine, it is advised to build the maintenance platforms on recommended elevations. The width of the platforms should be at minimum 800 mm to allow adequate working space. The surface of maintenance platforms should be of non-slippery material (grating or chequer plate).

NOTE
Working Platforms should be designed and positioned to prevent personnel slipping, tripping or falling on or between the walkways and the engine

## 18.3 Transportation and storage of spare parts and tools

Transportation arrangement from engine room to storage and workshop has to be prepared for heavy engine components. This can be done with several chain blocks on rails or alternatively utilising pallet truck or trolley. If transportation must be carried out using several lifting equipment, coverage areas of adjacent cranes should be as close as possible to each other.

Engine room maintenance hatch has to be large enough to allow transportation of main components to/from engine room.

It is recommended to store heavy engine components on slightly elevated adaptable surface e.g. wooden pallets. All engine spare parts should be protected from corrosion and excessive vibration.

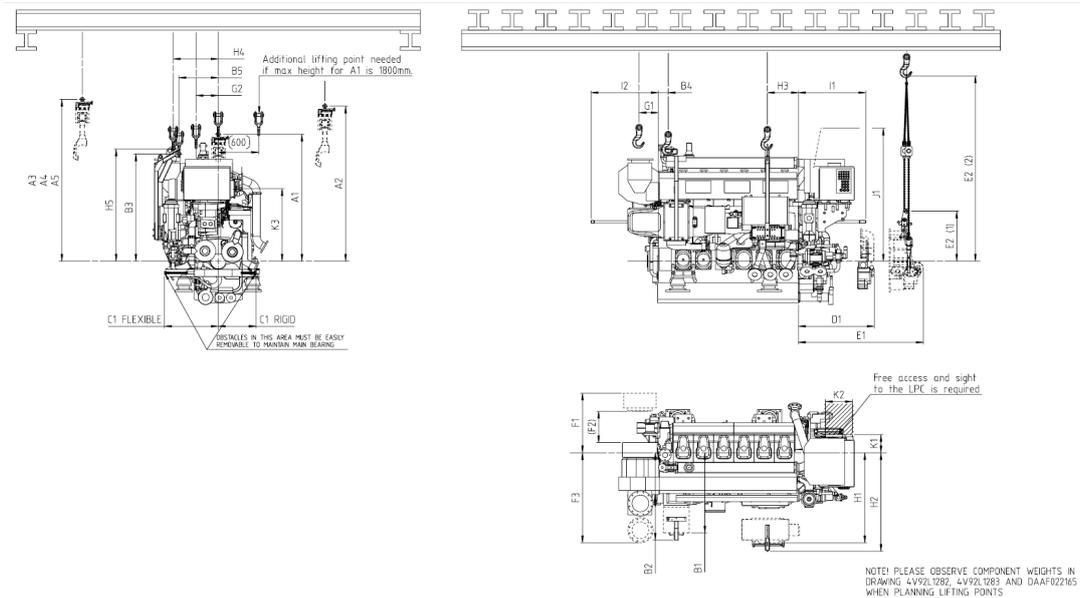
On single main engine (SME) installations it is important to store heavy engine parts close to the engine to make overhaul as quick as possible in an emergency situation.

## 18.4 Required deck area for service work

During engine overhaul some deck area is required for cleaning and storing dismantled components. Size of the service area is dependent of the overhauling strategy chosen, e.g. one cylinder at a time, one bank at a time or the whole engine at a time. Service area should be plain steel deck dimensioned to carry the weight of engine parts.

## 18.4.1 Service space requirement

### 18.4.1.1 Service space for engines with turbocharger in driving end



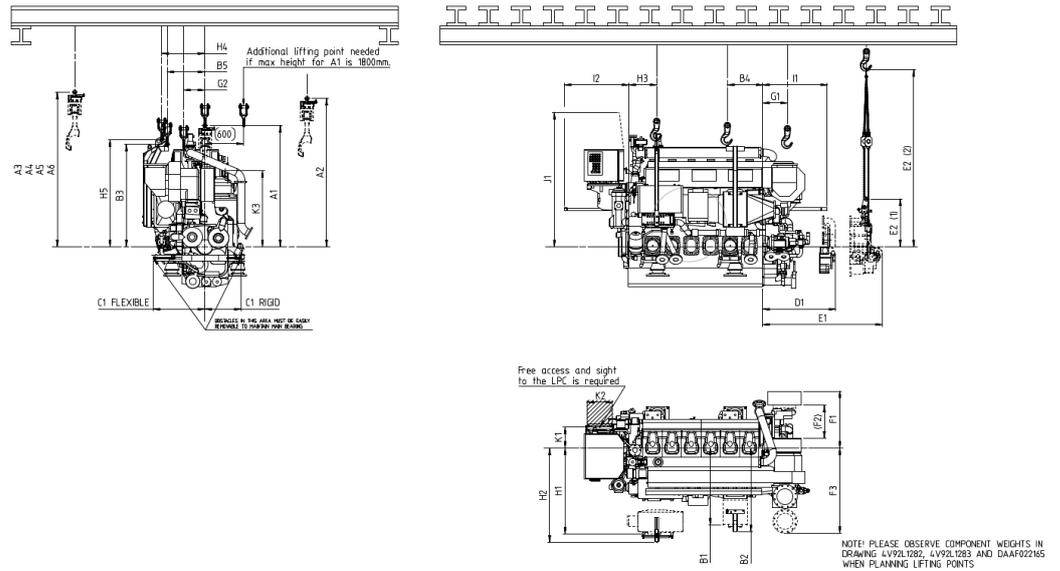
TC in driving end

Service space in [mm]	6L	8L	9L
A1. Height for overhauling piston and connecting rod		1800	
A2. Height for transporting piston and connecting rod freely over adjacent cylinder head covers		2300	
A3. Height for transporting piston and connecting rod freely over exhaust gas insulation box	2300	2400	2400
A4. Height needed for transporting piston and connecting rod freely over 50°C exhaust gas insulation box (SOLAS)	-	-	2720
A5. Height for transporting piston and connecting rod freely over gas manifold for W20DF		2470	
B1. Width for dismantling charge air cooler and air inlet box		1200	
B2. Width for dismantling charge air cooler and air inlet box sideways by using lifting tool		1310	
B3. Height of the lifting eye for the charge air cooler lifting tool		1600	
B4. Recommended lifting point for charge air cooler lifting tool	390 / LF = 270		
B5. Recommended lifting point for charge air cooler lifting tool		585	
C1. Removal of main bearing side screw, flexible / rigid mounting		800 / 560	
D1. Distance needed for dismantling lube oil and water pumps		635	
E1. Distance needed for dismantling pump cover with fitted pumps		With PTD: length = 515 Without PTD: 650	
E2. Height of the lifting eye for the pump cover with fitted pumps, with lifting tool 1 / alternative lifting tool 2		750 / 2770	
F1. The recommended axial clearance for dismantling and assembly of silencers	650	710	710
FP1. Minimum axial clearance		100	
F3. Recommended distance for dismantling the gas outlet elbow	990	1170	1170
G1. Recommended lifting point for the turbocharger		300	
G2. Recommended lifting point sideways for the turbocharger		345	
H1. Width for dismantling lubricating oil module and/or plate cooler		1250	
H2. Width for dismantling lube oil module with lifting tool		1480	
H3. Recommended lifting point for dismantling lubricating oil module and/or plate cooler		445	
H4. Recommended lifting point sideways for dismantling lubricating oil module and/or plate cooler		1045	
H5. Height of lifting eye for dismantling lube oil module with lifting tool		1675	
I1. Camshaft screw overhaul distance (free end)	1000	1300	1600
I2. Camshaft screw overhaul distance (flywheel end)	1300	1600	1600
J1. Space necessary for access to connecting box		2050	
K1. Distance to LCP (Local Control Panel)		270	
K2. Width of LCP		400	
K3. Distance to LCP		1150	

NOTE!  
It is sufficient if one of I1 or I2 are fulfilled.

Fig 18-3 Service space for engines with turbocharger in driving end (V69C0301H)

### 18.4.1.2 Service space for engines with turbocharger in free end



TC in free end

Service space in [mm]	4L	6L	8L	9L
A1. Height for overhauling piston and connecting rod				1600
A2. Height for transporting piston and connecting rod freely over adjacent cylinder head covers				2300
A3. Height for transporting piston and connecting rod freely over exhaust gas insulation box	2230	2300	2400	2400
A4. Height needed for transporting piston and connecting rod freely over 60°C exhaust gas insulation box (SQ/AS)	-	-	-	2720
A5. Height for transporting piston and connecting rod freely over exhaust gas insulation box for W20 with UNE 6-series	2320	2320	2420	2420
A6. Height for transporting piston and connecting rod freely over gas manifold for W20DF	-	-	-	2470
B1. Width for dismantling charge air cooler and air inlet box				1200
B2. Width for dismantling charge air cooler and air inlet box sideways by using lifting tool				1310
B3. Height of the lifting eye for the charge air cooler lifting tool				1600
B4. Recommended lifting point for charge air cooler lifting tool	260	550 / DF=430		
B5. Recommended lifting point for charge air cooler lifting tool				585
C1. Removal of main bearing side screw, flexible / rigid mounting				800 / 560
D1. Distance needed for dismantling lube oil and water pump				635
E1. Distance needed for dismantling pump cover with fitted pumps				With PTD length = 575 Without PTD: 650
E2. Height of the lifting eye for the pump cover with fitted pumps, with lifting tool 1 / alternative lifting tool 2				750 / 2770
F1. The recommended axial clearance for dismantling and assembly of silencers	590	650	750	750
F2. Minimum axial clearance				100
F3. Recommended distance for dismantling the gas outlet elbow	890	990	1120	1120
G1. Recommended lifting point for the turbocharger				350
G2. Recommended lifting point sideways for the turbocharger				320
H1. Width for dismantling lubricating oil module and/or plate cooler				1250
H2. Width for dismantling lube oil module with lifting tool				1480
H3. Recommended lifting point for dismantling lubricating oil module and/or plate cooler				445
H4. Recommended lifting point sideways for dismantling lubricating oil module and/or plate cooler				1045
H5. Height of lifting eye for dismantling lube oil module with lifting tool				1675
I1. Camshaft screw overhaul distance (free end)	700	1000	1300	1660
I2. Camshaft screw overhaul distance (flywheel end)	1000	1300	1600	1660
J1. Space necessary for access to connecting box				2300
K1. Distance to LCP (Local Control Panel)				300
K2. Width of LCP				360
K3. Distance to LCP				1200

NOTE!  
It is sufficient if one of I1 or I2 are fulfilled.

Fig 18-4 Service space for engines with turbocharger in free end (V69C03021)

### 18.4.1.3 Service space for generating sets

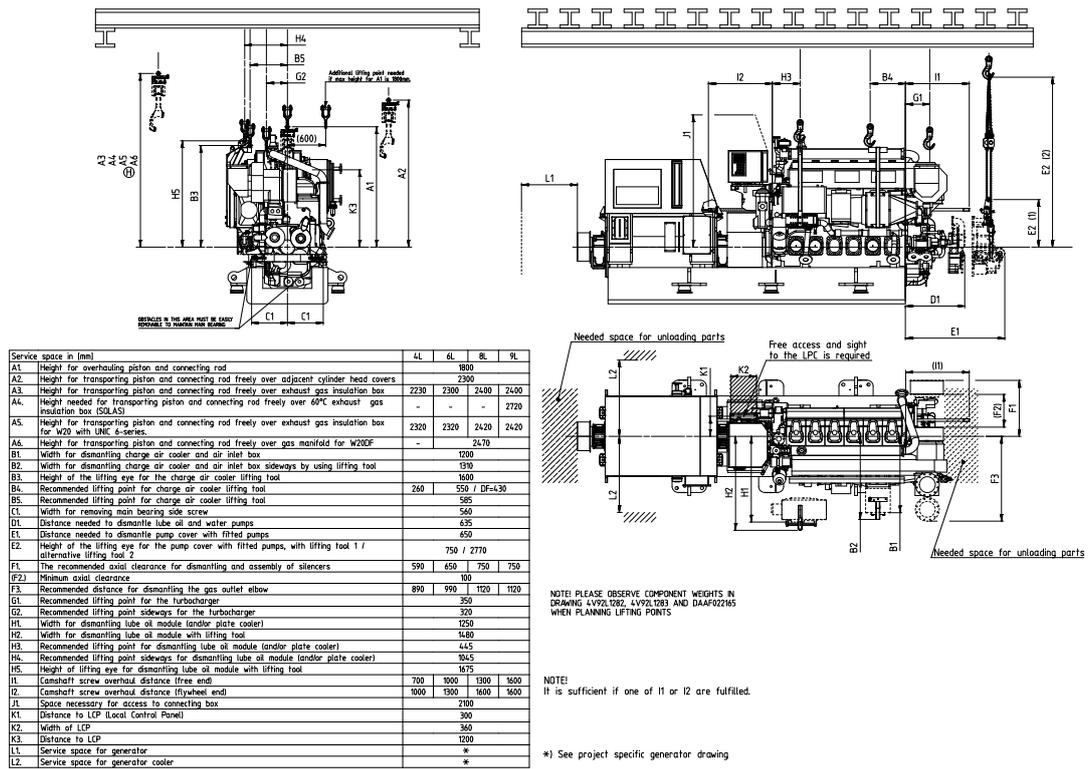


Fig 18-5 Service space for generating sets (DAAE006367H)

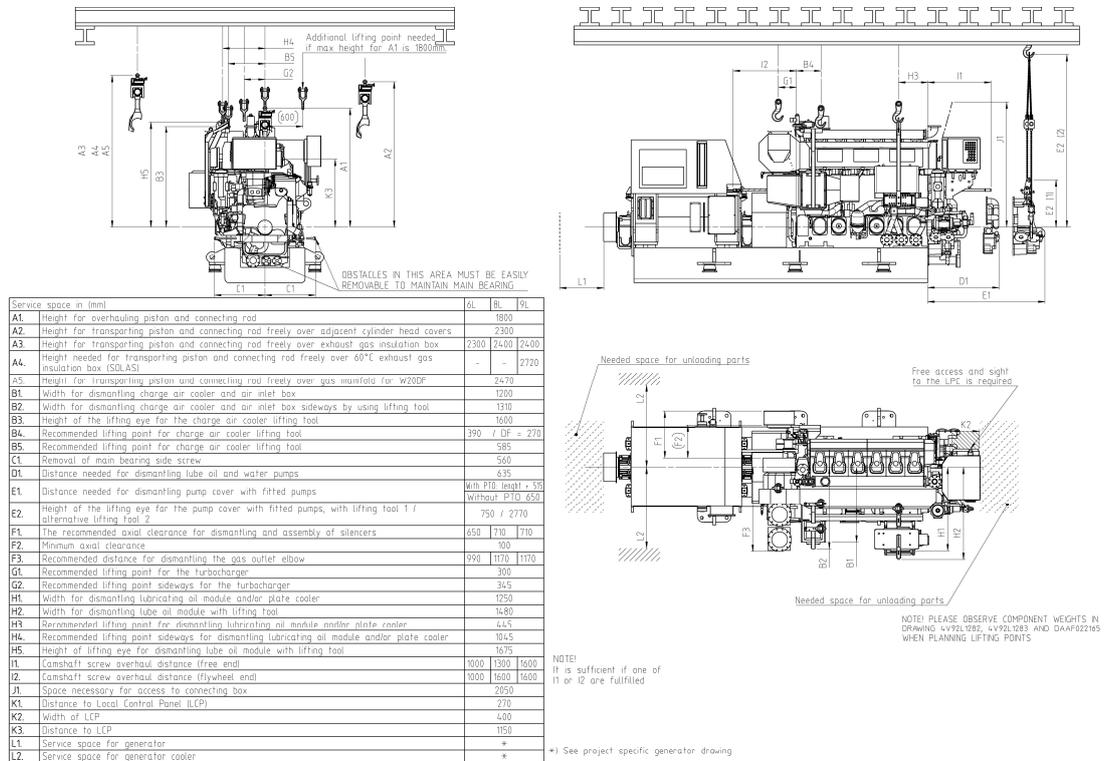


Fig 18-6 Service space for generating sets with turbocharger at driving end (DAAF566384)

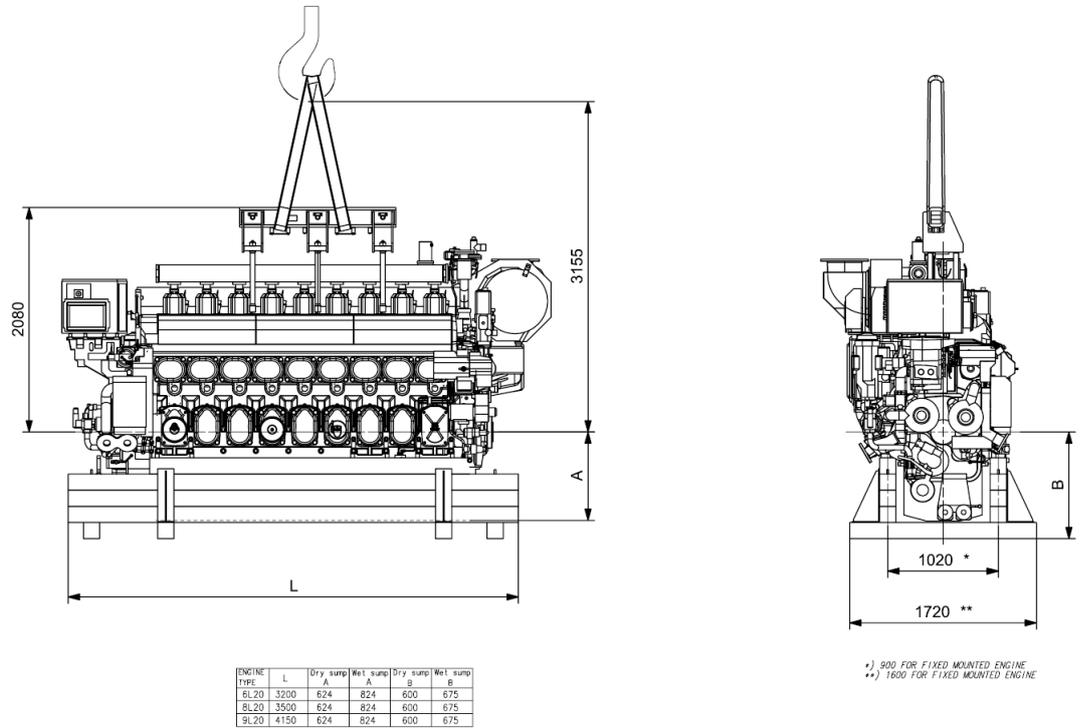
**NOTE**

It is sufficient if one of I1 or I2 are fulfilled.

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# 19. Transport Dimensions and Weights

## 19.1 Lifting of engines



**Fig 19-1 Lifting of main engines (DAAF016244A)**

Engine type	L	Dry sump A	Wet sump A	Dry sump B	Wet sump B
W 6L20DF	3200	624	824	600	675
W 8L20DF	3500	624	824	600	675
W 9L20DF	4150	624	824	600	675

## 19.2 Lifting of gensets

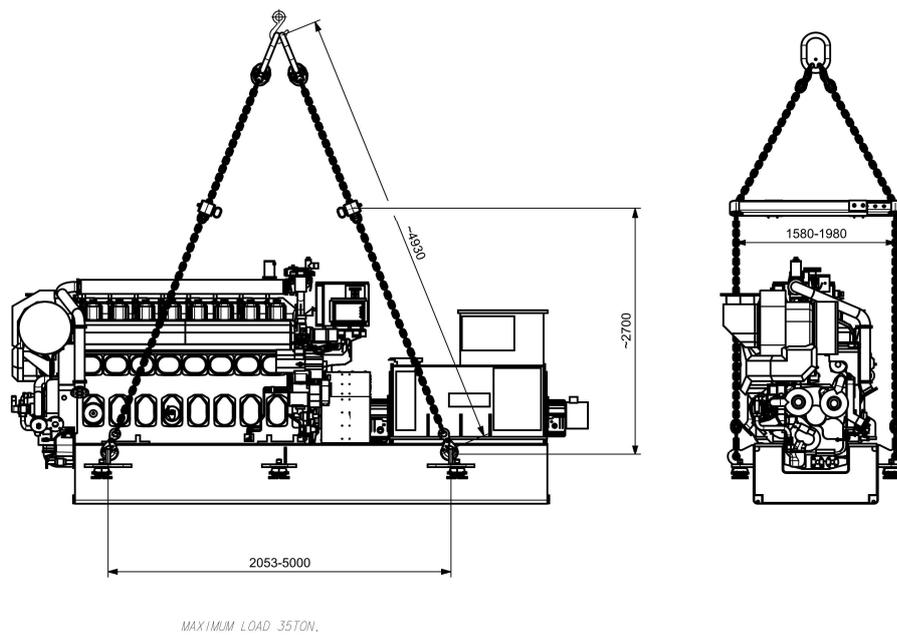


Fig 19-2 Lifting of generating sets (DAAF016285B)

## 19.3 Engine components

### 19.3.1 Turbocharger and cooler inserts (DAAE031768D)

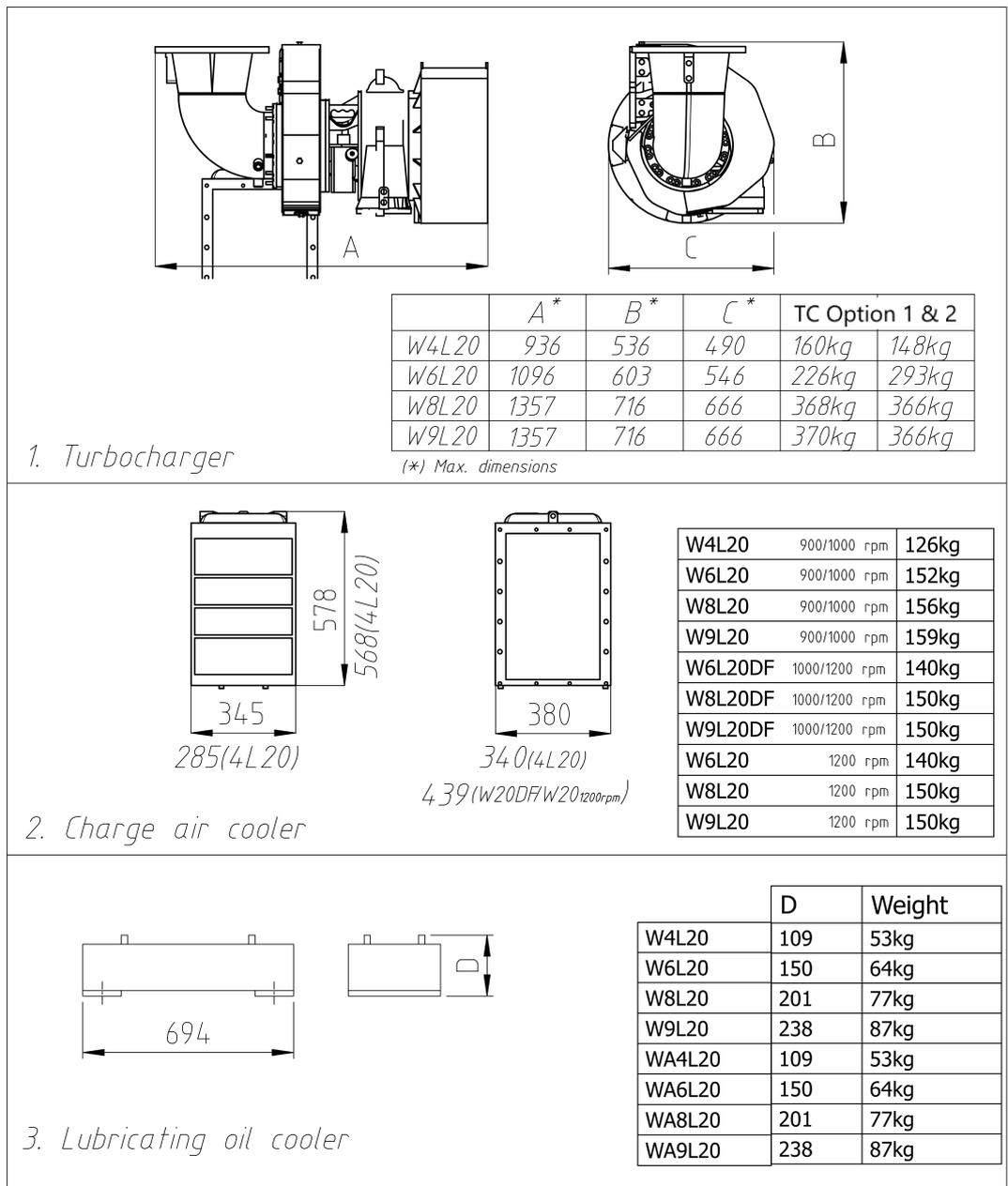
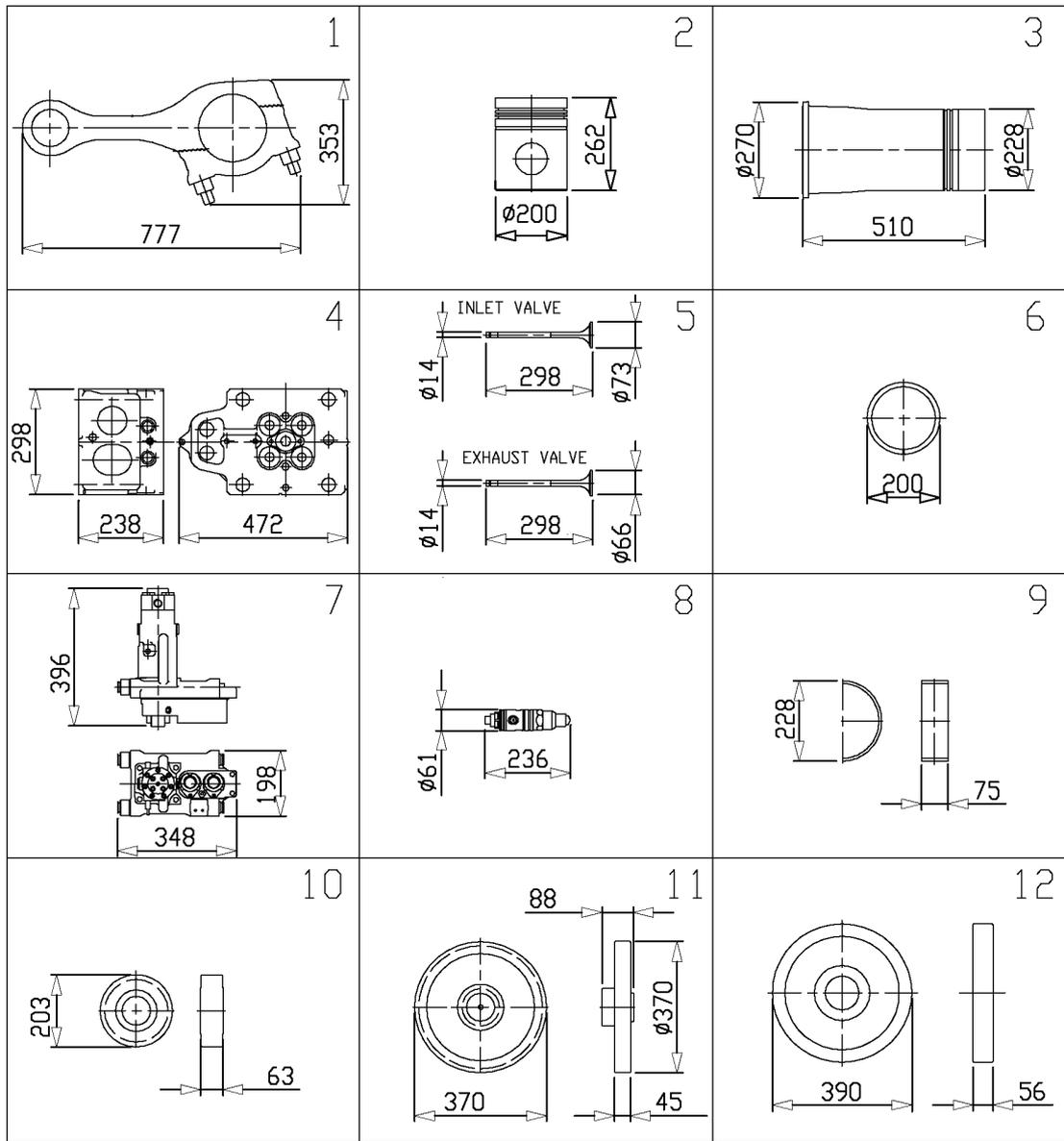


Fig 19-3 Turbocharger and cooler (DAAE031768D)



**Fig 19-4 Major spare parts (DAAF022165)**

No	Description	Weight [kg]	No	Description	Weight [kg]	No	Description	Weight [kg]
1	Connecting rod	39	5	Valve	0.8	9	Main bearing shell	1.4
2	Piston	28.5	6	Piston ring	0.2	10	Small intermediate gear	11.4
3	Cylinder liner	42	7	Injection pump	27	11	Large intermediate gear	23.5
4	Cylinder head	89	8	Injection valve	3.2	12	Camshaft drive gear	25

## 20. Product Guide Attachments

This and all other product guides can be accessed on the internet, at [www.wartsila.com](http://www.wartsila.com). Product guides are available both in web and PDF format. Engine outline drawings are available not only in [2D](#) drawings (in PDF, DXF format), but also in [3D](#) models. Please consult your sales contact at Wärtsilä for more information.

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

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# 21. ANNEX

## 21.1 Unit conversion tables

The tables below will help you to convert units used in this product guide to other units. Where the conversion factor is not accurate a suitable number of decimals have been used.

*Length conversion factors*

Convert from	To	Multiply by
mm	in	0.0394
mm	ft	0.00328

*Mass conversion factors*

Convert from	To	Multiply by
kg	lb	2.205
kg	oz	35.274

*Pressure conversion factors*

Convert from	To	Multiply by
kPa	psi (lbf/in <sup>2</sup> )	0.145
kPa	lbf/ft <sup>2</sup>	20.885
kPa	inch H <sub>2</sub> O	4.015
kPa	foot H <sub>2</sub> O	0.335
kPa	mm H <sub>2</sub> O	101.972
kPa	bar	0.01

*Volume conversion factors*

Convert from	To	Multiply by
m <sup>3</sup>	in <sup>3</sup>	61023.744
m <sup>3</sup>	ft <sup>3</sup>	35.315
m <sup>3</sup>	Imperial gallon	219.969
m <sup>3</sup>	US gallon	264.172
m <sup>3</sup>	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 <sup>2</sup>	lbf ft <sup>2</sup>	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 <sup>3</sup> /h (liquid)	US gallon/min	4.403
m <sup>3</sup> /h (gas)	ft <sup>3</sup> /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 <sup>3</sup>	lb/US gallon	0.00834
kg/m <sup>3</sup>	lb/Imperial gallon	0.01002
kg/m <sup>3</sup>	lb/ft <sup>3</sup>	0.0624

### 21.1.1 Prefix

**Table 21-1 The most common prefix multipliers**

Name	Symbol	Factor	Name	Symbol	Factor	Name	Symbol	Factor
tera	T	10 <sup>12</sup>	kilo	k	10 <sup>3</sup>	nano	n	10 <sup>-9</sup>
giga	G	10 <sup>9</sup>	milli	m	10 <sup>-3</sup>			
mega	M	10 <sup>6</sup>	micro	μ	10 <sup>-6</sup>			

# 21.2 Collection of drawing symbols used in drawings

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
1 2101		Valve (general)	10 X2113		Check valve globe type	17 X2131		Control valve with electric motor actuator
2 X8068		Valve, globe type	11 X8078		Swing check valve (Form 1)	18 X2103		Two-way valve with solenoid actuator
3 X8071		Valve, ball type	12 X8165		Swing check valve (Form 2)	19		Two-way valve with double-acting cylinder actuator (pneumatic)
4 X8074		Valve, gate type	13 X2124		Safety valve, spring loaded, globe type	20 X2104		Two-way valve with electric motor actuator
5 X8075		Valve, butterfly type (Form 1)	14 X1021		Manual operation of valve	21 X2101		Two-way valve with diaphragm actuator (pneumatic)
6 X8075		Valve, butterfly type (Form 2)	15 X2001		Weight-loaded safety valve detained in open position after operation	22		Two-way control valve with diaphragm actuator (pneumatic)
7 X8076		Valve, needle type	16 X2134		Float-operated control valve	23 X2002		Spring-loaded safety two-way valve with automatic return after operation
8 X8087		Valve, control type, continuously operated						
9 X8077		Check valve (general), (Two-way non-return valve, flow from left to right)						

**Fig 21-1 List of symbols (DAAF406507A - 1)**

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
24		Manually operated control valve	33 X8070		Valve, three way globe type	40		Three-way control valve with diaphragm actuator
25 X2112		Combinated non-return valve and manually actuated stop valve. Flow from left to right	34 X8073		Valve, three way ball type	41		Self-operating pressure reducing three-way control valve
26		Spring-loaded non-return valve. Flow from left to right	35		Three-way control valve with electrical motor actuator	42		Self-operating thermostatic three-way control valve
27 X2133		Self-operating pressure reducing control valve	36 X2103		Three-way valve with solenoid actuator	43		Self-contained thermostat valve
28		Pressure control valve (spring loaded)	37 X2107		Three-way valve with double-acting cylinder actuator (pneumatic)	44 2102		Valve, angle type (general)
29		Pressure control valve (remote pressure sensing)	38		Three-way valve with electric motor actuator	45 X8069		Valve, angle globe type
30		Pneumatically actuated valve, spring-loaded cylinder actuator	39 X2102		Three-way valve with diaphragm actuator			
31		Quick-closing valve						
32 2103		Valve, three way type (general)						

**Fig 21-2 List of symbols (DAAF406507A - 2)**

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
46 X8072		Valve, angle ball type	55 772		Orifice plate	62		Valve 1/2 Pneum/Pneum
47 X2125		Safety valve, spring loaded, globe angle type	56 X2182		Shuttle valve with "AND-function"	63		Valve 1/2 Pneum/Spring
48		Weight loaded angled valve defained in open position after operation	57		Valve 1/2 Pneum/Pneum	64		Valve 1/2 Solenoid/Spring
49		Spring-loaded safety angled valve with automatic return after operation	58		Valve 1/2 Pneum/Spring	65		Valve 1/2 Lever/Spring
50		Non-return angled two-way valve. Flow from left to right	59		Valve 1/2 Solenoid/Spring	66		Valve 1/2 Manual/Spring
51		Non-return angled two-way valve hand operating. Flow from left to right	60		Valve 1/2 Lever/Spring	67		Valve 1/2 Pneum/Pneum
52 2181		Self-operating release valve (steam trap)	61		Valve 1/2 Manual/Spring			
53 X2212		Adjustable restrictor (valve)						
54 2031	X	Restrictor						

Fig 21-3 List of symbols (DAAF406507A - 3)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
68		Valve 1/2 Pneum/Spring	77		Electrically driven compressor	84 X8079		Heat exchanger (general), condenser
69		Valve 1/2 Solenoid/Spring	78 2302		Compressor, vacuum pump (general)	85 X2674		Pneumatic-air lubricator
70		Valve 1/2 Lever/Spring	79 2301		Pump, liquid type (general)	86 X8111		Cooling tower, dry with induced draught
71		Valve 1/2 Manual/Spring	80 2401		Hydraulic pump	87 2521		Cooling tower (general) (Deaerator)
72		Turbogenerator	81		Manual hydraulic pump	88 2040		Funnel
73		Turbogenerator with gear transmission	82 X2071		Boiler feedwater vessel with deaerator	89		Trough or drip tray with drain funnel
74		Turbocharger	83 2501		Heating or cooling coil			
75 C0082		Electric motor (general)						
76		Electrically driven pump						

Fig 21-4 List of symbols (DAAF406507A - 4)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
90 517		Flanged dummy cover (Blind flange pair)	99 564		Quick-release coupling element of female type	106		Air vent + flame arrester
91 511		Flanged connection	100 563		Quick-release coupling element of male type	107 2036		Flame arrester
92 518		End cap	101 X4.11		Hose	108 X322		Pipeline with thermal insulation
93 514		Screwed joint	102 532		Expansion sleeve	109 X8174		Piping, heated or cooled and insulated
94 516		Reducer	103 533		Compensator (Expansion bellows)	110 X2619		High speed centrifuge (separator)
95		Joint with change of pipe dimension, pipe reducer eccentric	104 2038		Siphon	111 X2614		Centrifuge with perforated shell (centrifugal filter)
96 565		Quick-release coupling element which fits into another coupling element of the same type	105 2039		Vent (outlet to the atmosphere for steam/gas)			
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						

Fig 21-5 List of symbols (DAAF406507A - 5)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
112 X8116		Liquid filter (general)	121 X8123		Screening device, sieve, strainer, general	128 X2069		Vessel with dished ends and heating / cooling jacket
113 X8117		Liquid filter, bag, candle or cartridge type	122 X8031		Gravity separator, settling chamber	129 2033		Silencer
114		Automatic filter with by-pass filter	123 X2618		Separator, cyclone type	130 2034		Viewing glass
115 X8019		Suction filter	124 X8090		Strainer	131		Receiver, pulse damper
116 X8119		Liquid rotary filter, drum or disc type	125 2073		Pressure vessel with diaphragm for example expansion vessel	132		Indicating measuring instrument
117		Duplex filter	126 2062		Pressure or vacuum vessel	133		Local instrument
118		Candle filter with rotating drum with by-pass	127 301		Tank, vessel			
119 X8122		Gas filter (general)						
120 X8022		Gas filter, bag, candle or cartridge type						

Fig 21-6 List of symbols (DAAF406507A - 6)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
134		Local panel	141 X1032		Automatic operation of valve with two stable positions open and close	148 X2233		Pilot-operated non-return valve, opened by pilot pressure against return spring
135		Signal to control board	142 2006		Bearing	149 X2192		Single-stage pressure-relief valve
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 OS = Flow switch TSZ = Temperature switch	143 X8080		Rupture disc	150 X2199		Pressure-reducing valve
137 X2122		Overflow safety valve	144 513		Clamped flange coupling	151 X2180		Shuttle valve with OR-function 1
138 X1048		Flow rate indication	145 C0100		Coupling	152 X2180		Shuttle valve with OR-function 2
139 X1056		Recording of flow rate with summation of volume	146 X2231		Spring-loaded non-return valve			
140 X1036		Automatic operation of valve with infinite number of stable positions	147 X2232		Pilot-operated non-return valve, closed by pilot pressure			

Fig 21-7 List of symbols (DAAF406507A - 7)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
153 2113		L-bore in a three-way valve	162 2126		Valve disc or butterfly type	169 X2125		Angled, globe-type, spring-loaded vacuum valve operating when pressure p lower than set value
154 2114		T-bore in a three-way valve	163 X2114		Swing-type non-return valve	170		Angled, globe-type, spring-loaded vacuum valve operating when pressure p higher than set value
155 2104		Four-way valve	164 X2115		Spring-loaded ball-type non-return valve	171 2123		Valve Plug type
156		four-way valve globe type	165		Spring-loaded globe-type non-return valve	172		Manual operation of Three-way valve
157		four-way valve ball type	166 X2121		Safety valve which opens when pressure p higher than set value			
158		L-bore in a four-way valve	167 X2121		Pipe break valve which closes when flow rate q is higher than set value			
159		T-bore in a four-way valve	168 X2124		Globe type spring-loaded safety valve operating when pressure p higher than set value			
160 2115		Double L-bore in a four-way valve						
161 2127		Piston type; plunger type						

Fig 21-8 List of symbols (DAAF406507A - 8)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
173		Valve body 2 position 2-3-4 port	182		3-2 Valve 1	189		4-3 Valve open 2
174		Valve body 2 position 5 port	183		3-2 Valve 2	190		4-3 Valve empty 1
175		Valve body 3 position 2-3-4 port	184		4-2 Valve 1	191		4-3 Valve empty 2
176		Valve body 3 position 5 port	185		4-2 Valve 2	192		5-3 Valve open 1
177		Valve body 4 position 2-3-4 port	186		5-2 Valve 1	193		5-3 Valve open 2
178		Valve body 4 position 5 port	187		5-2 Valve 2	194		5-3 Valve empty 1
179		2-2 Valve arrow up	188		4-3 Valve open 1	195		5-3 Valve empty 2
180		2-2 Valve arrow down						
181		2-2 Valve both arrows						

**Fig 21-9 List of symbols (DAAF406507A - 9)**

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
196		2-port closed	205		4-port crossed	212		5-port closed
197		2-port single arrow	206		4-port tandem single arrow	213		5-port arrows same direction
198		2-port double arrow	207		4-port tandem double arrow	214		5-port arrows opposite direction
199		3-port single arrow	208		4-port crossover single arrow	215		5-port crossover arrows same
200		3-port double arrow	209		4-port crossover double arrow	216		5-port crossover opposite arrows
201		3-port crossover single arrow	210		4-port open	217		5-port crossover arrows same up
202		3-port crossover double arrow	211		4-port semi-connected			
203		4-port						
204		4-port closed						

**Fig 21-10 List of symbols (DAAF406507A - 10)**

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
218		Spring for valve	227		Pedal for valve	234		Single acting cylinder with spring (1)
219		Spring for valve variable	228		Electrical actuation for valve	235		Single acting cylinder with spring (2)
220 711		Plunger for valve	229		Electrical actuation for valve variable	236 724		Double acting cylinder
221		Plunger for valve variable	230		Pilot operation for valve			
222		Roller for valve	231		Exhaust port for valve			
223		Roller for valve variable	232 723		Single acting cylinder			
224		Manual override for valve	233		Double ended cylinder			
225		Pull / push button for valve						
226		Lever for valve						

**Fig 21-11 List of symbols (DAAF406507A - 11)**

Wärtsilä specific symbols for P&I diagrams			Wärtsilä specific symbols for P&I diagrams			Wärtsilä specific symbols for P&I diagrams		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
238		Cam profile 1	247		Water tank	254		Bearing upper and lower
239		Flywheel	248		Description arrow for flow in one direction	255		L-engine
240		Gear wheel	249		Description arrow for flow in both directions	256		V-engine
241		Spray nozzle	250		Line jump	257		square heat exchanger
242		Leak collector	251		Arrow for flow	258		Starting air valve for cylinder head
243		Oil sump	252		Starting air distributor	259		External connection
244		Dipstick 1	253		Starting air distributor 2	260		Automatic filter
245		Dipstick 2						
246		Cylinder						

**Fig 21-12 List of symbols (DAAF406507A - 12)**

Wärtsilä specific symbols for P&I diagrams			Wärtsilä specific symbols for P&I diagrams			Wärtsilä specific symbols for P&I diagrams		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
261		Separator	270		Booster for valve mechanism	277		
262		Separator with filter	271			278		
263		Filter	272			279		
264		Flexible double wall pipe	273			280		
265		Cartridge valve with spring	274			281		
266		Cartridge valve	275			282		
267		Revision mark	276					
268		PT sensor with gauge valve						
269		Hydraulic wastegate valve						

**Fig 21-13 List of symbols (DAAF406507A - 13)**





Wärtsilä is a global leader in complete lifecycle power solutions for the marine and energy markets. By emphasising technological innovation and total efficiency, Wärtsilä maximises the environmental and economic performance of the vessels and power plants of its customers.

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