WÄRTSILÄ


# WÄRTSILÄ 50DF PRODUCT GUIDE

# Introduction

This Product Guide provides data and system proposals for the early design phase of marine engine installations. For contracted projects specific instructions for planning the installation are always delivered. Any data and information herein is subject to revision without notice. This 2/2016 issue replaces all previous issues of the Wärtsilä 50DF Project Guides.

| Issue | Published | Updates |
|---|---|---|
| 2/2016 | 09.09.2016 | Technical data updated |
| 1/2016 | 30.06.2016 | Fuel sharing added. Other minor updates |
| 1/2014 | 13.06.2014 | Chapter Technical data and numerous updates throughout the project guide |
| 1/2012 | 03.12.2012 | Minor updates throughout the product guide |

Wärtsilä, Marine Solutions

Vaasa, September 2016

# Table of contents

# 1. Main Data and Outputs

The Wärtsilä 50DF 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 ........................ 500 mm

Stroke .................................. 580 mm

Piston displacement ............ 113.9 l/cyl

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

Cylinder configuration .......... 6, 8 and 9 in-line; 12, 16 and 18 in V-form

V-angle ................................ 45°

Direction of rotation ............. clockwise

Speed .................................. 500, 514 rpm

Mean piston speed ............... 9.7, 9.9 m/s

## 1.1 Maximum continuous output

**Table 1-1 Rating table for Wärtsilä 50DF**

| Cylinder configuration | Main engines 514 rpm | Diesel electric applications | | | |
|---|---|---|---|---|---|
| | | 500 rpm | | 514 rpm | |
| | Engine [kW] | kW | BHP | kW | BHP |
| W 6L50DF | 5850 | 5700 | 7750 | 5850 | 7950 |
| W 8L50DF | 7800 | 7600 | 10340 | 7800 | 10600 |
| W 9L50DF | 8775 | 8550 | 11630 | 8775 | 11930 |
| W 12V50DF | 11700 | 11400 | 15500 | 11700 | 15910 |
| W 16V50DF | 15600 | 15200 | 20670 | 15600 | 21210 |
| W 18V50DF | N/A | 17100 | 23260 | 17550 | 23860 |

Nominal speed 514 rpm is recommended for mechanical propulsion engines.

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)

# 1.2 Output limitations in gas mode

## 1.2.1 Output limitations due to methane number

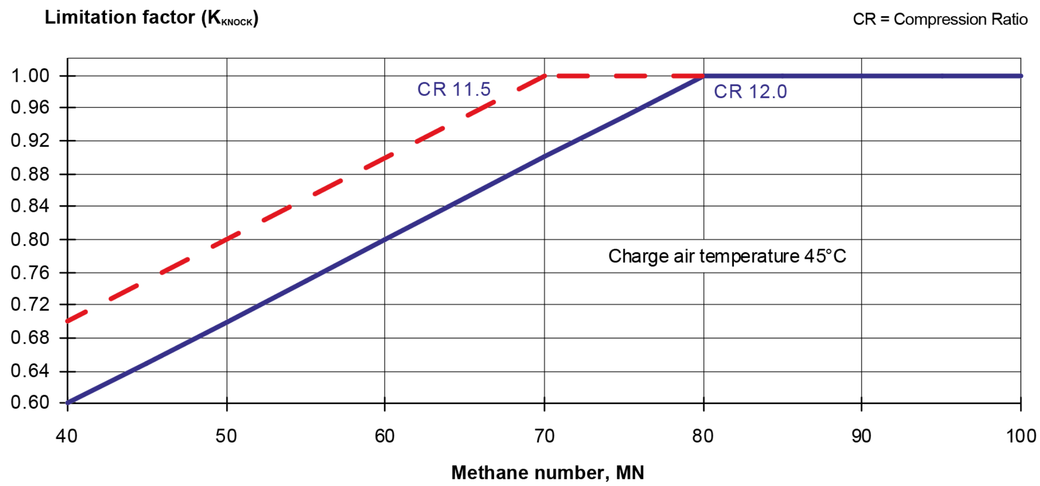


**Fig 1-1 Output limitations due to methane number**

**Notes:**

Compensating a low methane number gas by lowering the receiver temperature below 45°C is not allowed.

Compensating a higher charge air temperature than 45°C by a high methane number gas is not allowed.

The engine can be optimized for a lower methane number but that will affect the performance.

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.

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

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

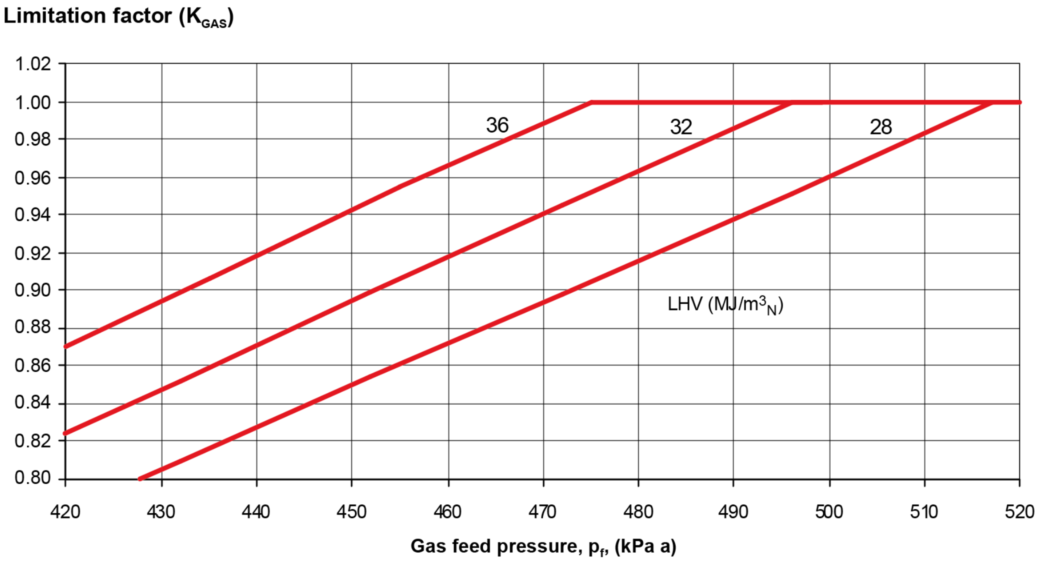


**Fig 1-2 Output limitation factor due to gas feed pressure / LHV**

**Notes:**

The above given values for gas feed pressure (absolute pressure) are at engine inlet. The pressure drop over the gas valve unit (GVU) is approx. 80 kPa.

Values given in $m^3_N$ are at 0°C and 101.3 kPa.

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 $MJ/m^3_N$ .

## 1.3 Reference conditions

The output is available within a range of ambient conditions and coolant temperatures specified in the chapter *Technical Data*. 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 stated in the chapter *Technical Data*. The statement applies to engines operating in ambient conditions according to ISO 3046-1:2002 (E).

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

Correction factors for the fuel oil consumption in other ambient conditions are given in standard ISO 3046-1:2002.

## 1.4 Operation in inclined position

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

- Transverse inclination, permanent (list) 15.0°
- Transverse inclination, momentary (roll) 22.5°
- Permanent fore-and-aft inclinations 10.0°

# 1.5 Dimensions and weights

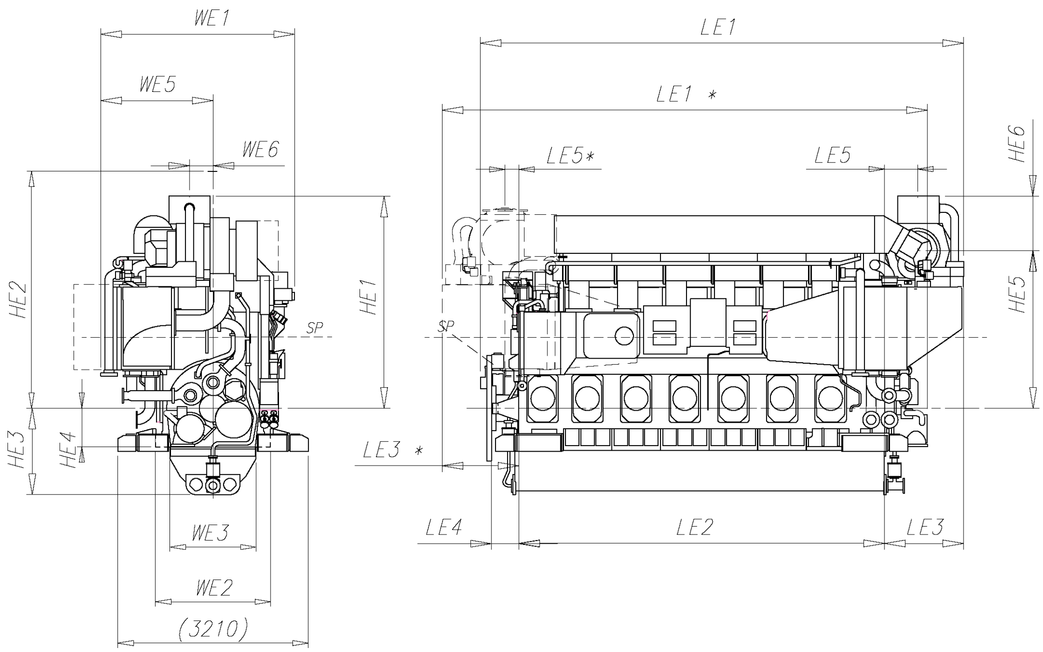


**Fig 1-3 In-line engines (DAAE000316d)**

| Engine | TC | LE1 | LE1* | LE2 | LE3 | LE3* | LE4 | LE5 | LE5* | HE1 | HE2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| W 6L50DF | NA357 | 8205 | 8310 | 6170 | 1295 | 1295 | 460 | 555 | 160 | 3580 | 4000 |
| | TPL71 | 8120 | 8310 | 6170 | 1295 | 1295 | 460 | 555 | 230 | 3475 | 4000 |
| W 8L50DF | TPL76 | 10270 | - | 7810 | 1775 | - | 460 | 700 | - | 3920 | 4000 |
| W 9L50DF | TPL76 | 11140 | - | 8630 | 1775 | - | 460 | 700 | - | 3920 | 4000 |

| Engine | TC | HE3 | HE4 | HE5 | HE6 | WE1 | WE2 | WE3 | WE5 | WE6 | Weight |
|---|---|---|---|---|---|---|---|---|---|---|---|
| W 6L50DF | NA357 | 1455 | 650 | 2655 | 925 | 3270 | 1940 | 1445 | 1895 | 395 | 96 |
| | TPL71 | 1455 | 650 | 2685 | 790 | 3270 | 1940 | 1445 | 1895 | 420 | 96 |
| W 8L50DF | TPL76 | 1455 | 650 | 2820 | 1100 | 3505 | 1940 | 1445 | 2100 | 340 | 128 |
| W 9L50DF | TPL76 | 1455 | 650 | 2820 | 1100 | 3505 | 1940 | 1445 | 2100 | 340 | 137.5 |

* TC in driving end

All dimensions in mm. Weights are dry engines, in metric tons, of rigidly mounted engines without flywheel.

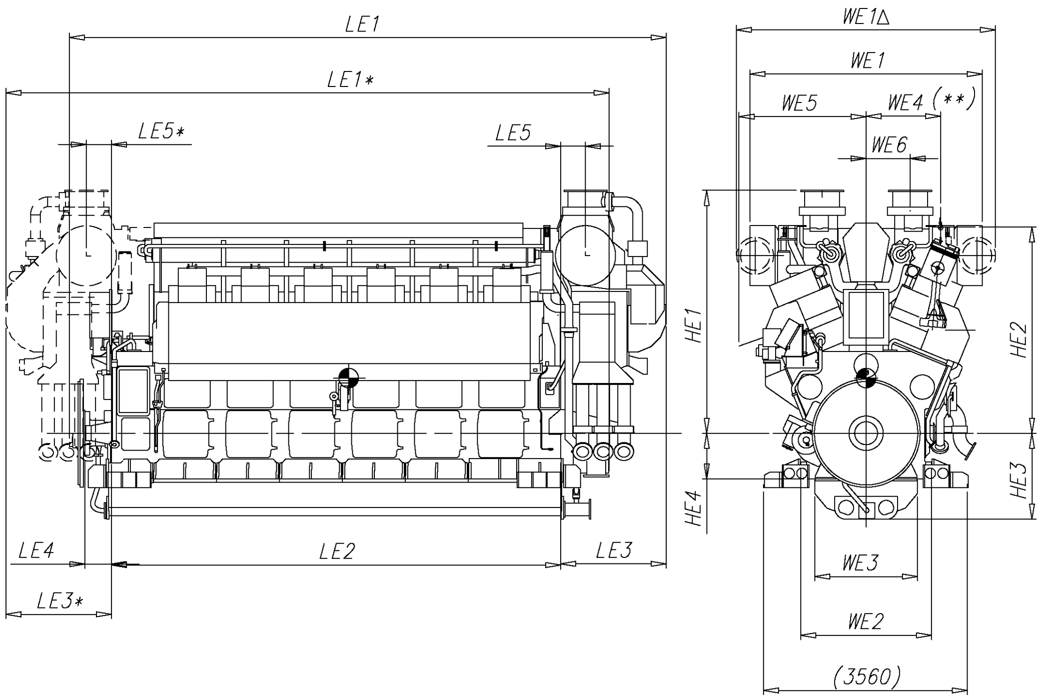


**Fig 1-4 V-engines (DAAE000413c)**

| Engine | TC | LE1 | LE1* | LE2 | LE3 | LE3* | LE4 | LE5 | LE5* | HE1 | HE2 | HE3 | HE4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W 12V50DF | NA357 | 10410 | 10540 | 7850 | 1840 | 1840 | 460 | 500 | 500 | 4055 | 3600 | 1500 | 800 |
| | TPL71 | 10425 | 10540 | 7850 | 1840 | 1840 | 460 | 435 | 435 | 4240 | 3600 | 1500 | 800 |
| W 16V50DF | TPL76 | 13830 | 13200 | 10050 | 2300 | 2300 | 460 | 680 | 680 | 4400 | 3600 | 1500 | 800 |
| W 18V50DF | TPL76 | 14180 | - | 11150 | 2300 | - | 460 | 680 | - | 4400 | 3600 | 1500 | 800 |

| Engine | TC | HE5 | HE6 | WE1 | WE1Δ | WE2 | WE3 | WE4 | WE4** | WE5 | WE6 | Weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W 12V50DF | NA357 | 3080 | 925 | 3810 | 4520 | 2290 | 1800 | 1495 | 1300 | 2220 | 765 | 175 |
| | TPL71 | 3100 | 1140 | 4055 | 4525 | 2290 | 1800 | 1495 | 1300 | 2220 | 770 | 175 |
| W 16V50DF | TPL76 | 3300 | 1100 | 4730 | 5325 | 2290 | 1800 | 1495 | 1300 | 2220 | 930 | 224 |
| W 18V50DF | TPL76 | 3300 | 1100 | 4730 | 5325 | 2290 | 1800 | 1495 | 1300 | 2220 | 930 | 244 |

* TC in driving end

** With monospex (exhaust manifold)

Δ With air suction branches

All dimensions in mm. Weights are dry engines, in metric tons, of rigidly mounted engines without flywheel.

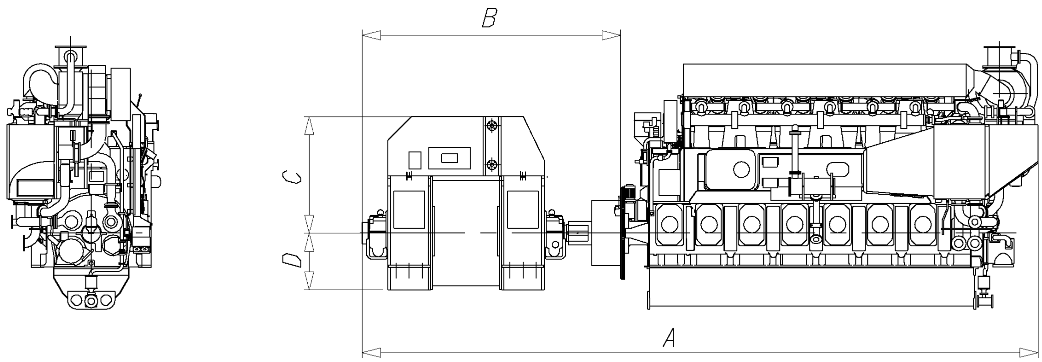


**Fig 1-5 Example of total installation lengths, in-line engines (DAAE000489)**

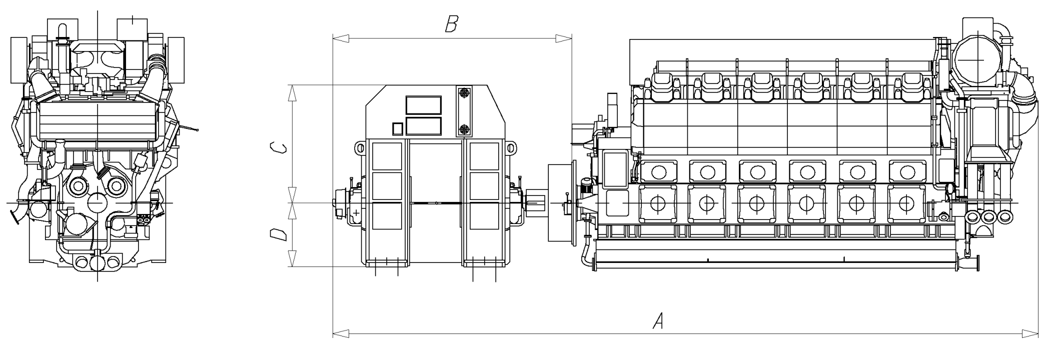


**Fig 1-6 Example of total installation lengths, V-engines (DAAE000489)**

| Engine | A | B | C | D | Genset weight [ton] |
|---|---|---|---|---|---|
| W 6L50DF | 12940 | 4940 | 2235 | 1090 | 138 |
| W 8L50DF | 15060 | 5060 | 2825 | 1020 | 171 |
| W 9L50DF | 15910 | 5060 | 2825 | 1020 | 185 |
| W 12V50DF | 15475 | 5253 | 2593 | 1365 | 239 |
| W 16V50DF | 17540 | 4690 | 2050 | 1590 | 288 |
| W 18V50DF | 18500 | 4690 | 2050 | 1590 | 315 |

*Values are indicative only and are based on Wärtsilä 50DF engine with built-on pumps and turbocharger at free end of the engine.*

*Generator make and type will effect width, length, height and weight.*

*[All dimensions are in mm]*

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# 2. Operating Ranges

## 2.1 Engine operating range

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. Operation in the shaded area is permitted only temporarily during transients. Minimum speed is indicated in the diagram, but project specific limitations may apply.

### 2.1.1 Controllable pitch propellers

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

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

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

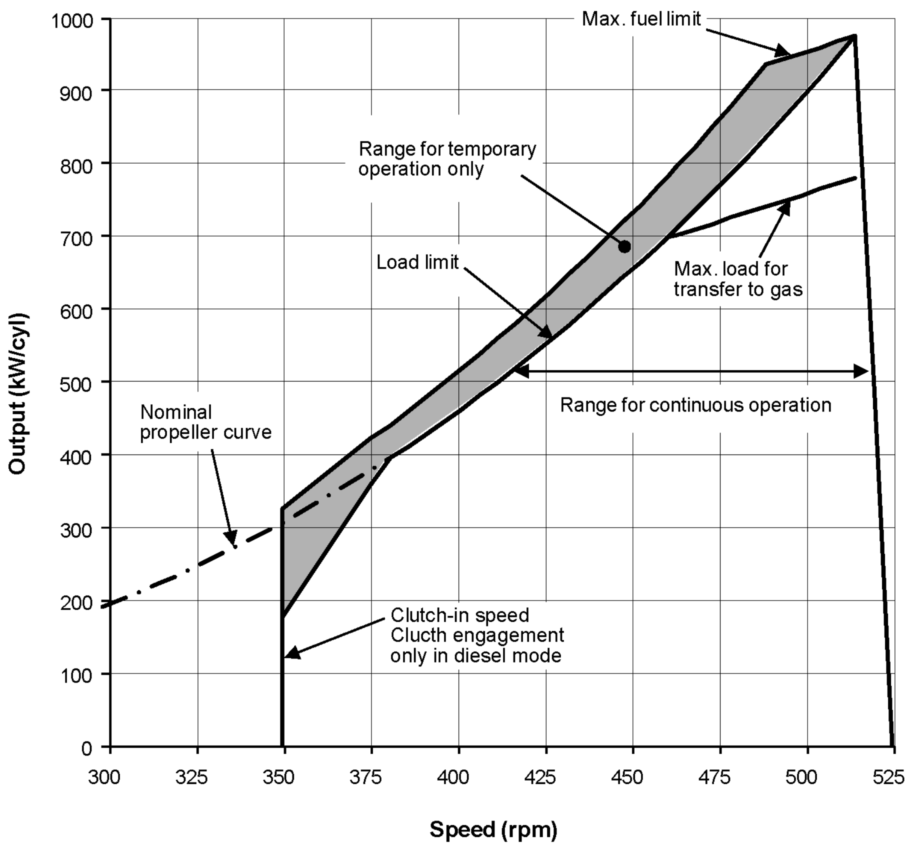



**Fig 2-1** **Operating field for CP-propeller, 975 kW/cyl, rated speed 514 rpm**

**Remarks:** The maximum output may have to be reduced depending on gas properties and gas pressure, refer to section "*Derating of output in gas mode*". 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 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 “preheated, normal gas” (see figures) can be used as the default loading rate for both diesel and gas mode. If the control system has only one load increase ramp, then the ramp for a preheated engine must be used. The HT-water temperature in a preheated engine must be at least 60ºC, preferably 70ºC, and the lubricating oil temperature must be at least 40ºC.

The loading ramp “max. capacity gas” indicates the maximum capability of the engine in gas mode. Faster loading may result in alarms, knock and undesired trips to diesel. This ramp can also be used as normal loading rate in diesel mode once the engine has attained normal operating temperature.

The maximum loading rate “emergency diesel” is close to the maximum capability of the engine in diesel mode. It shall not be used as the normal loading rate in diesel mode.

Emergency loading may only be possible by activating an emergency function, which generates visual and audible alarms in the control room and on the bridge.

The load should always be applied gradually in normal operation. Acceptable load increments are smaller in gas mode than in diesel mode and also smaller at high load, which must be taken into account in applications with sudden load changes. The time between load increments must be such that the maximum loading rate is not exceeded. In the case of electric power generation, the classification society shall be contacted at an early stage in the project regarding system specifications and engine loading capacity.

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 also result in automatic transfer to diesel when operating close to 100% output. Expected variations in gas fuel quality and momentary load level must be taken into account to ensure that gas operation can be maintained in normal operation.

## 2.2.1 Mechanical propulsion, controllable pitch propeller (CPP)

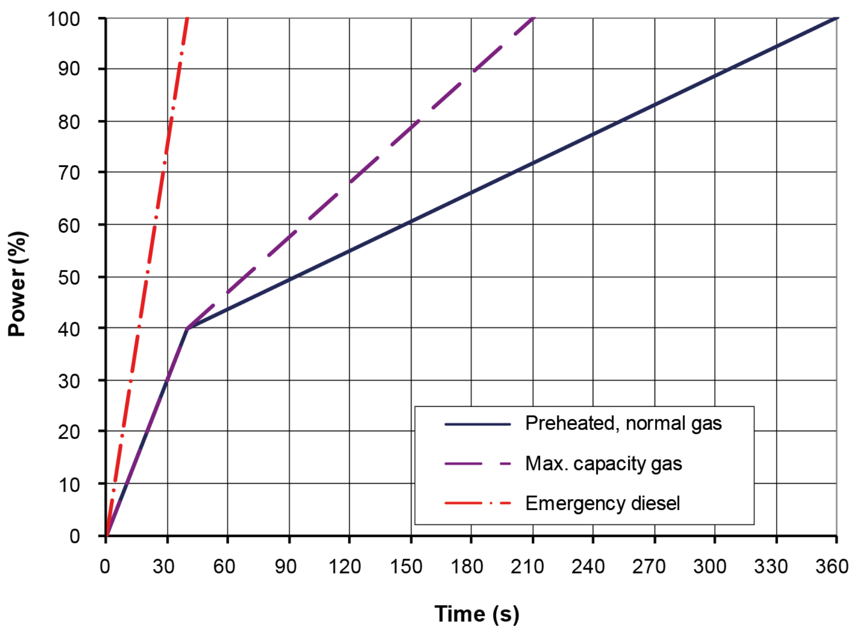



**Fig 2-2 Maximum load increase rates for variable speed engines**

The propulsion control must not permit faster load reduction than 20 s from 100% to 0% without automatic transfer to diesel first.

## 2.2.2 Constant speed applications

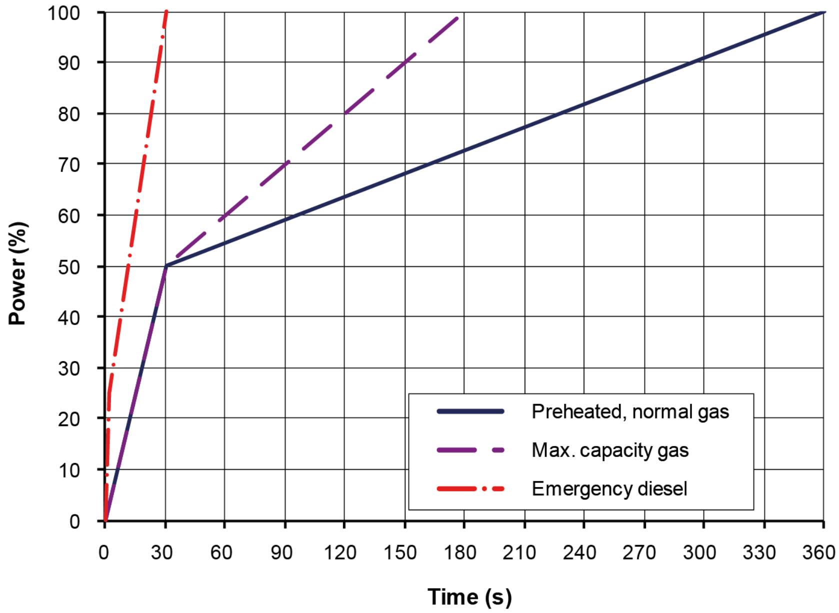



**Fig 2-3 Maximum load increase rates for engines operating at nominal speed**

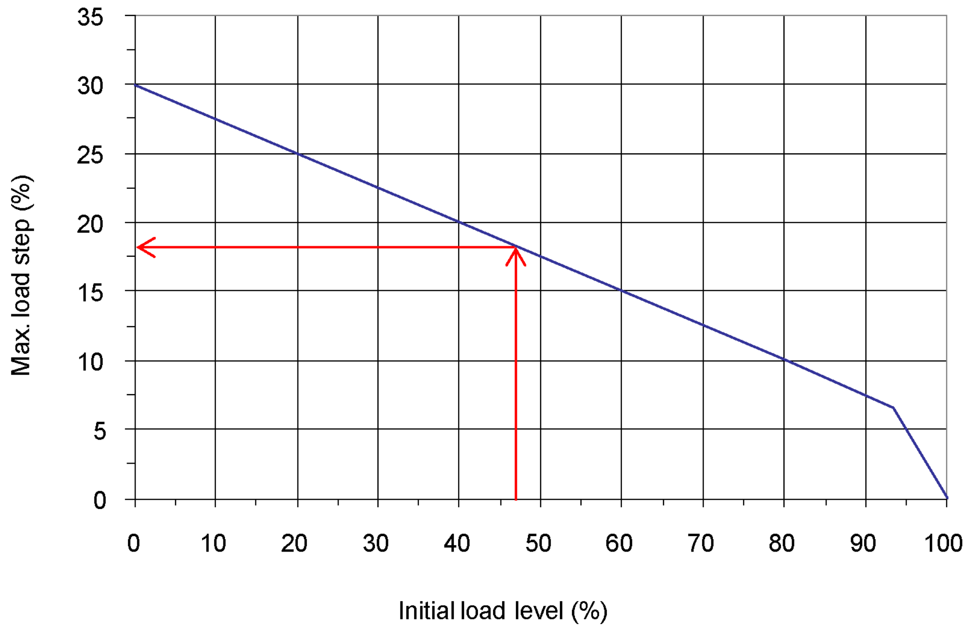
The propulsion control and the power management system must not permit faster load reduction than 20 s from 100% to 0% without automatic transfer to diesel first.

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.

### 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.

### Gas mode




When performing the electric load analysis for the vessel in various operating conditions, evaluate possible scenarios that cause sudden load changes and check against the engine capacity in gas mode as shown in the diagram.

**Fig 2-4 Maximum instant load steps in % of MCR in gas mode**

- Maximum step-wise load increases according to figure
- Steady-state frequency band ≤ 1.5 %
- Maximum speed drop 10 %
- Recovery time ≤ 10 s
- Time between load steps ≥ 30 s
- Maximum step-wise load reductions: 100-75-45-0%

### Diesel mode

- Maximum step-wise load increase 33% of MCR
- Steady-state frequency band ≤ 1.0 %
- Maximum speed drop 10 %
- Recovery time ≤ 5 s
- Time between load steps ≥ 10 s

### 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 provided that the engine is preheated and the air receiver temperature is at required level. It will then start on MDF and gas fuel will be used as soon as the pilot check is completed and the gas supply system is ready.

Start and stop on heavy fuel is not restricted.

## 2.3 Operation at low load and idling

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

- Maximum 10 minutes if the engine is to be stopped after the idling. 3-5 minutes idling before stop is recommended.
- Maximum 2 hours on HFO if the engine is to be loaded after the idling.
- Maximum 8 hours on MDF or gas if the engine is to be loaded after the idling.

**Operation below 20 % load on HFO or below 10 % load on MDF or gas:**

- Maximum 100 hours continuous operation. At intervals of 100 operating hours the engine must be loaded to min. 70% of the rated output for 1 hour.
- If operated longer than 30h in liquid fuel mode, the engine must be loaded to minimum 70% of rated output for 1 hour before transfer to gas.
- Before operating below 10% in gas mode the engine must run above 10% load for at least 10 minutes. It is however acceptable to change to gas mode directly after the engine has started, provided that the charge air temperature is above 55°C.

**Operation above 20 % load on HFO or above 10 % load on MDF or gas:**

- No restrictions.

## 2.4 Low air temperature

The minimum inlet air temperature of 5°C applies, when the inlet air is taken from the engine room.

Engines can run in colder conditions at high loads (suction air lower than 5°C) provided that special provisions are considered to prevent too low HT-water temperature and T/C surge.

For start, idling and low load operations (Ch 2.3), suction air temperature shall be maintained at 5°C.

If necessary, the preheating arrangement can be designed to heat the running engine (capacity to be checked).

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

# 3. Technical Data

## 3.1 Introduction

This chapter contains technical data of the engine (heat balance, flows, pressures etc.) for design of ancillary systems. Further design criteria for external equipment and system layouts are presented in the respective chapter.

Separate data is given for engines driving propellers "ME" and engines driving generators "DE".

### 3.1.1 Engine driven pumps

The basic fuel consumption given in the technical data tables are with engine driven lubricating oil and cooling water pumps. The decrease in fuel consumption, without engine driven pumps, in g/kWh is given in the table below:

| Decrease in fuel consumption | | Engine load [%] | | |
|---|---|---|---|---|
| | | 100 | 75 | 50 |
| Lubricating oil pump | g/kWh | 2 | 3 | 4 |
| HT- and LT-water pump | g/kWh | 1 | 1.6 | 2 |

For calculation of gas consumption adjusted without engine driven pumps; use values in the table below calculated using above table and with Methane ($CH_4$) as reference fuel gas, with lower calorific value of 50 MJ/kg.

| Decrease in gas consumption | | Engine load [%] | | |
|---|---|---|---|---|
| | | 100 | 75 | 50 |
| Lubricating oil pump | kJ/kWh | 100 | 150 | 200 |
| HT- and LT-water pump | kJ/kWh | 50 | 80 | 100 |

# 3.2 Wärtsilä 6L50DF

| Wärtsilä 6L50DF | | DE | | DE | | ME | |
|---|---|---|---|---|---|---|---|
| | | Gas mode | Diesel mode | Gas mode | Diesel mode | Gas mode | Diesel mode |
| **Cylinder output** | **kW** | **950** | | **975** | | **975** | |
| **Engine speed** | **rpm** | **500** | | **514** | | **514** | |
| Engine output | kW | 5700 | | 5850 | | 5850 | |
| Mean effective pressure | MPa | 2.0 | | 2.0 | | 2.0 | |
| IMO compliance | | Tier 3 | Tier 2 | Tier 3 | Tier 2 | Tier 3 | Tier 2 |
| | | | | | | | |
| **Combustion air system (Note 1)** | | | | | | | |
| Flow at 100% load | kg/s | 9.2 | 11.3 | 9.2 | 11.3 | 9.2 | 11.0 |
| Temperature at turbocharger intake, max. | °C | 45 | | 45 | | 45 | |
| Temperature after air cooler, nom. (TE 601) | °C | 45 | 50 | 45 | 50 | 45 | 50 |
| | | | | | | | |
| **Exhaust gas system** | | | | | | | |
| Flow at 100% load | kg/s | 9.0 | 10.8 | 9.6 | 11.4 | 9.6 | 12.0 |
| Flow at 75% load | kg/s | 7.2 | 9.0 | 7.2 | 9.0 | 7.2 | 9.0 |
| Flow at 50% load | kg/s | 5.4 | 6.0 | 5.4 | 6.6 | 6.0 | 7.2 |
| Temperature after turbocharger at 100% load (TE 517) | °C | 375 | 345 | 378 | 347 | 379 | 325 |
| Temperature after turbocharger at 75% load (TE 517) | °C | 424 | 332 | 428 | 330 | 401 | 332 |
| Temperature after turbocharger at 50% load (TE 517) | °C | 430 | 377 | 433 | 373 | 386 | 300 |
| Backpressure, max. | kPa | 4 | | 4 | | 4 | |
| Calculated exhaust diameter for 35 m/s | mm | 773 | 827 | 800 | 851 | 801 | 858 |
| | | | | | | | |
| **Heat balance at 100% load (Note 2)** | | | | | | | |
| Jacket water, HT-circuit | kW | 654 | 966 | 936 | 1008 | 684 | 1020 |
| Charge air, HT-circuit | kW | 900 | 1212 | 678 | 1302 | 948 | 1368 |
| Charge air, LT-circuit | kW | 450 | 612 | 462 | 630 | 462 | 696 |
| Lubricating oil, LT-circuit | kW | 462 | 726 | 474 | 750 | 480 | 762 |
| Radiation | kW | 156 | 168 | 162 | 180 | 162 | 180 |
| | | | | | | | |
| **Fuel consumption (Note 3)** | | | | | | | |
| Total energy consumption at 100% load | kJ/kWh | 7410 | - | 7440 | - | 7460 | - |
| Total energy consumption at 75% load | kJ/kWh | 7740 | - | 7780 | - | 7580 | - |
| Total energy consumption at 50% load | kJ/kWh | 8410 | - | 8440 | - | 8080 | - |
| Fuel gas consumption at 100% load | kJ/kWh | 7365 | - | 7397 | - | 7412 | - |
| Fuel gas consumption at 75% load | kJ/kWh | 7677 | - | 7710 | - | 7511 | - |
| Fuel gas consumption at 50% load | kJ/kWh | 8300 | - | 8336 | - | 7979 | - |
| Fuel oil consumption at 100% load | g/kWh | 1.0 | 187 | 1.0 | 189 | 1.0 | 189 |
| Fuel oil consumption at 75% load | g/kWh | 1.5 | 187 | 1.5 | 188 | 1.5 | 185 |
| Fuel oil consumption 50% load | g/kWh | 2.4 | 198 | 2.4 | 198 | 2.3 | 193 |
| | | | | | | | |
| **Fuel gas system (Note 4)** | | | | | | | |
| Gas pressure at engine inlet, min (PT901) | kPa (a) | 472 | - | 472 | - | 472 | - |
| Gas pressure to Gas Valve unit, min | kPa (a) | 592 | - | 592 | - | 592 | - |
| Gas temperature before Gas Valve Unit | °C | 0...60 | - | 0...60 | - | 0...60 | - |

| Wärtsilä 6L50DF | | DE | | DE | | ME | |
|---|---|---|---|---|---|---|---|
| | | Gas mode | Diesel mode | Gas mode | Diesel mode | Gas mode | Diesel mode |
| **Cylinder output** | **kW** | **950** | | **975** | | **975** | |
| **Engine speed** | **rpm** | **500** | | **514** | | **514** | |
| | | | | | | | |
| **Fuel oil system** | | | | | | | |
| Pressure before injection pumps (PT 101) | kPa | 800±50 | | 800±50 | | 800±50 | |
| Fuel oil flow to engine, approx | $m^3/h$ | 6.0 | | 6.2 | | 6.2 | |
| HFO viscosity before the engine | cSt | - | 16...24 | - | 16...24 | - | 16...24 |
| Max. HFO temperature before engine (TE 101) | °C | - | 140 | - | 140 | - | 140 |
| MDF viscosity, min. | cSt | 2.0 | | 2.0 | | 2.0 | |
| Max. MDF temperature before engine (TE 101) | °C | 45 | | 45 | | 45 | |
| Leak fuel quantity (HFO), clean fuel at 100% load | kg/h | - | 4.5 | - | 4.5 | - | 4.7 |
| Leak fuel quantity (MDF), clean fuel at 100% load | kg/h | 12.0 | 22.6 | 12.0 | 22.6 | 11.7 | 23.3 |
| Pilot fuel (MDF) viscosity before the engine | cSt | 2...11 | | 2...11 | | 2...11 | |
| Pilot fuel pressure at engine inlet (PT 112) | kPa | 400...800 | | 400...800 | | 400...800 | |
| Pilot fuel outlet pressure, max | kPa | 150 | | 150 | | 150 | |
| Pilot fuel return flow at 100% load | kg/h | 276 | | 276 | | 276 | |
| | | | | | | | |
| **Lubricating oil system (Note 5)** | | | | | | | |
| Pressure before bearings, nom. (PT 201) | kPa | 400 | | 400 | | 400 | |
| Pressure after pump, max. | kPa | 800 | | 800 | | 800 | |
| Suction ability, including pipe loss, max. | kPa | 40 | | 40 | | 40 | |
| Priming pressure, nom. (PT 201) | kPa | 80 | | 80 | | 80 | |
| Temperature before bearings, nom. (TE 201) | °C | 63 | | 63 | | 63 | |
| Temperature after engine, approx. | °C | 78 | | 78 | | 78 | |
| Pump capacity (main), engine driven | $m^3/h$ | 149 | | 153 | | 157 | |
| Pump capacity (main), electrically driven | $m^3/h$ | 140 | | 140 | | 140 | |
| Oil flow through engine | $m^3/h$ | 120 | | 120 | | 120 | |
| Priming pump capacity (50/60Hz) | $m^3/h$ | 34.0 / 34.0 | | 34.0 / 34.0 | | 34.0 / 34.0 | |
| Oil volume in separate system oil tank | $m^3$ | 8 | | 8 | | 8 | |
| Oil consumption at 100% load, approx. | g/kWh | 0.5 | | 0.5 | | 0.5 | |
| Crankcase ventilation flow rate at full load | l/min | 1300 | | 1300 | | 1300 | |
| Crankcase volume | $m^3$ | 14.6 | | 14.6 | | 14.6 | |
| Crankcase ventilation backpressure, max. | Pa | 500 | | 500 | | 500 | |
| Oil volume in turning device | l | 8.5...9.5 | | 8.5...9.5 | | 8.5...9.5 | |
| Oil volume in speed governor | l | 1.4 | | 1.4 | | 1.4 | |
| | | | | | | | |
| **HT cooling water system** | | | | | | | |
| Pressure at engine, after pump, nom. (PT 401) | kPa | 250 + static | | 250 + static | | 250 + static | |
| Pressure at engine, after pump, max. (PT 401) | kPa | 480 | | 480 | | 480 | |
| Temperature before cylinders, approx. (TE 401) | °C | 74 | | 74 | | 74 | |
| Temperature after charge air cooler, nom. | °C | 96 | | 96 | | 96 | |
| Capacity of engine driven pump, nom. | $m^3/h$ | 135 | | 135 | | 135 | |
| Pressure drop over engine, total | kPa | 50 | | 50 | | 50 | |
| Pressure drop in external system, max. | kPa | 150 | | 150 | | 150 | |

| Wärtsilä 6L50DF | | DE | | DE | | ME | |
|---|---|---|---|---|---|---|---|
| | | Gas mode | Diesel mode | Gas mode | Diesel mode | Gas mode | Diesel mode |
| **Cylinder output** | **kW** | **950** | | **975** | | **975** | |
| **Engine speed** | **rpm** | **500** | | **514** | | **514** | |
| Pressure from expansion tank | kPa | 70...150 | | 70...150 | | 70...150 | |
| Water volume in engine | $m^3$ | 0.95 | | 0.95 | | 0.95 | |
| | | | | | | | |
| **LT cooling water system** | | | | | | | |
| Pressure at engine, after pump, nom. (PT 471) | kPa | 250+ static | | 250+ static | | 250+ static | |
| Pressure at engine, after pump, max. (PT 471) | kPa | 440 | | 440 | | 440 | |
| Temperature before engine, max. (TE 471) | °C | 55 | | 55 | | 55 | |
| Temperature before engine, min. (TE 471) | °C | 36 | | 36 | | 36 | |
| Capacity of engine driven pump, nom. | $m^3/h$ | 135 | | 135 | | 135 | |
| Pressure drop over charge air cooler | kPa | 30 | | 30 | | 30 | |
| Pressure drop in external system, max. | kPa | 200 | | 200 | | 200 | |
| Pressure from expansion tank | kPa | 70...150 | | 70...150 | | 70...150 | |
| | | | | | | | |
| **Starting air system (Note 6)** | | | | | | | |
| Pressure, nom. (PT 301) | kPa | 3000 | | 3000 | | 3000 | |
| Pressure at engine during start, min. (20 °C) | kPa | 1000 | | 1000 | | 1000 | |
| Pressure, max. (PT 301) | kPa | 3000 | | 3000 | | 3000 | |
| Low pressure limit in starting air vessel | kPa | 1800 | | 1800 | | 1800 | |
| Consumption per start at 20 °C (successful start) | $Nm^3$ | 3.6 | | 3.6 | | 3.6 | |
| Consumption per start at 20 °C (with slowturn) | $Nm^3$ | 4.3 | | 4.3 | | 4.3 | |

**Notes:**

Note 1 At Gas LHV 49620kJ/kg

Note 2 At 100% output and nominal speed. The figures are valid for ambient conditions according to ISO 15550, except for LT-water temperature, which is 35ºC in gas operation and 45ºC in back-up fuel operation. And with engine driven water, lube oil and pilot fuel pumps.

Note 3 According to ISO 15550, lower calorific value 42700 kJ/kg, with engine driven pumps (two cooling water + one lubricating oil pumps). Tolerance 5%. Gas Lower heating value >28 MJ/m3N and Methane Number High (>80). The fuel consumption BSEC and SFOC are guaranteed at 100% load and the values at other loads are given for indication only.

Note 4 Fuel gas pressure given at LHV ≥ 36MJ/m³N. Required fuel gas pressure depends on fuel gas LHV and need to be increased for lower LHV's. Pressure drop in external fuel gas system to be considered. See chapter Fuel system for further information.

Note 5 Lubricating oil treatment losses and oil changes are not included in oil consumption. The lubricating oil volume of the governor is depending of the governor type.

Note 6 At manual starting the consumption may be 2...3 times lower.

ME = Engine driving propeller, variable speed

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

# 3.3 Wärtsilä 8L50DF

| Wärtsilä 8L50DF | | DE | | DE | | ME | |
|---|---|---|---|---|---|---|---|
| | | Gas mode | Diesel mode | Gas mode | Diesel mode | Gas mode | Diesel mode |
| **Cylinder output** | **kW** | **950** | | **975** | | **975** | |
| **Engine speed** | **rpm** | **500** | | **514** | | **514** | |
| Engine output | kW | 7600 | | 7800 | | 7800 | |
| Mean effective pressure | MPa | 2.0 | | 2.0 | | 2.0 | |
| IMO compliance | | Tier 3 | Tier 2 | Tier 3 | Tier 2 | Tier 3 | Tier 2 |
| | | | | | | | |
| **Combustion air system (Note 1)** | | | | | | | |
| Flow at 100% load | kg/s | 12.2 | 15.0 | 12.2 | 15.0 | 12.2 | 14.6 |
| Temperature at turbocharger intake, max. | °C | 45 | | 45 | | 45 | |
| Temperature after air cooler, nom. (TE 601) | °C | 45 | 50 | 45 | 50 | 45 | 50 |
| | | | | | | | |
| **Exhaust gas system** | | | | | | | |
| Flow at 100% load | kg/s | 12.0 | 14.4 | 12.8 | 15.2 | 12.8 | 16.0 |
| Flow at 75% load | kg/s | 9.6 | 12.0 | 9.6 | 12.0 | 9.6 | 12.0 |
| Flow at 50% load | kg/s | 7.2 | 8.0 | 7.2 | 8.8 | 8.0 | 9.6 |
| Temperature after turbocharger at 100% load (TE 517) | °C | 375 | 345 | 378 | 347 | 379 | 325 |
| Temperature after turbocharger at 75% load (TE 517) | °C | 424 | 332 | 428 | 330 | 401 | 332 |
| Temperature after turbocharger at 50% load (TE 517) | °C | 430 | 377 | 433 | 373 | 386 | 300 |
| Backpressure, max. | kPa | 4 | | 4 | | 4 | |
| Calculated exhaust diameter for 35 m/s | mm | 893 | 955 | 924 | 983 | 925 | 990 |
| | | | | | | | |
| **Heat balance at 100% load (Note 2)** | | | | | | | |
| Jacket water, HT-circuit | kW | 872 | 1288 | 1248 | 1344 | 912 | 1360 |
| Charge air, HT-circuit | kW | 1200 | 1616 | 904 | 1736 | 1264 | 1824 |
| Charge air, LT-circuit | kW | 600 | 816 | 616 | 840 | 616 | 928 |
| Lubricating oil, LT-circuit | kW | 616 | 968 | 632 | 1000 | 640 | 1016 |
| Radiation | kW | 208 | 224 | 216 | 240 | 216 | 240 |
| | | | | | | | |
| **Fuel consumption (Note 3)** | | | | | | | |
| Total energy consumption at 100% load | kJ/kWh | 7410 | - | 7440 | - | 7460 | - |
| Total energy consumption at 75% load | kJ/kWh | 7740 | - | 7780 | - | 7580 | - |
| Total energy consumption at 50% load | kJ/kWh | 8410 | - | 8440 | - | 8080 | - |
| Fuel gas consumption at 100% load | kJ/kWh | 7365 | - | 7397 | - | 7412 | - |
| Fuel gas consumption at 75% load | kJ/kWh | 7677 | - | 7710 | - | 7511 | - |
| Fuel gas consumption at 50% load | kJ/kWh | 8300 | - | 8336 | - | 7979 | - |
| Fuel oil consumption at 100% load | g/kWh | 1.0 | 187 | 1.0 | 189 | 1.0 | 189 |
| Fuel oil consumption at 75% load | g/kWh | 1.5 | 187 | 1.5 | 188 | 1.5 | 185 |
| Fuel oil consumption 50% load | g/kWh | 2.4 | 198 | 2.4 | 198 | 2.3 | 193 |
| | | | | | | | |
| **Fuel gas system (Note 4)** | | | | | | | |
| Gas pressure at engine inlet, min (PT901) | kPa (a) | 472 | - | 472 | - | 472 | - |
| Gas pressure to Gas Valve unit, min | kPa (a) | 592 | - | 592 | - | 592 | - |
| Gas temperature before Gas Valve Unit | °C | 0...60 | - | 0...60 | - | 0...60 | - |

| Wärtsilä 8L50DF | | DE | | DE | | ME | |
|---|---|---|---|---|---|---|---|
| | | Gas mode | Diesel mode | Gas mode | Diesel mode | Gas mode | Diesel mode |
| **Cylinder output** | **kW** | **950** | | **975** | | **975** | |
| **Engine speed** | **rpm** | **500** | | **514** | | **514** | |
| | | | | | | | |
| **Fuel oil system** | | | | | | | |
| Pressure before injection pumps (PT 101) | kPa | 800±50 | | 800±50 | | 800±50 | |
| Fuel oil flow to engine, approx | m³/h | 8.0 | | 8.3 | | 8.3 | |
| HFO viscosity before the engine | cSt | - | 16...24 | - | 16...24 | - | 16...24 |
| Max. HFO temperature before engine (TE 101) | °C | - | 140 | - | 140 | - | 140 |
| MDF viscosity, min. | cSt | 2.0 | | 2.0 | | 2.0 | |
| Max. MDF temperature before engine (TE 101) | °C | 45 | | 45 | | 45 | |
| Leak fuel quantity (HFO), clean fuel at 100% load | kg/h | - | 6.0 | - | 6.0 | - | 6.2 |
| Leak fuel quantity (MDF), clean fuel at 100% load | kg/h | 16.0 | 30.1 | 16.0 | 30.1 | 15.5 | 31.1 |
| Pilot fuel (MDF) viscosity before the engine | cSt | 2...11 | | 2...11 | | 2...11 | |
| Pilot fuel pressure at engine inlet (PT 112) | kPa | 400...800 | | 400...800 | | 400...800 | |
| Pilot fuel outlet pressure, max | kPa | 150 | | 150 | | 150 | |
| Pilot fuel return flow at 100% load | kg/h | 284 | | 284 | | 284 | |
| | | | | | | | |
| **Lubricating oil system (Note 5)** | | | | | | | |
| Pressure before bearings, nom. (PT 201) | kPa | 400 | | 400 | | 400 | |
| Pressure after pump, max. | kPa | 800 | | 800 | | 800 | |
| Suction ability, including pipe loss, max. | kPa | 40 | | 40 | | 40 | |
| Priming pressure, nom. (PT 201) | kPa | 80 | | 80 | | 80 | |
| Temperature before bearings, nom. (TE 201) | °C | 63 | | 63 | | 63 | |
| Temperature after engine, approx. | °C | 78 | | 78 | | 78 | |
| Pump capacity (main), engine driven | m³/h | 149 | | 153 | | 198 | |
| Pump capacity (main), electrically driven | m³/h | 145 | | 145 | | 145 | |
| Oil flow through engine | m³/h | 125 | | 125 | | 125 | |
| Priming pump capacity (50/60Hz) | m³/h | 45.0 / 45.0 | | 45.0 / 45.0 | | 45.0 / 45.0 | |
| Oil volume in separate system oil tank | m³ | 11 | | 11 | | 11 | |
| Oil consumption at 100% load, approx. | g/kWh | 0.5 | | 0.5 | | 0.5 | |
| Crankcase ventilation flow rate at full load | l/min | 1500 | | 1500 | | 1500 | |
| Crankcase volume | m³ | 19.5 | | 19.5 | | 19.5 | |
| Crankcase ventilation backpressure, max. | Pa | 500 | | 500 | | 500 | |
| Oil volume in turning device | l | 8.5...9.5 | | 8.5...9.5 | | 8.5...9.5 | |
| Oil volume in speed governor | l | 1.4 | | 1.4 | | 1.4 | |
| | | | | | | | |
| **HT cooling water system** | | | | | | | |
| Pressure at engine, after pump, nom. (PT 401) | kPa | 250 + static | | 250 + static | | 250 + static | |
| Pressure at engine, after pump, max. (PT 401) | kPa | 480 | | 480 | | 480 | |
| Temperature before cylinders, approx. (TE 401) | °C | 74 | | 74 | | 74 | |
| Temperature after charge air cooler, nom. | °C | 96 | | 96 | | 96 | |
| Capacity of engine driven pump, nom. | m³/h | 180 | | 180 | | 180 | |
| Pressure drop over engine, total | kPa | 50 | | 50 | | 50 | |
| Pressure drop in external system, max. | kPa | 150 | | 150 | | 150 | |

| Wärtsilä 8L50DF | | DE | | DE | | ME | |
|---|---|---|---|---|---|---|---|
| | | Gas mode | Diesel mode | Gas mode | Diesel mode | Gas mode | Diesel mode |
| **Cylinder output** | **kW** | **950** | | **975** | | **975** | |
| **Engine speed** | **rpm** | **500** | | **514** | | **514** | |
| Pressure from expansion tank | kPa | 70...150 | | 70...150 | | 70...150 | |
| Water volume in engine | $m^3$ | 1.35 | | 1.35 | | 1.35 | |
| | | | | | | | |
| **LT cooling water system** | | | | | | | |
| Pressure at engine, after pump, nom. (PT 471) | kPa | 250+ static | | 250+ static | | 250+ static | |
| Pressure at engine, after pump, max. (PT 471) | kPa | 440 | | 440 | | 440 | |
| Temperature before engine, max. (TE 471) | °C | 55 | | 55 | | 55 | |
| Temperature before engine, min. (TE 471) | °C | 36 | | 36 | | 36 | |
| Capacity of engine driven pump, nom. | $m^3/h$ | 180 | | 180 | | 180 | |
| Pressure drop over charge air cooler | kPa | 30 | | 30 | | 30 | |
| Pressure drop in external system, max. | kPa | 200 | | 200 | | 200 | |
| Pressure from expansion tank | kPa | 70...150 | | 70...150 | | 70...150 | |
| | | | | | | | |
| **Starting air system (Note 6)** | | | | | | | |
| Pressure, nom. (PT 301) | kPa | 3000 | | 3000 | | 3000 | |
| Pressure at engine during start, min. (20 °C) | kPa | 1000 | | 1000 | | 1000 | |
| Pressure, max. (PT 301) | kPa | 3000 | | 3000 | | 3000 | |
| Low pressure limit in starting air vessel | kPa | 1800 | | 1800 | | 1800 | |
| Consumption per start at 20 °C (successful start) | $Nm^3$ | 4.8 | | 4.8 | | 4.8 | |
| Consumption per start at 20 °C (with slowturn) | $Nm^3$ | 5.8 | | 5.8 | | 5.8 | |

**Notes:**

Note 1 At Gas LHV 49620kJ/kg

Note 2 At 100% output and nominal speed. The figures are valid for ambient conditions according to ISO 15550, except for LT-water temperature, which is 35ºC in gas operation and 45ºC in back-up fuel operation. And with engine driven water, lube oil and pilot fuel pumps.

Note 3 According to ISO 15550, lower calorific value 42700 kJ/kg, with engine driven pumps (two cooling water + one lubricating oil pumps). Tolerance 5%. Gas Lower heating value >28 MJ/m3N and Methane Number High (>80). The fuel consumption BSEC and SFOC are guaranteed at 100% load and the values at other loads are given for indication only.

Note 4 Fuel gas pressure given at LHV ≥ 36MJ/m³N. Required fuel gas pressure depends on fuel gas LHV and need to be increased for lower LHV's. Pressure drop in external fuel gas system to be considered. See chapter Fuel system for further information.

Note 5 Lubricating oil treatment losses and oil changes are not included in oil consumption. The lubricating oil volume of the governor is depending of the governor type.

Note 6 At manual starting the consumption may be 2...3 times lower.

ME = Engine driving propeller, variable speed

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

# 3.4 Wärtsilä 9L50DF

| Wärtsilä 9L50DF | | DE | | DE | | ME | |
|---|---|---|---|---|---|---|---|
| | | Gas mode | Diesel mode | Gas mode | Diesel mode | Gas mode | Diesel mode |
| **Cylinder output** | **kW** | **950** | | **975** | | **975** | |
| **Engine speed** | **rpm** | **500** | | **514** | | **514** | |
| Engine output | kW | 8550 | | 8775 | | 8775 | |
| Mean effective pressure | MPa | 2.0 | | 2.0 | | 2.0 | |
| IMO compliance | | Tier 3 | Tier 2 | Tier 3 | Tier 2 | Tier 3 | Tier 2 |
| | | | | | | | |
| **Combustion air system (Note 1)** | | | | | | | |
| Flow at 100% load | kg/s | 13.7 | 16.9 | 13.7 | 16.9 | 13.7 | 16.4 |
| Temperature at turbocharger intake, max. | °C | 45 | | 45 | | 45 | |
| Temperature after air cooler, nom. (TE 601) | °C | 45 | 50 | 45 | 50 | 45 | 50 |
| | | | | | | | |
| **Exhaust gas system** | | | | | | | |
| Flow at 100% load | kg/s | 13.5 | 16.2 | 14.4 | 17.1 | 14.4 | 18.0 |
| Flow at 75% load | kg/s | 10.8 | 13.5 | 10.8 | 13.5 | 10.8 | 13.5 |
| Flow at 50% load | kg/s | 8.1 | 9.0 | 8.1 | 9.9 | 9.0 | 10.8 |
| Temperature after turbocharger at 100% load (TE 517) | °C | 375 | 345 | 378 | 347 | 379 | 325 |
| Temperature after turbocharger at 75% load (TE 517) | °C | 424 | 332 | 428 | 330 | 401 | 332 |
| Temperature after turbocharger at 50% load (TE 517) | °C | 430 | 377 | 433 | 373 | 386 | 300 |
| Backpressure, max. | kPa | 4 | | 4 | | 4 | |
| Calculated exhaust diameter for 35 m/s | mm | 947 | 1013 | 980 | 1042 | 981 | 1050 |
| | | | | | | | |
| **Heat balance at 100% load (Note 2)** | | | | | | | |
| Jacket water, HT-circuit | kW | 981 | 1449 | 1404 | 1512 | 1026 | 1530 |
| Charge air, HT-circuit | kW | 1350 | 1818 | 1017 | 1953 | 1422 | 2052 |
| Charge air, LT-circuit | kW | 675 | 918 | 693 | 945 | 693 | 1044 |
| Lubricating oil, LT-circuit | kW | 693 | 1089 | 711 | 1125 | 720 | 1143 |
| Radiation | kW | 234 | 252 | 243 | 270 | 243 | 270 |
| | | | | | | | |
| **Fuel consumption (Note 3)** | | | | | | | |
| Total energy consumption at 100% load | kJ/kWh | 7410 | - | 7440 | - | 7460 | - |
| Total energy consumption at 75% load | kJ/kWh | 7740 | - | 7780 | - | 7580 | - |
| Total energy consumption at 50% load | kJ/kWh | 8410 | - | 8440 | - | 8080 | - |
| Fuel gas consumption at 100% load | kJ/kWh | 7365 | - | 7397 | - | 7412 | - |
| Fuel gas consumption at 75% load | kJ/kWh | 7677 | - | 7710 | - | 7511 | - |
| Fuel gas consumption at 50% load | kJ/kWh | 8300 | - | 8336 | - | 7979 | - |
| Fuel oil consumption at 100% load | g/kWh | 1.0 | 187 | 1.0 | 189 | 1.0 | 189 |
| Fuel oil consumption at 75% load | g/kWh | 1.5 | 187 | 1.5 | 188 | 1.5 | 185 |
| Fuel oil consumption 50% load | g/kWh | 2.4 | 198 | 2.4 | 198 | 2.3 | 193 |
| | | | | | | | |
| **Fuel gas system (Note 4)** | | | | | | | |
| Gas pressure at engine inlet, min (PT901) | kPa (a) | 472 | - | 472 | - | 472 | - |
| Gas pressure to Gas Valve unit, min | kPa (a) | 592 | - | 592 | - | 592 | - |
| Gas temperature before Gas Valve Unit | °C | 0...60 | - | 0...60 | - | 0...60 | - |

| Wärtsilä 9L50DF | | DE | | DE | | ME | |
|---|---|---|---|---|---|---|---|
| | | Gas mode | Diesel mode | Gas mode | Diesel mode | Gas mode | Diesel mode |
| **Cylinder output** | **kW** | **950** | | **975** | | **975** | |
| **Engine speed** | **rpm** | **500** | | **514** | | **514** | |
| | | | | | | | |
| **Fuel oil system** | | | | | | | |
| Pressure before injection pumps (PT 101) | kPa | 800±50 | | 800±50 | | 800±50 | |
| Fuel oil flow to engine, approx | m³/h | 9.0 | | 9.3 | | 9.3 | |
| HFO viscosity before the engine | cSt | - | 16...24 | - | 16...24 | - | 16...24 |
| Max. HFO temperature before engine (TE 101) | °C | - | 140 | - | 140 | - | 140 |
| MDF viscosity, min. | cSt | 2.0 | | 2.0 | | 2.0 | |
| Max. MDF temperature before engine (TE 101) | °C | 45 | | 45 | | 45 | |
| Leak fuel quantity (HFO), clean fuel at 100% load | kg/h | - | 6.8 | - | 6.8 | - | 7.0 |
| Leak fuel quantity (MDF), clean fuel at 100% load | kg/h | 18.0 | 33.9 | 18.0 | 33.9 | 17.5 | 35.0 |
| Pilot fuel (MDF) viscosity before the engine | cSt | 2...11 | | 2...11 | | 2...11 | |
| Pilot fuel pressure at engine inlet (PT 112) | kPa | 400...800 | | 400...800 | | 400...800 | |
| Pilot fuel outlet pressure, max | kPa | 150 | | 150 | | 150 | |
| Pilot fuel return flow at 100% load | kg/h | 288 | | 288 | | 288 | |
| | | | | | | | |
| **Lubricating oil system (Note 5)** | | | | | | | |
| Pressure before bearings, nom. (PT 201) | kPa | 400 | | 400 | | 400 | |
| Pressure after pump, max. | kPa | 800 | | 800 | | 800 | |
| Suction ability, including pipe loss, max. | kPa | 40 | | 40 | | 40 | |
| Priming pressure, nom. (PT 201) | kPa | 80 | | 80 | | 80 | |
| Temperature before bearings, nom. (TE 201) | °C | 63 | | 63 | | 63 | |
| Temperature after engine, approx. | °C | 78 | | 78 | | 78 | |
| Pump capacity (main), engine driven | m³/h | 157 | | 162 | | 198 | |
| Pump capacity (main), electrically driven | m³/h | 160 | | 160 | | 160 | |
| Oil flow through engine | m³/h | 130 | | 130 | | 130 | |
| Priming pump capacity (50/60Hz) | m³/h | 51.0 / 51.0 | | 51.0 / 51.0 | | 51.0 / 51.0 | |
| Oil volume in separate system oil tank | m³ | 12 | | 12 | | 12 | |
| Oil consumption at 100% load, approx. | g/kWh | 0.5 | | 0.5 | | 0.5 | |
| Crankcase ventilation flow rate at full load | l/min | 1900 | | 1900 | | 1900 | |
| Crankcase volume | m³ | 22.0 | | 22.0 | | 22.0 | |
| Crankcase ventilation backpressure, max. | Pa | 500 | | 500 | | 500 | |
| Oil volume in turning device | l | 68.0...70.0 | | 68.0...70.0 | | 68.0...70.0 | |
| Oil volume in speed governor | l | 1.4 | | 1.4 | | 1.4 | |
| | | | | | | | |
| **HT cooling water system** | | | | | | | |
| Pressure at engine, after pump, nom. (PT 401) | kPa | 250 + static | | 250 + static | | 250 + static | |
| Pressure at engine, after pump, max. (PT 401) | kPa | 480 | | 480 | | 480 | |
| Temperature before cylinders, approx. (TE 401) | °C | 74 | | 74 | | 74 | |
| Temperature after charge air cooler, nom. | °C | 96 | | 96 | | 96 | |
| Capacity of engine driven pump, nom. | m³/h | 200 | | 200 | | 200 | |
| Pressure drop over engine, total | kPa | 50 | | 50 | | 50 | |
| Pressure drop in external system, max. | kPa | 150 | | 150 | | 150 | |

| Wärtsilä 9L50DF | | DE | | DE | | ME | |
|---|---|---|---|---|---|---|---|
| | | Gas mode | Diesel mode | Gas mode | Diesel mode | Gas mode | Diesel mode |
| **Cylinder output** | **kW** | **950** | | **975** | | **975** | |
| **Engine speed** | **rpm** | **500** | | **514** | | **514** | |
| Pressure from expansion tank | kPa | 70...150 | | 70...150 | | 70...150 | |
| Water volume in engine | $m^3$ | 1.5 | | 1.5 | | 1.5 | |
| | | | | | | | |
| **LT cooling water system** | | | | | | | |
| Pressure at engine, after pump, nom. (PT 471) | kPa | 250+ static | | 250+ static | | 250+ static | |
| Pressure at engine, after pump, max. (PT 471) | kPa | 440 | | 440 | | 440 | |
| Temperature before engine, max. (TE 471) | °C | 55 | | 55 | | 55 | |
| Temperature before engine, min. (TE 471) | °C | 36 | | 36 | | 36 | |
| Capacity of engine driven pump, nom. | $m^3/h$ | 200 | | 200 | | 200 | |
| Pressure drop over charge air cooler | kPa | 30 | | 30 | | 30 | |
| Pressure drop in external system, max. | kPa | 200 | | 200 | | 200 | |
| Pressure from expansion tank | kPa | 70...150 | | 70...150 | | 70...150 | |
| | | | | | | | |
| **Starting air system (Note 6)** | | | | | | | |
| Pressure, nom. (PT 301) | kPa | 3000 | | 3000 | | 3000 | |
| Pressure at engine during start, min. (20 °C) | kPa | 1000 | | 1000 | | 1000 | |
| Pressure, max. (PT 301) | kPa | 3000 | | 3000 | | 3000 | |
| Low pressure limit in starting air vessel | kPa | 1800 | | 1800 | | 1800 | |
| Consumption per start at 20 °C (successful start) | $Nm^3$ | 5.4 | | 5.4 | | 5.4 | |
| Consumption per start at 20 °C (with slowturn) | $Nm^3$ | 6.5 | | 6.5 | | 6.5 | |

**Notes:**

Note 1 At Gas LHV 49620kJ/kg

Note 2 At 100% output and nominal speed. The figures are valid for ambient conditions according to ISO 15550, except for LT-water temperature, which is 35°C in gas operation and 45°C in back-up fuel operation. And with engine driven water, lube oil and pilot fuel pumps.

Note 3 According to ISO 15550, lower calorific value 42700 kJ/kg, with engine driven pumps (two cooling water + one lubricating oil pumps). Tolerance 5%. Gas Lower heating value >28 MJ/m3N and Methane Number High (>80). The fuel consumption BSEC and SFOC are guaranteed at 100% load and the values at other loads are given for indication only.

Note 4 Fuel gas pressure given at LHV ≥ 36MJ/m³N. Required fuel gas pressure depends on fuel gas LHV and need to be increased for lower LHV's. Pressure drop in external fuel gas system to be considered. See chapter Fuel system for further information.

Note 5 Lubricating oil treatment losses and oil changes are not included in oil consumption. The lubricating oil volume of the governor is depending of the governor type.

Note 6 At manual starting the consumption may be 2...3 times lower.

ME = Engine driving propeller, variable speed

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

# 3.5 Wärtsilä 12V50DF

| Wärtsilä 12V50DF | | DE | | DE | | ME | |
|---|---|---|---|---|---|---|---|
| | | Gas mode | Diesel mode | Gas mode | Diesel mode | Gas mode | Diesel mode |
| **Cylinder output** | **kW** | **950** | | **975** | | **975** | |
| **Engine speed** | **rpm** | **500** | | **514** | | **514** | |
| Engine output | kW | 11400 | | 11700 | | 11700 | |
| Mean effective pressure | MPa | 2.0 | | 2.0 | | 2.0 | |
| IMO compliance | | Tier 3 | Tier 2 | Tier 3 | Tier 2 | Tier 3 | Tier 2 |
| | | | | | | | |
| **Combustion air system (Note 1)** | | | | | | | |
| Flow at 100% load | kg/s | 18.3 | 22.5 | 18.3 | 22.5 | 18.3 | 21.9 |
| Temperature at turbocharger intake, max. | °C | 45 | | 45 | | 45 | |
| Temperature after air cooler, nom. (TE 601) | °C | 45 | 50 | 45 | 50 | 45 | 50 |
| | | | | | | | |
| **Exhaust gas system** | | | | | | | |
| Flow at 100% load | kg/s | 18.0 | 21.6 | 19.2 | 22.8 | 19.2 | 24.0 |
| Flow at 75% load | kg/s | 14.4 | 18.0 | 14.4 | 18.0 | 14.4 | 18.0 |
| Flow at 50% load | kg/s | 10.8 | 12.0 | 10.8 | 13.2 | 12.0 | 14.4 |
| Temperature after turbocharger at 100% load (TE 517) | °C | 375 | 345 | 378 | 347 | 379 | 325 |
| Temperature after turbocharger at 75% load (TE 517) | °C | 424 | 332 | 428 | 330 | 401 | 332 |
| Temperature after turbocharger at 50% load (TE 517) | °C | 430 | 377 | 433 | 373 | 386 | 300 |
| Backpressure, max. | kPa | 4 | | 4 | | 4 | |
| Calculated exhaust diameter for 35 m/s | mm | 1093 | 1170 | 1132 | 1204 | 1133 | 1213 |
| | | | | | | | |
| **Heat balance at 100% load (Note 2)** | | | | | | | |
| Jacket water, HT-circuit | kW | 1308 | 1932 | 1872 | 2016 | 1368 | 2040 |
| Charge air, HT-circuit | kW | 1800 | 2424 | 1356 | 2604 | 1896 | 2736 |
| Charge air, LT-circuit | kW | 900 | 1224 | 924 | 1260 | 924 | 1392 |
| Lubricating oil, LT-circuit | kW | 924 | 1452 | 948 | 1500 | 960 | 1524 |
| Radiation | kW | 312 | 336 | 324 | 360 | 324 | 360 |
| | | | | | | | |
| **Fuel consumption (Note 3)** | | | | | | | |
| Total energy consumption at 100% load | kJ/kWh | 7410 | - | 7440 | - | 7460 | - |
| Total energy consumption at 75% load | kJ/kWh | 7740 | - | 7780 | - | 7580 | - |
| Total energy consumption at 50% load | kJ/kWh | 8410 | - | 8440 | - | 8080 | - |
| Fuel gas consumption at 100% load | kJ/kWh | 7365 | - | 7397 | - | 7412 | - |
| Fuel gas consumption at 75% load | kJ/kWh | 7677 | - | 7710 | - | 7511 | - |
| Fuel gas consumption at 50% load | kJ/kWh | 8300 | - | 8336 | - | 7979 | - |
| Fuel oil consumption at 100% load | g/kWh | 1.0 | 187 | 1.0 | 189 | 1.0 | 189 |
| Fuel oil consumption at 75% load | g/kWh | 1.5 | 187 | 1.5 | 188 | 1.5 | 185 |
| Fuel oil consumption 50% load | g/kWh | 2.4 | 198 | 2.4 | 198 | 2.3 | 193 |
| | | | | | | | |
| **Fuel gas system (Note 4)** | | | | | | | |
| Gas pressure at engine inlet, min (PT901) | kPa (a) | 472 | - | 472 | - | 472 | - |
| Gas pressure to Gas Valve unit, min | kPa (a) | 592 | - | 592 | - | 592 | - |
| Gas temperature before Gas Valve Unit | °C | 0...60 | - | 0...60 | - | 0...60 | - |

| Wärtsilä 12V50DF | | DE | | DE | | ME | |
|---|---|---|---|---|---|---|---|
| | | Gas mode | Diesel mode | Gas mode | Diesel mode | Gas mode | Diesel mode |
| **Cylinder output** | **kW** | **950** | | **975** | | **975** | |
| **Engine speed** | **rpm** | **500** | | **514** | | **514** | |
| | | | | | | | |
| **Fuel oil system** | | | | | | | |
| Pressure before injection pumps (PT 101) | kPa | 800±50 | | 800±50 | | 800±50 | |
| Fuel oil flow to engine, approx | m³/h | 12.0 | | 12.4 | | 12.5 | |
| HFO viscosity before the engine | cSt | - | 16...24 | - | 16...24 | - | 16...24 |
| Max. HFO temperature before engine (TE 101) | °C | - | 140 | - | 140 | - | 140 |
| MDF viscosity, min. | cSt | 2.0 | | 2.0 | | 2.0 | |
| Max. MDF temperature before engine (TE 101) | °C | 45 | | 45 | | 45 | |
| Leak fuel quantity (HFO), clean fuel at 100% load | kg/h | - | 9.0 | - | 9.0 | - | 9.3 |
| Leak fuel quantity (MDF), clean fuel at 100% load | kg/h | 24.1 | 45.2 | 24.1 | 45.2 | 23.3 | 46.6 |
| Pilot fuel (MDF) viscosity before the engine | cSt | 2...11 | | 2...11 | | 2...11 | |
| Pilot fuel pressure at engine inlet (PT 112) | kPa | 400...800 | | 400...800 | | 400...800 | |
| Pilot fuel outlet pressure, max | kPa | 150 | | 150 | | 150 | |
| Pilot fuel return flow at 100% load | kg/h | 300 | | 300 | | 300 | |
| | | | | | | | |
| **Lubricating oil system (Note 5)** | | | | | | | |
| Pressure before bearings, nom. (PT 201) | kPa | 400 | | 400 | | 400 | |
| Pressure after pump, max. | kPa | 800 | | 800 | | 800 | |
| Suction ability, including pipe loss, max. | kPa | 40 | | 40 | | 40 | |
| Priming pressure, nom. (PT 201) | kPa | 80 | | 80 | | 80 | |
| Temperature before bearings, nom. (TE 201) | °C | 63 | | 63 | | 63 | |
| Temperature after engine, approx. | °C | 78 | | 78 | | 78 | |
| Pump capacity (main), engine driven | m³/h | 215 | | 221 | | 263 | |
| Pump capacity (main), electrically driven | m³/h | 210 | | 210 | | 210 | |
| Oil flow through engine | m³/h | 170 | | 170 | | 170 | |
| Priming pump capacity (50/60Hz) | m³/h | 65.0 / 65.0 | | 65.0 / 65.0 | | 65.0 / 65.0 | |
| Oil volume in separate system oil tank | m³ | 16 | | 16 | | 16 | |
| Oil consumption at 100% load, approx. | g/kWh | 0.5 | | 0.5 | | 0.5 | |
| Crankcase ventilation flow rate at full load | l/min | 2600 | | 2600 | | 2600 | |
| Crankcase volume | m³ | 29.5 | | 29.5 | | 29.5 | |
| Crankcase ventilation backpressure, max. | Pa | 500 | | 500 | | 500 | |
| Oil volume in turning device | l | 68.0...70.0 | | 68.0...70.0 | | 68.0...70.0 | |
| Oil volume in speed governor | l | 6.2 | | 6.2 | | 6.2 | |
| | | | | | | | |
| **HT cooling water system** | | | | | | | |
| Pressure at engine, after pump, nom. (PT 401) | kPa | 250 + static | | 250 + static | | 250 + static | |
| Pressure at engine, after pump, max. (PT 401) | kPa | 480 | | 480 | | 480 | |
| Temperature before cylinders, approx. (TE 401) | °C | 74 | | 74 | | 74 | |
| Temperature after charge air cooler, nom. | °C | 96 | | 96 | | 96 | |
| Capacity of engine driven pump, nom. | m³/h | 270 | | 270 | | 270 | |
| Pressure drop over engine, total | kPa | 50 | | 50 | | 50 | |
| Pressure drop in external system, max. | kPa | 150 | | 150 | | 150 | |

| Wärtsilä 12V50DF | | DE | | DE | | ME | |
|---|---|---|---|---|---|---|---|
| | | Gas mode | Diesel mode | Gas mode | Diesel mode | Gas mode | Diesel mode |
| **Cylinder output** | **kW** | **950** | | **975** | | **975** | |
| **Engine speed** | **rpm** | **500** | | **514** | | **514** | |
| Pressure from expansion tank | kPa | 70...150 | | 70...150 | | 70...150 | |
| Water volume in engine | $m^3$ | 1.7 | | 1.7 | | 1.7 | |
| | | | | | | | |
| **LT cooling water system** | | | | | | | |
| Pressure at engine, after pump, nom. (PT 471) | kPa | 250+ static | | 250+ static | | 250+ static | |
| Pressure at engine, after pump, max. (PT 471) | kPa | 440 | | 440 | | 440 | |
| Temperature before engine, max. (TE 471) | °C | 55 | | 55 | | 55 | |
| Temperature before engine, min. (TE 471) | °C | 36 | | 36 | | 36 | |
| Capacity of engine driven pump, nom. | $m^3/h$ | 270 | | 270 | | 270 | |
| Pressure drop over charge air cooler | kPa | 30 | | 30 | | 30 | |
| Pressure drop in external system, max. | kPa | 200 | | 200 | | 200 | |
| Pressure from expansion tank | kPa | 70...150 | | 70...150 | | 70...150 | |
| | | | | | | | |
| **Starting air system (Note 6)** | | | | | | | |
| Pressure, nom. (PT 301) | kPa | 3000 | | 3000 | | 3000 | |
| Pressure at engine during start, min. (20 °C) | kPa | 1000 | | 1000 | | 1000 | |
| Pressure, max. (PT 301) | kPa | 3000 | | 3000 | | 3000 | |
| Low pressure limit in starting air vessel | kPa | 1800 | | 1800 | | 1800 | |
| Consumption per start at 20 °C (successful start) | $Nm^3$ | 6.0 | | 6.0 | | 6.0 | |
| Consumption per start at 20 °C (with slowturn) | $Nm^3$ | 7.2 | | 7.2 | | 7.2 | |

**Notes:**

Note 1 At Gas LHV 49620kJ/kg

Note 2 At 100% output and nominal speed. The figures are valid for ambient conditions according to ISO 15550, except for LT-water temperature, which is 35ºC in gas operation and 45ºC in back-up fuel operation. And with engine driven water, lube oil and pilot fuel pumps.

Note 3 According to ISO 15550, lower calorific value 42700 kJ/kg, with engine driven pumps (two cooling water + one lubricating oil pumps). Tolerance 5%. Gas Lower heating value >28 MJ/m3N and Methane Number High (>80). The fuel consumption BSEC and SFOC are guaranteed at 100% load and the values at other loads are given for indication only.

Note 4 Fuel gas pressure given at LHV ≥ 36MJ/m³N. Required fuel gas pressure depends on fuel gas LHV and need to be increased for lower LHV's. Pressure drop in external fuel gas system to be considered. See chapter Fuel system for further information.

Note 5 Lubricating oil treatment losses and oil changes are not included in oil consumption. The lubricating oil volume of the governor is depending of the governor type.

Note 6 At manual starting the consumption may be 2...3 times lower.

ME = Engine driving propeller, variable speed

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

## 3.6 Wärtsilä 16V50DF

| Wärtsilä 16V50DF | | DE | | DE | | ME | |
|---|---|---|---|---|---|---|---|
| | | Gas mode | Diesel mode | Gas mode | Diesel mode | Gas mode | Diesel mode |
| **Cylinder output** | **kW** | **950** | | **975** | | **975** | |
| **Engine speed** | **rpm** | **500** | | **514** | | **514** | |
| Engine output | kW | 15200 | | 15600 | | 15600 | |
| Mean effective pressure | MPa | 2.0 | | 2.0 | | 2.0 | |
| IMO compliance | | Tier 3 | Tier 2 | Tier 3 | Tier 2 | Tier 3 | Tier 2 |
| | | | | | | | |
| **Combustion air system (Note 1)** | | | | | | | |
| Flow at 100% load | kg/s | 24.5 | 30.1 | 24.4 | 30.0 | 24.4 | 29.1 |
| Temperature at turbocharger intake, max. | °C | 45 | | 45 | | 45 | |
| Temperature after air cooler, nom. (TE 601) | °C | 45 | 50 | 45 | 50 | 45 | 50 |
| | | | | | | | |
| **Exhaust gas system** | | | | | | | |
| Flow at 100% load | kg/s | 24.0 | 28.8 | 25.6 | 30.4 | 25.6 | 32.0 |
| Flow at 75% load | kg/s | 19.2 | 24.0 | 19.2 | 24.0 | 19.2 | 24.0 |
| Flow at 50% load | kg/s | 14.4 | 16.0 | 14.4 | 17.6 | 16.0 | 19.2 |
| Temperature after turbocharger at 100% load (TE 517) | °C | 375 | 345 | 378 | 347 | 379 | 325 |
| Temperature after turbocharger at 75% load (TE 517) | °C | 424 | 332 | 428 | 330 | 401 | 332 |
| Temperature after turbocharger at 50% load (TE 517) | °C | 430 | 377 | 433 | 373 | 386 | 300 |
| Backpressure, max. | kPa | 4 | | 4 | | 4 | |
| Calculated exhaust diameter for 35 m/s | mm | 1262 | 1350 | 1307 | 1390 | 1308 | 1400 |
| | | | | | | | |
| **Heat balance at 100% load (Note 2)** | | | | | | | |
| Jacket water, HT-circuit | kW | 1744 | 2576 | 2496 | 2688 | 1824 | 2720 |
| Charge air, HT-circuit | kW | 2400 | 3232 | 1808 | 3472 | 2528 | 3648 |
| Charge air, LT-circuit | kW | 1200 | 1632 | 1232 | 1680 | 1232 | 1856 |
| Lubricating oil, LT-circuit | kW | 1232 | 1936 | 1264 | 2000 | 1280 | 2032 |
| Radiation | kW | 416 | 448 | 432 | 480 | 432 | 480 |
| | | | | | | | |
| **Fuel consumption (Note 3)** | | | | | | | |
| Total energy consumption at 100% load | kJ/kWh | 7410 | - | 7440 | - | 7460 | - |
| Total energy consumption at 75% load | kJ/kWh | 7740 | - | 7780 | - | 7580 | - |
| Total energy consumption at 50% load | kJ/kWh | 8410 | - | 8440 | - | 8080 | - |
| Fuel gas consumption at 100% load | kJ/kWh | 7365 | - | 7397 | - | 7412 | - |
| Fuel gas consumption at 75% load | kJ/kWh | 7677 | - | 7710 | - | 7511 | - |
| Fuel gas consumption at 50% load | kJ/kWh | 8300 | - | 8336 | - | 7979 | - |
| Fuel oil consumption at 100% load | g/kWh | 1.0 | 187 | 1.0 | 189 | 1.0 | 189 |
| Fuel oil consumption at 75% load | g/kWh | 1.5 | 187 | 1.5 | 188 | 1.5 | 185 |
| Fuel oil consumption 50% load | g/kWh | 2.4 | 198 | 2.4 | 198 | 2.3 | 193 |
| | | | | | | | |
| **Fuel gas system (Note 4)** | | | | | | | |
| Gas pressure at engine inlet, min (PT901) | kPa (a) | 472 | - | 472 | - | 472 | - |
| Gas pressure to Gas Valve unit, min | kPa (a) | 592 | - | 592 | - | 592 | - |
| Gas temperature before Gas Valve Unit | °C | 0...60 | - | 0...60 | - | 0...60 | - |

| Wärtsilä 16V50DF | | DE | | DE | | ME | |
|---|---|---|---|---|---|---|---|
| | | Gas mode | Diesel mode | Gas mode | Diesel mode | Gas mode | Diesel mode |
| **Cylinder output** | **kW** | **950** | | **975** | | **975** | |
| **Engine speed** | **rpm** | **500** | | **514** | | **514** | |
| | | | | | | | |
| **Fuel oil system** | | | | | | | |
| Pressure before injection pumps (PT 101) | kPa | 800±50 | | 800±50 | | 800±50 | |
| Fuel oil flow to engine, approx | m³/h | 16.0 | | 16.6 | | 16.6 | |
| HFO viscosity before the engine | cSt | - | 16...24 | - | 16...24 | - | 16...24 |
| Max. HFO temperature before engine (TE 101) | °C | - | 140 | - | 140 | - | 140 |
| MDF viscosity, min. | cSt | 2.0 | | 2.0 | | 2.0 | |
| Max. MDF temperature before engine (TE 101) | °C | 45 | | 45 | | 45 | |
| Leak fuel quantity (HFO), clean fuel at 100% load | kg/h | - | 12.1 | - | 12.1 | - | 12.4 |
| Leak fuel quantity (MDF), clean fuel at 100% load | kg/h | 32.1 | 60.3 | 32.1 | 60.3 | 31.1 | 62.2 |
| Pilot fuel (MDF) viscosity before the engine | cSt | 2...11 | | 2...11 | | 2...11 | |
| Pilot fuel pressure at engine inlet (PT 112) | kPa | 400...800 | | 400...800 | | 400...800 | |
| Pilot fuel outlet pressure, max | kPa | 150 | | 150 | | 150 | |
| Pilot fuel return flow at 100% load | kg/h | 317 | | 317 | | 317 | |
| | | | | | | | |
| **Lubricating oil system (Note 5)** | | | | | | | |
| Pressure before bearings, nom. (PT 201) | kPa | 400 | | 400 | | 400 | |
| Pressure after pump, max. | kPa | 800 | | 800 | | 800 | |
| Suction ability, including pipe loss, max. | kPa | 40 | | 40 | | 40 | |
| Priming pressure, nom. (PT 201) | kPa | 80 | | 80 | | 80 | |
| Temperature before bearings, nom. (TE 201) | °C | 63 | | 63 | | 63 | |
| Temperature after engine, approx. | °C | 78 | | 78 | | 78 | |
| Pump capacity (main), engine driven | m³/h | 263 | | 272 | | 279 | |
| Pump capacity (main), electrically driven | m³/h | 260 | | 260 | | 260 | |
| Oil flow through engine | m³/h | 230 | | 230 | | 230 | |
| Priming pump capacity (50/60Hz) | m³/h | 85.0 / 85.0 | | 85.0 / 85.0 | | 85.0 / 85.0 | |
| Oil volume in separate system oil tank | m³ | 22 | | 22 | | 22 | |
| Oil consumption at 100% load, approx. | g/kWh | 0.5 | | 0.5 | | 0.5 | |
| Crankcase ventilation flow rate at full load | l/min | 3600 | | 3600 | | 3600 | |
| Crankcase volume | m³ | 39.4 | | 39.4 | | 39.4 | |
| Crankcase ventilation backpressure, max. | Pa | 500 | | 500 | | 500 | |
| Oil volume in turning device | l | 68.0...70.0 | | 68.0...70.0 | | 68.0...70.0 | |
| Oil volume in speed governor | l | 6.2 | | 6.2 | | 6.2 | |
| | | | | | | | |
| **HT cooling water system** | | | | | | | |
| Pressure at engine, after pump, nom. (PT 401) | kPa | 250 + static | | 250 + static | | 250 + static | |
| Pressure at engine, after pump, max. (PT 401) | kPa | 480 | | 480 | | 480 | |
| Temperature before cylinders, approx. (TE 401) | °C | 74 | | 74 | | 74 | |
| Temperature after charge air cooler, nom. | °C | 96 | | 96 | | 96 | |
| Capacity of engine driven pump, nom. | m³/h | 355 | | 355 | | 355 | |
| Pressure drop over engine, total | kPa | 50 | | 50 | | 50 | |
| Pressure drop in external system, max. | kPa | 150 | | 150 | | 150 | |

| Wärtsilä 16V50DF | | DE | | DE | | ME | |
|---|---|---|---|---|---|---|---|
| | | Gas mode | Diesel mode | Gas mode | Diesel mode | Gas mode | Diesel mode |
| **Cylinder output** | **kW** | **950** | | **975** | | **975** | |
| **Engine speed** | **rpm** | **500** | | **514** | | **514** | |
| Pressure from expansion tank | kPa | 70...150 | | 70...150 | | 70...150 | |
| Water volume in engine | $m^3$ | 2.1 | | 2.1 | | 2.1 | |
| | | | | | | | |
| **LT cooling water system** | | | | | | | |
| Pressure at engine, after pump, nom. (PT 471) | kPa | 250+ static | | 250+ static | | 250+ static | |
| Pressure at engine, after pump, max. (PT 471) | kPa | 440 | | 440 | | 440 | |
| Temperature before engine, max. (TE 471) | °C | 55 | | 55 | | 55 | |
| Temperature before engine, min. (TE 471) | °C | 36 | | 36 | | 36 | |
| Capacity of engine driven pump, nom. | $m^3/h$ | 355 | | 355 | | 355 | |
| Pressure drop over charge air cooler | kPa | 30 | | 30 | | 30 | |
| Pressure drop in external system, max. | kPa | 200 | | 200 | | 200 | |
| Pressure from expansion tank | kPa | 70...150 | | 70...150 | | 70...150 | |
| | | | | | | | |
| **Starting air system (Note 6)** | | | | | | | |
| Pressure, nom. (PT 301) | kPa | 3000 | | 3000 | | 3000 | |
| Pressure at engine during start, min. (20 °C) | kPa | 1000 | | 1000 | | 1000 | |
| Pressure, max. (PT 301) | kPa | 3000 | | 3000 | | 3000 | |
| Low pressure limit in starting air vessel | kPa | 1800 | | 1800 | | 1800 | |
| Consumption per start at 20 °C (successful start) | $Nm^3$ | 7.8 | | 7.8 | | 7.8 | |
| Consumption per start at 20 °C (with slowturn) | $Nm^3$ | 9.4 | | 9.4 | | 9.4 | |

**Notes:**

Note 1 At Gas LHV 49620kJ/kg

Note 2 At 100% output and nominal speed. The figures are valid for ambient conditions according to ISO 15550, except for LT-water temperature, which is 35ºC in gas operation and 45ºC in back-up fuel operation. And with engine driven water, lube oil and pilot fuel pumps.

Note 3 According to ISO 15550, lower calorific value 42700 kJ/kg, with engine driven pumps (two cooling water + one lubricating oil pumps). Tolerance 5%. Gas Lower heating value >28 MJ/m3N and Methane Number High (>80). The fuel consumption BSEC and SFOC are guaranteed at 100% load and the values at other loads are given for indication only.

Note 4 Fuel gas pressure given at LHV ≥ 36MJ/m³N. Required fuel gas pressure depends on fuel gas LHV and need to be increased for lower LHV's. Pressure drop in external fuel gas system to be considered. See chapter Fuel system for further information.

Note 5 Lubricating oil treatment losses and oil changes are not included in oil consumption. The lubricating oil volume of the governor is depending of the governor type.

Note 6 At manual starting the consumption may be 2...3 times lower.

ME = Engine driving propeller, variable speed

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

# 3.7 Wärtsilä 18V50DF

| Wärtsilä 18V50DF | | DE | | DE | |
|---|---|---|---|---|---|
| | | Gas mode | Diesel mode | Gas mode | Diesel mode |
| **Cylinder output** | **kW** | **950** | | **975** | |
| **Engine speed** | **rpm** | **500** | | **514** | |
| Engine output | kW | 17100 | | 17550 | |
| Mean effective pressure | MPa | 2.0 | | 2.0 | |
| IMO compliance | | Tier 3 | Tier 2 | Tier 3 | Tier 2 |
| | | | | | |
| **Combustion air system (Note 1)** | | | | | |
| Flow at 100% load | kg/s | 27.5 | 33.8 | 27.5 | 33.7 |
| Temperature at turbocharger intake, max. | °C | 45 | | 45 | |
| Temperature after air cooler, nom. (TE 601) | °C | 45 | 50 | 45 | 50 |
| | | | | | |
| **Exhaust gas system** | | | | | |
| Flow at 100% load | kg/s | 27.0 | 32.4 | 28.8 | 34.2 |
| Flow at 75% load | kg/s | 21.6 | 27.0 | 21.6 | 27.0 |
| Flow at 50% load | kg/s | 16.2 | 18.0 | 16.2 | 19.8 |
| Temperature after turbocharger at 100% load (TE 517) | °C | 375 | 345 | 378 | 347 |
| Temperature after turbocharger at 75% load (TE 517) | °C | 424 | 332 | 428 | 330 |
| Temperature after turbocharger at 50% load (TE 517) | °C | 430 | 377 | 433 | 373 |
| Backpressure, max. | kPa | 4 | | 4 | |
| Calculated exhaust diameter for 35 m/s | mm | 1339 | 1432 | 1386 | 1474 |
| | | | | | |
| **Heat balance at 100% load (Note 2)** | | | | | |
| Jacket water, HT-circuit | kW | 1962 | 2898 | 2808 | 3024 |
| Charge air, HT-circuit | kW | 2700 | 3636 | 2034 | 3906 |
| Charge air, LT-circuit | kW | 1350 | 1836 | 1386 | 1890 |
| Lubricating oil, LT-circuit | kW | 1386 | 2178 | 1422 | 2250 |
| Radiation | kW | 468 | 504 | 486 | 540 |
| | | | | | |
| **Fuel consumption (Note 3)** | | | | | |
| Total energy consumption at 100% load | kJ/kWh | 7410 | - | 7440 | - |
| Total energy consumption at 75% load | kJ/kWh | 7740 | - | 7780 | - |
| Total energy consumption at 50% load | kJ/kWh | 8410 | - | 8440 | - |
| Fuel gas consumption at 100% load | kJ/kWh | 7365 | - | 7397 | - |
| Fuel gas consumption at 75% load | kJ/kWh | 7677 | - | 7710 | - |
| Fuel gas consumption at 50% load | kJ/kWh | 8300 | - | 8336 | - |
| Fuel oil consumption at 100% load | g/kWh | 1.0 | 187 | 1.0 | 189 |
| Fuel oil consumption at 75% load | g/kWh | 1.5 | 187 | 1.5 | 188 |
| Fuel oil consumption 50% load | g/kWh | 2.4 | 198 | 2.4 | 198 |
| | | | | | |
| **Fuel gas system (Note 4)** | | | | | |
| Gas pressure at engine inlet, min (PT901) | kPa (a) | 472 | - | 472 | - |
| Gas pressure to Gas Valve unit, min | kPa (a) | 592 | - | 592 | - |
| Gas temperature before Gas Valve Unit | °C | 0...60 | - | 0...60 | - |

| Wärtsilä 18V50DF | | DE | | DE | |
|---|---|---|---|---|---|
| | | Gas mode | Diesel mode | Gas mode | Diesel mode |
| **Cylinder output** | **kW** | **950** | | **975** | |
| **Engine speed** | **rpm** | **500** | | **514** | |
| | | | | | |
| **Fuel oil system** | | | | | |
| Pressure before injection pumps (PT 101) | kPa | 800±50 | | 800±50 | |
| Fuel oil flow to engine, approx | m³/h | 18.0 | | 18.6 | |
| HFO viscosity before the engine | cSt | - | 16...24 | - | 16...24 |
| Max. HFO temperature before engine (TE 101) | °C | - | 140 | - | 140 |
| MDF viscosity, min. | cSt | 2.0 | | 2.0 | |
| Max. MDF temperature before engine (TE 101) | °C | 45 | | 45 | |
| Leak fuel quantity (HFO), clean fuel at 100% load | kg/h | - | 13.6 | - | 13.6 |
| Leak fuel quantity (MDF), clean fuel at 100% load | kg/h | 36.1 | 68.0 | 36.1 | 68.0 |
| Pilot fuel (MDF) viscosity before the engine | cSt | 2...11 | | 2...11 | |
| Pilot fuel pressure at engine inlet (PT 112) | kPa | 400...800 | | 400...800 | |
| Pilot fuel outlet pressure, max | kPa | 150 | | 150 | |
| Pilot fuel return flow at 100% load | kg/h | 325 | | 325 | |
| | | | | | |
| **Lubricating oil system (Note 5)** | | | | | |
| Pressure before bearings, nom. (PT 201) | kPa | 400 | | 400 | |
| Pressure after pump, max. | kPa | 800 | | 800 | |
| Suction ability, including pipe loss, max. | kPa | 40 | | 40 | |
| Priming pressure, nom. (PT 201) | kPa | 80 | | 80 | |
| Temperature before bearings, nom. (TE 201) | °C | 63 | | 63 | |
| Temperature after engine, approx. | °C | 78 | | 78 | |
| Pump capacity (main), engine driven | m³/h | 335 | | 345 | |
| Pump capacity (main), electrically driven | m³/h | 335 | | 335 | |
| Oil flow through engine | m³/h | 260 | | 260 | |
| Priming pump capacity (50/60Hz) | m³/h | 100.0 / 100.0 | | 100.0 / 100.0 | |
| Oil volume in separate system oil tank | m³ | 25 | | 25 | |
| Oil consumption at 100% load, approx. | g/kWh | 0.5 | | 0.5 | |
| Crankcase ventilation flow rate at full load | l/min | 4200 | | 4200 | |
| Crankcase volume | m³ | 44.3 | | 44.3 | |
| Crankcase ventilation backpressure, max. | Pa | 500 | | 500 | |
| Oil volume in turning device | l | 68.0...70.0 | | 68.0...70.0 | |
| Oil volume in speed governor | l | 6.2 | | 6.2 | |
| | | | | | |
| **HT cooling water system** | | | | | |
| Pressure at engine, after pump, nom. (PT 401) | kPa | 250 + static | | 250 + static | |
| Pressure at engine, after pump, max. (PT 401) | kPa | 480 | | 480 | |
| Temperature before cylinders, approx. (TE 401) | °C | 74 | | 74 | |
| Temperature after charge air cooler, nom. | °C | 96 | | 96 | |
| Capacity of engine driven pump, nom. | m³/h | 400 | | 400 | |
| Pressure drop over engine, total | kPa | 50 | | 50 | |
| Pressure drop in external system, max. | kPa | 150 | | 150 | |

| Wärtsilä 18V50DF | | DE | | DE | |
|---|---|---|---|---|---|
| | | Gas mode | Diesel mode | Gas mode | Diesel mode |
| **Cylinder output** | **kW** | **950** | | **975** | |
| **Engine speed** | **rpm** | **500** | | **514** | |
| Pressure from expansion tank | kPa | 70...150 | | 70...150 | |
| Water volume in engine | $m^3$ | 2.6 | | 2.6 | |
| | | | | | |
| **LT cooling water system** | | | | | |
| Pressure at engine, after pump, nom. (PT 471) | kPa | 250+ static | | 250+ static | |
| Pressure at engine, after pump, max. (PT 471) | kPa | 440 | | 440 | |
| Temperature before engine, max. (TE 471) | °C | 55 | | 55 | |
| Temperature before engine, min. (TE 471) | °C | 36 | | 36 | |
| Capacity of engine driven pump, nom. | $m^3/h$ | 400 | | 400 | |
| Pressure drop over charge air cooler | kPa | 30 | | 30 | |
| Pressure drop in external system, max. | kPa | 200 | | 200 | |
| Pressure from expansion tank | kPa | 70...150 | | 70...150 | |
| | | | | | |
| **Starting air system (Note 6)** | | | | | |
| Pressure, nom. (PT 301) | kPa | 3000 | | 3000 | |
| Pressure at engine during start, min. (20 °C) | kPa | 1000 | | 1000 | |
| Pressure, max. (PT 301) | kPa | 3000 | | 3000 | |
| Low pressure limit in starting air vessel | kPa | 1800 | | 1800 | |
| Consumption per start at 20 °C (successful start) | $Nm^3$ | 9.0 | | 9.0 | |
| Consumption per start at 20 °C (with slowturn) | $Nm^3$ | 10.8 | | 10.8 | |

**Notes:**

Note 1 At Gas LHV 49620kJ/kg

Note 2 At 100% output and nominal speed. The figures are valid for ambient conditions according to ISO 15550, except for LT-water temperature, which is 35ºC in gas operation and 45ºC in back-up fuel operation. And with engine driven water, lube oil and pilot fuel pumps.

Note 3 According to ISO 15550, lower calorific value 42700 kJ/kg, with engine driven pumps (two cooling water + one lubricating oil pumps). Tolerance 5%. Gas Lower heating value >28 MJ/m3N and Methane Number High (>80). The fuel consumption BSEC and SFOC are guaranteed at 100% load and the values at other loads are given for indication only.

Note 4 Fuel gas pressure given at LHV ≥ 36MJ/m³N. Required fuel gas pressure depends on fuel gas LHV and need to be increased for lower LHV's. Pressure drop in external fuel gas system to be considered. See chapter Fuel system for further information.

Note 5 Lubricating oil treatment losses and oil changes are not included in oil consumption. The lubricating oil volume of the governor is depending of the governor type.

Note 6 At manual starting the consumption may be 2...3 times lower.

ME = Engine driving propeller, variable speed

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

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# 4. Description of the Engine

## 4.1 Definitions

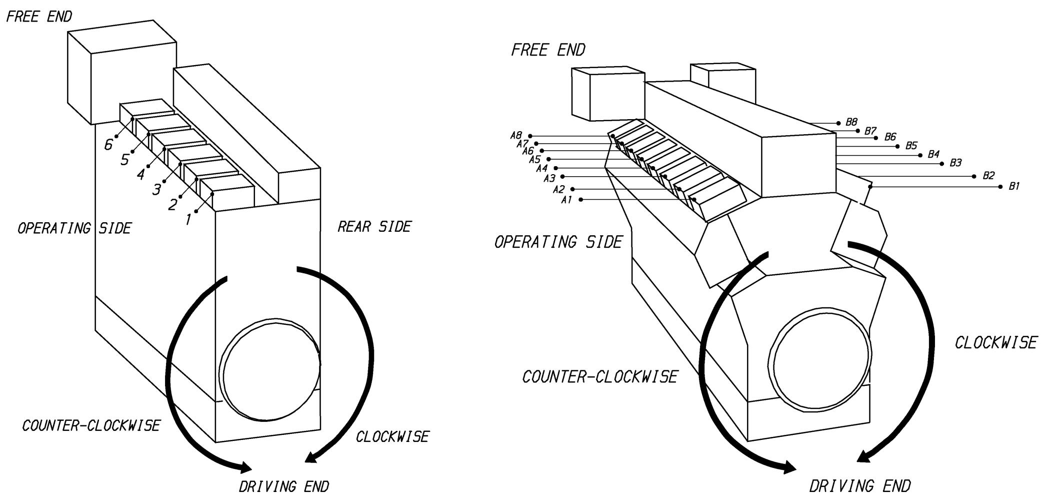



**Fig 4-1 In-line engine and V-engine definitions (1V93C0029 / 1V93C0028)**

## 4.2 Main components and systems

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

### 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 of dry sump type and includes the main distributing pipe for lubricating oil. The dry sump is drained at both ends to a separate system oil tank. For applications with restricted height a low sump can be specified for in-line engines, however without the hydraulic jacks.

### 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. In V-engines the connecting rods are arranged side-by-side on the same crank pin in order to obtain a high degree of standardization. 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.

The gear wheel for the camshaft drive is bolted on the flywheel end. Both the gear wheel for the pump drive and the torsional vibration damper are bolted on the free end if installed.

### 4.2.3 Connection rod

The connecting rod is made of forged alloy steel. It comprises a three-piece design, which gives a minimum dismantling height and enables the piston to be dismounted without opening the big end bearing. All connecting rod studs are hydraulically tightened. Oil is led to the gudgeon pin bearing and piston through a bore in the connecting rod. The gudgeon pin bearing is of tri-metal type.

### 4.2.4 Main bearings and big end bearings

The main bearing consists of two replaceable precision type bearing shells, the upper and the lower shell. Both shells are peripherally slightly longer than the housing thus providing the shell fixation. The main bearing located closest to the flywheel is an extra support to both the flywheel and the coupling. Four thrust bearing segments provide the axial guidance of the crankshaft.

The main bearings and the big end bearings are of tri-metal design with steel back, lead-bronze lining and a soft and thick running layer.

### 4.2.5 Cylinder liner

The cylinder liner is centrifugally cast of a special grey cast iron alloy developed for good wear resistance and high strength. It is designed with a high and rigid collar, making it resistant against deformations. A distortion free liner bore in combination with excellent lubrication improves the running conditions for the piston and piston rings, and reduces wear.

The liner is of wet type, sealed against the engine block metallically at the upper part and by O-rings at the lower part. Accurate temperature control of the cylinder liner is achieved with optimally located longitudinal cooling bores. 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 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 campiece 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.

## 4.2.11 Fuel system

The Wärtsilä 50DF engine is designed for continuous operation on fuel gas (natural gas) or Marine Diesel Fuel (MDF). 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*.

### 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 cylinder head (for V-engines) or on the intake duct of the cylinder head (for in-line engines). 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 (90 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.

The fuel gas fine filter is a full flow unit preventing impurities from entering the fuel gas system. The fineness of the filter is 5 μm absolute mesh size (0.5 μm at 98.5% separation). The filter is located in the external system if double wall gas piping is used.

## Main fuel oil injection

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
- Twin 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 twin injection valve is a combined main fuel oil injection and pilot fuel oil injection valve, which is centrally located in the cylinder head. The main diesel injection part of the valve uses traditional spring loaded needle design.

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.

## Pilot fuel injection

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 injection system uses the same external fuel feed system as the main fuel oil injection system.

The pilot fuel system comprises the following built-on equipment:

- Pilot fuel oil filter
- Common rail high pressure pump
- Common rail piping
- Twin 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 fineness of the filter is 10 μm.

The high pressure pilot fuel pump is of engine-driven type in case of diesel-electric engines driving generators and electrically driven type in case of variable speed engines driving propellers. The pilot fuel pump is mounted in the free end of the engine. The delivered fuel pressure is controlled by the engine control system and is approximately 100 MPa.

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 diesel injection part of the twin fuel oil injection valve has a needle 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 manifold pipes are made of special heat resistant nodular cast iron alloy.

The connections to the cylinder head are of the clamp ring type.

The complete exhaust gas system is enclosed in an insulating box consisting of easily removable panels fitted to a resiliently mounted frame. Mineral wool is used as insulating material.

### 4.2.13 Lubricating system

The engine internal lubricating oil system consists mainly of engine-driven pump with pressure regulating valve, main distribution pipe, running-in filters, and by-pass centrifugal filter. Other equipment are external. The lubricating oil system is handled in more detail later in the chapter *Lubricating oil system*.

### 4.2.14 Cooling system

The cooling water system is divided into low temperature (LT) and high temperature (HT) circuits. The engine internal cooling system consists of engine-driven LT and HT pumps, cylinder head and liner cooling circuits, and LT and HT charge air coolers. All other equipment are external. The cooling water system is handled in more detail the chapter *Cooling water system*.

### 4.2.15 Turbocharging and charge air cooling

The SPEX (Single Pipe EXhaust system) turbocharging system 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.

In-line engines have one turbocharger and V-engines have one turbocharger per cylinder bank. The turbocharger(s) are installed transversely, and are placed at the free 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 mode and gas mode operation, a pressure relief valve system “waste gate” is installed on the exhaust gas side. The waste gate is activated at high load.

The charge air cooler is as standard of 2-stage type, consisting of HT- and LT-water stage. Fresh water is used for both circuits.

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 50DF 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

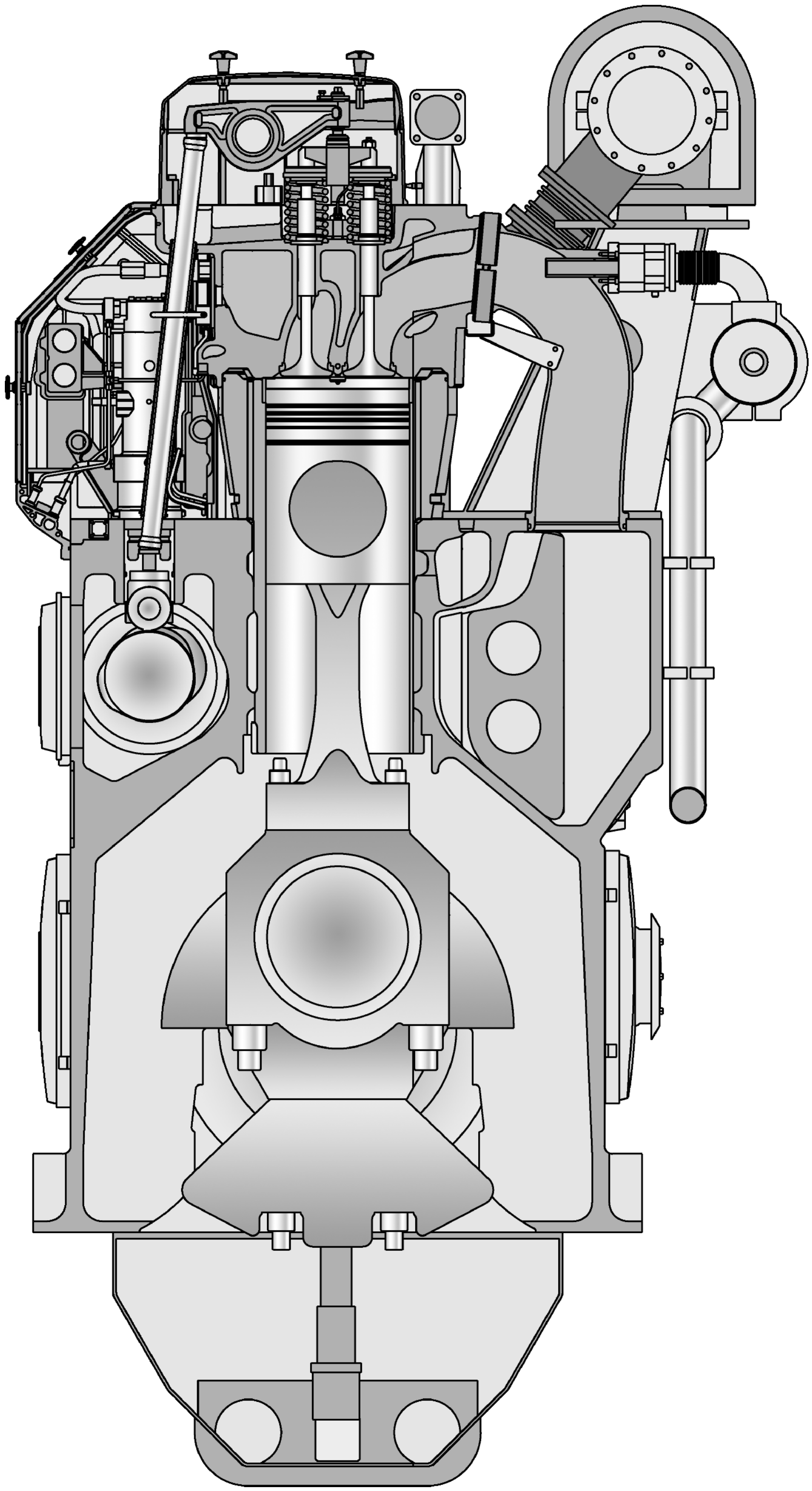


Fig 4-2 Cross section of the in-line engine (1V58B2480)

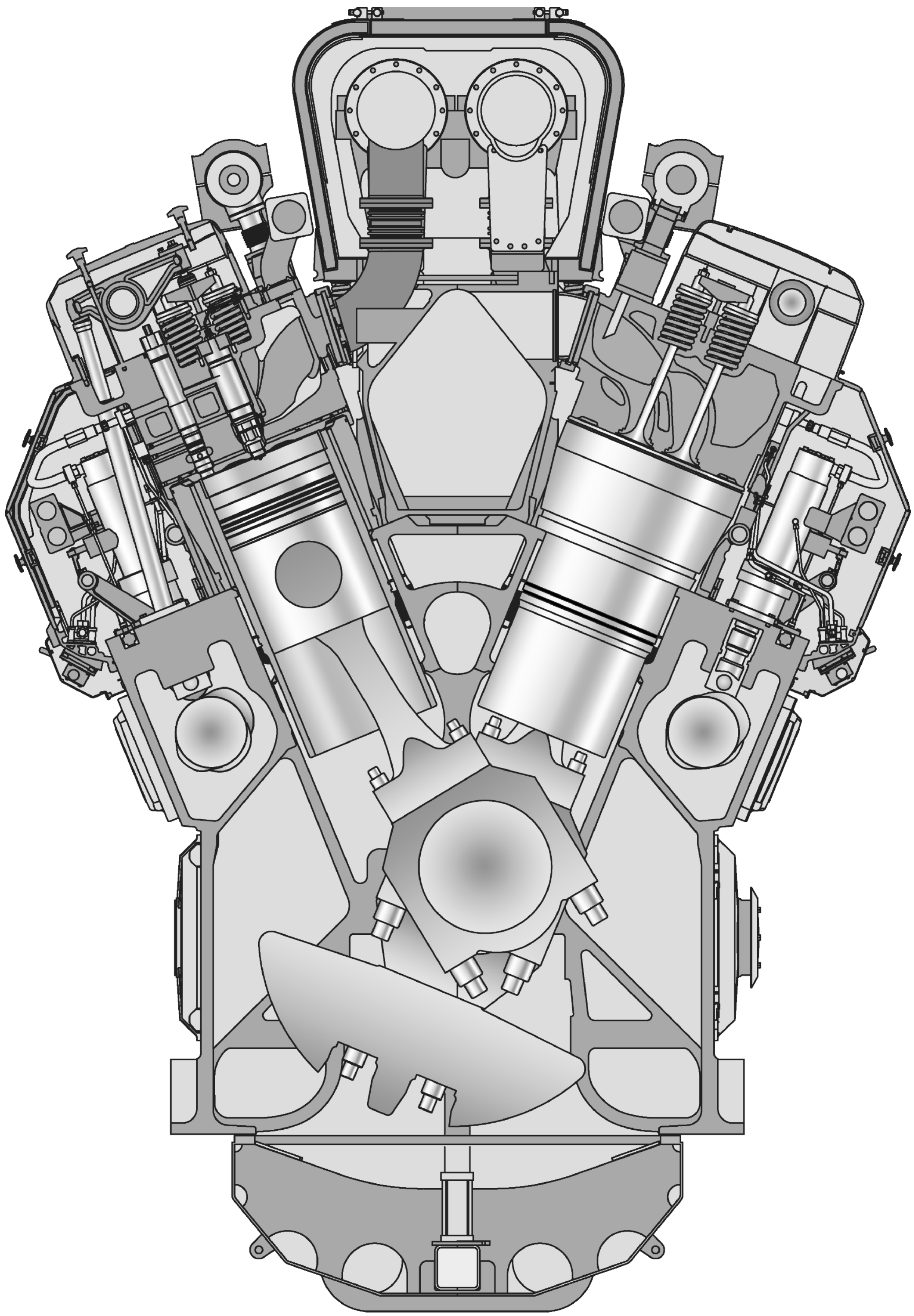


Fig 4-3 Cross section of the V-engine (1V58B2523)

## 4.4 Free end cover

All engine driven pumps are installed on the free end cover. The torsional vibration damper, if fitted, is fully covered by the free end cover.

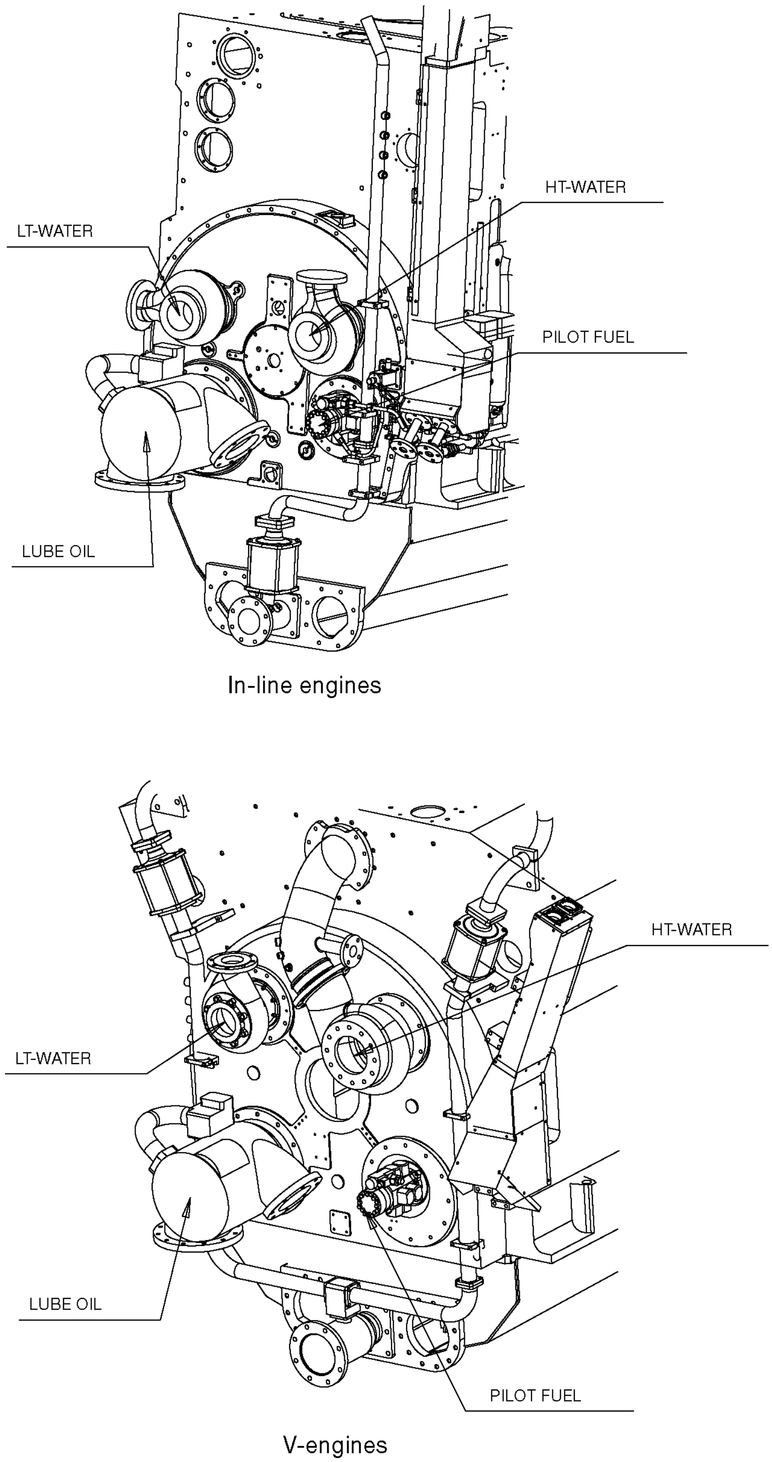



**Fig 4-4 Built-on pumps at the free ends of the in-line and V-engines**

## 4.5 Overhaul intervals and expected life times

The following overhaul intervals and lifetimes are for guidance only. Actual figures will be different depending on operating conditions, average loading of the engine, fuel quality used, fuel handling system, performance of maintenance etc. Expected component lifetimes have been adjusted to match overhaul intervals.

**Table 4-1 Time between overhauls and expected component lifetimes**

| Component | Time between inspection or overhaul [h] | | Expected component lifetimes [h] | |
|---|---|---|---|---|
| | MDF/GAS operation | HFO operation | MDF/GAS operation | HFO operation |
| Piston, crown | 18000-24000 | 12000 | 96000-120000 | 36000 |
| Piston, skirt | 18000-24000 | 12000 | 96000-120000 | 60000 |
| Piston rings | 18000-24000 | 12000 | 18000-24000 | 12000 |
| Cylinder liner | 18000-24000 | 12000 | 180000 | 72000 |
| Cylinder head | 18000 | 12000 | 72000 | 60000 |
| Inlet valve | 18000 | 12000 | 36000 | 24000 |
| Inlet valve seat | 18000 | 12000 | 36000 | 24000 |
| Exhaust valve | 18000 | 12000 | 36000 | 24000 |
| Exhaust valve seat | 18000 | 12000 | 36000 | 24000 |
| Injection valve nozzle | 6000 | 6000 | 6000 | 6000 |
| Injection valve complete | 6000 | 6000 | 18000 | 18000 |
| Injection pump element | 12000-18000 | 12000 | 24000-36000 | 24000 |
| Pilot fuel pump | 24000 | 24000 | 24000 | 24000 |
| Main bearing | 18000-24000 1) | 18000 1) | 36000 | 36000 |
| Big end bearing | 18000-24000 1) | 18000 1) | 36000 | 36000 |
| Small end bearing | 18000-24000 1) | 18000-24000 1) | 36000 | 36000 |
| Camshaft bearing | 36000 1) | 36000 1) | 72000 | 72000 |
| Turbocharger bearing | 12000 | 12000 | 36000 | 36000 |
| Main gas admission valve | 18000 | 18000 | 18000 | 18000 |
| *1) Inspection of one* | | | | |

## 4.6 Engine storage

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

# 5. Piping Design, Treatment and Installation

This chapter provides general guidelines for the design, construction and 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.

**NOTE**

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

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

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 (MDF and HFO) | 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 |

**NOTE**

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

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

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

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

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

## 5.2 Trace heating

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

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

## 5.3 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<br>D,F [1)] |
| Fuel oil | A,B,C,D,F |
| Lubricating oil | A,B,C,D,F |

| 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 Pickling

Prefabricated pipe spools are pickled before installation onboard.

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

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

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

## 5.8 Flexible pipe connections

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

Great care must be taken to ensure proper installation of flexible pipe connections between resiliently mounted engines and ship's piping.

- 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
- Bolts are to be tightened crosswise in several stages
- Flexible elements must not be painted
- Rubber bellows must be kept clean from oil and fuel
- The piping must be rigidly supported close to the flexible piping connections.

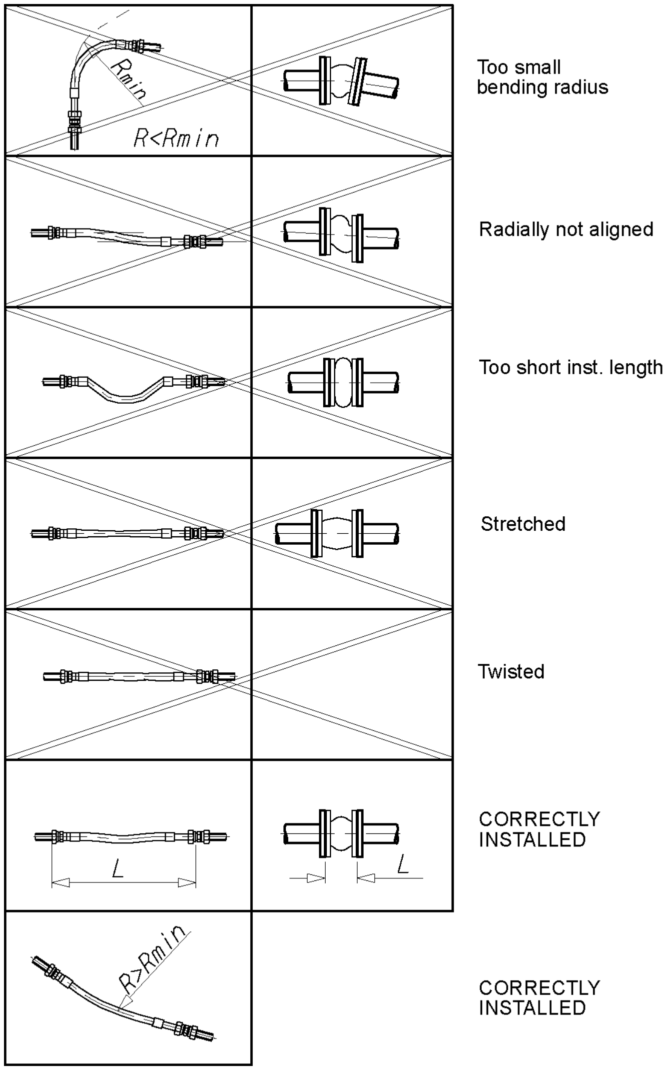



**Fig 5-1 Flexible hoses**

# 5.9 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.

Examples of flange support structures are shown in Figure *5-2*. A typical pipe clamp for a fixed support is shown in Figure *5-3*. Pipe clamps must be made of steel; plastic clamps or similar may not be used.

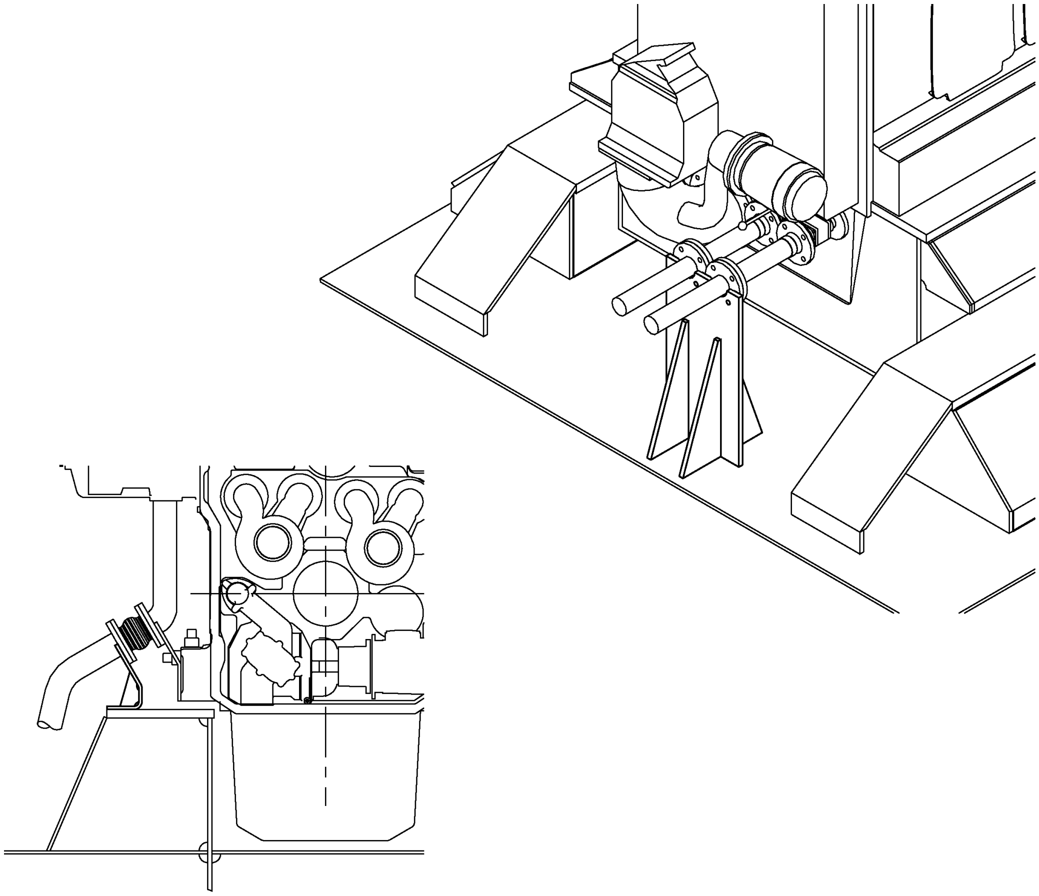
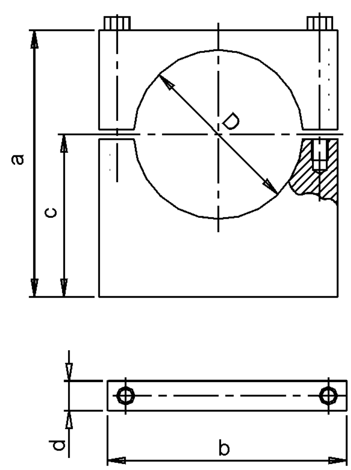


**Fig 5-2** **Flange supports of flexible pipe connections (4V60L0796)**




| 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 |

$d_u$ = Pipe outer diameter

**Fig 5-3** **Pipe clamp for fixed support (4V61H0842)**

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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 50DF engine is designed for continuous operation in gas operating mode or diesel operating mode. For continuous operation without reduction in the rated output, the gas used as main fuel in gas operating mode has to fulfill the below mentioned quality requirements.

**Table 6-1 Fuel Gas Specifications**

| Property | Unit | Value |
|---|---|---|
| Lower heating value (LHV), min 1) | MJ/m³N 2) | 28 |
| Methane number (MN), min 3) | | 80 (IMO Tier 2) |
| Methane ($CH_4$), min | % volume | 70 |
| Hydrogen sulphide ($H_2S$), max | % volume | 0.05 |
| Hydrogen ($H_2$), max 4) | % volume | 3 |
| Ammonia, max | mg/m³N | 25 |
| Chlorine + Fluorines, max | mg/m³N | 50 |
| Particles or solids at engine inlet, max | mg/m³N | 50 |
| Particles or solids at engine inlet, max size | um | 5 |
| Gas inlet temperature | °C | 0…60 |
| Water and hydrocarbon condensates at engine inlet not allowed 5) | | |

1) *The required gas feed pressure is depending on the LHV (see section Output limitations in gas mode).*

2) *Values given in $m^3_N$ are at 0°C and 101.3 kPa.*

3) *The methane number (MN) of the gas is to be defined by using AVL's "Methane 3.20" software. The MN is a calculated value that gives a scale for evaluation of the resistance to knock of gaseous fuels. Above table is valid for a low MN optimized engine. Minimum value is depending on engine configuration, which will affect the performance data.*
*However, if the total content of hydrocarbons C5 and heavier is more than 1% volume Wärtsilä has to be contacted for further evaluation.*

4) *Hydrogen content higher than 3% volume has to be considered project specifically.*

5) *Dew point of natural gas is below the minimum operating temperature and pressure.*

### 6.1.2 Liquid fuel specification

The fuel specifications are based on the ISO 8217:2012 (E) standard. Observe that a few additional properties not included in the standard are listed in the tables. For maximum fuel temperature before the engine, see chapter "*Technical Data*".

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.

#### Marine Diesel Fuel (MDF)

Distillate fuel grades are ISO-F-DMX, DMA, DMZ, DMB. These fuel grades are referred to as MDF (Marine Diesel Fuel).

**The distillate grades mentioned above can be described as follows:**

- DMX: A fuel which is suitable for use at ambient temperatures down to -15°C without heating the fuel. Especially in merchant marine applications its use is restricted to lifeboat engines and certain emergency equipment due to the reduced flash point. The low flash point which is not meeting the SOLAS requirement can also prevent the use in other marine applications, unless the fuel system is built according to special requirements. Also the low viscosity (min. 1.4 cSt) can prevent the use in engines unless the fuel can be cooled down enough to meet the min. injection viscosity limit of the engine.
- DMA: A high quality distillate, generally designated as MGO (Marine Gas Oil).
- DMZ: A high quality distillate, generally designated as MGO (Marine Gas Oil). An alternative fuel grade for engines requiring a higher fuel viscosity than specified for DMA grade fuel.
- 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 as MDO (Marine Diesel Oil).

**Table 6-2 MDF specifications**

| Property | Unit | ISO-F-DMA | ISO-F-DMZ | ISO-F-DMB | Test method ref. |
|---|---|---|---|---|---|
| Viscosity before pilot fuel pump, min. 1) | cSt | 2.0 | 2.0 | 2.0 | |
| Viscosity, before pilot fuel pump, max. 1) | cSt | 11.0 | 11.0 | 11.0 | |
| Viscosity, before main injection pumps, min. 1) | cSt | 2.0 | 2.0 | 2.0 | |
| Viscosity, before main fuel injection pumps, max. 1) | cSt | 24.0 | 24.0 | 24.0 | |
| Temperature before pilot fuel pump, min. 9) | °C | 5 | 5 | 5 | |
| Temperature before pilot fuel pump, max 9) | °C | 50 | 50 | 50 | |
| Viscosity at 40°C, min. | cSt | 2 | 3 | 2 | |
| Viscosity at 40°C, max. | cSt | 6 | 6 | 11 | ISO 3104 |
| Density at 15°C, max. | kg/m³ | 890 | 890 | 900 | ISO 3675 or 12185 |
| Cetane index, min. | | 40 | 40 | 35 | ISO 4264 |
| Sulphur, max. | % mass | 1.5 | 1.5 | 2 | ISO 8574 or 14596 |
| Flash point, min. | °C | 60 | 60 | 60 | ISO 2719 |
| Hydrogen sulfide. max. 2) | mg/kg | 2 | 2 | 2 | IP 570 |
| Acid number, max. | mg KOH/g | 0.5 | 0.5 | 0.5 | ASTM D664 |
| Total sediment by hot filtration, max. | % mass | — | — | 0.1 3) | ISO 10307-1 |
| Oxidation stability, max. | g/m³ | 25 | 25 | 25 4) | ISO 12205 |
| Carbon residue: micro method on the 10% volume distillation residue max. | % mass | 0.30 | 0.30 | — | ISO 10370 |
| Carbon residue: micro method, max. | % mass | — | — | 0.30 | ISO 10370 |
| Pour point (upper) , winter quality, max. 5) | °C | -6 | -6 | 0 | ISO 3016 |
| Pour point (upper) , summer quality, max. 5) | °C | 0 | 0 | 6 | ISO 3016 |
| Appearance | — | Clear and bright 6) | | 3) 4) 7) | |
| Water, max. | % volume | — | — | 0.3 3) | ISO 3733 |
| Ash, max. | % mass | 0.01 | 0.01 | 0.01 | ISO 6245 |
| Lubricity, corrected wear scar diameter (wsd 1.4) at 60°C , max. 8) | μm | 520 | 520 | 520 7) | ISO 12156-1 |

Remarks:

1) Additional properties specified by Wärtsilä, which are not included in the ISO specification.

2) The implementation date for compliance with the limit shall be 1 July 2012. Until that the specified value is given for guidance.

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

4) If the sample is not clear and bright, the test cannot be undertaken and hence the oxidation stability limit shall not apply.

5) It shall be ensured that the pour point is suitable for the equipment on board, especially if the ship operates in cold climates.

6) If the sample is dyed and not transparent, then the water limit and test method ISO 12937 shall apply.

7) If the sample is not clear and bright, the test cannot be undertaken and hence the lubricity limit shall not apply.

8) The requirement is applicable to fuels with a sulphur content below 500 mg/kg (0.050 % mass).

9) Additional properties specified by the engine manufacturer, which are not included in the ISO 8217:2012(E) standard. The min. fuel temperature has to be always at least 10 °C above fuel's pour point, cloud point and cold filter plugging point.

**NOTE**

Pilot fuel quality must be according to DMX, DMA, DMZ or DMB.

Lubricating oil, foreign substances or chemical waste, hazardous to the safety of the installation or detrimental to the performance of engines, should not be contained in the fuel.

## Heavy Fuel Oil (HFO)

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

**Table 6-3 HFO specifications**

| Property | Unit | Limit HFO 1 | Limit HFO 2 | Test method ref. |
|---|---|---|---|---|
| Viscosity, before injection pumps 1) | cSt | 16...24 | 16...24 | |
| Viscosity at 50°C, max. | cSt | 700 | 700 | ISO 3104 |
| Density at 15°C, max. | kg/m³ | 991 / 1010 2) | 991 / 1010 2) | ISO 3675 or 12185 |
| CCAI, max.3) | | 850 | 870 | ISO 8217, Annex F |
| Sulphur, max. 4) 5) | % mass | Statutory requirements | | ISO 8754 or 14596 |
| Flash point, min. | °C | 60 | 60 | ISO 2719 |
| Hydrogen sulfide, max. 6) | mg/kg | 2 | 2 | IP 570 |
| Acid number, max. | mg KOH/g | 2.5 | 2.5 | ASTM D664 |
| Total sediment aged, max. | % mass | 0.1 | 0.1 | ISO 10307-2 |
| Carbon residue, micro method, max. | % mass | 15 | 20 | ISO 10370 |
| Asphaltenes, max.1) | % mass | 8 | 14 | ASTM D 3279 |
| Pour point (upper), max. 7) | °C | 30 | 30 | ISO 3016 |
| Water, max. | % volume | 0.5 | 0.5 | ISO 3733 or ASTM D6304-C 1) |
| Water before engine, max.1) | % volume | 0.3 | 0.3 | ISO 3733 or ASTM D6304-C 1) |
| Ash, max. | % mass | 0.05 | 0.15 | ISO 6245 or LP1001 1) |
| Vanadium, max. 5) | mg/kg | 100 | 450 | ISO 14597 or IP 501 or IP 470 |
| Sodium, max. 5) | mg/kg | 50 | 100 | IP 501 or IP 470 |
| Sodium before engine, max.1) 5) | mg/kg | 30 | 30 | IP 501 or IP 470 |
| Aluminium + Silicon, max. | mg/kg | 30 | 60 | ISO 10478 or IP 501 or IP 470 |
| Aluminium + Silicon before engine, max.1) | mg/kg | 15 | 15 | ISO 10478 or IP 501 or IP 470 |
| Used lubricating oil, calcium, max. 8) | mg/kg | 30 | 30 | IP 501 or IP 470 |
| Used lubricating oil, zinc, max. 8) | mg/kg | 15 | 15 | IP 501 or IP 470 |
| Used lubricating oil, phosphorus, max. 8) | mg/kg | 15 | 15 | IP 501 or IP 500 |

Remarks:

1) Additional properties specified by Wärtsilä, which are not included in the ISO specification.

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

3) Straight run residues show CCAI values in the 770 to 840 range and have very good ignition quality. 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 the ignition properties of the fuel, especially concerning fuels originating from modern and more complex refinery process.

4) The max. sulphur content must be defined in accordance with relevant statutory limitations.

5) Sodium contributes to hot corrosion on the 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 and 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.

6) The implementation date for compliance with the limit shall be 1 July 2012. Until that, the specified value is given for guidance.

7) It shall be ensured that the pour point is suitable for the equipment on board, especially if the ship operates in cold climates.

8) 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
- Calcium > 30 mg/kg and phosphorus > 15 mg/kg

### 6.1.3 Liquid bio fuels

The engine can be operated on liquid bio fuels according to the specifications in tables "*6-4 Straight liquid bio fuel specification*" or "*6-5 Biodiesel specification based on EN 14214:2012 standard*". Liquid bio fuels have typically lower heating value than fossil fuels, the capacity of the fuel injection system must be checked for each installation.

If a liquid bio fuel is to be used as pilot fuel, only pilot fuel according to table "*Biodiesel specification based on EN 14214:2012 standard*" is allowed.

Table "*Straight liquid bio fuel specification*" is valid for straight liquid bio fuels, like palm oil, coconut oil, copra oil, rape seed oil, jathropha oil etc. but is not valid for other bio fuel qualities like animal fats.

Renewable biodiesel can be mixed with fossil distillate fuel. Fossil fuel being used as a blending component has to fulfill the requirement described earlier in this chapter.

**Table 6-4 Straight liquid bio fuel specification**

| Property | Unit | Limit | Test method ref. |
|---|---|---|---|
| Viscosity at 40°C, max.[1] | cSt | 100 | ISO 3104 |
| Viscosity, before injection pumps, min. | cSt | 2.0 | |
| Viscosity, before injection pumps, max. | cSt | 24 | |
| Density at 15°C, max. | kg/m³ | 991 | ISO 3675 or 12185 |
| Ignition properties [2] | | | FIA test |
| Sulphur, max. | % mass | 0.05 | ISO 8574 |
| Total sediment existent, max. | % mass | 0.05 | ISO 10307-1 |
| Water before engine, max. | % volume | 0.20 | ISO 3733 |
| Micro carbon residue, max. | % mass | 0.50 | ISO 10370 |
| Ash, max. | % mass | 0.05 | ISO 6245 / LP1001 |
| Phosphorus, max. | mg/kg | 100 | ISO 10478 |
| Silicon, max. | mg/kg | 15 | ISO 10478 |
| Alkali content (Na+K), max. | mg/kg | 30 | ISO 10478 |
| Flash point (PMCC), min. | °C | 60 | ISO 2719 |
| Cloud point, max. | °C | [3] | ISO 3015 |
| Cold filter plugging point, max. | °C | [3] | IP 309 |
| Copper strip corrosion (3h at 50°C), max. | Rating | 1b | ASTM D130 |
| Steel corrosion (24/72h at 20, 60 and 120°C), max. | Rating | No signs of corrosion | LP 2902 |
| 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 | ISO 3961 |
| Synthetic polymers | % mass | Report [4] | LP 2401 ext. and LP 3402 |

Remarks:

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

2) Ignition properties have to be equal to or better than requirements for fossil fuels, i.e. CN min. 35 for MDF and CCAI max. 870 for HFO.

3) Cloud point and cold filter plugging point have to be at least 10°C below the fuel injection temperature.

4) 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.

## Table 6-5 Biodiesel specification based on EN 14214:2012 standard

| Property | Unit | Limit | Test method ref. |
|---|---|---|---|
| Viscosity at 40°C, min...max. | cSt | 3.5...5 | ISO 3104 |
| Viscosity, before injection pumps, min. | cSt | 2.0 | |
| Density at 15°C, min...max. | kg/m³ | 860...900 | ISO 3675 / 12185 |
| Cetane number, min. | | 51 | ISO 5165 |
| Sulphur, max. | mg/kg | 10 | ISO 20846 / 20884 |
| Sulphated ash, max. | % mass | 0.02 | ISO 3987 |
| Total contamination, max. | mg/kg | 24 | EN 12662 |
| Water, max. | mg/kg | 500 | ISO 12937 |
| Phosphorus, max. | mg/kg | 4 | EN 14107 |
| Group 1 metals (Na+K), max. | mg/kg | 5 | EN 14108 / 14109 / 14538 |
| Group 2 metals (Ca+Mg), max. | mg/kg | 5 | EN 14538 |
| Flash point, min. | °C | 101 | ISO 2719A / 3679 |
| Cold filter plugging point, max. 1) | °C | -44...+5 | EN 116 |
| Oxidation stability at 110°C, min. | h | 8 | EN 14112 |
| Copper strip corrosion (3h at 50°C), max. | Rating | Class 1 | ISO 2160 |
| Acid number, max. | mg KOH/g | 0.5 | EN 14104 |
| Iodine number, max. | g iodine / 100 g | 120 | EN 14111 / 16300 |
| FAME content, min 2) | % mass | 96.5 | EN 14103 |
| Linolenic acid methyl ester, max. | % mass | 12 | EN 14103 |
| Polyunsaturated methyl esters, max. | % mass | 1 | EN 15779 |
| Methanol content, max. | % mass | 0.2 | EN 14110 |
| Monoglyceride content, max. | % mass | 0.7 | EN 14105 |
| Diglyceride content, max. | % mass | 0.2 | EN 14105 |
| Triglyceride content, max. | % mass | 0.2 | EN 14105 |
| Free glycerol, max. | % mass | 0.02 | EN 14105 / 14106 |
| Total glycerol, max. | % mass | 0.25 | EN 14105 |

Remarks:

1) Cold flow properties of renewable bio diesel 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.

2) Valid only for transesterified biodiesel (FAME)

## 6.2 Operating principles

Wärtsilä 50DF 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 (MDF).

### 6.2.1 Gas mode operation

In gas operating mode the main fuel is natural gas which is injected into the engine at a low pressure. The gas is ignited by injecting a small amount of pilot diesel fuel (MDF). 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. MDF or HFO is used as fuel with a conventional diesel fuel injection system. The MDF 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 MDF pilot injection system is not active and operation longer than 30 minutes (with HFO) or 10 hours (with MDF) may cause clogging of the pilot fuel injection nozzles.

### 6.2.4 Fuel sharing mode operation (optional)

As an optional feature, the engine can be equipped with fuel sharing mode. When this mode is activated, the engine will run on a mix of gas, main liquid fuel (MDF or HFO) and pilot fuel. The required gas/liquid fuel mixing ratio can be chosen by the operator. For more info, see chapter .

# 6.3 Fuel gas system

## 6.3.1 Internal fuel gas system

### Internal fuel gas system for in-line engines

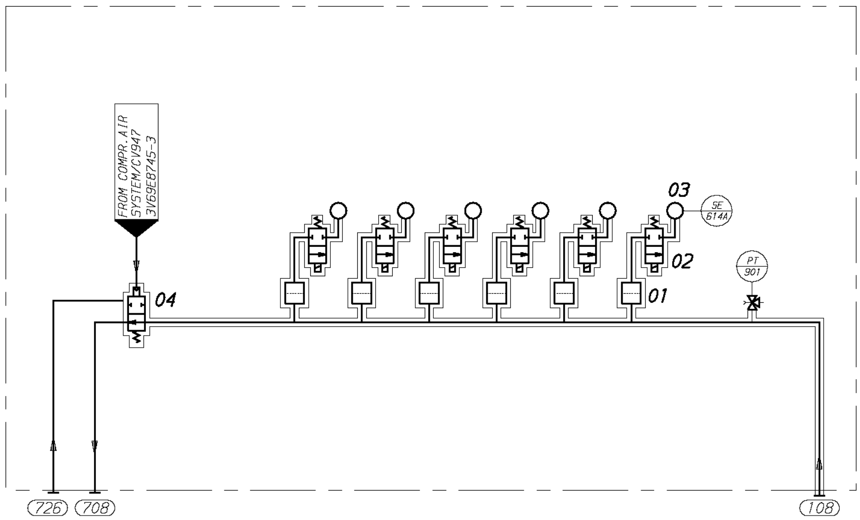



**Fig 6-1 Internal fuel gas system, in-line engines (DAAE010198b)**

| System components: | | | |
|---|---|---|---|
| 01 | Safety filter | 03 | Cylinder |
| 02 | Gas admission valve | 04 | Venting valve |

| Pipe connections: | | Size | Pressure class | Standard |
|---|---|---|---|---|
| 108 | Gas inlet | DN100/150 | PN16 | ISO 7005-1 |
| 708 | Gas system ventilation | DN50 | PN40 | ISO 7005-1 |
| 726 | Air inlet to double wall gas system | M42x2 | | |

| Sensors and indicators: | | | |
|---|---|---|---|
| SE614A...SE6#4A | Knock sensor | PT901 | Gas pressure |

# Internal fuel gas system for V-engines

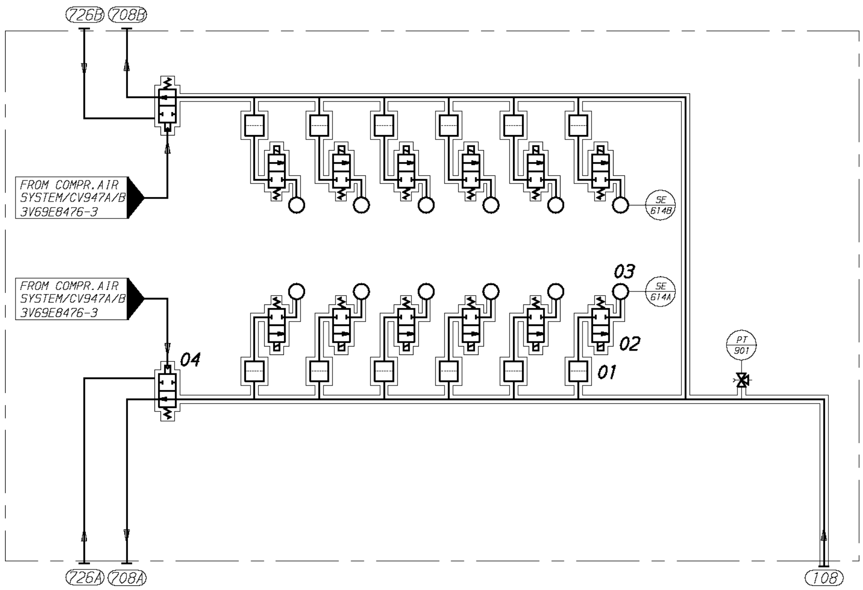



**Fig 6-2 Internal fuel gas system,V-engines (DAAE010199c)**

| System components | | | |
|---|---|---|---|
| 01 | Safety filter | 03 | Cylinder |
| 02 | Gas admission valve | 04 | Venting valve |

| Sensors and indicators | | | |
|---|---|---|---|
| SE614A/B...SE6#4A/B | Knock sensor | PT901 | Gas pressure |

| Pipe connections | | Size | Pressure class | Standard |
|---|---|---|---|---|
| 108 | Gas inlet | DN100/150 | PN16 | ISO 7005-1 |
| 708A/B | Gas system ventilation | DN50 | PN40 | ISO 7005-1 |
| 726A/B | Air inlet to double wall gas system | M42x2 | | |

When operating the engine in gas mode, the gas is injected through gas admission valves into the inlet channel of each cylinder. The gas is mixed with the combustion air immediately upstream of the inlet valve in the cylinder head. Since the gas valve is timed independently of the inlet valve, scavenging of the cylinder is possible without risk that unburned gas is escaping directly from the inlet to the exhaust.

The gas piping is double wall type. The annular space in double wall piping installations is mechanically ventilated by a fan. The air inlets to the annular space are located at the engine and close to tank connection space. Air can be taken directly from the engine room or from a location outside the engine room, through dedicated piping.

## 6.3.2 External fuel gas system

### Fuel gas system, with instrument cabinet

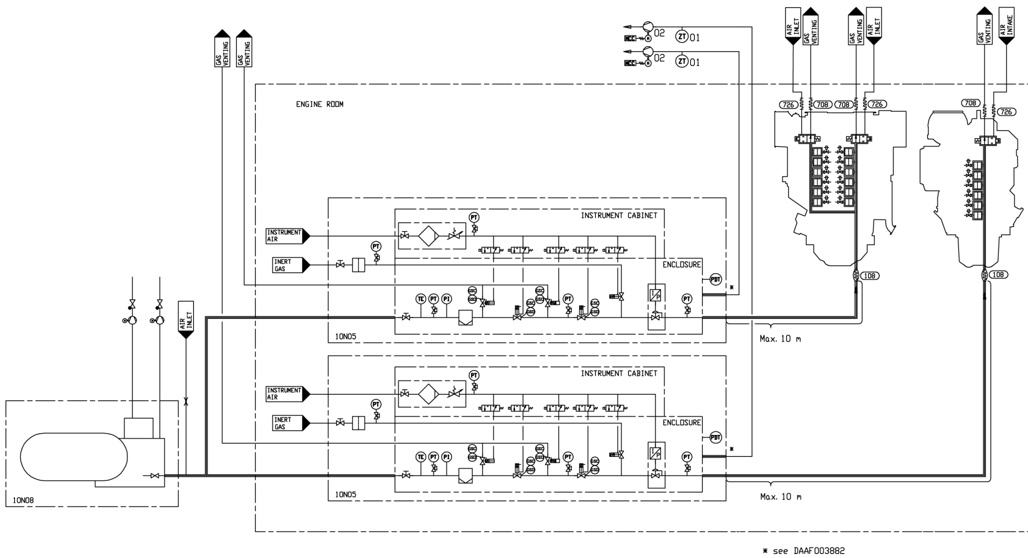



**Fig 6-3 Example of fuel gas system with instrument cabinet (DAAF022750D)**

| System components | | Pipe connections | |
|---|---|---|---|
| 01 | Gas detector | 108 | Gas inlet |
| 02 | Gas double wall system ventilation fan | 708 | Gas system ventilation |
| 10N05 | Gas valve unit | 726 | Air inlet to double wall gas system |
| 10N08 | LNGPAC | | |

## Fuel gas system, with solenoid valve cabinet

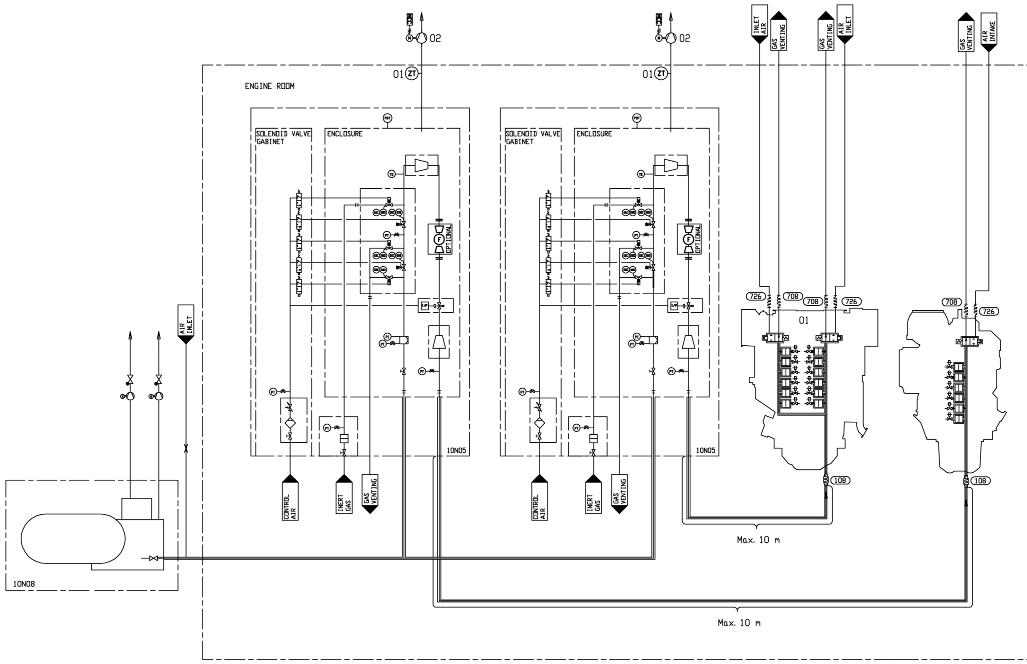



**Fig 6-4** **Example of fuel gas system with solenoid valve cabinet (DAAF077105)**

| System components | | Pipe connections | |
|---|---|---|---|
| 01 | Gas detector | 108 | Gas inlet |
| 02 | Gas double wall system ventilation fan | 708 | Gas system ventilation |
| 10N05 | Gas valve unit | 726 | Air inlet to double wall gas system |
| 10N08 | LNGPAC | | |

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.

## 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 GVU 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 GVU this 30 air changes per hour normally correspond to -20 mbar inside the GVU 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.

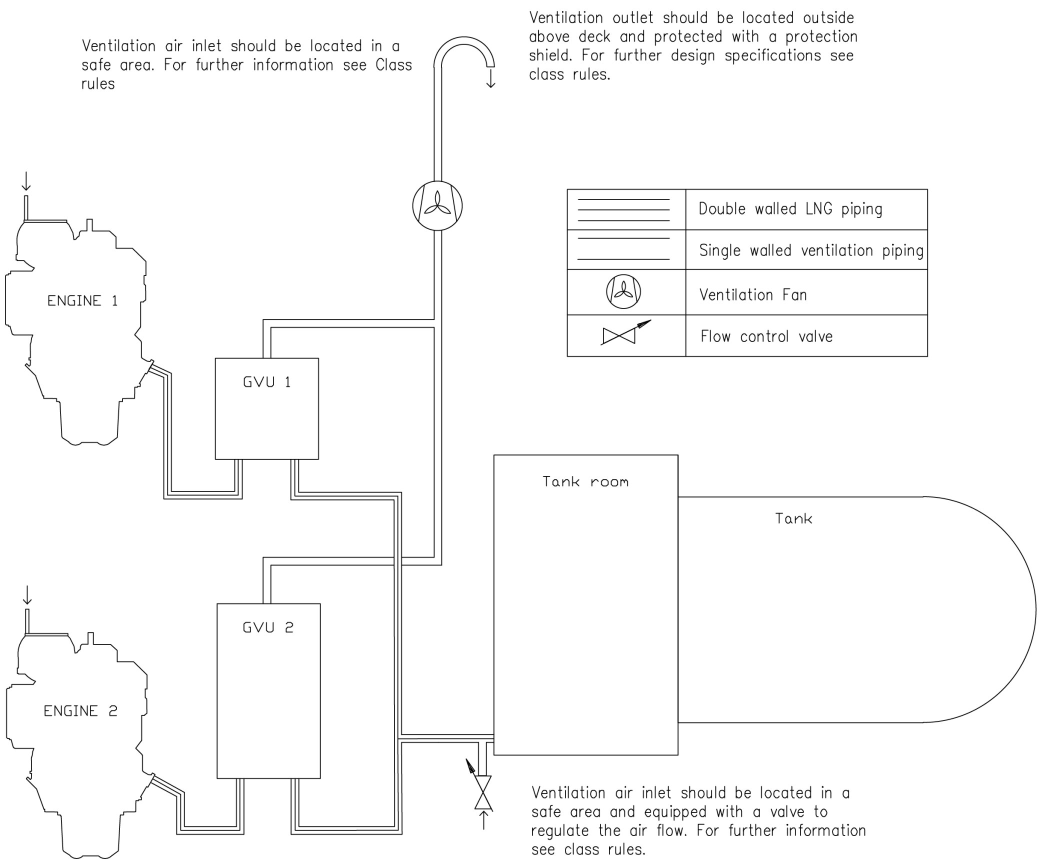



Fig 6-5 **Example arrangement drawing of ventilation in double wall piping system with enclosed GVUs (DBAC588146)**

## 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 on control cabinet of the GVU.

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 relief 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 10 m.

Inert gas and compressed air are to be dry and clean. Inert gas pressure max 1.5 MPa (15 bar). The requirements for compressed air quality are presented in chapter "*Compressed air system*".

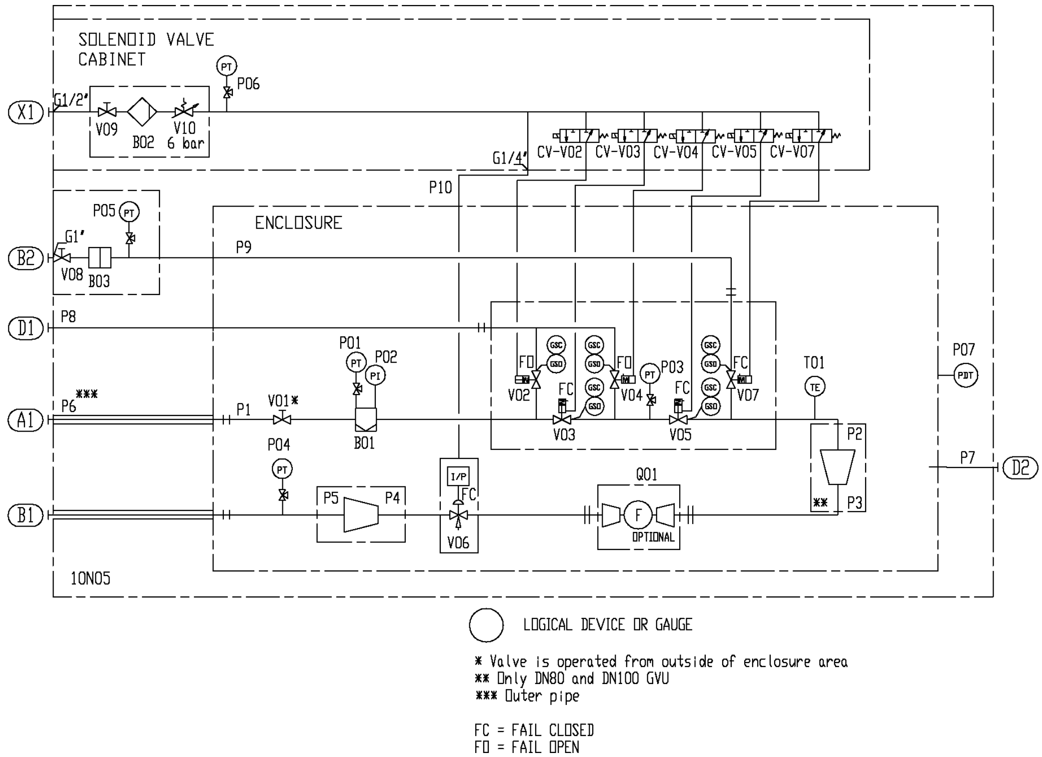



**Fig 6-6** **Gas valve unit P&I diagram (DAAF051037C)**

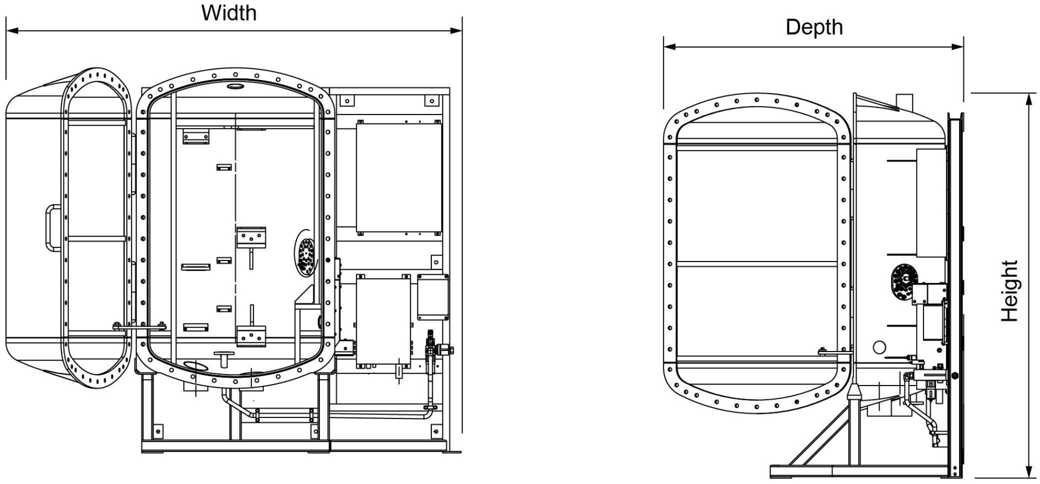
| **Unit components:** | | | | | |
|---|---|---|---|---|---|
| B01 | Gas filter | V03 | First block valve | V08 | Shut off valve |
| B02 | Control air filter | V04 | Vent valve | V09 | Shut off valve |
| B03 | Inert gas filter | V05 | Second block valve | V10 | Pressure regulator |
| V01 | Manual shut off valve | V06 | Gas control valve | CV-V0# | Solenoid valve |
| V02 | Vent valve | V07 | Inerting valve | Q01 | Mass flow meter |

| **Sensors and indicators** | | | |
|---|---|---|---|
| P01 | Pressure transmitter, gas inlet | P05 | Pressure transmitter, inert gas |
| P02 | Pressure manometer, gas inlet | P06 | Pressure transmitter, control air |
| P03 | Pressure transmitter | P07 | Pressure difference transmitter |
| P04 | Pressure transmitter, gas outlet | T01 | Temperature sensor, gas inlet |

| **Pipe connections** | | | |
|---|---|---|---|
| A1 | Gas inlet [5-10 bar(g)] | D1 | Gas venting |
| B1 | Gas to engine | D2 | Air venting |
| B2 | Inert gas [max 15 bar(g)] | X1 | Instrument air [6-8 bar(g)] |

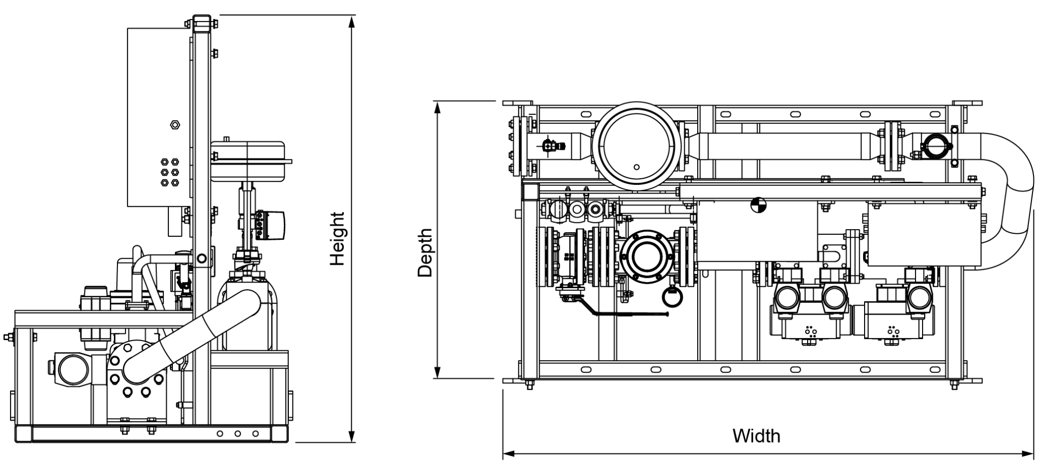
| **Pipe size** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Pos | DN50 GVU | DN80 GVU | DN100 GVU | Pos | DN50 GVU | DN80 GVU | DN100 GVU |
| P1 | DN50 | DN80 | DN100 | PN6 | DN100 | DN125 | DN150 |
| P2 | DN40 | DN80 | DN100 | PN7 | DN50 | DN80 | DN100 |
| P3 | DN40 | DN50 | DN80 | PN8 | OD18 | OD28 | OD42 |
| P4 | DN40 | DN50 | DN80 | PN9 | OD22 | OD28 | OD28 |

| Pipe size | | | | | | | |
|---|---|---|---|---|---|---|---|
| P5 | DN65 | DN80 | DN100 | PN10 | 10mm | 10mm | 10mm |




| | DN 80 | DN 100 |
|---|---|---|
| Height | 2335 mm | 2710 mm |
| Width | 2710 mm | 3200 mm |
| Depth | 1730 mm | 2200 mm |

**Fig 6-7 Main dimensions of the enclosed GVU for W50DF (DAAF060741)**




| | DN 80 | DN 100 |
|---|---|---|
| Height | 1450 mm | 1330 mm |
| Width | 1800 mm | 2195 mm |
| Depth | 980 mm | 1000mm |

**Fig 6-8 Main dimensions of the open GVU for W50DF (DAAF075752A)**

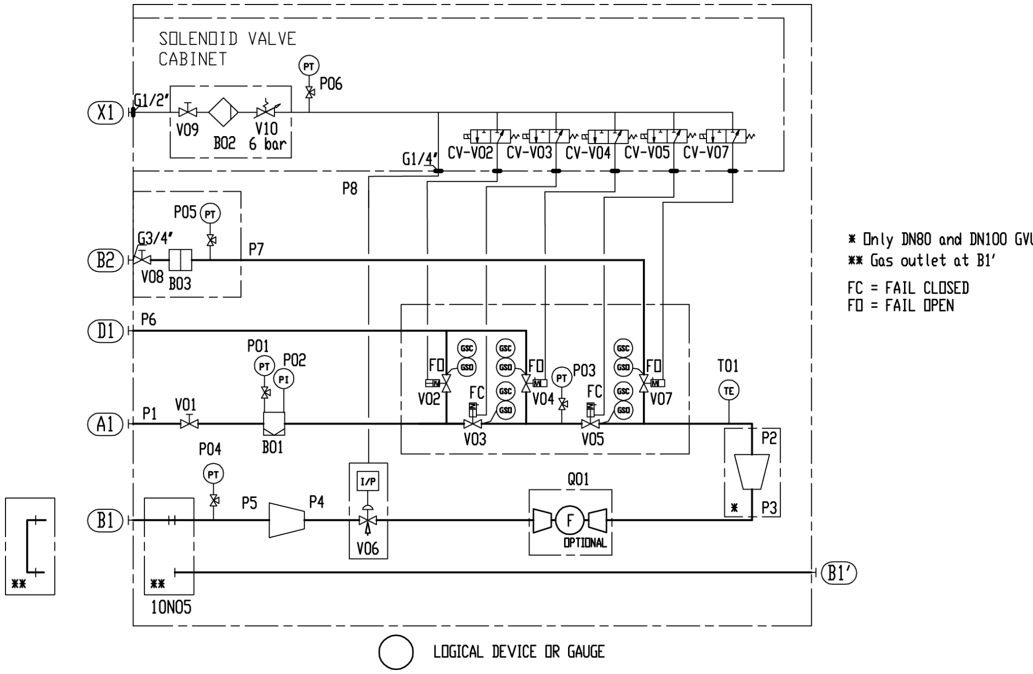



**Fig 6-9 Gas valve unit, open type (DAAF072567)**

| System components: | | | | | |
|---|---|---|---|---|---|
| B01 | Gas filter | V03 | First block valve | V08 | Shut off valve |
| B02 | Control air filter | V04 | Vent valve | V09 | Shut off valve |
| B03 | Inert gas filter | V05 | Second block valve | V10 | Pressure regulator |
| V01 | Manual shut off valve | V06 | Gas control valve | CV-V0# | Solenoid valve |
| V02 | Vent valve | V07 | Inerting valve | Q01 | Mass flow meter |

| Sensors and indicators: | | | |
|---|---|---|---|
| P01 | Pressure transmitter, gas inlet | P05 | Pressure transmitter, inert gas |
| P02 | Pressure manometer, gas inlet | P06 | Pressure transmitter, control air |
| P03 | Pressure transmitter | T01 | Temperature sensor |
| P04 | Pressure transmitter, gas outlet | | |

| Pipe connections | | Size GVU DN80 | Size GVU DN100 | Pressure class | Standard |
|---|---|---|---|---|---|
| A1 | Gas inlet [5-10 bar(g)] | DN80 / DN125 | DN100 / DN150 | PN16 | ISO 7005-1 |
| B1 | Gas outlet | DN80 / DN125 | DN100 / DN150 | PN16 | ISO 7005-1 |
| B2 | Inert gas [max 15 bar(g)] | G1 ' ' | G1 ' ' | PN16 | DIN 2353 |
| D1 | Gas venting | OD28 | DN32 | | DIN 2353 |
| D2 | Air venting | DN80 | DN100 | PN16 | |
| X1 | Instrument air [6-8 bar(g)] | G1/2 ' ' | G1/2 ' ' | | DIN 2353 |

## Master fuel gas valve

For LNG carriers, IMO IGC 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.

## 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.

**NOTE**

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!

## 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. **Max filling flow: 200l/min/cylinder**
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: 2.44 $m^3$/crank (inline) & 2.46 $m^3$/crank (v-engine)**

## 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$^3$ at 0°C and 101.3 kPa. For pressure requirements, see section "*Technical Data*" and chapter "*1.3.2 Output limitations due to gas feed pressure and lower heating value*"

For pressure requirements, see chapters *Technical Data* and *Output limitations due to methane number*.

- 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.

# 6.4 Fuel oil system

## 6.4.1 Internal fuel oil system

### Internal fuel oil system for in-line engines

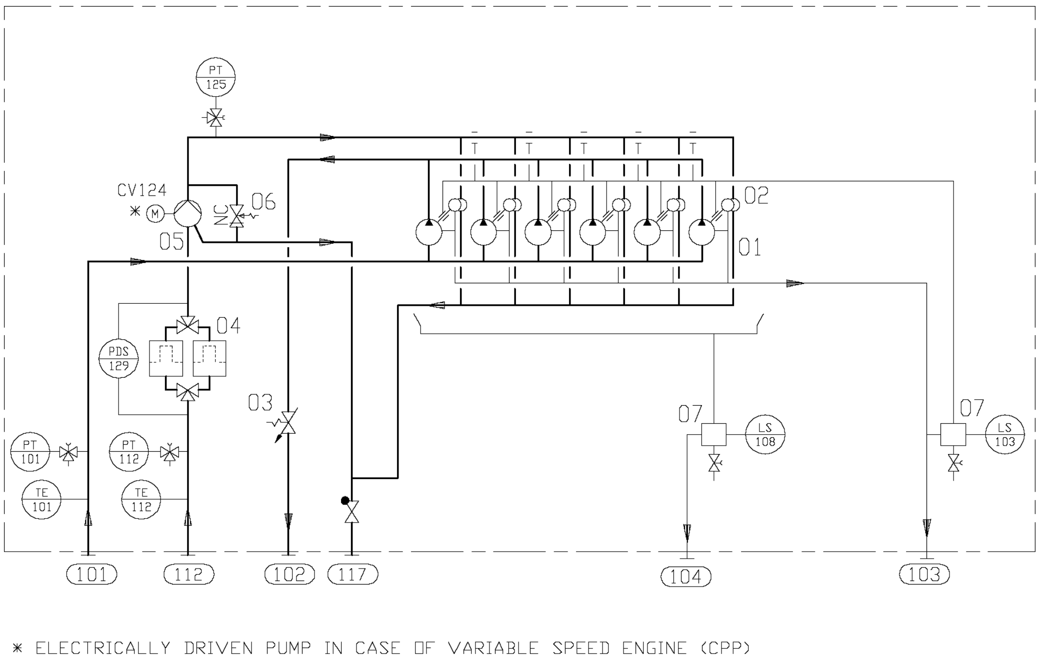



**Fig 6-10 Internal fuel oil system, in-line engines (3V69E8745-1i)**

| System components: | | | |
|---|---|---|---|
| 01 | Injection pump | 05 | Pilot fuel pump |
| 02 | Injection valve with pilot solenoid and nozzle | 06 | Pilot fuel safety valve |
| 03 | Pressure control valve | 07 | Fuel leakage collector |
| 04 | Pilot fuel filter | 08 | Water separator |

| Sensors and indicators: | | | |
|---|---|---|---|
| PT101 | Fuel oil inlet pressure | LS108 | Dirty fuel oil leakage level |
| TE101 | Fuel oil inlet temperature | CV124 | Pilot fuel pressure control valve |
| PT112 | Pilot fuel oil inlet pressure | PT125 | Pilot fuel pressure |
| TE112 | Pilot fuel oil inlet temperature | PDS129 | Pilot fuel diff.pressure over filter |
| LS103 | Clean fuel oil leakage level | | |

| Pipe connections | | Size | Pressure class | Standard |
|---|---|---|---|---|
| 101 | Fuel inlet | DN32 | PN40 | ISO 7005-1 |
| 102 | Fuel outlet | DN32 | PN40 | ISO 7005-1 |
| 103 | Leak fuel drain, clean fuel | OD28 | | DIN 2353 |
| 104 | Leak fuel drain, dirty fuel | OD48 | | DIN 2353 |
| 112 | Pilot fuel inlet | DN15 | PN40 | ISO 7005-1 |
| 117 | Pilot fuel outlet | DN15 | PN40 | ISO 7005-1 |

## Internal fuel oil system for V-engines

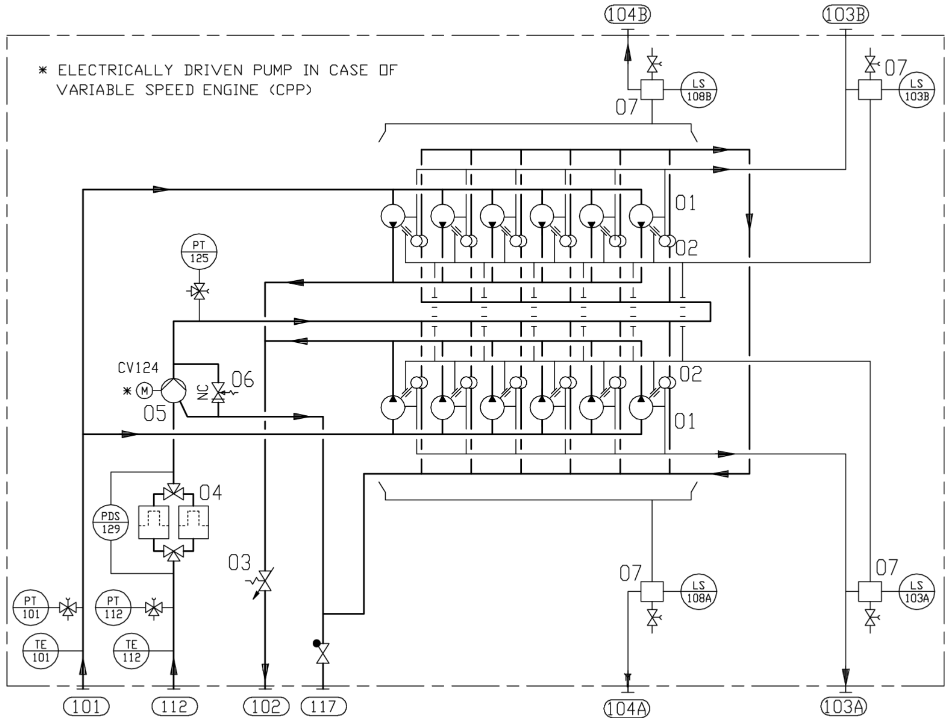



**Fig 6-11 Internal fuel oil system, V-engines (3V69E8746-1h)**

| System components: | | | | | |
|---|---|---|---|---|---|
| 01 | Injection pump | 04 | Pilot fuel filter | 07 | Fuel leakage collector |
| 02 | Injection valve with pilot solenoid and nozzle | 05 | Pilot fuel pump | 08 | Water separator |
| 03 | Pressure control valve | 06 | Pilot fuel safety valve | | |

| Sensors and indicators: | | | |
|---|---|---|---|
| PT101 | Fuel oil inlet pressure | LS108A | Dirty fuel oil leakage level, A-bank |
| TE101 | Fuel oil inlet temperature | LS108B | Dirty fuel oil leakage level, B-bank |
| PT112 | Pilot fuel oil inlet pressure | CV124 | Pilot fuel pressure control valve |
| TE112 | Pilot fuel oil inlet temperature | PT125 | Pilot fuel pressure |
| LS103A | Clean fuel oil leakage level, A-bank | PDS129 | Pilot fuel diff.pressure over filter |
| LS103B | Clean fuel oil leakage level, B-bank | | |

| Pipe connections | | Size | Pressure class | Standard |
|---|---|---|---|---|
| 101 | Fuel inlet | DN32 | PN40 | ISO 7005-1 |
| 102 | Fuel outlet | DN32 | PN40 | ISO 7005-1 |
| 103 | Leak fuel drain, clean fuel | OD28 | | DIN 2353 |
| 104 | Leak fuel drain, dirty fuel | OD48 | | DIN 2353 |
| 112 | Pilot fuel inlet | DN15 | PN40 | ISO 7005-1 |
| 117 | Pilot fuel outlet | DN15 | PN40 | ISO 7005-1 |

There are separate pipe connections for the main fuel oil and pilot fuel oil. Main fuel oil can be Marine Diesel Fuel (MDF) or Heavy Fuel Oil (HFO). Pilot fuel oil is always MDF and the pilot fuel system is in operation in both gas- and diesel mode operation.

A pressure control valve in the main fuel oil return line on the engine maintains desired pressure before the injection pumps.

### Leak fuel system

Clean leak fuel from the injection valves and the injection pumps is collected on the engine and drained by gravity through a clean leak fuel connection. The clean leak fuel can be re-used without separation. The quantity of clean leak fuel is given in chapter *Technical data*.

Other possible leak fuel and spilled water and oil is separately drained from the hot-box through dirty fuel oil connections and it shall be led to a sludge tank.

## 6.4.2 External fuel oil system

The design of the external fuel system may vary from ship to ship, but every system should provide well cleaned fuel of correct viscosity and pressure to each engine. Temperature control is required to maintain stable and correct viscosity of the fuel before the injection pumps (see *Technical data*). Sufficient circulation through every engine connected to the same circuit must be ensured in all operating conditions.

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

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

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

**NOTE**

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

### Fuel heating requirements HFO

Heating is required for:

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

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

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

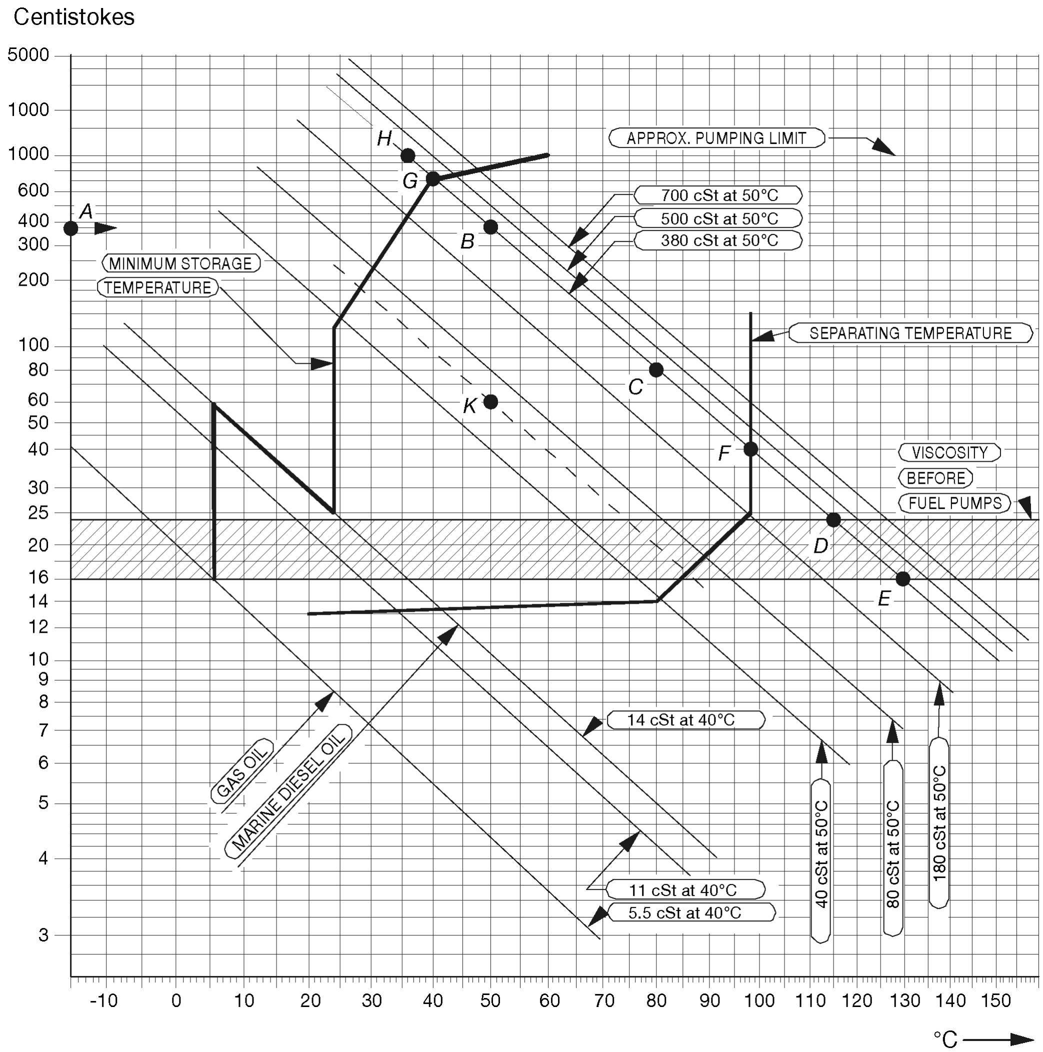



**Fig 6-12** **Fuel oil viscosity-temperature diagram for determining the pre-heating temperatures of fuel oils (4V92G0071b)**

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

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

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

## Fuel tanks

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

### Settling tank, HFO (1T02) and MDF (1T10)

Separate settling tanks for HFO and MDF are recommended.

To ensure sufficient time for settling (water and sediment separation), the capacity of each tank should be sufficient for min. 24 hours operation at maximum fuel consumption.

The tanks should be provided with internal baffles to achieve efficient settling and have a sloped bottom for proper draining.

The temperature in HFO settling tanks should be maintained between 50°C and 70°C, which requires heating coils and insulation of the tank. Usuallly MDF 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 MDF (1T06)

Two day tanks for HFO are to be provided, each with a capacity sufficient for at least 8 hours operation at maximum fuel consumption.

A separate tank is to be provided for MDF. The capacity of the MDF tank should ensure fuel supply for 8 hours.

Settling tanks may not be used instead of day tanks.

The day tank must be designed so that accumulation of sludge near the suction pipe is prevented and the bottom of the tank should be sloped to ensure efficient draining.

HFO day tanks shall be provided with heating coils and insulation. It is recommended that the viscosity is kept below 140 cSt in the day tanks. Due to risk of wax formation, fuels with a viscosity lower than 50 cSt at 50°C must be kept at a temperature higher than the viscosity would require. Continuous separation is nowadays common practice, which means that the HFO day tank temperature normally remains above 90°C.

The temperature in the MDF day tank should be in the range 20...40°C.

The level of the tank must ensure a positive static pressure on the suction side of the fuel feed pumps. If black-out starting with MDF from a gravity tank is foreseen, then the tank must be located at least 15 m above the engine crankshaft.

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

Clean leak fuel is drained by gravity from the engine. The fuel should be collected in a separate clean leak fuel tank, from where it can be pumped to the day tank and reused without separation. The pipes from the engine to the clean leak fuel tank should be arranged continuosly sloping. The tank and the pipes must be heated and insulated, unless the installation is designed for operation on MDF only.

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

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

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

#### Separator mode of operation

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

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

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

#### Separation efficiency

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

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

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

**where:**

$n$ = separation efficiency [%]

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

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

### 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

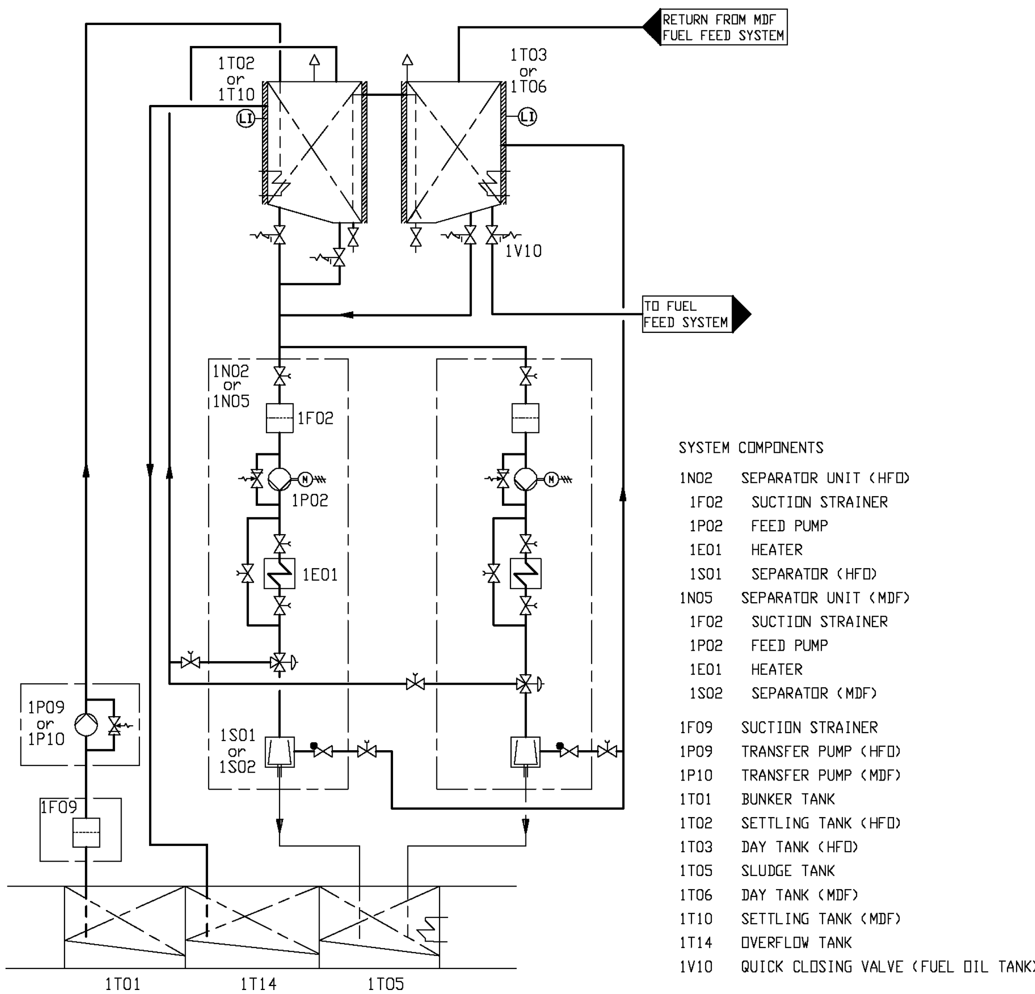



**Fig 6-13** **Fuel transfer and separating system (V76F6626F)**

### Separator feed pumps (1P02)

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

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

| **Design data:** | **HFO** | **MDF** |
|---|---|---|
| Design pressure | 0.5 MPa (5 bar) | 0.5 MPa (5 bar) |
| Design temperature | 100°C | 50°C |
| Viscosity for dimensioning electric motor | 1000 cSt | 100 cSt |

### Separator pre-heater (1E01)

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

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

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

The required minimum capacity of the heater is:

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

**where:**

P = heater capacity [kW]

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

ΔT = temperature rise in heater [°C]

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

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

### Separator (1S01/1S02)

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

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

**where:**

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

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

ρ = density of the fuel [kg/m$^3$]

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

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

Sample valves must be placed before and after the separator.

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

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

### 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.

## Fuel feed system - MDF installations

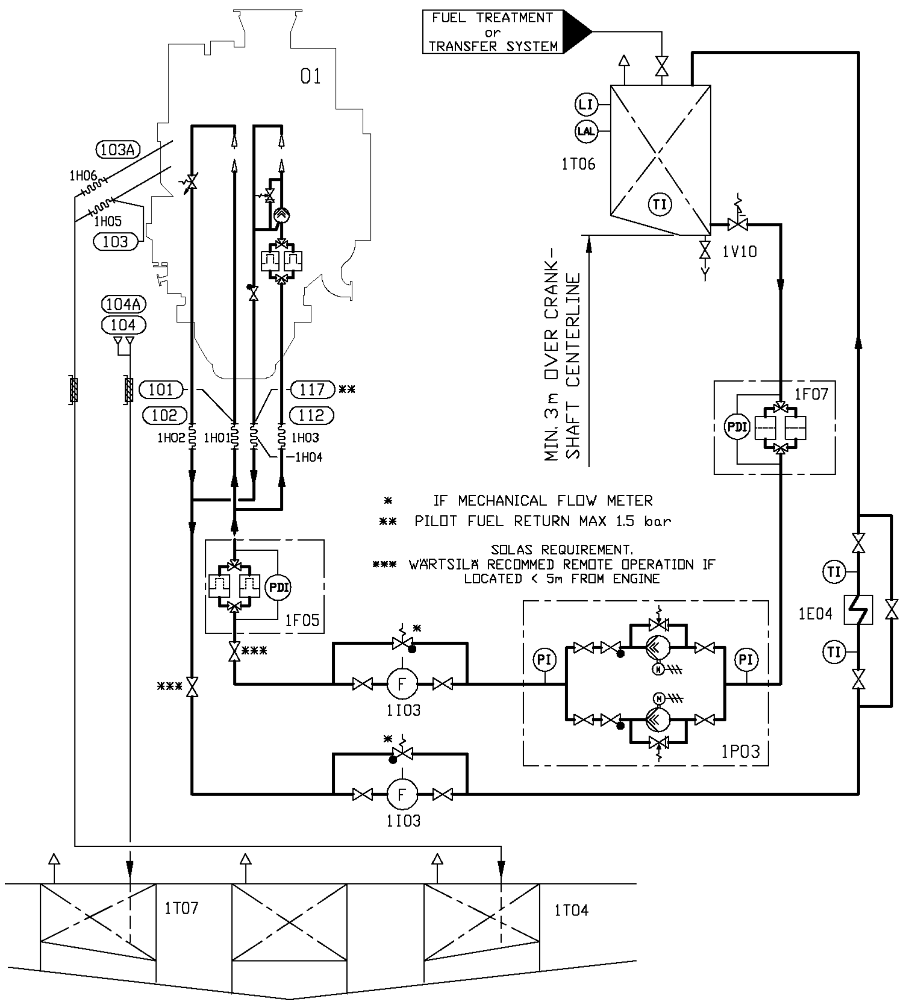



**Fig 6-14 Example of fuel feed system, single L-engine installation (DAAF335502)**

| System components: | | | |
|---|---|---|---|
| 01 | WL50DF | 1P03 | Circulation pump (MDF) |
| 1E04 | Cooler (MDF) | 1T04 | Leak fuel tank (clean fuel) |
| 1F05 | Fine filter (MDF) | 1T06 | Day tank (MDF) |
| 1F07 | Suction strainer (MDF) | 1T07 | Leak fuel tank (dirty fuel) |
| 1H0X | Flexible pipe connections | 1V10 | Quick closing valve (fuel oil tank) |
| 1I03 | Flowmeter (MDF) | | |

| Pipe connections | | Size | Pipe connections | | Size |
|---|---|---|---|---|---|
| 101 | Fuel inlet | DN32 | 104 | Leak fuel drain, dirty fuel | 2*OD48 |
| 102 | Fuel outlet | DN32 | 112 | Pilot fuel inlet | DN15 |
| 103 | Leak fuel drain, clean fuel | 2*OD28 | 117 | Pilot fuel outlet | DN15 |

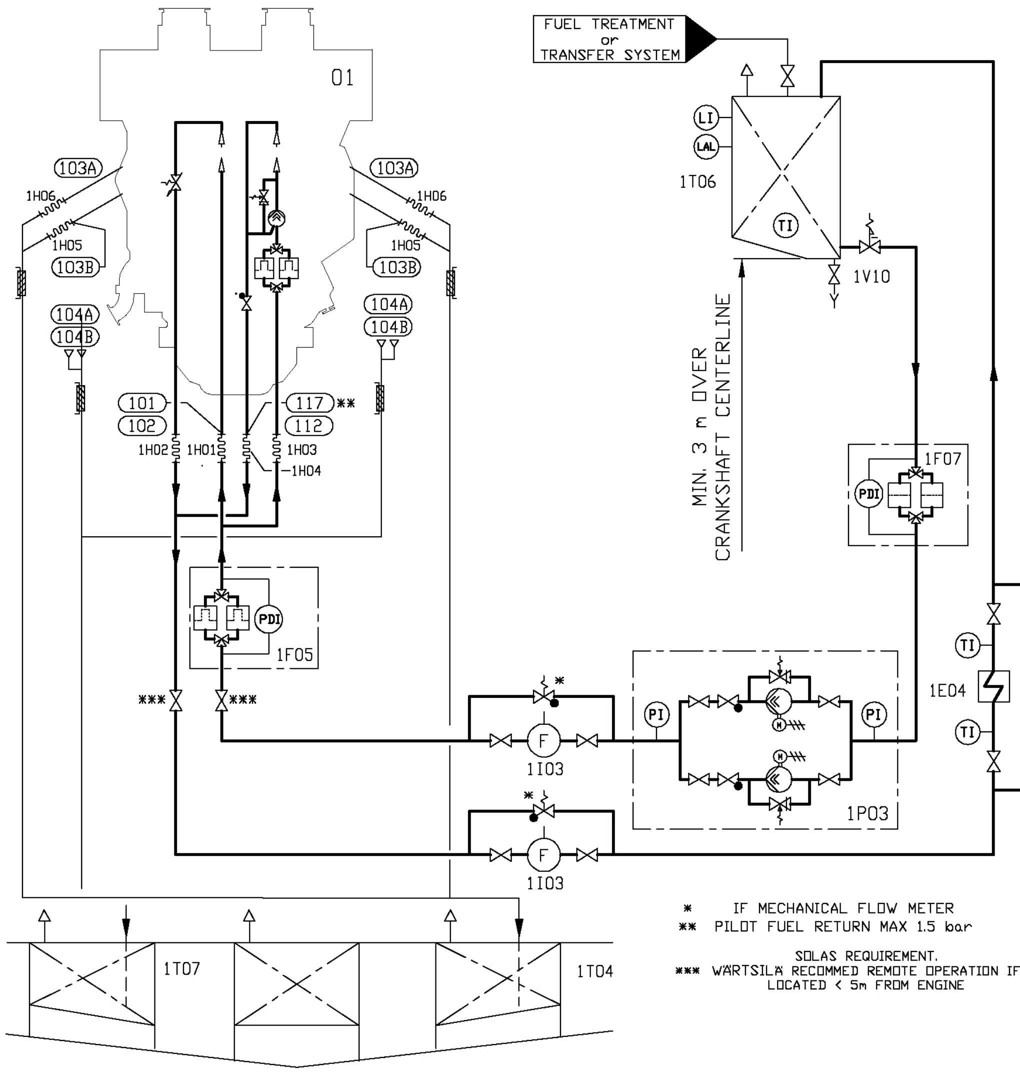



**Fig 6-15** **Example of fuel feed system, single V-engine installation (DAAF335503)**

| System components: | | | |
|---|---|---|---|
| 01 | WV50DF | 1P03 | Circulation pump (MDF) |
| 1E04 | Cooler (MDF) | 1T04 | Leak fuel tank (clean fuel) |
| 1F05 | Fine filter (MDF) | 1T06 | Day tank (MDF) |
| 1F07 | Suction strainer (MDF) | 1T07 | Leak fuel tank (dirty fuel) |
| 1H0X | Flexible pipe connections | 1V10 | Quick closing valve (fuel oil tank) |
| 1I03 | Flowmeter (MDF) | | |

| Pipe connections | | Size | Pipe connections | | Size |
|---|---|---|---|---|---|
| 101 | Fuel inlet | DN32 | 104 | Leak fuel drain, dirty fuel | 2*OD48 |
| 102 | Fuel outlet | DN32 | 112 | Pilot fuel inlet | DN15 |
| 103 | Leak fuel drain, clean fuel | 2*OD28 | 117 | Pilot fuel outlet | DN15 |

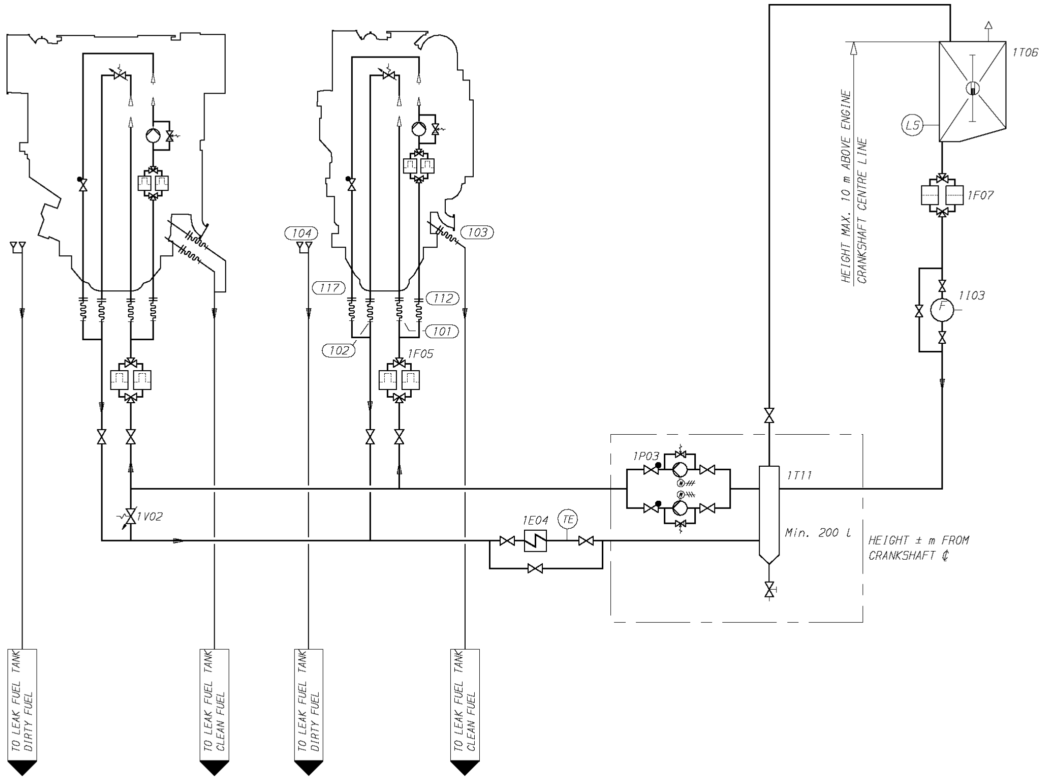



**Fig 6-16 Example of fuel feed system, multiple engine installation (DAAE015150D)**

| System components: | | | |
|---|---|---|---|
| 1E04 | Cooler (MDF) | 1P03 | Circulation pump (MDF) |
| 1F05 | Fine filter (MDF) | 1T06 | Day tank (MDF) |
| 1F07 | Suction strainer (MDF) | 1T11 | Mixing tank, min. 200 l |
| 1I03 | Flowmeter (MDF) | 1V02 | Pressure control valve (MDF) |

| Pipe connections: | | | |
|---|---|---|---|
| 101 | Fuel inlet | 104 | Leak fuel drain, dirty fuel |
| 102 | Fuel outlet | 112 | Pilot fuel inlet |
| 103 | Leak fuel drain, clean fuel | 117 | Pilot fuel outlet |

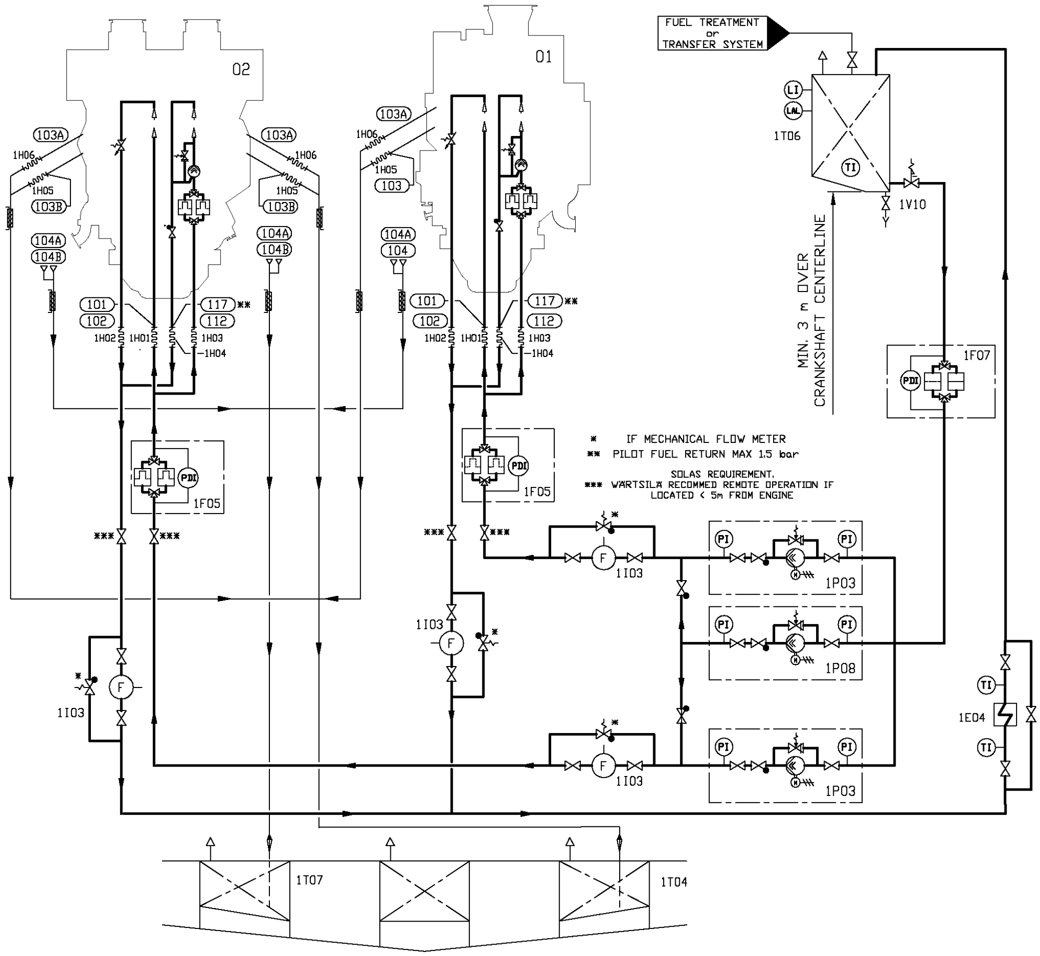



**Fig 6-17** **Example of fuel feed system, multiple engine with stand-by pump (DAAF335504)**

| System components: | | | |
|---|---|---|---|
| 01 | WL50DF | 1P03 | Circulation pump (MDF) |
| 02 | WV50DF | 1P08 | Stand-by pump (MDF) |
| 1E04 | Cooler (MDF) | 1T04 | Leak fuel tank (clean fuel) |
| 1F05 | Fine filter (MDF) | 1T06 | Day tank (MDF) |
| 1F07 | Suction strainer (MDF) | 1T07 | Leak fuel tank (dirty fuel) |
| 1H0X | Flexible pipe connections | 1V10 | Quick closing valve (dirty fuel) |
| 1I03 | Flowmeter (MDF) | | |

| Pipe connections | | V50DF | L50DF | Pipe connections | | V50DF | L50DF |
|---|---|---|---|---|---|---|---|
| 101 | Fuel inlet | DN32 | DN32 | 104 | Leak fuel drain, dirty fuel | 4*OD48 | 4*OD48 |
| 102 | Fuel outlet | DN32 | DN32 | 112 | Pilot fuel inlet | DN15 | DN15 |
| 103 | Leak fuel drain, clean fuel | 4*OD28 | 4*OD28 | 117 | Pilot fuel outlet | DN15 | DN15 |

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

## Circulation pump, MDF (1P03)

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

| **Design data:** | |
|---|---|
| Capacity | 4 x the total consumption of the connected engines and the flush quantity of a possible automatic filter |
| Design pressure | 1.6 MPa (16 bar) |
| Max. total pressure (safety valve) | 1.0 MPa (10 bar) |
| Nominal pressure | see chapter "*Technical Data*" |
| Design temperature | 50°C |
| Viscosity for dimensioning of electric motor | 90 cSt |

## Flow meter, MDF (1I03)

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

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

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

## Fine filter, MDF (1F05)

The fuel oil fine 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 | Larger than feed/circulation pump capacity |
| Design pressure | 1.6 MPa (16 bar) |
| Fineness | 37 μm (absolute mesh size) |
| | |
| Maximum permitted pressure drops at 14 cSt: | |
| - clean filter | 20 kPa (0.2 bar) |
| - alarm | 80 kPa (0.8 bar) |

### MDF cooler (1E04)

The fuel viscosity may not drop below the minimum value stated in *Technical data*. When operating on MDF, the practical consequence is that the fuel oil inlet temperature must be kept below 45°C. Very light fuel grades may require even lower temperature.

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

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

| **Design data:** | |
|---|---|
| Heat to be dissipated | 4 kW/cyl at full load and 0.5 kW/cyl at idle |
| Max. pressure drop, fuel oil | 80 kPa (0.8 bar) |
| Max. pressure drop, water | 60 kPa (0.6 bar) |
| Margin (heat rate, fouling) | min. 15% |
| Design temperature MDF/HFO installation | 50/150°C |

### Return fuel tank (1T13)

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

### Black out start

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

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

# Fuel feed system - HFO installations

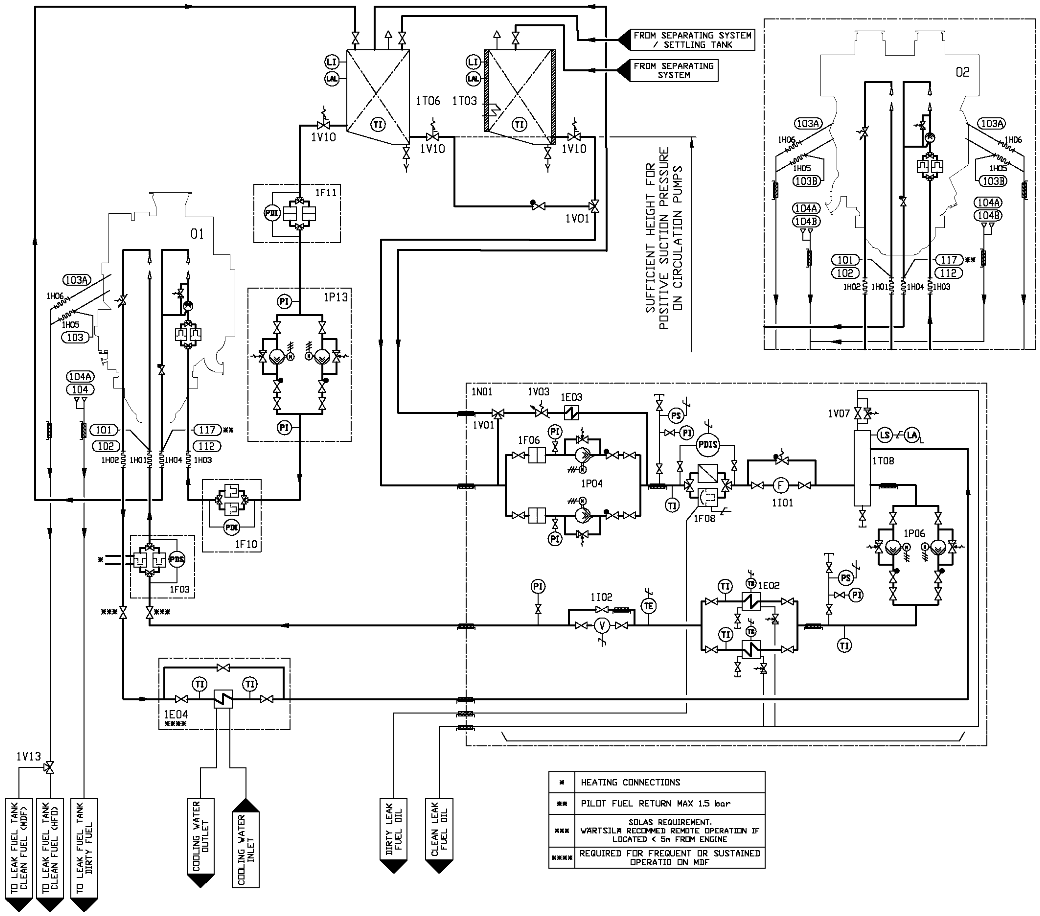



**Fig 6-18** **Example of fuel oil system (HFO), single main engine (DAAF335564)**

| System components: | | | |
|---|---|---|---|
| 01 | WL50DF | 1P04 | Fuel feed pump (booster unit) |
| 02 | WV50DF | 1P06 | Circulation pump (booster unit) |
| 1E02 | Heater (booster unit) | 1P13 | Pilot fuel feed pump (MDF) |
| 1E03 | Cooler (booster unit) | 1T03 | Day tank (HFO) |
| 1E04 | Cooler (MDF) | 1T06 | Day tank (MDF) |
| 1F03 | Safety filter (HFO) | 1T08 | De-aeration tank (booster unit) |
| 1F06 | Suction filter (booster unit) | 1V01 | Changeover valve |
| 1F08 | Automatic filter (booster unit) | 1V03 | Pressure control valve (booster unit) |
| 1F10 | Pilot fuel fine filter (MDF) | 1V07 | Venting valve (booster unit) |
| 1I01 | Flow meter (booster unit) | 1V10 | Quick closing valve (fuel oil tank) |
| 1I02 | Viscosity meter (booster unit) | 1V13 | Change over valve for leak fuel |
| 1N01 | Feeder/booster unit | | |

| Pipe connections | | V50DF | L50DF | Pipe connections | | V50DF | L50DF |
|---|---|---|---|---|---|---|---|
| 101 | Fuel inlet | DN32 | DN32 | 104 | Leak fuel drain, dirty fuel | 4*OD48 | 4*OD48 |
| 102 | Fuel outlet | DN32 | DN32 | 112 | Pilot fuel inlet | DN15 | DN15 |
| 103 | Leak fuel drain, clean fuel | 4*OD28 | 4*OD28 | 117 | Pilot fuel outlet | DN15 | DN15 |

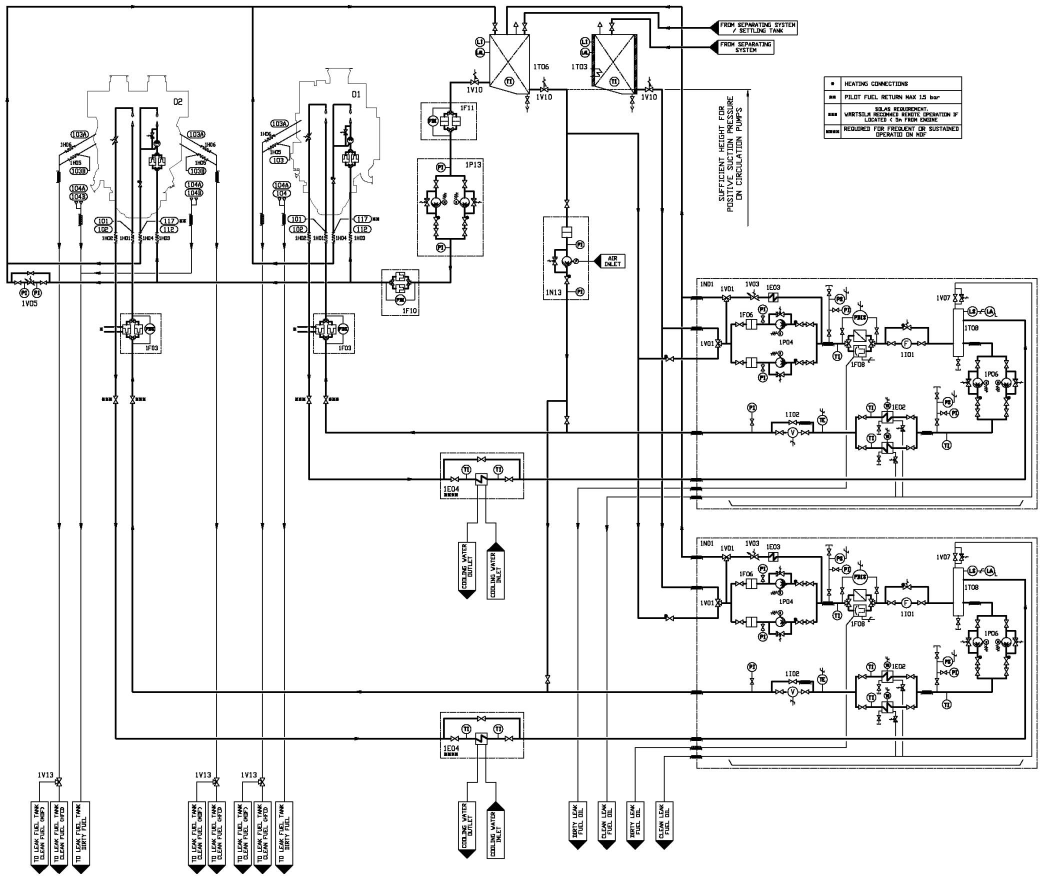
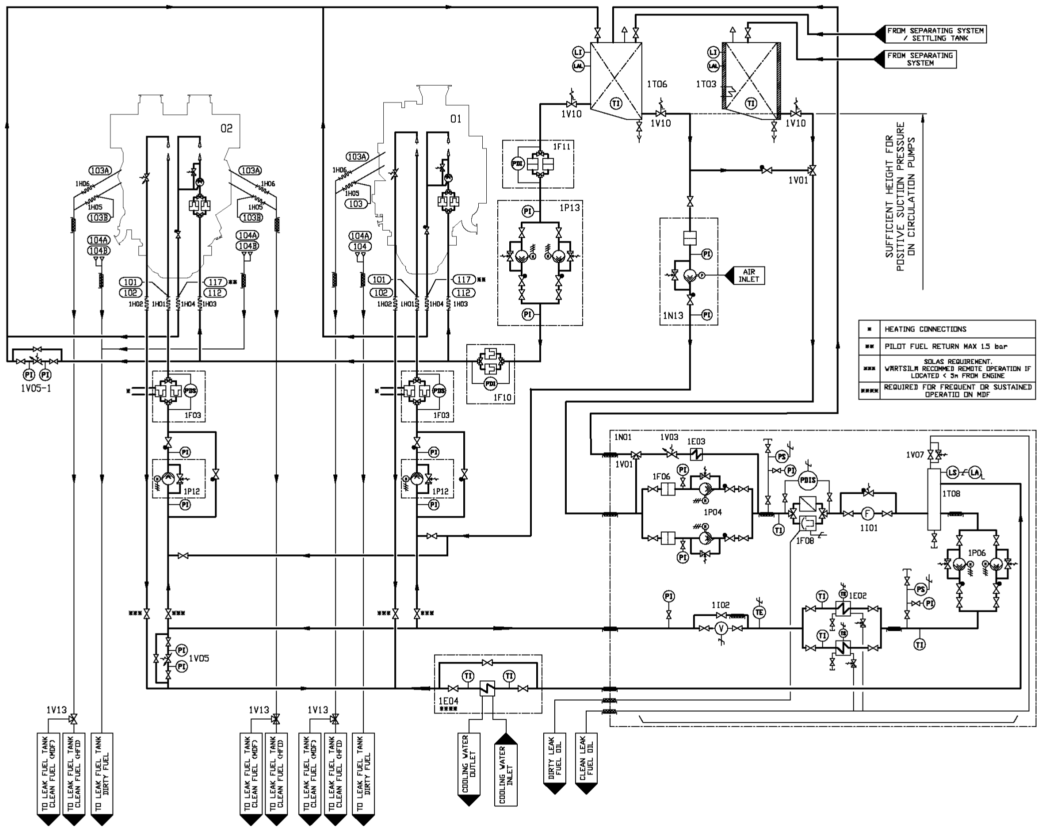


**Fig 6-19 Example of fuel oil system (HFO), separate booster units (DAAF335565)**

| System components: | | | |
|---|---|---|---|
| 01 | WL50DF | 1N13 | Black start fuel oil pump unit |
| 02 | WV50DF | 1P04 | Fuel feed pump (booster unit) |
| 1E02 | Heater (booster unit) | 1P06 | Circulation pump (booster unit) |
| 1E03 | Cooler (booster unit) | 1P13 | Pilot fuel feed pump (MDF) |
| 1E04 | Cooler (MDF) | 1T03 | Day tank (HFO) |
| 1F03 | Safety filter (HFO) | 1T06 | Day tank (MDF) |
| 1F06 | Suction filter (booster unit) | 1T08 | De-aeration tank (booster unit) |
| 1F08 | Automatic filter (booster unit) | 1V01 | Changeover valve |
| 1F10 | Pilot fuel fine filter (MDF) | 1V03 | Pressure control valve (booster unit) |
| 1F11 | Suction strainer for pilot fuel (MDF) | 1V05 | Overflow valve (HFO/MDF) |
| 1H0X | Flexible pipe connections | 1V07 | Venting valve (booster unit) |
| 1I01 | Flow meter (booster unit) | 1V10 | Quick closing valve (fuel oil tank) |
| 1I02 | Viscosity meter (booster unit) | 1V13 | Change over valve for leak fuel |
| 1N01 | Feeder/booster unit | | |

| Pipe connections | | V50DF | L50DF | Pipe connections | | V50DF | L50DF |
|---|---|---|---|---|---|---|---|
| 101 | Fuel inlet | DN32 | DN32 | 104 | Leak fuel drain, dirty fuel | 4*OD48 | 4*OD48 |
| 102 | Fuel outlet | DN32 | DN32 | 112 | Pilot fuel inlet | DN15 | DN15 |
| 103 | Leak fuel drain, clean fuel | 4*OD28 | 4*OD28 | 117 | Pilot fuel outlet | DN15 | DN15 |




## Fig 6-20 Example of fuel oil system (HFO), one booster unit (DAAF335566)

| System components: | | | |
|---|---|---|---|
| 01 | WL50DF | 1N13 | Black start fuel oil pump unit |
| 02 | WV50DF | 1P04 | Fuel feed pump (booster unit) |
| 1E02 | Heater (booster unit) | 1P06 | Circulation pump (booster unit) |
| 1E03 | Cooler (booster unit) | 1P13 | Pilot fuel feed pump (MDF) |
| 1E04 | Cooler (MDF) | 1T03 | Day tank (HFO) |
| 1F03 | Safety filter (HFO) | 1T06 | Day tank (MDF) |
| 1F06 | Suction filter (booster unit) | 1T08 | De-aeration tank (booster unit) |
| 1F08 | Automatic filter (booster unit) | 1V01 | Changeover valve |
| 1F10 | Pilot fuel fine filter (MDF) | 1V03 | Pressure control valve (booster unit) |
| 1F11 | Suction strainer for pilot fuel (MDF) | 1V05 | Overflow valve (HFO/MDF) |
| 1H0X | Flexible pipe connections | 1V05-1 | Overflow valve (HFO/MDF) |
| 1I01 | Flow meter (booster unit) | 1V07 | Venting valve (booster unit) |
| 1I02 | Viscosity meter (booster unit) | 1V10 | Quick closing valve (fuel oil tank) |
| 1N01 | Feeder/booster unit | 1V13 | Change over valve for leak fuel |

| Pipe connections | | V50DF | L50DF | Pipe connections | | V50DF | L50DF |
|---|---|---|---|---|---|---|---|
| 101 | Fuel inlet | DN32 | DN32 | 104 | Leak fuel drain, dirty fuel | 4*OD48 | 4*OD48 |
| 102 | Fuel outlet | DN32 | DN32 | 112 | Pilot fuel inlet | DN15 | DN15 |
| 103 | Leak fuel drain, clean fuel | 4*OD28 | 4*OD28 | 117 | Pilot fuel outlet | DN15 | DN15 |

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 sha ll be possible to shut off the heating of the pipes when operating on MDF (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 MDF for start and stop is not required.

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

### Changeover from HFO to MDF

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

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

### Number of engines in the same system

When the fuel feed unit serves Wärtsilä 50DF 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.

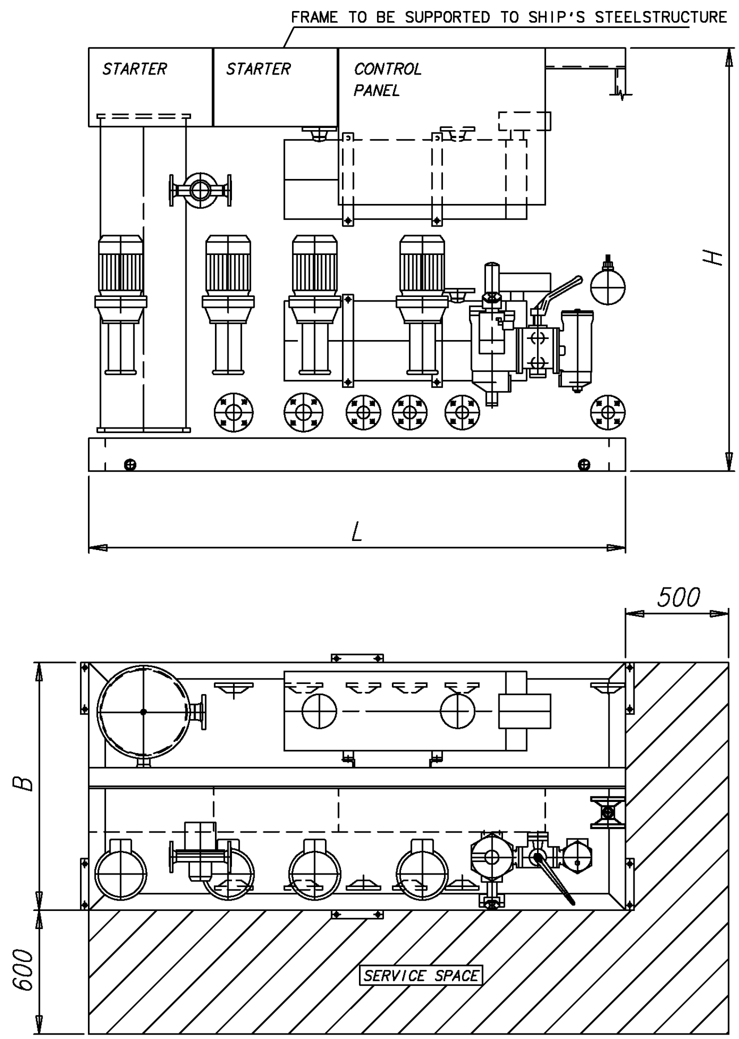
### Feeder/booster unit (1N01)

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 by-pass filter
- One viscosimeter for control of the heaters

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

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




| | H | L | B |
|---|---|---|---|
| STEAM | 1800 | 2500 | 1100 |
| ELECTRICAL | 2050 | 2600 | 1200 |

All dimensions in mm.

**Fig 6-21 Feeder/booster unit, example (DAAE006659)**

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

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

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

**Design data:**

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

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

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

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

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

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

| Design data: | |
|---|---|
| Fuel viscosity | According to fuel specification |
| Design temperature | 100°C |
| Preheating | If fuel viscosity is higher than 25 cSt/100°C |
| Design flow | Equal to feed pump capacity |
| Design pressure | 1.6 MPa (16 bar) |
| Fineness: | |
| - automatic filter | 35 μm (absolute mesh size) |
| - by-pass filter | 35 μm (absolute mesh size) |

| 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 the chapter *Technical data*. By circulating the fuel in the system it also maintains correct viscosity, and keeps the piping and the injection pumps at operating temperature.

| **Design data:** | |
|---|---|
| Capacity: | |
| - without circulation pumps (1P12) | 4 x the total consumption of the connected engines |
| - with circulation pumps (1P12) | 15% more than total capacity of all circulation pumps |
| Design pressure | 1.6 MPa (16 bar) |
| Max. total pressure (safety valve) | 1.0 MPa (10 bar) |
| Design temperature | 150°C |
| Viscosity for dimensioning of electric motor | 500 cSt |

### Heater, booster unit (1E02)

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

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

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

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

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

**where:**

P = heater capacity (kW)

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

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

| Design data: | |
|---|---|
| Capacity | 4 x the fuel consumption of the engine |
| Design pressure | 1.6 MPa (16 bar) |
| Max. total pressure (safety valve) | 1.0 MPa (10 bar) |
| Design temperature | 150°C |
| Pressure for dimensioning of electric motor (ΔP): | |
| - if MDF is fed directly from day tank | 0.7 MPa (7 bar) |
| - if all fuel is fed through feeder/booster unit | 0.3 MPa (3 bar) |
| Viscosity for dimensioning of electric motor | 500 cSt |

### Safety filter (1F03)

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

| Design data: | |
|---|---|
| Fuel viscosity | according to fuel specification |
| Design temperature | 150°C |
| Design flow | Equal to circulation pump capacity |

| | |
|---|---|
| Design pressure | 1.6 MPa (16 bar) |
| Filter fineness | 37 µm (absolute mesh size) |
| 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 |

### Pilot fuel feed pump, MDF (1P13)

The pilot fuel feed pump is needed in HFO installations. The pump feed the engine with MDF fuel to the pilot fuel system. No HFO is allowed to enter the pilot fuel system.

It is recommended to use a screw pump as circulation pump. A suction strainer with a fineness of 0.5 mm should be installed before each pump. There must be a positive static pressure of about 30 kPa on the suction side of the pump.

| **Design data:** | |
|---|---|
| Capacity | 1 $m^3$/h per engine |
| Design pressure | 1.6 MPa (16 bar) |
| Max. total pressure (safety valve) | 1.0 MPa (10 bar) |
| Nominal pressure | see chapter "*Technical Data*" |
| Design temperature | 50°C |
| Viscosity for dimensioning of electric motor | 90 cSt |

## 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, as shown in the table below. BN is an abbreviation of Base Number. The value indicates milligrams KOH per gram of oil.

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

| Category | Fuel standard | | Lubricating oil BN | Fuel S content, [% m/m] |
|---|---|---|---|---|
| A | ASTM D 975-01,<br>BS MA 100: 1996<br>CIMAC 2003<br>ISO 8217: 2012(E) | GRADE 1-D, 2-D, 4-D<br>DMX, DMA, DMB<br>DX, DA, DB<br>ISO-F-DMX - DMB | 10...20 | 0.4 |
| B | ASTM D 975-01<br>BS MA 100: 1996<br>CIMAC 2003<br>ISO 8217: 2012(E) | GRADE 1-D, 2-D, 4-D<br>DMX, DMA, DMB<br>DX, DA, DB<br>ISO-F-DMX - DMB | 15...20 | 0.4 - 2.0 |
| C | LIQUID BIO FUEL (LBF) | | 10...20 | 0.05 |

If gas oil or MDF 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 MDF, 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 975-01<br>ASTM D 396-04,<br>BS MA 100: 1996<br>CIMAC 2003,<br>ISO 8217: 2012 (E) | GRADE NO. 4D<br>GRADE NO. 5-6<br>DMC, RMA10-RMK55<br>DC, A30-K700<br>RMA10-RMK700 | 30...55 | 4.5 |

In installation where engines are running periodically with different fuel qualities, i.e. natural gas, MDF 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 Catalyctic 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.

It is not harmful to the engine to use a higher BN than recommended for the fuel grade.

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

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

### 7.1.2 Oil in speed governor or actuator

An oil of viscosity class SAE 30 or SAE 40 is acceptable in normal operating conditions. Usually the same oil as in the engine can be used. At low ambient temperatures it may be necessary to use a multigrade oil (e.g. SAE 5W-40) to ensure proper operation during start-up with cold oil.

### 7.1.3 Oil in turning device

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

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

# 7.2 Internal lubricating oil system

## 7.2.1 Internal LO system, in-line engines

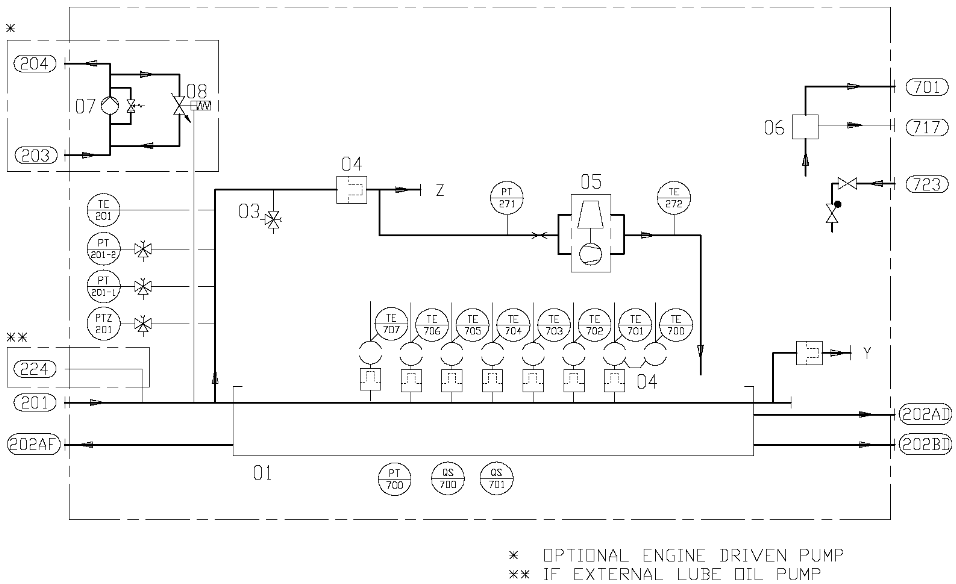


**Fig 7-1 Internal lubricating oil system, in-line engines (3V69E8745-2i)**

| System components: | | | | | |
|---|---|---|---|---|---|
| 01 | Oil sump | 05 | Turbocharger | 07 | Lubricating oil main pump |
| 03 | Sampling cock | 06 | Crankcase breather | 08 | Pressure control valve |
| 04 | Running-in filter 1) | | | | |
| 1) *To be removed after commisioning* | | | | | |

| Sensors and indicators | | | |
|---|---|---|---|
| PTZ201 | Lubricating oil inlet pressure | TE272 | Lubricating oil temperature after turbocharger |
| PT201-1 | Lubricating oil inlet pressure | PT700 | Crankcase pressure |
| PT201-2 | Lubricating oil inlet pressure, backup | QS700 | Oil mist in crankcase, alarm |
| TE201 | Lubricating oil inlet temperature | QS701 | Oil mist in crankcase, shutdown |
| PT271 | Lubricating oil before turbocharger pressure | TE700... | Main bearing temperature |

| Pipe connections | | Size | Pressure class | Standard |
|---|---|---|---|---|
| 201 | Lubricating oil inlet (to manifold) | DN125 | PN16 | ISO 7005-1 |
| 202AD | Lubricating oil outlet (from oil sump), D.E. | DN200 | PN10 | ISO 7005-1 |
| 202AF | Lubricating oil outlet (from oil sump), F.E. | DN200 | PN10 | ISO 7005-1 |
| 202BD | Lubricating oil outlet (from oil sump), D.E. | DN200 | PN10 | ISO 7005-1 |
| 203 | Lubricating oil to engine driven pump | DN250 | PN10 | ISO 7005-1 |
| 204 | Lubricating oil from engine driven pump | DN150 | PN16 | ISO 7005-1 |
| 224 | Control oil to lube oil pressure control valve<br>(if external lube oil pump) | M18 x 1.5 | | |
| 701 | Crankcase air vent | 6, 8L: OD114<br>9L: OD140 | | DIN 2353 |
| 717 | Crankcase breather drain | - | | |
| 723 | Inert gas inlet (option) | DN50 | PN40 | ISO 7005-1 |

## 7.2.2 Internal LO system, V-engines

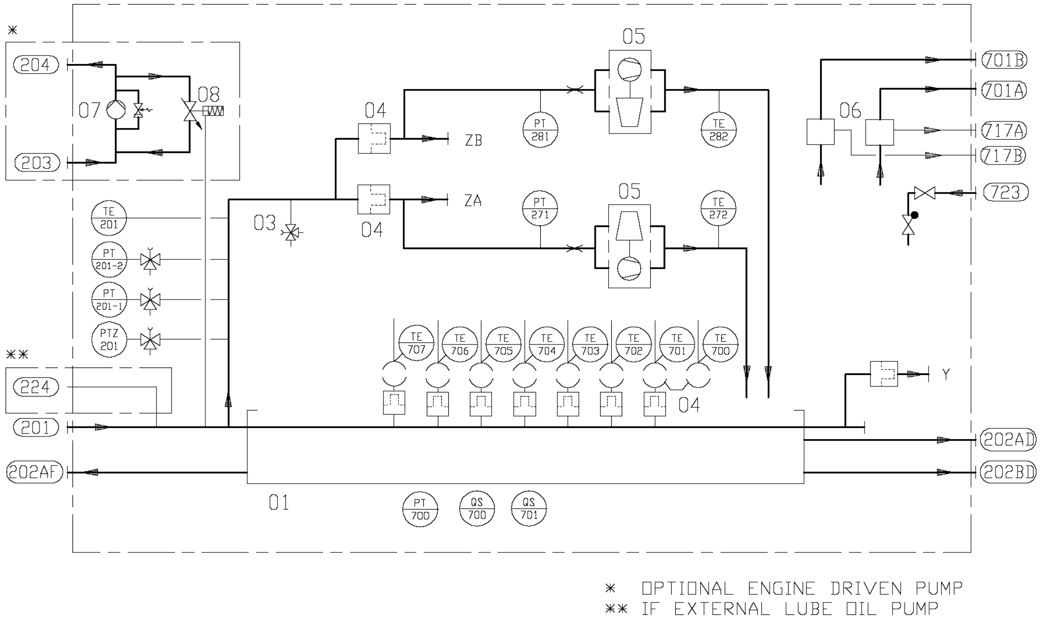


**Fig 7-2 Internal lubricating oil system, V-engines (3V69E8746-2h)**

| System components: | | | | | |
|---|---|---|---|---|---|
| 01 | Oil sump | 05 | Turbocharger | 07 | Lubricating oil main pump |
| 03 | Sampling cock | 06 | Crankcase breather | 08 | Pressure control valve |
| 04 | Running-in filter 1) | | | | |
| 1) *To be removed after commisioning* | | | | | |

| Sensors and indicators: | | | |
|---|---|---|---|
| PTZ201 | Lubricating oil inlet pressure | PT281 | Lube oil before turbocharger pressure, B-bank |
| PT201-1 | Lubricating oil inlet pressure | TE282 | Lube oil temperature after turbocharger, B-bank |
| PT201-2 | Lubricating oil inlet pressure, backup | PT700 | Crankcase pressure |
| TE201 | Lube oil inlet temperature | QS700 | Oil mist in crankcase, alarm |
| PT271 | Lube oil before turbocharger pressure, A-bank | QS701 | Oil mist in crankcase, shutdown |
| TE272 | Lube oil temp after turbocharger, A-bank | TE700... | Main bearing temperature |

| Pipe connections | | Size | Pressure class | Standard |
|---|---|---|---|---|
| 201 | Lubricating oil inlet (to manifold) | DN200 | PN10 | ISO 7005-1 |
| 202AD | Lubricating oil outlet (from oil sump), D.E. | DN250 | PN10 | ISO 7005-1 |
| 202AF | Lubricating oil outlet (from oil sump), F.E. | DN250 | PN10 | ISO 7005-1 |
| 202BD | Lubricating oil outlet (from oil sump), D.E. | DN250 | PN10 | ISO 7005-1 |
| 203 | Lubricating oil to engine driven pump | DN300 | PN10 | ISO 7005-1 |
| 204 | Lubricating oil from engine driven pump | DN200 | PN10 | ISO 7005-1 |
| 224 | Control oil to lube oil pressure control valve (if external lube oil pump) | M18 x 1.5 | | |
| 701A/B | Crankcase air vent, A-bank | 12, 16V: OD114 18V: OD140 | | DIN 2353 |
| 717A/B | Crankcase breather drain | - | | |
| 723 | Inert gas inlet | DN50 | PN40 | ISO 7005-1 |

The oil sump is of dry sump type. There are two oil outlets at each end of the engine. One outlet at the free end and both outlets at the driving end must be connected to the system oil tank.

The direct driven lubricating oil pump is of screw type and is equipped with a pressure control valve. Concerning suction height, flow rate and pressure of the engine driven pump, *see Technical Data*.

All engines are delivered with a running-in filter before each main bearing, before the turbocharger and before the intermediate gears. These filters are to be removed after commissioning.

## 7.3 External lubricating oil system

### 7.3.1 External LO system with engine driven pumps

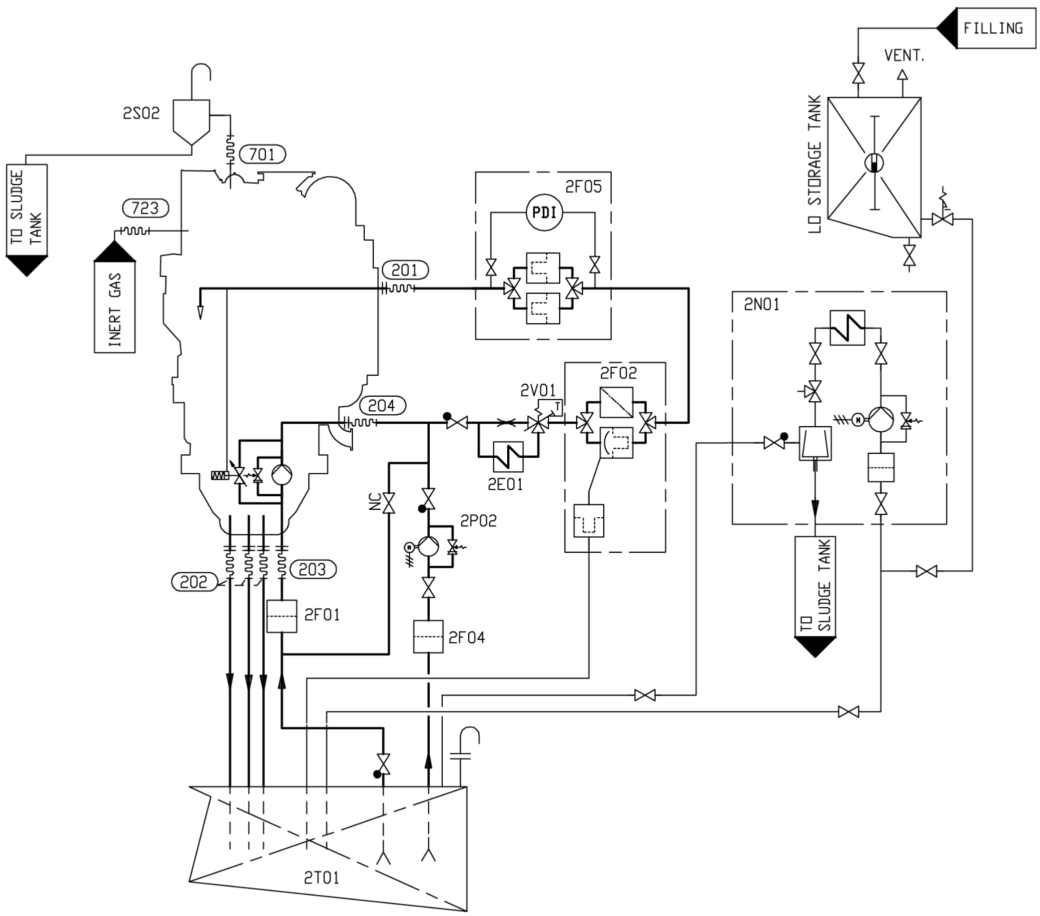


**Fig 7-3** **Example of lubricating oil system, with engine driven pumps (DAAE021746B)**

| System components: | | | |
|---|---|---|---|
| 2E01 | Lubricating oil cooler | 2N01 | Separator unit |
| 2F01 | Suction strainer (main lubricating oil pump) | 2P02 | Prelubricating oil pump |
| 2F02 | Automatic filter | 2S02 | Condensate trap |
| 2F04 | Suction strainer (pre lubricating oil pump) | 2T01 | System oil tank |
| 2F05 | Safety filter (LO) | 2V01 | Temperature control valve |

| Pipe connections: | | L50DF | V50DF | Notes |
|---|---|---|---|---|
| 201 | Lubricating oil inlet | DN125 | DN200 | |
| 202 | Lubricating oil outlet | DN200 | DN250 | |
| 203 | Lubricating oil to engine driven pump | DN250 | DN300 | 9L50DF: DN300 |
| 204 | Lubricating oil from engine driven pump | DN150 | DN200 | 9L50DF: DN200 |
| 701 | Crankcase air vent | OD114 | 2 * OD114 | |
| 723 | Inert gas inlet (optional) | DN50 | DN50 | |

## 7.3.2 External LO system without engine driven pumps

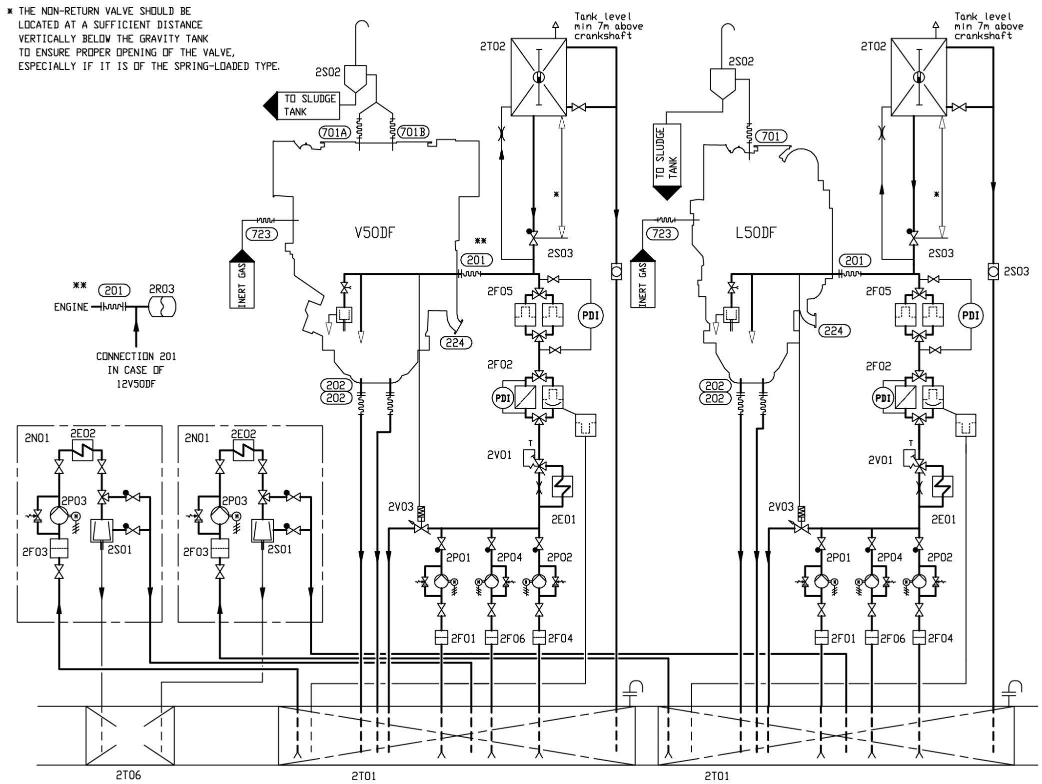


**Fig 7-4** **Example of lubricating oil system, without engine driven pumps (DAAF001973A)**

| System components: | | | |
|---|---|---|---|
| 2E01 | Lubricating oil cooler | 2P03 | Separator pump (separator unit) |
| 2E02 | Heater (separator unit) | 2P04 | Stand-by pump |
| 2F01 | Suction strainer (main lubricating oil pump) | 2R03 | Lubricating oil damper |
| 2F02 | Automatic filter | 2S01 | Separator |
| 2F03 | Suction filter (separator unit) | 2S02 | Condensate trap |
| 2F04 | Suction strainer (pre lubricating oil pump) | 2S03 | Sight glass |
| 2F05 | Safety filter (LO) | 2T01 | System oil tank |
| 2F06 | Suction strainer (stand-by pump) | 2T02 | Gravity tank |
| 2N01 | Separator unit | 2T06 | Sludge tank |
| 2P01 | Main lubricating oil pump | 2V01 | Temperature control valve |
| 2P02 | Pre lubricating oil pump | 2V03 | Pressure control valve |

| Pipe connections: | | L50DF | V50DF |
|---|---|---|---|
| 201 | Lubricating oil inlet | DN125 | |
| 202 | Lubricating oil outlet 1) | DN200 | |
| 224 | Control oil to lube oil pressure control valve | M18*1.5 | |
| 701 | Crankcase air vent | OD114 | |
| 723 | Inert gas inlet | DN50 | |

*1) Two outlets in each end are available, outlets to be used:*
*6L, 12V: FE 1, DE 1*
*8L, 9L, 16V, 18V: FE 1, DE 2*

## 7.3.3 Separation system

### Separator unit (2N01)

Each main engine must have a dedicated lubricating oil separator and the separators shall be dimensioned for continuous separating. If the installation is designed to operate on gas/MDF only, then intermittent separating might be sufficient.

Two engines may have a common lubricating oil separator unit, if the engines operate on gas/MDF. In installations with four or more engines two lubricating oil separator units should be installed. In installations where HFO is used as fuel, each engine has to have a dedicated lubricating oil separator.

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.

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 = number of through-flows of tank volume per day: 5 for HFO, 4 for MDF

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

### Sludge tank (2T06)

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

## 7.3.4 System oil tank (2T01)

Recommended oil tank volume is stated in chapter *Technical data.*

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

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

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

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

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

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

Fuel gas in the crankcase is soluble in very small portions into lubricating oil. Therefore, it is possible that small amounts of fuel gas may be carried with lubricating oil into the DF-engine system oil tank and evaporate there in the free space above the oil level. Therefore, the system oil tank has to be of the closed-top type. The DF-engine system oil tank has to be treated similarly to the gas pipe ventilation or crankcase ventilation. Openings into open air from the system oil tank other than the breather pipe have to be either closed or of a type that does not allow fuel gas to exit the tank (e.g. overflow pipe arrangement with water lock). The system oil tank breathing pipes of engines located in the same engine room must not be combined.

The structure and the arrangement of the system oil tank may need to be approved by a Classification Society project-specifically. Any instrumentation installed in the system oil tank has to be certified Ex apparatus.

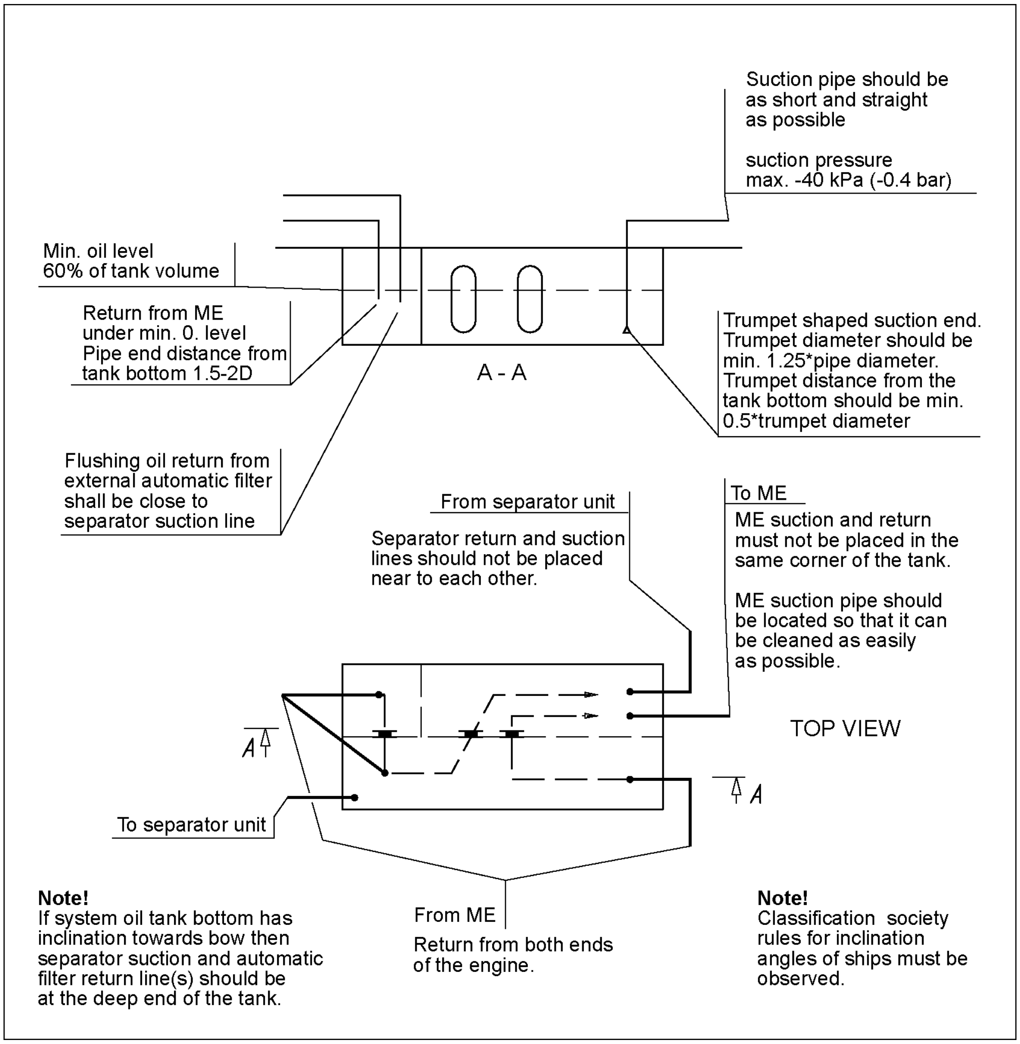


**Fig 7-5 Example of system oil tank arrangement (DAAE007020e)**

| **Design data:** | |
|---|---|
| Oil tank volume | 1.2...1.5 l/kW, see also *Technical data* |
| Oil level at service | 75...80% of tank volume |
| Oil level alarm | 60% of tank volume |

## 7.3.5 Gravity tank (2T02)

In installations without engine driven pump it is required to have a lubricating oil gravity tank, to ensure some lubrication during the time it takes for the engine to stop rotating in a blackout situation.

The required height of the tank is about 7 meters above the crankshaft. A minimum pressure of 50 kPa (0.5 bar) must be measured at the inlet to the engine.

| Engine type | Tank volume [$m^3$] |
|---|---|
| 6L50DF | 1.0 |
| 8L-, 9L-, 12V50DF | 2.0 |

| | |
|---|---|
| 16-, 18V50DF | 3.0 |

## 7.3.6 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 |

## 7.3.7 Pre-lubricating oil pump (2P02)

The pre-lubricating oil pump is a separately installed scew or gear pump, which is to be equipped with a safety valve.

The installation of a pre-lubricating pump is mandatory. An electrically driven main pump or standby pump (with full pressure) may not be used instead of a dedicated pre-lubricating pump, as the maximum permitted pressure is 200 kPa (2 bar) to avoid leakage through the labyrinth seal in the turbocharger (not a problem when the engine is running). A two speed electric motor for a main or standby pump is not accepted.

The piping shall be arranged so that the pre-lubricating oil pump fills the main oil pump, when the main pump is engine driven.

The pre-lubricating pump should always be running, when the engine is stopped.

Depending on the foreseen oil temperature after a long stop, the suction ability of the pump and the geometric suction height must be specially considered with regards to high viscosity. With cold oil the pressure at the pump will reach the relief pressure of the safety valve.

| **Design data:** | |
|---|---|
| Capacity | see *Technical data* |
| Design pressure | 1.0 MPa (10 bar) |
| Max. pressure (safety valve) | 350 kPa (3.5 bar) |
| Design temperature | 100°C |
| Viscosity for dimensioning of the electric motor | 500 cSt |

## 7.3.8 Lubricating oil cooler (2E01)

The external lubricating oil cooler can be of plate or tube type.

For calculation of the pressure drop a viscosity of 50 cSt at 60°C can be used (SAE 40, VI 95).

| **Design data:** | |
|---|---|
| Oil flow through cooler | see *Technical data, "Oil flow through engine"* |
| Heat to be dissipated | see *Technical data* |
| Max. pressure drop, oil | 80 kPa (0.8 bar) |
| Water flow through cooler | see *Technical data, "LT-pump capacity"* |
| Max. pressure drop, water | 60 kPa (0.6 bar) |

| | |
|---|---|
| Water temperature before cooler | 45°C |
| Oil temperature before engine | 63°C |
| Design pressure | 1.0 MPa (10 bar) |
| Margin (heat rate, fouling) | min. 15% |

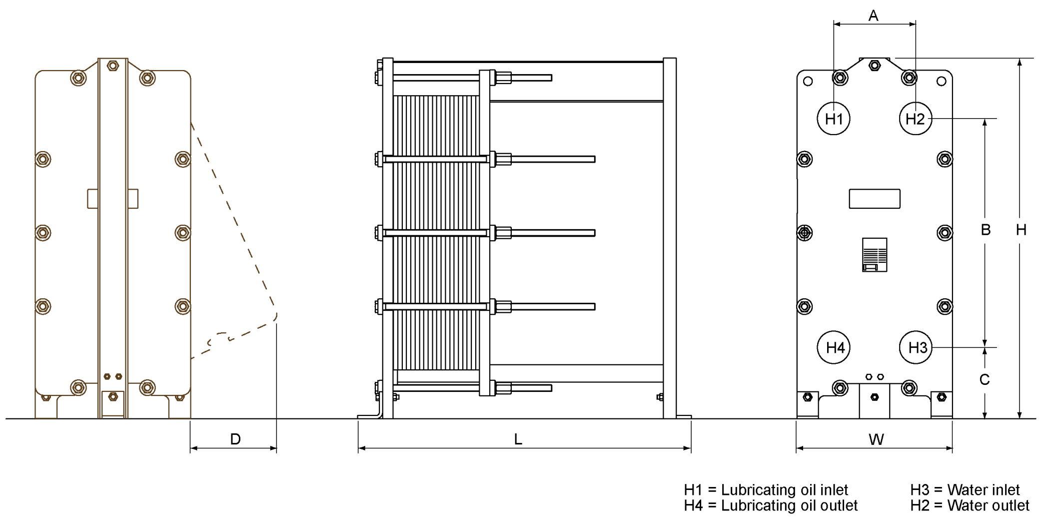


**Fig 7-6 Main dimensions of the lubricating oil cooler**

| Engine | Weight, dry [kg] | Dimensions [mm] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | H | W | L | A | B | C | D |
| W 6L50DF | 1180 | 1675 | 720 | 1237 | 380 | 1057 | 330 | 300 |
| W 8L50DF | 1220 | 1675 | 720 | 1237 | 380 | 1057 | 330 | 300 |
| W 9L50DF | 1250 | 1675 | 720 | 1487 | 380 | 1057 | 330 | 300 |
| W 12V50DF | 1390 | 1675 | 720 | 1737 | 380 | 1057 | 330 | 300 |
| W 16V50DF | 1560 | 1675 | 720 | 1987 | 380 | 1057 | 330 | 300 |
| W 18V50DF | 2150 | 1937 | 877 | 1534 | 465 | 1290 | 330 | 400 |

**NOTE**

These dimensions are for guidance only.

## 7.3.9 Temperature control valve (2V01)

The temperature control valve maintains desired oil temperature at the engine inlet, by directing part of the oil flow through the bypass line instead of through the cooler.

When using a temperature control valve with wax elements, the set-point of the valve must be such that 63°C at the engine inlet is not exceeded. This means that the set-point should be e.g. 57°C, in which case the valve starts to open at 54°C and at 63°C it is fully open. If selecting a temperature control valve with wax elements that has a set-point of 63°C, the valve may not be fully open until the oil temperature is e.g. 68°C, which is too high for the engine at full load.

A viscosity of 50 cSt at 60°C can be used for evaluation of the pressure drop (SAE 40, VI 95).

| **Design data:** | |
|---|---|
| Temperature before engine, nom | 63°C |
| Design pressure | 1.0 MPa (10 bar) |
| Pressure drop, max | 50 kPa (0.5 bar) |

## 7.3.10 Automatic filter (2F02)

It is recommended to select an automatic filter with an insert filter in the bypass line, thus enabling easy changeover to the insert filter during maintenance of the automatic filter. The backflushing oil must be filtered before it is conducted back to the system oil tank. The backflushing filter can be either integrated in the automatic filter or separate.

Automatic filters are commonly equipped with an integrated safety filter. However, some automatic filter types, especially automatic filter designed for high flows, may not have the safety filter built-in. In such case a separate safety filter (2F05) must be installed before the engine.

| **Design data:** | |
|---|---|
| Oil viscosity | 50 cSt (SAE 40, VI 95, appox. 63°C) |
| Design flow | see *Technical data, "Oil flow through engine"* |
| Design temperature | 100°C |
| Design pressure | 1.0 MPa (10 bar) |
| Fineness: | |
| - automatic filter | 35 µm (absolute mesh size) |
| - insert filter | 35 µm (absolute mesh size) |
| Max permitted pressure drops at 50 cSt: | |
| - clean filter | 30 kPa (0.3 bar ) |
| - alarm | 80 kPa (0.8 bar) |

## 7.3.11 Safety filter (2F05)

A separate safety filter (2F05) must be installed before the engine, unless it is integrated in the automatic filter. The safety filter (2F05) should be a duplex filter with steelnet filter elements.

| **Design data:** | |
|---|---|
| Oil viscosity | 50 cSt (SAE 40, VI 95, appox. 63°C) |
| Design flow | see *Technical data, "Oil flow through engine"* |
| Design temperature | 100 °C |
| Design pressure | 1.0 MPa (10 bar) |
| Fineness (absolute) max. | 60 µm (absolute mesh size) |
| Maximum permitted pressure drop at 50 cSt: | |
| - clean filter | 30 kPa (0.3 bar ) |
| - alarm | 80 kPa (0.8 bar) |

## 7.3.12 Lubricating oil damper (2R03)

The 12V engine is delivered with a damper to be installed in the external piping.

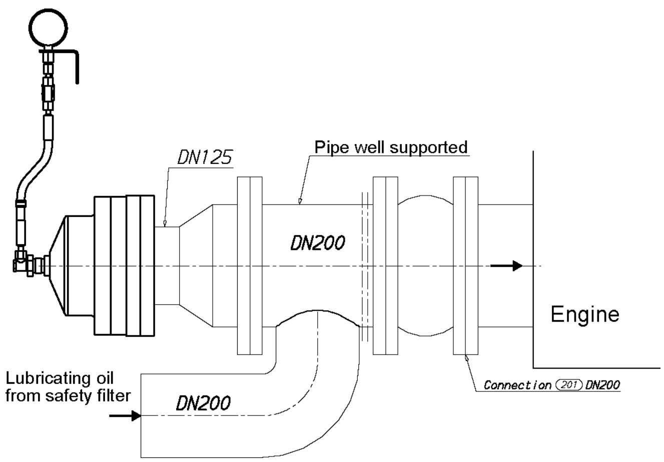


**Fig 7-7 Lubricating oil damper arrangement to external piping (3V35L3112)**

# 7.4 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 must be fitted on the vent pipe near the engine.

The connection between engine and pipe is to be flexible.

| **Design data:** | |
|---|---|
| Flow | see *Technical data* |
| Backpressure, max. | see *Technical data* |
| Temperature | 80°C |

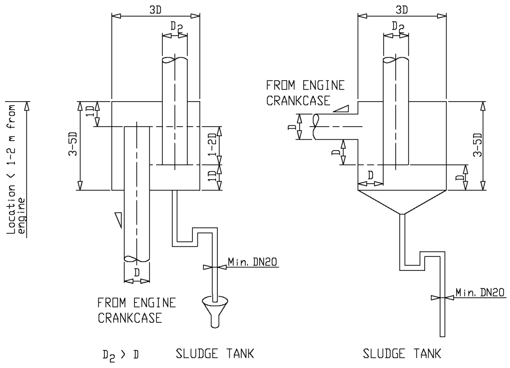


**Fig 7-8** **Condensate trap (DAAE032780B)**

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

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

# 7.5 Flushing instructions

Flushing instructions in this Product Guide are for guidance only. For contracted projects, read the specific instructions included in the installation planning instructions (IPI).

## 7.5.1 Piping and equipment built on the engine

Flushing of the piping and equipment built on the engine is not required and flushing oil shall not be pumped through the engine oil system (which is flushed and clean from the factory). It is however acceptable to circulate the flushing oil via the engine sump if this is advantageous. Cleanliness of the oil sump shall be verified after completed flushing.

## 7.5.2 External oil system

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

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 (2N01) 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 is installed this pump shall primarily be used for the flushing but also the pre-lubricating pump (2P02) shall be operated for some hours to flush the pipe branch.

Run the pumps 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 pumps shall be protected by the suction strainers (2F04, 2F06).

The automatic filter (2F02) should be by-passed to prevent damage. It is also recommended to by-pass the lubricating oil cooler (2E01).

## 7.5.3 Type of flushing oil

### Viscosity

In order for the flushing oil to be able to remove dirt and transport it with the flow, ideal viscosity is 10...50 cSt. The correct viscosity can be achieved by heating engine oil to about 65°C or by using a separate flushing oil which has an ideal viscosity in ambient temperature.

### Flushing with engine oil

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

### 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.

## 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.

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# 8. Compressed Air System

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

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

## 8.1 Instrument air quality

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

| **Instrument air specification:** | |
|---|---|
| Design pressure | 1 MPa (10 bar) |
| Nominal pressure | 0.7 MPa (7 bar) |
| Dew point temperature | +3°C |
| Max. oil content | 1 mg/m$^3$ |
| Max. particle size | 3 μm |

## 8.2 Internal compressed air system

All engines are started by means of compressed air with a nominal pressure of 3 MPa, the minimum recommended air pressure is 1.8 MPa. The start is performed by direct injection of air into the cylinders through the starting air valves in the cylinder heads.

All engines have built-on non-return valves and flame arrestors. The engine can not be started when the turning gear is engaged.

The main starting valve, built on the engine, can be operated both manually and electrically. In addition to starting system, the compressed air system is also used for operating the following systems:

- Electro-pneumatic overspeed trip device
- Starting fuel limiter
- Slow turning
- Fuel actuator booster
- Waste gate valve
- Turbocharger cleaning
- HT charge air cooler by-pass valve
- Charge air shut-off valve (optional)
- Fuel gas venting valve
- Oil mist detector

## 8.2.1 Internal compressed air system for in-line engines

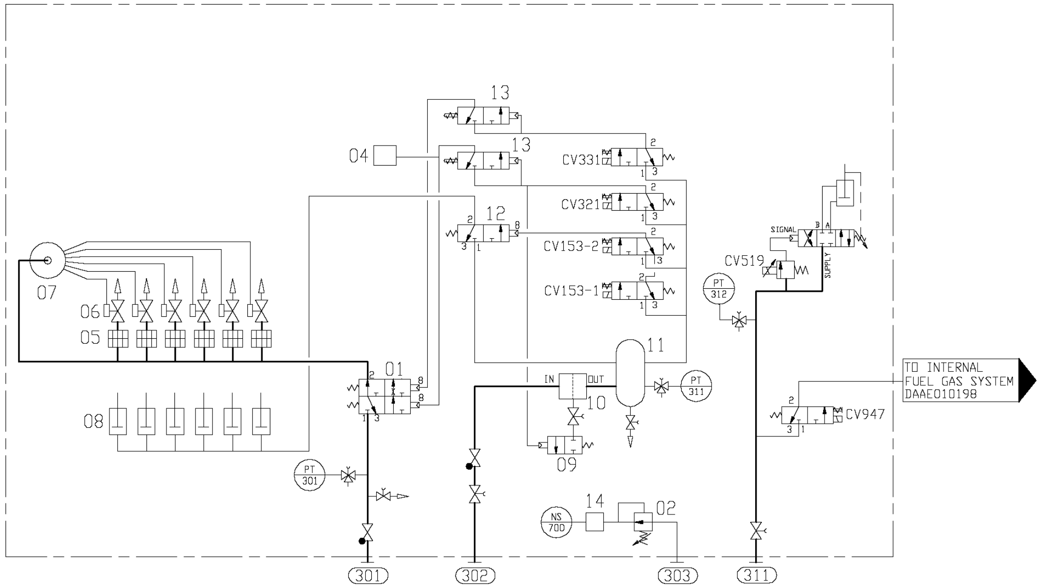



**Fig 8-1** Internal compressed air system, in-line engines (3V69E8745-3i)

| System components: | | | |
|---|---|---|---|
| 01 | Starting air master valve | 09 | Valve for automatic draining |
| 02 | Pressure control valve | 10 | High pressure filter |
| 04 | Starting booster for speed governor | 11 | Air container |
| 05 | Flame arrester | 12 | Stop valve |
| 06 | Starting air valve in cylinder head | 13 | Blocking valve, when turning gear engaged |
| 07 | Starting air distributor | 14 | Oil mist detector |
| 08 | Pneumatic stop cylinder at each injection pump | | |

| Sensors and indicators: | | | |
|---|---|---|---|
| CV153-1 | Stop solenoid | CV321 | Starting solenoid |
| CV153-2 | Stop solenoid | CV331 | Slow turning solenoid |
| PT301 | Starting air inlet pressure | CV519 | I/P converter for wastegate valve |
| PT311 | Control air pressure | CV947 | Gas venting solenoid |
| PT312 | Low pressure control air pressure | NS700 | Oil mist detector |

| Pipe connections | | Size | Pressure class | Standard |
|---|---|---|---|---|
| 301 | Starting air inlet, 3 MPa | DN50 | PN40 | ISO 7005-1 |
| 302 | Control air inlet, 3 MPa | OD18 | | DIN 2353 |
| 303 | Driving air inlet to oil mist detector, 0.2...1.2 MPa | OD10 | | DIN 2353 |
| 311 | Control air inlet, 0.8 MPa | OD12 | | DIN 2353 |

## 8.2.2 Internal compressed air system for V-engines

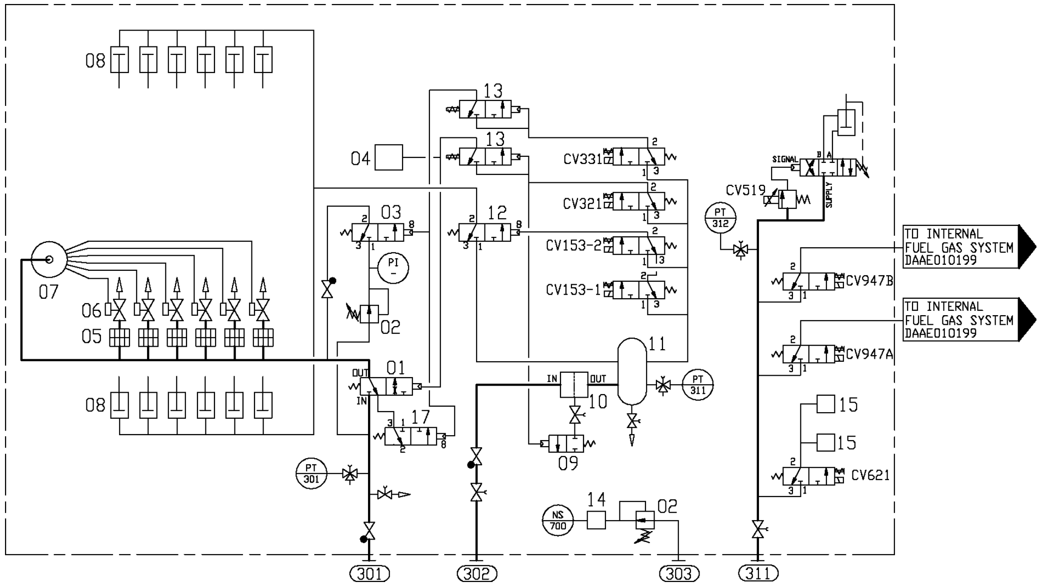



**Fig 8-2 Internal compressed air system, V-engines (3V69E8746-3h)**

| System components: | | | |
|---|---|---|---|
| 01 | Starting air master valve | 09 | Valve for automatic draining |
| 02 | Pressure control valve | 10 | High pressure filter |
| 03 | Slow turning valve | 11 | Air container |
| 04 | Starting booster for speed governor | 12 | Stop valve |
| 05 | Flame arrestor | 13 | Blocking valve, when turning gear engaged |
| 06 | Starting air valve in cylinder head | 14 | Oil mist detector |
| 07 | Starting air distributor | 15 | Charge air shut-off valve (optional) |
| 08 | Pneumatic cylinder at each injection pump | 17 | Drain valve |

| Sensors and indicators: | | | |
|---|---|---|---|
| CV153-1 | Stop solenoid | CV331 | Slow turning solenoid |
| CV153-2 | Stop solenoid | CV519 | I/P converter for waste gate valve |
| PT301 | Starting air inlet pressure | CV621 | Charge air shut-off valve (optional) |
| PT311 | Control air pressure | CV947 | Gas venting solenoid |
| PT312 | Low pressure control air pressure | NS700 | Oil mist detector |
| CV321 | Starting solenoid | PI | Manometer |

| Pipe connections | | Size | Pressure class | Standard |
|---|---|---|---|---|
| 301 | Starting air inlet, 3 MPa | DN50 | PN40 | ISO 7005-1 |
| 302 | Control air inlet, 3 MPa | OD18 | | DIN 2353 |
| 303 | Driving air inlet to oil mist detector, 0.2...1.2 MPa | OD10 | | DIN 2353 |
| 311 | Control air inlet, 0.8 MPa | OD12 | | DIN 2353 |

## 8.3 External compressed air system

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

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

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

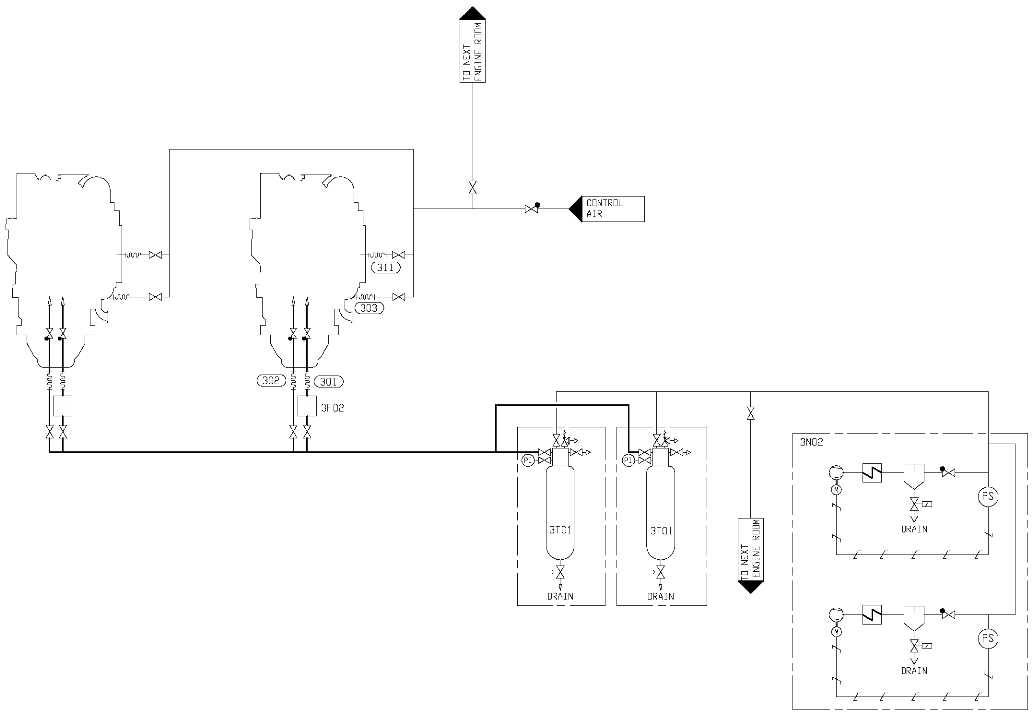



**Fig 8-3 Example of external compressed air system (3V76H4173D)**

| System components | | Pipe connections | |
|---|---|---|---|
| 3F02 | Air filter (starting air inlet) | 301 | Starting air inlet, 3 MPa |
| 3N02 | Starting air compressor unit | 302 | Control air inlet, 3 MPa |
| 3T01 | Starting air receiver | 303 | Driving air to oil mist detector, 0.8 MPa |
| | | 311 | Control air to bypass / wastegate valve, 0.8 MPa |
| | | 314 | Air supply to turbine and compressor cleaning unit (ABB TC) |

### 8.3.1 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.

## 8.3.2 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.

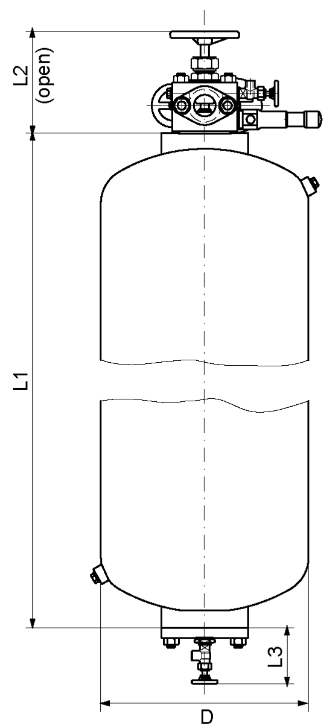
## 8.3.3 Starting air vessel (3T01)

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

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

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

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




| Size [Litres] | Dimensions [mm] | | | | Weight [kg] |
|---|---|---|---|---|---|
| | L1 | L2 [1)] | L3 [1)] | D | |
| 500 | 3204 | 243 | 133 | 480 | 450 |
| 1000 | 3560 | 255 | 133 | 650 | 810 |
| 1250 | 2930 | 255 | 133 | 800 | 980 |
| 1500 | 3460 | 255 | 133 | 800 | 1150 |
| 1750 | 4000 | 255 | 133 | 800 | 1310 |
| 2000 | 4610 | 255 | 133 | 800 | 1490 |

[1)] Dimensions are approximate.

**Fig 8-4 Starting air vessel**

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

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

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

**where:**

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

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

$V_E$ = air consumption per start [$Nm^3$] See *Technical data*

n = required number of starts according to the classification society

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

$p_{Rmin}$ = minimum starting air pressure = See *Technical data*

**NOTE**

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

## 8.3.4 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 400 µm. The pressure drop should not exceed 20 kPa (0.2 bar) for the engine specific starting air consumption under a time span of 4 seconds.

# 9. Cooling Water System

## 9.1 Water quality

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

| | |
|---|---|
| pH ............................... | min. 6.5...8.5 |
| Hardness ..................... | max. 10 °dH |
| Chlorides ..................... | max. 80 mg/l |
| Sulphates .................... | max. 150 mg/l |

Good quality tap water can be used, but shore water is not always suitable. It is recommended to use water produced by an onboard evaporator. Fresh water produced by reverse osmosis plants often has higher chloride content than permitted. Rain water is unsuitable as cooling water due to the high content of oxygen and carbon dioxide.

Only treated fresh water containing approved corrosion inhibitors may be circulated through the engines. It is important that water of acceptable quality and approved corrosion inhibitors are used directly when the system is filled after completed installation.

### 9.1.1 Corrosion inhibitors

The use of an approved cooling water additive is mandatory. An updated list of approved products is supplied for every installation and it can also be found in the Instruction manual of the engine, together with dosage and further instructions.

### 9.1.2 Glycol

Use of glycol in the cooling water is not recommended unless it is absolutely necessary. Glycol raises the charge air temperature, which may require de-rating of the engine depending on gas properties and glycol content. Max. 60% glycol is permitted.

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

# 9.2 Internal cooling water system

## 9.2.1 Internal cooling water system for in-line engines

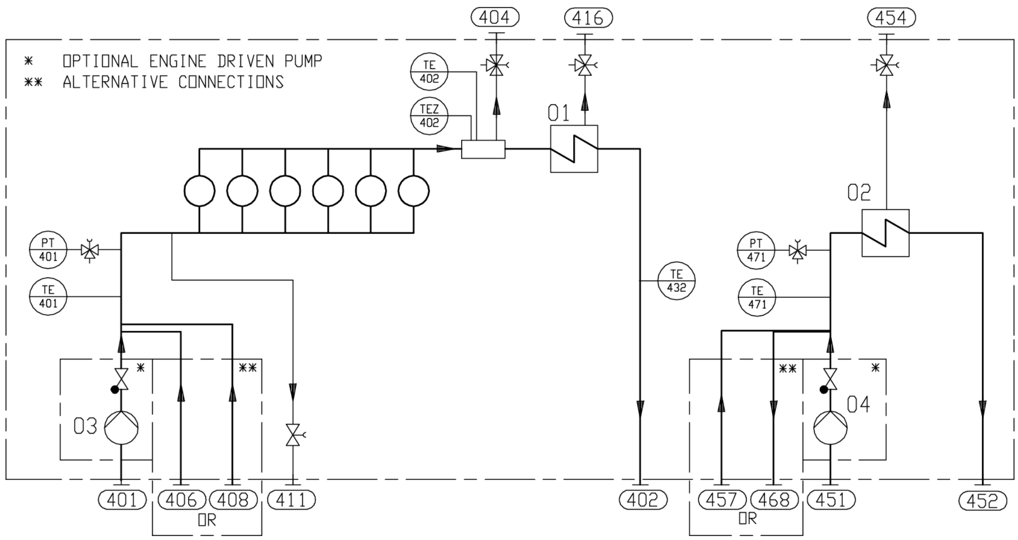



**Fig 9-1** Internal cooling water system, in-line engines (3V69E8745-4i)

| System components: | | | |
|---|---|---|---|
| 01 | Charge air cooler (HT) | 03 | HT-water pump |
| 02 | Charge air cooler (LT) | 04 | LT-water pump |

| Sensors and indicators: | | | |
|---|---|---|---|
| PT401 | HT water inlet pressure | TE432 | HT water temp after charge air cooler |
| TE401 | HT water inlet temperature | PT471 | LT water inlet pressure |
| TE402 | HT water outlet temperature | TE471 | LT water inlet temperature |
| TEZ402 | HT water outlet temperature | | |

| Pipe connections | | Size | Pressure class | Standard |
|---|---|---|---|---|
| 401 | HT-water inlet | DN150 | PN16 | ISO 7005-1 |
| 402 | HT-water outlet | DN150 | PN16 | ISO 7005-1 |
| 404 | HT-water air vent | OD12 | | DIN 2353 |
| 406 | Water from preheater to HT-circuit | DN40 | PN40 | ISO 7005-1 |
| 408 | HT-water from stand-by pump | DN150 | PN16 | ISO 7005-1 |
| 411 | HT-water drain | OD48 | | DIN 2353 |
| 416 | HT-water air vent from air cooler | OD12 | | DIN 2353 |
| 451 | LT-water inlet | DN150 | PN16 | ISO 7005-1 |
| 452 | LT-water outlet | DN150 | PN16 | ISO 7005-1 |
| 454 | LT-water air vent from air cooler | OD12 | | DIN 2353 |
| 457 | LT-water from stand-by pump | DN125 | PN16 | ISO 7005-1 |
| 468 | LT-water to air cooler by-pass or generator | DN125 | PN16 | ISO 7005-1 |

## 9.2.2 Internal cooling water system for V-engines

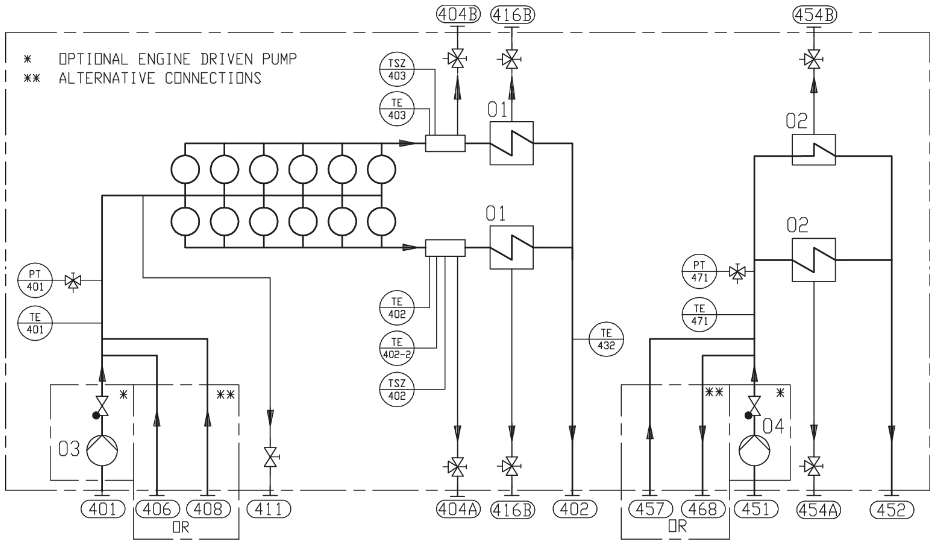



**Fig 9-2 Internal cooling water system, V-engines (3V69E8746-4h)**

| System components: | | | |
|---|---|---|---|
| 01 | Charge air cooler (HT) | 03 | HT-water pump |
| 02 | Charge air cooler (LT) | 04 | LT-water pump |

| Sensors and indicators: | | | |
|---|---|---|---|
| PT401 | HT-water inlet pressure | TSZ403 | HT-water outlet temperature |
| TE401 | HT-water inlet temperature | TE432 | HT-water temperature after charge air cooler |
| TE402 | HT-water outlet temperature, A-bank | PT471 | LT-water inlet pressure |
| TE403 | HT-water outlet temperature, B-bank | TE471 | LT-water inlet temperature |
| TEZ402 | HT-water outlet temperature | | |

| Pipe connections | | Size | Pressure class | Standard |
|---|---|---|---|---|
| 401 | HT-water inlet | DN200 | PN10 | ISO 7005-1 |
| 402 | HT-water outlet | DN200 | PN10 | ISO 7005-1 |
| 404A/B | HT-water air vent | OD12 | | DIN 2353 |
| 406 | Water from preheater to HT-circuit | DN40 | PN40 | ISO 7005-1 |
| 408 | HT-water from stand-by pump | DN150 | PN16 | ISO 7005-1 |
| 411 | HT-water drain | OD48 | | DIN 2353 |
| 416A/B | HT-water air vent from air cooler | OD12 | | DIN 2353 |
| 451 | LT-water inlet | DN200 | PN10 | ISO 7005-1 |
| 452 | LT-water outlet | DN200 | PN10 | ISO 7005-1 |
| 454A/B | LT-water air vent from air cooler | OD12 | | DIN 2353 |
| 457 | LT-water from stand-by pump | DN200 | PN10 | ISO 7005-1 |
| 468 | LT-water, air cooler by-pass | DN200 | PN10 | ISO 7005-1 |

The fresh water cooling system is divided into a high temperature (HT) and a low temperature (LT) circuit. The HT water circulates through cylinder jackets, cylinder heads and the 1st stage of the charge air cooler. The HT water passes through the cylinder jackets before it enters the HT-stage of the charge air cooler. The LT water cools the 2nd stage of the charge air cooler and the lubricating oil. The lubricating oil cooler is external. A two-stage charge air cooler enables more efficient heat recovery and heating of cold combustion air.

In the HT circuit the temperature control is based on the water temperature after the engine, while the charge air temperature is maintained on a constant level with the arrangement of the LT circuit. The LT water partially bypasses the charge air cooler depending on the operating condition to maintain a constant air temperature after the cooler.

## 9.2.3 Engine driven circulating pumps

The LT and HT cooling water pumps are engine driven. The engine driven pumps are located at the free end of the engine.

Pump curves for engine driven pumps are shown in the diagrams. The nominal pressure and capacity can be found in the chapter *Technical data*.

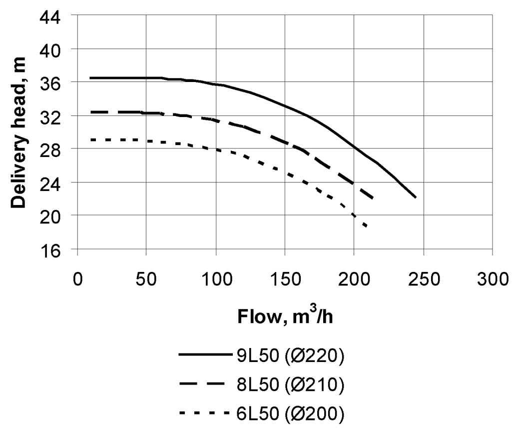



**Fig 9-3** **Wärtsilä 50DF 500 rpm in-line engine HT and LT cooling water pump curves (4V19L0332A)**

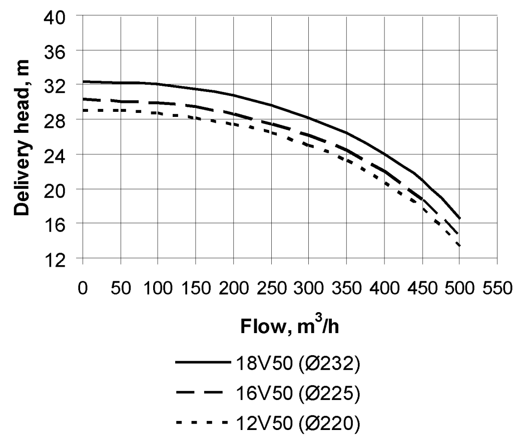



**Fig 9-4** **Wärtsilä 50DF 500 rpm V-engine HT and LT cooling water pump curves (4V19L0333A)**

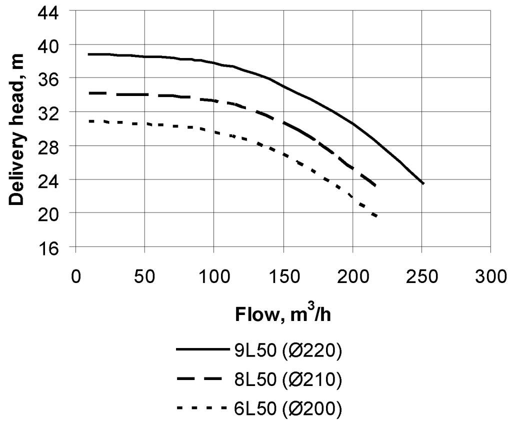



**Fig 9-5** **Wärtsilä 50DF 514 rpm in-line engine HT and LT cooling water pump curves (4V19L0332A)**

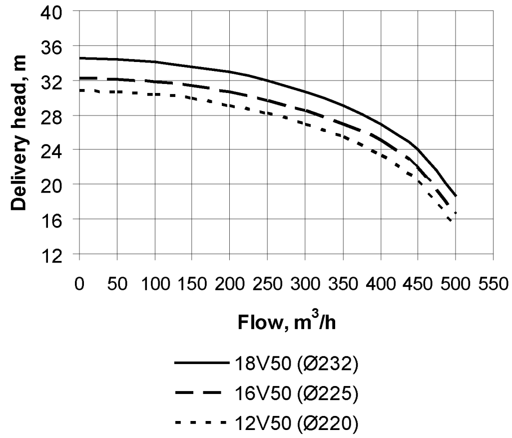



**Fig 9-6** **Wärtsilä 50DF 514 rpm V-engine HT and LT cooling water pump curves (4V19L0333A)**

# 9.3 External cooling water system

## 9.3.1 CW system for in-line engine in common circuit built-on pumps and evaporator

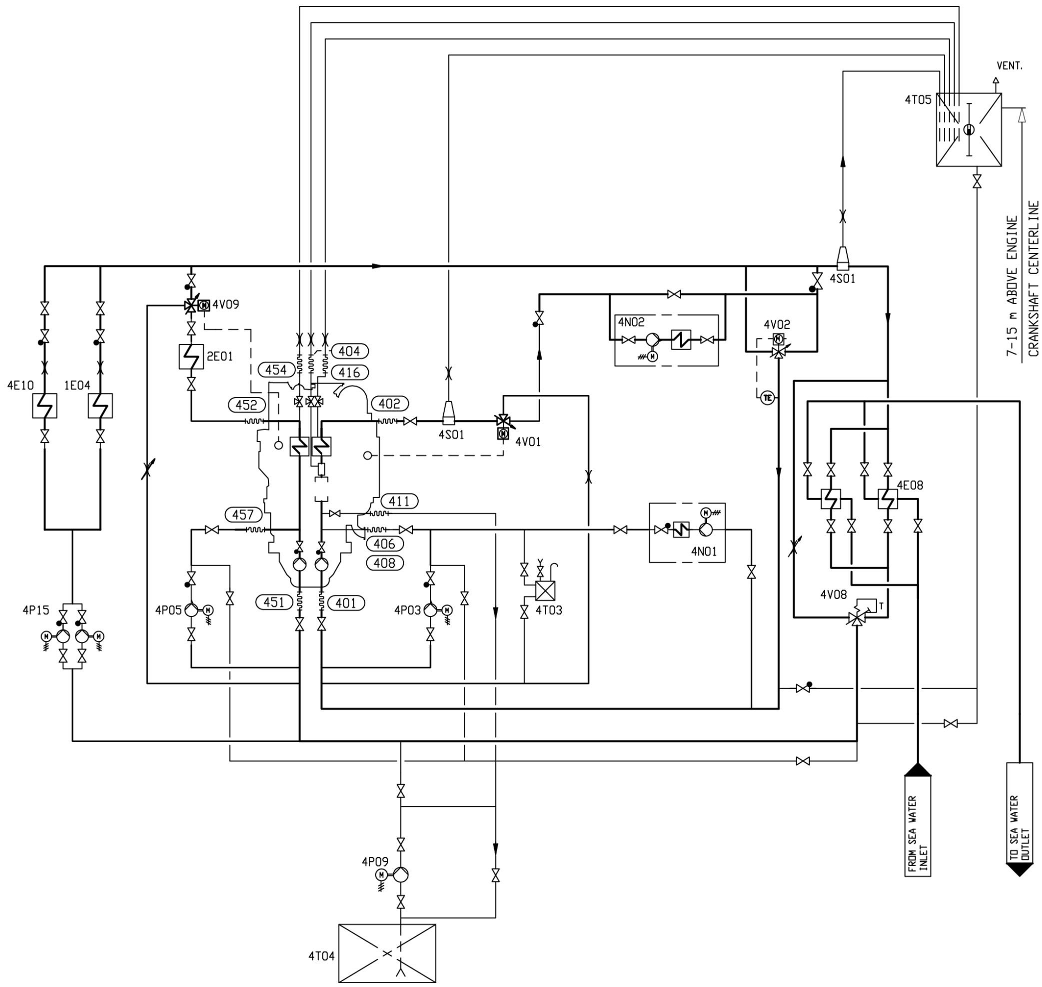



**Fig 9-7** **Cooling water system, in-line engine in common circuit built-on pumps and evaporator (DAAF072992)**

| System components: | | | |
|---|---|---|---|
| 1E04 | Cooler (MDF return line) | 4P15 | Circulating pump |
| 2E01 | Lubricating oil cooler | 4S01 | Air venting |
| 4E08 | Central cooler | 4T03 | Additive dosing tank |
| 4E10 | Cooler (Reduction gear) | 4T04 | Drain tank |
| 4N01 | Preheating unit | 4T05 | Expansion tank |
| 4N02 | Evaporator unit | 4V01 | Temperature control valve (HT) |
| 4P03 | Stand-by pump (HT) | 4V02 | Temperature control valve (Heat recovery) |
| 4P05 | Stand-by pump (LT) | 4V08 | Temperature control valve (LT) |
| 4P09 | Transfer pump | 4V09 | Temperature control valve (charge air) |
| | | | |
| *Pipe connections are listed in section "Internal cooling water system".* | | | |

## 9.3.2 CW system for engines in dedicated circuits with built-on pumps, generator cooling and evaporator

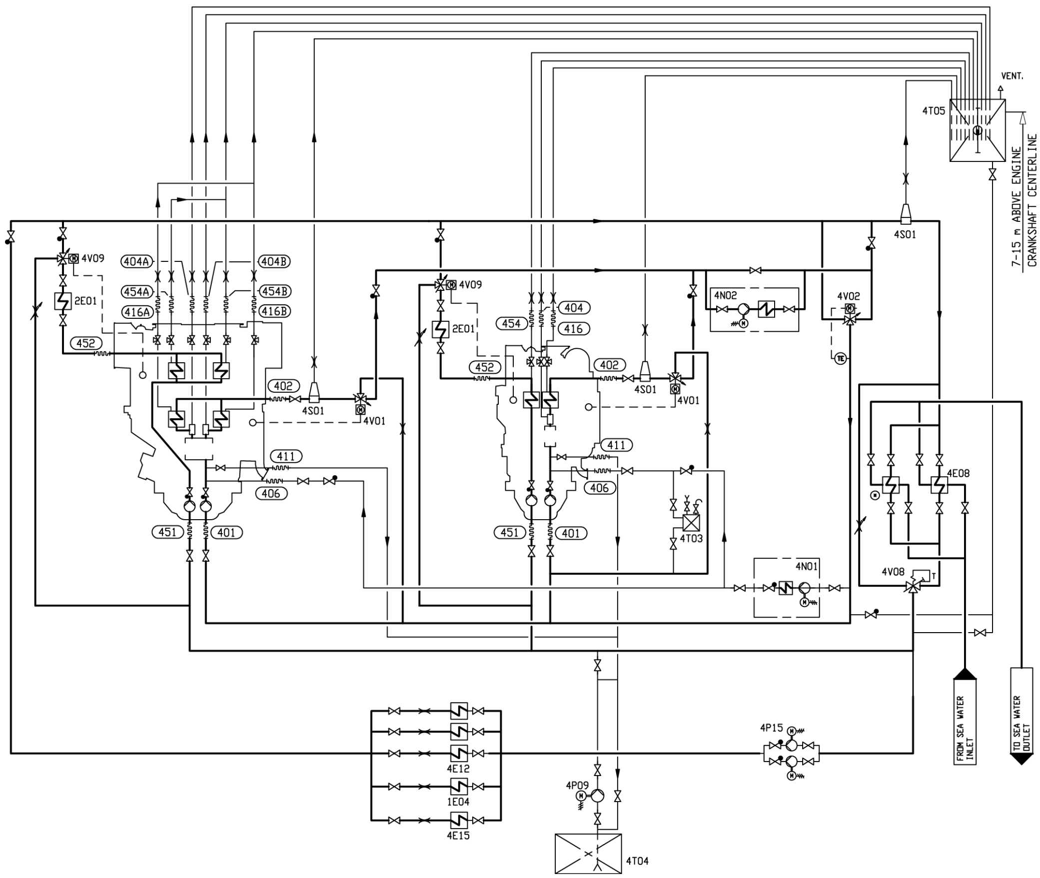


**Fig 9-8 Cooling water system, in-line and V-engines in dedicated circuits with built-on pumps, generator cooling and evaporator (DAAF072974)**

| **System components:** | | | |
|---|---|---|---|
| 1E04 | Cooler (MDF return line) | 4S01 | Air venting |
| 2E01 | Lubricating oil cooler | 4T03 | Additive dosing tank |
| 4E08 | Central cooler | 4T04 | Drain tank |
| 4E12 | Cooler (installation parts) | 4T05 | Expansion tank |
| 4E15 | Cooler (generator) | 4V01 | Temperature control valve (HT) |
| 4N01 | Preheating unit | 4V02 | Temperature control valve (Heat recovery) |
| 4N02 | Evaporator unit | 4V08 | Temperature control valve (LT) |
| 4P09 | Transfer pump | 4V09 | Temperature control valve (charge air) |
| 4P15 | Circulating pump | | |
| | | | |
| *Pipe connections are listed in section "Internal cooling water system".* | | | |

## 9.3.3 CW system system for in-line engine with combined LT/HT cooling systems

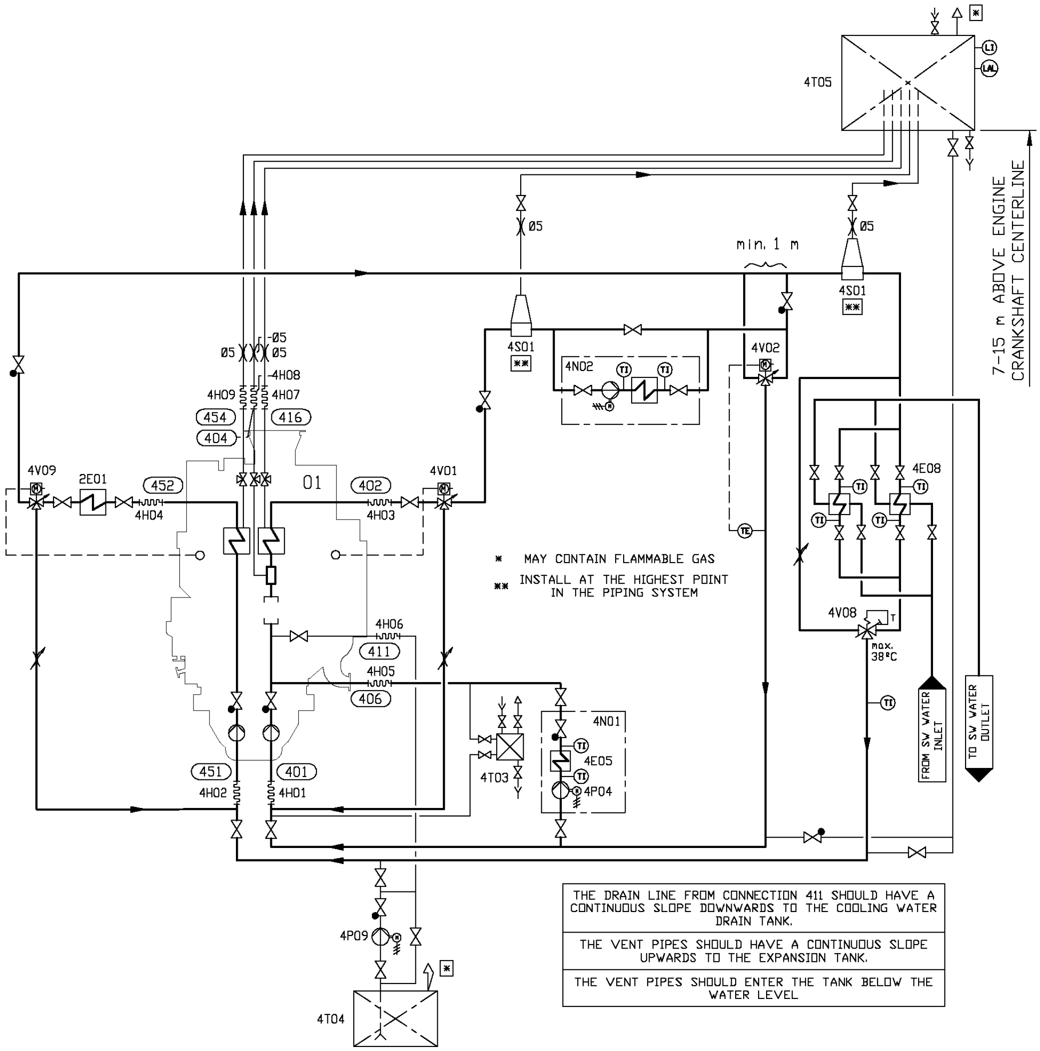



**Fig 9-9** **Cooling water system, in-line engines with combined LT/HT cooling systems (DAAF333647)**

| **System components:** | | | |
|---|---|---|---|
| 01 | WL50DF | 4S01 | Air venting |
| 2E01 | Lube oil cooler | 4T03 | Additive dosing tank |
| 4E05 | Heater (preheater) | 4T04 | Drain tank |
| 4E08 | Central cooler | 4T05 | Expansion tank |
| 4H0X | Flexible pipe connections | 4V01 | Temperature control valve (HT) |
| 4N01 | Preheating unit | 4V02 | Temperature control valve (Heat recovery) |
| 4N02 | Evaporator unit | 4V08 | Temperature control valve (central cooler) |
| 4P04 | Circulating pump (preheater) | 4V09 | Temperature control valve (charge air) |
| 4P09 | Transfer pump | | |
| | | | |
| *Pipe connections are listed in section "Internal cooling water system".* | | | |

## 9.3.4 CW system system for V-engine with combined LT/HT cooling systems

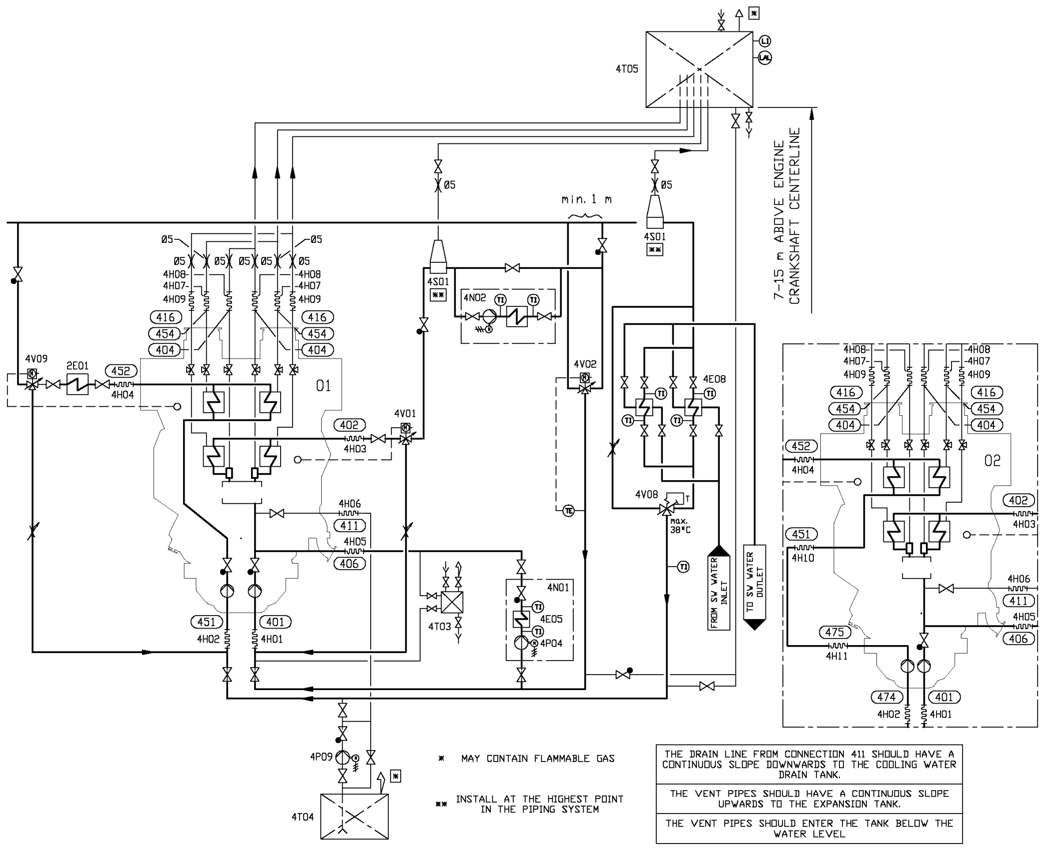



**Fig 9-10** **Cooling water system, V-engines with combined LT/HT cooling systems (DAAF333651)**

| **System components:** | | | |
|---|---|---|---|
| 01 | WV50DF TC/FE | 4P09 | Transfer pump |
| 02 | WV50DF TC/DE | 4S01 | Air venting |
| 2E01 | Lube oil cooler | 4T03 | Additive dosing tank |
| 4E05 | Heater (preheater) | 4T04 | Drain tank |
| 4E08 | Central cooler | 4T05 | Expansion tank |
| 4H0X | Flexible pipe connections | 4V01 | Temperature control valve (HT) |
| 4N01 | Preheating unit | 4V02 | Temperature control valve (Heat recovery) |
| 4N02 | Evaporator unit | 4V08 | Temperature control valve (central cooler) |
| 4P04 | Circulating pump (preheater) | 4V09 | Temperature control valve (charge air) |
| | | | |
| *Pipe connections are listed in section "Internal cooling water system".* | | | |

## 9.3.5 CW system system for V-engine with separate LT/HT cooling systems

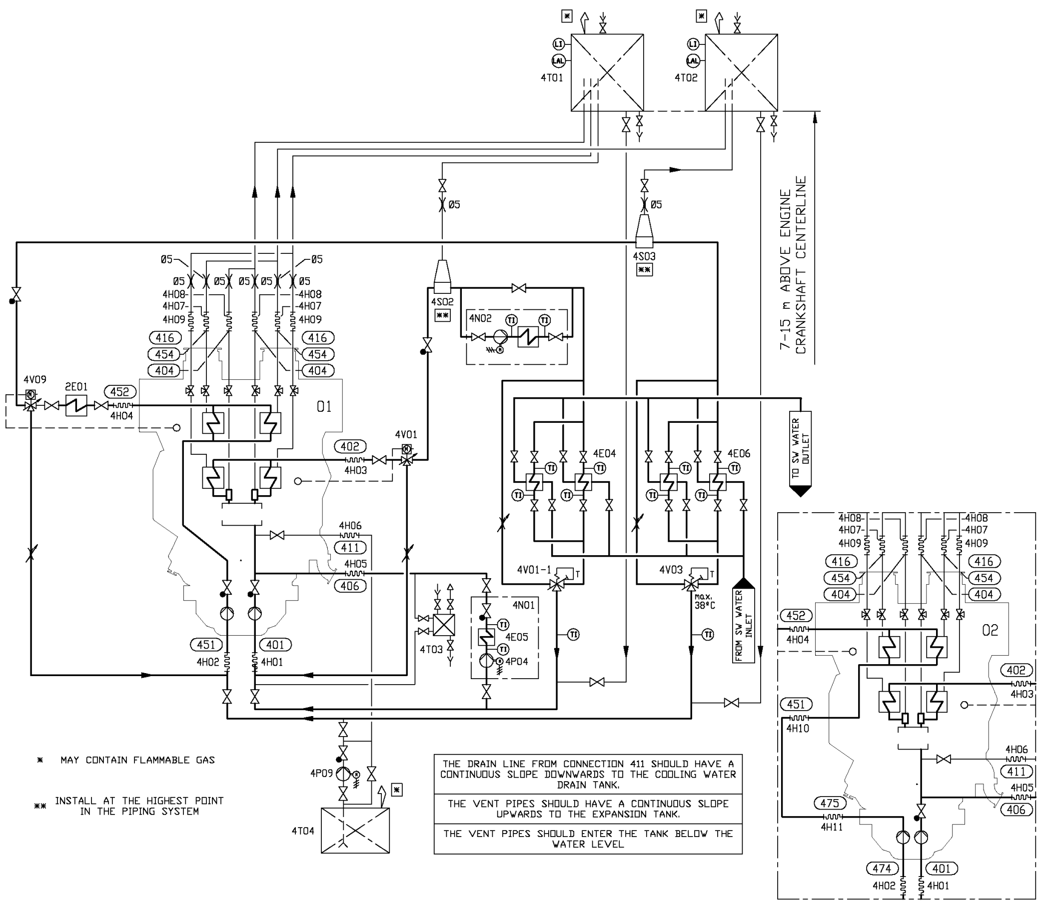


**Fig 9-11 Cooling water system, V-engines with separate LT/HT cooling systems (DAAF333806)**

| System components: | | | |
|---|---|---|---|
| 01 | WV50DF TC/FE | 4S02 | Air daerator (HT) |
| 02 | WV50DF TC/DE | 4S03 | Air daerator (LT) |
| 2E01 | Lube oil cooler | 4T03 | Additive dosing tank |
| 4E04 | Raw water cooler (HT) | 4T01 | Expansion tank (HT) |
| 4E05 | Heater (preheater) | 4T02 | Expansion tank (LT) |
| 4E06 | Raw water cooler (LT) | 4T03 | Additive dosing tank |
| 4H0X | Flexible pipe connections | 4T04 | Drain tank |
| 4N01 | Preheating unit | 4V01 | Temperature control valve (HT) |
| 4N02 | Evaporator unit | 4V01-1 | Temperature control valve (HT) |
| 4P04 | Circulating pump (preheater) | 4V03 | Temperature control valve (LT) |
| 4P09 | Transfer pump | 4V09 | Temperature control valve (charge air) |
| | | | |
| *Pipe connections are listed in section "Internal cooling water system".* | | | |

## 9.3.6 CW system system for multiple engines with separate LT/HT cooling systems

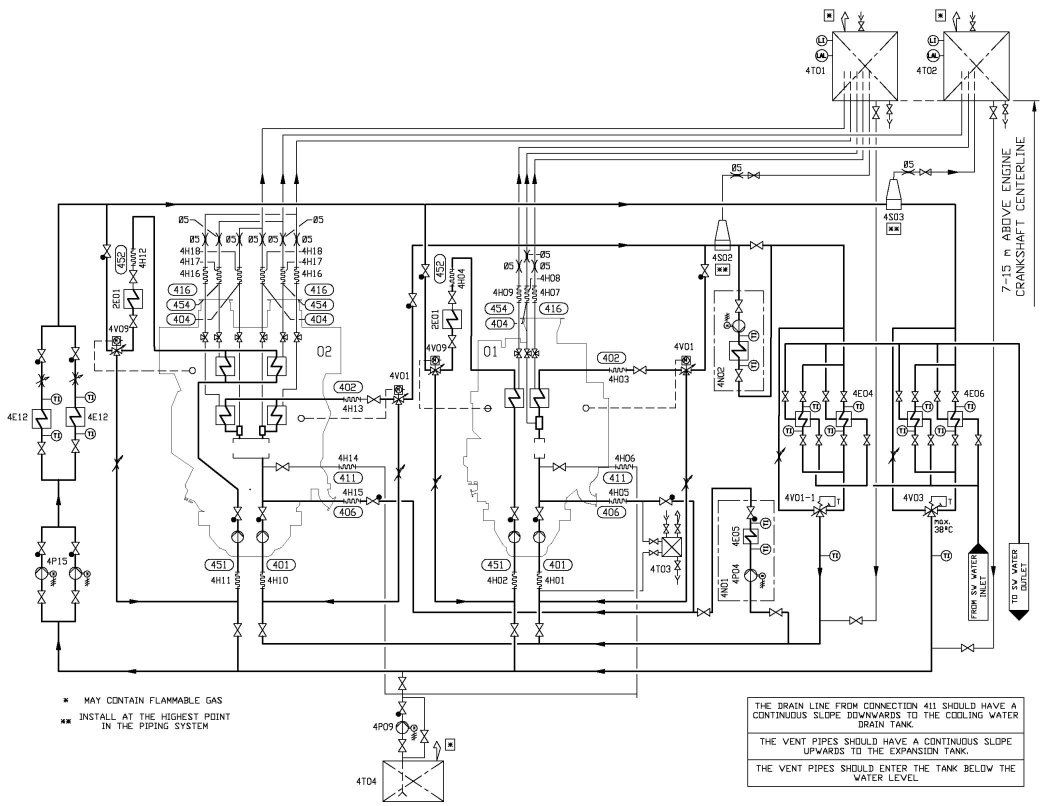



**Fig 9-12** **Cooling water system, multiple engines with separate LT/HT cooling systems (DAAF333808)**

| System components: | | | |
|---|---|---|---|
| 01 | Wärtsilä L50DF | 4P15 | Circulating pump (LT) |
| 02 | Wärtsilä V50DF | 4S02 | Air daerator (HT) |
| 2E01 | Lube oil cooler | 4S03 | Air daerator (LT) |
| 4E04 | Raw water cooler (HT) | 4T01 | Expansion tank (HT) |
| 4E05 | Heater (preheater) | 4T02 | Expansion tank (LT) |
| 4E06 | Raw water cooler (LT) | 4T03 | Additive dosing tank |
| 4E12 | Cooler (Installation parts) | 4T04 | Drain tank |
| 4H0X | Flexible pipe connections | 4V01 | Temperature control valve (HT) |
| 4N01 | Preheating unit | 4V01-1 | Temperature control valve (HT) |
| 4N02 | Evaporator unit | 4V03 | Temperature control valve (LT) |
| 4P04 | Circulating pump (preheater) | 4V09 | Temperature control valve (charge air) |
| 4P09 | Transfer pump | | |
| | | | |
| *Pipe connections are listed in section "Internal cooling water system".* | | | |

## 9.3.7 CW system system for multiple engines with combined LT/HT cooling systems

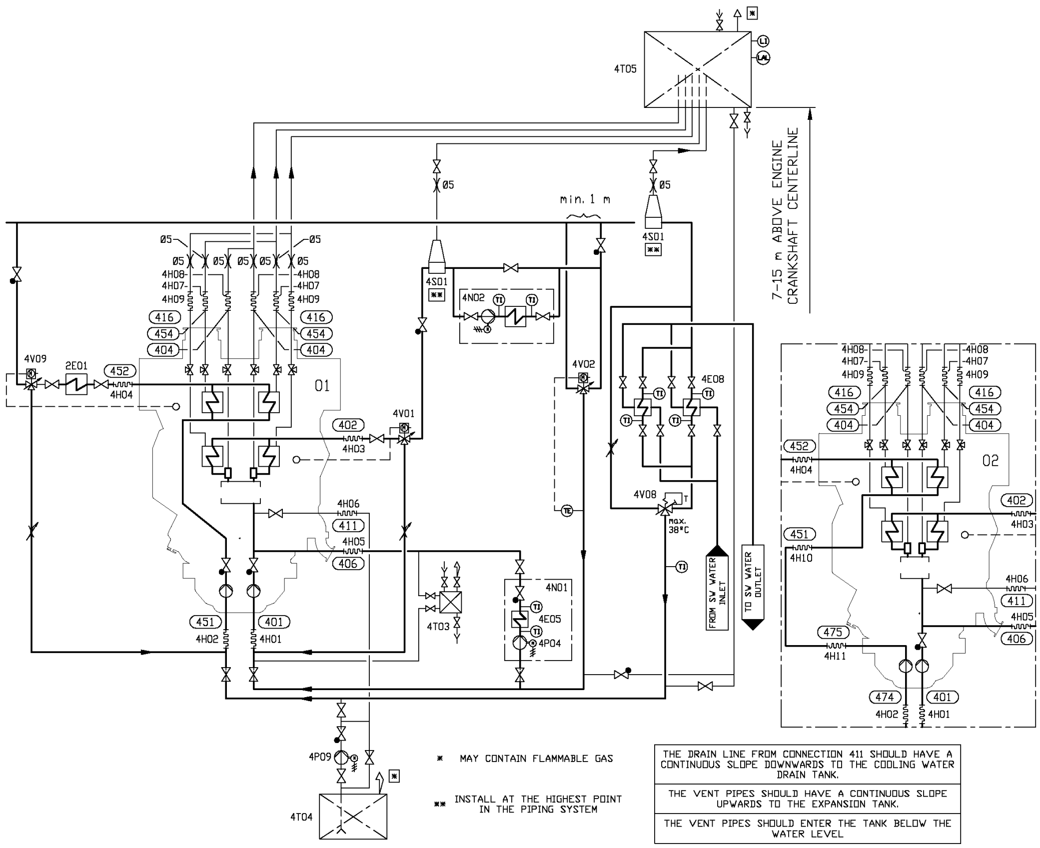



**Fig 9-13 Cooling water system, multiple engines with combined LT/HT cooling systems (DAAF333807)**

| System components: | | | |
|---|---|---|---|
| 01 | WL50DF | 4P09 | Transfer pump |
| 02 | WV50DF | 4P15 | Circulating pump (LT) |
| 2E01 | Lube oil cooler | 4S01 | Air venting |
| 4E05 | Heater (preheater) | 4T03 | Additive dosing tank |
| 4E08 | Central cooler | 4T04 | Drain tank |
| 4E12 | Cooler (installation parts) | 4T05 | Expansion tank |
| 4H0X | Flexible pipe connections | 4V01 | Temperature control valve (HT) |
| 4N01 | Preheating unit | 4V02 | Temperature control valve (Heat recovery) |
| 4N02 | Evaporator unit | 4V08 | Temperature control valve (central cooler) |
| 4P04 | Circulating pump (preheater) | 4V09 | Temperature control valve (charge air) |
| | | | |

*Pipe connections are listed in section "Internal cooling water system".*

## 9.3.8 CW system system for in-line engine, single main engine

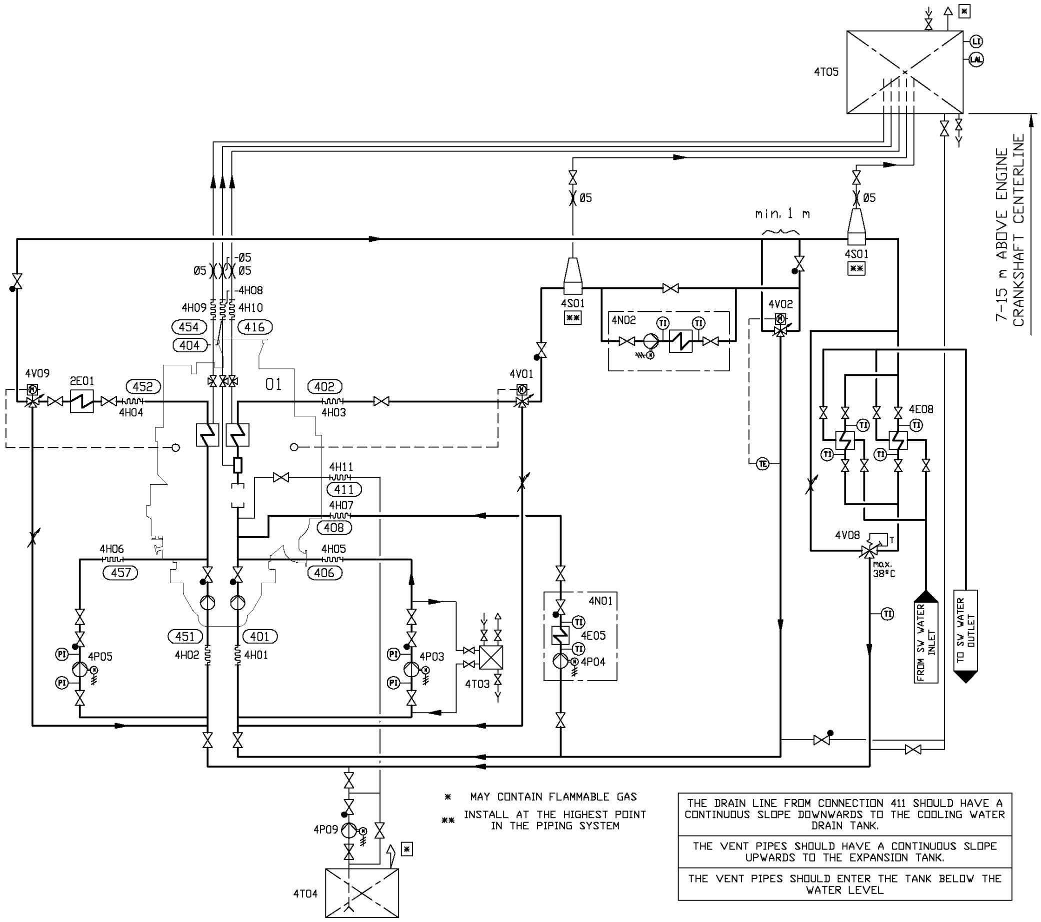



**Fig 9-14 Cooling water system for in-line single main engine (DAAF333648)**

| System components: | | | |
|---|---|---|---|
| 01 | WL50DF | 4P09 | Transfer pump |
| 2E01 | Lube oil cooler | 4S01 | Air venting |
| 4E05 | Heater (preheater) | 4T03 | Additive dosing tank |
| 4E08 | Central cooler | 4T04 | Drain tank |
| 4H0X | Flexible pipe connections | 4T05 | Expansion tank |
| 4N01 | Preheating unit | 4V01 | Temperature control valve (HT) |
| 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 are listed in section "Internal cooling water system".* | | | |

## 9.3.9 CW system system for V-engine, single main engine

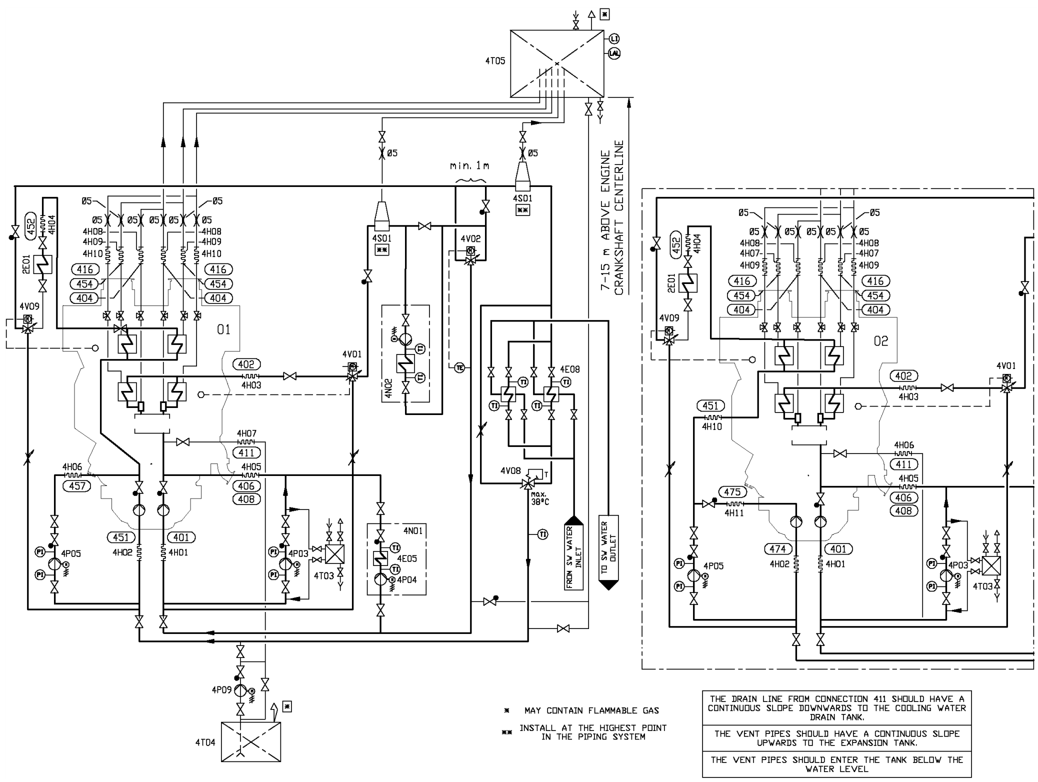



**Fig 9-15 Cooling water system for V-engine, single main engine (DAAF333652)**

| System components: | | | |
|---|---|---|---|
| 01 | WV50DF TC/FE | 4P05 | Stand-by pump (LT) |
| 02 | WV50DF TC/DE | 4P09 | Transfer pump |
| 2E01 | Lube oil cooler | 4S01 | Air venting |
| 4E05 | Heater (preheater) | 4T03 | Additive dosing tank |
| 4E08 | Central cooler | 4T04 | Drain tank |
| 4H0X | Flexible pipe connections | 4T05 | Expansion tank |
| 4N01 | Preheating unit | 4V01 | Temperature control valve (HT) |
| 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) |
| | | | |
| *Pipe connections are listed in section "Internal cooling water system".* | | | |

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

The external system shall be designed so that flows, pressures and temperatures are close to the nominal values in *Technical data* 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.

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

### 9.3.10 Sea water pump (4P11)

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

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

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

### 9.3.11 Temperature control valve, HT-system (4V01)

The temperature control valve is installed directly after the engine and is electrically controlled by the engine control system (UNIC / TE402). It controls the temperature of the water out from the engine by circulating some water back to the HT pump. Each engine must have a dedicated temperature control valve.

| | |
|---|---|
| Set point | 82°C |

**NOTE**

Note: HT water temperature after CAC (TE432) at engine outlet: ~91°C.

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

The temperature control valve is installed after the central cooler and it controls the temperature of the LT water before the engine, by partly bypassing the cooler. The control valve can be either self-actuated or electrically actuated. Normally there is one temperature control valve per circuit.

The set-point of the control valve is 35 °C, or lower if required by other equipment connected to the same circuit.

### 9.3.13 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.

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

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

The set-point is usually somewhere close to 75 °C.

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

### 9.3.15 Lubricating oil cooler (2E01)

The lubricating oil cooler is connected in series with the charge air cooler in the LT circuit. The full water flow in the LT circuit is circulated through the lubricating oil cooler (whereas the charge air cooler can be partly by-passed).

The cooler should be dimensioned for an inlet water temperature of 45 °C. The amount of heat to be dissipated and flow rates are stated in *Technical data*. Further design guidelines are given in the chapter *Lubricating oil system*.

### 9.3.16 Coolers for other equipment and MDF coolers

The engine driven LT circulating pump can supply cooling water to one or two small coolers installed in parallel to the engine charge air and lubricating oil cooler, for example a MDF cooler or a generator cooler. Separate circulating pumps are required for larger flows.

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

### 9.3.17 Fresh water central cooler (4E08)

Plate type coolers are most common, but tube coolers can also be used. Several engines can share the same cooler.

If the system layout is according to one of the example diagrams, then the flow capacity of the cooler should be equal to the total capacity of the LT circulating pumps in the circuit. The flow may be higher for other system layouts and should be calculated case by case.

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

| **Design data:** | |
|---|---|
| Fresh water flow | see chapter *Technical Data* |
| Heat to be dissipated | see chapter *Technical Data* |
| 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 cooler | max. 38°C |
| Margin (heat rate, fouling) | 15% |

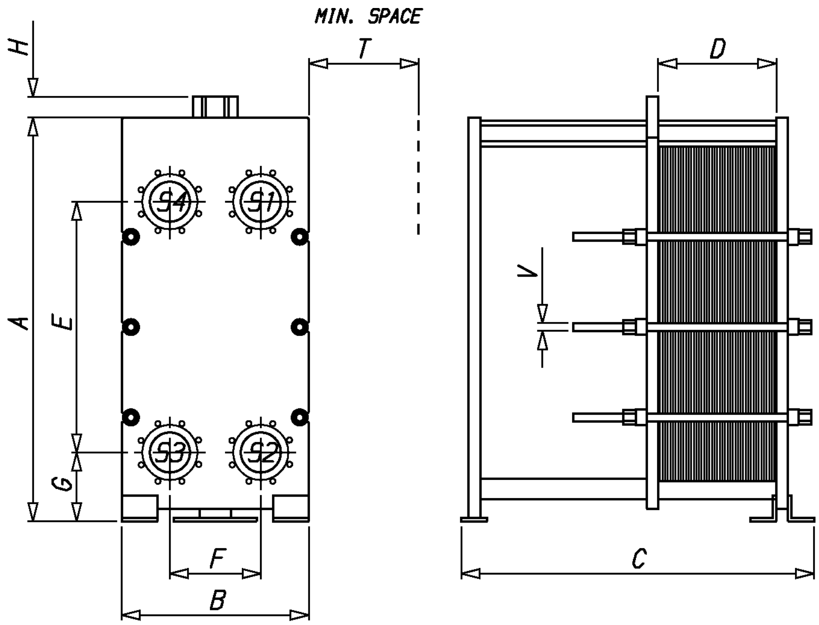



**Fig 9-16** **Central cooler main dimensions (4V47F0004). Example for guidance only**

| Number of cylinders | A [mm] | B [mm] | C [mm] | H [mm] | T [mm] | Weight [kg] |
|---|---|---|---|---|---|---|
| 6 | 1910 | 720 | 1135 | 55 | 450 | 1350 |
| 8 | 1910 | 720 | 1135 | 55 | 450 | 1400 |
| 9 | 1910 | 720 | 1435 | 55 | 450 | 1430 |
| 12 | 1910 | 720 | 1435 | 55 | 450 | 1570 |
| 16 | 2080 | 790 | 2060 | 55 | 500 | 2020 |
| 18 | 2690 | 790 | 2060 | 55 | 500 | 2070 |

## 9.3.18 Waste heat recovery

The waste heat in the HT cooling water can be used for fresh water production, central heating, tank heating etc. The system should in such case be provided with a temperature control valve to avoid unnecessary cooling, as shown in the example diagrams. With this arrangement the HT water flow through the heat recovery can be increased.

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

## 9.3.19 Air venting

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

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

The vent pipes must be continuously rising.

## Air separator (4S01)

It is recommended to install efficient air separators in addition to the vent pipes from the engine to ensure fast evacuation of entrained air. These separators should be installed:

1. **Directly after the HT water outlet on the engine.**
2. **After the connection point of the HT and LT circuits.**
3. **Directly after the LT water outlet on the engine if the HT and LT circuits are separated.**

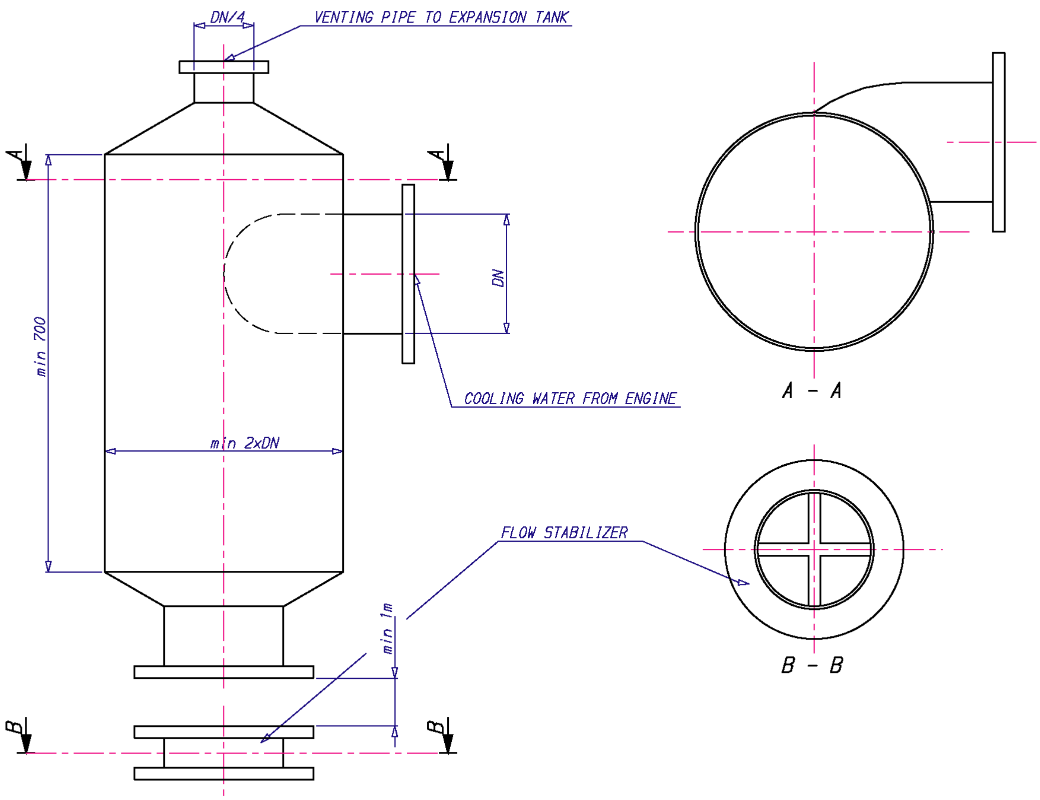



**Fig 9-17** **Example of air venting device (3V76C4757)**

## 9.3.20 Expansion tank (4T05)

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

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

**NOTE**

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

Concerning the water volume in the engine, see chapter *Technical data*.

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.

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 ø 5 mm orifice |
|---|---|---|
| DN 40 | 1.2 | 6 |
| DN 50 | 1.3 | 10 |
| DN 65 | 1.4 | 17 |
| DN 80 | 1.5 | 28 |

## 9.3.21 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, see chapter *Technical data*. The water volume in the LT circuit of the engine is small.

## 9.3.22 Additive dosing tank (4T03)

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

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

## 9.3.23 Preheating

The cooling water circulating through the cylinders must be preheated to at least 60 °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.

## 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 12 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 6 kW/cyl is required to keep a hot engine warm.

| **Design data:** | |
|---|---|
| Preheating temperature | min. 60°C |
| Required heating power | 12 kW/cyl |
| Heating power to keep hot engine warm | 6 kW/cyl |

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

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

where:

| | |
|---|---|
| $P$ = | Preheater output [kW] |
| $T_1$ = | Preheating temperature = 60...70 °C |
| $T_0$ = | Ambient temperature [°C] |
| $m_{eng}$ = | Engine weight [ton] |
| $V_{FW}$ = | HT water volume [m$^3$] |
| $t$ = | Preheating time [h] |
| $k_{eng}$ = | Engine specific coefficient = 3 kW |
| $n_{cyl}$ = | Number of cylinders |

The formula above should not be used for $P < 10$ kW/cyl

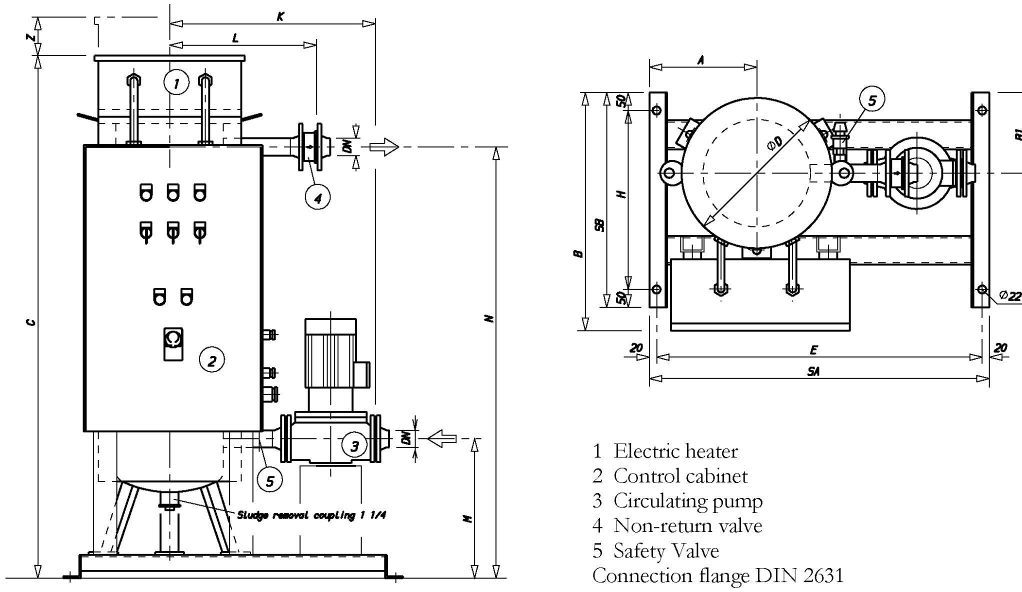
## Circulation pump for preheater (4P04)

| **Design data:** | |
|---|---|
| Capacity | 1.6 m$^3$/h per cylinder |
| Delivery pressure | 80...100 kPa (0.8...1.0 bar) |

## 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




1 Electric heater
2 Control cabinet
3 Circulating pump
4 Non-return valve
5 Safety Valve
Connection flange DIN 2631
Operating pressure max. 6 bar
Operating temperature max. 95°C

**Fig 9-18 Example of preheating unit, electric (4V47K0045)**

**Table 9-2 Example of preheating unit**

| Capacity [kW] | B | C | SA | Z | Water content [kg] | Weight [kg] |
|---|---|---|---|---|---|---|
| 72 | 665 | 1455 | 950 | 900 | 67 | 225 |
| 81 | 665 | 1455 | 950 | 900 | 67 | 225 |
| 108 | 715 | 1445 | 1000 | 900 | 91 | 260 |
| 135 | 715 | 1645 | 1000 | 1100 | 109 | 260 |
| 147 | 765 | 1640 | 1100 | 1100 | 143 | 315 |
| 169 | 765 | 1640 | 1100 | 1100 | 142 | 315 |
| 203 | 940 | 1710 | 1200 | 1100 | 190 | 375 |
| 214 | 940 | 1710 | 1200 | 1100 | 190 | 375 |
| 247 | 990 | 1715 | 1250 | 1100 | 230 | 400 |
| 270 | 990 | 1715 | 1250 | 1100 | 229 | 400 |
| ***All dimensions are in mm*** | | | | | | |

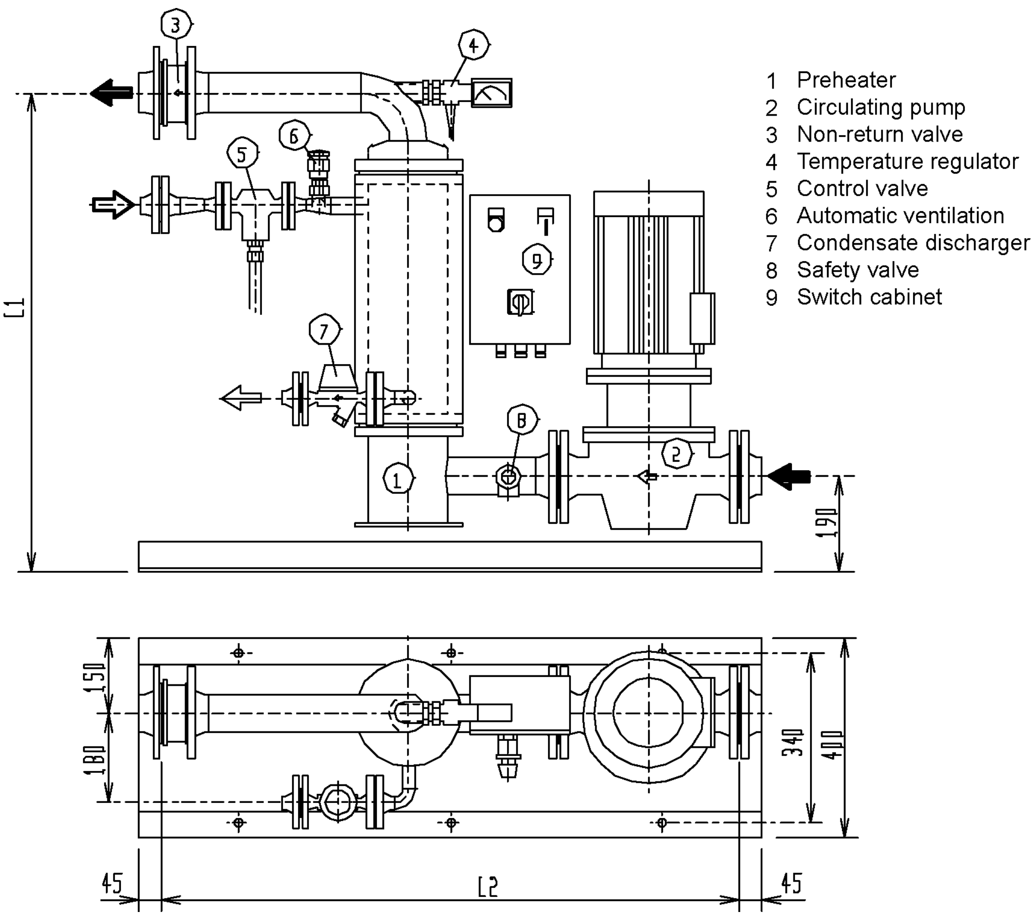



**Fig 9-19 Example of preheating unit, steam**

| Type | kW | L1 [mm] | L2 [mm] | Dry weight [kg] |
|---|---|---|---|---|
| KVDS-72 | 72 | 960 | 1160 | 190 |
| KVDS-96 | 96 | 960 | 1160 | 190 |
| KVDS-108 | 108 | 960 | 1160 | 190 |
| KVDS-135 | 135 | 960 | 1210 | 195 |
| KVDS-150 | 150 | 960 | 1210 | 195 |
| KVDS-170 | 170 | 1190 | 1210 | 200 |
| KVDS-200 | 200 | 1190 | 1260 | 200 |
| KVDS-240 | 240 | 1190 | 1260 | 205 |
| KVDS-270 | 270 | 1430 | 1260 | 205 |

## 9.3.24 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.

### 9.3.25 Thermometers and pressure gauges

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

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 to 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 Φ to evacuate. To determine Φ, all heat sources shall be considered, e.g.:

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

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

The amount of air required for ventilation (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:**

qv = air flow [m³/s]

Φ = total heat emission to be evacuated [kW]

ρ = air density 1.13 kg/m³

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

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

The heat emitted by the engine is listed in chapter *Technical data*.

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.

## 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, see section *Technical data*.

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

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

**where:**

$q_c$ = combustion air volume flow [m³/s]

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

ρ = air density 1.15 kg/m³

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

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

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

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

For very cold conditions heating of the supply air must be arranged. This can be arranged by combustion air heating (externally in air ducting) or by utilizing the engine built charge air cooler (including external CW system and preheater) as combustion air heater. During start, idling and low load operations, the combustion air to be drawn from the engine room in order to secure correct air temperature. 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 and flow. 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, "rigsaver" (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, especially in tropical conditions. The engine equipped with a small drain pipe from the charge air cooler for condensed water.

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

**Example, according to the diagram:**

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

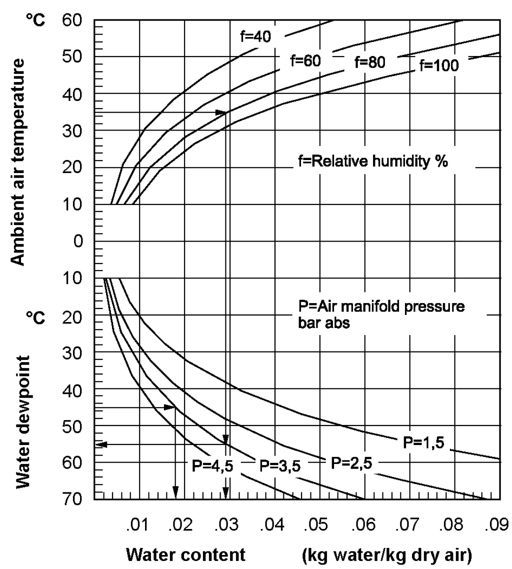



**Fig 10-1 Condensation in charge air coolers**

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# 11. Exhaust Gas System

## 11.1 Internal exhaust gas system

### 11.1.1 Internal combustion air and exhaust gas system for in-line engines

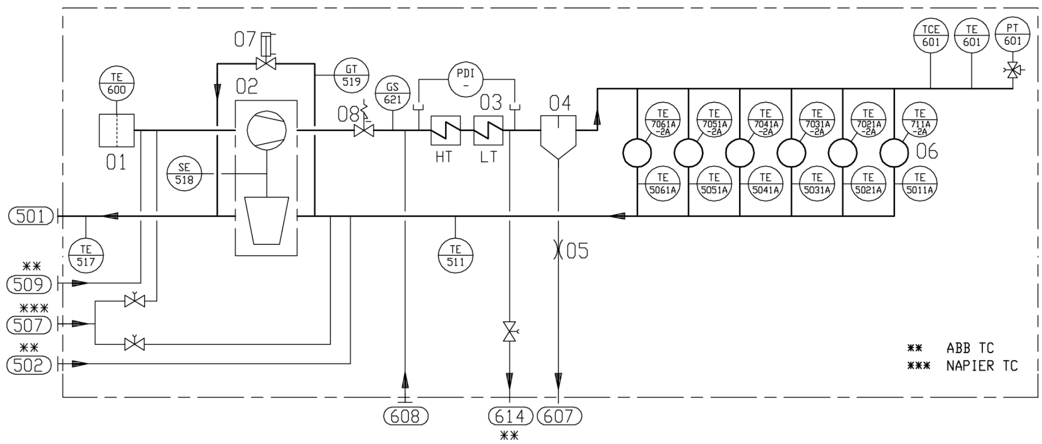



**Fig 11-1 Internal combustion air and exhaust gas system, in-line engines (3V69E8745-5i)**

| System components: | | | | | |
|---|---|---|---|---|---|
| 01 | Air filter | 04 | Water separator | 07 | Waste gate valve |
| 02 | Turbocharger | 05 | Restrictor | 08 | Charge air shut-off valve (optional) |
| 03 | Charge air cooler | 06 | Cylinder | | |

| Sensors and indicators: | | | |
|---|---|---|---|
| TE5011A.. | Exhaust gas temperature after each cylinder | TE600 | Air temperature, turbocharger inlet |
| TE711A.. | Cylinder liner temperature | TE601 | Charge air temperature after CAC |
| TE511 | Exhaust gas temperature before turbine | TCE601 | Charge air temp after CAC (LT-water control) |
| TE517 | Exhaust gas temperature after turbine | GS621 | Charge air shut-off valve postition (optional) |
| SE518 | Turbine speed | GT519 | Waste gate valve position |
| PT601 | Charge air pressure after CAC | PDI | Pressure difference indic. (over CAC, portable) |

| Pipe connections | | Size | Pressure class | Standard |
|---|---|---|---|---|
| 501 | Exhaust gas outlet | see section "*Exhaust gas outlet*" | | |
| 502 | Cleaning water to turbine (if ABB TC) | DN32 | PN40 | ISO 7005-1 |
| 507 | Cleaning water to turbine and compressor (If Napier TC) | R1 | | |
| 509 | Cleaning water to compressor (if ABB TC) | OD18 | | DIN 2353 |
| 607 | Condensate after air cooler | OD28 | | DIN 2353 |
| 608 | Cleaning water to charge air cooler (optional) | OD10 | | DIN 2353 |
| 614 | Scavenging air outlet to TC cleaning valve unit (if ABB TC) | OD18 | | DIN 2353 |

## 11.1.2 Internal combustion air and exhaust gas system for V-engines

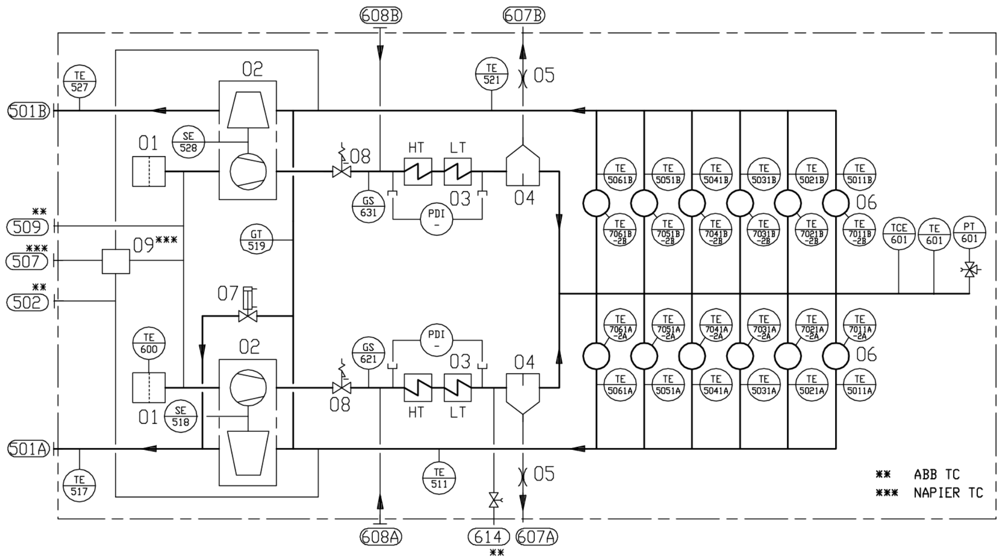


**Fig 11-2 Internal combustion air and exhaust gas system, V-engines (3V69E8746-5h)**

| System components: | | | | | |
|---|---|---|---|---|---|
| 01 | Air filter | 04 | Water separator | 07 | Waste gate valve |
| 02 | Turbocharger | 05 | Restrictor | 08 | Charge air shut-off valve (optional) |
| 03 | Charge air cooler | 06 | Cylinder | 09 | Turbocharger cleaning device (if Napier TC) |

| Sensors and indicators | | | |
|---|---|---|---|
| TE5011A.. | Exhaust gas temperature after each cylinder | PT601 | Charge air pressure after CAC |
| TE711A.. | Cylinder liner temperature | TE600 | Air temperature, turbocharger inlet |
| TE511 | Exhaust gas temp before turbine, A-bank | TE601 | Charge air temperature after CAC |
| TE521 | Exhaust gas temp before turbine, B-bank | TCE601 | Charge air temp after CAC (LT-water control) |
| TE517 | Exhaust gas temperature after turbine, A-bank | GS621 | Charge air shut-off valve postition (optional) |
| TE527 | Exhaust gas temperature after turbine, B-bank | GS631 | Charge air shut-off valve postition (optional) |
| SE518 | Turbine speed, A-bank | GT519 | Waste gate valve position |
| SE528 | Turbine speed, B-bank | PDI | Pressure difference indic. (over CAC, portable) |

| Pipe connections | | Size | Pressure class | Standard |
|---|---|---|---|---|
| 501A/B | Exhaust gas outlet | see section *Exhaust gas outlet* | | |
| 502 | Cleaning water to turbine (if ABB TC) | DN32 | PN40 | ISO 7005-1 |
| 507 | Cleaning water to turbine and compressor (if Napier TC) | R1 | | |
| 509 | Cleaning water to compressor (if ABB TC) | OD18 | | DIN 2353 |
| 607A/B | Condensate after air cooler | 12, 16V: OD28<br>18V: OD22 | | DIN 2353 |
| 608A/B | Cleaning water to charge air cooler (optional) | OD10 | | DIN 2353 |
| 614 | Scavenging air outlet to TC cleaning valve unit (if ABB TC) | OD18 | | DIN 2353 |

## 11.2 Exhaust gas outlet

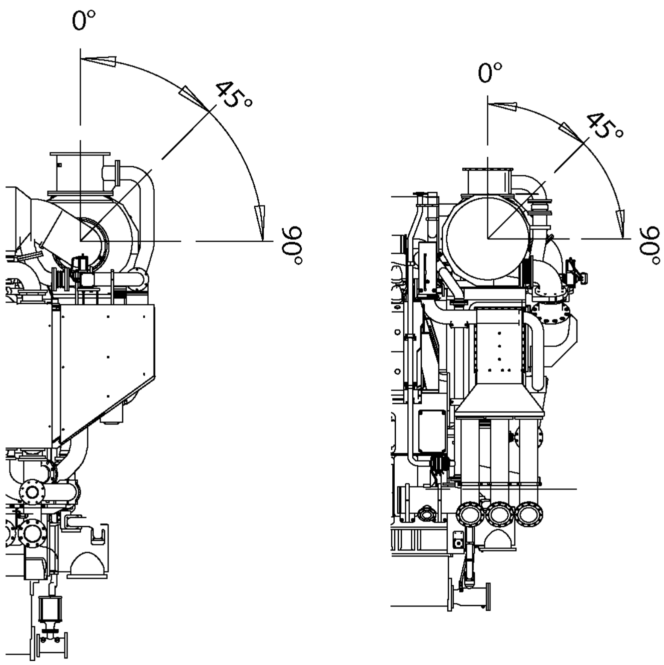



**Fig 11-3 Exhaust pipe connection,(4V58F0057d, -58d)**

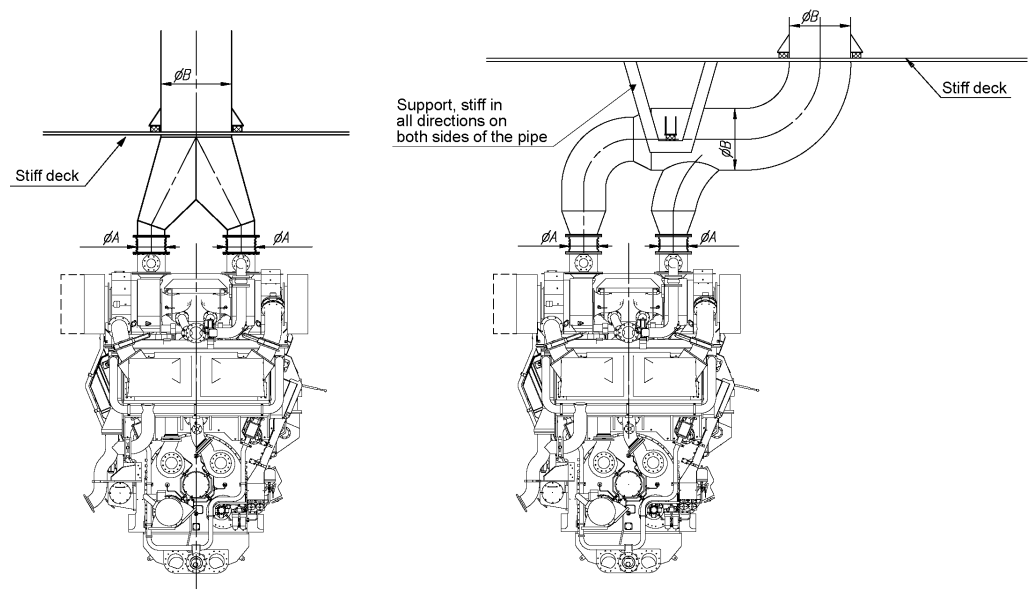



**Fig 11-4 Exhaust pipe, diameters and support**

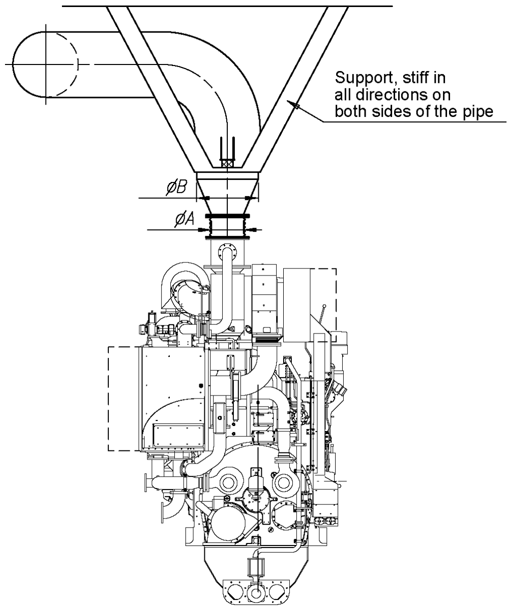


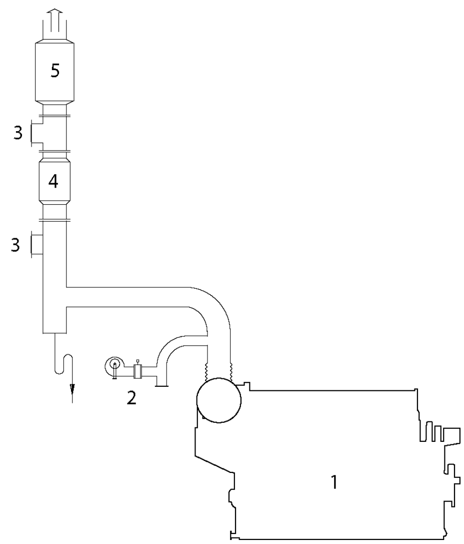

**Fig 11-5** **Exhaust pipe, diameters and support**

| Engine type | TC type | A [mm] | B [mm] |
|---|---|---|---|
| W 6L50DF | TPL71<br>NA357 | DN600<br>DN450 | 900<br>900 |
| W 8L50DF | TPL76C | DN800 | 1000 |
| W 9L50DF | TPL76 | DN800 | 1000 |
| W 12V50DF | TPL71<br>NA357 | DN600<br>DN450 | 1200<br>1200 |
| W 16V50DF | TPL76 | DN800 | 1400 |
| W 18V50DF | TPL76 | DN800 | 1400 |

# 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.




1 Duel Fuel engine

2 Exhaust gas ventilation unit

3 Rupture discs

4 Exhaust gas boiler

5 Silencer

**Fig 11-6 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.

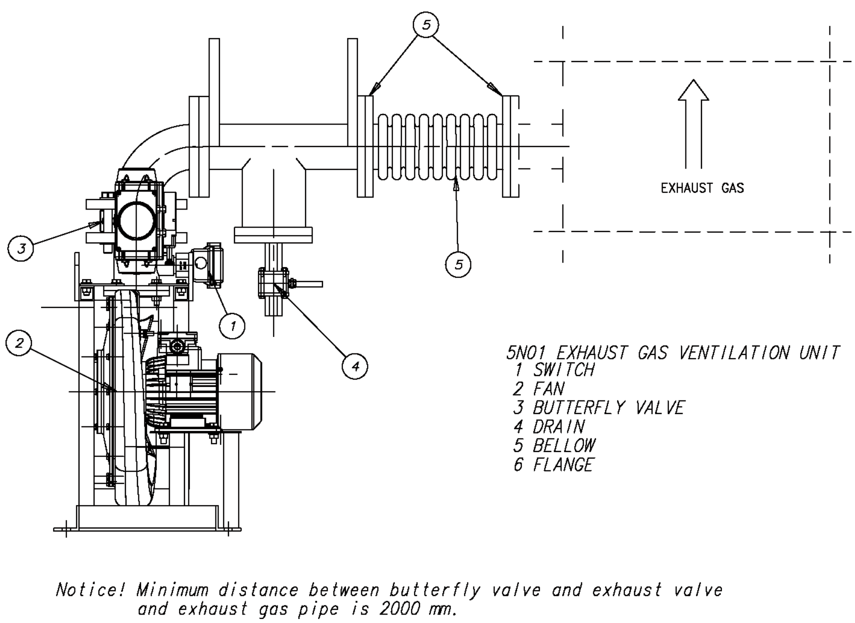



**Fig 11-7 Exhaust gas ventilation arrangement (DAAF315146)**

## 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 chapter *Technical data* 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 long bellows, 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 chapter *Technical Data*. 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 chapter *Technical Data* 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.*

In gas mode the SCR unit is not required as IMO Tier 3 is met.

### 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 chapter *Technical data* may be used.

### 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 an explosion relief vent (option), 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).

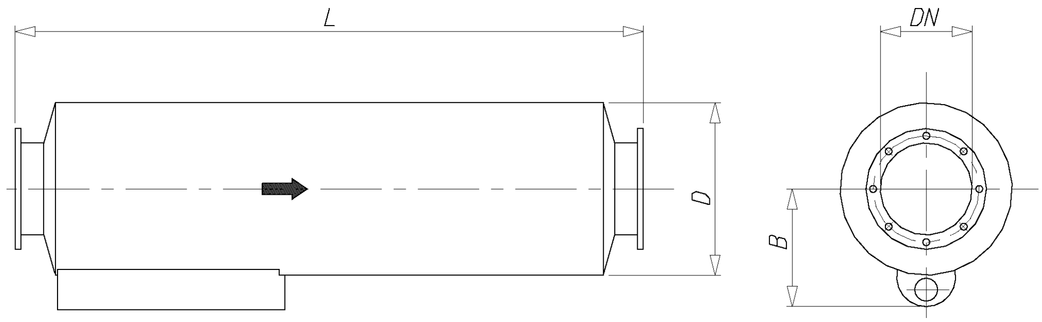



**Fig 11-8** **Exhaust gas silencer (4V49E0156A)**

**Table 11-1** **Typical dimensions of exhaust gas silencers, Attenuation 35 dB (A)**

| NS | L [mm] | D [mm] | B [mm] | Weight [kg] |
|---|---|---|---|---|
| 900 | 7470 | 1800 | 1190 | 4600 |
| 1000 | 8000 | 1900 | 1280 | 5300 |
| 1200 | 9000 | 2300 | 1440 | 7600 |
| 1300 | 9500 | 2300 | 1440 | 8000 |
| **Flanges: DIN 2501** | | | | |

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# 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 in the operation manual must be carefully followed.

Regular cleaning of the turbine is not necessary when operating on gas.

## 12.1 Napier turbochargers

Engines equipped with Napier turbochargers are delivered with a dosing unit consisting of a flow meter and an adjustable throttle valve. 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 (3,0 bar) |
| Max. pressure | 2,0 MPa (20,0 bar) |
| Max. temperature | 80 °C |
| Flow | 35-70 l/min (depending on cylinder configuration) |

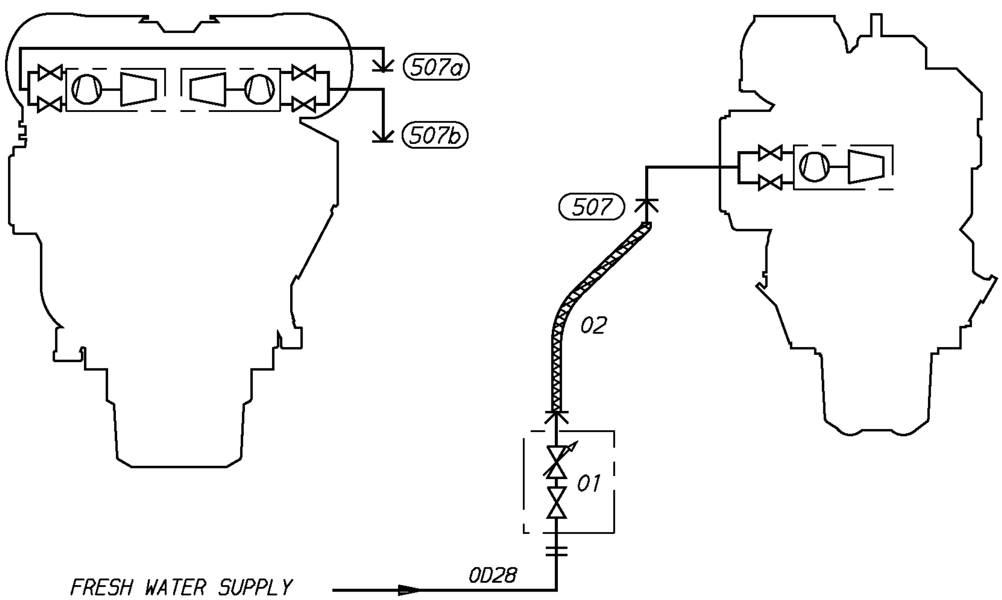



**Fig 12-1 Turbocharger cleaning system, Napier turbochargers (4V76A2574b)**

| System components | | Pipe connections | | Size |
|---|---|---|---|---|
| 01 | Dosing unit with shut-off valve | 507 | Cleaning water to turbine and compressor | Quick coupling |

| System components | | Pipe connections | | Size |
|---|---|---|---|---|
| 02 | Rubber hose | | | |

## 12.2 ABB turbochargers

Engines equipped with TPL turbochargers are delivered with an automatic cleaning system, which comprises a valve unit mounted in the engine room close to the turbocharger and a common control unit for up to six engines. Cleaning is started from the control panel on the control unit and the cleaning sequence is then controlled automatically. A flow meter and a pressure control valve are supplied for adjustment of the water flow.

The water supply line must be dimensioned so that the required pressure can be maintained at the specified flow. If it is necessary to install the valve unit at a distance from the engine, stainless steel pipes must be used between the valve unit and the engine. The valve unit should not be mounted more than 5 m from the engine. The water pipes between the valve unit and the turbocharger are constantly purged with charge air from the engine when the engine is operating above 25% load. External air supply is needed below 25% load.

**Water supply:**

Fresh water

| | |
|---|---|
| Pressure | 0.4...0.8 MPa (4...8 bar) |
| Max. temperature | 40 °C |
| Flow, in-line engines | 22...34 l/min |
| Flow, V-engines | 44...68 l/min |

Washing time ~10 minutes per engine.

**Air supply:**

| | |
|---|---|
| Pressure | 0.4...0.8 MPa (4...8 bar) |
| Max. temperature | 55 °C |
| Flow, in-line engines | 0.3...0.5 kg/min |
| Flow, V-engines | 0.6...1.0 kg/min |

Air consumption only below 25% engine load.

| | |
|---|---|
| Electric supply: | 100...240 VAC / 120 W |

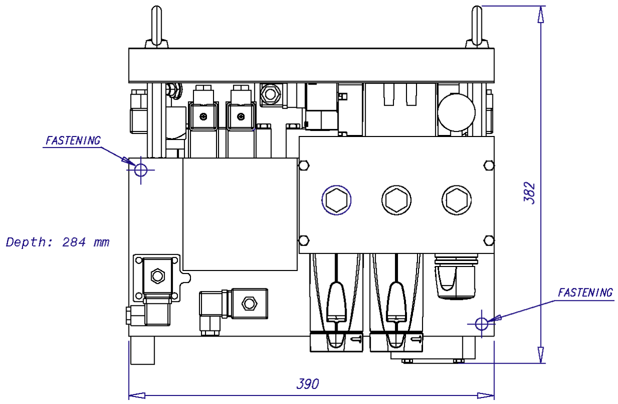



**Fig 12-2 Valve unit**

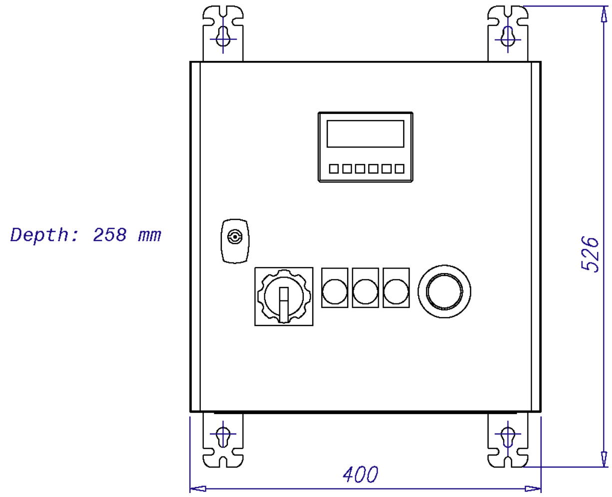



**Fig 12-3 Control unit**

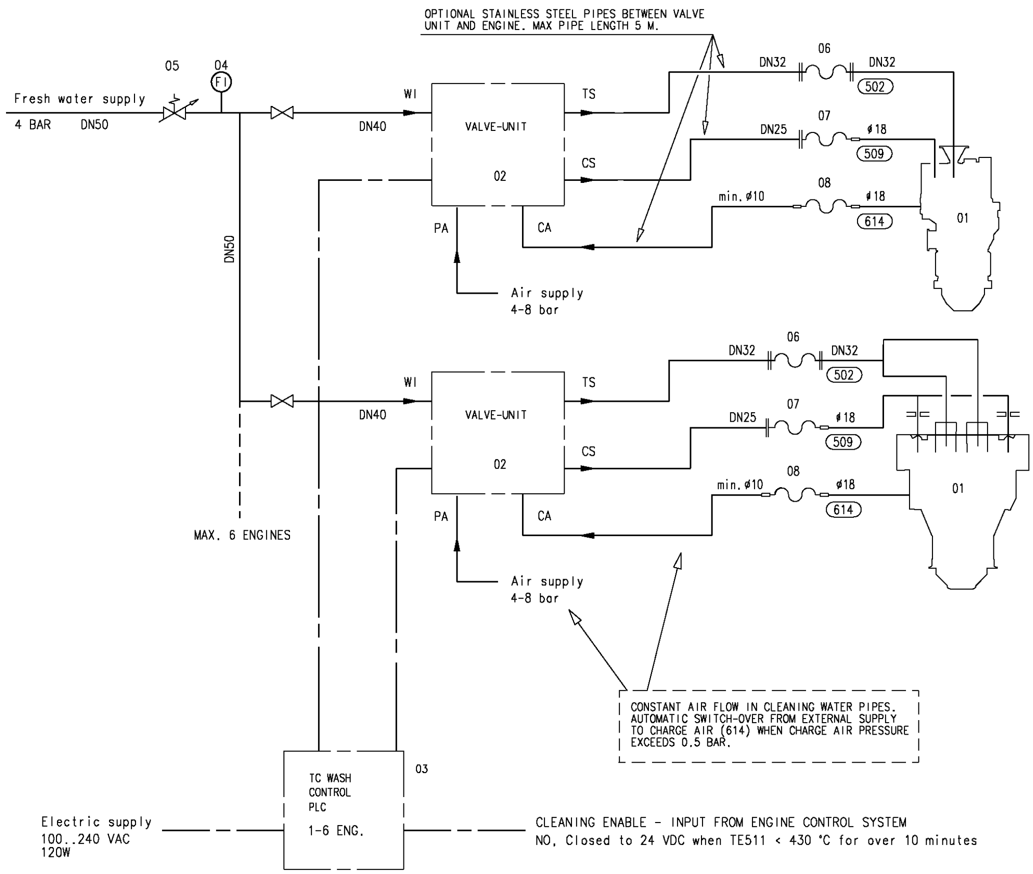



**Fig 12-4 Turbocharger cleaning system (DAAE066685A).**

| System components | | | |
|---|---|---|---|
| 01 | Diesel engine | 04 | Flow meter |
| 02 | Valve unit | 05 | Pressure control valve |
| 03 | Control unit | 06 | Flexible hose (Flexible hose length 1.3m) |

| Pipe connections on engine | | Size | Pressure class | Standard |
|---|---|---|---|---|
| 502 | Cleaning water to turbine | DN32 | PN40 | ISO 7005-1 |
| 509 | Cleaning water to compressor | OD18 | | DIN 2353 |
| 614 | Charge air outlet | OD18 | | DIN 2353 |

| Pipe connections on valve unit | | Size | Pressure class | Standard |
|---|---|---|---|---|
| WI | Water inlet | DN40 | PN40 | ISO 7005-1 |
| TS | Cleaning water to turbine | DN32 | PN40 | ISO 7005-1 |
| CS | Cleaning water to compressor | DN25 | PN40 | ISO 7005-1 |
| CA | Charge air | G3/8" ISO 228 | | |
| PA | Compressed air | G3/8" ISO 228 | | |

Wärtsilä 50DF engines are delivered with an automatic cleaning system, which comprises a valve unit mounted in the engine room close to the turbocharger and a common control unit for up to six engines. Cleaning is started from the control panel on the control unit and the cleaning sequence is then controlled automatically. A flow meter and a pressure control valve are supplied for adjustment of the water flow.

The water supply line must be dimensioned so that the required pressure can be maintained at the specified flow. If it is necessary to install the valve unit at a distance from the engine, stainless steel pipes must be used between the valve unit and the engine. The valve unit should not be mounted more than 5 m from the engine. The water pipes between the valve unit and the turbocharger are constantly purged with charge air from the engine when the engine is operating above 25% load. External air supply is needed below 25% load.

## 12.3 Turbocharger cleaning system

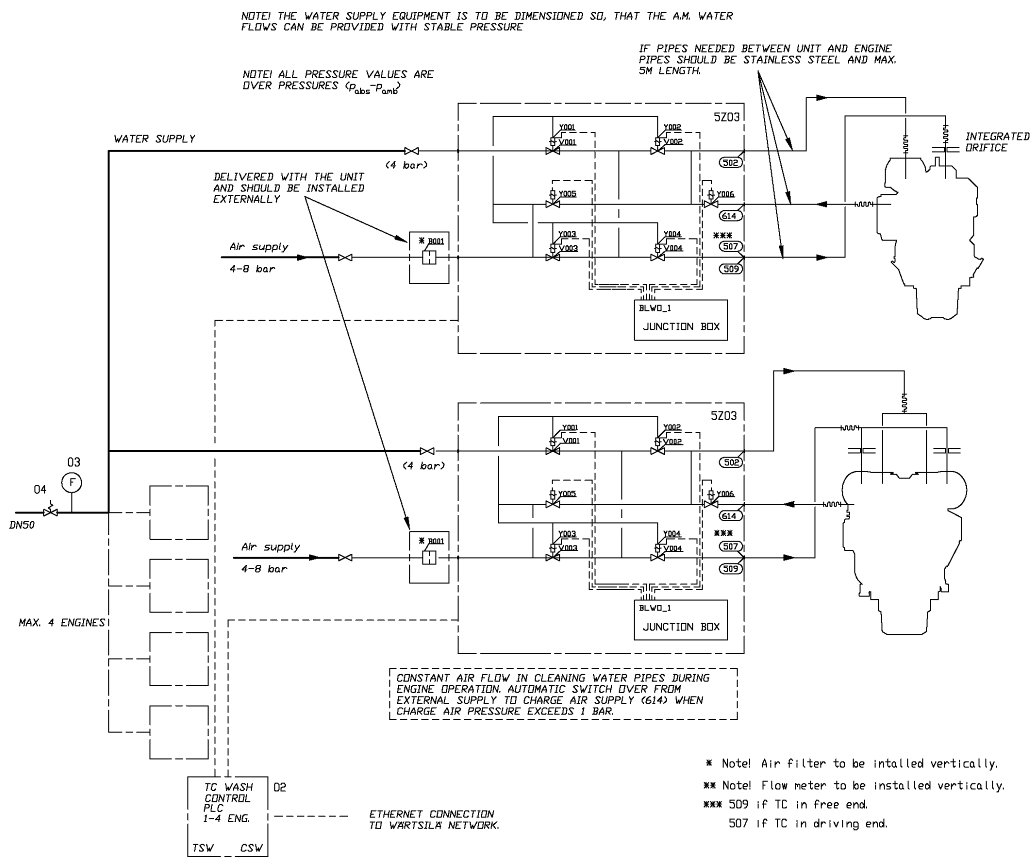


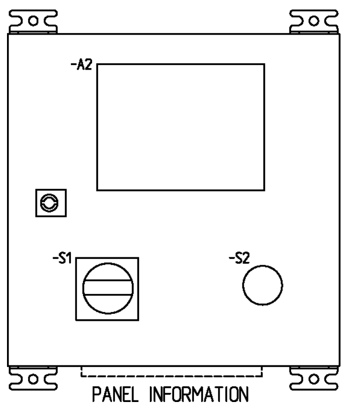

**Fig 12-5 Turbocharger cleaning system (DAAF023164G)**

| System components: | |
|---|---|
| 5Z03 | TC cleaning device |
| 02 | Control unit C1 for 2 engines |
| 02 | Control unit C2 & C3 for 4 engines |
| 03 | Flow meter/control (0 - 80 l/min) |
| 04 | Pressure control |

| | | | |
|---|---|---|---|
| Engine | Water | Air | Flow meter |

| Engine | Turbocharger | Water inlet press before contr. valve (bar) | Nom water inlet press after press contr. valve | Water inlet flow rate (l/min) | Water consump-tion/wash (l) | System air for scavening at low load (l/min) | (0-80 l/min) |
|---|---|---|---|---|---|---|---|
| 6L50DF | TPL71-C | 5.0 - 8.0 | (4.0) | 24 | 240 | - | KK4DA-X |
| 8L50DF | TPL76-C | 5.0 - 8.0 | (4.0) | 37 | 370 | - | KK4DA-X |
| 9L50DF | TPL76-C | 5.0 - 8.0 | (4.0) | 37 | 370 | - | KK4DA-X |
| 12V50DF | 2 * TPL71-C | 5.0 - 8.0 | (4.0) | 48 | 480 | - | KK4DA-X |
| 16V50DF | 2 * TPL76-C | 5.0 - 8.0 | (4.0) | 74 | 740 | - | KK4DA-X |

# 12.4 Wärtsilä control unit for four engines, UNIC C2 & C3




| | |
|---|---|
| Width: | 380 mm |
| Height: | 380 mm |
| Depth: | 210 mm |
| Weight: | 35 kg appr. |
| Max ambient temp: | 50°C |

**Fig 12-6 Wärtsilä control unit (DAAF010946D)**

# 13. Exhaust Emissions

Exhaust emissions from the dual fuel engine mainly consist of nitrogen, carbon dioxide (CO2) and water vapour with smaller quantities of carbon monoxide (CO), sulphur oxides (SOx) and nitrogen oxides (NOx), 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 NOx 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 NOx emissions from the Wärtsilä DF engine is very low, complying with most existing legislation. In gas mode most stringent emissions of IMO, EPA 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 SOx from the dual fuel engine are negligable. 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.

#### MARPOL Annex VI - Air Pollution

The MARPOL 73/78 Annex VI entered into force 19 May 2005. The Annex VI sets limits on Nitrogen Oxides, Sulphur Oxides and Volatile Organic Compounds emissions from ship exhausts and prohibits deliberate emissions of ozone depleting substances.

##### Nitrogen Oxides, $NO_x$ Emissions

The MARPOL 73/78 Annex VI regulation 13, Nitrogen Oxides, applies to diesel engines over 130 kW installed on ships built (defined as date of keel laying or similar stage of construction) on or after January 1, 2000 and different levels (Tiers) of NOx control apply based on the ship construction date. The $NO_x$ emissions limit is expressed as dependent on engine speed. IMO has developed a detailed $NO_x$ Technical Code which regulates the enforcement of these rules.

###### EIAPP Certification

An EIAPP (Engine International Air Pollution Prevention) Certificate is issued for each engine showing that the engine complies with the $NO_x$ regulations set by the IMO.

When testing the engine for $NO_x$ emissions, the reference fuel is Marine Diesel Oil (distillate) and the test is performed according to ISO 8178 test cycles. Subsequently, the $NO_x$ value has to be calculated using different weighting factors for different loads that have been corrected to ISO 8178 conditions. The used ISO 8178 test cycles are presented in the following table.

**Table 13-1 ISO 8178 test cycles**

| D2: Constant-speed auxiliary engine application | Speed (%) | 100 | 100 | 100 | 100 | 100 |
|---|---|---|---|---|---|---|
| | Power (%) | 100 | 75 | 50 | 25 | 10 |
| | Weighting factor | 0.05 | 0.25 | 0.3 | 0.3 | 0.1 |

| E2: Constant-speed main propulsion application including diesel-electric drive and all controllable-pitch propeller installations | Speed (%) | 100 | 100 | 100 | 100 |
|---|---|---|---|---|---|
| | Power (%) | 100 | 75 | 50 | 25 |
| | Weighting factor | 0.2 | 0.5 | 0.15 | 0.15 |

| C1: Variable -speed and -load auxiliary engine application | Speed | Rated | | | | Intermediate | | | Idle |
|---|---|---|---|---|---|---|---|---|---|
| | Torque (%) | 100 | 75 | 50 | 10 | 100 | 75 | 50 | 0 |
| | Weighting factor | 0.15 | 0.15 | 0.15 | 0.1 | 0.1 | 0.1 | 0.1 | 0.15 |

### Engine family/group

As engine manufacturers have a variety of engines ranging in size and application, the $NO_x$ Technical Code allows the organising of engines into families or groups. By definition, an engine family is a manufacturer's grouping, which through their design, are expected to have similar exhaust emissions characteristics i.e., their basic design parameters are common. When testing an engine family, the engine which is expected to develop the worst emissions is selected for testing. The engine family is represented by the parent engine, and the certification emission testing is only necessary for the parent engine. Further engines can be certified by checking document, component, setting etc., which have to show correspondence with those of the parent engine.

### Technical file

According to the IMO regulations, a Technical File shall be made for each engine. The Technical File contains information about the components affecting $NO_x$ emissions, and each critical component is marked with a special IMO number. The allowable setting values and parameters for running the engine are also specified in the Technical File. The EIAPP certificate is part of the IAPP (International Air Pollution Prevention) Certificate for the whole ship.

### IMO NOx emission standards

The first IMO Tier 1 NOx emission standard entered into force in 2005 and applies to marine diesel engines installed in ships constructed on or after 1.1.2000 and prior to 1.1.2011.

The Marpol Annex VI and the $NO_x$ Technical Code were later undertaken a review with the intention to further reduce emissions from ships and a final adoption for IMO Tier 2 and Tier 3 standards were taken in October 2008.

The IMO Tier 2 NOx standard entered into force 1.1.2011 and replaced the IMO Tier 1 NOx emission standard globally. The Tier 2 NOx standard applies for marine diesel engines installed in ships constructed on or after 1.1.2011.

The IMO Tier 3 $NO_x$ emission standard effective date starts from year 2016. The Tier 3 standard will apply in designated emission control areas (ECA). The ECAs are to be defined by the IMO. So far, the North American ECA and the US Caribbean Sea ECA have been defined and will be effective for marine diesel engines installed in ships constructed on or after 1.1.2016. For other ECAs which might be designated in the future for Tier 3 NOx control, the entry into force date would apply to ships constructed on or after the date of adoption by the MEPC of such an ECA, or a later date as may be specified separately. The IMO Tier 2 $NO_x$ emission standard will apply outside the Tier 3 designated areas.

The $NO_x$ emissions limits in the IMO standards are expressed as dependent on engine speed. These are shown in the following figure.

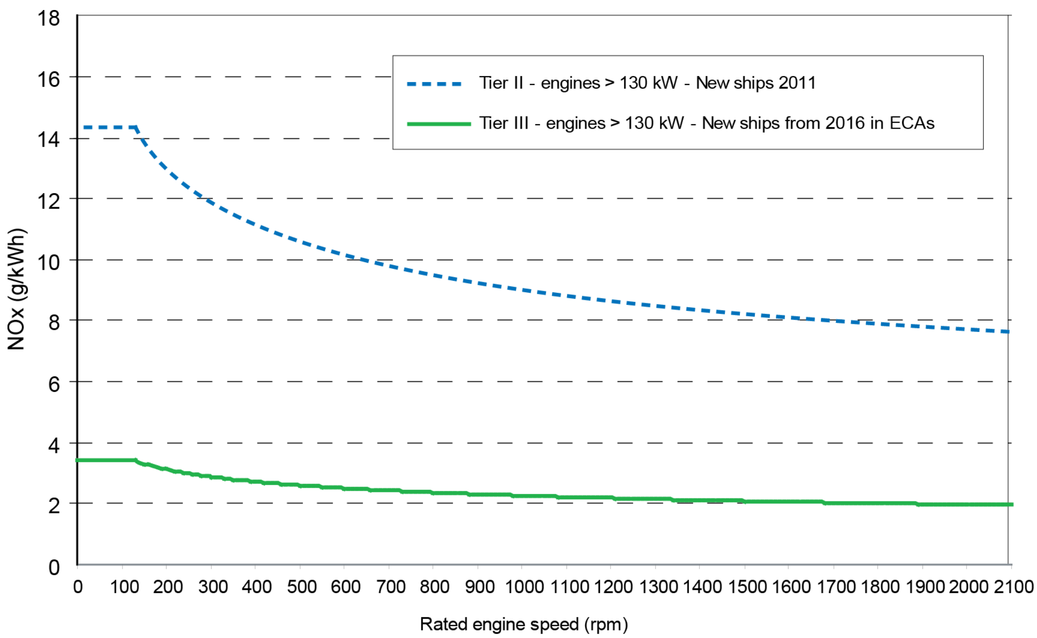



**Fig 13-1 IMO $NO_x$ emission limits**

### IMO Tier 2 $NO_x$ emission standard (new ships 2011)

The IMO Tier 2 $NO_x$ emission standard entered into force in 1.1.2011 and applies globally for new marine diesel engines > 130 kW installed in ships which keel laying date is 1.1.2011 or later.

**The IMO Tier 2 $NO_x$ limit is defined as follows:**

$NO_x$ [g/kWh] $= 44 \times rpm^{-0.23}$ when $130 < rpm < 2000$

The $NO_x$ level is a weighted average of $NO_x$ emissions at different loads, and the test cycle is based on the engine operating profile according to ISO 8178 test cycles. The IMO Tier 2 NOx level is met by engine internal methods.

### IMO Tier 3 $NO_x$ emission standard (new ships from 2016 in ECAs)

The IMO Tier 3 $NO_x$ emission standard will enter into force from year 2016. It will by then apply for new marine diesel engines > 130 kW installed in ships which keel laying date is 1.1.2016 or later when operating inside the North American ECA and the US Caribbean Sea ECA.

**The IMO Tier 3 $NO_x$ limit is defined as follows:**

$NO_x$ [g/kWh] $= 9 \times rpm^{-0.2}$ when $130 < rpm < 2000$

The IMO Tier 3 $NO_x$ emission level corresponds to an 80% reduction from the IMO Tier 2 NOx emission standard. The reduction can be reached by applying a secondary exhaust gas emission control system. A Selective Catalytic Reduction (SCR) system is an efficient way for diesel engines to reach the NOx reduction needed for the IMO Tier 3 standard.

If the Wärtsilä NOx Reducer SCR system is installed together with the engine, the engine + SCR installation complies with the maximum permissible NOx emission according to the IMO Tier 3 NOx emission standard and the Tier 3 EIAPP certificate will be delivered for the complete installation.

**NOTE**

The Dual Fuel engines fulfil the IMO Tier 3 NOx emission level as standard in gas mode operation without the need of a secondary exhaust gas emission control system.

### Sulphur Oxides, $SO_x$ emissions

Marpol Annex VI has set a maximum global fuel sulphur limit of currently 3,5% (from 1.1.2012) in weight for any fuel used on board a ship. Annex VI also contains provisions allowing for special SOx Emission Control Areas (SECA) to be established with more stringent controls on sulphur emissions. In a SECA, which currently comprises the Baltic Sea, the North Sea, the English Channel, the US Caribbean Sea and the area outside North America (200 nautical miles), the sulphur content of fuel oil used onboard a ship must currently not exceed 0,1 % in weight.

The Marpol Annex VI has undertaken a review with the intention to further reduce emissions from ships. The current and upcoming limits for fuel oil sulphur contents are presented in the following table.

**Table 13-2 Fuel sulphur caps**

| Fuel sulphur cap | Area | Date of implementation |
|---|---|---|
| Max 3.5% S in fuel | Globally | 1 January 2012 |
| Max. 0.1% S in fuel | SECA Areas | 1 January 2015 |
| Max. 0.5% S in fuel | Globally | 1 January 2020 |

Abatement technologies including scrubbers are allowed as alternatives to low sulphur fuels. The exhaust gas system can be applied to reduce the total emissions of sulphur oxides from ships, including both auxiliary and main propulsion engines, calculated as the total weight of sulphur dioxide emissions.

### 13.2.2 Other Legislations

There are also other local legislations in force in particular regions.

## 13.3 Methods to reduce exhaust emissions

All standard Wärtsilä engines meet the NOx emission level set by the IMO (International Maritime Organisation) and most of the local emission levels without any modifications. Wärtsilä has also developed solutions to significantly reduce NOx emissions when this is required.

Diesel engine exhaust emissions can be reduced either with primary or secondary methods. The primary methods limit the formation of specific emissions during the combustion process. The secondary methods reduce emission components after formation as they pass through the exhaust gas system.

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.

Refer to the "*Wärtsilä Environmental Product Guide*" for information about exhaust gas emission control systems.

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# 14. Automation System

Wärtsilä Unified Controls – UNIC is a modular embedded automation system. UNIC C3 is used for engines with electronically controlled fuel injection and has a hardwired interface for control functions and a bus communication interface for alarm and monitoring.

## 14.1 UNIC C3

UNIC C3 is a fully embedded and distributed engine management system, which handles all control functions on the engine; for example start sequencing, start blocking, fuel injection, cylinder balancing, knock control, speed control, load sharing, normal stops and safety shutdowns.

The distributed modules communicate over a CAN-bus. CAN is a communication bus specifically developed for compact local networks, where high speed data transfer and safety are of utmost importance.

The CAN-bus and the power supply to each module are both 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.

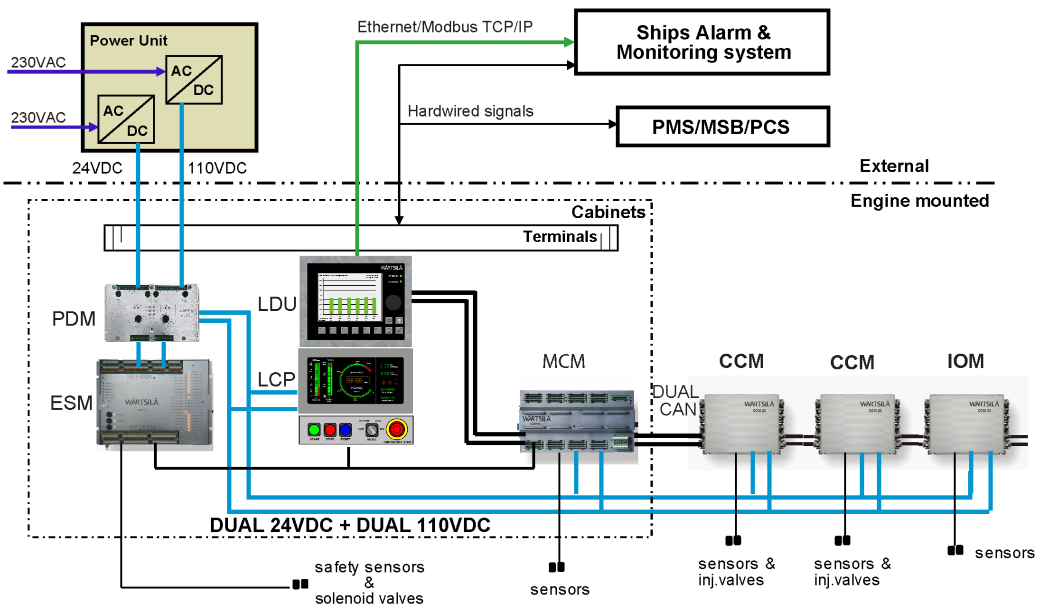



**Fig 14-1 Architecture of UNIC C3**

Short explanation of the modules used in the system:

**MCM** Main Control Module. Handles all strategic control functions (such as start/stop sequencing and speed/load control) of the engine.

**ESM** Engine Safety Module handles fundamental engine safety, for example shutdown due to overspeed or low lubricating oil pressure.

**LCP** Local Control Panel is equipped with push buttons and switches for local engine control, as well as indication of running hours and safety-critical operating parameters.

| | |
|---|---|
| **LDU** | Local Display Unit offers a set of menus for retrieval and graphical display of operating data, calculated data and event history. The module also handles communication with external systems over Modbus TCP. |
| **PDM** | Power Distribution Module handles fusing, power distribution, earth fault monitoring and EMC filtration in the system. It provides two fully redundant supplies to all modules. |
| **IOM** | Input/Output Module handles measurements and limited control functions in a specific area on the engine. |
| **CCM** | Cylinder Control Module handles fuel injection control and local measurements for the cylinders. |

The above equipment and instrumentation are prewired on the engine. The ingress protection class is IP54.

## 14.1.1 Local control panel and local display unit

**Operational functions available at the LCP:**

- Local start
- Local stop
- Local emergency speed setting selectors (mechanical propulsion):
  - Normal / emergency mode
  - Decrease / Increase speed
- Local emergency stop
- Local shutdown reset

  Local mode selector switch with the following positions:
  - Local: Engine start and stop can be done only at the local control panel
  - Remote: Engine can be started and stopped only remotely
  - Slow: In this position it is possible to perform a manual slow turning by activating the start button.
  - Blocked: Normal start of the engine is not possible

**The LCP has back-up indication of the following parameters:**

- Engine speed
- Turbocharger speed
- Running hours
- Lubricating oil pressure
- HT cooling water temperature

The local display unit has a set of menus for retrieval and graphical display of operating data, calculated data and event history.

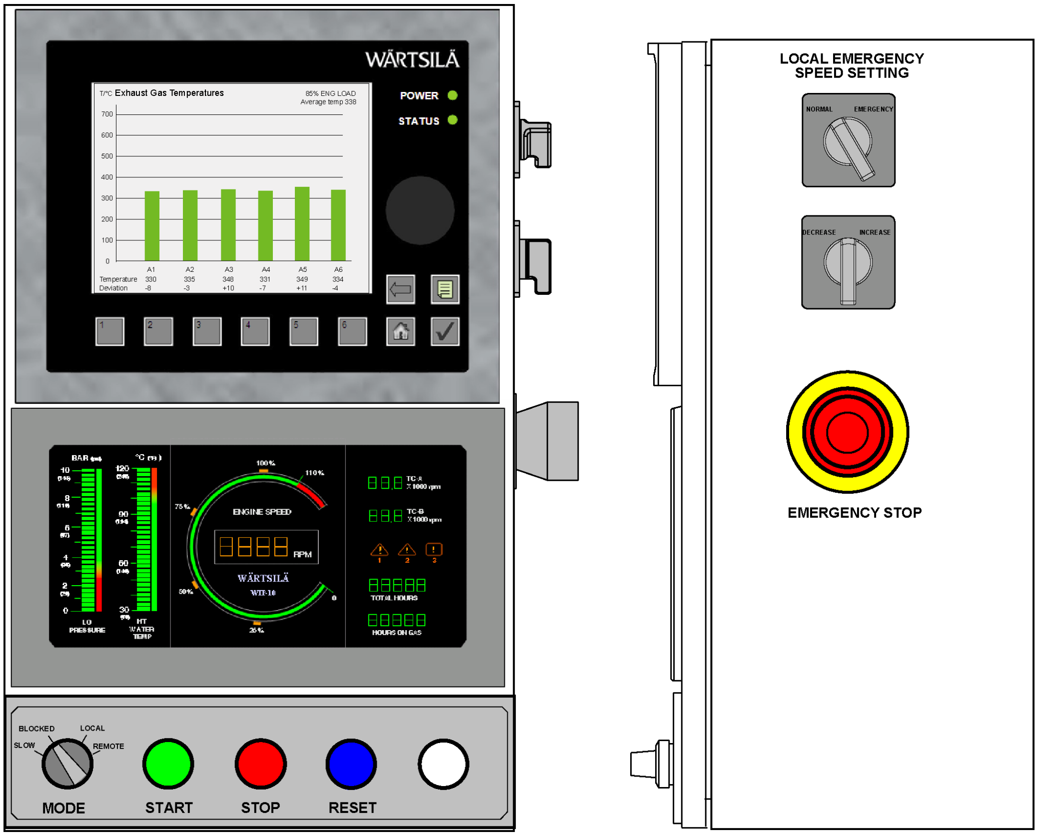



**Fig 14-2 Local control panel and local display unit**

## 14.1.2 Engine safety system

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

Main features:

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

## 14.1.3 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. 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 equipment on the engine with 2 x 24 VDC and 2 x 110 VDC.

Power supply from ship's system:

- Supply 1: 230 VAC / abt. 1500 W
- Supply 2: 230 VAC / abt. 1500 W

## 14.1.4 Cabling and system overview

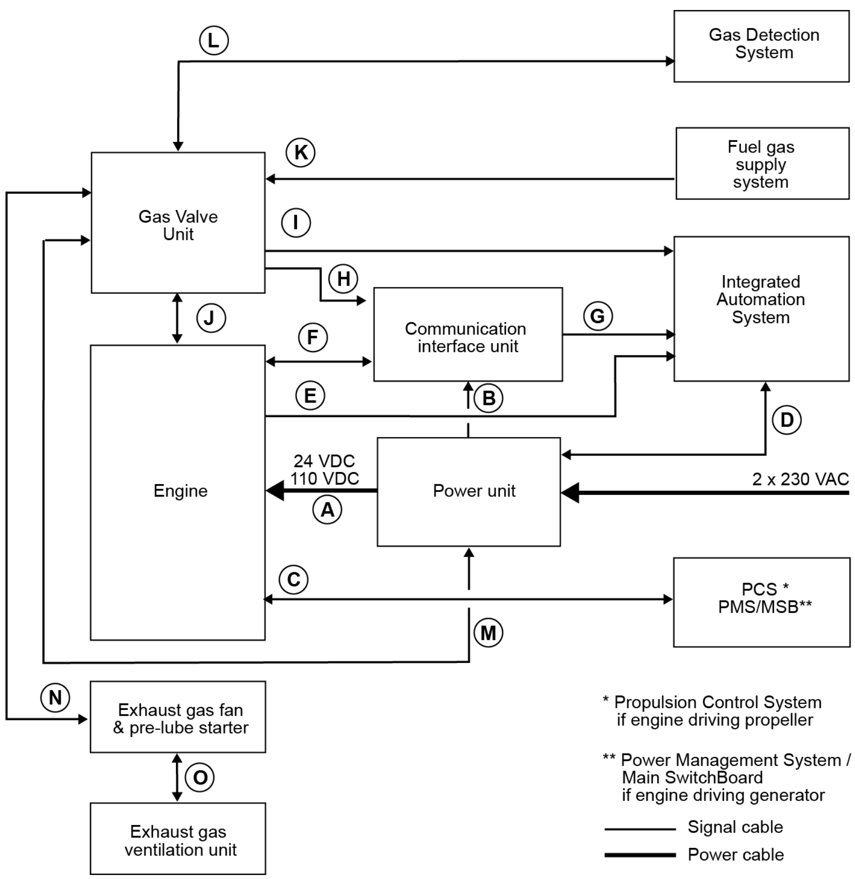



**Fig 14-3 UNIC C3 overview**

**Table 14-1 Typical amount of cables**

| Cable | From <=> To | Cable types (typical) |
|---|---|---|
| | | |
| A | Engine <=> Power Unit | 2 x 2.5 mm$^2$ (power supply) *<br>2 x 2.5 mm$^2$ (power supply) *<br>2 x 2.5 mm$^2$ (power supply) *<br>2 x 2.5 mm$^2$ (power supply) * |
| B | Power unit => Communication interface unit | 2 x 2.5 mm$^2$ (power supply) * |

| Cable | From <=> To | Cable types (typical) |
|---|---|---|
| C | Engine <=> Propulsion Control System<br>Engine <=> Power Management System / Main Switch-board | 1 x 2 x 0.75 mm$^2$<br>1 x 2 x 0.75 mm$^2$<br>1 x 2 x 0.75 mm$^2$<br>24 x 0.75 mm$^2$<br>24 x 0.75 mm$^2$ |
| D | Power unit <=> Integrated Automation System | 2 x 0.75 mm$^2$ |
| E | Engine <=> Integrated Automation System | 3 x 2 x 0.75 mm$^2$ |
| F | Engine => Communication interface unit | 1 x Ethernet CAT 5 |
| G | Communication interface unit => Integrated automation system | 1 x Ethernet CAT 5 |
| H | Gas valve unit => Communication interface unit | 1 x Ethernet CAT 5 |
| I | Gas Valve Unit <=> Integrated Automation System | 2 x 2 x 0.75 mm$^2$<br>1 x Ethernet CAT5 |
| J | Engine <=> Gas Valve Unit | 4 x 2 x 0.75 mm$^2$<br>2 x 2 x 0.75 mm$^2$<br>3 x 2 x 0.75 mm$^2$ |
| K | Gas Valve Unit <=> Fuel gas supply system | 4 x 2 x 0.75 mm$^2$ |
| L | Gas Valve Unit <=> Gas detection system | 1 x 2 x 0.75 mm$^2$ |
| M | Power unit <=> Gas Valve Unit | 2 x 2.5 mm$^2$ (power supply) *<br>2 x 2.5 mm$^2$ (power supply) *<br>3 x 2 x 0.75 mm$^2$ |
| N | Gas Valve Unit <=> Exhaust gas fan and pre-lube starter | 3 x 2 x 0.75 mm$^2$<br>2 x 5 x 0.75 mm$^2$ |
| O | Exhaust gas fan and pre-lube starter <=> Exhaust gas ventilation unit | 4 x 2 x 0.75 mm$^2$<br>3 x 2.5 x 2.5 mm$^2$ |

**NOTE**

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*.

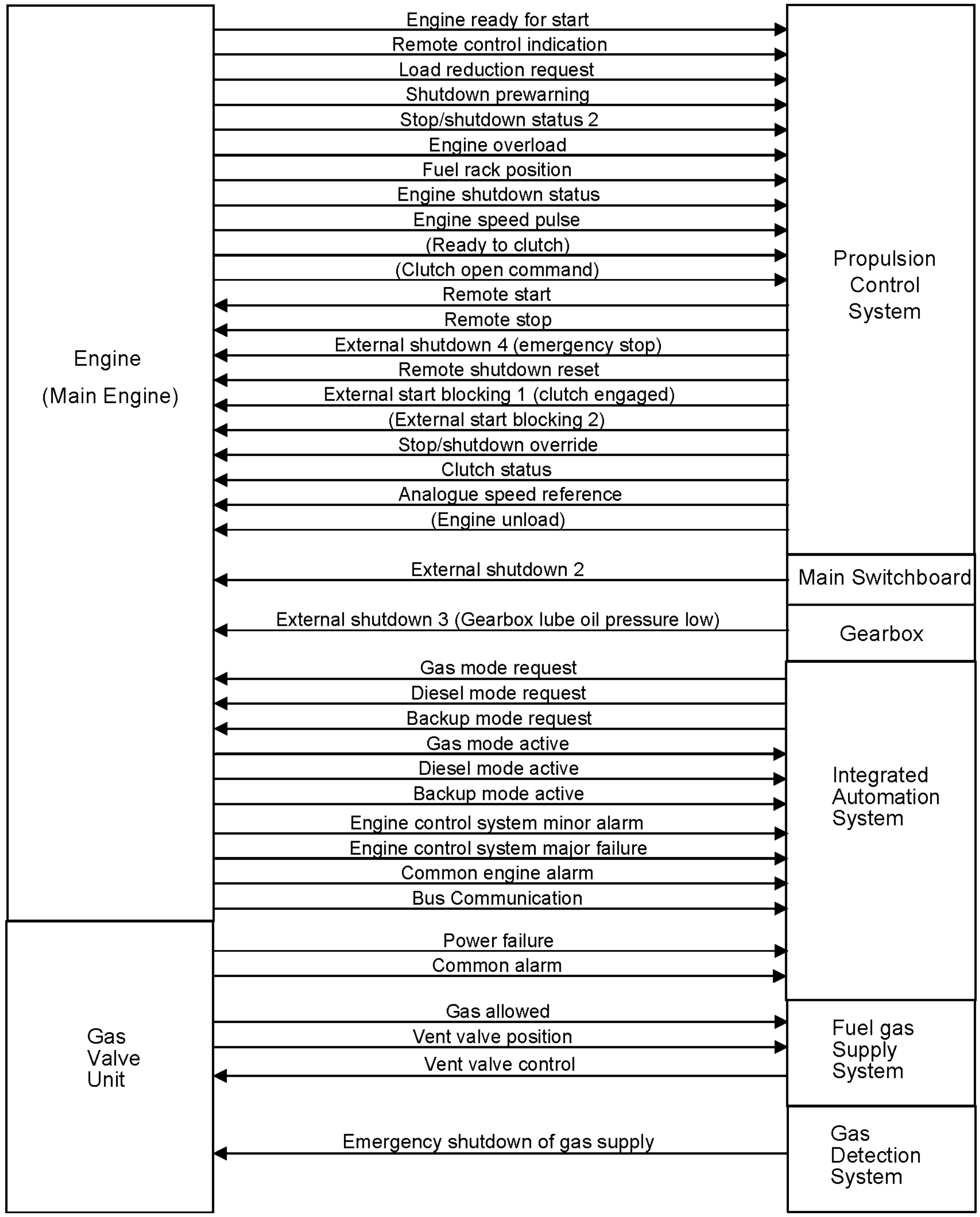



**Fig 14-4 Signal overview (Main engine)**

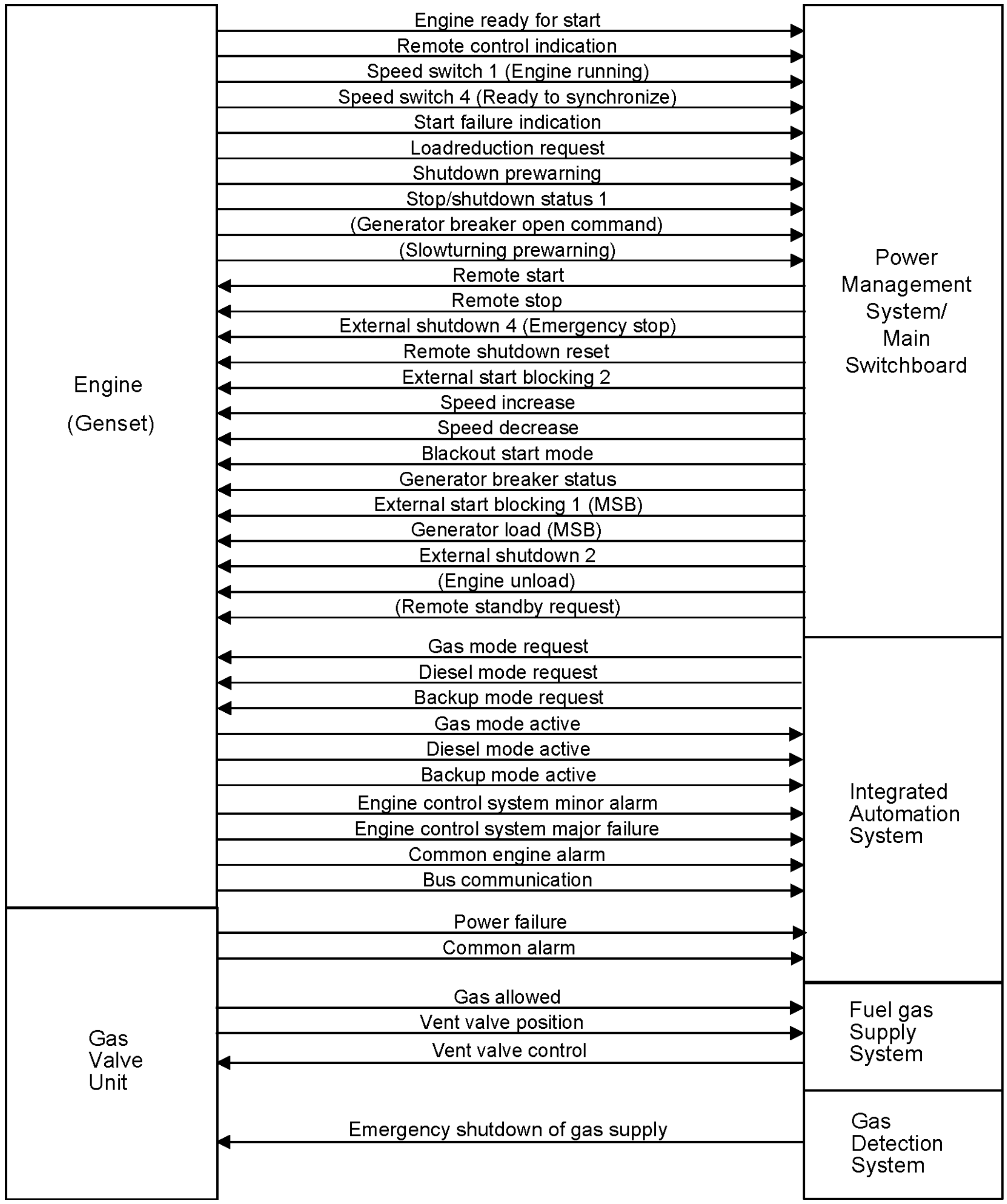



**Fig 14-5 Signal overview (Generating set)**

## 14.2 Functions

### 14.2.1 Engine operating modes

The operator can select four different fuel operating modes:

- Gas operating mode (gas fuel + pilot fuel injection)
- Diesel operating mode (conventional diesel fuel injection + pilot fuel injection)
- Fuel sharing mode (optional)

In addition, engine control and safety system or the blackout detection system can force the engine to run in backup operating mode (conventional diesel fuel injection only).

It is possible to transfer a running engine from gas- into diesel operating mode. 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. Request for diesel operating mode will always override request for gas 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

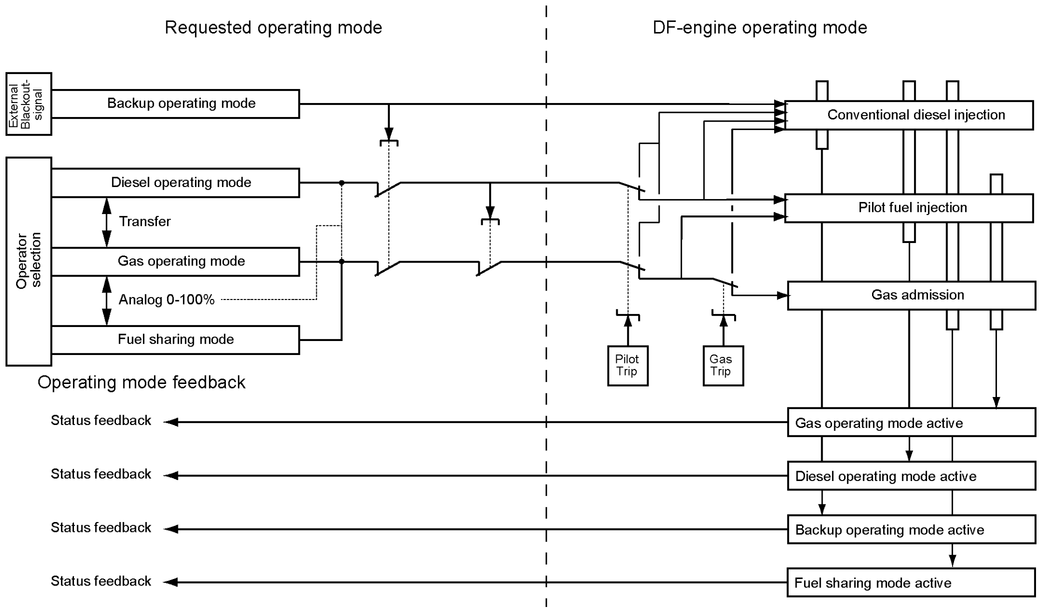



**Fig 14-6 Principle of engine operating modes**

## Fuel sharing mode (optional)

As option, the engine can be equipped with a fuel sharing mode. When this mode is activated, the engine will utilise gas injection, main fuel injection and pilot injection. The major benefits of the fuel sharing feature is maximum fuel flexibility, meaning optimized operation of engines and optimized utilization of boil-off gas. In installations, where engines have fuel sharing included, this must be considered and implemented in the vessel automation system and hardwiring.

All existing safeties for gas mode remain in use when operating in fuel sharing mode. I.e. the safety is at the same high level as if operating in normal gas mode. In addition, a trip to liquid mode is initiated if a cylinder pressure sensor is failing and fuel sharing is active.

The gas and main liquid fuel mixing ratio can be chosen by the operator according to the fuel sharing map (see fig *14-7*). The engine will switch to liquid mode if the engine load is lower or higher than the allowed engine load level for fuel sharing operation. If the fuel sharing set point is outside the fuel sharing map, it will automatically be restricted to the closest point within the fuel sharing map. It is possible to enter fuel sharing mode directly from liquid mode or from gas mode. It is also possible to enter gas mode or liquid mode directly from fuel sharing mode. Entering gas mode operation directly from fuel sharing mode, can only be done with MDO fuel. If HFO fuel has been in the system, a 30 minute period of MDO fuel operation is required.

This optional feature is valid for constant speed engines and has no impact on the loading capability. I.e. standard loading capability apply. The standard component life time and overhaul intervals apply. IMO Tier 2 emissions are fulfilled in fuel sharing mode. In normal gas mode, IMO Tier 3 emissions are fulfilled.

The engine efficiency change depending on fuel mix ratio and engine load, please contact Wärtsilä for further information.

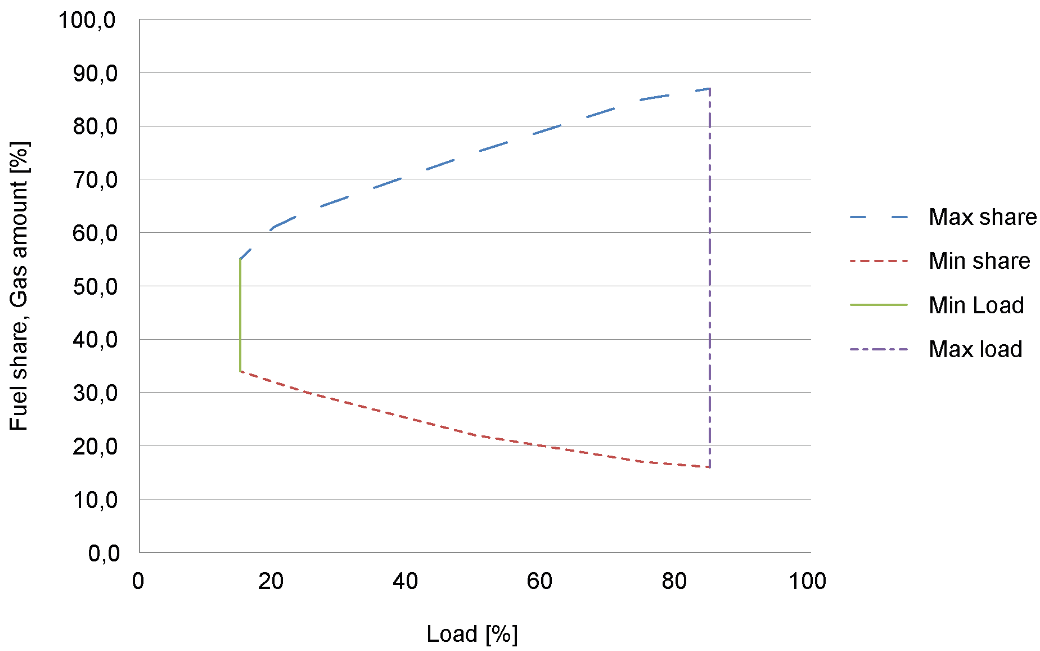



**Fig 14-7 Fuel mixing ratio**

## 14.2.2 Start

### Start blocking

Starting is inhibited by the following functions:

- Stop lever in stop position
- 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 of 0.5 bar)
- Stop signal to engine activated (safety shut-down, emergency stop, normal stop)
- External start block active
- Exhaust gas ventilation not performed
- HFO selected or fuel oil temperature > 70°C (Gas mode only)
- Charge air shut-off valve closed (optional device)
- Start block exist due to low HT temp (overridden in case of blackout start)

### 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:

- A GVU gas leakage test
- The starting air is activated
- Pilot fuel injection is enabled and pilot fuel pump is activated (if electric-driven) along with pilot fuel pressure control

- A combustion check (verify that all cylinders are firing)
- Gas admission is started and engine speed is raised to nominal

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 pilot 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 in backup operating mode. The start is performed similarly to a conventional diesel engine, i.e. after receiving start signal the engine will start and ramp up to nominal speed using only the conventional diesel fuel system. The blackout signal disables some of the start blocks to get the engine running as quickly as possible. All checks during start-up that are related to gas fuel system or pilot fuel system are omitted. Therefore the engine is not able to transfer from backup operating mode to gas- or diesel operating mode before the gas and pilot system related safety measures have been performed. This is done by stopping the engine and re-starting it in diesel- or gas operating mode.

After the blackout situation is over (i.e. when the first engine is started in backup operating mode, connected to switchboard, loaded, and consequently blackout-signal cleared), more engines should be started, and the one running in backup mode stopped and re-started in gas- or diesel operating mode.

## 14.2.3 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 at engine load below 80% in case no gas trips are active, no pilot trip has occurred and the engine was not started in backup operating mode (excluding combustion check).

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 done by restarting the engine.

A leakage test on the GVU is automatically done before each gas transfer.

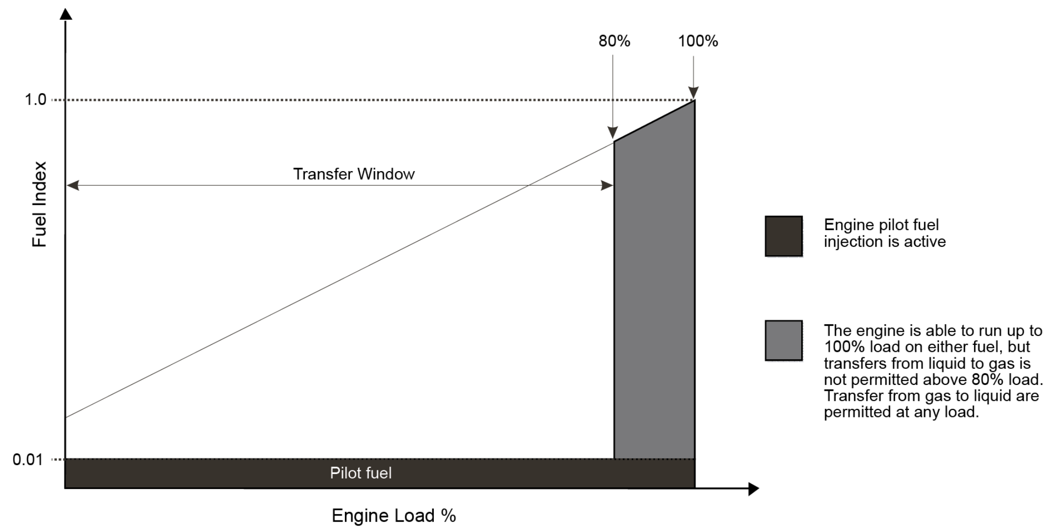



**Fig 14-8 Operating modes are load dependent**

## 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

# 14.2.4 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 GVU performs gas shut-off and ventilation. The pilot injection is active during the first part of the deceleration in order to ensure that all gas remaining in engine is burned.

In case the engine has been running on gas within two minutes prior to the stop the exhaust gas system is ventilated to discharge any unburned gas.

## Shutdown mode

Shutdown mode is initiated automatically as a response to 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.

## 14.2.5 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*".

For single main engines a fuel rack actuator with a mechanical-hydraulic backup governor is specified. Mechanical back-up can also be specified for twin screw vessels with one engine per propeller shaft. Mechanical back-up is not an option in installations with two engines connected to the same reduction gear.

### Generating sets

The electronic speed control is integrated in the engine automation system.

The load sharing can be based on traditional speed droop, or handled independently by the speed control units without speed droop. The later load sharing principle is commonly referred to as isochronous load sharing. With isochronous load sharing there is no need for load balancing, frequency adjustment, or generator loading/unloading control in the external control system.

In a speed droop system each individual speed control unit decreases its internal speed reference when it senses increased load on the generator. Decreased network frequency with higher system load causes all generators to take on a proportional share of the increased total load. Engines with the same speed droop and speed reference will share load equally. Loading and unloading of a generator is accomplished by adjusting the speed reference of the individual speed control unit. The speed droop is normally 4%, which means that the difference in frequency between zero load and maximum load is 4%.

In isochronous mode the speed reference remains constant regardless of load level. Both isochronous load sharing and traditional speed droop are standard features in the speed control and either mode can be easily selected. If the ship has several switchboard sections with tie breakers between the different sections, then the status of each tie breaker is required for control of the load sharing in isochronous mode.

# 14.3 Alarm and monitoring signals

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

## 14.4 Electrical consumers

### 14.4.1 Motor starters and operation of electrically driven pumps

Separators, preheaters, compressors and fuel feed units are normally supplied as pre-assembled units with the necessary motor starters included. The engine turning device and various electrically driven pumps require separate motor starters. Motor starters for electrically driven pumps are to be dimensioned according to the selected pump and electric motor.

Motor starters are not part of the control system supplied with the engine, but available as optional delivery items.

#### Engine turning device (9N15)

The crankshaft can be slowly rotated with the turning device for maintenance purposes. The motor starter must be designed for reversible control of the motor. The electric motor ratings are listed in the table below.

**Table 14-2 Electric motor ratings for engine turning device**

| Engine | Voltage [V] | Frequency [Hz] | Power [kW] | Current [A] |
|---|---|---|---|---|
| 6L, 8L engines | 3 x 400 / 440 | 50 / 60 | 2.2 / 2.6 | 5.0 / 5.3 |
| 9L, V engines | 3 x 400 / 440 | 50 / 60 | 5.5 / 6.4 | 12.3 / 12.3 |

#### Pre-lubricating oil pump

The pre-lubricating oil pump must always be running when the engine is stopped. The pump shall start when the engine stops, and stop when the engine starts. 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.

#### 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*.

#### Gas valve unit (GVU)

The gas valve unit is engine specific and controls the gas flow to the engine. The GVU is equipped with a built-on control system. For further information, see chapter *Fuel system*.

#### Stand-by pump, lubricating oil (if installed) (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. There is a dedicated sensor on the engine for this purpose.

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 installed) (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. There is a dedicated sensor on the engine for this purpose.

## Stand-by pump, LT cooling water (if installed) (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. There is a dedicated sensor on the engine for this purpose.

## 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 via a motor starter.

# 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 shown in the chapter *Vibration and noise*.

## 15.1 Steel structure design

The system oil tank should not extend under the generator, if the oil tank is located beneath the engine foundation. 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 and the generator.

The foundation should be dimensioned and designed so that harmful deformations are avoided.

The foundation of the generator should be integrated with the engine foundation.

## 15.2 Engine mounting

The engine can be either rigidly or resiliently mounted. The generator is rigidly mounted and connected to the engine with a flexible coupling.

### 15.2.1 Rigid mounting

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

The holding down bolts are usually through-bolts with a lock nut at the lower end and a hydraulically tightened nut at the upper end.

Bolts number two and three from the flywheel end on each side of the engine are to be Ø46 H7/n6 fitted bolts. The rest of the holding down bolts are clearance bolts.

A distance sleeve should be used together with the fitted bolts. The distance sleeve must be mounted between the seating top plate and the lower nut in order to provide a sufficient guiding length for the fitted bolt in the seating top plate. The guiding length in the seating top plate should be at least equal to the bolt diameter.

The design of the various holding down bolts appear from the foundation drawing. It is recommended that the bolts are made from a high-strength steel, e.g. 42CrMo4 or similar, but the bolts are designed to allow the use of St 52-3 steel quality, if necessary. A high strength material makes it possible to use a higher bolt tension, which results in a larger bolt elongation (strain). A large bolt elongation improves the safety against loosening of the nuts.

To avoid a gradual reduction of tightening tension due to unevenness in threads, the threads should be machined to a finer tolerance than the normal threads. The bolt thread must fulfil tolerance 6G and the nut thread must fulfil tolerance 6H.

In order to avoid bending stress in the bolts and to ensure proper fastening, the contact face of the nut underneath the seating top plate should be counterbored.

The tensile stress in the bolts is allowed to be max. 80% of the material yield strength. It is however permissible to exceed this value during installation in order to compensate for setting of the bolt connection, but it must be verified that this does not make the bolts yield. Bolts made from St 52-3 are to be tightened to 80% of the material yield strength. It is however sufficient to tighten bolts that are made from a high strength steel, e.g. 42CrMo4 or similar, to about 60-70% of the material yield strength.

The tool included in the standard set of engine tools is used for hydraulic tightening of the holding down bolts. The piston area of the tools is 72.7 $cm^2$ and the hydraulic tightening pressures mentioned in the following sections only apply when using this tool.

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.

## Resin chocks

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

During normal conditions, the support face of the engine feet has a maximum temperature of about 75°C, which should be considered when selecting the type of resin.

The recommended dimensions of the resin chocks are 600 x 180 mm for Wärtsilä 50DF in-line engines and 1000 x 180 mm for V-engines.

The total surface pressure on the resin must not exceed the maximum value, which is determined by the type of resin and the requirements of the classification society. It is recommended to select a resin type, which has a type approval from the relevant classification society for a total surface pressure of 5N/$mm^2$. (A typical conservative value is $P_{tot}$ 3.5 N/$mm^2$ ).

The bolts must be made as tensile bolts with a reduced shank diameter to ensure a sufficient elongation, since the bolt force is limited by the permissible surface pressure on the resin.

For a given bolt diameter the permissible bolt tension is limited either by the strength of the bolt material (max. stress 80% of the yield strength), or by the maximum permissible surface pressure on the resin. Assuming bolt dimensions and chock dimensions according to drawing 1V69L0082a and 1V69L0083b the following hydraulic tightening pressures should be used:

- In-line engine, St 52-3 bolt material, maximum total surface pressure 2.9 N/$mm^2$ $p_{hyd}$ = 200 bar
- In-line engine, 42CrMo4 bolt material, maximum total surface pressure 4.5 N/$mm^2$ $p_{hyd}$ = 335 bar
- V-engine, St 52-3 bolt material, maximum total surface pressure 3.5 N/$mm^2$ $p_{hyd}$ = 310 bar
- V-engine, 42CrMo4 bolt material, maximum total surface pressure 5.0 N/$mm^2$ $p_{hyd}$ = 475 bar

Locking of the upper nuts is required when using St 52-3 material or when the total surface pressure on the resin chocks is below 4 MPa with the recommended chock dimensions. The lower nuts should always be locked regardless of the bolt tension.

## Steel chocks

The top plates of the engine girders are normally inclined outwards with regard to the centre line of the engine. The inclination of the supporting surface should be 1/100. The seating top plate should be designed so that the wedge-type steel chocks can easily be fitted into their positions. The wedge-type chocks also have an inclination of 1/100 to match the inclination of the seating. If the top plate of the engine girder is fully horizontal, a chock is welded to each point of support. The chocks should be welded around the periphery as well as through holes drilled for this purpose at regular intervals to avoid possible relative movement in the surface layer. The welded chocks are then face-milled to an inclination of 1/100. The surfaces of the welded chocks should be large enough to fully cover the wedge-type chocks.

The size of the wedge type chocks should be 200x360 mm. The chocks should always cover two bolts to prevent it from turning (except the chock closest to the flywheel, which has a single hole). The material may be cast iron or steel.

The supporting surface of the seating top plate should be machined so that a bearing surface of at least 75% is obtained. The chock should be fitted so that the distance between the bolt holes and the edges is equal on both sides.

The cutout in the chocks for the clearance bolts should be about 2 mm larger than the bolt diameter. Holes are to be drilled and reamed to the correct tolerance for the fitted bolts after the coupling alignment has been checked and the chocks have been lightly knocked into position.

Depending on the material of the bolts, the following hydraulic tightening pressures should be used, provided that the minimum diameter is 35 mm:

- St52-3 Tightened to 80% of yield strength, $p_{hyd}$ = 420 bar
- 42CrMo4 Tightened to 70% of yield strength, $p_{hyd}$ =710 bar

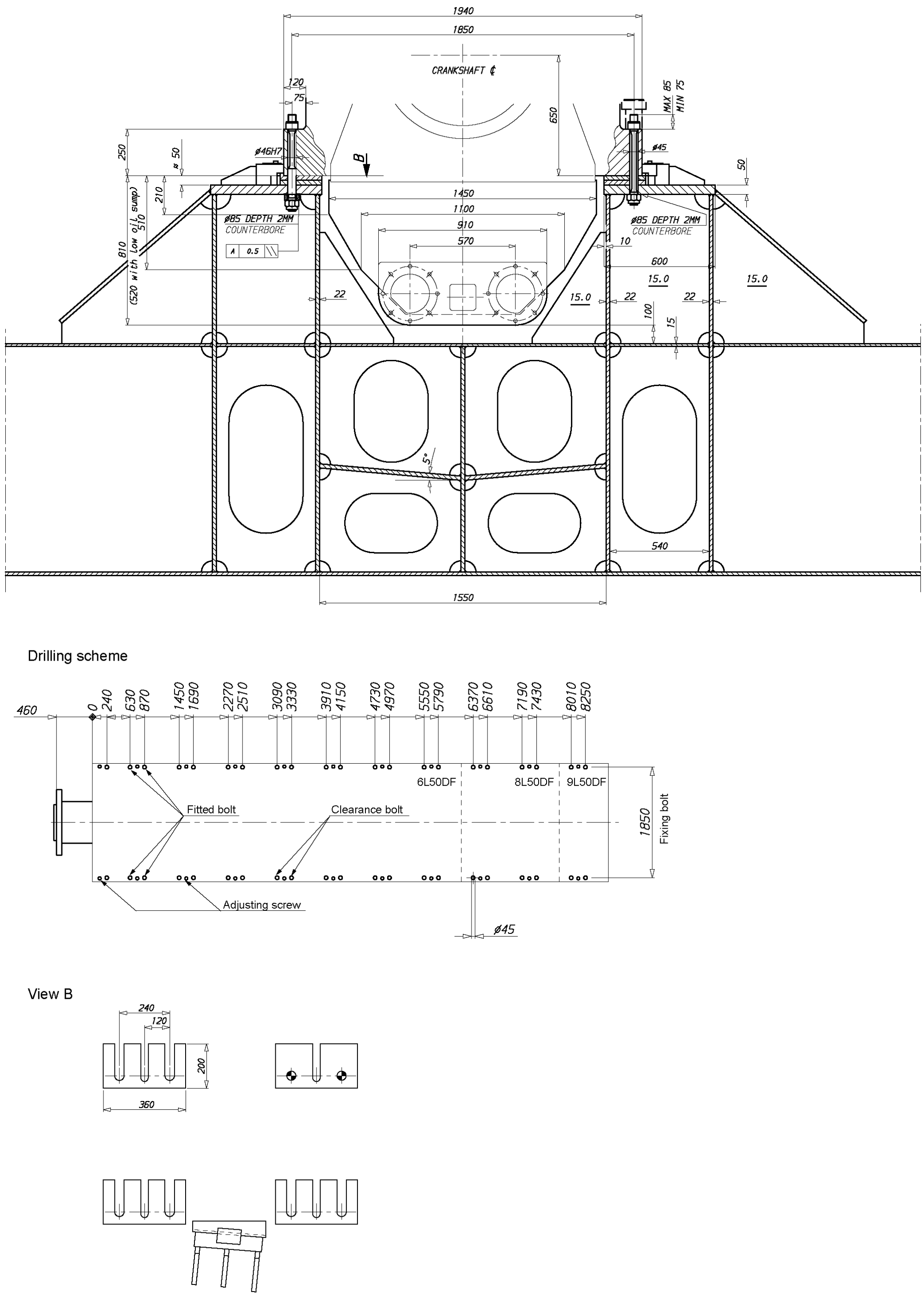
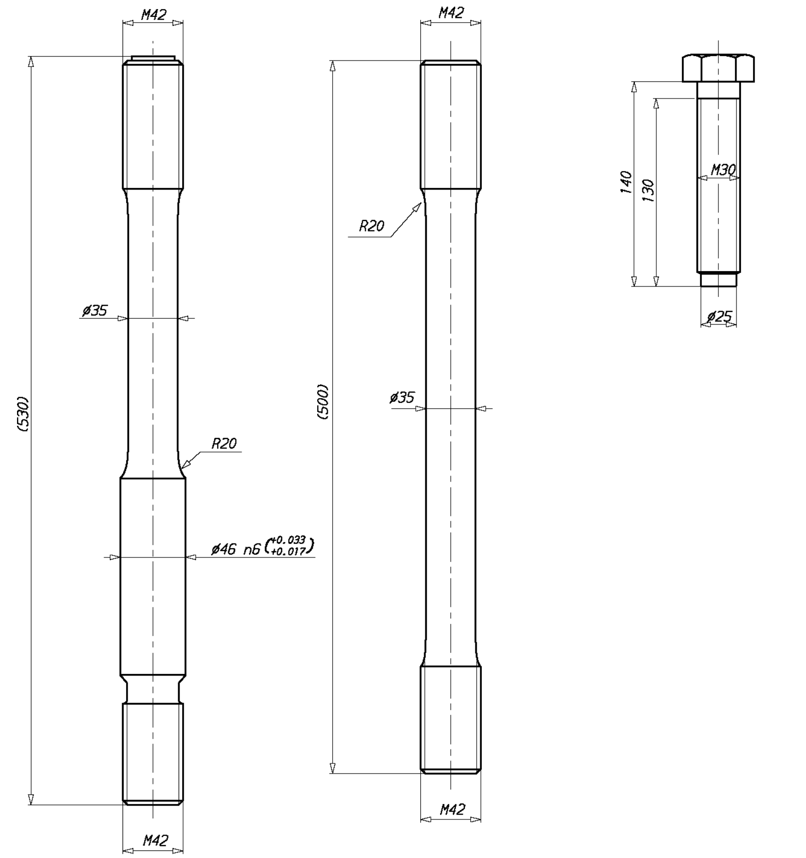
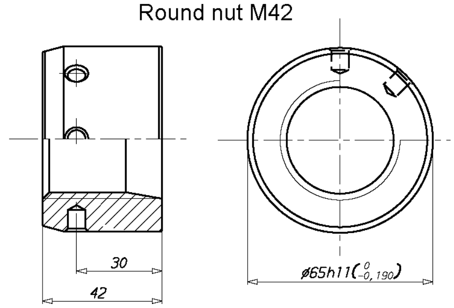



**Fig 15-1** **Seating and fastening, rigidly mounted in-line engines on steel chocks (1V69L1651a)**

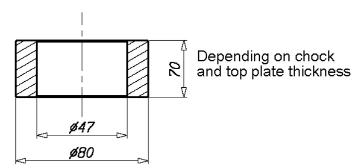
Fitted bolt Clearance bolt Adjusting screw




Round nut M42




Distance sleeve




| Number of pieces per engine | | | |
|---|---|---|---|
| **Component** | **W 6L50DF** | **W 8L50DF** | **W 9L50DF** |
| Fitted bolt | 4 | 4 | 4 |
| Clearance bolt | 26 | 34 | 38 |
| Adjusting screw | 16 | 20 | 22 |
| Distance sleeve | 4 | 4 | 4 |
| Round nut | 30 | 38 | 42 |

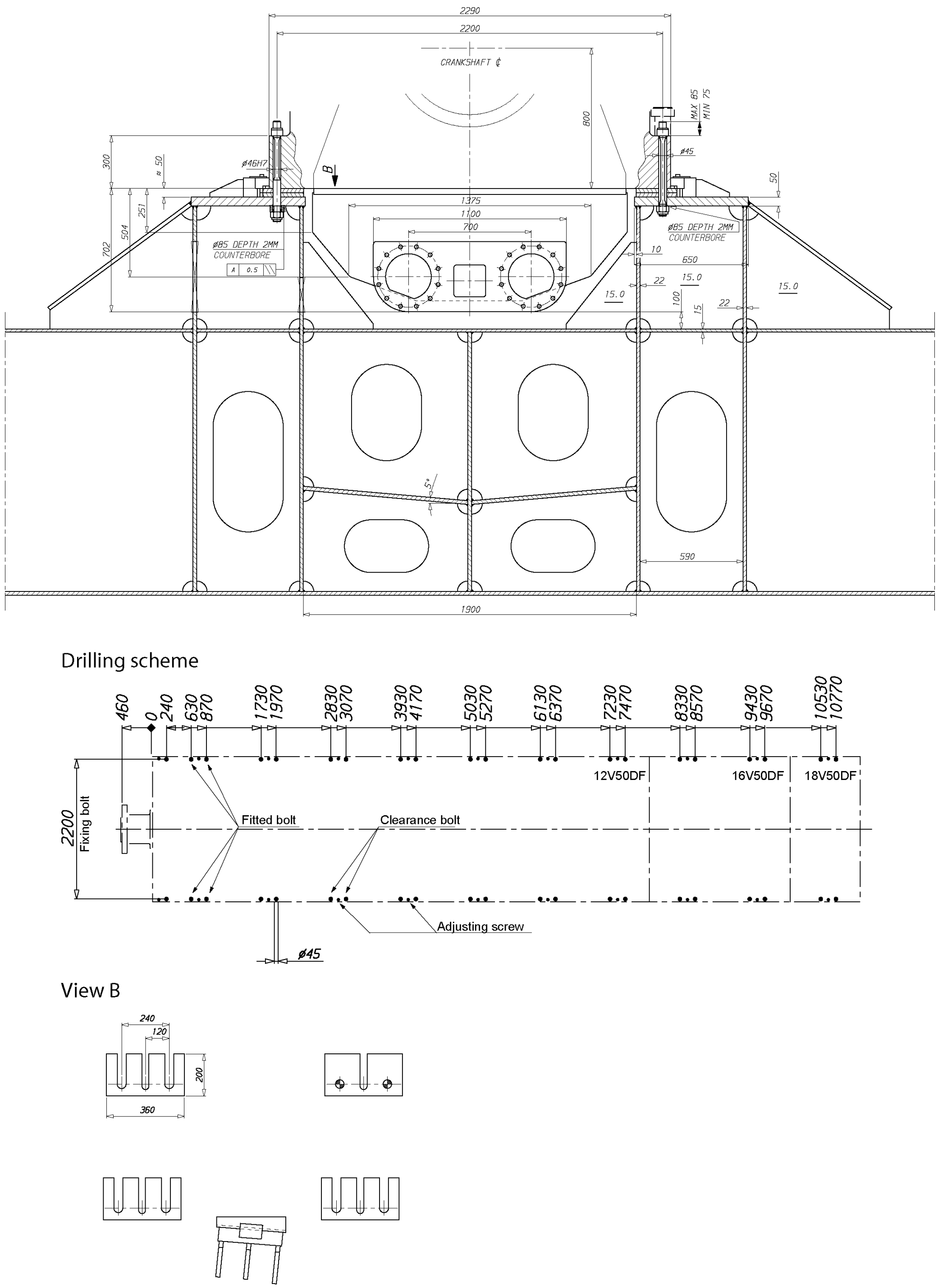
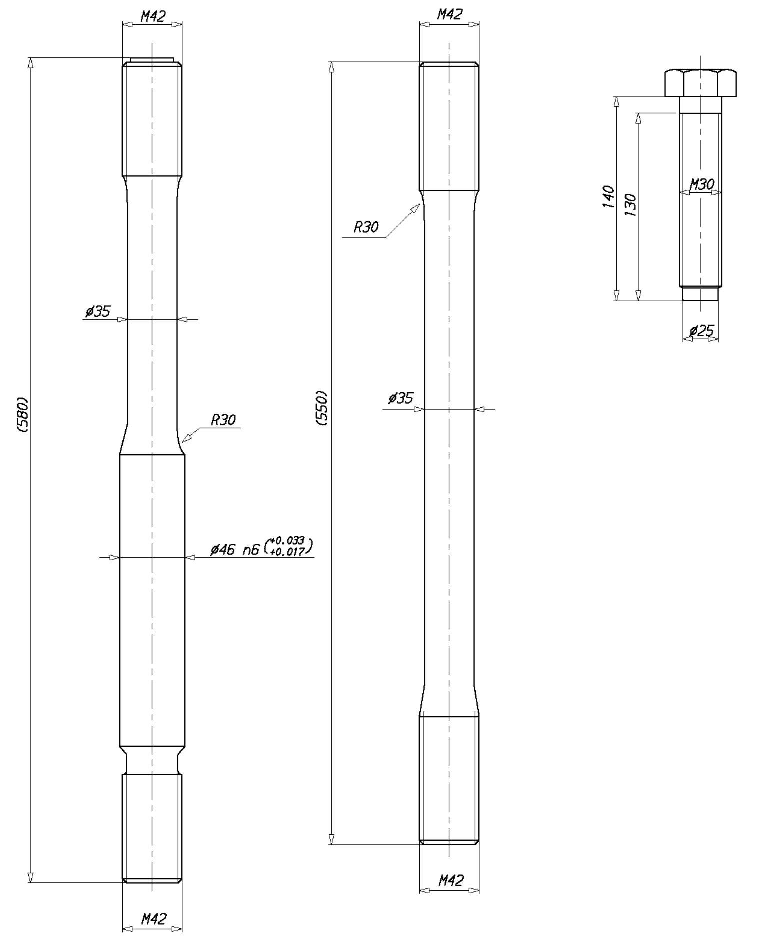
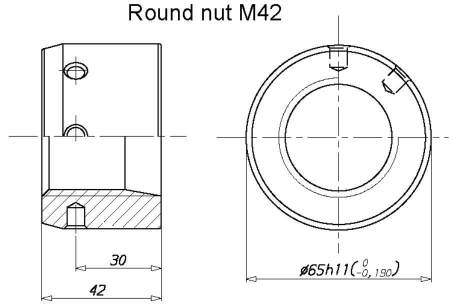



**Fig 15-2** **Seating and fastening, rigidly mounted V-engines on steel chocks (1V69L1659a)**

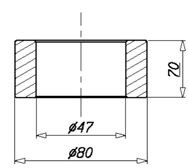
Fitted bolt Clearance bolt Adjusting screw




Round nut M42

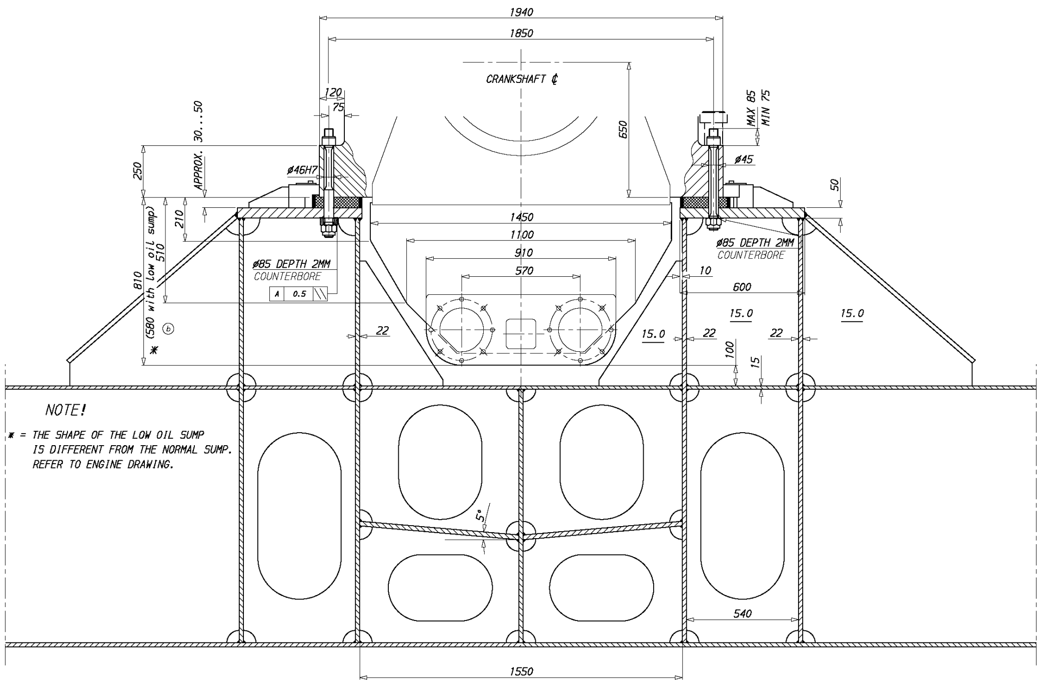



Distance sleeve

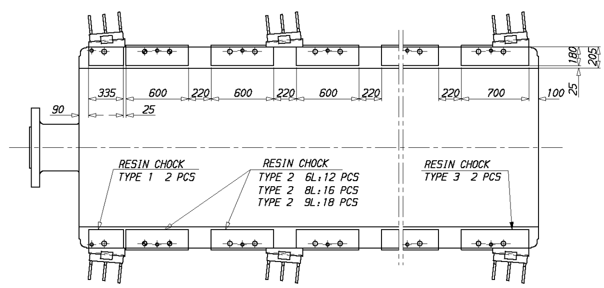



| Number of pieces per engine | | | |
|---|---|---|---|
| **Component** | **W 12V50DF** | **W 16V50DF** | **W 18V50DF** |
| Fitted bolt | 4 | 4 | 4 |
| Clearance bolt | 26 | 34 | 38 |
| Adjusting screw | 16 | 20 | 22 |
| Distance sleeve | 4 | 4 | 4 |

| Number of pieces per engine | | | |
|---|---|---|---|
| **Component** | **W 12V50DF** | **W 16V50DF** | **W 18V50DF** |
| Round nut | 30 | 38 | 42 |




Plan view of chock arrangement




Drilling scheme

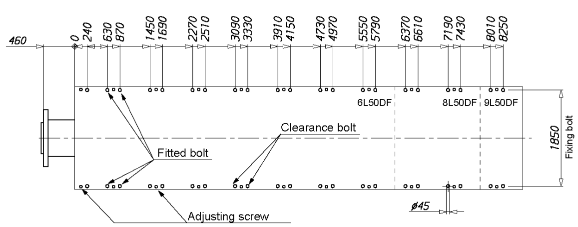
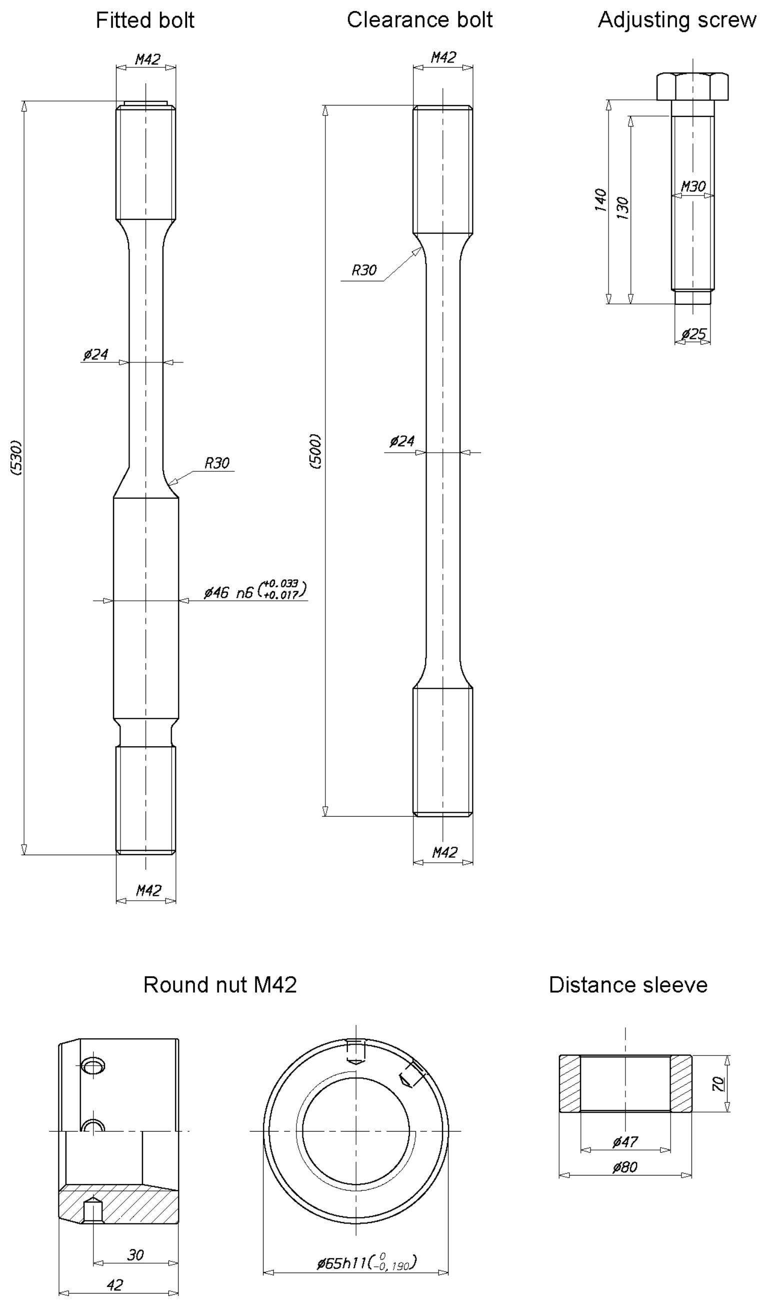
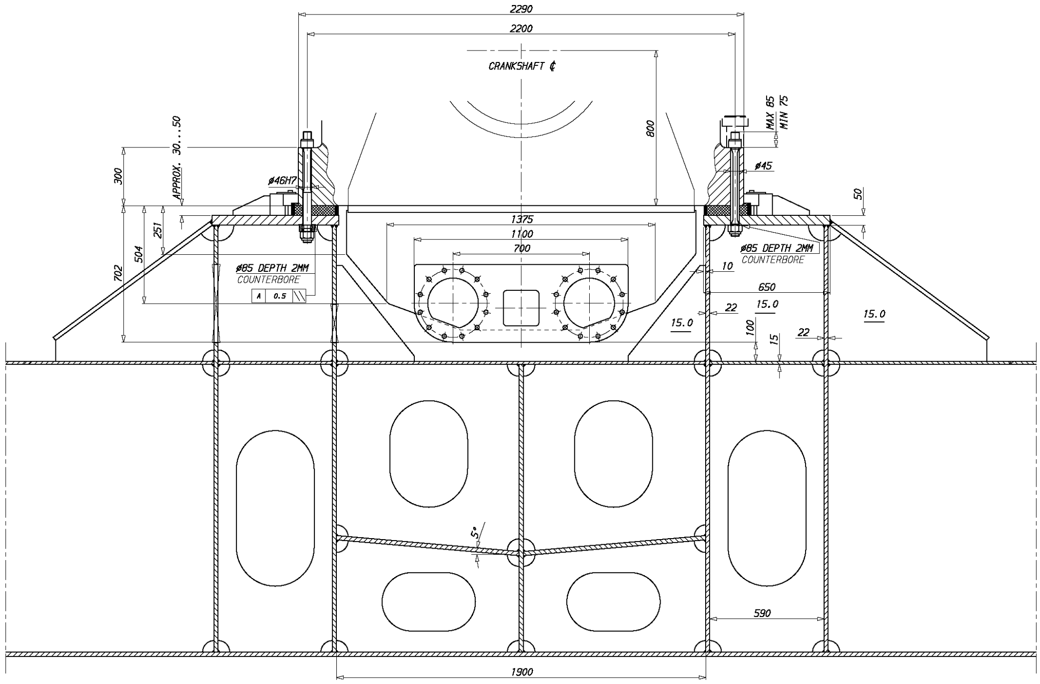


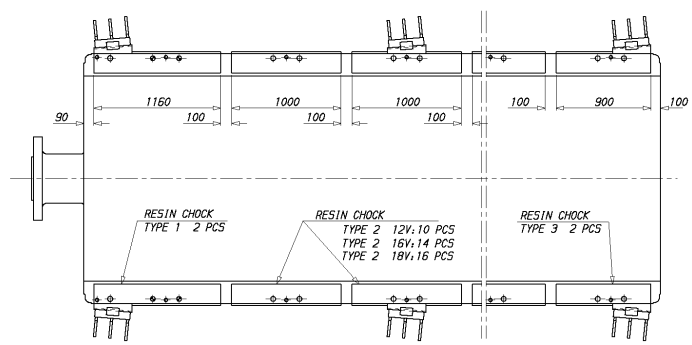

**Fig 15-3** **Seating and fastening, rigidly mounted in-line engines on resin chocks (1V69L0082c)**




| Number of pieces per engine | | | |
|---|---|---|---|
| **Component** | **W 6L50DF** | **W 8L50DF** | **W 9L50DF** |
| Fitted bolt | 4 | 4 | 4 |
| Clearance bolt | 26 | 34 | 38 |
| Adjusting screw | 16 | 20 | 22 |
| Distance sleeve | 4 | 4 | 4 |
| Round nut | 30 | 38 | 42 |




Plan view of chock arrangement




Drilling scheme

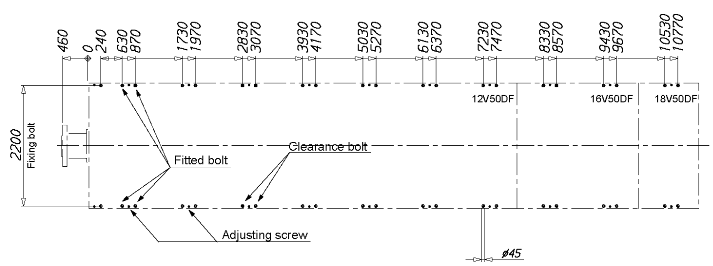
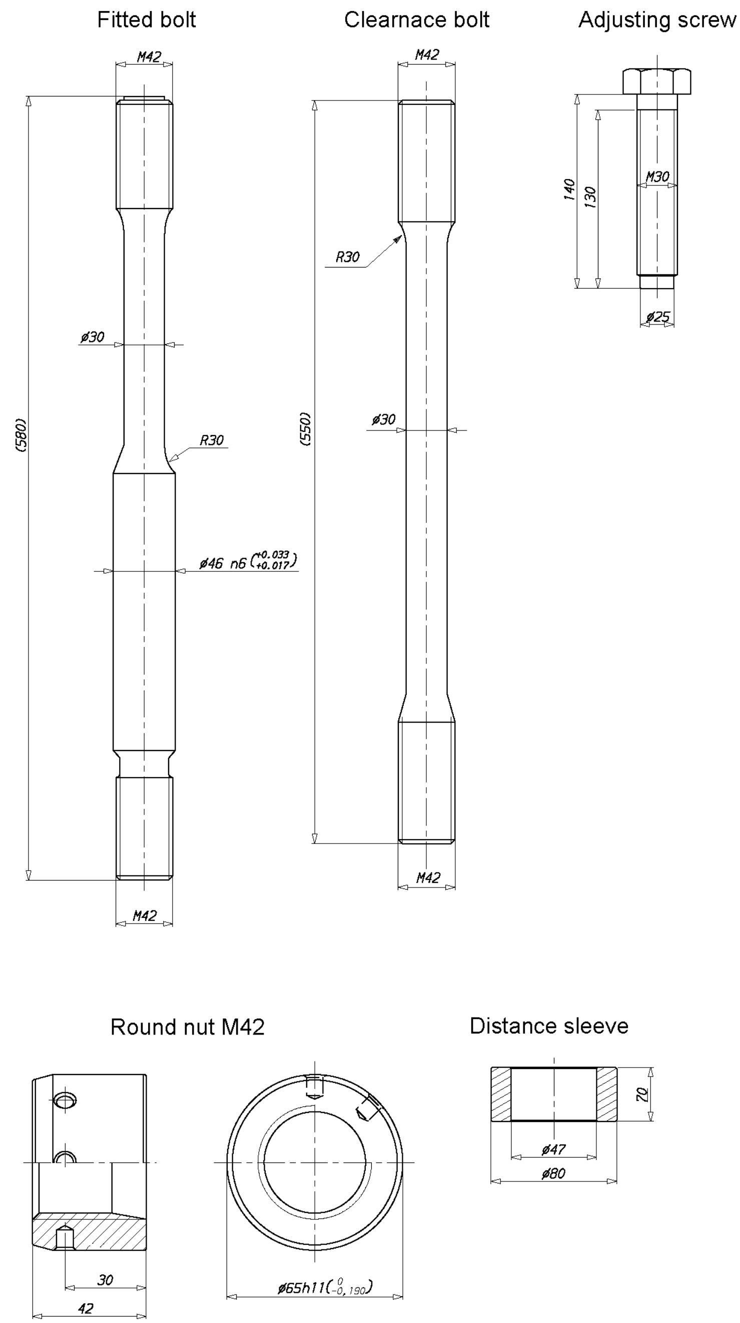



**Fig 15-4 Seating and fastening, rigidly mounted V-engines on resin chocks (1V69L0083c)**




| Number of pieces per engine | | | |
|---|---|---|---|
| **Component** | **W 12V50DF** | **W 16V50DF** | **W 18V50DF** |
| Fitted bolt | 4 | 4 | 4 |
| Clearance bolt | 26 | 34 | 38 |
| Adjusting screw | 16 | 20 | 22 |
| Distance sleeve | 4 | 4 | 4 |
| Round nut | 30 | 38 | 42 |

### 15.2.2 Resilient mounting

In order to reduce vibrations and structure borne noise, engines may be resiliently mounted on rubber elements.

The engine block is so rigid that no intermediate base frame is required. Rubber mounts are fixed to the engine feet by means of a fixing rail. The advantage of vertical type mounting is ease of alignment.

Typical material of the flexible elements is natural rubber, which has superior vibration technical properties, but unfortunately is prone to damage by mineral oil. The rubber mounts are protected against dripping and splashing by means of covers.

A machining tool for machining of the top plate under the resilient or rubber element can be supplied by Wärtsilä.

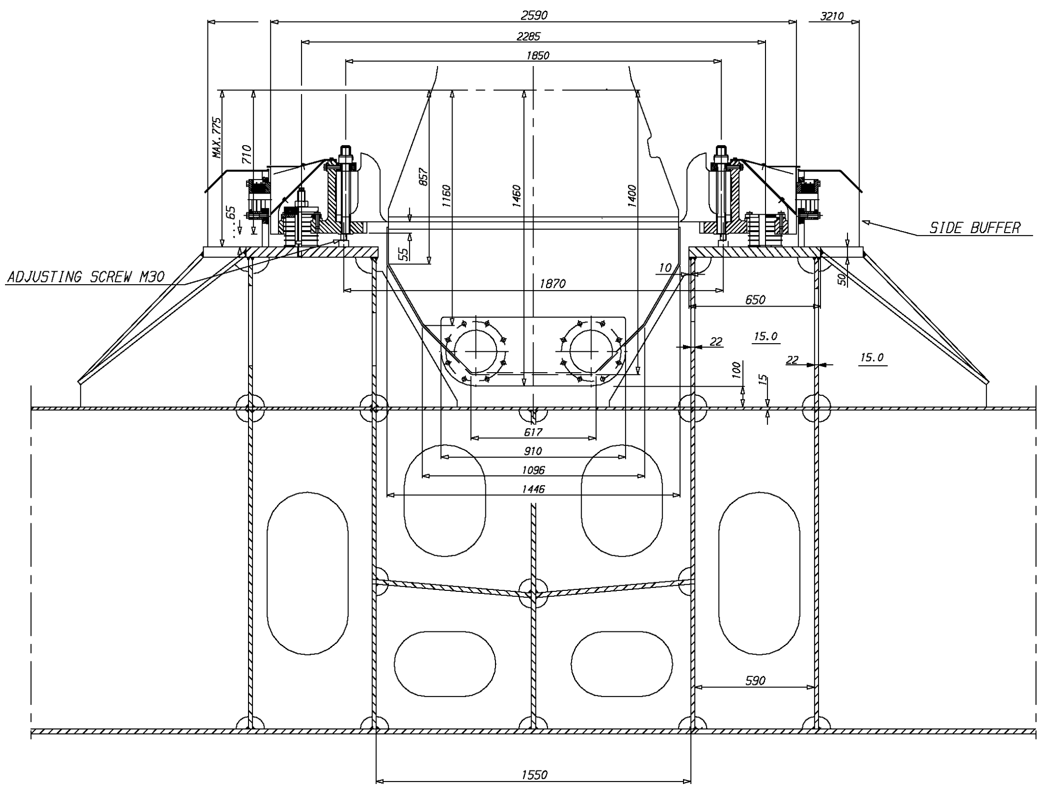



**Fig 15-5 Seating and fastening, resiliently mounted in-line engine (DAAE001883)**

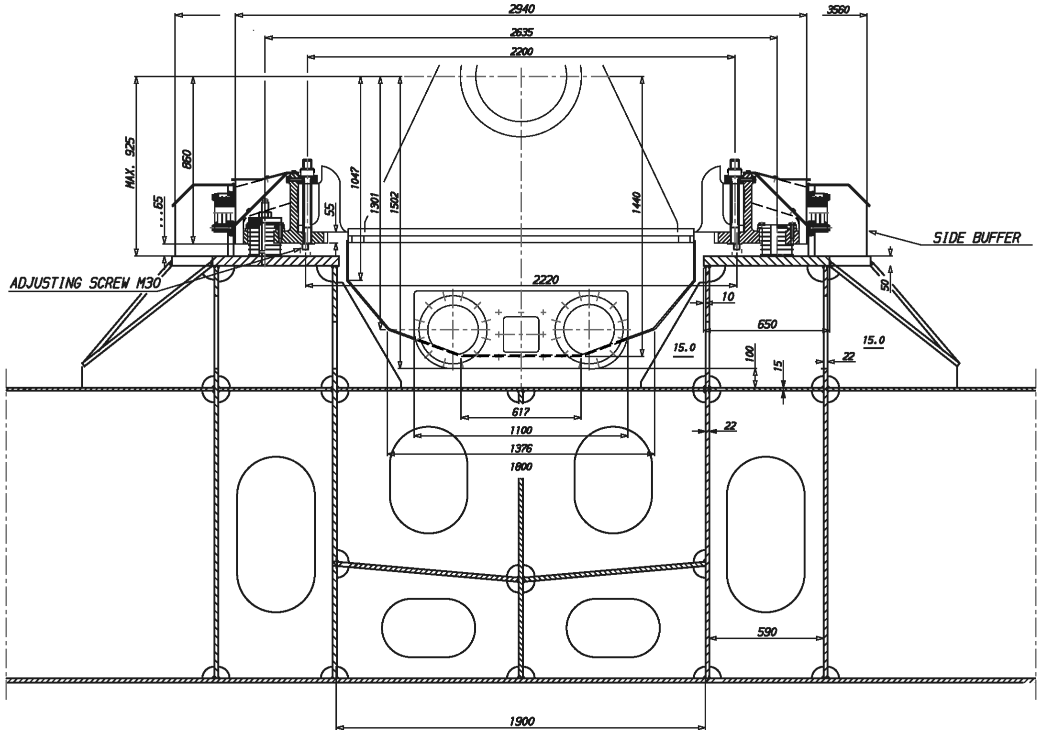



**Fig 15-6 Seating and fastening, resiliently mounted V-engine (DAAE001882)**

The machining tool permits a maximum distance of 85mm between the fixing rail and the top plate.

The brackets of the side and end buffers are welded to the foundation.

Due to the soft mounting the engine will move when passing resonance speeds at start and stop. Typical amplitudes are +/- 1mm at the crankshaft centre and +/- 5mm at top of the engine. The torque reaction will cause a displacement of the engine of up to 1.5mm at the crankshaft centre and 10 mm at the turbocharger outlet. Furthermore the creep and thermal expansion of the rubber mounts have to be considered when installing and aligning the engine.

## 15.3 Flexible pipe connections

When the engine is resiliently installed, all connections must be flexible and no grating nor ladders may be fixed to the engine. Especially the connection to the turbocharger must be arranged so that the above mentioned displacements can be absorbed. 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.

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.

See the chapter *Piping design, treatment and installation* for more detailed information.

# 16. Vibration and Noise

Wärtsilä 50DF engines comply with vibration levels according to ISO 10816-6 Class 5.

## 16.1 External forces and couples

Some cylinder configurations produce external forces and couples. These are listed in the tables below.

The ship designer should avoid natural frequencies of decks, bulkheads and superstructures close to the excitation frequencies. The double bottom should be stiff enough to avoid resonances especially with the rolling frequencies.

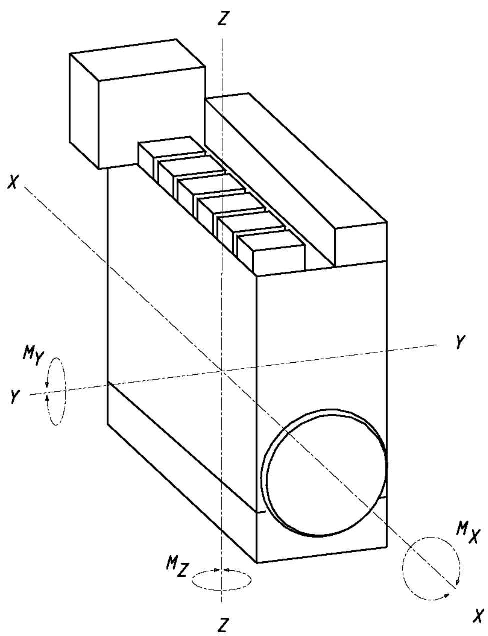



**Fig 16-1 Coordinate system of the external torques**

**Table 16-1 External forces**

| Engine | Speed [rpm] | Frequency [Hz] | $F_Y$ [kN] | $F_Z$ [kN] | Frequency [Hz] | $F_Y$ [kN] | $F_Z$ [kN] | Frequency [Hz] | $F_Y$ [kN] | $F_Z$ [kN] |
|---|---|---|---|---|---|---|---|---|---|---|
| W 8L50DF | 500 | 8.3 | – | – | 16.7 | – | – | 33.3 | – | 8.3 |
| | 514 | 8.6 | – | – | 17.1 | – | – | 34.3 | – | 8.8 |
| W 16V50DF | 500 | 8.3 | – | – | 16.7 | – | – | 33.3 | 6.4 | – |
| | 514 | 8.6 | – | – | 17.1 | – | – | 34.3 | 6.7 | – |
| *– forces are zero or insignificant* | | | | | | | | | | |

**Table 16-2 External couples**

| Engine | Speed [rpm] | Frequency [Hz] | $M_Y$ [kNm] | $M_Z$ [kNm] | Frequency [Hz] | $M_Y$ [kNm] | $M_Z$ [kNm] | Frequency [Hz] | $M_Y$ [kNm] | $M_Z$ [kNm] |
|---|---|---|---|---|---|---|---|---|---|---|
| W 9L50DF | 500 | 8.3 | – | – | 16.7 | 84 | – | 33.3 | 4 | – |
| | 514 | 8.6 | – | – | 17.1 | 89 | – | 34.3 | 5 | – |
| W 18V50DF | 500 | 8.3 | 305 | 305 | 16.7 | 147 | 61 | 33.3 | – | 4 |
| | 514 | 8.6 | 322 | 322 | 17.1 | 156 | 65 | 34.3 | – | 5 |
| ***– couples are zero or insignificant*** | | | | | | | | | | |

## 16.2 Torque variations

**Table 16-3 Torque variations**

| Engine | Speed [rpm] | Frequency [Hz] | $M_X$ [kNm] | Frequency [Hz] | $M_X$ [kNm] | Frequency [Hz] | $M_X$ [kNm] |
|---|---|---|---|---|---|---|---|
| W 6L50DF | 500 | 25.0 | 66.9 | 50.0 | 46.4 | 75.0 | 14.4 |
| | 514 | 25.7 | 56.6 | 51.4 | 45.2 | 77.1 | 14.0 |
| W 6L50DF idle | 500 | 25.0 | 80.0 | 50.0 | 10.4 | 75.0 | 2.5 |
| | 514 | 25.7 | 87.7 | 51.4 | 10.2 | 77.1 | 2.4 |
| W 8L50DF | 500 | 33.3 | 145.9 | 66.7 | 26.8 | 100.0 | 8.3 |
| | 514 | 34.3 | 141.1 | 68.5 | 26.1 | 102.8 | 8.1 |
| W 9L50DF | 500 | 37.5 | 136.9 | 75.0 | 21.6 | 112.5 | 6.6 |
| | 514 | 38.6 | 133.2 | 77.1 | 21.0 | 115.7 | 6.4 |
| W 12V50DF | 500 | 25.0 | 51.2 | 50.0 | 65.6 | 75.0 | 26.5 |
| | 514 | 25.7 | 43.3 | 51.4 | 63.9 | 77.1 | 25.8 |
| W 12V50DF idle | 500 | 25.0 | 61.2 | 50.0 | 14.7 | 75.0 | 4.5 |
| | 514 | 25.7 | 67.1 | 51.4 | 14.3 | 77.1 | 4.4 |
| W 16V50DF | 500 | 33.3 | - | 66.7 | 53.6 | 133.3 | 6.1 |
| | 514 | 34.3 | - | 68.5 | 52.2 | 137.1 | 5.9 |
| W 18V50DF alternating firing order | 500 | 37.5 | 268.5 | 75.0 | 39.8 | 112.5 | 10.9 |
| | 514 | 38.6 | 261.2 | 77.1 | 38.7 | 115.7 | 10.7 |
| ***- couple are zero or insignificant*** | | | | | | | |

## 16.3 Mass moment of inertia

These typical inertia values include the flexible coupling part connected to the flywheel and torsional vibration damper, if needed.

| Polar mass moment of inertia J [kgm$^2$] | | |
|---|---|---|
| | Speed [rpm] | |
| Engine | 500 | 514 |

| Polar mass moment of inertia J [kgm²] | | |
|---|---|---|
| W 6L50DF | 3020 | 2900 |
| W 8L50DF | 3570 | 3540 |
| W 9L50DF | 4580 | 4580 |
| W 12V50DF | 5310 | 5310 |
| W 16V50DF | 7250 | 6790 |
| W 18V50DF | 8820 | 8820 |

## 16.4 Structure borne noise

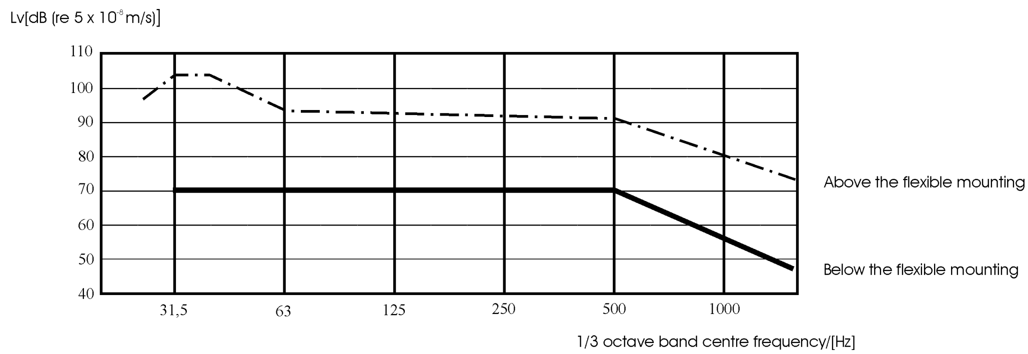



**Fig 16-2 Typical structure borne noise levels**

## 16.5 Air borne noise

The airborne noise of the engine is measured as a sound power level according to ISO 9614-2. Noise level is given as sound power emitted by the whole engine, reference level 1 pW. The values presented in the graphs below are typical values, cylinder specific graphs are included in the Installation Planning Instructions (IPI) delivered for all contracted projects.

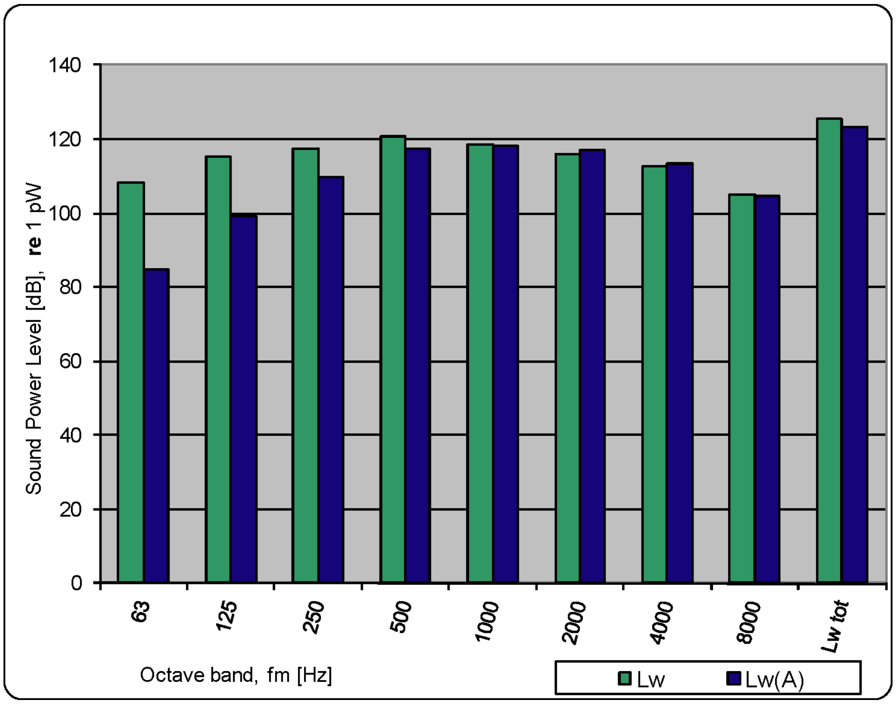



**Fig 16-3 Typical sound power level for W L50DF**

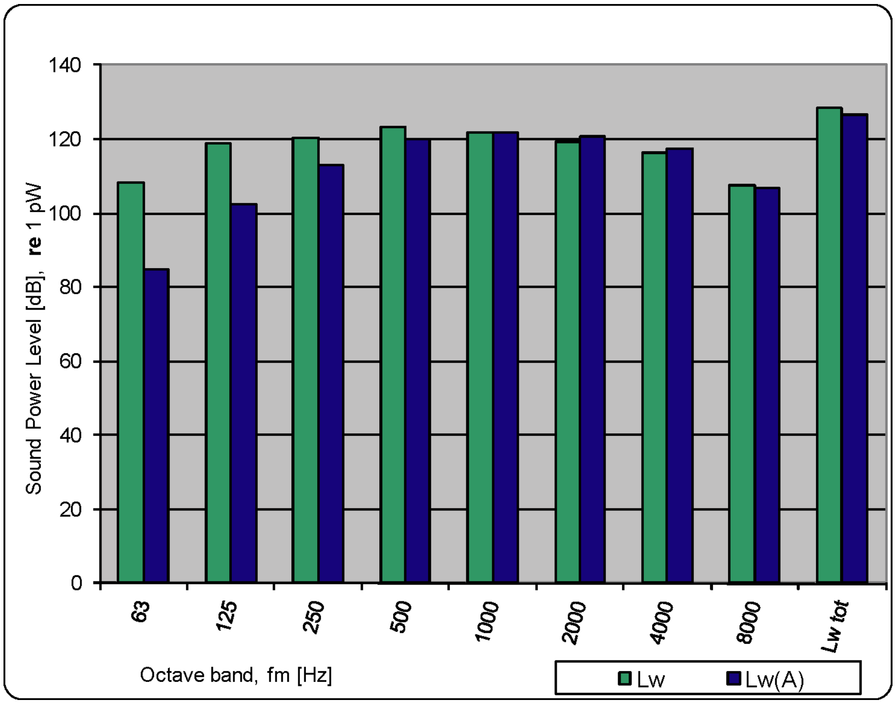



**Fig 16-4 Typical sound power level for W V50DF**

## 16.6 Exhaust noise

The exhaust noise of the engine is measured as the sound power emitted from the turbocharger outlet without exhaust gas piping connected. Reference value 1 pW. The values presented in the graphs below are typical values, cylinder specific graphs are included in the Installation Planning Instructions (IPI) delivered for all contracted projects.

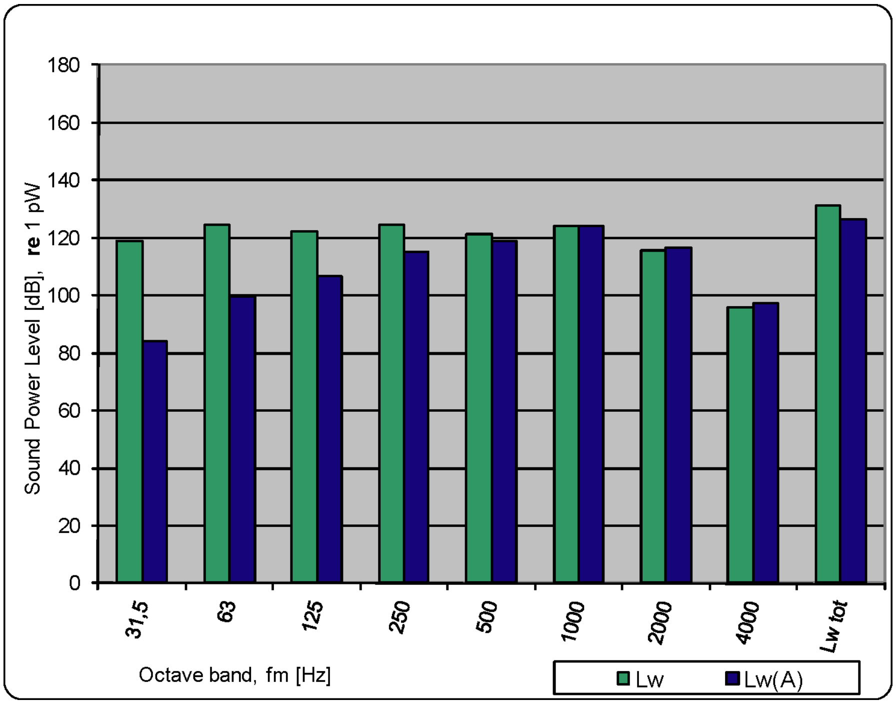



**Fig 16-5** **Typical sound power level for exhaust noise, W L50DF**

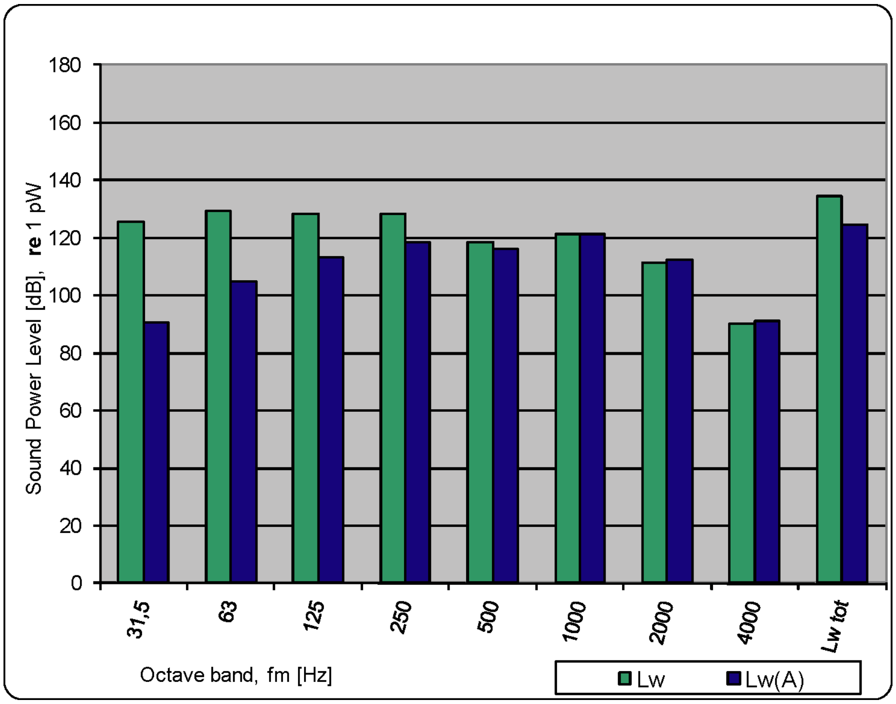



**Fig 16-6** **Typical sound power level for exhaust noise, W V50DF**

# 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 shield 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.

## 17.2 Torque flange

In mechanical propulsion applications, a torque meter has to be installed in order to measure the absorbed power. The torque flange has an installation length of 300 mm for all cylinder configurations and is installed after the flexible coupling.

## 17.3 Clutch

In dual fuel engine installations with mechanical drive, it must be possible to disconnect the propeller shaft from the engine by using a clutch. The use of multiple plate hydraulically actuated clutches built into the reduction gear is recommended.

A clutch is also 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 also be fitted to be able to secure the propeller shaft in position so that wind milling is avoided. This is necessary because even an open hydraulic clutch can transmit some torque. Wind milling at a low propeller speed (<10 rpm) can due to poor lubrication cause excessive wear of the bearings.

The shaft locking device can be either a bracket and key or an easier to use brake disc with calipers. In both cases a stiff and strong support to the ship's construction must be provided.

To permit maintenance of a stopped engine clutches must be installed in twin screw vessels which can operate on one shaft line only. A shaft locking device should also be fitted to be able to secure the propeller shaft in position so that wind milling is avoided. This is necessary because even an open hydraulic clutch can transmit some torque. Wind milling at a low propeller speed (<10 rpm) can due to poor lubrication cause excessive wear of the bearings.

The shaft locking device can be either a bracket and key or an easier to use brake disc with calipers. In both cases a stiff and strong support to the ship's construction must be provided.

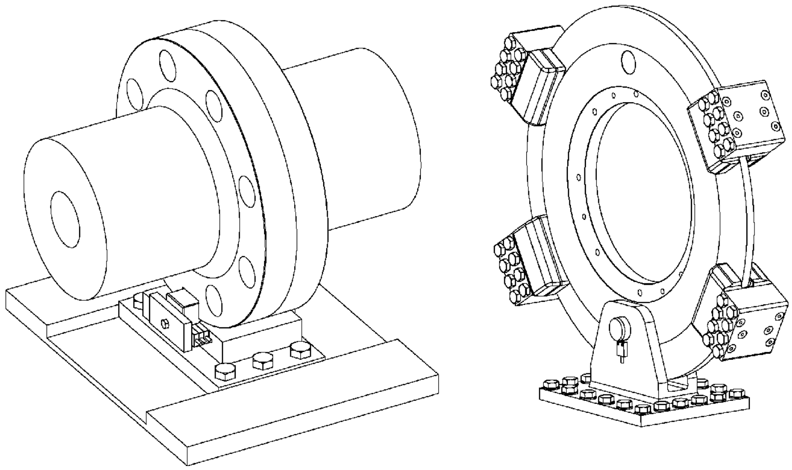


Fig 17-1 **Shaft locking device and brake disc with calipers**

## 17.5 Input data for torsional vibration calculations

A torsional vibration calculation is made for each installation. For this purpose exact data of all components included in the shaft system are required. See list below.

**Installation**

- Classification
- Ice class
- Operating modes

**Reduction gear**

A mass elastic diagram showing:

- All clutching possibilities
- Sense of rotation of all shafts
- Dimensions of all shafts
- Mass moment of inertia of all rotating parts including shafts and flanges
- Torsional stiffness of shafts between rotating masses
- Material of shafts including tensile strength and modulus of rigidity
- Gear ratios
- Drawing number of the diagram

**Propeller and shafting**

A 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 at full/zero pitch in water
- Torsional stiffness or dimensions of the shaft
- Material of the shaft including tensile strength and modulus of rigidity
- Drawing number of the diagram or drawing

**Main generator or shaft generator**

A mass-elastic diagram or an generator shaft drawing showing:

- Generator output, speed and sense of rotation
- Mass moment of inertia of all rotating parts or a total inertia value of the rotor, including the shaft
- Torsional stiffness or dimensions of the shaft
- Material of the shaft including tensile strength and modulus of rigidity
- Drawing number of the diagram or drawing

**Flexible coupling/clutch**

If a certain make of flexible coupling has to be used, the following data of it must be informed:

- Mass moment of inertia of all parts of the coupling
- Number of flexible elements
- Linear, progressive or degressive torsional stiffness per element
- Dynamic magnification or relative damping
- Nominal torque, permissible vibratory torque and permissible power loss
- Drawing of the coupling showing make, type and drawing number

**Operational data**

- Operational profile (load distribution over time)
- Clutch-in speed
- Power distribution between the different users
- Power speed curve of the load

## 17.6 Turning gear

The engine is equipped with an electrical driven turning gear, capable of turning the generator in most installations.

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# 18. Engine Room Layout

## 18.1 Crankshaft distances

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

### 18.1.1 In-line engines

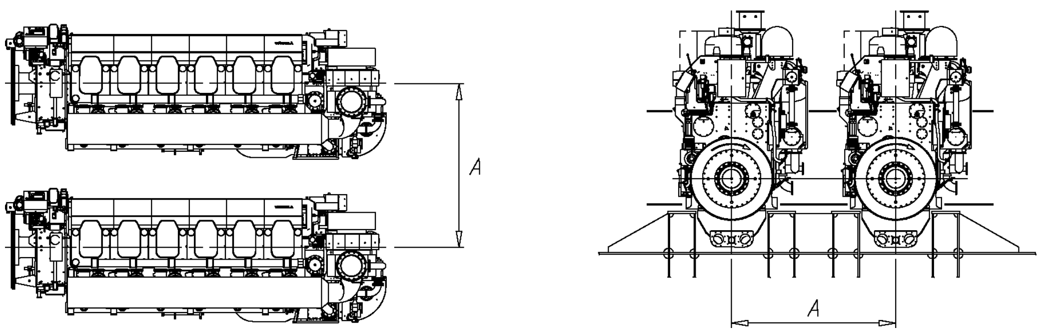


**Fig 18-1 Crankshaft distances, in-line engines (3V69C0320b)**

| Engine type | Min. A [mm] |
|---|---|
| W 6L50DF | 3500 |
| W 8L50DF | 3700 |
| W 9L50DF | 3700 |

### 18.1.2 V-engines

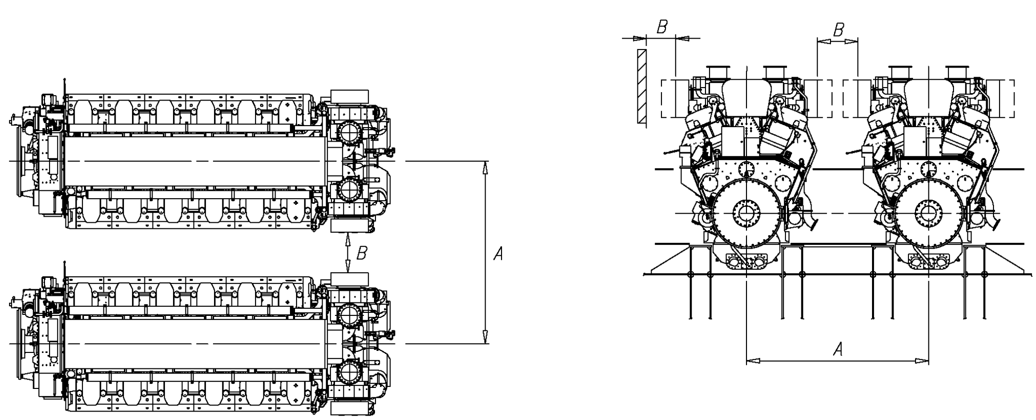


**Fig 18-2 Crankshaft distances, V-engines (3V69C0319D)**

| Engine type | Minimum [mm] | | Recommended [mm] | |
|---|---|---|---|---|
| | A | B | A | B |
| W 12V50DF | 4700 | 450 | 4900 | 650 |

| Engine type | Minimum [mm] | | Recommended [mm] | |
|---|---|---|---|---|
| | A | B | A | B |
| W 16V50DF | 5600 | 900 | 5800 | 1100 |
| W 18V50DF | 5600 | 900 | 5800 | 1100 |

# 18.2 Space requirements for maintenance

## 18.2.1 Working space around the engine

The required working space around the engine is mainly determined by the dismounting dimensions of engine components, and space requirement of some special tools. It is especially important that no obstructive structures are built next to engine driven pumps, as well as camshaft and crankcase doors.

However, also at locations where no space is required for dismounting of engine parts, a minimum of 1000 mm free space is recommended for maintenance operations everywhere around the engine.

## 18.2.2 Engine room height and lifting equipment

The required engine room height is determined by the transportation routes for engine parts. If there is sufficient space in transverse and longitudinal direction, there is no need to transport engine parts over the rocker arm covers or over the exhaust pipe and in such case the necessary height is minimized.

Separate lifting arrangements are usually required for overhaul of the turbocharger since the crane travel is limited by the exhaust pipe. A chain block on a rail located over the turbocharger axis is recommended.

### 18.2.3 Maintenance platforms

In order to enable efficient maintenance work on the engine, it is advised to build the maintenance platforms on recommended elevations. The width of the platforms should be at minimum 800 mm to allow adequate working space. The surface of maintenance platforms should be of non-slippery material (grating or chequer plate).

**NOTE**

Working Platforms should be designed and positioned to prevent personnel slipping, tripping or falling on or between the walkways and the engine

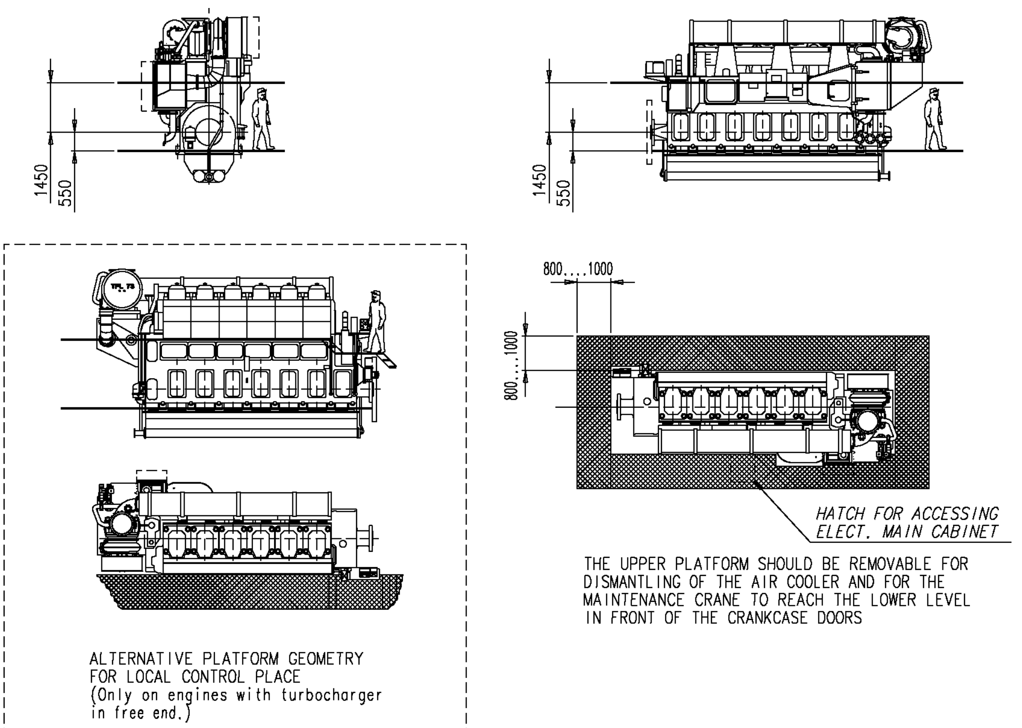


**Fig 18-3 Maintenance platforms, in-line engine (3V69C0246a)**

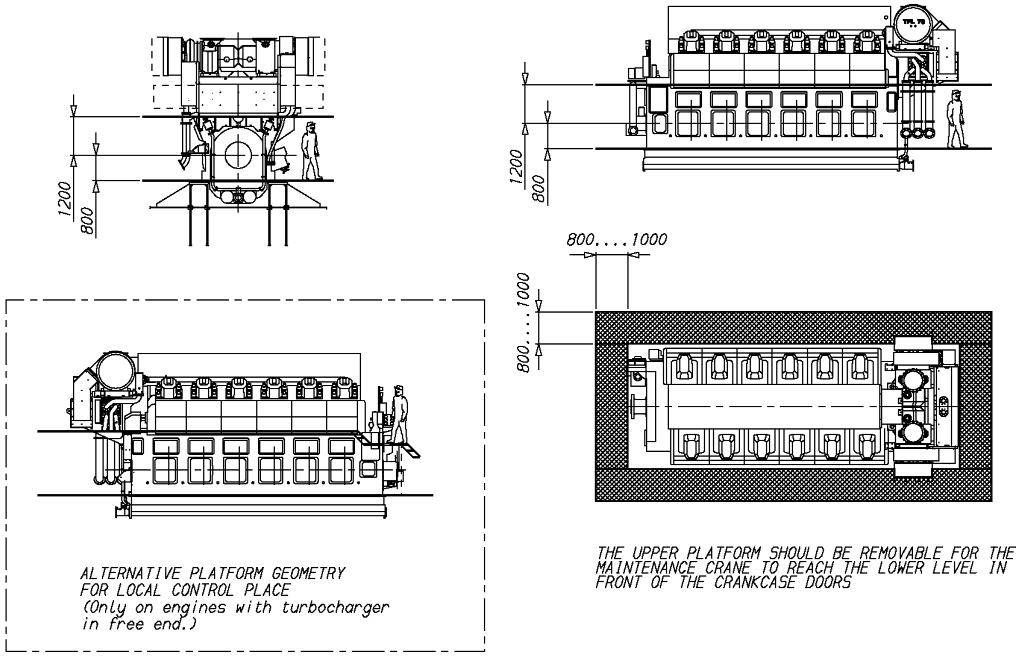


**Fig 18-4 Maintenance platforms, V-engine (3V69C0244)**

## 18.3 Transportation and storage of spare parts and tools

Transportation arrangements from engine room to workshop and storage locations must be provided for heavy engine components, for example by means of several chain blocks on rails, or by suitable routes for trolleys.

The engine room maintenance hatch must be large enough to allow transportation of all main components to/from the engine room.

It is recommended to store heavy engine components on a slightly elevated and adaptable surface, e.g. wooden pallets. All engine spare parts should be protected from corrosion and excessive vibration.

## 18.4 Required deck area for service work

During engine overhaul a free deck area is required for cleaning and storing dismantled components. The size of the service area depends on the overhaul strategy , e.g. one cylinder at time or the whole engine at time. The service area should be a plain steel deck dimensioned to carry the weight of engine parts.

### 18.4.1 Service space requirement for the in-line engine

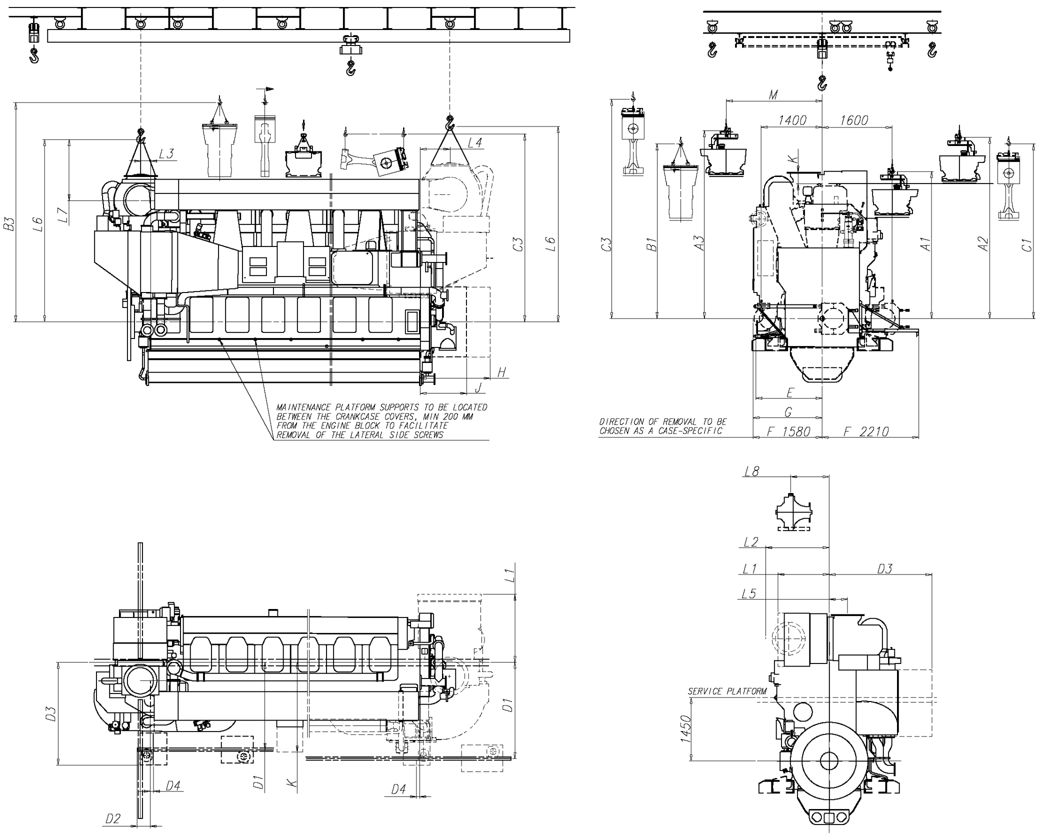


**Fig 18-5** **Service space requirement (DAAE093286C)**

| Services spaces in mm | | 6L50DF | 8L-9L50DF |
|---|---|---|---|
| A1 | Height needed for overhauling cylinder head freely over injection pump | 3370 | 3370 |
| A2 | Height needed for transporting cylinder head freely over adjacent cylinder head covers | 4000 | 4000 |
| A3 | Height needed for overhauling cylinder head freely over exhaust gas insulation box | 4300 | 4300 |
| B1 | Height needed for transporting cylinder liner freely over injection pump | 4000 | 4000 |
| B2 | Height needed for transporting cylinder liner freely over adjacent cylinder head covers | 4840 | 4840 |
| B3 | Height needed for transporting cylinder liner freely over exhaust gas insulation box | 5020 | 5020 |
| C1 | Height needed for overhauling piston and connecting rod | 4000 | 4000 |
| C2 | Height needed for transporting piston and connecting rod freely over adjacent cylinder head covers | 4840 | 4840 |
| C3 | Height needed for transporting piston and connecting rod freely over exhaust gas insulation box | 5020 | 5020 |
| D1 | Recommended lifting point for charge air cooler lifting tool | 2000 | 2200 |
| D2 | Height of the lifting eye for CAC lifting tool | 300 | 800 |
| D3 | Width needed for dismantling charge air cooler and air inlet box sideways by using lifting tool | 2100 | 2350 |
| D4 | Recommended lifting point for CAC lifting tool | 75 | 75 |
| E | Width needed for removing main bearing side screw | 1525 | 1525 |
| F | Width needed for dismantling connecting rod big end bearing | 2210 | 2210 |
| G | Width of lifting tool for hydraulic cylinder / main bearing nuts | 1590 | 1590 |
| H | Distance needed to dismantle lube oil pump | 1060 | 1060 |
| J | Distance needed to dismantle water pumps | 1600 | 1600 |
| K | Space necessary for opening the cover main cabinet | 2050 | 2100 |
| L1 | Rec. axial clearance for dismantling and assembly of silencer is 500mm, min. clearance is mm for 6L50DF/TPL71 and 180mm for 8-9L50DF/TPL76. The given dimension L1 includes the min. maintenance space. | NA357: 1100<br>TPL71: 1000 | TPL76: 1270 |
| L2 | Rec. axial clearance for dismantling and assembly of suction branch is 500mm, min. clearance is mm for 6L50DF/TPL71 and 180mm for 8-9L50DF/TPL76. The given dimension L2 includes the min. maintenance space. | NA357: 1360<br>TPL71: 1200 | TPL76: 1570 |
| L3 | Recommended lifting point for the TC (driving end) | NA357: 160<br>TPL71: 310 | TPL76: n/a |
| L4 | Recommended lifting point for the TC (free end) | NA357: 555<br>TPL71: 785 | TPL76: 700 |
| L5 | Recommended lifting point sideways for the TC | NA357: 395<br>TPL71: 472 | TPL76: 340 |
| L6 | Height needed for dismantling the TC | NA357: 4060<br>TPL71: 3800 | TPL76: 4800 |
| L7 | Height needed for dismantling the TC from center of TC | NA357: 1400<br>TPL71: 1150 | TPL76: 1980 |
| L8 | Recommended lifting point for the TC (cartridge group) | NA357: 905<br>TPL71: n/a | TPL76: 960 |
| M | Recommended lifting point for main parts to pass CAC housing | 2200 | 2400 |

## 18.4.2 Service space requirement for the V-engine

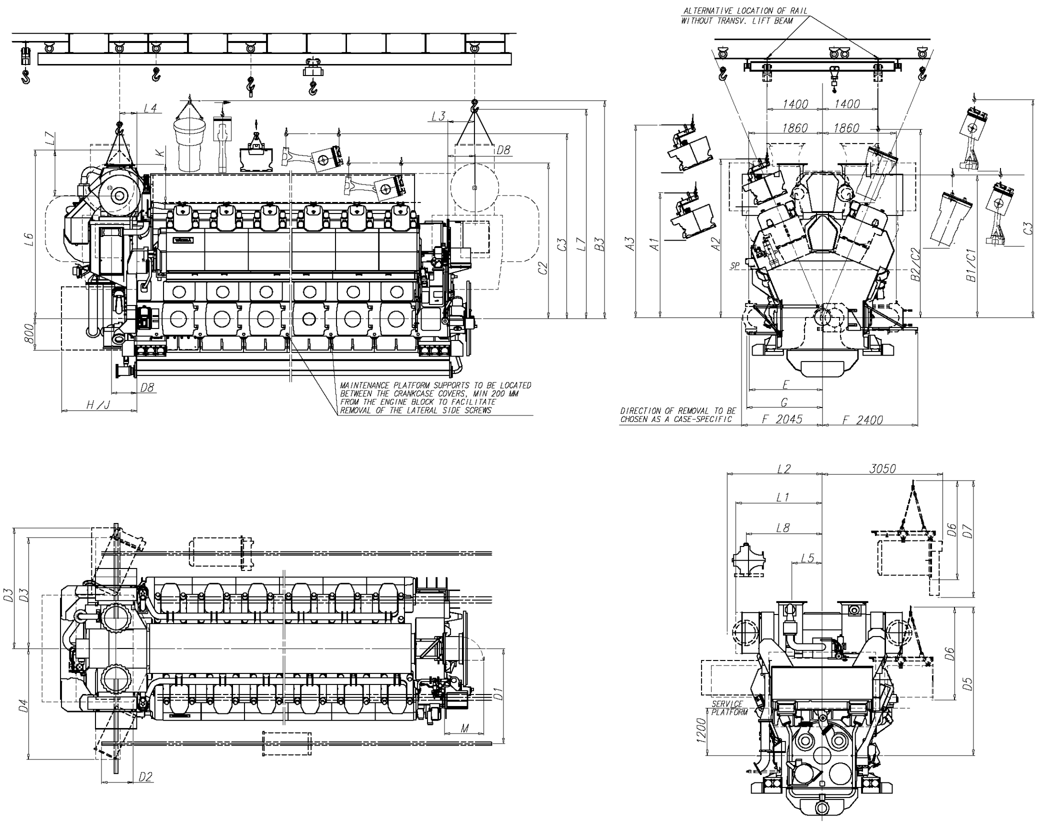


**Fig 18-6** **Service space requirement (DAAE093288A)**

| Services spaces in mm | | 12V50DF | 16V-, 18V50DF |
|---|---|---|---|
| A1 | Height needed for overhauling cylinder head freely over injection pump | 3150 | 3150 |
| A2 | Height needed for overhauling cylinder head freely over adjacent cylinder head covers | 4000 | 4000 |
| A3 | Height needed for overhauling cylinder head freely over exhaust gas insulation box | 4860 | 4860 |
| B1 | Height needed for transporting cylinder liner freely over injection pump | 3600 | 3600 |
| B2 | Height needed for transporting cylinder liner freely over adjacent cylinder head covers | 4750 | 4750 |
| B3 | Height needed for transporting cylinder liner freely over exhaust gas insulation box | 5500 | 5500 |
| C1 | Height needed for overhauling piston and connecting rod | 3600 | 3600 |
| C2 | Height needed for transporting piston and connecting rod freely over adjacent cylinder head covers | 4750 | 4750 |
| C3 | Height needed for transporting piston and connecting rod freely over exhaust gas insulation box | 5500 | 5500 |
| D1 | Recommended location of rail dismantling CAC sideways by using lifting tool | 2400 | 2400 |
| D2 | Recommended location of starting point for rails | 800 | 1000 |
| D3 | Min width needed for dismantling CAC with end cover of CAC by using lifting tool | 2800 | 3050 |
| D4 | Min width needed for dismantling CAC without end cover of CAC by using lifting tool | 2800 | 2900 |
| D5 | Height needed for overhauling CAC | 3725 | 3915 |
| D6 | Height needed for overhauling CAC without end cover | 2350 | 2500 |
| D7 | Height needed for overhauling CAC with end cover | - | 2950 |
| D8 | Recommended location of rail dismantling CAC | 640 | 690 |
| E | Width needed for removing main bearing side screw | 1850 | 1850 |
| F | Width needed for dismantling connecting rod big end bearing | 2400 | 2400 |
| G | Width of lifting tool for hydraulic cylinder / main bearing nuts | 1915 | 1915 |
| H | Distance needed to dismantle lube oil pump | 1900 | 1900 |
| J | Distance needed to dismantle water pumps | 1900 | 1900 |
| K | Distance between cylinder head cap and TC flange | NA357: 1130<br>TPL71: 970 | 1480 |
| L1 | Rec. axial clearance for dismantling and assembly of silencer is 500mm, min. clearance is 140mm for 12V50DF/TPL71 and 180mm for 16-18V50DF/TPL76. The given dimension L1 includes the min. maintenance space. | NA357: 2300<br>TPL71: 2180 | TPL76: 2560 |
| L2 | Rec. axial clearance for dismantling and assembly of suction branch is 500mm, min. clearance is 140mm for 12V50DF/TPL71 and 180mm for 16-18V50DF/TPL76. The given dimension L2 includes the min. maintenance space. | NA357: 2440<br>TPL71: 2405 | TPL76: 2845 |
| L3 | Recommended lifting point for the TC (driving end) | NA357: -<br>TPL71: 435 | TPL76: 680 |
| L4 | Recommended lifting point for the TC (free end) | NA357: 500<br>TPL71: 435 | TPL76: 680 |
| L5 | Recommended lifting point sideways for the TC | NA357: 765<br>TPL71: 770 | TPL76: 930 |
| L6 | Height needed for dismantling the TC | NA357: 4530<br>TPL71: 4250 | TPL76: 5280 |
| L7 | Height needed for dismantling the TC from center of TC | NA357: 1400<br>TPL71: 1150 | TPL76: 1300 |
| L8 | Recommended lifting point for the TC (cartridge) | NA357: 2120<br>TPL71: 1920 | TPL76: 2230 |
| M | Space necessary for opening the cover of the main cabinet | 1000 | 1000 |

# 19. Transport Dimensions and Weights

## 19.1 Lifting of engines

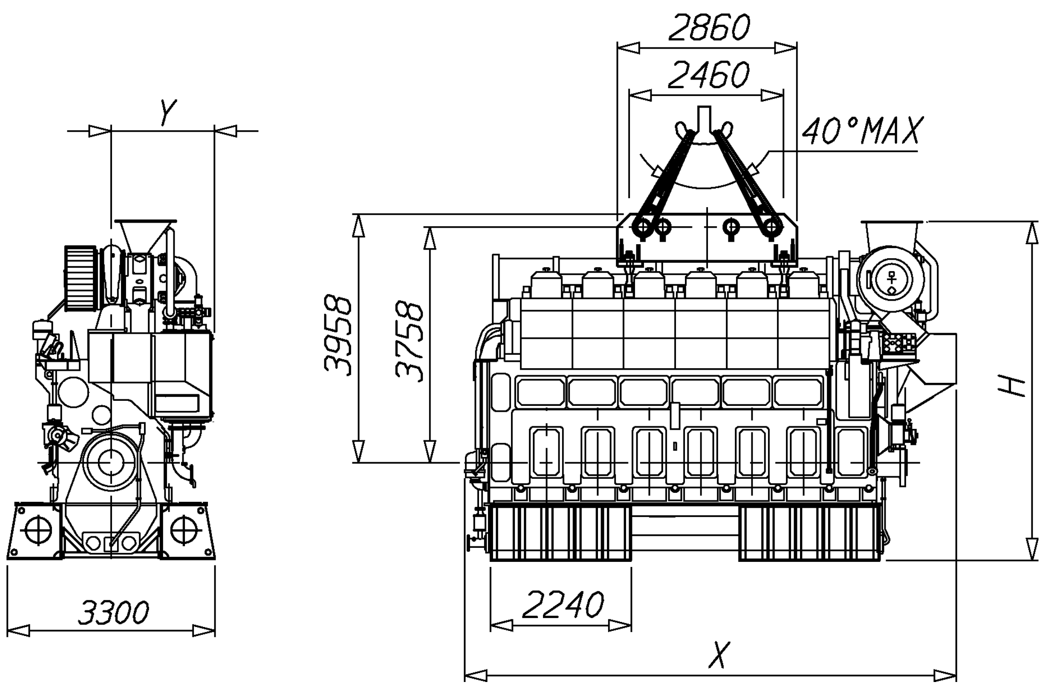


Fig 19-1 Lifting of rigidly mounted in-line engines (4V83D0212c)

| Engine type | X [mm] | Y [mm] | H [mm] | Weights without flywheel [ton] | | | |
|---|---|---|---|---|---|---|---|
| | | | | Engine | Lifting device | Transport cradle | Total weight |
| W 6L50DF | 8115 | 1600 | 5510 | 96 | 3.5 | 6.5 | 106 |
| W 8L50DF | 9950 | 1860 | 5510 | 128 | 3.5 | 6.5 | 138 |
| W 9L50DF | 10800 | 1860 | 5675 | 148 | 3.5 | 9.5 | 161 |

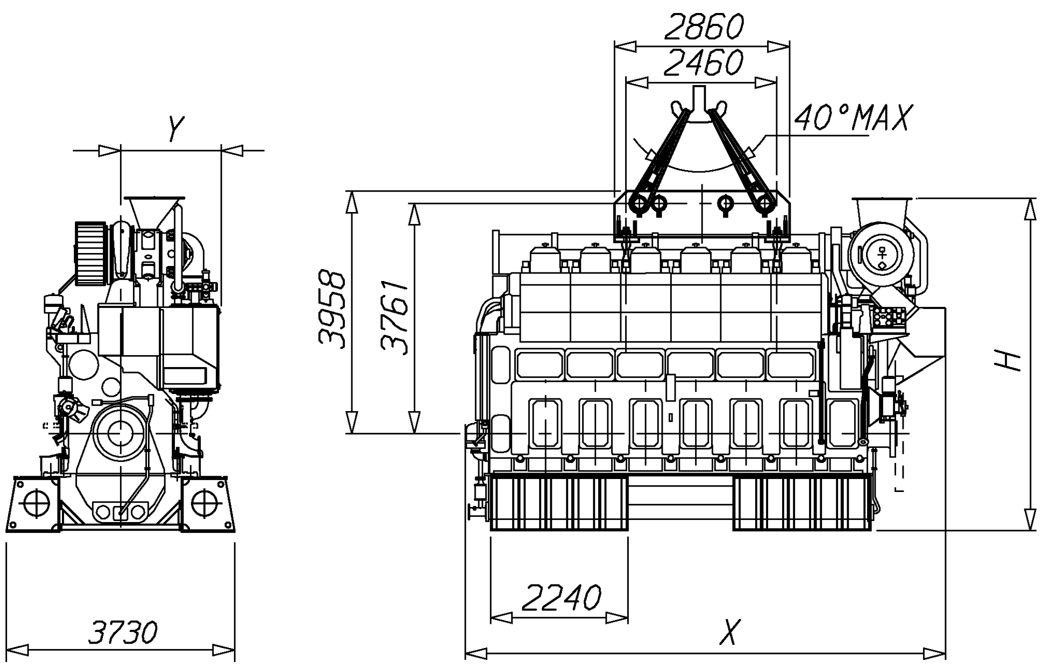


**Fig 19-2** **Lifting of flexibly mounted in-line engines (4V83D0211c)**

| Engine type | X [mm] | Y [mm] | H [mm] | Weights without flywheel [ton] | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Engine | Fixing rails | Lifting device | Transport cradle | Total weight |
| W 6L50DF | 8115 | 1600 | 5650 | 96 | 4.0 | 3.5 | 6.5 | 110 |
| W 8L50DF | 9950 | 1860 | 5650 | 128 | 5.0 | 3.5 | 6.5 | 143 |
| W 9L50DF | 10800 | 1860 | 5815 | 148 | 5.0 | 3.5 | 9.5 | 166 |

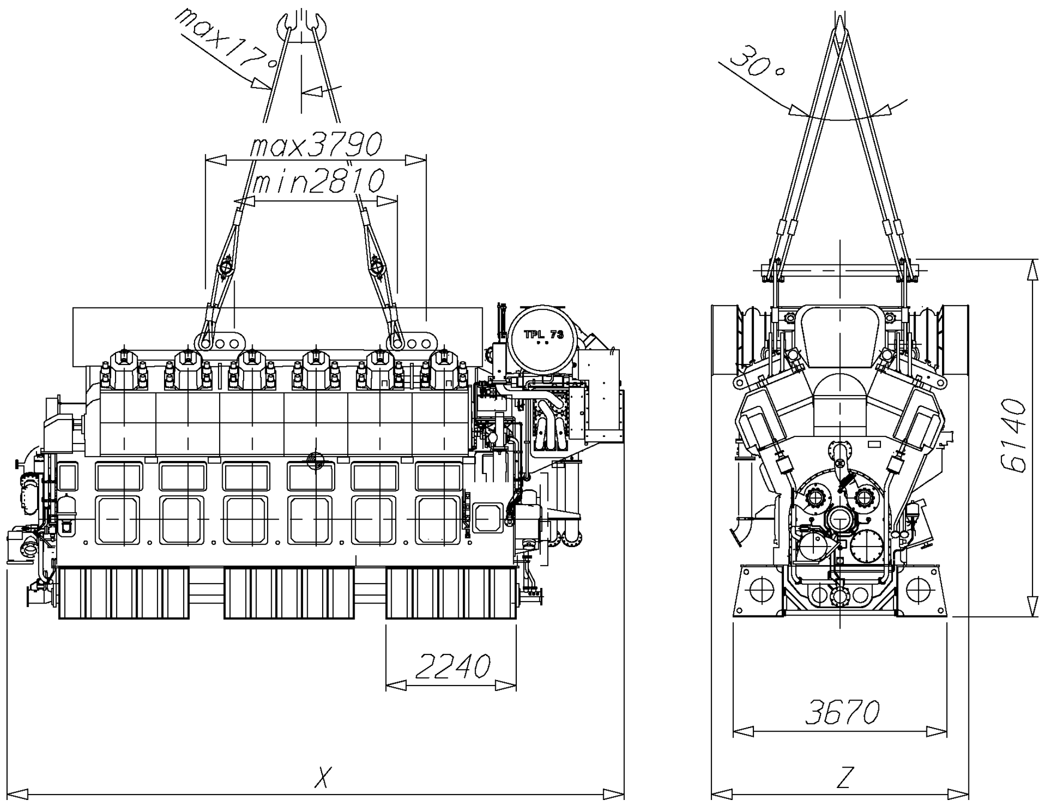


**Fig 19-3 Lifting of rigidly mounted V-engines (4V83D0248C)**

| Engine type | X 1) [mm] | X 2) [mm] | Z [mm] | Weights without flywheel [ton] | | | |
|---|---|---|---|---|---|---|---|
| | | | | Engine | Lifting device | Transport cradle | total weight |
| W 12V50DF | 10380 | 10600 | 4530 | 166 | 3.4 | 9.6 | 179 |
| W 16V50DF | 12580 | 12460 | 4530 | 211 | 3.4 | 9.6 | 224 |
| W 18V50DF | 13830 | - | 5350 | 237 | 3.4 | 9.6 | 250 |

*2) Turbocharger at the flywheel end*

*1) Turbocharger at the free end*

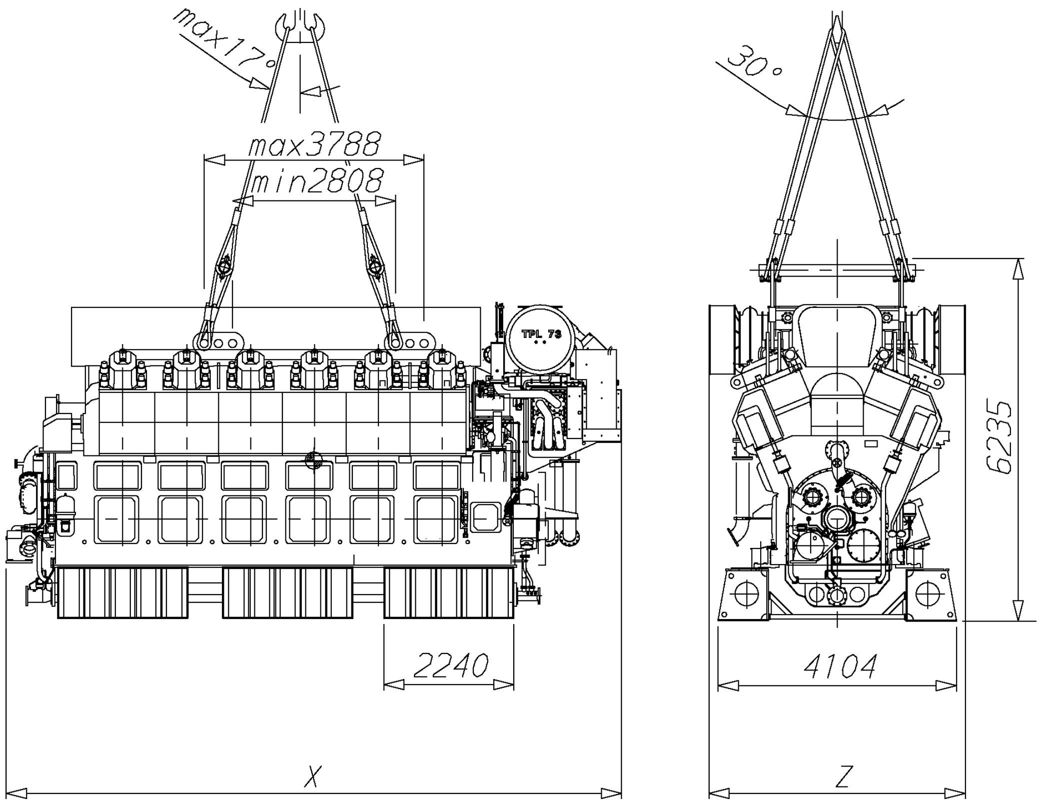


**Fig 19-4** **Lifting of flexibly mounted V-engines (4V83D0249C)**

| Engine type | X 1) [mm] | X 2) [mm] | Z [mm] | Weights without flywheel [ton] | | | |
|---|---|---|---|---|---|---|---|
| | | | | Engine | Lifting device | Transport cradle | Total weight |
| W 12V50DF | 10211 | 10601 | 4532 | 166.1 | 3.4 | 9.6 | 179.1 |
| W 16V50DF | 12300 | 12801 | 5350 | 213.9 | 3.4 | 9.6 | 226.9 |
| W 18V50DF | 13667 | - | 5975 | 237.0 | 3.4 | 9.6 | 250.0 |

*2) Turbocharger at the flywheel end*

*1) Turbocharger at the free end*

## 19.2 Engine components

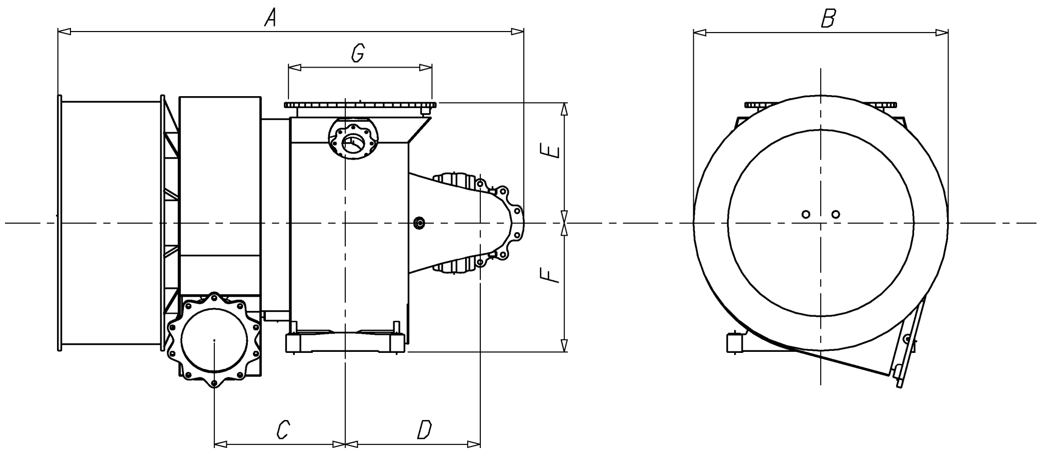


**Fig 19-5 Turbocharger (3V92L1224e)**

| Engine type | Turbochar-ger | A | B | C | D | E | F | G | Weight, com-plete | Weight, rotor block cart-ridge |
|---|---|---|---|---|---|---|---|---|---|---|
| W 6L50DF | NA 357 | 1874 | 1024 | 545 | 524 | 525 | 510 | DN 500 | 1460 | 270 |
| W 6L50DF | TPL 71 | 2003 | 1050 | 540 | 598 | 791 | 530 | DN 600 | 1957 | 464 |
| W 8L50DF<br>W 9L50DF | TPL 76 | 2301 | 1340 | 641 | 688 | 1100 | 690 | DN 800 | 3575 | 815 |
| W 12V50DF | NA 357 | 1874 | 1024 | 545 | 524 | 525 | 510 | DN 500 | 1460 | 270 |
| W 12V50DF | TPL 71 | 2003 | 1050 | 540 | 598 | 791 | 530 | DN 600 | 1957 | 464 |
| W 16V50DF<br>W 18V50DF | TPL 76 | 2301 | 1340 | 641 | 688 | 1100 | 690 | DN 800 | 3575 | 815 |

All dimensions in mm. Weight in kg.

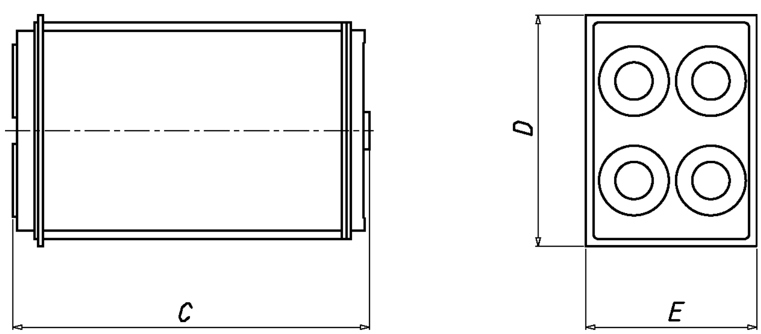


**Fig 19-6 Charge air cooler inserts (3V92L1063)**

| Engine type | Model | C [mm] | D [mm] | E [mm] | Weight [kg] |
|---|---|---|---|---|---|
| W 6L50DF | NA357 | 1650 | 730 | 615 | 765 |
| | TPL71 | 1650 | 840 | 615 | 1105 |
| W 8L50DF | TPL71 | 1650 | 840 | 615 | 1105 |
| W 9L50DF | TPL71 | 1650 | 840 | 615 | 1105 |
| W 12V50DF | NA357 | 1220 | 790 | 555 | 720 |
| | TPL71 | 1220 | 790 | 555 | 720 |
| W 16V50DF | TPL71 | 1330 | 870 | 625 | 1375 |
| W 18V50DF | TPL71 | 1330 | 870 | 625 | 1485 |

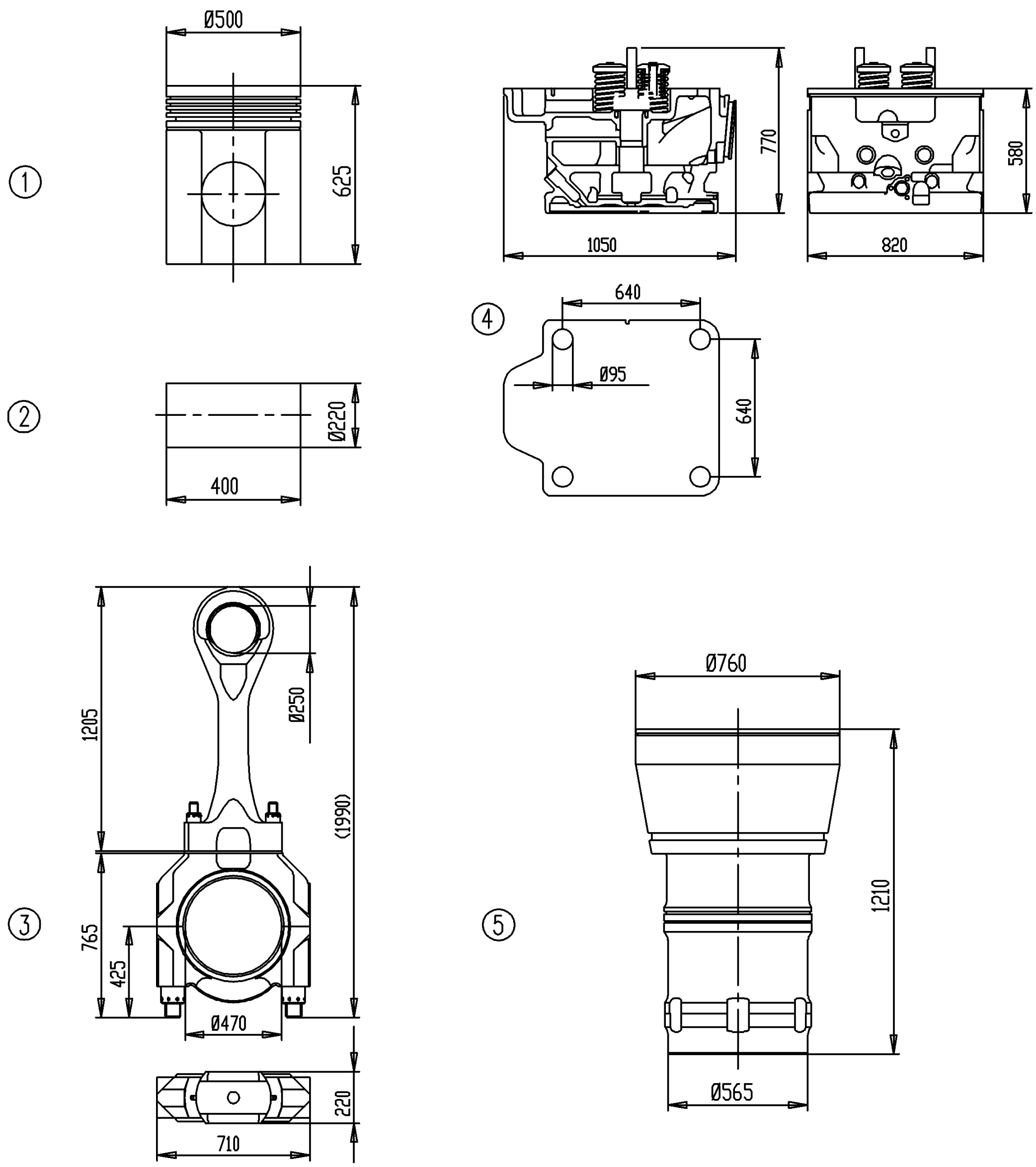


**Fig 19-7** **Major spare parts (4V92L1476)**

| Item | Description | Weight [kg] |
|---|---|---|
| 1. | Piston | 255 |
| 2. | Gudgeon pin | 110 |
| 3. | Connecting rod, upper part | 280 |
| | Connecting rod, lower part | 460 |
| 4. | Cylinder head | 1250 |
| 5. | Cylinder liner | 950 |

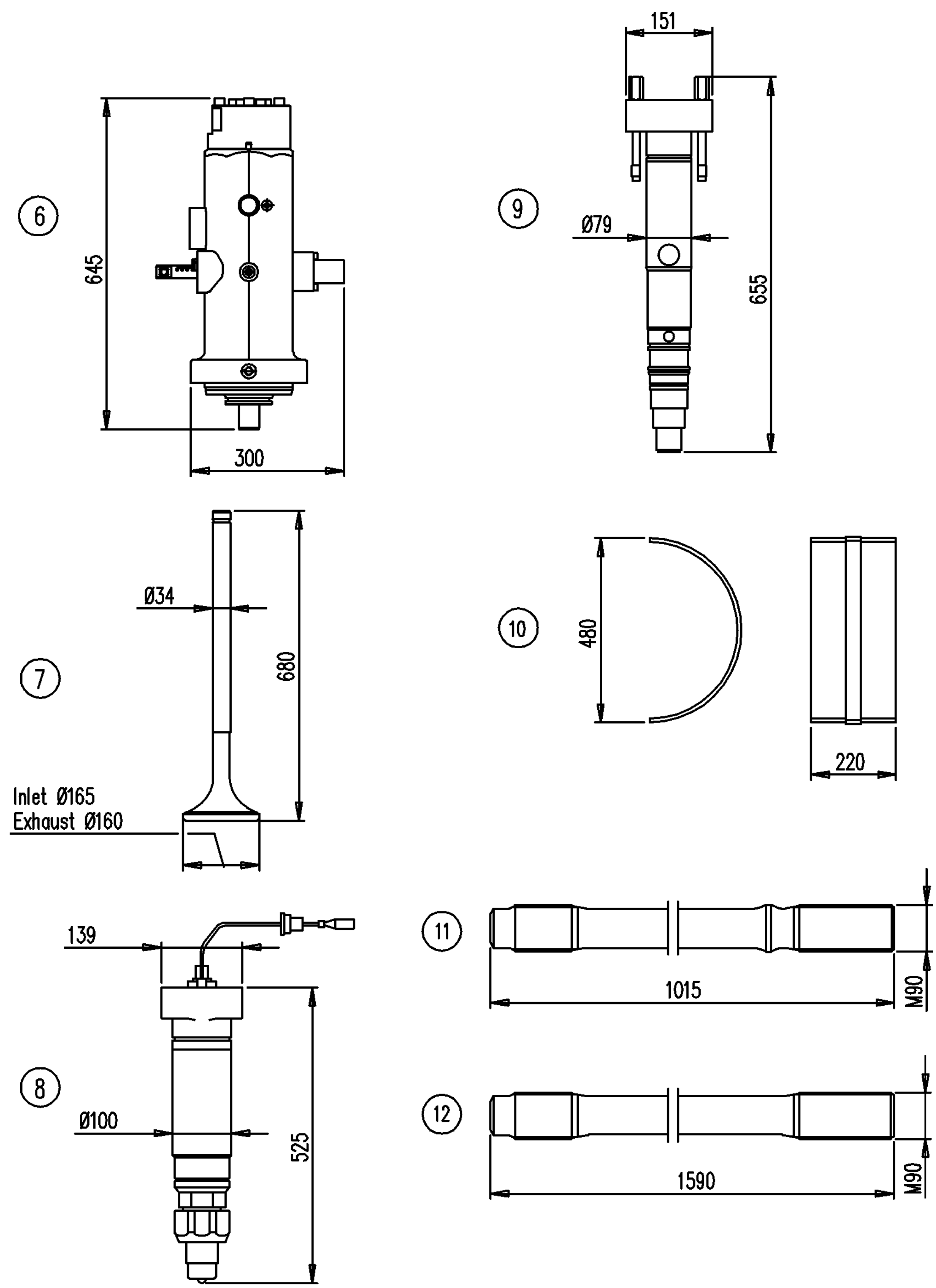


**Fig 19-8** **Major spare parts (4V92L1477)**

| Item | Description | Weight [kg] |
|---|---|---|
| 6. | Injection pump | 100 |
| 7. | Valve | 10 |
| 8. | Injection valve | 20 |
| 9. | Starting air valve | 25 |
| 10. | Main bearing shell | 15 |

| Item | Description | Weight [kg] |
|---|---|---|
| 11. | Main bearing screw | 60 |
| 12. | Cylinder head screw | 80 |

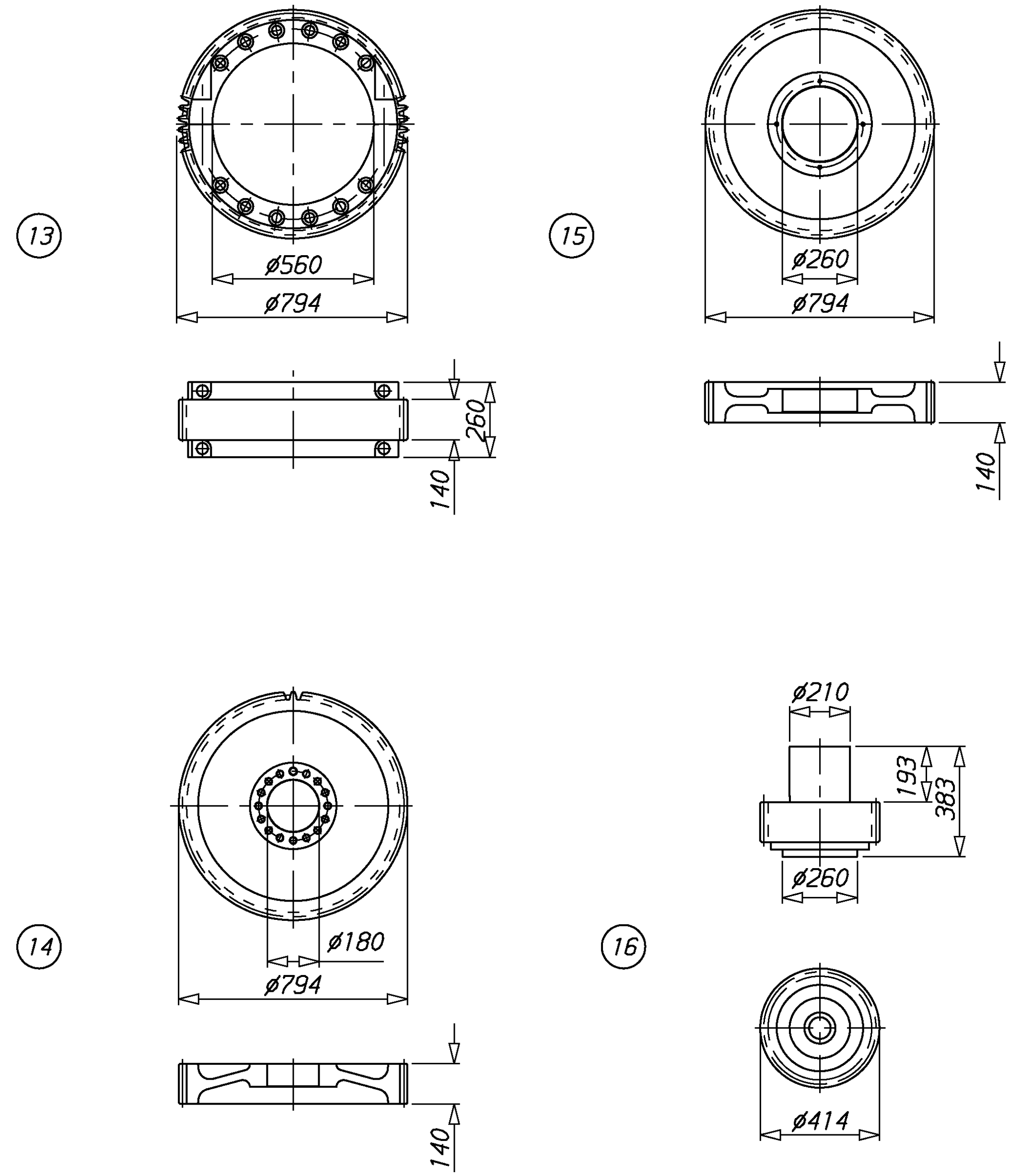


**Fig 19-9 Major spare parts (4V92L0931a)**

| Item | Description | Weight [kg] |
|---|---|---|
| 13. | Split gear wheel | 360 |
| 14. | Camshaft gear wheel | 685 |
| 15. | Bigger intermediate wheel | 685 |
| 16. | Smaller intermediate wheel | 550 |

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# 20. Product Guide Attachments

This and other product guides can be accessed on the internet, from the Business Online Portal at www.wartsila.com. Product guides are available both in web and PDF format. Drawings are available in PDF and DXF format, and in near future also as 3D models. Consult your sales contact at Wärtsilä to get more information about the product guides on the Business Online Portal.

The attachments are not available in the printed version of the product guide.

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# 21. ANNEX

## 21.1 Unit conversion tables

The tables below will help you to convert units used in this product guide to other units. Where the conversion factor is not accurate a suitable number of decimals have been used.

*Length conversion factors*

| Convert from | To | Multiply by |
|---|---|---|
| mm | in | 0.0394 |
| mm | ft | 0.00328 |

*Mass conversion factors*

| Convert from | To | Multiply by |
|---|---|---|
| kg | lb | 2.205 |
| kg | oz | 35.274 |

*Pressure conversion factors*

| Convert from | To | Multiply by |
|---|---|---|
| kPa | psi (lbf/in$^2$) | 0.145 |
| kPa | lbf/ft$^2$ | 20.885 |
| kPa | inch $H_2O$ | 4.015 |
| kPa | foot $H_2O$ | 0.335 |
| kPa | mm $H_2O$ | 101.972 |
| kPa | bar | 0.01 |

*Volume conversion factors*

| Convert from | To | Multiply by |
|---|---|---|
| m$^3$ | in$^3$ | 61023.744 |
| m$^3$ | ft$^3$ | 35.315 |
| m$^3$ | Imperial gallon | 219.969 |
| m$^3$ | US gallon | 264.172 |
| m$^3$ | l (litre) | 1000 |

*Power conversion*

| Convert from | To | Multiply by |
|---|---|---|
| kW | hp (metric) | 1.360 |
| kW | US hp | 1.341 |

*Moment of inertia and torque conversion factors*

| Convert from | To | Multiply by |
|---|---|---|
| kgm$^2$ | lbft$^2$ | 23.730 |
| kNm | lbf ft | 737.562 |

*Fuel consumption conversion factors*

| Convert from | To | Multiply by |
|---|---|---|
| g/kWh | g/hph | 0.736 |
| g/kWh | lb/hph | 0.00162 |

*Flow conversion factors*

| Convert from | To | Multiply by |
|---|---|---|
| m$^3$/h (liquid) | US gallon/min | 4.403 |
| m$^3$/h (gas) | ft$^3$/min | 0.586 |

*Temperature conversion factors*

| Convert from | To | Multiply by |
|---|---|---|
| °C | F | F = 9/5 *C + 32 |
| °C | K | K = C + 273.15 |

*Density conversion factors*

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

### 21.1.1 Prefix

**Table 21-1 The most common prefix multipliers**

| Name | Symbol | Factor | Name | Symbol | Factor | Name | Symbol | Factor |
|---|---|---|---|---|---|---|---|---|
| tera | T | $10^{12}$ | kilo | k | $10^3$ | nano | n | $10^{-9}$ |
| giga | G | $10^9$ | milli | m | $10^{-3}$ | | | |
| mega | M | $10^6$ | micro | μ | $10^{-6}$ | | | |

## 21.2 Collection of drawing symbols used in drawings

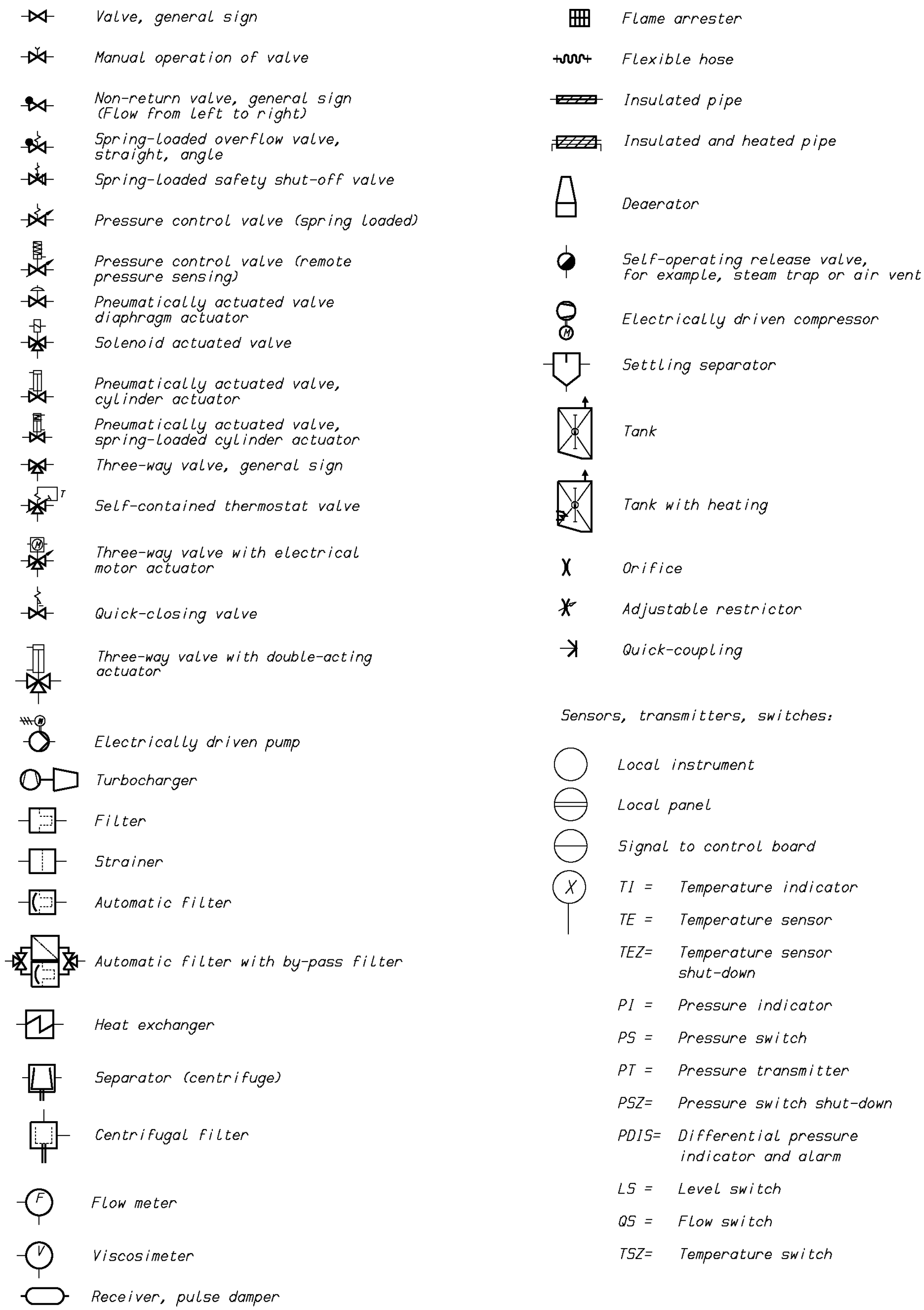


**Fig 21-1** **List of symbols (DAAE000806c)**

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