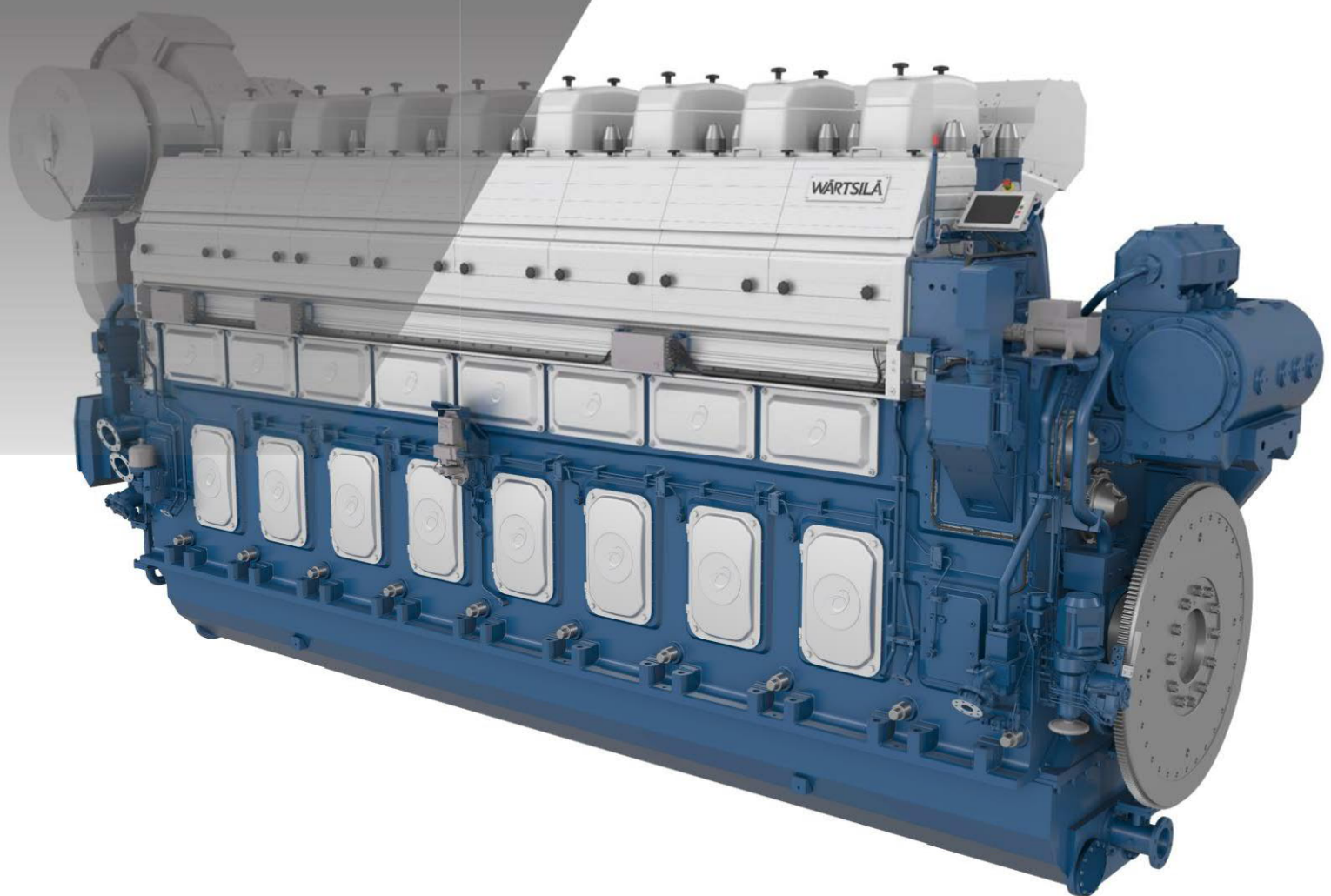


# Wärtsilä 46F

PRODUCT GUIDE



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# Introduction

This Product Guide provides data and system proposals for the early design phase of marine engine installations. For contracted projects specific instructions for planning the installation are always delivered. Any data and information herein is subject to revision without notice. This 1/2020 issue replaces all previous issues of the Wärtsilä 46F Product Guides.

<b>Issue</b>	<b>Published</b>	<b>Updates</b>
1/2020	12.02.2020	Small updates in technical data section
2/2019	05.09.2019	Small updates in technical data section
1/2019	26.07.2019	Several updates throughout the product guide
3/2017	07.11.2017	Technical data updated
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1/2016	27.06.2016	Flow diagrams updated, other minor updates
1/2013	27.08.2013	Several updates throughout the product guide

Wärtsilä, Marine Solutions

Vaasa, February 2020

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# 1. Main Data and Outputs

The Wärtsilä 46F is a 4-stroke, non-reversible, turbocharged and intercooled diesel engine with direct fuel injection (twin pump).

Cylinder bore	460 mm
Stroke	580 mm
Piston displacement	96.4 l/cyl
Number of valves	2 inlet valves and 2 exhaust valves
Cylinder configuration	6, 7, 8 and 9 in-line; 12, 14 and 16 in V-form
Direction of rotation	clockwise, counter-clockwise on request
Speed	600 rpm
Mean piston speed	11.6 m/s

## 1.1 Maximum continuous output

**Table 1-1 Maximum continuous output**

Cylinder configuration	IMO Tier 2	
	kW	bhp
W 6L46F	7200	9790
W 7L46F	8400	11420
W 8L46F	9600	13050
W 9L46F	10800	14680
W 12V46F	14400	19580
W 14V46F	16800	22840
W 16V46F	19200	26110

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 Reference conditions

The output is available up to an air temperature of max. 45°C. For higher temperatures, the output has to be reduced according to the formula stated in ISO 3046-1:2002 (E).

The specific fuel oil consumption is stated in the chapter *Technical data*. The stated specific fuel oil consumption applies to engines with engine driven pumps, operating in ambient conditions according to ISO 15550:2002 (E). The ISO standard reference conditions are:

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

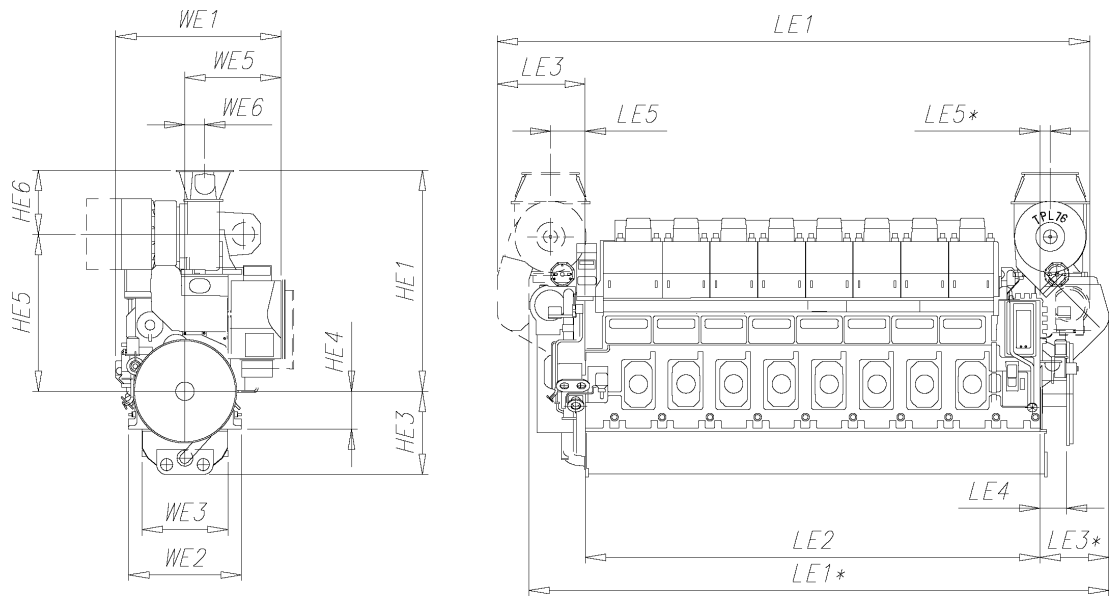
Correction factors for the fuel oil consumption in other ambient conditions are given in standard ISO 15550:2002 (E).

## 1.3 Operation in inclined position

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

- Permanent athwart ship inclinations 15.0°
- Temporary athwart ship inclinations 22.5°
- Permanent fore-and-aft inclinations 10.0°

# 1.4 Dimensions and weights



**Fig 1-1 In-line engines (DAAE012051c)**

Engine	LE1*	LE1	LE2	LE3*	LE3	LE4	LE5*	LE5	HE1	HE3
6L46F	8470	8620	6170	1320	1550	460	180	690	3500	1430
7L46F	9435	9440	6990	1465	1550	460	180	800	3800	1430
8L46F	10255	10260	7810	1465	1550	460	180	800	3800	1430
9L46F	11075	11080	8630	1465	1550	460	180	800	3800	1430

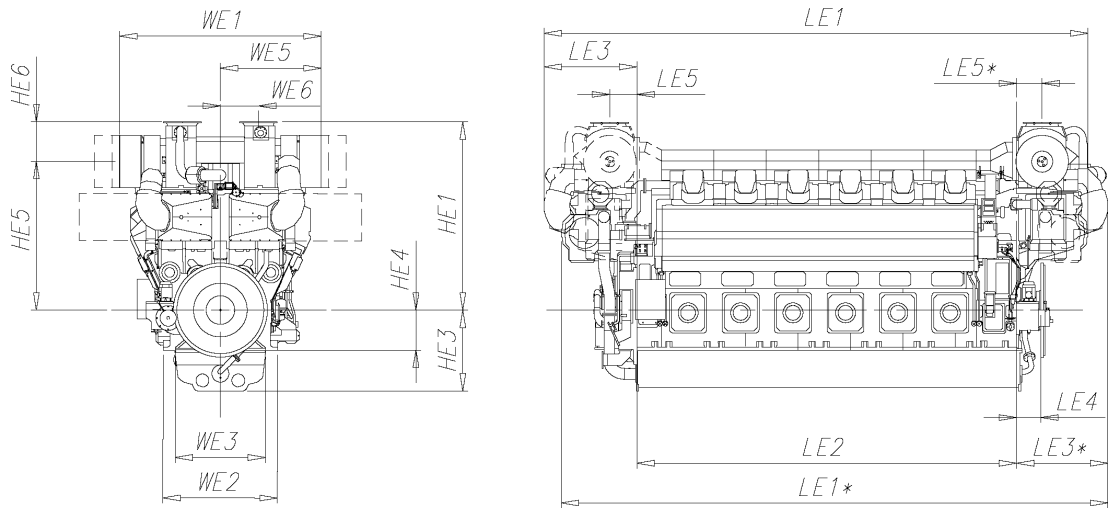
Engine	HE4	HE5	HE6	WE1	WE2	WE3	WE5	WE6	Weight [ton]
6L46F	650	2710	790	2905	1940	1480	1535	385	97
7L46F	650	2700	1100	3130	1940	1480	1760	340	113
8L46F	650	2700	1100	3130	1940	1480	1760	340	124
9L46F	650	2700	1100	3130	1940	1480	1760	340	140

\* Turbocharger at flywheel end

All dimensions in mm. The weights are dry weights of rigidly mounted engines without flywheel.

**Table 1-2 Additional weights [ton]:**

Item	6L46F	7L46F	8L46F	9L46F
Flywheel	1...2	1...2	1...2	1...2
Flexible mounting (without limiters)	3	3	3	3



**Fig 1-2 V-engines (DAAE075826B)**

Engine	LE1*	LE1	LE2	LE3*	LE3	LE4	LE5*	LE5	HE1	HE3
12V46F	10945	10284	7600	1830	1952	460	520	774	3765* / 3770	1620
14V46F	-	11728	8650	-	2347	485	-	872	4234	1620
16V46F	-	12871	9700	-	2347	485	-	872	4234	1620

Engine	HE4	HE5	HE6	WE1	WE2	WE3	WE5	WE6	Weight [ton]
12V46F	800	2975* / 2980	790	4040* / 4026	2290	1820	2825* / 3150	760	177
14V46F	800	3134	1100	4678	2290	1820	3150	892	216
16V46F	800	3134	1100	4678	2290	1820	3150	892	233

\* Turbocharger in flywheel end

All dimensions in mm. The weights are dry weights of rigidly mounted engines without flywheel.

**Table 1-3 Additional weights [ton]:**

Item	12V46F	14V46F	16V46F
Flywheel	1...2	1...2	1...2
Flexible mounting (without limiters)	3	3	3

## 2. Operating Ranges

### 2.1 Engine operating range

Running below nominal speed the load must be limited according to the diagrams in this chapter in order to maintain engine operating parameters within acceptable limits. 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. The engine load is derived from fuel rack position and actual engine speed (not speed demand).

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

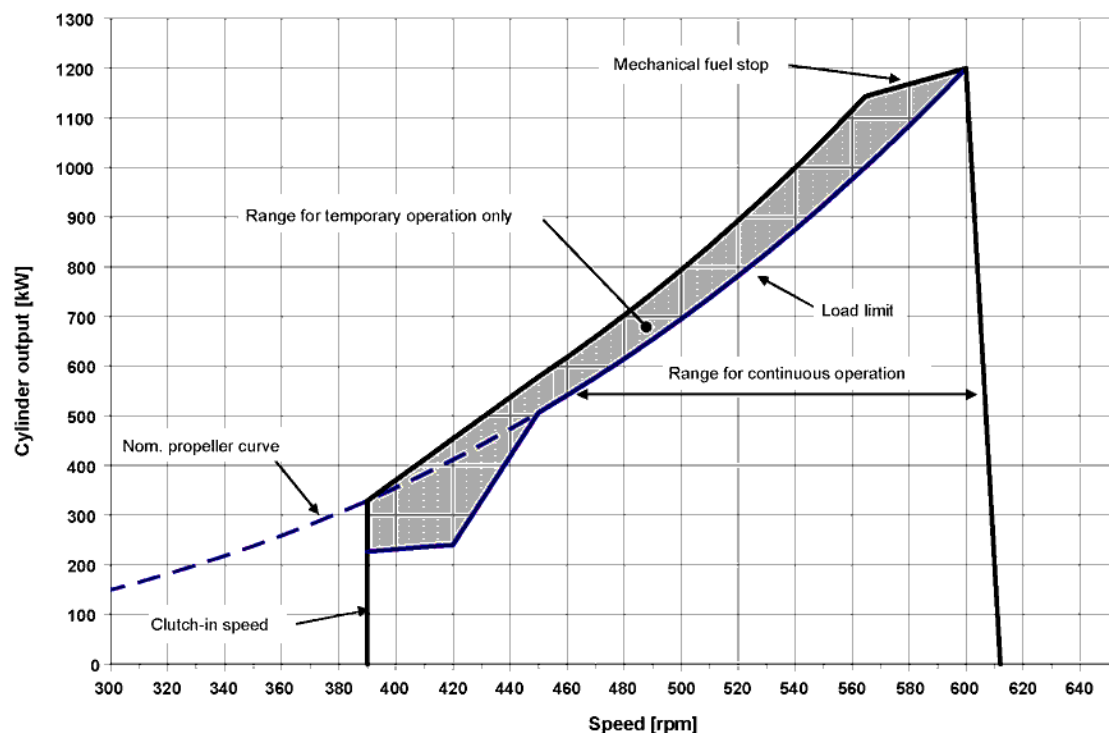


Fig 2-1 Operating field for CP Propeller, IMO Tier 2, 1200 kW/cyl, 600 rpm

### 2.2 Loading capacity

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

If the control system has only one load increase ramp, then the ramp for a preheated engine should be used. The HT-water temperature in a preheated engine must be at least 70 °C and the lubricating oil temperature must be at least 40 °C.

The loading ramp “normal” can be taken into use when the engine has been operating above 30% load for 6 minutes. All engines respond equally to a change in propulsion power (or total load), also when a recently connected engine is still uploading to even load sharing with parallel engines. A recently connected generator shall therefore not be taken into account as “available power” until after 6 minutes, or alternatively the available power from this generator is ramped up to 100% during 10 minutes. If the load sharing is based on speed drop, the power management system ramps up the load on a recently connected generator according to the ramp “preheated”.

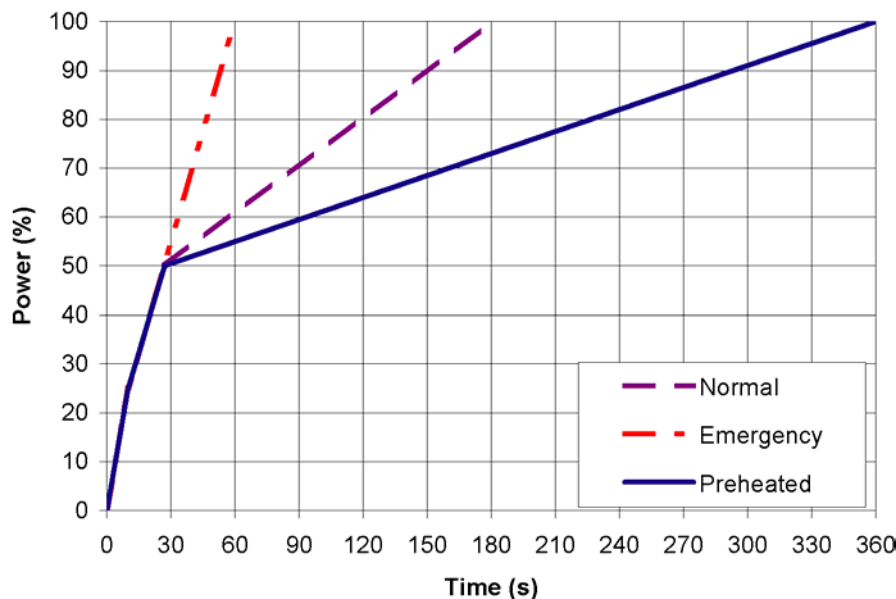
The “emergency” loading ramp can be used in critical situations, e.g. to steer as fast as possible.

The emergency ramp can be activated manually or according to some predefined condition, and there shall be a visible alarm indicating that emergency loading is activated.

The load should always be applied gradually in normal operation. Class rules regarding load acceptance capability of diesel generators should not be interpreted as guidelines on how to apply load in normal operation. The class rules define what the engine must be capable of, if an unexpected event causes a sudden load step.

Electric generators must be capable of 10% overload. The maximum engine output is 110% in diesel mode.

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

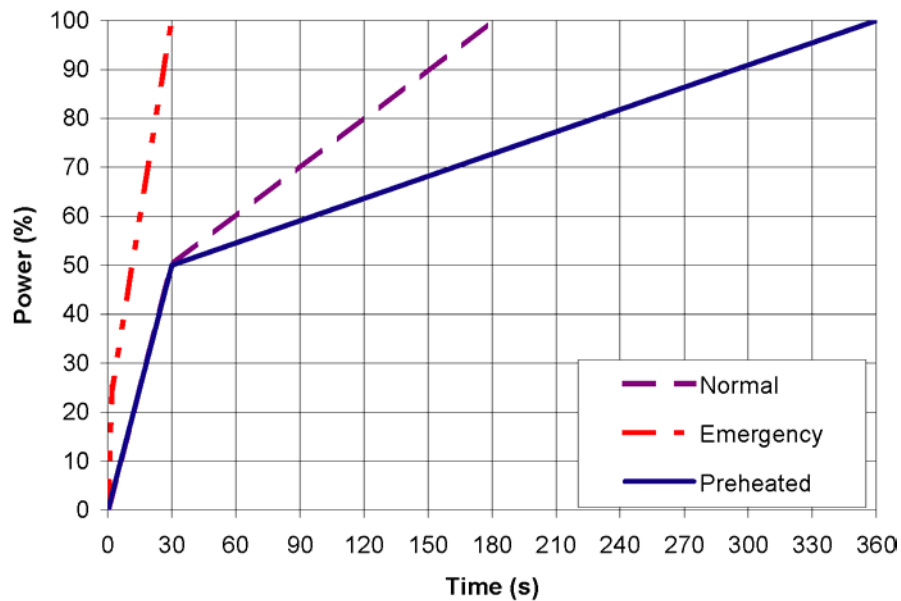


**Fig 2-2 Maximum load increase rates for variable speed engines**

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

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

## 2.2.2 Diesel electric propulsion



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

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

The maximum deviation from steady state speed is less than 10%, when applying load according to the emergency loading ramp. Load increase according to the normal ramp correspondingly results in less than 3% speed deviation.

### 2.2.2.1 Maximum instant load steps

The electrical system must be designed so that tripping of breakers can be safely handled. This requires that the engines are protected from load steps exceeding their maximum load acceptance capability. The maximum permissible load step for an engine that has attained normal operating temperature is 33% MCR. The resulting speed drop is less than 10% and the recovery time to within 1% of the steady state speed at the new load level is max. 5 seconds.

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

### 2.2.2.2 Start-up time

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

## 2.3 Operation at low load and idling

The engine can be started, stopped and operated on heavy fuel under all operating conditions. Continuous operation on heavy fuel is preferred rather than changing over to diesel fuel at low load operation and manoeuvring. The following recommendations apply:

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

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

**Operation below 20 % load**

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

**Operation above 20 % load**

- No restrictions.

**2.3.1****Operating at low and load and idling with S.C.R. (Warstila NOR)**

When engine is coupled with a Selective Catalytic Reduction system, the following recommendations apply:

**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 in LFO if the engine is to be loaded after the idling. Before further operation at idling, the engine must be loaded according to the indications reported in the Selective Catalytic Reduction system resetting operation section.
- Maximum 1 hour in HFO if the engine is to be loaded after the idling. Before further operation at idling, the engine must be loaded according to the indications reported in the Selective Catalytic Reduction system resetting operation section.

**Operation below 10% MCR**

- Max continuous operation time: 6h in LFO. At intervals of 6 operating hours, the engine must be loaded according to the indications reported in the Selective Catalytic Reduction system resetting operation section.
- Max continuous operation time: 3h in LFO. At intervals of 3 operating hours, the engine must be loaded according to the indications reported in the Selective Catalytic Reduction system resetting operation section.

**Operation below 25% MCR**

- Max continuous operation time: 24h in LFO. At intervals of 24 operating hours, the engine must be loaded according to the indications reported in the Selective Catalytic Reduction system resetting operation section.
- Max continuous operation time: 12h in HFO. At intervals of 12 operating hours, the engine must be loaded according to the indications reported in the Selective Catalytic Reduction system resetting operation section.

**Operation above 25% MCR**

- No restrictions.

**Selective Catalytic Reduction system resetting operation**

In case engine has to be run for prolonged time at low loads, Selective Catalytic Reduction system resetting operation must be performed at the intervals indicated, as follows:

Engine must be loaded to minimum 70 % of the rated output for 1 hour or to minimum 50 % of the rated output for 2 hours or alternatively engine must be loaded to minimum 25 % of the rated output for 4 hours.

SCR resetting operation can be split into multiple operational events in case extended high load operation is not feasible. As an example, one 1 hour engine operation at 70 % of the rated output can be replaced by 2 times 30 minute engine operation at 70 % of the rated output. Note that shorter duration than 30 minutes is not recommended.



## 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*.

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## **3. Technical Data**

### **3.1 Introduction**

This chapter contains technical data of the engine (heat balance, flows, pressures etc.) for design of auxiliary 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”.

## 3.2 Wärtsilä 6L46F

Wärtsilä 6L46F		ME CPP Variable Speed	ME CPP Con- stant Speed	DE Constant Speed
<b>Cylinder output</b>	<b>kW</b>	<b>1200</b>	<b>1200</b>	<b>1200</b>
<b>Engine speed</b>	<b>rpm</b>	<b>600</b>	<b>600</b>	<b>600</b>
Engine output	kW	7200	7200	7200
Mean effective pressure	MPa	2.49	2.49	2.49
<b>Combustion air system (Note 1)</b>				
Flow at 100% load	kg/s	12.6	12.6	12.6
Temperature at turbocharger intake, max. (TE 600)	°C	45	45	45
Temperature after air cooler, nom. (TE 601)	°C	50	50	50
<b>Exhaust gas system (Note 2)</b>				
Flow at 100% load	kg/s	13.08	13.08	13.08
Flow at 85% load	kg/s	11.16	11.34	11.34
Flow at 75% load	kg/s	10.44	11.1	11.1
Flow at 50% load	kg/s	6.96	8.76	8.76
Temp. after turbo, 100% load (TE 517)	°C	364	364	364
Temp. after turbo, 85% load (TE 517)	°C	336	330	330
Temp. after turbo, 75% load (TE 517)	°C	338	330	330
Temp. after turbo, 50% load (TE 517)	°C	356	300	300
Backpressure, max.	kPa	3	3	3
Calculated pipe diameter for 35 m/s	mm	924	924	924
<b>Heat balance at 100% load (Note 3)</b>				
Jacket water, HT-circuit	kW	912	912	912
Charge air, HT-circuit	kW	1542	1572	1572
Charge air, LT-circuit	kW	786	762	762
Lubricating oil, LT-circuit	kW	732	732	732
Radiation	kW	210	210	210
<b>Fuel system (Note 4)</b>				
Pressure before injection pumps (PT 101) at 85% load	kPa	900...950	900...950	900...950
Pressure before injection pumps (PT 101) at idle speed (check value)	kPa	1000...1050	1000...1050	1000...1050
Fuel oil flow to engine, range	m <sup>3</sup> /h	4.9...5.4	4.9...5.4	4.9...5.4
HFO viscosity before 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	4,5
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	22,5	22,5	22,5
SFOC at 100% load (HFO)	g/kWh	183.4	182.5	182.5
SFOC at 85% load (HFO)	g/kWh	174.9	174.9	176.8
SFOC at 75% load (HFO)	g/kWh	179.2	185.0	186.9
SFOC at 50% load (HFO)	g/kWh	182.2	191.2	197.0
SFOC at 100% load (LFO)	g/kWh	186.3	185.3	185.3
SFOC at 85% load (LFO)	g/kWh	176.8	176.8	178.7

Wärtsilä 6L46F		ME CPP Variable Speed	ME CPP Con- stant Speed	DE DE Constant Speed
<b>Cylinder output</b>	<b>kW</b>	<b>1200</b>	<b>1200</b>	<b>1200</b>
<b>Engine speed</b>	<b>rpm</b>	<b>600</b>	<b>600</b>	<b>600</b>
SFOC at 75% load (LFO)	g/kWh	181.1	186.9	188.8
SFOC at 50% load (LFO)	g/kWh	183.1	192.2	197.9
<b>Lubricating oil system</b>				
Pressure before bearings, nom. (PT 201)	kPa	500	500	500
Pressure after pump, max.	kPa	800	800	800
Suction ability main pump, including pipe loss, max.	kPa	40	40	40
Prelubricating pressure, nom. (PT 201)	kPa	80	80	80
Temperature before bearings, nom. (TE 201)	°C	56	56	56
Temperature after engine, approx.	°C	75	75	75
Pump capacity (main), engine driven	m <sup>3</sup> /h	191	175	175
Pump capacity (main), electrically driven	m <sup>3</sup> /h	191	158	158
Oil flow through engine	m <sup>3</sup> /h	130	130	130
Prelubricating pump capacity (50/60Hz)	m <sup>3</sup> /h	35	35	35
Oil tank volume in separate system, min	m <sup>3</sup>	13.0	13.0	13.0
Oil consumption at 100% load, approx.	g/kWh	0.7	0.7	0.7
Crankcase ventilation flow rate at full load	l/min	1350	1350	1350
Crankcase ventilation backpressure, max.	kPa	0.4	0.4	0.4
Oil volume in turning device	l	9.5	9.5	9.5
Oil volume in speed governor	l	1.7	1.7	1.7
<b>HT cooling water system</b>				
Pressure at engine, after pump, nom. (PT 401)	kPa	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 401)	kPa	530	530	530
Temperature before cylinders, approx. (TE 401)	°C	74	74	74
Temperature after charge air cooler, nom. (TE432)	°C	91...95	91...95	91...95
Capacity of engine driven pump, nom.	m <sup>3</sup> /h	115	115	115
Pressure drop over engine (including HT CAC and temperature control valve)	kPa	150	150	150
Pressure drop in external system, max.	kPa	100	100	100
Pressure from expansion tank	kPa	70...150	70...150	70...150
Water volume in engine	m <sup>3</sup>	1.0	1.0	1.0
<b>LT cooling water system (Note 5)</b>				
Pressure at engine, after pump, nom. (PT 471)	kPa	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 471)	kPa	530	530	530
Temperature before engine, max. (TE 471)	°C	38	38	38
Temperature before engine, min. (TE 471)	°C	25	25	25
Capacity of engine driven pump, nom.	m <sup>3</sup> /h	115	115	115
Pressure drop over charge air cooler	kPa	50	50	50
Pressure drop over built-on lube oil cooler, max	kPa	20	20	20
Pressure drop over built-on temp. control valve	kPa	30	30	30
Pressure drop in external system, max.	kPa	150	150	150
Pressure from expansion tank	kPa	70 ... 150	70 ... 150	70 ... 150
Water volume in engine	m <sup>3</sup>	0.3	0.3	0.3

Wärtsilä 6L46F		ME CPP Variable Speed	ME CPP Con- stant Speed	DE DE Constant Speed
Cylinder output	kW	1200	1200	1200
Engine speed	rpm	600	600	600
<b>Starting air system (Note 6)</b>				
Pressure, nom. (PT 301)	kPa	3000	3000	3000
Pressure at engine during start, min. (20°C) (PT 301)	kPa	1500	1500	1500
Pressure at engine during start, max. (20°C) (PT 301)	kPa	3000	3000	3000
Low pressure limit in air vessels	kPa	1800	1800	1800
Consumption per start at 20°C (successful start)	Nm <sup>3</sup>	6.0	6.0	6.0
Consumption per start at 20°C, (with slowturn)	Nm <sup>3</sup>	7.0	7.0	7.0

**Notes:**

- Note 1 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 5%.
- Note 2 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C). Flow tolerance 5% and temperature tolerance 20°C.
- Note 3 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Tolerance for cooling water heat 10%, tolerance for radiation heat 30%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers.
- Note 4 According to ISO 15550, lower calorific value 42700 kJ/kg, with engine driven pumps (two cooling water + one lubricating oil pumps). Tolerance 5%. The fuel consumption at 85 % load is guaranteed and the values at other loads are given for indication only. Consumption values in DE constant speed are valid for D2/E2 IMO cycles. If Wärtsilä NOR is installed SFOC consumption values may vary. Please contact Wärtsilä to have further information. Fuel consumption values for EEDI calculation available upon request.
- Note 5 Pressure drop over lubricating oil cooler and over thermostatic valve are valid only if these components are mounted on engine.
- Note 6 At manual starting the consumption may be 2...3 times lower.

ME = Engine driving propeller, variable or constant speed

DE = Diesel-Electric engine driving generator at constant speed

Subject to revision without notice.

## 3.3 Wärtsilä 7L46F

Wärtsilä 7L46F		ME CPP Variable Speed	ME CPP Con- stant Speed	DE DE Constant Speed
<b>Cylinder output</b>	<b>kW</b>	<b>1200</b>	<b>1200</b>	<b>1200</b>
<b>Engine speed</b>	<b>rpm</b>	<b>600</b>	<b>600</b>	<b>600</b>
Engine output	kW	8400	8400	8400
Mean effective pressure	MPa	2.49	2.49	2.49
<b>Combustion air system (Note 1)</b>				
Flow at 100% load	kg/s	14.7	14.7	14.7
Temperature at turbocharger intake, max. (TE 600)	°C	45	45	45
Temperature after air cooler, nom. (TE 601)	°C	50	50	50
<b>Exhaust gas system (Note 2)</b>				
Flow at 100% load	kg/s	15.26	15.26	15.26
Flow at 85% load	kg/s	13.02	13.23	13.23
Flow at 75% load	kg/s	12.18	12.95	12.95
Flow at 50% load	kg/s	8.12	10.22	10.22
Temp. after turbo, 100% load (TE 517)	°C	364	364	364
Temp. after turbo, 85% load (TE 517)	°C	336	330	330
Temp. after turbo, 75% load (TE 517)	°C	338	330	330
Temp. after turbo, 50% load (TE 517)	°C	356	300	300
Backpressure, max.	kPa	3	3	3
Calculated pipe diameter for 35 m/s	mm	998	998	998
<b>Heat balance at 100% load (Note 3)</b>				
Jacket water, HT-circuit	kW	1064	1064	1064
Charge air, HT-circuit	kW	1799	1834	1834
Charge air, LT-circuit	kW	917	889	889
Lubricating oil, LT-circuit	kW	854	854	854
Radiation	kW	245	245	245
<b>Fuel system (Note 4)</b>				
Pressure before injection pumps (PT 101) at 85% load	kPa	900...950	900...950	900...950
Pressure before injection pumps (PT 101) at idle speed (check value)	kPa	1000...1050	1000...1050	1000...1050
Fuel oil flow to engine, range	m <sup>3</sup> /h	5.7...6.3	5.7...6.3	5.7...6.3
HFO viscosity before 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	4,5
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	22,5	22,5	22,5
SFOC at 100% load (HFO)	g/kWh	183.4	182.5	182.5
SFOC at 85% load (HFO)	g/kWh	174.9	174.9	176.8
SFOC at 75% load (HFO)	g/kWh	179.2	185.0	186.9
SFOC at 50% load (HFO)	g/kWh	182.2	191.2	197.0
SFOC at 100% load (LFO)	g/kWh	186.3	185.3	185.3
SFOC at 85% load (LFO)	g/kWh	176.8	176.8	178.7

Wärtsilä 7L46F		ME CPP Variable Speed	ME CPP Con- stant Speed	DE DE Constant Speed
<b>Cylinder output</b>	<b>kW</b>	<b>1200</b>	<b>1200</b>	<b>1200</b>
<b>Engine speed</b>	<b>rpm</b>	<b>600</b>	<b>600</b>	<b>600</b>
SFOC at 75% load (LFO)	g/kWh	181.1	186.9	188.8
SFOC at 50% load (LFO)	g/kWh	183.1	192.2	197.9
<b>Lubricating oil system</b>				
Pressure before bearings, nom. (PT 201)	kPa	500	500	500
Pressure after pump, max.	kPa	800	800	800
Suction ability main pump, including pipe loss, max.	kPa	40	40	40
Prelubricating pressure, nom. (PT 201)	kPa	80	80	80
Temperature before bearings, nom. (TE 201)	°C	56	56	56
Temperature after engine, approx.	°C	75	75	75
Pump capacity (main), engine driven	m <sup>3</sup> /h	207	191	191
Pump capacity (main), electrically driven	m <sup>3</sup> /h	207	179	179
Oil flow through engine	m <sup>3</sup> /h	150	150	150
Prelubricating pump capacity (50/60Hz)	m <sup>3</sup> /h	45	45	45
Oil tank volume in separate system, min	m <sup>3</sup>	15.0	15.0	15.0
Oil consumption at 100% load, approx.	g/kWh	0.7	0.7	0.7
Crankcase ventilation flow rate at full load	l/min	1600	1600	1600
Crankcase ventilation backpressure, max.	kPa	0.4	0.4	0.4
Oil volume in turning device	l	9.5	9.5	9.5
Oil volume in speed governor	l	1.7	1.7	1.7
<b>HT cooling water system</b>				
Pressure at engine, after pump, nom. (PT 401)	kPa	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 401)	kPa	530	530	530
Temperature before cylinders, approx. (TE 401)	°C	74	74	74
Temperature after charge air cooler, nom. (TE432)	°C	91...95	91...95	91...95
Capacity of engine driven pump, nom.	m <sup>3</sup> /h	150	150	150
Pressure drop over engine (including HT CAC and temperature control valve)	kPa	150	150	150
Pressure drop in external system, max.	kPa	100	100	100
Pressure from expansion tank	kPa	70...150	70...150	70...150
Water volume in engine	m <sup>3</sup>	1.3	1.3	1.3
<b>LT cooling water system (Note 5)</b>				
Pressure at engine, after pump, nom. (PT 471)	kPa	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 471)	kPa	530	530	530
Temperature before engine, max. (TE 471)	°C	38	38	38
Temperature before engine, min. (TE 471)	°C	25	25	25
Capacity of engine driven pump, nom.	m <sup>3</sup> /h	150	150	150
Pressure drop over charge air cooler	kPa	50	50	50
Pressure drop over built-on lube oil cooler, max	kPa	20	20	20
Pressure drop over built-on temp. control valve	kPa	30	30	30
Pressure drop in external system, max.	kPa	150	150	150
Pressure from expansion tank	kPa	70 ... 150	70 ... 150	70 ... 150
Water volume in engine	m <sup>3</sup>	0.4	0.4	0.4



Wärtsilä 7L46F		ME CPP Variable Speed	ME CPP Con- stant Speed	DE DE Constant Speed
Cylinder output	kW	1200	1200	1200
Engine speed	rpm	600	600	600
<b>Starting air system (Note 6)</b>				
Pressure, nom. (PT 301)	kPa	3000	3000	3000
Pressure at engine during start, min. (20°C) (PT 301)	kPa	1500	1500	1500
Pressure at engine during start, max. (20°C) (PT 301)	kPa	3000	3000	3000
Low pressure limit in air vessels	kPa	1800	1800	1800
Consumption per start at 20°C (successful start)	Nm <sup>3</sup>	7.0	7.0	7.0
Consumption per start at 20°C, (with slowturn)	Nm <sup>3</sup>	8.0	8.0	8.0

**Notes:**

- Note 1 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 5%.
- Note 2 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C). Flow tolerance 5% and temperature tolerance 20°C.
- Note 3 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Tolerance for cooling water heat 10%, tolerance for radiation heat 30%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers.
- Note 4 According to ISO 15550, lower calorific value 42700 kJ/kg, with engine driven pumps (two cooling water + one lubricating oil pumps). Tolerance 5%. The fuel consumption at 85 % load is guaranteed and the values at other loads are given for indication only. Consumption values in DE constant speed are valid for D2/E2 IMO cycles. If Wärtsilä NOR is installed SFOC consumption values may vary. Please contact Wärtsilä to have further information. Fuel consumption values for EEDI calculation available upon request.
- Note 5 Pressure drop over lubricating oil cooler and over thermostatic valve are valid only if these components are mounted on engine.
- Note 6 At manual starting the consumption may be 2...3 times lower.

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Subject to revision without notice.

## 3.4 Wärtsilä 8L46F

Wärtsilä 8L46F		ME CPP Variable Speed	ME CPP Con- stant Speed	DE Constant Speed
<b>Cylinder output</b>	<b>kW</b>	<b>1200</b>	<b>1200</b>	<b>1200</b>
<b>Engine speed</b>	<b>rpm</b>	<b>600</b>	<b>600</b>	<b>600</b>
Engine output	kW	9600	9600	9600
Mean effective pressure	MPa	2.49	2.49	2.49
<b>Combustion air system (Note 1)</b>				
Flow at 100% load	kg/s	16.8	16.8	16.8
Temperature at turbocharger intake, max. (TE 600)	°C	45	45	45
Temperature after air cooler, nom. (TE 601)	°C	50	50	50
<b>Exhaust gas system (Note 2)</b>				
Flow at 100% load	kg/s	17.44	17.44	17.44
Flow at 85% load	kg/s	14.88	15.12	15.12
Flow at 75% load	kg/s	13.92	14.8	14.8
Flow at 50% load	kg/s	9.28	11.68	11.68
Temp. after turbo, 100% load (TE 517)	°C	364	364	364
Temp. after turbo, 85% load (TE 517)	°C	336	330	330
Temp. after turbo, 75% load (TE 517)	°C	338	330	330
Temp. after turbo, 50% load (TE 517)	°C	356	300	300
Backpressure, max.	kPa	3	3	3
Calculated pipe diameter for 35 m/s	mm	1067	1067	1067
<b>Heat balance at 100% load (Note 3)</b>				
Jacket water, HT-circuit	kW	1216	1216	1216
Charge air, HT-circuit	kW	2056	2096	2096
Charge air, LT-circuit	kW	1048	1016	1016
Lubricating oil, LT-circuit	kW	976	976	976
Radiation	kW	280	280	280
<b>Fuel system (Note 4)</b>				
Pressure before injection pumps (PT101) at 85% load - HFO	kPa	900...950	900...950	900...950
Pressure before injection pumps (PT 101) at idle speed (check value)	kPa	1000...1050	1000...1050	1000...1050
Fuel oil flow to engine, range	m <sup>3</sup> /h	6.5...7.2	6.5...7.2	6.5...7.2
HFO viscosity before 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	4,5
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	22,5	22,5	22,5
SFOC at 100% load (HFO)	g/kWh	183.4	182.5	182.5
SFOC at 85% load (HFO)	g/kWh	174.9	174.9	176.8
SFOC at 75% load (HFO)	g/kWh	179.2	185.0	186.9
SFOC at 50% load (HFO)	g/kWh	182.2	191.2	197.0
SFOC at 100% load (LFO)	g/kWh	186.3	185.3	185.3
SFOC at 85% load (LFO)	g/kWh	176.8	176.8	178.7

Wärtsilä 8L46F		ME CPP Variable Speed	ME CPP Con- stant Speed	DE DE Constant Speed
<b>Cylinder output</b>	<b>kW</b>	<b>1200</b>	<b>1200</b>	<b>1200</b>
<b>Engine speed</b>	<b>rpm</b>	<b>600</b>	<b>600</b>	<b>600</b>
SFOC at 75% load (LFO)	g/kWh	181.1	186.9	188.8
SFOC at 50% load (LFO)	g/kWh	183.1	192.2	197.9
<b>Lubricating oil system</b>				
Pressure before bearings, nom. (PT 201)	kPa	500	500	500
Pressure after pump, max.	kPa	800	800	800
Suction ability main pump, including pipe loss, max.	kPa	40	40	40
Prelubricating pressure, nom. (PT 201)	kPa	80	80	80
Temperature before bearings, nom. (TE 201)	°C	56	56	56
Temperature after engine, approx.	°C	75	75	75
Pump capacity (main), engine driven	m³/h	228	207	207
Pump capacity (main), electrically driven	m³/h	228	198	198
Oil flow through engine	m³/h	170	170	170
Prelubricating pump capacity (50/60Hz)	m³/h	45	45	45
Oil tank volume in separate system, min	m³	17.0	17.0	17.0
Oil consumption at 100% load, approx.	g/kWh	0.7	0.7	0.7
Crankcase ventilation flow rate at full load	l/min	1700	1700	1700
Crankcase ventilation backpressure, max.	kPa	0.4	0.4	0.4
Oil volume in turning device	l	9.5	9.5	9.5
Oil volume in speed governor	l	1.7	1.7	1.7
<b>HT cooling water system</b>				
Pressure at engine, after pump, nom. (PT 401)	kPa	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 401)	kPa	530	530	530
Temperature before cylinders, approx. (TE 401)	°C	74	74	74
Temperature after charge air cooler, nom. (TE432)	°C	91...95	91...95	91...95
Capacity of engine driven pump, nom.	m³/h	150	150	150
Pressure drop over engine (including HT CAC and temperature control valve)	kPa	150	150	150
Pressure drop in external system, max.	kPa	100	100	100
Pressure from expansion tank	kPa	70...150	70...150	70...150
Water volume in engine	m³	1.4	1.4	1.4
<b>LT cooling water system (Note 5)</b>				
Pressure at engine, after pump, nom. (PT 471)	kPa	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 471)	kPa	530	530	530
Temperature before engine, max. (TE 471)	°C	38	38	38
Temperature before engine, min. (TE 471)	°C	25	25	25
Capacity of engine driven pump, nom.	m³/h	150	150	150
Pressure drop over charge air cooler	kPa	50	50	50
Pressure drop over built-on lube oil cooler, max	kPa	20	20	20
Pressure drop over built-on temp. control valve	kPa	30	30	30
Pressure drop in external system, max.	kPa	150	150	150
Pressure from expansion tank	kPa	70 ... 150	70 ... 150	70 ... 150
Water volume in engine	m³	0.4	0.4	0.4

Wärtsilä 8L46F		ME CPP Variable Speed	ME CPP Con- stant Speed	DE DE Constant Speed
Cylinder output	kW	1200	1200	1200
Engine speed	rpm	600	600	600
<b>Starting air system (Note 6)</b>				
Pressure, nom. (PT 301)	kPa	3000	3000	3000
Pressure at engine during start, min. (20°C) (PT 301)	kPa	1500	1500	1500
Pressure at engine during start, max. (20°C) (PT 301)	kPa	3000	3000	3000
Low pressure limit in air vessels	kPa	1800	1800	1800
Consumption per start at 20°C (successful start)	Nm <sup>3</sup>	8.0	8.0	8.0
Consumption per start at 20°C, (with slowturn)	Nm <sup>3</sup>	9.0	9.0	9.0

**Notes:**

- Note 1 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 5%.
- Note 2 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C). Flow tolerance 5% and temperature tolerance 20°C.
- Note 3 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Tolerance for cooling water heat 10%, tolerance for radiation heat 30%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers.
- Note 4 According to ISO 15550, lower calorific value 42700 kJ/kg, with engine driven pumps (two cooling water + one lubricating oil pumps). Tolerance 5%. The fuel consumption at 85 % load is guaranteed and the values at other loads are given for indication only. Consumption values in DE constant speed are valid for D2/E2 IMO cycles. If Wärtsilä NOR is installed SFOC consumption values may vary. Please contact Wärtsilä to have further information. Fuel consumption values for EEDI calculation available upon request.
- Note 5 Pressure drop over lubricating oil cooler and over thermostatic valve are valid only if these components are mounted on engine.
- Note 6 At manual starting the consumption may be 2...3 times lower.

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Subject to revision without notice.

## 3.5 Wärtsilä 9L46F

Wärtsilä 9L46F		ME CPP Variable Speed	ME CPP Con- stant Speed	DE DE Constant Speed
<b>Cylinder output</b>	<b>kW</b>	<b>1200</b>	<b>1200</b>	<b>1200</b>
<b>Engine speed</b>	<b>rpm</b>	<b>600</b>	<b>600</b>	<b>600</b>
Engine output	kW	10800	10800	10800
Mean effective pressure	MPa	2.49	2.49	2.49
<b>Combustion air system (Note 1)</b>				
Flow at 100% load	kg/s	18.9	18.9	18.9
Temperature at turbocharger intake, max. (TE 600)	°C	45	45	45
Temperature after air cooler, nom. (TE 601)	°C	50	50	50
<b>Exhaust gas system (Note 2)</b>				
Flow at 100% load	kg/s	19.62	19.62	19.62
Flow at 85% load	kg/s	16.74	17.01	17.01
Flow at 75% load	kg/s	15.66	16.65	16.65
Flow at 50% load	kg/s	10.44	13.14	13.14
Temp. after turbo, 100% load (TE 517)	°C	364	364	364
Temp. after turbo, 85% load (TE 517)	°C	336	330	330
Temp. after turbo, 75% load (TE 517)	°C	338	330	330
Temp. after turbo, 50% load (TE 517)	°C	356	300	300
Backpressure, max.	kPa	3	3	3
Calculated pipe diameter for 35 m/s	mm	1132	1132	1132
<b>Heat balance at 100% load (Note 3)</b>				
Jacket water, HT-circuit	kW	1368	1368	1368
Charge air, HT-circuit	kW	2313	2358	2358
Charge air, LT-circuit	kW	1179	1143	1143
Lubricating oil, LT-circuit	kW	1098	1098	1098
Radiation	kW	315	315	315
<b>Fuel system (Note 4)</b>				
Pressure before injection pumps (PT101) at 85% load -HFO	kPa	900...950	900...950	900...950
Pressure before injection pumps (PT 101) at idle speed (check value)	kPa	1000...1050	1000...1050	1000...1050
Fuel oil flow to engine, range	m <sup>3</sup> /h	7.3...8.1	7.3...8.1	7.3...8.1
HFO viscosity before 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	4,5
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	22,5	22,5	22,5
SFOC at 100% load (HFO)	g/kWh	183.4	182.5	182.5
SFOC at 85% load (HFO)	g/kWh	174.9	174.9	176.8
SFOC at 75% load (HFO)	g/kWh	179.2	185.0	186.9
SFOC at 50% load (HFO)	g/kWh	182.2	191.2	197.0
SFOC at 100% load (LFO)	g/kWh	186.3	185.3	185.3
SFOC at 85% load (LFO)	g/kWh	176.8	176.8	178.7

Wärtsilä 9L46F		ME CPP Variable Speed	ME CPP Const- ant Speed	DE DE Constant Speed
<b>Cylinder output</b>	<b>kW</b>	<b>1200</b>	<b>1200</b>	<b>1200</b>
<b>Engine speed</b>	<b>rpm</b>	<b>600</b>	<b>600</b>	<b>600</b>
SFOC at 75% load (LFO)	g/kWh	181.1	186.9	188.8
SFOC at 50% load (LFO)	g/kWh	183.1	192.2	197.9
<b>Lubricating oil system</b>				
Pressure before bearings, nom. (PT 201)	kPa	500	500	500
Pressure after pump, max.	kPa	800	800	800
Suction ability main pump, including pipe loss, max.	kPa	40	40	40
Prelubricating pressure, nom. (PT 201)	kPa	80	80	80
Temperature before bearings, nom. (TE 201)	°C	56	56	56
Temperature after engine, approx.	°C	75	75	75
Pump capacity (main), engine driven	m <sup>3</sup> /h	253	228	228
Pump capacity (main), electrically driven	m <sup>3</sup> /h	253	218	218
Oil flow through engine	m <sup>3</sup> /h	190	190	190
Prelubricating pump capacity (50/60 Hz)	m <sup>3</sup> /h	50	50	50
Oil tank volume in separate system, min	m <sup>3</sup>	19.0	19.0	19.0
Oil consumption at 100% load, approx.	g/kWh	0.7	0.7	0.7
Crankcase ventilation flow rate at full load	l/min	1800	1800	1800
Crankcase ventilation backpressure, max.	kPa	0.4	0.4	0.4
Oil volume in turning device	l	70.0	70.0	70.0
Oil volume in speed governor	l	1.7	1.7	1.7
<b>HT cooling water system</b>				
Pressure at engine, after pump, nom. (PT 401)	kPa	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 401)	kPa	530	530	530
Temperature before cylinders, approx. (TE 401)	°C	74	74	74
Temperature after charge air cooler, nom. (TE432)	°C	91...95	91...95	91...95
Capacity of engine driven pump, nom.	m <sup>3</sup> /h	180	180	180
Pressure drop over engine (including HT CAC and temperature control valve)	kPa	150	150	150
Pressure drop in external system, max.	kPa	100	100	100
Pressure from expansion tank	kPa	70...150	70...150	70...150
Water volume in engine	m <sup>3</sup>	1.5	1.5	1.5
<b>LT cooling water system (Note 5)</b>				
Pressure at engine, after pump, nom. (PT 471)	kPa	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 471)	kPa	530	530	530
Temperature before engine, max. (TE 471)	°C	38	38	38
Temperature before engine, min. (TE 471)	°C	25	25	25
Capacity of engine driven pump, nom.	m <sup>3</sup> /h	180	180	180
Pressure drop over charge air cooler	kPa	50	50	50
Pressure drop over built-on lube oil cooler, max	kPa	20	20	20
Pressure drop over built-on temp. control valve	kPa	30	30	30
Pressure drop in external system, max.	kPa	150	150	150
Pressure from expansion tank	kPa	70 ... 150	70 ... 150	70 ... 150
Water volume in engine	m <sup>3</sup>	0.5	0.5	0.5

Wärtsilä 9L46F		ME CPP Variable Speed	ME CPP Con- stant Speed	DE DE Constant Speed
Cylinder output	kW	1200	1200	1200
Engine speed	rpm	600	600	600
<b>Starting air system (Note 6)</b>				
Pressure, nom. (PT 301)	kPa	3000	3000	3000
Pressure at engine during start, min. (20°C) (PT 301)	kPa	1500	1500	1500
Pressure at engine during start, max. (20°C) (PT 301)	kPa	3000	3000	3000
Low pressure limit in air vessels	kPa	1800	1800	1800
Consumption per start at 20°C (successful start)	Nm <sup>3</sup>	9.0	9.0	9.0
Consumption per start at 20°C, (with slowturn)	Nm <sup>3</sup>	10.0	10.0	10.0

**Notes:**

- Note 1 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 5%.
- Note 2 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C). Flow tolerance 5% and temperature tolerance 20°C.
- Note 3 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Tolerance for cooling water heat 10%, tolerance for radiation heat 30%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers.
- Note 4 According to ISO 15550, lower calorific value 42700 kJ/kg, with engine driven pumps (two cooling water + one lubricating oil pumps). Tolerance 5%. The fuel consumption at 85 % load is guaranteed and the values at other loads are given for indication only. Consumption values in DE constant speed are valid for D2/E2 IMO cycles. If Wärtsilä NOR is installed SFOC consumption values may vary. Please contact Wärtsilä to have further information. Fuel consumption values for EEDI calculation available upon request.
- Note 5 Pressure drop over lubricating oil cooler and over thermostatic valve are valid only if these components are mounted on engine.
- Note 6 At manual starting the consumption may be 2...3 times lower.

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DE = Diesel-Electric engine driving generator at constant speed

Subject to revision without notice.

## 3.6 Wärtsilä 12V46F

Wärtsilä 12V46F		ME CPP Variable Speed	ME CPP Con- stant Speed	DE Constant Speed
<b>Cylinder output</b>	<b>kW</b>	<b>1200</b>	<b>1200</b>	<b>1200</b>
<b>Engine speed</b>	<b>rpm</b>	<b>600</b>	<b>600</b>	<b>600</b>
Engine output	kW	14400	14400	14400
Mean effective pressure	MPa	2.49	2.49	2.49
<b>Combustion air system (Note 1)</b>				
Flow at 100% load	kg/s	25.1	25.1	25.1
Temperature at turbocharger intake, max. (TE 600)	°C	45	45	45
Temperature after air cooler, nom. (TE 601)	°C	50	50	50
<b>Exhaust gas system (Note 2)</b>				
Flow at 100% load	kg/s	26.16	25.92	25.92
Flow at 85% load	kg/s	22.2	22.44	22.44
Flow at 75% load	kg/s	20.64	21.84	21.84
Flow at 50% load	kg/s	13.8	17.4	17.4
Temp. after turbo, 100% load (TE 517)	°C	364	364	364
Temp. after turbo, 85% load (TE 517)	°C	336	330	330
Temp. after turbo, 75% load (TE 517)	°C	338	330	330
Temp. after turbo, 50% load (TE 517)	°C	356	297	297
Backpressure, max.	kPa	3	3	3
Calculated pipe diameter for 35 m/s	mm	1307	1301	1301
<b>Heat balance at 100% load (Note 3)</b>				
Jacket water, HT-circuit	kW	1800	1824	1824
Charge air, HT-circuit	kW	3084	3108	3108
Charge air, LT-circuit	kW	1572	1512	1512
Lubricating oil, LT-circuit	kW	1464	1464	1464
Radiation	kW	420	420	420
<b>Fuel system (Note 4)</b>				
Pressure before injection pumps (PT101) at 85% load - HFO	kPa	900...950	900...950	900...950
Pressure before injection pumps (PT 101) at idle speed (check value)	kPa	1000...1050	1000...1050	1000...1050
Fuel oil flow to engine, range	m <sup>3</sup> /h	9.8...10.8	9.8...10.8	9.8...10.8
HFO viscosity before 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	4,5
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	22,5	22,5	22,5
SFOC at 100% load (HFO)	g/kWh	180.6	179.6	179.6
SFOC at 85% load (HFO)	g/kWh	173.0	173.0	174.9
SFOC at 75% load (HFO)	g/kWh	176.4	182.1	184.0
SFOC at 50% load (HFO)	g/kWh	179.3	188.4	194.1
SFOC at 100% load (LFO)	g/kWh	183.4	182.5	182.5
SFOC at 85% load (LFO)	g/kWh	174.9	174.9	176.8



Wärtsilä 12V46F		ME CPP Variable Speed	ME CPP Con- stant Speed	DE DE Constant Speed
<b>Cylinder output</b>	<b>kW</b>	<b>1200</b>	<b>1200</b>	<b>1200</b>
<b>Engine speed</b>	<b>rpm</b>	<b>600</b>	<b>600</b>	<b>600</b>
SFOC at 75% load (LFO)	g/kWh	178.3	184.0	185.9
SFOC at 50% load (LFO)	g/kWh	180.3	189.3	195.0
<b>Lubricating oil system</b>				
Pressure before bearings, nom. (PT 201)	kPa	500	500	500
Pressure after pump, max.	kPa	800	800	800
Suction ability main pump, including pipe loss, max.	kPa	40	40	40
Prelubricating pressure, nom. (PT 201)	kPa	80	80	80
Temperature before bearings, nom. (TE 201)	°C	56	56	56
Temperature after engine, approx.	°C	75	75	75
Pump capacity (main), engine driven	m³/h	306	260	260
Pump capacity (main), electrically driven	m³/h	259	210	210
Oil flow through engine	m³/h	200	200	200
Prelubricating pump capacity (50/60Hz)	m³/h	70	70	70
Oil tank volume in separate system, min	m³	22.5	22.5	22.5
Oil consumption at 100% load, approx.	g/kWh	0.7	0.7	0.7
Crankcase ventilation flow rate at full load	l/min	3540	3540	3540
Crankcase ventilation backpressure, max.	kPa	0.4	0.4	0.4
Oil volume in turning device	l	70.0	70.0	70.0
Oil volume in speed governor	l	7.1	7.1	7.1
<b>HT cooling water system</b>				
Pressure at engine, after pump, nom. (PT 401)	kPa	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 401)	kPa	530	530	530
Temperature before cylinders, approx. (TE 401)	°C	74	74	74
Temperature after charge air cooler, nom. (TE432)	°C	91...95	91...95	91...95
Capacity of engine driven pump, nom.	m³/h	210	210	210
Pressure drop over engine (including HT CAC and temperature control valve)	kPa	150	150	150
Pressure drop in external system, max.	kPa	100	100	100
Pressure from expansion tank	kPa	70...150	70...150	70...150
Water volume in engine	m³	2.0	2.0	2.0
<b>LT cooling water system (Note 5)</b>				
Pressure at engine, after pump, nom. (PT 471)	kPa	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 471)	kPa	530	530	530
Temperature before engine, max. (TE 471)	°C	38	38	38
Temperature before engine, min. (TE 471)	°C	25	25	25
Capacity of engine driven pump, nom.	m³/h	210	210	210
Pressure drop over charge air cooler	kPa	50	50	50
Pressure drop over built-on lube oil cooler, max	kPa	20	20	20
Pressure drop over built-on temp. control valve	kPa	30	30	30
Pressure drop in external system, max.	kPa	150	150	150
Pressure from expansion tank	kPa	70 ... 150	70 ... 150	70 ... 150
Water volume in engine	m³	0.6	0.6	0.6

Wärtsilä 12V46F		ME CPP Variable Speed	ME CPP Con- stant Speed	DE DE Constant Speed
Cylinder output	kW	1200	1200	1200
Engine speed	rpm	600	600	600
<b>Starting air system (Note 6)</b>				
Pressure, nom. (PT 301)	kPa	3000	3000	3000
Pressure at engine during start, min. (20°C) (PT 301)	kPa	1500	1500	1500
Pressure at engine during start, max. (20°C) (PT 301)	kPa	3000	3000	3000
Low pressure limit in air vessels	kPa	1800	1800	1800
Consumption per start at 20°C (successful start)	Nm <sup>3</sup>	12.0	12.0	12.0
Consumption per start at 20°C, (with slowturn)	Nm <sup>3</sup>	15.0	15.0	15.0

**Notes:**

- Note 1 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 5%.
- Note 2 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C). Flow tolerance 5% and temperature tolerance 20°C.
- Note 3 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Tolerance for cooling water heat 10%, tolerance for radiation heat 30%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers.
- Note 4 According to ISO 15550, lower calorific value 42700 kJ/kg, with engine driven pumps (two cooling water + one lubricating oil pumps). Tolerance 5%. The fuel consumption at 85 % load is guaranteed and the values at other loads are given for indication only. Consumption values in DE constant speed are valid for D2/E2 IMO cycles. If Wärtsilä NOR is installed SFOC consumption values may vary. Please contact Wärtsilä to have further information. Fuel consumption values for EEDI calculation available upon request.
- Note 5 Pressure drop over lubricating oil cooler and over thermostatic valve are valid only if these components are mounted on engine.
- Note 6 At manual starting the consumption may be 2...3 times lower.

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Subject to revision without notice.

## 3.7

## Wärtsilä 14V46F

Wärtsilä 14V46F		ME CPP Variable Speed	ME CPP Con- stant Speed	DE DE Constant Speed
<b>Cylinder output</b>	<b>kW</b>	<b>1200</b>	<b>1200</b>	<b>1200</b>
<b>Engine speed</b>	<b>rpm</b>	<b>600</b>	<b>600</b>	<b>600</b>
Engine output	kW	16800	16800	16800
Mean effective pressure	MPa	2.49	2.49	2.49
<b>Combustion air system (Note 1)</b>				
Flow at 100% load	kg/s	29.3	29.3	29.3
Temperature at turbocharger intake, max. (TE 600)	°C	45	45	45
Temperature after air cooler, nom. (TE 601)	°C	50	50	50
<b>Exhaust gas system (Note 2)</b>				
Flow at 100% load	kg/s	30.52	30.24	30.24
Flow at 85% load	kg/s	25.9	26.18	26.18
Flow at 75% load	kg/s	24.08	25.48	25.48
Flow at 50% load	kg/s	16.1	20.3	20.3
Temp. after turbo, 100% load (TE 517)	°C	364	364	364
Temp. after turbo, 85% load (TE 517)	°C	336	330	330
Temp. after turbo, 75% load (TE 517)	°C	338	330	330
Temp. after turbo, 50% load (TE 517)	°C	356	297	297
Backpressure, max.	kPa	3	3	3
Calculated pipe diameter for 35 m/s	mm	1412	1405	1405
<b>Heat balance at 100% load (Note 3)</b>				
Jacket water, HT-circuit	kW	2100	2128	2128
Charge air, HT-circuit	kW	3598	3626	3626
Charge air, LT-circuit	kW	1834	1764	1764
Lubricating oil, LT-circuit	kW	1708	1708	1708
Radiation	kW	490	490	490
<b>Fuel system (Note 4)</b>				
Pressure before injection pumps (PT101) at 85% load - HFO	kPa	900...950	900...950	900...950
Pressure before injection pumps (PT 101) at idle speed (check value)	kPa	1000...1050	1000...1050	1000...1050
Fuel oil flow to engine, range	m <sup>3</sup> /h	11.4...12.6	11.4...12.6	11.4...12.6
HFO viscosity before 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	4,5
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	22,5	22,5	22,5
SFOC at 100% load (HFO)	g/kWh	180.6	179.6	179.6
SFOC at 85% load (HFO)	g/kWh	173.0	173.0	174.9
SFOC at 75% load (HFO)	g/kWh	176.4	182.1	184.0
SFOC at 50% load (HFO)	g/kWh	179.3	188.4	194.1
SFOC at 100% load (LFO)	g/kWh	183.4	182.5	182.5
SFOC at 85% load (LFO)	g/kWh	174.9	174.9	176.8

Wärtsilä 14V46F		ME CPP Variable Speed	ME CPP Con- stant Speed	DE DE Constant Speed
<b>Cylinder output</b>	<b>kW</b>	<b>1200</b>	<b>1200</b>	<b>1200</b>
<b>Engine speed</b>	<b>rpm</b>	<b>600</b>	<b>600</b>	<b>600</b>
SFOC at 75% load (LFO)	g/kWh	178.3	184.0	185.9
SFOC at 50% load (LFO)	g/kWh	180.3	189.3	195.0
<b>Lubricating oil system</b>				
Pressure before bearings, nom. (PT 201)	kPa	500	500	500
Pressure after pump, max.	kPa	800	800	800
Suction ability main pump, including pipe loss, max.	kPa	40	40	40
Prelubricating pressure, nom. (PT 201)	kPa	80	80	80
Temperature before bearings, nom. (TE 201)	°C	56	56	56
Temperature after engine, approx.	°C	75	75	75
Pump capacity (main), engine driven	m <sup>3</sup> /h	335	306	306
Pump capacity (main), electrically driven	m <sup>3</sup> /h	297	250	250
Oil flow through engine	m <sup>3</sup> /h	230	230	230
Prelubricating pump capacity (50/60Hz)	m <sup>3</sup> /h	80	80	80
Oil tank volume in separate system, min	m <sup>3</sup>	26.3	26.3	26.3
Oil consumption at 100% load, approx.	g/kWh	0.7	0.7	0.7
Crankcase ventilation flow rate at full load	l/min	4180	4180	4180
Crankcase ventilation backpressure, max.	kPa	0.4	0.4	0.4
Oil volume in turning device	l	70.0	70.0	70.0
Oil volume in speed governor	l	7.1	7.1	7.1
<b>HT cooling water system</b>				
Pressure at engine, after pump, nom. (PT 401)	kPa	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 401)	kPa	530	530	530
Temperature before cylinders, approx. (TE 401)	°C	74	74	74
Temperature after charge air cooler, nom. (TE432)	°C	91...95	91...95	91...95
Capacity of engine driven pump, nom.	m <sup>3</sup> /h	240	240	240
Pressure drop over engine (including HT CAC and temperature control valve)	kPa	150	150	150
Pressure drop in external system, max.	kPa	100	100	100
Pressure from expansion tank	kPa	70...150	70...150	70...150
Water volume in engine	m <sup>3</sup>	2.3	2.3	2.3
<b>LT cooling water system (Note 5)</b>				
Pressure at engine, after pump, nom. (PT 471)	kPa	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 471)	kPa	530	530	530
Temperature before engine, max. (TE 471)	°C	38	38	38
Temperature before engine, min. (TE 471)	°C	25	25	25
Capacity of engine driven pump, nom.	m <sup>3</sup> /h	240	240	240
Pressure drop over charge air cooler	kPa	50	50	50
Pressure drop over built-on lube oil cooler, max	kPa	20	20	20
Pressure drop over built-on temp. control valve	kPa	30	30	30
Pressure drop in external system, max.	kPa	150	150	150
Pressure from expansion tank	kPa	70 ... 150	70 ... 150	70 ... 150
Water volume in engine	m <sup>3</sup>	0.7	0.7	0.7

Wärtsilä 14V46F		ME CPP Variable Speed	ME CPP Con- stant Speed	DE DE Constant Speed
Cylinder output	kW	1200	1200	1200
Engine speed	rpm	600	600	600
<b>Starting air system (Note 6)</b>				
Pressure, nom. (PT 301)	kPa	3000	3000	3000
Pressure at engine during start, min. (20°C) (PT 301)	kPa	1500	1500	1500
Pressure at engine during start, max. (20°C) (PT 301)	kPa	3000	3000	3000
Low pressure limit in air vessels	kPa	1800	1800	1800
Consumption per start at 20°C (successful start)	Nm <sup>3</sup>	14.0	14.0	14.0
Consumption per start at 20°C, (with slowturn)	Nm <sup>3</sup>	17.0	17.0	17.0

**Notes:**

- Note 1 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 5%.
- Note 2 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C). Flow tolerance 5% and temperature tolerance 20°C.
- Note 3 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Tolerance for cooling water heat 10%, tolerance for radiation heat 30%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers.
- Note 4 According to ISO 15550, lower calorific value 42700 kJ/kg, with engine driven pumps (two cooling water + one lubricating oil pumps). Tolerance 5%. The fuel consumption at 85 % load is guaranteed and the values at other loads are given for indication only. Consumption values in DE constant speed are valid for D2/E2 IMO cycles. If Wärtsilä NOR is installed SFOC consumption values may vary. Please contact Wärtsilä to have further information. Fuel consumption values for EEDI calculation available upon request.
- Note 5 Pressure drop over lubricating oil cooler and over thermostatic valve are valid only if these components are mounted on engine.
- Note 6 At manual starting the consumption may be 2...3 times lower.

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## 3.8 Wärtsilä 16V46F

Wärtsilä 16V46F		ME CPP Variable Speed	ME CPP Con- stant Speed	DE Constant Speed
<b>Cylinder output</b>	<b>kW</b>	<b>1200</b>	<b>1200</b>	<b>1200</b>
<b>Engine speed</b>	<b>rpm</b>	<b>600</b>	<b>600</b>	<b>600</b>
Engine output	kW	19200	19200	19200
Mean effective pressure	MPa	2.49	2.49	2.49
<b>Combustion air system (Note 1)</b>				
Flow at 100% load	kg/s	33.5	33.5	33.5
Temperature at turbocharger intake, max. (TE 600)	°C	45	45	45
Temperature after air cooler, nom. (TE 601)	°C	50	50	50
<b>Exhaust gas system (Note 2)</b>				
Flow at 100% load	kg/s	34.88	34.56	34.56
Flow at 85% load	kg/s	29.6	29.92	29.92
Flow at 75% load	kg/s	27.52	29.12	29.12
Flow at 50% load	kg/s	18.4	23.2	23.2
Temp. after turbo, 100% load (TE 517)	°C	364	364	364
Temp. after turbo, 85% load (TE 517)	°C	336	330	330
Temp. after turbo, 75% load (TE 517)	°C	338	330	330
Temp. after turbo, 50% load (TE 517)	°C	356	297	297
Backpressure, max.	kPa	3	3	3
Calculated pipe diameter for 35 m/s	mm	1509	1502	1502
<b>Heat balance at 100% load (Note 3)</b>				
Jacket water, HT-circuit	kW	2400	2432	2432
Charge air, HT-circuit	kW	4112	4144	4144
Charge air, LT-circuit	kW	2096	2016	2016
Lubricating oil, LT-circuit	kW	1952	1952	1952
Radiation	kW	560	560	560
<b>Fuel system (Note 4)</b>				
Pressure before injection pumps (PT101) at 85% load -HFO	kPa	900...950	900...950	900...950
Pressure before injection pumps (PT 101) at idle speed (check value)	kPa	1000...1050	1000...1050	1000...1050
Fuel oil flow to engine, range	m³/h	13.0...14.4	13.0...14.4	13.0...14.4
HFO viscosity before 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	4,5
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	22,5	22,5	22,5
SFOC at 100% load (HFO)	g/kWh	180.6	179.6	179.6
SFOC at 85% load (HFO)	g/kWh	173.0	173.0	174.9
SFOC at 75% load (HFO)	g/kWh	176.4	182.1	184.0
SFOC at 50% load (HFO)	g/kWh	179.3	188.4	194.1
SFOC at 100% load (LFO)	g/kWh	183.4	182.5	182.5
SFOC at 85% load (LFO)	g/kWh	174.9	174.9	176.8

Wärtsilä 16V46F		ME CPP Variable Speed	ME CPP Con- stant Speed	DE DE Constant Speed
<b>Cylinder output</b>	<b>kW</b>	<b>1200</b>	<b>1200</b>	<b>1200</b>
<b>Engine speed</b>	<b>rpm</b>	<b>600</b>	<b>600</b>	<b>600</b>
SFOC at 75% load (LFO)	g/kWh	178.3	184.0	185.9
SFOC at 50% load (LFO)	g/kWh	180.3	189.3	195.0
<b>Lubricating oil system</b>				
Pressure before bearings, nom. (PT 201)	kPa	500	500	500
Pressure after pump, max.	kPa	800	800	800
Suction ability main pump, including pipe loss, max.	kPa	40	40	40
Prelubricating pressure, nom. (PT 201)	kPa	80	80	80
Temperature before bearings, nom. (TE 201)	°C	56	56	56
Temperature after engine, approx.	°C	75	75	75
Pump capacity (main), engine driven	m <sup>3</sup> /h	335	335	335
Pump capacity (main), electrically driven	m <sup>3</sup> /h	331	260	260
Oil flow through engine	m <sup>3</sup> /h	250	250	250
Prelubricating pump capacity (50/60Hz)	m <sup>3</sup> /h	90	90	90
Oil tank volume in separate system, min	m <sup>3</sup>	30.0	30.0	30.0
Oil consumption at 100% load, approx.	g/kWh	0.7	0.7	0.7
Crankcase ventilation flow rate at full load	l/min	4520	4520	4520
Crankcase ventilation backpressure, max.	kPa	0.4	0.4	0.4
Oil volume in turning device	l	70.0	70.0	70.0
Oil volume in speed governor	l	7.1	7.1	7.1
<b>HT cooling water system</b>				
Pressure at engine, after pump, nom. (PT 401)	kPa	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 401)	kPa	530	530	530
Temperature before cylinders, approx. (TE 401)	°C	74	74	74
Temperature after charge air cooler, nom. (TE 432)	°C	91...95	91...95	91...95
Capacity of engine driven pump, nom.	m <sup>3</sup> /h	280	280	280
Pressure drop over engine (including HT CAC and temperature control valve)	kPa	150	150	150
Pressure drop in external system, max.	kPa	100	100	100
Pressure from expansion tank	kPa	70...150	70...150	70...150
Water volume in engine	m <sup>3</sup>	2.6	2.6	2.6
<b>LT cooling water system (Note 5)</b>				
Pressure at engine, after pump, nom. (PT 471)	kPa	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 471)	kPa	530	530	530
Temperature before engine, max. (TE 471)	°C	38	38	38
Temperature before engine, min. (TE 471)	°C	25	25	25
Capacity of engine driven pump, nom.	m <sup>3</sup> /h	280	280	280
Pressure drop over charge air cooler	kPa	50	50	50
Pressure drop over built-on lube oil cooler, max	kPa	20	20	20
Pressure drop over built-on temp. control valve	kPa	30	30	30
Pressure drop in external system, max.	kPa	150	150	150
Pressure from expansion tank	kPa	70 ... 150	70 ... 150	70 ... 150
Water volume in engine	m <sup>3</sup>	0.8	0.8	0.8

Wärtsilä 16V46F		ME CPP Variable Speed	ME CPP Con- stant Speed	DE DE Constant Speed
Cylinder output	kW	1200	1200	1200
Engine speed	rpm	600	600	600
<b>Starting air system (Note 6)</b>				
Pressure, nom. (PT 301)	kPa	3000	3000	3000
Pressure at engine during start, min. (20°C) (PT 301)	kPa	1500	1500	1500
Pressure at engine during start, max. (20°C) (PT 301)	kPa	3000	3000	3000
Low pressure limit in air vessel	kPa	1800	1800	1800
Consumption per start at 20°C (successful start)	Nm <sup>3</sup>	16.0	16.0	16.0
Consumption per start at 20°C, (with slowturn)	Nm <sup>3</sup>	19.0	19.0	19.0

**Notes:**

- Note 1 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 5%.
- Note 2 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C). Flow tolerance 5% and temperature tolerance 20°C.
- Note 3 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Tolerance for cooling water heat 10%, tolerance for radiation heat 30%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers.
- Note 4 According to ISO 15550, lower calorific value 42700 kJ/kg, with engine driven pumps (two cooling water + one lubricating oil pumps). Tolerance 5%. The fuel consumption at 85 % load is guaranteed and the values at other loads are given for indication only. Consumption values in DE constant speed are valid for D2/E2 IMO cycles. If Wärtsilä NOR is installed SFOC consumption values may vary. Please contact Wärtsilä to have further information. Fuel consumption values for EEDI calculation available upon request.
- Note 5 Pressure drop over lubricating oil cooler and over thermostatic valve are valid only if these components are mounted on engine.
- Note 6 At manual starting the consumption may be 2...3 times lower.

ME = Engine driving propeller, variable or constant speed

DE = Diesel-Electric engine driving generator at constant speed

Subject to revision without notice.



## 4. Description of the Engine

### 4.1 Definitions

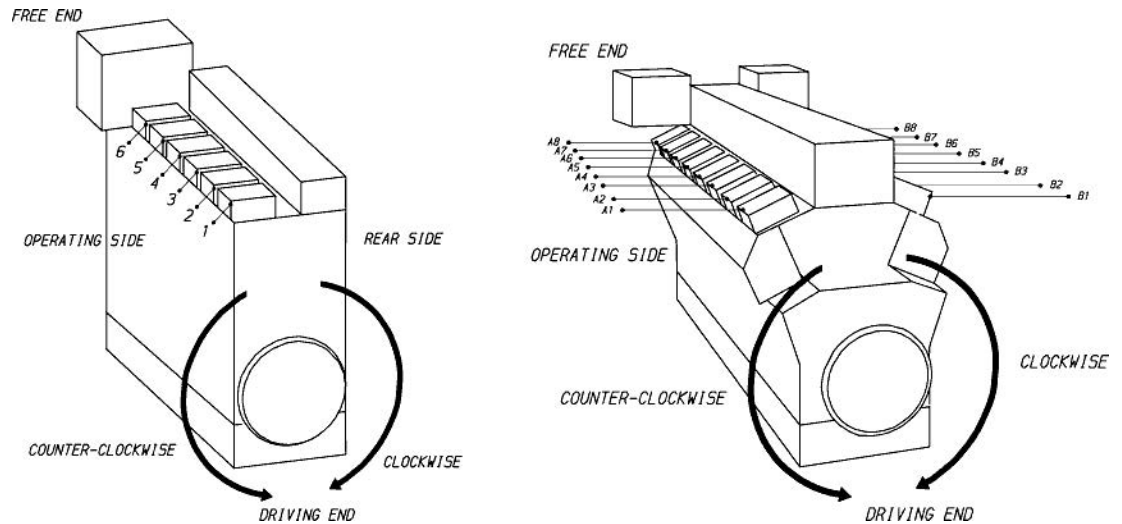


Fig 4-1 In-line engine and V-engine definitions (1V93C0029 / 1V93C0028)

## 4.2 Main components and systems

Main dimensions and weights are shown in section 1.4 Principal dimensions and weights.

### 4.2.1 Engine block

The engine block is made of nodular cast iron and it is cast in one piece.

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 supported by main bearing caps made of nodular cast iron. The bearing caps are guided sideways by the engine block, both at the top and at the bottom. Hydraulically tensioned bearing cap screws and horizontal side screws secure the main bearing caps.

At the driving end there is a combined thrust bearing and radial bearing for the camshaft drive and flywheel. The bearing housing of the intermediate gear is integrated in the engine block.

The cooling water is distributed around the cylinder liners with water distribution rings at the lower end of the cylinder collar. There is no wet space in the engine block around the cylinder liner, which eliminates the risk of water leakage into the crankcase.

### 4.2.2 Crankshaft

Low bearing loads, robust design and a crank gear capable of high cylinder pressures were set out to be the main design criteria for the crankshaft. The moderate bore to stroke ratio is a key element to achieve high rigidity.

The crankshaft line is built up from three-pieces: crankshaft, gear and end piece. The crankshaft itself is forged in one piece. Each crankthrow is individually fully balanced for safe bearing function. Clean steel technology minimizes the amount of slag forming elements and guarantees superior material properties.

All crankshafts can be equipped with a torsional vibration damper at the free end of the engine, if required by the application. Full output is available also from the free end of the engine through a power-take-off (PTO).

The main bearing and crankpin bearing temperatures are continuously monitored.

### 4.2.3 Connecting rod

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

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

Oil is led to the gudgeon pin bearing and piston through a bore in the connecting rod.

### 4.2.4 Main bearings and big end bearings

The main bearings and the big end bearings have steel backs and thin layers for good resistance against fatigue and corrosion. Both tri-metal and bi-metal bearings are used.

### 4.2.5 Cylinder liner

The centrifugally cast cylinder liner has a high and rigid collar preventing deformations due to the cylinder pressure and pretension forces. A distortion-free liner bore in combination with wear resistant materials and good lubrication provide optimum running conditions for the piston and piston rings. The liner material is a special grey cast iron alloy developed for excellent wear resistance and high strength.

Accurate temperature control is achieved with precisely positioned longitudinal cooling water bores.

An anti-polishing ring removes deposits from piston top land, which eliminates increased lubricating oil consumption due to bore polishing and liner wear.

### 4.2.6 Piston

The piston is of two-piece design with nodular cast iron skirt and steel crown. Wärtsilä patented skirt lubrication minimizes frictional losses and ensure appropriate lubrication of both the piston skirt and piston rings under all operating conditions.

### 4.2.7 Piston rings

The piston ring set consists of two compression rings and one spring-loaded conformable oil scraper ring. All piston rings have a wear resistant coating. Two compression rings and one oil scraper ring in combination with pressure lubricated piston skirt give low friction and high seizure resistance. Both compression ring grooves are hardened for good wear resistance.

### 4.2.8 Cylinder head

A rigid box/cone-like design ensures even circumferential contact pressure and permits high cylinder pressure. Only four hydraulically tightened cylinder head studs simplify the maintenance and leaves more room for optimisation of the inlet and outlet port flow characteristics.

The exhaust valve seats are water cooled. Closed seat rings without water pocket between the seat and the cylinder head ensure long lifetime for valves and seats. Both inlet and exhaust valves are equipped with valve rotators.

## 4.2.9 Camshaft and valve mechanism

The camshaft is built of forged pieces with integrated cams, one section per cylinder. The camshaft sections are connected through separate bearing journals, which makes it possible to remove single camshaft sections sideways. The bearing housings are integrated in the engine block casting and thus completely closed.

## 4.2.10 Camshaft drive

The camshaft is driven by the crankshaft through a gear train. The gear wheel on the crankshaft is clamped between the crankshaft and the end piece with expansion bolts.

## 4.2.11 Fuel injection equipment

The low pressure fuel lines consist of drilled channels in cast parts that are firmly clamped to the engine block. The entire fuel system is enclosed in a fully covered compartment for maximum safety. All leakages from injection valves, pumps and pipes are collected in a closed system. The pumps are completely sealed off from the camshaft compartment and provided with drain for leakage oil.

The injection nozzles are cooled by lubricating oil.

Wärtsilä 46F engines are equipped with twin plunger pumps that enable control of the injection timing. In addition to the timing control, the twin plunger solution also combines high mechanical strength with cost efficient design.

One plunger controls the start of injection, i.e. the timing, while the other plunger controls when the injection ends, thus the quantity of injected fuel. Timing is controlled according to engine revolution speed and load level (also other options), while the quantity is controlled as normally by the speed control.

## 4.2.12 Lubricating oil system

The engine is equipped with a dry oil sump.

In the standard configuration the engine is also equipped with an engine driven lubricating oil pump, located in free end, and a lubricating oil module located in the opposite end to the turbocharger. The lubricating oil module consists of an oil cooler with temperature control valves and an automatic filter. A centrifugal filter on the engine serves as an indication filter.

The pre-lubricating oil pump is to be installed in the external system.

## 4.2.13 Cooling water system

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

In the most complete configuration the HT and LT cooling water pumps are both engine driven, and the electrically actuated temperature control valves are built on the engine. When desired, it is however possible to configure the engine without engine driven LT-pump, or even without both cooling water pumps.

The temperature control valves are equipped with a hand wheel for emergency operation.

## 4.2.14 Turbocharging and charge air cooling

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

exhaust side. The wastegate arrangement permits a part of the exhaust gas to bypass the turbine in the turbocharger at high engine load.

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

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

The engines have a transversely installed turbocharger. The turbocharger can be located at either end of the engine and the exhaust gas outlet can be vertical, or inclined 45 degrees in the longitudinal direction of the engine.

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

## 4.2.15 Automation system

This engine is equipped with a modular embedded automation system, Wärtsilä Unified Controls - UNIC.

The system version UNIC C2 has a hardwired interface for control functions and a bus communication interface for alarm and monitoring.

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

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

Conventional heavy duty cables are used on the engine and the number of connectors are minimized. 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.

## 4.2.16 Variable Inlet valve Closure, optional

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

### 4.3 Cross section of the engine

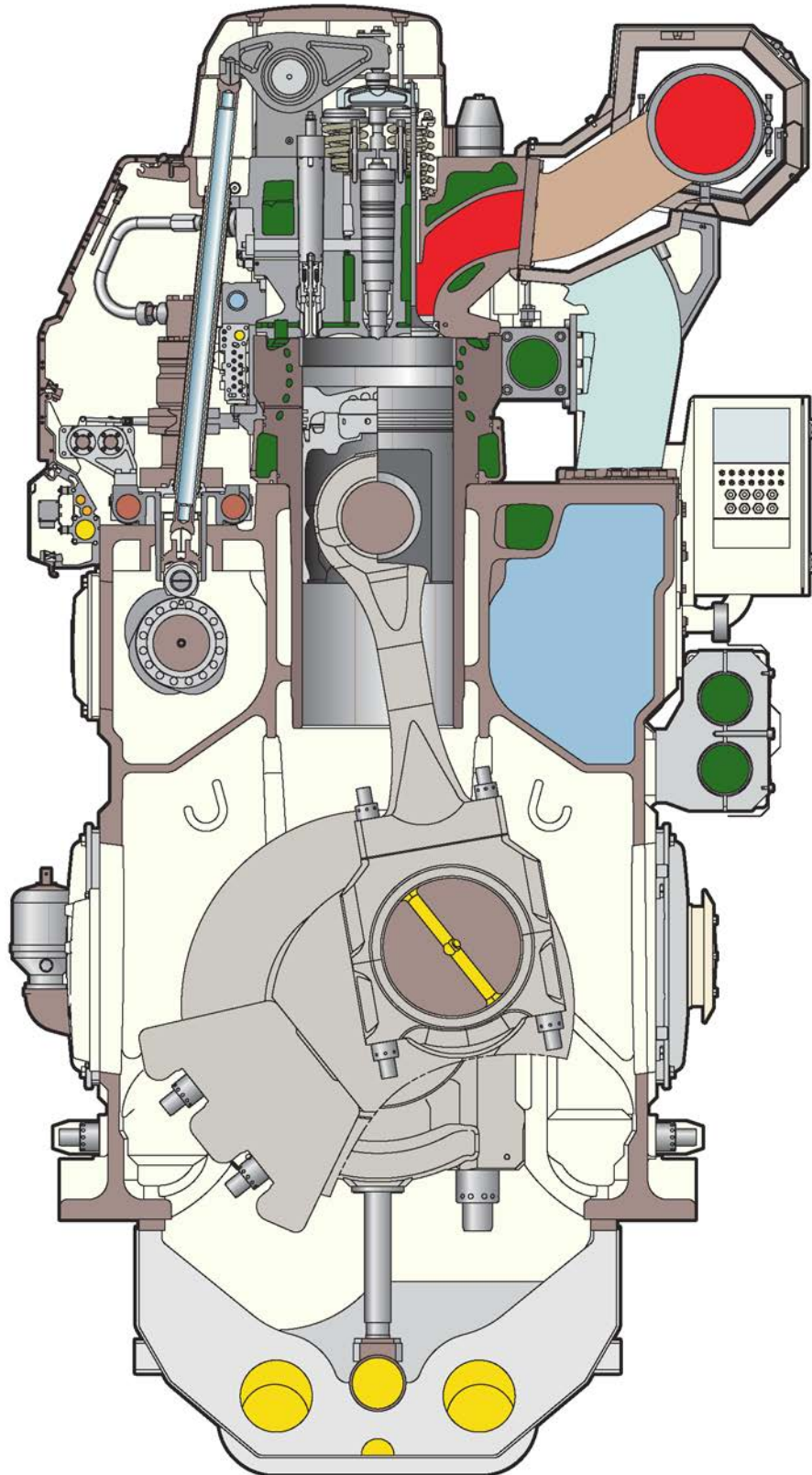
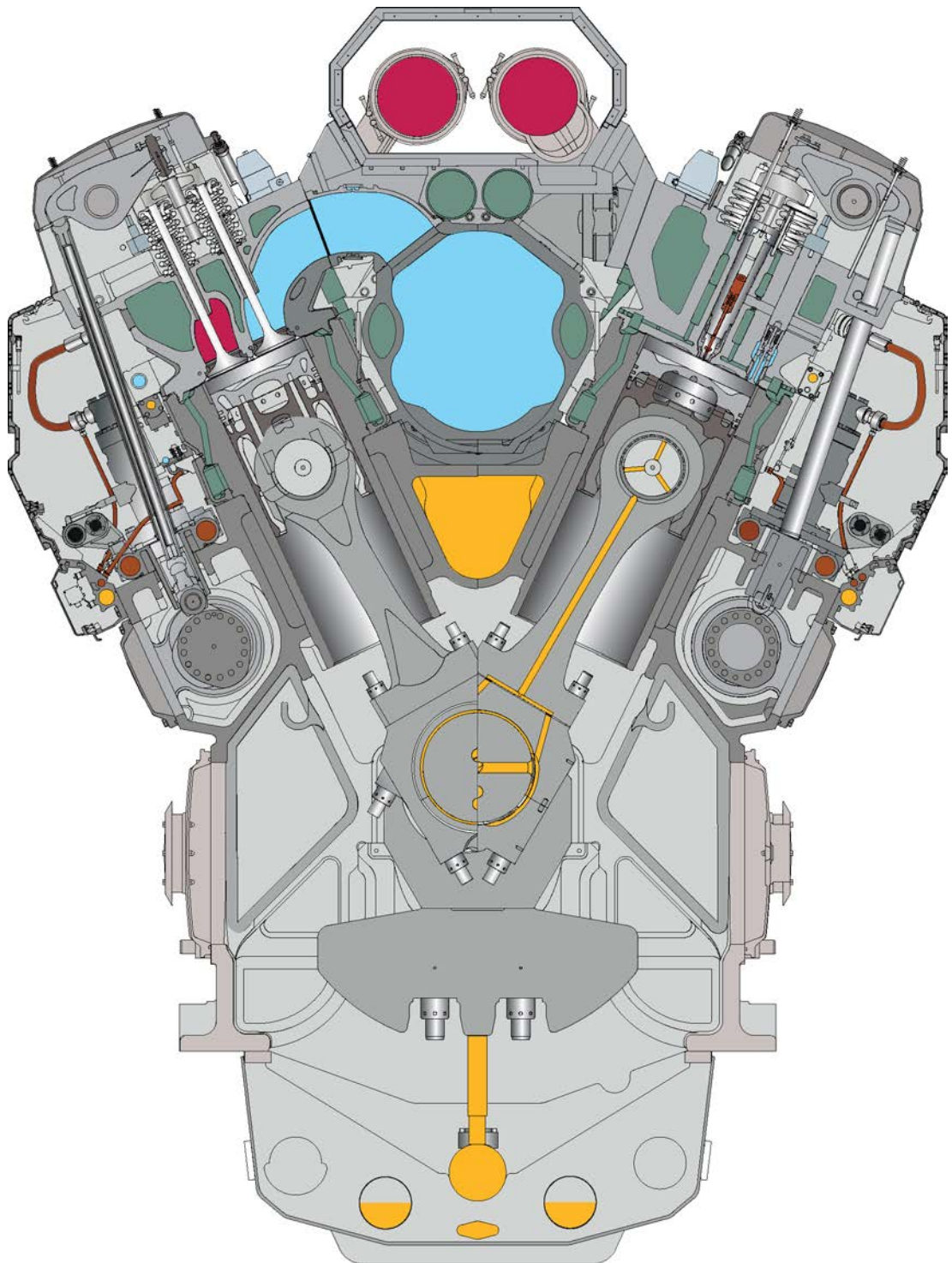


Fig 4-2 Cross section of the in-line engine





**Fig 4-3** Cross section of the V-engine

## 4.4 Overhaul intervals and expected life times

The following overhaul intervals and lifetimes are for guidance only. Achievable lifetimes depend on operating conditions, average loading of the engine, fuel quality used, fuel handling system, performance of maintenance etc.

Expected lifetime is different depending on fuel used. For detailed information on fuel qualities, please see Table Heavy fuel oils.

**Table 4-1 Time between Overhaul**

Component	Time between inspection or overhaul (h)		
	LFO operation	HFO1 operation	HFO2 operation
Twin pump fuel injection			
- Injection nozzle			
- Injection pump element	12000	12000	12000
Cylinder head	20000	16000	12000
- Inlet valve seat			
- Inlet valve, guide and rotator			
- Exhaust valve seat			
- Exhaust valve, guide and rotator			
Piston crown, including recondition			
Piston skirt			
- Piston skirt/crown dismantling one	20000	16000	12000
- Piston skirt/crown dismantling all	32000	28000	24000
Piston rings			
Cylinder liner	20000	16000	12000
Antipolishing ring			
Gudgeon pin, inspection	20000	16000	12000
Gudgeon pin bearing, inspection	20000	16000	12000
Big end bearing			
- Big end bearing, inspection of one	20000	16000	12000
- Big end bearing, replacement of all	36000	36000	36000
Main bearing			
- Main bearing, inspection of one	20000	16000	12000
- Main bearing, replacement of all	36000	36000	36000
Camshaft bearing			
- Camshaft bearing, inspection of one	36000	36000	36000
- Camshaft bearing, replacement of all	60000	60000	60000
Turbocharger inspection, cleaning	12000	12000	12000
Charge air cooler	6000	6000	6000
Rubber elements for flexible mounting			

**Table 4-2 Expected Life Time**

Component	Expected life time (h)		
	LFO operation	HFO1 operation	HFO2 operation
Twin pump fuel injection			
- Injection nozzle	6000	6000	6000
- Injection pump element	24000	24000	24000
Cylinder head	60000	60000	60000

Component	Expected life time (h)		
	LFO operation	HFO1 operation	HFO2 operation
- Inlet valve seat	36000	36000	36000
- Inlet valve, guide and rotator	24000	24000	24000
- Exhaust valve seat	36000	36000	36000
- Exhaust valve, guide and rotator	20000	16000	12000
Piston crown, including recondition	36000	36000	36000
Piston skirt	60000	60000	60000
- Piston skirt/crown dismantling one			
- Piston skirt/crown dismantling all			
Piston rings	20000	16000	12000
Cylinder liner	60000	60000	60000
Antipolishing ring	20000	16000	12000
Gudgeon pin, inspection	60000	60000	60000
Gudgeon pin bearing, inspection	36000	36000	36000
Big end bearing	36000	36000	36000
- Big end bearing, inspection of one			
- Big end bearing, replacement of all			
Main bearing	36000	36000	36000
- Main bearing, inspection of one			
- Main bearing, replacement of all			
Camshaft bearing	60000	60000	60000
- Camshaft bearing, inspection of one			
- Camshaft bearing, replacement of all			
Turbocharger inspection, cleaning			
Charge air cooler	36000	36000	36000
Rubber elements for flexible mounting	60000	60000	60000

## 4.5 Engine storage

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



## 5. Piping Design, Treatment and Installation

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

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

Sea-water piping should be in Cunifer or hot dip galvanized 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).

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

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

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

### 5.1 Pipe dimensions

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

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

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

Piping	Pipe material	Max velocity [m/s]
Fuel piping (MDF and HFO)	Black steel	1.0
Lubricating oil piping	Black steel	1.5
Fresh water piping	Black steel	2.5

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

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).

- The minimum design pressure is 0.5 MPa (5 bar) shall be selected.
- The nearest pressure class to be selected is PN6.
- Piping test pressure is normally 1.5 x the design pressure = 0.75 MPa (7.5 bar).

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

## 5.4 Pipe class

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

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

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

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

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

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

## 5.5 Insulation

**The following pipes shall be insulated:**

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

**Insulation is also recommended for:**

- Pipes between engine or system oil tank and lubricating oil separator

- Pipes between engine and jacket water preheater

## 5.6 Local gauges

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

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

## 5.7 Cleaning procedures

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

### 5.7.1 Cleanliness during pipe installation

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

Piping cleaning methods are summarised in table below:

**Table 5-3 Pipe cleaning**

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

1) In case of carbon steel pipes

#### Methods applied during prefabrication of pipe spools

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

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

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

#### Methods applied after installation onboard

*C = Purging with compressed air*

*F = Flushing*

### 5.7.2 Fuel oil pipes

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

Disconnect all the fuel pipes at the engine inlet and outlet . Install a temporary pipe or hose to connect the supply line to the return line, bypassing the engine. The pump used for flushing should have high enough capacity to ensure highly turbulent flow, minimum same as the max

nominal flow. Heaters, automatic filters and the viscosimeter should be bypassed to prevent damage caused by debris in the piping. The automatic fuel filter must not be used as flushing filter.

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

The cleanliness should be minimum ISO 4406 (c) 20/18/15, NAS9. A measurement certificate shows required cleanliness has been reached there is still risk that impurities may occur after a time of operation.

Note! The engine must not be connected during flushing.

### 5.7.3 Lubricating oil pipes

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

It is however acceptable to circulate the flushing oil via the engine sump if this is advantageous. Cleanliness of the oil sump shall be verified after completed flushing and is acceptable when the cleanliness has reached a level in accordance with ISO 4406 (c) 21/19/15, NAS10. All pipes connected to the engine, the engine wet sump or to the external engine wise oil tank shall be flushed. Oil used for filling shall have a cleanliness of ISO 4406 (c) 21/19/15, NAS10.

Note! The engine must not be connected during flushing

### 5.7.4 Pickling

Prefabricated pipe spools are pickled before installation onboard.

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

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

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

## 5.8 Flexible pipe connections

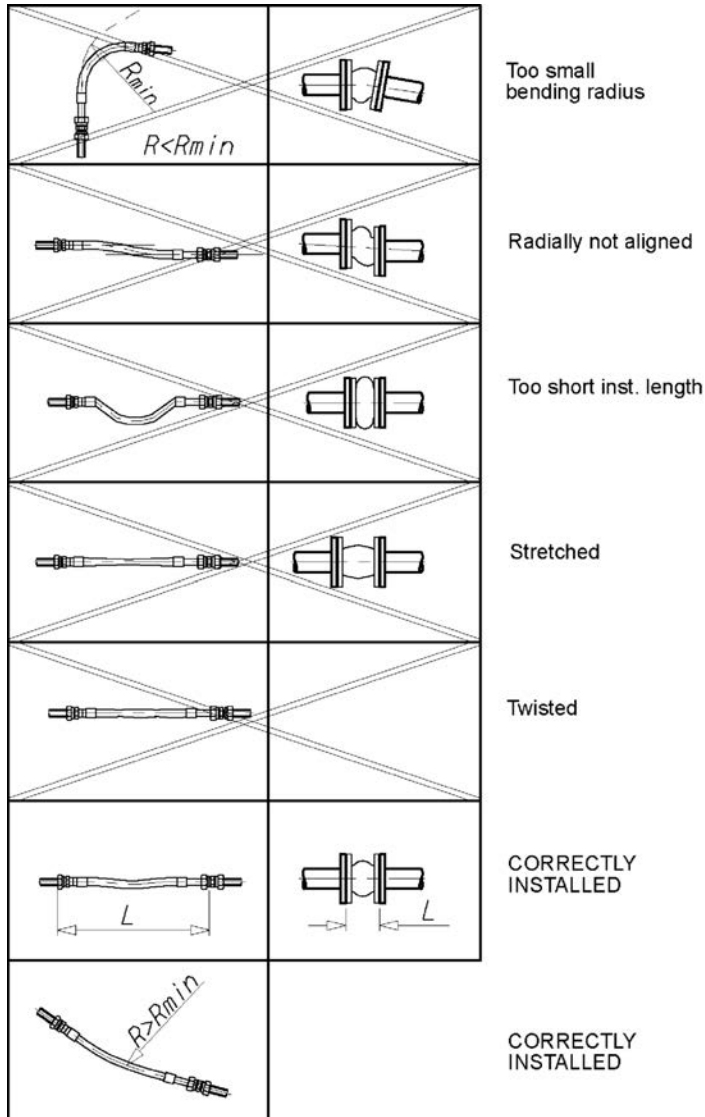
All external pipes must be precisely aligned to the fitting or the flange of the engine to minimize causing external forces to the engine connection.

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

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

- Flexible pipe connections must not be twisted
- Installation length of flexible pipe connections must be correct
- Minimum bending radius must be respected
- Piping must be concentrically aligned
- When specified, the flow direction must be observed
- Mating flanges shall be clean from rust, burrs and anticorrosion coatings

- If not otherwise instructed, bolts are to be tightened crosswise in several stages
- Painting of flexible elements is not allowed
- Rubber bellows must be kept clean from oil and fuel
- The piping must be rigidly supported close to the flexible piping connections.



**Fig 5-1 Flexible hoses**

### NOTE



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

## 5.9

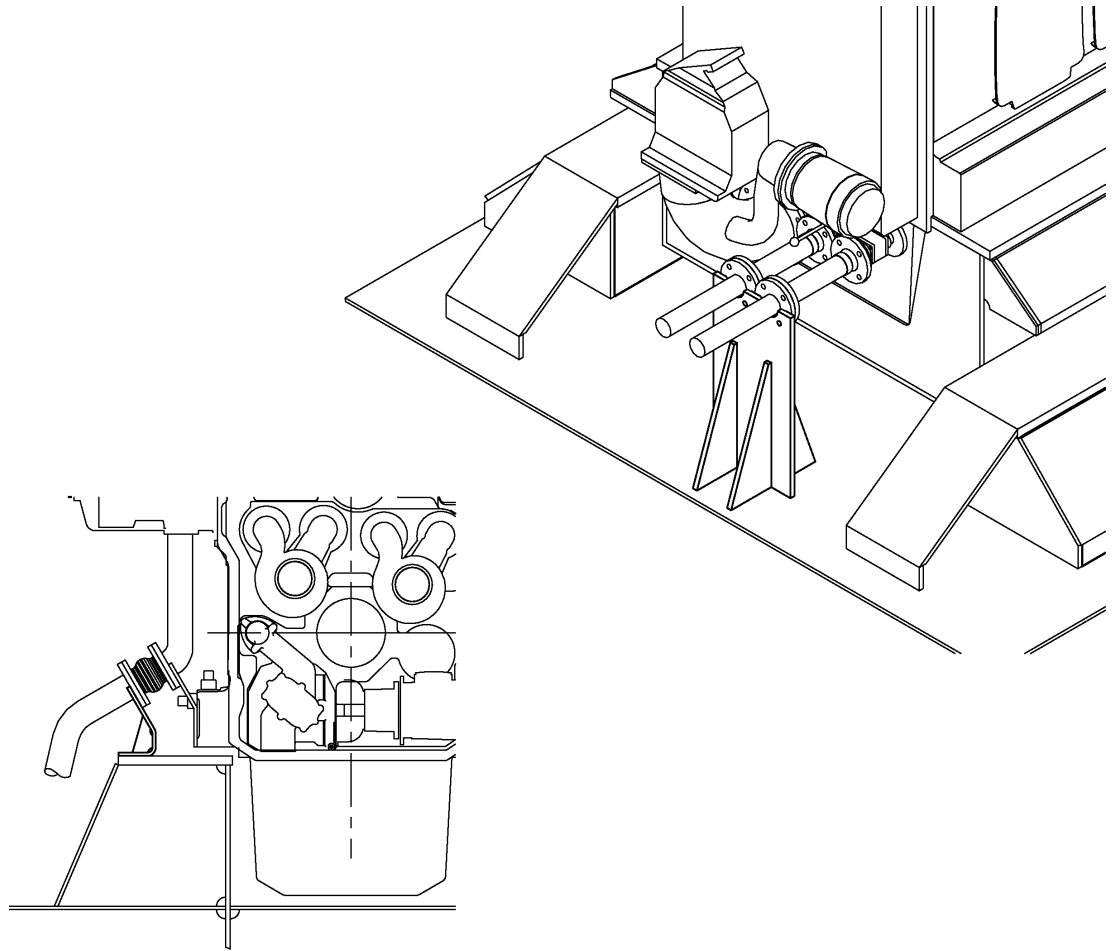
### Clamping of pipes

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

- Pipe clamps and supports next to the engine must be very rigid and welded to the steel structure of the foundation.

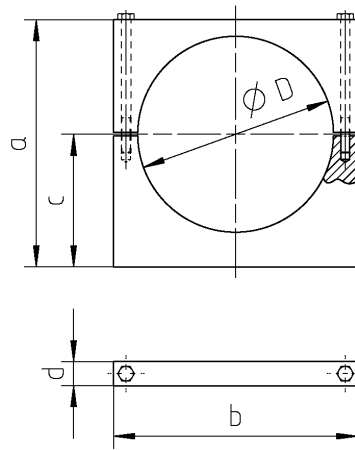
- The first support should be located as close as possible to the flexible connection. Next support should be 0.3-0.5 m from the first support.
- First three supports closest to the engine or generating set should be fixed supports. Where necessary, sliding supports can be used after these three fixed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

Examples of flange support structures are shown in [Flange supports of flexible pipe connections](#). A typical pipe clamp for a fixed support is shown in Figure "Pipe clamp for fixed support". Pipe clamps must be made of steel; plastic clamps or similar may not be used.



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

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



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

$d_u$  = Pipe outer diameter

**Fig 5-3 Pipe clamp for fixed support (V61H0842A)**



## 6. Fuel Oil System

### 6.1 Acceptable fuel characteristics

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

#### 6.1.1 Marine Diesel Fuel (MDF)

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

The distillate grades mentioned above can be described as follows:

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

#### 6.1.1.1 Table Light fuel oils

**Table 6-1 Distillate fuel specifications**

Characteristics	Unit	Lim- it	Category ISO-F						Test meth- od(s) and ref- erences
			DMX	DMA	DFA	DMZ	DFZ	DMB	
Kinematic viscosity at 40 °C <sup>1)</sup>	mm <sup>2</sup> /s <sup>a)</sup>	Max	5,500	6,000	6,000	11,00			ISO 3104
		Min	1,400 <sup>1)</sup>	2,000	3,000	2,000			
Density at 15 °C	kg/m <sup>3</sup>	Max	-	890,0	890,0	900,0			ISO 3675 or ISO 12185

Characteristics	Unit	Limit	Category ISO-F						Test method(s) and references	
			DMX	DMA	DFA	DMZ	DFZ	DVB		DFB
Cetane index		Min	45	40	40			35	ISO 4264	
Sulphur <sup>b, k)</sup>	% m/m	Max	1,00	1,00	1,00			1,50	ISO 8754 or ISO 14596, ASTM D4294	
Flash point	°C	Min	43,0 <sup>l)</sup>	60,0	60,0			60,0	ISO 2719	
Hydrogen sulfide	mg/kg	Max	2,00	2,00	2,00			2,00	IP 570	
Acid number	mg KOH/g	Max	0,5	0,5	0,5			0,5	ASTM D664	
Total sediment by hot filtration	% m/m	Max	-	-	-			0,10 <sup>c)</sup>	ISO 10307-1	
Oxidation stability	g/m <sup>3</sup>	Max	25	25	25			25 <sup>d)</sup>	ISO 12205	
Fatty acid methyl ester (FAME) <sup>e)</sup>	% v/v	Max	-	-	7,0	-	7,0	-	7,0	ASTM D7963 or IP 579
Carbon residue – Micro method on 10% distillation residue	% m/m	Max	0,30	0,30	0,30			-	ISO 10370	
Carbon residue – Micro method	% m/m	Max	-	-	-			0,30	ISO 10370	
Cloud point <sup>f)</sup>	winter	°C	Max	-16	Report	Report		-	ISO 3015	
	summer			-16	-	-	-			
Cold filter plugging point <sup>f)</sup>	winter	°C	Max	-	Report	Report		-	IP 309 or IP 612	
	summer			-	-	-	-			
Pour point <sup>f)</sup>	winter	°C	Max	-	-6	-6		0	ISO 3016	
	summer			-	0	0	6			
Appearance		-	Clear and bright <sup>g)</sup>					<sup>c)</sup>	-	
Water	% v/v	Max	-	-	-			0,30 <sup>c)</sup>	ISO 3733 or ASTM D6304-C <sup>m)</sup>	
Ash	% m/m	Max	0,010	0,010	0,010			0,010	ISO 6245	
Lubricity, corr. wear scar diam. <sup>h)</sup>	µm	Max	520	520	520			520 <sup>d)</sup>	ISO 12156-1	

**NOTE**

- a)  $1 \text{ mm}^2/\text{s} = 1 \text{ cSt}$ .
- b) Notwithstanding the limits given, the purchaser shall define the maximum sulphur content in accordance with relevant statutory limitations.
- c) If the sample is not clear and bright, the total sediment by hot filtration and water tests shall be required.
- d) If the sample is not clear and bright, the Oxidation stability and Lubricity tests cannot be undertaken and therefore, compliance with this limit cannot be shown.
- e) See ISO 8217:2017(E) standard for details.
- f) Pour point cannot guarantee operability for all ships in all climates. The purchaser should confirm that the cold flow characteristics (pour point, cloud point, cold filter clogging point) are suitable for ship's design and intended voyage.
- g) If the sample is dyed and not transparent, see ISO 8217:2017(E) standard for details related to water analysis limits and test methods.
- h) The requirement is applicable to fuels with a sulphur content below 500 mg/kg (0,050 % m/m).

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

- i) Low min. viscosity of  $1,400 \text{ mm}^2/\text{s}$  can prevent the use ISO-F-DMX category fuels in Wärtsilä® 4-stroke engines unless a fuel can be cooled down enough to meet the specified min. injection viscosity limit.
- j) Allowed kinematic viscosity before the injection pumps for this engine type is 2,0- 24  $\text{mm}^2/\text{s}$ .
- k) There doesn't exist any minimum sulphur content limit for Wärtsilä® 4-stroke diesel engines and also the use of Ultra Low Sulphur Diesel (ULSD) is allowed provided that the fuel quality fulfils other specified properties.
- l) Low flash point of min.  $43 \text{ }^\circ\text{C}$  can prevent the use ISO-F-DMX category fuels in Wärtsilä® engines in marine applications unless the ship's fuel system is built according to special requirements allowing the use or that the fuel supplier is able to guarantee that flash point of the delivered fuel batch is above  $60 \text{ }^\circ\text{C}$  being a requirement of SOLAS and classification societies.
- m) Alternative test method.

## 6.1.2 0,10% m/m sulphur fuels for SECA areas

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

The new 0,10% m/m sulphur fuels are called as Ultra Low Sulphur Fuel Oils (ULSFO) or “hybrid” fuels, since those can contain properties of both distillate and residual fuels. In the existing ISO 8217:2017(E) standard the fuels are classed as RMA 10, RMB 30 or RMD 80, if not fulling the DM grade category requirements, though from their properties point of view this is generally not an optimum approach. These fuels can be used in the Wärtsilä® 46F engine type, but special attention shall be paid to optimum operating conditions. See also Services Instruction WS02Q312.

Characteristics	Unit	RMA 10	RMB 30	RMD 80	Test method reference
Kinematic viscosity bef. injection pumps <sup>c)</sup>	mm <sup>2</sup> /s <sup>a)</sup>	6,0 - 24	6,0 - 24	6,0 - 24	-
Kinematic viscosity at 50 °C, max.	mm <sup>2</sup> /s <sup>a)</sup>	10,00	30,00	80,00	ISO 3104
Density at 15 °C, max.	kg/m <sup>3</sup>	920,0	960,0	975,0	ISO 3675 or ISO 12185
CCAI, max. <sup>e)</sup>	-	850	860	860	ISO 8217, Annex F
Sulphur, max. <sup>b)</sup>	% m/m	0,10	0,10	0,10	ISO 8574 or ISO 14596
Flash point, min.	°C	60,0	60,0	60,0	ISO 2719
Hydrogen sulfide, max.	mg/kg	2,00	2,00	2,00	IP 570
Acid number, max.	mg KOH/g	2,5	2,5	2,5	ASTM D664
Total sediment aged, max.	% m/m	0,10	0,10	0,10	ISO 10307-2
Carbon residue, micro method, max.	% m/m	2,50	10,00	14,00	ISO 10370
Asphaltenes, max. <sup>c)</sup>	% m/m	1,5	6,0	8,0	ASTM D3279
Pour point (upper), max., winter quality <sup>d)</sup>	°C	0	0	30	ISO 3016
Pour point (upper), max., summer quality <sup>d)</sup>	°C	6	6	30	ISO 3016
Water max.	% v/v	0,30	0,50	0,50	ISO 3733 or ASTM D6304-C <sup>c)</sup>
Water bef. engine, max. <sup>c)</sup>	% v/v	0,30	0,30	0,30	ISO 3733 or ASTM D6304-C <sup>c)</sup>
Ash, max.	% m/m	0,040	0,070	0,070	ISO 6245 or LP1001 <sup>c, h)</sup>
Vanadium, max. <sup>f)</sup>	mg/kg	50	150	150	IP 501, IP 470 or ISO 14597
Sodium, max. <sup>f)</sup>	mg/kg	50	100	100	IP 501 or IP 470
Sodium bef. engine, max. <sup>c, f)</sup>	mg/kg	30	30	30	IP 501 or IP 470
Aluminium + Silicon, max.	mg/kg	25	40	40	IP 501, IP 470 or ISO 10478
Aluminium + Silicon bef. engine, max. <sup>c)</sup>	mg/kg	15	15	15	IP 501, IP 470 or ISO 10478

Characteristics	Unit	RMA 10	RMB 30	RMD 80	Test method reference
Used lubricating oil: 9)					
- Calcium, max.	mg/kg	30	30	30	IP 501 or IP 470
- Zinc, max.	mg/kg	15	15	15	IP 501 or IP 470
- Phosphorus, max.	mg/kg	15	15	15	IP 501 or IP 500

## NOTE



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

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

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

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

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

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

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

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

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

### 6.1.3 Heavy fuel oil operation (residual)

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

**Table 6-2 Residual fuel specifications**

Characteristics	Unit	Limit HFO 1	Limit HFO 2	Test method reference
Kinematic viscosity bef. inj. pumps <sup>e)</sup>	mm <sup>2</sup> /s <sup>b)</sup>	20 ± 4	20 ± 4	-
Kinematic viscosity at 50 °C, max.	mm <sup>2</sup> /s <sup>b)</sup>	700,0	700,0	ISO 3104
Density at 15 °C, max.	kg/m <sup>3</sup>	991,0 / 1010,0 <sup>a)</sup>	991,0 / 1010,0 <sup>a)</sup>	ISO 3675 or ISO 12185
CCAI, max. <sup>f)</sup>	-	850	870	ISO 8217, Annex F
Sulphur, max. <sup>c, g)</sup>	%m/m	Statutory requirements		ISO 8754 or ISO 14596
Flash point, min.	°C	60,0	60,0	ISO 2719
Hydrogen sulfide, max.	mg/kg	2,00	2,00	IP 570
Acid number, max.	mg KOH/g	2,5	2,5	ASTM D664
Total sediment aged, max.	%m/m	0,10	0,10	ISO 10307-2
Carbon residue, micro method, max.	%m/m	15,00	20,00	ISO 10370
Asphaltenes, max. <sup>d)</sup>	%m/m	8,0	14,0	ASTM D3279
Pour point (upper), max. <sup>e)</sup>	°C	30	30	ISO 3016
Water, max. <sup>d)</sup>	%V/V	0,50	0,50	ISO 3733 or ASTM D6304-C <sup>d)</sup>
Water before engine, max. <sup>d)</sup>	%V/V	0,30	0,30	ISO 3733 or ASTM D6304-C <sup>d)</sup>
Ash, max.	%m/m	0,050	0,150	ISO 6245 or LP1001 <sup>d, i)</sup>
Vanadium, max. <sup>g)</sup>	mg/kg	100	450	IP 501, IP 470 or ISO 14597
Sodium, max. <sup>g)</sup>	mg/kg	50	100	IP 501 or IP 470
Sodium before engine, max. <sup>d, g)</sup>	mg/kg	30	30	IP 501 or IP 470
Aluminium + Silicon, max. <sup>d)</sup>	mg/kg	30	60	IP 501, IP 470 or ISO 10478
Aluminium + Silicon before engine, max. <sup>d)</sup>	mg/kg	15	15	IP 501, IP 470 or ISO 10478
Used lubricating oil <sup>h)</sup>				
- Calcium, max.	mg/kg	30	30	IP 501 or IP 470
- Zinc, max.	mg/kg	15	15	IP 501 or IP 470
- Phosphorus, max.	mg/kg	15	15	IP 501 or IP 500

**NOTE**

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

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

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

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

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

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

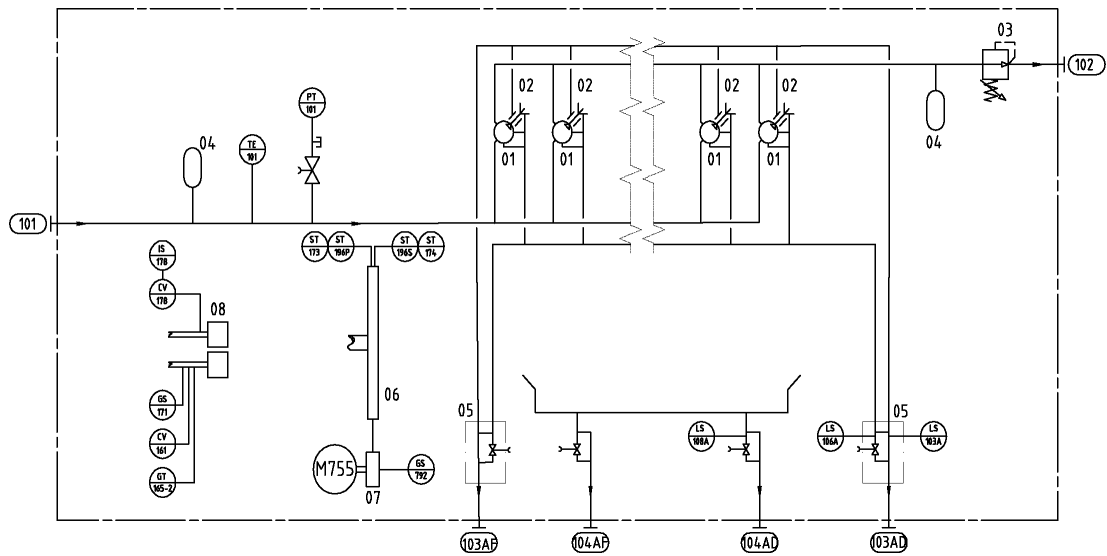
**g)** Sodium contributes to hot corrosion on exhaust valves when combined with high sulphur and vanadium contents. Sodium also strongly contributes to fouling of the exhaust gas turbine blading at high loads. The aggressiveness of the fuel depends on its proportions of sodium and vanadium, but also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

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

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

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

## 6.2 Internal fuel oil system



**Fig 6-1 Internal fuel system, in-line engine (DAAF424885)**

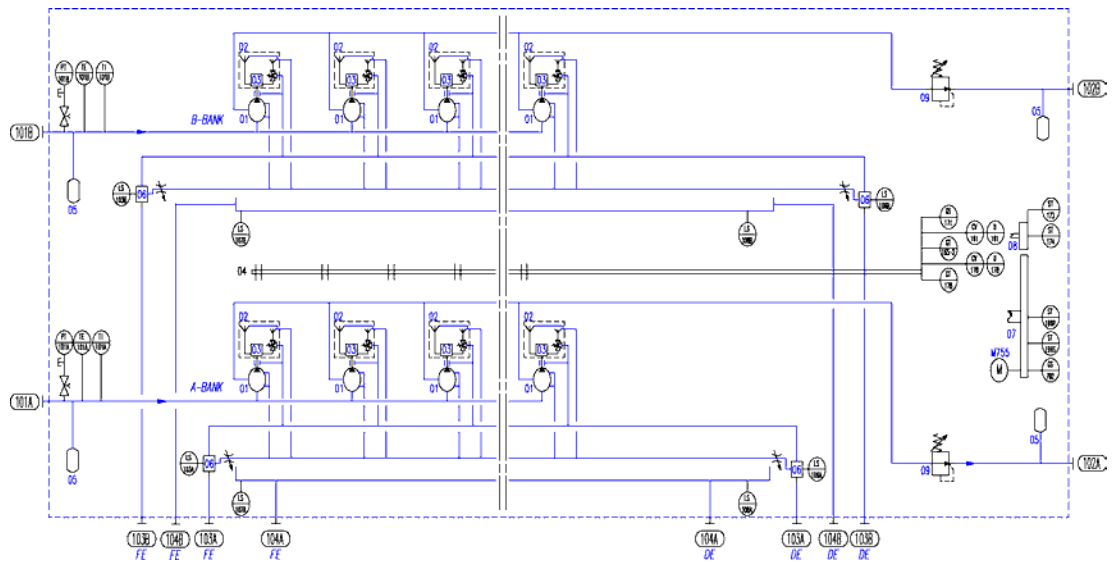
System components			
01	Injection pump	05	Fuel oil leakage collector
02	Injection valve	06	Flywheel
03	Pressure control valve	07	Turning device
04	Pulse damper	08	Fuel and timing rack

Sensor and indicators			
PT101	Fuel oil pressure, engine inlet	CV178	Timing rack control
TE101	Fuel oil temperature, engine inlet	IS178	Timing actuator driver not ready
LS103A	Fuel oil leakage, clean primary	ST173	Engine speed 1
LS106A	Fuel oil leakage, clean secondary	ST174	Engine speed 2
LS108A	Fuel oil leakage, dirty fuel DE	ST196P	Engine speed, primary
GS171	Stop lever in stop position	ST196S	Engine speed, secondary
GS792	Turning gear engaged	GT165-2	Fuel rack position
CV161	Fuel rack control		

Pipe connections			
101	Fuel inlet	103AD	Leak fuel drain, clean fuel DE
102	Fuel outlet	104AF	Leak fuel drain, dirty fuel FE
103AF	Leak fuel drain, clean fuel FE	104AD	Leak fuel drain, dirty fuel DE

Electrical Instruments	
M755	Electric motor





**Fig 6-2 Internal fuel system, V-engine (DAAR030664)**

System components					
01	Injection pump	04	Fuel & timing rack	07	Flywheel
02	Injection valve	05	Pulse damper	08	Camshaft
03	Switching valve	06	Fuel oil leakage collector	09	Pressure regulating valve

Sensors and indicators			
PT101A/B	Fuel oil pressure, engine inlet	ST173	Engine speed 1 (safety)
TE101A/B	Fuel oil temperature, engine inlet	ST174	Engine speed 2 (safety)
TI101A/B	Fuel oil temperature, engine inlet (local)	CV178	Timing rack actuator
TE102A/B	Fuel oil temperature, engine outlet	GT178	Timing rack position
LS103A/B	Fuel oil (clean) leakage - DE	ST191	Engine speed for torsional vibration
LS106A/B	Fuel oil (clean) leakage - FE	ST196P	Engine speed, prime
LS107A/B	Fuel oil (dirty) leakage - FE	U161	Drive unit for CV161
LS108A/B	Fuel oil (dirty) leakage - DE	ST196S	Engine speed, back-up
CV161	Fuel rack actuator	GS792	Turning gear engaged
GT165-2	Fuel rack position	M755	Electric motor for turning gear
GS171	Stop lever in stop position	U178	Drive unit for CV178

Pipe connections	
101A/B	Fuel inlet
102A/B	Fuel outlet
103A/B	Leak fuel drain, clean fuel
104A/B	Leak fuel drain, dirty fuel

The engine is designed for continuous operation on heavy fuel oil (HFO). On request the engine can be built for operation exclusively on marine diesel fuel (MDF). It is however possible to operate HFO engines on MDF intermittently without any alternations. Continuous operation on HFO is recommended as far as possible.

If the operation of the engine is changed from HFO to continuous operation on MDF, then a change of exhaust valves from Nimonic to Stellite is recommended.

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

### 6.2.1 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 (103). 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.

## 6.3 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.

### 6.3.1 Definitions Filtration term used

- mesh size:** opening of the mesh (surface filtration), and often used as commercial name at purchase. Only approximately related to Efficiency and Beta-value. Insufficient to compare two filters from two suppliers. Good to compare two meshes of same filter model from same supplier. Totally different than micron absolute, that is always much bigger size in micron.
  - e.g. a real example: 30 micron mesh size = approx. 50 micron  $\beta_{50} = 75$
- XX micron, nominal:** commercial name of that mesh, at purchase. Not really related to filtration capability, especially when comparing different suppliers. Typically, a totally different value than XX micron, absolute.
  - e.g. a real example: 10 micron nominal ( $\epsilon_{10} = 60\%$ ) = approx. 60 micron absolute.
- XX micron, absolute:** intended here as  $\beta_{xx} = 75$  ISO 16889 (similar to old  $\epsilon_{xx} = 98,7\%$ )
  - Beta value  $\beta_{xx} = YY$  : ISO name with ISO 16889 standardised test method. Weak repeatability for dust bigger than 25..45 microns.

- Example:  $\beta_{20} = 75$  means “every 75 particles 20 micron ISO dust sent, one passes”.
- Efficiency  $\epsilon_{xx} = YY\%$  : same meaning as Beta-value, but not any ISO standardised test method, hence sometimes used for particles larger than 25..45 micron.
- Example:  $\epsilon_{20} = 98,7\%$  means “every 75 particles 20 micron non-ISO dust sent, one passes, which is 98,7% stopped.”

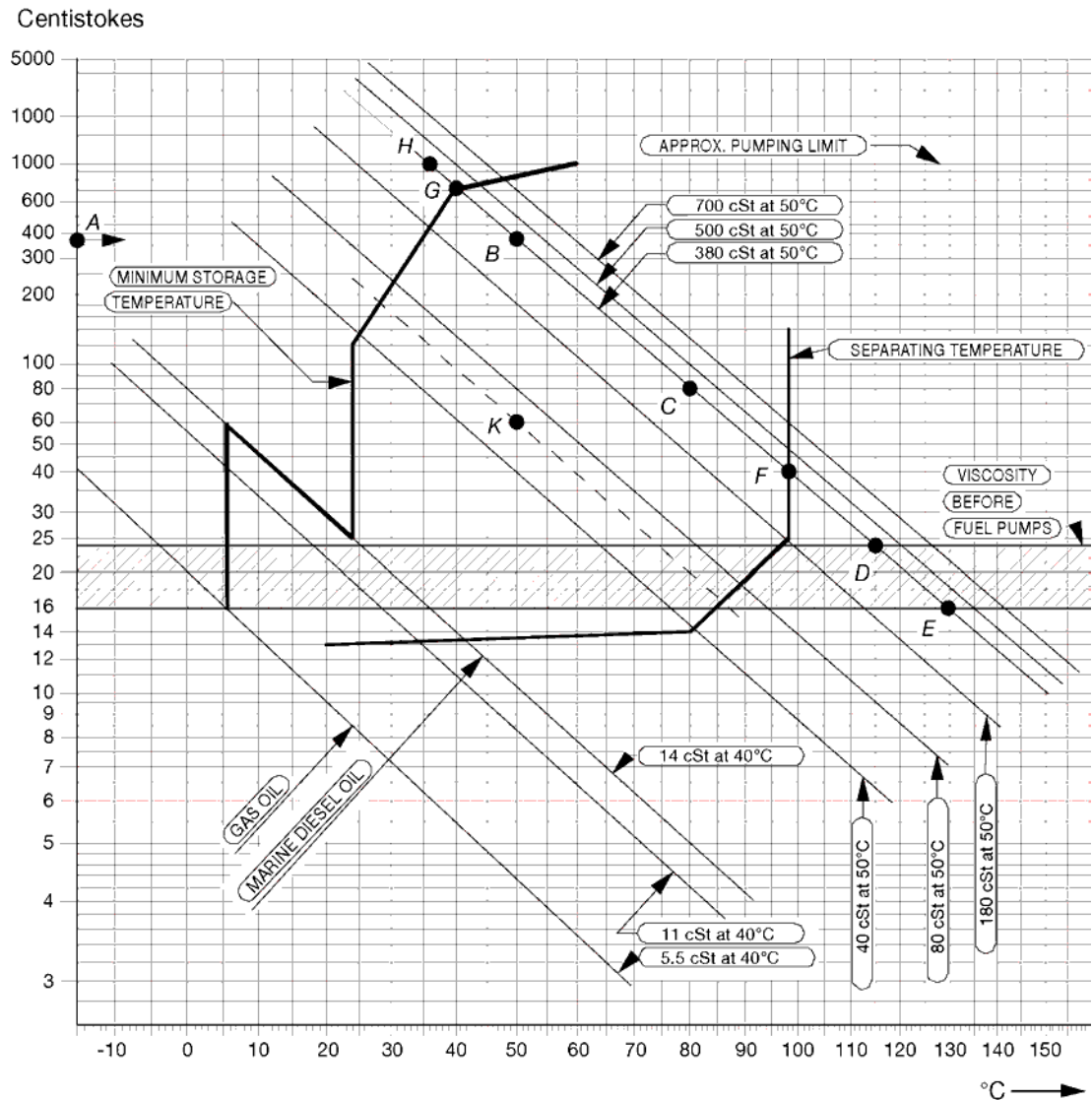
### 6.3.2 Fuel heating requirements HFO

Heating is required for:

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

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

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



**Fig 6-3 Fuel oil viscosity-temperature diagram for determining the pre-heating temperatures of fuel oils (4V92G0071b)**

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

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

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

### 6.3.3 Fuel tanks

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

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

Separate settling tanks for HFO and MDF are recommended.

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

### 6.3.3.2 Day tank, HFO (1T03) and MDF (1T06)

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

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

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

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

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

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

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

Dirty leak fuel shall be led to a sludge tank. The tank and the pipes must be heated and insulated, unless the installation is designed for operation exclusively on MDF.

## 6.3.4 Fuel treatment

### 6.3.4.1 Separation

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

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

All recommendations from the separator manufacturer must be closely followed.

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

#### Separator mode of operation

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

Separators with monitoring of cleaned fuel (without gravity disc) operating on a continuous basis can handle fuels with densities exceeding 991 kg/m<sup>3</sup> at 15°C. In this case the main and stand-by separators should be run in parallel.

When separators with gravity disc are used, then each stand-by separator should be operated in series with another separator, so that the first separator acts as a purifier and the second as clarifier. This arrangement can be used for fuels with a density of max. 991 kg/m<sup>3</sup> at 15°C. The separators must be of the same size.

#### Separation efficiency

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

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

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

where:

n = separation efficiency [%]

C<sub>out</sub> = number of test particles in cleaned test oil

C<sub>in</sub> = number of test particles in test oil before separator

### 6.3.4.2 Separator unit (1N02/1N05)

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

Typically separator modules are equipped with:

- Suction strainer (1F02)

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

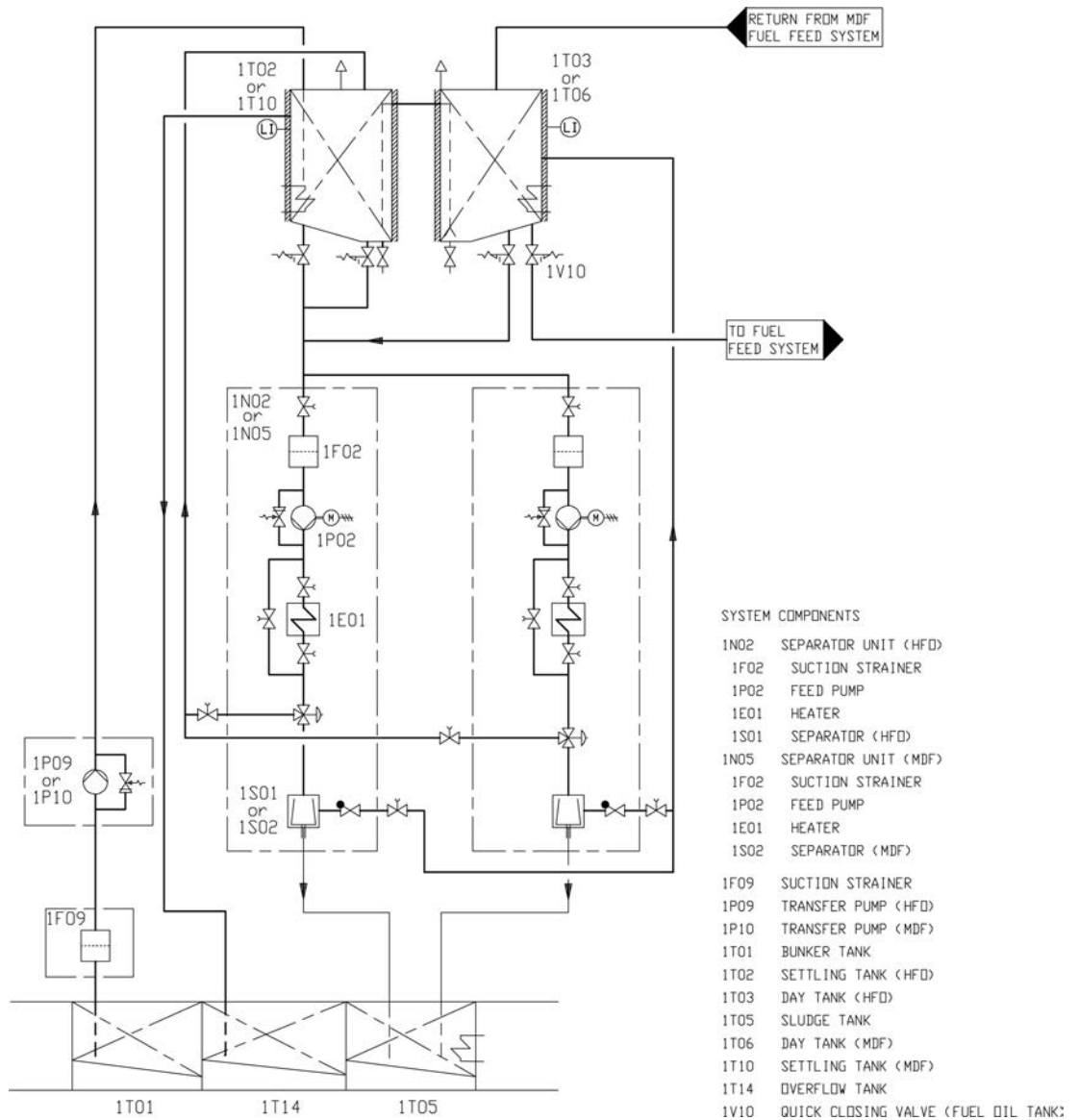


Fig 6-4 Fuel transfer and separating system (V76F6626G)

### 6.3.4.3 Separator feed pumps (1P02)

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

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

Design data:	HFO	MDF
Design pressure	0.5 MPa (5 bar)	0.5 MPa (5 bar)

Design temperature	100°C	50°C
Viscosity for dimensioning electric motor	1000 cSt	100 cSt

#### 6.3.4.4 Separator pre-heater (1E01)

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

The surface temperature in the heater must not be too high in order to avoid cracking of the fuel. The temperature control must be able to maintain the fuel temperature within  $\pm 2^\circ\text{C}$ .

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

The required minimum capacity of the heater is:

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

where:

P = heater capacity [kW]

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

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

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

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

#### 6.3.4.5 Separator (1S01/1S02)

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

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

where:

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

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

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

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

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

Sample valves must be placed before and after the separator.



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

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

### 6.3.4.7 Sludge tank (1T05)

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

### 6.3.5 Fuel feed system - MDF installations

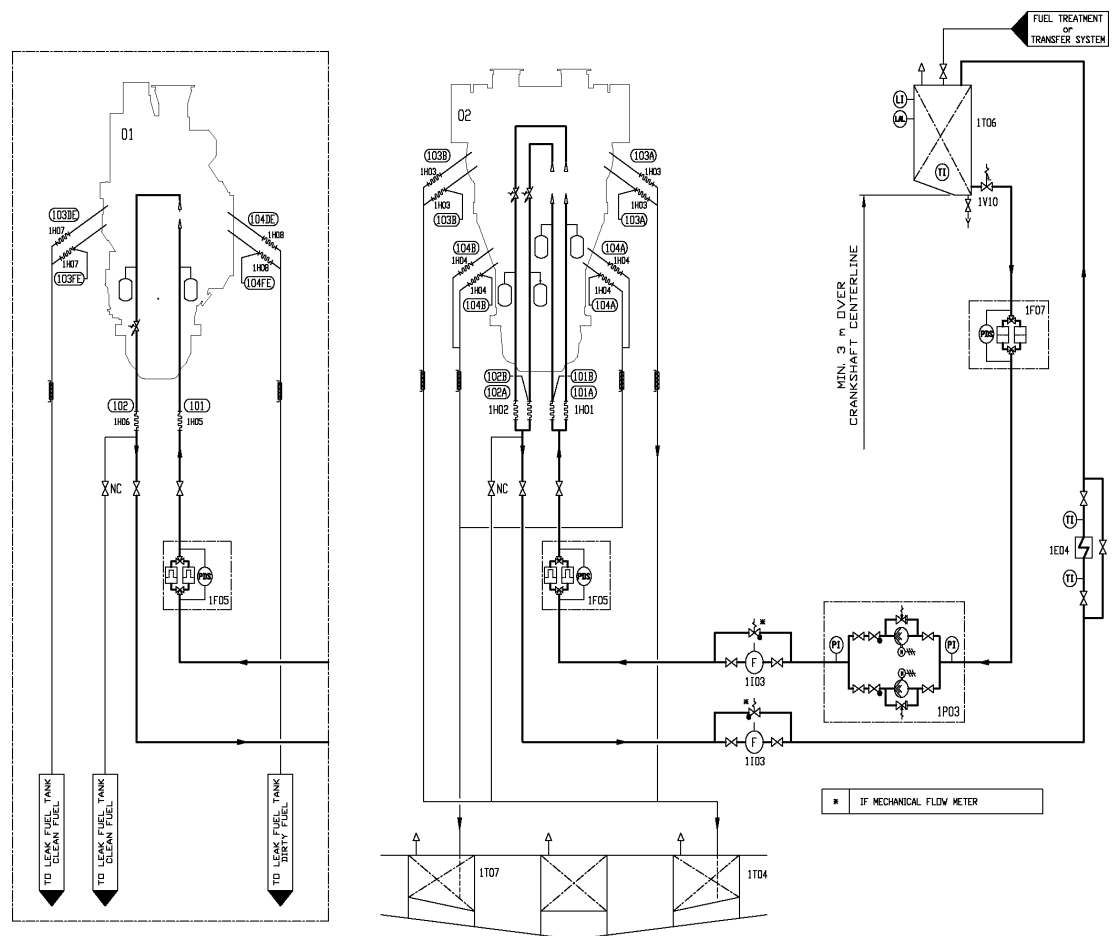


Fig 6-5 Example of fuel oil system, MDF (DAAF42878)

**System components**

01	Diesel engine Wärtsilä L46F	1P03	Circulation pump (MDF)
02	Adaptor	1T04	Leak fuel tank, clean fuel
1E04	Cooler (MDF)	1T06	Day tank (MDF)
1F05	Fine filter (MDF)	1T07	Leak fuel tank, dirty fuel
1F07	Suction strainer (MDF)	1V10	Quick closing valve
1I03	Flow meter (MDF)	104	Leak fuel drain, dirty fuel

**Pipe connections**

101	Fuel inlet
-----	------------



### 6.3.5.1 Circulation pump, MDF (1P03)

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

**Design data:**

Capacity	Allowed range at 2 cSt: see chapter Technical Data
Design pressure	1.6 MPa (16 bar)
Max. total pressure (safety valve)	1.2 MPa (12 bar)
Nominal pressure	see chapter "Technical Data"
Design temperature	50°C
Viscosity for dimensioning of electric motor	90 cSt

### 6.3.5.2 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 bypass line around the consumption meter. For mechanical flowmeter, the bypass line should open automatically in case of excessive pressure drop.

### 6.3.5.3 Fine filter, MDF (1F05,1F10)

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	34 µm (absolute) ( $\beta_{50} = 75$ , ISO16889)

Maximum permitted pressure drops at 14 cSt:

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

### 6.3.5.4 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

### 6.3.5.5 Black out start

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

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

### 6.3.6 Fuel feed system - HFO installations

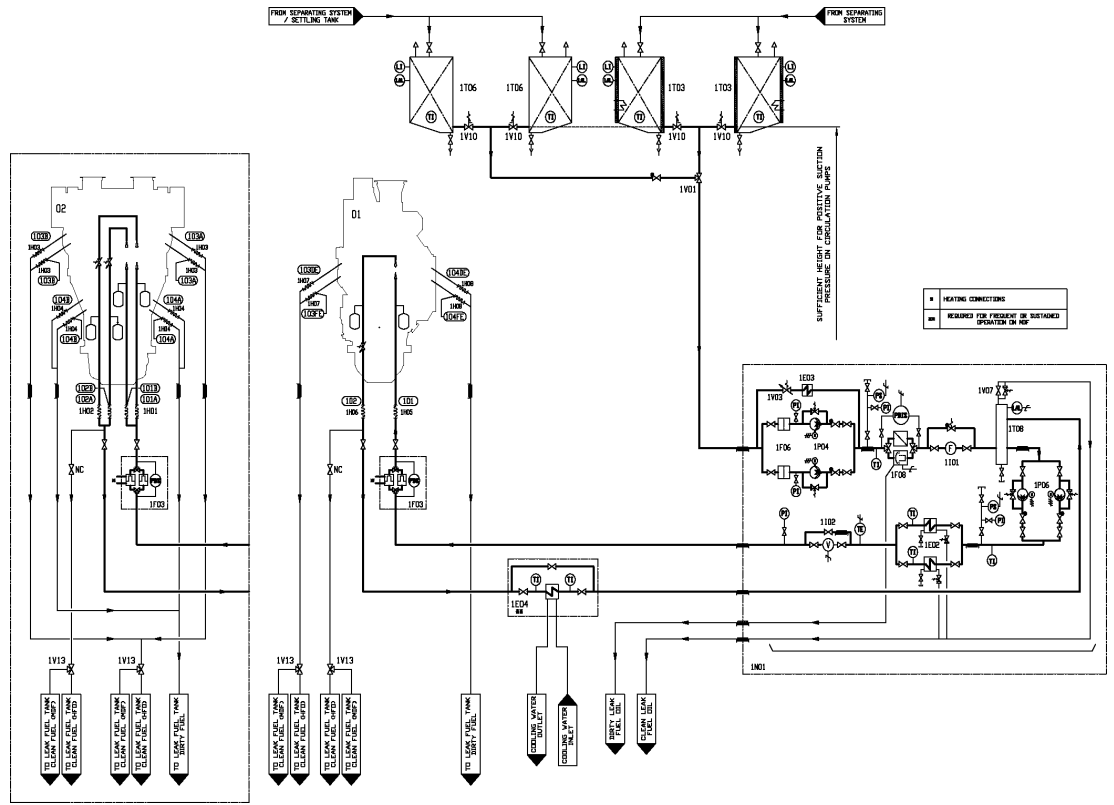


Fig 6-7 Example of fuel oil system, HFO (DAAF424853)

System components			
01	Diesel engine Wärtsilä V46F	1N01	Feeder/booster unit
02	Diesel engine Wärtsilä L46F	1P04	Fuel feed pump (Booster Unit)
03	Adapter	1P06	Circulation pump (Booster Unit)
1E02	Heater (Booster Unit)	1T03	Day tank (HFO)
1E03	Cooler (Booster Unit)	1T06	Day tank (MDF)
1E04	Cooler (MDF)	1T08	De-aeration tank (Booster Unit)
1F03	Safety filter (HFO)	1V01	Change-over valve
1F06	Suction filter (Booster Unit)	1V03	Pressure control valve (Booster Unit)
1F08	Automatic filter (Booster Unit)	1V07	Venting valve (Booster Unit)
1101	Flow meter (Booster Unit)	1V10	Quick closing valve (Fuel oil tank)
1102	Viscosity meter (Booster Unit)	1V13	Change over valve for leak fuel

Pipe connections	
101	Fuel inlet
102	Fuel outlet
103	Leak fuel drain, clean fuel
104	Leak fuel drain, dirty fuel

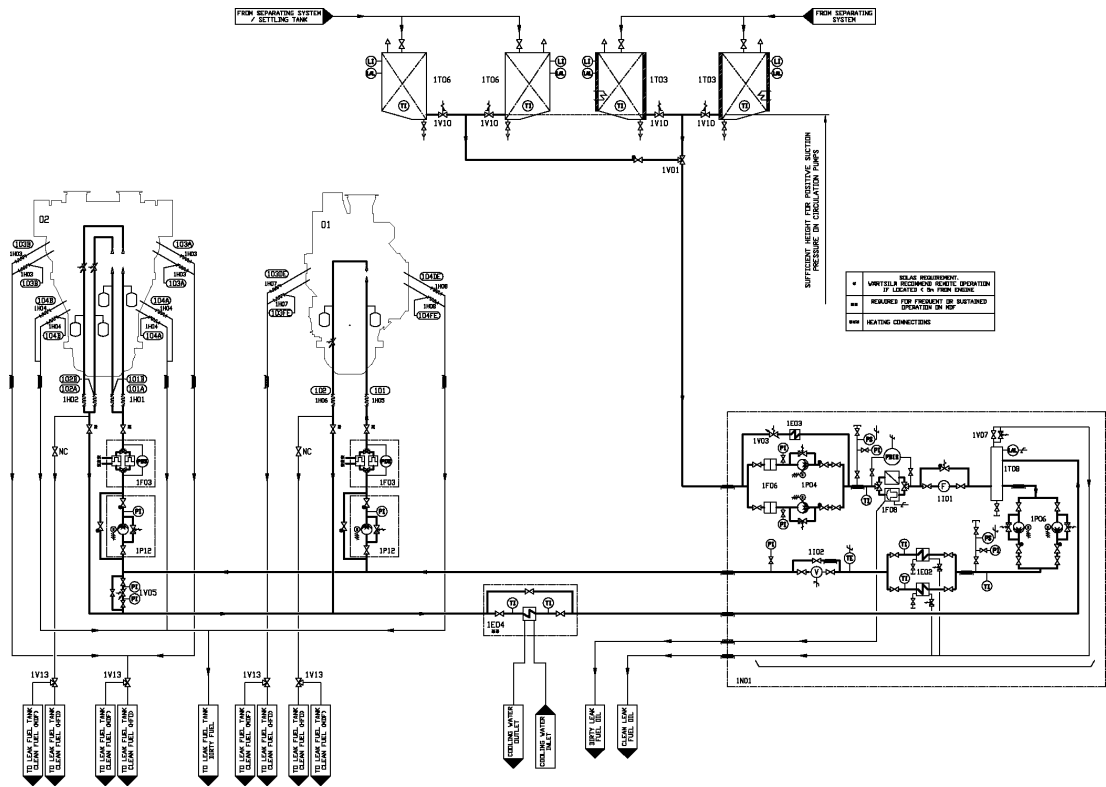


Fig 6-8 Example of fuel oil system, HFO (DAAF424854)

System components			
01	Diesel engine Wärtsilä V46F	1P04	Fuel feed pump (Booster Unit)
02	Diesel engine Wärtsilä L46F	1P06	Circulation pump (Booster unit)
03	Adapter	1P12	Circulation pump (HFO/MDF)
1E02	Heater (Booster Unit)	1T03	Day tank (HFO)
1E03	Cooler (Booster Unit)	1T06	Day tank (MDF)
1E04	Cooler (MDF)	1T08	De-aeration tank (Booster unit)
1F03	Safety filter (HFO)	1V01	Change-over valve
1F06	Suction filter (Booster Unit)	1V03	Pressure control valve (Booster unit)
1F08	Automatic filter (Booster Unit)	1V05	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	
101	Fuel inlet
102	Fuel outlet
103	Leak fuel drain, clean fuel
104	Leak fuel drain, dirty fuel

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

### 6.3.6.1 Starting and stopping

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

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

### 6.3.6.2 Changeover from HFO to MDF

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

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

### 6.3.6.3 Number of engines in the same system

When the fuel feed unit serves a single Wärtsilä 46DF engine only, a feeder/booster unit (1N01) shall be installed. On multiple installation of W46DF engines, it's possible to install a single feeder/booster unit (1N01) followed by one individual circulation pump before each W46DF engine (1P12). It's anyhow recommended to consider redundancy of feeder/booster unit (1N01) for higher installation reliability.

In addition the following guidelines apply:

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

Main engines and auxiliary engines should preferably have separate feeder/booster units (1N01). 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. Pilot line of multiple W46DF engines can have a single pilot fuel feed pump (1P13), at condition that any flow balancing distribution is prevented.

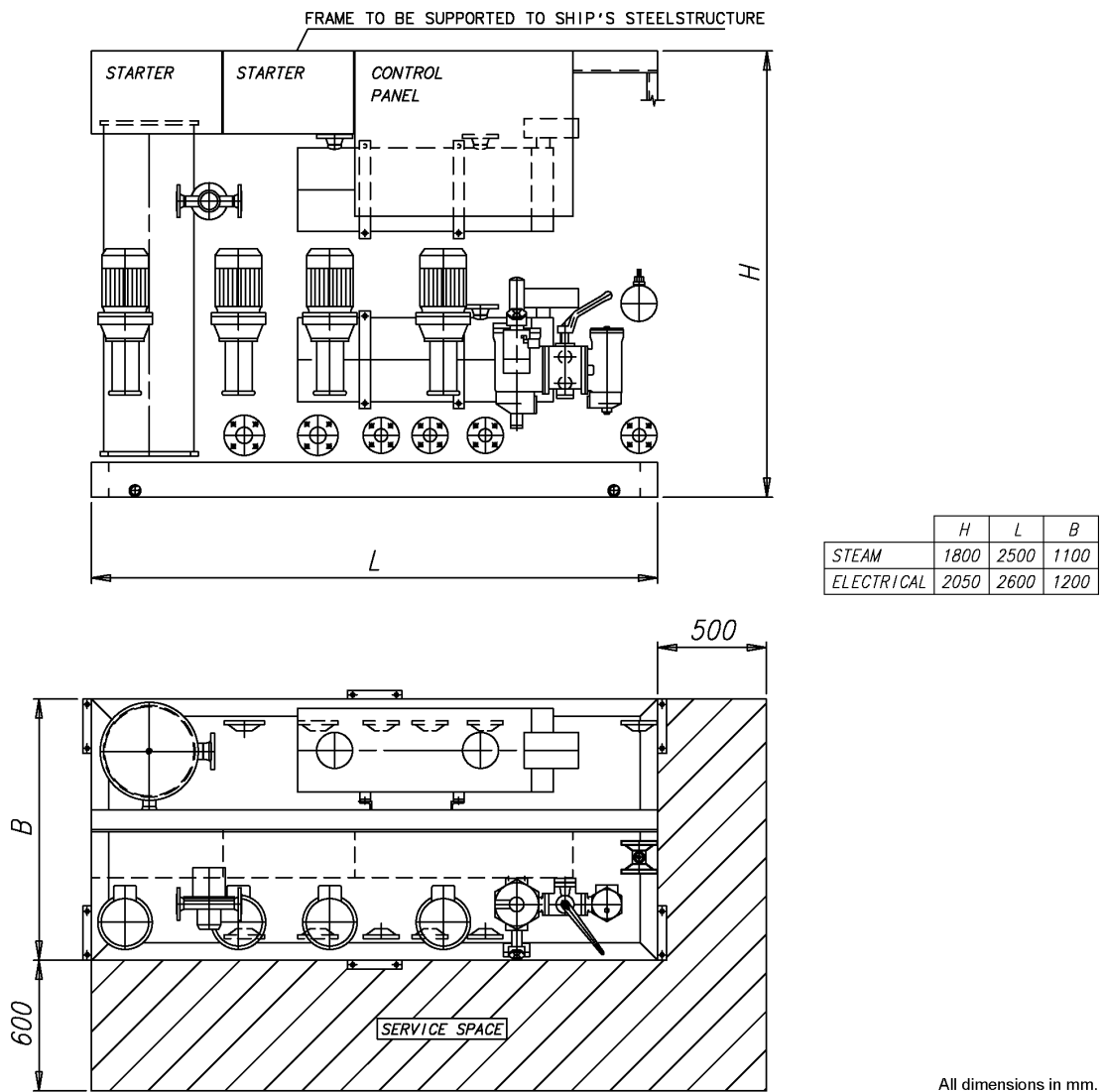
### 6.3.6.4 Feeder/booster unit (1N01)

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

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

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



**Fig 6-9 Feeder/booster unit, example (DAAE006659)**

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

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

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

#### Design data:



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

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

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

#### Design data:

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

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

It is recommended to select an automatic filter with a manually cleaned filter in the 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); 20 µm β <sub>20</sub> =10, ISO16889
- by-pass filter	35 µm (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, for single-engine circuit, or before circulation pumps (1P12) for multi-engines circuit. Pressure 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:

- single engine, without circulation pumps (1P12)	LFO:2cSt HFO:20cSt: See chapter "Technical data"
- with circulation pumps (1P12)	15% more than total capacity of all circulation pumps

Frequency Converter:

- HFO single engine, without circulation pumps (1P12)	Not needed
- Bi-fuel single engine, without circulation pumps (1P12)	Required
- with circulation pumps (1P12)	Not needed on 1P06

Design pressure: 1.6 MPa (16 bar)

Max. total pressure (safety valve) 1.0 MPa with 1P12  
1.2 MPa without 1P12

Design temperature 150°C

Viscosity for dimensioning of electric motor 500cSt

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

### 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<sup>2</sup>.

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

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

**where:**

P = heater capacity (kW)

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

ΔT = temperature rise in heater [°C]

### Viscosimeter, booster unit (1I02)

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

#### Design data:

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

## 6.3.6.5 Pump and filter unit (1N03)

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

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

### Circulation pump (1P12)

The purpose of the circulation pump is to ensure equal circulation through all engines and to maintain the required pressure at the injection pumps.

#### Design data:

Capacity	LFO:2cSt HFO:20cSt
Frequency converter:	
- HFO engines	- Not needed
- Bi - fuel engines	- Required
Design pressure	1.6 MPa (16 bar)
Design temperature	150°C
Pressure for dimensioning of electric motor (ΔP):	
- 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)

### 6.3.6.6 Overflow valve, HFO (1V05)

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

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

#### Design data:

Capacity	Equal to circulation pump (1P06)
Design pressure	1.6 MPa (16 bar)
Design temperature	150°C
Set-point ( $\Delta p$ )	0.2...0.7 MPa (2...7 bar)

### 6.3.7 Flushing

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

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

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

## 7. Lubricating Oil System

### 7.1 Lubricating oil requirements

#### 7.1.1 Engine lubricating oil

The lubricating oil must be of viscosity class SAE 40 and have a viscosity index (VI) of minimum 95. The lubricating oil alkalinity (BN) is tied to the fuel grade, as shown in the table below. BN is an abbreviation of Base Number. The value indicates milligrams KOH per gram of oil.

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

Category	Fuel standard		Lubricating oil BN	Fuel S content, [% m/m]
A	ASTM D 975-17, BS MA 100: 1996 CIMAC 2003 ISO 8217:2017(E)	GRADE 1-D, 2-D, 4-D DMX, DMA, DMB DX, DA, DB ISO-F-DMX - DMB	10...20 21-30*)	< 0.4
B	ASTM D 975-17 BS MA 100: 1996 CIMAC 2003 ISO 8217:2017(E)	GRADE 1-D, 2-D, 4-D DMX, DMA, DMB DX, DA, DB ISO-F-DMX - DMB	15...20 10-14)** 21-30*)	0.4 - 1.5

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

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

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

Category	Fuel standard		Lubricating oil BN	Fuel S content, [% m/m]
C	ASTM D 975-17 ASTM D 396-17, BS MA 100: 1996 CIMAC 2003, ISO 8217:2017(E)	GRADE NO. 4D GRADE NO. 5-6 DMC, RMA10-RMK55 DC, A30-K700 RMA10-RMK700	30...55	≤ 3.50 or statutory requirements***)

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

It is recommended to use in the first place BN 50 - 55 lubricants when operating on residual fuel. This recommendation is valid especially for engines having wet lubricating oil sump and using residual fuel with sulphur content above 2,0 % mass.

BN 40 lubricants can be used when operating on residual fuel as well if experience shows that the lubricating oil BN equilibrium remains at an acceptable level.

In residual fuel operation BN 30 lubricants are recommended to be used only in special cases, like e.g. such as installations equipped with an SCR catalyst. Lower BN products eventually have a positive influence on cleanliness of the SCR catalyst.

With BN 30 oils lubricating oil change intervals may be rather short, but lower total operating costs may be achieved because of better plant availability provided that the maintenance intervals of the SCR catalyst can be increased.

If both distillate fuel and residual fuel are used in turn as fuel, lubricating oil quality has to be chosen according to instructions being valid for residual fuel operation, i.e. BN 30 is the minimum.

Optimum BN in this kind of operation depends on the length of operating periods on both fuel qualities as well as of sulphur content of fuels in question. Thus in particular cases BN 40 or even higher BN lubricating oils should be used.

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

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

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

## 7.1.2 Oil in speed governor or actuator

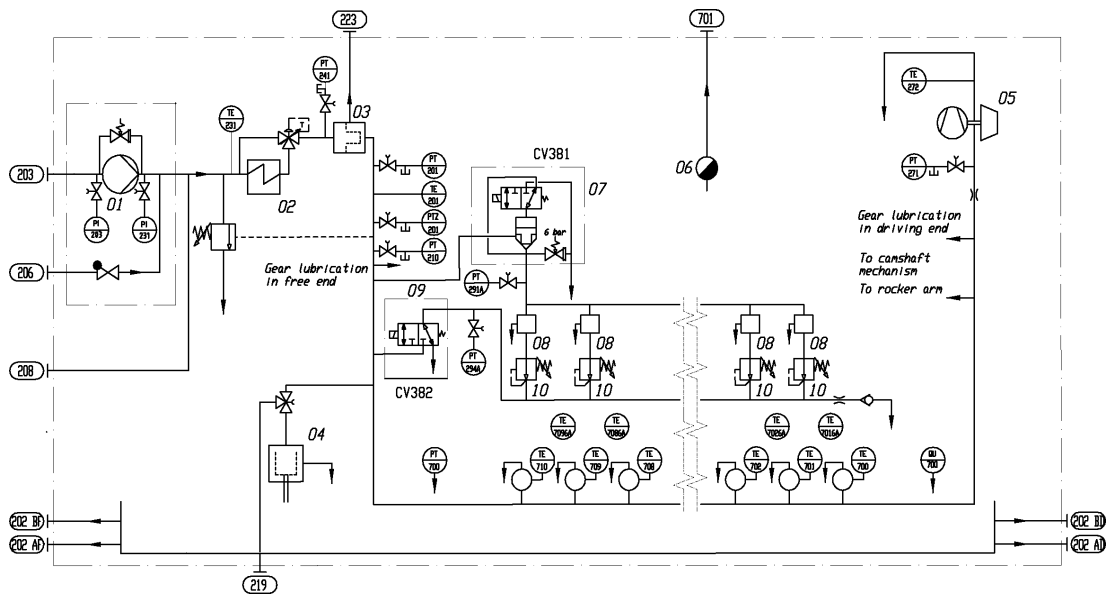
An oil of viscosity class SAE 30 or SAE 40 is acceptable in normal operating conditions. Usually the same oil as in the engine can be used. At low ambient temperatures it may be necessary to use a multigrade oil (e.g. SAE 5W-40) to ensure proper operation during start-up with cold oil.

## 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



**Fig 7-1 Internal lubricating oil system, in-line engine (DAAF422227)**

System components			
01	Main lubricating oil pump (engine driven)	06	Crankcase breather
02	Lubricating oil cooler	07	VIC - Control valve, CV381
03	Lubricating oil automatic filter	08	VIC - Variable inlet valve closing
04	Centrifugal filter for indication	09	Vic-Half VIC Activation, CV382
05	Turbocharger	10	Pressure valve for 3-Timing VIC
©* If engine is equipped with 3-Timing VIC			

Sensors and indicators			
PT201	Lube oil pressure, engine inlet	TE016A/08A	Big end bearing temperature
TE201	Lube oil temperature, engine inlet	PT271	Lube oil pressure, TC inlet
PTZ201	LO pressure, engine inlet	TE272	Lube oil temperature, TC outlet
PT291A	Control oil pressure after VIC Valve	PT700	Crankcase pressure
PT294A	Control oil pressure after half VIC Valve	CV381	Vic control valve
TE231	Lube oil temperature, LOC inlet	CV382	Half vic activation
TE700...710	Main bearing temperature		

Pipe connections			
202 AF	Lubricating oil outlet at FE A-bank (from oil sump)	223	Flushing oil from automatic filter
202 BF	Lubricating oil outlet at FE B-bank (from oil sump)	701	Crankcase air vent
202 AD	Lubricating oil outlet at DE A-bank (from oil sump)	201	Lube oil inlet (to manifold)
202 BD	Lubricating oil outlet at DE B-bank (from oil sump)	208	Lube oil from eldriven pump
203	Lubricating oil inlet to engine driven pump	209	Lube oil to external filter
206	Lubricating oil from priming pump	212	Lube oil from cooler
219	Lube oil sample		

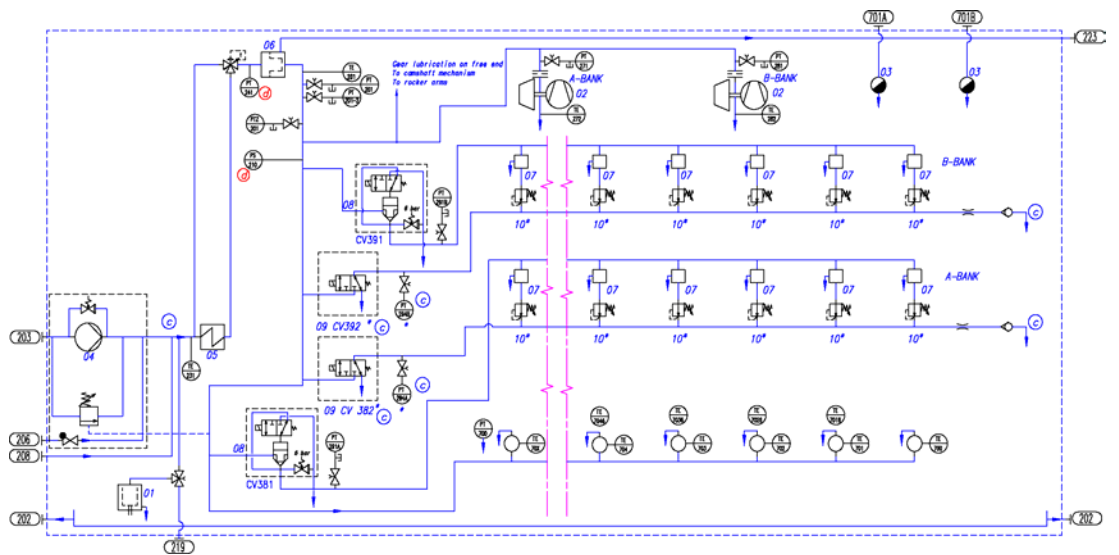


Fig 7-2 Internal lubricating oil system, V-engine (DAAR011169D)

System components			
01	Centrifugal filter (for indicating)	06	Lubricating oil automatic filter
02	Turbocharger	*07	VIC - Variable Inlet valve Closing
03	Crankcase breather	*08	VIC - Control valve
04	Main lubricating oil pump (engine driven)	©09	Vic-Half VIC Activation
05	Lubricating oil cooler	©10	Pressure valve for 3-Timing VIC
©* If engine is equipped with 3-Timing VIC			

Sensors and indicators			
PT201	Lube oil pressure, engine inlet	CV381	VIC control valve, A-bank
PT201-2	Lube oil pressure, engine inlet	PT271	Lube oil pressure, TC A inlet

Sensors and indicators			
PTZ201	Lube oil pressure, engine inlet	TE272	Lube oil temperature, TC A outlet
TE201	Lube oil temperature, engine inlet	PT700	Crankcase pressure
TI201	Lube oil temperature, engine inlet (local)	PT241	LO press, filter inlet
PT281	LO pressure, TC B inlet	TE700-X	Main bearing temperature
PS210	Lube oil stand-by pump start	TE7016-46	Big end bearing temperature
TE231	Lube oil temperature, LOC inlet	*PT294A	3-Timing VIC system., A-bank ©
TE282	LO temperature, TC B outlet	*PT294B	3-Timing VIC system, B-bank ©
©*CV382	VIC half VIC activation, A-bank	CV391	VIC control valve, B-bank
©*CV392	VIC half VIC activation, B-bank	PT291A/B	LO press. after VIC control
©* If engine is equipped with 3-Timing VIC			

Pipe connections	
202	Lubricating oil outlet (from oil sump)
203	Lubricating oil inlet to engine driven pump
206	Lubricating oil from priming pump
208	Lubricating oil from electric driven pump
223	Flushing oil from internal automatic filter
219	Sample
701A/B	Crankcase air vent

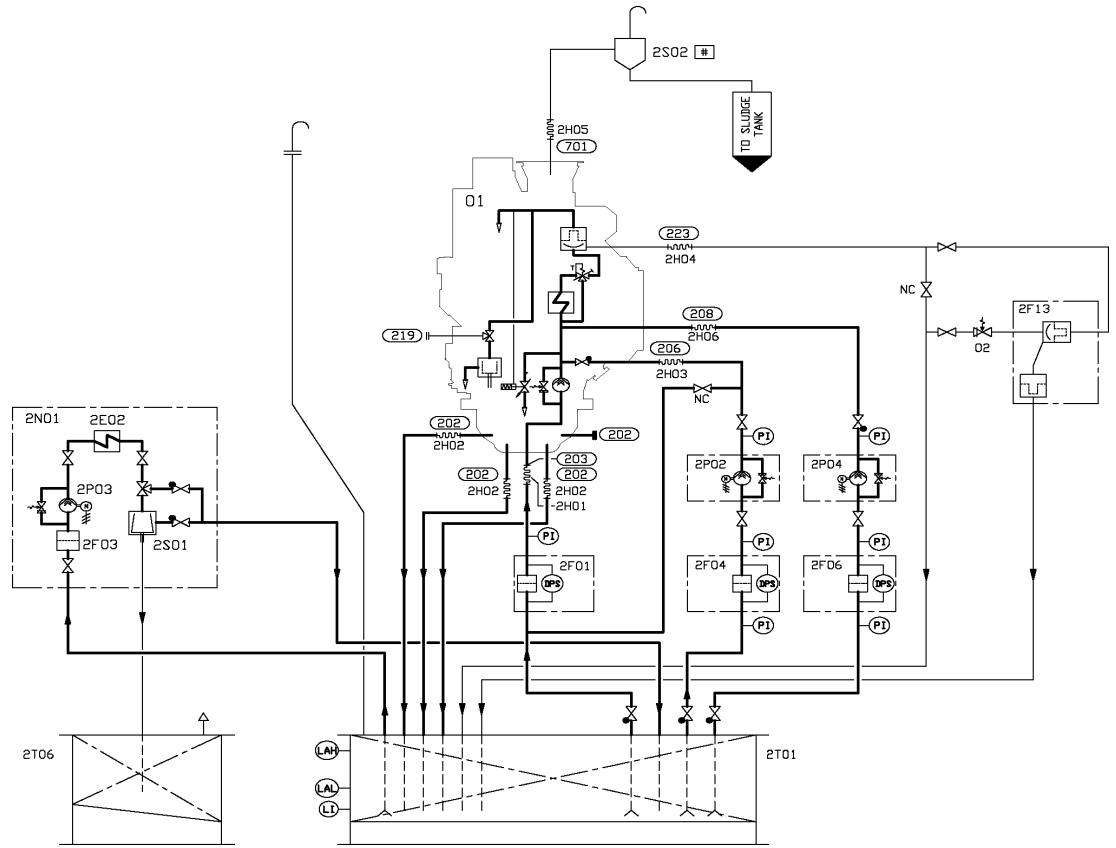
The oil sump is of dry sump type. There are two oil outlets at each end of the engine. One outlet at the free end and both outlets at the driving end must be connected to the system oil tank.

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.



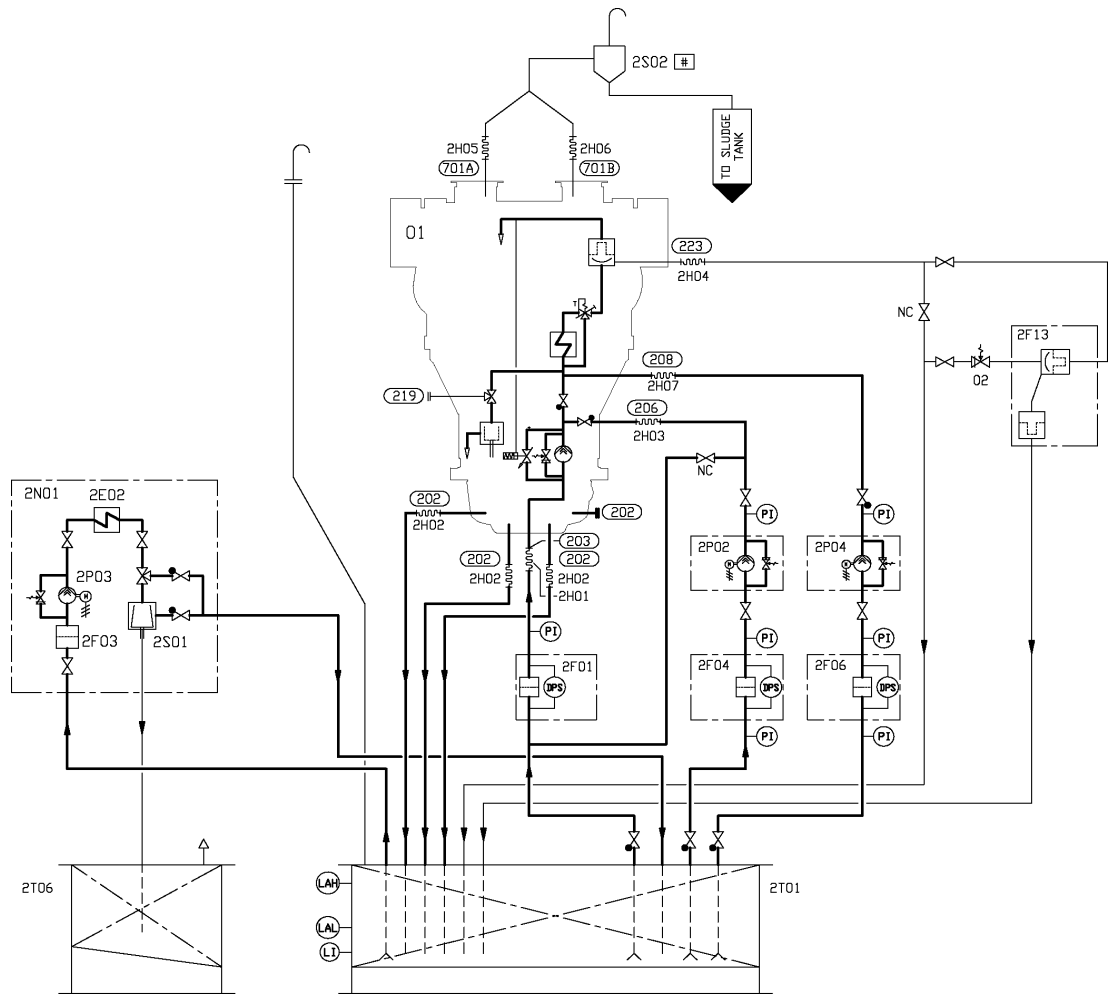
### 7.3 External lubricating oil system



**Fig 7-3 External lubricating oil system, engine driven & stand by pumps (DAAF423923)**

System components			
01	Diesel engine Wärtsilä L46F	2N01	Separator unit
02	Pressure control valve	2P02	Pre-lubricating oil pump
2H0X	Flexible pipe connections	2P03	Separator pump
2E02	Heater (Separator unit)	2P04	Stand-by pump
2F01	Suction strainer (Main lubricating oil pump)	2S01	Separator
2F03	Suction filter (Separator unit)	2S02	Condensate trap
2F04	Suction strainer (Pre lubricating oil pump)	2T01	System oil tank
2F06	Suction strainer (Stand by pump)	2T06	Sludge tank
2F13	Automatic filter (LO back flush)		

Pipe connections			
202	Lubricating oil outlet *)	208	Lubricating oil from electric driven pump
203	Lubricating oil to engine driven pump	223	Flushing oil from internal automatic filter
206	Lubricating oil from priming pump	701	Crankcase air vent
219	LO Sample		
*) Two outlets in each end are available			

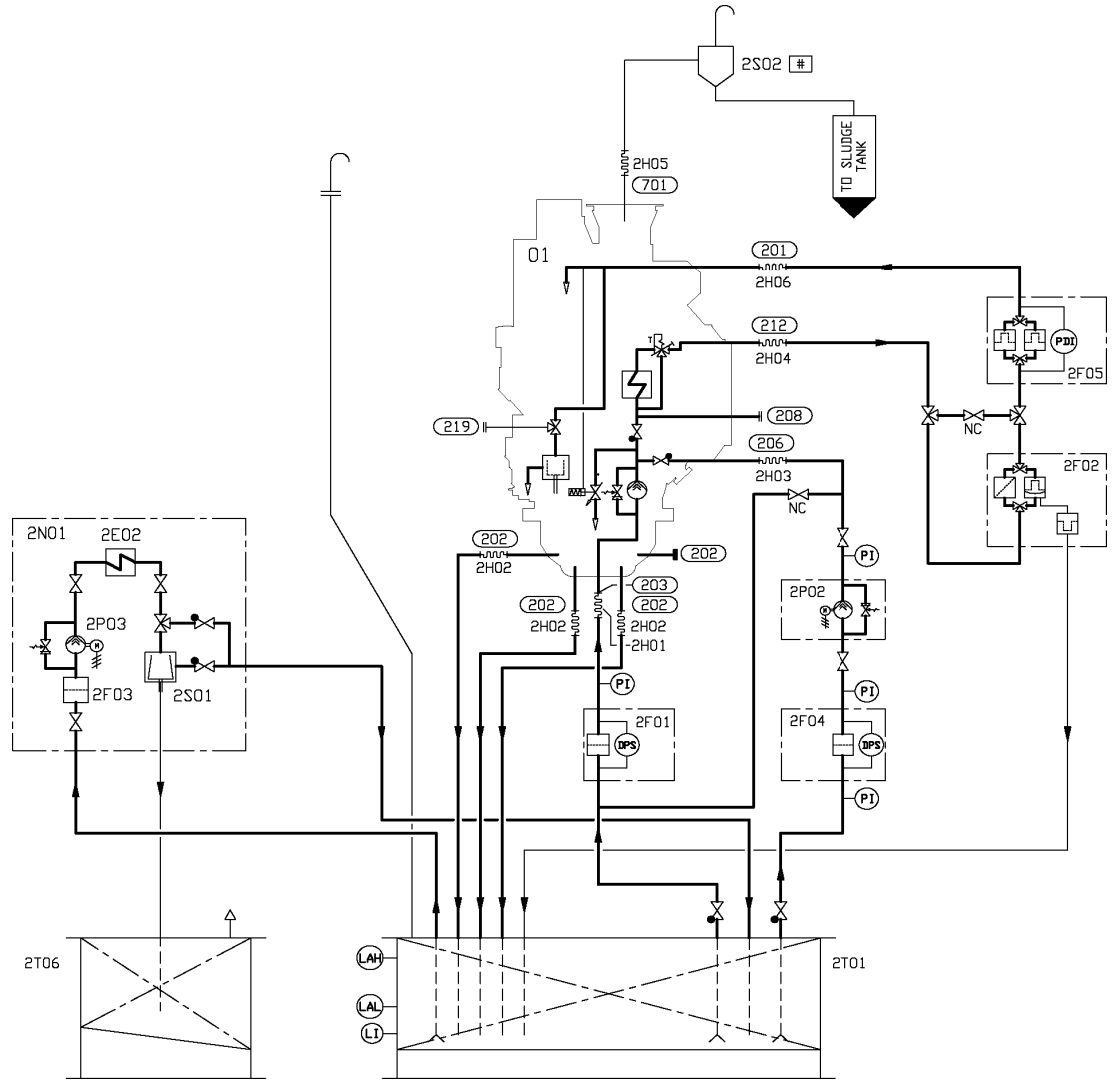


**Fig 7-4 External lubricating oil system, engine driven & stand by pumps (DAAF423924)**

System components:			
01	Diesel engine Wärtsilä L46F	2P02	Pre-lubricating oil pump
02	Pressure control valve	2P03	Separator pump (Separator unit)
2H0X	Flexible pipe connections	2P04	Stand-by pump
2E02	Heater (separator unit)	2S01	Separator (Separator unit)
2F01	Suction strainer (main lube pump)	2S02	Condensate trap
2F03	Suction strainer (separator unit)	2T01	System oil tank
2F04	Suction strainer (prelube oil pump)	2T06	Sludge tank
2F06	Suction strainer		
2F13	Automatic filter (LO back flush)		
2N01	Separator unit		

Pipe connections:	
202	Lubricating oil outlet *)
203	Lube oil to engine driven pump
206	Lube oil from priming pump
208	Lubricating oil from electric driven pump
219	Lube oil sample
223	Flushing oil from internal automatic filter
*) Two outlets in each end are available	

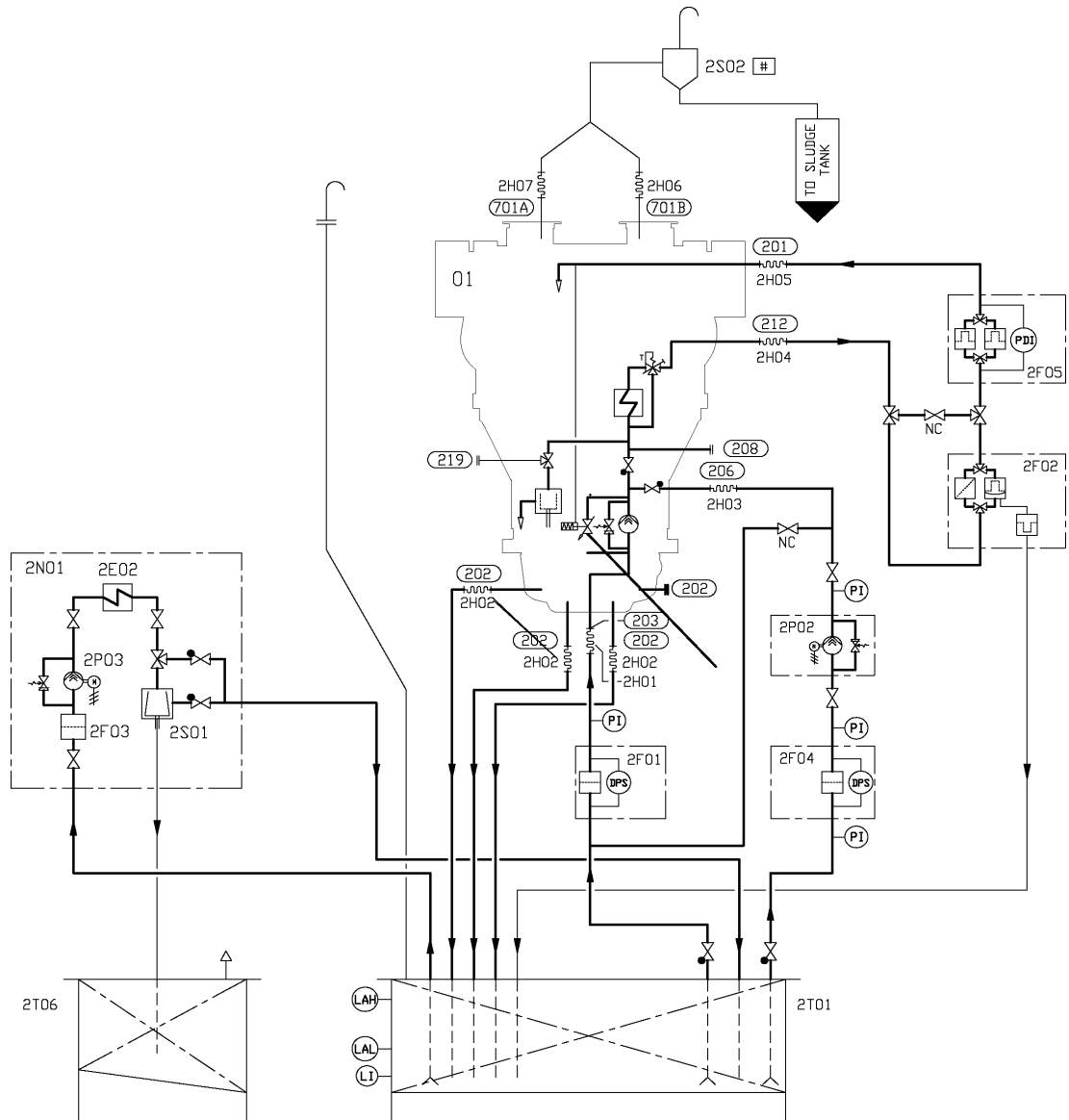
Pipe connections:	
701 A/B	Crankcase ventilation
*) Two outlets in each end are available	



**Fig 7-5 External lubricating oil system, without engine built automatic filter (DAAF423925)**

System components:			
01	Diesel engine Wärtsilä L46F	2P03	Separator pump (Separator unit)
2H0X	Flexible pipe connections	2S01	Separator (Separator unit)
2E02	Heater (separator unit)	2S02	Condensate trap
2F01	Suction strainer (main lube pump)	2P04	Stand-by pump
2F02	Automatic filter (LO)	2T01	System oil tank
2F03	Suction strainer (separator unit)	2T06	Sludge tank
2F04	Suction strainer (pre lubricating oil pump)		
2F05	Safety filter (LO)		
2N01	Separator unit		
2P02	Pre-lubricating oil pump		

Pipe connections:	
201	Lube oil inlet (to manifold)
202	Lubricating oil outlet *)
203	Lube oil to engine driven pump
206	Lube oil from priming pump
208	Lubricating oil from electric driven pump
212	Lube oil from cooler
219	Lube oil sample
701	Crankcase ventilation
*) Two outlets in each end are available	



**Fig 7-6 External lubricating oil system, without engine built automatic filter (DAAF423926)**

System components:			
01	Diesel engine Wärtsilä L46F	2P03	Separator pump (Separator unit)
2H0X	Flexible pipe connections	2S01	Separator (Separator unit)
2E02	Heater (separator unit)	2S02	Condensate trap

System components:			
2F01	Suction strainer (main lube pump)	2P04	Stand-by pump
2F02	Automatic filter (LO)	2T01	System oil tank
2F03	Suction strainer (separator unit)	2T06	Sludge tank
2F04	Suction strainer (pre lubricating oil pump)		
2F05	Safety filter (LO)		
2N01	Separator unit		
2P02	Pre-lubricating oil pump		

Pipe connections:	
201	Lube oil inlet (to manifold)
202	Lubricating oil outlet <sup>*)</sup>
203	Lube oil to engine driven pump
206	Lube oil from priming pump
208	Lubricating oil from electric driven pump
212	Lube oil from cooler
219	Lube oil sample
701	Crankcase ventilation
*) Two outlets in each end are available	

## 7.3.1 Separation system

### 7.3.1.1 Separator unit (2N01)

Each 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 MDF only, then intermittent separating might be sufficient.

Separators are usually supplied as pre-assembled units.

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

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

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

#### Separator feed pump (2P03)

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

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

#### Separator preheater (2E02)

The preheater is to be dimensioned according to the feed pump capacity and the temperature in the system oil tank. When the engine is running, the temperature in the system oil tank

located in the ship's bottom is normally 65...75°C. To enable separation with a stopped engine the heater capacity must be sufficient to maintain the required temperature without heat supply from the engine.

Recommended oil temperature after the heater is 95°C.

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

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

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

### Separator (2S01)

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

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

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

where:

$Q$  = volume flow [l/h]

$P$  = engine output [kW]

$n$  = 5 for HFO, 4 for MDF

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

### Sludge tank (2T06)

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

## 7.3.2 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.

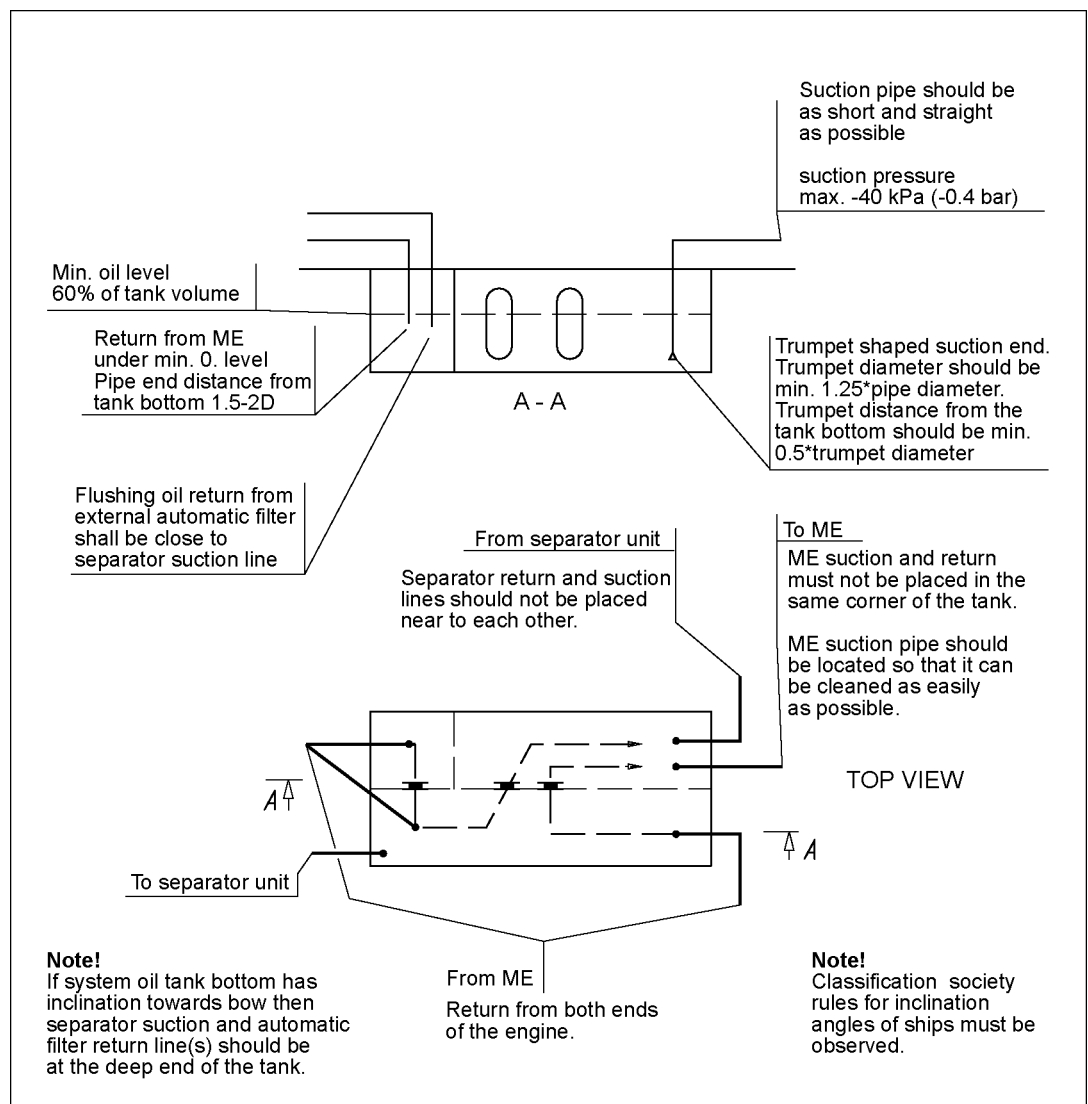


Fig 7-7 Example of system oil tank arrangement (DAAE007020e)

**Design data:**

Oil tank volume	see <i>Technical data</i>
Oil level at service	75...80% of tank volume
Oil level alarm	60% of tank volume

### 7.3.3 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

### 7.3.4 Lubricating oil pump ( 2P04)

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

**Design data:**

Capacity see *Technical data*

Design pressure 1.0 MPa (10 bar)

Max. pressure (safety valve) 800 kPa (8 bar)

Design temperature 100°C

Viscosity for dimensioning the electric motor 500 cSt

Example of required power, oil temperature 40°C. The actual power requirement is determined by the type of pump and the flow resistance in the external system.

	6L46F	7L46F	8L46F	9L46F	12V46F	14V46F	16V46F
Pump [kW]	45	50	50	60	65	78	78
Electric motor [kW]	55	55	55	75	75	87	87

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

The pre-lubricating oil pump is a separately installed scrow 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*



Max. pressure (safety valve)	350 kPa (3.5 bar)
Design temperature	100°C
Viscosity for dimensioning of the electric motor	500 cSt

Example of required power, oil temperature 40°C.

	6L46F	7L46F	8L46F	9L46F	12V46F	14V46F	16V46F
Pump [kW]	5	6	6	8	10	11.5	11.5
Electric motor [kW]	7.5	7.5	7.5	11	15	15	15

Example of required power, oil temperature 20°C.

	6L46F	7L46F	8L46F	9L46F	12V46F	14V46F	16V46F
Pump [kW]	11	14	14	17	23	17.5	17.5
Electric motor [kW]	15	15	15	18.5	30	22	22

### 7.3.6 Automatic filter (2F02)

When off-engine main filter, 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.

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, approx. 63°C)
Design flow	see <i>Technical data</i> , "Oil flow through engine"
Design temperature	100°C
Design pressure	1.0 MPa (10 bar)
Fineness:	
- automatic filter	35 µm (absolute)
- insert filter	35 µm (absolute)
Max permitted pressure drops at 50 cSt:	
- clean filter	30 kPa (0.3 bar)
- alarm	80 kPa (0.8 bar)

### 7.3.7 Safety filter (2F05)

When off-engine main filter, 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, approx. 63°C)
Design flow	see <i>Technical data</i> , "Oil flow through engine"
Design temperature	100 °C
Design pressure	1.0 MPa (10 bar)

Fineness (absolute) max.	60 µm (mesh size)
Maximum permitted pressure drop at 50 cSt:	
- clean filter	30 kPa (0.3 bar )
- alarm	80 kPa (0.8 bar)

### 7.3.8 Automatic filter, backflush flow (2F13)

When on-engine filter, It is recommended to select an automatic filter with an insert filter in the backflushing line, thus enabling easy changeover to the insert filter during maintenance of the automatic filter. Clean oil from backflush filter can go directly to oil tank. Some backflush filter models operates properly when they have a moderate counterpressure at clean oil discharge, thus these models have a simple pressure regulating valve afterwards.

Backflush filter sludge oil must be discharged to sludge tank, when no further post-filtration occurs. To be re-used, it must be filtered by a sludge cartridge filter before it is conducted back to the system oil tank. The sludge cartridge filter can be either integrated in the automatic filter or separate. A bypass line discharging the oil from on-engine filter directly to tank allows backflush filter maintenance, which should be bypassed for less time as possible.

#### Design data:

Oil viscosity	50 cSt (SAE 40, VI 95, approx. 63°C)
Design flow	17 m <sup>3</sup> /h for Line engines, 25 m <sup>3</sup> /h for Vee engines
Design temperature	100 °C
Design pressure	1.0 MPa (10 bar)
Fineness (absolute) max.	
- automatic filter	34 µm (mesh size), corresponding to approx 50 µm absolute
- sludge cartridge filter	50 µm (absolute)
Maximum permitted pressure drop at 50 cSt:	
- clean filter	30 kPa (0.3 bar )
- alarm	80 kPa (0.8 bar)

## 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.

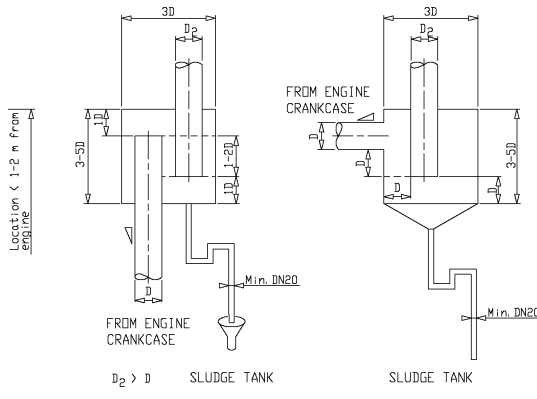
The diameter of the pipe shall be large enough to avoid excessive back pressure. Other possible equipment in the piping must also be designed and dimensioned to avoid excessive flow resistance.

A condensate trap must be fitted on the vent pipe near the engine.

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

**Design data:**

Flow	see <i>Technical data</i>
Backpressure, max.	see <i>Technical data</i>
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). The fineness of the flushing filter and further instructions are found from 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.

### 7.5.3 Type of flushing oil

#### 7.5.3.1 Viscosity

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

#### 7.5.3.2 Flushing with engine oil

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

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

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

### **7.5.3.4 Lubricating oil sample**

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

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

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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)
Max water in air	+3°C (vapour pressure dewpoint)
Max. oil content	1 mg/m <sup>3</sup>
Max. particle size	3 µm

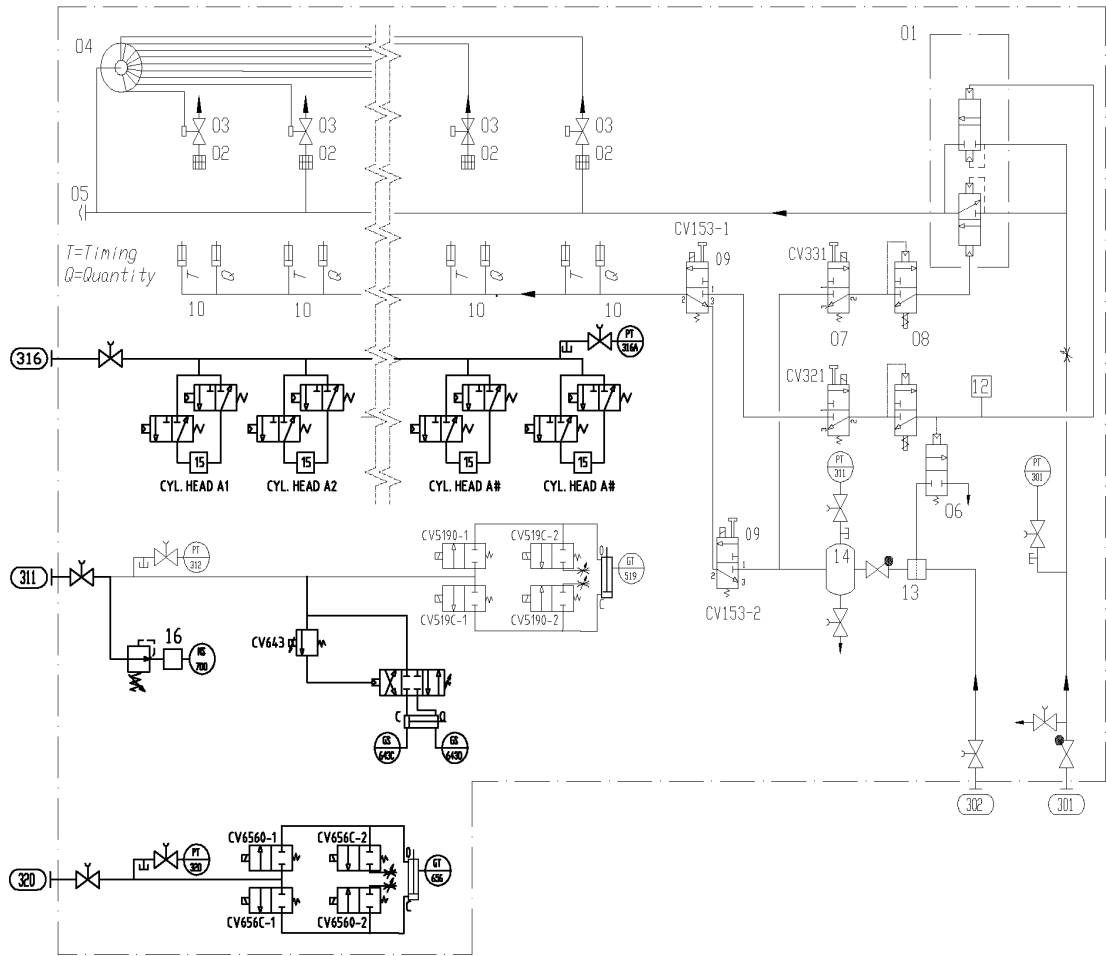
### 8.2 Internal compressed air system

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)
- Oil mist detector



**Fig 8-1 Internal compressed air system, in-line engine (DAAF424886)**

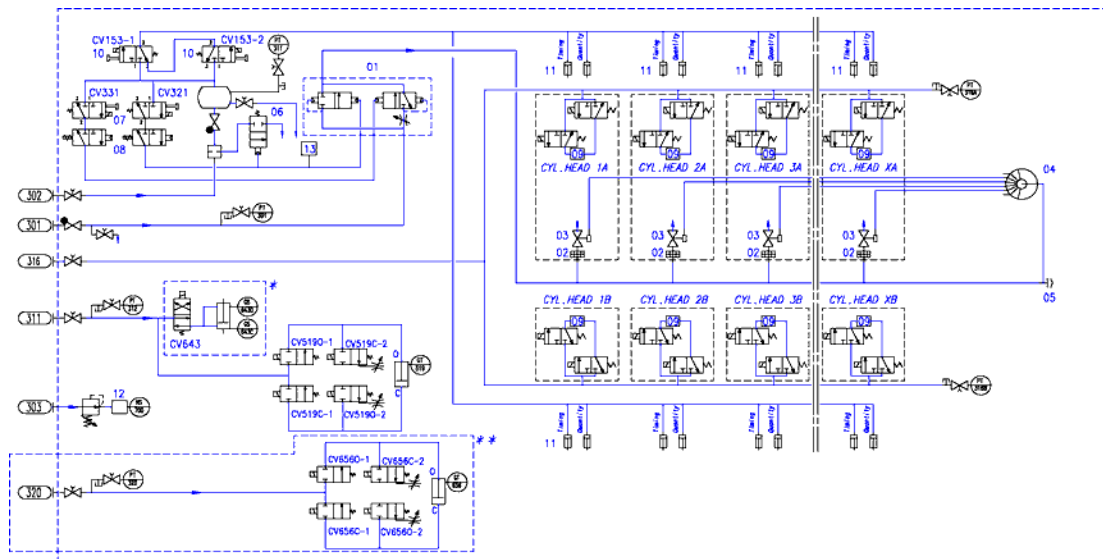
System components			
01	Main starting valve	09	Pilot controlled valves for stopping
02	Flame arrestor	10	Pneumatic stopping cylinders
03	Starting air valve in cylinder head	11	Oil mist detector
04	Starting air distributor	12	Starting booster for governor
05	Bursting disc (break pressure 40 bar)	13	Air filter
06	Valve for automatic draining	14	Air container
07	Starting and slow turning valve	15	Switch valve for twin needle
08	Blocking valve for turning gear	16	Oil mist detector

Sensors and indicators			
CV153-1	Stop/shutdown solenoid valve 1	CV656C-1	Air wastegate valve, close
CV153-2	Stop/shutdown solenoid valve 2	CV656C-2	Air wastegate valve, close
CV321	Starting solenoid valve	CV643	Charge air by-pass valve
CV331	Slow turning solenoid	GS643.O	Charge air by-pass valve position, open
CV5190-1	Exhaust wastegate valve, open	GS643.C	Charge air by-pass valve position, closed
CV5190-2	Exhaust wastegate valve, open	PT301	Starting air pressure, engine inlet
CV519C-1	Exhaust wastegate valve, close	PT311	Control air pressure
CV519C-2	Exhaust wastegate valve, close	PT312	Instrument air pressure



<b>Sensors and indicators</b>			
GT519	Exhaust wastegate valve position	PT320	Air wastegate air pressure, 4-8 BAR
CV6560-1	Air wastegate valve, open	QU700	Oil mist detector
CV6560-2	Air wastegate valve, open	NS700	Oil mist detector failure

<b>Pipe connections</b>	
301	Starting air inlet, 30 bar
302	Control air inlet, 30 bar
303	Driving air to oil mist detector
311	Control air to by-pass/waste-gate valve, 4-8 bar
316	Control air to fuel injection valve, 8 bar
320	Control air to air wastegate valve, 4-8 bar



**Fig 8-2 Internal compressed air system, V-engine (DAAR030690)**

System components			
01	Main starting valve	08	Blocking valve for turning gear
02	Flame arrester	09	Switching valve
03	Starting air valve in cylinder head	10	Pilot controlled valves for stopping
04	Starting air distributor	11	Pneumatic stopping cylinders
05	Bursting disc (break pressure 40 bar)	12	Oil mist detector
06	Valve for automatic draining	13	Starting booster for governor
07	Starting and slow turning valve		

Sensors and indicators			
CV153-1	Stop/shutdown solenoid valve 1	CV519C-2	Exhaust wastegate valve, close
CV153-2	Stop/shutdown solenoid valve 2	GT519	Exhaust wastegate valve position
PT301	Starting air pressure, engine inlet	CV643	Charge air by-pass valve control
PT311	Control air pressure	GS643.O	Charge air by-pass valve position, open
PT312	Instrument air pressure, 4-8 bar	GS643.C	Charge air by-pass valve position, closed
CV321	Starting solenoid valve	GT656	Air wastegate valve position
CV331	Slow turning solenoid	CV6560-1	Air wastegate valve, open
PT320	Air westgate air pressure, 4-8 bar	CV6560-2	Air wastegate valve, open
PT316A/B	Control air pressure, 10 bar A/B bank	CV656C-1	Air wastegate valve, close
CV5190-1	Exhaust wastegate valve, open	CV656C-2	Air wastegate valve, close
CV5190-2	Exhaust wastegate valve, open	NS700	Oil mist detector failure
CV519C-1	Exhaust wastegate valve, close		

Pipe connections	
301	Starting air inlet, 30 bar
302	Control air inlet, 30 bar
303	Driving air to oil mist detector
311	Control air to by-pass/waste-gate valve, 4-8 bar
316	Control air to fuel injection valve, 8 bar

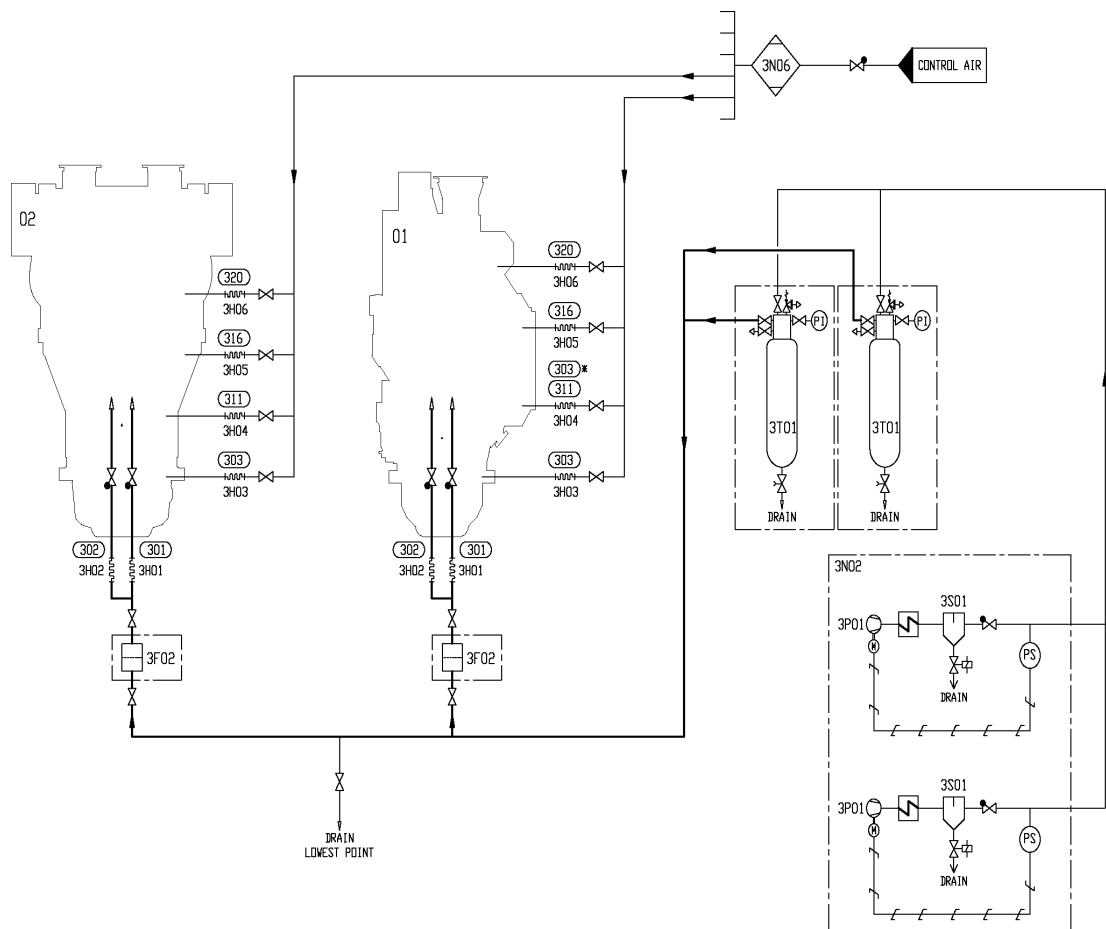
Pipe connections	
320	Control air to air wastegate valve, 4-8 bar
* If variable speed engine or arctic conditions ** if SCR or arctic conditions	

## 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 (DAAF432964)**

System components			
01	Diesel engine WV46F	3N06	Air dryer unit
02	Diesel engine WV46F	3P01	Compressor (Starting air compressor unit)
3H0X	Flexible pipe connection	3S01	Separator (Starting air compressor unit)
3F02	Air filter (starting air inlet)	3T01	Starting air vessel
3N02	Starting air compressor unit		

Pipe connections	
301	Starting air inlet
302	Control air inlet
303	Driving air to oil mist detector

Pipe connections	
311	Control air to by-pass/waste-gate valve
316	Air supply for flushing
320	Instrument air inlet

### 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.

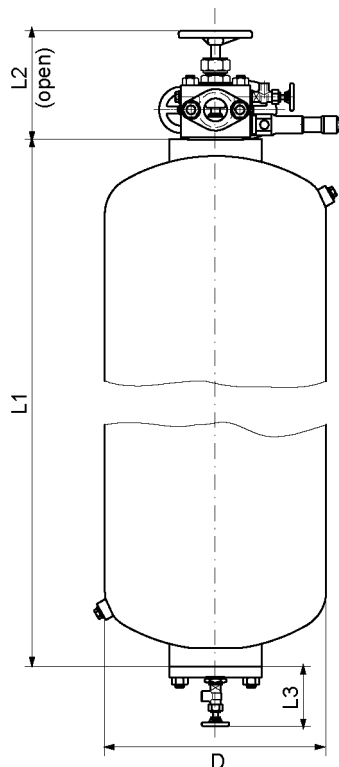
### 8.3.3 Starting air vessel (3T01)

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 <sup>1)</sup>	L3 <sup>1)</sup>	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

<sup>1)</sup> 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:

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

**where:**

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

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

$V_E$  = air consumption per start [Nm<sup>3</sup>] 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

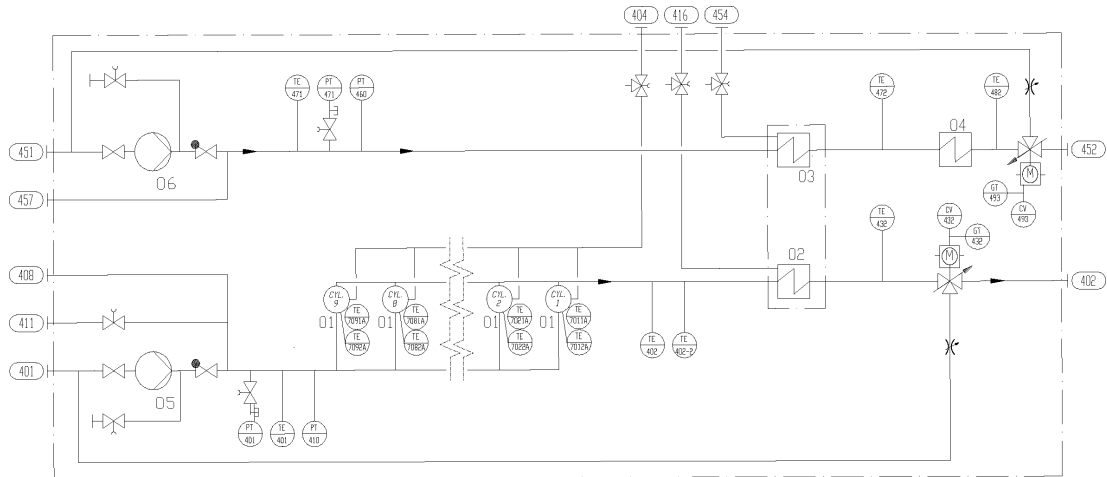
The use of an approved cooling water additive is mandatory. An updated list of approved products is supplied for every installation and it can also be found in the Instruction manual of the engine, together with dosage and further instructions.

#### 9.1.2 Glycol

Use of glycol in the cooling water is not recommended unless it is absolutely necessary. Starting from 20% glycol the engine is to be de-rated 0.23 % per 1% glycol in the water. Max. 60% glycol is permitted.

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

## 9.2 Internal cooling water system



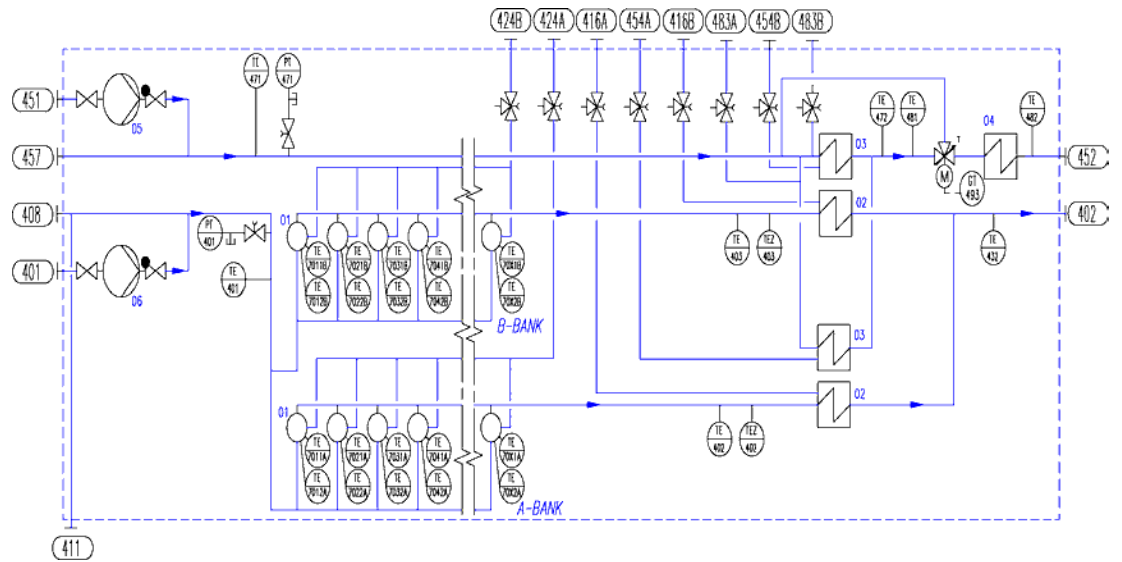
**Fig 9-1 Internal cooling water system, in-line engine (DAAF420187)**

System components			
01	Cylinder head	04	Lubricating oil cooler
02	Charge air cooler (HT)	05	HT water pump (engine driven)
03	Charge air cooler (LT)	06	LT water pump (engine driven)

Sensors and indicators, in-line engines			
PT401	HT-water pressure,jacket inlet	TE482	LT-water temperature, LOC outlet
TE401	HT-water temperature, jacket inlet	TE01A91A	Liner temperature 1, CYL A01...A09
TE402	HT-water temperature, jacket outlet	TE02A92A	Liner temperature 2, CYL A01...A09
TE432	HT-water temperature, HT CAC outlet	PT460	LT water pressure stand by-pump
TE402-2	External thermostatic valve control	PT410	HT water pressure stand by-pump
PT471	LT-water pressure, LT CAC inlet	CV432	HT cooling water thermostat control
TE471	LT-water temperature, LT CAC inlet	GT 432	HT cooling water thermostat position
TE472	LT-water temperature, LT CAC outlet		

Pipe connections, in-line engines	
401	HT-water inlet
402	HT-water outlet
404	HT water air vent
406	HT water preheating
408	HT-water from stand-by pump
411	HT-water drain
416	HT-water air vent from air cooler
451	LT water inlet
452	LT water inlet
454	LT-water air vent form air cooler
457	LT-water from stand-by pump





**Fig 9-2 Internal cooling water system, V-engine (DAAR01165B)**

System components, in-line engines			
01	Cylinder head	04	Lubricating oil cooler
02	Charge air cooler (HT)	05	LT water pump (engine driven)
03	Charge air cooler (LT)	06	HT water pump (engine driven)

Sensors and indicators, in-line engines			
PT401	HT-water pressure,engine inlet	PT471	LT-water pressure, CAC inlet
TE401	HT-water temperature, engine inlet	TE472	LT-water temperature, LT CAC outlet
TE402	HT-water temperature, jacket outlet (A-bank)	TE471	LT water temperature, CAC inlet
TEZ402	HT-water temperature, jacket outlet (A-bank)	TE481	LT water temperature, LOC inlet
TE403	HT-water temperature, jacket outlet (B-bank)	TE482	LT-water temperature, LOC outlet
TEZ403	HT-water temperature, jacket outlet (B-bank)	TE01AXA	Liner temperature 01 of cylinder (A-bank)
PS410	HT- stand-by pump start	TE02AXA	Liner temperature 02 of cylinder (A-bank)
TE01AXB	Liner temperature 01 of cylinder (B-bank)	GT493	LT-water thermostat valve position
TE02AXB	Liner temperature 02 of cylinder (B-bank)	x	Number of cylinders
TE432	HT-water temperature, CAC outlet		

Pipe connections, in-line engines	
401	HT-water inlet
402	HT-water outlet
408	HT-water from stand-by pump
411	HT-water drain
416	HT-water air vent from air cooler
424	HT-water air vent from exhaust valve seat and cylinder head
451	LT-water inlet

Pipe connections, in-line engines	
452	LT-water outlet
454	LT-water air vent from air cooler
457	LT-water from stand by pump
483	LT-water air vent

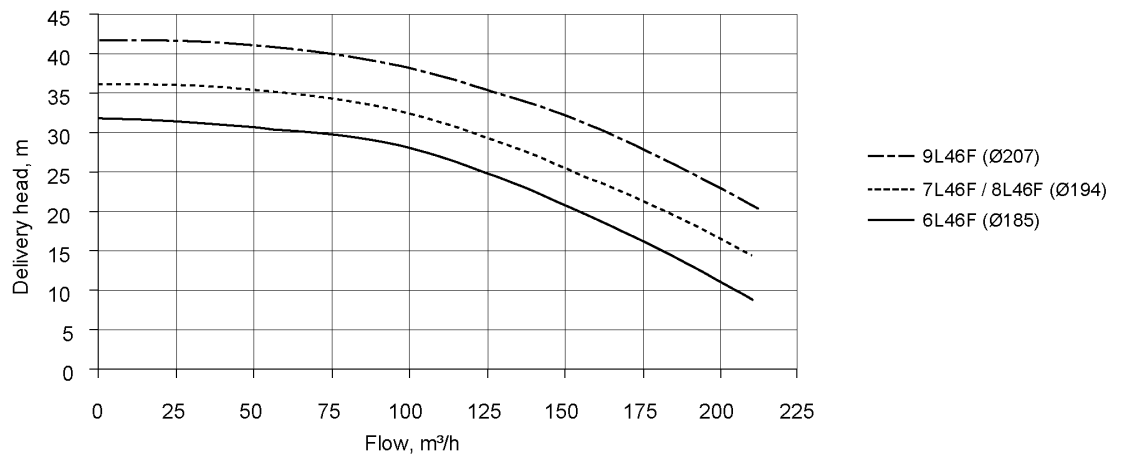
The fresh water cooling system is divided into a high temperature (HT) and a low temperature (LT) circuit. The HT water circulates through cylinder jackets, cylinder heads and the 1st stage of the charge air cooler. The HT water passes through the cylinder jackets before it enters the HT-stage of the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

The cooling water temperature after the cylinder heads is controlled in the HT circuit, 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.

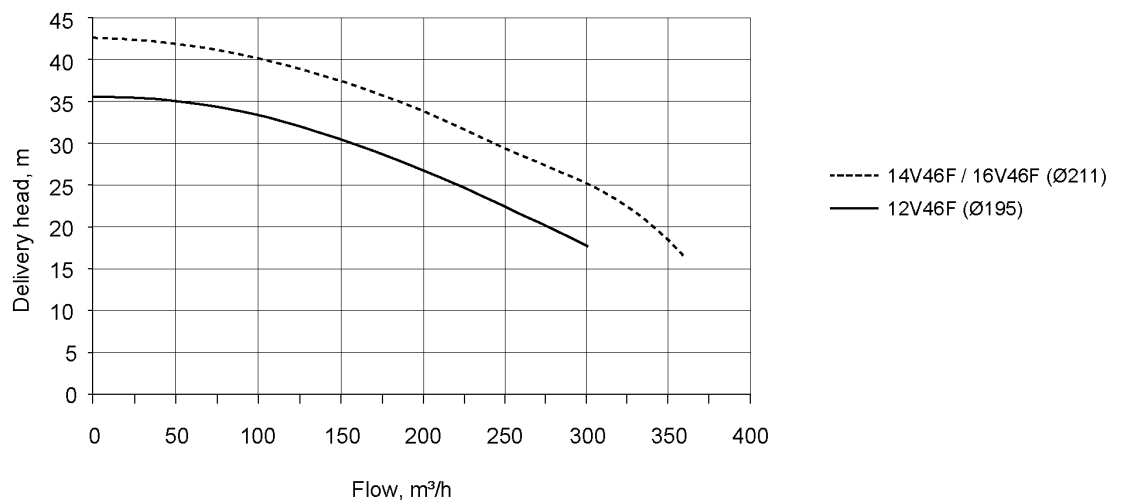
### 9.2.1 Engine driven circulating pumps

The LT and HT cooling water pumps are usually engine driven. In some installations it can however be desirable to have separate LT pumps, and therefore engines are also available without built-on LT/HT pump. Engine driven pumps are located at the free end of the engine. Connections for stand-by pumps are available with engine driven pumps (option).

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



**Fig 9-3 L46F engine driven HT- and LT-pumps**



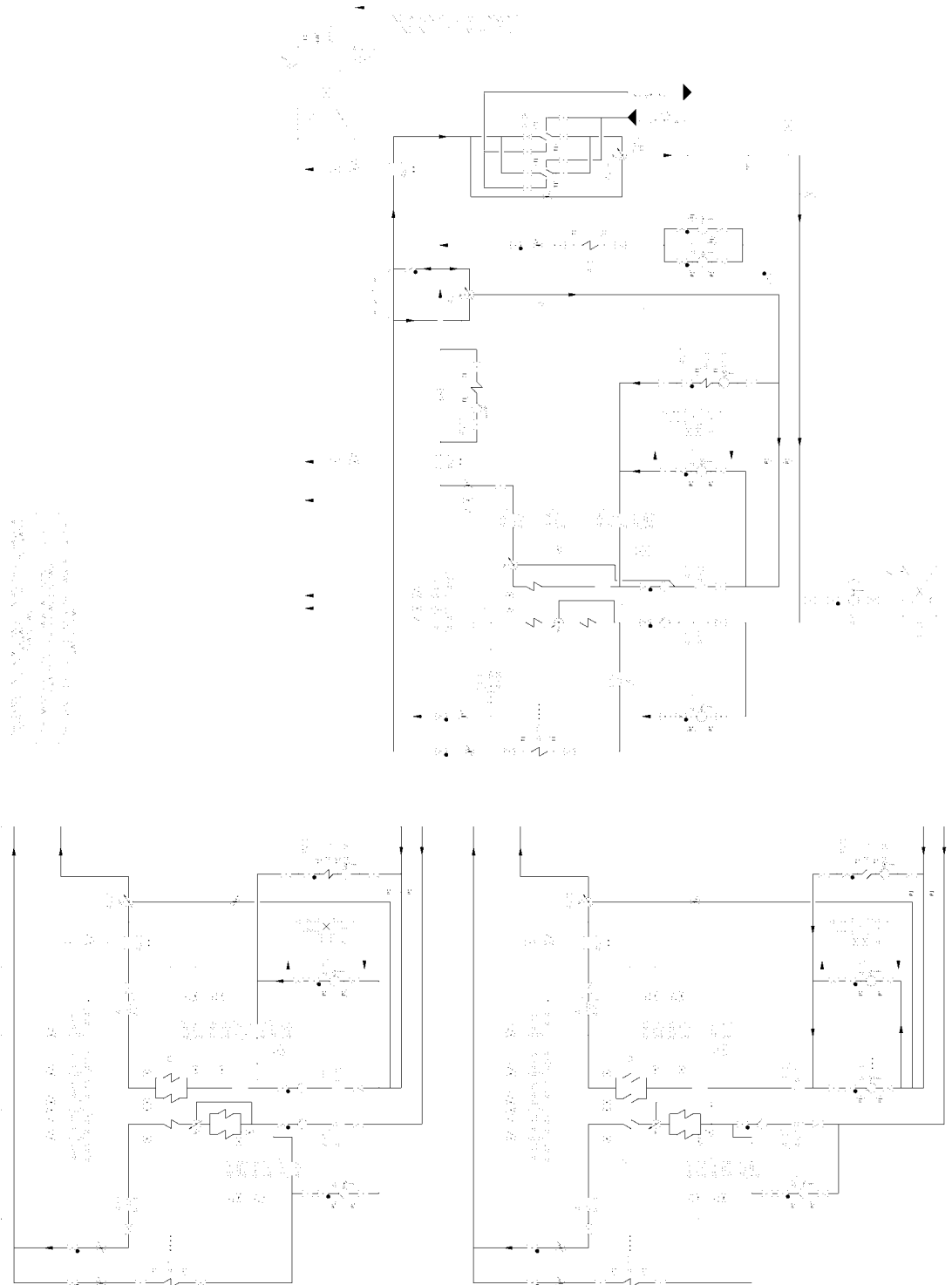
**Fig 9-4 V46F engine driven HT- and LT-pump**

## 9.3 External cooling water system

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

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

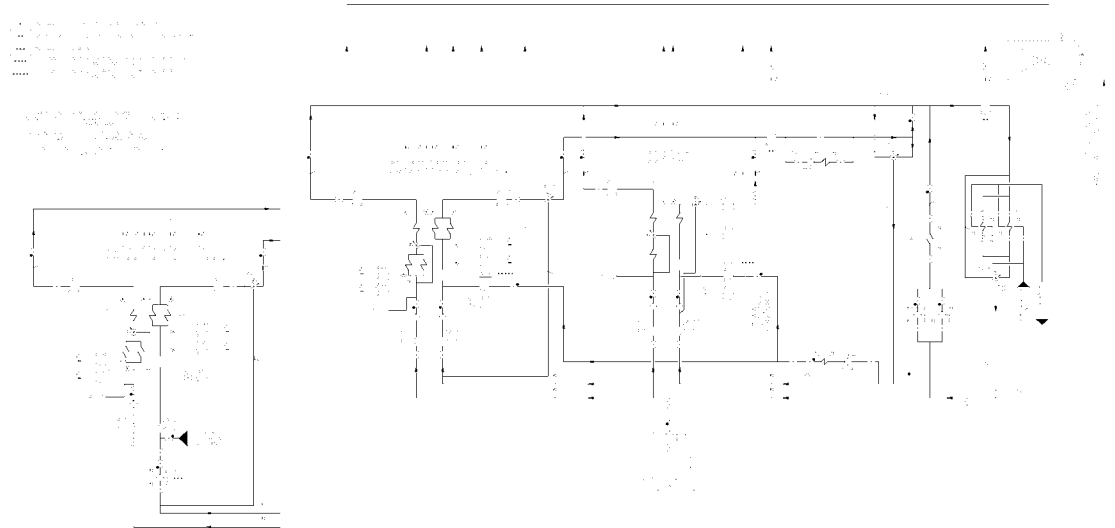


**Fig 9-5 External cooling water system (DAAF424312)**

System components			
4E05	Heater (pre-heating unit)	4P09	Transfer pump
4E08	Central cooler	4P14 / 4P15	Circulation pump (HT) / (LT)
4E12	Cooler (installation equipment)	4S01	Air venting
4H0X	Flexible pipe connections	4T03	Additive dosing tank
4N01	Pre-heating unit	4T04	Drain tank
4N02	Evaporator unit	4T05	Expansion tank

System components			
4P03	Stand-by pump (HT)	4V02	Temperature control valve (heat recovery)
4P04	Circulation pump (preheater)	4V08	Temperature control valve (central cooler)
4P05	Stand-by pump (LT)		
*	In case of turbocharger at driving end	**	Install at the highest point in the piping system
***	In case of W14V46DF	****	Alternative location with oversized pump

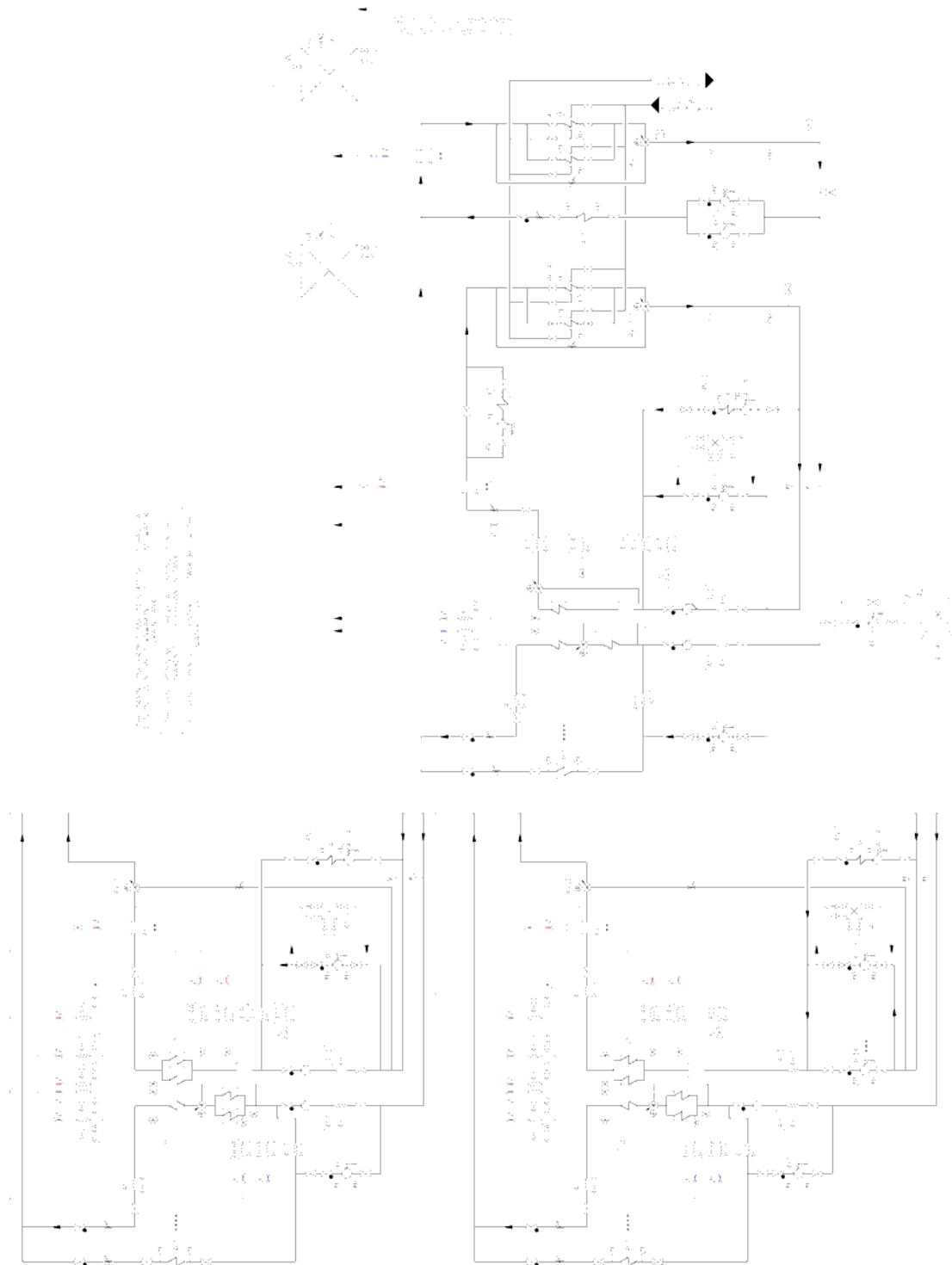
Pipe connections			
401	HT-water inlet	451	LT-water inlet
402	HT-water outlet	452	LT-water outlet
404	HT-water air vent	454	LT-water air vent from air cooler
406	HT- water from preheater to HT-circuit	457	LT-water from stand-by pump
408	HT-water from stand-by pump	483	LT-water air vent
411	HT-water drain		
416	HT-water air vent from air cooler		



**Fig 9-6 External cooling water system ( DAAF424313)**

System components			
4E05	Heater (preheater)	4P14 / 4P15	Circulating pump (HT) / (LT)
4E08	Central cooler	4S01	Air venting
4E12	Cooler (installation equipment)	4T03	Additive dosing tank
4H0X	Flexible pipe connections	4T04	Drain tank
4N01	Pre-heating unit	4T05	Expansion tank
4N02	Evaporator unit	4V01	Temperature control valve (HT)
4P04	Circulation pump (preheater)	4V02	Temperature control valve (heat recovery)
4P09	Transfer pump	4V08	Temperature control valve (central cooler)

Pipe connections			
401	HT-water inlet	451	LT-water inlet
402	HT-water outlet	452	LT-water outlet
404	HT-water air vent	454	LT-water air vent from air cooler
406	HT-water from preheater to HT-circuit	457	LT-water air vent from stand-by pump
408	HT-water from stand by pump	483	LT-water air vent
411	HT-water drain		
416	HT-water air vent from air cooler		



**Fig 9-7 External cooling water system (DAAF424314)**

The drain line from connection 411 should have a continuous slope downwards to the cooling water drain tank.

The vent pipes should have a continuous slope upwards to the expansion tank.

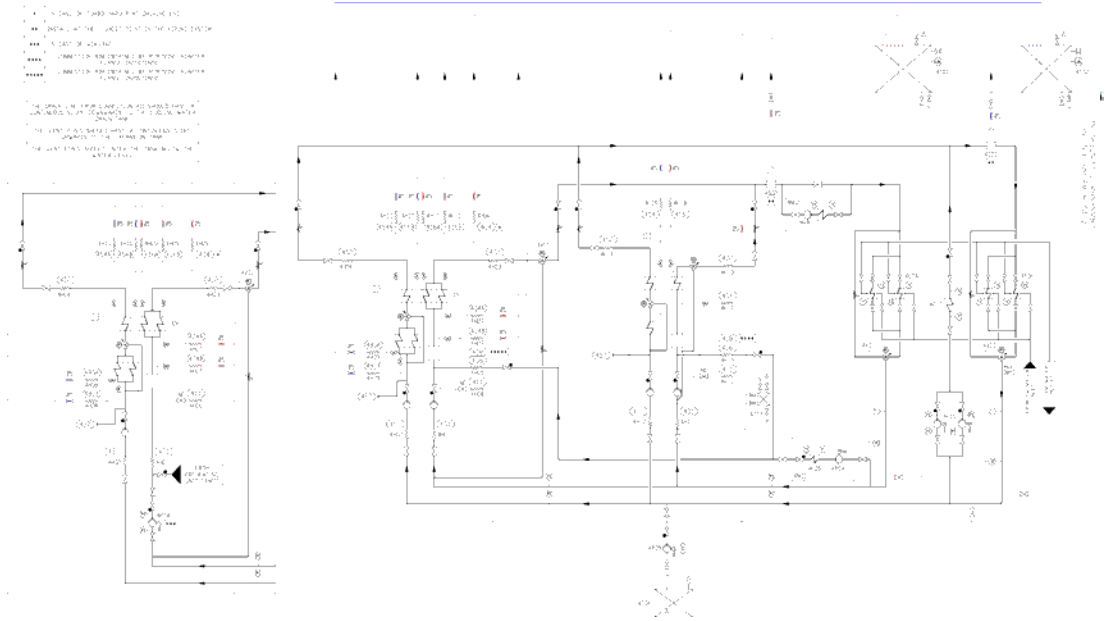
The vent pipes should enter the tank below the water level.

System components			
4E04	Raw water cooler (HT)	4P09	Transfer pump



System components			
4E05	Heater (preheater)	4P14 / 4P15	Circulating pump (HT) / (LT)
4E06	Raw water cooler (LT)	4S02 / 4S03	Air dearator (HT) / (LT)
4H0X	Flexible pipe connections	4T01 / 4T02	Expansion tank (HT) / (LT)
4E12	Cooler (installation equipment)	4T03	Additive dosing tank
4N01	Pre-heating unit	4T04	Drain tank
4N02	Evaporator unit	4V01	Temperature control valve (HT)
4P03	Stand by pump (HT)	4V01-1	Temperature control valve (HT)
4P04	Circulation pump (preheater)	4V03	Temperature control valve (LT)
4P05	Stand by pump (LT)		

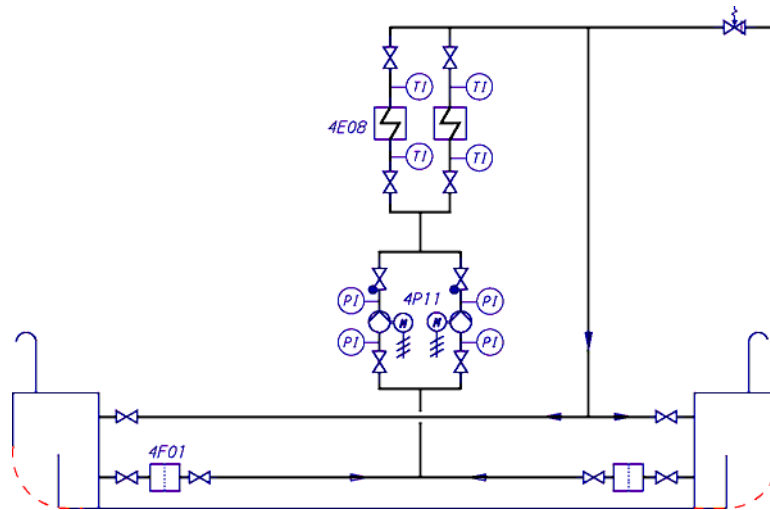
Pipe connections			
401	HT-water inlet	451	LT-water inlet
402	HT-water outlet	452	LT-water outlet
404	HT-water air vent	454	LT-water air vent from air cooler
406	HT-water from preheater to HT-circuit	457	LT-water from stand by pump
408	HT-water from stand by pump	483	LT-water air vent
411	HT-water drain		
416	HT-water air vent from air cooler		



**Fig 9-8 External cooling water system (DAAF424315)**

System components			
4E08	Central cooler	4S01	Air venting
4E10	Cooler (reduction gear)	4T03	Additive dosing tank
4E12	Cooler (installation equipment)	4T04	Drain tank
4N01	Preheating unit	4T05	Expansion tank
4N02	Evaporator unit	4V01	Temperature control valve (HT)
4P06	Circulating pump	4V02	Temperature control valve (heat recovery)
4P09	Transfer pump	4V08	Temperature control valve (central cooler)

Pipe connections			
401	HT-water inlet	424	HT-water air vent from exhaust valve seat
402	HT-water outlet	451	LT-water inlet
404	HT-water air vent	452	LT-water outlet
406	Water to preheater to HT-circuit	454	LT-water air vent from air cooler
411	HT-water drain	483	LT-water air vent
416	HT-water air vent from air cooler		



**Fig 9-9 Sea water system DAAE020523**

System components	
4E08	Central cooler
4F01	Suction strainer (sea water)
4P11	Circulation pump (sea water)

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
- 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.

### 9.3.1 Electrically driven HT and LT circulation pumps (4P03, 4P05, 4P14, 4P15)

Electrically driven pumps should be of centrifugal type. Required capacities and delivery pressures for stand-by pumps are stated in *Technical data*.

In installations without engine driven LT pumps, several engines can share a common LT circulating pump, also together with other equipment such as reduction gear, generator and compressors. When such an arrangement is preferred and the number of engines in operation varies, significant energy savings can be achieved with frequency control of the LT pumps.

#### Note

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

### 9.3.2 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.

### 9.3.3 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.

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

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

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

### 9.3.5 Coolers for other equipment and MDF coolers

The engine driven LT circulating pump can supply cooling water to one or two small coolers installed in parallel to the engine 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*.

### 9.3.6 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.

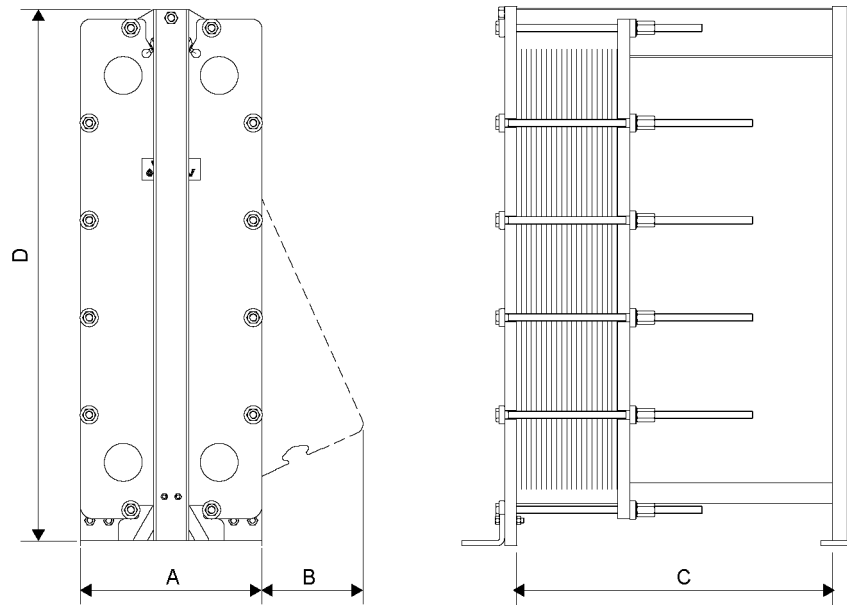
If the system layout is according to one of the example diagrams, then the flow capacity of the cooler should be equal to the total capacity of the LT circulating pumps in the circuit. The flow may be higher for other system layouts and should be calculated case by case.

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 <i>Technical Data</i>
Heat to be dissipated	see chapter <i>Technical Data</i>
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 9-10 Central cooler main dimensions. Example for guidance only**

Engine type	A [mm]	C [mm]	D [mm]	Weight [kg]
6L46F	690	1005	2149	860
7L46F	690	1005	2149	900
8L46F	690	1005	2149	900
9L46F	690	1255	2149	960
12V46F	690	1255	2149	990
14V46F	690	1505	2149	1120
16V46F	690	1505	2149	1120

### 9.3.7 Waste heat recovery

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

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

### 9.3.8 Air venting

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

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

The vent pipes must be continuously rising.

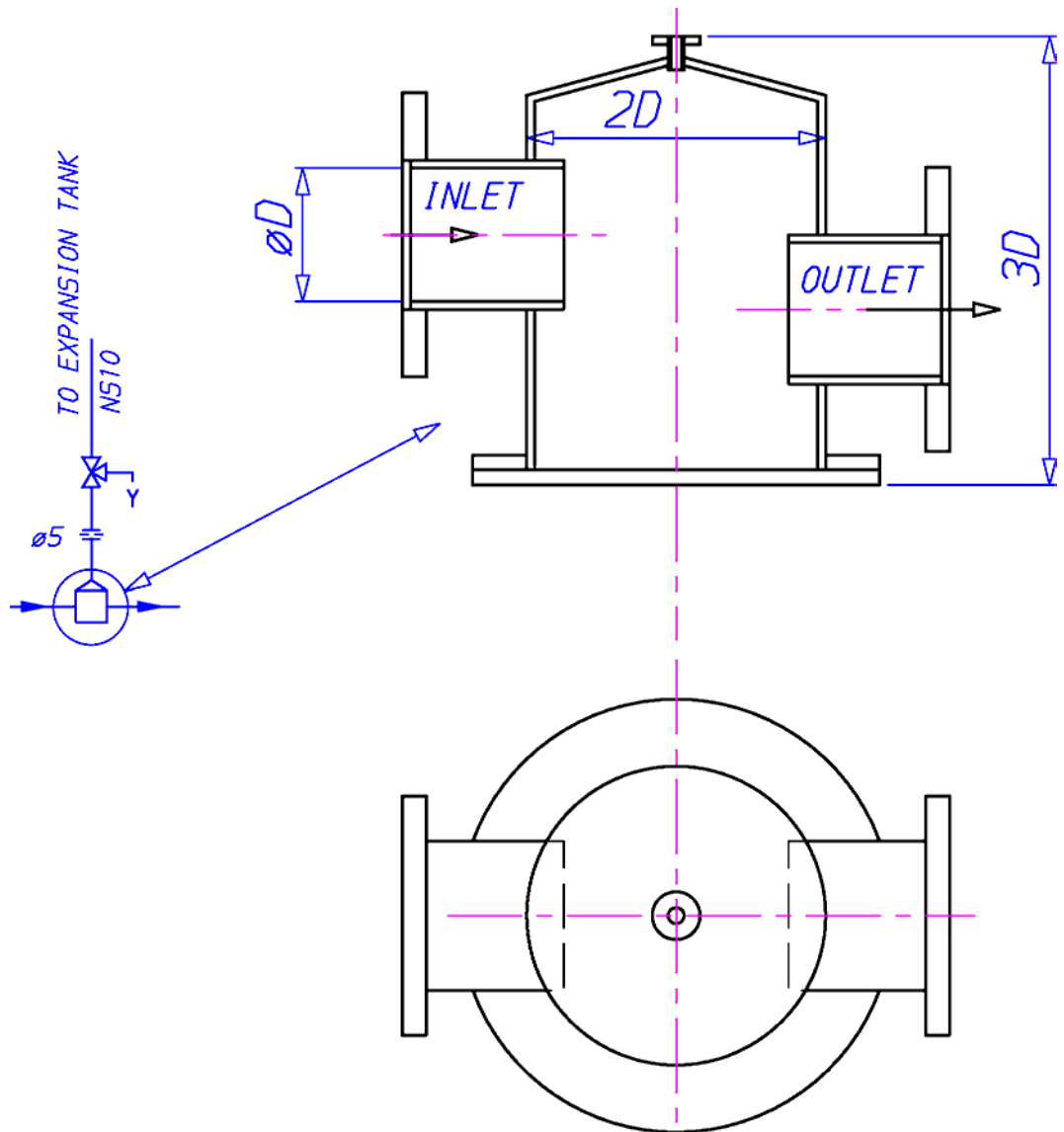


Fig 9-11 Example of air venting device (V60D0343)

### 9.3.9 Expansion tank (4T05)

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

**Design data:**

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

**NOTE**

**i** 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.

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

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

Nominal pipe size	Max. flow velocity (m/s)	Max. number of vent pipes with $\varnothing$ 5 mm orifice
DN 40	1.2	6
DN 50	1.3	10
DN 65	1.4	17
DN 80	1.5	28

### 9.3.10 Drain tank (4T04)

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

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

### 9.3.11 Additive dosing tank (4T03)

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

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

### 9.3.12 HT 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.

#### 9.3.12.1 HT heater (4E05)

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



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

The minimum required heating power is 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 for starts at LFO; Min 70°C for startings at HFO
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:

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

where:

P =	Preheater output [kW]
T <sub>1</sub> =	Preheating temperature = 60...70 °C
T <sub>0</sub> =	Ambient temperature [°C]
m <sub>eng</sub> =	Engine weight [ton]
V <sub>FW</sub> =	HT water volume [m <sup>3</sup> ]
t =	Preheating time [h]
k <sub>eng</sub> =	Engine specific coefficient = 3 kW
n <sub>cyl</sub> =	Number of cylinders

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

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

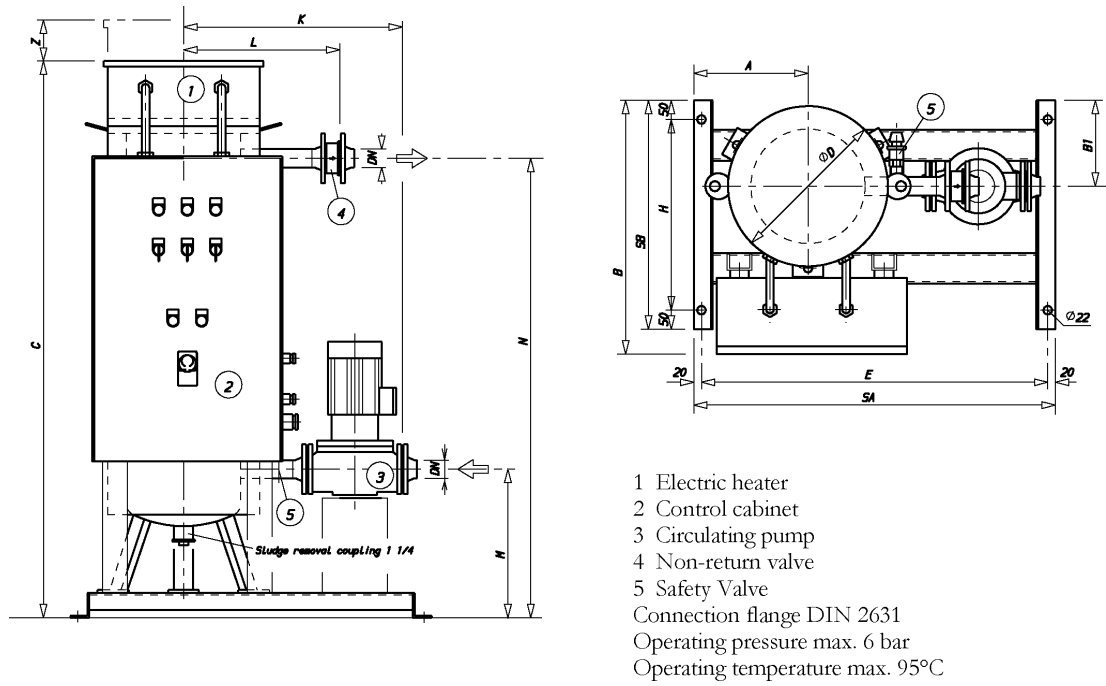
**Design data:**

Capacity	1.6 m <sup>3</sup> /h per cylinder
Delivery pressure	80...100 kPa (0.8...1.0 bar)

### 9.3.12.3 Preheating unit (4N01)

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

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



**Fig 9-12 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*

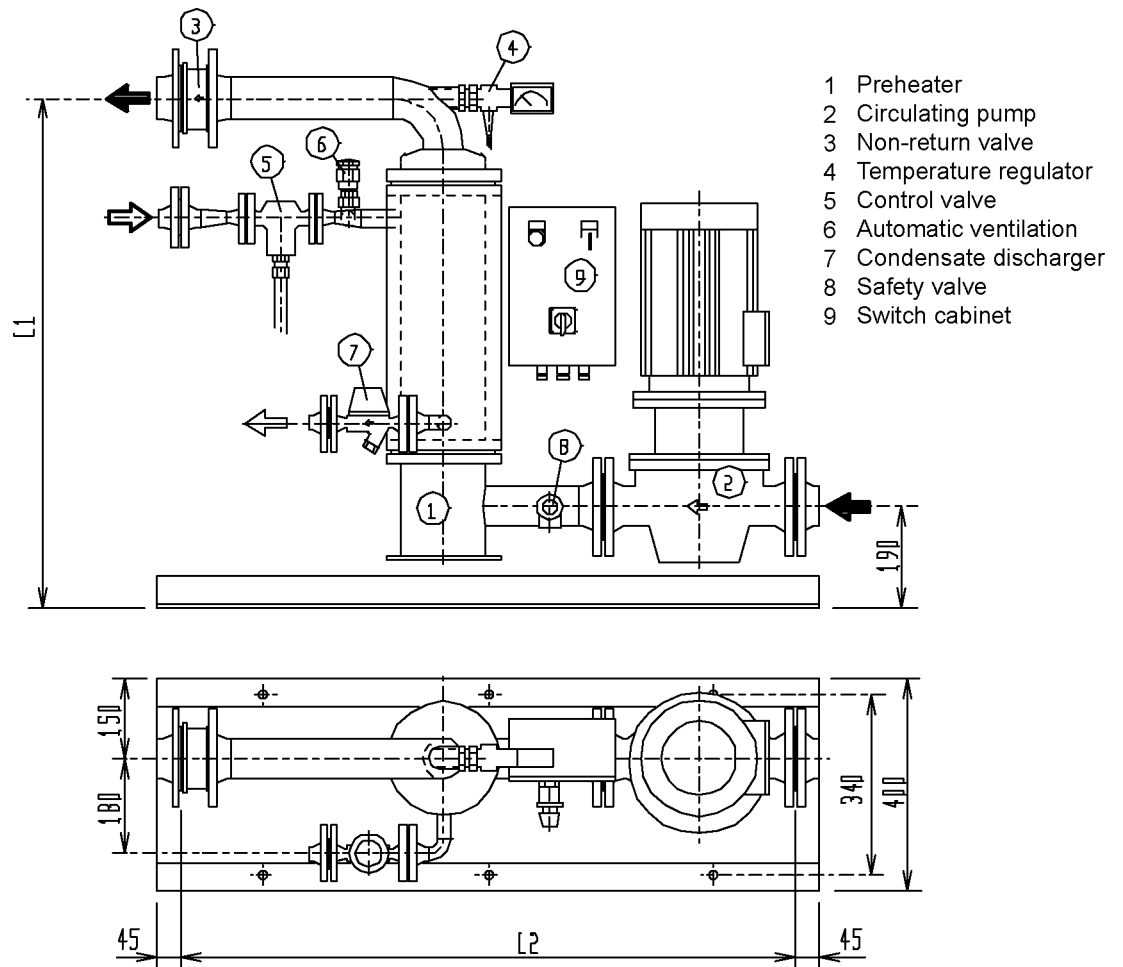


Fig 9-13 Example of preheating unit, steam

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

### 9.3.13 Throttles

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

### **9.3.14 Thermometers and pressure gauges**

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

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

## 10. Combustion Air System

### 10.1 Engine room ventilation

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

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

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

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

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

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

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

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

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

**where:**

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

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

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

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

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

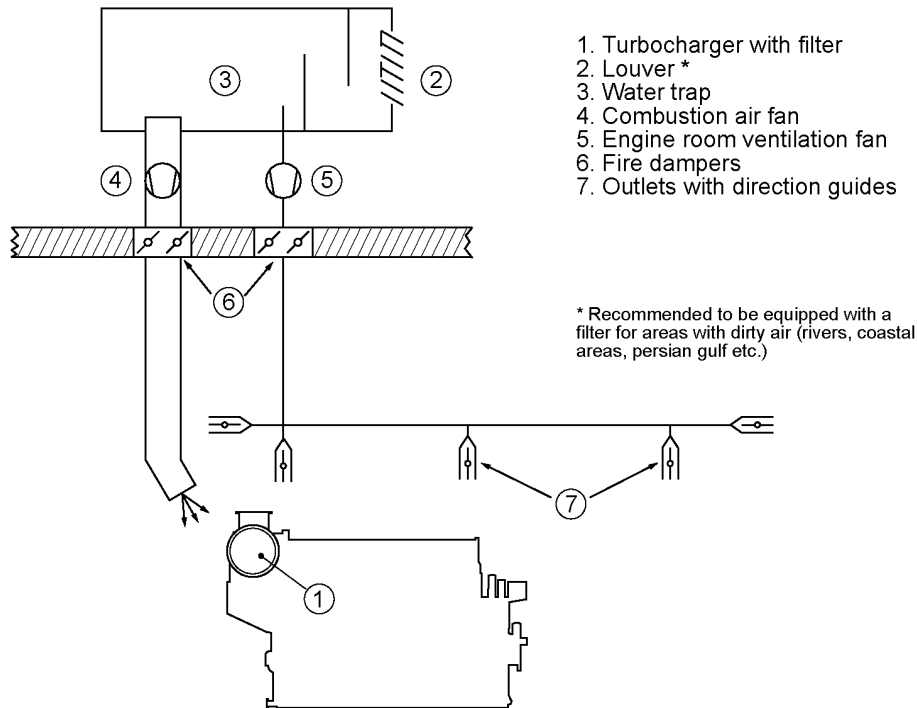
The heat emitted by the engine is listed in chapter *Technical data*.

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).

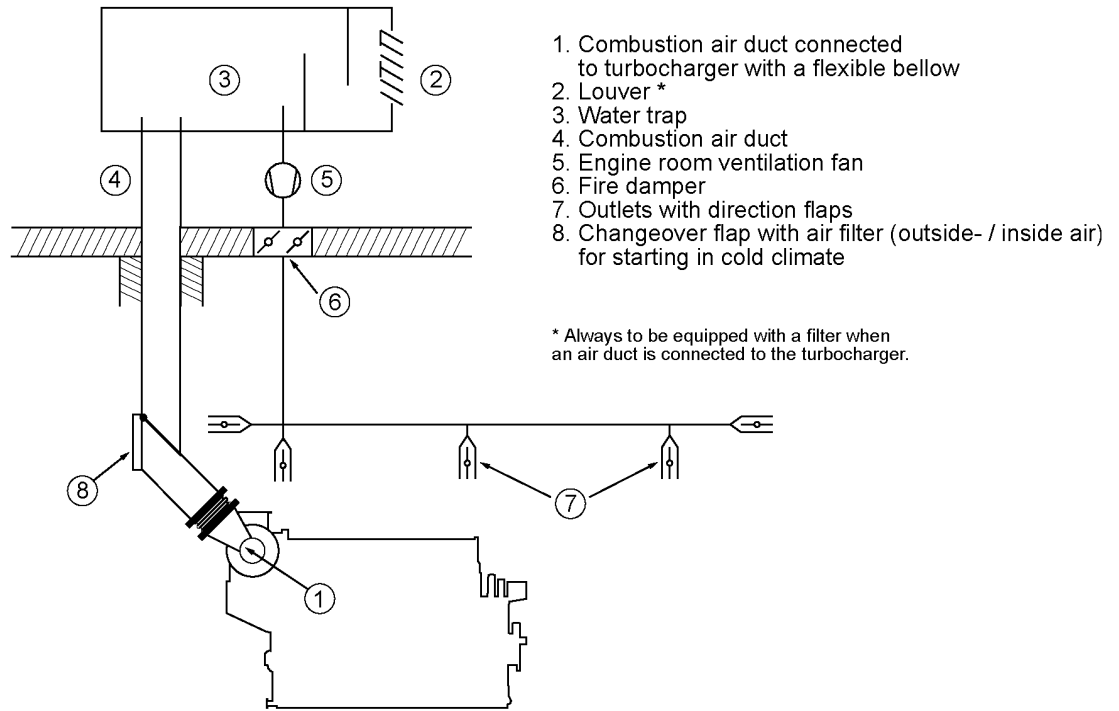
The ventilation air is to be equally distributed in the engine room considering air flows from points of delivery towards the exits. This is usually done so that the funnel serves as exit for most of the air. To avoid stagnant air, extractors can be used.

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.



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



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

## 10.2 Combustion air system design

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

For the required amount of combustion air, 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 [m<sup>3</sup>/s]

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

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

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

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

The combustion air should be delivered through a dedicated duct close to the turbocharger, directed towards the turbocharger air intake. The outlet of the duct should be equipped with

a flap for controlling the direction and amount of air. Also other combustion air consumers, for example other engines, gas turbines and boilers shall be served by dedicated combustion air ducts.

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

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

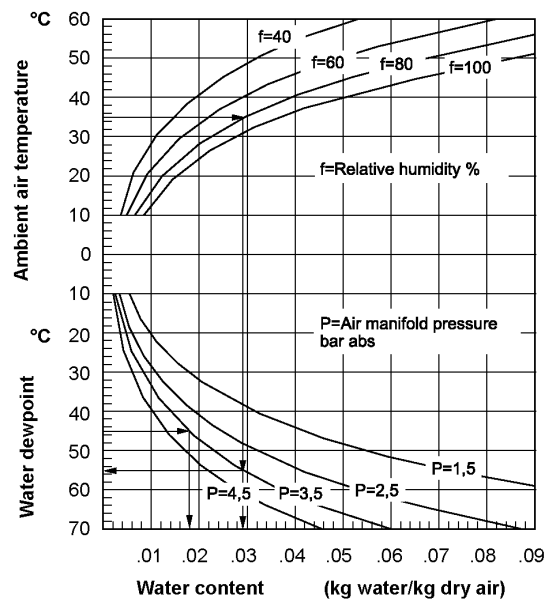
### 10.2.1 Condensation in charge air coolers

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.

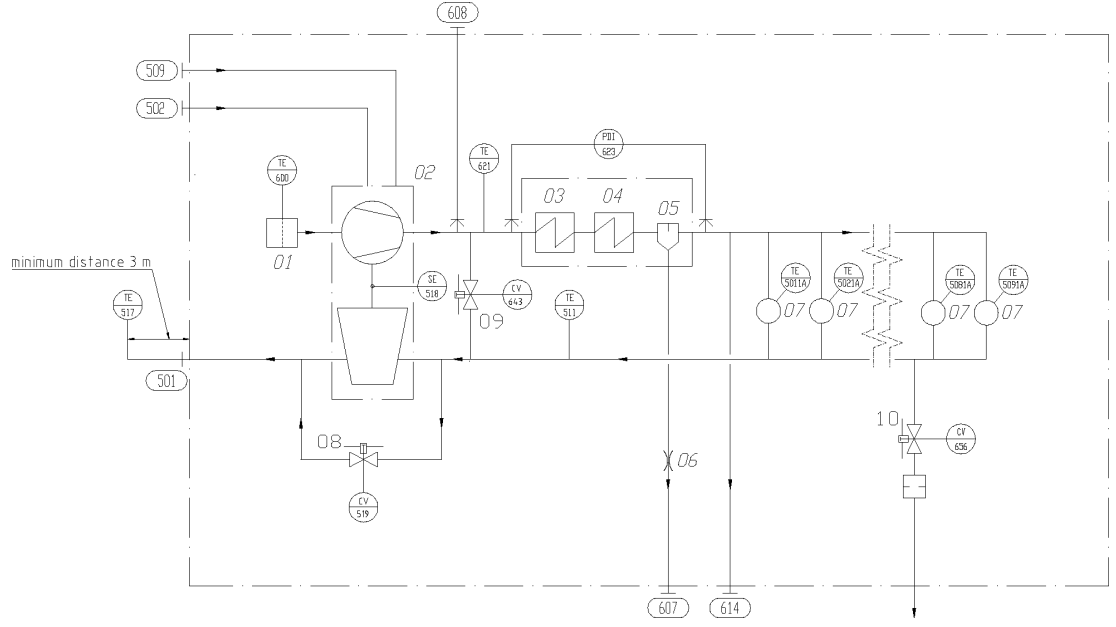


**Fig 10-3 Condensation in charge air coolers**



# 11. Exhaust Gas System

## 11.1 Internal exhaust gas system

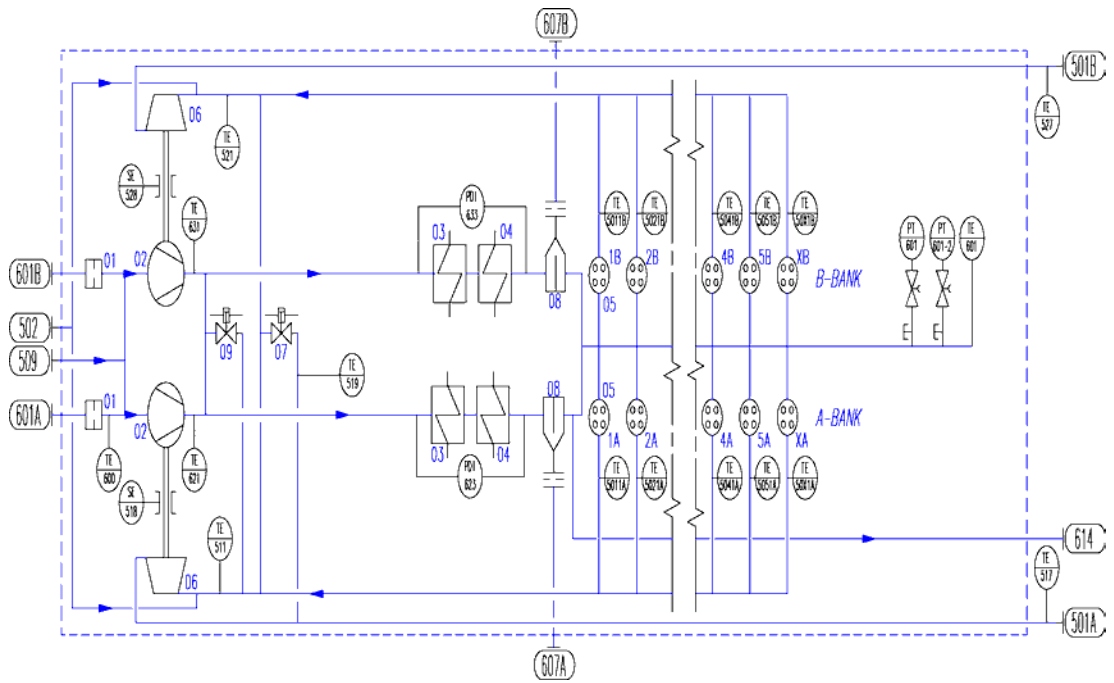


**Fig 11-1 Charge air and exhaust gas system, in-line engines (DAAF422688)**

System components			
01	Air filter	06	Orifice
02	Turbocharger	07	Cylinder head
03	Charge air cooler (HT)	08	Exhaust waste gate valve
04	Charge air cooler (LT)	09	By pass valve
05	Water mist catcher	10	Air waste gate valve

Sensors and indicators			
TE600	Air temperature, TC inlet	CV 656	Air waste gate
TE621	Charge air temperature, CAC inlet	TE50_1A	Exhaust gas temp for CYL_A
PDI623	CAC pressure difference (separate tool)	TE511	Exhaust gas temp TC inlet
CV519	Exhaust wastegate	TE517	Exhaust gas temp TC outlet
CV643	By-pass valve	SE518	TC Speed

Pipe connections	
501	Exhaust gas outlet
502	Cleaning water to turbine
509	Cleaning water to compressor
607	Condensate after air cooler
608	Cleaning water to CAC
614	Scavenging air outlet to TC cleaning valve unit



**Fig 11-2 Charge air and exhaust gas system, V-engines (DAAR011167)**

System components			
01	Air filter	06	Turbine
02	Compressor	07	Wastegate valve (CV519)
03	Charge air cooler (HT)	08	Water mist catcher
04	Charge air cooler (LT)	09	By-pass valve (CV643)
05	Cylinders		

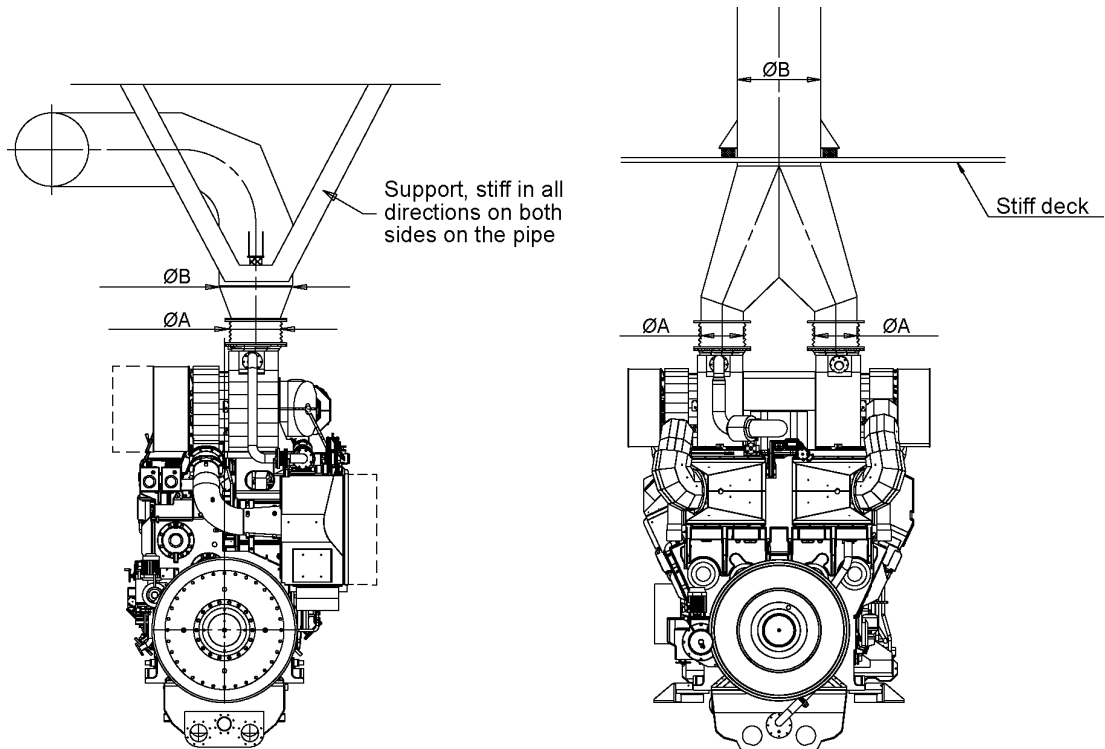
Sensors and indicators			
TE511	Exhaust gas temperature, TC inlet (A-bank)	TE5011B / TE50X1B	Exhaust gas temperature after cylinder head (B-bank)
PT601-2	Charge air pressure, engine inlet	PT601	Charge air pressure, engine inlet
TE517	Exhaust gas temperature, TC outlet (A-bank)	TE601	Charge air temperature, engine inlet
SE518	Turbocharger A speed	PDI623	Pressure difference over CAC (transportable) (A-bank)
TE519	Exhaust gas temperature after wastegate	TE621	Charge air temperature, CAC inlet (A-bank)
TE521	Exhaust gas temperature, TC inlet (B-bank)	PDI623	CAC pressure difference, A-bank
TE600	Air temperature, TC inlet	TE631	Charge air temperature, CAC inlet (B-bank)
TE527	Exhaust gas temperature, TC outlet (B-bank)	PDI633	Pressure difference over CAC (transportable) (B-bank)
SE528	Turbocharger B speed		x = cylinder number
TE5011A / TE50X1A	Exhaust gas temperature after cylinder head (A-bank)		

Pipe connections		Size
501A	Exhaust gas outlet, A-bank	DN600
501B	Exhaust gas outlet, B-bank	DN600
502	Cleaning water to turbine	DN32
509	Cleaning water to compressor	OD18
601A	Air inlet to turbocharger, A-bank	
601B	Air inlet to turbocharger, B-bank	

Pipe connections		Size
607A	Condensate water after charge air cooler, A-bank	OD22
607B	Condensate water after charge air cooler, B-bank	OD22
614	Scavenging air outlet to TC cleaning valve unit	OD18

## 11.2 Exhaust gas outlet

Exhaust gas outlet pipe connection is available with 0° orientation for all engine configurations. Exhaust gas outlet pipe connection with 45° degree orientation is achievable with additional bellows.



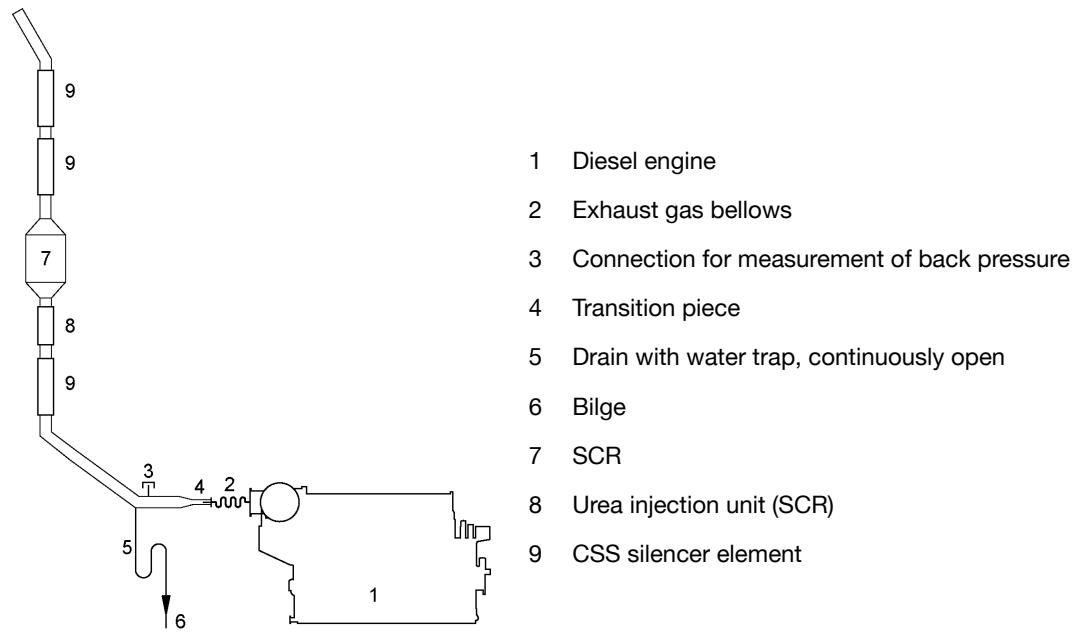
**Fig 11-3 Exhaust pipe, diameters and support (DAAE048775B, DAAE075828A)**

Engine type	TC type	ØA [mm]	ØB [mm]
6L46F	TPL 71C	DN600	DN900
7L46F	TPL 76C	DN800	DN1000
8L46F	TPL 76C	DN800	DN1000
9L46F	TPL 76C	DN800	DN1100
12V46F	TPL 71C	2 x DN600	DN1300
14V46F	TPL 76C	2 x DN800	DN1400
16V46F	TPL 76C	2 x DN800	DN1500

## 11.3 External exhaust gas system

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

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



**Fig 11-4 External exhaust gas system**

### 11.3.1 Piping

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

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.

### 11.3.2 Supporting

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

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

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

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

### 11.3.3 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.

### 11.3.4 Exhaust gas bellows (5H01, 5H03)

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

### 11.3.5 SCR-unit (11N14)

The SCR-unit requires special arrangement on the engine in order to keep the exhaust gas temperature and backpressure into SCR-unit working range. The exhaust gas piping must be straight at least 3...5 meters in front of the SCR unit. If both an exhaust gas boiler and a SCR unit will be installed, then the exhaust gas boiler shall be installed after the SCR. Arrangements

must be made to ensure that water cannot spill down into the SCR, when the exhaust boiler is cleaned with water.

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

### **11.3.6 Exhaust gas boiler**

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

For dimensioning the boiler, the exhaust gas quantities and temperatures given in chapter *Technical data* may be used.

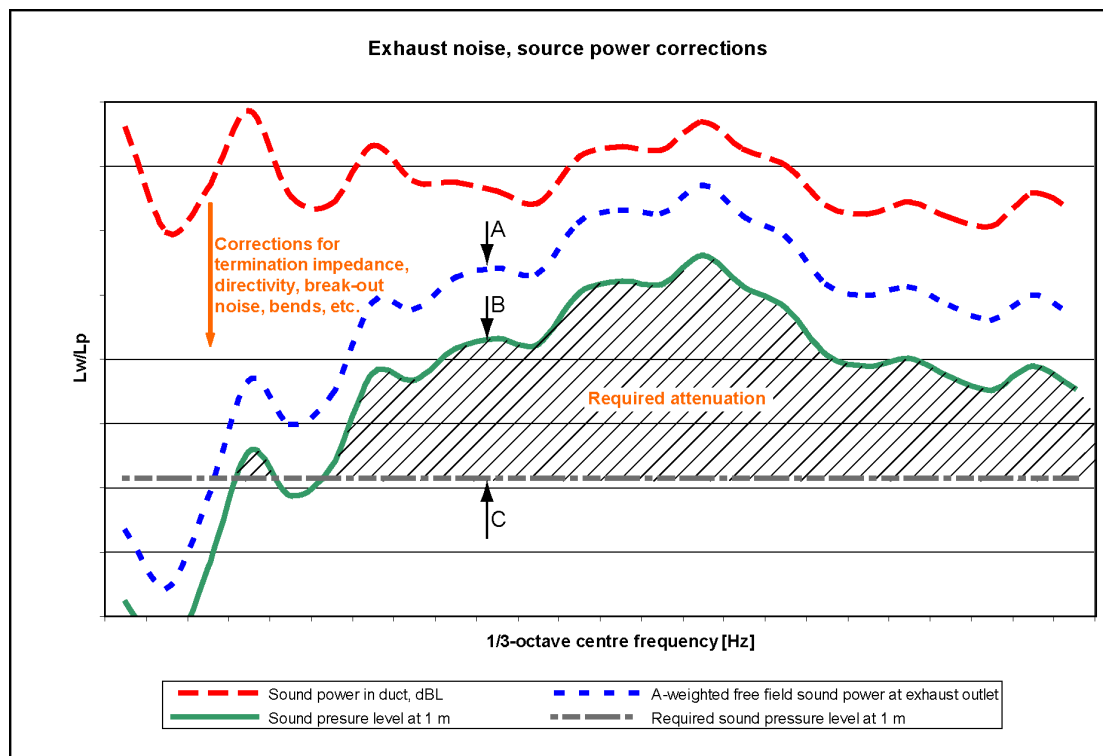
## 11.3.7 Exhaust gas silencers

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

### 11.3.7.1 Exhaust noise

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

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



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

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



### 11.3.7.2 Silencer system comparison

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

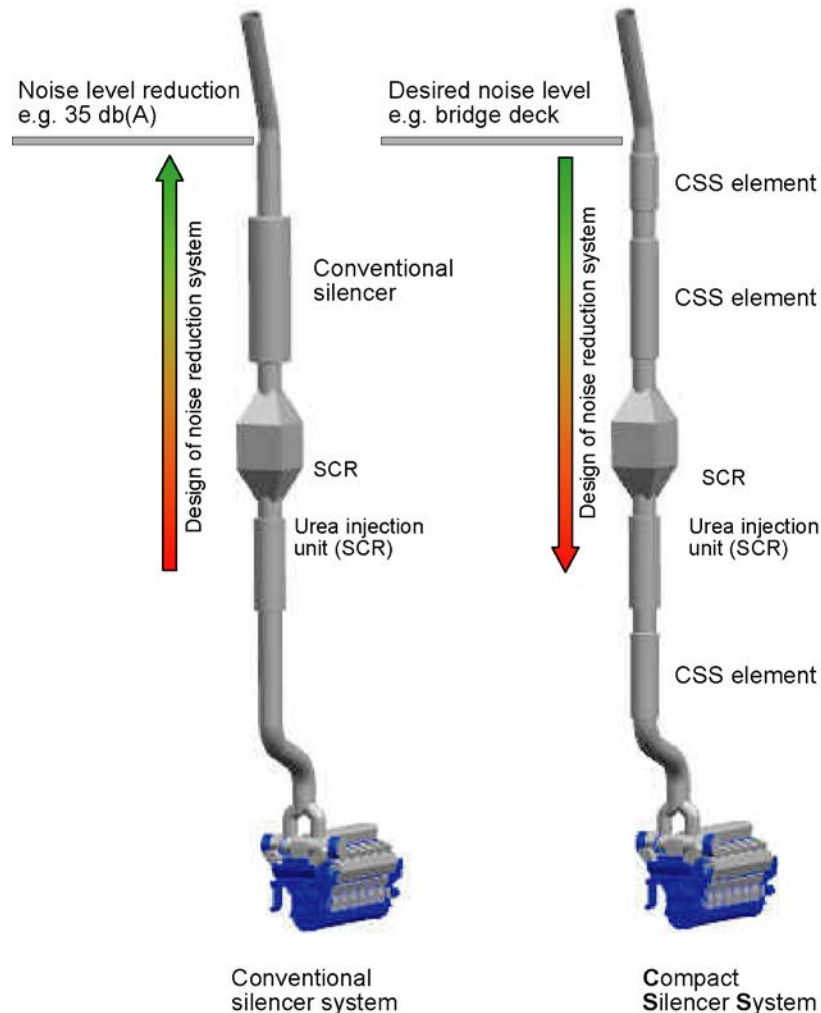


Fig 11-6 Silencer system comparison

### 11.3.7.3 Compact silencer system (5N02)

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

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

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

### 11.3.7.4 Conventional exhaust gas silencer (5R02)

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

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

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

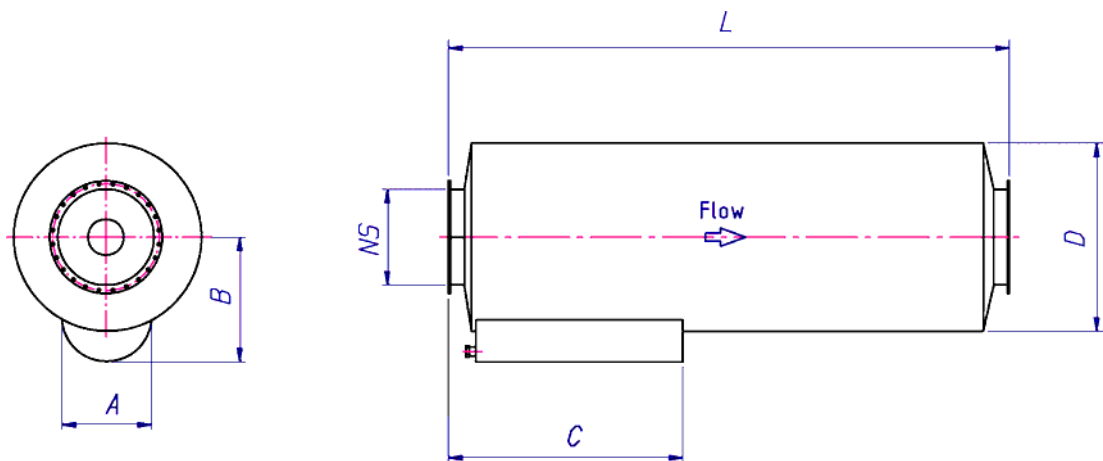


Fig 11-7 Exhaust gas silencer

Table 11-1 Typical dimensions of exhaust gas silencers

NS	A [mm]	B [mm]	C [mm]	ØD [mm]	Attenuation: 25 dB(A)		Attenuation: 35 dB(A)	
					L [mm]	Weight [kg]	L [mm]	Weight [kg]
900	860	1190	2240	1800	5360	2295	6870	2900
1000	870	1280	2340	1900	5880	2900	7620	3730
1100	900	1340	2600	2100	6200	3590	8200	4780
1300	950	1440	2650	2300	7500	4980	9500	6540
1400	950	1490	2680	2400	8165	5800	10165	7120
1500	1000	1540	2680	2500	8165	6180	10165	7650

**Flanges: DIN 2501**

# 12. Turbocharger Cleaning

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

Wärtsilä 46F 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.

## 12.1 Turbocharger cleaning system

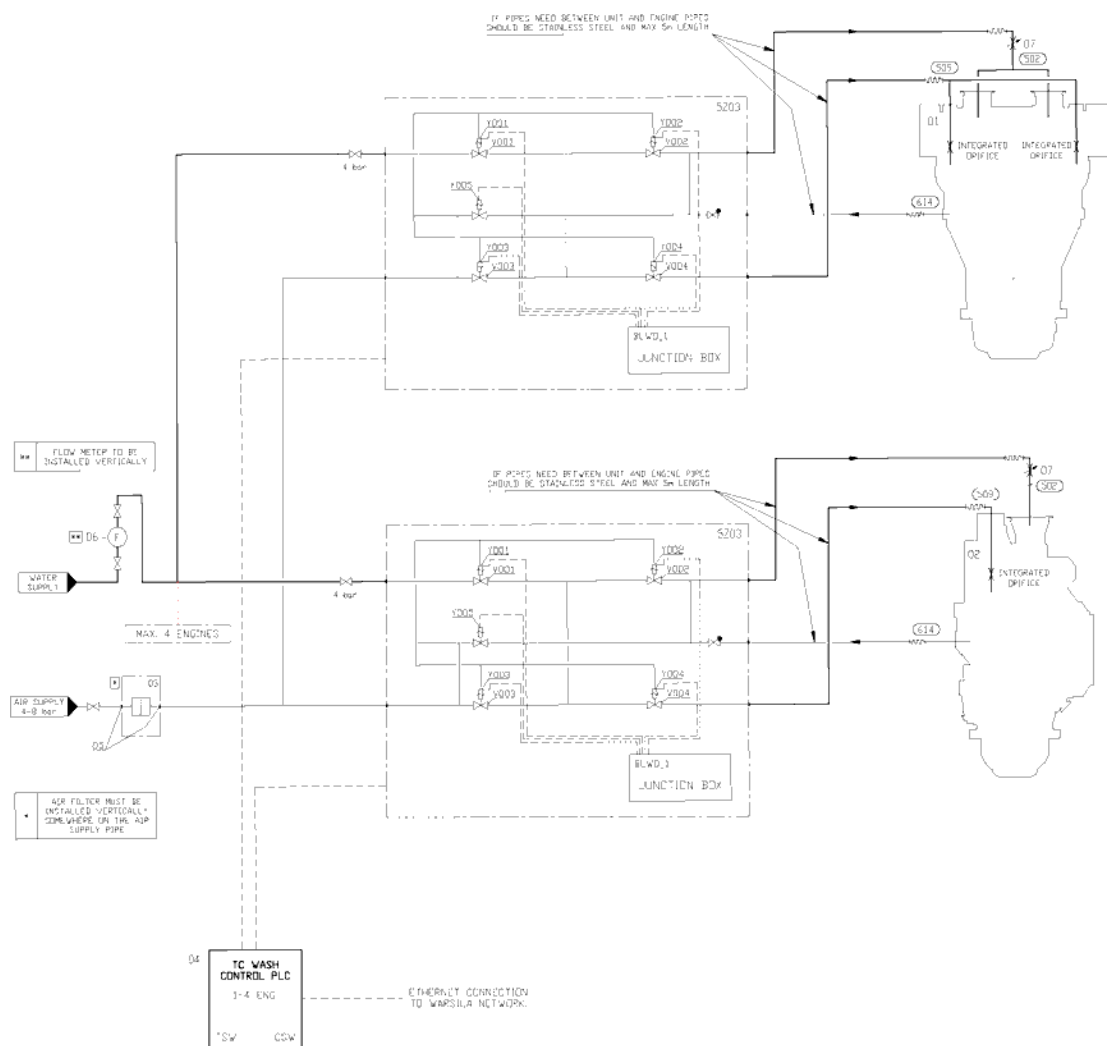


Fig 12-1 Turbocharger cleaning system (DAAF346215A)

System components:	
5Z03	TC cleaning device
03	Air filter
04	TC wash control unit
05	Male stud GR18LR71
06	Flow meter/control
07	Constant flow valve

Engine		Water			Air
Engine	Turbocharger	Nom water inlet press after before cleaning device(bar)	Water inlet flow rate(l/min)	Water consumption/wash (l)	System air for scavenging at low load (l/min)
6L46F	TPL71-C	4	24	240	-
7L46F	TPL76-C	4	37	370	-
8L46F	TPL76-C	4	37	370	-
9L46F	TPL76-C	4	37	370	-
12V46F	2*TPL71-C	4	48	480	-
14V46F	2*TPL76-C	4	74	740	-
16V46F	2*TPL76-C	4	74	740	-

## 13. Exhaust Emissions

Exhaust emissions from the diesel engine mainly consist of nitrogen, oxygen and combustion products like carbon dioxide (CO<sub>2</sub>), water vapour and minor quantities of carbon monoxide (CO), sulphur oxides (SO<sub>x</sub>), nitrogen oxides (NO<sub>x</sub>), partially reacted and non-combusted hydrocarbons (HC) and particulate matter (PM).

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

### 13.1 Diesel engine exhaust components

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

CO<sub>2</sub> and water are the main combustion products. Secondary combustion products are carbon monoxide, hydrocarbons, nitrogen oxides, sulphur oxides, soot and particulate matters.

In a diesel engine the emission of carbon monoxide and hydrocarbons are low compared to other internal combustion engines, thanks to the high air/fuel ratio in the combustion process. The air excess allows an almost complete combustion of the HC and oxidation of the CO to CO<sub>2</sub>, hence their quantity in the exhaust gas stream are very low.

#### 13.1.1 Nitrogen oxides (NO<sub>x</sub>)

The combustion process gives secondary products as Nitrogen oxides. At high temperature the nitrogen, usually inert, react with oxygen to form Nitric oxide (NO) and Nitrogen dioxide (NO<sub>2</sub>), which are usually grouped together as NO<sub>x</sub> emissions. Their amount is strictly related to the combustion temperature.

NO can also be formed through oxidation of the nitrogen in fuel and through chemical reactions with fuel radicals. NO in the exhaust gas flow is in a high temperature and high oxygen concentration environment, hence oxidizes rapidly to NO<sub>2</sub>. The amount of NO<sub>2</sub> emissions is approximately 5 % of total NO<sub>x</sub> emissions.

#### 13.1.2 Sulphur Oxides (SO<sub>x</sub>)

Sulphur oxides (SO<sub>x</sub>) are direct result of the sulphur content of the fuel oil. During the combustion process the fuel bound sulphur is rapidly oxidized to sulphur dioxide (SO<sub>2</sub>). A small fraction of SO<sub>2</sub> may be further oxidized to sulphur trioxide (SO<sub>3</sub>).

#### 13.1.3 Particulate Matter (PM)

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

#### 13.1.4 Smoke

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

Smoke can be black, blue, white, yellow or brown in appearance. Black smoke is mainly comprised of carbon particulates (soot). Blue smoke indicates the presence of the products

of the incomplete combustion of the fuel or lubricating oil. White smoke is usually condensed water vapour. Yellow smoke is caused by NO<sub>x</sub> emissions. When the exhaust gas is cooled significantly prior to discharge to the atmosphere, the condensed NO<sub>2</sub> component can have a brown appearance.

## **13.2 Marine exhaust emissions legislation**

### **13.2.1 International Maritime Organization (IMO)**

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

The IMO Tier 3 NO<sub>x</sub> emission standard has entered into force from year 2016. It applies for new marine diesel engines that:

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

From 1.1.2021 onwards Baltic sea and North sea will be included in to IMO Tier 3 NO<sub>x</sub> requirements.

### **13.2.2 Other Legislations**

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

## 13.3 Methods to reduce exhaust emissions

All standard Wärtsilä engines meet the NO<sub>x</sub> emission level set by the IMO (International Maritime Organisation) and most of the local emission levels without any modifications. Wärtsilä has also developed solutions to significantly reduce NO<sub>x</sub> emissions when this is required.

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

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

The distributed modules communicate over an internal communication bus.

The power supply to each module is physically doubled on the engine for full redundancy.

Control signals to/from external systems are connected to the main cabinet on the engine. Process data for alarm and monitoring are communicated over a Modbus TCP, or RS-485 serial link Modbus RTU connection to external systems.

## 14.1 Technical data and system overview

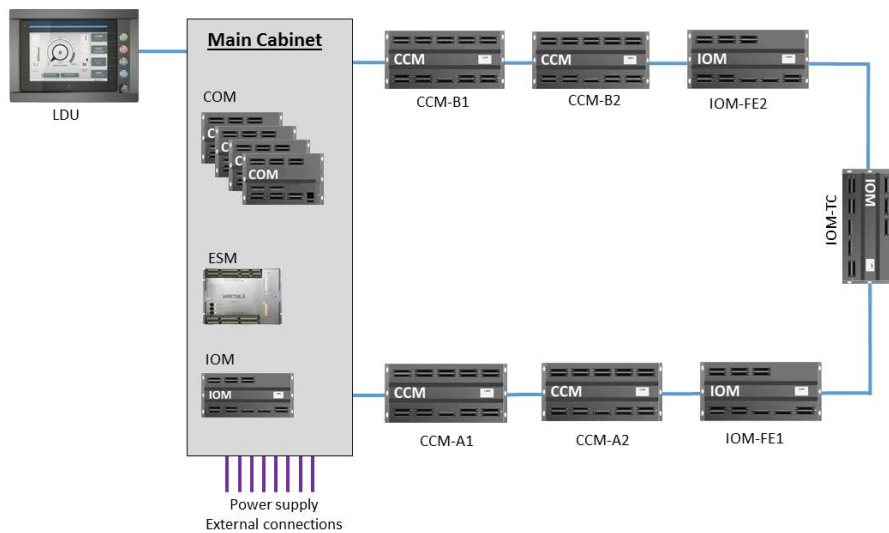
### 14.1.1 Ingress protection

The ingress protection class of the system is IP54.

### 14.1.2 Ambient temp for automation system

The system design and implementation of the engine allows for an ambient engine room temperature of 55°C.

Single components such as electronic modules have a temperature rating not less than 70°C.



**Fig 14-1 Architecture of UNIC**

Short explanation of the modules used in the system:

- COM** Communication Module. Handles strategic control functions (such as start/stop sequencing and speed/load control, i.e. "speed governing") of the engine. The communication modules handle engine internal and external communication, as well as hardwired external interfaces.
- LOP** The LOP (local operator panel) shows all engine measurements (e.g. temperatures and pressures) and provides various engine status indications as well as an event history.

<b>IOM</b>	Input/Output Module handles measurements and limited control functions in a specific area on the engine.
<b>CCM</b>	Cylinder Control Module handles fuel injection control and local measurements for the cylinders.
<b>ESM</b>	Engine Safety Module handles fundamental engine safety, for example shutdown due to overspeed or low lubricating oil pressure.

The above equipment and instrumentation are prewired on the engine.

### 14.1.3 Local operator panel

- The Local operator panel (LOP) consist of a display unit (LDU) with touch screen and pushbuttons as well as an emergency stop button built on the engine.

The local operator panel shows all engine measurements (e.g. temperatures and pressures) and provides various engine status indications as well as an event history

The following control functions are available:

- Local/remote control selection
- Local start & stop
- Emergency stop
- Local emergency speed setting (mechanical propulsion):



Fig 14-2 Local operator panel

### 14.1.4 Engine safety system

The engine safety module handles fundamental safety functions, for example overspeed protection.

Main features:

- Redundant design for power supply, speed inputs and stop solenoid control
- Fault detection on sensors, solenoids and wires

- Led indication of status and detected faults
- Digital status outputs
- Shutdown latching and reset
- Shutdown pre-warning
- Shutdown override (configuration depending on application)

### 14.1.5 Power unit

A power unit is delivered with each engine. The power unit supplies DC power to the automation system on the engine and provides isolation from other power supply 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 automation system on the engine with 24 VDC and 48 VDC.

Power supply from ship's system:

- Supply 1: 230 VAC / abt. 750 W
- Supply 2: 230 VAC / abt. 750 W

### 14.1.6 Ethernet communication unit

In case of TCP/IP communication, Ethernet switch and firewall/router are installed in a steel sheet cabinet for bulkhead mounting, protection class IP44.

## 14.2 Functions

### 14.2.1 Start

The engine is started by injecting compressed air directly into the cylinders.

The engine can be started locally, or remotely if applicable for the installation e.g. from the power management system or control room. In an emergency situation it is also possible to operate the starting air valve manually.

Starting is blocked both pneumatically and electrically when the turning gear is engaged.

The engine is equipped with a slow turning system, which rotates the engine without fuel injection for a few turns before start. Slow turning is performed automatically at predefined intervals, if the engine has been selected as stand-by.

#### 14.2.1.1 Startblockings

Starting is inhibited by the following functions:

- Turning gear engaged
- Pre-lubricating pressure low
- Blocked by operator from the local operator panel
- Stop or shutdown active
- External start blockings active
- Engine running

## 14.2.2 Stop and shutdown

A normal stop can be initiated locally, or remotely if applicable for the installation. At normal stop the stop sequence is active until the engine has come to standstill. Thereafter the system automatically returns to “ready for start” mode in case no start block functions are active, i.e. there is no need for manually resetting a normal stop.

Emergency stop can be activated with the local emergency stop button, or from a remote location as applicable.

The engine safety module handles safety shutdowns. Safety shutdowns can be initiated either independently by the safety module, or executed by the safety module upon a shutdown request from some other part of the automation system.

### Typical shutdown functions are:

- Lubricating oil pressure low
- Overspeed
- Oil mist in crankcase
- Lubricating oil pressure low in reduction gear

Depending on the application it is possible to override a shutdown via a separate input. It is not possible to override a shutdown due to overspeed or emergency stop.

Before restart the reason for the shutdown must be thoroughly investigated and rectified.

## 14.2.3 Speed control

### 14.2.3.1 Main engines (mechanical propulsion)

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

The remote speed setting from the propulsion control is an analogue 4-20 mA signal. It is also possible to select an operating mode in which the speed reference can be adjusted with increase/decrease signals.

The electronic speed control handles load sharing between parallel engines, fuel limiters, and various other control functions (e.g. ready to open/close clutch, speed filtering). Overload protection and control of the load increase rate must however be included in the propulsion control as described in the chapter [Operating Ranges](#).

### 14.2.3.2 Generating sets

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

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

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

In isochronous mode the speed reference remains constant regardless of load level. Both isochronous load sharing and traditional speed droop are standard features in the speed control and either mode can be easily selected. If the ship has several switchboard sections

with tie breakers between the different sections, then the status of each tie breaker is required for control of the load sharing in isochronous mode.

## 14.3 Alarm and monitoring signals

Regarding sensors on the engine, the actual configuration of signals and the alarm levels are found in the project specific documentation supplied for all contracted projects.

## 14.4 Electrical consumers

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

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

#### 14.4.1.1 Engine turning device (9N15)

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

**Table 14-1 Electric motor ratings for engine turning device**

Engine type	Voltage [V]	Frequency [Hz]	Power [kW]	Current [A]
Wärtsilä 46F (6L,7L,8L)	3 x 400/440	50 / 60	2.2/2.6	5
Wärtsilä 46F (9L,V-engines)	3 x 400/440	50 / 60	5.5/6.4	12

#### 14.4.1.2 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.

#### 14.4.1.3 Stand-by pump, lubricating oil (if applicable) (2P04)

The engine control system starts the pump automatically via a motor starter, if the lubricating oil pressure drops below a preset level when the engine is running. 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.

#### 14.4.1.4 Stand-by pump, HT cooling water (if applicable) (4P03)

The engine control system starts the pump automatically via a motor starter, if the cooling water pressure drops below a preset level when the engine is running. There is a dedicated sensor on the engine for this purpose.

**14.4.1.5 Stand-by pump, LT cooling water (if applicable) (4P05)**

The engine control system starts the pump automatically via a motor starter, if the cooling water pressure drops below a preset level when the engine is running. There is a dedicated sensor on the engine for this purpose.

**14.4.1.6 Circulating pump for preheater (4P04)**

The preheater pump shall start when the engine stops (to ensure water circulation through the hot engine) and stop when the engine starts. The engine control system handles start/stop of the pump automatically via a motor starter.

## 14.5 Guideline for electrical and automation system

Load increase during ship acceleration, manoeuvring, and load transfer between generators must be controlled according to instructions in chapter 2.2 *Loading Capacity*. The total load increase rate on a recently connected generator (preheated engine) is the sum of the uploading that is performed by the load sharing control and by the propulsion control.

Fastest possible loading up to high load should only be available by activating an “emergency loading” function, which is indicated by an alarm in the control room and on the bridge. In applications with highly cyclic load, e.g. dynamic positioning, maximum loading can be used in operating modes that require fast response. Other operating modes should have slower loading rates. Maximum possible loading and unloading is also required for e.g. tugs.

Load reductions from high load must be rate limited in normal operation as described in chapter 2.2 *Loading Capacity*. Crash stop can be recognised by for example a large lever movement from ahead to astern. In the low load range, which is typically used during manoeuvring, the load can be reduced without rate limitation.

The response to increase and decrease pulses from PMS or synchroniser is 0.1 Hz per second by default, but the rate is adjustable. This is the rate for the speed setting. Actual speed and/or load change at a much slower rate, especially when the adjustments are small. Recommended deadband for load balancing (PMS control) is  $\pm 2\%$  of rated power.

The engine can absorb 5% reverse power. Recommended setting for the reverse power protection is 5% of rated power with 10 s delay.

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## 15. Foundation

Engines can be either rigidly mounted on chocks, or resiliently mounted on steel spring elements. If resilient mounting is considered, Wärtsilä must be informed about existing excitations such as propeller blade passing frequency. Dynamic forces caused by the engine are listed in the chapter *Vibration and noise*.

### 15.1 Steel structure design

The system oil tank should not extend under the reduction gear or generator, if the oil tank is located beneath the engine foundation. Neither should the tank extend under the support bearing, in case there is a PTO arrangement in the free end. The oil tank must also be symmetrically located in transverse direction under the engine.

The foundation and the double bottom should be as stiff as possible in all directions to absorb the dynamic forces caused by the engine, reduction gear and thrust bearing.

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

The foundation of the driven equipment should be integrated with the engine foundation.

### 15.2 Engine mounting

The mounting arrangement is similar for diesel electric installations and conventional propulsion.

#### 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 through-bolts with a lock nut at the lower end and a hydraulically tightened nut at the upper end. The tool included in the standard set of engine tools is used for hydraulic tightening of the holding down bolts. 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 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. 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 normal threads. The bolt thread must fulfil tolerance 6g and the nut thread must fulfil tolerance 6H. In order to avoid bending stress in the bolts and to ensure proper fastening, the contact face of the nut underneath the seating top plate should be counterbored.

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

### 15.2.1.1 Resin chocks

The recommended dimensions of the resin chocks are 600 x 180 mm. The total surface pressure on the resin must not exceed the maximum value, which is determined by the type of resin and the requirements of the classification society.

It is recommended to select a resin type that is approved by the relevant classification society for a total surface pressure of 5 N/mm<sup>2</sup>. (A typical conservative value is  $P_{tot}$  3.5 N/mm<sup>2</sup>).

During normal conditions, the support face of the engine feet has a maximum temperature of about 75°C, which should be considered when selecting the type of resin.

The bolts must be made as tensile bolts with a reduced shank diameter to ensure 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.

Locking of the upper nuts is required 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.

### 15.2.1.2 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.

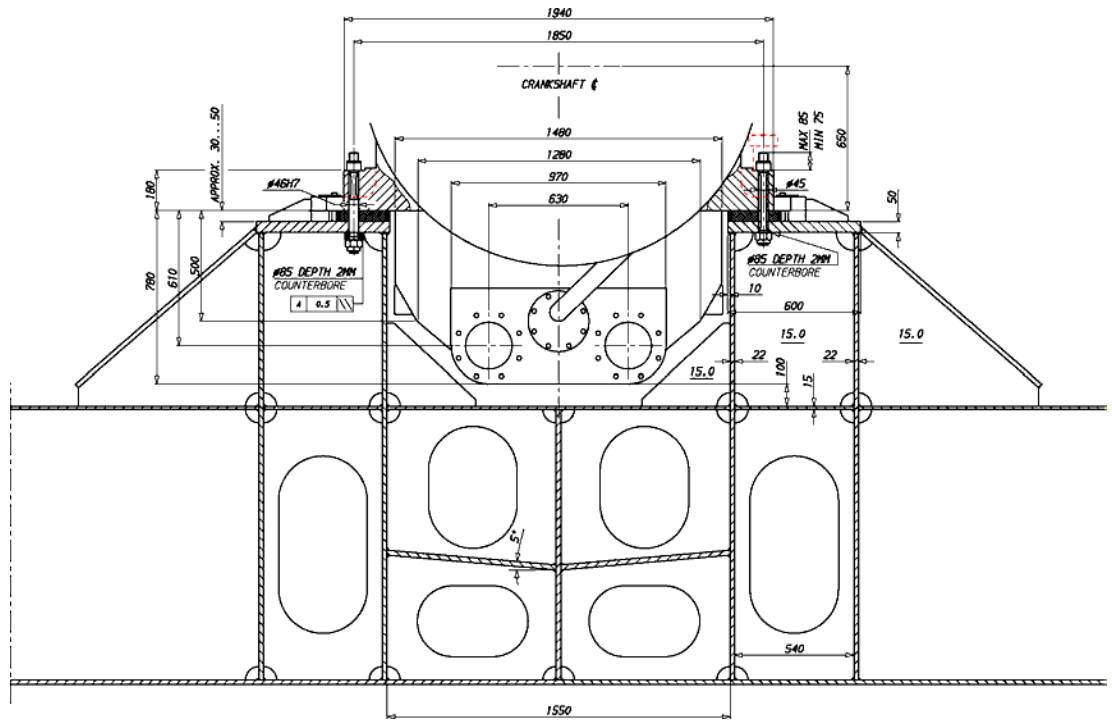
The supporting surface of the seating top plate should be machined so that a bearing surface of at least 75% is obtained. The chock should be fitted so that they are approximately equally inserted under the engine on both sides.

The chocks should always cover two bolts, except the chock closest to the flywheel, which accommodates only one bolt. Steel is preferred, but cast iron chocks are also accepted.

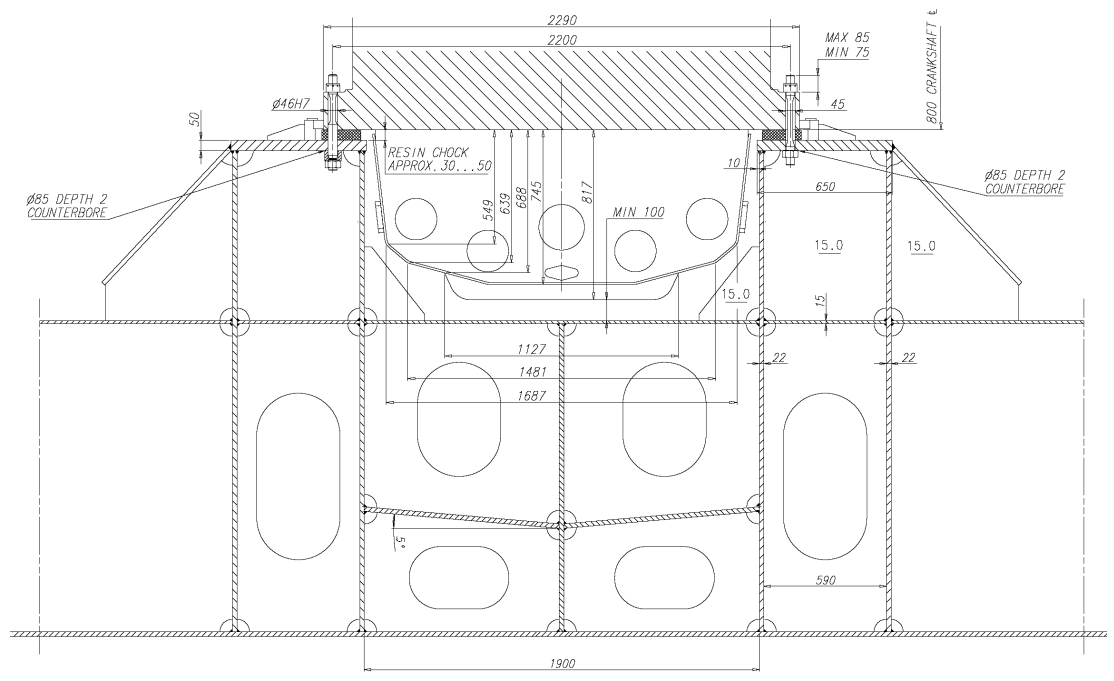
Holes are to be drilled and reamed to the correct tolerance for the fitted bolts after the coupling alignment has been checked and the chocks have been lightly knocked into position.

### 15.2.1.3 Steel chocks with adjustable height

As an alternative to resin chocks or conventional steel chocks it is also permitted to install the engine on adjustable steel chocks. The chock height is adjustable between 45 mm and 65 mm for the approved type of chock. There must be a chock of adequate size at the position of each holding down bolt.



**Fig 15-1 Seating and fastening, rigidly mounted in-line engine on resin chocks (DAAE012078a)**



**Fig 15-2 Seating and fastening, rigidly mounted V-engine on resin chocks (DAAE074226A)**

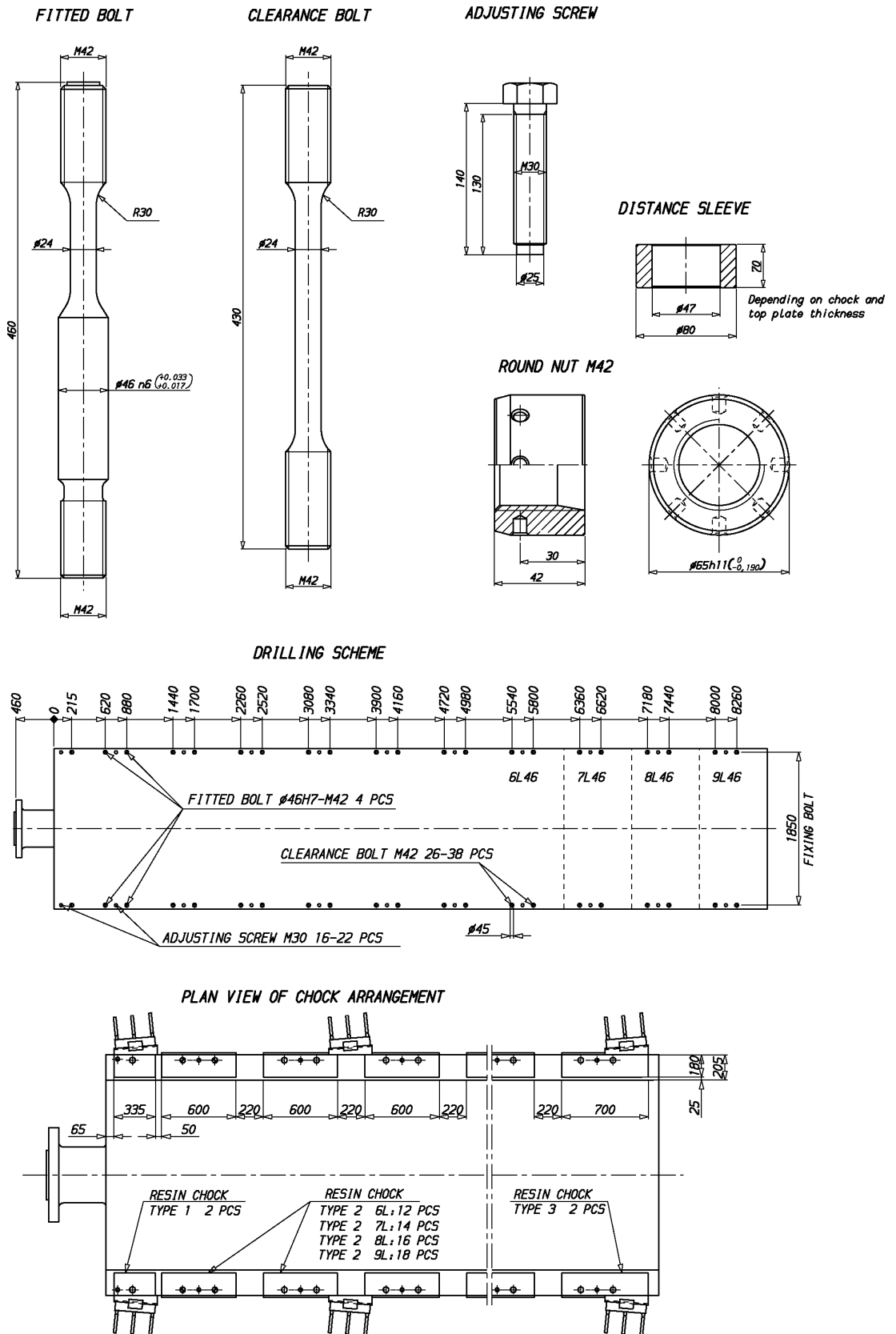
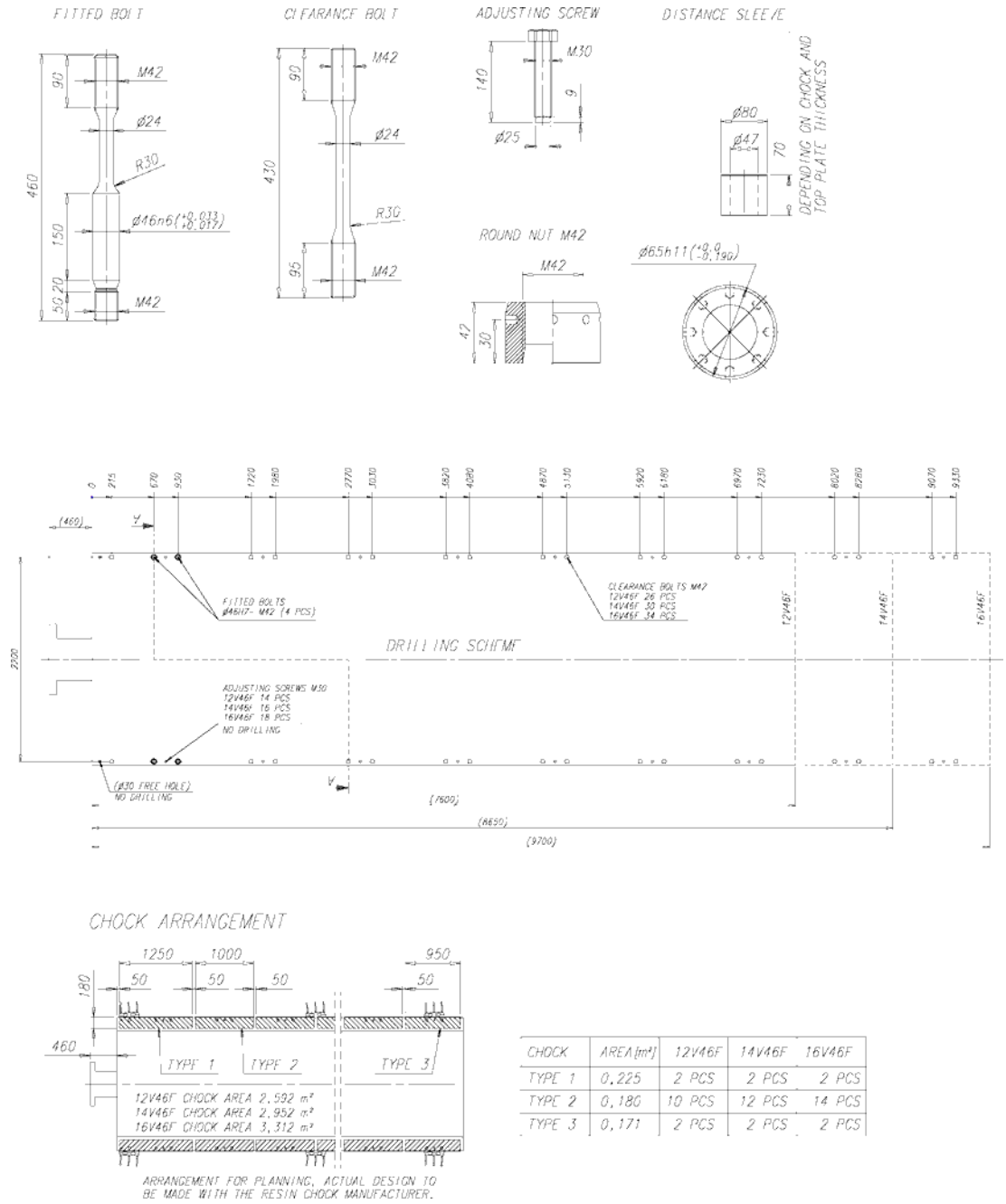


Fig 15-3 Seating and fastening, rigidly mounted in-line engine on resin chocks (DAAE012078a)



**Fig 15-4 Seating and fastening, rigidly mounted V-engine on resin chocks (DAAE074226A)**

## 15.2.2 Resilient mounting

In order to reduce vibrations and structure borne noise, engines can be resiliently mounted on steel spring elements. The transmission of forces emitted by the engine is 10-20% when using resilient mounting. Typical structure borne noise levels can be found in chapter 16.

The resilient elements consist of an upper steel plate fastened directly to the engine, vertical steel springs, and a lower steel plate fastened to the foundation. Resin chocks are cast under the lower steel plate after final alignment adjustments and drilling of the holes for the fastening screws. The steel spring elements are compressed to the calculated height under load and locked in position on delivery. Compression screws and distance pieces between the two steel plates are used for this purpose.

Rubber elements are used in the transverse and longitudinal buffers. Steel chocks must be used under the horizontal buffers.

The speed range is limited to 450-600 rpm for resiliently mounted 8L46F engines. For other cylinder configurations a speed range of 400-600 rpm is generally available.

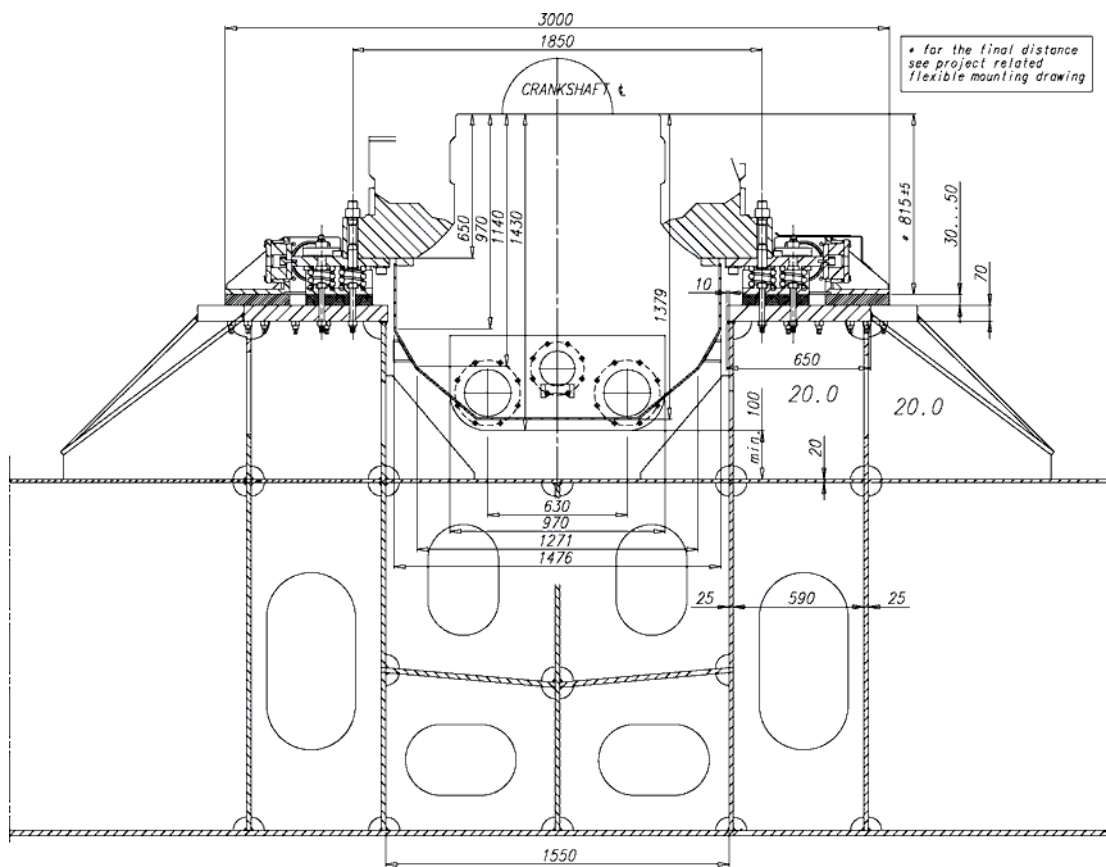


Fig 15-5 Seating and fastening, resiliently mounted in-line engine (DAAE029031A)

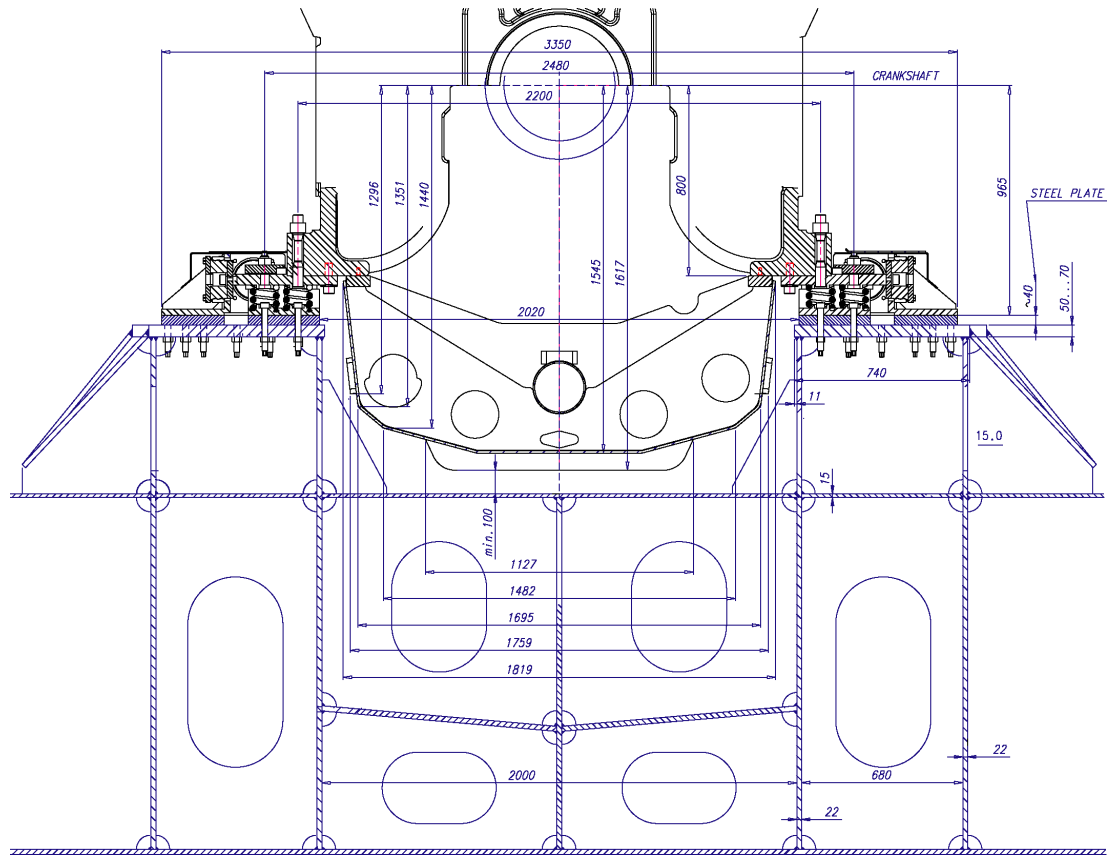


Fig 15-6 Seating and fastening, resiliently mounted V-engine (DAAE057412)

### 15.2.2.1 Flexible pipe connections

When the engine is resiliently mounted, 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, without large forces on the turbocharger.

Proper fixing of pipes next to flexible pipe connections is not less important for resiliently mounted engines. See the chapter *Piping design, treatment and installation* for more detailed information.

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# 16. Vibration and Noise

Resiliently mounted engines comply with the requirements of the following standards regarding vibration level on the engine:

Main engine ISO 10816-6 Class 5  
 Generating set (not on a common base frame) ISO 8528-9

## 16.1 External forces and couples

Some cylinder configurations produce dynamic forces and couples. These are listed in the tables below.

The ship designer should avoid natural frequencies of decks, bulkheads and superstructures close to the excitation frequencies. The double bottom should be stiff enough to avoid resonances especially with the rolling frequencies.

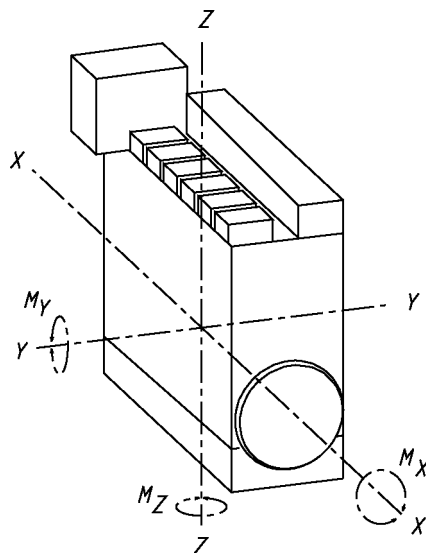


Fig 16-1 Coordinate system

Table 16-1 External forces

Engine	Speed [rpm]	Frequency [Hz]	F <sub>Y</sub> [kN]	F <sub>Z</sub> [kN]
8L46F	600	40	-	12.3
- forces are zero or insignificant				

Table 16-2 External couples

Engine	Speed [rpm]	Frequency [Hz]	M <sub>Y</sub> [kNm]	M <sub>Z</sub> [kNm]	Frequency [Hz]	M <sub>Y</sub> [kNm]	M <sub>Z</sub> [kNm]	Frequency [Hz]	M <sub>Y</sub> [kNm]	M <sub>Z</sub> [kNm]
7L46F	600	10	63	63	20	104.2	- <sup>1)</sup>	40	12.4	-
9L46F	600	10	30	30	20	163	-	40	11	-
14V46F	600	10	103	103	20	155	86	40	5	13
14V46F <sup>2)</sup>	600	10	-	-	20	155	86	40	5	13

<sup>1)</sup> zero or insignificant value marked as "-"

<sup>2)</sup> balancing device adopted

## 16.2 Torque variations

**Table 16-3 Torque variation at full load**

Engine type	Speed [rpm]	Frequency [Hz]	M <sub>x</sub> [kNm]	Frequency [Hz]	M <sub>x</sub> [kNm]	Frequency [Hz]	M <sub>x</sub> [kNm]
6L46F	600	30	67	60	65	90	16
7L46F	600	35	221	70	47	105	10
8L46F	600	40	202	80	34	120	6
9L46F	600	45	185	90	24	135	4
12V46F	600	30	35	60	112	90	22
14V46F	600	30	20	60	90	90	2
16V46F	600	40	65	80	63	120	6

## 16.3 Mass moments of inertia

These typical inertia values include the flexible coupling part connected to the flywheel and the torsional vibration damper, if needed.

**Table 16-4 Polar mass moments of inertia**

Engine type	Inertia [kgm <sup>2</sup> ]
6L46F	3620
7L46F	2920
8L46F	4160
9L46F	4110
12V46F	4660
14V46F	5350
16V46F	6100

## 16.4 Structure borne noise

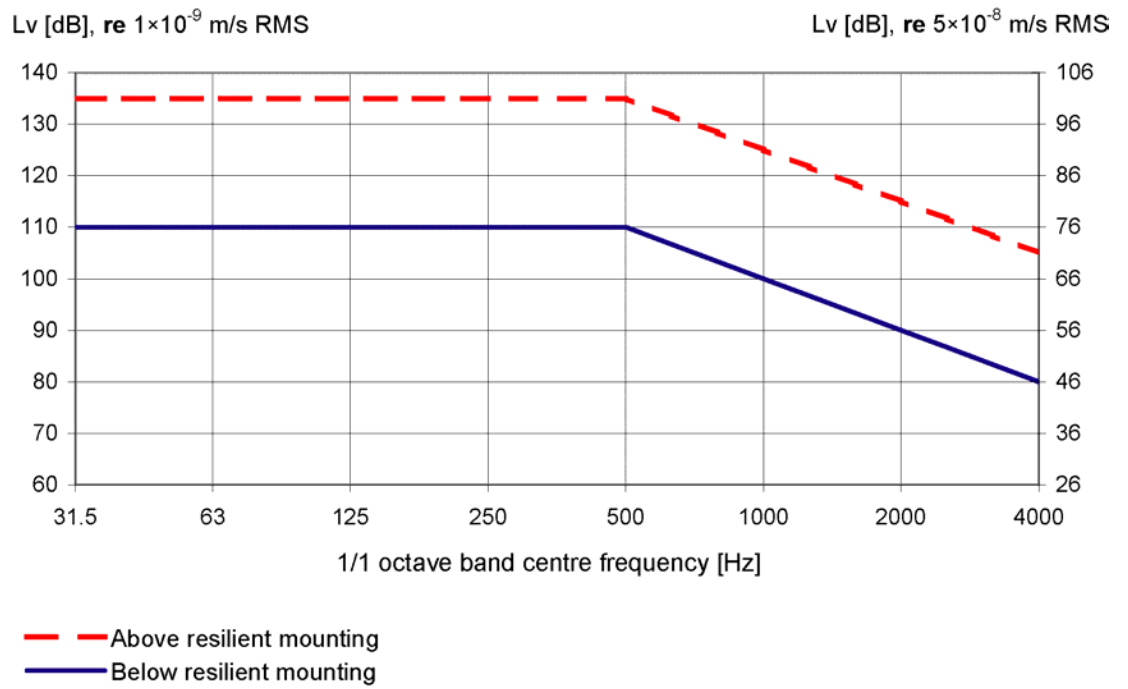
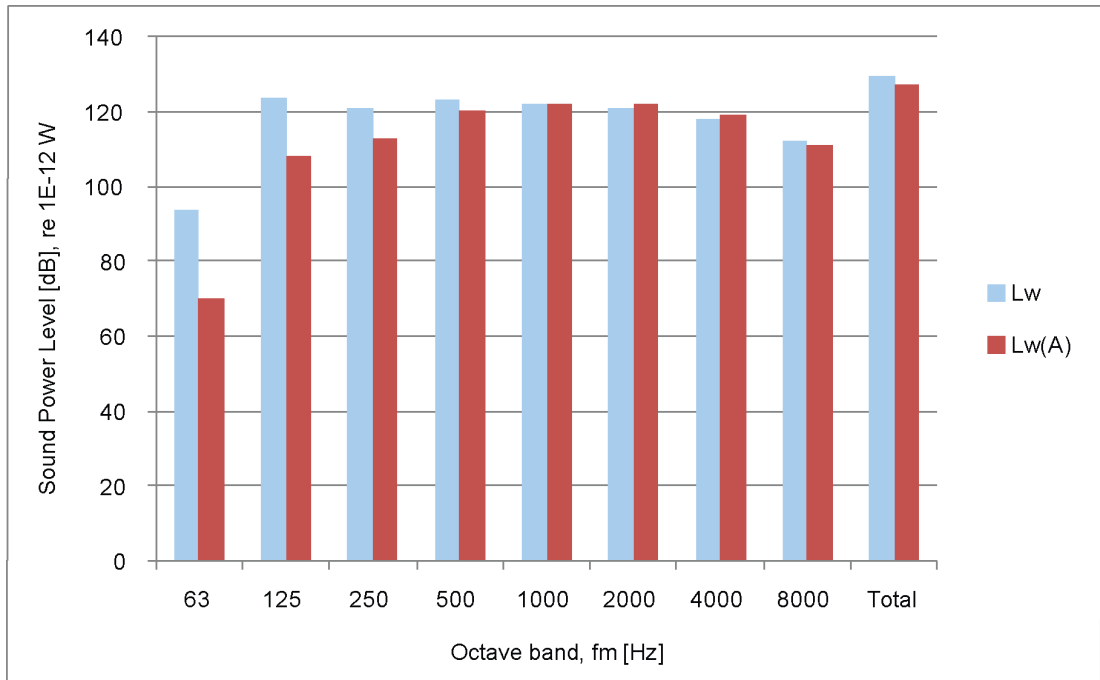


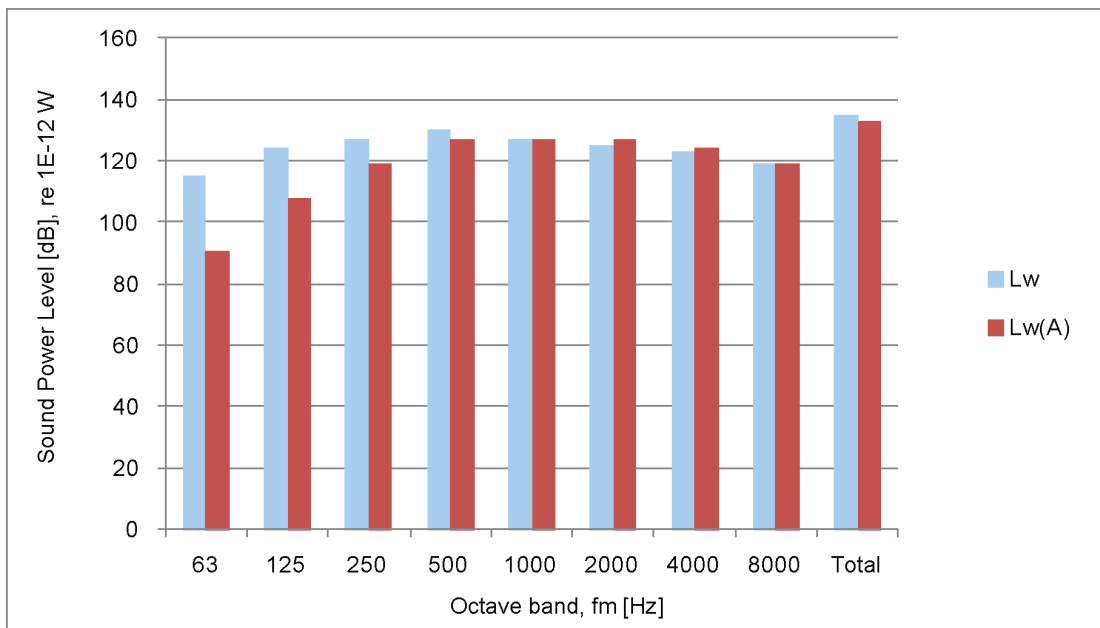
Fig 16-2 Typical structure borne noise levels

## 16.5 Air borne noise

The airborne noise from the engine is measured as a sound power level according to ISO 3746. The results are presented with A-weighting in octave bands, reference level 1 pW. The values are applicable with an intake air filter on the turbocharger and 1m from the engine. 90% of all measured noise levels are below the values in the graphs. 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 levels of engine noise, W L46F**



**Fig 16-4 Typical sound power levels of engine noise, W V46F**

## 16.6 Exhaust noise

The exhaust noise is measured as a sound power level according to ISO 9614-2. The results are presented with A-weighting in octave bands, 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.

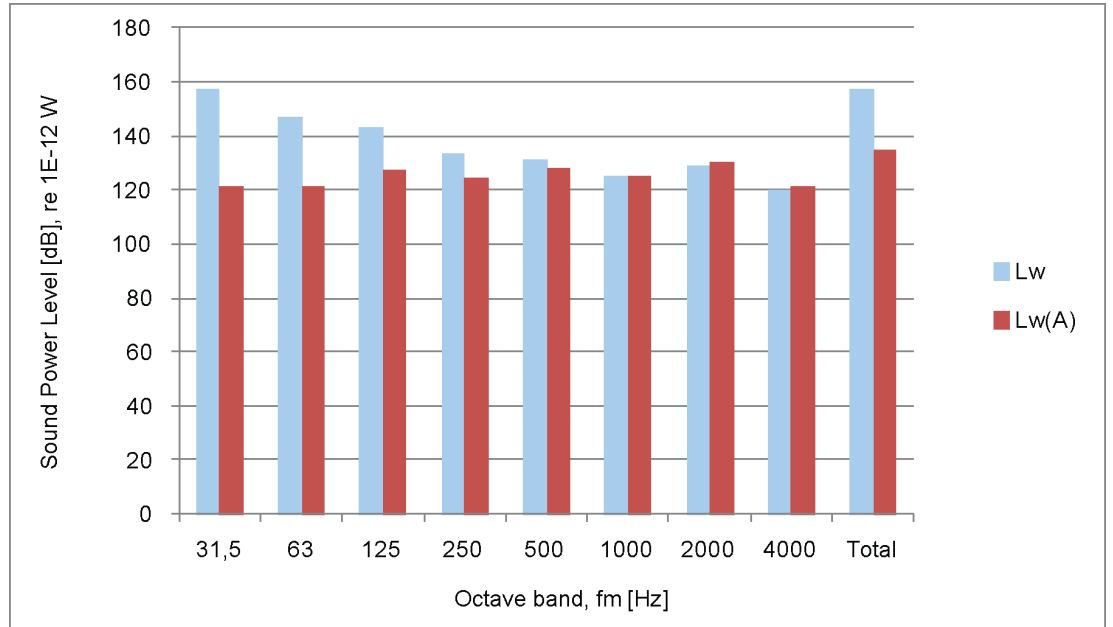


Fig 16-5 Typical sound power levels of exhaust noise, W L46F

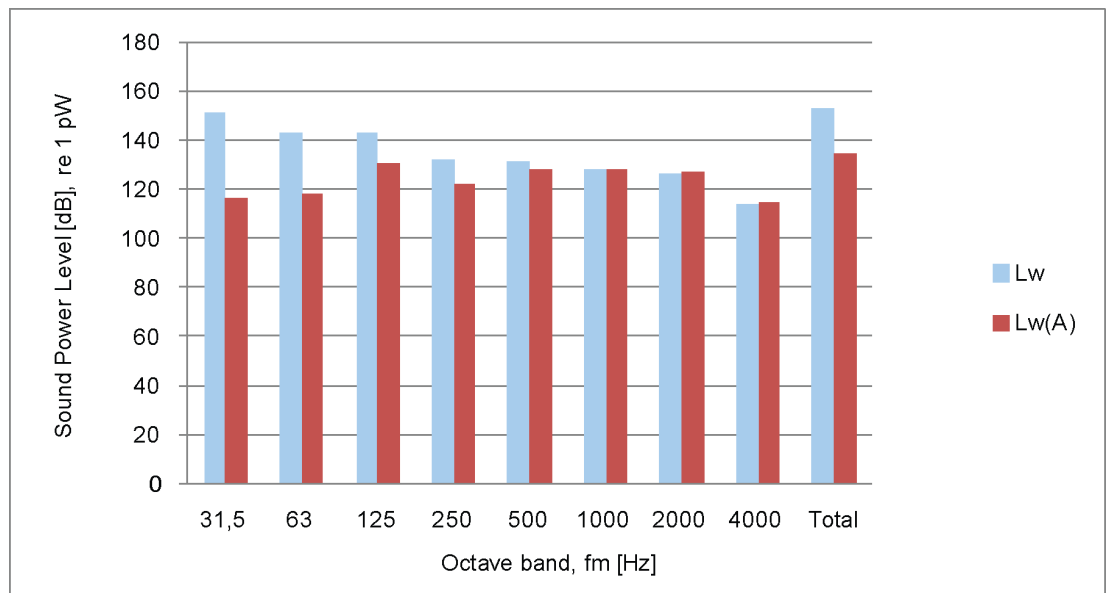


Fig 16-6 Typical sound power levels of exhaust noise, W V46F

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## 17. Power Transmission

### 17.1 Flexible coupling

The engine is connected to the reduction gear or generator with a flexible coupling. The type of flexible coupling is determined separately for each installation based on the torsional vibration calculations.

### 17.2 Clutch

Hydraulically operated multi-plate clutches in the reduction gear are recommended.

A clutch is not absolutely required in single main engine installations, provided that the friction torque of the shaft line does not exceed the torque capacity of the turning gear, or there is a tooth coupling so that the engine can be separated from the propeller shaft. A combined flexible coupling and clutch mounted on the flywheel is usually possible without intermediate bearings, because the engine is equipped with an additional bearing at the flywheel end.

Clutches are required when two or more engines are connected to the same reduction gear.

To permit maintenance of a stopped engine, either clutches or tooth couplings are required in twin screw vessels, if the vessel can operate with only one propeller.

### 17.3 Shaft locking device

A shaft locking device should also be fitted to be able to secure the propeller shaft in position so that wind milling is avoided. This is necessary because even an open hydraulic clutch can transmit some torque. Wind milling at a low propeller speed (<10 rpm) can due to poor lubrication cause excessive wear of the bearings.

The shaft locking device can be either a bracket and key or an easier to use brake disc with calipers. In both cases a stiff and strong support to the ship's construction must be provided.

To permit maintenance of a stopped engine clutches must be installed in twin screw vessels which can operate on one shaft line only.

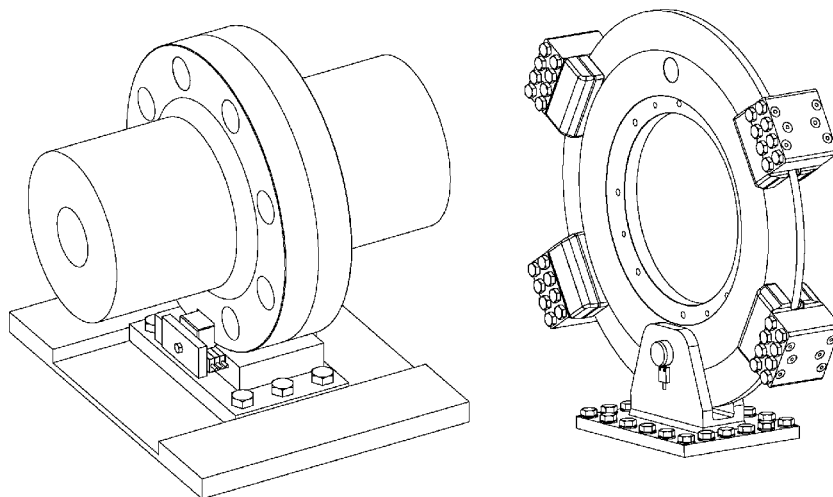


Fig 17-1 Shaft locking device and brake disc with calipers

## 17.4 Power-take-off from the free end

Full output is available also from the free end of the engine. The weight of the coupling determines whether a support bearing is needed, and for this reason each installation must be evaluated separately. Such a support bearing is possible only with rigidly mounted engines. The permissible coupling weight can be increased if the engine is configured without built-on pumps.



## 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 electrically driven turning gear, which is capable of turning the propeller shaft line in most installations. The need for a separate turning gear with higher torque capacity should be considered for example in the cases listed below:

- Installations with a stern tube with a high friction torque
- Installations with a heavy ice-classed shaft line
- Installations with several engines connected to the same shaft line
- If the shaft line and a heavy generator are to be turned at the same time.

**Table 17-1 Turning gear torque**

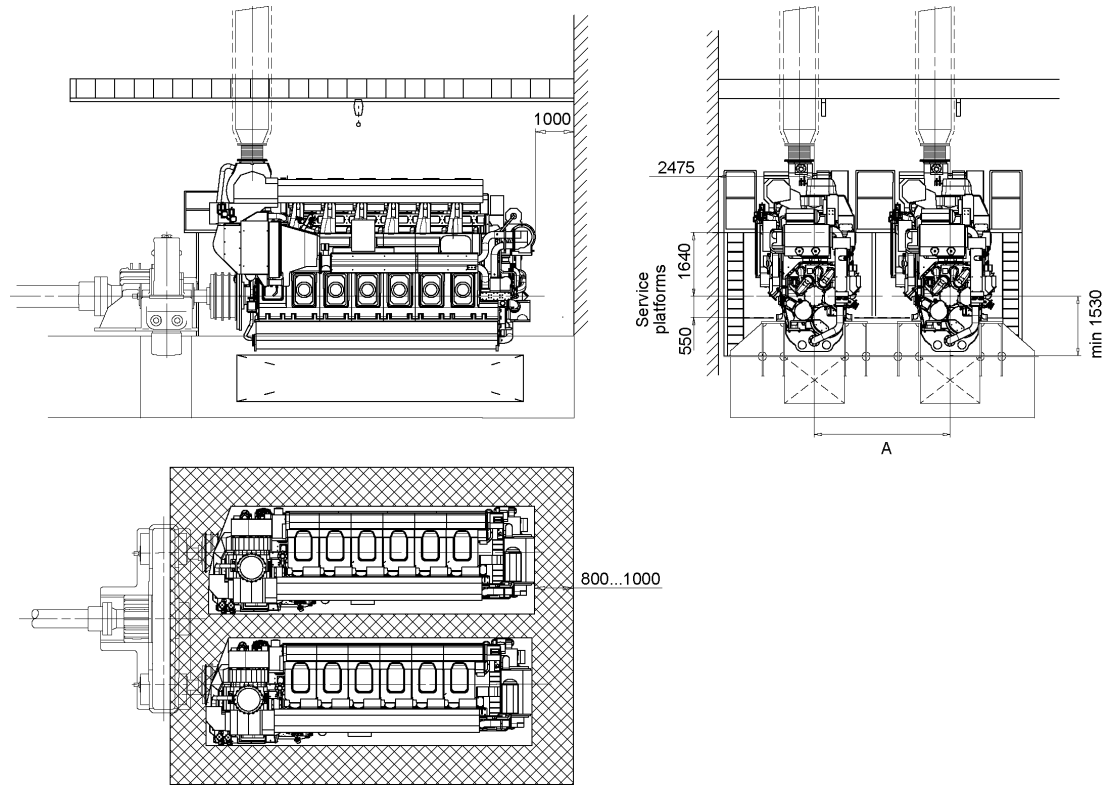
Cylinder number	Type of turning gear	Max. torque at crankshaft [kNm]	Torque needed to turn the engine [kNm]	Additional torque available [kNm]
6L	LKV 145	18	12	6
7L	LKV 145	18	13	5
8L	LKV 145	18	15	3
9L	LKV 250	75	17	58
12V	LKV 250	75	25	50
14V	LKV 250	75	30	45
16V	LKV 250	75	35	40

# 18. Engine Room Layout

## 18.1 Crankshaft distances

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

### 18.1.1 In-line engines

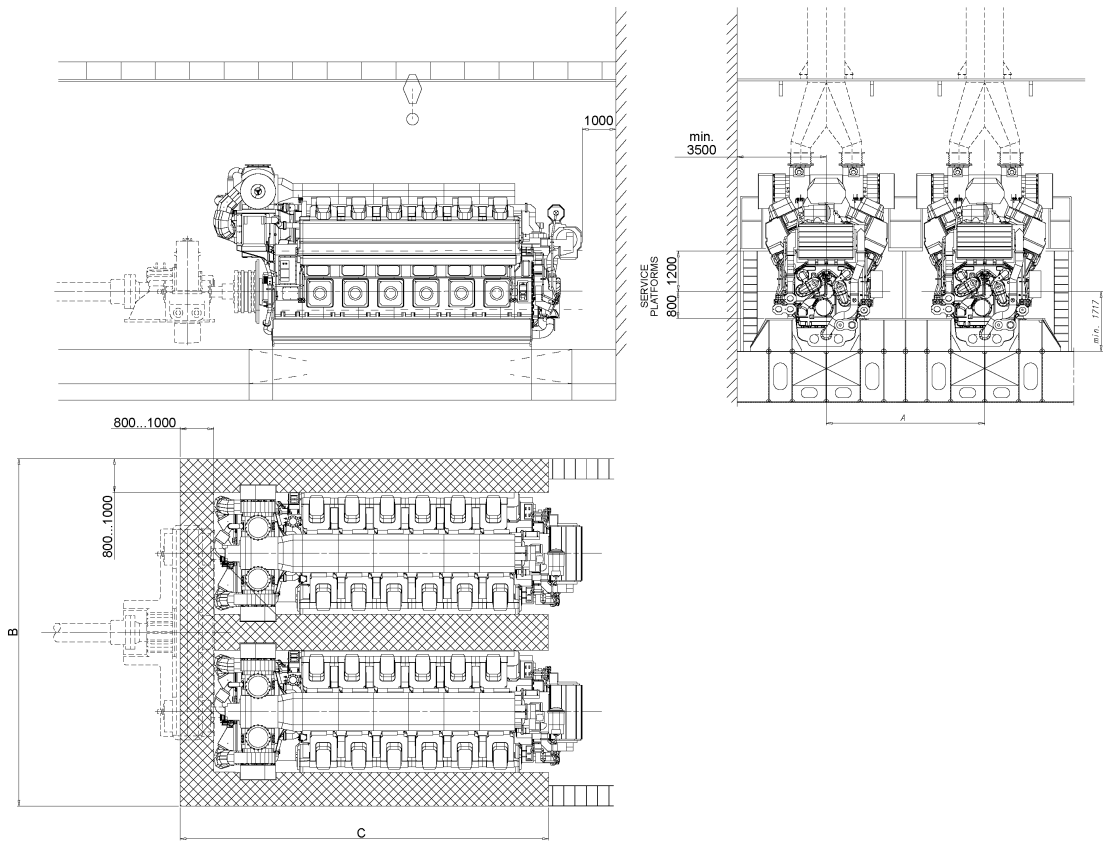


**Fig 18-1 Engine room arrangement, in-line engines (DAAE044913B)**

**Table 18-1 Min. crankshaft distance**

Engine type	TC type	A [mm]	
		Min	Recommended
6L46F	TPL 71C	3200	3400
7L, 8L, 9L46F	TPL 76C	3500	3700

### 18.1.2 V-engine

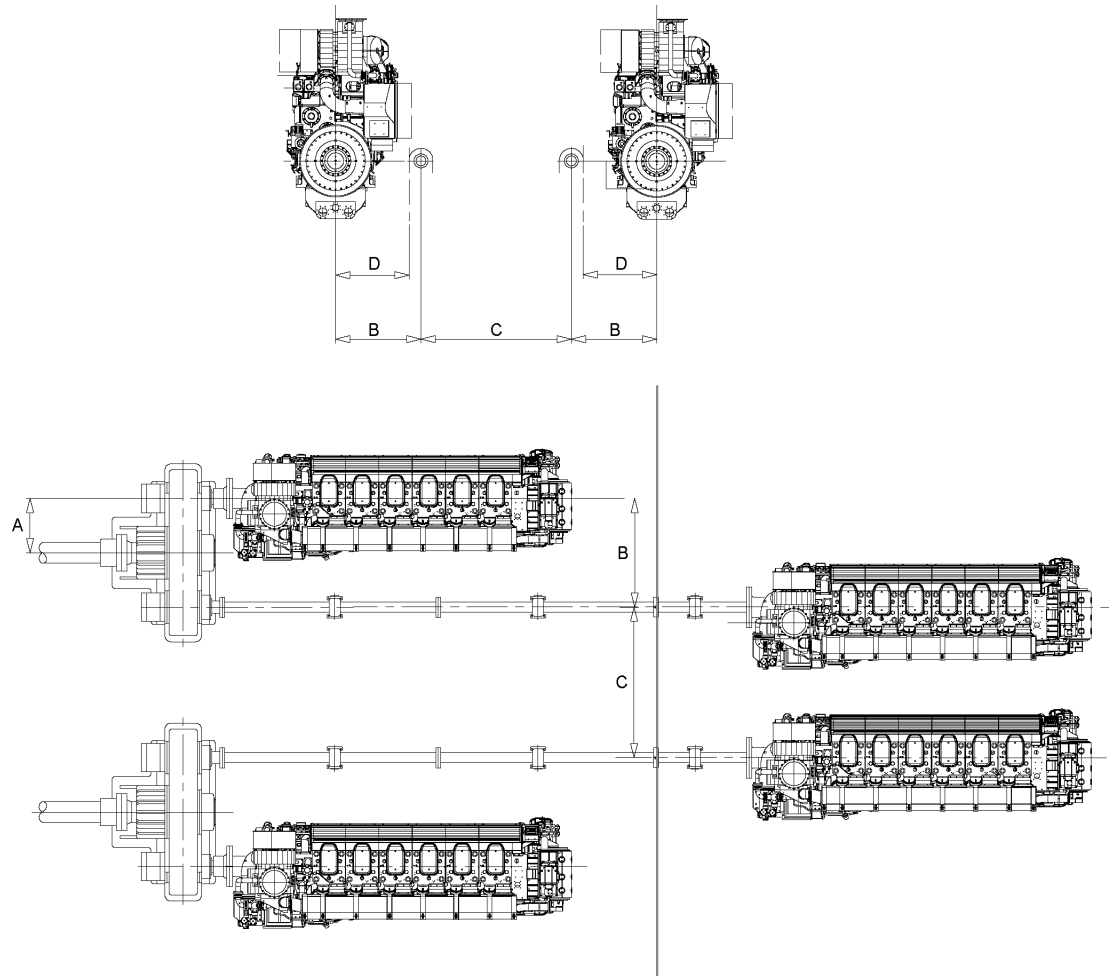


**Fig 18-2 Engine room arrangement, V-engine (DAAE075829B)**

Min. crankshaft distances [dimensions in mm]				
Engine type	TC type	A	B <sup>1)</sup>	C <sup>1)</sup>
12V46F	TPL 71C	5600	11000	11200
14V46F	TPL 76C	5900	11300	12700
16V46F	TPL 76C	5900	11300	13700

<sup>1)</sup> Indicative dimension.

### 18.1.3 Four-engine installations



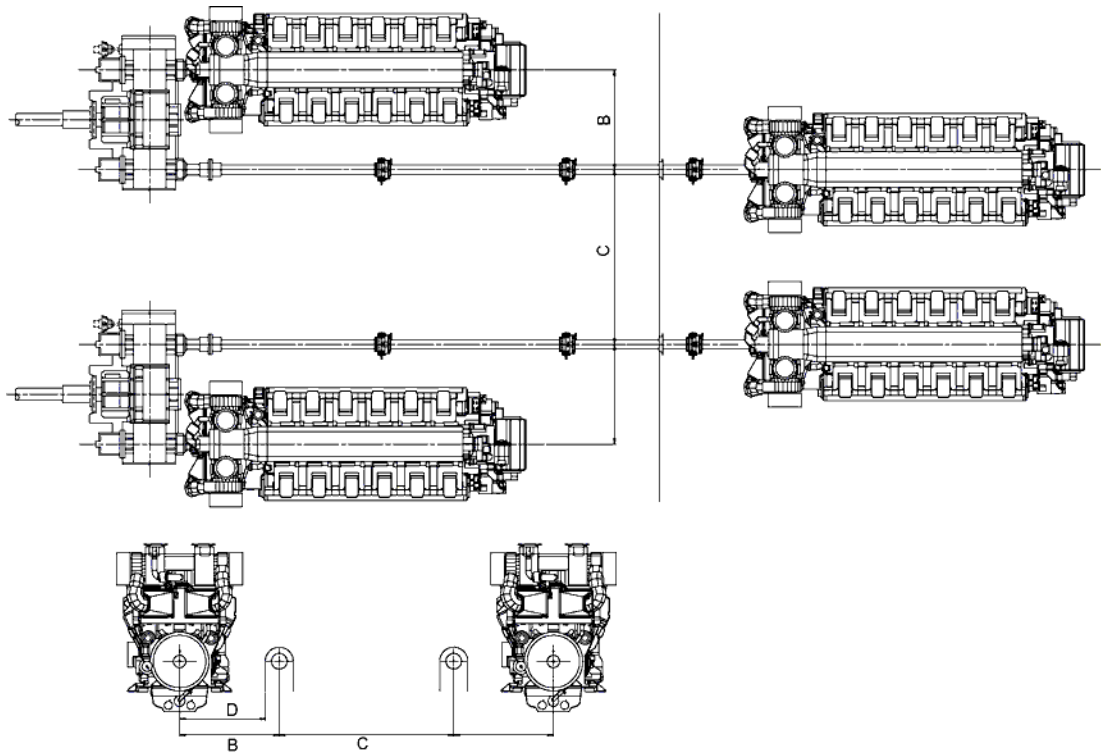
**Fig 18-3 Main engine arrangement, 4 x L46F (DAAE045069)**

Engine type	A [mm]	B [mm]	C [mm]	D [mm] <sup>1)</sup>
6L46F	1050	2100	3400	1850
7L, 8L, 9L46F	1050	2250	3700	1850

<sup>1)</sup> Minimum free space.

Intermediate shaft diameter to be determined case by case.

Dismantling of big end bearing requires 1500 mm on one side and 2300 mm on the other side. Direction may be freely chosen.



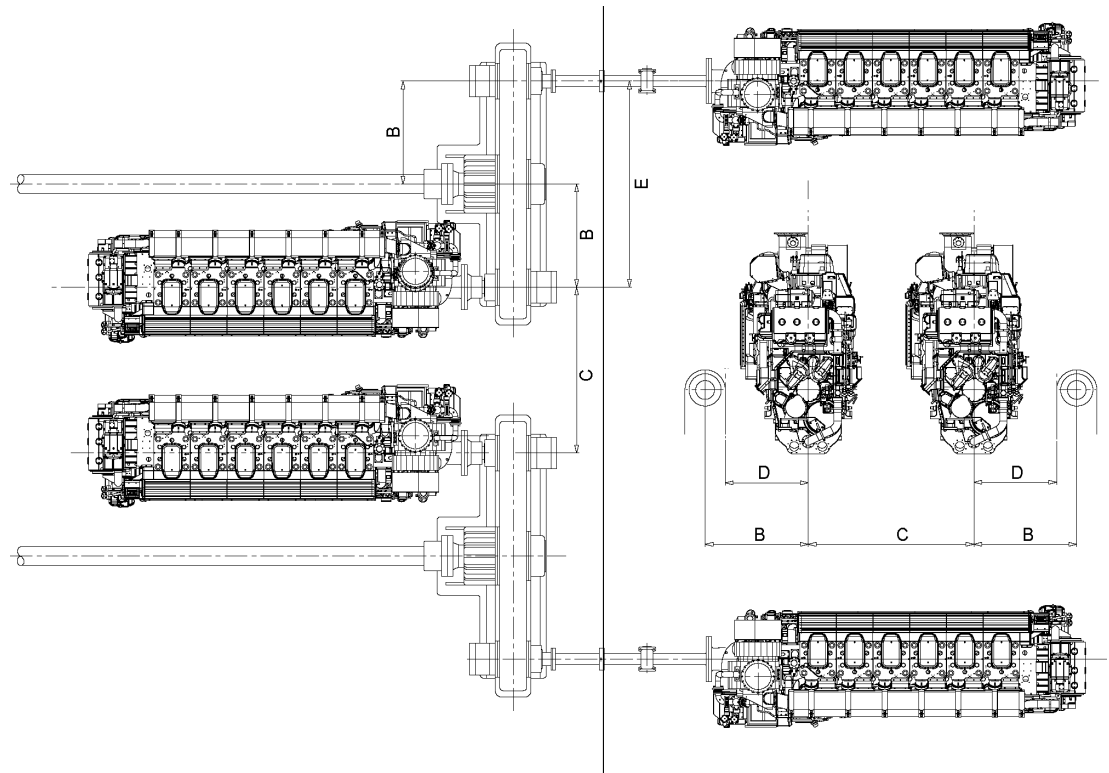
**Fig 18-4 Main engine arrangement, 4 x V46F (DAAE076528a)**

Engine type	B [mm] <sup>1)</sup>	C [mm]	D [mm] <sup>2)</sup>
12V46F	3200	5600	1900
14V46F	3200	5900	1900
16V46F	3200	5900	1900

1) Depending on the type of reduction gear.

2) Minimum free space.

Intermediate shaft diameter to be determined case by case.



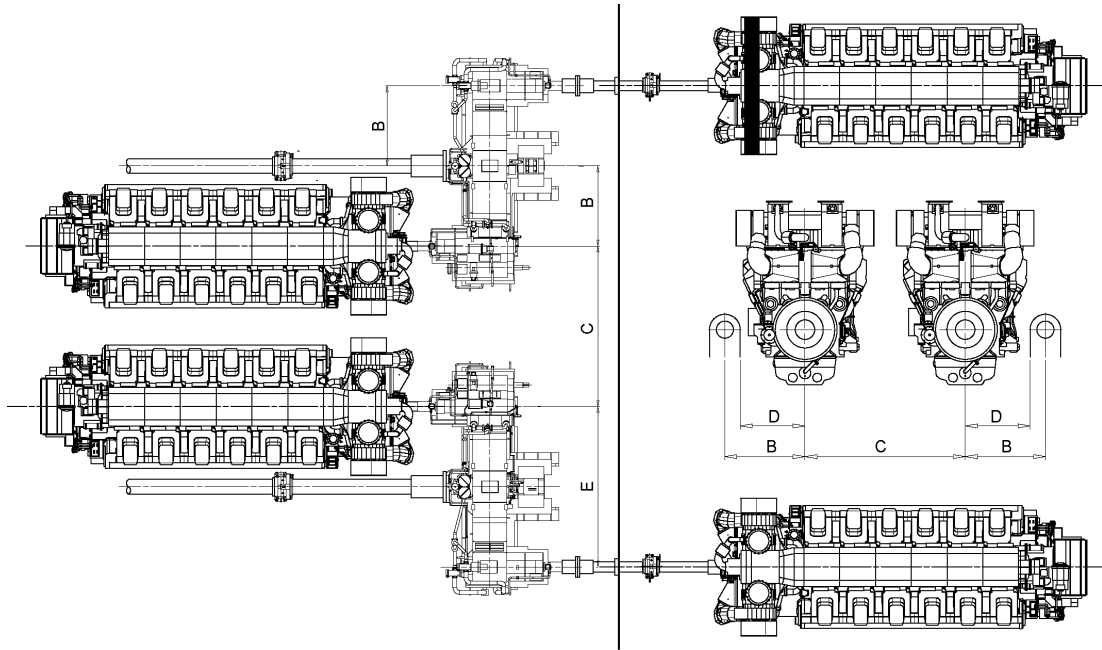
**Fig 18-5 Main engine arrangement, 4 x L46F (DAAE045142)**

Engine type	B [mm]	C [mm]	D [mm] <sup>1)</sup>	E [mm]
6L46F	2300	3400	1850	4600
7L, 8L, 9L46F	2450	3700	1850	4900

<sup>1)</sup> Minimum free space.

Propeller shaft diameter to be determined case by case.

Dismantling of big end bearing requires 1500 mm on one side and 2300 mm on the other side. Direction may be freely chosen.



**Fig 18-6 Main engine arrangement, 4 x V46F (DAAE075827a)**

Engine type	B [mm] <sup>1)</sup>	C [mm]	D [mm] <sup>2)</sup>	E [mm] <sup>1)</sup>
12V46F	2350	5600	1900	4700
14V46F	2350	5900	1900	4700
16V46F	2350	5900	1900	4700

1) Depending on the type of reduction gear.

2) Minimum free space

Intermediate shaft diameter to be determined case by case.



## 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 dismantling 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. Additional space is required for maintenance personnel operations.

However, also at locations where no space is required for dismantling 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).

Recommended height of the maintenance platforms are shown in figures [18-1](#) and [18-2](#).

#### NOTE



Working Platforms should be designed and positioned to prevent personnel slipping, tripping or falling on or between the walkways and the engine

## 18.3 Transportation and storage of spare parts and tools

Transportation 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.

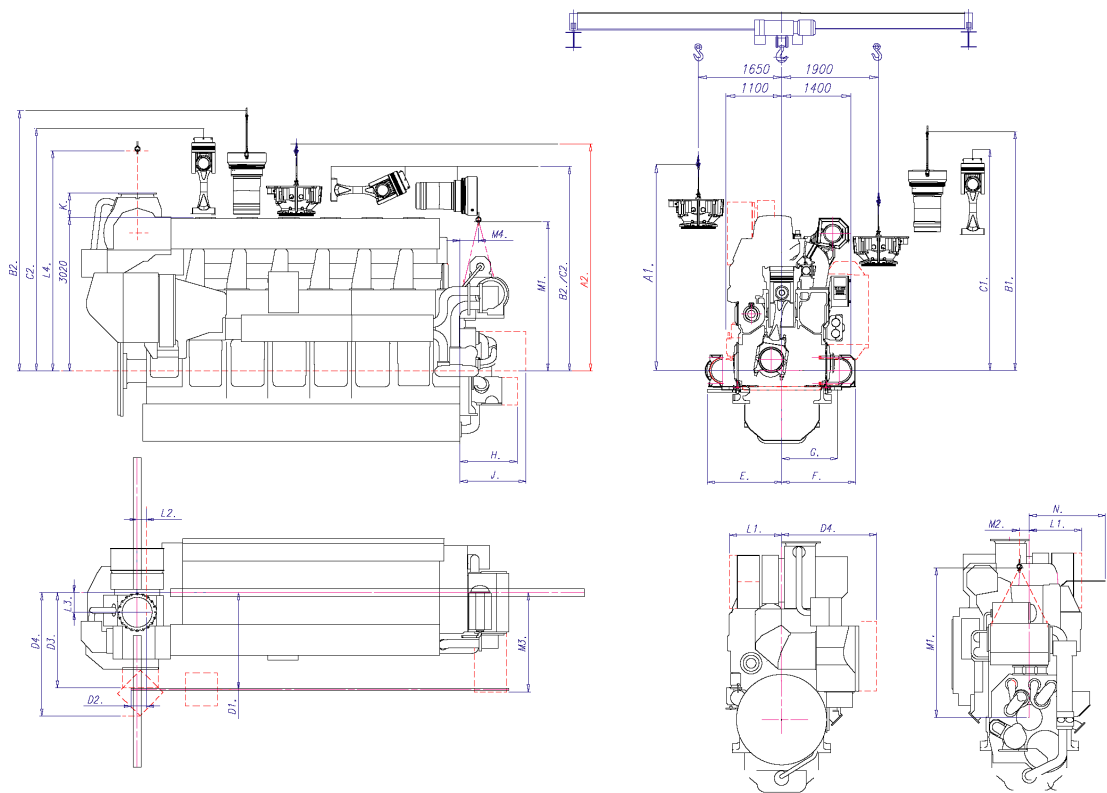
The engine room maintenance hatch must be large enough to allow transportation of all main components to/from the engine room.

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



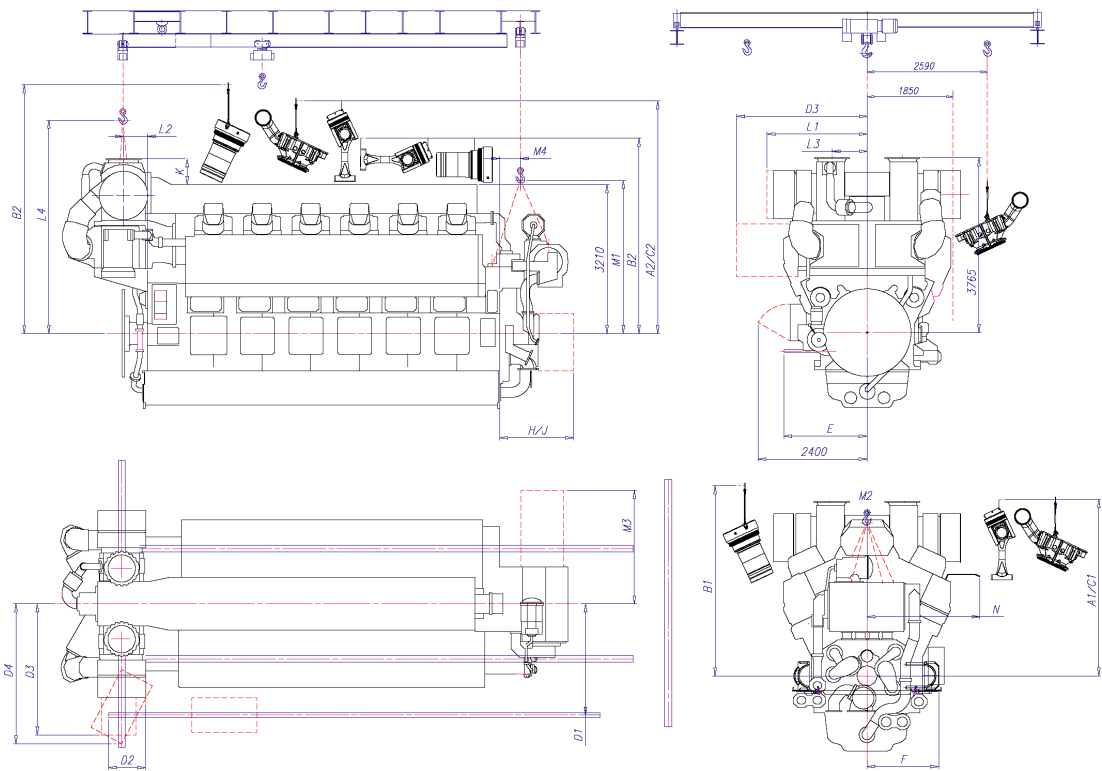
**Fig 18-7 Service space requirement, turbocharger in driving end (DAAE075830)**

Services spaces in mm		6L46F	7L-9L46F
A1	Height needed for overhauling cylinder head over accumulator	4060	4060
A2	Height needed for transporting cylinder head freely over adjacent cylinder head covers	4470	4470
B1	Height needed for overhauling cylinder liner	4700	4700
B2	Height needed for transporting cylinder liner freely over adjacent cylinder head covers	4020/5120	4020/5120
C1	Height needed for overhauling piston and connecting rod	4350	4350
C2	Height needed for transporting piston and connecting rod freely over adjacent cylinder head covers	4020/4770	4020/4770
D1	Recommended location of rail for removing the CAC on engine rear side	1900	1900
D2	Recommended location of starting point for rails.	300	300
D3	Minimum width needed for CAC overhauling	1870	2220
D4	Minimum width needed for turning of overhauled CAC.	2040	2430
E	Width needed for removing main bearing side screw	1470	1470
F	Width needed for dismantling connecting rod big end bearing	1450	1450
G	Width of lifting tool for hydraulic cylinder / main bearing nuts	1100	1100
H	Distance needed to dismantle lube oil pump	1125	1125
J	Distance needed to dismantle water pumps	1300	1300
K	Dimension between Cylinder head cap and TC flange	480	780
L1	Minimum maintenance space for TC dismantling and assembly. Values include minimum clearances 140 mm for 6L46F and 180 mm for 7-9L46F from silencer. The recommended axial clearance from silencer is 500mm.	1020	1270
L2	Recommended lifting point for the turbocharger	180	180
L3	Recommended lifting point sideways for the turbocharger	385	340
L4	Height needed for dismantling the turbocharger Recommended space needed to dismantle insulation, minimum space is 330mm	4340	4680
M1	Recommended height of lube oil module lifting tool eye	2940	2940

Services spaces in mm		6L46F	7L-9L46F
M2	Recommended width of lube oil module lifting tool eye	195	195
M3	Width needed for dismantling lube oil module insert	1915	1915
M4	Recommended lifting point for the lube oil module insert	365	365
N	Space necessary for opening the side cover	1500	1500

If a component is transported over TC, dimension K to be added to min. height values.

### 18.4.2 Service space requirement for the V-engine

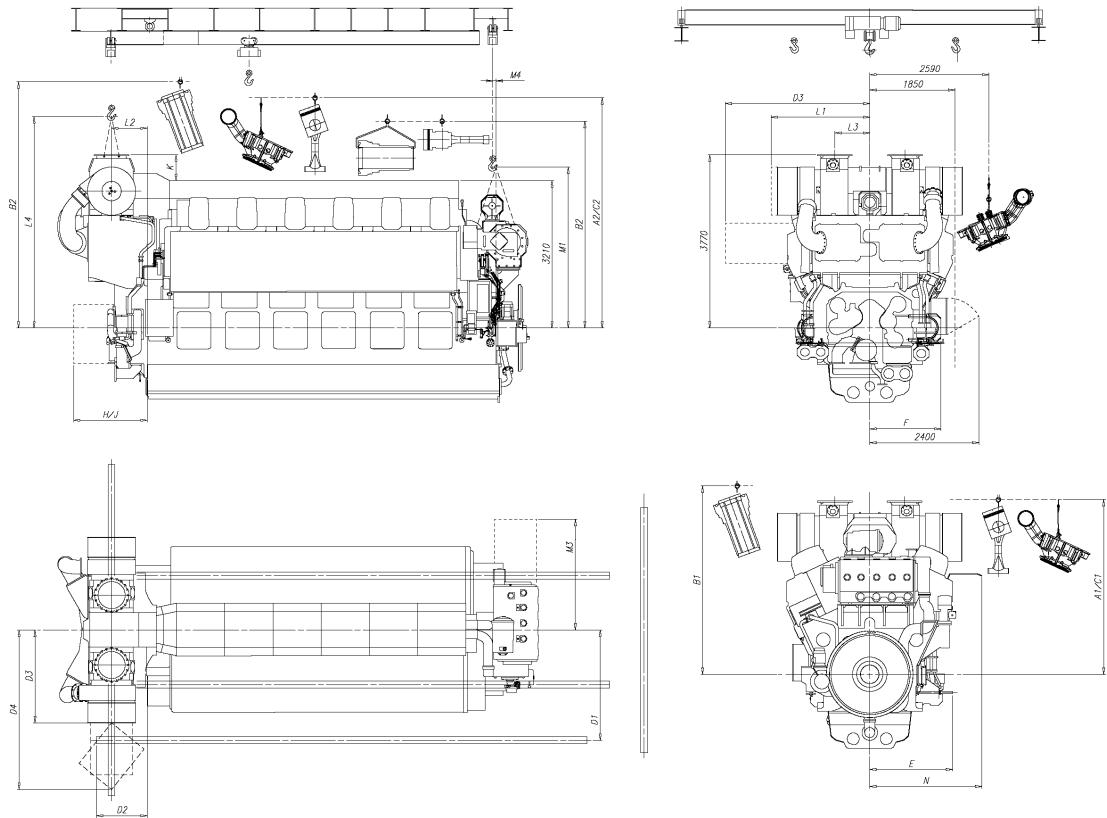


**Fig 18-8 Service space requirement, turbocharger in driving end (DAAE077270)**

Services spaces in mm		12V46F
A1	Height needed for overhauling cylinder head over accumulator	3800
A2	Height needed for transporting cylinder head freely over adjacent cylinder head covers	5010
B1	Height needed for transporting cylinder liner	4100
B2	Height needed for transporting cylinder liner freely over adjacent cylinder head covers	5360/4210
C1	Height needed for overhauling piston and connecting rod	3800
C2	Height needed for transporting piston and connecting rod freely over exhaust gas insulation box	5010
D1	Recommended location of rail for removing the CAC.	2400
D2	Recommended location of starting point for rails.	800
D3	Minimum width needed for CAC overhauling	2825
D4	Minimum width needed for turning of overhauled CAC.	3015
E	Width needed for removing main bearing side screw	1800
F	Width needed for dismantling connecting rod big end bearing	1550
H	Distance needed to dismantle lube oil pump	1600
J	Distance needed to dismantle water pumps	1600
K	Dimension between cylinder head cap and TC flange	555
L1	Minimum maintenance space for TC dismantling and assembly. Values include minimum clearances 140 mm from silencer. The recommended axial clearance from silencer is 500mm.	2165
L2	Recommended lifting point for the turbocharger	515
L3	Recommended lifting point sideways for the turbocharger	760
L4	Height needed for dismantling the turbocharger	4600
M1	Recommended height of lube oil module lifting tool eye	3300
M2	Recommended width of lube oil module lifting tool eye	0
M3	Width needed for dismantling lube oil module insert	2440
M4	Recommended lifting point for the lube oil module insert	450

Services spaces in mm		12V46F
N	Space necessary for opening the side cover	2450

If a component is transported over TC, dimension K to be added to min. height values.



**Fig 18-9 Service space requirement, turbocharger in free end (DAAR006874)**

Services spaces in mm		12V46F	14V, 16V46F
A1	Height needed for overhauling cylinder head over accumulator	3800	3800
A2	Height needed for transporting cylinder head freely over adjacent cylinder head covers	5010	5010
B1	Height needed for transporting cylinder liner	4100	4100
B2	Height needed for transporting cylinder liner freely over adjacent cylinder head covers	5360/4000	5360/4500
C1	Height needed for overhauling piston and connecting rod	3800	3800
C2	Height needed for transporting piston and connecting rod freely over exhaust gas insulation box	5010	5010
D1	Recommended location of rail for removing the CAC from A/B bank	2400	2400
D2	Recommended location of starting point for rails.	1100	1200
D3	Minimum width needed for CAC overhauling from A/B bank	3150	3150
D4	Minimum width needed for turning of overhauled CAC from A/B bank	3480	3480
E	Width needed for removing main bearing side screw	1800	1800
F	Width needed for dismantling connecting rod big end bearing	1550	1550
H	Distance needed to dismantle lube oil pump	1600	1600
J	Distance needed to dismantle water pumps	1600	1600
K	Dimension between cylinder head cap and TC flange	562	1026
L1	Minimum maintenance space for TC dismantling and assembly. Values include minimum clearances 140 mm (12V46F) and 180mm (14V, 16V46F) from silencer. The recommended axial clearance from silencer is 500mm.	2170	2520
L2	Recommended lifting point for the turbocharger	775	872
L3	Recommended lifting point sideways for the turbocharger	760	892
L4	Height needed for dismantling the turbocharger	4600	5120
M1	Recommended height of lube oil module lifting tool eye	3500	3500
M2	Recommended width of lube oil module lifting tool eye	0	0
M3	Width needed for dismantling lube oil module insert	2440	2440
M4	Recommended lifting point for the lube oil module insert	100	100

Services spaces in mm		12V46F	14V, 16V46F
N	Space necessary for opening the side cover	2450	2450

If a component is transported over TC, dimension K to be added to min. height values.

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# 19. Transport Dimensions and Weights

## 19.1 Lifting the in-line engine

Dimensions and weights are given for indication and may vary depending upon project specific configuration and the selected engine mounting type.

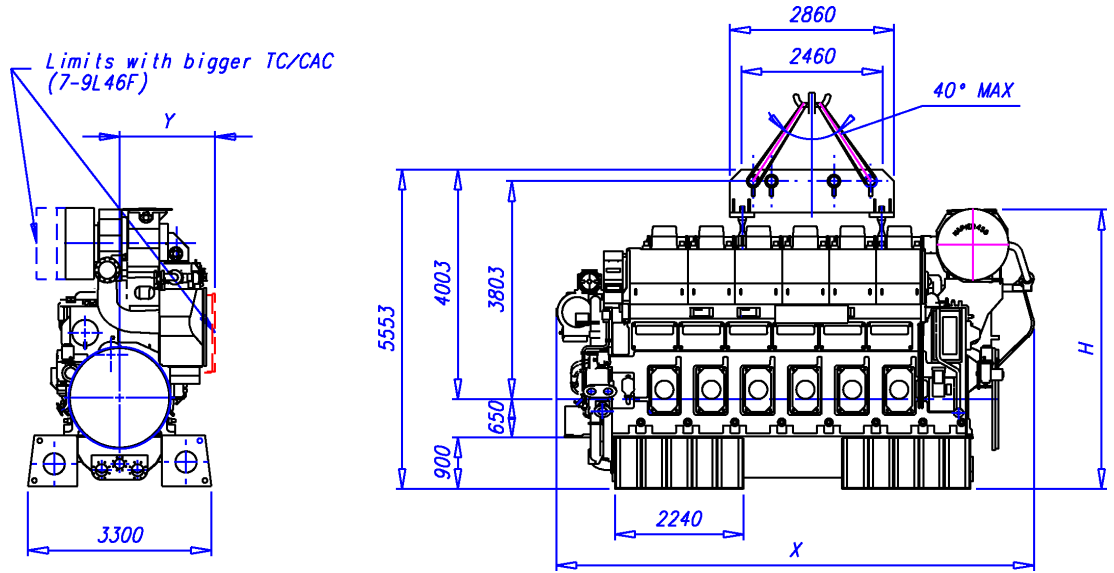
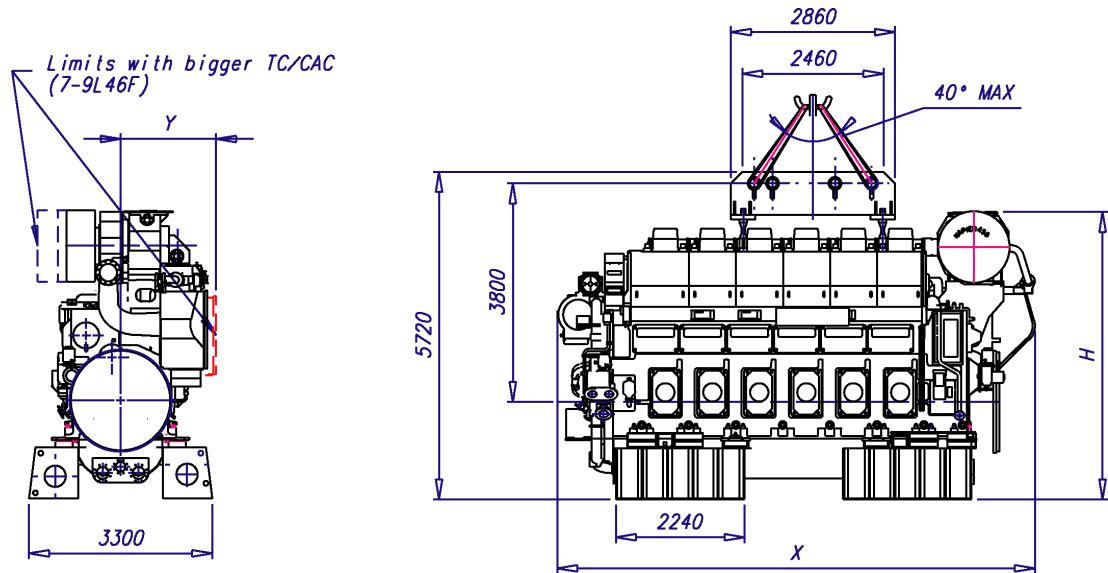


Fig 19-1 Lifting inline engines (DAAE016050a)

Engine type	X [mm]	Y [mm]	H [mm]	Weights without flywheel [ton]			
				Engine	Lifting device	Transport cradle	Total weight
6L46F	8330 <sup>1)</sup>	1520	5050	97	3.3	6.4	106.7
	8350 <sup>2)</sup>	1520	5050	97	3.3	6.4	106.7
7L46F	9380 <sup>1)</sup>	1720	5350	113	3.3	6.4	122.7
	9430 <sup>2)</sup>	1720	5350	113	3.3	6.4	122.7
8L46F	10200 <sup>1)</sup>	1720	5350	124	3.3	6.4	133.7
	10250 <sup>2)</sup>	1720	5350	124	3.3	6.4	133.7
9L46F	11020 <sup>1)</sup>	1720	5350	140	3.3	9.6	152.9
	11070 <sup>2)</sup>	1720	5350	140	3.3	9.6	152.9

1) Turbocharger at free end  
 2) Turbocharger at flywheel end



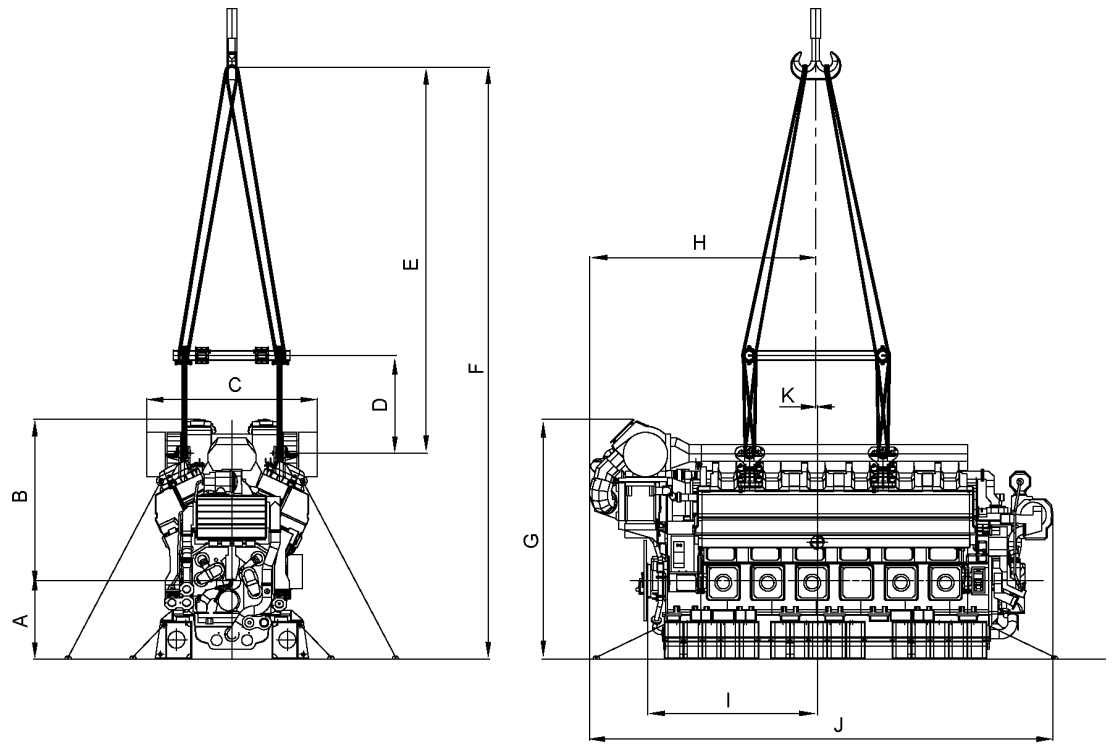
**Fig 19-2 Lifting of resiliently mounted engines (DAAE038985)**

Engine type	X [mm]	Y [mm]	H [mm]	Weights without flywheel [ton]				
				Engine	Lifting device	Transport cradle	Res. mounting	Total weight
6L46F	8330 <sup>1)</sup>	1515	5000	97	3.3	6.4	3.2	109.9
	8330 <sup>2)</sup>	1515	5000	97	3.3	6.4	3.2	109.9
7L46F	9380 <sup>1)</sup>	1720	5530	113	3.3	6.4	3.3	126.0
	9150 <sup>2)</sup>	1720	5530	113	3.3	6.4	3.3	126.0
8L46F	10200 <sup>1)</sup>	1720	5530	124	3.3	6.4	3.4	137.1
	9970 <sup>2)</sup>	1720	5530	124	3.3	6.4	3.4	137.1
9L46F	11020 <sup>1)</sup>	1720	5520	140	3.3	9.6	3.5	156.4
	10790 <sup>2)</sup>	1720	5530	140	3.3	9.6	3.5	156.4

<sup>1)</sup> Turbocharger at free end  
<sup>2)</sup> Turbocharger at flywheel end

## 19.2 Lifting the V-engine

Dimensions and weights are given for indication and may vary depending upon the selected engine mounting type.

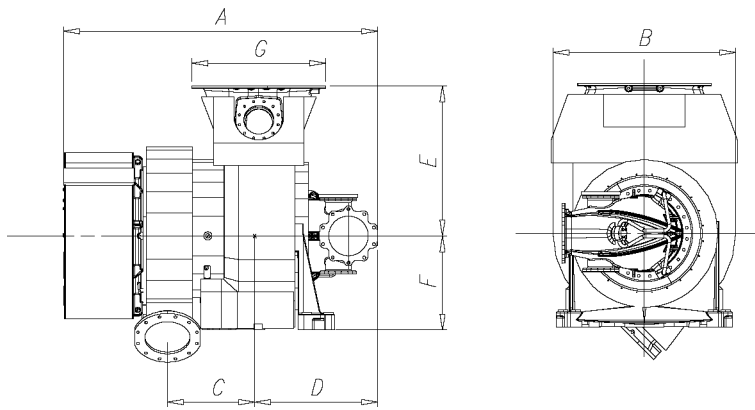


**Fig 19-3 Lifting of V engines (DAAF385502, DAAF383762,DAAF371508)**

Engine type	A [mm]	B [mm]	C [mm]	D [mm]	E [mm]	F [mm]	G [mm]	H [mm]	I [mm]	J [mm]	K [mm]
W12V46F	2066	3834	4050	2300	~9100	~14300	5900	5010	4080±150	10200	310±150
W14V46F	2066	4225	4650	2300	~9100	~14300	~6300	6060	3930±150	11480	130±150
W16V46F	1750	4250	4650	2300	~9100	~13900	~6000	6450±150	-	~12550	80±150

Engine type	Weights [ton]									
	Engine	Flexible mounting	Flywheel	Lifting tools	Transport cradle	Tarpaulin	Total Engine (±2.5)	Lifting device	Ropes	Total weight
W12V46F	175.0	9.2	1.2	2.8	9.6	0.2	197.6	1.5	2.0	201.1
W14V46F	216.0	10.2	1.1	2.5	9.6	0.2	238.6	1.5	2.0	242.1
W16V46F	219	9.1	1.6	2.8	9.6	0.3	242.4	1.5	2	245.9

### 19.3 Engine components



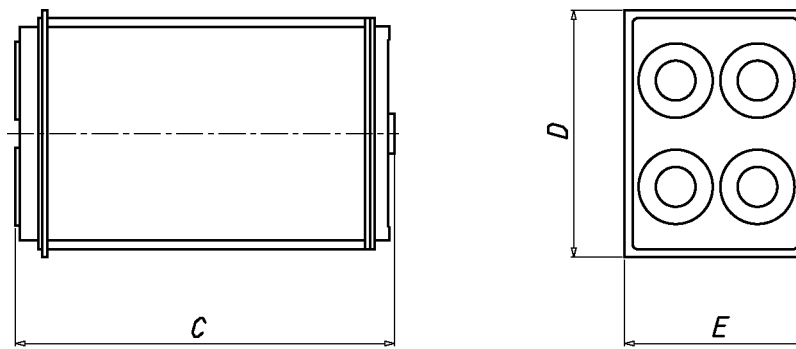
**Fig 19-4 Turbocharger (DAAE049544A)**

TC type	A	B	C	D	E	F	G	Weight rotor block cartridge	Weight complete
TPL 71C	2003	946	540	815	791	530	DN600	465	1960
TPL 76C	2301	1342	641	902	1100	690	DN800	815	3660
TPL 76C	2301	1342	641	902	1100	690	DN800	815	3660

6L and 12V46F are equipped with TPL 71C.

7L, 8L, 9L, 14V and 16V46F are equipped with TPL 76C.

Dimensions in mm. Weight in kg.



**Fig 19-5 Charge air cooler inserts (DAAR013169)**

Engine type	C	D	E	Weight
6L46F	1950	660	650	770
7-9L46F	1950	860	970	960
12V46F	1407	1115	810	1350
14V46F	1607	1115	820	1430
16V46F	1607	1115	820	1430

Dimensions in mm. Weight in kg.

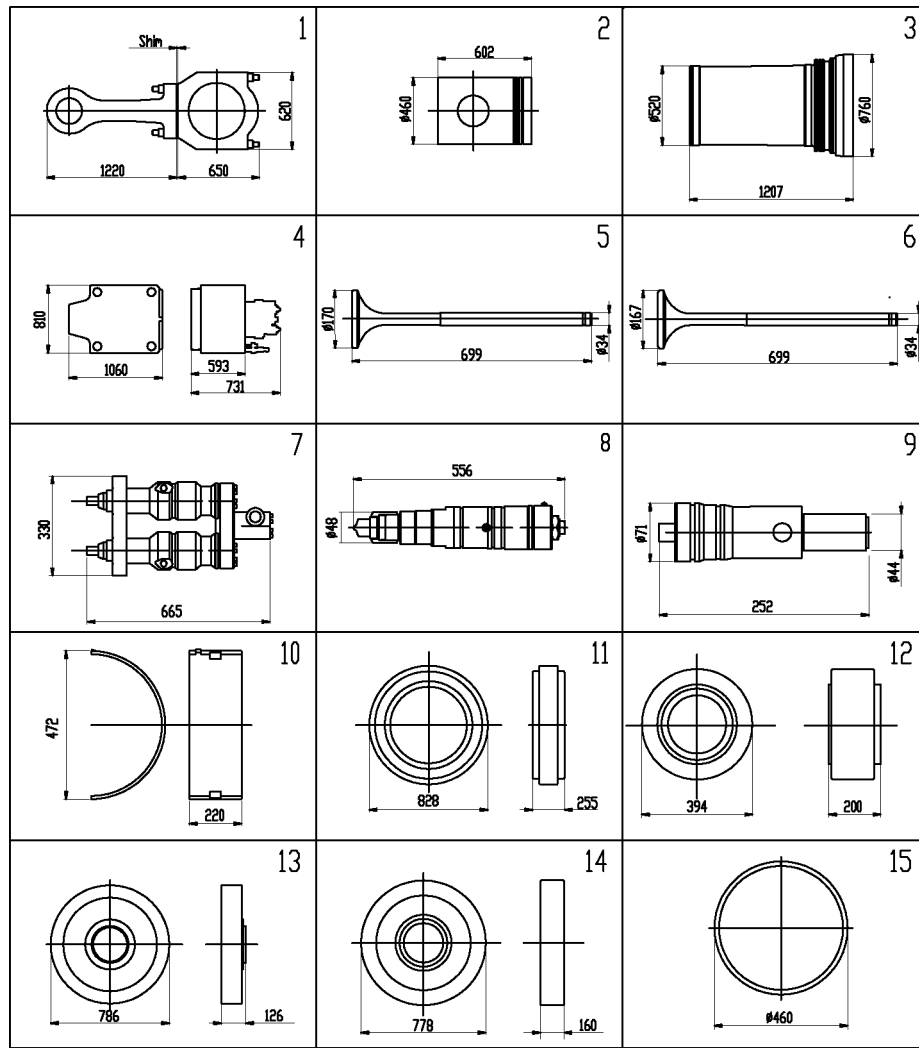


Fig 19-6 Major spare parts (DAAE029505)

Item	Description	Weight [kg]	Item	Description	Weight [kg]
1	Connecting rod	615	9	Starting valve	4.2
2	Piston	211	10	Main bearing shell	12
3	Cylinder liner	932.5	11	Split gear wheel	-
4	Cylinder head	1170	12	Small intermediate gear	111
5	Inlet valve	10	13	Large intermediate gear	214
6	Exhaust valve	10.6	14	Camshaft gear wheel	252
7	Injection pump	142	15	Piston ring set	2.5
8	Injection valve	25		Piston ring	0.5

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## 20. Product Guide Attachments

This and all other product guides can be accessed on the internet, at [www.wartsila.com](http://www.wartsila.com). Product guides are available both in web and PDF format. Engine outline drawings are available not only in 2D drawings (in PDF, DXF format), but also in 3D models in near future. Please consult your sales contact at Wärtsilä for more information.

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

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# 21. ANNEX

## 21.1 Unit conversion tables

The tables below will help you to convert units used in this product guide to other units. Where the conversion factor is not accurate a suitable number of decimals have been used.

*Length conversion factors*

Convert from	To	Multiply by
mm	in	0.0394
mm	ft	0.00328

*Mass conversion factors*

Convert from	To	Multiply by
kg	lb	2.205
kg	oz	35.274

*Pressure conversion factors*

Convert from	To	Multiply by
kPa	psi (lbf/in <sup>2</sup> )	0.145
kPa	lbf/ft <sup>2</sup>	20.885
kPa	inch H <sub>2</sub> O	4.015
kPa	foot H <sub>2</sub> O	0.335
kPa	mm H <sub>2</sub> O	101.972
kPa	bar	0.01

*Volume conversion factors*

Convert from	To	Multiply by
m <sup>3</sup>	in <sup>3</sup>	61023.744
m <sup>3</sup>	ft <sup>3</sup>	35.315
m <sup>3</sup>	Imperial gallon	219.969
m <sup>3</sup>	US gallon	264.172
m <sup>3</sup>	l (litre)	1000

*Power conversion*

Convert from	To	Multiply by
kW	hp (metric)	1.360
kW	US hp	1.341

*Moment of inertia and torque conversion factors*

Convert from	To	Multiply by
kgm <sup>2</sup>	lbft <sup>2</sup>	23.730
kNm	lbf ft	737.562

*Fuel consumption conversion factors*

Convert from	To	Multiply by
g/kWh	g/hph	0.736
g/kWh	lb/hph	0.00162

*Flow conversion factors*

Convert from	To	Multiply by
m <sup>3</sup> /h (liquid)	US gallon/min	4.403
m <sup>3</sup> /h (gas)	ft <sup>3</sup> /min	0.586

*Temperature conversion factors*

Convert from	To	Multiply by
°C	F	$F = 9/5 \text{ °C} + 32$
°C	K	$K = C + 273.15$

*Density conversion factors*

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

### 21.1.1 Prefix

**Table 21-1 The most common prefix multipliers**

Name	Symbol	Factor	Name	Symbol	Factor	Name	Symbol	Factor
tera	T	10 <sup>12</sup>	kilo	k	10 <sup>3</sup>	nano	n	10 <sup>-9</sup>
giga	G	10 <sup>9</sup>	milli	m	10 <sup>-3</sup>			
mega	M	10 <sup>6</sup>	micro	μ	10 <sup>-6</sup>			

## 21.2 Collection of drawing symbols used in drawings

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
1 2101		Valve (general)	10 X2113		Check valve globe type	17 X2131		Control valve with electric motor actuator
2 X8068		Valve, globe type	11 X8078		Swing check valve (Form 1)	18 X2103		Two-way valve with solenoid actuator
3 X8071		Valve, ball type	12 X8165		Swing check valve (Form 2)	19		Two-way valve with double-acting cylinder actuator (pneumatic)
4 X8074		Valve, gate type	13 X2124		Safety valve, spring loaded, globe type	20 X2104		Two-way valve with electric motor actuator
5 X8075		Valve, butterfly type (Form 1)	14 X1021		Manual operation of valve	21 X2101		Two-way valve with diaphragm actuator (pneumatic)
6 X8075		Valve, butterfly type (Form 2)	15 X2001		Weight-loaded safety valve detained in open position after operation	22		Two-way control valve with diaphragm actuator (pneumatic)
7 X8076		Valve, needle type	16 X2134		Float-operated control valve	23 X2002		Spring-loaded safety two-way valve with automatic return after operation
8 X8087		Valve, control type, continuously operated						
9 X8077		Check valve (general), (Two-way non-return valve, flow from left to right)						

Fig 21-1 List of symbols (DAAF406507 - 1)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
24		Manually operated control valve	33 X8070		Valve, three way globe type	40		Three-way control valve with diaphragm actuator
25 X2112		Combinated non-return valve and manually actuated stop valve. Flow from left to right	34 X8073		Valve, three way ball type	41		Self-operating pressure reducing three-way control valve
26		Spring-loaded non-return valve. Flow from left to right	35		Three-way control valve with electrical motor actuator	42		Self-operating thermostatic three-way control valve
27 X2133		Self-operating pressure reducing control valve	36 X2103		Three-way valve with solenoid actuator	43		Self-contained thermostat valve
28		Pressure control valve (spring loaded)	37 X2107		Three-way valve with double-acting cylinder actuator (pneumatic)	44 2102		Valve, angle type (general)
29		Pressure control valve (remote pressure sensing)	38		Three-way valve with electric motor actuator	45 X8069		Valve, angle globe type
30		Pneumatically actuated valve, spring-loaded cylinder actuator	39 X2102		Three-way valve with diaphragm actuator			
31		Quick-closing valve						
32 2103		Valve, three way type (general)						

Fig 21-2 List of symbols (DAAF406507 - 2)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
46 X8072		Valve, angle ball type	55 772		Orifice plate	62		Valve 2/2 Pneum/Pneum
47 X2125		Safety valve, spring loaded, globe angle type	56 X2182		Shuttle valve with "AND-function"	63		Valve 2/2 Pneum/Spring
48		Weight loaded angled valve detained in open position after operation	57		Valve 2/2 Pneum/Pneum	64		Valve 2/2 Solenoid/Spring
49		Spring-loaded safety angled valve with automatic return after operation	58		Valve 2/2 Pneum/Spring	65		Valve 2/2 Lever/Spring
50		Non-return angled two-way valve. Flow from left to right	59		Valve 2/2 Solenoid/Spring	66		Valve 2/2 Manual/Spring
51		Non-return angled two-way valve hand operating. Flow from left to right	60		Valve 2/2 Lever/Spring	67		Valve 2/2 Pneum/Pneum
52 2181		Self-operating release valve (steam trap)	61		Valve 2/2 Manual/Spring			
53 X2212		Adjustable restrictor (valve)						
54 2031		Restrictor						

Fig 21-3 List of symbols (DAAF406507 - 3)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
68		Valve 2/2 Pneum/Spring	77		Electrically driven compressor	84 X8079		Heat exchanger (general), condenser
69		Valve 2/2 Solenoid/Spring	78 2302		Compressor, vacuum pump (general)	85 X2674		Pneumatic-air lubricator
70		Valve 2/2 Lever/Spring	79 2301		Pump, liquid type (general)	86 X8111		Cooling tower, dry with induced draught
71		Valve 2/2 Manual/Spring	80 2401		Hydraulic pump	87 2521		Cooling tower (general) (Deerator)
72		Turbogenerator	81		Manual hydraulic pump	88 2040		Funnel
73		Turbogenerator with gear transmission	82 X2071		Boiler feedwater vessel with deerator	89		Trough or drip tray with drain funnel
74		Turbocharger	83 2501		Heating or cooling coil			
75 C0082		Electric motor (general)						
76		Electrically driven pump						

Fig 21-4 List of symbols (DAAF406507 - 4)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
90 517		Flanged dummy cover (Blind flange pair)	99 564		Quick-release coupling element of female type	106		Air vent + flame arrestor
91 511		Flanged connection	100 563		Quick-release coupling element of male type	107 2036		Flame arrestor
92 518		End cap	101 X411		Hose	108 X322		Pipeline with thermal insulation
93 514		Screwed joint	102 532		Expansion sleeve	109 X8174		Piping, heated or cooled and insulated
94 516		Reducer	103 533		Compensator (Expansion bellows)	110 X2619		High speed centrifuge (Separator)
95		Joint with change of pipe dimension, pipe reducer eccentric	104 2038		Siphon	111 X2614		Centrifuge with perforated shell (Centrifugal filter)
96 565		Quick-release coupling element which fits into another coupling element of the same type	105 2039		Vent (outlet to the atmosphere for steam/gas)			
97 567		Quick-release coupling element of female type with automatic closing when decoupled						
98 566		Quick-release coupling element of male type with automatic closing when decoupled						

Fig 21-5 List of symbols (DAAF406507 - 5)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
112 X8116		Liquid filter (general)	121 X8123		Screening device, sieve, strainer, general	128 X2069		Vessel with dished ends and heating / cooling jacket
113 X8117		Liquid filter, bag, candle or cartridge type	122 X8031		Gravity separator, settling chamber	129 2033		Silencer
114		Automatic filter with by-pass filter	123 X2618		Separator, cyclone type	130 2034		Viewing glass
115 X8019		Suction filter	124 X8090		Strainer	131		Receiver, pulse damper
116 X8119		Liquid rotary filter, drum or disc type	125 2073		Pressure vessel with diaphragm, for example expansion vessel	132		Indicating measuring instrument P = Pressure 106 T = Temperature 107 Y = Density 102 F = Flow rate 108
117		Duplex filter	126 2062		Pressure or vacuum vessel	133		Local instrument
118		Candle filter with rotating drum with by-pass	127 301		Tank, vessel			
119 X8122		Gas filter (general)						
120 X8022		Gas filter, bag, candle or cartridge type						

Fig 21-6 List of symbols (DAAF406507 - 6)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
134		Local panel	141 X1032		Automatic operation of valve with two stable positions open and close	148		
135		Signal to control board	142			149		
136		TI = Temperature indicator TE = Temperature sensor TEZ = Temperature sensor shut-down PI = Pressure indicator PS = Pressure switch PT = Pressure transmitter PSZ = Pressure switch shut-down FOIS = Differential pressure indicator and alarm LS = Level switch QS = Flow switch TSZ = Temperature switch	143			150		
137 X2122		Overflow safety valve	144			151		
138 X1048		Flow rate indication	145			152		
139 X1056		Recording of flow rate with summation of volume	146			153		
140 X1036		Automatic operation of valve with infinite number of stable positions	147					

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





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