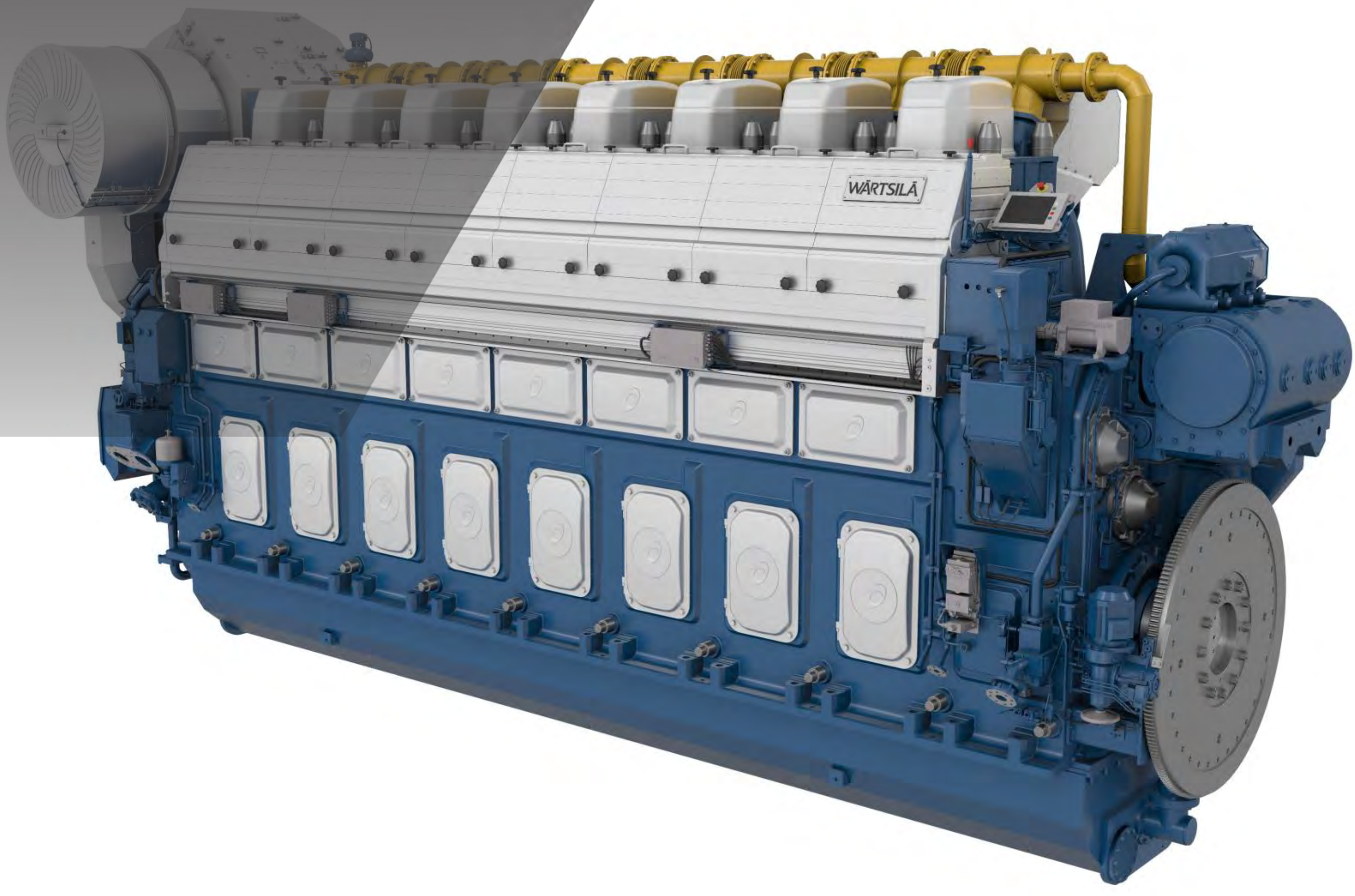
Wärtsilä 46DF

PRODUCT GUIDE



Introduction

This Product Guide provides data and system proposals for the early design phase of marine engine installations. For contracted projects specific instructions for planning the installation are always delivered. Any data and information herein is subject to revision without notice. This 02/2019 issue replaces all previous issues of the Wärtsilä 46DF Project Guides.

Issue	Published	Updates
2/2019	20.11.2019	Various update through the Product Guide
1/2019	13.05.2019	Many updates/changes to the whole Product Guide
3/2016	XX.11.2016	New front- and backcovers for pdf version. Technical data updated. Other minor updates.
2/2016	04.11.2016	Small update to technical data
1/2016	09.09.2016	Technical data updated
1/2014	03.10.2014	First version of W46DF product guide

Wärtsilä, Marine Solutions

Vaasa, November 2019

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1. Main Data and Outputs

The Wärtsilä 46DF is a 4-stroke, non-reversible, turbocharged and inter-cooled dual fuel engine with direct injection of liquid fuel and indirect injection of gas fuel. The engine can be operated in gas mode or in diesel mode.

Cylinder bore	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 6L46DF	6870	9340
W 7L46DF	8015	10900
W 8L46DF	9160	12450
W 9L46DF	10305	14010
W 12V46DF	13740	18680
W 14V46DF	16030	21790
W 16V46DF	18320	24910

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

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

where:

P_e = mean effective pressure [bar]

P = output per cylinder [kW]

n = engine speed [r/min]

D = cylinder diameter [mm]

L = length of piston stroke [mm]

c = operating cycle (4)

1.2 Output limitations in gas mode

1.2.1 Output limitations due to methane number

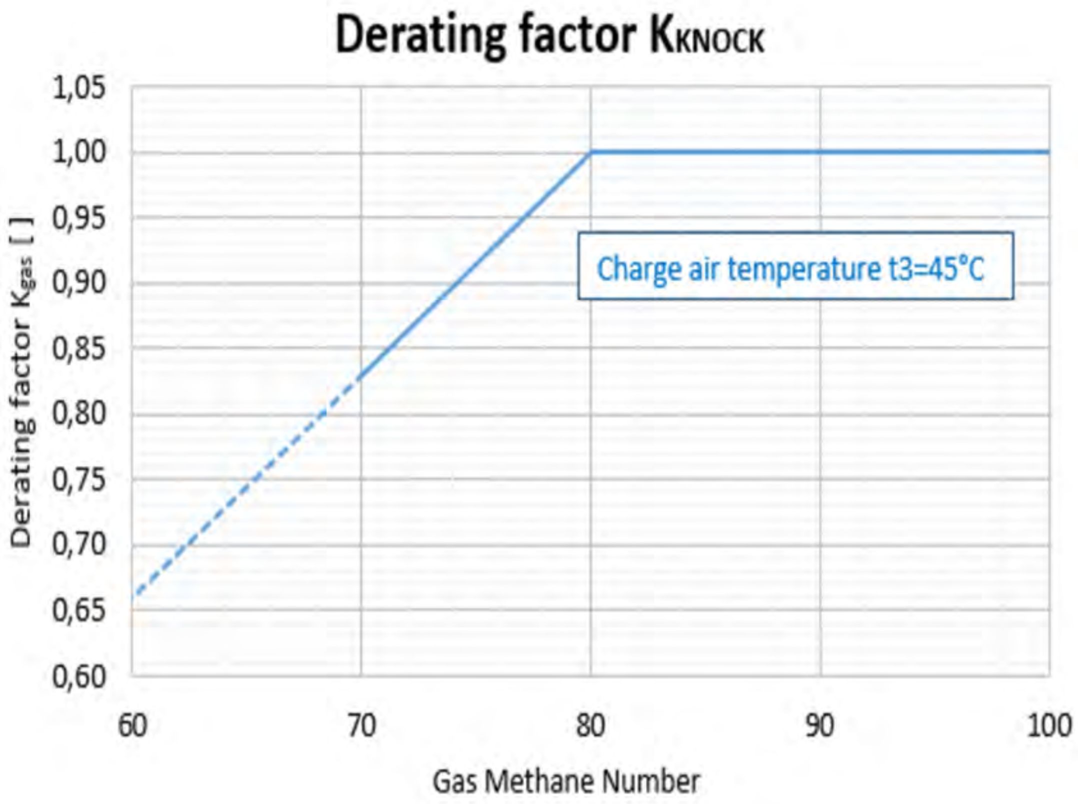

Fig 1-1 Output limitations due to methane number

Calculation Formulas for different compression ratios	
CR 12.7:1	if MN ≥ 80 and tbax ≤ 45 → KKNOCK = 1
	if MN < 80 and/or tbax > 45 → KKNOCK = 1 - 0.017*(80 - MN) - (1 - (1 + 0.01*(45 - tbax)))

NOTE

In case of MN <80 and MN >70 derating factor could be 1%/1MN with a penalization of efficiency.

NOTE

1) Gas fuel methane number refers to the gas quality at the engine inlet. This may differ from the average gas quality in LNG tank.

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

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

4) The dew point shall be calculated for the specific site conditions. The minimum charge air receiver temperature shall be above the dew point, otherwise condensation will occur in the charge air cooler.

5) The charge air receiver temperature is approximately 5 °C higher than the charge air coolant temperature at rated load (CAC Team to be involved for LT water temperature info).

6) Glycol usage in cooling water according to document DAAE062266.

7) Min. suction air temperature is 5 °C.

8) High suction air temperature gives a higher air temperature after compressor, before the charge air cooler, and therefore a higher heat output from the 1-stage of the charge air cooler, compared to low suction air temperature.

9) Temperatures given above are max. (continuous) operating temperature at site. For suction air temperatures 40°C, please contact Product Engineering department.

10) The permissible pressure drop in the inlet pipe before the turbocharger is max. 1kPa.

11) The total sum of exhaust gas back pressure and air inlet pressure drop is not allowed to be higher than 5 kPa.

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

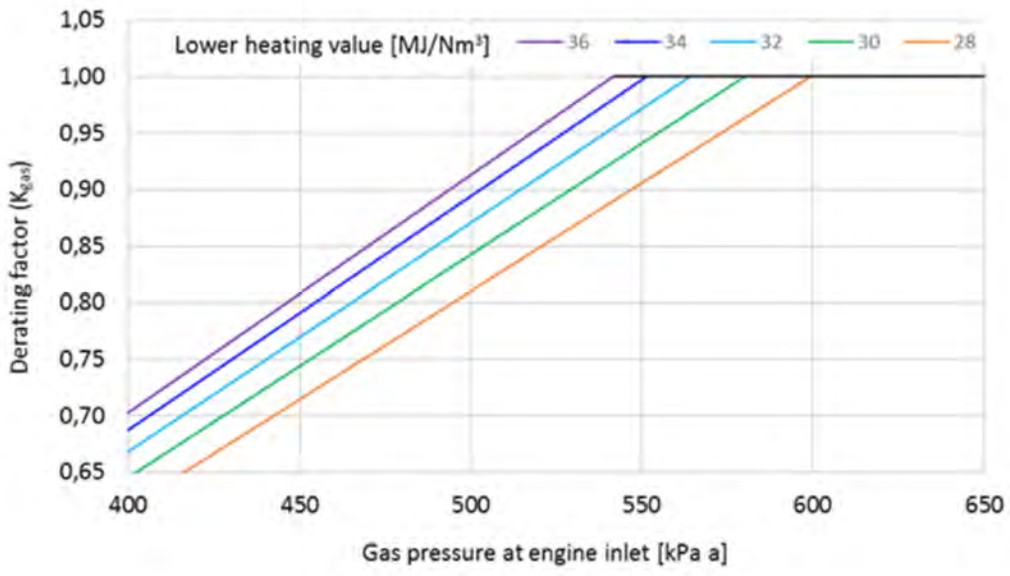

Fig 1-2 Derating of output for gas feed pressure and LHV

		MJ/Nm3				
KGAS	36	34	32	30	28	
1	542	552	564	580	599	kPa a
0,5	303	309	317	326	338	

NOTE

1) Values given in m3 are valid at 0°C and 101.3 kPa.

2) The values for gas feed pressure are valid at the engine inlet i.e. after the gas regulating unit.

3) Receiver pressure requirement is dependent on humidity. Receiver pressure level influences on the required gas feed pressure. These values are valid for the humidity up to 30g water/kg dry air.

4) Fuel gas feed pressure is not allowed to decrease from the level given for 36 MJ/Nm3 with LHV higher than 36 MJ/Nm3.

5) Gas fuel lower heating value refers to the gas quality at the engine inlet. This may differ from the average gas quality in LNG tank.

6) No compensation (uprating) of the engine output is allowed, neither for gas feed pressure higher than required in the graph above nor lower heating value above 36 MJ/Nm3.

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

1.3 Reference conditions

The output is available within a range of ambient conditions and coolant temperatures specified in the chapter *Technical Data*. The required fuel quality for maximum output is specified in the section *Fuel characteristics*. For ambient conditions or fuel qualities outside the specification, the output may have to be reduced.

The specific fuel consumption is stated in the chapter *Technical Data*. The statement applies to engines operating in ambient conditions according to ISO 15550:2002 (E).

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

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

1.4 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°

1.5 Dimensions and weights

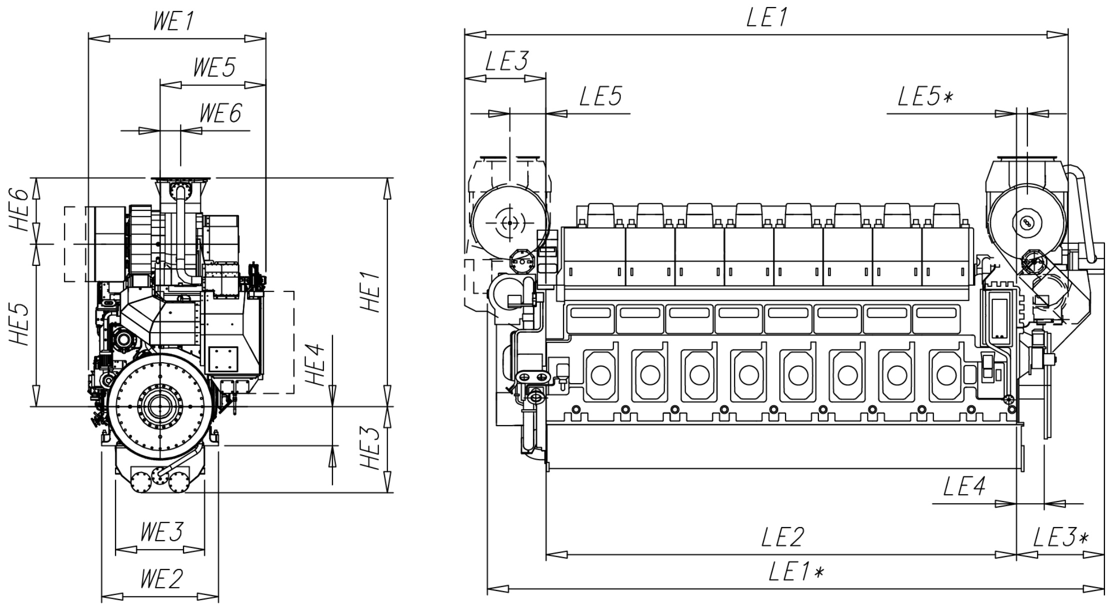

Fig 1-3 In-line engines (DAAR038987)

Engine	LE1*	LE1	LE2	LE3*	LE3	LE4	LE5*	LE5	HE1	HE3
6L46DF	8670	8953	6170	1520	-	460	292	699	3255	1430
7L46DF	9635	9773	6990	1520	-	460	292	699	3255	1430
8L46DF	10310	10593	7810	1520	1883	460	292	658	3445	1430
9L46DF	11130	11413	8630	1520	1883	460	292	658	3445	1430

Engine	HE4	HE5	HE6	WE1	WE2	WE3	WE5	WE6	Weight [ton]
6L46DF	650	2605	650	3185	1940	1480	1780	330	102
7L46DF	650	2605	650	3185	1940	1480	1780	330	118
8L46DF	650	2605	755	3185	1940	1480	1780	398	130
9L46DF	650	2605	755	3185	1940	1480	1780	398	146

* Turbocharger at driving end

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

Table 1-2 Additional weights [ton]:

Item	6L46DF	7L46DF	8L46DF	9L46DF
Flywheel	1-2	1-2	1-2	1-2
Flexible mounting (without limiters)	3.2	3.4	3.4	3.4

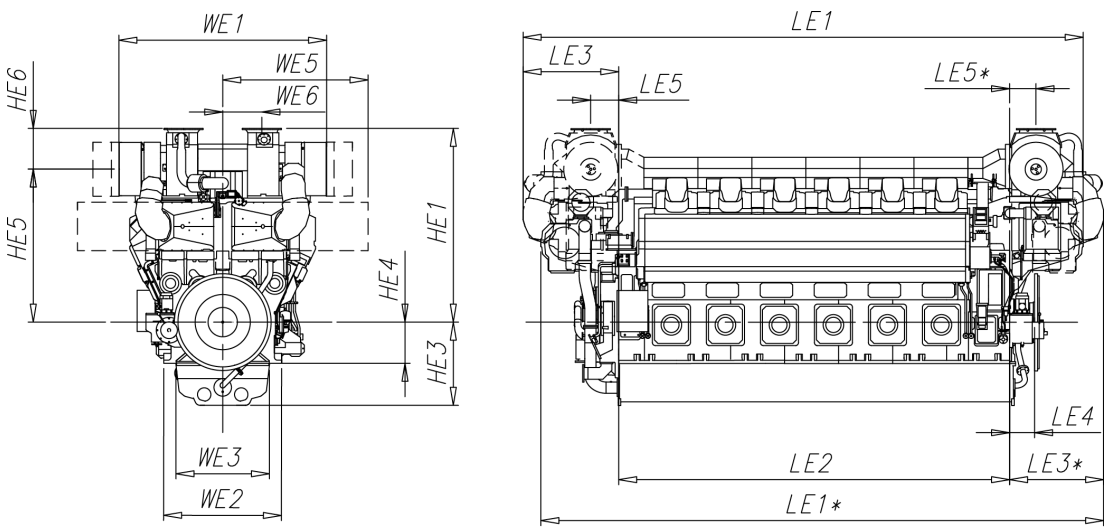

Fig 1-4 V-engines (DAAR038992)

Engine	LE1*	LE1	LE2	LE3*	LE3	LE4	LE5*	LE5	HE1	HE3
12V46DF*	11036	-	7600	1921	-	460	430	-	3670	1620
12V46DF	-	10375	7600	-	2043	485	-	684	3670	1620
14V46DF	-	11425	8650	-	2043	485	-	684	3670	1620
16V46DF	-	12687	9700	-	2347	485	-	689	3860	1620

Engine	HE4	HE5	HE6	WE1	WE2	WE3	WE5	WE6	Weight [ton]
12V46DF*	800	3020	650	4555	2290	1820	3225	781	184
12V46DF	800	3020	650	4555	2290	1820	3225	781	184
14V46DF	800	3020	650	4555	2290	1820	3225	781	223
16V46DF	800	3110	750	5174	2290	1820	3225	858	235

* Turbocharger at driving end

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

Table 1-3 Additional weights [ton]:

Item	12V46DF	14V46DF	16V46DF
Flywheel	1-2	1-2	1-2
Flexible mounting (without limiters)	8	10	10

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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. Engine load is determined from measured shaft power and actual engine speed. The shaft power meter is supplied by Wärtsilä.

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

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

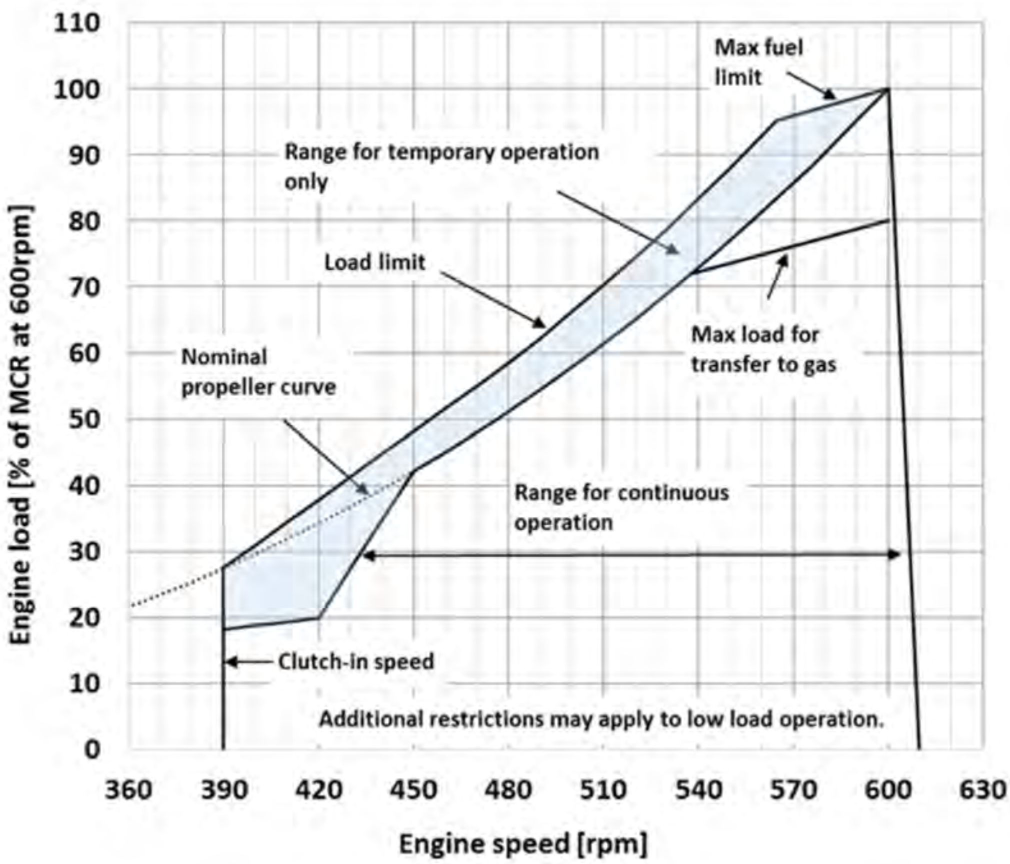


Fig 2-1 Operating field for CP Propeller, 1145 kW/cyl, 600 rpm

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

Restrictions for low load operation to be observed.

2.2 Loading capacity

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

The loading ramp “preheated” (see figures) can be used as the default loading rate for both diesel and gas mode. If the control system has only one load increase ramp, then the ramp for a preheated engine must be used. The HT-water temperature in a preheated engine must be at least 70ºC, and the lubricating oil temperature at least 40ºC.

The loading ramp “Normal operating temperature” are recommended to be taken into use when the engine is warm. 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 control system has only one load increase ramp, then the ramp for a preheated engine is to be used.

Fast load changes must be avoided during transfer from diesel to gas mode.

The “emergency” loading ramp in diesel mode can be used in critical situations, e.g. when recovering from a fault condition to regain sufficient propulsion and steering 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.

In applications with highly cyclic load, e.g. dynamic positioning and manoeuvring, maximum loading and unloading capacity in gas mode (see figure 2-3) can be used in operating modes that requires fast response. Other operating modes should have slower loading rates.

Maximum possible loading and unloading can also be required in other special applications. The engine control does not limit the loading rate in gas mode (it only acts on deviation from reference speed). If the loading rate is faster than the capacity in gas mode, the engine trips to diesel.

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

2.2.1 Mechanical propulsion, controllable pitch propeller (CPP)

For successive loading rates and max ramp in variable speed, please contact Wartsila to have further informations.

2.2.2 Constant speed application

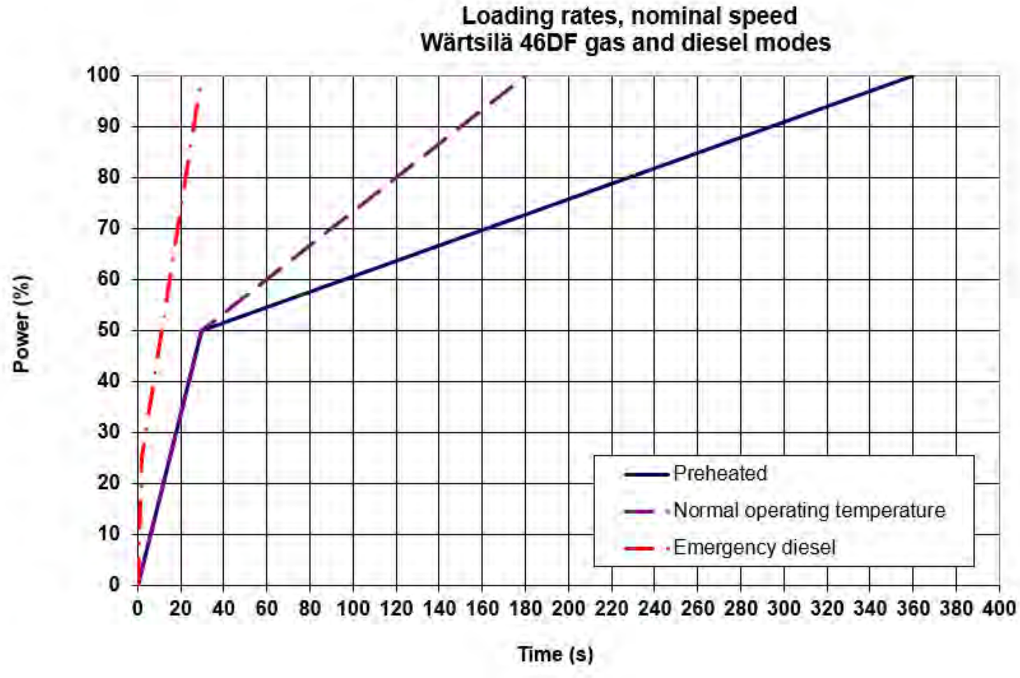


Fig 2-2 Successive Loading

The loading rates in gas mode in the diagrams above are to be applied when the gas Methane Number is ≥ 80. For MN below 80, please contact Wartsila for further information.

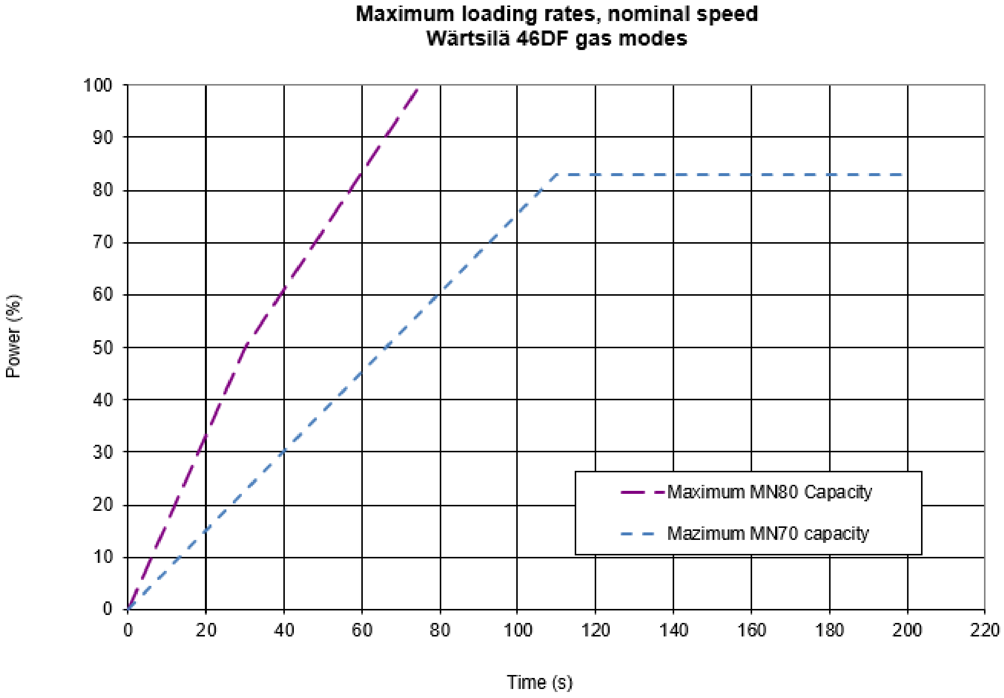


Fig 2-3 Maximum Loading capacity in gas

Unloading:

In normal operation the load should not be reduced from high load to low load (much) faster than the load is increased. Crash stop can be recognised with a large lever movement from ahead to astern within some seconds, which overrides normal load reduction.

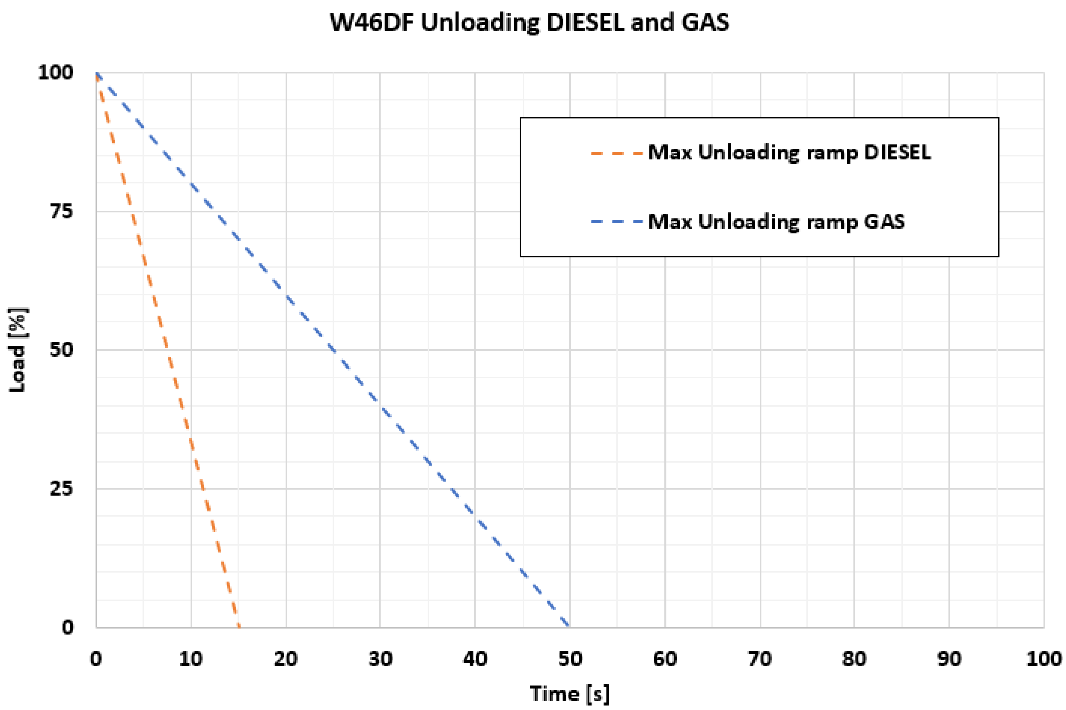


Fig 2-4 Unloading ramps

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

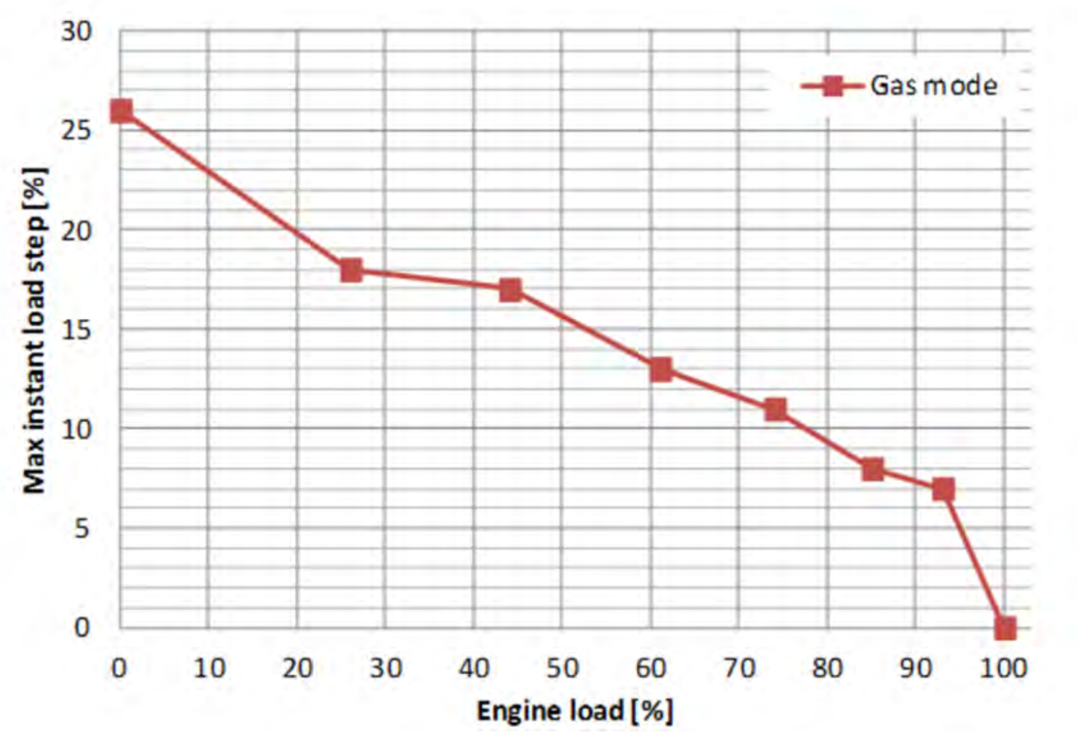


Fig 2-5 Maximum permissible load step in gas mode

Gas - Mode	
Instant Load Application	**Stepwise Load Reduction**
•Maximum load step according to figure above	•Maximum load step according to figure above
•Steady-state frequency band ≤ 1.5 %	•Steady-state frequency band ≤ 1.5 %
•Maximum speed drop 10 %	•Maximum speed increase 10 %
•Recovery time ≤ 10 s	•Recovery time ≤ 10 s
•Time between load steps ≥ 20 s [1])	•Time between load steps ≥ 20 s [2])

Diesel Mode	
Instant Load Application	**Stepwise Load Reduction**
•Instant load step: 0% - 33% - 56% - 77% - 100%	•Instant load step 100% - 50% - 0%
•Steady-state frequency band ≤ 1.0 %	•Steady-state frequency band ≤ 1.0 %
•Maximum speed drop 10 %	•Maximum speed increase 10 %
•Recovery time ≤ 10 s	•Recovery time ≤ 10 s
•Time between load steps ≥ 5 s)	

NOTE

1) In case instant load steps are applied on top of Successive loading (ramp), the minimum time between load steps is 45 s and the maximum load application rate between steps is 10% / 60 s. However the maximum loading limit may not be exceeded.

2) For exceptional situations which require fast unloading (e.g. propulsion crash stop manoeuvring) it is recommended that the engine control system be configured for automatic transfer to diesel-mode for fastest possible unloading.

Note that the recovery time is longer than the normal class requirement (5 s). The steady-state frequency band in gas mode also exceeds the normal class requirement (1.0 %).

2.3 Operation at low load and idling

Absolute idling (declutched main engine, disconnected generator):

- Maximum 10 minutes if the engine is to be stopped after the idling. 3-5 minutes idling before stop is recommended.
- Maximum 8 hours if the engine is to be loaded after the idling.
- After a gas start it is recommended to synchronize and load the engine within 1 minute after nominal speed is reached.

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

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

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

- No restrictions.

Operation at low load and idling with SCR (NOR)

LFO/MGO

- **Idling** Max continuous operation time: 2h; Requirements before further operation at low load can be continues: above 25% load for 1 h
- **Below 10%MCR** Max continuous operation time: 6h; Requirements before further operation at low load can be continues: above 70% load for 1 h or above 50% load for 2 h
- **Below 25%MCR** Max continuous operation time: 24h; Requirements before further operation at low load can be continues: above 70% load for 1 h or above 50% load for 2 h

Gas (MN≥=70)

- **Idling** Max continuous operation time: 5 min; Requirements before further operation at low load can be continues: above 20% load for 30 min or change to back-up fuel (trip to diesel is also included as an automatic back-up feature)
- **Below 5% MCR** Max continuous operation time: 10 min; Requirements before further operation at low load can be continues: above 20% load for 30 min or change to back-up fuel (trip to diesel is also included as an automatic back-up feature)

- **Between 5% and 10% MCR** Max continuous operation time: 15 min; Requirements before further operation at low load can be continues: above 20% load for 30 min or change to back-up fuel (trip to diesel is also included as an automatic back-up feature)
- **Above 10% MCR** No restrictions

Gas (MN<70)

- **Idling** Max continuous operation time: 3 min; Requirements before further operation at low load can be continues: above 20% load for 30 min or change to back-up fuel (trip to diesel is also included as an automatic back-up feature)
- **Below 10% MCR** Max continuous operation time: 5 min; Requirements before further operation at low load can be continues: above 20% load for 30 min or change to back-up fuel (trip to diesel is also included as an automatic back-up feature)
- **Above 10% MCR** No restrictions

NOTE

Typically, less strict requirements for the operation can be set based on a detailed analysis of project specific conditions such as operational profile, fuel composition and engine type and tuning.

In low load gas operation the oxidation of unburned hydrocarbons on the catalyst elements can increase the temperature above the limit for catalyst elements and/or the exhaust gas system. The extent of the temperature increase depends on combustion parameters, operational profile, ambient conditions and especially on the gas compositions.

The solution for allowing trouble free operation in low load gas operation includes the following:

1) Use of dilution air to provide cooling in low load operation.

2) Recommendations for duration of low load operation. These recommendations will in normal conditions ensure that the temperature will remain in the allowed area.

3) SCR temperature monitoring will trigger a transfer to liquid fuel operation to protect the SCR in situations with increased temperatures.

2.3.1 Nominal Start-up time

2.3.1.1 For preheated engine

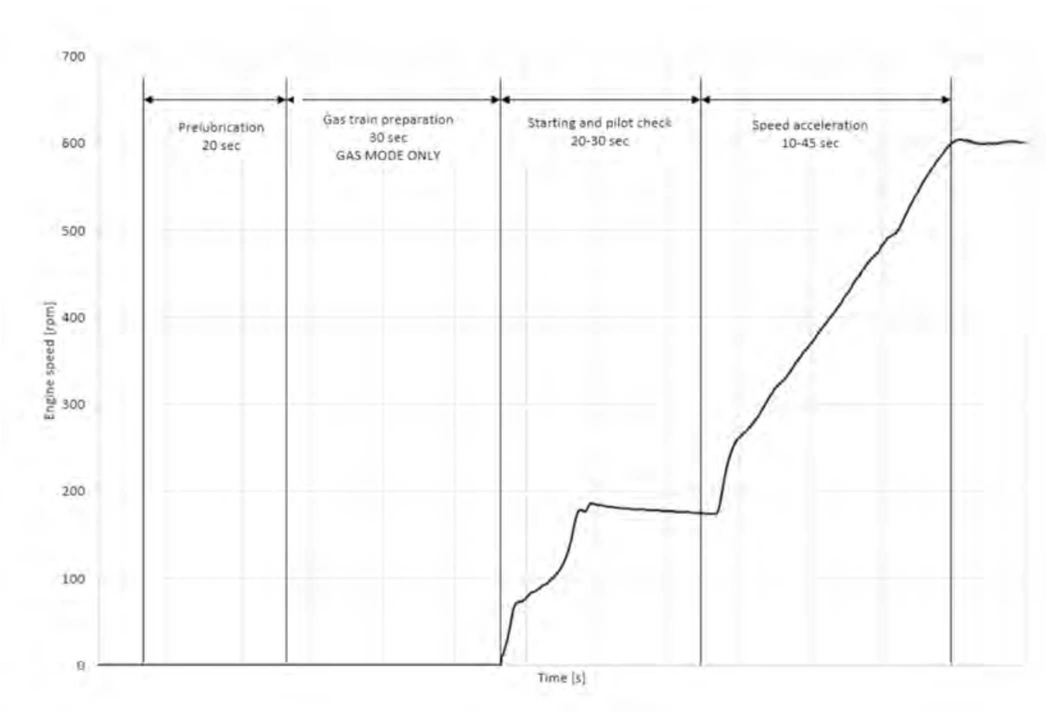


Fig 2-6 Nominal start-up time

NOTE

Continuous prelubrication of the engine can be done when the engine is in stop mode if shorter start-up time is required.

2.4 Low air temperature

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

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

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

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

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

3. Technical Data

3.1 Introduction

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

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

3.2 Wärtsilä 6L46DF

Wärtsilä 6L46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
Engine output	kW	6870		6870		6870	
Mean effective pressure	MPa	2.38		2.38		2.38	
Combustion air system (Note 1)							
Flow at 100% load	kg/s	11.1	12.3	11.1	12.3	11.1	12.3
Temperature at turbocharger intake, max.	°C	45		45		45	
Temperature after air cooler, nom. (TE 601)	°C	45	50	45	50	45	50
Exhaust gas system (Note 2)							
Flow at 100% load	kg/s	11.0	13.7	11.0	13.7	11.0	13.4
Flow at 75% load	kg/s	8.2	10.7	8.3	11.6	8.3	11.5
Temperature after turbocharger at 100% load (TE 517)	°C	367	301	367	301	365	314
Temperature after turbocharger at 85% load (TE 517)	°C	384	294	392	292	390	305
Temperature after turbocharger at 75% load (TE 517)	°C	390	304	409	292	407	304
Temperature after turbocharger at 50% load (TE 517)	°C	347	298	449	297	449	306
Backpressure, max.	kPa	4		4		4	
Calculated exhaust diameter for 35 m/s	mm	849	897	849	897	847	899
Heat balance at 100% load (Note 3)							
Jacket water, HT-circuit	kW	834	1080	834	1080	828	1068
Charge air, HT-circuit	kW	1386	2016	1386	2016	1386	1878
Charge air, LT-circuit	kW	636	882	636	882	636	858
Lubricating oil, LT-circuit	kW	402	768	402	768	402	762
Radiation	kW	192	204	192	204	192	204
Fuel consumption (Note 4)							
BSEC total at 100% load	kJ/kWh	7410	-	7410	-	7390	-
BSEC total at at 85% load	kJ/kWh	7420	-	7540	-	7530	-

Wärtsilä 6L46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
BSEC total at at 75% load	kJ/kWh	7470	-	7680	-	7660	-
BSEC total at at 50% load	kJ/kWh	7710	-	8230	-	8210	-
BSEC gas fuel at 100% load	kJ/kWh	7365	-	7365	-	7350	-
BSEC gas fuel at 85% load	kJ/kWh	7373	-	7501	-	7485	-
BSEC gas fuel at 75% load	kJ/kWh	7422	-	7611	-	7594	-
BSEC gas fuel at 50% load	kJ/kWh	7620	-	8091	-	8071	-
Pilot fuel consumption at 100% load	g/kWh	1.0	0.6	1.0	0.6	1.0	0.6
Pilot fuel consumption at 85% load	g/kWh	1.2	0.7	1.2	0.8	1.2	0.8
Pilot fuel consumption at 75% load	g/kWh	1.3	0.7	1.3	0.8	1.3	0.8
Pilot fuel consumption at 50% load	g/kWh	2.0	1.0	3.5	1.3	3.5	1.3
SFOC at 100% load - LFO	g/kWh	-	186.3	-	186.3	-	185.3
SFOC at 85 % load - LFO	g/kWh	-	178.2	-	181.0	-	181.0
SFOC at 75% load - LFO	g/kWh	-	189.1	-	193.0	-	193.0
SFOC at 50% load - LFO	g/kWh	-	192.3	-	198.5	-	198.5
SFOC at 100% load - HFO	g/kWh	-	186.3	-	186.3	-	185.3
SFOC at 85% load - HFO	g/kWh	-	177.2	-	180.1	-	180.1
SFOC at 75% load - HFO	g/kWh	-	191	-	195	-	195
SFOC at 50% load - HFO	g/kWh	-	197	-	203	-	203
Fuel gas system (Note 5)							
Gas pressure at engine inlet, min (PT901) at 100% load	kPa (a)	600...800	-	600...800	-	600...800	-
Pressure drop over the Gas Valve unit, min	kPa (a)	120	-	120	-	120	-
Gas temperature at engine inlet	°C	0...60	-	0...60	-	0...60	-
Fuel oil system							
Pressure before injection pumps (PT101) 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^3/h	5.1...6.0		5.1...6.0		5.1...6.0	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140
MDF viscosity, min.	cSt	2.0		2.0		2.0	
Max. MDF temperature before engine (TE 101)	°C	40		40		40	
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	12.0	22.5	12.0	22.5	12.0	22.5
Pilot fuel (MDF) viscosity before the engine	cSt	2...11		2...11		2...11	
Pilot fuel pressure at engine inlet (PT 112)	kPa(g)	550...750		550...750		550...750	
Pilot fuel outlet pressure, max	kPa(g)	150		150		150	
Pilot fuel return flow at 100% load	kg/h	410		410		410	
External Pilot fuel feed pump, 1 feeder per engine allowed flow range	l/h	750...1500		750...1500		750...1500	

Wärtsilä 6L46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
External Pilot fuel feed pump, 1 feeder per multiple engines allowed flow range	l/h	=(850...1500) x numb_of_eng		=(850...1500) x numb_of_eng		=(850...1500) x numb_of_eng	
Pilot line, temperature before pilot pumps (TE112)	°C	5...50		5...50		5...50	
Lubricating oil system							
Pressure before bearings, nom. (PT 201)	kPa	500		500		500	
Pressure after pump, max.	kPa	800		800		800	
Suction ability, including pipe loss, max.	kPa	40		40		40	
Prelubricating pressure, nom. (PT 201)	kPa	80		80		80	
Temperature before bearings, nom. (TE 201)	°C	55...58		55...58		55...58	
Temperature after engine, approx.	°C	75		75		75	
Pump capacity (main), engine driven	m^3/h	191		175		175	
Pump capacity (main), electrically driven	m^3/h	158		158		158	
Oil flow through engine	m^3/h	130		130		130	
Prelubricating pump capacity (50/60Hz)	m^3/h	35.0 / 35.0		35.0 / 35.0		35.0 / 35.0	
Oil volume in separate system oil tank	m^3	13		13		13	
Oil consumption at 100% load, approx.	g/kWh	0.5		0.5		0.5	
Crankcase ventilation flow rate at full load	l/min	2800		2800		2800	
Crankcase volume	m^3	17.8		17.8		17.8	
Crankcase ventilation backpressure, max.	kPa	0.5		0.5		0.5	
Oil volume in turning device	l	8.5...9.5		8.5...9.5		8.5...9.5	
Oil volume in speed governor	l	1.7		1.7		1.7	
HT cooling water system							
Pressure at engine, after pump, nom. (PT 401)	kPa	250 + static		250 + static		250 + static	
Pressure at engine, after pump, max. (PT 401) at 100% nom.	kPa	530		530		530	
Temperature to HT suction, max (before by-pass pipe return to HT pump suction)	°C	70		70		70	
Temperature before cylinders (TE 401) at 100% nom.	°C	75	72	75	72	75	72
Temperature after charge air cooler (TE432) at 100% nom.	°C	93	97	93	97	93	97
Capacity of engine driven pump, nom.	m^3/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^3	1.0		1.0		1.0	
LT cooling water system (Note 6)							
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 charge air cooler (TE471) at 100% nom.	°C	38	42	38	42	38	42
Capacity of engine driven pump, nom.	m^3/h	150		150		150	

Wärtsilä 6L46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
Pressure drop over charge air cooler	kPa	50		50		50	
Pressure drop over lubricating oil cooler insert, max	kPa	35		35		35	
Pressure drop over thermostatic valve (built on)	kPa	30		30		30	
Pressure drop in external system, max.	kPa	135		135		135	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Starting air system (Note 7)							
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) (PT301)	kPa	3000		3000		3000	
Low pressure limit in starting air vessel	kPa	1800		1800		1800	
Consumption per start at 20 °C (successful start)	Nm^3	6.0		6.0		6.0	
Consumption per start at 20 °C (with slowturn)	Nm^3	7.0		7.0		7.0	

Notes:

Note 1 At ISO 15550 conditions (ambient air temperature 25°C) and 100% load. Flow tolerance 8%.

Note 2 At ISO 15550 conditions (ambient air temperature 25°C). Flow tolerance 8% and temperature tolerance 15°C. Available max backpressure is 6 kPa; in this condition all consumption and HB value have to be evaluated. Please contact Wärtsilä to have further information.

Note 3 At ISO 15550 conditions (ambient air temperature 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 constant speed are valid for D2/E2 IMO cycles. Fuel consumption values for EEDI calculation available upon request.
*If SCR (with a max Sulphur content of 0.5%m/m) is applied SFOC consumption values @ 85% may vary in this way: SFOC(85%) + 0.5g/kWh + (335- (Temperature after turbocharger at 85%))*0.04 g/kWh. Please contact Wärtsilä to have further information.

Note 5 Fuel gas pressure given at LHV ≥ $28MJ/Nm^3$. Required fuel gas pressure depends on fuel gas LHV and need to be increased for lower LHV's. Pressure drop in external fuel gas system to be considered. See chapter Fuel system for further information.

Note 6 Pressure drop over lubricating oil cooler and over thermostatic valve are valid only if these components are mounted on engine.

Note 7 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

Subject to revision without notice.

3.3 Wärtsilä 7L46DF

Wärtsilä 7L46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
Engine output	kW	8015		8015		8015	
Mean effective pressure	MPa	2.38		2.38		2.38	
Combustion air system (Note 1)							
Flow at 100% load	kg/s	12.9	14.3	12.9	14.3	12.9	14.3
Temperature at turbocharger intake, max.	°C	45		45		45	
Temperature after air cooler, nom. (TE 601)	°C	45	50	45	50	45	50
Exhaust gas system (Note 2)							
Flow at 100% load	kg/s	12.8	16.0	12.8	16.0	12.8	15.7
Flow at 75% load	kg/s	9.6	12.5	9.7	13.6	9.7	13.4
Temperature after turbocharger at 100% load (TE 517)	°C	367	301	367	301	365	314
Temperature after turbocharger at 85% load (TE 517)	°C	384	294	392	292	390	305
Temperature after turbocharger at 75% load (TE 517)	°C	390	304	409	292	407	304
Temperature after turbocharger at 50% load (TE 517)	°C	347	298	449	297	449	306
Backpressure, max.	kPa	4		4		4	
Calculated exhaust diameter for 35 m/s	mm	917	969	917	969	915	971
Heat balance at 100% load (Note 3)							
Jacket water, HT-circuit	kW	973	1260	973	1260	966	1246
Charge air, HT-circuit	kW	1617	2352	1617	2352	1617	2191
Charge air, LT-circuit	kW	742	1029	742	1029	742	1001
Lubricating oil, LT-circuit	kW	469	896	469	896	469	889
Radiation	kW	224	238	224	238	224	238
Fuel consumption (Note 4)							
BSEC total at 100% load	kJ/kWh	7410	-	7410	-	7390	-
BSEC total at 85% load	kJ/kWh	7420	-	7540	-	7530	-
BSEC total at 75% load	kJ/kWh	7470	-	7680	-	7660	-
BSEC total at 50% load	kJ/kWh	7710	-	8230	-	8210	-
BSEC gas fuel at 100% load	kJ/kWh	7365	-	7365	-	7350	-
BSEC gas fuel at 85% load	kJ/kWh	7373	-	7501	-	7485	-
BSEC gas fuel at 75% load	kJ/kWh	7422	-	7611	-	7594	-
BSEC gas fuel at 50% load	kJ/kWh	7620	-	8091	-	8071	-
Pilot fuel consumption at 100% load	g/kWh	1.0	0.6	1.0	0.6	1.0	0.6
Pilot fuel consumption at 85% load	g/kWh	1.2	0.7	1.2	0.8	1.2	0.8
Pilot fuel consumption at 75% load	g/kWh	1.3	0.7	1.3	0.8	1.3	0.8
Pilot fuel consumption at 50% load	g/kWh	2.0	1.0	3.5	1.3	3.5	1.3
SFOC at 100% load - LFO	g/kWh	-	186.3	-	186.3	-	185.3
SFOC at 85% load - LFO	g/kWh	-	178.2	-	181.0	-	181.0

Wärtsilä 7L46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
SFOC at 75% load - LFO	g/kWh	-	189.1	-	193.0	-	193.0
SFOC at 50% load - LFO	g/kWh	-	192.3	-	198.5	-	198.5
SFOC at 100% load - HFO	g/kWh	-	186.3	-	186.3	-	185.3
SFOC at 85% load - HFO	g/kWh	-	177.2	-	180.1	-	180.1
SFOC at 75% load - HFO	g/kWh	-	191	-	195	-	195
SFOC at 50% load - HFO	g/kWh	-	197	-	203	-	203
Fuel gas system (Note 5)							
Gas pressure at engine inlet, min (PT901) at 100% load	kPa (a)	600...800	-	600...800	-	600...800	-
Pressure drop over the Gas Valve unit, min	kPa (a)	120	-	120	-	120	-
Gas temperature at engine inlet	°C	0...60	-	0...60	-	0...60	-
Fuel oil system							
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^3/h	5.9...7.0		5.9...7.0		5.9...7.0	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140
MDF viscosity, min.	cSt	2.0		2.0		2.0	
Max. MDF temperature before engine (TE 101)	°C	40		40		40	
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h	-	5.2	-	5.2	-	5.2
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	14.0	26.5	14.0	26.5	14.0	26.5
Pilot fuel (MDF) viscosity before the engine	cSt	2...11		2...11		2...11	
Pilot fuel pressure at engine inlet (PT 112)	kPa(g)	550...750		550...750		550...750	
Pilot fuel outlet pressure, max	kPa(g)	150		150		150	
Pilot fuel return flow at 100% load	kg/h	420		420		420	
External Pilot fuel feed pump, 1 feeder per engine allowed flow range	l/h	750...1500		750...1500		750...1500	
External Pilot fuel feed pump, 1 feeder per multiple engines allowed flow range	l/h	=(850...1500) x numb_of_eng		=(850...1500) x numb_of_eng		=(850...1500) x numb_of_eng	
Pilot line, temperature before pilot pumps (TE112)	°C	5...50		5...50		5...50	
Lubricating oil system							
Pressure before bearings, nom. (PT 201)	kPa	500		500		500	
Pressure after pump, max.	kPa	800		800		800	
Suction ability, including pipe loss, max.	kPa	40		40		40	
Priming pressure, nom. (PT 201)	kPa	80		80		80	
Temperature before bearings, nom. (TE 201)	°C	55...58		55...58		55...58	
Temperature after engine, approx.	°C	75		75		75	
Pump capacity (main), engine driven	m^3/h	207		191		191	
Pump capacity (main), electrically driven	m^3/h	179		179		179	

Wärtsilä 7L46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
Oil flow through engine	m^3/h	150		150		150	
Priming pump capacity (50/60Hz)	m^3/h	45.0 / 45.0		45.0 / 45.0		45.0 / 45.0	
Oil volume in separate system oil tank	m^3	15		15		15	
Oil consumption at 100% load, approx.	g/kWh	0.5		0.5		0.5	
Crankcase ventilation flow rate at full load	l/min	2950		2950		2950	
Crankcase volume	m^3	20.1		20.1		20.1	
Crankcase ventilation backpressure, max.	kPa	0.5		0.5		0.5	
Oil volume in turning device	l	8.5...9.5		8.5...9.5		8.5...9.5	
Oil volume in speed governor	l	1.7		1.7		1.7	
HT cooling water system							
Pressure at engine, after pump, nom. (PT 401)	kPa	250 + static		250 + static		250 + static	
Pressure at engine, after pump, max. (PT 401) at 100% nom.	kPa	530		530		530	
Temperature to HT suction, max (before by-pass pipe return to HT pump suction)	°C	70		70		70	
Temperature before cylinders (TE 401) at 100% nom.	°C	75	72	75	72	75	72
Temperature after charge air cooler (TE432)	°C	93	97	93	97	93	97
Capacity of engine driven pump, nom.	m^3/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^3	1.3		1.3		1.3	
LT cooling water system (Note 6)							
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 charge air cooler (TE471) at 100% nom.	°C	38	42	38	42	38	42
Capacity of engine driven pump, nom.	m^3/h	150		150		150	
Pressure drop over charge air cooler	kPa	50		50		50	
Pressure drop over lubricating oil cooler insert, max	kPa	35		35		35	
Pressure drop over thermostatic valve (built on)	kPa	30		30		30	
Pressure drop in external system, max.	kPa	135		135		135	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Starting air system (Note 7)							
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 starting air vessel	kPa	1800		1800		1800	

Wärtsilä 7L46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
Consumption per start at 20 °C (successful start)	Nm^3	7.0		7.0		7.0	
Consumption per start at 20 °C (with slowturn)	Nm^3	8.0		8.0		8.0	

Notes:

Note 1 At ISO 15550 conditions (ambient air temperature 25°C) and 100% load. Flow tolerance 8%.

Note 2 At ISO 15550 conditions (ambient air temperature 25°C). Flow tolerance 8% and temperature tolerance 15°C. Available max backpressure is 6 kPa; in this condition all consumption and HB value have to be evaluated. Please contact Wärtsilä to have further information.

Note 3 At ISO 15550 conditions (ambient air temperature 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 constant speed are valid for D2/E2 IMO cycles. Fuel consumption values for EEDI calculation available upon request.
*If SCR (with a max Sulphur content of 0.5%m/m) is applied SFOC consumption values @ 85% may vary in this way: SFOC(85%) + 0.5g/kWh + (335- (Temperature after turbocharger at 85%))*0.04 g/kWh. Please contact Wärtsilä to have further information.

Note 5 Fuel gas pressure given at LHV ≥ 28MJ/Nm³. Required fuel gas pressure depends on fuel gas LHV and need to be increased for lower LHV's. Pressure drop in external fuel gas system to be considered. See chapter Fuel system for further information.

Note 6 Pressure drop over lubricating oil cooler and over thermostatic valve are valid only if these components are mounted on engine.

Note 7 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

Subject to revision without notice.

3.4 Wärtsilä 8L46DF

Wärtsilä 8L46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
Engine output	kW	9160		9160		9160	
Mean effective pressure	MPa	2.38		2.38		2.38	
Combustion air system (Note 1)							
Flow at 100% load	kg/s	14.7	16.4	14.7	16.4	14.7	16.4
Temperature at turbocharger intake, max.	°C	45		45		45	
Temperature after air cooler, nom. (TE 601)	°C	45	50	45	50	45	50
Exhaust gas system (Note 2)							
Flow at 100% load	kg/s	14.6	18.2	14.6	18.2	14.6	17.9
Flow at 75% load	kg/s	11.0	14.3	11.1	15.5	11.1	15.3
Temperature after turbocharger at 100% load (TE 517)	°C	367	301	367	301	365	314
Temperature after turbocharger at 85% load (TE 517)	°C	384	294	392	292	390	305
Temperature after turbocharger at 75% load (TE 517)	°C	390	304	409	292	407	304
Temperature after turbocharger at 50% load (TE 517)	°C	347	298	449	297	449	306
Backpressure, max.	kPa	4		4		4	
Calculated exhaust diameter for 35 m/s	mm	980	1036	980	1036	978	1038
Heat balance at 100% load (Note 3)							
Jacket water, HT-circuit	kW	1112	1440	1112	1440	1104	1424
Charge air, HT-circuit	kW	1848	2688	1848	2688	1848	2504
Charge air, LT-circuit	kW	848	1176	848	1176	848	1144
Lubricating oil, LT-circuit	kW	536	1024	536	1024	536	1016
Radiation	kW	256	272	256	272	256	272
Fuel consumption (Note 4)							
BSEC total at 100% load	kJ/kWh	7410.0	-	7410.0	-	7390.0	-
BSEC total at 85% load	kJ/kWh	7420.0	-	7540.0	-	7530.0	-
BSEC total at 75% load	kJ/kWh	7470.0	-	7680.0	-	7660.0	-
BSEC total at 50% load	kJ/kWh	7710.0	-	8230.0	-	8210.0	-
BSEC gas fuel at 100% load	kJ/kWh	7365.0	-	7365.0	-	7350.0	-
BSEC gas fuel at 85% load	kJ/kWh	7373.0	-	7501.0	-	7485.0	-
BSEC gas fuel at 75% load	kJ/kWh	7422.0	-	7611.0	-	7594.0	-
BSEC gas fuel at 50% load	kJ/kWh	7620.0	-	8091.0	-	8071.0	-
Pilot fuel consumption at 100% load	kJ/kWh	1.0	0.6	1.0	0.6	1.0	0.6
Pilot fuel consumption at 85% load	kJ/kWh	1.2	0.7	1.2	0.8	1.2	0.8
Pilot fuel consumption at 75% load	kJ/kWh	1.3	0.7	1.3	0.8	1.3	0.8
Pilot fuel consumption at 50% load	kJ/kWh	2.0	1.0	3.5	1.3	3.5	1.3
SFOC at 100% load - LFO	g/kWh	-	186.3	-	186.3	-	185.3
SFOC at 85% load - LFO	g/kWh	-	178.2	-	181.0	-	181.0

Wärtsilä 8L46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
SFOC at 75% load - LFO	g/kWh	-	189.1	-	193.0	-	193.0
SFOC at 50% load - LFO	g/kWh	-	192.3	-	198.5	-	198.5
SFOC at 100% load - HFO	g/kWh	-	186.3	-	186.3	-	185.3
SFOC at 85% load - HFO	g/kWh	-	177.2	-	180.1	-	180.1
SFOC at 75% load - HFO	g/kWh	-	186	-	186	-	185
SFOC at 50% load - HFO	g/kWh	-	197	-	203	-	203
Fuel gas system (Note 5)							
Gas pressure at engine inlet, min (PT901) at 100% load	kPa (a)	600...800	-	600...800	-	600...800	-
Pressure drop over the Gas Valve unit, min	kPa (a)	120	-	120	-	120	-
Gas temperature at engine inlet	°C	0...60	-	0...60	-	0...60	-
Fuel oil system							
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	6.8...8.0		6.8...8.0		6.8...8.0	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140
MDF viscosity, min.	cSt	2.0		2.0		2.0	
Max. MDF temperature before engine (TE 101)	°C	40		40		40	
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h	-	6.0	-	6.0	-	6.0
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	16.0	30.0	16.0	30.0	16.0	30.0
Pilot fuel (MDF) viscosity before the engine	cSt	2...11		2...11		2...11	
Pilot fuel pressure at engine inlet (PT 112)	kPa(g)	550...750		550...750		550...750	
Pilot fuel outlet pressure, max	kPa(g)	150		150		150	
Pilot fuel return flow at 100% load	kg/h	430		430		430	
External Pilot fuel feed pump, 1 feeder per engine allowed flow range	l/h	750...1500		750...1500		750...1500	
External Pilot fuel feed pump, 1 feeder per multiple engines allowed flow range	l/h	=(850...1500) x numb_of_eng		=(850...1500) x numb_of_eng		=(850...1500) x numb_of_eng	
Pilot line, temperature before pilot pumps (TE112)	°C	5...50		5...50		5...50	
Lubricating oil system							
Pressure before bearings, nom. (PT 201)	kPa	500		500		500	
Pressure after pump, max.	kPa	800		800		800	
Suction ability, including pipe loss, max.	kPa	40		40		40	
Priming pressure, nom. (PT 201)	kPa	80		80		80	
Temperature before bearings, nom. (TE 201)	°C	55...58		55...58		55...58	
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	198		198		198	

Wärtsilä 8L46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
Oil flow through engine	m³/h	170		170		170	
Priming pump capacity (50/60Hz)	m³/h	45.0 / 45.0		45.0 / 45.0		45.0 / 45.0	
Oil volume in separate system oil tank	m³	17		17		17	
Oil consumption at 100% load, approx.	g/kWh	0.5		0.5		0.5	
Crankcase ventilation flow rate at full load	l/min	3600		3600		3600	
Crankcase volume	m³	22.4		22.4		22.4	
Crankcase ventilation backpressure, max.	kPa	0.5		0.5		0.5	
Oil volume in turning device	l	8.5...9.5		8.5...9.5		8.5...9.5	
Oil volume in speed governor	l	1.7		1.7		1.7	
HT cooling water system							
Pressure at engine, after pump, nom. (PT 401)	kPa	250 + static		250 + static		250 + static	
Pressure at engine, after pump, max. (PT 401) at 100% nom.	kPa	530		530		530	
Temperature to HT suction, max (before by-pass pipe return to HT pump suction)	°C	70		70		70	
Temperature before cylinders (TE 401) at 100% nom.	°C	75	72	75	72	75	72
Temperature after charge air cooler (TE432)	°C	93	97	93	97	93	97
Capacity of engine driven pump, nom.	m³/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	m³	1.4		1.4		1.4	
LT cooling water system (Note 6)							
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 charge air cooler (TE471) at 100% nom.	°C	38	42	38	42	38	42
Capacity of engine driven pump, nom.	m³/h	180		180		180	
Pressure drop over charge air cooler	kPa	50		50		50	
Pressure drop over lubricating oil cooler insert, max.	kPa	35		35		35	
Pressure drop over thermostatic valve (built on)	kPa	30		30		30	
Pressure drop in external system, max.	kPa	135		135		135	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Starting air system (Note 7)							
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 starting air vessel	kPa	1800		1800		1800	

Wärtsilä 8L46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
Consumption per start at 20 °C (successful start)	Nm^3	8.0		8.0		8.0	
Consumption per start at 20 °C (with slowturn)	Nm^3	9.0		9.0		9.0	

Notes:

Note 1 At ISO 15550 conditions (ambient air temperature 25°C) and 100% load. Flow tolerance 8%.

Note 2 At ISO 15550 conditions (ambient air temperature 25°C). Flow tolerance 8% and temperature tolerance 15°C. Available max backpressure is 6 kPa; in this condition all consumption and HB value have to be evaluated. Please contact Wärtsilä to have further information.

Note 3 At ISO 15550 conditions (ambient air temperature 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 constant speed are valid for D2/E2 IMO cycles. Fuel consumption values for EEDI calculation available upon request.
*If SCR (with a max Sulphur content of 0.5%m/m) is applied SFOC consumption values @ 85% may vary in this way: SFOC(85%) + 0.5g/kWh + (335- (Temperature after turbocharger at 85%))*0.04 g/kWh. Please contact Wärtsilä to have further information.

Note 5 Fuel gas pressure given at LHV $\geq$ 28MJ/Nm^3. Required fuel gas pressure depends on fuel gas LHV and need to be increased for lower LHV's. Pressure drop in external fuel gas system to be considered. See chapter Fuel system for further information.

Note 6 Pressure drop over lubricating oil cooler and over thermostatic valve are valid only if these components are mounted on engine.

Note 7 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

Subject to revision without notice.

3.5 Wärtsilä 9L46DF

Wärtsilä 9L46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
Engine output	kW	10305		10305		10305	
Mean effective pressure	MPa	2.38		2.38		2.38	
Combustion air system (Note 1)							
Flow at 100% load	kg/s	16.6	18.4	16.6	18.4	16.6	18.4
Temperature at turbocharger intake, max.	°C	45		45		45	
Temperature after air cooler, nom. (TE 601)	°C	45	50	45	50	45	50
Exhaust gas system (Note 2)							
Flow at 100% load	kg/s	16.5	20.5	16.5	20.5	16.5	20.2
Flow at 75% load	kg/s	12.3	16.1	12.5	17.5	12.5	17.2
Temperature after turbocharger at 100% load (TE 517)	°C	367	301	367	301	365	314
Temperature after turbocharger at 85% load (TE 517)	°C	384	294	392	292	390	305
Temperature after turbocharger at 75% load (TE 517)	°C	390	304	409	292	407	304
Temperature after turbocharger at 50% load (TE 517)	°C	347	298	449	297	449	306
Backpressure, max.	kPa	4		4		4	
Calculated exhaust diameter for 35 m/s	mm	1039	1099	1039	1099	1038	1101
Heat balance at 100% load (Note 3)							
Jacket water, HT-circuit	kW	1251	1620	1251	1620	1242	1602
Charge air, HT-circuit	kW	2079	3024	2079	3024	2079	2817
Charge air, LT-circuit	kW	954	1323	954	1323	954	1287
Lubricating oil, LT-circuit	kW	603	1152	603	1152	603	1143
Radiation	kW	288	306	288	306	288	306
Fuel consumption (Note 4)							
BSEC total at 100% load	kJ/kWh	7410.0	-	7410.0	-	7390.0	-
BSEC total at 85% load	kJ/kWh	7420.0	-	7540.0	-	7530.0	-
BSEC total at 75% load	kJ/kWh	7470.0	-	7680.0	-	7660.0	-
BSEC total at 50% load	kJ/kWh	7710.0	-	8230.0	-	8210.0	-
BSEC gas fuel at 100% load	kJ/kWh	7365.0	-	7365.0	-	7350.0	-
BSEC gas fuel at 85% load	kJ/kWh	7373.0	-	7501.0	-	7485.0	-
BSEC gas fuel at 75% load	kJ/kWh	7422.0	-	7611.0	-	7594.0	-
BSEC gas fuel at 50% load	kJ/kWh	7620.0	-	8091.0	-	8071.0	-
Pilot fuel consumption at 100% load	kJ/kWh	1.0	0.6	1.0	0.6	1.0	0.6
Pilot fuel consumption at 85% load	kJ/kWh	1.2	0.7	1.2	0.8	1.2	0.8
Pilot fuel consumption at 75% load	kJ/kWh	1.3	0.7	1.3	0.8	1.3	0.8
Pilot fuel consumption at 50% load	kJ/kWh	2.0	1.0	3.5	1.3	3.5	1.3
SFOC at 100% load - LFO	g/kWh	-	186.3	-	186.3	-	185.3
SFOC at 85% load - LFO	g/kWh	-	186.3	-	186.3	-	185.3

Wärtsilä 9L46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
SFOC at 75% load - LFO	g/kWh	-	189	-	193	-	193
SFOC at 50% load - LFO	g/kWh	-	192	-	199	-	199
SFOC at 100% load - HFO	g/kWh	-	186.3	-	186.3	-	185.3
SFOC at 85% load - HFO	g/kWh	-	177.2	-	180.1	-	180.1
SFOC at 75% load - HFO	g/kWh	-	191.0	-	194.9	-	194.9
SFOC at 50% load - HFO	g/kWh	-	197.0	-	203.2	-	203.2
Fuel gas system (Note 5)							
Gas pressure at engine inlet, min (PT901) at 100% load	kPa (a)	600...800	-	600...800	-	600...800	-
Pressure drop over the Gas Valve unit, min	kPa (a)	120	-	120	-	120	-
Gas temperature at engine inlet	°C	0...60	-	0...60	-	0...60	-
Fuel oil system							
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	7.6...9.0		7.6...9.0		7.6...9.0	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140
MDF viscosity, min.	cSt	2.0		2.0		2.0	
Max. MDF temperature before engine (TE 101)	°C	40		40		40	
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h	-	6.75	-	6.75	-	6.75
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	18.0	33.75	18.0	33.75	18.0	33.75
Pilot fuel (MDF) viscosity before the engine	cSt	2...11		2...11		2...11	
Pilot fuel pressure at engine inlet (PT 112)	kPa(g)	550...750		550...750		550...750	
Pilot fuel outlet pressure, max	kPa(g)	150		150		150	
Pilot fuel return flow at 100% load	kg/h	440		440		440	
External Pilot fuel feed pump, 1 feeder per engine allowed flow range	l/h	750...1500		750...1500		750...1500	
External Pilot fuel feed pump, 1 feeder per multiple engines allowed flow range	l/h	=(850...1500) x numb_of_eng		=(850...1500) x numb_of_eng		=(850...1500) x numb_of_eng	
Pilot line, temperature before pilot pumps (TE112)	°C	5...50		5...50		5...50	
Lubricating oil system							
Pressure before bearings, nom. (PT 201)	kPa	500		500		500	
Pressure after pump, max.	kPa	800		800		800	
Suction ability, including pipe loss, max.	kPa	40		40		40	
Priming pressure, nom. (PT 201)	kPa	80		80		80	
Temperature before bearings, nom. (TE 201)	°C	55...58		55...58		55...58	
Temperature after engine, approx.	°C	75		75		75	
Pump capacity (main), engine driven	m³/h	253		228		228	
Pump capacity (main), electrically driven	m³/h	218		218		218	

Wärtsilä 9L46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
Oil flow through engine	m^3/h	190		190		190	
Priming pump capacity (50/60Hz)	m^3/h	50.0 / 50.0		50.0 / 50.0		50.0 / 50.0	
Oil volume in separate system oil tank	m^3	19		19		19	
Oil consumption at 100% load, approx.	g/kWh	0.5		0.5		0.5	
Crankcase ventilation flow rate at full load	l/min	3750		3750		3750	
Crankcase volume	m^3	24.7		24.7		24.7	
Crankcase ventilation backpressure, max.	kPa	0.5		0.5		0.5	
Oil volume in turning device	l	68.0...70.0		68.0...70.0		68.0...70.0	
Oil volume in speed governor	l	1.7		1.7		1.7	
HT cooling water system							
Pressure at engine, after pump, nom. (PT 401)	kPa	250 + static		250 + static		250 + static	
Pressure at engine, after pump, max. (PT 401) at 100% nom.	kPa	530		530		530	
Temperature to HT suction, max (before by-pass pipe return to HT pump suction)	°C	70		70		70	
Temperature before cylinders (TE 401) at 100% nom.	°C	75	72	75	72	75	72
Temperature after charge air cooler (TE432)	°C	93	97	93	97	93	97
Capacity of engine driven pump, nom.	m^3/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^3	1.5		1.5		1.5	
LT cooling water system (Note 6)							
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 charge air cooler (TE471) at 100% nom.	°C	38	42	38	42	38	42
Capacity of engine driven pump, nom.	m^3/h	180		180		180	
Pressure drop over charge air cooler	kPa	50		50		50	
Pressure drop over lubricating oil cooler insert, max	kPa	35		35		35	
Pressure drop over thermostatic valve (built on)	kPa	30		30		30	
Pressure drop in external system, max.	kPa	135		135		135	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Starting air system (Note 7)							
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 starting air vessel	kPa	1800		1800		1800	

Wärtsilä 9L46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
Consumption per start at 20 °C (successful start)	Nm^3	9.0		9.0		9.0	
Consumption per start at 20 °C (with slowturn)	Nm^3	10.0		10.0		10.0	

Notes:

Note 1 At ISO 15550 conditions (ambient air temperature 25°C) and 100% load. Flow tolerance 8%.

Note 2 At ISO 15550 conditions (ambient air temperature 25°C). Flow tolerance 8% and temperature tolerance 15°C. Available max backpressure is 6 kPa; in this condition all consumption and HB value have to be evaluated. Please contact Wärtsilä to have further information.

Note 3 At ISO 15550 conditions (ambient air temperature 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 constant speed are valid for D2/E2 IMO cycles. Fuel consumption values for EEDI calculation available upon request.
*If SCR (with a max Sulphur content of 0.5%m/m) is applied SFOC consumption values @ 85% may vary in this way: SFOC(85%) + 0.5g/kWh + (335- (Temperature after turbocharger at 85%))*0.04 g/kWh. Please contact Wärtsilä to have further information.

Note 5 Fuel gas pressure given at LHV ≥ 28MJ/Nm³. Required fuel gas pressure depends on fuel gas LHV and need to be increased for lower LHV's. Pressure drop in external fuel gas system to be considered. See chapter Fuel system for further information.

Note 6 Pressure drop over lubricating oil cooler and over thermostatic valve are valid only if these components are mounted on engine.

Note 7 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

Subject to revision without notice.

3.6 Wärtsilä 12V46DF

Wärtsilä 12V46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
Engine output	kW	13740		13740		13740	
Mean effective pressure	MPa	2.38		2.38		2.38	
Combustion air system (Note 1)							
Flow at 100% load	kg/s	22.1	24.6	22.1	24.6	22.1	24.6
Temperature at turbocharger intake, max.	°C	45		45		45	
Temperature after air cooler, nom. (TE 601)	°C	45	50	45	50	45	50
Exhaust gas system (Note 2)							
Flow at 100% load	kg/s	22.0	27.4	22.0	27.4	22.0	26.9
Flow at 75% load	kg/s	16.4	21.5	16.7	23.3	16.7	22.9
Temperature after turbocharger at 100% load (TE 517)	°C	367	301	367	301	365	314
Temperature after turbocharger at 85% load (TE 517)	°C	384	294	392	292	390	305
Temperature after turbocharger at 75% load (TE 517)	°C	390	304	409	292	407	304
Temperature after turbocharger at 50% load (TE 517)	°C	347	298	449	297	449	306
Backpressure, max.	kPa	4		4		4	
Calculated exhaust diameter for 35 m/s	mm	1200	1269	1200	1269	1198	1272
Heat balance at 100% load (Note 3)							
Jacket water, HT-circuit	kW	1668	2160	1668	2160	1656	2136
Charge air, HT-circuit	kW	2772	4032	2772	4032	2772	3756
Charge air, LT-circuit	kW	1272	1764	1272	1764	1272	1716
Lubricating oil, LT-circuit	kW	804	1536	804	1536	804	1524
Radiation	kW	384	408	384	408	384	408
Fuel consumption (Note 4)							
BSEC total at 100% load	kJ/kWh	7410.0	-	7410.0	-	7390.0	-
BSEC total at 85% load	kJ/kWh	7420.0	-	7540.0	-	7530.0	-
BSEC total at 75% load	kJ/kWh	7470.0	-	7680.0	-	7660.0	-
BSEC total at 50% load	kJ/kWh	7710.0	-	8230.0	-	8210.0	-
BSEC gas fuel at 100%	kJ/kWh	7365.0	-	7365.0	-	7350.0	-
BSEC gas fuel at 85%	kJ/kWh	7373.0	-	7501.0	-	7485.0	-
BSEC gas fuel at 75%	kJ/kWh	7422.0	-	7611.0	-	7594.0	-
BSEC gas fuel at 50%	kJ/kWh	7620.0	-	8091.0	-	8071.0	-
Pilot fuel consumption at 100% load	g/kWh	1.0	0.6	1.0	0.6	1.0	0.6
Pilot fuel consumption at 85% load	g/kWh	1.2	0.7	1.2	0.8	1.2	0.8
Pilot fuel consumption at 75% load	g/kWh	1.3	0.7	1.3	0.8	1.3	0.8
Pilot fuel consumption 50% load	g/kWh	2.0	1.0	3.5	1.3	3.5	1.3
SFOC at 100% load - LFO	g/kWh	-	186.3	-	186.3	-	185.3
SFOC at 85% load - LFO	g/kWh	-	178.2	-	181.0	-	181.0

Wärtsilä 12V46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
SFOC at 75% load - LFO	g/kWh	-	189.1	-	193.0	-	193.0
SFOC at 50% load - LFO	g/kWh	-	192.3	-	198.5	-	198.5
SFOC at 100% load - HFO	g/kWh	-	186.3	-	186.3	-	185.3
SFOC at 85% load - HFO	g/kWh	-	177.2	-	180.1	-	180.1
SFOC at 75% load - HFO	g/kWh	-	191	-	195	-	195
SFOC at 50% load - HFO	g/kWh	-	197	-	203	-	203
Fuel gas system (Note 5)							
Gas pressure at engine inlet, min (PT901) at 100% load	kPa (a)	600...800	-	600...800	-	600...800	-
Pressure drop over the Gas Valve unit, min	kPa (a)	120	-	120	-	120	-
Gas temperature at engine inlet	°C	0...60	-	0...60	-	0...60	-
Fuel oil system							
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	10.2...12.0		10.2...12.0		10.2...12.0	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140
MDF viscosity, min.	cSt	2.0		2.0		2.0	
Max. MDF temperature before engine (TE 101)	°C	40		40		40	
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h	-	9.0	-	9.0	-	9.0
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	24.0	45.0	24.0	45.0	24.0	45.0
Pilot fuel (MDF) viscosity before the engine	cSt	2...11		2...11		2...11	
Pilot fuel pressure at engine inlet (PT 112)	kPa(g)	550...750		550...750		550...750	
Pilot fuel outlet pressure, max	kPa(g)	150		150		150	
Pilot fuel return flow at 100% load	kg/h	470		470		470	
External Pilot fuel feed pump, 1 feeder per engine allowed flow range	l/h	750...1500		750...1500		750...1500	
External Pilot fuel feed pump, 1 feeder per multiple engines allowed flow range	l/h	=(850...1500) x numb_of_eng		=(850...1500) x numb_of_eng		=(850...1500) x numb_of_eng	
Pilot line, temperatur before pilot pumps (TE112)	°C	5...50		5...50		5...50	
Lubricating oil system							
Pressure before bearings, nom. (PT 201)	kPa	500		500		500	
Pressure after pump, max.	kPa	800		800		800	
Suction ability, including pipe loss, max.	kPa	40		40		40	
Priming pressure, nom. (PT 201)	kPa	80		80		80	
Temperature before bearings, nom. (TE 201)	°C	55...58		55...58		55...58	
Temperature after engine, approx.	°C	75		75		75	
Pump capacity (main), engine driven	m³/h	299		256		256	
Pump capacity (main), electrically driven	m³/h	256		256		256	

Wärtsilä 12V46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
Oil flow through engine	m^3/h	220		220		220	
Priming pump capacity (50/60Hz)	m^3/h	60.0 / 60.0		60.0 / 60.0		60.0 / 60.0	
Oil volume in separate system oil tank	m^3	22.5		22.5		22.5	
Oil consumption at 100% load, approx.	g/kWh	0.5		0.5		0.5	
Crankcase ventilation flow rate at full load	l/min	5600		5600		5600	
Crankcase volume	m^3	30.1		30.1		30.1	
Crankcase ventilation backpressure, max.	kPa	0.5		0.5		0.5	
Oil volume in turning device	l	68.0...70.0		68.0...70.0		68.0...70.0	
Oil volume in speed governor	l	7.1		7.1		7.1	
HT cooling water system							
Pressure at engine, after pump, nom. (PT 401)	kPa	250 + static		250 + static		250 + static	
Pressure at engine, after pump, max. (PT 401) at 100% nom.	kPa	530		530		530	
Temperature to HT suction, max (before by-pass pipe return to HT pump suction)	°C	70		70		70	
Temperature before cylinders (TE 401) at 100% nom.	°C	75	72	75	72	75	72
Temperature after charge air cooler (TE432)	°C	93	97	93	97	93	97
Capacity of engine driven pump, nom.	m^3/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^3	2.0		2.0		2.0	
LT cooling water system (Note 6)							
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 charge air cooler (TE471) at 100% nom.	°C	38	42	38	42	38	42
Capacity of engine driven pump, nom.	m^3/h	240		240		240	
Pressure drop over charge air cooler	kPa	50		50		50	
Pressure drop over lubricating oil cooler in-sert, max	kPa	35		35		35	
Pressure drop over thermostatic valve (built on)	kPa	30		30		30	
Pressure drop in external system, max.	kPa	135		135		135	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Starting air system (Note 7)							
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 starting air vessel	kPa	1800		1800		1800	

Wärtsilä 12V46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
Consumption per start at 20 °C (successful start)	Nm^3	12.0		12.0		12.0	
Consumption per start at 20 °C (with slowturn)	Nm^3	15.0		15.0		15.0	

Notes:

Note 1 At ISO 15550 conditions (ambient air temperature 25°C) and 100% load. Flow tolerance 8%.

Note 2 At ISO 15550 conditions (ambient air temperature 25°C). Flow tolerance 8% and temperature tolerance 15°C. Available max backpressure is 6 kPa; in this condition all consumption and HB value have to be evaluated. Please contact Wärtsilä to have further information.

Note 3 At ISO 15550 conditions (ambient air temperature 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 constant speed are valid for D2/E2 IMO cycles. Fuel consumption values for EEDI calculation available upon request.
*If SCR (with a max Sulphur content of 0.5%m/m) is applied SFOC consumption values @ 85% may vary in this way: SFOC(85%) + 0.5g/kWh + (335- (Temperature after turbocharger at 85%))*0.04 g/kWh. Please contact Wärtsilä to have further information.

Note 5 Fuel gas pressure given at LHV ≥ 28MJ/Nm³. Required fuel gas pressure depends on fuel gas LHV and need to be increased for lower LHV's. Pressure drop in external fuel gas system to be considered. See chapter Fuel system for further information.

Note 6 Pressure drop over lubricating oil cooler and over thermostatic valve are valid only if these components are mounted on engine.

Note 7 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

Subject to revision without notice.

3.7 Wärtsilä 14V46DF

Wärtsilä 14V46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
Engine output	kW	16030		16030		16030	
Mean effective pressure	MPa	2.38		2.38		2.38	
Combustion air system (Note 1)							
Flow at 100% load	kg/s	25.8	28.7	25.8	28.7	25.8	28.7
Temperature at turbocharger intake, max.	°C	45		45		45	
Temperature after air cooler, nom. (TE 601)	°C	45	50	45	50	45	50
Exhaust gas system (Note 2)							
Flow at 100% load	kg/s	25.6	31.9	25.6	31.9	25.6	31.4
Flow at 75% load	kg/s	19.2	25.1	19.5	27.2	19.5	26.7
Temperature after turbocharger at 100% load (TE 517)	°C	367	301	367	301	365	314
Temperature after turbocharger at 85% load (TE 517)	°C	384	294	392	292	390	305
Temperature after turbocharger at 75% load (TE 517)	°C	390	304	409	292	407	304
Temperature after turbocharger at 50% load (TE 517)	°C	347	298	449	297	449	306
Backpressure, max.	kPa	4		4		4	
Calculated exhaust diameter for 35 m/s	mm	1296	1370	1296	1370	1294	1373
Heat balance at 100% load (Note 3)							
Jacket water, HT-circuit	kW	1946	2520	1946	2520	1932	2492
Charge air, HT-circuit	kW	3234	4704	3234	4704	3234	4382
Charge air, LT-circuit	kW	1484	2058	1484	2058	1484	2002
Lubricating oil, LT-circuit	kW	938	1792	938	1792	938	1778
Radiation	kW	448	476	448	476	448	476
Fuel consumption (Note 4)							
BSEC total at 100% load	kJ/kWh	7410.0	-	7410.0	-	7390.0	-
BSEC total at 85% load	kJ/kWh	7420.0	-	7540.0	-	7530.0	-
BSEC total at 75% load	kJ/kWh	7470.0	-	7680.0	-	7660.0	-
BSEC total at 50% load	kJ/kWh	7710.0	-	8230.0	-	8210.0	-
BSEC gas fuel at 100%	kJ/kWh	7365.0	-	7365.0	-	7350.0	-
BSEC gas fuel at 85%	kJ/kWh	7373.0	-	7501.0	-	7485.0	-
BSEC gas fuel at75%	kJ/kWh	7422.0	-	7611.0	-	7594.0	-
BSEC gas fuel at 50%	kJ/kWh	7620.0	-	8091.0	-	8071.0	-
Pilot fuel consumption at 100% load	g/kWh	1.0	0.6	1.0	0.6	1.0	0.6
Pilot fuel consumption at 85% load	g/kWh	1.2	0.7	1.2	0.8	1.2	0.8
Pilot fuel consumption at 75% load	g/kWh	1.3	0.7	1.3	0.8	1.3	0.8
Pilot fuel consumption at 50% load	g/kWh	2.0	1.0	3.5	1.3	3.5	1.3
SFOC at 100% load - LFO	g/kWh	-	186.3	-	186.3	-	185.3
SFOC at 85% load - LFO	g/kWh	-	178.2	-	181.0	-	181.0

Wärtsilä 14V46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
SFOC at 75% load - LFO	g/kWh	-	189.1	-	193.0	-	193.0
SFOC at 50% load - LFO	g/kWh	-	192.3	-	198.5	-	198.5
SFOC at 100% load - HFO	g/kWh	-	186.3	-	186.3	-	185.3
SFOC at 85% load - HFO	g/kWh	-	177.2	-	180.1	-	180.1
SFOC at 75% load - HFO	g/kWh	-	189	-	193	-	193
SFOC at 50% load - HFO	g/kWh	-	197	-	203	-	203
Fuel gas system (Note 5)							
Gas pressure at engine inlet, min (PT901) at 100% load	kPa (a)	600...800	-	600...800	-	600...800	-
Pressure drop over the Gas Valve unit, min	kPa (a)	120	-	120	-	120	-
Gas temperature at engine inlet	°C	0...60	-	0...60	-	0...60	-
Fuel oil system							
Pressure before injection pumps (PT101) at 85% load - HFO	kPa	900...950		900...950		900...950	
Pressure before injection pumps (PT101) at idle speed (check value)	kPa	1000...1050		1000...1050		1000...1050	
Fuel oil flow to engine, range	m³/h	11.9...14.0		11.9...14.0		11.9...14.0	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140
MDF viscosity, min.	cSt	2.0		2.0		2.0	
Max. MDF temperature before engine (TE 101)	°C	45		45		45	
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h	-	10.5	-	10.5	-	10.5
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	32.0	53.0	32.0	53.0	32.0	53.0
Pilot fuel (MDF) viscosity before the engine	cSt	2...11		2...11		2...11	
Pilot fuel pressure at engine inlet (PT 112)	kPa(g)	550...750		550...750		550...750	
Pilot fuel outlet pressure, max	kPa(g)	150		150		150	
Pilot fuel return flow at 100% load	kg/h	490		490		490	
External Pilot fuel feed pump, 1 feeder per engine allowed flow range	l/h	750...1500		750...1500		750...1500	
External Pilot fuel feed pump, 1 feeder per multiple engines allowed flow range	l/h	=(850...1500) x numb_of_eng		=(850...1500) x numb_of_eng		=(850...1500) x numb_of_eng	
Pilot line, temperature before pilot pumps (TE112)	°C	5...50		5...50		5...50	
Lubricating oil system							
Pressure before bearings, nom. (PT 201)	kPa	500		500		500	
Pressure after pump, max.	kPa	800		800		800	
Suction ability, including pipe loss, max.	kPa	40		40		40	
Priming pressure, nom. (PT 201)	kPa	80		80		80	
Temperature before bearings, nom. (TE 201)	°C	55...58		55...58		55...58	
Temperature after engine, approx.	°C	75		75		75	
Pump capacity (main), engine driven	m³/h	314		299		299	
Pump capacity (main), electrically driven	m³/h	299		299		299	

Wärtsilä 14V46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
Oil flow through engine	m^3/h	245		245		245	
Priming pump capacity (50/60Hz)	m^3/h	70.0 / 70.0		70.0 / 70.0		70.0 / 70.0	
Oil volume in separate system oil tank	m^3	26.3		26.3		26.3	
Oil consumption at 100% load, approx.	g/kWh	0.5		0.5		0.5	
Crankcase ventilation flow rate at full load	l/min	5900		5900		5900	
Crankcase volume	m^3	34.6		34.6		34.6	
Crankcase ventilation backpressure, max.	kPa	0.5		0.5		0.5	
Oil volume in turning device	l	68.0...70.0		68.0...70.0		68.0...70.0	
Oil volume in speed governor	l	7.1		7.1		7.1	
HT cooling water system							
Pressure at engine, after pump, nom. (PT 401)	kPa	250 + static		250 + static		250 + static	
Pressure at engine, after pump, max. (PT 401) at 100% nom.	kPa	530		530		530	
Temperature to HT suction, max (before by-pass pipe return to HT pump suction)	°C	70		70		70	
Temperature before cylinders (TE 401) at 100% nom.	°C	75	72	75	72	75	72
Temperature after charge air cooler (TE432)	°C	93	97	93	97	93	97
Capacity of engine driven pump, nom.	m^3/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^3	2.3		2.3		2.3	
LT cooling water system (Note 6)							
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 charge air cooler (TE471) at 100% nom.	°C	38	42	38	42	38	42
Capacity of engine driven pump, nom.	m^3/h	280		280		280	
Pressure drop over charge air cooler	kPa	50		50		50	
Pressure drop over lubricating oil cooler in-sert, max.	kPa	35		35		35	
Pressure drop over thermostatic valve (built on)	kPa	30		30		30	
Pressure drop in external system, max.	kPa	135		135		135	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Starting air system (Note 7)							
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 starting air vessel	kPa	1800		1800		1800	

Wärtsilä 14V46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
Consumption per start at 20 °C (successful start)	Nm^3	14.0		14.0		14.0	
Consumption per start at 20 °C (with slowturn)	Nm^3	17.0		17.0		17.0	

Notes:

Note 1 At ISO 15550 conditions (ambient air temperature 25°C) and 100% load. Flow tolerance 8%.

Note 2 At ISO 15550 conditions (ambient air temperature 25°C). Flow tolerance 8% and temperature tolerance 15°C. Available max backpressure is 6 kPa; in this condition all consumption and HB value have to be evaluated. Please contact Wärtsilä to have further information.

Note 3 At ISO 15550 conditions (ambient air temperature 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 constant speed are valid for D2/E2 IMO cycles. Fuel consumption values for EEDI calculation available upon request.
*If SCR (with a max Sulphur content of 0.5%m/m) is applied SFOC consumption values @ 85% may vary in this way: SFOC(85%) + 0.5g/kWh + (335- (Temperature after turbocharger at 85%))*0.04 g/kWh. Please contact Wärtsilä to have further information.

Note 5 Fuel gas pressure given at LHV ≥ 28MJ/Nm^3. Required fuel gas pressure depends on fuel gas LHV and need to be increased for lower LHV's. Pressure drop in external fuel gas system to be considered. See chapter Fuel system for further information.

Note 6 Pressure drop over lubricating oil cooler and over thermostatic valve are valid only if these components are mounted on engine.

Note 7 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

Subject to revision without notice.

3.8 Wärtsilä 16V46DF

Wärtsilä 16V46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
Engine output	kW	18320		18320		18320	
Mean effective pressure	MPa	2.38		2.38		2.38	
Combustion air system (Note 1)							
Flow at 100% load	kg/s	29.5	32.8	29.5	32.8	29.5	32.8
Temperature at turbocharger intake, max.	°C	45		45		45	
Temperature after air cooler, nom. (TE 601)	°C	45	50	45	50	45	50
Exhaust gas system (Note 2)							
Flow at 100% load	kg/s	29.3	36.5	29.3	36.5	29.3	35.8
Flow at 75% load	kg/s	21.9	28.6	22.2	31.0	22.2	30.6
Temperature after turbocharger at 100% load (TE 517)	°C	367	301	367	301	365	314
Temperature after turbocharger at 85% load (TE 517)	°C	384	294	392	292	390	305
Temperature after turbocharger at 75% load (TE 517)	°C	390	304	409	292	407	304
Temperature after turbocharger at 50% load (TE 517)	°C	347	298	449	297	449	306
Backpressure, max.	kPa	4		4		4	
Calculated exhaust diameter for 35 m/s	mm	1386	1465	1386	1465	1384	1468
Heat balance at 100% load (Note 3)							
Jacket water, HT-circuit	kW	2224	2880	2224	2880	2208	2848
Charge air, HT-circuit	kW	3696	5376	3696	5376	3696	5008
Charge air, LT-circuit	kW	1696	2352	1696	2352	1696	2288
Lubricating oil, LT-circuit	kW	1072	2048	1072	2048	1072	2032
Radiation	kW	512	544	512	544	512	544
Fuel consumption (Note 4)							
BSEC total at 100% load	kJ/kWh	7410.0	-	7410.0	-	7390.0	-
BSEC total at 85% load	kJ/kWh	7420.0	-	7540.0	-	7530.0	-
BSEC total at 75% load	kJ/kWh	7470.0	-	7680.0	-	7660.0	-
BSEC total at 50% load	kJ/kWh	7710.0	-	8230.0	-	8210.0	-
BSEC gas fuel at 100%	kJ/kWh	7364.8	-	7364.8	-	7349.5	-
BSEC gas fuel at 85%	kJ/kWh	7373.3	-	7501.0	-	7484.8	-
BSEC gas fuel at 75%	kJ/kWh	7421.9	-	7611.4	-	7594.3	-
BSEC gas fuel at 50%	kJ/kWh	7620.0	-	8091.4	-	8071.4	-
Pilot fuel consumption at 100% load	g/kWh	1.0	0.6	1.0	0.6	1.0	0.6
Pilot fuel consumption at 85% load	g/kWh	1.2	0.7	1.2	0.8	1.2	0.8
Pilot fuel consumption at 75% load	g/kWh	1.3	0.7	1.3	0.8	1.3	0.8
Pilot fuel consumption at 50% load	g/kWh	2.0	1.0	3.5	1.3	3.5	1.3
SFOC at 100% load - LFO	g/kWh	-	186.3	-	186.3	-	185.3
SFOC at 85% load - LFO	g/kWh	-	178.2	-	181.0	-	181.0

Wärtsilä 16V46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
SFOC at 75% load - LFO	g/kWh	-	189.1	-	193.0	-	193.0
SFOC at 50% load - LFO	g/kWh	-	192.3	-	198.5	-	198.5
SFOC at 100% load - HFO	g/kWh	-	186.3	-	186.3	-	185.3
SFOC at 85% load - HFO	g/kWh	-	177.2	-	180.1	-	180.1
SFOC at 75% load - HFO	g/kWh	-	191	-	195	-	195
SFOC at 50% load - HFO	g/kWh	-	197.0	-	203.2	-	203.2
Fuel gas system (Note 5)							
Gas pressure at engine inlet, min (PT901) at 100% load	kPa (a)	600...800	-	600...800	-	600...800	-
Pressure drop over the Gas Valve unit, min	kPa (a)	120	-	120	-	120	-
Gas temperature at engine inlet	°C	0...60	-	0...60	-	0...60	-
Fuel oil system							
Pressure before injection pumps (PT101) at 85% load - HFO	kPa	900...950		900...950		900...950	
Pressure before injection pumps (PT101) at idle speed (check value)	kPa	1000...1050		1000...1050		1000...1050	
Fuel oil flow to engine, approx	m³/h	13.6...16.0		13.6...16.0		13.6...16.0	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140
MDF viscosity, min.	cSt	2.0		2.0		2.0	
Max. MDF temperature before engine (TE 101)	°C	40		40		40	
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h	-	12.0	-	12.0	-	12.0
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	36.0	60.0	36.0	60.0	36.0	60.0
Pilot fuel (MDF) viscosity before the engine	cSt	2...11		2...11		2...11	
Pilot fuel pressure at engine inlet (PT 112)	kPa(g)	550...750		550...750		550...750	
Pilot fuel outlet pressure, max	kPa(g)	150		150		150	
Pilot fuel return flow at 100% load	kg/h	510		510		510	
External Pilot fuel feed pump, 1 feeder per engine allowed flow range	l/h	750...1500		750...1500		750...1500	
External Pilot fuel feed pump, 1 feeder per multiple engines allowed flow range	l/h	=(850...1500) x numb_of_eng		=(850...1500) x numb_of_eng		=(850...1500) x numb_of_eng	
Pilot line, temperature before pilot pumps (TE112)	°C	5...50		5...50		5...50	
Lubricating oil system							
Pressure before bearings, nom. (PT 201)	kPa	500		500		500	
Pressure after pump, max.	kPa	800		800		800	
Suction ability, including pipe loss, max.	kPa	40		40		40	
Priming pressure, nom. (PT 201)	kPa	80		80		80	
Temperature before bearings, nom. (TE 201)	°C	55...58		55...58		55...58	
Temperature after engine, range	°C	75		75		75	
Pump capacity (main), engine driven	m³/h	342		314		314	
Pump capacity (main), electrically driven	m³/h	314		314		314	

Wärtsilä 16V46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
Oil flow through engine	m^3/h	275		275		275	
Priming pump capacity (50/60Hz)	m^3/h	80.0 / 80.0		80.0 / 80.0		80.0 / 80.0	
Oil volume in separate system oil tank	m^3	30		30		30	
Oil consumption at 100% load, approx.	g/kWh	0.5		0.5		0.5	
Crankcase ventilation flow rate at full load	l/min	7200		7200		7200	
Crankcase volume	m^3	38.7		38.7		38.7	
Crankcase ventilation backpressure, max.	kPa	0.5		0.5		0.5	
Oil volume in turning device	l	68.0...70.0		68.0...70.0		68.0...70.0	
Oil volume in speed governor	l	7.1		7.1		7.1	
HT cooling water system							
Pressure at engine, after pump, nom. (PT 401)	kPa	250 + static		250 + static		250 + static	
Pressure at engine, after pump, max. (PT 401) at 100% nom.	kPa	530		530		530	
Temperature to HT suction, max (before by-pass pipe return to HT pump suction)	°C	70		70		70	
Temperature before cylinders (TE 401) at 100% nom.	°C	75	72	75	72	75	72
Temperature after charge air cooler (TE432)	°C	93	97	93	97	93	97
Capacity of engine driven pump, nom.	m^3/h	340		340		340	
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^3	2.6		2.6		2.6	
LT cooling water system (Note 6)							
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 charge air cooler (TE471) at 100% nom.	°C	38	42	38	42	38	42
Capacity of engine driven pump, nom.	m^3/h	340		340		340	
Pressure drop over charge air cooler	kPa	50		50		50	
Pressure drop over lubricating oil cooler insert, max.	kPa	35		35		35	
Pressure drop over thermostatic valve (built on)	kPa	30		30		30	
Pressure drop in external system, max.	kPa	135		135		135	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Starting air system (Note 7)							
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 starting air vessel	kPa	1800		1800		1800	

Wärtsilä 16V46DF		ME CPP Variable Speed		ME CPP Constant Speed		DE DE Constant Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**		**600**	
Consumption per start at 20 °C (successful start)	Nm^3	16.0		16.0		16.0	
Consumption per start at 20 °C (with slowturn)	Nm^3	19.0		19.0		19.0	

Notes:

Note 1 At ISO 15550 conditions (ambient air temperature 25°C) and 100% load. Flow tolerance 8%.

Note 2 At ISO 15550 conditions (ambient air temperature 25°C). Flow tolerance 8% and temperature tolerance 15°C. Available max backpressure is 6 kPa; in this condition all consumption and HB value have to be evaluated. Please contact Wärtsilä to have further information.

Note 3 At ISO 15550 conditions (ambient air temperature 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 constant speed are valid for D2/E2 IMO cycles. Fuel consumption values for EEDI calculation available upon request.
*If SCR (with a max Sulphur content of 0.5%m/m) is applied SFOC consumption values @ 85% may vary in this way: SFOC(85%) + 0.5g/kWh + (335- (Temperature after turbocharger at 85%))*0.04 g/kWh. Please contact Wärtsilä to have further information.

Note 5 Fuel gas pressure given at LHV ≥ 28MJ/Nm³. Required fuel gas pressure depends on fuel gas LHV and need to be increased for lower LHV's. Pressure drop in external fuel gas system to be considered. See chapter Fuel system for further information.

Note 6 Pressure drop over lubricating oil cooler and over thermostatic valve are valid only if these components are mounted on engine.

Note 7 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

Subject to revision without notice.

4. Description of the Engine

4.1 Definitions

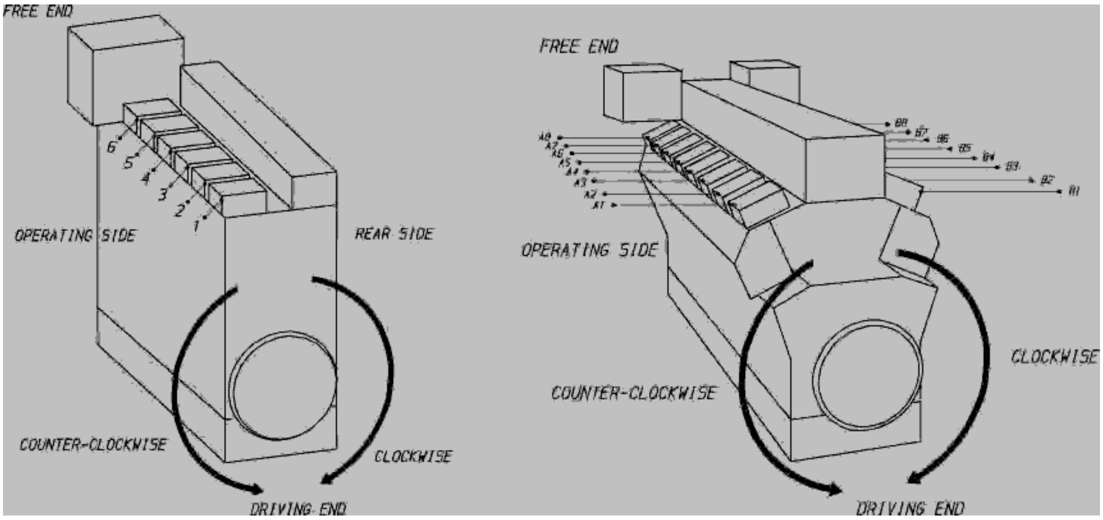


Fig 4-1 In-line engine and V-engine definitions (1V93C0029 / 1V93C0028)

4.2 Main components and systems

Main dimensions and weights are shown in section 1.5 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

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

4.2.11.1 Fuel gas system

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

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

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

The gas admission valves (one per cylinder) are electronically controlled and actuated to feed each individual cylinder with the correct amount of gas. The gas admission valves are controlled by the engine control system to regulate engine speed and power. The valves are located on the cylinder head. The gas admission valve is a direct actuated solenoid valve. The valve is closed by a spring (positive sealing) when there is no electrical signal. With the engine control system it is possible to adjust the amount of gas fed to each individual cylinder for load balancing of the engine, while the engine is running. The gas admission valves also include safety filters (90 μm).

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

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

4.2.11.2 Main fuel oil injection system

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 46DF 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.

4.2.11.3 Pilot fuel injection system

The pilot fuel injection system is used to ignite the air-gas mixture in the cylinder when operating the engine in gas mode. The pilot fuel injection system uses the same external fuel feed system as the main fuel oil injection system.

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

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

The pilot fuel filter is a full flow duplex unit preventing impurities entering the pilot fuel system. The fineness of the filter is 20 µm.

The high pressure pilot fuel pump is of engine driven type. The pilot fuel pump is mounted in the free end of the engine. The delivered fuel pressure is controlled by the engine control system and is approximately 100 MPa.

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

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

4.2.12 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 system) turbocharging system combines the advantages of both pulse and constant pressure systems. The complete exhaust gas manifold is enclosed by a heat insulation box to ensure low surface temperatures.

In-line engines have one turbocharger and V-engines have one turbocharger per cylinder bank. The turbocharger(s) are installed transversely, and are placed at the free end of the engine. Vertical, longitudinally inclined, and horizontal exhaust gas outlets are available.

In order to optimize the turbocharging system for both high and low load performance, as well as diesel mode and gas mode operation, a pressure relief valve system “waste gate” is installed on the exhaust gas side. The waste gate is activated at high load.

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

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

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

4.2.15 Automation system

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

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

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

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

4.2.16 Variable Inlet valve Closure

Variable Inlet valve Closure (VIC), 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

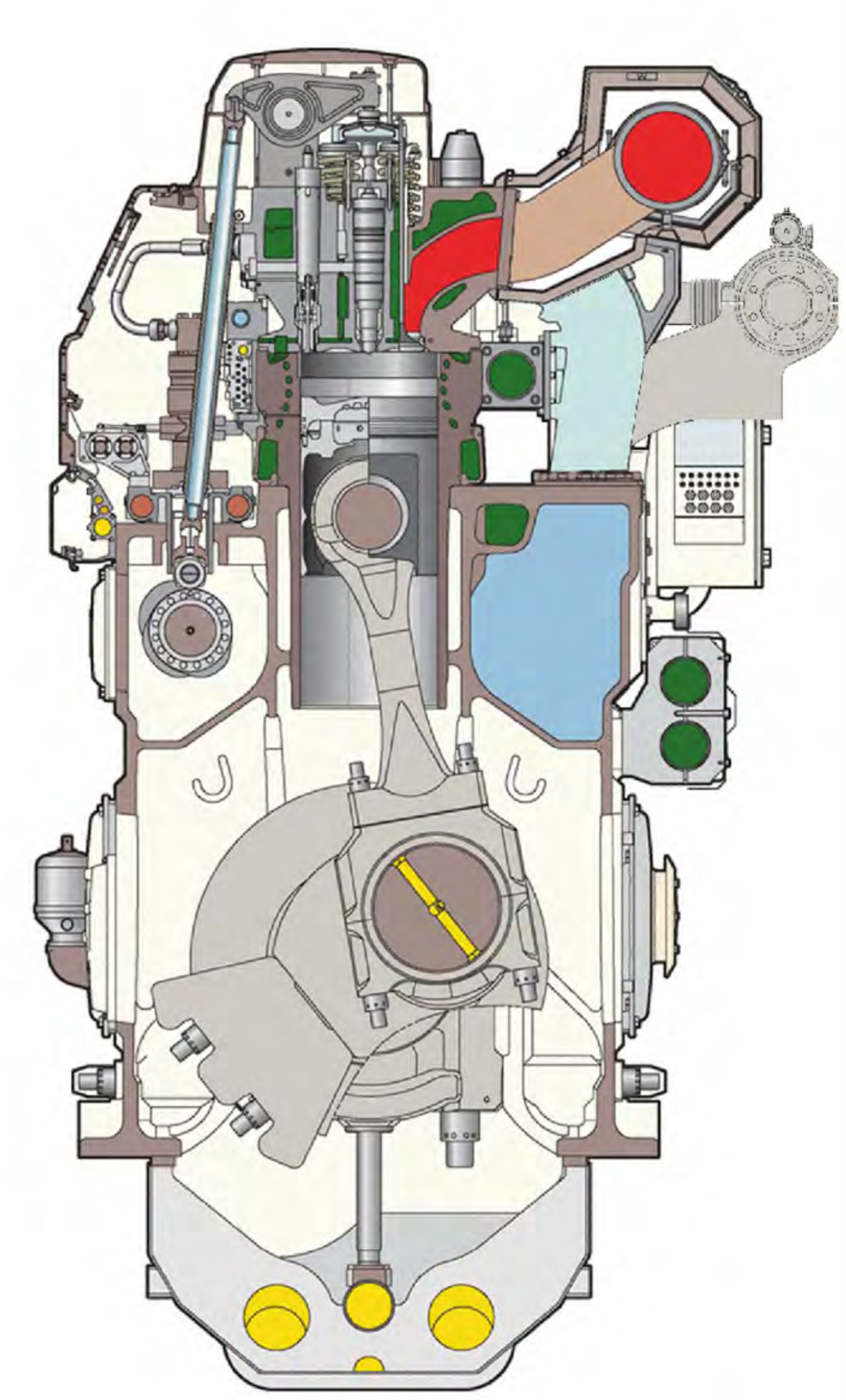


Fig 4-2 Cross section of the in-line engine

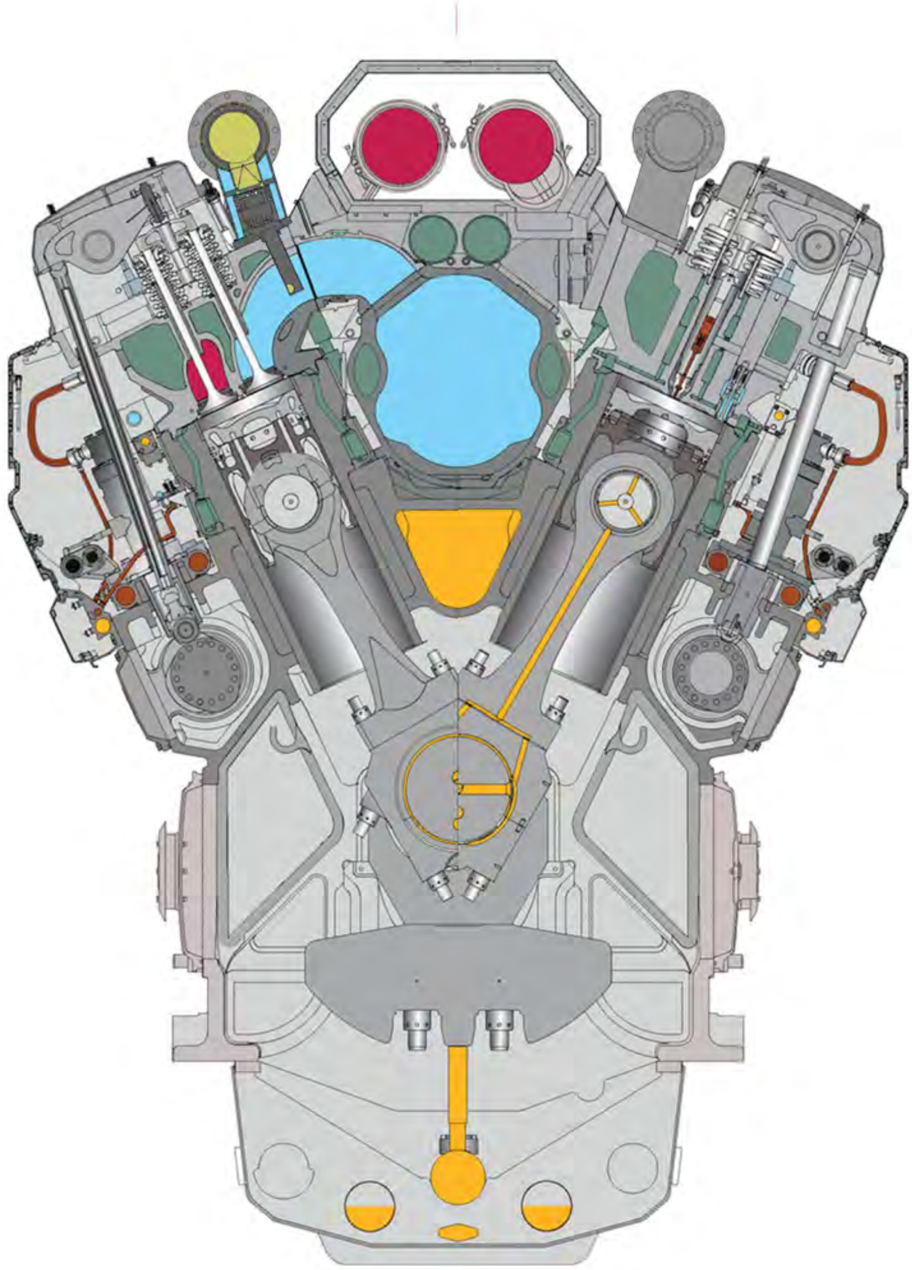


Fig 4-3 Cross section of the V-engine

4.4 Overhaul intervals and expected life times

The following component lifetimes are for guidance only. Actual figures will be different depending on operating conditions, average loading of the engine, fuel quality used, fuel handling system, performance of maintenance etc.

Expected component lifetimes have been adjusted to match with Time between overhaul data.

Table 4-1 Expected times between overhauls (TBO) and expected lifetimes (ELT)

Component	Maintenance interval (h) LFO/GAS operation	Expected lifetime (h) LFO/GAS operation	Maintenance interval (h) LFO/HFO operation	Expected life time (h) LFO/HFO operation
- Big end bearing	20000	36000	16000	36000
- Cylinder head	18000...20000	60000...72000	12000 (HFO2) 16000 (HFO1)	60000
- Cylinder liner	24000	180000	16000	180000
- Exhaust valve	12000...18000	36000	12000...18000	12000...18000
- Inj. valve complete [2]) [3])	8000	32000		
- Injection nozzles [1])	8000	8000	8000	8000
- Injection pump (Twin Pump)	-	-	12000 (HFO2) 16000 (HFO1) 20000 (LFO)	24000
- Injection pump, pilot	24000	24000	24000	24000
- Inlet valve	12000...18000	36000	12000...18000	24000
- Main bearing	24000	36000	24000	36000
- Main gas admission valve	18000	18000	-	-
- Piston	24000 [1]) / 48000 [2])	120000	16000 [1]) / 24000 [2])	36000
- Piston rings	24000	24000	16000	16000

NOTE

1) Inspection of one

2) Inspection of all

3) 3000 hours maintenance interval in the first installation required, Needle Operating Pressure (NOP) test to be performed

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 planning of piping systems, however, not excluding other solutions of at least equal standard. Installation related instructions are included in the project specific instructions delivered for each installation.

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

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

NOTE

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

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

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

The following aspects shall be taken into consideration:

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

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

5.1 Pipe dimensions

When selecting the pipe dimensions, take into account:

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

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

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

NOTE

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

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

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

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

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

5.2 Trace heating

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

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

5.3 Pressure class

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

The pressure in the system can:

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

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

Example 1:

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

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

Example 2:

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

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

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

5.4 Pipe class

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

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

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

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

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

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

Relevant DNV rules:

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

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

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

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

5.5 Insulation

The following pipes shall be insulated:

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

Insulation is also recommended for:

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

5.6 Local gauges

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

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

5.7 Cleaning procedures

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

5.7.1 Cleanliness during pipe installation

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

Piping cleaning methods are summarised in table below:

Table 5-3 Pipe cleaning

System	Methods
Fuel gas	A,B,C D,F 1)
Fuel oil	A,B,C,D,F
Lubricating oil	A,B,C,D,F

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

[1)] In case of carbon steel pipes

Methods applied during prefabrication of pipe spools

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

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

D = Pickling (not required for seamless precision tubes)

Methods applied after installation onboard

C = Purging with compressed air

F = Flushing

5.7.2 Fuel oil pipes

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

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

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

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

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

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.

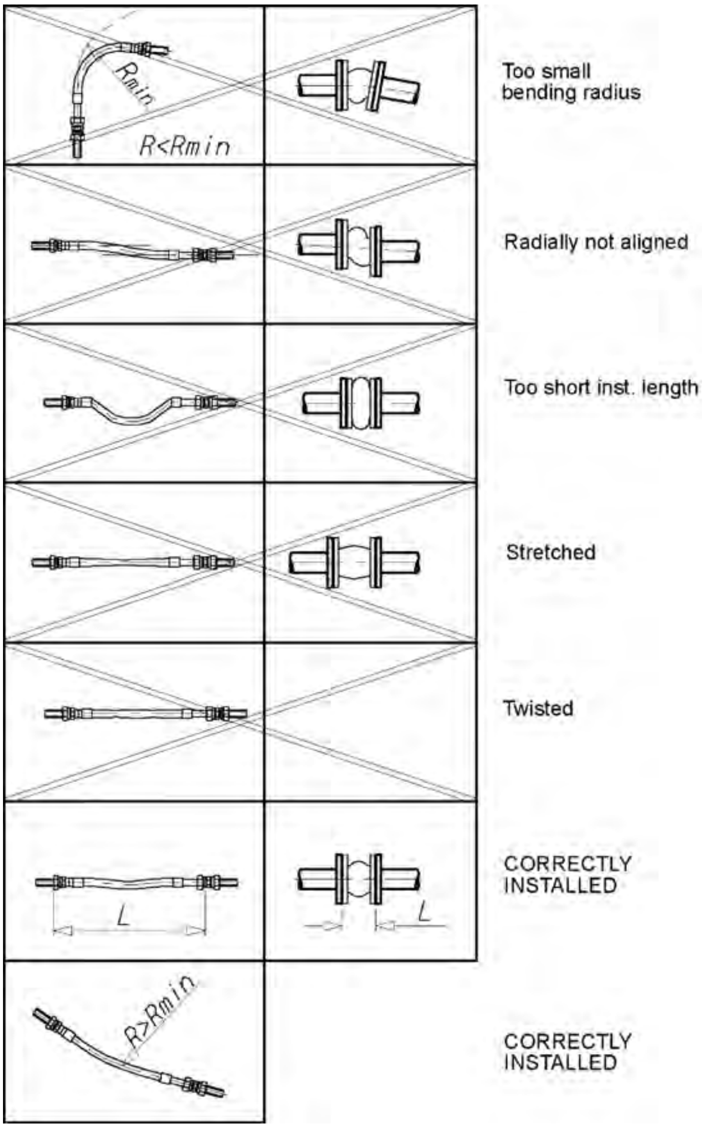


Fig 5-1 Flexible hoses

Drawing V60L0796 below is showing how pipes shall be clamped.

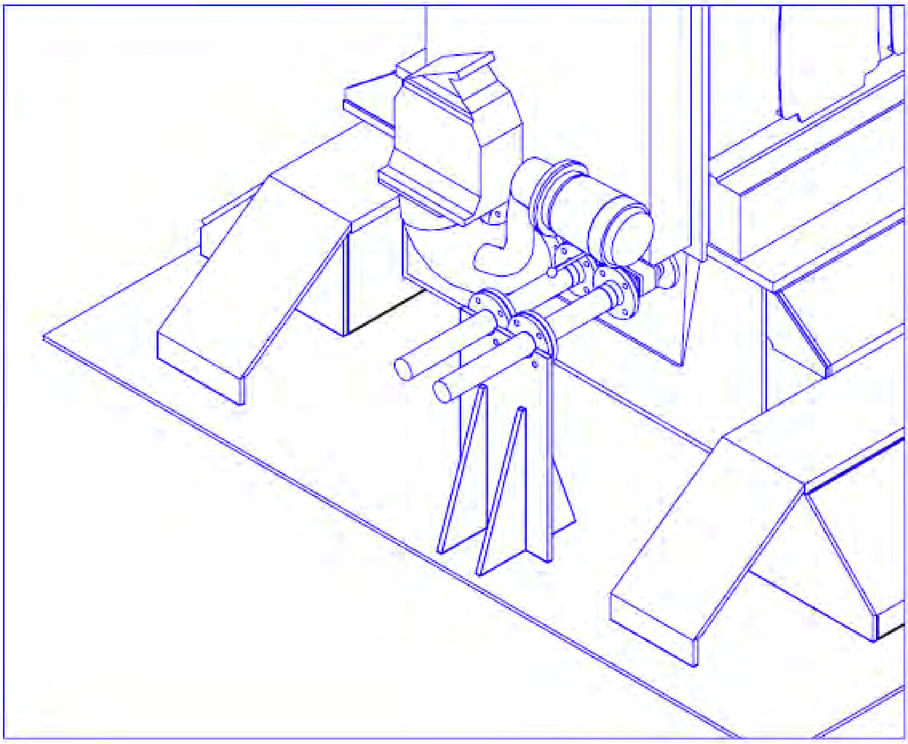


Fig 5-2 Flexible pipe connections (V60L0796)

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 5-4. Pipe clamps must be made of steel; plastic clamps or similar may not be used.

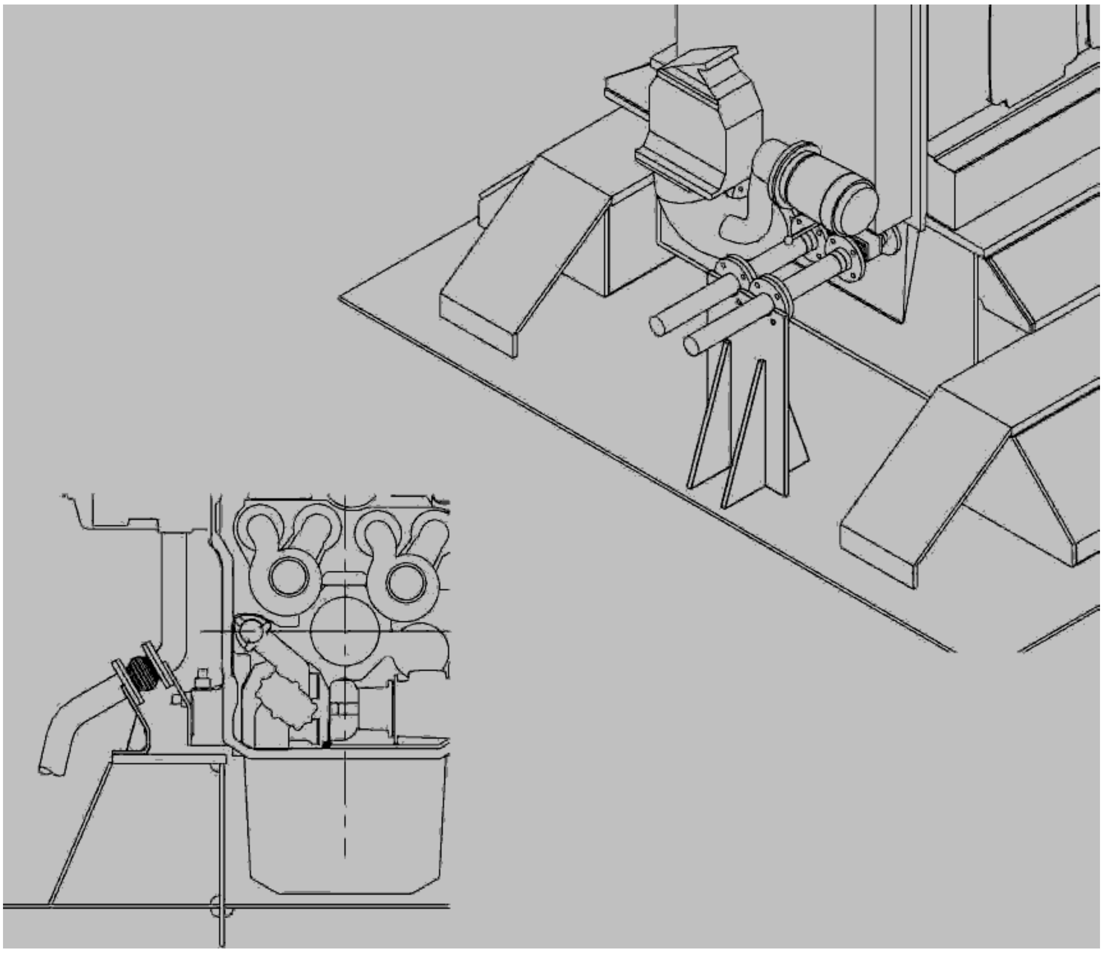
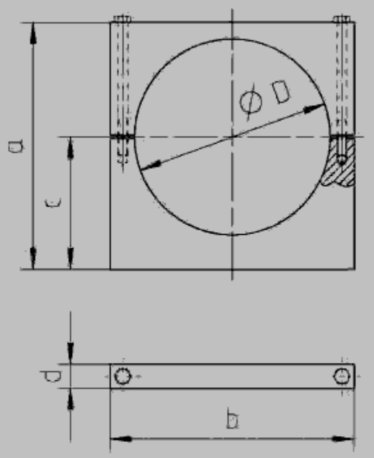


Fig 5-3 Flange supports of flexible pipe connections V60L0796

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
(A)	300	323.9	325	410	405	220	40	M16x220

d_u = Pipe outer diameter

Fig 5-4 Pipe clamp for fixed support (V61H0842A)

6. Fuel System

6.1 Acceptable fuel characteristics

6.1.1 Gas fuel specification

As a dual fuel engine, the Wärtsilä 46DF engine is designed for continuous operation in gas operating mode or diesel operating mode. For continuous operation in the rated output, the gas used as main fuel in gas operating mode has to fulfill the below mentioned quality requirements.

Table 6-1 Fuel Gas Specifications

Property	Unit	Value
Lower heating value (LHV), min 1)	MJ/m³N 2)	28
Methane number (MN), min 3)		80
Methane (CH_4), min	% v/v	70
Hydrogen sulphide (H_2S), max	% v/v	0.05
Hydrogen (H_2), max 4)	% v/v	3
Oil content, max.	mg/m³N	0,01
Ammonia, max	mg/m³N	25
Chlorine + Fluorines, max	mg/m³N	50
Particles or solids at engine inlet, max	mg/m³N	50
Particles or solids at engine inlet, max size	µm	5
Gas inlet temperature	°C	0…60
Water and hydrocarbon condensate at engine inlet not allowed 5)		

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

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

3) *Given Methane Number limits are valid for charge air temperature of 45 °C (see section Output limitations in gas mode). Methane Number (MN) can be assigned to any gaseous fuel indicating the percentage by volume of methane in blend with hydrogen that exactly matches the knock intensity of the unknown gas mixture under specified operating conditions in a knock testing engine. The Methane Number (MN) gives a scale for evaluation of the resistance to knock of gaseous fuels.*
To define the Methane Number (MN) of the gas, the method included in the EN 16726-2015 standard shall be used. Additionally, Wärtsilä has developed an internal MN calculator. Depending on the gas composition, the MN results obtained with those two methods can differ from each other, and therefore it is recommended to calculate MN also with the Wärtsilä method. If the difference of MN for a specific gas quality calculated with the two above mentioned methods is bigger than 3 units, Wärtsilä has to be contacted for further evaluation.
Further, if the total concentration of the heavier hydrocarbons than butane (C_4), i.e. pentane (C_5), hexane (C_6), heptane (C_7), etc. exceeds 1,0 % v/v, Wärtsilä has to be contacted for further evaluation.

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

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

6.1.2 Liquid fuel specification

The fuel specifications are based on the ISO 8217:2017(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.

6.1.2.1 Light fuel oil operation (distillate)

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

The distillate grades mentioned above can be described as follows:

- DMX: A fuel which is suitable for use at ambient temperatures down to –15 °C without heating the fuel. Especially in merchant marine applications its use is restricted to lifeboat engines and certain emergency equipment due to reduced flash point.
- DMA: A high quality distillate, generally designated MGO (Marine Gas Oil) in the marine field.
- DFA: A similar quality distillate fuel compared to DMA category fuels but a presence of max. 7,0% v/v of Fatty acid methyl ester (FAME) is allowed.
- DMZ: A high quality distillate, generally designated MGO (Marine Gas Oil) in the marine field. An alternative fuel grade for engines requiring a higher fuel viscosity than specified for DMA grade fuel.
- DFZ: A similar quality distillate fuel compared to DMZ category fuels but a presence of max. 7,0% v/v of Fatty acid methyl ester (FAME) is allowed.
- DMB: A general purpose fuel which may contain trace amounts of residual fuel and is intended for engines not specifically designed to burn residual fuels. It is generally designated MDO (Marine Diesel Oil) in the marine field.
- DFB: A similar quality distillate fuel compared to DMB category fuels but a presence of max. 7,0% v/v of Fatty acid methyl ester (FAME) is allowed.

For maximum fuel temperature before the engine, see the Technical Data or section "Fuel condition requirements" in Installation Manual.

Table 6-2 Light fuel oils

Characteristics	Unit	Limit	Category ISO-F							Test method(s) and references
			DMX	DMA	DFA	DMZ	DFZ	DMB	DFB	
Kinematic viscosity at 40 °C	mm^2/s [a]	Max	5,500	6,000		6,000		11,00		ISO 3104
		Min	1,400 [i]	2,000		3,000		2,000		
Density at 15 °C	kg/m^3	Max	-	890,0		890,0		900,0		ISO 3675 or ISO 12185
Cetane index [j]		Min	45	40		40		35		ISO 4264
Sulphur [b, k]	% m/m	Max	1,00	1,00		1,00		1,50		ISO 8754 or ISO 14596, ASTM D4294
Flash point	°C	Min	43,0 [l]	60,0		60,0		60,0		ISO 2719
Hydrogen sulfide	mg/kg	Max	2,00	2,00		2,00		2,00		IP 570
Acid number	mg KOH/g	Max	0,5	0,5		0,5		0,5		ASTM D664
Total sediment by hot filtration	% m/m	Max	-	-		-		0,10 [c]		ISO 10307-1
Oxidation stability	g/m^3	Max	25	25		25		25 [d]		ISO 12205
Fatty acid methyl ester (FAME) [e]	% v/v	Max	-	-	7,0	-	7,0	-	7,0	ASTM D7963 or IP 579

Characteristics		Unit	Limit	Category ISO-F DMX	DMA DFA	DMZ DFZ	DMB DFB	Test method(s) and references
Carbon residue – Micro method On 10% distillation residue		% m/m	Max	0,30	0,30	0,30	-	ISO 10370
Carbon residue – Micro method		% m/m	Max	-	-	-	0,30	ISO 10370
Cloud point f)	winter	°C	Max	-16	Report	Report	-	ISO 3015
	summer			-16	-	-	-	
Cold filter plugging point f)	winter	°C	Max	-	Report	Report	-	IP 309 or IP 612
	summer			-	-	-	-	
Pour point f)	winter	°C	Max	-	-6	-6	0	ISO 3016
	summer			-	0	0	6	
Appearance				Clear and bright g)			c)	-
Water		% v/v	Max	-	-	-	0,30 c)	ISO 3733, ASTM D6304-C m)
Ash		% m/m	Max	0,010	0,010	0,010	0,010	ISO 6245
Lubricity, corr. wear scar diam. h)		µm	Max	520	520	520	520 d)	ISO 12156-1

NOTE

a) 1 mm²/s = 1 cSt.

b) Notwithstanding the limits given, the purchaser shall define the maximum sulphur content in accordance with relevant statutory limitations.

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

d) If the sample is not clear and bright, the Oxidation stability and Lubricity tests cannot be undertaken and therefore, compliance with this limit cannot be shown.

e) See ISO 8217:2017(E) standard for details.

f) Pour point cannot guarantee operability for all ships in all climates. The purchaser should confirm that the cold flow characteristics (pour point, cloud point, cold filter clogging point) are suitable for ship's design and intended voyage.

g) If the sample is dyed and not transparent, see ISO 8217:2017(E) standard for details related to water analysis limits and test methods.

h) The requirement is applicable to fuels with sulphur content below 500 mg/kg (0,050 % m/m).

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

i) Low min. viscosity of 1,400 mm²/s can prevent the use ISO-F-DMX category fuels in Wärtsilä® engines unless a fuel can be cooled down enough to meet the injection viscosity limits stated in the table Kinematic Viscosity before fuel pumps.

j) When operating engine in gas mode, the Cetane Index limits specified for pilot fuel as per table Pilot Fuel oils have to be fulfilled.

k) There doesn't exist any minimum sulphur content limit for Wärtsilä® DF engines and also the use of Ultra Low Sulphur Diesel (ULSD) is allowed provided that the fuel quality fulfils other specified requirements.

l) Low flash point (min. 43 °C) can prevent the use ISO-F-DMX category fuels in Wärtsilä® engines in marine applications unless the ship's fuel system is built according to special requirements allowing the use or that the fuel supplier is able to guarantee that flash point of the delivered fuel batch is above 60 °C being a requirement of SOLAS and classification societies.

m) Alternative test method.

Pilot fuel quality in GAS operation

In order to provide the engine efficiency in GAS operation stated in this document while also complying to IMO Tier III NO_x legislation when running in GAS operation, the pilot fuel shall fulfil the characteristics specified in table 6-2, except that the following additional requirement is valid for Cetane Index related to ISO 8217:2017(E) fuel categories DMX, DMA, DFA, DMZ, DFZ, DMB and DFB.

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

Table 6-3 Pilot fuel oils

Characteristics	Unit	Limit	Test method reference
Cetane index, min.	-	40	ISO 4264

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

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

Table 6-4 Kinematic viscosity before fuel pumps

Characteristics	Unit	Limit
Kinematic viscosity before pilot fuel pump, min.	mm^2/s a)	2
Kinematic viscosity before pilot fuel pump, max.	mm^2/s a)	11
Kinematic viscosity before standard main fuel pump, min.	mm^2/s a)	2
Kinematic viscosity before standard main fuel pump, max.	mm^2/s a)	24

NOTE

a) 1 mm^2/s = 1 cSt.

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

6.1.2.2 0,10% m/m sulphur fuels for SECA areas

Due to the tightened 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 sometimes also as “hybrid” fuels, since those can contain properties of both distillate and residual fuels. In the existing ISO 8217:2017(E) standard the fuels are classed as RMA 10, RMB 30 or RMD 80, 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, but special attention shall be paid to optimum operating conditions. See also Services Instruction WS02Q312.

RMA 10, RMB 30 and RMD 80 category fuels are accepted only when operating the engine in back-up or diesel mode. Use of these fuel qualities as a pilot fuel in gas mode is not allowed, but a fuel quality fulfilling the distillate fuel specification included in chapter Light fuel oil operation (distillate) has to be used.

Characteristics	Unit	RMA 10	RMB 30	RMD 80	Test method reference
Kinematic viscosity bef. injection pumps c)	mm^2/s a)	6,0 - 24	6,0 - 24	6,0 - 24	-
Kinematic viscosity at 50 °C, max.	mm^2/s a)	10,00	30,00	80,00	ISO 3104
Density at 15 °C, max.	kg/m^3	920,0	960,0	975,0	ISO 3675 or ISO 12185
CCAI, max. e)	-	850	860	860	ISO 8217, Annex F
Sulphur, max. b)	% 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. c)	% m/m	1,5	6,0	8,0	ASTM D3279
Pour point (upper), max., winter quality d)	°C	0	0	30	ISO 3016
Pour point (upper), max., summer quality d)	°C	6	6	30	ISO 3016
Water max.	% v/v	0,30	0,50	0,50	ISO 3733 or ASTM D6304-C c)
Water bef. engine, max. c)	% v/v	0,30	0,30	0,30	ISO 3733 or ASTM D6304-C c)
Ash, max.	% m/m	0,040	0,070	0,070	ISO 6245 or LP1001 c, h)
Vanadium, max. f)	mg/kg	50	150	150	IP 501, IP 470 or ISO 14597
Sodium, max. f)	mg/kg	50	100	100	IP 501 or IP 470
Sodium bef. engine, max. c, f)	mg/kg	30	30	30	IP 501 or IP 470

Characteristics	Unit	RMA 10	RMB 30	RMD 80	Test method reference
Aluminium + Silicon, max.	mg/kg	25	40	40	IP 501, IP 470 or ISO 10478
Aluminium + Silicon bef. engine, max.[c)]	mg/kg	15	15	15	IP 501, IP 470 or ISO 10478
Used lubricating oil: [g)] - Calcium, max. - Zinc, max. - Phosphorus, max.	 mg/kg mg/kg mg/kg	 30 15 15	 30 15 15	 30 15 15	 IP 501 or IP 470 IP 501 or IP 470 IP 501 or IP 500

NOTE

a) 1 mm²/s = 1 cSt.

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

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

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

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

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

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

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

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

6.1.2.3 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).

HFO is accepted only for back-up fuel system. Use of HFO as pilot fuel is not allowed, but a fuel quality fulfilling the MDF specification included in section *Light fuel oil operation (distillate)* has to be used.

Table 6-5 Heavy fuel oils

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

NOTE

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

b) 1 mm²/s = 1 cSt.

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

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.

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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 Operating principles

Wärtsilä 46DF engines are usually installed for dual fuel operation meaning the engine can be run either in gas or diesel operating mode. The operating mode can be changed while the engine is running, within certain limits, without interruption of power generation. If the gas supply would fail, the engine will automatically transfer to diesel mode operation (MDF).

6.2.1 Gas mode operation

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

Instant transfer from any load is possible to Diesel Mode and Back-up Mode. In case of failure in pilot fuel system, engine safety system will change operating mode instantly to Back-up Mode

6.2.2 Diesel mode operation

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

Transfer to Gas Mode is possible under 80% engine load. In case of failure in pilot fuel system, engine safety system will change operating mode instantly to Back-up Mode.

6.2.3 Backup mode operation

The engine control and safety system or the blackout detection system can in some situations transfer the engine to backup mode operation. In this mode the MDF pilot injection system is not active and operation longer than 30 minutes (with HFO) or 10 hours (with MDF) may cause clogging of the pilot fuel injection nozzles.

Transfer to Gas or to Diesel Mode is not possible. If transfer from Backup mode to Diesel or to Gas mode is desired, the engine must be stopped in order to allow engine to perform pilot system diagnostic check, which is performed as a part of engine start sequence.

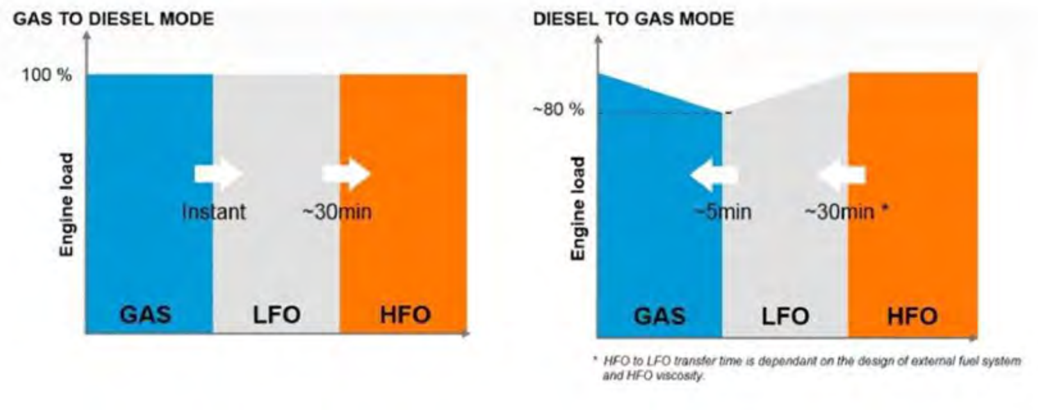

Fig 6-1 Transfer Gas/Diesel

6.3 Fuel gas system

6.3.1 Internal fuel gas system

On the engine, the gas is supplied through common main gas pipes, double wall, running along the engine, continuing with individual feed pipes to each main gas admission valve located on the cylinder head. At the gas outlet end there is a gas vent system including the MCC de-gassing valve (formerly called “venting valve”) which releases the gas pressure.

The gas pressure is controlled on the external Gas Valve Unit (GVU), by the engine control system based on the engine load. The gas goes through the gas manifold which feeds the main Gas Admission Valves. The gas is mixed with the intake air immediately upstream of the inlet valve in the cylinder head. Combustion is initiated by a small amount of pilot fuel oil injected into the cylinder (pilot fuel), through the smaller nozzle of the injection valve.

A safety filter is placed before every gas admission valve, preventing particles from entering the valve, with a filtration degree of 80 microns nominal.

Double-wall pipes are used. The gas flows to the cylinders through inner pipes, and the annular space between the walls is ventilated.

Venting of internal of gas pipes let residual gas fuel dissipate at engine stop, at tripping from gas to diesel, and in some other situations. The on-engine MCC De-gassing valve releases the gas pressure from the on-engine pipe and from the external branch between engine and external GVU gas pressure control valve, to a safe external place. Its other function occurs at gas mode activation: it shortly opens to let the gas fill the gas pipes.

Ventilation of annular space between the walls is made artificially by underpressure with flushing air. External ventilation fans installed close to GVU unit brings directly any gas leakage occurred into the annular space to the gas detectors. Gas detectors sense abnormal presence of gas particles leaked in the intermediate wall of the pipe, and are installed close to the external ventilation fans, one per each GVU.

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Gas detectors have to be installed in engine room, above engine, to detect gas leakage, due to a classification societies requirement.

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Gas detectors have to be installed in engine room, above engine, to detect gas leakage, due to a classification societies requirement.

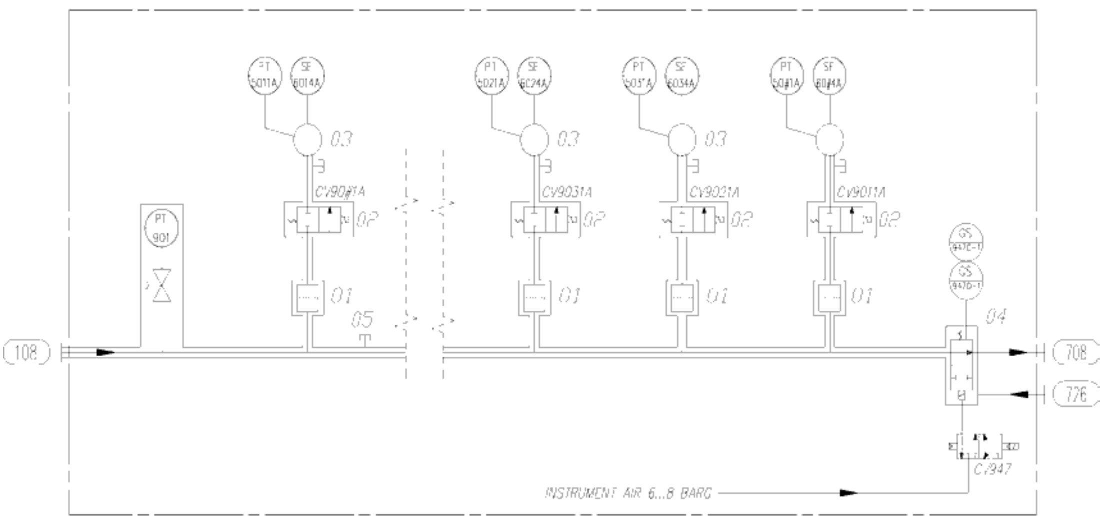

Fig 6-2 Internal fuel gas system, in-line engines (DAAF447413)

System components:					
01	Safety filter	03	Cylinder	05	Sniffer probe connection
02	Gas admission valve	04	MCC de-gassing valve		

Pipe connections:	
108	Gas inlet
708	Gas system ventilation
726	Air inlet to double wall gas system

Sensors and indicators:			
SE614A...SE60#4A	Knock, cyl A01...A0#	PT901	Main gas pressure
PT5011A...PT50#4A	Cylinder pressure, cyl A01...A0#	GS9470-1	MCC, de-gassing valve 1 position, open
CV9011A...CV90#1A	Main gas valve control, cyl A01...A0#	GS947C-1	MCC, de-gassing valve 1 position, closed
CV947	MCC, de-gassing valve control		

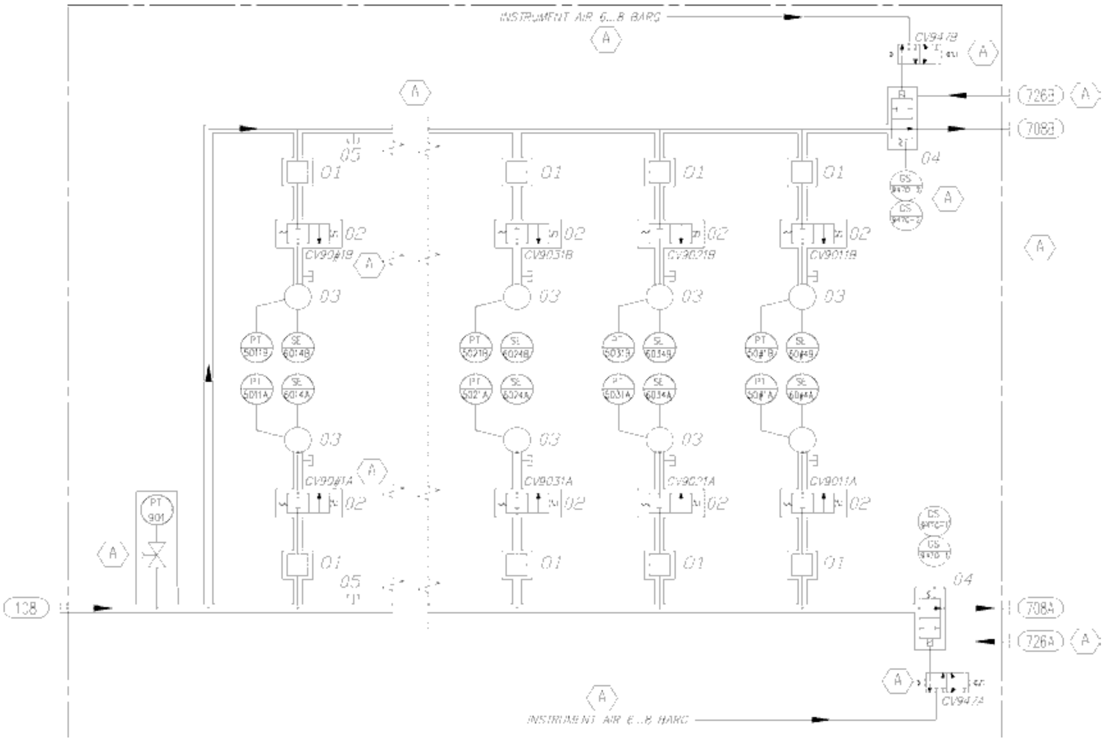

Fig 6-3 Internal fuel gas system,V-engines (DAAF381078A)

Sensors and indicators:			
SE6014A...SE60#4A	Knock, cyl A01...A0#	PT901	Main gas pressure
SE6014B...SE60#4B	Knock, cyl B01...B0#	CV947 A/B	MCC, de-gassing valve control A/B bank
PT5011A...PT50#4A	Cylinder pressure, cyl A01...A0#	GS9470-1	MCC, de-gassing valve 1 position, open
PT5011B...PT50#4B	Cylinder pressure, cyl B01...B0#	GS947C-1	MCC, de-gassing valve 1 position, closed
CV9011A...CV90#1A	Main gas valve control, cyl A01...A0#	GS9470-2	MCC, de-gassing valve 2 position, open
CV9011B...CV90#1B	Main gas valve control, cyl B01...B0#	GS947C-2	MCC, de-gassing valve 2 position, closed

System components			
01	Safety filter	04	MCC de-gassing valve
02	Gas admission valve	05	Sniffer probe connection
03	Cylinder		

Pipe connections	
108	Gas inlet
708A/B	Gas system ventilation
726A/B	Air inlet to double wall gas system

6.3.1.1 Injection Equipment

For gas operation:

When running in gas mode the main components are the gas admission valves and the smaller needle in the dual fuel injection valve.

Gas admission valve

The gas admission valves are working as the engine speed regulator and are controlling the amount of gas fed to each cylinder of the engine. The valve is located on the cylinder head and the gas is fed into the inlet channel of the cylinder head. The main gas valve is a direct actuated solenoid valve. The engine automation system (UNIC) adjusts the amount of gas fed to individual cylinders.

On-engine MCC de-gassing valve (formerly called “venting valve”)

The Main Combustion Chamber line de-gassing valve (MCC) is one of the venting valves of gas system. Other venting valves are placed in the external gas system. MCC de-gassing valve is on-engine, at end of gas manifold. Line engines have internally one MCC de-gassing valve. Vee engines have internally two of them, one per bank. An MCC de-gassing valve releases the gas pressure when changing from gas mode to diesel mode, or backup mode, or at engine stopping in gas mode. It acts shortly also at gas mode initiation. It acts also at automation purging.

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

6.3.2 External fuel gas system

Before the gas is supplied to the engine, it passes a Gas Valve Unit (GVU).

The **Gas Valve Unit (GVU)** supplies filtered gas at proper pressure to the engine, and contains safety functions, and has several block & bleed valves. The unit includes a manual shut-off valve, inerting connection, filter, fuel gas pressure control valve, shut-off valves, venting valves, pressure transmitters/gauges, a gas temperature transmitter and control cabinets.

The off-engine venting valves vent or purge the gas pipes inner section that are inside and before GVU. They can remain closed at engine venting (MCC de-gassing valve open), or act in coordination with the MCC de-gassing valve, according to need. Off-engine venting valves for inner gas pipes acts also at purging. The off-engine venting valves that are for annular space are for ventilation. No corresponding valve is on-engine. The gas supply system on engine is equipped with double wall gas pipes. A Gas Valve Unit (GVU) is required for each engine and has to be located as close the engine as possible.

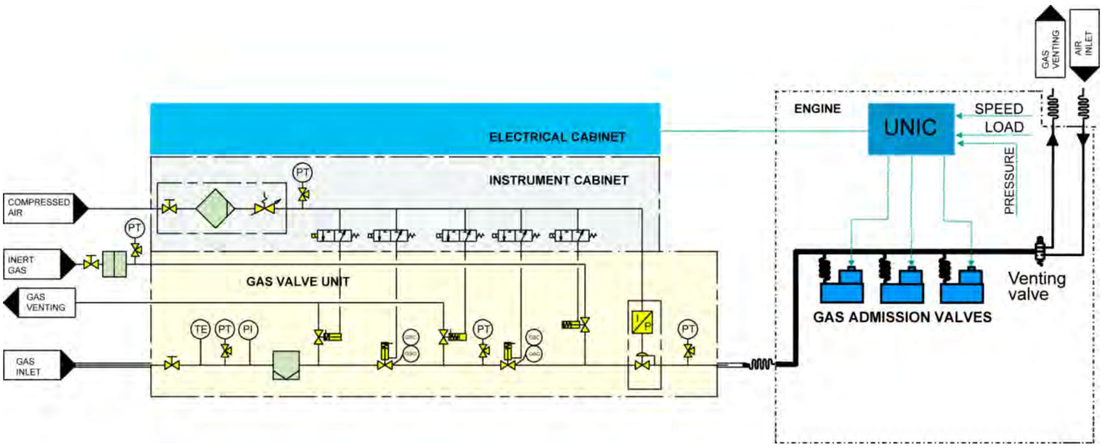

Fig 6-4 Gas supply system with the Gas Valve Unit (GVU) and the main components

6.3.2.1 Requirements on the external gas system equipment

The design of the external gas system may vary from installation to installation but every system shall be designed to provide the engine with gas of correct flow, pressure and according to fuel specification in the Product Guide.

Design, manufacturing and installation of pipes and other equipment has to fulfil all local authority requirements.

Piping material before the engine and after the external gas filter has to be in stainless steel.

The gas connections to/from engine have to be flexible. No external loads on the engine gas inlet/outlet connections are allowed.

The pipe diameter of the outlet gas ventilation connection on the engine is DN50. The external ventilation pipe is recommended to be one size larger in order not to influence negatively on the programmed engine gas venting sequences.

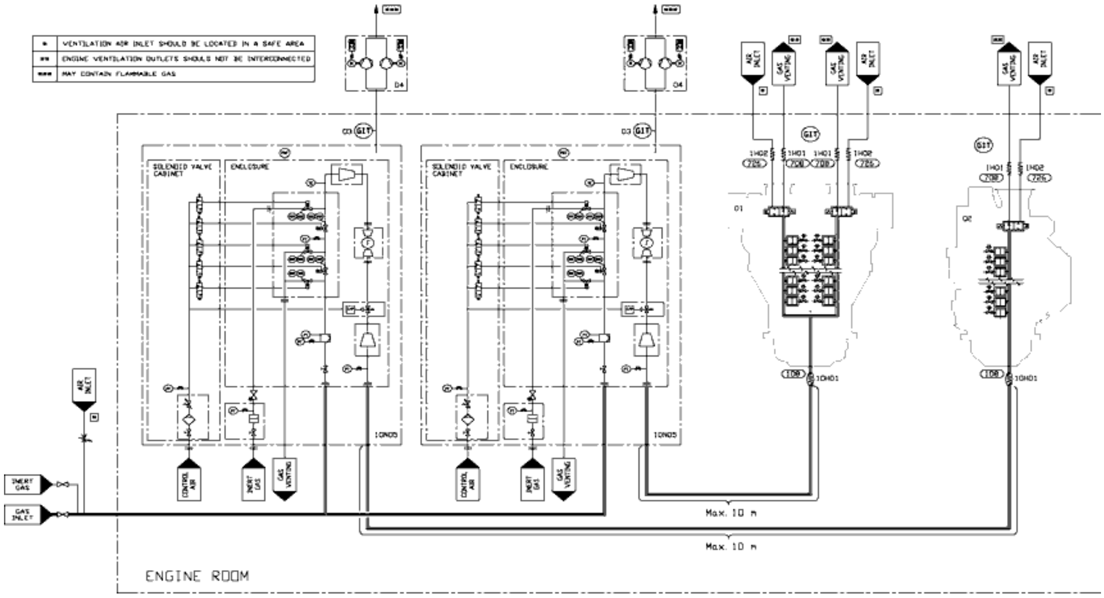

Fig 6-5 External fuel gas system GVU with enclouse (DAAF366889)

System components		Pipe connections	
03	Gas detector	108	Gas inlet
04	Gas double wall system ventilation fan	708	Safety ventilation
10N05	Gas valve unit	726	Air inlet to double wall gas system
10H01	Flexible pipe connections for DF engines		

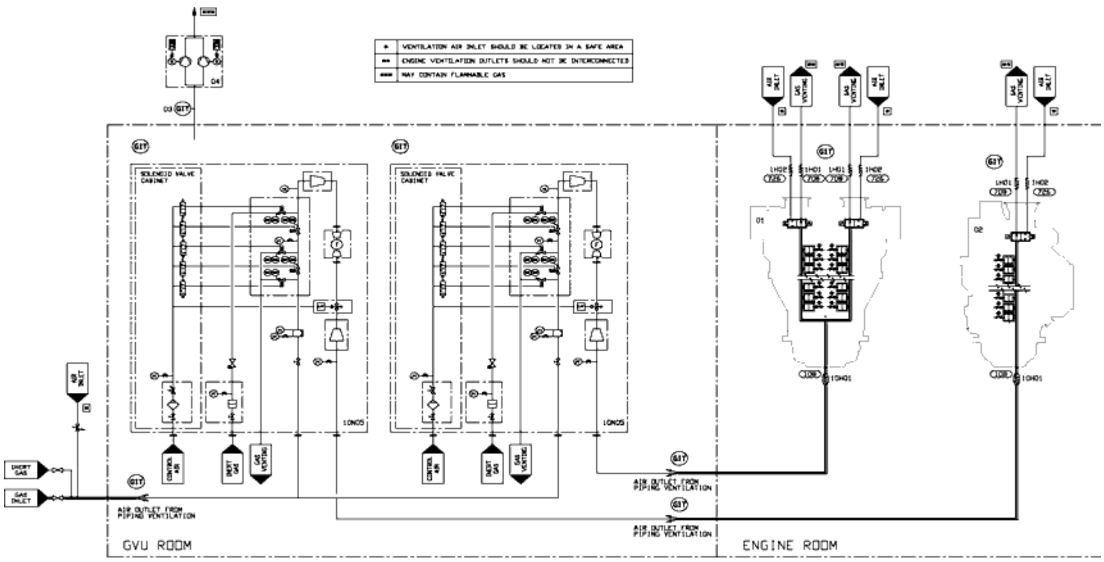

Fig 6-6 External fuel gas system GVU without enclouse with cabinet (DAAF366890)

System components		Pipe connections	
03	Gas detector	108	Gas inlet
04	Gas double wall system ventilation fan	708	Safety ventilation
10N05	Gas valve unit	726	Air inlet to double wall gas system
10H01	Flexible pipe connections for DF engines		

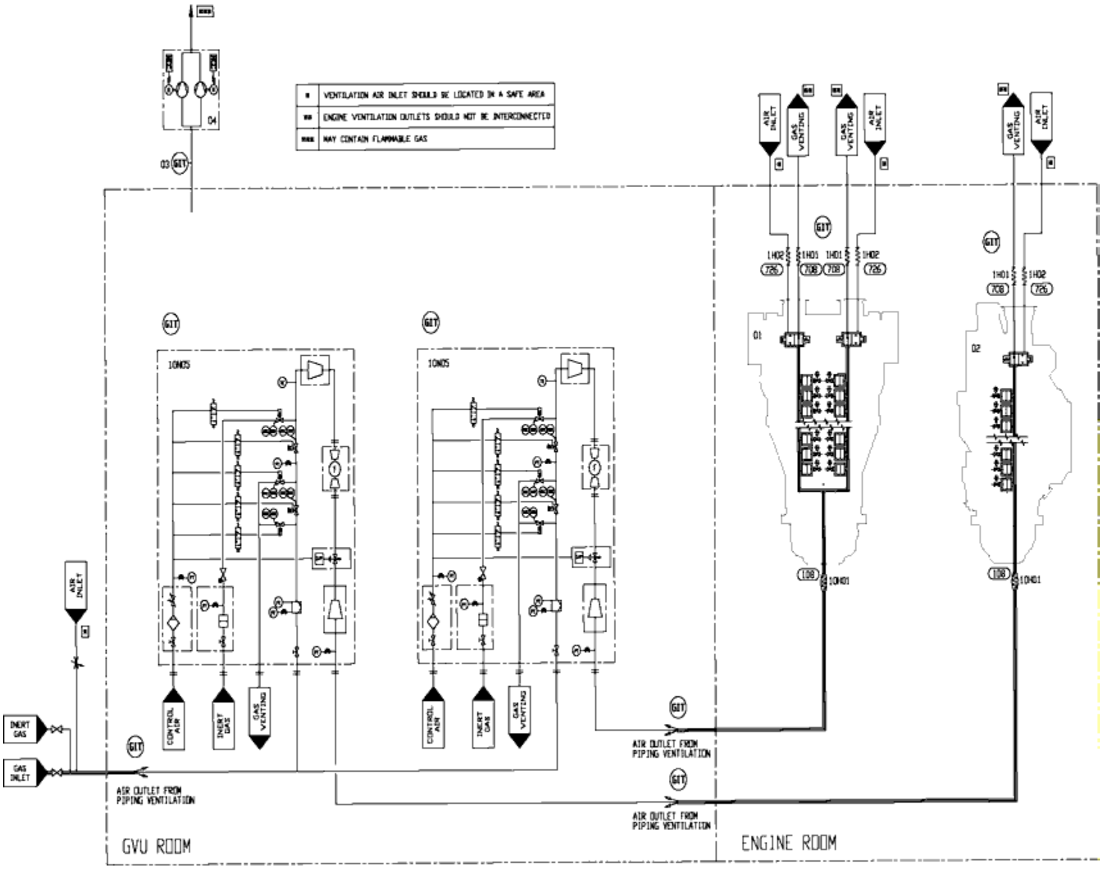

Fig 6-7 **External fuel gas system GVU without enclouse without cabinet (DAAF366891)**

System components		Pipe connections	
03	Gas detector	108	Gas inlet
04	Gas double wall system ventilation fan	708	Safety ventilation
10N05	Gas valve unit	726	Air inlet to double wall gas system
10H01	Flexible pipe connections for DF engines		

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

6.3.2.2 Double wall gas piping and the ventilation of the piping

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

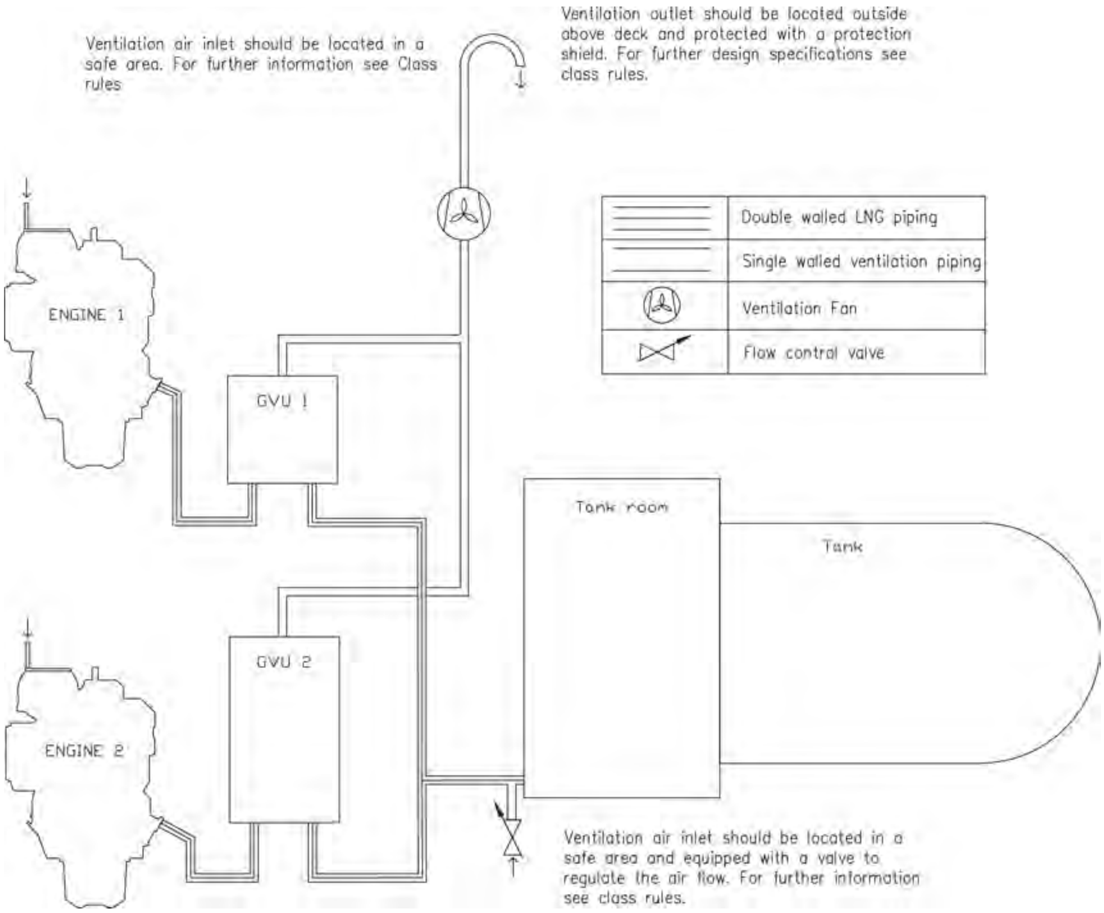

Fig 6-8 Example arrangement drawing of ventilation in double wall piping system with enclosed GVUs (DBAC588146)

6.3.2.3 Gas valve unit (10N05)

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

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

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

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

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

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

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

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

One GVU is required for each engine. The GVU has to be located close to the engine to ensure engine response to transient conditions. The maximum length of fuel gas pipe between the GVU and the engine gas inlet is 10 m.

On some specific GVU, it can be more meters, depending on GVU model and volume in pipe diameter.

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

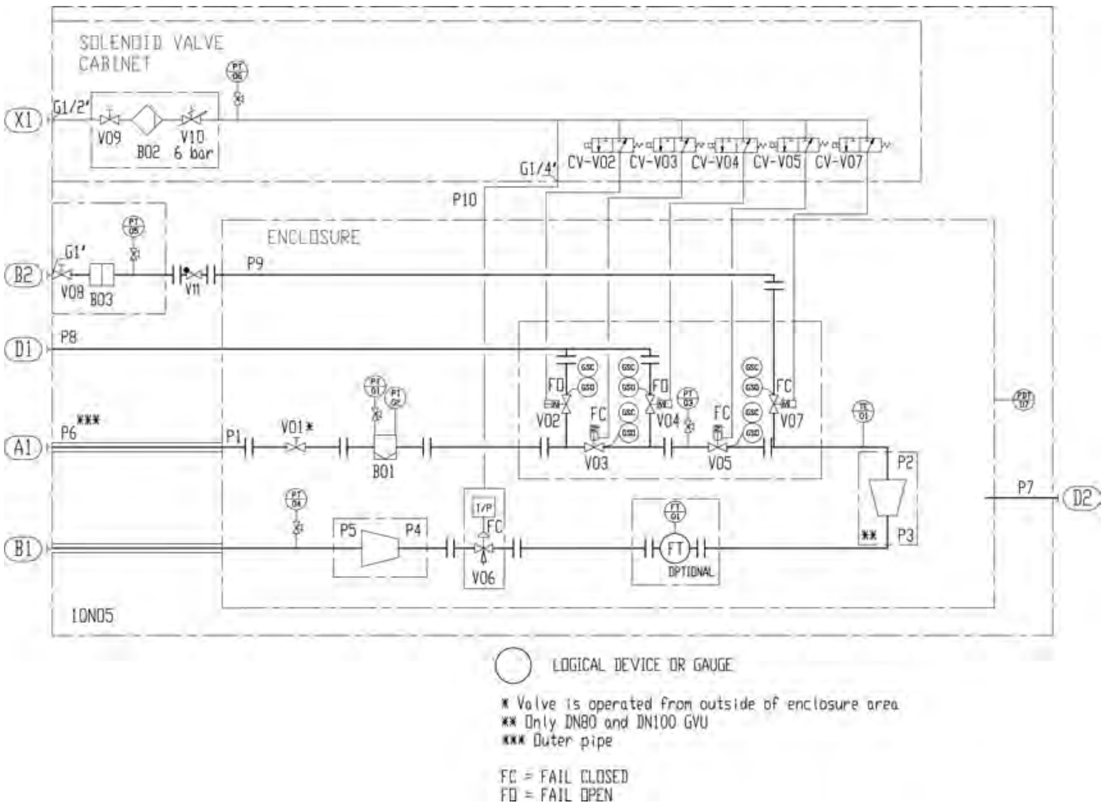

Fig 6-9 Gas valve unit P&I diagram (DAAF051037D)

Unit components:					
B01	Gas filter	V03	First block valve	V08	Shut off valve
B02	Control air filter	V04	Vent valve	V09	Shut off valve
B03	Inert gas filter	V05	Second block valve	V10	Pressure regulator
V01	Manual shut off valve	V06	Gas control valve	CV-V0#	Solenoid valve
V02	Vent valve	V07	Inerting valve	FT01	Mass flow meter
V11	Non return valve				

Sensors and indicators					
PT01	Pressure transmitter, gas inlet	PT04	Pressure transmitter, gas outlet	PDT07	Pressure difference transmitter
PI02	Pressure manometer, gas inlet	PT05	Pressure transmitter, inert gas	FT01	Mass flow meter
PT03	Pressure transmitter	PT06	Pressure transmitter, control air	TE01	Temperature sensor, gas inlet

Pipe connections					
A1	[5 - 10bar (g)]	B2	[max 10 bar(g)]	D2	Air venting
B1	Gas to engine	D1	Gas venting	X1	Control air [6-8 bar(g)]

Pipe size							
Pos	DN50 GVU	DN80 GVU	DN100 GVU	Pos	DN50 GVU	DN80 GVU	DN100 GVU
P1	DN50	DN80	DN100	P6	DN100	DN125	DN150
P2	DN40	DN80	DN100	P7	DN50	DN80	DN100
P3	DN40	DN50	DN80	P8	OD18	OD28	OD42
P4	DN40	DN50	DN80	P9	OD22	OD28	OD28
P5	DN65	DN80	DN100	P10	10mm	10mm	10mm

6.3.2.4 Master fuel gas valve

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

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

6.3.2.5 Fuel gas venting

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

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

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

NOTE

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

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

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

To prevent gas ventilation to another engine during maintenance vent lines from gas supply or GVU of different engines cannot be interconnected. However, vent lines from the same engine can be interconnected to a common header, which shall be lead to the atmosphere. Connecting the engine or GVU venting lines to the LNGPac venting mast is not allowed, due to risk for backflow of gas into the engine room when LNGPac gas is vented!

6.3.2.6 Purging by inert gas

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

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

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

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

1. **Max filling flow: 200l/min/cylinder**
2. **A sniffer is recommended to be installed in the crankcase breather pipe in order to indicate when the crankcase have been flushed from toxic gases.**

3 Crankcase size: 2.30 m^3/crank (inline) & 4.12 m^3/crank (v-engine)

6.3.2.7 Gas feed pressure

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

6.4 Fuel oil system

6.4.1 Internal fuel oil system

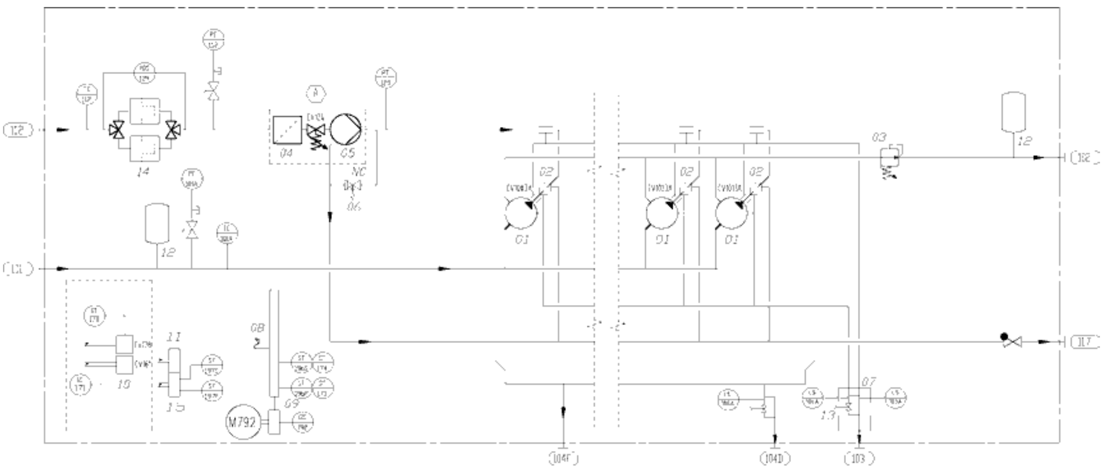

Fig 6-10 Internal fuel oil system, in-line engines (DAAF447414)

System components:					
01	Injection pump	06	Pilot fuel safety valve	12	Pulse damper
02	Inj. valve with pilot solenoid and nozzle	07	Fuel leakage collector	13	Adjustable valve
03	Pressure control valve	08	Flywheel	14	Pilot fuel filter (duplex)
04	Pilot fuel filter	09	Turning device	15	Camshaft
05	Pilot fuel pump	10	Fuel and timing rack		

Sensors and indicators:			
GS171	Stop lever in stop position	LS108A	FO leakage dirty fuel DE
GS792	Turning gear engaged	PT125	Pilot fuel press. pump outlet
PT101	Fuel oil press. engine inlet	PDS129	Pilot fuel filter pressure difference
TE101	Fuel oil temp. engine inlet	ST196P/ST173	Engine speed primary
PT112	Pilot fuel press. inlet	ST196P/ST174	Engine speed secondary
TE112	Pilot fuel temp. inlet	ST197P	Engine phase primary
LS103A	FO leakage clean primary	ST197S	Engine phase secondary
LS106A	FO leakage clean secondary		

Pipe connections					
101	Fuel inlet	104F	Leak fuel drain, dirty fuel FE	117	Pilot fuel outlet
102	Fuel outlet	104D	Leak fuel drain, dirty fuel DE		
103D	Leak fuel drain, clean fuel DE	112	Pilot fuel inlet		

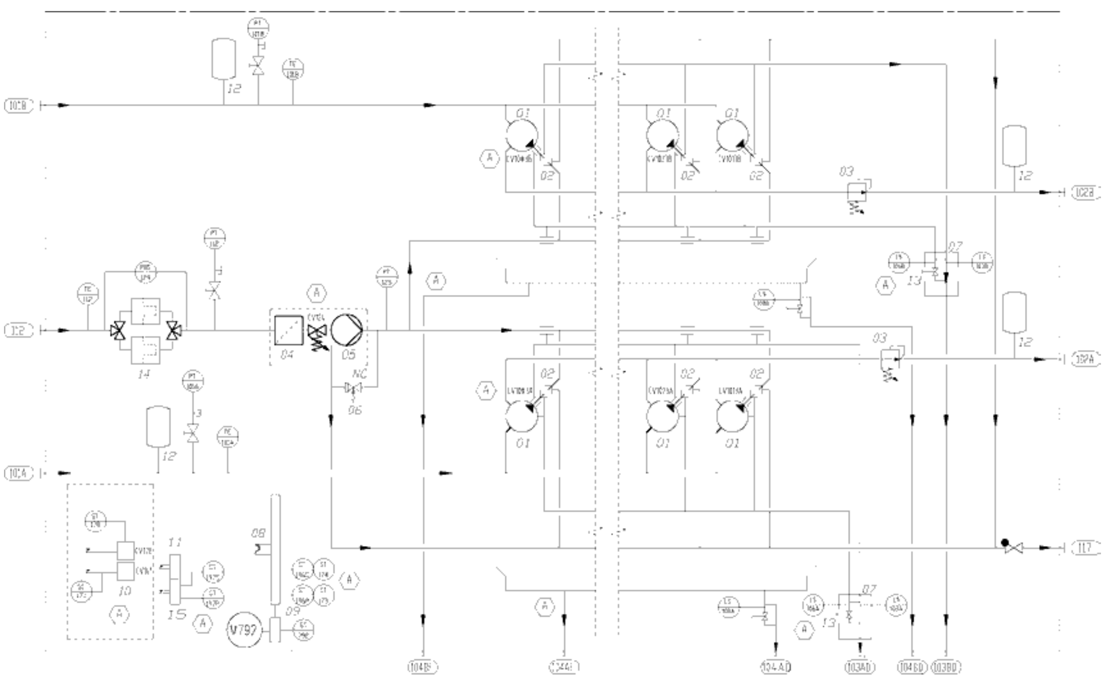

Fig 6-11 Internal fuel oil system, V-engines (DAAF381079A)

System components:			
01	Injection pump	08	Flywheel
02	Injection valve with pilot solenoid and nozzle	09	Turning device
03	Pressure control valve	10	Fuel and timing rack
04	Pilot fuel filter	12	Pulse damper
05	Pilot fuel pump	13	Adjustable valve
06	Pilot fuel safety valve	14	Pilot fuel filter (duplex)
07	Fuel leakage collector	15	Camshaft

Pipe connections			
101 A/B	Fuel inlet A/B bank	104AD	Leak fuel drain, dirty fuel A-bank DE
102 A/B	Fuel outlet A/B -bank	104BF	Leak fuel drain, dirty fuel B-bank FE
103AD	Leak fuel drain, clean fuel A-bank DE	104BD	Leak fuel drain, dirty fuel B-bank DE
103BD	Leak fuel drain, clean fuel B-bank DE	112	Pilot fuel inlet
104AF	Leak fuel drain, dirty fuel A-bank FE	117	Pilot fuel outlet

Sensors and indicators:			
GS171	Stop lever in stop position	LS108A/B	FO leakage dirty fuel DE A/B bank
GS792	Turning gear engaged	PT125	Pilot fuel press. pump outlet
PT101A/B	Fuel oil press. engine inlet A/B bank	PDS129	Pilot fuel filter pressure difference
TE101A/B	Fuel oil temp. engine inlet A/B bank	ST196P/ST173	Engine speed primary
PT112	Pilot fuel press. inlet	ST196P/ST174	Engine speed secondary
TE112	Pilot fuel temp. inlet	ST197P	Engine phase primary

Sensors and indicators:			
LS103A/B	FO leakage clean primary A/B bank	ST197S	Engine phase secondary
LS106A/B	FO leakage clean secondary A/B bank		

Electrical instruments:	
GT178	Timing rack position (in actuator)
CV161	Fuel rack control
CV178	Timing rack control
CV124	Pilot fuel pressure control
CV1013A...CV10#3A	Pilot injection valve, cyl A01...A0#
CV1013B...CV10#3B	Pilot injection valve, cyl B01...B0#
M792	Electric motor

Main fuel oil can be Marine Diesel Fuel (MDF) or Heavy Fuel Oil (HFO). Pilot fuel oil is always MDF and the pilot fuel system is in operation in both gas and diesel mode operation.

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

6.4.1.1 Leak fuel system

Main 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).

Pilot fuel max outlet pressure: See technical data

The clean leak fuel can be re-used without separation treatment whenever LFO and HFO doesn't mix together.

6.4.2 External fuel oil system

External pilot fuel circuit shall be separated from main fuel circuit, if using HFO as main fuel.

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.

6.4.2.1 Definitions Filtration term used

- **mesh size**: opening of the mesh (surface filtration), and often used as commercial name at purchase. Only approximately related to Efficiency and Beta-value. Insufficient to compare two filters from two suppliers. Good to compare two meshes of same filter model from same supplier. Totally different than micron absolute, that is always much bigger size in micron.

  - e.g. a real example: 30 micron mesh size = approx. 50 micron $ß_{50}$ = 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 (ε10 = 60%) = approx. 60 micron absolute.

- **XX micron, absolute**: intended here as $ß_{xx}$ = 75 ISO 16889 (similar to old εxx = 98,7%)

  - Beta value $ß_{xx}$ = YY : ISO name with ISO 16889 standardised test method. Weak repeteability for dust bigger than 25..45 microns.

  - Example: $ß_{20}$ = 75 means “every 75 particles 20 micron ISO dust sent, one passes”.

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

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

6.4.2.2 Fuel heating requirements HFO

Heating is required for:

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

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

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

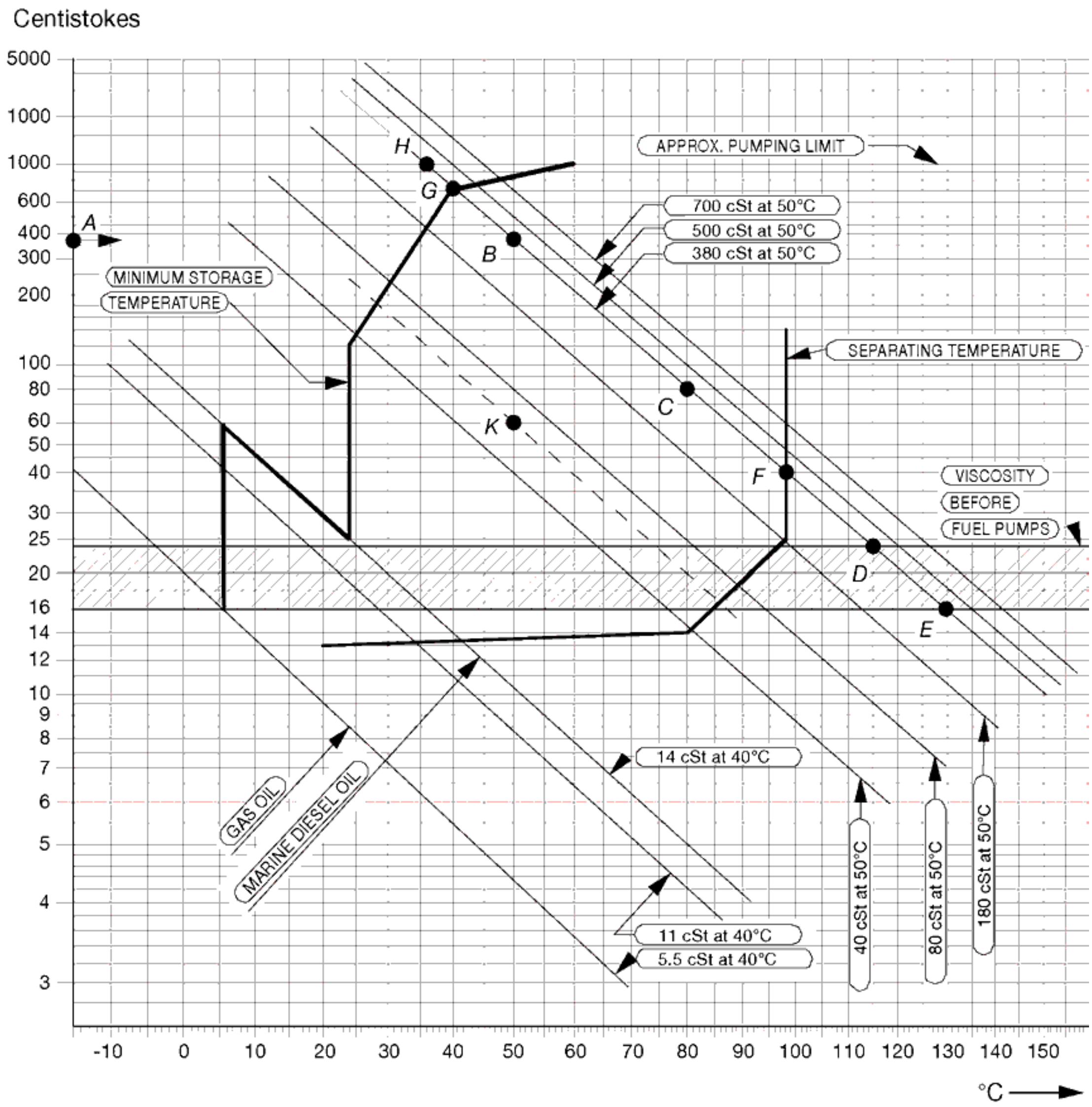

Fig 6-12 **Fuel oil viscosity-temperature diagram for determining the pre-heating temperatures of fuel oils (4V92G0071b)**

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

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

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

6.4.2.3 Fuel tanks

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

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.

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

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

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

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

Leak fuel tank, clean fuel (1T04)

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

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

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

Refer to section "*Fuel feed system - HFO installations*" for an example of the external HFO fuel oil system.

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

Leak fuel tank, dirty fuel (1T07)

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

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

6.4.2.4 Fuel treatment

Separation

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

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

All recommendations from the separator manufacturer must be closely followed.

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

Separator mode of operation

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

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

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

Separation efficiency

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

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

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

where:

n = separation efficiency [%]

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

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

Separator unit (1N02/1N05)

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

Typically separator modules are equipped with:

- Suction strainer (1F02)

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

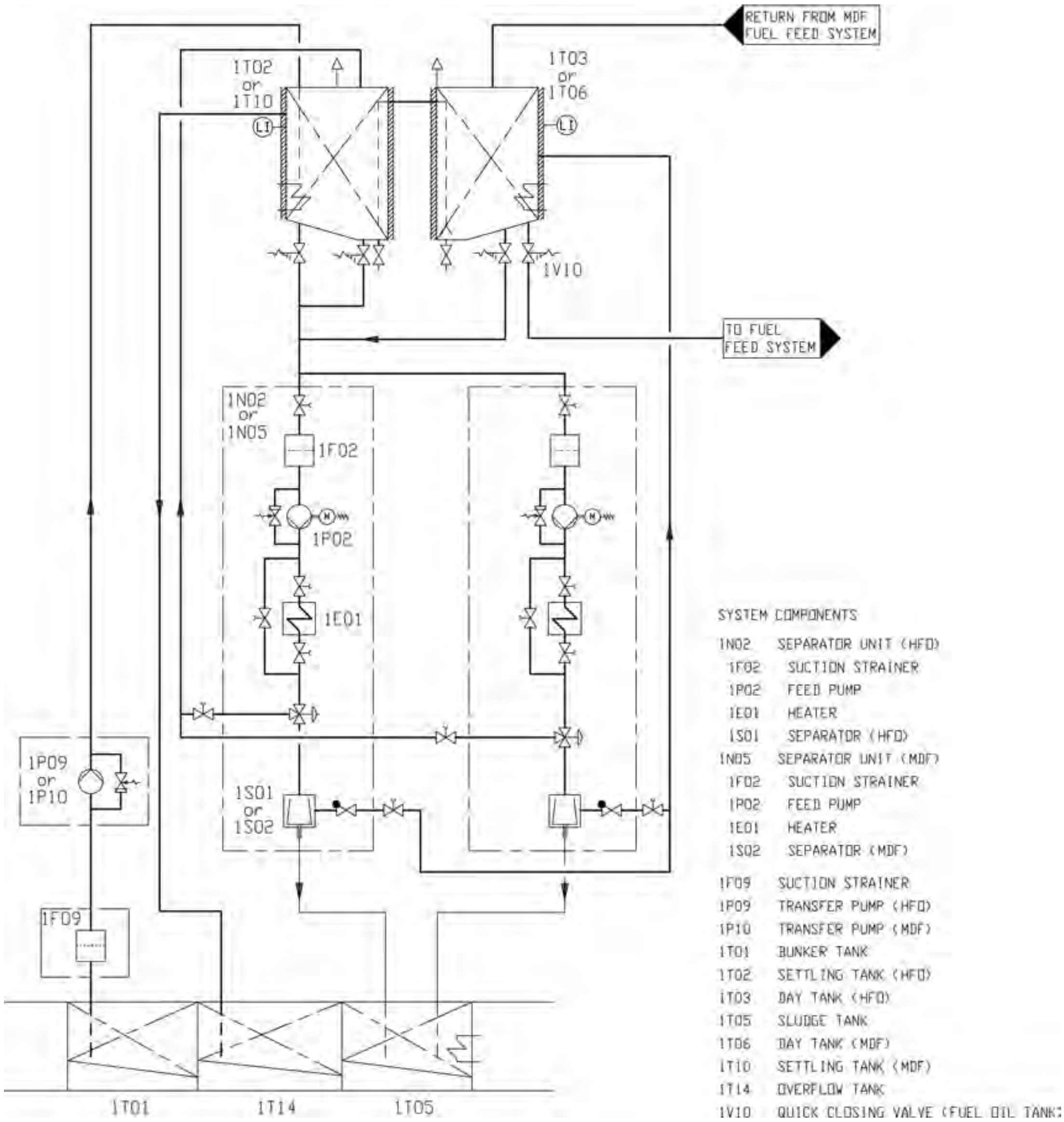

Fig 6-13 Fuel transfer and separating system (V76F6626G)

Separator feed pumps (1P02)

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

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

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

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

Separator pre-heater (1E01)

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

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

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

The required minimum capacity of the heater is:

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

where:

P = heater capacity [kW]

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

ΔT = temperature rise in heater [°C]

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

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

Separator (1S01/1S02)

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

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

where:

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

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

ρ = density of the fuel [kg/m^3]

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

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

Sample valves must be placed before and after the separator.

MDF separator in HFO installations (1S02)

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

Sludge tank (1T05)

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

6.4.2.5 Fuel feed system - MDF installations

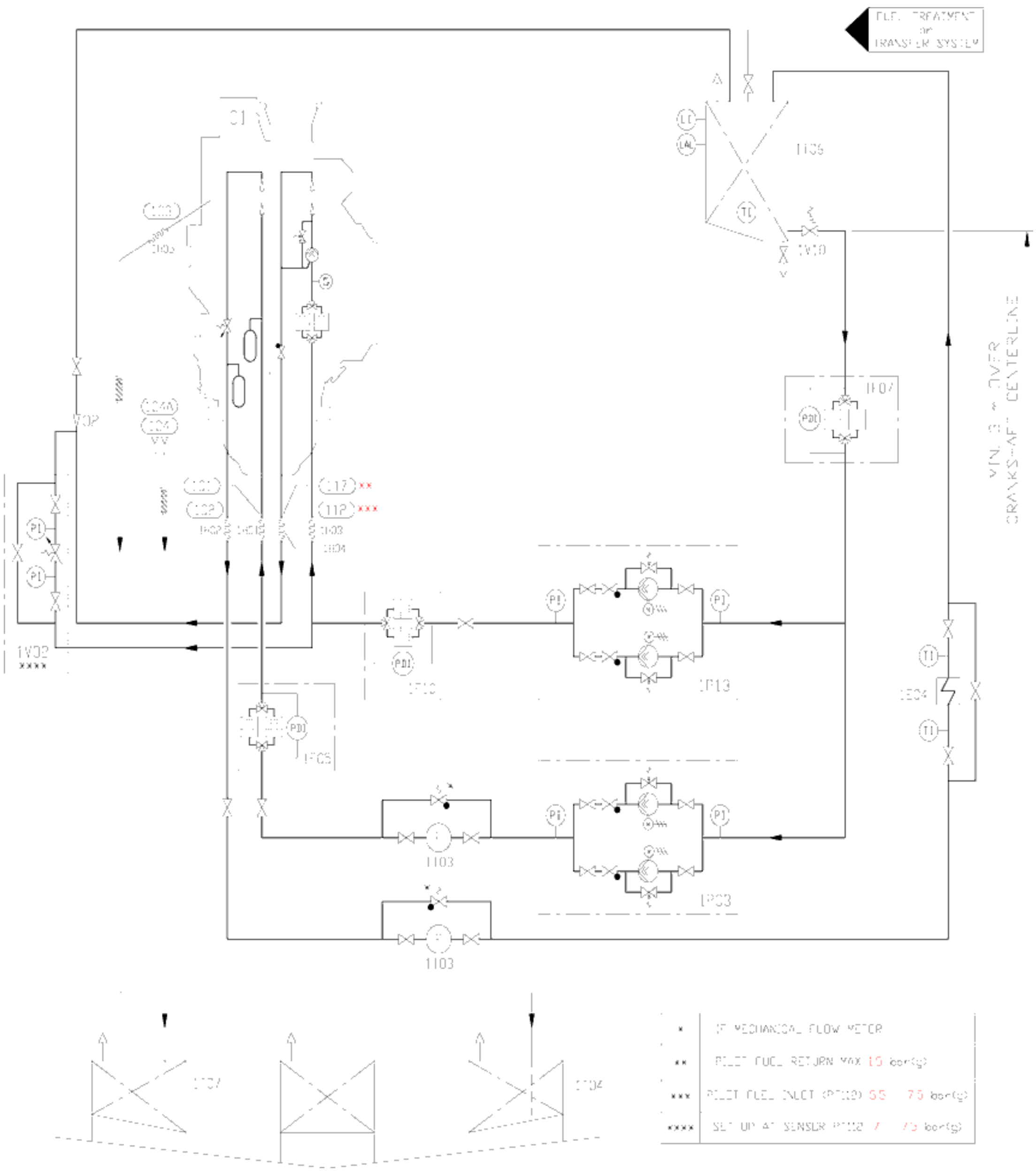

Fig 6-14 Example of fuel feed system, MDF (DAAF366919 C)

System components:			
01	Diesel engine Wärtsilä L46DF	1P03	Circulation pump (MDF)

System components:			
02	Adaptor	1P13	Pilot fuel feed pump (MDF)
1E04	Cooler (MDF)	1T04	Leak fuel tank (Clean Fuel)
1F05	Fine filter (MDF)	1T06	Day tank (MDF)
1F07	Suction strainer (MDF)	1T07	Leak fuel tank (Dirty fuel)
1F10	Pilot fuel fine filter (MDF)	1V02	Pressure control valve (MDF)
1I03	Flow meter (MDF)	1V10	Quick closing valve (fuel oil tank)
1HX0	Flexible pipe connection		

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

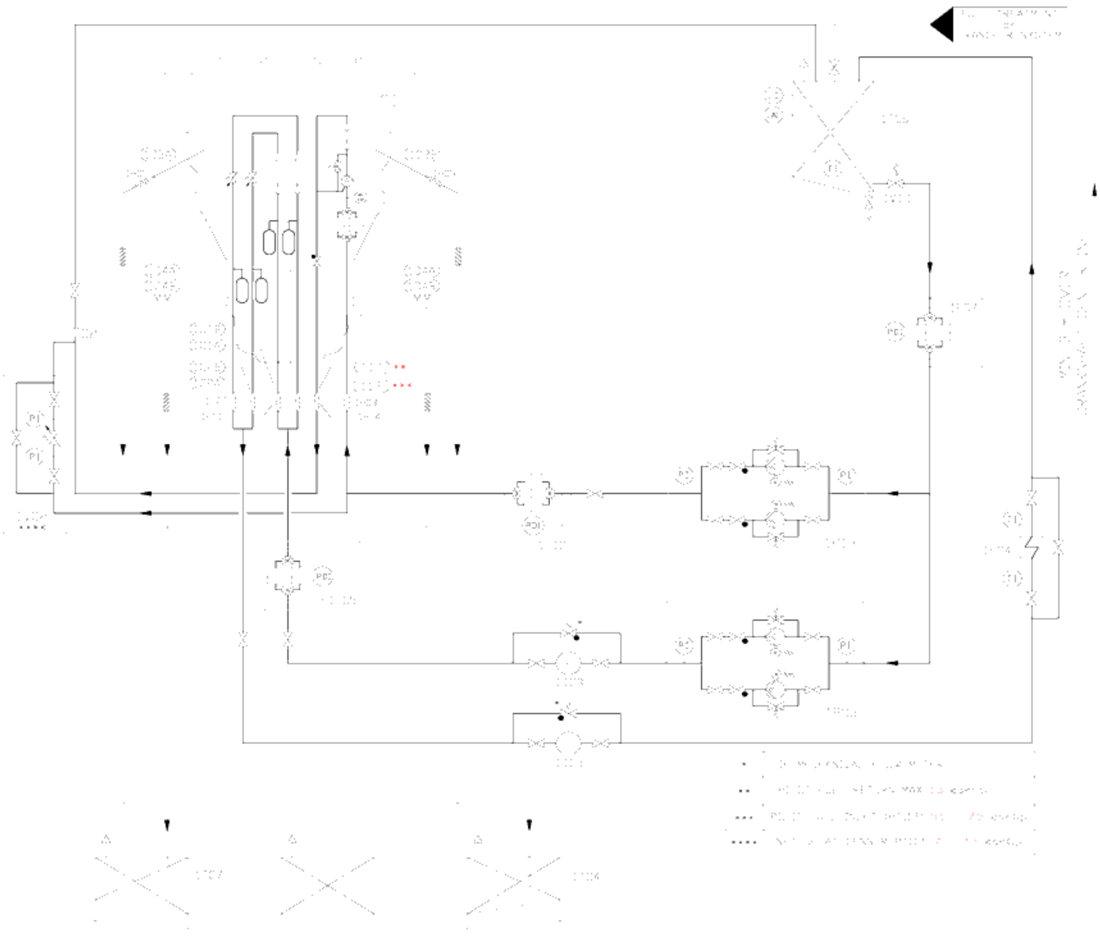

Fig 6-15 Example of fuel feed system, MDF (DAAF366911 C)

System components:			
01	Diesel engine Wärtsilä V46DF	1P03	Circulation pump (MDF)
02	Adapter	1P13	Pilot fuel feed pump (MDF)

System components:			
1E04	Cooler (MDF)	IT04	Leak fuel tank (Clean Fuel)
1F05	Fine filter (MDF)	1T06	Day tank (MDF)
1F07	Suction strainer (MDF)	1T07	Leak fuel tank (Dirty fuel)
1F10	Pilot fuel fine filter (MDF)	1V02	Pressure control valve (MDF)
1I03	Flow meter (MDF)	1V10	Quick closing valve (fuel oil tank)

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

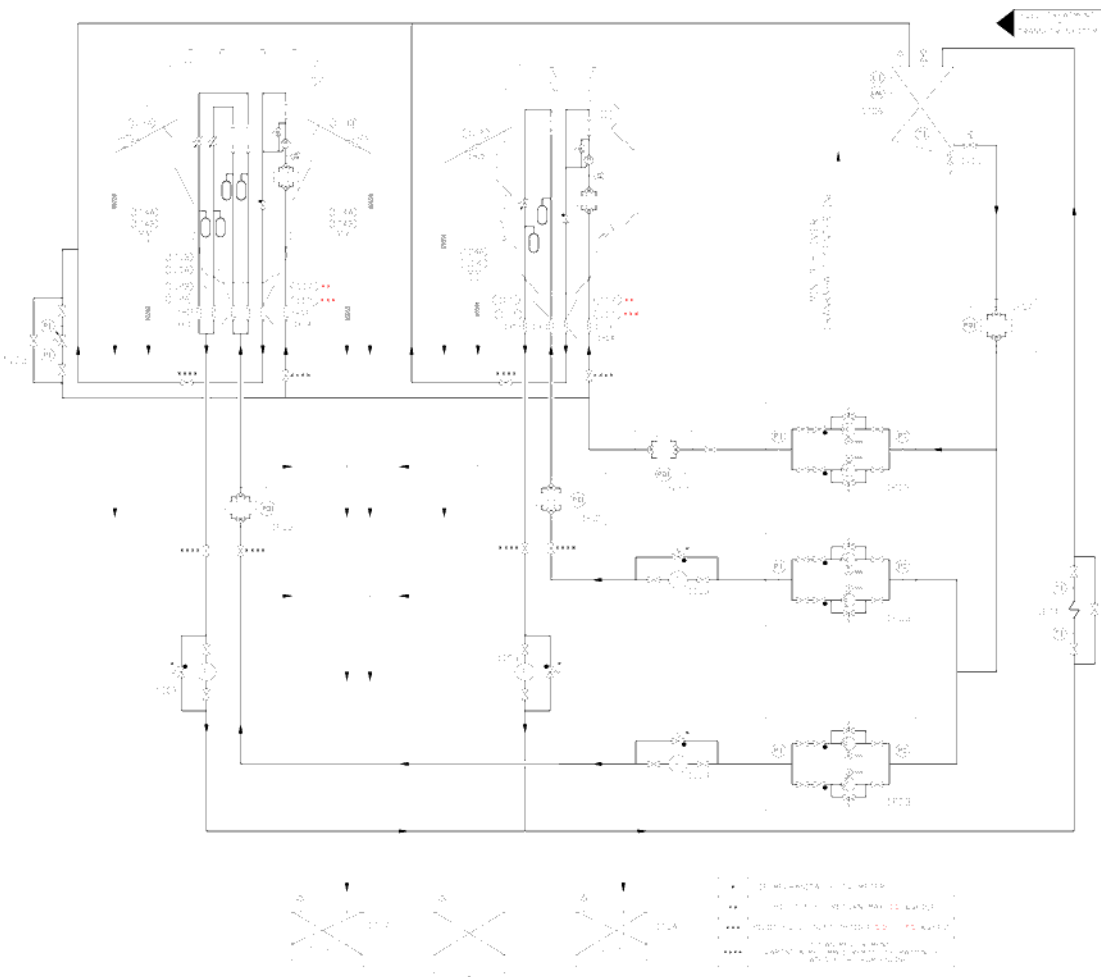

Fig 6-16 Example of fuel feed system, MDF (DAAF366912 C)

System components:			
01	Diesel engine Wärtsilä V46DF	1P03	Circulation pump (MDF)
02	Diesel engine Wärtsilä L46DF	1P13	Pilot fuel feed pump (MDF)
1E04	Cooler (MDF)	IT04	Leak fuel tank (Clean Fuel)

System components:			
1F05	Fine filter (MDF)	1T06	Day tank (MDF)
1F07	Suction strainer (MDF)	1T07	Leak fuel tank (Dirty fuel)
1F10	Pilot fuel fine filter (MDF)	1V05	Overflow valve (HFO/MDF)
1I03	Flow meter (MDF)	1V10	Quick closing valve (fuel oil tank)

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

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

Circulation pump, MDF (1P03)

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

Design data:	
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

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 consuption meter. For mechanical flowmeter, the bypass line should open automatically in case of excessive pressure drop.

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) ($ß_{50}$ = 75, ISO16889)

Maximum permitted pressure drops at 14 cSt:	
- clean filter	20 kPa (0.2 bar)
- alarm	80 kPa (0.8 bar)

MDF cooler (1E04)

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

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

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

Design data:

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

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

6.4.2.6 Fuel feed system - HFO installations

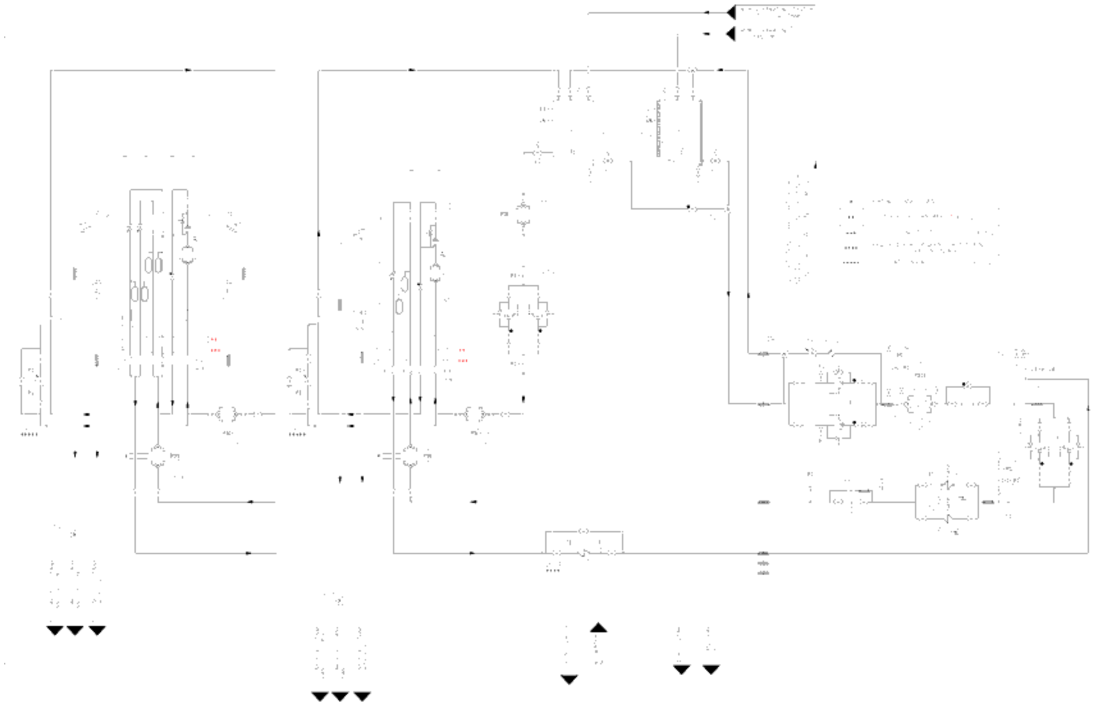

Fig 6-17 Example of fuel oil system, HFO (DAAF366913 B)

System components:			
01	Diesel engine Wärtsilä V46DF	1P04	Fuel feed pump (booster unit)
02	Diesel engine Wärtsilä L46DF	1P06	Circulation pump (booster unit)
03	Adapter	1P13	Pilot fuel feed pump (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	Changeover valve
1F06	Suction filter (booster unit)	1V02	Pressure control valve (MDF)
1F08	Automatic filter (booster unit)	1V03	Pressure control valve (booster unit)
1F10	Pilot fuel fine filter (MDF)	1V07	Venting valve (booster unit)
1F11	Suction strainer for pilot fuel (MDF)	1V10	Quick closing valve (fuel oil tank)
1I01	Flow meter (booster unit)	1V13	Change over valve for leak fuel
1I02	Viscosity meter (booster unit)	1H0X	Flexible pipe connections
1N01	Feeder/booster unit		

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

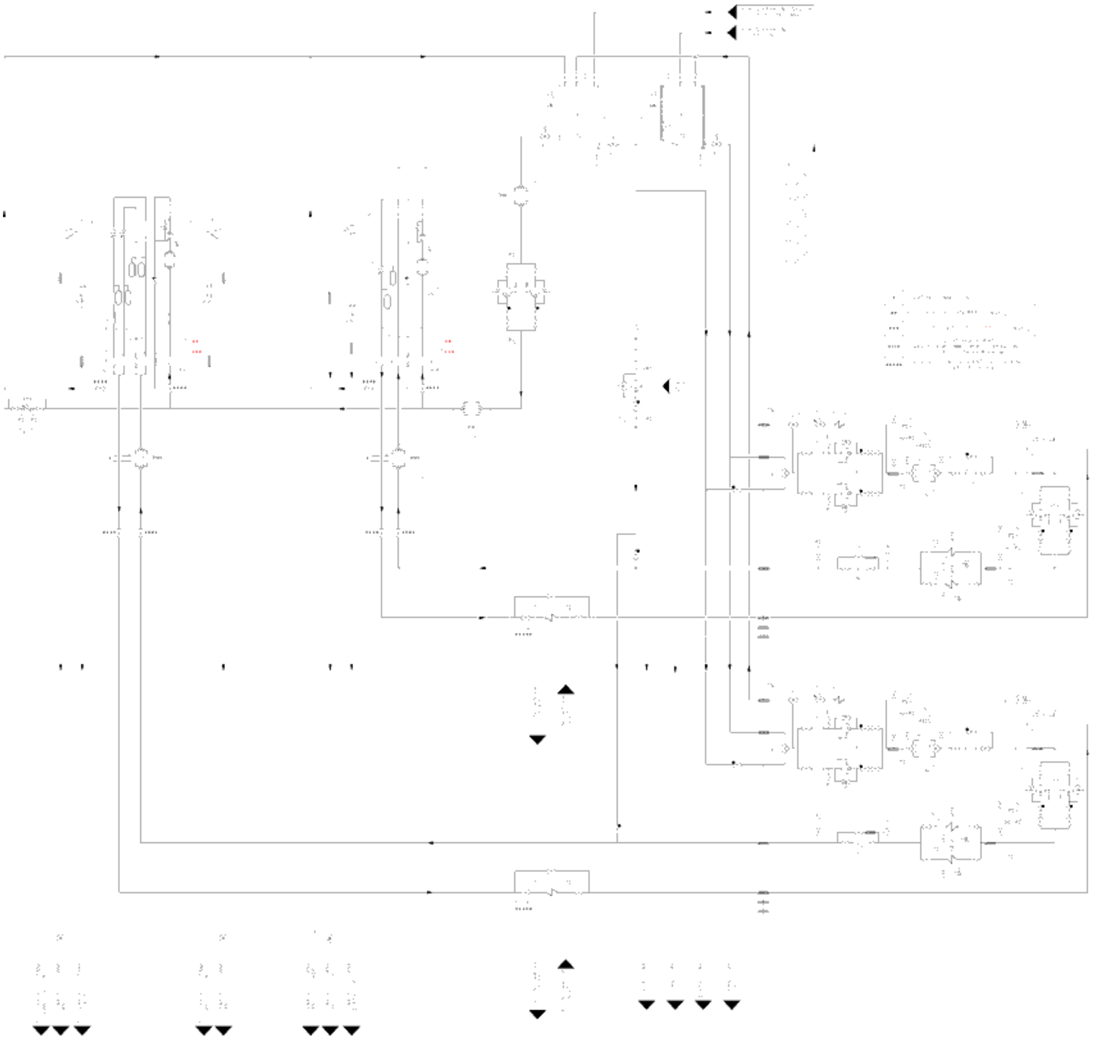

Fig 6-18 Example of fuel oil system, HFO (DAAF366915 B)

System components:			
01	Diesel engine Wärtsilä V46DF	1P04	Fuel feed pump (booster unit)
02	Diesel engine Wärtsilä L46DF	1P06	Circulation pump (booster unit)
1E02	Heater (booster unit)	1P13	Pilot fuel feed pump (MDF)
1E03	Cooler (booster unit)	1T03	Day tank (HFO)
1E04	Cooler (MDF)	1T06	Day tank (MDF)
1F03	Safety filter (HFO)	1T08	De-aeration tank (booster unit)
1F06	Suction filter (booster unit)	1V01	Change over valve
1F08	Automatic filter (booster unit)	1V03	Pressure control valve (booster unit)
1F10	Pilot fuel fine filter (MDF)	1V05	Overflow valve (HFO/MDF)
1F11	Suction strainer for pilot fuel (MDF)	1V07	Venting valve (booster unit)
1I01	Flow meter (booster unit)	1V10	Quick closing valve (fuel oil tank)
1I02	Viscosity meter (booster unit)	1V13	Change over valve for leak fuel
1N01	Feeder/booster unit	1H0X	Flexible pipe connections
1N13	Black start fuel oil pump unit		

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

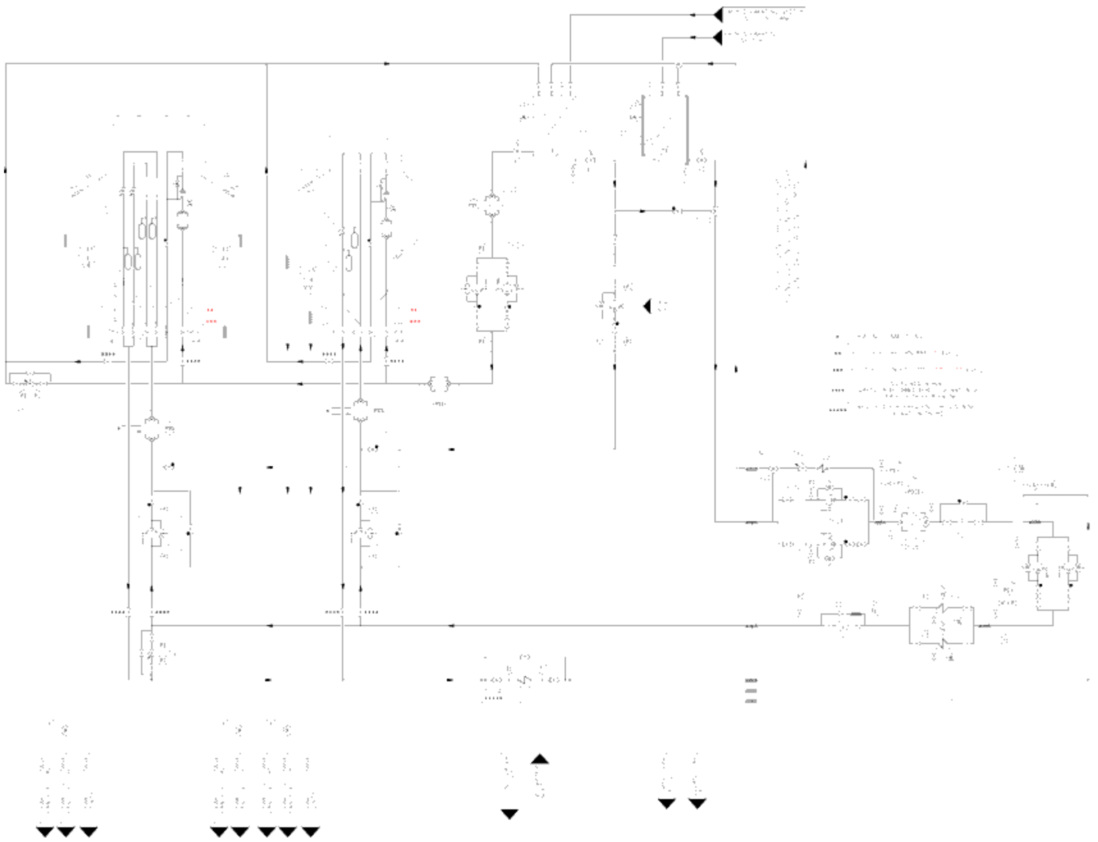

Fig 6-19 Example of fuel oil system, HFO (DAAF366916 B)

System components:			
01	Diesel engine Wärtsilä V46DF	1P04	Fuel feed pump (booster unit)
02	Diesel engine Wärtsilä L46DF	1P06	Circulation pump (booster unit)
1E02	Heater (booster unit)	1P12	Circulating pump (HFO/MDF)
1E03	Cooler (booster unit)	1P13	Pilot fuel feed pump (MDF)
1E04	Cooler (MDF)	1T03	Day tank (HFO)
1F03	Safety filter (HFO)	1T06	Day tank (MDF)
1F06	Suction filter (booster unit)	1T08	De-aeration tank (booster unit)
1F08	Automatic filter (booster unit)	1V01	Change over valve
1F10	Pilot fuel fine filter (MDF)	1V03	Pressure control valve (booster unit)
1F11	Suction strainer for pilot fuel (MDF)	1V05	Overflow valve (HFO/MDF)
1I01	Flow meter (booster unit)	1V05-1	Overflow valve (HFO/MDF)
1I02	Viscosity meter (booster unit)	1V07	Venting valve (booster unit)
1N01	Feeder/booster unit	1V10	Quick closing valve (fuel oil tank)

System components:			
1N13	Black start fuel oil pump unit	1V13	Change over valve for leak fuel
1HX0	Flexible pipe connections		

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

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).

Starting and stopping

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

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

Changeover from HFO to MDF

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

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

Number of engines in the same system

When the fuel feed unit serves 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.

Feeder/booster unit (1N01)

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

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

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

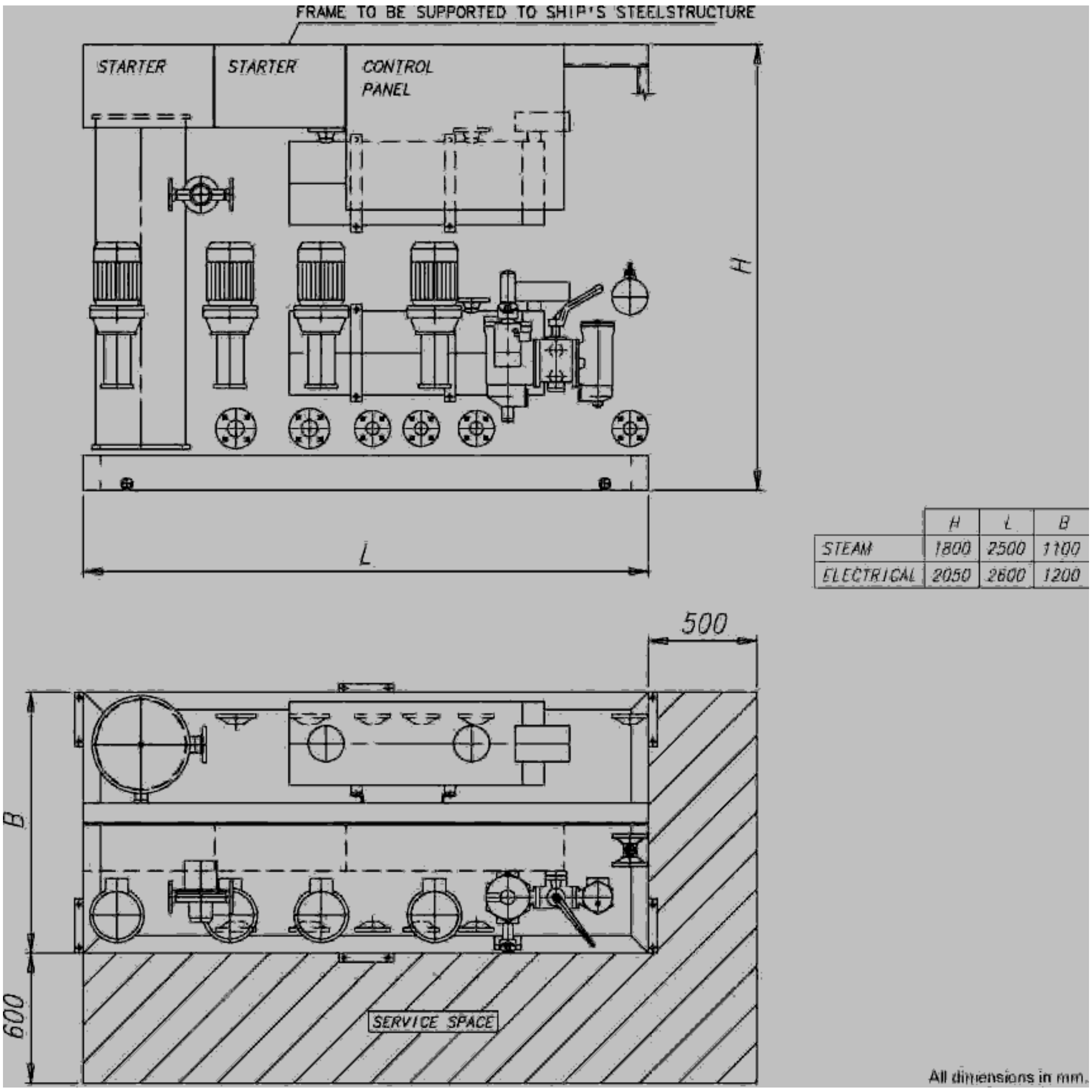

Fig 6-20 Feeder/booster unit, example (DAAE006659)

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 ß20=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/ Gas single engine, without circulation pumps (1P12)	Not needed
- Tri-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^2.

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

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

where:

P = heater capacity (kW)

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

ΔT = temperature rise in heater [°C]

Viscosimeter, booster unit (1I02)

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

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

Pump and filter unit (1N03)

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 maitain the required pressure at the injection pumps.

Design data:	
Capacity	LFO:2cSt HFO:20cSt
Frequency converter: - HFO/Gas engines - Tri - fuel engines	- Not needed - 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 (mesh size)
Maximum permitted pressure drops at 14 cSt:	
- clean filter	20 kPa (0.2 bar)
- alarm	80 kPa (0.8 bar)

Overflow valve, HFO (1V05)

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

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

Design data:	
Capacity	Equal to circulation pump (1P06)
Design pressure	1.6 MPa (16 bar)
Design temperature	150°C
Set-point (Δp)	0.2...0.7 MPa (2...7 bar)

Pilot fuel feed pump, MDF (1P13)

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

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

Piping connecting one pilot fuel feed pump to multiple engines must secure equal flow distribution.

Design data:	
Capacity, one engine	Allowed range at 2 cSt: 0.75…1.5 m3/h
Capacity, "N" engines	Allowed range at 2 cSt: (0.85…1.5) x N m3/h

Design pressure	1.6 MPa (16 bar)
Max. total pressure (safety valve)	1.0 MPa (10 bar)
Nominal pressure	see chapter "*Technical Data*"
Design temperature	50°C
Viscosity for dimensioning of electric motor	90 cSt

6.4.2.7 Flushing

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

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

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

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7. Lubricating Oil System

7.1 Lubricating oil requirements

7.1.1 Engine lubricating oil

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

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

Category	Fuel standard		Lubricating oil BN	Fuel S content, [% m/m]
A	ASTM D 975-01, 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...15 16-20*	< 0.4
B	ASTM D 975-01 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**)	0.4 - 1.5

*) In case low sulphur distillate fuels are used, lubricating oils with BN 10 – 15 are preferred in the first place.

**) Due to low lubricating oil consumption BN 10 – 14 lubricating oils will cause shortened oil changed intervals resulting from BN depletion if operating takes place on > 0,40 % m/m sulphur distillate fuels. On the other hand use of BN 10 – 14 lubricating oils can have a positive influence on deposit formation on combustion chamber component surfaces and reduce the risk of preignition.

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

If the engine is equipped with either an SCR or oxidation catalyst, lubricating oil with lower BN decreases the risk of fouling and may result in longer maintenance intervals of the catalyst.

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

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

Category	Fuel standard		Lubricating oil BN	Fuel S content, [% m/m]
C	ASTM D 975-01 ASTM D 396-04, 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 20***)	≤ 4.5

***) Use of BN 20 lubricating oils is allowed provided that the operating conditions are followed:

Residual fuel qualities fulfilling ISO 8217:2017(E) ISO-F-RMA 10 – RMK 700 standard and having sulphur content of max. 1,0 % m/m:

- Max. operating hours per month: 15% of total monthly operating hours

Residual fuel qualities fulfilling ISO 8217:2017(E) ISO-F-RMA 10 – RMK 700 standard and having sulphur content of 1,0 - 2,5 % m/m:

- Max. operating hours per month: 5% of total monthly operating hours

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

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

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

Engine oil selection

For the recommendation considering the lubrication oil BN, please refer to the table below.

Recommendation is for engines running mainly in gas mode**.**

Table 7-3 Engine oil selection

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

For more information about oil selection, please refer to Service Bulletin WS02N001.

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

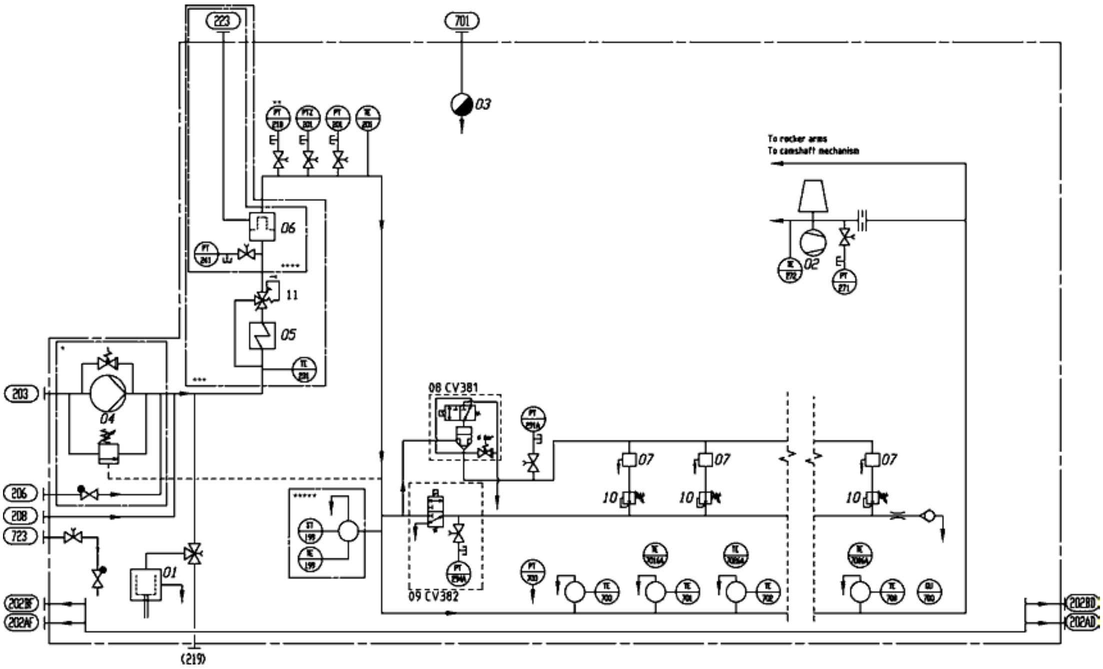

Fig 7-1 Internal lubricating oil system, in-line engines (DAAF447415)

System components:					
01	Centrifugal filter for indication	05***	Lube oil cooler	09	VIC-Half VIC Activation
02	Turbocharger	06****	Lube oil automatic filter	10	Pressure valve for 3-Timing VIC
03	Crankcase breather	07	VIC- Variable inlet valve closing	11***	LO Thermostatic valve
04*	Main lube oil pump (engine driven)	08	VIC- Control valve	12*****	Balancing device

* Alternatively: Lube oil pump off-engine
*** Alternatively: Lube oil pump off-engine. Sensor included
**** Alternatively: Oil filter off-engine, lube oil cooler on-engine
***** Default on 7L and 9L. Option on 6L and 8L with TFRS

Sensors and indicators:			
PT201	LO press. engine inlet	PT291A	Control oil pressure after VIC valve
PTZ201	LO press. engine inlet	TE272	LO temp. TC A outlet
TE231***	LO temperature, LOC inlet	PT700	Crankcase pressure
TE201	LO temp. engine inlet	ST199*****	Speed, balancing system monitoring
CV381	VIC control valve, A -bank	TE199*****	Temperature, balanving system monitoring
PT210**	LO press.stand by pump	TE700-TE7##	Main bearing 00...## temperature
PT241****	LO press, filter inlet	TE7016A-70#6A	Big end bearing temp, cyl 01A...0#A
CV382	Half VIC activation	PT294A	Control oil pressure, after half VIC valve
PT271	LO pressure, TC A inlet		

** For stand- by oil pump
*** Alternatively: Lube oil pump off-engine. Sensor included
**** Alternatively: Oil filter off-engine, lube oil cooler on-engine
***** Default on 7L and 9L. Option on 6L and 8L with TFRS

Pipe connections			
202 AD/BD	Lube oil outlet, (from oil sump), driving end	208	LO from electric driven pump

Pipe connections			
202 AF/BF	Lube oil outlet, (from oil sump), free end	219	LO, Sample
203	Lube oil to engine driven pump	223****	Flushing oil from automatic filter
206	Lubre oil from priming pump	701	Crankcase air vent
**** Alternatively: Oil filter off-engine, lube oil cooler on-engine			

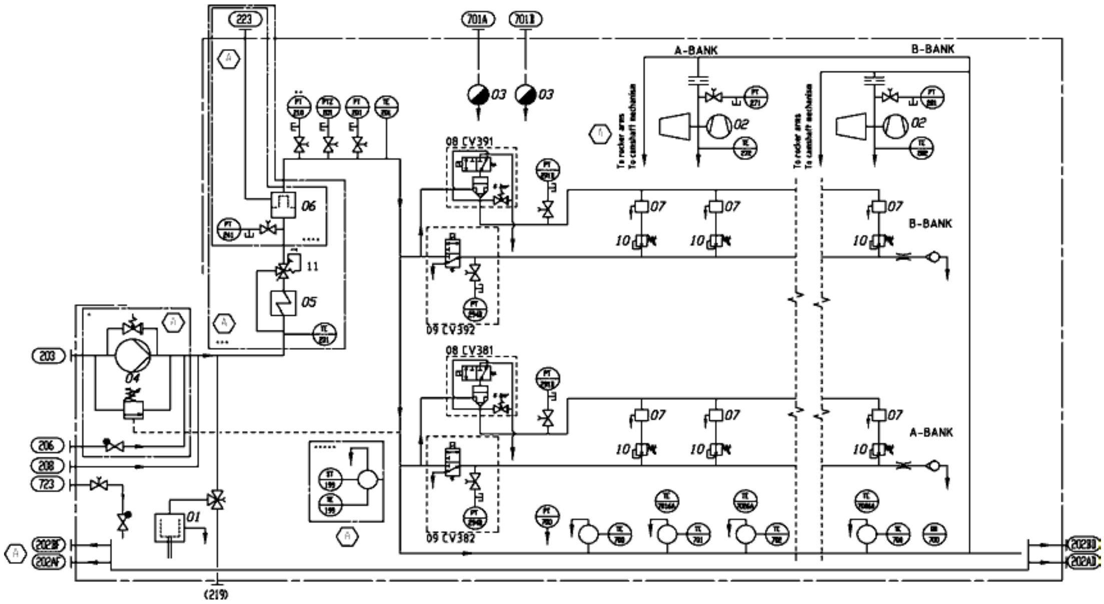

Fig 7-2 Typical lubricating oil system, V-engines (DAAF381080A)

System components:					
01	Centrifugal filter for indication	05***	Lube oil cooler	09	VIC-Half VIC Activation
02	Turbocharger	06****	Lube oil automatic filter	10	Pressure valve for 3-Timing VIC
03	Crankcase breather	07	VIC- Variable inlet valve closing	11***	LO Thermostatic valve
04*	Main lube oil pump (engine driven)	08	VIC- Control valve	12*****	Balancing device
* Alternatively: Lube oil pump off-engine *** Alternatively: Lube oil pump off-engine. Sensor included **** Alternatively: Oil filter off-engine, lube oil cooler on-engine ***** Default on 7L and 9L. Option on 6L and 8L with TFRS					

Sensors and indicators:			
PT201	LO press. engine inlet	PT291A/B	Control oil pressure after VIC valve, A/B bank
PTZ201	LO press. engine inlet	TE272	LO temp. TC A outlet
TE231***	LO temperature, LOC inlet	PT700	Crankcase pressure
TE201	LO temp. engine inlet	ST199*****	Speed, balancing system monitoring
CV381	VIC control valve, A -bank	TE199*****	Temperature, balanving system monitoring
PT210**	LO press.stand by pump	TE700-TE7##	Main bearing 00...## temperature
PT241****	LO press, filter inlet	TE7016A-70#6A	Big end bearing temp, cyl 01A...0#A
CV382	Half VIC activation	PT294A/B	Control oil pressure, after half VIC valve, A/B bank
PT271	LO pressure, TC A inlet	PT281	LO pressure, TC B inlet
TE282	LO temperature, TC B outlet	CV392	Half VIC activation, B-bank
CV391	VIC control valve, B-bank		
** For stand- by oil pump *** Alternatively: Lube oil pump off-engine. Sensor included **** Alternatively: Oil filter off-engine, lube oil cooler on-engine ***** Default on 7L and 9L. Option on 6L and 8L with TFRS			

Pipe connections			
202 AD/BD	Lube oil outlet, (from oil sump), driving end, A/B bank	208	LO from electric driven pump
202 AF/BF	Lube oil outlet, (from oil sump), free end, A/B bank	219	LO, Sample
203	Lube oil to engine driven pump	223****	Flushing oil from automatic filter
206	Lubre oil from priming pump	701A/B	Crankcase air vent
**** Alternatively: Oil filter off-engine, lube oil cooler on-engine			

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

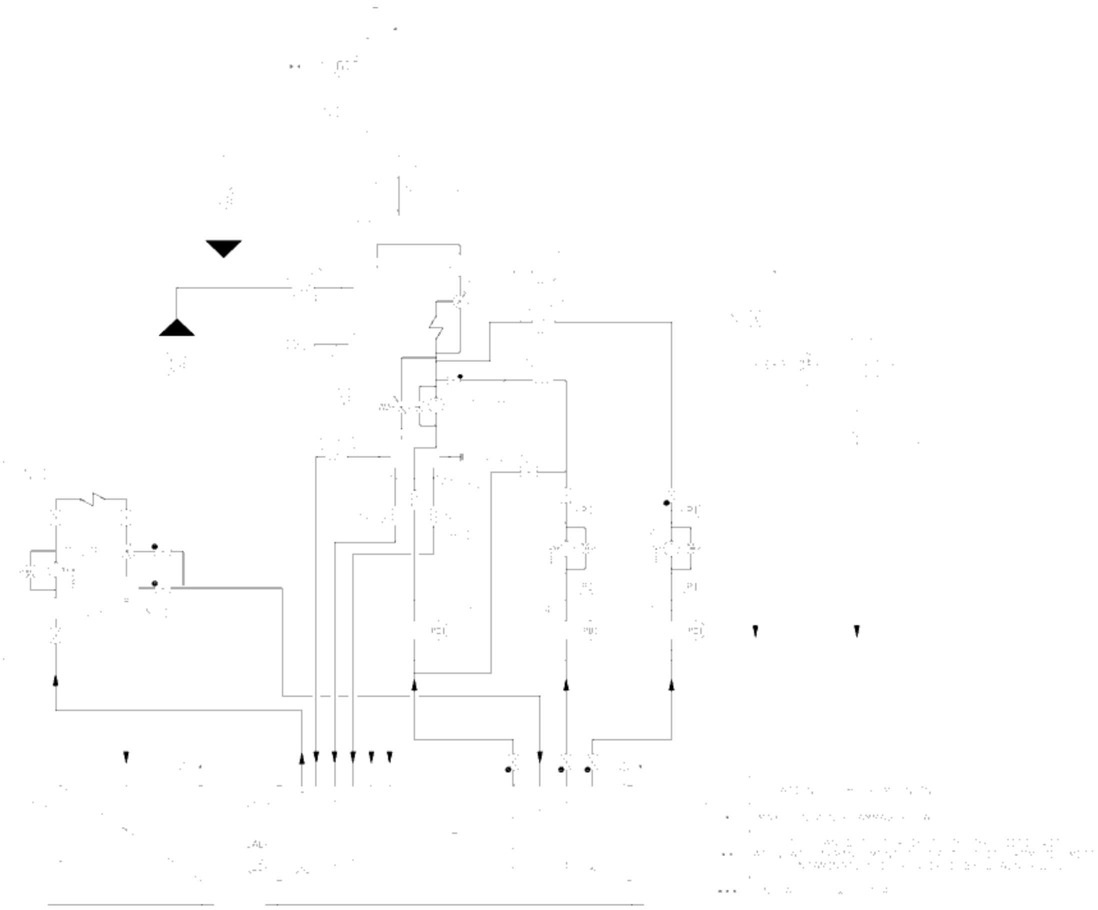

Fig 7-3 Example of lubricating oil system with engine driven & stand by pumps (DAAF371772 A)

System components:			
01	Diesel engine Wärtsilä L46DF	2N01	Separator unit
02 **	Gas detector	2P02	Prelubricating oil pump
03	Pressure control valve	2P03	Separator pump (separator unit)
2E02	Heater (separator unit)	2P04	Stand-by pump
2F01	Suction strainer (main lube oil pump)	2S01	Separator (separator unit)
2F03	Suction filter (separator unit)	2S02	Condensate trap
2F04	Suction strainer (prelube oil pump)	2T01	System oil tank
2F06	Suction filter (stand-by pump)	2T06	Sludge tank
2F13	Automatic filter (LO backflush)	2H0X	Flexible pipe connections

Pipe connections:					
202	LO outlet	206	LO from priming pump	223	Flushing oil from autom filter
203	LO to engine driven pump	208	LO from el. driven pump	701	Crankcase air vent
		219	Lube oil, sample	723	Inert gas inlet

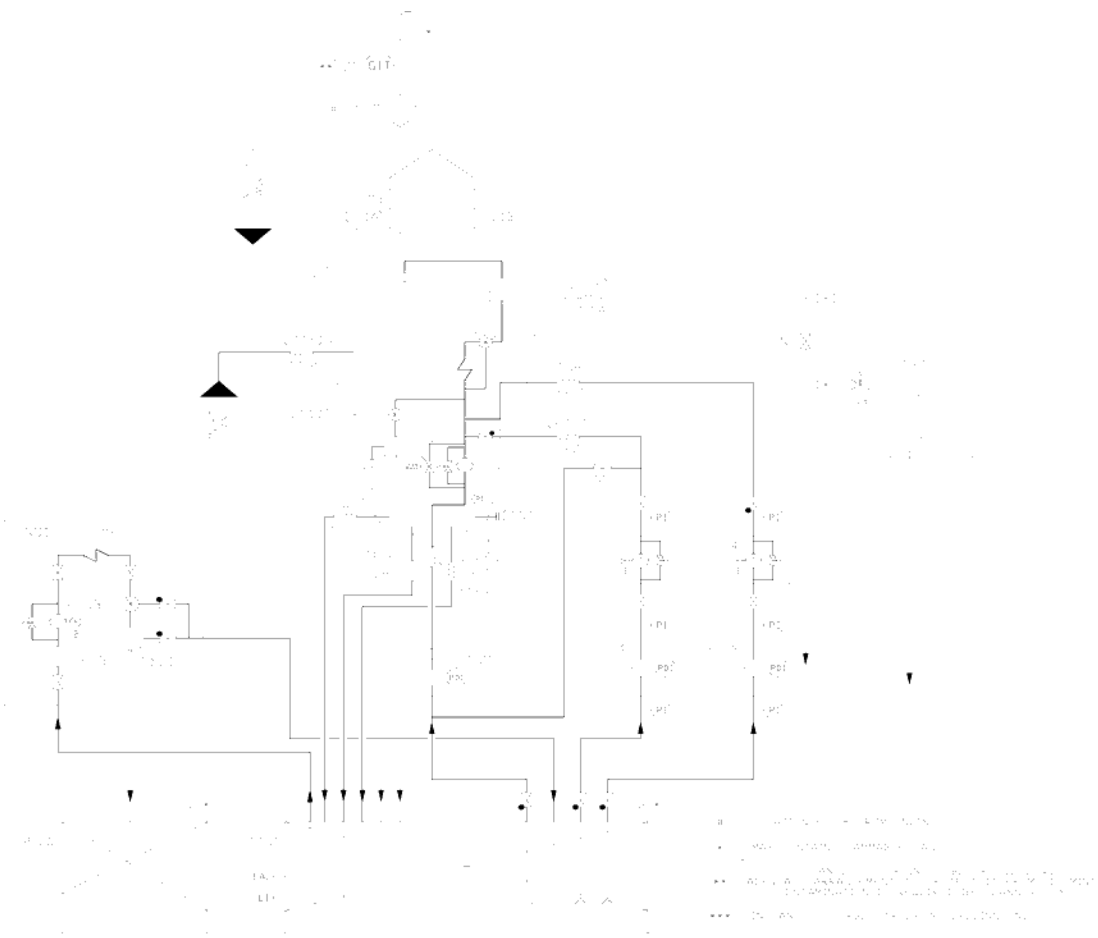

Fig 7-4 Example of lubricating oil system with engine driven & stand by pumps (DAAF371773 A)

System components:			
01	Diesel engine Wärtsilä V46DF	2N01	Separator unit
02 **	Gas detector	2P02	Prelubricating oil pump
03	Pressure control valve	2P03	Separator pump (separator unit)
2E02	Heater (separator unit)	2P04	Stand-by pump
2F01	Suction strainer (main lube oil pump)	2S01	Separator (separator unit)
2F03	Suction filter (separator unit)	2S02	Condensate trap
2F04	Suction strainer (prelube oil pump)	2T01	System oil tank
2F06	Suction filter (stand-by pump)	2T06	Sludge tank
2F13	Automatic filter (LO backflush)	2HX0	Flexible pipe connections

Pipe connections:					
202	LO outlet	206	LO from priming pump	223	Flushing oil from autom filter
203	LO to engine driven pump	208	LO from el. driven pump	701 A/B	Crankcase air vent
		219	Lube oil, sample	723	Inert gas inlet

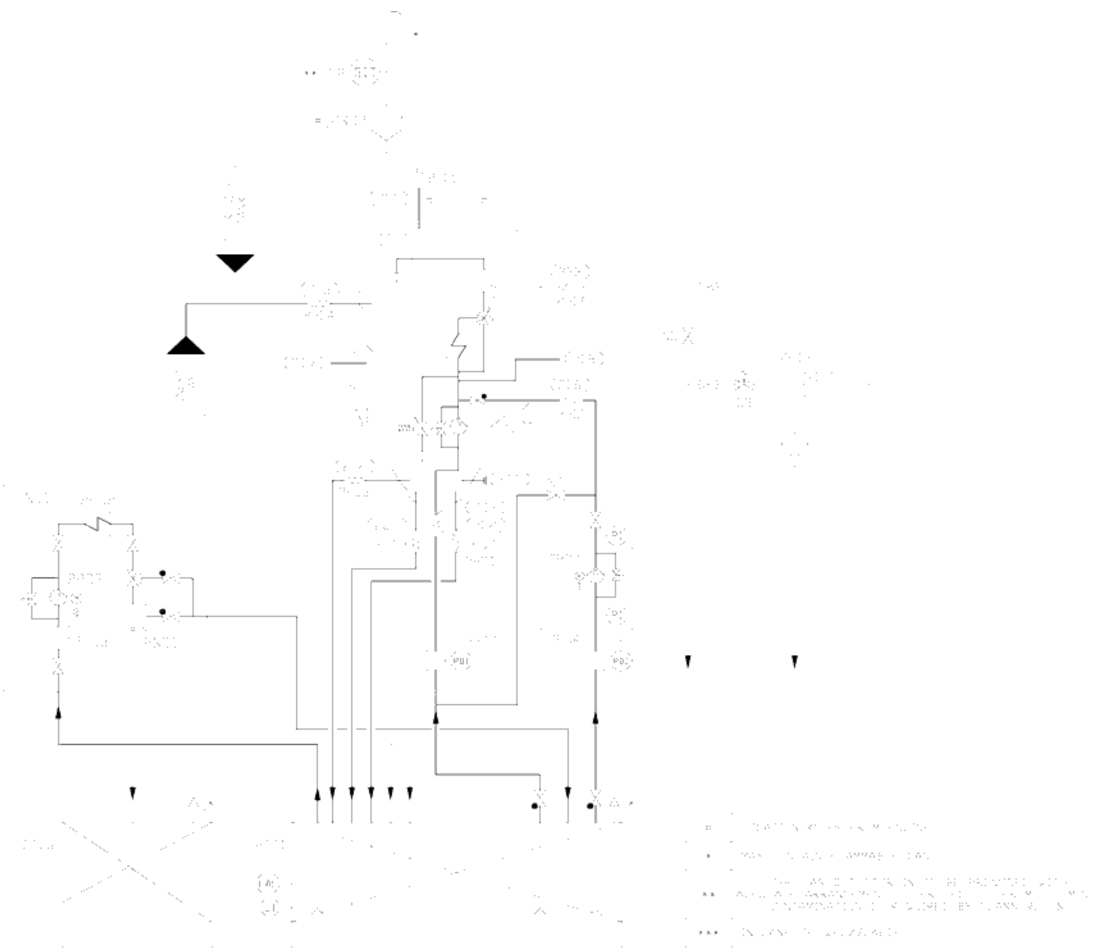

Fig 7-5 Example of lubricating oil system with engine driven pump (DAAF371774 A)

System components:			
01	Diesel engine Wärtsilä L46DF	2N01	Separator unit
02 **	Gas detector	2P02	Prelubricating oil pump
03	Pressure control valve	2P03	Separator pump (separator unit)
2E02	Heater (separator unit)	2S01	Separator (separator unit)
2F01	Suction strainer (main lube oil pump)	2S02	Condensate trap
2F03	Suction filter (separator unit)	2T01	System oil tank
2F04	Suction strainer (prelube oil pump)	2T06	Sludge tank
2F13	Automatic filter (LO backflush)	2HX0	Flexible pipe connections

Pipe connections:					
202	LO outlet	206	LO from priming pump	223	Flushing oil from autom filter
203	LO to engine driven pump	208	LO from el. driven pump	701	Crankcase air vent
		219	Lube oil, sample	723	Inert gas inlet

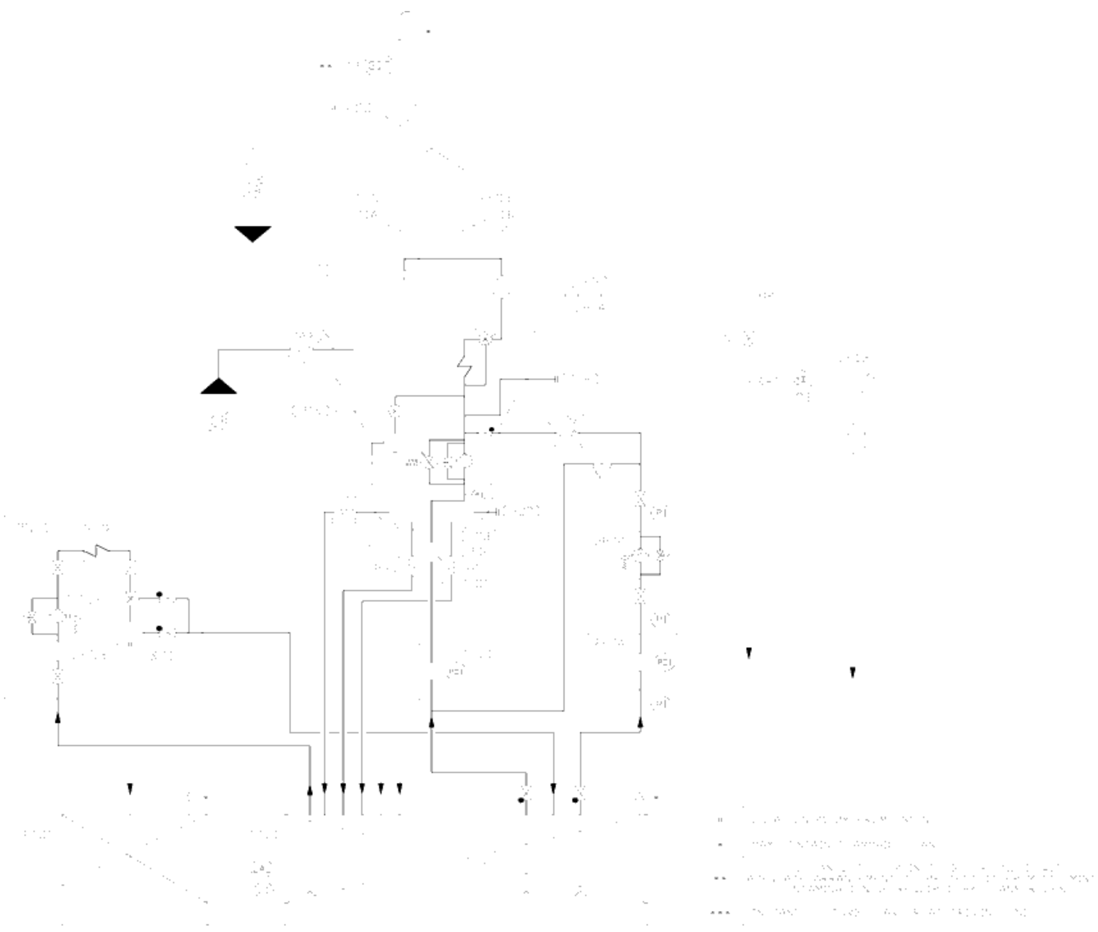

Fig 7-6 Example of lubricating oil system with engine driven pump (DAAF371775 A)

System components:			
01	Diesel engine Wärtsilä V46DF	2N01	Separator unit
02 **	Gas detector	2P02	Prelubricating oil pump
03	Pressure control valve	2P03	Separator pump (separator unit)
2E02	Heater (separator unit)	2S01	Separator (Separator unit)
2F01	Suction strainer (main lube oil pump)	2S02	Condensate trap
2F03	Suction filter (separator unit)	2T01	System oil tank
2F04	Suction strainer (prelube oil pump)	2T06	Sludge tank
2F13	Automatic filter (LO backflush)	2H0X	Flexible pipe connections

Pipe connections:					
202	LO outlet	206	LO from priming pump	223	Flushing oil from autom filter
203	LO to engine driven pump	208	LO from el. driven pump	701 A/B	Crankcase air vent
		219	Lube oil, sample	723	Inert gas inlet

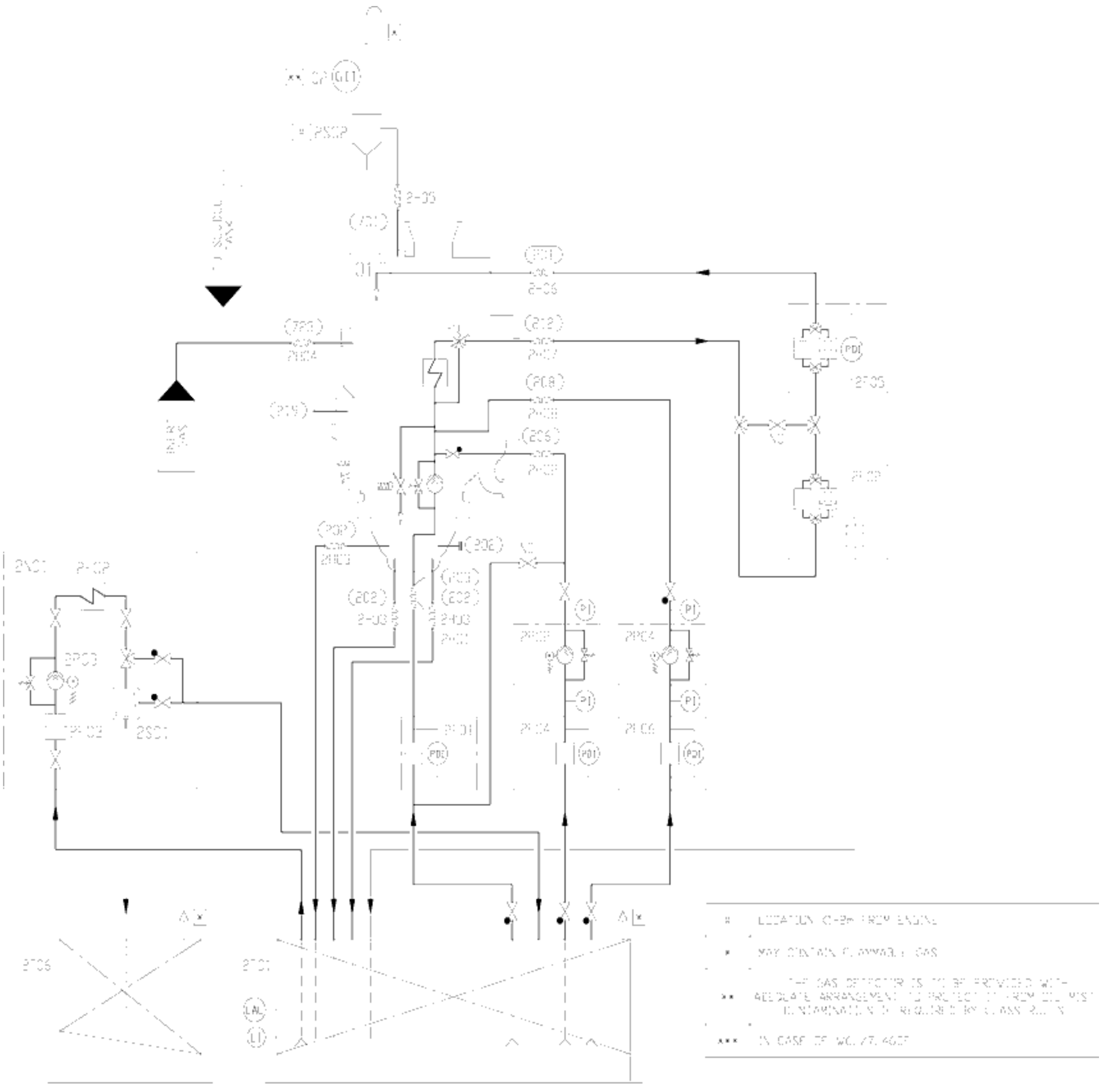

Fig 7-7 Example of lubricating oil system without automatic filter (DAAF371776 A)

System components:			
01	Diesel engine Wärtsilä L46DF	2N01	Separator unit
02 **	Gas detector	2P02	Prelubricating oil pump
2E02	Heater (separator unit)	2P03	Separator pump (separator unit)
2F01	Suction strainer (main lube oil pump)	2P04	Stand by pump
2F02	Automatic filter (LO)	2S01	Separator (Separator unit)
2F03	Suction filter (separator unit)	2S02	Condensate trap
2F04	Suction strainer (prelube oil pump)	2T01	System oil tank
2F05	Safety filter (LO)	2T06	Sludge tank
2F06	Suction filter (Stand by pump)	2HX0	Flexible pipe connections

Pipe connections:					
201	Lube oil inlet (to manifold)	206	LO from priming pump	219	Lube oil, sample
202	LO outlet	208	LO from el. driven pump	701	Crankcase air vent
203	LO to engine driven pump	212	Lube oil from cooler	723	Inert gas inlet

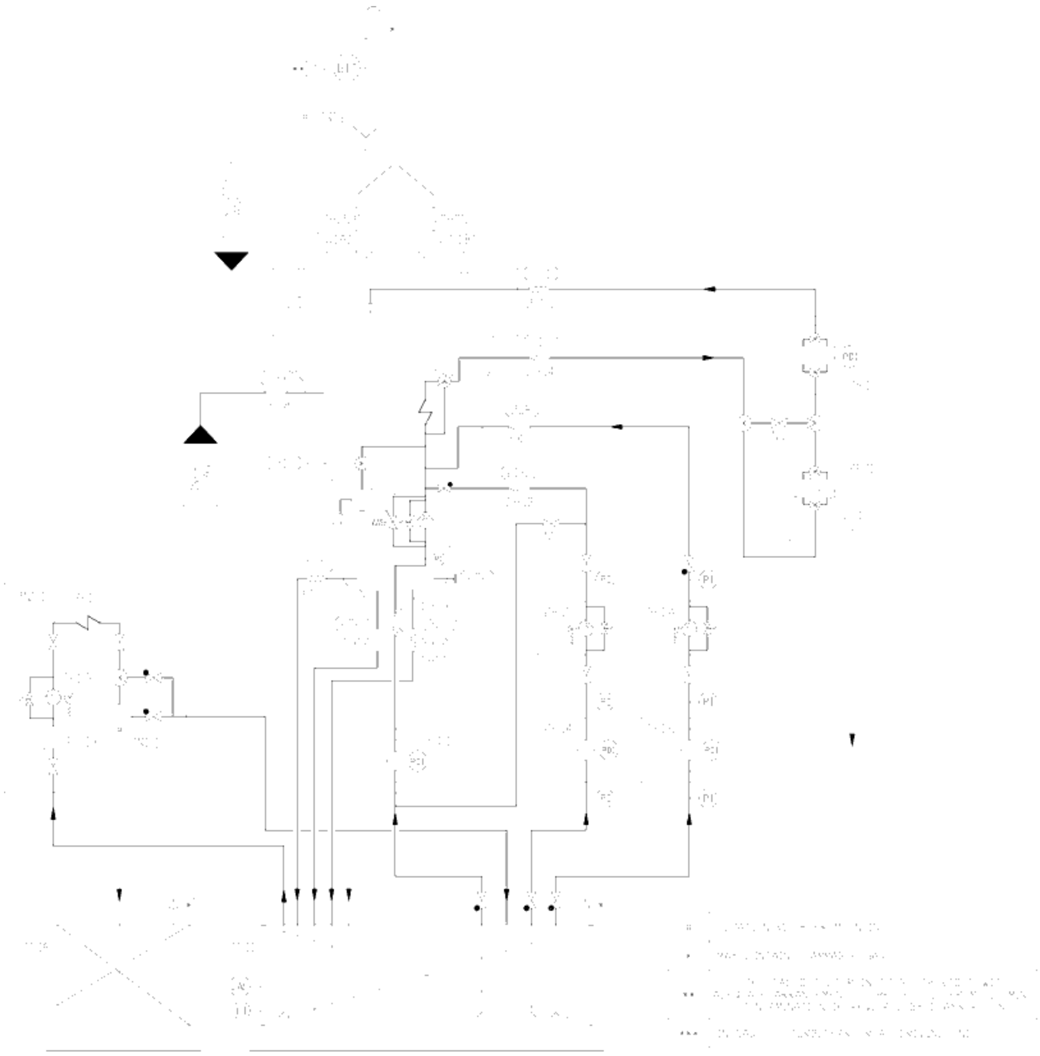

Fig 7-8 Example of lubricating oil system without automatic filter (DAAF371777 A)

System components:			
01	Diesel engine Wärtsilä V46DF	2N01	Separator unit
02 **	Gas detector	2P02	Prelubricating oil pump
2E02	Heater (separator unit)	2P03	Separator pump (separator unit)
2F01	Suction strainer (main lube oil pump)	2P04	Stand by pump
2F02	Automatic filter (LO)	2S01	Separator (Separator unit)
2F03	Suction filter (separator unit)	2S02	Condensate trap
2F04	Suction strainer (prelube oil pump)	2T01	System oil tank
2F05	Safety filter (LO)	2T06	Sludge tank
2F06	Suction filter (Stand by pump)	2H0X	Flexible pipe connections

Pipe connections:					
201	Lube oil inlet (to manifold)	206	LO from priming pump	219	Lube oil, sample
202	LO outlet	208	LO from el. driven pump	701 A/B	Crankcase air vent
203	LO to engine driven pump	212	Lube oil from cooler	723	Inert gas inlet

7.3.1 Separation system

7.3.1.1 Separator unit (2N01)

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

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 = total combined output of all engines supplied by the separator

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.

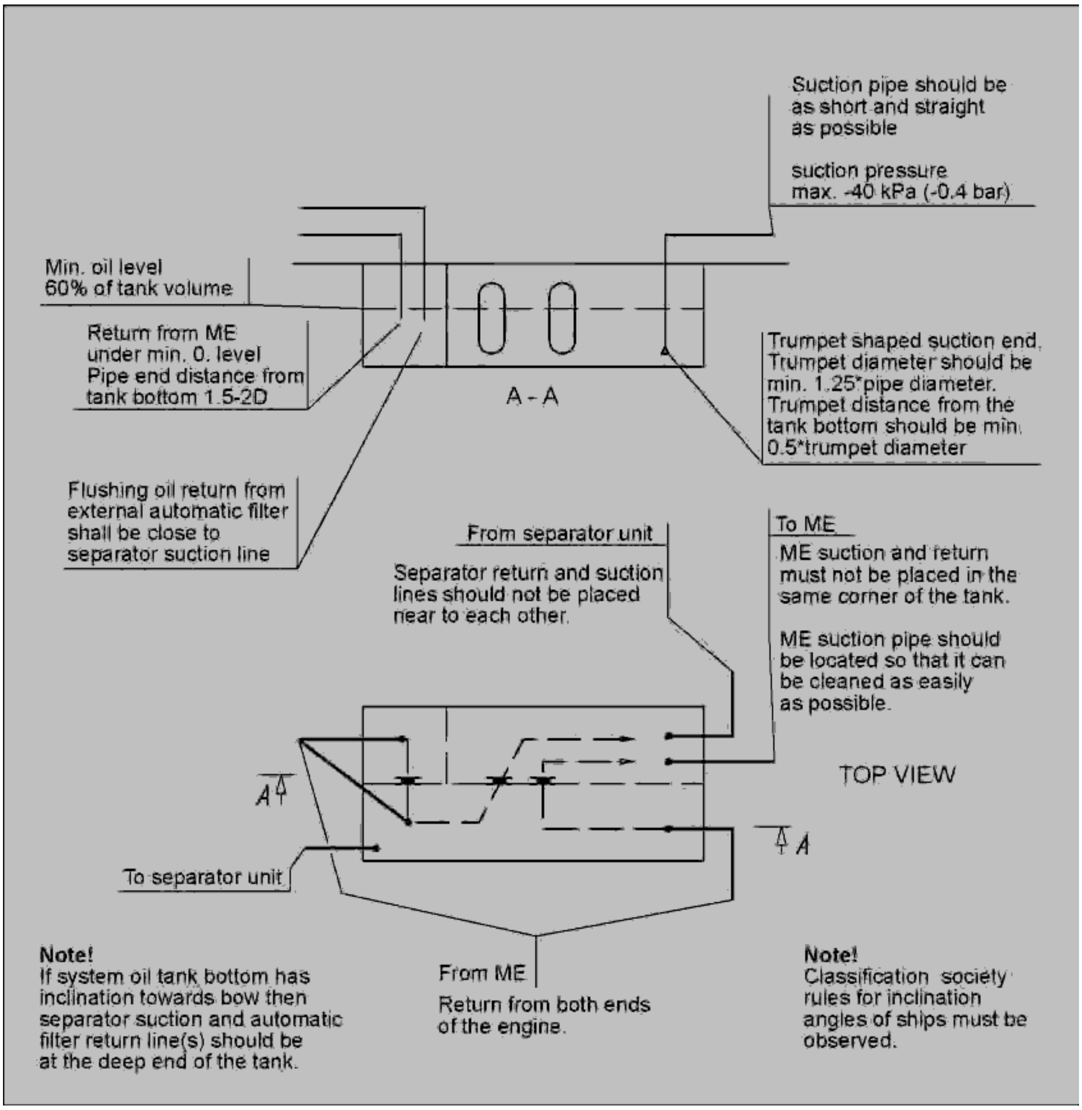

Fig 7-9 Example of system oil tank arrangement (DAAE007020e)

Design data:

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

7.3.3 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)

A lubricating oil pump of screw type is recommended. The pump must be provided with a safety valve.

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.

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.

	6L46DF	7L46DF	8L46DF	9L46DF	12V46DF	14V46DF	16V46DF
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 scew or gear pump, which is to be equipped with a safety valve.

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

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

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

Depending on the foreseen oil temperature after a long stop, the suction ability of the pump and the geometric suction height must be specially considered with regards to high viscosity.

With cold oil the pressure at the pump will reach the relief pressure of the safety valve.

Design data:

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

7.3.6 Lubricating oil cooler (2E01)

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

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

Design data:	
Oil flow through cooler	see *Technical data, "Oil flow through engine"*
Heat to be dissipated	see *Technical data*
Max. pressure drop, oil	80 kPa (0.8 bar)
Water flow through cooler	see *Technical data, "LT-pump capacity"*
Max. pressure drop, water	60 kPa (0.6 bar)
Water temperature before cooler	49°C
Oil temperature before engine	56°C
Design pressure	1.0 MPa (10 bar)
Margin (heat rate, fouling)	min. 15%

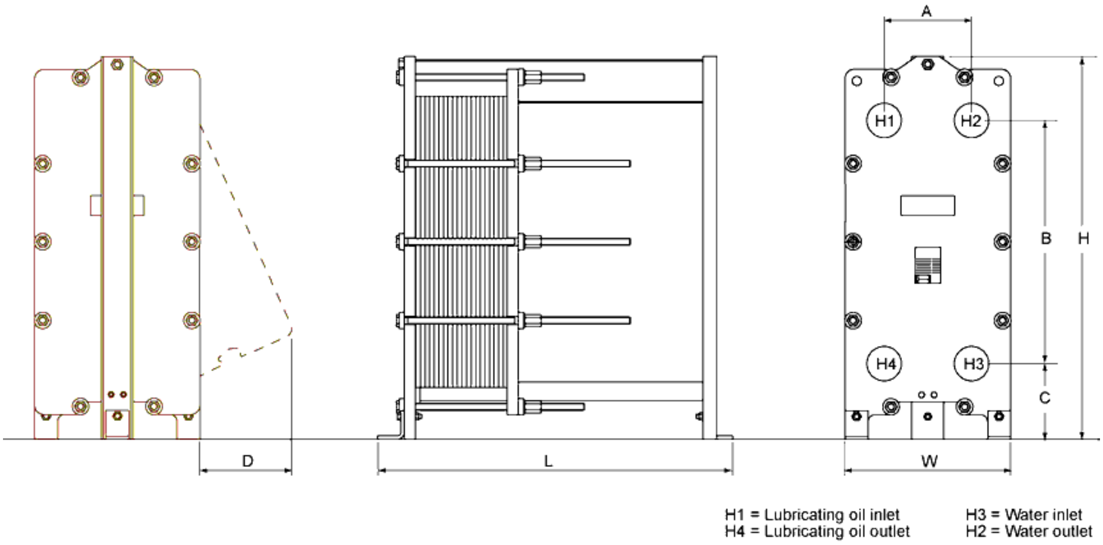

Fig 7-10 Main dimensions of the lubricating oil cooler

Engine	Weight, dry [kg]	Dimensions [mm]						
		H	W	L	A	B	C	D
W 6L46DF	840	1675	690	1217	380	1057	330	300
W 7L46DF	890	1675	690	1467	380	1057	330	300
W 8L46DF	950	1675	690	1467	380	1057	330	300
W 9L46DF	1010	1675	690	1717	380	1057	330	300
W 12V46DF	1070	1675	690	1717	380	1057	330	300
W 14V46DF	1190	1675	690	1967	380	1057	330	300
W 16V46DF	1240	1675	690	1967	380	1057	330	300

NOTE

These dimensions are for guidance only.

7.3.7 Temperature control valve (2V01)

The temperature control valve maintains desired oil temperature at the engine inlet, by directing part of the oil flow through the bypass line instead of through the cooler. When using a temperature control valve with wax elements, the set-point of the valve must be such that 55°C..58°C at the engine inlet is not exceeded. This means that the set-point should be e.g. 49°C. In which case of 49°C nominal, the valve starts to open at 43°C and at 55°C it is fully open. If selecting a temperature control valve with wax elements that has a set-point of 57°C, the valve may not be fully open until the oil temperature is e.g. 63°C, which is too high for the engine at full load.

Design data:	
Temperature before engine, nom	56°C
Design pressure	1.0 MPa (10 bar)
Pressure drop, max	50 kPa (0.5 bar)

7.3.8 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. The backflushing oil must be filtered before it is conducted back to the system oil tank. The backflushing filter can be either integrated in the automatic filter or separate.

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

Design data:	
Oil viscosity	50 cSt (SAE 40, VI 95, appox. 63°C)
Design flow	see *Technical data, "Oil flow through engine"*
Design temperature	100°C
Design pressure	1.0 MPa (10 bar)
Fineness:	
- automatic filter	35 µm (absolute)
- 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)

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

7.3.10 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 allowsbackflush filter maintenance, which should be bypassed for less time as possible.

Design data:	
Oil viscosity	50 cSt (SAE 40, VI 95, appox. 63°C)
Design flow	17 m3/h for Line engines, 25 m3/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 *Technical data*
Backpressure, max.	see *Technical data*
Temperature	80°C

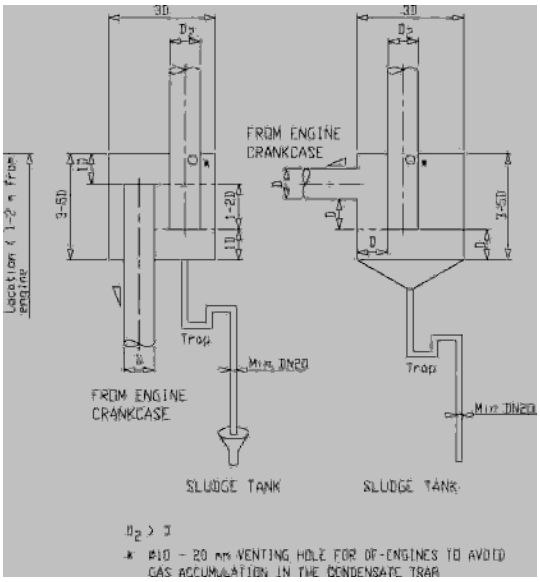

Fig 7-11 Condensate trap (DAAF369903)

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^3
Max. particle size	3 µm

8.2 Internal compressed air system

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

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

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

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

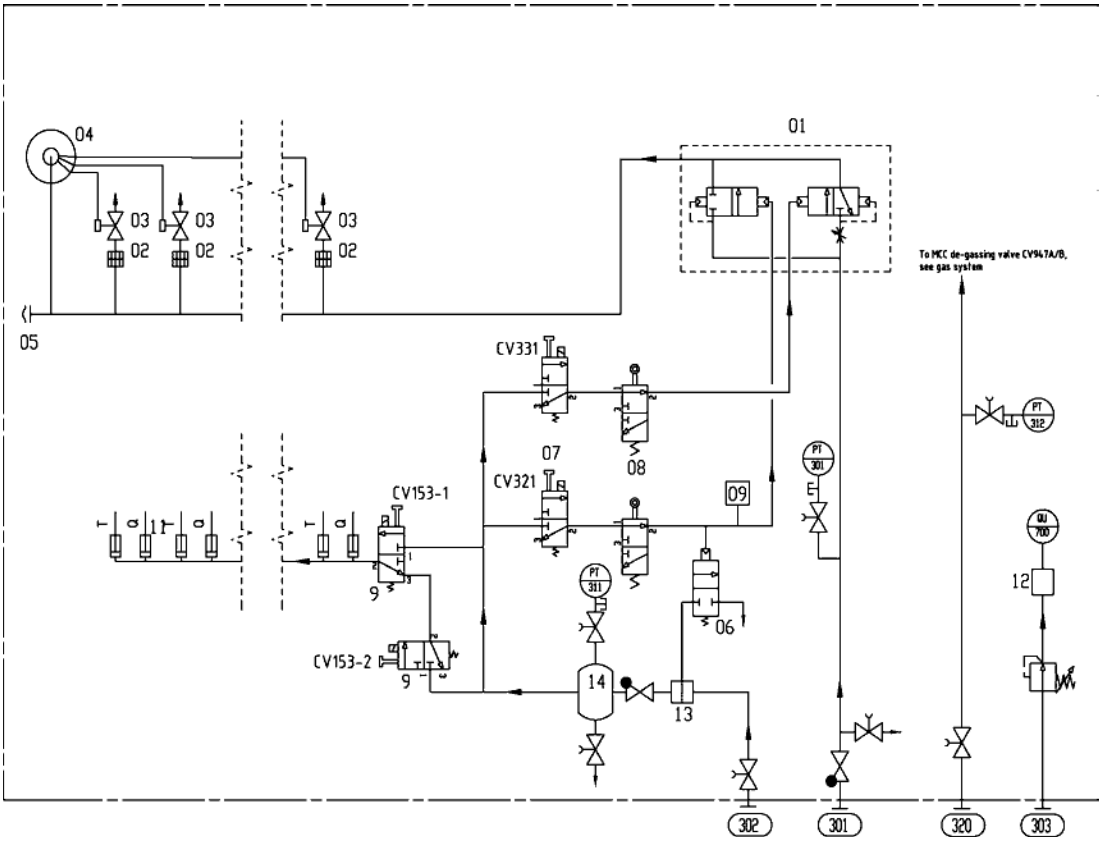


Fig 8-1 Internal compressed air system, in-line engines (DAAF447416)

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

Instruments:			
CV153-1	Stop/shutdown solenoid valve 1	PT301	Starting air press. engine inlet
CV153-2	Stop/shutdown solenoid valve 2	PT311	Control air pressure
CV321	Starting solenoid valve	PT312	Instrument air pressure, 4...8 bar
CV331	Slow turning solenoid	QU700	Oil mist detector

Pipe connections	
301	Starting air inlet, 30 bar
302	Control air inlet, 30 bar
303	Driving air inlet to oil mist detector (6-8 bar)

Pipe connections	
320	Instrument air inlet

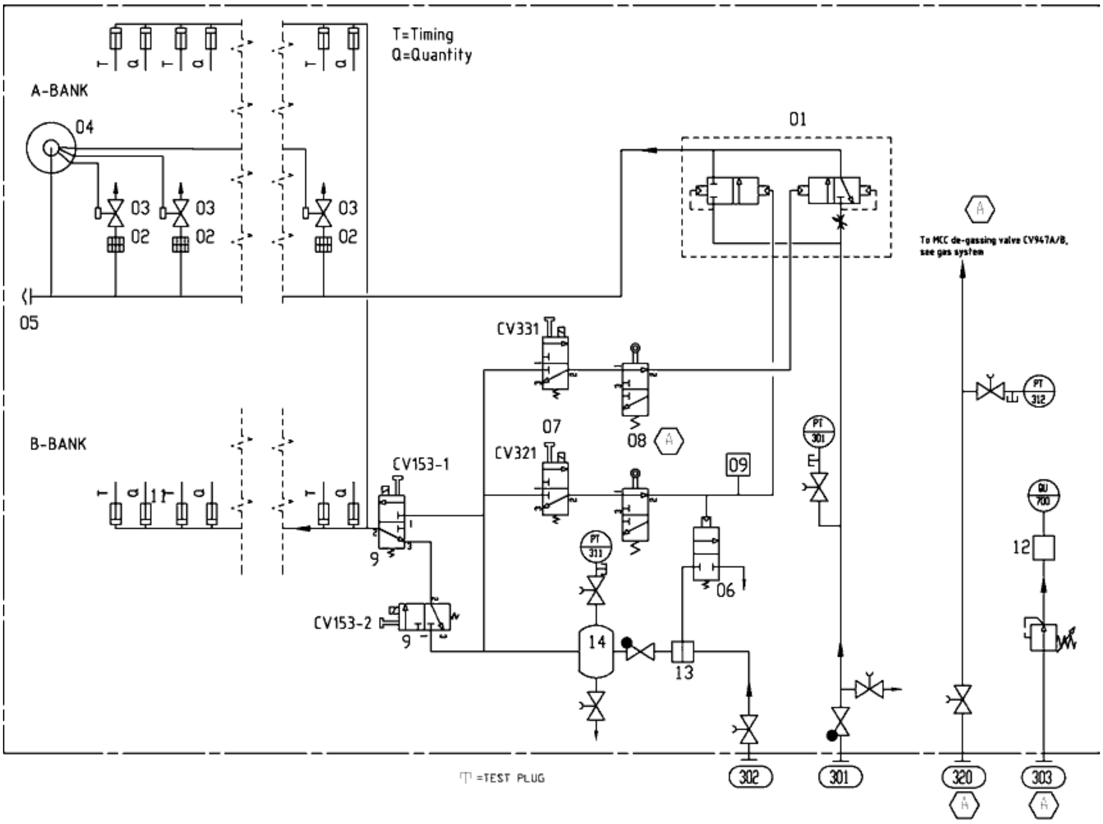


Fig 8-2 Typical Internal compressed air system, V-engines (DAAF381081A)

System components:			
01	Main starting valve	08	Blocking valve of turning gear
02	Flame arrestor	09	Starting booster for governor
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	Air filter
07	Starting and slow turning valve	14	Air container

Sensors and indicators:			
CV153-1	Stop / shutdown solenoid valve 1	PT301	Starting air pressure, engine inlet
CV153-2	Stop / shutdown solenoid valve 2	PT311	Control air pressure
CV321	Start solenoid valve	PT312	Instrument air pressure
CV331	Slow turning solenoid	QU700	Oil mist detector

Pipe connections	
301	Starting air inlet, 30 bar
302	Control air inlet, 30 bar
303	Driving air inlet to oil mist detector (6-8 bar)
320	Instrument air inlet

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.

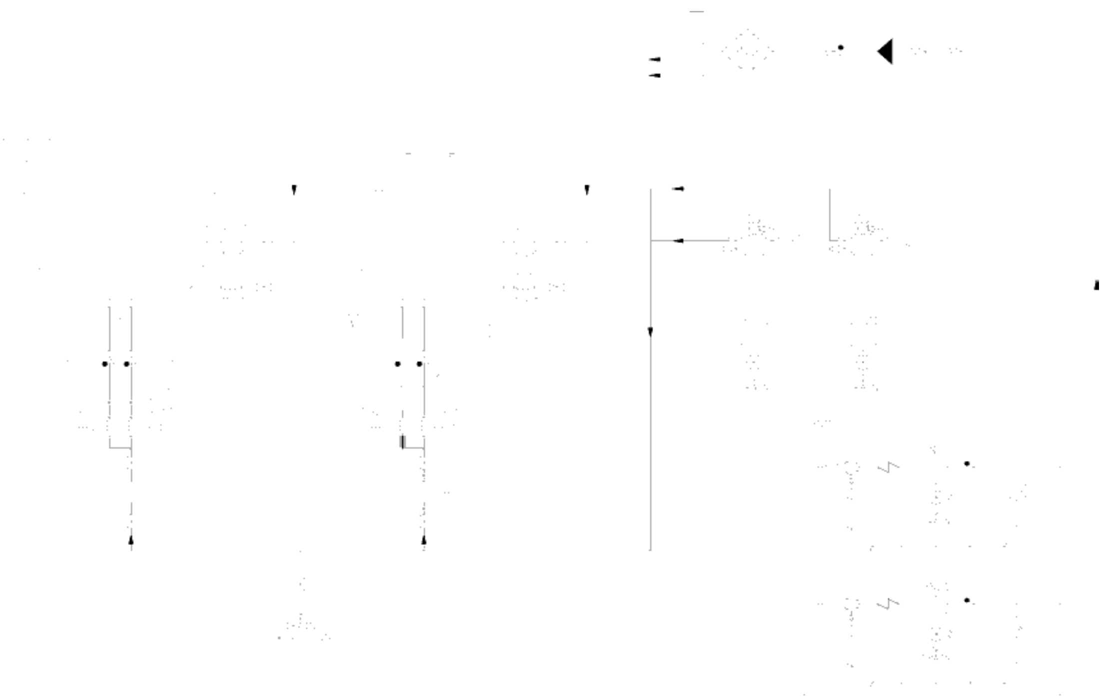


Fig 8-3 Example of external compressed air system (DAAF372066 A)

System components		Pipe connections	
01	Diesel engine WV46DF	301	Starting air inlet
02	Diesel engine WV46DF	302	Control air inlet
3H0X	Flexible pipe connection	303	Driving air to oil mist detector
3F02	Air filter (starting air inlet)	311	Control air to bypass / wastegate valve
3N02	Starting air compressor unit		
3N06	Air dryer unit		
3P01	Compressor (Starting air compressor unit)		
3S01	Separator (Stsrting air compressor unit)		
3T01	Starting air vessel		

8.3.1 Starting air compressor unit (3N02)

At least two starting air compressors must be installed. It is recommended that the compressors are capable of filling the starting air vessel from minimum (1.8 MPa) to maximum pressure in

15...30 minutes. For exact determination of the minimum capacity, the rules of the classification societies must be followed.

8.3.2 Oil and water separator (3S01)

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

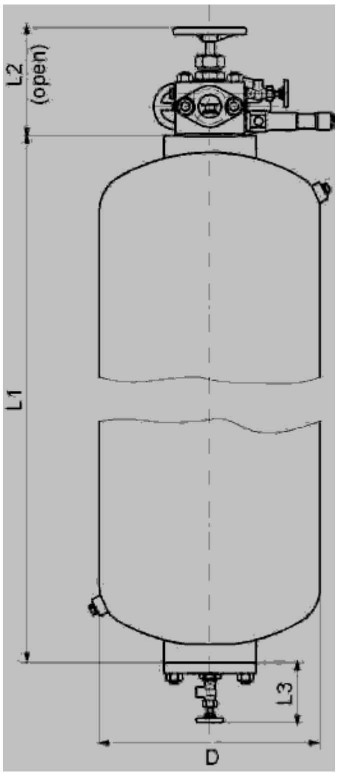
8.3.3 Starting air vessel (3T01)

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

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

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

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



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

[1)] Dimensions are approximate.

Fig 8-4 Starting air vessel

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

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

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

where:

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

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

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

n = required number of starts according to the classification society

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

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

NOTE

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

8.3.4 Air filter, starting air inlet (3F02)

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

An Y-type strainer can be used with a stainless steel screen and mesh size 400 µm. The pressure drop should not exceed 20 kPa (0.2 bar) for the engine specific starting air consumption under a time span of 4 seconds.

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9. Cooling Water System

9.1 Water quality

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

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

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

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

9.1.1 Corrosion inhibitors

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

9.1.2 Glycol

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

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

9.2 Internal cooling water system

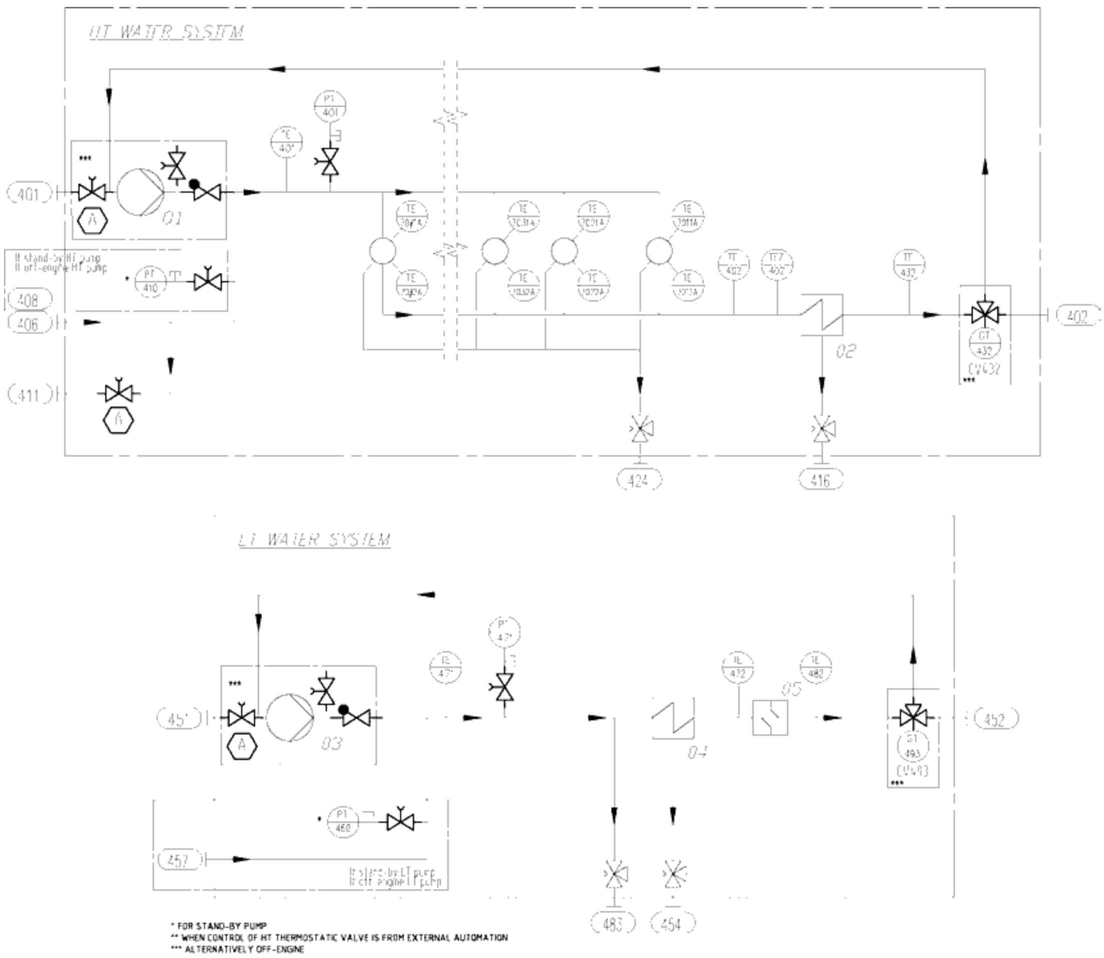

Fig 9-1 Internal cooling water system, in-line engines (DAAF447417)

System components:			
01	HT-water pump	04	Charge air cooler (LT)
02	Charge air cooler (HT)	05	Lube oil cooler
03	LT-water pump		

Sensors and indicators HT line :			
PT401	HT-water press. jacket inlet	TE402-2**	HT water temp. jacket outlet
PT410*	HT-water pressure. stand by pump	TEZ402	HT water temp. jacket outlet
TE401	HT water temp. jacket inlet	TE432	HT water temp. HT CAC outlet
TE7011A..#1A	Liner temperature 1, cyl A-bank	CV432***	HT cooling water thermostat valve control (external)
TE7012A..#2A	Liner temperature 2, cyl A-bank	GT432***	HT cooling water thermostat valve position (external)
TE402	HT water temp. jacket outlet		

Sensors and indicators LT line :			
PT471	LT water pressure, LT CAC inlet	TE482	LT water temp. LOC outlet
PT460*	LT-water pressure. stand by pump	CV493***	LT cooling water thermostat valve control (external)
TE471	LT water temp. LT CAC inlet	GT493***	LT cooling water thermostat valve control (external)
TE472	LT water temp. LT CAC outlet		

Pipe connections			
401	HT-water inlet	424	HT-water air vent from exh. valve and cyl. head
402	HT-water outlet	451	LT-water inlet
406	Water from preheater for HT-circuit	452	LT - water outlet
408	HT-water from stand-by pump	454	LT- water air vent from CAC
411	HT-water drain	457	LT-water from stand by pump
416	HT-water air vent from air cooler	483	LT-water air vent

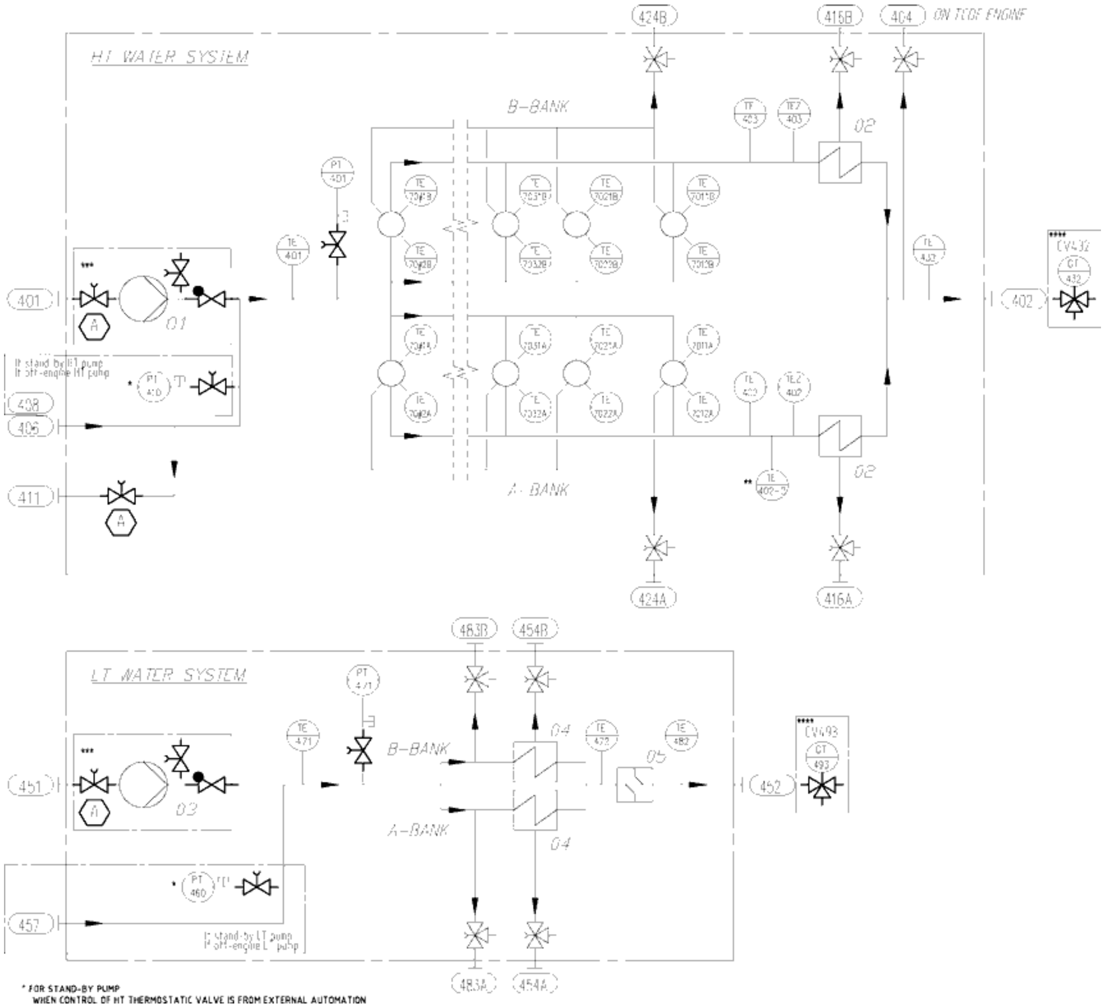

Fig 9-2 Typical internal cooling water system, V-engines (DAAF381077A)

System components:			
01	HT-water pump	04	Charge air cooler (LT)
02	Charge air cooler (HT)	05	Lube oil cooler
03	LT-water pump		

Sensors and indicators HT line :			
PT401	HT-water press. jacket inlet	TEZ402-2**	HT water temp. jacket outlet A-bank
PT410*	HT-water pressure. stand by pump	TEZ402	HT water temp. jacket outlet A-bank
TE401	HT water temp. jacket inlet	TE432	HT water temp. HT CAC outlet
TE7011A..#1A	Liner temperature 1, cyl A-bank	CV432***	HT cooling water thermostat valve control (external)
TE7012A..#2A	Liner temperature 2, cyl A-bank	GT432***	HT cooling water thermostat valve position (external)
TE7011B..#1B	Liner temperature 1, cyl B-bank	TE403	HT water temp. jacket outlet B-bank
TE7012B..#2B	Liner temperature 2, cyl B-bank	TEZ403	HT water temp. jacket outlet B-bank
TE402	HT water temp. jacket outlet A-bank		

Sensors and indicators LT line :			
PT471	LT water pressure, LT CAC inlet	TE482	LT water temp. LOC outlet
PT460*	LT-water pressure. stand by pump	CV493***	LT cooling water thermostat valve control (external)
TE471	LT water temp. LT CAC inlet	GT493***	LT cooling water thermostat valve control (external)
TE472	LT water temp. LT CAC outlet		

Pipe connections			
401	HT-water inlet	424 A/B	HT-water air vent from exh. valve seat A/B bank
402	HT-water outlet	451	LT-water inlet
404	HT-water air vent	452	LT - water outlet
406	Water from preheater for HT-circuit	454 A/B	LT- water air vent from CAC A/B bank
408	HT-water from stand-by pump	457	LT-water from stand by pump
411	HT-water drain	483 A/B	LT-water air vent A/B bank
416 A/B	HT-water air vent from air cooler A/B bank		

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/HT pumps, and therefore engines are also available without built-on LT/HTpumps. 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*.

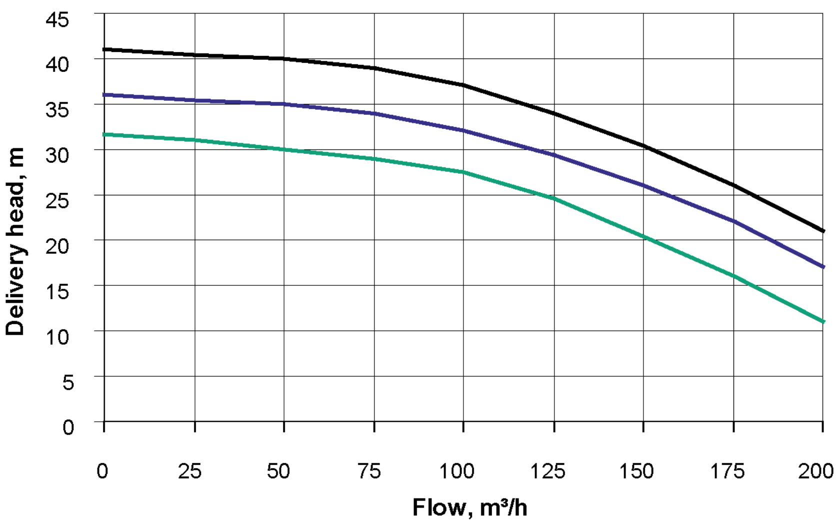

Fig 9-3 L46DF engine driven HT- and LT-pumps

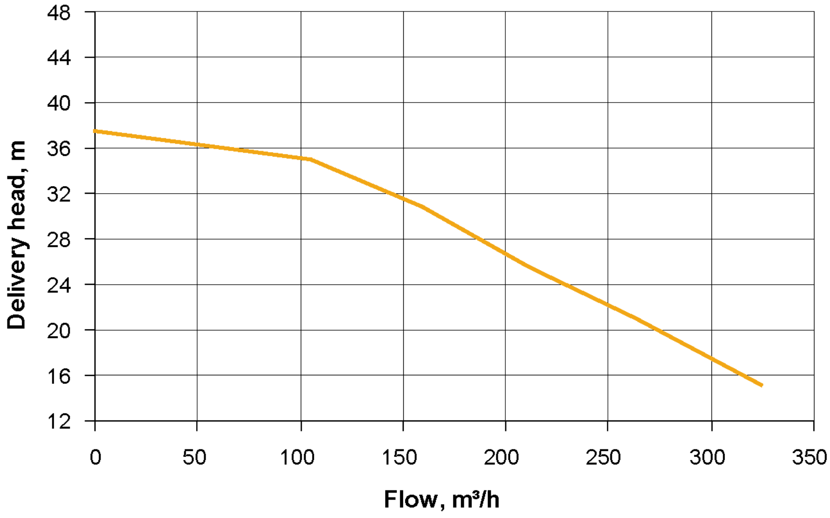

Fig 9-4 **V46DF engine driven HT- and LT-pump**

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.

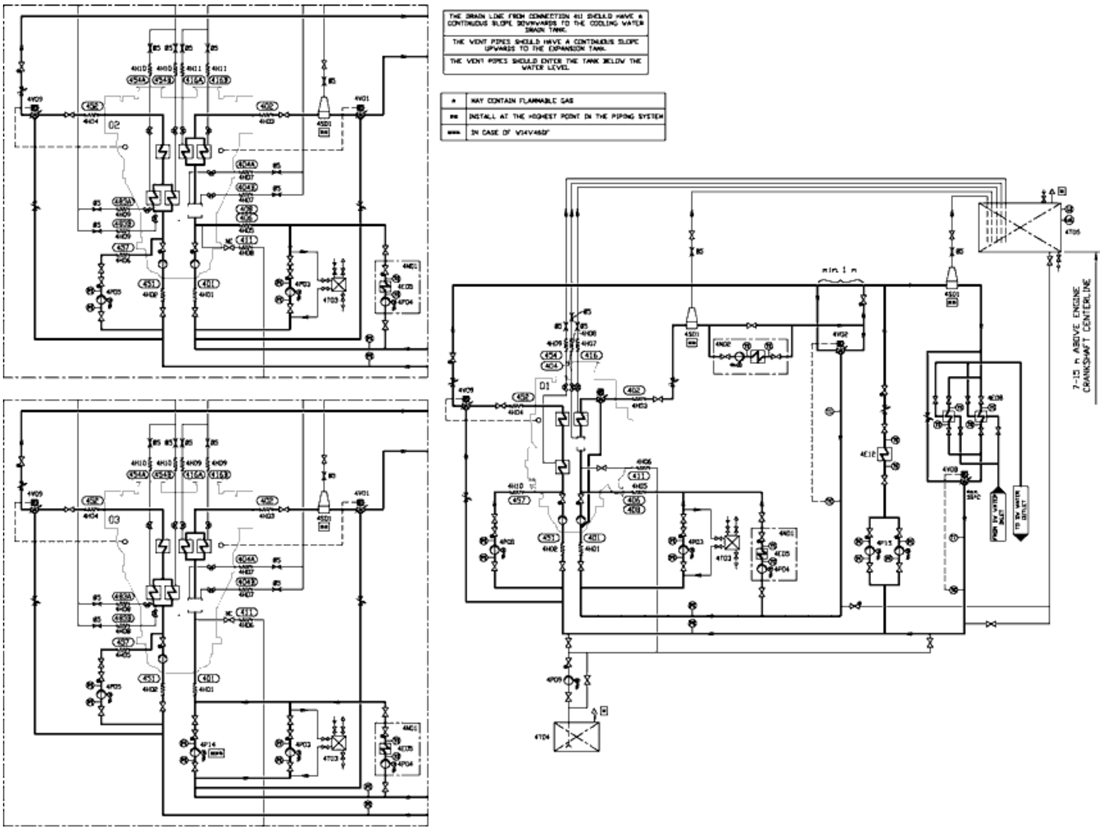

Fig 9-5 Cooling water system, single main engine combined LT/HT (DAAF418507)

System components:			
4E05	Heater (preheater)	4S01	Air venting
4E08	Central cooler	4T03	Additive dosing tank
4E12	Cooler (Installation parts)	4T04	Drain tank
4N01	Preheating unit	4T05	Expansion tank
4N02	Evaporator unit	4V01	Temperature control valve (HT)
4P03	Stand-by pump (LT)	4V02	Temp control valve (heat recovery)
4P04	Circulating pump (preheater)	4V08	Temp control valve (central cooler)
4P05	Stand-by pump (LT)	4V09	Temperature control valv (charge air)
4P09	Transfer pump		

System components:			
4P14	Circulating pump (HT)		
4P15	Circulating pump (LT)		

Pipe connections:		Size
401	HT-water inlet	DN150
402	HT-water outlet	DN150
404	HT-water air vent	OD15
406	Water from preheater to HT-circuit	DN150
408	HT-water from stand-by pump	DN150
411	HT-water drain	OD22
416	HT-water air vent from CAC	OD15
451	LT-water inlet	DN150
452	LT-water outlet	DN150
454	LT-water air vent from air cooler	OD15
457	LT-water from stand-by pump	DN150
483	LT-water air vent	

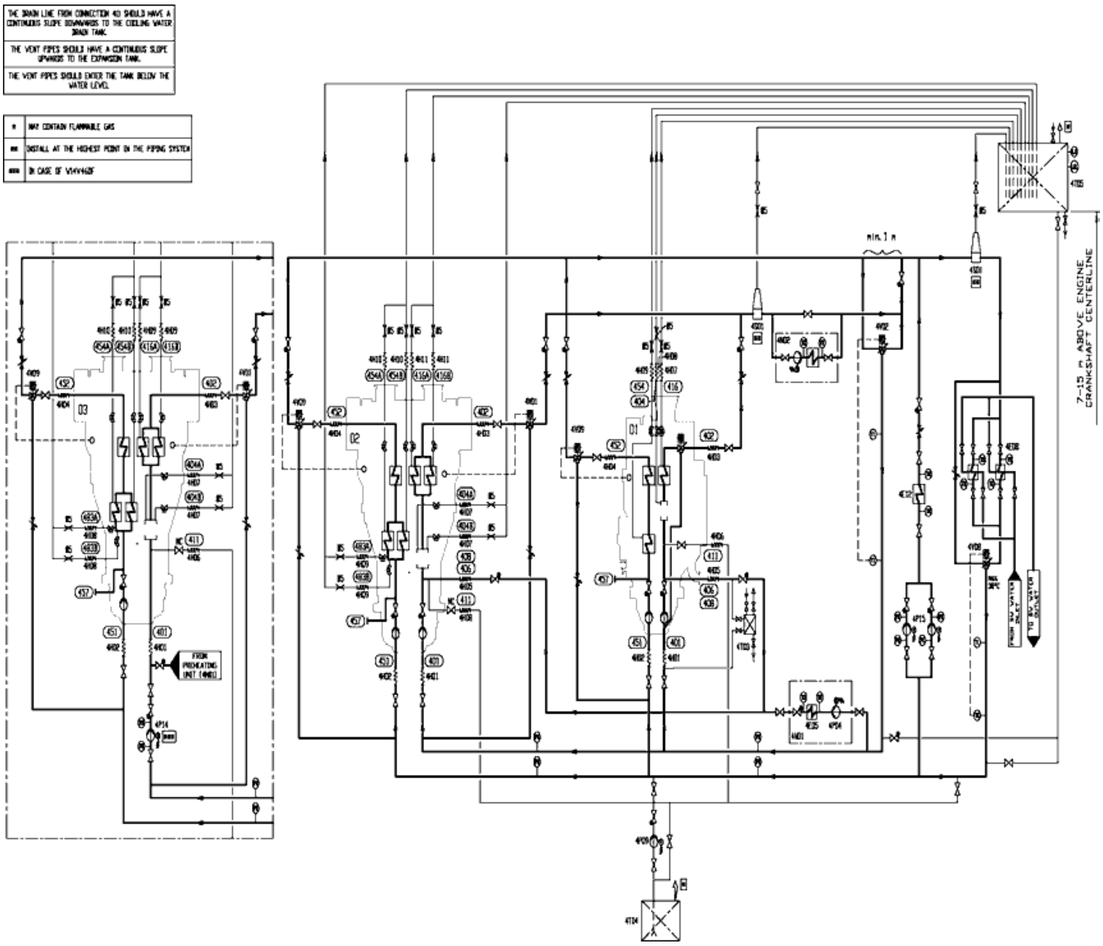

Fig 9-6 Cooling water system, multiple engine combined LT/HT (DAAF418508)

System components:			
4E05	Heater (preheater)	4S01	Air venting
4E08	Central cooler	4T03	Additive dosing tank
4E12	Cooler (Installation parts)	4T04	Drain tank
4N01	Preheating unit	4T05	Expansion tank
4N02	Evaporator unit	4V01	Temperature control valve (HT)
4P09	Transfer pump	4V02	Temp control valve (heat recovery)
4P14	Circulating pump (HT)	4V08	Temp control valve (central cooler)
4P15	Circulating pump (LT)	4V09	Temperature control valv (charge air)

Pipe connections:		Size
401	HT-water inlet	DN150
402	HT-water outlet	DN150
404	HT-water air vent	OD15
406	HT-water from preheater to HT-circuit	DN150
408	HT-water from stand-by pump	DN150
411	HT-water drain	OD22

Pipe connections:		Size
416	HT-water air vent from CAC	OD15
451	LT-water inlet	DN150
452	LT-water outlet	DN150
454	LT-water air vent from air cooler	OD15
457	LT-water from stand-by pump	DN150
483	LT-water air vent	

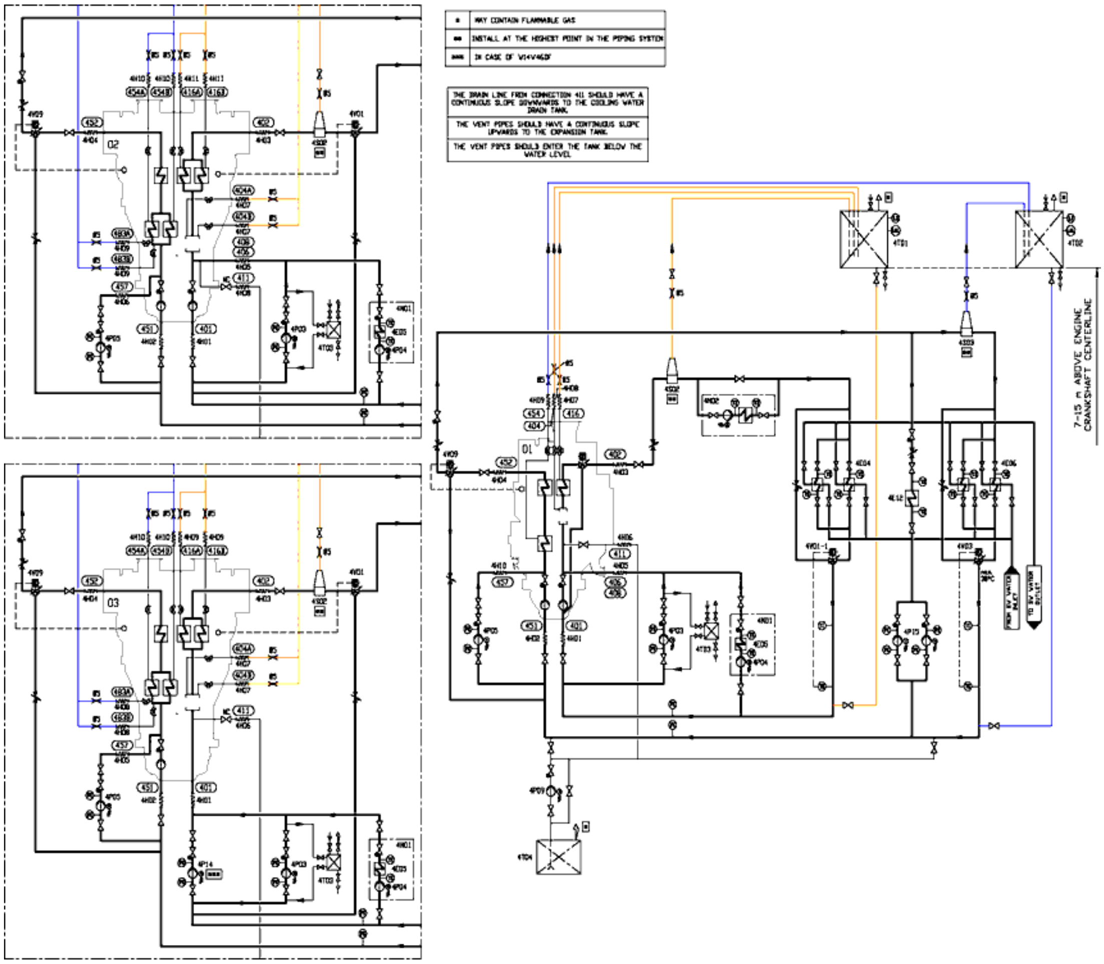

Fig 9-7 Cooling water system, single main engine separeted LT/HT (DAAF418509)

System components:			
4E04	Raw water cooler (HT)	4S02	Air dearator (HT)
4E05	Heater (preheater)	4S03	Air dearator (LT)
4E06	Raw water cooler (LT)	4T01	Expansion tank (HT)
4E12	Cooler (Installation parts)	4T02	Expansion tank (LT)
4N01	Preheating unit	4T03	Additive dosing tank
4N02	Evaporator unit	4T04	Drain tank
4P03	Stand-by pump (HT)	4V01	Temperature control valve (HT)

System components:			
4P04	Circulating pump (preheater)	4V01-1	Temperature control valve (HT)
4P05	Stand-by pump (LT)	4V03	Temperature control valve (LT)
4P09	Transfer pump	4V09	Temperature control valv (charge air)
4P14	Circulating pump (HT)		
4P15	Circulating pump (LT)		

Pipe connections:		Size
401	HT-water inlet	DN150
402	HT-water outlet	DN150
404	HT-water air vent	OD15
406	HT-water from preheater to HT-circuit	DN150
408	HT-water from stand-by pump	DN150
411	HT-water drain	OD22
416	HT-water air vent from CAC	OD15
451	LT-water inlet	DN150
452	LT-water outlet	DN150
454	LT-water air vent from air cooler	OD15
457	LT-water from stand-by pump	DN150
483	LT-water air vent	

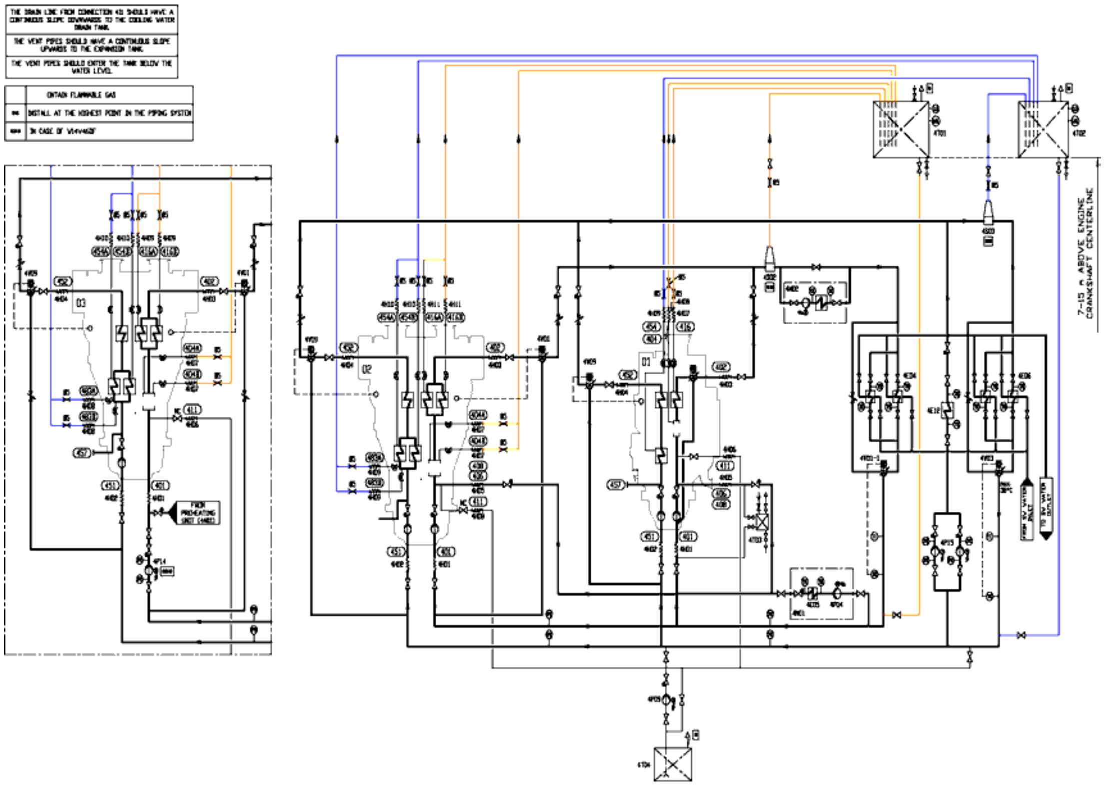

Fig 9-8 Cooling water system, multiple engine separated LT/HT (DAAF418510)

Pipe connections:		Size
401	HT-water inlet	DN150
402	HT-water outlet	DN150
404	HT-water air vent	OD15
406	HT-water from preheater to HT-circuit	DN150
408	HT-water from stand-by pump	DN150
411	HT-water drain	OD22
416	HT-water air vent from CAC	OD15
451	LT-water inlet	DN150
452	LT-water outlet	DN150
454	LT-water air vent from air cooler	OD15
457	LT-water from stand-by pump	DN150
483	LT-water air vent	

System components:			
4E04	Raw water cooler (HT)	4S02	Air dearator (HT)
4E05	Heater (preheater)	4S03	Air dearator (LT)
4E06	Raw water cooler (LT)	4T01	Expansion tank (HT)
4E12	Cooler (Installation parts)	4T02	Expansion tank (LT)
4N01	Preheating unit	4T03	Additive dosing tank

System components:			
4N02	Evaporator unit	4T04	Drain tank
4P03	Stand-by pump (HT)	4V01	Temperature control valve (HT)
4P04	Circulating pump (preheater)	4V01-1	Temperature control valve (HT)
4P09	Transfer pump	4V03	Temperature control valve (LT)
4P14	Circulating pump (HT)	4V09	Temperature control valv (charge air)
4P15	Circulating pump (LT)		

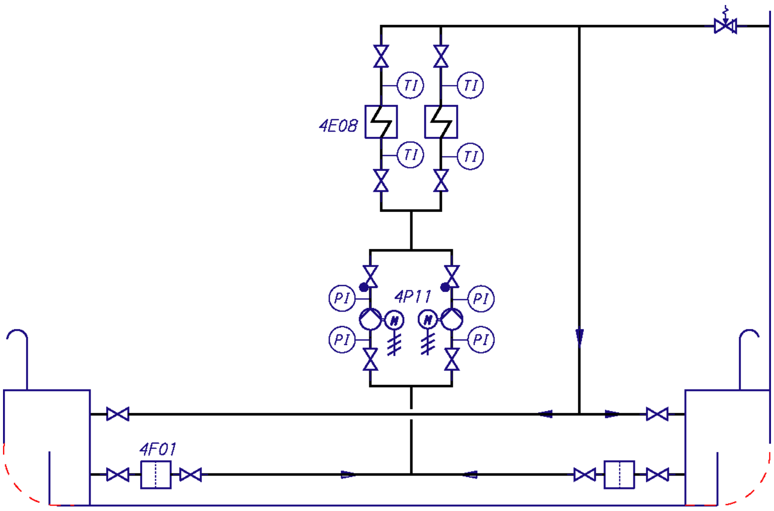

Fig 9-9 Sea water system DAAE020523

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 Charge air temperature control valve (4V09)

The temperature of the charge air is maintained on desired level with an electrically actuated temperature control valve in the external LT circuit. The control valve regulates the recirculating water flow (after the LO Cooler) through (to) the LT-stage of the charge air cooler in order to reach and maintain the correct charge air receiver temperature.

9.3.5 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.

9.3.6 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*.

9.3.7 Fresh water central cooler (4E08)

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

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

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

Design data:	
Fresh water flow	see chapter *Technical Data*
Heat to be dissipated	see chapter *Technical Data*
Pressure drop on fresh water side	max. 60 kPa (0.6 bar)
Sea-water flow	acc. to cooler manufacturer, normally 1.2 - 1.5 x the fresh water flow
Pressure drop on sea-water side, norm.	acc. to pump head, normally 80 - 140 kPa (0.8 - 1.4 bar)
Fresh water temperature after cooler	max. 38°C
Margin (heat rate, fouling)	15%

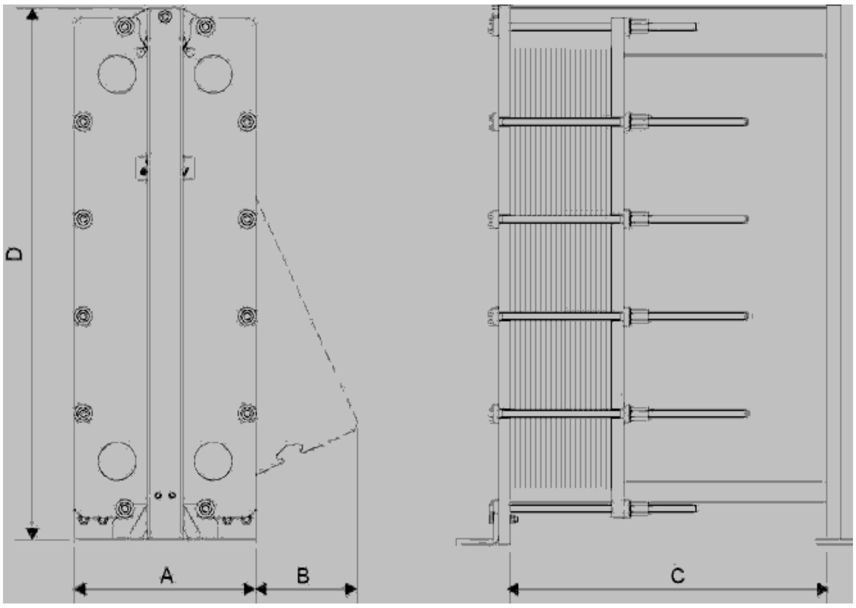

Fig 9-10 Central cooler main dimensions. Example for guidance only

Engine type	A [mm]	C [mm]	D [mm]	Weight [kg]
6L46DF	690	1005	2149	860
7L46DF	690	1005	2149	900
8L46DF	690	1005	2149	900
9L46DF	690	1255	2149	960
12V46DF	690	1255	2149	990
14V46DF	690	1505	2149	1120

Engine type	A [mm]	C [mm]	D [mm]	Weight [kg]
16V46DF	690	1505	2149	1120

9.3.8 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.

9.3.9 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.

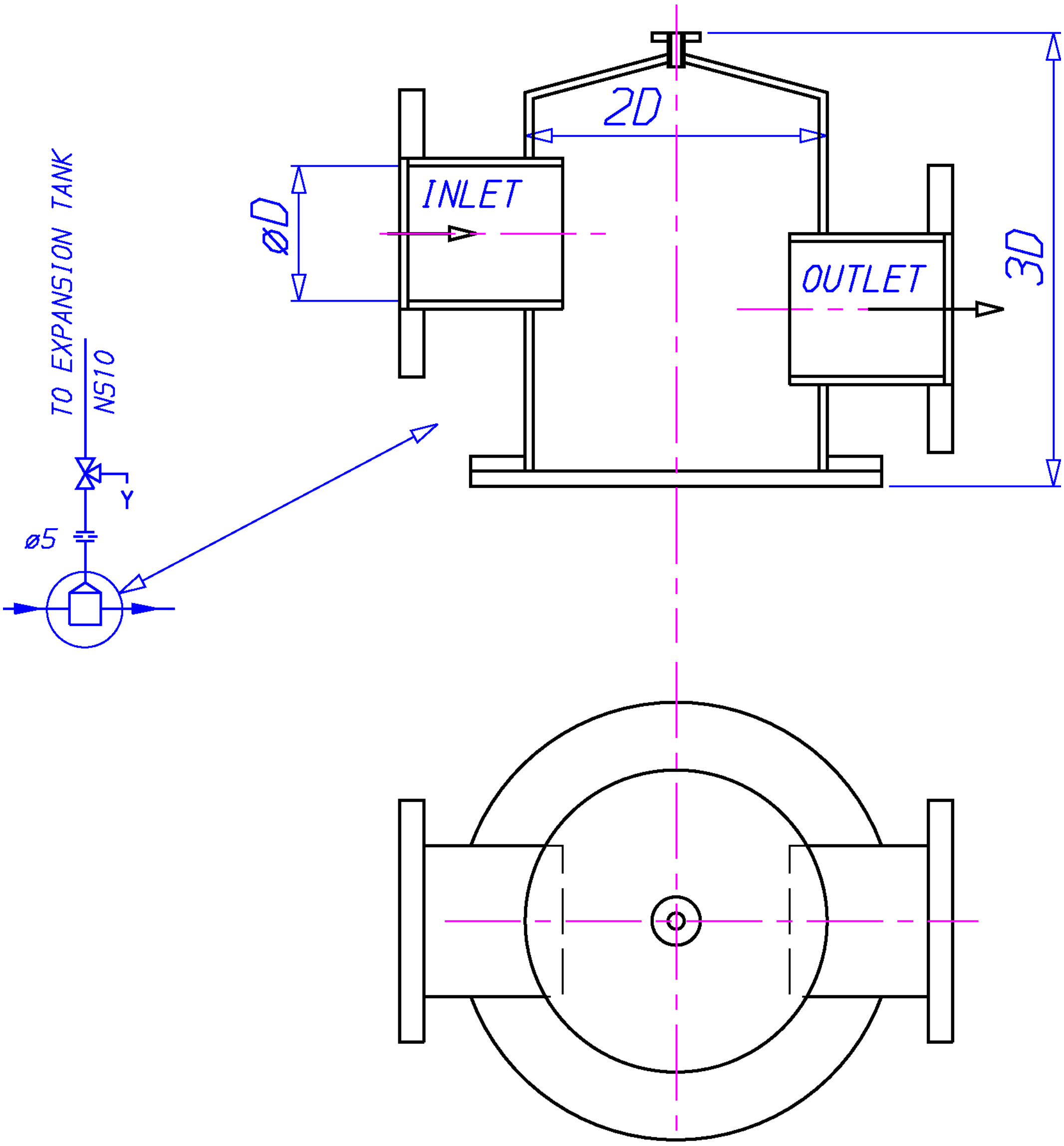

Fig 9-11 Example of air venting device (V60D0343)

9.3.10 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:	
Volume	min. 10% of the total system volume

NOTE

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

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

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

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

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

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

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

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

Table 9-1 Minimum diameter of balance pipe

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

9.3.11 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.

9.3.12 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 ºC to 60...70 ºC in 10-15 hours. The required heating power for shorter heating time can be estimated with the formula below. About 6 kW/cyl is required to keep a hot engine warm.

Design data:	
Preheating temperature	min. 60°C for starts at LFO or gas; 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:

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

where:

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

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

9.3.12.2 Circulation pump for HT preheater (4P04)

Design data:	
Capacity	1.6 m^3/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

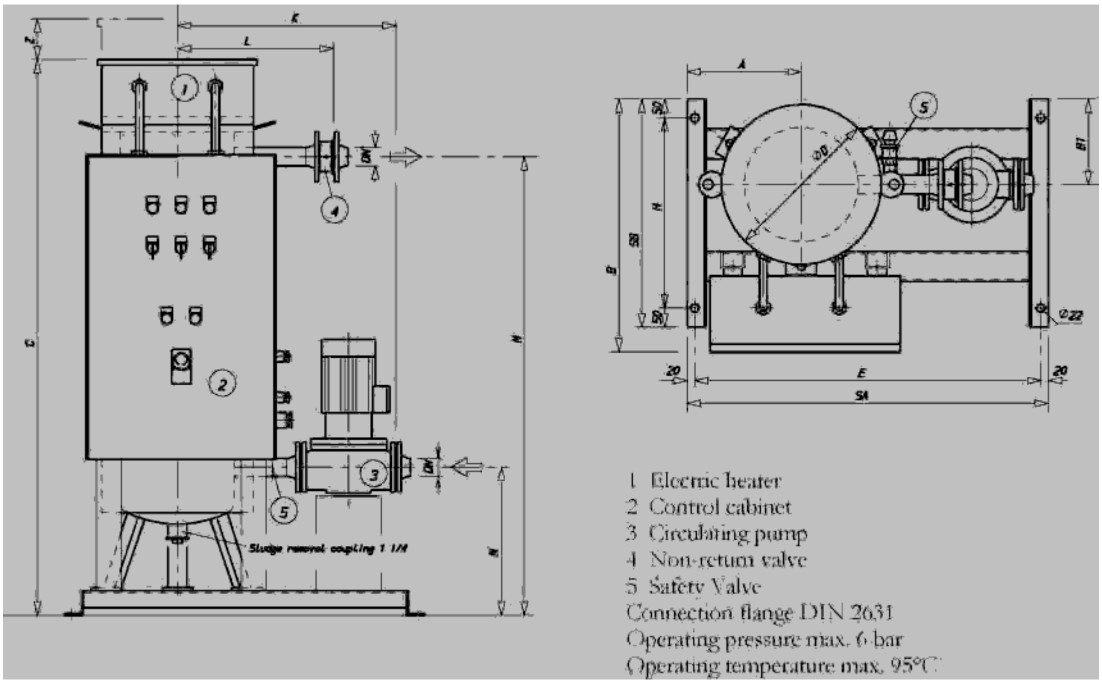

Fig 9-12 Example of preheating unit, electric (4V47K0045)

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						

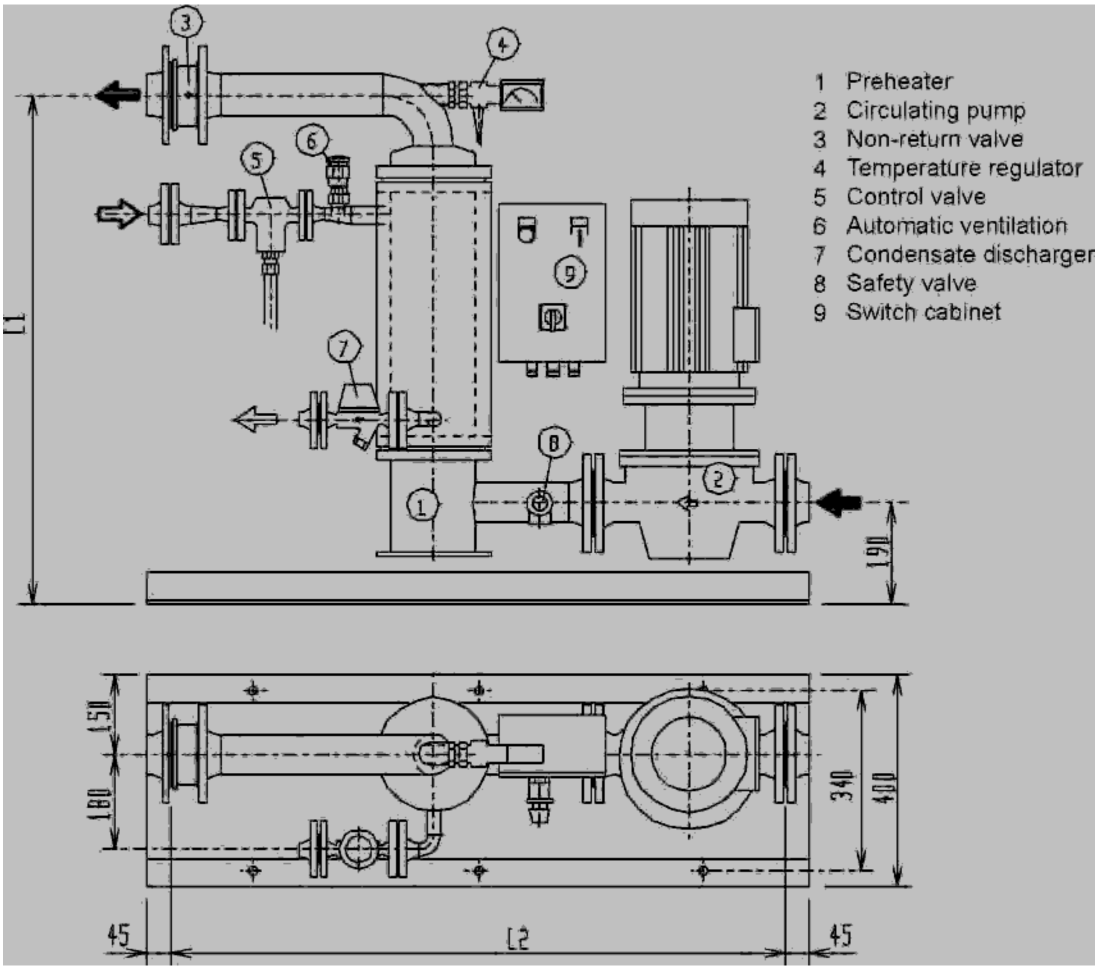

Fig 9-13 **Example of preheating unit, steam**

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 to shall be paid to the engine room ventilation and the supply of combustion air.

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

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

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

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

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

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

where:

q_v = air flow [m³/s]

Φ = total heat emission to be evacuated [kW]

ρ = air density 1.13 kg/m³

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

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

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

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

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

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

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

10.2 Combustion air system design

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

For the required amount of combustion air, see section *Technical data*.

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

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

where:

q_c = combustion air volume flow [m³/s]

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

ρ = air density 1.15 kg/m³

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

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

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

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

For very cold conditions 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.

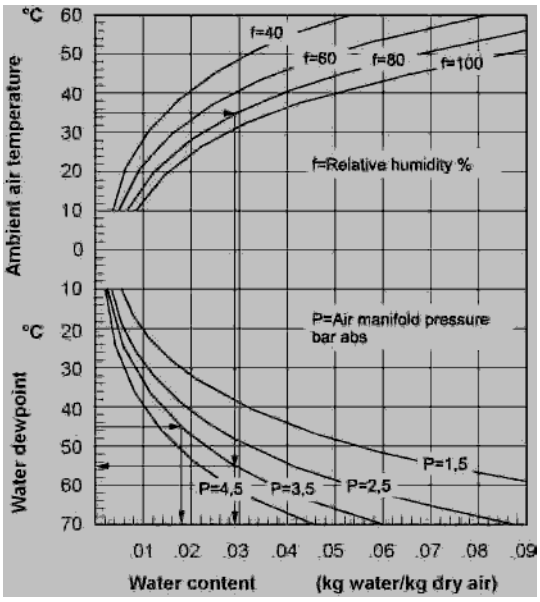

Fig 10-1 Condensation in charge air coolers

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11. Exhaust Gas System

11.1 Internal exhaust gas system

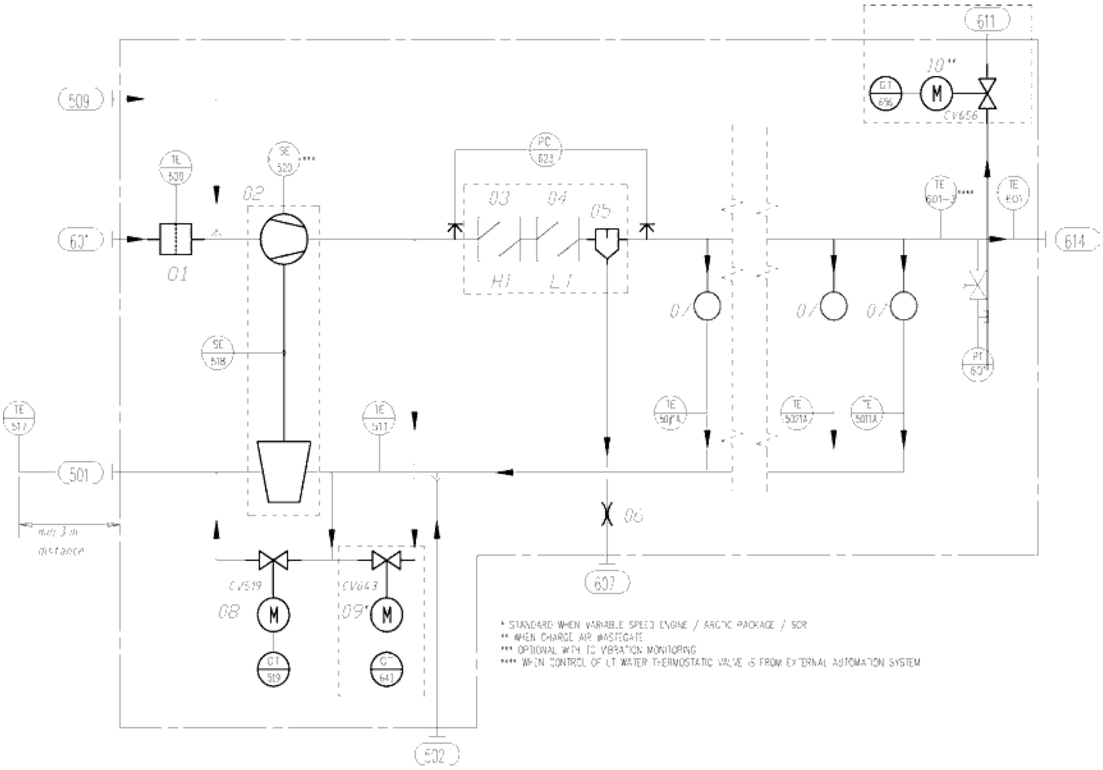


Fig 11-1 Internal combustion air and exhaust gas system, in-line engines (DAAF447418)

System components:					
01	Air filter	05	Water mist catcher	09*	Charge air by-pass valve
02	Turbocharger	06	Orifice	10**	Charge air wastegate valve
03	Charge air cooler (HT)	07	Cylinder head and valves		
04	Charge air cooler (LT)	08	Exh. wastegate valve		

Sensors and indicators			
TE50#1A	Exh. gas temperature cyl 0#A	CV519	Exhaust wastegate control
TE511	Exh. gas temperature TC inlet	GT519	Exhaust wastegate position
TE517	Exh. gas temperature TC outlet	CV643*	Charge air by pass control
SE518	TC A speed	GT643*	Charge air by pass position
PT601	Charge air pressure, engine inlet	CV656**	Charge air wastegate control
TE600	Air temperature TC inlet	GT656**	Charge air wastegate position
TE601	Charge air temp engine inlet	SE520***	TC vibration
TE601-2****	Charge air temp engine inlet		
PDI623	CAC pressure difference		

Pipe connections			
501	Exhaust gas outlet	601	Air inlet to TC

Pipe connections			
502	Cleaning water to turbine	611**	Charge air wastegate outlet
509	Cleaning water to compressor	614	Scavenging air outlet to TC cleaning valve unit
607	Condensate after air cooler		

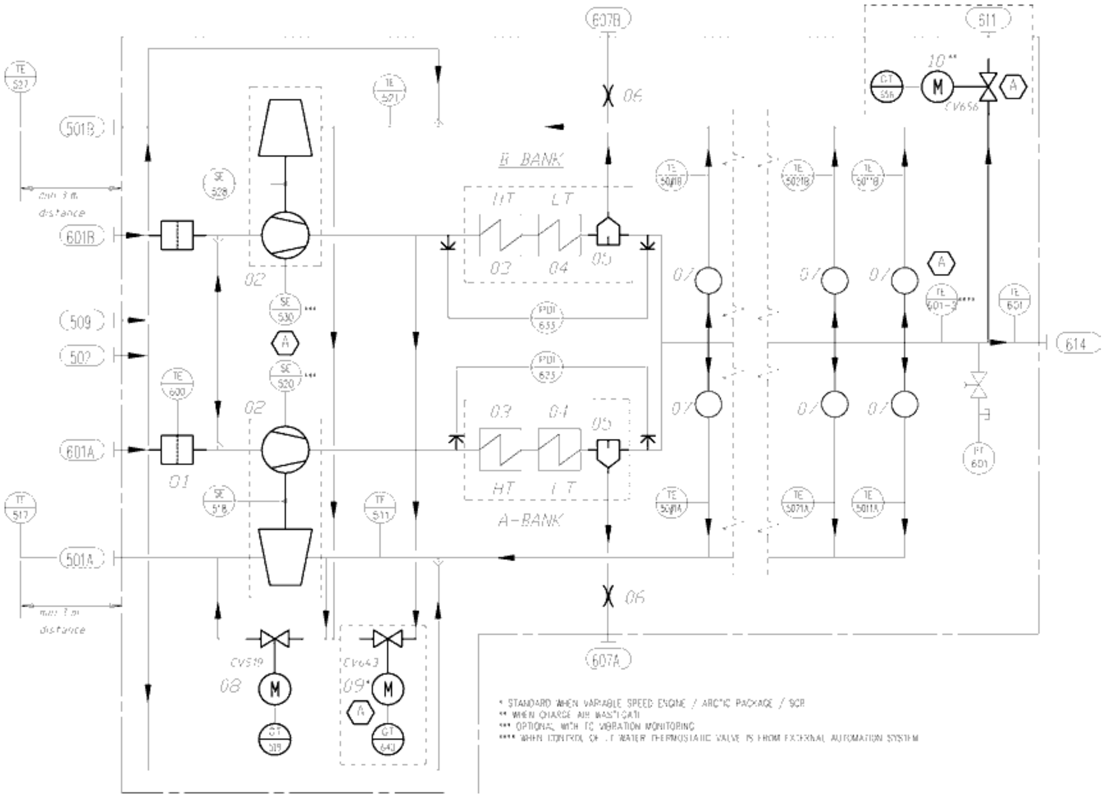


Fig 11-2 Typical Internal charge air/exh gas system, V-engines (DAAF381076A)

System components:					
01	Air filter	05	Water mist catcher	09*	Charge air by-pass valve
02	Turbocharger	06	Orifice	10**	Charge air wastegate valve
03	Charge air cooler (HT)	07	Cylinder head and valves		
04	Charge air cooler (LT)	08	Exh. wastegate valve		

Sensors and indicators			
TE50#1A/B	Exh. gas temperature cyl 0#A/B	CV519	Exhaust wastegate control
TE511	Exh. gas temperature TC A inlet	GT519	Exhaust wastegate position
TE517	Exh. gas temperature TC A outlet	CV643*	Charge air by pass control
TE521	Exh. gas temperature TC B inlet	PDI633	CAC pressure difference B bank
TE527	Exh. gas temperature TC B outlet	GT643*	Charge air by pass position
SE518	TC A speed	CV656**	Charge air wastegate control
SE528	TC B speed	GT656**	Charge air wastegate position
PT601	Charge air pressure, engine inlet	SE520***	TC A vibration
TE600	Air temperature TC inlet	SE530***	TC B vibration
TE601	Charge air temp engine inlet		
TE601-2****	Charge air temp engine inlet		
PDI623	CAC pressure difference A bank		

Pipe connections			
501 A/B	Exhaust gas outlet A/B bank	601 A/B	Air inlet to TC A/B bank
502	Cleaning water to turbine	611**	Charge air wastegate outlet
509	Cleaning water to compressor	614	Scavenging air outlet to TC cleaning valve unit
607 A/B	Condensate after air cooler A/B bank		

11.2 Exhaust gas outlet

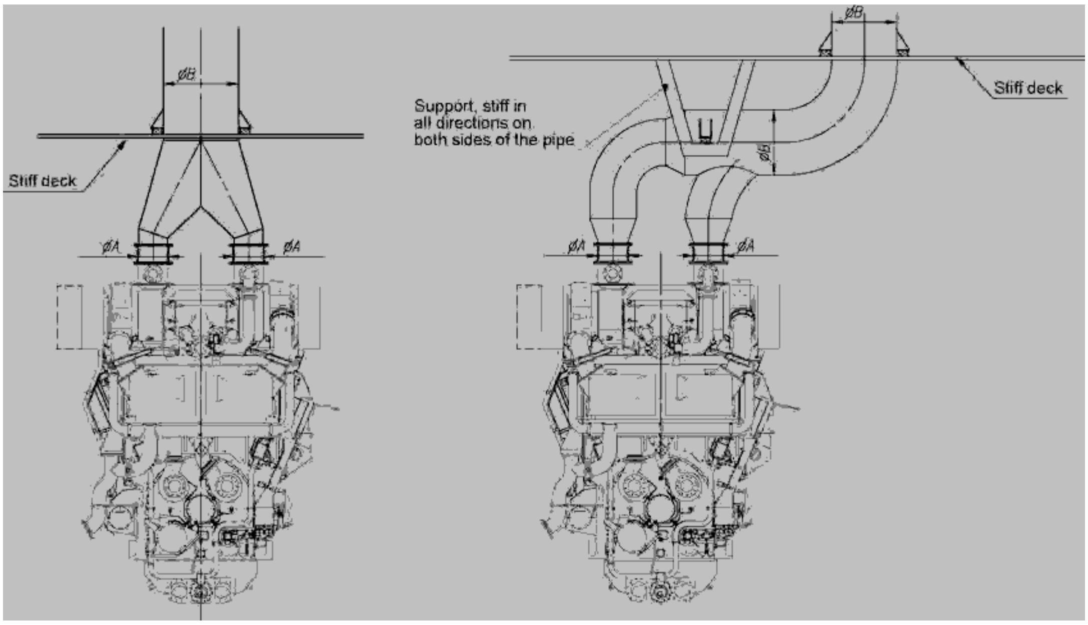


Fig 11-3 Exhaust pipe, diameters and support

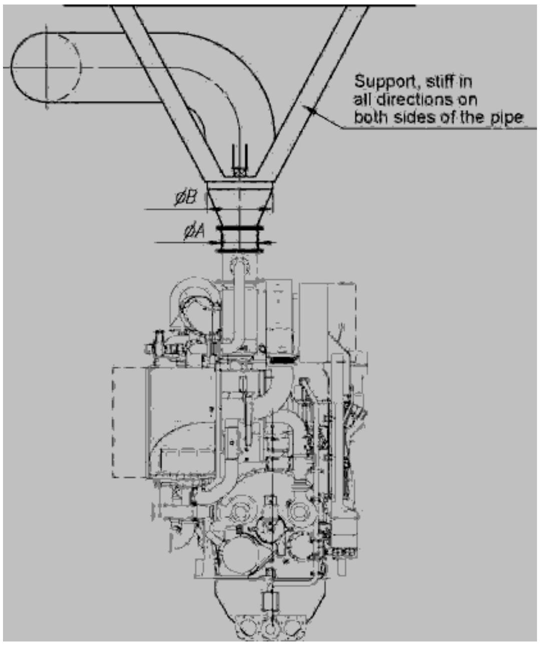


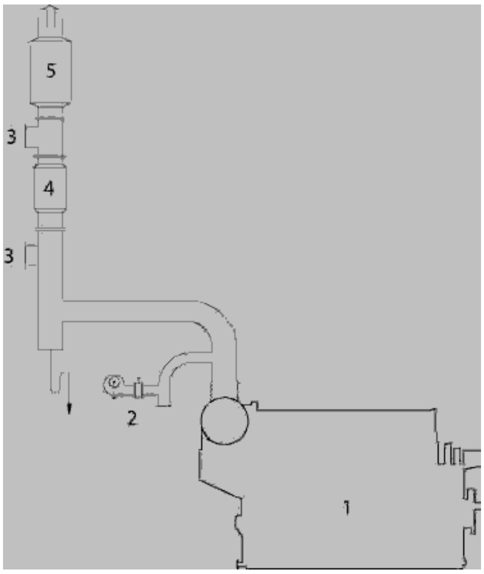
Fig 11-4 Exhaust pipe, diameters and support

Engine type	TC type	A [mm]	B [mm]
W 6L46DF	A170	650	DN900
W 7L46DF	A170	650	DN1000
W 8L46DF	A175	750	DN1000
W 9L46DF	A175	750	DN1100
W 12V46DF	A170	650	DN1300
W 14V46DF	A170	650	DN1400
W 16V46DF	A175	750	D1500

11.3 External exhaust gas system

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

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



1 Duel Fuel engine
2 Exhaust gas ventilation unit
3 Rupture discs
4 Exhaust gas boiler
5 Silencer

Fig 11-5 External exhaust gas system

11.3.1 System design - safety aspects

Natural gas may enter the exhaust system if a malfunction occurs during gas operation. The gas may accumulate in the exhaust piping and it could be ignited in case a source of ignition (such as a spark) appears in the system. The external exhaust system must therefore be designed so that the pressure build-up in case of an explosion does not exceed the maximum permissible pressure for any of the components in the system. The engine can tolerate a pressure of at least 200 kPa. Other components in the system might have a lower maximum pressure limit. The consequences of a possible gas explosion can be minimized with proper design of the exhaust system; the engine will not be damaged and the explosion gases will be safely directed through predefined routes. The following guidelines should be observed, when designing the external exhaust system:

- The piping and all other components in the exhaust system should have a constant upward slope to prevent gas from accumulating in the system. If horizontal pipe sections cannot be completely avoided, their length should be kept to a minimum. The length of a single horizontal pipe section should not exceed five times the diameter of the pipe. Silencers and exhaust boilers etc. must be designed so that gas cannot accumulate inside.
- The exhaust system must be equipped with explosion relief devices, such as rupture discs, in order to ensure safe discharge of explosion pressure. The outlets from explosion relief devices must be in locations where the pressure can be safely released.

In addition the control and automation systems include the following safety functions:

- Before start the engine is automatically ventilated, i.e. rotated without injecting any fuel.
- During the start sequence, before activating the gas admission to the engine, an automatic combustion check is performed to ensure that the pilot fuel injection system is working correctly.

- The combustion in all cylinders is continuously monitored and should it be detected that all cylinders are not firing reliably, then the engine will automatically trip to diesel mode.
- The exhaust gas system is ventilated by a fan after the engine has stopped, if the engine was operating in gas mode prior to the stop.

11.3.2 Exhaust gas ventilation unit (5N01)

An exhaust gas ventilation system is required to purge the exhaust piping after the engine has been stopped in gas mode. The exhaust gas ventilation system is a class requirement. The ventilation unit is to consist of a centrifugal fan, a flow switch and a butterfly valve with position feedback. The butterfly valve has to be of gas-tight design and able to withstand the maximum temperature of the exhaust system at the location of installation.

The fan can be located inside or outside the engine room as close to the turbocharger as possible. The exhaust gas ventilation sequence is automatically controlled by the GVU.

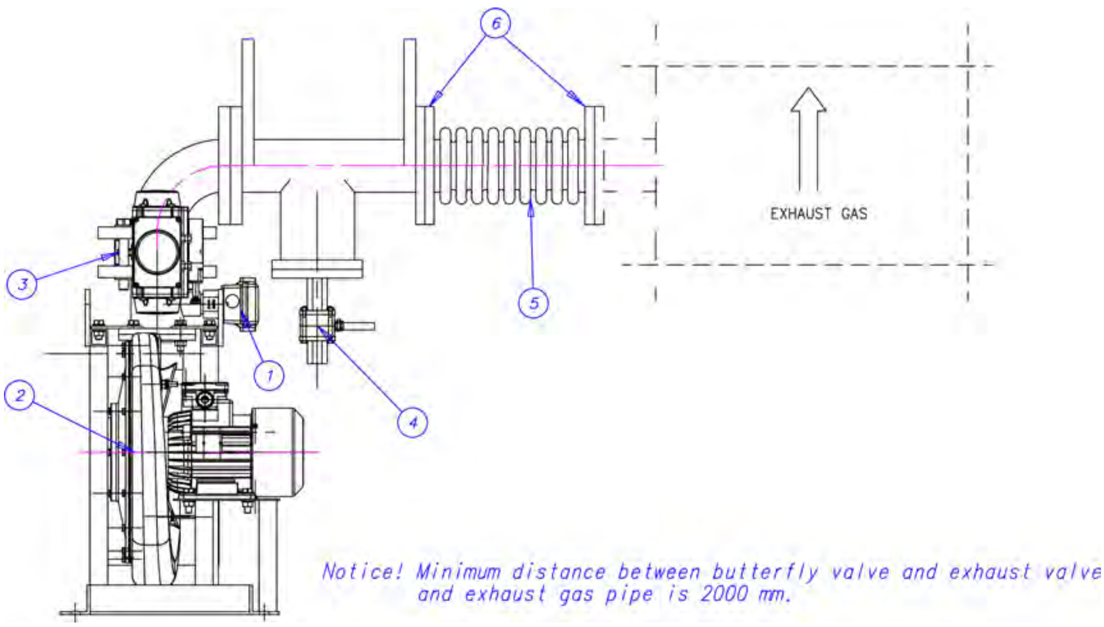


Fig 11-6 Exhaust gas ventilation arrangement (DAAF315146A)

Unit components			
1	Switch	4	Drain
2	Fan	5	Bellow
3	Butterfly valve	6	Flange

11.3.3 Relief devices - rupture discs

Explosion relief devices such as rupture discs are to be installed in the exhaust system. Outlets are to discharge to a safe place remote from any source of ignition. The number and location of explosion relief devices shall be such that the pressure rise caused by a possible explosion cannot cause any damage to the structure of the exhaust system.

This has to be verified with calculation or simulation. Explosion relief devices that are located indoors must have ducted outlets from the machinery space to a location where the pressure can be safely released. The ducts shall be at least the same size as the rupture disc. The ducts shall be as straight as possible to minimize the back-pressure in case of an explosion.

For under-deck installation the rupture disc outlets may discharge into the exhaust casing, provided that the location of the outlets and the volume of the casing are suitable for handling the explosion pressure pulse safely. The outlets shall be positioned so that personnel are not present during normal operation, and the proximity of the outlet should be clearly marked as a hazardous area.

11.3.4 Piping

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

The recommended flow velocity in the pipe is maximum 35…40 m/s at full output. If there are many resistance factors in the piping, or the pipe is very long, then the flow velocity needs to be lower. The exhaust gas mass flow given in chapter *Technical data* can be translated to velocity using the formula:

$$v = \frac{4 \times m'}{1.3 \times \left(\frac{273}{273 + T}\right) \times \pi \times D^2}$$

where:

v = gas velocity [m/s]

m' = exhaust gas mass flow [kg/s]

T = exhaust gas temperature [°C]

D = exhaust gas pipe diameter [m]

The exhaust pipe must be insulated with insulation material approved for concerned operation conditions, minimum thickness 30 mm considering the shape of engine mounted insulation. Insulation has to be continuous and protected by a covering plate or similar to keep the insulation intact.

Closest to the turbocharger the insulation should consist of a hook on padding to facilitate maintenance. It is especially important to prevent the airstream to the turbocharger from detaching insulation, which will clog the filters.

After the insulation work has been finished, it has to be verified that it fulfils SOLAS-regulations. Surface temperatures must be below 220°C on whole engine operating range.

11.3.5 Supporting

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

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

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

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

11.3.6 Back pressure

The maximum permissible exhaust gas back pressure is stated in chapter *Technical Data*. The back pressure in the system must be calculated by the shipyard based on the actual piping design and the resistance of the components in the exhaust system. The exhaust gas mass flow and temperature given in chapter *Technical Data* may be used for the calculation.

Each exhaust pipe should be provided with a connection for measurement of the back pressure. The back pressure must be measured by the shipyard during the sea trial.

11.3.7 Exhaust gas bellows (5H01, 5H03)

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

11.3.8 SCR-unit (11N14)

The SCR-unit requires special arrangement on the engine in order to keep the exhaust gas temperature and backpressure into SCR-unit working range. The exhaust gas piping must be straight at least 3...5 meters in front of the SCR unit. If both an exhaust gas boiler and a SCR unit will be installed, then the exhaust gas boiler shall be installed after the SCR. Arrangements must be made to ensure that water cannot spill down into the SCR, when the exhaust boiler is cleaned with water.

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

11.3.9 Exhaust gas boiler

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

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

11.3.10 Exhaust gas silencer (5R09)

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

When included in the scope of supply, the standard silencer is of the absorption type, equipped with a spark arrester. It is also provided with an explosion relief vent (option), a soot collector and a condense drain, but it comes without mounting brackets and insulation. The silencer should be mounted vertically.

The noise attenuation of the standard silencer is either 25 or 35 dB(A).

12. Turbocharger Cleaning

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

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

Wärtsilä 46DF 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

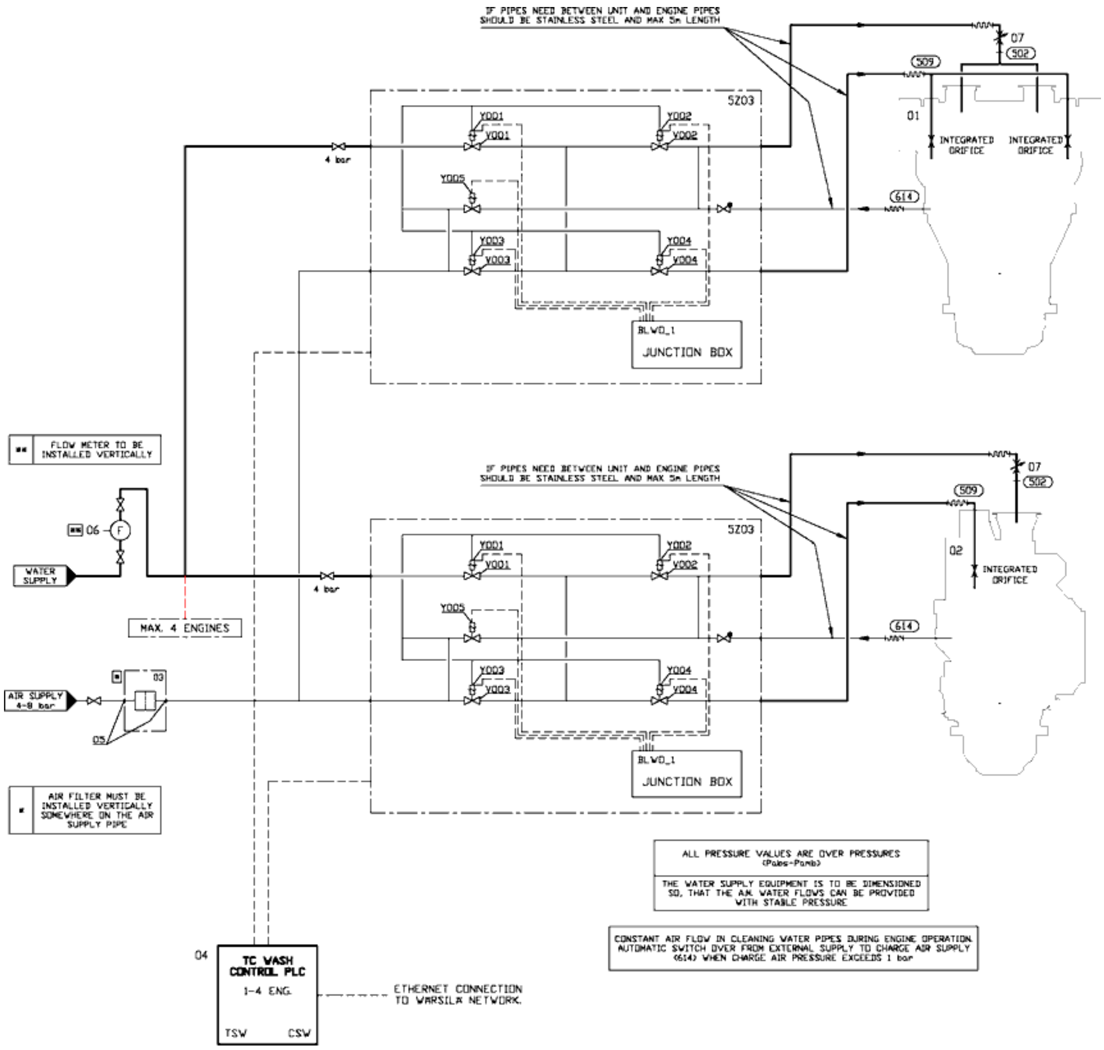


Fig 12-1 Turbocharger cleaning system (DAAF363744)

System components:	
01	W46DF
02	W46DF
5Z03	TC cleaning device
03	Air filter
04	TC wash unit control
05	Male stud GR18LR71
06	Flow meter / control (10-105 l/min)
07	Constant flow valve

Engine					Air
Engine	Turbocharger	Nominal water inlet press before cleaning device (bar)	Water inlet flow rate (l/min)	Water consumption/wash (l)	System air for scavening at low load (l/min)
6L46DF	A170-M	4	30	300	-
7L46DF	A170-M	4	30	300	-
8L46DF	A175-M	4	41	410	-
9L46DF	A175-M	4	41	410	-

12V46DF	2 * A170-M	4	60	600	-
14V46DF	2 * A170-M	4	60	600	-
16V46DF	2 * A175-M	-	-	-	-

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13. Exhaust Emissions

Exhaust emissions from the dual fuel engine mainly consist of nitrogen, carbon dioxide (CO2) and water vapour with smaller quantities of carbon monoxide (CO), sulphur oxides (SOx) and nitrogen oxides (NOx), partially reacted and non-combusted hydrocarbons and particulates.

13.1 Dual fuel engine exhaust components

Due to the high efficiency and the clean fuel used in a dual fuel engine in gas mode, the exhaust gas emissions when running on gas are extremely low. In a dual fuel engine, the air-fuel ratio is very high, and uniform throughout the cylinders. Maximum temperatures and subsequent NOx formation are therefore low, since the same specific heat quantity released to combustion is used to heat up a large mass of air. Benefitting from this unique feature of the lean-burn principle, the NOx emissions from the Wärtsilä DF engine is very low, complying with most existing legislation. In gas mode most stringent emissions of IMO, EPA and SECA are met, while in diesel mode the dual fuel engine is a normal diesel engine.

To reach low emissions in gas operation, it is essential that the amount of injected diesel fuel is very small. The Wärtsilä DF engines therefore use a "micro-pilot" with less than 1% diesel fuel injected at nominal load. Thus the emissions of SOx from the dual fuel engine are negligable. When the engine is in diesel operating mode, the emissions are in the same range as for any ordinary diesel engine, and the engine will be delivered with an EIAPP certificate to show compliance with the MARPOL Annex VI.

13.2 Marine exhaust emissions legislation

13.2.1 International Maritime Organization (IMO)

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

The IMO Tier 3 NOx emission standard will enter into force from year 2016. It will by then apply for new marine diesel engines that:

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

From 1.1.2021 onwards Baltic sea and North sea will be included in to IMO Tier 3 NOx requirements.

13.2.2 Other Legislations

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

13.3 Methods to reduce exhaust emissions

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

Diesel engine exhaust emissions can be reduced either with primary or secondary methods. The primary methods limit the formation of specific emissions during the combustion process.

The secondary methods reduce emission components after formation as they pass through the exhaust gas system.

For dual fuel engines same methods as mentioned above can be used to reduce exhaust emissions when running in diesel mode. In gas mode there is no need for scrubber or SCR.

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

14. Automation System

Wärtsilä Unified Controls - UNIC is a fully embedded and distributed engine management system, which handles all control functions on the engine; for example start sequencing, start blocking, fuel injection, cylinder balancing, knock control, 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 hardwired to the terminals in the main cabinet on the engine. Process data for alarm and monitoring are communicated over a Modbus TCP connection to external systems.

14.1 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.

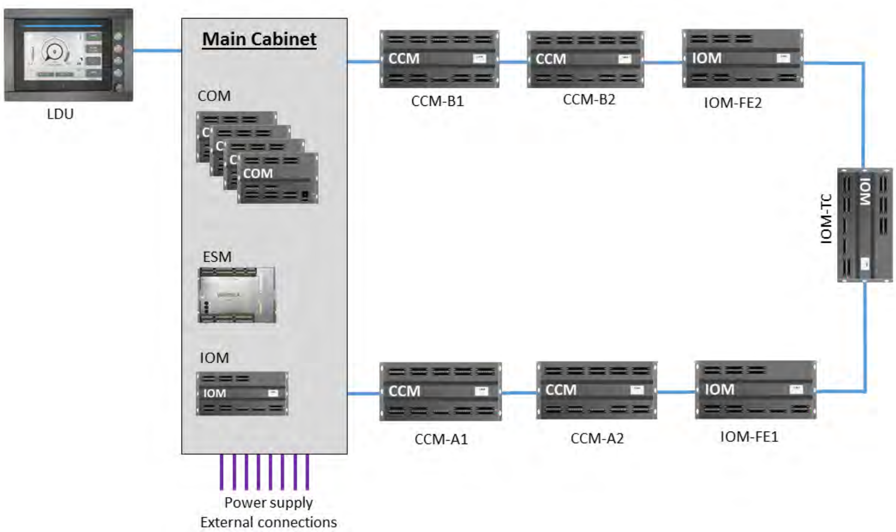

Fig 14-1 Architecture of UNIC

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.
IOM	Input/Output Module handles measurements and limited control functions in a specific area on the engine.
CCM	Cylinder Control Module handles fuel injection control and local measurements for the cylinders.
ESM	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 110 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

Ethernet switch and firewall/router are installed in a steel sheet cabinet for bulkhead mounting, protection class IP44.

14.2 Functions

14.2.1 Engine operating modes

The operator can select two different fuel operating modes:

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

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

It is possible to transfer a running engine from gas- into diesel operating mode. Below a certain load limit the engine can be transferred from diesel- into gas operating mode. The engine will automatically trip from gas- into diesel operating mode (gas trip) in several alarm situations. Request for diesel operating mode will always override request for gas operating mode.

The engine control system automatically forces the engine to backup operating mode (regardless of operator choice of operating mode) in two cases:

- Pilot fuel injection system related fault is detected (pilot trip)
- Engine is started while the blackout start mode signal (from external source) is active

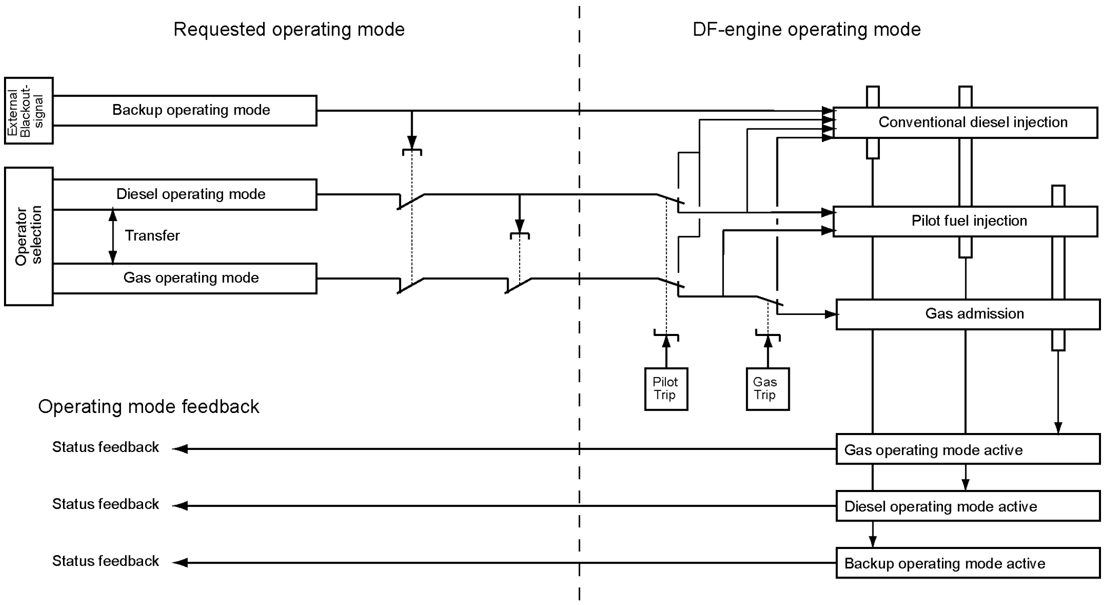

Fig 14-3 Principle of engine operating modes

14.2.2 Start

14.2.2.1 Start blocking

Starting is inhibited by the following functions:

- Turning device engaged
- Pre-lubricating pressure low (override if black-out input is high and within last 30 minutes after the pressure has dropped below the set point of 0.8 bar)
- Stop signal to engine activated (safety shut-down, emergency stop, normal stop)
- External start block active
- Exhaust gas ventilation not performed
- HFO selected or fuel oil temperature > 70°C (Gas mode only)
- Charge air shut-off valve closed (optional device)

14.2.2.2 Start in gas operating mode

If the engine is ready to start in gas operating mode the output signals "engine ready for gas operation" (no gas trips are active) and "engine ready for start" (no start blockings are active) are activated. In gas operating mode the following tasks are performed automatically:

- A GVU gas leakage test
- The starting air is activated
- Pilot fuel injection and pilot fuel pressure control is enabled
- A combustion check (verify that all cylinders are firing)
- Gas admission is started and engine speed is raised to nominal

The start mode is interrupted in case of abnormalities during the start sequence. The start sequence takes about 1.5 minutes to complete.

14.2.2.3 Start in diesel operating mode

When starting an engine in diesel operating mode the GVU check is omitted. The pilot combustion check is performed to ensure correct functioning of the pilot fuel injection in order to enable later transfer into gas operating mode. The start sequence takes about one minute to complete.

14.2.2.4 Start in blackout mode

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

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

14.2.3 Gas/diesel transfer control

14.2.3.1 Transfer from gas- to diesel-operating mode

The engine will transfer from gas to diesel operating mode at any load within 1s. This can be initiated in three different ways: manually, by the engine control system or by the gas safety system (gas operation mode blocked).

14.2.3.2 Transfer from diesel- to gas-operating mode

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

Fuel transfers to gas usually takes about 2 minutes to complete, in order to minimize disturbances to the gas fuel supply systems.

The engine can run in backup operating mode in case the engine has been started with the blackout start input active or a pilot trip has occurred. A transfer to gas operating mode can only be done after a combustion check, which is done by restarting the engine.

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

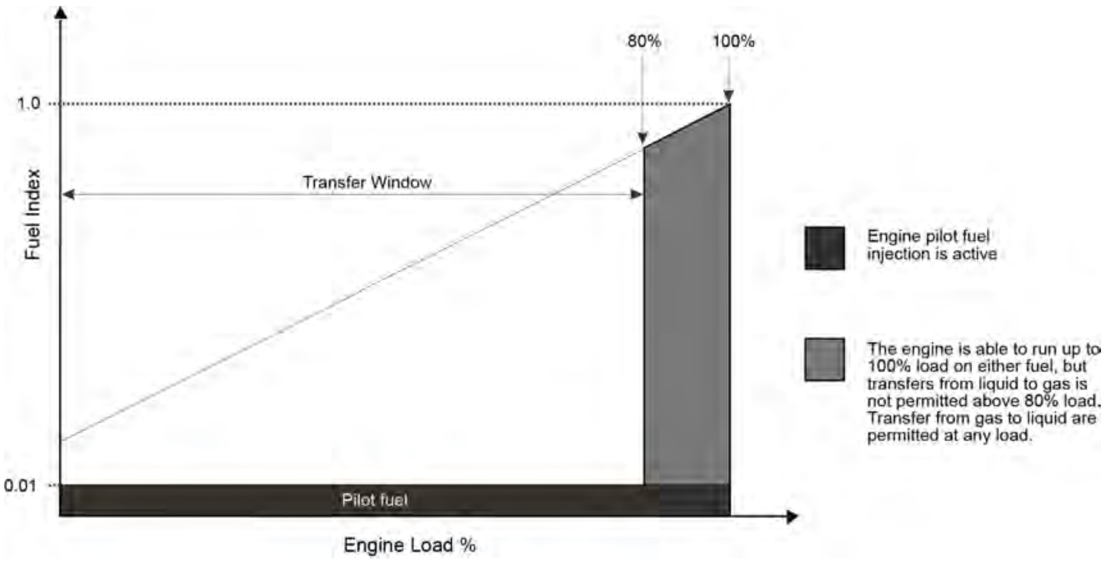

Fig 14-4 Operating modes are load dependent

14.2.3.3 Points for consideration when selecting fuels

When selecting the fuel operating mode for the engine, or before transferring between operating modes, the operator should consider the following:

- To prevent an overload of the gas supply system, transfer one engine at a time to gas operating mode
- Before a transfer command to gas operating mode is given to an engine, the PMS or operator must ensure that the other engines have enough ‘spinning reserve’ during the transfers. This because the engine may need to be unloaded below the upper transfer limit before transferring
- If engine load is within the transfer window, the engine will be able to switch fuels without unloading
- Whilst an engine is transferring, the starting and stopping of heavy electric consumers should be avoided

14.2.4 Stop, shutdown and emergency stop

14.2.4.1 Stop mode

Before stopping the engine, the control system shall first unload the engine slowly (if the engine is loaded), and after that open the generator breaker and send a stop signal to the engine.

Immediately after the engine stop signal is activated in gas operating mode, the GVU performs gas shut-off and ventilation. The pilot injection is active during the first part of the deceleration in order to ensure that all gas remaining in engine is burned.

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

14.2.4.2 Shutdown mode

Shutdown mode is initiated automatically as a response to measurement signals.

In shutdown mode the clutch/generator breaker is opened immediately without unloading. The actions following a shutdown are similar to normal engine stop.

Shutdown mode must be reset by the operator and the reason for shutdown must be investigated and corrected before re-start.

14.2.4.3 Emergency stop mode

The sequence of engine stopping in emergency stop mode is similar to shutdown mode, except that also the pilot fuel injection is de-activated immediately upon stop signal.

Emergency stop is the fastest way of manually shutting down the engine. In case the emergency stop push-button is pressed, the button is automatically locked in pressed position.

To return to normal operation the push button must be pulled out and alarms acknowledged.

14.2.5 Speed control

14.2.5.1 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*.

14.2.5.2 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 46DF (6L,7L,8L)	3 x 400/440	50 / 60	2.2/2.6	5
Wärtsilä 46DF (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.

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

14.5 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 in diesel mode 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 ±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.

There can be significant load swings between parallel generators in gas engine installations (short peaks, frequency >1.5 Hz). This is a harmless phenomenon, which is caused by cycle to cycle variations in cylinder pressure when the engines run on gas fuel. Load limitation and load reduction functions should therefore act on the average generator load, not short spikes on individual generators. It is however recommended to monitor also network frequency, because it is possible that an engine loses power, but not to the extent that the generator trips on reverse power. In such a situation the average power is on an acceptable level, but the parallel engines might still be overloaded.

The load should be kept as stable as possible while an engine is transferring from diesel to gas mode. Since the engines are running in speed control, they will all respond to rapid load changes. The load variations on a transferring engine can be significantly reduced (but not totally eliminated) by running the transferring engine in speed droop and the parallel engines in isochronous load sharing mode.

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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^2. (A typical conservative value is P_{tot} 3.5 N/mm^2).

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.

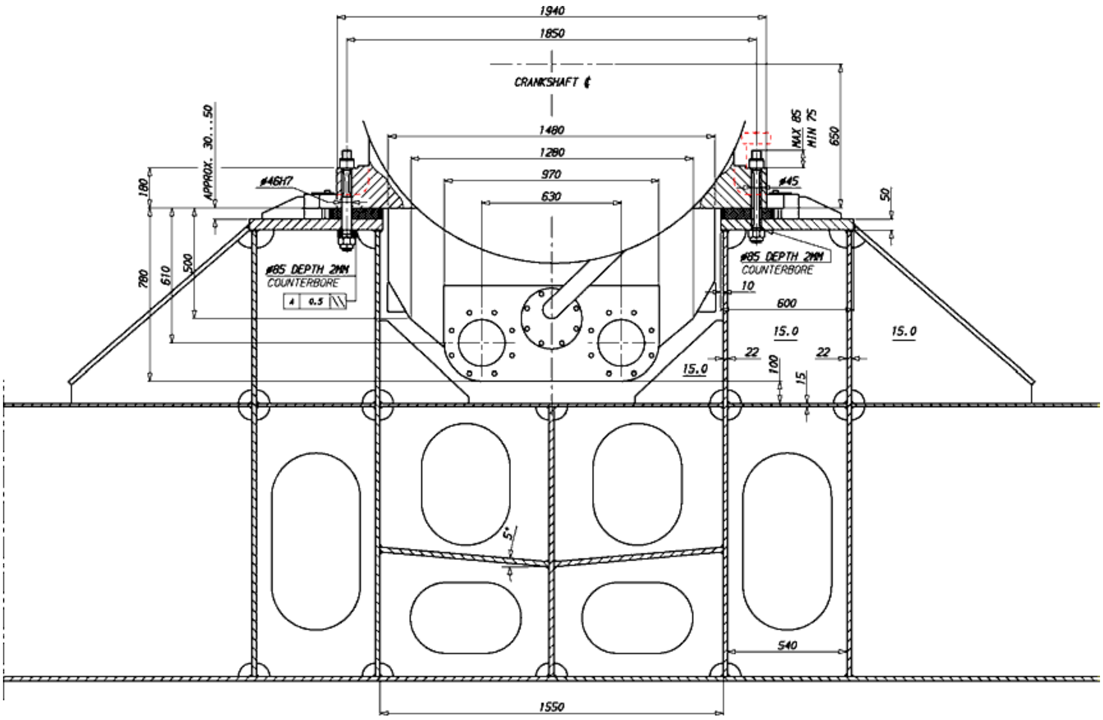


Fig 15-1 **Seating and fastening, rigidly mounted in-line engine on resin chocks (DAAE012078a)**

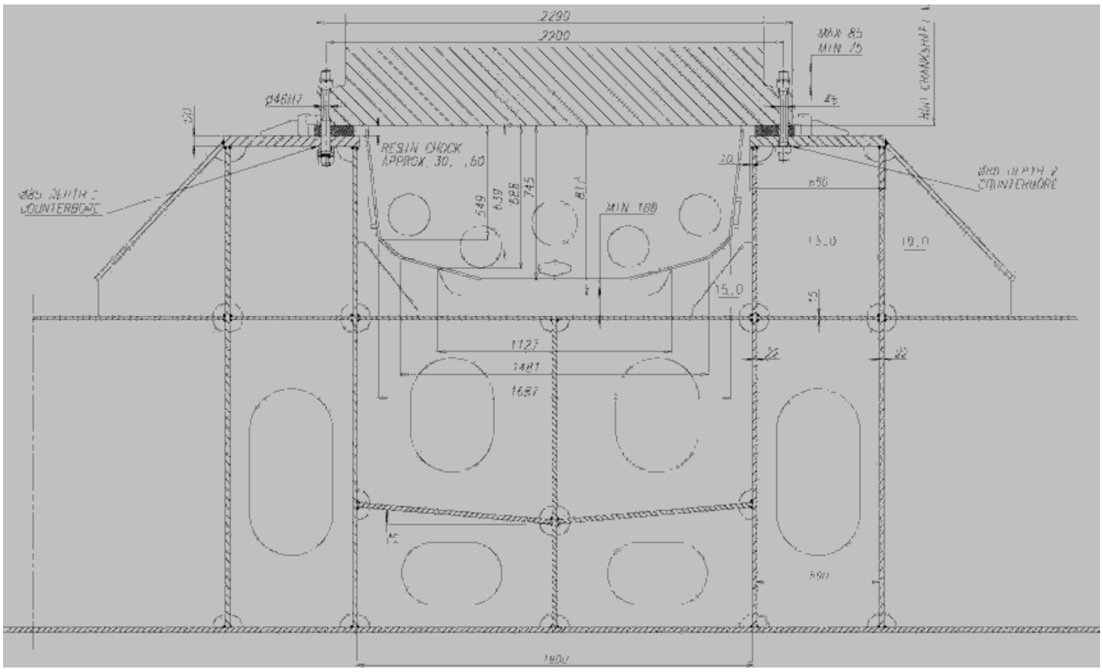


Fig 15-2 **Seating and fastening, rigidly mounted V-engine on resin chocks (DAAE074226A)**

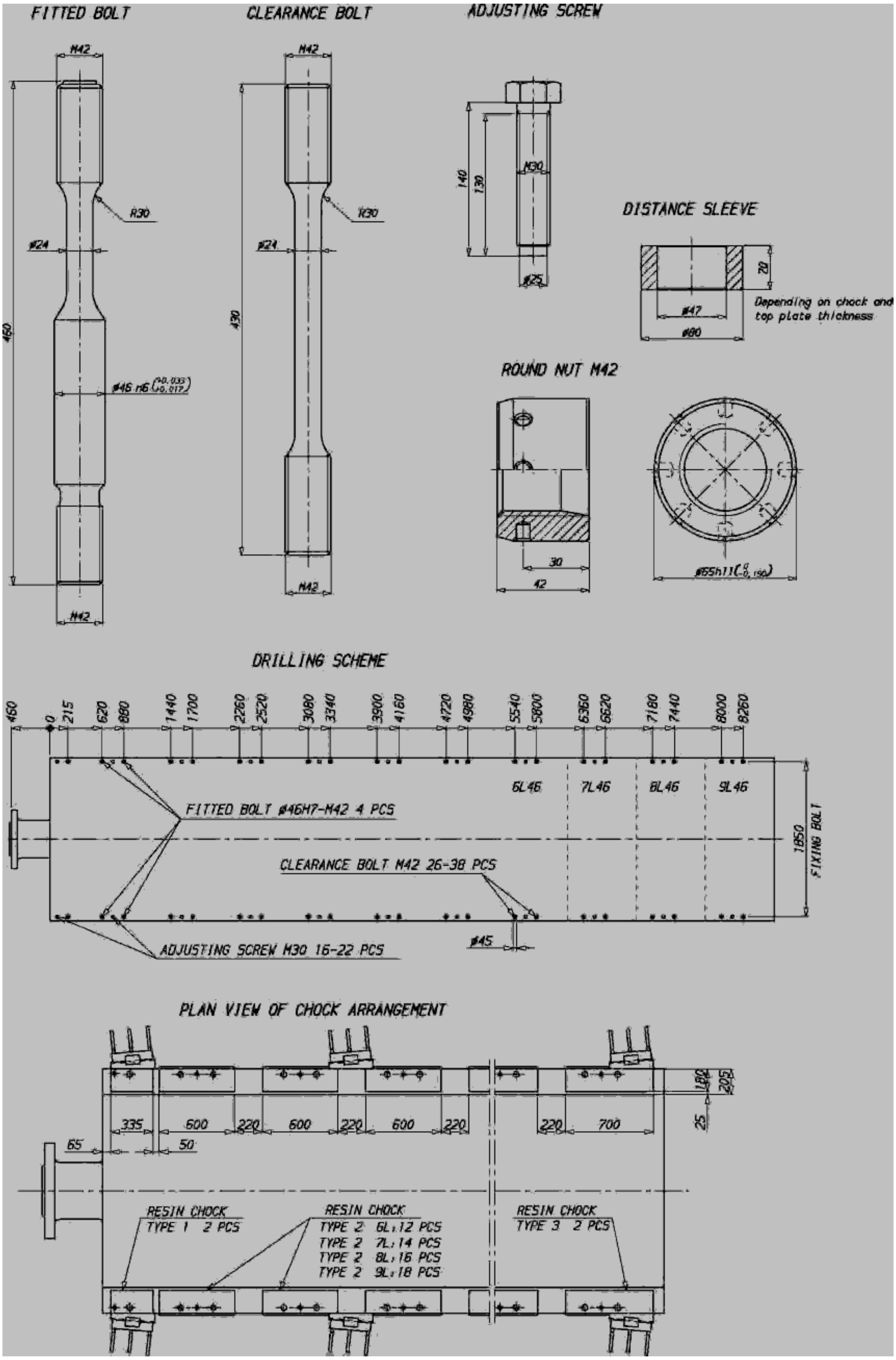
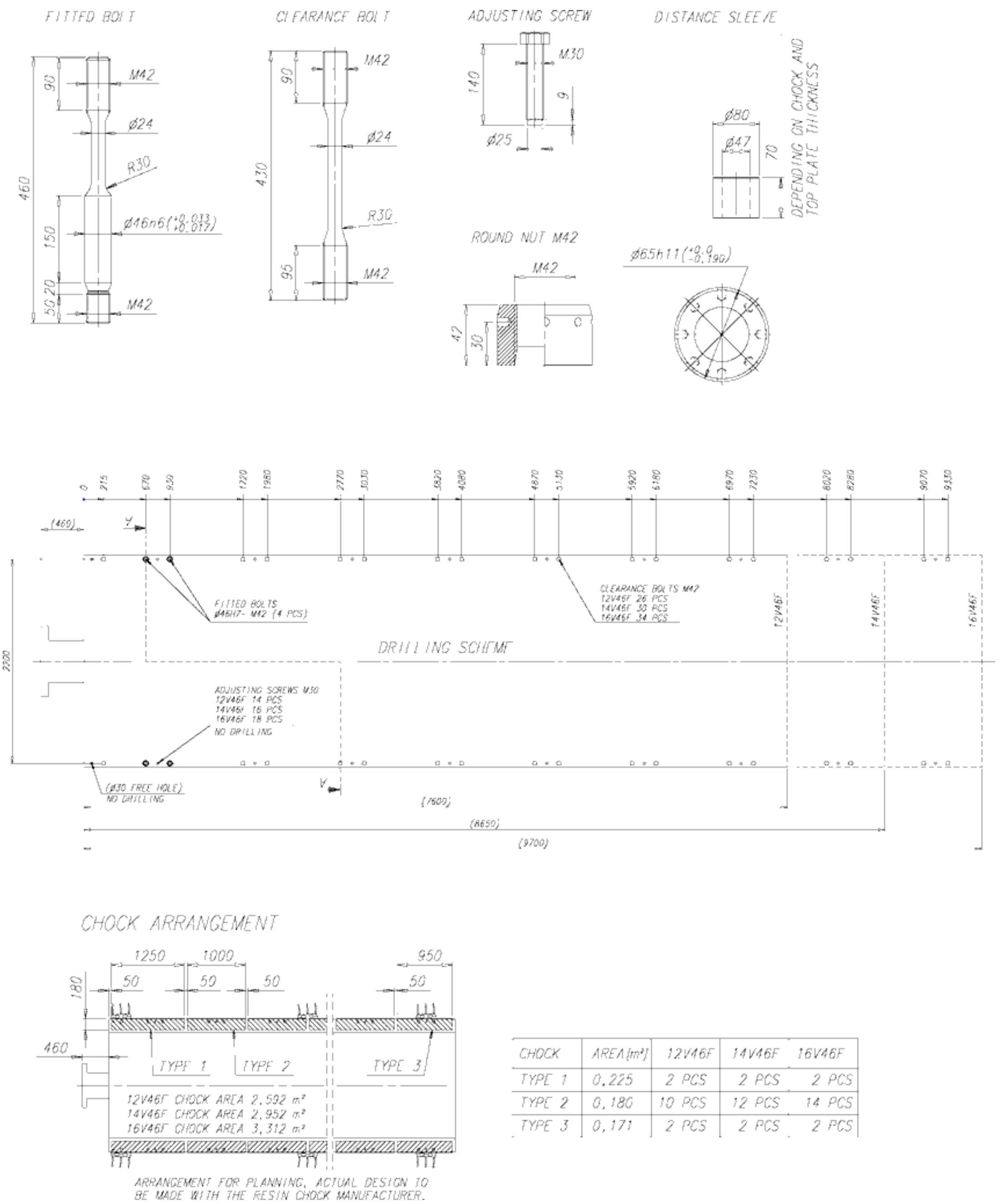


Fig 15-3 Seating and fastening, rigidly mounted in-line engine on resin chocks (DAAE012078a)



CHOCK	AREA [m²]	12V46F	14V46F	16V46F
TYPE 1	0,225	2 PCS	2 PCS	2 PCS
TYPE 2	0,180	10 PCS	12 PCS	14 PCS
TYPE 3	0,171	2 PCS	2 PCS	2 PCS

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 17.

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 8L46DF engines. For other cylinder configurations a speed range of 400-600 rpm is generally available.

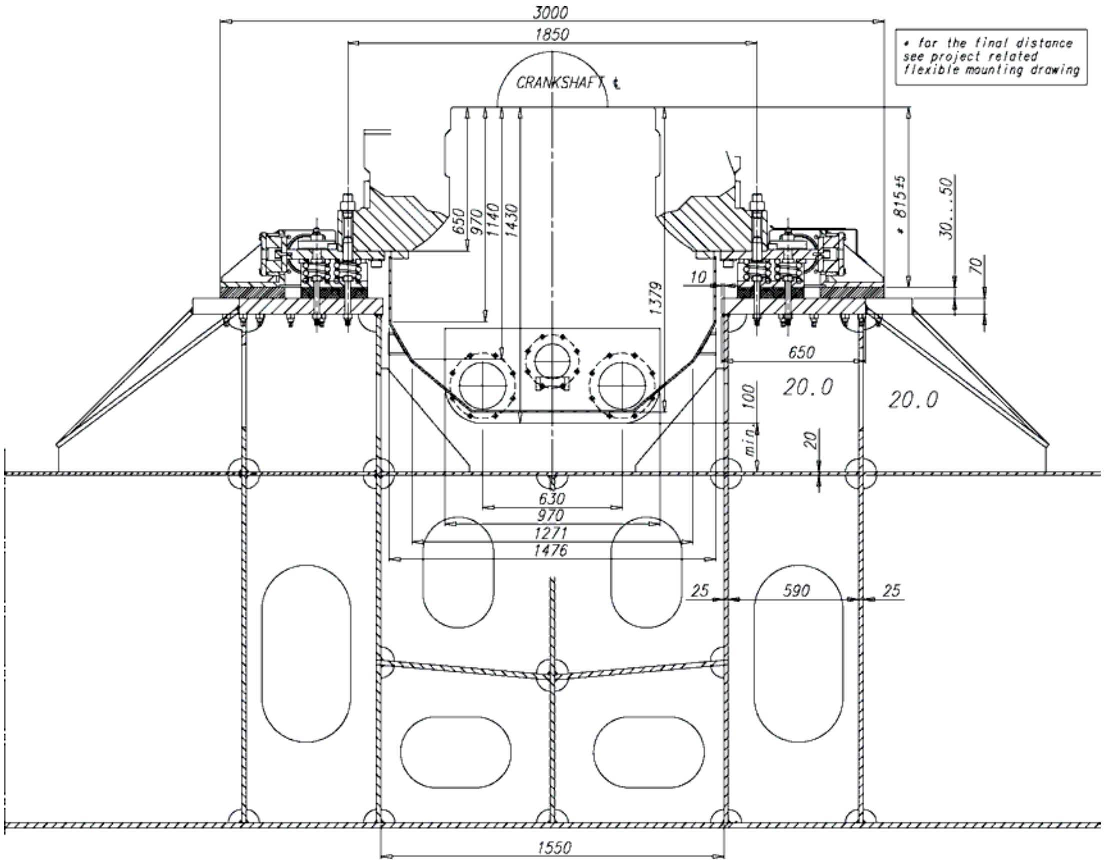


Fig 15-5 Seating and fastening, resiliently mounted in-line engine (DAAE029031 A)

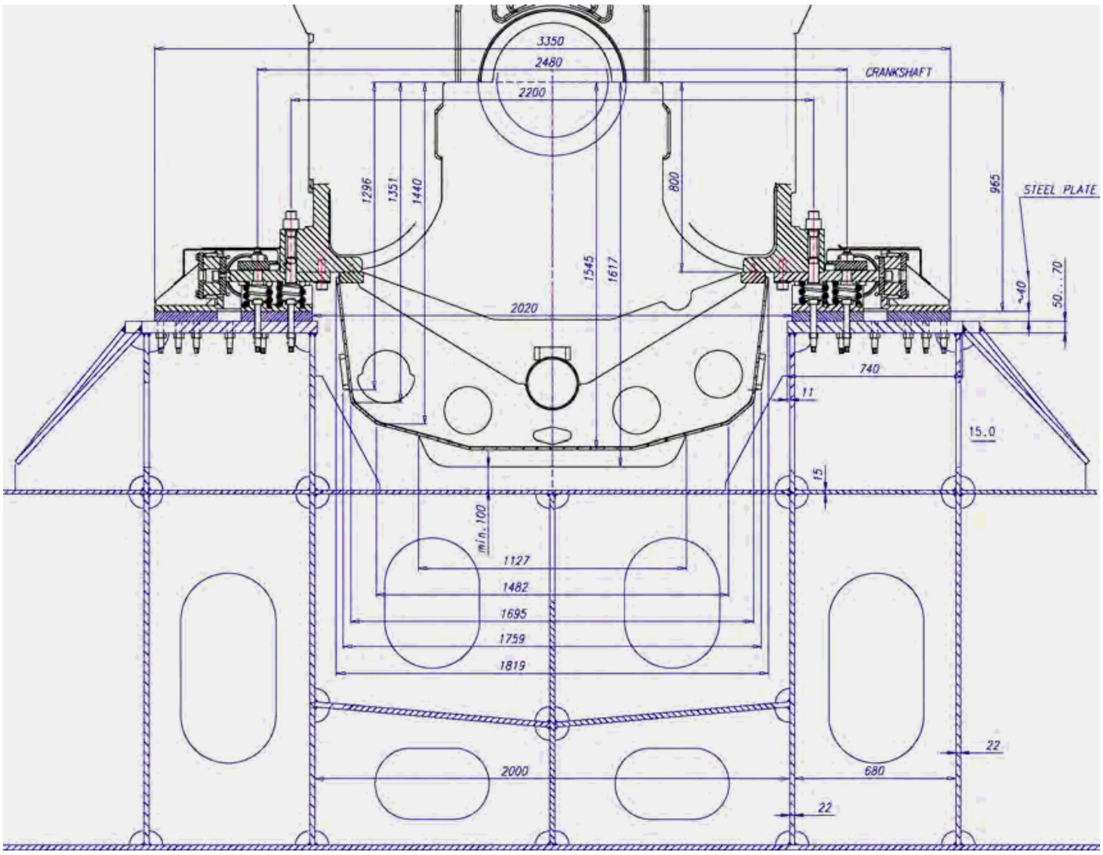


Fig 15-6 Seating and fastening, resiliently mounted V-engine (DAAE057412)

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.

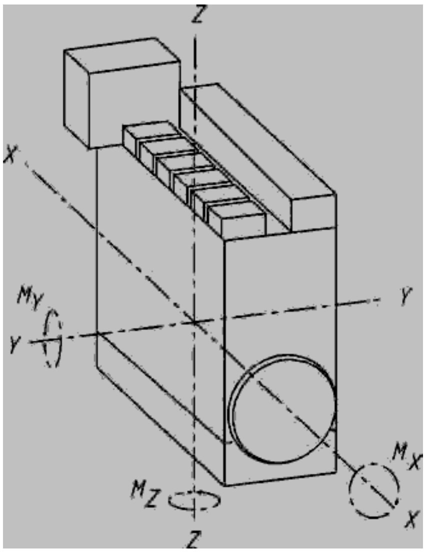


Fig 16-1 Coordinate system

Table 16-1 External forces

Engine	Speed [rpm]	Frequency [Hz]	F_Y [kN]	F_Z [kN]
8L46DF	600	40	–	12.3
– forces are zero or insignificant				

Table 16-2 External couples

Engine	Speed [rpm]	Frequency [Hz]	M_Y [kNm]	M_Z [kNm]	Frequency [Hz]	M_Y [kNm]	M_Z [kNm]	Frequency [Hz]	M_Y [kNm]	M_Z [kNm]
7L46DF	600	10	63	63	20	104.2	– [1]	40	12.4	–

Engine	Speed [rpm]	Frequency [Hz]	M_Y [kNm]	M_Z [kNm]	Frequency [Hz]	M_Y [kNm]	M_Z [kNm]	Frequency [Hz]	M_Y [kNm]	M_Z [kNm]
9L46DF	600	10	30	30	20	163	–	40	11	–
14V46DF	600	10	103	103	20	155	86	40	5	13
14V46DF[2)]	600	10	–	–	20	155	86	40	5	13

[1)] *zero or insignificant value marked as* "-"

[2)] *balancing device adopted*

16.2 Torque variations

Table 16-3 Torque variation at full load

Engine	Speed [rpm]	Frequency [Hz]	M_X [kNm]	Frequency [Hz]	M_X [kNm]	Frequency [Hz]	M_X [kNm]
6L46DF	600	30	67	60	65	90	16
7L46DF	600	35	221	70	47	105	10
8L46DF	600	40	202	80	34	120	6
9L46DF	600	45	185	90	24	135	4
12V46DF	600	30	35	60	112	90	22
14V46DF	600	30	20	60	90	90	2
16V46DF	600	40	65	80	63	120	6

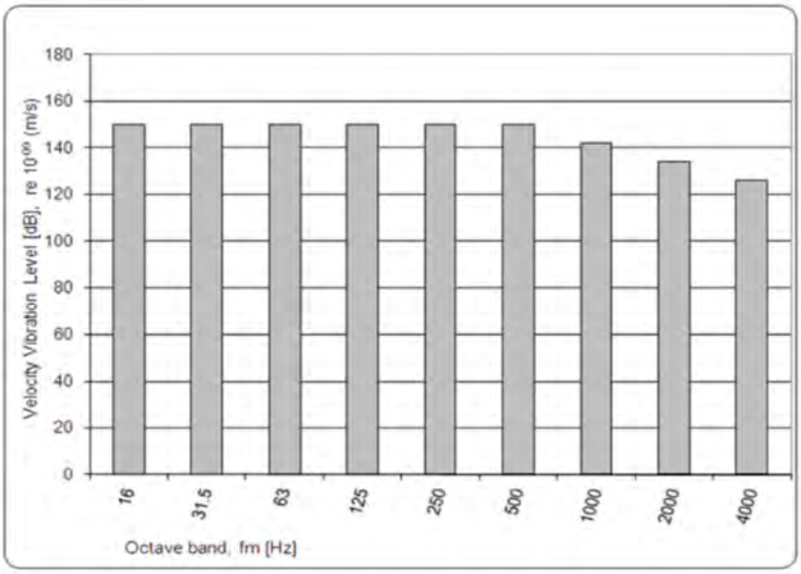
16.3 Mass moments of inertia

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^2]
6L46DF	3620
7L46DF	2920
8L46DF	4160
9L46DF	4110
12V46DF	4660
14V46DF	5350
16V46DF	6100

16.4 Structure borne noise



Octave fm [Hz]	Lv, (dB)
16	150
31.5	150
63	150
125	150
250	150
500	150
1000	142
2000	134
4000	126

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.

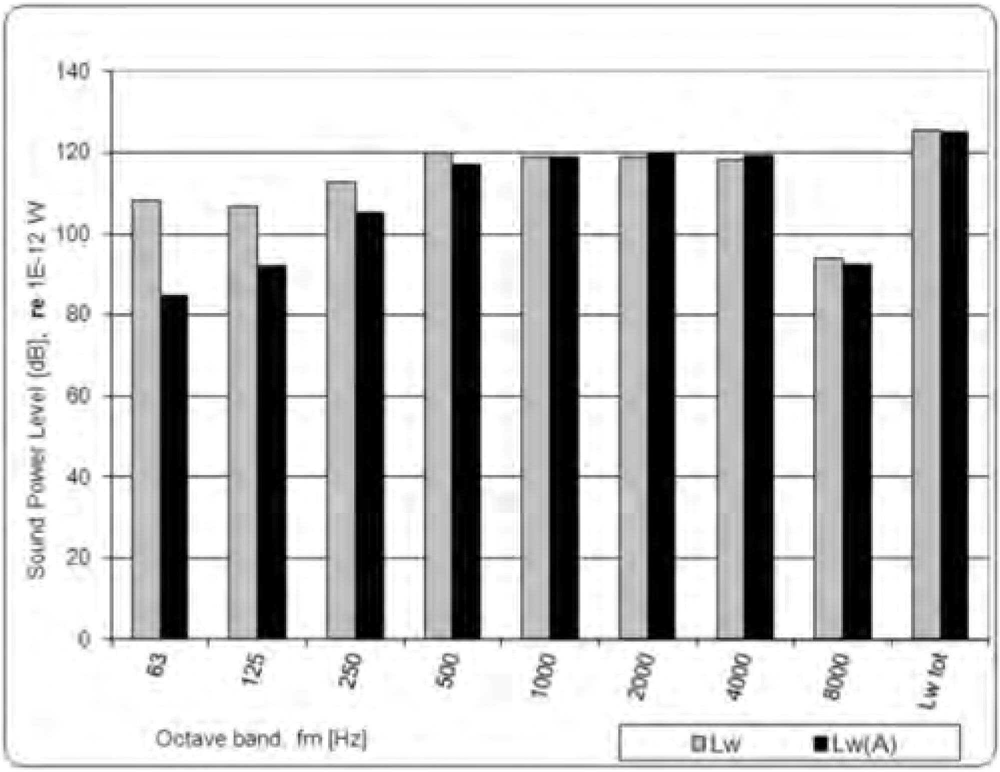


Fig 16-3 Typical sound power levels of engine noise, W6L46DF

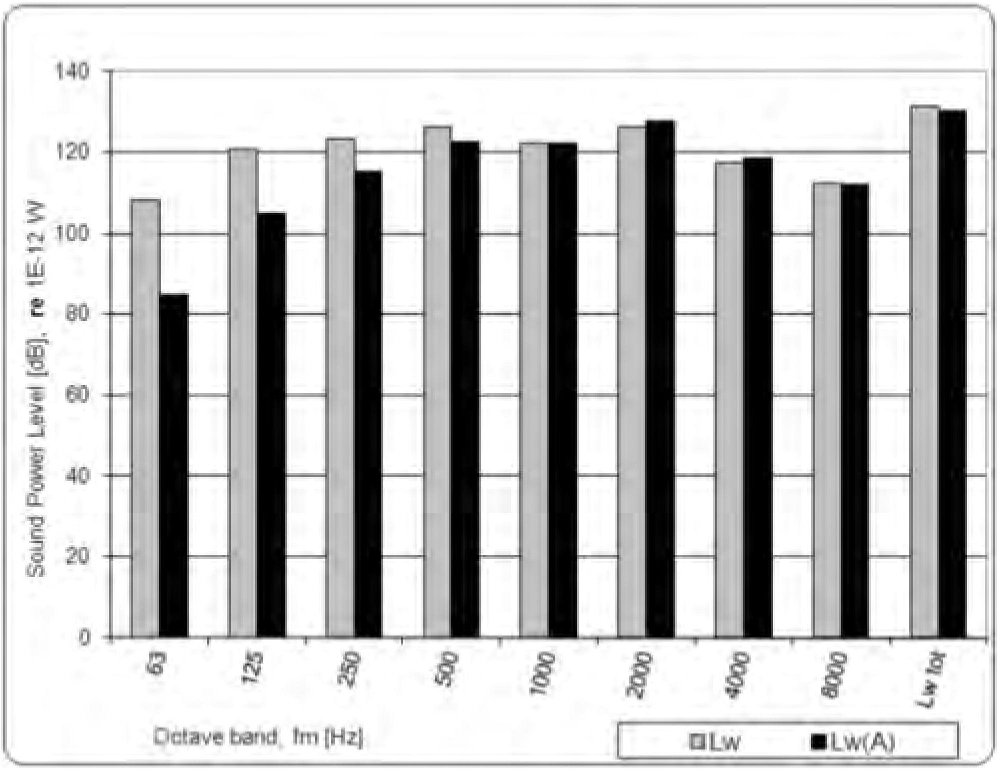


Fig 16-4 Typical sound power levels of engine noise, W12V46DF

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.

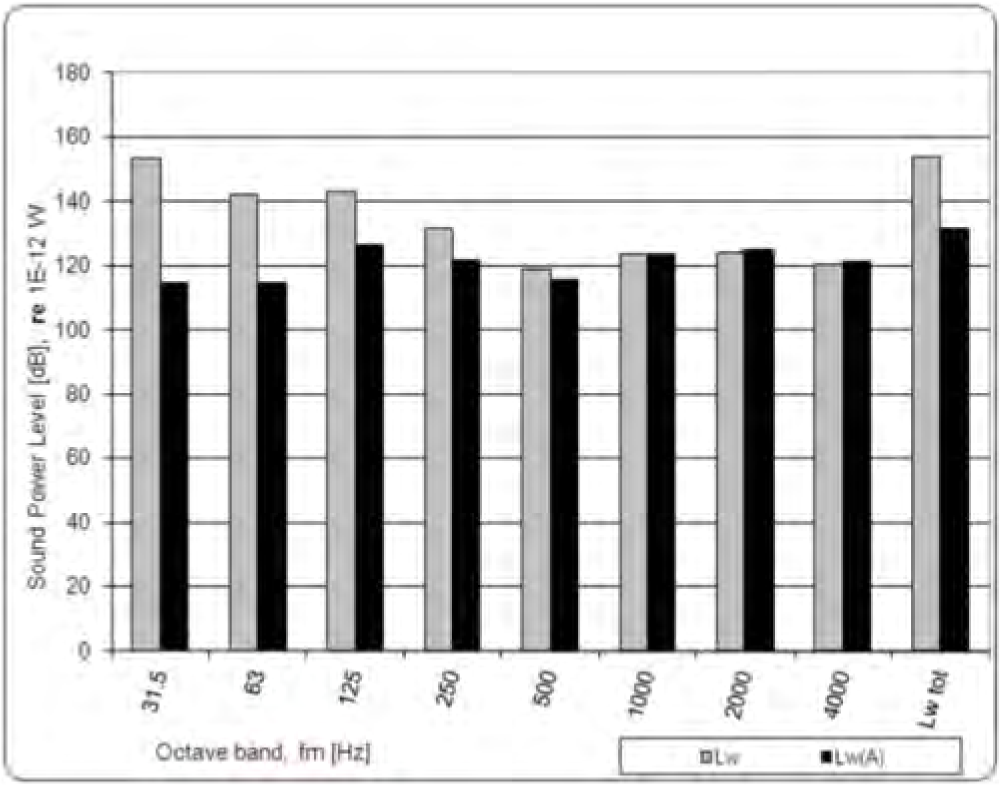


Fig 16-5 Typical sound power levels of exhaust noise, W6L46DF

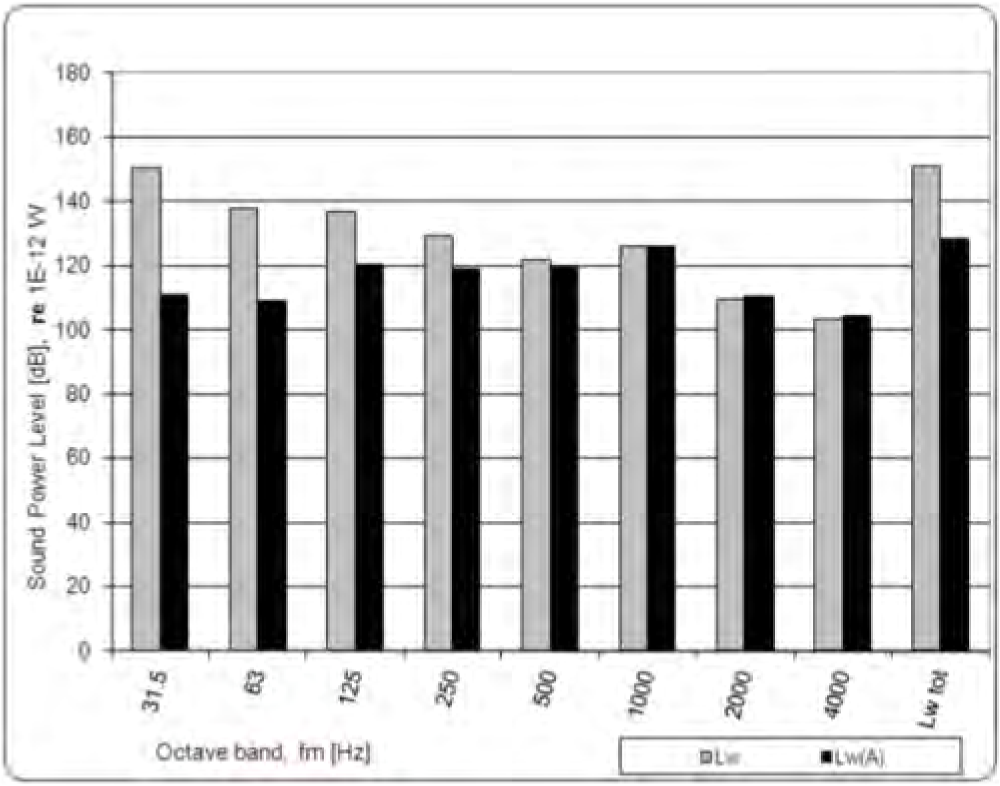


Fig 16-6 Typical sound power levels of exhaust noise, W12V46DF

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17. Power Transmission

17.1 Flexible coupling

The power transmission of propulsion engines is accomplished through a flexible coupling or a combined flexible coupling and clutch mounted on the flywheel. The crankshaft is equipped with an additional shield bearing at the flywheel end. Therefore also a rather heavy coupling can be mounted on the flywheel without intermediate bearings.

The type of flexible coupling to be used has to be decided separately in each case on the basis of the torsional vibration calculations.

In case of two bearing type generator installations a flexible coupling between the engine and the generator is required.

17.2 Clutch

In dual fuel engine installations with mechanical drive, it must be possible to disconnect the propeller shaft from the engine by using a clutch. The use of multiple plate hydraulically actuated clutches built into the reduction gear is recommended.

A clutch is also required when two or more engines are connected to the same driven machinery such as a reduction gear.

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

17.3 Shaft locking device

To permit maintenance of a stopped engine clutches must be installed in twin screw vessels which can operate on one shaft line only. A shaft locking device should also be fitted to be able to secure the propeller shaft in position so that wind milling is avoided. This is necessary because even an open hydraulic clutch can transmit some torque. Wind milling at a low propeller speed (<10 rpm) can due to poor lubrication cause excessive wear of the bearings.

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

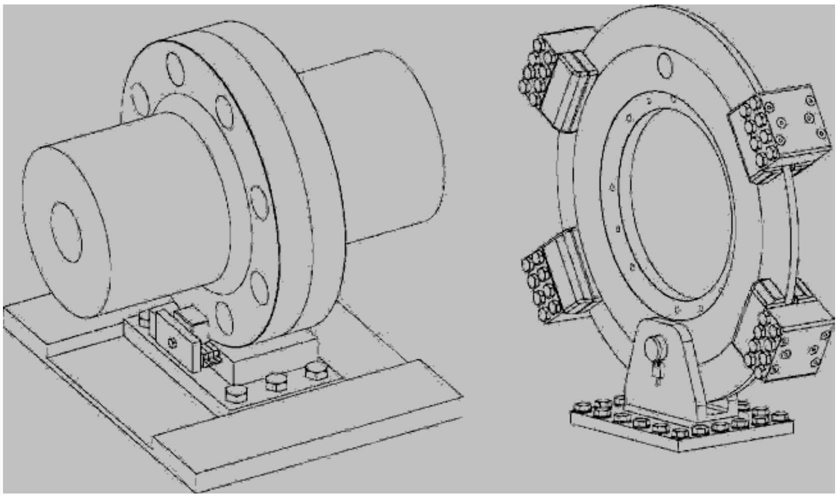

Fig 17-1 Shaft locking device and brake disc with calipers

17.4 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

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18. Engine Room Layout

18.1 Crankshaft distances

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

18.1.1 In-line engines

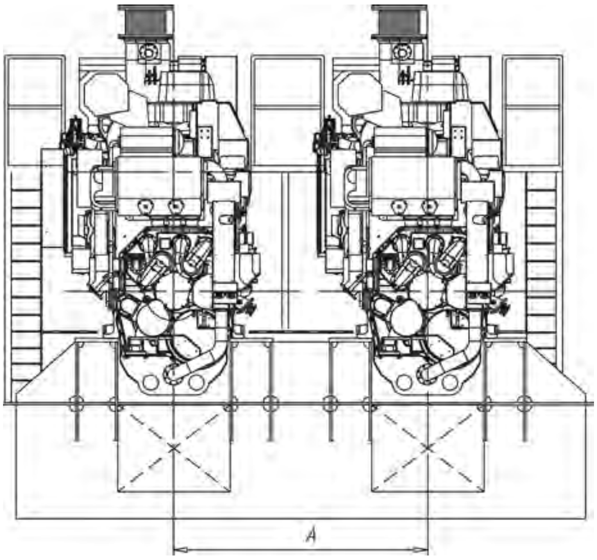

Fig 18-1 Crankshaft distances, in-line engines (DAAR039225)

Engine type	Min. A [mm]
W 6L46DF	3600
W 7L46DF	3600
W 8L46DF	3600
W 9L46DF	3600

18.1.2 V-engines

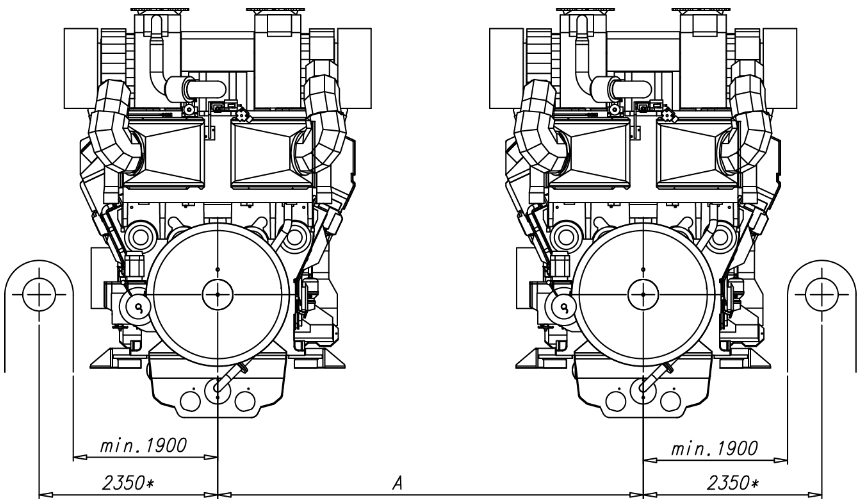

Fig 18-2 Crankshaft distances, V-engines (DAAR038996)

Engine type	Min. A [mm]
W 12V46DF	5900
W 14V46DF	5900
W 16V46DF	6200

18.1.3 Four-engine installations

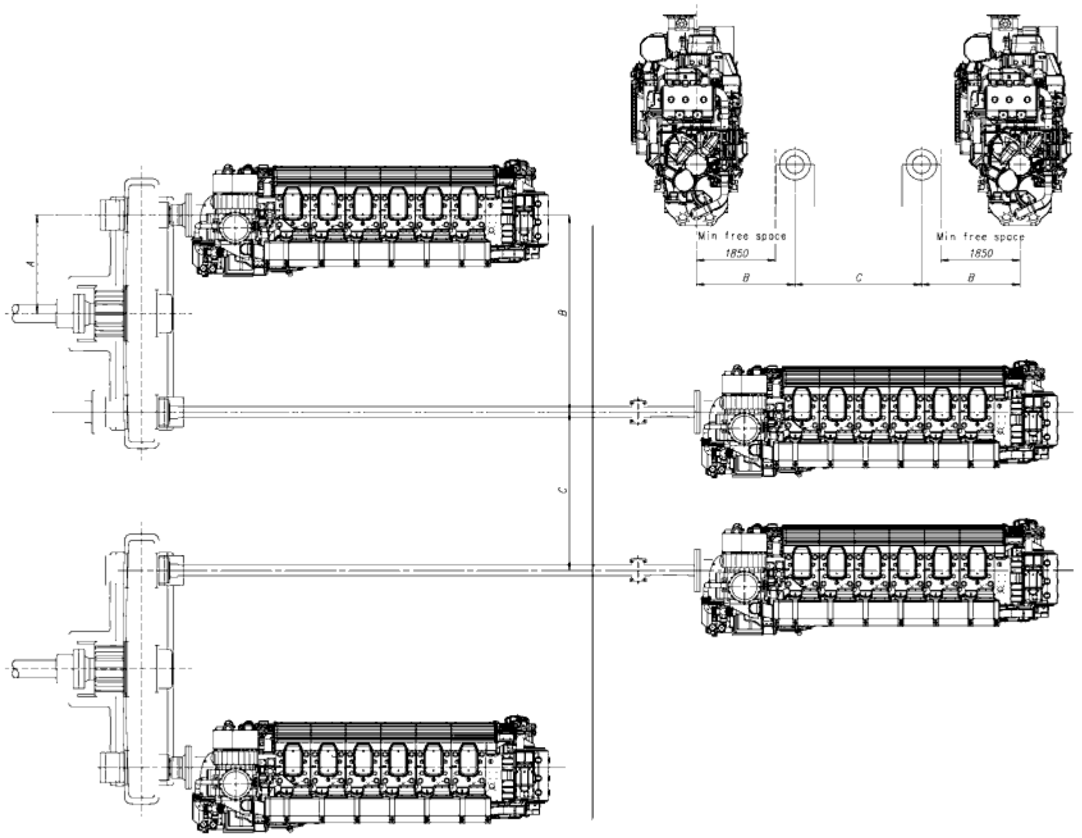

Fig 18-3 Main engine arrangement, 4 x L46DF (DAAR039322)

Engine type	A [mm]	B [mm]	C [mm]
6L46DF	1100	2200	3600
7L, 8L, 9L46DF	1100	2200	3600

1) 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.

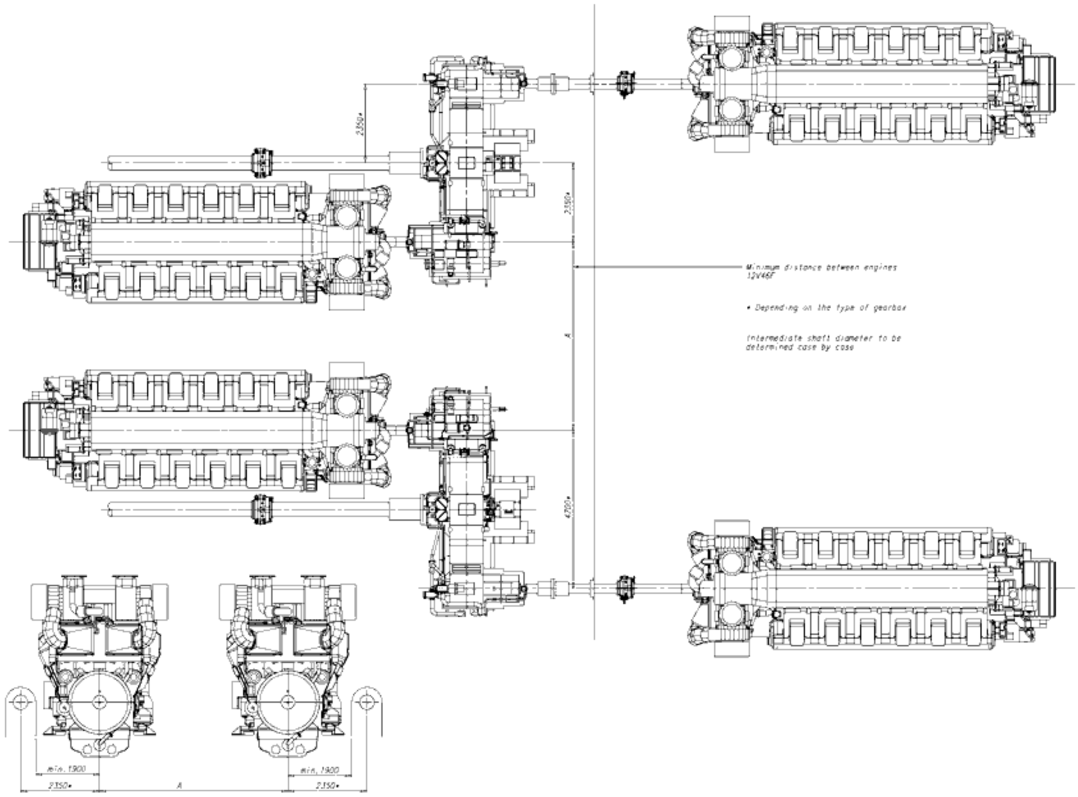

Fig 18-4 Main engine arrangement, 4 x V46DF (DAAR038996)

Engine type	Turbocharger	A
12V46DF	ABB-A170	5900
14V46DF	ABB-A170	5900
16V46DF	ABB-A175	6200

Engine type	A [mm] 1)	B [mm] 2)	C [mm]
12V46DF	5900	3200	min. 1900
14V46DF	5900	3200	min. 1900
16V46DF	6200	3200	min. 1900

1) Minimum distance between engines.

2) Depending on the type of gearbox.

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 dismounting dimensions of engine components, and space requirement of some special tools. It is especially important that no obstructive structures are built next to engine driven pumps, as well as camshaft and crankcase doors.

However, also at locations where no space is required for dismounting of engine parts, a minimum of 1000 mm free space is recommended for maintenance operations everywhere around the engine.

18.2.2 Engine room height and lifting equipment

The required engine room height is determined by the transportation routes for engine parts. If there is sufficient space in transverse and longitudinal direction, there is no need to transport engine parts over the rocker arm covers or over the exhaust pipe and in such case the necessary height is minimized.

Separate lifting arrangements are usually required for overhaul of the turbocharger since the crane travel is limited by the exhaust pipe. A chain block on a rail located over the turbocharger axis is recommended.

18.2.3 Maintenance platforms

In order to enable efficient maintenance work on the engine, it is advised to build the maintenance platforms on recommended elevations. The width of the platforms should be at minimum 800 mm to allow adequate working space. The surface of maintenance platforms should be of non-slippery material (grating or chequer plate).

NOTE

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

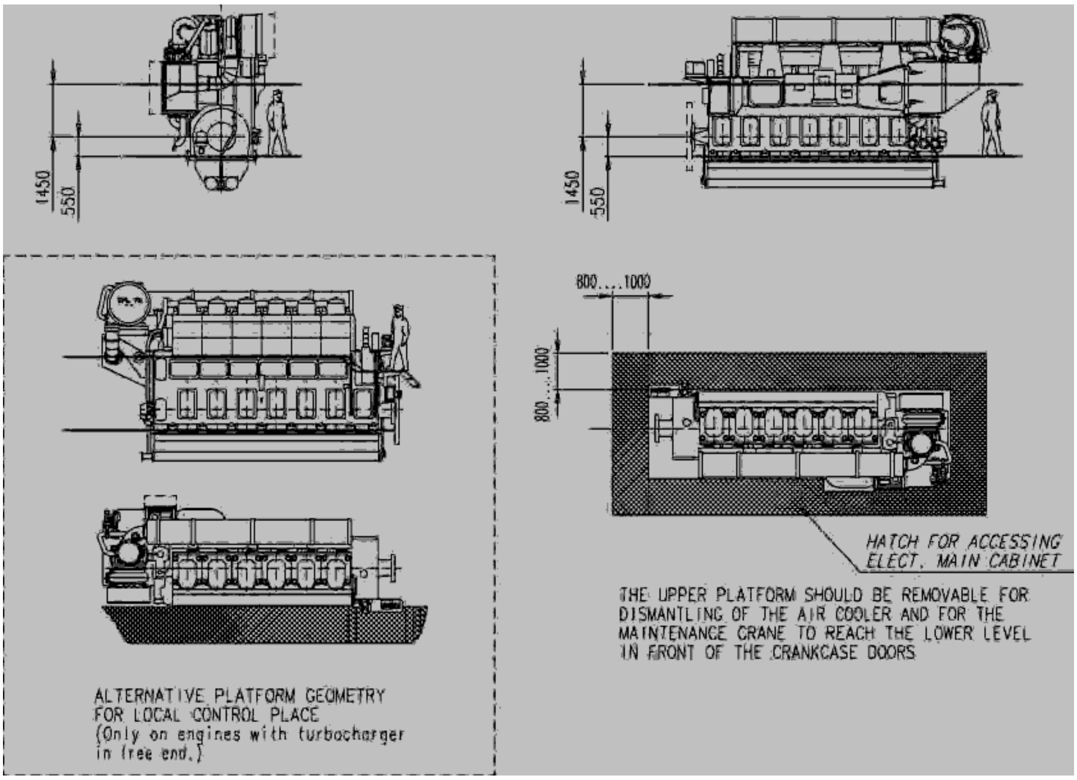

Fig 18-5 **Maintenance platforms, in-line engine (3V69C0246a)**

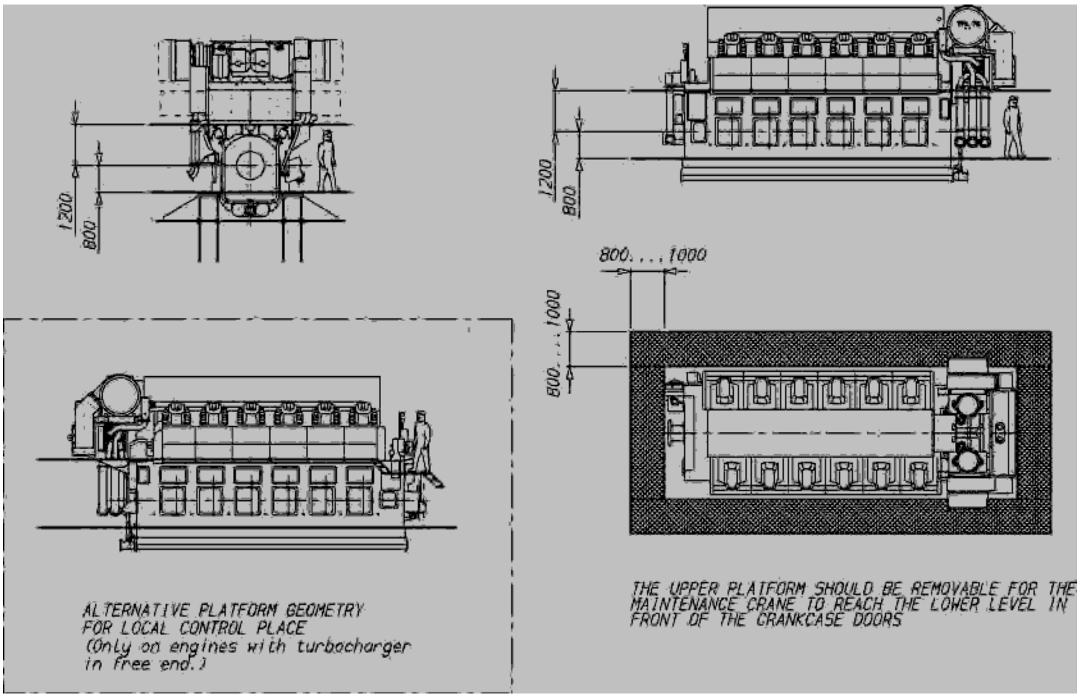

Fig 18-6 Maintenance platforms, V-engine (3V69C0244)

18.3 Transportation and storage of spare parts and tools

Transportation arrangements from engine room to workshop and storage locations must be provided for heavy engine components, for example by means of several chain blocks on rails, or by suitable routes for trolleys.

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

It is recommended to store heavy engine components on a slightly elevated and adaptable surface, e.g. wooden pallets. All engine spare parts should be protected from corrosion and excessive vibration.

18.4 Required deck area for service work

During engine overhaul a free deck area is required for cleaning and storing dismantled components. The size of the service area depends on the overhaul strategy , e.g. one cylinder at time or the whole engine at time. The service area should be a plain steel deck dimensioned to carry the weight of engine parts.

18.4.1 Service space requirement for the in-line engine

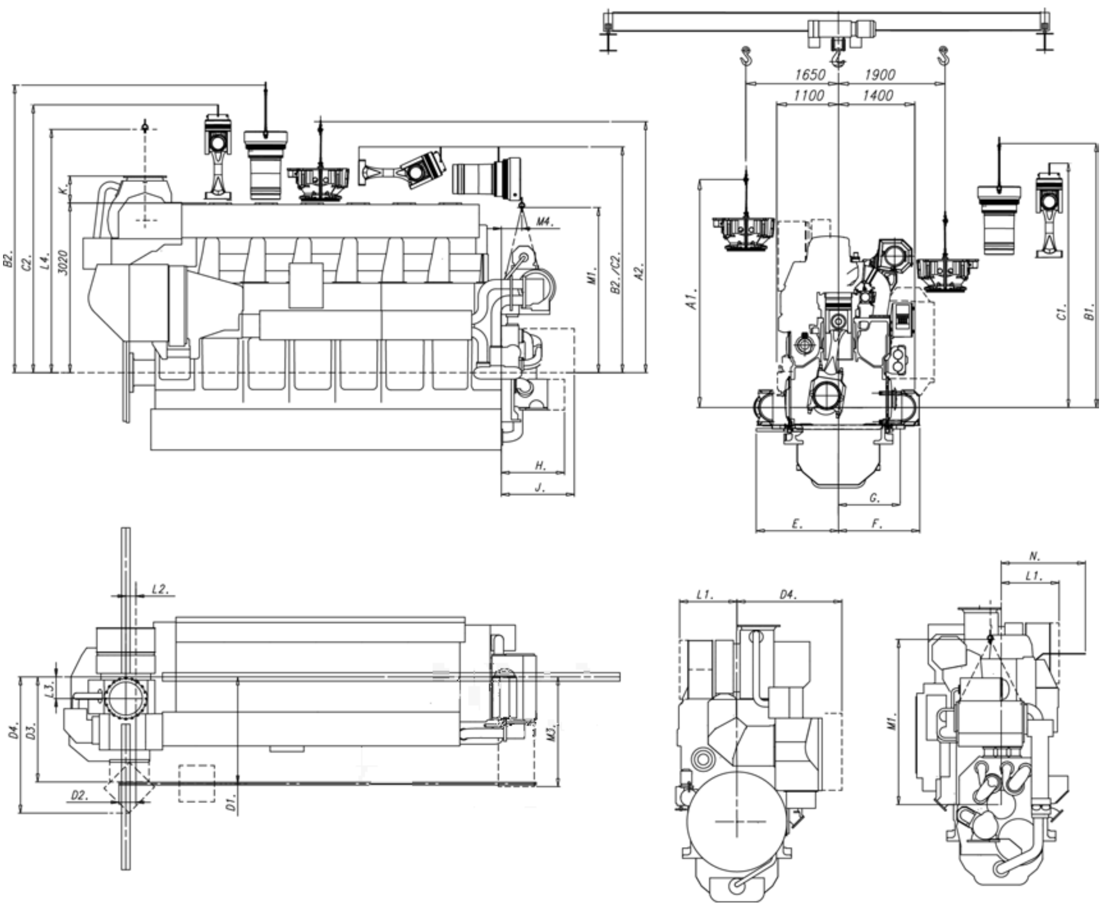

Fig 18-7 Service space requirement (DAAR038989)

Services spaces in mm		6-7L46DF	8L-9L46DF
A1	Height needed for overhauling cylinder head over accumulator	4060	
A2	Height needed for transporting cylinder head freely over adjacent cylinder head covers	4470	
B1	Height needed for overhauling cylinder liner	4700	
B2	Height needed for transporting cylinder liner freely over adjucent cylinder head covers	4020 / 5120	
C1	Height needed for overhauling piston and connecting rod	4350	
C2	Height needed for transporting piston and connecting rod freely over adjacent cylinder head covers	4020 / 4770	
D1	Recommended location of rail for removing the CAC on engine rear side	1900	2100
D2	Recommended location of starting point for rails	400	
D3	Minimum width needed for CAC overhauling	1950	2300
D4	Minimum width needed for turning of overhauled CAC	2120	2510
E	Width needed for removing main bearing side screw	1470	
F	Width needed for dismantling connecting rod big end bearing	1450	
G	Width of lifting tool for hydraulic cylinder / main bearing nuts	1100	
H	Distance needed to dismantle lube oil pump	1125	
J	Distance needed to dismnatle water pumps	1300	
K	Dimension between cylinder head cap and TC flange	378	404
L1	Minimum maintenance space for TC dismantling and assembly. Values include minimum clearances 140 mm for A170 and 180 for A175 from silencer. The recommended axial clearance from silencer is 500 mm.	1250	1500
L2	Recommended lifting point for the turbocharger	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 330 mm.	4450	4650
M1	Recommended height of lube oil module lifting tool eye	2940	
M3	Width needed for dismantling lube oil module insert	1915	
M4	Recommended lifting point for the lube oil module insert	365	
N	Space necessary for opening the side cover	1500	

NOTE

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

18.4.2 Service space requirement for the V-engine

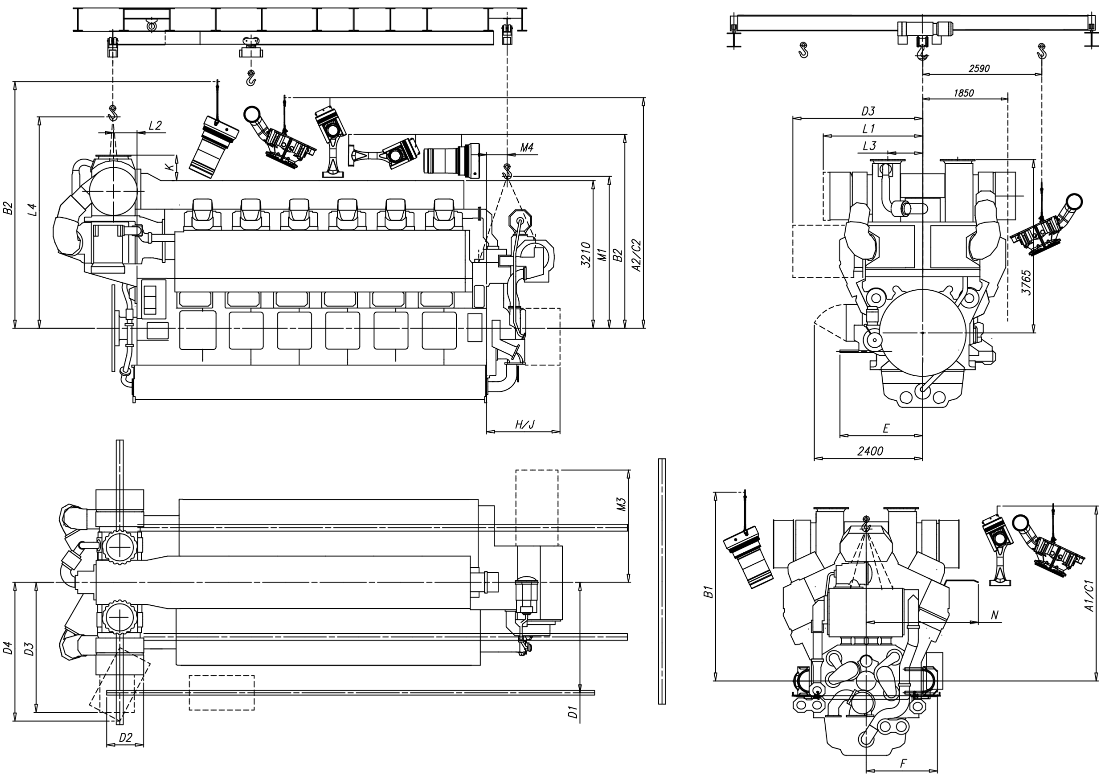

Fig 18-8 Service space requirement (DAAR038988)

<table>
<tr><th colspan="2">Services spaces in mm</th><th>12V</th><th>14V</th><th>16V</th></tr>
<tr><td>A1</td><td>Height needed for overhauling cylinder head over accumulator</td><td colspan="3">3800</td></tr>
<tr><td>A2</td><td>Height needed for transporting cylinder head freely over adjacent cylinder head covers</td><td colspan="3">5010</td></tr>
<tr><td>B1</td><td>Height needed for transporting cylinder liner</td><td colspan="3">4100</td></tr>
<tr><td>B2</td><td>Height needed for transporting cylinder liner freely over adjacent cylinder head covers</td><td colspan="3">5360 / 4500</td></tr>
<tr><td>C1</td><td>Height needed for overhauling piston and connecting rod</td><td colspan="3">3800</td></tr>
<tr><td>C2</td><td>Height needed for transporting piston and connecting rod freely over exhaust gas insulation box</td><td colspan="3">5010</td></tr>
<tr><td>D1</td><td>Recommended location of rail for removing the CAC either on A- or B-bank</td><td colspan="2">2400</td><td>2600</td></tr>
<tr><td>D2</td><td>Recommended location of starting point for rails</td><td colspan="2">1200</td><td>1300</td></tr>
<tr><td>D3</td><td>Minimum width needed for CAC overhauling from A / B-bank</td><td colspan="3">3225</td></tr>
<tr><td>D4</td><td>Minimum width needed for turning of overhauled CAC from A / B-bank</td><td colspan="3">3555</td></tr>
<tr><td>E</td><td>Width needed for removing main bearing side screw</td><td colspan="3">1800</td></tr>
<tr><td>F</td><td>Width needed for dismantling connecting rod big end bearing</td><td colspan="3">1550</td></tr>
<tr><td>H</td><td>Distance needed to dismantle lube oil pump</td><td colspan="3">1600</td></tr>
<tr><td>J</td><td>Distance needed to dismnatle water pumps</td><td colspan="3">1600</td></tr>
<tr><td>K</td><td>Dimension between cylinder head cap and TC flange</td><td colspan="2">460</td><td>650</td></tr>
<tr><td>L1</td><td>Minimum maintenance space for TC dismantling and assembly. Values include minimum clearances 140 mm for A170 and 180 for A175 from silencer. The recommended axial clearance from silencer is 500 mm.</td><td colspan="2">2400</td><td>2750</td></tr>
<tr><td>L2</td><td>Recommended lifting point for the turbocharger</td><td colspan="2">684</td><td>701</td></tr>
<tr><td>L3</td><td>Recommended lifting point sideways for the turbocharger</td><td>760</td><td colspan="2">892</td></tr>
<tr><td>L4</td><td>Height needed for dismantling the turbocharger.</td><td colspan="2">4700</td><td>4900</td></tr>
<tr><td>M1</td><td>Recommended height of lube oil module lifting tool eye</td><td colspan="3">3500</td></tr>
<tr><td>M3</td><td>Width needed for dismantling lube oil module insert</td><td colspan="3">2440</td></tr>
<tr><td>M4</td><td>Recommended lifting point for the lube oil module insert</td><td colspan="3">100</td></tr>
<tr><td>N</td><td>Space necessary for opening the side cover</td><td colspan="3">2450</td></tr>
</table>

NOTE

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

19. Transport Dimensions and Weights

19.1 Lifting of engines

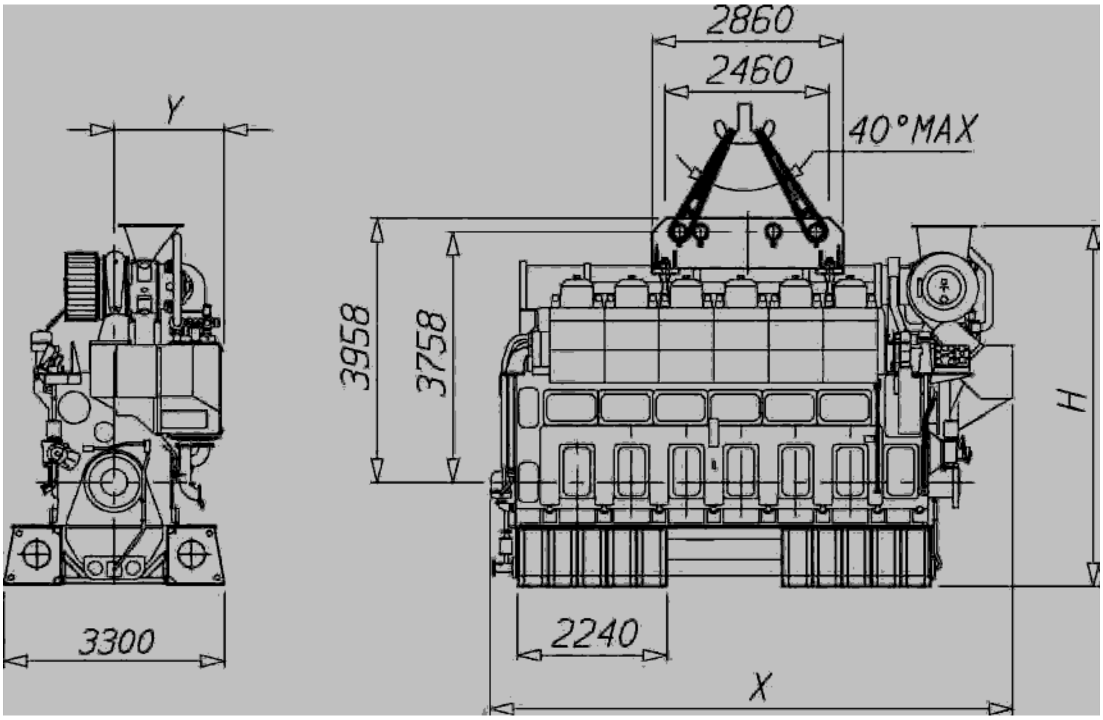

Fig 19-1 Lifting of rigidly mounted in-line engines (4V83D0212c)

Engine type	X [mm]	Y [mm]	H [mm]	Weights without flywheel [ton]			
				Engine	Lifting device	Transport cradle	Total weight
W 6L46DF	8115	1600	5510	96	3.5	6.5	106
W 8L46DF	9950	1860	5510	128	3.5	6.5	138
W 9L46DF	10800	1860	5675	148	3.5	9.5	161

19.2 Engine components

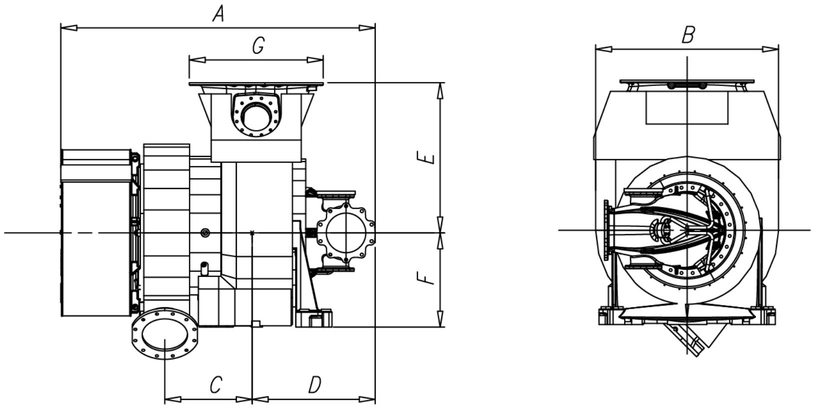

Fig 19-2 Turbocharger (DAAR038993)

Engine type	Turbocharger	A	B	C	D	E	F	G	Weight, com-plete
W 6L46DF	ABB A170-M	2256	1154	275	1215	650	584	Ø650	3100
W 7L46DF	ABB A170-M	2256	1154	275	1215	650	584	Ø650	3100
W 8L46DF	ABB A175-M	2568	1332	317	1366	750	674	Ø750	4600
W 9L46DF	ABB A175-M	2568	1332	317	1366	750	674	Ø750	4600
W 12V46DF	ABB A170-M	2256	1154	275	1215	650	584	Ø584	3100
W 14V46DF	ABB A170-M	2256	1154	275	1215	650	584	Ø584	3100
W 16V46DF	ABB A175-M	2568	1332	317	1366	750	674	Ø750	4600

All dimensions in mm. Weight in kg.

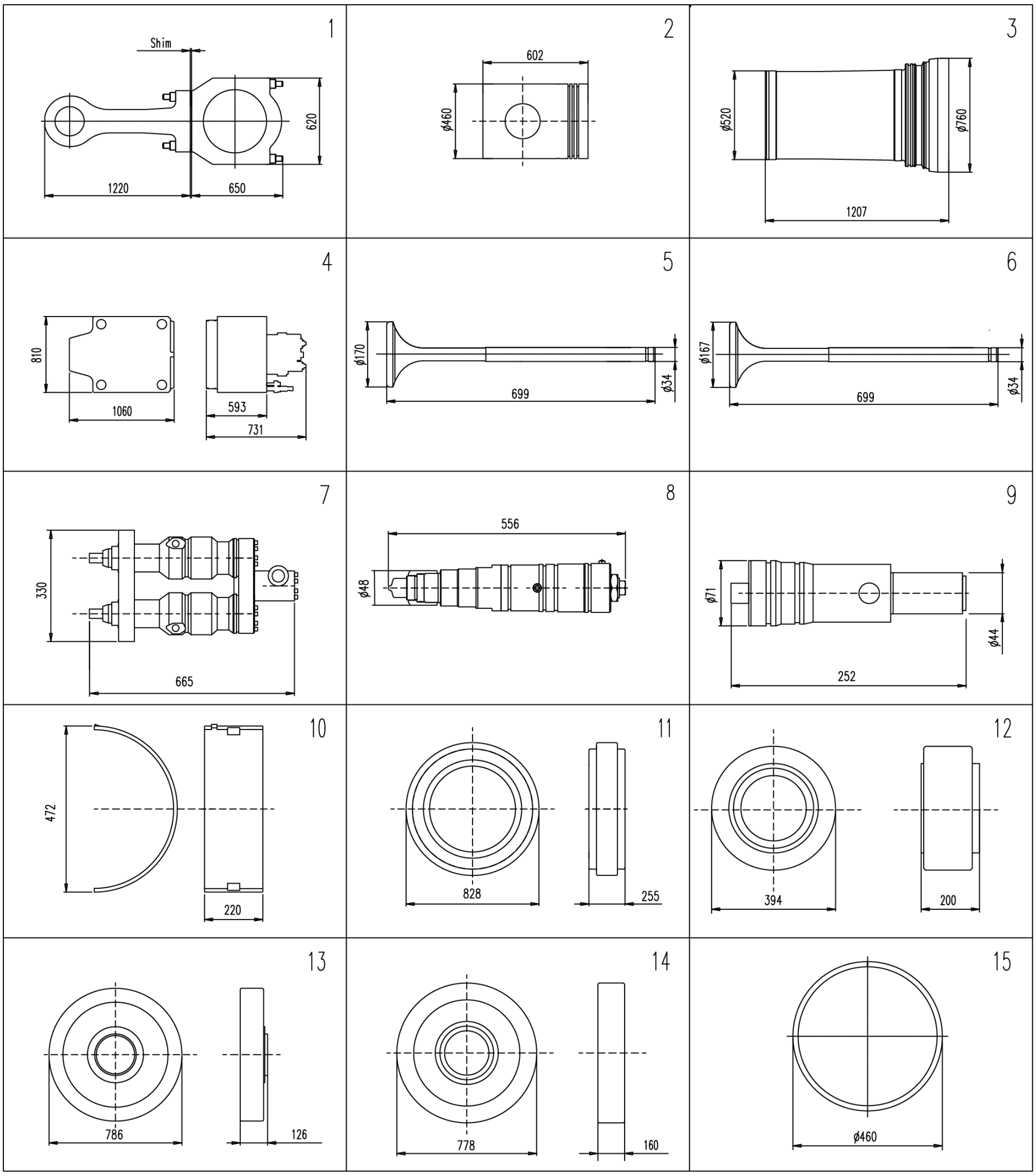

Fig 19-3 Major spare parts (DAAR039305)

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	935.5	11	Split gear wheel	-
4	Cylinder head	1170	12	Smaller intermediate gear	111
5	Inlet valve	10	13	Bigger intermediate gear	214
6	Exhaust valve	10.6	14	Gear wheel to camshaft	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. 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^2)	0.145
kPa	lbf/ft^2	20.885
kPa	inch H_2O	4.015
kPa	foot H_2O	0.335
kPa	mm H_2O	101.972
kPa	bar	0.01

Volume conversion factors

Convert from	To	Multiply by
m^3	in^3	61023.744
m^3	ft^3	35.315
m^3	Imperial gallon	219.969
m^3	US gallon	264.172
m^3	l (litre)	1000

Power conversion

Convert from	To	Multiply by
kW	hp (metric)	1.360
kW	US hp	1.341

Moment of inertia and torque conversion factors

Convert from	To	Multiply by
kgm^2	lbft^2	23.730
kNm	lbf ft	737.562

Fuel consumption conversion factors

Convert from	To	Multiply by
g/kWh	g/hph	0.736
g/kWh	lb/hph	0.00162

Flow conversion factors

Convert from	To	Multiply by
m^3/h (liquid)	US gallon/min	4.403
m^3/h (gas)	ft^3/min	0.586

Temperature conversion factors

Convert from	To	Multiply by
°C	F	F = 9/5 *C + 32
°C	K	K = C + 273.15

Density conversion factors

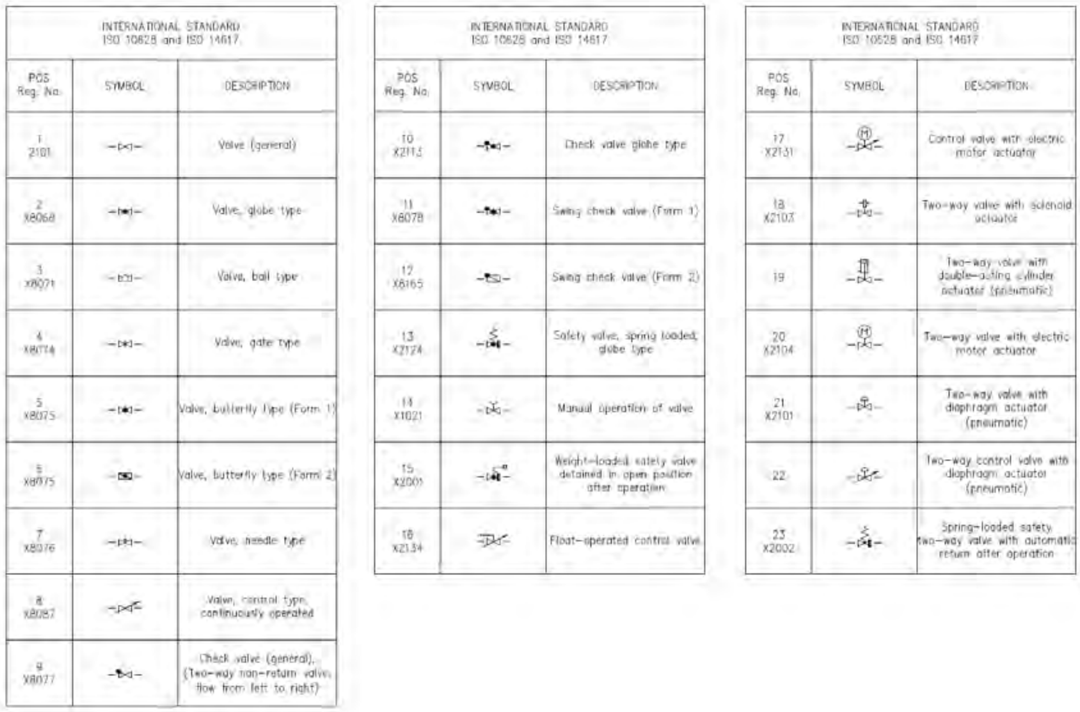
Convert from	To	Multiply by
kg/m^3	lb/US gallon	0.00834
kg/m^3	lb/Imperial gallon	0.01002
kg/m^3	lb/ft^3	0.0624

21.1.1 Prefix

Table 21-1 The most common prefix multipliers

Name	Symbol	Factor	Name	Symbol	Factor	Name	Symbol	Factor
tera	T	10^{12}	kilo	k	10^3	nano	n	10^{-9}
giga	G	10^9	milli	m	10^{-3}			
mega	M	10^6	micro	μ	10^{-6}			

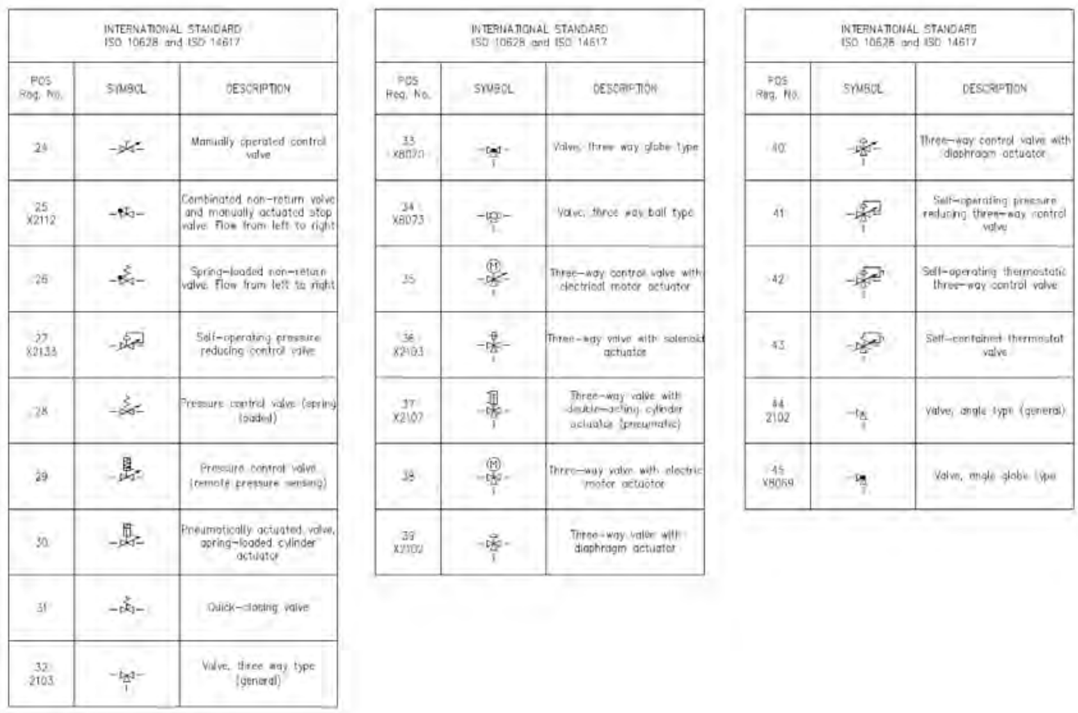
21.2 Collection of drawing symbols used in drawings



INTERNATIONAL STANDARD ISO 10628 and ISO 14617

POS Reg. No.	SYMBOL	DESCRIPTION
1 2101		Valve (general)
2 X8068		Valve, globe type
3 X8071		Valve, ball type
4 X8074		Valve, gate type
5 X8075		Valve, butterfly type (Form 1)
6 X8075		Valve, butterfly type (Form 2)
7 X8076		Valve, needle type
8 X8087		Valve, control type, continuously operated
9 X8077		Check valve (general), (Two-way non-return valve, flow from left to right)
10 X2113		Check valve globe type
11 X8078		Swing check valve (Form 1)
12 X8165		Swing check valve (Form 2)
13 X2124		Safety valve, spring loaded, globe type
14 X1021		Manual operation of valve
15 X2001		Weight-loaded safety valve detained in open position after operation
16 X2134		Float-operated control valve
17 X2131		Control valve with electric motor actuator
18 X2103		Two-way valve with solenoid actuator
19		Two-way valve with double-acting cylinder actuator (pneumatic)
20 X2104		Two-way valve with electric motor actuator
21 X2101		Two-way valve with diaphragm actuator (pneumatic)
22		Two-way control valve with diaphragm actuator (pneumatic)
23 X2002		Spring-loaded safety two-way valve with automatic return after operation

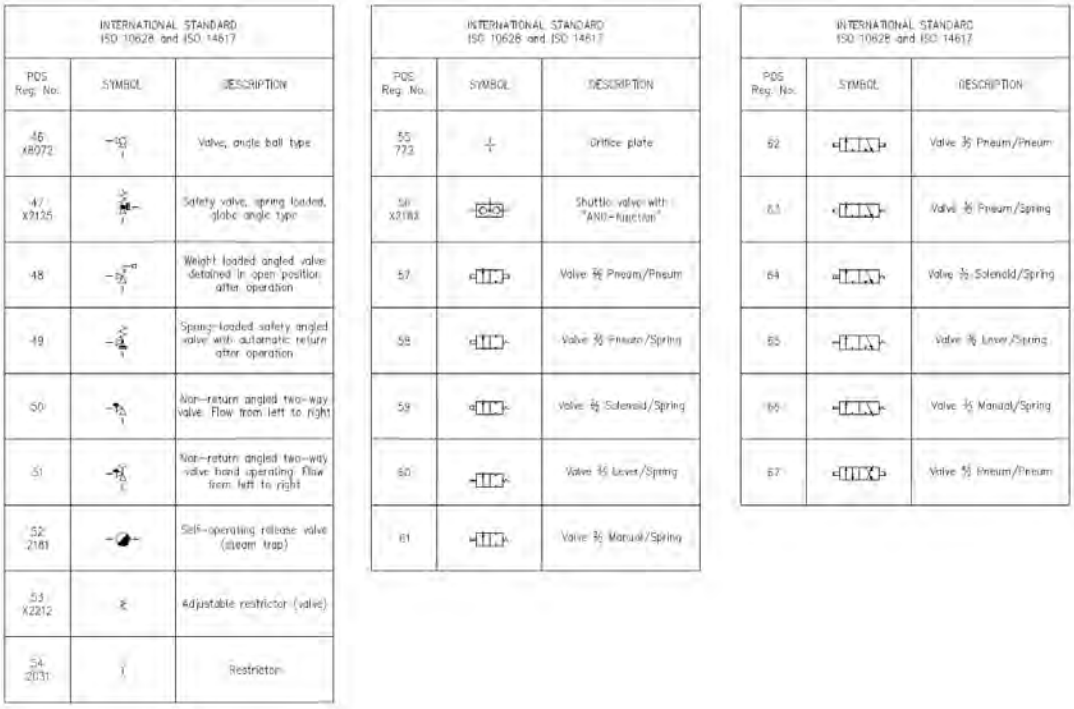
Fig 21-1 List of symbols (DAAF406507 - 1)



INTERNATIONAL STANDARD ISO 10628 and ISO 14617

POS Reg. No.	SYMBOL	DESCRIPTION
24		Manually operated control valve
25 X2112		Combinated non-return valve and manually actuated stop valve. Flow from left to right
26		Spring-loaded non-return valve. Flow from left to right
27 X2133		Self-operating pressure reducing control valve
28		Pressure control valve (spring loaded)
29		Pressure control valve (remote pressure sensing)
30		Pneumatically actuated valve, spring-loaded cylinder actuator
31		Quick-closing valve
32 2103		Valve, three way type (general)
33 X8070		Valve, three way globe type
34 X8073		Valve, three way ball type
35		Three-way control valve with electrical motor actuator
36 X2103		Three-way valve with solenoid actuator
37 X2107		Three-way valve with double-acting cylinder actuator (pneumatic)
38		Three-way valve with electric motor actuator
39 X2102		Three-way valve with diaphragm actuator
40		Three-way control valve with diaphragm actuator
41		Self-operating pressure reducing three-way control valve
42		Self-operating thermostatic three-way control valve
43		Self-contained thermostat valve
44 2102		Valve, angle type (general)
45 X8069		Valve, angle globe type

Fig 21-2 List of symbols (DAAF406507 - 2)



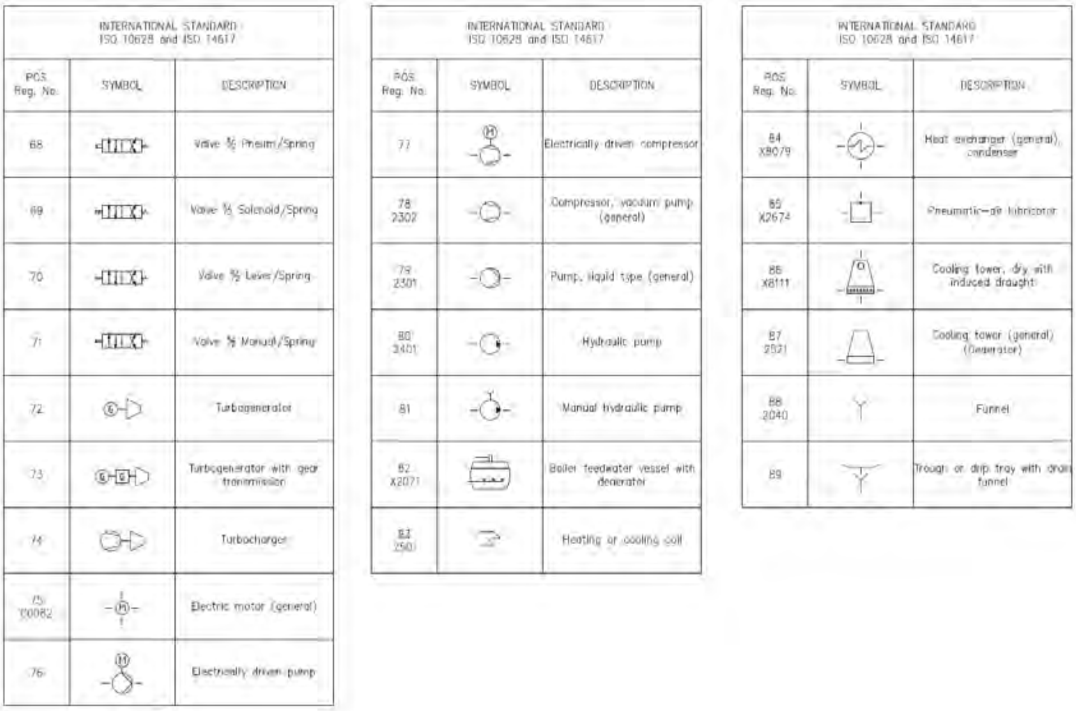
INTERNATIONAL STANDARD ISO 10628 and ISO 14617

POS Reg. No.	SYMBOL	DESCRIPTION
46 X8072		Valve, angle ball type
47 X2125		Safety valve, spring loaded, globe angle type
48		Weight loaded angled valve detained in open position after operation
49		Spring-loaded safety angled valve with automatic return after operation
50		Non-return angled two-way valve. Flow from left to right
51		Non-return angled two-way valve hand operating. Flow from left to right
52 2181		Self-operating release valve (steam trap)
53 X2212		Adjustable restrictor (valve)
54 2031		Restrictor

POS Reg. No.	SYMBOL	DESCRIPTION
55 773		Orifice plate
56 X2183		Shuttle valve with "AND-function"
57		Valve 3/2 Pneum/Pneum
58		Valve 3/2 Pneum/Spring
59		Valve 3/2 Solenoid/Spring
60		Valve 3/2 Lever/Spring
61		Valve 3/2 Manual/Spring

POS Reg. No.	SYMBOL	DESCRIPTION
62		Valve 3/5 Pneum/Pneum
63		Valve 3/5 Pneum/Spring
64		Valve 3/5 Solenoid/Spring
65		Valve 3/5 Lever/Spring
66		Valve 3/5 Manual/Spring
67		Valve 3/5 Pneum/Pneum

Fig 21-3 List of symbols (DAAF406507 - 3)



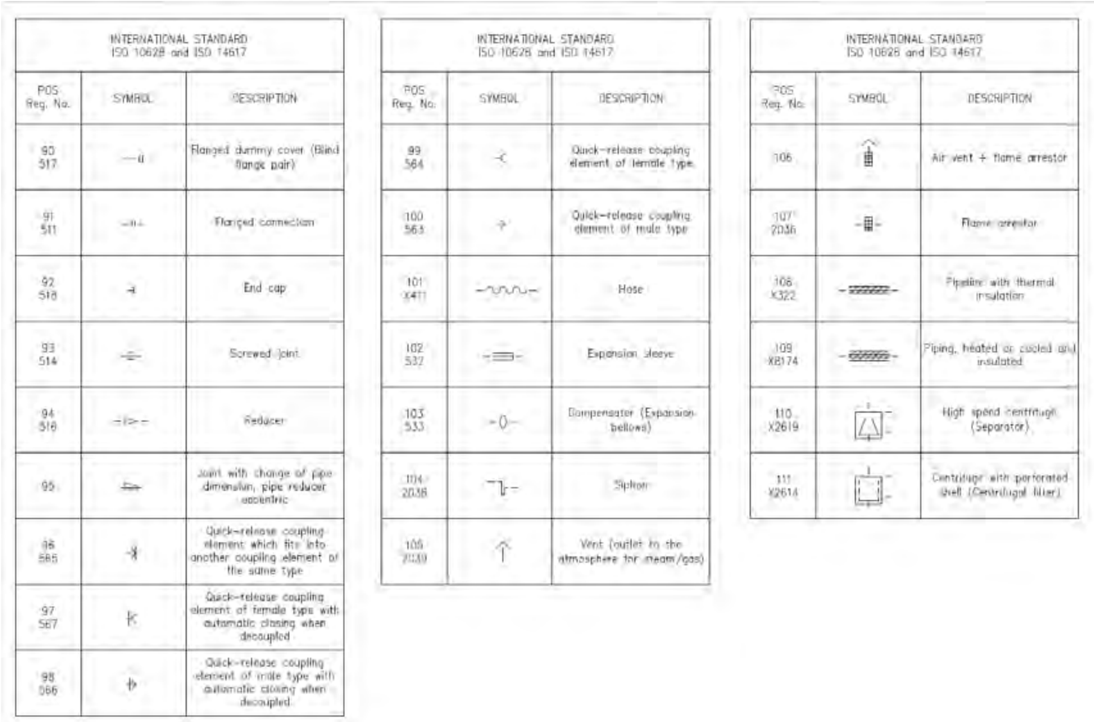
INTERNATIONAL STANDARD ISO 10628 and ISO 14617

POS Reg. No.	SYMBOL	DESCRIPTION
68		Valve 5/2 Pneum/Spring
69		Valve 5/2 Solenoid/Spring
70		Valve 5/2 Lever/Spring
71		Valve 5/2 Manual/Spring
72		Turbogenerator
73		Turbogenerator with gear transmission
74		Turbocharger
75 X0082		Electric motor (general)
76		Electrically driven pump

POS Reg. No.	SYMBOL	DESCRIPTION
77		Electrically driven compressor
78 2302		Compressor, vacuum pump (general)
79 2301		Pump, liquid type (general)
80 2401		Hydraulic pump
81		Manual hydraulic pump
82 X2071		Boiler feedwater vessel with deaerator
83 2501		Heating or cooling coil

POS Reg. No.	SYMBOL	DESCRIPTION
84 X8079		Heat exchanger (general), condenser
85 X2674		Pneumatic-air lubricator
86 X8111		Cooling tower, dry with induced draught
87 2521		Cooling tower (general) (Deaerator)
88 2040		Funnel
89		Trough or drip tray with drain funnel

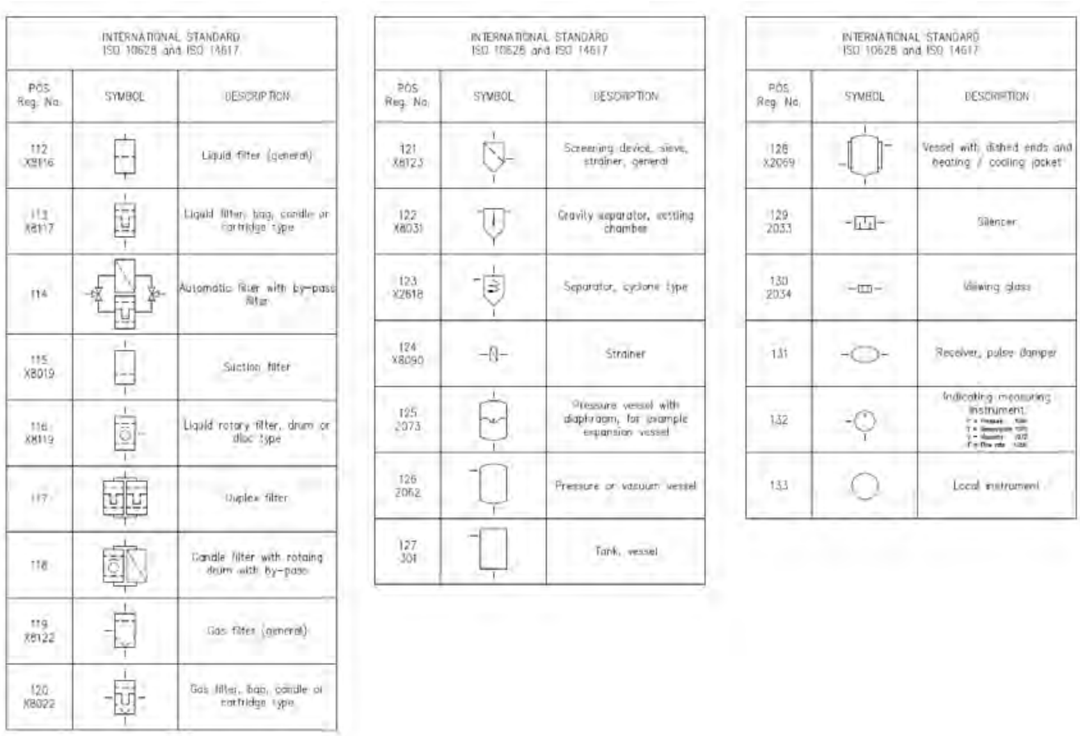
Fig 21-4 List of symbols (DAAF406507 - 4)



POS Reg. No.	SYMBOL	DESCRIPTION
90 517		Flanged dummy cover (Blind flange pair)
91 511		Flanged connection
92 518		End cap
93 514		Screwed joint
94 516		Reducer
95		Joint with change of pipe dimension, pipe reducer eccentric
96 565		Quick-release coupling element which fits into another coupling element of the same type
97 567		Quick-release coupling element of female type with automatic closing when decoupled
98 566		Quick-release coupling element of male type with automatic closing when decoupled
99 564		Quick-release coupling element of female type
100 563		Quick-release coupling element of male type
101 X411		Hose
102 537		Expansion sleeve
103 533		Compensator (Expansion bellows)
104 2038		Siphon
105 2039		Vent (outlet to the atmosphere for steam/gas)
106		Air vent + flame arrestor
107 2036		Flame arrestor
108 X322		Pipeline with thermal insulation
109 X8174		Piping, heated or cooled and insulated
110 X2619		High speed centrifuge (Separator)
111 X2614		Centrifuge with perforated shell (Centrifugal filter)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617

Fig 21-5 List of symbols (DAAF406507 - 5)



POS Reg. No.	SYMBOL	DESCRIPTION
112 X8116		Liquid filter (general)
113 X8117		Liquid filter, bag, candle or cartridge type
114		Automatic filter with by-pass filter
115 X8019		Suction filter
116 X8119		Liquid rotary filter, drum or disc type
117		Duplex filter
118		Candle filter with rotaing drum with by-pass
119 X8122		Gas filter (general)
120 X8022		Gas filter, bag, candle or cartridge type
121 X8123		Screening device, sieve, strainer, general
122 X8031		Gravity separator, settling chamber
123 X2618		Separator, cyclone type
124 X8090		Strainer
125 2073		Pressure vessel with diaphragm, for example expansion vessel
126 2062		Pressure or vacuum vessel
127 301		Tank, vessel
128 X2069		Vessel with dished ends and heating / cooling jacket
129 2033		Silencer
130 2034		Viewing glass
131		Receiver, pulse damper
132		Indicating measuring instrument
133		Local instrument

INTERNATIONAL STANDARD ISO 10628 and ISO 14617

Fig 21-6 List of symbols (DAAF406507 - 6)

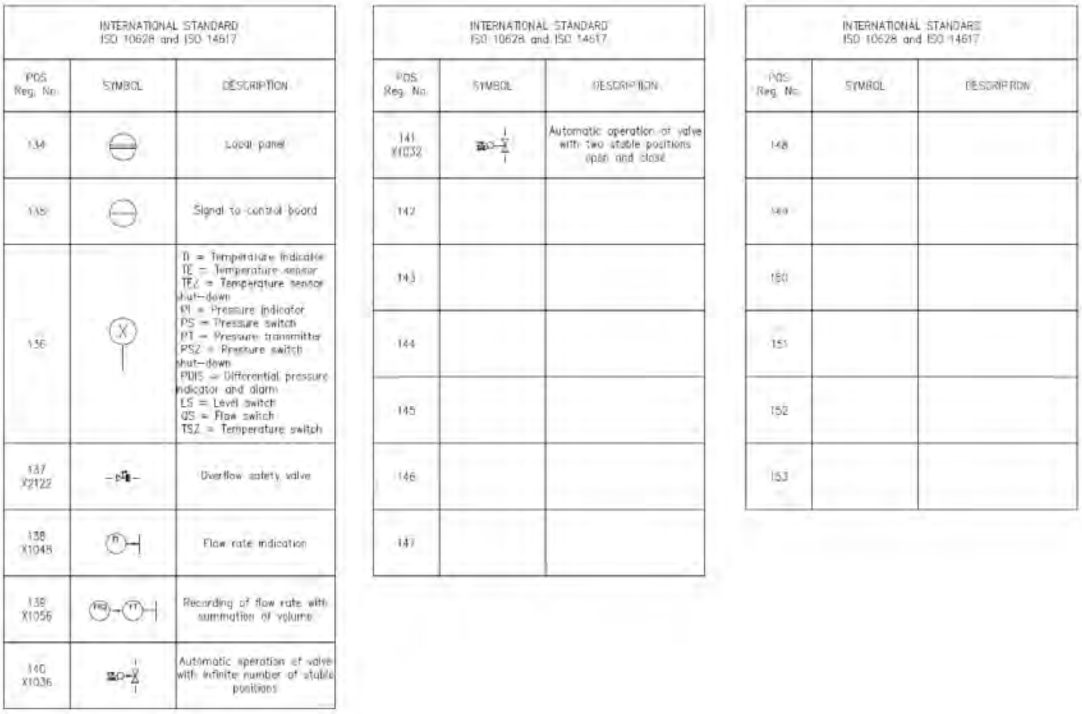


Fig 21-7 List of symbols (DAAF406507 - 7)

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