

Wärtsilä 50DF

PRODUCT GUIDE



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Introduction

This Product Guide provides data and system proposals for the early design phase of marine engine installations. For contracted projects specific instructions for planning the installation are always delivered. Any data and information herein is subject to revision without notice. This 7/2019 issue replaces all previous issues of the Wärtsilä 50DF Project Guides.

Issue	Published	Updates
1/2019	22.07.2019	Updates throughout the product guide
1/2018	28.06.2018	Updates throughout the product guide
4/2016	XX.12.2016	Updates throughout the product guide
3/2016	04.11.2016	Small update to technical data
2/2016	09.09.2016	Technical data updated
1/2016	30.06.2016	Fuel sharing added. Other minor updates
1/2014	13.06.2014	Chapter Technical data and numerous updates throughout the project guide

Wärtsilä, Marine Solutions

Vaasa, July 2019

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1. Main Data and Outputs

The Wärtsilä 50DF is a 4-stroke, non-reversible, turbocharged and inter-cooled dual fuel engine with direct injection of liquid fuel and indirect injection of gas fuel. The engine can be operated in gas mode or in diesel mode.

Cylinder bore	500 mm
Stroke	580 mm
Piston displacement	113.9 l/cyl
Number of valves	2 inlet valves and 2 exhaust valves
Cylinder configuration	6, 8 and 9 in-line; 12, 16 in V-form
V-angle	45°
Direction of rotation	clockwise
Speed	500, 514 rpm
Mean piston speed	9.7, 9.9 m/s

1.1 Maximum continuous output

Table 1-1 Rating table for Wärtsilä 50DF

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

Nominal speed 514 rpm is recommended for mechanical propulsion engines.

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

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

where:

- P_e = mean effective pressure [bar]
- P = output per cylinder [kW]
- n = engine speed [r/min]
- D = cylinder diameter [mm]
- L = length of piston stroke [mm]
- c = operating cycle (4)

1.2 Output limitations in gas mode

1.2.1 Output limitations due to methane number

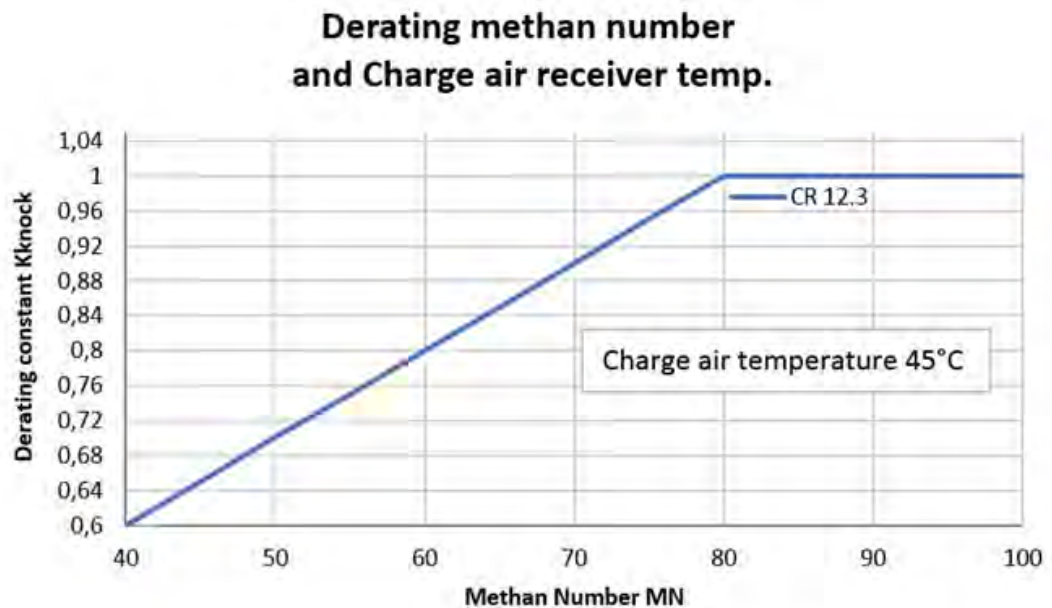


Fig 1-1 Output limitations due to methane number

Notes:

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

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

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

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

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

Limitation factor (K_{GAS})

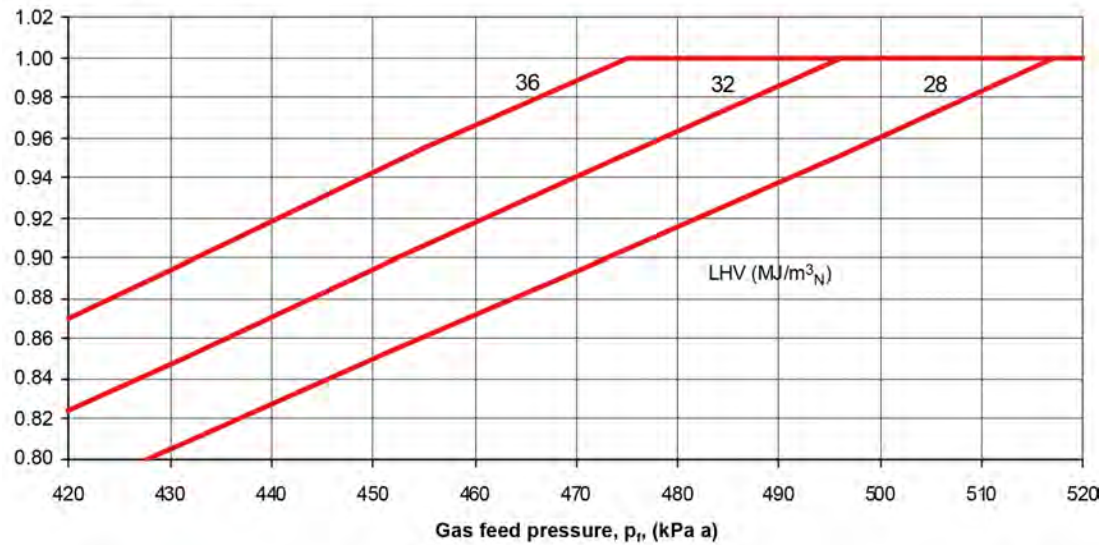


Fig 1-2 Output limitation factor due to gas feed pressure / LHV

Notes:

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

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

No compensation (uprating) of the engine output is allowed, neither for gas feed pressure higher than required in the graph above nor lower heating value above 36 MJ/m³_N.

1.3 Reference conditions

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

The specific fuel consumption is stated in the chapter *Technical Data*. The statement applies to engines operating in ambient conditions according to ISO 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

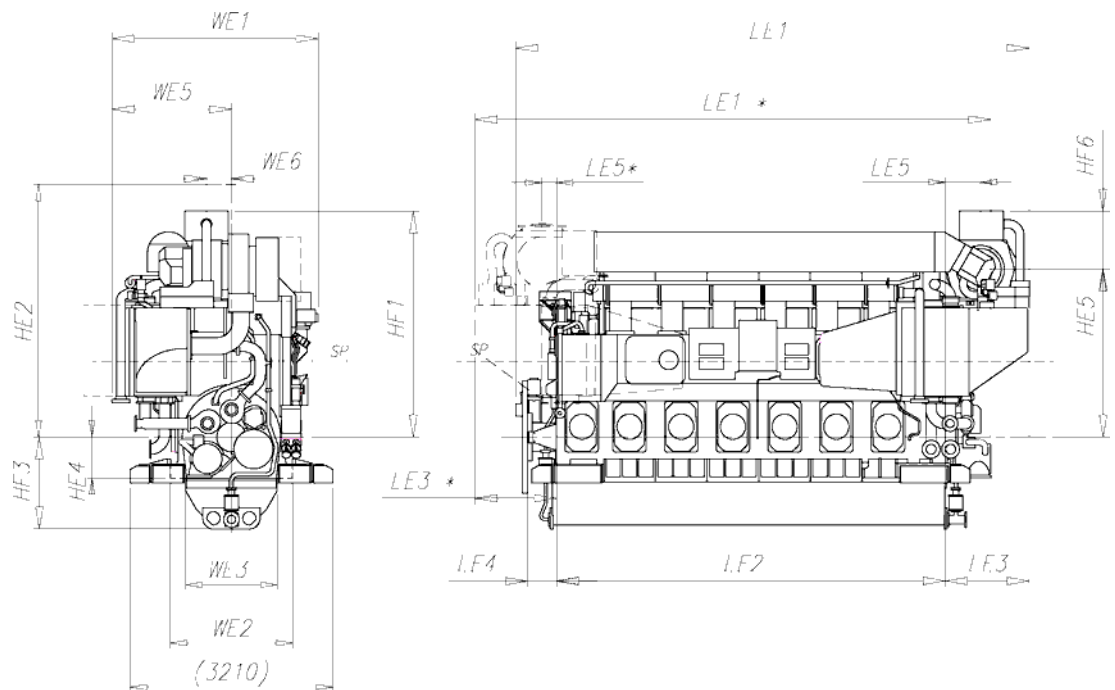


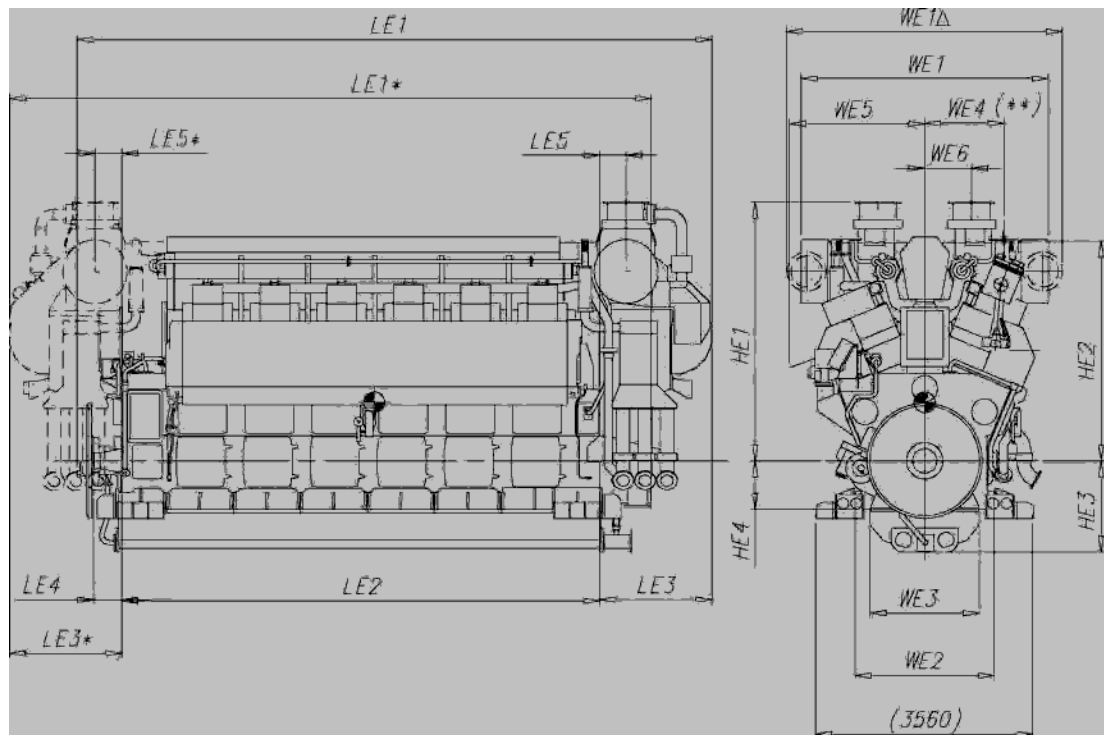
Fig 1-3 In-line engines (DAAE000316d)

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

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

* TC in driving end

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

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

Engine	TC	LE1	LE1*	LE2	LE3	LE3*	LE4	LE5	LE5*	HE1	HE2	HE3	HE4
W 12V50DF	TPL71	10425	10540	7850	1840	1840	460	435	435	4240	3600	1500	800
W 16V50DF	TPL76	13830	13200	10050	2300	2300	460	680	680	4400	3600	1500	800

Engine	TC	HE5	HE6	WE1	WE1Δ	WE2	WE3	WE4	WE4**	WE5	WE6	Weight
W 12V50DF	TPL71	3100	1140	4055	4525	2290	1800	1495	1300	2220	770	175
W 16V50DF	TPL76	3300	1100	4730	5325	2290	1800	1495	1300	2220	930	224

* TC in driving end

** With monospex (exhaust manifold)

Δ With air suction branches

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

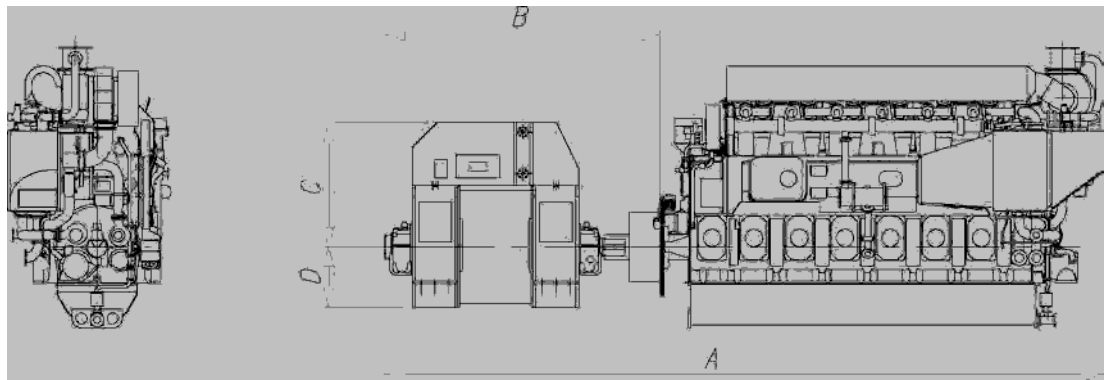


Fig 1-5 Example of total installation lengths, in-line engines (DAAE000489)

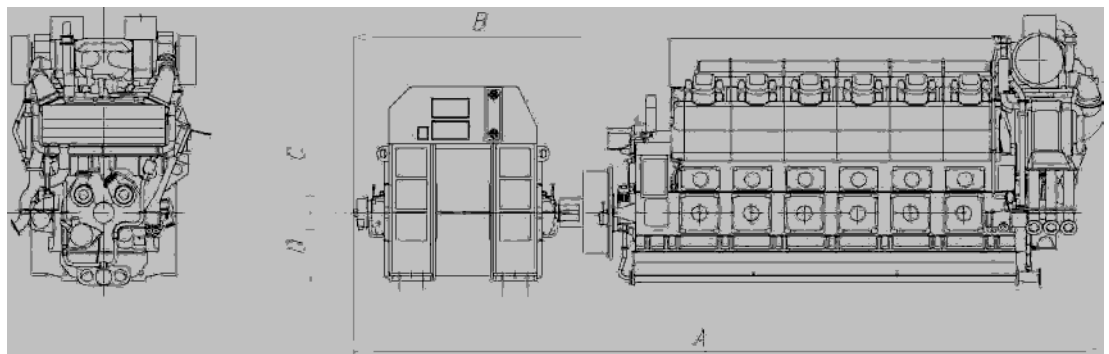


Fig 1-6 Example of total installation lengths, V-engines (DAAE000489)

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

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

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

[All dimensions are in mm]

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2. Operating Ranges

2.1 Engine operating range

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 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.

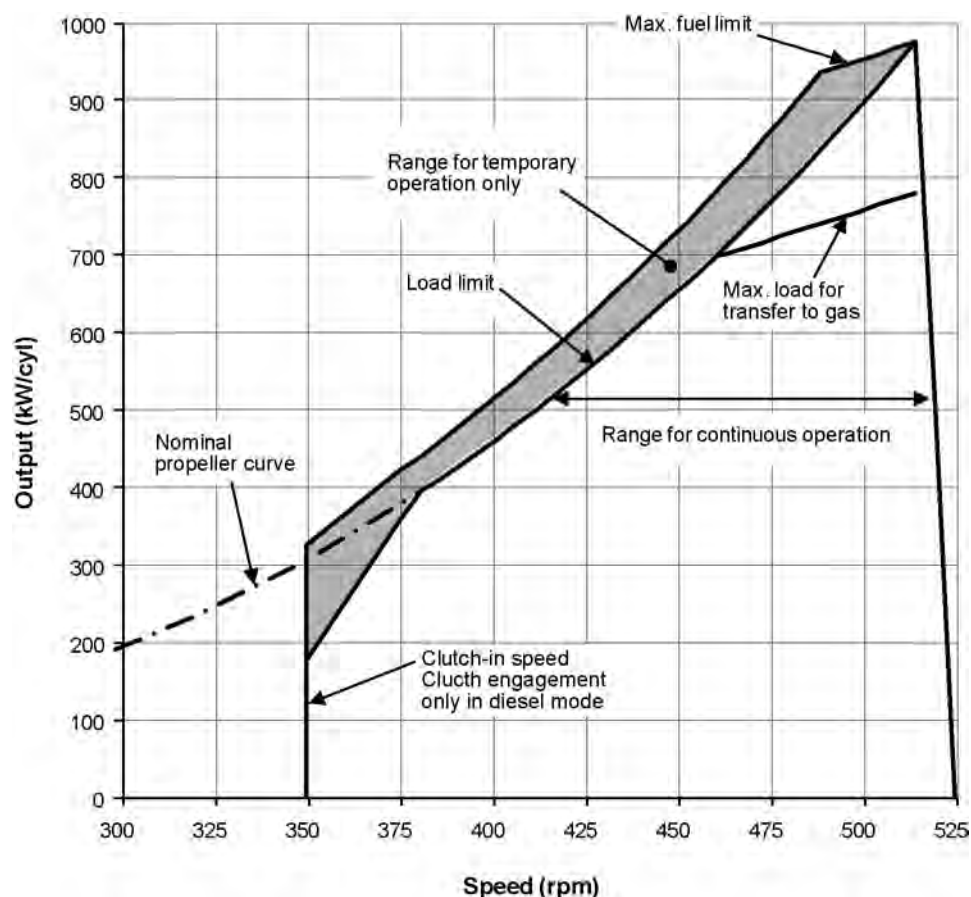


Fig 2-1 Operating field for CP-propeller, 975 kW/cyl, rated speed 514 rpm

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 60°C, preferably 70°C, and the lubricating oil temperature must be at least 40°C. The loading ramp “normal” can be taken into use when the engine has been operating above 30% load for 3 minutes. All engines respond equally to a change in propulsion power (or total

load), also when a recently connected engine is still uploading to even load sharing with parallel engines. A recently connected generator shall therefore not be taken into account as “available power” until after 3 minutes, or alternatively the available power from this generator is ramped

up to 100% during 5 minutes. If the load sharing is based on speed droop, the power management system ramps up the load on a recently connected generator according to the ramp “preheated”. 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. Emergency loading may only be possible by activating an emergency function, which generates visual and audible alarms in the control room and on the bridge.

In applications with highly cyclic load, e.g. dynamic positioning, maximum loading capacity in gas mode (see figure) 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. 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. Transfer to diesel mode takes place automatically in case of overload. Lower than specified methane number may result in automatic transfer to diesel when operating close to 100% output. Load taking ability also suffers from low methane number. 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)

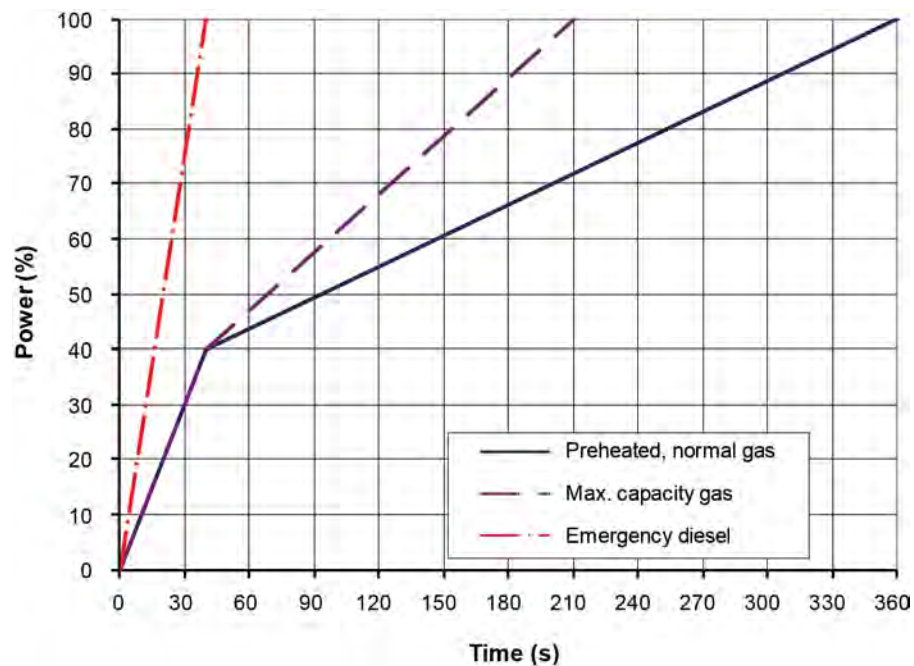


Fig 2-2 Maximum load increase rates for variable speed engines

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

2.2.2 Constant speed applications

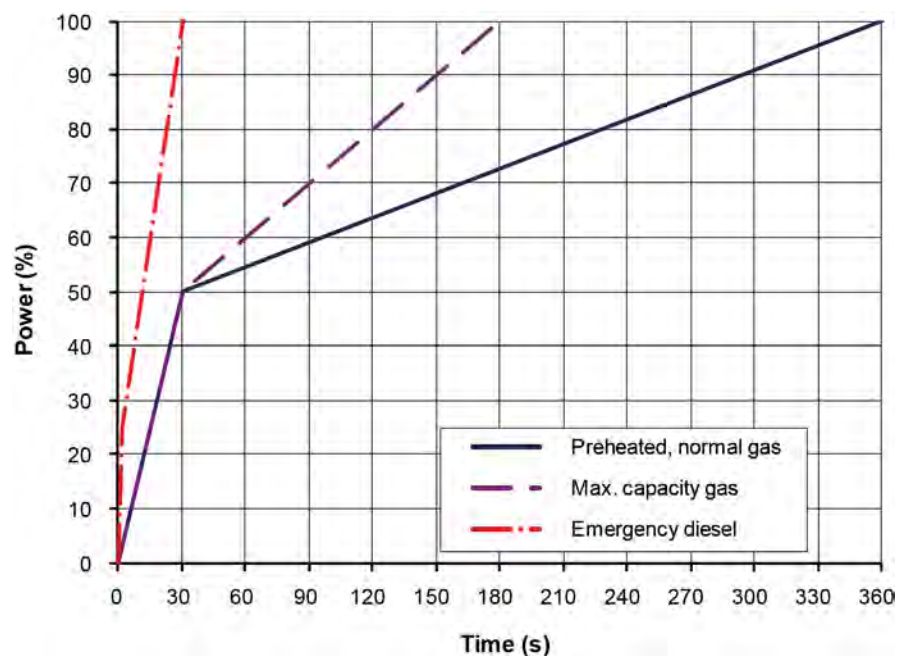


Fig 2-3 Maximum load increase rates for engines operating at nominal speed

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

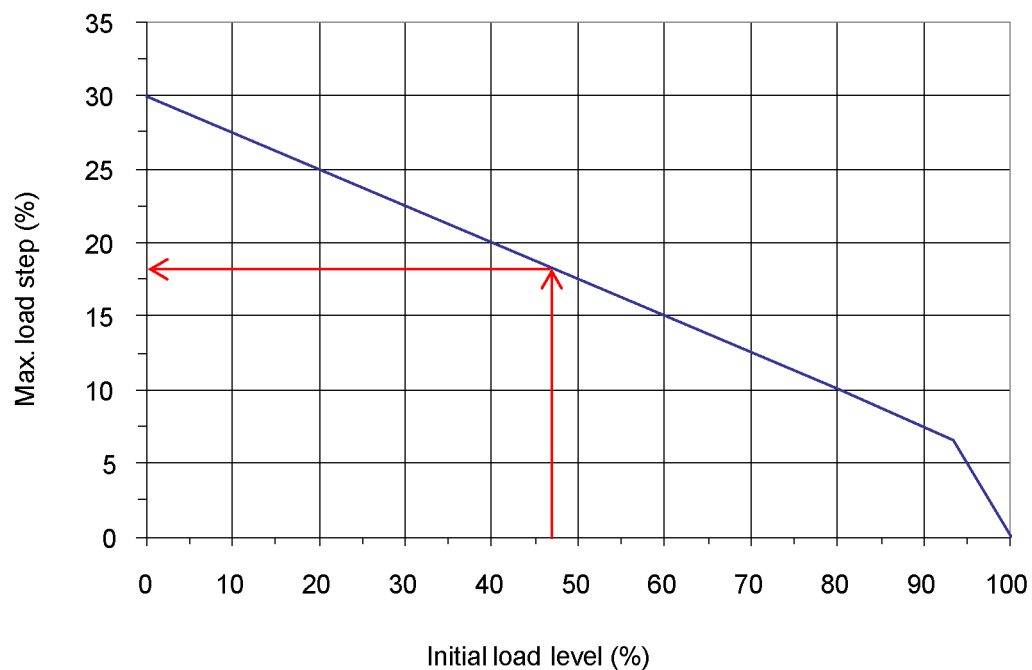
In electric propulsion applications loading ramps are implemented both in the propulsion control and in the power management system, or in the engine speed control in case isochronous load sharing is applied. When the load sharing is based on speed droop, it must be taken into account that the load increase rate of a recently connected generator is the sum of the load transfer performed by the power management system and the load increase performed by the propulsion control.

2.2.3 Maximum instant load steps

The electrical system must be designed so that tripping of breakers can be safely handled. This requires that the engines are protected from load steps exceeding their maximum load acceptance capability. If fast load shedding is complicated to implement or undesired, the instant load step capacity can be increased with a fast acting signal that requests transfer to diesel mode.

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

2.2.3.1 Gas mode



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

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

Gas - Mode	
Instant Load Application	Stepwise Load Reduction
•Maximum load step according to figure above	•Unloading in steps 100-75-45-0%
•Steady-state frequency band ≤ 1.5 %	•Steady-state frequency band ≤ 1.5 %
•Maximum speed drop 10 %	•Maximum speed increase 10 %

Gas - Mode	
•Recovery time ≤ 10 s	•Recovery time ≤ 10 s
•Time between load steps ≥ 30 s ¹⁾	•Time between load steps ≥ 15 s ²⁾

Diesel Mode	
Instant Load Application	Stepwise Load Reduction
•Maximum load step according to figure above	•Instant load step 100% - 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 %).

3) On diesel and natural gas operation the 100% load is 975kW/cyl.

2.2.4

Start-up

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

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

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

Start and stop on heavy fuel is not restricted.

2.3

Operation at low load and idling

Absolute idling (declutched main engine, disconnected generator), and below 5% MCR load:

- Maximum 10 minutes if the engine is to be stopped after the idling. 3-5 minutes idling before stop is recommended.
- Maximum 2 hours on HFO if the engine is to be loaded after the idling.
- Maximum 8 hours on MDF or gas if the engine is to be loaded after the idling.
- 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 started, provided that the charge air temperature is above 55°C.

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

- No restrictions.

2.4 Low air temperature

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

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

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

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

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

3. Technical Data

3.1 Introduction

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

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

3.2 Wärtsilä 6L50DF

Wärtsilä 6L50DF		DE DE Constant Speed		DE DE Constant Speed		ME CPP Variable Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	kW	950		975		975	
Engine speed	rpm	500		514		514	
Engine output	kW	5700		5850		5850	
Mean effective pressure	MPa	2.0		2.0		2.0	
IMO compliance		Tier 3	Tier 2	Tier 3	Tier 2	Tier 3	Tier 2
Combustion air system (Note 1)							
Flow at 100% load	kg/s	9.2	11.3	9.2	11.3	9.2	11.0
Temperature at turbocharger intake, max.	°C	45		45		45	
Temperature after air cooler, nom. (TE 601)	°C	45	50	45	50	45	50
Exhaust gas system (Note 2)							
Flow at 100% load	kg/s	8.9	11.3	9.2	11.9	9.0	12.4
Flow at 75% load	kg/s	6.9	9.1	7.1	9.5	7.2	9.2
Flow at 50% load	kg/s	5.2	7.0	5.3	7.1	5.4	8.3
Temperature after turbocharger at 100% load (TE 517)	°C	401	337	401	337	402	316
Temperature after turbocharger at 75% load (TE 517)	°C	445	319	445	319	418	321
Temperature after turbocharger at 50% load (TE 517)	°C	442	319	442	319	397	255
Backpressure, max.	kPa	4		4		4	
Calculated exhaust diameter for 35 m/s	mm	786	842	796	862	789	864
Heat balance at 100% load (Note 3)							
Jacket water, HT-circuit	kW	654	978	678	996	684	1008
Charge air, HT-circuit	kW	780	1224	828	1308	840	1374
Charge air, LT-circuit	kW	432	648	450	696	450	768
Lubricating oil, LT-circuit	kW	462	732	474	744	480	756
Radiation	kW	156	174	162	180	162	180
Fuel consumption (Note 4)							
BSEC total at 100% load	kJ/kWh	7360	-	7390	-	7410	-
BSEC total at 85% load	kJ/kWh	7530	-	7570	-	0	-

Wärtsilä 6L50DF		DE DE Constant Speed		DE DE Constant Speed		ME CPP Variable Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	kW	950		975		975	
Engine speed	rpm	500		514		514	
BSEC total at 75% load	kJ/kWh	7720	-	7750	-	7550	-
BSEC total at 50% load	kJ/kWh	8560	-	8580	-	8220	-
BSEC gas fuel at 100% load	kJ/kWh	7318	-	7350	-	7365	-
BSEC gas fuel at 85% load	kJ/kWh	7481	-	7513	-	0	-
BSEC gas fuel at 75% load	kJ/kWh	7658	-	7692	-	7493	-
BSEC gas fuel at 50% load	kJ/kWh	8456	-	8476	-	8122	-
Pilot fuel consumption at 100% load	g/kWh	1.0	0.0	1.0	0.0	1.0	0.0
Pilot fuel consumption at 85% load	g/kWh	1.3	0.0	1.3	0.0	0.0	0.0
Pilot fuel consumption at 75% load	g/kWh	1.5	0.0	1.5	0.0	1.5	0.0
Pilot fuel consumption 50% load	g/kWh	2.5	0.0	2.5	0.0	2.4	0.0
SFOC at 100% load - LFO	g/kWh	-	190.1	-	192.0	-	189.6
SFOC at 85 % load - LFO	g/kWh	-	187.7	-	189.1	-	185.8
SFOC at 75 % load - LFO	g/kWh	-	188.2	-	189.1	-	184.4
SFOC at 50 % load - LFO	g/kWh	-	197.5	-	197.5	-	190.4
SFOC at 100% load - HFO	g/kWh	-	190.1	-	192.0	-	189.6
SFOC at 85% load - HFO	g/kWh	-	187.7	-	189.1	-	185.8
SFOC at 75% load - HFO	g/kWh	-	188	-	189	-	184
SFOC at 50% load - HFO	g/kWh	-	198	-	198	-	190
Fuel gas system (Note 5)							
Gas pressure at engine inlet, min (PT901)	kPa (a)	472	-	472	-	472	-
Gas pressure to Gas Valve unit, min	kPa (a)	592	-	592	-	592	-
Gas temperature before Gas Valve Unit	°C	0...60	-	0...60	-	0...60	-
Fuel oil system							
Pressure before injection pumps (PT 101)	kPa	800±50		800±50		800±50	
Fuel oil flow to engine, approx	m³/h	6.1		6.3		6.3	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140
MDF viscosity, min.	cSt	2.0		2.0		2.0	
Max. MDF temperature before engine (TE 101)	°C	45		45		45	
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h	-	4.5	-	4.5	-	4.7
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	12.0	22.6	12.0	22.6	11.7	23.3
Pilot fuel (MDF) viscosity before the engine	cSt	2...11		2...11		2...11	
Pilot fuel pressure at engine inlet (PT 112)	kPa	400...800		400...800		400...800	
Pilot fuel outlet pressure, max	kPa	150		150		150	
Pilot fuel return flow at 100% load	kg/h	276		276		276	
Lubricating oil system (Note 6)							
Pressure before bearings, nom. (PT 201)	kPa	400		400		400	
Pressure after pump, max.	kPa	800		800		800	
Suction ability, including pipe loss, max.	kPa	40		40		40	

Wärtsilä 6L50DF		DE DE Constant Speed		DE DE Constant Speed		ME CPP Variable Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	kW	950		975		975	
Engine speed	rpm	500		514		514	
Priming pressure, nom. (PT 201)	kPa	80		80		80	
Temperature before bearings, nom. (TE 201)	°C	63		63		63	
Temperature after engine, approx.	°C	78		78		78	
Pump capacity (main), engine driven	m³/h	157		162		174	
Pump capacity (main), electrically driven	m³/h	150		150		150	
Oil flow through engine	m³/h	129		129		129	
Priming pump capacity (50/60Hz)	m³/h	34.0 / 34.0		34.0 / 34.0		34.0 / 34.0	
Oil volume in separate system oil tank	m³	8		8		8	
Oil consumption at 100% load, approx.	g/kWh	0.5		0.5		0.5	
Crankcase ventilation flow rate at full load	l/min	1300		1300		1300	
Crankcase volume	m³	14.6		14.6		14.6	
Crankcase ventilation backpressure, max.	Pa	500		500		500	
Oil volume in turning device	l	8.5...9.5		8.5...9.5		8.5...9.5	
Oil volume in speed governor	l	1.4		1.4		1.4	
HT cooling water system							
Pressure at engine, after pump, nom. (PT 401)	kPa	510 + static		510 + static		510 + static	
Pressure at engine, after pump, max. (PT 401)	kPa	480		480		480	
Temperature before cylinders, approx. (TE 401)	°C	74		74		74	
Temperature after charge air cooler, nom.	°C	94		94		94	
Capacity of engine driven pump, nom.	m³/h	135		135		135	
Pressure drop over engine, total	kPa	100		100		100	
Pressure drop in external system, max.	kPa	150		150		150	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Water volume in engine	m³	0.95		0.95		0.95	
LT cooling water system							
Pressure at engine, after pump, nom. (PT 471)	kPa	360+ static		360+ static		360+ static	
Pressure at engine, after pump, max. (PT 471)	kPa	440		440		440	
Temperature before engine, max. (TE 471)	°C	55		55		55	
Temperature before engine, min. (TE 471)	°C	36		36		36	
Capacity of engine driven pump, nom.	m³/h	135		135		135	
Pressure drop over charge air cooler	kPa	70		70		70	
Pressure drop in external system, max.	kPa	200		200		200	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Starting air system (Note 7)							
Pressure, nom. (PT 301)	kPa	3000		3000		3000	
Pressure at engine during start, min. (20 °C)	kPa	1000		1000		1000	
Pressure, max. (PT 301)	kPa	3000		3000		3000	
Low pressure limit in starting air vessel	kPa	1800		1800		1800	
Consumption per start at 20 °C (successful start)	Nm³	3.6		3.6		3.6	

Wärtsilä 6L50DF		DE DE Constant Speed		DE DE Constant Speed		ME CPP Variable Speed	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	kW	950		975		975	
Engine speed	rpm	500		514		514	
Consumption per start at 20 °C (with slowturn)	Nm ³	4.3		4.3		4.3	

Notes:

- Note 1 According to ISO 15550 and 100% load. Flow tolerance 8%
- Note 2 According to ISO 15550. Flow tolerance 8% and temperature tolerance 15°C. Higher backpressure can be applied: in this condition all consumption and HB value have to be evaluated. Please contact Wärtsilä to have further informations.
- Note 3 At 100% output and nominal speed. The figures are valid for ambient conditions according to ISO 15550, except for LT-water temperature, which is 35°C in gas operation and 45°C in back-up fuel operation. And with engine driven water, lube oil and pilot fuel pumps.
- Note 4 According to ISO 15550, lower calorific value 42700 kJ/kg, with engine driven pumps (two cooling water + one lubricating oil pumps). Tolerance 5%. Gas Lower heating value >28 MJ/m³N and Methane Number High (>80). The fuel consumption BSEC and SFOC are guaranteed at 100% load and the values at other loads are given for indication only. Consumption values in constant speed are valid for D2/E2 IMO cycles.
- Note 5 Fuel gas pressure given at LHV ≥ 36 MJ/m³N. Required fuel gas pressure depends on fuel gas LHV and need to be increased for lower LHV's. Pressure drop in external fuel gas system to be considered. See chapter Fuel system for further information.
- Note 6 Lubricating oil treatment losses and oil changes are not included in oil consumption. The lubricating oil volume of the governor is depending of the governor type.
- Note 7 At manual starting the consumption may be 2...3 times lower.

ME = Engine driving propeller, variable speed

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

3.3 Wärtsilä 8L50DF

Wärtsilä 8L50DF		DE DE Constant Speed		DE DE Constant Speed		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	kW	950		975		975	
Engine speed	rpm	500		514		514	
Engine output	kW	7600		7800		7800	
Mean effective pressure	MPa	2.0		2.0		2.0	
IMO compliance		Tier 3	Tier 2	Tier 3	Tier 2	Tier 3	Tier 2
Combustion air system (Note 1)							
Flow at 100% load	kg/s	12.2	15.0	12.2	15.0	12.2	14.6
Temperature at turbocharger intake, max.	°C	45		45		45	
Temperature after air cooler, nom. (TE 601)	°C	45	50	45	50	45	50
Exhaust gas system (Note 2)							
Flow at 100% load	kg/s	11.9	15.1	12.2	15.8	12.0	16.5
Flow at 75% load	kg/s	9.2	12.2	9.5	12.6	9.6	12.3
Flow at 50% load	kg/s	7.0	9.3	7.1	9.5	7.2	11.1
Temperature after turbocharger at 100% load (TE 517)	°C	401	337	401	337	402	316
Temperature after turbocharger at 75% load (TE 517)	°C	445	319	445	319	418	321
Temperature after turbocharger at 50% load (TE 517)	°C	442	319	442	319	397	255
Backpressure, max.	kPa	4		4		4	
Calculated exhaust diameter for 35 m/s	mm	907	972	919	995	911	997
Heat balance at 100% load (Note 3)							
Jacket water, HT-circuit	kW	872	1304	904	1328	912	1344
Charge air, HT-circuit	kW	1040	1632	1104	1744	1120	1832
Charge air, LT-circuit	kW	576	864	600	928	600	1024
Lubricating oil, LT-circuit	kW	616	976	632	992	640	1008
Radiation	kW	208	232	216	240	216	240
Fuel consumption (Note 4)							
BSEC total at 100% load	kJ/kWh	7360	-	7390	-	7410	-
BSEC total at 85% load	kJ/kWh	7530.0	-	7570.0	-	0.0	-
BSEC total at 75% load	kJ/kWh	7720	-	7750	-	7550	-
BSEC total at 50% load	kJ/kWh	8560	-	8580	-	8220	-
BSEC gas fuel at 100% load	kJ/kWh	7318	-	7350	-	7365	-
BSEC gas fuel at 85% load	kJ/kWh	7481.0	-	7513.0	-	0.0	-
BSEC gas fuel at 75% load	kJ/kWh	7658	-	7692	-	7493	-
BSEC gas fuel at 50% load	kJ/kWh	8456	-	8476	-	8122	-
Pilot fuel consumption at 100% load	g/kWh	1.0	0.0	1.0	0.0	1.0	0.0
Pilot fuel consumption at 85% load	g/kWh	1.3	0.0	1.3	0.0	0.0	0.0
Pilot fuel consumption at 75% load	g/kWh	1.5	0.0	1.5	0.0	1.5	0.0
Pilot fuel consumption 50% load	g/kWh	2.5	0.0	2.5	0.0	2.4	0.0
SFOC at 100% load - LFO	g/kWh	-	190.1	-	192.0	-	189.6

Wärtsilä 8L50DF		DE DE Constant Speed		DE DE Constant Speed		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	kW	950		975		975	
Engine speed	rpm	500		514		514	
SFOC at 85% load - LFO	g/kWh	-	187.7	-	189.1	-	185.8
SFOC at 75% load - LFO	g/kWh	-	188.2	-	189.1	-	184.4
SFOC at 50% load - LFO	g/kWh	-	197.5	-	197.5	-	190.4
SFOC at 100% load - HFO	g/kWh	-	190.1	-	192.0	-	189.6
SFOC at 85% load - HFO	g/kWh	-	187.7	-	189.1	-	185.8
SFOC at 75% load - HFO	g/kWh	-	190	-	192	-	190
SFOC at 50% load - HFO	g/kWh	-	198	-	198	-	190
Fuel gas system (Note 5)							
Gas pressure at engine inlet, min (PT901)	kPa (a)	472	-	472	-	472	-
Gas pressure to Gas Valve unit, min	kPa (a)	592	-	592	-	592	-
Gas temperature before Gas Valve Unit	°C	0...60	-	0...60	-	0...60	-
Fuel oil system							
Pressure before injection pumps (PT 101)	kPa	800±50		800±50		800±50	
Fuel oil flow to engine, approx	m³/h	8.2		8.5		8.3	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140
MDF viscosity, min.	cSt	2.0		2.0		2.0	
Max. MDF temperature before engine (TE 101)	°C	45		45		45	
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h	-	6.0	-	6.0	-	6.2
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	16.0	30.1	16.0	30.1	15.5	31.1
Pilot fuel (MDF) viscosity before the engine	cSt	2...11		2...11		2...11	
Pilot fuel pressure at engine inlet (PT 112)	kPa	400...800		400...800		400...800	
Pilot fuel outlet pressure, max	kPa	150		150		150	
Pilot fuel return flow at 100% load	kg/h	284		284		284	
Lubricating oil system (Note 6)							
Pressure before bearings, nom. (PT 201)	kPa	400		400		400	
Pressure after pump, max.	kPa	800		800		800	
Suction ability, including pipe loss, max.	kPa	40		40		40	
Priming pressure, nom. (PT 201)	kPa	80		80		80	
Temperature before bearings, nom. (TE 201)	°C	63		63		63	
Temperature after engine, approx.	°C	78		78		78	
Pump capacity (main), engine driven	m³/h	202		207		223	
Pump capacity (main), electrically driven	m³/h	165		165		165	
Oil flow through engine	m³/h	136		136		136	
Priming pump capacity (50/60Hz)	m³/h	45.0 / 45.0		45.0 / 45.0		45.0 / 45.0	
Oil volume in separate system oil tank	m³	11		11		11	
Oil consumption at 100% load, approx.	g/kWh	0.5		0.5		0.5	
Crankcase ventilation flow rate at full load	l/min	2000		2000		2000	
Crankcase volume	m³	19.5		19.5		19.5	

Wärtsilä 8L50DF		DE DE Constant Speed		DE DE Constant Speed		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	kW	950		975		975	
Engine speed	rpm	500		514		514	
Crankcase ventilation backpressure, max.	Pa	500		500		500	
Oil volume in turning device	l	8.5...9.5		8.5...9.5		8.5...9.5	
Oil volume in speed governor	l	1.4		1.4		1.4	
HT cooling water system							
Pressure at engine, after pump, nom. (PT 401)	kPa	510 + static		510 + static		510 + static	
Pressure at engine, after pump, max. (PT 401)	kPa	480		480		480	
Temperature before cylinders, approx. (TE 401)	°C	74		74		74	
Temperature after charge air cooler, nom.	°C	94		94		94	
Capacity of engine driven pump, nom.	m³/h	180		180		180	
Pressure drop over engine, total	kPa	100		100		100	
Pressure drop in external system, max.	kPa	150		150		150	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Water volume in engine	m³	1.35		1.35		1.35	
LT cooling water system							
Pressure at engine, after pump, nom. (PT 471)	kPa	360+ static		360+ static		360+ static	
Pressure at engine, after pump, max. (PT 471)	kPa	440		440		440	
Temperature before engine, max. (TE 471)	°C	55		55		55	
Temperature before engine, min. (TE 471)	°C	36		36		36	
Capacity of engine driven pump, nom.	m³/h	180		180		180	
Pressure drop over charge air cooler	kPa	70		70		70	
Pressure drop in external system, max.	kPa	200		200		200	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Starting air system (Note 7)							
Pressure, nom. (PT 301)	kPa	3000		3000		3000	
Pressure at engine during start, min. (20 °C)	kPa	1000		1000		1000	
Pressure, max. (PT 301)	kPa	3000		3000		3000	
Low pressure limit in starting air vessel	kPa	1800		1800		1800	
Consumption per start at 20 °C (successful start)	Nm³	4.8		4.8		4.8	
Consumption per start at 20 °C (with slowturn)	Nm³	5.8		5.8		5.8	

Notes:

- Note 1 According to ISO 15550 and 100% load. Flow tolerance 8%
- Note 2 According to ISO 15550. Flow tolerance 8% and temperature tolerance 15°C. Higher backpressure can be applied: in this condition all consumption and HB value have to be evaluated. Please contact Wärtsilä to have further informations.
- Note 3 At 100% output and nominal speed. The figures are valid for ambient conditions according to ISO 15550, except for LT-water temperature, which is 35°C in gas operation and 45°C in back-up fuel operation. And with engine driven water, lube oil and pilot fuel pumps.
- Note 4 According to ISO 15550, lower calorific value 42700 kJ/kg, with engine driven pumps (two cooling water + one lubricating oil pumps). Tolerance 5%. Gas Lower heating value >28 MJ/m³N and Methane Number High (>80). The fuel consumption BSEC and SFOC are guaranteed at 100% load and the values at other loads are given for indication only. Consumption values in constant speed are valid for D2/E2 IMO cycles.

- Note 5 Fuel gas pressure given at $LHV \geq 36 \text{ MJ/m}^3 \text{N}$. 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 Lubricating oil treatment losses and oil changes are not included in oil consumption. The lubricating oil volume of the governor is depending of the governor type.
- Note 7 At manual starting the consumption may be 2...3 times lower.

ME = Engine driving propeller, variable speed

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

3.4 Wärtsilä 9L50DF

Wärtsilä 9L50DF		DE DE Constant Speed		DE DE Constant Speed		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	kW	950		975		975	
Engine speed	rpm	500		514		514	
Engine output	kW	8550		8775		8775	
Mean effective pressure	MPa	2.0		2.0		2.0	
IMO compliance		Tier 3	Tier 2	Tier 3	Tier 2	Tier 3	Tier 2
Combustion air system (Note 1)							
Flow at 100% load	kg/s	13.7	16.9	13.7	16.9	13.7	16.4
Temperature at turbocharger intake, max.	°C	45		45		45	
Temperature after air cooler, nom. (TE 601)	°C	45	50	45	50	45	50
Exhaust gas system (Note 2)							
Flow at 100% load	kg/s	13.4	17.0	13.8	17.8	13.5	18.5
Flow at 75% load	kg/s	10.4	13.7	10.7	14.2	10.8	13.9
Flow at 50% load	kg/s	7.8	10.4	8.0	10.7	8.1	12.5
Temperature after turbocharger at 100% load (TE 517)	°C	401	337	401	337	402	316
Temperature after turbocharger at 75% load (TE 517)	°C	445	319	445	319	418	321
Temperature after turbocharger at 50% load (TE 517)	°C	442	319	442	319	397	255
Backpressure, max.	kPa	4		4		4	
Calculated exhaust diameter for 35 m/s	mm	962	1031	975	1055	966	1058
Heat balance at 100% load (Note 3)							
Jacket water, HT-circuit	kW	981	1467	1017	1494	1026	1512
Charge air, HT-circuit	kW	1170	1836	1242	1962	1260	2061
Charge air, LT-circuit	kW	648	972	675	1044	675	1152
Lubricating oil, LT-circuit	kW	693	1098	711	1116	720	1134
Radiation	kW	234	261	243	270	243	270
Fuel consumption (Note 4)							
BSEC total at 100% load	kJ/kWh	7360	-	7390	-	7410	-
BSEC total at 85% load	kJ/kWh	7530.0	-	7570.0	-	0.0	-
BSEC total at 75% load	kJ/kWh	7720	-	7750	-	7550	-
BSEC total at 50% load	kJ/kWh	8560	-	8580	-	8220	-
BSEC gas fuel at 100% load	kJ/kWh	7318	-	7350	-	7365	-
BSEC gas fuel at 85% load	kJ/kWh	7481.0	-	7513.0	-	0.0	-
BSEC gas fuel at 75% load	kJ/kWh	7658	-	7692	-	7493	-
BSEC gas fuel at 50% load	kJ/kWh	8456	-	8476	-	8122	-
Pilot fuel consumption at 100% load	g/kWh	1.0	0.0	1.0	0.0	1.0	0.0
Pilot fuel consumption at 85% load	g/kWh	1.3	0.0	1.3	0.0	0.0	0.0
Pilot fuel consumption at 75% load	g/kWh	1.5	0.0	1.5	0.0	1.5	0.0
Pilot fuel consumption 50% load	g/kWh	2.5	0.0	2.5	0.0	2.4	0.0
SFOC at 100% load - LFO	g/kWh	-	190.1	-	192.0	-	189.6

Wärtsilä 9L50DF		DE DE Constant Speed		DE DE Constant Speed		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	kW	950		975		975	
Engine speed	rpm	500		514		514	
SFOC at 85% load - LFO	g/kWh	-	190.1	-	192.0	-	189.6
SFOC at 75% load - LFO	g/kWh	-	188	-	189	-	184
SFOC at 50% load - LFO	g/kWh	-	198	-	198	-	190
SFOC at 100% load - HFO	g/kWh	-	190.1	-	192.0	-	189.6
SFOC at 85% load - HFO	g/kWh	-	187.7	-	189.1	-	185.8
SFOC at 75% load - HFO	g/kWh	-	188.2	-	189.1	-	184.4
SFOC at 50% load - HFO	g/kWh	-	197.5	-	197.5	-	190.4
Fuel gas system (Note 5)							
Gas pressure at engine inlet, min (PT901)	kPa (a)	472	-	472	-	472	-
Gas pressure to Gas Valve unit, min	kPa (a)	592	-	592	-	592	-
Gas temperature before Gas Valve Unit	°C	0...60	-	0...60	-	0...60	-
Fuel oil system							
Pressure before injection pumps (PT 101)	kPa	800±50		800±50		800±50	
Fuel oil flow to engine, approx	m³/h	9.2		9.5		9.4	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140
MDF viscosity, min.	cSt	2.0		2.0		2.0	
Max. MDF temperature before engine (TE 101)	°C	45		45		45	
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h	-	6.8	-	6.8	-	7.0
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	18.0	33.9	18.0	33.9	17.5	35.0
Pilot fuel (MDF) viscosity before the engine	cSt	2...11		2...11		2...11	
Pilot fuel pressure at engine inlet (PT 112)	kPa	400...800		400...800		400...800	
Pilot fuel outlet pressure, max	kPa	150		150		150	
Pilot fuel return flow at 100% load	kg/h	288		288		288	
Lubricating oil system (Note 6)							
Pressure before bearings, nom. (PT 201)	kPa	400		400		400	
Pressure after pump, max.	kPa	800		800		800	
Suction ability, including pipe loss, max.	kPa	40		40		40	
Priming pressure, nom. (PT 201)	kPa	80		80		80	
Temperature before bearings, nom. (TE 201)	°C	63		63		63	
Temperature after engine, approx.	°C	78		78		78	
Pump capacity (main), engine driven	m³/h	223		229		248	
Pump capacity (main), electrically driven	m³/h	180		180		180	
Oil flow through engine	m³/h	143		143		143	
Priming pump capacity (50/60Hz)	m³/h	51.0 / 51.0		51.0 / 51.0		51.0 / 51.0	
Oil volume in separate system oil tank	m³	12		12		12	
Oil consumption at 100% load, approx.	g/kWh	0.5		0.5		0.5	
Crankcase ventilation flow rate at full load	l/min	2100		2100		2100	
Crankcase volume	m³	22.0		22.0		22.0	

Wärtsilä 9L50DF		DE DE Constant Speed		DE DE Constant Speed		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	kW	950		975		975	
Engine speed	rpm	500		514		514	
Crankcase ventilation backpressure, max.	Pa	500		500		500	
Oil volume in turning device	l	68.0...70.0		68.0...70.0		68.0...70.0	
Oil volume in speed governor	l	1.4		1.4		1.4	
HT cooling water system							
Pressure at engine, after pump, nom. (PT 401)	kPa	510 + static		510 + static		510 + static	
Pressure at engine, after pump, max. (PT 401)	kPa	480		480		480	
Temperature before cylinders, approx. (TE 401)	°C	74		74		74	
Temperature after charge air cooler, nom.	°C	94		94		94	
Capacity of engine driven pump, nom.	m³/h	200		200		200	
Pressure drop over engine, total	kPa	100		100		100	
Pressure drop in external system, max.	kPa	150		150		150	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Water volume in engine	m³	1.5		1.5		1.5	
LT cooling water system							
Pressure at engine, after pump, nom. (PT 471)	kPa	360+ static		360+ static		360+ static	
Pressure at engine, after pump, max. (PT 471)	kPa	440		440		440	
Temperature before engine, max. (TE 471)	°C	55		55		55	
Temperature before engine, min. (TE 471)	°C	36		36		36	
Capacity of engine driven pump, nom.	m³/h	200		200		200	
Pressure drop over charge air cooler	kPa	70		70		70	
Pressure drop in external system, max.	kPa	200		200		200	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Starting air system (Note 7)							
Pressure, nom. (PT 301)	kPa	3000		3000		3000	
Pressure at engine during start, min. (20 °C)	kPa	1000		1000		1000	
Pressure, max. (PT 301)	kPa	3000		3000		3000	
Low pressure limit in starting air vessel	kPa	1800		1800		1800	
Consumption per start at 20 °C (successful start)	Nm³	5.4		5.4		5.4	
Consumption per start at 20 °C (with slowturn)	Nm³	6.5		6.5		6.5	

Notes:

- Note 1 According to ISO 15550 and 100% load. Flow tolerance 8%
- Note 2 According to ISO 15550. Flow tolerance 8% and temperature tolerance 15°C. Higher backpressure can be applied: in this condition all consumption and HB value have to be evaluated. Please contact Wärtsilä to have further informations.
- Note 3 At 100% output and nominal speed. The figures are valid for ambient conditions according to ISO 15550, except for LT-water temperature, which is 35°C in gas operation and 45°C in back-up fuel operation. And with engine driven water, lube oil and pilot fuel pumps.
- Note 4 According to ISO 15550, lower calorific value 42700 kJ/kg, with engine driven pumps (two cooling water + one lubricating oil pumps). Tolerance 5%. Gas Lower heating value >28 MJ/m³N and Methane Number High (>80). The fuel consumption BSEC and SFOC are guaranteed at 100% load and the values at other loads are given for indication only. Consumption values in constant speed are valid for D2/E2 IMO cycles.

- Note 5 Fuel gas pressure given at $LHV \geq 36 \text{ MJ/m}^3 \text{N}$. 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 Lubricating oil treatment losses and oil changes are not included in oil consumption. The lubricating oil volume of the governor is depending of the governor type.
- Note 7 At manual starting the consumption may be 2...3 times lower.

ME = Engine driving propeller, variable speed

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

3.5

Wärtsilä 12V50DF

Wärtsilä 12V50DF		DE DE Constant Speed		DE DE Constant Speed		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	kW	950		975		975	
Engine speed	rpm	500		514		514	
Engine output	kW	11400		11700		11700	
Mean effective pressure	MPa	2.0		2.0		2.0	
IMO compliance		Tier 3	Tier 2	Tier 3	Tier 2	Tier 3	Tier 2
Combustion air system (Note 1)							
Flow at 100% load	kg/s	18.3	22.5	18.3	22.5	18.3	21.9
Temperature at turbocharger intake, max.	°C	45		45		45	
Temperature after air cooler, nom. (TE 601)	°C	45	50	45	50	45	50
Exhaust gas system (Note 2)							
Flow at 100% load	kg/s	17.9	22.7	18.4	23.8	18.0	24.7
Flow at 75% load	kg/s	13.8	18.2	14.3	19.0	14.4	18.5
Flow at 50% load	kg/s	10.4	13.9	10.7	14.3	10.8	16.7
Temperature after turbocharger at 100% load (TE 517)	°C	401	337	401	337	402	316
Temperature after turbocharger at 75% load (TE 517)	°C	445	319	445	319	418	321
Temperature after turbocharger at 50% load (TE 517)	°C	442	319	442	319	397	255
Backpressure, max.	kPa	4		4		4	
Calculated exhaust diameter for 35 m/s	mm	1111	1191	1126	1219	1116	1221
Heat balance at 100% load (Note 3)							
Jacket water, HT-circuit	kW	1308	1956	1356	1992	1368	2016
Charge air, HT-circuit	kW	1560	2448	1656	2616	1680	2748
Charge air, LT-circuit	kW	864	1296	900	1392	900	1536
Lubricating oil, LT-circuit	kW	924	1464	948	1488	960	1512
Radiation	kW	312	348	324	360	324	360
Fuel consumption (Note 4)							
BSEC total at 100% load	kJ/kWh	7360	-	7390	-	7410	-
BSEC total at 85% load	kJ/kWh	7530.0	-	7570.0	-	0.0	-
BSEC total at 75% load	kJ/kWh	7720	-	7750	-	7550	-
BSEC total at 50% load	kJ/kWh	8560	-	8580	-	8220	-
BSEC gas fuel at 100% load	kJ/kWh	7318	-	7350	-	7365	-
BSEC gas fuel at 85% load	kJ/kWh	7481.0	-	7513.0	-	0.0	-
BSEC gas fuel at 75% load	kJ/kWh	7658	-	7692	-	7493	-
BSEC gas fuel at 50% load	kJ/kWh	8456	-	8476	-	8122	-
Pilot fuel consumption at 100% load	g/kWh	1.0	0.0	1.0	0.0	1.0	0.0
Pilot fuel consumption at 85% load	g/kWh	1.3	0.0	1.3	0.0	0.0	0.0
Pilot fuel consumption at 75% load	g/kWh	1.5	0.0	1.5	0.0	1.5	0.0
Pilot fuel consumption 50% load	g/kWh	2.5	0.0	2.5	0.0	2.4	0.0
SFOC at 100% load - LFO	g/kWh	-	190.1	-	192.0	-	189.6

Wärtsilä 12V50DF		DE DE Constant Speed		DE DE Constant Speed		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	kW	950		975		975	
Engine speed	rpm	500		514		514	
SFOC at 85% load - LFO	g/kWh	-	187.7	-	189.1	-	185.8
SFOC at 75% load - LFO	g/kWh	-	188.2	-	189.1	-	184.4
SFOC at 50% load - LFO	g/kWh	-	197.5	-	197.5	-	190.4
SFOC at 100% load - HFO	g/kWh	-	190.1	-	192.0	-	189.6
SFOC at 85% load - HFO	g/kWh	-	187.7	-	189.1	-	185.8
SFOC at 75% load - HFO	g/kWh	-	188	-	189	-	184
SFOC at 50% load - HFO	g/kWh	-	198	-	198	-	190
Fuel gas system (Note 5)							
Gas pressure at engine inlet, min (PT901)	kPa (a)	472	-	472	-	472	-
Gas pressure to Gas Valve unit, min	kPa (a)	592	-	592	-	592	-
Gas temperature before Gas Valve Unit	°C	0...60	-	0...60	-	0...60	-
Fuel oil system							
Pressure before injection pumps (PT 101)	kPa	800±50		800±50		800±50	
Fuel oil flow to engine, approx	m³/h	12.2		12.7		12.5	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140
MDF viscosity, min.	cSt	2.0		2.0		2.0	
Max. MDF temperature before engine (TE 101)	°C	45		45		45	
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h	-	9.0	-	9.0	-	9.3
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	24.1	45.2	24.1	45.2	23.3	46.6
Pilot fuel (MDF) viscosity before the engine	cSt	2...11		2...11		2...11	
Pilot fuel pressure at engine inlet (PT 112)	kPa	400...800		400...800		400...800	
Pilot fuel outlet pressure, max	kPa	150		150		150	
Pilot fuel return flow at 100% load	kg/h	300		300		300	
Lubricating oil system (Note 6)							
Pressure before bearings, nom. (PT 201)	kPa	400		400		400	
Pressure after pump, max.	kPa	800		800		800	
Suction ability, including pipe loss, max.	kPa	40		40		40	
Priming pressure, nom. (PT 201)	kPa	80		80		80	
Temperature before bearings, nom. (TE 201)	°C	63		63		63	
Temperature after engine, approx.	°C	78		78		78	
Pump capacity (main), engine driven	m³/h	248		255		310	
Pump capacity (main), electrically driven	m³/h	220		220		220	
Oil flow through engine	m³/h	187		187		187	
Priming pump capacity (50/60Hz)	m³/h	65.0 / 65.0		65.0 / 65.0		65.0 / 65.0	
Oil volume in separate system oil tank	m³	16		16		16	
Oil consumption at 100% load, approx.	g/kWh	0.5		0.5		0.5	
Crankcase ventilation flow rate at full load	l/min	2600		2600		2600	
Crankcase volume	m³	29.5		29.5		29.5	

Wärtsilä 12V50DF		DE DE Constant Speed		DE DE Constant Speed		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	kW	950		975		975	
Engine speed	rpm	500		514		514	
Crankcase ventilation backpressure, max.	Pa	500		500		500	
Oil volume in turning device	l	68.0...70.0		68.0...70.0		68.0...70.0	
Oil volume in speed governor	l	6.2		6.2		6.2	
HT cooling water system							
Pressure at engine, after pump, nom. (PT 401)	kPa	510 + static		510 + static		510 + static	
Pressure at engine, after pump, max. (PT 401)	kPa	480		480		480	
Temperature before cylinders, approx. (TE 401)	°C	74		74		74	
Temperature after charge air cooler, nom.	°C	94		94		94	
Capacity of engine driven pump, nom.	m³/h	270		270		270	
Pressure drop over engine, total	kPa	100		100		100	
Pressure drop in external system, max.	kPa	150		150		150	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Water volume in engine	m³	1.7		1.7		1.7	
LT cooling water system							
Pressure at engine, after pump, nom. (PT 471)	kPa	360+ static		360+ static		360+ static	
Pressure at engine, after pump, max. (PT 471)	kPa	440		440		440	
Temperature before engine, max. (TE 471)	°C	55		55		55	
Temperature before engine, min. (TE 471)	°C	36		36		36	
Capacity of engine driven pump, nom.	m³/h	270		270		270	
Pressure drop over charge air cooler	kPa	70		70		70	
Pressure drop in external system, max.	kPa	200		200		200	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Starting air system (Note 7)							
Pressure, nom. (PT 301)	kPa	3000		3000		3000	
Pressure at engine during start, min. (20 °C)	kPa	1000		1000		1000	
Pressure, max. (PT 301)	kPa	3000		3000		3000	
Low pressure limit in starting air vessel	kPa	1800		1800		1800	
Consumption per start at 20 °C (successful start)	Nm³	6.0		6.0		6.0	
Consumption per start at 20 °C (with slowturn)	Nm³	7.2		7.2		7.2	

Notes:

- Note 1 According to ISO 15550 and 100% load. Flow tolerance 8%.
- Note 2 According to ISO 15550. Flow tolerance 8% and temperature tolerance 15°C. Higher backpressure can be applied: in this condition all consumption and HB value have to be evaluated. Please contact Wärtsilä to have further informations.
- Note 3 At 100% output and nominal speed. The figures are valid for ambient conditions according to ISO 15550, except for LT-water temperature, which is 35°C in gas operation and 45°C in back-up fuel operation. And with engine driven water, lube oil and pilot fuel pumps.
- Note 4 According to ISO 15550, lower calorific value 42700 kJ/kg, with engine driven pumps (two cooling water + one lubricating oil pumps). Tolerance 5%. Gas Lower heating value >28 MJ/m³N and Methane Number High (>80). The fuel consumption BSEC and SFOC are guaranteed at 100% load and the values at other loads are given for indication only. Consumption values in constant speed are valid for D2/E2 IMO cycles.

- Note 5 Fuel gas pressure given at $LHV \geq 36 \text{ MJ/m}^3 \text{N}$. 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 Lubricating oil treatment losses and oil changes are not included in oil consumption. The lubricating oil volume of the governor is depending of the governor type.
- Note 7 At manual starting the consumption may be 2...3 times lower.

ME = Engine driving propeller, variable speed

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

3.6

Wärtsilä 16V50DF

Wärtsilä 16V50DF		DE DE Constant Speed		DE DE Constant Speed		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	kW	950		975		975	
Engine speed	rpm	500		514		514	
Engine output	kW	15200		15600		15600	
Mean effective pressure	MPa	2.0		2.0		2.0	
IMO compliance		Tier 3	Tier 2	Tier 3	Tier 2	Tier 3	Tier 2
Combustion air system (Note 1)							
Flow at 100% load	kg/s	24.4	30.1	24.4	30.0	24.4	29.1
Temperature at turbocharger intake, max.	°C	45		45		45	
Temperature after air cooler, nom. (TE 601)	°C	45	50	45	50	45	50
Exhaust gas system (Note 2)							
Flow at 100% load	kg/s	23.8	30.2	24.5	31.7	24.0	33.0
Flow at 75% load	kg/s	18.4	24.3	19.0	25.3	19.2	24.6
Flow at 50% load	kg/s	13.9	18.6	14.2	19.0	14.4	22.2
Temperature after turbocharger at 100% load (TE 517)	°C	401	337	401	337	402	316
Temperature after turbocharger at 75% load (TE 517)	°C	445	319	445	319	418	321
Temperature after turbocharger at 50% load (TE 517)	°C	442	319	442	319	397	255
Backpressure, max.	kPa	4		4		4	
Calculated exhaust diameter for 35 m/s	mm	1283	1375	1300	1407	1288	1410
Heat balance at 100% load (Note 3)							
Jacket water, HT-circuit	kW	1744	2608	1808	2656	1824	2688
Charge air, HT-circuit	kW	2080	3264	2208	3488	2240	3664
Charge air, LT-circuit	kW	1152	1728	1200	1856	1200	2048
Lubricating oil, LT-circuit	kW	1232	1952	1264	1984	1280	2016
Radiation	kW	416	464	432	480	432	480
Fuel consumption (Note 4)							
BSEC total at 100% load	kJ/kWh	7360	-	7390	-	7410	-
BSEC total at 85% load	kJ/kWh	7530.0		7570.0		0.0	
BSEC total at 75% load	kJ/kWh	7720	-	7750	-	7550	-
BSEC total at 50% load	kJ/kWh	8560	-	8580	-	8220	-
BSEC gas fuel at 100% load	kJ/kWh	7318	-	7350	-	7365	-
BSEC gas fuel at 85% load	kJ/kWh	7481.0	-	7513.3	-	0.0	-
BSEC gas fuel at 75% load	kJ/kWh	7658	-	7692	-	7493	-
BSEC gas fuel at 50% load	kJ/kWh	8456	-	8476	-	8122	-
Pilot fuel consumption at 100% load	g/kWh	1.0	0.0	1.0	0.0	1.0	0.0
Pilot fuel consumption at 85% load	g/kWh	1.3	0.0	1.3	0.0	0.0	0.0
Pilot fuel consumption at 75% load	g/kWh	1.5	0.0	1.5	0.0	1.5	0.0
Pilot fuel consumption 50% load	g/kWh	2.5	0.0	2.5	0.0	2.4	0.0
SFOC at 100% load - LFO	g/kWh	-	190.1	-	192.0	-	189.6

Wärtsilä 16V50DF		DE DE Constant Speed		DE DE Constant Speed		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	kW	950		975		975	
Engine speed	rpm	500		514		514	
SFOC at 85% load - LFO	g/kWh	-	187.7	-	189.1	-	185.8
SFOC at 75% load - LFO	g/kWh	-	188.2	-	189.1	-	184.4
SFOC at 50% load - LFO	g/kWh	-	197.5	-	197.5	-	190.4
SFOC at 100% load - HFO	g/kWh	-	190.1	-	192.0	-	189.6
SFOC at 85% load - HFO	g/kWh	-	187.7	-	189.1	-	185.8
SFOC at 75% load - HFO	g/kWh	-	188	-	189	-	184
SFOC at 50% load - HFO	g/kWh	-	197.5	-	197.5	-	190.4
Fuel gas system (Note 5)							
Gas pressure at engine inlet, min (PT901)	kPa (a)	472	-	472	-	472	-
Gas pressure to Gas Valve unit, min	kPa (a)	592	-	592	-	592	-
Gas temperature before Gas Valve Unit	°C	0...60	-	0...60	-	0...60	-
Fuel oil system							
Pressure before injection pumps (PT 101)	kPa	800±50		800±50		800±50	
Fuel oil flow to engine, approx	m³/h	16.3		16.9		16.7	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140
MDF viscosity, min.	cSt	2.0		2.0		2.0	
Max. MDF temperature before engine (TE 101)	°C	45		45		45	
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h	-	12.1	-	12.1	-	12.4
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	32.1	60.3	32.1	60.3	31.1	62.2
Pilot fuel (MDF) viscosity before the engine	cSt	2...11		2...11		2...11	
Pilot fuel pressure at engine inlet (PT 112)	kPa	400...800		400...800		400...800	
Pilot fuel outlet pressure, max	kPa	150		150		150	
Pilot fuel return flow at 100% load	kg/h	317		317		317	
Lubricating oil system (Note 6)							
Pressure before bearings, nom. (PT 201)	kPa	400		400		400	
Pressure after pump, max.	kPa	800		800		800	
Suction ability, including pipe loss, max.	kPa	40		40		40	
Priming pressure, nom. (PT 201)	kPa	80		80		80	
Temperature before bearings, nom. (TE 201)	°C	63		63		63	
Temperature after engine, approx.	°C	78		78		78	
Pump capacity (main), engine driven	m³/h	335		345		335	
Pump capacity (main), electrically driven	m³/h	270		270		270	
Oil flow through engine	m³/h	253		253		253	
Priming pump capacity (50/60Hz)	m³/h	85.0 / 85.0		85.0 / 85.0		85.0 / 85.0	
Oil volume in separate system oil tank	m³	22		22		22	
Oil consumption at 100% load, approx.	g/kWh	0.5		0.5		0.5	
Crankcase ventilation flow rate at full load	l/min	4000		4000		4000	
Crankcase volume	m³	39.4		39.4		39.4	

Wärtsilä 16V50DF		DE DE Constant Speed		DE DE Constant Speed		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	kW	950		975		975	
Engine speed	rpm	500		514		514	
Crankcase ventilation backpressure, max.	Pa	500		500		500	
Oil volume in turning device	l	68.0...70.0		68.0...70.0		68.0...70.0	
Oil volume in speed governor	l	6.2		6.2		6.2	
HT cooling water system							
Pressure at engine, after pump, nom. (PT 401)	kPa	510 + static		510 + static		510 + static	
Pressure at engine, after pump, max. (PT 401)	kPa	480		480		480	
Temperature before cylinders, approx. (TE 401)	°C	74		74		74	
Temperature after charge air cooler, nom.	°C	94		94		94	
Capacity of engine driven pump, nom.	m³/h	355		355		355	
Pressure drop over engine, total	kPa	100		100		100	
Pressure drop in external system, max.	kPa	150		150		150	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Water volume in engine	m³	2.1		2.1		2.1	
LT cooling water system							
Pressure at engine, after pump, nom. (PT 471)	kPa	360+ static		360+ static		360+ static	
Pressure at engine, after pump, max. (PT 471)	kPa	440		440		440	
Temperature before engine, max. (TE 471)	°C	55		55		55	
Temperature before engine, min. (TE 471)	°C	36		36		36	
Capacity of engine driven pump, nom.	m³/h	355		355		355	
Pressure drop over charge air cooler	kPa	70		70		70	
Pressure drop in external system, max.	kPa	200		200		200	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Starting air system (Note 7)							
Pressure, nom. (PT 301)	kPa	3000		3000		3000	
Pressure at engine during start, min. (20 °C)	kPa	1000		1000		1000	
Pressure, max. (PT 301)	kPa	3000		3000		3000	
Low pressure limit in starting air vessel	kPa	1800		1800		1800	
Consumption per start at 20 °C (successful start)	Nm³	7.8		7.8		7.8	
Consumption per start at 20 °C (with slowturn)	Nm³	9.4		9.4		9.4	

Notes:

- Note 1 According to ISO 15550 and 100% load. Flow tolerance 8%.
- Note 2 According to ISO 15550. Flow tolerance 8% and temperature tolerance 15°C. Higher backpressure can be applied: in this condition all consumption and HB value have to be evaluated. Please contact Wärtsilä to have further informations.
- Note 3 At 100% output and nominal speed. The figures are valid for ambient conditions according to ISO 15550, except for LT-water temperature, which is 35°C in gas operation and 45°C in back-up fuel operation. And with engine driven water, lube oil and pilot fuel pumps.
- Note 4 According to ISO 15550, lower calorific value 42700 kJ/kg, with engine driven pumps (two cooling water + one lubricating oil pumps). Tolerance 5%. Gas Lower heating value >28 MJ/m³N and Methane Number High (>80). The fuel consumption BSEC and SFOC are guaranteed at 100% load and the values at other loads are given for indication only. Consumption values in constant speed are valid for D2/E2 IMO cycles.

- Note 5 Fuel gas pressure given at $LHV \geq 36 \text{ MJ/m}^3 \text{N}$. 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 Lubricating oil treatment losses and oil changes are not included in oil consumption. The lubricating oil volume of the governor is depending of the governor type.
- Note 7 At manual starting the consumption may be 2...3 times lower.

ME = Engine driving propeller, variable speed

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

4. Description of the Engine

4.1 Definitions

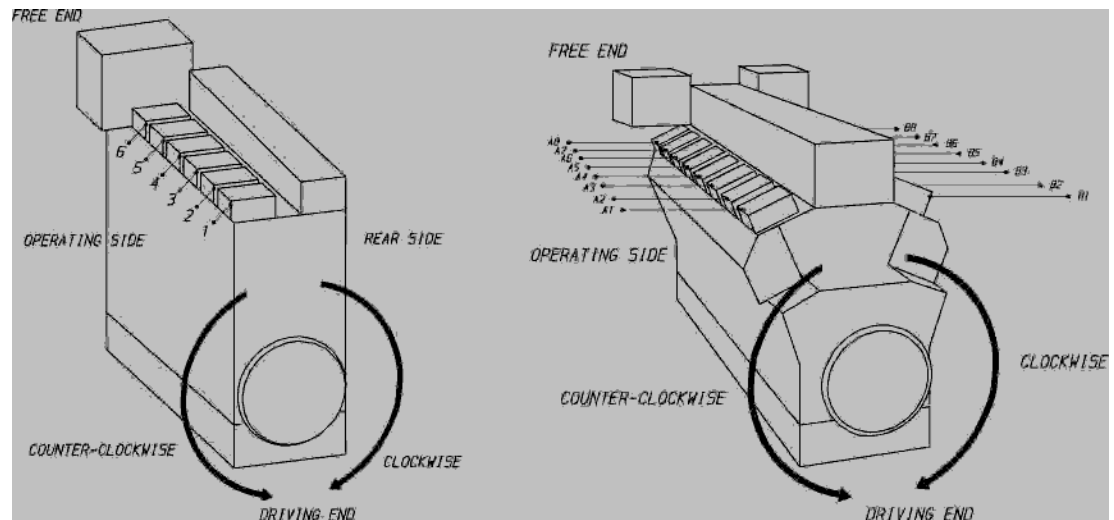


Fig 4-1 In-line engine and V-engine definitions (1V93C0029 / 1V93C0028)

4.2 Main components and systems

Main dimensions and weights are presented in chapter [Main Data and Outputs](#).

4.2.1 Engine Block

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

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

A hydraulic jack, supported in the oil sump, offers the possibility to lower and lift the main bearing caps, e.g. when inspecting the bearings. Lubricating oil is led to the bearings and piston through this jack. A combined flywheel/thrust bearing is located at the driving end of the engine. The oil sump, a light welded design, is mounted on the engine block from below and sealed by O-rings.

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

4.2.2 Crankshaft

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

The crankshaft is forged in one piece and mounted on the engine block in an under-slung way. In V-engines the connecting rods are arranged side-by-side on the same crank pin in

order to obtain a high degree of standardization. The journals are of same size regardless of number of cylinders.

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

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

4.2.3 Connection rod

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

4.2.4 Main bearings and big end bearings

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

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

4.2.5 Cylinder liner

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

The liner is of wet type, sealed against the engine block metallicity at the upper part and by O-rings at the lower part. Accurate temperature control of the cylinder liner is achieved with optimally located inclined cooling bores. To eliminate the risk of bore polishing the liner is equipped with an anti-polishing ring.

4.2.6 Piston

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

4.2.7 Piston rings

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

4.2.8 Cylinder head

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

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

4.2.9 Camshaft and valve mechanism

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

4.2.10 Camshaft drive

The camshafts are driven by the crankshaft through a gear train.

The driving gear is fixed to the crankshaft by means of flange connection.

4.2.11 Fuel system

The Wärtsilä 50DF engine is designed for continuous operation on fuel gas (natural gas) or Marine Diesel Fuel (MDF). It is also possible to operate the engine on Heavy Fuel Oil (HFO). Dual fuel operation requires external gas feed system and fuel oil feed system. For more details about the fuel system see chapter [Fuel System](#).

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 (for V-engines) or on the intake duct of the cylinder head (for in-line engines). The gas admission valve is a direct actuated solenoid valve. The valve is closed by a spring (positive sealing) when there is no electrical signal. With the engine control system it is possible to adjust the amount of gas fed to each individual cylinder for load balancing of the engine, while the engine is running. The gas admission valves also include safety filters (90 µm).

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

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

4.2.11.2 Main fuel oil injection

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

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

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

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

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

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

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

4.2.11.3 Pilot fuel injection

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

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

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

The pilot fuel filter is a full flow duplex unit preventing impurities entering the pilot fuel system. The fineness of the filter is 10 µm.

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

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

The pilot diesel injection part of the twin fuel oil injection valve has a needle actuated by a solenoid, which is controlled by the engine control system. The pilot diesel fuel is admitted

through a high pressure connection screwed in the nozzle holder. When the engine runs in diesel mode the pilot fuel injection is also in operation to keep the needle clean.

4.2.12 Exhaust pipes

The exhaust manifold pipes are made of special heat resistant nodular cast iron alloy.

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

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

4.2.13 Lubricating system

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

4.2.14 Cooling system

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

4.2.15 Turbocharging and charge air cooling

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

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

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

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

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

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

4.2.16 Automation system

Wärtsilä 50DF is equipped with a modular embedded automation system, Wärtsilä Unified Controls - UNIC.

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

showing the most important operating parameters. Speed control is included in the automation system on the engine.

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

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

4.2.17 Variable Inlet valve Closure

Variable Inlet valve Closure (VIC), offers flexibility to apply early inlet valve closure at high load for lowest NO_x 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

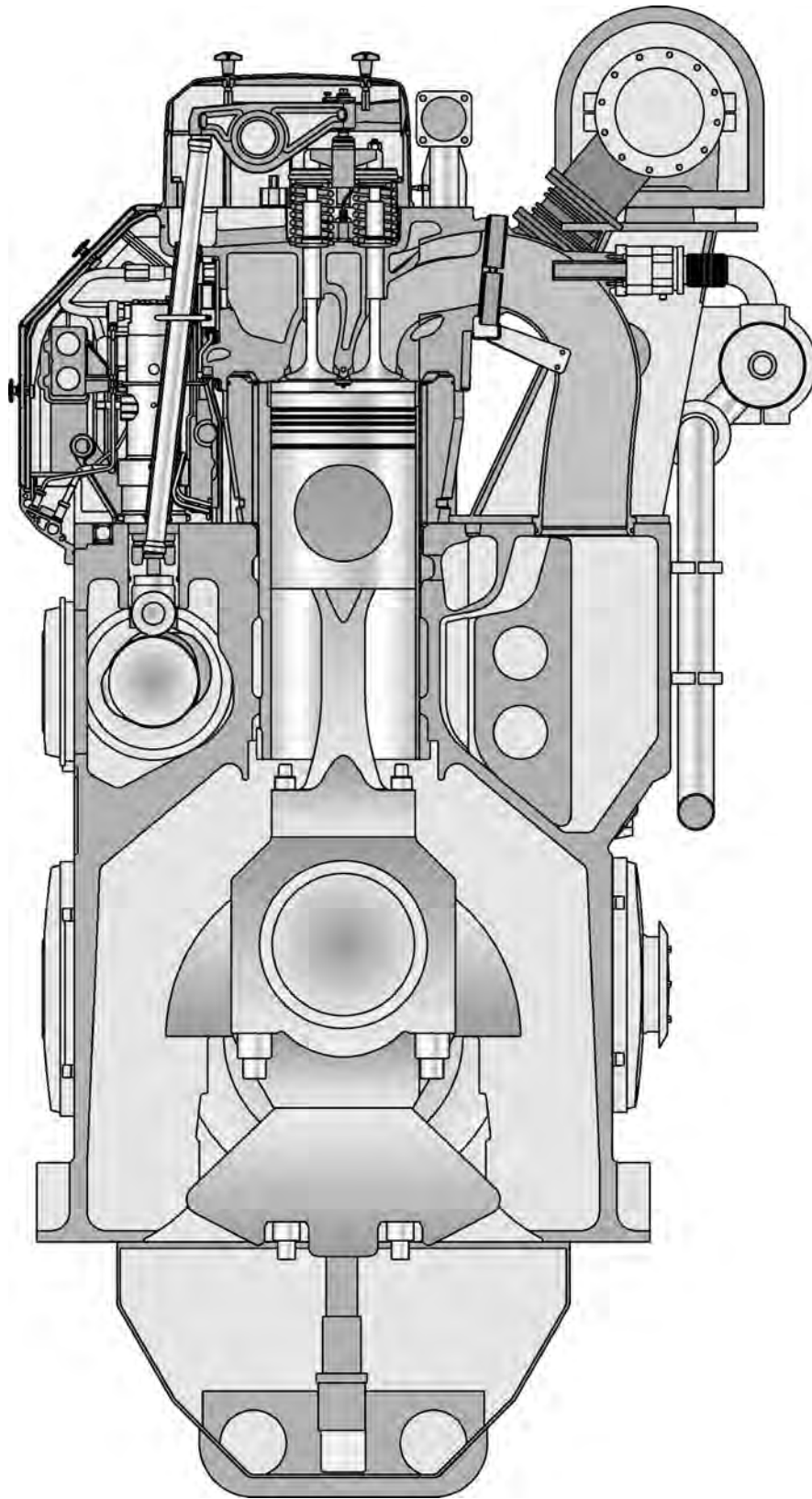


Fig 4-2 Cross section of the in-line engine (1V58B2480)

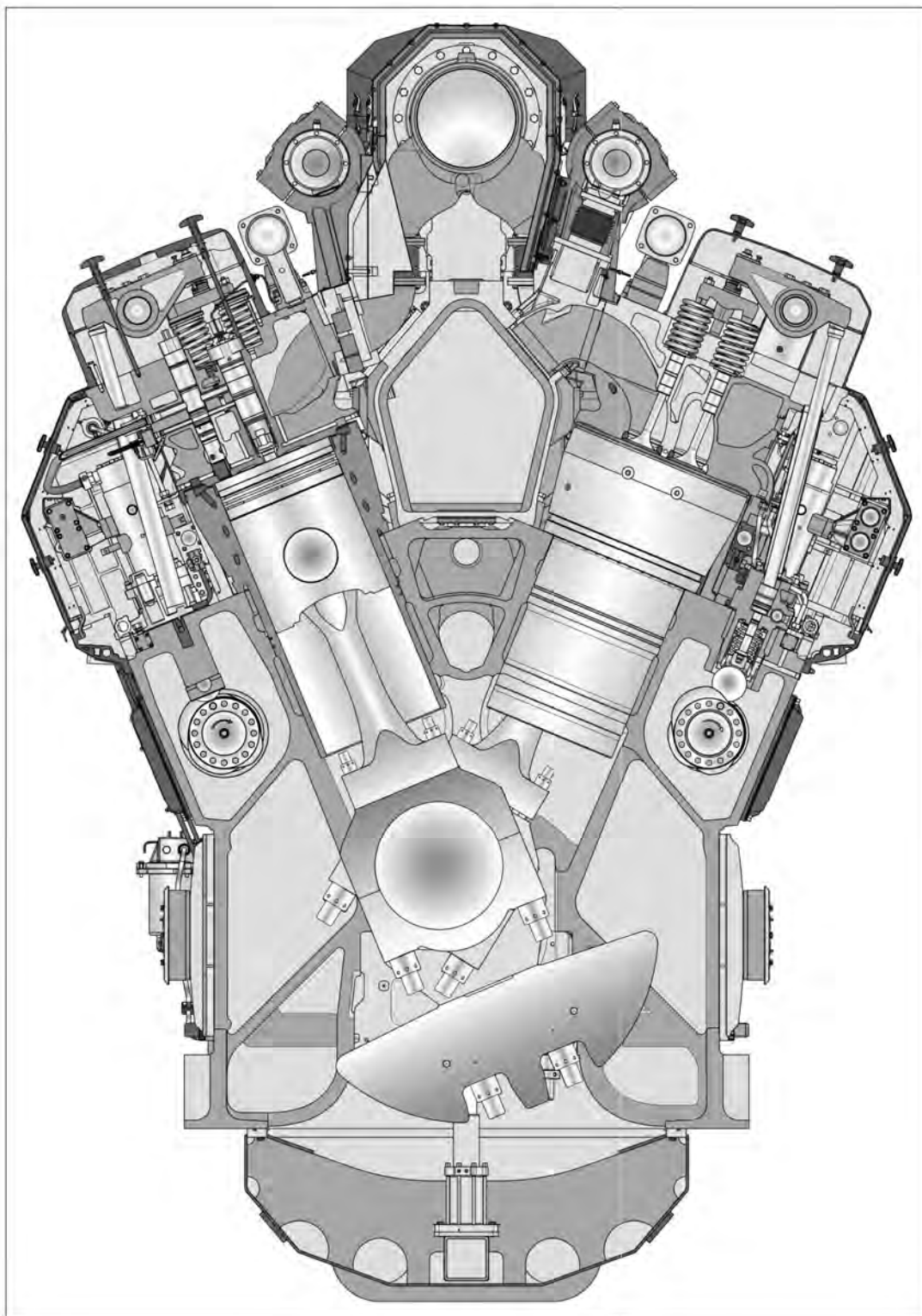


Fig 4-3 **Cross section of the V-engine (DAAF414513)**

4.4 Free end cover

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

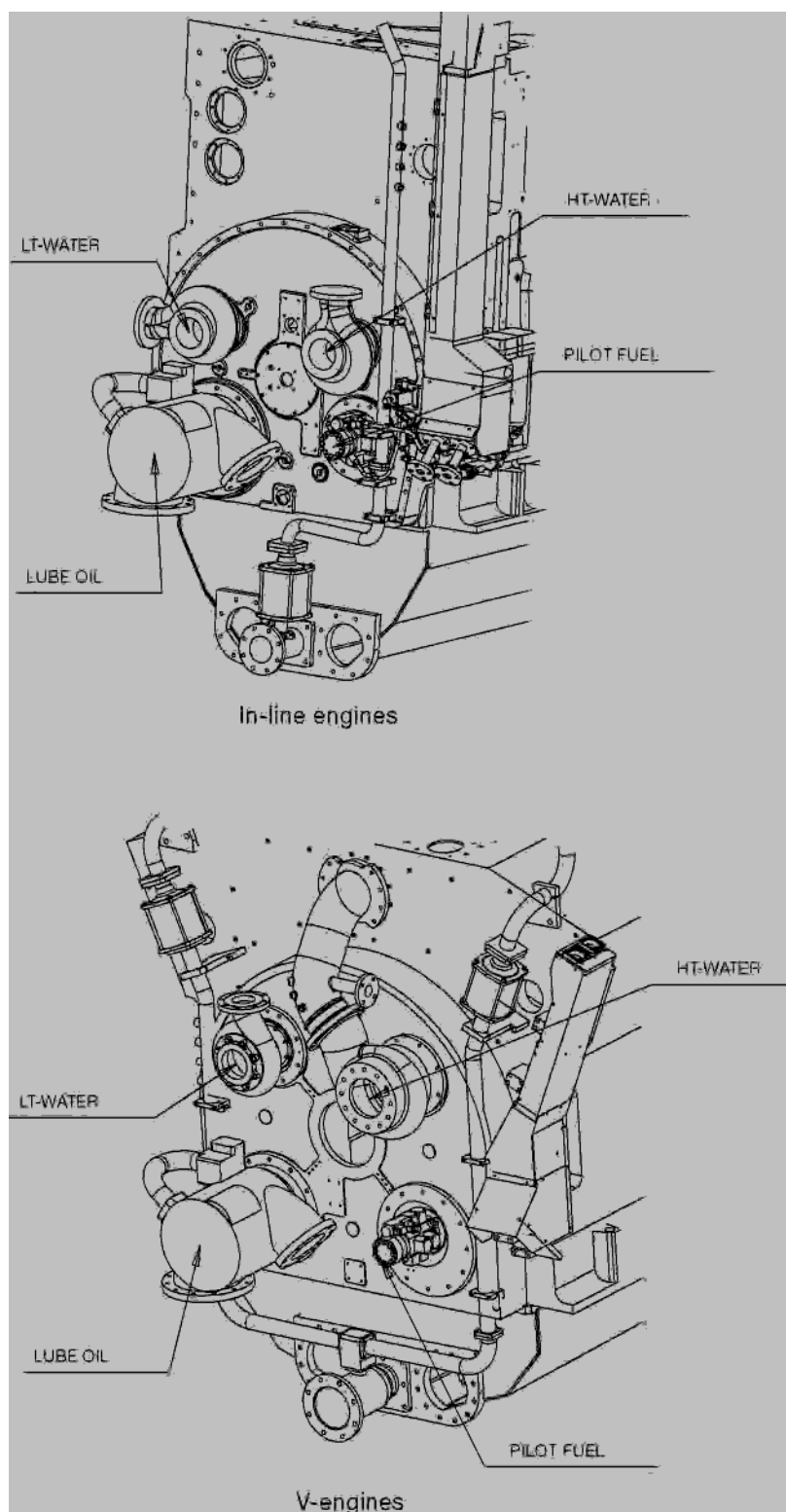


Fig 4-4 Built-on pumps at the free ends of the in-line and V-engines

4.5 Overhaul intervals and expected life times

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

Table 4-1 Time between overhauls and expected component lifetimes

Component	Time between inspection or overhaul [h]		Expected component lifetimes [h]	
	MDF/GAS operation	HFO operation	MDF/GAS operation	HFO operation
Piston, crown	18000-24000	12000	96000-120000	36000
Piston, skirt	18000-24000	12000	96000-120000	60000
Piston rings	18000-24000	12000	18000-24000	12000
Cylinder liner	18000-24000	12000	180000	72000
Cylinder head	18000-24000	12000	72000-96000	60000
Inlet valve	18000-24000	12000	36000-48000	24000
Inlet valve seat	18000-24000	12000	36000-48000	24000
Exhaust valve	18000-24000	12000	36000-48000	24000
Exhaust valve seat	18000-24000	12000	36000-48000	24000
Injection valve nozzle	6000	6000	6000	6000
Injection valve complete	6000	6000	18000	18000
Injection pump element	12000-18000	12000	24000-36000	24000
Pilot fuel pump	24000	24000	24000	24000
Main bearing	18000-24000 ¹⁾	18000 ¹⁾	36000	36000
Big end bearing	18000-24000 ¹⁾	18000 ¹⁾	36000	36000
Small end bearing	18000-24000 ¹⁾	18000-24000 ¹⁾	36000	36000
Camshaft bearing	36000 ¹⁾	36000 ¹⁾	72000	72000
Turbocharger bearing	12000	12000	36000	36000
Main gas admission valve	18000	18000	18000	18000
1) Inspection of one				

4.6 Engine storage

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

5. Piping Design, Treatment and Installation

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

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

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

NOTE



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

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

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

The following aspects shall be taken into consideration:

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

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

5.1 Pipe dimensions

When selecting the pipe dimensions, take into account:

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

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

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

NOTE

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

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

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

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

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

5.2 Trace heating

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

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

5.3 Pressure class

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

The pressure in the system can:

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

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

Example 1:

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

- A design pressure of not less than 1.2 MPa (12 bar) has to be selected.
- The nearest pipe class to be selected is PN16.
- Piping test pressure is normally $1.5 \times$ 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 $1.5 \times$ 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.

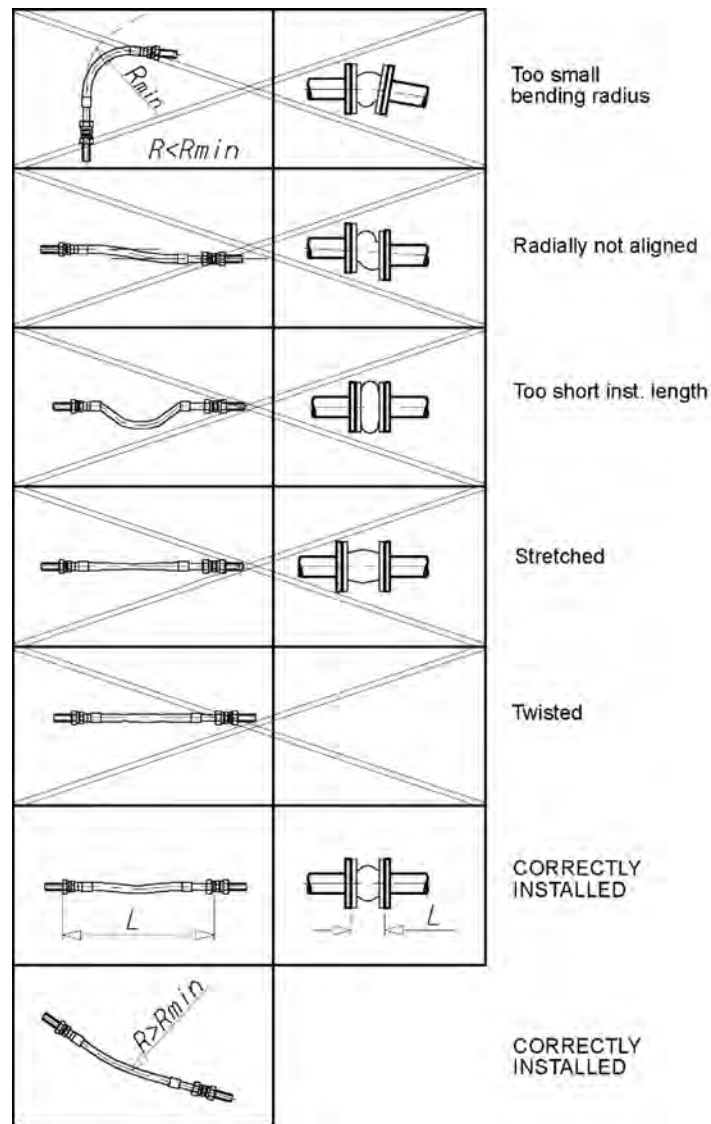


Fig 5-1 Flexible hoses

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 5-3. Pipe clamps must be made of steel; plastic clamps or similar may not be used.

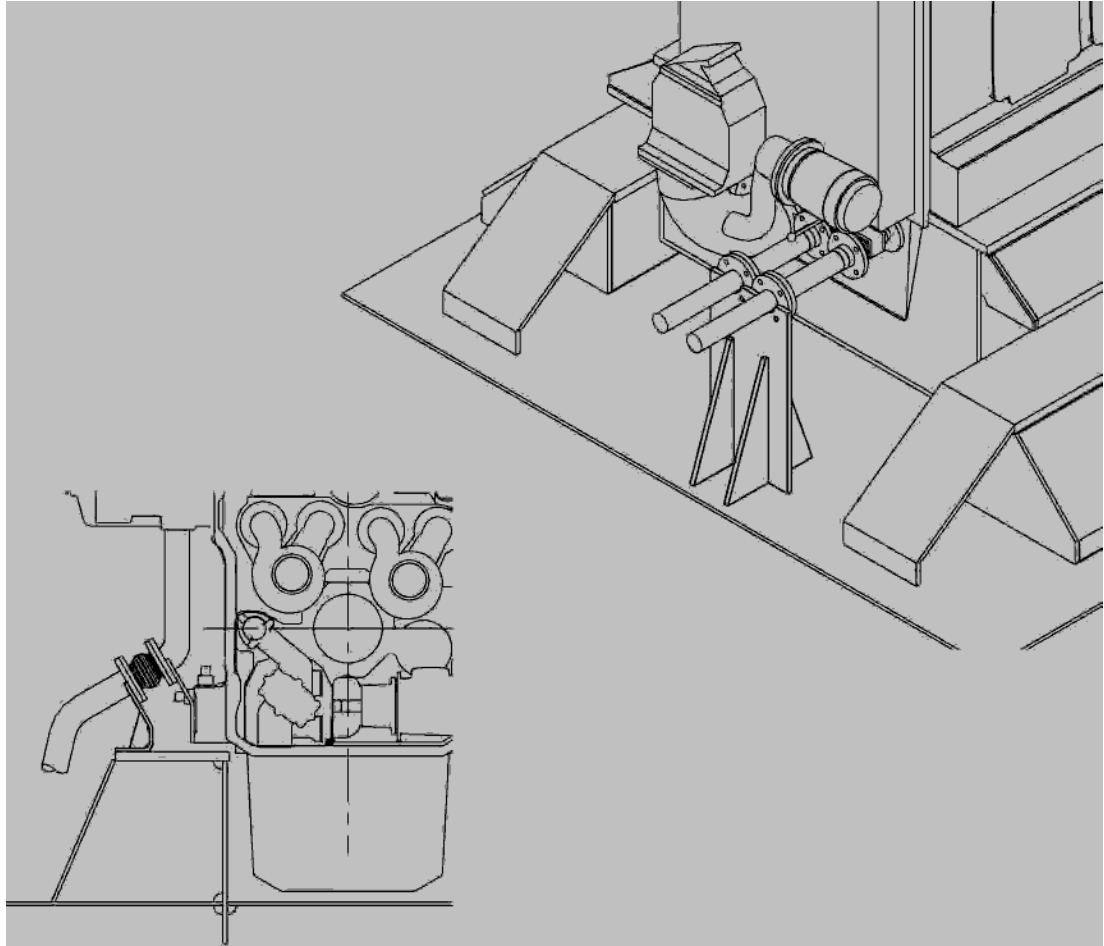
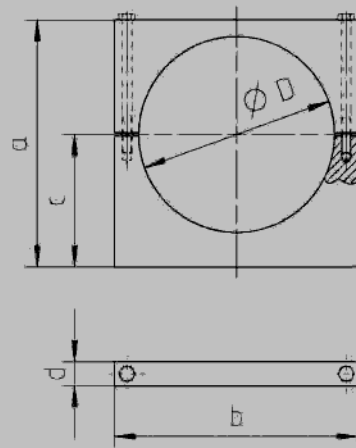


Fig 5-2 Flange supports of flexible pipe connections V60L0796

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 5-3 Pipe clamp for fixed support (V61H0842A)

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6. Fuel System

6.1 Acceptable fuel characteristics

6.1.1 Gas fuel specification

As a dual fuel engine, the Wärtsilä 50DF engine is designed for continuous operation in gas operating mode or diesel operating mode. For continuous operation in the rated output, the gas used as main fuel in gas operating mode has to fulfill the below mentioned quality requirements.

6.1.1.1 Natural Gas (LNG)

Table 6-1 Fuel Gas Specifications

Property	Unit	Value
Lower heating value (LHV), min ¹⁾	MJ/m ³ N ²⁾	28
Methane number (MN), min ³⁾		80
Methane (CH ₄), min	% volume	70
Hydrogen sulphide (H ₂ S), max	% volume	0.05
Hydrogen (H ₂), max ⁴⁾	% volume	3
Oil content, max.	mg/m ³ N	0,01
Ammonia, max	mg/m ³ N	25
Chlorine + Fluorines, max	mg/m ³ N	50
Particles or solids at engine inlet, max	mg/m ³ N	50
Particles or solids at engine inlet, max size	um	5
Gas inlet temperature	°C	0...60
Water and hydrocarbon condensates at engine inlet not allowed ⁵⁾		

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

2) Values given in m³N are at 0°C and 101.3 kPa.

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

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

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

6.1.1.2 Ethane fuel (LEG)

For Ethane usage 50DF engine has to be configured on specific project as NON standard product, and rated output and technical data re defined accordingly.

Table 6-2 Gas quality specification for W50DF burning Ethane fuel in Gas Mode

Property	Unit	Limit
Lower Heating Value (LHVM), min.(°a)	MJ/kg b)	46
Methane Number (MN), min.(°c)		42

Property	Unit	Limit
Methane (CH ₄) + Ethane (C ₂ H ₆) content, min.	%v/v	97.0
Content of other alkanes, propane (C ₃ H ₈), butane (C ₄ H ₁₀) and heavier, max.	%v/v	3.0
Hydrogen sulphide (H ₂ S) content, max.	%v/v	0.05
Hydrogen (H ₂) content, max. (*d)	%v/v	3.0
Water and hydrocarbon condensate bef. engine, max. (*e)	%v/v	Not allowed
Ammonia content, max.	mg/Nm ³	25
Chlorine + Fluorine content, max.	mg/Nm ³	50
Particles or solids content in engine inlet, max.	mg/Nm ³	50
Particles or solids size in engine inlet, max.	µm	5
Gas inlet temperature	°C	20 - 40

- a) The required gas feed pressure is depending on the LHV (see section Output limitations in gas mode).
- b) Values given in m³_N are at 0°C and 101.3 kPa.
- c) Engine output is depending on the Methane Number. Methane Number (MN) can be assigned to any gaseous fuel indicating the percentage by volume of methane in blend with hydrogen that exactly matches the knock intensity of the unknown gas mixture under specified operating conditions in a knock testing engine. The Methane Number (MN) gives a scale for evaluation of the resistance to knock of gaseous fuels. To define the Methane Number (MN) of the gas, AVL's "Methane 3.11" software is to be used.
- d) If the hydrogen (H₂) content of gas is higher than 3.0 % v/v, the use of gas has to be considered case by case and Marine Solutions Engines/ Product Engineering is to be contacted for further evaluation.
- e) In the specified operating conditions (temperature and pressure) dew point of gas has to be low enough in order to prevent any formation of condensate.
- f) In the gas contains CO₂, Marine Solution Engines/ Product Engineering is to be contacted for further evaluation.

6.1.2 Liquid fuel specification

The fuel specifications are based on the ISO 8217:2017(E) standard. Observe that a few additional properties not included in the standard are listed in the tables. 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 Pilot fuel oil

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

6.1.2.2 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 Installation Manual.

Table 6-3 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
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

Characteristics		Unit	Limit	Category ISO-F							Test method(s) and references
				DMX	DMA	DFA	DMZ	DFZ	DVB	DFB	
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 has 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.

6.1.2.3**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 Light fuel oils, 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 6-4 Pilot fuel oils

Characteristics	Unit	Limit	Test method reference
Cetane index, min.	-	42	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 6-5 Kinematic viscosity before fuel pumps

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

NOTE



a) 1 mm²/s = 1 cSt.

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

6.2 Operating principles

Wärtsilä 50DF engines are usually installed for dual fuel operation meaning the engine can be run either in gas or diesel operating mode. The operating mode can be changed while the engine is running, within certain limits, without interruption of power generation. If the gas supply would fail, the engine will automatically transfer to diesel mode operation (MDF).

6.2.1 Gas mode operation

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

6.2.2 Diesel mode operation

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

6.2.3 Backup mode operation

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

6.2.4 Fuel sharing mode operation (optional)

As an optional feature, the engine can be equipped with fuel sharing mode. When this mode is activated, the engine will run on a mix of gas, main liquid fuel (MDF or HFO) and pilot fuel. The required gas/liquid fuel mixing ratio can be chosen by the operator. For more info, see Fuel Sharing Mode in chapter 14. Automation.

6.3 Fuel gas system

6.3.1 Internal fuel gas system

6.3.1.1 Internal fuel gas system for in-line engines

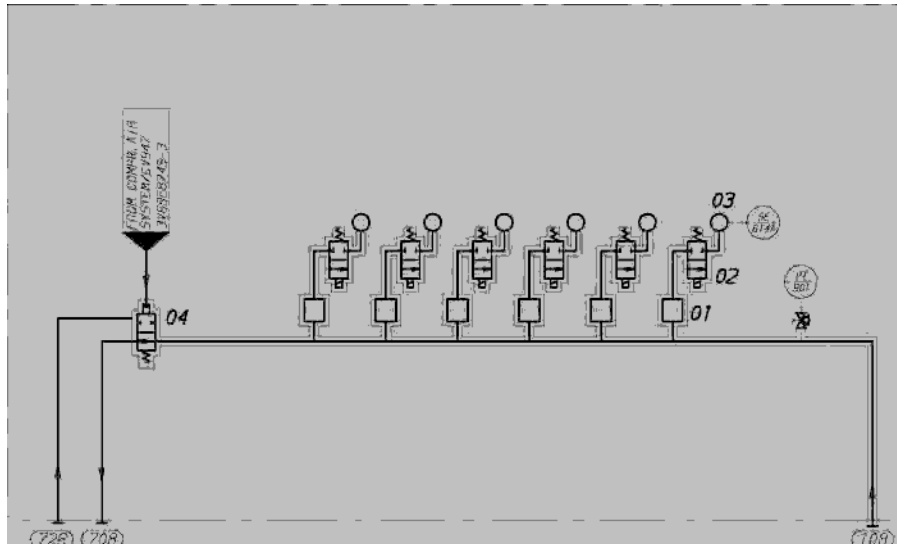


Fig 6-1 Internal fuel gas system, in-line engines (DAAE010198b)

System components:

01	Safety filter	03	Cylinder
02	Gas admission valve	04	Venting valve

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

Sensors and indicators:

SE614A...SE6#4A	Knock sensor	PT901	Gas pressure
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6.3.1.2 Internal fuel gas system for V-engines

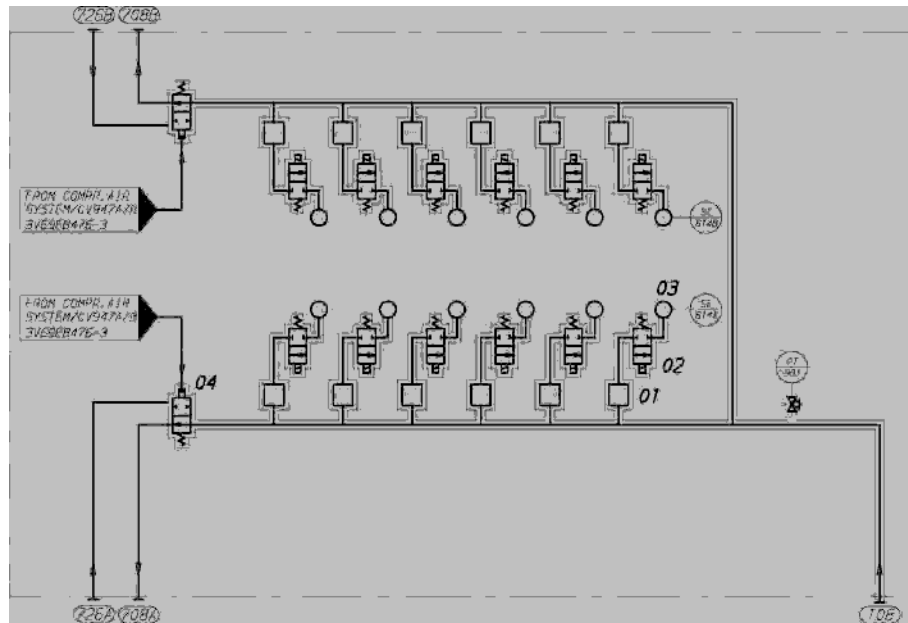


Fig 6-2 Internal fuel gas system,V-engines (DAAE010199c)

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

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

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

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

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

6.3.2 External fuel gas system

6.3.2.1 Fuel gas system, with open type GVU

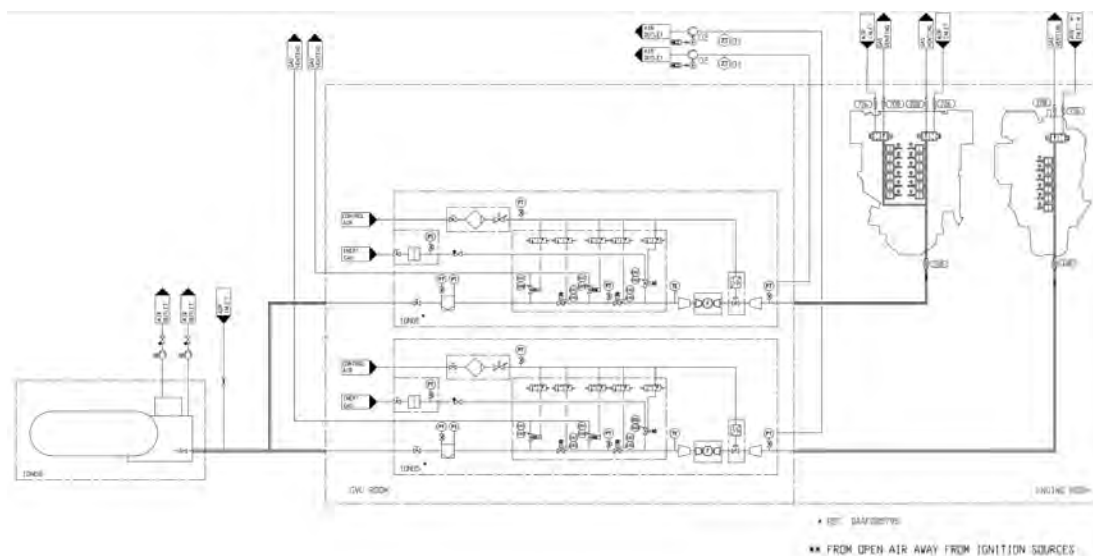


Fig 6-3 Example of fuel gas operation with open type GUV (DAAF022750G)

System components		Supplier
01	Gas detector	-
02	Gas double wall system ventilation fan	-
10N05	Gas valve unit	Wärtsilä
10N08	LNGPAC	Wärtsilä

Pipe connections		Size
108	Gas inlet	DN100 / DN150
708	Gas system ventilation	DN50
726	Air inlet to double wall gas system	M42"2

6.3.2.2 Fuel gas system, with enclosed GVU

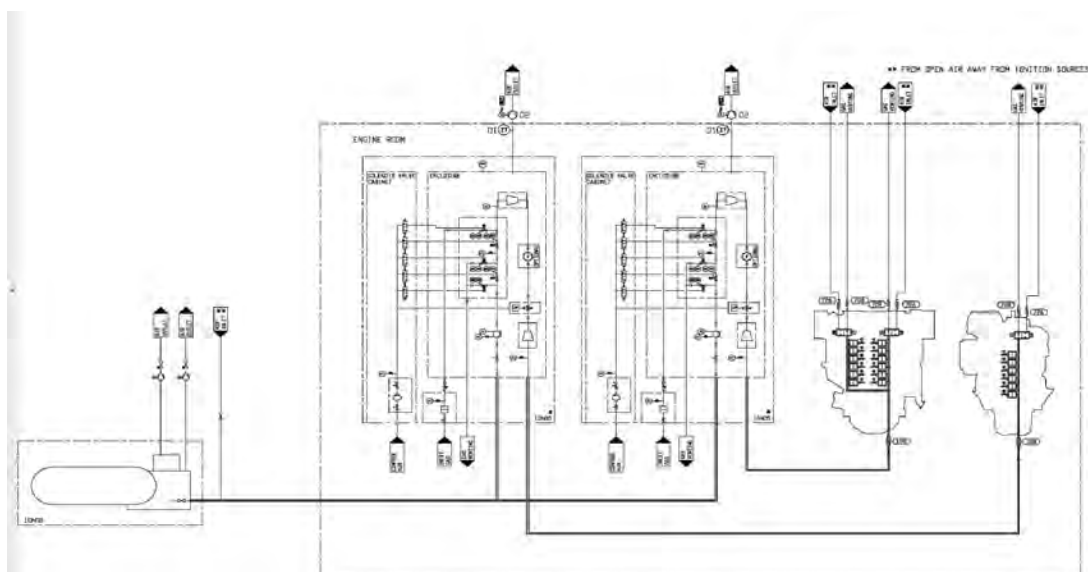


Fig 6-4 Example of fuel gas system with enclosed GVU (DAAF077105C)

System components		Supplier
01	Gas detector	-
02	Gas double wall system ventilation fan	-
10N05	Gas valve unit	Wärtsilä
10N08	LNGPAC	Wärtsilä

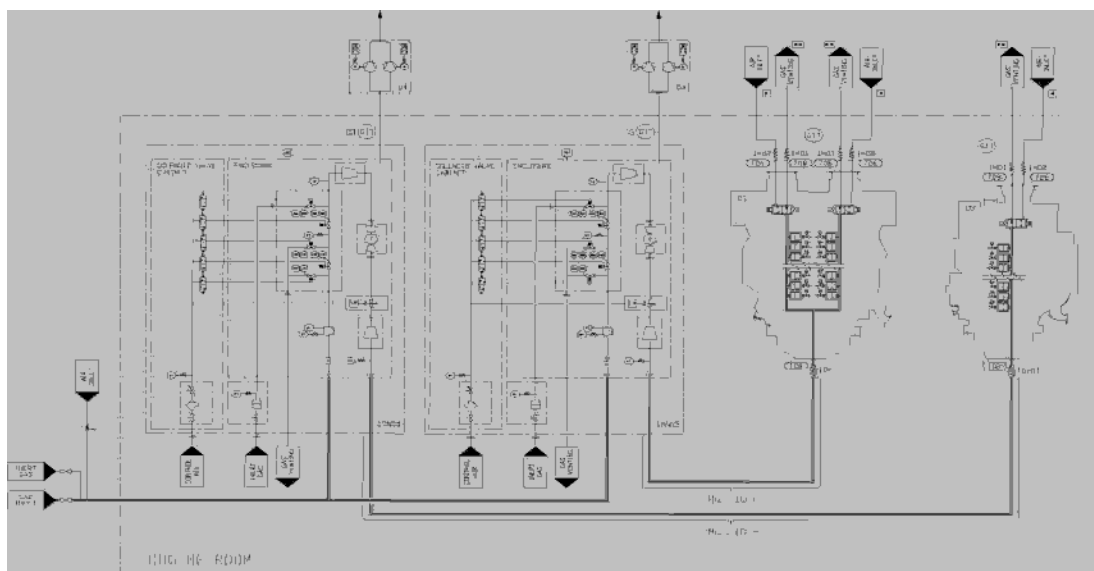


Fig 6-5 Example of fuel gas system with enclosed GVU (DAAF333561 A)

System components		Supplier
03	Gas detector	-
04	Gas double wall system ventilation fan	-
10N05	Gas valve unit	Wärtsilä

Pipe connections		Size
108	Gas inlet	DN100 / DN150
708	Gas system ventilation	DN50
726	Air inlet to double wall gas system	M42*2

6.3.2.3 Fuel gas system, without enclosed GUV

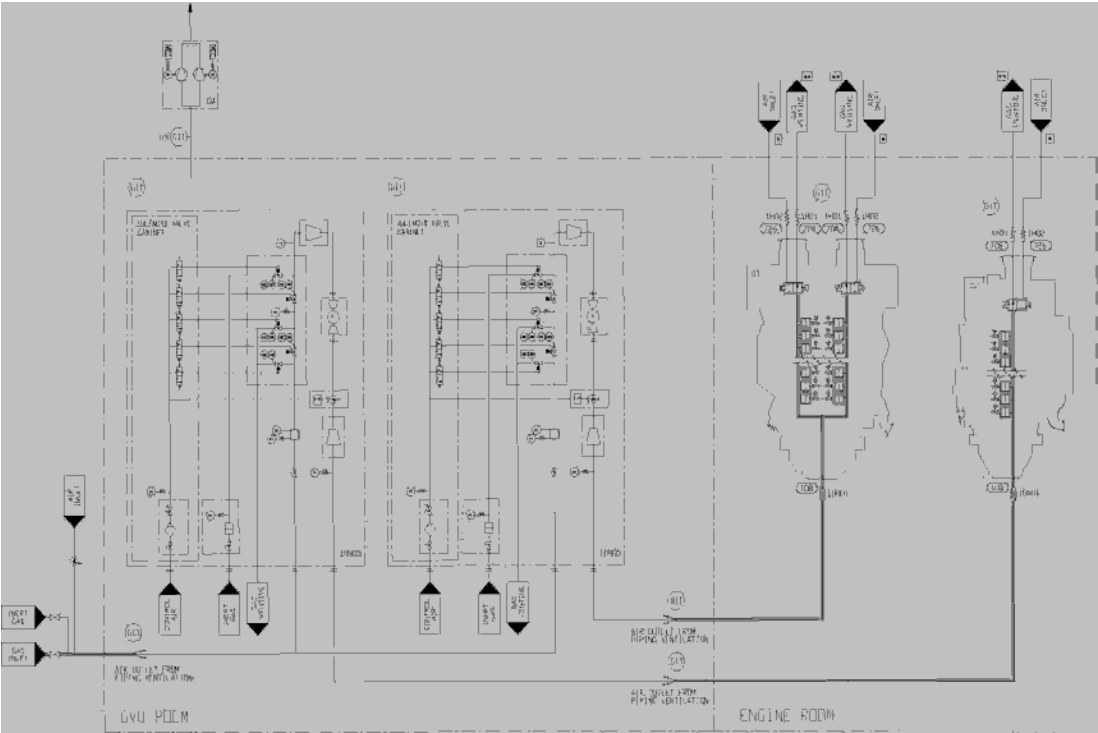


Fig 6-6 Example of fuel gas system without enclosed GUV with solenoid valve cabinet (DAAF333562 A)

System components		Supplier
03	Gas detector	-
04	Gas double wall system ventilation fan	-
10N05	Gas valve unit	Wärtsilä

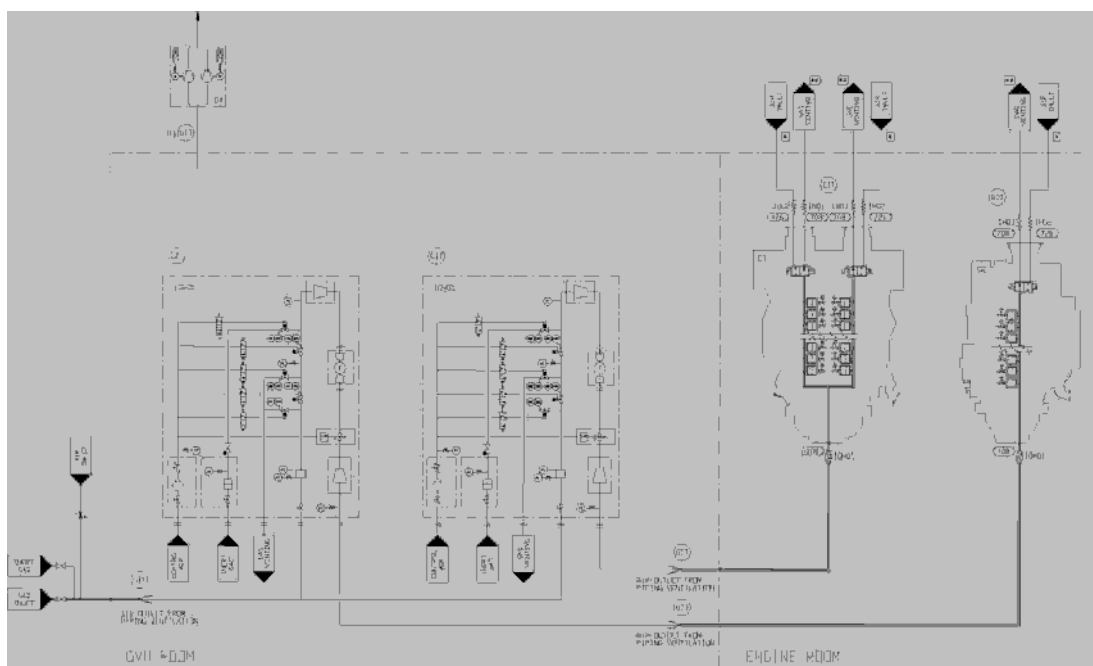


Fig 6-7 Example of fuel gas system without enclosed GUV without solenoid valve cabinet (DAAF333563 A)

System components		Supplier
03	Gas detector	-
04	Gas double wall system ventilation fan	-
10N05	Gas valve unit	Wärtsilä

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.

6.3.2.4 Double wall gas piping and the ventilation of the piping

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

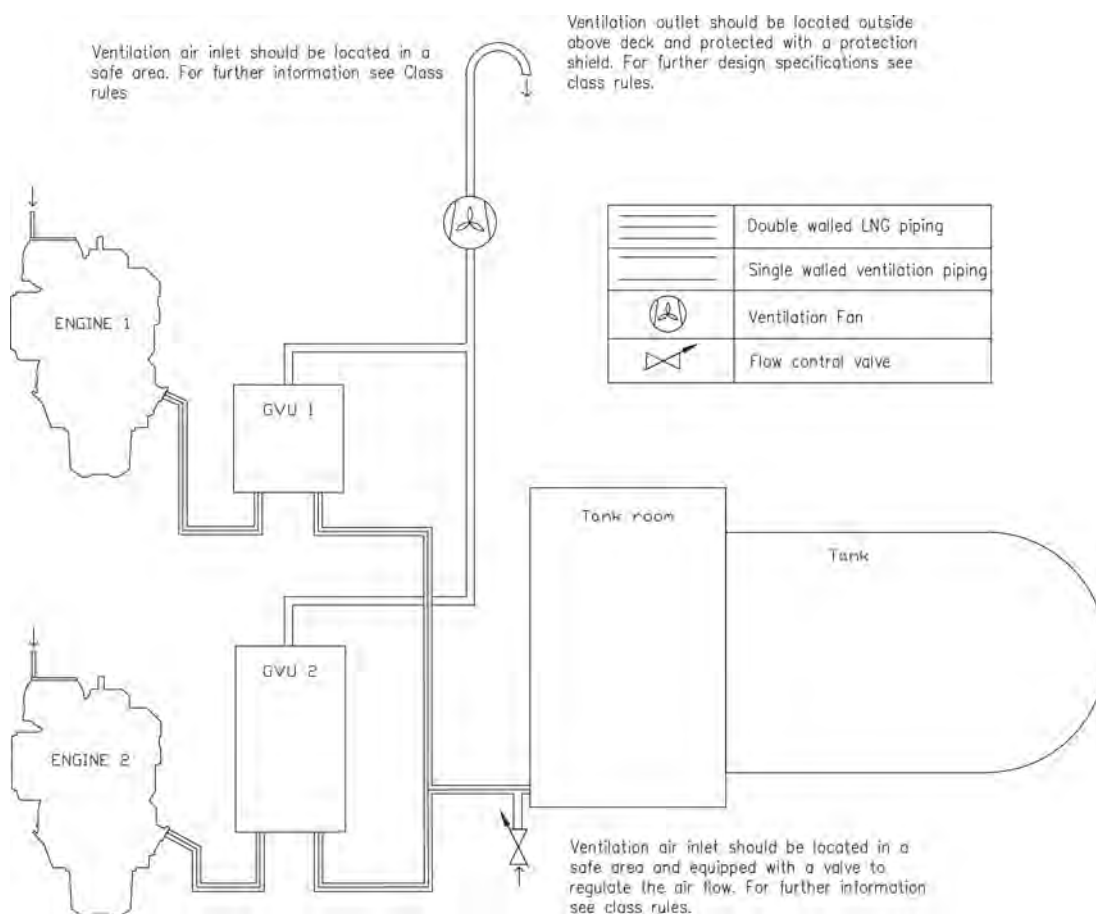


Fig 6-8 Example arrangement drawing of ventilation in double wall piping system with enclosed GVUs (DBAC588146)

6.3.2.5 Gas valve unit (10N05)

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

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

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

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

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

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

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

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

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

Inert gas and compressed air are to be dry and clean. Inert gas pressure max 1.0 MPa (10bar). The requirements for compressed air quality are presented in chapter "*Compressed air system*".

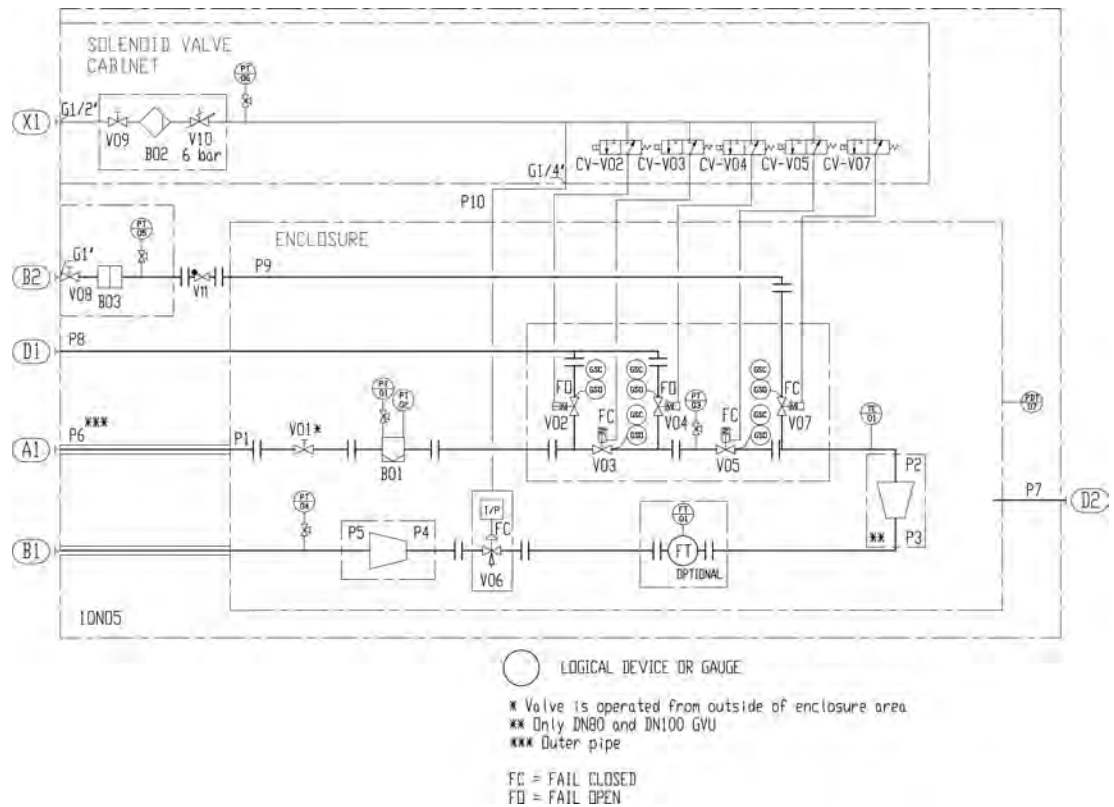


Fig 6-9 Gas valve unit P&I diagram (DAAF051037D)

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	Gas inlet [5 - 10bar (g)]	B2	Inert gas [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 GUV	DN80 GUV	DN100 GUV	Pos	DN50 GUV	DN80 GUV	DN100 GUV
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

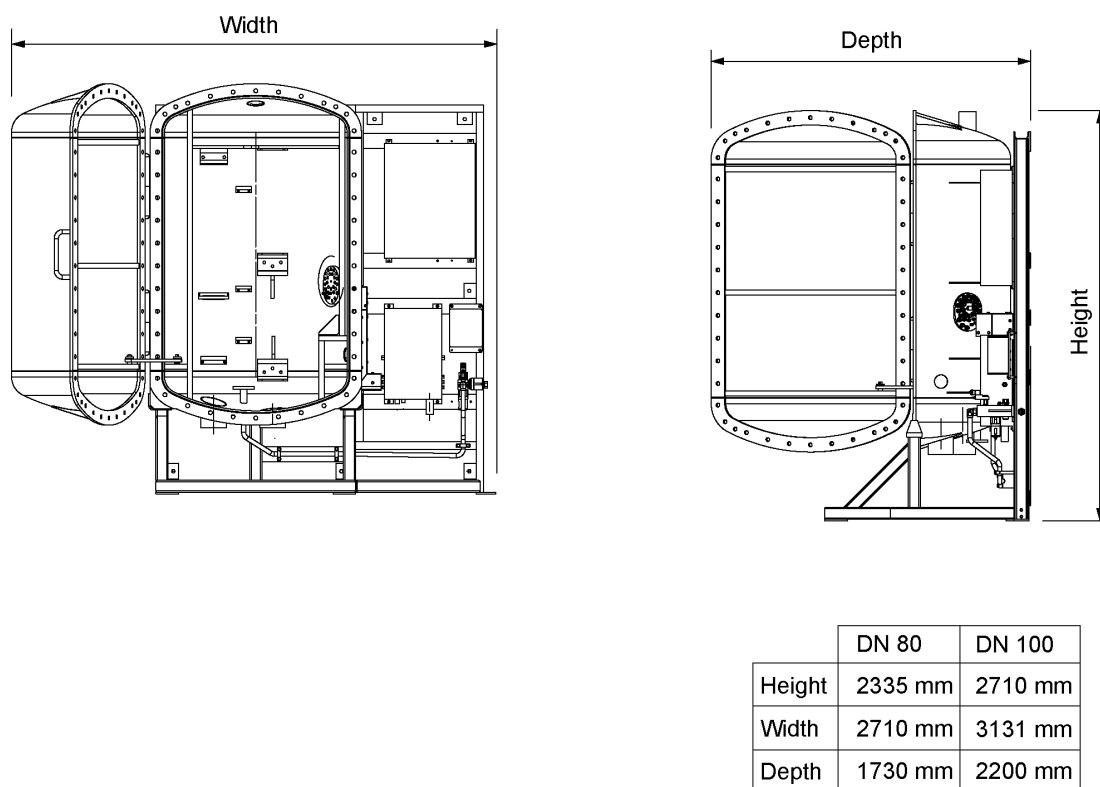


Fig 6-10 Main dimensions of the enclosed GVU (DAAF060741A)

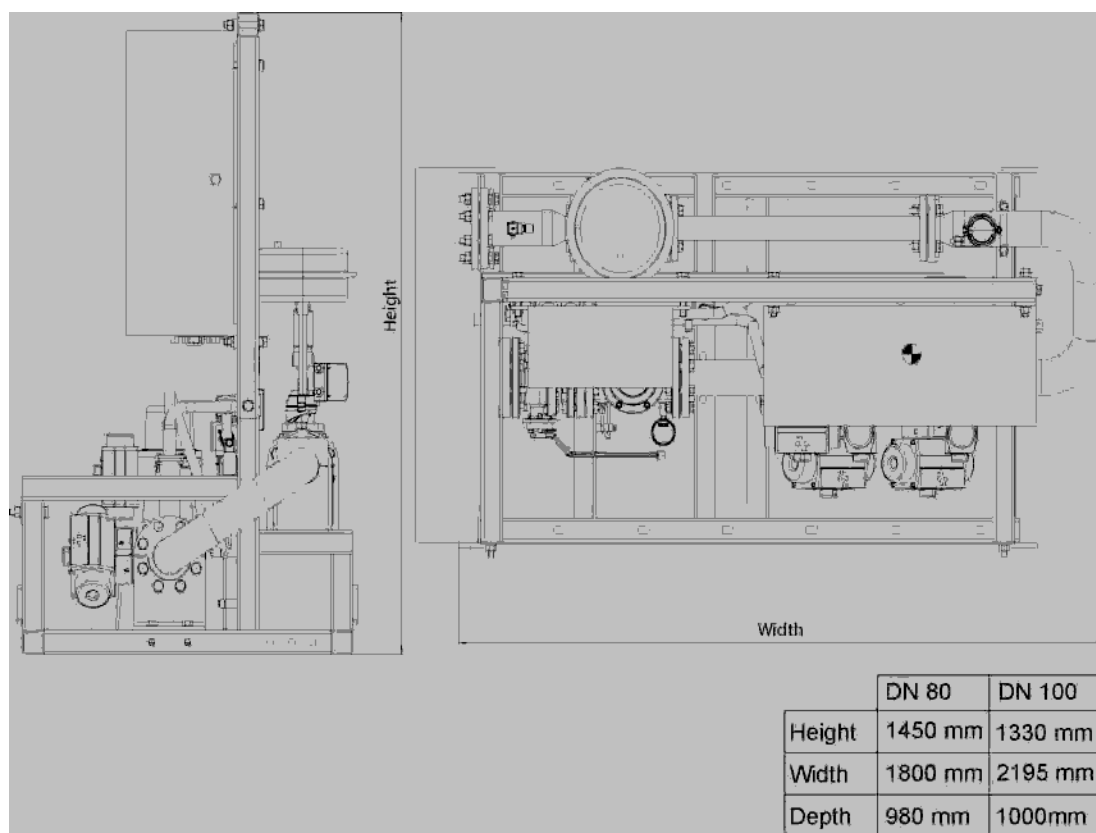


Fig 6-11 Main dimensions of the open GVU (DAAF075752E)

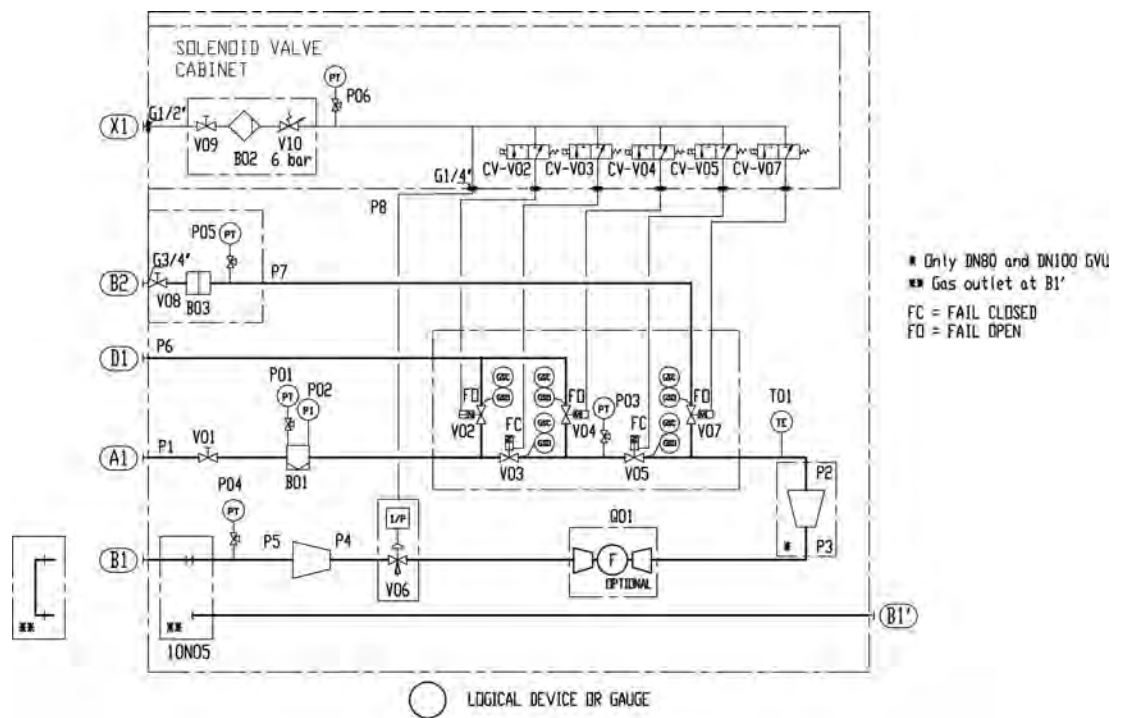


Fig 6-12 Gas valve unit, open type (DAAF072567A)

System components:

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

Sensors and indicators:

P01	Pressure transmitter, gas inlet	P05	Pressure transmitter, inert gas
P02	Pressure manometer, gas inlet	P06	Pressure transmitter, control air
P03	Pressure transmitter	T01	Temperature sensor
P04	Pressure transmitter, gas outlet		

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

6.3.2.6 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.

6.3.2.7 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 GVV 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 GVV.

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 GVV 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 GVV 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!

6.3.2.8 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 GVV and the enclosure of the GVV hasn't been opened, it is enough to inert the fuel gas pipe between the GVV and engine by triggering the starting sequence from the GVV control cabinet.

If maintenance work is done on the GVV and the enclosure of the GVV need to be opened, the fuel gas pipes before and after the GVV need to be inerted. Downstream from the GVV including the engine built gas piping, inerting is performed by triggering the inerting sequence from the GVV control cabinet. Regarding the engine crankcase inerting, a separate inert gas connection exist located on the engine. Upstream from the GVV 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 GVV 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: 2.46 m³/crank (inline) & 4.92 m³/crank (v-engine)**

6.3.2.9 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

6.4.1.1 Internal fuel oil system for in-line engines

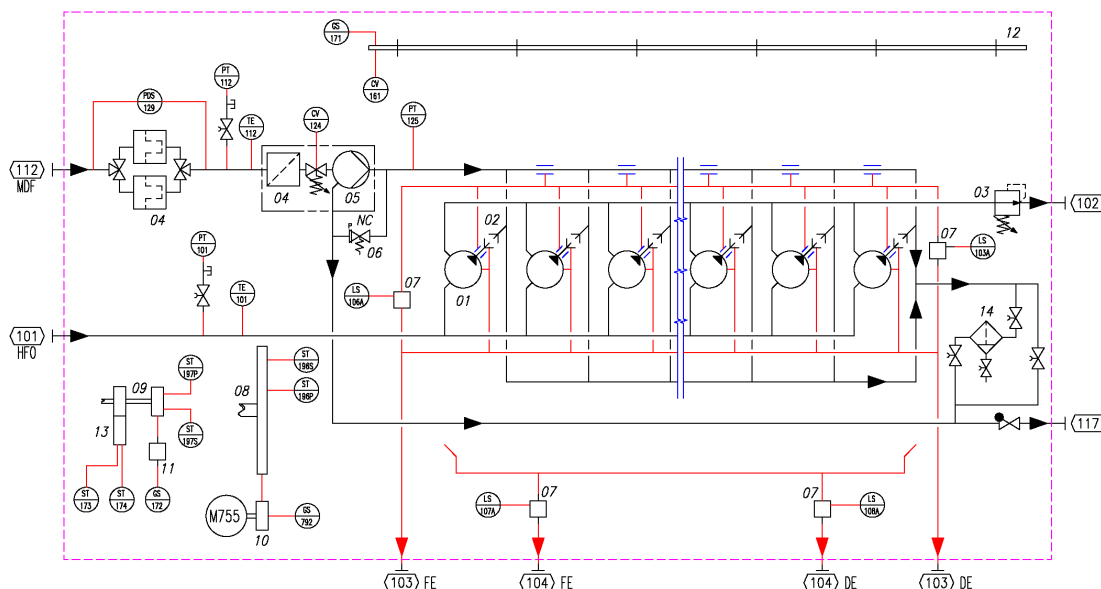


Fig 6-13 Internal fuel oil system, in-line engines (DAAF425041)

System components:

01	Injection pump	05	Pilot fuel pump
02	Injection valve with pilot solenoid and nozzle	06	Pilot fuel safety valve
03	Pressure control valve	07	Fuel leakage collector
04	Pilot fuel filter	08	Flywheel
09	Camshaft	10	Turning device
11	Mechanical overspeed trip device	12	Fuel and timing rack
13	Intermediate gear	14	Filter with water separator with manual drain

Sensors and indicators:

PT101	Fuel oil inlet pressure	LS108A	Fuel oil leakage, dirty fuel de
TE101	Fuel oil inlet temperature	CV124	Pilot fuel oil pressure control
PT112	Pilot fuel oil inlet pressure	PT125	Pilot fuel pressure, pump outlet
TE112	Pilot fuel oil inlet temperature	PDS129	Pilot fuel diff.pressure over filter
LS103A	Fuel oil leakage, clean primary		
LS106A	Fuel oil leakage, clean secondary		
LS107A	Fuel oil leakage, dirty fuel FE		

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

Pipe connections		Size	Pressure class	Standard
117	Pilot fuel outlet	DN15	PN40	ISO 7005-1

6.4.1.2 Internal fuel oil system for V-engines

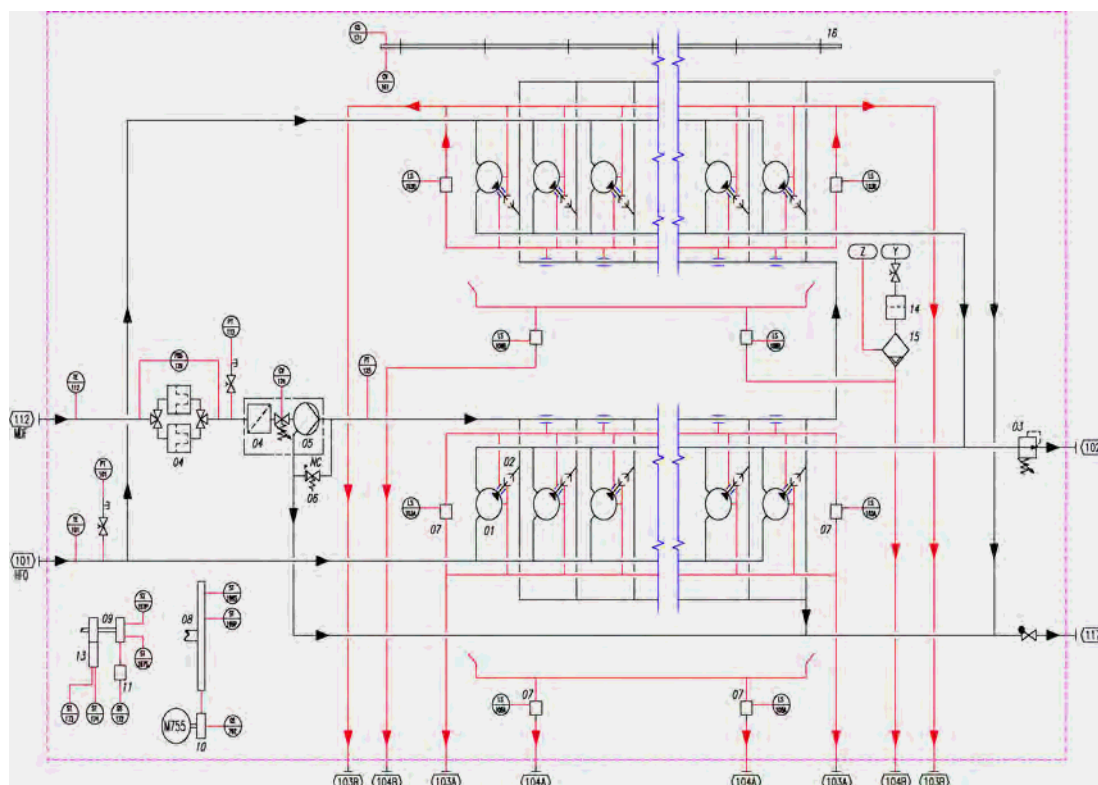


Fig 6-14 Internal fuel oil system, V-engines (DAAF425138)

System components:					
01	Injection pump	04	Pilot fuel filter	07	Fuel leakage collector
02	Injection valve with pilot solenoid and nozzle	05	Pilot fuel pump	08	Flywheel
03	Pressure control valve	06	Pilot fuel safety valve	09	Camshaft
10	Turning device	11	Mechanical overspeed trip device	12	Fuel and timing rack
13	Intermediate gear	14	Strainer	15	Water separator with automatic condensate drain

Sensors and indicators:			
PT101	Fuel oil inlet pressure	LS108A/B	Fuel oil leakage, dirty fuel de A/B-bank
TE101	Fuel oil inlet temperature	CV124	Pilot fuel oil pressure control
PT112	Pilot fuel oil inlet pressure	PT125	Pilot fuel pressure, pump outlet
TE112	Pilot fuel oil inlet temperature	PDS129	Pilot fuel diff.pressure over filter
LS103A/B	Fuel oil leakage, clean primary, A/B-bank		

Pipe connections		Size	Pressure class	Standard
101	Fuel inlet	DN32	PN40	ISO 7005-1
102	Fuel outlet	DN32	PN40	ISO 7005-1
103A/B	Leak fuel drain, clean fuel	OD28		DIN 2353
104A/B	Leak fuel drain, dirty fuel	OD48		DIN 2353
112	Pilot fuel inlet	DN15	PN40	ISO 7005-1
117	Pilot fuel outlet	DN15	PN40	ISO 7005-1
Y	Leak from charge air receiver			

Pipe connections		Size	Pressure class	Standard
Z	Air to charge air receiver			

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.

6.4.1.3 Leak fuel system

Clean leak fuel from the injection valves and the injection pumps is collected on the engine and drained by gravity through a clean leak fuel connection (103). The clean leak fuel can be re-used without separation. The quantity of clean leak fuel is given in chapter *Technical data*.

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

6.4.2 External fuel oil system

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

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

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

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

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

NOTE



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

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 β_{50} = 75

- **XX micron, nominal:** commercial name of that mesh, at purchase. Not really related to filtration capability, especially when comparing different suppliers. Typically, a totally different value than XX micron, absolute.
 - e.g. a real example: 10 micron nominal ($\epsilon_{10} = 60\%$) = approx. 60 micron absolute.
- **XX micron, absolute:** intended here as $\beta_{xx} = 75$ ISO 16889 (similar to old $\epsilon_{xx} = 98,7\%$)
 - Beta value $\beta_{xx} = YY$: ISO name with ISO 16889 standardised test method. Weak repeatability for dust bigger than 25..45 microns.
 - Example: $\beta_{20} = 75$ means “every 75 particles 20 micron ISO dust sent, one passes”.
 - Efficiency $\epsilon_{xx} = YY\%$: same meaning as Beta-value, but not any ISO standardised test method, hence sometimes used for particles larger than 25..45 micron.
 - Example: $\epsilon_{20} = 98,7\%$ means “every 75 particles 20 micron non-ISO dust sent, one passes, which is 98,7% stopped.”

6.4.2.2 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.

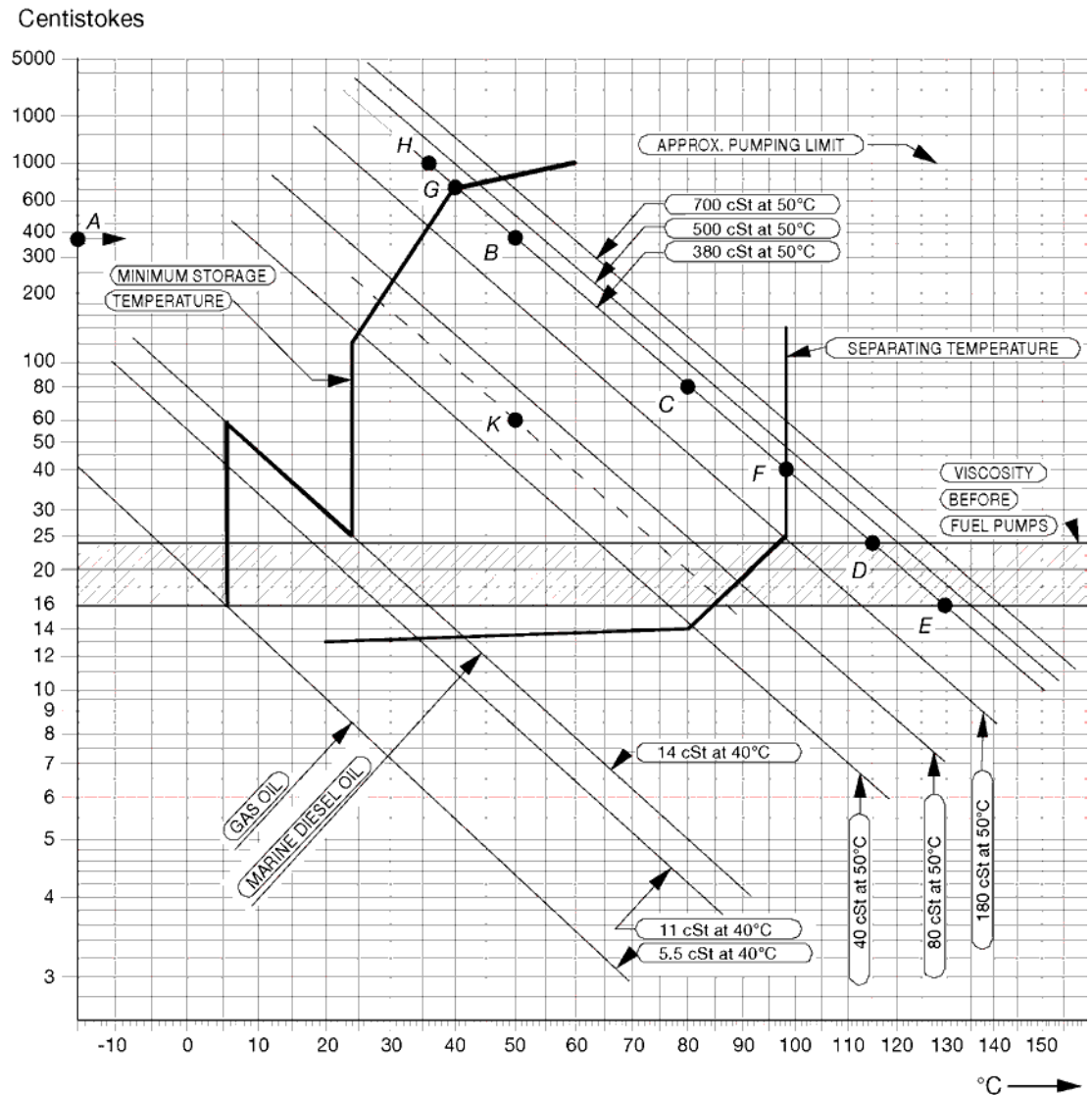


Fig 6-15 Fuel oil viscosity-temperature diagram for determining the pre-heating temperatures of fuel oils (4V92G0071b)

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

In HFO installations the change over valve for leak fuel (1V13) is needed to avoid mixing of the MDF and HFO clean leak fuel. When operating the engines in 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

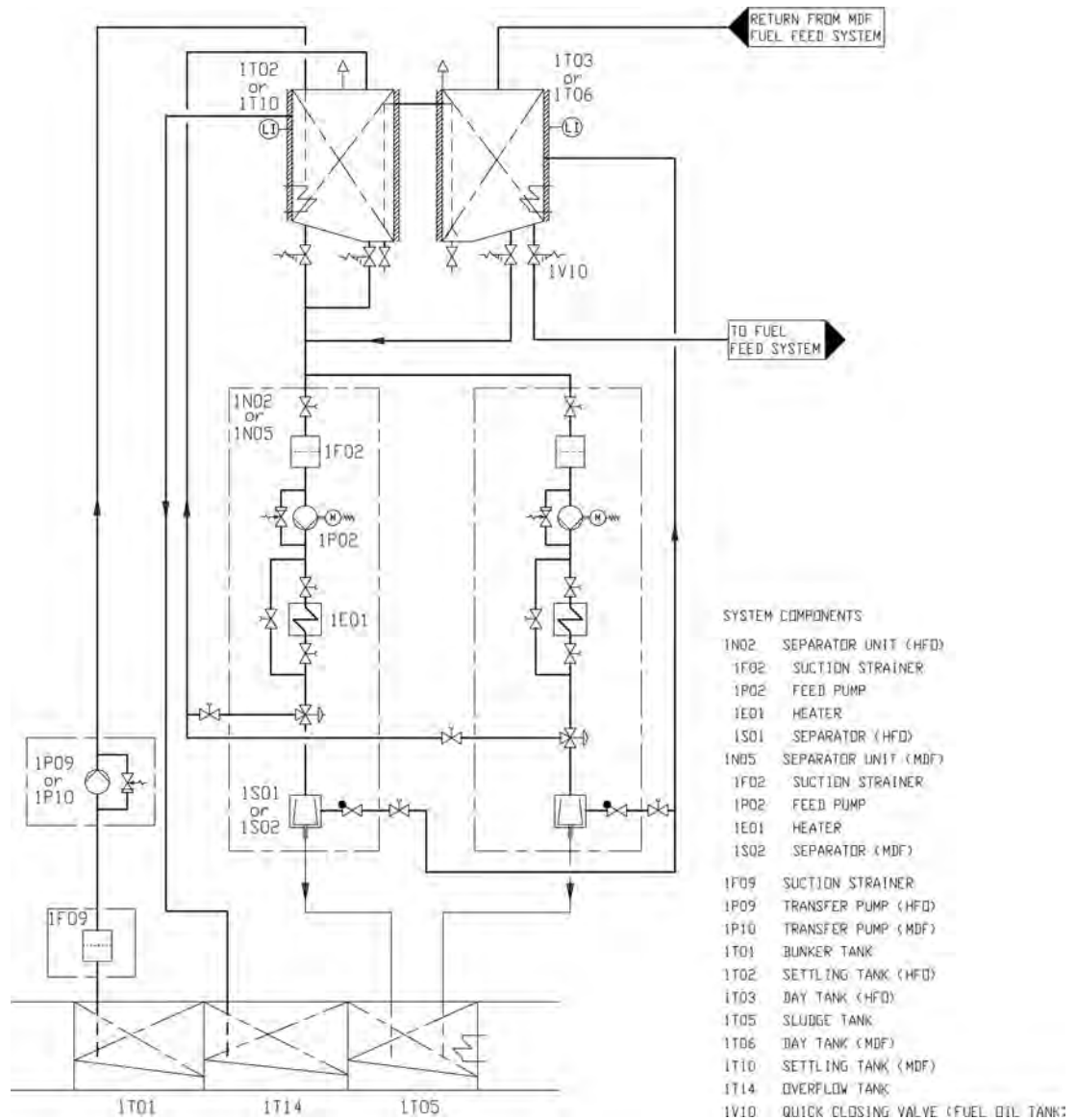


Fig 6-16 Fuel transfer and separating system (V76F6626G)

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:

Design pressure

HFO

0.5 MPa (5 bar)

MDF

0.5 MPa (5 bar)

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

Separator pre-heater (1E01)

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

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

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

The required minimum capacity of the heater is:

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

where:

P = heater capacity [kW]

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

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

For heavy fuels $\Delta T = 48^\circ\text{C}$ can be used, i.e. a settling tank temperature of 50°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:

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

where:

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

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

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

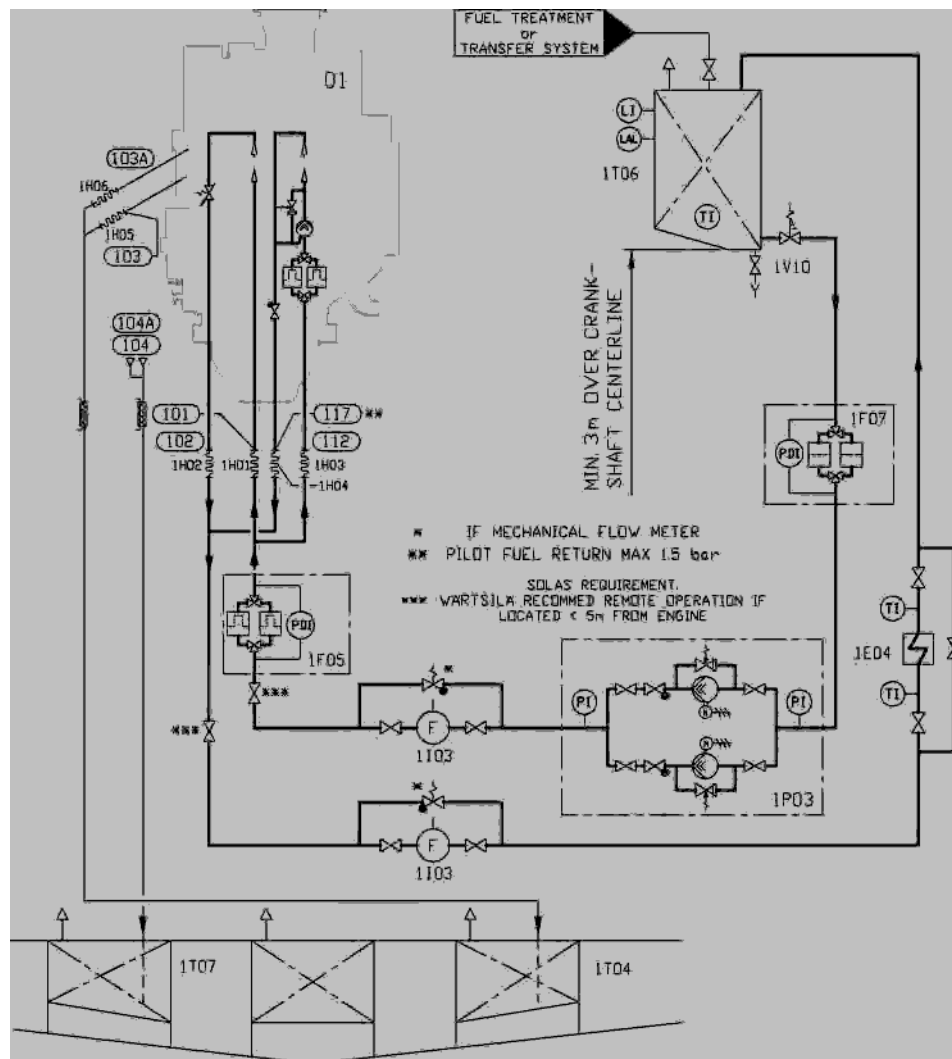


Fig 6-17 Example of fuel feed system, single L-engine installation (DAAF335502 B)

System components:

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

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

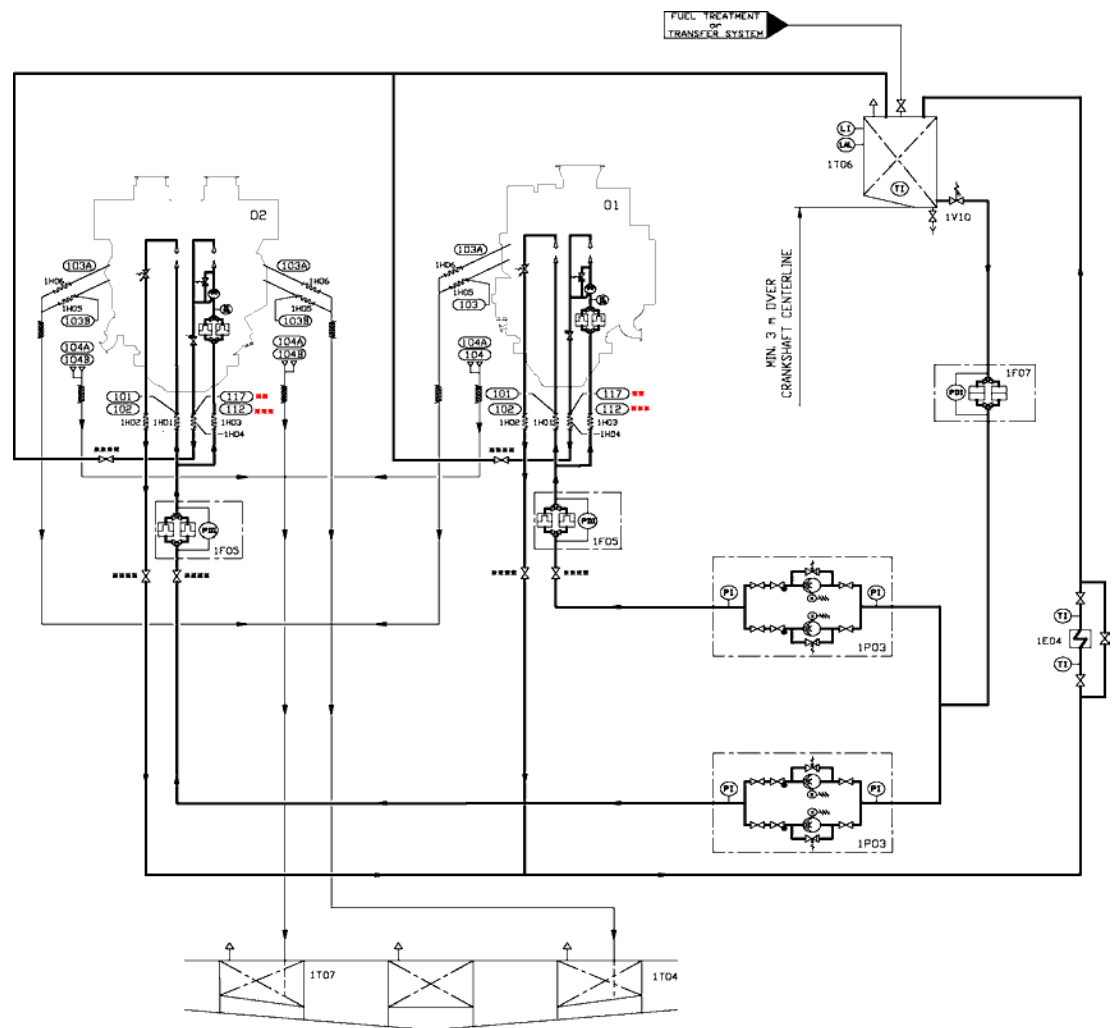


Fig 6-19 Example of fuel feed system, multiple engine with stand-by pump (DAAF335504 A)

System components:

01	WL50DF	1P03	Circulation pump (MDF)
02	WV50DF	1T04	Leak fuel tank (clean fuel)
1E04	Cooler (MDF)	1T06	Day tank (MDF)
1F05	Fine filter (MDF)	1T07	Leak fuel tank (dirty fuel)
1F07	Suction strainer (MDF)	1V10	Quick closing valve (dirty fuel)
1H0X	Flexible pipe connections		

Pipe connections		V50DF	L50DF	Pipe connections		V50DF	L50DF
101	Fuel inlet	DN32	DN32	104	Leak fuel drain, dirty fuel	4"OD48	2"OD48
102	Fuel outlet	DN32	DN32	112	Pilot fuel inlet	DN15	DN15
103	Leak fuel drain, clean fuel	4"OD28	2"OD28	117	Pilot fuel outlet	DN15	DN15

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

Circulation pump, MDF (1P03)

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

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

Flow meter, MDF (1I03)

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

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

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

Fine filter, MDF (1F05)

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

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

Design data:

Fuel viscosity	according to fuel specifications
Design temperature	50°C
Design flow	Larger than feed/circulation pump capacity
Design pressure	1.6 MPa (16 bar)
Fineness	25 µm (absolute mesh size)

Maximum permitted pressure drops at 14 cSt:

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

MDF cooler (1E04)

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

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

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

Design data:

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

Return fuel tank (1T13)

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

Black out start

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

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

6.4.2.6 Fuel feed system - HFO installations

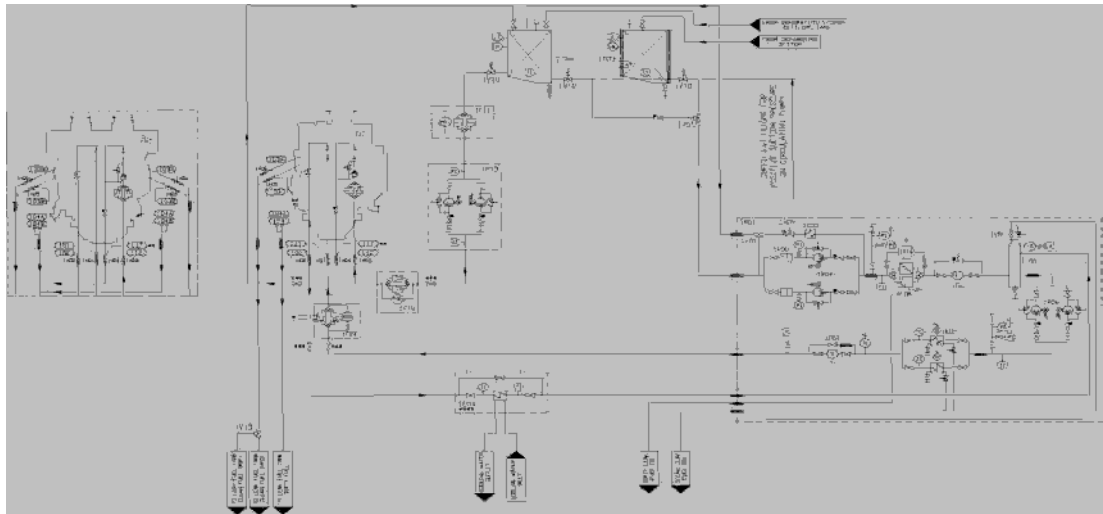


Fig 6-20 Example of fuel oil system (HFO), single main engine (DAAF335564 B)

System components:			
01	WL50DF		
02	WV50DF	1P04	Fuel feed pump (booster unit)
1E02	Heater (booster unit)	1P06	Circulation pump (booster unit)
1E03	Cooler (booster unit)	1P13	Pilot fuel feed pump (MDF)
1E04	Cooler (MDF)	1T03	Day tank (HFO)
1F03	Safety filter (HFO)	1T06	Day tank (MDF)
1F06	Suction filter (booster unit)	1T08	De-aeration tank (booster unit)
1F08	Automatic filter (booster unit)	1V01	Changeover valve
1F10	Pilot fuel fine filter (MDF)	1V02	Pressure control valve (MDF)
1F11	Suction strainer for pilot fuel (MDF)	1V03	Pressure control valve (booster unit)
1H0X	Flexible pipe connections	1V07	Venting valve (booster unit)
1I01	Flow meter (booster unit)	1V10	Quick closing valve (fuel oil tank)
1I02	Viscosity meter (booster unit)	1V13	Change over valve for leak fuel
1N01	Feeder/booster unit		

Pipe connections		V50DF	L50DF	Pipe connections		V50DF	L50DF
101	Fuel inlet	DN32	DN32	104	Leak fuel drain, dirty fuel	4*OD48	2*OD48
102	Fuel outlet	DN32	DN32	112	Pilot fuel inlet	DN15	DN15
103	Leak fuel drain, clean fuel	4*OD28	2*OD28	117	Pilot fuel outlet	DN15	DN15

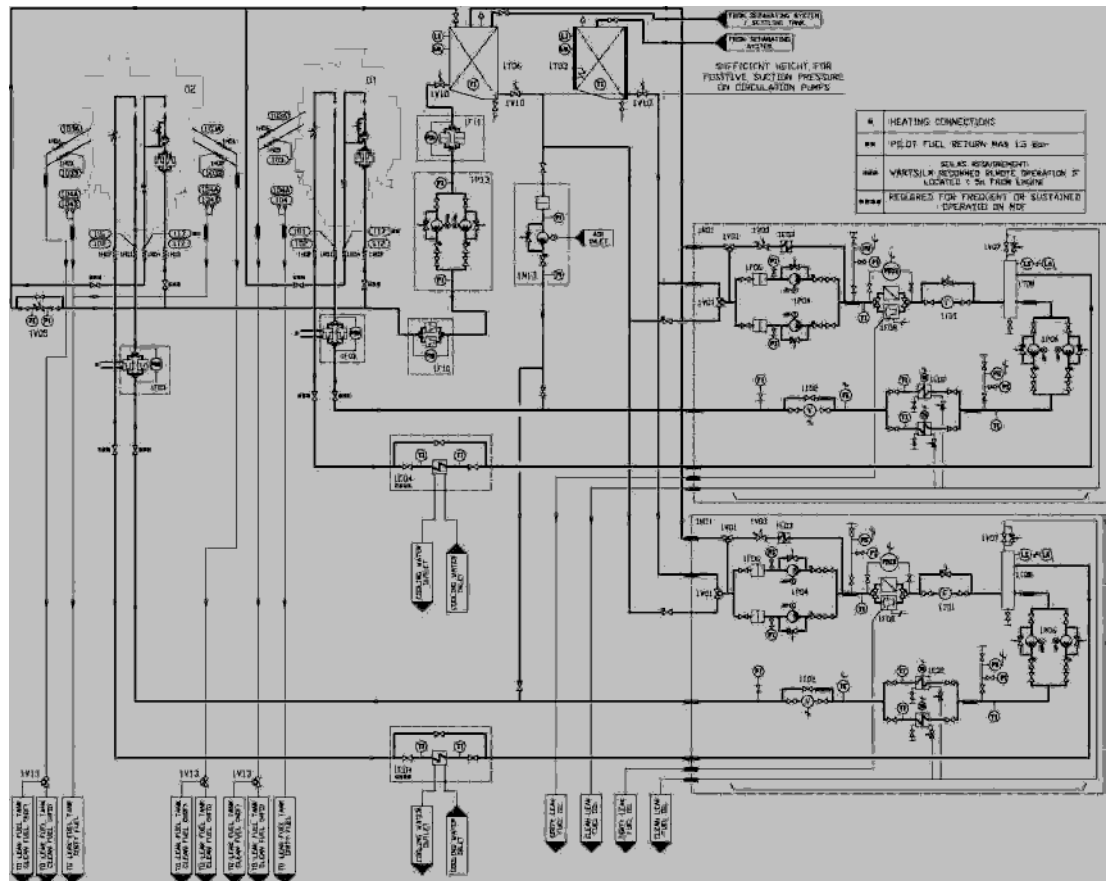


Fig 6-21 Example of fuel oil system (HFO), separate booster units (DAAF335565 B)

System components:

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

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

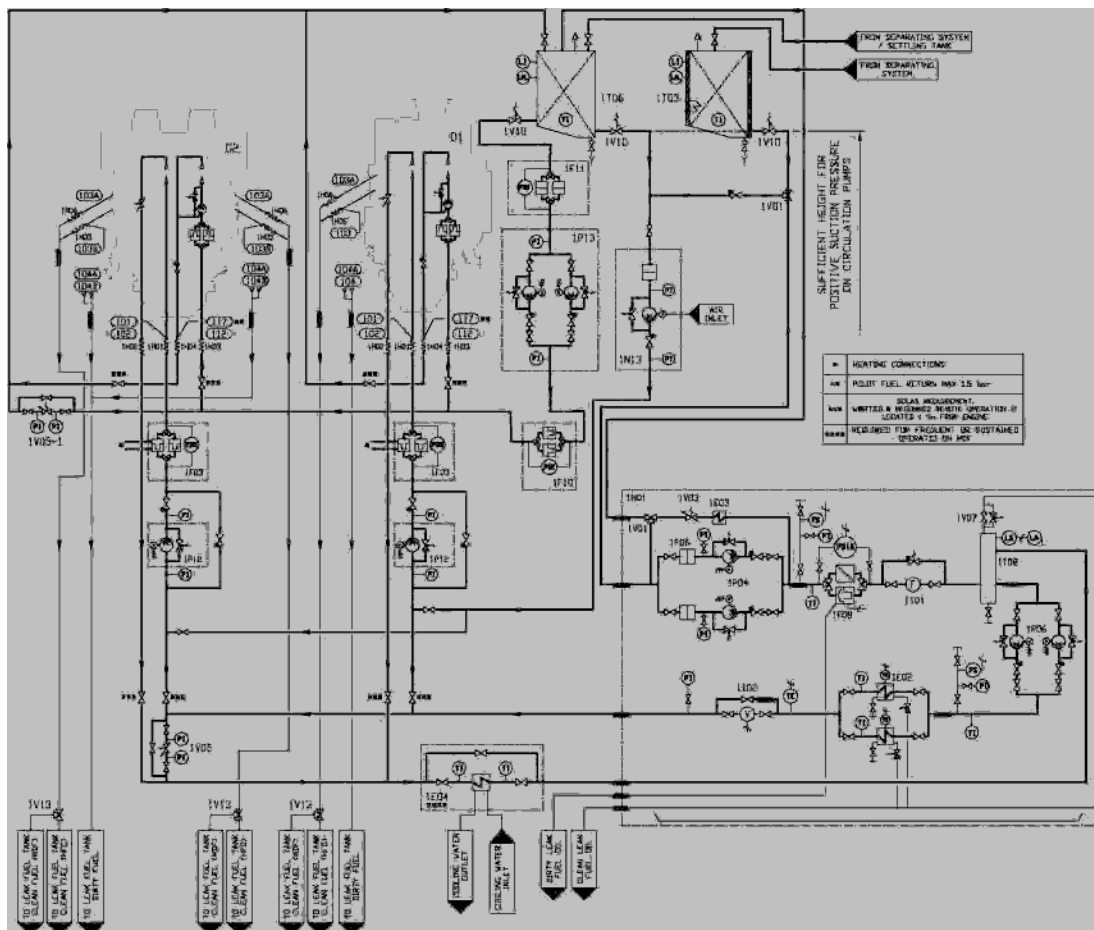


Fig 6-22 Example of fuel oil system (HFO), one booster unit (DAAF335566B)

System components:

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

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

HFO pipes shall be properly insulated. If the viscosity of the fuel is 180 cSt/50°C or higher, the pipes must be equipped with trace heating. It 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 Wärtsilä 50DF engines only, maximum two engines should be connected to the same fuel feed circuit, unless individual circulating pumps before each engine are installed.

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

In addition the following guidelines apply:

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

Feeder/booster unit (1N01)

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

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

- One control valve for steam or thermal oil heaters, a control cabinet for electric heaters
- One 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.

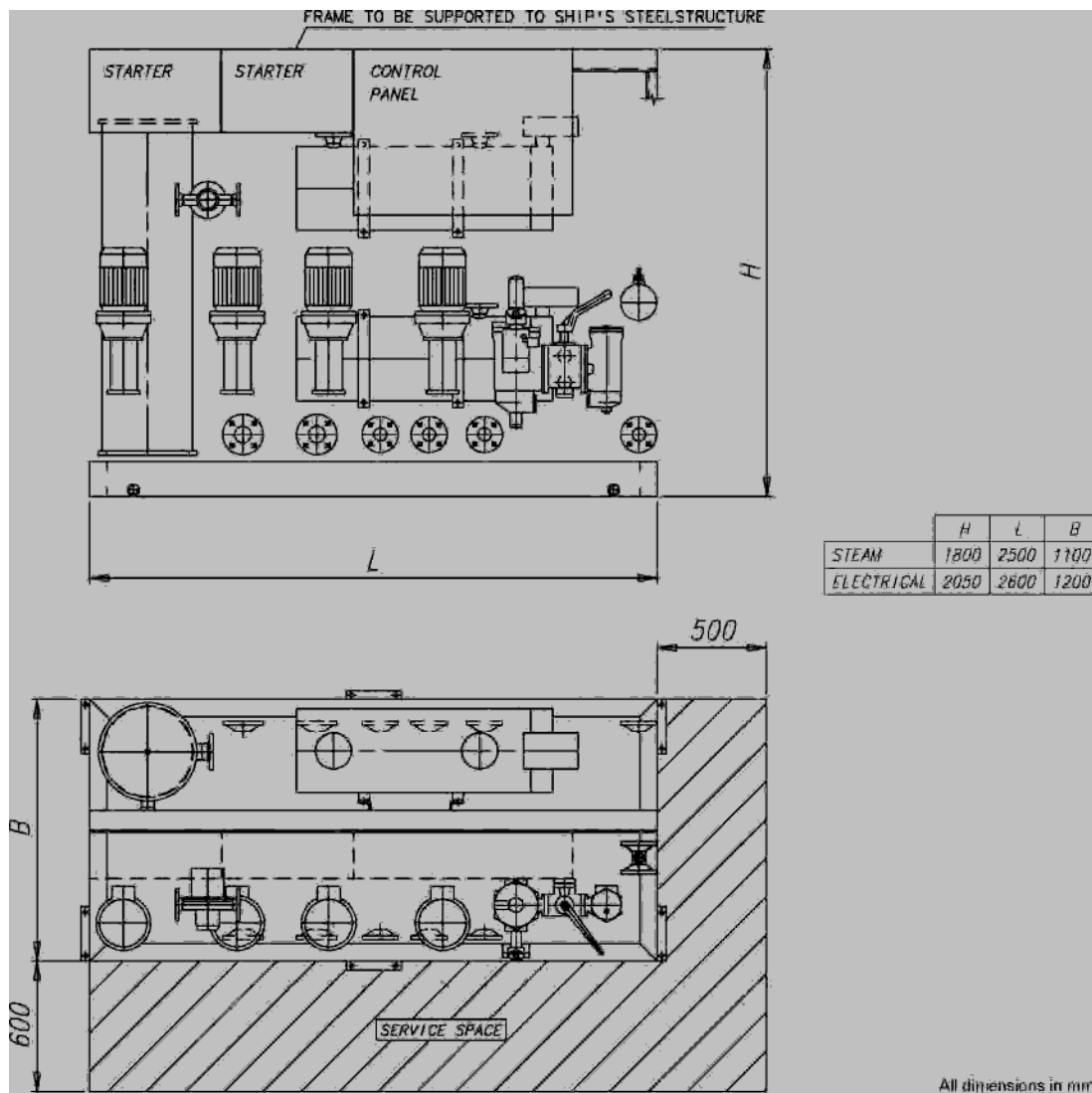


Fig 6-23 Feeder/booster unit, example (DAAE006659)

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 ($\beta_{50} = 75$, $\beta_{35} = 2$, ISO 16889)
- by-pass filter	35 µm absolute ($\beta_{50} = 75$, $\beta_{35} = 2$, ISO 16889)
Maximum permitted pressure drops at 14 cSt:	
- clean filter	20 kPa (0.2 bar)
- alarm	80 kPa (0.8 bar)

Flow meter, booster unit (1I01)

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

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

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

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

De-aeration tank, booster unit (1T08)

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

Circulation pump, booster unit (1P06)

The purpose of this pump is to circulate the fuel in the system and to maintain the required pressure at the injection pumps, which is stated in the chapter *Technical data*. By circulating the fuel in the system it also maintains correct viscosity, and keeps the piping and the injection pumps at operating temperature.

Design data:

Capacity:

- without circulation pumps (1P12) 4 x the total consumption of the connected engines
- with circulation pumps (1P12) 15% more than total capacity of all circulation pumps

Design pressure 1.6 MPa (16 bar)

Max. total pressure (safety valve) 1.0 MPa (10 bar)

Design temperature 150°C

Viscosity for dimensioning of electric motor 500 cSt

Heater, booster unit (1E02)

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

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

To avoid cracking of the fuel the surface temperature in the heater must not be too high. The heat transfer rate in relation to the surface area must not exceed 1.5 W/cm².

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)

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

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

Circulation pump (1P12)

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

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

Design data:

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

Safety filter (1F03)

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

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

Design pressure	1.6 MPa (16 bar)
Filter fineness	37 µm (absolute mesh size)
Maximum permitted pressure drops at 14 cSt:	
- clean filter	20 kPa (0.2 bar)
- alarm	80 kPa (0.8 bar)

Overflow valve, HFO (1V05)

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

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

Design data:

Capacity	Equal to circulation pump (1P06)
Design pressure	1.6 MPa (16 bar)
Design temperature	150°C

Pilot fuel feed pump, MDF (1P13)

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

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

Design data:

Capacity	1 m ³ /h per engine
Design pressure	1.6 MPa (16 bar)
Max. total pressure (safety valve)	1.0 MPa (10 bar)
Nominal pressure	see chapter " <i>Technical Data</i> "
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.

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	< 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	0.4 - 1.5
C	LIQUID BIO FUEL (LBF)		10...20	<= 0.05

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

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

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

Category	Fuel standard		Lubricating oil BN	Fuel S content, [% m/m]
C	ASTM D 975-01 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	4.5

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

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

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

7.1.2 Oil in speed governor or actuator

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

7.1.3 Oil in turning device

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

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

7.2 Internal lubricating oil system

7.2.1 Internal LO system, in-line engines

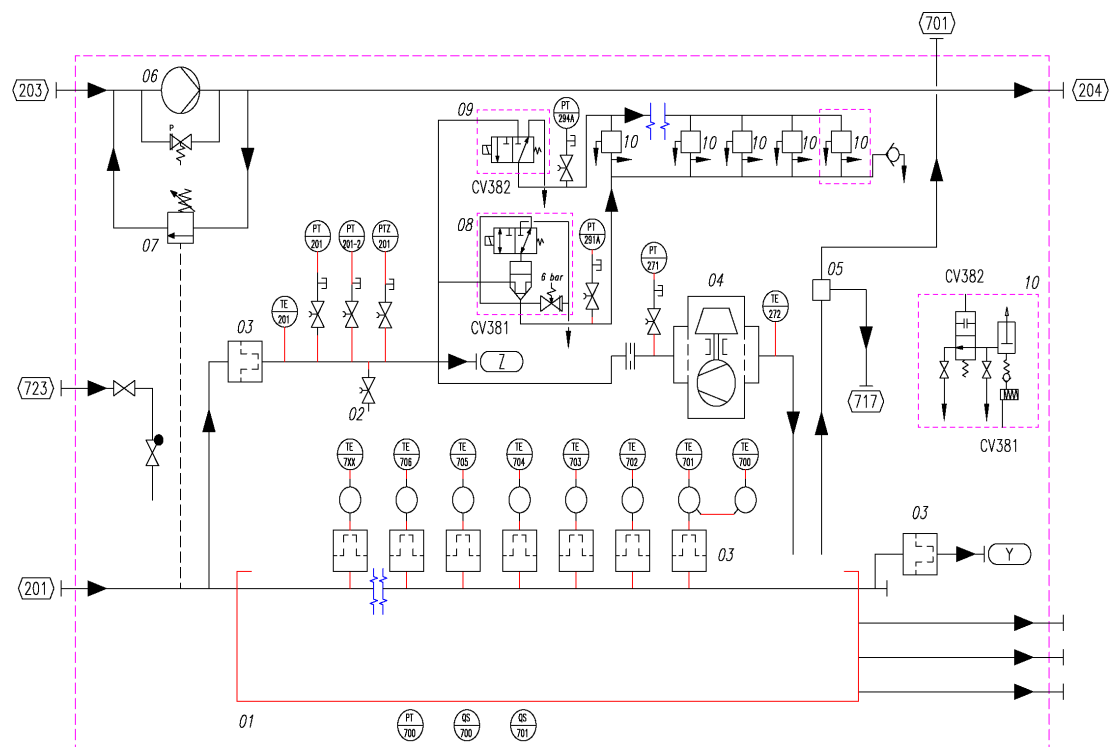


Fig 7-1 Internal lubricating oil system, in-line engines (DAAF425043)

System components:

01	Oil sump	04	Turbocharger	06	Lubricating oil main pump
02	Sampling cock	05	Crankcase breather	07	Pressure control valve
03	Running-in filter ¹⁾	08	Vic control valve	09	Half Vic control valve
10	Guide block for Vic (one per cylinder)				

1) To be removed after commissioning

Sensors and indicators

PT201	Lubricating oil inlet pressure	TE272	Lubricating oil temperature after turbocharger
PT201-1	Lubricating oil inlet pressure	PT700	Crankcase pressure
PT201-2	Lubricating oil inlet pressure	QS700	Oil mist detector, alarm
TE201	Lubricating oil inlet temperature	QS701	Oil mist detector, shutdown
PT271	Lubricating oil before turbocharger pressure	TE700...	Main bearing temperature
CV381	Vic control solenoid valve	CV382	Half - vic activation
PT291A	Control oil pressure after vic valve	PT294A	Control oil pressure after half vic valve

Pipe connections

		Size	Pressure class	Standard
201	Lubricating oil inlet (to manifold)	DN125	PN16	ISO 7005-1
202AD	Lubricating oil outlet (from oil sump), D.E.	DN200	PN10	ISO 7005-1
202AF	Lubricating oil outlet (from oil sump), F.E.	DN200	PN10	ISO 7005-1
202BD	Lubricating oil outlet (from oil sump), D.E.	DN200	PN10	ISO 7005-1
203	Lubricating oil to engine driven pump	DN250	PN10	ISO 7005-1

Pipe connections		Size	Pressure class	Standard
204	Lubricating oil from engine driven pump	DN150	PN16	ISO 7005-1
701	Crankcase air vent	6, 8L: OD114 9L: OD140		DIN 2353
717	Crankcase breather drain	-		
723	Inert gas inlet	DN50	PN40	ISO 7005-1
Y	Lube oil to intermediate gear wheels			
Z	Lube oil to valve gear, camshaft, etc...			

7.2.2 Internal LO system, V-engines

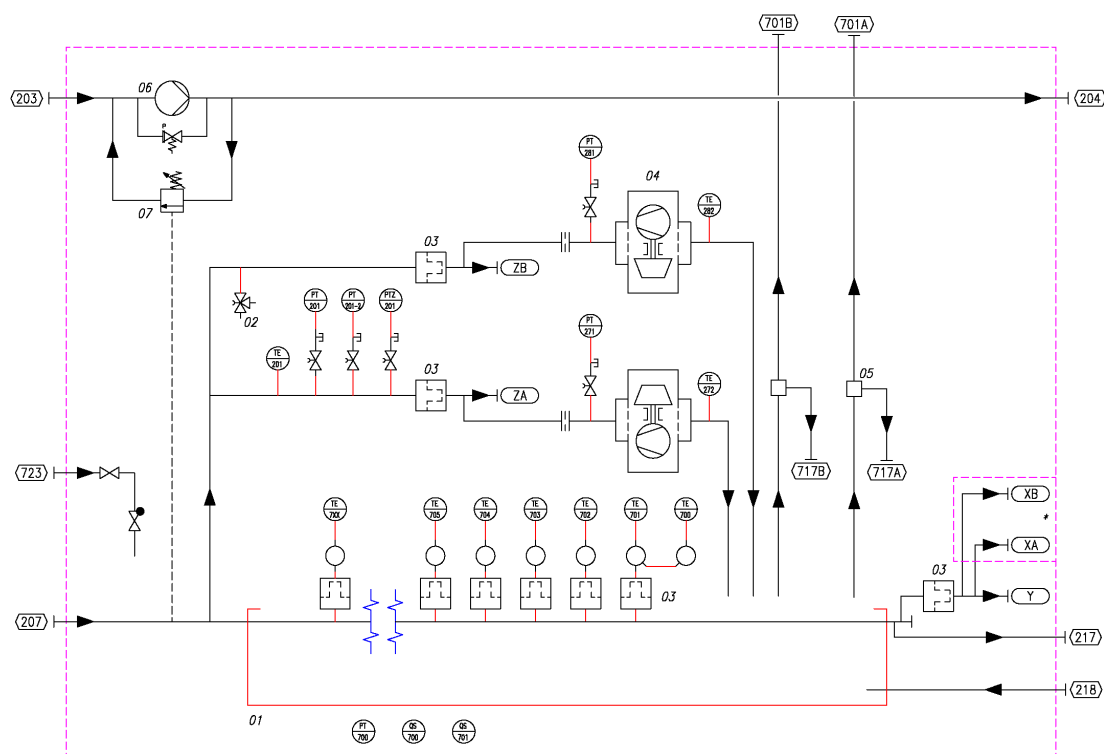


Fig 7-2 Internal lubricating oil system, V-engines (DAAF425173)

System components:

01	Oil sump	04	Turbocharger	06	Lubricating oil main pump
02	Sampling cock	05	Crankcase breather	07	Pressure control valve
03	Running-in filter ¹⁾				

1) To be removed after commissioning

Sensors and indicators

PTZ201	Lubricating oil inlet pressure	TE272	Lubricating oil temperature TC A outlet
PT201-1	Lubricating oil inlet pressure	PT700	Crankcase pressure
PT201-2	Lubricating oil inlet pressure	QS700	Oil mist detector, alarm
TE201	Lubricating oil inlet temperature	QS701	Oil mist detector, shutdown
PT271	Lubricating oil pressure, TC A inlet	TE700...	Main bearing temperature
PT281	Lube oil pressure, TC B inlet		

Pipe connections	Size	Pressure class	Standard
201 Lubricating oil inlet (to manifold)	DN125	PN16	ISO 7005-1
202AD Lubricating oil outlet (from oil sump), D.E.	DN200	PN10	ISO 7005-1
202AF Lubricating oil outlet (from oil sump), F.E.	DN200	PN10	ISO 7005-1
202BD Lubricating oil outlet (from oil sump), D.E.	DN200	PN10	ISO 7005-1
203 Lubricating oil to engine driven pump	DN250	PN10	ISO 7005-1
204 Lubricating oil from engine driven pump	DN150	PN16	ISO 7005-1
701A/B Crankcase air vent A/B Bank	6, 8L: OD114 9L: OD140		DIN 2353
717A/B Crankcase breather drain A/B Bank	-		
723 Inert gas inlet	DN50	PN40	ISO 7005-1

Pipe connections	Size	Pressure class	Standard
Y	Lube oil to intermediate gear wheels		
Z A/B	Lube oil to valve gear, camshaft, etc...A/B Bank		

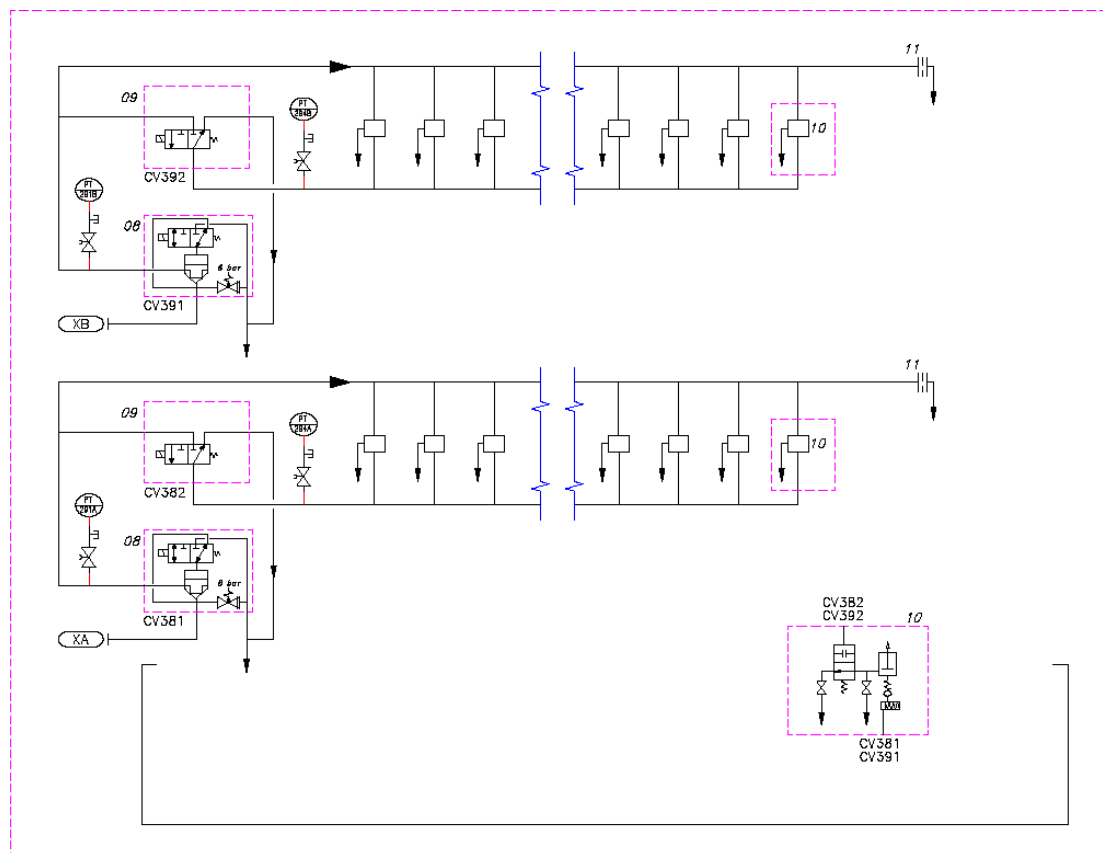


Fig 7-3 Internal lubricating oil system, V-engines (DAAF425173-)

System components:

- 08 Vic control valve
- 09 Half- vic control valve
- 10 Guide block for Vic, one per cylinder
- 11 Orifice

Sensors and indicators

PT291A/B	Control oil pressure after vic valve
PT294A/B	Control oil pressure after half-vic valve
CV381	Vic control solenoid valve, A-Bank
CV382	Half-vic activation, A-Bank
CV391	Vic control solenoid valve, B-Bank
CV392	Half-vic activation, B-Bank

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

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

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

7.3 External lubricating oil system

7.3.1 External LO system with engine driven pumps

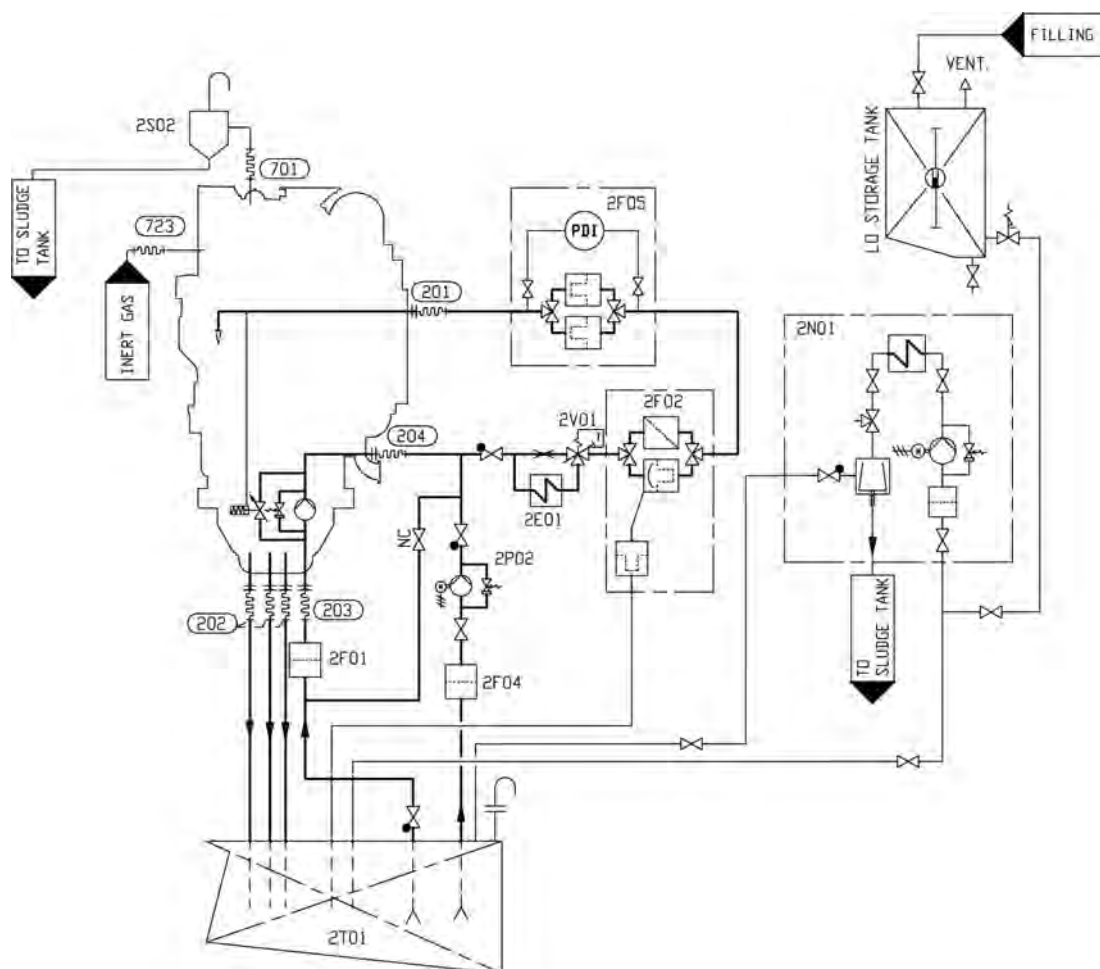


Fig 7-4 Example of lubricating oil system, with engine driven pumps (DAAE021746B)

System components:

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

Pipe connections:

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

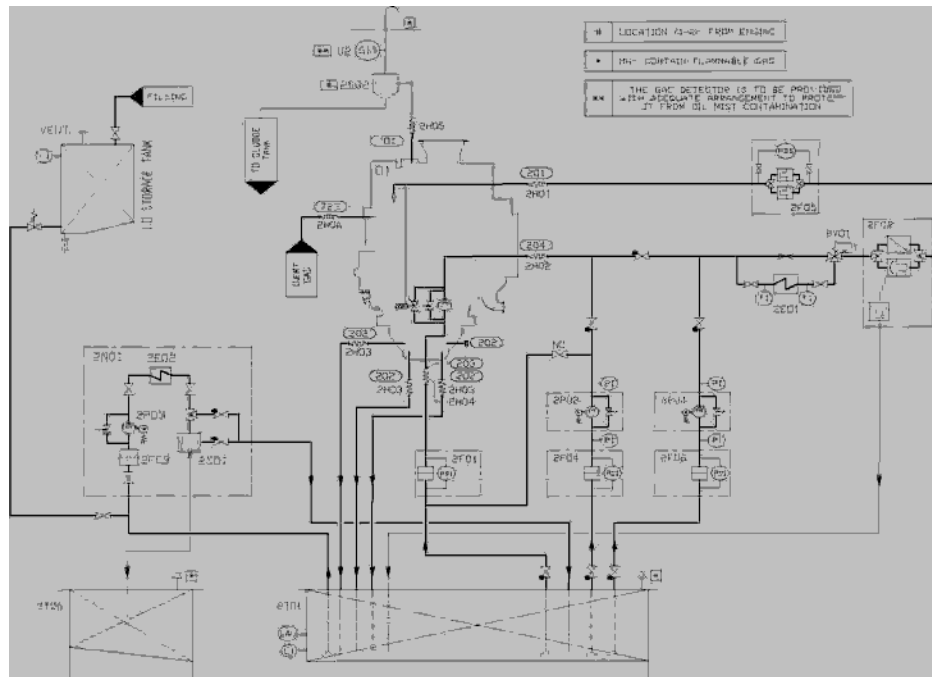


Fig 7-5 Example of lubricating oil system, with engine driven pumps (DAAF333578 A)

System components:			
2E01	Lubricating oil cooler	2HOX	Flexible pipe connections
2E02	Heater (separator unit)	2N01	Separator unit
2F01	Suction strainer (main lubricating oil pump)	2P02	Prelubricating oil pump
2F02	Automatic filter (LO)	2P03	Separator pump (separator unit)
2F03	Suction filter (separator unit)	2P04	Stand-by pump
2F04	Suction strainer (pre lubricating oil pump)	2S02	Condensate trap
2F05	Safety filter (LO)	2T01	System oil tank
2F06	Suction strainer (stand-by-pump)	2T06	Sludge tank
		2V01	Temperature control valve

Pipe connections:		6L50DF	8/9L50DF	Notes
201	Lubricating oil inlet	DN125	DN125	
202	Lubricating oil outlet	4xDN200	4xDN200	
203	Lubricating oil to engine driven pump	DN250	DN250	
204	Lubricating oil from engine driven pump	DN150	DN150	
701	Crankcase air vent	OD139,7	OD139,7	
723	Inert gas inlet (optional)	DN50	DN50	

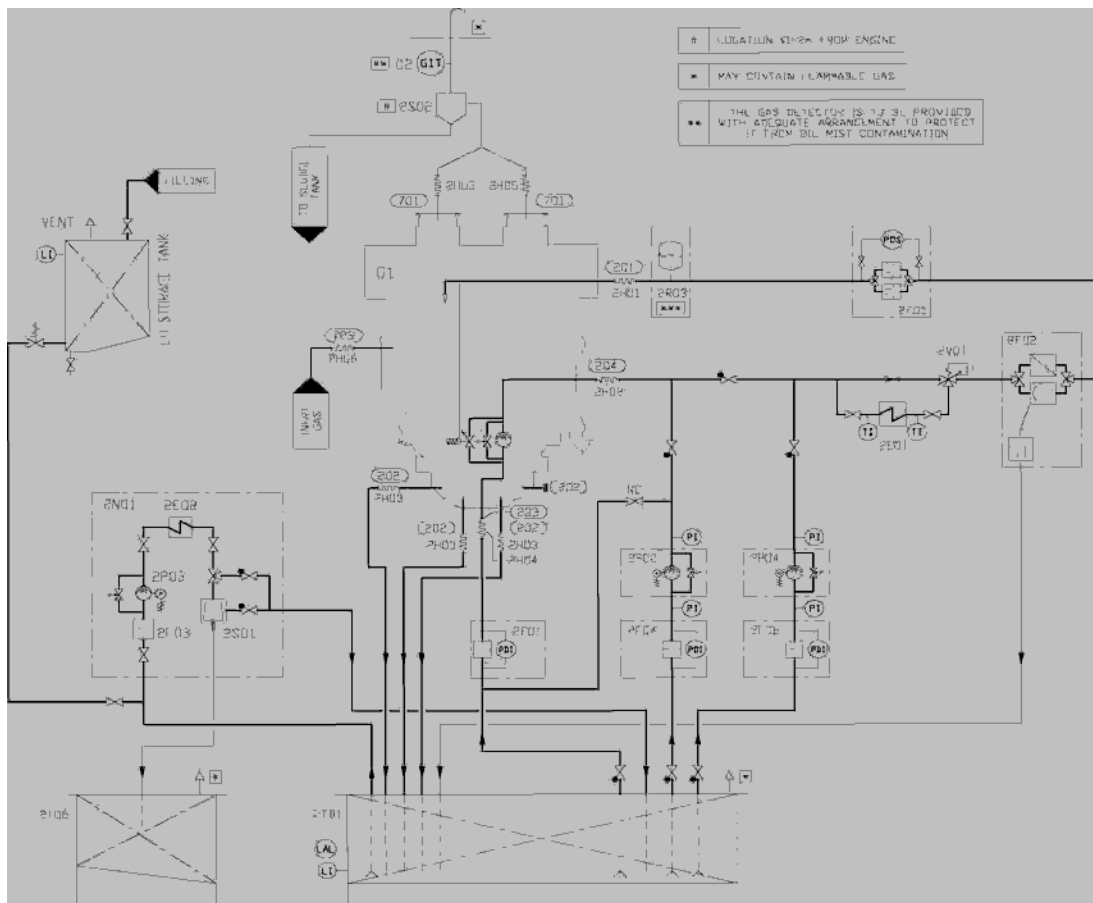


Fig 7-6 Example of lubricating oil system, with engine driven pumps (DAAF333579 A)

System components:

2E01	Lubricating oil cooler	2HOX	Flexible pipe connections
2E02	Heater (separator unit)	2N01	Separator unit
2F01	Suction strainer (main lubricating oil pump)	2P02	Prelubricating oil pump
2F02	Automatic filter (LO)	2P03	Separator pump (separator unit)
2F03	Suction filter (separator unit)	2P04	Stand-by pump
2F04	Suction strainer (pre lubricating oil pump)	2S02	Condensate trap
2F05	Safety filter (LO)	2T01	System oil tank
2F06	Suction strainer (stand-by-pump)	2T06	Sludge tank
		2V01	Temperature control valve

Pipe connections:

Pipe connections:	V50DF
201	Lubricating oil inlet
202	Lubricating oil outlet
203	Lubricating oil to engine driven pump
204	Lubricating oil from engine driven pump
701	Crankcase air vent
723	Inert gas inlet (optional)

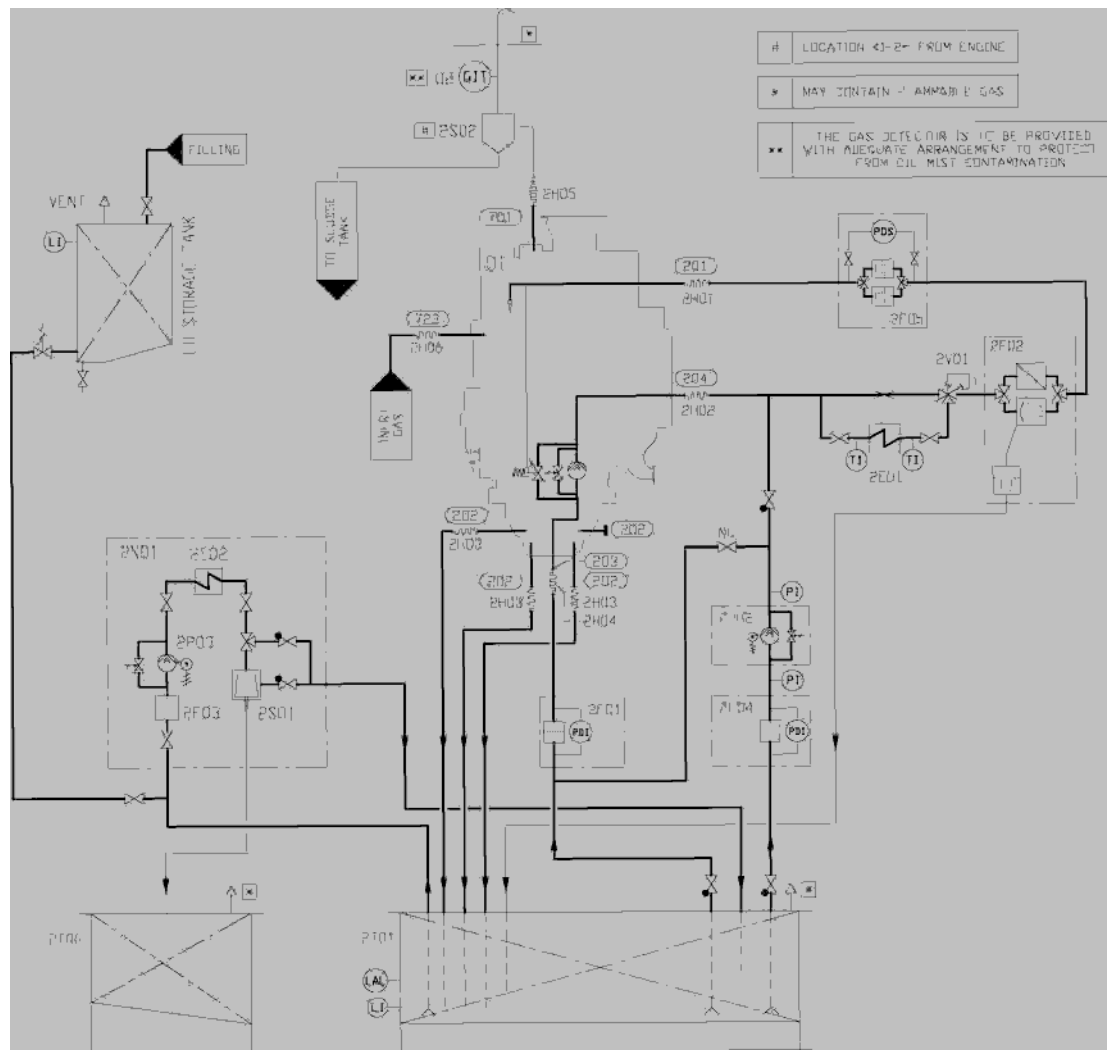


Fig 7-7 Example of lubricating oil system, with engine driven pumps (DAAF333580 A)

System components:

2E01	Lubricating oil cooler	2HOX	Flexible pipe connections
2E02	Heater (separator unit)	2N01	Separator unit
2F01	Suction strainer (main lubricating oil pump)	2P02	Prelubricating oil pump
2F02	Automatic filter (LO)	2P03	Separator pump (separator unit)
2F03	Suction filter (separator unit)	2S01	Separator (Separator unit)
2F04	Suction strainer (pre lubricating oil pump)	2S02	Condensate trap
2F05	Safety filter (LO)	2T01	System oil tank
		2T06	Sludge tank
		2V01	Temperature control valve

Pipe connections:

		6L50DF	8/9L50DF	Notes
201	Lubricating oil inlet	DN125	DN125	
202	Lubricating oil outlet	4xDN200	4xDN200	
203	Lubricating oil to engine driven pump	DN250	DN250	
204	Lubricating oil from engine driven pump	DN150	DN150	
701	Crankcase air vent	OD139,7	OD139,7	
723	Inert gas inlet (optional)	DN50	DN50	

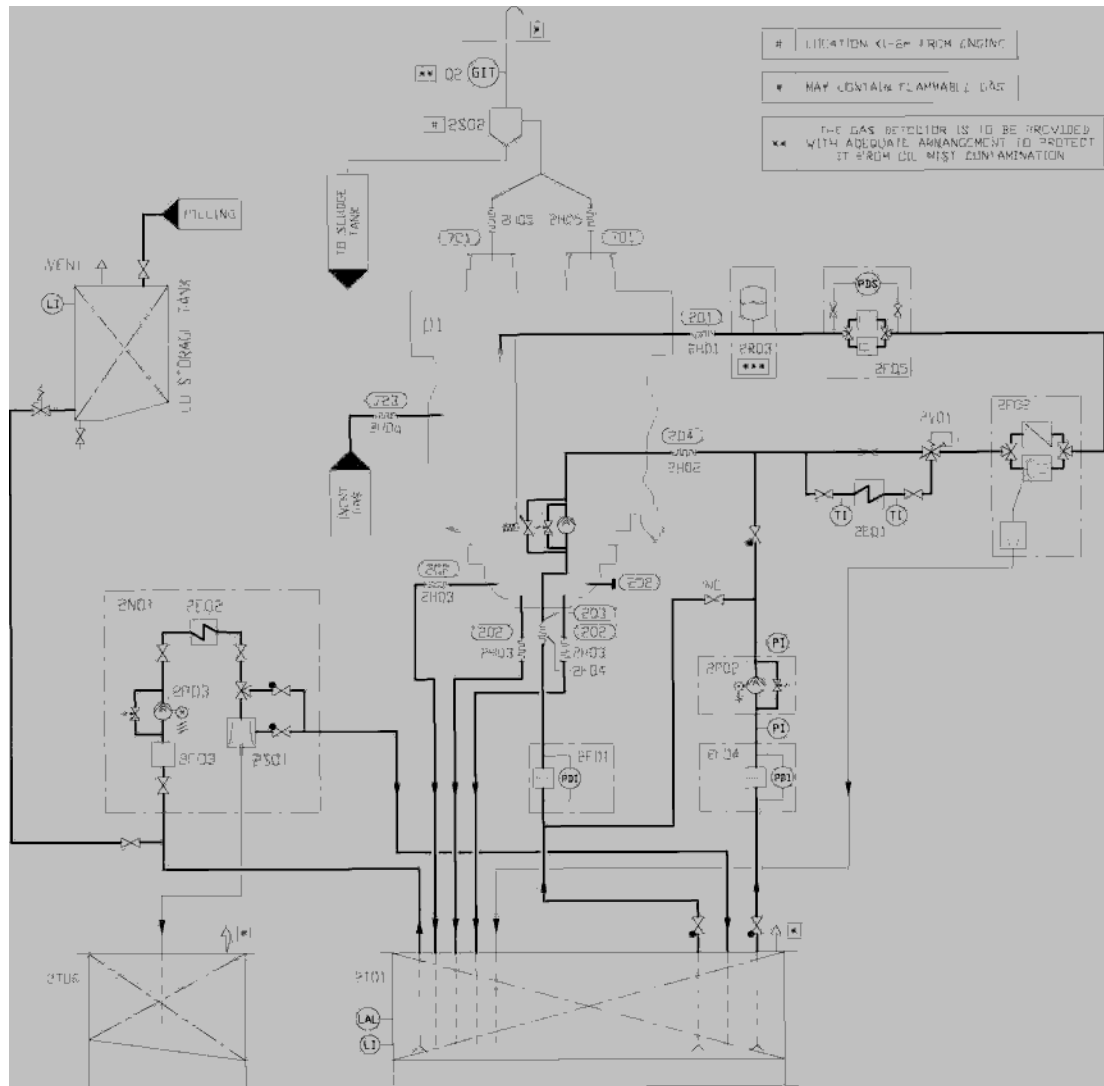


Fig 7-8 Example of lubricating oil system, with engine driven pumps (DAAF333581 A)

System components:			
2E01	Lubricating oil cooler	2HOX	Flexible pipe connections
2E02	Heater (separator unit)	2N01	Separator unit
2F01	Suction strainer (main lubricating oil pump)	2P02	Prelubricating oil pump
2F02	Automatic filter (LO)	2P03	Separator pump (separator unit)
2F03	Suction filter (separator unit)	2S01	Separator (Separator unit)
2F04	Suction strainer (pre lubricating oil pump)	2S02	Condensate trap
2F05	Safety filter (LO)	2T01	System oil tank
2R03	Lubricating oil damper	2T06	Sludge tank
		2V01	Temperature control valve

Pipe connections:		V50DF
201	Lubricating oil inlet	DN200
202	Lubricating oil outlet	4xDN250
203	Lubricating oil to engine driven pump	DN300
204	Lubricating oil from engine driven pump	DN200
701	Crankcase air vent	2XOD114

Pipe connections:		V50DF
723	Inert gas inlet (optional)	DN50

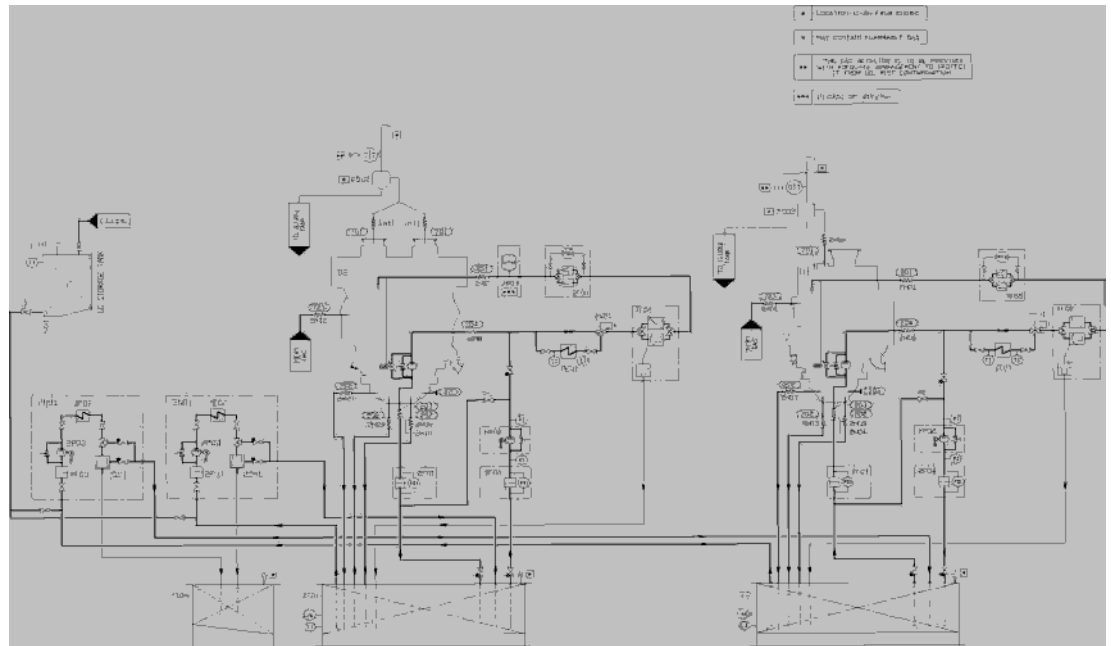


Fig 7-9 Example of lubricating oil system, with engine driven pumps (DAAF333582 A)

System components:			
2E01	Lubricating oil cooler	2HOX	Flexible pipe connections
2E02	Heater (separator unit)	2N01	Separator unit
2F01	Suction strainer (main lubricating oil pump)	2P02	Prelubricating oil pump
2F02	Automatic filter (LO)	2P03	Separator pump (separator unit)
2F03	Suction filter (separator unit)	2S01	Separator (Separator unit)
2F04	Suction strainer (pre lubricating oil pump)	2S02	Condensate trap
2F05	Safety filter (LO)	2T01	System oil tank
		2T06	Sludge tank
		2V01	Temperature control valve

Pipe connections:		6L50DF	8/9L50DF	Notes
201	Lubricating oil inlet	DN125	DN125	
202	Lubricating oil outlet	4xDN200	4xDN200	
203	Lubricating oil to engine driven pump	DN250	DN250	
204	Lubricating oil from engine driven pump	DN150	DN150	
701	Crankcase air vent	OD139,7	OD139,7	OD114 if TB is NA357
723	Inert gas inlet (optional)	DN50	DN50	

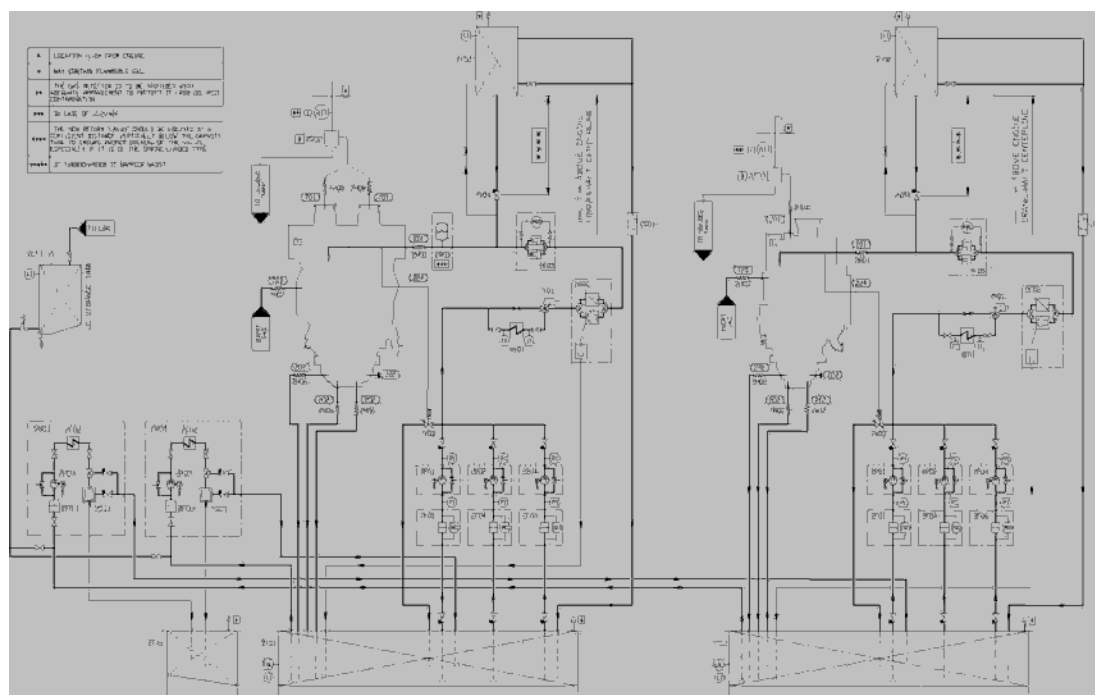


Fig 7-11 Example of lubricating oil system, without engine driven pumps (DAAF333583 A)

System components:			
2E01	Lubricating oil cooler	2P03	Separator pump (separator unit)
2E02	Heater (separator unit)	2P04	Stand-by pump
2F01	Suction strainer (main lubricating oil pump)	2R03	Lubricating oil damper
2F02	Automatic filter	2S01	Separator
2F03	Suction filter (separator unit)	2S02	Condensate trap
2F04	Suction strainer (pre lubricating oil pump)	2S03	Sight glass
2F05	Safety filter (LO)	2T01	System oil tank
2F06	Suction strainer (stand-by pump)	2T02	Gravity tank
2H0X	Flexible pipe connection	2T06	Sludge tank
2N01	Separator unit	2V01	Temperature control valve
2P01	Main lubricating oil pump	2V03	Pressure control valve
2P02	Pre lubricating oil pump	2V04	Non-return valve

Pipe connections:		L50DF	V50DF
201	Lubricating oil inlet	DN125	DN200
202	Lubricating oil outlet ¹⁾	4xDN200	4xDN250
224	Control oil to lube oil pressure control valve	M26x1.5	
701	Crankcase air vent	ODI139,7	2xOD114
723	Inert gas inlet	DN50	

7.3.3 Separation system

7.3.3.1 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.

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

Separators are usually supplied as pre-assembled units.

Typically lubricating oil separator units are equipped with:

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

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

Separator feed pump (2P03)

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

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

Separator preheater (2E02)

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

Recommended oil temperature after the heater is 95°C.

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

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

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

Separator (2S01)

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

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

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

where:

Q = volume flow [l/h]

P = engine output [kW]

n = 5 for HFO, 4 for MDF

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

Sludge tank (2T06)

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

7.3.4 System oil tank (2T01)

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

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

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

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

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

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

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

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

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

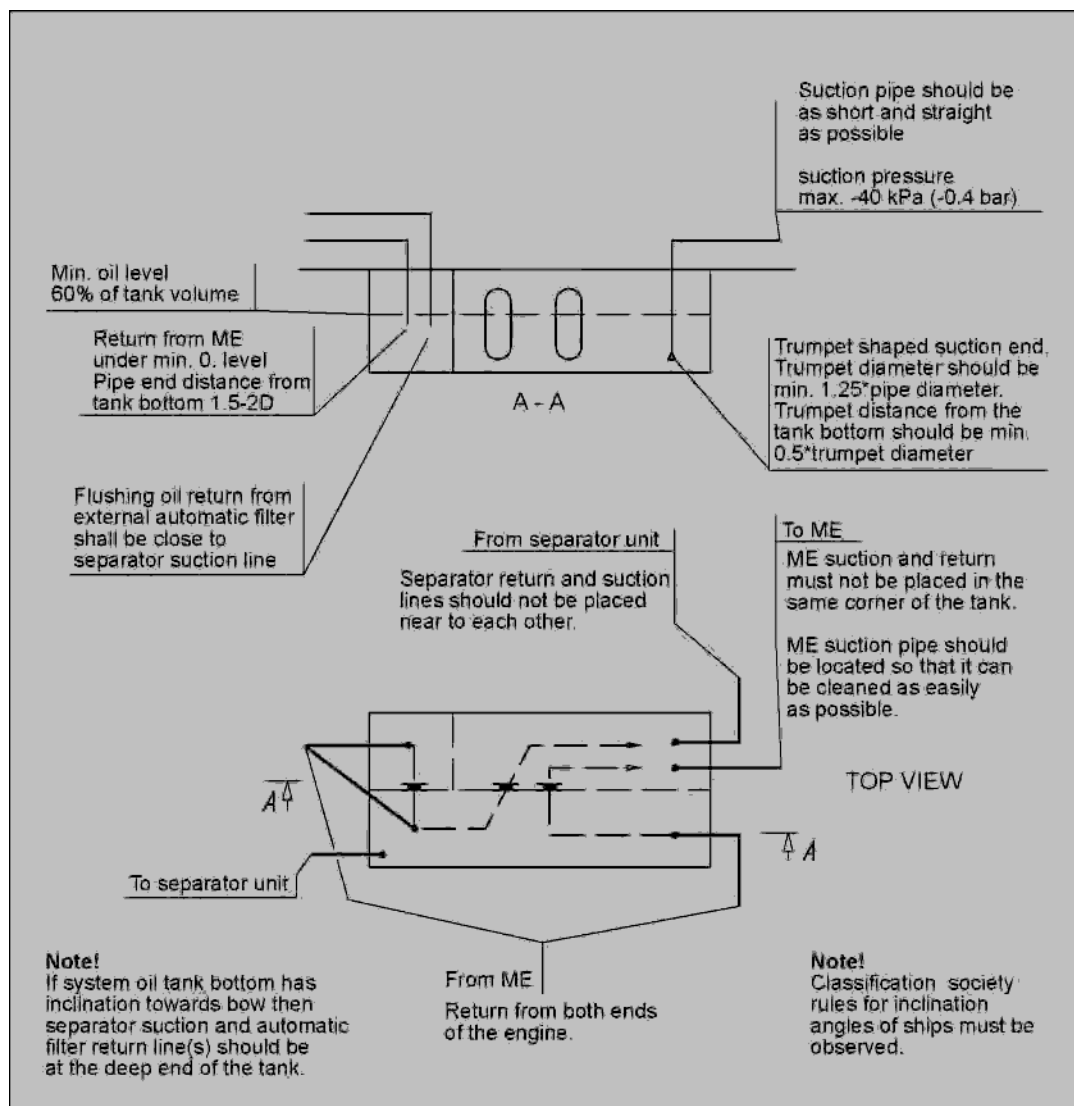


Fig 7-12 Example of system oil tank arrangement (DAAE007020e)

Design data:

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

7.3.5 Gravity tank (2T02)

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

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

Engine type	Tank volume [m ³]
6L50DF	1.0
8L-, 9L-, 12V50DF	2.0
16VDF	3.0

7.3.6 Suction strainers (2F01, 2F04, 2F06)

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

Design data:

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

7.3.7 Pre-lubricating oil pump (2P02)

The pre-lubricating oil pump is a separately installed scREW 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 <i>Technical data</i>
Max. pressure (safety valve)	350 kPa (3.5 bar)
Design temperature	100°C
Viscosity for dimensioning of the electric motor	500 cSt

7.3.8 Lubricating oil cooler (2E01)

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

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

Design data:	
Oil flow through cooler	see <i>Technical data</i> , "Oil flow through engine"
Heat to be dissipated	see <i>Technical data</i>
Max. pressure drop, oil	80 kPa (0.8 bar)

Water flow through cooler	see <i>Technical data</i> , "LT-pump capacity"
Max. pressure drop, water	60 kPa (0.6 bar)
Water temperature before cooler	45°C
Oil temperature before engine	63°C
Design pressure	1.0 MPa (10 bar)
Margin (heat rate, fouling)	min. 15%

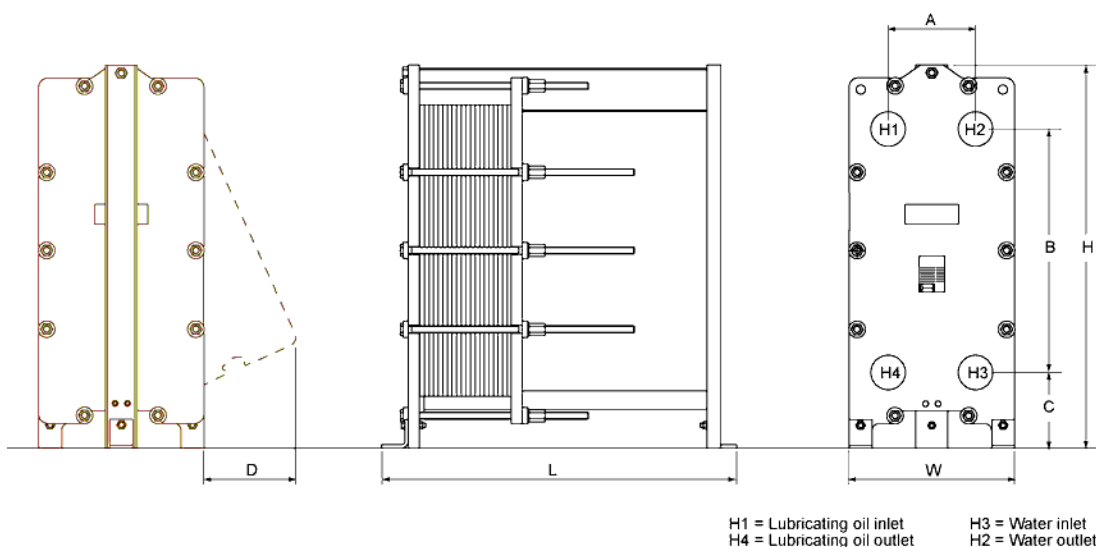


Fig 7-13 Main dimensions of the lubricating oil cooler

Engine	Weight, dry [kg]	Dimensions [mm]						
		H	W	L	A	B	C	D
W 6L50DF	1180	1675	720	1237	380	1057	330	300
W 8L50DF	1220	1675	720	1237	380	1057	330	300
W 9L50DF	1250	1675	720	1487	380	1057	330	300
W 12V50DF	1390	1675	720	1737	380	1057	330	300
W 16V50DF	1560	1675	720	1987	380	1057	330	300

NOTE



These dimensions are for guidance only.

7.3.9 Temperature control valve (2V01)

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

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

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

Design data:

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

7.3.10 Automatic filter (2F02)

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

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

Design data:

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

7.3.11 Safety filter (2F05)

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

Design data:

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

7.3.12 Lubricating oil damper (2R03)

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

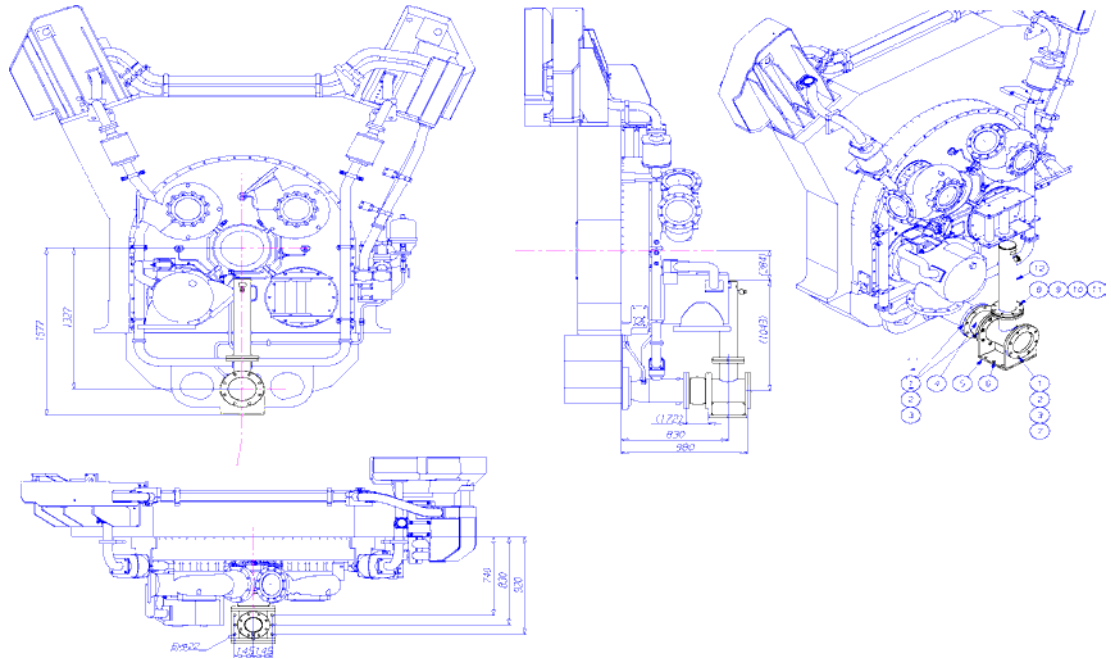


Fig 7-14 Lubricating oil damper arrangement to external piping (3V35L4209A)

7.4 Crankcase ventilation system

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

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

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

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

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

Design data:

Flow	see <i>Technical data</i>
Backpressure, max.	see <i>Technical data</i>
Temperature	80°C

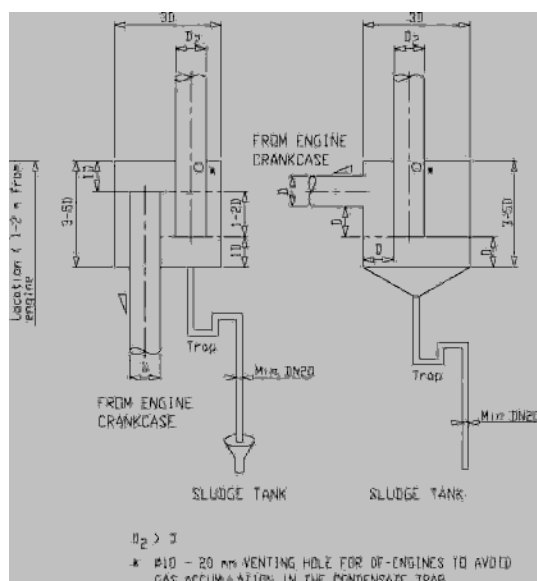


Fig 7-15 Condensate trap (DAAF369903)

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.

The external oil tanks, new oil tank and the system oil tank (2T01) shall be verified to be clean before bunkering oil.

Operate the separator unit (2N01) continuously during the flushing (not less than 24 hours). Leave the separator running also after the flushing procedure, this to ensure that any remaining contaminants are removed.

If an electric motor driven stand-by pump is installed this pump shall primarily be used for the flushing but also the pre-lubricating pump (2P02) shall be operated for some hours to flush the pipe branch.

Run the pumps circulating engine oil through a temporary external oil filter (recommended mesh 34 microns) into the engine oil sump through a hose and a crankcase door. The pumps shall be protected by the suction strainers (2F04, 2F06).

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

7.5.3 Type of flushing oil

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)
Dew point temperature	+3°C
Max. oil content	1 mg/m ³
Max. particle size	3 µm

8.2 Internal compressed air system

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

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

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

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

8.2.1 Internal compressed air system for in-line engines

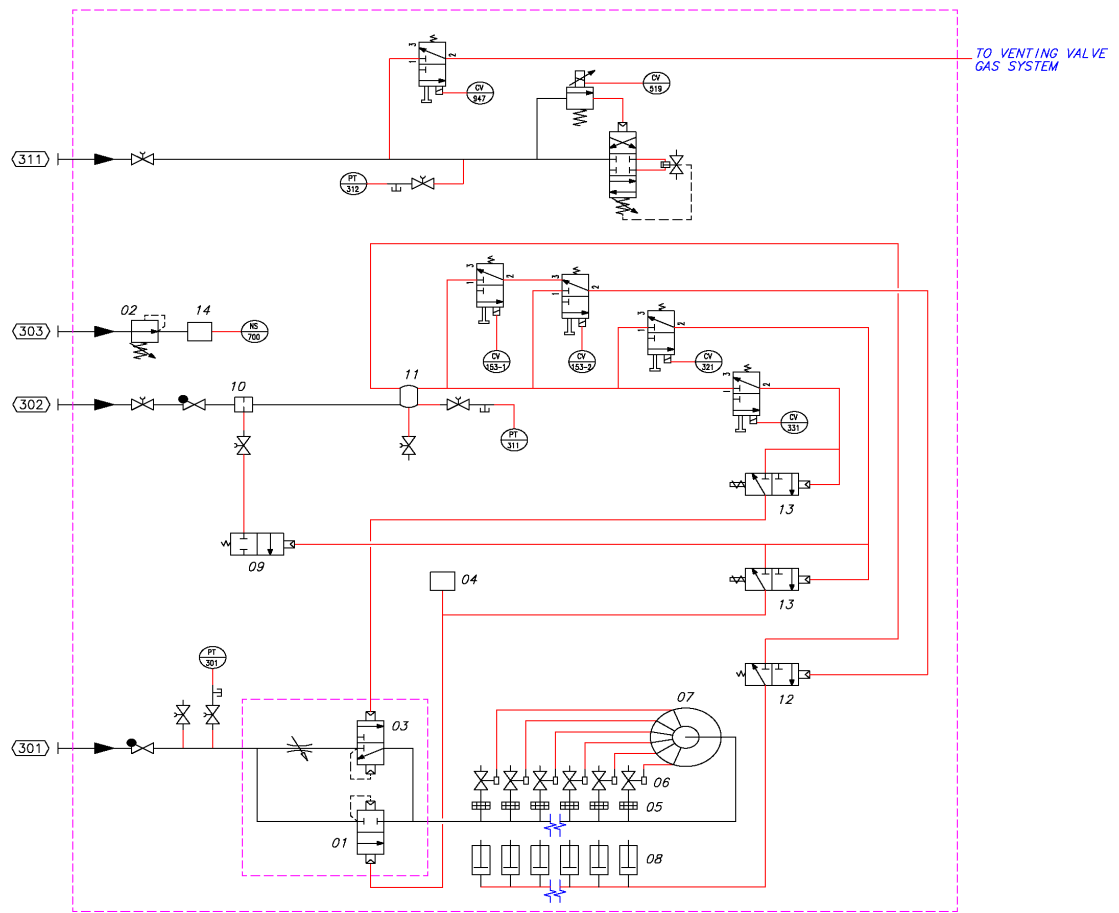


Fig 8-1 Internal compressed air system, in-line engines (DAAF425044)

System components:

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

Sensors and indicators:

PT301	Starting air inlet pressure	CV321	Starting solenoid
PT311	Control air pressure	CV331	Slow turning solenoid
PT312	Low pressure control air pressure	CV519	I/P converter for wastegate valve
NS700	Oil mist detector	CV497	Gas venting solenoid
PI	Manometer		

Pipe connections

301	Starting air inlet
302	Control air inlet

Pipe connections	
303	Driving air inlet to oil mist detector
311	Control air inlet

8.2.2 Internal compressed air system for V-engines

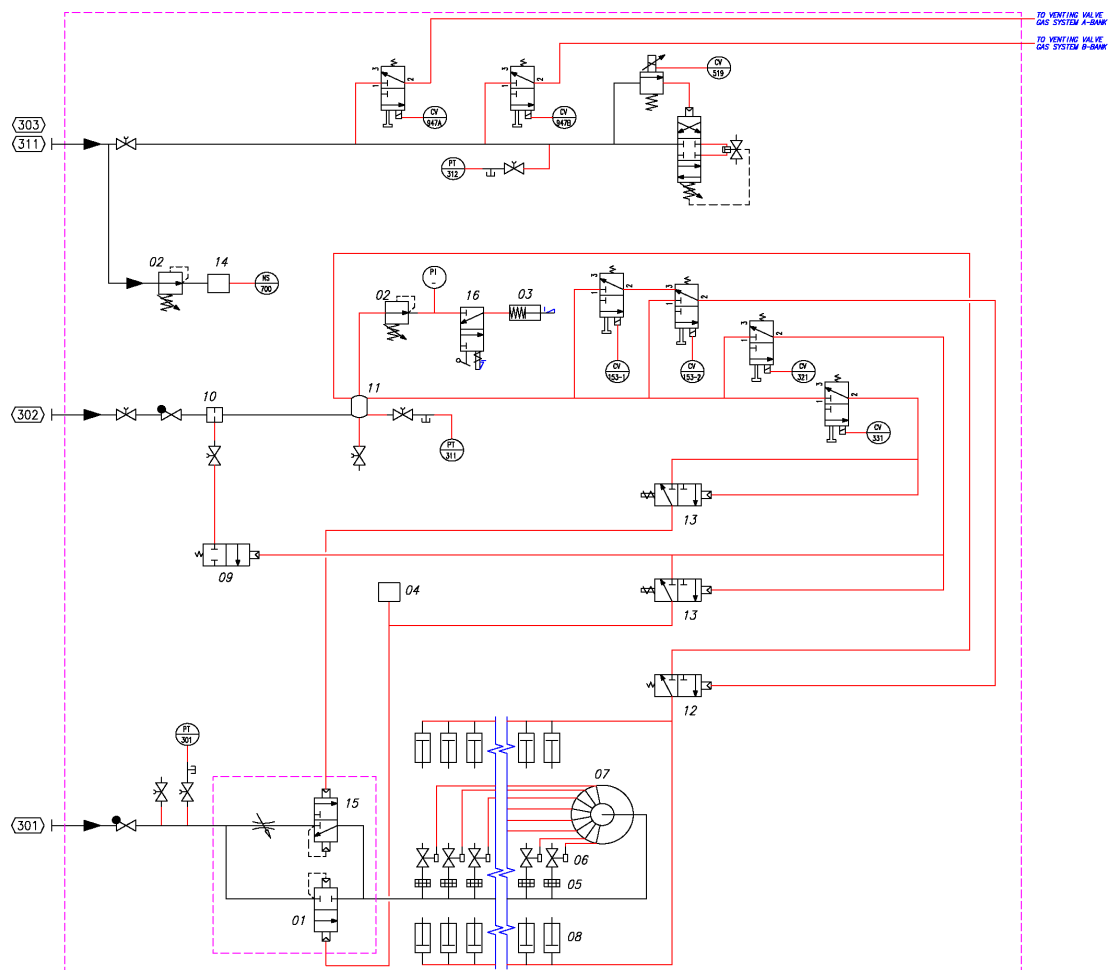


Fig 8-2 Internal compressed air system, V-engines (DAAF425136)

System components:

01	Starting air master valve	09	Valve for automatic draining
02	Pressure control valve	10	High pressure filter
03	Mechanical overspeed trip device	11	Air container
04	Starting booster for speed governor	12	Stop valve
05	Flame arrester	13	Blocking valve, when turning gear engaged
06	Starting air valve in cylinder head	14	Oil mist detector
07	Starting air distributor	15	Slow turning valve
08	Pneumatic cylinder at each injection pump	16	Closing valve

Sensors and indicators:

PT301	Starting air inlet pressure	CV321	Starting solenoid
PT311	Control air pressure	CV331	Slow turning solenoid
PT312	Low pressure control air pressure	CV519	I/P converter for wastegate valve
NS700	Oil mist detector	CV947	Gas venting solenoid
PI	Manometer		

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

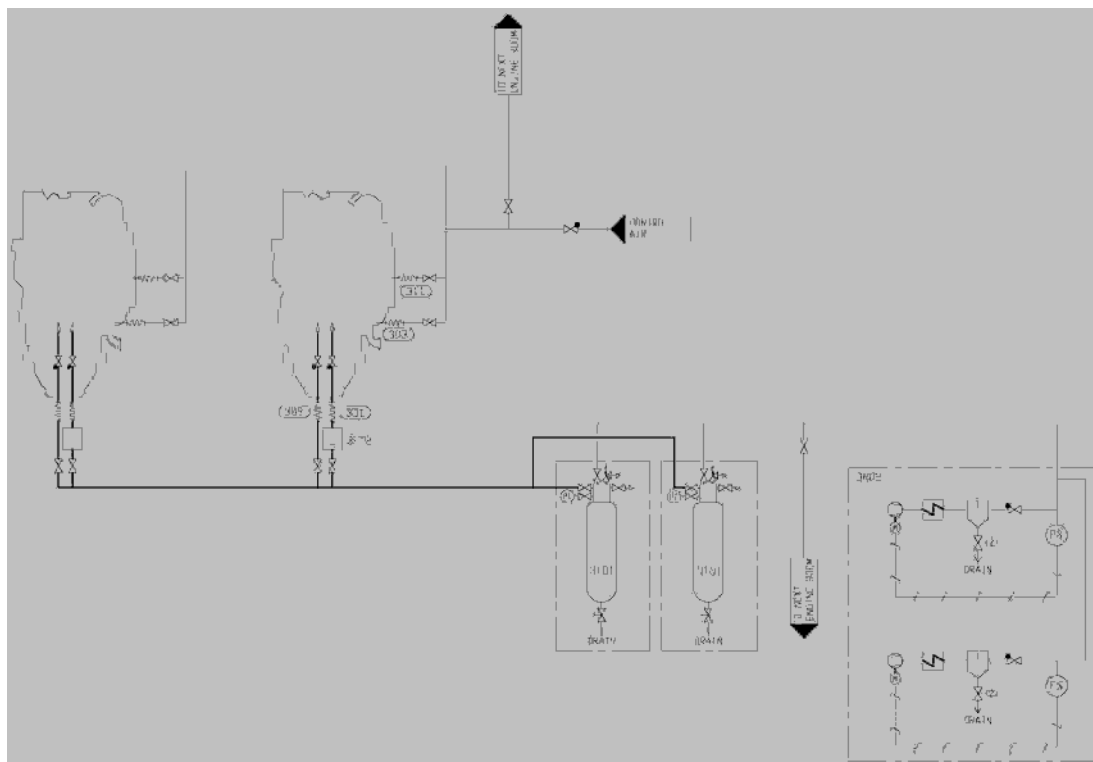


Fig 8-3 Example of external compressed air system (3V76H4173D)

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

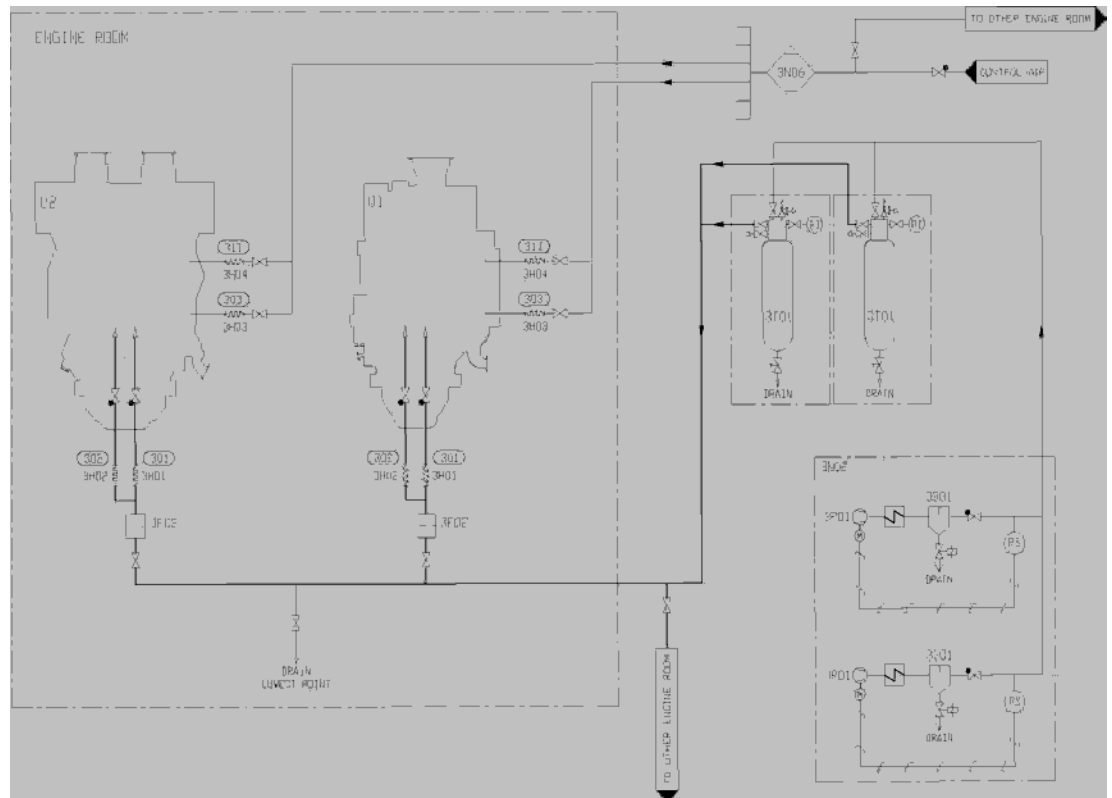


Fig 8-4 Example of external starting air system (DAAF333596A)

System components		Pipe connections	
3F02	Air filter (starting air inlet)	301	Starting air inlet, 3 MPa
3N02	Starting air compressor unit	302	Control air inlet, 3 MPa
3T01	Starting air receiver	303	Driving air to oil mist detector, 0.8 MPa
3H01	Flexible pipe connection	311	Control air to bypass / wastegate valve, 0.8 MPa
3N06	Air dryer unit		
3P01	Compressor (Starting air compressor unit)		
3S01	Separator (Starting air compressor unit)		

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.

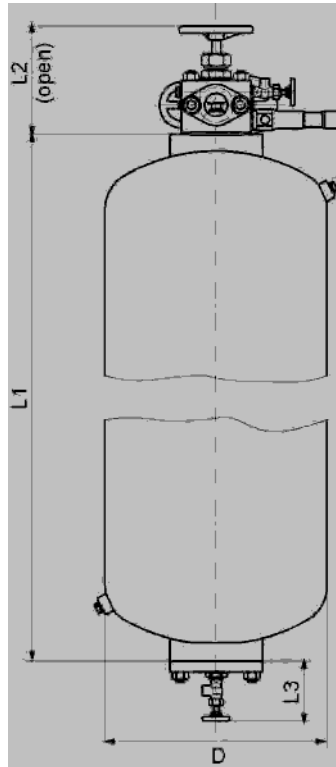
8.3.3 Starting air vessel (3T01)

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 8-5 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 [m³]

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

V_E = air consumption per start [Nm³] 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

9.2.1 Internal cooling water system for in-line engines

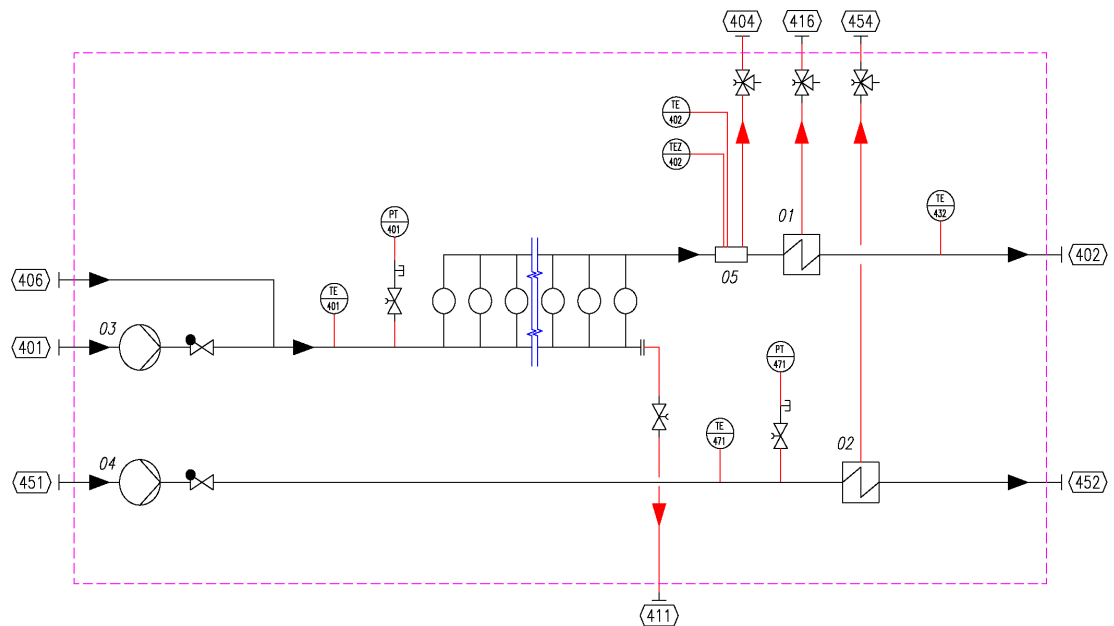


Fig 9-1 Internal cooling water system, in-line engines (DAAF425040)

System components:

01	Charge air cooler (HT)	03	HT-water pump
02	Charge air cooler (LT)	04	LT-water pump
05	Circulating water box		

Sensors and indicators:

PT401	HT water pressure, Jacket inlet	TE432	HT water temp, HT charge air cooler outlet
TE401	HT water temperature, Jacket inlet	PT471	LT water inlet pressure, LT charge air cooler inlet
TE402	HT water temperature, Jacket outlet	TE471	LT water inlet temperature, LT charge air cooler inlet
TEZ402	HT water temperature, Jacket outlet		

Pipe connections		Size	Pressure class	Standard
401	HT-water inlet	DN150	PN16	ISO 7005-1
402	HT-water outlet	DN150	PN16	ISO 7005-1
404	HT-water air vent	OD12		DIN 2353
406	Water from preheater to HT-circuit	DN40	PN40	ISO 7005-1
411	HT-water drain	OD48		DIN 2353
416	HT-water air vent from air cooler	OD12		DIN 2353
451	LT-water inlet	DN150	PN16	ISO 7005-1
452	LT-water outlet	DN150	PN16	ISO 7005-1
454	LT-water air vent from air cooler	OD12		DIN 2353

9.2.2 Internal cooling water system for V-engines

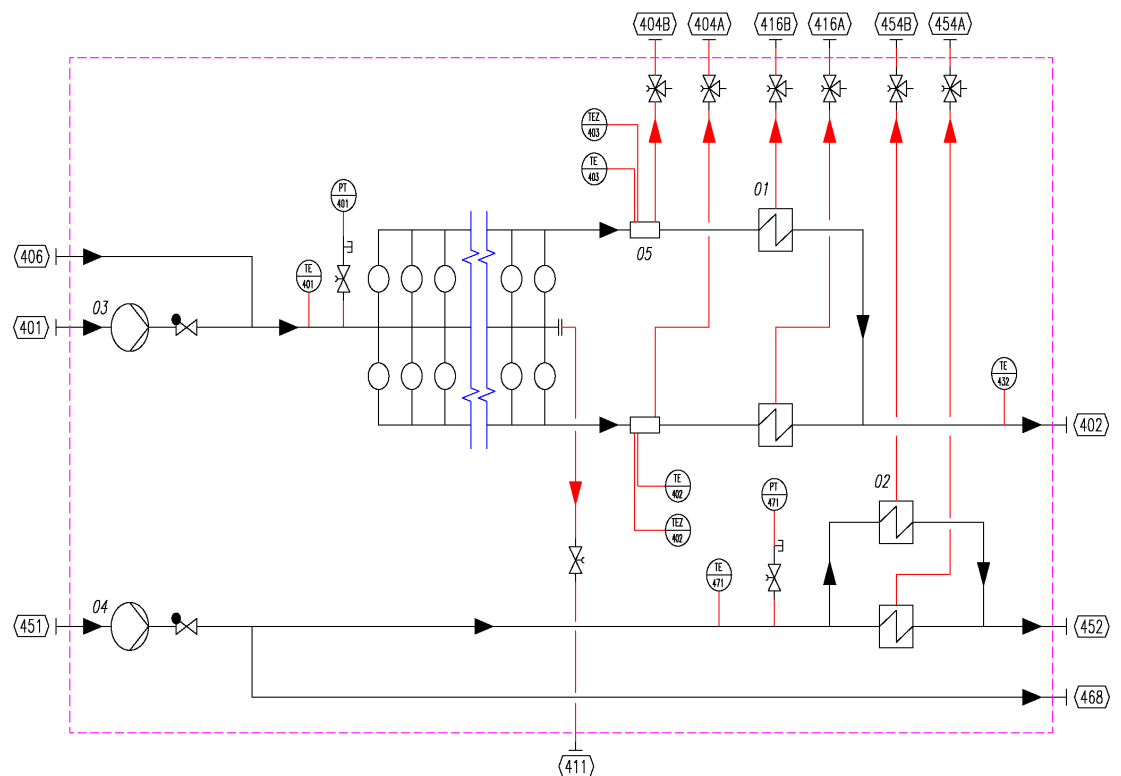


Fig 9-2 Internal cooling water system, V-engines (DAAF425137)

System components:

01	Charge air cooler (HT)	03	HT-water pump
02	Charge air cooler (LT)	04	LT-water pump
05	Circulating water box		

Sensors and indicators:

PT401	HT water pressure, Jacket inlet	TE432	HT water temp, HT charge air cooler outlet
TE401	HT water temperature, Jacket inlet	PT471	LT water inlet pressure, LT charge air cooler inlet
TE402	HT water temperature, Jacket outlet A-bank	TE471	LT water inlet temperature, LT charge air cooler inlet
TE403	HT water temperature, Jacket outlet B-bank		
TEZ402	HT water temperature, Jacket outlet A-bank		
TEZ403	HT water temperature, Jacket outlet A-bank		

Pipe connections		Size	Pressure class	Standard
401	HT-water inlet	DN200	PN10	ISO 7005-1
402	HT-water outlet	DN200	PN10	ISO 7005-1
404A/B	HT-water air vent A/B bank	OD12		DIN 2353
406	Water from preheater to HT-circuit	DN40	PN40	ISO 7005-1
411	HT-water drain	OD48		DIN 2353
416A/B	HT-water air vent from air cooler A/B bank	OD12		DIN 2353
451	LT-water inlet	DN200	PN10	ISO 7005-1
452	LT-water outlet	DN200	PN10	ISO 7005-1
454A/B	LT-water air vent from air cooler A/B bank	OD12		DIN 2353

Pipe connections		Size	Pressure class	Standard
468	LT-water, air cooler by-pass	DN200	PN10	ISO 7005-1

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

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

9.2.3 Engine driven circulating pumps

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

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

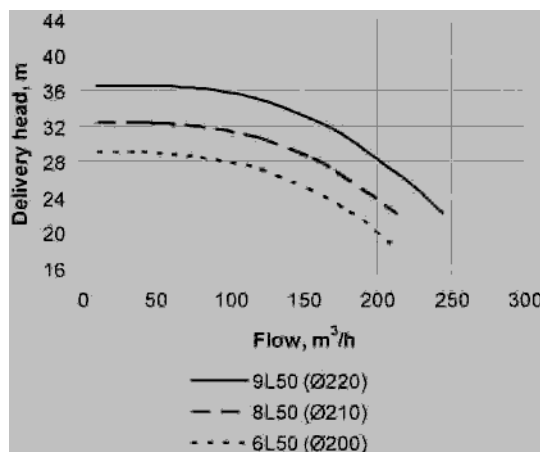


Fig 9-3 Wärtsilä 50DF 500 rpm in-line engine HT and LT cooling water pump curves (4V19L0332A)

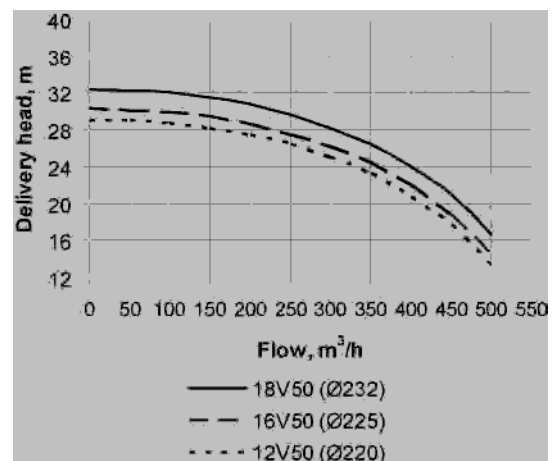


Fig 9-4 Wärtsilä 50DF 500 rpm V-engine HT and LT cooling water pump curves (4V19L0333A)

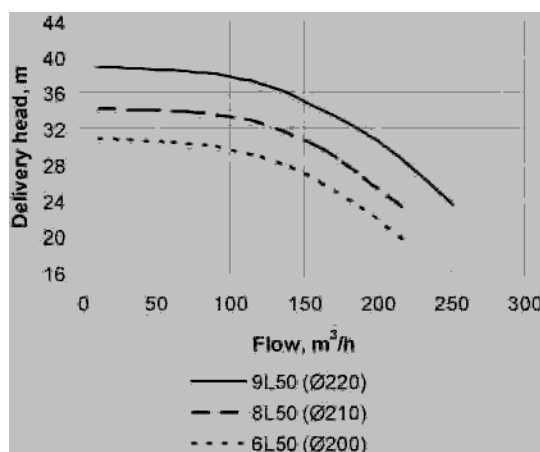


Fig 9-5 Wärtsilä 50DF 514 rpm in-line engine HT and LT cooling water pump curves (4V19L0332A)

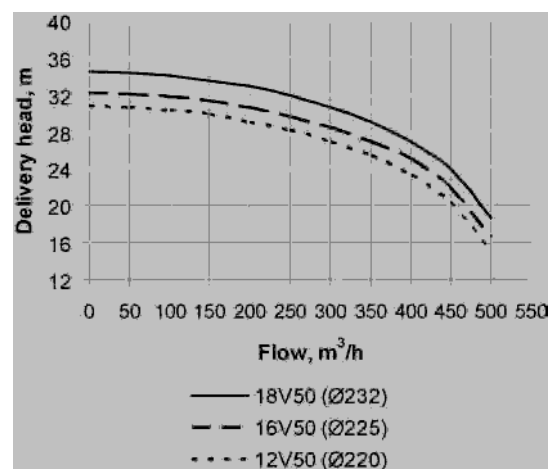


Fig 9-6 Wärtsilä 50DF 514 rpm V-engine HT and LT cooling water pump curves (4V19L0333A)

9.3 External cooling water system

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

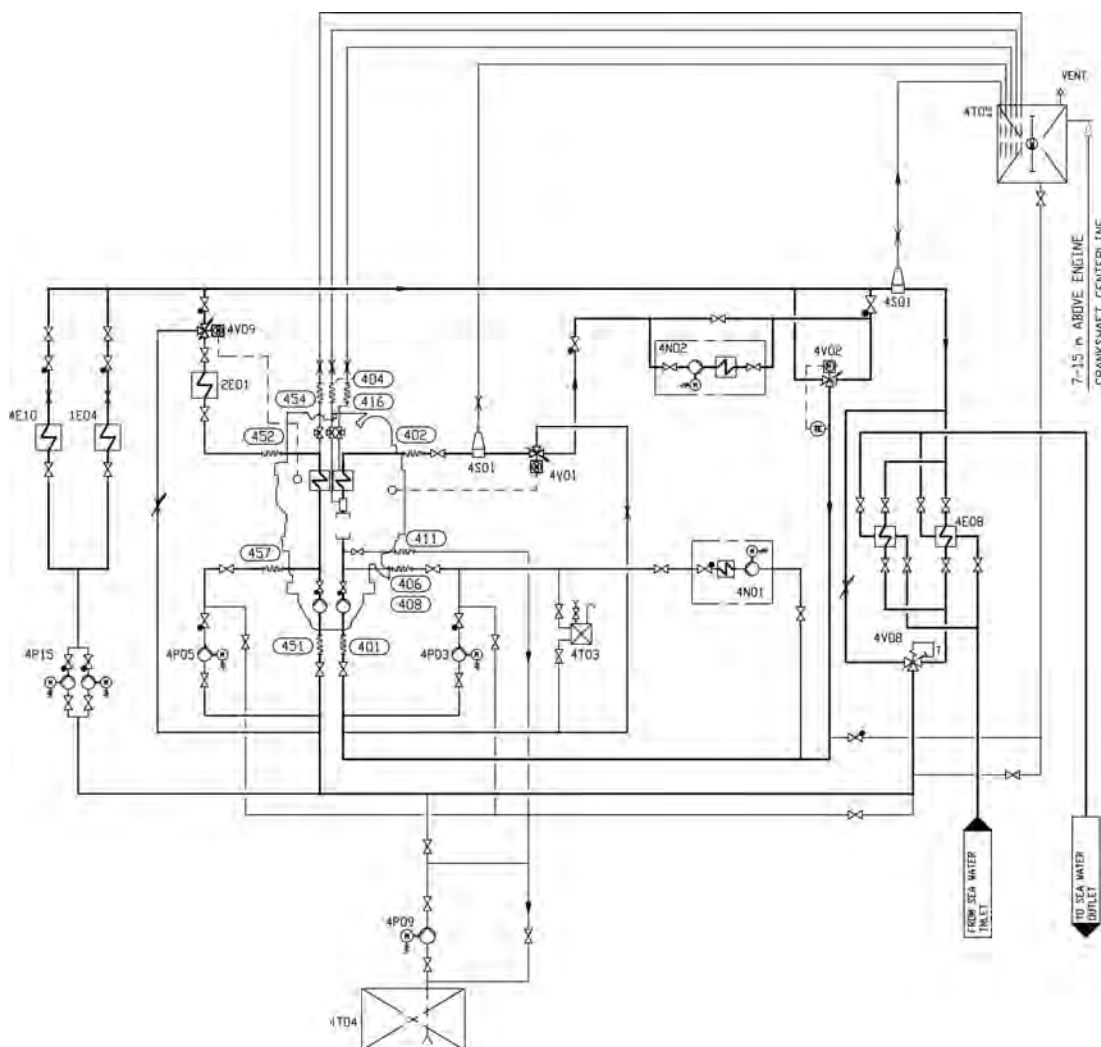


Fig 9-7 Cooling water system, in-line engine in common circuit built-on pumps and evaporator (DAAF072992)

System components:

1E04	Cooler (MDF return line)	4P15	Circulating pump
2E01	Lubricating oil cooler	4S01	Air venting

System components:			
4E08	Central cooler	4T03	Additive dosing tank
4E10	Cooler (Reduction gear)	4T04	Drain tank
4N01	Preheating unit	4T05	Expansion tank
4N02	Evaporator unit	4V01	Temperature control valve (HT)
4P03	Stand-by pump (HT)	4V02	Temperature control valve (Heat recovery)
4P05	Stand-by pump (LT)	4V08	Temperature control valve (LT)
4P09	Transfer pump	4V09	Temperature control valve (charge air)
Pipe connections are listed in section "Internal cooling water system".			

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

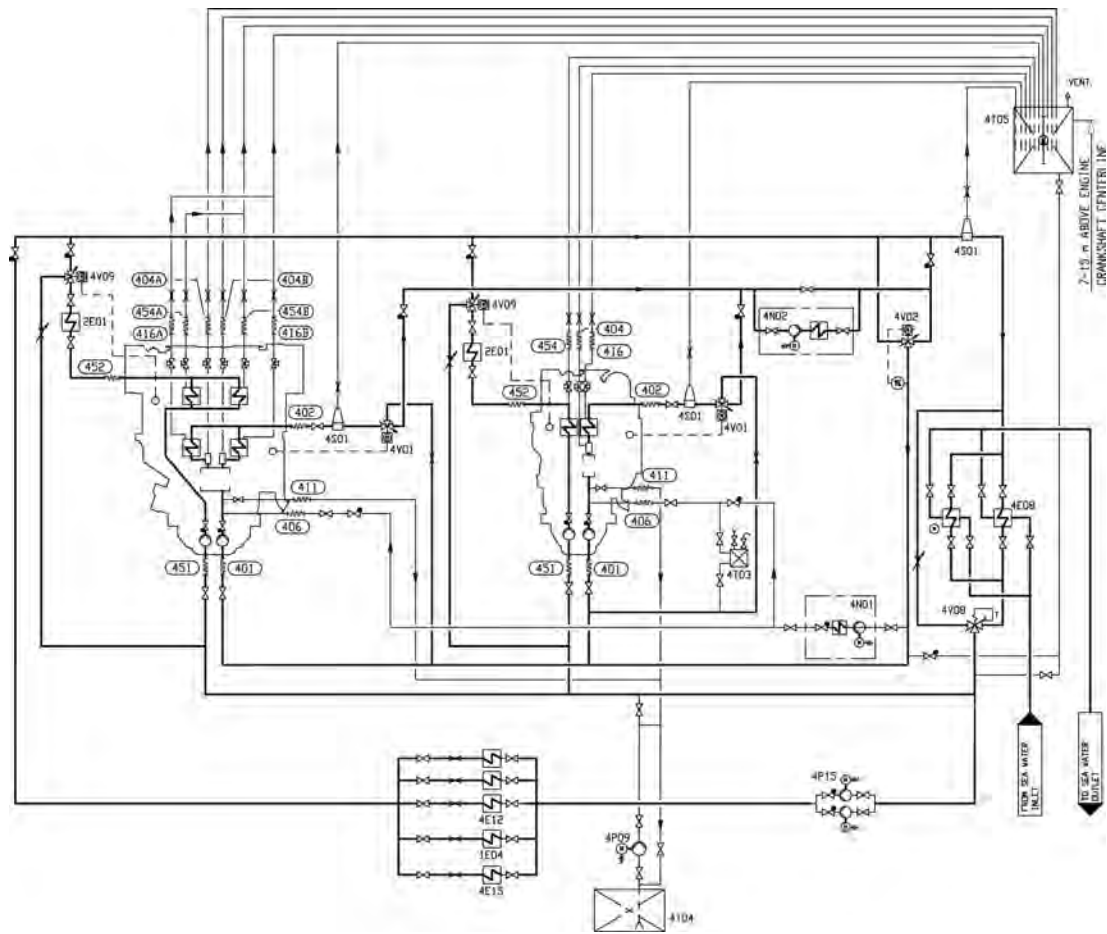


Fig 9-8 Cooling water system, in-line and V-engines in dedicated circuits with built-on pumps, generator cooling and evaporator (DAAF072974)

System components:

1E04	Cooler (MDF return line)	4S01	Air venting
2E01	Lubricating oil cooler	4T03	Additive dosing tank
4E08	Central cooler	4T04	Drain tank
4E12	Cooler (installation parts)	4T05	Expansion tank
4E15	Cooler (generator)	4V01	Temperature control valve (HT)
4N01	Preheating unit	4V02	Temperature control valve (Heat recovery)
4N02	Evaporator unit	4V08	Temperature control valve (LT)
4P09	Transfer pump	4V09	Temperature control valve (charge air)
4P15	Circulating pump		

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

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

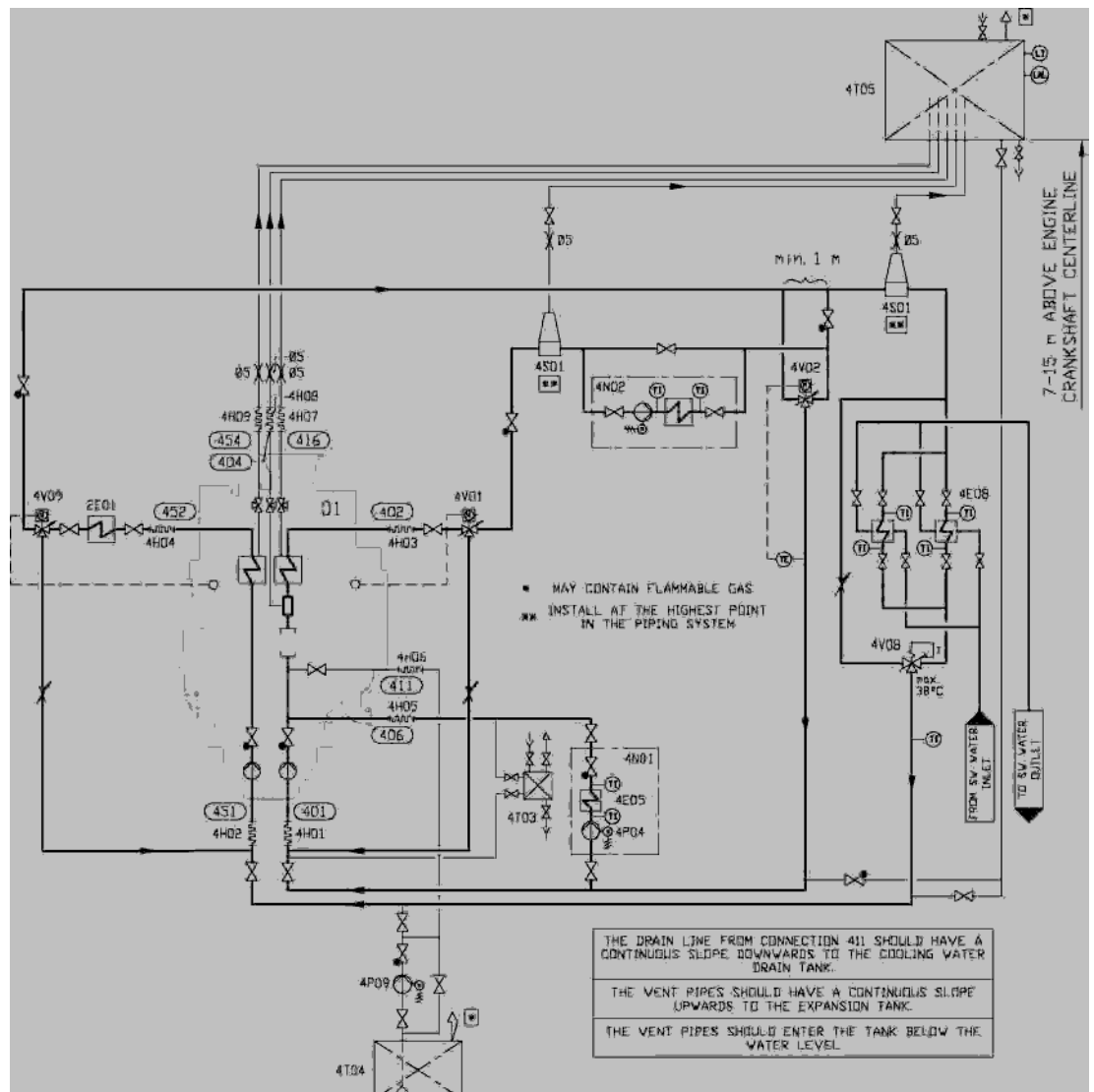


Fig 9-9 Cooling water system, in-line engines with combined LT/HT cooling systems (DAAF333647 A)

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

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

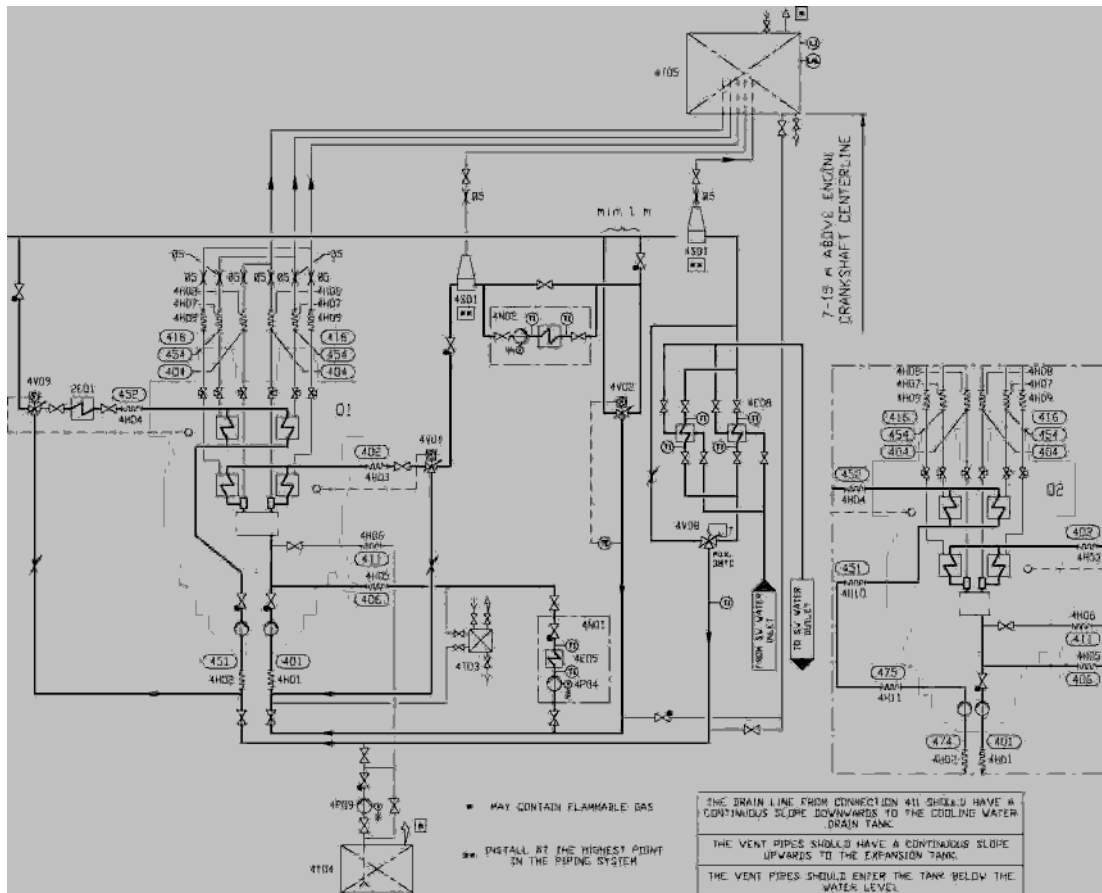


Fig 9-10 Cooling water system, V-engines with combined LT/HT cooling systems (DAAF333651 A)

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

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

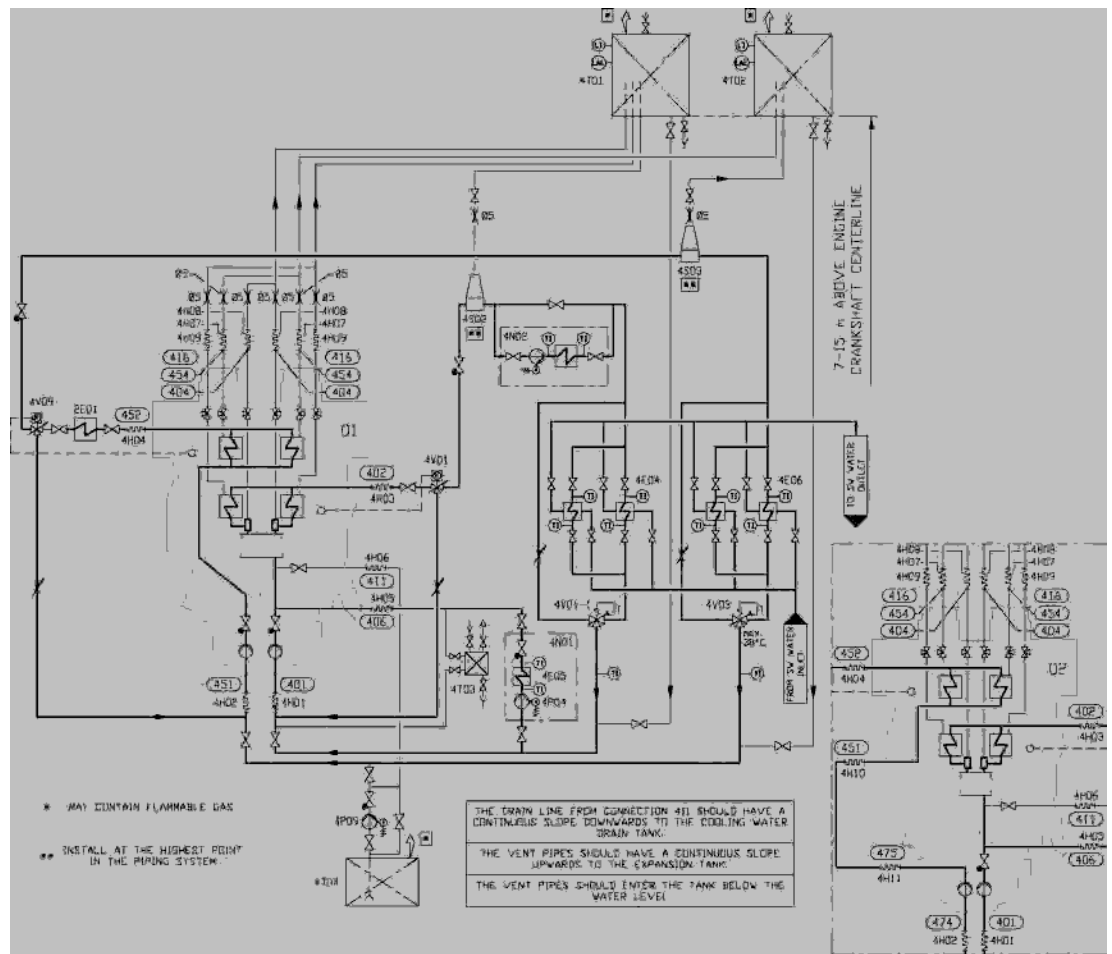


Fig 9-11 Cooling water system, V-engines with separate LT/HT cooling systems (DAAF333806 A)

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

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

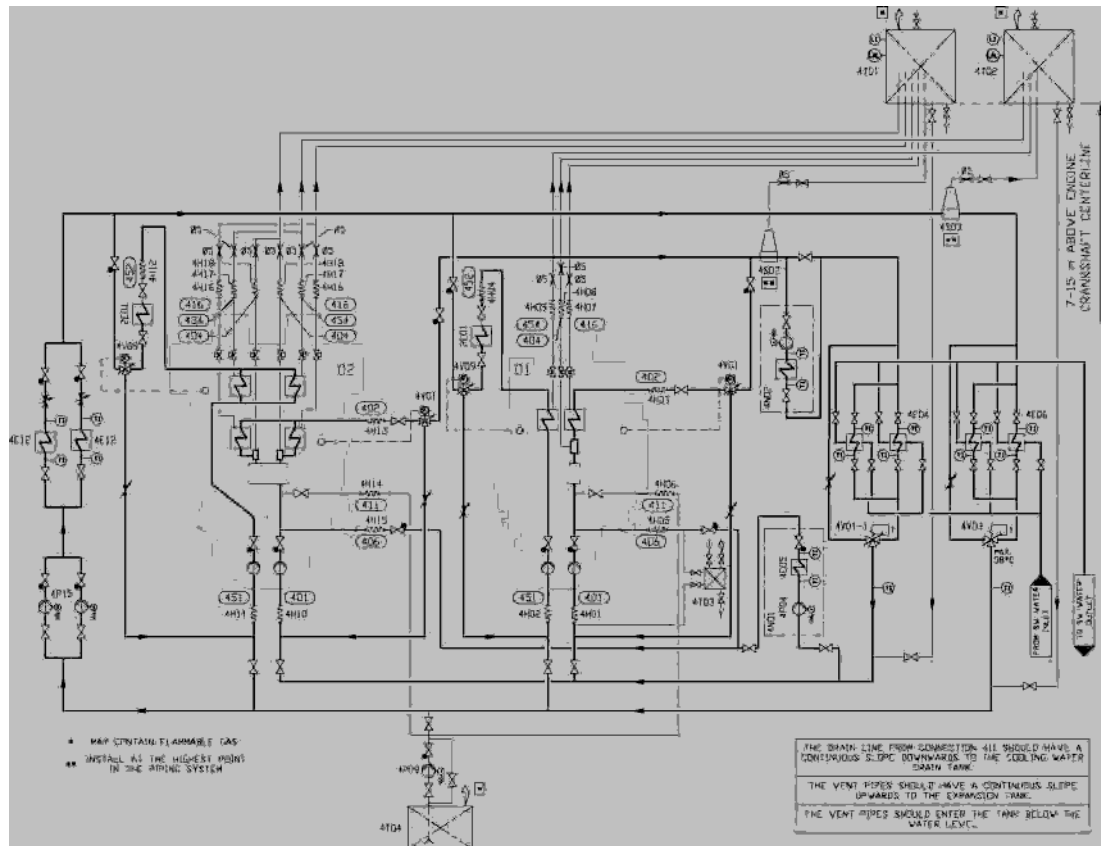


Fig 9-12 Cooling water system, multiple engines with separate LT/HT cooling systems (DAAF333808 A)

System components:

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

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

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

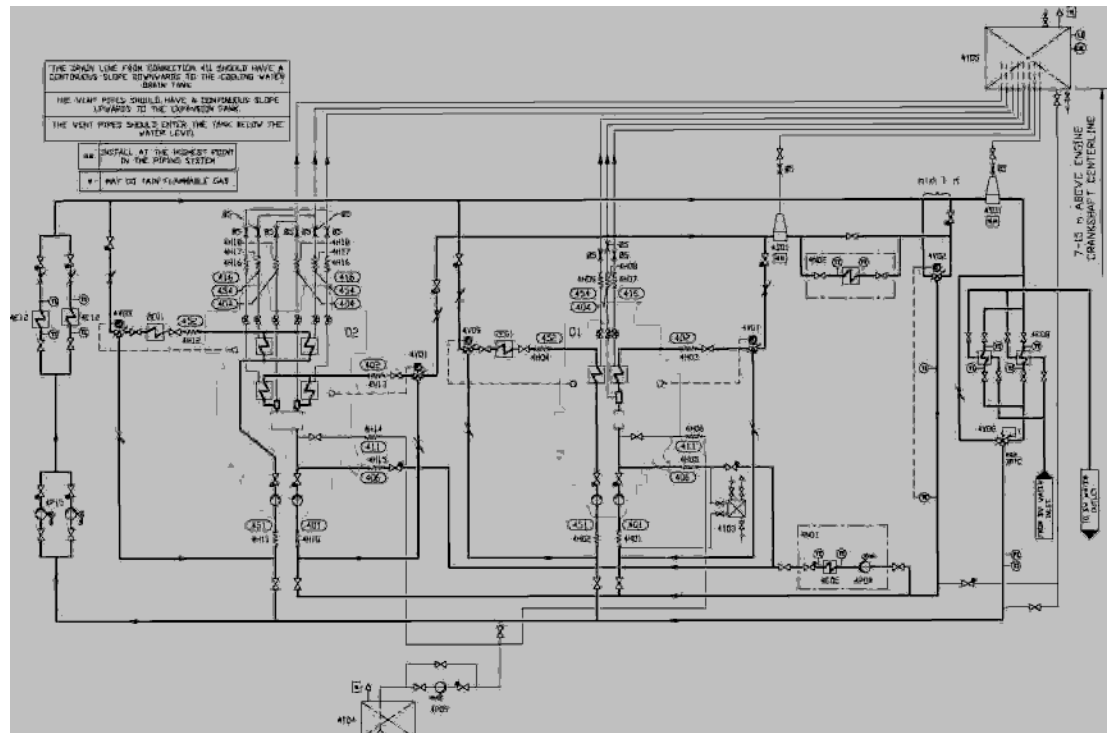


Fig 9-13 Cooling water system, multiple engines with combined LT/HT cooling systems (DAAF333807 A)

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

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

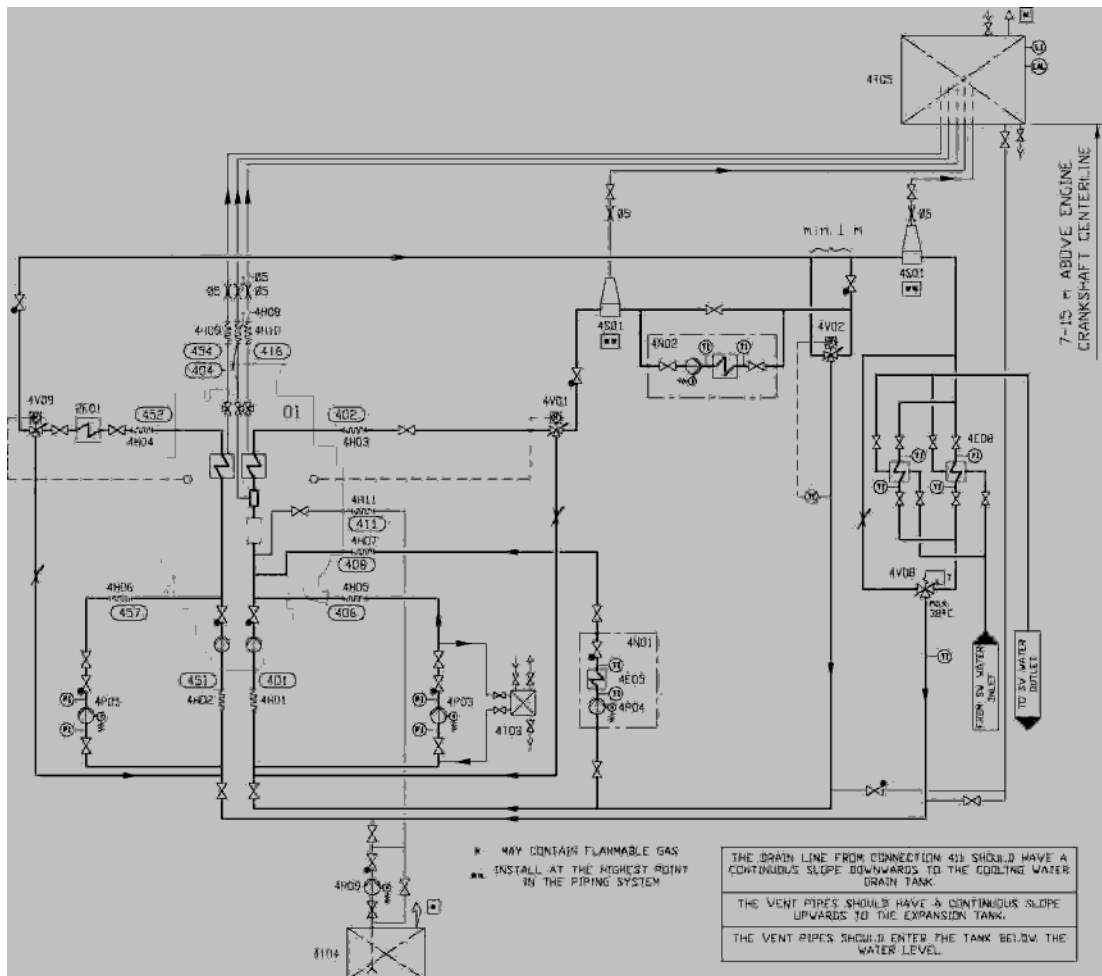


Fig 9-14 Cooling water system for in-line single main engine (DAAF333648 A)

System components:

01	WL50DF	4P09	Transfer pump
2E01	Lube oil cooler	4S01	Air venting
4E05	Heater (preheater)	4T03	Additive dosing tank
4E08	Central cooler	4T04	Drain tank
4H0X	Flexible pipe connections	4T05	Expansion tank
4N01	Preheating unit	4V01	Temperature control valve (HT)
4N02	Evaporator unit	4V02	Temperature control valve (Heat recovery)
4P03	Stand-by pump (HT)	4V08	Temperature control valve (central cooler)
4P04	Circulating pump (preheater)	4V09	Temperature control valve (charge air)
4P05	Stand-by pump (LT)		

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

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

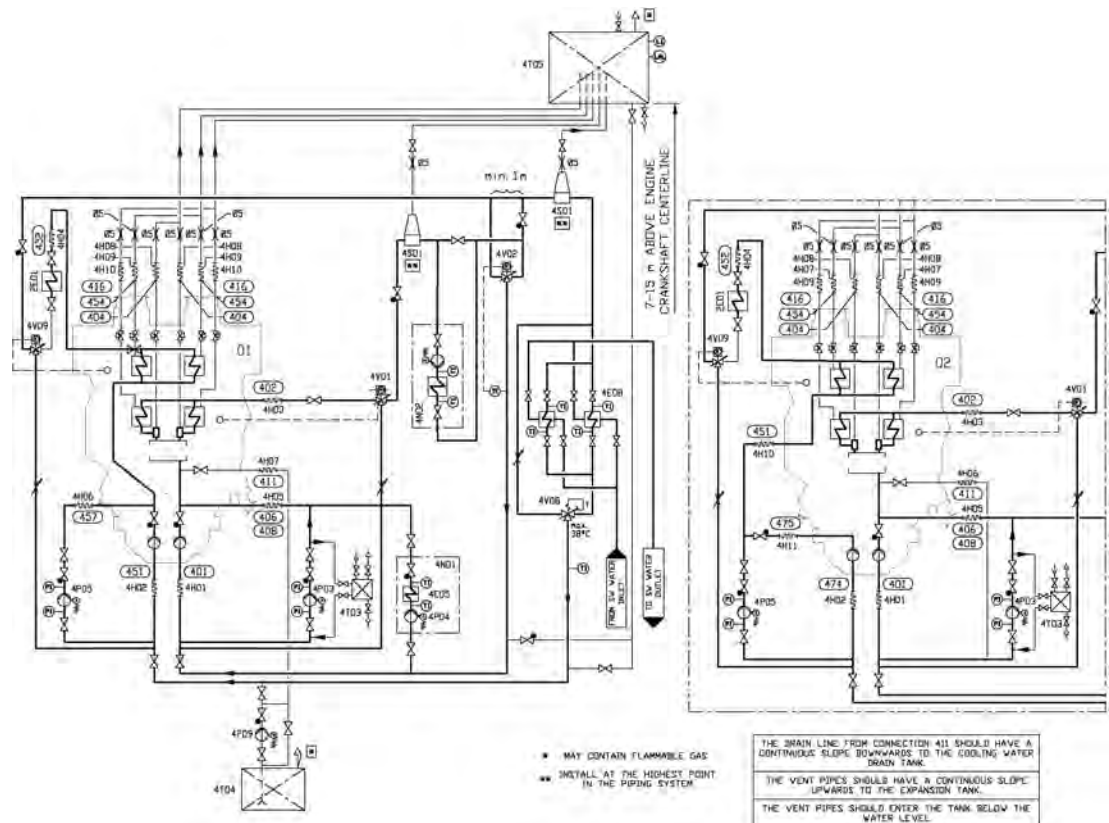


Fig 9-15 Cooling water system for V-engine, single main engine (DAAF333652 A)

System components:			
01	WV50DF TC/FE	4P05	Stand-by pump (LT)
02	WV50DF TC/DE	4P09	Transfer pump
2E01	Lube oil cooler	4S01	Air venting
4E05	Heater (preheater)	4T03	Additive dosing tank
4E08	Central cooler	4T04	Drain tank
4H0X	Flexible pipe connections	4T05	Expansion tank
4N01	Preheating unit	4V01	Temperature control valve (HT)
4N02	Evaporator unit	4V02	Temperature control valve (Heat recovery)
4P03	Stand-by pump (HT)	4V08	Temperature control valve (central cooler)
4P04	Circulating pump (preheater)	4V09	Temperature control valve (charge air)
Pipe connections are listed in section "Internal cooling water system".			

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

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

9.3.10 Sea water pump (4P11)

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

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

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

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

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

Set point +91°C (at 100% load)..+96°C (at 0% oad) - Linear trend

NOTE



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

9.3.12 Temperature control valve for central cooler (4V08)

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

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

9.3.13 Charge air temperature control valve (4V09)

The temperature of the charge air is maintained on desired level with an electrically actuated temperature control valve in the external LT circuit. The control valve regulates the 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.

9.3.14 Temperature control valve for heat recovery (4V02)

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

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

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

9.3.15 Lubricating oil cooler (2E01)

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

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

9.3.16 Coolers for other equipment and MDF coolers

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

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

9.3.17 Fresh water central cooler (4E08)

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

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

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

Design data:

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

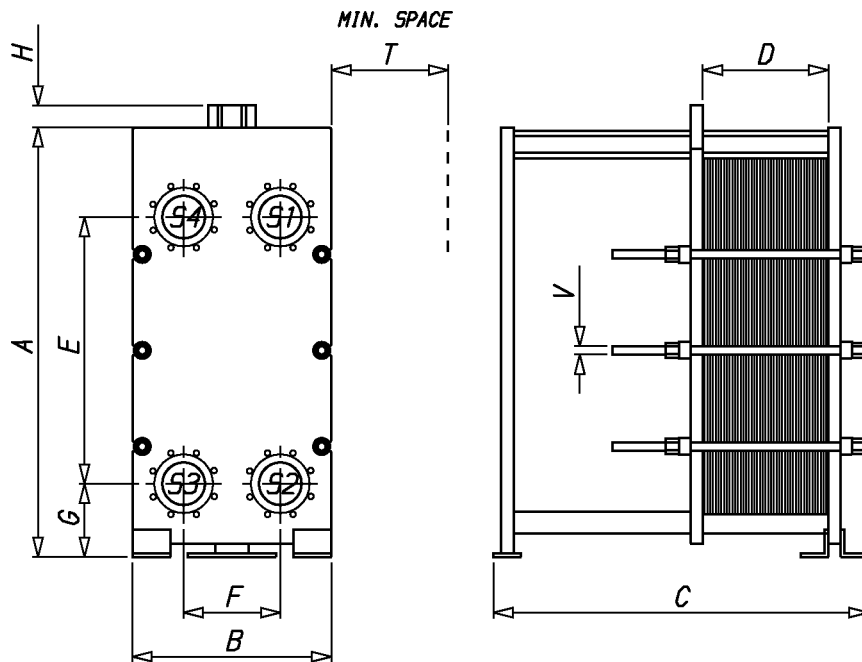


Fig 9-16 Central cooler main dimensions (4V47F0004). Example for guidance only

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

9.3.18 Waste heat recovery

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

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

9.3.19 Air venting

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

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

The vent pipes must be continuously rising.

9.3.19.1 Air separator (4S01)

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

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

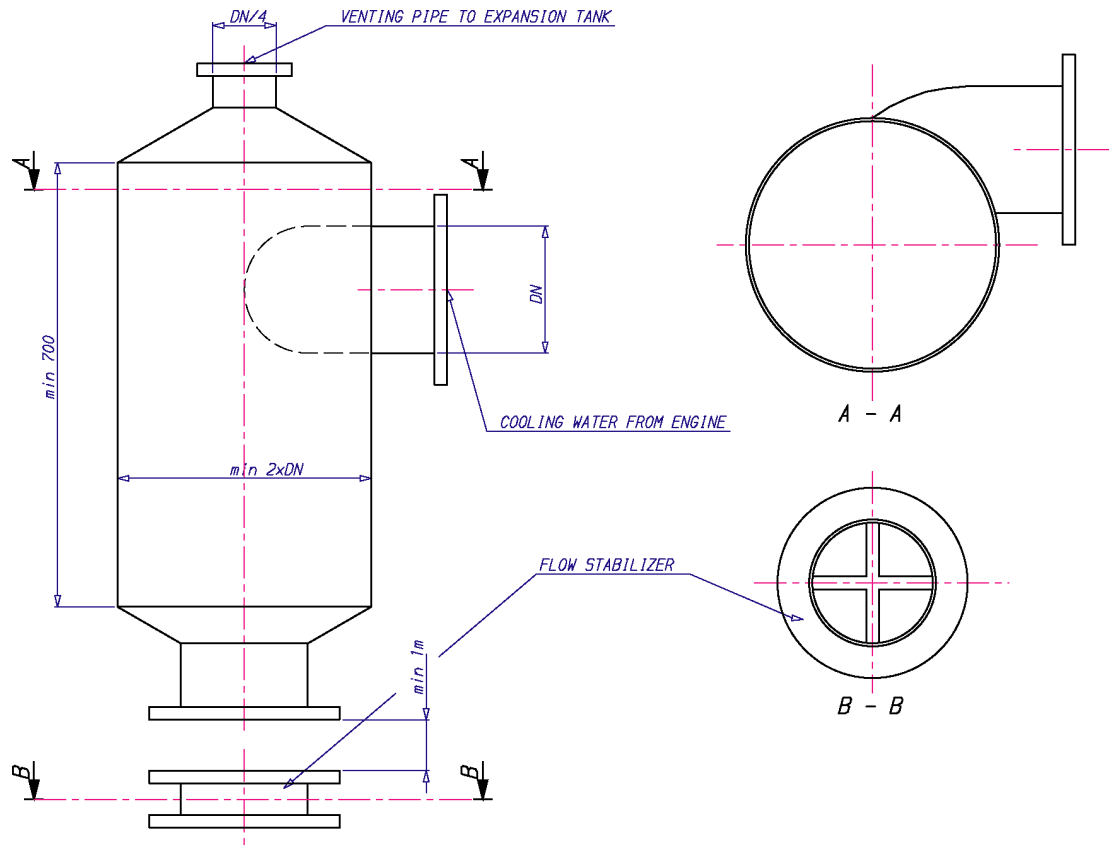


Fig 9-17 Example of air venting device (3V76C4757)

9.3.20 Expansion tank (4T05)

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

Design data:

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

NOTE



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

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

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

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

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

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

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

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

Table 9-1 Minimum diameter of balance pipe

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

9.3.21 Drain tank (4T04)

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

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

9.3.22 Additive dosing tank (4T03)

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

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

9.3.23 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.

9.3.23.1 HT heater (4E05)

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

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

The minimum required heating power is 12 kW/cyl, which makes it possible to warm up the engine from 20 °C to 60...70 °C in 10-15 hours. The required heating power for shorter heating time can be estimated with the formula below. About 6 kW/cyl is required to keep a hot engine warm.

Design data:

Preheating temperature	min. 60°C for starts at LFO 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:

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

where:

P =	Preheater output [kW]
T 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

9.3.23.2 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)

9.3.23.3 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

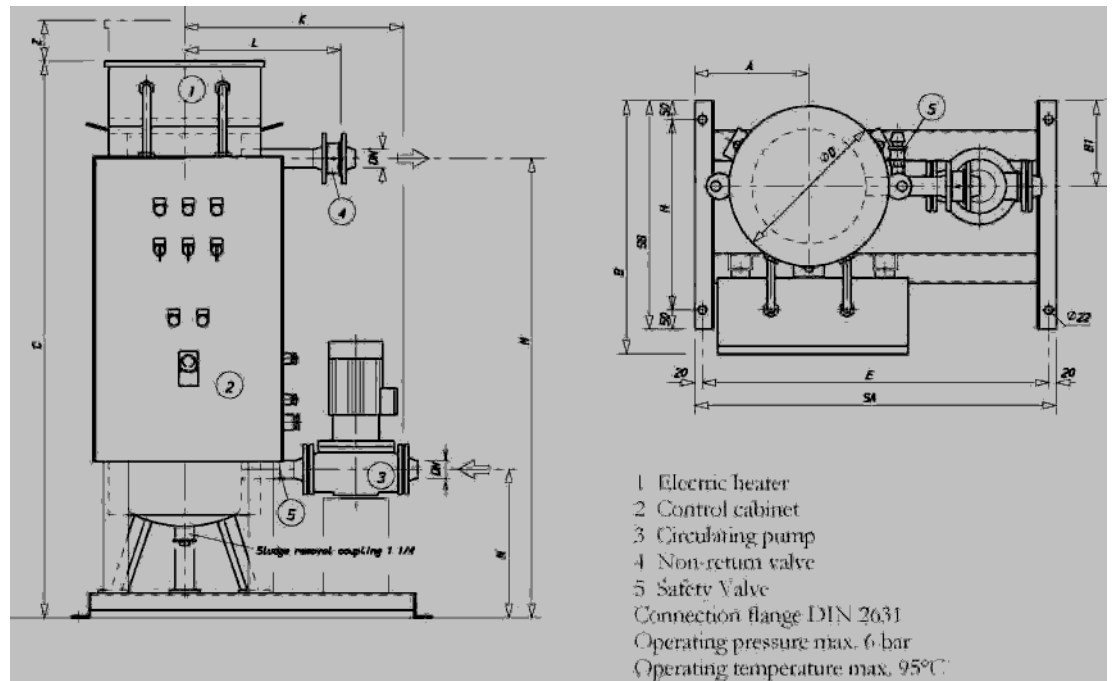


Fig 9-18 Example of preheating unit, electric (4V47K0045)

Table 9-2 Example of preheating unit

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

All dimensions are in mm

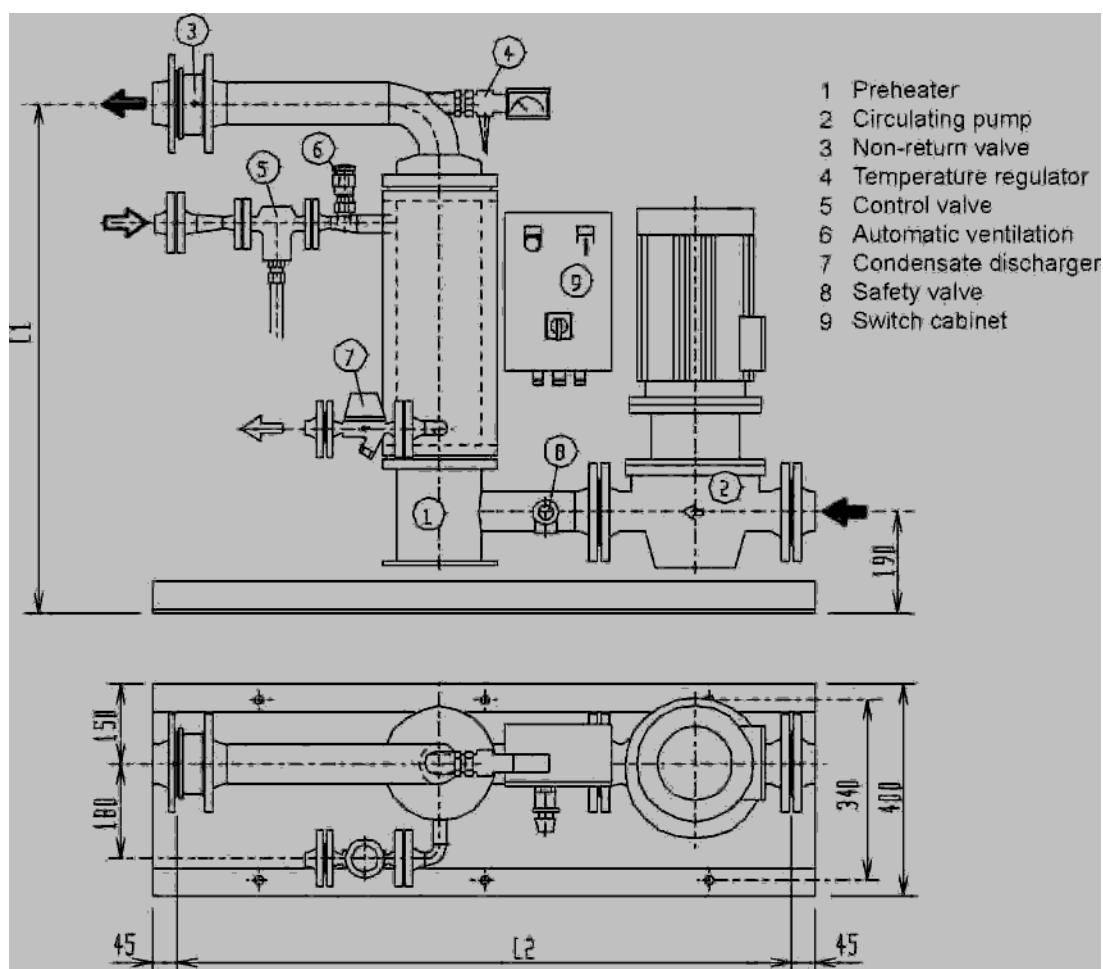


Fig 9-19 Example of preheating unit, steam

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

9.3.24

Throttles

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

9.3.25 Thermometers and pressure gauges

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

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

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10. Combustion Air System

10.1 Engine room ventilation

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

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

The amount of air required for ventilation is calculated from the total heat emission 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 heating of the supply air must be arranged. This can be arranged by combustion air heating (externally in air ducting) or by utilizing the engine built charge air cooler (including external CW system and preheater) as combustion air heater. During start, idling and low load operations, the combustion air to be drawn from the engine room in order to secure correct air temperature. After start either the ventilation air supply, or the combustion air supply, or both in combination must be able to maintain the minimum required combustion air temperature and flow. The air supply from the combustion air fan is to be directed away from the engine, when the intake air is cold, so that the air is allowed to heat up in the engine room.

10.2.1 Condensation in charge air coolers

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

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

Example, according to the diagram:

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

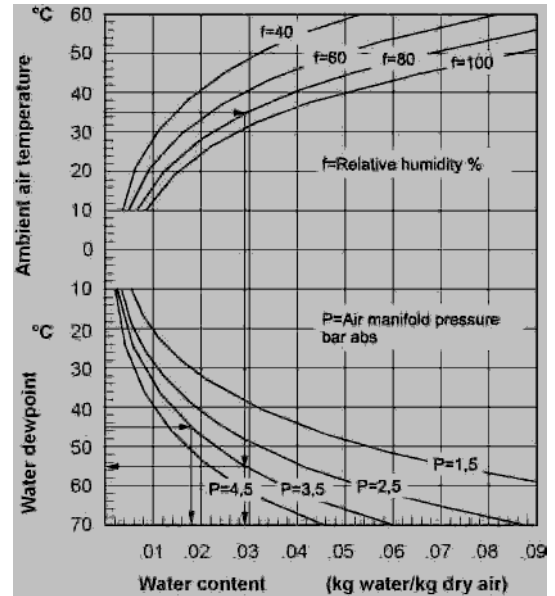


Fig 10-1 Condensation in charge air coolers

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11. Exhaust Gas System

11.1 Internal exhaust gas system

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

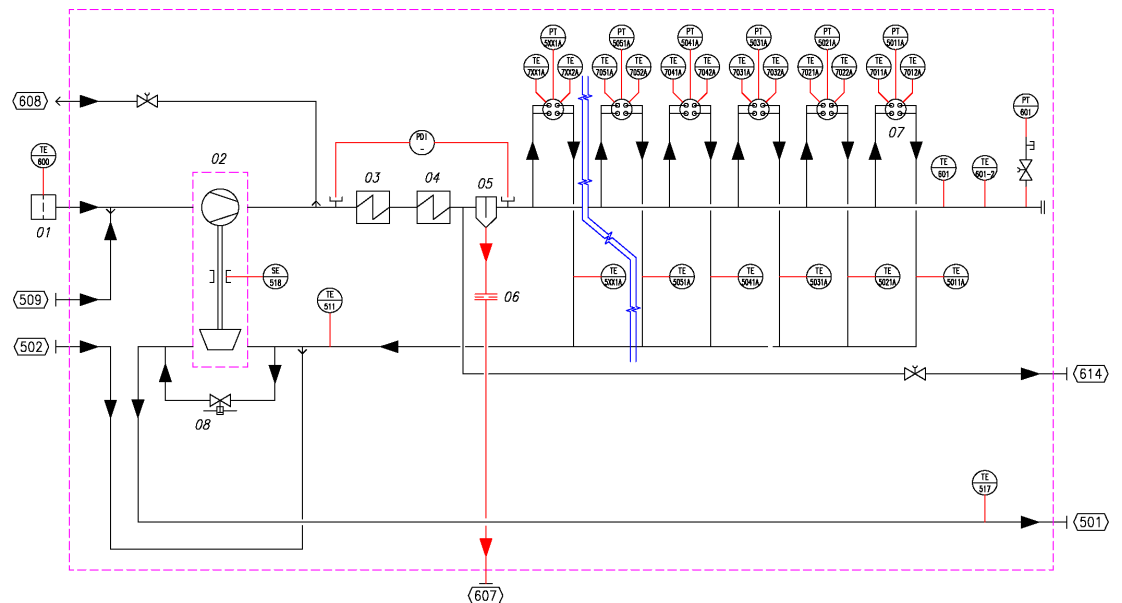


Fig 11-1 Internal combustion air and exhaust gas system, in-line engines (DAAF425039)

System components:					
01	Air filter	04	Charge air cooler (LT)	07	Cylinder and valve
02	Turbocharger	05	Water mist catcher	08	Wastegate valve
03	Charge air cooler (HT)	06	Orifice		

Sensors and indicators:			
TE5011A..	Exhaust gas temperature after each cylinder	TE600	Air temperature, turbocharger inlet
TE7011A.. TE7012A..	Cylinder liner temperature	TE601	Charge air temperature, turbocharger inlet
TE511	Exhaust gas temperature before turbine	TE601-2	Charge air temp (LT-water control), engine inlet (LT-water control)
TE517	Exhaust gas temperature after turbine	PDI	Pressure difference indic. (over CAC, portable)
SE518	Turbine speed	PT5011A	Cylinder pressure transmitters
PT601	Charge air pressure, engine inlet		

Pipe connections		Size	Pressure class	Standard
501	Exhaust gas outlet	see section " <i>Exhaust gas outlet</i> "		
502	Cleaning water to turbine	DN32	PN40	ISO 7005-1
509	Cleaning water to compressor	OD18		DIN 2353
607	Condensate after air cooler	OD28		DIN 2353
608	Cleaning water to charge air cooler (quick coupling)	OD10		DIN 2353

Pipe connections	Size	Pressure class	Standard
614 Scavenging air outlet to TC cleaning valve unit	OD18		DIN 2353

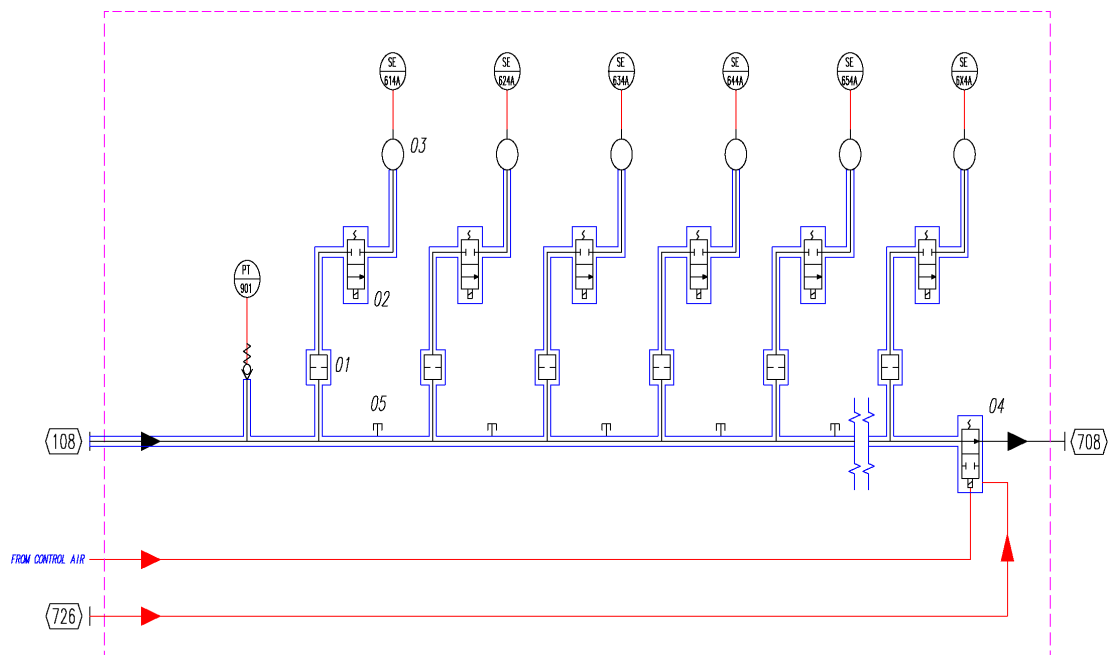


Fig 11-2 Gas system double wall (DAAF425042)

System components:

01	Safety filter	04	Venting valve
02	Gas admission valve	05	Sniffer probe connection
03	Cylinder		

Sensors and indicators:

SE614A..	Knock sensor
PT901	Main gas pressure

Pipe connections

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

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

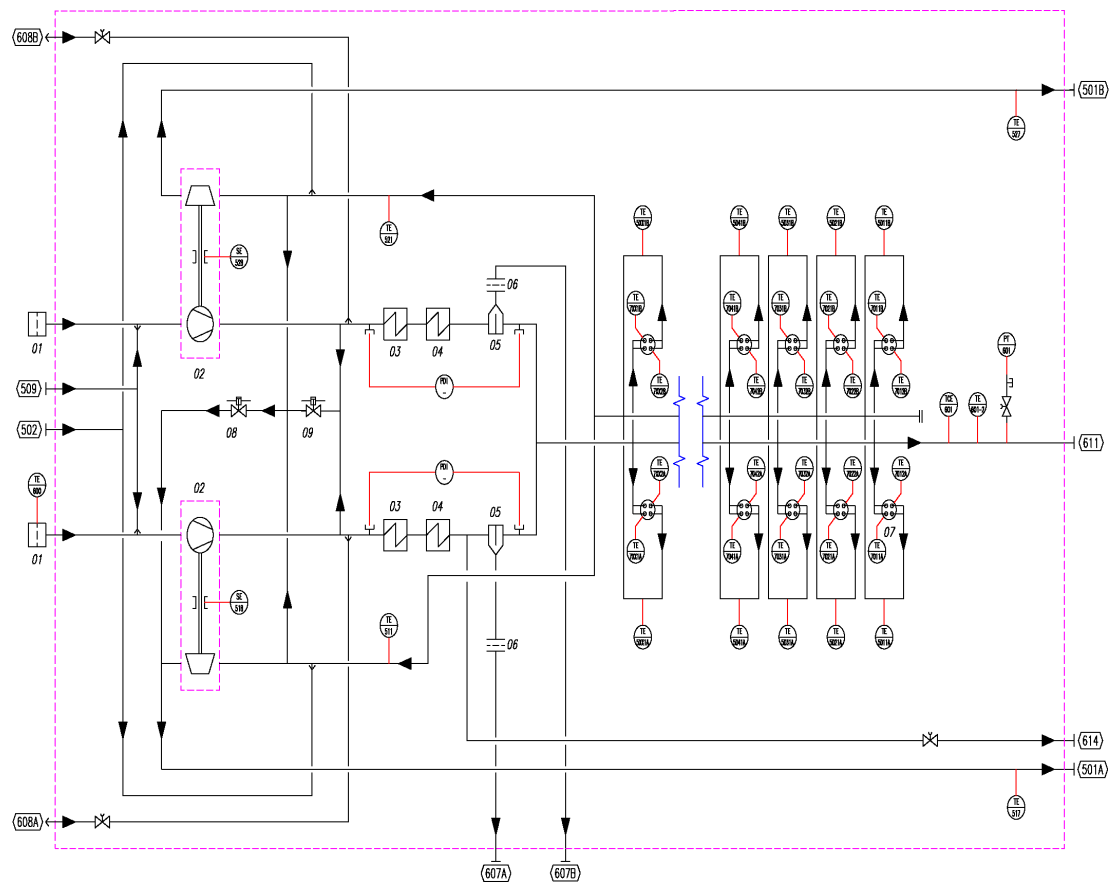


Fig 11-3 Internal combustion air and exhaust gas system, V-engines (DAAF425133)

System components:					
01	Air filter	04	Charge air cooler (LT)	07	Cylinder and valve
02	Turbocharger	05	Water mist catcher	08	Wastegate valve

Sensors and indicators					
TE5011A/B	Exhaust gas temperature after each cylinder	PT601	CAC pressure, engine inlet		
TE7011A/B	Cylinder liner temperature	TE600	Air temperature, turbocharger inlet		
TE7012A/B	Cylinder liner temperature	TE601	Charge air temperature, engine inlet		
TE511	Exhaust gas temp TC A-bank inlet	TE601-2	Charge air temperature for LT control, engine inlet		
TE521	Exhaust gas temp TC B-bank inlet	PDI	Pressure difference indic. (over CAC, portable)		
TE517	Exhaust gas temp TC A-bank outlet				
TE527	Exhaust gas temp TC B-bank outlet				
SE518	Turbine speed, A-bank				
SE528	Turbine speed, B-bank				

Pipe connections		Size	Pressure class	Standard
501A/B	Exhaust gas outlet	see section Exhaust gas outlet		
502	Cleaning water to turbine	DN32	PN40	ISO 7005-1
509	Cleaning water to compressor	OD18		DIN 2353

Pipe connections		Size	Pressure class	Standard
607A/B	Condensate after air cooler	12, 16V: OD28		DIN 2353
608A/B	Cleaning water to charge air cooler (quick coupling)	OD10		DIN 2353
611	Charge air wastegate outlet			
614	Scavenging air outlet to TC cleaning valve unit (if ABB TC)	OD18		DIN 2353
Z	Air to charge air receiver			

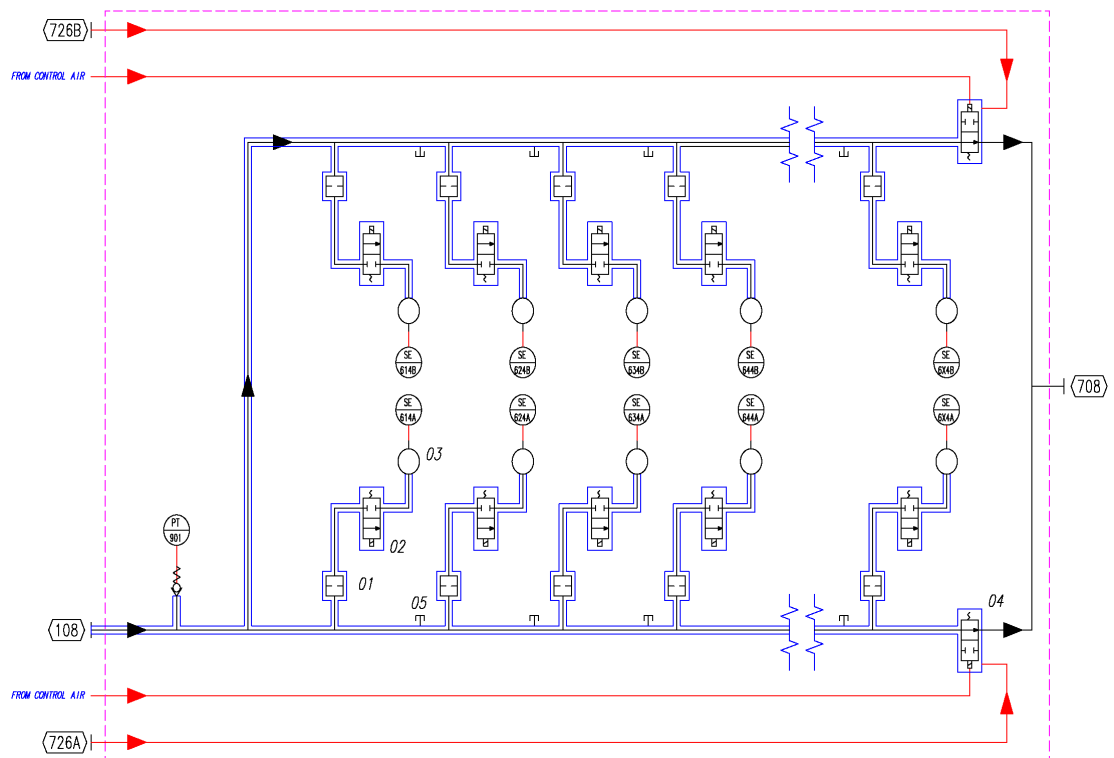


Fig 11-4 Gas system double wall (DAAF425134)

System components:

01	Safety filter	04	Venting valve
02	Gas admission valve	05	Sniffer probe predisposition
03	Cylinder		

Sensors and indicators:

SE614A/B	Knock sensor
PT901	Main gas pressure

Pipe connections

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

11.2 Exhaust gas outlet

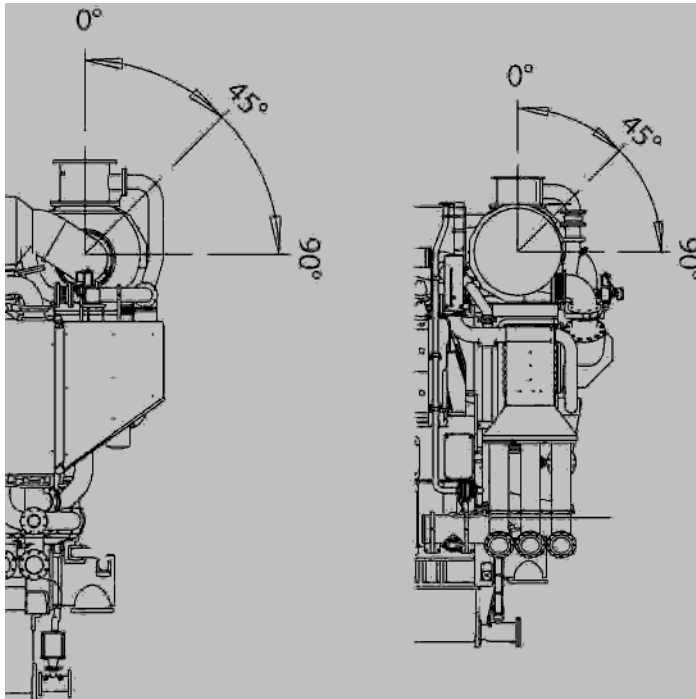


Fig 11-5 Exhaust pipe connection, (4V58F0057d, -58d)

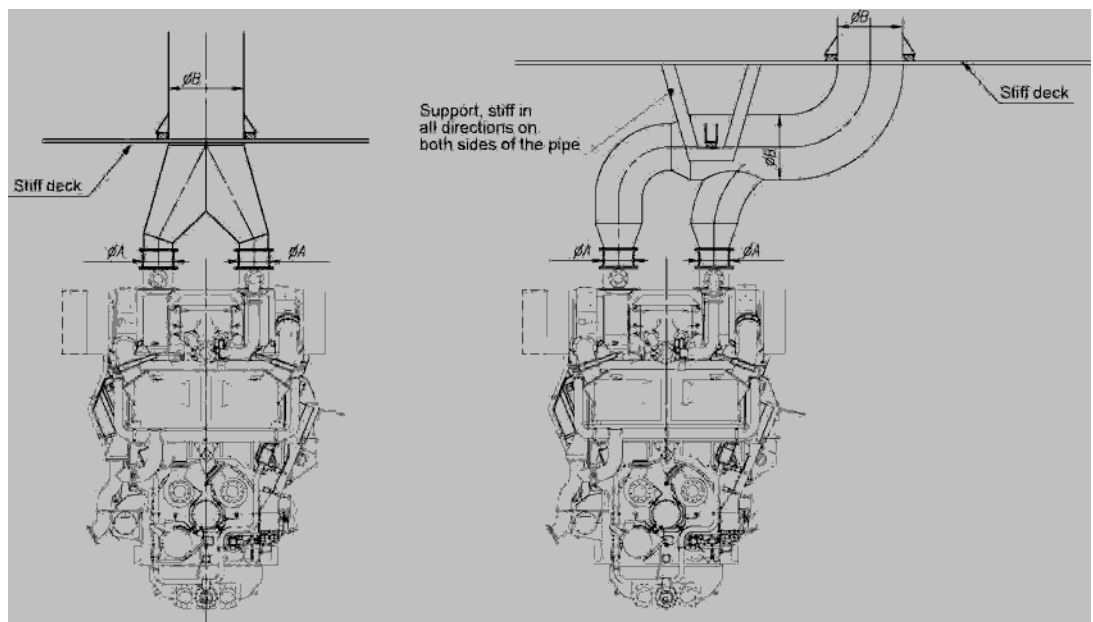
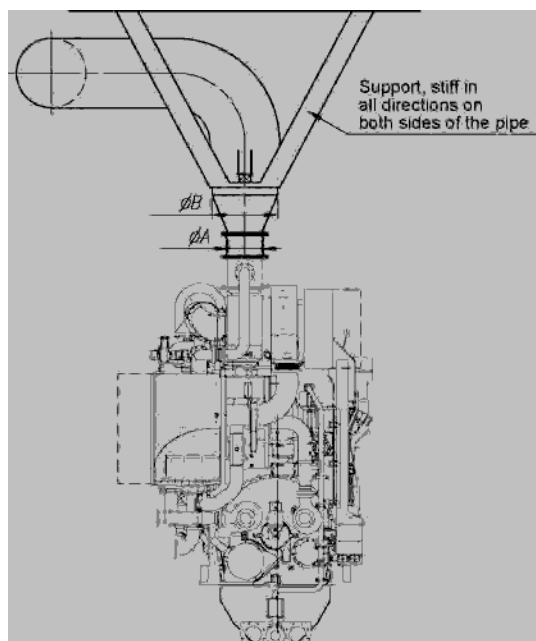


Fig 11-6 Exhaust pipe, diameters and support



Engine type	TC type	A [mm]	B [mm]
W 6L50DF	TPL71	DN600	900
W 8L50DF	TPL76C	DN800	1000
W 9L50DF	TPL76	DN800	1000
W 12V50DF	TPL71	DN600	1200
W 16V50DF	TPL76	DN800	1400

Fig 11-7 Exhaust pipe, diameters and support

11.3 External exhaust gas system

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

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

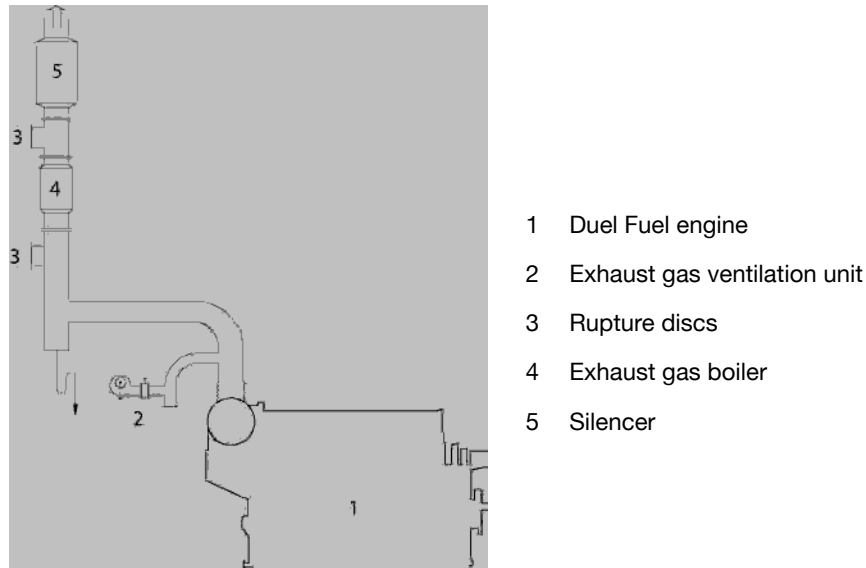


Fig 11-8 External exhaust gas system

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.

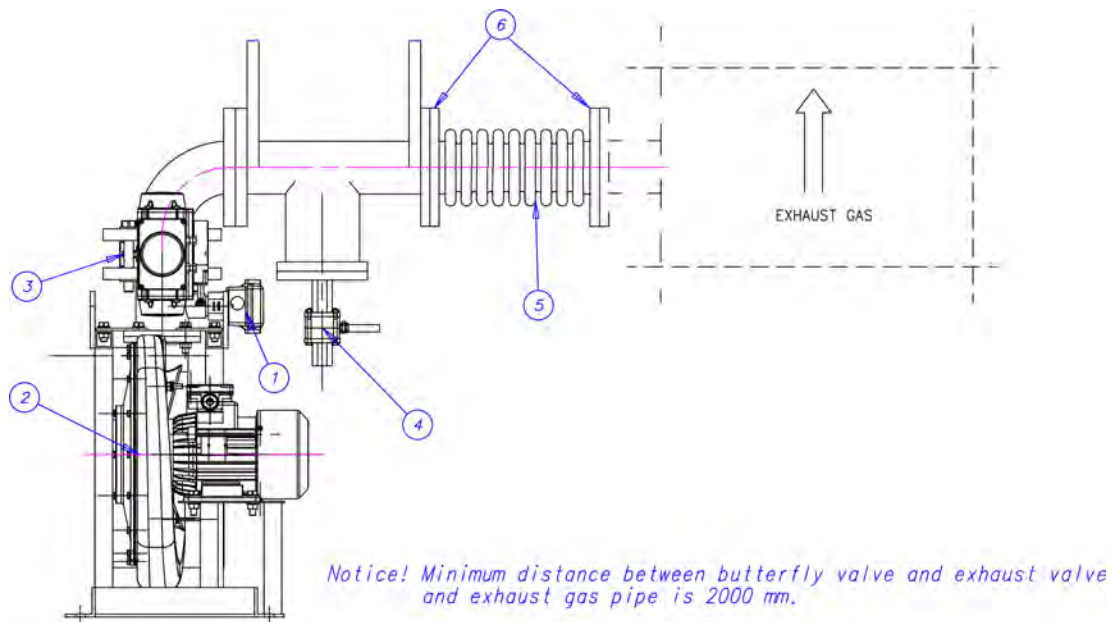


Fig 11-9 Exhaust gas ventilation arrangement (DAAF315146A)

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 $1.5 \times D$.

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

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

where:

v = gas velocity [m/s]

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

T = exhaust gas temperature [°C]

D = exhaust gas pipe diameter [m]

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

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

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

11.3.5 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).

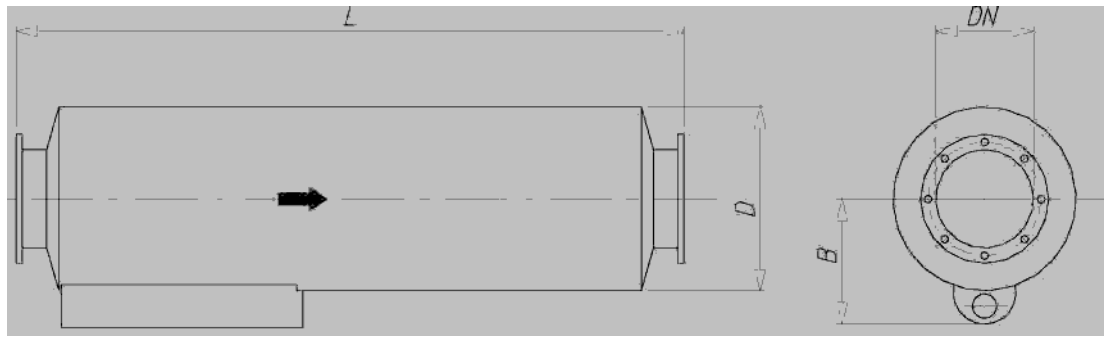


Fig 11-10 Exhaust gas silencer (4V49E0156A)

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

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

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12. Turbocharger Cleaning

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

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

12.1 ABB turbochargers

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

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

Water supply:

Fresh water

Pressure 0.4...0.8 MPa (4...8 bar)

Max. temperature 40 °C

Flow, in-line engines 22...34 l/min

Flow, V-engines 44...68 l/min

Washing time ~10 minutes per engine.

Air supply:

Pressure 0.4...0.8 MPa (4...8 bar)

Max. temperature 55 °C

Flow, in-line engines 0.3...0.5 kg/min

Flow, V-engines 0.6...1.0 kg/min

Air consumption only below 25% engine load.

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

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

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

12.2 Turbocharger cleaning system

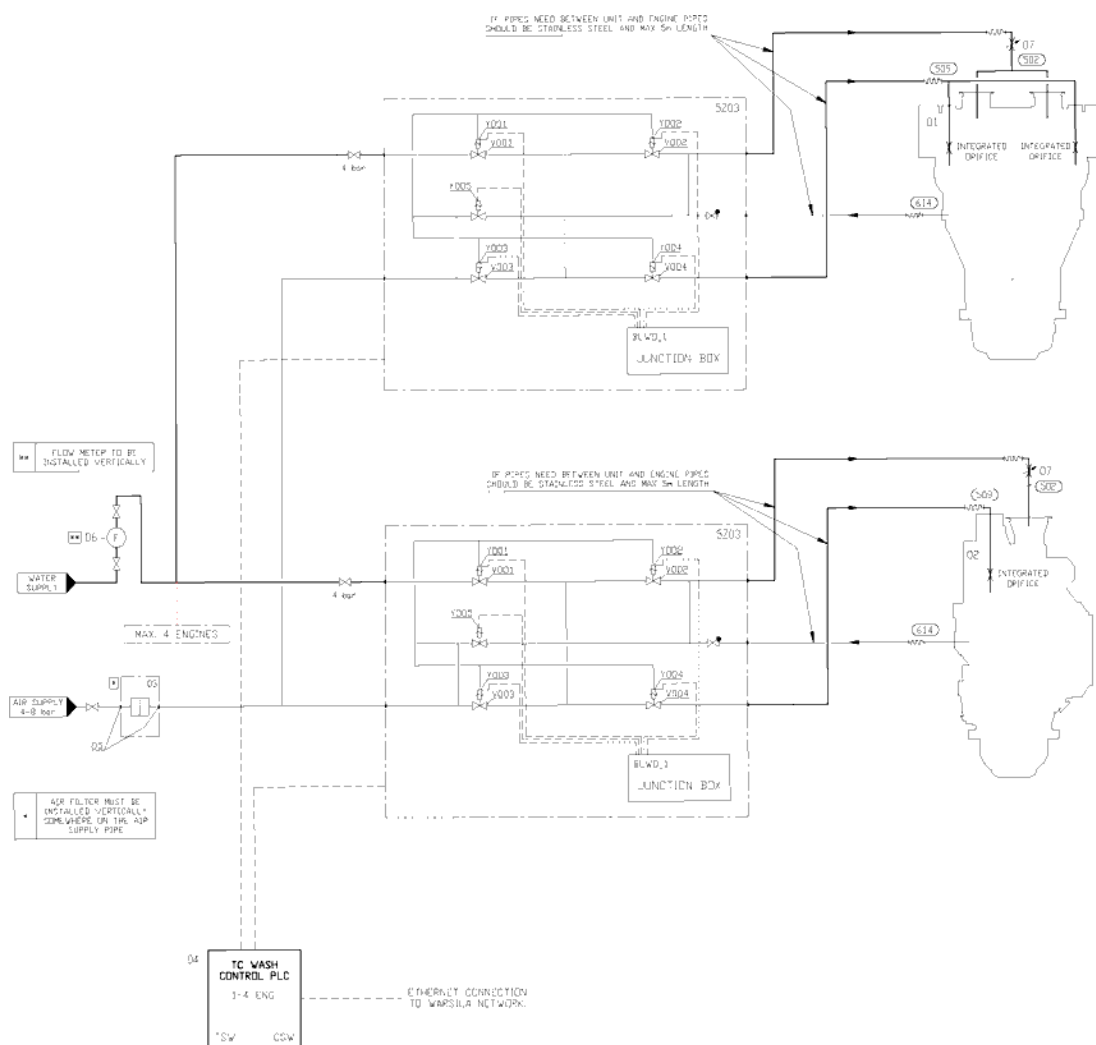


Fig 12-1 Turbocharger cleaning system (DAAF346215A)

System components:

5Z03	TC cleaning device
03	Air filter
04	TC wash control unit
05	Male stud GR18LR71
06	Flow meter/control

System components:	
07	Constant flow valve



Fig 12-2 Turbocharger cleaning device (DAAF065261C)

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

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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 (SO_x) and nitrogen oxides (NO_x), partially reacted and non-combusted hydrocarbons and particulates.

13.1 Dual fuel engine exhaust components

Due to the high efficiency and the clean fuel used in a dual fuel engine in gas mode, the exhaust gas emissions when running on gas are extremely low. In a dual fuel engine, the air-fuel ratio is very high, and uniform throughout the cylinders. Maximum temperatures and subsequent NO_x formation are therefore low, since the same specific heat quantity released to combustion is used to heat up a large mass of air. Benefitting from this unique feature of the lean-burn principle, the NO_x 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 SO_x from the dual fuel engine are negligible. When the engine is in diesel operating mode, the emissions are in the same range as for any ordinary diesel engine, and the engine will be delivered with an EIAPP certificate to show compliance with the MARPOL Annex VI.

13.2 Marine exhaust emissions legislation

13.2.1 International Maritime Organization (IMO)

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

The IMO Tier 3 NO_x 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 NO_x requirements.

13.2.2 Other Legislations

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

13.3 Methods to reduce exhaust emissions

All standard Wärtsilä engines meet the NO_x emission level set by the IMO (International Maritime Organisation) and most of the local emission levels without any modifications. Wärtsilä has also developed solutions to significantly reduce NO_x 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 modular embedded automation system. UNIC C3 is used for engines with electronically controlled fuel injection and has a hardwired interface for control functions and a bus communication interface for alarm and monitoring.

14.1 UNIC C3

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

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

The CAN-bus and the power supply to each module are both physically doubled on the engine for full redundancy.

Control signals to/from external systems are hardwired to the terminals in the main cabinet on the engine. Process data for alarm and monitoring are communicated over a Modbus TCP connection to external systems.

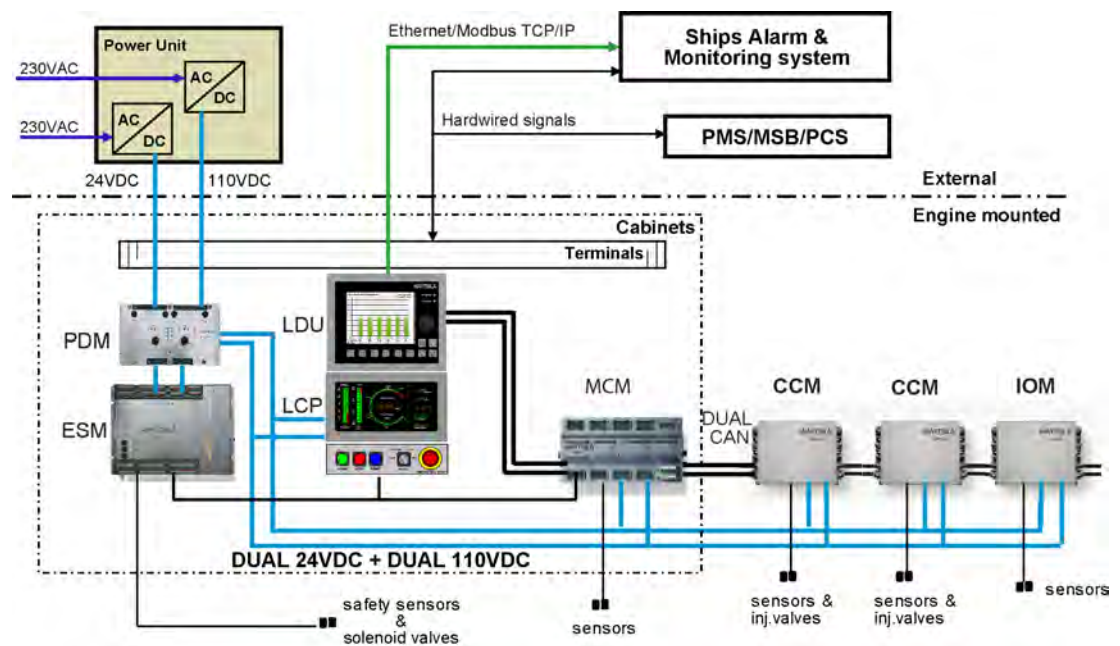


Fig 14-1 Architecture of UNIC C3

Short explanation of the modules used in the system:

- | | |
|------------|---|
| MCM | Main Control Module. Handles all strategic control functions (such as start/stop sequencing and speed/load control) of the engine. |
| ESM | Engine Safety Module handles fundamental engine safety, for example shutdown due to overspeed or low lubricating oil pressure. |
| LCP | Local Control Panel is equipped with push buttons and switches for local engine control, as well as indication of running hours and safety-critical operating parameters. |

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

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

14.1.1 Local control panel and local display unit

Operational functions available at the LCP:

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

Local mode selector switch with the following positions:

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

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

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

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

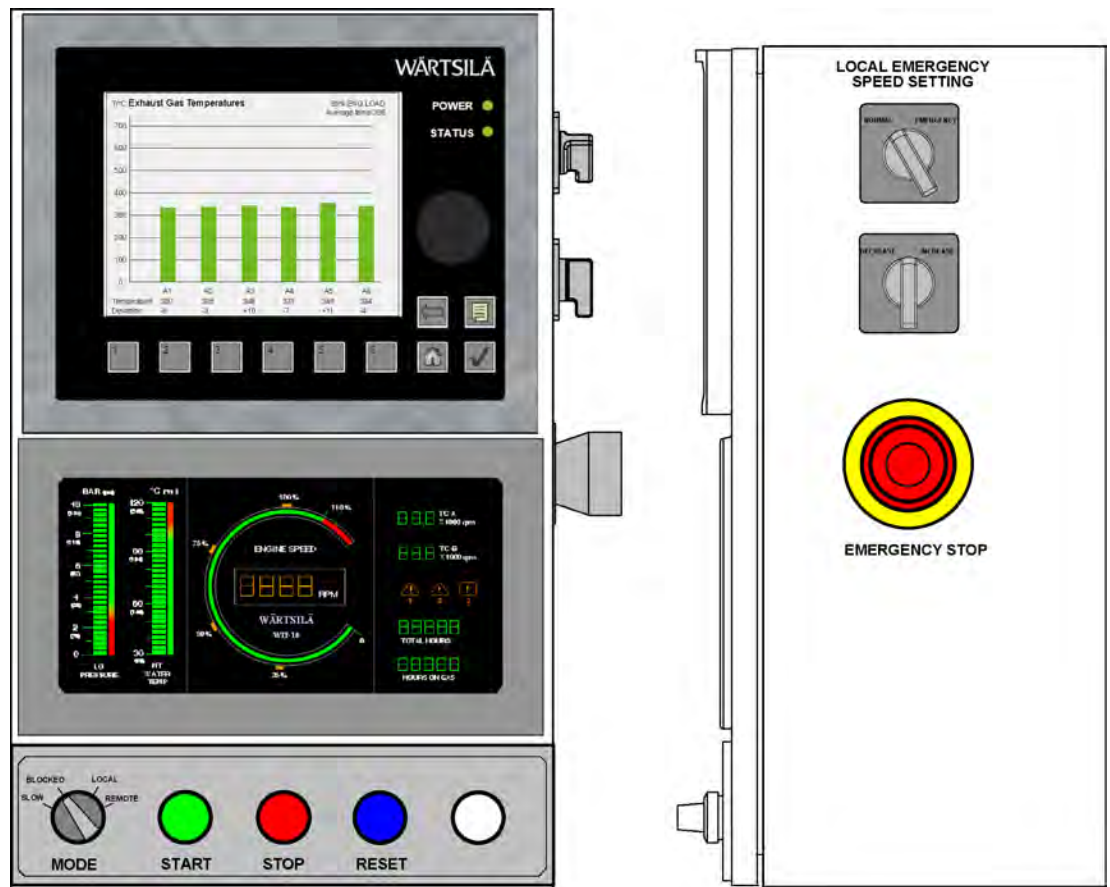


Fig 14-2 Local control panel and local display unit

14.1.2 Engine safety system

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

Main features:

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

14.1.3 Power unit

A power unit is delivered with each engine. The power unit supplies DC power to the automation system on the engine and provides isolation from other DC systems onboard. The cabinet is designed for bulkhead mounting, protection degree IP44, max. ambient temperature 50°C.

The power unit contains redundant power converters, each converter dimensioned for 100% load. At least one of the two incoming supplies must be connected to a UPS. The power unit supplies the equipment on the engine with 2 x 24 VDC and 2 x 110 VDC.

Power supply from ship's system:

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

14.1.4 Cabling and system overview

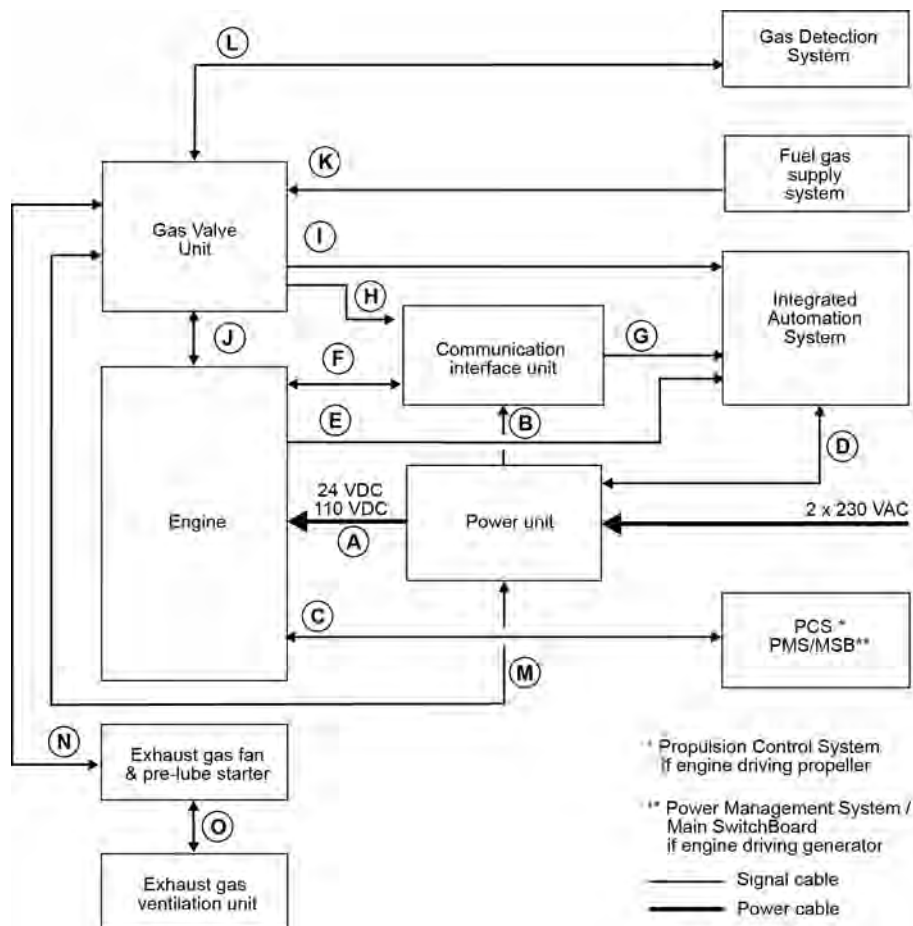


Fig 14-3 UNIC C3 overview

Table 14-1 Typical amount of cables

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

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

NOTE



Cable types and grouping of signals in different cables will differ depending on installation.

* Dimension of the power supply cables depends on the cable length.

Power supply requirements are specified in section *Power unit*.

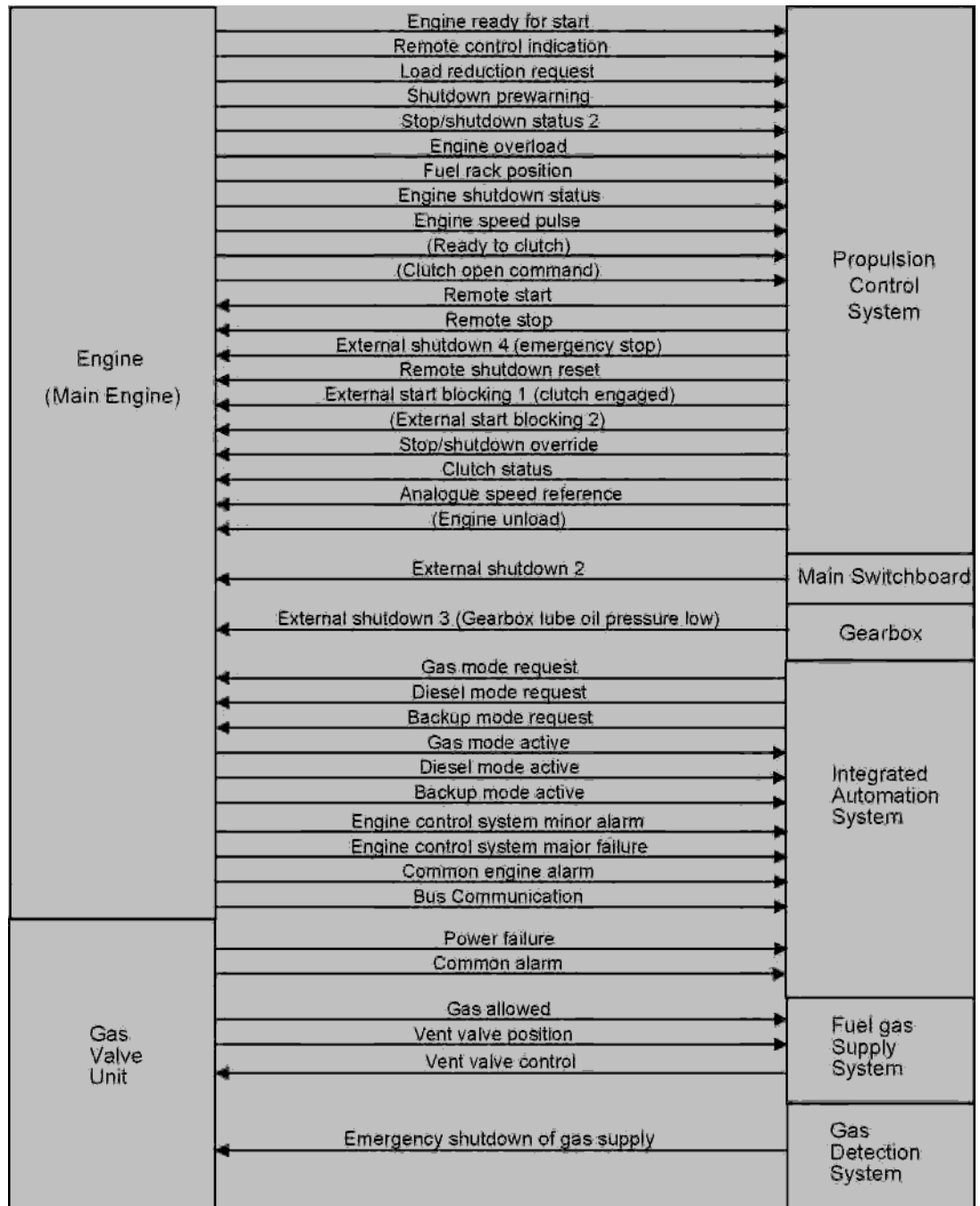


Fig 14-4 Signal overview (Main engine)

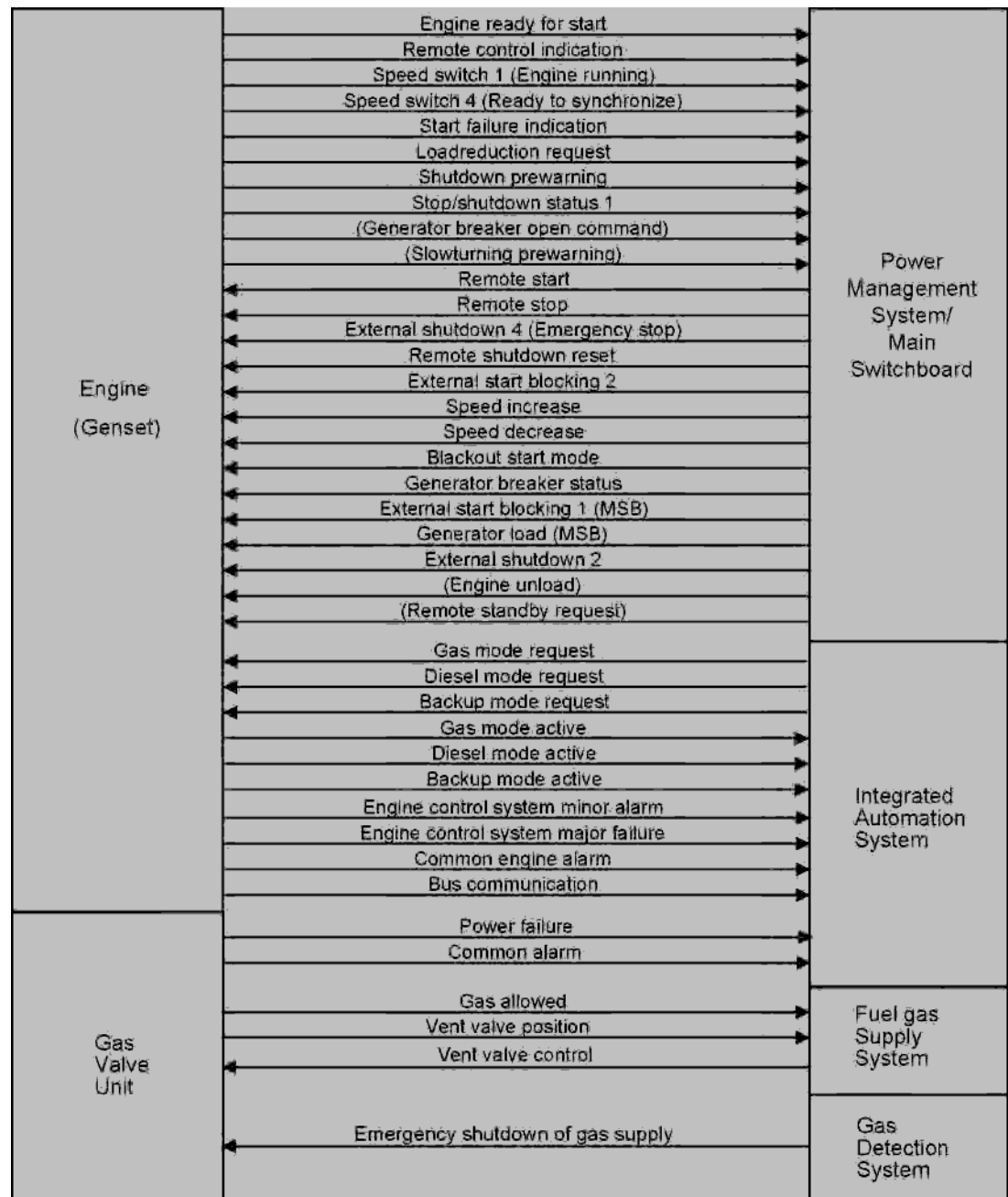


Fig 14-5 Signal overview (Generating set)

14.2 Function

14.2.1 Engine operating modes

The operator can select four different fuel operating modes:

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

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

It is possible to transfer a running engine from gas- into diesel operating mode. Below a certain load limit the engine can be transferred from diesel- into gas operating mode. The engine will

automatically trip from gas- into diesel operating mode (gas trip) in several alarm situations. Request for diesel operating mode will always override request for gas operating mode.

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

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

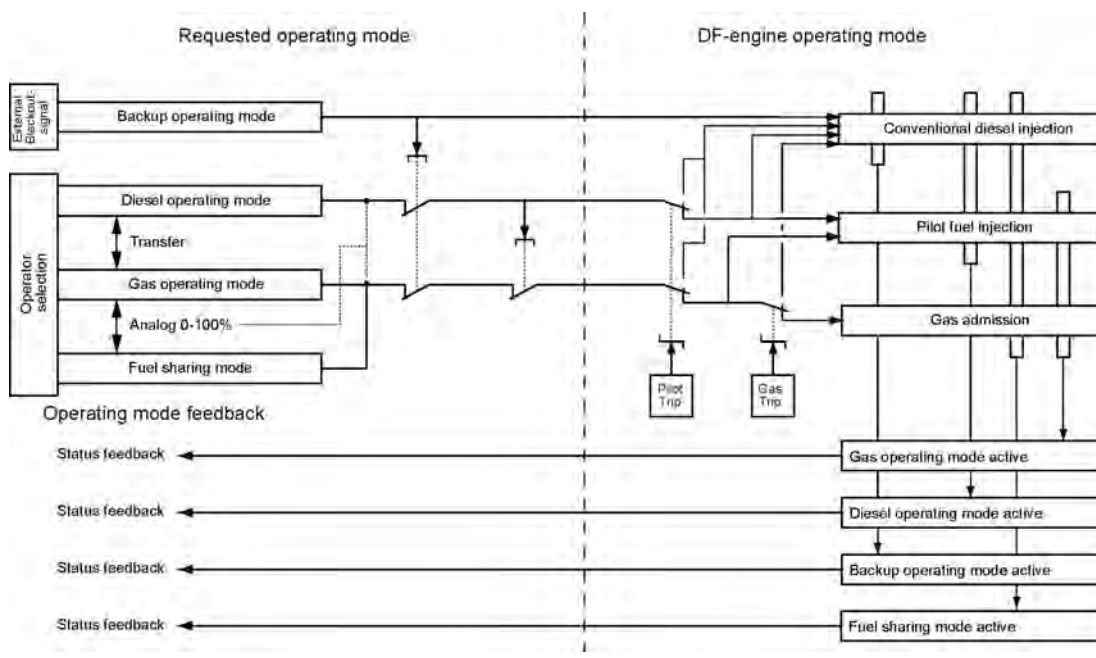


Fig 14-6 Principle of engine operating modes

14.2.1.1 Fuel sharing mode (optional)

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

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

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

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

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

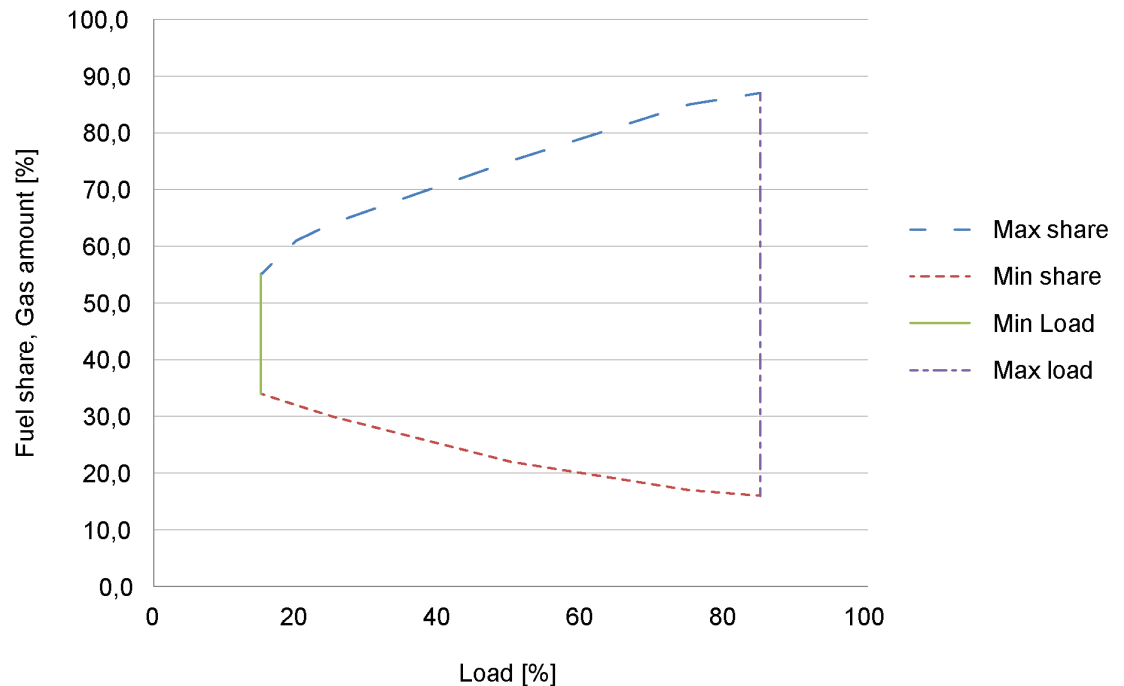


Fig 14-7 Fuel mixing ratio

14.2.2 Start

14.2.2.1 Start blocking

Starting is inhibited by the following functions:

- Stop lever in stop position
- Turning device engaged
- Pre-lubricating pressure low (override if black-out input is high and within last 30 minutes after the pressure has dropped below the set point of 0.5 bar)
- Stop signal to engine activated (safety shut-down, emergency stop, normal stop)
- External start block active
- Exhaust gas ventilation not performed
- HFO selected or fuel oil temperature > 70°C (Gas mode only)
- Charge air shut-off valve closed (optional device)
- Start block exist due to low HT temp (overridden in case of blackout start)

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 is enabled and pilot fuel pump is activated (if electric-driven) along with pilot fuel pressure control

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

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

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 conventional diesel engine, i.e. after receiving start signal the engine will start and ramp up to nominal speed using only the conventional diesel fuel system. The blackout signal disables some of the start blocks to get the engine running as quickly as possible. All checks during start-up that are related to gas fuel system or pilot fuel system are omitted. There is possibility to change an operating mode to the diesel mode when an engine is running. When an engine tries to change the diesel mode, the pilot check will be conducted. But if it fails, the engine will trip to the backup 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 can be stopped and re-started in gas- or diesel operating mode or change the operating mode to the diesel 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.

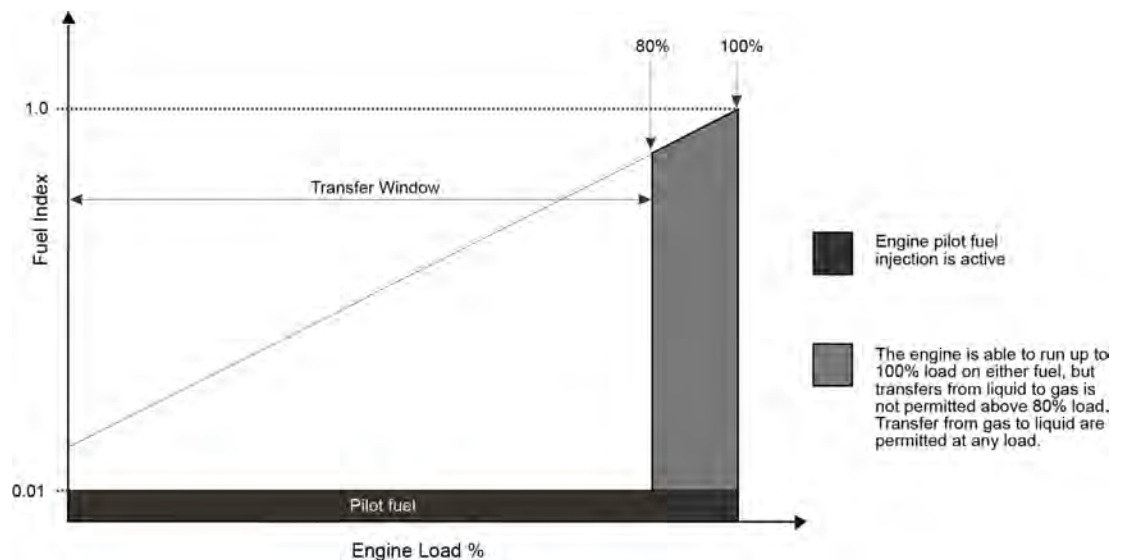


Fig 14-8 Operating modes are load dependent

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*".

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

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 normally 4%, which means that the difference in frequency between zero load and maximum load is 4%.

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

14.3 Alarm and monitoring signals

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

14.4 Electrical consumers

14.4.1 Motor starters and operation of electrically driven pumps

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

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

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 14-2 Electric motor ratings for engine turning device

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

14.4.1.2 Pre-lubricating oil pump

The pre-lubricating oil pump must always be running when the engine is stopped. When engine stops, there is need for TC cooling by post-lubrication. Therefore the pre-lubrication pump shall run at least 90 minutes after an engine stop.

- The lubricating oil pressure should be between 0.6 – 0.7 bar and must be higher than the start blocking pressure
- Engines equipped with an air by-pass valve can, if possible, keep the air by-pass valve open when the engine is stopped to increase the cooling ability

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 Exhaust gas ventilation unit

The exhaust gas ventilating unit is engine specific and includes an electric driven fan, flow switch and closing valve. For further information, see chapter *Exhaust gas system*.

14.4.1.4 Gas valve unit (GVU)

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

14.4.1.5 Stand-by pump, lubricating oil (if installed) (2P04)

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

The pump must not be running when the engine is stopped, nor may it be used for pre-lubricating purposes. Neither should it be operated in parallel with the main pump, when the main pump is in order.

14.4.1.6 Stand-by pump, HT cooling water (if installed) (4P03)

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

14.4.1.7 Stand-by pump, LT cooling water (if installed) (4P05)

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

14.4.1.8 Circulating pump for HT preheater (4P04)

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

15. Foundation

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

15.1 Steel structure design

The system oil tank should not extend under the generator, if the oil tank is located beneath the engine foundation. The oil tank must also be symmetrically located in transverse direction under the engine.

The foundation and the double bottom should be as stiff as possible in all directions to absorb the dynamic forces caused by the engine and the generator.

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

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

15.2 Engine mounting

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

15.2.1 Rigid mounting

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

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

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

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

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

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

In order to avoid bending stress in the bolts and to ensure proper fastening, the contact face of the nut underneath the seating top plate should be counterbored.

The tensile stress in the bolts is allowed to be max. 80% of the material yield strength. It is however permissible to exceed this value during installation in order to compensate for setting of the bolt connection, but it must be verified that this does not make the bolts yield. Bolts made from St 52-3 are to be tightened to 80% of the material yield strength. It is however sufficient to tighten bolts that are made from a high strength steel, e.g. 42CrMo4 or similar, to about 60-70% of the material yield strength.

The tool included in the standard set of engine tools is used for hydraulic tightening of the holding down bolts. The piston area of the tools is 72.7 cm² and the hydraulic tightening pressures mentioned in the following sections only apply when using this tool.

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

15.2.1.1 Resin chocks

Installation of engines on resin chocks is possible provided that the requirements of the classification societies are fulfilled.

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

The recommended dimensions of the resin chocks are 600 x 180 mm for Wärtsilä 50DF in-line engines and 1000 x 180 mm for V-engines.

The total surface pressure on the resin must not exceed the maximum value, which is determined by the type of resin and the requirements of the classification society. It is recommended to select a resin type, which has a type approval from the relevant classification society for a total surface pressure of 5 N/mm². (A typical conservative value is P_{tot} 3.5 N/mm²).

The bolts must be made as tensile bolts with a reduced shank diameter to ensure a sufficient elongation, since the bolt force is limited by the permissible surface pressure on the resin.

For a given bolt diameter the permissible bolt tension is limited either by the strength of the bolt material (max. stress 80% of the yield strength), or by the maximum permissible surface pressure on the resin. Assuming bolt dimensions and chock dimensions according to drawing 1V69L0082a and 1V69L0083b the following hydraulic tightening pressures should be used:

- In-line engine, St 52-3 bolt material, maximum total surface pressure 2.9 N/mm² p_{hyd} = 200 bar
- In-line engine, 42CrMo4 bolt material, maximum total surface pressure 4.5 N/mm² p_{hyd} = 335 bar
- V-engine, St 52-3 bolt material, maximum total surface pressure 3.5 N/mm² p_{hyd} = 310 bar
- V-engine, 42CrMo4 bolt material, maximum total surface pressure 5.0 N/mm² p_{hyd} = 475 bar

Locking of the upper nuts is required when using St 52-3 material or when the total surface pressure on the resin chocks is below 4 MPa with the recommended chock dimensions. The lower nuts should always be locked regardless of the bolt tension.

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.

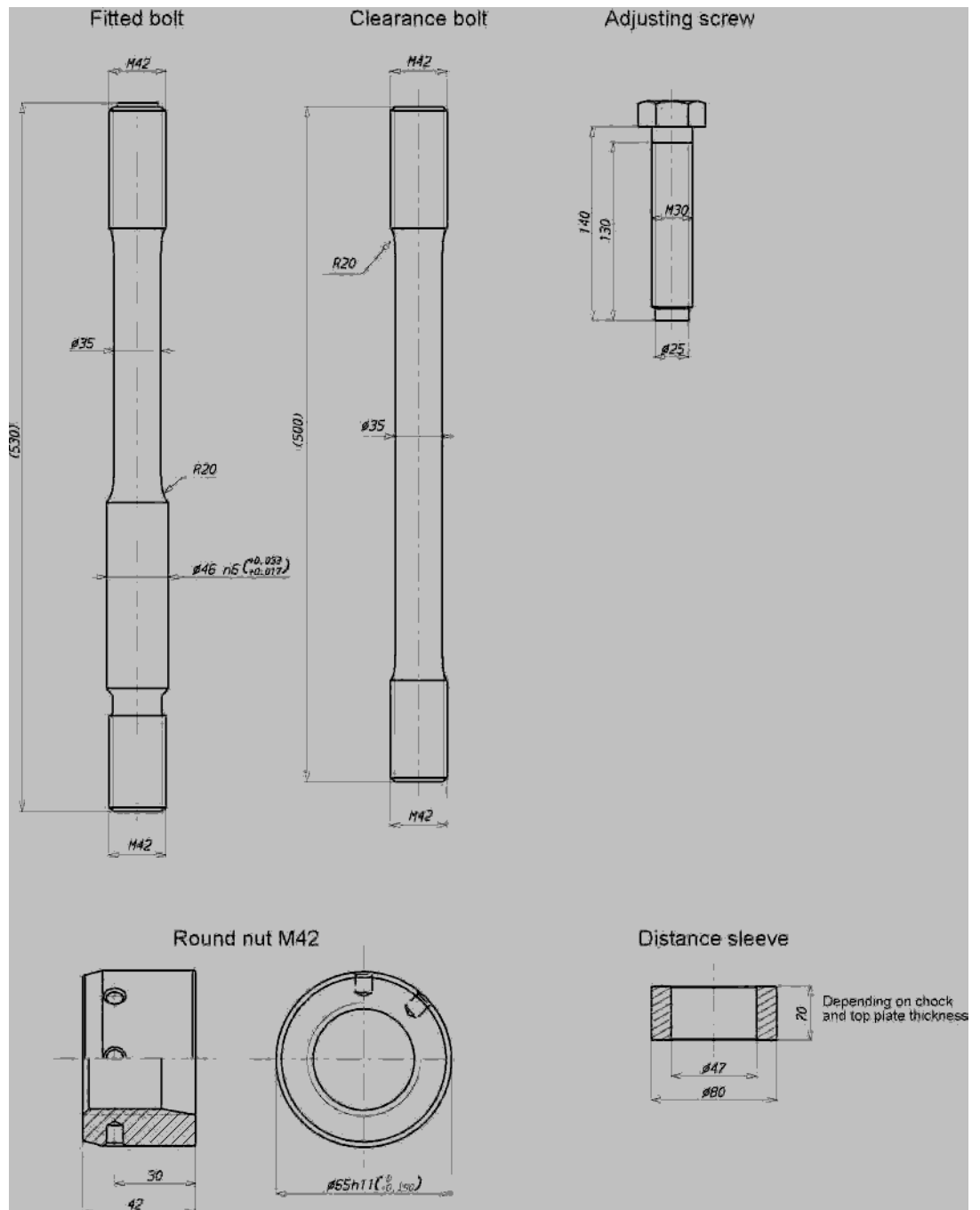
The size of the wedge type chocks should be 200x360 mm. The chocks should always cover two bolts to prevent it from turning (except the chock closest to the flywheel, which has a single hole). The material may be cast iron or steel.

The supporting surface of the seating top plate should be machined so that a bearing surface of at least 75% is obtained. The chock should be fitted so that the distance between the bolt holes and the edges is equal on both sides.

The cutout in the chocks for the clearance bolts should be about 2 mm larger than the bolt diameter. Holes are to be drilled and reamed to the correct tolerance for the fitted bolts after the coupling alignment has been checked and the chocks have been lightly knocked into position.

Depending on the material of the bolts, the following hydraulic tightening pressures should be used, provided that the minimum diameter is 35 mm:

- St52-3 Tightened to 80% of yield strength, $p_{hyd} = 420$ bar
- 42CrMo4 Tightened to 70% of yield strength, $p_{hyd} = 710$ bar



Number of pieces per engine			
Component	W 6L50DF	W 8L50DF	W 9L50DF
Fitted bolt	4	4	4
Clearance bolt	26	34	38
Adjusting screw	16	20	22
Distance sleeve	4	4	4
Round nut	30	38	42

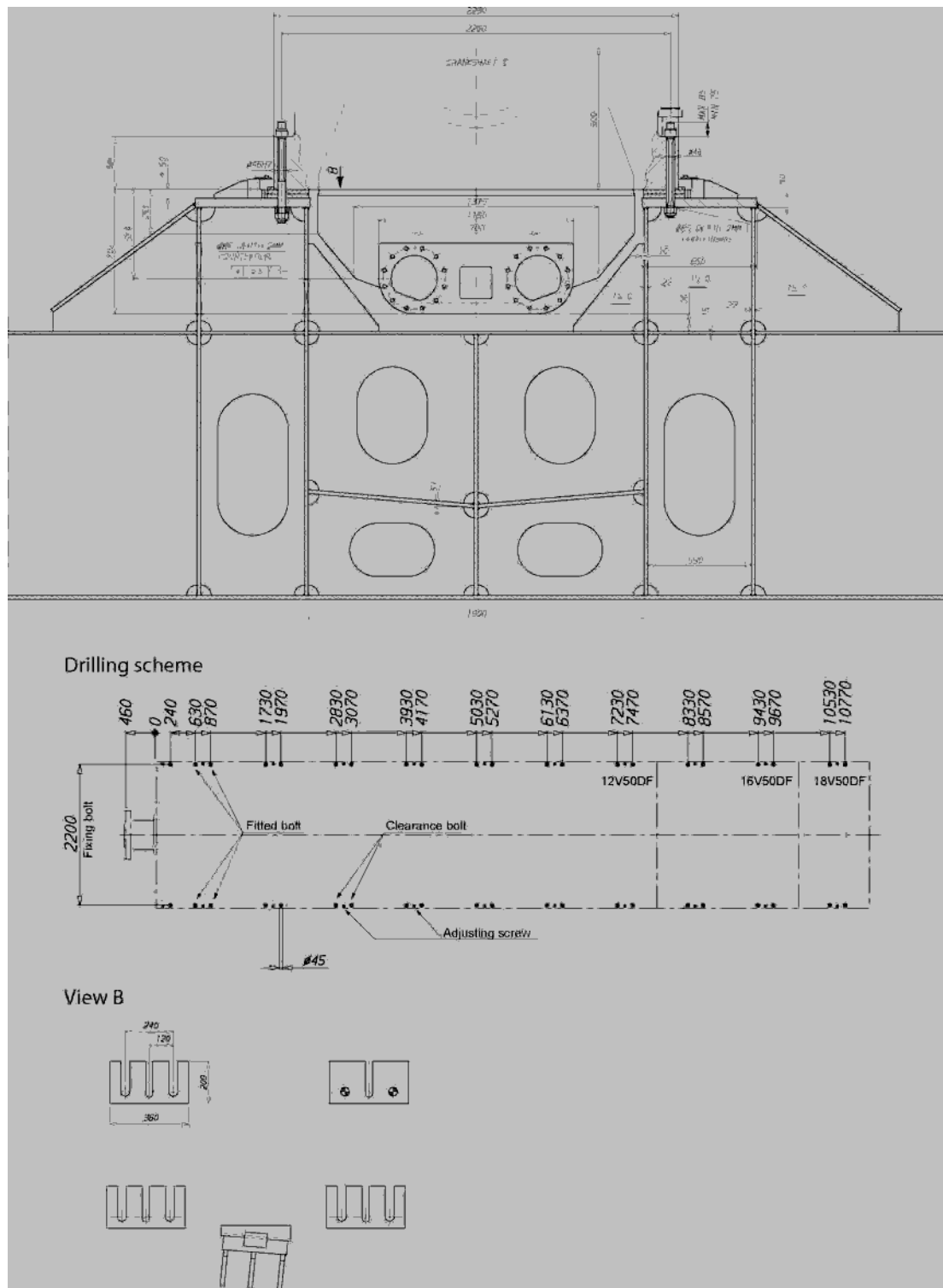
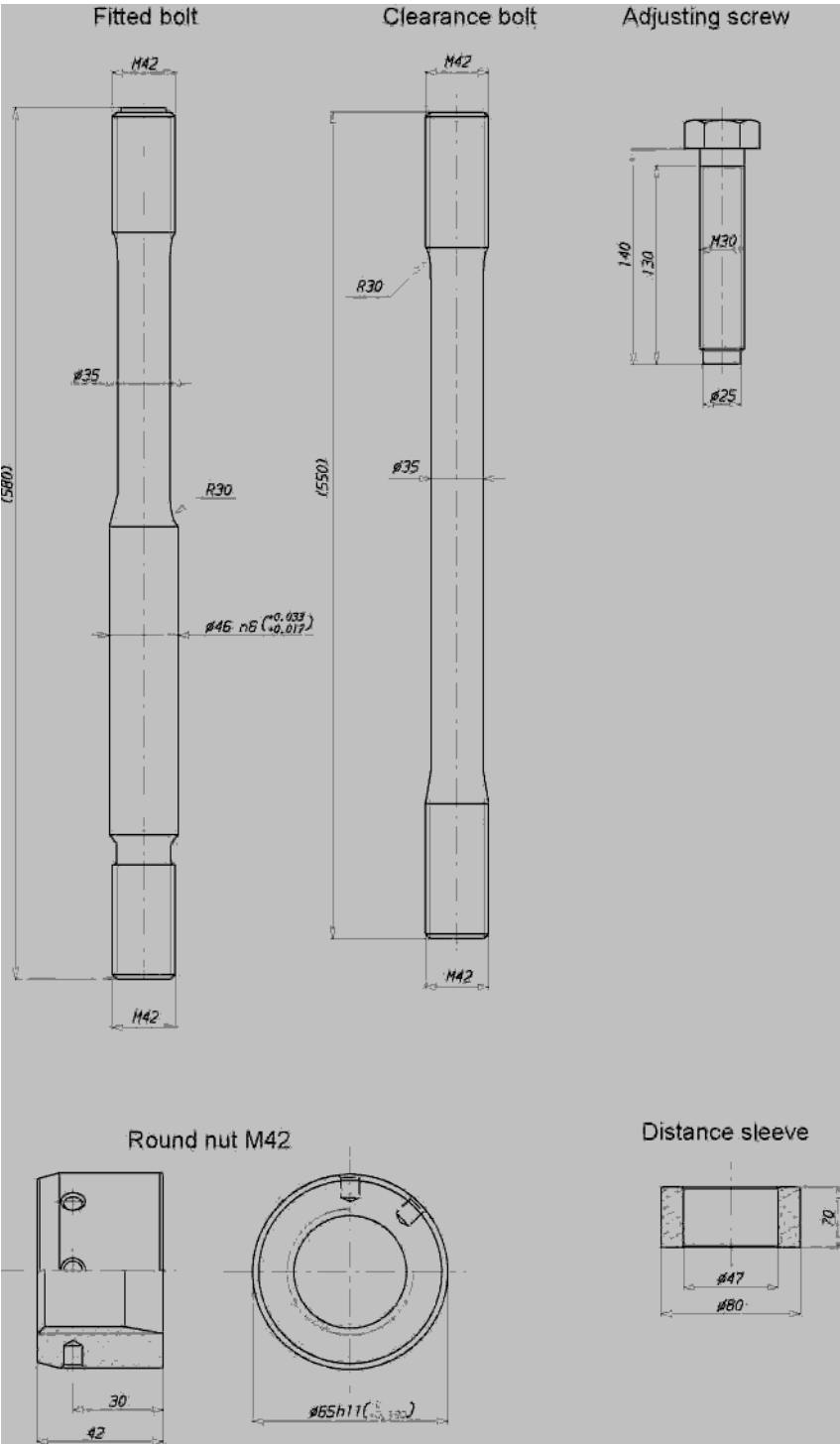


Fig 15-2 Seating and fastening, rigidly mounted V-engines on steel chocks (1V69L1659a)



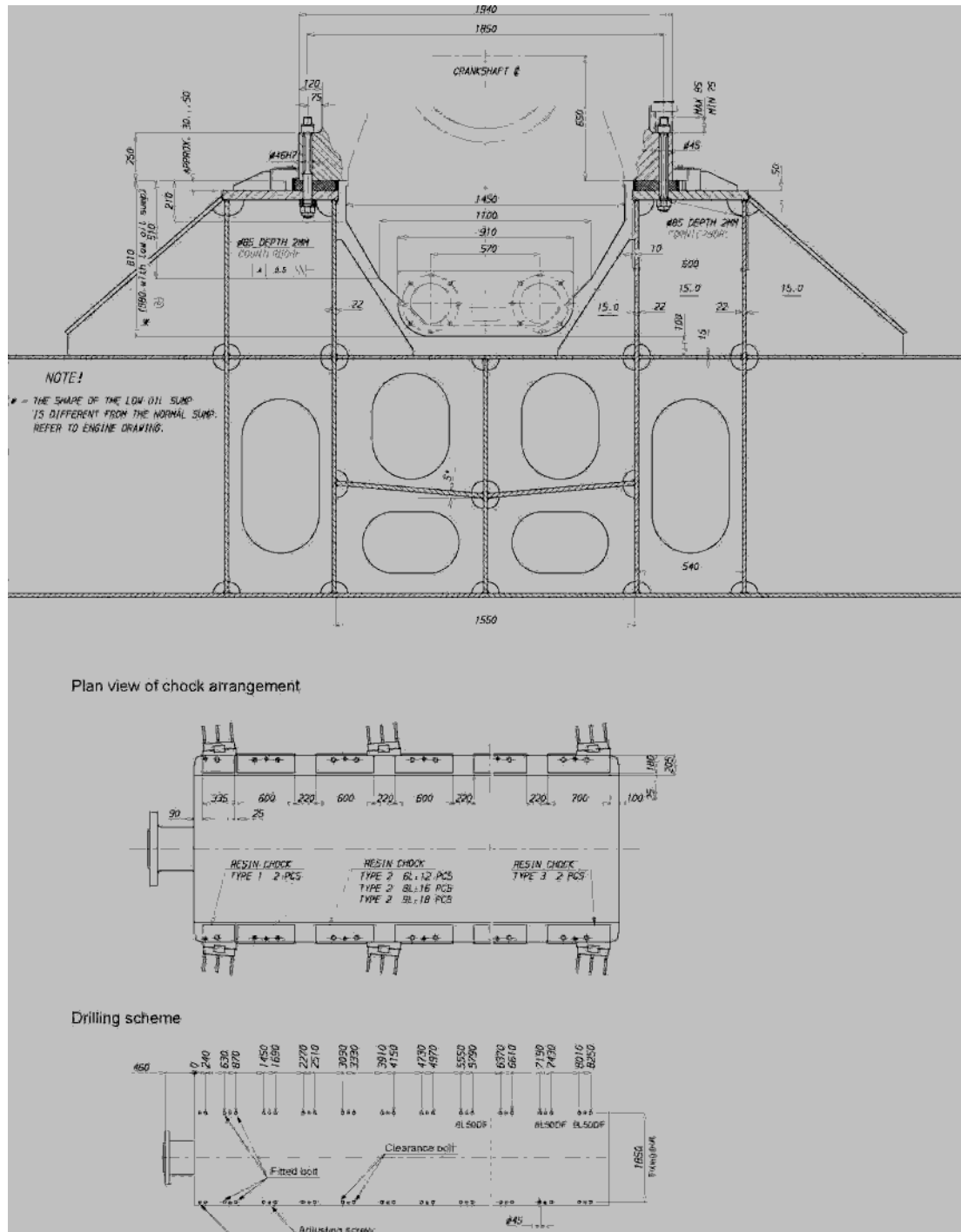
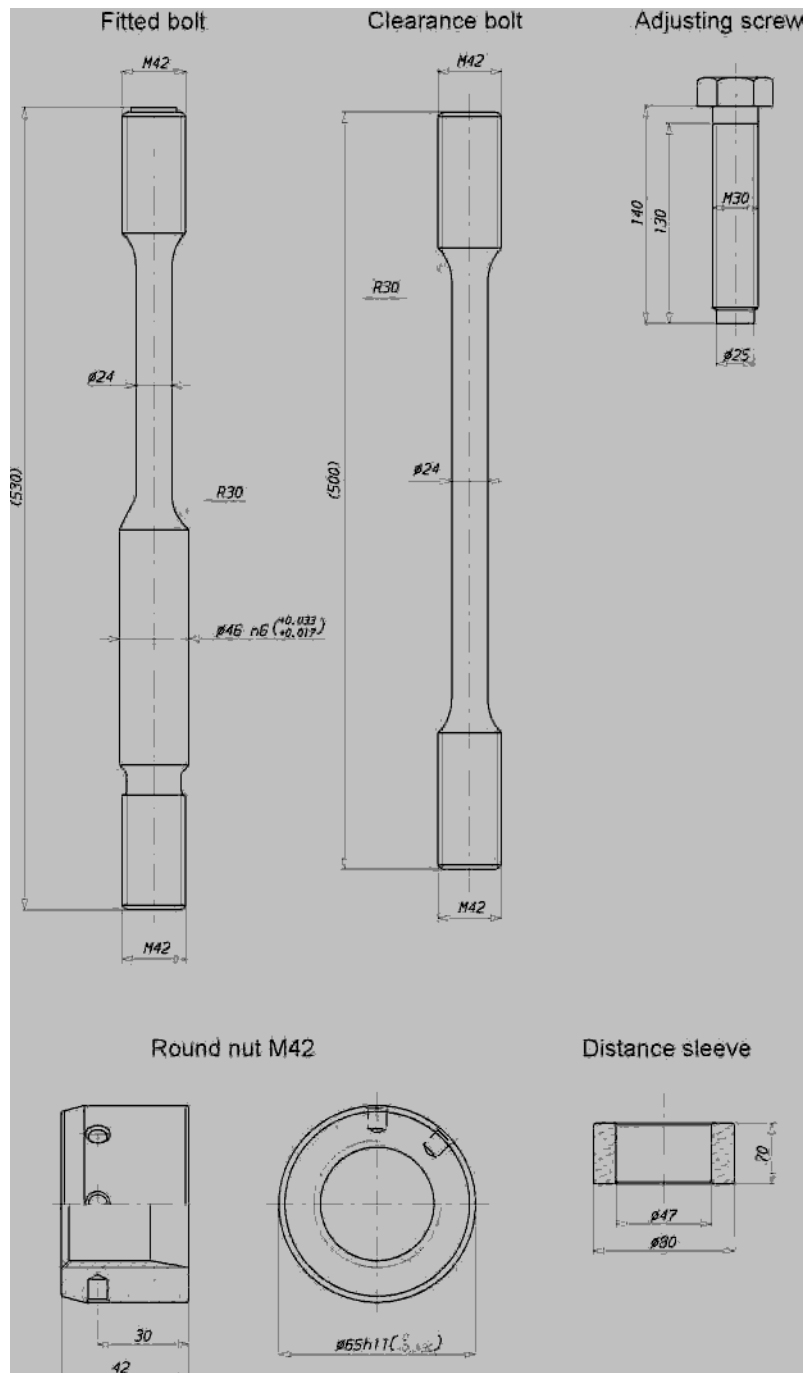


Fig 15-3 Seating and fastening, rigidly mounted in-line engines on resin chocks (1V69L0082c)



Number of pieces per engine			
Component	W 6L50DF	W 8L50DF	W 9L50DF
Fitted bolt	4	4	4
Clearance bolt	26	34	38
Adjusting screw	16	20	22
Distance sleeve	4	4	4
Round nut	30	38	42

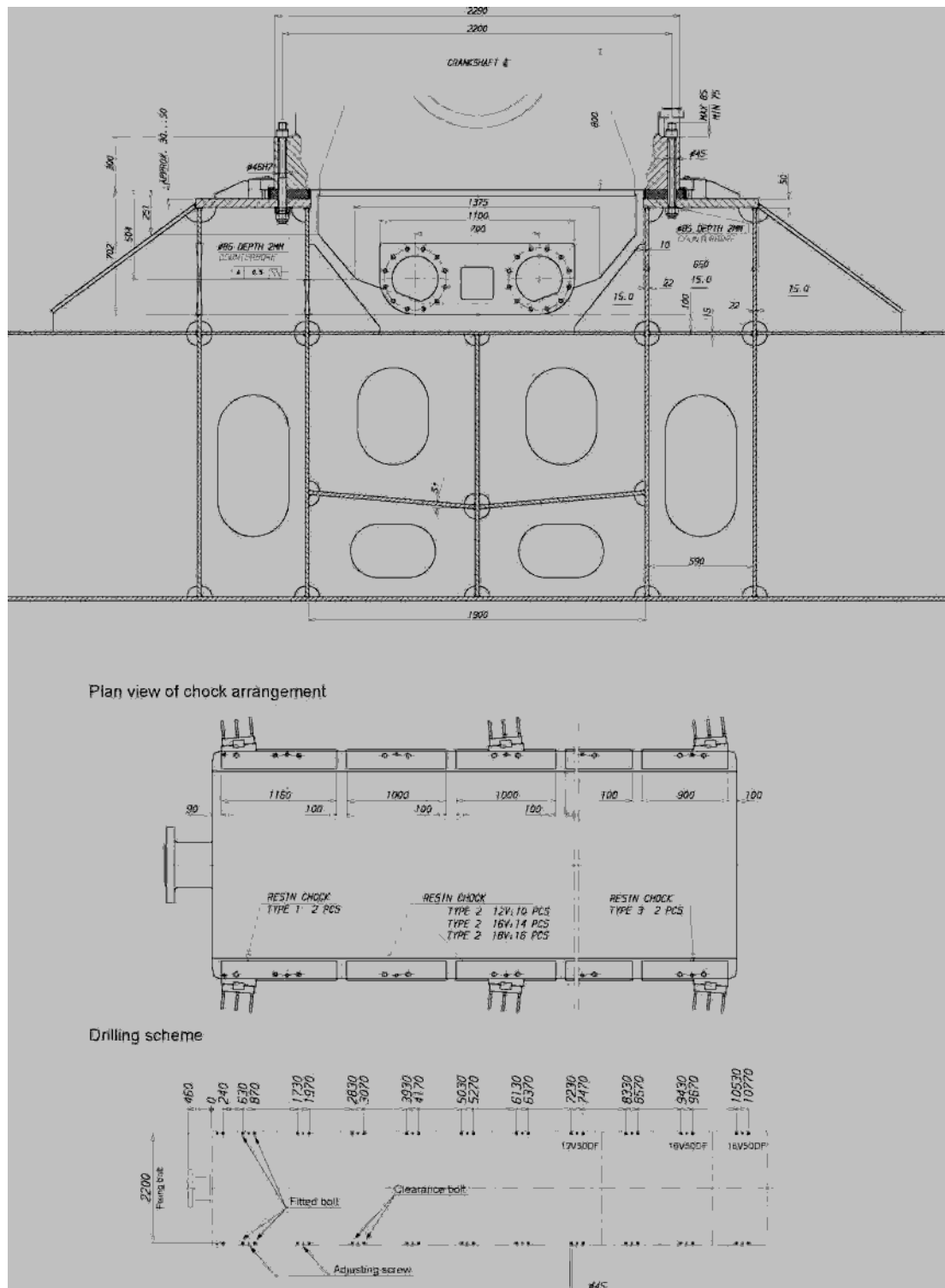
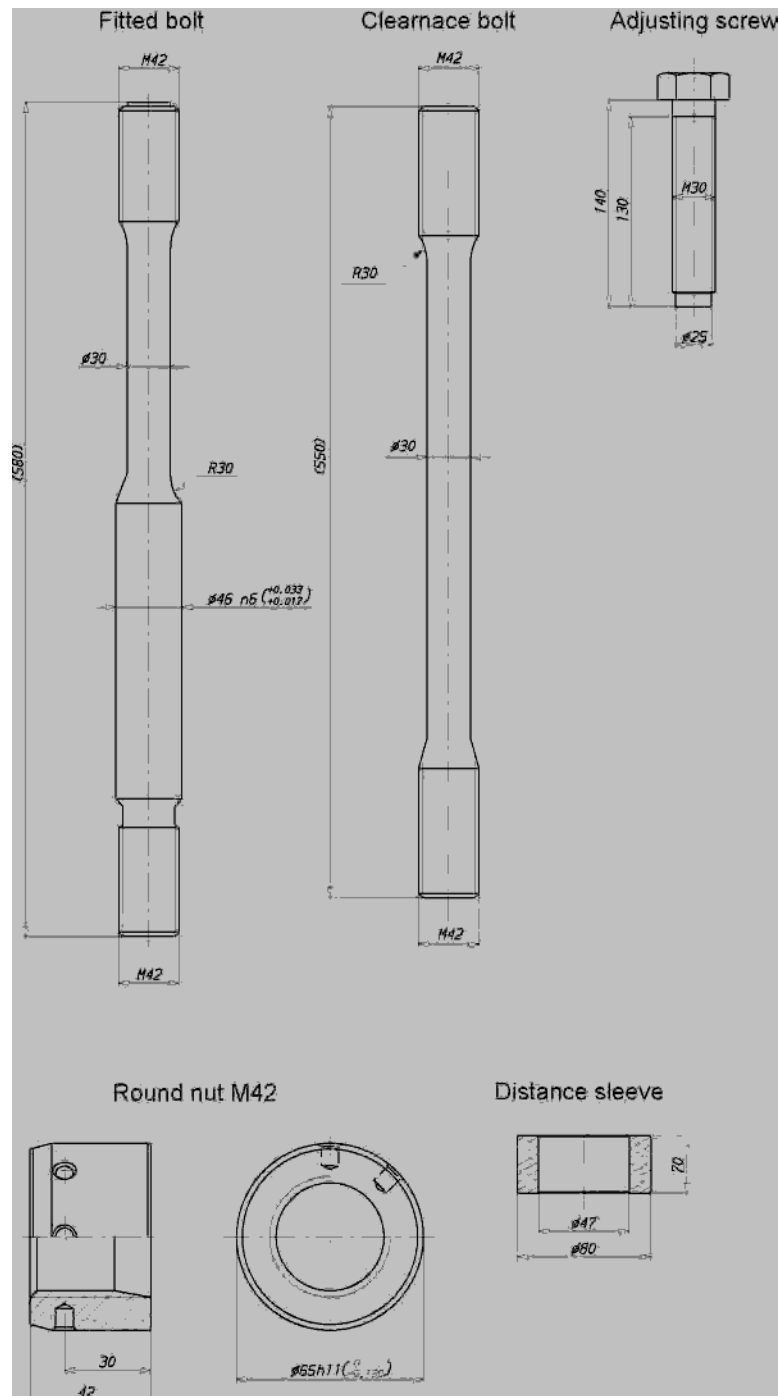


Fig 15-4 Seating and fastening, rigidly mounted V-engines on resin chocks (1V69L0083c)



15.2.2 Resilient mounting

In order to reduce vibrations and structure borne noise, engines may be resiliently mounted on rubber elements.

The engine block is so rigid that no intermediate base frame is required. Rubber mounts are fixed to the engine feet by means of a fixing rail. The advantage of vertical type mounting is ease of alignment.

Typical material of the flexible elements is natural rubber, which has superior vibration technical properties, but unfortunately is prone to damage by mineral oil. The rubber mounts are protected against dripping and splashing by means of covers.

A machining tool for machining of the top plate under the resilient or rubber element can be supplied by Wärtsilä.

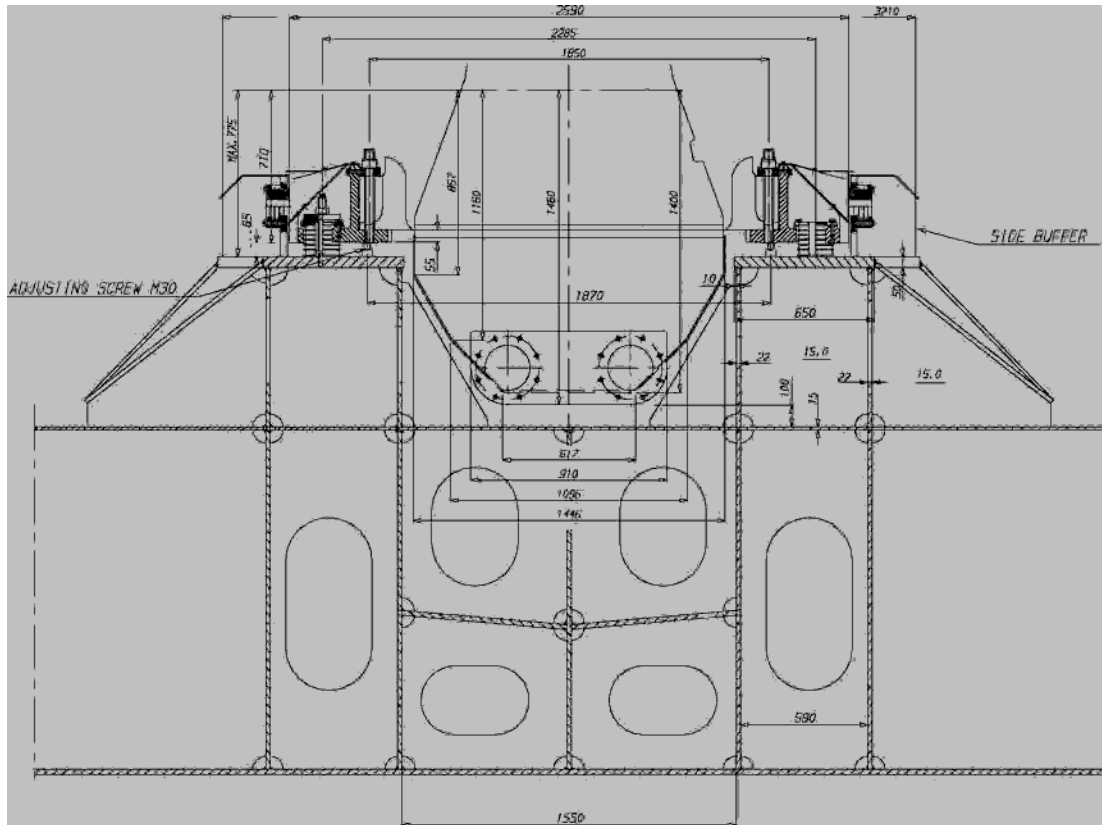


Fig 15-5 Seating and fastening, resiliently mounted in-line engine (DAAE001883)

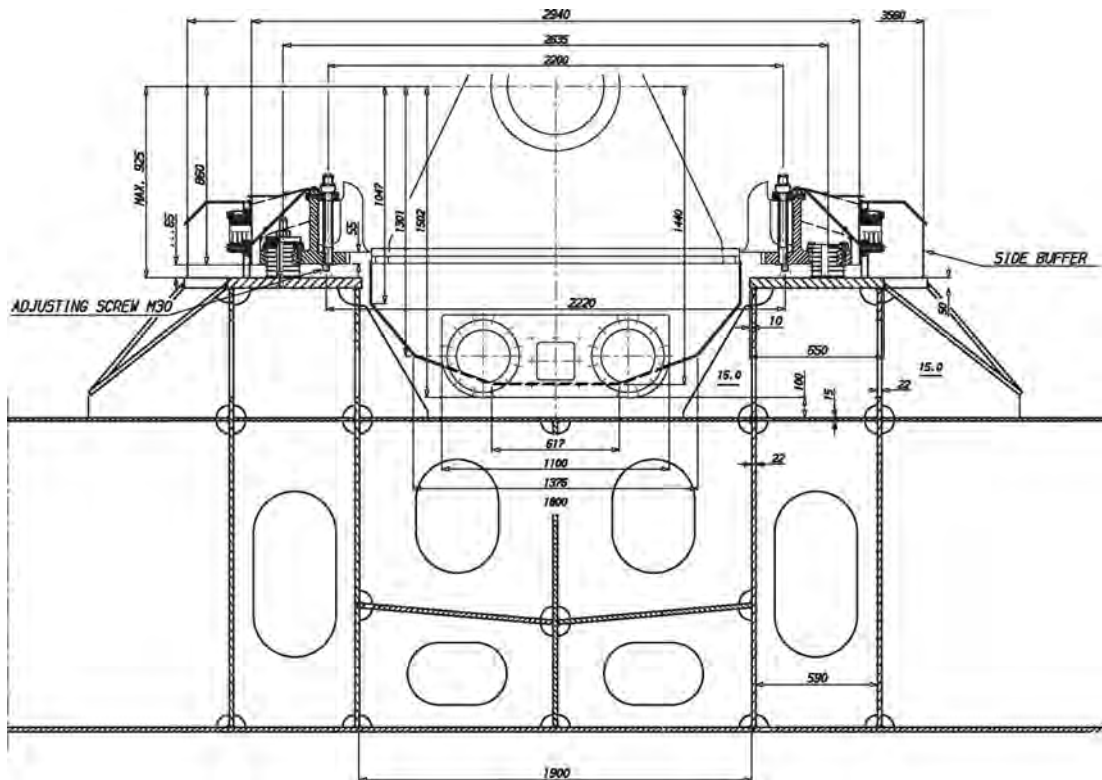


Fig 15-6 Seating and fastening, resiliently mounted V-engine (DAAE001882)

The machining tool permits a maximum distance of 85mm between the fixing rail and the top plate.

The brackets of the side and end buffers are welded to the foundation.

Due to the soft mounting the engine will move when passing resonance speeds at start and stop. Typical amplitudes are +/- 1mm at the crankshaft centre and +/- 5mm at top of the engine. The torque reaction will cause a displacement of the engine of up to 1.5mm at the crankshaft centre and 10 mm at the turbocharger outlet. Furthermore the creep and thermal expansion of the rubber mounts have to be considered when installing and aligning the engine.

15.3 Flexible pipe connections

When the engine is resiliently installed, all connections must be flexible and no grating nor ladders may be fixed to the engine. Especially the connection to the turbocharger must be arranged so that the above mentioned displacements can be absorbed. When installing the flexible pipe connections, unnecessary bending or stretching should be avoided. The external pipe must be precisely aligned to the fitting or flange on the engine.

The pipe clamps for the pipe outside the flexible connection must be very rigid and welded to the steel structure of the foundation to prevent vibrations, which could damage the flexible connection.

See the chapter *Piping design, treatment and installation* for more detailed information.

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16. Vibration and Noise

Wärtsilä 50DF engines comply with vibration levels according to ISO 10816-6 Class 5.

16.1 External forces and couples

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

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

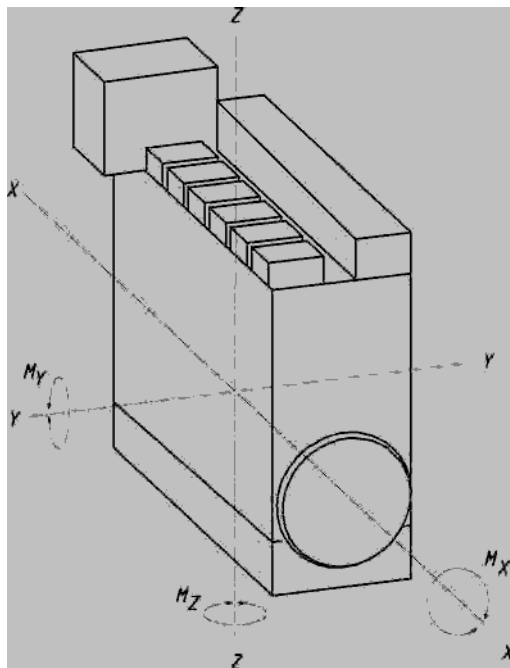


Fig 16-1 Coordinate system of the external torques

Table 16-1 External forces

Engine	Speed [rpm]	Frequency [Hz]	F_Y [kN]	F_Z [kN]	Frequency [Hz]	F_Y [kN]	F_Z [kN]	Frequency [Hz]	F_Y [kN]	F_Z [kN]
W 8L50DF	500	8.3	–	–	16.7	–	–	33.3	–	8.3
	514	8.6	–	–	17.1	–	–	34.3	–	8.8
W 16V50DF	500	8.3	–	–	16.7	–	–	33.3	6.4	–
	514	8.6	–	–	17.1	–	–	34.3	6.7	–
– forces are zero or insignificant										

Table 16-2 External couples

Engine	Speed [rpm]	Frequency [Hz]	M _Y [Nm]	M _Z [Nm]	Frequency [Hz]	M _Y [Nm]	M _Z [Nm]	Frequency [Hz]	M _Y [Nm]	M _Z [Nm]
W 9L50DF	500	8.3	–	–	16.7	84	–	33.3	4	–
	514	8.6	–	–	17.1	89	–	34.3	5	–
– couples are zero or insignificant										

16.2 Torque variations

Table 16-3 Torque variations

Engine	Speed [rpm]	Frequency [Hz]	M _X [kNm]	Frequency [Hz]	M _X [kNm]	Frequency [Hz]	M _X [kNm]
W 6L50DF	500	25.0	66.9	50.0	46.4	75.0	14.4
	514	25.7	56.6	51.4	45.2	77.1	14.0
W 6L50DF idle	500	25.0	80.0	50.0	10.4	75.0	2.5
	514	25.7	87.7	51.4	10.2	77.1	2.4
W 8L50DF	500	33.3	145.9	66.7	26.8	100.0	8.3
	514	34.3	141.1	68.5	26.1	102.8	8.1
W 9L50DF	500	37.5	136.9	75.0	21.6	112.5	6.6
	514	38.6	133.2	77.1	21.0	115.7	6.4
W 12V50DF	500	25.0	51.2	50.0	65.6	75.0	26.5
	514	25.7	43.3	51.4	63.9	77.1	25.8
W 12V50DF idle	500	25.0	61.2	50.0	14.7	75.0	4.5
	514	25.7	67.1	51.4	14.3	77.1	4.4
W 16V50DF	500	33.3	–	66.7	53.6	133.3	6.1
	514	34.3	–	68.5	52.2	137.1	5.9
– couple are zero or insignificant							

16.3 Mass moment of inertia

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

Polar mass moment of inertia J [kgm ²]		
Engine	Speed [rpm]	
	500	514
W 6L50DF	3020	2900
W 8L50DF	3570	3540
W 9L50DF	4580	4580
W 12V50DF	5310	5310

Polar mass moment of inertia J [kgm ²]		
W 16V50DF	7250	6790

16.4 Structure borne noise

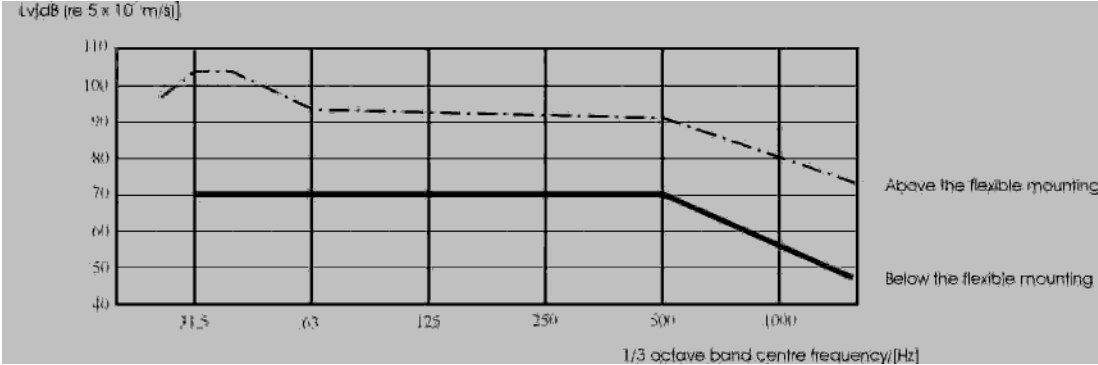


Fig 16-2 Typical structure borne noise levels

16.5 Air borne noise

The airborne noise of the engine is measured as a sound power level according to ISO 9614-2. Noise level is given as sound power emitted by the whole engine, reference level 1 pW. The values presented in the graphs below are typical values, cylinder specific graphs are included in the Installation Planning Instructions (IPI) delivered for all contracted projects.

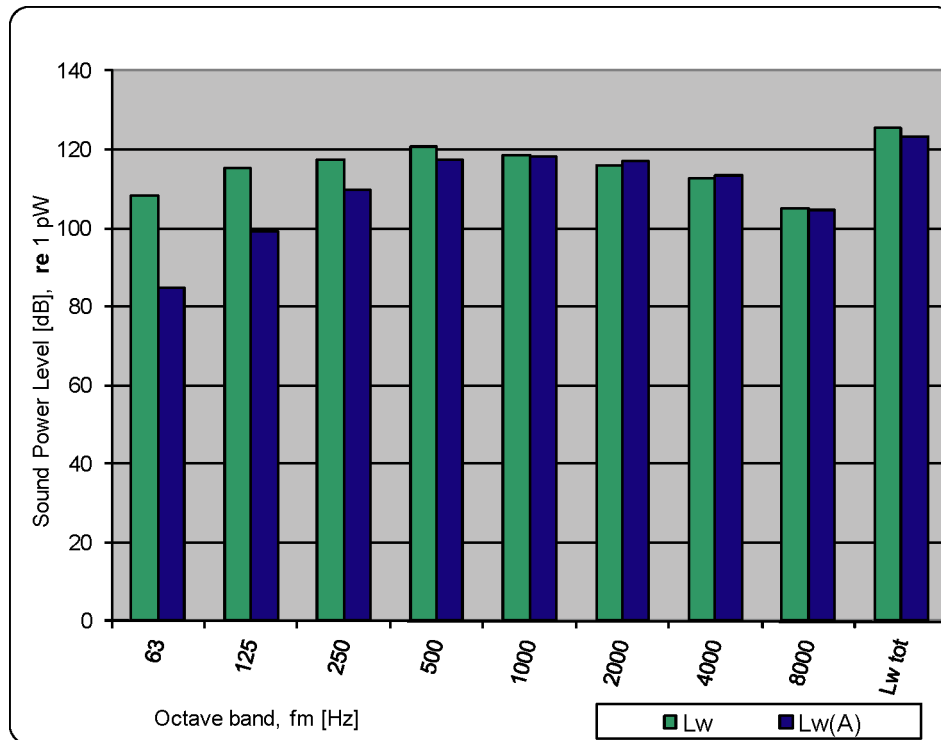


Fig 16-3 Typical sound power level for W L50DF

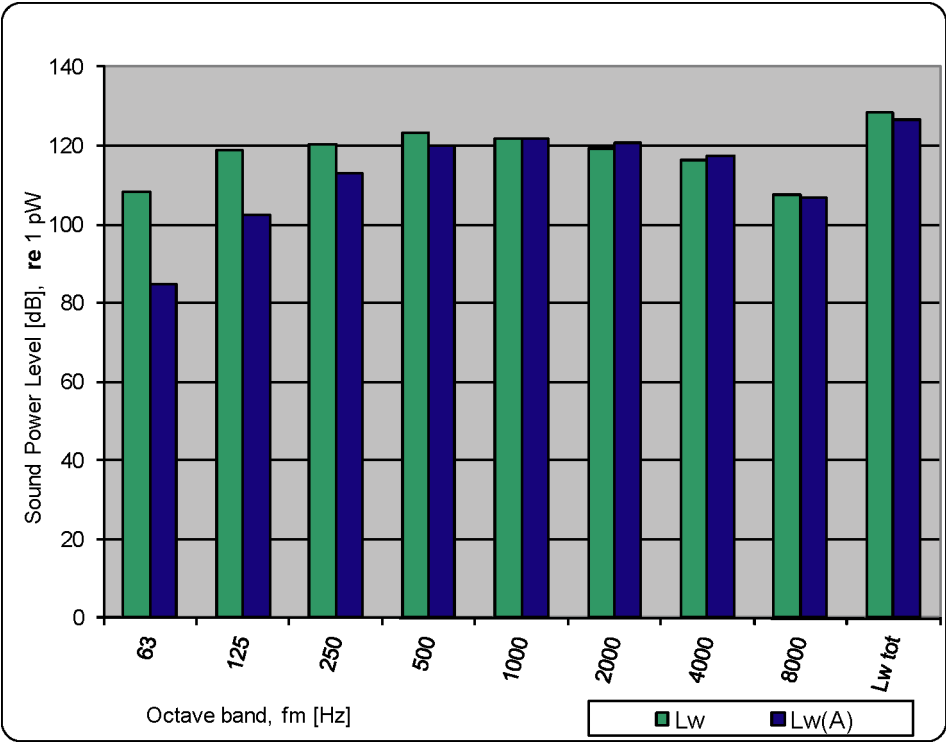


Fig 16-4 Typical sound power level for W V50DF

16.6

Exhaust noise

The exhaust noise of the engine is measured as the sound power emitted from the turbocharger outlet without exhaust gas piping connected. Reference value 1 pW. The values presented in the graphs below are typical values, cylinder specific graphs are included in the Installation Planning Instructions (IPI) delivered for all contracted projects.

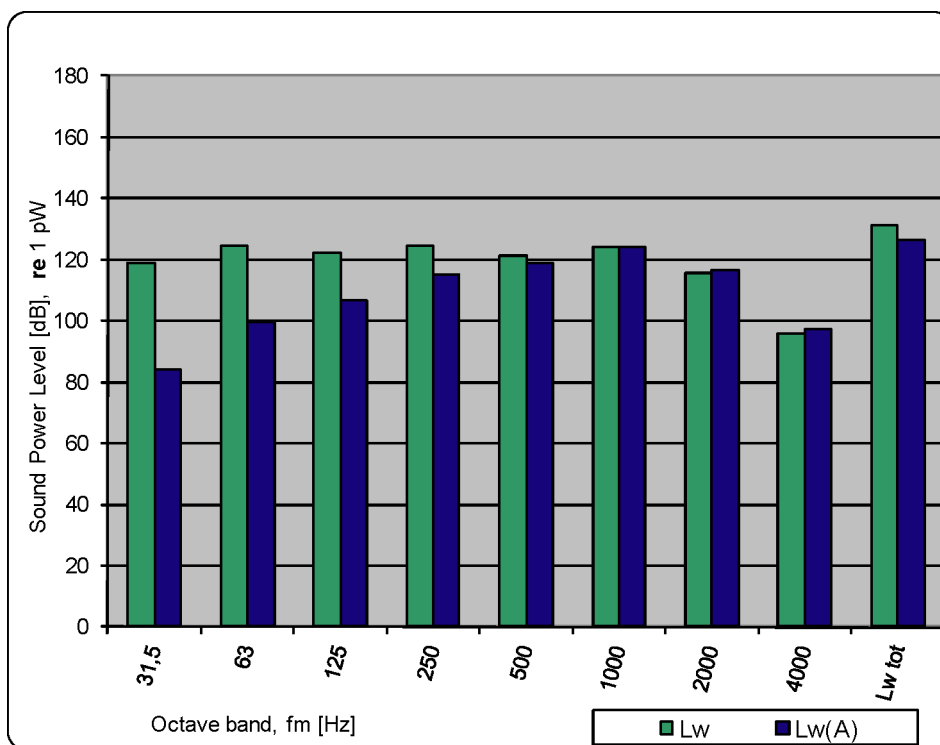


Fig 16-5 Typical sound power level for exhaust noise, W L50DF

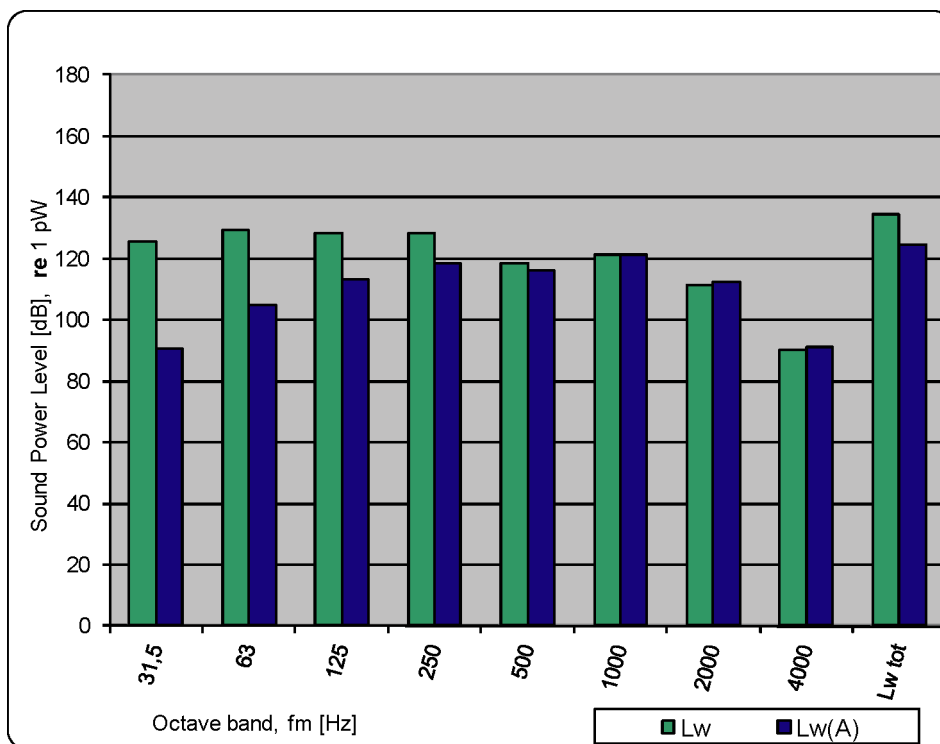


Fig 16-6 Typical sound power level for exhaust noise, W V50DF

17. Power Transmission

17.1 Flexible coupling

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

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

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

17.2 Torque flange

In mechanical propulsion applications, a torque meter has to be installed in order to measure the absorbed power. The torque flange has an installation length of 300 mm for all cylinder configurations and is installed after the flexible coupling.

17.3 Clutch

In dual fuel engine installations with mechanical drive, it must be possible to disconnect the propeller shaft from the engine by using a clutch. The use of multiple plate hydraulically actuated clutches built into the reduction gear is recommended.

A clutch is also required when two or more engines are connected to the same driven machinery such as a reduction gear.

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

17.4 Shaft locking device

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

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

To permit maintenance of a stopped engine clutches must be installed in twin screw vessels which can operate on one shaft line only. A shaft locking device should also be fitted to be able to secure the propeller shaft in position so that wind milling is avoided. This is necessary because even an open hydraulic clutch can transmit some torque. Wind milling at a low propeller speed (<10 rpm) can due to poor lubrication cause excessive wear of the bearings.

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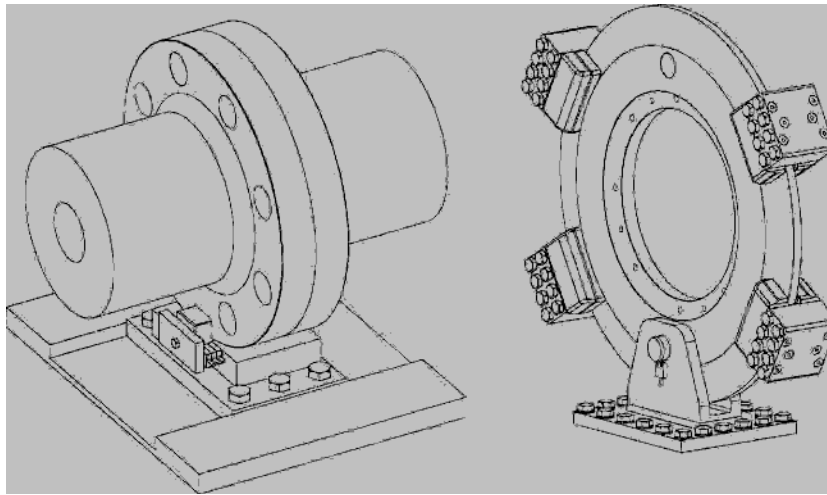


Fig 17-1 Shaft locking device and brake disc with calipers

17.5 Input data for torsional vibration calculations

A torsional vibration calculation is made for each installation. For this purpose exact data of all components included in the shaft system are required. See list below.

Installation

- Classification
- Ice class
- Operating modes

Reduction gear

A mass elastic diagram showing:

- All clutching possibilities
- Sense of rotation of all shafts
- Dimensions of all shafts
- Mass moment of inertia of all rotating parts including shafts and flanges
- Torsional stiffness of shafts between rotating masses
- Material of shafts including tensile strength and modulus of rigidity
- Gear ratios
- Drawing number of the diagram

Propeller and shafting

A mass-elastic diagram or propeller shaft drawing showing:

- Mass moment of inertia of all rotating parts including the rotating part of the OD-box, SKF couplings and rotating parts of the bearings
- Mass moment of inertia of the propeller at full/zero pitch in water
- Torsional stiffness or dimensions of the shaft
- Material of the shaft including tensile strength and modulus of rigidity
- Drawing number of the diagram or drawing

Main generator or shaft generator

A mass-elastic diagram or an generator shaft drawing showing:

- Generator output, speed and sense of rotation
- Mass moment of inertia of all rotating parts or a total inertia value of the rotor, including the shaft
- Torsional stiffness or dimensions of the shaft
- Material of the shaft including tensile strength and modulus of rigidity
- Drawing number of the diagram or drawing

Flexible coupling/clutch

If a certain make of flexible coupling has to be used, the following data of it must be informed:

- Mass moment of inertia of all parts of the coupling
- Number of flexible elements
- Linear, progressive or degressive torsional stiffness per element
- Dynamic magnification or relative damping
- Nominal torque, permissible vibratory torque and permissible power loss
- Drawing of the coupling showing make, type and drawing number

Operational data

- Operational profile (load distribution over time)
- Clutch-in speed
- Power distribution between the different users
- Power speed curve of the load

17.6 Turning gear

The engine is equipped with an electrical driven turning gear, capable of turning the generator in most installations.

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18. Engine Room Layout

18.1 Crankshaft distances

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

18.1.1 In-line engines

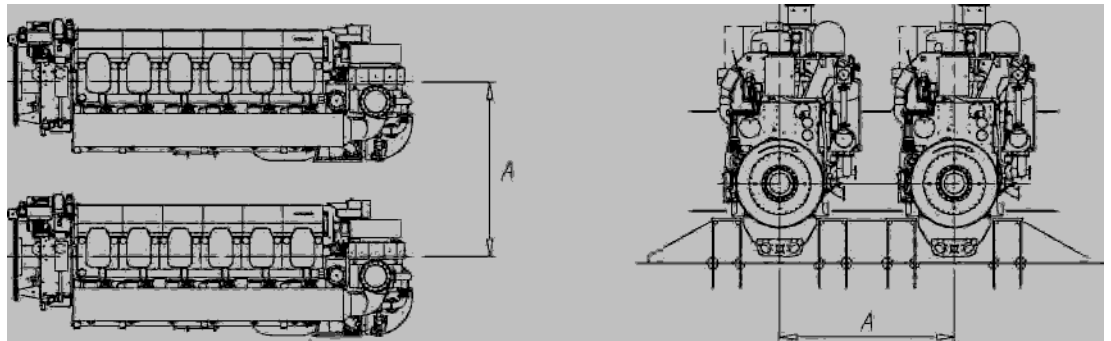


Fig 18-1 Crankshaft distances, in-line engines (3V69C0320b)

Engine type	Min. A [mm]
W 6L50DF	3500
W 8L50DF	3700
W 9L50DF	3700

18.1.2 V-engines

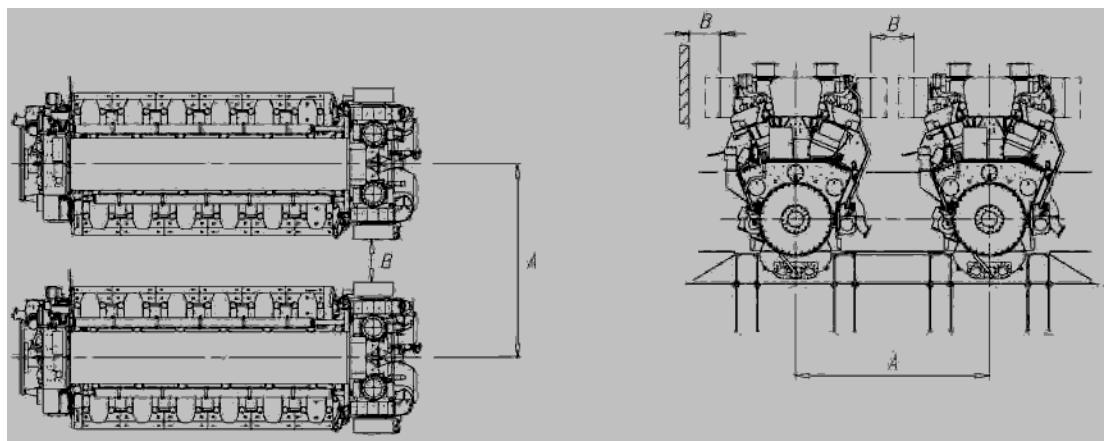


Fig 18-2 Crankshaft distances, V-engines (3V69C0319D)

Engine type	Minimum [mm]		Recommended [mm]	
	A	B	A	B
W 12V50DF	4700	450	4900	650

Engine type	Minimum [mm]		Recommended [mm]	
	A	B	A	B
W 16V50DF	5600	900	5800	1100

18.2 Space requirements for maintenance

18.2.1 Working space around the engine

The required working space around the engine is mainly determined by the dismantling dimensions of engine components, and space requirement of some special tools. It is especially important that no obstructive structures are built next to engine driven pumps, as well as camshaft and crankcase doors.

However, also at locations where no space is required for dismantling of engine parts, a minimum of 1000 mm free space is recommended for maintenance operations everywhere around the engine.

18.2.2 Engine room height and lifting equipment

The required engine room height is determined by the transportation routes for engine parts. If there is sufficient space in transverse and longitudinal direction, there is no need to transport engine parts over the rocker arm covers or over the exhaust pipe and in such case the necessary height is minimized.

Separate lifting arrangements are usually required for overhaul of the turbocharger since the crane travel is limited by the exhaust pipe. A chain block on a rail located over the turbocharger axis is recommended.

18.2.3 Maintenance platforms

In order to enable efficient maintenance work on the engine, it is advised to build the maintenance platforms on recommended elevations. The width of the platforms should be at minimum 800 mm to allow adequate working space. The surface of maintenance platforms should be of non-slippery material (grating or chequer plate).

NOTE



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

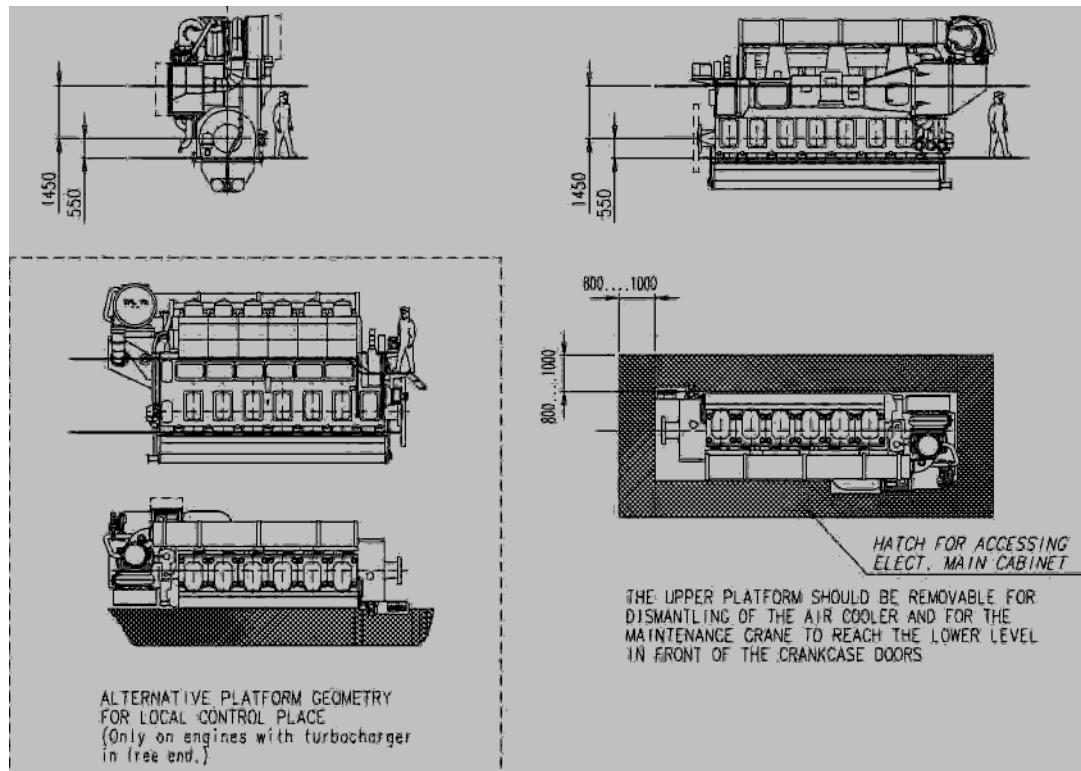


Fig 18-3 Maintenance platforms, in-line engine (3V69C0246a)

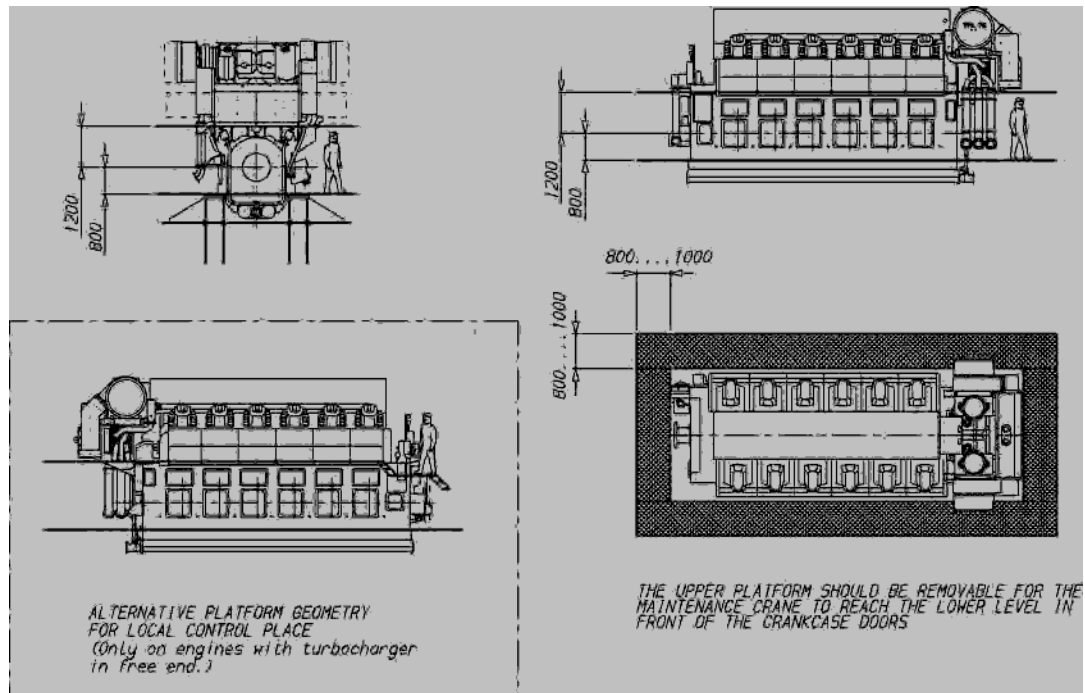


Fig 18-4 Maintenance platforms, V-engine (3V69C0244)

18.3 Transportation and storage of spare parts and tools

Transportation arrangements from engine room to workshop and storage locations must be provided for heavy engine components, for example by means of several chain blocks on rails, or by suitable routes for trolleys.

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

It is recommended to store heavy engine components on a slightly elevated and adaptable surface, e.g. wooden pallets. All engine spare parts should be protected from corrosion and excessive vibration.

18.4 Required deck area for service work

During engine overhaul a free deck area is required for cleaning and storing dismantled components. The size of the service area depends on the overhaul strategy, e.g. one cylinder at time or the whole engine at time. The service area should be a plain steel deck dimensioned to carry the weight of engine parts.

18.4.1 Service space requirement for the in-line engine

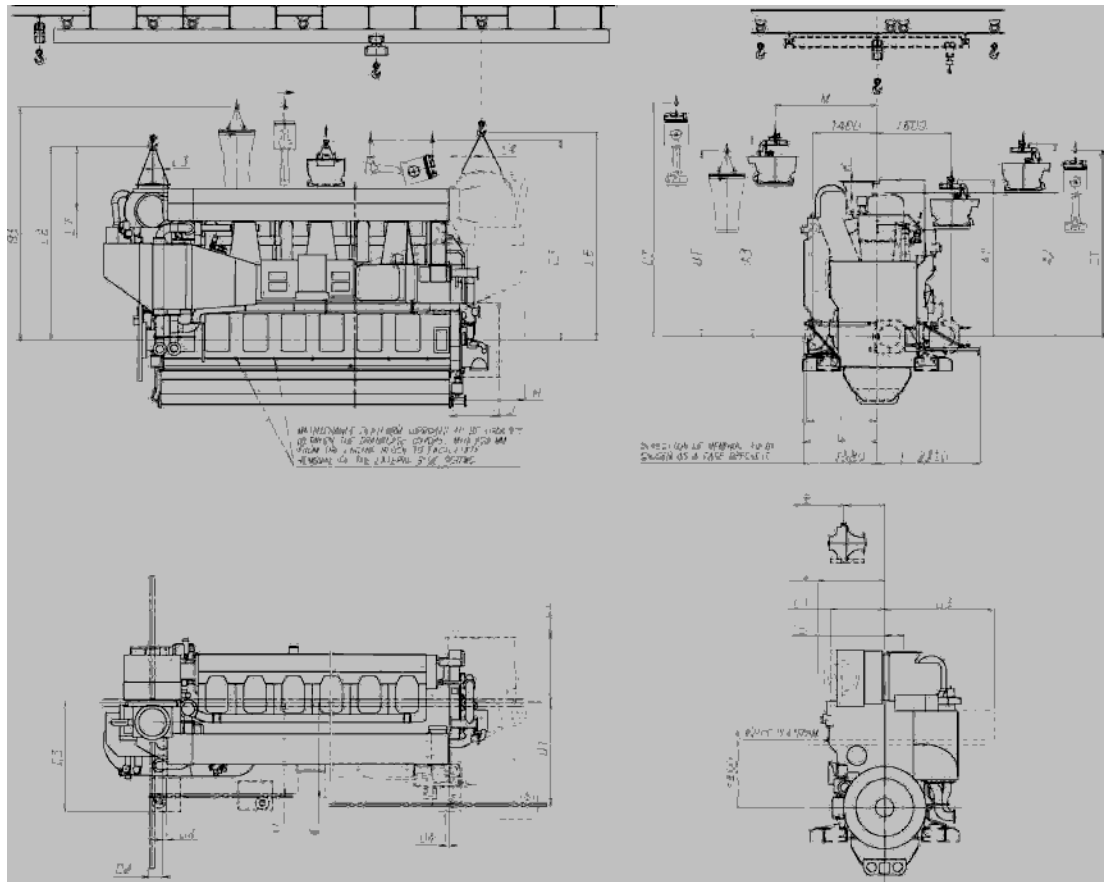


Fig 18-5 Service space requirement (DAAE093286C)

Services spaces in mm		6L50DF	8L-9L50DF
A1	Height needed for overhauling cylinder head freely over injection pump	3370	3370
A2	Height needed for transporting cylinder head freely over adjacent cylinder head covers	4000	4000
A3	Height needed for overhauling cylinder head freely over exhaust gas insulation box	4300	4300
B1	Height needed for transporting cylinder liner freely over injection pump	4000	4000
B2	Height needed for transporting cylinder liner freely over adjacent cylinder head covers	4840	4840
B3	Height needed for transporting cylinder liner freely over exhaust gas insulation box	5020	5020
C1	Height needed for overhauling piston and connecting rod	4000	4000
C2	Height needed for transporting piston and connecting rod freely over adjacent cylinder head covers	4840	4840
C3	Height needed for transporting piston and connecting rod freely over exhaust gas insulation box	5020	5020
D1	Recommended lifting point for charge air cooler lifting tool	2000	2200
D2	Height of the lifting eye for CAC lifting tool	300	800
D3	Width needed for dismantling charge air cooler and air inlet box sideways by using lifting tool	2100	2350
D4	Recommended lifting point for CAC lifting tool	75	75
E	Width needed for removing main bearing side screw	1525	1525
F	Width needed for dismantling connecting rod big end bearing	2210	2210
G	Width of lifting tool for hydraulic cylinder / main bearing nuts	1590	1590
H	Distance needed to dismantle lube oil pump	1060	1060
J	Distance needed to dismantle water pumps	1600	1600
K	Space necessary for opening the cover main cabinet	2050	2100
L1	Rec. axial clearance for dismantling and assembly of silencer is 500mm, min. clearance is mm for 6L50DF/TPL71 and 180mm for 8-9L50DF/TPL76. The given dimension L1 includes the min. maintenance space.	TPL71: 1000	TPL76: 1270
L2	Rec. axial clearance for dismantling and assembly of suction branch is 500mm, min. clearance is mm for 6L50DF/TPL71 and 180mm for 8-9L50DF/TPL76. The given dimension L2 includes the min. maintenance space.	TPL71: 1200	TPL76: 1570
L3	Recommended lifting point for the TC (driving end)	TPL71: 310	TPL76: n/a
L4	Recommended lifting point for the TC (free end)	TPL71: 785	TPL76: 700
L5	Recommended lifting point sideways for the TC	TPL71: 472	TPL76: 340
L6	Height needed for dismantling the TC	TPL71: 3800	TPL76: 4800
L7	Height needed for dismantling the TC from center of TC	TPL71: 1150	TPL76: 1980
L8	Recommended lifting point for the TC (cartridge group)	TPL71: n/a	TPL76: 960
M	Recommended lifting point for main parts to pass CAC housing	2200	2400

18.4.2 Service space requirement for the V-engine

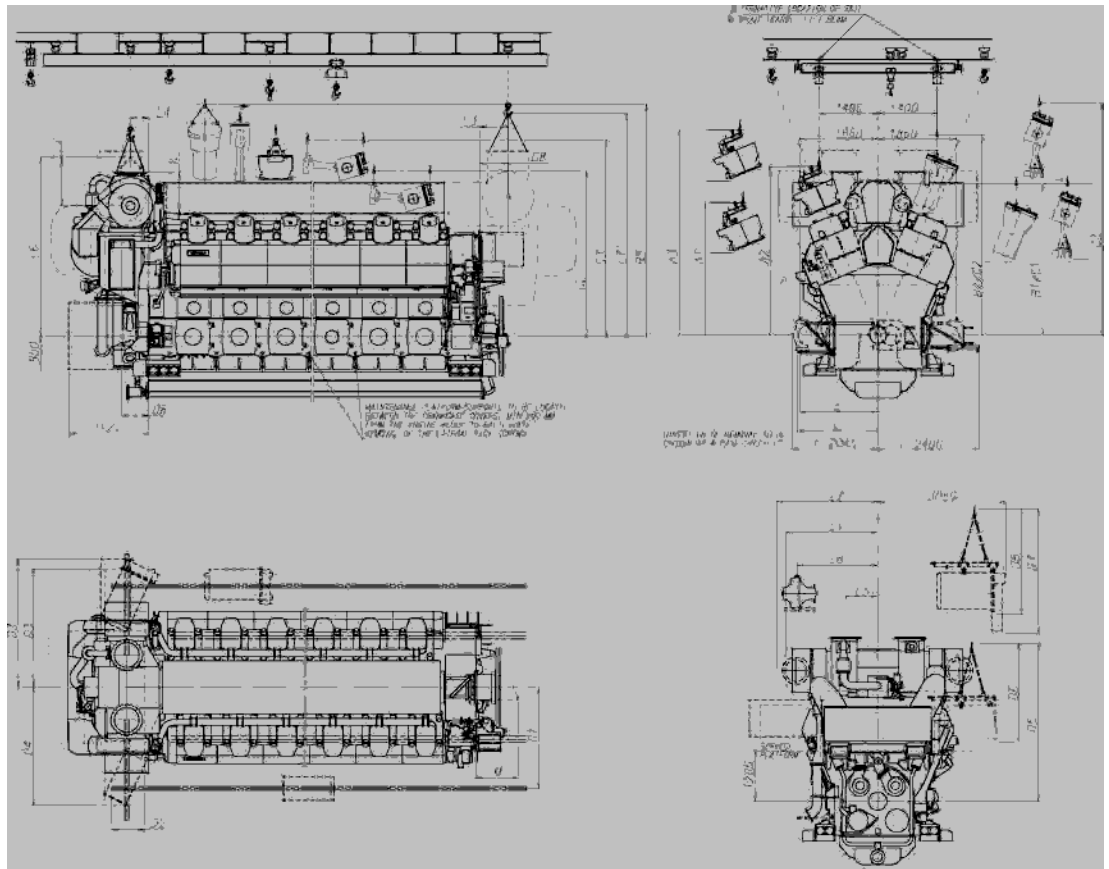


Fig 18-6 Service space requirement (DAAE093288A)

Services spaces in mm		12V50DF	16V50DF
A1	Height needed for overhauling cylinder head freely over injection pump	3150	3150
A2	Height needed for overhauling cylinder head freely over adjacent cylinder head covers	4000	4000
A3	Height needed for overhauling cylinder head freely over exhaust gas insulation box	4860	4860
B1	Height needed for transporting cylinder liner freely over injection pump	3600	3600
B2	Height needed for transporting cylinder liner freely over adjacent cylinder head covers	4750	4750
B3	Height needed for transporting cylinder liner freely over exhaust gas insulation box	5500	5500
C1	Height needed for overhauling piston and connecting rod	3600	3600
C2	Height needed for transporting piston and connecting rod freely over adjacent cylinder head covers	4750	4750
C3	Height needed for transporting piston and connecting rod freely over exhaust gas insulation box	5500	5500
D1	Recommended location of rail dismantling CAC sideways by using lifting tool	2400	2400
D2	Recommended location of starting point for rails	800	1000
D3	Min width needed for dismantling CAC with end cover of CAC by using lifting tool	2800	3050
D4	Min width needed for dismantling CAC without end cover of CAC by using lifting tool	2800	2900
D5	Height needed for overhauling CAC	3725	3915
D6	Height needed for overhauling CAC without end cover	2350	2500
D7	Height needed for overhauling CAC with end cover	-	2950
D8	Recommended location of rail dismantling CAC	640	690
E	Width needed for removing main bearing side screw	1850	1850
F	Width needed for dismantling connecting rod big end bearing	2400	2400
G	Width of lifting tool for hydraulic cylinder / main bearing nuts	1915	1915
H	Distance needed to dismantle lube oil pump	1900	1900
J	Distance needed to dismantle water pumps	1900	1900
K	Distance between cylinder head cap and TC flange	TPL71: 970	1480
L1	Rec. axial clearance for dismantling and assembly of silencer is 500mm, min. clearance is 140mm for 12V50DF/TPL71 and 180mm for 16-TPL76. The given dimension L1 includes the min. maintenance space.	TPL71: 2180	TPL76: 2560
L2	Rec. axial clearance for dismantling and assembly of suction branch is 500mm, min. clearance is 140mm for 12V50DF/TPL71 and 180mm for 16-TPL76. The given dimension L2 includes the min. maintenance space.	TPL71: 2405	TPL76: 2845
L3	Recommended lifting point for the TC (driving end)	TPL71: 435	TPL76: 680
L4	Recommended lifting point for the TC (free end)	TPL71: 435	TPL76: 680
L5	Recommended lifting point sideways for the TC	TPL71: 770	TPL76: 930
L6	Height needed for dismantling the TC	TPL71: 4250	TPL76: 5280
L7	Height needed for dismantling the TC from center of TC	TPL71: 1150	TPL76: 1300
L8	Recommended lifting point for the TC (cartridge)	TPL71: 1920	TPL76: 2230
M	Space necessary for opening the cover of the main cabinet	1000	1000

19. Transport Dimensions and Weights

19.1 Lifting of engines

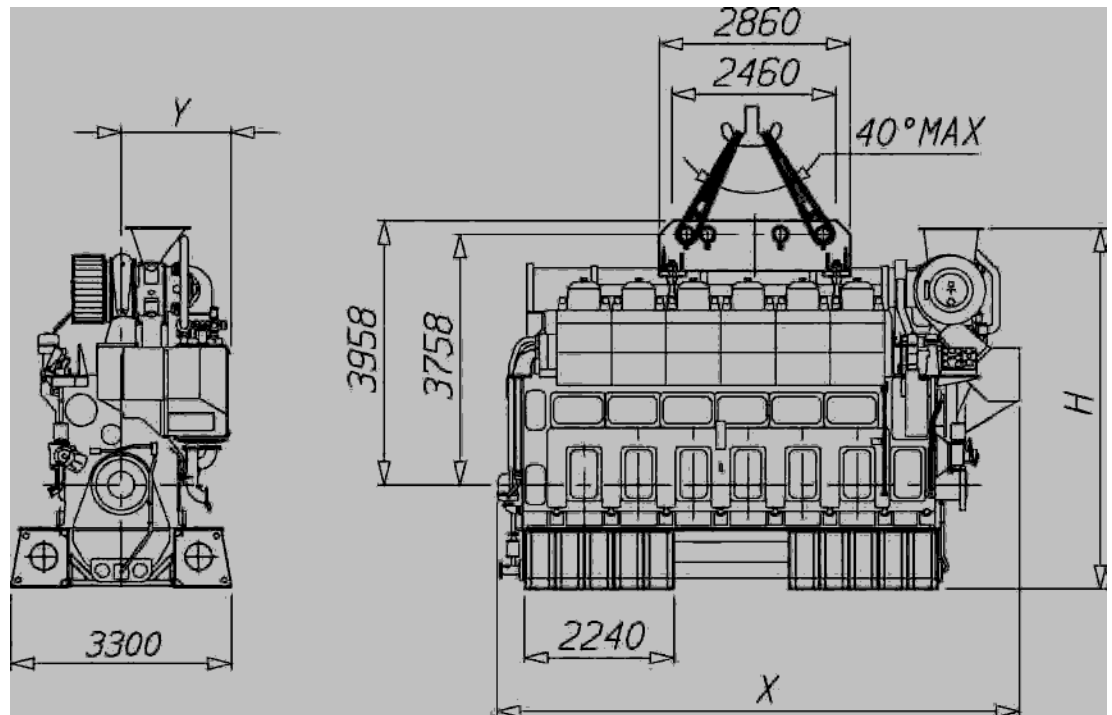


Fig 19-1 Lifting of rigidly mounted in-line engines (4V83D0212c)

Engine type	X [mm]	Y [mm]	H [mm]	Weights without flywheel [ton]			
				Engine	Lifting device	Transport cradle	Total weight
W 6L50DF	8115	1600	5510	96	3.5	6.5	106
W 8L50DF	9950	1860	5510	128	3.5	6.5	138
W 9L50DF	10800	1860	5675	148	3.5	9.5	161

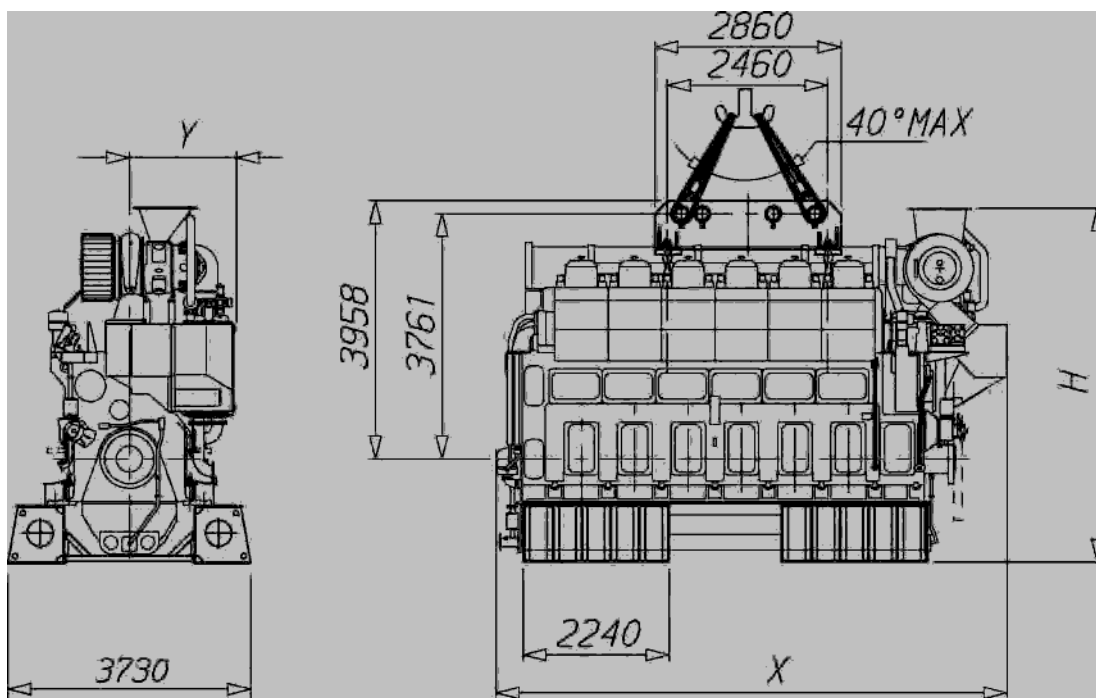


Fig 19-2 Lifting of flexibly mounted in-line engines (4V83D0211c)

Engine type	X [mm]	Y [mm]	H [mm]	Weights without flywheel [ton]				
				Engine	Fixing rails	Lifting device	Transport cradle	Total weight
W 6L50DF	8115	1600	5650	96	4.0	3.5	6.5	110
W 8L50DF	9950	1860	5650	128	5.0	3.5	6.5	143
W 9L50DF	10800	1860	5815	148	5.0	3.5	9.5	166

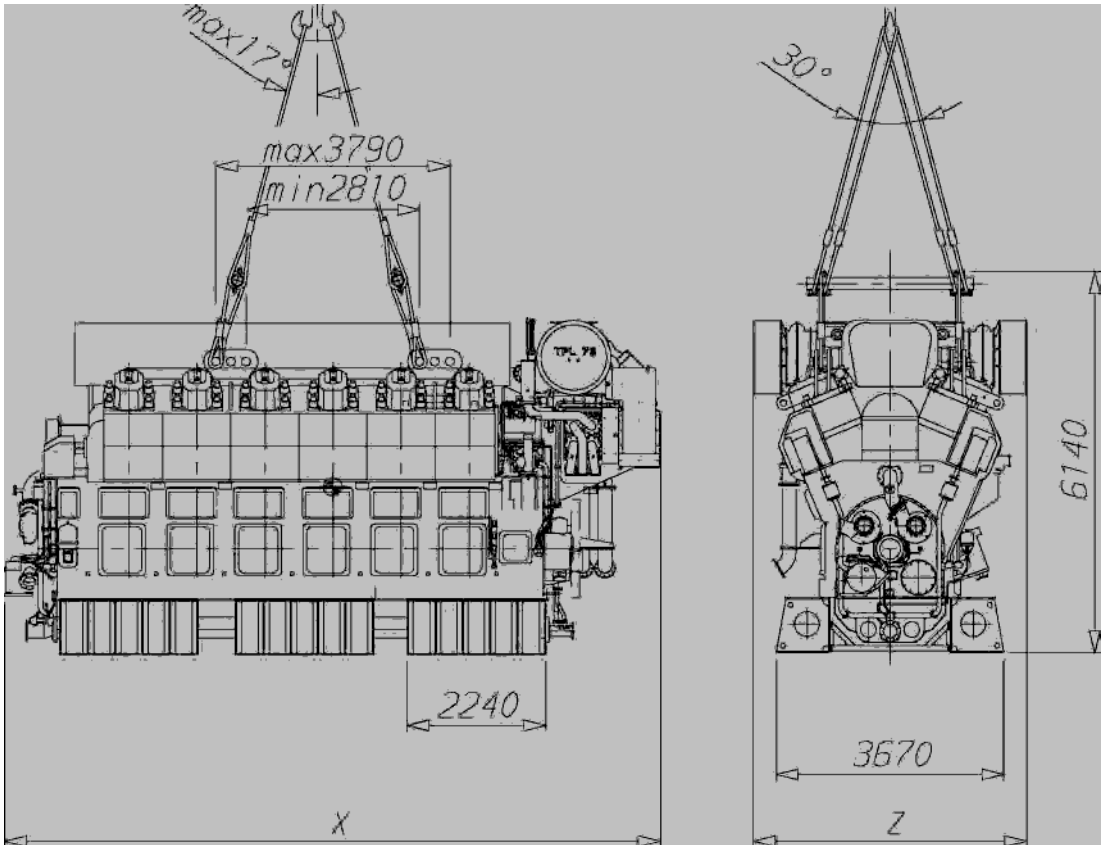


Fig 19-3 Lifting of rigidly mounted V-engines (4V83D0248C)

Engine type	X 1) [mm]	X 2) [mm]	Z [mm]	Weights without flywheel [ton]			
				Engine	Lifting device	Transport cradle	total weight
W 12V50DF	10380	10600	4530	166	3.4	9.6	179
W 16V50DF	12580	12460	4530	211	3.4	9.6	224

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

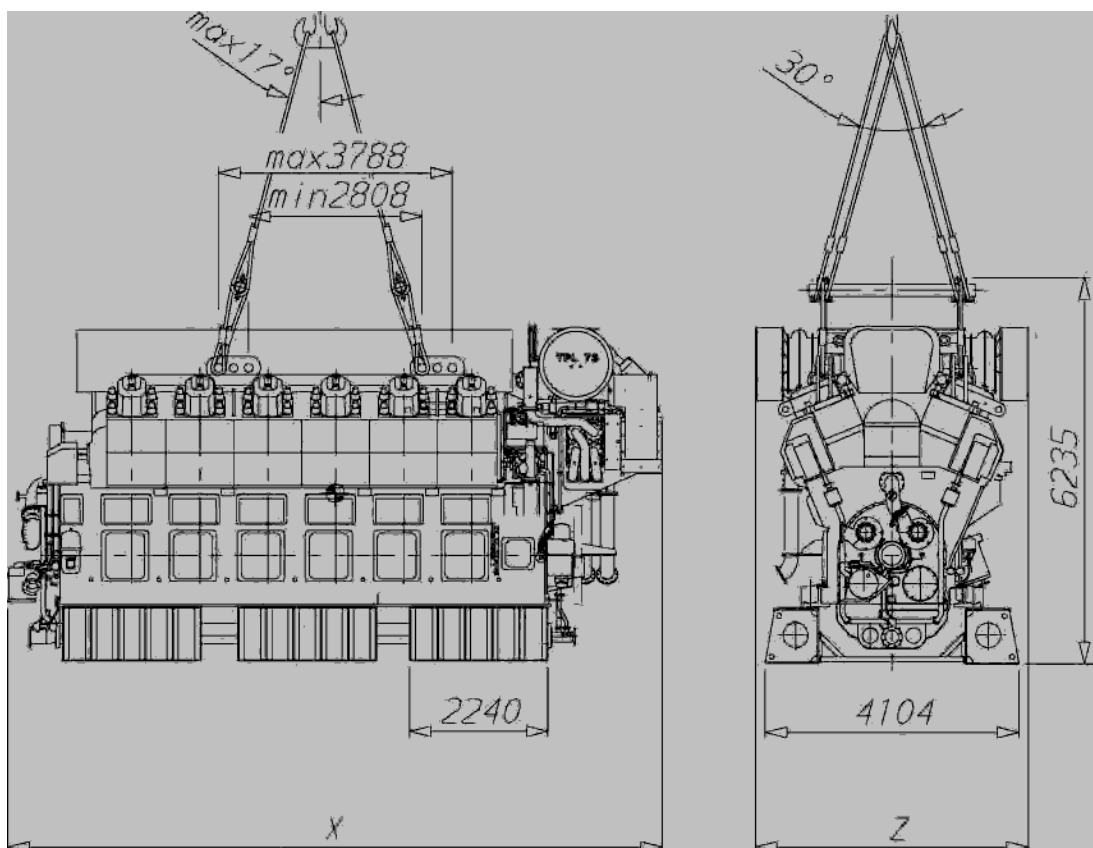


Fig 19-4 Lifting of flexibly mounted V-engines (4V83D0249C)

Engine type	X 1) [mm]	X 2) [mm]	Z [mm]	Weights without flywheel [ton]			
				Engine	Lifting device	Transport cradle	Total weight
W 12V50DF	10211	10601	4532	166.1	3.4	9.6	179.1
W 16V50DF	12300	12801	5350	213.9	3.4	9.6	226.9

2) Turbocharger at the flywheel end

1) Turbocharger at the free end

19.2 Engine components

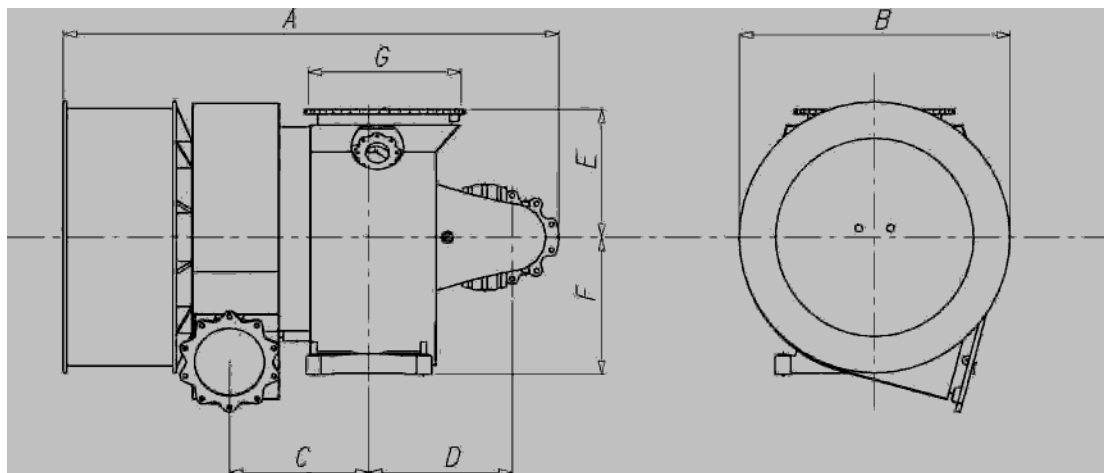


Fig 19-5 Turbocharger (3V92L1224e)

Engine type	Turbocharger	A	B	C	D	E	F	G	Weight, complete	Weight, rotor block cartridge
W 6L50DF	TPL 71	2003	1050	540	598	791	530	DN 600	1957	464
W 8L50DF W 9L50DF	TPL 76	2301	1340	641	688	1100	690	DN 800	3575	815
W 12V50DF	TPL 71	2003	1050	540	598	791	530	DN 600	1957	464
W 16V50DF	TPL 76	2301	1340	641	688	1100	690	DN 800	3575	815

All dimensions in mm. Weight in kg.

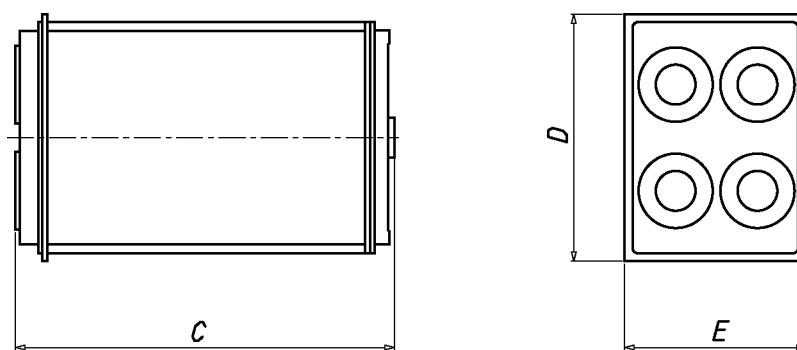


Fig 19-6 Charge air cooler inserts (3V92L1063)

Engine type	Model	C [mm]	D [mm]	E [mm]	Weight [kg]
W 6L50DF	TPL71	1650	840	615	1105
W 8L50DF	TPL71	1650	840	615	1105
W 9L50DF	TPL71	1650	840	615	1105

Engine type	Model	C [mm]	D [mm]	E [mm]	Weight [kg]
W 12V50DF	TPL71	1220	790	555	720
W 16V50DF	TPL71	1330	870	625	1375

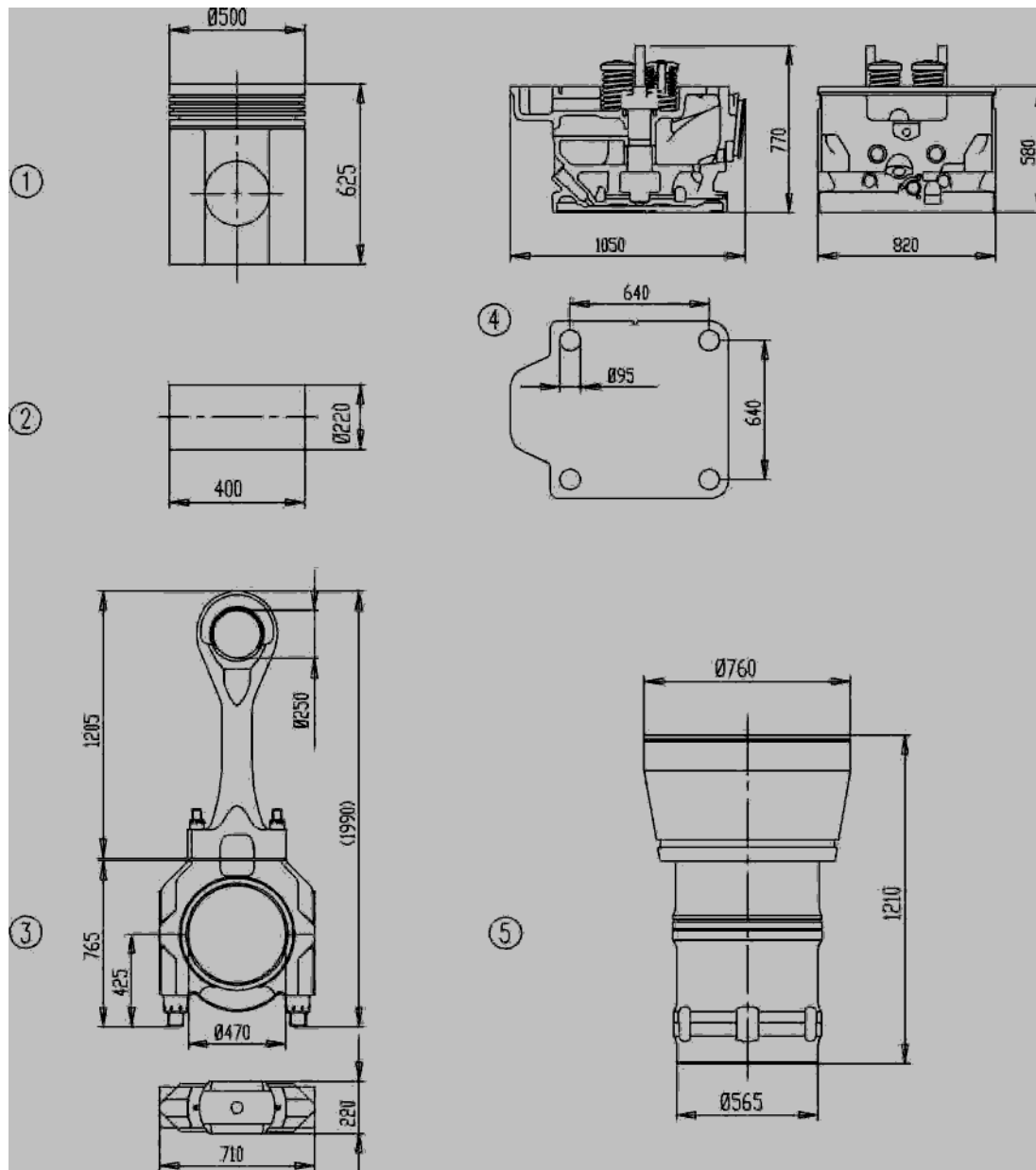


Fig 19-7 Major spare parts (4V92L1476)

Item	Description	Weight [kg]
1.	Piston	255
2.	Gudgeon pin	110
3.	Connecting rod, upper part	280
	Connecting rod, lower part	460
4.	Cylinder head	1250

Item	Description	Weight [kg]
5.	Cylinder liner	950

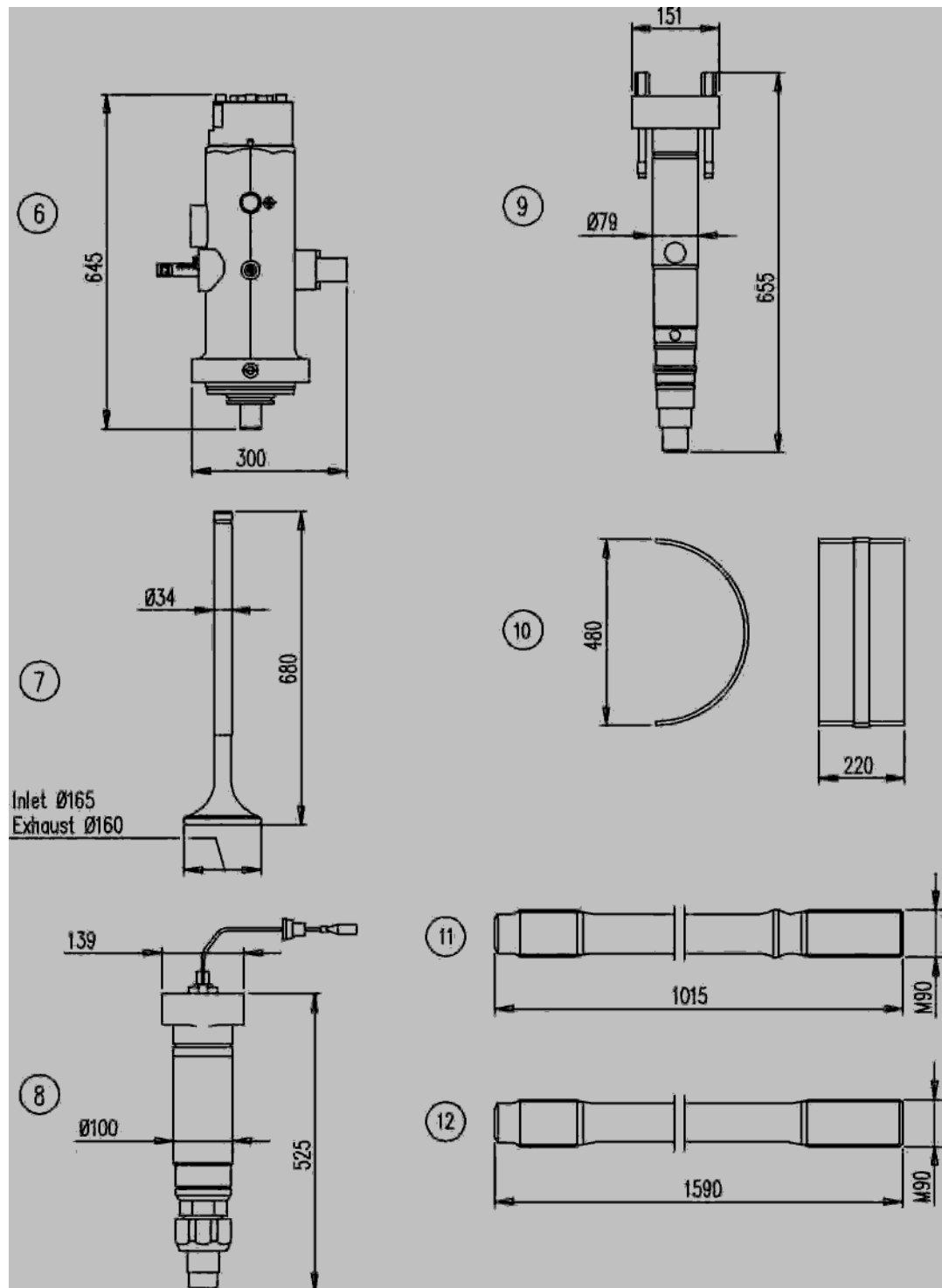


Fig 19-8 Major spare parts (4V92L1477)

Item	Description	Weight [kg]
6.	Injection pump	100
7.	Valve	10

Item	Description	Weight [kg]
8.	Injection valve	20
9.	Starting air valve	25
10.	Main bearing shell	15
11.	Main bearing screw	60
12.	Cylinder head screw	80

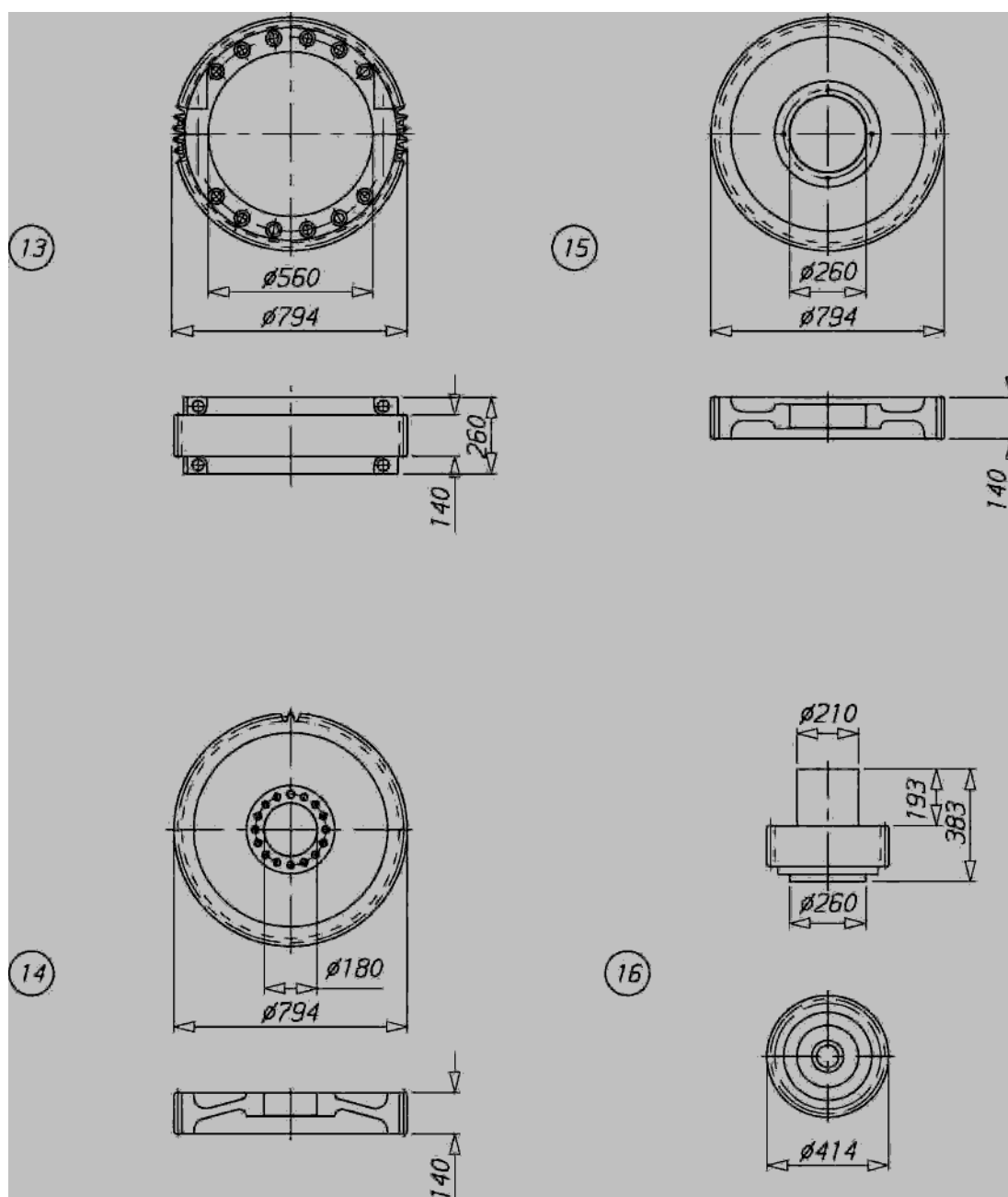


Fig 19-9 Major spare parts (4V92L0931a)

Item	Description	Weight [kg]
13.	Split gear wheel	360

Item	Description	Weight [kg]
14.	Camshaft gear wheel	685
15.	Bigger intermediate wheel	685
16.	Smaller intermediate wheel	550

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20. Product Guide Attachments

This and 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 ₂ O	4.015
kPa	foot H ₂ O	0.335
kPa	mm H ₂ O	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	$F = 9/5 \text{ } ^\circ\text{C} + 32$
°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			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
1 X2101		Valve (general)	10 X2113		Check valve globe type	17 X2131		Control valve with electric motor actuator
2 X8068		Valve, globe type	11 X8078		Swing check valve (Form 1)	18 X2103		Two-way valve with solenoid actuator
3 X8071		Valve, ball type	12 X8165		Swing check valve (Form 2)	19		Two-way valve with double-acting cylinder actuator (pneumatic)
4 X8074		Valve, gate type	13 X2174		Safety valve, spring loaded, globe type	20 X2104		Two-way valve with electric motor actuator
5 X8075		Valve, butterfly type (Form 1)	14 X1021		Manual operation of valve	21 X2101		Two-way valve with diaphragm actuator (pneumatic)
6 X8075		Valve, butterfly type (Form 2)	15 X2001		Weight-loaded safety valve detained in open position after operation	22		Two-way control valve with diaphragm actuator (pneumatic)
7 X8076		Valve, needle type	16 X2134		Float-operated control valve	23 X2002		Spring-loaded safety two-way valve with automatic return after operation
8 X8087		Valve, control type, continuously operated						
9 X8077		Check valve (general), (Two-way non-return valves, flow from left to right)						

Fig 21-1 List of symbols (DAAF406507 - 1)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
24		Manually operated control valve	33 X8070		Valves, three way globe type	40		Three-way control valve with diaphragm actuator
25 X2112		Combined non-return valve and manually actuated stop valve, flow from left to right	34 X8073		Valves, three way ball type	41		Self-operating pressure reducing three-way control valve
26		Spring-loaded non-return valve, flow from left to right	35		Three-way control valve with electrical motor actuator	42		Self-operating thermostatic three-way control valve
27 X2133		Self-operating pressure reducing control valve	36 X2103		Three-way valve with solenoid actuator	43		Self-contained thermostat valve
28		Pressure control valve (spring loaded)	37 X2107		Three-way valve with double-acting cylinder actuator (pneumatic)	44 2102		Valve, angle type (general)
29		Pressure control valve (remote pressure sensing)	38		Three-way valve with electric motor actuator	45 X8069		Valve, angle globe type
30		Pneumatically actuated valve, spring-loaded cylinder actuator	39 X2102		Three-way valve with diaphragm actuator			
31		Quick-closing valve						
32 2103		Valve, three way type (general)						

Fig 21-2 List of symbols (DAAF406507 - 2)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
PDS Reg. No.	SYMBOL	DESCRIPTION	PDS Reg. No.	SYMBOL	DESCRIPTION	PDS Reg. No.	SYMBOL	DESCRIPTION
45 X8972		Valve, angle ball type	55 772		Orifice plate	62		Valve 3/2 Pneum/Pneum
47 X9125		Safety valve, spring loaded, globe angle type	56 X2183		Shuttle valve with "AND"-function	63		Valve 3/2 Pneum/Spring
48		Weight loaded angled valve detained in open position after operation	57		Valve 3/2 Pneum/Pneum	64		Valve 3/2 Solenoid/Spring
49		Spring-loaded safety angled valve with automatic return after operation	58		Valve 3/2 Pneum/Spring	65		Valve 3/2 Lever/Spring
50		Non-return angled two-way valve. Flow from left to right	59		Valve 3/2 Solenoid/Spring	66		Valve 3/2 Manual/Spring
51		Non-return angled two-way valve hand operating. Flow from left to right	60		Valve 3/2 Lever/Spring	67		Valve 3/2 Pneum/Pneum
52 2181		Self-operating release valve (steam trap)	61		Valve 3/2 Manual/Spring			
53 X2212		Adjustable restrictor (valve)						
54 2031		Restrictor						

Fig 21-3 List of symbols (DAAF406507 - 3)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
PDS Reg. No.	SYMBOL	DESCRIPTION	PDS Reg. No.	SYMBOL	DESCRIPTION	PDS Reg. No.	SYMBOL	DESCRIPTION
68		Valve 3/2 Pneum/Spring	77		Electrically driven compressor	84 X8079		Heat exchanger (general), condenser
69		Valve 3/2 Solenoid/Spring	78 2302		Compressor, vacuum pump (general)	85 X2674		Pneumatic-air lubricator
70		Valve 3/2 Lever/Spring	79 2301		Pump, liquid type (general)	86 X8111		Cooling tower, dry with induced draught
71		Valve 3/2 Manual/Spring	80 2401		Hydraulic pump	87 2021		Cooling tower (general) (degenerator)
72		Turbogenerator	81		Manual hydraulic pump	88 2040		Funnel
73		Turbogenerator with gear transmission	82 X2071		Boiler feedwater vessel with deaerator	89		Trough or drip tray with drain funnel
74		Turbocharger	83 2501		Heating or cooling coil			
75 20082		Electric motor (general)						
76		Electrically driven pump						

Fig 21-4 List of symbols (DAAF406507 - 4)























INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
PDS Reg. No.	SYMBOL	DESCRIPTION	PDS Reg. No.	SYMBOL	DESCRIPTION	PDS Reg. No.	SYMBOL	DESCRIPTION
90 517		Flanged dummy cover (Bled flange pair)	99 564		Quick-release coupling element of female type	106		Air vent + flame arrestor
91 511		Flanged connection	100 563		Quick-release coupling element of male type	107 2036		Flame arrestor
92 518		End cap	101 x411		Hose	108 x322		Pipeline with thermal insulation
93 514		Screwed joint	102 537		Expansion sleeve	109 x8174		Piping, heated or cooled and insulated
94 516		Reducer	103 533		Compensator (Expansion bellows)	110 x2619		High speed centrifugal separator
95		Joint with change of pipe dimension, pipe reducer acoustical	104 2038		Siphon	111 x2614		Centrifuge with perforated shell (Centrifugal filter)
96 565		Quick-release coupling element which fits into another coupling element of the same type	105 2039		Vent (outlet to the atmosphere for steam/gas)			
97 567		Quick-release coupling element of female type with automatic closing when decoupled						
98 566		Quick-release coupling element of male type with automatic closing when decoupled						

Fig 21-5 List of symbols (DAAF406507 - 5)























INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
PDS Reg. No.	SYMBOL	DESCRIPTION	PDS Reg. No.	SYMBOL	DESCRIPTION	PDS Reg. No.	SYMBOL	DESCRIPTION
112 x8116		Liquid filter (general)	121 x8123		Screening device, sieve, strainer, general	126 x2069		Vessel with heated ends and heating / cooling jacket
113 x8117		Liquid filter, bag, candle or cartridge type	122 x8031		Gravity separator, settling chamber	129 2033		Silencer
114		Automatic filter with by-pass filter	123 x2618		Separator, cyclone type	130 2034		Blowing glass
115 x8019		Suction filter	124 x8090		Strainer	131		Receiver, pulse damper
116 x8119		Liquid rotary filter, drum or disc type	125 2073		Pressure vessel with diaphragm, for example expansion vessel	132		Indicating measuring instrument P = Pressure, Q = Flow, T = Temperature, V = Volume, W = Weight
117		Duplex filter	126 2062		Pressure or vacuum vessel	133		Local instrument
118		Candle filter with rotating drum with by-pass	127 301		Tank, vessel			
119 x8122		Gas filter (general)						
120 x8022		Gas filter, bag, candle or cartridge type						

Fig 21-6 List of symbols (DAAF406507 - 6)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
PDS Reg. No.	SYMBOL	DESCRIPTION	PDS Reg. No.	SYMBOL	DESCRIPTION	PDS Reg. No.	SYMBOL	DESCRIPTION
134		Local panel	141 X1032		Automatic operation of valve with two stable positions open and close	148		
135		Signal to control board	142			149		
136		TI = Temperature indicator TE = Temperature sensor TFC = Temperature sensor shut-down PI = Pressure indicator PS = Pressure switch PT = Pressure transmitter PSZ = Pressure switch shut-down PDIS = Differential pressure indicator and alarm LS = Level switch QS = Flow switch TSZ = Temperature switch	143			150		
137 X2122		Overflow safety valve	144			151		
138 X1045		Flow rate indication	145			152		
139 X1056		Recording of flow rate with summation of volume	146			153		
140 X1036		Automatic operation of valve with infinite number of stable positions	147					

Fig 21-7 List of symbols (DAAF406507 - 7)

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