WÄRTSILÄ

WÄRTSILÄ Engines

Wärtsilä 20DF

PRODUCT GUIDE

Introduction

This Product Guide provides data and system proposals for the early design phase of marine engine installations. For contracted projects specific instructions for planning the installation are always delivered. Any data and information herein is subject to revision without notice. This 1/2018 issue replaces all previous issues of the Wärtsilä 20DF Product Guides.

Issue	Published	Updates
1/2018	17.9.2018	Technical data section updated. Other minor updates.
3/2016	13.09.2016	Technical data updated
2/2016	20.05.2016	Cetane index for pilot fuel oils added
1/2016	18.03.2016	Performance data update. Other minor updates.
1/2015	27.02.2015	Updates throughout the product guide
1/2013	19.12.2013	Information for W20DF engines with cylinder output 185kW added

Wärtsilä, Marine Solutions

Vaasa, September 2018

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1. Main Data and Outputs

1.1 Technical main data

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

Cylinder bore .... 200 mm

Stroke .... 280 mm

Piston displacement .... 8.8 l/cyl

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

Cylinder configuration .... 6, 8 and 9 in-line

Direction of rotation .... clockwise, counterclockwise on request

Speed .... 1000, 1200 rpm

Mean piston speed .... 9.3, 11.2 m/s

1.2 Maximum continuous output

Table 1-1 Rating table for Wärtsilä 20DF

Engine type	Main Engines		Generating sets			
	1200 rpm		1000 rpm		1200 rpm	
	kW	BHP	Engine [kW]	Generator [kVA]	Engine [kW]	Generator [kVA]
Wärtsilä 6L20DF	1056	1440	876	1050	1056	1270
	1110	1510	960	1150	1110	1330
Wärtsilä 8L20DF	1408	1920	1168	1400	1408	1690
	1480	2010	1280	1540	1480	1780
Wärtsilä 9L20DF	1584	2150	1314	1580	1584	1900
	1665	2260	1440	1730	1665	2000

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

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

where:

P_e = mean effective pressure [bar]

P = output per cylinder [kW]

n = engine speed [r/min]

D = cylinder diameter [mm]

L = length of piston stroke [mm]

c = operating cycle (4)

1.3 Output limitations in gas mode

1.3.1 Output limitations due to methane number

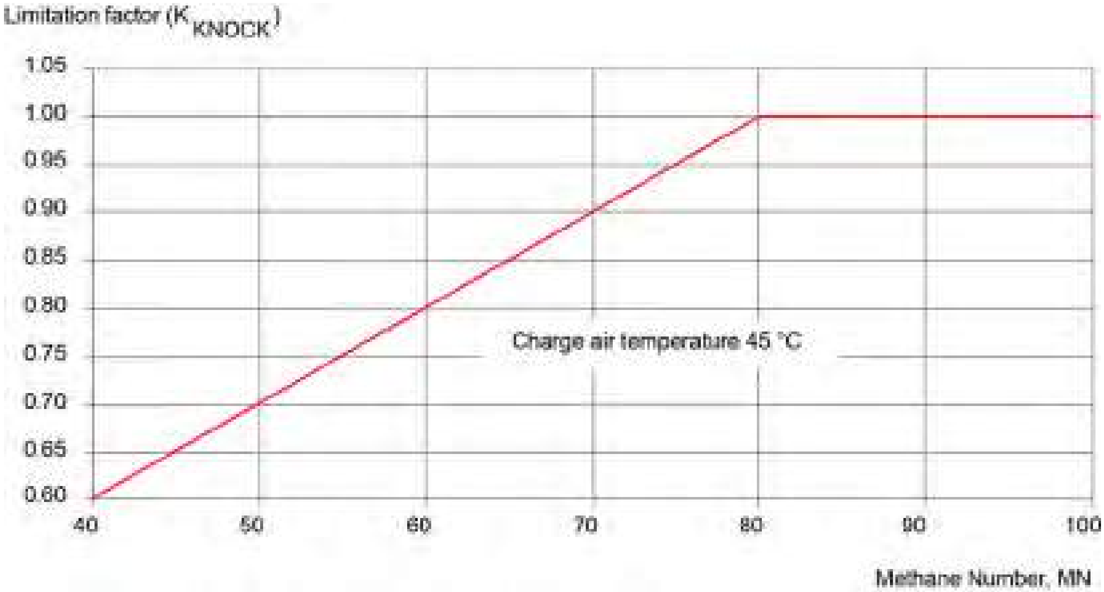

Fig 1-1 Output limitation due to methane number

Notes:

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

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

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

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

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

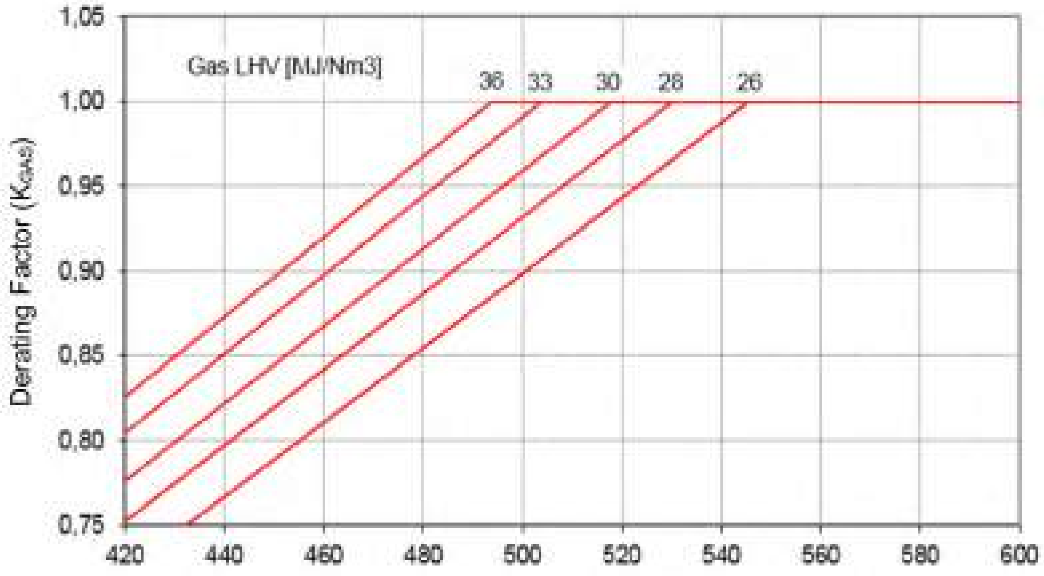

Fig 1-2 **Output limitation due to gas feed pressure and LHV**

Notes:

The above given values for gas feed pressure are at engine inlet (before the gas filter).

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/Nm^3.

Values are given in Nm^3 is at 0 °C and 101.3 kPa.

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

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

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

1.4 Reference conditions

The output is available within a range of ambient conditions and coolant temperatures 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).

1.5 Operation in inclined position (only for Marine Solutions engines)

The engine is designed to ensure proper engine operation at inclination positions, specified under IACS M46.2 (1982) (Rev.1 June 2002) - Main and auxiliary machinery.

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

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

Inclination in all directions requires special arrangements.

NOTE

- Athwartships and fore-end-aft inclinations may occur simultaneously

- Inclination angles are applicable ONLY to marine main and auxiliary machinery engines. Emergency power installations are not currently available

- If inclination exceeds some of the above mentioned IACS requirements, a special arrangement might be needed. Please fill in a NSR (Non-standard request)

1.6 Principal dimensions and weights

1.6.1 Main engines

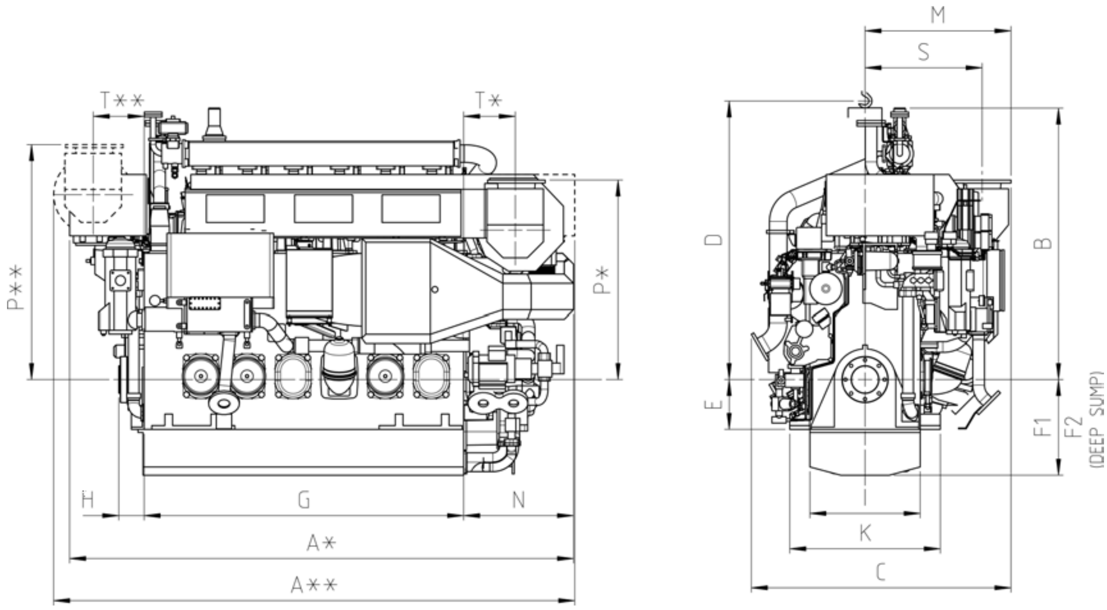

Fig 1-3 Main engines (DAAF014777A)

Engine type	A*	A**	B	C*	C**	D	E	F1	F2	G	H
W 6L20DF	3218	3383	1767	1690	1690	1800	325	624	824	2080	155
W 8L20DF	3888	4099	1767	1824	1860	1800	325	624	824	2680	155
W 9L20DF	4200	4401	1767	1824	1845	1800	325	624	824	2980	155

Engine type	I	K	M*	M**	N*	N**	P*	P**	S*	S**	T*	T**
W 6L20DF	718	980	950	951	653	717	1297	1528	781	763	336	266
W 8L20DF	718	980	1084	1127	723	717	1390	1614	863	907	339	329
W 9L20DF	718	980	1084	1127	723	717	1390	1614	863	907	339	329

Engine type	Wet Sump*	Deep Sump*	Wet Sump**	Deep Sump*
W 6L20DF	9.3	9.5	9.5	9.7
W 8L20DF	11.6	11.8	-	-
W 9L20DF	12.6	12.8	13.1	13.4

* Turbocharger at free end
**Turbocharger at flywheel end
Dimensions in mm. Weight in tonnes.

A	Total length of the engine
B	Height from the crankshaft centerline to the highest point of the engine
C	Total width of the engine
D	Minimum height when removing a piston
E	Dimension from the crankshaft centerline to the engine feet

F1	Dimension from the crankshaft centerline to the bottom of the oil sump, with wet sump
F2	Dimension from the crankshaft centerline to the bottom of the oil sump, with deep oil sump
G	Length of the engine block
H	Dimension from the end of the engine block to the end of the crankshaft
I	Width of oil sump
K	Width of the engine block at the engine feet
M	Dimension from the center of the crankshaft to the outermost part on the back side of the engine
N	Outer dimension from the engine block
P	Dimension from the crankshaft to the center of the exhaust gas outlet
S	Dimension from the center of the crankshaft to the exhaust gas outlet
T	Dimension from the end of the engine block to the center of the exhaust gas outlet

1.6.2 Generating sets

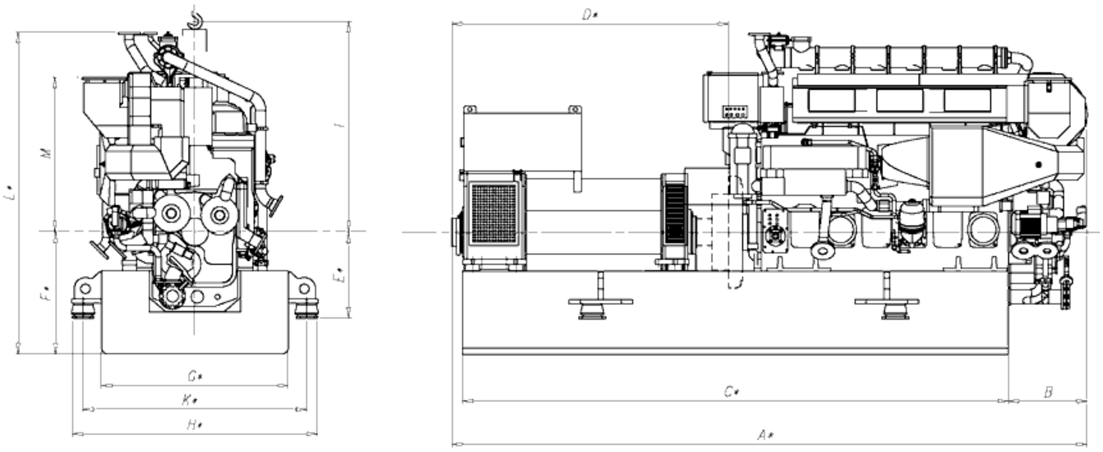

Fig 1-4 Generating sets (DAAF014947A)

Engine type	A*	B	C*	D*	E*	F*	G*	H*	I	K*	L*	M*	Weight*
W 6L20DF	5325	663	4575	2300	725	895 975 1025	1270 1420 1570	1770 1920 2070	1800	1580 1730 1880	2605 2681 2731	1299	16.9
W 8L20DF	6030	731	5100	2310	725	1025 1075	1420 1570	1920 2070	1800	1730 1880	2731 2781	1390	20.8
W 9L20DF	6535	731	5400	2580	725	1075 1125	1570 1800	2070 2300	1800	1880 2110	2781 2831	1390	23.9

** Dependent on generator and flexible coupling.*

All dimensions in mm. Weight in metric tonnes with liquids.

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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 Wärtsilä supply.

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

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

2.1.1.1 Operating field for CP Propeller

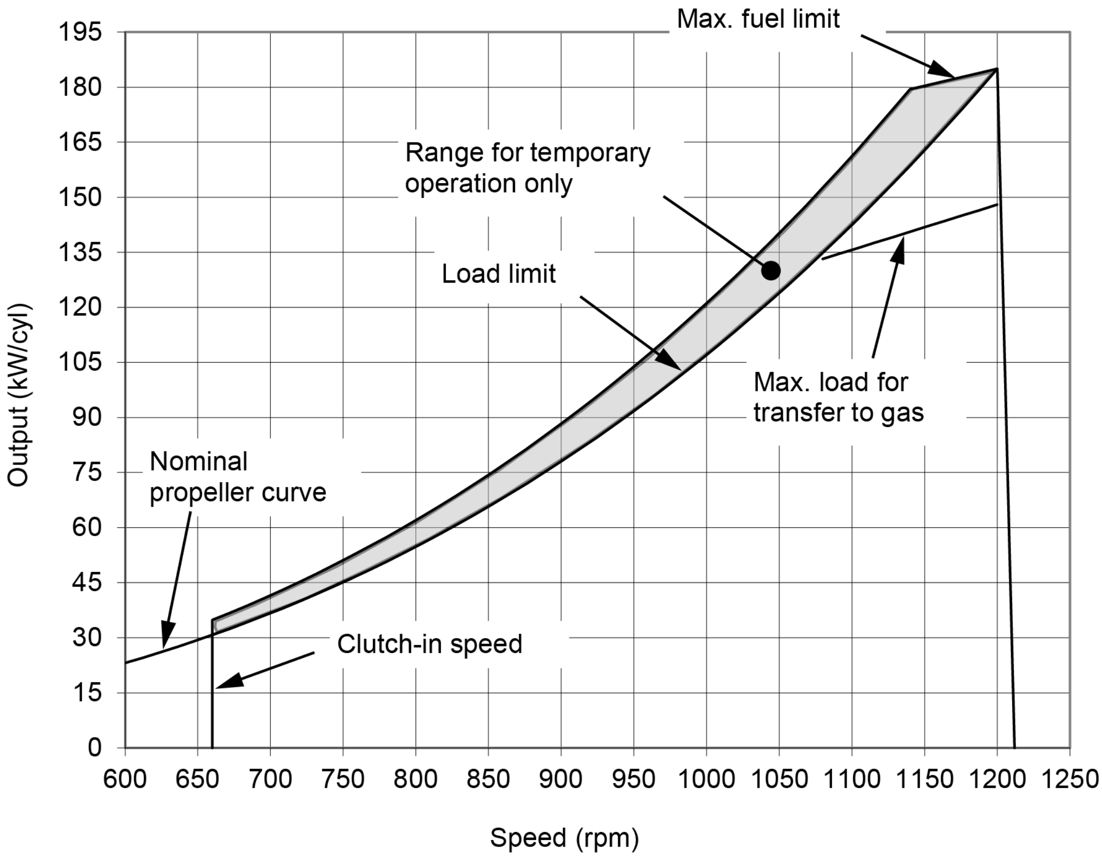

Fig 2-1 **Operating field for CP Propeller, rated speed 1200 rpm**

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 “nominal” (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 this ramp must be used. Minimum temperatures for loading the engine are, minimum HT temperature 60ºC, preferably 70ºC, minimum lubricating oil temperature 40ºC, minimum receiver temperature 45ºC when engine starts and keeps running in gas mode (by using LT preheating). Transferring from diesel to gas operation, fast load changes must be avoided.

The loading ramp Diesel operation max is the maximum capability of the engine in diesel mode. It shall not be used as the normal loading rate in diesel mode. This can be used in critical situations e.g. when recovering from a fault condition to regain sufficient propulsion and steering as fast as possible.

The loading ramp Gas operation max indicates the maximum capability of the engine in gas mode. Faster loading may result in alarms, knock and undesired trips to diesel.

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).

The load should always be applied gradually in normal operation. Acceptable load incensements are smaller in gas mode than in diesel mode and also at high load, during which sudden load changes must be taken into account in certain applications. The time between load incensements must be such that the maximum loading rate is not exceeded.

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)

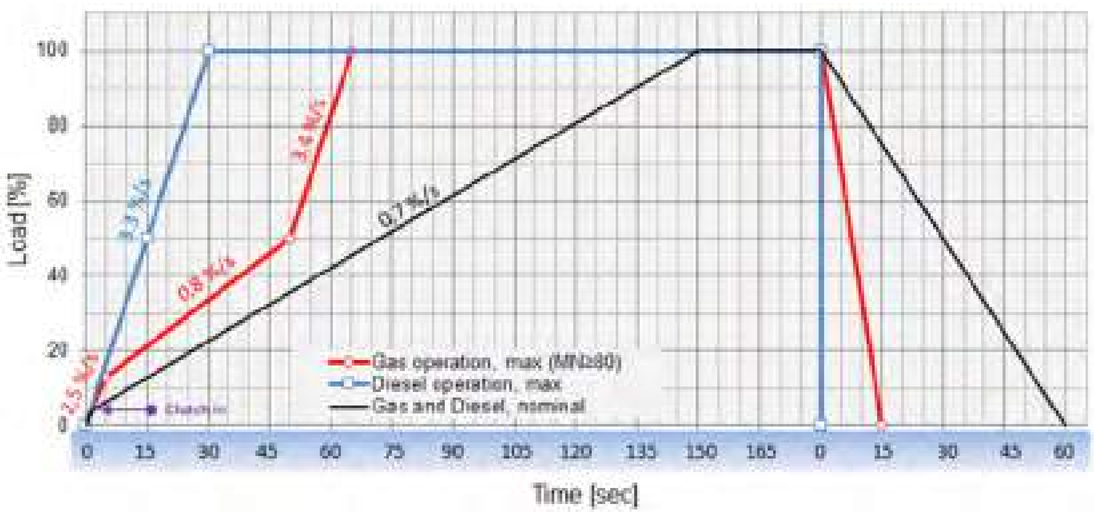

Fig 2-2 Maximum load increase rates for variable speed engines

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

2.2.2 Constant speed applications

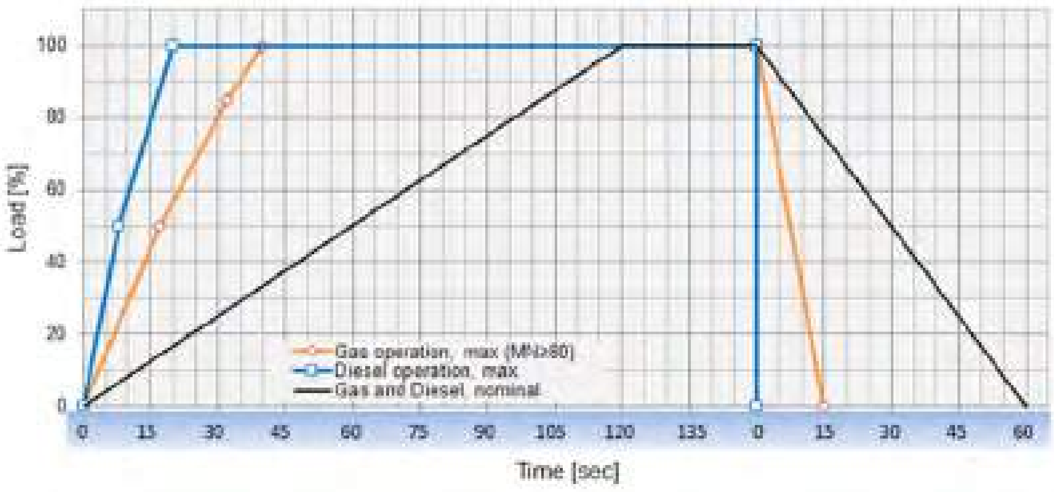

Fig 2-3 Increasing load successively from 0 to 100% MCR

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

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

2.2.2.1 Maximum instant load steps

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

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

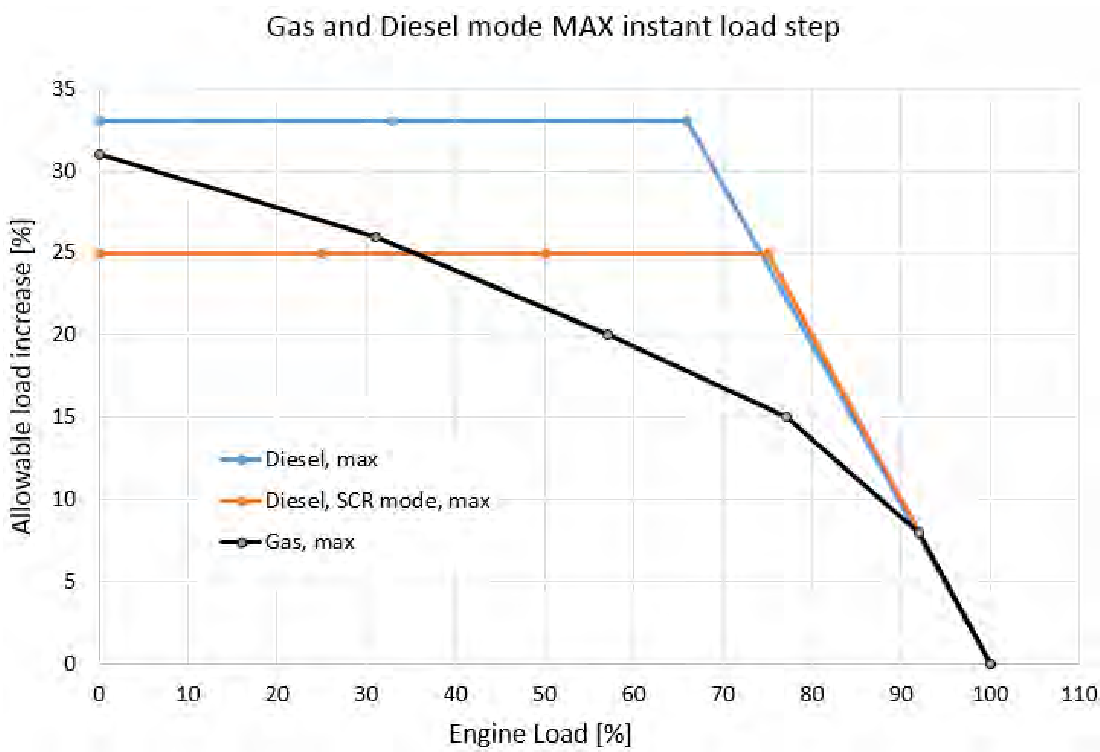

Fig 2-4 Maximum instant load steps in % of MCR

Gas mode

- Maximum step-wise load increases according to figure
- Steady-state frequency band ≤ 1.5 %
- Maximum speed drop 10 %
- Steady-state recovery time ≤ 10 s
- Time between load steps of maximum size ≥ 15 s
- Maximum step-wise load reductions: 100-75-45-0%

Diesel mode

- Maximum step-wise load increase 33% of MCR
- Steady-state frequency band ≤ 1.0 %
- Maximum speed drop 10 %
- Steady-state recovery time ≤ 5 s
- Time between load steps of maximum size ≥ 8 s

Start-up

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

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

The engine can be started with gas mode selected. It will then start using gas fuel 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 Low load operation

2.3.1 Operation at low load and idling

Absolute idling (declutched main engine, disconnected generator):

- Maximum 10 minutes if the engine is to be stopped after the idling. 3-5 minutes idling before stop is recommended.
- Maximum 6 hours if the engine is to be loaded after the idling.
- Maximum idling speed is 1000 rpm (see note).

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 minimum 70 % of the rated output for 1 hour.

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

- No restrictions.

NOTE

Idling is performed at 1000 rpm. For 1200 rpm engines the engine speed is increased to 1200 rpm when synchronization is selected. In case the generator breaker is opened the engine automatically goes to 1000 rpm if a stop command is not given.

3. Technical Data

3.1 Introduction

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

3.1.1 Engine driven pumps

The fuel consumption stated in the technical data tables is with engine driven pumps. The fuel consumption of engine driven pump is given below, correction in g/kWh.

Table 3-1 Constant speed engines

Engine driven pump	Engine load [%]			
	100	85	75	50
Lube Oil	2.7	3.0	3.5	5.4
LT Water	0.6	0.7	0.8	1.2
HT Water	0.6	0.7	0.8	1.1

Table 3-2 Variable speed engines

Engine driven pump	Engine load [%]			
	100	85	75	50
Lube Oil	3.8	4.1	4.5	5.8
LT Water	0.7	0.6	0.6	0.6
HT Water	0.6	0.6	0.6	0.6

3.2 Wärtsilä 6L20DF

3.2.1 AUX DE ME 1000 & 1200 rpm

Wärtsilä 6L20DF		AE/DE		AE/DE		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**160**		**185**		**185**	
Engine speed	rpm	1000		1200		1200	
Speed mode		Constant		Constant		Variable	
Engine output	kW	960		1110		1110	
Mean effective pressure	MPa	2.18		2.1		2.1	
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	1.5	1.9	1.8	2.2	1.8	2.2
Temperature at turbocharger intake, max.	°C	45		45		45	
Temperature after air cooler (TE 601)	°C	45	50	45	50	45	50
Exhaust gas system (Note 2)							

Wärtsilä 6L20DF		AE/DE		AE/DE		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**160**		**185**		**185**	
Flow at 100% load	kg/s	1.6	1.9	1.8	2.2	1.8	2.3
Flow at 75% load	kg/s	1.2	1.5	1.4	1.7	1.4	1.7
Flow at 50% load	kg/s	0.9	1.0	1.1	1.2	1.1	1.2
Temperature after turbocharger at 100% load (TE 517)	°C	370	325	380	330	380	315
Temperature after turbocharger at 75% load (TE 517)	°C	400	330	415	325	410	325
Temperature after turbocharger at 50% load (TE 517)	°C	410	360	385	360	375	325
Backpressure, max.	kPa	5		5		5	
Calculated exhaust diameter for 35 m/s	mm	321	343	347	370	347	371
Heat balance at 100% load (Note 3)							
Jacket water, HT-circuit	kW	200	210	245	250	245	245
Charge air, LT-circuit	kW	260	330	300	410	310	430
Lubricating oil, LT-circuit	kW	145	140	165	175	165	175
Radiation	kW	45	45	50	50	50	50
Fuel consumption (Note 4)							
Total energy consumption at 100% load	kJ/kWh	8180	-	8330	-	8370	-
Total energy consumption at 85% load	kJ/kWh	8390	-	8510	-	8460	-
Total energy consumption at 75% load	kJ/kWh	8520	-	8720	-	8550	-
Total energy consumption at 50% load	kJ/kWh	9130	-	9500	-	9090	-
Fuel gas consumption at 100% load	kJ/kWh	8048	-	8189	-	8222	-
Fuel gas consumption at 85% load	kJ/kWh	8219	-	8314	-	8286	-
Fuel gas consumption at 75% load	kJ/kWh	8326	-	8493	-	8359	-
Fuel gas consumption at 50% load	kJ/kWh	8862	-	9211	-	8859	-
Fuel oil consumption at 100% load	g/kWh	3.2	194.6	3.5	197.2	3.6	196.3
Fuel oil consumption at 85% load	g/kWh	4.2	194.4	4.9	196.3	4.2	195.3
Fuel oil consumption at 75% load	g/kWh	4.7	195.3	5.5	197.2	4.6	195.3
Fuel oil consumption 50% load	g/kWh	6.7	206.1	7.0	208.0	5.6	197.5
Fuel gas system (Note 5)							
Gas pressure at engine inlet, min (PT901)	kPa (a)	520	-	550	-	550	-
Gas pressure to Gas Valve unit, min	kPa (a)	640	-	670	-	670	-
Gas temperature before Gas Valve Unit	°C	0...60	-	0...60	-	0...60	-
Fuel oil system							
Pressure before injection pumps (PT 101)	kPa	700±50		700±50		700±50	
Pressure before engine driven fuel feed pump, min. (MDF only)	kPa	15		15		15	
Fuel oil flow to engine, approx	m^3/h	1.1		1.2		1.2	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24
MDF viscosity, min.	cSt	1.8		1.8		1.8	
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h	-	0.8	-	0.9	-	0.9
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	2.0	3.9	2.3	4.6	2.3	4.6
Pilot fuel (MDF) viscosity before the engine	cSt	1.8...11.0		1.8...11.0		1.8...11.0	

Wärtsilä 6L20DF		AE/DE		AE/DE		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**160**		**185**		**185**	
Pilot fuel pressure at engine inlet (112)	kPa	10...40		10...40		10...40	
Pilot fuel pressure drop after engine, max	kPa	13		13		13	
Lubricating oil system							
Pressure before bearings, nom. (PT 201)	kPa	450		450		450	
Suction ability, including pipe loss, max.	kPa	20		20		20	
Priming pressure, nom. (PT 201)	kPa	80		80		80	
Temperature before bearings, nom. (TE 201)	°C	66		66		66	
Temperature after engine, approx.	°C	78		78		78	
Pump capacity (main), engine driven	m^3/h	34		34		48	
Pump capacity (main), electrically driven	m^3/h	21		21		21	
Priming pump capacity (50/60Hz)	m^3/h	8.6 / 10.5		8.6 / 10.5		8.6 / 10.5	
Oil volume, wet sump	m^3	0.38		0.38		0.5	
Oil volume in separate system oil tank	m^3	2		2		2	
Oil consumption at 100% load, approx.	g/kWh	0.4		0.4		0.4	
Crankcase ventilation flow rate at full load	l/min	726		726		726	
Crankcase ventilation backpressure, max.	Pa	300		300		300	
Oil volume in speed governor	l	1.4...2.2		1.4...2.2		1.4...2.2	
HT cooling water system							
Pressure at engine, after pump, nom. (PT 401)	kPa	200 + static		200 + static		200 + static	
Pressure at engine, after pump, max. (PT 401)	kPa	500		500		350	
Temperature before cylinders, approx. (TE 401)	°C	83		83		83	
Temperature after engine, nom.	°C	91		91		91	
Capacity of engine driven pump, nom.	m^3/h	30		30		30	
Pressure drop over engine, total	kPa	90		90		90	
Pressure drop in external system, max.	kPa	150 (1.5)		150 (1.5)		150 (1.5)	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Water volume in engine	m^3	0.12		0.12		0.12	
Delivery head of stand-by pump	kPa	200		200		200	
LT cooling water system							
Pressure at engine, after pump, nom. (PT 471)	kPa	200+ static		200+ static		200+ static	
Pressure at engine, after pump, max. (PT 471)	kPa	500		500		350	
Temperature before engine, max. (TE 471)	°C	38		38		38	
Temperature before engine, min. (TE 471)	°C	25		25		25	
Capacity of engine driven pump, nom.	m^3/h	36		39		39	
Pressure drop over charge air cooler	kPa	30		30		30	
Pressure drop in external system, max.	kPa	120 (1.2)		120 (1.2)		120 (1.2)	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Delivery head of stand-by pump	kPa	200		200		200	
Starting air system							
Pressure, nom.	kPa	3000		3000		3000	
Pressure, max.	kPa	3000		3000		3000	
Low pressure limit in air vessels	kPa	1800		1800		1800	

Wärtsilä 6L20DF		AE/DE		AE/DE		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**160**		**185**		**185**	
Starting air consumption, start (successful)	Nm^3	1.2		1.2		1.2	

Notes:

Note 1 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 5%.

Note 2 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C). Flow tolerance 5% and temperature tolerance 15°C.

Note 3 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Tolerance for cooling water heat 10%, tolerance for radiation heat 30%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers.

Note 4 At ambient conditions according to ISO 15550 and receiver temperature 45 °C. Lower calorific value 42 700 kJ/kg for pilot fuel and 49 620 kJ/kg for gas fuel. With engine driven pumps (two cooling water pumps, one lubricating oil pump and pilot fuel pump). Tolerance 5%.

Note 5 Fuel gas pressure given at LHV = 36MJ/m³N. Required fuel gas pressure depends on fuel gas LHV and need to be increased for lower LHV's. Pressure drop in external fuel gas system to be considered. See chapter Fuel system for further information.

ME = Engine driving propeller, variable speed

AE = Auxiliary engine driving generator

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

3.2.2 SCR Ready

Wärtsilä 6L20DF (SCR Ready)		AE/DE		AE/DE		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**160**		**185**		**185**	
Engine speed	rpm	1000		1200		1200	
Speed mode		Constant		Constant		Variable	
Engine output	kW	960		1110		1110	
Mean effective pressure	MPa	2.18		2.1		2.1	
IMO compliance		Tier 3		Tier 3		Tier 3	
Combustion air system (Note 1)							
Flow at 100% load	kg/s	1.5	1.8	1.8	2.1	1.8	2.1
Temperature at turbocharger intake, max.	°C	45		45		45	
Temperature after air cooler (TE 601)	°C	45	50	45	50	45	50
Exhaust gas system (Note 2)							
Flow at 100% load	kg/s	1.6	1.9	1.8	2.2	1.8	2.2
Flow at 75% load	kg/s	1.2	1.4	1.4	1.7	1.4	1.6
Flow at 50% load	kg/s	0.9	1.0	1.1	1.2	1.1	1.1
Temperature after turbocharger at 100% load (TE 517)	°C	370	340	380	340	380	340
Temperature after turbocharger at 75% load (TE 517)	°C	400	340	415	340	410	340
Temperature after turbocharger at 50% load (TE 517)	°C	410	360	385	360	375	340
Backpressure, max.	kPa	5		5		5	

Wärtsilä 6L20DF (SCR Ready)		AE/DE		AE/DE		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**160**		**185**		**185**	
Calculated exhaust diameter for 35 m/s	mm	321	342	347	368	347	368
Heat balance at 100% load (Note 3)							
Jacket water, HT-circuit	kW	200	215	245	260	245	255
Charge air, LT-circuit	kW	260	320	300	400	310	410
Lubricating oil, LT-circuit	kW	145	140	165	175	165	175
Radiation	kW	45	45	50	50	50	50
Fuel consumption (Note 4)							
Total energy consumption at 100% load	kJ/kWh	8180	-	8330	-	8370	-
Total energy consumption at 85% load	kJ/kWh	8390	-	8510	-	8460	-
Total energy consumption at 75% load	kJ/kWh	8520	-	8720	-	8550	-
Total energy consumption at 50% load	kJ/kWh	9130	-	9500	-	9090	-
Fuel gas consumption at 100% load	kJ/kWh	8048	-	8189	-	8222	-
Fuel gas consumption at 85% load	kJ/kWh	8219	-	8314	-	8286	-
Fuel gas consumption at 75% load	kJ/kWh	8326	-	8493	-	8359	-
Fuel gas consumption at 50% load	kJ/kWh	8862	-	9211	-	8859	-
Fuel oil consumption at 100% load	g/kWh	3.2	196.5	3.5	200.1	3.6	198.8
Fuel oil consumption at 85% load	g/kWh	4.2	196.3	4.9	198.2	4.2	197.4
Fuel oil consumption at 75% load	g/kWh	4.7	196.6	5.5	198.5	4.6	197.2
Fuel oil consumption 50% load	g/kWh	6.7	206.1	7.0	208.0	5.6	199.4
Fuel gas system (Note 5)							
Gas pressure at engine inlet, min (PT901)	kPa (a)	520	-	550	-	550	-
Gas pressure to Gas Valve unit, min	kPa (a)	640	-	670	-	670	-
Gas temperature before Gas Valve Unit	°C	0...60	-	0...60	-	0...60	-
Fuel oil system							
Pressure before injection pumps (PT 101)	kPa	700±50		700±50		700±50	
Pressure before engine driven fuel feed pump, min. (MDF only)	kPa	15		15		15	
Fuel oil flow to engine, approx	m³/h	1.1		1.3		1.2	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24
MDF viscosity, min.	cSt	1.8		1.8		1.8	
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h	-	0.8	-	0.9	-	0.9
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	2.0	3.9	2.3	4.6	2.3	4.6
Pilot fuel (MDF) viscosity before the engine	cSt	1.8...11.0		1.8...11.0		1.8...11.0	
Pilot fuel pressure at engine inlet (112)	kPa	0...40		0...40		0...40	
Pilot fuel pressure drop after engine, max	kPa	13		13		13	
Lubricating oil system							
Pressure before bearings, nom. (PT 201)	kPa	450		450		450	
Suction ability, including pipe loss, max.	kPa	20		20		20	
Priming pressure, nom. (PT 201)	kPa	80		80		80	
Temperature before bearings, nom. (TE 201)	°C	66		66		66	
Temperature after engine, approx.	°C	78		78		78	

Wärtsilä 6L20DF (SCR Ready)		AE/DE		AE/DE		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**160**		**185**		**185**	
Pump capacity (main), engine driven	m³/h	34		34		48	
Pump capacity (main), electrically driven	m³/h	21		21		21	
Priming pump capacity (50/60Hz)	m³/h	8.6 / 10.5		8.6 / 10.5		8.6 / 10.5	
Oil volume, wet sump	m³	0.38		0.38		0.5	
Oil volume in separate system oil tank	m³	2		2		2	
Oil consumption at 100% load, approx.	g/kWh	0.4		0.4		0.4	
Crankcase ventilation flow rate at full load	l/min	726		726		726	
Crankcase ventilation backpressure, max.	Pa	300		300		300	
Oil volume in speed governor	l	1.4...2.2		1.4...2.2		1.4...2.2	
HT cooling water system							
Pressure at engine, after pump, nom. (PT 401)	kPa	200 + static		200 + static		200 + static	
Pressure at engine, after pump, max. (PT 401)	kPa	500		500		350	
Temperature before cylinders, approx. (TE 401)	°C	83		83		83	
Temperature after engine, nom.	°C	91		91		91	
Capacity of engine driven pump, nom.	m³/h	30		30		30	
Pressure drop over engine, total	kPa	90		90		90	
Pressure drop in external system, max.	kPa	150 (1.5)		150 (1.5)		150 (1.5)	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Water volume in engine	m³	0.12		0.12		0.12	
Delivery head of stand-by pump	kPa	200		200		200	
LT cooling water system							
Pressure at engine, after pump, nom. (PT 471)	kPa	200+ static		200+ static		200+ static	
Pressure at engine, after pump, max. (PT 471)	kPa	500		500		350	
Temperature before engine, max. (TE 471)	°C	38		38		38	
Temperature before engine, min. (TE 471)	°C	25		25		25	
Capacity of engine driven pump, nom.	m³/h	36		39		39	
Pressure drop over charge air cooler	kPa	30		30		30	
Pressure drop in external system, max.	kPa	120 (1.2)		120 (1.2)		120 (1.2)	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Delivery head of stand-by pump	kPa	200		200		200	
Starting air system							
Pressure, nom.	kPa	3000		3000		3000	
Pressure, max.	kPa	3000		3000		3000	
Low pressure limit in air vessels	kPa	1800		1800		1800	
Starting air consumption, start (successful)	Nm³	1.2		1.2		1.2	

Notes:

Note 1 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 5%.

Note 2 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C). Flow tolerance 5% and temperature tolerance 15°C.

Note 3 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Tolerance for cooling water heat 10%, tolerance for radiation heat 30%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers.

Note 4 At ambient conditions according to ISO 15550 and receiver temperature 45 °C. Lower calorific value 42 700 kJ/kg for pilot fuel and 49 620 kJ/kg for gas fuel. With engine driven pumps (two cooling water pumps, one lubricating oil pump and pilot fuel pump). Tolerance 5%.

Note 5 Fuel gas pressure given at LHV = 36MJ/m³N. Required fuel gas pressure depends on fuel gas LHV and need to be increased for lower LHV's. Pressure drop in external fuel gas system to be considered. See chapter Fuel system for further information.

ME = Engine driving propeller, variable speed

AE = Auxiliary engine driving generator

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

3.3 Wärtsilä 8L20DF

3.3.1 AUX DE ME 1000 & 1200 rpm

Wärtsilä 8L20DF		AE/DE		AE/DE		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**160**		**185**		**185**	
Engine speed	rpm	1000		1200		1200	
Speed mode		Constant		Constant		Variable	
Engine output	kW	1280		1480		1480	
Mean effective pressure	MPa	2.18		2.1		2.1	
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	2.0	2.5	2.3	2.9	2.3	3.0
Temperature at turbocharger intake, max.	°C	45		45		45	
Temperature after air cooler (TE 601)	°C	45	50	45	50	45	50
Exhaust gas system (Note 2)							
Flow at 100% load	kg/s	2.1	2.6	2.4	3.0	2.4	3.0
Flow at 75% load	kg/s	1.6	2.0	1.8	2.3	1.8	2.2
Flow at 50% load	kg/s	1.2	1.4	1.5	1.6	1.4	1.6
Temperature after turbocharger at 100% load (TE 517)	°C	370	325	380	330	380	315
Temperature after turbocharger at 75% load (TE 517)	°C	400	330	415	325	410	325
Temperature after turbocharger at 50% load (TE 517)	°C	410	360	385	360	375	325
Backpressure, max.	kPa	5		5		5	
Calculated exhaust diameter for 35 m/s	mm	370	396	401	428	401	428
Heat balance at 100% load (Note 3)							
Jacket water, HT-circuit	kW	266	280	326	334	326	326
Charge air, LT-circuit	kW	346	440	400	546	414	574
Lubricating oil, LT-circuit	kW	194	186	220	234	220	234
Radiation	kW	60	60	66	66	66	66
Fuel consumption (Note 4)							
Total energy consumption at 100% load	kJ/kWh	8180	-	8330	-	8370	-
Total energy consumption at 85% load	kJ/kWh	8390	-	8510	-	8460	-
Total energy consumption at 75% load	kJ/kWh	8520	-	8720	-	8550	-
Total energy consumption at 50% load	kJ/kWh	9130	-	9500	-	9090	-
Fuel gas consumption at 100% load	kJ/kWh	8048	-	8189	-	8222	-
Fuel gas consumption at 85% load	kJ/kWh	8219	-	8314	-	8286	-
Fuel gas consumption at 75% load	kJ/kWh	8326	-	8493	-	8359	-
Fuel gas consumption at 50% load	kJ/kWh	8862	-	9211	-	8859	-
Fuel oil consumption at 100% load	g/kWh	3.2	194.6	3.5	197.2	3.6	196.3
Fuel oil consumption at 85% load	g/kWh	4.2	194.4	4.9	196.3	4.2	195.3
Fuel oil consumption at 75% load	g/kWh	4.7	195.3	5.5	197.2	4.6	195.3
Fuel oil consumption 50% load	g/kWh	6.7	206.1	7.0	208.0	5.6	197.5

Wärtsilä 8L20DF		AE/DE		AE/DE		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**160**		**185**		**185**	
Fuel gas system (Note 5)							
Gas pressure at engine inlet, min (PT901)	kPa (a)	520	-	550	-	550	-
Gas pressure to Gas Valve unit, min	kPa (a)	640	-	670	-	670	-
Gas temperature before Gas Valve Unit	°C	0...60	-	0...60	-	0...60	-
Fuel oil system							
Pressure before injection pumps (PT 101)	kPa	700±50		700±50		700±50	
Pressure before engine driven fuel feed pump, min. (MDF only)	kPa	15		15		15	
Fuel oil flow to engine, approx	m³/h	1.4		1.6		1.6	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24
MDF viscosity, min.	cSt	1.8		1.8		1.8	
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h	-	1.0	-	1.2	-	1.2
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	2.6	5.2	3.1	6.1	3.1	6.1
Pilot fuel (MDF) viscosity before the engine	cSt	1.8...11.0		1.8...11.0		1.8...11.0	
Pilot fuel pressure at engine inlet (112)	kPa	10...40		10...40		10...40	
Pilot fuel pressure drop after engine, max	kPa	13		13		13	
Lubricating oil system							
Pressure before bearings, nom. (PT 201)	kPa	450		450		450	
Suction ability, including pipe loss, max.	kPa	20		20		20	
Priming pressure, nom. (PT 201)	kPa	80		80		80	
Temperature before bearings, nom. (TE 201)	°C	66		66		66	
Temperature after engine, approx.	°C	78		78		78	
Pump capacity (main), engine driven	m³/h	48		48		64	
Pump capacity (main), electrically driven	m³/h	27		27		27	
Priming pump capacity (50/60Hz)	m³/h	8.6 / 10.5		8.6 / 10.5		8.6 / 10.5	
Oil volume, wet sump	m³	0.49		0.49		0.64	
Oil volume in separate system oil tank	m³	2		2		2	
Oil consumption at 100% load, approx.	g/kWh	0.4		0.4		0.4	
Crankcase ventilation flow rate at full load	l/min	823		823		823	
Crankcase ventilation backpressure, max.	Pa	300		300		300	
Oil volume in speed governor	l	1.4...2.2		1.4...2.2		1.4...2.2	
HT cooling water system							
Pressure at engine, after pump, nom. (PT 401)	kPa	200 + static		200 + static		200 + static	
Pressure at engine, after pump, max. (PT 401)	kPa	500		500		350	
Temperature before cylinders, approx. (TE 401)	°C	83		83		83	
Temperature after engine, nom.	°C	91		91		91	
Capacity of engine driven pump, nom.	m³/h	40		41		41	
Pressure drop over engine, total	kPa	90		90		90	
Pressure drop in external system, max.	kPa	150 (1.5)		150 (1.5)		150 (1.5)	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Water volume in engine	m³	0.15		0.15		0.15	
Delivery head of stand-by pump	kPa	200		200		200	

Wärtsilä 8L20DF		AE/DE		AE/DE		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**160**		**185**		**185**	
LT cooling water system							
Pressure at engine, after pump, nom. (PT 471)	kPa	200+ static		200+ static		200+ static	
Pressure at engine, after pump, max. (PT 471)	kPa	500		500		350	
Temperature before engine, max. (TE 471)	°C	38		38		38	
Temperature before engine, min. (TE 471)	°C	25		25		25	
Capacity of engine driven pump, nom.	m³/h	48		51		51	
Pressure drop over charge air cooler	kPa	30		30		30	
Pressure drop in external system, max.	kPa	120 (1.2)		120 (1.2)		120 (1.2)	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Delivery head of stand-by pump	kPa	200		200		200	
Starting air system							
Pressure, nom.	kPa	3000		3000		3000	
Pressure, max.	kPa	3000		3000		3000	
Low pressure limit in air vessels	kPa	1800		1800		1800	
Starting air consumption, start (successful)	Nm³	1.2		1.2		1.2	

Notes:

Note 1 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 5%.

Note 2 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C). Flow tolerance 5% and temperature tolerance 15°C.

Note 3 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Tolerance for cooling water heat 10%, tolerance for radiation heat 30%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers.

Note 4 At ambient conditions according to ISO 15550 and receiver temperature 45 °C. Lower calorific value 42 700 kJ/kg for pilot fuel and 49 620 kJ/kg for gas fuel. With engine driven pumps (two cooling water pumps, one lubricating oil pump and pilot fuel pump). Tolerance 5%.

Note 5 Fuel gas pressure given at LHV = 36MJ/m³N. Required fuel gas pressure depends on fuel gas LHV and need to be increased for lower LHV's. Pressure drop in external fuel gas system to be considered. See chapter Fuel system for further information.

ME = Engine driving propeller, variable speed

AE = Auxiliary engine driving generator

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

3.3.2 SCR Ready

Wärtsilä 8L20DF (SCR Ready)		AE/DE		AE/DE		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**160**		**185**		**185**	
Engine speed	rpm	1000		1200		1200	
Speed mode		Constant		Constant		Variable	
Engine output	kW	1280		1480		1480	
Mean effective pressure	MPa	2.18		2.1		2.1	
IMO compliance		Tier 3		Tier 3		Tier 3	

Wärtsilä 8L20DF (SCR Ready)		AE/DE		AE/DE		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**160**		**185**		**185**	
Combustion air system (Note 1)							
Flow at 100% load	kg/s	2.0	2.4	2.3	2.8	2.3	2.8
Temperature at turbocharger intake, max.	°C	45		45		45	
Temperature after air cooler (TE 601)	°C	45	50	45	50	45	50
Exhaust gas system (Note 2)							
Flow at 100% load	kg/s	2.1	2.5	2.4	2.9	2.4	2.9
Flow at 75% load	kg/s	1.6	1.9	1.8	2.2	1.8	2.2
Flow at 50% load	kg/s	1.2	1.4	1.5	1.6	1.4	1.4
Temperature after turbocharger at 100% load (TE 517)	°C	370	340	380	340	380	340
Temperature after turbocharger at 75% load (TE 517)	°C	400	340	415	340	410	340
Temperature after turbocharger at 50% load (TE 517)	°C	410	360	385	360	375	340
Backpressure, max.	kPa	5		5		5	
Calculated exhaust diameter for 35 m/s	mm	370	395	401	425	401	425
Heat balance at 100% load (Note 3)							
Jacket water, HT-circuit	kW	266	286	326	346	326	340
Charge air, LT-circuit	kW	346	426	400	534	414	546
Lubricating oil, LT-circuit	kW	194	186	220	234	220	234
Radiation	kW	60	60	66	66	66	66
Fuel consumption (Note 4)							
Total energy consumption at 100% load	kJ/kWh	8180	-	8330	-	8370	-
Total energy consumption at 85% load	kJ/kWh	8390	-	8510	-	8460	-
Total energy consumption at 75% load	kJ/kWh	8520	-	8720	-	8550	-
Total energy consumption at 50% load	kJ/kWh	9130	-	9500	-	9090	-
Fuel gas consumption at 100% load	kJ/kWh	8048	-	8189	-	8222	-
Fuel gas consumption at 85% load	kJ/kWh	8219	-	8314	-	8286	-
Fuel gas consumption at 75% load	kJ/kWh	8326	-	8493	-	8359	-
Fuel gas consumption at 50% load	kJ/kWh	8862	-	9211	-	8859	-
Fuel oil consumption at 100% load	g/kWh	3.2	196.5	3.5	200.1	3.6	198.8
Fuel oil consumption at 85% load	g/kWh	4.2	196.3	4.9	198.2	4.2	197.4
Fuel oil consumption at 75% load	g/kWh	4.7	196.6	5.5	198.5	4.6	197.2
Fuel oil consumption 50% load	g/kWh	6.7	206.1	7.0	208.0	5.6	199.4
Fuel gas system (Note 5)							
Gas pressure at engine inlet, min (PT901)	kPa (a)	520	-	550	-	550	-
Gas pressure to Gas Valve unit, min	kPa (a)	640	-	670	-	670	-
Gas temperature before Gas Valve Unit	°C	0...60	-	0...60	-	0...60	-
Fuel oil system							
Pressure before injection pumps (PT 101)	kPa	700±50		700±50		700±50	
Pressure before engine driven fuel feed pump, min. (MDF only)	kPa	15		15		15	
Fuel oil flow to engine, approx	m^3/h	1.4		1.7		1.7	

Wärtsilä 8L20DF (SCR Ready)		AE/DE		AE/DE		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**160**		**185**		**185**	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24
MDF viscosity, min.	cSt	1.8		1.8		1.8	
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h	-	1.1	-	1.2	-	1.2
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	2.6	5.3	3.1	6.2	3.1	6.1
Pilot fuel (MDF) viscosity before the engine	cSt	1.8...11.0		1.8...11.0		1.8...11.0	
Pilot fuel pressure at engine inlet (112)	kPa	0...40		0...40		0...40	
Pilot fuel pressure drop after engine, max	kPa	13		13		13	
Lubricating oil system							
Pressure before bearings, nom. (PT 201)	kPa	450		450		450	
Suction ability, including pipe loss, max.	kPa	20		20		20	
Priming pressure, nom. (PT 201)	kPa	80		80		80	
Temperature before bearings, nom. (TE 201)	°C	66		66		66	
Temperature after engine, approx.	°C	78		78		78	
Pump capacity (main), engine driven	m^3/h	48		48		64	
Pump capacity (main), electrically driven	m^3/h	27		27		27	
Priming pump capacity (50/60Hz)	m^3/h	8.6 / 10.5		8.6 / 10.5		8.6 / 10.5	
Oil volume, wet sump	m^3	0.49		0.49		0.64	
Oil volume in separate system oil tank	m^3	2		2		2	
Oil consumption at 100% load, approx.	g/kWh	0.4		0.4		0.4	
Crankcase ventilation flow rate at full load	l/min	823		823		823	
Crankcase ventilation backpressure, max.	Pa	300		300		300	
Oil volume in speed governor	l	1.4...2.2		1.4...2.2		1.4...2.2	
HT cooling water system							
Pressure at engine, after pump, nom. (PT 401)	kPa	200 + static		200 + static		200 + static	
Pressure at engine, after pump, max. (PT 401)	kPa	500		500		350	
Temperature before cylinders, approx. (TE 401)	°C	83		83		83	
Temperature after engine, nom.	°C	91		91		91	
Capacity of engine driven pump, nom.	m^3/h	40		41		41	
Pressure drop over engine, total	kPa	90		90		90	
Pressure drop in external system, max.	kPa	150 (1.5)		150 (1.5)		150 (1.5)	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Water volume in engine	m^3	0.15		0.15		0.15	
Delivery head of stand-by pump	kPa	200		200		200	
LT cooling water system							
Pressure at engine, after pump, nom. (PT 471)	kPa	200+ static		200+ static		200+ static	
Pressure at engine, after pump, max. (PT 471)	kPa	500		500		350	
Temperature before engine, max. (TE 471)	°C	38		38		38	
Temperature before engine, min. (TE 471)	°C	25		25		25	
Capacity of engine driven pump, nom.	m^3/h	48		51		51	
Pressure drop over charge air cooler	kPa	30		30		30	
Pressure drop in external system, max.	kPa	120 (1.2)		120 (1.2)		120 (1.2)	
Pressure from expansion tank	kPa	70...150		70...150		70...150	

Wärtsilä 8L20DF (SCR Ready)		AE/DE		AE/DE		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**160**		**185**		**185**	
Delivery head of stand-by pump	kPa	200		200		200	
Starting air system							
Pressure, nom.	kPa	3000		3000		3000	
Pressure, max.	kPa	3000		3000		3000	
Low pressure limit in air vessels	kPa	1800		1800		1800	
Starting air consumption, start (successful)	Nm^3	1.2		1.2		1.2	

Notes:

Note 1 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 5%.

Note 2 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C). Flow tolerance 5% and temperature tolerance 15°C.

Note 3 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Tolerance for cooling water heat 10%, tolerance for radiation heat 30%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers.

Note 4 At ambient conditions according to ISO 15550 and receiver temperature 45 °C. Lower calorific value 42 700 kJ/kg for pilot fuel and 49 620 kJ/kg for gas fuel. With engine driven pumps (two cooling water pumps, one lubricating oil pump and pilot fuel pump). Tolerance 5%.

Note 5 Fuel gas pressure given at LHV = $36MJ/m^3N$. 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.

ME = Engine driving propeller, variable speed

AE = Auxiliary engine driving generator

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

3.4 Wärtsilä 9L20DF

3.4.1 AUX DE ME 1000 & 1200 rpm

Wärtsilä 9L20DF		AE/DE		AE/DE		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**160**		**185**		**185**	
Engine speed	rpm	1000		1200		1200	
Speed mode		Constant		Constant		Variable	
Engine output	kW	1440		1665		1665	
Mean effective pressure	MPa	2.18		2.1		2.1	
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	2.3	2.8	2.6	3.2	2.6	3.3
Temperature at turbocharger intake, max.	°C	45		45		45	
Temperature after air cooler (TE 601)	°C	45	50	45	50	45	50
Exhaust gas system (Note 2)							
Flow at 100% load	kg/s	2.3	2.9	2.7	3.3	2.7	3.4
Flow at 75% load	kg/s	1.8	2.3	2.1	2.6	2.1	2.5
Flow at 50% load	kg/s	1.4	1.5	1.7	1.8	1.6	1.8
Temperature after turbocharger at 100% load (TE 517)	°C	370	325	380	330	380	315
Temperature after turbocharger at 75% load (TE 517)	°C	400	330	415	325	410	325
Temperature after turbocharger at 50% load (TE 517)	°C	410	360	385	360	375	325
Backpressure, max.	kPa	5		5		5	
Calculated exhaust diameter for 35 m/s	mm	393	420	425	454	425	454
Heat balance at 100% load (Note 3)							
Jacket water, HT-circuit	kW	300	315	367	375	367	367
Charge air, LT-circuit	kW	390	495	450	615	465	645
Lubricating oil, LT-circuit	kW	218	210	248	263	248	263
Radiation	kW	68	68	75	75	75	75
Fuel consumption (Note 4)							
Total energy consumption at 100% load	kJ/kWh	8180	-	8330	-	8370	-
Total energy consumption at 85% load	kJ/kWh	8390	-	8510	-	8460	-
Total energy consumption at 75% load	kJ/kWh	8520	-	8720	-	8550	-
Total energy consumption at 50% load	kJ/kWh	9130	-	9500	-	9090	-
Fuel gas consumption at 100% load	kJ/kWh	8048	-	8189	-	8222	-
Fuel gas consumption at 85% load	kJ/kWh	8219	-	8314	-	8286	-
Fuel gas consumption at 75% load	kJ/kWh	8326	-	8493	-	8359	-
Fuel gas consumption at 50% load	kJ/kWh	8862	-	9211	-	8859	-
Fuel oil consumption at 100% load	g/kWh	3.2	194.6	3.5	197.2	3.6	196.3
Fuel oil consumption at 85% load	g/kWh	4.2	194.4	4.9	196.3	4.2	195.3
Fuel oil consumption at 75% load	g/kWh	4.7	195.3	5.5	197.2	4.6	195.3
Fuel oil consumption 50% load	g/kWh	6.7	206.1	7.0	208.0	5.6	197.5

Wärtsilä 9L20DF		AE/DE		AE/DE		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**160**		**185**		**185**	
Fuel gas system (Note 5)							
Gas pressure at engine inlet, min (PT901)	kPa (a)	520	-	550	-	550	-
Gas pressure to Gas Valve unit, min	kPa (a)	640	-	670	-	670	-
Gas temperature before Gas Valve Unit	°C	0...60	-	0...60	-	0...60	-
Fuel oil system							
Pressure before injection pumps (PT 101)	kPa	700±50		700±50		700±50	
Pressure before engine driven fuel feed pump, min. (MDF only)	kPa	15		15		15	
Fuel oil flow to engine, approx	m³/h	1.6		1.9		1.8	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24
MDF viscosity, min.	cSt	1.8		1.8		1.8	
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h	-	1.2	-	1.4	-	1.4
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	2.9	5.9	3.4	6.9	3.4	6.8
Pilot fuel (MDF) viscosity before the engine	cSt	1.8...11.0		1.8...11.0		1.8...11.0	
Pilot fuel pressure at engine inlet (112)	kPa	10...40		10...40		10...40	
Pilot fuel pressure drop after engine, max	kPa	13		13		13	
Lubricating oil system							
Pressure before bearings, nom. (PT 201)	kPa	450		450		450	
Suction ability, including pipe loss, max.	kPa	20		20		20	
Priming pressure, nom. (PT 201)	kPa	80		80		80	
Temperature before bearings, nom. (TE 201)	°C	66		66		66	
Temperature after engine, approx.	°C	78		78		78	
Pump capacity (main), engine driven	m³/h	48		48		64	
Pump capacity (main), electrically driven	m³/h	30		30		30	
Priming pump capacity (50/60Hz)	m³/h	8.6 / 10.5		8.6 / 10.5		8.6 / 10.5	
Oil volume, wet sump	m³	0.55		0.55		0.71	
Oil volume in separate system oil tank	m³	2		2		2	
Oil consumption at 100% load, approx.	g/kWh	0.4		0.4		0.4	
Crankcase ventilation flow rate at full load	l/min	871		871		871	
Crankcase ventilation backpressure, max.	Pa	300		300		300	
Oil volume in speed governor	l	1.4...2.2		1.4...2.2		1.4...2.2	
HT cooling water system							
Pressure at engine, after pump, nom. (PT 401)	kPa	200 + static		200 + static		200 + static	
Pressure at engine, after pump, max. (PT 401)	kPa	500		500		350	
Temperature before cylinders, approx. (TE 401)	°C	83		83		83	
Temperature after engine, nom.	°C	91		91		91	
Capacity of engine driven pump, nom.	m³/h	45		46		46	
Pressure drop over engine, total	kPa	90		90		90	
Pressure drop in external system, max.	kPa	150 (1.5)		150 (1.5)		150 (1.5)	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Water volume in engine	m³	0.16		0.16		0.16	
Delivery head of stand-by pump	kPa	200		200		200	

Wärtsilä 9L20DF		AE/DE		AE/DE		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**160**		**185**		**185**	
LT cooling water system							
Pressure at engine, after pump, nom. (PT 471)	kPa	200+ static		200+ static		200+ static	
Pressure at engine, after pump, max. (PT 471)	kPa	500		500		350	
Temperature before engine, max. (TE 471)	°C	38		38		38	
Temperature before engine, min. (TE 471)	°C	25		25		25	
Capacity of engine driven pump, nom.	m³/h	54		51		51	
Pressure drop over charge air cooler	kPa	30		30		30	
Pressure drop in external system, max.	kPa	120 (1.2)		120 (1.2)		120 (1.2)	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Delivery head of stand-by pump	kPa	200		200		200	
Starting air system							
Pressure, nom.	kPa	3000		3000		3000	
Pressure, max.	kPa	3000		3000		3000	
Low pressure limit in air vessels	kPa	1800		1800		1800	
Starting air consumption, start (successful)	Nm³	1.2		1.2		1.2	

Notes:

Note 1 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 5%.

Note 2 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C). Flow tolerance 5% and temperature tolerance 15°C.

Note 3 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Tolerance for cooling water heat 10%, tolerance for radiation heat 30%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers.

Note 4 At ambient conditions according to ISO 15550 and receiver temperature 45 °C. Lower calorific value 42 700 kJ/kg for pilot fuel and 49 620 kJ/kg for gas fuel. With engine driven pumps (two cooling water pumps, one lubricating oil pump and pilot fuel pump). Tolerance 5%.

Note 5 Fuel gas pressure given at LHV = 36MJ/m³N. Required fuel gas pressure depends on fuel gas LHV and need to be increased for lower LHV's. Pressure drop in external fuel gas system to be considered. See chapter Fuel system for further information.

ME = Engine driving propeller, variable speed

AE = Auxiliary engine driving generator

DE = Diesel-Electric engine driving generator

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3.4.2 SCR Ready

Wärtsilä 9L20DF (SCR Ready)		AE/DE		AE/DE		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**160**		**185**		**185**	
Engine speed	rpm	1000		1200		1200	
Speed mode		Constant		Constant		Variable	
Engine output	kW	1440		1665		1665	
Mean effective pressure	MPa	2.18		2.1		2.1	
IMO compliance		Tier 3		Tier 3		Tier 3	

Wärtsilä 9L20DF (SCR Ready)		AE/DE		AE/DE		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**160**		**185**		**185**	
Combustion air system (Note 1)							
Flow at 100% load	kg/s	2.3	2.7	2.6	3.1	2.6	3.1
Temperature at turbocharger intake, max.	°C	45		45		45	
Temperature after air cooler (TE 601)	°C	45	50	45	50	45	50
Exhaust gas system (Note 2)							
Flow at 100% load	kg/s	2.3	2.8	2.7	3.2	2.7	3.2
Flow at 75% load	kg/s	1.8	2.2	2.1	2.5	2.1	2.4
Flow at 50% load	kg/s	1.4	1.5	1.7	1.8	1.6	1.6
Temperature after turbocharger at 100% load (TE 517)	°C	370	340	380	340	380	340
Temperature after turbocharger at 75% load (TE 517)	°C	400	340	415	340	410	340
Temperature after turbocharger at 50% load (TE 517)	°C	410	360	385	360	375	340
Backpressure, max.	kPa	5		5		5	
Calculated exhaust diameter for 35 m/s	mm	393	419	425	451	425	451
Heat balance at 100% load (Note 3)							
Jacket water, HT-circuit	kW	300	322	367	390	367	383
Charge air, LT-circuit	kW	390	480	450	600	465	615
Lubricating oil, LT-circuit	kW	218	210	248	263	248	263
Radiation	kW	68	68	75	75	75	75
Fuel consumption (Note 4)							
Total energy consumption at 100% load	kJ/kWh	8180	-	8330	-	8370	-
Total energy consumption at 85% load	kJ/kWh	8390	-	8510	-	8460	-
Total energy consumption at 75% load	kJ/kWh	8520	-	8720	-	8550	-
Total energy consumption at 50% load	kJ/kWh	9130	-	9500	-	9090	-
Fuel gas consumption at 100% load	kJ/kWh	8048	-	8189	-	8222	-
Fuel gas consumption at 85% load	kJ/kWh	8219	-	8314	-	8286	-
Fuel gas consumption at 75% load	kJ/kWh	8326	-	8493	-	8359	-
Fuel gas consumption at 50% load	kJ/kWh	8862	-	9211	-	8859	-
Fuel oil consumption at 100% load	g/kWh	3.2	196.5	3.5	200.1	3.6	198.8
Fuel oil consumption at 85% load	g/kWh	4.2	196.3	4.9	198.2	4.2	197.4
Fuel oil consumption at 75% load	g/kWh	4.7	196.6	5.5	198.5	4.6	197.2
Fuel oil consumption 50% load	g/kWh	6.7	206.1	7.0	208.0	5.6	199.4
Fuel gas system (Note 5)							
Gas pressure at engine inlet, min (PT901)	kPa (a)	520	-	550	-	550	-
Gas pressure to Gas Valve unit, min	kPa (a)	640	-	670	-	670	-
Gas temperature before Gas Valve Unit	°C	0...60	-	0...60	-	0...60	-
Fuel oil system							
Pressure before injection pumps (PT 101)	kPa	700±50		700±50		700±50	
Pressure before engine driven fuel feed pump, min. (MDF only)	kPa	15		15		15	
Fuel oil flow to engine, approx	m^3/h	1.6		1.9		1.9	

Wärtsilä 9L20DF (SCR Ready)		AE/DE		AE/DE		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**160**		**185**		**185**	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24
MDF viscosity, min.	cSt	1.8		1.8		1.8	
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h	-	1.2	-	1.4	-	1.4
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	2.9	5.9	3.4	7.0	3.4	6.9
Pilot fuel (MDF) viscosity before the engine	cSt	1.8...11.0		1.8...11.0		1.8...11.0	
Pilot fuel pressure at engine inlet (112)	kPa	0...40		0...40		0...40	
Pilot fuel pressure drop after engine, max	kPa	13		13		13	
Lubricating oil system							
Pressure before bearings, nom. (PT 201)	kPa	450		450		450	
Suction ability, including pipe loss, max.	kPa	20		20		20	
Priming pressure, nom. (PT 201)	kPa	80		80		80	
Temperature before bearings, nom. (TE 201)	°C	66		66		66	
Temperature after engine, approx.	°C	78		78		78	
Pump capacity (main), engine driven	m^3/h	48		48		64	
Pump capacity (main), electrically driven	m^3/h	30		30		30	
Priming pump capacity (50/60Hz)	m^3/h	8.6 / 10.5		8.6 / 10.5		8.6 / 10.5	
Oil volume, wet sump	m^3	0.55		0.55		0.71	
Oil volume in separate system oil tank	m^3	2		2		2	
Oil consumption at 100% load, approx.	g/kWh	0.4		0.4		0.4	
Crankcase ventilation flow rate at full load	l/min	871		871		871	
Crankcase ventilation backpressure, max.	Pa	300		300		300	
Oil volume in speed governor	l	1.4...2.2		1.4...2.2		1.4...2.2	
HT cooling water system							
Pressure at engine, after pump, nom. (PT 401)	kPa	200 + static		200 + static		200 + static	
Pressure at engine, after pump, max. (PT 401)	kPa	500		500		350	
Temperature before cylinders, approx. (TE 401)	°C	83		83		83	
Temperature after engine, nom.	°C	91		91		91	
Capacity of engine driven pump, nom.	m^3/h	45		46		46	
Pressure drop over engine, total	kPa	90		90		90	
Pressure drop in external system, max.	kPa	150 (1.5)		150 (1.5)		150 (1.5)	
Pressure from expansion tank	kPa	70...150		70...150		70...150	
Water volume in engine	m^3	0.16		0.16		0.16	
Delivery head of stand-by pump	kPa	200		200		200	
LT cooling water system							
Pressure at engine, after pump, nom. (PT 471)	kPa	200+ static		200+ static		200+ static	
Pressure at engine, after pump, max. (PT 471)	kPa	500		500		350	
Temperature before engine, max. (TE 471)	°C	38		38		38	
Temperature before engine, min. (TE 471)	°C	25		25		25	
Capacity of engine driven pump, nom.	m^3/h	54		51		51	
Pressure drop over charge air cooler	kPa	30		30		30	
Pressure drop in external system, max.	kPa	120 (1.2)		120 (1.2)		120 (1.2)	
Pressure from expansion tank	kPa	70...150		70...150		70...150	

Wärtsilä 9L20DF (SCR Ready)		AE/DE		AE/DE		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**160**		**185**		**185**	
Delivery head of stand-by pump	kPa	200		200		200	
Starting air system							
Pressure, nom.	kPa	3000		3000		3000	
Pressure, max.	kPa	3000		3000		3000	
Low pressure limit in air vessels	kPa	1800		1800		1800	
Starting air consumption, start (successful)	Nm^3	1.2		1.2		1.2	

Notes:

Note 1 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 5%.

Note 2 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C). Flow tolerance 5% and temperature tolerance 15°C.

Note 3 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Tolerance for cooling water heat 10%, tolerance for radiation heat 30%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers.

Note 4 At ambient conditions according to ISO 15550 and receiver temperature 45 °C. Lower calorific value 42 700 kJ/kg for pilot fuel and 49 620 kJ/kg for gas fuel. With engine driven pumps (two cooling water pumps, one lubricating oil pump and pilot fuel pump). Tolerance 5%.

Note 5 Fuel gas pressure given at LHV = 36MJ/m³N. Required fuel gas pressure depends on fuel gas LHV and need to be increased for lower LHV's. Pressure drop in external fuel gas system to be considered. See chapter Fuel system for further information.

ME = Engine driving propeller, variable speed

AE = Auxiliary engine driving generator

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

NOTE

Fuel consumptions in SCR operation guaranteed only when using Wärtsilä SCR unit

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4. Description of the Engine

4.1 Definitions

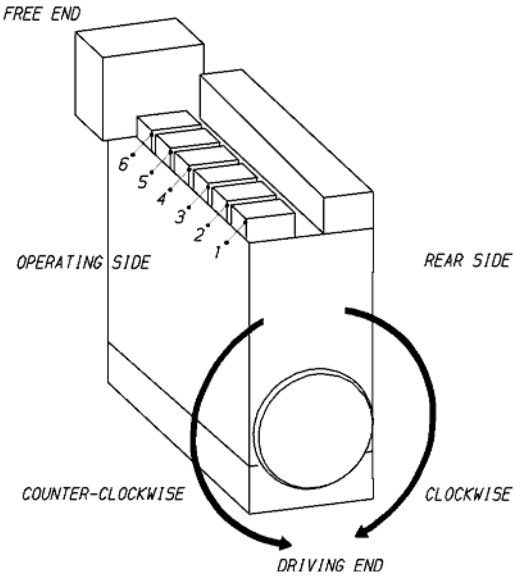


Fig 4-1 In-line engine definitions (1V93C0029)

4.2 Main components and systems

The dimensions and weights of engines are shown in section *1.6 Principal dimensions and weights.*

4.2.1 Engine Block

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

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

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

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

4.2.2 Crankshaft

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

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

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

4.2.3 Connection rod

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

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

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

4.2.4 Main bearings and big end bearings

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

4.2.5 Cylinder liner

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

4.2.6 Piston

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

4.2.7 Piston rings

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

4.2.8 Cylinder head

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

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

4.2.9 Camshaft and valve mechanism

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

4.2.10 Camshaft drive

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

4.2.11 Fuel system

The Wärtsilä 20DF engine is designed for continuous operation on fuel gas (natural gas) or Marine Diesel Fuel (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 intake duct of the cylinder head. The gas admission valve is a direct actuated solenoid valve. The valve is closed by a spring (positive sealing) when there is no electrical signal. With the engine control system it is possible to adjust the amount of gas fed to each individual cylinder for load balancing of the engine, while the engine is running. The gas admission valves also include safety filters (80 μm).

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

4.2.11.2 Main fuel oil injection system

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

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

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

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

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

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

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

4.2.11.3 Pilot fuel injection system

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

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

The pilot fuel filter is a full flow duplex unit preventing impurities entering the pilot fuel system. The filtration degree is 2 μm absolute.

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

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

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

4.2.12 Exhaust pipes

The exhaust 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 oil system

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

4.2.14 Cooling system

The fresh water cooling system is divided into a high temperature (HT) and a low temperature (LT) circuit.

The HT-water cools cylinder liners, cylinder heads. The LT-water cools the charge air cooler and the lubricating oil.

4.2.15 Turbocharging and charge air cooling

The 176kW engine version is equipped with pulse turbocharging system. The complete exhaust gas manifold is enclosed by a heat insulation box to ensure low surface temperatures.

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

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

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

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

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

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

4.2.16 Automation system

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

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

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

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

4.3 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.

4.3.1 Expected Life Time

NOTE

- Time Between Overhaul data can be found in Services Engine Operation and Maintenance Manual (O&MM)
- Expected lifetime values may differ from values found in Services O&MM manual
- Achieved life times very much depend on the operating conditions, average loading of the engine, fuel quality used, fuel handling systems, performance of maintenance etc
- Lower value in life time range is for engine load more than 75%. Higher value is for loads less than 75%

Component	Expected life time (h)	
	MDF, GAS	HFO1 / HFO2
Piston	48000...60000	42000...48000
Piston rings	16000...20000	12000...16000
Cylinder liner	80000	48000...64000
Cylinder head	48000...60000	48000...56000
Inlet valve	32000...40000	32000...36000
Exhaust valve 1)	32000...40000	24000...32000
Injection valve nozzle	4000	4000
Injection pump	32000...40000	24000...32000
Pilot injection valve	8000	-
Pilot fuel pump	8000	-
Main bearing	40000...48000	36000...48000
Big end bearing	16000...20000	12000...16000
Main gas admission valve	16000	-

NOTE

1) Nimonic Exhaust valve lifetime at ULS is 12000h

NOTE

Turbocharger lifetime for W20DFB Dredger applications are 25000 hours for Constant Speed engines and 50000 hours for Constant Torque engines.

NOTE

For detailed information of HFO1 and HFO2 qualities, please see chapter *6.1.2.4*

4.4 Engine storage

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

5. Piping Design, Treatment and Installation

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

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

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

NOTE

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

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

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

The following aspects shall be taken into consideration:

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

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

5.1 Pipe dimensions

When selecting the pipe dimensions, take into account:

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

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

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

NOTE

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

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

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

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

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

5.2 Trace heating

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

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

5.3 Pressure class

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

The pressure in the system can:

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

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

Example 1:

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

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

Example 2:

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

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

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

5.4 Pipe class

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

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

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

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

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

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

Relevant DNV rules:

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

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

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

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

5.5 Insulation

The following pipes shall be insulated:

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

Insulation is also recommended for:

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

5.6 Local gauges

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

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

5.7 Cleaning procedures

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

5.7.1 Cleanliness during pipe installation

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

Piping cleaning methods are summarised in table below:

Table 5-3 Pipe cleaning

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

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

1) In case of carbon steel pipes

Methods applied during prefabrication of pipe spools

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

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

D = Pickling (not required for seamless precision tubes)

Methods applied after installation onboard

C = Purging with compressed air

F = Flushing

5.7.2 Pickling

Prefabricated pipe spools are pickled before installation onboard.

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

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

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

5.8 Flexible pipe connections

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

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

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

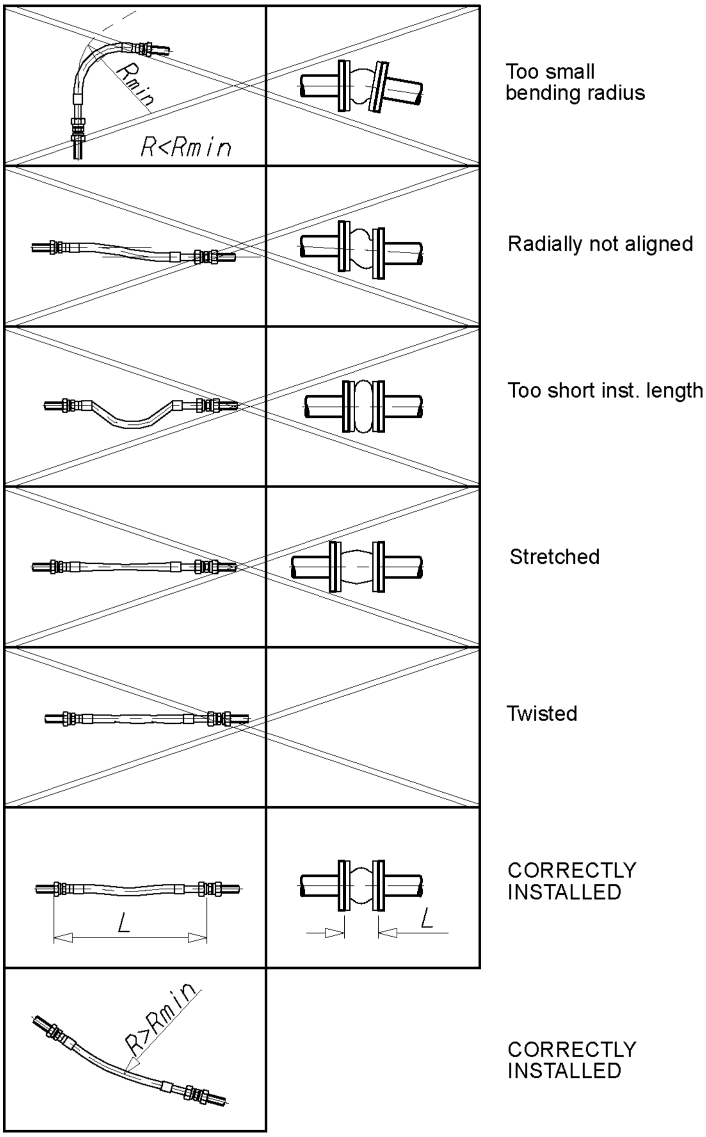


Fig 5-1 Flexible hoses

5.9 Clamping of pipes

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

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

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

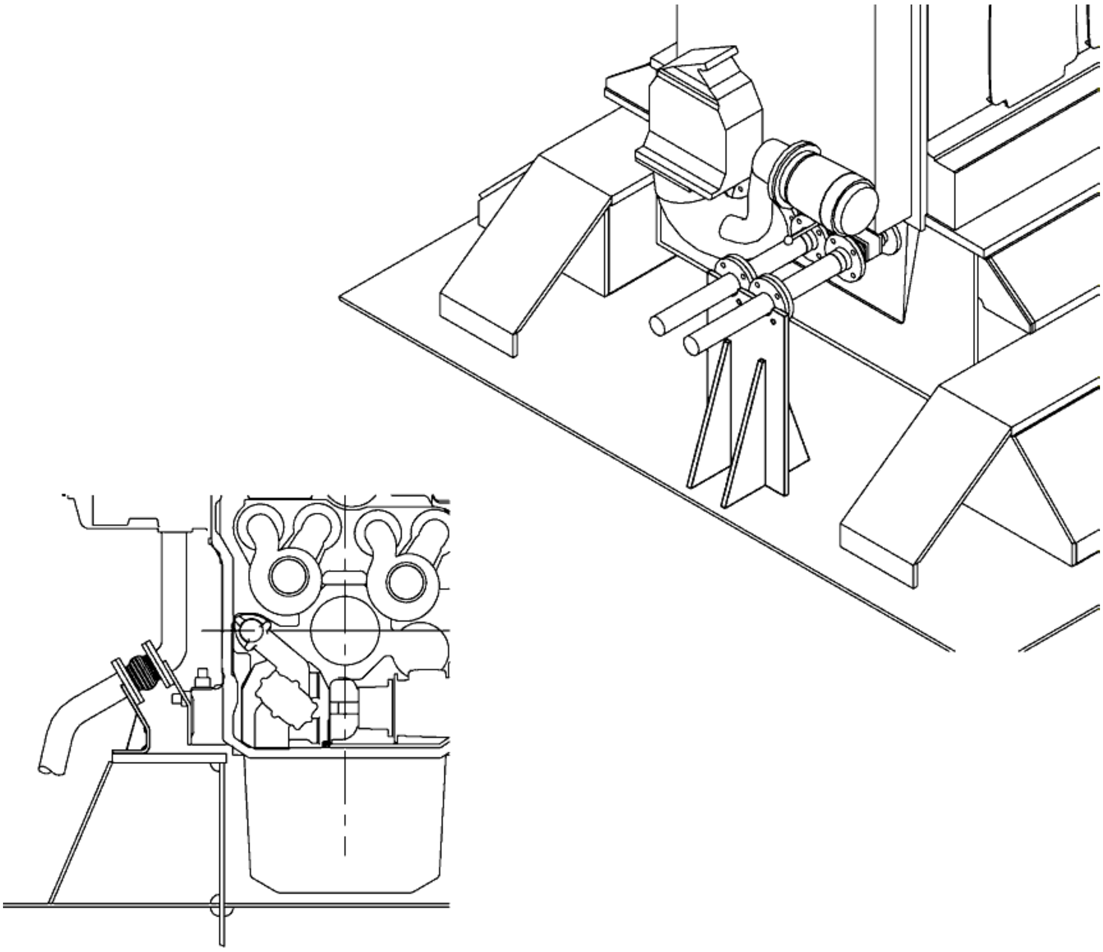
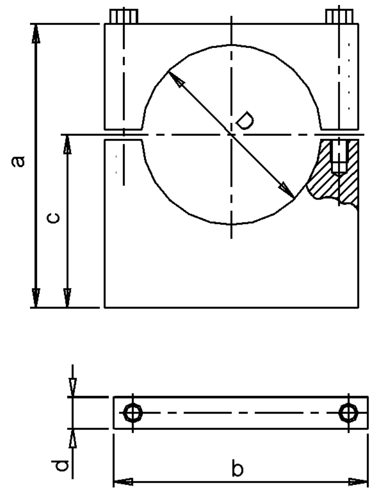


Fig 5-2 Flange supports of flexible pipe connections (4V60L0796)



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

d_u = Pipe outer diameter

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

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6. Fuel System

6.1 Acceptable fuel characteristics

6.1.1 Gas fuel specification

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

Table 6-1 Fuel Gas Specifications

Property	Unit	Value
Lower heating value (LHV), min 1)	MJ/m³N 2)	26
Methane number (MN), min 3)		80
Methane (CH_4), min	% volume	70
Hydrogen sulphide (H_2S), max	% volume	0.05
Hydrogen (H_2), max 4)	% volume	3
Oil content, max.	mg/m³N	0,01
Ammonia, max	mg/m³N	25
Chlorine + Fluorines, max	mg/m³N	50
Particles or solids at engine inlet, max	mg/m³N	50
Particles or solids at engine inlet, max size	um	5
Gas inlet temperature	°C	0…60
Water and hydrocarbon condensates at engine inlet not allowed 5)		

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

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

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

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

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

6.1.2 Liquid fuel specification

The fuel specifications are based on the ISO 8217:2017(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 pilot fuel shall fulfill the characteristics specified in table *Light fuel oil operation (distillate)*, except that the following additional requirement is valid for Cetane Index:

Table 6-2 Pilot fuel oils

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

6.1.2.2 Light fuel oil operation (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/m³	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

Characteristics		Unit	Limit	Category ISO-F							Test method(s) and references
				DMX	DMA	DFA	DMZ	DFZ	DMB	DFB	
Total sediment by hot filtration		% m/m	Max	-	-		-		0,10 c)		ISO 10307-1
Oxidation stability		g/m³	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
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 *6-4*.

j) -

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

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

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

Table 6-4 Kinematic viscosity before fuel pumps

Characteristics	Unit	Limit
• Kinematic viscosity before pilot fuel pump, min. • Kinematic viscosity before pilot fuel pump, max	mm²/s a)	• 1,8 • 11,0
• Kinematic viscosity before main fuel pump, min. • Kinematic viscosity before main fuel pump, max.	mm²/s a)	• 1,8 • 24,0

NOTE

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

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

6.1.2.3 0,10% m/m sulphur fuels for SECA areas

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

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

Characteristics	Unit	RMA 10	RMB 30	RMD 80	Test method reference
Kinematic viscosity bef. injection pumps c)	mm²/s a)	6,0 - 24	6,0 - 24	6,0 - 24	-
Kinematic viscosity at 50 °C, max.	mm²/s a)	10,00	30,00	80,00	ISO 3104
Density at 15 °C, max.	kg/m³	920,0	960,0	975,0	ISO 3675 or ISO 12185
CCAI, max. e)	-	850	860	860	ISO 8217, Annex F
Sulphur, max. b)	% m/m	0,10	0,10	0,10	ISO 8574 or ISO 14596
Flash point, min.	°C	60,0	60,0	60,0	ISO 2719
Hydrogen sulfide, max.	mg/kg	2,00	2,00	2,00	IP 570
Acid number, max.	mg KOH/g	2,5	2,5	2,5	ASTM D664
Total sediment aged, max.	% m/m	0,10	0,10	0,10	ISO 10307-2
Carbon residue, micro method, max.	% m/m	2,50	10,00	14,00	ISO 10370
Asphaltenes, max. c)	% m/m	1,5	6,0	8,0	ASTM D3279
Pour point (upper), max., winter quality d)	°C	0	0	30	ISO 3016
Pour point (upper), max., summer quality d)	°C	6	6	30	ISO 3016
Water max.	% v/v	0,30	0,50	0,50	ISO 3733 or ASTM D6304-C c)
Water bef. engine, max. c)	% v/v	0,30	0,30	0,30	ISO 3733 or ASTM D6304-C c)
Ash, max.	% m/m	0,040	0,070	0,070	ISO 6245 or LP1001 c, h)
Vanadium, max. f)	mg/kg	50	150	150	IP 501, IP 470 or ISO 14597
Sodium, max. f)	mg/kg	50	100	100	IP 501 or IP 470
Sodium bef. engine, max. c, f)	mg/kg	30	30	30	IP 501 or IP 470
Aluminium + Silicon, max.	mg/kg	25	40	40	IP 501, IP 470 or ISO 10478
Aluminium + Silicon bef. engine, max. c)	mg/kg	15	15	15	IP 501, IP 470 or ISO 10478

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

NOTE

a) 1 mm²/s = 1 cSt.

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

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

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

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

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

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

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

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

6.1.2.4 Heavy fuel oil operation (residual)

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

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

Table 6-5 Heavy fuel oils

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

NOTE

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

b) 1 mm²/s = 1 cSt.

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

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

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

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

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

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

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

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

6.1.2.5 Crude oil operation

NOTE

- CRO is accepted only for back-up fuel system, but a NSR is always to be made.

For maximum fuel temperature before the engine, see the Installation Manual.

Table 6-6 Crude oils

Property	Unit	Limit	Test method reference
Kinematic viscosity before main injection pumps, min.	mm²/s a)	2,0 e)	-
Kinematic viscosity before main injection pumps, max.	mm²/s a)	24 e)	-
Kinematic viscosity at 50 °C, max.	mm²/s a)	700,0	ISO 3104
Density at 15 °C, max.	kg/m³	991,0 / 1010,0 b)	ISO 3675 or ISO 12185

Property	Unit	Limit	Test method reference
CCAI, max.	-	870	ISO 8217, Annex F
Water before engine, max.	% v/v	0,30	ISO 3733 or ASTM D6304-C
Sulphur, max. [c]	% m/m	4,50	ISO 8574 or ISO 14596
Ash, max.	% m/m	0,150	ISO 6245 or LP1001 [f]
Vanadium, max.	mg/kg	450	IP 501, IP 470 or ISO 14597
Sodium, max.	mg/kg	100	IP 501 or IP 470
Sodium bef. engine, max.	mg/kg	30	IP 501 or IP 470
Aluminium + Silicon, max.	mg/kg	30	IP 501, IP 470 or ISO 10478
Aluminium + Silicon bef. engine, max.	mg/kg	15	IP 501, IP 470 or ISO 10478
Calcium + Potassium + Magnesium bef. engine, max.	mg/kg	50	IP 501 or 500 for Ca and ISO 10478 for K and Mg
Carbon residue, micro method, max.	% m/m	20,00	ISO 10370
Asphaltenes, max.	% m/m	14,0	ASTM D3279
Reid vapour pressure, max. at 37.8°C, max.	kPa	65	ASTM D323
Pour point (upper), max.	°C	30	ISO 3016
Cloud point, max. or Cold filter plugging point, max.	°C	60 [d]	ISO 3015 IP 309
Total sediment aged, max.	% m/m	0,10	ISO 10307-2
Hydrogen sulfide, max.	mg/kg	5,00	IP 399 or IP 570
Acid number, max.	mg KOH/g	3,0	ASTM D664

NOTE

a) 1 mm^2/s = 1 cSt

b) Max. 1010 kg/m^3 at 15 °C, provided the fuel treatment system can reduce water and solids (sediment, sodium, aluminium, silicon, calcium, potassium, magnesium) before engine to the specified levels.

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

d) Fuel temperature in the whole fuel system including storage tanks must be kept during stand-by, start-up and operation 10 – 15 °C above the cloud point in order to avoid crystallization and formation of solid waxy compounds (typically paraffins) causing blocking of fuel filters and small size orifices. Additionally, fuel viscosity sets a limit to cloud point so that fuel must not be heated above the temperature resulting in a lower viscosity before the injection pumps than specified above.

e) Viscosity of different crude oils varies a lot. The min. limit is meant for low viscous crude oils being comparable with distillate fuels. The max. limit is meant for high viscous crude oils being comparable with heavy fuels.

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

The fuel should not include any added substance, used lubricating oil 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 additional air pollution.

6.2 Operating principles

Wärtsilä 20DF engines are usually installed for dual fuel operation meaning the engine can be run either in gas or diesel operating mode. The operating mode can be changed while the engine is running, within certain limits, without interruption of power generation. If the gas supply would fail, the engine will automatically transfer to diesel mode operation (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 5 hours (with MDF) may cause clogging of the pilot fuel injection nozzles.

Engine load must also be kept below 70%.

6.3 Fuel gas system

6.3.1 Internal fuel gas system

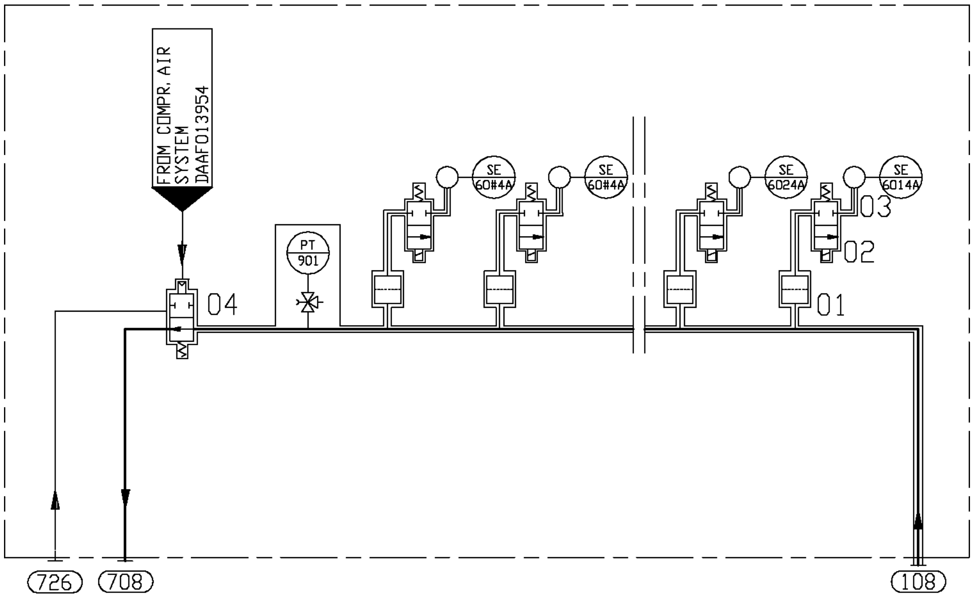


Fig 6-1 **Internal fuel gas system (DAAF013944E)**

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

Sensors and indicators	
SE60#4A..	Knock sensor, cyl A0#
PT901	Main gas pressure

Pipe connections		Size
108	Gas inlet	DN65/100
708	Gas system ventilation	DN25
726	Air inlet to double wall gas system	M26*1.5

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 annular space in double wall piping is ventilated artificially by underpressure created by ventilation fans. The air inlet to the annular space is located at the engine. The ventilation air is to be taken from a location outside the engine room, through dedicated piping. In addition, the ventilation requirements from the project specific classification society is to be considered in the design.

6.3.2 External fuel gas system

6.3.2.1 Fuel gas system, with open type GVU

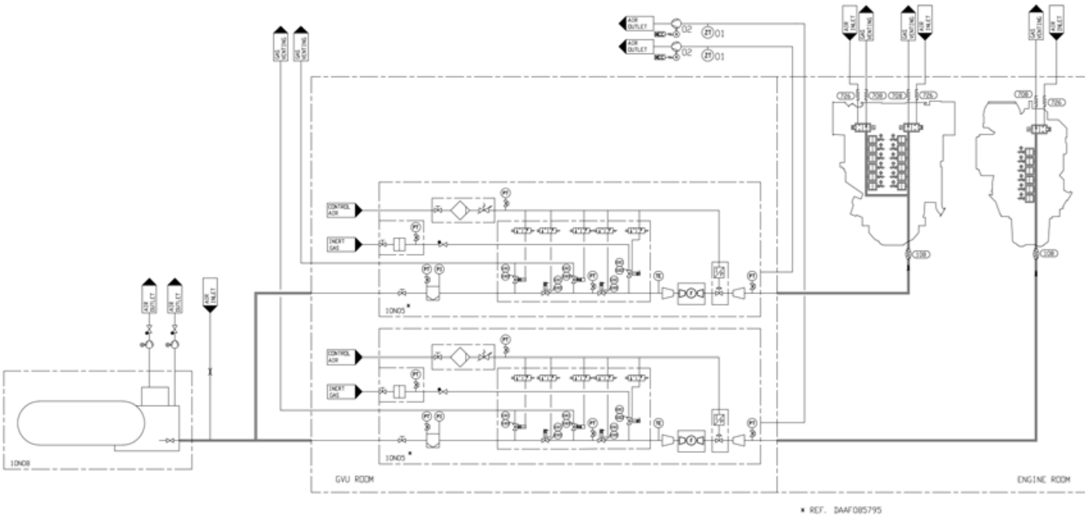


Fig 6-2 Example of fuel gas operation with open type GVU (DAAF022750F)

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	DN65/DN100
708	Gas system ventilation	DN25
726	Air inlet to double wall gas system	M26*1.5

6.3.2.2 Fuel gas system, with enclosed GVU

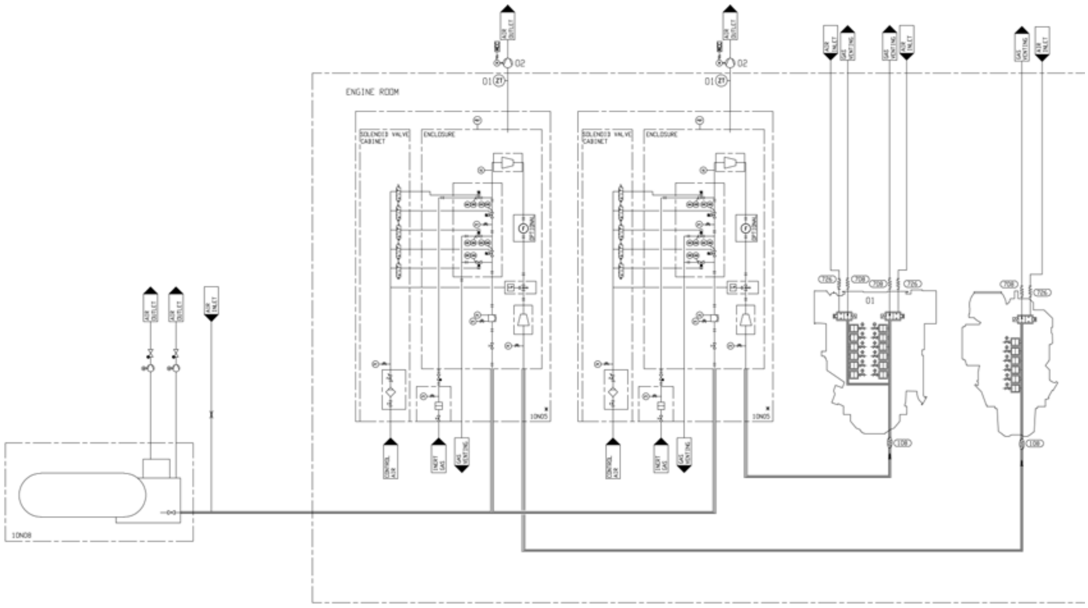


Fig 6-3 Example of fuel gas system with enclosed GVU (DAAF077105B)

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	DN65/DN100
708	Gas system ventilation	DN25
726	Air inlet to double wall gas system	M26*1.5

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.

6.3.2.3 Double wall gas piping and the ventilation of the piping

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

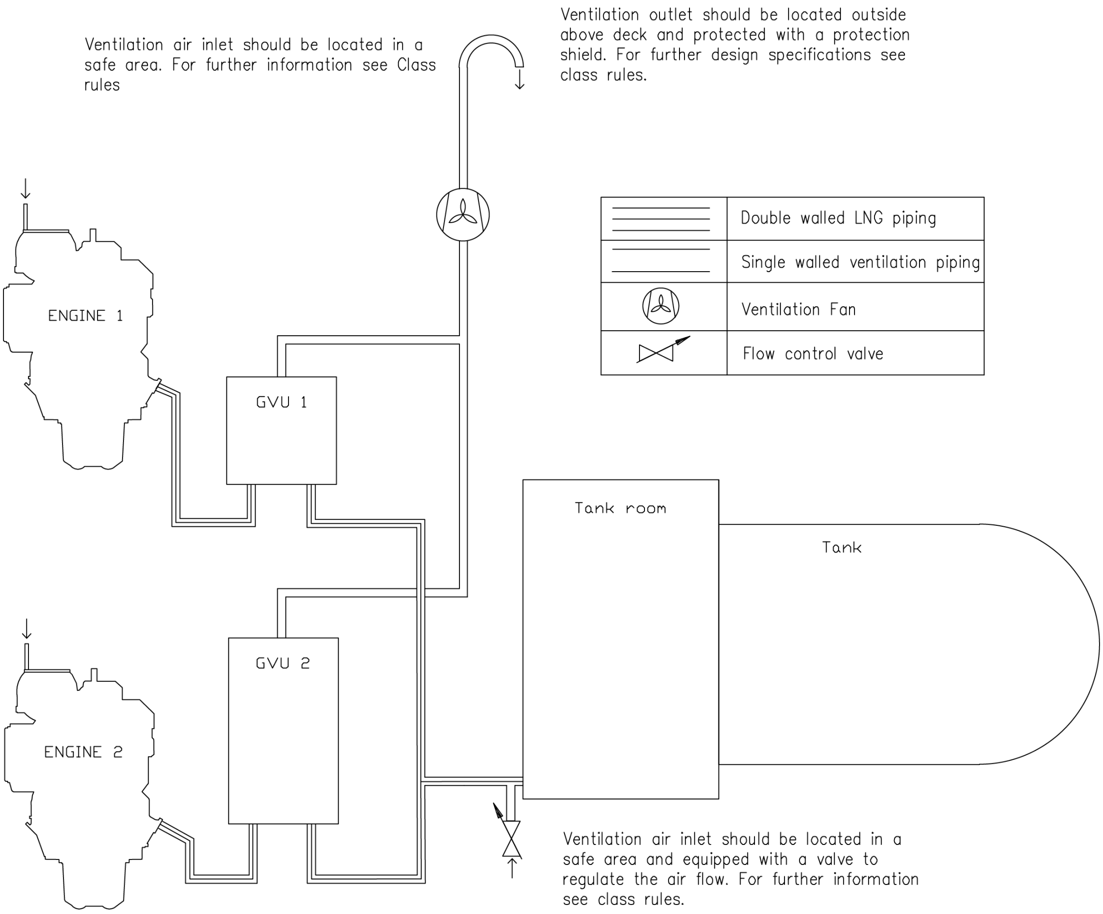


Fig 6-4 **Example arrangement drawing of ventilation in double wall piping system with enclosed GVUs (DBAC588146)**

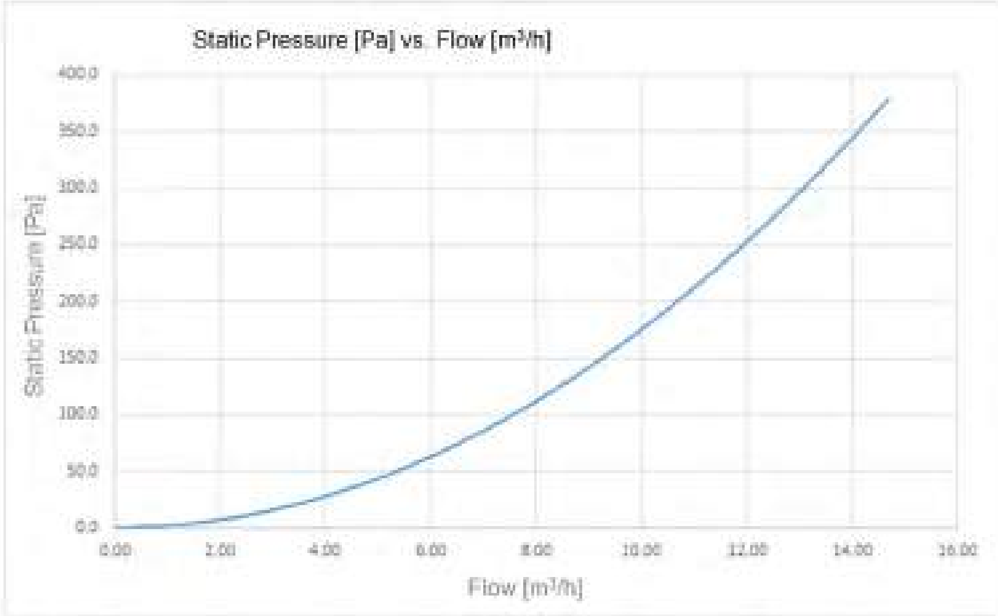


Fig 6-5 W20DF Pressure drop over annular space (gas manifold + gas inlet pipe on engine)

Cylinder Configuration	Annular Space Volume (Gas Manifold + Gas Inlet Pipe on Engine) in Liter
6L	23.9
8L	28.4
9L	30.6

6.3.2.4 Gas valve unit (10N05)

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

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

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

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

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

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

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

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

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

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

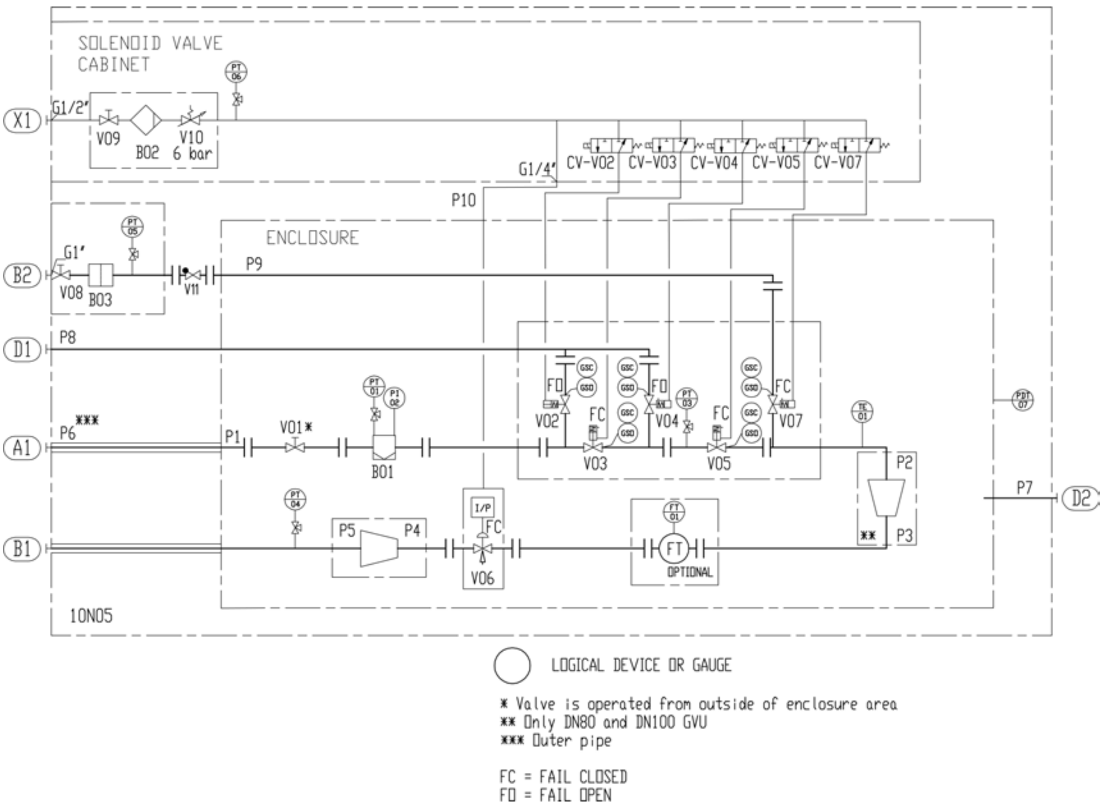


Fig 6-6 **Gas valve unit P&I diagram (DAAF051037D)**

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 [5-10 bar(g)]	B2	Inert gas [max 10 bar(g)]	D2	Air venting
B1	Gas to engine	D1	Gas venting	X1	Instrument air [6-8 bar(g)]

Pipe size							
Pos	DN50 GVU	DN80 GVU	DN100 GVU	Pos	DN50 GVU	DN80 GVU	DN100 GVU
P1	DN50	DN80	DN100	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

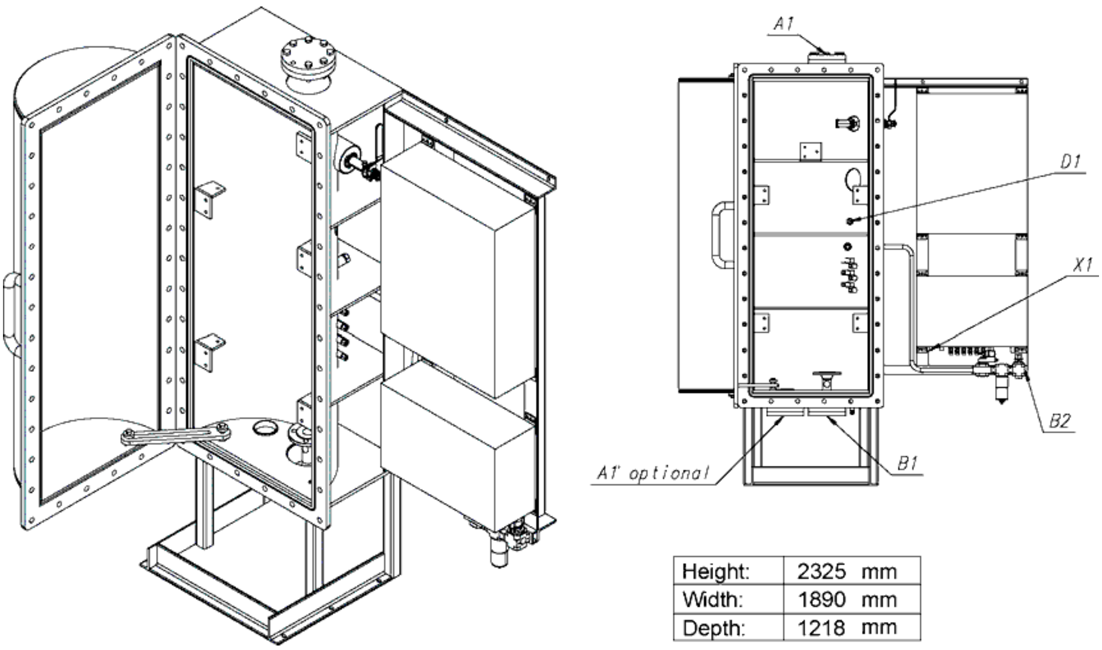


Fig 6-7 Main dimensions of the GVU (DAAF018131A)

6.3.2.5 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.

6.3.2.6 Fuel gas venting

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

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

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

NOTE

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

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

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

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

6.3.2.7 Purging by inert gas

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

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

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

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

1 **Max filling flow: 50l/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: 0.22m^3/crank**

6.3.2.8 Gas feed pressure

The required fuel gas feed pressure depends on the expected minimum lower heating value (LHV) of the fuel gas, as well as the pressure losses in the feed system to the engine. The LHV of the fuel gas has to be above 28 MJ/m^3 at 0°C and 101.3 kPa. For pressure requirements, see section "*Technical Data*" and chapter "*1.3.2 Output limitations due to gas feed pressure and lower heating value*"

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

- The pressure losses in the gas feed system to engine has to be added to get the required gas pressure.

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

6.4 Fuel oil system

6.4.1 Internal fuel oil system

6.4.1.1 Internal fuel oil system MDF, with engine driven fuel feed pump

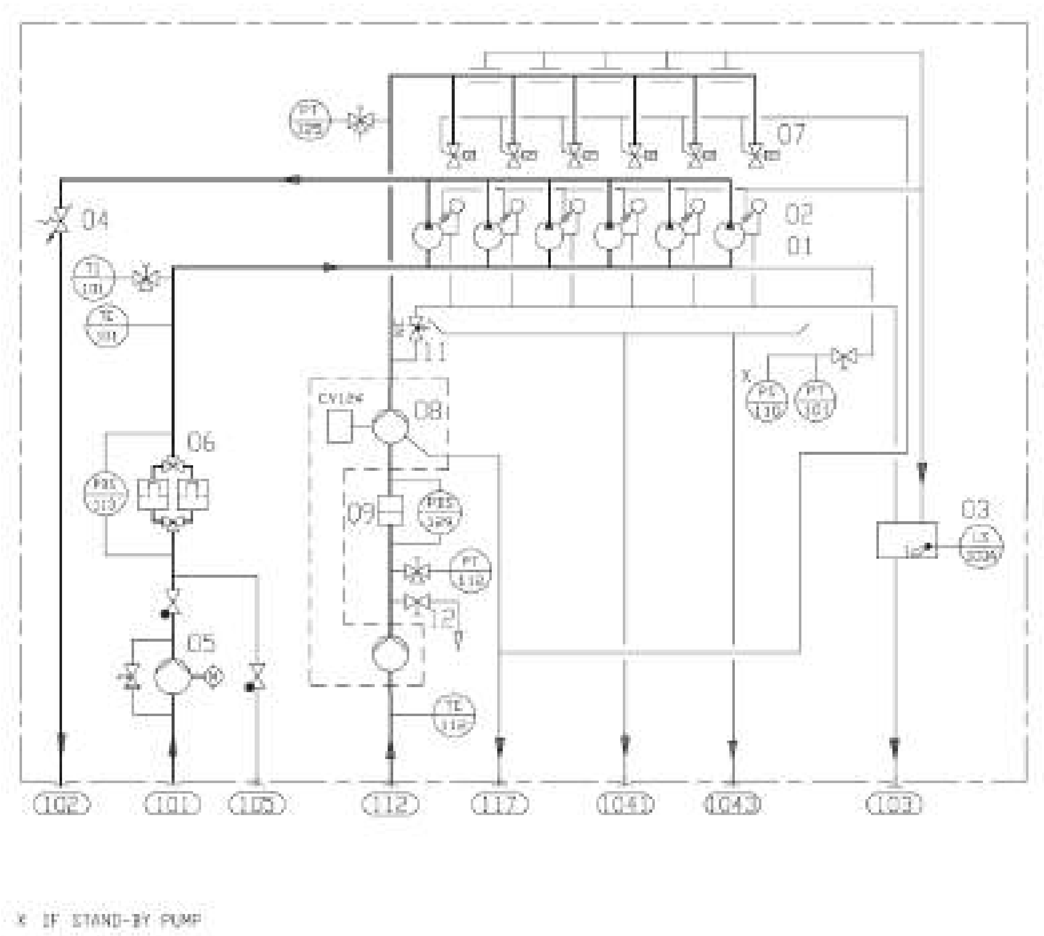


Fig 6-8 Internal fuel oil system MDF, with engine driven fuel feed pump (DAAF013947E)

System components					
01	Injection pump	05	Engine driven fuel feed pump	09	Particle filter
02	Injection valve	06	Fuel filter	11	Pilot fuel safety valve
03	Level alarm for leak fuel oil from injection pipes	07	Pilot injector	12	Pilot fuel valve
04	Pressure relief valve	08	Pilot fuel pump		

Sensors and indicators			
PT101	Fuel oil pressure, engine inlet	TE112	Pilot fuel oil temperature, inlet
TE101	Fuel oil temperature, engine inlet	PDS113	Fuel oil filter pressure difference
TI101	Fuel oil temperature, engine inlet	CV124	Pilot fuel oil pressure control

Sensors and indicators			
LS103A	Fuel oil leakage, clean primary, A-bank	PT125	Pilot fuel oil pressure, pump outlet
PS110	FO stand-by pump start (if stand-by pump)	PDS129	Pilot fuel filter pressure difference
PT112	Pilot fuel oil pressure, inlet		

Pipe connections		Size	Standard
101	Fuel inlet	OD28	DIN 2353
102	Fuel outlet	OD28	DIN 2353
103	Leak fuel drain, clean fuel	OD18	DIN 2353
105	Fuel stand-by connection (if stand-by pump)	OD22	DIN 2353
112	Pilot fuel inlet	OD10	DIN 2353
117	Pilot fuel outlet	OD15	DIN 2353
1041	Leak fuel drain, dirty fuel free end	OD22	DIN 2353
1043	Leak fuel drain, dirty fuel flywheel end	OD18	DIN 2353

6.4.1.2 Internal fuel oil system MDF, without engine driven fuel feed pump

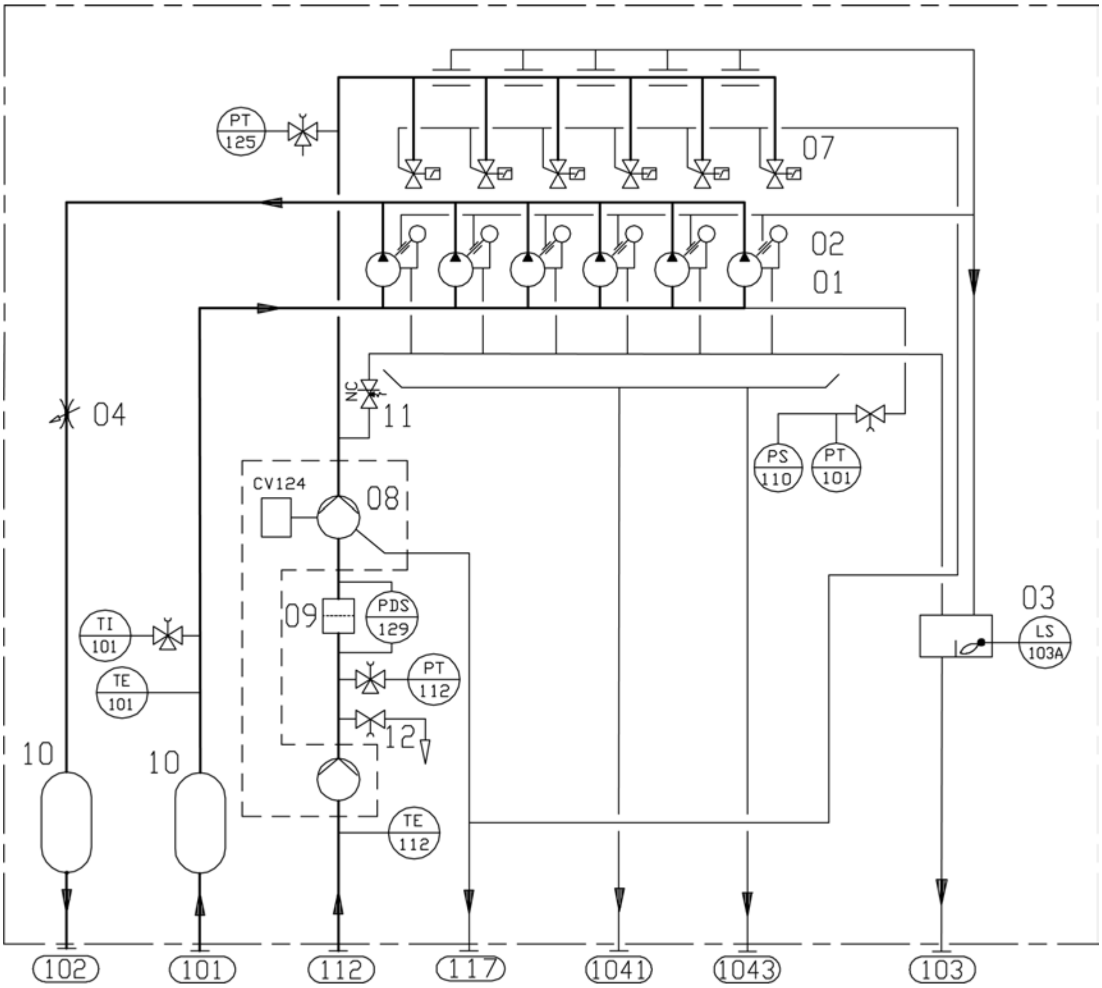


Fig 6-9 **Internal fuel oil system MDF/HFO, without engine driven fuel feed pump (DAAF013946E)**

System components			
01	Injection pump	08	Pilot fuel pump
02	Injection valve	09	Pilot fuel fine filter
03	Level alarm for leak fuel oil from injection pipes	10	Pulse damper
04	Adjustable orifice	11	Pilot fuel safety valve
07	Pilot injector	12	Pilot fuel valve

Sensors and indicators			
PT101	Fuel oil pressure, engine inlet	PT112	Pilot fuel oil pressure, inlet
TE101	Fuel oil temperature, engine inlet	TE112	Pilot fuel oil temperature, inlet
TI101	Fuel oil temperature, engine inlet	CV124	Pilot fuel oil pressure control
LS103A	Fuel oil leakage, clean primary, A-bank	PT125	Pilot fuel oil pressure, pump outlet
PS110	Fuel oil stand-by pump start	PDS129	Pilot fuel filter pressure difference

Pipe connections		Size	Standard
101	Fuel inlet	OD18	DIN 2353
102	Fuel outlet	OD18	DIN 2353

Pipe connections		Size	Standard
103	Leak fuel drain, clean fuel	OD18	DIN 2353
112	Pilot fuel inlet	OD10	DIN 2353
117	Pilot fuel outlet	OD15	DIN 2353
1041	Leak fuel drain, dirty fuel free end	OD22	DIN 2353
1043	Leak fuel drain, dirty fuel flywheel end	OD18	DIN 2353

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. 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 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.

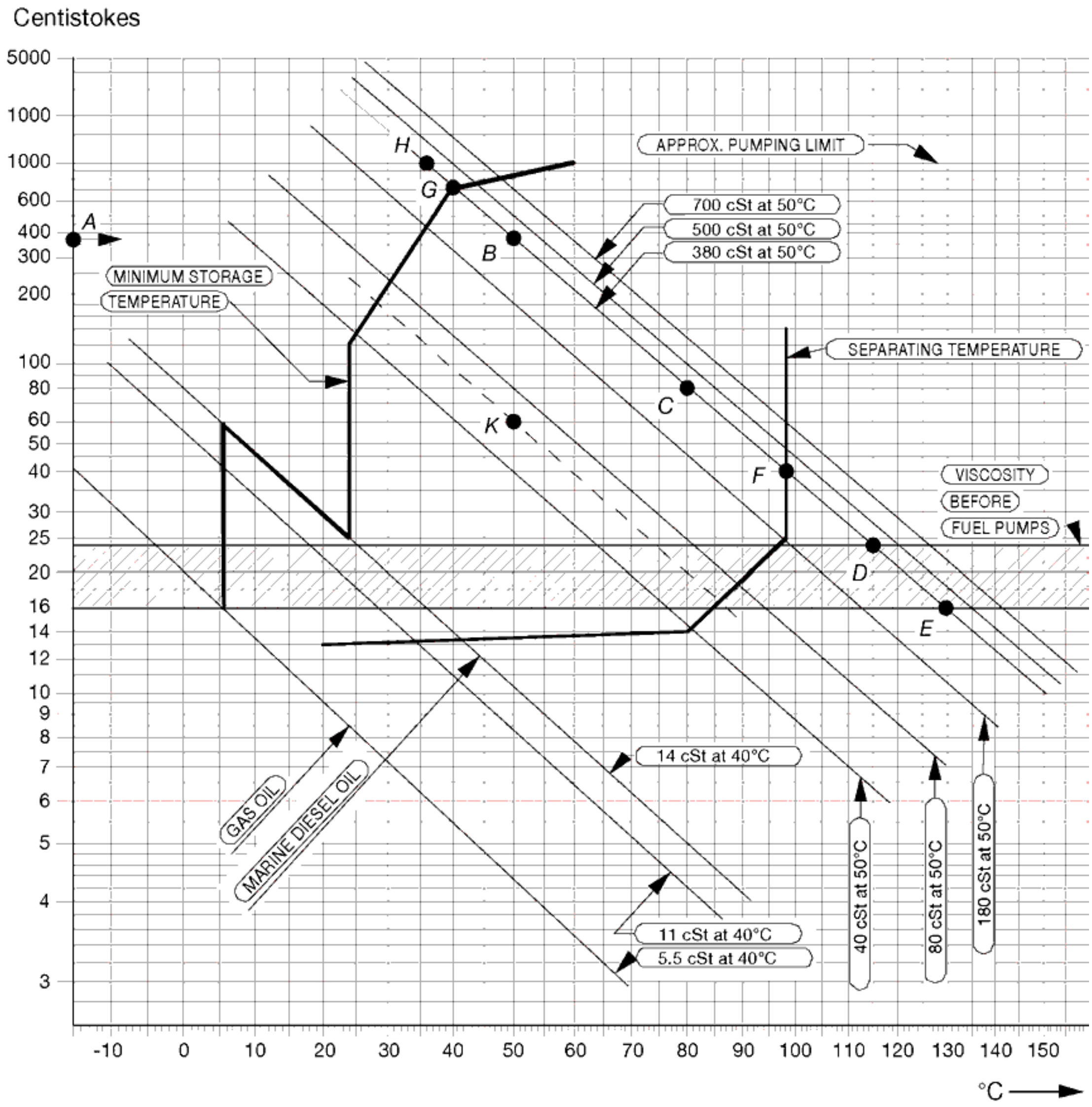


Fig 6-10 **Fuel oil viscosity-temperature diagram for determining the pre-heating temperatures of fuel oils (4V92G0071b)**

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.

6.4.2.2 Fuel tanks

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

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

Separate settling tanks for HFO and MDF are recommended.

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

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

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

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

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

Leak fuel tank, clean fuel (1T04)

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

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

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

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

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

Leak fuel tank, dirty fuel (1T07)

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

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

Pilot fuel tank, LFO (1T15)

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

The pilot fuel tank should be situated below the pilot fuel pump.

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

6.4.2.3 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

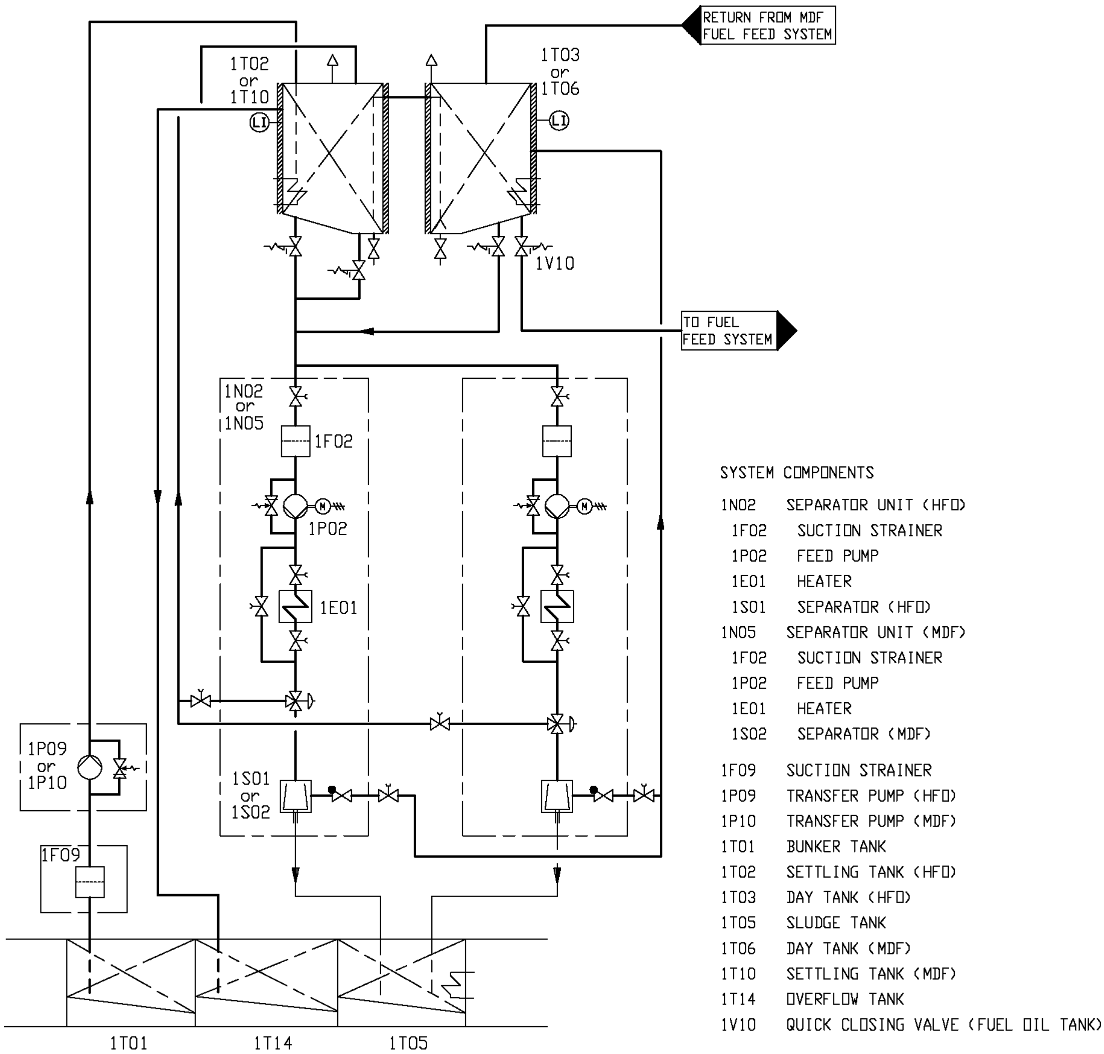


Fig 6-11 Fuel transfer and separating system (V76F6626F)

Separator feed pumps (1P02)

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

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

Design data:	HFO	MDF
Design pressure	0.5 MPa (5 bar)	0.5 MPa (5 bar)
Design temperature	100°C	50°C

Viscosity for dimensioning electric motor	1000 cSt	100 cSt

Separator pre-heater (1E01)

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

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

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

The required minimum capacity of the heater is:

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

where:

P = heater capacity [kW]

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

ΔT = temperature rise in heater [°C]

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

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

Separator (1S01/1S02)

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

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

where:

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

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

ρ = density of the fuel [kg/m^3]

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

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

Sample valves must be placed before and after the separator.

MDF separator in HFO installations (1S02)

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

Sludge tank (1T05)

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

6.4.2.4 Fuel feed system - MDF installations

Fuel oil system (MDF), single engine installation

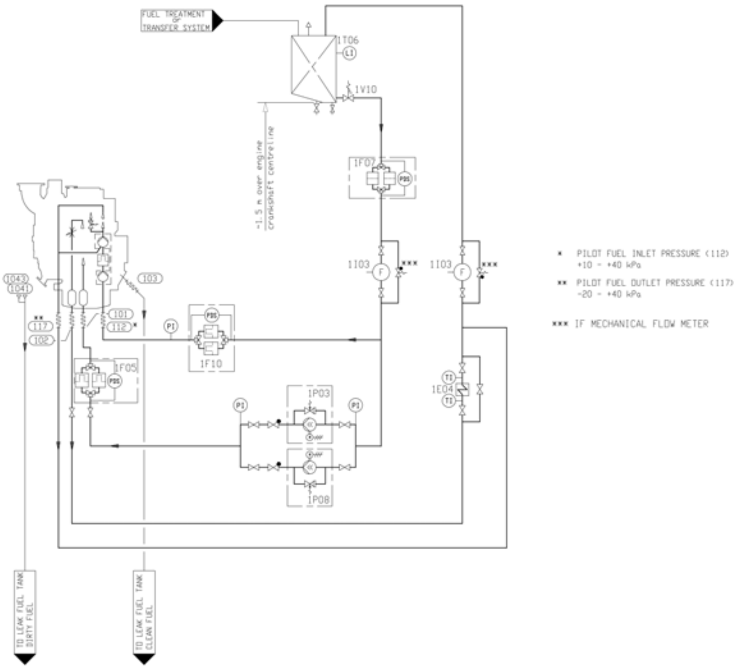


Fig 6-12 Example of fuel oil system (MDF), single engine installation (DAAF013948F)

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

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

Fuel oil system (MDF), with black start unit

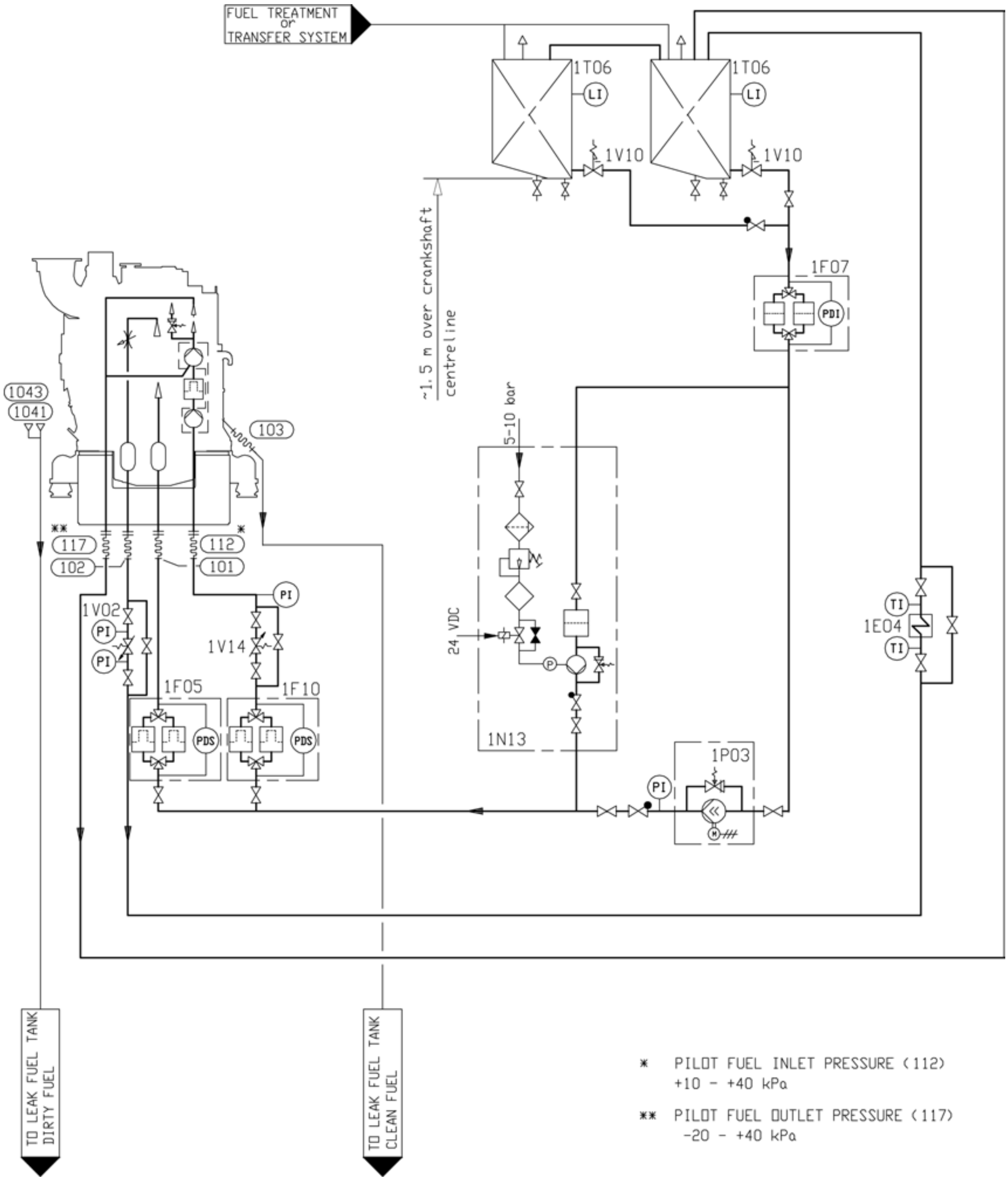


Fig 6-13 **Example of fuel oil system (MDF), with black start unit (DAAF056783C)**

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

Fuel oil system (MDF), multiple engine installation

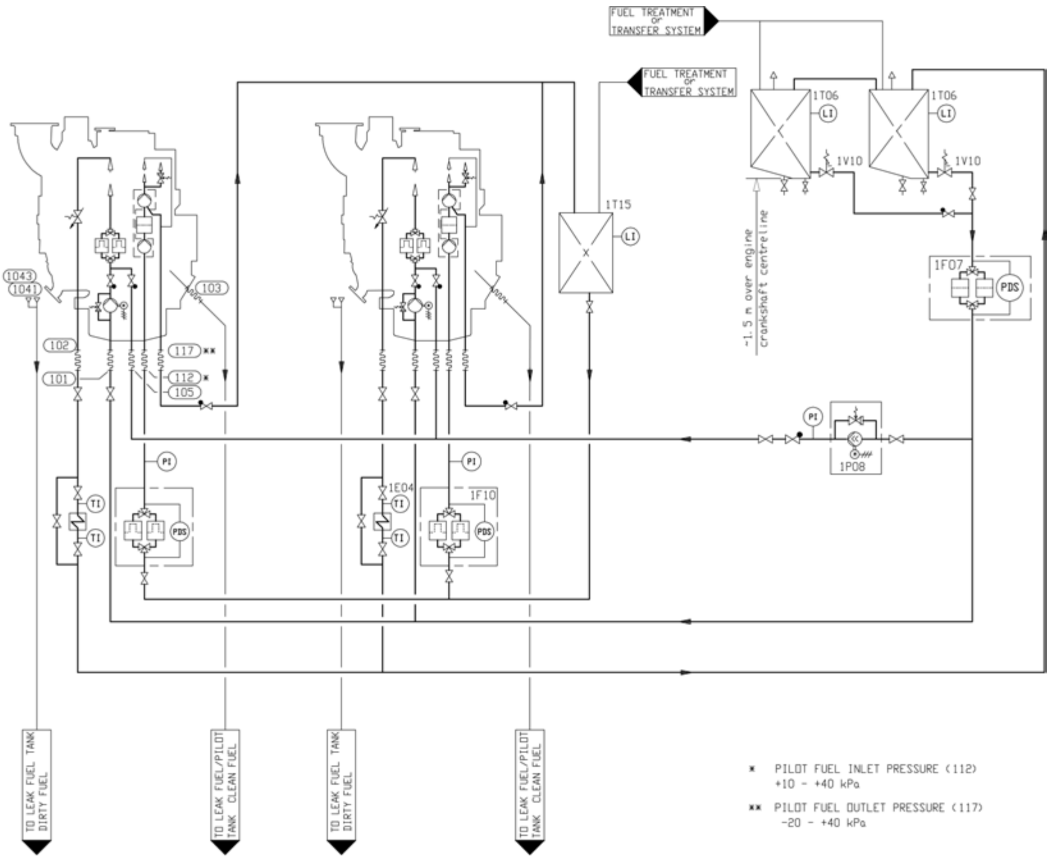


Fig 6-14 **Example of fuel oil system (MDF), multiple engine installation (DAAF013949E)**

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

If the engines are to be operated on 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	5 x the total consumption of the connected engines
Design pressure	1.6 MPa (16 bar)
Max. total pressure (safety valve)	1.0 MPa (10 bar)
Nominal pressure	see chapter "*Technical Data*"
Design temperature	50°C
Viscosity for dimensioning of electric motor	90 cSt

Flow meter, MDF (1I03)

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

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

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

Fine filter, MDF (1F05)

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

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

Design data:	
Fuel viscosity	according to fuel specifications
Design temperature	50°C
Design flow	Larger than feed/circulation pump capacity
Design pressure	1.6 MPa (16 bar)
Fineness	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)

Pilot fuel fine filter, MDF (1F10)

The pilot 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	acc to max pilot fuel flow 160kg/h (192L/h)
Design pressure	1.6 MPa (16 bar)
Fineness	10 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	1 kW/cyl
Max. pressure drop, fuel oil	80 kPa (0.8 bar)
Max. pressure drop, water	60 kPa (0.6 bar)
Margin (heat rate, fouling)	min. 15%
Design temperature 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

6.4.2.5 Fuel feed system - HFO installations

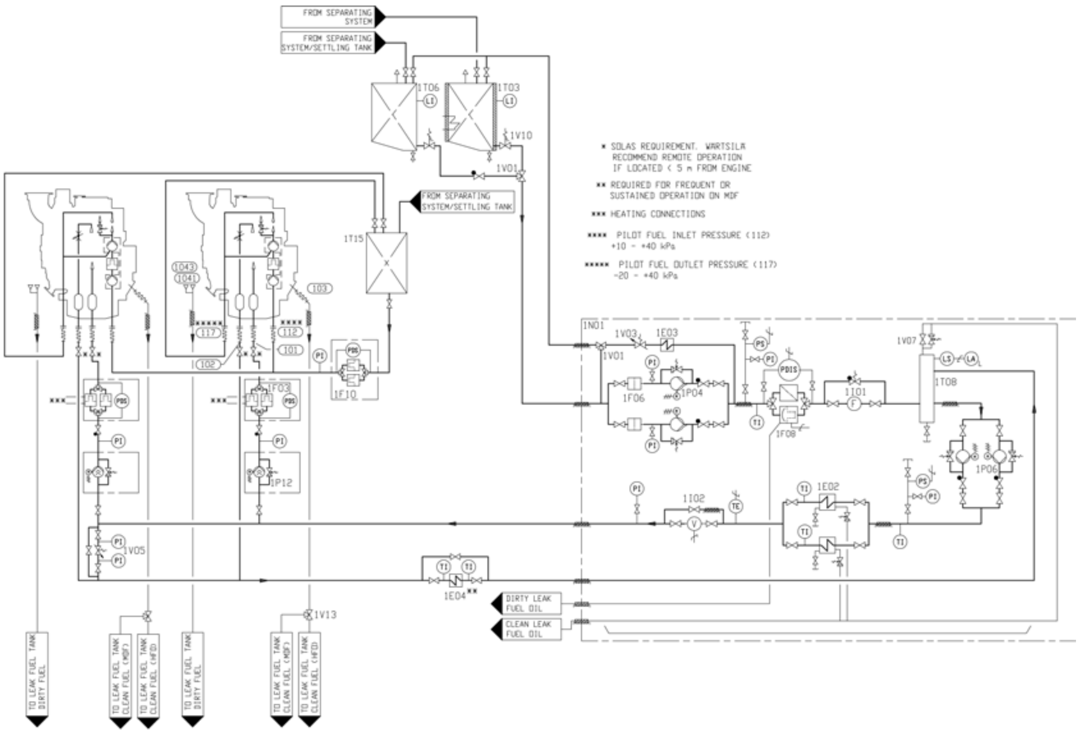


Fig 6-15 Example of fuel oil system (HFO), multiple engine installation (DAAF013950G)

System components:			
1E02	Heater (booster unit)	1P06	Circulation pump (booster unit)
1E03	Cooler (booster unit)	IP12	Circulation pump (HFO/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)	1T15	Day tank (pilot fuel)
1F10	Pilot fuel line filter (MDF)	1V01	Changeover valve
1I01	Flow meter (booster unit)	1V03	Pressure control valve (booster unit)
1I02	Viscosity meter (booster unit)	1V05	Overflow valve (HFO/MDF)
1N01	Feeder / Booster unit	1V07	Venting valve (booster unit)
1P04	Fuel feed pump (booster unit)	1V10	Quick closing valve (fuel oil tank)
		1V13	Change over valve for leak fuel

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

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

Starting and stopping

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

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

Changeover from HFO to MDF

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

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

Number of engines in the same system

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

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

In addition the following guidelines apply:

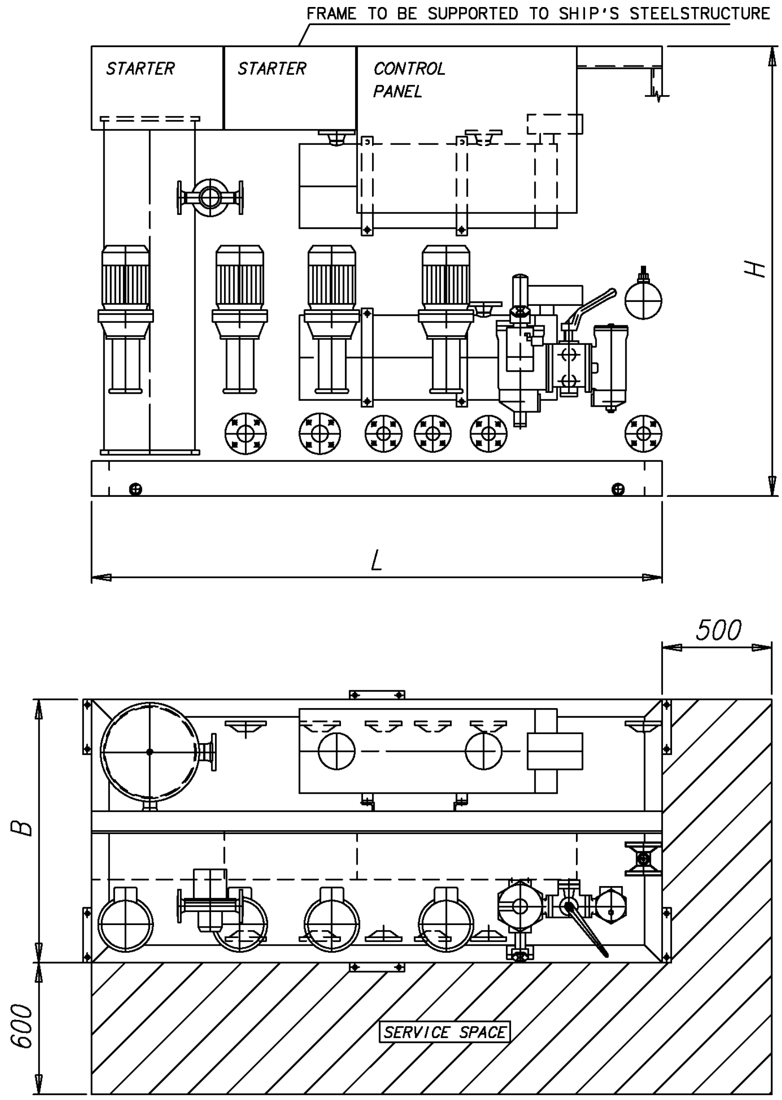
- Twin screw vessels with two engines should have a separate fuel feed circuit for each propeller shaft.
- Twin screw vessels with four engines should have the engines on the same shaft connected to different fuel feed circuits. One engine from each shaft can be connected to the same circuit.

Feeder/booster unit (1N01)

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

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



	H	L	B
STEAM	1800	2500	1100
ELECTRICAL	2050	2600	1200

All dimensions in mm.

Fig 6-16 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 mesh size)
- by-pass filter	35 μm (absolute mesh size)

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

Flow meter, booster unit (1I01)

If a fuel consumption meter is required, it should be fitted between the feed pumps and the de-aeration tank. When it is desired to monitor the fuel consumption of individual engines in a multiple engine installation, two flow meters per engine are to be installed: one in the feed line and one in the return line of each engine.

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

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

De-aeration tank, booster unit (1T08)

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

Circulation pump, booster unit (1P06)

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

Design data:

Capacity	5 x the total consumption of the connected engines
Design pressure	1.6 MPa (16 bar)
Max. total pressure (safety valve)	1.0 MPa (10 bar)
Design temperature	150°C
Viscosity for dimensioning of electric motor	500 cSt

Heater, booster unit (1E02)

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

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

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

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

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

where:

P = heater capacity (kW)

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

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	5 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
Set-point (Δp)	0.1...0.2 MPa (1...2 bar)

Pressure control valve (1V04)

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

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

6.4.2.6 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...20	0.4
B	ASTM D 975-01 BS MA 100: 1996 CIMAC 2003 ISO 8217:2017(E)	GRADE 1-D, 2-D, 4-D DMX, DMA, DMB DX, DA, DB ISO-F-DMX - DMB	15...20	0.4 - 2.0

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 Catalyctic Reduction) installations, if better total economy can be achieved despite shorter oil change intervals. Lower BN may have a positive influence on the lifetime of the SCR catalyst.

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

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

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

7.1.2 Oil in speed governor or actuator

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

7.1.3 Pilot fuel pump

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

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

7.2 Internal lubricating oil system

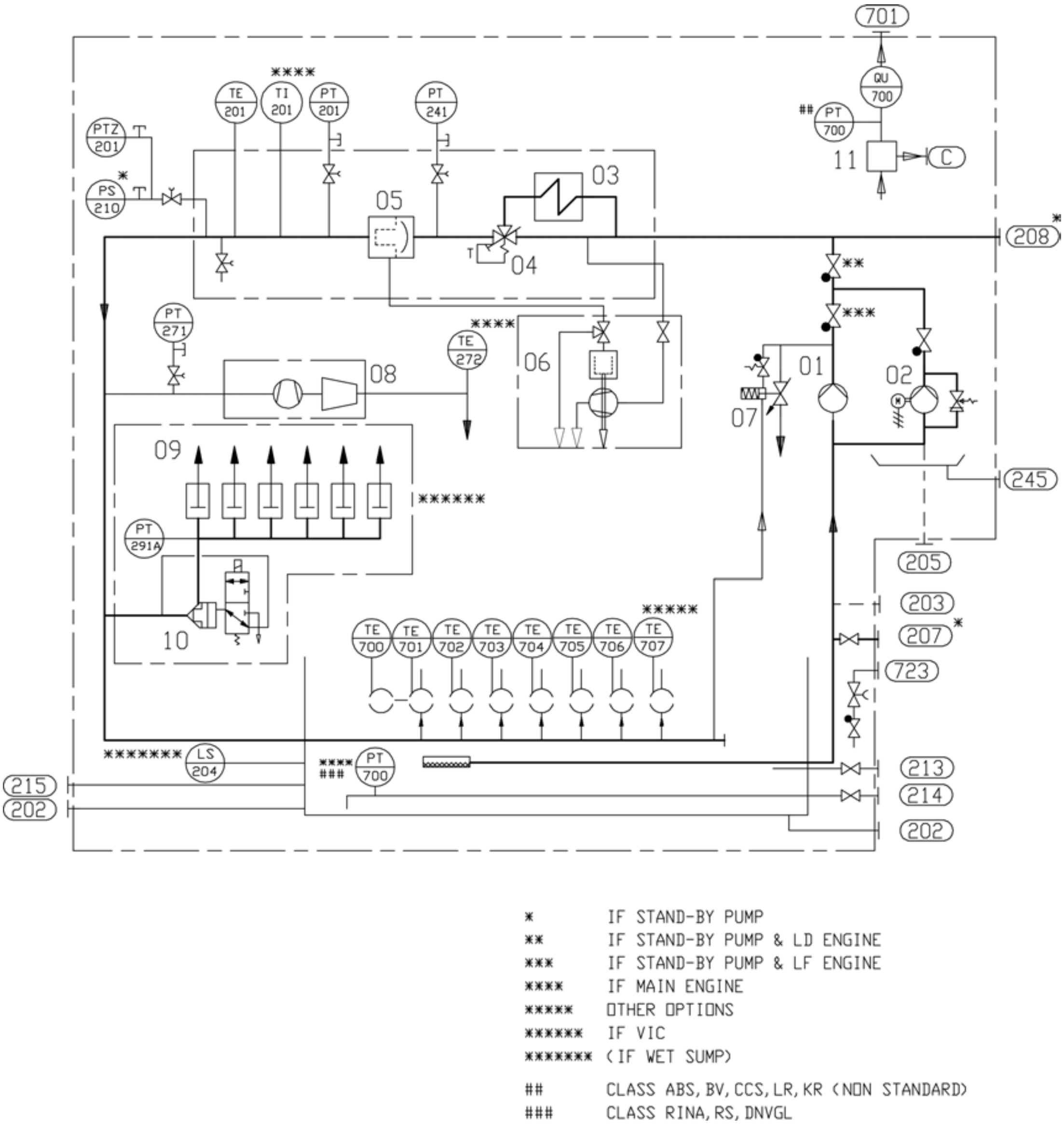


Fig 7-1 Internal lubricating oil system (DAAF013951J)

System components:					
01	Lubricating oil main pump	05	Automatic filter	09	Guide block
02	Prelubricating oil pump	06	Centrifugal filter	10	On/Off control valve (if VIC)
03	Lubricating oil cooler	07	Pressure control valve	11	Crankcase breather
04	Thermostatic valve	08	Turbocharger		

Sensors and indicators:			
PT201	Lubricating oil pressure, engine inlet	PT241	Lube oil pressure, filter inlet
PTZ201	Lubricating oil pressure, engine inlet	PT271	Lubricating oil pressure, TC A inlet (if ME)
TE201	Lubricating oil temp, engine inlet	TE272	Lubricating oil temperature, TC A outlet (if ME)
TI201	Lubricating oil temp, engine inlet (if ME)	PT291A	Control oil pressure, after VIC Valve A-bank
LS204	Lubricating oil low level (wet sump)	PT700	Crankcase pressure
PS210	Lubricating oil stand-by pump start (if stand-by pump)	TE7##	Main bearing temperature
		QU700	Oil mist detector

Pipe connections		Size
202	Lubricating oil outlet	DN100
203	Lubricating oil to engine driven pump (if dry sump)	DN100
205	Lubricating oil to priming pump (if dry sump)	DN32
207	Lubricating oil to electric driven pump (if stand-by pump)	DN100
208	Lubricating oil from electric driven pump (if stand-by pump)	DN80
213	Lubricating oil from separator and filling	DN32
214	Lubricating oil to separator and drain	DN32
215	Lubricating oil filling (if wet sump)	M48*2
245	Priming pump lubrication drain	M12
701	Crankcase air vent	DN65
723	Inert gas inlet	DN50
C	Crankcase breather	

The lubricating oil sump is of wet sump type for auxiliary and diesel-electric engines. Dry sump is recommended for main engines operating on HFO. The dry sump type has two oil outlets at each end of the engine. Two of the outlets shall be connected to the system oil tank.

The direct driven lubricating oil pump is of gear type and equipped with a pressure control valve. The pump is dimensioned to provide sufficient flow even at low speeds. A stand-by pump connection is available as option. Concerning suction height, flow rate and pressure of the pump, *see Technical data.*

The pre-lubricating pump is an electric motor driven gear pump equipped with a safety valve. The pump should always be running, when the engine is stopped. Concerning suction height, flow rate and pressure of the pump, *see Technical data.*

The lubricating oil module built on the engine consists of the lubricating oil cooler, thermostatic valve and automatic filter.

The centrifugal filter is installed to clean the back-flushing oil from the automatic filter.

7.3 External lubricating oil system

7.3.1 Lubricating oil system, wet oil sump

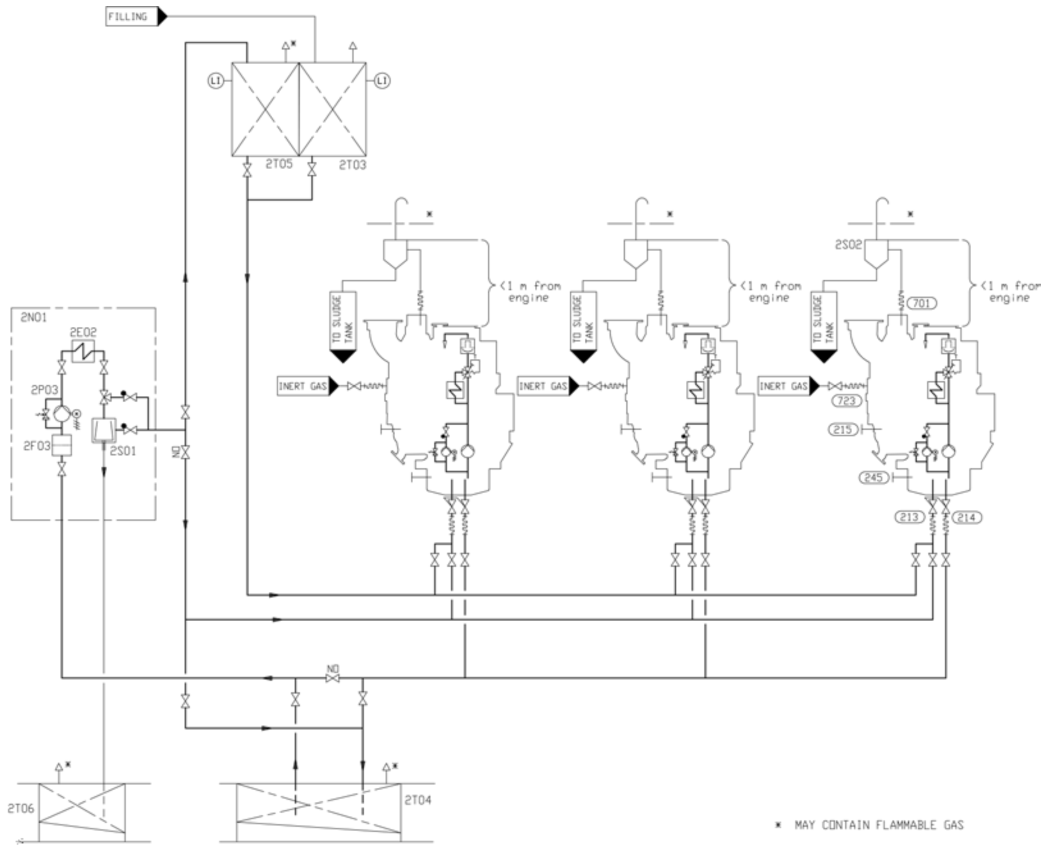


Fig 7-2 Example of lubricating oil system, wet oil sump (DAAF013952E)

System components		Pipe connections		Size
2E02	Heater (separator unit)	213	Lubricating oil from separator and filling	DN32
2F03	Suction filter (separator unit)	214	Lubricating oil to separator and drain	DN32
2N01	Separator unit	215	Lube oil filling	M48*2
2P03	Separator pump (separator unit)	245	Priming pump lubrication drain	M12
2S01	Separator	701	Crankcase air vent	DN65
2S02	Condensate trap	723	Inert gas inlet	DN50
2T03	New oil tank			
2T04	Renovating oil tank			
2T05	Renovated oil tank			
2T06	Sludge tank			

7.3.2 Lubricating oil system, dry oil sump

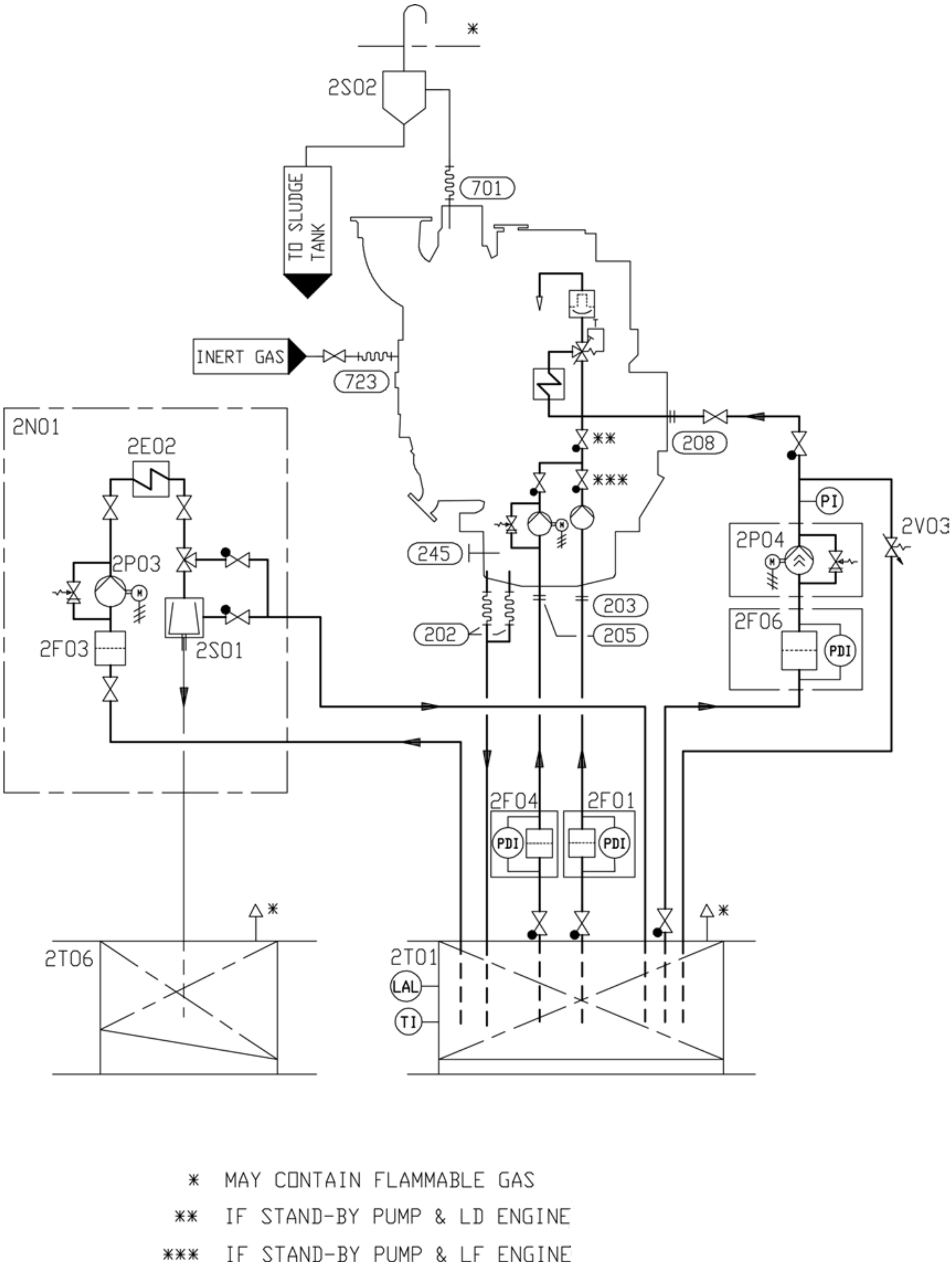


Fig 7-3 Example of lubricating oil system, dry oil sump (DAAF013953D)

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

System components		Pipe connections		Size
2P03	Separator pump (separator unit)	723	Inert gas inlet	DN50
2P04	Stand-by pump			
2S01	Separator			
2S02	Condensate trap			
2T01	System oil tank			
2T06	Sludge tank			
2V03	Pressure control valve			

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.

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.

7.3.3.2 Renovating oil tank (2T04)

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

7.3.3.3 Renovated oil tank (2T05)

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

7.3.4 New oil tank (2T03)

In engines with wet sump, the lubricating oil may be filled into the engine, using a hose or an oil can, through the dedicated lubricating oil filling connection (215). Alternatively, trough the crankcase cover or through the separator pipe. The system should be arranged so that it is possible to measure the filled oil volume.

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

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

Design data:	
Fineness	0.5...1.0 mm

7.3.6 Lubricating oil pump, stand-by (2P04)

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

Design data:	
Capacity	see *Technical data*
Design pressure, max	0.8 MPa (8 bar)
Design temperature, max.	100°C
Lubricating oil viscosity	SAE 40
Viscosity for dimensioning the electric motor	500 mm^2/s (cSt)

7.4 Crankcase ventilation system

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

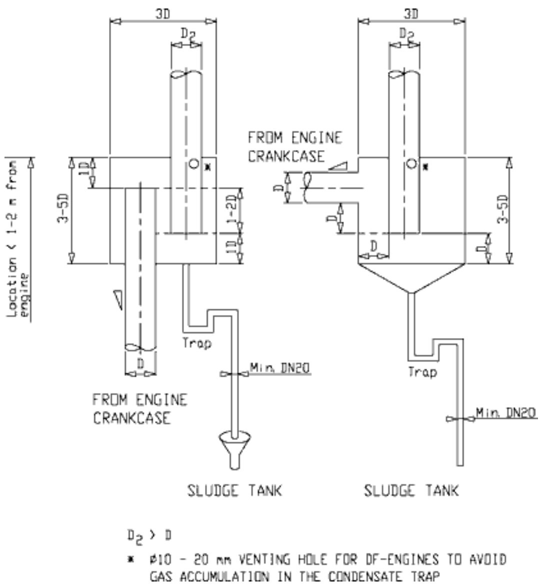
Each engine must have its own vent pipe into open air. The crankcase ventilation pipes may not be combined with other ventilation pipes, e.g. vent pipes from the system oil tank.

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

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

The connection between engine and pipe is to be flexible.

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



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

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

Fig 7-4 Condensate trap (DAAF369903)

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.

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

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

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

If an electric motor driven stand-by pump (2P04) is installed then piping shall be flushed running the pump circulating engine oil through a temporary external oil filter (recommended mesh 34 microns) into the engine oil sump through a hose and a crankcase door. The pump shall be protected by a suction strainer (2F06).

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

7.5.3 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.

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
Consumption	Approx. 5,5 Nm^3/h (running engine) Approx. 5,0 Nm^3/h (engine not in operation)

8.2 Internal compressed air system

The engine is equipped with a pneumatic starting motor driving the engine through a gear rim on the flywheel.

The compressed air system of the electro-pneumatic overspeed trip is connected to the starting air system. For this reason, the air supply to the engine must not be closed during operation.

The nominal starting air pressure of 3 MPa (30 bar) is reduced with a pressure regulator before the pneumatic starting motor.

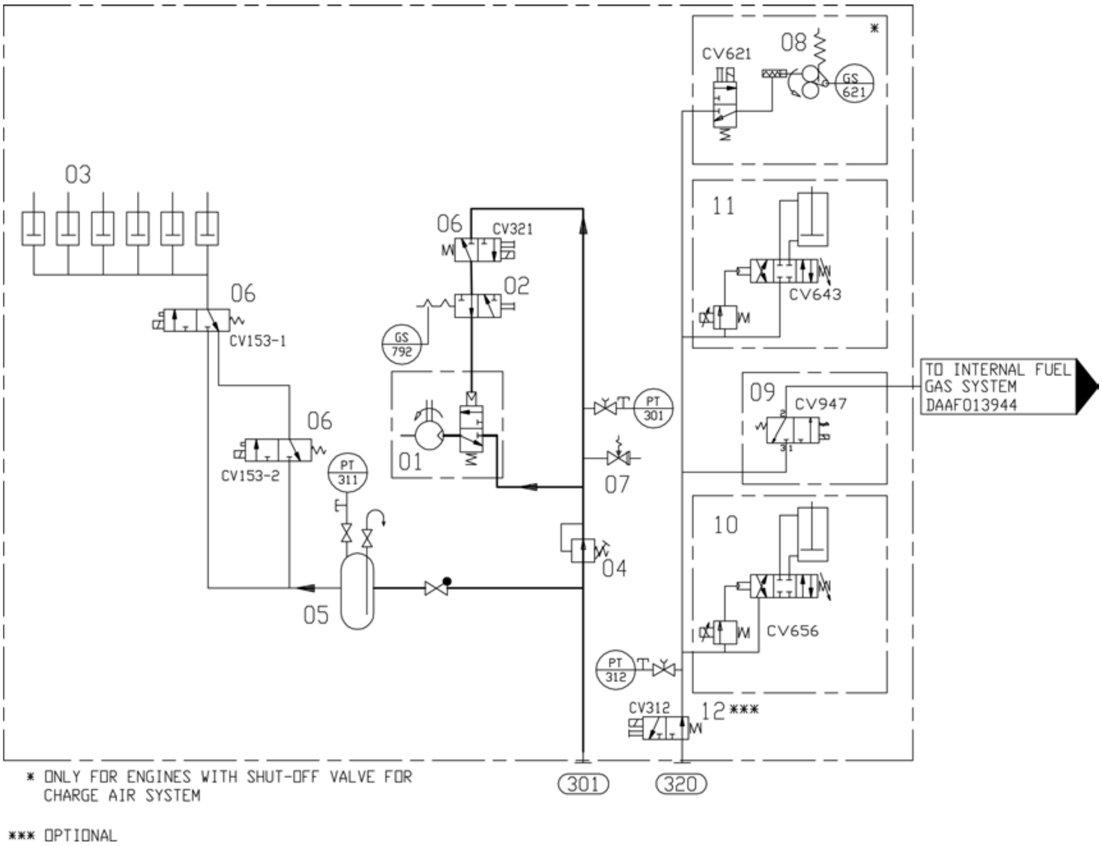


Fig 8-1 Internal compressed air system (DAAF013954G)

System components					
01	Turbine starter	05	Air container	09	Degasing valve
02	Blocking valve, when turning gear engaged	06	Solenoid valve	10	Charge air waste gate
03	Pneumatic cylinder(s) for stop/shut down	07	Safety valve	11	Charge air by-pass (if engine with 185kW/cyl)
04	Pressure regulator	08	Charge air shut-off valve	12	Solenoid valve CV312

Sensors and indicators			
CV153-1	Stop/shutdown solenoid valve	CV621	Charge air shut-off valve control
CV153-2	Stop/shutdown solenoid valve	GS621	Charge air shut-off valve position, A-bank
PT301	Starting air pressure, engine inlet	CV643	Charge air by-pass valve control
PT311	Control air pressure	CV656	Air WG control
PT312	Instrument air pressure	GS792	Turning gear engaged
CV312	Instrument air valve control	CV947	MCC, degasing valve control
CV321	Start solenoid valve		

Pipe connections		Size	Standard
301	Starting air inlet	OD28	DIN2353
320	Instrument air inlet	OD12	

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.

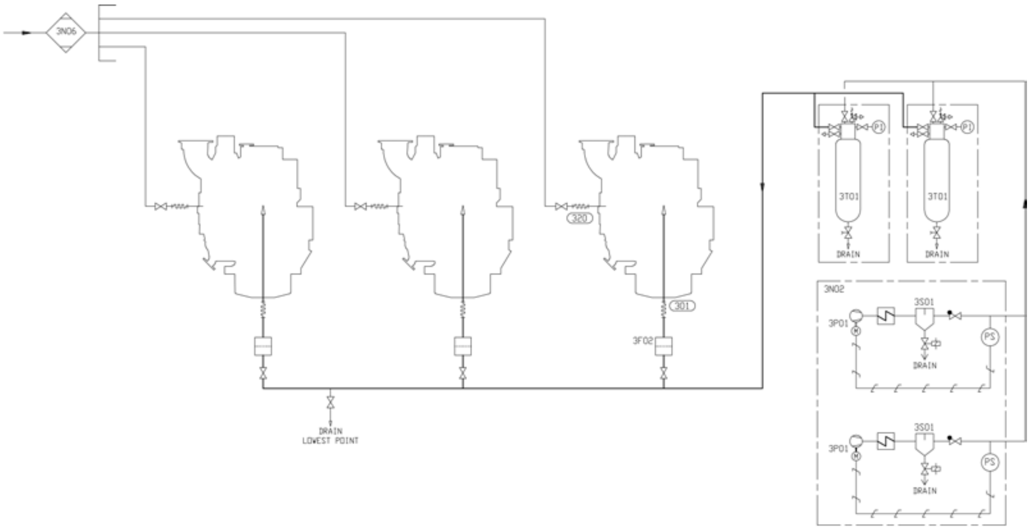


Fig 8-2 Example of external compressed air system (DAAF013955E)

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

8.3.1 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.

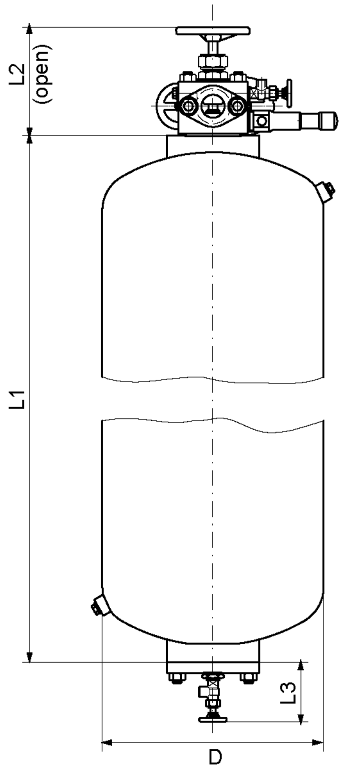
8.3.3 Starting air vessel (3T01)

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	
125	1807	243	110	324	170
180	1217	243	110	480	200
250	1767	243	110	480	274
500	3204	243	133	480	450

1) Dimensions are approximate.

Fig 8-3 Starting air vessel

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

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

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

where:

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

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

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

n = required number of starts according to the classification society

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

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

NOTE

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

8.3.4 Air filter, starting air inlet (3F02)

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

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

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

9. Cooling Water System

9.1 Water quality

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

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

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

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

9.1.1 Corrosion inhibitors

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

9.1.2 Glycol

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

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

9.2 Internal cooling water system

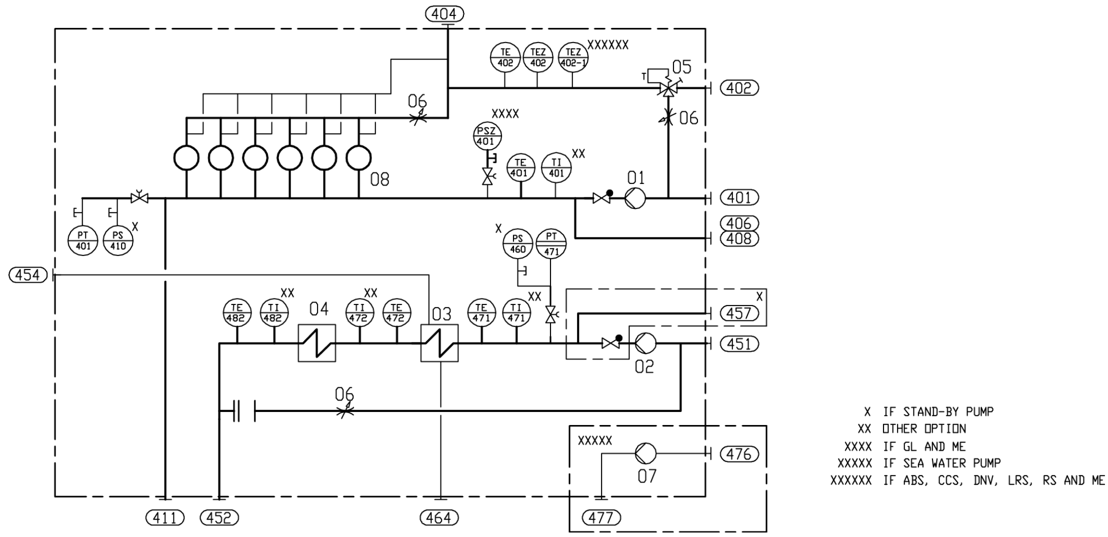


Fig 9-1 **Internal cooling water system (DAAF013956D)**

System components:					
01	HT-cooling water pump	04	Lubricating oil cooler	07	Sea water pump
02	LT-cooling water pump	05	HT-thermostatic valve	08	Cylinders
03	Charge air cooler	06	Adjustable orifice		

Sensors and indicators:			
PSZ401	HT-water pressure SW, jacket inlet	PS460	LT-water stand-by pump start
PT401	HT-water pressure, jacket inlet	PT471	LT-water pressure, LT CAC inlet
TE401	HT-water temp, jacket inlet	TE471	LT-water temp, LT CAC inlet
TI401	HT-water temp, engine inlet	TI471	LT-water temp, LT CAC inlet
TE402	HT-water temp, jacket outlet A-bank	TE472	LT-water temp, LT CAC outlet
TEZ402	HT-water temp, jacket outlet A-bank	TI472	LT-water temp, LT CAC outlet
TEZ402-1	HT-water temp, jacket outlet A-bank	TE482	LT-water temp, LOC outlet
PS410	HT-water stand-by pump start	TI482	LT-water temp, LOC outlet

Pipe connections		Size	Pressure class	Standard
401	HT-water inlet	DN65	PN16	ISO 7005-1
402	HT-water outlet	DN65	PN16	ISO 7005-1
404	HT-water air vent	OD12		DIN 2353
406	Water from preheater to HT-circuit	DN65		ISO 7005-1
408	HT-water from stand-by pump	DN65		ISO 7005-1
411	HT-water drain	M10*1		
451	LT-water inlet	DN80	PN16	ISO 7005-1
452	LT-water outlet	DN80	PN16	ISO 7005-1
454	LT-water air vent	OD12		DIN 2353
457	LT-water from stand-by pump	DN80	PN16	ISO 7005-1
464	LT-water drain	M18*1.5		
476	Sea water to engine driven pump (option)			
477	Sea water from engine driven pump (option)			

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 and cylinder heads.

The LT water circulates through the charge air cooler and the lubricating oil cooler, which is built on the engine.

Temperature control valves regulate the temperature of the water out from the engine, by circulating some water back to the cooling water pump inlet. The HT temperature control valve is mounted on the engine, while the LT temperature control valve is mounted in the external LT circuit after the engine. The LT temperature control valve (4V09) is electrically controlled for exact adjustment of the charge air receiver temperature.

9.2.1 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*.

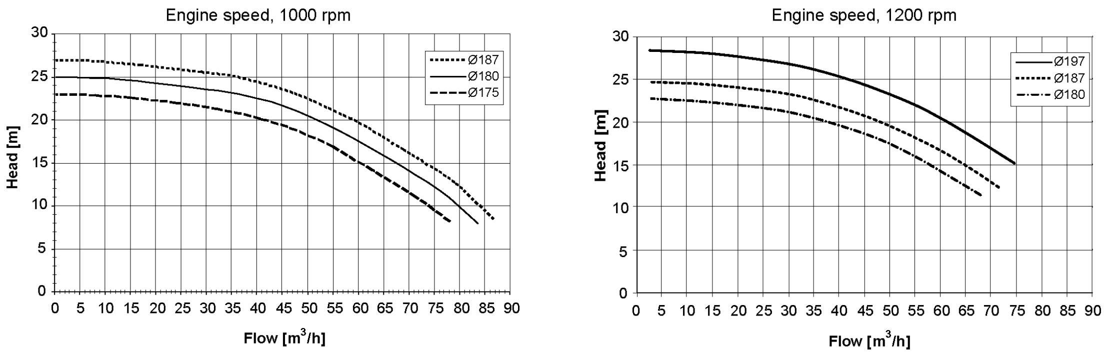


Fig 9-2 Pump curves

Table 9-1 Impeller diameters of engine driven HT & LT pumps

Engine	Engine speed [rpm]	HT impeller [Ø mm]	LT impeller [Ø mm]
W 6L20DF	1000 1200	175 180	175 187
W 8L20DF	1000 1200	180 187	187 197
W 9L20DF	1000 1200	180 187	187 197

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 External cooling water system, generating sets

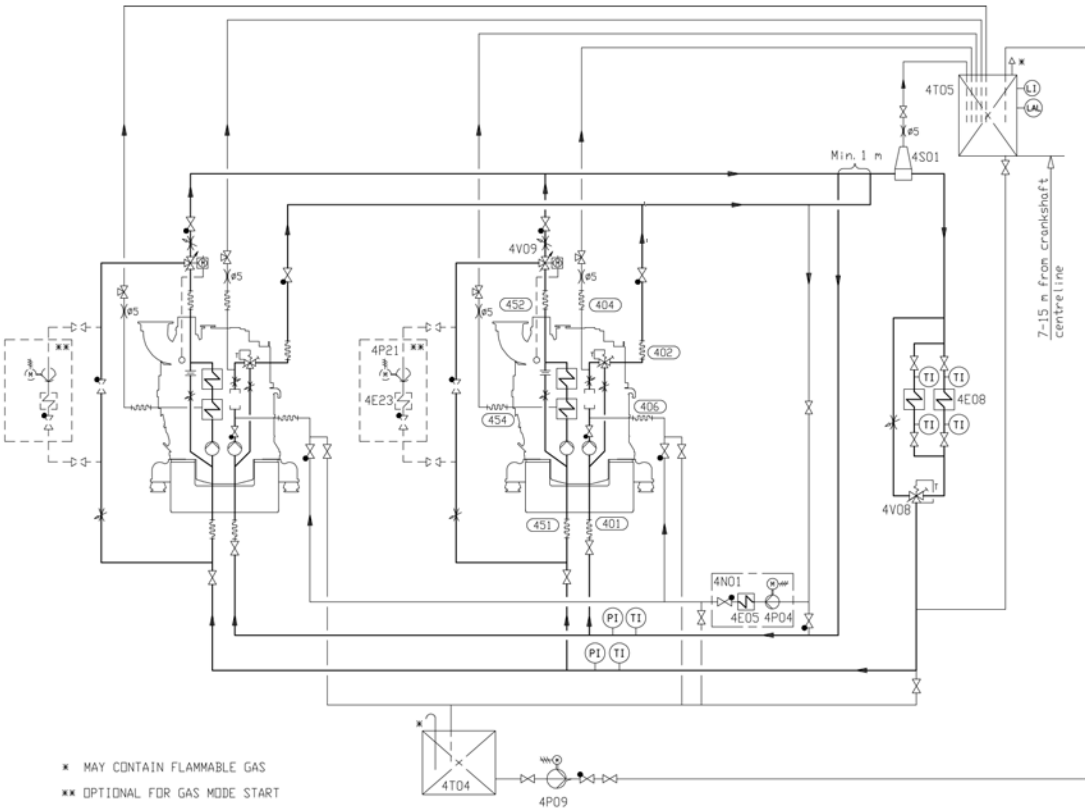


Fig 9-3 External cooling water system, generating sets (DAAF013957E)

System components:			
4E05	Heater (preheater)	4P21	Circulating pump (preheating LT)
4E08	Central cooler	4S01	Air venting
4E23	Heater (LT)	4T04	Drain tank
4N01	Preheating unit	4T05	Expansion tank
4P04	Circulating pump (preheater)	4V08	Temperature control valve (central cooler)
4P09	Transfer pump	4V09	Temperature control valve (charge air)

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

9.3.2 External cooling water system, main engines

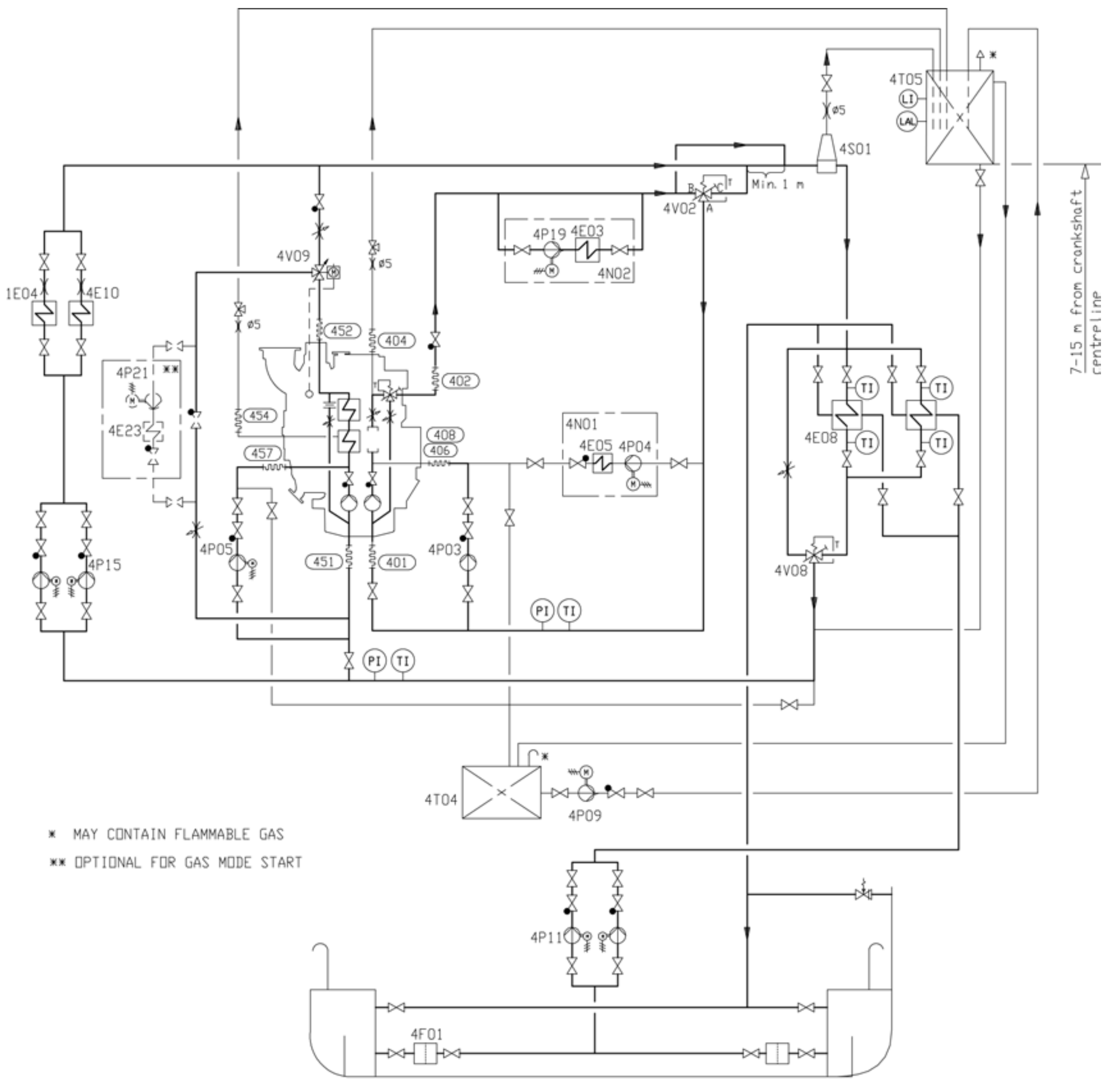


Fig 9-4 External cooling water system, main engines (DAAF013958D)

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

Pipe connections:					
401	HT-water inlet	DN65	451	LT-water inlet	DN80

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

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

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

9.3.3 Stand-by circulation pumps (4P03, 4P05)

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

NOTE

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

9.3.4 Sea water pump (4P11)

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

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

9.3.5 Temperature control valve for central cooler (4V08)

When external equipment (e.g. a reduction gear, generator or MDO cooler) are installed in the same cooling water circuit, there must be a common LT temperature control valve and separate pump 4P15 in the external system. The common LT temperature control valve is installed after the central cooler and controls the temperature of the water before the engine and the external equipment, by partly bypassing the central cooler. The valve can be either direct acting or electrically actuated.

The recommended set-point of the temperature control valve 4V08 is 35 °C.

NOTE

Max LT cooling water temperature before engine is 38 °C.

9.3.6 Charge air temperature control valve (4V09)

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

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

9.3.7 Temperature control valve for heat recovery (4V02)

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

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

The set-point is usually up to 75 °C.

9.3.8 Coolers for other equipment and MDF coolers

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

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

9.3.9 Fresh water central cooler (4E08)

The fresh water cooler can be of either plate, tube or box cooler type. Plate coolers are most common. Several engines can share the same cooler.

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

The flow to the fresh water cooler must be calculated case by case based on how the circuit is designed.

In case the fresh water central cooler is used for combined LT and HT water flows in a parallel system the total flow can be calculated with the following formula:

$$q = q_{LT} + \frac{3.6 \times \Phi}{4.15 \times (T_{OUT} - T_{IN})}$$

where:

q = total fresh water flow [m³/h]

q_{LT} = nominal LT pump capacity[m³/h]

Φ = heat dissipated to HT water [kW]

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

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

Design data:

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

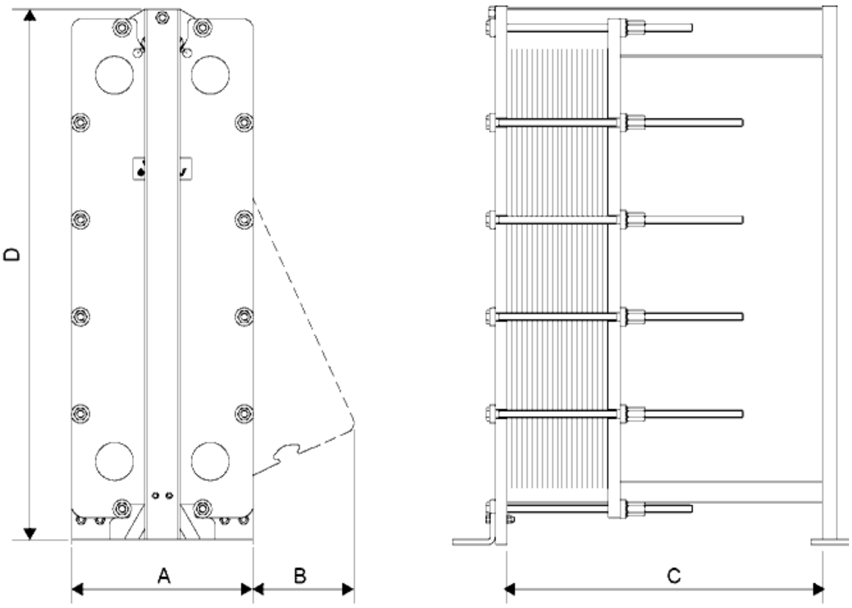


Fig 9-5 **Central cooler main dimensions. Example for guidance only**

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

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

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

9.3.10 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.

9.3.11 Air venting

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

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

The vent pipes must be continuously rising.

9.3.12 Expansion tank (4T05)

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

Design data:

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

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 9-2 Minimum diameter of balance pipe

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

9.3.13 Drain tank (4T04)

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

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

9.3.14 HT preheating

The cooling water circulating through the cylinders must be preheated to at least 60 ºC, preferably 70 ºC. 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.

9.3.14.1 HT heater (4E05)

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

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

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

Design data:	
Preheating temperature	min. 60°C
Required heating power	2 kW/cyl
Heating power to keep hot engine warm	1 kW/cyl

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

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

where:

P =	Preheater output [kW]
T_1 =	Preheating temperature = 60...70 °C
T_0 =	Ambient temperature [°C]
m_{eng} =	Engine weight [tonne]
V_{LO} =	Lubricating oil volume [m^3] (wet sump engines only)
V_{FW} =	HT water volume [m^3]
t =	Preheating time [h]
k_{eng} =	Engine specific coefficient = 0.5 kW
n_{cyl} =	Number of cylinders

9.3.14.2 Circulation pump for HT preheater (4P04)

Design data:	
Capacity	0.3 m³/h per cylinder
Delivery pressure	80...100 kPa (0.8...1.0 bar)

9.3.14.3 LT preheater (4E23)

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

9.3.14.4 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

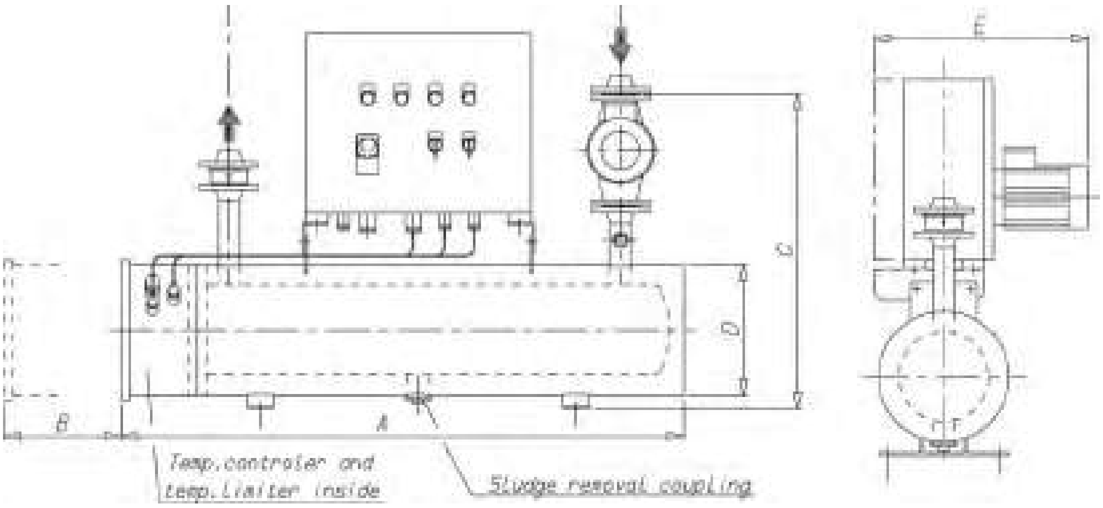


Fig 9-6 Preheating unit, electric (3V60L0653A)

Heater capacity	Pump capacity	Weight	Pipe connections	Dimensions				
kW	m³ / h	kg	Inlet / Outlet	A	B	C	D	E
7.5	3	75	DN40	1050	720	610	190	425
12	3	93	DN40	1050	550	660	240	450
15	3	93	DN40	1050	720	660	240	450
18	3	95	DN40	1250	900	660	240	450
22.5	8	100	DN40	1050	720	700	290	475
27	8	103	DN40	1250	900	700	290	475
30	8	105	DN40	1050	720	700	290	475
36	8	125	DN40	1250	900	700	290	475
45	8	145	DN40	1250	720	755	350	505
54	8	150	DN40	1250	900	755	350	505

9.3.15 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.

9.3.16 Thermometers and pressure gauges

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

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

10. Combustion Air System

10.1 Engine room ventilation

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

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

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

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

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

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

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

where:

q_v = air flow [m³/s]

Φ = total heat emission to be evacuated [kW]

ρ = air density 1.13 kg/m³

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

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

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

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

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

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

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

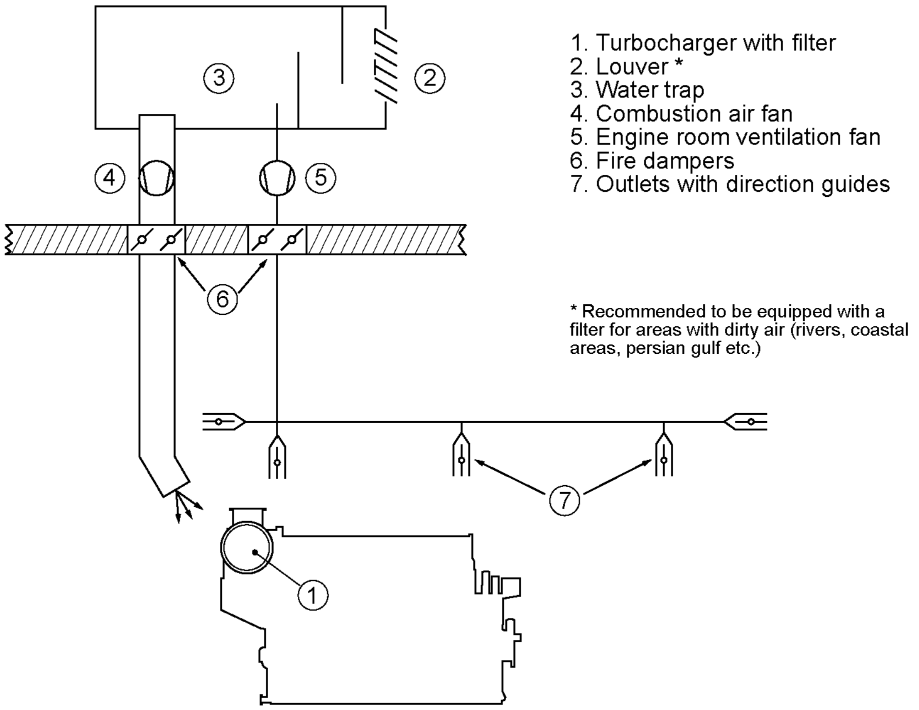


Fig 10-1 Engine room ventilation, turbocharger with air filter (DAAE092651)

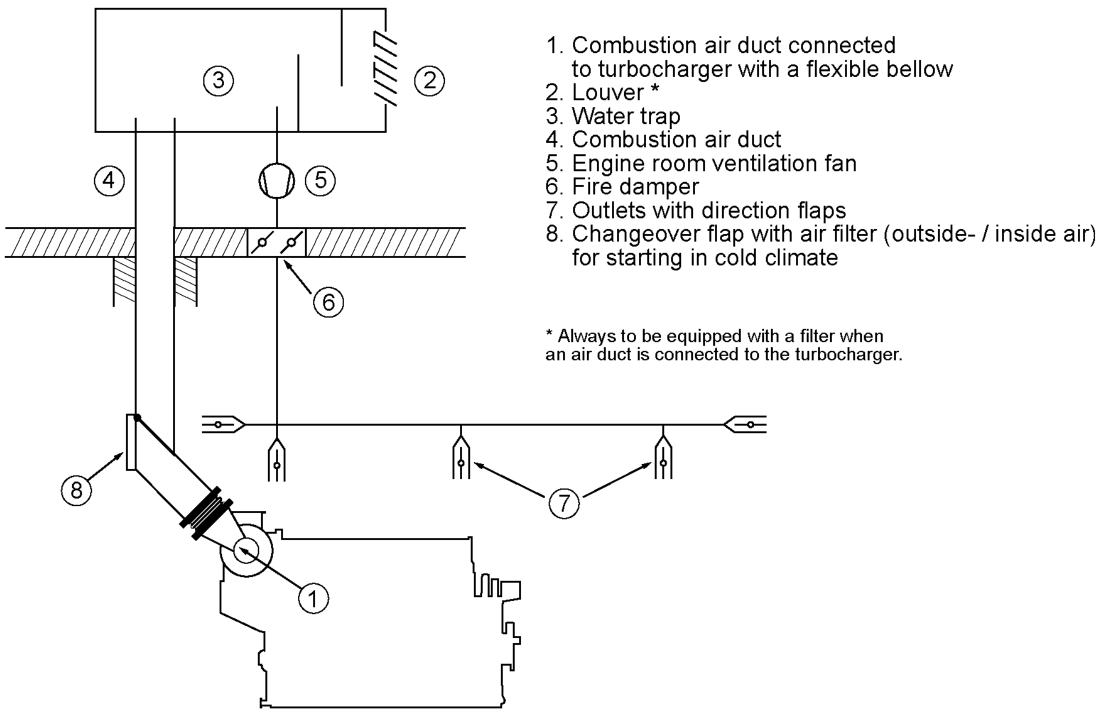


Fig 10-2 Engine room ventilation, air duct connected to the turbocharger (DAAE092652A)

10.2 Combustion air system design

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

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

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

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

where:

q_c = combustion air volume flow [m³/s]

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

ρ = air density 1.15 kg/m³

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

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

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

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

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

10.2.1 Charge air shut-off valve (optional)

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

10.2.2 Condensation in charge air coolers

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

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

Example, according to the diagram:

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

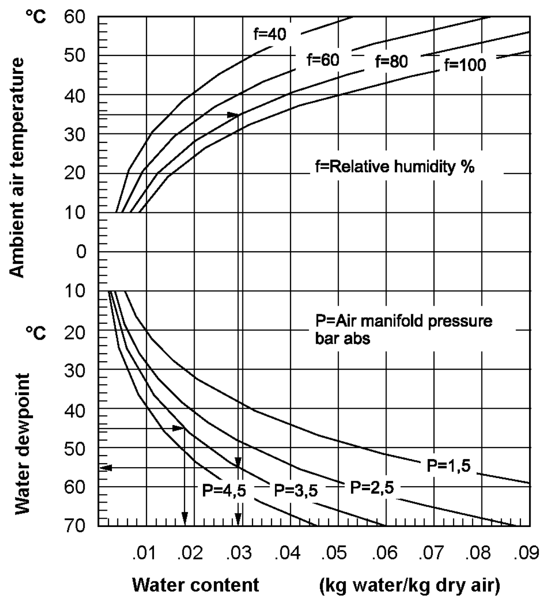


Fig 10-3 Condensation in charge air coolers

11. Exhaust Gas System

11.1 Internal exhaust gas system

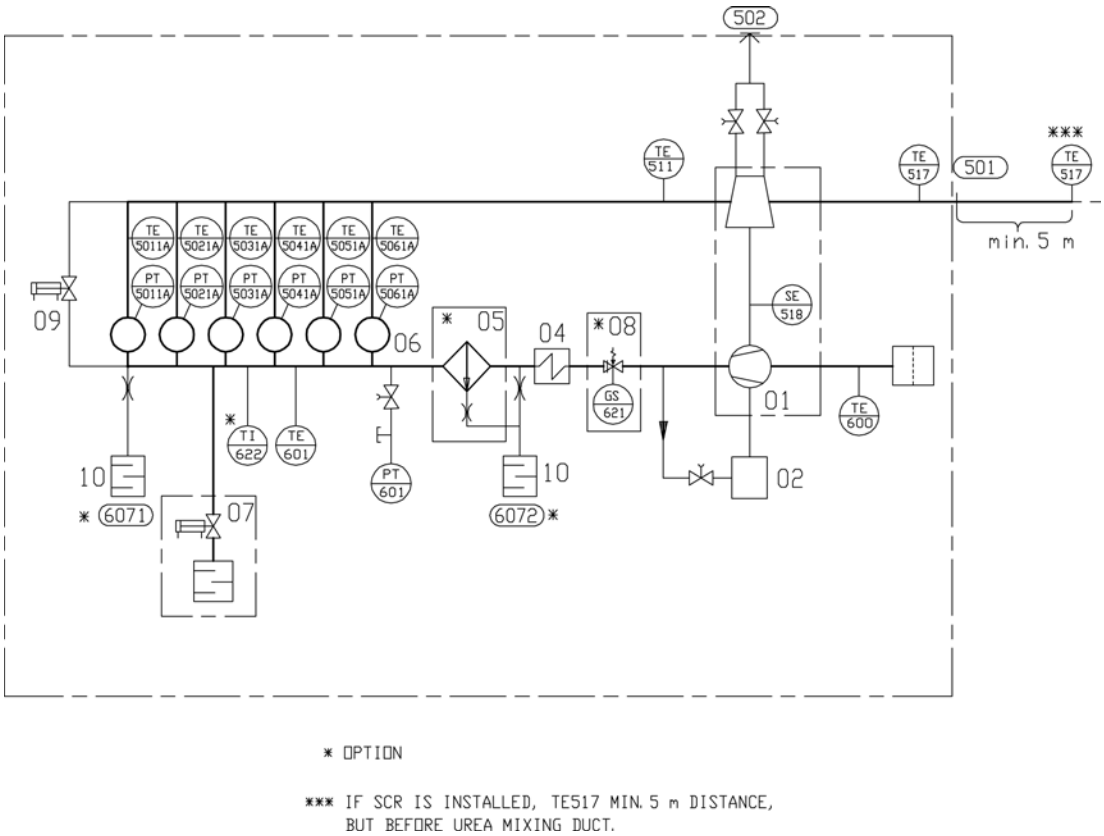


Fig 11-1 Charge air and exhaust gas system (DAAF013959E)

System components					
01	Turbocharger	*05	Water mist separator	*08	Charge air shut-off valve
02	Water container	06	Cylinders	09	By-pass valve
04	Charge air cooler	07	Air waste gate	10	Silencer

Sensors and indicators			
TE50#1A...	Exhaust gas temperature after each cylinder	TE600	Air temperature, TC inlet
PT50#1A...	Cylinder pressure, cyl A0#	PT601	Charge air pressure, engine inlet
TE511	Exhaust gas temperature TC A inlet	TE601	Charge air temperature, engine inlet
TE517	Exhaust gas temperature TC A outlet	GS621	Charge air shut-off valve, A-bank
SE518	TC A speed	TI622	Receiver temperature

Pipe connections		Size	Pressure class	Standard
501	Exhaust gas outlet	please refer to DAAF014083	PN6	ISO 7005-1
502	Cleaning water to turbine	OD15		DIN 2353
*6071	Condensate water from charge air reciever			
*6072	Condensate water from air cooler			

11.2 Exhaust gas outlet

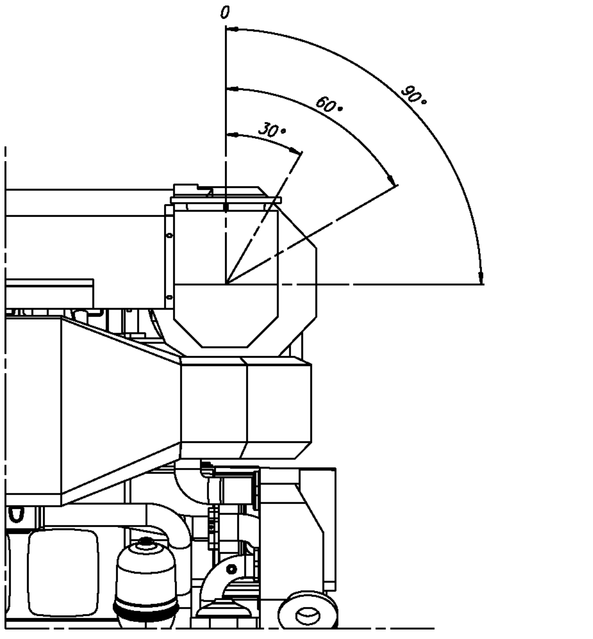


Fig 11-2 Exhaust pipe connections (DAAE066842)

Engine	TC in free end
W 6L20DF	0°, 30°, 60°, 90°
W 8L20DF	0°, 30°, 60°, 90°
W 9L20DF	0°, 30°, 60°, 90°

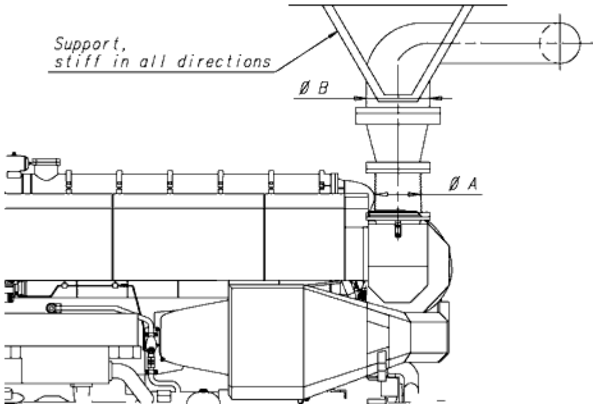


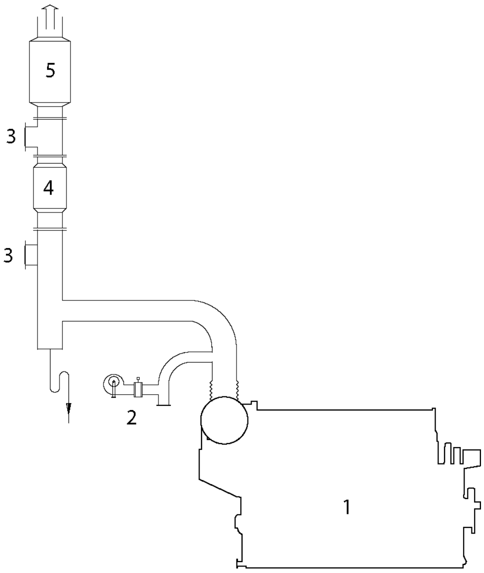
Fig 11-3 Exhaust pipe, diameters and support (DAAF014083)

Engine	ØA [mm]	ØB [mm]
W 6L20DF	250	300-350
W 8L20DF	300	350-450
W 9L20DF	300	350-450

11.3 External exhaust gas system

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

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



1 Duel Fuel engine

2 Exhaust gas ventilation unit

3 Rupture discs

4 Exhaust gas boiler

5 Silencer

Fig 11-4 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.

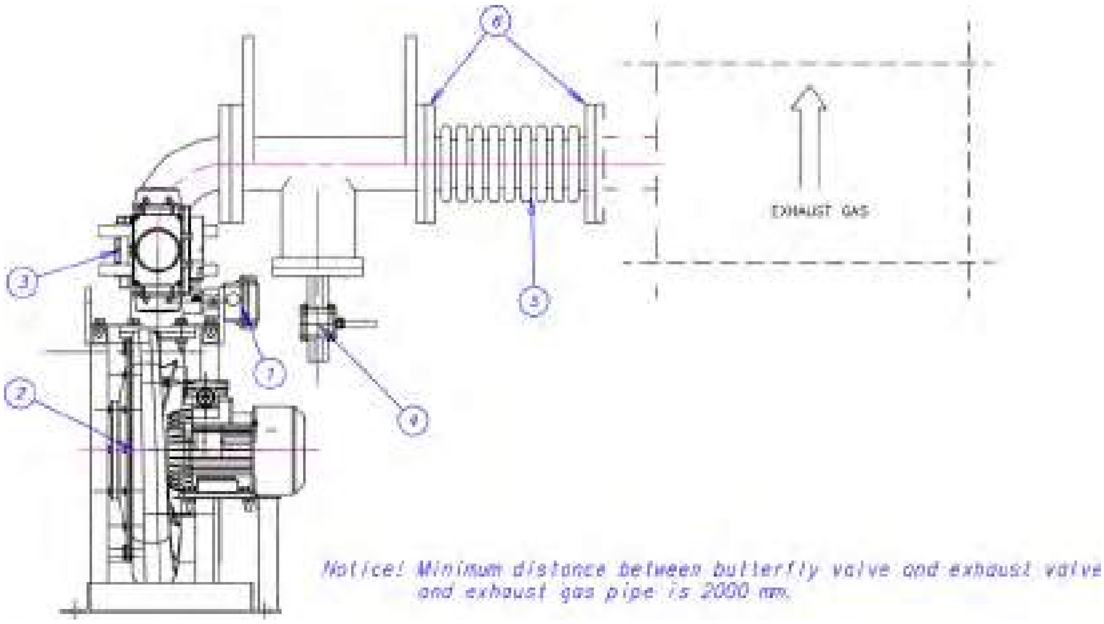


Fig 11-5 Exhaust gas ventilation arrangement (DAAF315146A)

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

11.3.3 Relief devices - rupture discs

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

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

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

11.3.4 Piping

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

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

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

where:

v = gas velocity [m/s]

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

T = exhaust gas temperature [°C]

D = exhaust gas pipe diameter [m]

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

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

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

11.3.5 Supporting

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

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

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

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

11.3.6 Back pressure

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

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

11.3.7 Exhaust gas bellows (5H01, 5H03)

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

11.3.8 SCR-unit (11N14)

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

In dual fuel engines the SCR system is not required, as IMO Tier 3 is met in gas mode.

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 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).

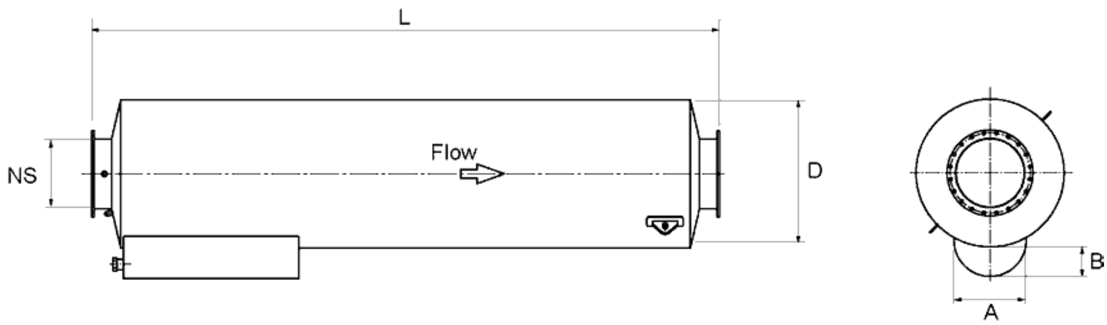


Fig 11-6 Exhaust gas silencer (DAAE087980)

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

NS	L [mm]	D [mm]	A [mm]	B [mm]	Weight [kg]
300	3530	860	305	150	455
350	3780	950	346	115	580
400	4280	1060	420	150	710
450	4280	1200	470	180	855
Flanges: DIN 2501					

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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 Turbine cleaning system

A dosing unit consisting of a flow meter and an adjustable throttle valve is delivered for each installation. The dosing unit is installed in the engine room and connected to the engine with a detachable rubber hose. The rubber hose is connected with quick couplings and the length of the hose is normally 10 m. One dosing unit can be used for several engines.

Water supply:	
Fresh water	
Min. pressure	0.3 MPa (3 bar)
Max. pressure	2 MPa (20 bar)
Max. temperature	80 °C
Flow	6-10 l/min (depending on cylinder configuration)

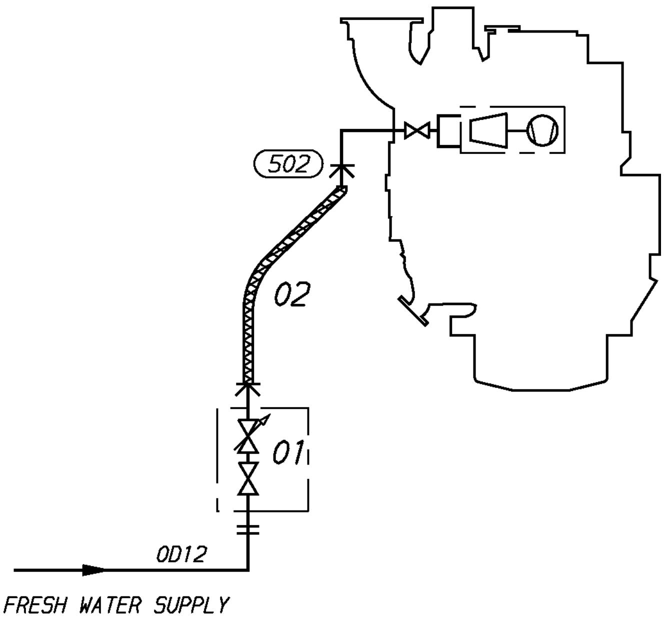

Fig 12-1 Turbine cleaning system (DAAE003884)

System components		Pipe connections		Size
01	Dosing unit with shut-off valve	502	Cleaning water to turbine	Quick coupling
02	Rubber hose			

12.2 Compressor cleaning system

The compressor side of the turbocharger is cleaned using a separate dosing vessel mounted on the engine.

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13. Exhaust Emissions

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

13.1 Dual fuel engine exhaust components

Due to the high efficiency and the clean fuel used in a dual fuel engine in gas mode, the exhaust gas emissions when running on gas are extremely low. In a dual fuel engine, the air-fuel ratio is very high, and uniform throughout the cylinders. Maximum temperatures and subsequent NOx formation are therefore low, since the same specific heat quantity released to combustion is used to heat up a large mass of air. Benefitting from this unique feature of the lean-burn principle, the NOx emissions from the Wärtsilä 20DF are very low, complying with most existing legislation. In gas mode most stringent emissions of IMO and SECA are met, while in diesel mode the dual fuel engine is a normal diesel engine.

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

13.2 Marine exhaust emissions legislation

13.2.1 International Maritime Organization (IMO)

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

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

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

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

13.2.2 Other Legislations

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

13.3 Methods to reduce exhaust emissions

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

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

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

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

14. Automation System

Wärtsilä Unified Controls – UNIC is a 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.

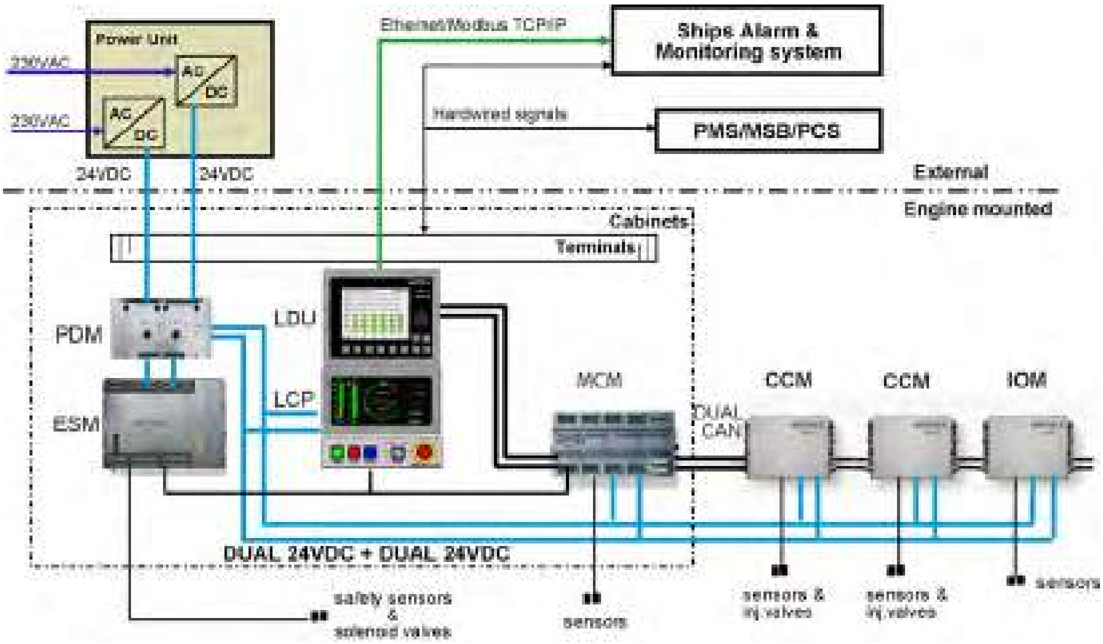

Fig 14-1 Architecture of UNIC C3

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
  - 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.

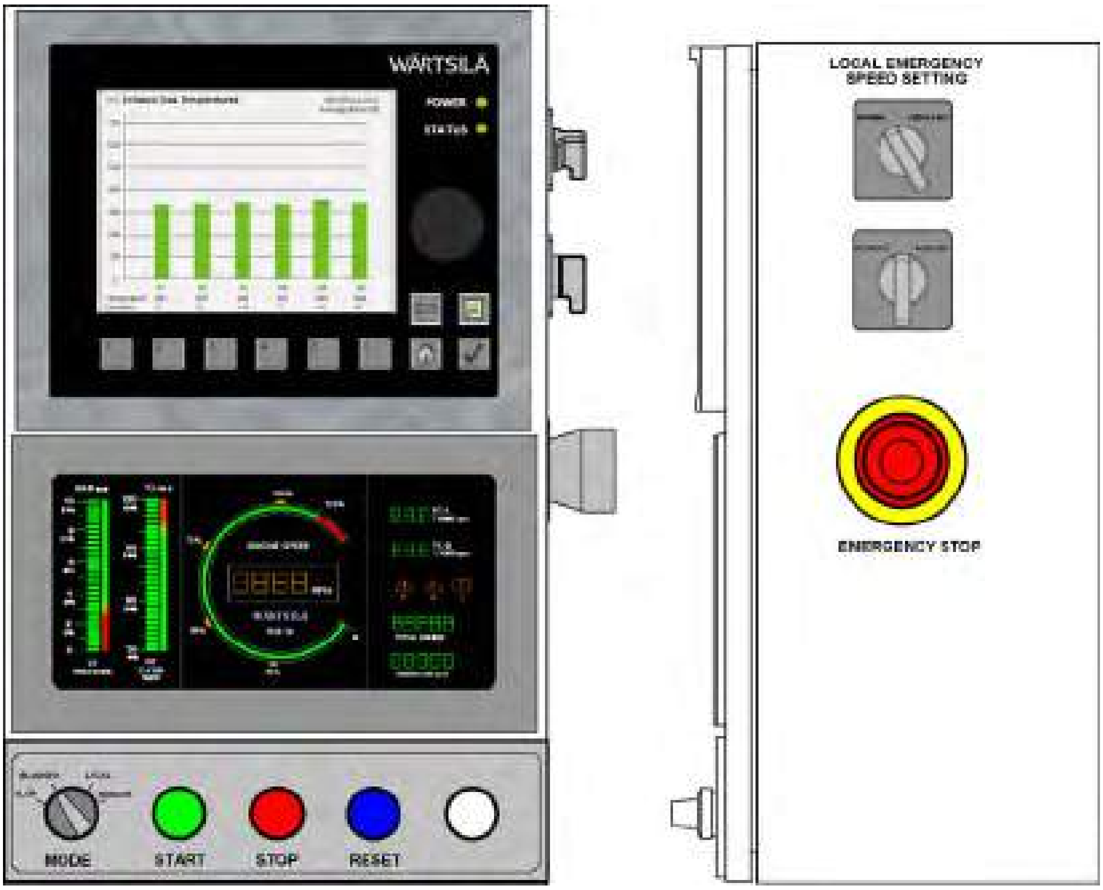

Fig 14-2 Local control panel and local display unit

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.

Power supply from ship's system:

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

14.1.4 Cabling and system overview

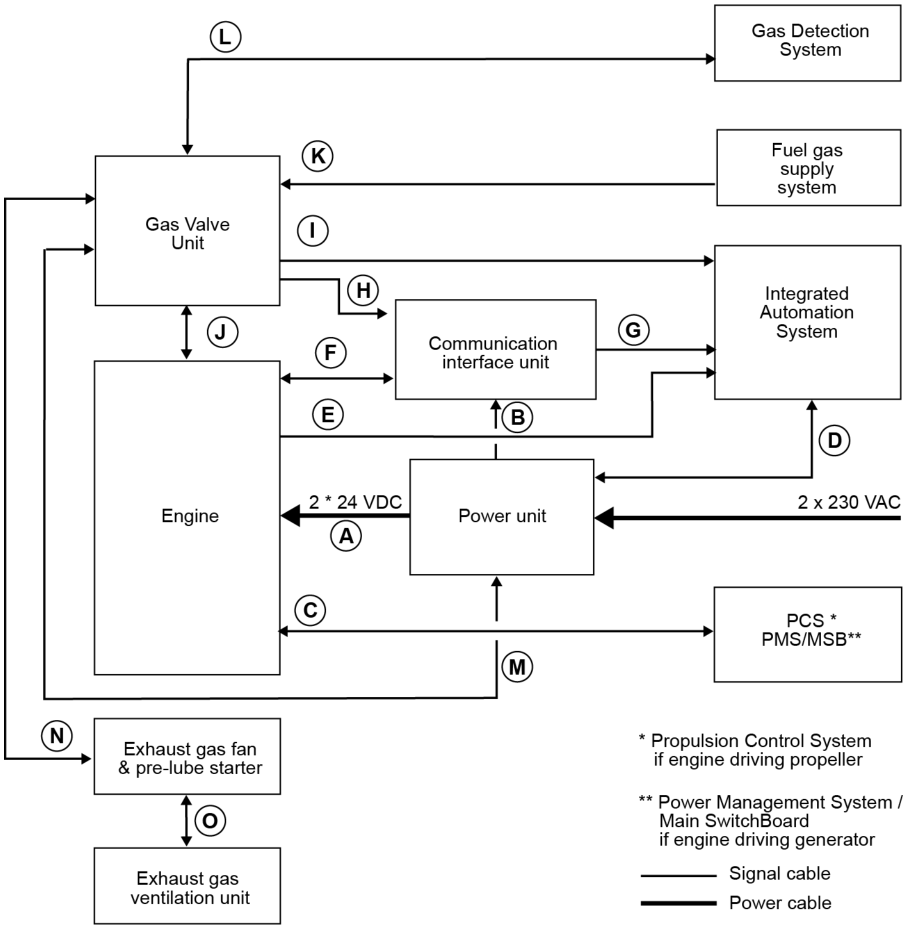

Fig 14-3 UNIC C3 overview

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) *
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

Cable	From <=> To	Cable types (typical)
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*.

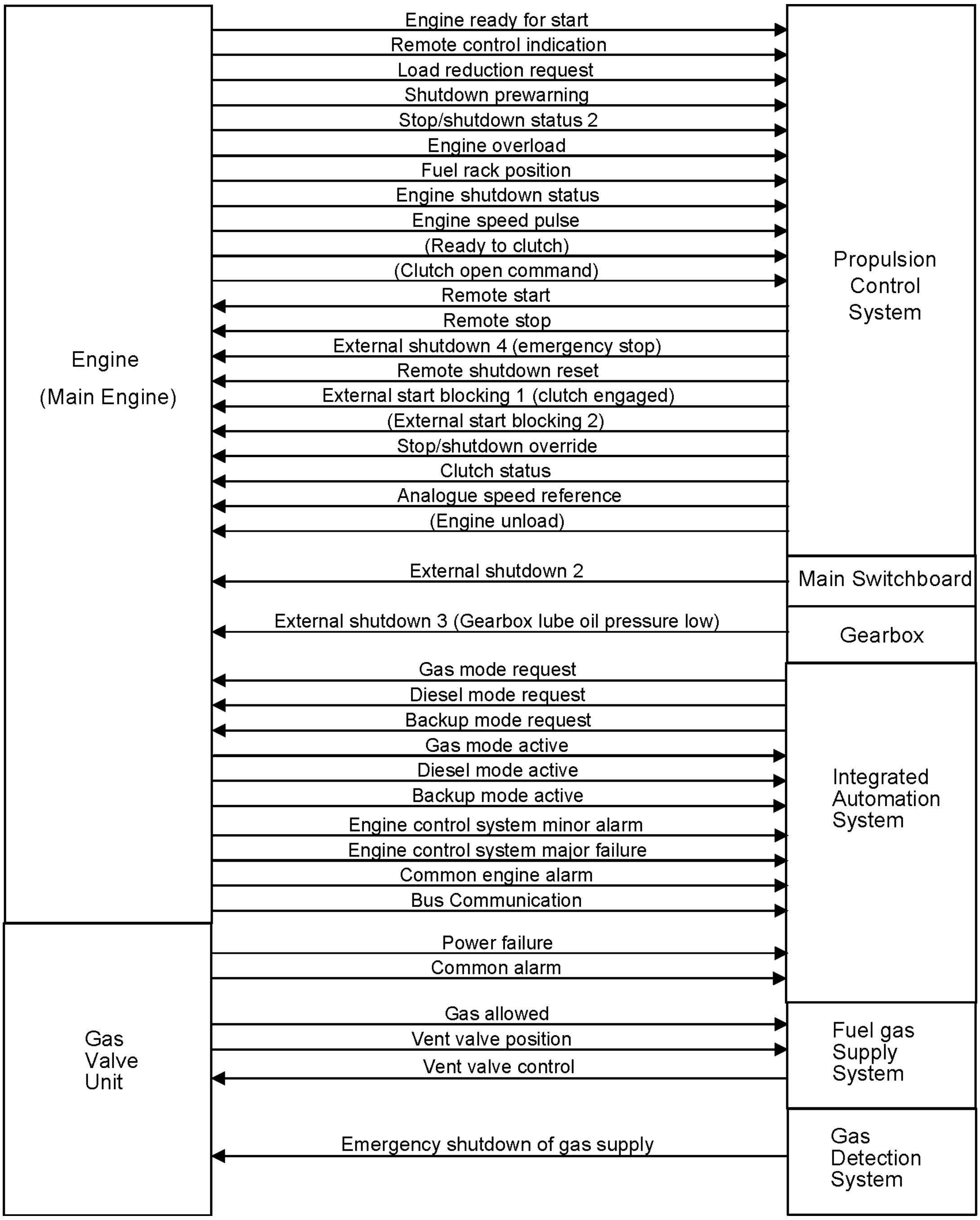

Fig 14-4 Signal overview (Main engine)

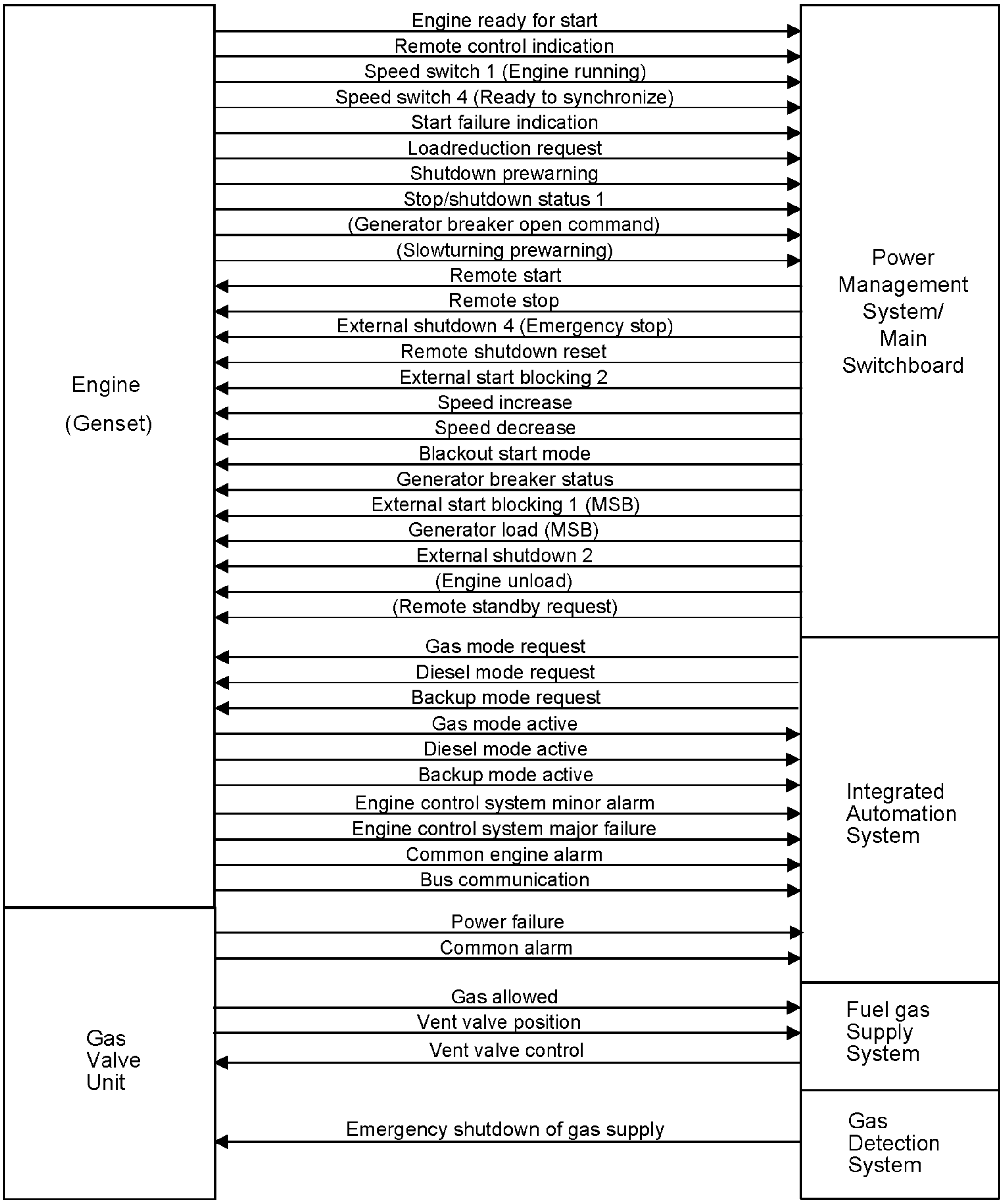

Fig 14-5 Signal overview (Generating set)

14.2 Functions

14.2.1 Engine operating modes

The operator can select two different fuel operating modes:

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

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

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

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

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

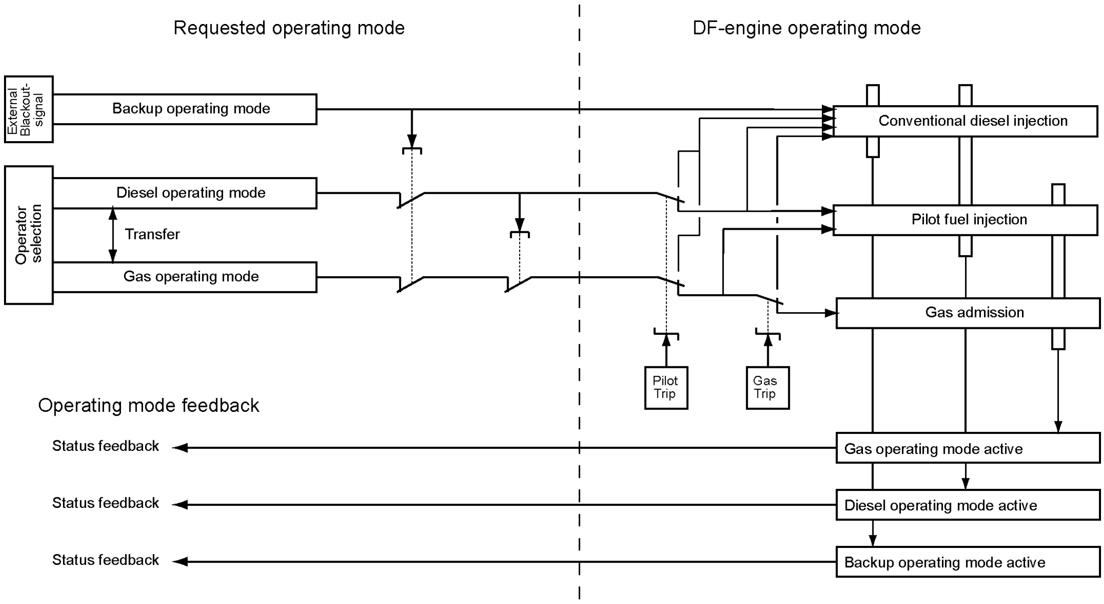

Fig 14-6 Principle of engine operating modes

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)

14.2.2.2 Start in gas operating mode

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

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

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

14.2.2.3 Start in diesel operating mode

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

14.2.2.4 Start in blackout mode

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

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

14.2.3 Gas/diesel transfer control

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.

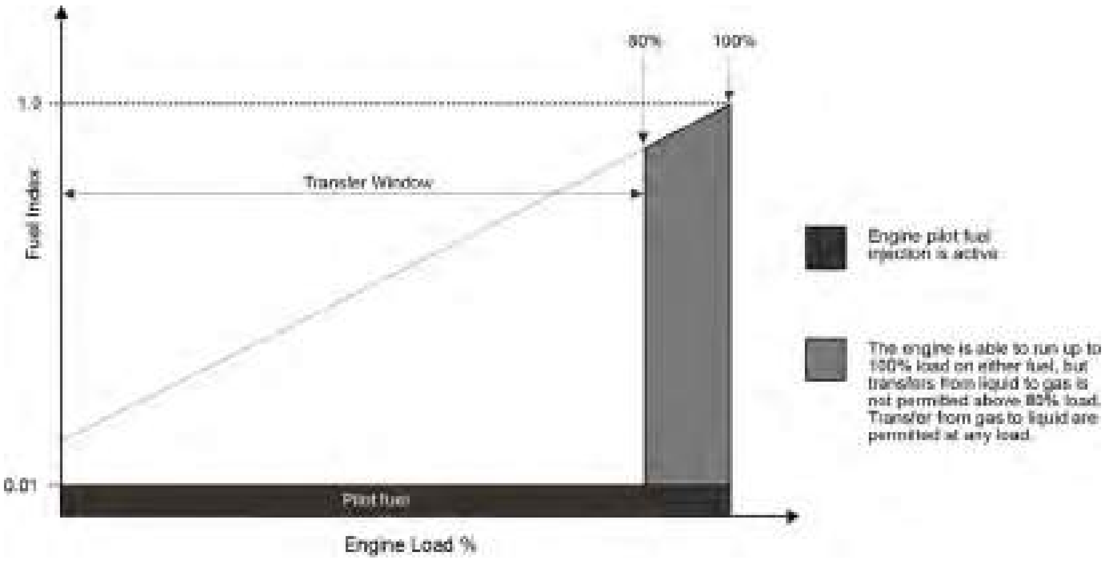

Fig 14-7 Operating modes are load dependent

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. 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 Pre-lubricating oil pump

The pre-lubricating oil pump must always be running when the engine is stopped. The pump shall start when the engine stops, and stop when the engine starts. The engine control system handles start/stop of the pump automatically via a motor starter.

It is recommended to arrange a back-up power supply from an emergency power source. Diesel generators serving as the main source of electrical power must be able to resume their operation in a black out situation by means of stored energy. Depending on system design and classification regulations, it may be permissible to use the emergency generator.

For dimensioning of the pre-lubricating oil pump starter, the values indicated below can be used. For different voltages, the values may differ slightly.

Table 14-2 Electric motor ratings for pre-lubricating pump

Engine type	Voltage [V]	Frequency [Hz]	Power [kW]	Current [A]
Wärtsilä 20DF	3 x 400	50	3.0	6.0
	3 x 440	60	3.5	6.2

14.4.1.2 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*.

14.4.1.3 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*.

14.4.1.4 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.

14.4.1.5 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.

14.4.1.6 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.

14.4.1.7 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.

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15. Foundation

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

15.1 Steel structure design

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

The foundation and the double bottom should be as stiff as possible in all directions to absorb the dynamic forces caused by the engine, reduction gear and thrust bearing. The foundation should be dimensioned and designed so that harmful deformations are avoided.

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

15.2 Mounting of main engines

15.2.1 Rigid mounting

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

Prior to installation the shipyard must send detailed plans and calculations of the chocking arrangement to the classification society and to Wärtsilä for approval.

The engine has four feet integrated to the engine block. There are two Ø22 mm holes for M20 holding down bolts and a threaded M16 hole for a jacking screw in each foot. The Ø22 holes in the seating top plate for the holding down bolts can be drilled though the holes in the engine feet. In order to avoid bending stress in the bolts and to ensure proper fastening, the contact face underneath the seating top plate should be counterbored.

Holding down bolts are through-bolts with lock nuts. Selflocking nuts are acceptable, but hot dip galvanized bolts should not be used together with selflocking (nyloc) nuts. Two of the holding down bolts are fitted bolts and the rest are clearance (fixing) bolts. The fixing bolts are M20 8.8 bolts according DIN 931, or equivalent. The two Ø23 H7/m6 fitted bolts are located closest to the flywheel, one on each side of the engine. The fitted bolts must be designed and installed so that a sufficient guiding length in the seating top plate is achieved, if necessary by installing a distance sleeve between the seating top plate and the lower nut. The guiding length in the seating top plate should be at least equal to the bolt diameter. The fitted bolts should be made from a high strength steel, e.g. 42CrMo4 or similar and the bolt should have a reduced shank diameter above the guiding part in order to ensure a proper elongation. The recommended shank diameter for the fitted bolts is 17 mm.

The tensile stress in the bolts is allowed to be max. 80% of the material yield strength and the equivalent stress during tightening should not exceed 90% of the yield strength.

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

15.2.1.1 Resin chocks

The recommended dimensions of resin chocks are 150 x 400 mm. The total surface pressure on the resin must not exceed the maximum value, which is determined by the type of resin and the requirements of the classification society. It is recommended to select a resin that has a type approval from the relevant classification society for a total surface pressure of 5 N/mm^2. (A typical conservative value is p_{tot} 3.5 N/mm^2).

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

The bolts must be made as tensile bolts with a reduced shank diameter to ensure sufficient elongation since the bolt force is limited by the permissible surface pressure on the resin. For a given bolt diameter the permissible bolt tension is limited either by the strength of the bolt material (max. stress 80% of the yield strength), or by the maximum permissible surface pressure on the resin.

15.2.1.2 Steel chocks

The top plates of the foundation girders are to be inclined outwards with regard to the centre line of the engine. The inclination of the supporting surface should be 1/100 and it should be machined so that a contact surface of at least 75% is obtained against the chocks.

Recommended size of the chocks are 115 x 170 mm at the position of the fitted bolts (2 pieces) and 115 x 190 mm at the position of the fixing bolts (6 pieces). The design should be such that the chocks can be removed, when the lateral supports are welded to the foundation and the engine is supported by the jacking screws. The chocks should have an inclination of 1:100 (inwards with regard to the engine centre line). The cut out in the chocks for the fixing bolts shall be 24...26 mm (M20 bolts), while the hole in the chocks for the fitted bolts shall be drilled and reamed to the correct size (ø23 H7) when the engine is finally aligned to the reduction gear.

The design of the holding down bolts is shown in figure *Chocking of main engines (3V69A0238C)*. The bolts are designed as tensile bolts with a reduced shank diameter to achieve a large elongation, which improves the safety against loosening of the nuts.

15.2.1.3 Steel chocks with adjustable height

As an alternative to resin chocks or conventional steel chocks it is also permitted to install the engine on adjustable steel chocks. The chock height is adjustable between 30...50 mm for the approved type of chock. There must be a chock of adequate size at the position of each holding down bolt.

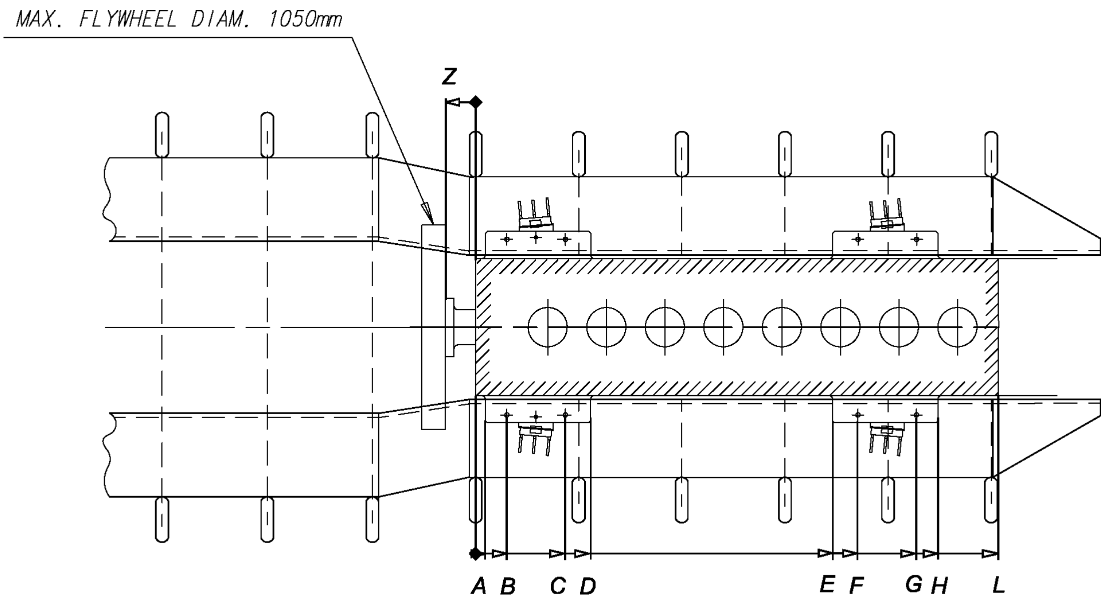


Fig 15-1 **Main engine seating, view from above (DAAF015003)**

Engine	Dimensions [mm]									
	A	B	C	D	E	F	G	H	L	Z
W 6L20DF	50	160	460	590	1530	1660	1960	2070	2080	155
W 8L20DF	50	160	460	590	1830	1960	2260	2370	2680	155
W 9L20DF	50	160	460	590	2130	2260	2560	2670	2980	155

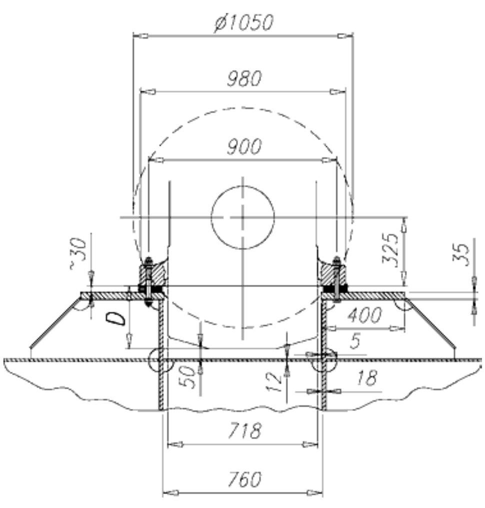


Fig 15-2 **Main engine seating, end view (DAAF015003)**

Engine type	(D) Deep sump [mm]	(D) Wet sump [mm]	(D) Dry sump [mm]
6L	500	300	300
8L	500	300	300
9L	500	300	300

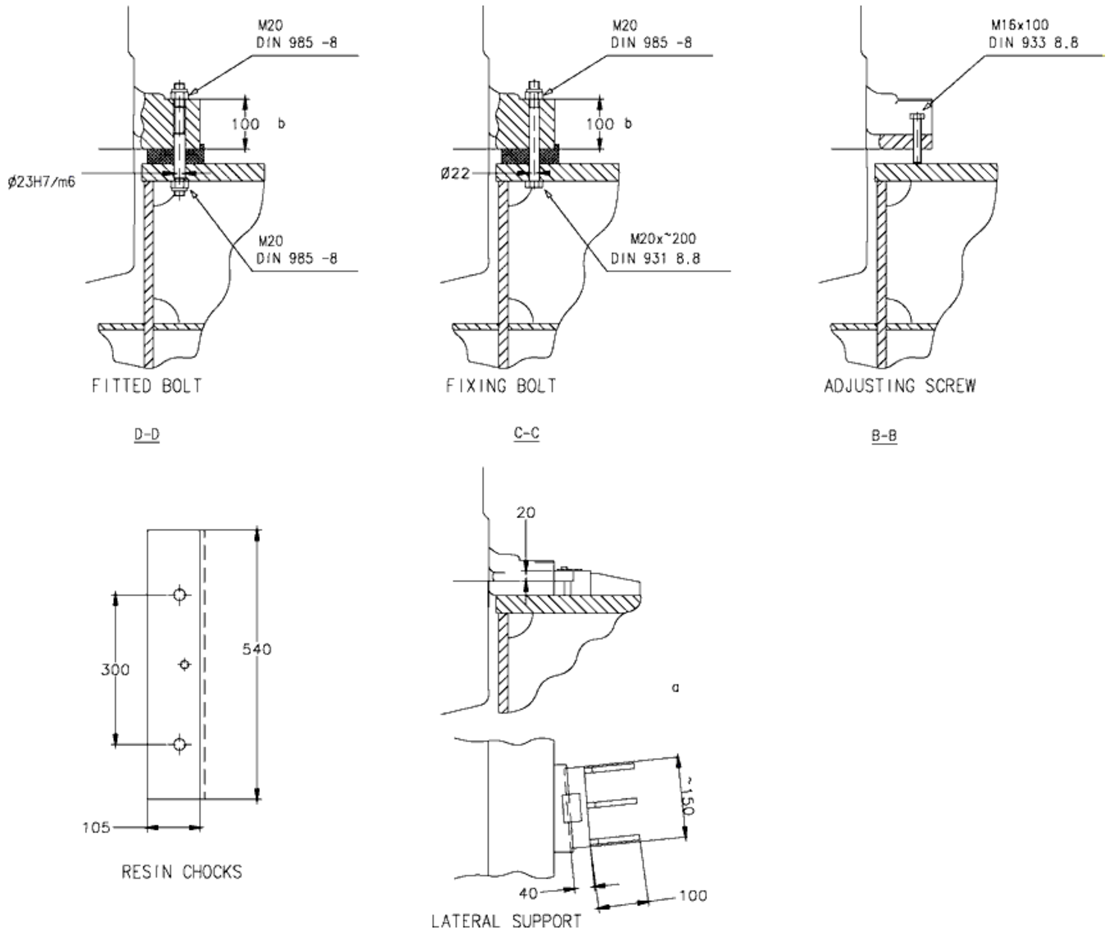
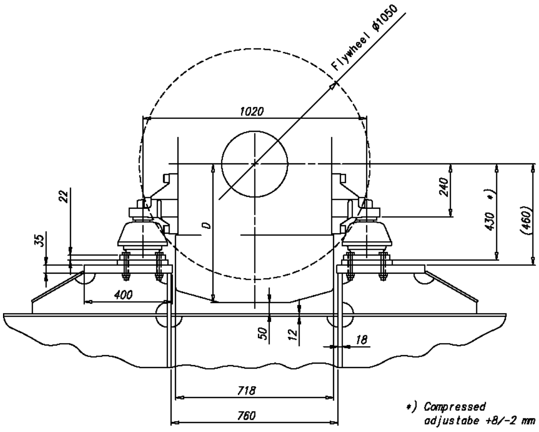


Fig 15-3 Chocking of main engines (3V69A0238C)

15.2.2 Resilient mounting

In order to reduce vibrations and structure borne noise, main engines can be resiliently mounted on rubber mounts. The transmission of forces emitted by a resiliently mounted engine is 10-20% compared to a rigidly mounted engine.



Engine type	(D) Deep sump [mm]	(D) Wet sump [mm]	(D) Dry sump [mm]
6L	825	625	625
8L	825	625	625
9L	825	625	625

Fig 15-4 **Resilient mounting (DAAF017144)**

15.3 Mounting of generating sets

15.3.1 Generator feet design

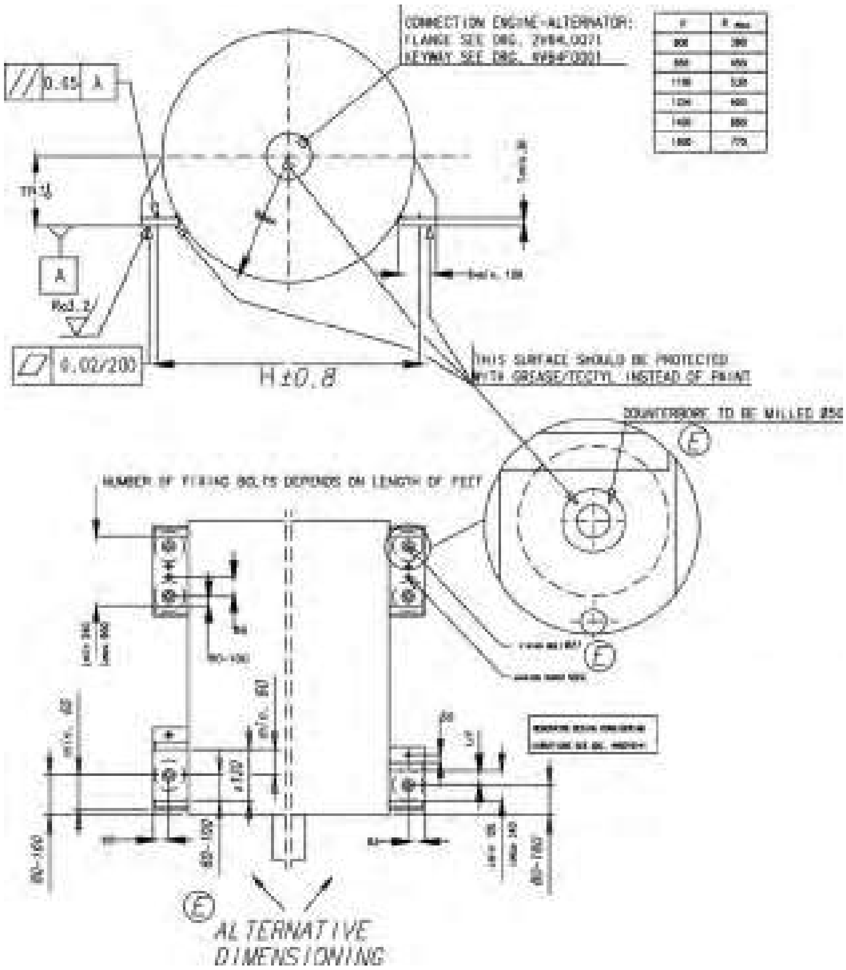


Fig 15-5 **Instructions for designing the feet of the generator and the distance between its holding down bolt (4V92F0134E)**

15.3.2 Resilient mounting

Generating sets, comprising engine and generator mounted on a common base frame, are usually installed on resilient mounts on the foundation in the ship.

The resilient mounts reduce the structure borne noise transmitted to the ship and also serve to protect the generating set bearings from possible fretting caused by hull vibration.

The number of mounts and their location is calculated to avoid resonance with excitations from the generating set engine, the main engine and the propeller.

NOTE

To avoid induced oscillation of the generating set, the following data must be sent by the shipyard to Wärtsilä at the design stage:

- main engine speed [rpm] and number of cylinders
- propeller shaft speed [rpm] and number of propeller blades

The selected number of mounts and their final position is shown in the generating set drawing.

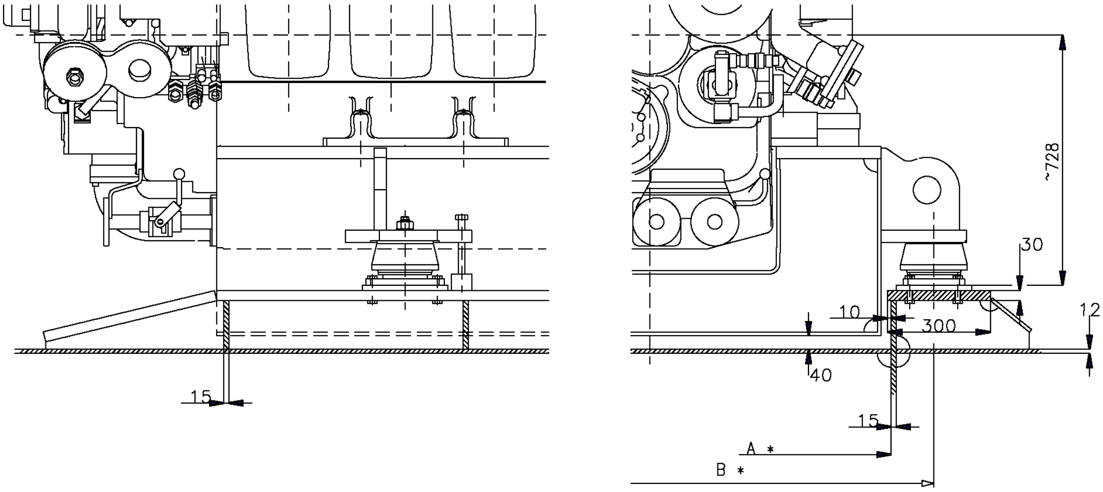


Fig 15-6 **Recommended design of the generating set seating (3V46L0720G)**

Engine type	A*	B*
6L	1330 / 1480 / 1630	1580 / 1730 / 1880
8L	1480 / 1630	1730 / 1880
9L	1480 / 1630 / 1860	1730 / 1880 / 2110

** Dependent on generator width*

15.3.3 Rubber mounts

The generating set is mounted on conical resilient mounts, which are designed to withstand both compression and shear loads. In addition the mounts are equipped with an internal buffer to limit movements of the generating set due to ship motions. Hence, no additional side or end buffers are required.

The rubber in the mounts is natural rubber and it must therefore be protected from oil, oily water and fuel.

The mounts should be evenly loaded, when the generating set is resting on the mounts. The maximum permissible variation in compression between mounts is 2.0 mm. If necessary, chocks or shims should be used to compensate for local tolerances. Only one shim is permitted under each mount.

The transmission of forces emitted by the engine is 10-20% when using conical mounts.

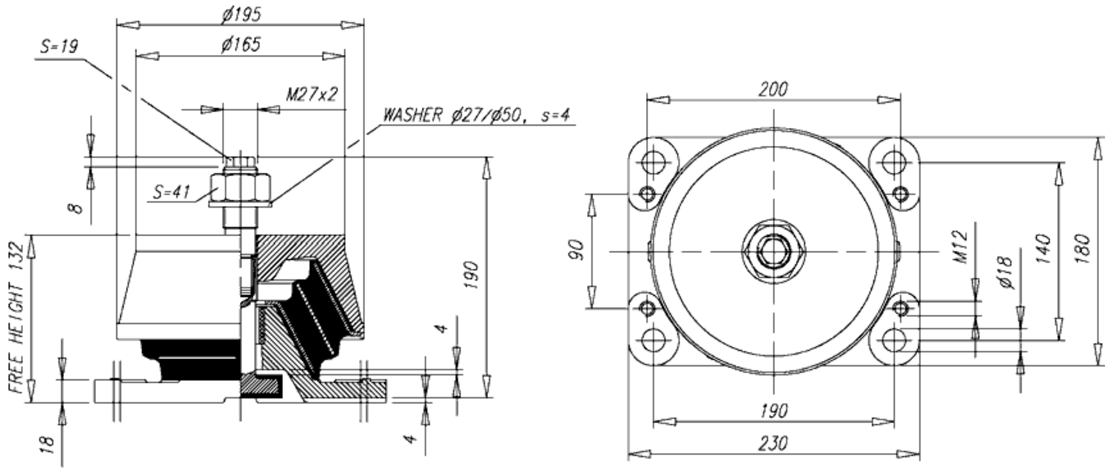


Fig 15-7 Rubber mounts (3V46L0706C)

15.4 Flexible pipe connections

When the engine or the generating set is resiliently installed, all connections must be flexible and no grating nor ladders may be fixed to the generating set. When installing the flexible pipe connections, unnecessary bending or stretching should be avoided. The external pipe must be precisely aligned to the fitting or flange on the engine. It is very important that the pipe clamps for the pipe outside the flexible connection must be very rigid and welded to the steel structure of the foundation to prevent vibrations, which could damage the flexible connection.

16. Vibration and Noise

Wärtsilä 20DF generating sets comply with vibration levels according to ISO 8528-9. Main engines comply with vibration levels according to ISO 10816-6 Class 5.

16.1 External forces 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.

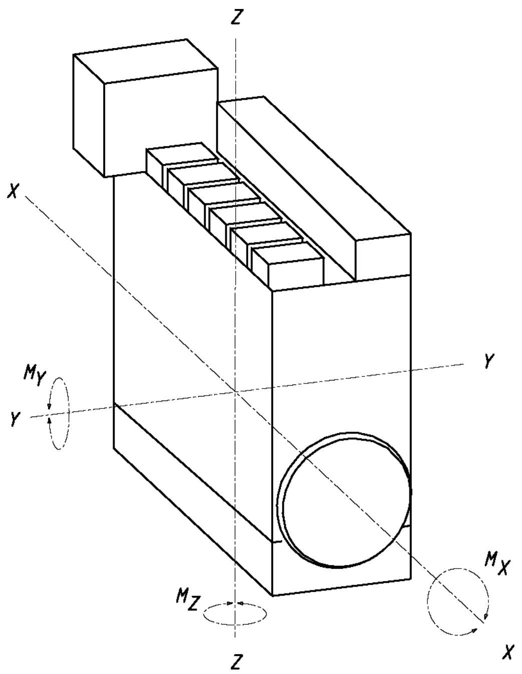


Fig 16-1 Coordinate system

Table 16-1 External forces

Engine	Speed [rpm]	Fre-quency [Hz]	F_Y [kNm]	F_Z [kNm]	Fre-quency [Hz]	F_Y [kNm]	F_Z [kNm]	Fre-quency [Hz]	F_Y [kNm]	F_Z [kNm]
W 6L20DF	1000 1200	– –	– –	– –	– –	– –	– –	– –	– –	– –
W 8L20DF	1000 1200	67 80	– –	3 4	– –	– –	– –	– –	– –	– –
W 9L20DF	1000 1200	– –	– –	– –	– –	– –	– –	– –	– –	– –

Table 16-2 External couples

Engine	Speed [rpm]	Fre-quency [Hz]	M_Y [kNm]	M_Z [kNm]	Fre-quency [Hz]	M_Y [kNm]	M_Z [kNm]	Fre-quency [Hz]	M_Y [kNm]	M_Z [kNm]
W 6L20DF	1000 1200	– –	– –	– –	– –	– –	– –	– –	– –	– –
W 8L20DF	1000 1200	– –	– –	– –	– –	– –	– –	– –	– –	– –
W 9L20DF	1000 1200	17 20	8 12	8 12	33 40	6 8	– –	67 80	1 1	– –

– couples are zero or insignificant.

16.2 Torque variations

Table 16-3 Torque variation at 100% load

Engine	Speed [rpm]	Frequency [Hz]	M_X [kNm]	Frequency [Hz]	M_X [kNm]	Frequency [Hz]	M_X [kNm]
W 6L20DF	1000 1200	50 60	6 3	100 120	5 5	150 180	1 2
W 8L20DF	1000 1200	67 80	13 13	133 160	3 3	200 240	1 1
W 9L20DF	1000 1200	75 90	13 14	150 180	2 3	225 270	1 1

16.3 Mass moments of inertia

The mass-moments of inertia of the main engines (including flywheel) are typically as follows:

Engine	J [kgm²]
W 6L20DF	90...150
W 8L20DF	110...160
W 9L20DF	100...170

16.4 Air borne noise

The airborne noise of the engines is measured as sound power level based on ISO 9614-2. The results represent typical engine A-weighted sound power level at full load and nominal speed.

Table 16-4 A-weighted Sound Power Level (Diesel Mode) in Octave Frequency Band [dB, ref. 1pW]

[Hz]	125	250	500	1000	2000	4000	8000	Total
6L	93	100	105	111	110	105	105	115
8L	99	103	107	113	112	111	110	118
9L	97	104	110	115	112	109	106	119

Table 16-5 A-weighted Sound Power Level (Gas Mode) in Octave Frequency Band [dB, ref. 1pW]

[Hz]	125	250	500	1000	2000	4000	8000	Total
6L	93	100	105	109	108	102	103	114
8L	97	103	108	111	111	107	107	117
9L	100	105	109	114	114	110	110	119

16.5 Exhaust noise

The results represent typical exhaust sound power level emitted from turbocharger outlet to free field at engine full load and nominal speed.

Table 16-6 Free Field Exhaust Gas Sound Power Level in Octave Frequency Band [dB, ref. 1pW]

[Hz]	32	63	125	250	500	1000	2000	4000	Total
6L	131	142	136	134	132	127	119	110	144
8L	127	142	138	138	132	124	108	99	145
9L	131	147	136	127	121	111	104	98	147

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.

17.1.1 Connection to generator

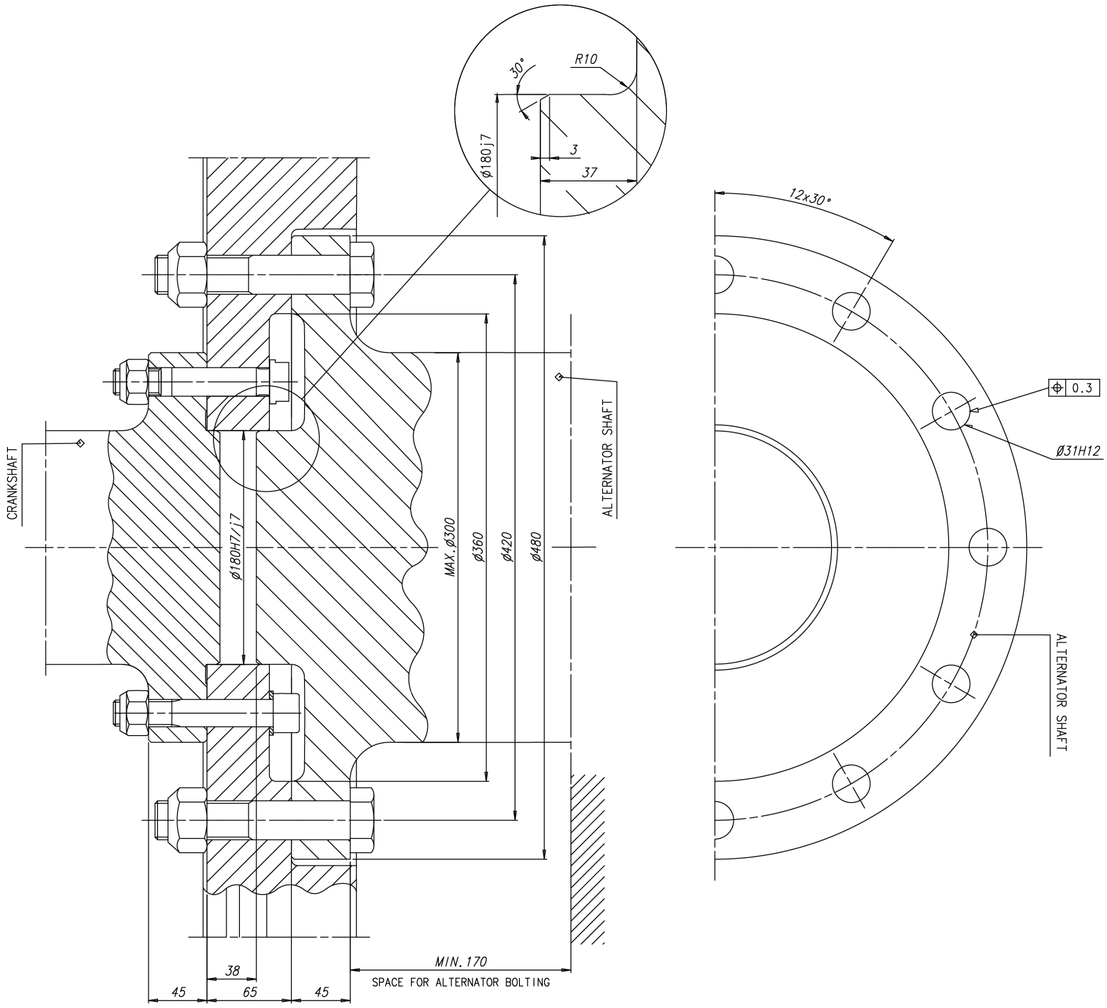


Fig 17-1 Connection engine/single bearing generator (2V64L0071B)

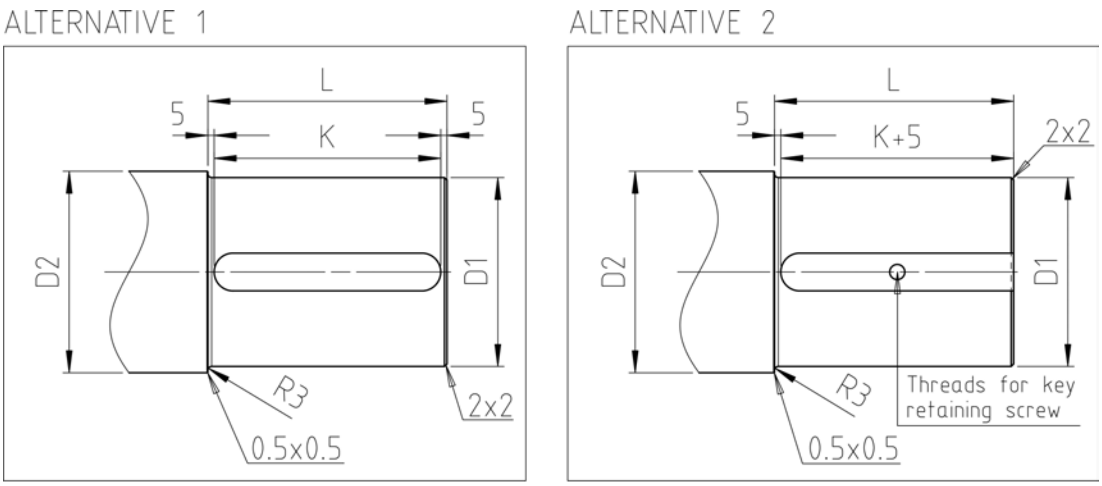


Fig 17-2 **Connection engine/two-bearing generator (4V64F0001C)**

Engine	Dimensions [mm]			
	D_1	L	K	min D
W 6L20DF	150	190	180	160
W 8L20DF	150	190	180	160
W 9L20DF	150	190	180	160

17.2 Torque flange

In mechanical propulsion applications, a torque meter has to be installed in order to measure the absorbed power. The torque flange has an installation length of 160 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.

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

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

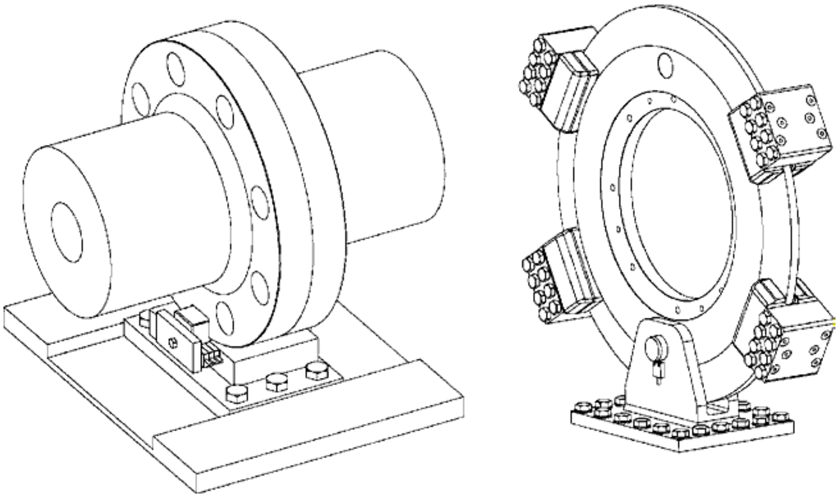


Fig 17-3 Shaft locking device and brake disc with calipers

17.5 Power-take-off from the free end

At the free end a shaft connection as a power take off can be provided. If required full output can be taken from the PTO shaft.

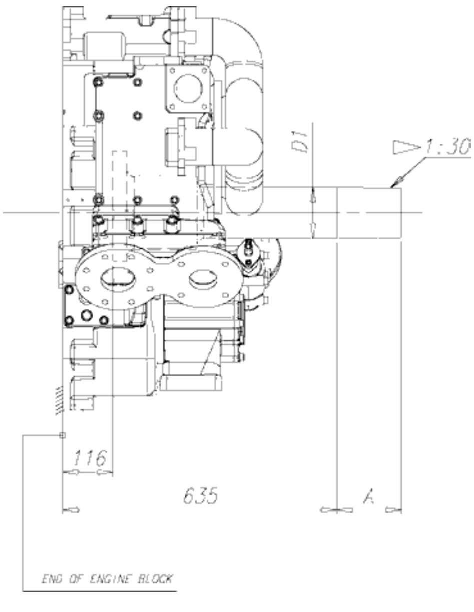


Fig 17-4 PTO alternative 1 (DAAE079074A)

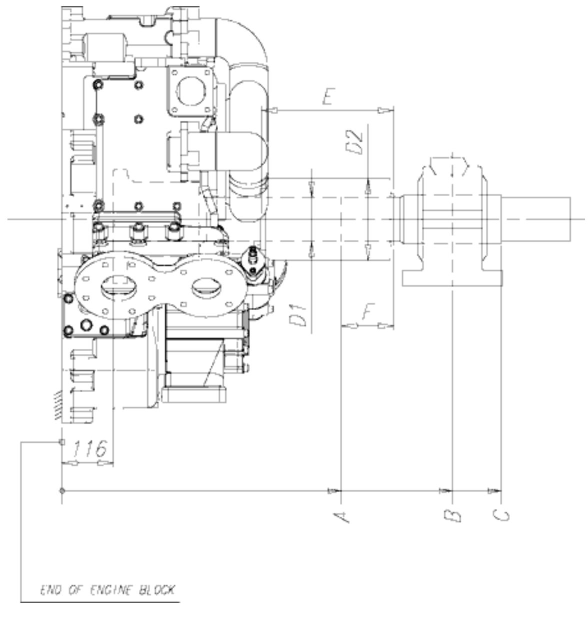


Fig 17-5 PTO alternative 2 (DAAE079045)

Rating [kW]	Dimensions [mm]	
	D1	A
700 1)	80	105
2300 1)	120	150

Rating is dependent on coupling hub. Max. output may also be restricted due to max coupling weight 135 kg. 1320 kW always accepted.

Rating [kW] 1)	Dimensions [mm]						
	D1	D2	A	B	C	E	F
1700 1)	100	170	610	860	970	280	108
2200 1)	110	185	630	880	990	300	118

External support bearing is not possible for resiliently mounted engines.

[1)] *PTO shaft design rating, engine output may be lower*

17.6 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

17.7 Turning gear

The engine can be turned with a manual ratchet tool after engaging a gear wheel on the flywheel gear rim. The ratchet tool is provided with the engine.

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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 Main engines

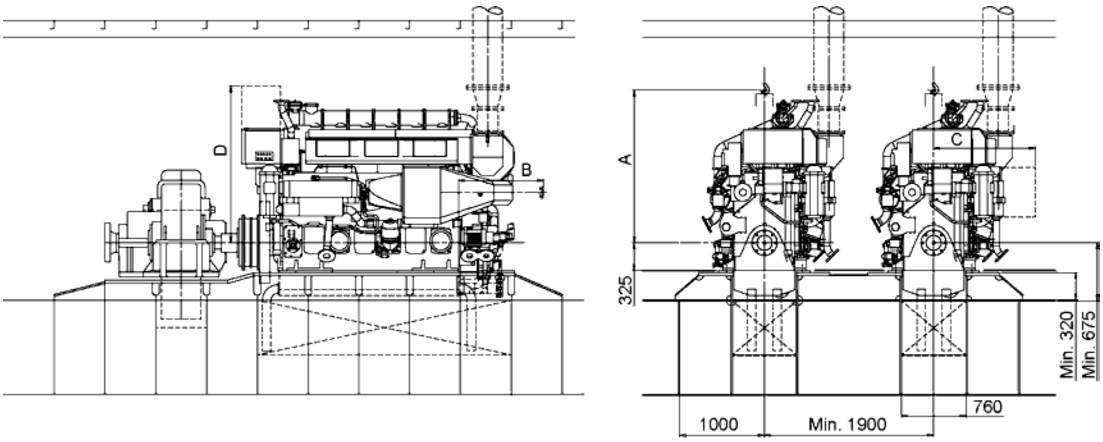

Fig 18-1 Crankshaft distances main engines (DAAF017589)

Engine	A	B	C	D
W 6L20DF	1800	1000	1200	1845
W 8L20DF	1800	1300	1200	1845
W 9L20DF	1800	1300	1200	1845

All dimensions in mm.

A - Minimum height when removing a piston

B - Camshaft overhaul distance

C - Charge air cooler overhaul distance

D - Space necessary for access to the connection box

18.1.2 Generating sets

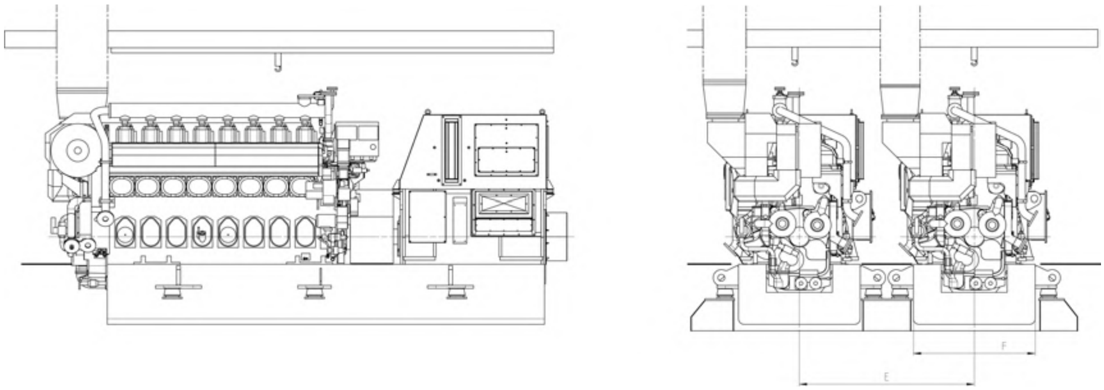

Fig 18-2 Crankshaft distances generating sets (DAAE007434D)

Table 18-1 Standard genset

Engine type	E*	F
W 6L20DF	1970 / 2040 / 2170	1270 / 1420 / 1570
W 8L20DF	2040 / 2170 / 2250	1420 / 1570 / 1700
W 9L20DF	2040 / 2200 / 2400	1420 / 1570 / 1700

Table 18-2 Double flexible installed genset

Engine type	E*	F
W 6L20DF	2450	1350
W 8L20DF	2450	1350
W 9L20DF	2450	1350

E = MIN. DISTANCE BETWEEN ENGINES DEPENDENT ON COMMON BASE PLATE
F = WIDTH OF THE COMMON BASE PLATE DEPENDENT ON WIDTH OF THE ALTERNATOR
** In case of extra wide lifting lugs needed, 230mm should be added to dimension E. Depending on final generator selection*
** Dimension E should be checked at all times with each project specific configuration due to generator service space*
All dimensions in mm.

18.2 Space requirements for maintenance

18.2.1 Working space around the engine

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

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

18.2.2 Engine room height and lifting equipment

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

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

18.2.3 Maintenance platforms

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

18.3 Transportation and storage of spare parts and tools

Transportation arrangement from engine room to storage and workshop has to be prepared for heavy engine components. This can be done with several chain blocks on rails or alternatively utilising pallet truck or trolley. If transportation must be carried out using several lifting equipment, coverage areas of adjacent cranes should be as close as possible to each other.

Engine room maintenance hatch has to be large enough to allow transportation of main components to/from engine room.

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

On single main engine installations it is important to store heavy engine parts close to the engine to make overhaul as quick as possible in an emergency situation.

18.4 Required deck area for service work

During engine overhaul some deck area is required for cleaning and storing dismantled components. Size of the service area is dependent of the overhauling strategy chosen, e.g. one cylinder at time, one bank at time or the whole engine at time. Service area should be plain steel deck dimensioned to carry the weight of engine parts.

18.4.1 Service space requirement

18.4.1.1 Service space for engines with turbocharger in driving end

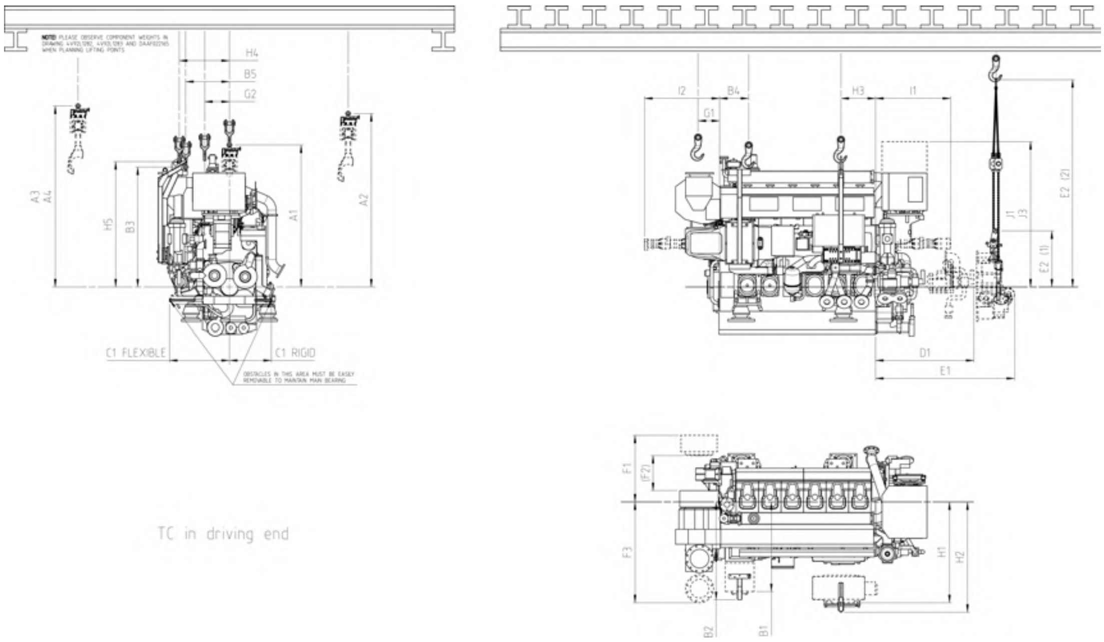

Fig 18-3 Service space for engines with turbocharger in driving end (V69C0301D)

Service spaces in mm		6L	8L	9L
A1	Height for overhauling piston and connecting rod	1800		
A2	Height for transporting piston and connecting rod freely over adjacent cylinder head covers	2300		
A3	Height for transporting piston and connecting rod freely over exhaust gas insulation box	2300	2400	2400
B1	Width for dismantling charge air cooler and air inlet box	1200		
B2	Width for dismantling charge air cooler and air inlet box sideways by using lifting tool	1310		
B3	Height of the lifting eye for the charge air cooler lifting tool	1600		
B4	Recommended lifting point for charge air cooler lifting tool	390		
B5	Recommended lifting point for charge air cooler lifting tool	585		
C1	Removal of main bearing side screw, flexible / rigid mounting	800 / 560		
D1	Distance needed for dismantling lubricating oil and water pumps	635		
E1	Distance needed for dismantling pump cover with fitted pumps	With PTO: lenght + 515 Without PTO: 650		
E2	Height of lifting eye for the pump cover with fitted pumps, with lifting tool 1/ alternative lifting tool 2	750 / 2770		
F1	The recommended axial clearance for dismantling and assembly of silencers	650	710	710
F2	Minimum axial clearance	100		
F3	Recommended distance for dismantling the gas outlet elbow	990	1170	1170
G1	Recommended lifting point for the turbocharger	300		
G2	Recommended lifting point sideways for the turbocharger	345		
H1	Width for dismantling lubricating oil module and/or plate cooler	1250		
H2	Width for dismantling lubricating oil module with lifting tool	1380		
H3	Recommended lifting point for dismantling lubricating oil module and/or plate cooler	445		
H4	Recommended lifting point sideways for dismantling lube oil module and/or plate cooler	1045		
H5	Height of lifting eye for dismantling lube oil module with lifting tool	1675		
I1	Camshaft overhaul distance (free end)	1000	1300	1300

Service spaces in mm		6L	8L	9L
I2	Camshaft overhaul distance (flywheel end)	1000	1300	1300
J1	Space necessary for access to connecting box	1785		

18.4.1.2 Service space for engines with turbocharger in free end

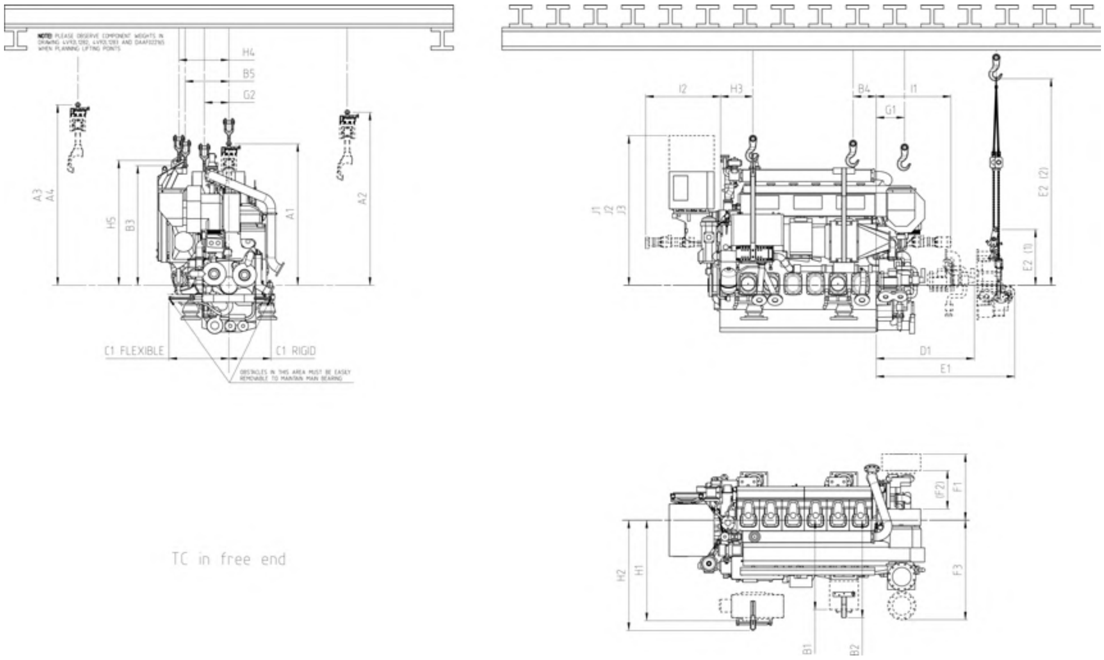

Fig 18-4 Service space for engines with turbocharger in free end (V69C0302D)

Service spaces in mm		6L	8L	9L
A1	Height for overhauling piston and connecting rod	1800		
A2	Height for transporting piston and connecting rod freely over adjacent cylinder head covers	2300		
A3	Height for transporting piston and connecting rod freely over exhaust gas insulation box	2300	2400	2400
A4	Height needed for transporting piston and connecting rod freely over 60°C exhaust gas insulation box (SOLAS)	-	-	2720
B1	Width for dismantling charge air cooler and air inlet box	1200		
B2	Width for dismantling charge air cooler and air inlet box sideways by using lifting tool	1310		
B3	Height of the lifting eye for the charge air cooler lifting tool	1600		
B4	Recommended lifting point for charge air cooler lifting tool	260	550	
B5	Recommended lifting point for charge air cooler lifting tool	585		
C1	Removal of main bearing side screw, flexible / rigid mounting	800 / 560		
D1	Distance needed for dismantling lubricating oil and water pumps	635		
E1	Distance needed for dismantling pump cover with fitted pumps	With PTO: lenght + 515 Without PTO: 650		
E2	Height of the lifting eye for the pump cover with fitted pumps, with lifting tool 1/ alternative lifting tool 2	750 / 2770		
F1	The recommended axial clearance for dismantling and assembly of silencers	650	750	750
F2	Minimum axial clearance	100		
F3	Recommended distance for dismantling the gas outlet elbow	990	1120	1120
G1	Recommended lifting point for the turbocharger	350		
G2	Recommended lifting point sideways for the turbocharger	320		
H1	Width for dismantling lubricating oil module and/or plate cooler	1250		
H2	Width for dismantling lubricating oil module with lifting tool	1480		
H3	Recommended lifting point for dismantling lubricating oil module and/or plate cooler	445		
H4	Recommended lifting point sideways for dismantling lube oil module and/or plate cooler	1045		
H5	Height of lifting eye for dismantling lube oil module with lifting tool	1675		
I1	Camshaft overhaul distance (free end)	1000	1300	1300

Service spaces in mm		6L	8L	9L
I2	Camshaft overhaul distance (flywheel end)	1000	1300	1300
J1	Space necessary for access to connecting box	1825		

18.4.1.3 Service space for generating sets

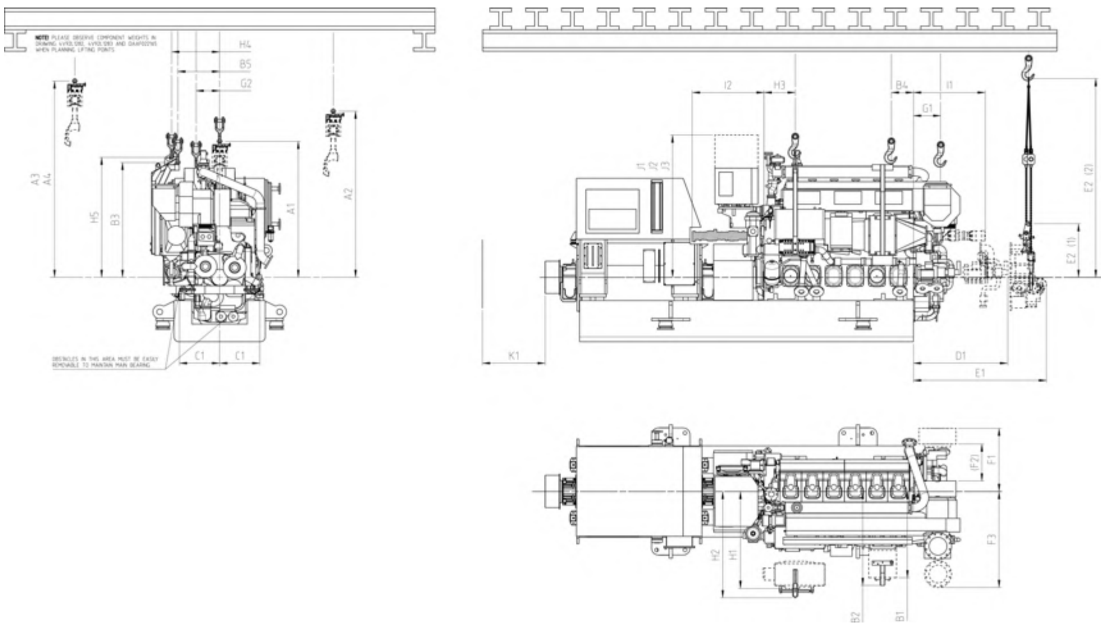

Fig 18-5 Service space for generating sets (DAAE006367C)

Service spaces in mm		6L	8L	9L
A1	Height for overhauling piston and connecting rod	1800		
A2	Height for transporting piston and connecting rod freely over adjacent cylinder head covers	2300		
A3	Height for transporting piston and connecting rod freely over exhaust gas insulation box	2300	2400	2400
A4	Height needed for transporting piston and connecting rod freely over 60°C exhaust gas insulation box (SOLAS)	-	-	2720
B1	Width for dismantling charge air cooler and air inlet box	1200		
B2	Width for dismantling charge air cooler and air inlet box sideways by using lifting tool	1310		
B3	Height of the lifting eye for the charge air cooler lifting tool	1600		
B4	Recommended lifting point for charge air cooler lifting tool	260	550	
B5	Recommended lifting point for charge air cooler lifting tool	585		
C1	width for removing main bearing side screw	560		
D1	Distance needed for dismantling lubricating oil and water pumps	635		
E1	Distance needed for dismantling pump cover with fitted pumps	650		
E2	Height of the lifting eye for the pump cover with fitted pumps, with lifting tool 1/ alternative lifting tool 2	750 / 2770		
F1	The recommended axial clearance for dismantling and assembly of silencers	650	750	750
F2	Minimum axial clearance	100		
F3	Recommended distance for dismantling the gas outlet elbow	990	1120	1120
G1	Recommended lifting point for the turbocharger	350		
G2	Recommended lifting point sideways for the turbocharger	320		
H1	Width for dismantling lubricating oil module and/or plate cooler	1250		
H2	Width for dismantling lubricating oil module with lifting tool	1480		
H3	Recommended lifting point for dismantling lubricating oil module and/or plate cooler	445		
H4	Recommended lifting point sideways for dismantling lube oil module and/or plate cooler	1045		
H5	Height of lifting eye for dismantling lube oil module with lifting tool	1670		
I1	Camshaft overhaul distance (free end)	1000	1300	1300
I2	Camshaft overhaul distance (flywheel end)	1000	1300	1300

Service spaces in mm		6L	8L	9L
J1	Space necessary for access to connecting box	1825		
K1	Service space for generator	500		

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19. Transport Dimensions and Weights

19.1 Lifting of main engines

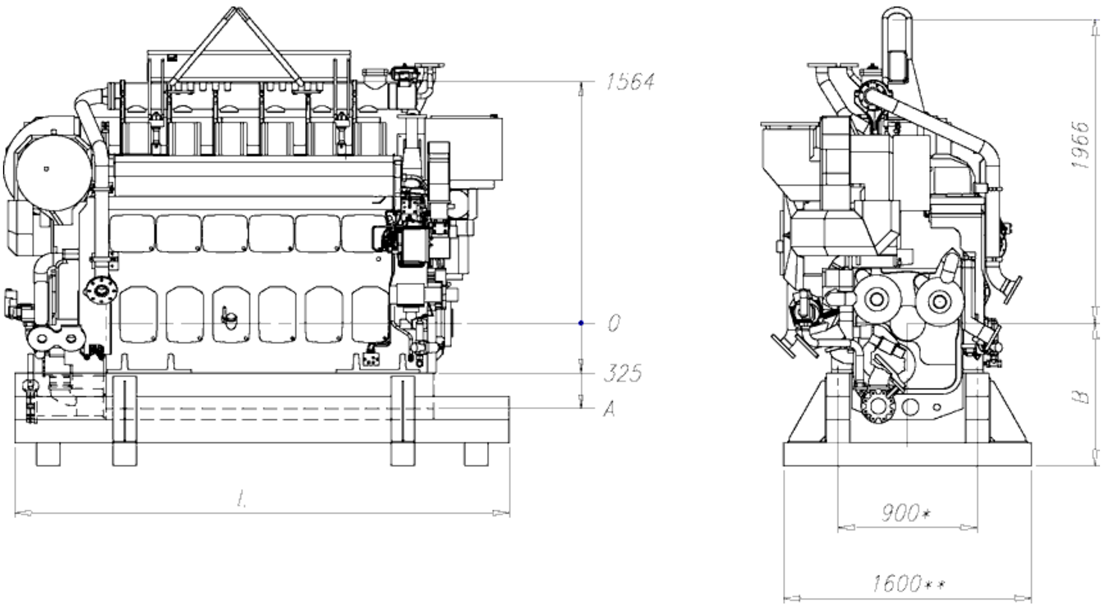


Fig 19-1 Lifting of main engines (DAAF016244)

Engine type	L [mm]	Dry sump		Wet sump	
		A [mm]	B [mm]	A [mm]	B [mm]
W 6L20DF	3200	624	824	600	675
W 8L20DF	3500	624	824	600	675
W 9L20DF	4100	624	824	600	675

19.2 Lifting of generating sets

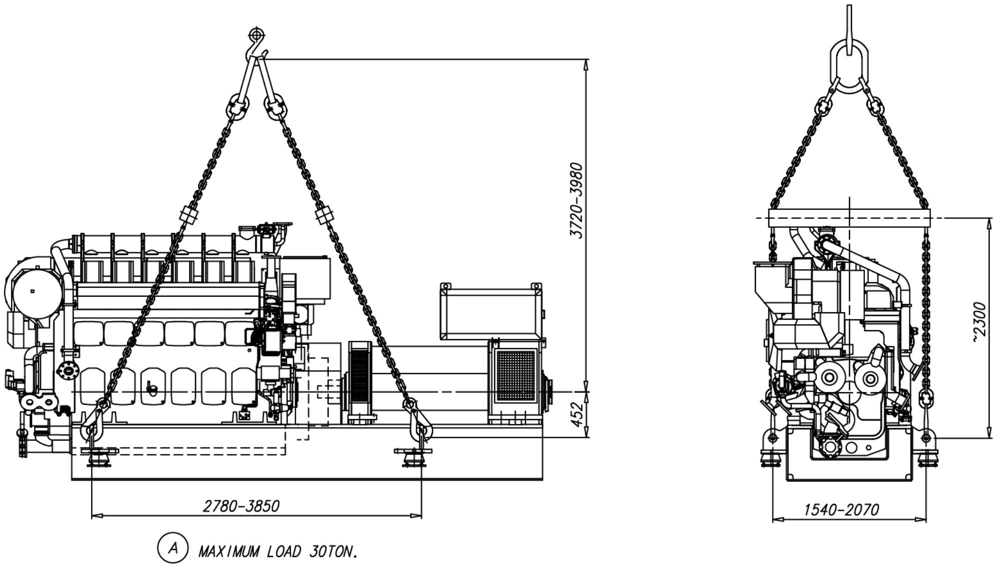
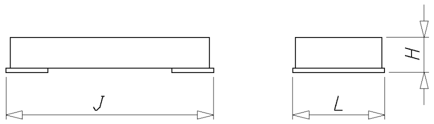


Fig 19-2 Lifting of generating sets (DAAF016285A)

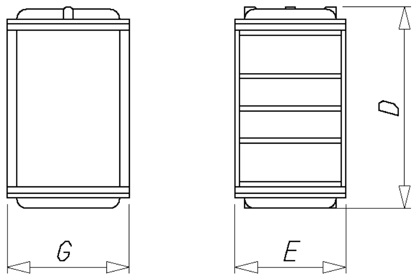
19.3 Engine components

Table 19-1 Lubricating oil insert (DAAE031768C)



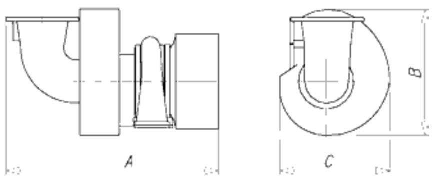
Engine	Dimensions [mm]			Weight [kg]
	H	J	L	
W 6L20DF	150	694	304	64
W 8L20DF	201	694	304	77
W 9L20DF	238	694	304	87

Table 19-2 Charge air cooler insert (DAAE031768C)



Engine	Dimensions [mm]			Weight [kg]
	D	E	G	
W 6L20DF	578	345	380	140
W 8L20DF	578	345	380	150
W 9L20DF	578	345	380	150

Table 19-3 Turbocharger (DAAE031768C)



Engine	Dimensions [mm]			Weight (kg)
	A	B	C	
W 6L20DF	1096	603	546	293
W 8L20DF	1357	716	666	368
W 9L20DF	1357	716	666	370

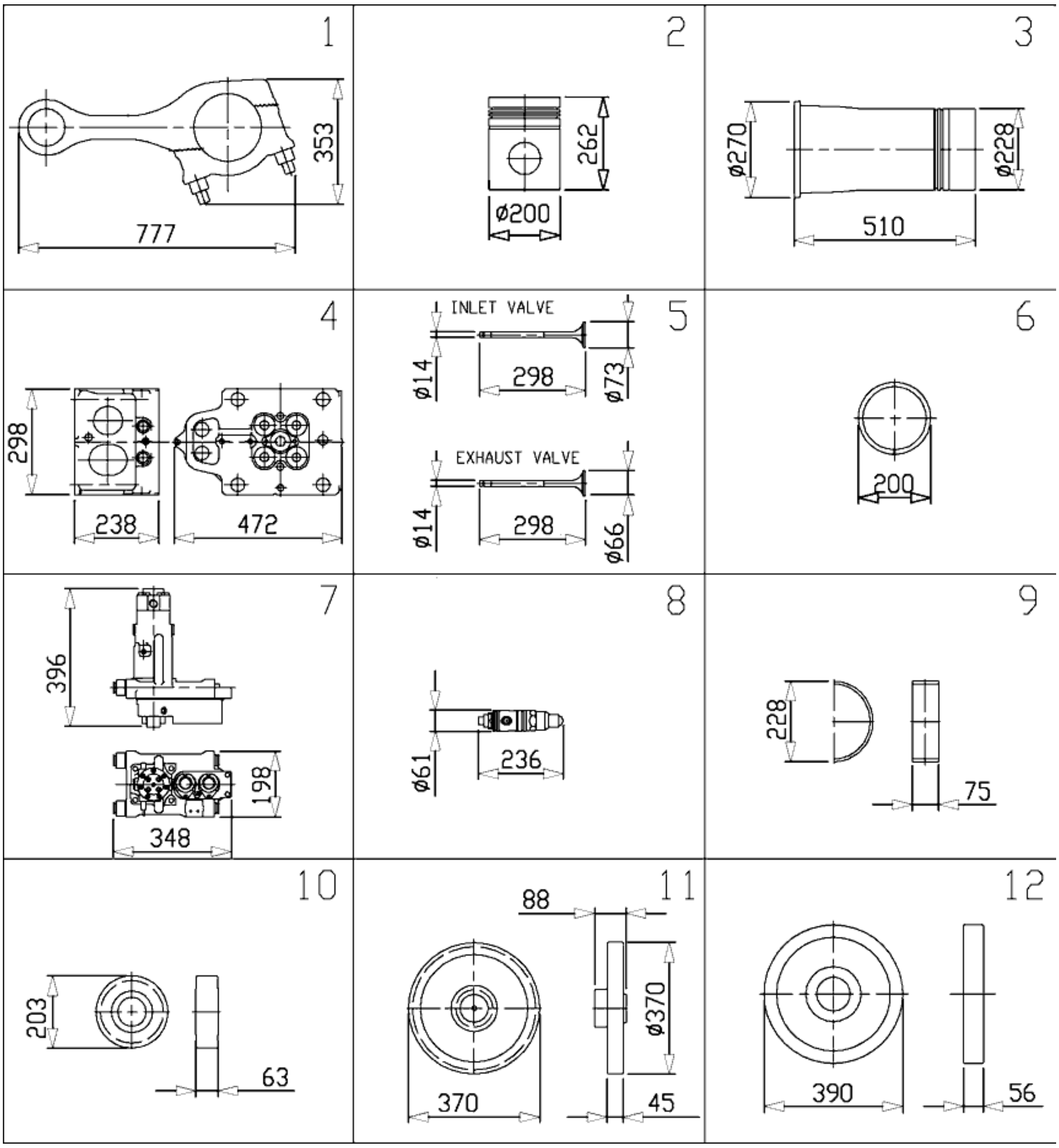


Fig 19-3 Major spare parts (DAAF022165)

No	Description	Weight [kg]	No	Description	Weight [kg]	No	Description	Weight [kg]
1	Connecting rod	39	5	Valve	0.8	9	Main bearing shell	1.4
2	Piston	28.5	6	Piston ring	0.2	10	Small intermediate gear	11.4
3	Cylinder liner	42	7	Injection pump	27	11	Large intermediate gear	23.5
4	Cylinder head	89	8	Injection valve	3.2	12	Camshaft drive gear	25

20. Product Guide Attachments

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

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

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21. ANNEX

21.1 Unit conversion tables

The tables below will help you to convert units used in this product guide to other units. Where the conversion factor is not accurate a suitable number of decimals have been used.

Length conversion factors

Convert from	To	Multiply by
mm	in	0.0394
mm	ft	0.00328

Mass conversion factors

Convert from	To	Multiply by
kg	lb	2.205
kg	oz	35.274

Pressure conversion factors

Convert from	To	Multiply by
kPa	psi (lbf/in^2)	0.145
kPa	lbf/ft^2	20.885
kPa	inch H_2O	4.015
kPa	foot H_2O	0.335
kPa	mm H_2O	101.972
kPa	bar	0.01

Volume conversion factors

Convert from	To	Multiply by
m^3	in^3	61023.744
m^3	ft^3	35.315
m^3	Imperial gallon	219.969
m^3	US gallon	264.172
m^3	l (litre)	1000

Power conversion

Convert from	To	Multiply by
kW	hp (metric)	1.360
kW	US hp	1.341

Moment of inertia and torque conversion factors

Convert from	To	Multiply by
kgm^2	lbft^2	23.730
kNm	lbf ft	737.562

Fuel consumption conversion factors

Convert from	To	Multiply by
g/kWh	g/hph	0.736
g/kWh	lb/hph	0.00162

Flow conversion factors

Convert from	To	Multiply by
m^3/h (liquid)	US gallon/min	4.403
m^3/h (gas)	ft^3/min	0.586

Temperature conversion factors

Convert from	To	Multiply by
°C	F	F = 9/5 *C + 32
°C	K	K = C + 273.15

Density conversion factors

Convert from	To	Multiply by
kg/m^3	lb/US gallon	0.00834
kg/m^3	lb/Imperial gallon	0.01002
kg/m^3	lb/ft^3	0.0624

21.1.1 Prefix

Table 21-1 The most common prefix multipliers

Name	Symbol	Factor	Name	Symbol	Factor	Name	Symbol	Factor
tera	T	10^{12}	kilo	k	10^3	nano	n	10^{-9}
giga	G	10^9	milli	m	10^{-3}			
mega	M	10^6	micro	μ	10^{-6}			

21.2 Collection of drawing symbols used in drawings

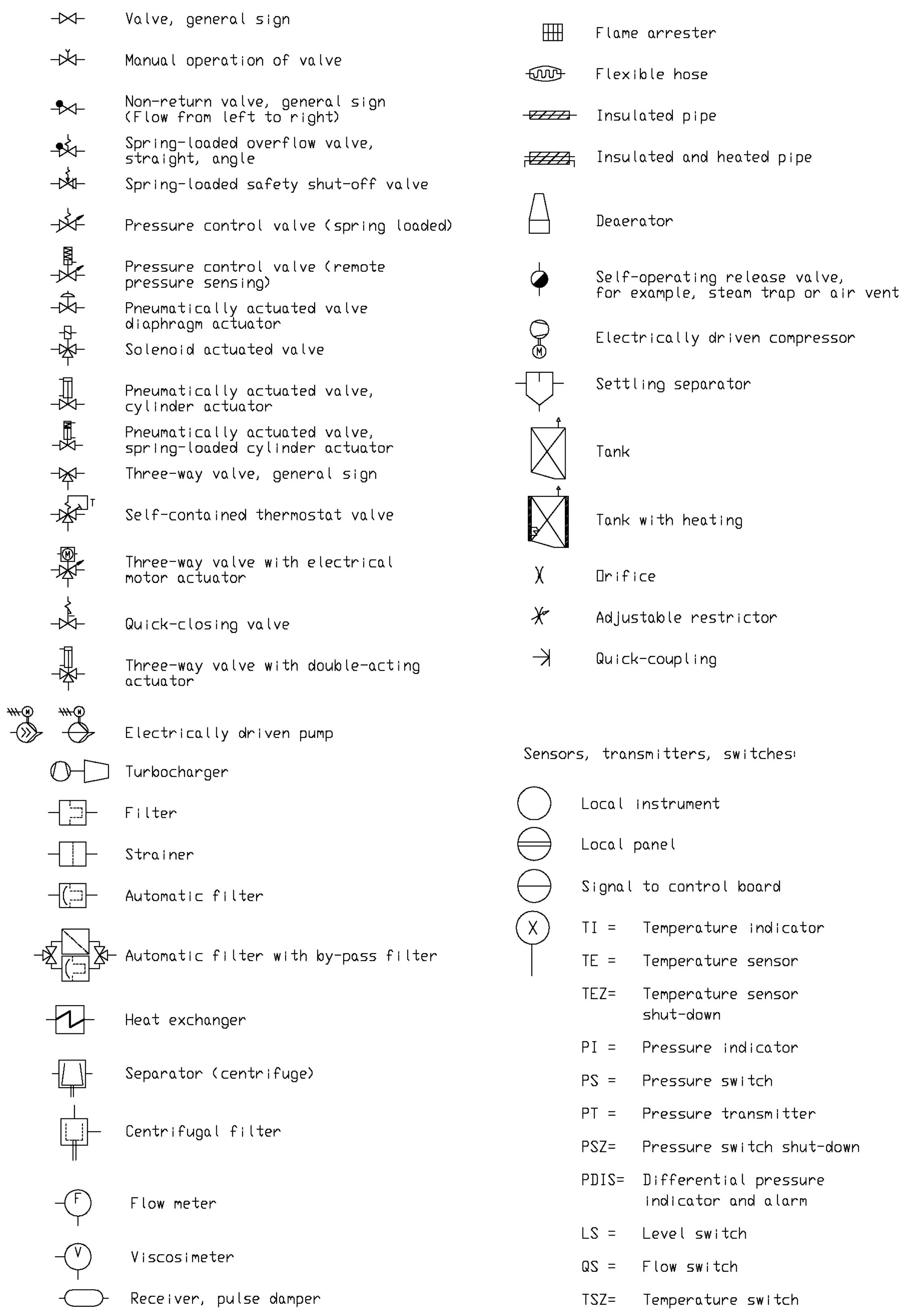

Fig 21-1 **List of symbols (DAAE000806D)**

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