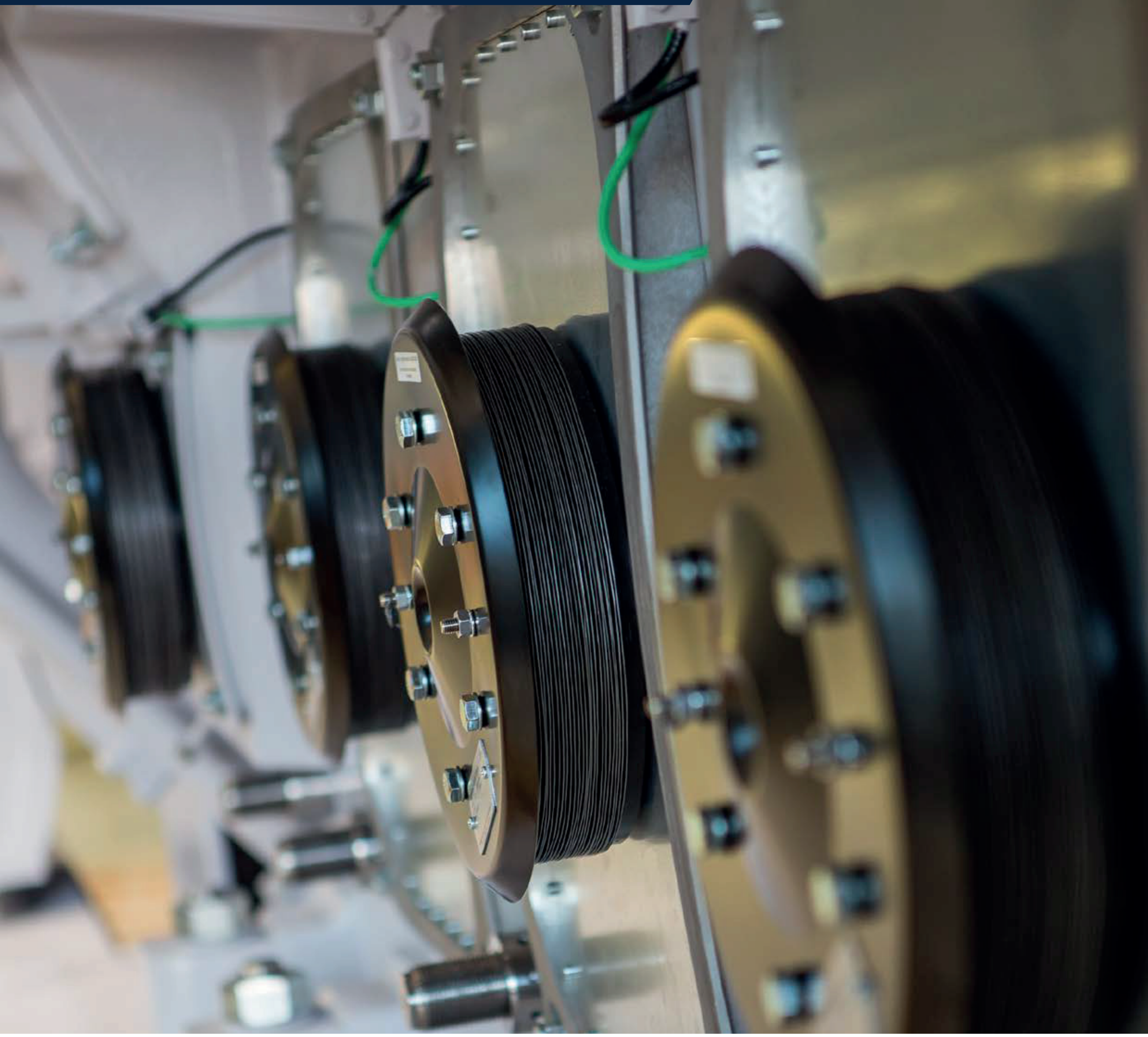
WÄRTSILÄ Engines

Wärtsilä 31DF

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 03/2019 issue replaces all previous issues of the Wärtsilä 31DF Project Guides.

Issue	Published	Updates
3/2019	10.10.2019	Updates throughout the guide
2/2019	26.9.2019	Updates throughout the guide
1/2019	14.3.2019	Updates throughout the guide
1/2018	26.1.2018	Updates throughout the guide
3/2017	22.05.2017	Updates throughout the guide
2/2017	17.03.2017	First version of the Wärtsilä 31DF Product Guide
1/2017	13.01.2017	Preliminary version of the Wärtsilä 31DF Product Guide.

Wärtsilä, Marine Solutions

Vaasa, October 2019

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1. Main Data and Outputs

The Wärtsilä 31DF is a 4-stroke, non-reversible, turbocharged and intercooled diesel engine with direct fuel injection.

Cylinder bore .... 310 mm

Stroke .... 430 mm

Number of valves .... 2 inlet valves, 2 exhaust valves

Cylinder configuration .... 8, 10, 12, 14 and 16

V-angle .... 50°

Direction of rotation .... Clockwise, counterclockwise

Speed .... 720, 750 rpm

Mean piston speed .... 10.32 - 10.75 m/s

1.1 Maximum continuous output

Table 1-1 Rating table for Wärtsilä 31DF

Cylinder configuration	Main engines	Generating sets			
	750 rpm	720 rpm		750 rpm	
	[kW]	Engine [kW]	Generator [kVA]	Engine [kW]	Generator [kVA]
W 8V31DF	4400	4240	5090	4400	5280
W 10V31DF	5500	5300	6360	5500	6600
W 12V31DF	6600	6360	7630	6600	7920
W 14V31DF	7700	7420	8900	7700	9240
W 16V31DF	8800	8480	10180	8800	10560

The mean effective pressure Pe can be calculated as follows:

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

where:

Pe = mean effective pressure [bar]

P = output per cylinder [kW]

n = engine speed [r/min]

D = cylinder diameter [mm]

L = length of piston stroke [mm]

c = operating cycle (4)

1.2 Reference conditions

The output is available 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).

1.3 Operation in inclined position

The engine is designed to ensure proper engine operation at inclination positions. Inclination angle according to IACS requirement M46.2 (1982) (Rev.1 June 2002) - Main and auxiliary machinery.

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

Table 1-2 Inclination with Normal Oil Sump

• Permanent athwart ship inclinations (list)	15°
• Temporary athwart ship inclinations (roll)	22.5°
• Permanent fore and aft inclinations (trim)	10°
• Temporary fore and aft inclinations (pitch)	10°

1.4 Principle dimensions and weights

1.4.1 Main engines

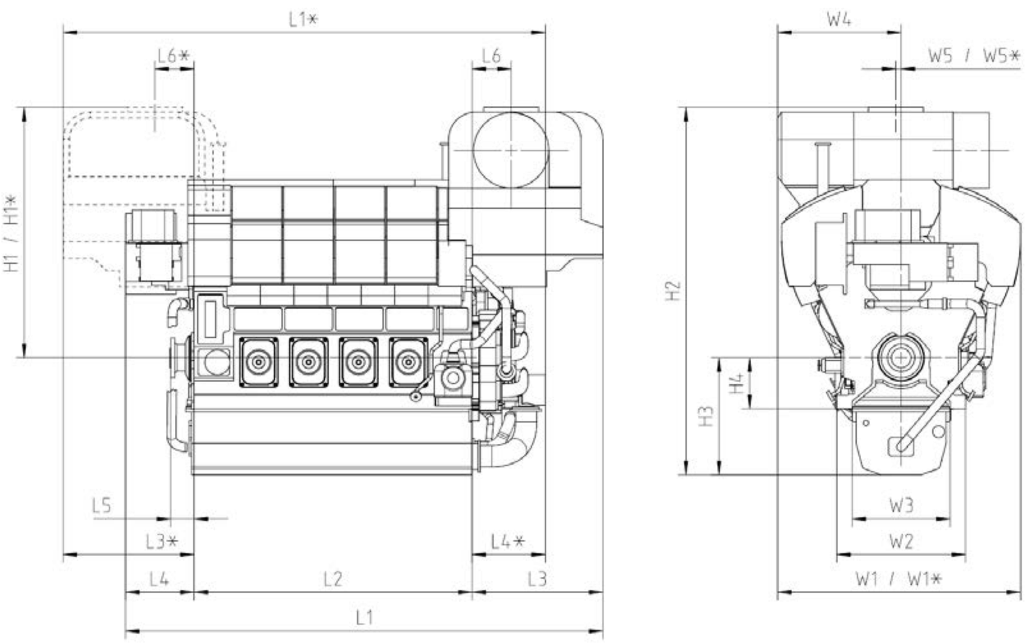

Fig 1-1 W8V31 & W10V31 Main engine dimensions

Engine	L1	L1*	L2	L3	L3*	L4	L4*	L5	L6	L6*
W8V31	6087	6196	3560	1650	1650	877	986	300	500	500
W10V31	6727	6836	4200	1650	1650	877	986	300	500	500

Engine	H1	H1*	H2	H3	H4	W1	W1*	W2	W3	W4	W5	W5*	Weight Engine **	Weight Liquids
W8V31	3205	3205	4701	1496	650	3115	3115	1600	1153	1585	67	-67	53/ 53,7*	3,3
W10V31	3205	3205	4701	1496	650	3115	3115	1600	1153	1585	67	-67	61,6	3,95

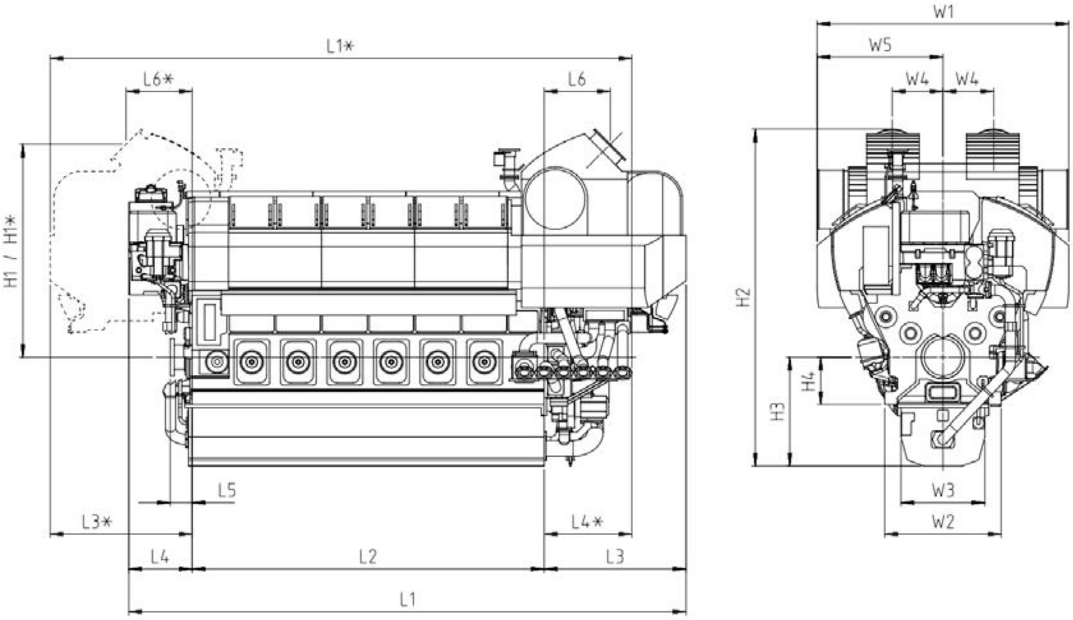

Fig 1-2 W12V31, W14V31 & W16V31 Main engine dimensions

Engine	L1	L1*	L2	L3	L3*	L4	L4*	L5	L6	L6*
W12V31	7840	8090	4840	2000	2000	1000	1250	300	908	908
W14V31	8480	8730	5480	2000	2000	1000	1250	300	908	908
W16V31	9120	9370	6120	2000	2000	1000	1250	300	908	908

Engine	H1	H1*	H2	H3	H4	W1	W2	W3	W4	W5	Weight Engine **	Weight Liquids
W12V31	2926	2926	4633	1496	650	3500	1600	1153	698	1750	72.1	4.95
W14V31	2926	2926	4633	1496	650	3500	1600	1153	698	1750	79.1	5.5
W16V31	2926	2926	4633	1496	650	3500	1600	1153	698	1750	87.0	6.25

L1	Total length of engine
L2	Length of the engine block
L3	Length from the engine block to the outer most point in turbocharger end
L4	Length from the engine block to the outer most point in non-turbocharger end
L5	Length from engine block to crankshaft flange
L6	Length from engine block to center of exhaust gas outlet
H1	Height from the crankshaft centerline to center of exhaust gas outlet
H2	Total height of engine (normal wet sump)
H3	Height from crankshaft centerline to bottom of the oil sump (normal wet sump)
H4	Height from the crankshaft centerline to engine feet (fixed mounted)
W1	Total width of engine
W2	Width of engine block at the engine feet
W3	Width of oil sump
W4	Width from crankshaft centerline to center of exhaust gas outlet
W5	Width from crankshaft centerline to the outer most point of the engine

* Turbocharger at flywheel end;

** Weight without liquids, damper and flywheel (as a rule of thumb, add 60kg per cylinder on top of 8 and or 10V engine weight or, add 50kg per cylinder for 12, 14 and 16V engines for additional gas components weight);

All dimensions in mm, weights in tonne.

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2. Operating Ranges

2.1 Engine operating range

Running below nominal speed the load must be limited according to the diagrams in this chapter in order to maintain engine operating parameters within acceptable limits. Operation in the shaded area is permitted only temporarily during transients. Minimum speed is indicated in the diagram, but project specific limitations may apply.

2.1.1 Controllable pitch propellers

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

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

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

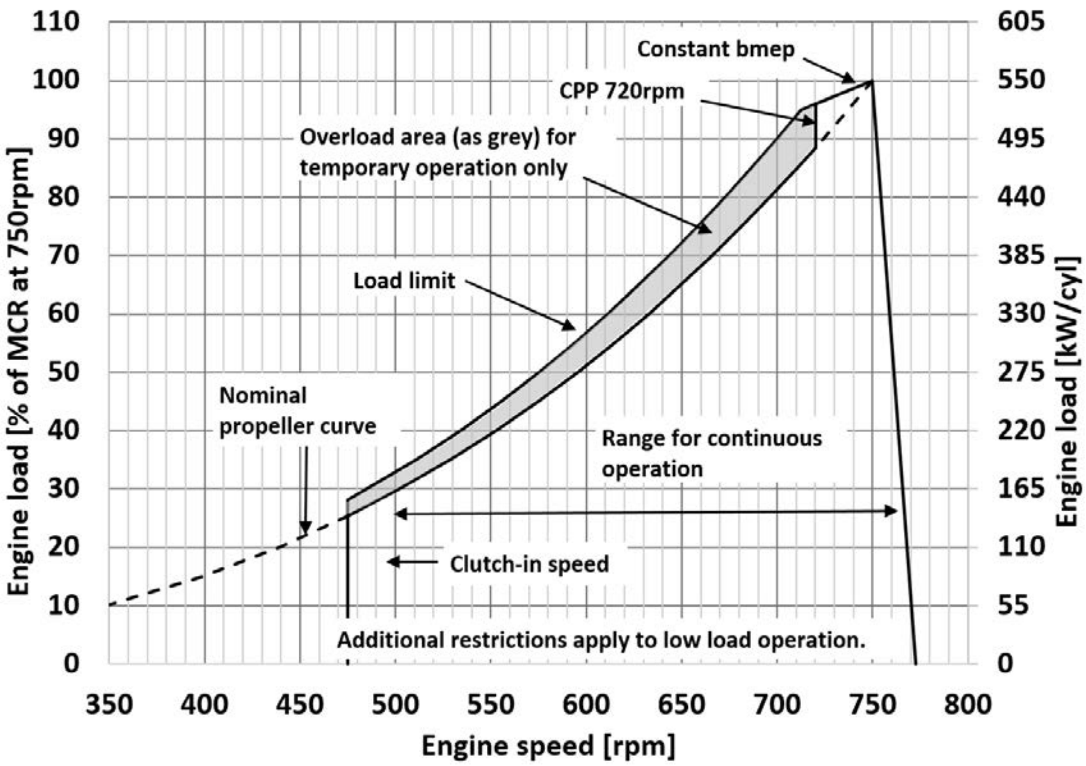

Fig 2-1 Operating field for CP Propeller (DAAF389037B)

NOTE

1) Valid for both gas operation and diesel operation.

2) Minimum engine speed is restricted to 472rpm with engine driven oil pump.

3) Additional restrictions apply to low load operation.

4) Project specific idling and clutch in speed depends on clutch, gearbox and the Torsional Vibration Calculations.

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.

2.2 Loading capacity

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

The engine can be loaded immediately after start, provided that the engine is pre-heated to:

- High Temperature (HT) water temperature is minimum 70°C
- Lubricating oil temperature is minimum 40°C

The ramp for normal loading applies to engines that have reached normal operating temperature.

2.2.1 Mechanical propulsion

2.2.1.1 Loading Rates Variable speed engines (CPP)

Normal loading rate, variable speed engines, 750 rpm

Table 2-1 Loading rate

Engine load [% of MCR]	Nominal loading [s]	Fast loading [s]	Emergency, diesel operation only [s]
0	0	0	0
100	300	120	30

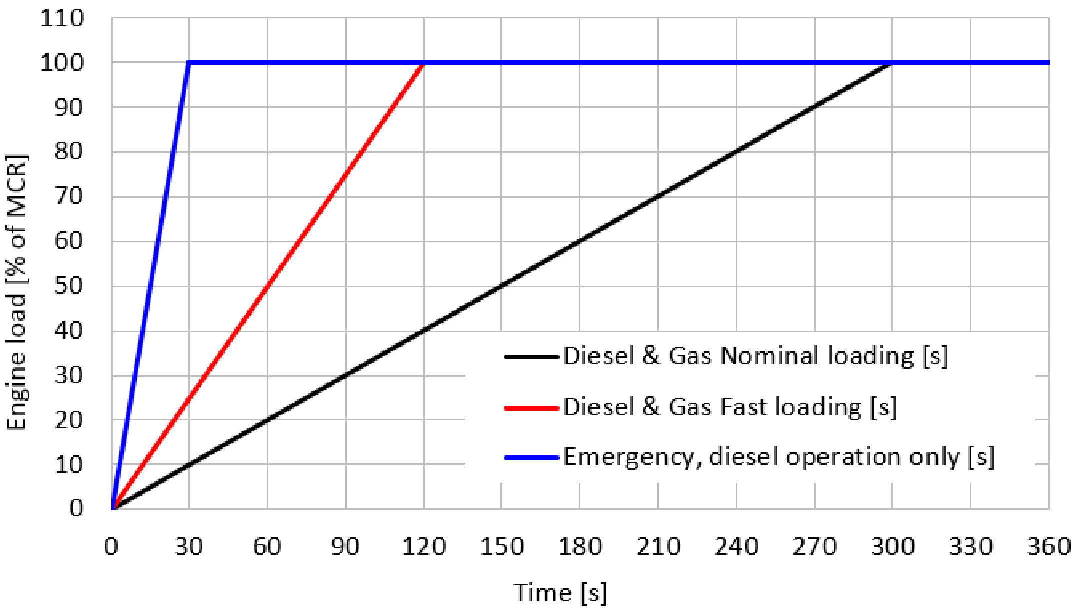

Fig 2-2 Normal Loading rate, variable speed engines, 750 rpm

NOTE

If normal loading rate is chosen low load running is limited to normal low load restriction curve. Please see chapter 2.3.1.

Unloading rate, variable speed engines, 750 rpm

Table 2-2 Unloading rate

Engine load [% of MCR]	Nominal loading [s]	Fast loading [s]	Emergency, diesel operation only [s]
100	0	N/A	0
0	60	N/A	0

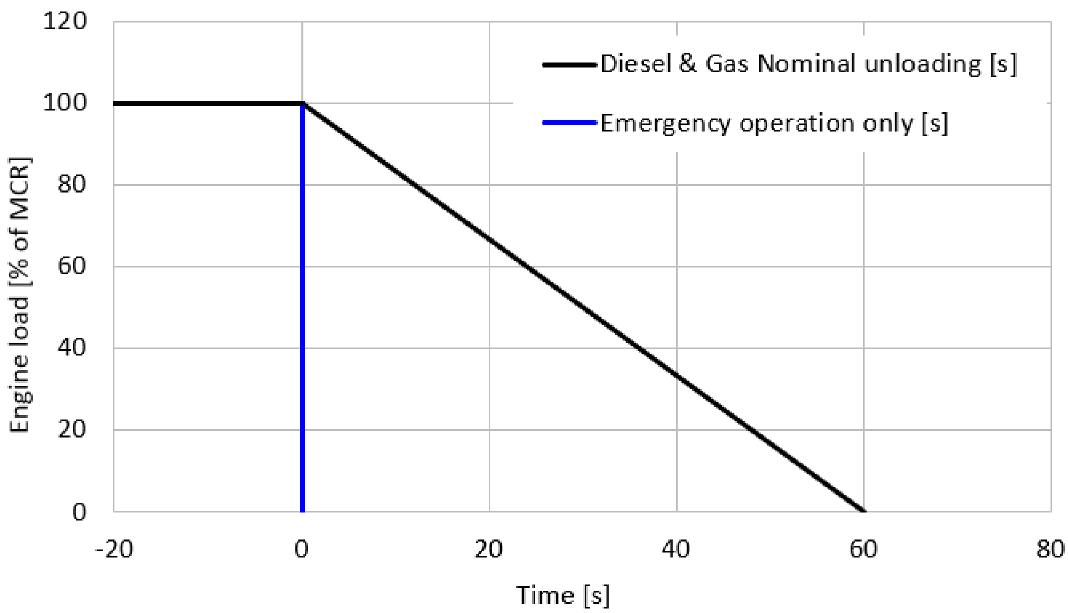

Fig 2-3 Unloading rate, variable speed engines, 750 rpm

The propulsion control must include automatic limitation of the load increase rate. If the control system has only one load increase ramp, then the ramp for a preheated engine should be used. In tug applications the engines have usually reached normal operating temperature before the tug starts assisting. The “emergency” curve is close to the maximum capability of the engine.

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

2.2.2 Diesel electric propulsion and auxiliary engines

2.2.2.1 Loading rates Constant speed engines (DE / Aux / CPP)

Normal loading rate, constant speed engines, 720/750 rpm (DE / Aux / CPP)

Table 2-3 Normal Loading rate

Engine load [% of MCR]	Nominal loading [s]	Fast loading (MN70) [s]	Fast loading (MN80) [s]	Emergency, diesel operation only [s]
0	0	0	0	0
50	60	45	35	10
100	200	90	70	20

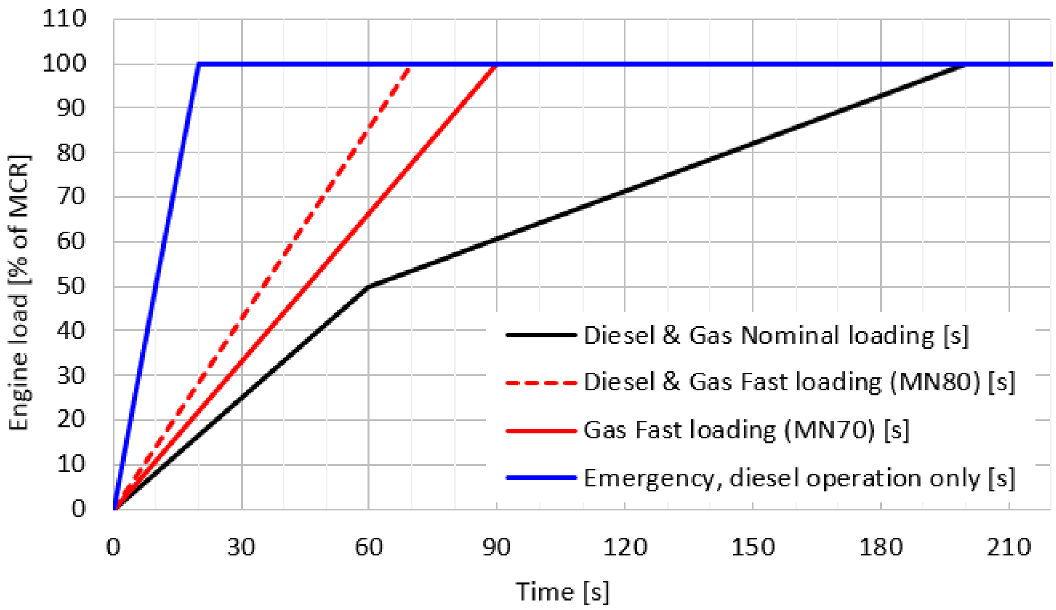

Fig 2-4 Normal Loading rate, constant speed engines, 720/750 rpm (DE / Aux / CPP)

NOTE

If normal loading rate is chosen low load running is limited to normal low load restriction curve. Please see chapter *2.3.1*.

Unloading rate, constant speed engines, 720/750 rpm (DE / Aux / CPP)

Table 2-4 Unloading rate

Engine load [% of MCR]	Nominal loading [s]	Fast loading [s]	Emergency, diesel operation only [s]
100	0	N/A	0
0	60	N/A	0

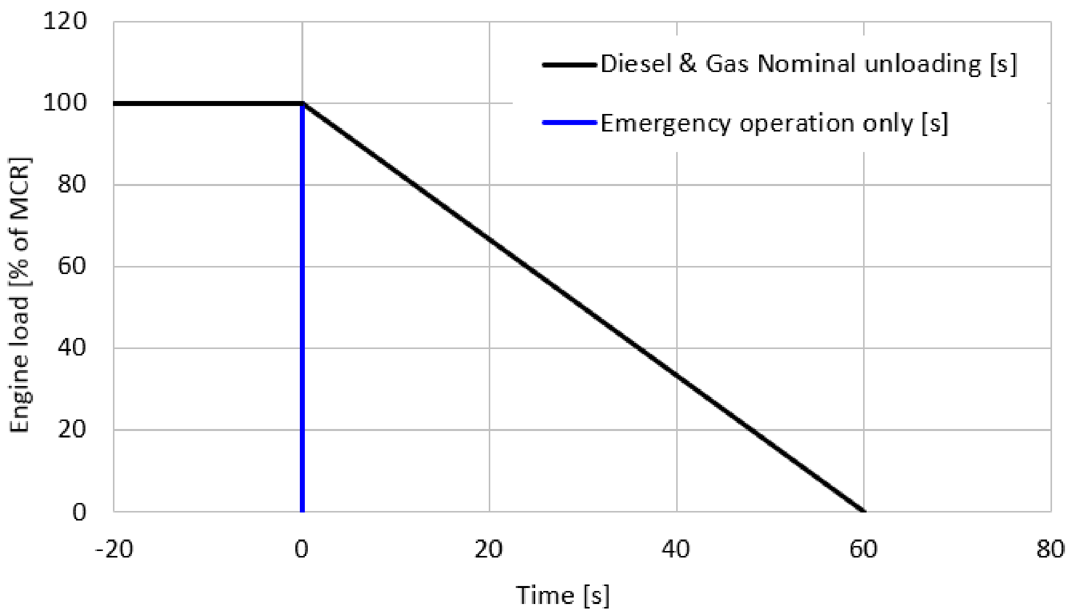

Fig 2-5 Unloading rate, constant speed engines, 720/750 rpm (DE / Aux / CPP)

In diesel electric installations 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. If a ramp without knee-point is used, it should not achieve 100% load in shorter time than the ramp in the figure. When the load sharing is based on speed droop, 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.

The “emergency” curve is close to the maximum capability of the engine and it shall not be used as the normal limit. In dynamic positioning applications loading ramps corresponding to 20-30 seconds from zero to full load are however normal. If the vessel has also other operating modes, a slower loading ramp is recommended for these operating modes.

In typical auxiliary engine applications there is usually no single consumer being decisive for the loading rate. It is recommended to group electrical equipment so that the load is increased in small increments, and the resulting loading rate roughly corresponds to the “normal” curve.

In normal operation the load should not be reduced from 100% to 0% in less than 15 seconds. If the application requires frequent unloading at a significantly faster rate, special arrangements can be necessary on the engine. In an emergency situation the full load can be thrown off instantly.

2.2.2.2 Instant Load Application

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.

Cyclic (wave) load-taking capability can be evaluated from the figures below:

- Max instant load step = cyclic load amplitude
  - Example: With cyclic loading at average load 57% the load variation amplitude can be 14%, i.e ±7% (=50% + 14%/2)

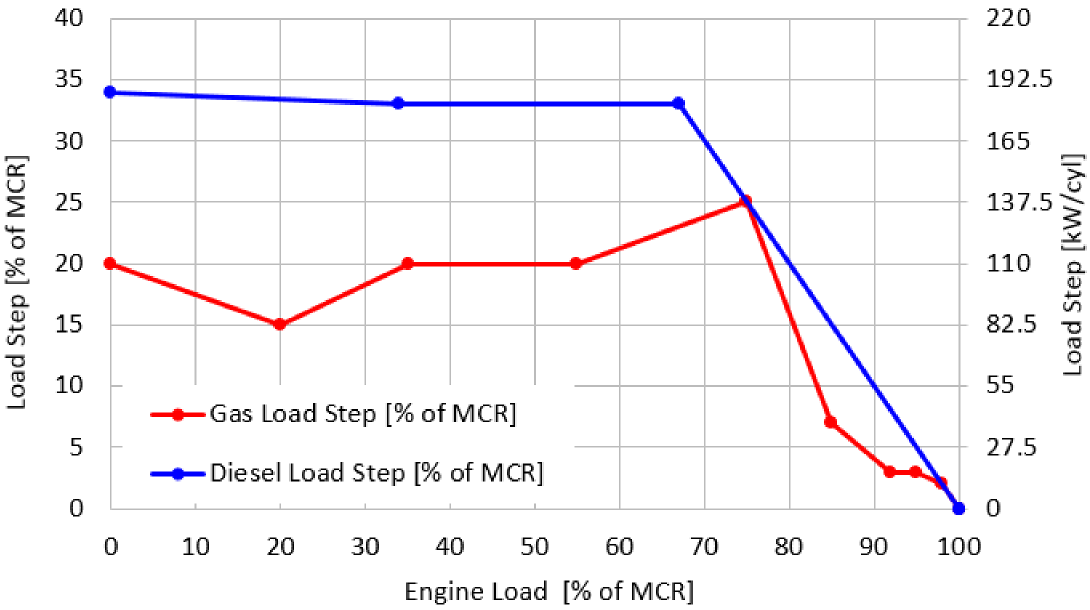

Fig 2-6 **Load Steps, CS 750 rpm**

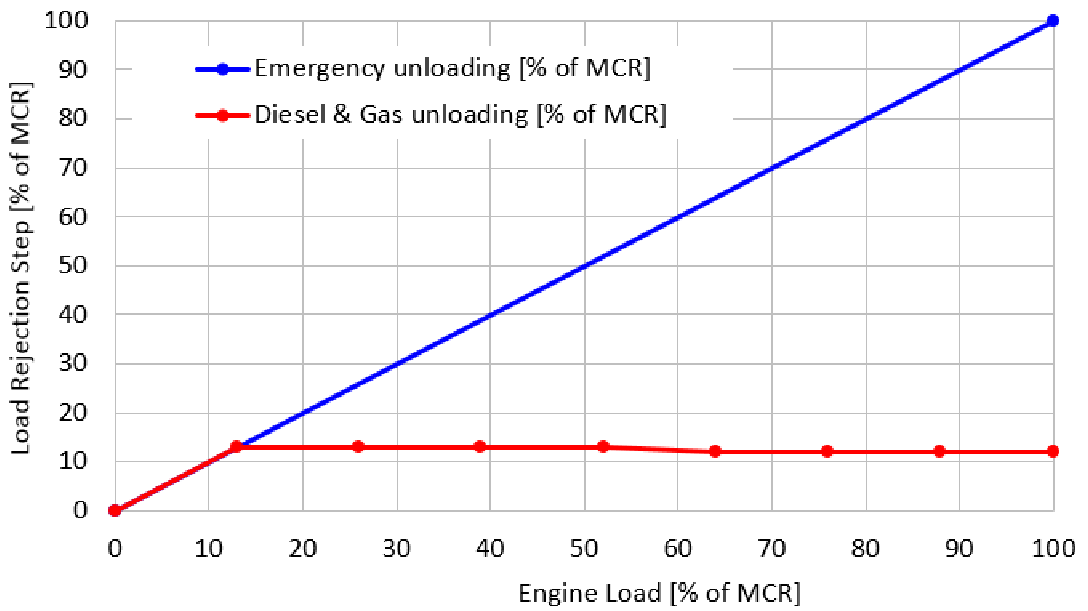

Fig 2-7 **Unloading Steps, CS 750 rpm**

2.2.2.3 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 blackout start active nominal speed is reached in about 25 s (pilot fuel injection disabled).

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

Start and stop on heavy fuel is not restricted.

2.3 Low load operation

2.3.1 Normal Low load operation - Normal load acceptance

In order to avoid fouling of the engine, recommended limits to the low load operation are given. Low load operation is all loads below 20% load. Cumulative low load operation should not exceed the recommended values given in the chart and table. The time is reset after a cleaning run at minimum 70% load for a minimum of 1 hour.

Black line (diesel mode) limit is valid in diesel mode when intention is to continue in diesel mode. In case the intention is to transfer to gas mode and continue operating in gas mode then blue line (gas mode limit) is valid also for diesel mode.

The loading rates according to Normal low load load operations, chapter load performance are allowed with these low load operation limits.

If recommended time limits are exceeded then engine shall not be loaded faster than the nominal loading curve in the chapter loading performance.

Absolute idling time 10 minutes if the engine is to be stopped, 5 hours in gas mode or 10 hours in diesel mode if engine is loaded afterwards.

Table 2-5 Max continous low load operation time for load acceptance according to Normal Load acceptance chapter

Load	%	0	2	10	17.5	20
W31DF on Gas, LFO pilot, 550kW/cyl	h	5	5	10	24	150
W31DF on Diesel, 550kW/cyl	h	5	5	47	87	100

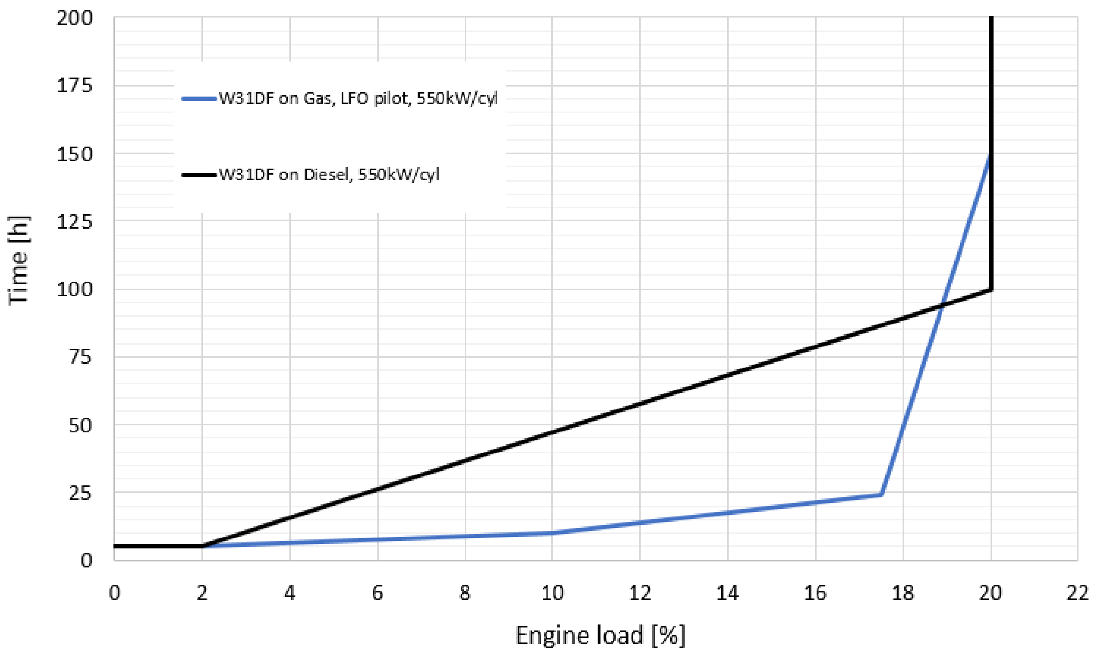

Fig 2-8 Low load operating restrictions

NOTE

Black line is intended for diesel mode operation and blue line is intended for gas mode operation.

2.3.2 Absolute 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 5 hours in gas mode and 10 hours in diesel mode if the engine is to be loaded after the idling.

NOTE

Operating restrictions on SCR applications in low load operation to be observed.

2.4 Low air temperature

In standard conditions the following minimum inlet air temperatures apply:

Gas mode:

- Low load + 5°C
- High load -10°C

Diesel mode:

- Starting + 5°C
- Idling - 5°C
- High load - 10°C

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

NOTE

Air Waste Gate (AWG) is needed when suction air temperature is below +5°C.

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 increase in fuel consumption with engine driven pumps is given in the table below; correction in g/kWh (in Diesel Mode) and or kJ/kWh (in Gas Mode).

3.1.1.1 Diesel mode

Table 3-1 Constant speed engines (DE, CPP, Aux), 750/720rpm, MDF/HFO

Engine driven pumps	Engine load [%]			
	100	85	75	50
Lube oil	-1.3	-1.5	-1.7	-2.7
LT Water	-0.5	-0.6	-0.7	-1.1
HT Water	-0.5	-0.6	-0.7	-1.1

Table 3-2 Variable speed engines (CPP), 750rpm, MDF/HFO

Engine driven pumps	Engine load [%]			
	100	85	75	50
Lube oil	-1.5	-1.4	-1.5	-1.5
LT Water	-0.5	-0.5	-0.5	-0.5
HT Water	-0.5	-0.5	-0.5	-0.5

3.1.1.2 Gas mode

Table 3-3 Constant speed engines (DE, CPP, Aux), 750/720rpm

Engine driven pumps	Engine load [%]			
	100	85	75	50
Lube oil	-53.0	-63.0	-72.0	-114.0
LT Water	-22.0	-26.0	-29.0	-47.0
HT Water	-22.0	-26.0	-29.0	-47.0

Table 3-4 Variable speed engines (CPP), 750rpm

Engine driven pumps	Engine load [%]			
	100	85	75	50
Lube oil	-60.0	-60.0	-60.0	-61.0
LT Water	-22.0	-22.0	-22.0	-22.0
HT Water	-22.0	-22.0	-22.0	-22.0

3.2 Wärtsilä 8V31DF

3.2.1 IMO Tier 2

Wärtsilä 8V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Engine output	kW	4240		4400		4240		4400		4400	
Mean effective pressure	MPa	2.72		2.71		2.72		2.71		2.71	
IMO compliance		Tier 3	Tier 2	Tier 3	Tier 2	Tier 3	Tier 2	Tier 3	Tier 2	Tier 3	Tier 2
Combustion air system (Note 1)											
Flow at 100% load	kg/s	6.9	7.9	7.2	8.5	6.9	7.9	7.2	8.5	7.2	8.5
Temperature at turbocharger intake, max.	°C	45		45		45		45		45	
Temperature after air cooler (TE 601)	°C	60	60	60	60	60	60	60	60	60	60
Exhaust gas system (Note 2)											
Flow at 100% load	kg/s	7.1	8.1	7.4	8.7	7.1	8.1	7.4	8.7	7.4	8.7
Flow at 85% load	kg/s	5.9	6.9	6.1	7.4	5.9	6.9	6.1	7.4	6.1	7.4
Flow at 75% load	kg/s	5.2	6.4	5.4	6.9	5.2	6.4	5.4	6.9	5.5	6.6
Flow at 50% load	kg/s	3.7	4.6	3.8	4.9	3.7	4.6	3.8	4.9	3.8	5.0
Temperature after turbocharger at 100% load (TE 517)	°C	300	270	300	270	300	270	300	270	300	270
Temperature after turbocharger at 85% load (TE 517)	°C	350	270	350	270	350	270	350	270	320	260
Temperature after turbocharger at 75% load (TE 517)	°C	350	260	350	260	350	260	350	260	310	270
Temperature after turbocharger at 50% load (TE 517)	°C	370	280	370	280	370	280	370	280	330	270
Backpressure, max.	kPa	5.0	6.5	5.0	6.5	5.0	6.5	5.0	6.5	5.0	6.5
Calculated exhaust diameter for 35 m/s	mm	647	671	657	697	647	671	657	697	657	697
Heat balance at 100% load (Note 3)											
Jacket water, HT-circuit	kW	344	408	360	424	344	408	360	424	360	424
Charge air, HT-circuit	kW	472	680	504	768	472	680	504	768	504	768
Charge air, LT-circuit	kW	1024	1208	1072	1304	1024	1208	1072	1304	1064	1296
Lubricating oil, LT-circuit	kW	392	472	408	488	392	472	408	488	408	488
Radiation	kW	120	120	120	120	120	120	120	120	120	120
Fuel consumption (Note 4) (Note 5)											
Total energy consumption at 100% load	kJ/kWh	7250	-	7280	-	7250	-	7280	-	7280	-
Total energy consumption at 85% load	kJ/kWh	7300	-	7350	-	7300	-	7350	-	7270	-
Total energy consumption at 75% load	kJ/kWh	7430	-	7500	-	7430	-	7500	-	7290	-
Total energy consumption at 50% load	kJ/kWh	7790	-	7820	-	7790	-	7820	-	7430	-

Wärtsilä 8V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Fuel gas consumption at 100% load	kJ/kWh	7097	-	7128	-	7097	-	7128	-	7128	-
Fuel gas consumption at 85% load	kJ/kWh	7121	-	7171	-	7121	-	7171	-	7100	-
Fuel gas consumption at 75% load	kJ/kWh	7226	-	7294	-	7226	-	7294	-	7122	-
Fuel gas consumption at 50% load	kJ/kWh	7484	-	7515	-	7484	-	7515	-	7250	-
Fuel oil consumption at 100% load	g/kWh	3.8	175.3	3.8	178.7	3.8	175.3	3.8	178.7	3.8	178.7
Fuel oil consumption at 85% load	g/kWh	4.4	174.4	4.5	176.3	4.4	174.4	4.5	176.3	4.2	174.9
Fuel oil consumption at 75% load	g/kWh	5.0	176.8	5.1	179.1	5.0	176.8	5.1	179.1	4.1	177.2
Fuel oil consumption 50% load	g/kWh	7.6	184.3	7.6	186.0	7.6	184.3	7.6	186.0	4.3	182.1
Fuel gas system											
Gas pressure at engine inlet, min (PT901)	kPa (a)	895	-	895	-	895	-	895	-	895	-
Gas pressure to Gas Valve Unit, min	kPa (a)	1015	-	1015	-	1015	-	1015	-	1015	-
Gas temperature before Gas Valve Unit	°C	0...60	-	0...60	-	0...60	-	0...60	-	0...60	-
Fuel oil system											
Pressure before HP pumps (PT 101)	kPa	1000±100		1000±100		1000±100		1000±100		1000±100	
Fuel oil flow to engine, approx.	m^3/h	3.6		3.6		3.6		3.6		3.6	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24	-	16...24	-	16...24
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140	-	140	-	140
MDF viscosity, min.	cSt	2.0		2.0		2.0		2.0		2.0	
Max. MDF temperature before engine (TE 101)	°C	45		45		45		45		45	
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h		0.5		0.5		0.5		0.5		0.5
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	0.9	1.5	0.9	1.5	0.9	1.5	0.9	1.5	0.9	1.5
Lubricating oil system											
Pressure before bearings, nom. (PT 201)	kPa	420		420		420		420		420	
Suction ability, including pipe loss, max.	kPa	40		40		40		40		40	
Priming pressure, nom. (PT 201)	kPa	100		100		100		100		100	
Suction ability priming pump, including pipe loss, max.	kPa	35		35		35		35		35	
Temperature before bearings, nom. (TE 201)	°C	70		70		70		70		70	
Temperature after engine, approx.	°C	82		82		82		82		82	
Pump capacity (main), engine driven	m^3/h	125		130		125		130		144	
Pump capacity (main), electrically driven	m^3/h	100		100		100		100		100	

Wärtsilä 8V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Priming pump capacity (50/60Hz)	m³/h	40.0 / 40.0		40.0 / 40.0		40.0 / 40.0		40.0 / 40.0		40.0 / 40.0	
Oil volume, wet sump, nom.	m³	2.8		2.8		2.8		2.8		2.8	
Oil volume in separate system oil tank	m³	5.7		5.9		5.7		5.9		5.9	
Oil consumption at 100% load, approx.	g/kWh	0.35	0.45	0.35	0.45	0.35	0.45	0.35	0.45	0.35	0.45
Crankcase ventilation flow rate at full load	l/min	1600		1600		1600		1600		1600	
Crankcase ventilation backpressure, max.	kPa	0.1		0.1		0.1		0.1		0.1	
Oil volume in turning device	l	9.5...11.5		9.5...11.5		9.5...11.5		9.5...11.5		9.5...11.5	
Cooling water system											
HT cooling water system											
Pressure at engine, after pump, nom. (PT 401)	kPa	358 + static		358 + static		358 + static		358 + static		358 + static	
Pressure at engine, after pump, max. (PT 401)	kPa	600		600		600		600		600	
Temperature before cylinders, approx. (TE 401)	°C	83		83		83		83		83	
Temperature after engine, nom.	°C	96		96		96		96		96	
Capacity of engine driven pump, nom.	m³/h	80		80		80		80		80	
Pressure drop over engine, total	kPa	210		210		210		210		210	
Pressure drop in external system, max.	kPa	100		100		100		100		100	
Pressure from expansion tank	kPa	70...150		70...150		70...150		70...150		70...150	
Water volume in engine	m³	0.35		0.35		0.35		0.35		0.35	
Delivery head of stand-by pump	kPa	365		365		365		365		365	
LT cooling water system											
Pressure at engine, after pump, nom. (PT 451)	kPa	650+ static		650+ static		650+ static		650+ static		650+ static	
Temperature before engine, nom (TE 451)	°C	40/ 45		40/ 45		40/ 45		40/ 45		40/ 45	
Capacity of engine driven pump, nom.	m³/h	80		80		80		80		80	
Pressure drop over charge air cooler (two-stage)	kPa	110		110		110		110		110	
Pressure drop in external system, max.	kPa	100		100		100		100		100	
Pressure from expansion tank	kPa	70...150		70...150		70...150		70...150		70...150	
Starting air system											
Pressure, nom.	kPa	3000		3000		3000		3000		3000	
Pressure at engine during start, min. (alarm) (20°C)	kPa	1500		1500		1500		1500		1500	
Pressure, max.	kPa	3000		3000		3000		3000		3000	
Low pressure limit in air vessels	kPa	1800		1800		1800		1800		1800	
Starting air consumption, start (successful)	Nm³	5.9		5.9		5.9		5.9		5.9	

Notes:

Note 1	At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 9%.
Note 2	At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 9% and temperature tolerance 10°C in gas mode operation. Flow tolerance 9% and temperature tolerance 15°C in diesel mode operation.
Note 3	At 100% output and nominal speed. The figures are valid for ambient conditions according to ISO 15550 except for LT-water temperature, which is corresponding to charge air receiver temperature 55ºC in gas operation and 60 ºC in diesel mode. With engine driven water and lubricating oil pumps. Tolerance for cooling water heat 10%, tolerance for radiation heat 20%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers. In arctic option all charge air coolers are in LT circuit.
Note 4	Validity of the data in diesel mode operation: at ambient conditions according to ISO 15550. Lower calorific value 42700 kJ/kg. With engine driven pumps (two cooling water + one lubricating oil pump). Tolerance 5%.
Note 5	Validity of the data in gas fuel operation: total barometric pressure, air temperature and relative humidity according to ISO 15550:2002(E), LT water temperature corresponding to receiver temperature 55°C, pilot fuel cetane index minimum 50 according to ISO 4264. Lower calorific value 42 700 kJ/kg for pilot fuel and 49 700 kJ/kg for gas fuel. With engine driven pumps (two cooling water pumps, one lubricating oil pump). Tolerance 5%.

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 8V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Engine output	kW	4240		4400		4240		4400		4400	
Mean effective pressure	MPa	2.72		2.71		2.72		2.71		2.71	
IMO compliance		Tier 3		Tier 3		Tier 3		Tier 3		Tier 3	
Combustion air system (Note 1)											
Flow at 100% load	kg/s	6.9	7.7	7.2	8.3	6.9	7.7	7.2	8.3	7.2	8.3
Temperature at turbocharger intake, max.	°C	45		45		45		45		45	
Temperature after air cooler (TE 601)	°C	60	60	60	60	60	60	60	60	60	60
Exhaust gas system (Note 2)											
Flow at 100% load	kg/s	7.1	7.9	7.4	8.6	7.1	7.9	7.4	8.6	7.4	8.6
Flow at 85% load	kg/s	5.9	6.8	6.1	7.4	5.9	6.8	6.1	7.4	6.1	7.2
Flow at 75% load	kg/s	5.2	6.2	5.4	6.7	5.2	6.2	5.4	6.7	5.5	6.5
Flow at 50% load	kg/s	3.7	4.6	3.8	4.9	3.7	4.6	3.8	4.9	3.8	5.0
Temperature after turbocharger at 100% load (TE 517)	°C	300	285	300	285	300	285	300	285	300	285
Temperature after turbocharger at 85% load (TE 517)	°C	350	285	350	285	350	285	350	285	320	285
Temperature after turbocharger at 75% load (TE 517)	°C	350	285	350	285	350	285	350	285	310	285
Temperature after turbocharger at 50% load (TE 517)	°C	370	285	370	285	370	285	370	285	330	285
Backpressure, max.	kPa	5.0	6.5	5.0	6.5	5.0	6.5	5.0	6.5	5.0	6.5
Calculated exhaust diameter for 35 m/s	mm	647	673	657	700	647	673	657	700	657	700
Heat balance at 100% load (Note 3)											
Jacket water, HT-circuit	kW	344	408	360	424	344	408	360	424	360	424
Charge air, HT-circuit	kW	472	648	504	736	472	648	504	736	504	744
Charge air, LT-circuit	kW	1024	1192	1072	1288	1024	1192	1072	1288	1064	1280
Lubricating oil, LT-circuit	kW	392	472	408	488	392	472	408	488	408	488
Radiation	kW	120	120	120	120	120	120	120	120	120	120
Fuel consumption (Note 4) (Note 5)											
Total energy consumption at 100% load	kJ/kWh	7250	-	7280	-	7250	-	7280	-	7280	-
Total energy consumption at 85% load	kJ/kWh	7300	-	7350	-	7300	-	7350	-	7230	-
Total energy consumption at 75% load	kJ/kWh	7430	-	7500	-	7430	-	7500	-	7250	-
Total energy consumption at 50% load	kJ/kWh	7790	-	7820	-	7790	-	7820	-	7330	-
Fuel gas consumption at 100% load	kJ/kWh	7097	-	7128	-	7097	-	7128	-	7128	-

Wärtsilä 8V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Fuel gas consumption at 85% load	kJ/kWh	7121	-	7171	-	7121	-	7171	-	7059	-
Fuel gas consumption at 75% load	kJ/kWh	7226	-	7294	-	7226	-	7294	-	7082	-
Fuel gas consumption at 50% load	kJ/kWh	7484	-	7515	-	7484	-	7515	-	7157	-
Fuel oil consumption at 100% load	g/kWh	3.8	175.8	3.8	179.1	3.8	175.8	3.8	179.1	3.8	179.1
Fuel oil consumption at 85% load	g/kWh	4.4	174.9	4.5	176.8	4.4	174.9	4.5	176.8	4.2	175.7
Fuel oil consumption at 75% load	g/kWh	5.0	177.6	5.1	180.0	5.0	177.6	5.1	180.0	4.1	177.7
Fuel oil consumption 50% load	g/kWh	7.6	184.5	7.6	186.2	7.6	184.5	7.6	186.2	4.3	182.6
Fuel gas system											
Gas pressure at engine inlet, min (PT901)	kPa (a)	895	-	895	-	895	-	895	-	895	-
Gas pressure to Gas Valve Unit, min	kPa (a)	1015	-	1015	-	1015	-	1015	-	1015	-
Gas temperature before Gas Valve Unit	°C	0...60	-	0...60	-	0...60	-	0...60	-	0...60	-
Fuel oil system											
Pressure before HP pumps (PT 101)	kPa	1000±100		1000±100		1000±100		1000±100		1000±100	
Fuel oil flow to engine, approx.	m^3/h	3.6		3.6		3.6		3.6		3.6	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24	-	16...24	-	16...24
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140	-	140	-	140
MDF viscosity, min.	cSt	2.0		2.0		2.0		2.0		2.0	
Max. MDF temperature before engine (TE 101)	°C	45		45		45		45		45	
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h		0.5		0.5		0.5		0.5		0.5
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	0.9	1.5	0.9	1.5	0.9	1.5	0.9	1.5	0.9	1.5
Lubricating oil system											
Pressure before bearings, nom. (PT 201)	kPa	420		420		420		420		420	
Suction ability, including pipe loss, max.	kPa	40		40		40		40		40	
Priming pressure, nom. (PT 201)	kPa	100		100		100		100		100	
Suction ability priming pump, including pipe loss, max.	kPa	35		35		35		35		35	
Temperature before bearings, nom. (TE 201)	°C	70		70		70		70		70	
Temperature after engine, approx.	°C	82		82		82		82		82	
Pump capacity (main), engine driven	m^3/h	125		130		125		130		144	
Pump capacity (main), electrically driven	m^3/h	100		100		100		100		100	
Priming pump capacity (50/60Hz)	m^3/h	40.0 / 40.0		40.0 / 40.0		40.0 / 40.0		40.0 / 40.0		40.0 / 40.0	

Wärtsilä 8V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Oil volume, wet sump, nom.	m^3	2.8		2.8		2.8		2.8		2.8	
Oil volume in separate system oil tank	m^3	5.7		5.9		5.7		5.9		5.9	
Oil consumption at 100% load, approx.	g/kWh	0.35	0.45	0.35	0.45	0.35	0.45	0.35	0.45	0.35	0.45
Crankcase ventilation flow rate at full load	l/min	1600		1600		1600		1600		1600	
Crankcase ventilation backpressure, max.	kPa	0.1		0.1		0.1		0.1		0.1	
Oil volume in turning device	l	9.5...11.5		9.5...11.5		9.5...11.5		9.5...11.5		9.5...11.5	
Cooling water system											
HT cooling water system											
Pressure at engine, after pump, nom. (PT 401)	kPa	358 + static		358 + static		358 + static		358 + static		358 + static	
Pressure at engine, after pump, max. (PT 401)	kPa	600		600		600		600		600	
Temperature before cylinders, approx. (TE 401)	°C	83		83		83		83		83	
Temperature after engine, nom.	°C	96		96		96		96		96	
Capacity of engine driven pump, nom.	m^3/h	80		80		80		80		80	
Pressure drop over engine, total	kPa	210		210		210		210		210	
Pressure drop in external system, max.	kPa	100		100		100		100		100	
Pressure from expansion tank	kPa	70...150		70...150		70...150		70...150		70...150	
Water volume in engine	m^3	0.35		0.35		0.35		0.35		0.35	
Delivery head of stand-by pump	kPa	365		365		365		365		365	
LT cooling water system											
Pressure at engine, after pump, nom. (PT 451)	kPa	650+ static		650+ static		650+ static		650+ static		650+ static	
Temperature before engine, nom (TE 451)	°C	40/ 45		40/ 45		40/ 45		40/ 45		40/ 45	
Capacity of engine driven pump, nom.	m^3/h	80		80		80		80		80	
Pressure drop over charge air cooler (two-stage)	kPa	110		110		110		110		110	
Pressure drop in external system, max.	kPa	100		100		100		100		100	
Pressure from expansion tank	kPa	70...150		70...150		70...150		70...150		70...150	
Starting air system											
Pressure, nom.	kPa	3000		3000		3000		3000		3000	
Pressure at engine during start, min. (alarm) (20°C)	kPa	1500		1500		1500		1500		1500	
Pressure, max.	kPa	3000		3000		3000		3000		3000	
Low pressure limit in air vessels	kPa	1800		1800		1800		1800		1800	
Starting air consumption, start (successful)	Nm^3	5.9		5.9		5.9		5.9		5.9	

Notes:

Note 1	At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 9%.
Note 2	At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 9% and temperature tolerance 10°C in gas mode operation. Flow tolerance 9% and temperature tolerance 15°C in diesel mode operation.
Note 3	At 100% output and nominal speed. The figures are valid for ambient conditions according to ISO 15550 except for LT-water temperature, which is corresponding to charge air receiver temperature 55ºC in gas operation and 60 ºC in diesel mode. With engine driven water and lubricating oil pumps. Tolerance for cooling water heat 10%, tolerance for radiation heat 20%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers. In arctic option all charge air coolers are in LT circuit.
Note 4	Validity of the data in diesel mode operation: at ambient conditions according to ISO 15550. Lower calorific value 42700 kJ/kg. With engine driven pumps (two cooling water + one lubricating oil pump). Tolerance 5%.
Note 5	Validity of the data in gas fuel operation: total barometric pressure, air temperature and relative humidity according to ISO 15550:2002(E), LT water temperature corresponding to receiver temperature 55°C, pilot fuel cetane index minimum 50 according to ISO 4264. Lower calorific value 42 700 kJ/kg for pilot fuel and 49 700 kJ/kg for gas fuel. With engine driven pumps (two cooling water pumps, one lubricating oil pump). Tolerance 5%.

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 10V31DF

3.3.1 IMO Tier 2

Wärtsilä 10V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Engine output	kW	5300		5500		5300		5500		5500	
Mean effective pressure	MPa	2.72		2.71		2.72		2.71		2.71	
IMO compliance		Tier 3	Tier 2	Tier 3	Tier 2	Tier 3	Tier 2	Tier 3	Tier 2	Tier 3	Tier 2
Combustion air system (Note 1)											
Flow at 100% load	kg/s	8.7	9.8	9.0	10.6	8.7	9.8	9.0	10.6	9.0	10.6
Temperature at turbocharger intake, max.	°C	45		45		45		45		45	
Temperature after air cooler (TE 601)	°C	60	60	60	60	60	60	60	60	60	60
Exhaust gas system (Note 2)											
Flow at 100% load	kg/s	8.9	10.1	9.2	10.9	8.9	10.1	9.2	10.9	9.2	10.9
Flow at 85% load	kg/s	7.4	8.6	7.6	9.3	7.4	8.6	7.6	9.3	7.6	9.2
Flow at 75% load	kg/s	6.5	8.0	6.7	8.6	6.5	8.0	6.7	8.6	6.9	8.3
Flow at 50% load	kg/s	4.6	5.7	4.7	6.1	4.6	5.7	4.7	6.1	4.8	6.2
Temperature after turbocharger at 100% load (TE 517)	°C	300	270	300	270	300	270	300	270	300	270
Temperature after turbocharger at 85% load (TE 517)	°C	350	270	350	270	350	270	350	270	320	260
Temperature after turbocharger at 75% load (TE 517)	°C	350	260	350	260	350	260	350	260	310	270
Temperature after turbocharger at 50% load (TE 517)	°C	370	280	370	280	370	280	370	280	330	270
Backpressure, max.	kPa	5.0	6.5	5.0	6.5	5.0	6.5	5.0	6.5	5.0	6.5
Calculated exhaust diameter for 35 m/s	mm	723	750	735	779	723	750	735	779	735	779
Heat balance at 100% load (Note 3)											
Jacket water, HT-circuit	kW	430	510	450	530	430	510	450	530	450	530
Charge air, HT-circuit	kW	590	850	630	960	590	850	630	960	630	960
Charge air, LT-circuit	kW	1280	1510	1340	1630	1280	1510	1340	1630	1330	1620
Lubricating oil, LT-circuit	kW	490	590	510	610	490	590	510	610	510	610
Radiation	kW	150	150	150	150	150	150	150	150	150	150
Fuel consumption (Note 4) (Note 5)											
Total energy consumption at 100% load	kJ/kWh	7250	-	7280	-	7250	-	7280	-	7280	-
Total energy consumption at 85% load	kJ/kWh	7300	-	7350	-	7300	-	7350	-	7270	-
Total energy consumption at 75% load	kJ/kWh	7430	-	7500	-	7430	-	7500	-	7290	-
Total energy consumption at 50% load	kJ/kWh	7790	-	7820	-	7790	-	7820	-	7430	-

Wärtsilä 10V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Fuel gas consumption at 100% load	kJ/kWh	7097	-	7128	-	7097	-	7128	-	7128	-
Fuel gas consumption at 85% load	kJ/kWh	7121	-	7171	-	7121	-	7171	-	7100	-
Fuel gas consumption at 75% load	kJ/kWh	7226	-	7294	-	7226	-	7294	-	7122	-
Fuel gas consumption at 50% load	kJ/kWh	7484	-	7515	-	7484	-	7515	-	7250	-
Fuel oil consumption at 100% load	g/kWh	3.8	175.3	3.8	178.7	3.8	175.3	3.8	178.7	3.8	178.7
Fuel oil consumption at 85% load	g/kWh	4.4	174.4	4.5	176.3	4.4	174.4	4.5	176.3	4.2	174.9
Fuel oil consumption at 75% load	g/kWh	5.0	176.8	5.1	179.1	5.0	176.8	5.1	179.1	4.1	177.2
Fuel oil consumption 50% load	g/kWh	7.6	184.3	7.6	186.0	7.6	184.3	7.6	186.0	4.3	182.1
Fuel gas system											
Gas pressure at engine inlet, min (PT901)	kPa (a)	895	-	895	-	895	-	895	-	895	-
Gas pressure to Gas Valve Unit, min	kPa (a)	1015	-	1015	-	1015	-	1015	-	1015	-
Gas temperature before Gas Valve Unit	°C	0...60	-	0...60	-	0...60	-	0...60	-	0...60	-
Fuel oil system											
Pressure before HP pumps (PT 101)	kPa	1000±100		1000±100		1000±100		1000±100		1000±100	
Fuel oil flow to engine, approx.	m^3/h	3.6		3.6		3.6		3.6		3.6	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24	-	16...24	-	16...24
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140	-	140	-	140
MDF viscosity, min.	cSt	2.0		2.0		2.0		2.0		2.0	
Max. MDF temperature before engine (TE 101)	°C	45		45		45		45		45	
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h		0.5		0.5		0.5		0.5		0.5
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	0.9	1.5	0.9	1.5	0.9	1.5	0.9	1.5	0.9	1.5
Lubricating oil system											
Pressure before bearings, nom. (PT 201)	kPa	420		420		420		420		420	
Suction ability, including pipe loss, max.	kPa	40		40		40		40		40	
Priming pressure, nom. (PT 201)	kPa	100		100		100		100		100	
Suction ability priming pump, including pipe loss, max.	kPa	35		35		35		35		35	
Temperature before bearings, nom. (TE 201)	°C	70		70		70		70		70	
Temperature after engine, approx.	°C	82		82		82		82		82	
Pump capacity (main), engine driven	m^3/h	125		130		125		130		144	
Pump capacity (main), electrically driven	m^3/h	120		120		120		120		120	

Wärtsilä 10V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Priming pump capacity (50/60Hz)	m³/h	50.0 / 50.0		50.0 / 50.0		50.0 / 50.0		50.0 / 50.0		50.0 / 50.0	
Oil volume, wet sump, nom.	m³	3.4		3.4		3.4		3.4		3.4	
Oil volume in separate system oil tank	m³	7.2		7.4		7.2		7.4		7.4	
Oil consumption at 100% load, approx.	g/kWh	0.35	0.45	0.35	0.45	0.35	0.45	0.35	0.45	0.35	0.45
Crankcase ventilation flow rate at full load	l/min	2000		2000		2000		2000		2000	
Crankcase ventilation backpressure, max.	kPa	0.1		0.1		0.1		0.1		0.1	
Oil volume in turning device	l	9.5...11.5		9.5...11.5		9.5...11.5		9.5...11.5		9.5...11.5	
Cooling water system											
HT cooling water system											
Pressure at engine, after pump, nom. (PT 401)	kPa	383 + static		383 + static		383 + static		383 + static		383 + static	
Pressure at engine, after pump, max. (PT 401)	kPa	600		600		600		600		600	
Temperature before cylinders, approx. (TE 401)	°C	83		83		83		83		83	
Temperature after engine, nom.	°C	96		96		96		96		96	
Capacity of engine driven pump, nom.	m³/h	90		90		90		90		90	
Pressure drop over engine, total	kPa	210		210		210		210		210	
Pressure drop in external system, max.	kPa	100		100		100		100		100	
Pressure from expansion tank	kPa	70...150		70...150		70...150		70...150		70...150	
Water volume in engine	m³	0.4		0.4		0.4		0.4		0.4	
Delivery head of stand-by pump	kPa	390		390		390		390		390	
LT cooling water system											
Pressure at engine, after pump, nom. (PT 451)	kPa	650+ static		650+ static		650+ static		650+ static		650+ static	
Temperature before engine, nom (TE 451)	°C	40/ 45		40/ 45		40/ 45		40/ 45		40/ 45	
Capacity of engine driven pump, nom.	m³/h	90		90		90		90		90	
Pressure drop over charge air cooler (two-stage)	kPa	110		110		110		110		110	
Pressure drop in external system, max.	kPa	100		100		100		100		100	
Pressure from expansion tank	kPa	70...150		70...150		70...150		70...150		70...150	
Starting air system											
Pressure, nom.	kPa	3000		3000		3000		3000		3000	
Pressure at engine during start, min. (alarm) (20°C)	kPa	1500		1500		1500		1500		1500	
Pressure, max.	kPa	3000		3000		3000		3000		3000	
Low pressure limit in air vessels	kPa	1800		1800		1800		1800		1800	
Starting air consumption, start (successful)	Nm³	6.1		6.1		6.1		6.1		6.1	

Notes:

Note 1	At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 9%.
Note 2	At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 9% and temperature tolerance 10°C in gas mode operation. Flow tolerance 9% and temperature tolerance 15°C in diesel mode operation.
Note 3	At 100% output and nominal speed. The figures are valid for ambient conditions according to ISO 15550 except for LT-water temperature, which is corresponding to charge air receiver temperature 55ºC in gas operation and 60 ºC in diesel mode. With engine driven water and lubricating oil pumps. Tolerance for cooling water heat 10%, tolerance for radiation heat 20%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers. In arctic option all charge air coolers are in LT circuit.
Note 4	Validity of the data in diesel mode operation: at ambient conditions according to ISO 15550. Lower calorific value 42700 kJ/kg. With engine driven pumps (two cooling water + one lubricating oil pump). Tolerance 5%.
Note 5	Validity of the data in gas fuel operation: total barometric pressure, air temperature and relative humidity according to ISO 15550:2002(E), LT water temperature corresponding to receiver temperature 55°C, pilot fuel cetane index minimum 50 according to ISO 4264. Lower calorific value 42 700 kJ/kg for pilot fuel and 49 700 kJ/kg for gas fuel. With engine driven pumps (two cooling water pumps, one lubricating oil pump). Tolerance 5%.

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 10V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Engine output	kW	5300		5500		5300		5500		5500	
Mean effective pressure	MPa	2.72		2.71		2.72		2.71		2.71	
IMO compliance		Tier 3		Tier 3		Tier 3		Tier 3		Tier 3	
Combustion air system (Note 1)											
Flow at 100% load	kg/s	8.7	9.6	9.0	10.4	8.7	9.6	9.0	10.4	9.0	10.4
Temperature at turbocharger intake, max.	°C	45		45		45		45		45	
Temperature after air cooler (TE 601)	°C	60	60	60	60	60	60	60	60	60	60
Exhaust gas system (Note 2)											
Flow at 100% load	kg/s	8.9	9.9	9.2	10.7	8.9	9.9	9.2	10.7	9.2	10.7
Flow at 85% load	kg/s	7.4	8.5	7.6	9.2	7.4	8.5	7.6	9.2	7.6	9.0
Flow at 75% load	kg/s	6.5	7.8	6.7	8.4	6.5	7.8	6.7	8.4	6.9	8.1
Flow at 50% load	kg/s	4.6	5.7	4.7	6.1	4.6	5.7	4.7	6.1	4.8	6.2
Temperature after turbocharger at 100% load (TE 517)	°C	300	285	300	285	300	285	300	285	300	285
Temperature after turbocharger at 85% load (TE 517)	°C	350	285	350	285	350	285	350	285	320	285
Temperature after turbocharger at 75% load (TE 517)	°C	350	285	380	285	350	285	380	285	310	285
Temperature after turbocharger at 50% load (TE 517)	°C	370	285	370	285	370	285	370	285	330	285
Backpressure, max.	kPa	5.0	6.5	5.0	6.5	5.0	6.5	5.0	6.5	5.0	6.5
Calculated exhaust diameter for 35 m/s	mm	723	752	735	782	723	752	735	782	735	782
Heat balance at 100% load (Note 3)											
Jacket water, HT-circuit	kW	430	510	450	530	430	510	450	530	450	530
Charge air, HT-circuit	kW	590	810	630	920	590	810	630	920	630	930
Charge air, LT-circuit	kW	1280	1490	1340	1610	1280	1490	1340	1610	1330	1600
Lubricating oil, LT-circuit	kW	490	590	510	610	490	590	510	610	510	610
Radiation	kW	150	150	150	150	150	150	150	150	150	150
Fuel consumption (Note 4) (Note 5)											
Total energy consumption at 100% load	kJ/kWh	7250	-	7280	-	7250	-	7280	-	7280	-
Total energy consumption at 85% load	kJ/kWh	7300	-	7350	-	7300	-	7350	-	7230	-
Total energy consumption at 75% load	kJ/kWh	7430	-	7500	-	7430	-	7500	-	7250	-
Total energy consumption at 50% load	kJ/kWh	7790	-	7820	-	7790	-	7820	-	7330	-
Fuel gas consumption at 100% load	kJ/kWh	7097	-	7128	-	7097	-	7128	-	7128	-

Wärtsilä 10V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Fuel gas consumption at 85% load	kJ/kWh	7121	-	7171	-	7121	-	7171	-	7059	-
Fuel gas consumption at 75% load	kJ/kWh	7226	-	7294	-	7226	-	7294	-	7082	-
Fuel gas consumption at 50% load	kJ/kWh	7484	-	7515	-	7484	-	7515	-	7157	-
Fuel oil consumption at 100% load	g/kWh	3.8	175.8	3.8	179.1	3.8	175.8	3.8	179.1	3.8	179.1
Fuel oil consumption at 85% load	g/kWh	4.4	174.9	4.5	176.8	4.4	174.9	4.5	176.8	4.2	175.7
Fuel oil consumption at 75% load	g/kWh	5.0	177.6	5.1	180.0	5.0	177.6	5.1	180.0	4.1	177.7
Fuel oil consumption 50% load	g/kWh	7.6	184.5	7.6	186.2	7.6	184.5	7.6	186.2	4.3	182.6
Fuel gas system											
Gas pressure at engine inlet, min (PT901)	kPa (a)	895	-	895	-	895	-	895	-	895	-
Gas pressure to Gas Valve Unit, min	kPa (a)	1015	-	1015	-	1015	-	1015	-	1015	-
Gas temperature before Gas Valve Unit	°C	0...60	-	0...60	-	0...60	-	0...60	-	0...60	-
Fuel oil system											
Pressure before HP pumps (PT 101)	kPa	1000±100		1000±100		1000±100		1000±100		1000±100	
Fuel oil flow to engine, approx.	m³/h	3.6		3.6		3.6		3.6		3.6	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24	-	16...24	-	16...24
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140	-	140	-	140
MDF viscosity, min.	cSt	2.0		2.0		2.0		2.0		2.0	
Max. MDF temperature before engine (TE 101)	°C	45		45		45		45		45	
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h		0.5		0.5		0.5		0.5		0.5
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	0.9	1.5	0.9	1.5	0.9	1.5	0.9	1.5	0.9	1.5
Lubricating oil system											
Pressure before bearings, nom. (PT 201)	kPa	420		420		420		420		420	
Suction ability, including pipe loss, max.	kPa	40		40		40		40		40	
Priming pressure, nom. (PT 201)	kPa	100		100		100		100		100	
Suction ability priming pump, including pipe loss, max.	kPa	35		35		35		35		35	
Temperature before bearings, nom. (TE 201)	°C	70		70		70		70		70	
Temperature after engine, approx.	°C	82		82		82		82		82	
Pump capacity (main), engine driven	m³/h	125		130		125		130		144	
Pump capacity (main), electrically driven	m³/h	120		120		120		120		120	
Priming pump capacity (50/60Hz)	m³/h	50.0 / 50.0		50.0 / 50.0		50.0 / 50.0		50.0 / 50.0		50.0 / 50.0	

Wärtsilä 10V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Oil volume, wet sump, nom.	m³	3.4		3.4		3.4		3.4		3.4	
Oil volume in separate system oil tank	m³	7.2		7.4		7.2		7.4		7.4	
Oil consumption at 100% load, approx.	g/kWh	0.35	0.45	0.35	0.45	0.35	0.45	0.35	0.45	0.35	0.45
Crankcase ventilation flow rate at full load	l/min	2000		2000		2000		2000		2000	
Crankcase ventilation backpressure, max.	kPa	0.1		0.1		0.1		0.1		0.1	
Oil volume in turning device	l	9.5...11.5		9.5...11.5		9.5...11.5		9.5...11.5		9.5...11.5	
Cooling water system											
HT cooling water system											
Pressure at engine, after pump, nom. (PT 401)	kPa	383 + static		383 + static		383 + static		383 + static		383 + static	
Pressure at engine, after pump, max. (PT 401)	kPa	600		600		600		600		600	
Temperature before cylinders, approx. (TE 401)	°C	83		83		83		83		83	
Temperature after engine, nom.	°C	96		96		96		96		96	
Capacity of engine driven pump, nom.	m³/h	90		90		90		90		90	
Pressure drop over engine, total	kPa	210		210		210		210		210	
Pressure drop in external system, max.	kPa	100		100		100		100		100	
Pressure from expansion tank	kPa	70...150		70...150		70...150		70...150		70...150	
Water volume in engine	m³	0.4		0.4		0.4		0.4		0.4	
Delivery head of stand-by pump	kPa	390		390		390		390		390	
LT cooling water system											
Pressure at engine, after pump, nom. (PT 451)	kPa	650+ static		650+ static		650+ static		650+ static		650+ static	
Temperature before engine, nom (TE 451)	°C	40/ 45		40/ 45		40/ 45		40/ 45		40/ 45	
Capacity of engine driven pump, nom.	m³/h	90		90		90		90		90	
Pressure drop over charge air cooler (two-stage)	kPa	110		110		110		110		110	
Pressure drop in external system, max.	kPa	100		100		100		100		100	
Pressure from expansion tank	kPa	70...150		70...150		70...150		70...150		70...150	
Starting air system											
Pressure, nom.	kPa	3000		3000		3000		3000		3000	
Pressure at engine during start, min. (alarm) (20°C)	kPa	1500		1500		1500		1500		1500	
Pressure, max.	kPa	3000		3000		3000		3000		3000	
Low pressure limit in air vessels	kPa	1800		1800		1800		1800		1800	
Starting air consumption, start (successful)	Nm³	6.1		6.1		6.1		6.1		6.1	

Notes:

Note 1	At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 9%.
Note 2	At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 9% and temperature tolerance 10°C in gas mode operation. Flow tolerance 9% and temperature tolerance 15°C in diesel mode operation.
Note 3	At 100% output and nominal speed. The figures are valid for ambient conditions according to ISO 15550 except for LT-water temperature, which is corresponding to charge air receiver temperature 55ºC in gas operation and 60 ºC in diesel mode. With engine driven water and lubricating oil pumps. Tolerance for cooling water heat 10%, tolerance for radiation heat 20%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers. In arctic option all charge air coolers are in LT circuit.
Note 4	Validity of the data in diesel mode operation: at ambient conditions according to ISO 15550. Lower calorific value 42700 kJ/kg. With engine driven pumps (two cooling water + one lubricating oil pump). Tolerance 5%.
Note 5	Validity of the data in gas fuel operation: total barometric pressure, air temperature and relative humidity according to ISO 15550:2002(E), LT water temperature corresponding to receiver temperature 55°C, pilot fuel cetane index minimum 50 according to ISO 4264. Lower calorific value 42 700 kJ/kg for pilot fuel and 49 700 kJ/kg for gas fuel. With engine driven pumps (two cooling water pumps, one lubricating oil pump). Tolerance 5%.

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 12V31DF

3.4.1 IMO Tier 2

Wärtsilä 12V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Engine output	kW	6360		6600		6360		6600		6600	
Mean effective pressure	MPa	2.72		2.71		2.72		2.71		2.71	
IMO compliance		Tier 3	Tier 2	Tier 3	Tier 2	Tier 3	Tier 2	Tier 3	Tier 2	Tier 3	Tier 2
Combustion air system (Note 1)											
Flow at 100% load	kg/s	10.4	11.8	10.8	12.7	10.4	11.8	10.8	12.7	10.8	12.7
Temperature at turbocharger intake, max.	°C	45		45		45		45		45	
Temperature after air cooler (TE 601)	°C	60	60	60	60	60	60	60	60	60	60
Exhaust gas system (Note 2)											
Flow at 100% load	kg/s	10.7	12.1	11.0	13.1	10.7	12.1	11.0	13.1	11.0	13.1
Flow at 85% load	kg/s	8.9	10.3	9.1	11.2	8.9	10.3	9.1	11.2	9.1	11.0
Flow at 75% load	kg/s	7.8	9.6	8.0	10.3	7.8	9.6	8.0	10.3	8.3	10.0
Flow at 50% load	kg/s	5.5	6.8	5.6	7.3	5.5	6.8	5.6	7.3	5.8	7.4
Temperature after turbocharger at 100% load (TE 517)	°C	300	270	300	270	300	270	300	270	300	270
Temperature after turbocharger at 85% load (TE 517)	°C	350	270	350	270	350	270	350	270	320	260
Temperature after turbocharger at 75% load (TE 517)	°C	350	260	350	260	350	260	350	260	310	270
Temperature after turbocharger at 50% load (TE 517)	°C	370	280	370	280	370	280	370	280	330	270
Backpressure, max.	kPa	5.0	6.5	5.0	6.5	5.0	6.5	5.0	6.5	5.0	6.5
Calculated exhaust diameter for 35 m/s	mm	792	821	805	853	792	821	805	853	805	853
Heat balance at 100% load (Note 3)											
Jacket water, HT-circuit	kW	516	612	540	636	516	612	540	636	540	636
Charge air, HT-circuit	kW	708	1020	756	1152	708	1020	756	1152	756	1152
Charge air, LT-circuit	kW	1536	1812	1608	1956	1536	1812	1608	1956	1596	1944
Lubricating oil, LT-circuit	kW	588	708	612	732	588	708	612	732	612	732
Radiation	kW	180	180	180	180	180	180	180	180	180	180
Fuel consumption (Note 4) (Note 5)											
Total energy consumption at 100% load	kJ/kWh	7250	-	7280	-	7250	-	7280	-	7280	-
Total energy consumption at 85% load	kJ/kWh	7300	-	7350	-	7300	-	7350	-	7270	-
Total energy consumption at 75% load	kJ/kWh	7430	-	7500	-	7430	-	7500	-	7290	-
Total energy consumption at 50% load	kJ/kWh	7790	-	7820	-	7790	-	7820	-	7430	-

Wärtsilä 12V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Fuel gas consumption at 100% load	kJ/kWh	7097	-	7128	-	7097	-	7128	-	7128	-
Fuel gas consumption at 85% load	kJ/kWh	7121	-	7171	-	7121	-	7171	-	7100	-
Fuel gas consumption at 75% load	kJ/kWh	7226	-	7294	-	7226	-	7294	-	7122	-
Fuel gas consumption at 50% load	kJ/kWh	7484	-	7515	-	7484	-	7515	-	7250	-
Fuel oil consumption at 100% load	g/kWh	3.8	175.3	3.8	178.7	3.8	175.3	3.8	178.7	3.8	178.7
Fuel oil consumption at 85% load	g/kWh	4.4	174.4	4.5	176.3	4.4	174.4	4.5	176.3	4.2	174.9
Fuel oil consumption at 75% load	g/kWh	5.0	176.8	5.1	179.1	5.0	176.8	5.1	179.1	4.1	177.2
Fuel oil consumption 50% load	g/kWh	7.6	184.3	7.6	186.0	7.6	184.3	7.6	186.0	4.3	182.1
Fuel gas system											
Gas pressure at engine inlet, min (PT901)	kPa (a)	895	-	895	-	895	-	895	-	895	-
Gas pressure to Gas Valve Unit, min	kPa (a)	1015	-	1015	-	1015	-	1015	-	1015	-
Gas temperature before Gas Valve Unit	°C	0...60	-	0...60	-	0...60	-	0...60	-	0...60	-
Fuel oil system											
Pressure before HP pumps (PT 101)	kPa	1000±100		1000±100		1000±100		1000±100		1000±100	
Fuel oil flow to engine, approx.	m^3/h	7.2		7.2		7.2		7.2		7.2	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24	-	16...24	-	16...24
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140	-	140	-	140
MDF viscosity, min.	cSt	2.0		2.0		2.0		2.0		2.0	
Max. MDF temperature before engine (TE 101)	°C	45		45		45		45		45	
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h		1.1		1.1		1.1		1.1		1.1
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	1.8	3.0	1.8	3.0	1.8	3.0	1.8	3.0	1.8	3.0
Lubricating oil system											
Pressure before bearings, nom. (PT 201)	kPa	420		420		420		420		420	
Suction ability, including pipe loss, max.	kPa	40		40		40		40		40	
Priming pressure, nom. (PT 201)	kPa	100		100		100		100		100	
Suction ability priming pump, including pipe loss, max.	kPa	35		35		35		35		35	
Temperature before bearings, nom. (TE 201)	°C	70		70		70		70		70	
Temperature after engine, approx.	°C	82		82		82		82		82	
Pump capacity (main), engine driven	m^3/h	138		144		138		144		170	
Pump capacity (main), electrically driven	m^3/h	137		137		137		137		137	

Wärtsilä 12V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Priming pump capacity (50/60Hz)	m³/h	60.0 / 60.0		60.0 / 60.0		60.0 / 60.0		60.0 / 60.0		60.0 / 60.0	
Oil volume, wet sump, nom.	m³	4.2		4.2		4.2		4.2		4.2	
Oil volume in separate system oil tank	m³	8.6		8.9		8.6		8.9		8.9	
Oil consumption at 100% load, approx.	g/kWh	0.35	0.45	0.35	0.45	0.35	0.45	0.35	0.45	0.35	0.45
Crankcase ventilation flow rate at full load	l/min	2400		2400		2400		2400		2400	
Crankcase ventilation backpressure, max.	kPa	0.1		0.1		0.1		0.1		0.1	
Oil volume in turning device	l	9.5...11.5		9.5...11.5		9.5...11.5		9.5...11.5		9.5...11.5	
Cooling water system											
HT cooling water system											
Pressure at engine, after pump, nom. (PT 401)	kPa	363 + static		363 + static		363 + static		363 + static		363 + static	
Pressure at engine, after pump, max. (PT 401)	kPa	600		600		600		600		600	
Temperature before cylinders, approx. (TE 401)	°C	83		83		83		83		83	
Temperature after engine, nom.	°C	96		96		96		96		96	
Capacity of engine driven pump, nom.	m³/h	110		110		110		110		110	
Pressure drop over engine, total	kPa	210		210		210		210		210	
Pressure drop in external system, max.	kPa	100		100		100		100		100	
Pressure from expansion tank	kPa	70...150		70...150		70...150		70...150		70...150	
Water volume in engine	m³	0.55		0.55		0.55		0.55		0.55	
Delivery head of stand-by pump	kPa	370		370		370		370		370	
LT cooling water system											
Pressure at engine, after pump, nom. (PT 451)	kPa	650+ static		650+ static		650+ static		650+ static		650+ static	
Temperature before engine, nom (TE 451)	°C	40/ 45		40/ 45		40/ 45		40/ 45		40/ 45	
Capacity of engine driven pump, nom.	m³/h	110		110		110		110		110	
Pressure drop over charge air cooler (two-stage)	kPa	110		110		110		110		110	
Pressure drop in external system, max.	kPa	100		100		100		100		100	
Pressure from expansion tank	kPa	70...150		70...150		70...150		70...150		70...150	
Starting air system											
Pressure, nom.	kPa	3000		3000		3000		3000		3000	
Pressure at engine during start, min. (alarm) (20°C)	kPa	1500		1500		1500		1500		1500	
Pressure, max.	kPa	3000		3000		3000		3000		3000	
Low pressure limit in air vessels	kPa	1800		1800		1800		1800		1800	
Starting air consumption, start (successful)	Nm³	6.4		6.4		6.4		6.4		6.4	

Notes:

Note 1	At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 9%.
Note 2	At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 9% and temperature tolerance 10°C in gas mode operation. Flow tolerance 9% and temperature tolerance 15°C in diesel mode operation.
Note 3	At 100% output and nominal speed. The figures are valid for ambient conditions according to ISO 15550 except for LT-water temperature, which is corresponding to charge air receiver temperature 55ºC in gas operation and 60 ºC in diesel mode. With engine driven water and lubricating oil pumps. Tolerance for cooling water heat 10%, tolerance for radiation heat 20%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers. In arctic option all charge air coolers are in LT circuit.
Note 4	Validity of the data in diesel mode operation: at ambient conditions according to ISO 15550. Lower calorific value 42700 kJ/kg. With engine driven pumps (two cooling water + one lubricating oil pump). Tolerance 5%.
Note 5	Validity of the data in gas fuel operation: total barometric pressure, air temperature and relative humidity according to ISO 15550:2002(E), LT water temperature corresponding to receiver temperature 55°C, pilot fuel cetane index minimum 50 according to ISO 4264. Lower calorific value 42 700 kJ/kg for pilot fuel and 49 700 kJ/kg for gas fuel. With engine driven pumps (two cooling water pumps, one lubricating oil pump). Tolerance 5%.

ME = Engine driving propeller, variable speed

AE = Auxiliary engine driving generator

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

3.4.2 SCR Ready

Wärtsilä 12V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Engine output	kW	6360		6600		6360		6600		6600	
Mean effective pressure	MPa	2.72		2.71		2.72		2.71		2.71	
IMO compliance		Tier 3		Tier 3		Tier 3		Tier 3		Tier 3	
Combustion air system (Note 1)											
Flow at 100% load	kg/s	10.4	11.6	10.8	12.5	10.4	11.6	10.8	12.5	10.8	12.5
Temperature at turbocharger intake, max.	°C	45		45		45		45		45	
Temperature after air cooler (TE 601)	°C	60	60	60	60	60	60	60	60	60	60
Exhaust gas system (Note 2)											
Flow at 100% load	kg/s	10.7	11.9	11.0	12.8	10.7	11.9	11.0	12.8	11.0	12.8
Flow at 85% load	kg/s	8.9	10.2	9.1	11.0	8.9	10.2	9.1	11.0	9.1	10.8
Flow at 75% load	kg/s	7.8	9.4	8.0	10.1	7.8	9.4	8.0	10.1	8.3	9.7
Flow at 50% load	kg/s	5.5	6.8	5.6	7.3	5.5	6.8	5.6	7.3	5.8	7.4
Temperature after turbocharger at 100% load (TE 517)	°C	300	285	300	285	300	285	300	285	300	285
Temperature after turbocharger at 85% load (TE 517)	°C	350	285	350	285	350	285	350	285	320	285
Temperature after turbocharger at 75% load (TE 517)	°C	350	285	350	285	350	285	350	285	310	285
Temperature after turbocharger at 50% load (TE 517)	°C	370	285	370	285	370	285	370	285	330	285
Backpressure, max.	kPa	5.0	6.5	5.0	6.5	5.0	6.5	5.0	6.5	5.0	6.5
Calculated exhaust diameter for 35 m/s	mm	792	824	805	857	792	824	805	857	805	857
Heat balance at 100% load (Note 3)											
Jacket water, HT-circuit	kW	516	612	540	636	516	612	540	636	540	636
Charge air, HT-circuit	kW	708	972	756	1104	708	972	756	1104	756	1116
Charge air, LT-circuit	kW	1536	1788	1608	1932	1536	1788	1608	1932	1596	1920
Lubricating oil, LT-circuit	kW	588	708	612	732	588	708	612	732	612	732
Radiation	kW	180	180	180	180	180	180	180	180	180	180
Fuel consumption (Note 4) (Note 5)											
Total energy consumption at 100% load	kJ/kWh	7250	-	7280	-	7250	-	7280	-	7280	-
Total energy consumption at 85% load	kJ/kWh	7300	-	7350	-	7300	-	7350	-	7230	-
Total energy consumption at 75% load	kJ/kWh	7430	-	7500	-	7430	-	7500	-	7250	-
Total energy consumption at 50% load	kJ/kWh	7790	-	7820	-	7790	-	7820	-	7330	-
Fuel gas consumption at 100% load	kJ/kWh	7097	-	7128	-	7097	-	7128	-	7128	-

Wärtsilä 12V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Fuel gas consumption at 85% load	kJ/kWh	7121	-	7171	-	7121	-	7171	-	7059	-
Fuel gas consumption at 75% load	kJ/kWh	7226	-	7294	-	7226	-	7294	-	7082	-
Fuel gas consumption at 50% load	kJ/kWh	7484	-	7515	-	7484	-	7515	-	7157	-
Fuel oil consumption at 100% load	g/kWh	3.8	175.8	3.8	179.1	3.8	175.8	3.8	179.1	3.8	179.1
Fuel oil consumption at 85% load	g/kWh	4.4	174.9	4.5	176.8	4.4	174.9	4.5	176.8	4.2	175.7
Fuel oil consumption at 75% load	g/kWh	5.0	177.6	5.1	180.0	5.0	177.6	5.1	180.0	4.1	177.7
Fuel oil consumption 50% load	g/kWh	7.6	184.5	7.6	186.2	7.6	184.5	7.6	186.2	4.3	182.6
Fuel gas system											
Gas pressure at engine inlet, min (PT901)	kPa (a)	895	-	895	-	895	-	895	-	895	-
Gas pressure to Gas Valve Unit, min	kPa (a)	1015	-	1015	-	1015	-	1015	-	1015	-
Gas temperature before Gas Valve Unit	°C	0...60	-	0...60	-	0...60	-	0...60	-	0...60	-
Fuel oil system											
Pressure before HP pumps (PT 101)	kPa	1000±100		1000±100		1000±100		1000±100		1000±100	
Fuel oil flow to engine, approx.	m^3/h	7.2		7.2		7.2		7.2		7.2	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24	-	16...24	-	16...24
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140	-	140	-	140
MDF viscosity, min.	cSt	2.0		2.0		2.0		2.0		2.0	
Max. MDF temperature before engine (TE 101)	°C	45		45		45		45		45	
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h		1.1		1.1		1.1		1.1		1.1
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	1.8	3.0	1.8	3.0	1.8	3.0	1.8	3.0	1.8	3.0
Lubricating oil system											
Pressure before bearings, nom. (PT 201)	kPa	420		420		420		420		420	
Suction ability, including pipe loss, max.	kPa	40		40		40		40		40	
Priming pressure, nom. (PT 201)	kPa	100		100		100		100		100	
Suction ability priming pump, including pipe loss, max.	kPa	35		35		35		35		35	
Temperature before bearings, nom. (TE 201)	°C	70		70		70		70		70	
Temperature after engine, approx.	°C	82		82		82		82		82	
Pump capacity (main), engine driven	m^3/h	138		144		138		144		170	
Pump capacity (main), electrically driven	m^3/h	137		137		137		137		137	
Priming pump capacity (50/60Hz)	m^3/h	60.0 / 60.0		60.0 / 60.0		60.0 / 60.0		60.0 / 60.0		60.0 / 60.0	

Wärtsilä 12V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Oil volume, wet sump, nom.	m^3	4.2		4.2		4.2		4.2		4.2	
Oil volume in separate system oil tank	m^3	8.6		8.9		8.6		8.9		8.9	
Oil consumption at 100% load, approx.	g/kWh	0.35	0.45	0.35	0.45	0.35	0.45	0.35	0.45	0.35	0.45
Crankcase ventilation flow rate at full load	l/min	2400		2400		2400		2400		2400	
Crankcase ventilation backpressure, max.	kPa	0.1		0.1		0.1		0.1		0.1	
Oil volume in turning device	l	9.5...11.5		9.5...11.5		9.5...11.5		9.5...11.5		9.5...11.5	
Cooling water system											
HT cooling water system											
Pressure at engine, after pump, nom. (PT 401)	kPa	363 + static		363 + static		363 + static		363 + static		363 + static	
Pressure at engine, after pump, max. (PT 401)	kPa	600		600		600		600		600	
Temperature before cylinders, approx. (TE 401)	°C	83		83		83		83		83	
Temperature after engine, nom.	°C	96		96		96		96		96	
Capacity of engine driven pump, nom.	m^3/h	110		110		110		110		110	
Pressure drop over engine, total	kPa	210		210		210		210		210	
Pressure drop in external system, max.	kPa	100		100		100		100		100	
Pressure from expansion tank	kPa	70...150		70...150		70...150		70...150		70...150	
Water volume in engine	m^3	0.55		0.55		0.55		0.55		0.55	
Delivery head of stand-by pump	kPa	370		370		370		370		370	
LT cooling water system											
Pressure at engine, after pump, nom. (PT 451)	kPa	650+ static		650+ static		650+ static		650+ static		650+ static	
Temperature before engine, nom (TE 451)	°C	40/ 45		40/ 45		40/ 45		40/ 45		40/ 45	
Capacity of engine driven pump, nom.	m^3/h	110		110		110		110		110	
Pressure drop over charge air cooler (two-stage)	kPa	110		110		110		110		110	
Pressure drop in external system, max.	kPa	100		100		100		100		100	
Pressure from expansion tank	kPa	70...150		70...150		70...150		70...150		70...150	
Starting air system											
Pressure, nom.	kPa	3000		3000		3000		3000		3000	
Pressure at engine during start, min. (alarm) (20°C)	kPa	1500		1500		1500		1500		1500	
Pressure, max.	kPa	3000		3000		3000		3000		3000	
Low pressure limit in air vessels	kPa	1800		1800		1800		1800		1800	
Starting air consumption, start (successful)	Nm^3	6.4		6.4		6.4		6.4		6.4	

Notes:

Note 1	At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 9%.
Note 2	At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 9% and temperature tolerance 10°C in gas mode operation. Flow tolerance 9% and temperature tolerance 15°C in diesel mode operation.
Note 3	At 100% output and nominal speed. The figures are valid for ambient conditions according to ISO 15550 except for LT-water temperature, which is corresponding to charge air receiver temperature 55ºC in gas operation and 60 ºC in diesel mode. With engine driven water and lubricating oil pumps. Tolerance for cooling water heat 10%, tolerance for radiation heat 20%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers. In arctic option all charge air coolers are in LT circuit.
Note 4	Validity of the data in diesel mode operation: at ambient conditions according to ISO 15550. Lower calorific value 42700 kJ/kg. With engine driven pumps (two cooling water + one lubricating oil pump). Tolerance 5%.
Note 5	Validity of the data in gas fuel operation: total barometric pressure, air temperature and relative humidity according to ISO 15550:2002(E), LT water temperature corresponding to receiver temperature 55°C, pilot fuel cetane index minimum 50 according to ISO 4264. Lower calorific value 42 700 kJ/kg for pilot fuel and 49 700 kJ/kg for gas fuel. With engine driven pumps (two cooling water pumps, one lubricating oil pump). Tolerance 5%.

ME = Engine driving propeller, variable speed

AE = Auxiliary engine driving generator

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

3.5 Wärtsilä 14V31DF

3.5.1 IMO Tier 2

Wärtsilä 14V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Engine output	kW	7420		7700		7420		7700		7700	
Mean effective pressure	MPa	2.72		2.71		2.72		2.71		2.71	
IMO compliance		Tier 3	Tier 2	Tier 3	Tier 2	Tier 3	Tier 2	Tier 3	Tier 2	Tier 3	Tier 2
Combustion air system (Note 1)											
Flow at 100% load	kg/s	12.2	13.8	12.6	14.9	12.2	13.8	12.6	14.9	12.6	14.9
Temperature at turbocharger intake, max.	°C	45		45		45		45		45	
Temperature after air cooler (TE 601)	°C	60	60	60	60	60	60	60	60	60	60
Exhaust gas system (Note 2)											
Flow at 100% load	kg/s	12.5	14.1	12.9	15.3	12.5	14.1	12.9	15.3	12.9	15.3
Flow at 85% load	kg/s	10.4	12.0	10.6	13.0	10.4	12.0	10.6	13.0	10.6	12.9
Flow at 75% load	kg/s	9.1	11.2	9.4	12.0	9.1	11.2	9.4	12.0	9.7	11.6
Flow at 50% load	kg/s	6.4	8.0	6.6	8.5	6.4	8.0	6.6	8.5	6.7	8.7
Temperature after turbocharger at 100% load (TE 517)	°C	300	270	300	270	300	270	300	270	300	270
Temperature after turbocharger at 85% load (TE 517)	°C	350	270	350	270	350	270	350	270	320	260
Temperature after turbocharger at 75% load (TE 517)	°C	350	260	350	260	350	260	350	260	310	270
Temperature after turbocharger at 50% load (TE 517)	°C	370	280	370	280	370	280	370	280	330	270
Backpressure, max.	kPa	5.0	6.5	5.0	6.5	5.0	6.5	5.0	6.5	5.0	6.5
Calculated exhaust diameter for 35 m/s	mm	855	887	870	921	855	887	870	921	870	921
Heat balance at 100% load (Note 3)											
Jacket water, HT-circuit	kW	602	714	630	742	602	714	630	742	630	742
Charge air, HT-circuit	kW	826	1190	882	1344	826	1190	882	1344	882	1344
Charge air, LT-circuit	kW	1792	2114	1876	2282	1792	2114	1876	2282	1862	2268
Lubricating oil, LT-circuit	kW	686	826	714	854	686	826	714	854	714	854
Radiation	kW	210	210	210	210	210	210	210	210	210	210
Fuel consumption (Note 4) (Note 5)											
Total energy consumption at 100% load	kJ/kWh	7250	-	7280	-	7250	-	7280	-	7280	-
Total energy consumption at 85% load	kJ/kWh	7300	-	7350	-	7300	-	7350	-	7270	-
Total energy consumption at 75% load	kJ/kWh	7430	-	7500	-	7430	-	7500	-	7290	-
Total energy consumption at 50% load	kJ/kWh	7790	-	7820	-	7790	-	7820	-	7430	-

Wärtsilä 14V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Fuel gas consumption at 100% load	kJ/kWh	7097	-	7128	-	7097	-	7128	-	7128	-
Fuel gas consumption at 85% load	kJ/kWh	7121	-	7171	-	7121	-	7171	-	7100	-
Fuel gas consumption at 75% load	kJ/kWh	7226	-	7294	-	7226	-	7294	-	7122	-
Fuel gas consumption at 50% load	kJ/kWh	7484	-	7515	-	7484	-	7515	-	7250	-
Fuel oil consumption at 100% load	g/kWh	3.8	175.3	3.8	178.7	3.8	175.3	3.8	178.7	3.8	178.7
Fuel oil consumption at 85% load	g/kWh	4.4	174.4	4.5	176.3	4.4	174.4	4.5	176.3	4.2	174.9
Fuel oil consumption at 75% load	g/kWh	5.0	176.8	5.1	179.1	5.0	176.8	5.1	179.1	4.1	177.2
Fuel oil consumption 50% load	g/kWh	7.6	184.3	7.6	186.0	7.6	184.3	7.6	186.0	4.3	182.1
Fuel gas system											
Gas pressure at engine inlet, min (PT901)	kPa (a)	895	-	895	-	895	-	895	-	895	-
Gas pressure to Gas Valve Unit, min	kPa (a)	1015	-	1015	-	1015	-	1015	-	1015	-
Gas temperature before Gas Valve Unit	°C	0...60	-	0...60	-	0...60	-	0...60	-	0...60	-
Fuel oil system											
Pressure before HP pumps (PT 101)	kPa	1000±100		1000±100		1000±100		1000±100		1000±100	
Fuel oil flow to engine, approx.	m^3/h	7.2		7.2		7.2		7.2		7.2	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24	-	16...24	-	16...24
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140	-	140	-	140
MDF viscosity, min.	cSt	2.0		2.0		2.0		2.0		2.0	
Max. MDF temperature before engine (TE 101)	°C	45		45		45		45		45	
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h		1.1		1.1		1.1		1.1		1.1
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	1.8	3.0	1.8	3.0	1.8	3.0	1.8	3.0	1.8	3.0
Lubricating oil system											
Pressure before bearings, nom. (PT 201)	kPa	420		420		420		420		420	
Suction ability, including pipe loss, max.	kPa	40		40		40		40		40	
Priming pressure, nom. (PT 201)	kPa	100		100		100		100		100	
Suction ability priming pump, including pipe loss, max.	kPa	35		35		35		35		35	
Temperature before bearings, nom. (TE 201)	°C	70		70		70		70		70	
Temperature after engine, approx.	°C	82		82		82		82		82	
Pump capacity (main), engine driven	m^3/h	164		170		164		170		189	
Pump capacity (main), electrically driven	m^3/h	160		160		160		160		160	

Wärtsilä 14V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Priming pump capacity (50/60Hz)	m^3/h	70.0 / 70.0		70.0 / 70.0		70.0 / 70.0		70.0 / 70.0		70.0 / 70.0	
Oil volume, wet sump, nom.	m^3	4.8		4.8		4.8		4.8		4.8	
Oil volume in separate system oil tank	m^3	10.0		10.4		10.0		10.4		10.4	
Oil consumption at 100% load, approx.	g/kWh	0.35	0.45	0.35	0.45	0.35	0.45	0.35	0.45	0.35	0.45
Crankcase ventilation flow rate at full load	l/min	2800		2800		2800		2800		2800	
Crankcase ventilation backpressure, max.	kPa	0.1		0.1		0.1		0.1		0.1	
Oil volume in turning device	l	9.5...11.5		9.5...11.5		9.5...11.5		9.5...11.5		9.5...11.5	
Cooling water system											
HT cooling water system											
Pressure at engine, after pump, nom. (PT 401)	kPa	398 + static		398 + static		398 + static		398 + static		398 + static	
Pressure at engine, after pump, max. (PT 401)	kPa	600		600		600		600		600	
Temperature before cylinders, approx. (TE 401)	°C	83		83		83		83		83	
Temperature after engine, nom.	°C	96		96		96		96		96	
Capacity of engine driven pump, nom.	m^3/h	130		130		130		130		130	
Pressure drop over engine, total	kPa	210		210		210		210		210	
Pressure drop in external system, max.	kPa	100		100		100		100		100	
Pressure from expansion tank	kPa	70...150		70...150		70...150		70...150		70...150	
Water volume in engine	m^3	0.6		0.6		0.6		0.6		0.6	
Delivery head of stand-by pump	kPa	405		405		405		405		405	
LT cooling water system											
Pressure at engine, after pump, nom. (PT 451)	kPa	650+ static		650+ static		650+ static		650+ static		650+ static	
Temperature before engine, nom (TE 451)	°C	40/ 45		40/ 45		40/ 45		40/ 45		40/ 45	
Capacity of engine driven pump, nom.	m^3/h	130		130		130		130		130	
Pressure drop over charge air cooler (two-stage)	kPa	110		110		110		110		110	
Pressure drop in external system, max.	kPa	100		100		100		100		100	
Pressure from expansion tank	kPa	70...150		70...150		70...150		70...150		70...150	
Starting air system											
Pressure, nom.	kPa	3000		3000		3000		3000		3000	
Pressure at engine during start, min. (alarm) (20°C)	kPa	1500		1500		1500		1500		1500	
Pressure, max.	kPa	3000		3000		3000		3000		3000	
Low pressure limit in air vessels	kPa	1800		1800		1800		1800		1800	
Starting air consumption, start (successful)	Nm^3	6.8		6.8		6.8		6.8		6.8	

Notes:

Note 1	At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 9%.
Note 2	At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 9% and temperature tolerance 10°C in gas mode operation. Flow tolerance 9% and temperature tolerance 15°C in diesel mode operation.
Note 3	At 100% output and nominal speed. The figures are valid for ambient conditions according to ISO 15550 except for LT-water temperature, which is corresponding to charge air receiver temperature 55ºC in gas operation and 60 ºC in diesel mode. With engine driven water and lubricating oil pumps. Tolerance for cooling water heat 10%, tolerance for radiation heat 20%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers. In arctic option all charge air coolers are in LT circuit.
Note 4	Validity of the data in diesel mode operation: at ambient conditions according to ISO 15550. Lower calorific value 42700 kJ/kg. With engine driven pumps (two cooling water + one lubricating oil pump). Tolerance 5%.
Note 5	Validity of the data in gas fuel operation: total barometric pressure, air temperature and relative humidity according to ISO 15550:2002(E), LT water temperature corresponding to receiver temperature 55°C, pilot fuel cetane index minimum 50 according to ISO 4264. Lower calorific value 42 700 kJ/kg for pilot fuel and 49 700 kJ/kg for gas fuel. With engine driven pumps (two cooling water pumps, one lubricating oil pump). Tolerance 5%.

ME = Engine driving propeller, variable speed

AE = Auxiliary engine driving generator

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

3.5.2 SCR Ready

Wärtsilä 14V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Engine output	kW	7420		7700		7420		7700		7700	
Mean effective pressure	MPa	2.72		2.71		2.72		2.71		2.71	
IMO compliance		Tier 3		Tier 3		Tier 3		Tier 3		Tier 3	
Combustion air system (Note 1)											
Flow at 100% load	kg/s	12.2	13.5	12.6	14.6	12.2	13.5	12.6	14.6	12.6	14.6
Temperature at turbocharger intake, max.	°C	45		45		45		45		45	
Temperature after air cooler (TE 601)	°C	60	60	60	60	60	60	60	60	60	60
Exhaust gas system (Note 2)											
Flow at 100% load	kg/s	12.5	13.9	12.9	15.0	12.5	13.9	12.9	15.0	12.9	15.0
Flow at 85% load	kg/s	10.4	11.9	10.6	12.9	10.4	11.9	10.6	12.9	10.6	12.6
Flow at 75% load	kg/s	9.1	10.9	9.4	11.8	9.1	10.9	9.4	11.8	9.7	11.3
Flow at 50% load	kg/s	6.4	8.0	6.6	8.5	6.4	8.0	6.6	8.5	6.7	8.7
Temperature after turbocharger at 100% load (TE 517)	°C	300	285	300	285	300	285	300	285	300	285
Temperature after turbocharger at 85% load (TE 517)	°C	350	285	350	285	350	285	350	285	320	285
Temperature after turbocharger at 75% load (TE 517)	°C	350	285	350	285	350	285	350	285	310	285
Temperature after turbocharger at 50% load (TE 517)	°C	370	285	370	285	370	285	370	285	330	285
Backpressure, max.	kPa	5.0	6.5	5.0	6.5	5.0	6.5	5.0	6.5	5.0	6.5
Calculated exhaust diameter for 35 m/s	mm	855	890	870	926	855	890	870	926	870	926
Heat balance at 100% load (Note 3)											
Jacket water, HT-circuit	kW	602	714	630	742	602	714	630	742	630	742
Charge air, HT-circuit	kW	826	1134	882	1288	826	1134	882	1288	882	1302
Charge air, LT-circuit	kW	1792	2086	1876	2254	1792	2086	1876	2254	1862	2240
Lubricating oil, LT-circuit	kW	686	826	714	854	686	826	714	854	714	854
Radiation	kW	210	210	210	210	210	210	210	210	210	210
Fuel consumption (Note 4) (Note 5)											
Total energy consumption at 100% load	kJ/kWh	7250	-	7280	-	7250	-	7280	-	7280	-
Total energy consumption at 85% load	kJ/kWh	7300	-	7350	-	7300	-	7350	-	7230	-
Total energy consumption at 75% load	kJ/kWh	7430	-	7500	-	7430	-	7500	-	7250	-
Total energy consumption at 50% load	kJ/kWh	7790	-	7820	-	7790	-	7820	-	7330	-
Fuel gas consumption at 100% load	kJ/kWh	7097	-	7128	-	7097	-	7128	-	7128	-

Wärtsilä 14V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Fuel gas consumption at 85% load	kJ/kWh	7121	-	7171	-	7121	-	7171	-	7059	-
Fuel gas consumption at 75% load	kJ/kWh	7226	-	7294	-	7226	-	7294	-	7082	-
Fuel gas consumption at 50% load	kJ/kWh	7484	-	7515	-	7484	-	7515	-	7157	-
Fuel oil consumption at 100% load	g/kWh	3.8	175.8	3.8	179.1	3.8	175.8	3.8	179.1	3.8	179.1
Fuel oil consumption at 85% load	g/kWh	4.4	174.9	4.5	176.8	4.4	174.9	4.5	176.8	4.2	175.7
Fuel oil consumption at 75% load	g/kWh	5.0	177.6	5.1	180.0	5.0	177.6	5.1	180.0	4.1	177.7
Fuel oil consumption 50% load	g/kWh	7.6	184.5	7.6	186.2	7.6	184.5	7.6	186.2	4.3	182.6
Fuel gas system											
Gas pressure at engine inlet, min (PT901)	kPa (a)	895	-	895	-	895	-	895	-	895	-
Gas pressure to Gas Valve Unit, min	kPa (a)	1015	-	1015	-	1015	-	1015	-	1015	-
Gas temperature before Gas Valve Unit	°C	0...60	-	0...60	-	0...60	-	0...60	-	0...60	-
Fuel oil system											
Pressure before HP pumps (PT 101)	kPa	1000±100		1000±100		1000±100		1000±100		1000±100	
Fuel oil flow to engine, approx.	m³/h	7.2		7.2		7.2		7.2		7.2	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24	-	16...24	-	16...24
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140	-	140	-	140
MDF viscosity, min.	cSt	2.0		2.0		2.0		2.0		2.0	
Max. MDF temperature before engine (TE 101)	°C	45		45		45		45		45	
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h		1.1		1.1		1.1		1.1		1.1
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	1.8	3.0	1.8	3.0	1.8	3.0	1.8	3.0	1.8	3.0
Lubricating oil system											
Pressure before bearings, nom. (PT 201)	kPa	420		420		420		420		420	
Suction ability, including pipe loss, max.	kPa	40		40		40		40		40	
Priming pressure, nom. (PT 201)	kPa	100		100		100		100		100	
Suction ability priming pump, including pipe loss, max.	kPa	35		35		35		35		35	
Temperature before bearings, nom. (TE 201)	°C	70		70		70		70		70	
Temperature after engine, approx.	°C	82		82		82		82		82	
Pump capacity (main), engine driven	m³/h	164		170		164		170		189	
Pump capacity (main), electrically driven	m³/h	160		160		160		160		160	
Priming pump capacity (50/60Hz)	m³/h	70.0 / 70.0		70.0 / 70.0		70.0 / 70.0		70.0 / 70.0		70.0 / 70.0	

Wärtsilä 14V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Oil volume, wet sump, nom.	m³	4.8		4.8		4.8		4.8		4.8	
Oil volume in separate system oil tank	m³	10.0		10.4		10.0		10.4		10.4	
Oil consumption at 100% load, approx.	g/kWh	0.35	0.45	0.35	0.45	0.35	0.45	0.35	0.45	0.35	0.45
Crankcase ventilation flow rate at full load	l/min	2800		2800		2800		2800		2800	
Crankcase ventilation backpressure, max.	kPa	0.1		0.1		0.1		0.1		0.1	
Oil volume in turning device	l	9.5...11.5		9.5...11.5		9.5...11.5		9.5...11.5		9.5...11.5	
Cooling water system											
HT cooling water system											
Pressure at engine, after pump, nom. (PT 401)	kPa	398 + static		398 + static		398 + static		398 + static		398 + static	
Pressure at engine, after pump, max. (PT 401)	kPa	600		600		600		600		600	
Temperature before cylinders, approx. (TE 401)	°C	83		83		83		83		83	
Temperature after engine, nom.	°C	96		96		96		96		96	
Capacity of engine driven pump, nom.	m³/h	130		130		130		130		130	
Pressure drop over engine, total	kPa	210		210		210		210		210	
Pressure drop in external system, max.	kPa	100		100		100		100		100	
Pressure from expansion tank	kPa	70...150		70...150		70...150		70...150		70...150	
Water volume in engine	m³	0.6		0.6		0.6		0.6		0.6	
Delivery head of stand-by pump	kPa	405		405		405		405		405	
LT cooling water system											
Pressure at engine, after pump, nom. (PT 451)	kPa	650+ static		650+ static		650+ static		650+ static		650+ static	
Temperature before engine, nom (TE 451)	°C	40/ 45		40/ 45		40/ 45		40/ 45		40/ 45	
Capacity of engine driven pump, nom.	m³/h	130		130		130		130		130	
Pressure drop over charge air cooler (two-stage)	kPa	110		110		110		110		110	
Pressure drop in external system, max.	kPa	100		100		100		100		100	
Pressure from expansion tank	kPa	70...150		70...150		70...150		70...150		70...150	
Starting air system											
Pressure, nom.	kPa	3000		3000		3000		3000		3000	
Pressure at engine during start, min. (alarm) (20°C)	kPa	1500		1500		1500		1500		1500	
Pressure, max.	kPa	3000		3000		3000		3000		3000	
Low pressure limit in air vessels	kPa	1800		1800		1800		1800		1800	
Starting air consumption, start (successful)	Nm³	6.8		6.8		6.8		6.8		6.8	

Notes:

Note 1	At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 9%.
Note 2	At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 9% and temperature tolerance 10°C in gas mode operation. Flow tolerance 9% and temperature tolerance 15°C in diesel mode operation.
Note 3	At 100% output and nominal speed. The figures are valid for ambient conditions according to ISO 15550 except for LT-water temperature, which is corresponding to charge air receiver temperature 55ºC in gas operation and 60 ºC in diesel mode. With engine driven water and lubricating oil pumps. Tolerance for cooling water heat 10%, tolerance for radiation heat 20%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers. In arctic option all charge air coolers are in LT circuit.
Note 4	Validity of the data in diesel mode operation: at ambient conditions according to ISO 15550. Lower calorific value 42700 kJ/kg. With engine driven pumps (two cooling water + one lubricating oil pump). Tolerance 5%.
Note 5	Validity of the data in gas fuel operation: total barometric pressure, air temperature and relative humidity according to ISO 15550:2002(E), LT water temperature corresponding to receiver temperature 55°C, pilot fuel cetane index minimum 50 according to ISO 4264. Lower calorific value 42 700 kJ/kg for pilot fuel and 49 700 kJ/kg for gas fuel. With engine driven pumps (two cooling water pumps, one lubricating oil pump). Tolerance 5%.

ME = Engine driving propeller, variable speed

AE = Auxiliary engine driving generator

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

3.6 Wärtsilä 16V31DF

3.6.1 IMO Tier 2

Wärtsilä 16V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Engine output	kW	8480		8800		8480		8800		8800	
Mean effective pressure	MPa	2.72		2.71		2.72		2.71		2.71	
IMO compliance		Tier 3	Tier 2	Tier 3	Tier 2	Tier 3	Tier 2	Tier 3	Tier 2	Tier 3	Tier 2
Combustion air system (Note 1)											
Flow at 100% load	kg/s	13.9	15.7	14.4	17.0	13.9	15.7	14.4	17.0	14.4	17.0
Temperature at turbocharger intake, max.	°C	45		45		45		45		45	
Temperature after air cooler (TE 601)	°C	60	60	60	60	60	60	60	60	60	60
Exhaust gas system (Note 2)											
Flow at 100% load	kg/s	14.2	16.2	14.7	17.4	14.2	16.2	14.7	17.4	14.7	17.4
Flow at 85% load	kg/s	11.8	13.8	12.2	14.9	11.8	13.8	12.2	14.9	12.2	14.7
Flow at 75% load	kg/s	10.4	12.8	10.7	13.8	10.4	12.8	10.7	13.8	11.0	13.3
Flow at 50% load	kg/s	7.4	9.1	7.5	9.8	7.4	9.1	7.5	9.8	7.7	9.9
Temperature after turbocharger at 100% load (TE 517)	°C	300	270	300	270	300	270	300	270	300	270
Temperature after turbocharger at 85% load (TE 517)	°C	350	270	350	270	350	270	350	270	320	260
Temperature after turbocharger at 75% load (TE 517)	°C	350	260	350	260	350	260	350	260	310	270
Temperature after turbocharger at 50% load (TE 517)	°C	370	280	370	280	370	280	370	280	330	270
Backpressure, max.	kPa	5.0	6.5	5.0	6.5	5.0	6.5	5.0	6.5	5.0	6.5
Calculated exhaust diameter for 35 m/s	mm	914	948	930	985	914	948	930	985	930	985
Heat balance at 100% load (Note 3)											
Jacket water, HT-circuit	kW	688	816	720	848	688	816	720	848	720	848
Charge air, HT-circuit	kW	944	1360	1008	1536	944	1360	1008	1536	1008	1536
Charge air, LT-circuit	kW	2048	2416	2144	2608	2048	2416	2144	2608	2128	2592
Lubricating oil, LT-circuit	kW	784	944	816	976	784	944	816	976	816	976
Radiation	kW	240	240	240	240	240	240	240	240	240	240
Fuel consumption (Note 4) (Note 5)											
Total energy consumption at 100% load	kJ/kWh	7250	-	7280	-	7250	-	7280	-	7280	-
Total energy consumption at 85% load	kJ/kWh	7300	-	7350	-	7300	-	7350	-	7270	-
Total energy consumption at 75% load	kJ/kWh	7430	-	7500	-	7430	-	7500	-	7290	-
Total energy consumption at 50% load	kJ/kWh	7790	-	7820	-	7790	-	7820	-	7430	-

Wärtsilä 16V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Fuel gas consumption at 100% load	kJ/kWh	7097	-	7128	-	7097	-	7128	-	7128	-
Fuel gas consumption at 85% load	kJ/kWh	7121	-	7171	-	7121	-	7171	-	7100	-
Fuel gas consumption at 75% load	kJ/kWh	7226	-	7294	-	7226	-	7294	-	7122	-
Fuel gas consumption at 50% load	kJ/kWh	7484	-	7515	-	7484	-	7515	-	7250	-
Fuel oil consumption at 100% load	g/kWh	3.8	175.3	3.8	178.7	3.8	175.3	3.8	178.7	3.8	178.7
Fuel oil consumption at 85% load	g/kWh	4.4	174.4	4.5	176.3	4.4	174.4	4.5	176.3	4.2	174.9
Fuel oil consumption at 75% load	g/kWh	5.0	176.8	5.1	179.1	5.0	176.8	5.1	179.1	4.1	177.2
Fuel oil consumption 50% load	g/kWh	7.6	184.3	7.6	186.0	7.6	184.3	7.6	186.0	4.3	182.1
Fuel gas system											
Gas pressure at engine inlet, min (PT901)	kPa (a)	895	-	895	-	895	-	895	-	895	-
Gas pressure to Gas Valve Unit, min	kPa (a)	1015	-	1015	-	1015	-	1015	-	1015	-
Gas temperature before Gas Valve Unit	°C	0...60	-	0...60	-	0...60	-	0...60	-	0...60	-
Fuel oil system											
Pressure before HP pumps (PT 101)	kPa	1000±100		1000±100		1000±100		1000±100		1000±100	
Fuel oil flow to engine, approx.	m^3/h	7.2		7.2		7.2		7.2		7.2	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24	-	16...24	-	16...24
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140	-	140	-	140
MDF viscosity, min.	cSt	2.0		2.0		2.0		2.0		2.0	
Max. MDF temperature before engine (TE 101)	°C	45		45		45		45		45	
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h		1.1		1.1		1.1		1.1		1.1
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	1.8	3.0	1.8	3.0	1.8	3.0	1.8	3.0	1.8	3.0
Lubricating oil system											
Pressure before bearings, nom. (PT 201)	kPa	420		420		420		420		420	
Suction ability, including pipe loss, max.	kPa	40		40		40		40		40	
Priming pressure, nom. (PT 201)	kPa	100		100		100		100		100	
Suction ability priming pump, including pipe loss, max.	kPa	35		35		35		35		35	
Temperature before bearings, nom. (TE 201)	°C	70		70		70		70		70	
Temperature after engine, approx.	°C	82		82		82		82		82	
Pump capacity (main), engine driven	m^3/h	182		189		182		189		223	
Pump capacity (main), electrically driven	m^3/h	176		176		176		176		176	

Wärtsilä 16V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Priming pump capacity (50/60Hz)	m³/h	80.0 / 80.0		80.0 / 80.0		80.0 / 80.0		80.0 / 80.0		80.0 / 80.0	
Oil volume, wet sump, nom.	m³	5.5		5.5		5.5		5.5		5.5	
Oil volume in separate system oil tank	m³	11.4		11.9		11.4		11.9		11.9	
Oil consumption at 100% load, approx.	g/kWh	0.35	0.45	0.35	0.45	0.35	0.45	0.35	0.45	0.35	0.45
Crankcase ventilation flow rate at full load	l/min	3200		3200		3200		3200		3200	
Crankcase ventilation backpressure, max.	kPa	0.1		0.1		0.1		0.1		0.1	
Oil volume in turning device	l	9.5...11.5		9.5...11.5		9.5...11.5		9.5...11.5		9.5...11.5	
Cooling water system											
HT cooling water system											
Pressure at engine, after pump, nom. (PT 401)	kPa	373 + static		373 + static		373 + static		373 + static		373 + static	
Pressure at engine, after pump, max. (PT 401)	kPa	600		600		600		600		600	
Temperature before cylinders, approx. (TE 401)	°C	83		83		83		83		83	
Temperature after engine, nom.	°C	96		96		96		96		96	
Capacity of engine driven pump, nom.	m³/h	150		150		150		150		150	
Pressure drop over engine, total	kPa	210		210		210		210		210	
Pressure drop in external system, max.	kPa	100		100		100		100		100	
Pressure from expansion tank	kPa	70...150		70...150		70...150		70...150		70...150	
Water volume in engine	m³	0.65		0.65		0.65		0.65		0.65	
Delivery head of stand-by pump	kPa	380		380		380		380		380	
LT cooling water system											
Pressure at engine, after pump, nom. (PT 451)	kPa	650+ static		650+ static		650+ static		650+ static		650+ static	
Temperature before engine, nom (TE 451)	°C	40/ 45		40/ 45		40/ 45		40/ 45		40/ 45	
Capacity of engine driven pump, nom.	m³/h	150		150		150		150		150	
Pressure drop over charge air cooler (two-stage)	kPa	110		110		110		110		110	
Pressure drop in external system, max.	kPa	100		100		100		100		100	
Pressure from expansion tank	kPa	70...150		70...150		70...150		70...150		70...150	
Starting air system											
Pressure, nom.	kPa	3000		3000		3000		3000		3000	
Pressure at engine during start, min. (alarm) (20°C)	kPa	1500		1500		1500		1500		1500	
Pressure, max.	kPa	3000		3000		3000		3000		3000	
Low pressure limit in air vessels	kPa	1800		1800		1800		1800		1800	
Starting air consumption, start (successful)	Nm³	7.3		7.3		7.3		7.3		7.3	

Notes:

Note 1	At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 9%.
Note 2	At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 9% and temperature tolerance 10°C in gas mode operation. Flow tolerance 9% and temperature tolerance 15°C in diesel mode operation.
Note 3	At 100% output and nominal speed. The figures are valid for ambient conditions according to ISO 15550 except for LT-water temperature, which is corresponding to charge air receiver temperature 55ºC in gas operation and 60 ºC in diesel mode. With engine driven water and lubricating oil pumps. Tolerance for cooling water heat 10%, tolerance for radiation heat 20%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers. In arctic option all charge air coolers are in LT circuit.
Note 4	Validity of the data in diesel mode operation: at ambient conditions according to ISO 15550. Lower calorific value 42700 kJ/kg. With engine driven pumps (two cooling water + one lubricating oil pump). Tolerance 5%.
Note 5	Validity of the data in gas fuel operation: total barometric pressure, air temperature and relative humidity according to ISO 15550:2002(E), LT water temperature corresponding to receiver temperature 55°C, pilot fuel cetane index minimum 50 according to ISO 4264. Lower calorific value 42 700 kJ/kg for pilot fuel and 49 700 kJ/kg for gas fuel. With engine driven pumps (two cooling water pumps, one lubricating oil pump). Tolerance 5%.

ME = Engine driving propeller, variable speed

AE = Auxiliary engine driving generator

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

3.6.2 SCR Ready

Wärtsilä 16V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Engine output	kW	8480		8800		8480		8800		8800	
Mean effective pressure	MPa	2.72		2.71		2.72		2.71		2.71	
IMO compliance		Tier 3		Tier 3		Tier 3		Tier 3		Tier 3	
Combustion air system (Note 1)											
Flow at 100% load	kg/s	13.9	15.4	14.4	16.7	13.9	15.4	14.4	16.7	14.4	16.7
Temperature at turbocharger intake, max.	°C	45		45		45		45		45	
Temperature after air cooler (TE 601)	°C	60	60	60	60	60	60	60	60	60	60
Exhaust gas system (Note 2)											
Flow at 100% load	kg/s	14.2	15.8	14.7	17.1	14.2	15.8	14.7	17.1	14.7	17.1
Flow at 85% load	kg/s	11.8	13.6	12.2	14.7	11.8	13.6	12.2	14.7	12.2	14.4
Flow at 75% load	kg/s	10.4	12.5	10.7	13.4	10.4	12.5	10.7	13.4	11.0	13.0
Flow at 50% load	kg/s	7.4	9.1	7.5	9.8	7.4	9.1	7.5	9.8	7.7	9.9
Temperature after turbocharger at 100% load (TE 517)	°C	300	285	300	285	300	285	300	285	300	285
Temperature after turbocharger at 85% load (TE 517)	°C	350	285	350	285	350	285	350	285	320	285
Temperature after turbocharger at 75% load (TE 517)	°C	350	285	350	285	350	285	350	285	310	285
Temperature after turbocharger at 50% load (TE 517)	°C	370	285	370	285	370	285	370	285	330	285
Backpressure, max.	kPa	5.0	6.5	5.0	6.5	5.0	6.5	5.0	6.5	5.0	6.5
Calculated exhaust diameter for 35 m/s	mm	914	952	930	989	914	952	930	989	930	989
Heat balance at 100% load (Note 3)											
Jacket water, HT-circuit	kW	688	816	720	848	688	816	720	848	720	848
Charge air, HT-circuit	kW	944	1296	1008	1472	944	1296	1008	1472	1008	1488
Charge air, LT-circuit	kW	2048	2384	2144	2576	2048	2384	2144	2576	2128	2560
Lubricating oil, LT-circuit	kW	784	944	816	976	784	944	816	976	816	976
Radiation	kW	240	240	240	240	240	240	240	240	240	240
Fuel consumption (Note 4) (Note 5)											
Total energy consumption at 100% load	kJ/kWh	7250	-	7280	-	7250	-	7280	-	7280	-
Total energy consumption at 85% load	kJ/kWh	7300	-	7350	-	7300	-	7350	-	7230	-
Total energy consumption at 75% load	kJ/kWh	7430	-	7500	-	7430	-	7500	-	7250	-
Total energy consumption at 50% load	kJ/kWh	7790	-	7820	-	7790	-	7820	-	7330	-
Fuel gas consumption at 100% load	kJ/kWh	7097	-	7128	-	7097	-	7128	-	7128	-

Wärtsilä 16V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Fuel gas consumption at 85% load	kJ/kWh	7121	-	7171	-	7121	-	7171	-	7059	-
Fuel gas consumption at 75% load	kJ/kWh	7226	-	7294	-	7226	-	7294	-	7082	-
Fuel gas consumption at 50% load	kJ/kWh	7484	-	7515	-	7484	-	7515	-	7157	-
Fuel oil consumption at 100% load	g/kWh	3.8	175.8	3.8	179.1	3.8	175.8	3.8	179.1	3.8	179.1
Fuel oil consumption at 85% load	g/kWh	4.4	174.9	4.5	176.8	4.4	174.9	4.5	176.8	4.2	175.7
Fuel oil consumption at 75% load	g/kWh	5.0	177.6	5.1	180.0	5.0	177.6	5.1	180.0	4.1	177.7
Fuel oil consumption 50% load	g/kWh	7.6	184.5	7.6	186.2	7.6	184.5	7.6	186.2	4.3	182.6
Fuel gas system											
Gas pressure at engine inlet, min (PT901)	kPa (a)	895	-	895	-	895	-	895	-	895	-
Gas pressure to Gas Valve Unit, min	kPa (a)	1015	-	1015	-	1015	-	1015	-	1015	-
Gas temperature before Gas Valve Unit	°C	0...60	-	0...60	-	0...60	-	0...60	-	0...60	-
Fuel oil system											
Pressure before HP pumps (PT 101)	kPa	1000±100		1000±100		1000±100		1000±100		1000±100	
Fuel oil flow to engine, approx.	m^3/h	7.2		7.2		7.2		7.2		7.2	
HFO viscosity before the engine	cSt	-	16...24	-	16...24	-	16...24	-	16...24	-	16...24
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140	-	140	-	140	-	140
MDF viscosity, min.	cSt	2.0		2.0		2.0		2.0		2.0	
Max. MDF temperature before engine (TE 101)	°C	45		45		45		45		45	
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h		1.1		1.1		1.1		1.1		1.1
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	1.8	3.0	1.8	3.0	1.8	3.0	1.8	3.0	1.8	3.0
Lubricating oil system											
Pressure before bearings, nom. (PT 201)	kPa	420		420		420		420		420	
Suction ability, including pipe loss, max.	kPa	40		40		40		40		40	
Priming pressure, nom. (PT 201)	kPa	100		100		100		100		100	
Suction ability priming pump, including pipe loss, max.	kPa	35		35		35		35		35	
Temperature before bearings, nom. (TE 201)	°C	70		70		70		70		70	
Temperature after engine, approx.	°C	82		82		82		82		82	
Pump capacity (main), engine driven	m^3/h	182		189		182		189		223	
Pump capacity (main), electrically driven	m^3/h	176		176		176		176		176	
Priming pump capacity (50/60Hz)	m^3/h	80.0 / 80.0		80.0 / 80.0		80.0 / 80.0		80.0 / 80.0		80.0 / 80.0	

Wärtsilä 16V31DF		DE		DE		AUX		AUX		ME	
		Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode	Gas mode	Diesel mode
Engine speed	**rpm**	**720**		**750**		**720**		**750**		**750**	
Cylinder output	**kW**	**530**		**550**		**530**		**550**		**550**	
Speed mode		**Constant**		**Constant**		**Constant**		**Constant**		**Variable**	
Oil volume, wet sump, nom.	m^3	5.5		5.5		5.5		5.5		5.5	
Oil volume in separate system oil tank	m^3	11.4		11.9		11.4		11.9		11.9	
Oil consumption at 100% load, approx.	g/kWh	0.35	0.45	0.35	0.45	0.35	0.45	0.35	0.45	0.35	0.45
Crankcase ventilation flow rate at full load	l/min	3200		3200		3200		3200		3200	
Crankcase ventilation backpressure, max.	kPa	0.1		0.1		0.1		0.1		0.1	
Oil volume in turning device	l	9.5...11.5		9.5...11.5		9.5...11.5		9.5...11.5		9.5...11.5	
Cooling water system											
HT cooling water system											
Pressure at engine, after pump, nom. (PT 401)	kPa	373 + static		373 + static		373 + static		373 + static		373 + static	
Pressure at engine, after pump, max. (PT 401)	kPa	600		600		600		600		600	
Temperature before cylinders, approx. (TE 401)	°C	83		83		83		83		83	
Temperature after engine, nom.	°C	96		96		96		96		96	
Capacity of engine driven pump, nom.	m^3/h	150		150		150		150		150	
Pressure drop over engine, total	kPa	210		210		210		210		210	
Pressure drop in external system, max.	kPa	100		100		100		100		100	
Pressure from expansion tank	kPa	70...150		70...150		70...150		70...150		70...150	
Water volume in engine	m^3	0.65		0.65		0.65		0.65		0.65	
Delivery head of stand-by pump	kPa	380		380		380		380		380	
LT cooling water system											
Pressure at engine, after pump, nom. (PT 451)	kPa	650+ static		650+ static		650+ static		650+ static		650+ static	
Temperature before engine, nom (TE 451)	°C	40/ 45		40/ 45		40/ 45		40/ 45		40/ 45	
Capacity of engine driven pump, nom.	m^3/h	150		150		150		150		150	
Pressure drop over charge air cooler (two-stage)	kPa	110		110		110		110		110	
Pressure drop in external system, max.	kPa	100		100		100		100		100	
Pressure from expansion tank	kPa	70...150		70...150		70...150		70...150		70...150	
Starting air system											
Pressure, nom.	kPa	3000		3000		3000		3000		3000	
Pressure at engine during start, min. (alarm) (20°C)	kPa	1500		1500		1500		1500		1500	
Pressure, max.	kPa	3000		3000		3000		3000		3000	
Low pressure limit in air vessels	kPa	1800		1800		1800		1800		1800	
Starting air consumption, start (successful)	Nm^3	7.3		7.3		7.3		7.3		7.3	

Notes:

Note 1	At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 9%.
Note 2	At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 9% and temperature tolerance 10°C in gas mode operation. Flow tolerance 9% and temperature tolerance 15°C in diesel mode operation.
Note 3	At 100% output and nominal speed. The figures are valid for ambient conditions according to ISO 15550 except for LT-water temperature, which is corresponding to charge air receiver temperature 55ºC in gas operation and 60 ºC in diesel mode. With engine driven water and lubricating oil pumps. Tolerance for cooling water heat 10%, tolerance for radiation heat 20%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers. In arctic option all charge air coolers are in LT circuit.
Note 4	Validity of the data in diesel mode operation: at ambient conditions according to ISO 15550. Lower calorific value 42700 kJ/kg. With engine driven pumps (two cooling water + one lubricating oil pump). Tolerance 5%.
Note 5	Validity of the data in gas fuel operation: total barometric pressure, air temperature and relative humidity according to ISO 15550:2002(E), LT water temperature corresponding to receiver temperature 55°C, pilot fuel cetane index minimum 50 according to ISO 4264. Lower calorific value 42 700 kJ/kg for pilot fuel and 49 700 kJ/kg for gas fuel. With engine driven pumps (two cooling water pumps, one lubricating oil pump). Tolerance 5%.

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.

NOTE

For proper operation of the Wärtsilä Nitrogen Oxide Reducer (NOR) systems, the exhaust temperature after the engine needs to be kept within a certain temperature window. Please consult your sales contact at Wärtsilä for more information about SCR Operation.

NOTE

Real-time product information including all technical data covered in this chapter will be available through Wärtsilä's website (an online tool called Engine Online Configurators) in late 2019. Please check online for the most updated technical data when they are available.

4. Description of the Engine

4.1 Definitions

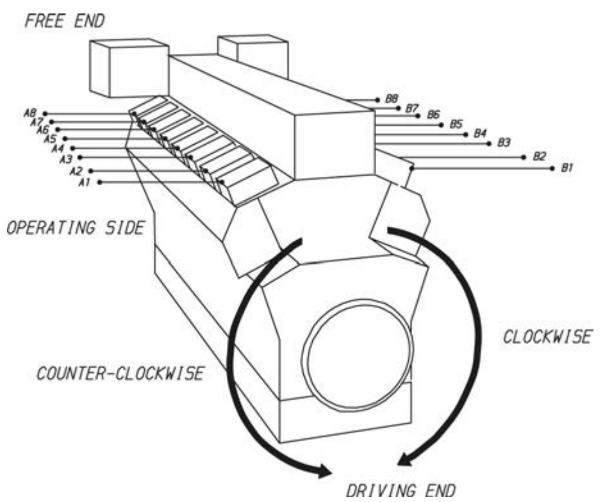

Fig 4-1 Engine definitions (V93C0028)

4.2 Main components and systems

Main dimensions and weights are shown in section "*Principle dimensions and weights*" in Chapter 1.

4.2.1 Engine block

The engine block, made of nodular cast iron, is cast in one piece for all cylinder numbers and it supports the underslung crankshaft. The block has been given a stiff and durable design to absorb internal forces and the engine can therefore also be resiliently mounted not requiring any intermediate foundations. It incorporates water and charge air main and side channels. Also camshaft bearing housings are incorporated in the engine block. The engines are equipped with crankcase explosion relief valve with flame arrester.

The main bearing caps, made of nodular cast iron, are fixed with two hydraulically tensioned screws from below. They are guided sideways and vertically by the engine block. Hydraulically tensioned horizontal side screws at the lower guiding provide a very rigid crankshaft bearing assembly.

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 through this jack.

The oil sump, a light welded design, is mounted on the engine block from below. The oil sump is available in two alternative designs, wet or dry sump, depending on the type of application. The wet oil sump includes a suction pipe to the lubricating oil pump. For wet sump there is a main distributing pipe for lubricating oil, suction pipes and return connections for the separator. For the dry sump there is a main distributing oil pipe for lubricating oil and drains at either end to a separate system oil tank.

The engine holding down bolts are hydraulically tightened in order to facilitate the engine installation to both rigid and resilient foundation.

4.2.2 Crankshaft

Crankshaft line is built up from several pieces: crankshaft, counter weights, split camshaft gear wheel and pumpdrive arrangement.

Crankshaft itself is forged in one piece. Both main bearings and big end bearings temperatures are continuously monitored.

Counterweights are fitted on every web. High degree of balancing results in an even and thick oil film for all bearings.

The connecting rods are arranged side-by-side and the diameters of the crank pins and journals are equal irrespective of the cylinder number.

All crankshafts can be provided with torsional vibration dampers or tuning masses at the free end of the engine, if necessary. Main features of crankshaft design: clean steel technology minimizes the amount of slag forming elements and guarantees superior material durability.

The crankshaft alignment is always done on a thoroughly warm engine after the engine is stopped.

4.2.3 Connecting rod

The connecting rod is of forged alloy steel. All connecting rod studs are hydraulically tightened.

The connecting rod is of a three-piece design, which gives a minimum dismantling height and enables the piston to be dismounted without opening the big end bearing.

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 with a Sn-flash for corrosion protection. Even minor form deviations can become visible on the bearing surface in the running in phase. This has no negative influence on the bearing function. A wireless system for real-time temperature monitoring of connecting rod big end bearings, "BEB monitoring system", is as standard.

4.2.5 Cylinder liner

The cylinder liners are centrifugally cast of a special alloyed cast iron. The top collar of the cylinder liner is provided with a water jacket for distributing cooling water through the cylinder liner cooling bores. This will give an efficient control of the liner temperature. An oil lubrication system inside the cylinder liner lubricates the gudgeon pin bearing and also cools piston crown through the oil channels underside of the piston.

4.2.6 Piston

The piston is of composite type with steel crown and nodular cast iron skirt. A piston skirt lubricating system, featuring oil bores in a groove on the piston skirt, lubricates the piston skirt/cylinder liner. The piston top is oil cooled by the same system mentioned above. The piston ring grooves are hardened for extended lifetime.

4.2.7 Piston rings

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

4.2.8 Cylinder head

The cross flow cylinder head is made of cast iron. The mechanical load is absorbed by a flame plate, which together with the upper deck and the side walls form a rigid box section. There are four hydraulically tightened cylinder head bolts. The exhaust valve seats and the flame deck are efficiently and direct water-cooled. The valve seat rings are made of alloyed steel, for wear resistance. All valves are hydraulic controlled with valve guides and equipped with valve springs and rotators.

A small side air receiver is located in the hot box, including charge air bends with integrated hydraulics and charge air riser pipes.

Following components are connected to the cylinder head:

- Charge air components for side receiver
- Exhaust gas pipe to exhaust system
- Cooling water collar
- Quill pipe with High Pressure (HP) fuel pipe connections
- Main gas admission valve

4.2.9 Camshaft and valve mechanism

The cams are integrated in the drop forged shaft material. The bearing journals are made in separate pieces, which are fitted, to the camshaft pieces by flange connections. 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 tappets are of piston type with self-adjustment of roller against cam to give an even distribution of the contact pressure. Inlet and exhaust valves have a special steam coating and hard facing on the seat surface, for long lifetime. The valve springs make the valve mechanism dynamically stable.

The step-less valve mechanism makes it possible to control the timing of both inlet & exhaust valves. It allows to always use a proper scavenging period. This is needed to optimize and balance emissions, fuel consumption, operational flexibility & load taking, whilst maintaining thermal and mechanical reliability. The design enables clearly longer maintenance interval, due to the reduced thermal and mechanical stress on most of the components in the valve mechanism.

4.2.10 Camshaft drive

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

4.2.11 Turbocharging and charge air cooling

The selected 2-stage turbocharging offers ideal combination of high-pressure ratios and good efficiency both at full and part load. The turbochargers can be placed at the free end or fly wheel end of the engine. For cleaning of the turbochargers during operation there is, as standard, a water washing device for the air (compressor) and exhaust gas (turbine) side of the LP stage and for the exhaust gas (turbine) side of the HP stage. The water washing device is to be connected to an external unit. The turbochargers are lubricated by engine lubricating oil with integrated connections.

An Exhaust gas Waste Gate (EWG) system controls the exhaust gas flow by-passing for both high pressure (HP) and low pressure (LP) turbine stages. EWG is needed in case of engines equipped with exhaust gas after treatment based on Selective Catalytic Reaction (SCR).

By using Air Waste Gate (AWG) the charge air pressure and the margin from LP compressor is controlled.

A step-less Air By-pass valve (ABP) system is used in all engine applications for preventing surging of turbocharger compressors in case of rapid engine load reduction.

The Charge Air Coolers (CAC) consist of a 2-stage type cooler (LP CAC) between the LP and HP compressor stages and a 1-stage cooler (HP CAC) between the HP compressor stage and the charge air receiver. The LP CAC is cooled with LT-water or in some cases by both HT- and LT-water. The HP CAC is always cooled by LT-water and fresh water is used for both circuits. When there is a risk for over-speeding of the engine due to presence of combustible gas or vapour in the inlet air, a UNIC automation controlled Charge Air Blocking device, can be installed.

See chapter *Exhaust gas & charge air systems* for more information.

4.2.12 Fuel injection equipment

The fuel injection equipment and system piping are located in a hotbox, providing maximum reliability and safety when using preheated heavy fuels. In the Wärtsilä electronic fuel injection system, the fuel is pressurized in the high pressure HP-pumps from where the fuel is fed to the injection valves which are rate optimized. The fuel system consists of different numbers of fuel oil HP pumps, depending of the cylinder configuration. HP pumps are located at the engine pump cover and from there high pressure pipes are connected to the system piping. A valve block is mounted at the fuel outlet pipe, including Pressure Drop and Safety Valve (PDSV), Circulation Valve (CV) and a fuel pressure discharge volume. The PDSV acts as mechanical safety valve and the fuel volume lowers the system pressure. The injection valves are electronic controlled and the injection timing is pre-set in the control system software.

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 and the gas/air mixture will flow into the cylinder during the intake stroke. 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 compressed gas/air mixture is ignited with a small amount of diesel fuel (pilot injection) which is integrated to the main fuel injection system and is also electronically controlled.

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 water system

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

For engines operating in normal conditions the HT-water is cooling the cylinders (jacket) and the first stage of the low pressure 2-stage charge air cooler. The LT-water is cooling the lubricating oil cooler, the second stage of the low pressure 2-stage charge air cooler and the high pressure 1-stage charge air cooler.

For engines operating in cold conditions the HT-water is cooling the cylinders (Jacket). A HT-water pump is circulating the cooling water in the circuit and a thermostatic valve mounted in the internal cooling water system, controls the outlet temperature of the circuit. The LT-circuit is cooling the Lubricating Oil Cooler (LOC), the second stage of the Low Pressure 2-stage charge air cooler, the High Pressure 1-stage charge air cooler and the first stage of the low pressure 2-stage charge air cooler. An LT-thermostatic valve mounted in the external cooling water system, controls the inlet temperature to the engine for achieving correct receiver temperature.

4.2.15 Exhaust pipes

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

The complete exhaust gas system is enclosed in an insulating box consisting of easily removable panels. Mineral wool is used as insulating material.

4.2.16 Automation system

The Wärtsilä 31 engine is equipped with an UNIC electronic control system. UNIC have hardwired interface for control functions and a bus communication interface for alarm and monitoring. Additionally UNIC includes fuel injection control for engines with electronic fuel injection rate optimized nozzles.

For more information, see chapter *Automation system*.

4.3 Time between Inspection or Overhaul & 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%
- Based on the fuel quality, intermediate mechanical cleaning might be necessary

Component	Time between inspection or overhaul (h)		Expected life time (h)	
	MDF/ GAS operation	HFO operation 1)	MDF/ GAS operation	HFO operation 1)
Piston	32000	24000	Min. 96000	Min. 72000
Piston rings	32000	24000	32000	24000
Cylinder liner	32000	24000	128000	96000
Cylinder head	32000	24000	64000...128000	48000...96000
Inlet valve	32000	24000	32000	24000
Exhaust valve	32000	24000	32000	24000
Main bearing	32000	24000	64000	48000
Big end bearing	32000	24000	32000	24000
Intermediate gear bearings	64000	64000	64000	64000
Balancing shaft bearings	32000	32000	32000	32000
Injection valve (wear parts)	8000	8000	N/A	N/A
High Pressure fuel pump	24000	24000	24000	24000
Main gas admission valve	16000	N/A	16000	N/A
LP and the HP turbochargers	16000	16000	64000	64000

NOTE

1) 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.

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5. Piping Design, Treatment and Installation

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

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

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

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

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

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

The following aspects shall be taken into consideration:

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

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

5.1 Pipe dimensions

When selecting the pipe dimensions, take into account:

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

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

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

NOTE

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

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

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

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

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

5.2 Trace heating

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

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

5.3 Pressure class

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

The pressure in the system can:

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

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

Example 1:

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

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

Example 2:

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

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

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

5.4 Pipe class

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

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

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

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

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

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

Relevant DNV rules:

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

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

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

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

5.5 Insulation

The following pipes shall be insulated:

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

Insulation is also recommended for:

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

5.6 Local gauges

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

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

5.7 Cleaning procedures

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

5.7.1 Cleanliness during pipe installation

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

Piping cleaning methods are summarised in table below:

Table 5-3 Pipe cleaning

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

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

1) In case of carbon steel pipes

Methods applied during prefabrication of pipe spools

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

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

D = Pickling (not required for seamless precision tubes)

Methods applied after installation onboard

C = Purging with compressed air

F = Flushing

5.7.2 Fuel oil pipes

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

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

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

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

Note! The engine must not be connected during flushing.

5.7.3 Lubricating oil pipes

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

It is however acceptable to circulate the flushing oil via the engine sump if this is advantageous. Cleanliness of the oil sump shall be verified after completed flushing and is acceptable when the cleanliness has reached a level in accordance with ISO 4406 © 21/19/15, or NAS 1638 code 10. All pipes connected to the engine, the engine wet sump or to the external engine wise oil tank shall be flushed. Oil used for filling shall have a cleanliness of ISO 4406 © 21/19/15, or NAS 1638 code 10.

Note! The engine must not be connected during flushing

5.7.4 Pickling

Prefabricated pipe spools are pickled before installation onboard.

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

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

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

5.8 Flexible pipe connections

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

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

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

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

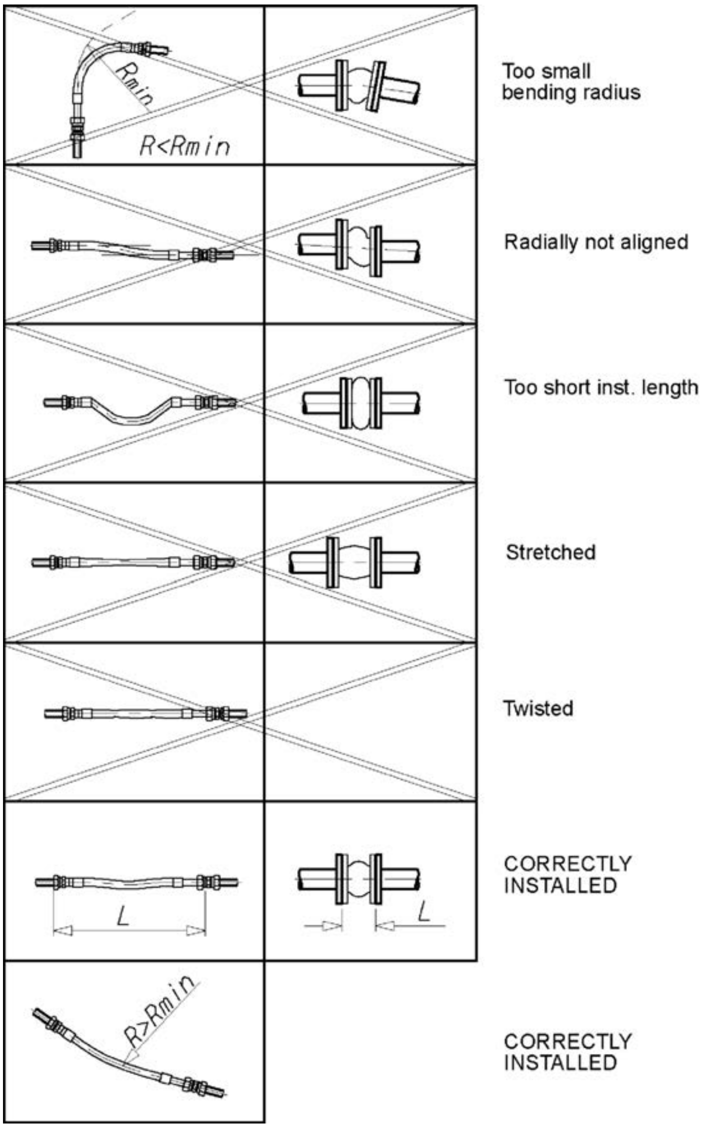


Fig 5-1 Flexible hoses

Drawing V60L0796 below is showing how pipes shall be clamped.

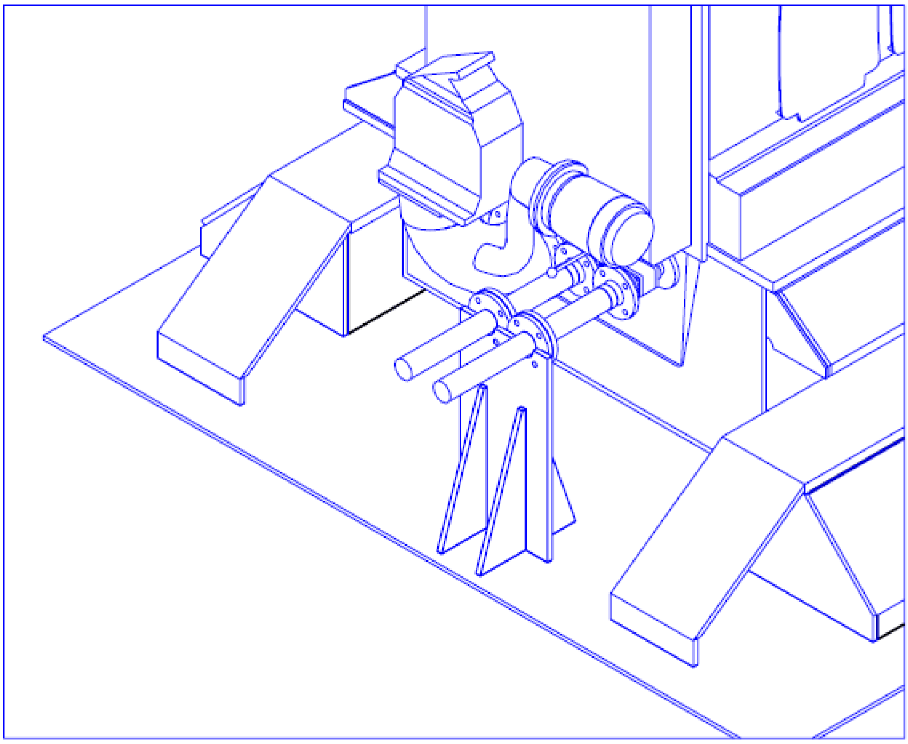


Fig 5-2 Flexible pipe connections (V60L0796)

NOTE

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

5.9 Clamping of pipes

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

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

Examples of flange support structures are shown in Flange supports of flexible pipe connections. A typical pipe clamp for a fixed support is shown in Figure 5-4. Pipe clamps must be made of steel; plastic clamps or similar may not be used.

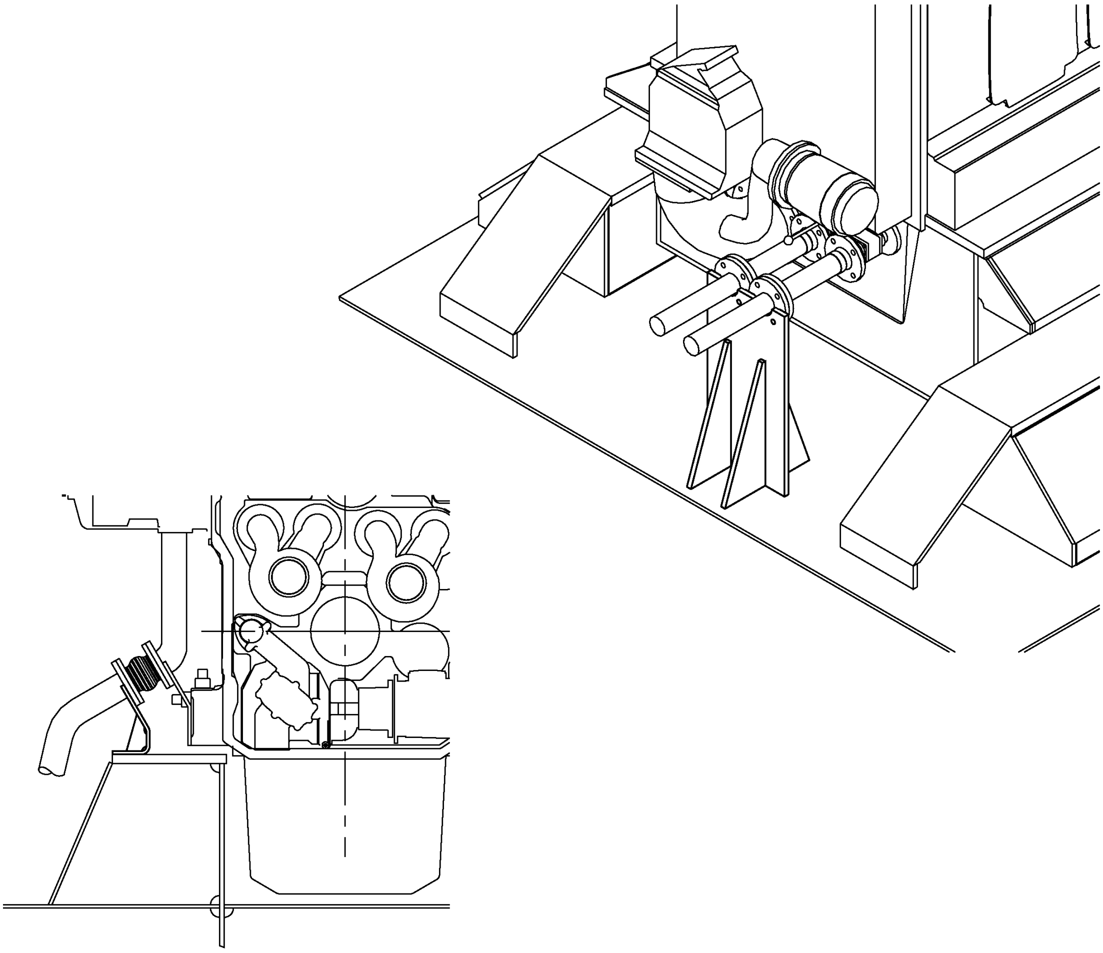
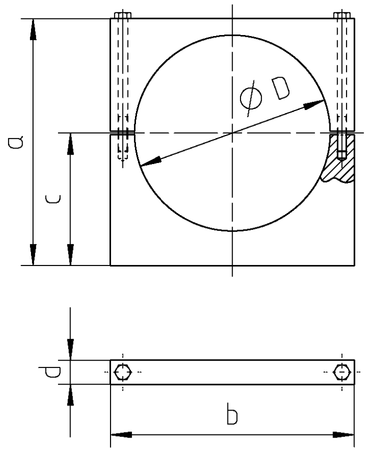


Fig 5-3 Flange supports of flexible pipe connections V60L0796

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



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

d_u= Pipe outer diameter

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

6. Fuel System

6.1 Acceptable fuel characteristics

6.1.1 Gas fuel specification

As a dual fuel engine, the Wärtsilä 31DF engine is designed for continuous operation in gas operating mode or diesel operating mode. For continuous operation in the rated output, the gas used as main fuel in gas operating mode has to fulfill the below mentioned quality requirements.

Table 6-1 Fuel Gas Specifications

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

1) *The required gas feed pressure is depending on the LHV (981 kPa (a) in gas mode for both Constant and Variable Speed applications).*

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

3) *Engine output is depending on the Methane Number. Methane Number (MN) can be assigned to any gaseous fuel indicating the percentage by volume of methane in blend with hydrogen that exactly matches the knock intensity of the unknown gas mixture under specified operating conditions in a knock testing engine. The Methane Number (MN) gives a scale for evaluation of the resistance to knock of gaseous fuels. To define the Methane Number (MN) of the gas, the method included in the EN 16726-2015 standard shall be used. Additionally, Wärtsilä has developed an MN calculator.*

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

5) *In the specified operating conditions (temperature and pressure) dew point of natural gas has to be low enough in order to prevent any formation of condensate.*

6.1.2 Liquid fuel specification

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

The fuel shall not contain any added substances or chemical waste, which jeopardizes the safety of installations or adversely affects the performance of the engines or is harmful to personnel or contributes overall to air pollution.

6.1.2.1 Pilot fuel oil

The optimum engine performance is achieved with fuel fulfilling the requirements in table below. However, normal operation of the engine is fully possible with a fuel according to the

ISO 8217:2017(E) with a possible impact on the engine efficiency. In case of questions regarding the engine performance please contact Wärtsilä.

Table 6-2 Pilot fuel oil

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 [i]	mm^2/s [a]	Max	5,500	6,000	6,000	11,00	ISO 3104
		Min	1,400 [i]	2,000	3,000	2,000	
Density at 15 °C	kg/m^3	Max	-	890,0	890,0	900,0	ISO 3675 or ISO 12185
Cetane index		Min	45	40	40	35	ISO 4264
Sulphur [b, j]	% m/m	Max	1,00	1,00	1,00	1,50	ISO 8754 or ISO 14596, ASTM D4294
Flash point	°C	Min	43,0 [k]	60,0	60,0	60,0	ISO 2719
Hydrogen sulfide	mg/kg	Max	2,00	2,00	2,00	2,00	IP 570

Characteristics		Unit	Limit	Category ISO-F							Test method(s) and references
				DMX	DMA	DFA	DMZ	DFZ	DMB	DFB	
Acid number		mg KOH/g	Max	0,5	0,5		0,5		0,5		ASTM D664
Total sediment by hot filtration		% m/m	Max	-	-		-		0,10 c)		ISO 10307-1
Oxidation stability		g/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 (upper) 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 mm^2/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 mm^2/s can prevent the use ISO-F-DMX category fuels in Wärtsilä® engines unless the fuel can be cooled down enough to meet the distillate fuel injection viscosity limit of Wärtsilä 31DF which is 2,0 - 24 mm^2/s.

j) There doesn't exist any minimum sulphur content limit for Wärtsilä 31DF engines and also the use of Ultra Low Sulphur Diesel (ULSD) is allowed provided that the fuel quality fulfils other specified requirements.

k) 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.

l) Alternative test method.

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 also called as Ultra Low Sulphur Fuel Oils (ULSFO) or “hybrid” fuels, since those can contain properties of both distillate and residual fuels. In the existing ISO 8217:2017(E) standard the fuels are classed as RMA 10, RMB 30 or RMD 80, if not fulling the DM grade category requirements, though from their properties point of view this is generally not an optimum approach.

These fuels can be used in the Wärtsilä 31DF engine type in back-up and diesel mode, but special attention shall be paid to optimum operating conditions. See also Services Instruction WS02Q312.

RMA 10, RMB 30 and RMD 80 category fuels are accepted only when operating the engine in back-up or diesel mode. Use of these fuel qualities as a pilot fuel in gas mode is not allowed, but a fuel quality fulfilling the distillate fuel specification included in chapter *6.1.2.2* has to be used.

Characteristics	Unit	RMA 10	RMB 30	RMD 80	Test method reference
Kinematic viscosity bef. inj. pumps [c)]	mm^2/s [a)]	6,0 - 24	6,0 - 24	6,0 - 24	-
Kinematic viscosity at 50 °C, max.	mm^2/s [a)]	10,00	30,00	80,00	ISO 3104
Density at 15 °C, max.	kg/m^3	920,0	960,0	975,0	ISO 3675 or ISO 12185
CCAI, max. [e)]	-	850	860	860	ISO 8217, Annex F
Sulphur, max.[b), f)]	% 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 existent, 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)]

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

NOTE

a) 1 mm^2/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 6-4 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 , Annex F
Sulphur, max. [c, g)]	% m/m	Statutory require-ments, 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

Characteristics	Unit	Limit HFO 1	Limit HFO 2	Test method reference
Used lubricating oil: h) - 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 6-5 Crude oils

Property	Unit	Limit	Test method reference
Kinematic viscosity before main injection pumps, min.	mm^2/s a)	2,0 e)	-
Kinematic viscosity before main injection pumps, max.	mm^2/s a)	24 e)	-
Kinematic viscosity at 50 °C, max.	mm^2/s a)	700,0	ISO 3104
Density at 15 °C, max.	kg/m^3	991,0 / 1010,0 b)	ISO 3675 or ISO 12185
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 31DF 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 common rail system / Electronic fuel injection rate optimized nozzle system. Pilot fuel injection is active in order to avoid clogging of pilot nozzle.

6.2.3 Backup mode operation

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

6.3 Fuel gas system

6.3.1 External fuel gas system

6.3.1.1 Fuel gas system, with open type GVU

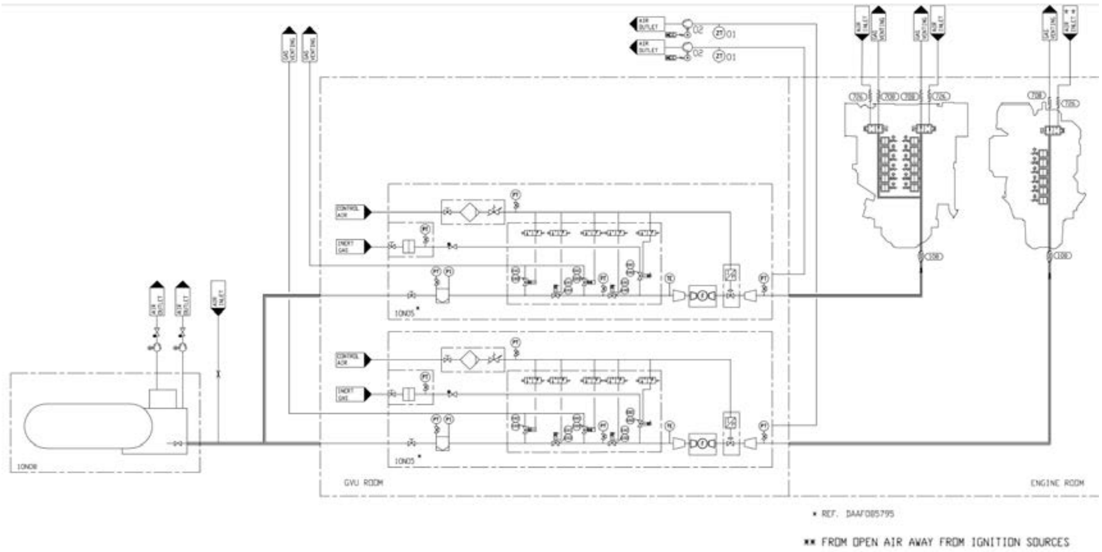


Fig 6-1 Example of fuel gas operation with open type GVU (DAAF022750G)

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

Pipe connections		Size
108	Gas inlet	DN50/DN65
708	Gas system ventilation	DN25 (DN50 16V)
726	Air inlet to double wall gas system	DN25

6.3.1.2 Fuel gas system, with enclosed GVU

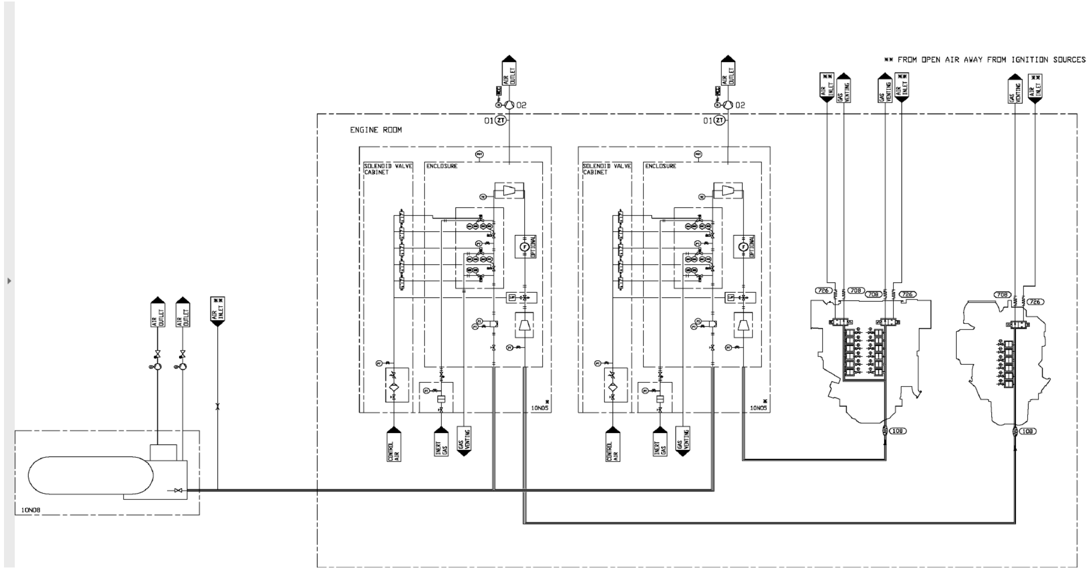


Fig 6-2 Example of fuel gas system with enclosed GVU (DAAF077105C)

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

Pipe connections		Size
108	Gas inlet	DN50/DN65
708	Gas system ventilation	DN25 (DN50 16V)
726	Air inlet to double wall gas system	DN25

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.

6.3.1.3 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.

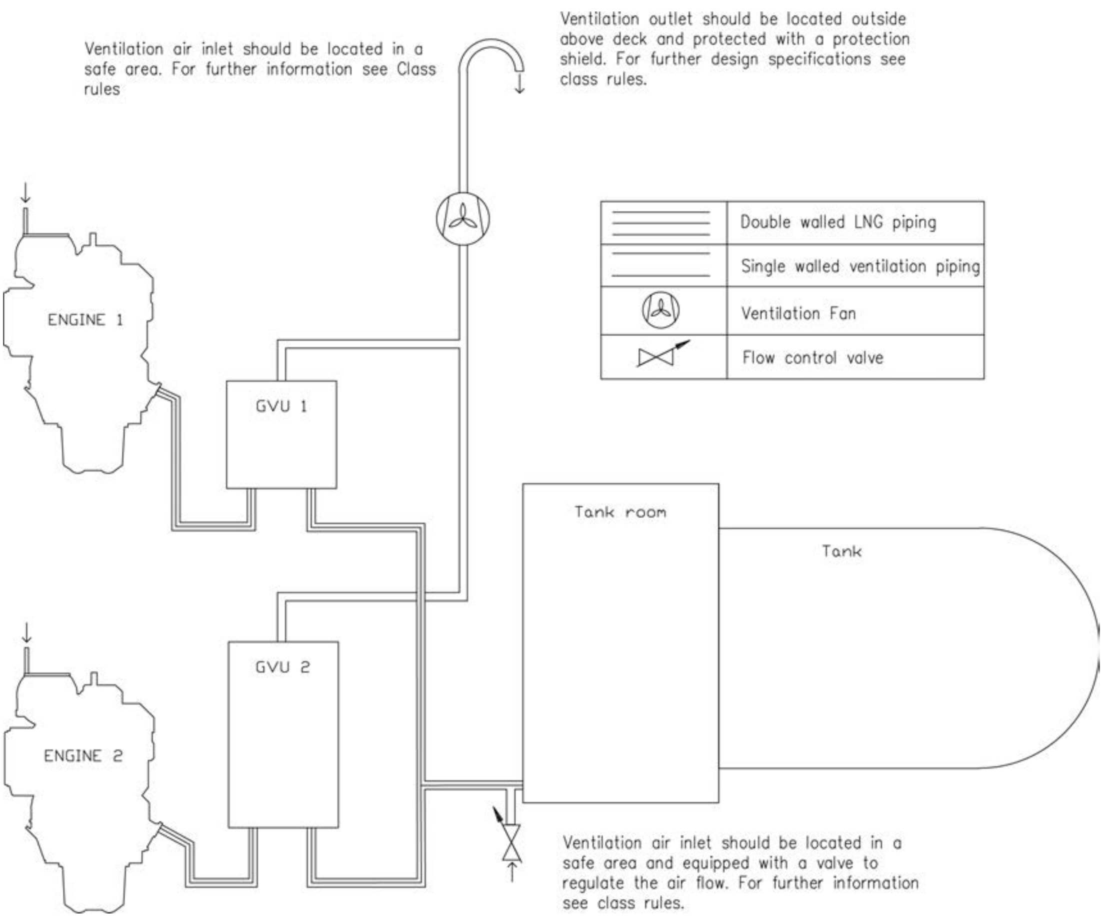


Fig 6-3 Example arrangement drawing of ventilation in double wall piping system with enclosed GVUs (DBAC588146)

6.3.1.4 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 30 m.

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

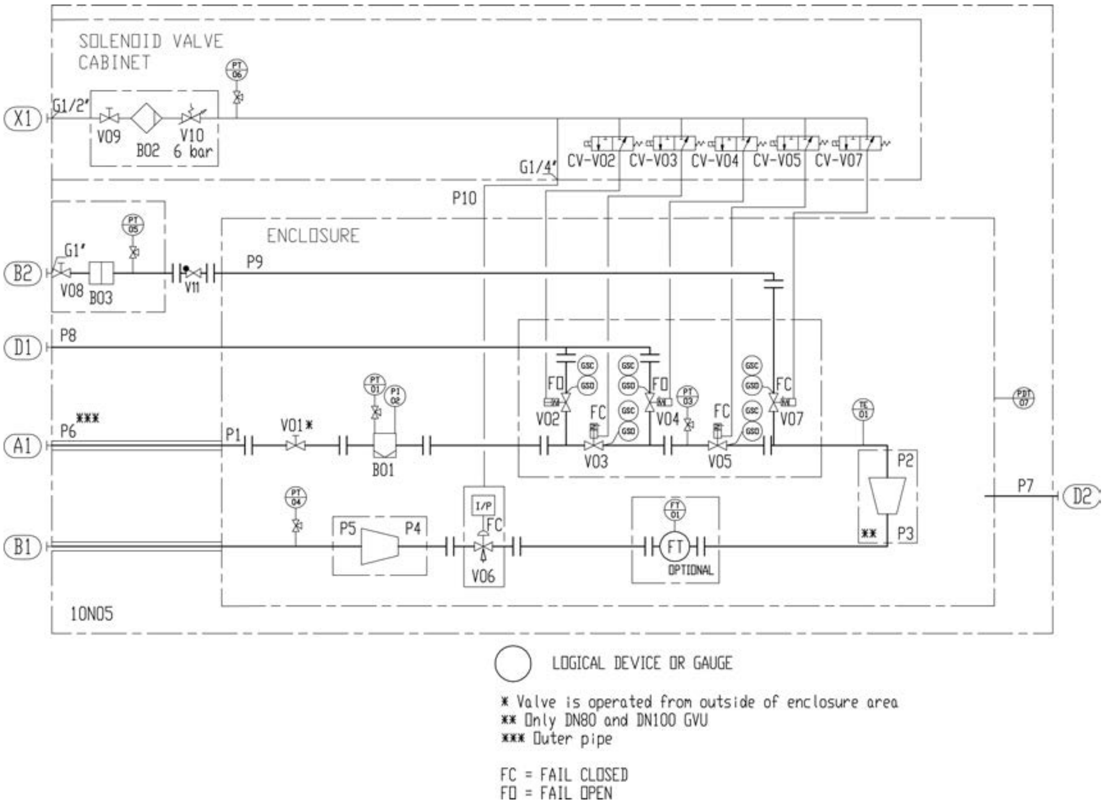


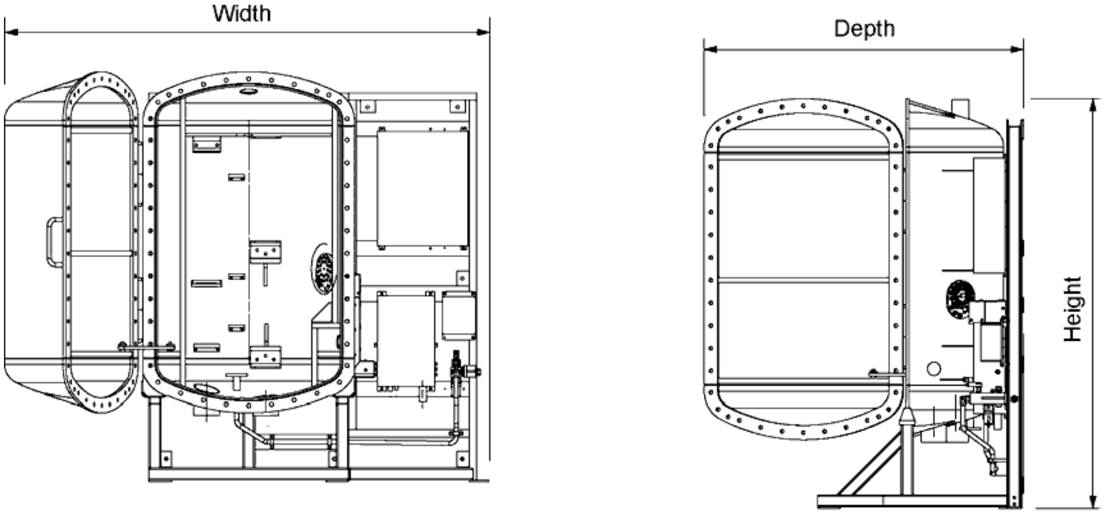
Fig 6-4 Gas valve unit P&I diagram (DAAF051037D)

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 - 14 bar(g)]	B2	Inert gas [5 - 9 bar(g)]	D2	Air venting
B1	Gas to engine	D1	Gas venting	X1	Control air [6-8 bar(g)]

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



	DN 80	DN 100
Height	2335 mm	2710 mm
Width	2710 mm	3131 mm
Depth	1730 mm	2200 mm

Fig 6-5 Main dimensions of the enclosed GVU (DAAF060741A)

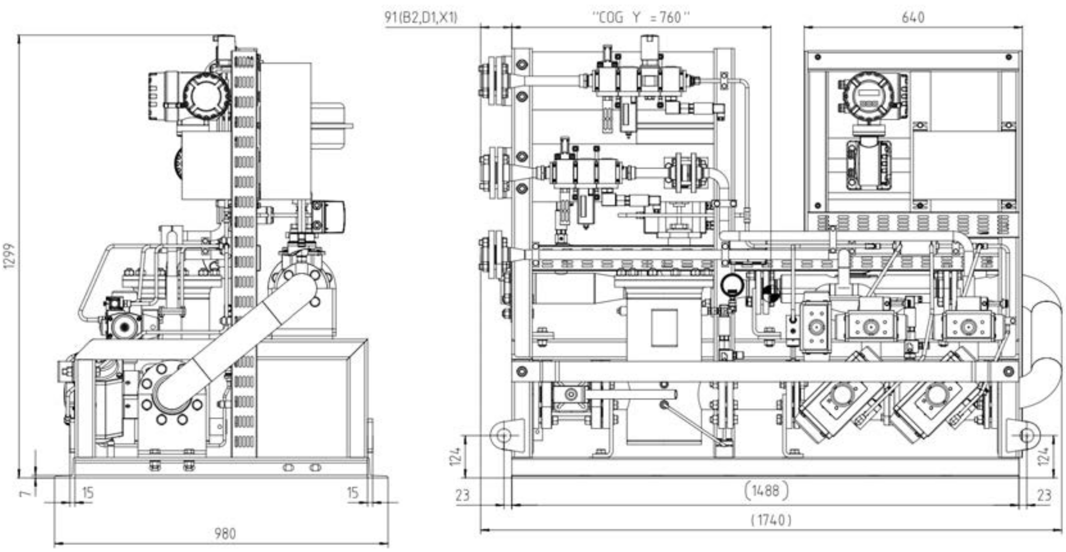


Fig 6-6 Main dimensions of the open GVU (DAAW010186B)

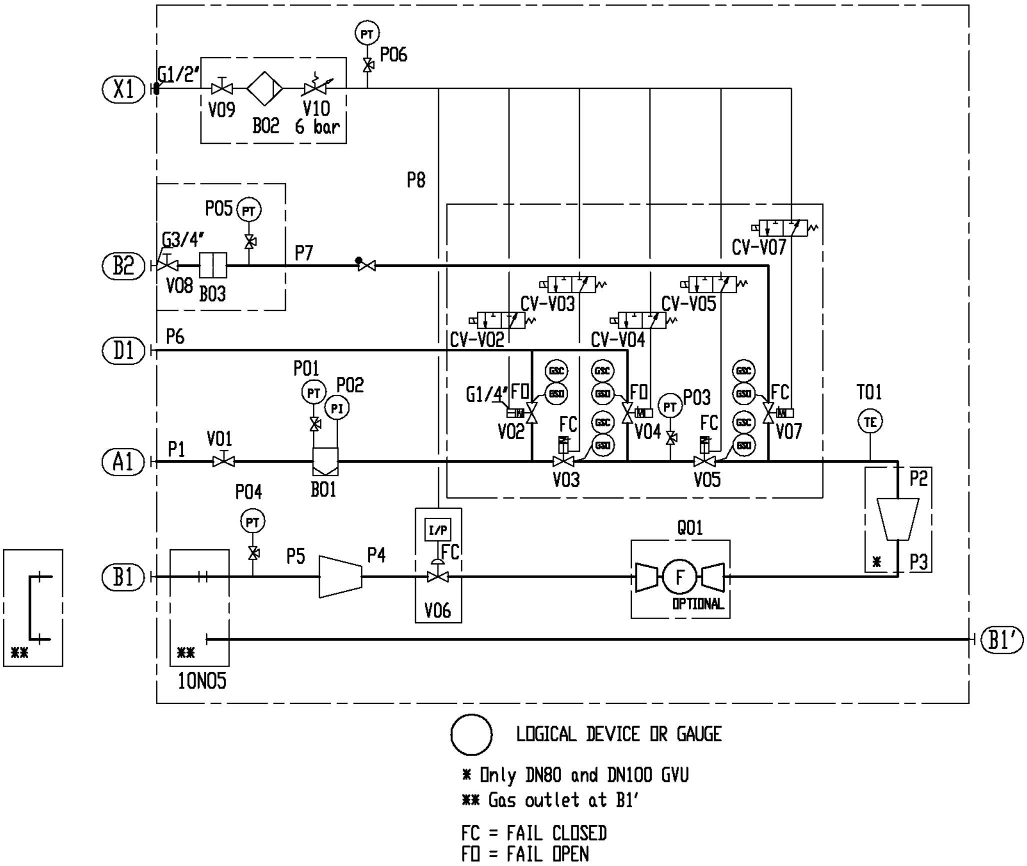


Fig 6-7 Gas valve unit P&I diagram, open type (DAAF085795A)

System components:					
B01	Gas filter	P05	Pressure transmitter	V04	Vent valve
B02	Air filter with water drain	P06	Pressure transmitter	V05	Second block valve
B03	Inert gas filter	Q01	Mass flow meter	V06	Gas control valve
P01	Pressure transmitter	T01	Temperature transmitter	V07	Inerting valve
P02	Local pressure indicator	V01	Manual shut off valve	V08	Shut off valve
P03	Pressure transmitter	V02	Vent valve	V09	Shut off valve
P04	Pressure transmitter	V03	First block valve	V10	Pressure regulator

Pipe connections	
A1	Gas inlet
B1	Gas to engine
B1'	Optional gas to engine
B2	Inert gas
D1	Gas venting
X1	Control air

Pipe size	DN50 GVU	DN80 GVU	DN100 GVU
P1	DN50	DN80	DN100
P2	DN40	DN80	DN100
P3	N/A	DN50	DN80
P4	DN40	DN50	DN80
P5	DN65	DN80	DN100

Pipe size	DN50 GVU	DN80 GVU	DN100 GVU
P6	OD18	OD28	OD42
P7	OD22	OD28	OD28
P8	10mm	10mm	10mm

6.3.1.5 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.

6.3.1.6 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!

6.3.1.7 Purging by inert gas

Nitrogen requirements

Wärtsilä recommends nitrogen with the following properties as a medium for purging.

Table 6-6 Nitrogen properties as a medium for purging

Property	Unit	Value
Content of mixture out of N2	≥ 95.0	%
Oxygen content	≤ 1.0	%
Dew point (atmospheric pressure)	≤ 40	°C

Property	Unit	Value
Pressure before purging value	8 ± 1.75	Bar(g)

The following guidelines apply for purging the fuel gas pipe between GVU and engine:

1. Required inert gas amount: 5 times the total volume of gas pipes that are to be purged
2. Flow: Standard purging time is 20 seconds; thus flow should be 5 times the gas pipe volume per 20 seconds

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

1. Max filling flow: 100l/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: 0.9 m3/crank (v-engine)

6.3.1.8 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*".

- 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 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 high pressure 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.

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.

6.4.1 Definitions Filtration term used

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

  - e.g. a real example: 30 micron mesh size = approx. 50 micron $ß_{50}$ = 75

- **XX micron, nominal**: commercial name of that mesh, at purchase. Not really related to filtration capability, especially when comparing different suppliers. Typically, a totally different value than XX micron, absolute.

  - e.g. a real example: 10 micron nominal (ε10 = 60%) = approx. 60 micron absolute.

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

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

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

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

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

6.4.2 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.

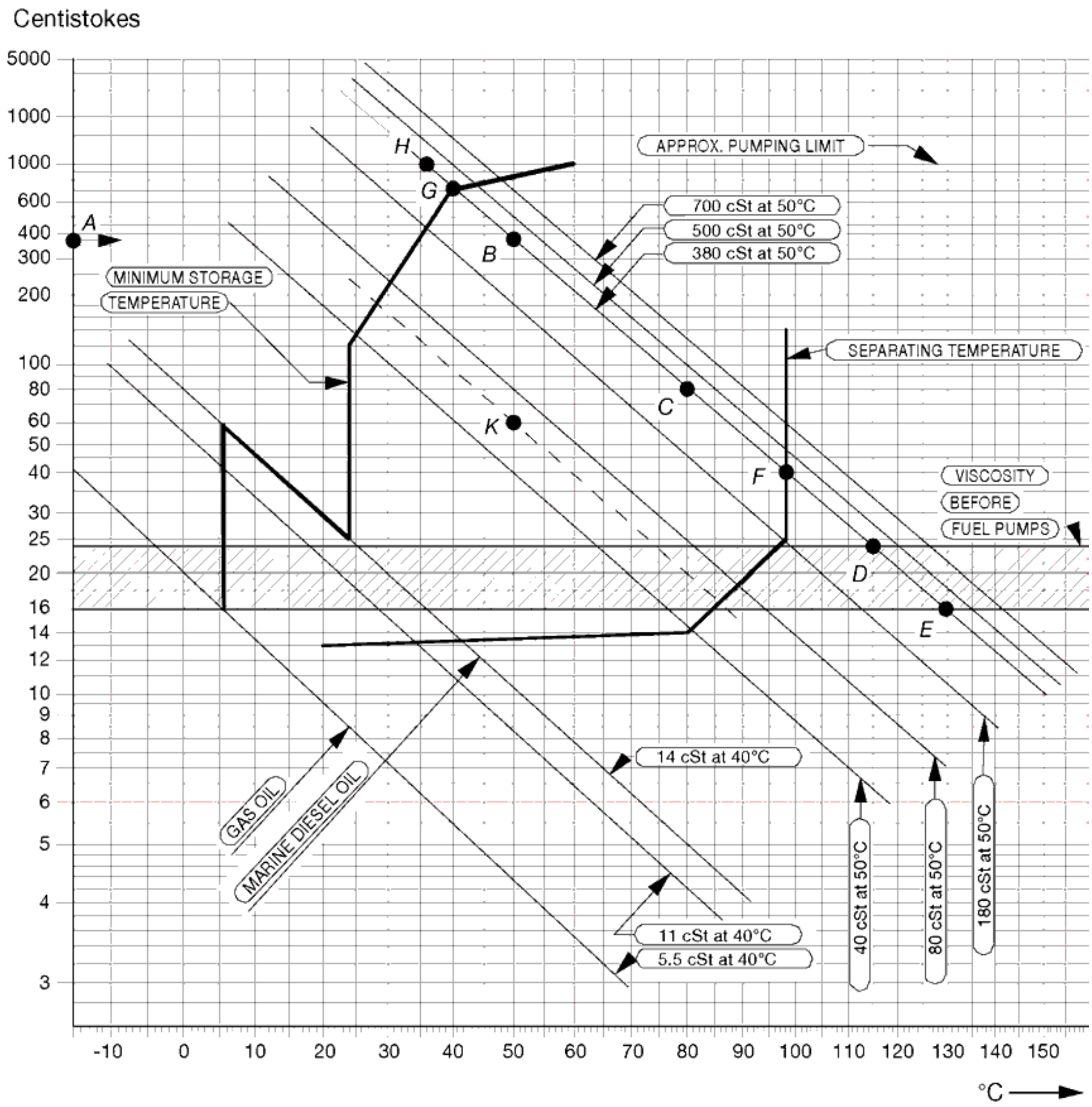


Fig 6-8 **Fuel oil viscosity-temperature diagram for determining the pre-heating temperatures of fuel oils (4V92G0071b)**

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 high pressure 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 high pressure pumps 74 - 87°C, separating temperature 86°C, minimum bunker tank temperature 28°C.

6.4.3 Fuel tanks

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

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

Separate settling tanks for HFO and MDF are recommended.

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

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

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

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

6.4.3.3 Leak fuel tank, clean fuel (1T04)

Clean leak fuel is drained by gravity from the engine. The fuel should be collected in a separate clean leak fuel tank, from where it can be pumped to the day tank and reused without separation. The pipes from the engine to the clean leak fuel tank should be arranged 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 MDF, the clean MDF leak fuel shall be directed to the MDF clean leak fuel tank. Thereby the MDF can be pumped back to the MDF day tank (1T06).

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

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

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

6.4.3.4 Leak fuel tank, dirty fuel (1T07)

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

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

6.4.4 Fuel treatment

6.4.4.1 Separation

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

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

All recommendations from the separator manufacturer must be closely followed.

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

Separator mode of operation

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

Separators with monitoring of cleaned fuel (without gravity disc) operating on a continuous basis can handle fuels with densities exceeding 991 kg/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

6.4.4.2 Separator unit (1N02/1N05)

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

Typically separator modules are equipped with:

- Suction strainer (1F02)
- Feed pump (1P02)
- Pre-heater (1E01)
- Sludge tank (1T05)
- Separator (1S01/1S02)

- Sludge pump
- Control cabinets including motor starters and monitoring

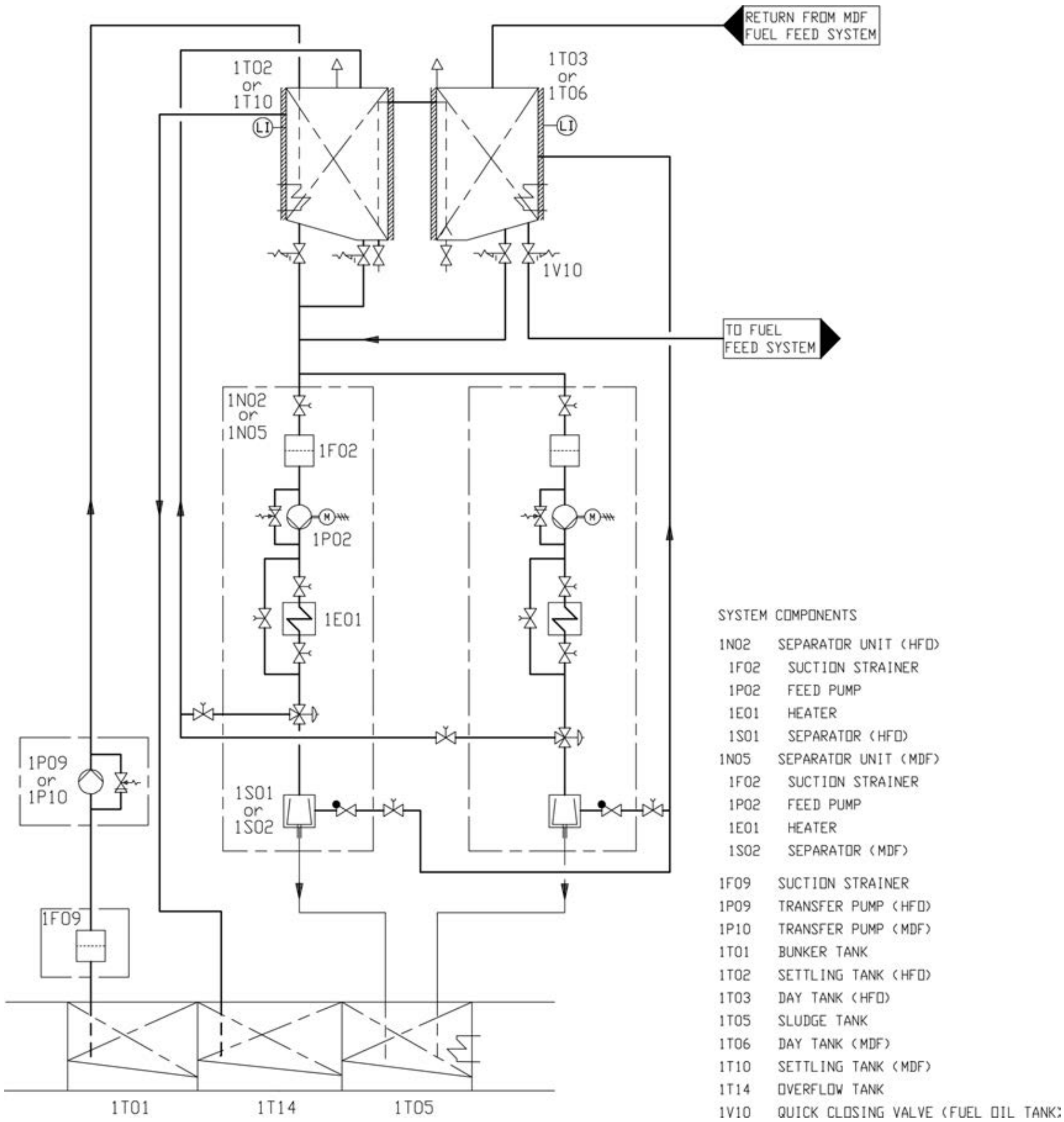


Fig 6-9 Fuel transfer and separating system (V76F6626G)

6.4.4.3 Separator feed pumps (1P02)

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

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

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

6.4.4.4 Separator pre-heater (1E01)

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

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

6.4.4.5 Separator (1S01/1S02)

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

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

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.

6.4.4.6 MDF separator in HFO installations (1S02)

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

6.4.4.7 Sludge tank (1T05)

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

6.4.5 Fuel feed system - MDF installations

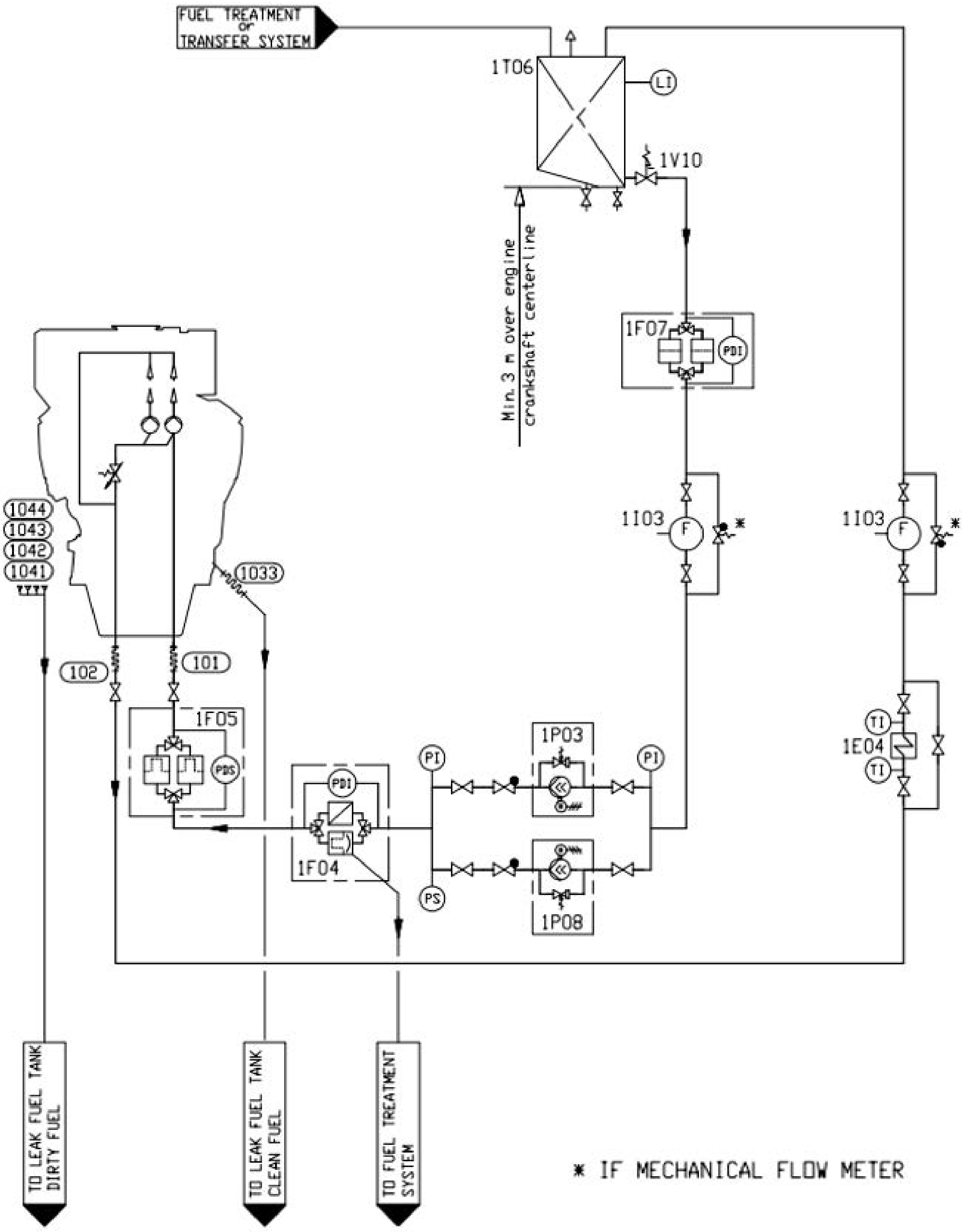


Fig 6-10 MDF fuel oil system with electric fuel circulation pump, single main engine (DAAF314554C)

System components		Pipe connections		Size
1E04	Cooler (MDF)	101	Fuel inlet	DN32
1F04	Automatic filter (MDF)	102	Fuel outlet	DN32
1F05	Fine filter (MDF)	1033	Leak fuel drain, clean fuel	OD28
1F07	Suction strainer (MDF)	1041	Leak fuel drain, dirty fuel	DN35
1I03	Flow meter (MDF)	1042	Leak fuel drain, dirty fuel	DN35
1P03	Circulation pump (MDF)	1043	Leak fuel drain, dirty fuel	DN35
1P08	Stand-by pump (MDF)	1044	Leak fuel drain, dirty fuel	DN35
1T06	Day tank (MDF)			

System components		Pipe connections		Size
1V10	Quick closing valve (fuel oil tank)			

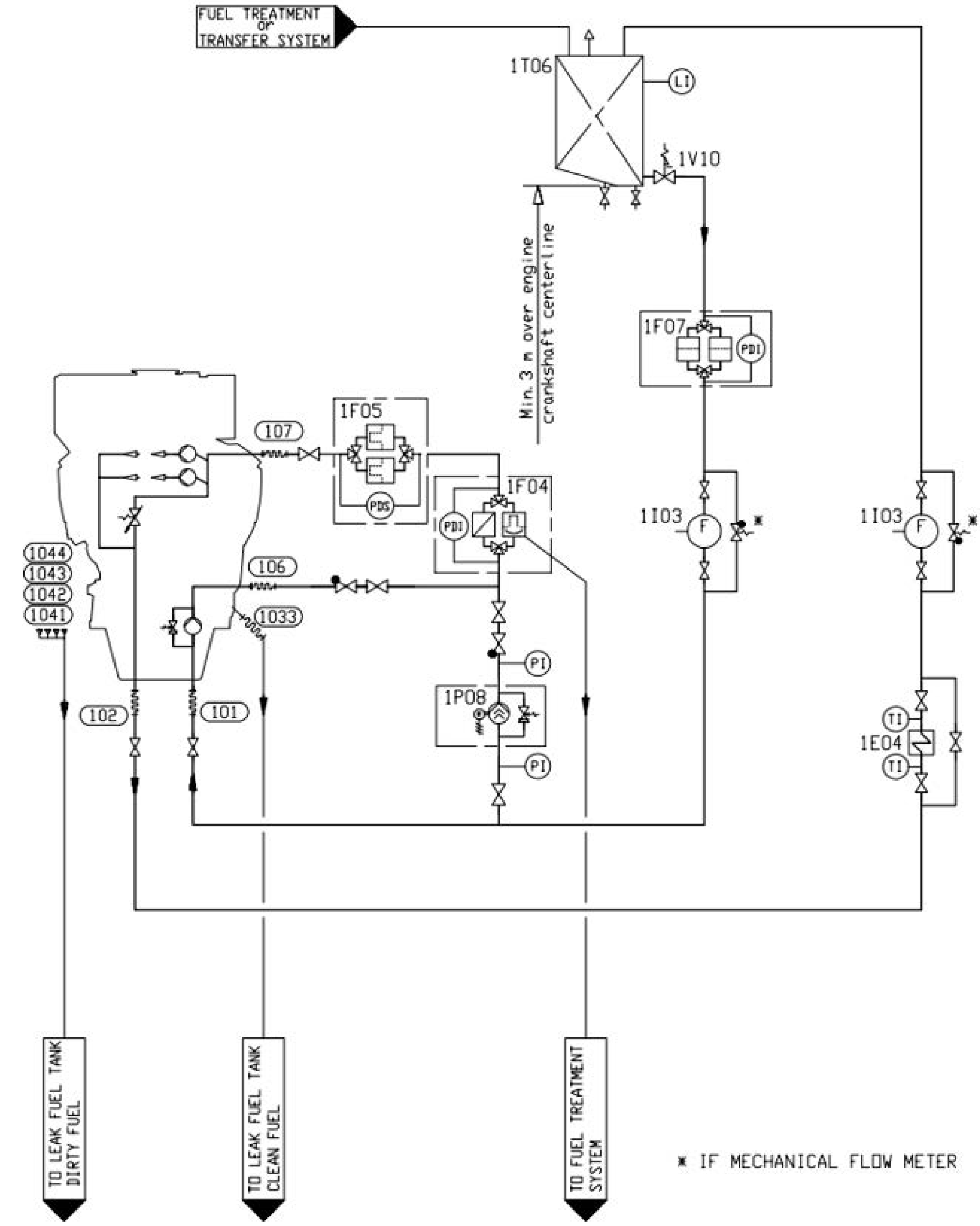


Fig 6-11 MDF fuel oil system, single main engine with engine driven fuel feed pump (DAAF301495C)

System components		Pipe connections		Size
1E04	Cooler (MDF)	101	Fuel inlet	DN40
1F04	Automatic filter (MDF)	102	Fuel outlet	DN32
1F05	Fine filter (MDF)	1033	Leak fuel drain, clean fuel	OD28
1F07	Suction strainer (MDF)	1041	Leak fuel drain, dirty fuel	DN35
1I03	Flow meter (MDF)	1042	Leak fuel drain, dirty fuel	DN35
1P08	Stand-by pump (MDF)	1043	Leak fuel drain, dirty fuel	DN35
1T06	Day tank (MDF)	1044	Leak fuel drain, dirty fuel	DN35
1V10	Quick closing valve (fuel oil tank)	106	Fuel to external filter	DN32
		107	Fuel from external filter	DN32

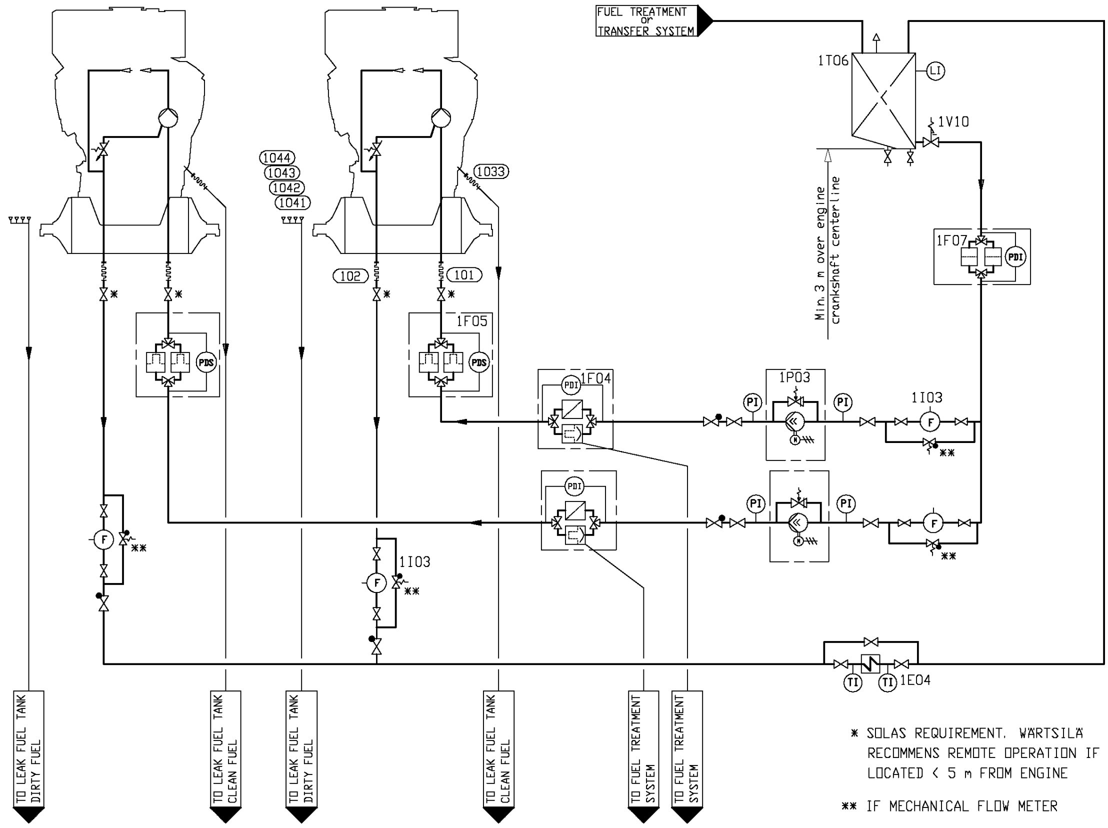


Fig 6-12 MDF fuel oil system, multiple engines (DAAF301496C)

System components		Pipe connections		Size
1E04	Cooler (MDF)	101	Fuel inlet	DN32
1F04	Automatic filter (MDF)	102	Fuel outlet	DN32
1F05	Fine filter (MDF)	1033	Leak fuel drain, clean fuel	OD28
1F07	Suction strainer (MDF)	1041	Leak fuel drain, dirty fuel	DN35
1I03	Flow meter (MDF)	1042	Leak fuel drain, dirty fuel	DN35
1P03	Circulation pump (MDF)	1043	Leak fuel drain, dirty fuel	DN35
1T06	Day tank (MDF)	1044	Leak fuel drain, dirty fuel	DN35
1V10	Quick closing valve (fuel oil tank)			

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.

6.4.5.1 Circulation pump, MDF (1P03)

The circulation pump maintains the pressure at the high pressure 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.

Dimensioning of the circulation pump depends on the total system design. In the multi engine installation circulation pump of 1P12 is used, the circulation pump 1P03 capacity needs to be approx. 10% higher than the other circulation pumps in the system. The nominal capacity for the specific engine is available in the technical data.

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

6.4.5.2 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:	
Design pressure	1.6 MPa (16 bar)
Max. total pressure (safety valve)	1.2 MPa (12 bar)
Design temperature	150°C
Pressure for dimensioning of electric motor (ΔP):	If MDF is fed directly from day tank: 0.12 MPa (1.2 bar) If all fuel is fed through feeder/booster unit: 0.6 MPa (6 bar)
Viscosity for dimensioning of electric motor	500 cSt

6.4.5.3 Flow meter, MDF (1I03)

If required, a flow meter is used for monitoring of the fuel consumption. 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.

6.4.5.4 Automatic filter (1F04)

It is recommended to use automatic filter as main filter, for one or multiple engines, through which only fuel consumption flow. For redundancy, it's recommended to have stand-by filter, especially when one main automatic filter is used for multiple engines. The coarser stand-by filter is only intended for temporary use, while the automatic filter is maintained. External fuel oil system must be made so that it's not possible to feed engine(s) with only 25-34 μm absolute mesh filtration for longer than 24 hours. In case stand-by filter is used for long time operation, the filtration must be β17 = 75, β6 = 2 according to ISO16889 and system control shall monitor how long time engines have been operated with unadequate fuel filtration.

Design data:	
Fuel viscosity	According to fuel specification
Design temperature	50°C
Design flow	Equal to feed pump capacity
Design pressure	1.6 MPa (16 bar)
Fineness:	
- automatic filter	6 μm (absolute mesh size) ($ß_{17}$ = 75, $ß_6$ = 2, ISO16889)
- stand-by filter	25 - 34 μm (absolute mesh size) ($ß_{25 - 34}$ = 2, $ß_{40 - 50}$ = 75, ISO16889)
Maximum permitted pressure drops at 14 cSt:	
- clean filter	20 kPa (0.2 bar)
- alarm	80 kPa (0.8 bar)

6.4.5.5 Fine filter, MDF (1F05)

The fuel oil fine filter is a full flow duplex type filter with steel net. It's sometimes called safety filter and it must be installed as near the engine as possible. The diameter of the pipe between the safety filter and the engine should be the same as the diameter before the filters.

External fuel oil system must be made so that it's not possible to operate with only safety filter for longer than 24 hours, and system control shall monitor how long time engines have been operated with unadequate fuel filtration.

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 - 34 μm (absolute mesh size) ($ß_{25 - 34}$ = 2, $ß_{40 - 50}$ = 75, ISO16889)
Maximum permitted pressure drops at 14 cSt:	
- clean filter	20 kPa (0.2 bar)
- alarm	80 kPa (0.8 bar)

6.4.5.6 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	30 kW per engine
Max. pressure drop, fuel oil	80 kPa (0.8 bar)
Max. pressure drop, water	60 kPa (0.6 bar)
Margin (heat rate, fouling)	min. 15%
Design temperature MDF/HFO installation	50/150°C

6.4.5.7 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

6.4.6 Fuel feed system - HFO installations

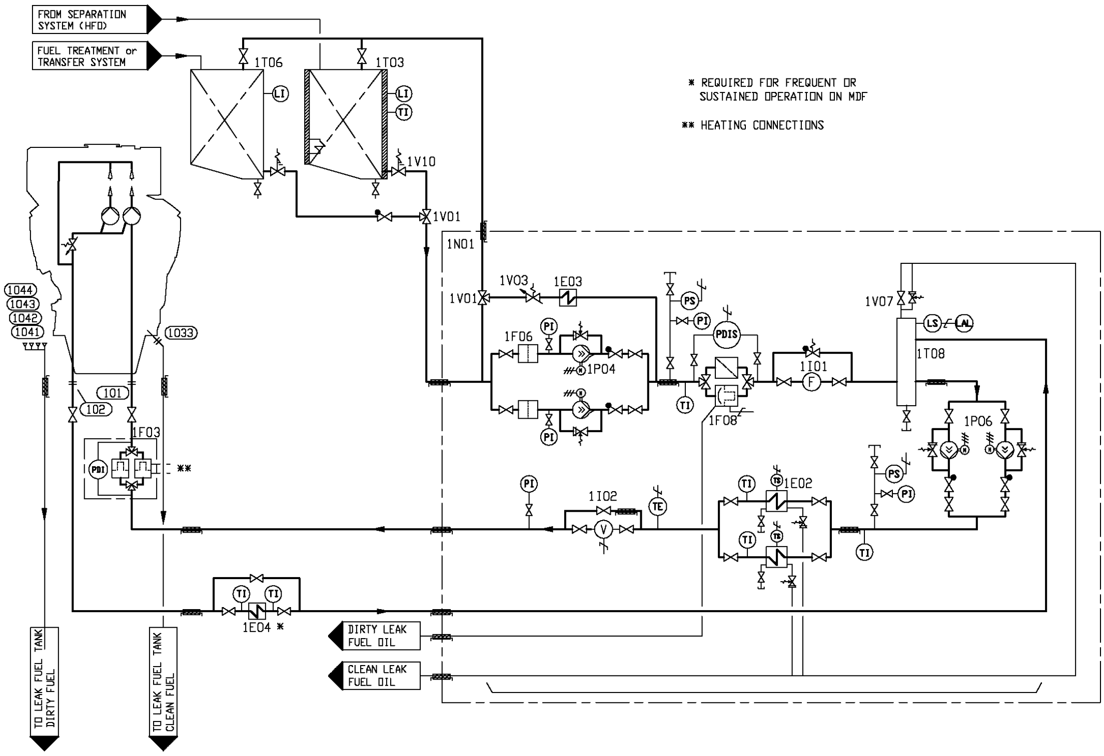


Fig 6-13 HFO fuel oil system, single main engine installation (DAAF301497C)

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

Pipe connections:		Size
101	Fuel inlet	DN32
102	Fuel outlet	DN32
1033	Leak fuel drain, clean fuel	OD28
1041-1044	Leak fuel drain, dirty fuel	DN35

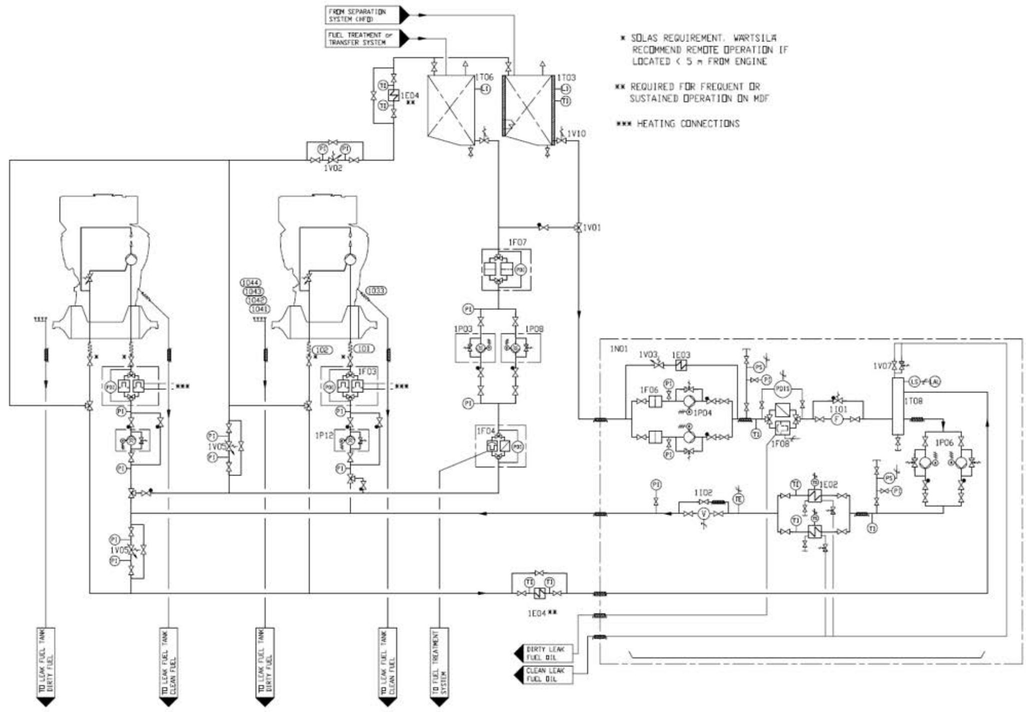


Fig 6-14 HFO fuel oil system, multiple engine installation (DAAF301498C)

System components:			
1E02	Heater (booster unit)	1P04	Fuel feed pump (booster unit)
1E03	Cooler (booster unit)	1P06	Circulation pump (booster unit)
1E04	Cooler (MDF)	1P12	Circulation pump (HFO/MDF)
1F03	Safety filter (HFO)	1T03	Day tank (HFO)
1F04	Automatic filter (MDF)	1T06	Day tank (MDF)
1F06	Suction filter (booster unit)	1T08	De-aeration tank (booster unit)
1F07	Suction strainer (MDF)	1V01	Changeover valve
1F08	Automatic filter (booster unit)	1V02	Pressure control valve (MDF)
1I01	Flow meter (booster unit)	1V03	Pressure control valve (booster unit)
1I02	Viscosity meter (booster unit)	1V05	Overflow valve (Booster unit)
1N01	Feeder/booster unit	1V07	Venting valve (booster unit)
1P03	Circulation pump (MDF)	1V10	Quick closing valve (fuel oil tank)

Pipe connections:		Size
101	Fuel inlet	DN32
102	Fuel outlet	DN32
1033	Leak fuel drain, clean fuel	OD28
1041-1044	Leak fuel drain, dirty fuel	DN35

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

6.4.6.1 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.

6.4.6.2 Changeover from HFO to MDF

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

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

6.4.6.3 Feeder/booster unit (1N01)

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

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

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

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 use automatic filter as main filter, for one or multiple engines, through which only fuel consumption flow. The automatic filter must be installed before the heater, between feed pump and the de-aeration tank and, it should be equipped with a heating jacket. Overheating (temperature exceeding 100°C), however, is to be prevented, and it must be possible to swich off heating for MDF operation. For redundancy, it's recommended to have stand-by filter, especially when one main automatic filter is used for multiple engines. The coarser stand-by filter is only intended for temporary use, while the automatic filter is maintained. External fuel oil system must be made so that it's not possible to feed engine(s) with only 25-34 µm absolute mesh filtration for longer than 24 hours. In case stand-by filter is used for long time operation, the filtration must be β_{17} = 75, β_6 = 2 according to ISO16889 and system control shall monitor how long time engines have been operated with unadequate fuel filtration.

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	β_{17} = 75, β_6 = 2, ISO16889 (typically reached with 6 µm absolute mesh size, β value is to be used for filter selection)
- stand-by filter	25 - 34 µm (absolute mesh size) (β_{25-34} = 2, β_{40-50} = 75, ISO16889)

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 high pressure 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 high pressure pumps at operating temperature.

Dimensioning of the circulation pump depends on the total system design. In the multi engine installation circulation pump of 1P12 is used, the circulation pump 1P06 capacity needs to be approx. 10% higher than the other circulation pumps in the system. The nominal capacity for the specific engine is available in the technical data.

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 high pressure 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 high pressure 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 high pressure pumps of the diesel engine.

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

6.4.6.4 Safety filter, HFO (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 a pump and filter uniit shall be installed as near the engine as possible.

External fuel oil system must be made so that it's not possible to operate with only safety filter for longer than 24 hours, and system control shall monitor how long time engines have been operated with unadequate fuel filtration.

Consider to have a filter with 25 - 34 µm absolute mesh size (approx. $\beta_{25\text{ - }34} = 2$, $\beta_{40\text{ - }50} = 75$ according to ISO16889) for pre-filtration before main filter $\beta_{17} = 75$, $\beta_6 = 2$ according to ISO16889.

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	25 - 34 µm (absolute mesh size) ($\beta_{25\text{ - }34} = 2$, $\beta_{40\text{ - }50} = 75$, ISO16889)
Maximum permitted pressure drops at 14 cSt:	Clean filter: 20 kPa (0.2 bar) Alarm: 80 kPa (0.8 bar)

6.4.6.5 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

6.4.7 Flushing

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

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

The fineness of the flushing filter should be 6 µm or finer.

7. Lubricating Oil System

7.1 Lubricating oil requirements

7.1.1 Engine lubricating oil

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

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

Category	Fuel standard		Lubricating oil BN	Fuel S content, [% m/m]
A	ASTM D 975-01, BS MA 100: 1996 CIMAC 2003 ISO 8217:2017(E)	GRADE 1-D, 2-D, 4-D DMX, DMA, DMB DX, DA, DB ISO-F-DMX - DMB	10...15	< 0.4
B	ASTM D 975-01 BS MA 100: 1996 CIMAC 2003 ISO 8217:2017(E)	GRADE 1-D, 2-D, 4-D DMX, DMA, DMB DX, DA, DB ISO-F-DMX - DMB	15...20	0.4 - 1.5

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.

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

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

7.2 External lubricating oil system

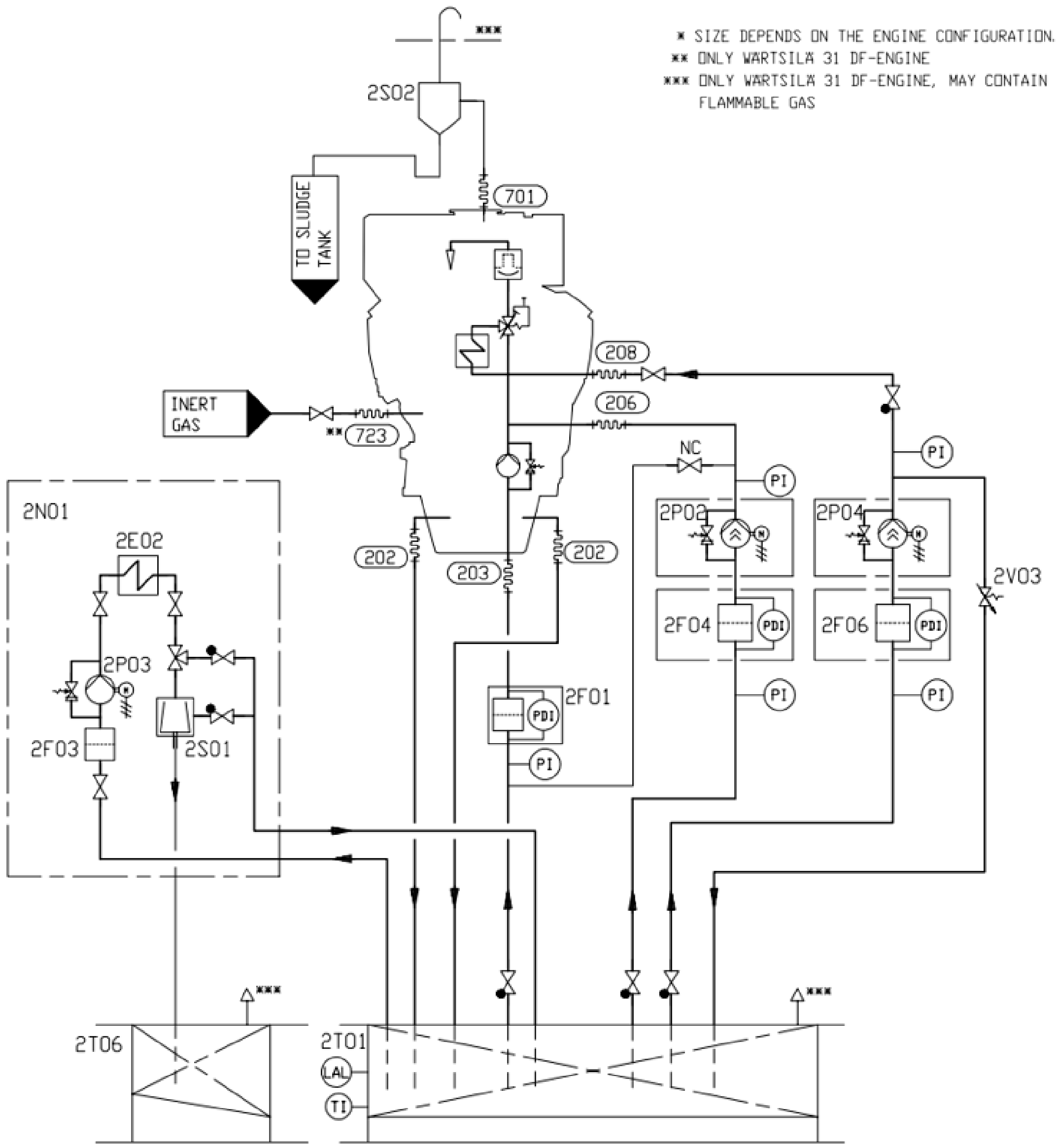


Fig 7-1 Lubricating oil system, single main engine HFO/MDF (DAAF301499B)

System components:			
2E02	Heater (separator unit)	2P03	Separator pump (separator unit)
2F01	Suction strainer (main lubricating oil pump)	2P04	Stand-by pump
2F03	Suction filter (separator unit)	2S01	Separator
2F04	Suction strainer (Prelubricating oil pump)	2S02	Condensate trap
2F06	Suction strainer (stand-by pump)	2T01	System oil tank
2N01	Separator unit	2T06	Sludge tank
2P02	Pre lube oil pump	2V03	Pressure control valve

Pipe connections:		8V - 10V	12V - 16V
*202	Lubricating oil outlet	DN200	DN250
*203	Lubricating oil to engine driven pump	DN200	DN250

Pipe connections:		8V - 10V	12V - 16V
206	Lubricating oil from priming pump	DN80	DN80
208	Lubricating oil from electric driven pump	DN125	DN125
701	Crankcase air vent	DN125	DN150
**723	Inert gas inlet	DN50	DN50

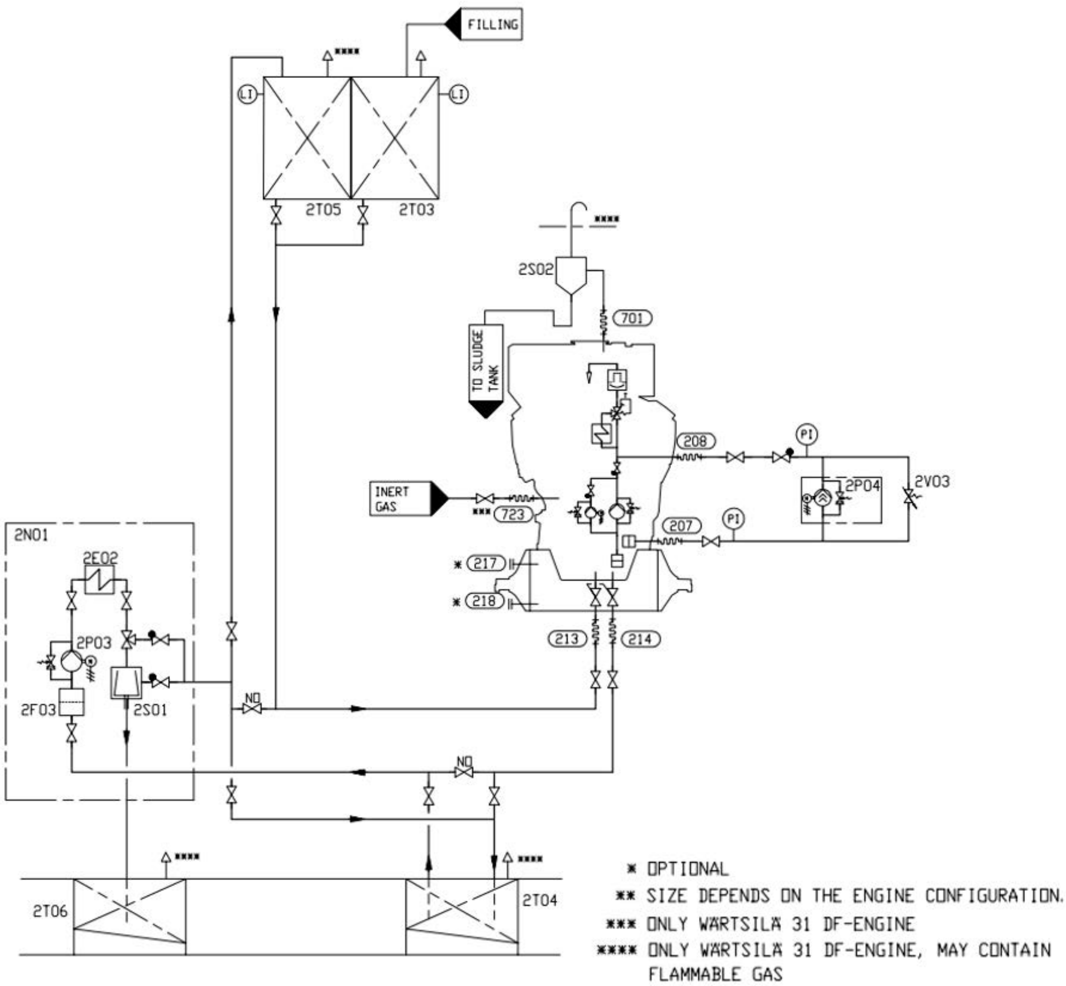


Fig 7-2 Lubricating oil system, single main engine MDF (DAAF301501C)

System components:			
2E02	Heater (separator unit)	2S02	Condensate trap
2F03	Suction filter (separator unit)	2T03	New oil tank
2N01	Separator unit	2T04	Renovating oil tank
2P03	Separator pump (separator unit)	2T05	Renovated oil tank
2P04	Stand-by pump	2T06	Sludge tank
2S01	Separator	2V03	Pressure control valve

Pipe connections:		8V - 10V	12V - 16V
**207	Lube oil to el. driven pump	DN200 / DN250	
208	Lube oil from el. driven pump	DN125	DN125
213	Lubricating oil from separator and filling	DN40	DN40
214	Lubricating oil to separator and drain	DN40	DN40
217	Lube oil to generator bearing	DN40	DN40
218	Lube oil from generator bearing	DN40	DN40
701	Crankcase air vent	DN125	DN150
***723	Inert gas inlet	DN50	DN50

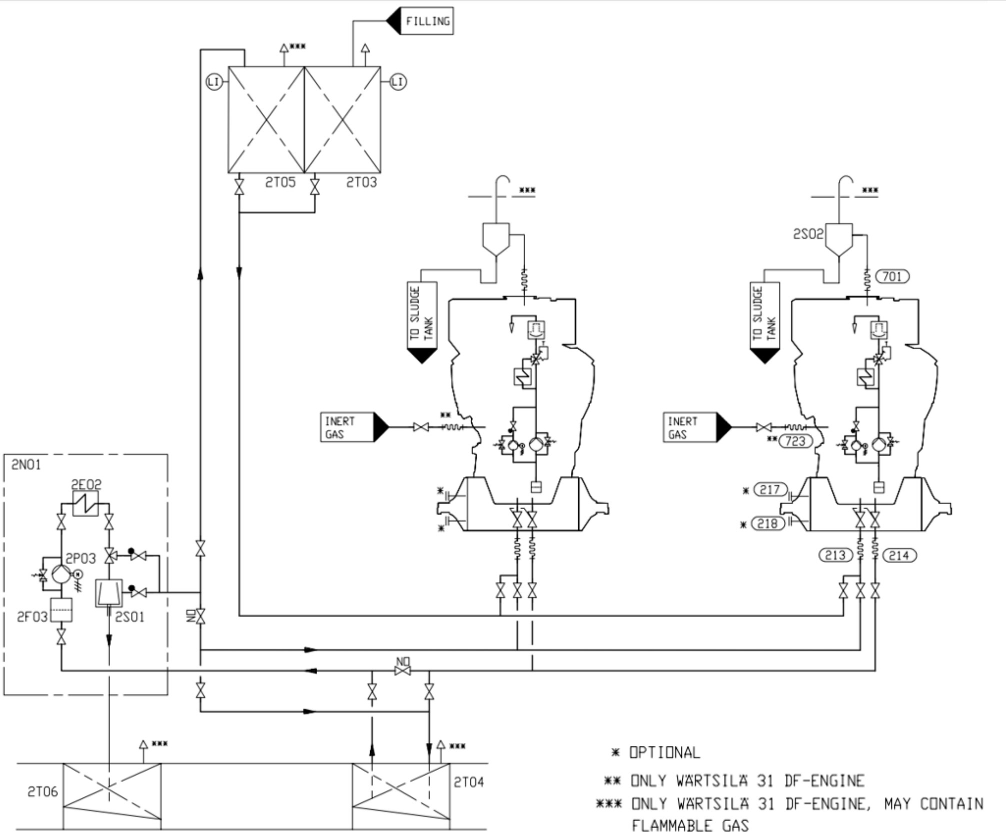


Fig 7-3 Lubricating oil system (MDF), multiple engine (DAAF301500B)

System components:			
2E02	Heater (separator unit)	2S02	Condensate trap
2F03	Suction filter (separator unit)	2T03	New oil tank
2N01	Separator unit	2T04	Renovating oil tank
2P03	Separator pump (separator unit)	2T05	Renovated oil tank
2S01	Separator	2T06	Sludge tank

Pipe connections:		8V - 10V	12V - 16V
213	Lubricating oil from separator and filling	DN40	DN40
214	Lubricating oil to separator and drain	DN40	DN40
217	Lube oil to generator bearing	DN40	DN40
218	Lube oil from generator bearing	DN40	DN40
701	Crankcase air vent	DN125	DN150
**723	Inert gas inlet	DN50	DN50

7.2.1 Separation system

7.2.1.1 Separator unit (2N01)

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

Separators are usually supplied as pre-assembled units.

Typically lubricating oil separator units are equipped with:

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

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

Separator feed pump (2P03)

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

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

Separator preheater (2E02)

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

Recommended oil temperature after the heater is 95°C.

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

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

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

Separator (2S01)

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

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

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

where:

Q = volume flow [l/h]

P = 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.

7.2.2 System oil tank (2T01)

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

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

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

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

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

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

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

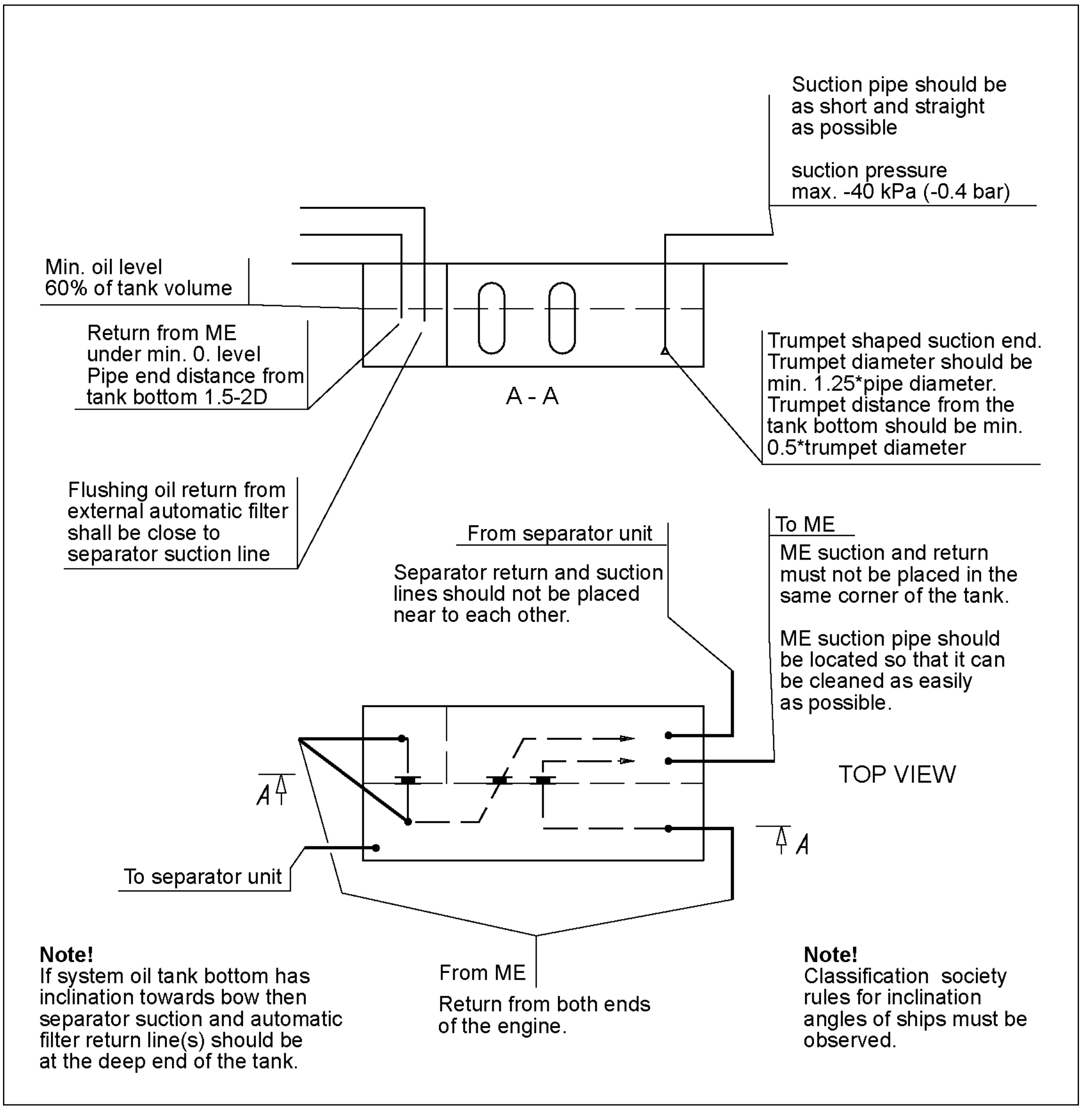


Fig 7-4 Example of system oil tank arrangement (DAAE007020e)

Design data:

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

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

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

Design data:

Fineness	0.5...1.0 mm

7.2.4 Pre-lubricating oil pump (2P02)

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

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

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

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

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

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

7.2.5 Pressure control valve (2V03)

Design data:	
Design pressure	1.0 MPa (10 bar)
Capacity	Difference between pump capacity and oil flow through engine
Design temperature	100 °C

7.2.6 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)

7.3 Crankcase ventilation system

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

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

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

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

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

Design data:

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

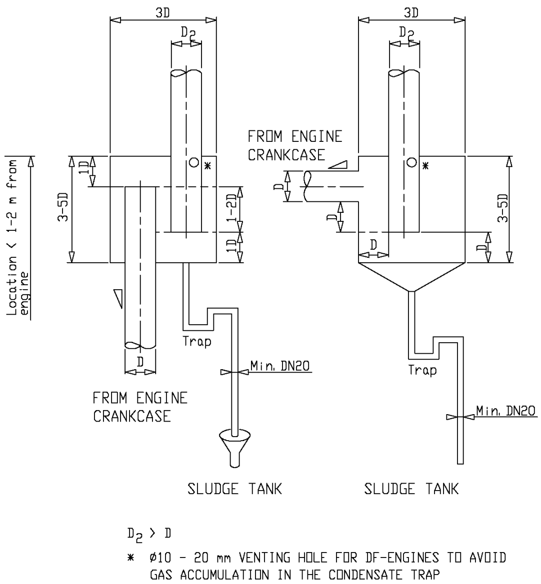


Fig 7-5 Condensate trap (DAAF369903)

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

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

7.4 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).

7.4.1 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.

7.4.2 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.

7.4.3 Type of flushing oil

7.4.3.1 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.

7.4.3.2 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.

7.4.3.3 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.

7.4.3.4 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

8.2 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.

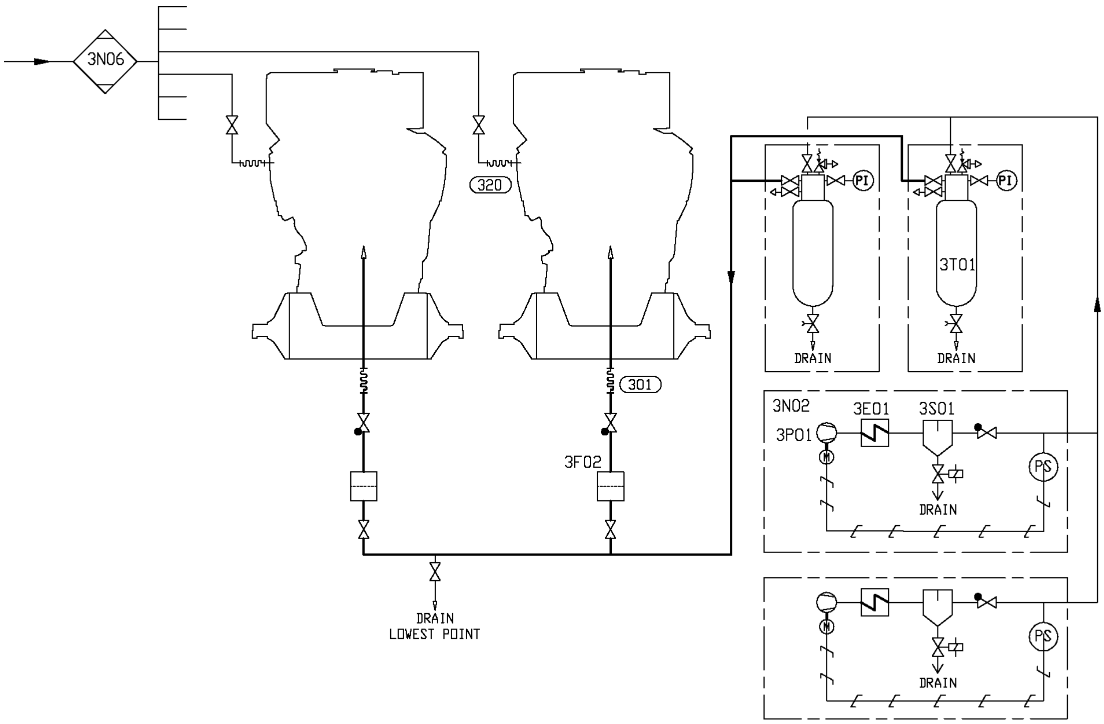


Fig 8-1 External starting air system (DAAF301502)

System components:		Pipe connections:		Size
3E01	Cooler (Starting air compressor unit)	301	Starting air inlet	DN32
3F02	Air filter (starting air inlet)	320	Instrument air inlet	OD12
3N02	Starting air compressor unit			
3N06	Air dryer unit			
3P01	Compressor (starting air compressor unit)			
3S01	Separator (starting air compressor unit)			
3T01	Starting air vessel			

8.2.1 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.

8.2.2 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.

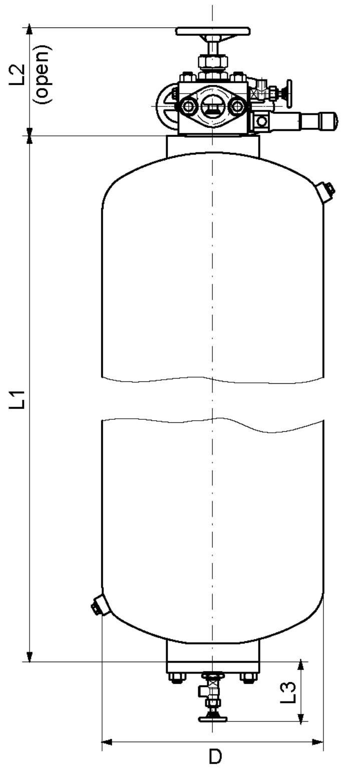
8.2.3 Starting air vessel (3T01)

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.



[1] Dimensions are approximate.

Fig 8-2 Starting air vessel

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

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

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

where:

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

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

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

n = required number of starts according to the classification society

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

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

NOTE

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

8.2.4 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.

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 External cooling water system

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

The external system shall be designed so that flows, pressures and temperatures are close to the nominal values in *Technical data* and the cooling water is properly de-aerated.

Pipes with galvanized inner surfaces are not allowed in the fresh water cooling system. Some cooling water additives react with zinc, forming harmful sludge. Zinc also becomes nobler than iron at elevated temperatures, which causes severe corrosion of engine components.

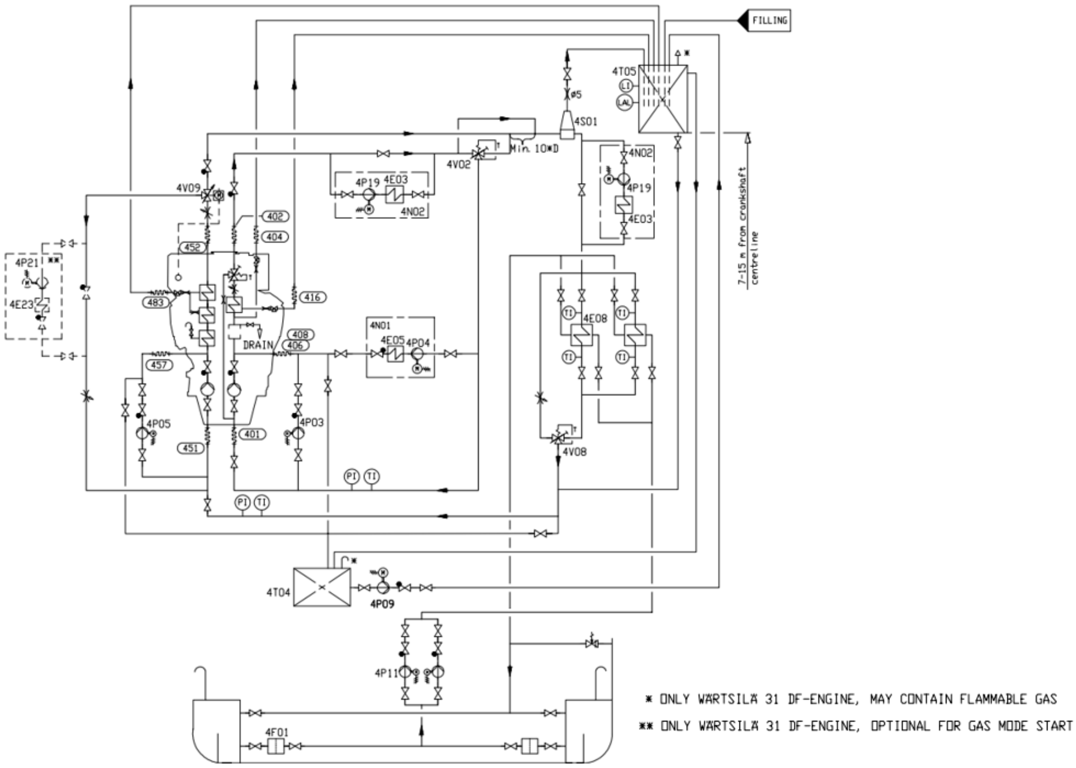


Fig 9-1 Single main engine with heat recovery (DAAF301503B)

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

Pipe connections:		8V - 10V	12V - 16V
401	HT-water inlet	DN100	DN125
402	HT-water	DN100	DN125

Pipe connections:		8V - 10V	12V - 16V
404	HT-water air vent	OD12	OD18
406	Water from preheater to HT-circuit	DN100	DN125
408	HT-water from stand-by pump	DN100	DN125
416	HT-water airvent from air cooler	OD12	OD18
451	LT-water inlet	DN100	D125
452	LT-water outlet	DN100	D125
457	LT-water from stand-by pump	DN100	D125
483	LT-water air vent	OD15	OD18

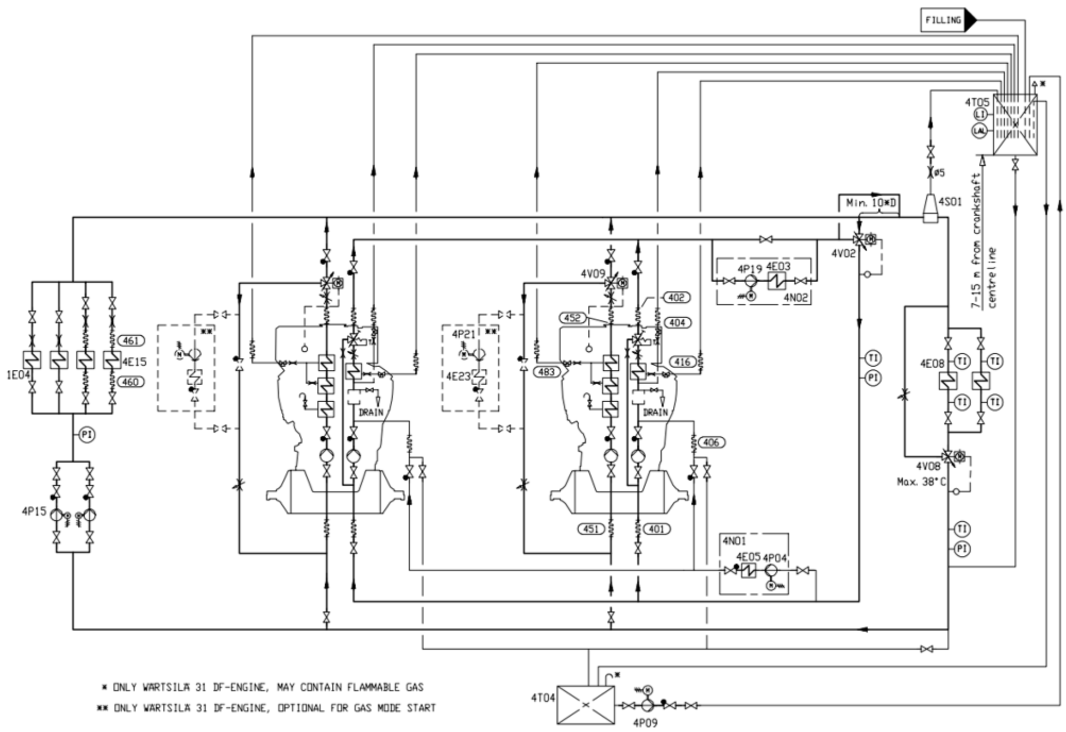


Fig 9-2 Multiple main engines with heat recovery (DAAF301505B)

System components:			
1E04	Cooler (MDF)	4P15	Circulating pump (LT)
4E03	Heat recovery (evaporator)	4P19	Circulating pump (evaporator)
4E05	Heater (preheater)	4S01	Air venting
4E08	Central cooler	4T04	Drain tank
4E15	Cooler (generator)	4T05	Expansion tank
4N01	Preheating unit	4V02	Temperature control valve (heat recovery)
4N02	Evaporator unit	4V08	Temperature control valve (central cooler)
4P04	Circulating pump (preheater)	4V09	Temperature control valve (charge air)
4P09	Transfer pump	**4P21	Circulating pump (preheating LT)
**4E23	Heater (LT)		

Pipe connections:		8V-10V	12V-16V
401	HT-water inlet	DN100	DN125
402	HT-water outlet	DN100	DN125
404	HT-water air vent	OD12	OD18
406	Water from preheater to HT-circuit	DN65	DN40
416	HT-water airvent from air cooler	OD12	OD18
451	LT-water inlet	DN100	DN125
452	LT-water outlet	DN100	DN125
460	LT-water to generator	-	-
461	LT-water from generator	-	-
483	LT-water air vent	OD15	OD18

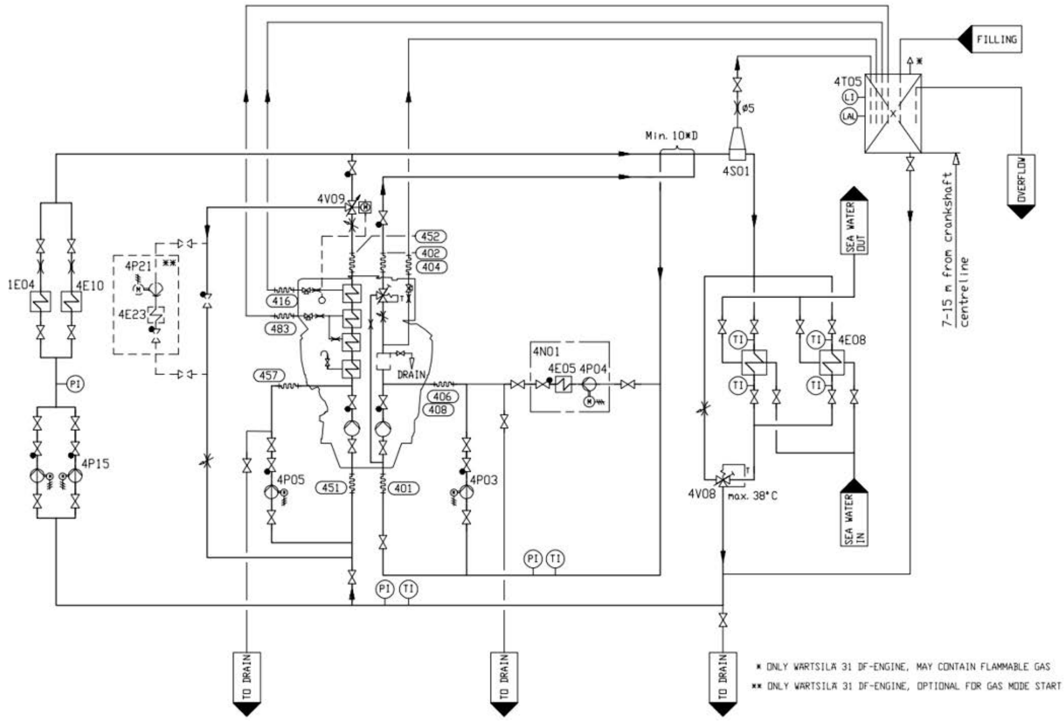


Fig 9-3 Cooling water system, single main engine arctic solution without heat recovery (DAAF320499B)

System components:			
1E04	Cooler (MDF)	4P05	Stand-by pump (LT)
4E05	Heater (preheater)	4P15	Circulating pump (LT)
4E08	Central cooler	4S01	Air venting
4E10	Cooler (reduction gear)	4T05	Expansion tank
4N01	Preheating unit	4V08	Temperature control valve (central cooler)
4P03	Stand-by pump (HT)	4V09	Temperature control valve (charge air)
4P04	Circulating pump (preheater)	**4P21	Circulating pump (preheating LT)
**4E23	Heater (LT)		

Pipe connections:		8V-10V	12V-16V
401	HT-water inlet	DN100	DN125
402	HT-water outlet	DN100	DN125
404	HT-water air vent	OD12	OD18
406	Water from preheater to HT-circuit	DN100	DN125
408	HT-water from stand-by pump	DN100	DN125
416	HT-water airvent from air cooler	OD12	OD18
451	LT-water inlet	DN100	DN125
452	LT-water outlet	DN100	DN125
457	LT-water from stand-by pump	DN100	DN125
483	LT-water air vent	OD15	OD18

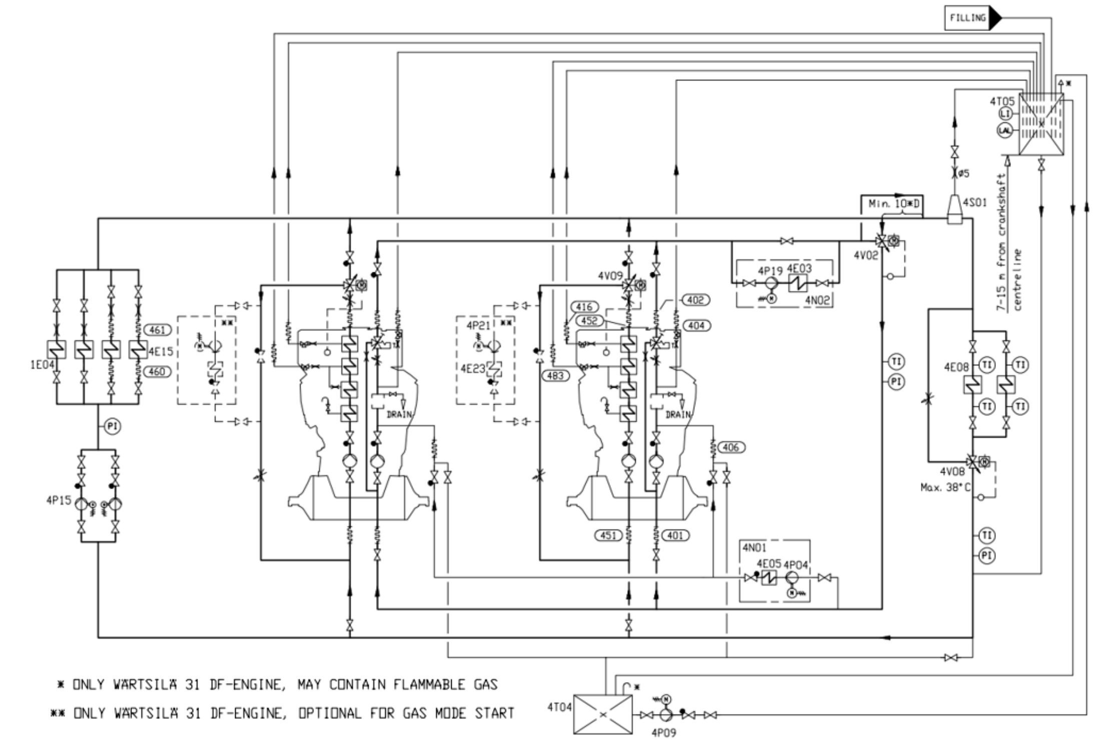


Fig 9-4 Cooling water system, multiple engines arctic solution with heat recovery (DAAF320500B)

System components:			
1E04	Cooler (MDF)	4P15	Circulating pump (LT)
4E03	Heat recovery (evaporator)	4P19	Transfer pump
4E05	Heater (preheater)	4S01	Air venting
4E08	Central cooler	4T04	Drain tank
4E15	Cooler (generator)	4T05	Expansion tank
4N01	Preheating unit	4V02	Temperature control valve (heat recovery)
4N02	Evaporator unit	4V08	Temperature control valve (central cooler)
4P04	Circulating pump (preheater)	4V09	Temperature control valve (charge air)
4P09	Transfer pump	**4P21	Circulating pump (preheating LT)
**4E23	LT-water air vent		

Pipe connections:		8V-10V	12V-16V
401	HT-water inlet	DN100	DN125
402	HT-water outlet	DN100	DN125
404	HT-water air vent	OD12	OD18
406	Water from preheater to HT-circuit	DN65	DN40
416	HT-water airvent from air cooler	OD12	OD18
451	LT-water inlet	DN100	DN125
452	LT-water outlet	DN100	DN125
460	LT-water to generator	-	-
461	LT-water from generator	-	-
483	LT-water air vent	OD15	OD18

9.2.1 Cooling water system for arctic conditions

At low engine loads the combustion air can be below zero degrees Celsius after the compressor stage, it cools down the cooling water and the engine instead of releasing heat to the cooling water in the charge air cooler. If the combustion air temperature reaching the cylinders is too cold, it can cause uneven burning of the fuel in the cylinder and possible misfires. Additionally overcooling the engine jacket can cause cold corrosion of the cylinder liners or even a stuck piston.

Thus maintaining nominal charge air receiver and HT-water inlet temperature are important factors, when designing the cooling water system for arctic conditions. Proper receiver temperatures must be ensured at all ambient temperatures. If needed, all charge air coolers can be installed in the LT-circuit. LT-circuit heaters can also be used.

9.2.1.1 The arctic sea water cooling system

In arctic conditions, the hot sea water from the central cooler outlet is typically returned back to the sea chest in order to prevent ice slush from blocking the sea water filters. An example flow diagram of the arctic sea water system is shown below.

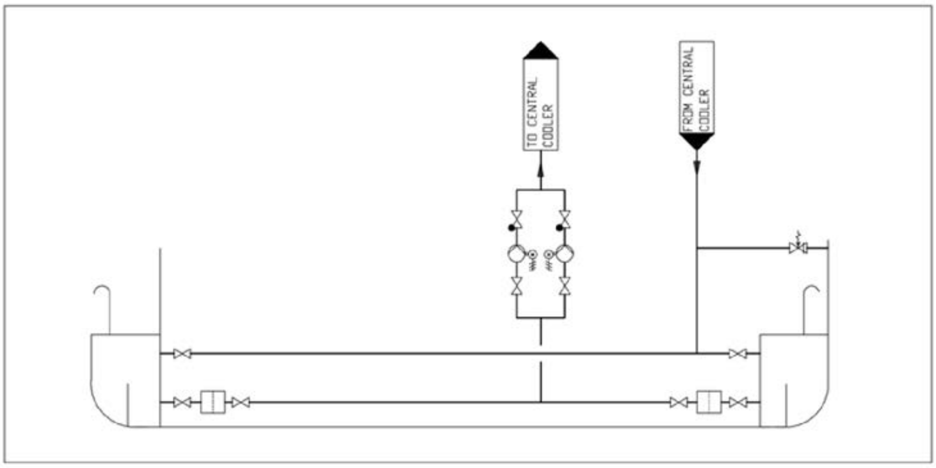


Fig 9-5 Example flow diagram of arctic sea water system

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

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

9.2.2 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*.

9.2.3 Sea water pump (4P11)

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

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

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

9.2.4 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 maximum inlet water temperature for those equipment is generally 38 °C. The set-point of the temperature control valve 4V08 can be up to 45 °C for the engine.

9.2.5 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.

9.2.6 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.

9.2.7 Coolers for other equipment and MDF coolers

The engine driven LT circulating pump can supply cooling water to one or two small coolers installed in parallel to the engine, for example a MDF cooler or a reduction gear cooler. This is only possible for engines operating on MDF, because the LT temperature control valve cannot be built on the engine to control the temperature after the engine. Separate circulating pumps are required for larger flows.

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

9.2.8 Fresh water central cooler (4E08)

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 (96°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 LT cooler	max. 38 °C
Fresh water temperature after HT cooler	max. 83 °C
Margin (heat rate, fouling)	15%

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.

9.2.9 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.

9.2.10 Air venting

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

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

The vent pipes must be continuously rising.

9.2.11 Expansion tank (4T05)

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

Design data:

Volume	min. 10% of the total system volume

NOTE

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

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

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

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

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

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

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

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

Table 9-1 Minimum diameter of balance pipe

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

9.2.12 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.

9.2.13 HT preheating

The cooling water circulating through the cylinders must be preheated to at least 60 °C, preferably 70 °C. This is an absolute requirement for installations that are designed to operate on heavy fuel, but strongly recommended also for engines that operate exclusively on marine diesel fuel.

The energy required for preheating of the HT cooling water can be supplied by a separate source or by a running engine, often a combination of both. In all cases a separate circulating pump must be used. It is common to use the heat from running auxiliary engines for preheating of main engines. In installations with several main engines the capacity of the separate heat source can be dimensioned for preheating of two engines, provided that this is acceptable for the operation of the ship. If the cooling water circuits are separated from each other, the energy is transferred over a heat exchanger.

9.2.13.1 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 5 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 2 kW/cyl is required to keep a hot engine warm.

Design data:	
Preheating temperature	min. 60°C for starts at LFO or gas; Min 70°C for startings at HFO
Required heating power	5 kW/cyl
Heating power to keep hot engine warm	2 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 = 1 kW

n_{cyl} = Number of cylinders

9.2.13.2 Circulation pump for HT preheater (4P04)

Design data:	
Delivery pressure	80...100 kPa (0.8...1.0 bar)

9.2.13.3 Preheating unit (4N01)

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

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

- Safety valve

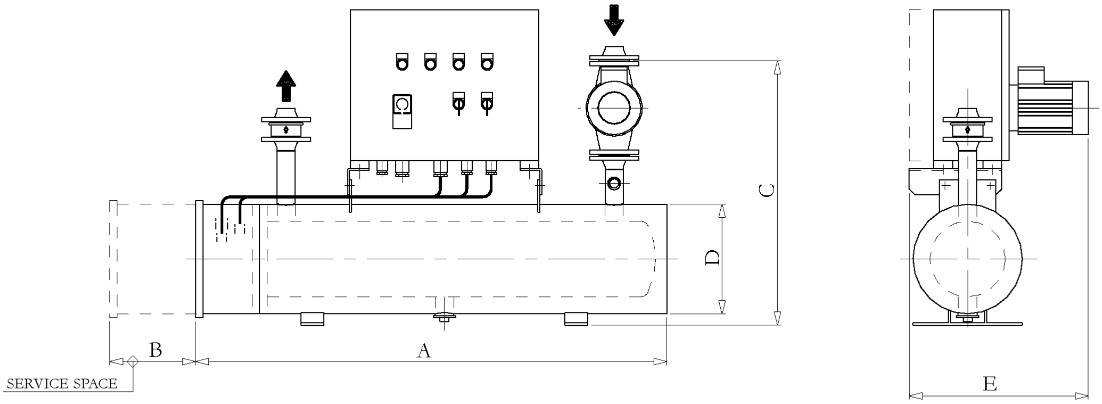


Fig 9-6 Preheating unit, electric (V60L0562C)

Heater capacity [kW]	Pump capacity [m³/h]		Weight [kg]	Pipe conn.	Dimensions [mm]				
	50 Hz	60 HZ		In/outlet	A	B	C	D	E
18	11	13	95	DN40	1250	900	660	240	460
22.5	11	13	100	DN40	1050	720	700	290	480
27	12	13	103	DN40	1250	900	700	290	480
30	12	13	105	DN40	1050	720	700	290	480
36	12	13	125	DN40	1250	900	700	290	480
45	12	13	145	DN40	1250	720	755	350	510
54	12	13	150	DN40	1250	900	755	350	510
72	12	13	187	DN40	1260	900	805	400	550
81	12	13	190	DN40	1260	900	805	400	550
108	12	13	215	DN40	1260	900	855	450	575

9.2.14 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.

9.2.15 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 applicable standards.

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

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.

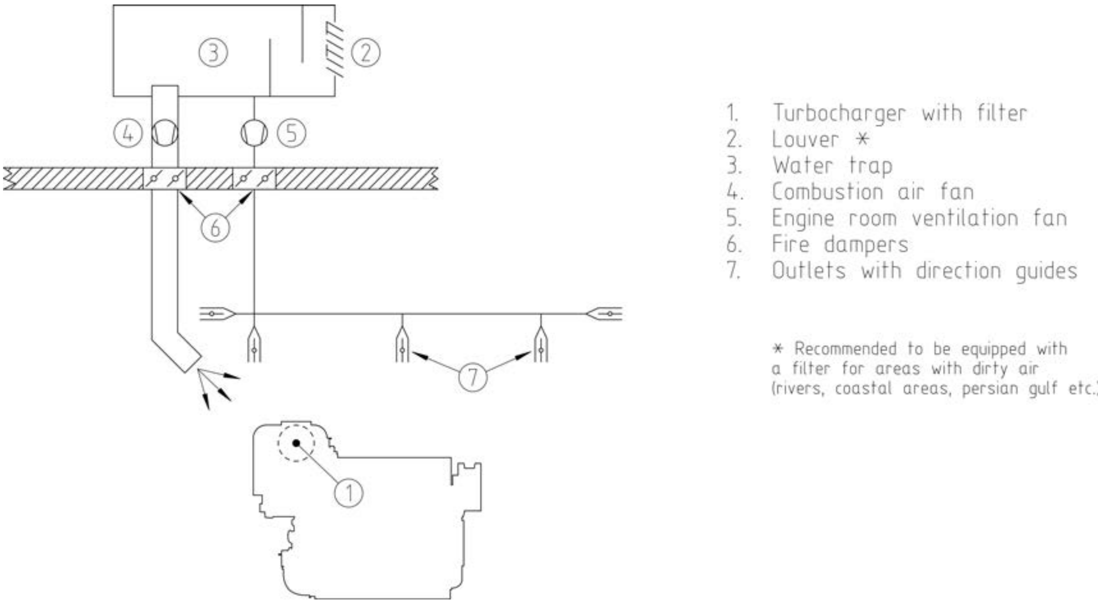


Fig 10-1 Engine room ventilation, turbocharger with air filter (DAAF391752)

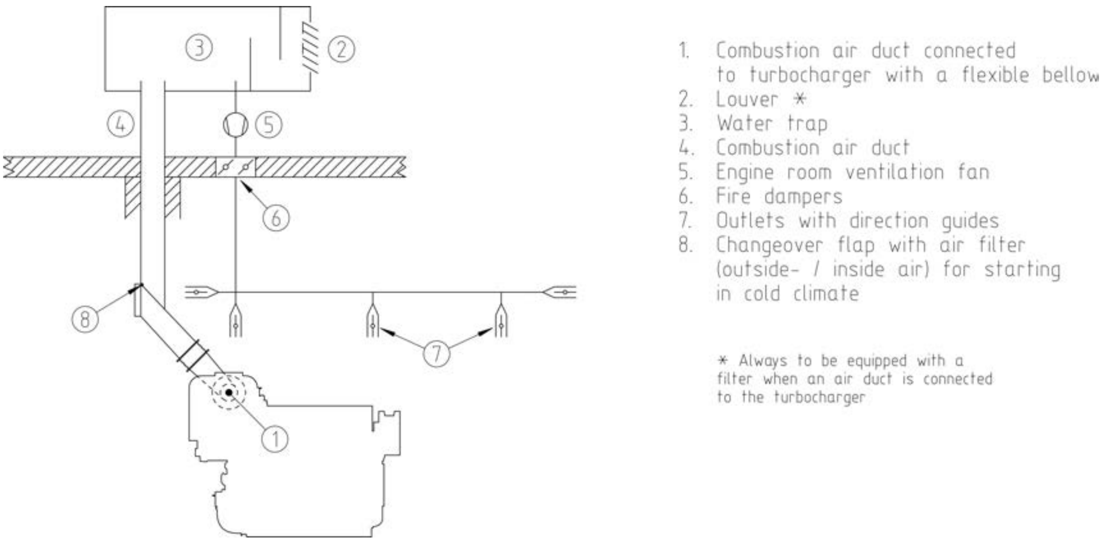


Fig 10-2 Engine room ventilation, air duct connected to the turbocharger (DAAF391711)

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 is equipped with an active dewpoint control to minimize condensation in the charge air coolers and -receiver, by raising the LT-cooling water temperature based on ambient humidity and charge air pressure. The engine is also equipped with a small drain pipe from the charge air cooler and receiver for possible condensed water. Humidity sensor is mounted in external system.

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11. Exhaust Gas System

11.1 Exhaust gas outlet

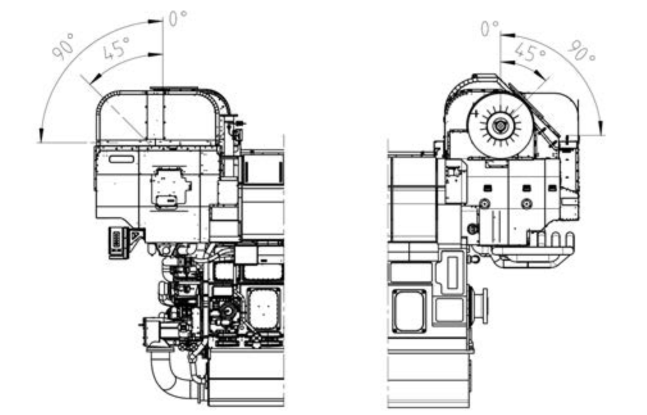

Fig 11-1 Exhaust pipe connections, W8V31 & W10V31 (DAAF343596A)

Engine	TC location	
	Free end	Driving end
W 8V31DF	0°, 45°, 90°	0°, 45°, 90°
W 10V31DF		

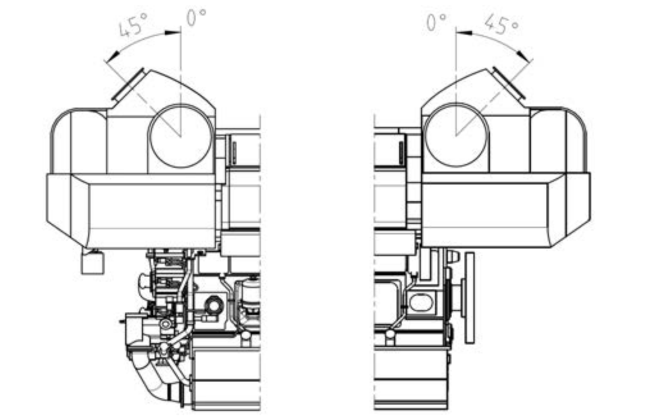

Fig 11-2 Exhaust pipe connections, W12V - W16V31 (DAAF343596A)

Engine	TC location	
	Free end	Driving end
W 12V31DF	0°, 45°	0°, 45°
W 14V31DF		
W 16V31DF		

NOTE

Pipe Connection 501 Exhaust Gas Outlet DIN86044, PN 6

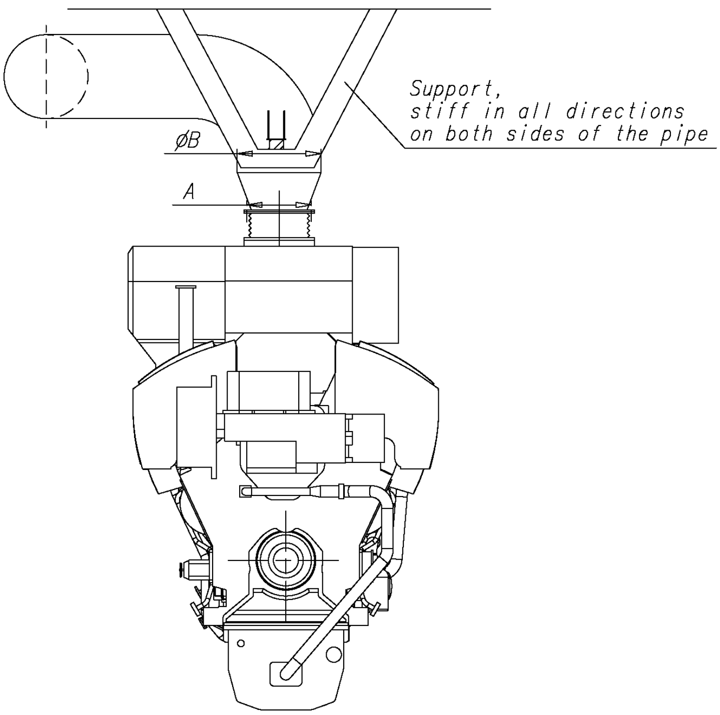

Fig 11-3 **Exhaust pipe, diameters and support (DAAF351047)**

Engine	A [mm]	ØB [mm]
W 8V31DF	DN550	700
W 10V31DF	DN550	800

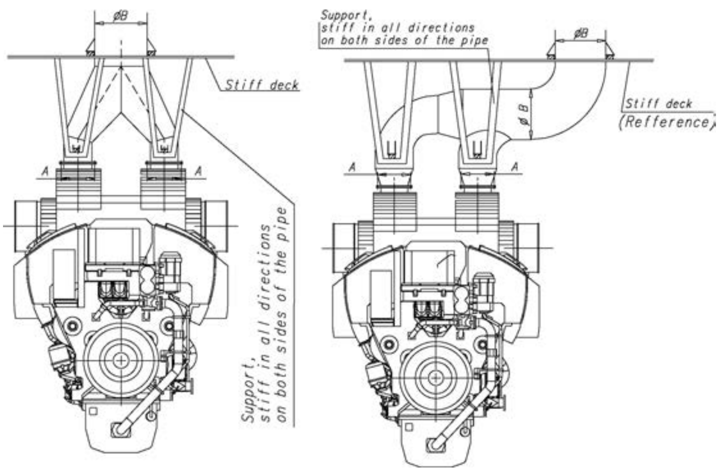

Fig 11-4 **Exhaust pipe, diameters and support (DAAF351275A, DAAF351507A)**

Engine	A [mm]	ØB [mm]
W 12V31DF	DN450	900
W 14V31DF	DN450	900
W 16V31DF	DN450	1000

11.2 External exhaust gas system

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

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

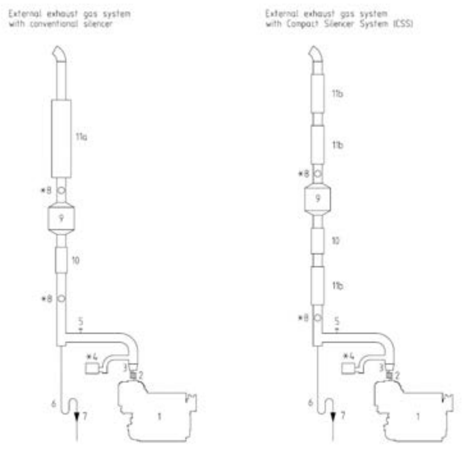

Fig 11-5 External exhaust gas system (DAAF391527)

1	Engine
2	Exhaust gas bellows
3	Transitions piece
4	Exhaust gas ventilation unit *
5	Connection for measurement of back pressure
6	Drain with water trap, continuosuly open
7	Bilge
8	Rupture disc *
9	Selective Catalytic Reactor (SCR)
10	Urea injection unit (SCR)
11a	Silencer with spark arrestor
11b	CSS silencer element

NOTE

* Only applicable for DF installations

11.2.1 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. 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.

11.2.2 Exhaust gas ventilation unit (5N01)

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

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

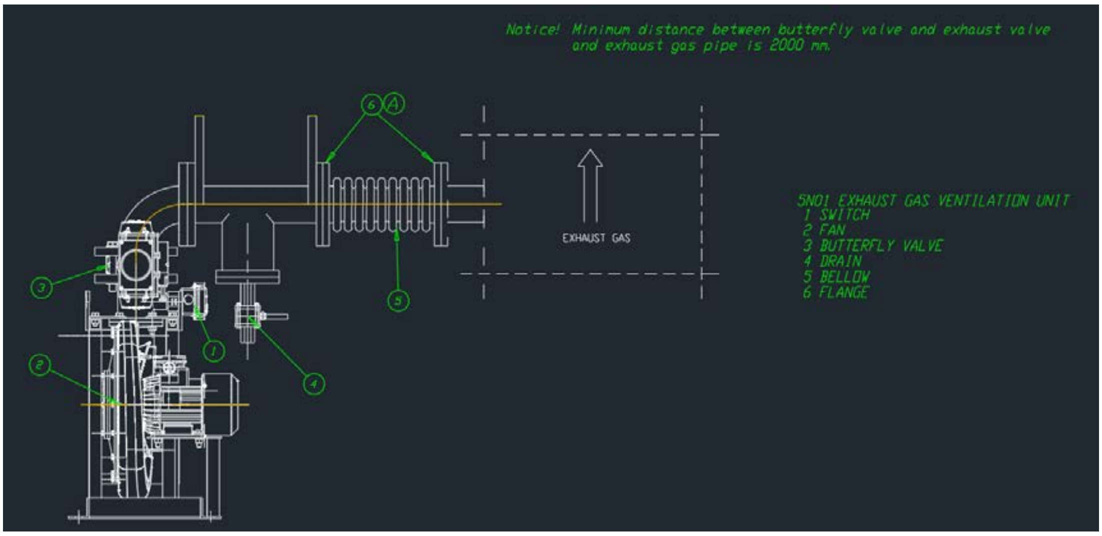

Fig 11-6 Exhaust gas ventilation arrangement (DAAF315146A)

11.2.3 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.

11.2.4 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.

11.2.5 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.

11.2.6 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.

11.2.7 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.

11.2.8 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.*

11.2.9 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.

11.2.10 Exhaust gas silencers

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

11.2.10.1 Exhaust noise

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

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

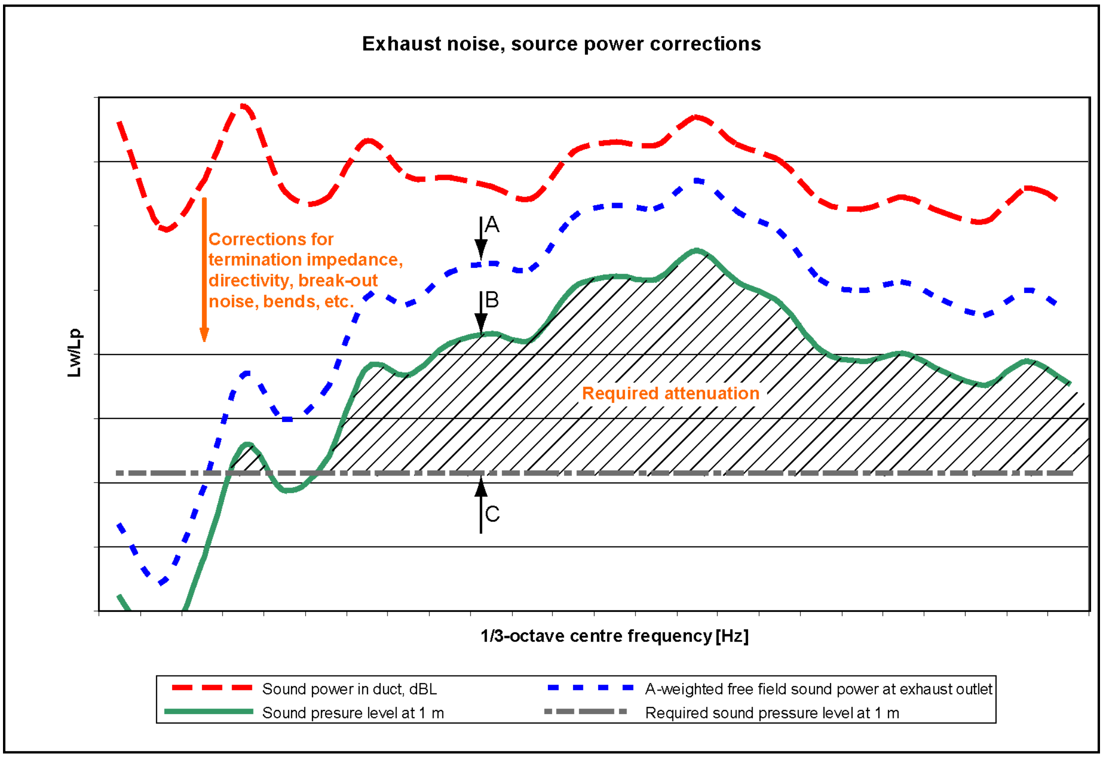

Fig 11-7 Exhaust noise, source power corrections

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

11.2.10.2 Silencer system comparison

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

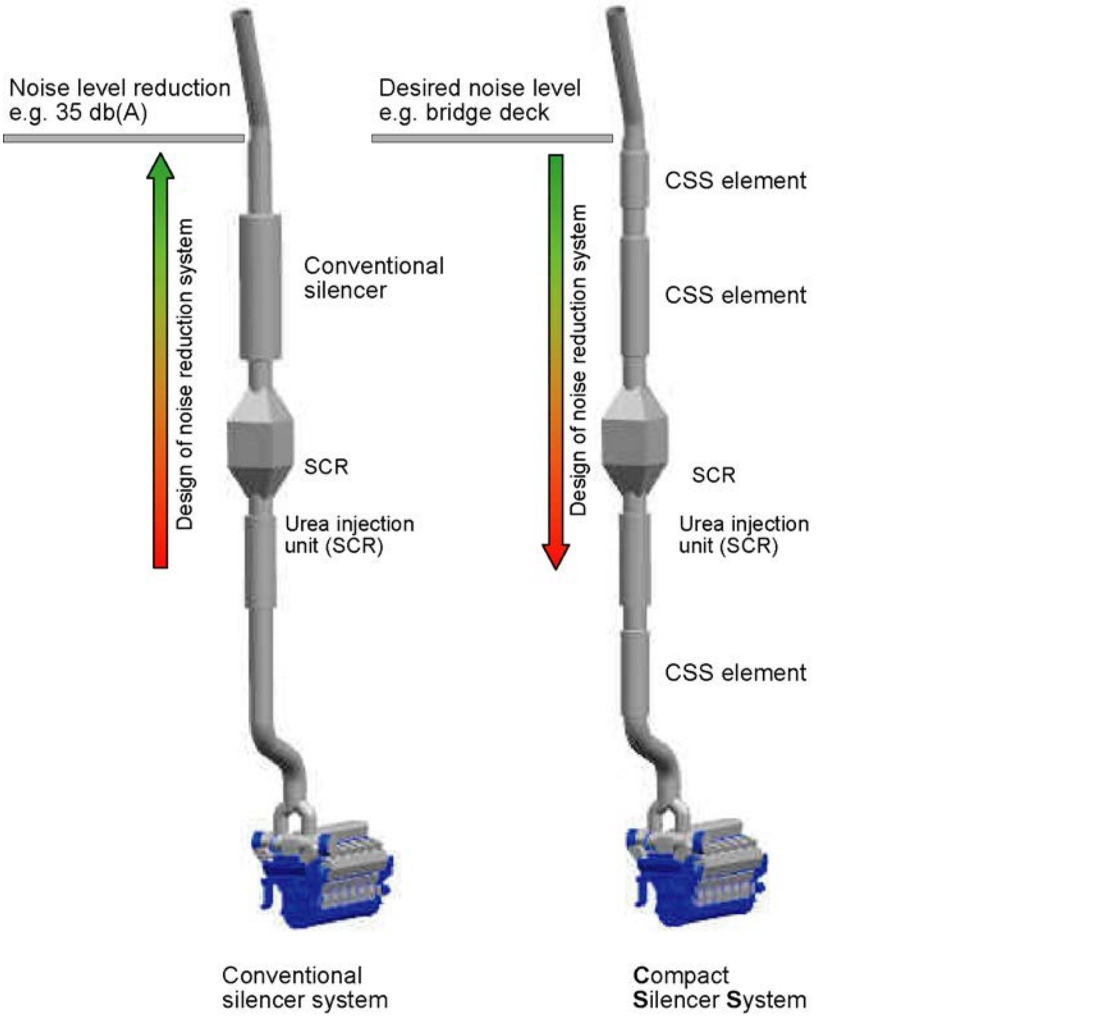

Fig 11-8 Silencer system comparison

11.2.10.3 Compact silencer system (5N02)

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

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

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

11.2.10.4 Conventional exhaust gas silencer (5R02)

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

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

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

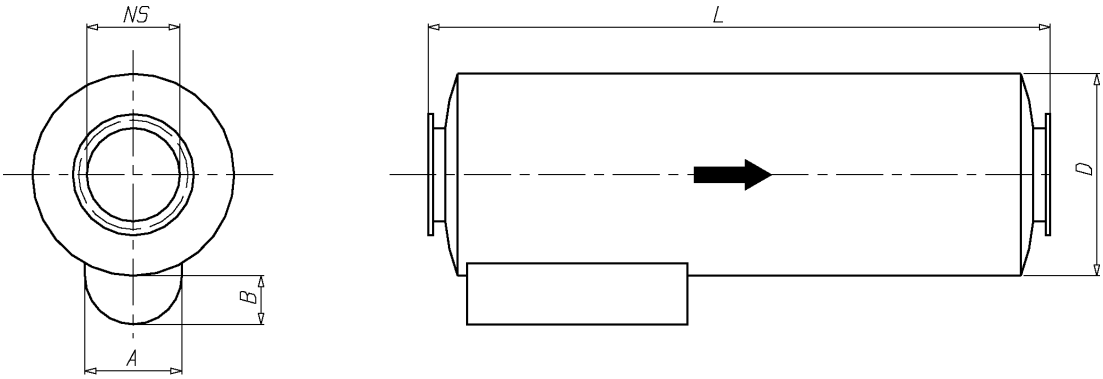

Fig 11-9 Exhaust gas silencer

Table 11-1 Typical dimensions of exhaust gas silencers

NS	D	A	B	Attenuation: 35 dB(A) L	Weight [kg]
700	1600	745	270	7260	2370
800	1800	840	280	7540	2995
900	1900	950	285	8060	3560
1000	2000	970	330	8310	4300

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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

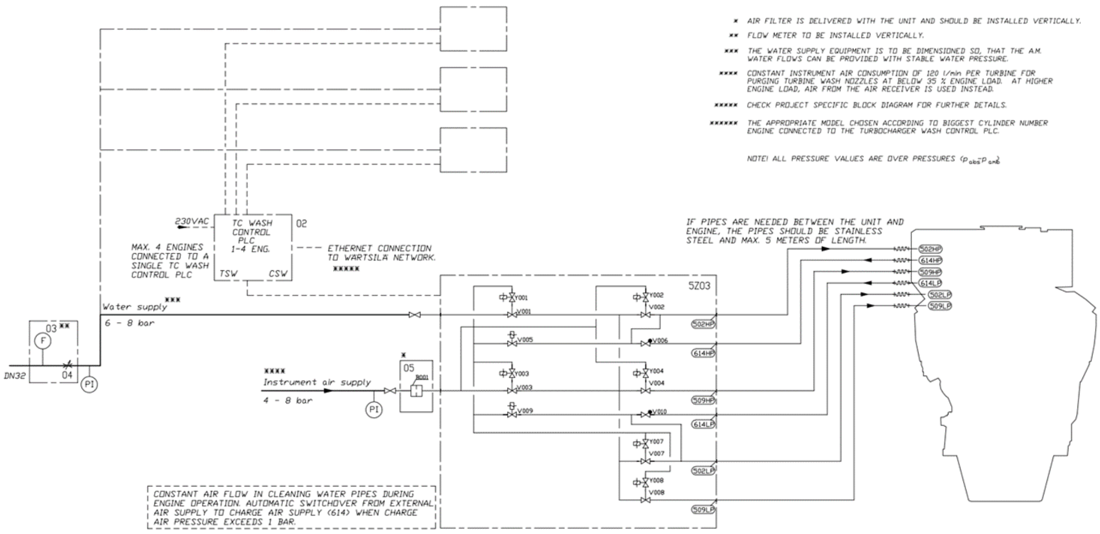

Fig 12-1 Turbocharger cleaning system (DAAF347567B)

System components		Pipe connections	
5Z03	TC cleaning device	502##	Cleaning water to turbine
02	Wärtsilä control unit for 4 engines	509##	Cleaning water to compressor
03******	Flow meter/control (7,5 - 40 l/min), if 8V - 10V	614##	Scavenging air outlet to TC cleaning valve unit
03******	Flow meter/control (10 - 85 l/min), if 12V - 16V		
04	Flow adjustment valve, built in		
05	Air filter		

Engine	Water	
Turbine / compressor	Water inlet flow rate (l/min)	Water consumption/wash (l)
LP-compressor	6.5	1
LP-turbine	18	180
HP-compressor	6.5	1
HP-turbine	22	220

12.2 Compressor cleaning system

The compressor side of the turbocharger is cleaned with the same equipment as the turbine.

NOTE

If the turbocharger suction air is below +5 °C, washing is not possible.

13. Exhaust Emissions

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

13.1 Dual fuel engine exhaust components

Due to the high efficiency and the clean fuel used in a dual fuel engine in gas mode, the exhaust gas emissions when running on gas are extremely low. In a dual fuel engine, the air-fuel ratio is very high, and uniform throughout the cylinders. Maximum temperatures and subsequent NOx formation are therefore low, since the same specific heat quantity released to combustion is used to heat up a large mass of air. Benefitting from this unique feature of the lean-burn principle, the NOx emissions from the Wärtsilä DF engine is very low, complying with most existing legislation. In gas mode most stringent emissions of IMO 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 1 ~ 2% diesel fuel injected at nominal load. Thus the emissions of SOx from the dual fuel engine are negligable. When the engine is in diesel operating mode, the emissions are in the same range as for any ordinary diesel engine, and the engine will be delivered with an EIAPP certificate to show compliance with the MARPOL Annex VI.

13.2 Marine exhaust emissions legislation

13.2.1 International Maritime Organization (IMO)

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

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

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

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

13.2.2 Other Legislations

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

13.3 Methods to reduce exhaust emissions

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

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

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

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

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

14. Automation System

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

The distributed modules communicate over an internal communication bus.

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

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

14.1 Technical data and system overview

14.1.1 Ingress protection

The ingress protection class of the system is IP54 if not otherwise mentioned for specific modules.

14.1.2 Ambient temp for automation system

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

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

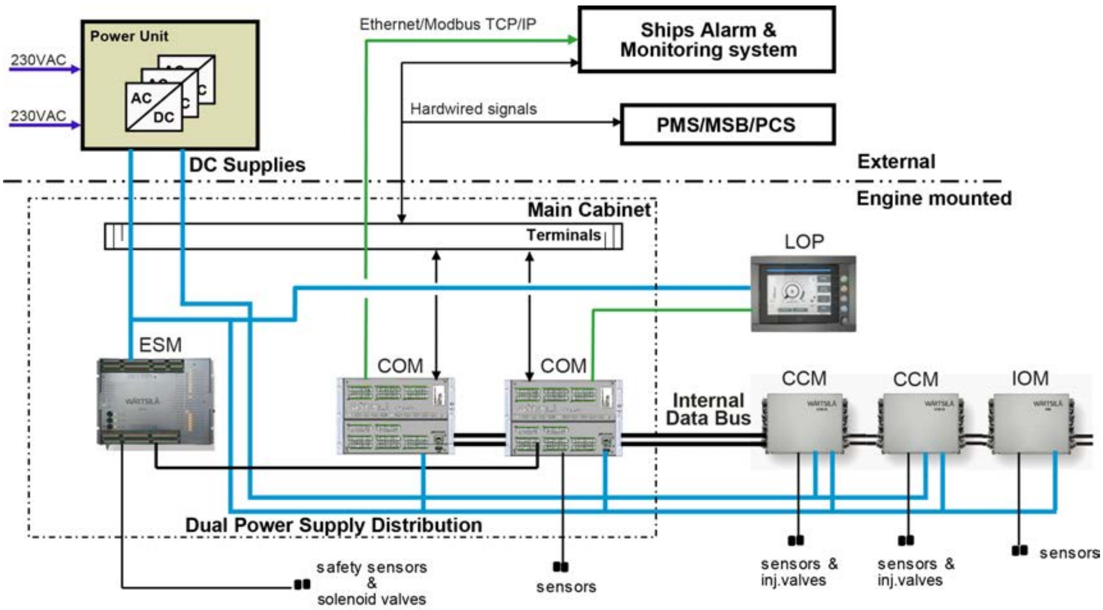

Fig 14-1 Architecture of UNIC

Short explanation of the modules used in the system:

COM Communication Module. Handles strategic control functions (such as start/stop sequencing and speed/load control, i.e. "speed governing") of the engine.
The communication modules handle engine internal and external communication, as well as hardwired external interfaces.

LOP	The LOP (local operator panel) shows all engine measurements (e.g. temperatures and pressures) and provides various engine status indications as well as an event history.
IOM	Input/Output Module handles measurements and limited control functions in a specific area on the engine.
CCM	Cylinder Control Module handles fuel injection control and local measurements for the cylinders.
ESM	Engine Safety Module handles fundamental engine safety, for example shutdown due to overspeed or low lubricating oil pressure.

The above equipment and instrumentation are prewired on the engine.

14.1.3 Local operator panel

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

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

  The following control functions are available:

  - Local/remote control selection

  - Local start & stop

  - Trip & Shutdown reset

  - Emergency stop

- Local emergency speed setting (mechanical propulsion):
- Local emergency stop

Fig 14-2 Local operator panel

14.1.4 Engine safety system

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

Main features:

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

14.1.5 Power unit

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

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

Power supply from ship's system:

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

14.1.6 Ethernet communication unit

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

14.1.7 Cabling and system overview

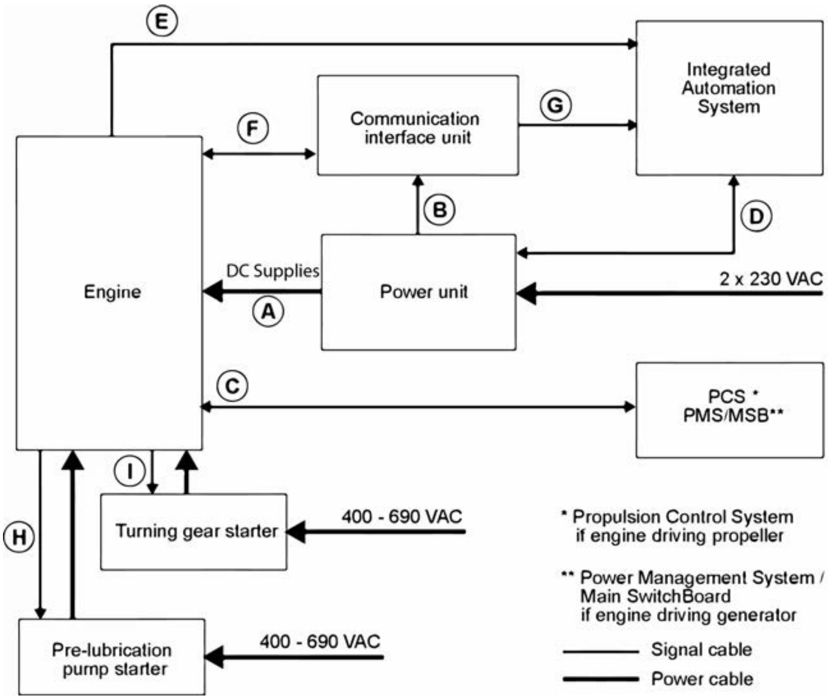

Fig 14-3 UNIC overview

Table 14-1 Typical amount of cables

Cable	From <=> To	Cable types (typical)
A	Engine <=> Power Unit	2 x 4 mm^2 (power supply) * 2 x 4 mm^2 (power supply) * 2 x 4 mm^2 (power supply) * 2 x 4 mm^2 (power supply) * 2 x 4 mm^2 (power supply) * 2 x 4 mm^2 (power supply) * 2 x 4 mm^2 (power supply) * 2 x 4 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
F	Engine => Communication interface unit	1 x Ethernet CAT 5
G	Communication interface unit => Integrated automation system	1 x Ethernet CAT 5
H	Engine => Pre-lubrication pump starter	2 x 0.75 mm^2
I	Engine => Turning gear starter	1 x CAN bus (120 ohm)

Cable	From <=> To	Cable types (typical)
I	Gas Valve Unit <=> Integrated Automation System	2 x 2 x 0.75 mm^2 1 x Ethernet CAT5
I	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
I	Gas Valve Unit <=> Fuel gas supply system	4 x 2 x 0.75 mm^2
I	Gas Valve Unit <=> Gas detection system	1 x 2 x 0.75 mm^2
I	Power unit <=> Gas Valve Unit	2 x 4 mm^2 (power supply) * 2 x 4 mm^2 (power supply) * 3 x 2 x 0.75 mm^2
I	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
I	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*.

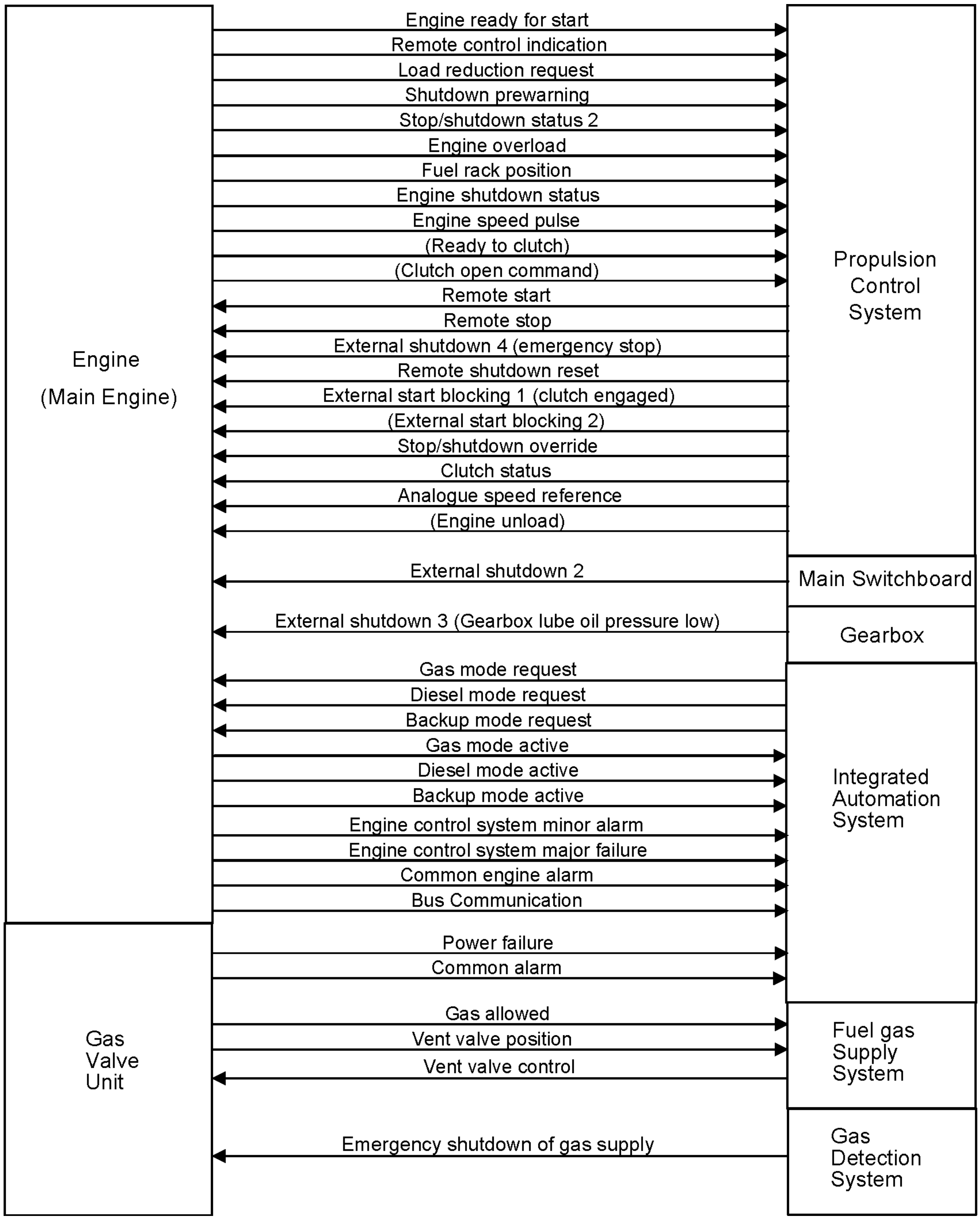

Fig 14-4 Typical signal overview (Main engine)

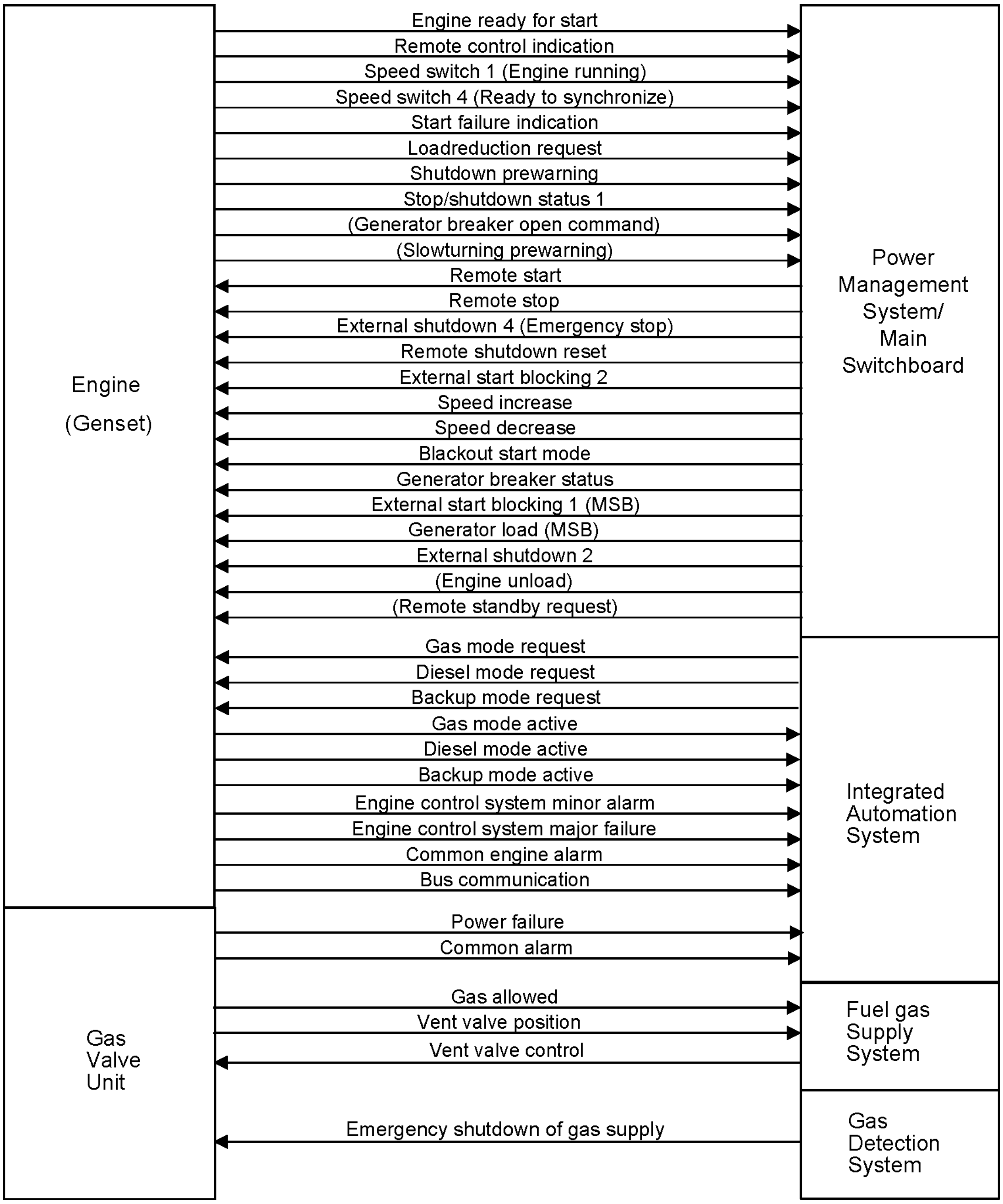

Fig 14-5 Typical signal overview (Generating set)

14.2 Functions

14.2.1 Start

14.2.1.1 Start blocking

Starting is inhibited by the following functions:

- Turning device engaged
- Pre-lubricating pressure low (override if black-out input is high and within last 30 minutes after the pressure has dropped below the set point of 0.8 bar)
- Stop signal to engine activated (safety shut-down, emergency stop, normal stop)
- External start block active

- Exhaust gas ventilation not performed
- HFO selected or fuel oil temperature > 70°C (Gas mode only)
- Charge air shut-off valve closed (optional device)

14.2.1.2 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
- 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.

14.2.1.3 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.

14.2.1.4 Start in blackout mode

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

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

14.2.2 Gas/diesel transfer control

14.2.2.1 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).

14.2.2.2 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.

NOTE

Transfer sequence from liquid to gas mode passes through LFO operation to engusre back-up fuel system is flushed clean of HFO. HFO to LFO transfer time is depend on the design of external fuel system and HFO viscosity. Usually HFO to LFO transfer takes about 30 minutes.

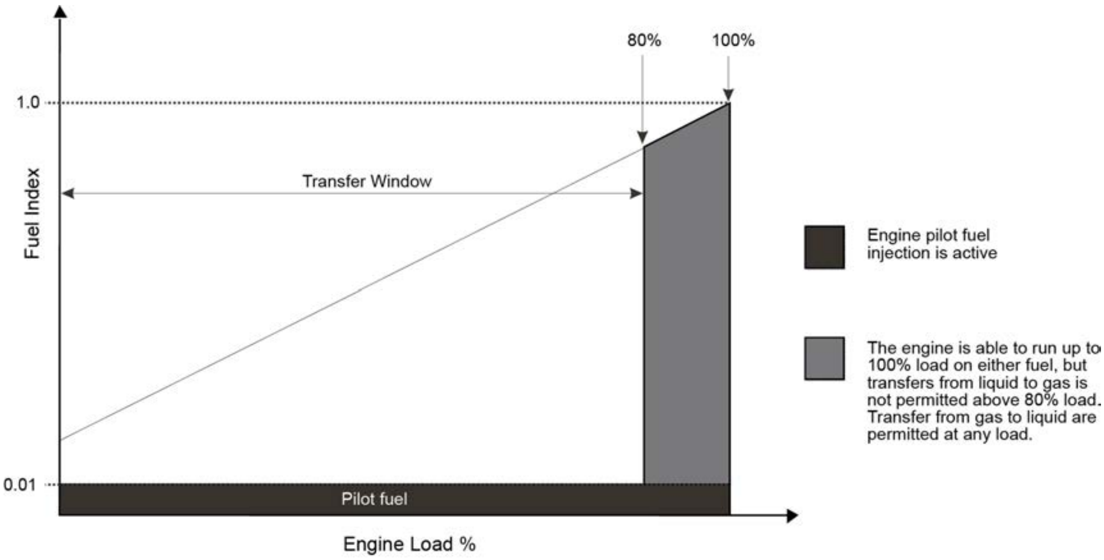

Fig 14-6 Operating modes are load dependent

14.2.2.3 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

14.2.3 Stop, shutdown and emergency stop

14.2.3.1 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.

14.2.3.2 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.

14.2.3.3 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.

14.2.4 Speed control

14.2.4.1 Main engines (mechanical propulsion)

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

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

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

14.2.4.2 Generating sets

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

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

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

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

14.3 Alarm and monitoring signals

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

14.4 Electrical consumers

14.4.1 Motor starters and operation of electrically driven pumps

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

14.4.1.1 Engine turning device (9N15)

The crankshaft can be slowly rotated with the turning device for maintenance purposes and for engine slowturning. The engine turning device is controlled with an electric motor via a frequency converter. The frequency converter is to be mounted on the external system. The electric motor ratings are listed in the table below.

Table 14-2 Electric motor ratings for engine turning device

Engine type	Voltage [V]	Frequency [Hz]	Power [kW]	Current [A]
Wärtsilä 31DF	3 x 400 - 690V	50 / 60	7.5	10 - 6A

14.4.1.2 Pre-lubricating oil pump

The pre-lubricating oil pump must always be running when the engine is stopped. 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.

Electric motor ratings are listed in the table below.

Table 14-3 Electric motor ratings for pre-lubricating pump

Engine type	Voltage [V]	Frequency [Hz]	Power [kW]	Current [A]
W31	3 x 400	50	15.0	28.4
	3 x 440	60	15.0	25.7

14.4.1.3 Exhaust gas ventilation unit

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

14.4.1.4 Gas valve unit (GVU)

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

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

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

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

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

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

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

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

14.4.1.8 Circulating pump for preheater (4P04)

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

14.5 System requirements and guidelines for diesel-electric propulsion

Typical features to be incorporated in the propulsion control and power management systems in a diesel-electric ship:

1. The load increase program must limit the load increase rate during ship acceleration and load transfer between generators according to the curves in chapter *2.2 Loading Capacity*.

- Continuously active limit: “normal max. loading in operating condition”.
- During the first 6 minutes after starting an engine: “preheated engine”

If the control system has only one load increase ramp, then the ramp for a preheated engine is to be used.

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, if the load sharing is based on speed droop. In a system with isochronous load sharing the loading rate of a recently connected generator is not affected by changes in the total system load (as long as the generators already sharing load equally are not loaded over 100%).

2. Rapid loading according to the “emergency” curve in chapter *2.2 Loading Capacity* may only be possible by activating an emergency function, which generates visual and audible alarms in the control room and on the bridge.

3. The propulsion control should be able to control the propulsion power according to the load increase rate at the diesel generators. Controlled load increase with different number of generators connected and in different operating conditions is difficult to achieve with only time ramps for the propeller speed.

4. The load reduction rate should also be limited in normal operation. Crash stop can be recognised by for example a large lever movement from ahead to astern.

5. Some propulsion systems can generate power back into the network. The diesel generator can absorb max. 5% reverse power.

6. The power management system performs loading and unloading of generators in a speed droop system, and it usually also corrects the system frequency to compensate for the droop offset, by adjusting the speed setting of the individual speed control units. The speed reference is adjusted by sending an increase/decrease pulse of a certain length to the speed control unit. The power management should determine the length of the increase/decrease pulse based on the size of the desired correction and then wait for 30 seconds or more before performing a new correction, in particular when performing small corrections.

The relation between duration of increase/decrease signal and change in speed reference is usually 0.1 Hz per second. The actual speed and/or load will change at a slower rate.

7. The full output of the generator is in principle available as soon as the generator is connected to the network, but only if there is no power limitation controlling the power demand. In practice the control system should monitor the generator load and reduce the system load, if the generator load exceeds 100%.

In speed droop mode all generators take an equal share of increased system load, regardless of any difference in initial load. If the generators already sharing load equally are loaded beyond their max. capacity, the recently connected generator will continue to pick up load according to the speed droop curve. Also in isochronous load sharing mode a generator still on the loading ramp will start to pick up load, if the generators in even load sharing have reached their max. capacity.

8. The system should monitor the network frequency and reduce the load, if the network frequency tends to drop excessively. To safely handle tripping of a breaker more direct action can be required, depending on the operating condition and the load step on the engine(s).

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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.

The holding down bolts are through-bolts with a lock nut at the lower end and a hydraulically tightened nut at the upper end. The tool included in the standard set of engine tools is used for hydraulic tightening of the holding down bolts. Two of the holding down bolts are fitted bolts and the rest are clearance bolts. The two Ø43H7/n6 fitted bolts are located closest to the flywheel, one on each side of the engine.

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

The design of the holding down bolts is shown in the foundation drawings. It is recommended that the bolts are made from a high-strength steel, e.g. 42CrMo4 or similar. A high strength material makes it possible to use a higher bolt tension, which results in a larger bolt elongation (strain). A large bolt elongation improves the safety against loosening of the nuts.

To avoid sticking during installation and gradual reduction of tightening tension due to unevenness in threads, the threads should be machined to a finer tolerance than normal threads. The bolt thread must fulfil tolerance 6g and the nut thread must fulfil tolerance 6H. In order to avoid bending stress in the bolts and to ensure proper fastening, the contact face of the nut underneath the seating top plate should be counterbored.

Lateral supports must be installed for all engines. One pair of supports should be located at flywheel 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 permissible value, which is determined by the type of resin and the requirements of the classification society. It is recommended to select a resin type that is approved by the relevant classification society for a total surface pressure of 5 N/mm^2. (A typical conservative value is Ptot 3.5 N/mm^2).

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

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

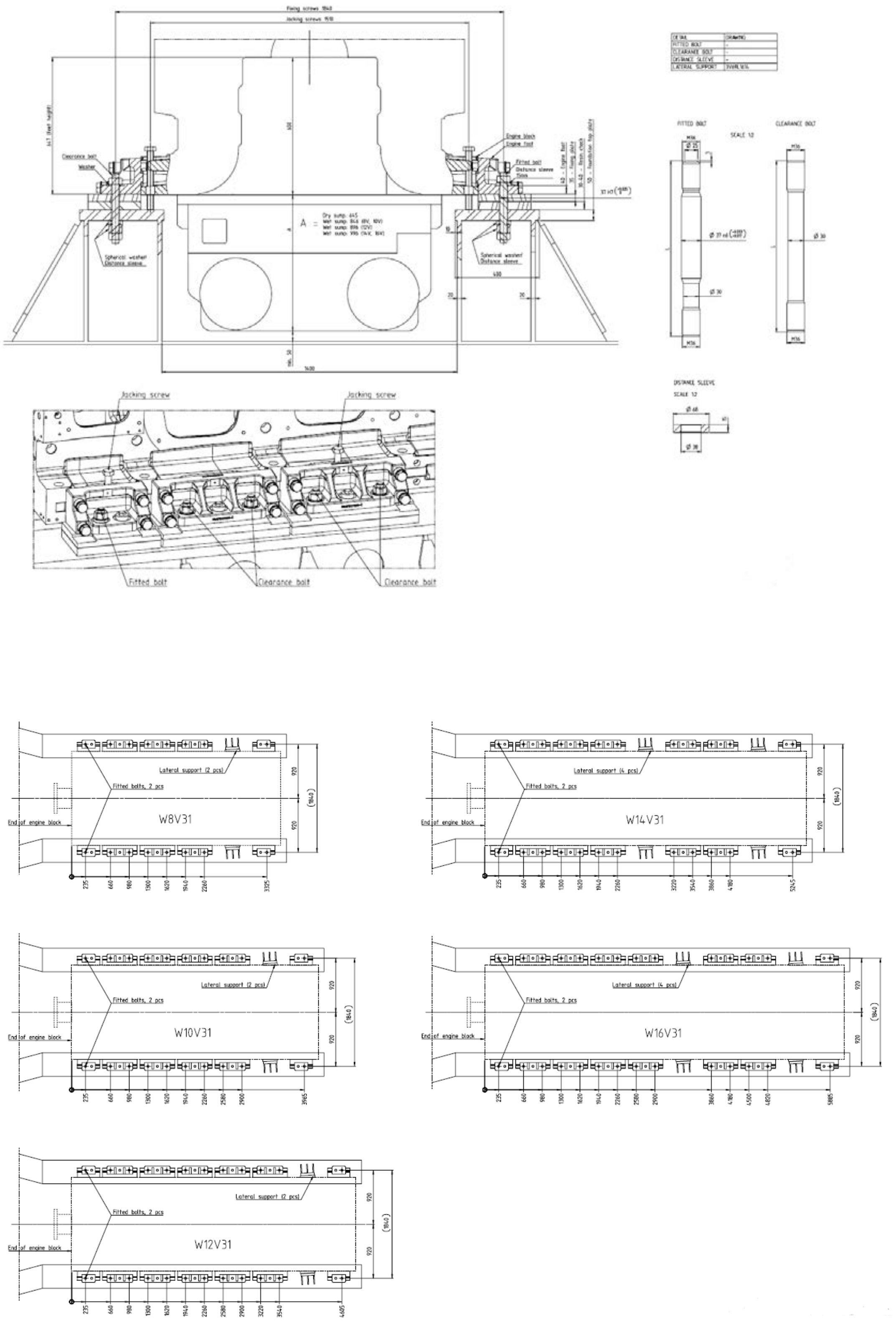


Fig 15-1 Fixed mounting with resin chocks (DAAF464160A)

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 chock dimensions are 250 x 200 mm and the chocks must have an inclination of 1:100, inwards with regard to the engine centre line. The cut-out in the chocks for the clearance bolts shall be 44 mm (M42 bolts), while the hole in the chocks for the fitted bolts shall be drilled and reamed to the correct size (Ø43H7) when the engine is finally aligned to the reduction gear.

The design of the holding down bolts is shown the foundation drawings. 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.

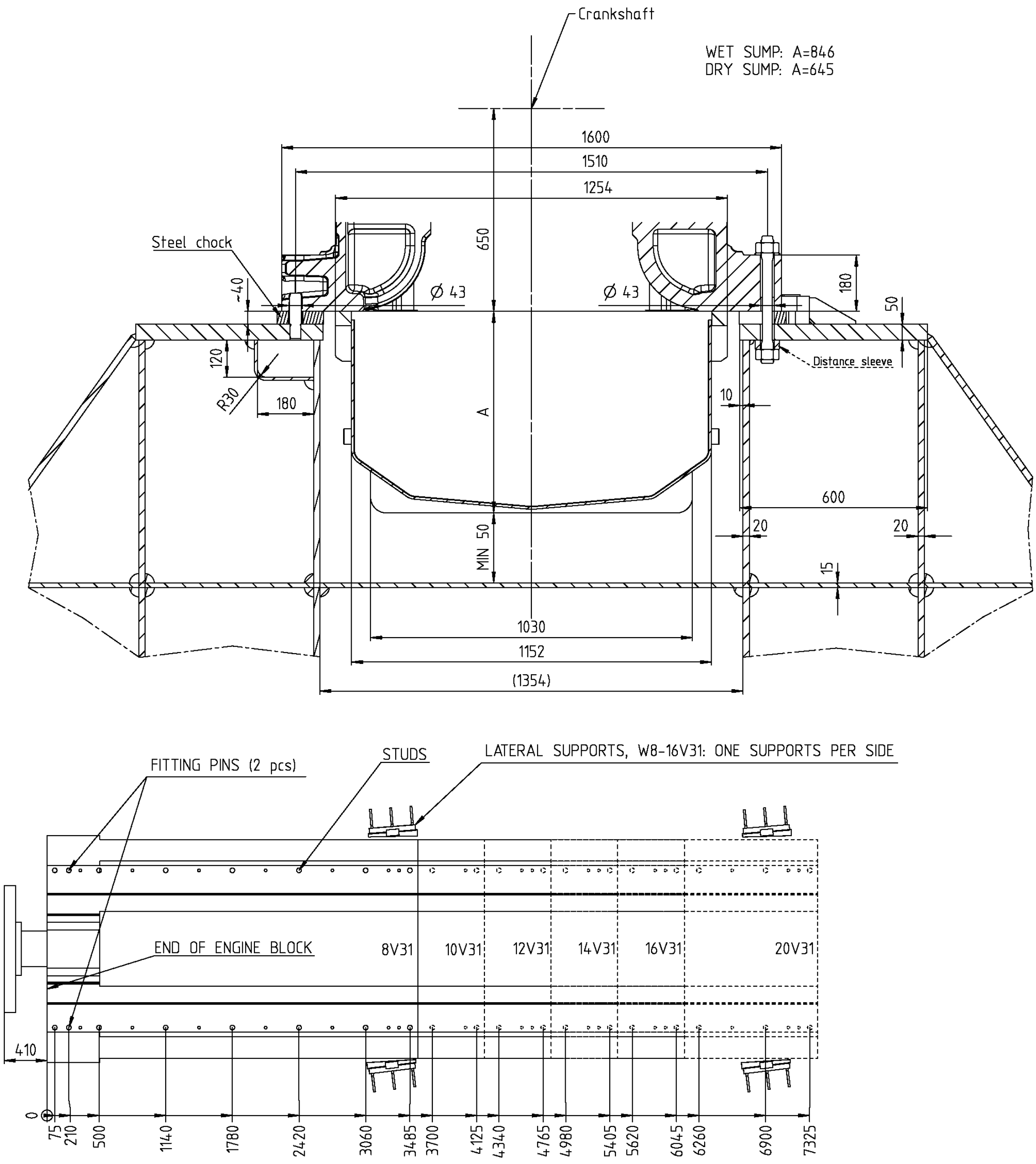
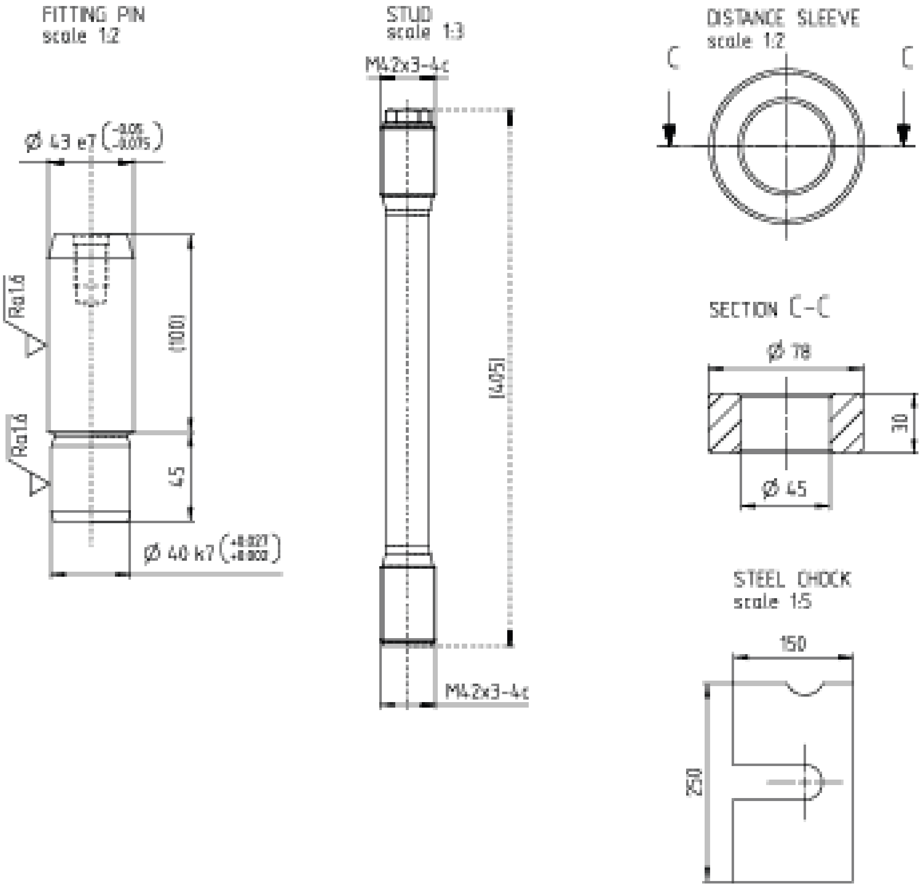


Fig 15-2 Main engine seating and fastening, steel chocks (DAAF343802)



15.2.1.3 Steel chocks with adjustable height

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

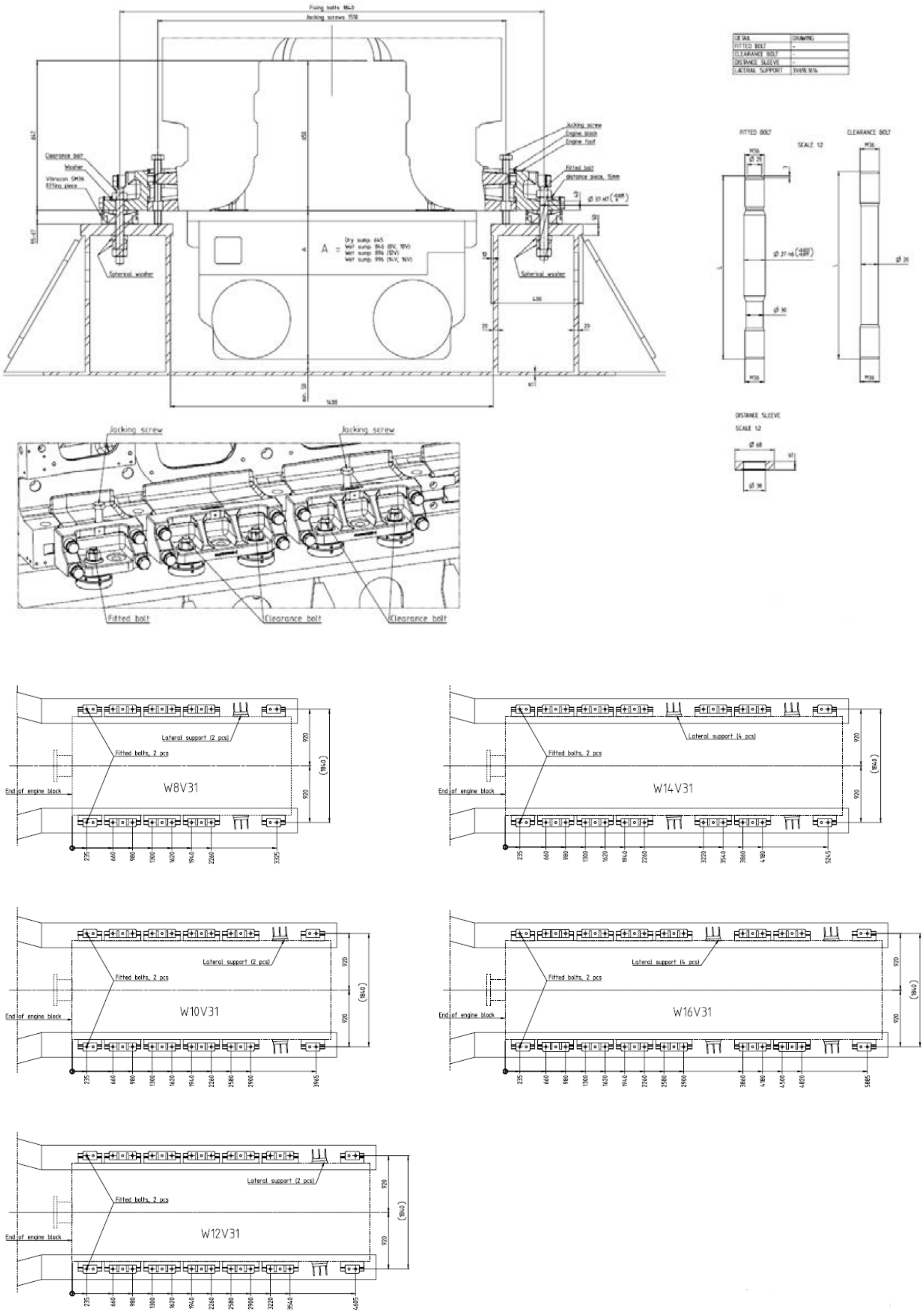


Fig 15-3 Adjustable steel chocks (DAAF448433A)

15.2.2 Resilient mounting

In order to reduce vibrations and structure borne noise, main engines can be resiliently mounted on rubber elements. The transmission of forces emitted by the engine is 10-20% when using resilient mounting. For resiliently mounted engines a speed range of 500-750 rpm is generally available.

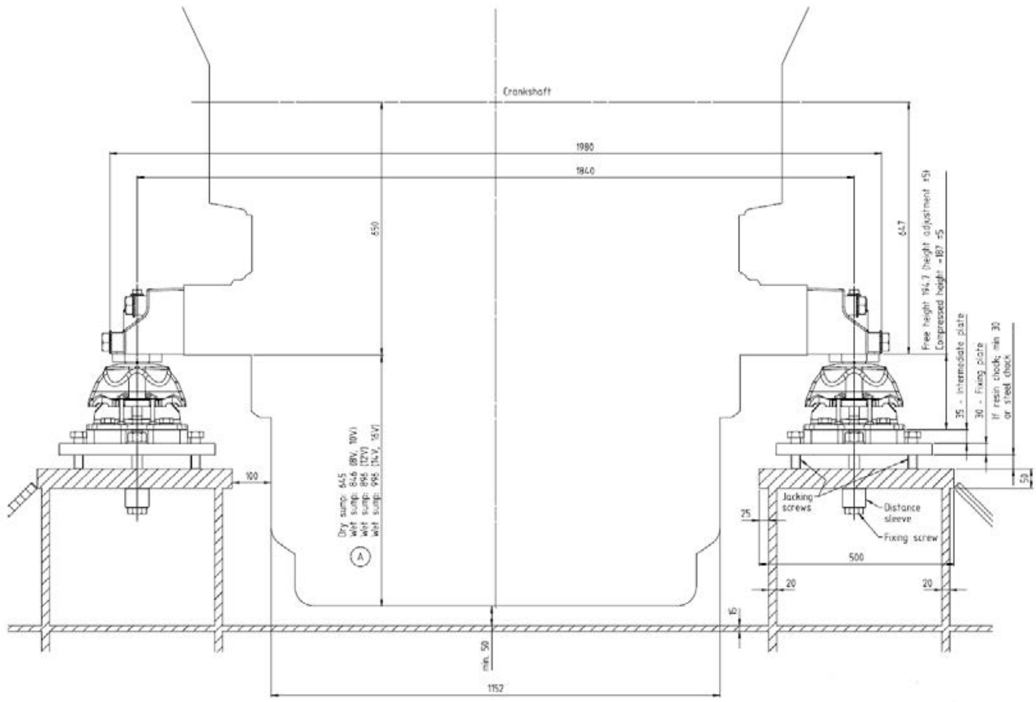


Fig 15-4 Principle of resilient mounting (DAAF409395A)

15.3 Mounting of generating sets

15.3.1 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.

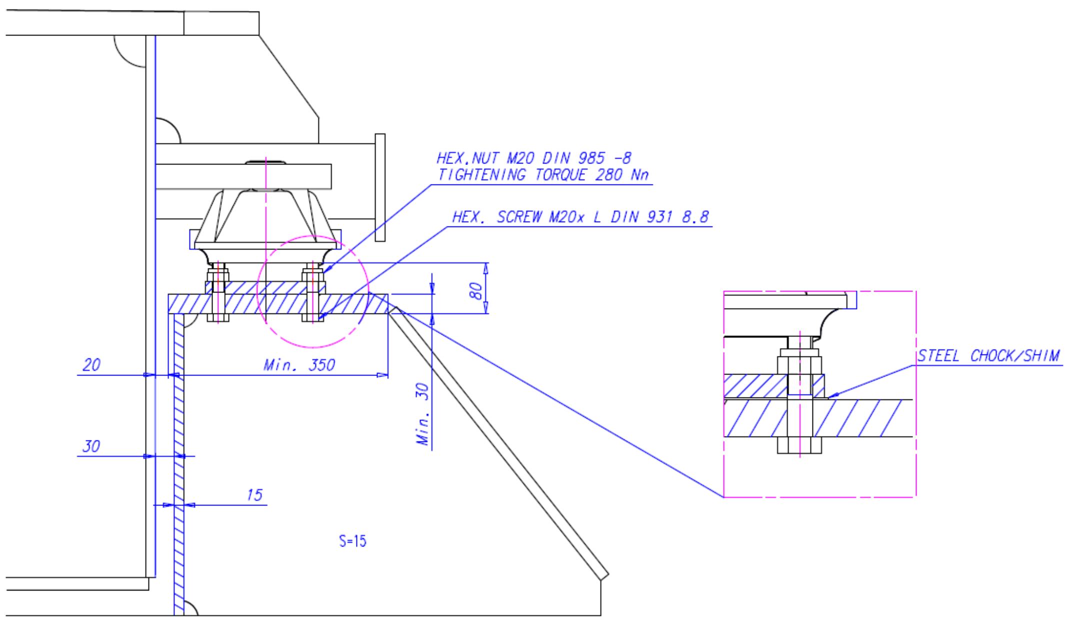


Fig 15-5 Recommended design of the generating set seating, Inline engines (V46L0295D)

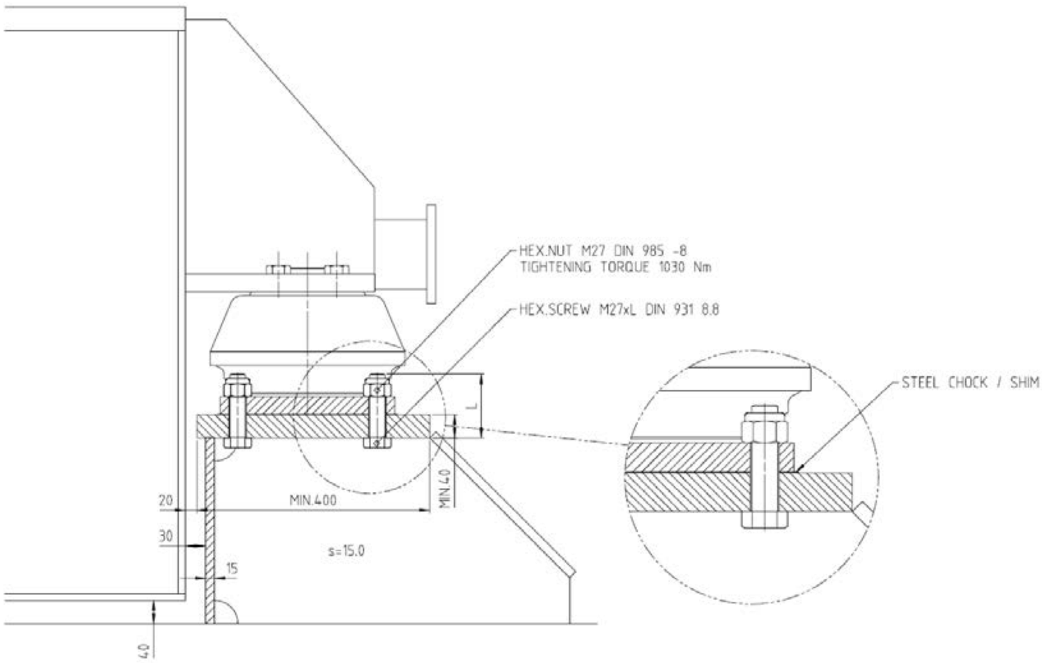


Fig 15-6 Recommended design of the generating set seating, V engines (DAAE020067B)

15.3.1.1 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 the 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. For the foundation design, see drawing 3V46L0294.

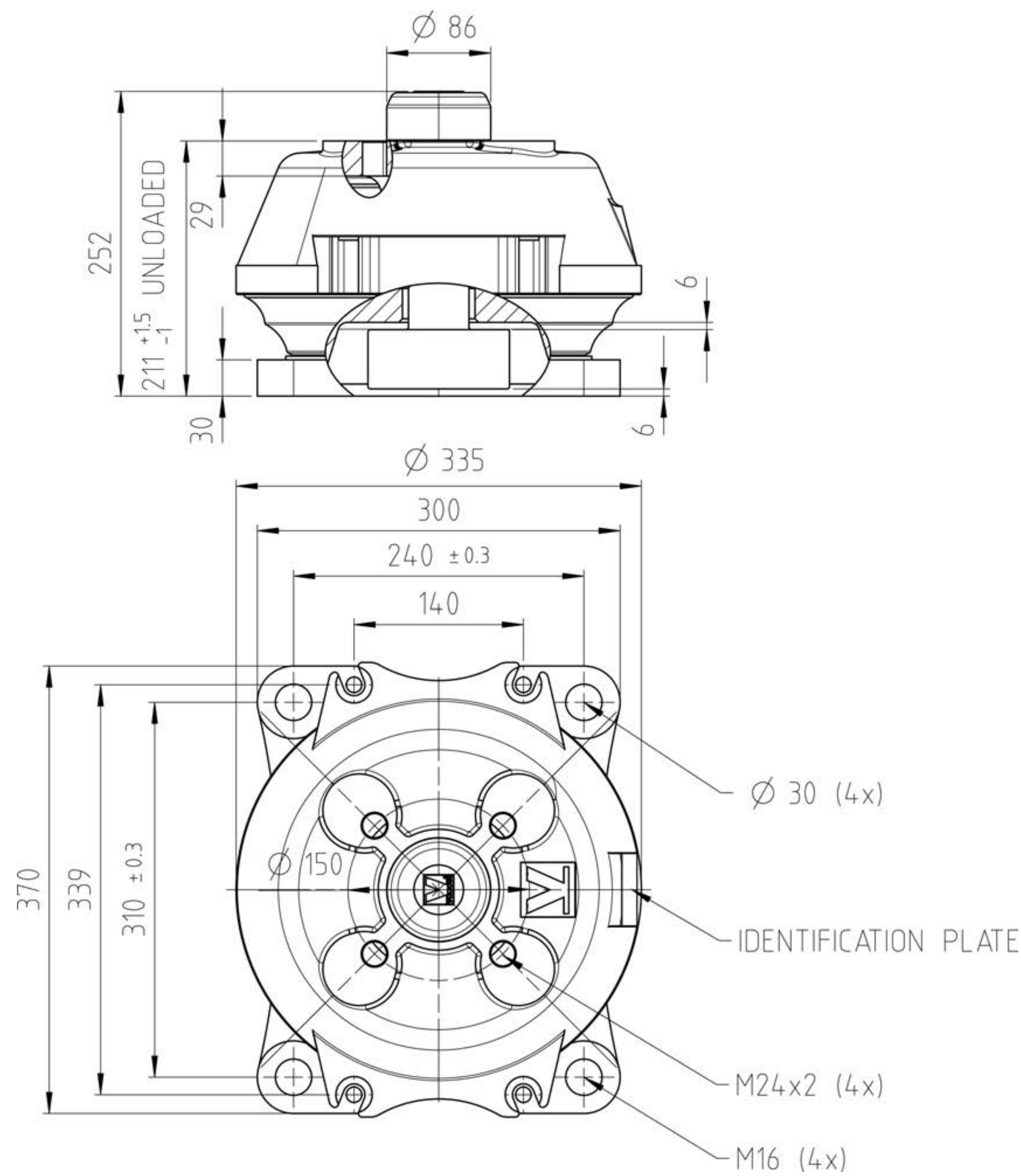


Fig 15-7 Rubber mount, (DAAE018766C)

15.4 Flexible pipe connections

When the engine or generating set is resiliently installed, all connections must be flexible and no grating nor ladders may be fixed to the engine or 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

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 & 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.

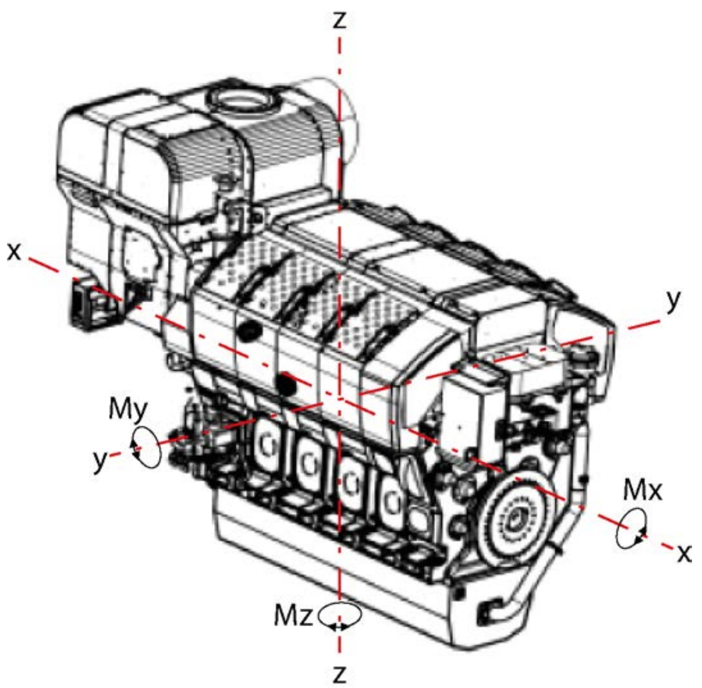


Fig 16-1 External forces, couples, variations

Table 16-1 External forces

Engine	Speed [RPM]	Freq. [Hz]	F_Y [kN]	F_Z [kN]	Freq. [Hz]	F_Y [kN]	F_Z [kN]	Freq. [Hz]	F_Y [kN]	F_Z [kN]
8V31DF	720 750	24 25	--- ---	--- ---	48 50	2 2	1 1	--- ---	--- ---	--- ---
10V31DF	720 750	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---
12V31DF	720 750	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---
14V31DF	720 750	48 50	4 5	2 2	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---
16V31DF	720 750	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---

--- couples and forces = zero or insignificant.

Table 16-2 External couples

Engine	Speed [RPM]	Freq. [Hz]	M_Y [kNm]	M_Z [kNm]	Freq. [Hz]	M_Y [kNm]	M_Z [kNm]	Freq. [Hz]	M_Y [kNm]	M_Z [kNm]
8V31DF	720 750	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---
10V31DF	720 750	12 12.5	38 41	38 41	24 25	--- ---	--- ---	48 50	--- ---	0.2 0.2
12V31DF	720 750	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---
14V31DF	720 750	12 12.5	22 24	22 24	24 25	35 38	20 21	48 50	1 1	3 4
16V31DF	720 750	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---

--- couples and forces = zero or insignificant.

Table 16-3 Torque variations

Engine	Speed [RPM]	Freq. [Hz]	M_X [kNm]	Freq. [Hz]	M_X [kNm]	Freq. [Hz]	M_X [kNm]	Freq. [Hz]	M_X [kNm]
8V31DF	720 750	24 25	16 15	48 50	11 11	72 75	23 23	--- ---	--- ---
10V31DF	720 750	24 25	25 27	30 31	71 71	60 63	31 32	90 94	17 17
12V31DF	720 750	36 37.5	18 16	72 75	34 34	108 112.5	5 5	144 150	1 1
14V31DF	720 750	42 44	7 7	84 88	27 27	126 131	1 1	168 175	1 1
16V31DF	720 750	48 50	22 22	96 100	17 17	144 150	1 1	192 200	1 1

--- couples and forces = zero or insignificant.

Table 16-4 Torque variations (at 0% load)

Engine	Speed [RPM]	Freq. [Hz]	M_X [kNm]	Freq. [Hz]	M_X [kNm]	Freq. [Hz]	M_X [kNm]	Freq. [Hz]	M_X [kNm]
8V31DF	720 750	24 25	74 82	48 50	2 2	72 75	6 6	96 96	2 2
10V31DF	720 750	24 25	25 27	30 31	12 12	60 63	6 6	90 94	3 3
12V31DF	720 750	36 37.5	17 19	72 75	6 6	108 112.5	1 1	144 150	--- ---
14V31DF	720 750	42 44	1 1	84 88	5 5	126 131	--- ---	168 175	--- ---
16V31DF	720 750	48 50	3 3	96 100	4 4	144 150	--- ---	192 200	--- ---

--- couples and forces = zero or insignificant.

16.2 Mass moments of inertia

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

Engine	J (kg m²)
8V31	640 – 740
10V31	720 – 820
12V31	800 – 900
14V31	890 – 990
16V31	980 – 1080

16.3 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 engine full load and nominal speed.

Engine A-weighted Sound Power Level in Octave Frequency Band [dB, ref. 1pW] - Diesel Mode								
[Hz]	125	250	500	1000	2000	4000	8000	Total
8V	100	109	115	121	119	116	114	125
10V	101	108	117	120	121	118	114	126
12V	101	106	113	113	113	110	103	119
14V	95	99	113	114	116	114	114	121
16V	103	109	117	121	121	118	114	126

Engine A-weighted Sound Power Level in Octave Frequency Band [dB, ref. 1pW] - Gas Mode								
[Hz]	125	250	500	1000	2000	4000	8000	Total
8V	103	109	115	117	113	109	108	121
10V	105	111	117	119	115	111	110	123
12V	106	112	118	120	116	112	111	124
14V	100	98	114	116	117	113	104	122
16V	105	111	118	121	117	115	111	125

16.4 Exhaust noise

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

Free Field Exhaust Gas Sound Power Level in Octave Frequency Band [dB, ref. 1pW]									
[Hz]	32	63	125	250	500	1000	2000	4000	Total
8V	146	148	134	129	124	119	113	110	150
10V	149	140	134	131	127	119	115	111	150
12V	138	135	126	126	118	112	104	101	140
14V	138	136	129	126	125	121	109	102	141
16V	142	144	130	126	120	113	105	101	146

The results represent typical unsilenced air inlet A-weighted sound power level at turbocharger inlet at engine full load and nominal speed.

A-weighted Air Inlet Sound Power Level in Octave Frequency Band [dB, ref. 1pW] - Diesel Mode									
[Hz]	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**Total**
8V	73	85	93	104	111	121	147	139	147
10V	73	87	95	106	112	132	149	142	150
12V	74	86	96	105	112	130	149	143	150
14V	74	86	96	107	112	130	150	143	150
16V	75	86	95	105	112	128	150	143	151

A-weighted Air Inlet Sound Power Level in Octave Frequency Band [dB, ref. 1pW] - Gas Mode									
[Hz]	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**Total**
10V	75	89	98	105	111	134	145	141	147
14V	72	86	95	108	113	128	148	144	150
16V	71	86	94	112	113	130	148	145	150

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17. Power Transmission

17.1 Flexible coupling

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

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

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

17.2 Torque flange

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

17.3 Clutch

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

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

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

17.4 Shaft locking device

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

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

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.

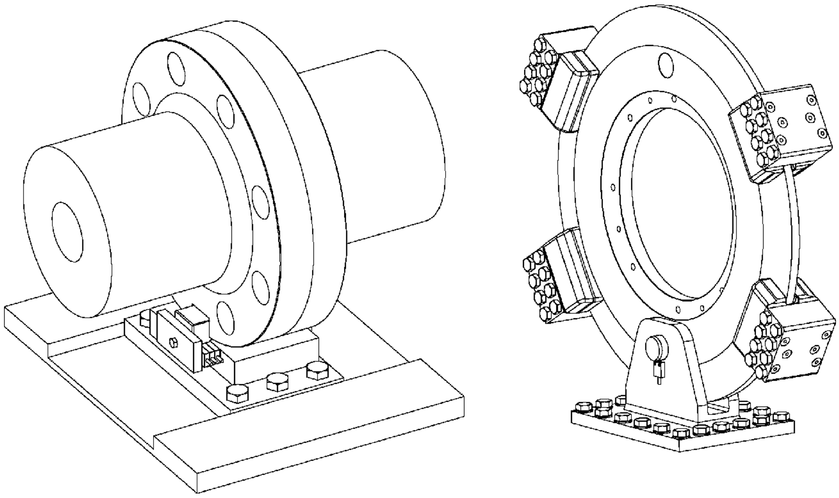

Fig 17-1 Shaft locking device and brake disc with calipers

17.5 Input data for torsional vibration calculations

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

Installation

- Classification
- Ice class
- Operating modes

Reduction gear

A mass elastic diagram showing:

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

Propeller and shafting

A mass-elastic diagram or propeller shaft drawing showing:

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

Main generator or shaft generator

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

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

Flexible coupling/clutch

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

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

Operational data

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

17.6 Turning gear

The engine is equipped with an electrical driven turning gear, capable of turning the flywheel and crankshaft.

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18. Engine Room Layout

18.1 Crankshaft distances

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

18.1.1 Main engines

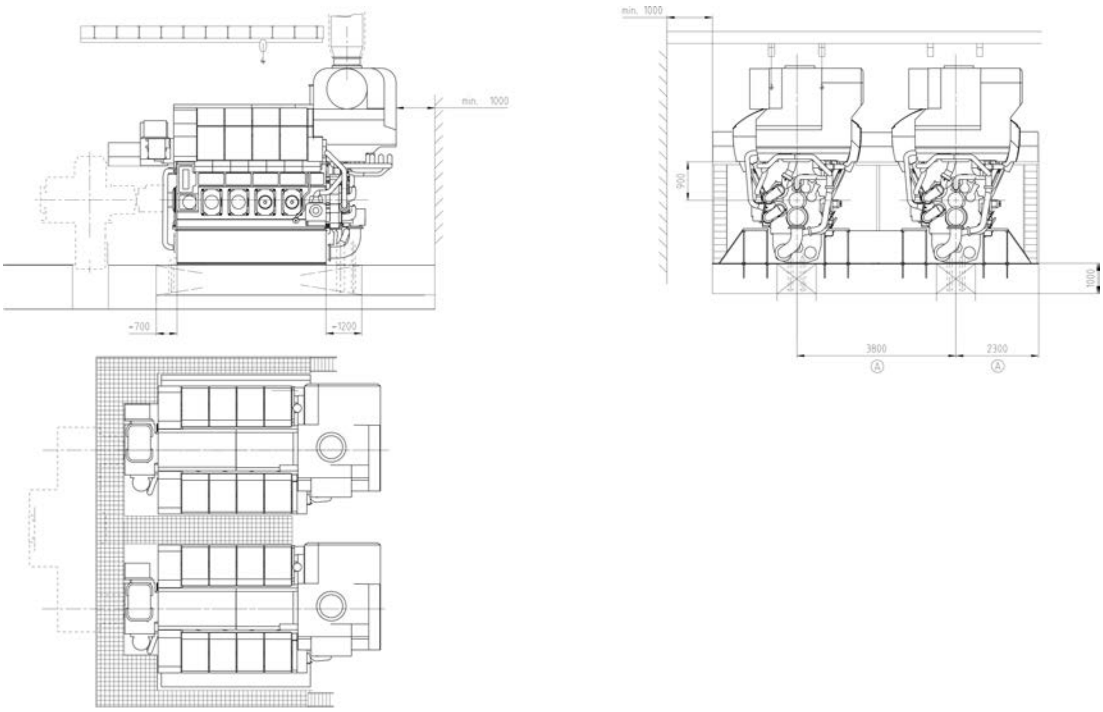


Fig 18-1 W8V31 & W10V31, turbocharger in free end (DAAF324239A)

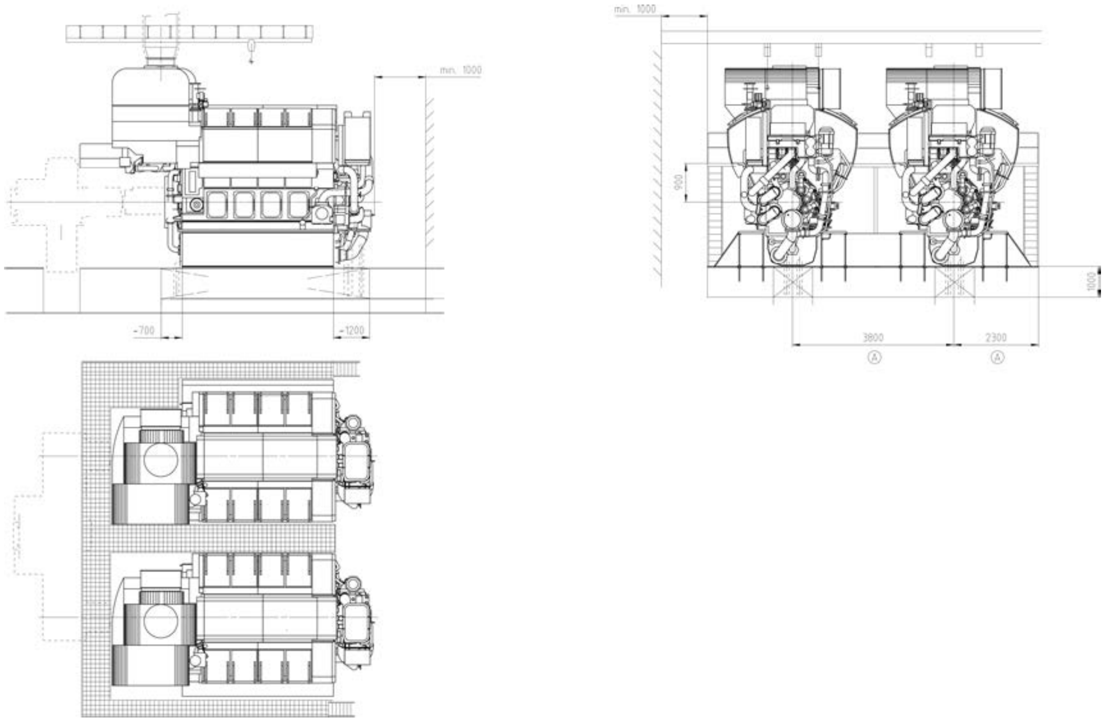


Fig 18-2 W8V31 & W10V31, turbocharger in driving end (DAAF353762A)

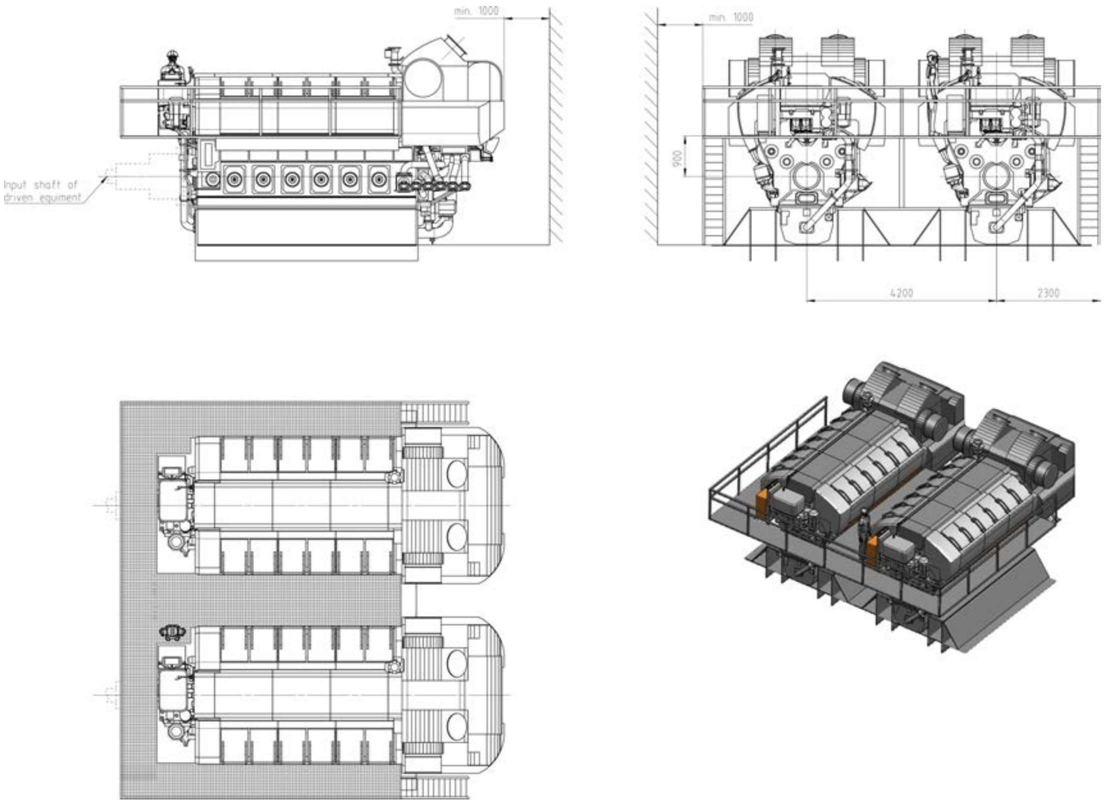


Fig 18-3 W12V31, W14V31 & W16V31, turbocharger in free end (DAAF392987)

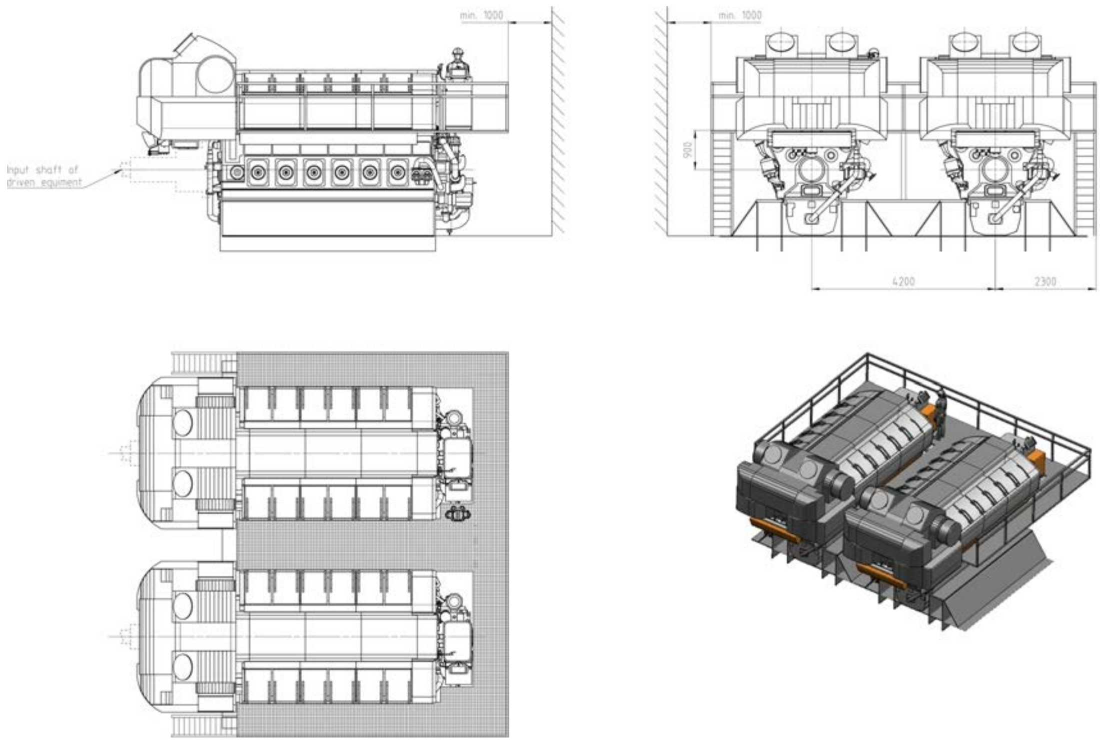


Fig 18-4 W12V31, W14V31 & W16V31, turbocharger in driving end (DAAF393139)

All dimensions in mm.

18.1.2 Generating sets

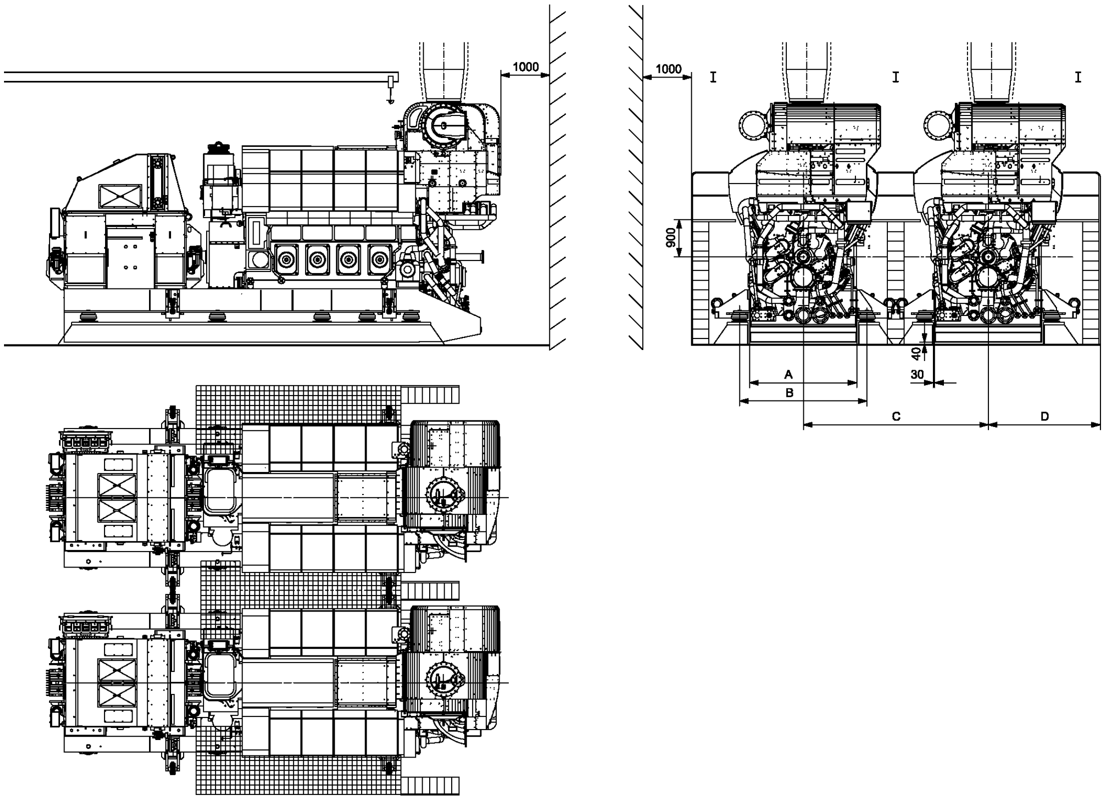


Fig 18-5 V-engines, turbocharger in free end (DAAF363645)

Engine	A	B	C	D
W 8V31DF	2200	2620	3800	2300

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 engine and in such case the necessary height is minimized. Separate lifting arrangements are usually required for overhaul of the turbocharger since the crane travel is limited by the exhaust pipe. A chain block on a rail located over the turbocharger axis is recommended.

18.2.3 Maintenance platforms

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

NOTE

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

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.

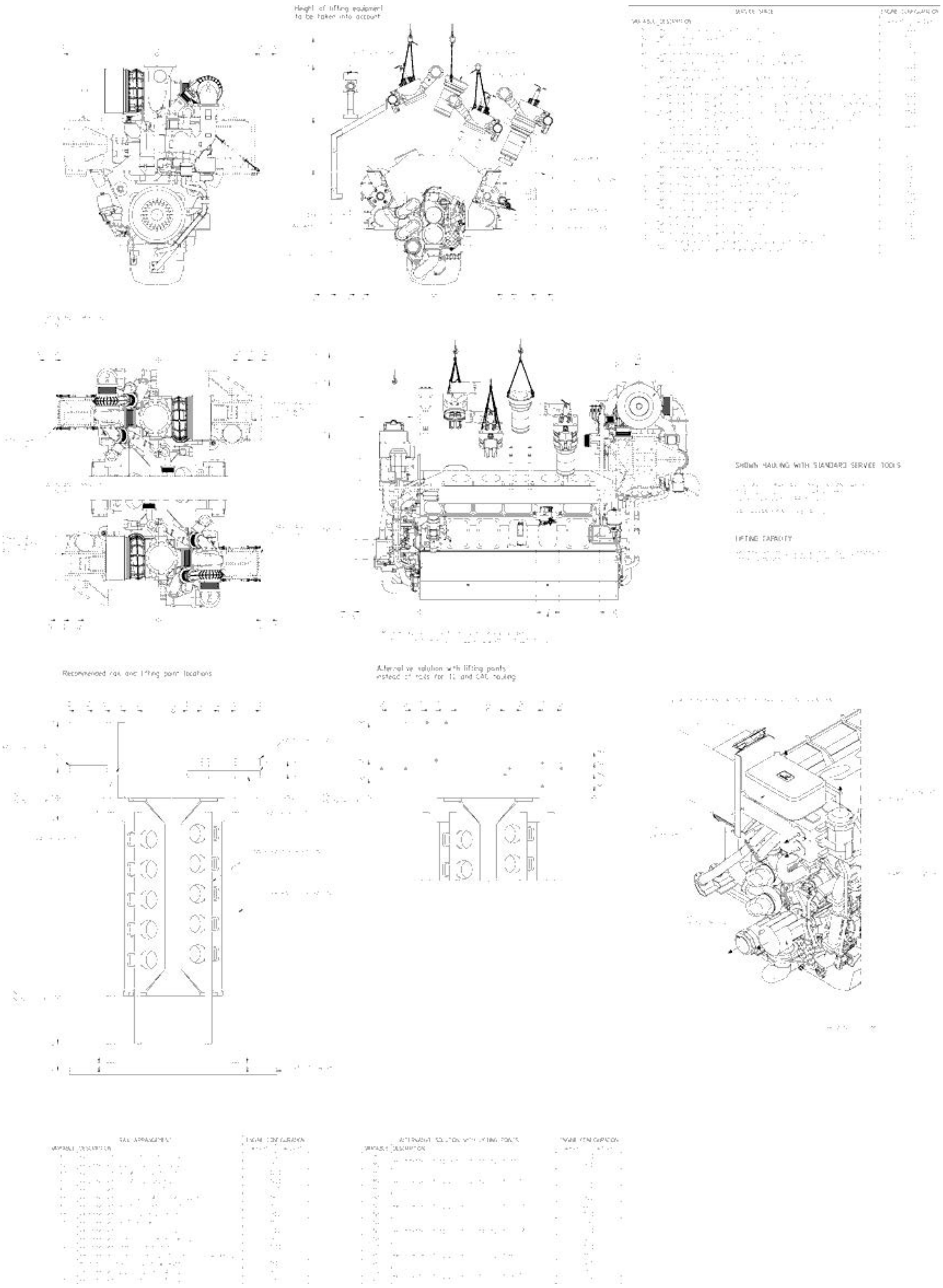
On single main engine installations it is important to store heavy engine parts close to the engine to make overhaul as quick as possible in an emergency situation.

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

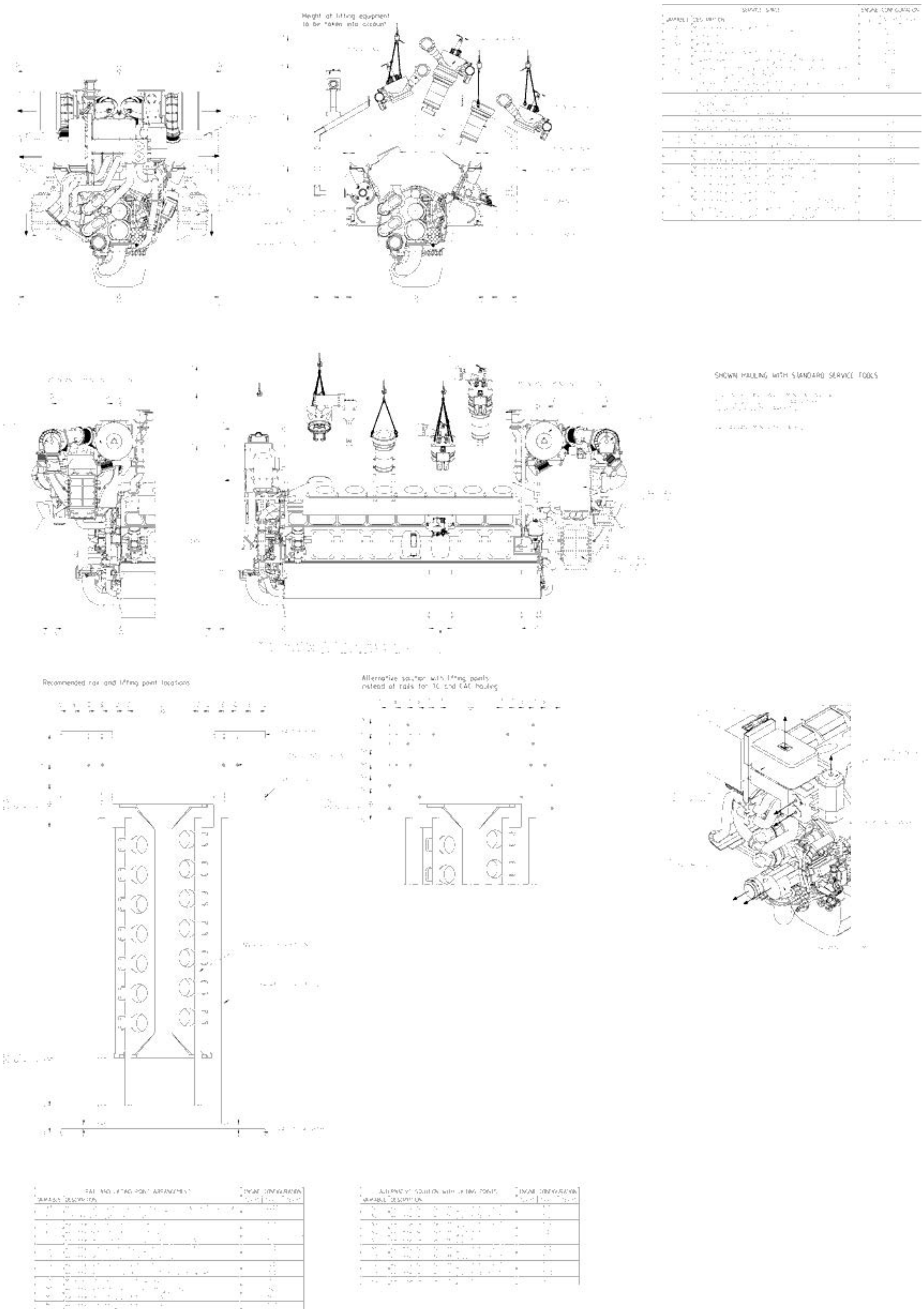
18.4.1.1 Service space requirement, main engine



NOTE

Please refer to DAAF336984 for Turbocharger and Cooler (Lubricating oil cooler, Charge air cooler) spare part dimensions and weights, both LP and HP stage.

Fig 18-6 Service space requirement, Main engine W8V31 & W10V31 (DAAF443904A)



NOTE

Please refer to DAAF410568 for Turbocharger and Cooler (Lubricating oil cooler, Charge air cooler) spare part dimensions and weights, both LP and HP stage.

Fig 18-7 Service space requirement, Main engine W12V31, W14V31 & W16V31 (DAAF438352)

19. Transport Dimensions and Weights

19.1 Lifting of main engines

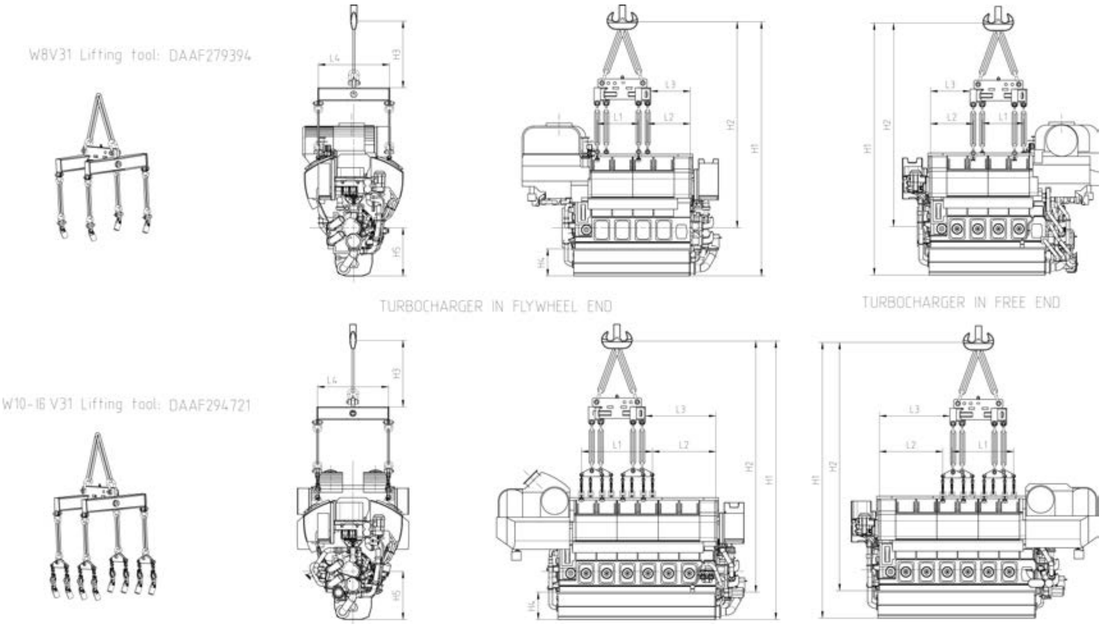


Fig 19-1 Lifting of main engines (DAAF336773C)

All dimensions in mm.

19.2 Lifting of generating sets

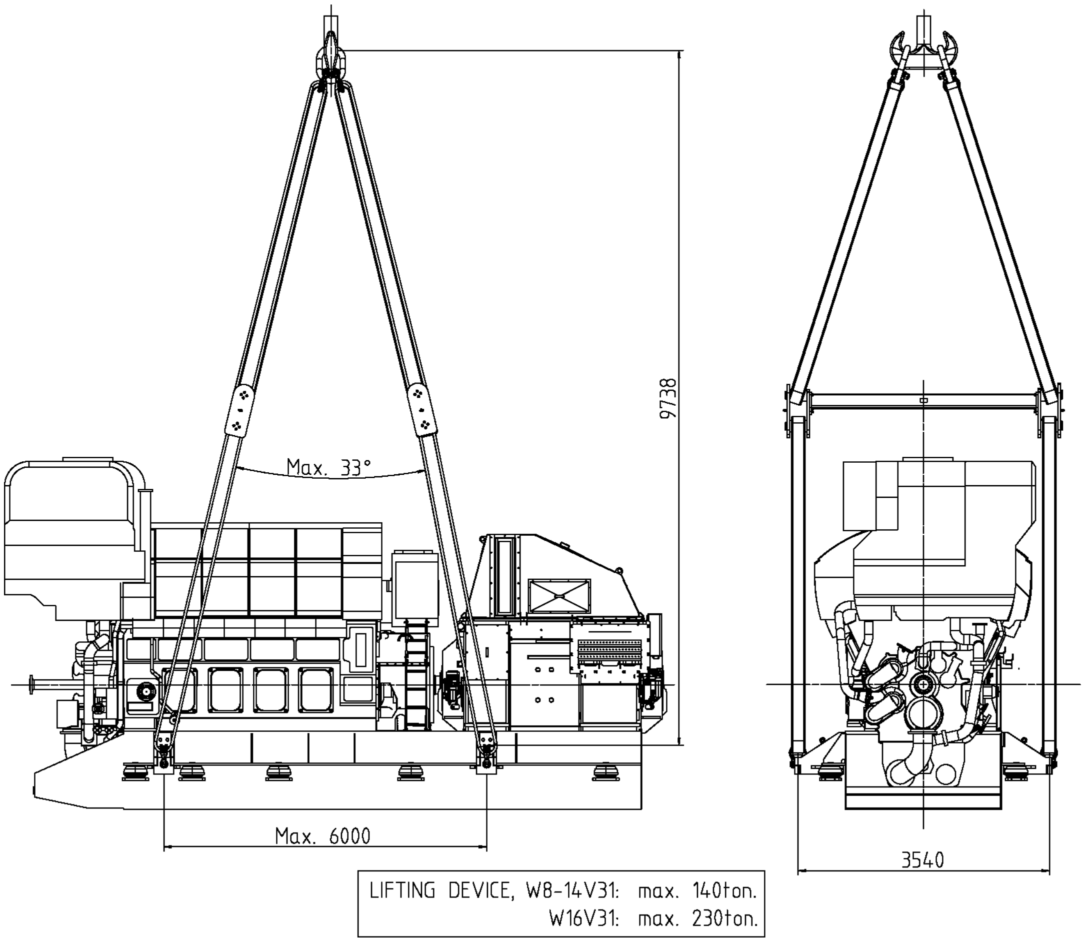


Fig 19-2 Lifting of generating sets (DAAF341224)

19.3 Engine components

Table 19-1 Turbocharger and cooler inserts (DAAF336984 for 8V, 10V & DAAF410568 for 12,14,16V)

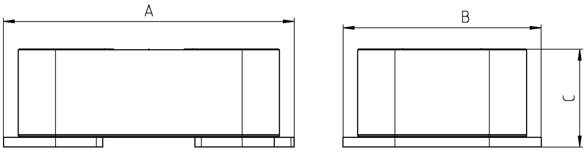


Fig 19-3 Lube oil cooler

Engine	Weight [kg]	Dimensions [mm]		
		A	B	C
W 8V31DF	232	830	537	335
W 10V31DF	232	830	537	335
W 12V31DF	282	830	537	440
W 14V31DF	282	830	537	440
W 16V31DF	305	830	537	488

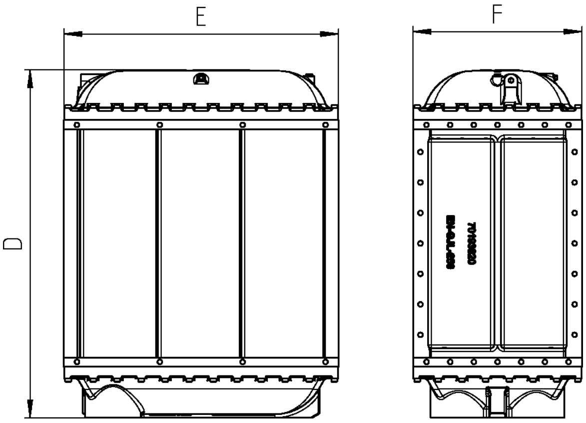


Fig 19-4 Charge air cooler (HP)

Engine	Weight [kg]	Dimensions [mm]		
		D	E	F
W 8V31DF	785	1165	915	625
W 10V31DF	785	1165	915	625
W 12V31DF	730	1135	912	625
W 14V31DF	730	1135	912	625
W 16V31DF	730	1135	912	625

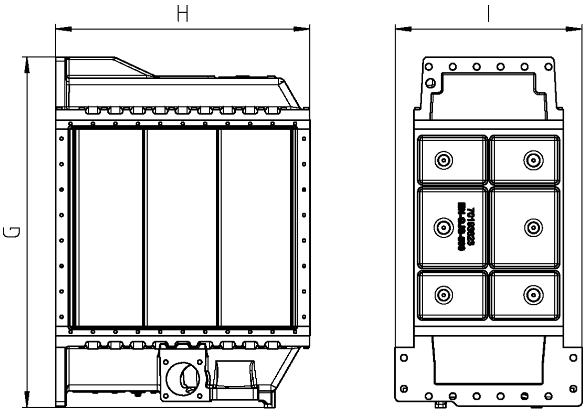


Fig 19-5 Charge air cooler (LP)

Engine	Weight [kg]	Dimensions [mm]		
		G	H	I
W 8V31DF	830	1155	850	625
W 10V31DF	830	1155	850	625
W 12V31DF	650	~1028	~639	558
W 14V31DF	650	~1028	~639	558
W 16V31DF	650	~1028	~639	558

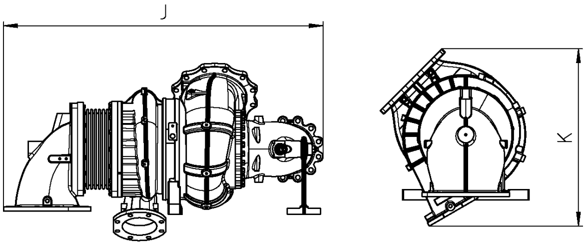


Fig 19-6 Turbocharger (HP)

Engine	Weight [kg]	Dimensions [mm]	
		J	K
W 8V31DF	680	1612	717
W 10V31DF	680	1612	717
W 12V31DF	443	1421	610
W 14V31DF	443	1421	610
W 16V31DF	443	1421	610

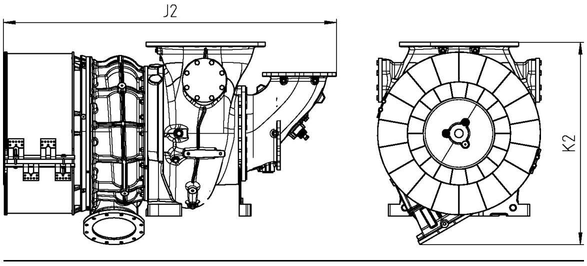


Fig 19-7 Turbocharger (LP)

Engine	Weight [kg]	Dimensions [mm]	
		J2	K2
W 8V31DF	1568	1633 (with filter) or 2160 (with suction branch)	1030
W 10V31DF	1568	1633 (with filter) or 2160 (with suction branch)	1030
W 12V31DF	1020	1411 (with filter) or 1861 (with suction branch)	876
W 14V31DF	1020	1411 (with filter) or 1861 (with suction branch)	876
W 16V31DF	1020	1411 (with filter) or 1861 (with suction branch)	876

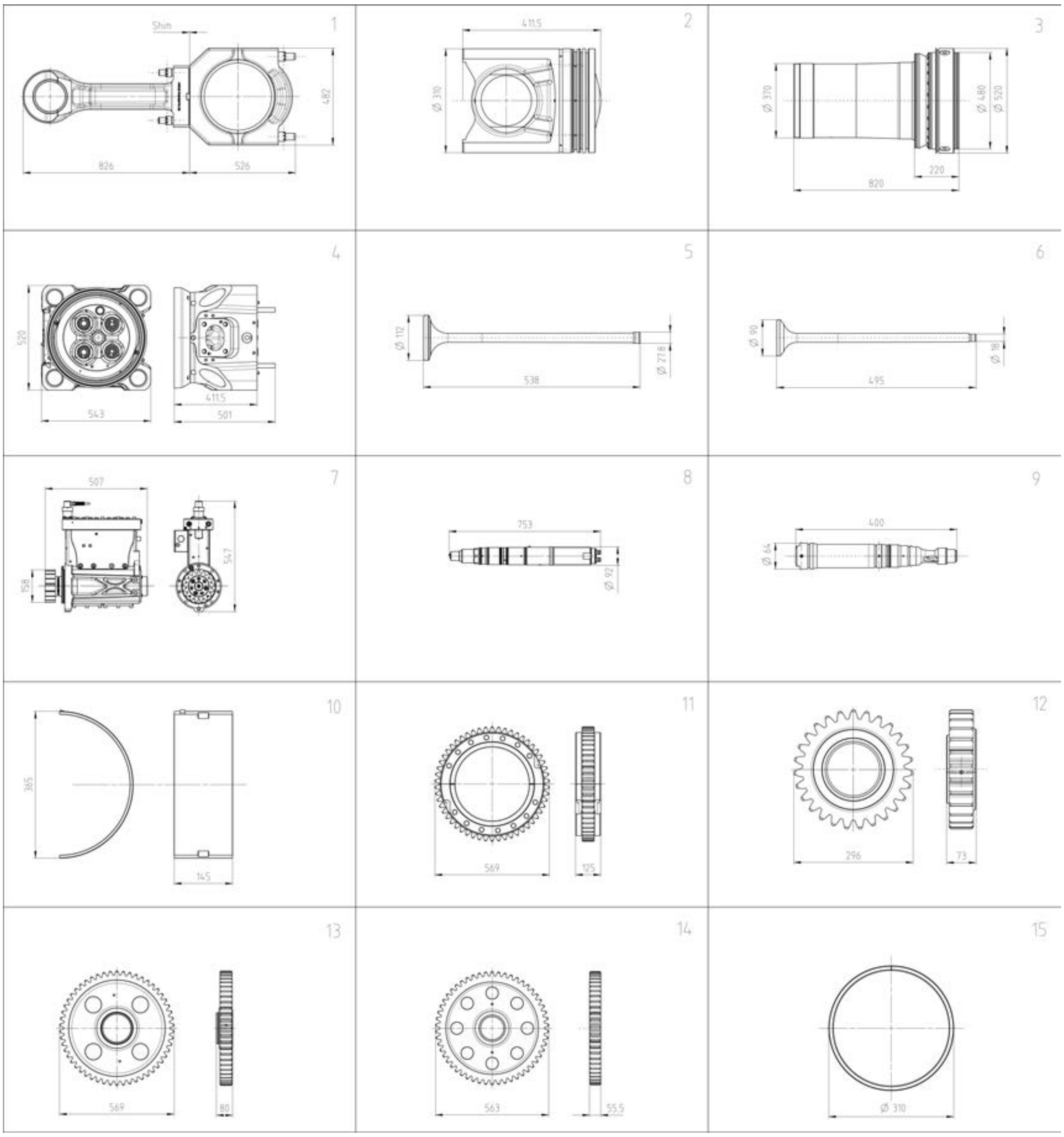


Fig 19-8 Major spare parts (DAAF337022)

Table 19-2 Weights

Item no	Description	Weight [kg]	Item No	Description	Weight [kg]
1	Connecting rod	192	9	Starting valve	7.6
2	Piston	72.4	10	Main bearing shell	4.7
3	Cylinder liner	307	11	Split gear wheel	94.7
4	Cylinder head	400	12	Small intermediate gear	21.6
5	Inlet valve	5.2	13	Large intermediate gear	60.6
6	Exhaust valve	3.3	14	Camshaft drive gear	61.8
7	HP fuel pump	134	15	Piston ring set	1.5
8	Injection valve	27		Piston ring	0.5

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20. Product Guide Attachments

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

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

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21. ANNEX

21.1 Unit conversion tables

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

Length conversion factors

Convert from	To	Multiply by
mm	in	0.0394
mm	ft	0.00328

Mass conversion factors

Convert from	To	Multiply by
kg	lb	2.205
kg	oz	35.274

Pressure conversion factors

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

Volume conversion factors

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

Power conversion

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

Moment of inertia and torque conversion factors

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

Fuel consumption conversion factors

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

Flow conversion factors

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

Temperature conversion factors

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

Density conversion factors

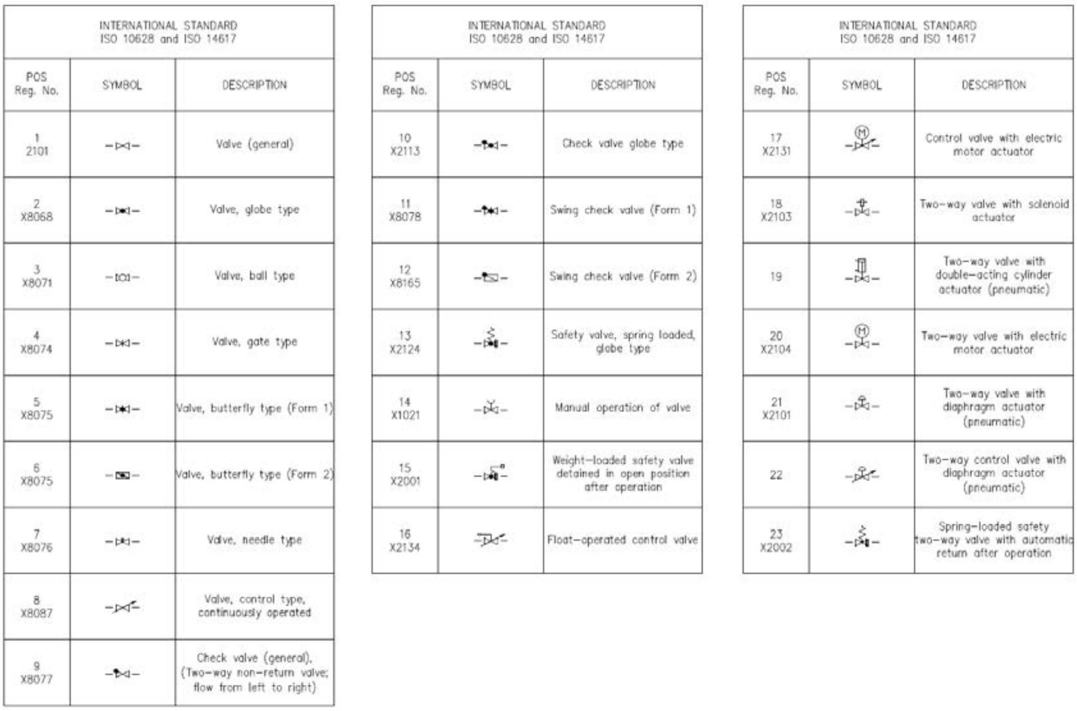
Convert from	To	Multiply by
kg/m^3	lb/US gallon	0.00834
kg/m^3	lb/Imperial gallon	0.01002
kg/m^3	lb/ft^3	0.0624

21.1.1 Prefix

Table 21-1 The most common prefix multipliers

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

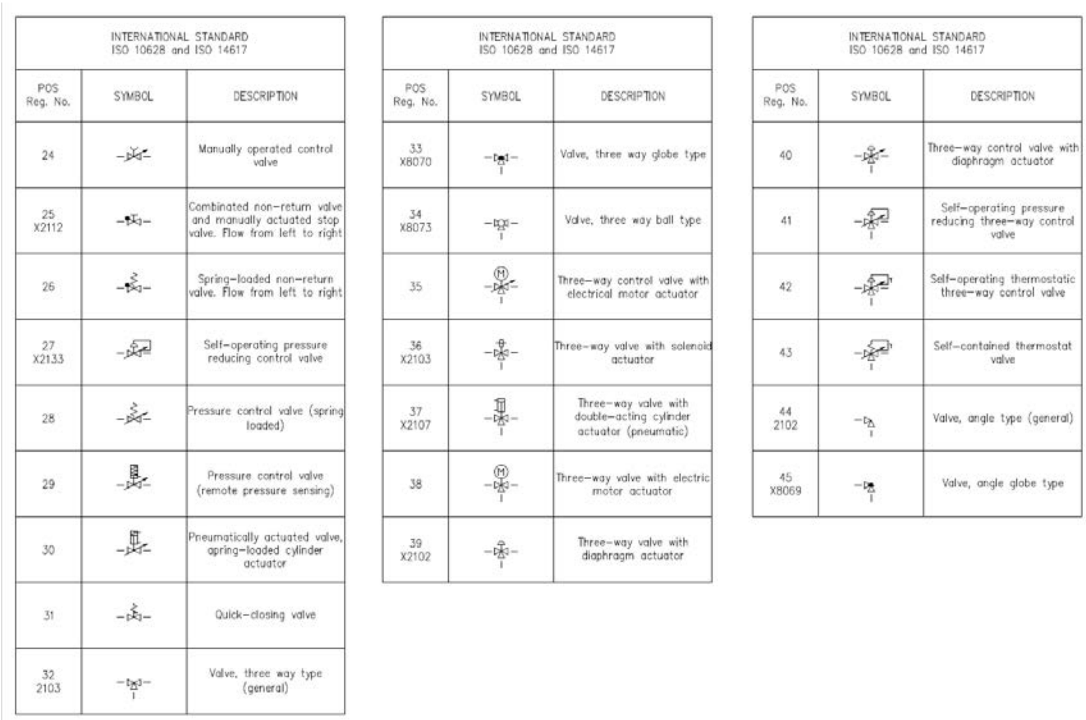
21.2 Collection of drawing symbols used in drawings



INTERNATIONAL STANDARD ISO 10628 and ISO 14617

POS Reg. No.	SYMBOL	DESCRIPTION
1 2101		Valve (general)
2 X8068		Valve, globe type
3 X8071		Valve, ball type
4 X8074		Valve, gate type
5 X8075		Valve, butterfly type (Form 1)
6 X8075		Valve, butterfly type (Form 2)
7 X8076		Valve, needle type
8 X8087		Valve, control type, continuously operated
9 X8077		Check valve (general), (Two-way non-return valve; flow from left to right)
10 X2113		Check valve globe type
11 X8078		Swing check valve (Form 1)
12 X8165		Swing check valve (Form 2)
13 X2124		Safety valve, spring loaded, globe type
14 X1021		Manual operation of valve
15 X2001		Weight-loaded safety valve detained in open position after operation
16 X2134		Float-operated control valve
17 X2131		Control valve with electric motor actuator
18 X2103		Two-way valve with solenoid actuator
19		Two-way valve with double-acting cylinder actuator (pneumatic)
20 X2104		Two-way valve with electric motor actuator
21 X2101		Two-way valve with diaphragm actuator (pneumatic)
22		Two-way control valve with diaphragm actuator (pneumatic)
23 X2002		Spring-loaded safety two-way valve with automatic return after operation

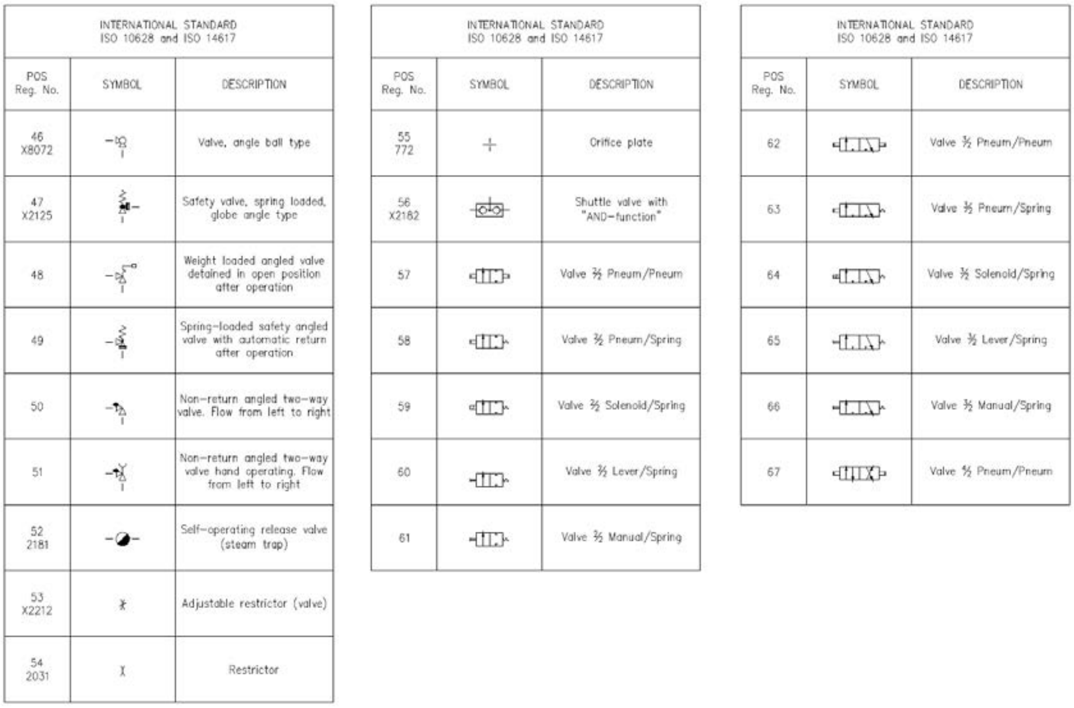
Fig 21-1 List of symbols (DAAF406507 - 1)



INTERNATIONAL STANDARD ISO 10628 and ISO 14617

POS Reg. No.	SYMBOL	DESCRIPTION
24		Manually operated control valve
25 X2112		Combinated non-return valve and manually actuated stop valve. Flow from left to right
26		Spring-loaded non-return valve. Flow from left to right
27 X2133		Self-operating pressure reducing control valve
28		Pressure control valve (spring loaded)
29		Pressure control valve (remote pressure sensing)
30		Pneumatically actuated valve, spring-loaded cylinder actuator
31		Quick-closing valve
32 2103		Valve, three way type (general)
33 X8070		Valve, three way globe type
34 X8073		Valve, three way ball type
35		Three-way control valve with electrical motor actuator
36 X2103		Three-way valve with solenoid actuator
37 X2107		Three-way valve with double-acting cylinder actuator (pneumatic)
38		Three-way valve with electric motor actuator
39 X2102		Three-way valve with diaphragm actuator
40		Three-way control valve with diaphragm actuator
41		Self-operating pressure reducing three-way control valve
42		Self-operating thermostatic three-way control valve
43		Self-contained thermostat valve
44 2102		Valve, angle type (general)
45 X8069		Valve, angle globe type

Fig 21-2 List of symbols (DAAF406507 - 2)

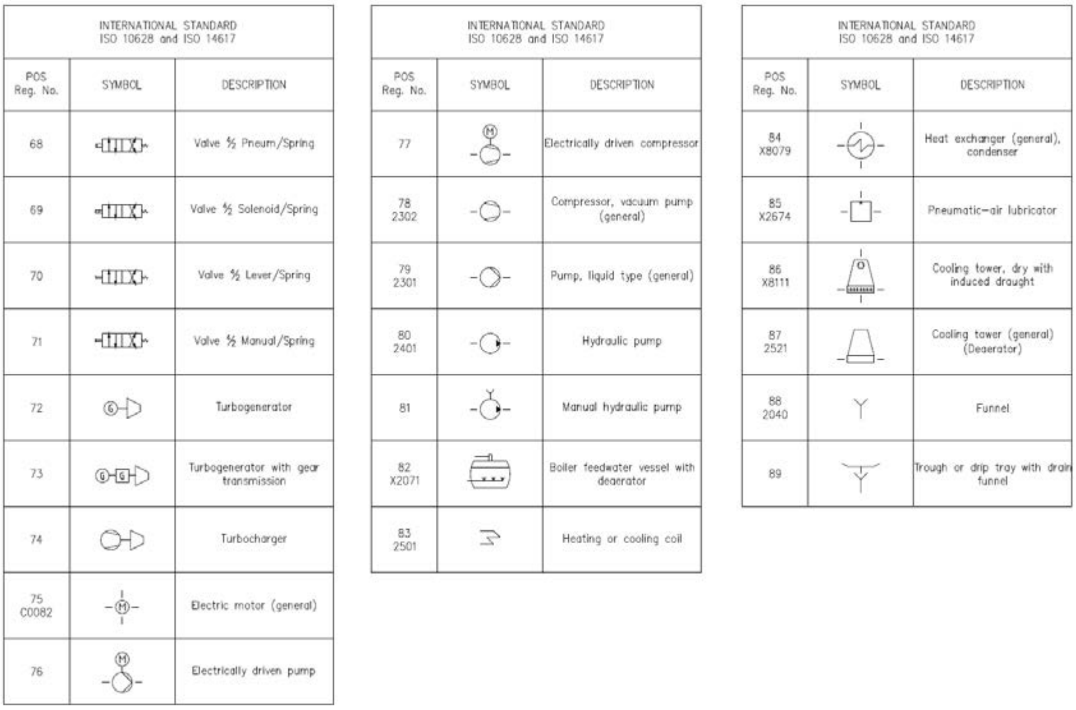


INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
46 X8072		Valve, angle ball type
47 X2125		Safety valve, spring loaded, globe angle type
48		Weight loaded angled valve detained in open position after operation
49		Spring-loaded safety angled valve with automatic return after operation
50		Non-return angled two-way valve. Flow from left to right
51		Non-return angled two-way valve hand operating. Flow from left to right
52 2181		Self-operating release valve (steam trap)
53 X2212		Adjustable restrictor (valve)
54 2031		Restrictor

INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
55 772		Orifice plate
56 X2182		Shuttle valve with "AND-function"
57		Valve 3/2 Pneum/Pneum
58		Valve 3/2 Pneum/Spring
59		Valve 3/2 Solenoid/Spring
60		Valve 3/2 Lever/Spring
61		Valve 3/2 Manual/Spring

INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
62		Valve 3/2 Pneum/Pneum
63		Valve 3/2 Pneum/Spring
64		Valve 3/2 Solenoid/Spring
65		Valve 3/2 Lever/Spring
66		Valve 3/2 Manual/Spring
67		Valve 5/2 Pneum/Pneum

Fig 21-3 List of symbols (DAAF406507 - 3)

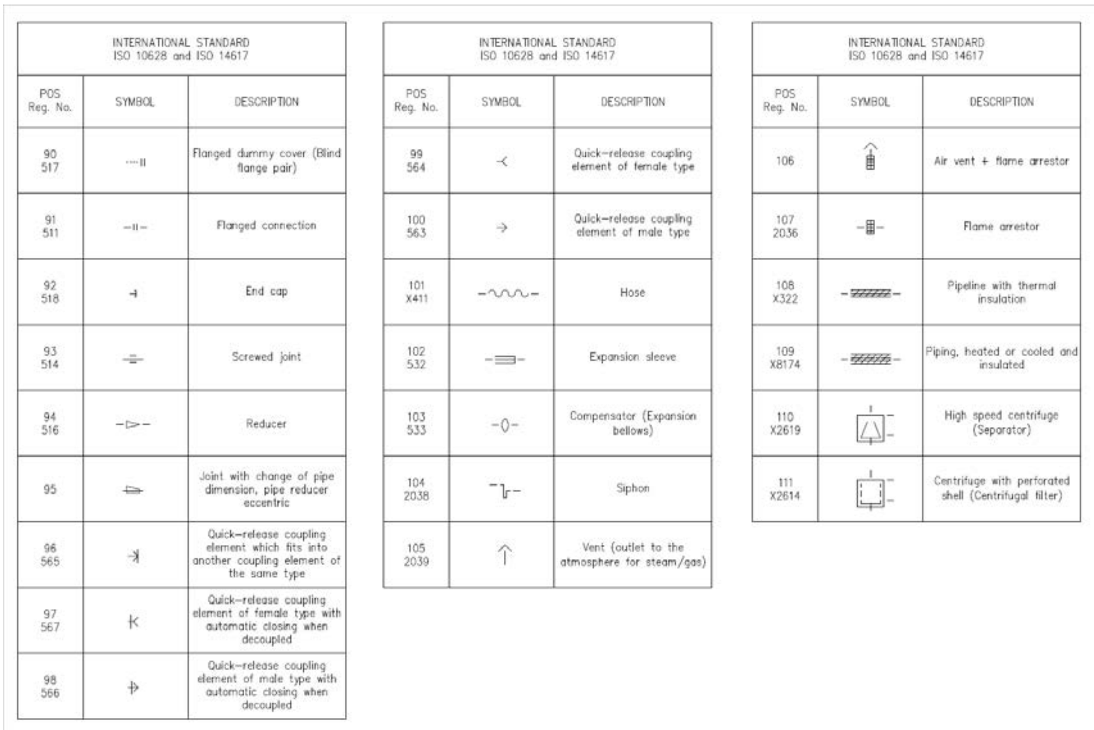


INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
68		Valve 5/2 Pneum/Spring
69		Valve 5/2 Solenoid/Spring
70		Valve 5/2 Lever/Spring
71		Valve 5/2 Manual/Spring
72		Turbogenerator
73		Turbogenerator with gear transmission
74		Turbocharger
75 C0082		Electric motor (general)
76		Electrically driven pump

INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
77		Electrically driven compressor
78 2302		Compressor, vacuum pump (general)
79 2301		Pump, liquid type (general)
80 2401		Hydraulic pump
81		Manual hydraulic pump
82 X2071		Boiler feedwater vessel with deaerator
83 2501		Heating or cooling coil

INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
84 X8079		Heat exchanger (general), condenser
85 X2674		Pneumatic-air lubricator
86 X8111		Cooling tower, dry with induced draught
87 2521		Cooling tower (general) (Deaerator)
88 2040		Funnel
89		Trough or drip tray with drain funnel

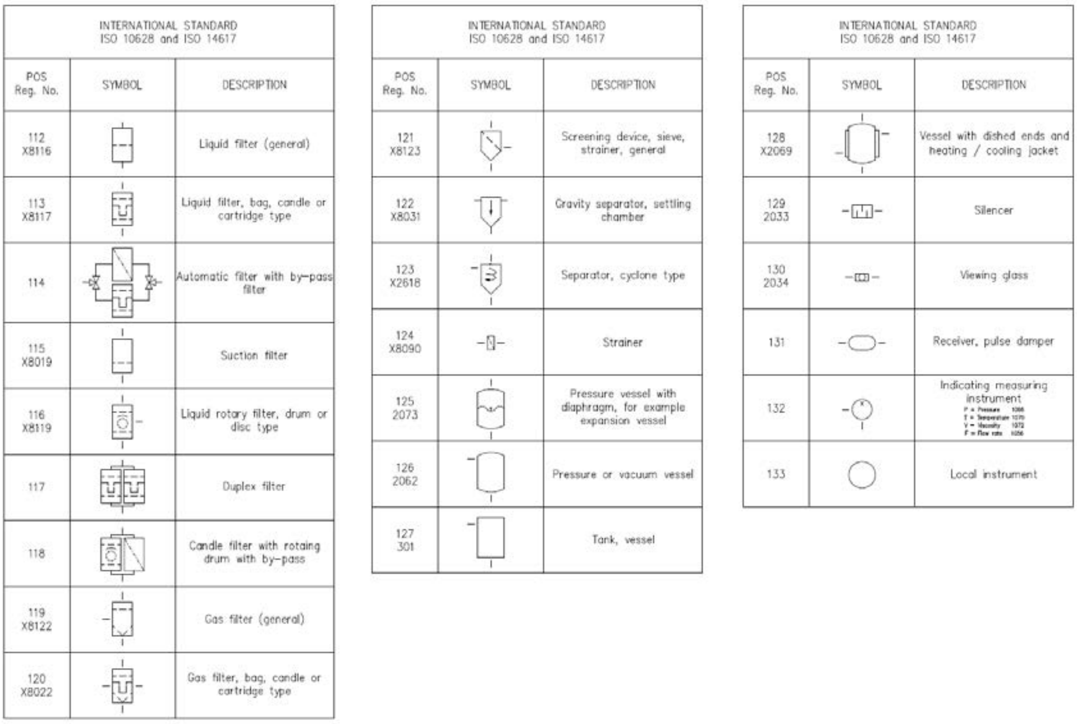
Fig 21-4 List of symbols (DAAF406507 - 4)



INTERNATIONAL STANDARD ISO 10628 and ISO 14617

POS Reg. No.	SYMBOL	DESCRIPTION
90 517		Flanged dummy cover (Blind flange pair)
91 511		Flanged connection
92 518		End cap
93 514		Screwed joint
94 516		Reducer
95		Joint with change of pipe dimension, pipe reducer eccentric
96 565		Quick-release coupling element which fits into another coupling element of the same type
97 567		Quick-release coupling element of female type with automatic closing when decoupled
98 566		Quick-release coupling element of male type with automatic closing when decoupled
99 564		Quick-release coupling element of female type
100 563		Quick-release coupling element of male type
101 X411		Hose
102 532		Expansion sleeve
103 533		Compensator (Expansion bellows)
104 2038		Siphon
105 2039		Vent (outlet to the atmosphere for steam/gas)
106		Air vent + flame arrestor
107 2036		Flame arrestor
108 X322		Pipeline with thermal insulation
109 X8174		Piping, heated or cooled and insulated
110 X2619		High speed centrifuge (Separator)
111 X2614		Centrifuge with perforated shell (Centrifugal filter)

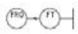
Fig 21-5 List of symbols (DAAF406507 - 5)



INTERNATIONAL STANDARD ISO 10628 and ISO 14617

POS Reg. No.	SYMBOL	DESCRIPTION
112 X8116		Liquid filter (general)
113 X8117		Liquid filter, bag, candle or cartridge type
114		Automatic filter with by-pass filter
115 X8019		Suction filter
116 X8119		Liquid rotary filter, drum or disc type
117		Duplex filter
118		Candle filter with rotaing drum with by-pass
119 X8122		Gas filter (general)
120 X8022		Gas filter, bag, candle or cartridge type
121 X8123		Screening device, sieve, strainer, general
122 X8031		Gravity separator, settling chamber
123 X2618		Separator, cyclone type
124 X8090		Strainer
125 2073		Pressure vessel with diaphragm, for example expansion vessel
126 2062		Pressure or vacuum vessel
127 301		Tank, vessel
128 X2069		Vessel with dished ends and heating / cooling jacket
129 2033		Silencer
130 2034		Viewing glass
131		Receiver, pulse damper
132		Indicating measuring instrument
133		Local instrument

Fig 21-6 List of symbols (DAAF406507 - 6)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
134		Local panel
135		Signal to control board
136		TI = Temperature indicator TE = Temperature sensor TEZ = Temperature sensor shut-down PI = Pressure indicator PS = Pressure switch PT = Pressure transmitter PSZ = Pressure switch shut-down PDIS = Differential pressure indicator and alarm LS = Level switch QS = Flow switch TSZ = Temperature switch
137 X2122		Overflow safety valve
138 X1048		Flow rate indication
139 X1056		Recording of flow rate with summation of volume
140 X1036		Automatic operation of valve with infinite number of stable positions

INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
141 X1032		Automatic operation of valve with two stable positions open and close
142		
143		
144		
145		
146		
147		

INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION
148		
149		
150		
151		
152		
153		

Fig 21-7 List of symbols (DAAF406507 - 7)

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