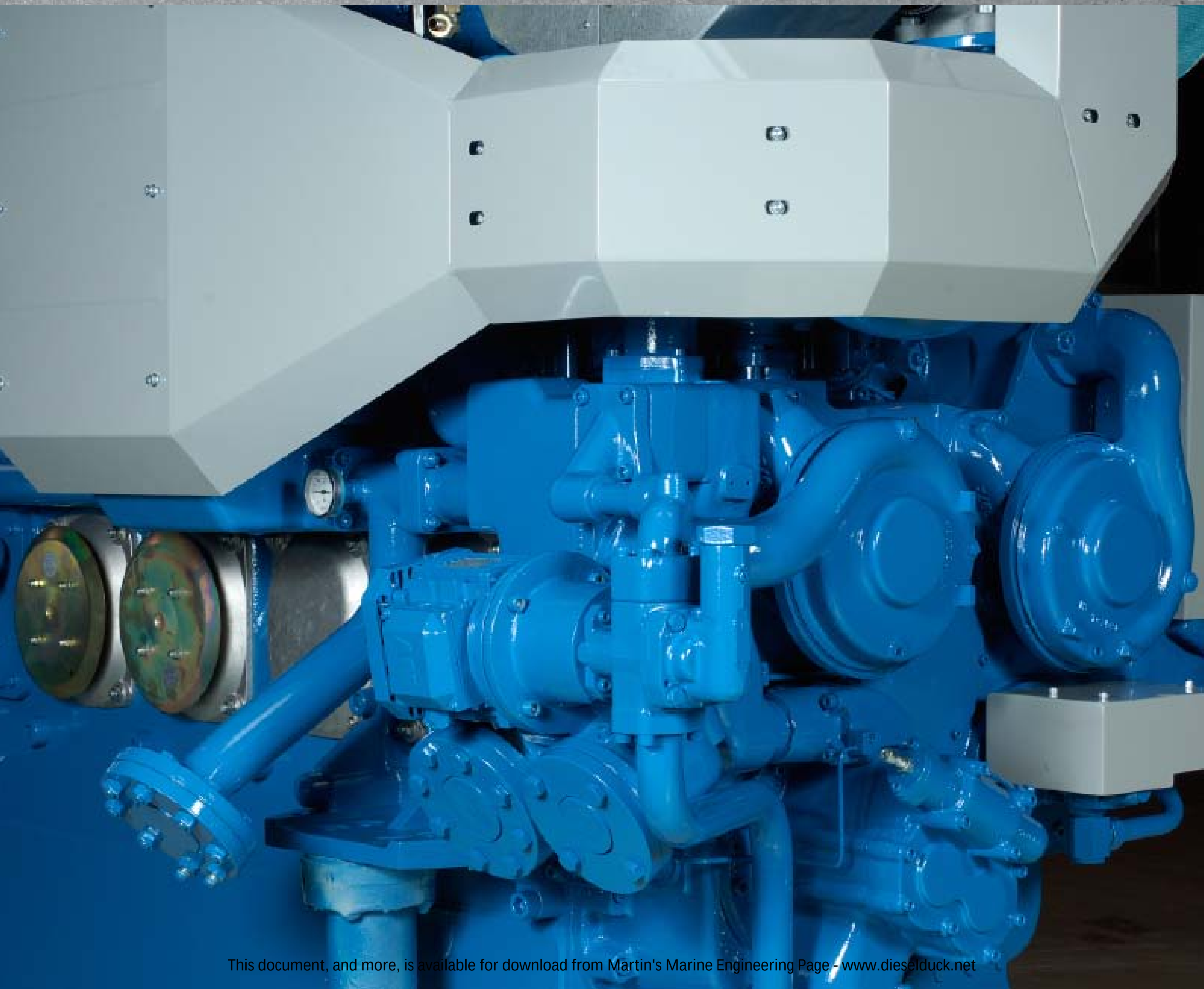
WÄRTSILÄ Engines

WÄRTSILÄ 20 PRODUCT GUIDE



Introduction

This Product Guide provides data and system proposals for the early design phase of marine engine installations. For contracted projects specific instructions for planning the installation are always delivered. Any data and information herein is subject to revision without notice. This 1/2015 issue replaces all previous issues of the Wärtsilä 20 Project Guides.

Issue	Published	Updates
1/2015	14.10.2015	Numerous updates throughout the product guide
1/2013	19.04.2013	Chapters Fuel Oil System and Lubrication Oil System updated with low sulphur operation, several other updates throughout the product guide.
3/2009	19.11.2009	Chapters Technical Data and Lubricating Oil System updated
2/2009	02.09.2009	Chapter Exhaust Emissions updated, service spaces updated, structure borne noise added and other minor updates

Wärtsilä, Marine Solutions

Vaasa, October 2015

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1. Main Data and Outputs

The Wärtsilä 20 is a 4-stroke, non-reversible, turbocharged and intercooled diesel engine with direct injection of fuel.

Cylinder bore	200 mm
Stroke	280 mm
Piston displacement	8.8 l/cyl
Number of valves	2 inlet valves and 2 exhaust valves
Cylinder configuration	4, 6, 8, 9, in-line
Direction of rotation	Clockwise, counterclockwise on request
Speed	900, 1000 rpm
Mean piston speed	8.4, 9.3 m/s

1.1 Maximum continuous output

Table 1.1.1 Rating table for Wärtsilä 20

Cylinder configuration	Main engines		Generating sets			
	1000 rpm		900 rpm / 60 Hz		1000 rpm / 50 Hz	
	kW	bhp	Engine [kW]	Generator [kVA]	Engine [kW]	Generator [kVA]
W 4L20	800	1080	740	880	800	950
W 6L20	1200	1630	1110	1320	1200	1420
W 8L20	1600	2170	1480	1760	1600	1900
W 9L20	1800	2440	1665	1980	1800	2140

The mean effective pressure p_e 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:

P_e = Mean effective pressure [bar]

P = Output per cylinder [kW]

n = Engine speed [r/min]

D = Cylinder diameter [mm]

L = Length of piston stroke [mm]

c = Operating cycle (4)

1.2 Reference conditions

The output is available up to a charge air coolant temperature of max. 38°C and an air temperature of max. 45°C. For higher temperatures, the output has to be reduced according to the formula stated in ISO 3046-1:2002 (E).

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

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

Correction factors for the fuel oil consumption in other ambient conditions are given in standard ISO 3046-1:2002.

1.3 Operation in inclined position

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

Transverse inclination, permanent (list) .... 15°

Transverse inclination, momentary (roll) .... 22.5°

Longitudinal inclination, permanent (trim) ..... 10°

Longitudinal inclination, momentary (pitch) ... 10°

1.4 Dimensions and weights

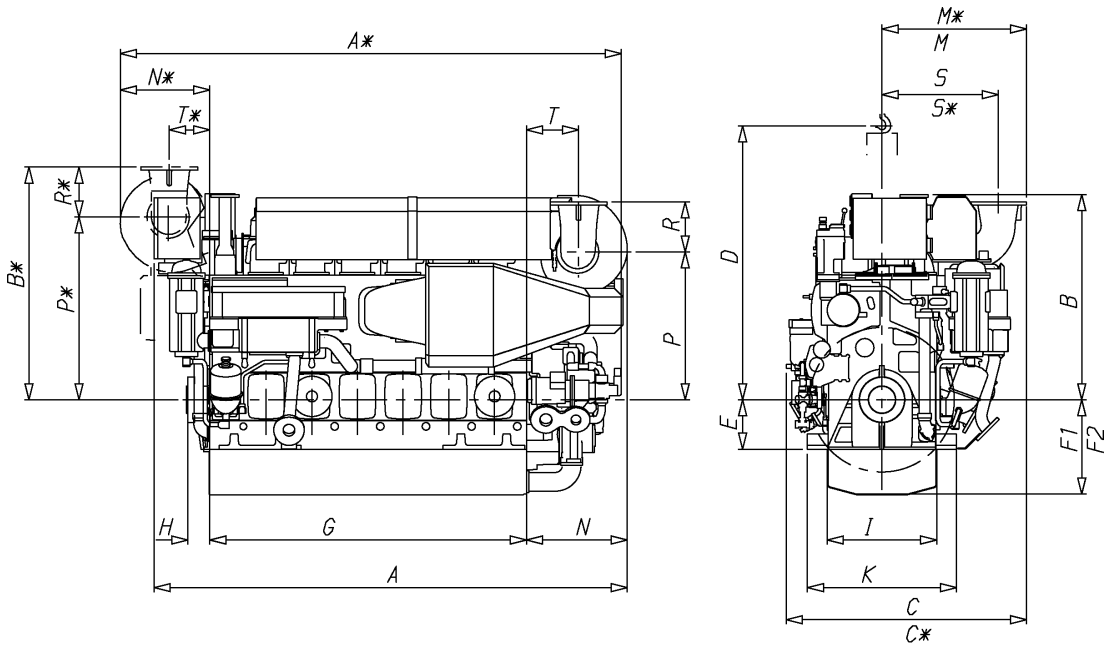

Fig 1.4.1 Main engines (3V92E0068c)

Engine	A*	A	B*	B	C*	C	D	E	F1	F2	G	H	I	K
W 4L20		2510		1348		1483	1800	325	725	725	1480	155	718	980
W 6L20	3292	3108	1528	1348	1580	1579	1800	325	624	824	2080	155	718	980
W 8L20	4011	3783	1614	1465	1756	1713	1800	325	624	824	2680	155	718	980
W 9L20	4299	4076	1614	1449	1756	1713	1800	325	624	824	2980	155	718	980

F1 for dry sump and F2 for deep wet sump

Engine	M*	M	N*	N	P*	P	R*	R	S*	S	T*	T	Weight
W 4L20		854		665		920		248		694		349	7.2
W 6L20	951	950	589	663	1200	971	328	328	762	763	266	343	9.3
W 8L20	1127	1084	708	738	1224	1000	390	390	907	863	329	339	11.0
W 9L20	1127	1084	696	731	1224	1000	390	390	907	863	329	339	11.6

** Turbocharger at flywheel end*
Dimensions in mm. Weight in tons.

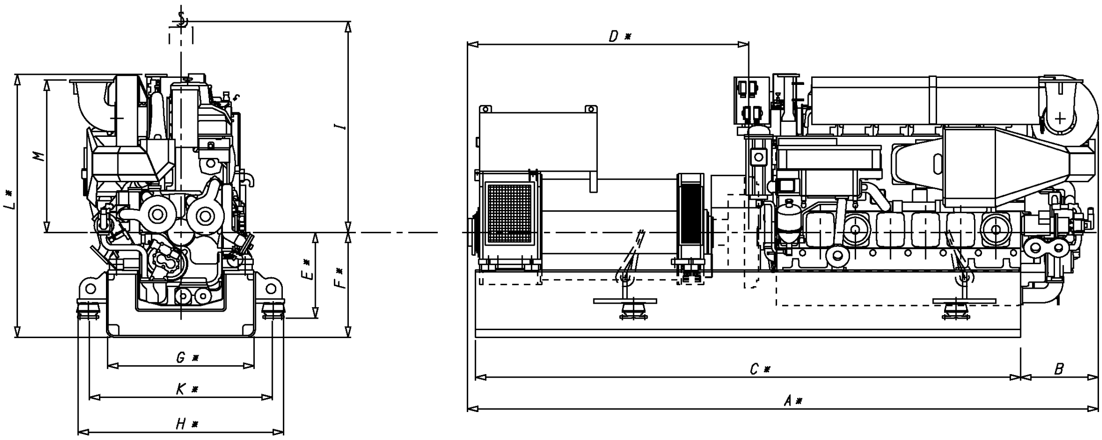

Fig 1.4.2 Generating sets (3V58E0576d)

Engine	A*	B	C*	D*	E*	F*	G*	H*	I	K*	L*	M	Weight *
W 4L20	4910	665	4050	2460	725	990	1270/1420	1770/1920	1800	1580/1730	2338	1168	14.0
W 6L20	5325	663	4575	2300	725	895/975/1025	1270/1420/1570	1770/1920/2070	1800	1580/1730/1880	2243/2323/2373	1299	16.8
W 8L20	6030	731	5100	2310	725	1025/1075	1420/1570	1920/2070	1800	1730/1880	2474/2524	1390	20.7
W 9L20	6535	731	5400	2580	725	1075/1125	1570/1800	2070/2300	1800	1880/2110	2524/2574	1390	23.8

** Dependent on generator type and size.*
Dimensions in mm. Weight in tons.

2. Operating Ranges

2.1 Engine operating modes

If the engine is configured for SCR use then it can be operated in two modes; IMO Tier 2 mode and SCR mode. The mode can be selected by an input signal to the engine automation system.

In SCR mode the exhaust gas temperatures after the turbocharger are actively monitored and adjusted to stay within the operating temperature window of the SCR.

2.2 Engine operating range

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.

2.2.1 Controllable pitch propellers

An automatic load control system is required to protect the engine from overload. The load control reduces the propeller pitch automatically, when a pre-programmed load versus speed curve (“engine limit curve”) is exceeded, overriding the combinator curve if necessary. The engine load is derived from fuel rack position and actual engine speed (not speed demand).

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

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

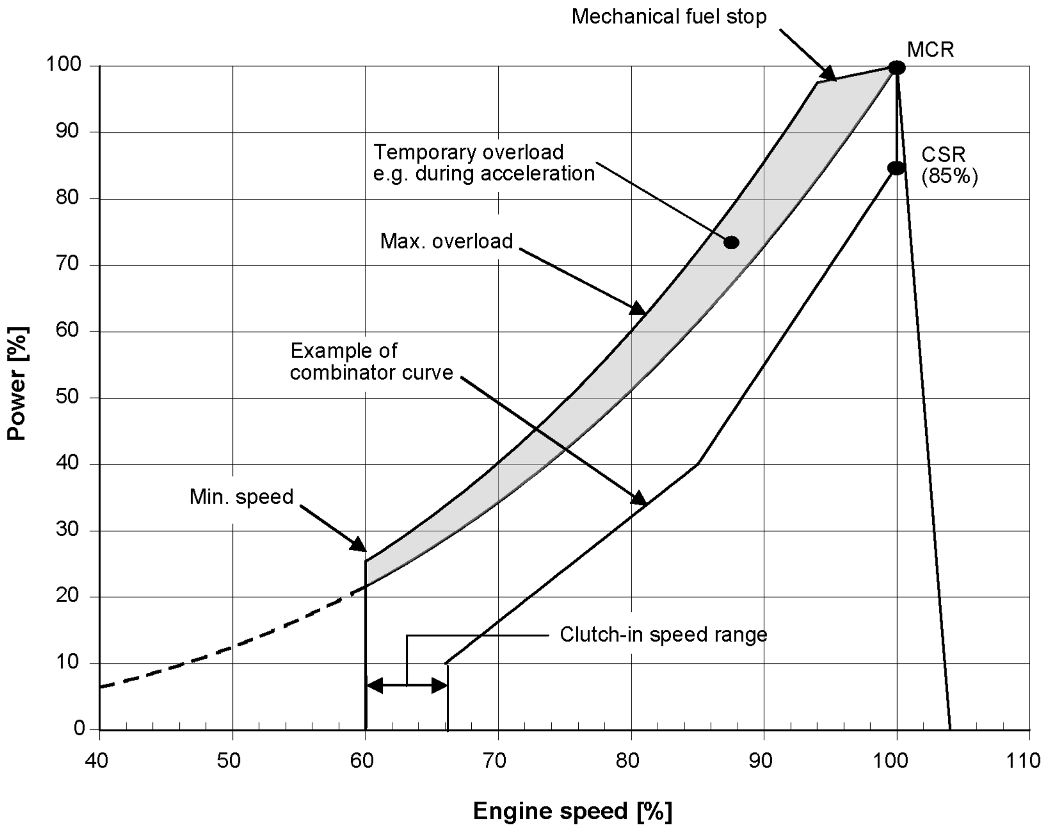

Fig 2.2.1.1 Operating field for CP Propeller (DAAF007339)

2.2.2 Fixed pitch propellers

The thrust and power absorption of a given fixed pitch propeller is determined by the relation between ship speed and propeller revolution speed. The power absorption during acceleration, manoeuvring or towing is considerably higher than during free sailing for the same revolution speed. Increased ship resistance, for reason or another, reduces the ship speed, which increases the power absorption of the propeller over the whole operating range.

Loading conditions, weather conditions, ice conditions, fouling of hull, shallow water, and manoeuvring requirements must be carefully considered, when matching a fixed pitch propeller to the engine. The nominal propeller curve shown in the diagram must not be exceeded in service, except temporarily during acceleration and manoeuvring. A fixed pitch propeller for a free sailing ship is therefore dimensioned so that it absorbs max. 85% of the engine output at nominal engine speed during trial with loaded ship. Typically this corresponds to about 82% for the propeller itself.

If the vessel is intended for towing, the propeller is dimensioned to absorb 95% of the engine power at nominal engine speed in bollard pull or towing condition. It is allowed to increase the engine speed to 101.7% in order to reach 100% MCR during bollard pull.

A shaft brake should be used to enable faster reversing and shorter stopping distance (crash stop). The ship speed at which the propeller can be engaged in reverse direction is still limited by the windmilling torque of the propeller and the torque capability of the engine at low revolution speed.

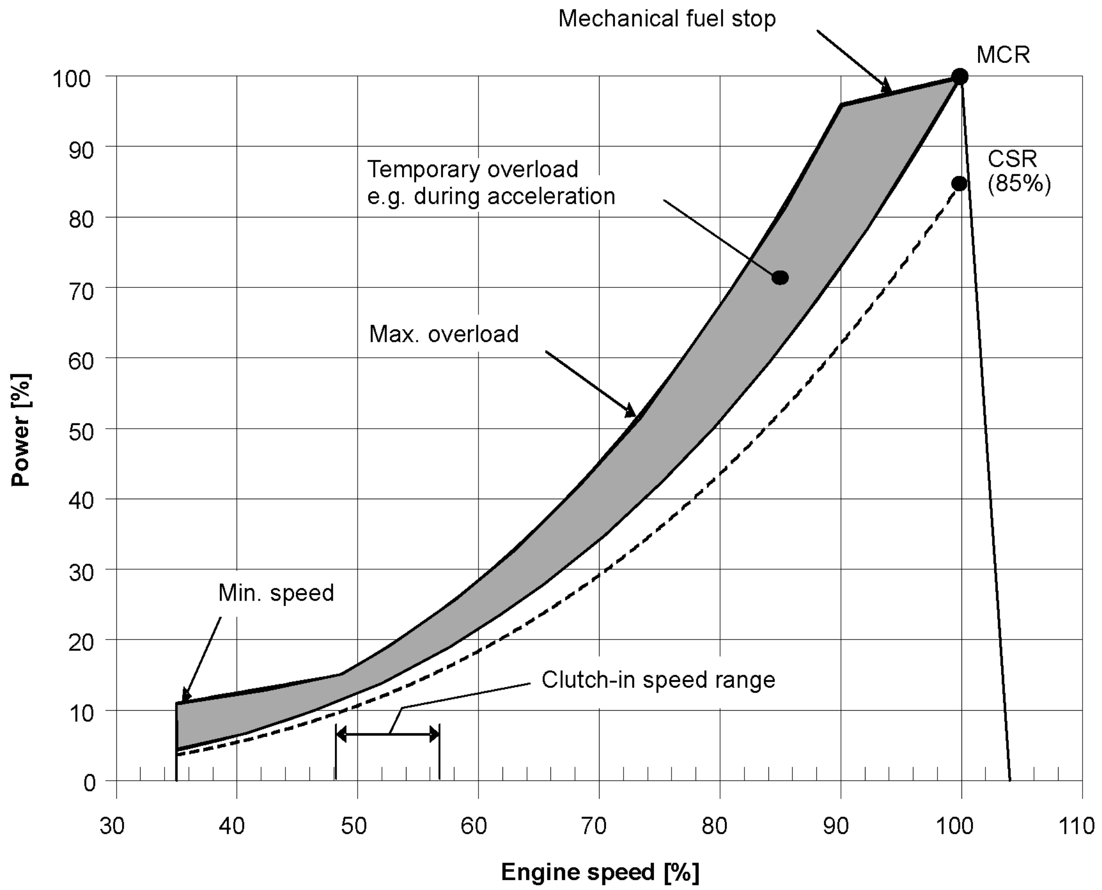

Fig 2.2.2.1 Operating field for FP Propeller (DAAF007340)

2.2.2.1 FP propellers in twin screw vessels

Requirements regarding manoeuvring response and acceleration, as well as overload with one engine out of operation must be very carefully evaluated if the vessel is designed for free sailing, in particular if open propellers are applied. If the bollard pull curve significantly exceeds the maximum overload limit, acceleration and manoeuvring response can be very slow. Nozzle propellers are less problematic in this respect.

2.2.3 Dredgers

Mechanically driven dredging pumps typically require a capability to operate with full torque down to 80% of nominal engine speed. This requirement results in significant de-rating of the engine.

2.3 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 a HT-water temperature of 60…70ºC, and the lubricating oil temperature is min. 40 ºC.

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

2.3.1 Mechanical propulsion

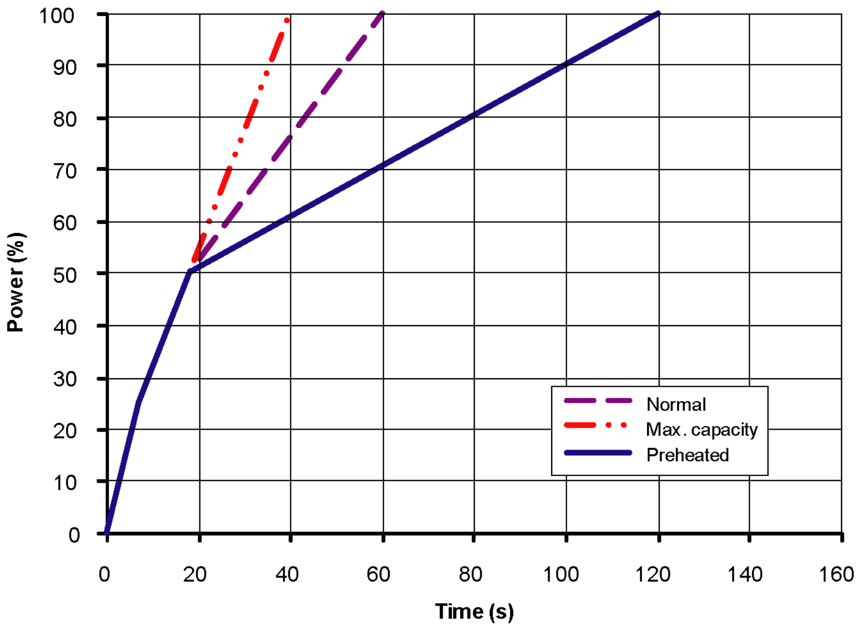

Fig 2.3.1.1 Maximum recommended load increase rates for variable speed engines

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.

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

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).

2.3.2 Diesel electric propulsion and auxiliary engines

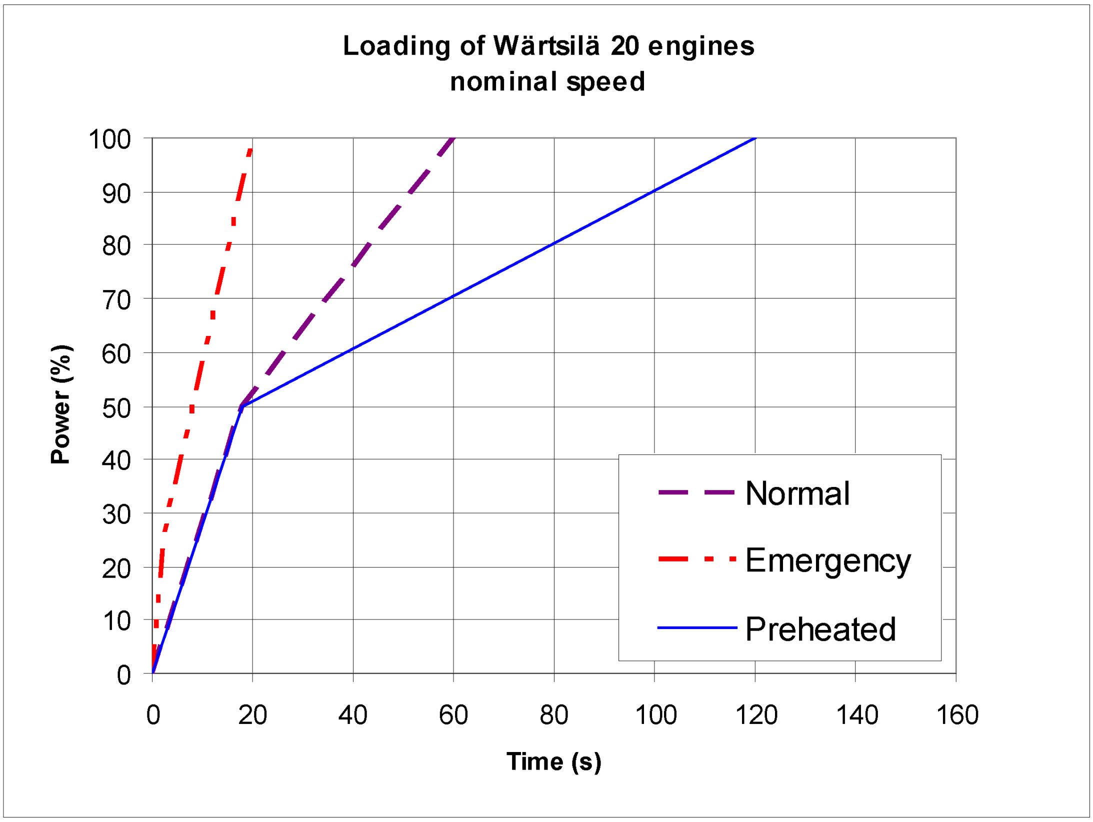

Fig 2.3.2.1 Maximum recommended load increase rates for engines operating at nominal speed

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.

2.3.2.1 Maximum instant load steps

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

When electrical power is restored after a black-out, consumers are reconnected in groups or in a fast sequence with few generators on the busbar, which may cause significant load steps. The engine must be allowed to recover for at least 7 seconds before applying the following load step, if the load is applied in maximum steps.

2.3.2.2 Start-up time

A diesel generator typically reaches nominal speed in about 20...25 seconds after the start signal. The acceleration is limited by the speed control to minimise smoke during start-up.

2.4 Operation at low load and idling

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

Absolute idling (declutched main engine, disconnected generator)

- Maximum 10 minutes if the engine is to be stopped after the idling. 3-5 minutes idling before stop is recommended.
- Maximum 6 hours if the engine is to be loaded after the idling.

Operation below 20 % load

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

Operation above 20 % load

- No restrictions.

NOTE

For operation profiles involving prolonged low load operation, please contact Wärtsilä.

2.5 Low air temperature

In cold conditions the following minimum inlet air temperatures apply:

Depending on the setup down to -45ºC.

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

3. Technical Data

3.1 Wärtsilä 4L20

Wärtsilä 4L20		AE/DE Tier 2 mode	AE/DE Tier 2 mode	ME Tier 2 mode	AE/DE SCR mode	AE/DE SCR mode	ME SCR mode
Cylinder output	**kW**	**185**	**200**	**200**	**185**	**200**	**200**
Engine speed	**RPM**	**900**	**1000**	**1000**	**900**	**1000**	**1000**
Engine output	kW	740	800	800	740	800	800
Mean effective pressure	MPa	2.8	2.73	2.73	2.8	2.73	2.73
Combustion air system (Note 1)							
Flow at 100% load	kg/s	1.38	1.5	1.5	1.38	1.5	1.5
Temperature at turbocharger intake, max.	°C	45	45	45	45	45	45
Temperature after air cooler (TE601)	°C	50...70	50...70	50...70	50...70	50...70	50...70
Exhaust gas system (Note 2)							
Flow at 100% load	kg/s	1.42	1.55	1.55	1.42	1.55	1.55
Flow at 85% load	kg/s	1.31	1.43	1.39	1.24	1.36	1.36
Flow at 75% load	kg/s	1.16	1.28	1.2	1.08	1.2	1.2
Flow at 50% load	kg/s	0.81	0.9	0.8	0.81	0.9	0.8
Temperature after turbocharger, 100% load (TE517)	°C	370	370	370	370	370	370
Temperature after turbocharger, 85% load (TE517)	°C	335	335	340	340	340	340
Temperature after turbocharger, 75% load (TE517)	°C	335	335	350	340	340	350
Temperature after turbocharger, 50% load (TE517)	°C	355	355	385	355	355	385
Backpressure, max.	kPa	5.0	5.0	5.0	5.0	5.0	5.0
Calculated pipe diameter for 35 m/s	mm	306	320	320	306	320	320
Heat balance (Note 3)							
Jacket water, HT-circuit	kW	166	175	175	166	175	175
Charge air, LT-circuit	kW	251	275	275	251	275	275
Lubricating oil, LT-circuit	kW	122	130	130	122	130	130
Radiation	kW	32	33	33	33	34	33
Fuel system (Note 4)							
Pressure before injection pumps (PT101)	kPa	700±50	700±50	700±50	700±50	700±50	700±50
Engine driven pump capacity (MDF only)	m^3/h	0.78	0.87	0.87	0.78	0.87	0.87
Fuel flow to engine (without engine driven pump), approx.	m^3/h	0.64	0.7	0.69	0.64	0.7	0.69
HFO viscosity before engine	cSt	16... 24	16... 24	16... 24	16... 24	16... 24	16... 24
Max. HFO temperature before engine (TE101)	°C	140	140	140	140	140	140
MDF viscosity, min.	cSt	1.8	1.8	1.8	1.8	1.8	1.8

Wärtsilä 4L20		AE/DE Tier 2 mode	AE/DE Tier 2 mode	ME Tier 2 mode	AE/DE SCR mode	AE/DE SCR mode	ME SCR mode
Cylinder output	**kW**	185	200	200	185	200	200
Engine speed	**RPM**	**900**	**1000**	**1000**	**900**	**1000**	**1000**
Max. MDF temperature before engine (TE101)	°C	45	45	45	45	45	45
Fuel consumption at 100% load	g/kWh	198	199	197	198	199	197
Fuel consumption at 85% load	g/kWh	195	196	194	196	197	195
Fuel consumption at 75% load	g/kWh	196	197	194	197	198	194
Fuel consumption at 50% load	g/kWh	203	204	196	203	204	196
Clean leak fuel quantity, MDF at 100% load	kg/h	3.1	3.3	3.3	3.1	3.3	3.3
Clean leak fuel quantity, HFO at 100% load	kg/h	0.6	0.7	0.7	0.6	0.7	0.7
Lubricating oil system							
Pressure before bearings, nom. (PT201)	kPa	450	450	450	450	450	450
Suction ability main pump, including pipe loss, max.	kPa	20	20	20	20	20	20
Priming pressure, nom. (PT201)	kPa	80	80	80	80	80	80
Suction ability priming pump, including pipe loss, max.	kPa	20	20	20	20	20	20
Temperature before bearings, nom. (TE201)	°C	66	66	66	66	66	66
Temperature after engine, approx.	°C	78	78	78	78	78	78
Pump capacity (main), engine driven	m³/h	24	27	34	24	27	34
Pump capacity (main), stand-by	m³/h	21	21	21	21	21	21
Priming pump capacity, 50Hz/60Hz	m³/h	8.6 / 10.4	8.6 / 10.4	8.6 / 10.5	8.6 / 10.4	8.6 / 10.4	8.6 / 10.5
Oil volume, wet sump, nom.	m³	0.27	0.27	0.27	0.27	0.27	0.27
Oil volume in separate system oil tank	m³	1.0	1.1	1.1	1.0	1.1	1.1
Filter fineness, nom.	microns	25	25	25	25	25	25
Oil consumption at 100% load, max.	g/kWh	0.5	0.5	0.5	0.5	0.5	0.5
Crankcase ventilation backpressure, max.	kPa	0.3	0.3	0.3	0.3	0.3	0.3
Oil volume in speed governor	liters	1.4...2.2	1.4...2.2	1.4...2.2	1.4...2.2	1.4...2.2	1.4...2.2
Cooling water system							
High temperature cooling water system							
Pressure at engine, after pump, nom. (PT401)	kPa	200 + static	200 + static	200 + static	200 + static	200 + static	200 + static
Pressure at engine, after pump, max. (PT401)	kPa	500	500	350	500	500	350
Temperature before cylinder, approx. (TE401)	°C	83	83	83	83	83	83
Temperature after engine, nom.	°C	91	91	91	91	91	91
Capacity of engine driven pump, nom.	m³/h	20	20	20	20	20	20
Pressure drop over engine, total	kPa	90	90	90	90	90	90
Pressure drop in external system, max.	kPa	120	120	120	120	120	120
Water volume in engine	m³	0.09	0.09	0.09	0.09	0.09	0.09
Pressure from expansion tank	kPa	70...150	70...150	70...150	70...150	70...150	70...150
Low temperature cooling water system							

Wärtsilä 4L20		AE/DE Tier 2 mode	AE/DE Tier 2 mode	ME Tier 2 mode	AE/DE SCR mode	AE/DE SCR mode	ME SCR mode
Cylinder output	**kW**	**185**	**200**	**200**	**185**	**200**	**200**
Engine speed	**RPM**	**900**	**1000**	**1000**	**900**	**1000**	**1000**
Pressure at engine, after pump, nom. (PT451)	kPa	200 + static	200 + static	200 + static	200 + static	200 + static	200 + static
Pressure at engine, after pump, max. (PT451)	kPa	500	500	350	500	500	350
Temperature before engine, min...max	°C	25...38	25...38	25...38	25...38	25...38	25...38
Capacity of engine driven pump, nom.	m³/h	23	24	24	23	24	24
Pressure drop over charge air cooler	kPa	30	30	30	30	30	30
Pressure drop over oil cooler	kPa	30	30	30	30	30	30
Pressure drop in external system, max.	kPa	120	120	120	120	120	120
Pressure from expansion tank	kPa	70...150	70...150	70...150	70...150	70...150	70...150
Starting air system							
Pressure, nom.	kPa	3000	3000	3000	3000	3000	3000
Pressure, max.	kPa	3000	3000	3000	3000	3000	3000
Low pressure limit in air vessels	kPa	1800	1800	1800	1800	1800	1800
Starting air consumption, start (successful)	Nm³	1.2	1.2	1.2	1.2	1.2	1.2

Notes:

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

Note 2 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 5% and temperature tolerance 10°C.

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

Note 4 At ambient conditions according to ISO 15550. Lower calorific value 42 700 kJ/kg. With engine driven pumps (two cooling water + 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 Wärtsilä 6L20

Wärtsilä 6L20		AE/DE Tier 2 mode	AE/DE Tier 2 mode	ME Tier 2 mode	AE/DE SCR mode	AE/DE SCR mode	ME SCR mode
Cylinder output	**kW**	**185**	**200**	**200**	**185**	**200**	**200**
Engine speed	**RPM**	**900**	**1000**	**1000**	**900**	**1000**	**1000**
Engine output	kW	1110	1200	1200	1110	1200	1200
Mean effective pressure	MPa	2.8	2.73	2.73	2.8	2.73	2.73
Combustion air system (Note 1)							
Flow at 100% load	kg/s	2.14	2.33	2.31	2.14	2.33	2.31
Temperature at turbocharger intake, max.	°C	45	45	45	45	45	45
Temperature after air cooler (TE601)	°C	50...70	50...70	50...70	50...70	50...70	50...70
Exhaust gas system (Note 2)							
Flow at 100% load	kg/s	2.2	2.4	2.38	2.2	2.4	2.38
Flow at 85% load	kg/s	1.9	2.06	2.12	1.9	2.05	2.12
Flow at 75% load	kg/s	1.66	1.83	1.84	1.66	1.83	1.84
Flow at 50% load	kg/s	1.18	1.29	1.11	1.18	1.29	1.11
Temperature after turbocharger, 100% load (TE517)	°C	355	355	355	355	355	355
Temperature after turbocharger, 85% load (TE517)	°C	330	330	320	340	340	340
Temperature after turbocharger, 75% load (TE517)	°C	339	339	330	340	340	340
Temperature after turbocharger, 50% load (TE517)	°C	364	364	400	364	364	400
Backpressure, max.	kPa	5.0	5.0	5.0	5.0	5.0	5.0
Calculated pipe diameter for 35 m/s	mm	376	393	391	376	393	391
Heat balance (Note 3)							
Jacket water, HT-circuit	kW	230	250	250	230	250	250
Charge air, LT-circuit	kW	368	403	405	368	403	405
Lubricating oil, LT-circuit	kW	150	170	170	150	170	170
Radiation	kW	46	50	49	46	50	49
Fuel system (Note 4)							
Pressure before injection pumps (PT101)	kPa	700±50	700±50	700±50	700±50	700±50	700±50
Engine driven pump capacity (MDF only)	m^3/h	1.34	1.49	1.49	1.34	1.49	1.49
Fuel flow to engine (without engine driven pump), approx.	m^3/h	0.94	1.03	1.02	0.94	1.03	1.02
HFO viscosity before engine	cSt	16... 24	16... 24	16... 24	16... 24	16... 24	16... 24
Max. HFO temperature before engine (TE101)	°C	140	140	140	140	140	140
MDF viscosity, min.	cSt	1.8	1.8	1.8	1.8	1.8	1.8
Max. MDF temperature before engine (TE101)	°C	45	45	45	45	45	45
Fuel consumption at 100% load	g/kWh	193	194	192	193	194	192
Fuel consumption at 85% load	g/kWh	190	191	189	192	193	192
Fuel consumption at 75% load	g/kWh	192	193	189	193	194	192

Wärtsilä 6L20		AE/DE Tier 2 mode	AE/DE Tier 2 mode	ME Tier 2 mode	AE/DE SCR mode	AE/DE SCR mode	ME SCR mode
Cylinder output	**kW**	**185**	**200**	**200**	**185**	**200**	**200**
Engine speed	**RPM**	**900**	**1000**	**1000**	**900**	**1000**	**1000**
Fuel consumption at 50% load	g/kWh	197	198	191	197	198	191
Clean leak fuel quantity, MDF at 100% load	kg/h	4.5	4.9	4.8	4.5	4.9	4.8
Clean leak fuel quantity, HFO at 100% load	kg/h	0.9	1.0	1.0	0.9	1.0	1.0
Lubricating oil system							
Pressure before bearings, nom. (PT201)	kPa	450	450	450	450	450	450
Suction ability main pump, including pipe loss, max.	kPa	20	20	20	20	20	20
Priming pressure, nom. (PT201)	kPa	80	80	80	80	80	80
Suction ability priming pump, including pipe loss, max.	kPa	20	20	20	20	20	20
Temperature before bearings, nom. (TE201)	°C	66	66	66	66	66	66
Temperature after engine, approx.	°C	78	78	78	78	78	78
Pump capacity (main), engine driven	m³/h	31	34	48	31	34	48
Pump capacity (main), stand-by	m³/h	25	25	25	25	25	25
Priming pump capacity, 50Hz/60Hz	m³/h	8.6 / 10.4	8.6 / 10.4	8.6 / 10.5	8.6 / 10.4	8.6 / 10.4	8.6 / 10.5
Oil volume, wet sump, nom.	m³	0.38	0.38	0.38	0.38	0.38	0.38
Oil volume in separate system oil tank	m³	1.5	1.6	1.6	1.5	1.6	1.6
Filter fineness, nom.	microns	25	25	25	25	25	25
Oil consumption at 100% load, max.	g/kWh	0.5	0.5	0.5	0.5	0.5	0.5
Crankcase ventilation backpressure, max.	kPa	0.3	0.3	0.3	0.3	0.3	0.3
Oil volume in speed governor	liters	1.4...2.2	1.4...2.2	1.4...2.2	1.4...2.2	1.4...2.2	1.4...2.2
Cooling water system							
High temperature cooling water system							
Pressure at engine, after pump, nom. (PT401)	kPa	200 + static	200 + static	200 + static	200 + static	200 + static	200 + static
Pressure at engine, after pump, max. (PT401)	kPa	500	500	350	500	500	350
Temperature before cylinder, approx. (TE401)	°C	83	83	83	83	83	83
Temperature after engine, nom.	°C	91	91	91	91	91	91
Capacity of engine driven pump, nom.	m³/h	29	30	30	29	30	30
Pressure drop over engine, total	kPa	90	90	90	90	90	90
Pressure drop in external system, max.	kPa	120	120	120	120	120	120
Water volume in engine	m³	0.12	0.12	0.12	0.12	0.12	0.12
Pressure from expansion tank	kPa	70...150	70...150	70...150	70...150	70...150	70...150
Low temperature cooling water system							
Pressure at engine, after pump, nom. (PT451)	kPa	200 + static	200 + static	200 + static	200 + static	200 + static	200 + static
Pressure at engine, after pump, max. (PT451)	kPa	500	500	350	500	500	350
Temperature before engine, min...max	°C	25...38	25...38	25...38	25...38	25...38	25...38
Capacity of engine driven pump, nom.	m³/h	34	36	36	34	36	36

Wärtsilä 6L20		AE/DE Tier 2 mode	AE/DE Tier 2 mode	ME Tier 2 mode	AE/DE SCR mode	AE/DE SCR mode	ME SCR mode
Cylinder output	**kW**	185	200	200	185	200	200
Engine speed	**RPM**	**900**	**1000**	**1000**	**900**	**1000**	**1000**
Pressure drop over charge air cooler	kPa	30	30	30	30	30	30
Pressure drop over oil cooler	kPa	30	30	30	30	30	30
Pressure drop in external system, max.	kPa	120	120	120	120	120	120
Pressure from expansion tank	kPa	70...150	70...150	70...150	70...150	70...150	70...150
Starting air system							
Pressure, nom.	kPa	3000	3000	3000	3000	3000	3000
Pressure, max.	kPa	3000	3000	3000	3000	3000	3000
Low pressure limit in air vessels	kPa	1800	1800	1800	1800	1800	1800
Starting air consumption, start (successful)	Nm^3	1.2	1.2	1.2	1.2	1.2	1.2

Notes:

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

Note 2 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 5% and temperature tolerance 10°C.

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

Note 4 At ambient conditions according to ISO 15550. Lower calorific value 42 700 kJ/kg. With engine driven pumps (two cooling water + 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 8L20

Wärtsilä 8L20		AE/DE Tier 2 mode	AE/DE Tier 2 mode	ME Tier 2 mode	AE/DE SCR mode	AE/DE SCR mode	ME SCR mode
Cylinder output	**kW**	**185**	**200**	**200**	**185**	**200**	**200**
Engine speed	**RPM**	**900**	**1000**	**1000**	**900**	**1000**	**1000**
Engine output	kW	1480	1600	1600	1480	1600	1600
Mean effective pressure	MPa	2.8	2.73	2.73	2.8	2.73	2.73
Combustion air system (Note 1)							
Flow at 100% load	kg/s	2.77	3.02	3.02	2.77	3.02	3.02
Temperature at turbocharger intake, max.	°C	45	45	45	45	45	45
Temperature after air cooler (TE601)	°C	50...70	50...70	50...70	50...70	50...70	50...70
Exhaust gas system (Note 2)							
Flow at 100% load	kg/s	2.85	3.11	3.11	2.85	3.11	3.11
Flow at 85% load	kg/s	2.62	2.85	2.77	2.48	2.69	2.69
Flow at 75% load	kg/s	2.33	2.56	2.4	2.18	2.39	2.4
Flow at 50% load	kg/s	1.63	1.8	1.61	1.63	1.8	1.61
Temperature after turbocharger, 100% load (TE517)	°C	370	370	370	370	370	370
Temperature after turbocharger, 85% load (TE517)	°C	335	335	340	340	340	340
Temperature after turbocharger, 75% load (TE517)	°C	335	335	350	340	340	350
Temperature after turbocharger, 50% load (TE517)	°C	355	355	385	355	355	385
Backpressure, max.	kPa	5.0	5.0	5.0	5.0	5.0	5.0
Calculated pipe diameter for 35 m/s	mm	433	453	453	433	453	453
Heat balance (Note 3)							
Jacket water, HT-circuit	kW	316	330	333	316	330	333
Charge air, LT-circuit	kW	489	535	535	489	535	535
Lubricating oil, LT-circuit	kW	245	260	260	245	260	260
Radiation	kW	62	66	66	63	67	66
Fuel system (Note 4)							
Pressure before injection pumps (PT101)	kPa	700±50	700±50	700±50	700±50	700±50	700±50
Engine driven pump capacity (MDF only)	m³/h	1.73	1.92	1.92	1.73	1.92	1.92
Fuel flow to engine (without engine driven pump), approx.	m³/h	1.28	1.39	1.37	1.28	1.39	1.37
HFO viscosity before engine	cSt	16... 24	16... 24	16... 24	16... 24	16... 24	16... 24
Max. HFO temperature before engine (TE101)	°C	140	140	140	140	140	140
MDF viscosity, min.	cSt	1.8	1.8	1.8	1.8	1.8	1.8
Max. MDF temperature before engine (TE101)	°C	45	45	45	45	45	45
Fuel consumption at 100% load	g/kWh	196	197	195	196	197	195
Fuel consumption at 85% load	g/kWh	193	194	193	194	195	194
Fuel consumption at 75% load	g/kWh	194	195	193	195	196	193

Wärtsilä 8L20		AE/DE Tier 2 mode	AE/DE Tier 2 mode	ME Tier 2 mode	AE/DE SCR mode	AE/DE SCR mode	ME SCR mode
Cylinder output	**kW**	**185**	**200**	**200**	**185**	**200**	**200**
Engine speed	**RPM**	**900**	**1000**	**1000**	**900**	**1000**	**1000**
Fuel consumption at 50% load	g/kWh	201	202	194	201	202	194
Clean leak fuel quantity, MDF at 100% load	kg/h	6.1	6.6	6.5	6.1	6.6	6.5
Clean leak fuel quantity, HFO at 100% load	kg/h	1.2	1.3	1.3	1.2	1.3	1.3
Lubricating oil system							
Pressure before bearings, nom. (PT201)	kPa	450	450	450	450	450	450
Suction ability main pump, including pipe loss, max.	kPa	20	20	20	20	20	20
Priming pressure, nom. (PT201)	kPa	80	80	80	80	80	80
Suction ability priming pump, including pipe loss, max.	kPa	20	20	20	20	20	20
Temperature before bearings, nom. (TE201)	°C	66	66	66	66	66	66
Temperature after engine, approx.	°C	78	78	78	78	78	78
Pump capacity (main), engine driven	m³/h	43	48	64	43	48	64
Pump capacity (main), stand-by	m³/h	31	31	31	31	31	31
Priming pump capacity, 50Hz/60Hz	m³/h	8.6 / 10.4	8.6 / 10.4	8.6 / 10.5	8.6 / 10.4	8.6 / 10.4	8.6 / 10.5
Oil volume, wet sump, nom.	m³	0.49	0.49	0.49	0.49	0.49	0.49
Oil volume in separate system oil tank	m³	2.0	2.2	2.2	2.0	2.2	2.2
Filter fineness, nom.	microns	25	25	25	25	25	25
Oil consumption at 100% load, max.	g/kWh	0.5	0.5	0.5	0.5	0.5	0.5
Crankcase ventilation backpressure, max.	kPa	0.3	0.3	0.3	0.3	0.3	0.3
Oil volume in speed governor	liters	1.4...2.2	1.4...2.2	1.4...2.2	1.4...2.2	1.4...2.2	1.4...2.2
Cooling water system							
High temperature cooling water system							
Pressure at engine, after pump, nom. (PT401)	kPa	200 + static	200 + static	200 + static	200 + static	200 + static	200 + static
Pressure at engine, after pump, max. (PT401)	kPa	500	500	350	500	500	350
Temperature before cylinder, approx. (TE401)	°C	83	83	83	83	83	83
Temperature after engine, nom.	°C	91	91	91	91	91	91
Capacity of engine driven pump, nom.	m³/h	39	40	40	39	40	40
Pressure drop over engine, total	kPa	90	90	90	90	90	90
Pressure drop in external system, max.	kPa	120	120	120	120	120	120
Water volume in engine	m³	0.15	0.15	0.15	0.15	0.15	0.15
Pressure from expansion tank	kPa	70...150	70...150	70...150	70...150	70...150	70...150
Low temperature cooling water system							
Pressure at engine, after pump, nom. (PT451)	kPa	200 + static	200 + static	200 + static	200 + static	200 + static	200 + static
Pressure at engine, after pump, max. (PT451)	kPa	500	500	350	500	500	350
Temperature before engine, min...max	°C	25...38	25...38	25...38	25...38	25...38	25...38
Capacity of engine driven pump, nom.	m³/h	45	48	48	45	48	48

Wärtsilä 8L20		AE/DE Tier 2 mode	AE/DE Tier 2 mode	ME Tier 2 mode	AE/DE SCR mode	AE/DE SCR mode	ME SCR mode
Cylinder output	**kW**	**185**	**200**	**200**	**185**	**200**	**200**
Engine speed	**RPM**	**900**	**1000**	**1000**	**900**	**1000**	**1000**
Pressure drop over charge air cooler	kPa	30	30	30	30	30	30
Pressure drop over oil cooler	kPa	30	30	30	30	30	30
Pressure drop in external system, max.	kPa	120	120	120	120	120	120
Pressure from expansion tank	kPa	70...150	70...150	70...150	70...150	70...150	70...150
Starting air system							
Pressure, nom.	kPa	3000	3000	3000	3000	3000	3000
Pressure, max.	kPa	3000	3000	3000	3000	3000	3000
Low pressure limit in air vessels	kPa	1800	1800	1800	1800	1800	1800
Starting air consumption, start (successful)	Nm^3	1.2	1.2	1.2	1.2	1.2	1.2

Notes:

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

Note 2 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 5% and temperature tolerance 10°C.

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

Note 4 At ambient conditions according to ISO 15550. Lower calorific value 42 700 kJ/kg. With engine driven pumps (two cooling water + 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 9L20

Wärtsilä 9L20		AE/DE Tier 2 mode	AE/DE Tier 2 mode	ME Tier 2 mode	AE/DE SCR mode	AE/DE SCR mode	ME SCR mode
Cylinder output	**kW**	**185**	**200**	**200**	**185**	**200**	**200**
Engine speed	**RPM**	**900**	**1000**	**1000**	**900**	**1000**	**1000**
Engine output	kW	1665	1800	1800	1665	1800	1800
Mean effective pressure	MPa	2.8	2.73	2.73	2.8	2.73	2.73
Combustion air system (Note 1)							
Flow at 100% load	kg/s	3.21	3.5	3.47	3.21	3.5	3.47
Temperature at turbocharger intake, max.	°C	45	45	45	45	45	45
Temperature after air cooler (TE601)	°C	50...70	50...70	50...70	50...70	50...70	50...70
Exhaust gas system (Note 2)							
Flow at 100% load	kg/s	3.3	3.6	3.57	3.3	3.6	3.57
Flow at 85% load	kg/s	2.84	3.09	3.18	2.84	3.09	3.09
Flow at 75% load	kg/s	2.49	2.75	2.76	2.49	2.75	2.75
Flow at 50% load	kg/s	1.76	1.94	1.67	1.76	1.94	1.67
Temperature after turbocharger, 100% load (TE517)	°C	355	355	355	355	355	355
Temperature after turbocharger, 85% load (TE517)	°C	330	330	320	340	340	340
Temperature after turbocharger, 75% load (TE517)	°C	339	339	330	340	340	340
Temperature after turbocharger, 50% load (TE517)	°C	364	364	400	364	364	400
Backpressure, max.	kPa	5.0	5.0	5.0	5.0	5.0	5.0
Calculated pipe diameter for 35 m/s	mm	461	481	479	461	481	479
Heat balance (Note 3)							
Jacket water, HT-circuit	kW	350	375	375	350	375	375
Charge air, LT-circuit	kW	554	607	610	554	607	610
Lubricating oil, LT-circuit	kW	250	270	270	250	270	270
Radiation	kW	69	76	74	69	76	74
Fuel system (Note 4)							
Pressure before injection pumps (PT101)	kPa	700±50	700±50	700±50	700±50	700±50	700±50
Engine driven pump capacity (MDF only)	m³/h	1.73	1.92	1.92	1.73	1.92	1.92
Fuel flow to engine (without engine driven pump), approx.	m³/h	1.42	1.55	1.53	1.42	1.55	1.53
HFO viscosity before engine	cSt	16... 24	16... 24	16... 24	16... 24	16... 24	16... 24
Max. HFO temperature before engine (TE101)	°C	140	140	140	140	140	140
MDF viscosity, min.	cSt	1.8	1.8	1.8	1.8	1.8	1.8
Max. MDF temperature before engine (TE101)	°C	45	45	45	45	45	45
Fuel consumption at 100% load	g/kWh	194	195	193	194	195	193
Fuel consumption at 85% load	g/kWh	191	192	190	193	194	193
Fuel consumption at 75% load	g/kWh	193	194	190	194	195	193

Wärtsilä 9L20		AE/DE Tier 2 mode	AE/DE Tier 2 mode	ME Tier 2 mode	AE/DE SCR mode	AE/DE SCR mode	ME SCR mode
Cylinder output	**kW**	**185**	**200**	**200**	**185**	**200**	**200**
Engine speed	**RPM**	**900**	**1000**	**1000**	**900**	**1000**	**1000**
Fuel consumption at 50% load	g/kWh	199	200	192	199	200	192
Clean leak fuel quantity, MDF at 100% load	kg/h	6.8	7.3	7.3	6.8	7.3	7.3
Clean leak fuel quantity, HFO at 100% load	kg/h	1.4	1.5	1.5	1.4	1.5	1.5
Lubricating oil system							
Pressure before bearings, nom. (PT201)	kPa	450	450	450	450	450	450
Suction ability main pump, including pipe loss, max.	kPa	20	20	20	20	20	20
Priming pressure, nom. (PT201)	kPa	80	80	80	80	80	80
Suction ability priming pump, including pipe loss, max.	kPa	20	20	20	20	20	20
Temperature before bearings, nom. (TE201)	°C	66	66	66	66	66	66
Temperature after engine, approx.	°C	78	78	78	78	78	78
Pump capacity (main), engine driven	m³/h	43	48	64	43	48	64
Pump capacity (main), stand-by	m³/h	34	34	34	34	34	34
Priming pump capacity, 50Hz/60Hz	m³/h	8.6 / 10.4	8.6 / 10.4	8.6 / 10.5	8.6 / 10.4	8.6 / 10.4	8.6 / 10.5
Oil volume, wet sump, nom.	m³	0.55	0.55	0.55	0.55	0.55	0.55
Oil volume in separate system oil tank	m³	2.2	2.4	2.4	2.2	2.4	2.4
Filter fineness, nom.	microns	25	25	25	25	25	25
Oil consumption at 100% load, max.	g/kWh	0.5	0.5	0.5	0.5	0.5	0.5
Crankcase ventilation backpressure, max.	kPa	0.3	0.3	0.3	0.3	0.3	0.3
Oil volume in speed governor	liters	1.4...2.2	1.4...2.2	1.4...2.2	1.4...2.2	1.4...2.2	1.4...2.2
Cooling water system							
High temperature cooling water system							
Pressure at engine, after pump, nom. (PT401)	kPa	200 + static	200 + static	200 + static	200 + static	200 + static	200 + static
Pressure at engine, after pump, max. (PT401)	kPa	500	500	350	500	500	350
Temperature before cylinder, approx. (TE401)	°C	83	83	83	83	83	83
Temperature after engine, nom.	°C	91	91	91	91	91	91
Capacity of engine driven pump, nom.	m³/h	44	45	45	44	45	45
Pressure drop over engine, total	kPa	90	90	90	90	90	90
Pressure drop in external system, max.	kPa	120	120	120	120	120	120
Water volume in engine	m³	0.16	0.16	0.16	0.16	0.16	0.16
Pressure from expansion tank	kPa	70...150	70...150	70...150	70...150	70...150	70...150
Low temperature cooling water system							
Pressure at engine, after pump, nom. (PT451)	kPa	200 + static	200 + static	200 + static	200 + static	200 + static	200 + static
Pressure at engine, after pump, max. (PT451)	kPa	500	500	350	500	500	350
Temperature before engine, min...max	°C	25...38	25...38	25...38	25...38	25...38	25...38
Capacity of engine driven pump, nom.	m³/h	50	54	54	50	54	54

Wärtsilä 9L20		AE/DE Tier 2 mode	AE/DE Tier 2 mode	ME Tier 2 mode	AE/DE SCR mode	AE/DE SCR mode	ME SCR mode
Cylinder output	**kW**	185	200	200	185	200	200
Engine speed	**RPM**	**900**	**1000**	**1000**	**900**	**1000**	**1000**
Pressure drop over charge air cooler	kPa	30	30	30	30	30	30
Pressure drop over oil cooler	kPa	30	30	30	30	30	30
Pressure drop in external system, max.	kPa	120	120	120	120	120	120
Pressure from expansion tank	kPa	70...150	70...150	70...150	70...150	70...150	70...150
Starting air system							
Pressure, nom.	kPa	3000	3000	3000	3000	3000	3000
Pressure, max.	kPa	3000	3000	3000	3000	3000	3000
Low pressure limit in air vessels	kPa	1800	1800	1800	1800	1800	1800
Starting air consumption, start (successful)	Nm^3	1.2	1.2	1.2	1.2	1.2	1.2

Notes:

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

Note 2 At ISO 15550 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 5% and temperature tolerance 10°C.

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

Note 4 At ambient conditions according to ISO 15550. Lower calorific value 42 700 kJ/kg. With engine driven pumps (two cooling water + 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.

4. Description of the Engine

4.1 Definitions

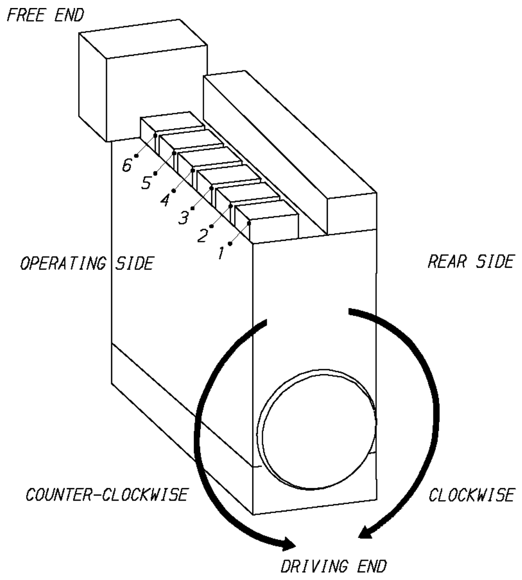

Fig 4.1.1 In-line engine definitions (1V93C0029)

4.2 Main components and systems

4.2.1 Engine block

The engine block is a one piece nodular cast iron component with integrated channels for lubricating oil and cooling water.

The main bearing caps are fixed from below by two hydraulically tensioned screws. They are guided sideways by the engine block at the top as well as at the bottom. Hydraulically tightened horizontal side screws at the lower guiding provide a very rigid crankshaft bearing.

4.2.2 Crankshaft

The crankshaft is forged in one piece and mounted on the engine block in an under-slung way.

4.2.3 Connecting rod

The connecting rod is of forged alloy steel. All connecting rod studs are hydraulically tightened. Oil is led to the gudgeon pin bearing and piston through a bore in the connecting rod.

4.2.4 Main bearings and big end bearings

The main bearings and the big end bearings are of the Al based bi-metal type with steel back.

4.2.5 Cylinder liner

The cylinder liners are centrifugally cast of a special grey cast iron alloy developed for good wear resistance and high strength. They are of wet type, sealed against the engine block metallically at the upper part and by O-rings at the lower part. To eliminate the risk of bore polishing the liner is equipped with an anti-polishing ring.

4.2.6 Piston

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

4.2.7 Piston rings

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

4.2.8 Cylinder head

The cylinder head is made of grey cast iron. The thermally loaded flame plate is cooled efficiently by cooling water led from the periphery radially towards the centre of the head. The bridges between the valves cooling channels are drilled to provide the best possible heat transfer.

The mechanical load is absorbed by a strong intermediate deck, which together with the upper deck and the side walls form a box section in the four corners of which the hydraulically tightened cylinder head bolts are situated. The exhaust valve seats are directly water-cooled.

All valves are equipped with valve rotators.

4.2.9 Camshaft and valve mechanism

There is one cam piece for each cylinder with separate bearing in between. The drop forged completely hardened camshaft pieces have fixed cams. The camshaft bearing housings are integrated in the engine block casting and are thus completely closed. The 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. The valve springs ensure that the valve mechanism is dynamically stable.

Variable Inlet valve Closure (VIC), which is available on IMO Tier 2 engines, offers flexibility to apply early inlet valve closure at high load for lowest NOx levels, while good part-load performance is ensured by adjusting the advance to zero at low load.

4.2.10 Camshaft drive

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

4.2.11 Fuel injection equipment

The injection pumps are one-cylinder pumps located in the “hot-box”, which has the following functions:

- Housing for the injection pump element
- Fuel supply channel along the whole engine
- Fuel return channel from each injection pump
- Lubricating oil supply to the valve mechanism
- Guiding for the valve tappets

The injection pumps have built-in roller tappets and are through-flow type to enable heavy fuel operation. They are also equipped with a stop cylinder, which is connected to the electro-pneumatic overspeed protection system.

The injection valve is centrally located in the cylinder head and the fuel is admitted sideways through a high pressure connection screwed in the nozzle holder. The injection pipe between the injection pump and the high pressure connection is well protected inside the hot box. The high pressure side of the injection system is completely separated from the hot parts of the exhaust gas components.

4.2.12 Turbocharging and charge air cooling

The selected turbo charger offers the ideal combination of high-pressure ratios and good efficiency.

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

4.2.13 Charge air waste gate

The charge air wastegate is used to reduce the charge air pressure by bleeding air from the charge air system.

4.2.14 Exhaust pipes

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

4.2.15 Automation system

Wärtsilä 20 is equipped with a modular embedded automation system, Wärtsilä Unified Controls - UNIC, which is available in two different versions. The basic functionality is the same in both versions, but the functionality can be easily expanded to cover different applications.

UNIC C1 has a completely hardwired signal interface with the external systems, whereas UNIC C2 and has hardwired interface for control functions and a bus communication interface for alarm and monitoring.

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

The major additional features of UNIC C2 are: all necessary engine control functions are handled by the equipment on the engine, bus communication to external systems and a more comprehensive local display unit.

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

4.3 Cross sections of the engine

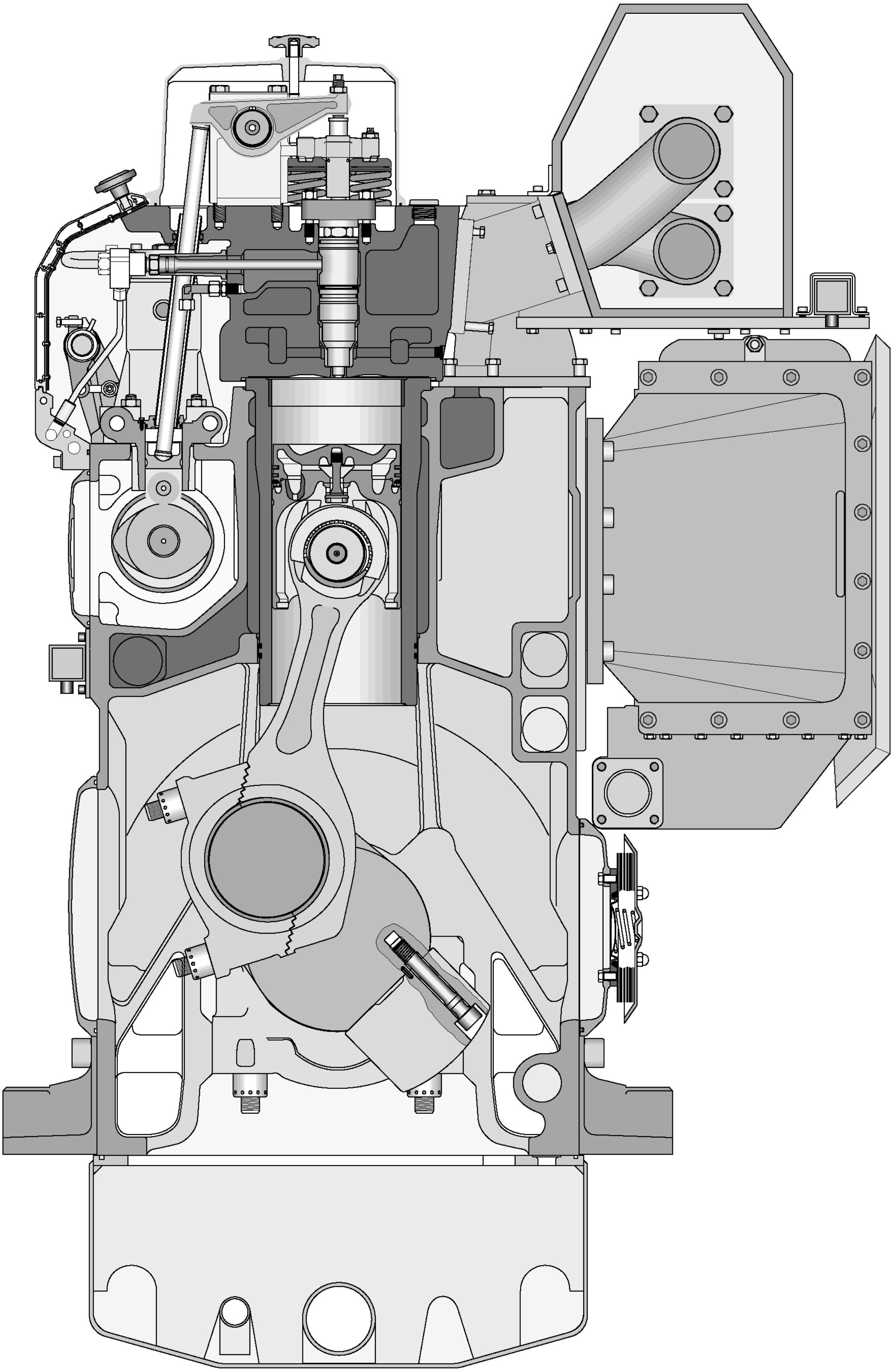

Fig 4.3.1 Cross sections of the engine

4.4 Overhaul intervals and expected lifetimes

The following overhaul intervals and lifetimes are for guidance only. Actual figures will be different depending on service conditions. Expected component lifetimes have been adjusted to match overhaul intervals.

In this list HFO is based on HFO2 specification stated in the chapter *6.. Fuel Oil System*.

Table 4.4.1 Time between overhauls and expected component lifetimes

Component	HFO	MDF	HFO	MDF
	Time between overhauls [h]		Expected component lifetimes [h]	
Piston crown	10000	20000	30000	40000
Piston rings	10000	20000	10000	20000
Cylinder liner	10000	20000	40000	60000
Cylinder head	10000	20000	50000	60000
Inlet valve	10000	20000	30000	40000
Exhaust valve	10000	20000	20000	40000
Injection nozzle	2000	2000	4000	4000
Injection element	10000	20000	20000	40000
Main bearing	10000	20000	30000	40000
Big end bearing	10000	20000	10000	20000

4.5 Engine storage

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

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5. Piping Design, Treatment and Installation

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

Fuel, lubricating oil, fresh water and compressed air piping is usually made in seamless carbon steel (DIN 2448) and seamless precision tubes in carbon or stainless steel (DIN 2391), exhaust gas piping in welded pipes of corten or carbon steel (DIN 2458). Pipes on the freshwater side of the cooling water system must not be galvanized. Sea-water piping should be made in hot dip galvanised steel, aluminium brass, cunifer or with rubber lined pipes.

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

The following aspects shall be taken into consideration:

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

Maintenance access and 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.

Recommended maximum fluid velocities on the delivery side of pumps are given as guidance in table *5.1.1*.

Table 5.1.1 Recommended maximum velocities on pump delivery side for guidance

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

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

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 Operating and design pressure

The pressure class of the piping shall be equal to or higher than the maximum operating pressure, which can be significantly higher than the normal operating pressure.

A design pressure is defined for components that are not categorized according to pressure class, and this pressure is also used to determine test pressure. The design pressure shall also be equal to or higher than the maximum pressure.

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 Product Guide 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 1.0 MPa (10 bar). The safety filter in dirty condition may cause a pressure loss of 0.1 MPa (1 bar). The viscosimeter, heater and piping may cause a pressure loss of 0.2 MPa (2 bar). Consequently the discharge pressure of the circulating pumps may rise to 1.3 MPa (13 bar), and the safety valve of the pump shall thus be adjusted e.g. to 1.4 MPa (14 bar).

- The minimum design pressure is 1.4 MPa (14 bar).
- The nearest pipe class to be selected is PN16.
- Piping test pressure is normally 1.5 x the design pressure = 2.1 MPa (21 bar).

Example 2:

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

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

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

5.4 Pipe class

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

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

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

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

Table 5.4.1 Classes of piping systems as per DNV rules

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

5.5 Insulation

The following pipes shall be insulated:

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

Insulation is also recommended for:

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

5.6 Local gauges

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

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

5.7 Cleaning procedures

Instructions shall be given to manufacturers and fitters of how different piping systems shall be treated, cleaned and protected before delivery and installation. All piping must be checked and cleaned from debris before installation. Before taking into service all piping must be cleaned according to the methods listed below.

Table 5.7.1 Pipe cleaning

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

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)

C = Purging with compressed air

D = Pickling

F = Flushing

5.7.1 Pickling

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 the 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.

5.7.2 Flushing

More detailed recommendations on flushing procedures are when necessary described under the relevant chapters concerning the fuel oil system and the lubricating oil system. Provisions are to be made to ensure that necessary temporary bypasses can be arranged and that flushing hoses, filters and pumps will be available when required.

5.8 Flexible pipe connections

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

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

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

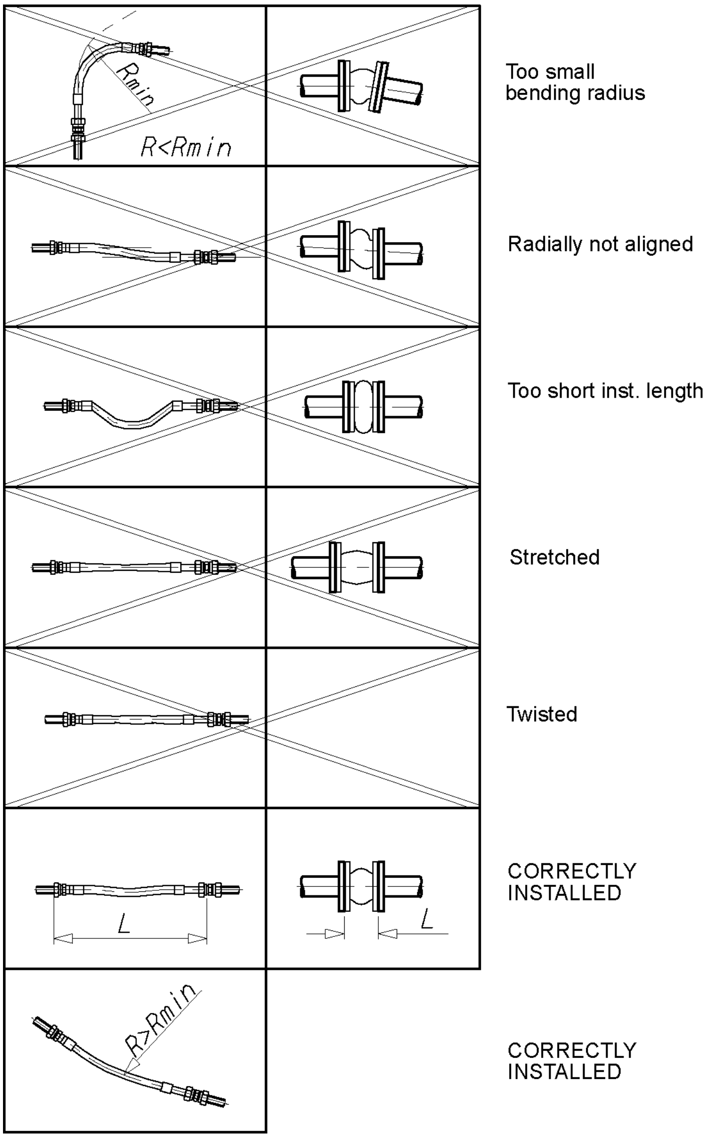


Fig 5.8.1 Flexible hoses (4V60B0100a)

5.9 Clamping of pipes

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

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

Examples of flange support structures are shown in Figure *5.9.1*. A typical pipe clamp for a fixed support is shown in Figure *5.9.2*. Pipe clamps must be made of steel; plastic clamps or similar may not be used.

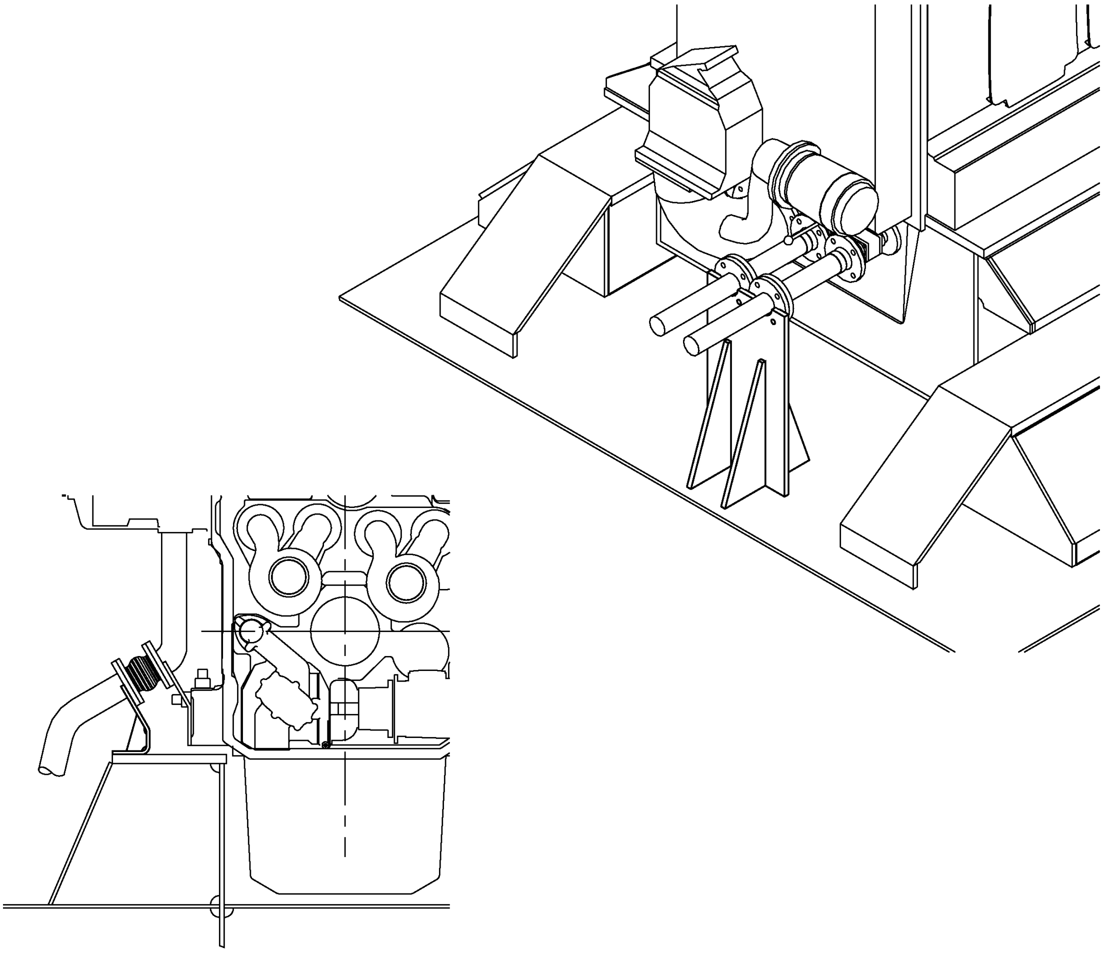
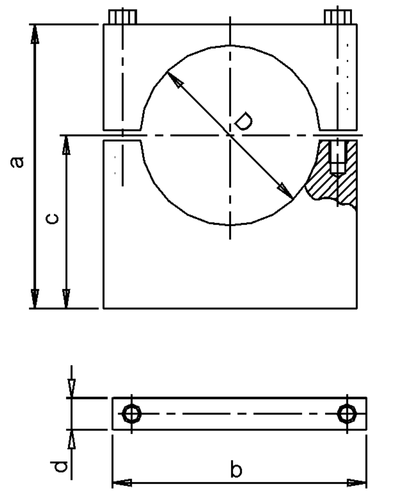


Fig 5.9.1 Flange supports of flexible pipe connections (4V60L0796)



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

d_u = Pipe outer diameter

Fig 5.9.2 Pipe clamp for fixed support (4V61H0842)

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6. Fuel Oil System

6.1 Acceptable fuel characteristics

The fuel specifications are based on the ISO 8217:2012 (E) standard. Observe that a few additional properties not included in the standard are listed in the tables. For maximum fuel temperature before the engine, see chapter "*Technical Data*".

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

6.1.1 Marine Diesel Fuel (MDF)

Distillate fuel grades are ISO-F-DMX, DMA, DMZ, DMB. These fuel grades are referred to as MDF (Marine Diesel Fuel).

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 the reduced flash point. The low flash point which is not meeting the SOLAS requirement can also prevent the use in other marine applications, unless the fuel system is built according to special requirements. Also the low viscosity (min. 1.4 cSt) can prevent the use in engines unless the fuel can be cooled down enough to meet the min. injection viscosity limit of the engine.
- DMA: A high quality distillate, generally designated as MGO (Marine Gas Oil).
- DMZ: A high quality distillate, generally designated as MGO (Marine Gas Oil). An alternative fuel grade for engines requiring a higher fuel viscosity than specified for DMA grade fuel.
- 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 as MDO (Marine Diesel Oil).

Table 6.1.1.1 MDF specifications

Property	Unit	ISO-F-DMA	ISO-F-DMZ	ISO-F-DMB	Test method ref.
Viscosity, before injection pumps, min. 1)	cSt	1.8	1.8	1.8	
Viscosity, before injection pumps, max. 1)	cSt	24	24	24	
Viscosity at 40°C, min.	cSt	2	3	2	
Viscosity at 40°C, max.	cSt	6	6	11	ISO 3104
Density at 15°C, max.	kg/m³	890	890	900	ISO 3675 or 12185
Cetane index, min.		40	40	35	ISO 4264
Sulphur, max.	% mass	1.5	1.5	2	ISO 8574 or 14596
Flash point, min.	°C	60	60	60	ISO 2719
Hydrogen sulfide. max. 2)	mg/kg	2	2	2	IP 570
Acid number, max.	mg KOH/g	0.5	0.5	0.5	ASTM D664
Total sediment by hot filtration, max.	% mass	—	—	0.1 3)	ISO 10307-1
Oxidation stability, max.	g/m³	25	25	25 4)	ISO 12205
Carbon residue: micro method on the 10% volume distillation residue max.	% mass	0.30	0.30	—	ISO 10370
Carbon residue: micro method, max.	% mass	—	—	0.30	ISO 10370
Pour point (upper) , winter quality, max. 5)	°C	-6	-6	0	ISO 3016

Property	Unit	ISO-F-DMA	ISO-F-DMZ	ISO-F-DMB	Test method ref.
Pour point (upper) , summer quality, max. 5)	°C	0	0	6	ISO 3016
Appearance	—	Clear and bright 6)		3) 4) 7)	
Water, max.	% volume	—	—	0.3 3)	ISO 3733
Ash, max.	% mass	0.01	0.01	0.01	ISO 6245
Lubricity, corrected wear scar diameter (wsd 1.4) at 60°C , max. 8)	µm	520	520	520 7)	ISO 12156-1

Remarks:

1) Additional properties specified by Wärtsilä, which are not included in the ISO specification.

2) The implementation date for compliance with the limit shall be 1 July 2012. Until that the specified value is given for guidance.

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

4) If the sample is not clear and bright, the test cannot be undertaken and hence the oxidation stability limit shall not apply.

5) It shall be ensured that the pour point is suitable for the equipment on board, especially if the ship operates in cold climates.

6) If the sample is dyed and not transparent, then the water limit and test method ISO 12937 shall apply.

7) If the sample is not clear and bright, the test cannot be undertaken and hence the lubricity limit shall not apply.

8) The requirement is applicable to fuels with a sulphur content below 500 mg/kg (0.050 % mass).

6.1.2 Heavy Fuel Oil (HFO)

Residual fuel grades are referred to as HFO (Heavy Fuel Oil). The fuel specification HFO 2 covers the categories ISO-F-RMA 10 to RMK 700. Fuels fulfilling the specification HFO 1 permit longer overhaul intervals of specific engine components than HFO 2.

Table 6.1.2.1 HFO specifications

Property	Unit	Limit HFO 1	Limit HFO 2	Test method ref.
Viscosity, before injection pumps 1)	cSt	16...24	16...24	
Viscosity at 50°C, max.	cSt	700	700	ISO 3104
Density at 15°C, max.	kg/m³	991 / 1010 2)	991 / 1010 2)	ISO 3675 or 12185
CCAI, max.3)		850	870	ISO 8217, Annex F
Sulphur, max. 4) 5)	% mass	Statutory requirements		ISO 8754 or 14596
Flash point, min.	°C	60	60	ISO 2719
Hydrogen sulfide, max. 6)	mg/kg	2	2	IP 570
Acid number, max.	mg KOH/g	2.5	2.5	ASTM D664
Total sediment aged, max.	% mass	0.1	0.1	ISO 10307-2
Carbon residue, micro method, max.	% mass	15	20	ISO 10370
Asphaltenes, max.1)	% mass	8	14	ASTM D 3279
Pour point (upper), max. 7)	°C	30	30	ISO 3016
Water, max.	% volume	0.5	0.5	ISO 3733 or ASTM D6304-C 1)
Water before engine, max.1)	% volume	0.3	0.3	ISO 3733 or ASTM D6304-C 1)
Ash, max.	% mass	0.05	0.15	ISO 6245 or LP1001 1)
Vanadium, max. 5)	mg/kg	100	450	ISO 14597 or IP 501 or IP 470
Sodium, max. 5)	mg/kg	50	100	IP 501 or IP 470
Sodium before engine, max.1) 5)	mg/kg	30	30	IP 501 or IP 470
Aluminium + Silicon, max.	mg/kg	30	60	ISO 10478 or IP 501 or IP 470
Aluminium + Silicon before engine, max.1)	mg/kg	15	15	ISO 10478 or IP 501 or IP 470
Used lubricating oil, calcium, max. 8)	mg/kg	30	30	IP 501 or IP 470
Used lubricating oil, zinc, max. 8)	mg/kg	15	15	IP 501 or IP 470
Used lubricating oil, phosphorus, max. 8)	mg/kg	15	15	IP 501 or IP 500

Remarks:

1) Additional properties specified by Wärtsilä, which are not included in the ISO specification.

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

3) Straight run residues show CCAI values in the 770 to 840 range and have very good ignition quality. 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 the ignition properties of the fuel, especially concerning fuels originating from modern and more complex refinery process.

4) The max. sulphur content must be defined in accordance with relevant statutory limitations.

5) Sodium contributes to hot corrosion on the 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 and 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.

6) The implementation date for compliance with the limit shall be 1 July 2012. Until that, the specified value is given for guidance.

7) It shall be ensured that the pour point is suitable for the equipment on board, especially if the ship operates in cold climates.

8) 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
- Calcium > 30 mg/kg and phosphorus > 15 mg/kg

6.1.3 Liquid bio fuels

The engine can be operated on liquid bio fuels according to the specifications in tables "*6.1.3.1 Straight liquid bio fuel specification*" or "*6.1.3.2 Biodiesel specification based on EN 14214:2012 standard*". Liquid bio fuels have typically lower heating value than fossil fuels, the capacity of the fuel injection system must be checked for each installation.

Table "*Straight liquid bio fuel specification*" is valid for straight liquid bio fuels, like palm oil, coconut oil, copra oil, rape seed oil, jathropha oil etc. but is not valid for other bio fuel qualities like animal fats.

Renewable biodiesel can be mixed with fossil distillate fuel. Fossil fuel being used as a blending component has to fulfill the requirement described earlier in this chapter.

Table 6.1.3.1 Straight liquid bio fuel specification

Property	Unit	Limit	Test method ref.
Viscosity at 40°C, max. 1)	cSt	100	ISO 3104
Viscosity, before injection pumps, min.	cSt	1.8	
Viscosity, before injection pumps, max.	cSt	24	
Density at 15°C, max.	kg/m³	991	ISO 3675 or 12185
Ignition properties 2)			FIA test
Sulphur, max.	% mass	0.05	ISO 8574
Total sediment existent, max.	% mass	0.05	ISO 10307-1
Water before engine, max.	% volume	0.20	ISO 3733
Micro carbon residue, max.	% mass	0.50	ISO 10370
Ash, max.	% mass	0.05	ISO 6245 / LP1001
Phosphorus, max.	mg/kg	100	ISO 10478
Silicon, max.	mg/kg	15	ISO 10478
Alkali content (Na+K), max.	mg/kg	30	ISO 10478
Flash point (PMCC), min.	°C	60	ISO 2719
Cloud point, max.	°C	3)	ISO 3015
Cold filter plugging point, max.	°C	3)	IP 309
Copper strip corrosion (3h at 50°C), max.	Rating	1b	ASTM D130
Steel corrosion (24/72h at 20, 60 and 120°C), max.	Rating	No signs of corrosion	LP 2902
Acid number, max.	mg KOH/g	15.0	ASTM D664
Strong acid number, max.	mg KOH/g	0.0	ASTM D664
Iodine number, max.	g iodine / 100 g	120	ISO 3961
Synthetic polymers	% mass	Report 4)	LP 2401 ext. and LP 3402

Remarks:

1) If injection viscosity of max. 24 cSt cannot be achieved with an unheated fuel, fuel oil system has to be equipped with a heater.

2) Ignition properties have to be equal to or better than requirements for fossil fuels, i.e. CN min. 35 for MDF and CCAI max. 870 for HFO.

3) Cloud point and cold filter plugging point have to be at least 10°C below the fuel injection temperature.

4) Biofuels originating from food industry can contain synthetic polymers, like e.g. styrene, propene and ethylene used in packing material. Such compounds can cause filter clogging and shall thus not be present in biofuels.

Table 6.1.3.2 Biodiesel specification based on EN 14214:2012 standard

Property	Unit	Limit	Test method ref.
Viscosity at 40°C, min...max.	cSt	3.5...5	ISO 3104
Viscosity, before injection pumps, min.	cSt	1.8	
Density at 15°C, min...max.	kg/m³	860...900	ISO 3675 / 12185
Cetane number, min.		51	ISO 5165
Sulphur, max.	mg/kg	10	ISO 20846 / 20884
Sulphated ash, max.	% mass	0.02	ISO 3987
Total contamination, max.	mg/kg	24	EN 12662
Water, max.	mg/kg	500	ISO 12937
Phosphorus, max.	mg/kg	4	EN 14107
Group 1 metals (Na+K), max.	mg/kg	5	EN 14108 / 14109 / 14538
Group 2 metals (Ca+Mg), max.	mg/kg	5	EN 14538
Flash point, min.	°C	101	ISO 2719A / 3679
Cold filter plugging point, max. 1)	°C	-44...+5	EN 116
Oxidation stability at 110°C, min.	h	8	EN 14112
Copper strip corrosion (3h at 50°C), max.	Rating	Class 1	ISO 2160
Acid number, max.	mg KOH/g	0.5	EN 14104
Iodine number, max.	g iodine / 100 g	120	EN 14111 / 16300
FAME content, min 2)	% mass	96.5	EN 14103
Linolenic acid methyl ester, max.	% mass	12	EN 14103
Polyunsaturated methyl esters, max.	% mass	1	EN 15779
Methanol content, max.	% mass	0.2	EN 14110
Monoglyceride content, max.	% mass	0.7	EN 14105
Diglyceride content, max.	% mass	0.2	EN 14105
Triglyceride content, max.	% mass	0.2	EN 14105
Free glycerol, max.	% mass	0.02	EN 14105 / 14106
Total glycerol, max.	% mass	0.25	EN 14105

Remarks:

1) Cold flow properties of renewable bio diesel can vary based on the geographical location and also based on the feedstock properties, which issues must be taken into account when designing the fuel system.

2) Valid only for transesterified biodiesel (FAME)

6.2 Internal fuel oil system

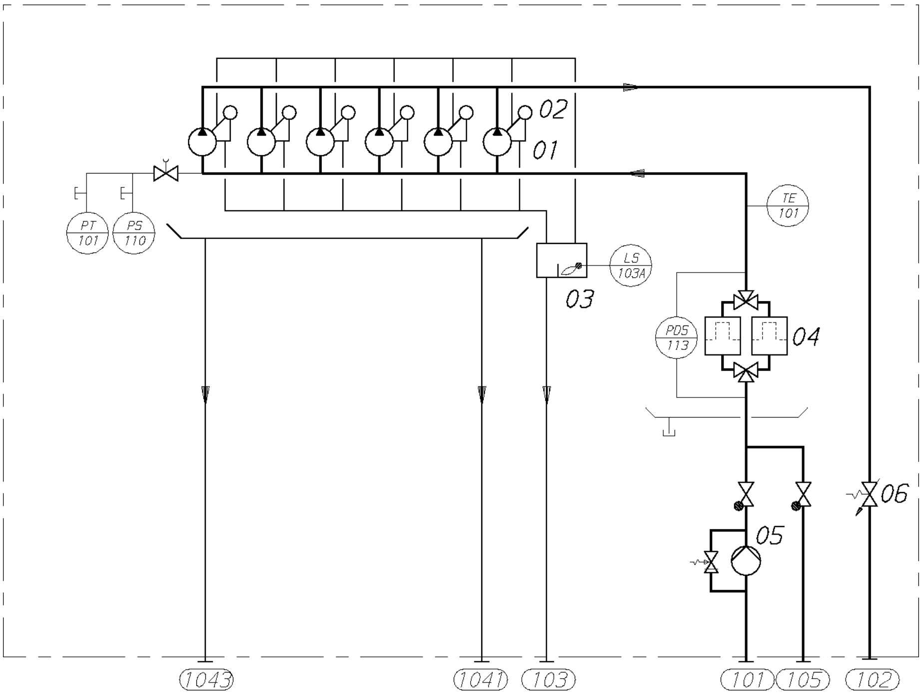


Fig 6.2.1 Internal fuel system, MDF (DAAE060385B)

System components:			
01	Injection pump	04	Duplex fine filter
02	Injection valve	05	Engine driven fuel feed pump
03	Fuel leakage collector	06	Pressure regulating valve

Sensors and indicators:			
PT101	Fuel oil pressure, engine inlet	PDS113	Fuel oil filter, press. diff. switch (option)
PS110	Stand-by pump switch	TE101	Fuel oil temperature, engine inlet
LS103A	Fuel oil leakage, injection pipe		

Pipe connections		Size	Pressure class	Standard
101	Fuel inlet	OD28	PN100	DIN 2353
102	Fuel outlet	OD28	PN100	DIN 2353
103	Leak fuel drain, clean fuel	OD18	-	ISO 3304
1041	Leak fuel drain, dirty fuel	OD22	-	ISO 3304
1043	Leak fuel drain, dirty fuel	OD18	-	ISO 3304
105	Fuel stand-by connection	OD22	PN160	DIN 2353

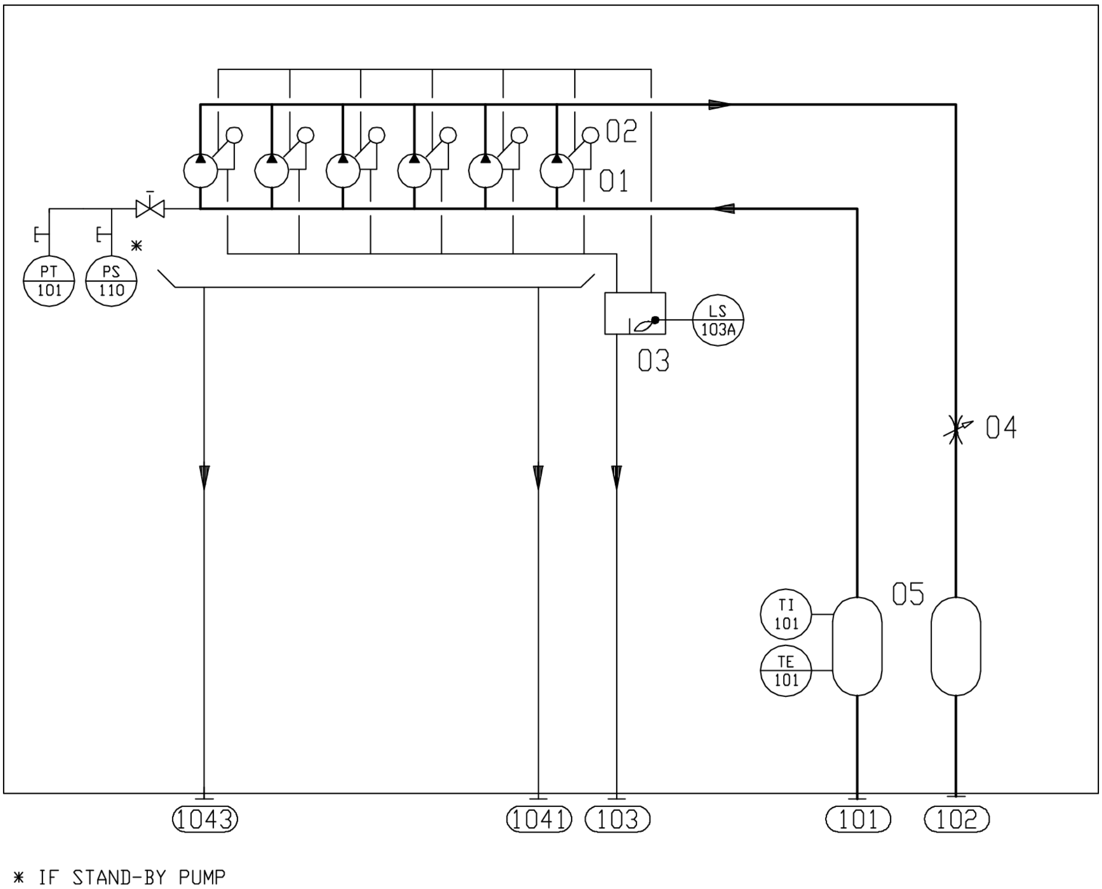


Fig 6.2.2 Internal fuel system, HFO (DAAE060384B)

System components:			
01	Injection pump	04	Adjustable throttle valve
02	Injection valve	05	Pulse dampers
03	Level alarm for leak fuel oil from injection pipes		

Sensors and indicators:			
PT101	Fuel oil pressure, engine inlet	TI101	Fuel oil temperature, engine inlet
PS110	Stand-by pump switch	TE101	Fuel oil temperature, engine inlet
LS103A	Fuel oil leakage, injection pipe		

Pipe connections		Size	Pressure class	Standard
101	Fuel inlet	OD18	PN160	DIN 2353
102	Fuel outlet	OD18	PN160	DIN 2353
103	Leak fuel drain, clean fuel	OD18	-	ISO 3304
1041	Leak fuel drain, dirty fuel	OD22	-	ISO 3304
1043	Leak fuel drain, dirty fuel	OD18	-	ISO 3304

The engine can be specified to either operate on heavy fuel oil (HFO) or on marine diesel fuel (MDF). The engine is designed for continuous operation on HFO. It is however possible to operate HFO engines on MDF intermittently without alternations. If the operation of the engine is changed from HFO to continuous operation on MDF, then a change of exhaust valves from Nimonic to Stellite is recommended.

HFO engines are equipped with an adjustable throttle valve in the fuel return line on the engine. For engines installed in the same fuel feed circuit, it is essential to distribute the fuel correctly to the engines. For this purpose the pressure drop differences around engines shall be compensated with the adjustable throttle valve.

MDF engines, with an engine driven fuel feed pump, are equipped with a pressure control valve in the fuel return line on the engine. This pressure control valve maintains desired pressure before the injection pumps.

6.2.1 Leak fuel system

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

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

6.3 External fuel oil system

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

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

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

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

NOTE

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

6.3.1 Low sulphur operation

For newbuildings expected to operate purely within SECAs, fuel and lubricating oil filling, storage, transfer, separation, and supply systems can in principle be arranged as on a traditional HFO ship.

However, if intention is to operate on different fuel quailties inside and outside SECAs it is beneficial to install double bunker tanks, settling tanks, service tanks and leak fuel tanks in order to avoid mixing incompatible fuels. Also check if flexible lube oil systems is needed, in order to avoid operation with high-sulphur fuel and too low lube oil BN.

6.3.2 Fuel heating requirements HFO

Heating is required for:

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

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

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

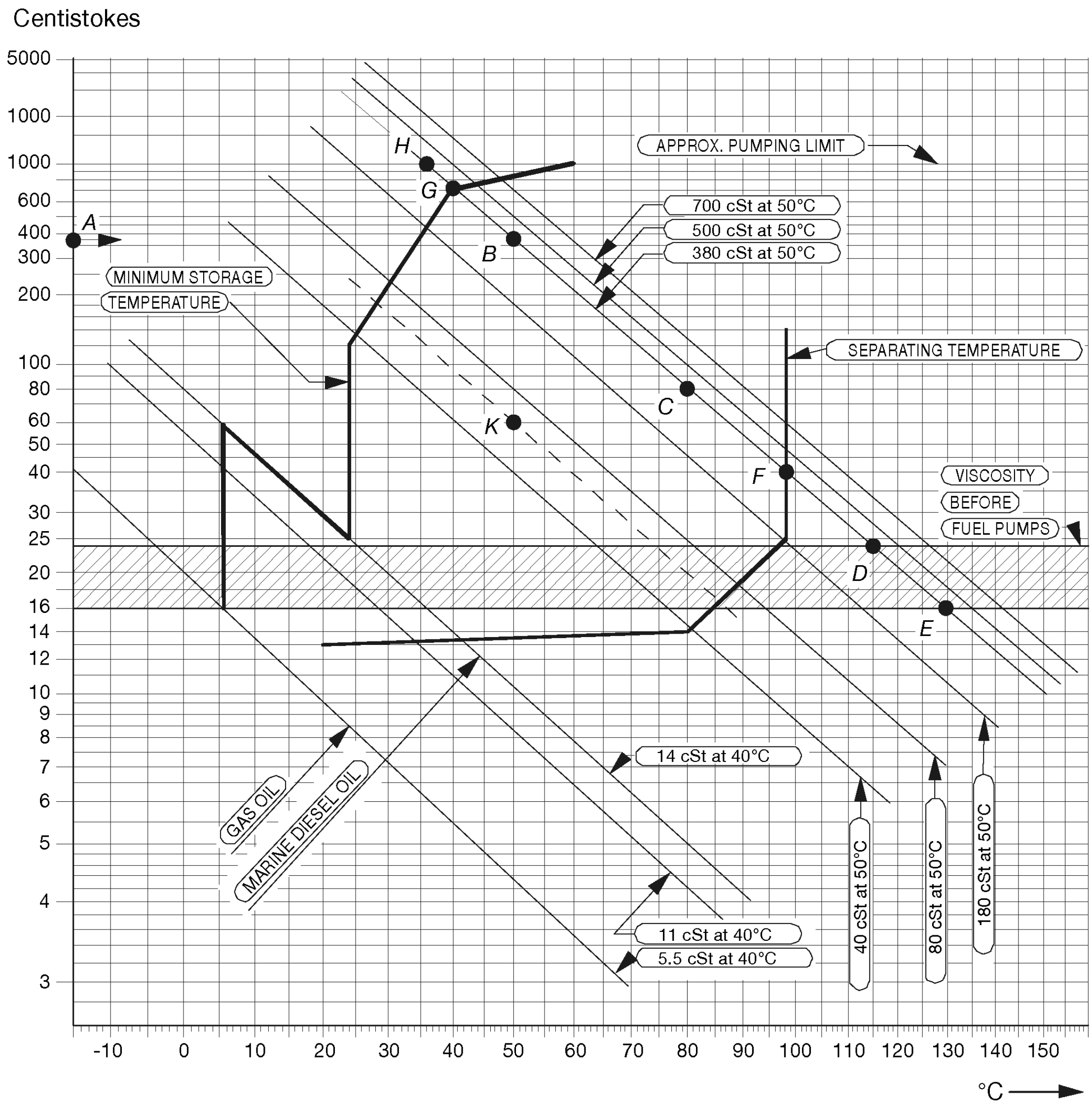


Fig 6.3.2.1 Fuel oil viscosity-temperature diagram for determining the pre-heating temperatures of fuel oils (4V92G0071b)

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

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

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

6.3.3 Fuel tanks

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

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

Separate settling tanks for HFO and MDF are recommended.

In case intention is to operate on low sulphur fuel it is beneficial to install double settling tanks to avoid incompability problems.

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. Usuallly MDF settling tanks do not need heating or insulation, but the tank temperature should be in the range 20...40°C.

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

Two day tanks for HFO are to be provided, each with a capacity sufficient for at least 8 hours operation at maximum fuel consumption.

A separate tank is to be provided for MDF. The capacity of the MDF tank should ensure fuel supply for 8 hours.

Settling tanks may not be used instead of day tanks.

In case intention is to operate on different fuel qualities (low sulphur fuel) it is beneficial to install double day tanks to avoid incompability problems.

The day tank must be designed so that accumulation of sludge near the suction pipe is prevented and the bottom of the tank should be sloped to ensure efficient draining.

HFO day tanks shall be provided with heating coils and insulation. It is recommended that the viscosity is kept below 140 cSt in the day tanks. Due to risk of wax formation, fuels with a viscosity lower than 50 cSt at 50°C must be kept at a temperature higher than the viscosity would require. Continuous separation is nowadays common practice, which means that the HFO day tank temperature normally remains above 90°C.

The temperature in the MDF day tank should be in the range 20...40°C.

The level of the tank must ensure a positive static pressure on the suction side of the fuel feed pumps. If black-out starting with MDF from a gravity tank is foreseen, then the tank must be located at least 15 m above the engine crankshaft.

6.3.3.3 Starting tank, MDF (1T09)

The starting tank is needed when the engine is equipped with the engine driven fuel feed pump and when the MDF day tank (1T06) cannot be located high enough, i.e. less than 1.5 meters above the engine crankshaft.

The purpose of the starting tank is to ensure that fuel oil is supplied to the engine during starting. The starting tank shall be located at least 1.5 meters above the engine crankshaft. The volume of the starting tank should be approx. 60 l.

6.3.3.4 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.

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

6.3.3.5 Leak fuel tank, dirty fuel (1T07)

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

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

6.3.3.6 Bunker tank (1T01)

In case intention is to operate on low sulphur fuel it is beneficial to install extra bunker tanks. This to permit the ship to bunker low sulphur fuel in empty tanks anytime, even if both fuel qualities are available in other tanks.

6.3.4 Fuel treatment

6.3.4.1 Separation

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

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

All recommendations from the separator manufacturer must be closely followed.

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

6.3.4.1.1 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.

6.3.4.1.2 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

6.3.4.2 Separator unit (1N02/1N05)

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

Typically separator modules are equipped with:

- Suction strainer (1F02)
- Feed pump (1P02)
- Pre-heater (1E01)
- Sludge tank (1T05)
- Separator (1S01/1S02)
- Sludge pump
- Control cabinets including motor starters and monitoring

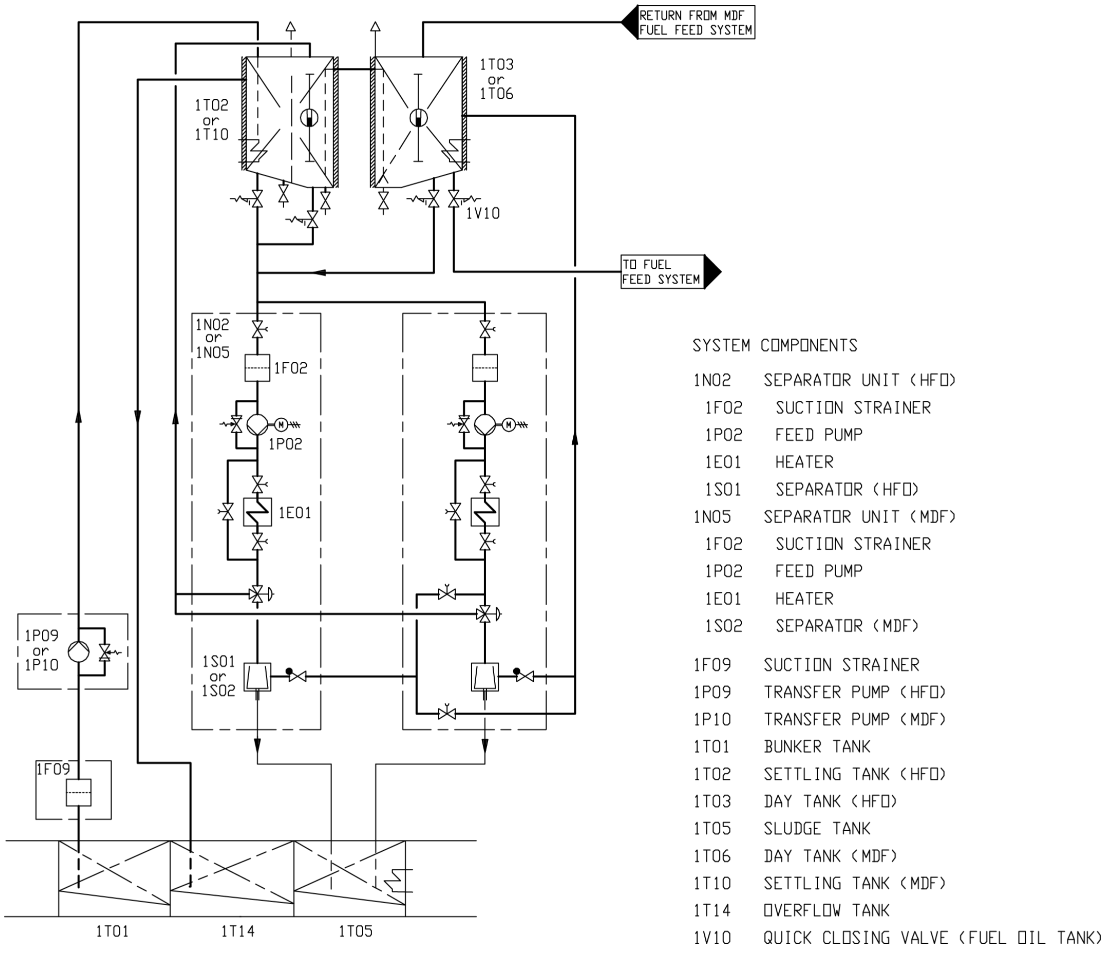


Fig 6.3.4.2.1 Fuel transfer and separating system (3V76F6626E)

6.3.4.3 Separator feed pumps (1P02)

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

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

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

6.3.4.4 Separator pre-heater (1E01)

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

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

6.3.4.5 Separator (1S01/1S02)

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

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

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.

6.3.4.6 MDF separator in HFO installations (1S02)

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

6.3.4.7 Sludge tank (1T05)

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

6.3.5 Fuel feed system - MDF installations

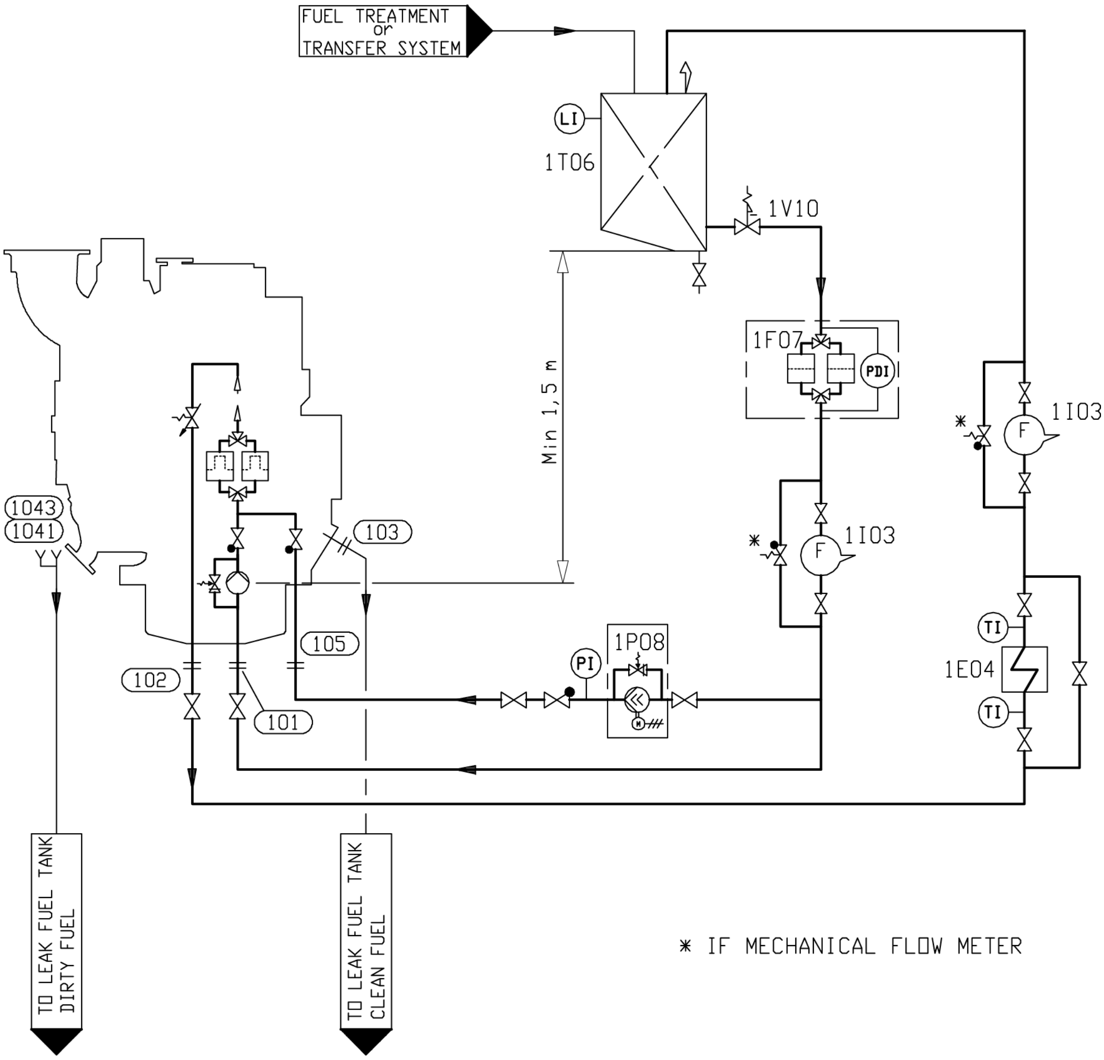


Fig 6.3.5.1 Fuel feed system, main engine (DAAE003608D)

System components			
1E04	Cooler (MDF)	1P08	Standby pump (MDF)
1F07	Suction strainer (MDF)	1T06	Day tank (MDF)
1I03	Flow meter (MDF)	1V10	Quick closing valve (FO tank)

Pipe connections		Size
101	Fuel inlet	OD28
102	Fuel outlet	OD28
103	Leak fuel drain, clean fuel	ID18
1041	Leak fuel drain, dirty fuel free end	OD22
1043	Leak fuel drain, dirty fuel FW-end	OD18
105	Fuel stand-by connection	OD22

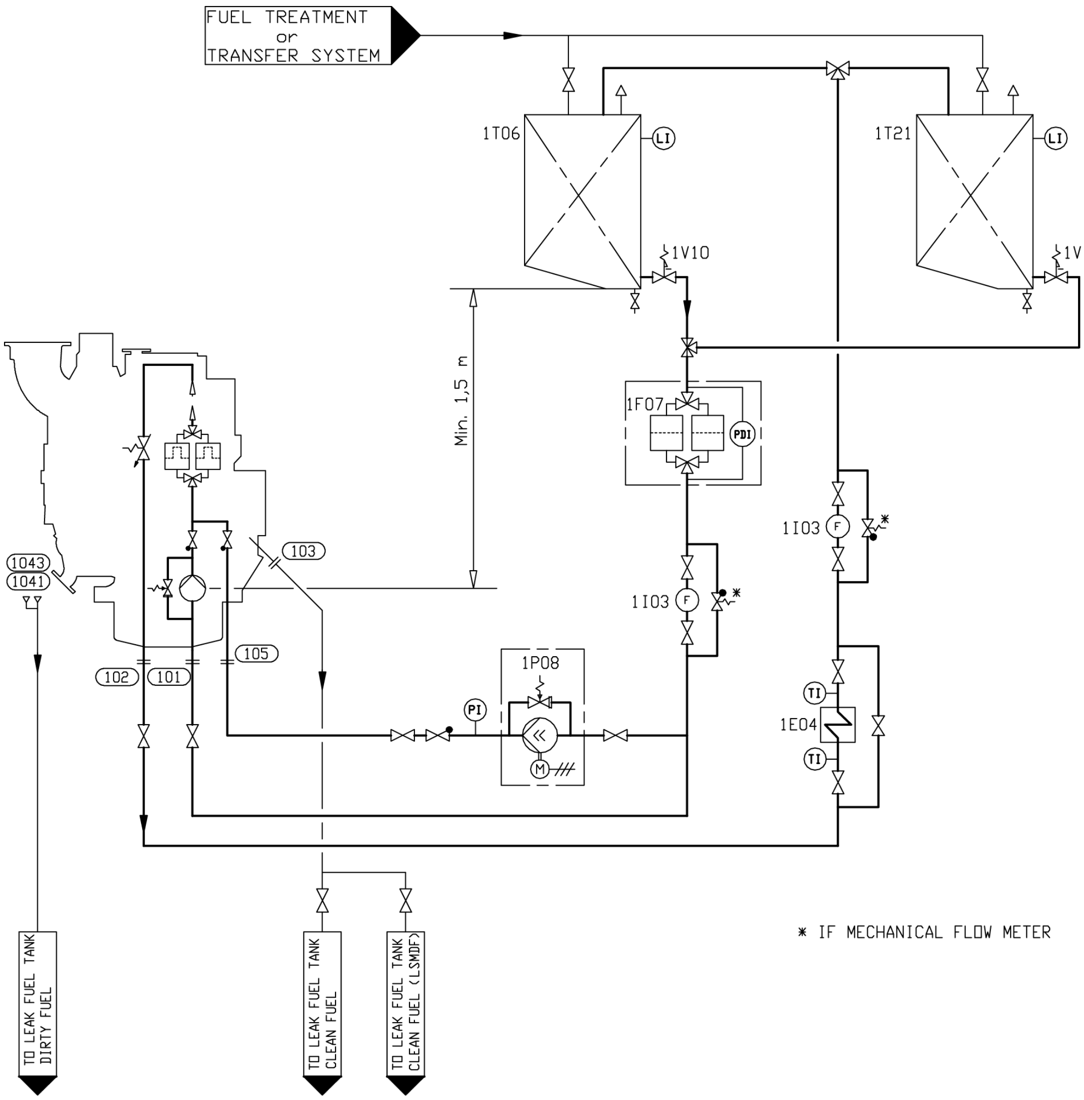


Fig 6.3.5.2 Fuel feed system for low sulphur operation, main engine (DAAF040654B)

System components			
1E04	Cooler (MDF)	1T06	Day tank (MDF)
1F07	Suction strainer (MDF)	1T21	Day tank (LSMDF)
1I03	Flowmeter (MDF)	1V10	Quick closing valve (FO tank)
1P08	Stand-by pump (MDF)		

Pos	Pipe connections	Size
101	Fuel inlet	OD28
102	Fuel outlet	OD28
103	Leak fuel drain, clean fuel	OD18
1041	Leak fuel drain, dirty fuel free end	OD22
1043	Leak fuel drain, dirty fuel FW-end	OD18
105	Fuel stand by connection	OD22

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.

6.3.5.1 Circulation pump, MDF (1P03)

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

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

6.3.5.2 Stand-by pump, MDF (1P08)

The stand-by pump is required in case of a single main engine equipped with an engine driven pump. It is recommended to use a screw pump as stand-by pump. The pump should be placed so that a positive static pressure of about 30 kPa is obtained on the suction side of the pump.

Design data:	
Capacity	5 x the total consumption of the connected engine
Design pressure	1.6 MPa (16 bar)
Max. total pressure (safety valve)	1.2 MPa (12 bar)
Design temperature	50°C
Viscosity for dimensioning of electric motor	90 cSt

6.3.5.3 Flow meter, MDF (1I03)

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

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

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

6.3.5.4 Fine filter, MDF (1F05)

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

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

Design data:	
Fuel viscosity	according to fuel specifications
Design temperature	50°C
Design flow	Larger than feed/circulation pump capacity
Design pressure	1.6 MPa (16 bar)
Fineness	37 μm (absolute mesh size)

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

6.3.5.5 Pressure control valve, MDF (1V02)

The pressure control valve is installed when the installation includes a feeder/booster unit for HFO and there is a return line from the engine to the MDF day tank. The purpose of the valve is to increase the pressure in the return line so that the required pressure at the engine is achieved.

Design data:	
Capacity	Equal to circulation pump
Design temperature	50°C
Design pressure	1.6 MPa (16 bar)
Set point	0.4...0.7 MPa (4...7 bar)

6.3.5.6 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	1 kW/cyl
Max. pressure drop, fuel oil	80 kPa (0.8 bar)
Max. pressure drop, water	60 kPa (0.6 bar)
Margin (heat rate, fouling)	min. 15%
Design temperature MDF/HFO installation	50/150°C

6.3.5.7 Return fuel tank (1T13)

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

6.3.5.8 Black out start

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

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

6.3.6 Fuel feed system - HFO installations

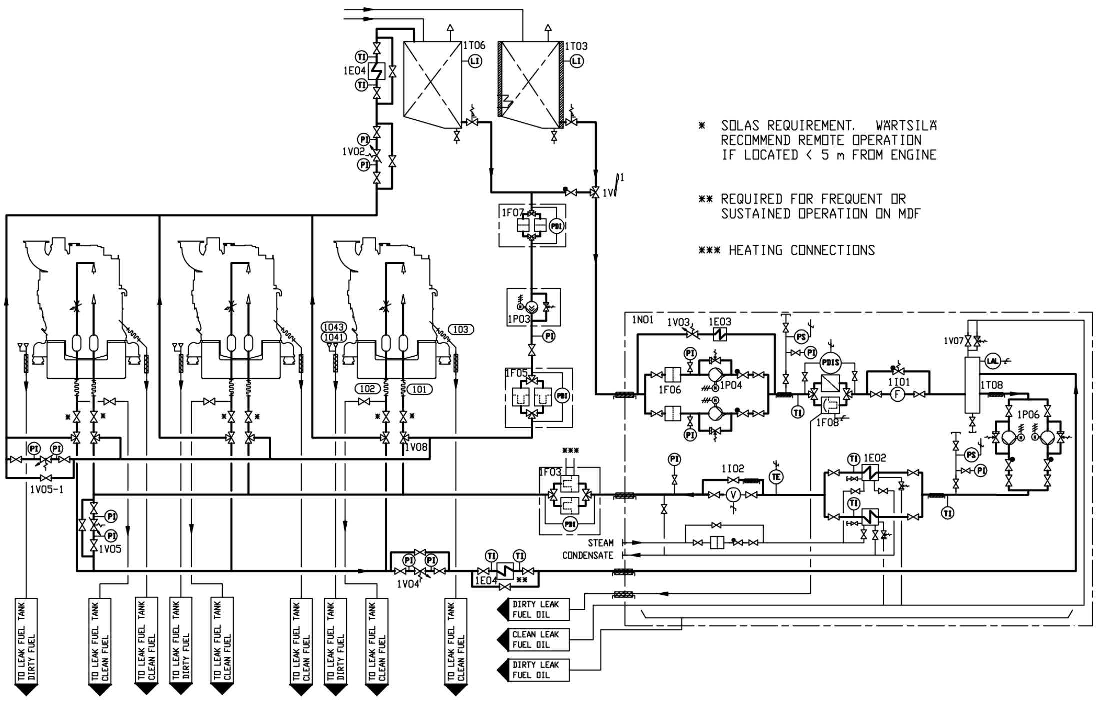


Fig 6.3.6.1 Example of fuel oil system (HFO), multiple engine installation (3V76F6656G)

System components			
1E02	Heater (booster unit)	1P06	Circulation pump (booster unit)
1E03	Cooler (booster unit)	1T03	Day tank (HFO)
1E04	Cooler (MDF)	1T06	Day tank (MDF)
1F03	Safety filter (HFO)	1T08	De-aeration tank (booster unit)
1F05	Fine filter (MDF)	1V01	Change over valve
1F06	Suction filter (booster unit)	1V02	Pressure control valve (MDF)
1F07	Suction strainer (MDF)	1V03	Pressure control valve (booster unit)
1F08	Automatic filter (booster unit)	1V04	Pressure control valve (HFO)
1I01	Flow meter (booster unit)	1V05	Overflow valve (HFO/MDF)
1I02	Viscosity meter (booster unit)	1V05-1	Overflow valve (HFO/MDF)
1N01	Feeder/Booster unit	1V07	Venting valve (booster unit)
1P03	Circulation pump (MDF)	1V08	Change over valve
1P04	Fuel feed pump (booster unit)		

Pipe connections		Size
101	Fuel inlet	OD18
102	Fuel outlet	OD18
103	Leak fuel drain, clean fuel	OD18
1041	Leak fuel drain, dirty fuel free end	OD22
1043	Leak fuel drain, dirty fuel driving-end	OD18

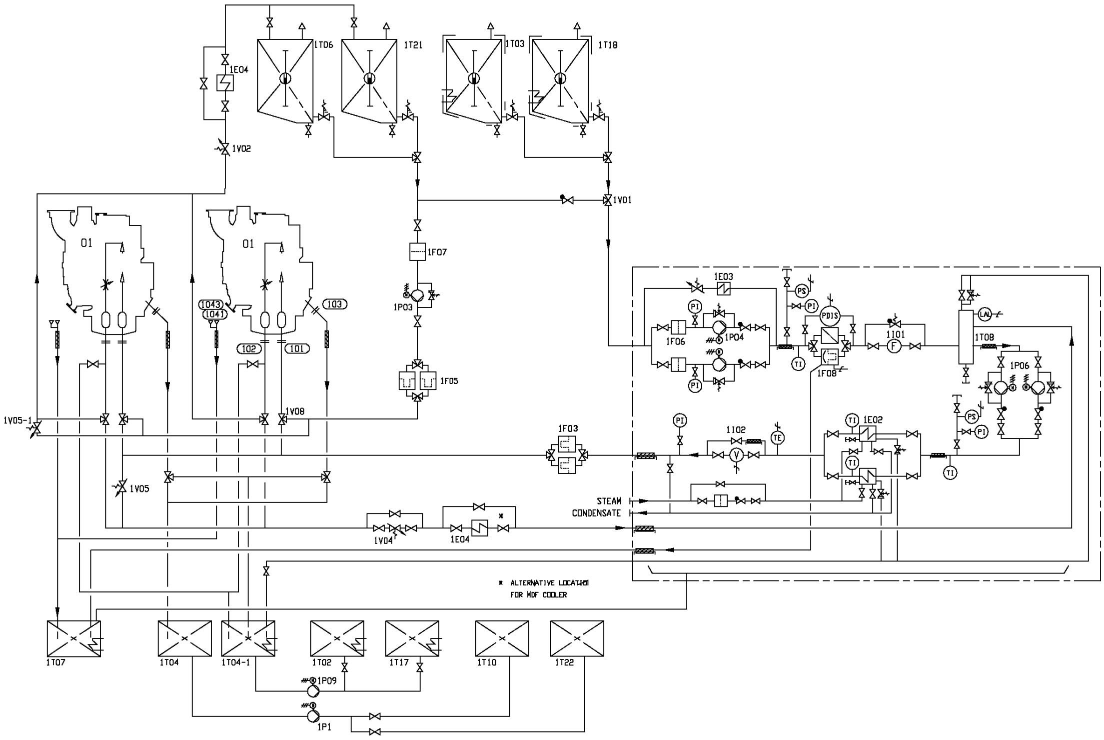


Fig 6.3.6.2 **Example of fuel oil system (HFO) for low sulphur operation, multiple engine installation (DAAF040653A)**

System components			
01	Diesel engine Wärtsilä L20	1T03	Day tank (HFO)
1E02	Heater (Booster unit)	1T04	Leak fuel tank (MDF clean fuel)
1E03	Cooler (Booster unit)	1T04-1	Leak fuel tank (HFO clean fuel)
1E04	Cooler (MDF return line)	1T06	Day tank (MDF)
1F03	Safety filter (HFO)	1T07	Leak fuel tank (Dirty fuel)
1F05	Fine filter (MDF)	1T08	De-aeration tank (Booster unit)
1F06	Suction filter (Booster unit)	1T10	Settling tank (MDF)
1F07	Suction strainer (MDF)	1T17	Settling tank (LSHFO)
1F08	Automatic filter (Booster unit)	1T18	Day tank (LSHFO)
1I01	Flow meter (Booster unit)	1T21	Day tank (LSMDF)
1I02	Viscosity meter (Booster unit)	1T22	Settling tank (LSMDF)
1P03	Circulation pump (MDF)	1V01	Changeover valve
1P04	Fuel feed pump (Booster unit)	1V02	Pressure control valve (MDF)
1P06	Circulation pump (Booster unit)	1V04	Pressure control valve (HFO)
1P09	Transfer pump (HFO)	1V05	Overflow valve (HFO/MDF)
1P10	Transfer pump (MDF)	1V05-1	Overflow valve (HFO/MDF)
1T02	Settling tank (HFO)	1V08	Changeover valve

Pos	Pipe connections	Size
101	Fuel inlet	OD18
102	Fuel outlet	OD18
103	Leak fuel drain, clean fuel	OD18
1041	Leak fuel drain, dirty fuel free end	OD22
1043	Leak fuel drain, dirty fuel FW-end	OD18

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

6.3.6.1 Starting and stopping

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

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

6.3.6.2 Changeover from HFO to MDF

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

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

6.3.6.3 Changeover to low sulphur fuel

- Fuel system should allow slow, controlled change in fuel temperature in order to avoid thermal shock in the injection pumps. The recommended fuel temperature change over rate at switching is maximum 2 °C / min.
- Check compatibility when using mixed fuels (clogging filters, separators etc). Wärtsilä 4-stroke engines are normally not sensitive for fuel lubricity and additives are not necessarily needed.
- HFO engines starting to alternate between HFO and MDF or LSMDF can typically continue with the same lubricant as before. Nimonic exhaust valves should be used to avoid hot corrosion.
- HFO engines starting to operate continuously on LSHFO can continue using lubricating oil with a BN of at least 30.
- Engines starting to operate continuously on MDF or LSMDF are recommended to start using lubricating oil with lower BN 10-20. Exhaust valves with stellite facing should be used.
- BN monitoring of lubricating oil should be established in order to prevent operating with too low BN (increased risk for corrosion).

6.3.6.4 Number of engines in the same system

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

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

In addition the following guidelines apply:

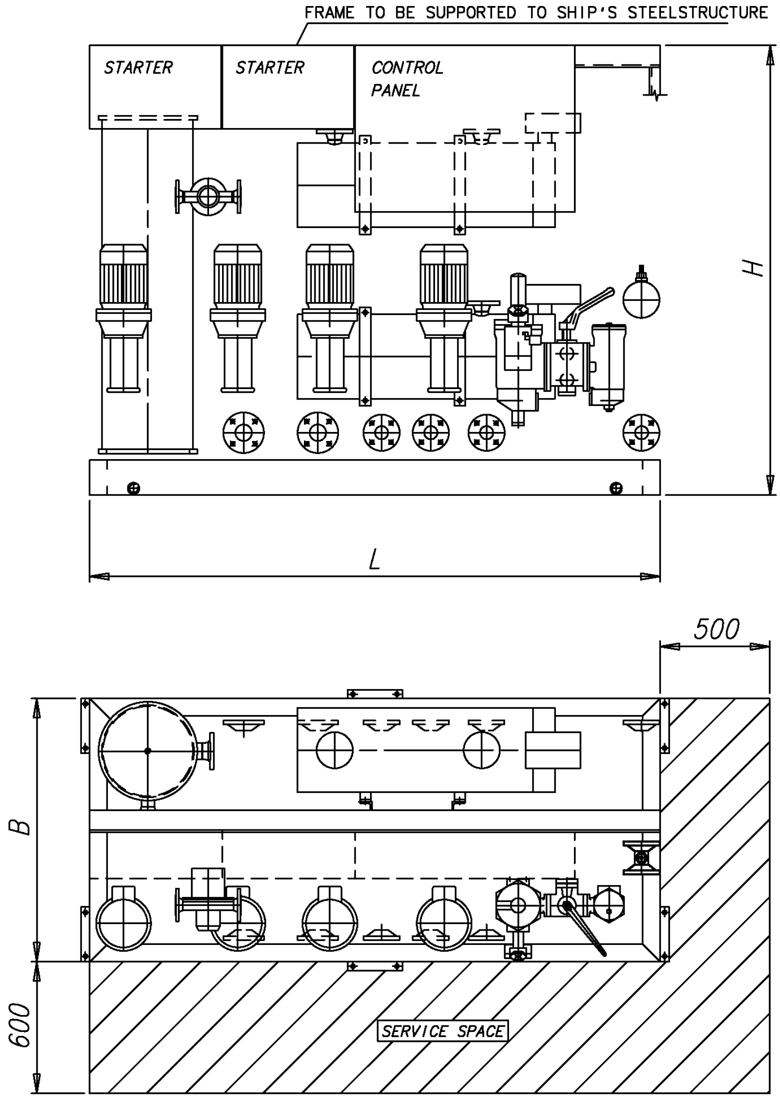
- Twin screw vessels with two engines should have a separate fuel feed circuit for each propeller shaft.
- Twin screw vessels with four engines should have the engines on the same shaft connected to different fuel feed circuits. One engine from each shaft can be connected to the same circuit.

6.3.6.5 Feeder/booster unit (1N01)

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

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

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



	H	L	B
STEAM	1800	2500	1100
ELECTRICAL	2050	2600	1200

All dimensions in mm.

Fig 6.3.6.5.1 Feeder/booster unit, example (DAAE006659)

6.3.6.5.1 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)
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

6.3.6.5.2 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)

6.3.6.5.3 Automatic filter, booster unit (1F08)

It is recommended to select an automatic filter with a manually cleaned filter in the bypass line. The automatic filter must be installed before the heater, between the feed pump and the de-aeration tank, and it should be equipped with a heating jacket. Overheating (temperature exceeding 100°C) is however to be prevented, and it must be possible to switch off the heating for operation on MDF.

Design data:	
Fuel viscosity	According to fuel specification
Design temperature	100°C
Preheating	If fuel viscosity is higher than 25 cSt/100°C
Design flow	Equal to feed pump capacity
Design pressure	1.6 MPa (16 bar)
Fineness:	
- automatic filter	35 μm (absolute mesh size)
- by-pass filter	35 μm (absolute mesh size)
Maximum permitted pressure drops at 14 cSt:	
- clean filter	20 kPa (0.2 bar)
- alarm	80 kPa (0.8 bar)

6.3.6.5.4 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.

6.3.6.5.5 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.

6.3.6.5.6 Circulation pump, booster unit (1P06)

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

Design data:

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

6.3.6.5.7 Heater, booster unit (1E02)

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

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

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

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

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

where:

P = heater capacity (kW)

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

ΔT = temperature rise in heater [°C]

6.3.6.5.8 Viscosimeter, booster unit (1I02)

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

Design data:

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

6.3.6.6 Safety filter (1F03)

The safety filter is a full flow duplex type filter with steel net. This safety filter must be installed as close as possible to the engines. The safety filter should be equipped with a heating jacket. In multiple engine installations it is possible to have a one common safety filter for all engines.

The diameter of the pipe between the safety filter and the engine should be the same as between the feeder/booster unit and the safety filter.

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)
Fineness	37 µm (absolute mesh size)
Maximum permitted pressure drops at 14 cSt:	
- clean filter	20 kPa (0.2 bar)
- alarm	80 kPa (0.8 bar)

6.3.6.7 Overflow valve, HFO (1V05)

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

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

Design data:	
Capacity	Equal to circulation pump (1P06)
Design pressure	1.6 MPa (16 bar)
Design temperature	150°C
Set-point (Δp)	0.1...0.2 MPa (1...2 bar)

6.3.6.8 Pressure control valve (1V04)

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

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

6.3.7 Flushing

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

The fuel pipes at the engine (connections 101 and 102) are disconnected and the supply and return lines are connected with a temporary pipe or hose on the installation side. All filter inserts are removed, except in the flushing filter of course. The automatic filter and the viscosimeter should be bypassed to prevent damage. The fineness of the flushing filter should be 35 µm or finer.

7. Lubricating Oil System

7.1 Lubricating oil requirements

7.1.1 Engine lubricating oil

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

Table 7.1.1.1 Fuel standards and lubricating oil requirements

Category	Fuel standard		Lubricating oil BN	Fuel S content, [% m/m]
A	ASTM D 975-01, BS MA 100: 1996 CIMAC 2003 ISO8217: 2012(E)	GRADE NO. 1-D, 2-D, 4-D DMX, DMA, DMB DX, DA, DB ISO-F-DMX - DMB	10...30	< 0.4
B	ASTM D 975-01 BS MA 100: 1996 CIMAC 2003 ISO 8217: 2012(E)	GRADE NO. 1-D, 2-D, 4-D DMX, DMA, DMB DX, DA, DB ISO-F-DMB	15...30	0.4 - 2.0
C	ASTM D 975-01, ASTM D 396-04, BS MA 100: 1996 CIMAC 2003 ISO 8217: 2012(E)	GRADE NO. 4-D GRADE NO. 5-6 DMC, RMA10-RMK55 DC, A30-K700 RMA 10-RMK 700	30...55	≤ 4.5
F	LIQUID BIO FUEL (LBF)		10...20	≤ 0.05

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

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

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

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

7.1.2 Oil in speed governor or actuator

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

7.2 Internal lubricating oil system

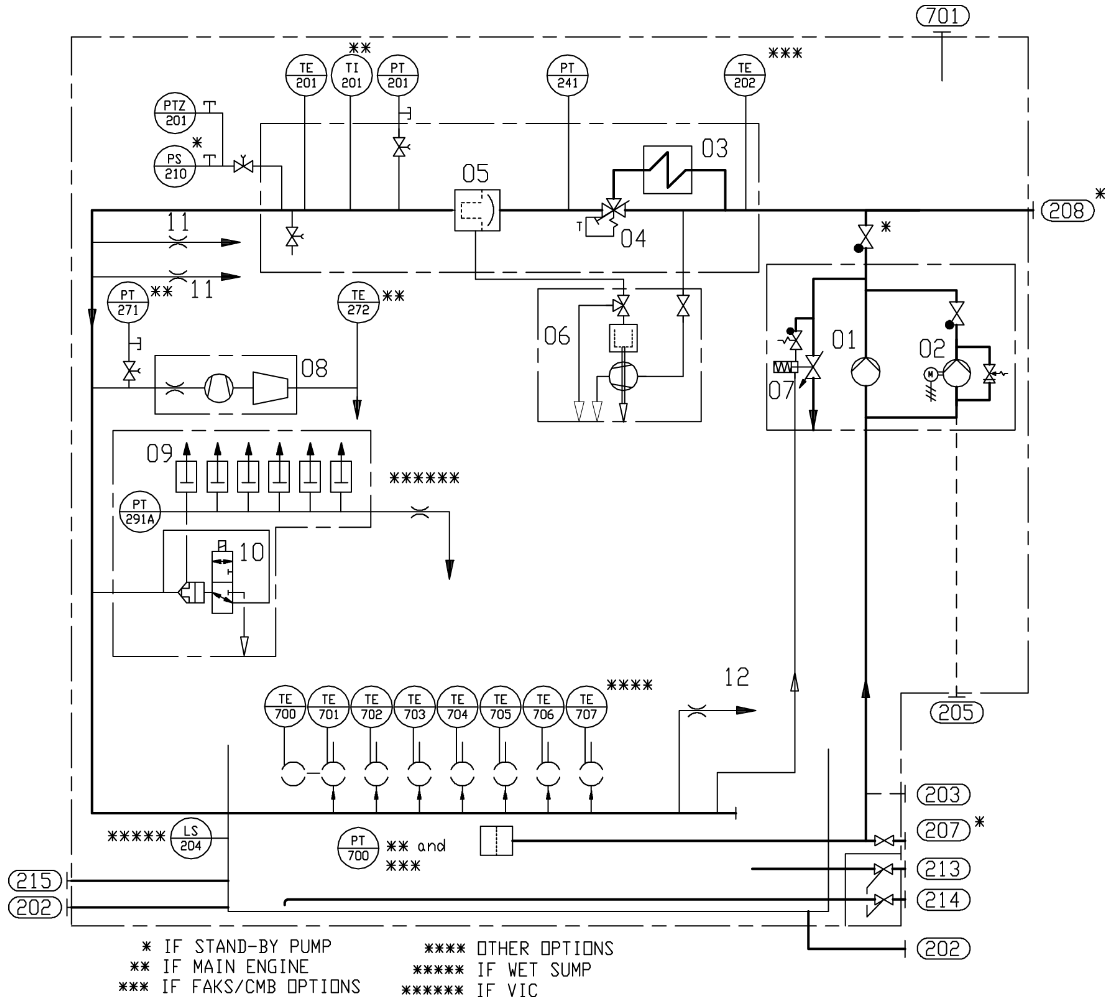


Fig 7.2.1 Internal lubricating oil system (DAAE060386F)

System components:			
01	Lubricating oil main pump	07	Pressure control valve
02	Prelubricating oil pump	08	Turbocharger
03	Lubricating oil cooler	09	Guide block for VIC
04	Thermostatic valve	10	Control valve for VIC
05	Automatic filter	11	Lube oil nozzle for gearwheel lube (FW end)
06	Centrifugal filter	12	Lube oil nozzle for gearwheel lube (free end)

Sensors and indicators:			
PT201	Lubricating oil pressure, engine inlet	TE201	Lubricating oil temp., engine inlet
PTZ201	Lubricating oil pressure, engine inlet	TI201	Lubricating oil temp., engine inlet (if ME)
PS210	Lubricating oil pressure switch, standby pump	TE202	Lubricating oil temp., engine outlet (if FAKS/CBM)
PT241	Lube oil pressure, filter inlet	TE272	Lubricating oil temp., TC outlet (if ME)
PT271	Lubricating oil pressure, TC inlet (if ME)	TE70#	Main bearing temp. (option)
PT291A	Control oil pressure, TC A inlet	LS204	Lubricating oil low level, oil sump (if wet sump)
PT700	Crankcase pressure (if FAKS/CBM)		

Pipe connections		Size
202	Lubricating oil outlet (if dry sump)	DN100
203	Lubricating oil to engine driven pump (if dry sump)	DN100
205	Lubricating oil to priming pump (if dry sump)	DN32
207	Lubricating oil to electric driven pump (if stand-by pump)	DN100
208	Lub. oil from electric driven pump (if stand-by pump)	DN80
213	Lubricating oil from separator and filling	DN32
214	Lubricating oil to separator and drain	DN32
215	Lube oil filling (if wet sump)	M48*2
701	Crankcase air vent	DN65

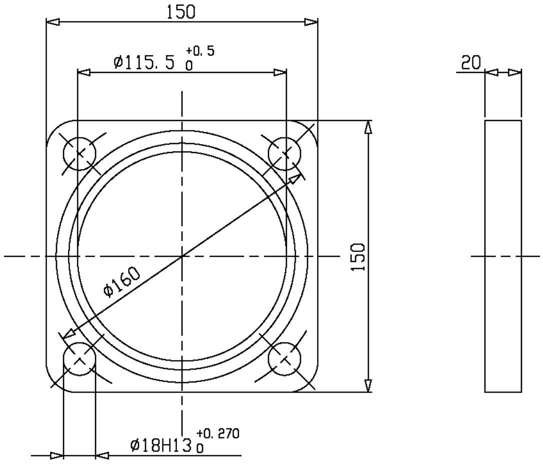


Fig 7.2.2 Flange for connections 202, 203, dry sump (4V32A0506a)

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

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

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

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

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

7.3 External lubricating oil system

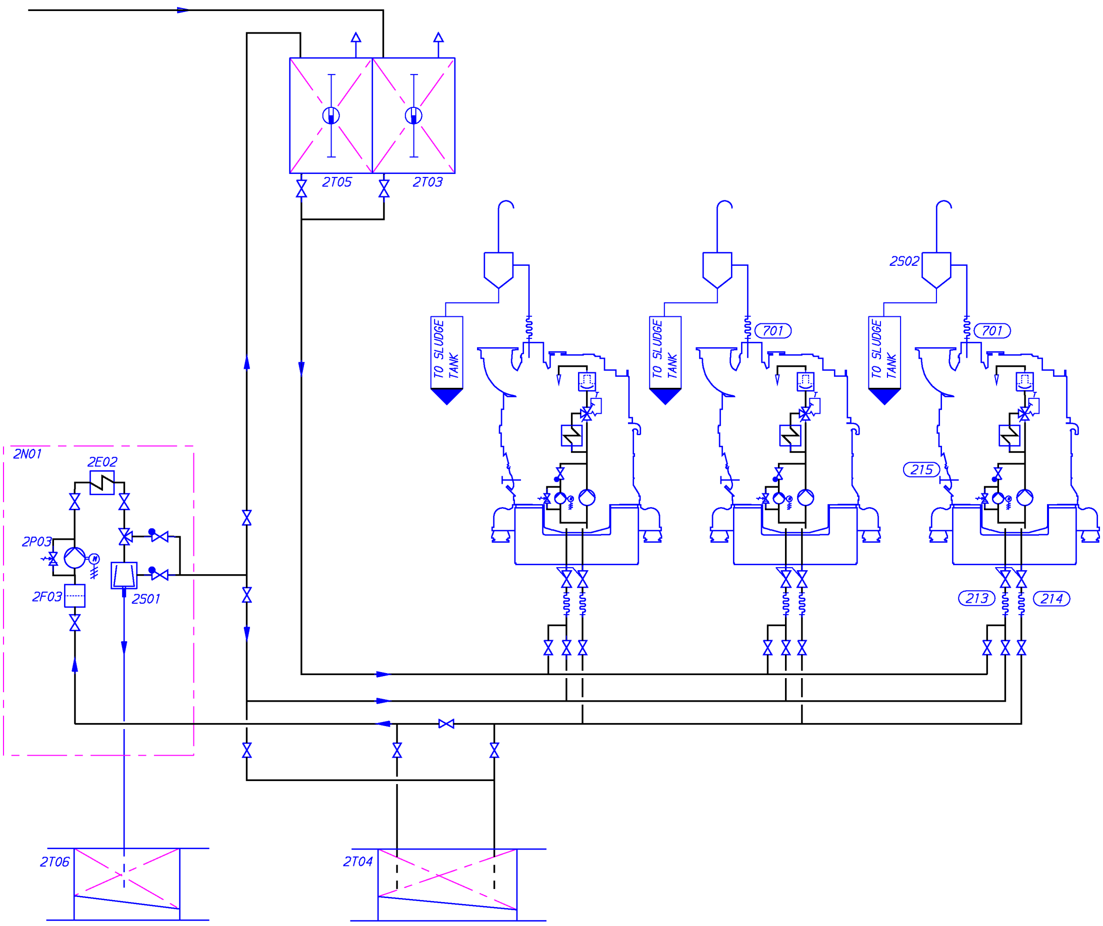


Fig 7.3.1 Lubricating oil system, auxiliary engines (3V76E4590C)

System components		Pipe connections	
2E02	Heater (Separator unit)	213	Lubricating oil from separator and filling
2F03	Suction filter (Separator unit)	214	Lubricating oil to separator and drain
2N01	Separator unit	215	Lubricating oil filling
2P03	Separator pump (Separator unit)	701	Crankcase air vent
2S01	Separator		
2S02	Condensate trap		
2T03	New oil tank		
2T04	Renovating oil tank		
2T05	Renovated oil tank		
2T06	Sludge tank		

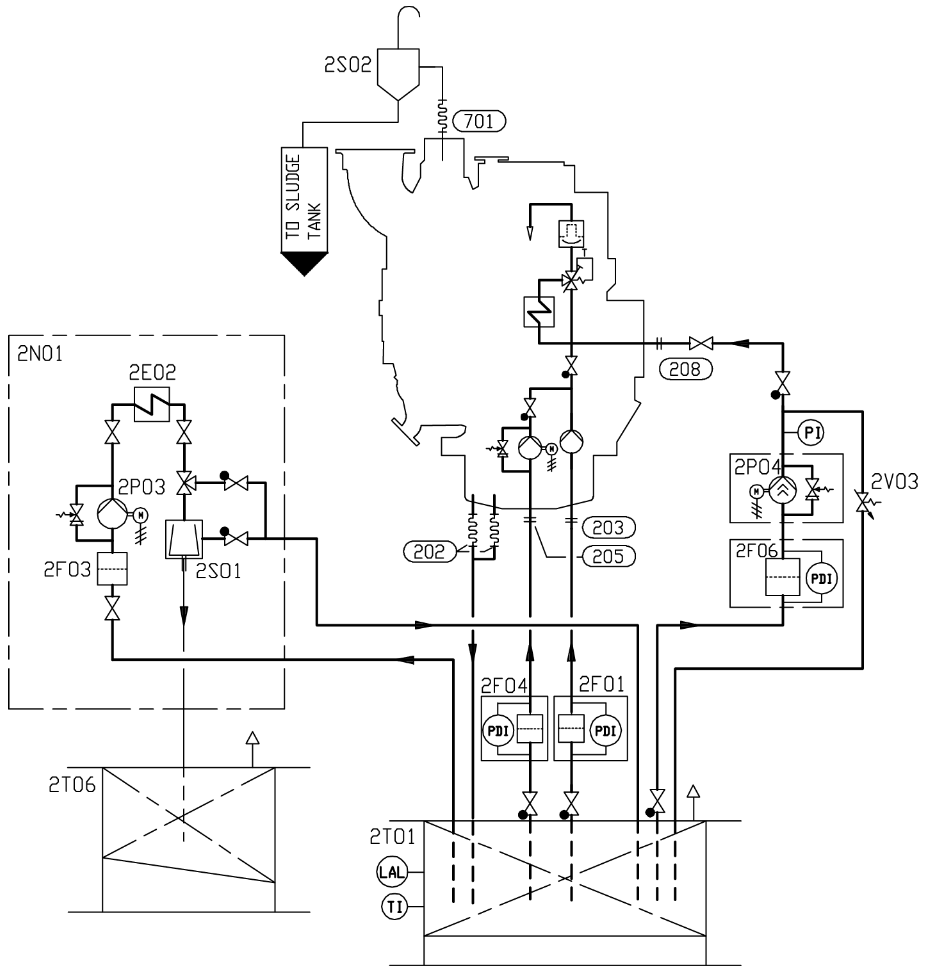


Fig 7.3.2 Lubricating oil system, main engine (3V76E4591F)

System components		Pipe connections		Size
2E02	Heater (Separator unit)	202	Lubricating oil outlet (from oil sump)	DN100
2F01	Suction strainer (Main lubricating oil pump)	203	Lubricating oil to engine driven pump	DN100
2F03	Suction filter (Separator unit)	205	Lubricating oil to priming pump	DN32
2F04	Suction strainer (Prelubricating oil pump)	208	Lubricating oil from electric driven pump	DN80
2F06	Suction strainer (Stand-by pump)	701	Crankcase air vent	DN65
2N01	Separator unit			
2P03	Separator pump (Separator unit)			
2P04	Stand-by pump			
2S01	Separator			
2S02	Condensate trap			
2T01	System oil tank			
2T06	Sludge tank			
2V03	Pressure control valve			

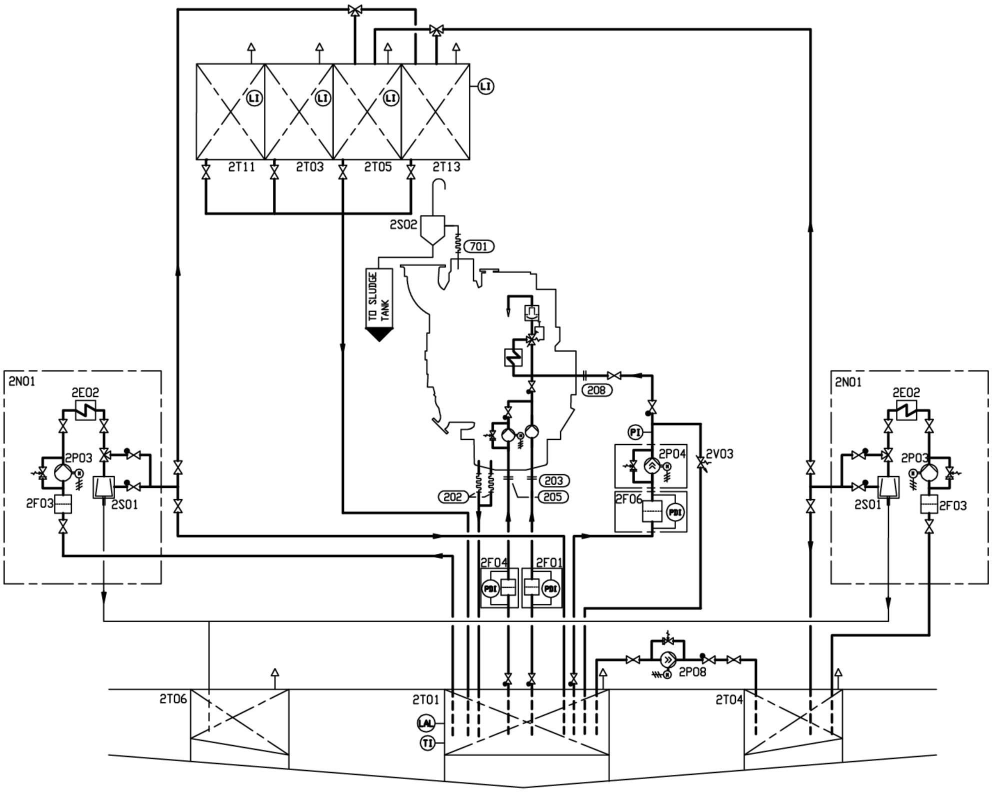


Fig 7.3.3 Lubricating oil system, main engine (DAAF040652B)

System components		Pipe connections	
2E02	Heater (Separator unit)	2S02	Condensate trap
2F01	Suction strainer (main LO pump)	2T01	System oil tank
2F03	Suction filter (separator unit)	2T03	New oil tank (high BN)
2F04	Suction strainer (prelube oil pump)	2T04	Renovating oil tank
2F06	Suction strainer (standby pump)	2T05	Renovated oil tank (high BN)
2N01	Separator unit	2T06	Sludge tank
2P03	Separator pump (separator unit)	2T11	New oil tank (Low sulphur)
2P04	Stand-by pump	2T13	Renovated oil tank (low sulphur)
2P08	Transfer pump	2V03	Pressure control valve
2S01	Separator		

Pipe connections		
Pos	**Pipe connections**	**Size**
202	Lubricating oil outlet (From oil sump)	DN100
203	Lubricating oil to engine driven pump	DN100
205	Lubricating oil to priming pump	DN32
208	Lubricating oil from electric driven pump	DN80
701	Crankcase air vent	DN65

7.3.1 Separation system

7.3.1.1 Separator unit (2N01)

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

Generating sets operating on a fuel having a viscosity of max. 380 cSt / 50°C may have a common lubricating oil separator unit. Three engines may have a common lubricating oil separator unit. In installations with four or more engines two lubricating oil separator units should be installed.

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.

7.3.1.1.1 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.

7.3.1.1.2 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.

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).

7.3.1.1.3 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 = number of through-flows of tank volume per day: 5 for HFO, 4 for MDF

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

7.3.1.1.4 Sludge tank (2T06)

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

7.3.1.2 Renovating oil tank (2T04)

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

7.3.1.3 Renovated oil tank (2T05)

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

7.3.2 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.

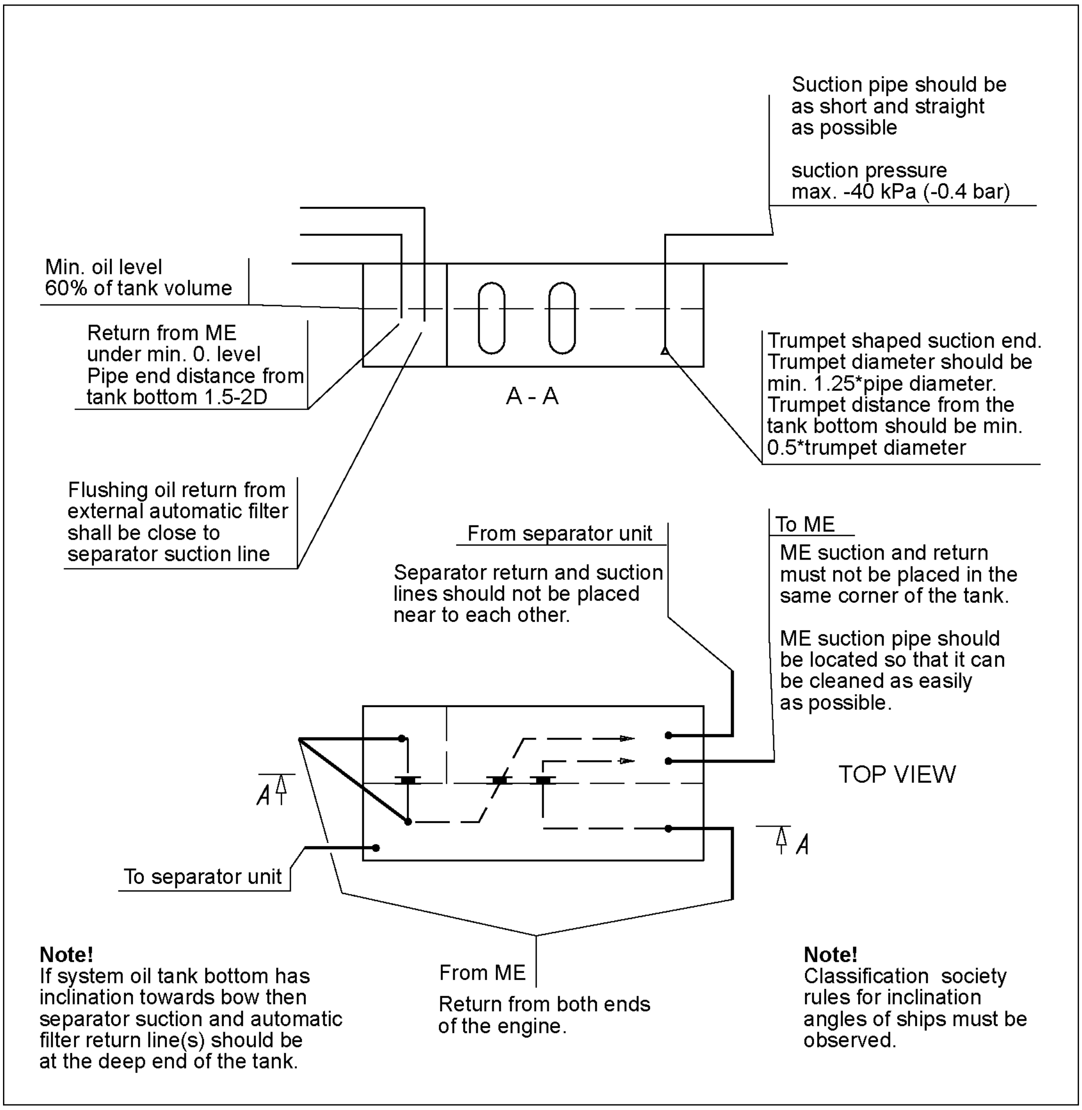


Fig 7.3.2.1 Example of system oil tank arrangement (DAAE007020e)

Design data:

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

7.3.3 New oil tank (2T03)

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

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

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

Design data:	
Fineness	0.5...1.0 mm

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

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

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

7.4 Crankcase ventilation system

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

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

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

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

The connection between engine and pipe is to be flexible.

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

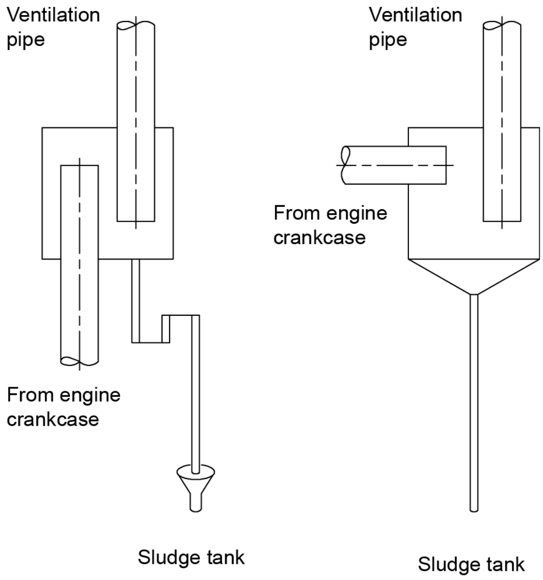


Fig 7.4.1 Condensate trap (DAAE032780A)

Minimum size of the ventilation pipe after the condensate trap is:

DN80

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

7.5 Flushing instructions

Flushing instructions in this Product Guide are for guidance only. For contracted projects, read the specific instructions included in the installation planning instructions (IPI).

7.5.1 Piping and equipment built on the engine

Flushing of the piping and equipment built on the engine is not required and flushing oil shall not be pumped through the engine oil system (which is flushed and clean from the factory). It is however acceptable to circulate the flushing oil via the engine sump if this is advantageous. Cleanliness of the oil sump shall be verified after completed flushing.

7.5.2 External oil system

Refer to the system diagram(s) in section *External lubricating oil system* for location/description of the components mentioned below.

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

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

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

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

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

7.5.3 Type of flushing oil

7.5.3.1 Viscosity

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

7.5.3.2 Flushing with engine oil

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

7.5.3.3 Flushing with low viscosity flushing oil

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

7.5.3.4 Lubricating oil sample

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

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

8. Compressed Air System

Compressed air is used to start engines and to provide actuating energy for safety and control devices. The use of starting air for other purposes is limited by the classification regulations.

To ensure the functionality of the components in the compressed air system, the compressed air has to be free from solid particles and oil.

8.1 Internal compressed air system

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

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

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

If an exhaust waste gate is not possible (e.g. with pulse systems) or not regarded feasible an air waste gate (AWG) should be used. The AWG can be equipped with a silencer or connected to a 3 m long hose with 24 mm inner diameter.

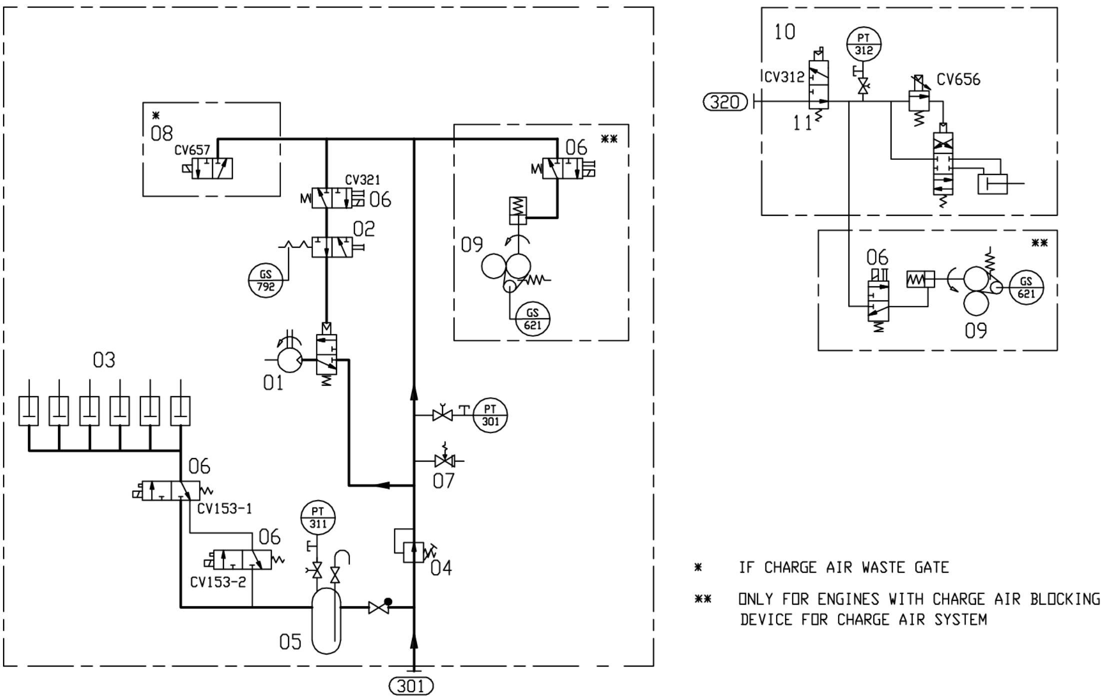


Fig 8.1.1 Internal starting air system (DAAE060387E)

System components:			
01	Turbine starter	07	Safety valve
02	Blocking valve, when turning gear engaged	08	Solenoid valve for air waste gate (if air waste gate)
03	Pneumatic cylinder for overspeed	09	Charge air blocking device
04	Pressure regulator	10	Charge air wastegate
05	Air container	11	Solenoid valve CV312 (Optional)
06	Solenoid valve		

Sensors and indicators:			
PT301	Starting air pressure, engine inlet	CV153-2	Stop solenoid 2
PT311	Control air pressure, engine inlet	CV321	Starting solenoid
GS792	Turning gear position	CV657-1	Air waste gate control 1
GS621	Charge air shut-off valve position	CV657-2	Air waste gate control 2
CV153-1	Stop solenoid 1		

Pipe connections		Size	Pressure class	Standard
301	Starting air inlet, 3MPa	OD28	PN100	DIN 2353
320	Instrument air inlet	OD6		

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.

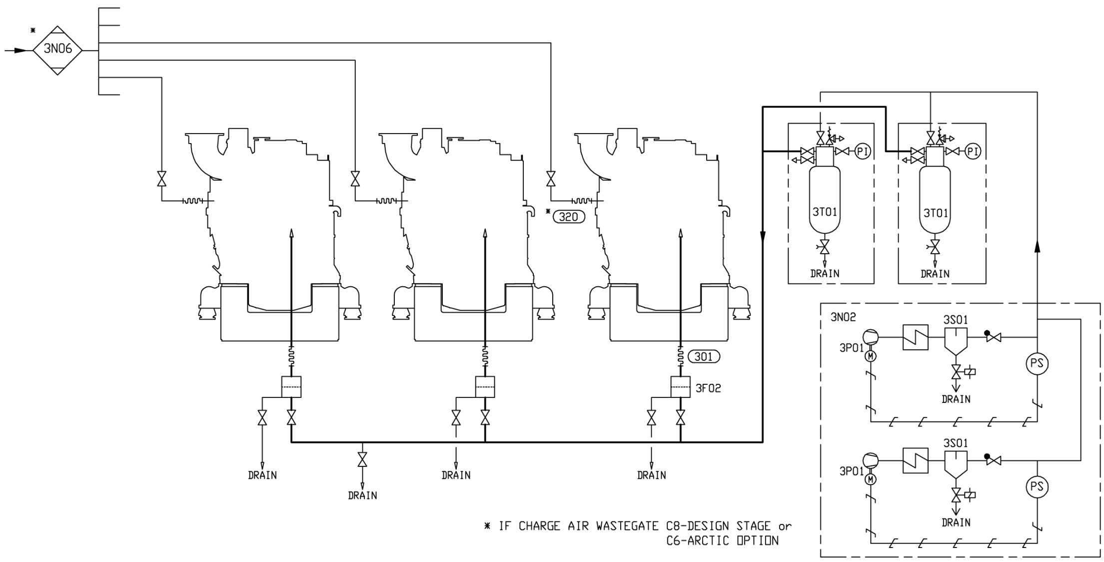


Fig 8.2.1 External starting air system (DAAE007204F)

System components			
3F02	Air filter (Starting air inlet)	3P01	Compressor (Starting air compressor unit)
3N02	Starting air compressor unit	3S01	Separator (Starting air compressor unit)
3N06	Air dryer unit	3T01	Starting air vessel

Pipe connections		Size
301	Staring air inlet	OD28
320	Instrument air inlet	OD6

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.

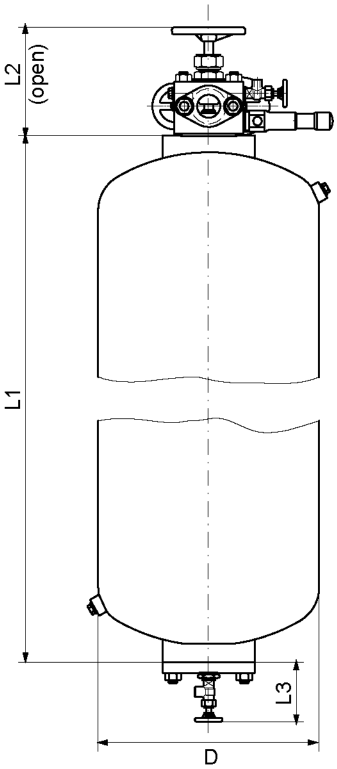
8.2.3 Starting air vessel (3T01)

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.



Size [Litres]	Dimensions [mm]				Weight [kg]
	L1	L2 1)	L3 1)	D	
125	1807	243	110	324	170
180	1217	243	110	480	200
250	1767	243	110	480	274
500	3204	243	133	480	450

1) Dimensions are approximate.

Fig 8.2.3.1 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 = 1.8 MPa

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.

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

The starting air filter is mandatory for Wärtsilä 20 engines.

8.2.5 Air filter, air assist inlet (3F03)

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

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

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9. Cooling Water System

9.1 Water quality

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

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

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

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

9.1.1 Corrosion inhibitors

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

9.1.2 Glycol

Use of glycol in the cooling water is not recommended unless it is absolutely necessary. Starting from 20% glycol the engine is to be de-rated 0.23 % per 1% glycol in the water. Max. 50% glycol is permitted.

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

9.2 Internal cooling water system

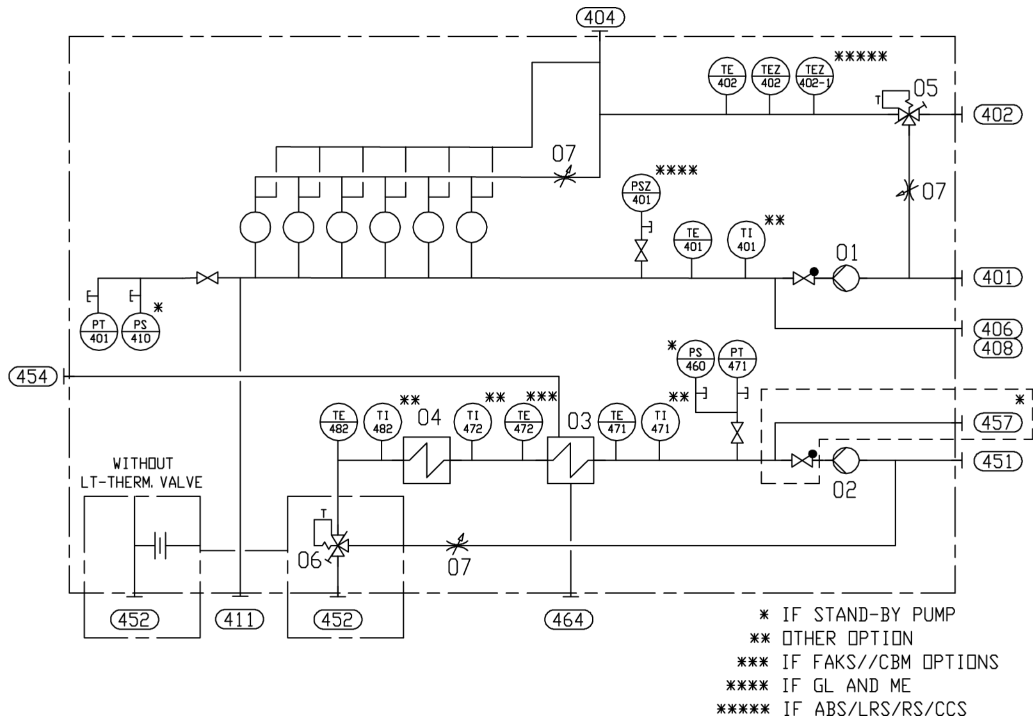


Fig 9.2.1 Internal cooling water system (DAAE060388C)

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

Sensors and Indicators:			
PT401	HT water pressure, jacket inlet	PS460	LT water pressure switch, stand-by pump
PSZ401	HT water pressure switch. jacket inlet (if GL and ME)	PT471	LT water pressure, CAC inlet
PS410	HT water pressure switch, stand-by pump	TE471	LT water temperature, CAC inlet
TE401	HT water temperature, jacket inlet	TI471	LT water temperature, CAC inlet (option)
TI401	HT water temperature, jacket inlet (option)	TE472	LT water temperature, CAC outlet (if FAKS/CBM)
TE402	HT water temperature, engine outlet	TI472	LT water temperature, CAC outlet (option)
TEZ402	HT water temperature, engine outlet	TE482	LT water temperature, LOC outlet
TEZ402-1	HT water temperature, engine outlet	TI482	LT water temperature, LOC outlet (option)
TEZ401-2	HT water temperature, engine outlet (if ABS/LRS/RS/CCS)		

Pipe connections		Size	Pressure class	Standard
401	HT-water inlet	DN65	PN16	ISO 7005-1
402	HT-water outlet	DN65	PN16	ISO 7005-1
404	HT-water air vent	OD12	PN250	DIN 2353
406	Water from preheater to HT-circuit	DN65	PN16	ISO 7005-1
408	HT-water from stand-by pump	DN65	PN16	ISO 7005-1
411	HT-water drain	M10 x 1	-	Plug

Pipe connections		Size	Pressure class	Standard
451	LT-water inlet	DN80	PN16	ISO 7005-1
452	LT-water outlet	DN80	PN16	ISO 7005-1
454	LT-water air vent from air cooler	OD12	PN250	DIN 2353
457	LT-water from stand-by pump	DN80	PN16	ISO 7005-1
464	LT-water drain	M18 x 1.5	-	Plug

The fresh water cooling system is divided into a high temperature (HT) and a low temperature (LT) circuit. The HT water circulates through cylinder jackets and cylinder heads.

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

Temperature control valves regulate the temperature of the water out from the engine, by circulating some water back to the cooling water pump inlet. The HT temperature control valve is always mounted on the engine, while the LT temperature control valve can be either on the engine or separate. In installations where the engines operate on MDF only it is possible to install the LT temperature control valve in the external system and thus control the LT water temperature before the engine.

9.2.1 Engine driven circulating pumps

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

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

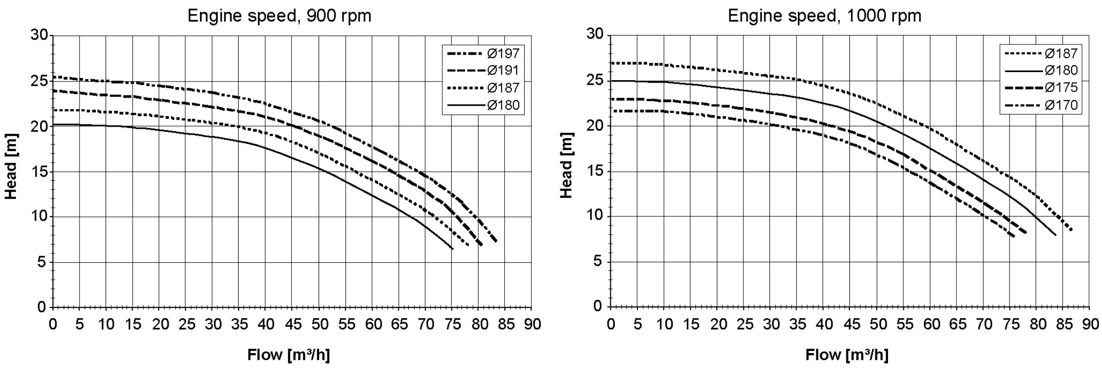


Fig 9.2.1.1 Pump curves

Table 9.2.1.1 Impeller diameters of engine driven HT & LT pumps

Engine type	Engine speed [rpm]	HT impeller [Ø mm]	LT impeller [Ø mm]
W 4L20	900 1000	180 170	187 170
W 6L20	900 1000	187 175	187 175
W 8L20	900 1000	191 180	197 187
W 9L20	900 1000	191 180	197 187

9.2.2 Engine driven sea water pump

An engine driven sea water pump is available for main engines:

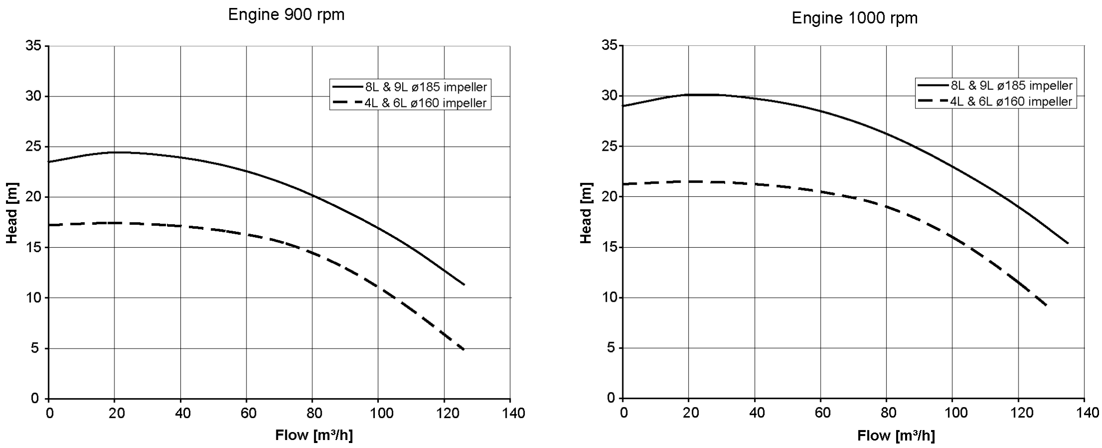


Fig 9.2.2.1 Engine driven sea water pump curves

9.3 External cooling water system

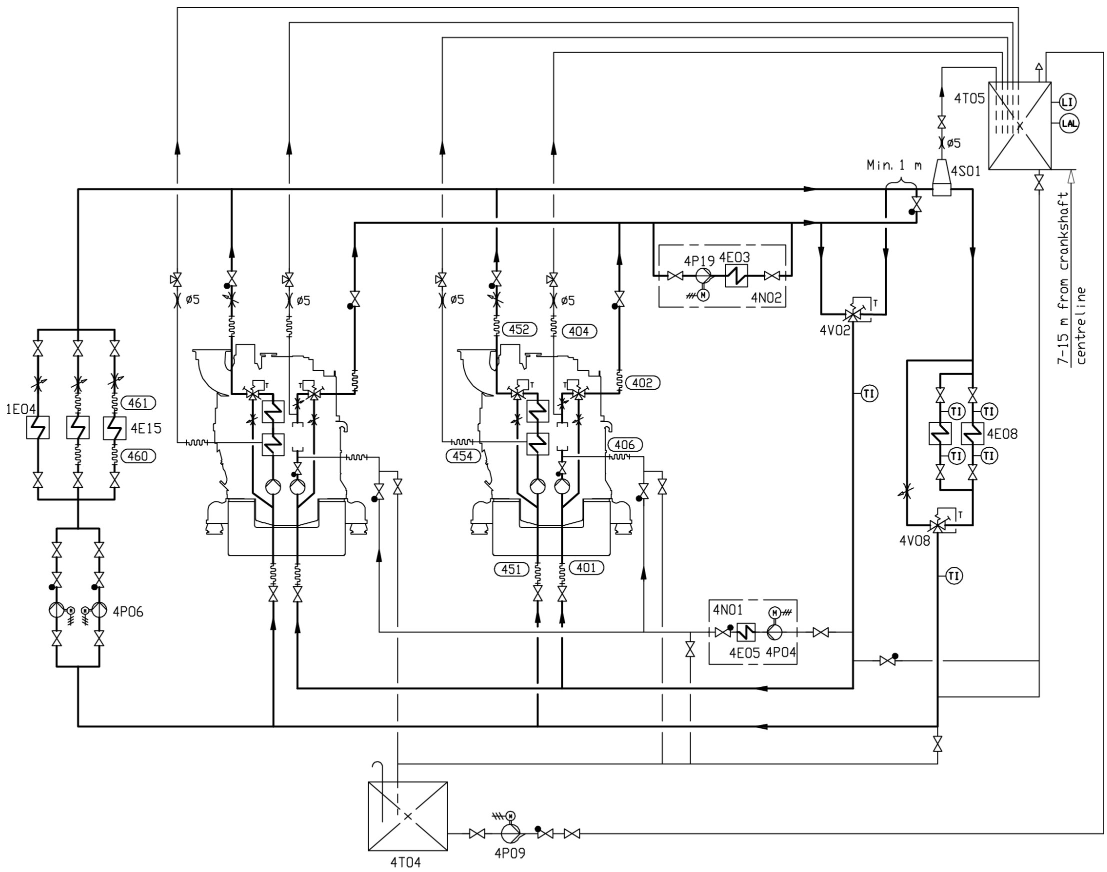


Fig 9.3.1 Cooling water system, inline engines (DAAF068123)

System components:			
1E04	Cooler (MDF)	4P06	Circulating pump
4E03	Heat recovery (Evaporator)	4P09	Transfer pump
4E05	Heater (Preheater)	4P19	Circulating pump
4E08	Central cooler	4S01	Air venting
4E15	Cooler (Generator)	4T04	Drain tank
4N01	Preheating unit	4T05	Expansion tank
4N02	Evaporator unit	4V02	Temperature control valve (Heat recovery)
4P04	Circulating pump (Preheater)	4V08	Temperature control valve (Central cooler)

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

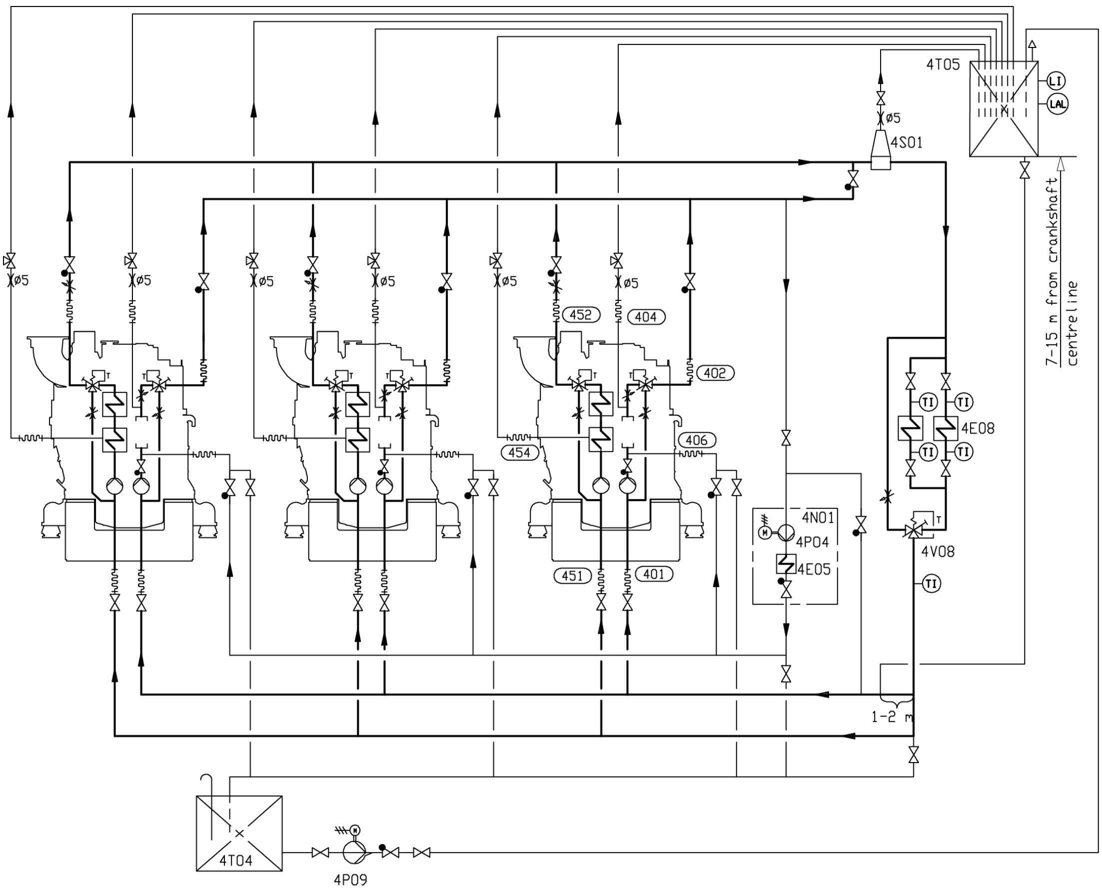


Fig 9.3.2 Cooling water system, auxiliary engines operating on HFO and MDO (3V76C5823B)

System components:			
4E05	Heater (Preheater)	4S01	Air venting
4E08	Central cooler	4T04	Drain tank
4N01	Preheating unit	4T05	Expansion tank
4P04	Circulating pump (Preheating unit)	4V08	Temperature control valve (central cooler)
4P09	Transfer pump		
Pipe connections are listed in section "Internal cooling water system".			

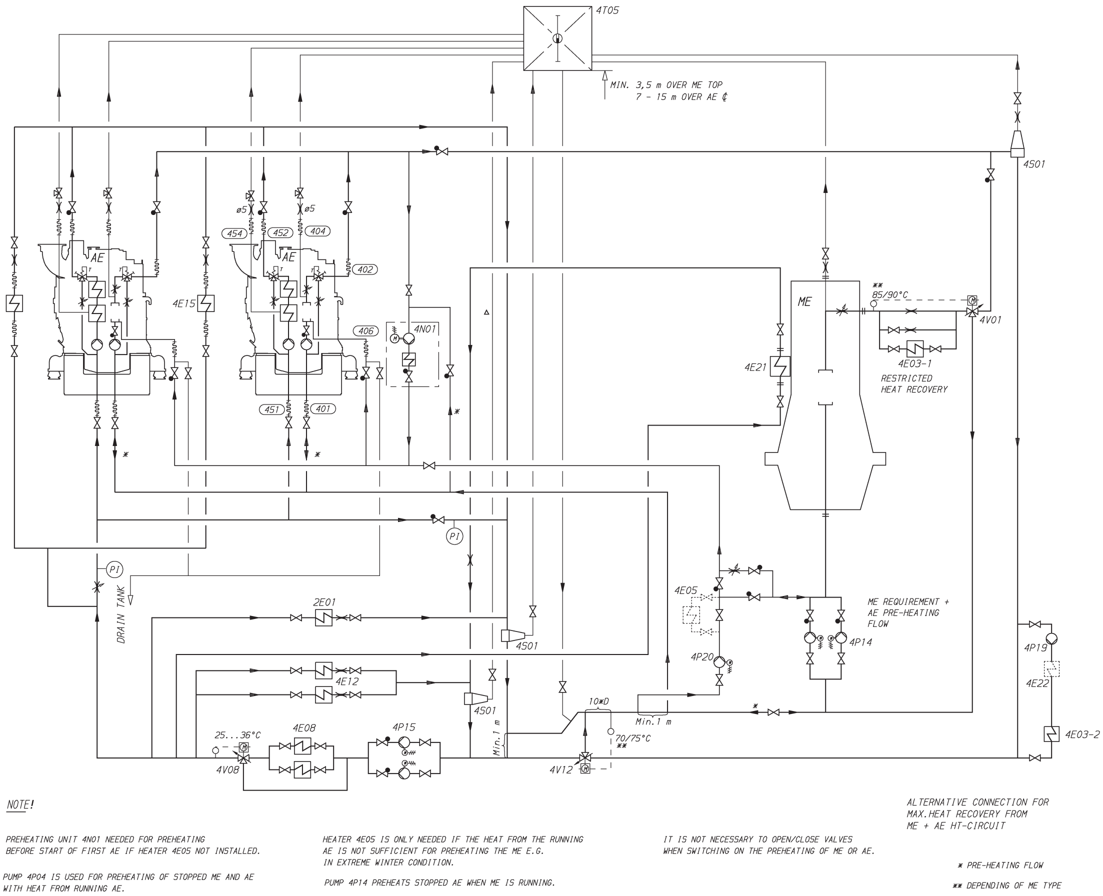


Fig 9.3.3 Cooling water system common for ME and AE, mixed LT and HT-circuit, common heatrecovery and preheating for ME and AE (DAAE030653)

System components			
2E01	Lubricating oil cooler	4P14	Circulating pump (HT)
4E03-1	Heat recovery (evaporator) ME	4P15	Circulating pump (LT)
4E03-2	Heat recovery (evaporator) ME+AE	4P19	Circulating pump (evaporator)
4E05	Heater (preheater) optional	4P20	Circulating pump (preheating HT)
4E08	Central cooler	4S01	Air venting
4E12	Cooler (installation parts)	4T05	Expansion tank
4E15	Cooler (generator) optional	4V01	Temperature control valve (HT)
4E21	Cooler (scavenge air)	4V08	Temperature control valve (central cooler)
4E22	Heater (booster) (optional)	4V12	Temperature control valve (heat recovery and preheating)
4N01	Preheating unit		
Pipe connections are listed in section "Internal cooling water system".			

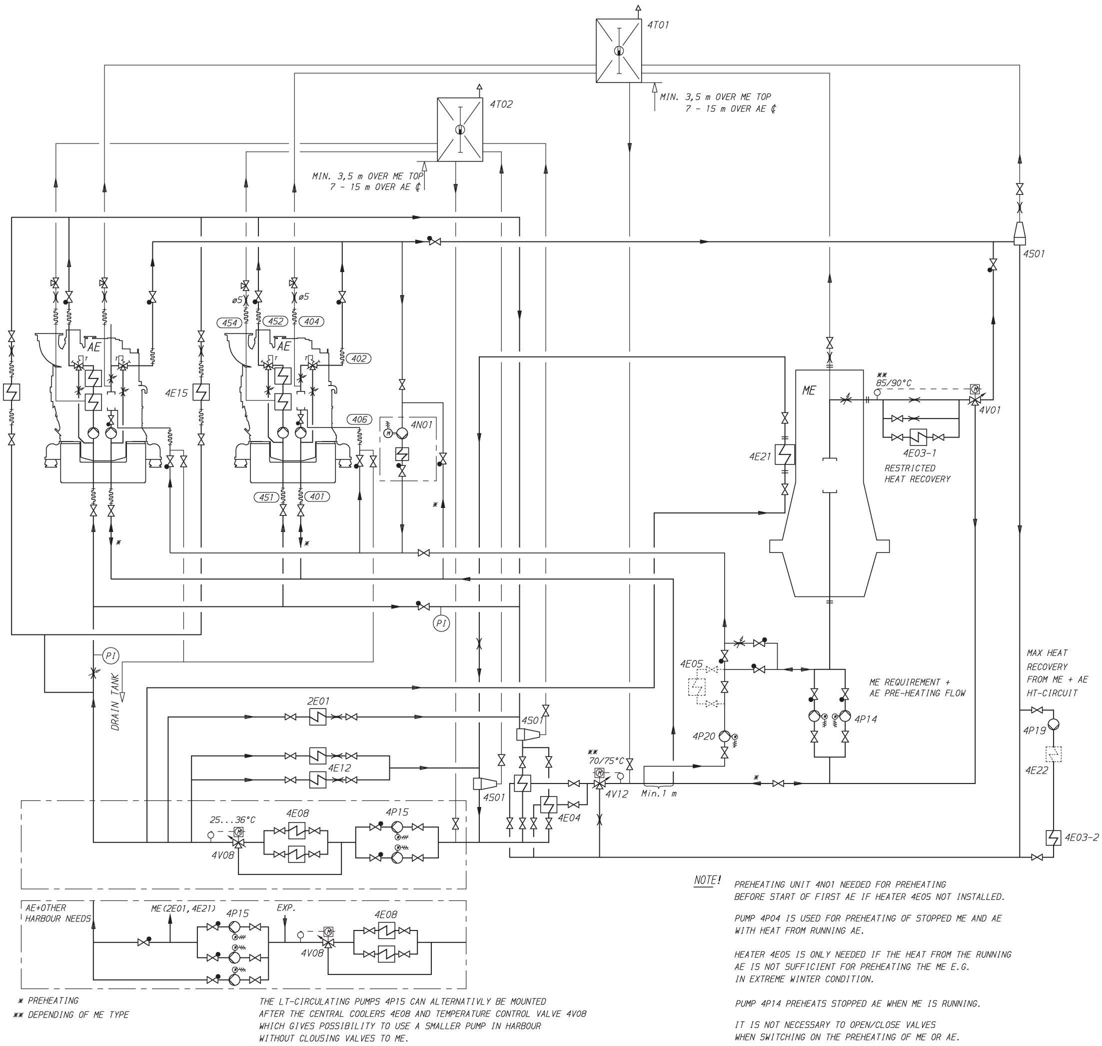


Fig 9.3.4 **Common cooling water system, split LT and HT-circuit, common heat recovery and preheating (DAAE030654)**

System components			
2E01	Lubricating oil cooler	4P14	Circulating pump (HT)
4E03-1	Heat recovery (evaporator) ME	4P15	Circulating pump (LT)
4E03-2	Heat recovery (evaporator) ME+AE	4P19	Circulating pump (evaporator)
4E04	Raw water cooler (HT)	4P20	Circulating pump (preheating HT)
4E05	Heater (preheater) optional	4S01	Air venting
4E08	Central cooler	4T01	Expansion tank (HT)
4E12	Cooler (installation parts)	4T02	Expansion tank (LT)
4E15	Cooler (generator) optional	4V01	Temperature control valve (HT)
4E21	Cooler (scavenge air)	4V08	Temperature control valve (central cooler)
4E22	Heater (booster) (optional)	4V12	Temperature control valve (heat recovery and preheating)
4N01	Preheating unit		
Pipe connections are listed in section "Internal cooling water system".			

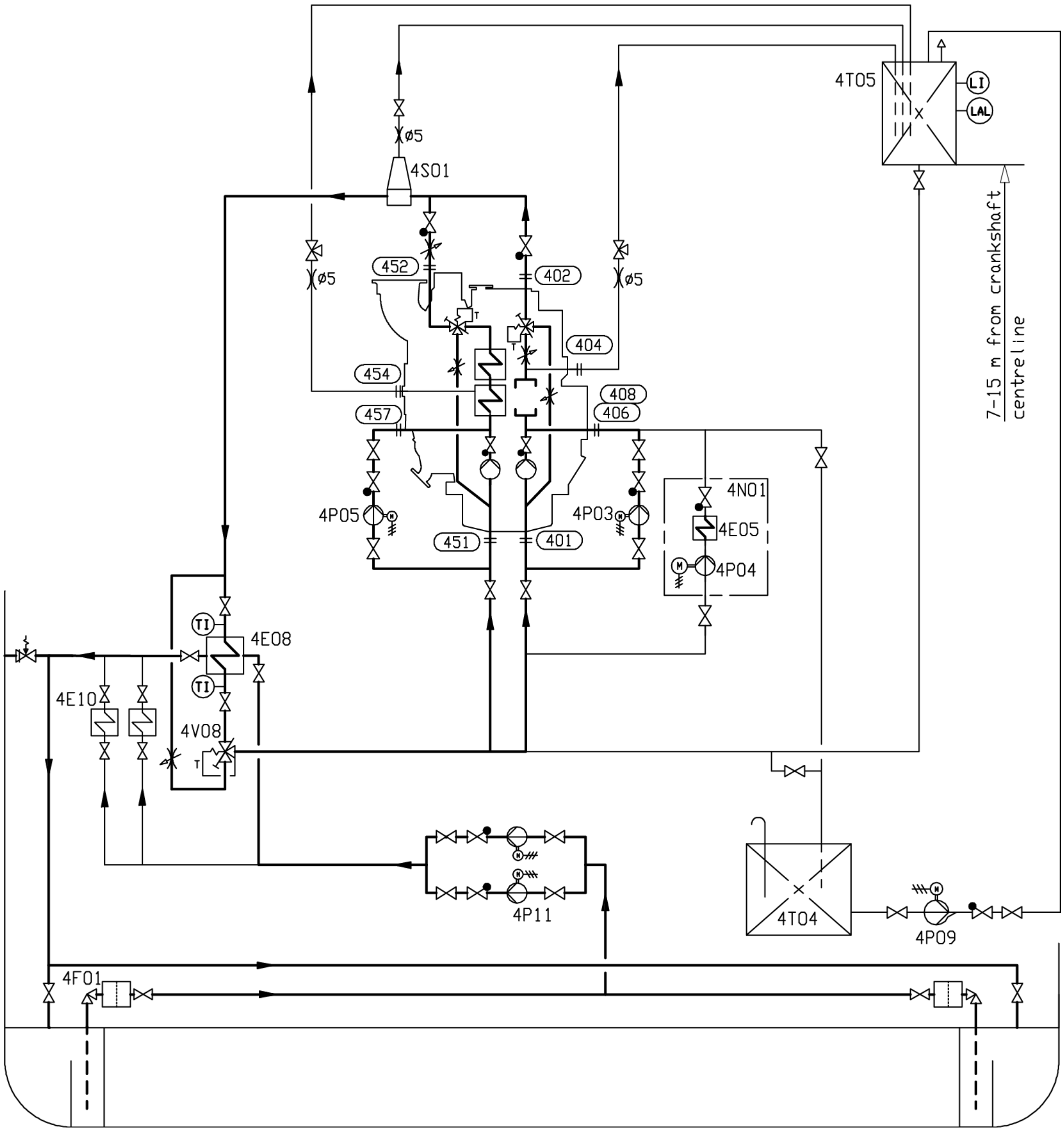


Fig 9.3.5 Cooling water system, main engine (3V76C5825B)

System components:			
4E05	Heater (Preheater)	4P05	Stand-by pump (LT)
4E08	Central cooler	4P09	Transfer pump
4E10	Cooler (Reduction gear)	4P11	Circulating pump (Sea water)
4F01	Suction strainer (Sea water)	4S01	Air venting
4N01	Preheating unit	4T04	Drain tank
4P03	Stand-by pump (HT)	4T05	Expansion tank
4P04	Circulating pump (Preheater)	4V08	Temperature control valve (central cooler)
Pipe connections are listed in section "Internal cooling water system".			

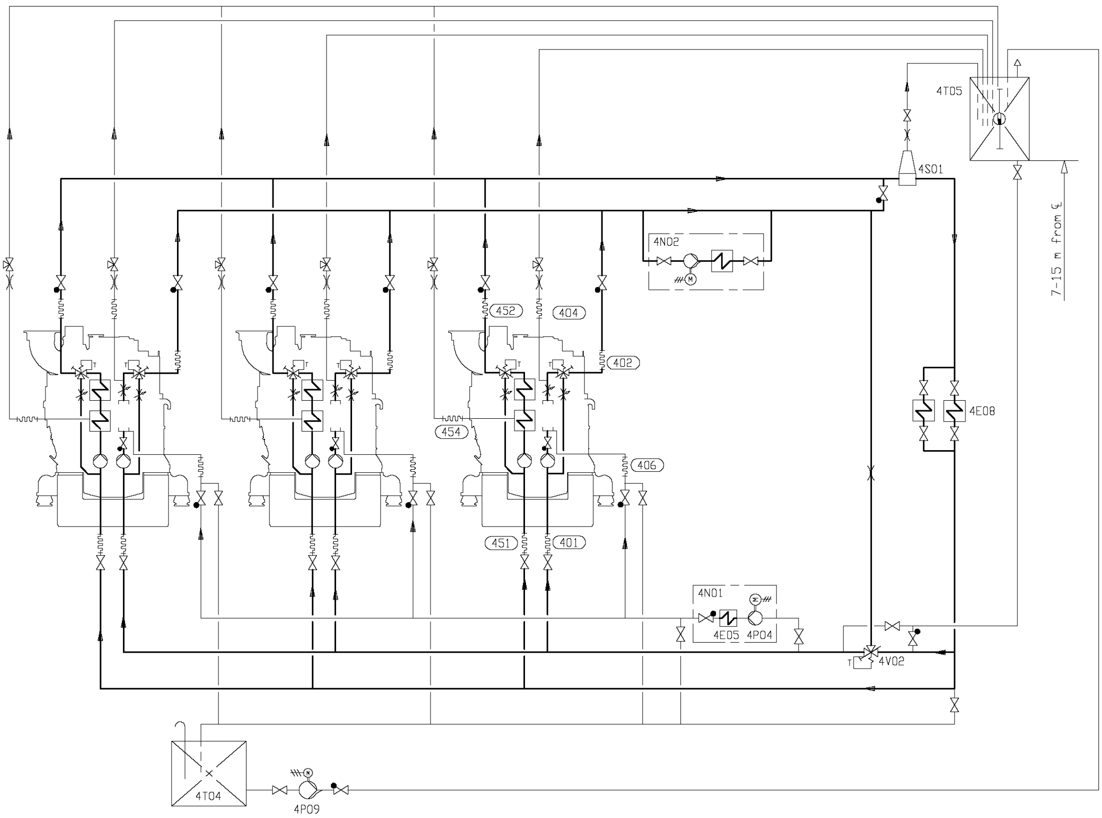


Fig 9.3.6 Cooling water system, HFO engines with evaporator (3V76C5826C)

System components:			
4E03	Heat recovery (Evaporator)	4P19	Circulating pump (Evaporator)
4E05	Heater (Preheater)	4S01	Air venting
4E08	Central cooler	4T04	Drain tank
4N01	Preheating unit	4T05	Expansion tank
4N02	Evaporator unit	4V02	Temperature control valve (Heat recovery)
4P04	Circulating pump (Preheater)	4V08	Temperature control valve (Central cooler)
4P09	Transfer pump		
Pipe connections are listed in section "Internal cooling water system".			

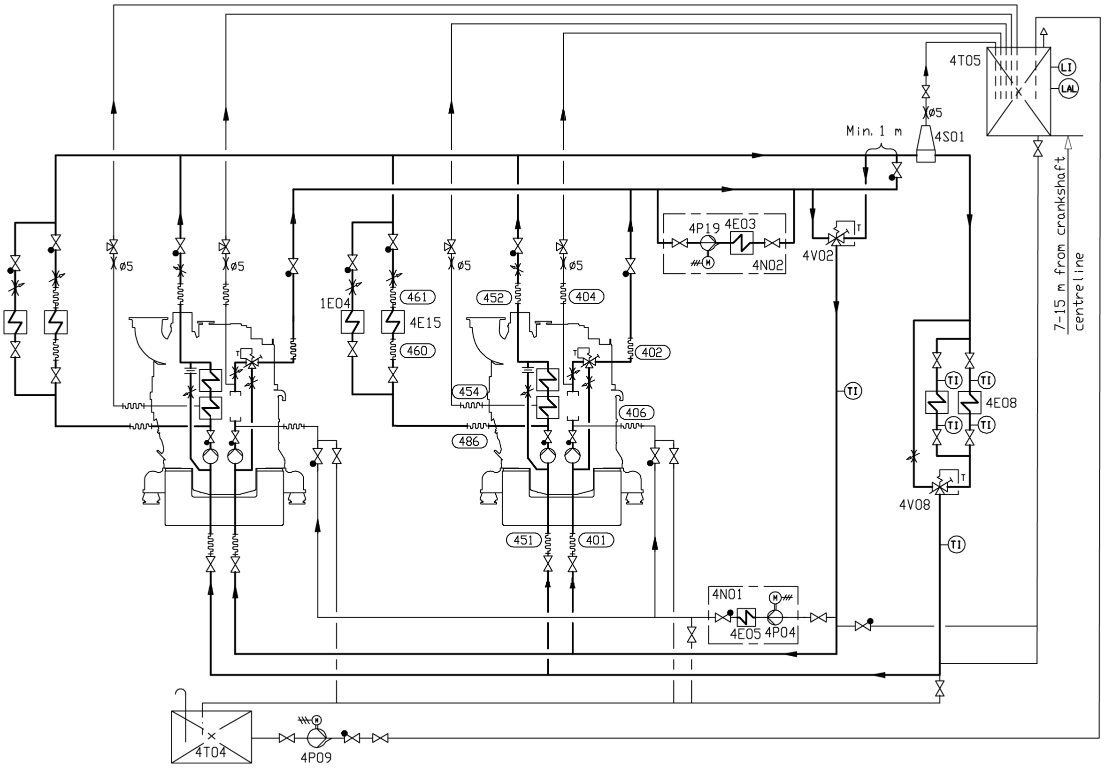


Fig 9.3.7 Cooling water system, MDF engines with evaporator (3V76C5827B)

System components:			
1E04	Cooler (MDF)	4P09	Transfer pump
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	Thermostatic valve (Heat recovery)
4N02	Evaporator unit	4V08	Thermostatic valve (LT)
4P04	Circulating pump (Preheater)		
Pipe connections are listed in section "Internal 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.

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

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

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

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

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

9.3.2 Sea water pump (4P11)

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

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

9.3.3 Temperature control valve for central cooler (4V08)

When it is desired to utilize the engine driven LT-pump for cooling of external equipment, e.g. a reduction or a generator, there must be a common LT temperature control valve in the external system, instead of an individual valve for each engine. 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 set-point of the temperature control valve 4V08 is 38 °C in the type of system described above.

Engines operating on HFO must have individual LT temperature control valves. A separate pump is required for the external equipment in such case, and the set-point of 4V08 can be lower than 38 °C if necessary.

9.3.4 Fresh water central cooler (4E08)

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

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

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

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

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

where:

q =	total fresh water flow [m³/h]
q_{LT} =	nominal LT pump capacity[m³/h]
Φ =	heat dissipated to HT water [kW]
T_{out} =	HT water temperature after engine (91°C)
T_{in} =	HT water temperature after cooler (38°C)

Design data:

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

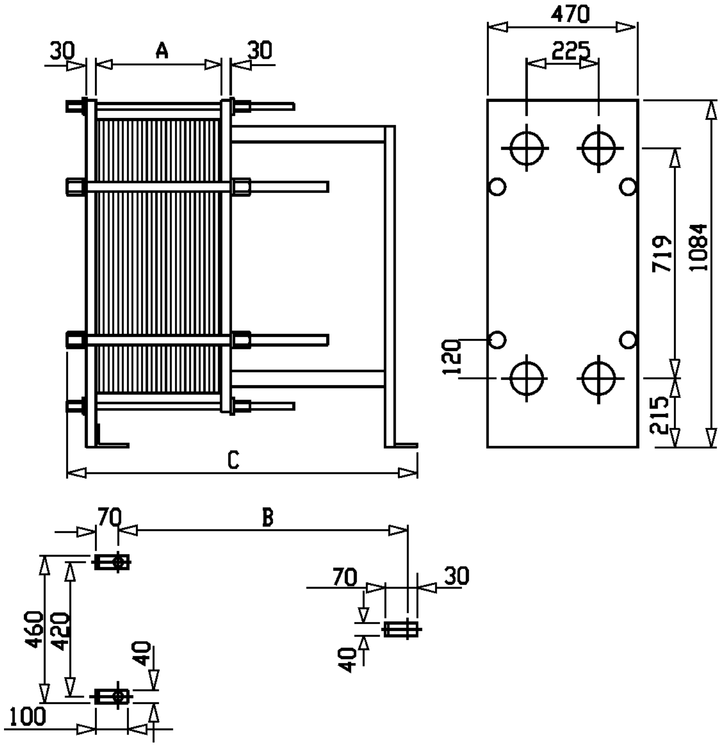


Fig 9.3.4.1 Central cooler, main dimensions (4V47E0188b)

		Cooling water			Sea water			Dimension [mm]			Weight [kg]	
Engine type	[rpm]	Flow [m³/h]	Tcw, in [°C]	Tcw, out [°C]	Flow [m³/h]	Tsw, in [°C]	Tsw, out [°C]	A	B	C	Dry	Wet
W 4L20	1000	27	54.3	38	36	32	44.3	106	505	695	275	298
W 6L20	1000	40	53.3	38	53	32	43.5	150	655	845	288	321
W 8L20	1000	53	53.6	38	71	32	43.8	198	655	845	298	341
W 9L20	1000	59	53.7	38	80	32	43.8	221	905	1095	305	354

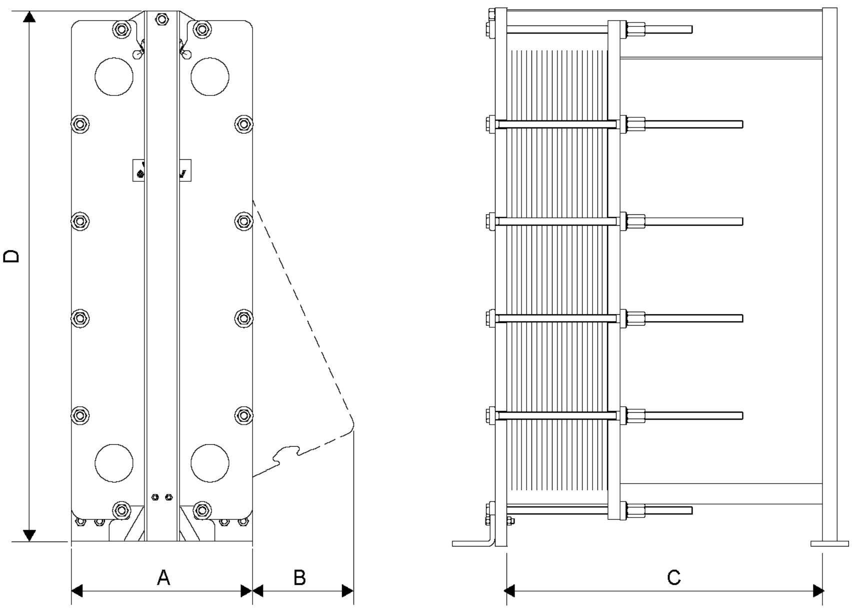


Fig 9.3.4.2 Central cooler main dimensions. Example for guidance only

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

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

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

9.3.5 Waste heat recovery

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

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

9.3.6 Air venting

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

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

The vent pipes must be continuously rising.

9.3.7 Expansion tank (4T05)

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

Design data:

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

NOTE

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

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

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

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

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

Table 9.3.7.1 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

9.3.8 Drain tank (4T04)

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

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

9.3.9 Preheating

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

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

9.3.9.1 Heater (4E05)

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

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

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

Design data:

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

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

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

where:

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

The formula above should not be used for $P < 2$ kW/cyl

9.3.9.2 Circulation pump for preheater (4P04)

Design data:	
Capacity	0.3 m^3/h per cylinder
Delivery pressure	80...100 kPa (0.8...1.0 bar)

9.3.9.3 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

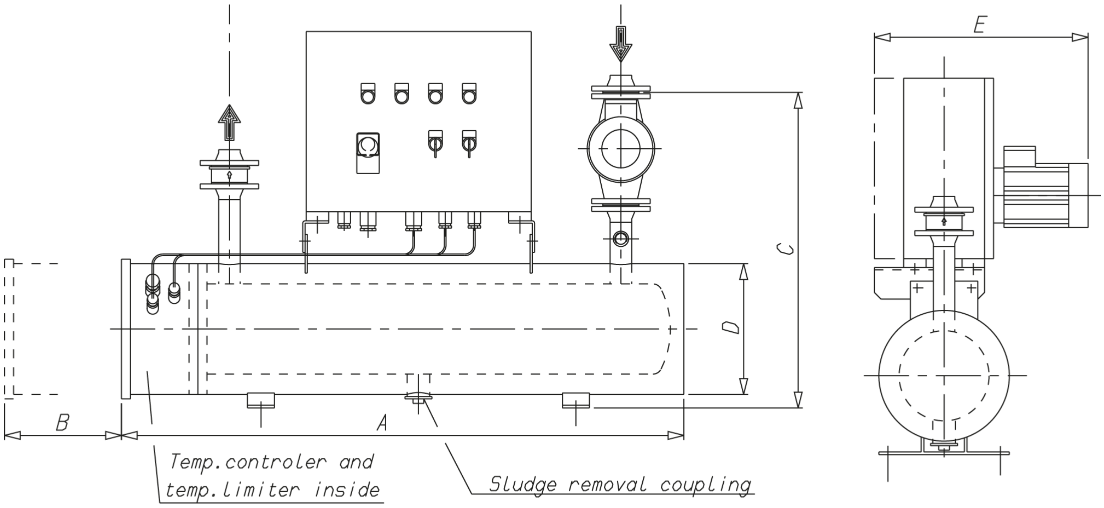


Fig 9.3.9.3.1 Preheating unit, electric (3V60L0653A)

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

9.3.10 Throttles

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

9.3.11 Thermometers and pressure gauges

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

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

10. Combustion Air System

10.1 Engine room ventilation

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

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

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

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

The amount of air required for ventilation is calculated from the total heat emission 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 is then calculated using the formula:

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

where:

qv = 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.

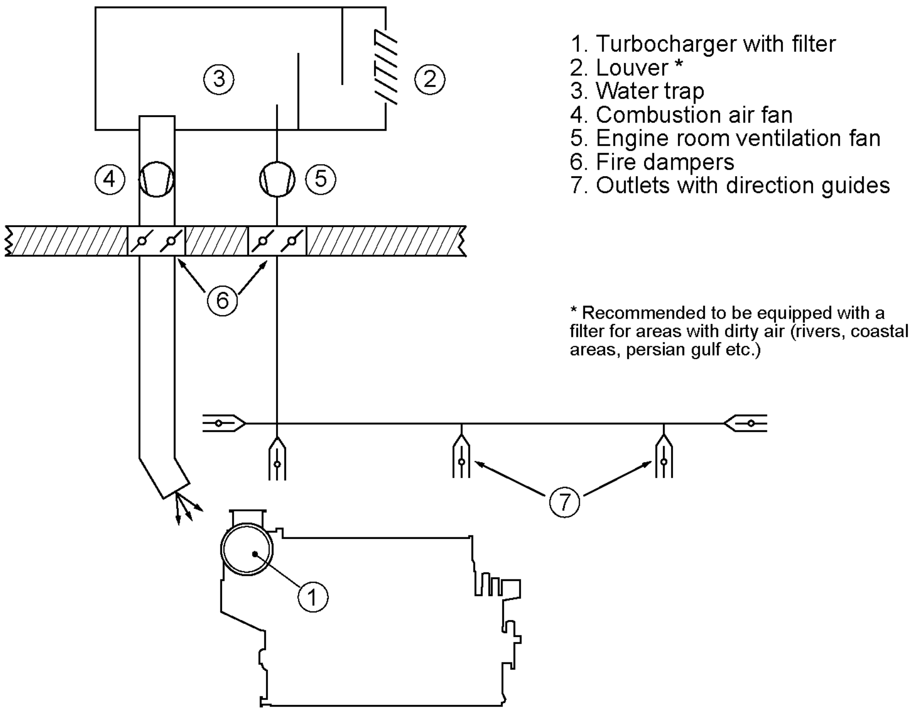


Fig 10.1.1 Engine room ventilation, turbocharger with air filter (DAAE092651)

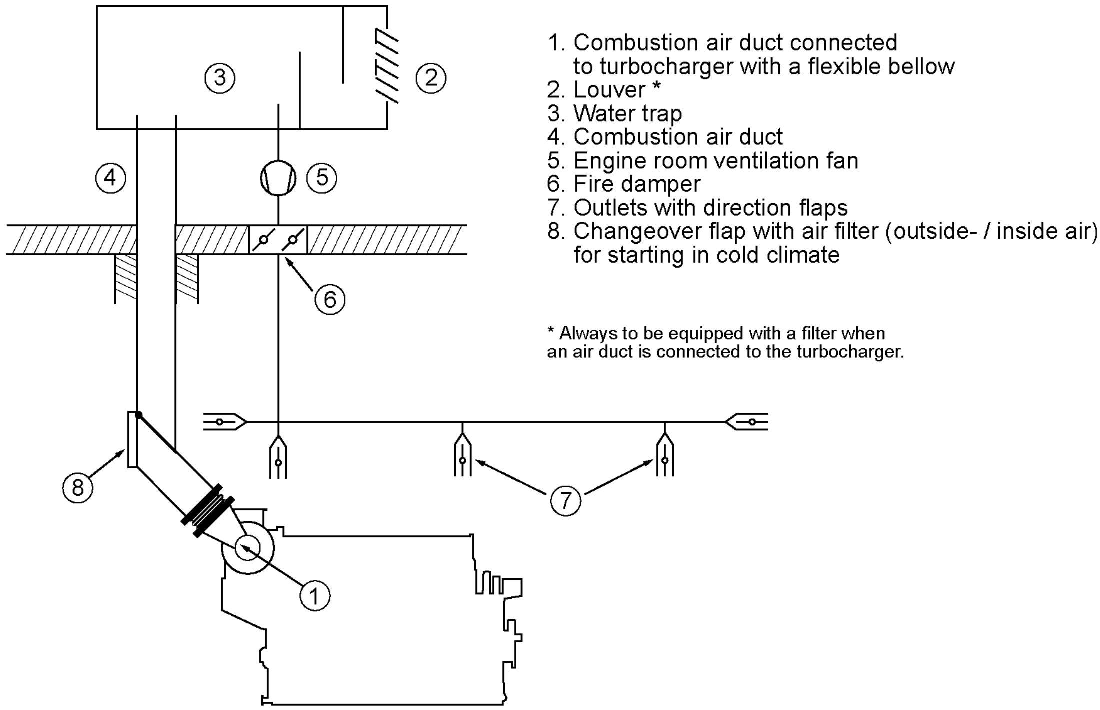


Fig 10.1.2 Engine room ventilation, air duct connected to the turbocharger (DAAE092652A)

10.2 Combustion air system design

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

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

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

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

where:

q_c = combustion air volume flow [m³/s]

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

ρ = air density 1.15 kg/m³

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

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

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

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

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

10.2.1 Charge air shut-off valve, "rigsaver" (optional)

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

10.2.2 Condensation in charge air coolers

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

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

Example, according to the diagram:

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

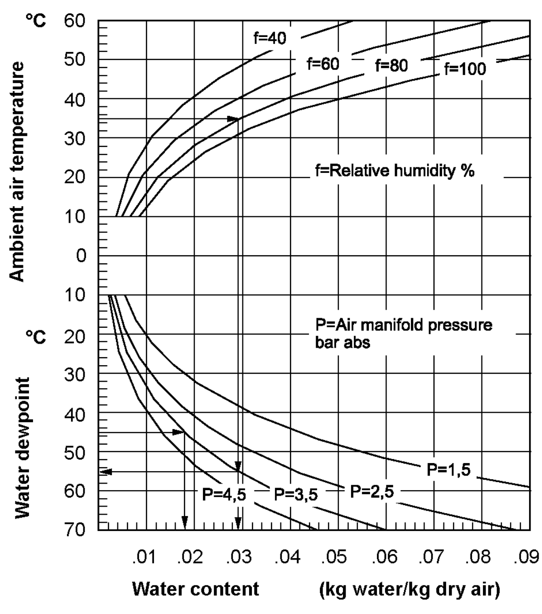


Fig 10.2.2.1 Condensation in charge air coolers

11. Exhaust Gas System

11.1 Internal exhaust gas system

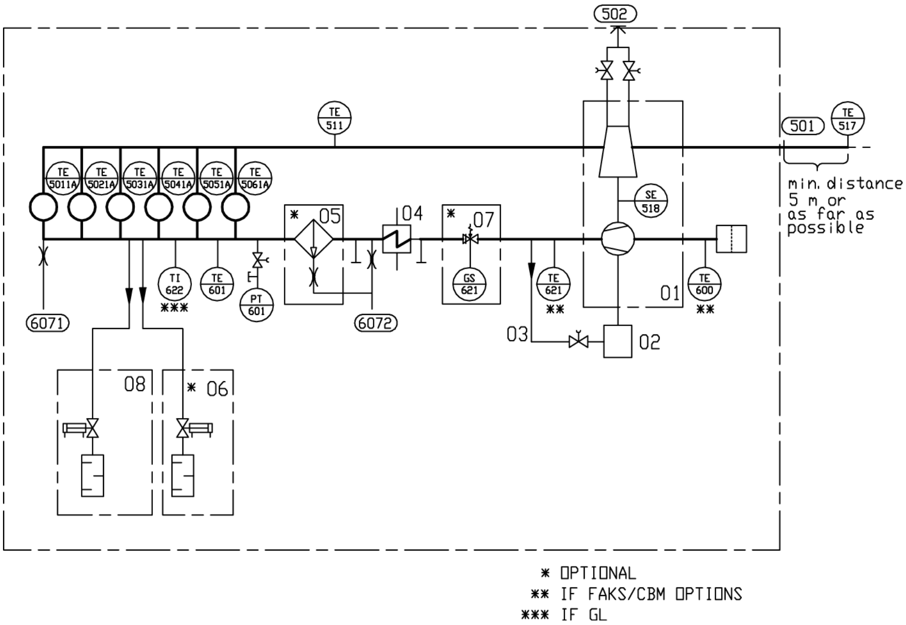


Fig 11.1.1 Internal exhaust gas system (DAAE060390F)

System components:			
01	Turbocharger	05	Water mist separator
02	Water container	06	Charge air waste gate
03	Pressure from air duct	07	Charge air shut off valve
04	Charge air cooler	08	Adjustable charge air wastegate (somas)

Sensors and indicators:			
TE50#1A	Exhaust gas temperature after each cylinder	PT601	Charge air pressure, CAC outlet
TE511	Exhaust gas temperature, TC inlet	PT601-2	Charge air pressure, CAC outlet
TE517	Exhaust gas temperature, TC outlet	TE600	Air temperature, TC inlet (if FAKS/CBM)
SE518	TC speed	TE621	Charge air temperature, CAC inlet (if FAKS/CBM)
		TE601	Charge air temperature, engine inlet
		TI622	Charge air temperature, CAC oulet (if GL)

Pipe connections		Size
501	Exhaust gas outlet	4L: DN200 6L: DN250 8L: DN250,DN300 9L: DN300
502	Cleaning water to turbine	OD15
6071	Condensate water from air receiver	-
6072	Condensate water from air cooler	-

11.2 Exhaust gas outlet

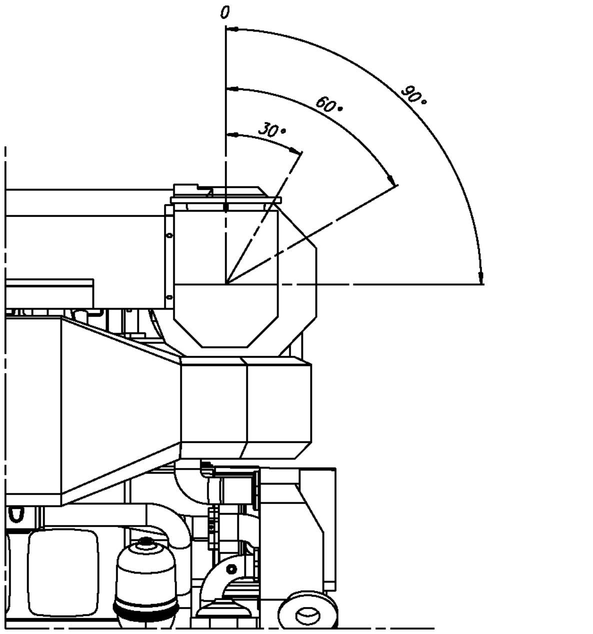


Fig 11.2.1 **Exhaust pipe connections (DAAE066842)**

Engine	TC in free end
W 6L20	0°, 30°, 60°, 90°
W 8L20	0°, 30°, 60°, 90°
W 9L20	0°, 30°, 60°, 90°

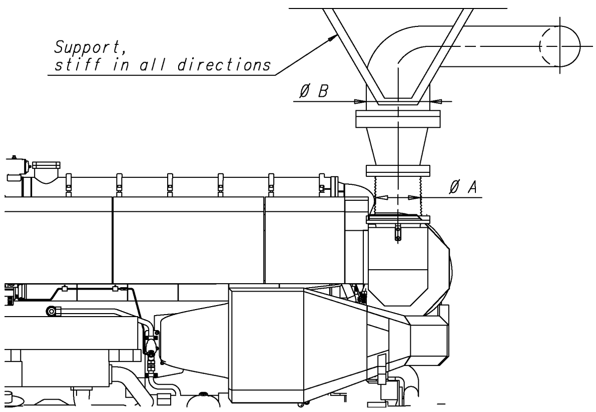


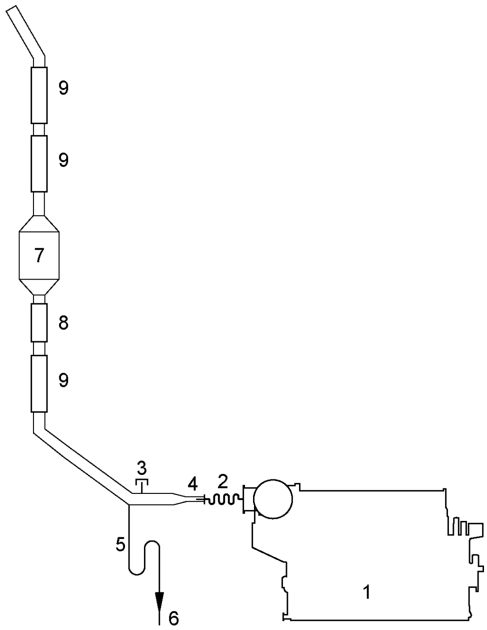
Fig 11.2.2 **Exhaust pipe, diameters and support (DAAF014083)**

Engine	ØA [mm]	ØB [mm]
W 6L20	250	300-350
W 8L20	300	350-450
W 9L20	300	350-450

11.3 External exhaust gas system

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

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



1 Diesel engine
2 Exhaust gas bellows
3 Connection for measurement of back pressure
4 Transition piece
5 Drain with water trap, continuously open
6 Bilge
7 SCR
8 Urea injection unit (SCR)
9 CSS silencer element

Fig 11.3.1 External exhaust gas system

11.3.1 Piping

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

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

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

where:

v = gas velocity [m/s]

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

T = exhaust gas temperature [°C]

D = exhaust gas pipe diameter [m]

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

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

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

11.3.2 Supporting

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

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

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

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

11.3.3 Back pressure

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

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

11.3.4 Exhaust gas bellows (5H01, 5H03)

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

11.3.5 SCR-unit (11N14)

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

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

11.3.6 Exhaust gas boiler

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

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

11.3.7 Exhaust gas silencers

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

11.3.7.1 Exhaust noise

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

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

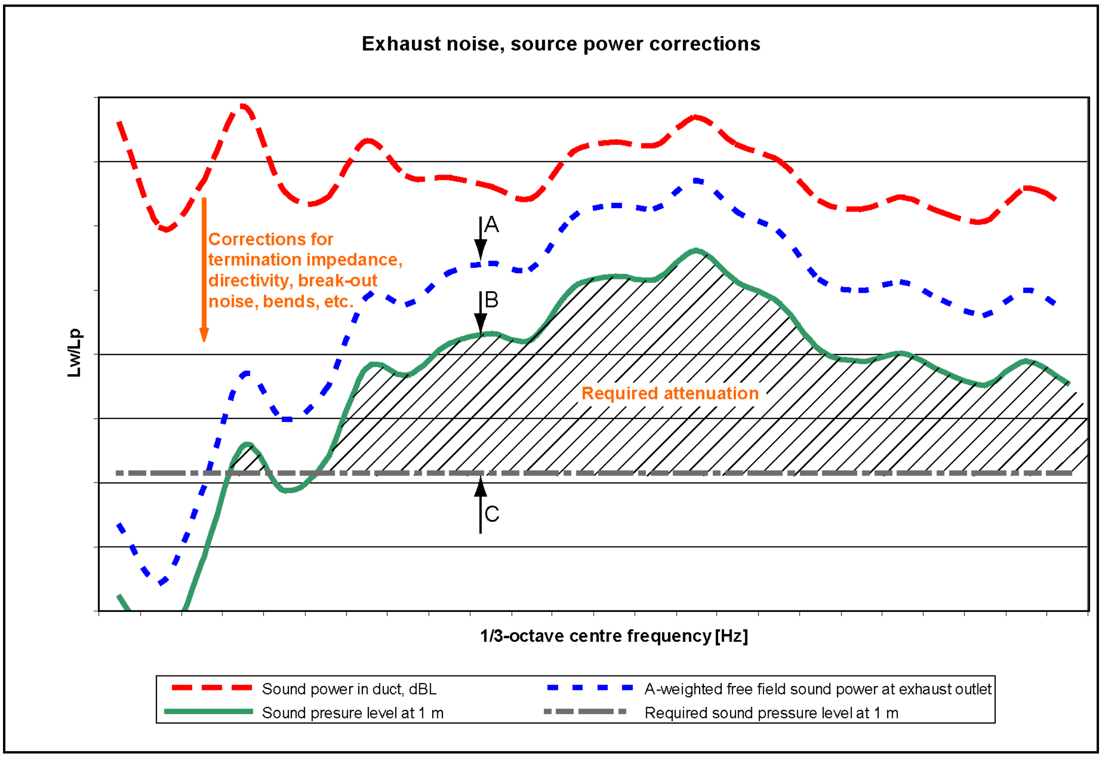


Fig 11.3.7.1.1 Exhaust noise, source power corrections

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

11.3.7.2 Silencer system comparison

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

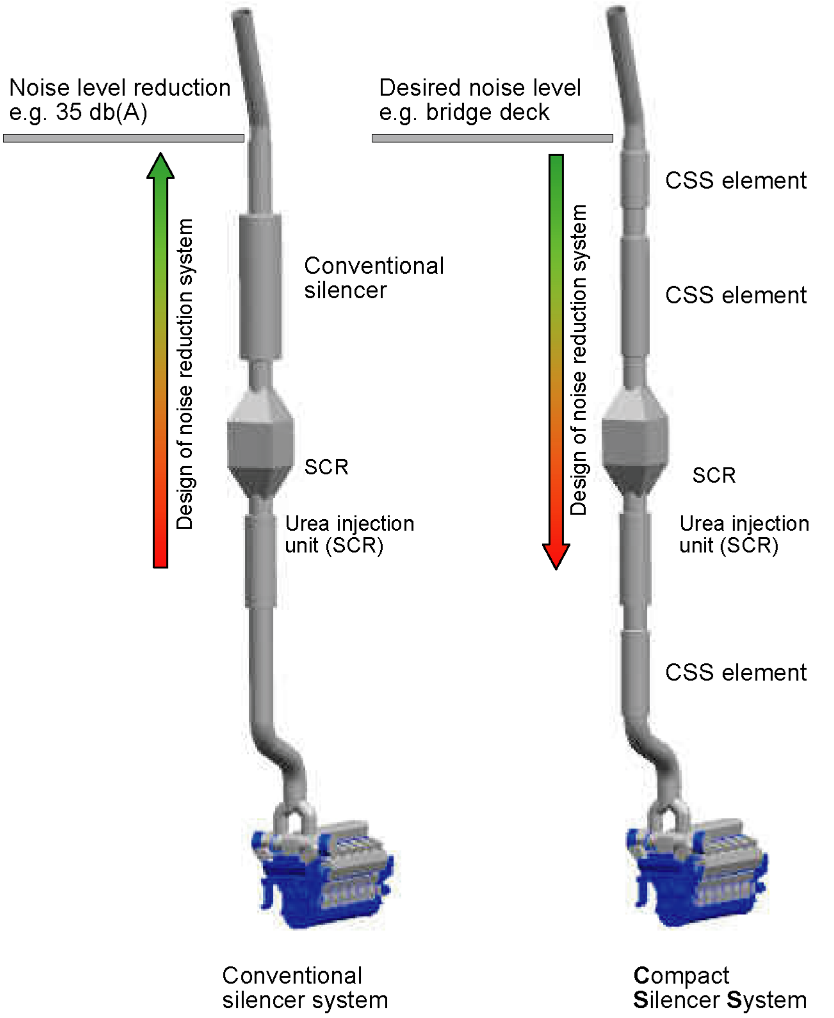


Fig 11.3.7.2.1 Silencer system comparison

11.3.7.3 Compact silencer system (5N02)

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

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

The noise attenuation is valid up to 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).

11.3.7.4 Conventional exhaust gas silencer (5R02)

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

When included in the scope of supply, the standard silencer is of the absorption type, equipped with a spark arrester. It is also provided with a soot collector and a 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.

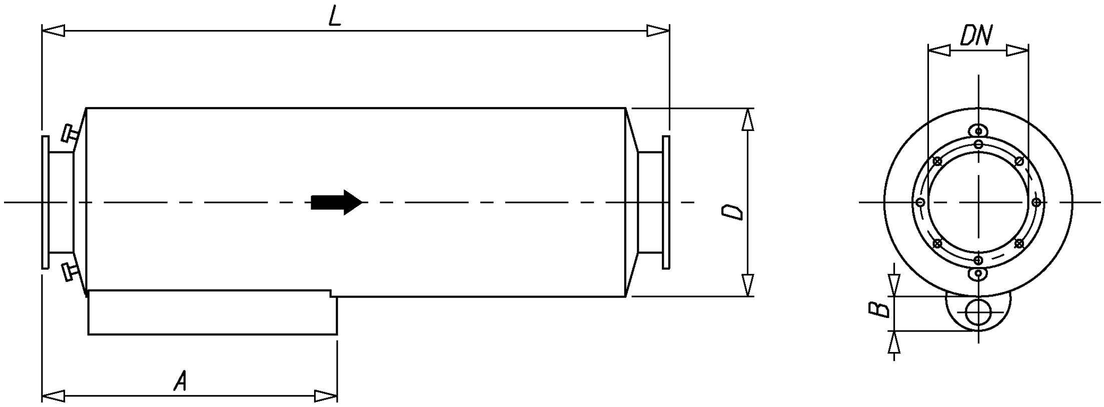


Fig 11.3.7.4.1 Exhaust gas silencer (4V49E0137b)

Table 11.3.7.4.1 Typical dimensions of exhaust gas silencers

NS	D [mm]	A [mm]	B [mm]	Attenuation: 25 dB(A)		Attenuation: 35 dB(A)	
				L [mm]	Weight [kg]	L [mm]	Weight [kg]
300	860	1250	150	2530	360	3530	455
350	950	1405	115	2780	440	3780	580
400	1060	1500	150	3280	570	4280	710
450	1200	1700	180	3430	685	4280	855
500	1200	1700	200	3430	685	4280	860
Flanges: DIN 2501							

12. Turbocharger Cleaning

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

12.1 Turbine cleaning system

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

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

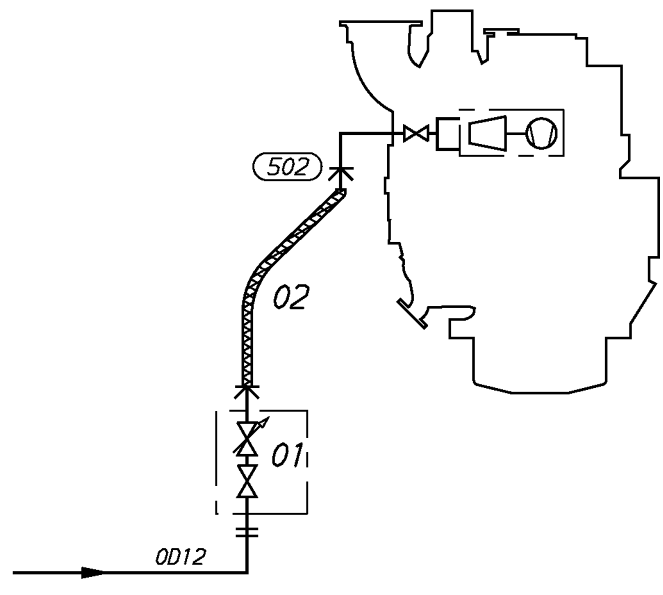


Fig 12.1.1 Turbine cleaning system (DAAE003884)

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

12.2 Compressor cleaning system

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

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13. Exhaust Emissions

Exhaust emissions from the diesel engine mainly consist of nitrogen, oxygen and combustion products like carbon dioxide (CO_2), water vapour and minor quantities of carbon monoxide (CO), sulphur oxides (SO_x), nitrogen oxides (NO_x), partially reacted and non-combusted hydrocarbons (HC) and particulate matter (PM).

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

13.1 Diesel engine exhaust components

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

CO_2 and water are the main combustion products. Secondary combustion products are carbon monoxide, hydrocarbons, nitrogen oxides, sulphur oxides, soot and particulate matters.

In a diesel engine the emission of carbon monoxide and hydrocarbons are low compared to other internal combustion engines, thanks to the high air/fuel ratio in the combustion process. The air excess allows an almost complete combustion of the HC and oxidation of the CO to CO_2, hence their quantity in the exhaust gas stream are very low.

13.1.1 Nitrogen oxides (NO_x)

The combustion process gives secondary products as Nitrogen oxides. At high temperature the nitrogen, usually inert, react with oxygen to form Nitric oxide (NO) and Nitrogen dioxide (NO_2), which are usually grouped together as NO_x emissions. Their amount is strictly related to the combustion temperature.

NO can also be formed through oxidation of the nitrogen in fuel and through chemical reactions with fuel radicals. NO in the exhaust gas flow is in a high temperature and high oxygen concentration environment, hence oxidizes rapidly to NO_2. The amount of NO_2 emissions is approximately 5 % of total NOx emissions.

13.1.2 Sulphur Oxides (SO_x)

Sulphur oxides (SO_x) are direct result of the sulphur content of the fuel oil. During the combustion process the fuel bound sulphur is rapidly oxidized to sulphur dioxide (SO_2). A small fraction of SO_2 may be further oxidized to sulphur trioxide (SO_3).

13.1.3 Particulate Matter (PM)

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

13.1.4 Smoke

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

Smoke can be black, blue, white, yellow or brown in appearance. Black smoke is mainly comprised of carbon particulates (soot). Blue smoke indicates the presence of the products of the incomplete combustion of the fuel or lubricating oil. White smoke is usually condensed water vapour. Yellow smoke is caused by NO_x emissions. When the exhaust gas is cooled significantly prior to discharge to the atmosphere, the condensed NO_2 component can have a brown appearance.

13.2 Marine exhaust emissions legislation

13.2.1 International Maritime Organization (IMO)

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

13.2.1.1 MARPOL Annex VI - Air Pollution

The MARPOL 73/78 Annex VI entered into force 19 May 2005. The Annex VI sets limits on Nitrogen Oxides, Sulphur Oxides and Volatile Organic Compounds emissions from ship exhausts and prohibits deliberate emissions of ozone depleting substances.

13.2.1.1.1 Nitrogen Oxides, NO_x Emissions

The MARPOL 73/78 Annex VI regulation 13, Nitrogen Oxides, applies to diesel engines over 130 kW installed on ships built (defined as date of keel laying or similar stage of construction) on or after January 1, 2000 and different levels (Tiers) of NOx control apply based on the ship construction date. The NO_x emissions limit is expressed as dependent on engine speed. IMO has developed a detailed NO_x Technical Code which regulates the enforcement of these rules.

13.2.1.1.1.1 EIAPP Certification

An EIAPP (Engine International Air Pollution Prevention) Certificate is issued for each engine showing that the engine complies with the NO_x regulations set by the IMO.

When testing the engine for NO_x emissions, the reference fuel is Marine Diesel Oil (distillate) and the test is performed according to ISO 8178 test cycles. Subsequently, the NO_x value has to be calculated using different weighting factors for different loads that have been corrected to ISO 8178 conditions. The used ISO 8178 test cycles are presented in the following table.

Table 13.2.1.1..1 ISO 8178 test cycles

D2: Auxiliary engine	Speed (%)	100	100	100	100	100
	Power (%)	100	75	50	25	10
	Weighting factor	0.05	0.25	0.3	0.3	0.1

E2: Diesel electric propulsion or controllable pitch propeller	Speed (%)	100	100	100	100
	Power (%)	100	75	50	25
	Weighting factor	0.2	0.5	0.15	0.15

E3: Fixed pitch propeller	Speed (%)	100	91	80	63
	Power (%)	100	75	50	25
	Weighting factor	0.2	0.5	0.15	0.15

C1: "Variable -speed and -load auxiliary engine application"	Speed	Rated				Intermediate			Idle
	Torque (%)	100	75	50	10	100	75	50	0
	Weighting factor	0.15	0.15	0.15	0.1	0.1	0.1	0.1	0.15

13.2.1.1.1.1.1 Engine family/group

As engine manufacturers have a variety of engines ranging in size and application, the NO_x Technical Code allows the organising of engines into families or groups. By definition, an engine family is a manufacturer's grouping, which through their design, are expected to have similar exhaust emissions characteristics i.e., their basic design parameters are common. When testing an engine family, the engine which is expected to develop the worst emissions is selected for testing. The engine family is represented by the parent engine, and the certification emission testing is only necessary for the parent engine. Further engines can be certified by checking document, component, setting etc., which have to show correspondence with those of the parent engine.

13.2.1.1.1.1.2 Technical file

According to the IMO regulations, a Technical File shall be made for each engine. The Technical File contains information about the components affecting NO_x emissions, and each critical component is marked with a special IMO number. The allowable setting values and parameters for running the engine are also specified in the Technical File. The EIAPP certificate is part of the IAPP (International Air Pollution Prevention) Certificate for the whole ship.

13.2.1.1.1.2 IMO NOx emission standards

The first IMO Tier 1 NOx emission standard entered into force in 2005 and applies to marine diesel engines installed in ships constructed on or after 1.1.2000 and prior to 1.1.2011.

The Marpol Annex VI and the NO_x Technical Code were later undertaken a review with the intention to further reduce emissions from ships and a final adoption for IMO Tier 2 and Tier 3 was taken by IMO/MEPC 58 in October 2008.

The IMO Tier 2 NOx standard entered into force 1.1.2011 and replaced the IMO Tier 1 NOx emission standard globally. The Tier 2 NOx standard applies for marine diesel engines installed in ships constructed on or after 1.1.2011.

The IMO Tier 3 NO_x emission standard effective date starts from year 2016. The Tier 3 standard will apply in designated emission control areas (ECA). The ECAs are to be defined by the IMO. So far, the North American ECA and the US Caribbean Sea ECA have been defined and will be effective for marine diesel engines installed in ships constructed on or after 1.1.2016. For other ECAs which might be designated in the future for Tier III NOx control, the entry into force date would apply to ships constructed on or after the date of adoption by the MEPC of such an ECA, or a later date as may be specified separately. The IMO Tier 2 NO_x emission standard will apply outside the Tier 3 designated areas.

The NO_x emissions limits in the IMO standards are expressed as dependent on engine speed. These are shown in figure 1.1.

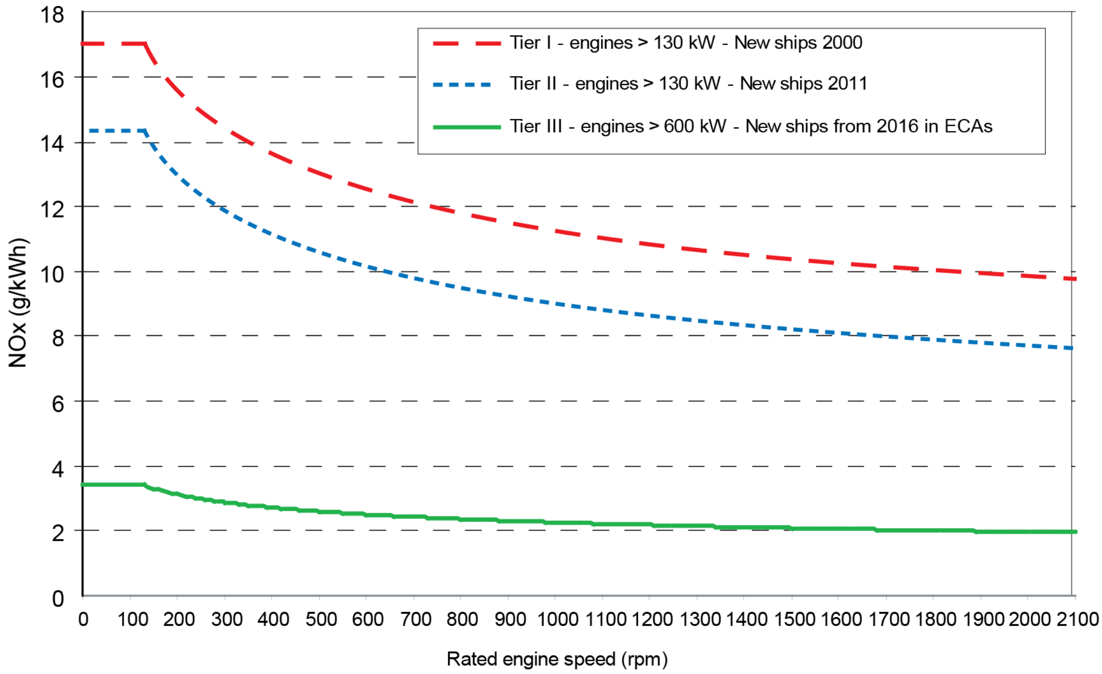

Fig 13.2.1.1..1 IMO NO_x emission limits

13.2.1.1.1.3 IMO Tier 1 NO_x emission standard

The IMO Tier 1 NOx emission standard applies to ship built from year 2000 until end 2010.

The IMO Tier 1 NO_x limit is defined as follows:

NO_x [g/kWh] = 45 x $rpm^{-0.2}$ when 130 < rpm < 2000

The NO_x level is a weigthed average of NO_x emissions at different loads, in accordance with the applicable test cycle for the specific engine operating profile.

13.2.1.1.1.4 IMO Tier 2 NO_x emission standard (new ships 2011)

The IMO Tier 2 NO_x emission standard entered into force in 1.1.2011 and applies globally for new marine diesel engines > 130 kW installed in ships which keel laying date is 1.1.2011 or later.

The IMO Tier 2 NO_x limit is defined as follows:

NO_x [g/kWh] = 44 x $rpm^{-0.23}$ when 130 < rpm < 2000

The NO_x level is a weighted average of NO_x emissions at different loads, and the test cycle is based on the engine operating profile according to ISO 8178 test cycles. IMO Tier 2 NO_x emission levels corresponds to about 20% reduction from the IMO Tier 1 NOx emission standard. This reduction is reached with engine optimization.

13.2.1.1.1.5 IMO Tier 3 NO_x emission standard (new ships, upcoming limit in ECA)

The IMO Tier 3 NO_x emission standard will enter into force from year 2016. It will by then apply for new marine diesel engines > 130 kW installed in ships which keel laying date is 1.1.2016 or later when operating inside the North American ECA and the US Caribbean Sea ECA.

The IMO Tier 3 NO_x limit is defined as follows:

NO_x [g/kWh] = 9 x $rpm^{-0.2}$ when 130 < rpm < 2000

The IMO Tier 3 NO_x emission level corresponds to an 80% reduction from the IMO Tier 1 NOx emission standard. The reduction can be reached by applying a secondary exhaust gas emission control system. A Selective Catalytic Reduction (SCR) system is an efficient way to reach the NOx reduction needed for the IMO Tier 3 standard for diesel engines.

NOTE

The Dual Fuel engines fulfil the IMO Tier 3 NOx emission level as standard in gas mode operation without the need of a secondary exhaust gas emission control system.

13.2.1.1.2 Sulphur Oxides, SO_x emissions

Marpol Annex VI has set a maximum global fuel sulphur limit of currently 3,5% (from 1.1.2012) in weight for any fuel used on board a ship. Annex VI also contains provisions allowing for special SOx Emission Control Areas (SECA) to be established with more stringent controls on sulphur emissions. In a SECA, which currently comprises the Baltic Sea, the North Sea, the English Channel, the US Caribbean Sea and the area outside North America (200 nautical miles), the sulphur content of fuel oil used onboard a ship must currently not exceed 0,1 % in weight.

The Marpol Annex VI has undertaken a review with the intention to further reduce emissions from ships. The current and upcoming limits for fuel oil sulphur contents are presented in the following table.

Table 13.2.1.1..2 Fuel sulphur caps

Fuel sulphur cap	Area	Date of implementation
Max. 1.0% S in fuel	SECA Areas	1 July 2010
Max 3.5% S in fuel	Globally	1 January 2012
Max. 0.1% S in fuel	SECA Areas	1 January 2015
Max. 0.5% S in fuel	Globally	1 January 2020

Abatement technologies including scrubbers are allowed as alternatives to low sulphur fuels. The exhaust gas system can be applied to reduce the total emissions of sulphur oxides from ships, including both auxiliary and main propulsion engines, calculated as the total weight of sulphur dioxide emissions.

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.

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

14. Automation System

Wärtsilä Unified Controls – UNIC is a modular embedded automation system. UNIC C2 has a hardwired interface for control functions and a bus communication interface for alarm and monitoring.

14.1 UNIC C2

UNIC C2 is a fully embedded and distributed engine management system, which handles all control functions on the engine; for example start sequencing, start blocking, speed control, load sharing, normal stops and safety shutdowns.

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

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

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

Alternatively modbus RTU serial line RS-485 is also available.

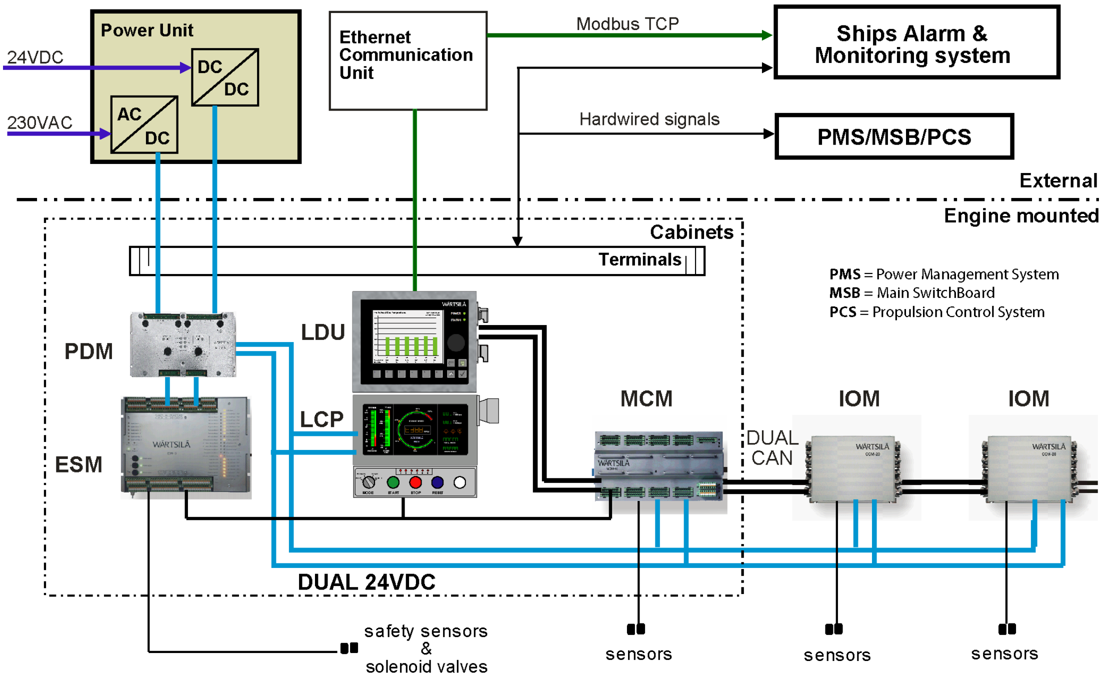

Fig 14.1.1 Architecture of UNIC C2

Short explanation of the modules used in the system:

MCM Main Control Module. Handles all strategic control functions (such as start/stop sequencing and speed/load control) of the engine.

ESM Engine Safety Module handles fundamental engine safety, for example shutdown due to overspeed or low lubricating oil pressure.

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

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

14.1.1 Local control panel and local display unit

Operational functions available at the LCP:

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

  Local mode selector switch with the following positions:
  - Local: Engine start and stop can be done only at the local control panel
  - Remote: Engine can be started and stopped only remotely
  - Blow: In this position it is possible to perform a “blow” (an engine rotation check with indicator valves open and disabled fuel injection) by the start button
  - Blocked: Normal start of the engine is not possible

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

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

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

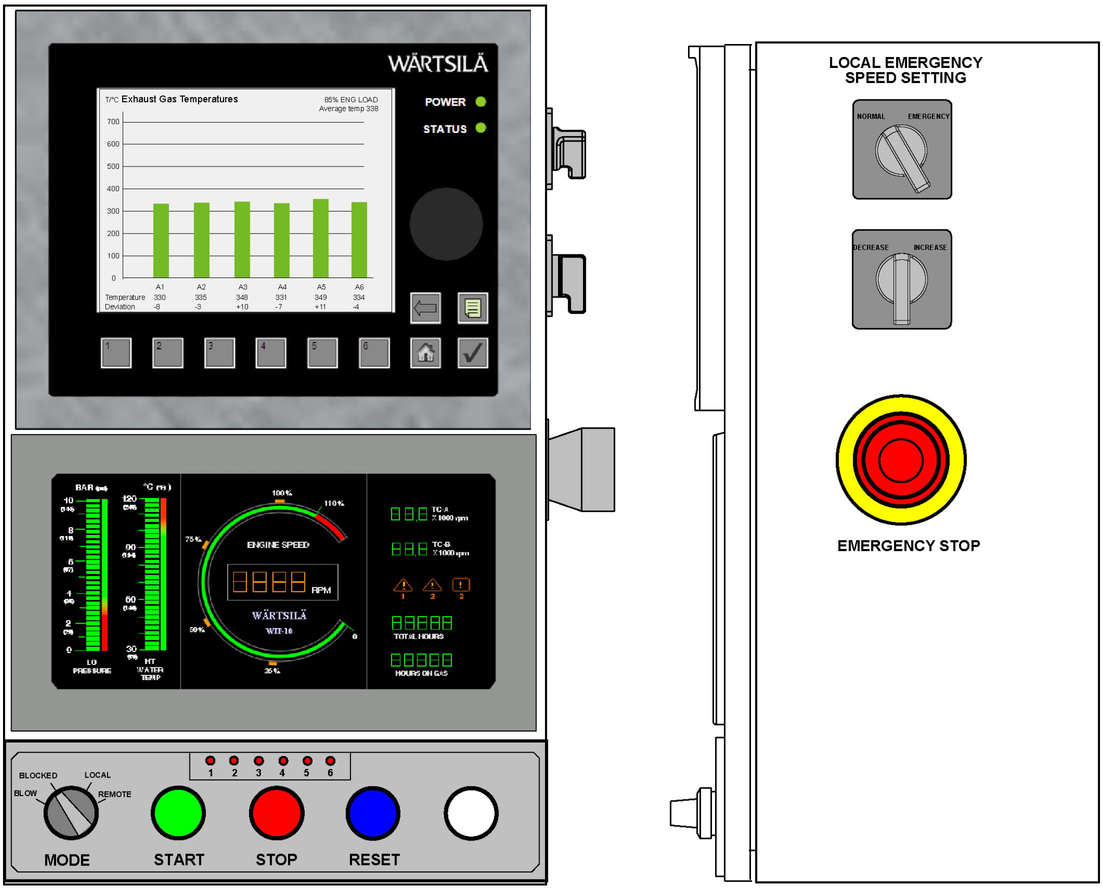

Fig 14.1.1.1 Local control panel and local display unit

14.1.2 Engine safety system

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

Main features:

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

14.1.3 Power unit

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

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

Power supply from ship's system:

- Supply 1: 230 VAC / abt. 250 W
- Supply 2: 24 VDC / abt. 250 W

14.1.4 Ethernet communication unit

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

14.1.5 Cabling and system overview

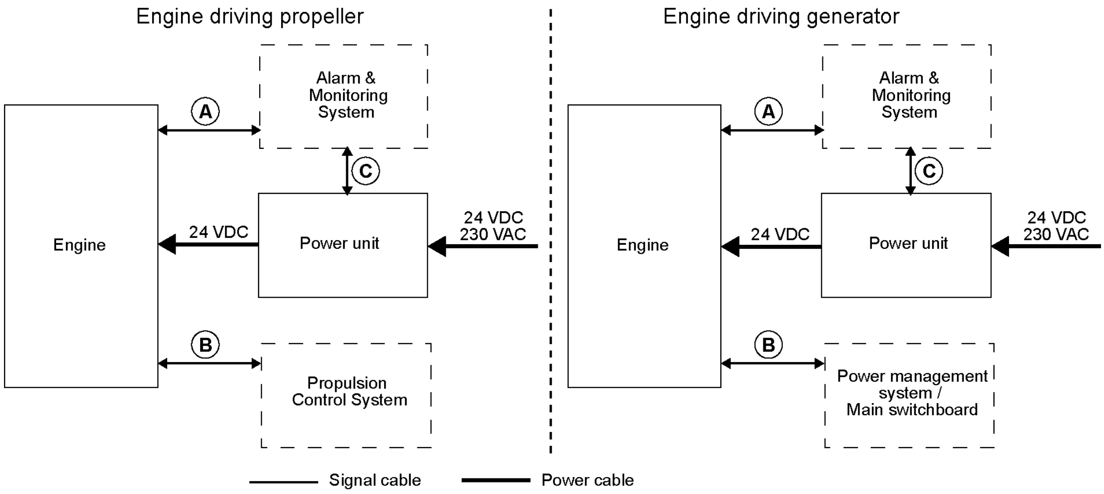

Fig 14.1.5.1 UNIC C2 overview

Table 14.1.5.1 Typical amount of cables

Cable	From <=> To	Cable types (typical)
A	Engine <=> Power Unit	2 x 2.5 mm² (power supply) * 2 x 2.5 mm² (power supply) *
B	Power unit => Communication interface unit	2 x 2.5 mm² (power supply) *
C	Engine <=> Propulsion Control System Engine <=> Power Management System / Main Switch-board	1 x 2 x 0.75 mm² 1 x 2 x 0.75 mm² 1 x 2 x 0.75 mm² 24 x 0.75 mm² 24 x 0.75 mm²
D	Power unit <=> Integrated Automation System	2 x 0.75 mm²
E	Engine <=> Integrated Automation System	3 x 2 x 0.75 mm²
F	Engine => Communication interface unit	1 x Ethernet CAT 5
G	Communication interface unit => Integrated automation system	1 x Ethernet CAT 5
H	Gas valve unit => Communication interface unit	1 x Ethernet CAT 5

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*.

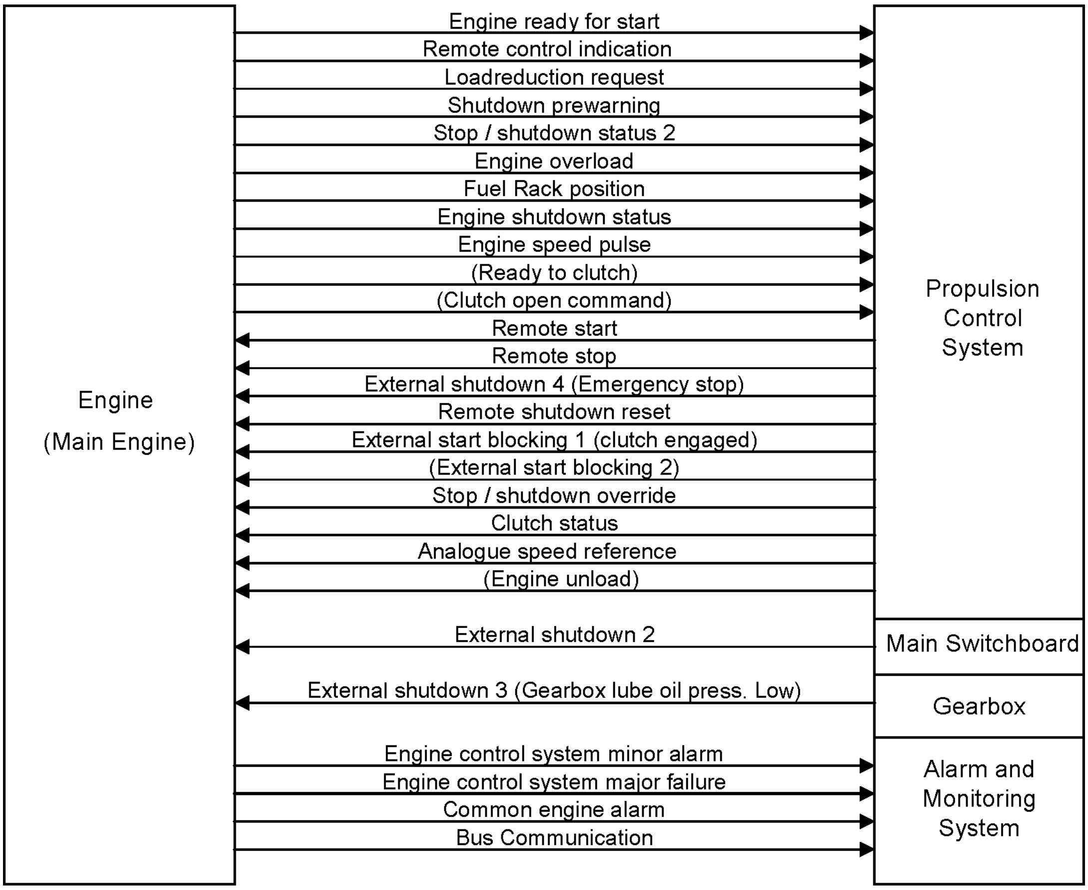

Fig 14.1.5.2 Signal overview (Main engine)

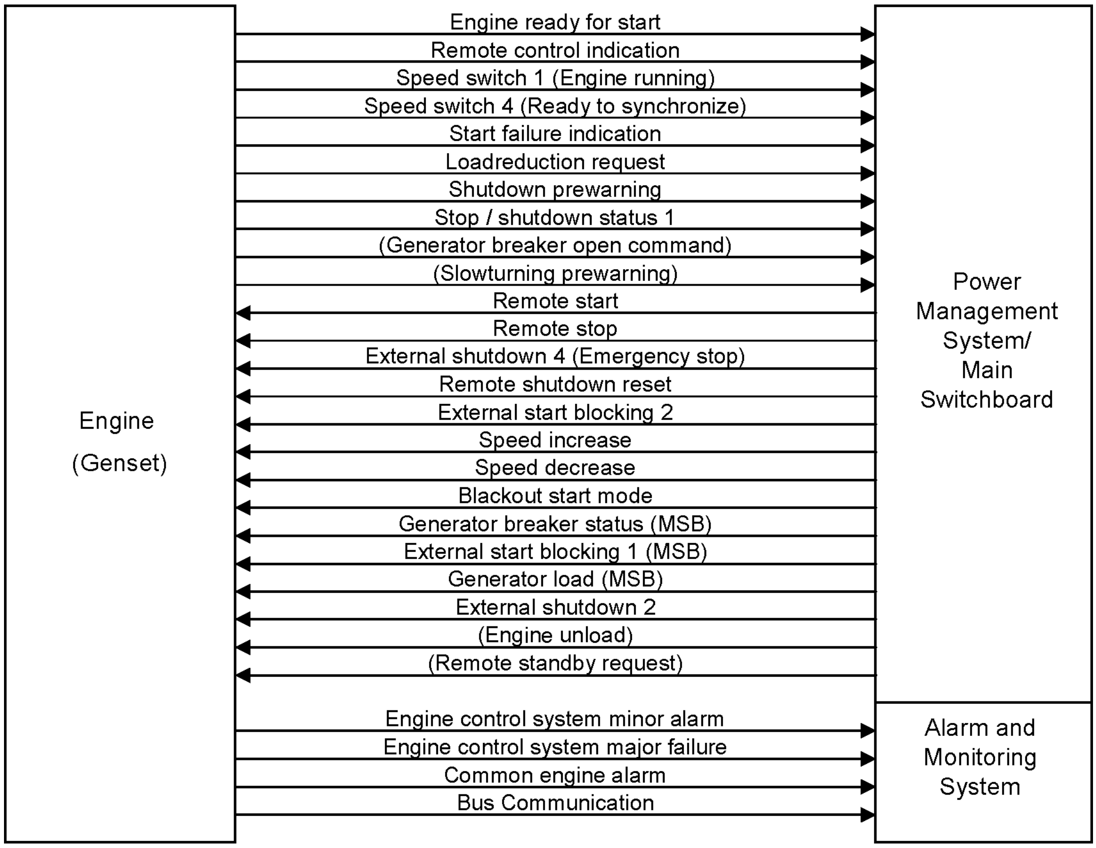

Fig 14.1.5.3 Signal overview (Generating set)

14.2 Functions

14.2.1 Start

The engine has a pneumatic starting motor controlled by a solenoid valve. The solenoid valve can be energized either locally with the start button, or from a remote control station. In an emergency situation it is also possible to operate the valve manually.

Starting is blocked both pneumatically and electrically when the turning gear is engaged. Fuel injection is blocked when the stop lever is in stop position (conventional fuel injection).

Startblockings are handled by the system on the engine (main control module).

14.2.1.1 Startblockings

Starting is inhibited by the following functions:

- Turning gear engaged
- Stop lever in stop position
- Pre-lubricating pressure low
- Local engine selector switch in blocked position
- Stop or shutdown active
- External start blocking 1 (e.g. reduction gear oil pressure)
- External start blocking 2 (e.g. clutch position)
- Engine running

For restarting of a diesel generator in a blackout situation, start blocking due to low pre-lubricating oil pressure can be suppressed for 30 min.

14.2.2 Stop and shutdown

Normal stop is initiated either locally with the stop button, or from a remote control station. The control devices on the engine are held in stop position for a preset time until the engine has come to a complete stop. Thereafter the system automatically returns to “ready for start” state, provided that no start block functions are active, i.e. there is no need for manually resetting a normal stop.

Manual emergency shutdown is activated with the local emergency stop button, or with a remote emergency stop located in the engine control room for example.

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

Typical shutdown functions are:

- Lubricating oil pressure low
- Overspeed
- Lubricating oil pressure low in reduction gear

Depending on the application it can be possible for the operator to override a shutdown. It is never possible to override a shutdown due to overspeed or an emergency stop.

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

14.2.3 Speed control

14.2.3.1 Main engines (mechanical propulsion)

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

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

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

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

14.2.3.2 Generating sets

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

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

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

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

14.3 Alarm and monitoring signals

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

14.4 Electrical consumers

14.4.1 Motor starters and operation of electrically driven pumps

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

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

14.4.1.1 Pre-lubricating oil pump

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

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

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

Table 14.4.1.1.1 Electric motor ratings for pre-lubricating pump

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

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

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

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

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

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

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

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

14.4.1.5 Circulating pump for preheater (4P04)

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

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15. Foundation

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

15.1 Steel structure design

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

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

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

15.2 Mounting of main engines

15.2.1 Rigid mounting

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

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

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

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

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

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

15.2.1.1 Resin chocks

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

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

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

15.2.1.2 Steel chocks

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

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

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

15.2.1.3 Steel chocks with adjustable height

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

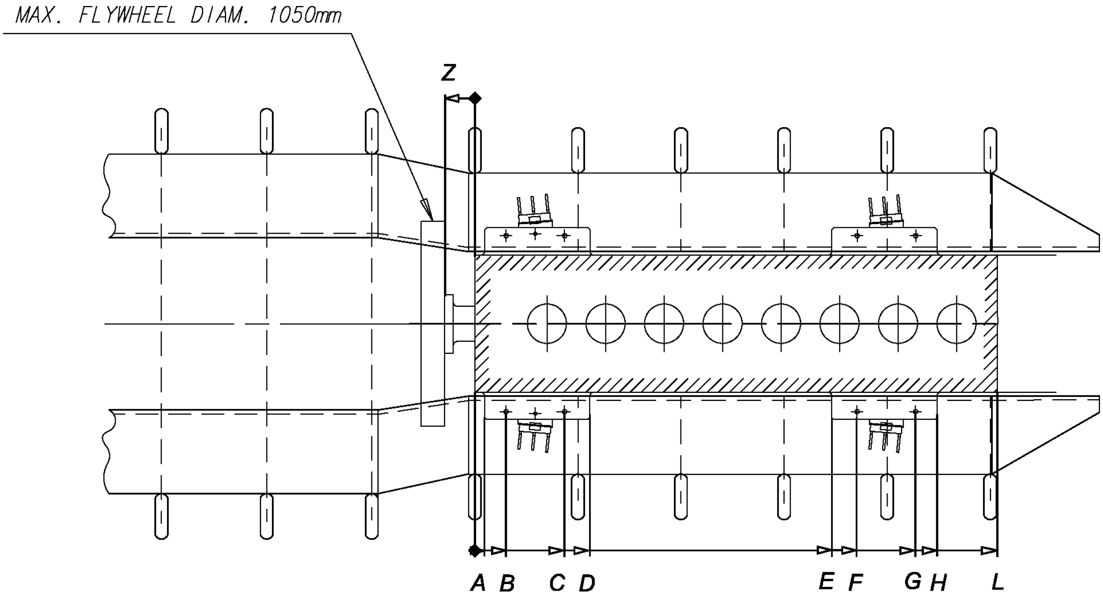

Fig 15.2.1.1 Main engine seating, view from above (DAAE017514a)

Engine	Dimensions [mm]									
	A	B	C	D	E	F	G	H	L	Z
W 4L20	50	160	460	590	930	1060	1360	1470	1480	155
W 6L20	50	160	460	590	1530	1660	1960	2070	2080	155
W 8L20	50	160	460	590	1830	1960	2260	2370	2680	155
W 9L20	50	160	460	590	2130	2260	2560	2670	2980	155

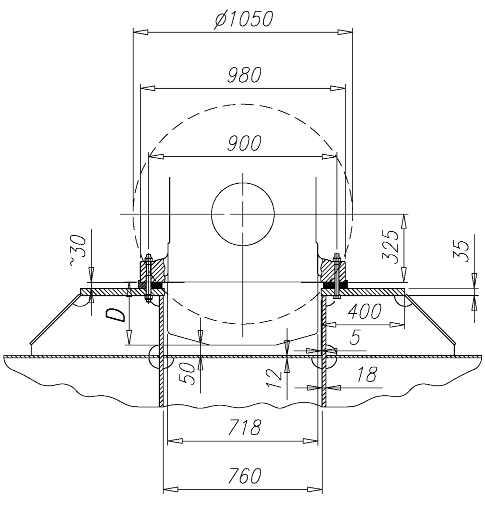

Fig 15.2.1.2 Main engine seating, end view (DAAE017514a)

Engine type	(D) Deep sump [mm]	(D) Wet sump [mm]	(D) Dry sump [mm]
4L	-	400	-
6L	500	300	300
8L	500	300	300
9L	500	300	300

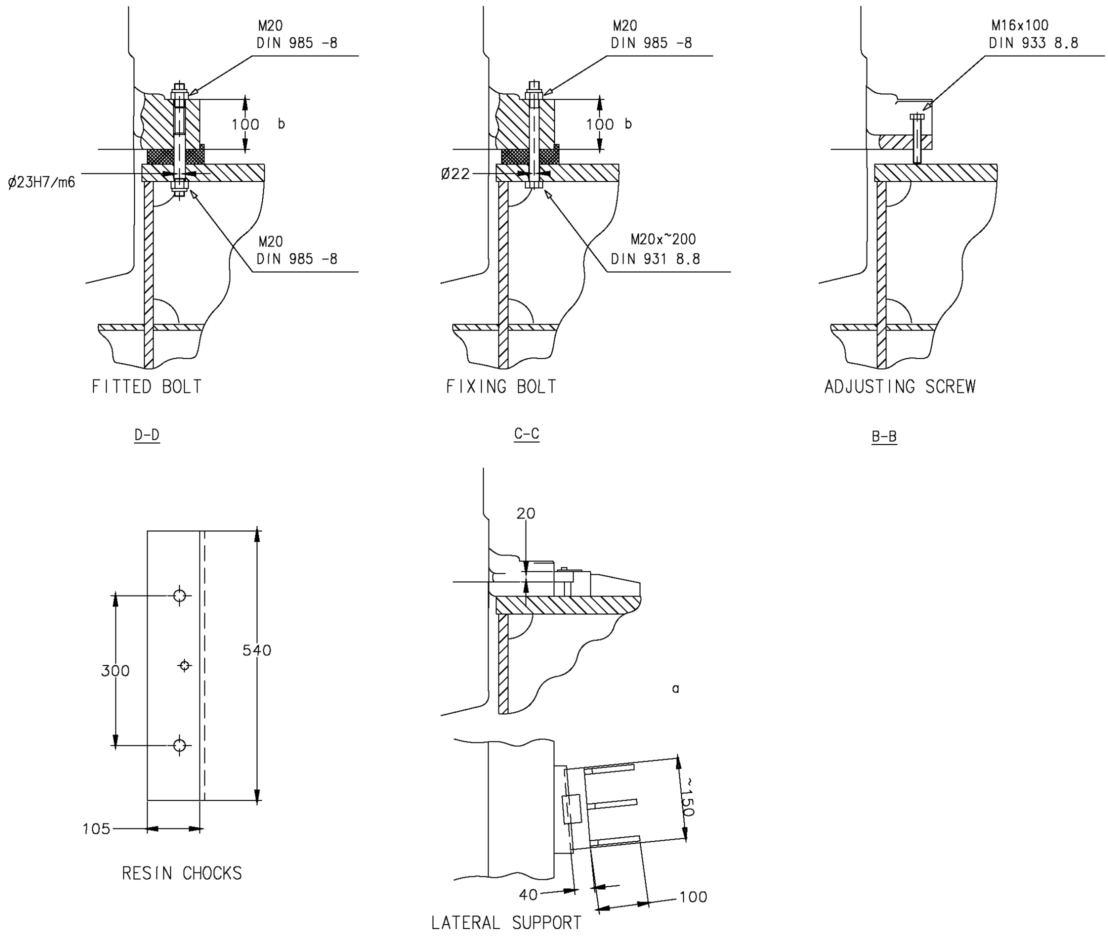

Fig 15.2.1.3 **Chocking of main engines (3V69A0238C)**

15.2.2 Resilient mounting

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

For resiliently mounted engines a speed range of 750-1000 rpm is generally available.

Conical rubber mounts are used in the normal mounting arrangement and additional buffers are thus not required. A different mounting arrangement can be required for wider speed ranges (e.g. FPP installations).

Resilient mounting is not available for W 4L20 engines.

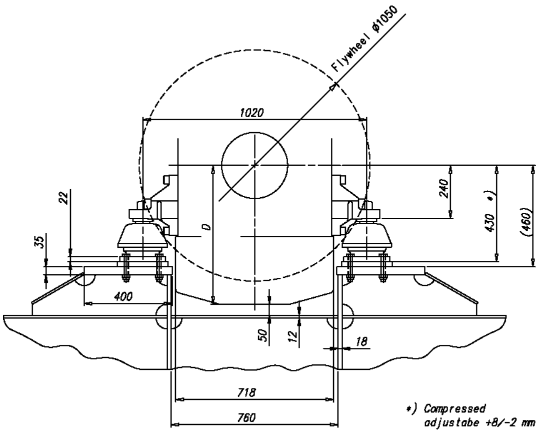

Fig 15.2.2.1 Resilient mounting (DAAE003263A)

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

15.3 Mounting of generating sets

15.3.1 Generator feet design

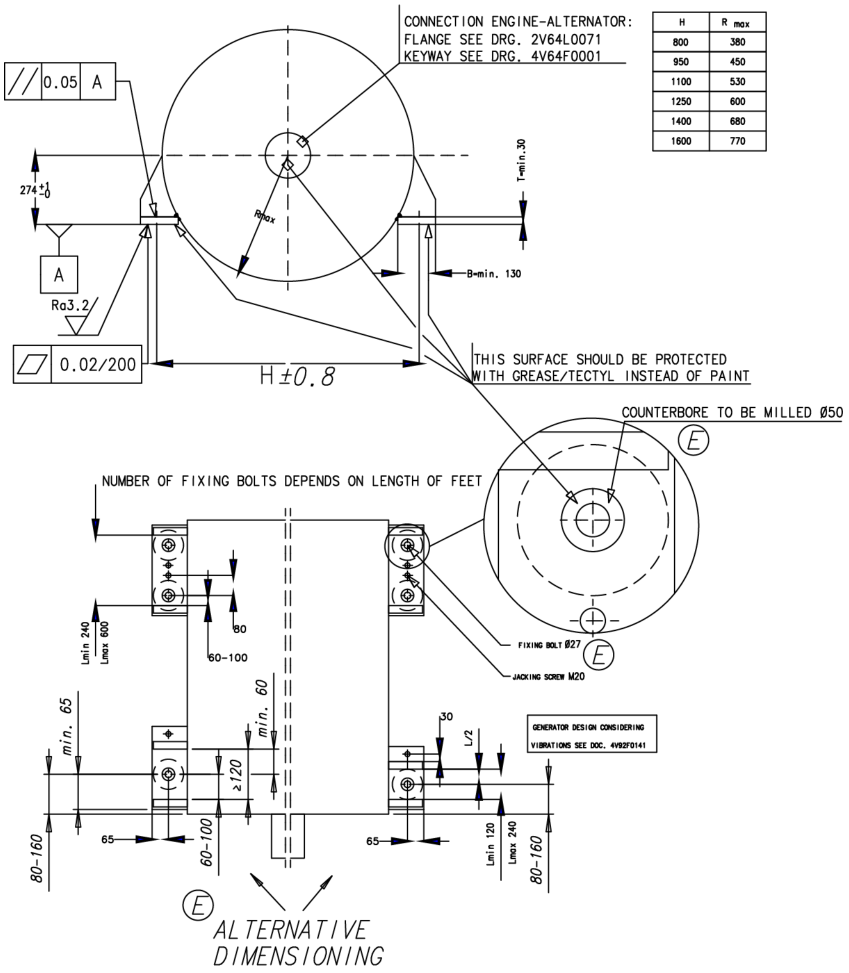

Fig 15.3.1.1 Instructions for designing the feet of the generator and the distance between its holding down bolt (4V92F0134E)

15.3.2 Resilient mounting

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

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

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

NOTE

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

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

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

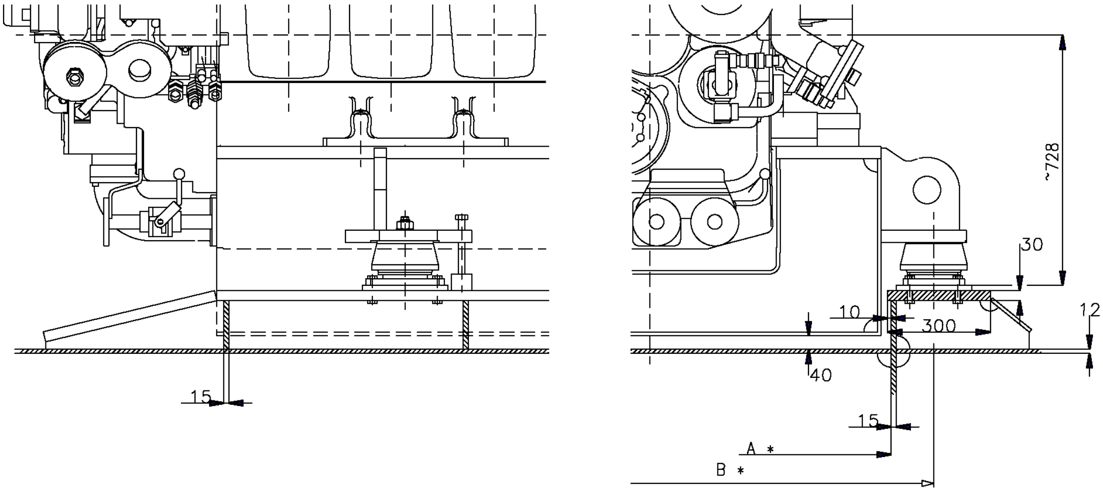

Fig 15.3.2.1 Recommended design of the generating set seating (3V46L0720G)

Engine type	A*	B*
4L	1330 / 1480	1580 / 1730
6L	1330 / 1480 / 1630	1580 / 1730 / 1880
8L	1480 / 1630	1730 / 1880
9L	1480 / 1630 / 1860	1730 / 1880 / 2110

** Dependent on generator width*

15.3.3 Rubber mounts

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

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

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

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

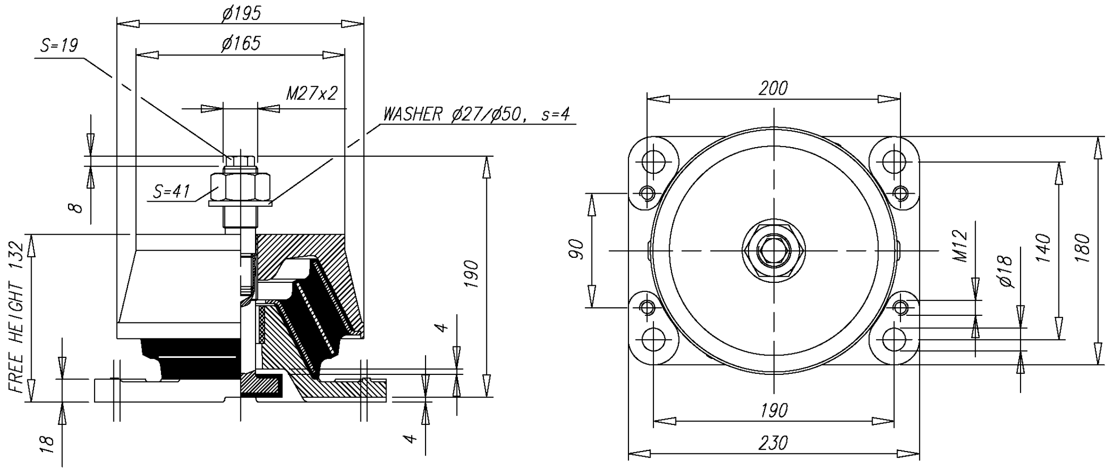

Fig 15.3.3.1 Rubber mounts (3V46L0706C)

15.4 Flexible pipe connections

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

16. Vibration and Noise

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

16.1 External forces and couples

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

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

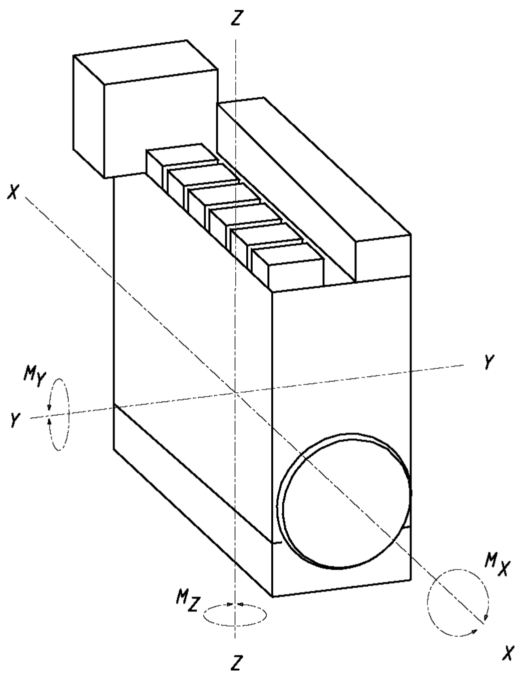

Fig 16.1.1 Coordinate system

Table 16.1.1 External forces

Engine	Speed [rpm]	Frequency [Hz]	Fz [kN]
W 4L20	900	30 60	- 1
	1000	33.3 67	- 1
W 8L20	900	60	2
	1000	66.7	3

F_Z = 0, F_Y = 0 and F_X = 0 for 6 and 9 cylinder engines

Table 16.1.2 External couples

Engine	Speed [rpm]	Frequency [Hz]	MY [kNm]	Frequency [Hz]	MZ [kNm]
W 9L20	900	15 30 60	7 4.8 0.4	15	7
	1000	16.7 33.3 66.7	8.6 5.9 0.5	16.7	8.6

M_Z = 0, M_Y = 0 for 4, 6 and 8 cylinder engines

16.2 Torque variations

Table 16.2.1 Rolling moments at 100% load

Engine	Speed [rpm]	Frequency [Hz]	M_X [kNm]	Frequency [Hz]	M_X [kNm]	Frequency [Hz]	M_X [kNm]
W 4L20	900 1000	30 33.3	9.9 6.6	60 66.7	9.8 9.6	90 100	3.5 3.5
W 6L20	900 1000	45 50	15.4 13.4	90 100	5.2 5.2	135 200	0.4 0.4
W 8L20	900 1000	60 66.7	19.6 19.3	120 133	1.5 1.5	180 200	0.5 0.5
W 9L20	900 1000	67.5 75	17.8 17.7	135 150	0.6 0.7	203 225	0.4 0.4

Table 16.2.2 Rolling moments at 0 % load

Engine	Speed [rpm]	Frequency [Hz]	M_X [kNm]	Frequency [Hz]	M_X [kNm]	Frequency [Hz]	M_X [kNm]
W 4L20	900 1000	30 33.3	10 13	60 66.7	1.4 1.3	90 100	0.9 0.9
W 6L20	900 1000	45 50	4.7 6.8	90 100	1.3 1.3	135 150	0.4 0.4
W 8L20	900 1000	60 66.7	2.8 2.6	120 133	0.7 0.7	- -	- -
W 9L20	900 1000	67.5 75	3.6 3.6	135 150	0.5 0.5	- -	- -

16.3 Mass moments of inertia

The mass-moments of inertia of the propulsion engines (including flywheel, coupling outer part and damper) are typically as follows:

Engine	J [kgm²]
W 4L20	90...120
W 6L20	90...150
W 8L20	110...160
W 9L20	100...170

16.4 Structure borne noise

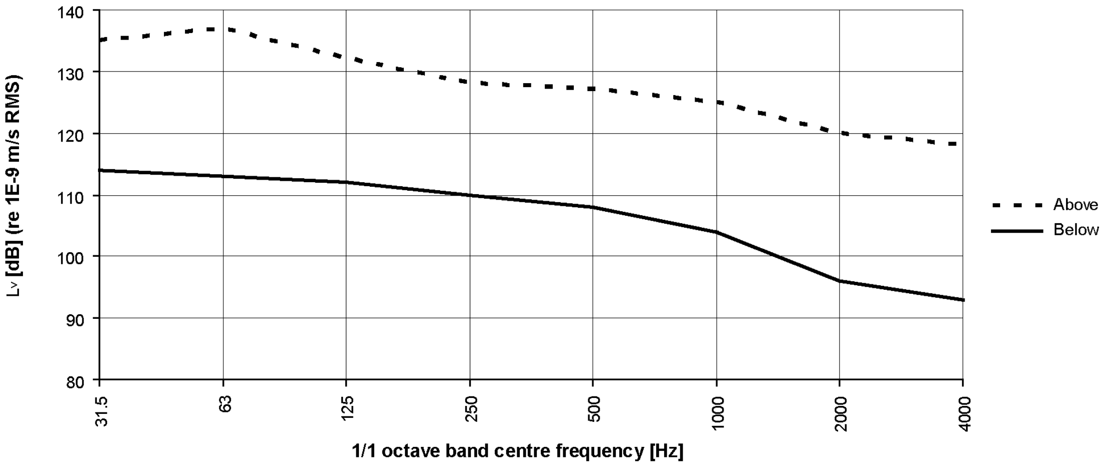

Fig 16.4.1 Main engines, typical structure borne noise levels above and below resilient mounts (DAAB814306)

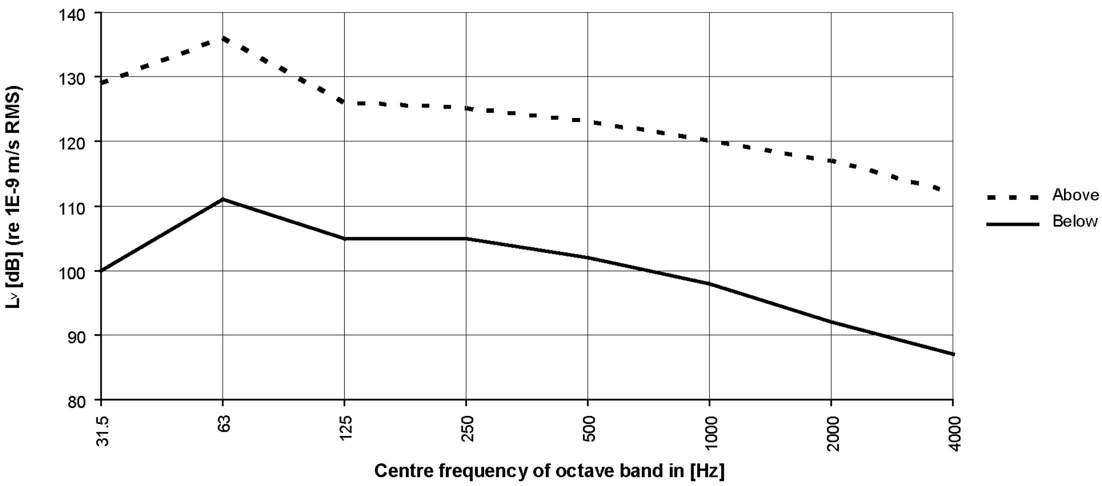

Fig 16.4.2 Generating sets, typical structure borne noise levels above and below resilient mounts (DBAB120103)

16.5 Air borne noise

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

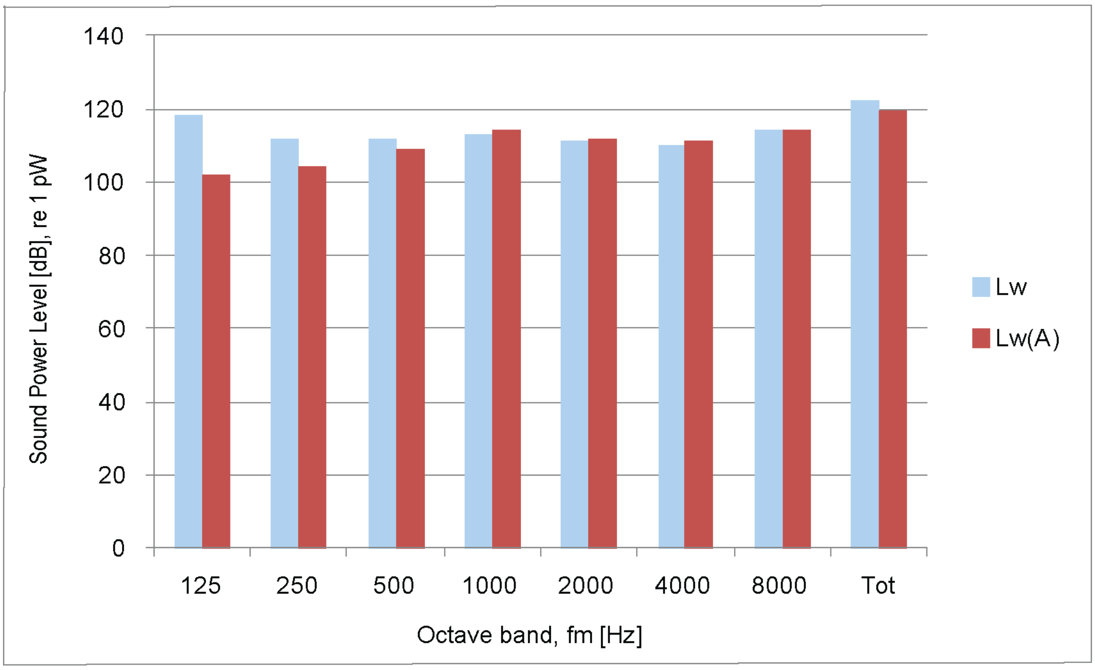

Fig 16.5.1 Sound power level for air borne noise

16.6 Exhaust noise

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

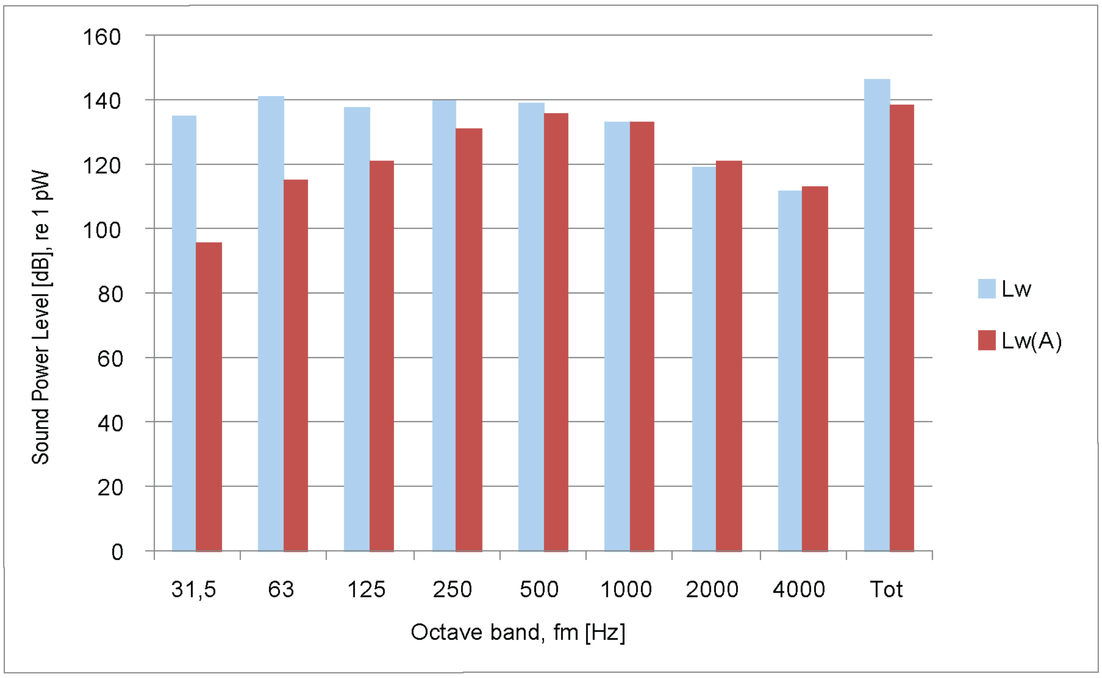

Fig 16.6.1 Sound power level for exhaust noise

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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.

17.1.1 Connection to generator

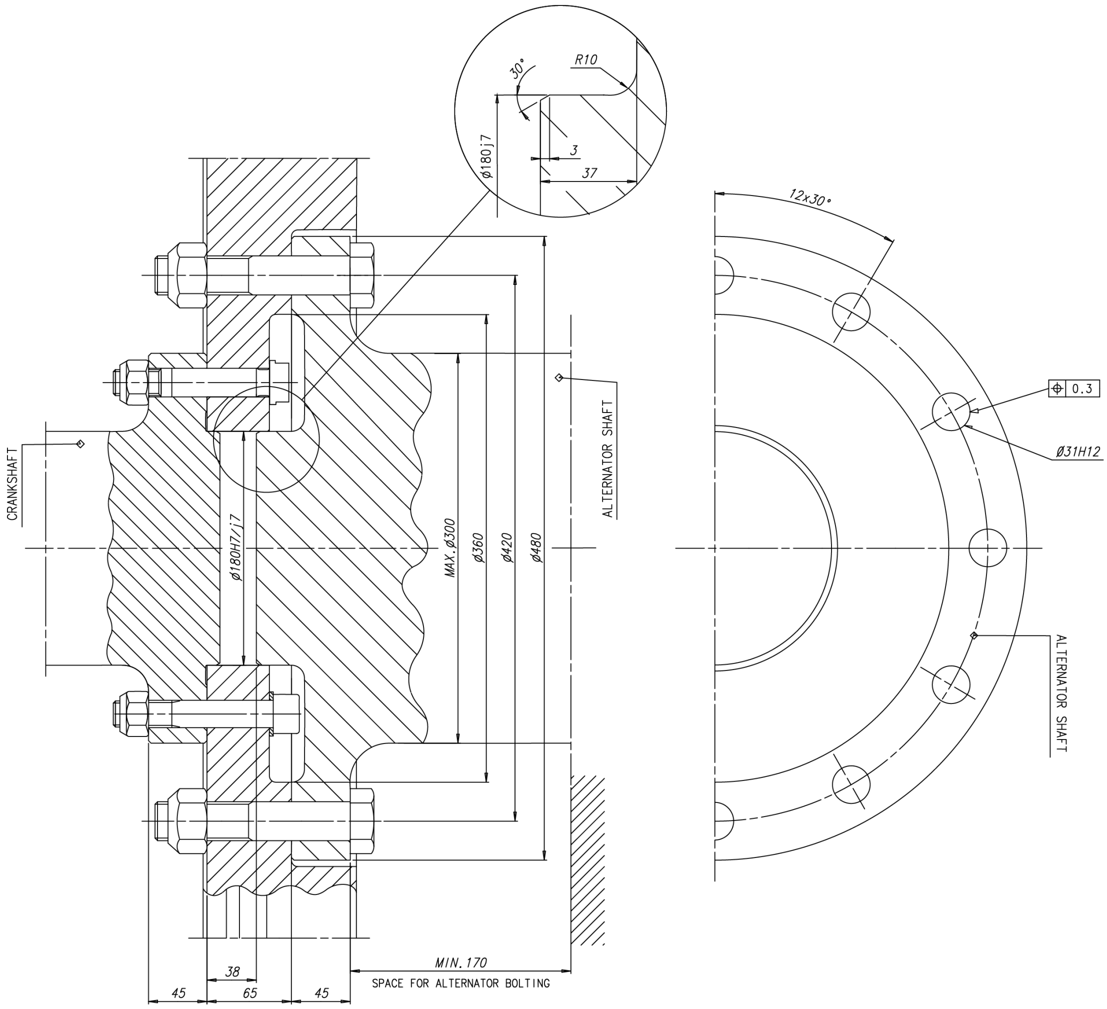

Fig 17.1.1.1 Connection engine/single bearing generator (2V64L0071B)

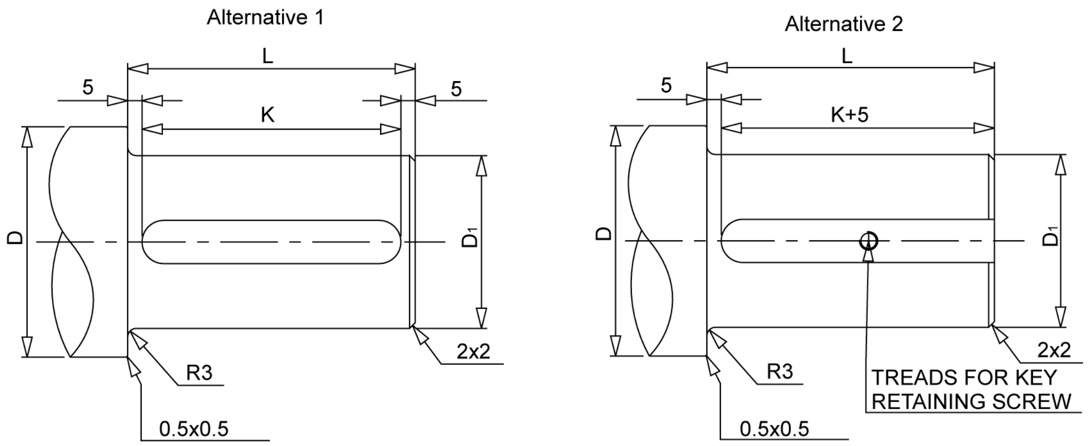

Fig 17.1.1.2 Connection engine/two-bearing generator (4V64F0001B)

Engine	Dimensions [mm]			
	D_1	L	K	min D
W 4L20	120	150	140	130
W 6L20	150	190	180	160
W 8L20	150	190	180	160
W 9L20	150	190	180	160

17.2 Clutch

In many installations the propeller shaft can be separated from the diesel engine using a clutch. The use of multiple plate hydraulically actuated clutches built into the reduction gear is recommended.

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

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

17.3 Shaft locking device

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

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

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

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

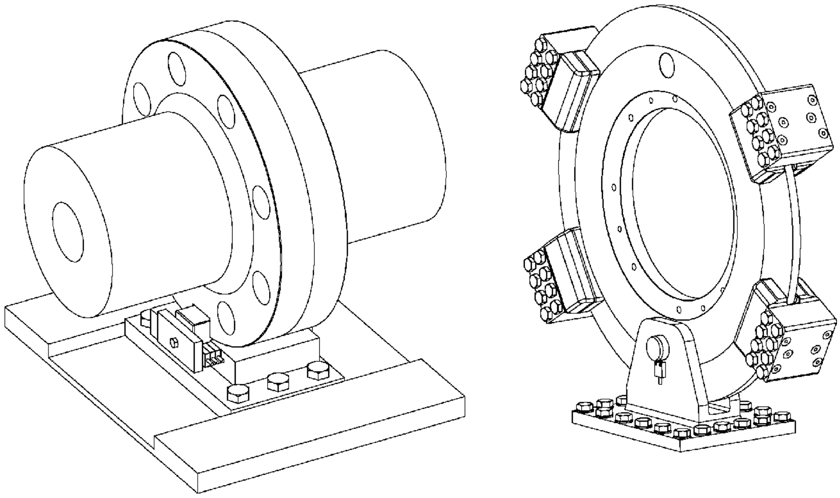

Fig 17.3.1 Shaft locking device and brake disc with calipers

17.4 Power-take-off from the free end

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

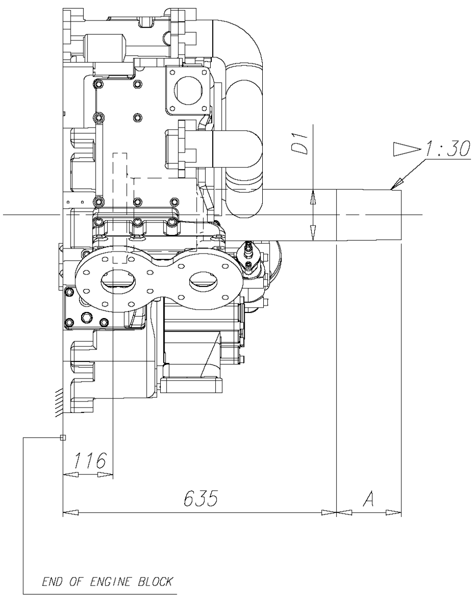

Fig 17.4.1 PTO alternative 1 (DAAE079074A)

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

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

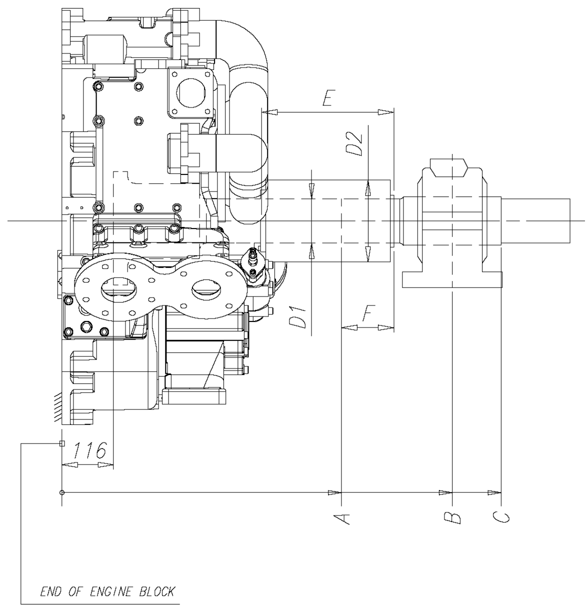

Fig 17.4.2 PTO alternative 2 (DAAE079045)

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

External support bearing is not possible for resiliently mounted engines.

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

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

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18. Engine Room Layout

18.1 Crankshaft distances

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

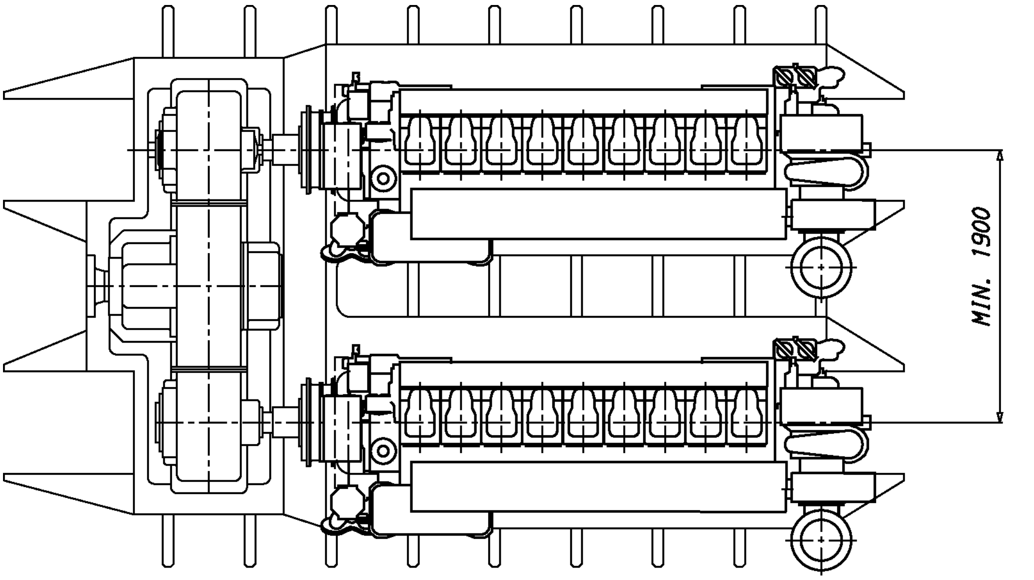
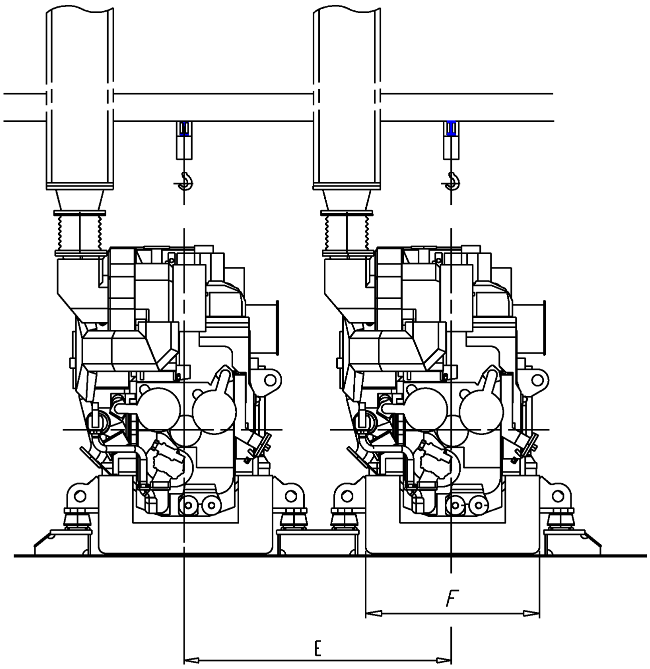


Fig 18.1.1 Minimum crankshaft distances, main engine (DAAE006291A)



Engine	E [mm]	F [mm]
W 4L20	1970 2020	1270 1420
W 6L20	1970 2020	1270 1420
W 8L20	2020	1420
W 9L20	2020 2170	1420 1570

Fig 18.1.2 Minimum crankshaft distances, generating sets (DAAE007434C)

E = Min. distance between engines dependent on common base frame

F = Width of the common base frame dependent on width of the generator

18.2 Space requirements for maintenance

18.2.1 Working space reservation

The required working space around the engine is mainly determined by the dismounting dimensions of some engine components, as well as 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 any engine part dismounting, a minimum of 1000 mm free space everywhere around the engine is recommended to be reserved for maintenance operations.

18.2.2 Lifting equipment

It is essential for efficient and safe working conditions that the lifting equipment are applicable for the job and they are correctly dimensioned and located.

The required engine room height depends on space reservation of the lifting equipment and also on the lifting and transportation arrangement. The minimum engine room height can be achieved if there is enough transversal and longitudinal space, so that there is no need to transport parts over insulation box or rocker covers.

Separate lifting arrangement for overhauling turbocharger is required (unless overhead travelling crane, which also covers the turbocharger is used). Turbocharger lifting arrangement is usually best handled with a chain block on a rail located above the turbocharger axis.

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.

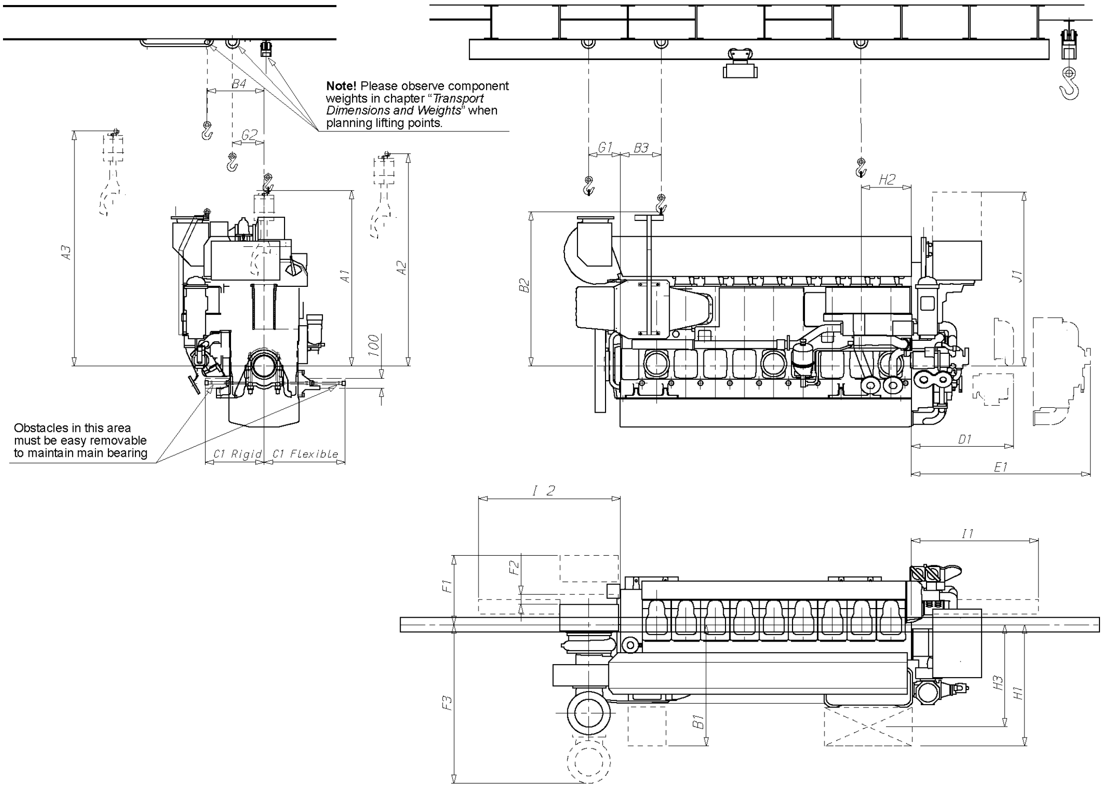


Fig 18.4.1 Service space for engines with turbocharger in driving end (1V69C0301C)

Service spaces in mm		6L	8L	9L
A1	Height for overhauling piston and connecting rod	1800		
A2	Height for transporting piston and connecting rod freely over adjacent cylinder head covers	2300		
A3	Height for transporting piston and connecting rod freely over exhaust gas insulation box	2300	2400	2400
B1	Width for dismantling charge air cooler and air inlet box sideways by using lifting tool	1200		
B2	Height of the lifting eye for the charge air cooler lifting tool	1580		
B3	Recommended lifting point for charge air cooler lifting tool	390		
B4	Recommended lifting point for charge air cooler lifting tool	590		
C1	Removal of main bearing side screw, flexible / rigid mounting	800 / 560		
D1	Distance needed for dismantling lubricating oil and water pumps	635		
E1	Distance needed for dismantling pump cover with fitted pumps	With PTO: lenght + 515 Without PTO: 650		
F1	The recommended axial clearance for dismantling and assembly of silencers. Minimum axial clearance: 100 mm (F2)	650	710	710
F3	Recommended distance for dismantling the gas outlet elbow	990	1170	1170
G1	Recommended lifting point for the turbocharger	300		
G2	Recommended lifting point sideways for the turbocharger	345		
H1	Width for dismantling lubricating oil module and/or plate cooler	1250		
H2	Recommended lifting point for dismantling lubricating oil module and/or plate cooler	445		
H3	Recommended lifting point sideways for dismantling lubricating oil module and/or plate cooler	1045		
I1	Camshaft overhaul distance (free end)	1000	1300	1300
I2	Camshaft overhaul distance (flywheel end)	1000	1300	1300
J1	Space necessary for access to the connection box	1783		

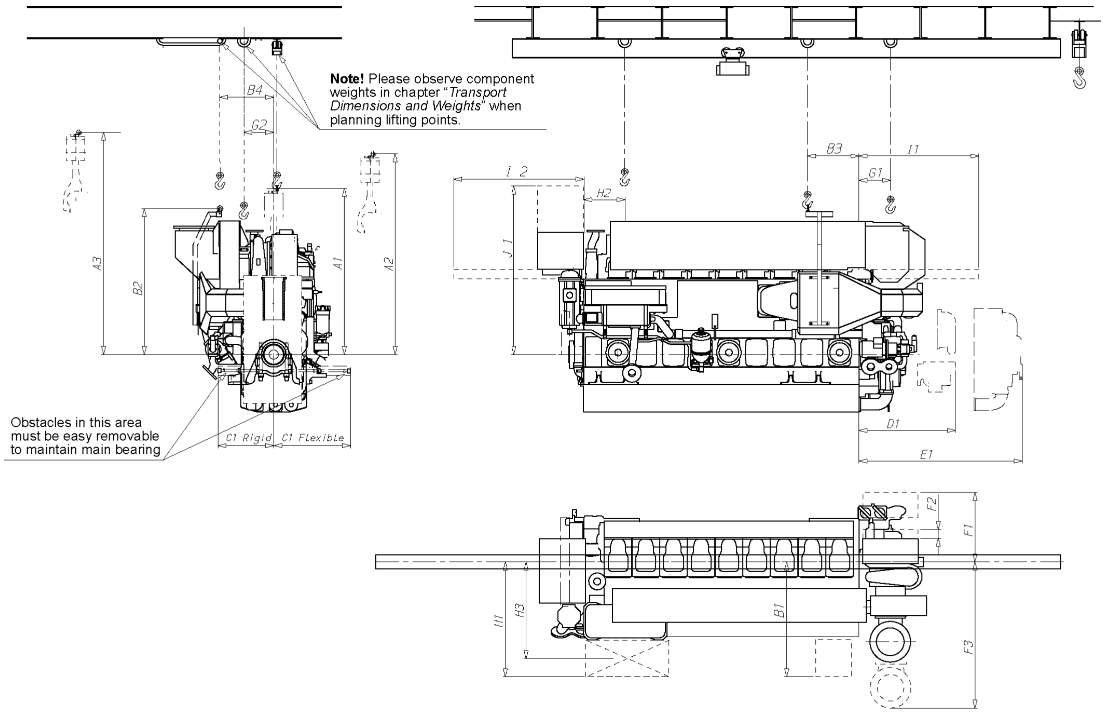


Fig 18.4.2 Service space for engines with turbocharger in free end (1V69C0302C)

Service spaces in mm		4L	6L	8L	9L
A1	Height for overhauling piston and connecting rod	1800			
A2	Height for transporting piston and connecting rod freely over adjacent cylinder head covers	2300			
A3	Height for transporting piston and connecting rod freely over exhaust gas insulation box	2230	2300	2400	2400
B1	Width for dismantling charge air cooler and air inlet box sideways by using lifting tool	1200			
B2	Height of the lifting eye for the charge air cooler lifting tool	1580			
B3	Recommended lifting point for charge air cooler lifting tool	260	550	550	550
B4	Recommended lifting point for charge air cooler lifting tool	560			
C1	Removal of main bearing side screw, flexible / rigid mounting	800 / 560			
D1	Distance for dismantling lubricating oil and water pump	635			
E1	Distance for dismantling pump cover with fitted pumps	With PTO: lenght + 515 Without PTO: 650			
F1	The recommended axial clearance for dismantling and assembly of silencers. Minimum axial clearance: 100 mm (F2)	590	650	750	750
F3	Recommended distance for dismantling the gas outlet elbow	890	990	1120	1120
G1	Recommended lifting point for the turbocharger	350			
G2	Recommended lifting point sideways for the turbocharger	320			
H1	Width for dismantling lubricating oil module and/or plate cooler	1250			
H2	Recommended lifting point for dismantling lubricating oil module and/or plate cooler	445			
H3	Recommended lifting point sideways for dismantling lubricating oil module and/or plate cooler	1045			
I1	Camshaft overhaul distance (free end)	700	1000	1300	1300
I2	Camshaft overhaul distance (flywheel end)	700	1000	1300	1300
J1	Space necessery for access to the connection box	1825			

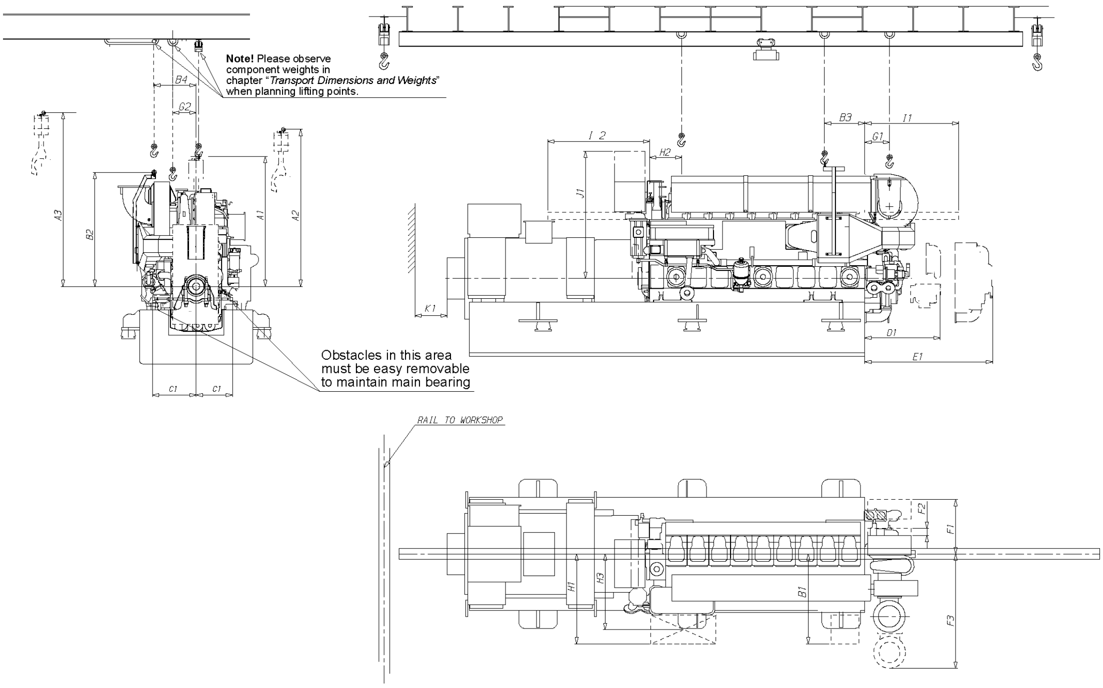


Fig 18.4.3 Service space for W20 generating sets (DAAE006367A)

Service spaces in mm		4L	6L	8L	9L
A1	Height for overhauling piston and connecting rod	1800			
A2	Height for transporting piston and connecting rod freely over adjacent cylinder head covers	2300			
A3	Height for transporting piston and connecting rod freely over exhaust gas insulation box	2230	2300	2400	2400
B1	Width for dismantling charge air cooler and air inlet box sideways by using lifting tool	1200			
B2	Height of the lifting eye for the charge air cooler lifting tool	1580			
B3	Recommended lifting point for charge air cooler lifting tool	260	550	550	550
B4	Recommended lifting point for charge air cooler lifting tool	560			
C1	Width for removing main bearing side screw	560			
D1	Distance needed to dismantle lube oil and water pump	635			
E1	Distance needed to dismantle pump cover with fitted pumps	650			
F1	The recommended axial clearance for dismantling and assembly of silencers Minimum axial clearance: 100 mm (F2)	590	650	750	750
F3	Recommended distance for dismantling the gas outlet elbow	890	990	1120	1120
G1	Recommended lifting point for the turbocharger	350			
G2	Recommended lifting point sideways for the turbocharger	320			
H1	Width for dismantling lube oil module	1250 (and/or plate cooler)			
H2	Recommended lifting point for dismantling lube oil module	445 (and/or plate cooler)			
H3	Recommended lifting point sideways for dismantling lube oil module	1045 (and/or plate cooler)			
I1	Camshaft overhaul distance (free end)	700	1000	1300	1300
I2	Camshaft overhaul distance (flywheel end)	700	1000	1300	1300
J1	Space necessary for access to the connection box	1825			
K1	Service space for generator	500			

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19. Transport Dimensions and Weights

19.1 Lifting of engines

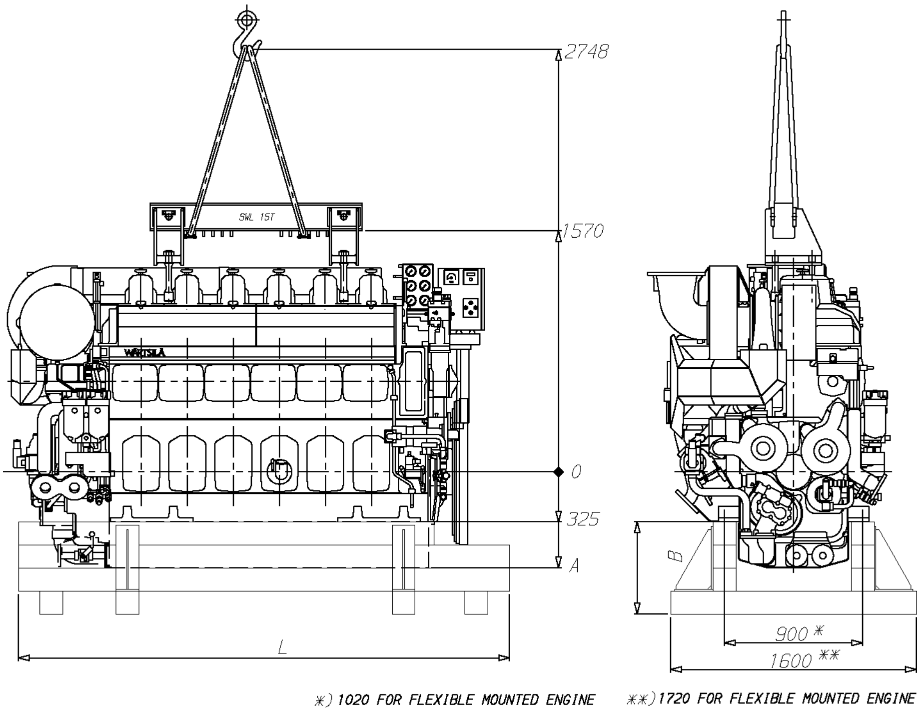


Fig 19.1.1 Lifting of main engines (3V83D0285c)

Engine	L [mm]	Dry sump		Wet sump	
		A [mm]	B [mm]	A [mm]	B [mm]
W 4L20	2600	725	600	725	600
W 6L20	3200	624	600	824	675
W 8L20	3500	624	600	824	675
W 9L20	4100	624	600	824	675

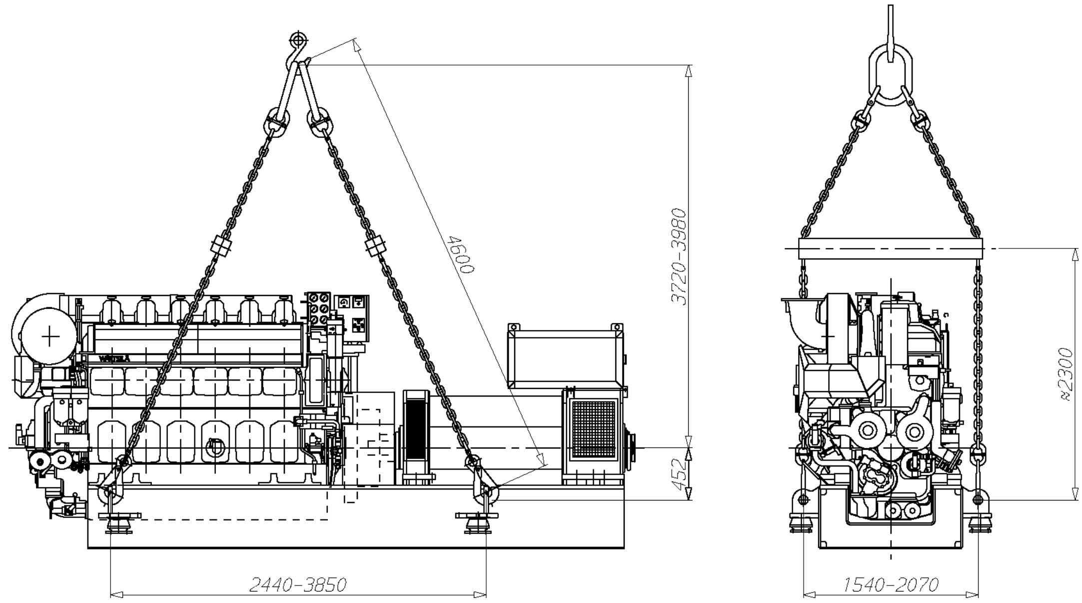
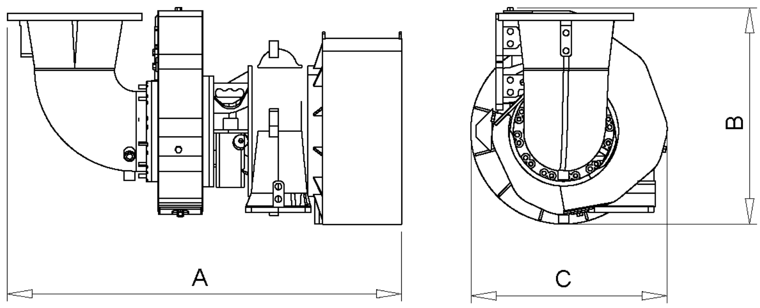
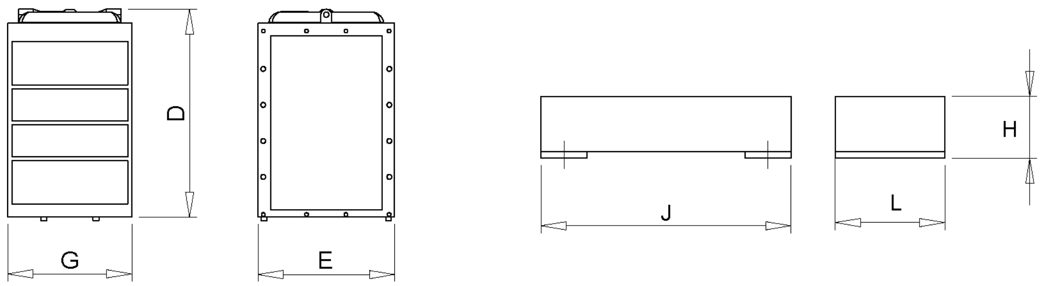


Fig 19.1.2 Lifting of generating sets (3V83D0300c)

19.2 Engine components

19.2.1 Turbocharger and cooler inserts

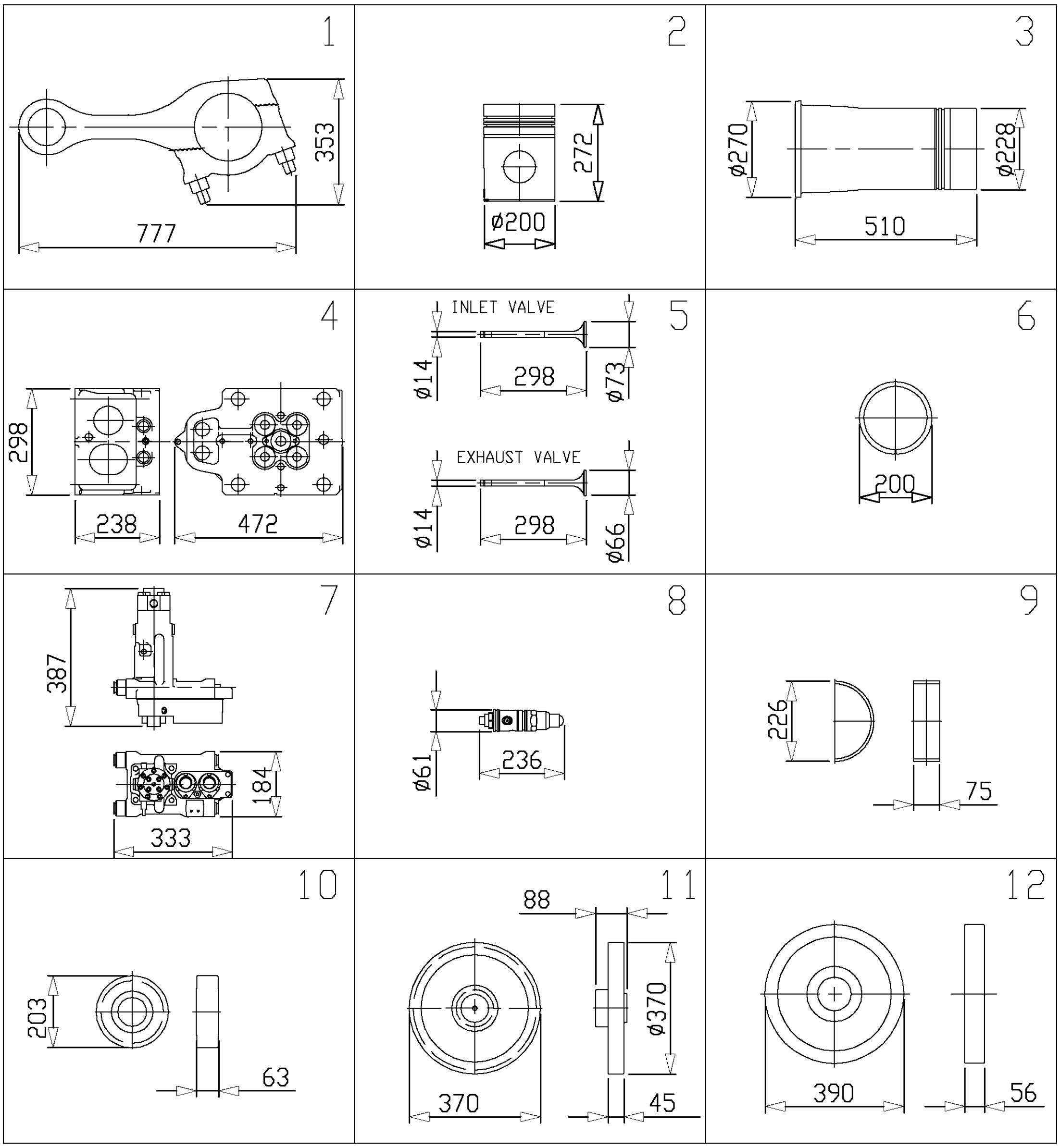




Engine	Turbocharger				Charge air cooler			
	A [mm]	B [mm]	C [mm]	Weight [kg]	D [mm]	E [mm]	G [mm]	Weight [kg]
W 4L20	945	576	480	150	616	285	340	120
W 6L20	1097	636	568	215	626	345	380	160
W 8L20	1339	760	675	340	626	345	380	160
W 9L20	1339	773	667	340	626	345	380	160

Engine	Lubricating oil cooler insert			
	H [mm]	J [mm]	L [mm]	Weight [kg]
W 4L20	150	896	396	80
W 6L20	196	896	396	100
W 8L20	247	896	396	125
W 9L20	275	896	396	140

19.2.2 Major spare parts



Item	Weight/kg	Item	Weight/kg
1 Connecting rod	39	7 Injection pump	27
2 Piston	21	8 Injection valve	3, 2
3 Cylinder liner	41	9 Main bearing shell	1, 4
4 Cylinder head	94	10 Smaller intermediate gear	11, 4
5 Valve	0, 8	11 Bigger intermediate gear	23, 5
6 Piston ring	0, 2	12 Camshaft drive gear	25

Fig 19.2.2.1 Major spare parts (4V92L1283b)

20. Product Guide Attachments

This and other product guides can be accessed on the internet, from the Business Online Portal at www.wartsila.com. Product guides are available both in web and PDF format. Drawings are available in PDF and DXF format, and in near future also as 3D models. Consult your sales contact at Wärtsilä to get more information about the product guides on the Business Online Portal.

The attachments are not available in the printed version of the 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 21.1.1.1 The most common prefix multipliers

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

21.2 Collection of drawing symbols used in drawings

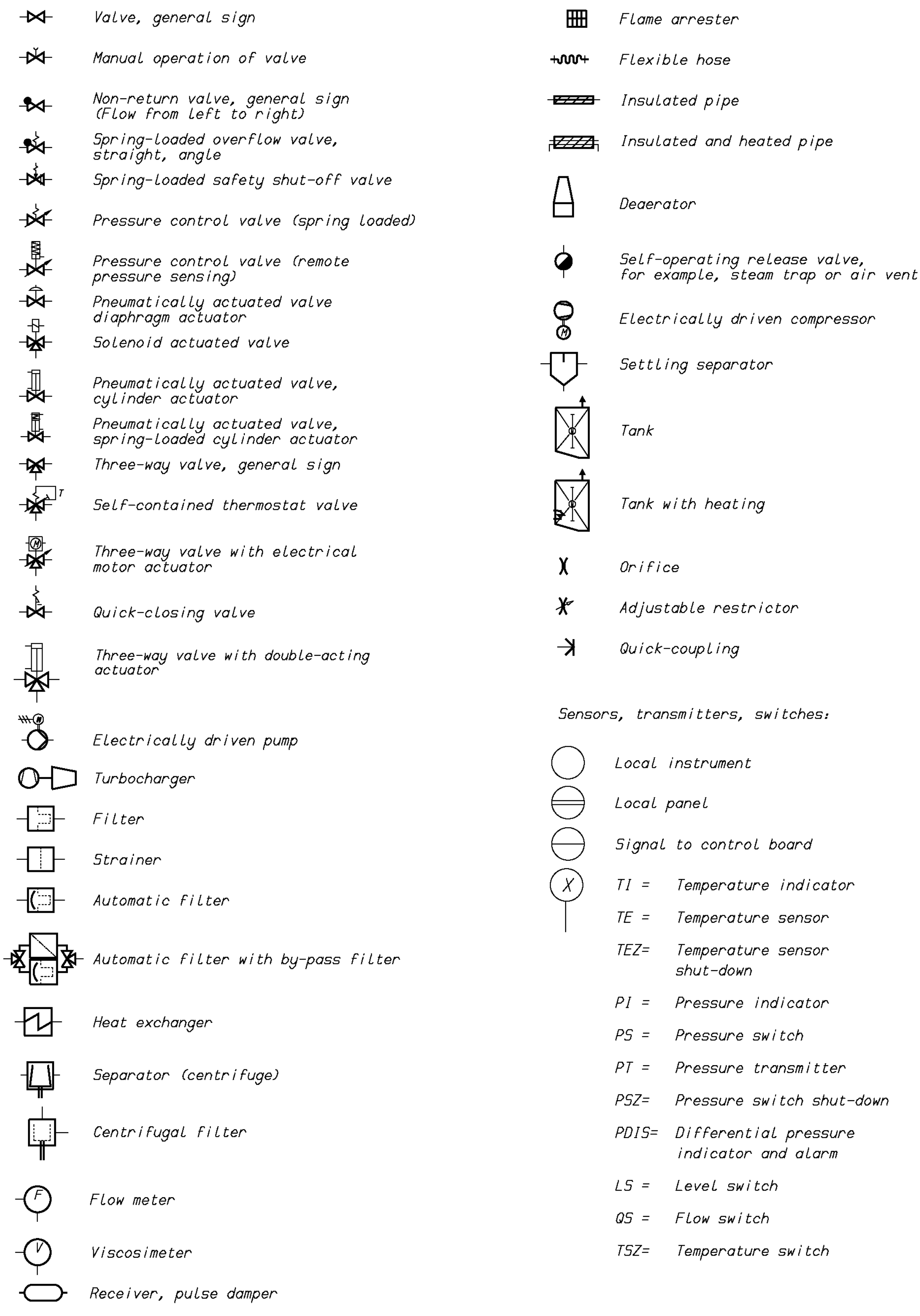

Fig 21.2.1 List of symbols (DAAE000806c)

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