WÄRTSILÄ Engines

WÄRTSILÄ 38 PROJECT GUIDE

Introduction

This Project 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 2/2008 issue replaces all previous issues of the Wärtsilä 38 Project Guides.

Issue	Published	Updates
2/2008	11.11.2008	Compact Silencer System added and other minor updates
1/2008	02.07.2008	General PG update
1/2007	31.10.2007	General PG update

Wärtsilä Ship Power

Technology, Product Support

Trieste, November 2008

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1. General data and outputs

1.1 Technical main data

The Wärtsilä 38 is a 4-stroke, turbocharged and intercooled diesel engine with direct injection of fuel.

Cylinder bore	380 [mm]
Stroke	475 [mm]
Piston diplacement	53.9 [l/cyl]
Number of valves	2 inlet valves and 2 exhaust valves
Cylinder configuration	6, 8, 9, in-line 12, 16 in V-form
V-angle	50°
Direction of rotation	Clockwise or counter-clockwise
Max. Cylinder pressure	21 [MPa] (210 bar)
Speed	600 [rpm]
Mean effective pressure	2.69 [MPa] (26.9 bar)
Mean piston speed	9.5 [m/s]

1.2 Maximum continuous output

Nominal speed is 600 rpm for propulsion engines. The mean effective pressure can be calculated as follows:

$$p_e = \frac{P \times c \times 24 \times 10^7}{D^2 \times n \times S \times \pi}$$

where:

p_e = Mean effective pressure [MPa]

P = Output per cylinder [kW]

c = Operating cycle (2)

D = Cylinder bore [mm]

S = Stroke [mm]

n = Engine speed [rpm]

Table 1.1 Maximum continuous output

Engine type	Diesel Electric [kW]	CPP [kW]	FPP [kW]
6L	4350	4350	4050
8L	5800	5800	5400
9L	6525	6525	6075
12V	8700	8700	8100
16V	11600	11600	10800

1.3 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.

1.4 Principal engine dimensions and weights

Figure 1.1 In-line engines (DAAE042634a)

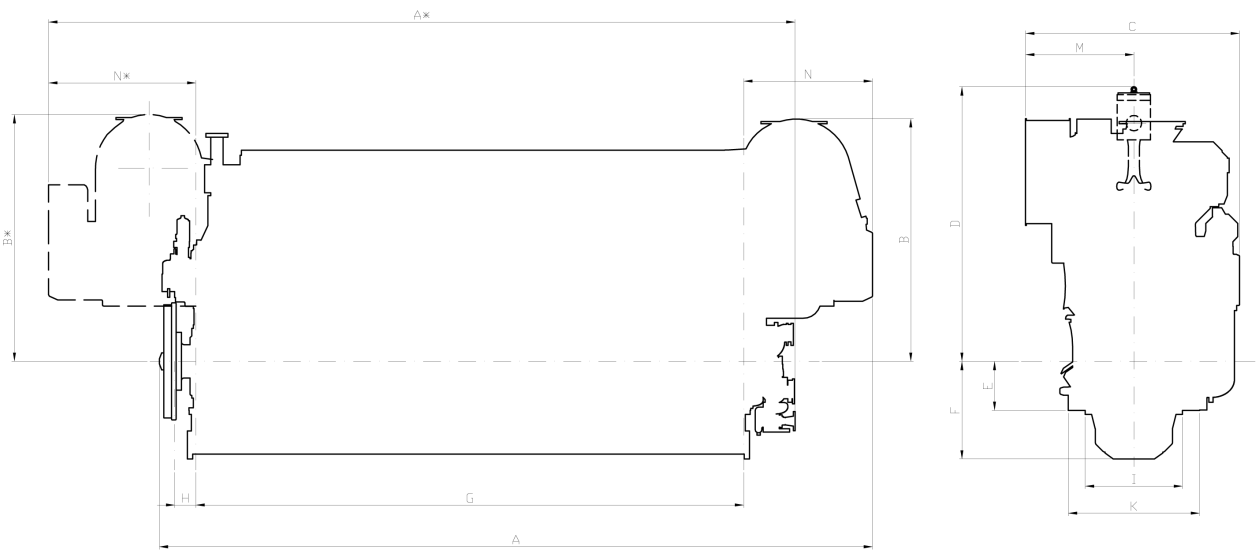
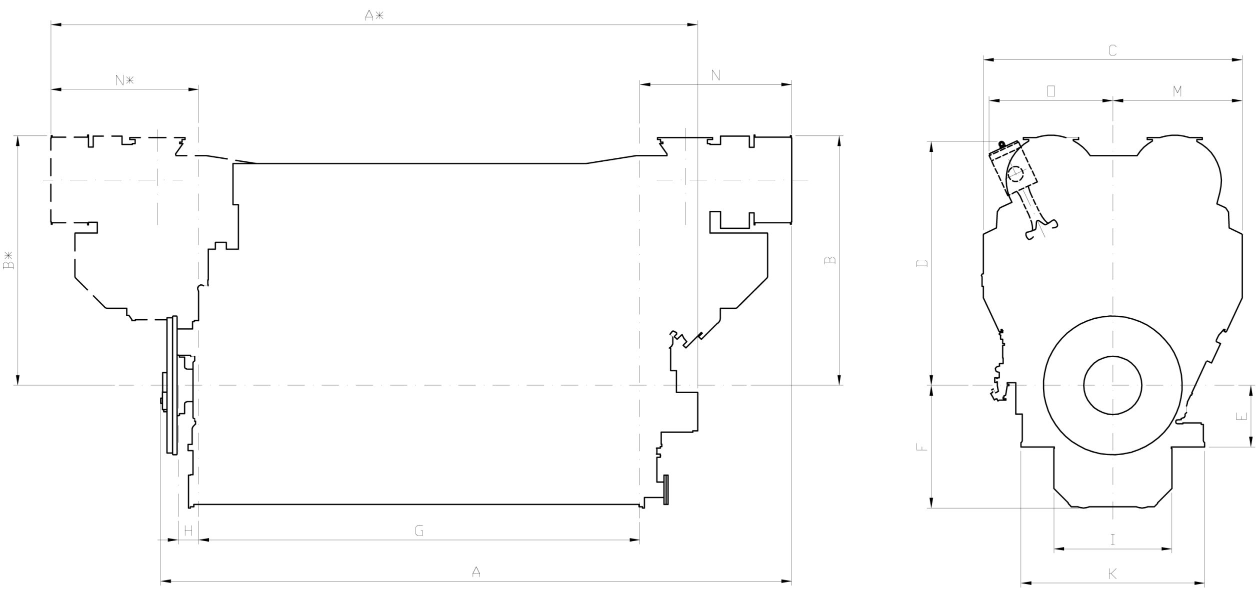


Figure 1.2 V-engines (DAAE042635)



A Total length of the engine
B Height from the crankshaft centerline to the highest point
C Total width of the engine
D** Minimum height when removing a piston
E Height from the crankshaft centerline to the engine feet
F Dimension from the crankshaft centerline to the bottom of the oil sump
G Length of the engine block
H Dimension from the end of the engine block to the end of the crankshaft
I Width of the oil sump
K Width of the engine block at the engine feet
M Distance from the center of the crankshaft to the outermost end of the engine
N Length from the engine block to the outermost point of the turbocharger
O Minimum width when removing a piston (V engines only)

Table 1.2 In-line engines dimensions

Engine	A* [mm]	A [mm]	B* [mm]	B [mm]	C [mm]	D** [mm]	E [mm]	F [mm]
6L	6345	6220	2830	2830	2190 (2210*)	3135	560	1115
8L	7925 (7875")	7545 (7495")	2820 (2735")	2770 (2690")	2445 (2185")	3135	560	1115
9L	8525	8145	2820	2770	2445	3135	560	1115

Engine	G [mm]	H [mm]	I [mm]	K [mm]	M [mm]	N* [mm]	N [mm]	Weight1) [tons]
6L	4455	240	1110	1500	1205	1295	1345	51
8L	5655	240	1110	1500	1240 (980")	1680 (1635")	1470 (1420")	63 (62")
9L	6255	240	1110	1500	1240	1680	1470	72

Table 1.3 V-engines dimensions

Engine	A* [mm]	A [mm]	B=B* [mm]	C [mm]	D** [mm]	E [mm]	F [mm]	G [mm]
12V	7615	7385	2930	3030	2855	720	1435	5165
16V	9130	8945	3105	3030	2855	720	1435	6565

Engine	H [mm]	I [mm]	K [mm]	M [mm]	N* [mm]	N [mm]	O** [mm]	Weight1) [tons]
12V	240	1382	2150	1515	1775	1775	1490	88
16V	240	1382	2150	1515	1890	1935	1490	110

** Dimension valid when turbocharger is located at flywheel end*

*** Dismantling dimension*

" Dimension valid for 8L, FPP application only

1) Tolerance 5 %, the masses are wet weights of rigidly mounted engines with flywheel and built-on pumps and without additional; e.g. hoisting tools, packing, torsional elastic coupling etc.

Table 1.4 Additional mass

Item	6L	8L	9L	12V	16V
Flexible mounting (without limiters) [tons]	4	5.5	6	4	4.5

1.5 Principal generating set dimensions

The engine can also be delivered as complete generating set. An engine and generator mounted together on a common base frame, which can be flexible mounted. For indicative main dimensions see figure 1.3 and tables 1.5 and 1.6.

Figure 1.3 Generating set (DAAE042636)

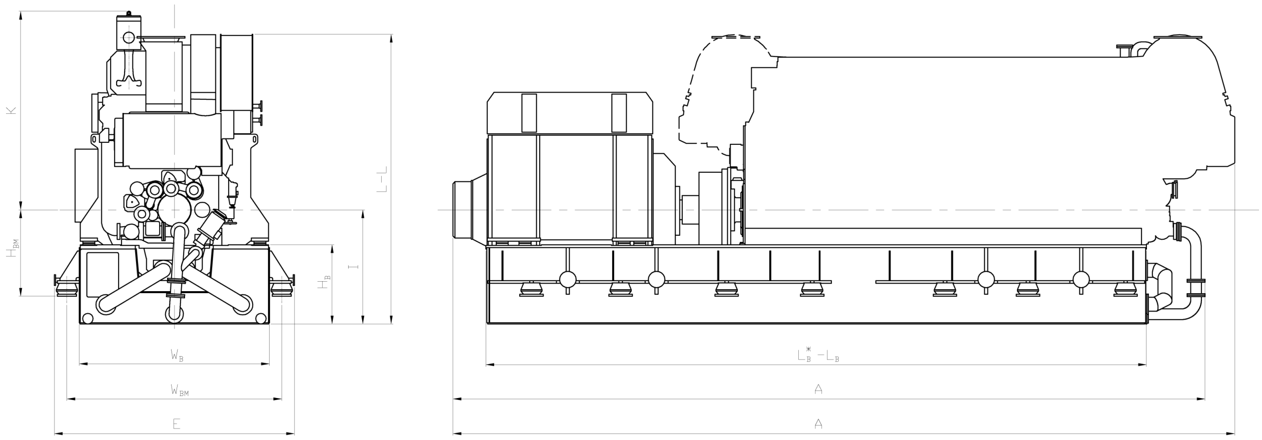


Table 1.5 Generating sets dimensions

Engine	A* [mm]	A [mm]	E [mm]	I [mm]	K [mm]	L [mm]	L* [mm]	Weigth [tons]
6L	9100	9600	2900	1655	3135	4485	4485	90
8L	11500	12000	2900	1705	3135	4475	4525	110
9L	11800	12300	3100	1805	3135	4575	4625	130
12V	11100	11900	3600	2015	2855	4945	4945	160
16V	12500	13300	3800	2015	2855	5120	5120	200

Table 1.6 Common Baseframe dimensions

	Lenght L* [mm]	Lenght L [mm]	Width W_B [mm]	Heigth H_B [mm]	W.mounts W_{BM} [mm]	H.mounts H_{BM} [mm]
6L	8300	8000	2200	1100	2600	1350
8L	10500	10000	2200	1150	2600	1350
9L	11000	10500	2400	1250	2800	1350
12V	9800	9600	2800	1300	3200	1550
16V	11200	11000	3000	1300	3400	1550

Indicative dimensions and wet weights (final values depend on generator type and size)

** T/C at flywheel end*

2. Operating ranges

2.1 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 and speed range for clutch engagement are indicated in the diagrams, but project specific limitations may apply.

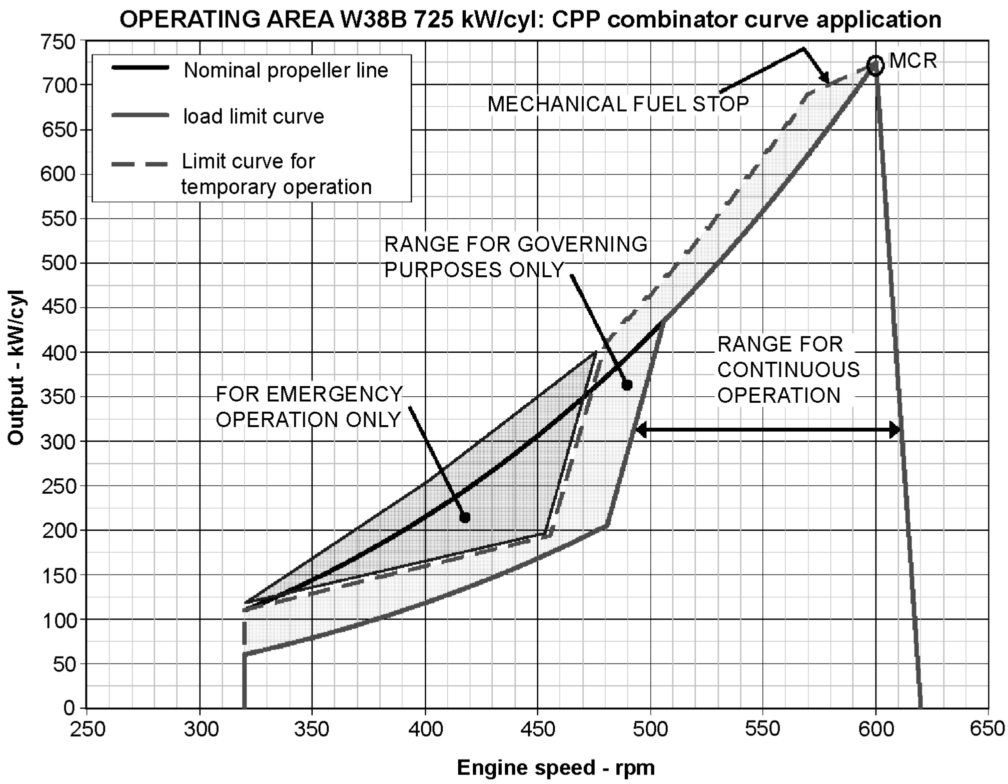
2.1.1 Controllable pitch propellers

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

The propulsion control should 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.

Figure 2.1 Operating field for CP Propeller (9910DT223)



2.1.2 Fixed pitch propellers

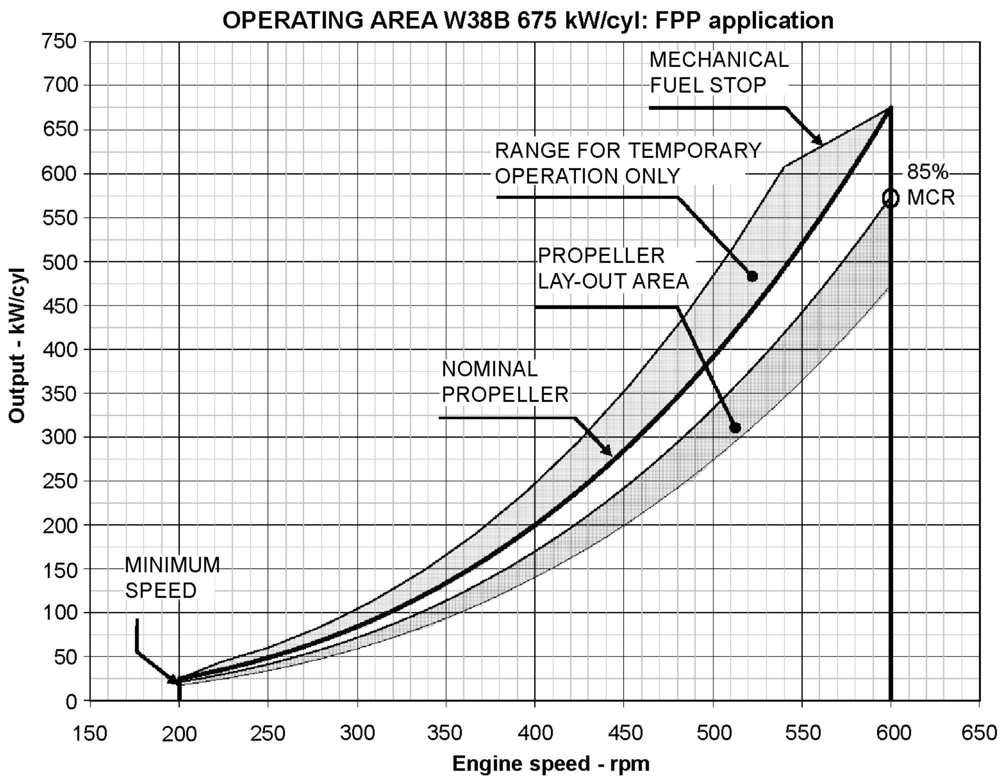
The thrust and power absorption of a given fixed pitch propeller is determined by the relation between ship speed and propeller revolution speed. The power absorption during acceleration, manoeuvring or towing is considerably higher than during free sailing for the same revolution speed. Increased ship 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.

Figure 2.2 Operating field for FP Propeller (9910DT224)



2.2 Loading capacity

Controlled load increase is essential for highly supercharged diesel engines, because the turbocharger needs time to accelerate before it can deliver the required amount of air. Sufficient time to achieve even temperature distribution in engine components must also be ensured. This is especially important for larger engines.

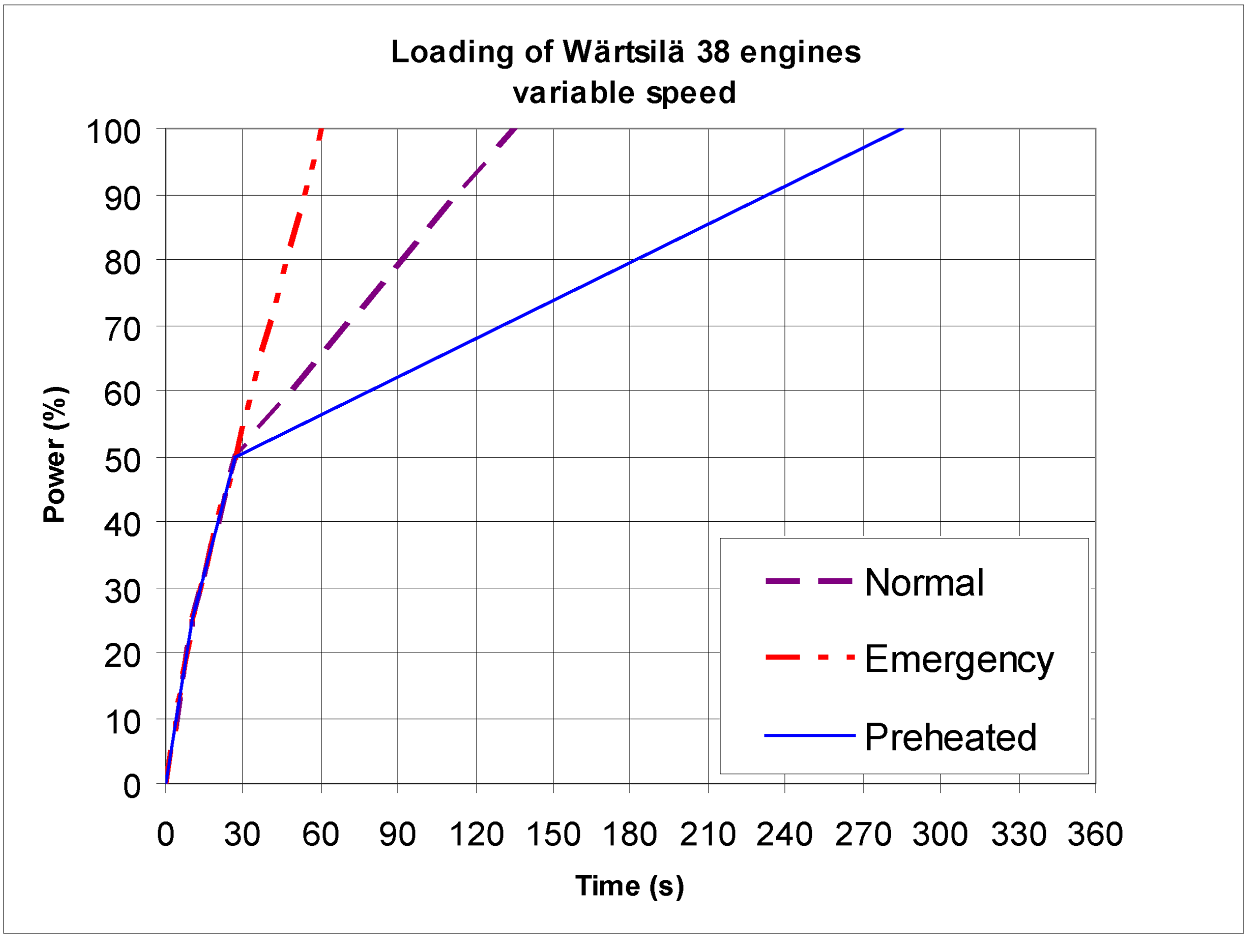
If the control system has only one load increase ramp, then the ramp for a preheated engine should be used. The HT-water temperature in a preheated engine must be at least 60 °C, preferably 70 °C, and the lubricating oil temperature must be at least 40 °C.

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

The load should always be applied gradually in normal operation. Class rules regarding load acceptance capability of diesel generators should not be interpreted as guidelines on how to apply load in normal operation. The class rules define what the engine must be capable of, if an unexpected event causes a sudden load step.

2.2.1 Mechanical propulsion, controllable pitch propeller (CPP)

Figure 2.3 Maximum load increase rates for variable speed engines

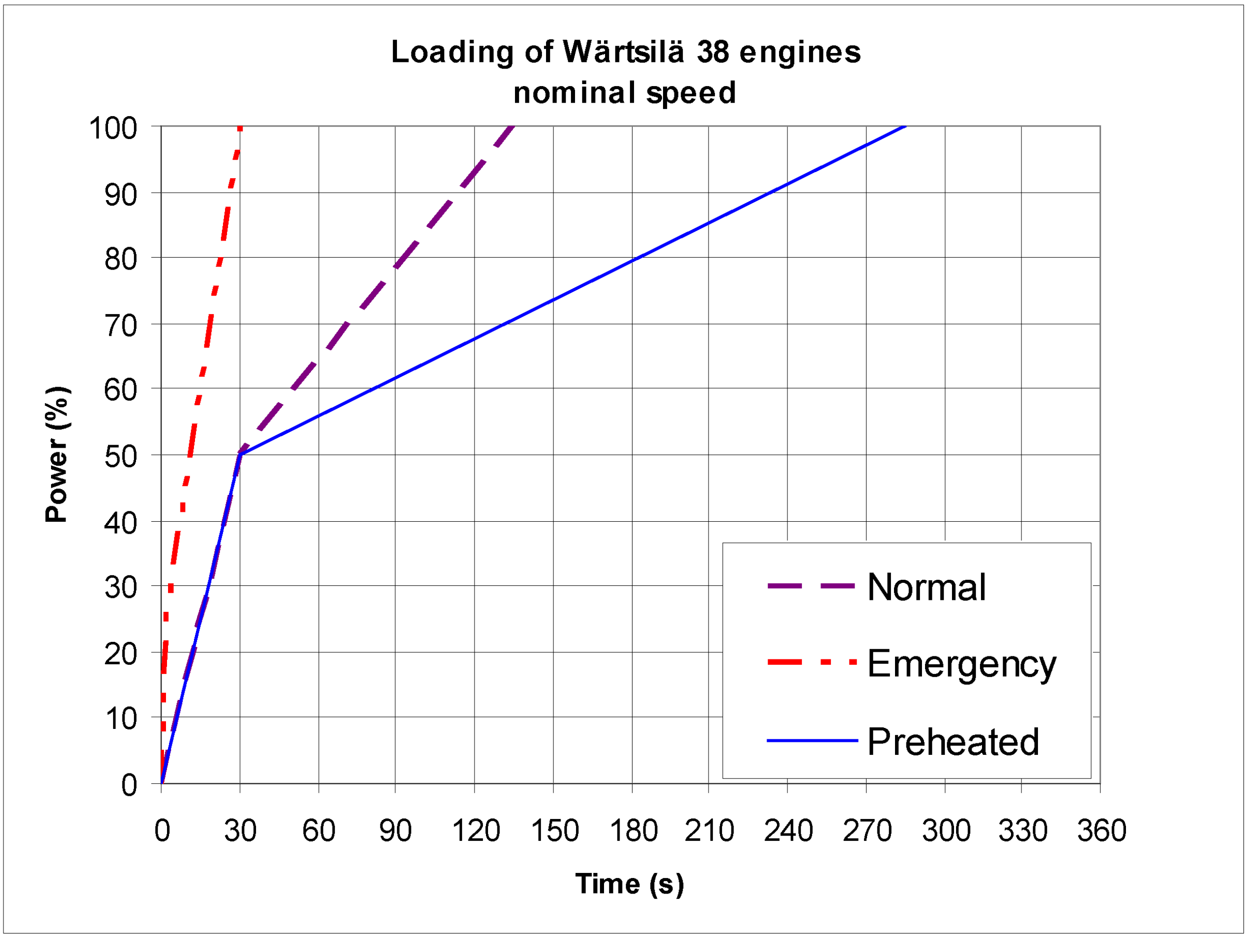


If minimum smoke during load increase is a major priority, slower loading rate than in the diagram can be necessary below 50% load.

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

2.2.2 Diesel electric propulsion

Figure 2.4 Maximum load increase rates for engines operating at nominal speed



In normal operation the load should not be reduced from 100% to 0% in less than 15 seconds. In an emergency situation the full load can be thrown off instantly.

The maximum deviation from steady state speed is less than 10%, when applying load according to the emergency loading ramp. Load increase according to the normal ramp correspondingly results in less than 3% speed deviation.

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 for an engine that has attained normal operating temperature 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, which may cause significant load steps. The engine must be allowed to recover for at least 10 seconds before applying the following load step, if the load is applied in maximum steps.

Start-up time

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

2.3 Low air temperature

In cold conditions the following minimum inlet air temperatures apply:

- Starting + 5°C

- Idling - 5°C
- High load - 10°C

Sustained operation between 0 and 40% load can require special provisions in cold conditions to prevent too low engine temperature.

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

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.

3. Technical data

3.1 Introduction

3.1.1 General

This chapter gives the technical data (heat balance data, exhaust gas parameters, pump capacities etc.) needed to design auxiliary systems. The technical data tables give separate exhaust gas and heat balance data for variable speed engines “CPP” and diesel-electric engines “DE”. Engines driving controllable-pitch propellers belong to the category “CPP” whether or not they have shaft generators (operated at constant speed).

3.1.2 Ambient conditions

The reference ambient conditions are described in chapter 1.3; ISO and tropical conditions. The influence of different ambient conditions on the heat balance (ref. ISO-conditions) is shown in following figures. The recommended LT-water system is based on maintaining a constant charge air temperature to minimize condensate. The external cooling water system should maintain an engine inlet temperature close to 38ºC.

3.1.3 Coolers

The coolers are typically dimensioned for tropical conditions, 45°C suction air and 32°C sea water temperature. A sea water temperature of 32°C typically translates to a LT-water temperature of 38°C. Correction factors are obtained from the following figures.

3.1.4 Heat recovery

For heat recovery purposes, dimensioning conditions have to be evaluated on a project specific basis as to engine load, operating modes, ambient conditions etc. The load dependent diagrams (after the tables) are valid under ISO-conditions, representing average conditions reasonably well in many cases.

3.1.5 Engine driven pumps

The basic fuel consumption given in the technical data tables include engine driven pumps. The increase in fuel consumption in g/kWh is given in table 3.1:

Table 3.1 Fuel consumption, built on pumps

		Load 100%	Load 85%	Load 75%	Load 50%
Constant speed	Lube oil pump [g/kWh]	2	2.3	2.6	4
	HT- & LT- pump total [g/kWh]	1	1.2	1.4	2
Variable speed	Lube oil pump [g/kWh]	2	2.1	2.2	3
	HT- & LT- pump total [g/kWh]	1	1.1	1.2	1.5

3.2 Technical data tables

3.2.1 Wärtsilä 6L38

Diesel engine Wärtsilä 6L38		**DE**	**CPP**
Engine speed	RPM	600	600
Engine output	kW	4350	4350
Cylinder bore	mm	380	380
Stroke	mm	475	475
Mean effective pressure	MPa	2.7	2.7
Mean piston speed	m/s	9.5	9.5
Idling speed	rpm	320	320
Combustion air system			
Flow of air at 100% load	kg/s	7.61	7.61
Ambient air temperature, max.	°C	45	45
Air temperature after air cooler (TE601)	°C	50	50
Air temperature after air cooler, alarm	°C	60	60
Exhaust gas system (Note 1)			
Exhaust gas flow, 100% load	kg/s	7.85	7.85
Exhaust gas flow, 85% load	kg/s	7.59	7.25
Exhaust gas flow, 75% load	kg/s	6.91	6.31
Exhaust gas flow, 50% load	kg/s	4.86	4.92
Exhaust gas temperature after turbocharger, 100% load (TE517)	°C	389	389
Exhaust gas temperature after turbocharger, 85% load (TE517)	°C	309	320
Exhaust gas temperature after turbocharger, 75% load (TE517)	°C	307	328
Exhaust gas temperature after turbocharger, 50% load (TE517)	°C	323	314
Exhaust gas back pressure, max.	kPa	3	3
Exhaust gas pipe diameter, min.	mm	650	650
Calculated exhaust diameter for 35 m/s	mm	730	730
Heat balance at 100% load (Note 2)			
Jacket water, HT-circuit	kW	501	501
Charge air, HT-circuit	kW	831	831
Lubricating oil, LT-circuit	kW	521	521
Charge air, LT-circuit	kW	385	385
Radiation	kW	170	170
Fuel system (Note 3)			
Pressure before injection pumps (PT101)	kPa	700	700
Viscosity before injection pumps (HFO)	cSt	16..24	16..24
Viscosity before injection pumps (MDF), min.	cSt	2	2
Fuel temperature before injection pumps (HFO) (TE101)	°C	< 140	< 140
Fuel temperature before injection pumps (MDF) (TE101)	°C	< 45	< 45
Circulating fuel flow / consumption ratio (100% load), min.		4:1	4:1
Fuel consumption (HFO), 100% load	g/kWh	183	183
Fuel consumption (HFO), 85% load	g/kWh	180	177
Fuel consumption (HFO), 75% load	g/kWh	180	177
Fuel consumption (HFO), 50% load	g/kWh	186	181
Leak fuel quantity, clean fuel (HFO), 100% load	kg/h	1.7	1.7
Leak fuel quantity, clean fuel (MDF), 100% load	kg/h	16.7	16.7
Lubricating oil system			
Pressure before engine, nom. (PT201)	kPa	450	450
Pressure before engine, alarm (PT201)	kPa	380	380
Pressure before engine, stop (PT201)	kPa	340	340
Priming pressure, nom. (PT201)	kPa	50	50
Temperature before engine, nom. (TE201)	°C	63	63
Temperature before engine, alarm (TE201)	°C	70	70
Temperature after engine, approx.	°C	78	78
Pump capacity (main), engine driven	m^3/h	91	91
Pump capacity (main), separate	m^3/h	80	80
Pump capacity (priming), 50/60 Hz	m^3/h	21 / 25	21 / 25
Suction ability of main engine driven pump (including pressure losses in pipes), max.	kPa	40	40
Suction ability of priming engine driven pump (including pressure losses in pipes), max.	kPa	35	35
Oil volume in separate system oil tank, nom.	m^3	5.9	5.9
Filter fineness, mesh size	µm	30	30
Filters difference pressure, alarm	kPa	100	100
Oil consumption (100% load), approx.	g/kWh	0.7	0.7

Diesel engine Wärtsilä 6L38		DE	CPP
Crankcase ventilation flow rate	l/min/cyl	210	210
Crankcase backpressure, max.	kPa	0.2	0.2
High temperature cooling water system			
Pressure before engine, nom. (PT401)	kPa	380 + static	380 + static
Pressure before engine, alarm (PT401)	kPa	250 + static	250 + static
Pressure before engine, max. (PT401)	kPa	460 + static	460 + static
Temperature before engine, approx. (TE401)	°C	73	73
Temperature after engine, nom. (TE402)	°C	93	93
Temperature after engine, alarm (TE402)	°C	103	103
Temperature after engine, stop (TE402)	°C	110	110
Pump capacity, nom.	m^3/h	66	66
Pressure drop over engine	kPa	180	180
Water volume in engine	m^3	0.3	0.3
Pressure from expansion tank	kPa	70...150	70...150
Pressure drop over external system, max.	kPa	160	160
Delivery head of stand-by pump	kPa	380	380
Low temperature cooling water system			
Pressure before charge air cooler, nom. (PT471)	kPa	340 + static	340 + static
Pressure before charge air cooler, alarm (PT471)	kPa	250 + static	250 + static
Pressure before charge air cooler, max. (PT471)	kPa	460 + static	460 + static
Temperature before engine, max. (TE471)	°C	38	38
Temperature after engine, min.	°C	44	44
Pump capacity, nom.	m^3/h	84	84
Pressure drop over engine	kPa	180	180
Water volume in engine	m^3	0.3	0.3
Pressure drop over external system, max.	kPa	120	120
Pressure from expansion tank	kPa	70...150	70...150
Delivery head of stand-by pump	kPa	340	340
Starting air system (Note 4)			
Air pressure, nom. (PT301)	kPa	3000	3000
Air pressure, min. (20°C) (PT301)	kPa	1200	1200
Air pressure, max. (PT301)	kPa	3000	3000
Low pressure limit in air vessels	kPa	1800	1800
Air consumption per start (20°C)	Nm^3	3.6	3.6
Air consumption per start, with generator (20°C)	Nm^3	5.6	5.6
COMMON RAIL			
Fuel system			
Pressure before injection pumps, min.	kPa	1000	1000
Viscosity before injection pumps (HFO)	cSt	16..24	16..24
Viscosity before injection pumps (MDF)	cSt	2	2
Quantity of clean leak fuel, HFO (100% load, excluding injector return)	kg/h	0.8	0.8
Quantity of clean leak fuel, MDF (100% load, excluding injector return)	kg/h	8.4	8.4
Clean return fuel from fuel injector, HFO (100% load)	kg/h	167	167
Clean return fuel from fuel injector, MDF (100% load)	kg/h	167	167
Fuel temperature before fuel pumps (HFO)	°C	< 140	< 140
Fuel temperature before fuel pumps (MDF)	°C	< 45	< 45
Circulating fuel flow / consumption ratio (100%) load, min.		3:1	3:1
Mixing tank pressure, max.	kPa	500	500
Filter absolute mesh size (HFO), max. (automatic fine filter)	µm	10	10
Filter absolute mesh size (MDF), max. (automatic or duplex filter)	µm	10	10
Safety filter absolute mesh size (HFO), max.	µm	25	25
Lubricating oil system			
Pressure at engine inlet, nom.	kPa	450	450
Pressure after control oil pump, nom.	kPa	25000	25000
Control oil flow to engine (engine running), nom.	l/min/cyl	0.5	0.5
Control oil flow to engine, max. momentary flow (= max. pump capacity)	l/min	110	110
Temperature before control oil pump, nom.	°C	63	63
Filter absolute mesh size, max. (automatic fine filter)	µm	10	10
Filter absolute mesh size, max. (by-pass filter for automatic filter)	µm	25	25
Running-in filters on injectors holder mesh size, max.	µm	100	100
Starting air system			
Air consumption per start (20°C)	Nm^3	3.6	3.6

3.2.2 Wärtsilä 8L38

Diesel engine Wärtsilä 8L38		**DE**	**CPP**
Engine speed	RPM	600	600
Engine output	kW	5800	5800
Cylinder bore	mm	380	380
Stroke	mm	475	475
Mean effective pressure	MPa	2.7	2.7
Mean piston speed	m/s	9.5	9.5
Idling speed	rpm	320	320
Combustion air system			
Flow of air at 100% load	kg/s	10.15	10.15
Ambient air temperature, max.	°C	45	45
Air temperature after air cooler (TE601)	°C	50	50
Air temperature after air cooler, alarm	°C	60	60
Exhaust gas system (Note 1)			
Exhaust gas flow, 100% load	kg/s	10.47	10.47
Exhaust gas flow, 85% load	kg/s	10.13	9.67
Exhaust gas flow, 75% load	kg/s	9.22	8.41
Exhaust gas flow, 50% load	kg/s	6.48	6.57
Exhaust gas temperature after turbocharger, 100% load (TE517)	°C	389	389
Exhaust gas temperature after turbocharger, 85% load (TE517)	°C	309	320
Exhaust gas temperature after turbocharger, 75% load (TE517)	°C	307	328
Exhaust gas temperature after turbocharger, 50% load (TE517)	°C	323	314
Exhaust gas back pressure, max.	kPa	3	3
Exhaust gas pipe diameter, min.	mm	750	750
Calculated exhaust diameter for 35 m/s	mm	843	843
Heat balance at 100% load (Note 2)			
Jacket water, HT-circuit	kW	668	668
Charge air, HT-circuit	kW	1108	1108
Lubricating oil, LT-circuit	kW	695	695
Charge air, LT-circuit	kW	513	513
Radiation	kW	227	227
Fuel system (Note 3)			
Pressure before injection pumps (PT101)	kPa	700	700
Viscosity before injection pumps (HFO)	cSt	16..24	16..24
Viscosity before injection pumps (MDF), min.	cSt	2	2
Fuel temperature before injection pumps (HFO) (TE101)	°C	< 140	< 140
Fuel temperature before injection pumps (MDF) (TE101)	°C	< 45	< 45
Circulating fuel flow / consumption ratio (100% load), min.		4:1	4:1
Fuel consumption (HFO), 100% load	g/kWh	183	183
Fuel consumption (HFO), 85% load	g/kWh	180	177
Fuel consumption (HFO), 75% load	g/kWh	180	177
Fuel consumption (HFO), 50% load	g/kWh	186	181
Leak fuel quantity, clean fuel (HFO), 100% load	kg/h	2.2	2.2
Leak fuel quantity, clean fuel (MDF), 100% load	kg/h	22.3	22.3
Lubricating oil system			
Pressure before engine, nom. (PT201)	kPa	450	450
Pressure before engine, alarm (PT201)	kPa	380	380
Pressure before engine, stop (PT201)	kPa	340	340
Priming pressure, nom. (PT201)	kPa	50	50
Temperature before engine, nom. (TE201)	°C	63	63
Temperature before engine, alarm (TE201)	°C	70	70
Temperature after engine, approx.	°C	79	79
Pump capacity (main), engine driven	m³/h	142	142
Pump capacity (main), separate	m³/h	102	102
Pump capacity (priming), 50/60 Hz	m³/h	27 / 33	27 / 33
Suction ability of main engine driven pump (including pressure losses in pipes), max.	kPa	40	40
Suction ability of priming engine driven pump (including pressure losses in pipes), max.	kPa	35	35
Oil volume in separate system oil tank, nom.	m³	7.9	7.9
Filter fineness, mesh size	µm	30	30
Filters difference pressure, alarm	kPa	100	100
Oil consumption (100% load), approx.	g/kWh	0.7	0.7
Crankcase ventilation flow rate	l/min/cyl	210	210
Crankcase backpressure, max.	kPa	0.2	0.2

Diesel engine Wärtsilä 8L38		DE	CPP
High temperature cooling water system			
Pressure before engine, nom. (PT401)	kPa	380 + static	380 + static
Pressure before engine, alarm (PT401)	kPa	250 + static	250 + static
Pressure before engine, max. (PT401)	kPa	460 + static	460 + static
Temperature before engine, approx. (TE401)	°C	73	73
Temperature after engine, nom. (TE402)	°C	93	93
Temperature after engine, alarm (TE402)	°C	103	103
Temperature after engine, stop (TE402)	°C	110	110
Pump capacity, nom.	m^3/h	88	88
Pressure drop over engine	kPa	180	180
Water volume in engine	m^3	0.4	0.4
Pressure from expansion tank	kPa	70...150	70...150
Pressure drop over external system, max.	kPa	160	160
Delivery head of stand-by pump	kPa	380	380
Low temperature cooling water system			
Pressure before charge air cooler, nom. (PT471)	kPa	340 + static	340 + static
Pressure before charge air cooler, alarm (PT471)	kPa	250 + static	250 + static
Pressure before charge air cooler, max. (PT471)	kPa	460 + static	460 + static
Temperature before engine, max. (TE471)	°C	38	38
Temperature after engine, min.	°C	44	44
Pump capacity, nom.	m^3/h	112	112
Pressure drop over engine	kPa	180	180
Water volume in engine	m^3	0.4	0.4
Pressure drop over external system, max.	kPa	120	120
Pressure from expansion tank	kPa	70...150	70...150
Delivery head of stand-by pump	kPa	340	340
Starting air system (Note 4)			
Air pressure, nom. (PT301)	kPa	3000	3000
Air pressure, min. (20°C) (PT301)	kPa	1200	1200
Air pressure, max. (PT301)	kPa	3000	3000
Low pressure limit in air vessels	kPa	1800	1800
Air consumption per start (20°C)	Nm^3	4.0	4.0
Air consumption per start, with generator (20°C)	Nm^3	6.0	6.0
COMMON RAIL			
Fuel system			
Pressure before injection pumps, min.	kPa	1000	1000
Viscosity before injection pumps (HFO)	cSt	16..24	16..24
Viscosity before injection pumps (MDF)	cSt	2	2
Quantity of clean leak fuel, HFO (100% load, excluding injector return)	kg/h	1.1	1.1
Quantity of clean leak fuel, MDF (100% load, excluding injector return)	kg/h	11.1	11.1
Clean return fuel from fuel injector, HFO (100% load)	kg/h	223	223
Clean return fuel from fuel injector, MDF (100% load)	kg/h	223	223
Fuel temperature before fuel pumps (HFO)	°C	< 140	< 140
Fuel temperature before fuel pumps (MDF)	°C	< 45	< 45
Circulating fuel flow / consumption ratio (100%) load, min.		3:1	3:1
Mixing tank pressure, max.	kPa	500	500
Filter absolute mesh size (HFO), max. (automatic fine filter)	µm	10	10
Filter absolute mesh size (MDF), max. (automatic or duplex filter)	µm	10	10
Safety filter absolute mesh size (HFO), max.	µm	25	25
Lubricating oil system			
Pressure at engine inlet, nom.	kPa	450	450
Pressure after control oil pump, nom.	kPa	25000	25000
Control oil flow to engine (engine running), nom.	l/min/cyl	0.5	0.5
Control oil flow to engine, max. momentary flow (= max. pump capacity)	l/min	110	110
Temperature before control oil pump, nom.	°C	63	63
Filter absolute mesh size, max. (automatic fine filter)	µm	10	10
Filter absolute mesh size, max. (by-pass filter for automatic filter)	µm	25	25
Running-in filters on injectors holder mesh size, max.	µm	100	100
Starting air system			
Air consumption per start (20°C)	Nm^3	4.0	4.0

3.2.3 Wärtsilä 9L38

Diesel engine Wärtsilä 9L38		**DE**	**CPP**
Engine speed	RPM	600	600
Engine output	kW	6525	6525
Cylinder bore	mm	380	380
Stroke	mm	475	475
Mean effective pressure	MPa	2.7	2.7
Mean piston speed	m/s	9.5	9.5
Idling speed	rpm	320	320
Combustion air system			
Flow of air at 100% load	kg/s	11.41	11.41
Ambient air temperature, max.	°C	45	45
Air temperature after air cooler (TE601)	°C	50	50
Air temperature after air cooler, alarm	°C	60	60
Exhaust gas system (Note 1)			
Exhaust gas flow, 100% load	kg/s	11.78	11.78
Exhaust gas flow, 85% load	kg/s	11.39	10.88
Exhaust gas flow, 75% load	kg/s	10.37	9.46
Exhaust gas flow, 50% load	kg/s	7.29	7.39
Exhaust gas temperature after turbocharger, 100% load (TE517)	°C	389	389
Exhaust gas temperature after turbocharger, 85% load (TE517)	°C	309	320
Exhaust gas temperature after turbocharger, 75% load (TE517)	°C	307	328
Exhaust gas temperature after turbocharger, 50% load (TE517)	°C	323	314
Exhaust gas back pressure, max.	kPa	3	3
Exhaust gas pipe diameter, min.	mm	800	800
Calculated exhaust diameter for 35 m/s	mm	894	894
Heat balance at 100% load (Note 2)			
Jacket water, HT-circuit	kW	751	751
Charge air, HT-circuit	kW	1247	1247
Lubricating oil, LT-circuit	kW	782	782
Charge air, LT-circuit	kW	577	577
Radiation	kW	255	255
Fuel system (Note 3)			
Pressure before injection pumps (PT101)	kPa	700	700
Viscosity before injection pumps (HFO)	cSt	16..24	16..24
Viscosity before injection pumps (MDF), min.	cSt	2	2
Fuel temperature before injection pumps (HFO) (TE101)	°C	< 140	< 140
Fuel temperature before injection pumps (MDF) (TE101)	°C	< 45	< 45
Circulating fuel flow / consumption ratio (100% load), min.		4:1	4:1
Fuel consumption (HFO), 100% load	g/kWh	183	183
Fuel consumption (HFO), 85% load	g/kWh	180	177
Fuel consumption (HFO), 75% load	g/kWh	180	177
Fuel consumption (HFO), 50% load	g/kWh	186	181
Leak fuel quantity, clean fuel (HFO), 100% load	kg/h	2.5	2.5
Leak fuel quantity, clean fuel (MDF), 100% load	kg/h	25.1	25.1
Lubricating oil system			
Pressure before engine, nom. (PT201)	kPa	450	450
Pressure before engine, alarm (PT201)	kPa	380	380
Pressure before engine, stop (PT201)	kPa	340	340
Priming pressure, nom. (PT201)	kPa	50	50
Temperature before engine, nom. (TE201)	°C	63	63
Temperature before engine, alarm (TE201)	°C	70	70
Temperature after engine, approx.	°C	79	79
Pump capacity (main), engine driven	m³/h	142	142
Pump capacity (main), separate	m³/h	112	112
Pump capacity (priming), 50/60 Hz	m³/h	27 / 33	27 / 33
Suction ability of main engine driven pump (including pressure losses in pipes), max.	kPa	40	40
Suction ability of priming engine driven pump (including pressure losses in pipes), max.	kPa	35	35
Oil volume in separate system oil tank, nom.	m³	8.9	8.9
Filter fineness, mesh size	μm	30	30
Filters difference pressure, alarm	kPa	100	100
Oil consumption (100% load), approx.	g/kWh	0.7	0.7
Crankcase ventilation flow rate	l/min/cyl	210	210
Crankcase backpressure, max.	kPa	0.2	0.2

Diesel engine Wärtsilä 9L38		DE	CPP
High temperature cooling water system			
Pressure before engine, nom. (PT401)	kPa	380 + static	380 + static
Pressure before engine, alarm (PT401)	kPa	250 + static	250 + static
Pressure before engine, max. (PT401)	kPa	460 + static	460 + static
Temperature before engine, approx. (TE401)	°C	73	73
Temperature after engine, nom. (TE402)	°C	93	93
Temperature after engine, alarm (TE402)	°C	103	103
Temperature after engine, stop (TE402)	°C	110	110
Pump capacity, nom.	m³/h	99	99
Pressure drop over engine	kPa	180	180
Water volume in engine	m³	0.45	0.45
Pressure from expansion tank	kPa	70...150	70...150
Pressure drop over external system, max.	kPa	160	160
Delivery head of stand-by pump	kPa	380	380
Low temperature cooling water system			
Pressure before charge air cooler, nom. (PT471)	kPa	340 + static	340 + static
Pressure before charge air cooler, alarm (PT471)	kPa	250 + static	250 + static
Pressure before charge air cooler, max. (PT471)	kPa	460 + static	460 + static
Temperature before engine, max. (TE471)	°C	38	38
Temperature after engine, min.	°C	44	44
Pump capacity, nom.	m³/h	126	126
Pressure drop over engine	kPa	180	180
Water volume in engine	m³	0.45	0.45
Pressure drop over external system, max.	kPa	120	120
Pressure from expansion tank	kPa	70...150	70...150
Delivery head of stand-by pump	kPa	340	340
Starting air system (Note 4)			
Air pressure, nom. (PT301)	kPa	3000	3000
Air pressure, min. (20°C) (PT301)	kPa	1200	1200
Air pressure, max. (PT301)	kPa	3000	3000
Low pressure limit in air vessels	kPa	1800	1800
Air consumption per start (20°C)	Nm³	4.3	4.3
Air consumption per start, with generator (20°C)	Nm³	6.3	6.3
COMMON RAIL			
Fuel system			
Pressure before injection pumps, min.	kPa	1000	1000
Viscosity before injection pumps (HFO)	cSt	16..24	16..24
Viscosity before injection pumps (MDF)	cSt	2	2
Quantity of clean leak fuel, HFO (100% load, excluding injector return)	kg/h	1.3	1.3
Quantity of clean leak fuel, MDF (100% load, excluding injector return)	kg/h	12.5	12.5
Clean return fuel from fuel injector, HFO (100% load)	kg/h	251	251
Clean return fuel from fuel injector, MDF (100% load)	kg/h	251	251
Fuel temperature before fuel pumps (HFO)	°C	< 140	< 140
Fuel temperature before fuel pumps (MDF)	°C	< 45	< 45
Circulating fuel flow / consumption ratio (100%) load, min.		3:1	3:1
Mixing tank pressure, max.	kPa	500	500
Filter absolute mesh size (HFO), max. (automatic fine filter)	µm	10	10
Filter absolute mesh size (MDF), max. (automatic or duplex filter)	µm	10	10
Safety filter absolute mesh size (HFO), max.	µm	25	25
Lubricating oil system			
Pressure at engine inlet, nom.	kPa	450	450
Pressure after control oil pump, nom.	kPa	25000	25000
Control oil flow to engine (engine running), nom.	l/min/cyl	0.5	0.5
Control oil flow to engine, max. momentary flow (= max. pump capacity)	l/min	110	110
Temperature before control oil pump, nom.	°C	63	63
Filter absolute mesh size, max. (automatic fine filter)	µm	10	10
Filter absolute mesh size, max. (by-pass filter for automatic filter)	µm	25	25
Running-in filters on injectors holder mesh size, max.	µm	100	100
Starting air system			
Air consumption per start (20°C)	Nm³	4.3	4.3

3.2.4 Wärtsilä 12V38

Diesel engine Wärtsilä 12V38		DE	CPP
Engine speed	RPM	600	600
Engine output	kW	8700	8700
Cylinder bore	mm	380	380
Stroke	mm	475	475
Mean effective pressure	MPa	2.7	2.7
Mean piston speed	m/s	9.5	9.5
Idling speed	rpm	320	320
Combustion air system			
Flow of air at 100% load	kg/s	15.22	15.22
Ambient air temperature, max.	°C	45	45
Air temperature after air cooler (TE601)	°C	50	50
Air temperature after air cooler, alarm	°C	60	60
Exhaust gas system (Note 1)			
Exhaust gas flow, 100% load	kg/s	15.7	15.7
Exhaust gas flow, 85% load	kg/s	15.19	14.5
Exhaust gas flow, 75% load	kg/s	13.83	12.62
Exhaust gas flow, 50% load	kg/s	9.72	9.85
Exhaust gas temperature after turbocharger, 100% load (TE517)	°C	389	389
Exhaust gas temperature after turbocharger, 85% load (TE517)	°C	309	320
Exhaust gas temperature after turbocharger, 75% load (TE517)	°C	307	328
Exhaust gas temperature after turbocharger, 50% load (TE517)	°C	323	314
Exhaust gas back pressure, max.	kPa	3	3
Exhaust gas pipe diameter, min.	mm	900	900
Calculated exhaust diameter for 35 m/s	mm	1032	1032
Heat balance at 100% load (Note 2)			
Jacket water, HT-circuit	kW	1001	1001
Charge air, HT-circuit	kW	1663	1663
Lubricating oil, LT-circuit	kW	1042	1042
Charge air, LT-circuit	kW	770	770
Radiation	kW	340	340
Fuel system (Note 3)			
Pressure before injection pumps (PT101)	kPa	700	700
Viscosity before injection pumps (HFO)	cSt	16..24	16..24
Viscosity before injection pumps (MDF), min.	cSt	2	2
Fuel temperature before injection pumps (HFO) (TE101)	°C	< 140	< 140
Fuel temperature before injection pumps (MDF) (TE101)	°C	< 45	< 45
Circulating fuel flow / consumption ratio (100% load), min.		4:1	4:1
Fuel consumption (HFO), 100% load	g/kWh	182	182
Fuel consumption (HFO), 85% load	g/kWh	178	176
Fuel consumption (HFO), 75% load	g/kWh	179	175
Fuel consumption (HFO), 50% load	g/kWh	185	180
Leak fuel quantity, clean fuel (HFO), 100% load	kg/h	3.3	3.3
Leak fuel quantity, clean fuel (MDF), 100% load	kg/h	33.1	33.1
Lubricating oil system			
Pressure before engine, nom. (PT201)	kPa	450	450
Pressure before engine, alarm (PT201)	kPa	380	380
Pressure before engine, stop (PT201)	kPa	340	340
Priming pressure, nom. (PT201)	kPa	50	50
Temperature before engine, nom. (TE201)	°C	63	63
Temperature before engine, alarm (TE201)	°C	70	70
Temperature after engine, approx.	°C	80	80
Pump capacity (main), engine driven	m³/h	155	155
Pump capacity (main), separate	m³/h	131	131
Pump capacity (priming), 50/60 Hz	m³/h	35 / 35	35 / 35
Suction ability of main engine driven pump (including pressure losses in pipes), max.	kPa	40	40
Oil volume in separate system oil tank, nom.	m³	11.8	11.8
Filter fineness, mesh size	µm	30	30
Filters difference pressure, alarm	kPa	100	100
Oil consumption (100% load), approx.	g/kWh	0.7	0.7
Crankcase ventilation flow rate	l/min/cyl	210	210
Crankcase backpressure, max.	kPa	0.2	0.2
High temperature cooling water system			

Diesel engine Wärtsilä 12V38		DE	CPP
Pressure before engine, nom. (PT401)	kPa	380 + static	380 + static
Pressure before engine, alarm (PT401)	kPa	250 + static	250 + static
Pressure before engine, max. (PT401)	kPa	460 + static	460 + static
Temperature before engine, approx. (TE401)	°C	73	73
Temperature after engine, nom. (TE402)	°C	93	93
Temperature after engine, alarm (TE402)	°C	103	103
Temperature after engine, stop (TE402)	°C	110	110
Pump capacity, nom.	m³/h	132	132
Pressure drop over engine	kPa	180	180
Water volume in engine	m³	0.6	0.6
Pressure from expansion tank	kPa	70...150	70...150
Pressure drop over external system, max.	kPa	160	160
Delivery head of stand-by pump	kPa	380	380
Low temperature cooling water system			
Pressure before charge air cooler, nom. (PT471)	kPa	340 + static	340 + static
Pressure before charge air cooler, alarm (PT471)	kPa	250 + static	250 + static
Pressure before charge air cooler, max. (PT471)	kPa	460 + static	460 + static
Temperature before engine, max. (TE471)	°C	38	38
Temperature after engine, min.	°C	44	44
Pump capacity, nom.	m³/h	168	168
Pressure drop over engine	kPa	180	180
Water volume in engine	m³	0.6	0.6
Pressure drop over external system, max.	kPa	120	120
Pressure from expansion tank	kPa	70...150	70...150
Delivery head of stand-by pump	kPa	340	340
Starting air system (Note 4)			
Air pressure, nom. (PT301)	kPa	3000	3000
Air pressure, min. (20°C) (PT301)	kPa	1200	1200
Air pressure, max. (PT301)	kPa	3000	3000
Low pressure limit in air vessels	kPa	1800	1800
Air consumption per start (20°C)	Nm³	4.7	4.7
Air consumption per start, with generator (20°C)	Nm³	6.7	6.7
COMMON RAIL			
Fuel system			
Pressure before injection pumps, min.	kPa	1000	1000
Viscosity before injection pumps (HFO)	cSt	16..24	16..24
Viscosity before injection pumps (MDF)	cSt	2	2
Quantity of clean leak fuel, HFO (100% load, excluding injector return)	kg/h	1.7	1.7
Quantity of clean leak fuel, MDF (100% load, excluding injector return)	kg/h	16.6	16.6
Clean return fuel from fuel injector, HFO (100% load)	kg/h	331	331
Clean return fuel from fuel injector, MDF (100% load)	kg/h	331	331
Fuel temperature before fuel pumps (HFO)	°C	< 140	< 140
Fuel temperature before fuel pumps (MDF)	°C	< 45	< 45
Circulating fuel flow / consumption ratio (100%) load, min.		3:1	3:1
Mixing tank pressure, max.	kPa	500	500
Filter absolute mesh size (HFO), max. (automatic fine filter)	µm	10	10
Filter absolute mesh size (MDF), max. (automatic or duplex filter)	µm	10	10
Safety filter absolute mesh size (HFO), max.	µm	25	25
Lubricating oil system			
Pressure at engine inlet, nom.	kPa	450	450
Pressure after control oil pump, nom.	kPa	25000	25000
Control oil flow to engine (engine running), nom.	l/min/cyl	0.5	0.5
Control oil flow to engine, max. momentary flow (= max. pump capacity)	l/min	110	110
Temperature before control oil pump, nom.	°C	63	63
Filter absolute mesh size, max. (automatic fine filter)	µm	10	10
Filter absolute mesh size, max. (by-pass filter for automatic filter)	µm	25	25
Running-in filters on injectors holder mesh size, max.	µm	100	100
Starting air system			
Air consumption per start (20°C)	Nm³	4.7	4.7

3.2.5 Wärtsilä 16V38

Diesel engine Wärtsilä 16V38		DE	CPP
Engine speed	RPM	600	600
Engine output	kW	11600	11600
Cylinder bore	mm	380	380
Stroke	mm	475	475
Mean effective pressure	MPa	2.7	2.7
Mean piston speed	m/s	9.5	9.5
Idling speed	rpm	320	320
Combustion air system			
Flow of air at 100% load	kg/s	20.29	20.29
Ambient air temperature, max.	°C	45	45
Air temperature after air cooler (TE601)	°C	50	50
Air temperature after air cooler, alarm	°C	60	60
Exhaust gas system (Note 1)			
Exhaust gas flow, 100% load	kg/s	20.93	20.93
Exhaust gas flow, 85% load	kg/s	20.25	19.34
Exhaust gas flow, 75% load	kg/s	18.44	16.82
Exhaust gas flow, 50% load	kg/s	12.96	13.13
Exhaust gas temperature after turbocharger, 100% load (TE517)	°C	389	389
Exhaust gas temperature after turbocharger, 85% load (TE517)	°C	309	320
Exhaust gas temperature after turbocharger, 75% load (TE517)	°C	307	328
Exhaust gas temperature after turbocharger, 50% load (TE517)	°C	323	314
Exhaust gas back pressure, max.	kPa	3	3
Exhaust gas pipe diameter, min.	mm	1000	1000
Calculated exhaust diameter for 35 m/s	mm	1192	1192
Heat balance at 100% load (Note 2)			
Jacket water, HT-circuit	kW	1335	1335
Charge air, HT-circuit	kW	2217	2217
Lubricating oil, LT-circuit	kW	1390	1390
Charge air, LT-circuit	kW	1026	1026
Radiation	kW	453	453
Fuel system (Note 3)			
Pressure before injection pumps (PT101)	kPa	700	700
Viscosity before injection pumps (HFO)	cSt	16..24	16..24
Viscosity before injection pumps (MDF), min.	cSt	2	2
Fuel temperature before injection pumps (HFO) (TE101)	°C	< 140	< 140
Fuel temperature before injection pumps (MDF) (TE101)	°C	< 45	< 45
Circulating fuel flow / consumption ratio (100% load), min.		4:1	4:1
Fuel consumption (HFO), 100% load	g/kWh	182	182
Fuel consumption (HFO), 85% load	g/kWh	178	176
Fuel consumption (HFO), 75% load	g/kWh	179	175
Fuel consumption (HFO), 50% load	g/kWh	185	180
Leak fuel quantity, clean fuel (HFO), 100% load	kg/h	4.4	4.4
Leak fuel quantity, clean fuel (MDF), 100% load	kg/h	44.2	44.2
Lubricating oil system			
Pressure before engine, nom. (PT201)	kPa	450	450
Pressure before engine, alarm (PT201)	kPa	380	380
Pressure before engine, stop (PT201)	kPa	340	340
Priming pressure, nom. (PT201)	kPa	50	50
Temperature before engine, nom. (TE201)	°C	63	63
Temperature before engine, alarm (TE201)	°C	70	70
Temperature after engine, approx.	°C	81	81
Pump capacity (main), engine driven	m³/h	205	205
Pump capacity (main), separate	m³/h	169	169
Pump capacity (priming), 50/60 Hz	m³/h	46 / 46	46 / 46
Suction ability of main engine driven pump (including pressure losses in pipes), max.	kPa	40	40
Oil volume in separate system oil tank, nom.	m³	15.7	15.7
Filter fineness, mesh size	µm	30	30
Filters difference pressure, alarm	kPa	100	100
Oil consumption (100% load), approx.	g/kWh	0.7	0.7
Crankcase ventilation flow rate	l/min/cyl	210	210
Crankcase backpressure, max.	kPa	0.2	0.2
High temperature cooling water system			

Diesel engine Wärtsilä 16V38		DE	CPP
Pressure before engine, nom. (PT401)	kPa	380 + static	380 + static
Pressure before engine, alarm (PT401)	kPa	250 + static	250 + static
Pressure before engine, max. (PT401)	kPa	460 + static	460 + static
Temperature before engine, approx. (TE401)	°C	73	73
Temperature after engine, nom. (TE402)	°C	93	93
Temperature after engine, alarm (TE402)	°C	103	103
Temperature after engine, stop (TE402)	°C	110	110
Pump capacity, nom.	m³/h	176	176
Pressure drop over engine	kPa	180	180
Water volume in engine	m³	0.8	0.8
Pressure from expansion tank	kPa	70...150	70...150
Pressure drop over external system, max.	kPa	160	160
Delivery head of stand-by pump	kPa	380	380
Low temperature cooling water system			
Pressure before charge air cooler, nom. (PT471)	kPa	340 + static	340 + static
Pressure before charge air cooler, alarm (PT471)	kPa	250 + static	250 + static
Pressure before charge air cooler, max. (PT471)	kPa	460 + static	460 + static
Temperature before engine, max. (TE471)	°C	38	38
Temperature after engine, min.	°C	44	44
Pump capacity, nom.	m³/h	224	224
Pressure drop over engine	kPa	180	180
Water volume in engine	m³	0.8	0.8
Pressure drop over external system, max.	kPa	120	120
Pressure from expansion tank	kPa	70...150	70...150
Delivery head of stand-by pump	kPa	340	340
Starting air system (Note 4)			
Air pressure, nom. (PT301)	kPa	3000	3000
Air pressure, min. (20°C) (PT301)	kPa	1200	1200
Air pressure, max. (PT301)	kPa	3000	3000
Low pressure limit in air vessels	kPa	1800	1800
Air consumption per start (20°C)	Nm³	5.0	5.0
Air consumption per start, with generator (20°C)	Nm³	7.0	7.0
COMMON RAIL			
Fuel system			
Pressure before injection pumps, min.	kPa	1000	1000
Viscosity before injection pumps (HFO)	cSt	16..24	16..24
Viscosity before injection pumps (MDF)	cSt	2	2
Quantity of clean leak fuel, HFO (100% load, excluding injector return)	kg/h	2.2	2.2
Quantity of clean leak fuel, MDF (100% load, excluding injector return)	kg/h	22.1	22.1
Clean return fuel from fuel injector, HFO (100% load)	kg/h	442	442
Clean return fuel from fuel injector, MDF (100% load)	kg/h	442	442
Fuel temperature before fuel pumps (HFO)	°C	< 140	< 140
Fuel temperature before fuel pumps (MDF)	°C	< 45	< 45
Circulating fuel flow / consumption ratio (100%) load, min.		3:1	3:1
Mixing tank pressure, max.	kPa	500	500
Filter absolute mesh size (HFO), max. (automatic fine filter)	µm	10	10
Filter absolute mesh size (MDF), max. (automatic or duplex filter)	µm	10	10
Safety filter absolute mesh size (HFO), max.	µm	25	25
Lubricating oil system			
Pressure at engine inlet, nom.	kPa	450	450
Pressure after control oil pump, nom.	kPa	25000	25000
Control oil flow to engine (engine running), nom.	l/min/cyl	0.5	0.5
Control oil flow to engine, max. momentary flow (= max. pump capacity)	l/min	110	110
Temperature before control oil pump, nom.	°C	63	63
Filter absolute mesh size, max. (automatic fine filter)	µm	10	10
Filter absolute mesh size, max. (by-pass filter for automatic filter)	µm	25	25
Running-in filters on injectors holder mesh size, max.	µm	100	100
Starting air system			
Air consumption per start (20°C)	Nm³	5.0	5.0

Notes:

Note 1 At ISO 3046/1 conditions and 100% load. Flow tolerance 5% and temperature tolerance ±10°C.

Note 2	At ISO 3046/1 conditions and 100% load. Tolerance for cooling water heat ±10%, tolerance for radiation heat ±15%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers.
Note 3	According to ISO 3046/1, lower calorofic value 42 700 kJ/kg at constant engine speed, with engine driven pumps. Tolerance 5%. Constant speed applications are Auxiliary and DE. Mechanical propulsion variable speed applications according to propeller law.
Note 4	Starting procedure performed by automation system. Starting air consumption is higher for propulsion engines without clutch.

Subject to revision without notice.

3.3 Exhaust gas and heat balance diagrams

Figure 3.1 Exhaust gas massflow, W38B DE/CPP

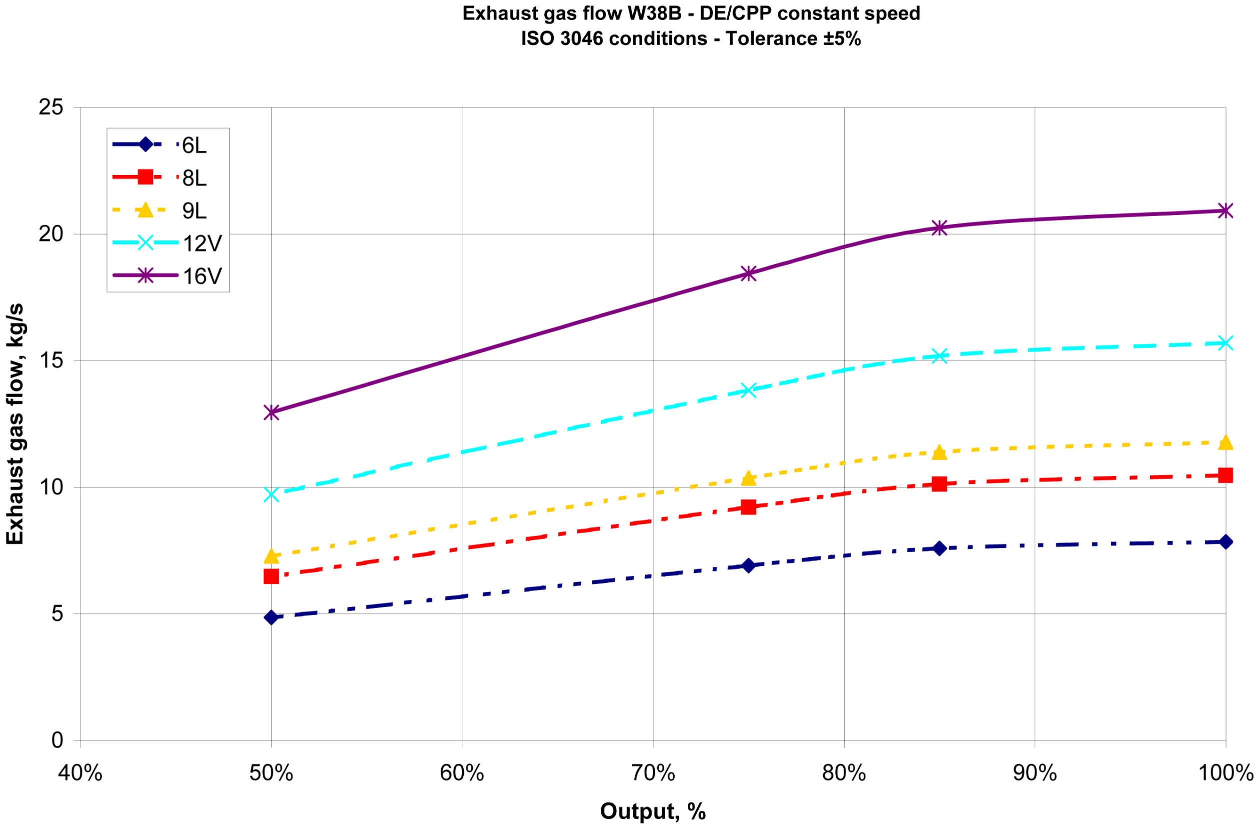


Figure 3.2 Exhaust gas massflow, W38B CPP

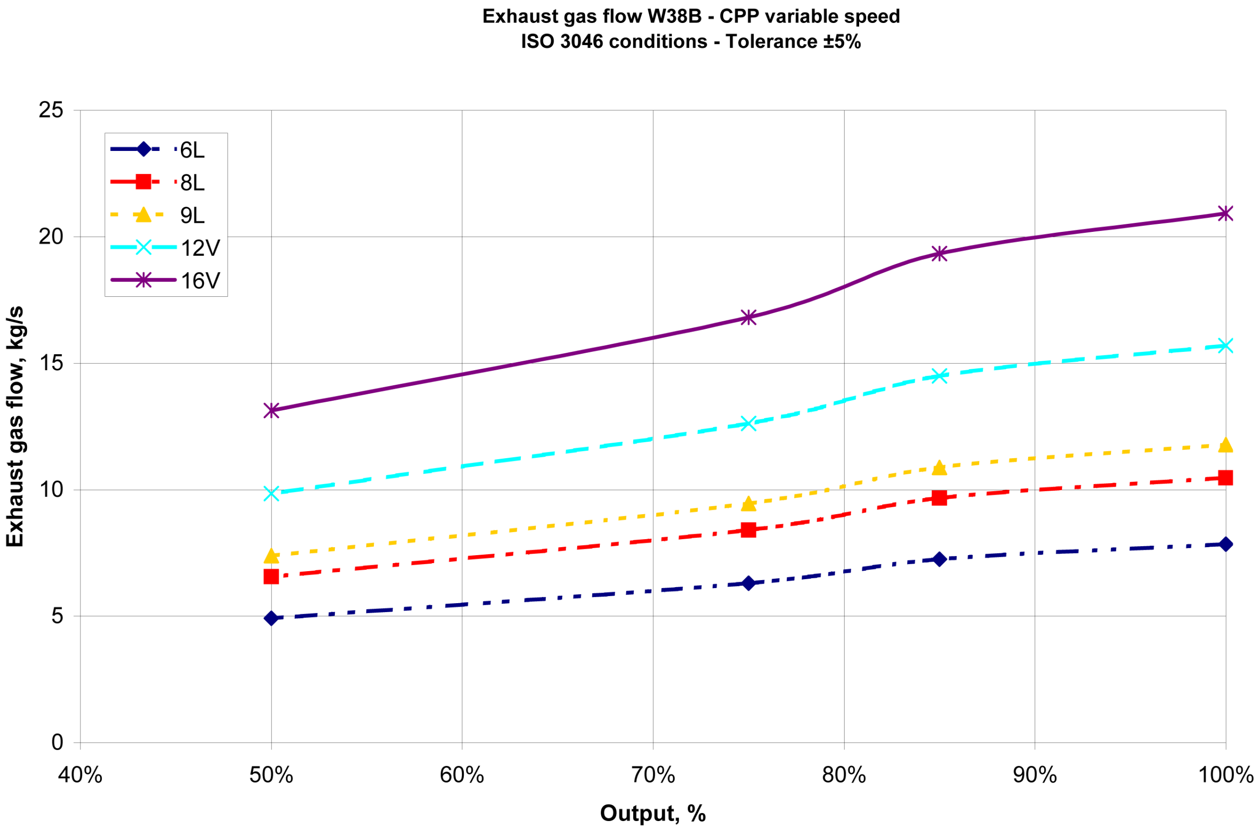


Figure 3.3 Exhaust gas massflow, W38B FPP

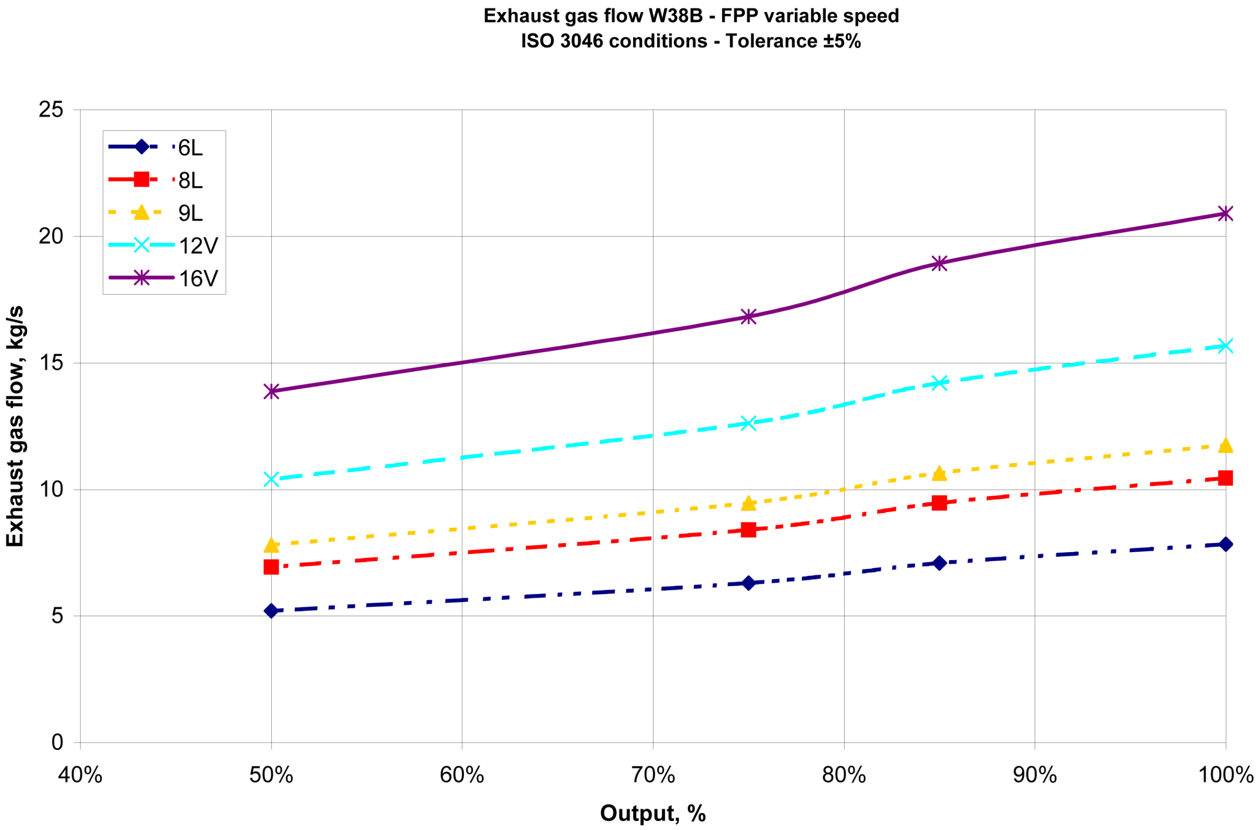


Figure 3.4 Exhaust gas temperature

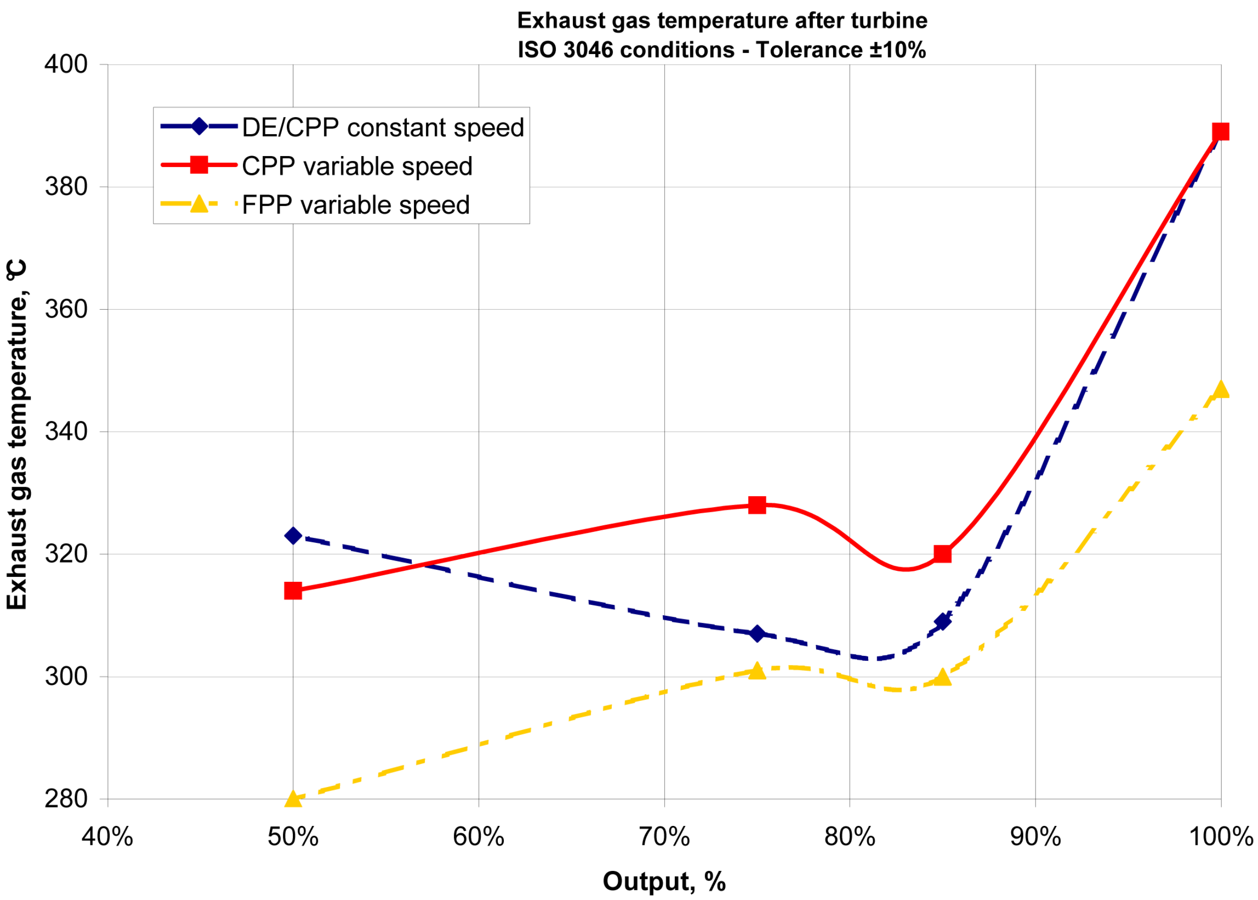


Figure 3.5 HT circuit, W38B DE/CPP

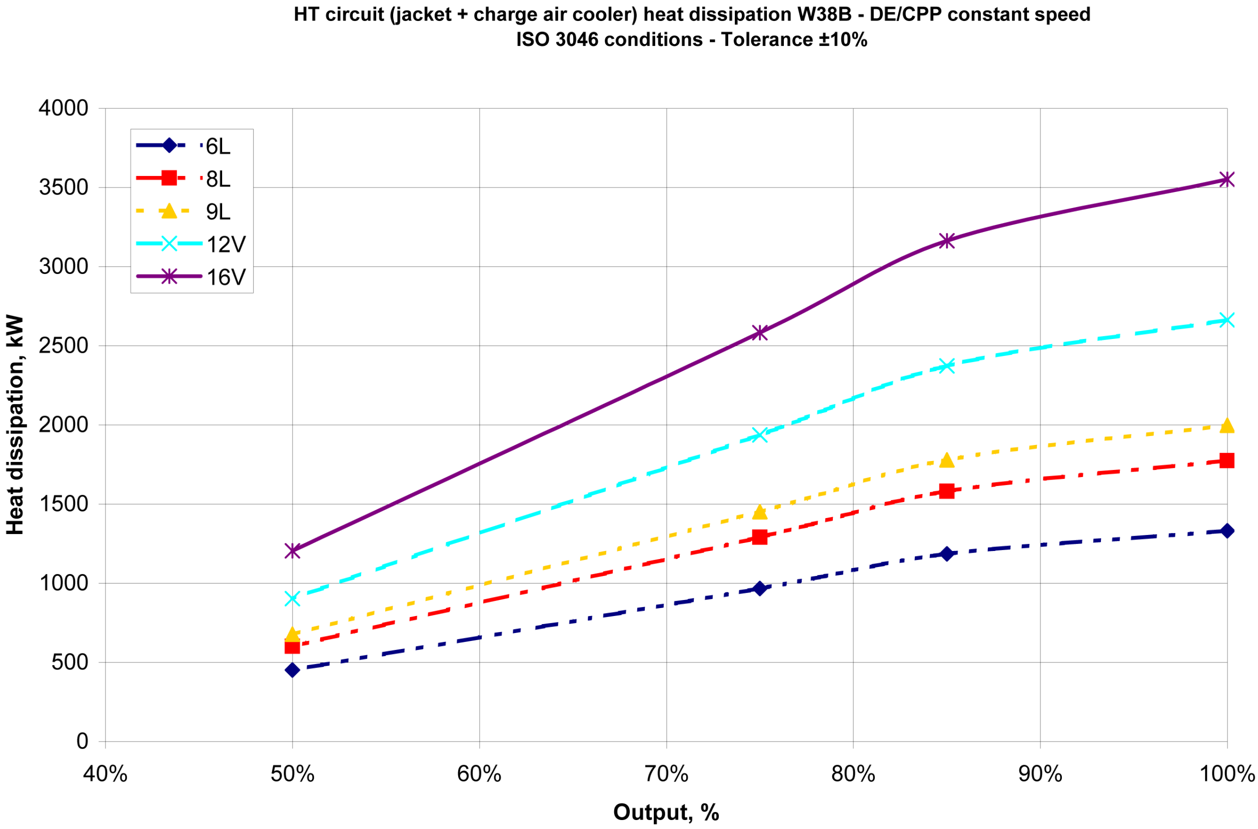


Figure 3.6 HT circuit, W38B CPP

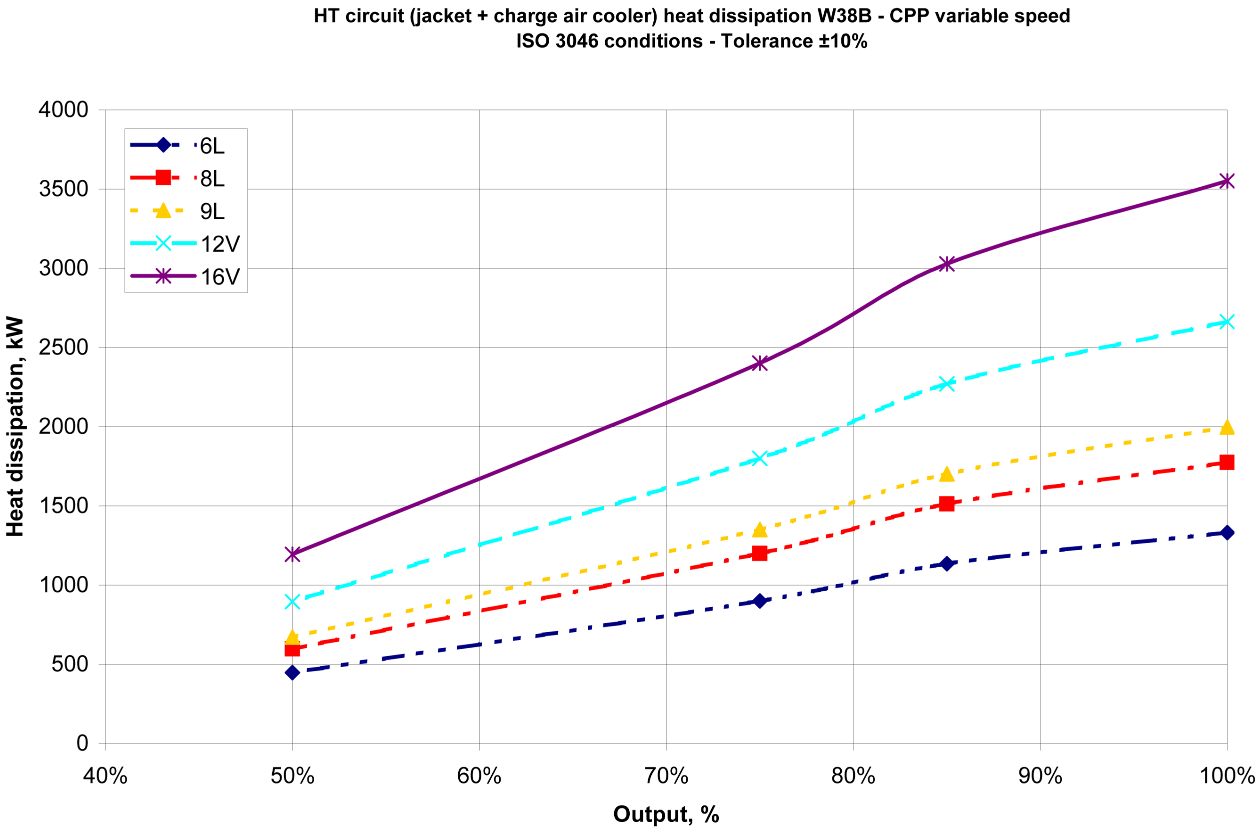


Figure 3.7 HT circuit, W38B FPP

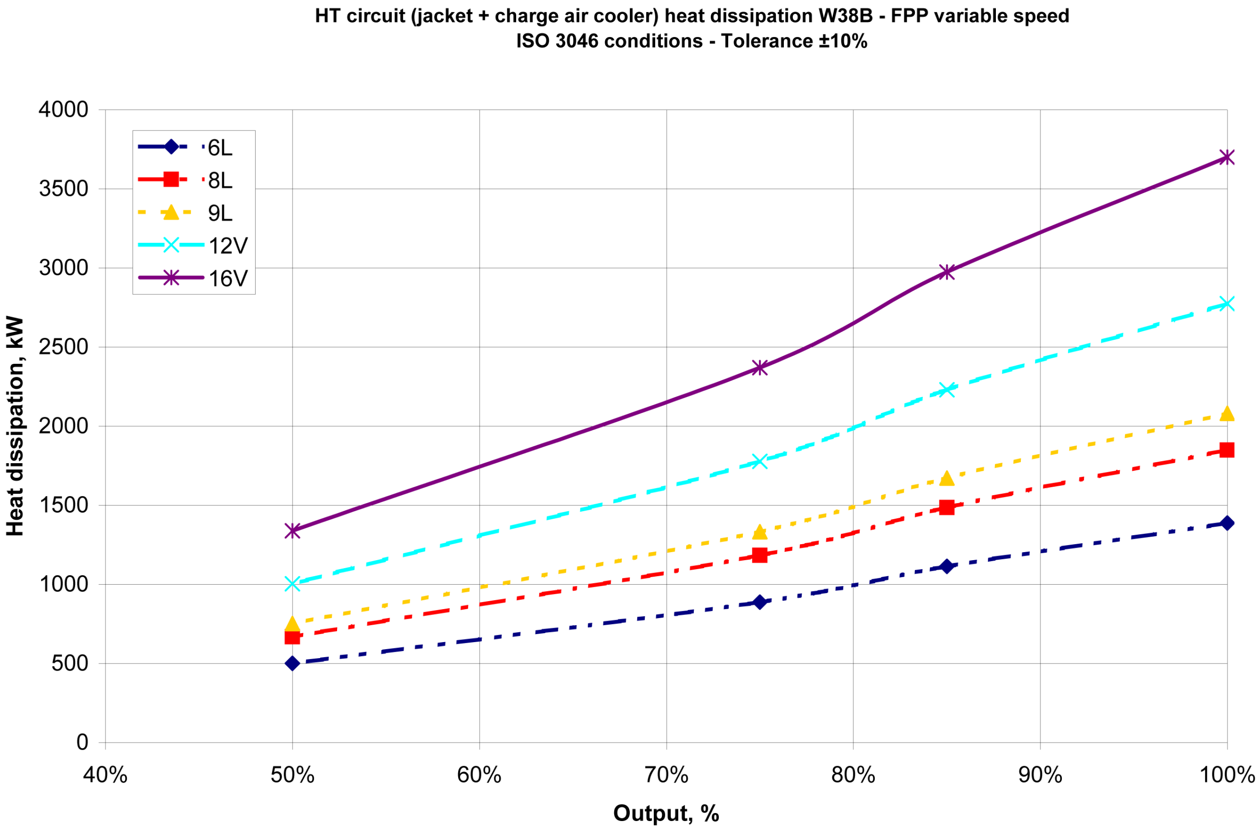


Figure 3.8 LT circuit, W38B DE/CPP

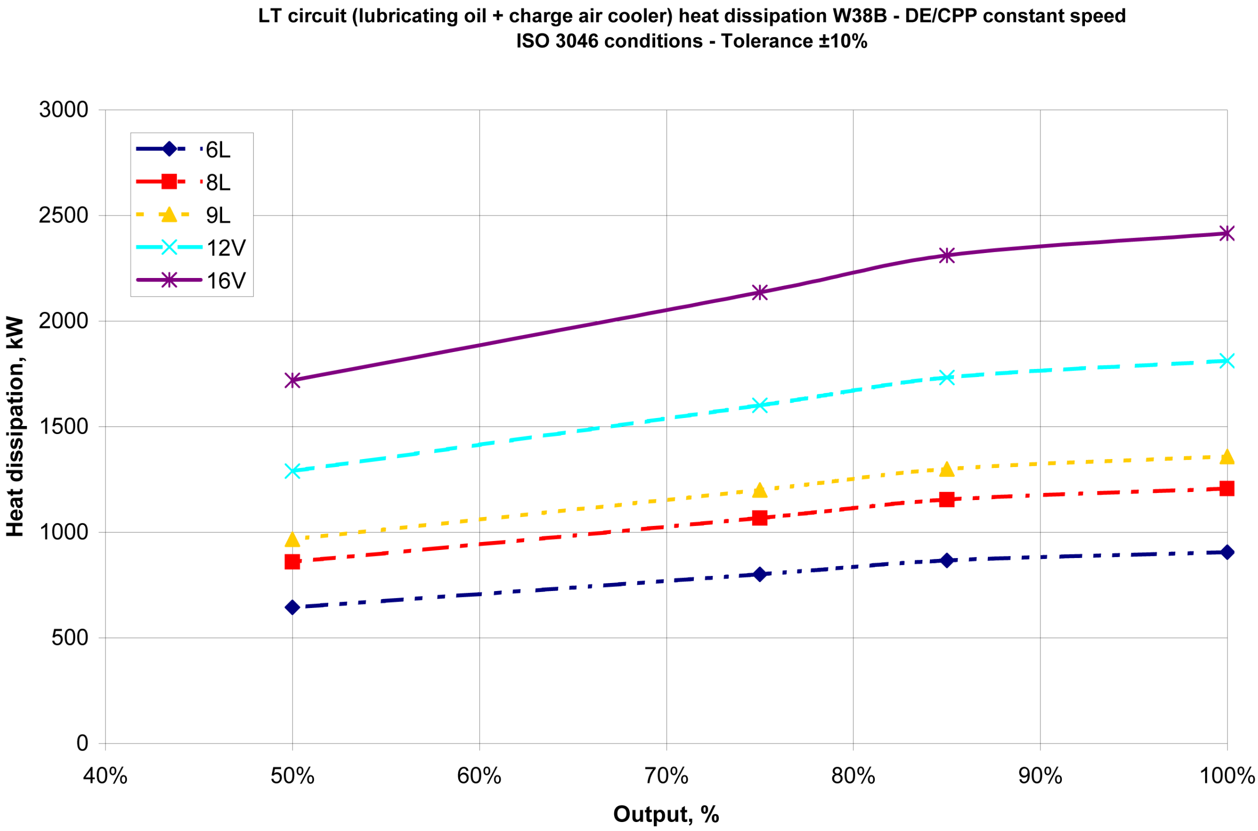


Figure 3.9 LT circuit, W38B CPP

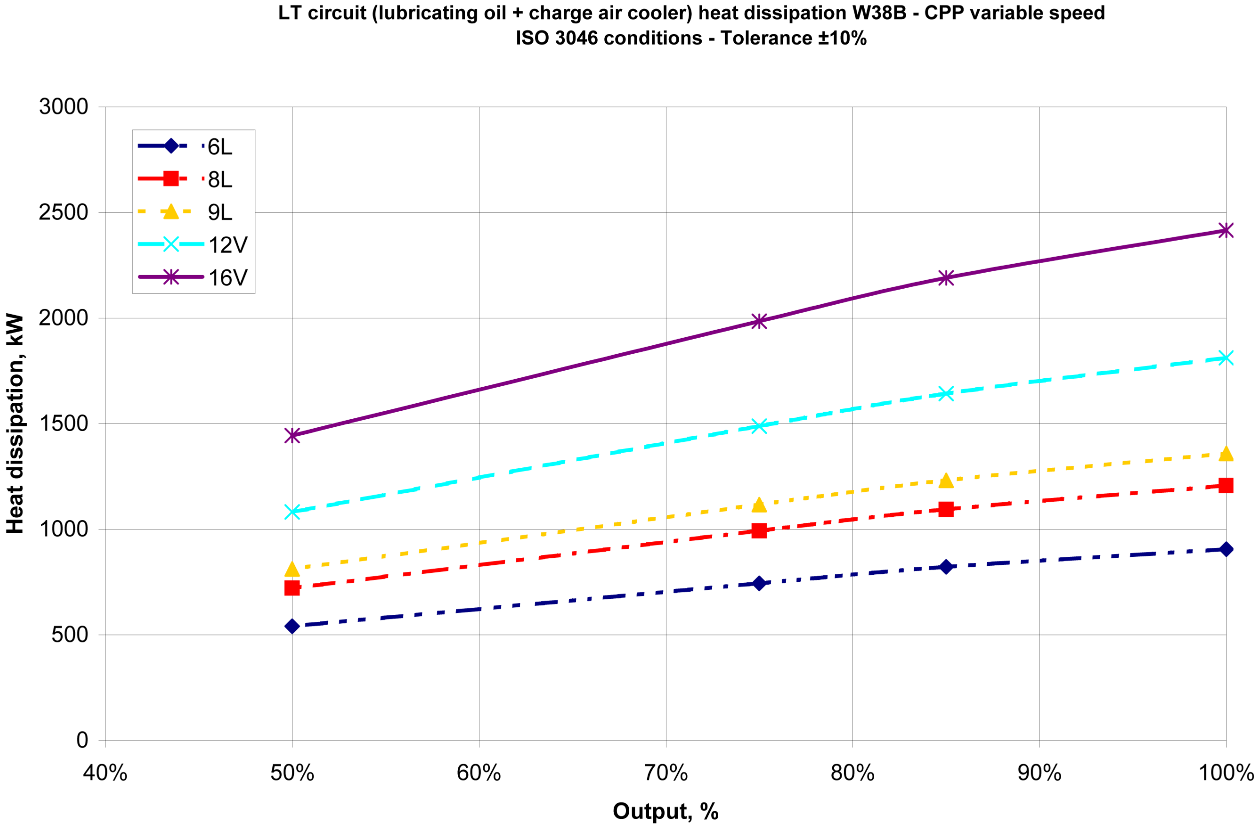


Figure 3.10 LT circuit, W38B FPP

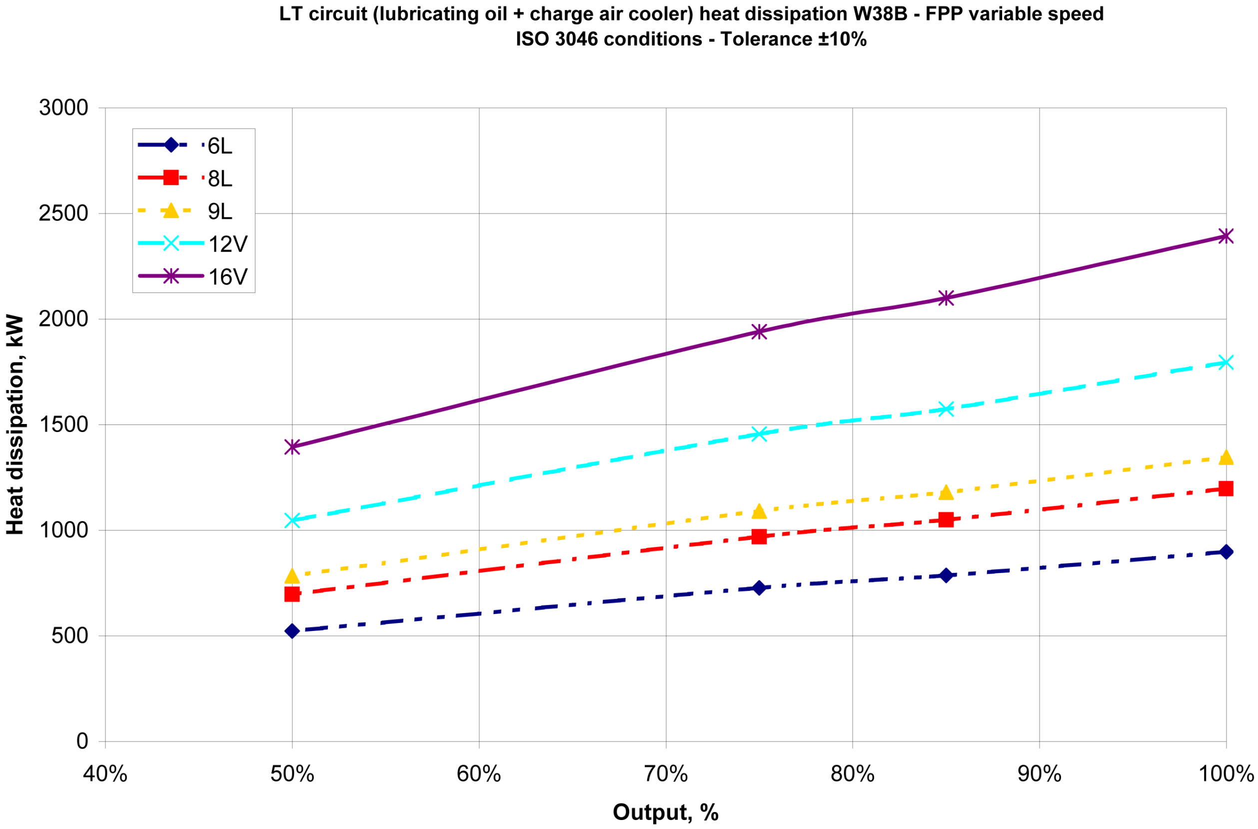


Table 3.2 Correction factor for suction air temperature

Air and exhaust mass flow [kg/s]	0.0 %	per 10°C higher suction air temp.
Exhaust gas temperature [°C]	+ 0.3 °C	per 10°C higher suction air temp.
Charge air heat, total [kW]	+ 10.1 %	per 10°C higher suction air temp.
HT [kW]	+ 14.1 %	per 10°C higher suction air temp.
LT [kW]	+ 3.2 %	per 10°C higher suction air temp.
Jacket water heat [kW]	+ 0.8 %	per 10°C higher suction air temp.
Lubricating oil heat [kW]	0.0 %	per 10°C higher suction air temp.
Air temp. after compressor [°C]	+ 16.1 °C	per 10°C higher suction air temp.

Table 3.3 Typical specific fuel oil consumption curves

Figure 3.11 L38B

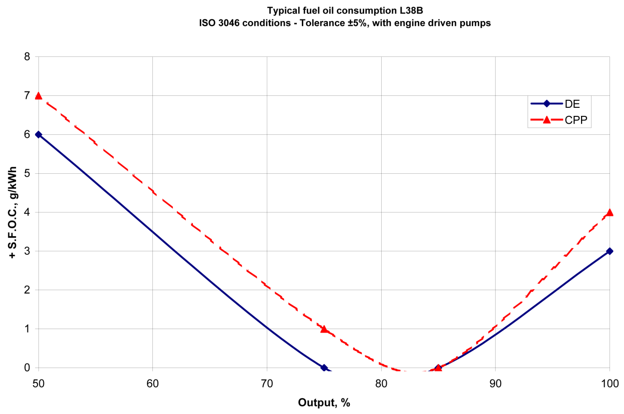
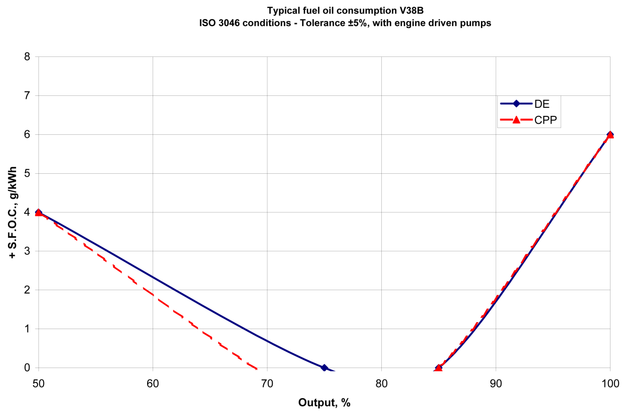


Figure 3.12 V38B



4. Description of the engine

4.1 Definitions

The following definitions are used in the Project Guide:

Operating side
Longitudinal side of the engine where the operating controls are located

Non-operating side
Longitudinal side opposite of the operating side

Driving end
End of the engine where the flywheel is located

Free end
The end opposite the driving end

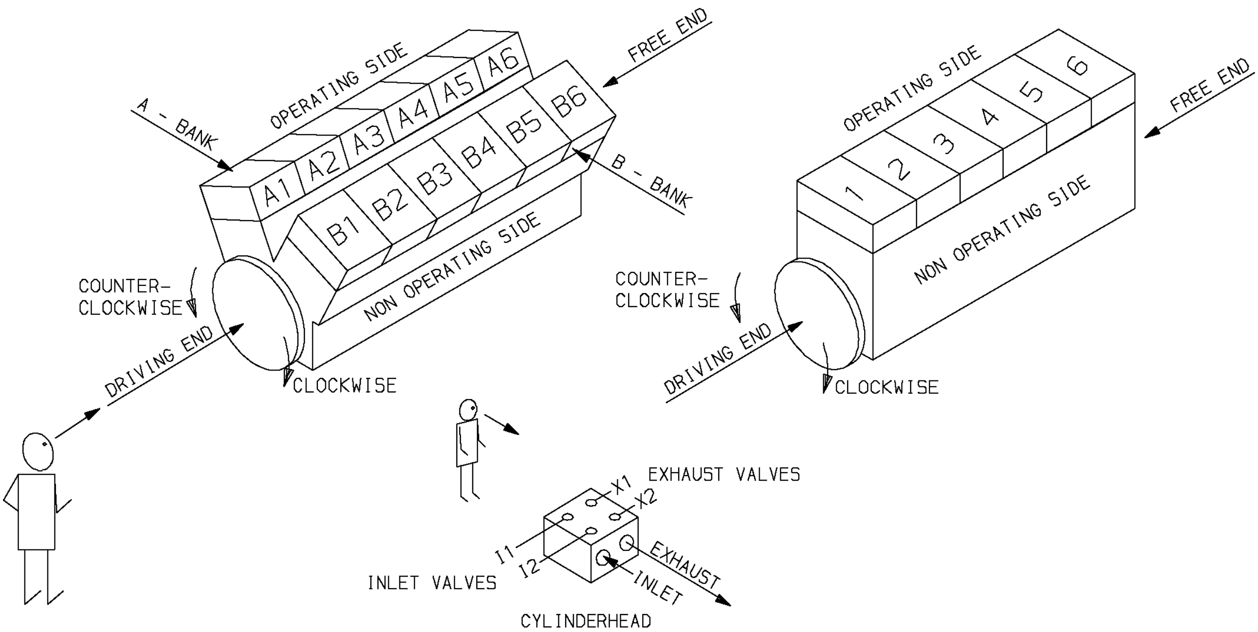
Designation of cylinders
Designation of cylinders begins at the driving end

Clockwise rotating
The rotation as viewed from the position of the observer

A-bank and B-bank
See figure 4.1 in relation to observer

Inlet and exhaust valves
See figure 4.1 in relation to observer

Figure 4.1 Definitions (9604DT105)



4.2 Engine block

The engine block, made of nodular cast iron, is cast in one piece for all cylinder numbers. It incorporates the jacket water manifold, the camshaft bearing housings and the charge air receiver. In V- engines the charge air receiver is located between the cylinder banks, partly in a separate casting.

The bearing caps, made of nodular cast iron, are fixed from below by two hydraulically tightened studs. They are guided sideways by the engine block at the top as well as the bottom. Hydraulically tightened horizontal side studs at the lower guiding provide a very rigid crankshaft bearing.

For in-line engines the lubricating oil is led to the bearings and piston through channels integrated in the engine block. For V-engines a hydraulic jack is integrated in the oil supply lines in the sump, in this case the lubricating oil is led to the bearings and piston through these jackets. A combined flywheel/axial bearing is located at the driving end of the engine.

The oil sump, a light welded design, is mounted from below on the engine block and sealed by O-rings. The oil sump is of the dry sump design. The dry sump is drained at either end (free choice) to a separate system oil tank.

The cast-on engine feet enables both rigid and resilient mounting. For resilient mounted in-line engines an additional support between the engine feet and flexible element is mounted (see chapter 16). In addition, in the latter the engine block is rigid that no intermediate base frame is necessary.

4.3 Crankshaft

The crankshaft is forged in one piece and mounted on the engine block in an underslung way. The crankshaft satisfies the requirements of all classification societies.

The connecting rods, at the same crank in the V-engine, are arranged side-by-side in order to achieve as vast standardization as possible of the In-line and V-engine details. For the same reason, the diameters of the crank pins and journals are equal irrespective of the cylinder number.

The crankshaft is fully balanced to counteract bearing loads from eccentric masses. The crankshaft is provided with a torsional vibration damper at the free end of the engine.

4.4 Connecting rod

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

The connecting rod is of forged alloy steel and fully machined with round sections. All connecting rod studs are hydraulically tightened. The gudgeon pin bearing is of tri-metal type. Oil is led to the gudgeon pin bearing and piston through a bore in the connecting rod.

4.5 Main bearings and big end bearings

The main bearings and the big end bearings are of bimetal design; the aluminum-tin running layer is attached to the steel back by a fatigue resistant bonding layer. This bearing design enables the combination of low wear rates with good running properties.

4.6 Cylinder liner

The cylinder liners are centrifugal cast of a special alloyed cast iron. The top collar of the cylinder liner is provided with bore cooling for efficient control of the liner temperature. The liner is equipped with an anti-polishing ring, preventing bore polishing.

4.7 Piston

The piston is of the composite type with steel crown and nodular cast iron skirt. A piston skirt lubricating system featuring two lubricating bores in a groove on the piston skirt lubricates the piston skirt/cylinder liner. The piston top is oil cooled by means of “the shaker effect”. For prolonged lifetime of piston rings and grooves, the piston ring grooves are hardened.

4.8 Piston rings

The piston ring set consists of two chromium-plated compression rings and one spring-loaded oil scraper ring with chromium-plated edges.

4.9 Cylinder head

The cylinder head is made of nodular cast iron. The thermally loaded flame plate is cooled efficiently by cooling water. Via cooling channels in the bridges between the valves, this water is led from the circumference of the cylinder liner towards the centre into the cylinder head. The exhaust valve seats are directly water-cooled.

All valves are equipped with valve rotators.

Three main connection pipes are fitted to the cylinder head. They connect the following media with the cylinder head:

- Charge air from the air receiver
- Exhaust gas to exhaust system
- Cooling water from cylinder head to the return manifold

There are also connections for the fuel supply and for the supply of oil used for lubricating components mounted on the cylinder head.

4.10 Camshaft and valve mechanism

The cam profiles are integrated in the drop forged shaft material. The bearing journals are made in separate pieces, which are fitted to the camshaft pieces by flange connections. This solution allows sideways removal of the camshaft pieces. The camshaft bearing housings are integrated in the engine block casting. The camshaft bearings are installed by means of frozen-in procedure and removed by means of a hydraulic tool. The camshaft covers, one for each cylinder, are sealed against the engine block by a closed sealing profile.

The valve tappets are of the piston type with a certain self-adjustment of roller against cam to give an even distribution of the contact pressure. The valve springs make the roller follow the cam continuously.

4.11 Camshaft drive

The camshafts is driven by the crankshaft by a gear train. The driving gearwheel is fixed to the crankshaft by means of flange connections.

4.12 Turbocharging and charge air cooling

The selected turbocharger offers the ideal combination of high-pressure ratios and good efficiency both at full and part load.

In-line engines are equipped with one turbocharger and V-engines with two turbochargers (one turbocharger per cylinder bank).

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

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

4.13 Injection equipment

There is one fuel injection pump per cylinder with shielded high-pressure pipe to the injector. The injection pumps, which are of the flow-through type, ensure good performance with all types of fuel. The pumps are completely sealed from the camshaft compartment and are provided with a separate drain for leak oil.

Setting the fuel rack to zero position stops the fuel injection. The fuel rack of each injection pump is fitted with a stop cylinder. The fuel pump housing is manufactured to tight tolerances, so pre-calibrated pumps are interchangeable.

The fuel injection pump design is a reliable mono-element type designed for injection pressures up to 180 [Mpa] (1800 bar). The constant pressure relief valve system provides for optimum injection, which guarantees long intervals between overhauls. The injector holder is designed for easy maintenance.

4.14 Exhaust pipes

The exhaust pipes are of nodular cast iron. The connections are of V-clamp type. The complete exhaust system is enclosed in an insulating box consisting of easily removable panels. For in-line engines, this box is supported on the inlet air bends. For V-engines, it is supported by additional brackets. Mineral wool is used as insulating material.

4.15 Cooling system

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

The HT-water cools cylinders, cylinder heads and the 1st stage of the charge air cooler.

The LT-water cools the 2nd stage of the charge air cooler and the lubricating oil cooler.

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

4.16 Fuel system

The low pressure fuel piping is located in a hotbox, providing maximum reliability and safety when using preheated heavy fuels. The fuel oil supply and discharge pipes are mounted directly to the injection pump housings.

Leakage fuel from pipes, fuel injector and pump is collected in closed piping system (clean fuel system)

The low-pressure fuel system has oversized supply-lines in order to achieve more volume. This additional volume, together with restrictions between supply line and injection pump plunger, will provide minimal pressure pulses in the low pressure fuel system.

4.17 Common Rail, optional

The design of the engine fuel system is prepared to implement common rail technologies. This gives optimal smoke behaviour especially at part load.

In the Common Rail fuel injection system fuel, Heavy Fuel Oil (HFO) or Marine Diesel Oil (MDO) is pressurised to a rail (accumulators and high pressure pipes) from where fuel is fed to each fuel injection valves. The fuel injection system consists of high pressure (HP) pumps, accumulators, start-up and safety valves (SSV), injection valves and high pressure (HP) pipes. The Wärtsilä CR system has one HP pump and one fuel accumulator per two cylinders. In case of odd cylinder number (per bank), one additional accumulator feeds one cylinder and it is connected to nearest accumulator. The fuel rail consists of a series of accumulators, which are joined by high pressure pipes. Some of the accumulators are equipped with an electro-hydraulic Start- up and Safety Valve (SSV) to depressurise the rail in shut down or in a failure situation and also to make the fuel circulation between pumps and accumulators possible before start-up. The injectors are electro-hydraulic valves. Hydraulic control oil pressure required in the CR system is generated with an engine driven piston pump using engine lubricating oil.

4.18 Lubricating oil system

For the in-line engine the engine mounted system consists of main lubricating oil pump, pre-lubricating oil pump, oil cooler, thermostatic valve, automatic back flush filter, centrifugal filter and oil dry sump. For V-engines the engine mounted system consists of main lubricating oil pump, centrifugal filter and oil dry sump.

The oil system is lubricating the main bearings, the cylinder liners, camshaft bearings, injection pump tappets, pistons, rocker arm bearings and valve mechanism and gear wheel bearings. The turbocharger is also connected to the engine lubricating system.

4.19 Starting air system

The engine starts by compressed air directly injected into the cylinders throught the starting air valves in the cylinder heads. V-engines are provided with starting air valves for the cylinders on the A-bank only. The main starting valve is built on the engine.

All engines have built-on non-return valves and flame arrester. As a precaution the engine can not be started when the turning gear is engaged.

Figure 4.2 Cross section of an in-line engine

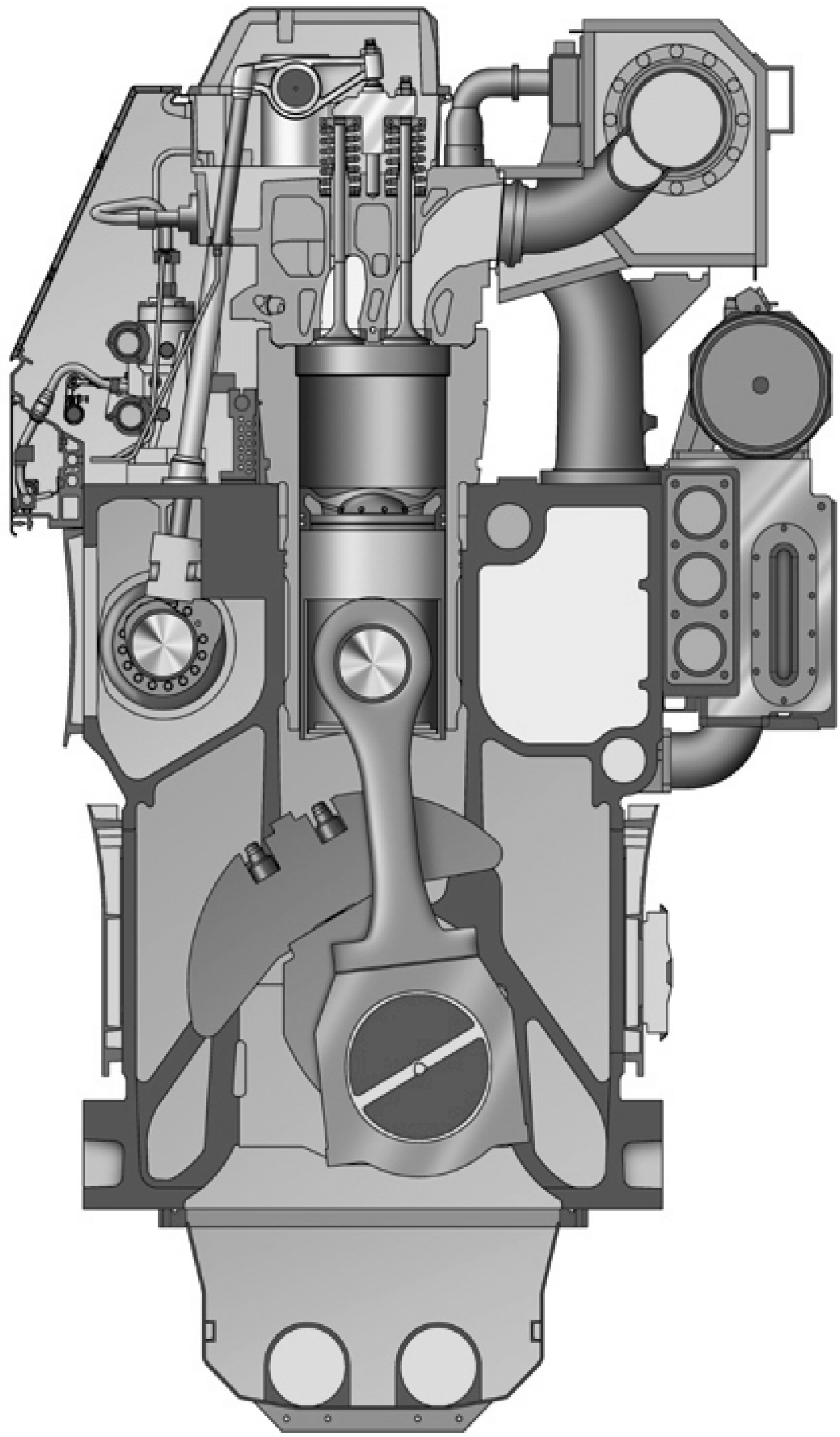
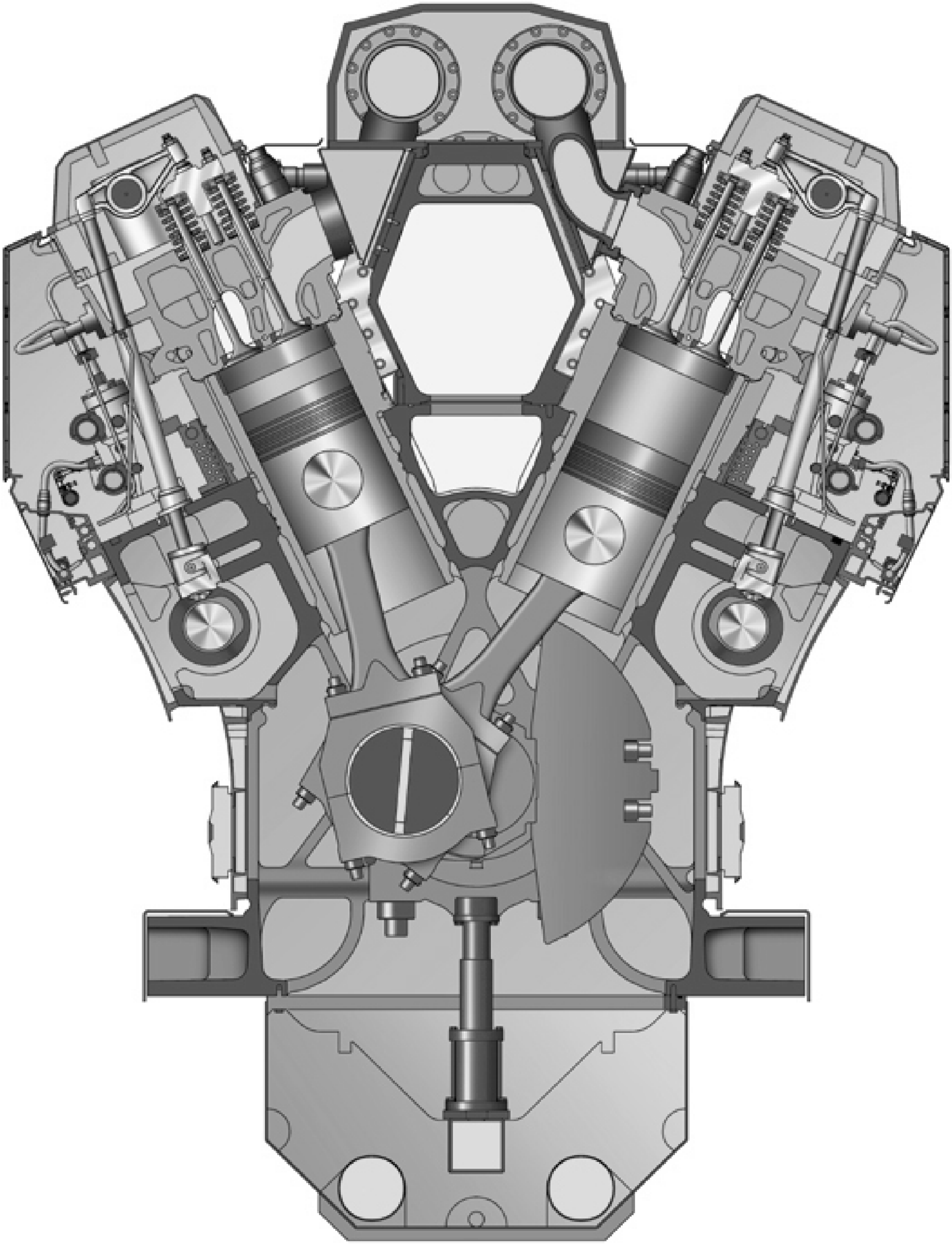


Figure 4.3 Cross section of V-engine



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*.

Table 5.1 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
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 and compressed air piping depends only on the allowed pressure loss in the piping, which has to be calculated project specifically.

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 Project 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 5.2 Classes of piping systems as per DNV rules

Media	Class I		Class II		Class III	
	MPa (bar)	°C	MPa (bar)	°C	MPa (bar)	°C
Steam	> 1.6 (16)	or > 300	< 1.6 (16)	and < 300	< 0.7 (7)	and < 170
Flammable fluid	> 1.6 (16)	or > 150	< 1.6 (16)	and < 150	< 0.7 (7)	and < 60
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 5.3 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.

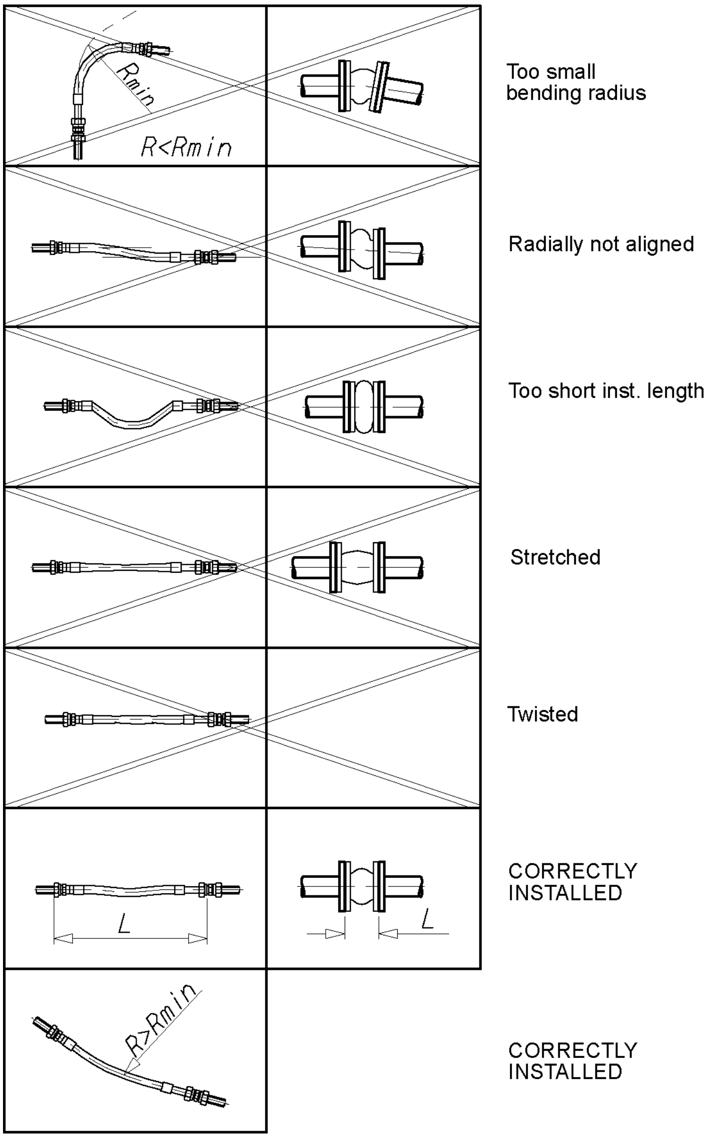
5.8 Flexible pipe connections

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.

Figure 5.1 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 *5.2*. A typical pipe clamp for a fixed support is shown in Figure *5.3*. Pipe clamps must be made of steel; plastic clamps or similar may not be used.

Figure 5.2 Flange supports of flexible pipe connections (4V60L0796)

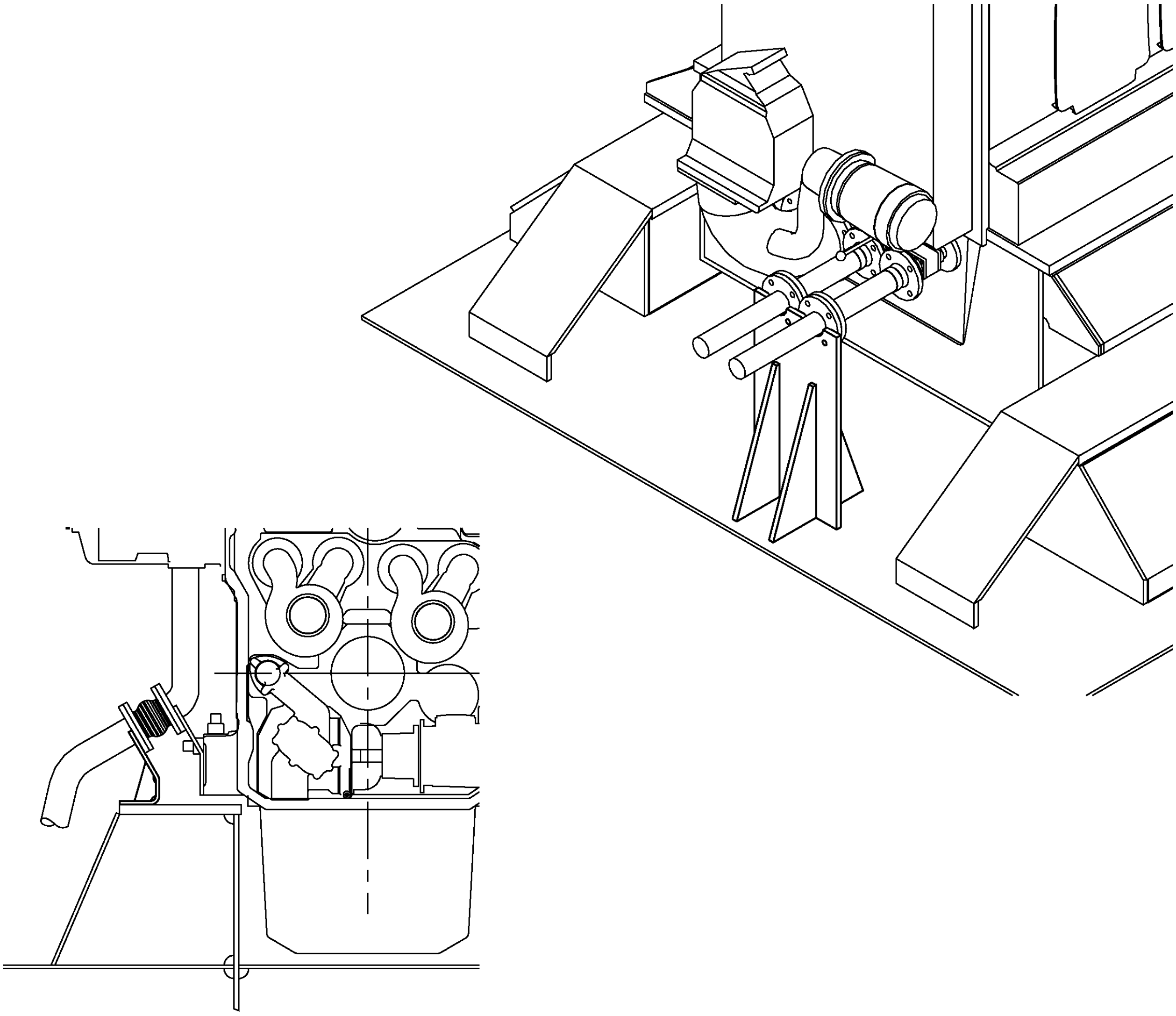
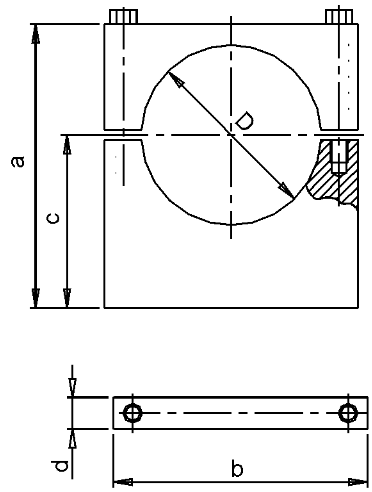


Figure 5.3 Pipe clamp for fixed support (4V61H0842)



DN	du [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

du = Pipe outer diameter

6. Fuel oil system

6.1 Acceptable fuel characteristics

The fuel specifications are based on the ISO 8217:2005 (E) standard. Observe that a few additional properties not included in the standard are listed in the tables.

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

Residual fuel grades are referred to as HFO (Heavy Fuel Oil). The fuel specification HFO 2 covers the categories ISO-F-RMA 30 to RMK 700. Fuels fulfilling the specification HFO 1 permit longer overhaul intervals of specific engine components than HFO 2.

Table 6.1 MDF specifications

Property	Unit	ISO-F-DMX	ISO-F-DMA	ISO-F-DMB	ISO-F-DMC 1)	Test method ref.
Appearance		Clear and bright		-	-	Visual inspection
Viscosity, before injection pumps, min. 2)	cSt	2.0	2.0	2.0	2.0	ISO 3104
Viscosity, before injection pumps, max. 2)	cSt	24	24	24	24	ISO 3104
Viscosity at 40°C, max.	cSt	5.5	6.0	11.0	14.0	ISO 3104
Density at 15°C, max.	kg/m³	—	890	900	920	ISO 3675 or 12185
Cetane index, min.		45	40	35	—	ISO 4264
Water, max.	% volume	—	—	0.3	0.3	ISO 3733
Sulphur, max.	% mass	1.0	1.5	2.0 3)	2.0 3)	ISO 8574 or 14596
Ash, max.	% mass	0.01	0.01	0.01	0.05	ISO 6245
Vanadium, max.	mg/kg	—	—	—	100	ISO 14597 or IP 501 or 470
Sodium before engine, max. 2)	mg/kg	—	—	—	30	ISO 10478
Aluminium + Silicon, max	mg/kg	—	—	—	25	ISO 10478 or IP 501 or 470
Aluminium + Silicon before engine, max. 2)	mg/kg	—	—	—	15	ISO 10478 or IP 501 or 470
Carbon residue on 10 % volume distillation bottoms, max.	% mass	0.30	0.30	—	—	ISO 10370
Carbon residue, max.	% mass	—	—	0.30	2.50	ISO 10370
Flash point (PMCC), min.	°C	60 2)	60	60	60	ISO 2719
Pour point, winter quality, max.	°C	—	-6	0	0	ISO 3016
Pour point, summer quality, max	°C	—	0	6	6	ISO 3016
Cloud point, max.	°C	-16	—	—	—	ISO 3015
Total sediment existent, max.	% mass	—	—	0.1	0.1	ISO 10307-1
Used lubricating oil, calcium, max. 4)	mg/kg	—	—	—	30	IP 501 or 470
Used lubricating oil, zinc, max. 4)	mg/kg	—	—	—	15	IP 501 or 470
Used lubricating oil, phosphorus, max. 4)	mg/kg	—	—	—	15	IP 501 or 500

Remarks:

1) Use of ISO-F-DMC category fuel is allowed provided that the fuel treatment system is equipped with a fuel centrifuge.

2) Additional properties specified by the engine manufacturer, which are not included in the ISO specification or differ from the ISO specification.

3) A sulphur limit of 1.5% mass will apply in SO_x emission controlled areas designated by IMO (International Maritime Organization). There may also be other local variations.

4) A fuel shall be considered to be free of used lubricating oil (ULO), if one or more of the elements calcium, zinc, and phosphorus are below or at the specified limits. All three elements shall exceed the same limits before a fuel shall be deemed to contain ULO's.

Table 6.2 HFO specifications

Property	Unit	Limit HFO 1	Limit HFO 2	Test method ref.
Viscosity at 100°C, max. Viscosity at 50°C, max. Viscosity at 100°F, max	cSt cSt Redwood No. 1 s	55 700 7200	55 700 7200	ISO 3104
Viscosity, before injection pumps [4]	cSt	16...24	16...24	
Density at 15°C, max.	kg/m³	991 / 1010 [1]	991 / 1010 [1]	ISO 3675 or 12185
CCAI, max.[4]		850	870 [2]	ISO 8217, Annex B
Water, max.	% volume	0.5	0.5	ISO 3733
Water before engine, max.[4]	% volume	0.3	0.3	ISO 3733
Sulphur, max.	% mass	1.5	4.5 [5]	ISO 8754 or 14596
Ash, max.	% mass	0.05	0.15	ISO 6245
Vanadium, max. [3]	mg/kg	100	600 [3]	ISO 14597 or IP 501 or 470
Sodium, max. [3,4]	mg/kg	50	50	ISO 10478
Sodium before engine, max.[3,4]	mg/kg	30	30	ISO 10478
Aluminium + Silicon, max.	mg/kg	30	80	ISO 10478 or IP 501 or 470
Aluminium + Silicon before engine, max.[4]	mg/kg	15	15	ISO 10478 or IP 501 or 470
Carbon residue, max.	% mass	15	22	ISO 10370
Asphaltenes, max.[4]	% mass	8	14	ASTM D 3279
Flash point (PMCC), min.	°C	60	60	ISO 2719
Pour point, max.	°C	30	30	ISO 3016
Total sediment potential, max.	% mass	0.10	0.10	ISO 10307-2
Used lubricating oil, calcium, max. [6]	mg/kg	30	30	IP 501 or 470
Used lubricating oil, zinc, max. [6]	mg/kg	15	15	IP 501 or 470
Used lubricating oil, phosphorus, max. [6]	mg/kg	15	15	IP 501 or 500

Remarks:

1) Max. 1010 kg/m³ at 15°C provided the fuel treatment system can remove water and solids.

2) 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.

3) Sodium contributes to hot corrosion on exhaust valves when combined with high sulphur and vanadium contents. Sodium also contributes strongly to fouling of the exhaust gas turbine at high loads. The aggressiveness of the fuel depends not only on its proportions of sodium and vanadium but also on the total amount of ash constituents. 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 that specified above, can cause hot corrosion on engine components.

4) Additional properties specified by the engine manufacturer, which are not included in the ISO specification.

5) A sulphur limit of 1.5% mass will apply in SO_x emission controlled areas designated by IMO (International Maritime Organization). There may also be other local variations.

6) A fuel shall be considered to be free of used lubricating oil (ULO), if one or more of the elements calcium, zinc, and phosphorus are below or at the specified limits. All three elements shall exceed the same limits before a fuel shall be deemed to contain ULO's.

The limits above concerning HFO 2 also correspond to the demands of the following standards:

- BS MA 100: 1996, RMH 55 and RMK 55
- CIMAC 2003, Grade K 700
- ISO 8217: 2005(E), ISO-F-RMK 700

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 Liquid bio fuels

The engine can be operated on liquid bio fuels, according to the specification below, without reduction in the rated output. However, since liquid bio fuels have typically lower heating value than fossil fuels, the capacity of the fuel injection system must be checked for each installation. Biodiesels that fulfil standards like ASTM D 6751-02 or DIN EN 14214 can be used as fuel oil as long as the specification is fulfilled.

The specification is valid for raw vegetable based liquid bio fuels, like palm oil, coconut oil, copra oil, rape seed oil, etc. but is not valid for animal based bio fuels.

Table 6.3 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	2.0	
Viscosity, before injection pumps, max.	cSt	24	
Density at 15°C, max.	kg/m^3	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	0.30	ISO 10370
Ash, max.	% mass	0.05	ISO 6245
Phosphorus, max.	mg/kg	100	ISO 10478
Silicon, max.	mg/kg	10	ISO 10478
Alkali content (Na+K), max.	mg/kg	30	ISO 10478
Flash point (PMCC), min.	°C	60	ISO 2719
Pour point, max.	°C	[3)]	ISO 3016
Cloud point, max.	°C	[3)]	ISO 3015
Cold filter plugging point, max.	°C	[3)]	IP 309
Copper strip corrosion (3h at 50°C), max.		1b	ASTM D130
Steel corrosion (24/72h at 20, 60 and 120°C), max.		No signs of corrosion	LP 2902
Acid number, max.	mg KOH/g	5.0	ASTM D664
Strong acid number, max.	mg KOH/g	0.0	ASTM D664
Iodine number, max.		120	ISO 3961

Remarks:

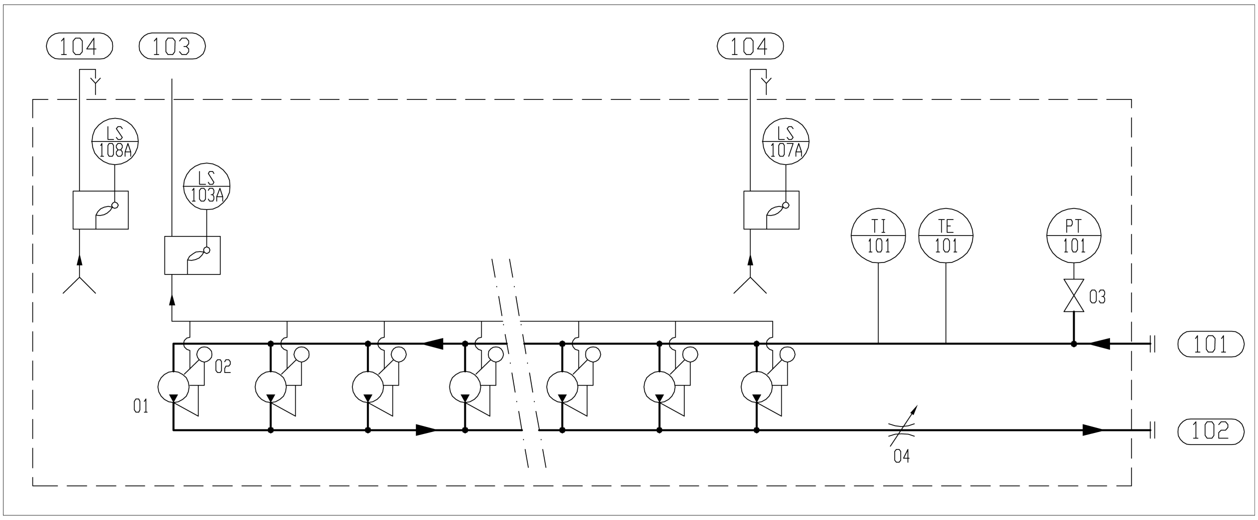
1) If injection viscosity of max. 24 cSt cannot be achieved with an unheated fuel, fuel oil system has to be equipped with a heater.

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

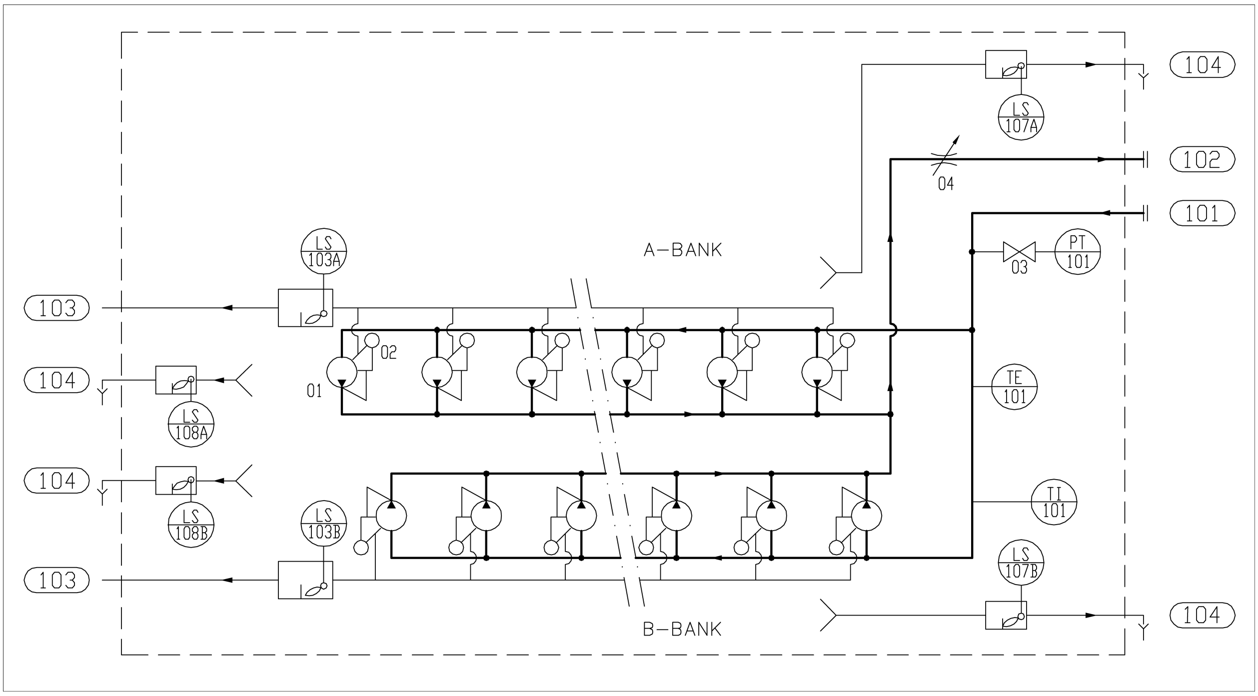
6.2 Internal fuel oil system

Figure 6.1 Internal fuel system, in-line engine (DAAE039748a)



System components		Sensors and indicators	
01	Injection pump	LS103A	Fuel oil leakage, injection pipe
02	Injection valve	LS107A/LS108A	Fuel oil leakage, dirty fuel
03	Valve	PT101	Fuel oil pressure, engine inlet
04	Adjustable orifice	TE101	Fuel oil temperature, engine inlet
		TI101	Fuel oil temperature, engine inlet (if GL)

Figure 6.2 Internal fuel system, V-engine (DAAE039749a)



System components		Sensors and indicators	
01	Injection pump	LS103A/LS103B	Fuel oil leakage, injection pipe, bank A/B
02	Injection valve	LS107A/LS107B	Fuel oil leakage, dirty fuel, bank A/B
03	Valve	LS108A/LS108B	Fuel oil leakage, dirty fuel, bank A/B
04	Adjustable orifice	PT101	Fuel oil pressure, engine inlet

System components	Sensors and indicators	
	TE101	Fuel oil temperature, engine inlet
	TI101	Fuel oil temperature, engine inlet (if GL)

Pipe connections		Size	Pressure class	Standard
101	Fuel inlet, in line	DN32	PN16	DIN2633/DIN2513 R13
101	Fuel inlet, V	DN50	PN16	DIN2633/DIN2513 V13
102	Fuel outlet, in line	DN32	PN16	DIN2633/DIN2513 R13
102	Fuel outlet, V	DN50	PN16	DIN2633/DIN2513 V13
103	Leak fuel drain, clean fuel	OD28	PN250	DIN2353
104	Leak fuel drain, dirty fuel, in line	OD18	PN400	DIN2353
104	Leak fuel drain, dirty fuel, V	OD28	PN250	DIN2353

Figure 6.3 Internal fuel and control oil system, in-line engine, common rail system (DAAE049807)

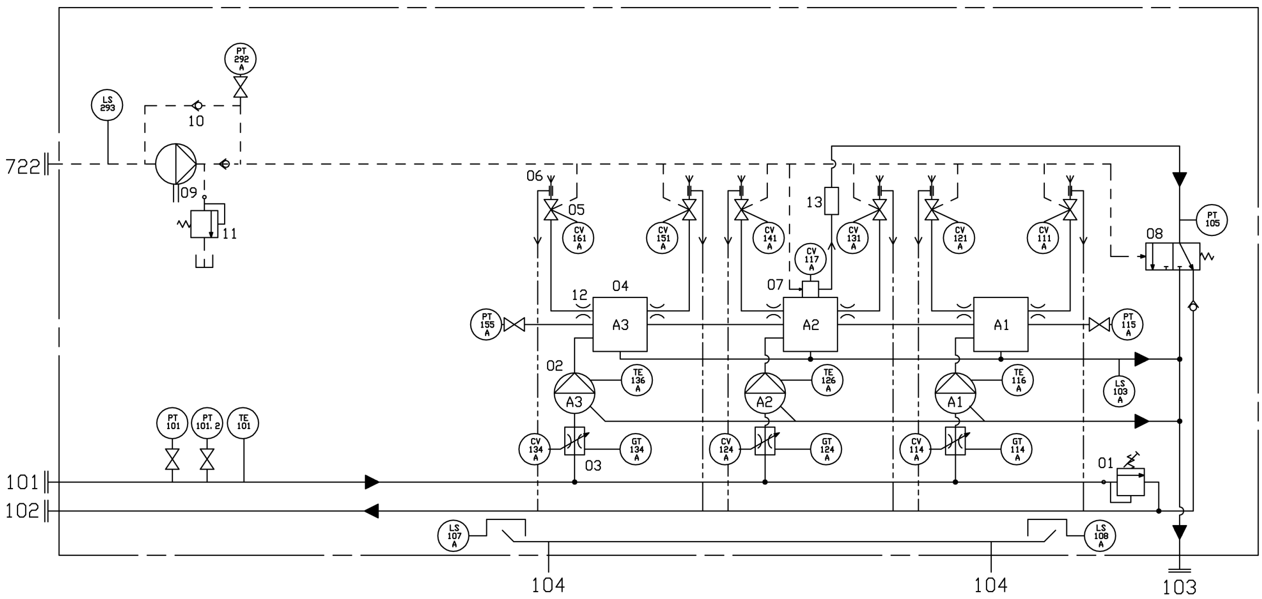
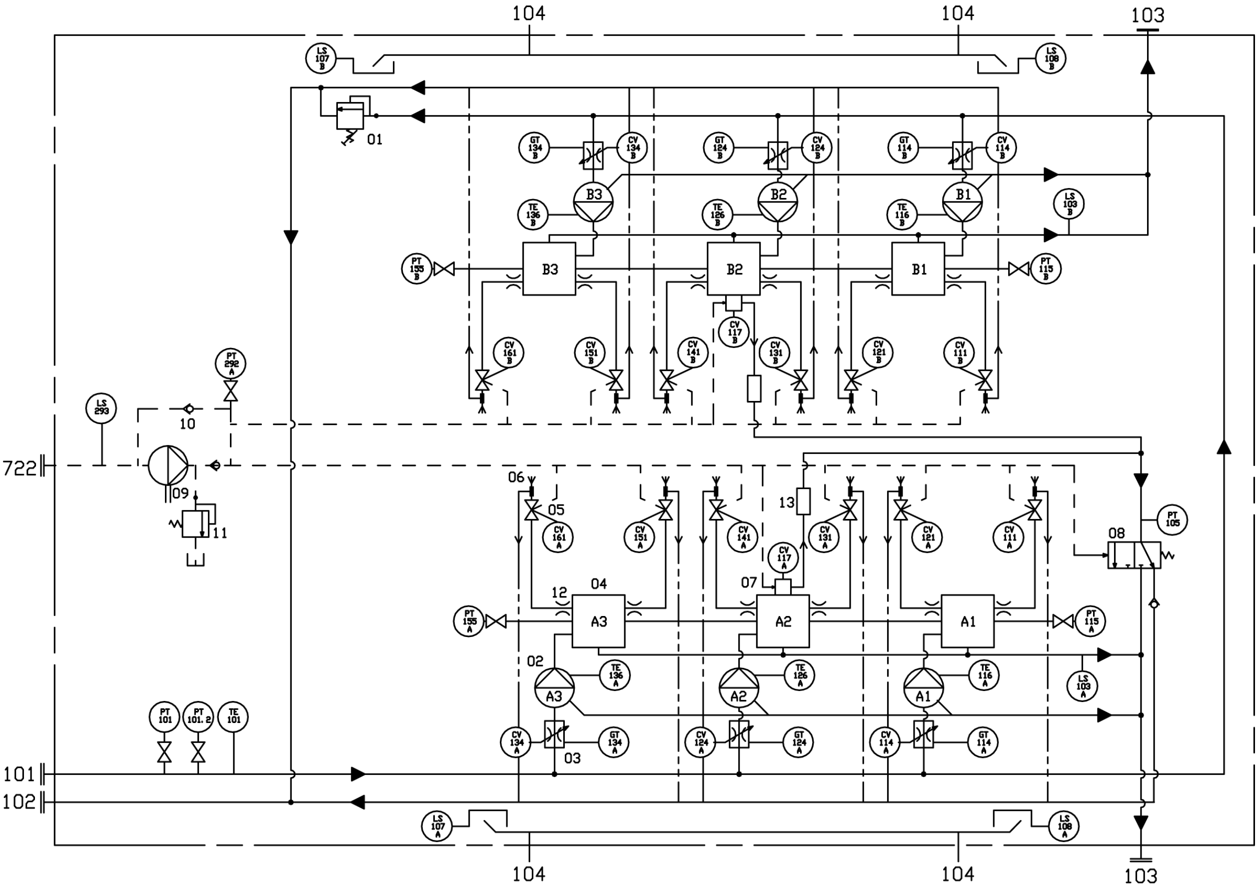


Figure 6.4 Internal fuel and control oil system, V-engine, common rail system (DAAE049809)



System components

01	Pressure regulating valve	08	3-way valve
02	Fuel pump (high pressure)	09	Control oil pump (high pressure)
03	Flow control valve	10	Non-return valve
04	Accumulator	11	Safety valve (29000 kPa)
05	Injector solenoid valve	12	Flow fuse
06	Fuel injector nozzle	13	Gas bottle
07	Start and safety valve (SSV)	Fluids:	------- Fuel line - - - - Control oil line

Pipe connections		Size	Pressure class	Standard
101	Fuel inlet, in-line engines	DN32	PN16	DIN 2633 / DIN 2513 R13
101	Fuel inlet, V engines	DN50	PN16	DIN 2633 / DIN 2513 R13
102	Fuel outlet, in-line engines	DN32	PN16	DIN 2633 / DIN 2513 R13
102	Fuel outlet, V engines	DN50	PN16	DIN 2633 / DIN 2513 R13
103	Leak fuel drain, clean fuel (to pressure-less tank)	DN25	PN16	DIN 2633 / DIN 2513 R13
104	Leak fuel drain, dirty fuel, in-line engines	OD18	PN250	DIN 2353
104	Leak fuel drain, dirty fuel, V engines	OD28	PN250	DIN 2353
722	Control oil from external filter	DN40	PN10	DIN 2576

Sensors and indicators

PT101	Fuel oil inlet pressure	CV114A/B...	Flow control valve (114...1X4)
TE101	Fuel oil inlet temperature	TE116A/B...	Fuel pump temperature (116...1X6)

Sensors and indicators

LS103A/B	Fuel oil leakage, injection pipe	PT115A/B	Rail pressure, DE
LS107A/108A	Fuel oil leakage, dirty fuel	PT155A/B	Rail pressure, FE
PT105	Fuel oil return flow valve inlet pressure	PT292	Control oil pressure, engine inlet
CV111A/B...	Fuel oil injection control (111...161)	LS293	Control oil leakage, high pressure pipe
CV117A/B	Start and safety valve (SSV)	PDS297	Control oil suction filter differential pressure (outside of the engine)
GT114A/B...	Flow control valve position (114...1X4)		

The engine is designed for continuous operation on heavy fuel oil (HFO). On request the engine can be built for operation exclusively on marine diesel fuel (MDF). It is however possible to operate HFO engines on MDF intermittently without any alternations. Continuous operation on HFO is recommended as far as possible.

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.

Engines with conventional fuel injection have a reducing valve in the fuel return line on the engine. The reducing valve ensures an even fuel flow through each engine. Engines with common rail fuel injection have a pressure control valve in the fuel return line on the engine, which maintains desired pressure before the injection pumps.

The engine is designed for continuous operation on heavy fuel oil (HFO). On request the engine can be built for operation exclusively on marine diesel fuel (MDF). It is however possible to operate HFO engines on MDF intermittently without any alternations. Continuous operation on HFO is recommended as far as possible.

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.

A pressure control valve in the fuel return line on the engine 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*.

The fuel rail on common rail engines is depressurized by discharging fuel into the clean leak fuel line when the engine is to be stopped. An amount of fuel is therefore discharged into the clean leak fuel line at every stop.

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 Fuel heating requirements HFO

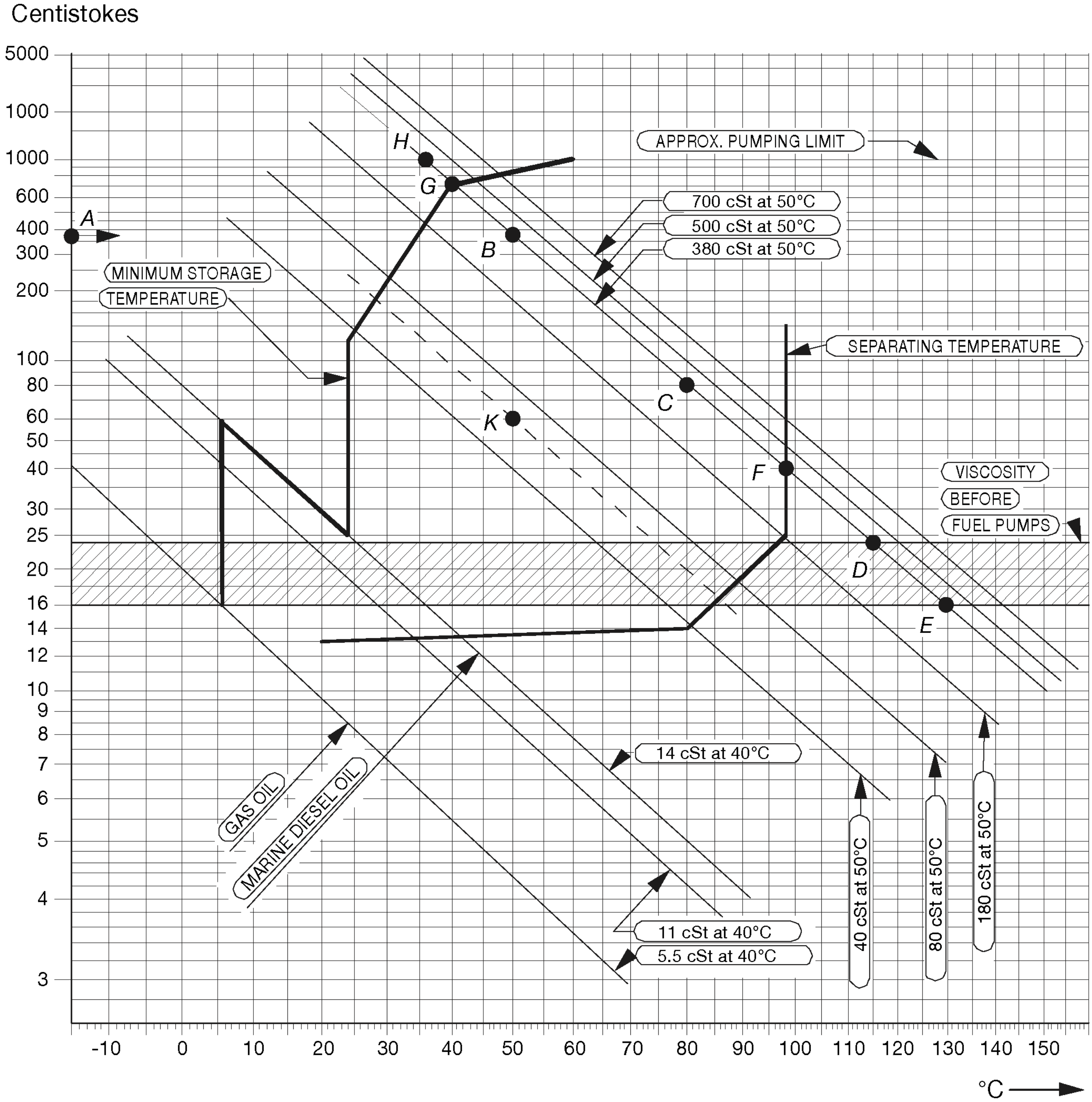
Heating is required for:

- 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.

Figure 6.5 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 storage 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 storage tank temperature 28°C.

6.3.2 Fuel tanks

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

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

Separate settling tanks for HFO and MDF are recommended.

To ensure sufficient time for settling (water and sediment separation), the capacity of each tank should be sufficient for min. 24 hours operation at maximum fuel consumption.

The tanks should be provided with internal baffles to achieve efficient settling and have a sloped bottom for proper draining.

The temperature in HFO settling tanks should be maintained between 50°C and 70°C, which requires heating coils and insulation of the tank. Usuallly MDF settling tanks do not need heating or insulation, but the tank temperature should be in the range 20...40°C.

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

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

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

Settling tanks may not be used instead of day tanks.

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

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

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

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

Leak fuel tank, clean fuel (1T04)

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

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

NOTE! The fuel rail on common rail engines is depressurized by discharging fuel into the clean leak fuel line. It is therefore very important that the leak fuel system can accommodate this volume at all times. The maximum volume discharged at an emergency stop is stated in chapter *Technical data*. Fuel will also be discharged into the clean leak fuel system in case of a malfunction causing excessive rail pressure. On common rail engines the clean leak fuel outlets at both ends of the engine must be connected to the leak fuel tank.

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 Fuel treatment

Separation

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

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

All recommendations from the separator manufacturer must be closely followed.

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

Separator mode of operation

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

Separators with monitoring of cleaned fuel (without gravity disc) operating on a continuous basis can handle fuels with densities exceeding 991 kg/m^3 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/m^3 at 15°C. The separators must be of the same size.

Separation efficiency

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

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

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

where:

n = separation efficiency [%]

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

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

Separator unit (1N02/1N05)

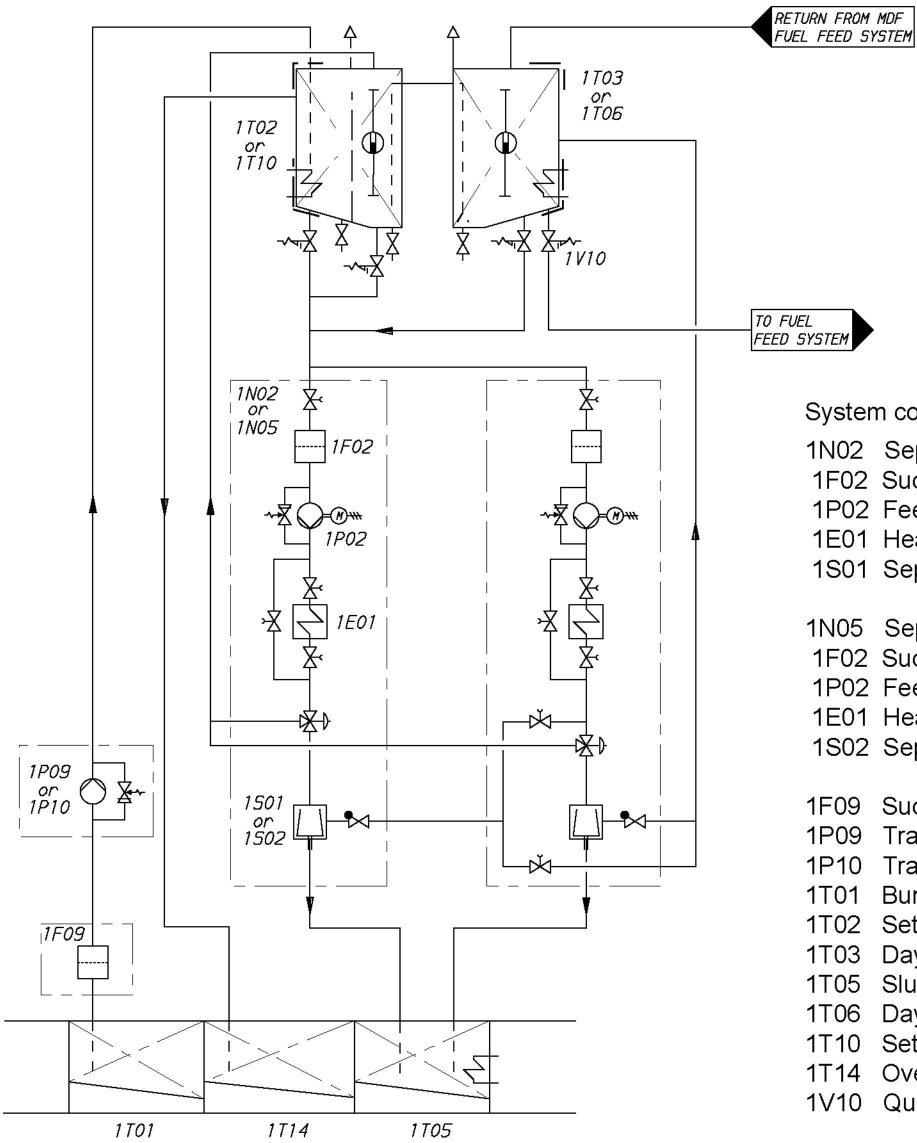
Separators are usually supplied as pre-assembled units designed by the separator manufacturer.

Typically separator modules are equipped with:

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

- Sludge pump
- Control cabinets including motor starters and monitoring

Figure 6.6 Fuel transfer and separating system (3V76F6626d)



System components:

1N02 Separator unit (HFO)
1F02 Suction strainer
1P02 Feed pump
1E01 Heater
1S01 Separator (HFO)

1N05 Separator unit (MDF)
1F02 Suction strainer
1P02 Feed pump
1E01 Heater
1S02 Separator (MDF)

1F09 Suction strainer
1P09 Transfer pump (HFO)
1P10 Transfer pump (MDF)
1T01 Bunker tank
1T02 Settling tank (HFO)
1T03 Day tank (HFO)
1T05 Sludge tank
1T06 Day tank (MDF)
1T10 Settling tank (MDF)
1T14 Overflow tank
1V10 Quick closing valve (Fuel oil tank)

Separator feed pumps (1P02)

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

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

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

Separator pre-heater (1E01)

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

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

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

The required minimum capacity of the heater is:

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

where:

P = heater capacity [kW]

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

ΔT = temperature rise in heater [°C]

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

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

Separator (1S01/1S02)

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

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

where:

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

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

ρ = density of the fuel [kg/m^3]

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

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

Sample valves must be placed before and after the separator.

MDF separator in HFO installations (1S02)

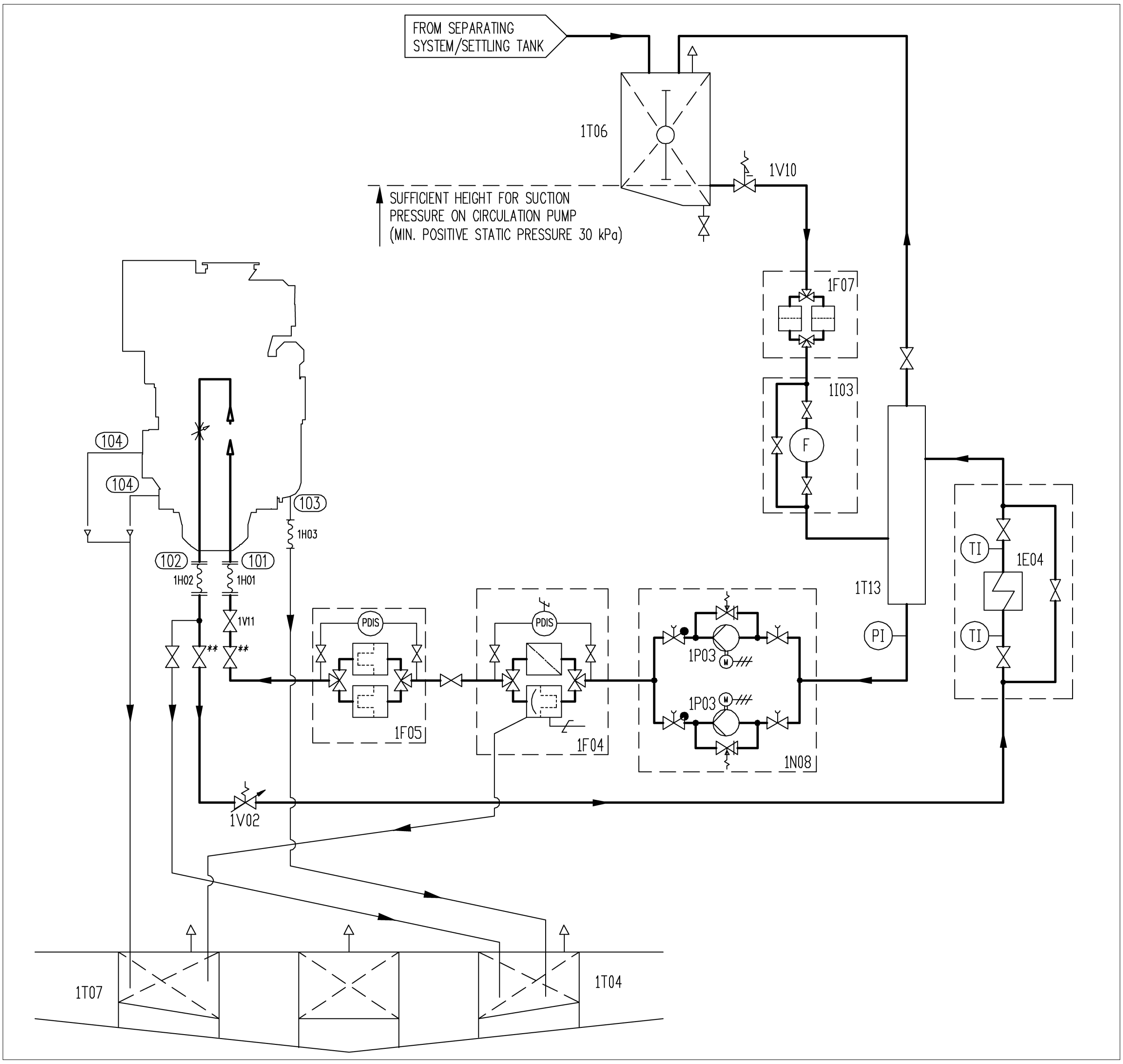
A separator for MDF is recommended also for installations operating primarily on HFO. The MDF separator can be a smaller size dedicated MDF separator, or a stand-by HFO separator used for MDF.

Sludge tank (1T05)

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

6.3.4 Fuel feed system - MDF installations

Figure 6.7 Fuel feed system, MDF (DAAE039765c)



System components		Pipe connections	
1E04	Cooler (MDF return line)	101	Fuel inlet
1F04	Automatic filter (MDF)	102	Fuel outlet
1F05	Fine filter (MDF)	103	Leak fuel drain, clean fuel
1F07	Suction strainer (MDF)	104	Leak fuel drain, dirty fuel
1H0X	Flexible pipe connection *		
1I03	Flow meter (MDF)		
1P03	Circulation pump (MDF)		
1T04	Leak fuel tank (clean fuel)		
1T06	Day tank (MDF)		
1T07	Leak fuel tank (dirty fuel)		
1T13	Return fuel tank		
1V02	Pressure control valve (MDF)		
1V10	Quick closing valve (fuel oil tank)		
1V11	Remote controlled shut off valve		

* Only required for resiliently mounted engines

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

Circulation pump, MDF (1P03)

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

Design data:	
Capacity:	
- conventional fuel injection	4 x the total consumption of the connected engines and the flush quantity of a possible automatic filter
- common rail fuel injection	3 x the total consumption of the connected engines and the flush quantity of a possible automatic filter
Design pressure	1.6 MPa (16 bar)
Max. total pressure (safety valve)	1.0 MPa (10 bar)
Max. total pressure (safety valve) common rail fuel injection	1.2 MPa (12 bar)
Design temperature	50°C
Viscosity for dimensioning of electric motor	90 cSt

Flow meter, MDF (1I03)

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

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

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

Automatic filter, MDF (1F04)

The use of an automatic back-flushing filter is recommended, normally as a duplex filter with an insert filter as the stand-by half. The circulating pump capacity must be sufficient to prevent pressure drop during the flushing operation.

Design data:	
Fuel viscosity	according to fuel specification
Design temperature	50°C
Design flow	Equal to feed/circulation pump capacity
Design pressure	1.6 MPa (16 bar)
Fineness, conventional fuel injection:	
- automatic filter	35 μm (absolute mesh size)
- bypass filter	35 μm (absolute mesh size)
Fineness, common rail fuel injection:	
- automatic filter	10 μm (absolute mesh size)
- bypass filter	25 μm (absolute mesh size)
Maximum permitted pressure drops at 14 cSt:	
- clean filter, 35 μm	20 kPa (0.2 bar)
- clean filter, 10 μm	30 kPa (0.3 bar)
- alarm	80 kPa (0.8 bar)

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	Equal to feed/circulation pump capacity
Design pressure	1.6 MPa (16 bar)
Fineness, conventional fuel injection	37 μm (absolute mesh size)
Fineness, common rail fuel injection	25 μm (absolute mesh size)
Maximum permitted pressure drops at 14 cSt:	
- clean filter	20 kPa (0.2 bar)
- alarm	80 kPa (0.8 bar)

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)

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...50°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.

Design data:	
Heat to be dissipated	3 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%

Return fuel tank (1T13)

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

Black out start

Diesel generators serving as the main source of electrical power must be able to resume their operation in a black out situation by means of stored energy. Depending on system design and classification regulations, it may in some cases be permissible to use the emergency generator. Sufficient fuel pressure to enable black out start can be achieved 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

6.3.5 Fuel feed system - HFO installations

Figure 6.8 External HFO fuel oil feed system, single engine (DAAE039762c)

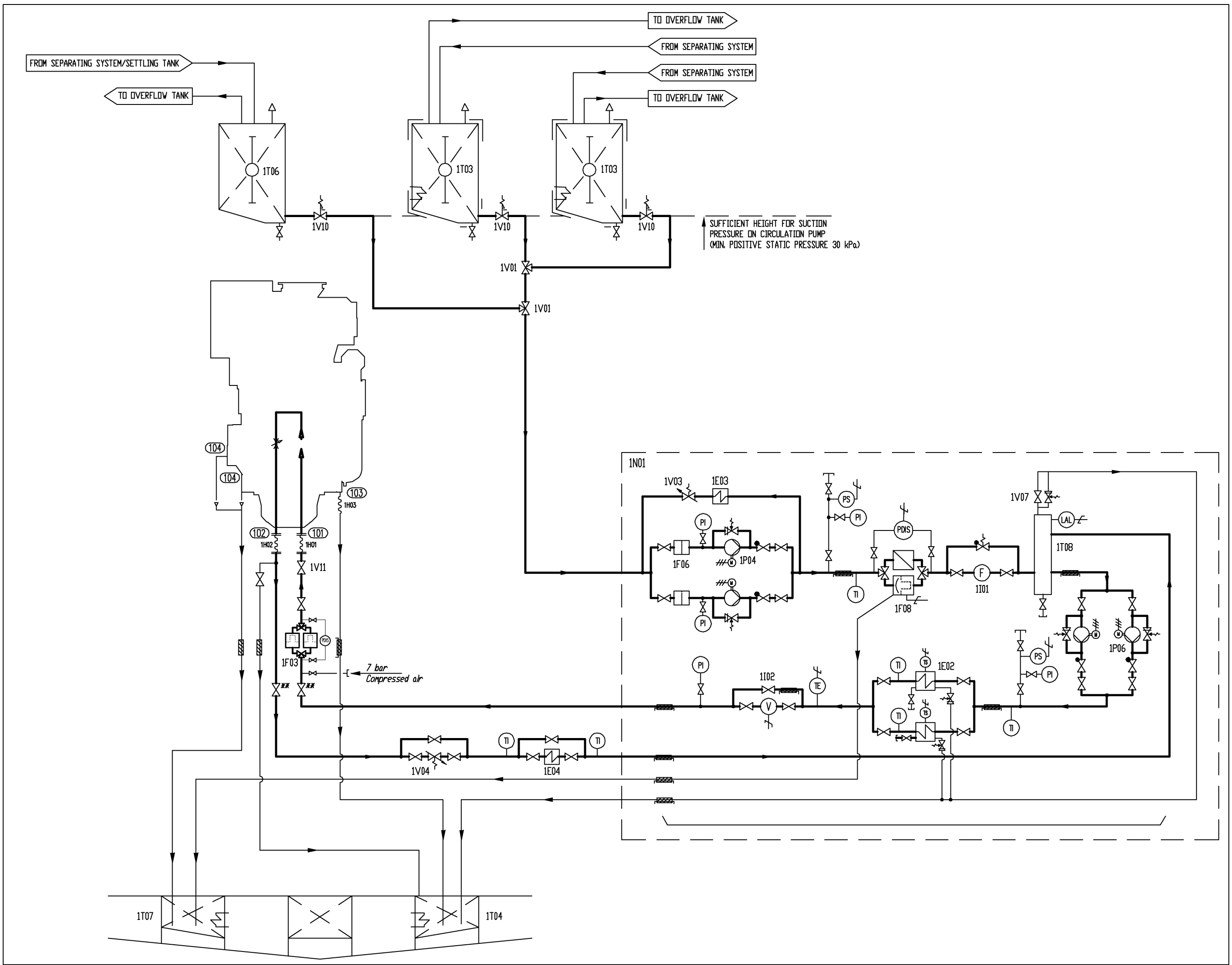


Figure 6.9 External HFO fuel oil feed system, multiple engines (DAAE039764c)

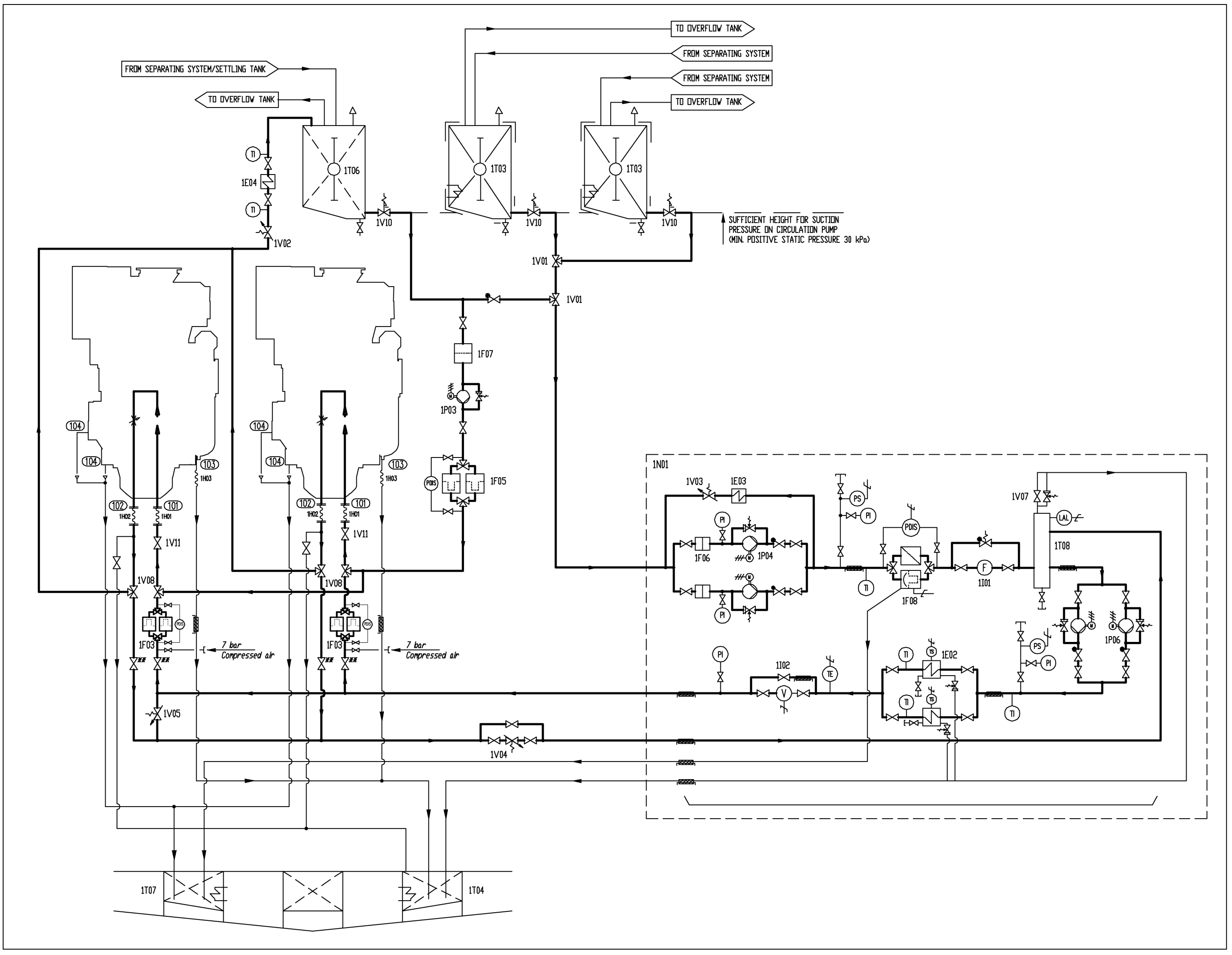
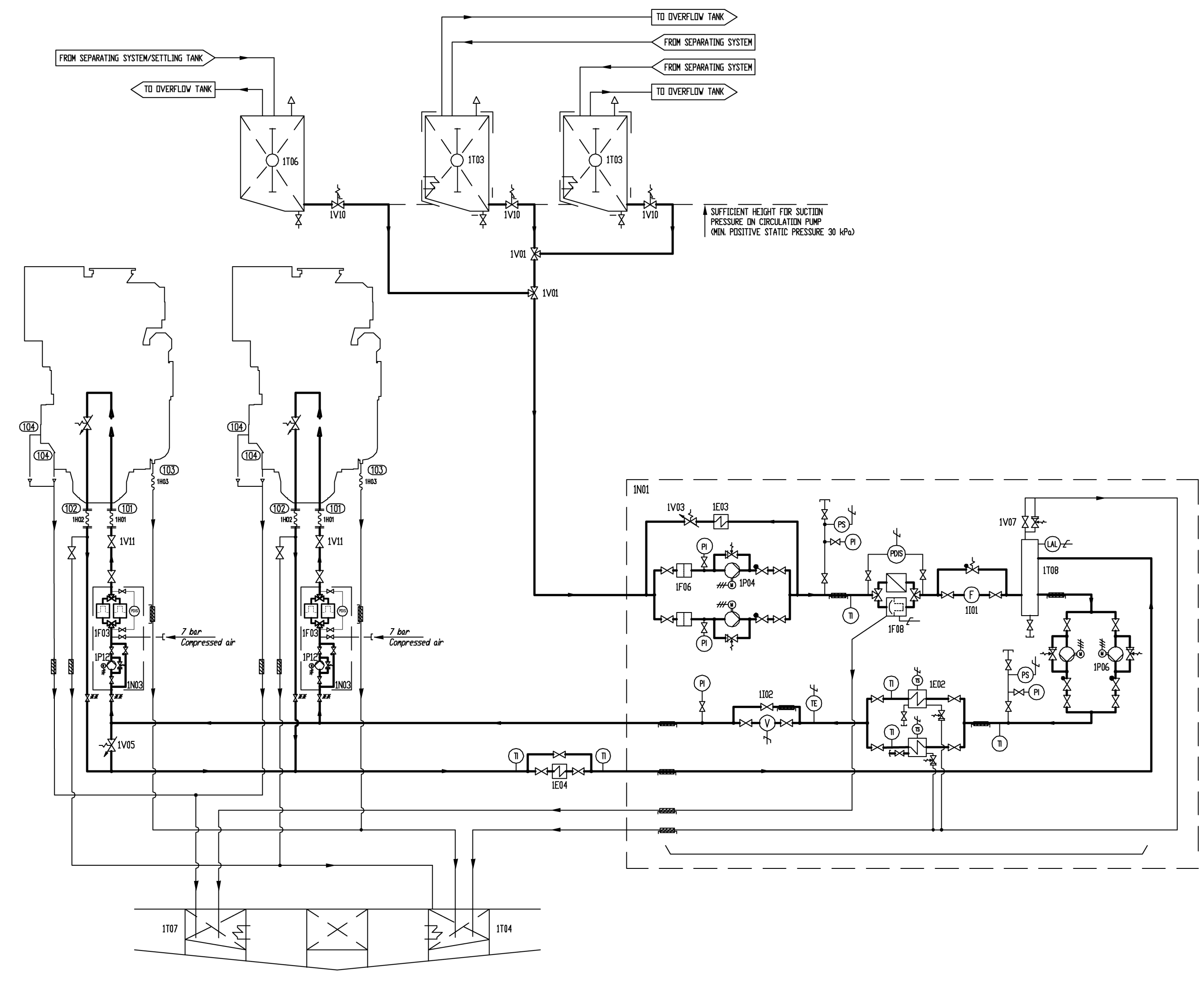


Figure 6.10 External HFO fuel oil feed system, multiple engines, common rail system (DAAE055102a)



System components	
1E02	Heater (booster unit)
1E03	Cooler (booster unit)
1F03	Safety filter (HFO)
1F05	Fine filter (MDF)
1F06	Suction filter (booster unit)
1F07	Suction strainer (MDF)
1F08	Automatic filter (booster unit)
1HXX	Flexible pipe connection
1I01	Flow meter (booster unit)
1I02	Viscosity meter (booster unit)
1N01	Feeder / Booster unit
1N03	Pump and filter unit
1P03	Circulation pump (MDF)
1P04	Fuel feed pump (booster unit)
1P06	Circulation pump (booster unit)
1T03	Day tank (HFO)
1T04	Leak fuel tank (clean fuel)

Pipe connections	
101	Fuel inlet
102	Fuel outlet
103	Leak fuel drain, clean fuel
104	Leak fuel drain, dirty fuel

System components		Pipe connections
1T06	Day tank (MDF)	
1T07	Leak fuel tank (dirty fuel)	
1T08	De-aeration tank (booster unit)	
1V01	Changeover valve	
1V02	Pressure control valve (MDF)	
1V03	Pressure control valve (booster unit)	
1V04	Pressure control valve (HFO)	
1V05	Overflow valve (HFO/MDF)	
1V07	Venting valve (booster unit)	
1V08	Changeover valve	
1V10	Quick closing valve (fuel oil tank)	
1V11	Remote controlled shut off valve	* Only required for resiliently mounted engines

The size of the piping in the installation to be calculated case by case, having typically a larger diameter than the connection on the engine. See chapter *Piping design, treatment and installation*

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

Starting and stopping

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 recommended.

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

Changeover from HFO to MDF

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

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

Number of engines in the same system

When the fuel feed unit serves Wärtsilä 38 engines only, maximum two engines should be connected to the same fuel feed circuit, unless individual circulating pumps before each engine are installed.

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

In addition the following guidelines apply:

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

Feeder/booster unit (1N01)

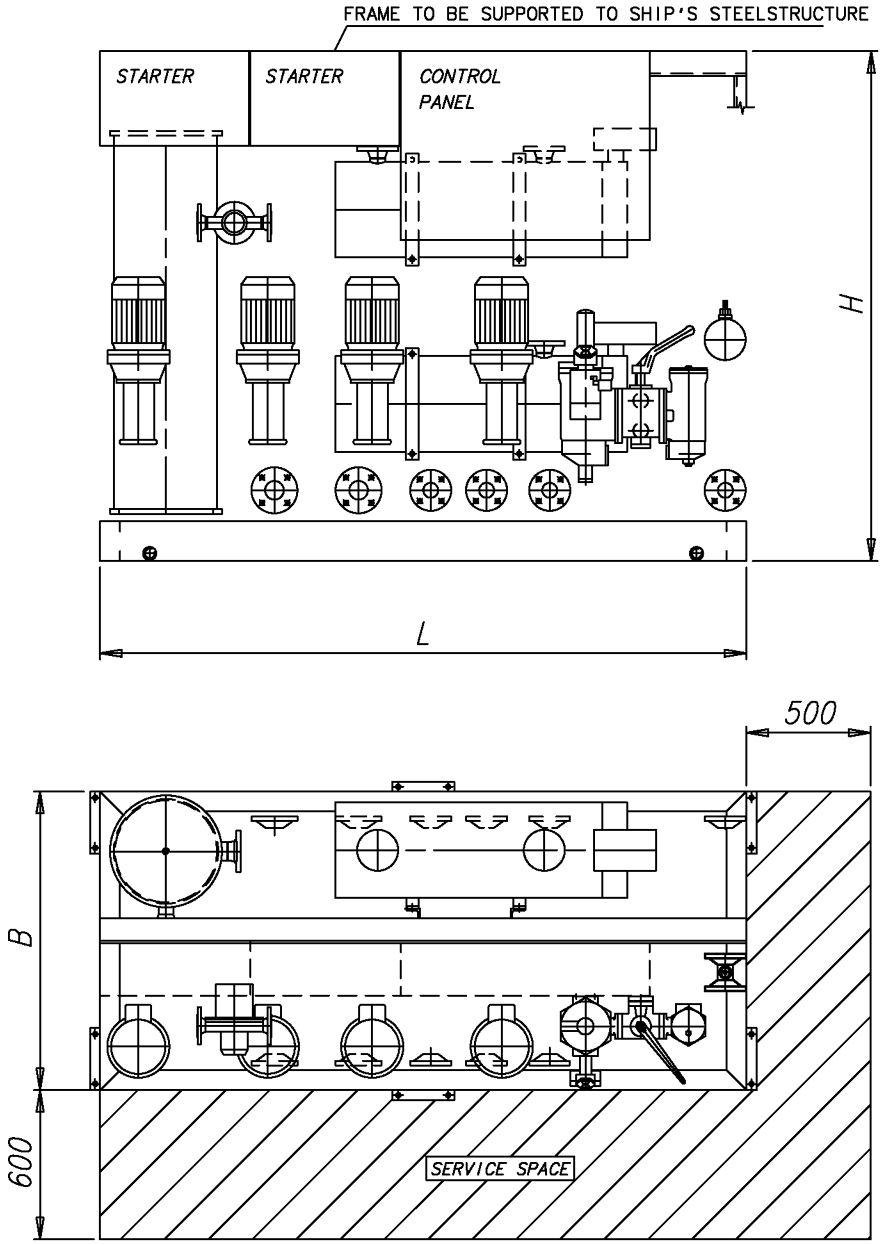
A completely assembled feeder/booster unit can be supplied. This unit comprises the following equipment:

- Two suction strainers

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

Figure 6.11 Feeder/booster unit, example (DAAE006659)



	H	L	B
STEAM	1800	2500	1100
ELECTRICAL	2050	2600	1200

All dimensions in mm.

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

Pressure control valve, booster unit (1V03)

The pressure control valve in the feeder/booster unit maintains the pressure in the de-aeration tank by directing the surplus flow to the suction side of the feed pump.

Design data:	
Capacity	Equal to feed pump
Design pressure	1.6 MPa (16 bar)
Design temperature	100°C
Set-point	0.3...0.5 MPa (3...5 bar)

Automatic filter, booster unit (1F08)

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

Design data:	
Fuel viscosity	According to fuel specification
Design temperature	100°C
Preheating	If fuel viscosity is higher than 25 cSt/100°C
Design flow	Equal to feed pump capacity
Design pressure	1.6 MPa (16 bar)
Fineness, conventional fuel injection:	
- automatic filter	35 μm (absolute mesh size)
- bypass filter	35 μm (absolute mesh size)
Fineness, common rail fuel injection:	
- automatic filter	10 μm (absolute mesh size)
- bypass filter	25 μm (absolute mesh size)
Maximum permitted pressure drops at 14 cSt:	
- clean filter, 35 μm	20 kPa (0.2 bar)
- clean filter, 10 μm	30 kPa (0.3 bar)
- alarm	80 kPa (0.8 bar)

Flow meter, booster unit (1I01)

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

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

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

De-aeration tank, booster unit (1T08)

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

Circulation pump, booster unit (1P06)

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

Design data, conventional fuel injection:

Capacity:	
- without circulation pumps (1P12)	4 x the total consumption of the connected engines
- with circulation pumps (1P12)	15% more than total capacity of all circulation pumps
Design pressure	1.6 MPa (16 bar)
Max. total pressure (safety valve)	1.0 MPa (10 bar)
Design temperature	150°C
Viscosity for dimensioning of electric motor	500 cSt

Design data, common rail fuel injection:

Capacity:	
- without circulation pumps (1P12)	3 x the total consumption of the connected engines
- with circulation pumps (1P12)	15% more than total capacity of all circulation pumps
Design pressure	1.6 MPa (16 bar)
Max. total pressure (safety valve)	1.2 MPa (12 bar)
Design temperature	150°C
Viscosity for dimensioning of electric motor	500 cSt

Heater, booster unit (1E02)

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

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

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

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

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

where:

P = heater capacity (kW)

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

ΔT = temperature rise in heater [°C]

Viscosimeter, booster unit (1I02)

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

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

Pump and filter unit (1N03)

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

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

Circulation pump (1P12)

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

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

A fuel feed line directly from the MDF day tank is not very attractive in installations with common rail engines, because a pump and filter unit would be required also in the feed line from the day tank due to the required filter fineness (10 μm).

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

Design data, common rail fuel injection:	
Capacity	3 x the consumption of the engine
Design pressure	1.6 MPa (16 bar)
Max. total pressure (safety valve)	1.2 MPa (12 bar)
Design temperature	150°C
Pressure for dimensioning of electric motor (Δp):	
- fuel is fed through feeder/booster unit	0.3 MPa (3 bar)

Design data, common rail fuel injection:	
Viscosity for dimensioning of electric motor	500 cSt

Safety filter (1F03)

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

Design data:	
Fuel viscosity	according to fuel specification
Design temperature	150°C
Design flow	Equal to circulation pump capacity
Design pressure	1.6 MPa (16 bar)
Fineness, conventional fuel injection	37 µm (absolute mesh size)
Fineness, common rail fuel injection	25 µm (absolute mesh size)
Maximum permitted pressure drops at 14 cSt:	
- clean filter	20 kPa (0.2 bar)
- alarm	80 kPa (0.8 bar)

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)	conventional fuel injection: 0.1...0.2 MPa (1...2 bar) common rail fuel injection: 0.2...0.7 MPa (2...7 bar) 0.2...0.7 MPa (2...7 bar)

Pressure control valve (1V04)

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

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

6.3.6 Flushing

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

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

7. Lubricating oil system

7.1 Lubricating oil requirements

7.1.1 Engine lubricating oil

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

Table 7.1 Fuel standards and lubricating oil requirements

Category	Fuel standard		Lubricating oil BN
A	ASTM D 975-01, BS MA 100: 1996 CIMAC 2003 ISO8217: 1996(E)	GRADE NO. 1-D, 2-D DMX, DMA DX, DA ISO-F-DMX, DMA	10...30
B	BS MA 100: 1996 CIMAC 2003 ISO 8217: 1996(E)	DMB DB ISO-F-DMB	15...30
C	ASTM D 975-01, ASTM D 396-04, BS MA 100: 1996 CIMAC 2003 ISO 8217: 1996(E)	GRADE NO. 4-D GRADE NO. 5-6 DMC, RMA10-RMK55 DC, A30-K700 ISO-F-DMC, RMA10-RMK55	30...55

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.

Crude oils with low sulphur content may permit the use of BN 30 lubricating oils. It is however not unusual that crude oils contain other acidic compounds, which requires a high BN oil although the sulphur content of the fuel is low.

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.

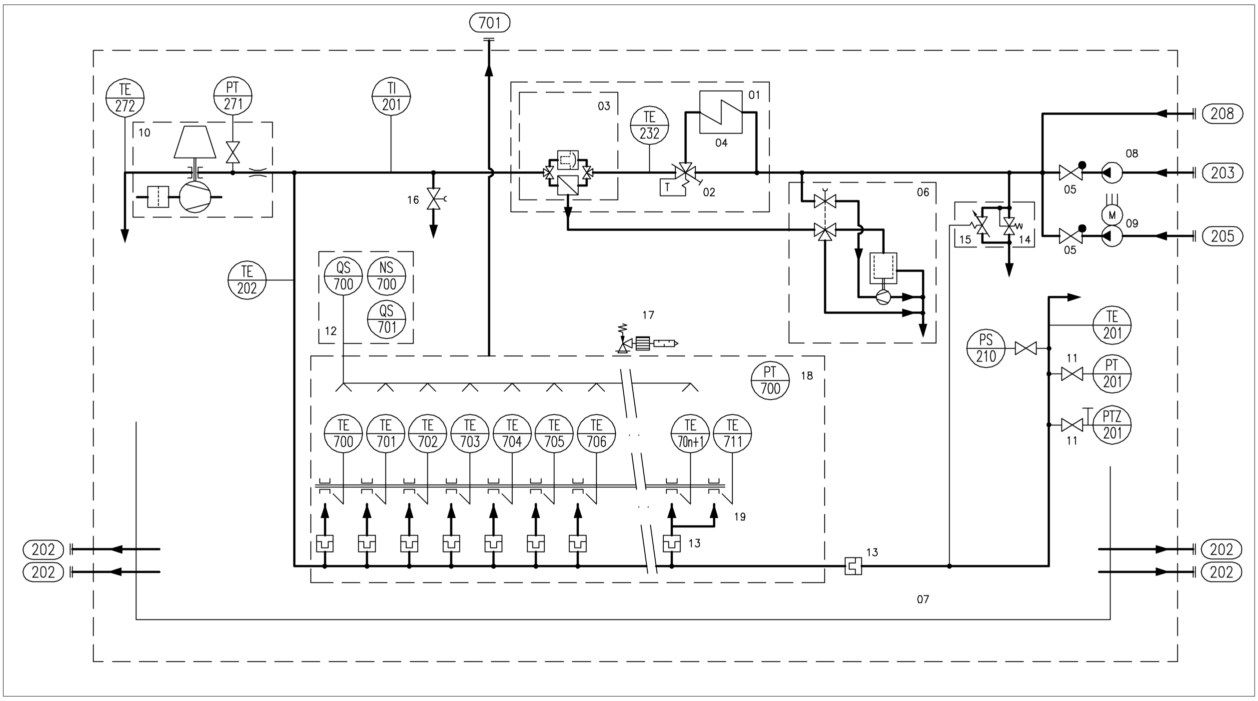
7.1.3 Oil in turning device

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

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

7.2 Internal lubricating oil system

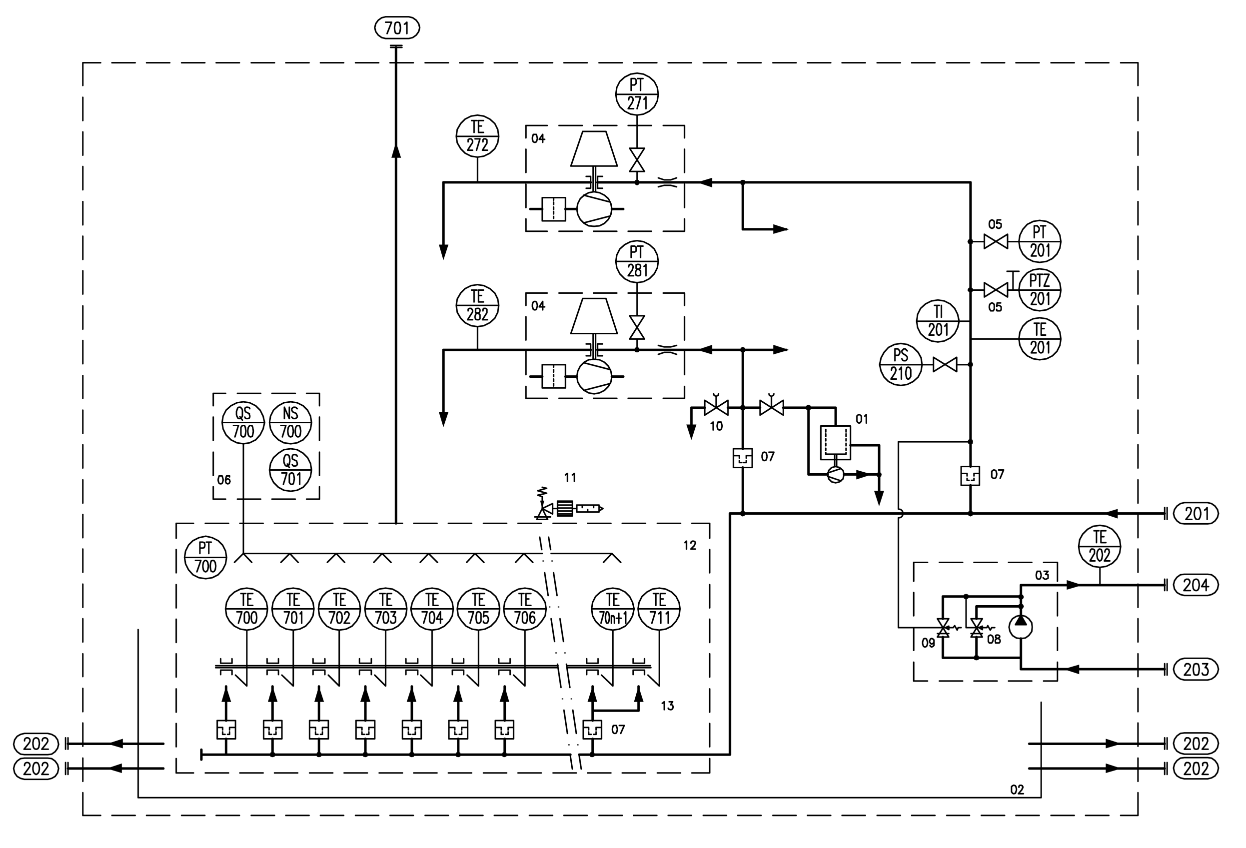
Figure 7.1 Internal lubricating oil system, in-line engine (DAAE039750a)



System components	
01	Lubricating oil module
02	Thermostatic valve
03	Automatic filter
04	Lubricating oil cooler
05	Non return valve
06	Centrifugal filter
07	Dry sump
08	Main lubricating oil pump engine driven
09	Prelubricating oil pump, electric driven
10	Turbocharger
11	Valve
12	Oil mist detector
13	Run-in filter
14	Safety valve
15	Control valve
16	Sample valve
17	Explosion valve
18	Crankcase
19	Integrated PTO shaft bearing (if PTO)

Sensors and indicators	
PS210	Lubricating oil stan-by pump start
PT201	Lubricating oil pressure, engine inlet
PTZ201	Lubricating oil pressure, engine inlet, backup
PT271	Lubricating oil pressure, TC inlet
PT700	Crankcase pressure (if FAKS)
NS700	Oil mist detector, failure
QS700	Oil mist detector, alarm
QS701	Oil mist detector, shutdown
TE201	Lubricating oil temperature, engine inlet
TE202	Lubricating oil temperature, engine outlet (if FAKS)
TE232	Lubricating oil temperature, LOC outlet (if FAKS)
TE272	Lubricating oil temperature, TC outlet (if ME)
TE70n	Main bearing temperature, cyl. n
TE711	Main bearing temperature (if PTO)
TI201	Lubricating oil temperature, engine inlet

Figure 7.2 Internal lubricating oil system, V-engine (DAAE039753a)



System components		Sensors and indicators	
01	Centrifugal filter	PS210	Lubricating oil stan-by pump start (i
02	Dry sump	PTZ201	Lubricating oil pressure, engine inlet
03	Main lubricating oil pump engine driven	PT201	Lubricating oil pressure, engine inlet
04	Turbocharger	PT271/PT281	Lubricating oil pressure, TC A/B inlet
05	Valve	PT700	Crankcase pressure (if FAKS)
06	Oil mist detector	NS700	Oil mist detector, failure
07	Run-in filter	QS700	Oil mist detector, alarm
08	Safety valve	QS701	Oil mist detector, shutdown
09	Control valve	TE201	Lubricating oil temperature, engine inlet
10	Sample valve	TE201	Lubricating oil temperature, engine outlet (if FAKS)
11	Explosion valve	TE272/TE282	Lubricating oil temperature, TC A/B outlet (if main engine)
12	Crankcase	TE70n	Main bearing temperature, cyl. n
13	Integrated PTO shaft bearing (if PTO)	TE711	Main bearing temperature (if PTO)
		TI201	Lubricating oil temperature, engine inlet

Pipe connections		Size	Pressure class	Standard
201	Lubricating oil inlet, V	DN200	PN10	DIN2576
202	Lubricating oil outlet (from oil dry sump)	DN200	PN6	DIN2573
203	Lubricating oil to engine driven pump, in line	DN150	PN10	DIN2576
203	Lubricating oil to engine driven pump, V	DN250	PN10	DIN2632
204	Lubricating oil from engine driven pump, V	DN150	PN16	DIN2633
205	Lubricating oil to priming pump, in line	DN100	PN10	DIN2576
208	Lubricating oil from el. driven pump (stand-by), in line	DN125	PN10	DIN2576

Pipe connections		Size	Pressure class	Standard
701	Crankcase air vent	DN125	PN10	DIN2576

The oil sump is of dry sump type. There are two oil outlets at each end of the engine. One outlet at each end must be connected to the system oil tank. On 16V engines totally three outlets must be connected to the system oil tank.

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

The in-lines engines are equipped with a pre-lubricating oil pump. The pre-lubricating oil 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 pre-lubricating oil pump, *see Technical data.*

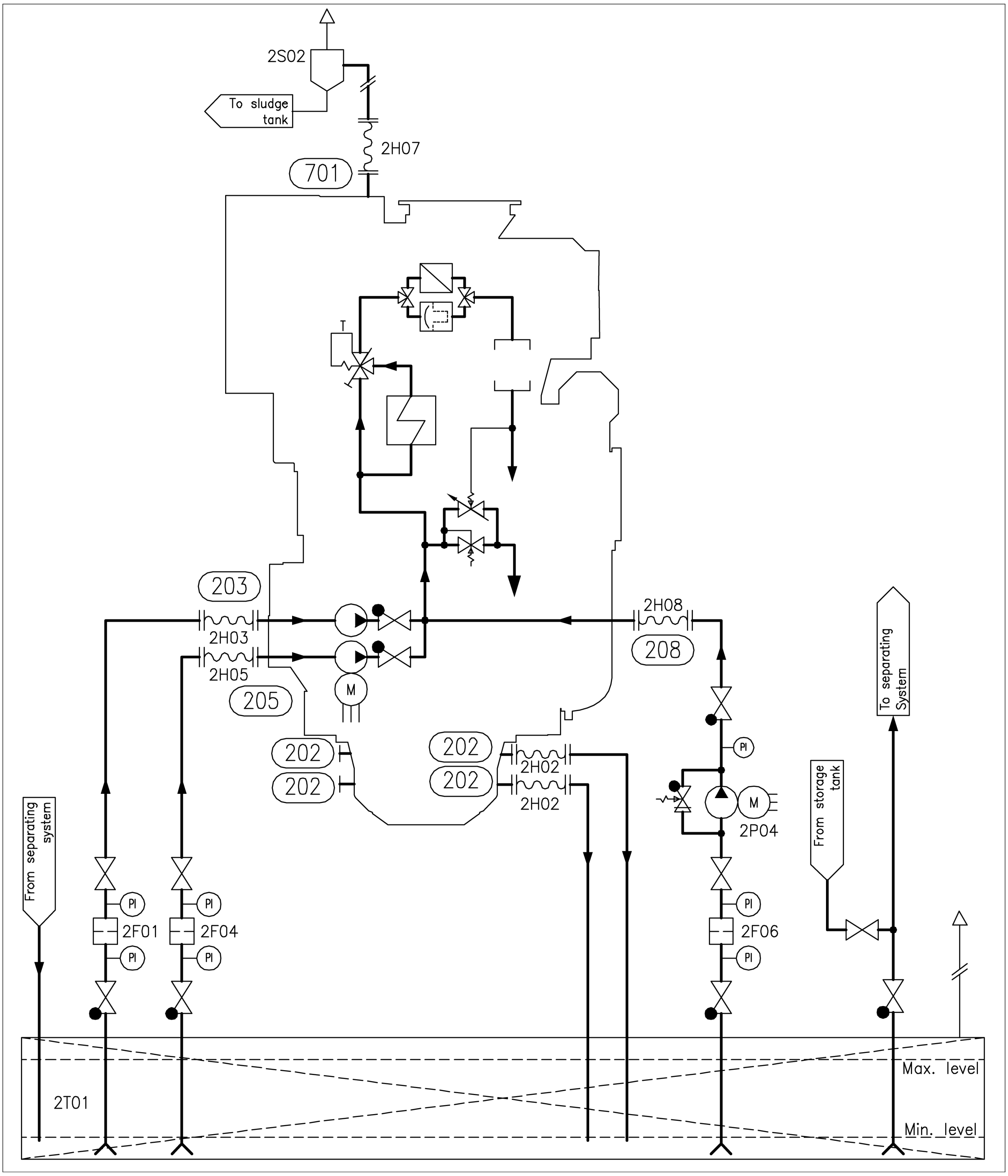
The in-line engines are equipped with a lubricating oil module built on the engine. The lubricating oil module consists of the lubricating oil cooler, thermostatic valve and automatic filter.

The centrifugal filter on the in-line engines is used to clean the back-flushing oil from the automatic filter. On the V engines the centrifugal filter serves as an indication filter.

All engines are delivered with a running-in filter before each main bearing, before the turbocharger and before the intermediate gears. These filters are to be removed a few hundred operating hours (100-500 h) after start-up.

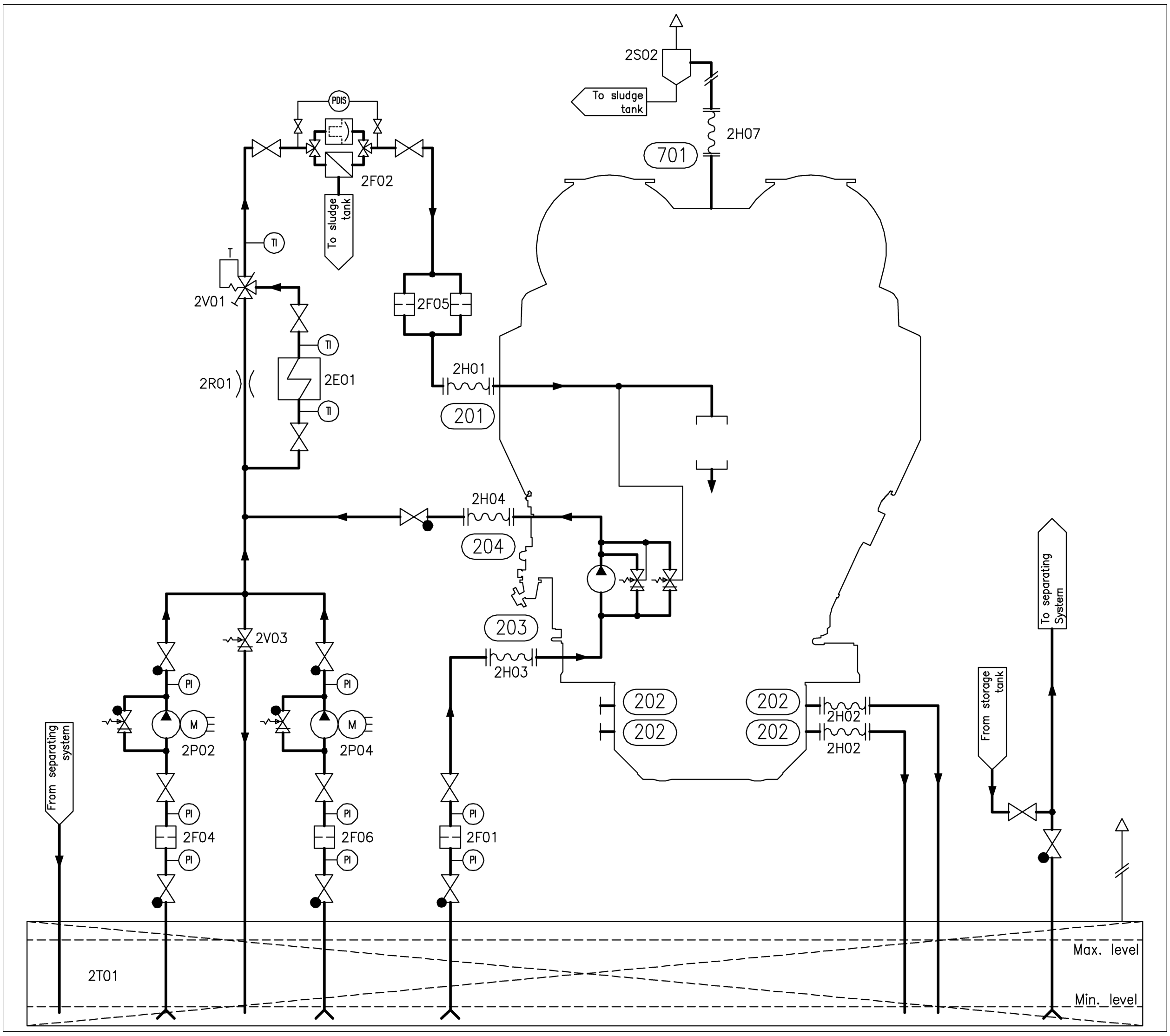
7.3 External lubricating oil system

Figure 7.3 External lubricating oil system, in-line engine (DAAE039778a)



System components		Pipe connections	
2F01	Suction strainer (main lubricating oil pump)	202	Lubricating oil outlet
2F04	Suction strainer (pre lubricating oil pump)	203	Lubricating oil to engine driven pump
2F06	Suction strainer (stand-by pump)	205	Lubricating oil to priming pump
2H0X	Flexible pipe connection *	208	Lubricating oil from electric driven pump
2H02	Flexible pipe connection	701	Crankcase air vent
7H01	Flexible pipe connection		
2P04	Stand-by pump		
2T01	System oil tank		* Only required for resiliently mounted engines

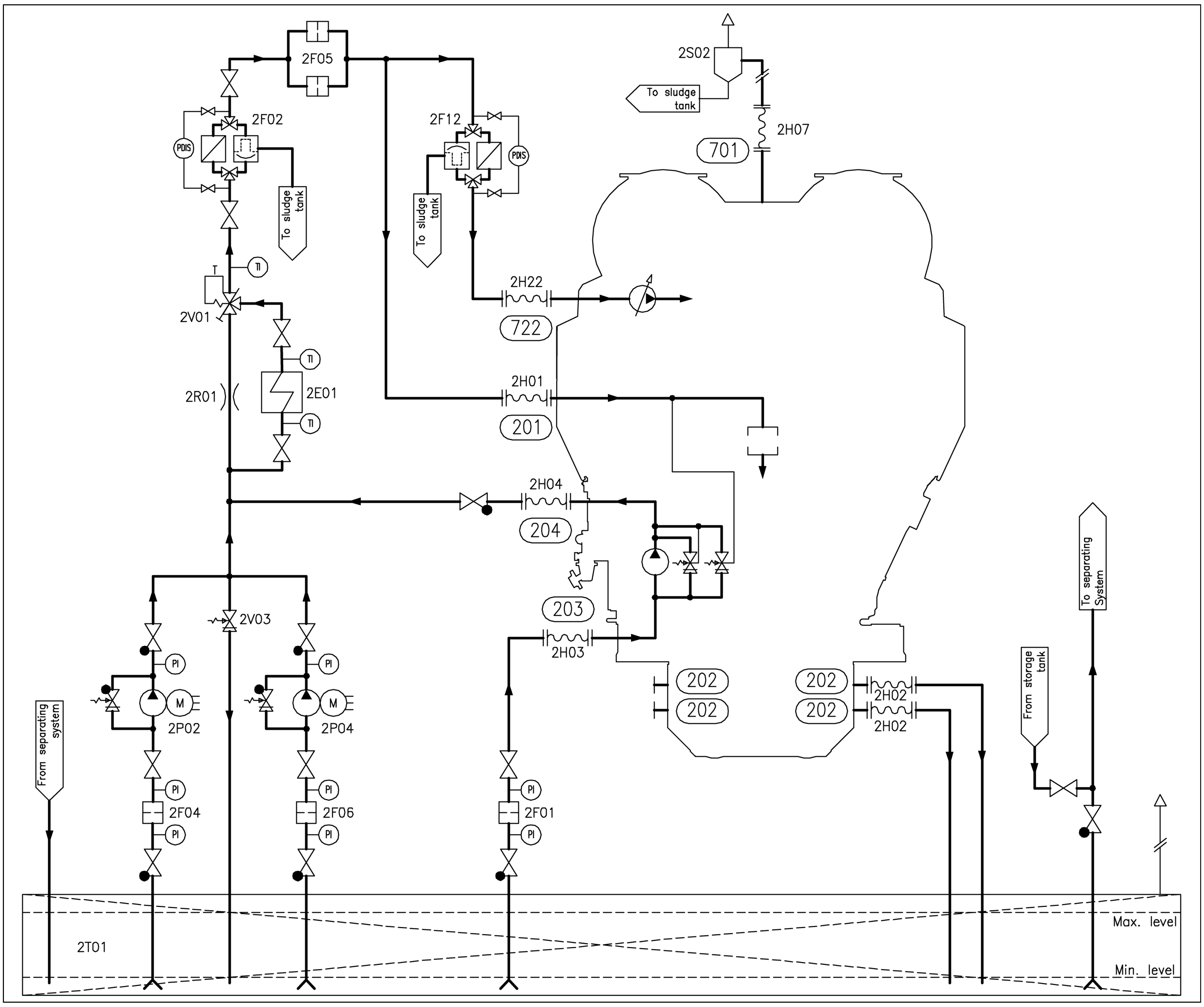
Figure 7.4 External lubricating oil system, V-engine (DAAE039780a)



System components		Pipe connections	
2E01	Lubricating oil cooler	201	Lubricating oil inlet
2F01	Suction strainer (main lubricating oil pump)	202	Lubricating oil outlet
2F02	Automatic filter (LO)	203	Lubricating oil to engine driven pump
2F04	Suction strainer (pre lubricating oil pump)	204	Lubricating oil from engine driven pump
2F05	Safety filter (LO)	701	Crankcase air vent
2F06	Suction strainer electric driven pump		
2H0X	Flexible pipe connection *		
2H02	Flexible pipe connection		
7H01	Flexible pipe connection		
2P02	Pre lubricating oil pump		
2P04	Stand-by pump		
2R01	Orifice (cooler)		
2T01	System oil tank		
2V01	Temperature control valve		
2V03	Pressure control valve		

* Only required for resiliently mounted engines

Figure 7.5 External lubricating oil system, V-engine, common rail system (DAAE054438)



System components	
2E01	Lubricating oil cooler
2F01	Suction strainer (main lubricating oil pump)
2F02	Automatic filter (LO)
2F04	Suction strainer (pre lubricating oil pump)
2F05	Safety filter (LO)
2F06	Suction strainer electric driven pump
2F12	Control oil automatic filter
2HXX	Flexible pipe connection *
2H02	Flexible pipe connection
7H01	Flexible pipe connection
2P02	Pre lubricating oil pump
2P04	Stand-by pump
2R01	Orifice (cooler)
2T01	System oil tank
2V01	Temperature control valve
2V03	Pressure control valve

Pipe connections	
201	Lubricating oil inlet
202	Lubricating oil outlet
203	Lubricating oil to engine driven pump
204	Lubricating oil from engine driven pump
701	Crankcase air vent
722	Control oil from external filter

* Only required for resiliently mounted engines

7.3.1 Separation system

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.

Separators are usually supplied as pre-assembled units.

Typically lubricating oil separator units are equipped with:

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

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

Separator feed pump (2P03)

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

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

Separator preheater (2E02)

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

Recommended oil temperature after the heater is 95°C.

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

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

Separator (2S01)

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

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

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

where:

Q = volume flow [l/h]

P = engine output [kW]

n = 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

Sludge tank (2T06)

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

7.3.2 System oil tank (2T01)

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

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

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.

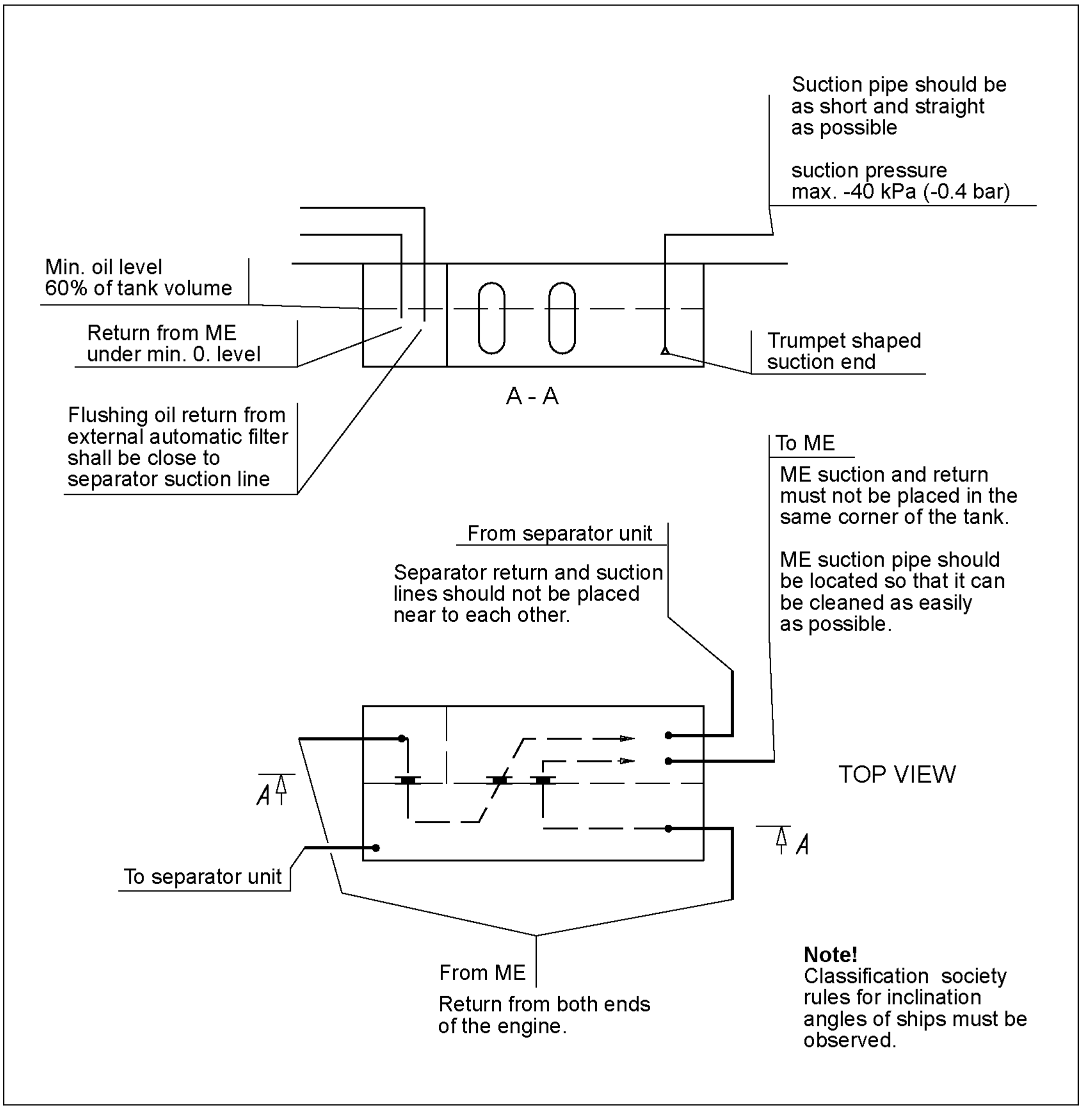
The suction pipe of the pump should have a trumpet shaped or conical inlet to minimise the pressure loss. For the same reason the suction pipe shall be as short and straight as possible and have a sufficient diameter. A pressure gauge shall be installed close to the inlet of the lubricating oil pump. 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.

Figure 7.6 Example of system oil tank arrangement (DAAE007020d)



Design data:

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

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

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

Design data:

Fineness	0.5...1.0 mm

7.3.4 Pre-lubricating oil pump (2P02)

The pre-lubricating oil pump is needed in V engine installations only.

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

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

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

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

Depending on the foreseen oil temperature after a long stop, the suction ability of the pump and the geometric suction height must be specially considered with regards to high viscosity. With cold oil the pressure at the pump will reach the relief pressure of the safety valve.

Design data:

Capacity	see *Technical data*
Design pressure	1.0 MPa (10 bar)
Max. pressure (safety valve)	350 kPa (3.5 bar)
Design temperature	100°C
Viscosity for dimensioning of the electric motor	500 cSt

7.3.5 Pressure control valve (2V03)

The pressure control valve is needed for V engine installations.

To protect the system against too high lubricating oil pressure a pressure control valve must be installed to control the pressure at engine inlet.

Design data:

Design pressure	1.0 MPa (10 bar)
Capacity	Difference between pump capacity and oil flow through engine
Design temperature	100 °C
Set point	450 kPa (4.5 bar) at engine inlet

7.3.6 Lubricating oil cooler (2E01)

The lubricating oil cooler is needed in V engine installations only.

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

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

Design data:

Oil flow through cooler	see *Technical data,* "*Oil flow through engine*"
Heat to be dissipated	see *Technical data*
Max. pressure drop, oil	80 kPa (0.8 bar)
Water flow through cooler	see *Technical data,* "*LT-pump capacity*"
Max. pressure drop, water	60 kPa (0.6 bar)
Water temperature before cooler	45°C
Oil temperature before engine	63°C
Design pressure	1.0 MPa (10 bar)
Margin (heat rate, fouling)	min. 15%

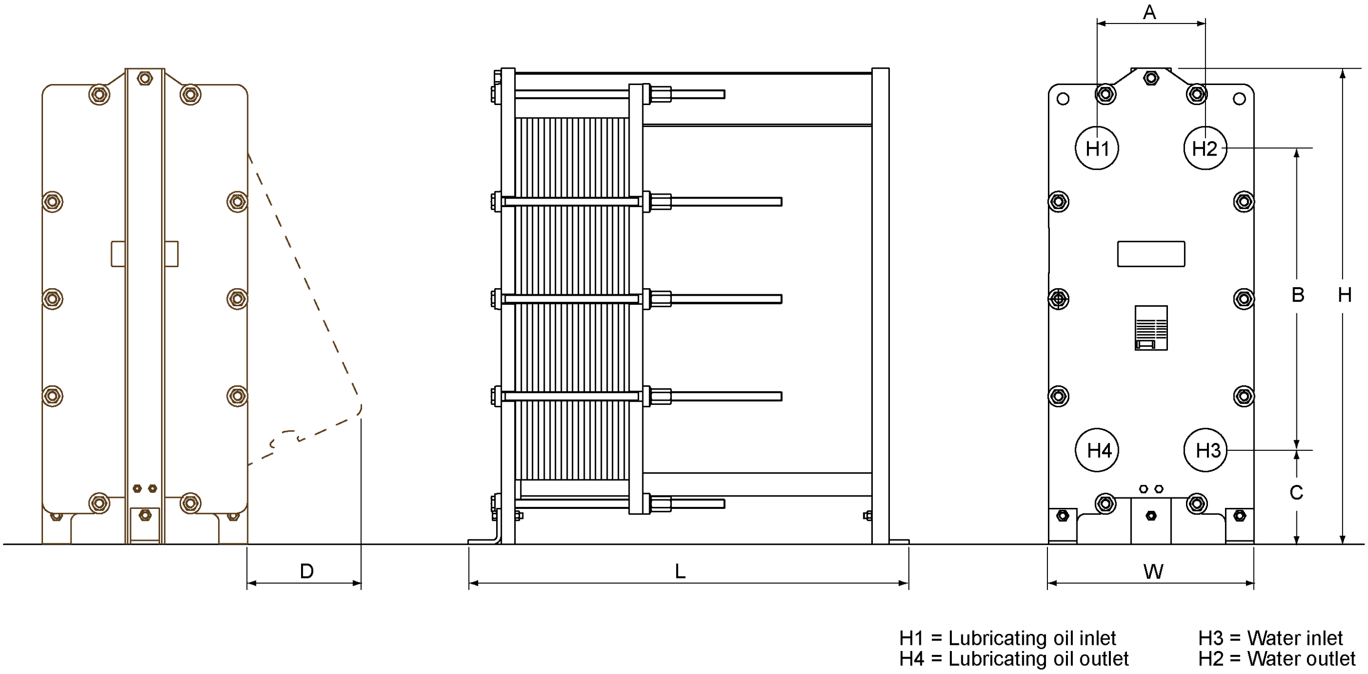


Figure 7.7 Main dimensions of the lubricating oil cooler

Engine	Weight, dry [kg]	Dimensions [mm]						
		H	W	L	A	B	C	D
W 12V38	1270	1675	720	1487	380	1057	330	300
W 16V38	1410	1675	720	1737	380	1057	330	300

NOTE! These dimensions are for guidance only.

7.3.7 Temperature control valve (2V01)

The temperature control valve is needed in V engine installations only.

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

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

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

Design data:

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

7.3.8 Automatic filter (2F02)

The automatic filter is needed in V engine installations only.

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

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

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

7.3.9 Safety filter (2F05)

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

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

7.3.10 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)

7.3.11 Common rail engines

Engine lubricating oil is used as control oil. An external automatic filter with finer mesh size than the normal lubricating oil filter is required for the control oil. The control oil automatic filter (2F12) should be installed as close as possible to the engine.

A flushing filter with finer mesh size must be used for the control oil circuit, see *section Flushing instructions*.

Apart from the control oil automatic filter (2F12) and the control oil connection on the engine, the external lubricating oil system can be designed and dimensioned following the same principles as for engines with conventional fuel injection.

Control oil automatic filter (2F12)

It is recommended to select an automatic filter with a manually cleaned filter in the bypass line, to enable easy changeover during maintenance of the automatic filter. A bypass filter must be installed separately if it is not an integrated part of the automatic filter.

A filter type without pressure drop during the flushing operation must be selected.

Design data:	
Oil viscosity	50 cSt (SAE 40, VI 95, appox. 63°C)
Design flow	see *Technical data* 1)
Design temperature	100°C
Design pressure	1.0 MPa (10 bar)
Fineness:	
- automatic filter	10 µm (absolute mesh size)
- insert filter	25 µm (absolute mesh size)
Max permitted pressure drops at 50 cSt:	
- clean filter	30 kPa (0.3 bar)
- alarm	80 kPa (0.8 bar)

1) The maximum temporary flow can occur during a few seconds when the engine is started. The filter must be able to withstand the maximum momentary flow without risk of damage (pressure drop is not essential for the momentary flow).

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.

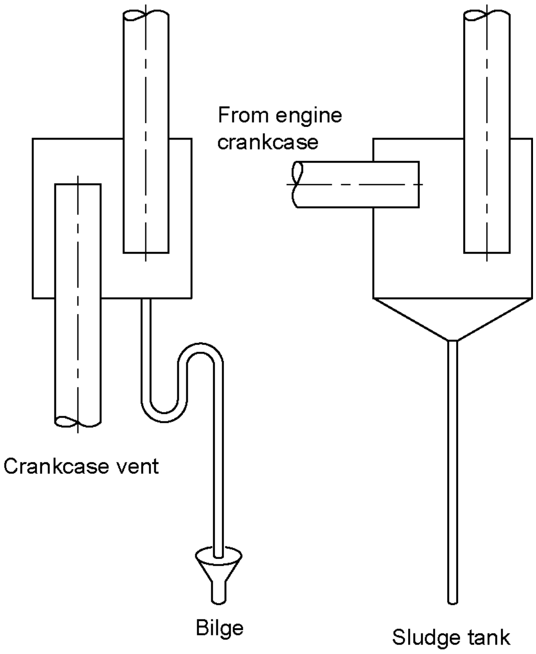
The diameter of the pipe shall be large enough to avoid excessive back pressure. Other possible equipment in the piping must also be designed and dimensioned to avoid excessive flow resistance.

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

Figure 7.8 Condensate trap (DAAE032780)



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

W L38: DN125
W V38: DN180

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

7.5 Flushing instructions

The external piping system must be thoroughly flushed before it is connected to the engine. Provisions for installation of a temporary flushing filter are therefore required. The fineness of the flushing filter shall be 35 µm or finer.

If an electrically driven standby or main lubricating oil pump is installed, this pump can be used for the flushing. Otherwise it must be possible to install a temporary pump of approximately the same capacity as the engine driven pump. The oil inlet to the engine is disconnected and the oil is discharged through a crankcase door into the engine oil sump. All filter inserts are removed, except in the flushing filter.

The automatic filter (2F02) and lubricating oil cooler (2E01) must be bypassed to prevent damage.

Lubricating oil separators should be in operation prior to and during the flushing. The flushing is more effective if a dedicated flushing oil of low viscosity is used. The oil is to be heated so that the system reaches at least normal operating temperature. Engine lubricating oil can also be used, but it is not permitted to use the flushing oil later, not even after separation.

The minimum recommended flushing time is 24 hours. During this time the welds in the piping should be gently knocked at with a hammer to release slag. The flushing filter is to be inspected and cleaned at regular intervals. Flushing is continued until no particles are collected in the filter.

7.5.1 Common rail engines

The piping between the control oil automatic filter (2F12) and the control oil inlet on the engine (connection 722) must be flushed with very clean oil. An additional flushing filter is therefore required for the control oil circuit. This flushing filter shall be 10 µm or finer and it shall be installed next to the normal control oil automatic filter (2F12). Connection 722 is open during the flushing and the oil is discharged into the crankcase. See system diagram in section *External lubricating oil system*.

8. Compressed air system

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

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

8.1 Instrument air quality

The quality of instrument air, from the ships instrument air system, for safety and control devices must fulfill the following requirements.

Instrument air specification:	
Design pressure	1 MPa (10 bar)
Nominal pressure	0.7 MPa (7 bar)
Dew point temperature	+3°C
Max. oil content	1 mg/m^3
Max. particle size	3 µm

8.2 Internal compressed air system

All engines, independent of cylinder number, are started by means of compressed air with a nominal pressure of 3 MPa (30 bar). The start is performed by direct injection of air into the cylinders through the starting air valves in the cylinder heads. V-engines are provided with starting air valves for the cylinders on the A-bank only. The master starting valve, built on the engine, can be operated both manually and electrically.

The engine is provided with a slow turning device (controlled by the engine automation system). This means that the engine will automatically turn two revolutions after a certain period of time (e.g. 30 minutes) or before actually starting. The engine is directly available for starting, without additional engine parameter checking.

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

Figure 8.1 Internal starting and compressed air system (DAAE039755b)

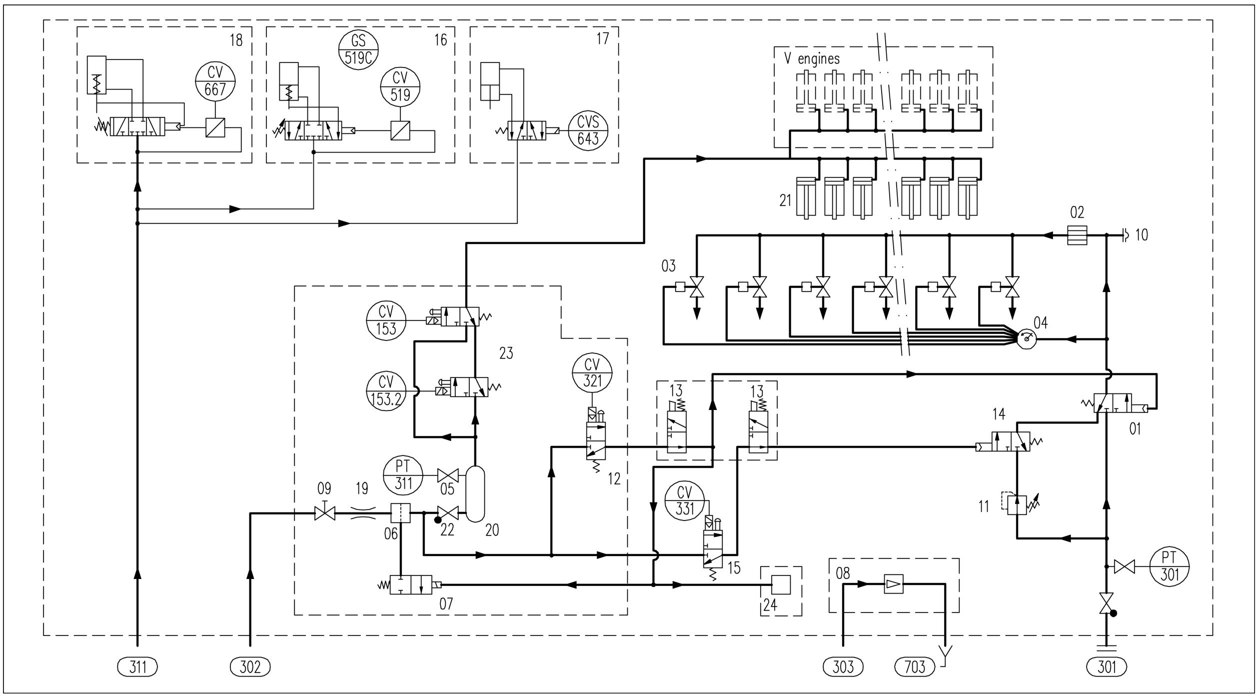
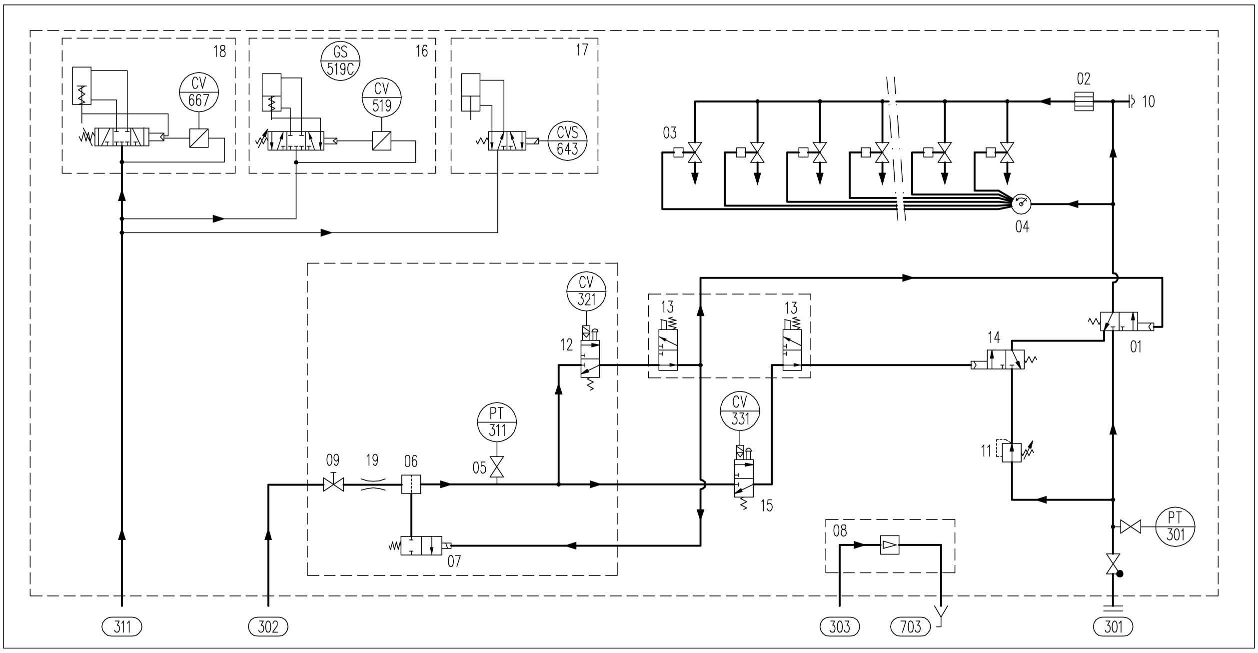


Figure 8.2 Internal starting and compressed air system, common rail system (DAAE039754b)



System components	
01	Main starting valve
02	Flame arrester
03	Starting air valve in cylinder head
04	Starting air distributer
05	Valve
06	Air filter
07	Valve for automatic draining
08	Oil mist detector
09	Ball valve
10	Bursting disc
11	Pressure regulating valve
12	Starting valve
13	Blocking valve on turning gear
14	Main slow turning valve
15	Slow turning valve
16	Waste gate valve
17	By-pass valve (variable speed application FPP/CPP)
18	Air waste gate valve
19	Orifice
20	Air container
21	Pneumatic stop cylinder at each HP fuel pump
22	Non return valve
23	Stopping valve HP fuel pump
24	Booster (mech. driven actuator)

Sensors and indicators	
CV153	Stop solenoid valve
CV153.2	Stop solenoid valve
CV321	Start control valve
CV331	Slow turning control valve
CV519	Waste gate valve
CV643	By-pass valve
PI301	Charge air pressure, engine inlet (if GL)
PI311	Control air pressure (if GL)
PT301	Charge air pressure, engine inlet
PT311	Control air pressure

Pipe connections		Size	Pressure class	Standard
301	Starting air inlet, 3 MPa	DN40	PN40	ISO7005-1
302	Control air inlet, 3 MPa	OD15	PN400	DIN2353
303	Driving air to oil mist detector, 0.2 ÷ 1.2 MPa	OD8	PN250	DIN2353

Pipe connections		Size	Pressure class	Standard
311	Instrument air, 0.8 MPa	OD8	PN250	DIN2353
703	Outlet from oil mist detector	OD22	PN250	DIN2353

8.3 External compressed air system

The design of the starting air system is partly determined by classification regulations. Most classification societies require that the total capacity is divided into two equally sized starting air receivers and starting air compressors. The requirements concerning multiple engine installations can be subject to special consideration by the classification society.

The starting air pipes should always be slightly inclined and equipped with manual or automatic draining at the lowest points.

Instrument air to safety and control devices must be treated in an air dryer.

Figure 8.3 Starting air system, single engine (DAAE039801b)

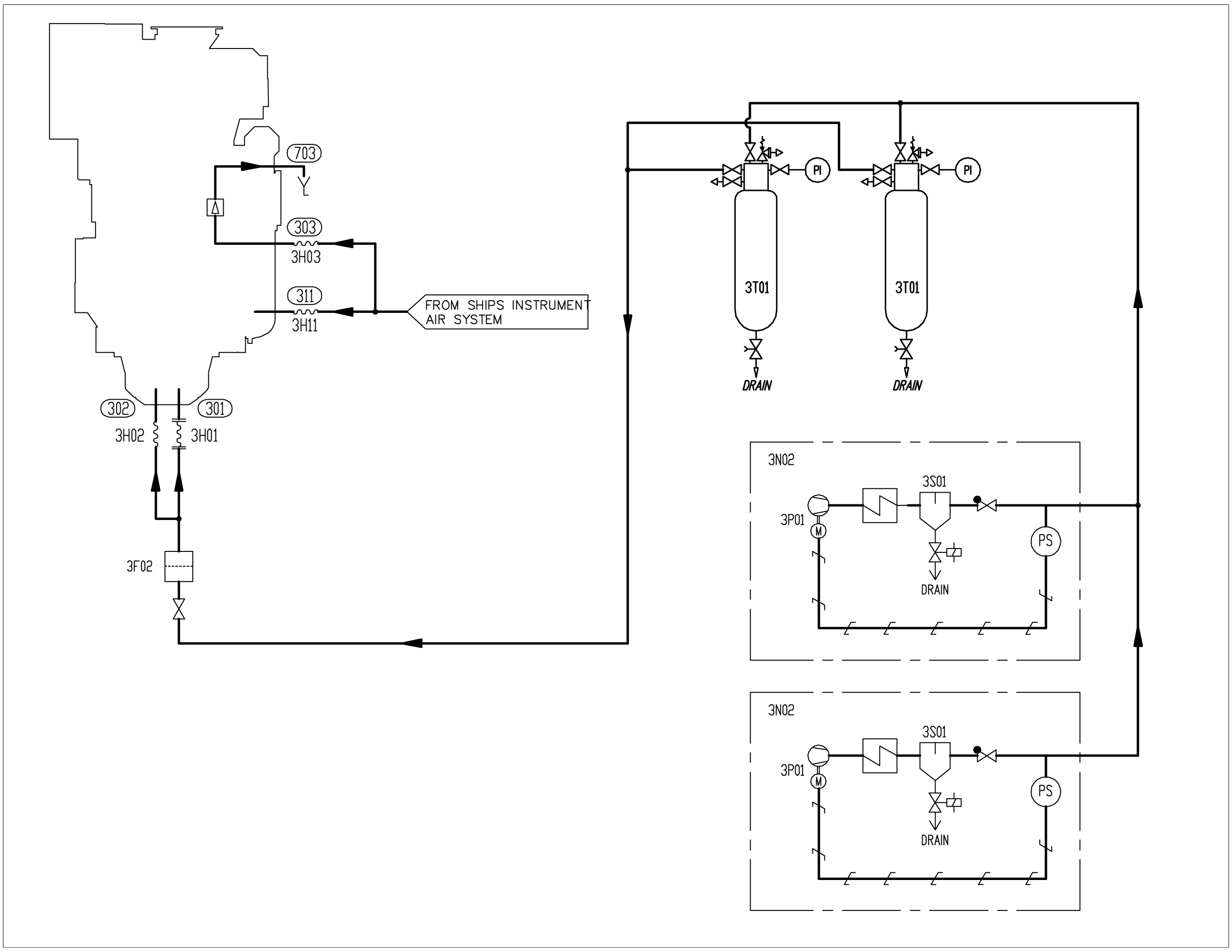
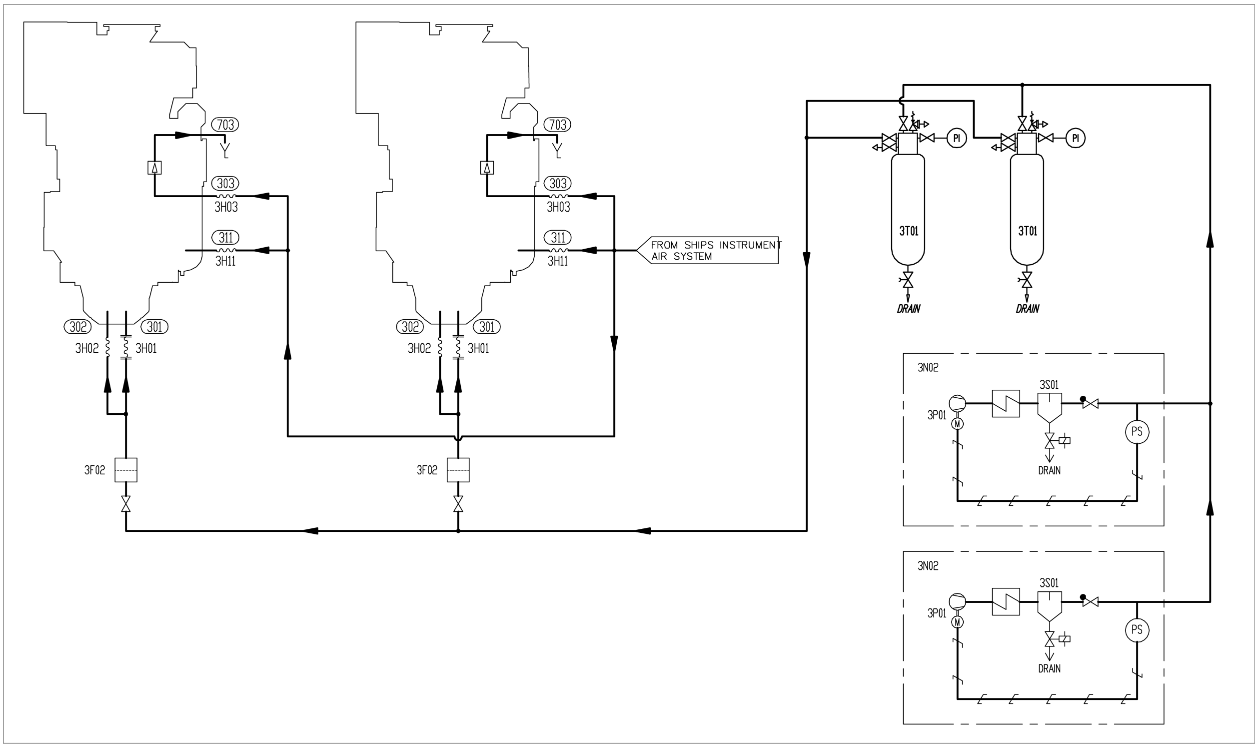


Figure 8.4 Starting air system, 2 engines (DAAE039802b)



System components		Pipe connections	
3F02	Air filter (starting air inlet)	301	Starting air inlet, 3MPa
3H0X	Flexible pipe connections	302	Starting air inlet, 3 MPa
3N02	Starting air compressor unit	303	Driving air to oil mist detector, 0.2÷1.2 MPa
3P01	Compressor (Starting air compressor unit)	311	Instrument air, 0.8 MPa
3S01	Separator (Starting air compressor unit)	703	Outlet from oil mist detector
3T01	Starting air vessel		

Recommended pressure losses in the piping between the starting air receiver and the engine are about 100 [kPa] (1 bar) during the starting process.

8.3.1 Starting air compressor unit (3N02)

At least two starting air compressors must be installed. It is recommended that the compressors are capable of filling the starting air vessel from minimum (1.8 MPa) to maximum pressure in 15...30 minutes. For exact determination of the minimum capacity, the rules of the classification societies must be followed.

8.3.2 Oil and water separator (3S01)

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

8.3.3 Starting air vessel (3T01)

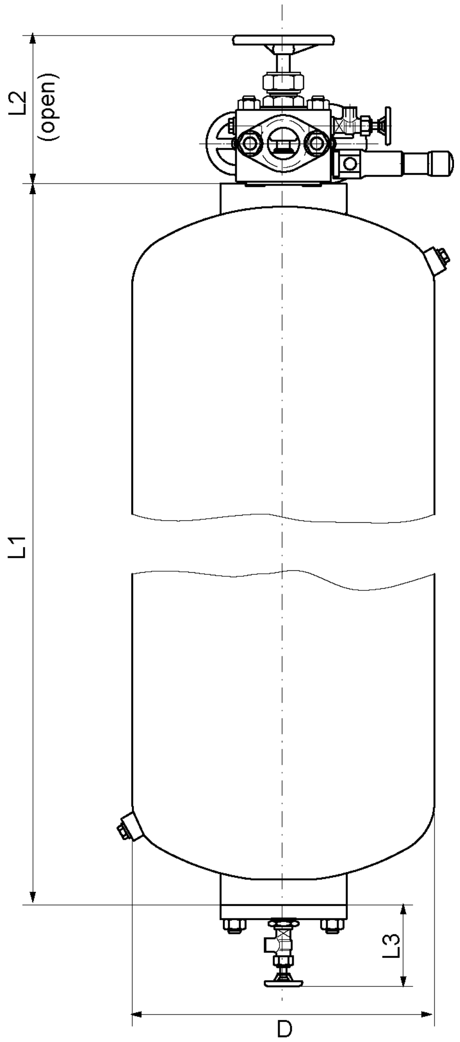
The starting air vessels should be dimensioned for a nominal pressure of 3 MPa.

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

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

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

Figure 8.5 Starting air vessel



Size [Litres]	Dimensions [mm]				Weight [kg]
	L1	L2 [1)]	L3 [1)]	D	
500	3204	243	133	480	450
710	2740	255	133	650	625
1000	3560	255	133	650	810
1250	2930	255	133	800	980
1500	3460	255	133	800	1150

1) Dimensions are approximate.

The starting air consumption stated in technical data is for a successful start. During a remote 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 remote 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 as remote starts, usually so that only the last starting attempt is successful.

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 [m³]

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

V_E = air consumption per start [Nm³] See *Technical data*

n = required number of starts according to the classification society

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

p_{Rmin} = minimum starting air pressure = 1.8 MPa

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

8.3.4 Starting air filter (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 opening size opening 40. 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.

9. Cooling water system

9.1 Water quality

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.

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

pH	min. 6.5
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.

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.

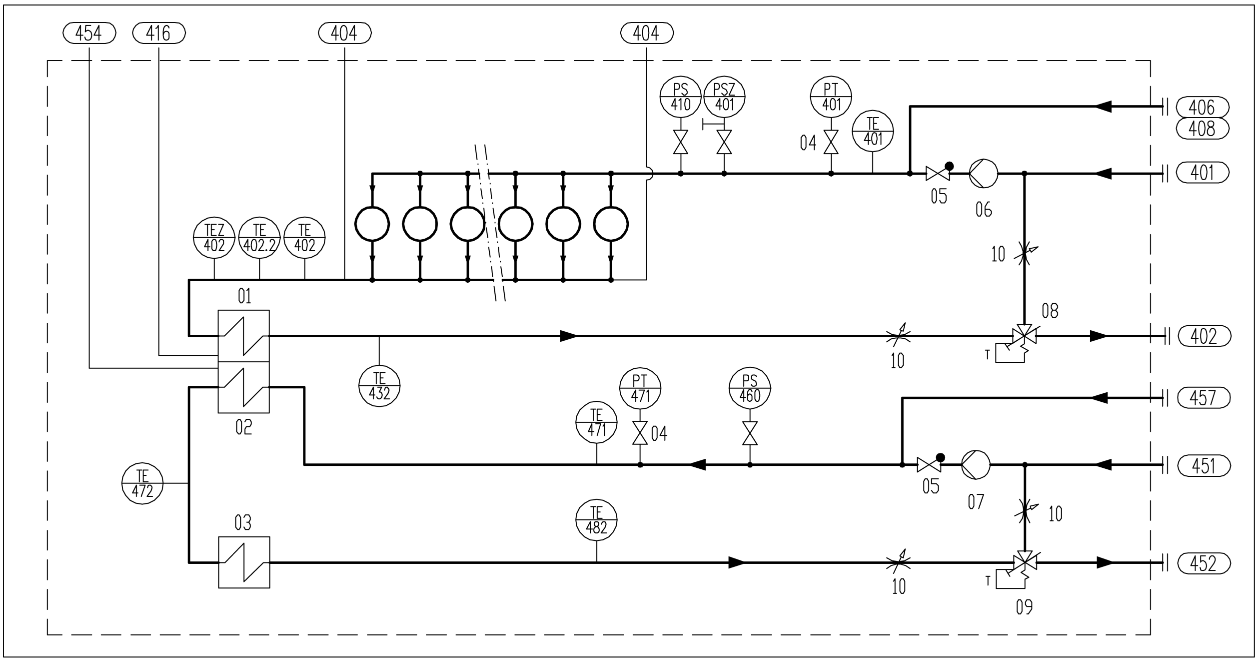
9.1.2 Glycol

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.

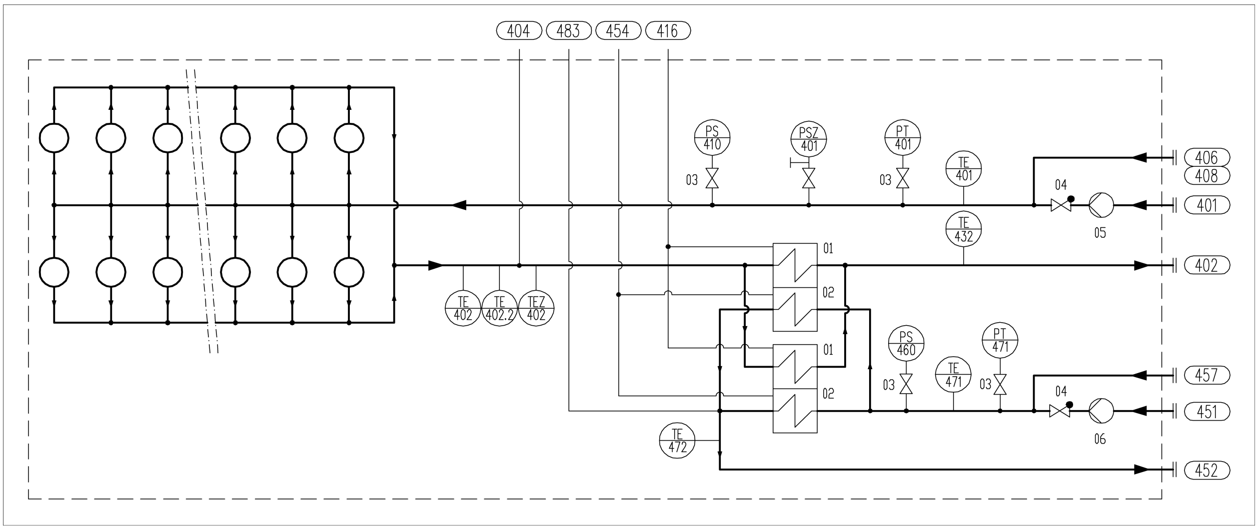
9.2 Internal cooling water system

Figure 9.1 Internal cooling water system, in-line engine (DAAE039756c)



System components		Sensors and indicators	
01	Charge air cooler, HT section	PS410	HT jacket water stand-by pump start (if GL)
02	Charge air cooler, LT section	PS460	LT stand-by pump start (if GL)
03	Lubricating oil cooler	PSZ401	HT cooling water pressure, jacket inlet (if GL)
04	Valve	PT401	HT cooling water pressure, engine inlet
05	Non return valve	PT432	HT cooling water pressure, HT CAC outlet (if FAKS)
06	HT cooling water pump	PT471	LT cooling water pressure, engine inlet
07	LT cooling water pump	TE401	HT cooling water temperature, jacket inlet
08	HT thermostatic valve	TE402	HT cooling water temperature, engine outlet
09	LT thermostatic valve	TEZ402	HT cooling water temperature, engine outlet
10	Adjustable orifice	TE471	LT cooling water temperature, engine inlet
		TE472	LT cooling water temperature, engine outlet

Figure 9.2 Internal cooling water system, V-engine (DAAE039757c)



System components		Sensors and indicators	
01	Charge air cooler, HT section	PS410	HT jacket water stand-by pump start (if GL)
02	Charge air cooler, LT section	PS460	LT stand-by pump start (if GL)
03	Valve	PSZ401	HT cooling water pressure, jacket inlet (if GL)
04	Non return valve	PT401	HT cooling water pressure, engine inlet
05	HT cooling water pump	PT432	HT cooling water pressure, HT CAC outlet (if FAKS)
06	LT cooling water pump	PT471	LT cooling water pressure, engine inlet
		TE401	HT cooling water temperature, jacket inlet
		TE402	HT cooling water temperature, engine outlet, bank A
		TEZ402	HT cooling water temperature, engine outlet, bank A
		TE471	LT cooling water temperature, engine inlet
		TE472	LT cooling water temperature, engine outlet (if FAKS)

Pipe connections		Size	Pressure class	Standard
401	HT cooling water inlet, in line	DN125	PN10	DIN2576
401	HT cooling water inlet, V engines	DN150	PN10	DIN2576
402	HT cooling water outlet, in line	DN125	PN10	DIN2576
402	HT cooling water outlet, V engines	DN150	PN10	DIN2576
404	HT cooling water air vent, in line	M18x1,5 OD12	- PN400	- DIN2353
404	HT cooling water air vent, V engines	OD12	PN400	DIN2353
406	HT cooling water from preheater, in line	DN100	PN10	DIN2576
406	HT cooling water from preheater, V engines	DN150	PN10	DIN2576
408	HT cooling water from stand-by pump, in line	DN100	PN10	DIN2576
408	HT cooling water from stand-by pump, V engines	DN150	PN10	DIN2576
416	HT cooling water air vent from charge air cooler	OD12	PN400	DIN2353
451	LT cooling water inlet, in line	DN125	PN10	DIN2576
451	LT cooling water inlet, V engines	DN150	PN10	DIN2576
452	LT cooling water outlet, in line	DN125	PN10	DIN2576
452	LT cooling water outlet, V engines	DN150	PN10	DIN2576
454	LT cooling water air vent from charge air cooler	OD12	PN400	DIN2353
457	LT cooling water from stand-by pump, in line	DN100	PN10	DIN2576
457	LT cooling water from stand-by pump, V engines	DN150	PN10	DIN2576
483	LT cooling water air vent from LT circuit, V engines	OD12	PN400	DIN2353

The fresh water cooling system is divided into a high temperature (HT) and a low temperature (LT) circuit. The HT water circulates through cylinder jackets, cylinder heads and the 1st stage of the charge air cooler. The HT water passes through the cylinder jackets before it enters the HT-stage of the charge air cooler.

A two-stage charge air cooler enables more efficient heat recovery and heating of cold combustion air.

The LT water circulates through the charge air cooler and the lubricating oil cooler. In-line engines are equipped with built on lubricating oil cooler, while V-engines require an external lubricating oil cooler.

In-line engines have built on temperature control valves and throttles for balancing of the flows. The temperature control valves are installed in the external system for V-engines

9.2.1 Engine driven circulating pumps

The LT and HT cooling water pumps are always engine driven. 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*.

Figure 9.3 6L38B, HT & LT pumps DW 20-10/6,5: impeller: 188 mm

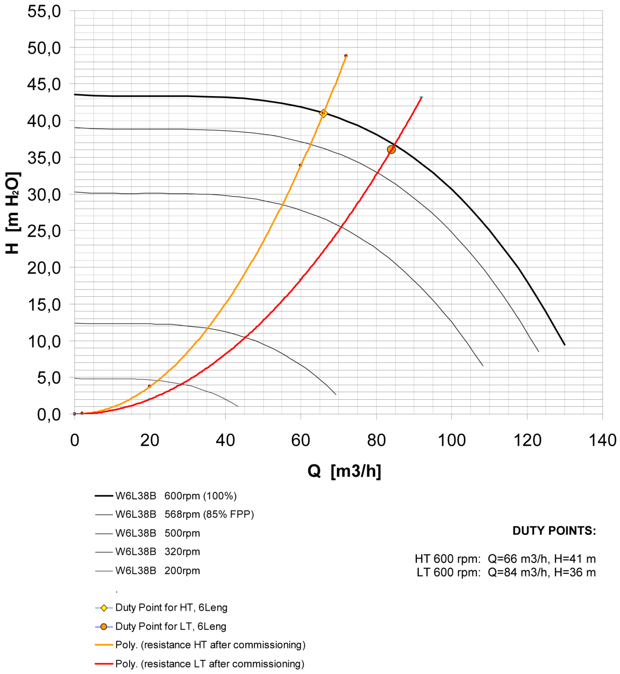


Figure 9.4 8/9L38B, HT & LT pumps DW 20-10/8: impeller: 190 mm; with throttle plate 60

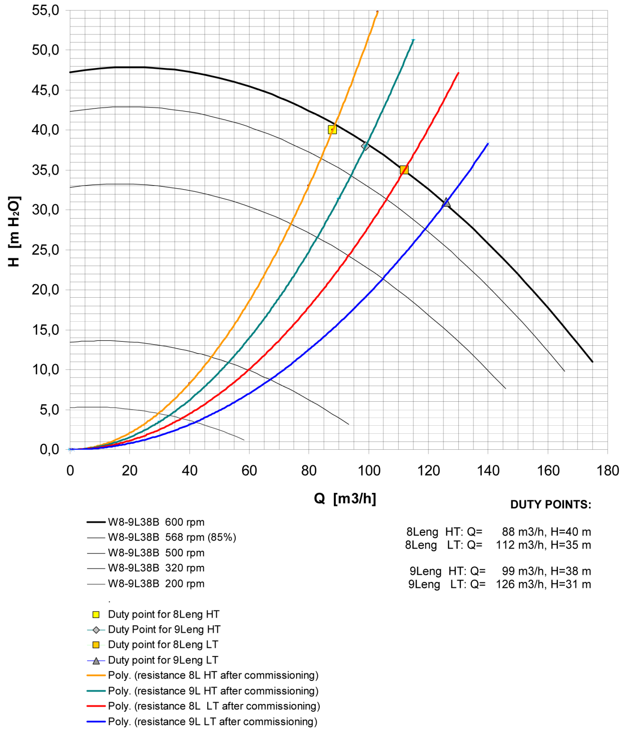


Figure 9.5 12V38B, HT & LT pumps WD-125: impeller: 195 mm

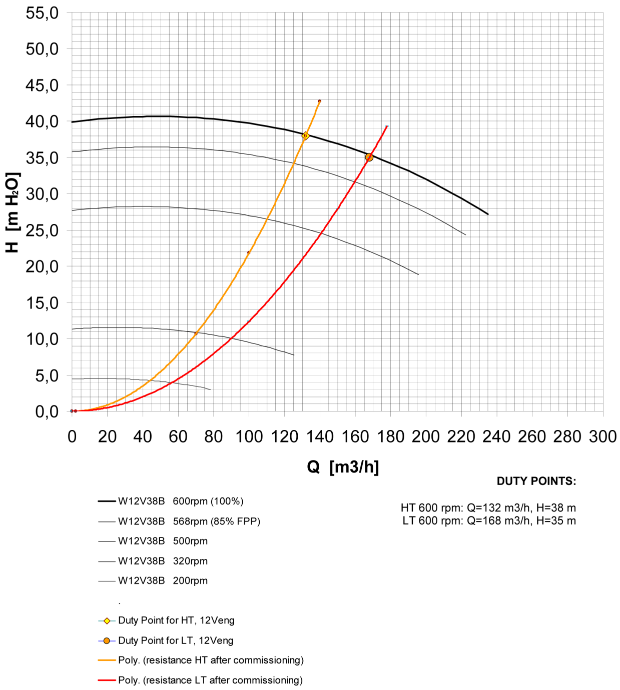
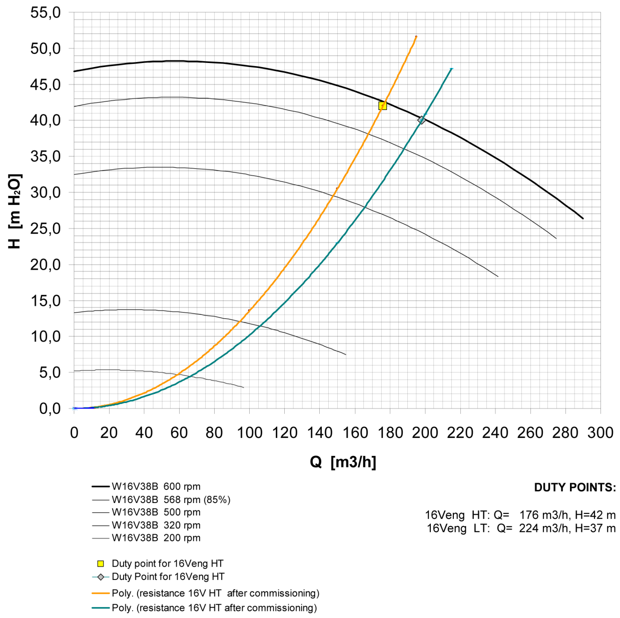


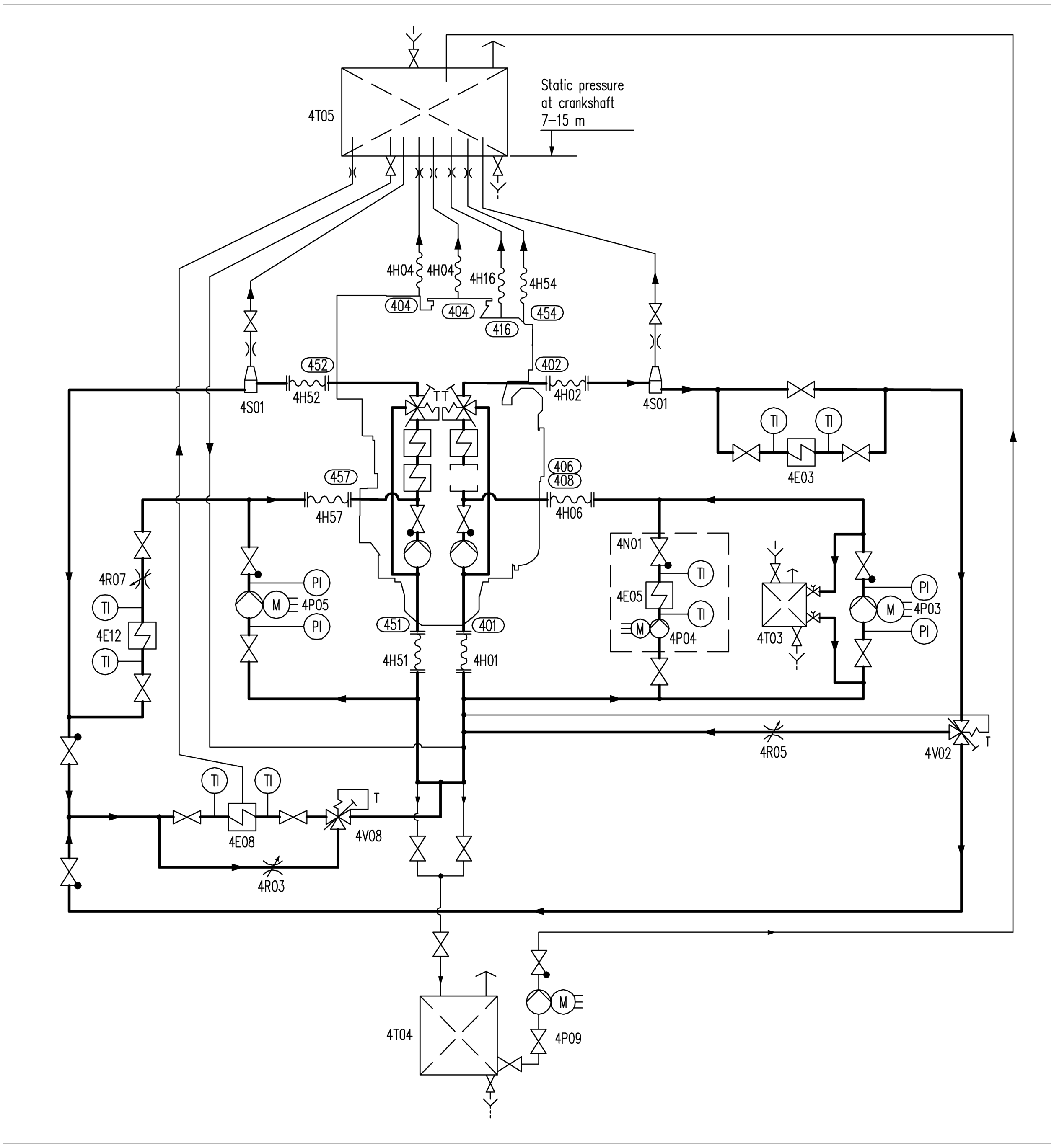
Figure 9.6 16V38B, HT & LT pumps WD-125: impeller: 210 mm



9.3 External cooling water system

9.3.1 Example system diagram

Figure 9.7 Cooling water system, combined coolers, in line engine (DAAE039805b)



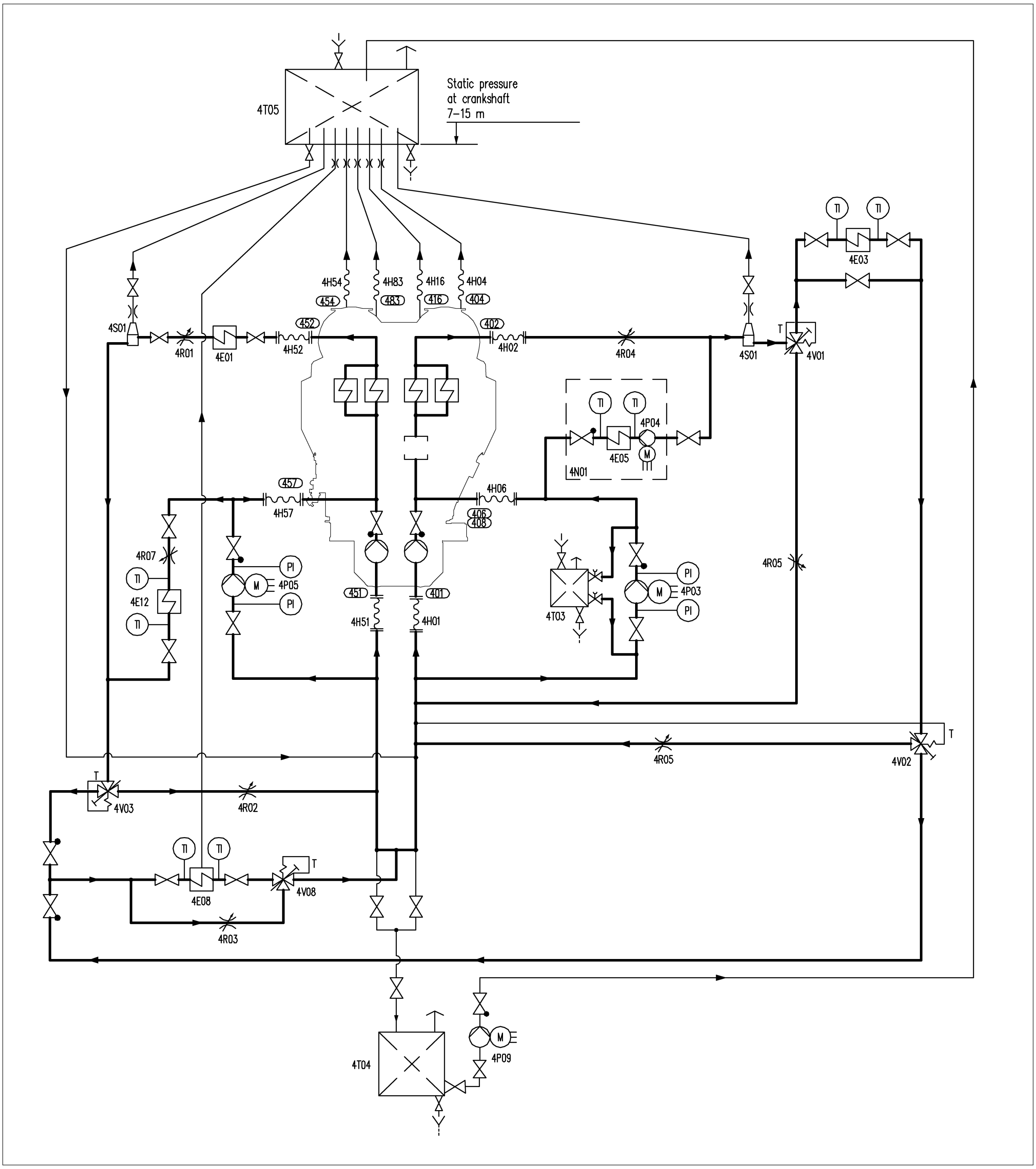
System components	
4E03	Heat recovery
4E05	Heater (preheater)
4E08	Central cooler
4E12	Cooler (installation parts)
4HXX	Flexible pipe connection*
4N01	Preheating unit
4P03	Stand-by pump (HT)

Pipe connections	
401	HT cooling water inlet
402	HT cooling water outlet
404	HT cooling water air vent
406	HT cooling water from preheater
408	HT cooling water from stand-by pump
416	HT cooling water air vent from charge air cooler
451	LT cooling water inlet

System components		Pipe connections	
4P04	Circulating pump (preheater)	452	LT cooling water outlet
4P05	Stand-by pump (LT)	454	LT cooling water air vent
4P09	Transfer pump	457	LT-water from stand-by pump
4R03	Adjustable throttle valve (LT cooler)		
4R05	Adjustable throttle valve (HT valve)		
4S01	Air venting		
4T03	Additive dosing tank		
4T04	Drain tank		
4T05	Expansion tank		
4V02	Temperature control valve (heat recovery)		
4V08	Temperature control valve (central cooler)		

* Only required for resiliently mounted engines

Figure 9.8 Cooling water system, combined coolers, V-engine (DAAE039807b)



System components	
4E01	Lubricating oil cooler
4E03	Heat recovery
4E05	Heater (preheater)
4E08	Central cooler
4E12	Cooler (installation parts)
4HXX	Flexible pipe connection*
4N01	Preheating unit
4P03	Stand-by pump (HT)
4P04	Circulating pump (preheater)

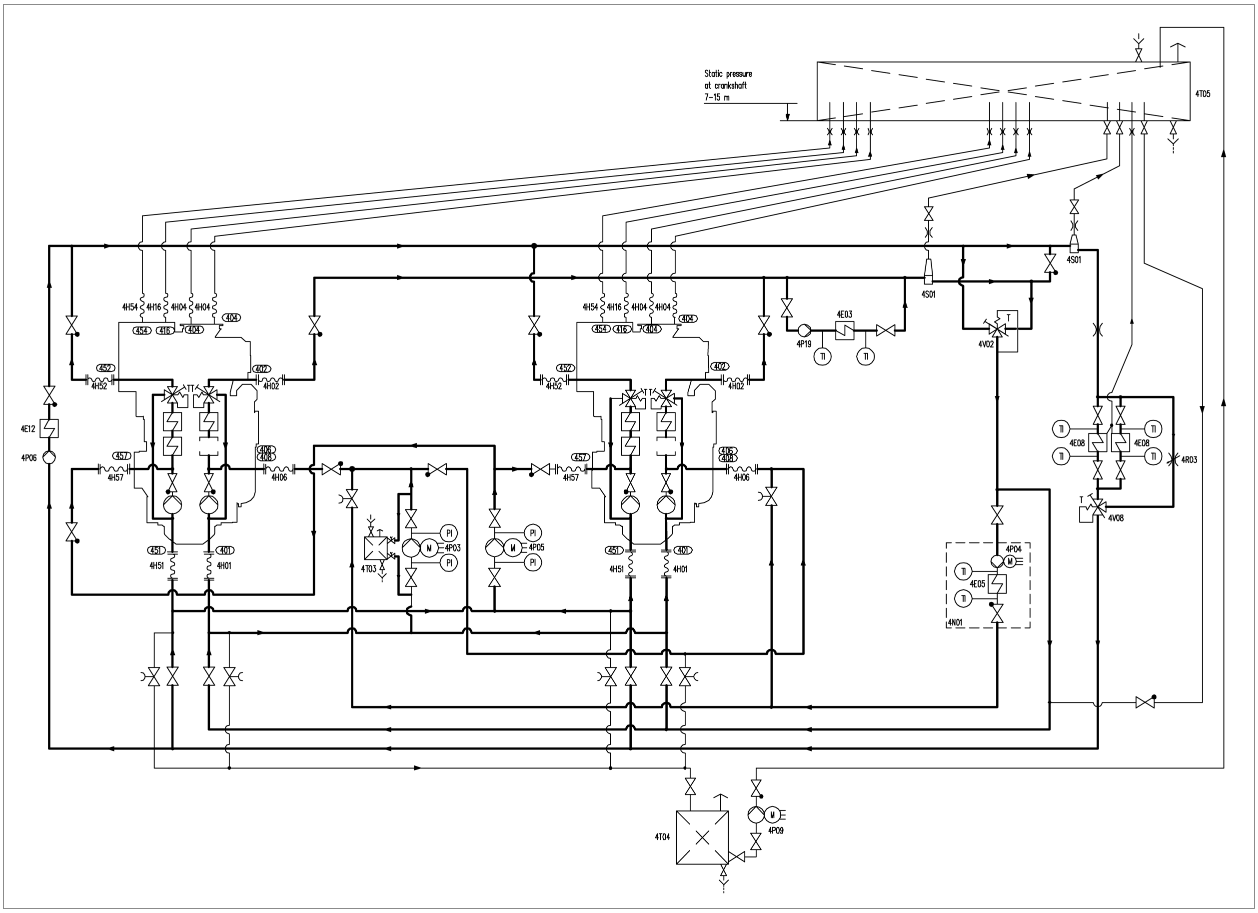
Pipe connections	
401	HT cooling water inlet
402	HT cooling water outlet
404	HT cooling water air vent
406	HT cooling water from preheater
408	HT cooling water from stand-by pump
416	HT cooling water air vent from charge air cooler
451	LT cooling water inlet
452	LT cooling water outlet
454	LT cooling water air vent

System components	
4P05	Stand-by pump (LT)
4P09	Transfer pump
4R0X	Adjustable throttle valve
4R05	Adjustable throttle valve (HT valve)
4S01	Air venting
4T03	Additive dosing tank
4T04	Drain tank
4T05	Expansion tank
4V01	Temperature control valve (HT)
4V02	Temperature control valve (heat recovery)
4V03	Temperature control valve (LT)
4V08	Temperature control valve (central cooler)

Pipe connections	
457	LT-water from stand-by pump
483	LT cooling water air vent from LT circuit

* Only required for resiliently mounted engines

Figure 9.9 Cooling water system, multiple in line engines (DAAE039808b)



System components	
4E01	Lubricating oil cooler
4E03	Heat recovery
4E05	Heater (preheater)
4E08	Central cooler
4E12	Cooler (installation parts)
4HXX	Flexible pipe connection*
4N01	Preheating unit
4P03	Stand-by pump (HT)

Pipe connections	
401	HT cooling water inlet
402	HT cooling water outlet
404	HT cooling water air vent
406	HT cooling water from preheater
408	HT cooling water from stand-by pump
416	HT cooling water air vent from charge air cooler
451	LT cooling water inlet
452	LT cooling water outlet

System components		Pipe connections	
4P04	Circulating pump (preheater)	454	LT cooling water air vent
4P05	Stand-by pump (LT)	457	LT-water from stand-by pump
4P09	Transfer pump		
4R0X	Adjustable throttle valve		
4R05	Adjustable throttle valve (HT valve)		
4S01	Air venting		
4T03	Additive dosing tank		
4T04	Drain tank		
4T05	Expansion tank		
4V01	Temperature control valve (HT)		
4V02	Temperature control valve (heat recovery)		
4V03	Temperature control valve (LT)		
4V08	Temperature control valve (central cooler)	* Only required for resiliently mounted engines	

The vent pipes should have a continuous slope upwards to the expansion tank. Size of the piping in the installation to be calculated case by case, having typically a larger diameter than the connection on the engine.

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

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

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

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.

9.3.3 Sea water pump (4P11)

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

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

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

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

The temperature control valve is installed directly after the engine. It controls the temperature of the water out from the engine, by circulating some water back to the HT pump. The control valve can be either self-actuated or electrically actuated. Each engine must have a dedicated temperature control valve.

Set point	93°C

9.3.5 Temperature control valve, LT-system (4V03)

The temperature control valve of the LT-circuit is installed to control the LT water temperature.

Set point	44°C

9.3.6 Temperature control valve for central cooler (4V08)

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

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

9.3.7 Temperature control valve for heat recovery (4V02)

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

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

9.3.8 Lubricating oil cooler (2E01)

The lubricating oil cooler is connected in series with the charge air cooler in the LT circuit.

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

9.3.9 Fresh water central cooler (4E08)

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

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

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%

Figure 9.10 Single cooler system

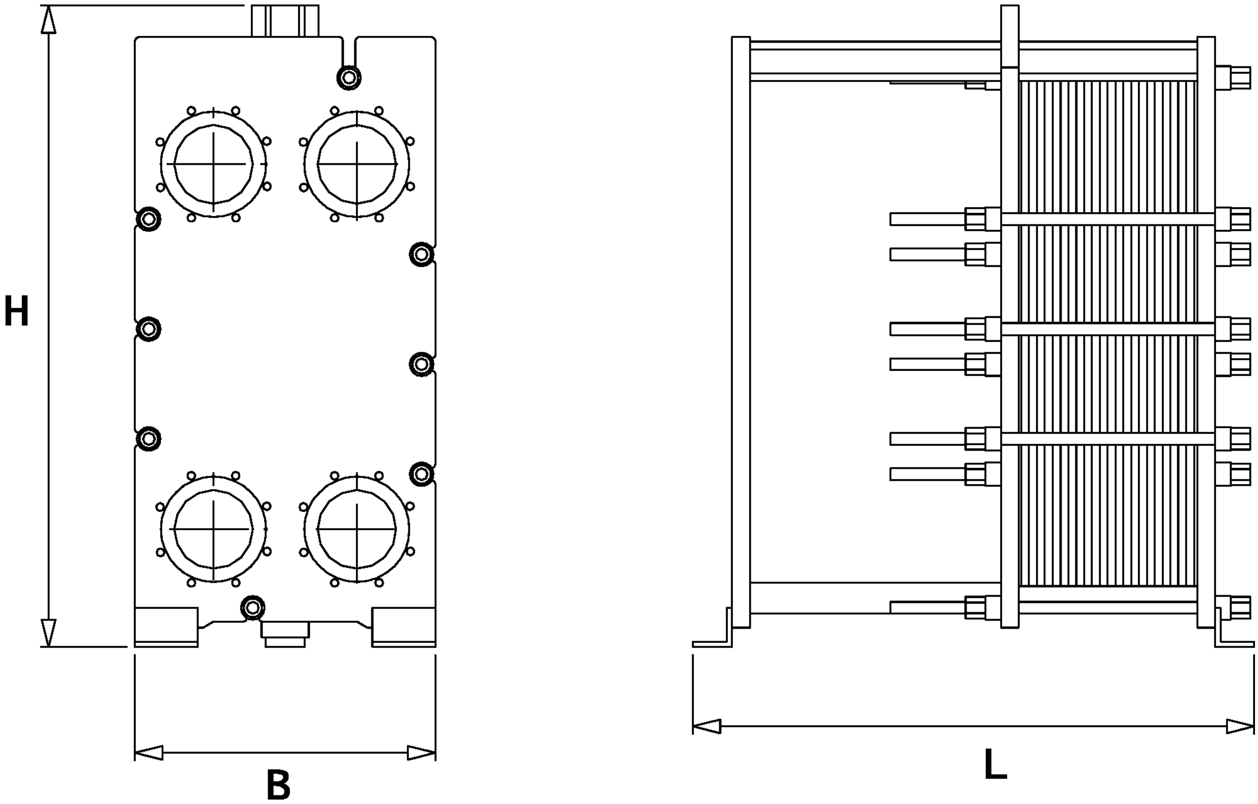


Table 9.1 Single cooler system (4E08)

Number of cylinders	H [mm]	B [mm]	L [mm]	Mass [kg] (wet)
6L	1100	470	1100	430
8L	1950	610	1150	1000
9L	1950	610	1150	1020
12V	1950	610	1450	1110
16V	1950	610	1450	1260
18V	2350	780	2070	2100

Table 9.2 Separate cooler system, HT cooler (4E04)

Number of cylinders	H [mm]	B [mm]	L [mm]	Mass [kg] (wet)
6L	1100	470	850	400
8L	1100	470	1100	425
9L	1100	470	1100	440
12V	1950	510	1150	1000
16V	1950	610	1150	1100
18V	1950	610	1150	1150

Table 9.3 Separate cooler system, LT cooler (4E06)

Number of cylinders	H [mm]	B [mm]	L [mm]	Mass [kg] (wet)
6L	1100	470	850	300
8L	1100	470	850	320
9L	1100	470	850	330
12V	1650	765	1130	850
16V	1650	765	1130	930
18V	1650	765	1130	1010

NOTE! Above mentioned sizes are for guidance only. These coolers are dimensioned to exchange the heat of the engine only, other equipment as CPP, gearbox, etc. Is not taken into account.

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.

9.3.10 Waste heat recovery

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

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

9.3.11 Air venting

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

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

The vent pipes must be continuously rising.

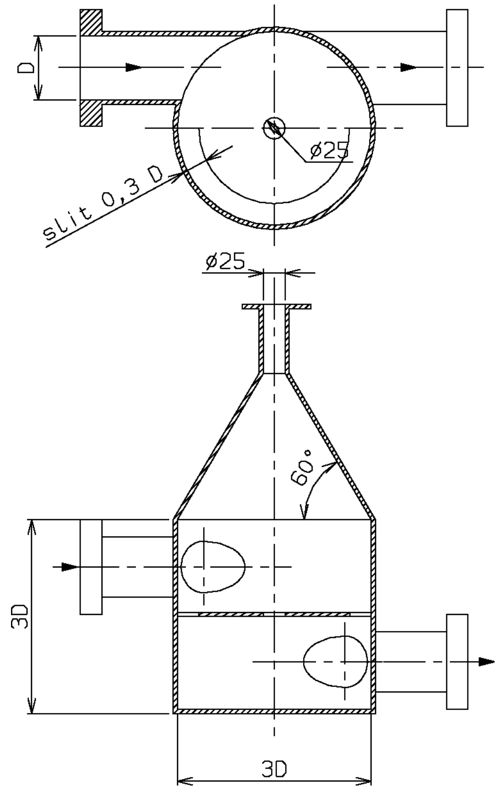
Air separator (4S01)

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

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

The water flow is forced in a circular movement in the air separator. Air and gas collect in the centre of the separator due to the higher centrifugal force on water.

Figure 9.11 Automatic de-aerator (9811MR102)



9.3.12 Expansion tank (4T05)

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

Design data:

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

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

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

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

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

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 9.4 Minimum diameter of balance pipe

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

9.3.13 Drain tank (4T04)

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

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

9.3.14 Additive dosing tank (4T03)

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

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

9.3.15 Preheating

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

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

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 6 kW/cyl, which makes it possible to warm up the engine from 20 ºC to 60...70 ºC in 10-15 hours. The required heating power for shorter heating time can be estimated with the formula below. About 3 kW/cyl is required to keep a hot engine warm.

Design data:	
Preheating temperature	min. 60°C
Required heating power	6 kW/cyl
Heating power to keep hot engine warm	3 kW/cyl

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

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

where:

P = Preheater output [kW]

T_1 = Preheating temperature = 60...70 °C

T_0 = Ambient temperature [°C]

m_{eng} = Engine weight [ton]

V_{FW} = HT water volume [m^3]

t = Preheating time [h]

k_{eng} = Engine specific coefficient = 1.5 kW

n_{cyl} = Number of cylinders

The formula above should not be used for $P < 5$ kW/cyl

Circulation pump for preheater (4P04)

Design data:	
Capacity	0.9 m³/h per cylinder
Delivery pressure	80 kPa (0.8 bar)

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

Figure 9.12 Pre-heating unit, electric (9507ZT655)

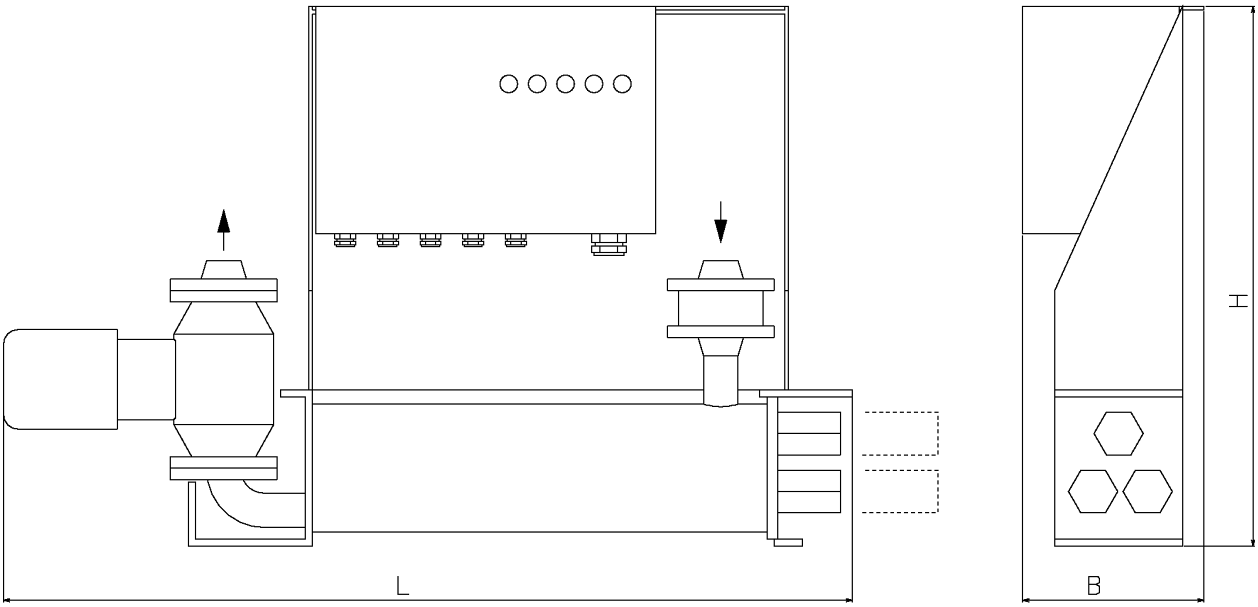


Table 9.5 Cooling water Pre-heating unit (4N01)

Heating power [kW]	L [mm]	H [mm]	B [mm]	Mass [kg] (wet)
18	1250	800	460	95
24	1250	840	480	103
27	1250	840	480	103
36	1250	840	480	125
48	1250	940	510	150
54	1250	1190	510	150
72	1260	1190	550	187
96	1260	1240	575	215
108	1260	1240	575	215

For installations with several engines the pre-heater unit can be dimensioned for heating up more engines. If the heat from a running engine can be used the power consumption of the heaters will be less than the nominal capacity.

9.3.16 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.

9.3.17 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:

$$Q_V = \frac{\Phi}{\rho \times \Delta t \times c}$$

where:

Qv = amount of ventilation air [m³/s]

Φ = total heat emission to be evacuated [kW]

ρ = density of ventilation air 1.13 kg/m³

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

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

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

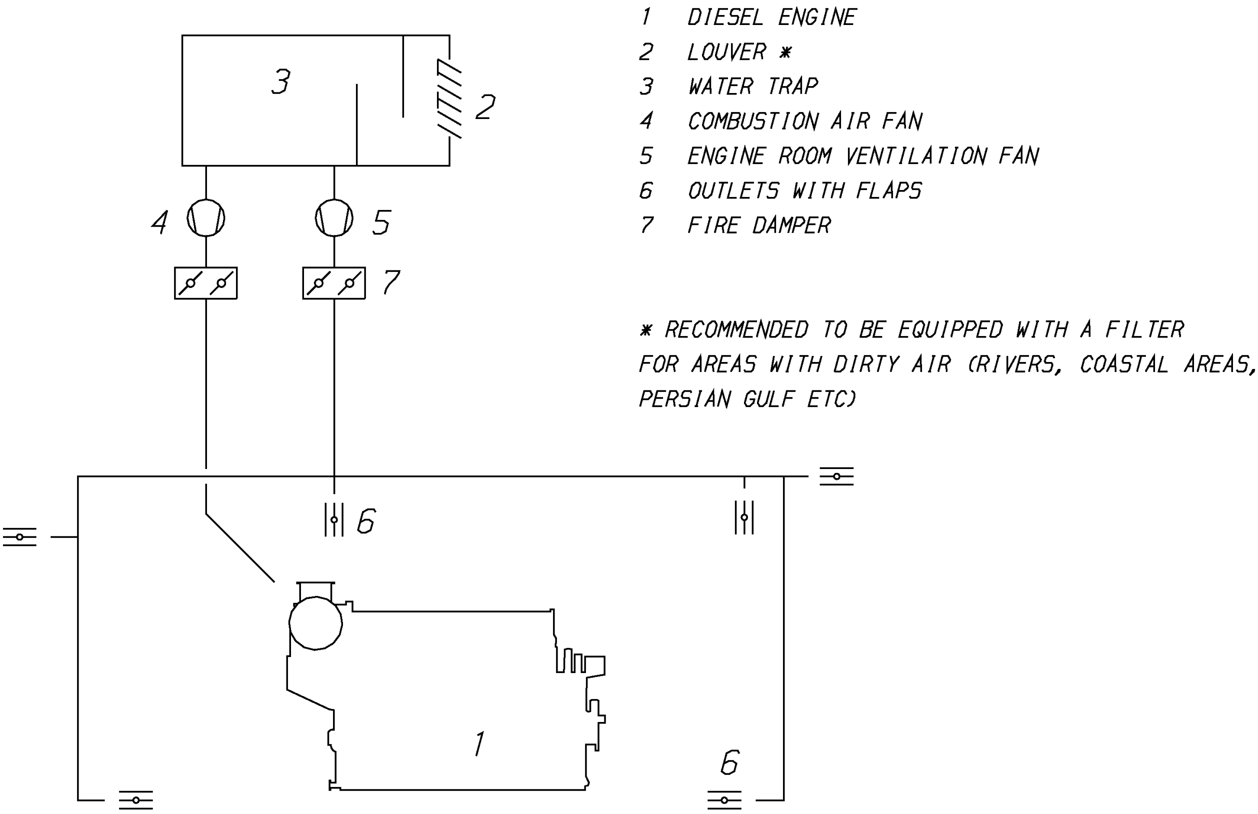
The engine room ventilation air has to be provided by separate ventilation fans. These fans should preferably have two-speed electric motors (or variable speed). The ventilation can then be reduced according to outside air temperature and heat generation in the engine room, for example during overhaul 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.

Figure 10.1 Engine room ventilation (4V69E8169b)



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.

During normal operating conditions the air temperature at turbocharger inlet should be kept between 15...35°C. Temporarily max. 45°C is allowed. For the required amount of combustion air, see chapter *Technical data*.

The combustion air shall be supplied by separate combustion air fans, with a capacity slightly higher than the maximum air consumption. The fans should preferably have two-speed electric motors (or variable speed) for enhanced flexibility. In addition to manual control, the fan speed can be controlled by engine load.

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

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

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

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

10.2.1 Condensation in charge air coolers

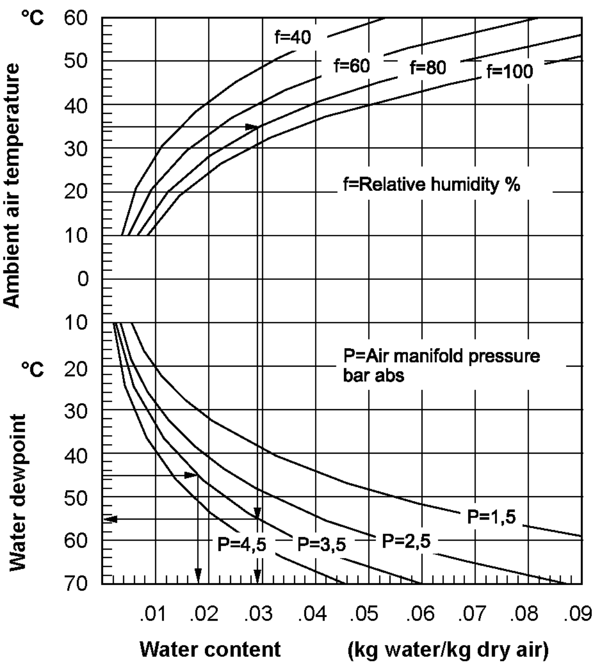
Air humidity may condense in the charge air cooler, especially in tropical conditions. The engine equipped with a small drain pipe from the charge air cooler for condensed water.

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

Example, according to the diagram:

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

Figure 10.2 Condensation in charge air coolers



11. Exhaust gas system

11.1 Internal exhaust gas system

Figure 11.1 Charge air and exhaust gas system, in-line engine (DAAE039759b)

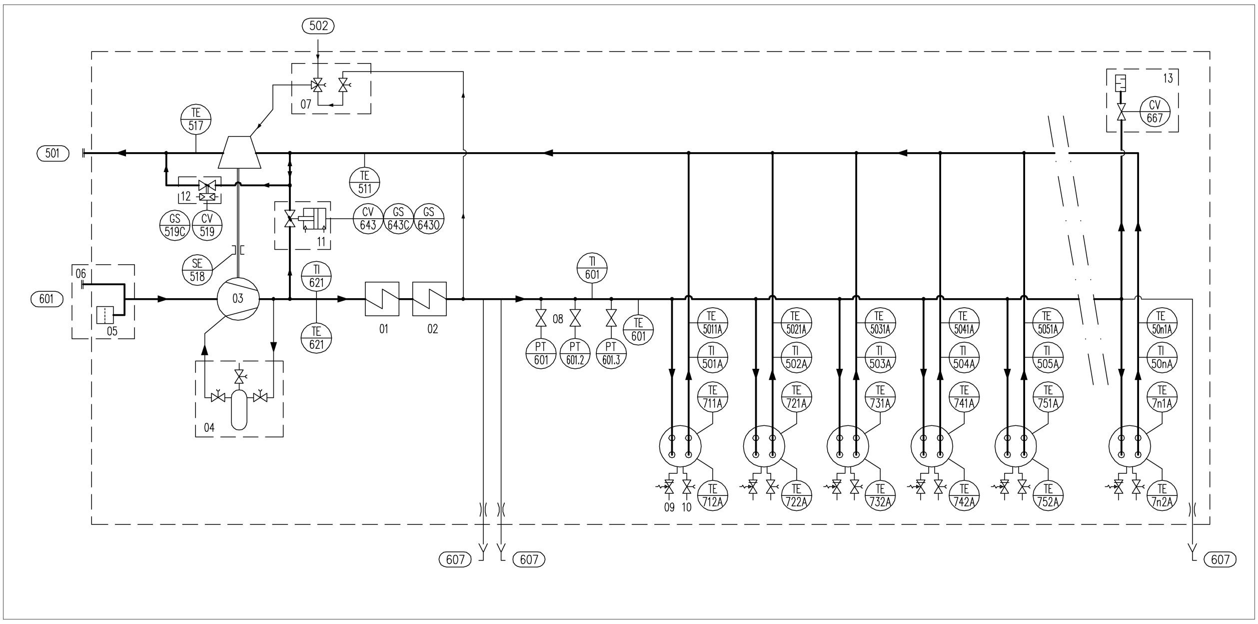
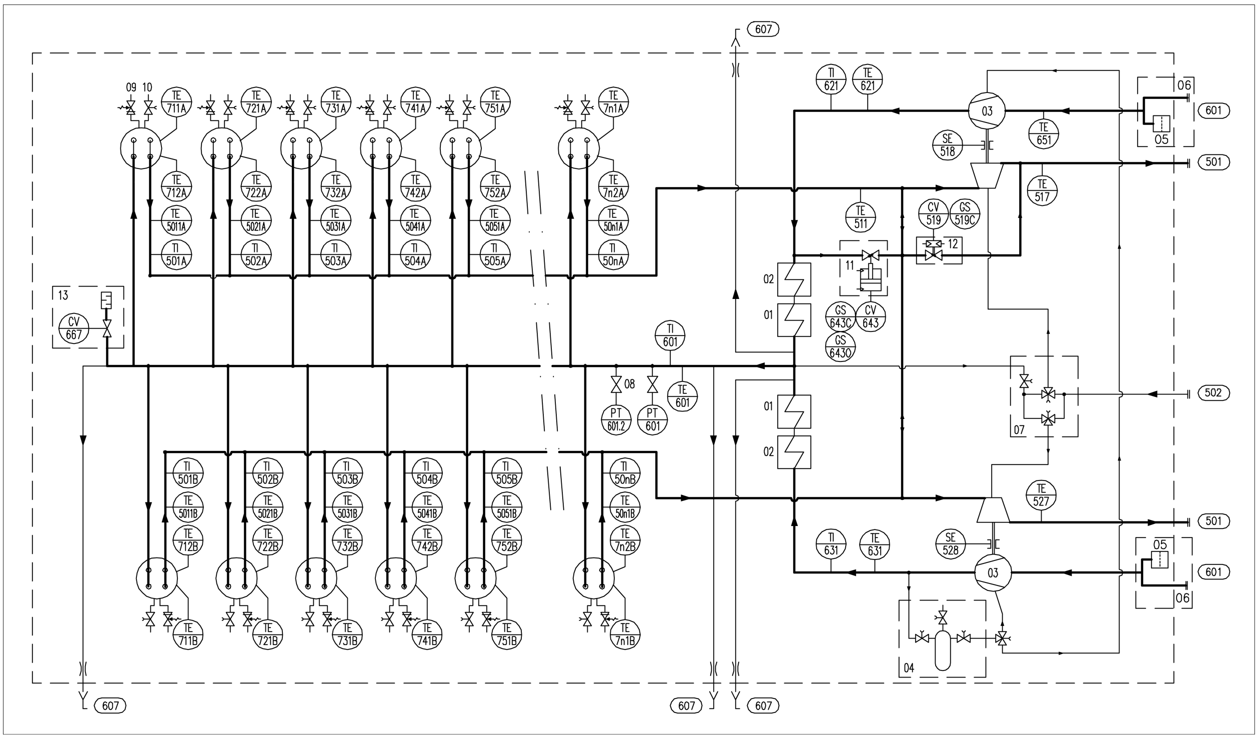


Figure 11.2 Charge air and exhaust gas system, V- engine (DAAE039761a)



System components		Sensors and indicators	
01	Charge air cooler, HT section	CV519	Exhaust waste gate valve control
02	Charge air cooler, LT section	CVS643	Charge air by-pass valve control
03	Turbocharger	GS643C	Charge air by-pass valve position, closed
04	Compressor manual cleaning device	GS643o	Charge air by-pass valve position, open
05	Air filter and silencer	PI601	Charge air pressure, engine inlet (if GL)

System components	
06	Suction branch (as alternative for 05)
07	Turbine manual cleaning device
08	Valve
09	Safety valve
10	Indicator valve
11	By-pass valve (application FPP/CPP)
12	Exhaust gas waste gate

Sensors and indicators	
PT601	Charge air pressure, engine inlet
PT601.2	Charge air pressure for external governor, engine inlet
PT601.3	Charge air pressure for waste gate, engine inlet
TE50n1A	Exhaust gas temperature, cyl. n, A bank
TE50n1B	Exhaust gas temperature, cyl. n, B bank
TE511	Exhaust gas temperature, TC inlet, A bank
TE521	Exhaust gas temperature, TC inlet, B bank
TE517	Exhaust gas temperature, TC outlet, A bank
TE527	Exhaust gas temperature, TC outlet, B bank
TE600	Charge air temperature, TC inlet (if FAKS)
TE601	Charge air temperature, engine inlet
TE621	Charge air temperature, CAC inlet, A bank (if FAKS)
TE631	Charge air temperature, CAC inlet, B bank (if FAKS)
TE651	Charge air temperature, TC inlet
TE7n1A TE7n2A	Cylinder liner temperature, cyl. n, A bank
TE7n1B TE7n2B	Cylinder liner temperature, cyl. n, B bank
TI50nA	Exhaust gas temperature, cyl. n, A bank (if GL)
TI50nB	Exhaust gas temperature, cyl. n, B bank (if GL)
TI601	Charge air temperature, engine inlet (if GL)
TI621	Charge air temperature, before CAC, A bank (if GL)
TI631	Charge air temperature, before CAC, B bank (if GL)
SE518	TC A speed
SE528	TC B speed

Pipe connections		Size	Pressure class	Standard
501	Exhaust gas outlet, 6L & 12V; 8L only FPP	DN500	PN2,5	DIN2501
501	Exhaust gas outlet, 8*/9L & 16V	DN600	PN2,5	DIN2501
502	Cleaning water to turbine	Quick coupling for socket Hansen 6S30 3/4"		
601	Air inlet to turbocharger, 6L & 12V; 8L only FPP	DN500	PN2,5	DIN2501
601	Air inlet to turbocharger, 8*/9L & 16V	DN600	PN2,5	DIN2501
607	Condensate after air cooler, in line	1xG1/2" 2xOD10	- -	- DIN910
607	Condensate after air cooler, V engine	OD15	-	DIN910

*) Unless 8L FPP

11.2 Exhaust gas outlet

Figure 11.3 Exhaust pipe connection, in-line engines (9506DT642)

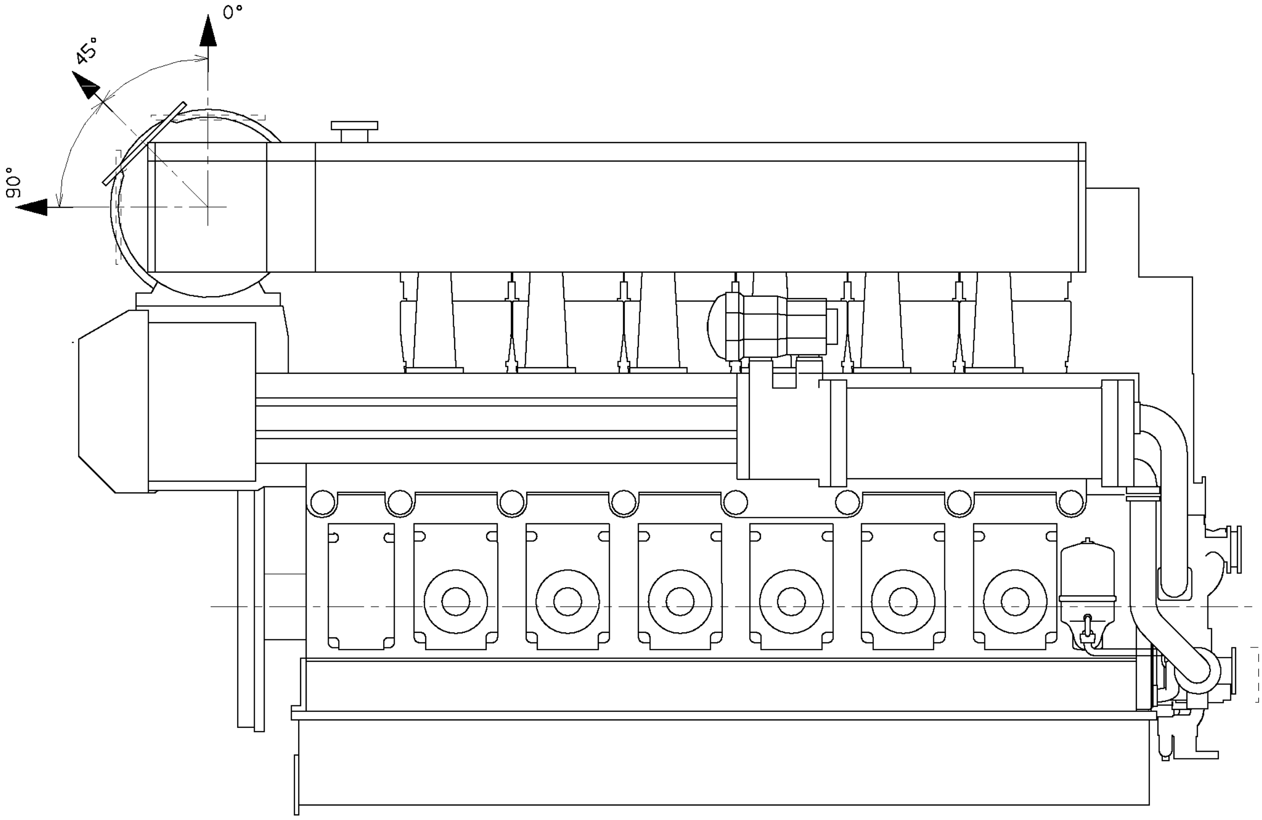


Figure 11.4 Exhaust pipe connection, V-engines (9506DT658)

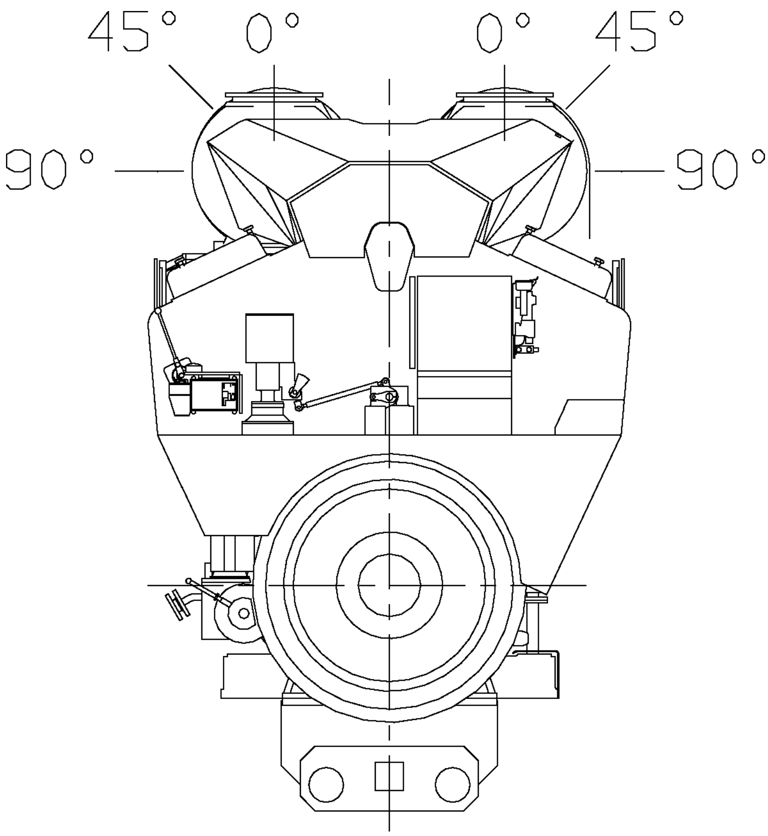
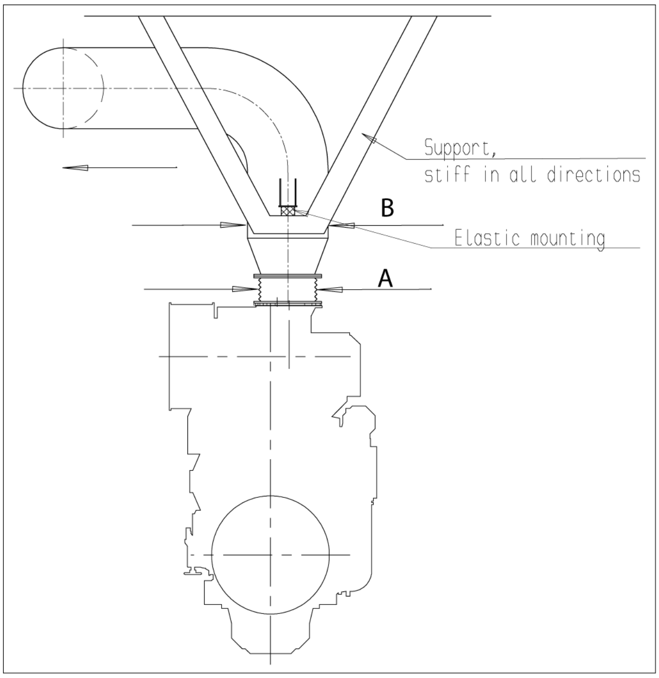
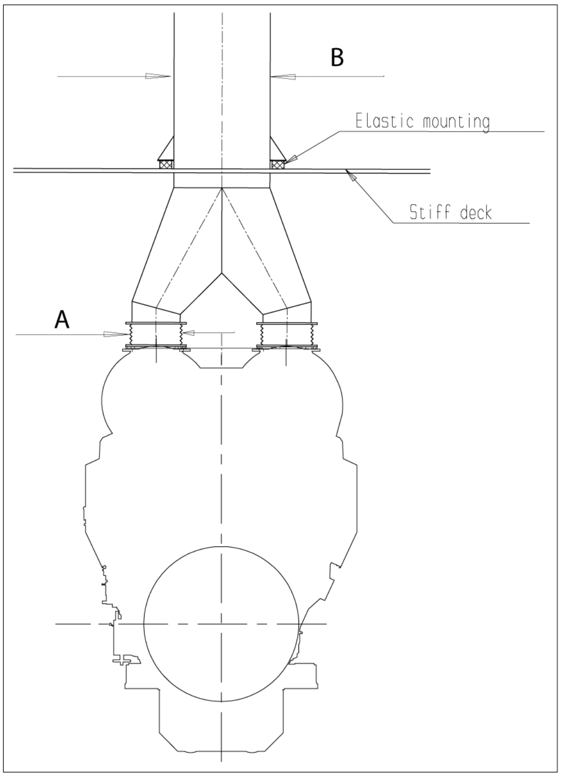
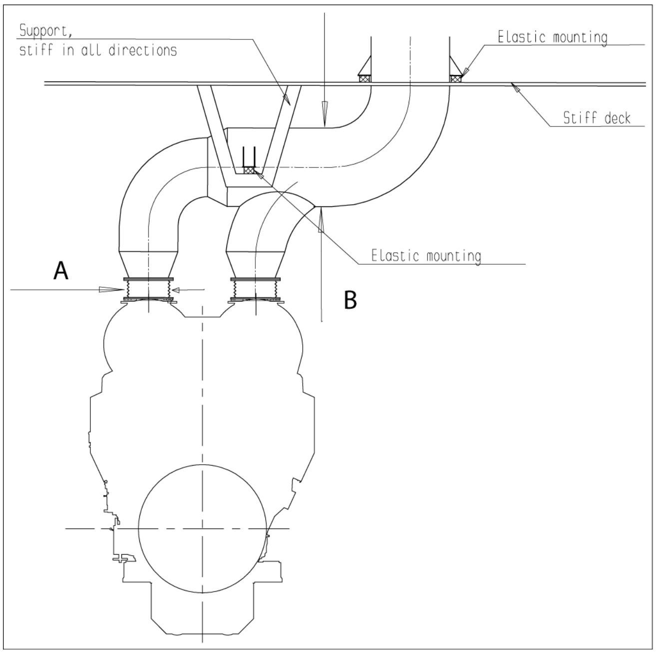


Table 11.1 Exhaust pipe diameters and support







Engine type	ØA [mm]	ØB [mm]
6L38	DN 500	650
8L38*	DN 600	750
9L38	DN 600	800
12V38	DN 500	900
16V38	DN 600	1000

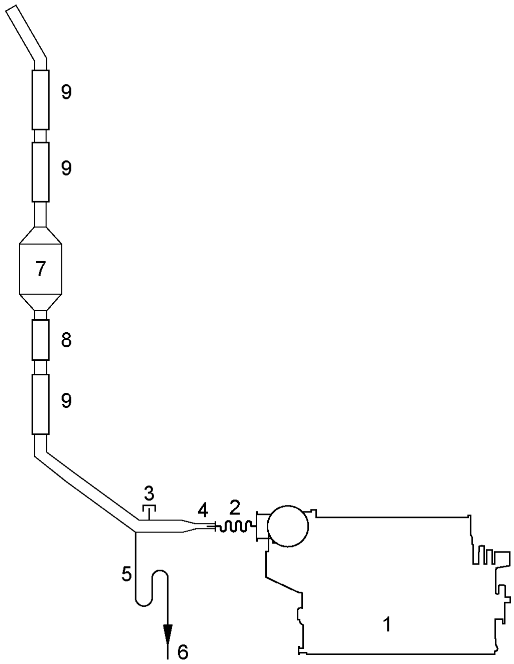
Note! For guidance only
*) DN 500 for 8L FPP

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.

Figure 11.5 External exhaust gas system



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

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 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]

Each exhaust pipe should be provided with a connection for measurement of the backpressure.

The exhaust gas pipe should be provided with water separating pockets and drain.

The exhaust pipe must be insulated all the way from the turbocharger and the insulation is to be 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 that insulation is detached by the strong airflow to the turbocharger.

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 3 kPa at full load. 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.

The back pressure must also be measured 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 Selective Catalytic Reduction (11N03)

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.

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

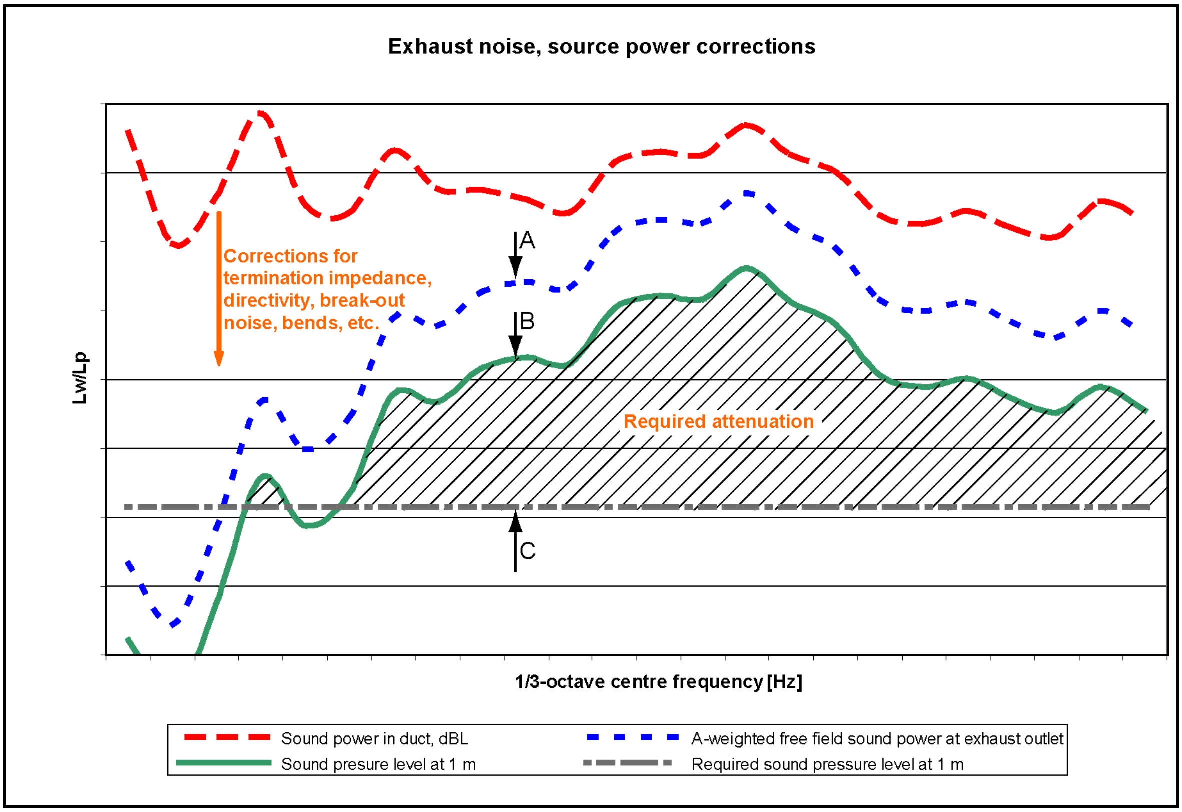
The exhaust gas silencing can be accomplished either by the patented Compact Silencer System (CSS) technology or by the conventional exhaust gas silencer.

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).

Figure 11.6 Exhaust noise, source power corrections

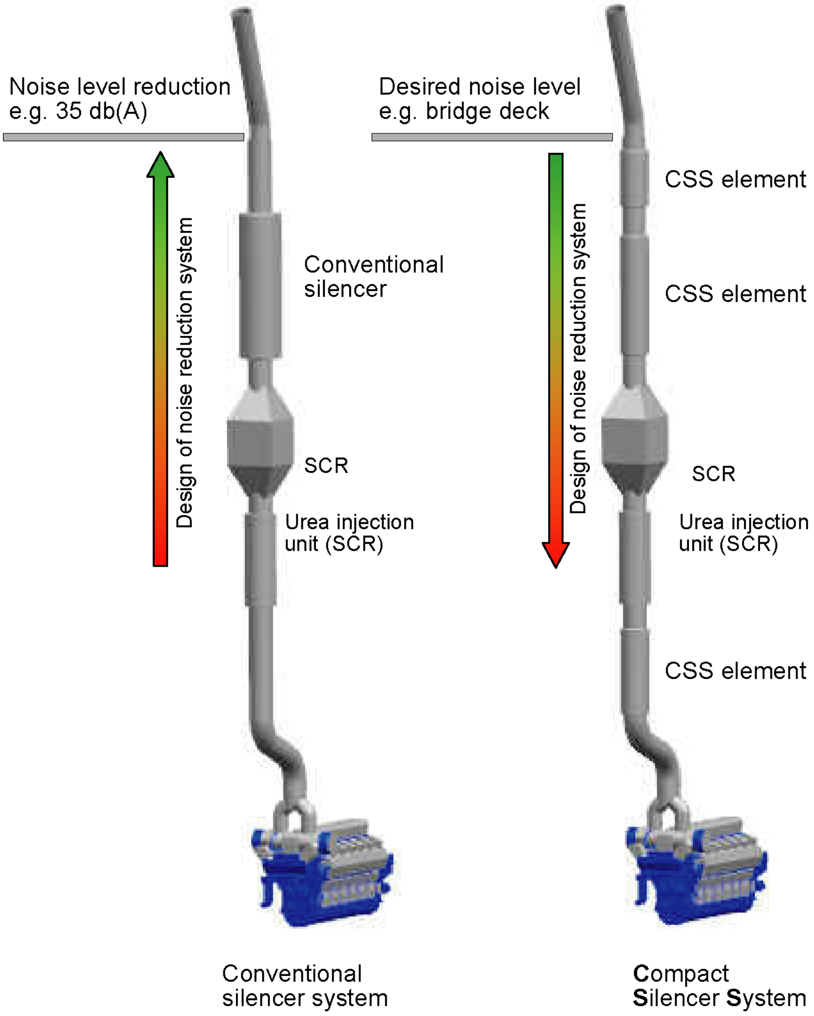


The conventional silencer is able to reduce the sound level in a certain area of the frequency spectrum. CSS is designed to cover the whole frequency spectrum.

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.

Figure 11.7 Silencer system comparison



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).

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.

Figure 11.8 Exhaust gas silencer (9855MR366)

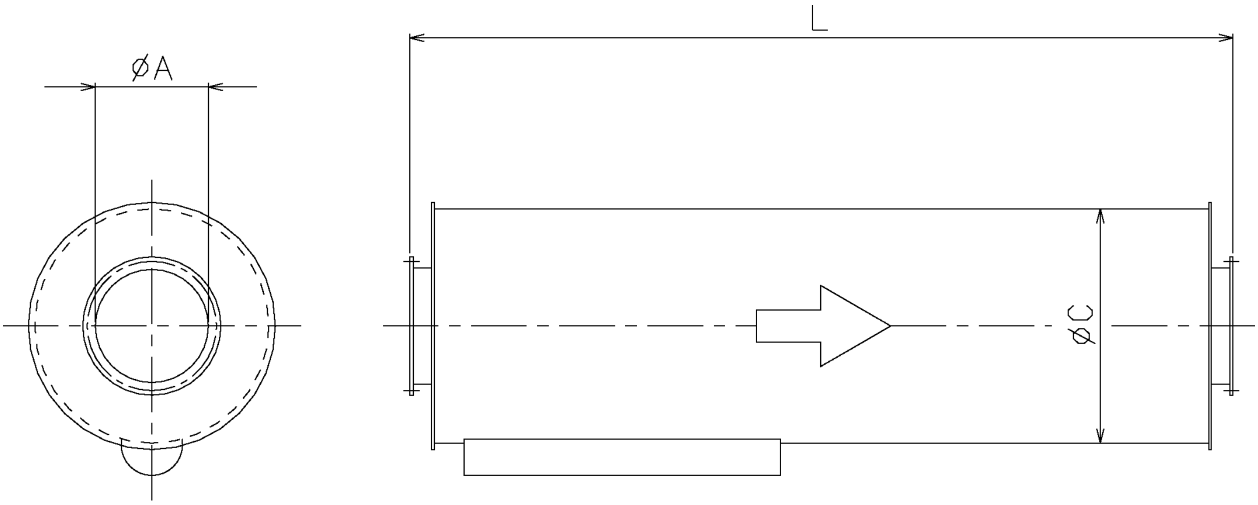


Table 11.2 Typical dimensions of the exhaust gas silencer, Attenuation 35 dB(A)

Engine type	A [mm]	C [mm]	L [mm]	Weight [kg]
6L38	DN 700	1500	5100	2200
8L38	DN 800	1550	5300	2350
9L38	DN 900	1850	6100	3950
12V38	DN 1100	1950	6700	4700
16V38	DN 1200	2050	7100	4950
18V38	DN 1300	2150	7500	5350
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.

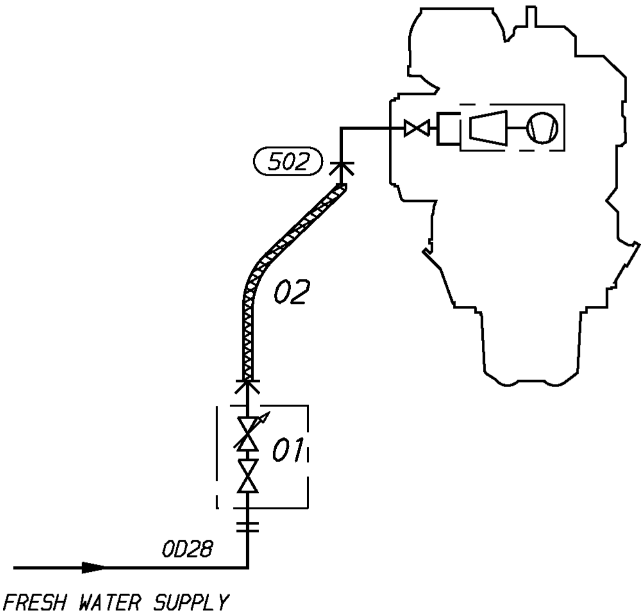
12.1 Turbine cleaning system

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 (3,0 bar)
Max. pressure	2,0 MPa (20,0 bar)
Max. temperature	80 °C
Flow	40-60 l/min (depending on cylinder configuration)

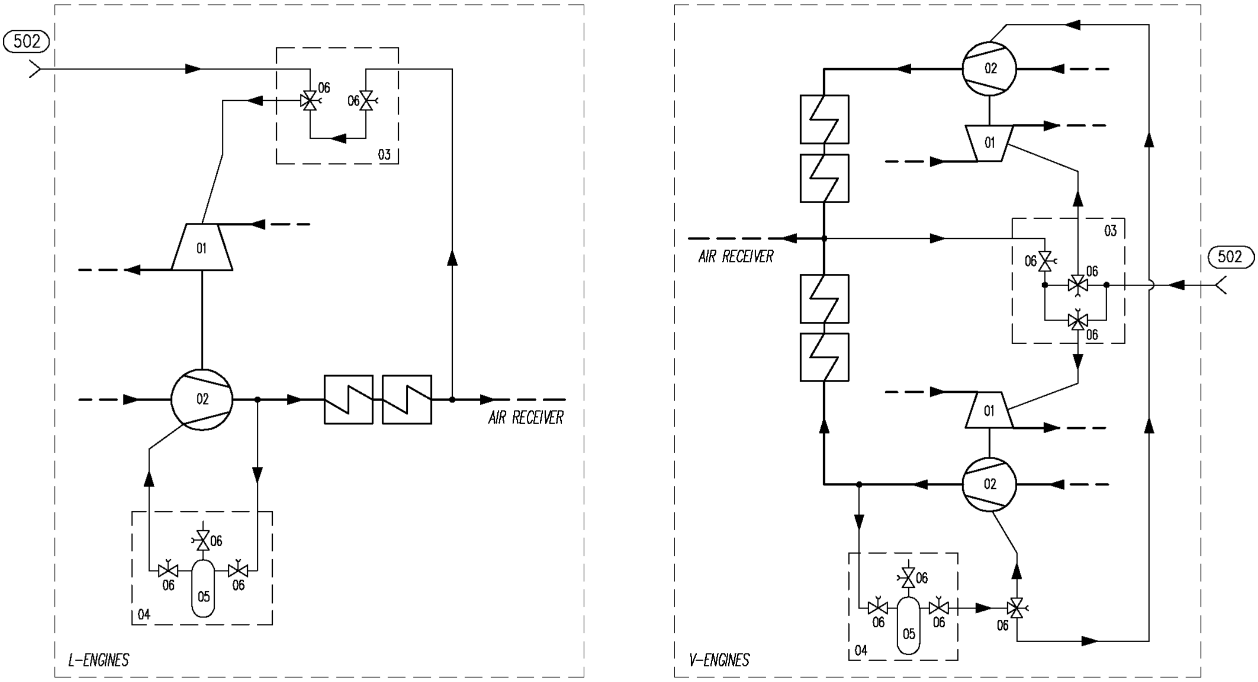
The turbocharges are cleaned one at a time on V-engines.

Figure 12.1 Turbine cleaning system



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

Figure 12.2 Turbocharger cleaning system on engine (DAAE054346).



System components		Pipe connections		Size
01	Turbine	502	Cleaning water to turbine	Quick coupling
02	Compressor			
03	Turbine cleaning			
04	Compressor cleaning			
05	Water container			
06	Valve			

12.2 Compressor cleaning system

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

13. Exhaust emissions

13.1 General

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.

13.2 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.

13.2.1 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.

13.2.2 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).

13.2.3 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.

13.2.4 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.

13.3 Marine exhaust emissions legislation

13.3.1 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.

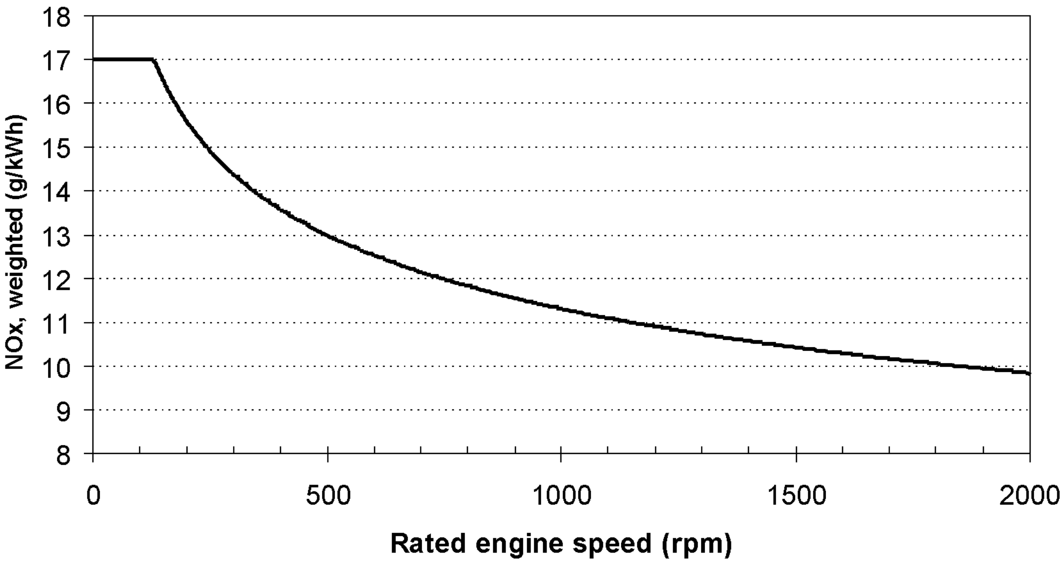
MARPOL Annex VI

MARPOL 73/78 Annex VI includes regulations for example on such emissions as nitrogen oxides, sulphur oxides, volatile organic compounds and ozone depleting substances. The Annex VI entered into force on the 19th of May 2005. The most important regulation of the MARPOL Annex VI is the control of NO_x emissions.

The IMO NO_x limit is defined as follows:

NOx [g/kWh]	= 17 when rpm < 130
	= 45 x $rpm^{-0.2}$ when 130 < rpm < 2000
	= 9.8 when rpm > 2000

Figure 13.1 IMO NO_x emission limit



The NO_x controls apply 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 along with engines which have undergone a major conversion on or after January 1, 2000.

The Wärtsilä engines comply with the NO_x levels set by the IMO in the MARPOL Annex VI.

For Wärtsilä 38 engines with a rated speed of 600 rpm, the NO_x level is below 12.5 g/kWh, when tested according to IMO regulations (NO_x Technical Code).

EIAPP Certificate

An EIAPP (Engine International Air Pollution Prevention) certificate will be 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 Fuel (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 most commonly used ISO 8178 test cycles are presented in the following table.

Table 13.1 ISO 8178 test cycles.

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

For EIAPP certification, the “engine family” or the “engine group” concepts may be applied. This has been done for the Wärtsilä 38 diesel engine. The engine families are represented by their parent engines and the certification emission testing is only necessary for these parent engines. Further engines can be certified by checking documents, components, settings etc., which have to show correspondence with those of the parent engine.

All non-standard engines, for instance over-rated engines, non-standard-speed engines etc. have to be certified individually, i.e. “engine family” or “engine group” concepts do not apply.

According to the IMO regulations, a Technical File shall be made for each engine. This Technical File contains information about the components affecting NO_x emissions, and each critical component is marked with a special IMO number. Such critical components are injection nozzle, injection pump, camshaft, cylinder head, piston, connecting rod, charge air cooler and turbocharger. The allowable setting values and parameters for running the engine are also specified in the Technical File.

The marked components can later, on-board the ship, be identified by the surveyor and thus an IAPP (International Air Pollution Prevention) certificate for the ship can be issued on basis of the EIAPP certificate and the on-board inspection.

Sulphur Emission Control Area (SECA)

MARPOL Annex VI sets a general global limit on sulphur content in fuels of 4.5% in weight. Annex VI also contains provisions allowing for special SOx Emission Control Areas (SECA) to be established with more stringent controls on sulphur emissions. In SECA areas, the sulphur content of fuel oil used onboard ships must not exceed 1.5% in weight. Alternatively, an exhaust gas cleaning system should be applied to reduce the total emission of sulphur oxides from ships, including both auxiliary and main propulsion engines, to 6.0 g/kWh or less calculated as the total weight of sulphur dioxide emission. At the moment Baltic Sea and North Sea are included in SECA.

13.3.2 Other Legislations

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

13.4 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.

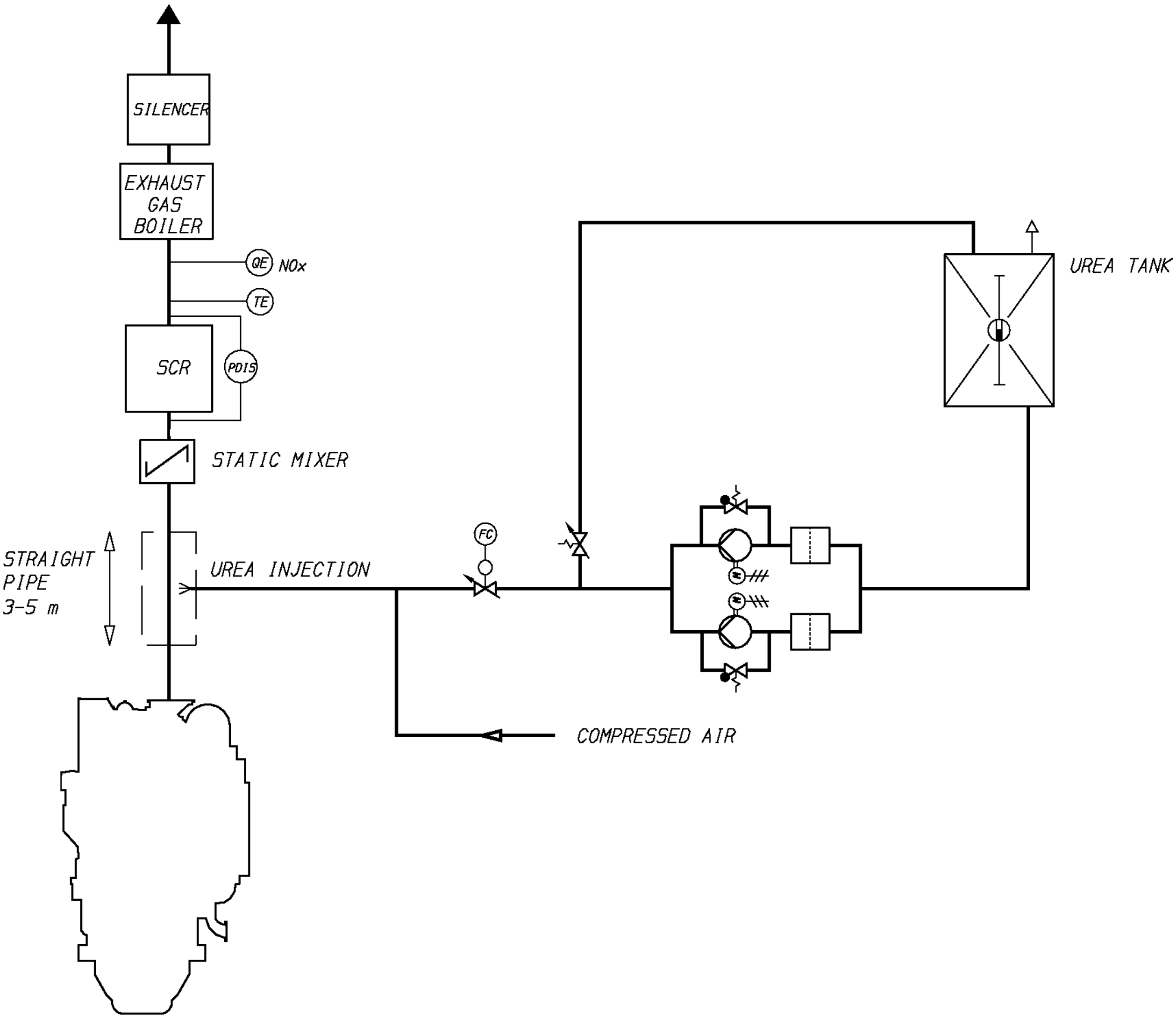
13.4.1 Selective Catalytic Reduction (SCR)

Selective Catalytic Reduction (SCR) is the only way to reach a NO_x reduction level of 85-95%. The disadvantages of the SCR are the large size and the relatively high installation and operation costs.

A reducing agent, aqueous solution of urea (40 wt-%), is injected into the exhaust gas directly after the turbocharger. Urea decays rapidly to ammonia (NH_3) and carbon dioxide. The mixture is passed through the catalyst where NO_x is converted to harmless nitrogen and water.

A typical SCR system comprises a urea solution storage tank, a urea solution pumping system, a reducing agent injection system and the catalyst housing with catalyst elements. In the next figure a typical SCR system is shown.

Figure 13.2 Typical P&ID for SCR system



The catalyst elements are of honeycomb type and are typically of a ceramic structure with the active catalytic material spread over the catalyst surface. The catalyst elements are arranged in layers and a soot blowing system should provided before each layer in order to avoid catalyst clogging.

The injection of urea is controlled by feedback from a NO_x measuring device after the catalyst. The rate of NO_x reduction depends on the amount of urea added, which can be expressed as NH_3/NO_x ratio. The increase of the catalyst volume can also increase the reduction rate.

When operating on HFO, the exhaust gas temperature before the SCR must be at least 330°C, depending on the sulphur content of the fuel. When operating on MDF, the exhaust gas temperature can be lower. If an exhaust gas boiler is specified, it should be installed after the SCR.

The lifetime of the catalyst is mainly dependent on the fuel oil quality and also to some extent on the lubricating oil quality. The lifetime of a catalyst is typically 3-5 years for liquid fuels and slightly longer if the engine is operating on gas. The total catalyst volume is usually divided into three layers of catalyst, and thus one layer at time can be replaced, and remaining activity in the older layers can be utilised.

Urea consumption and replacement of catalyst layers are generating the main running costs of the catalyst. The urea consumption is about 15 g/kWh of 40 wt-% urea. The urea solution can be prepared mixing urea granulates with water or the urea can be purchased as a 40 wt-% solution. The urea tank should be big enough for the ship to achieve the required autonomy.

14. Automation system

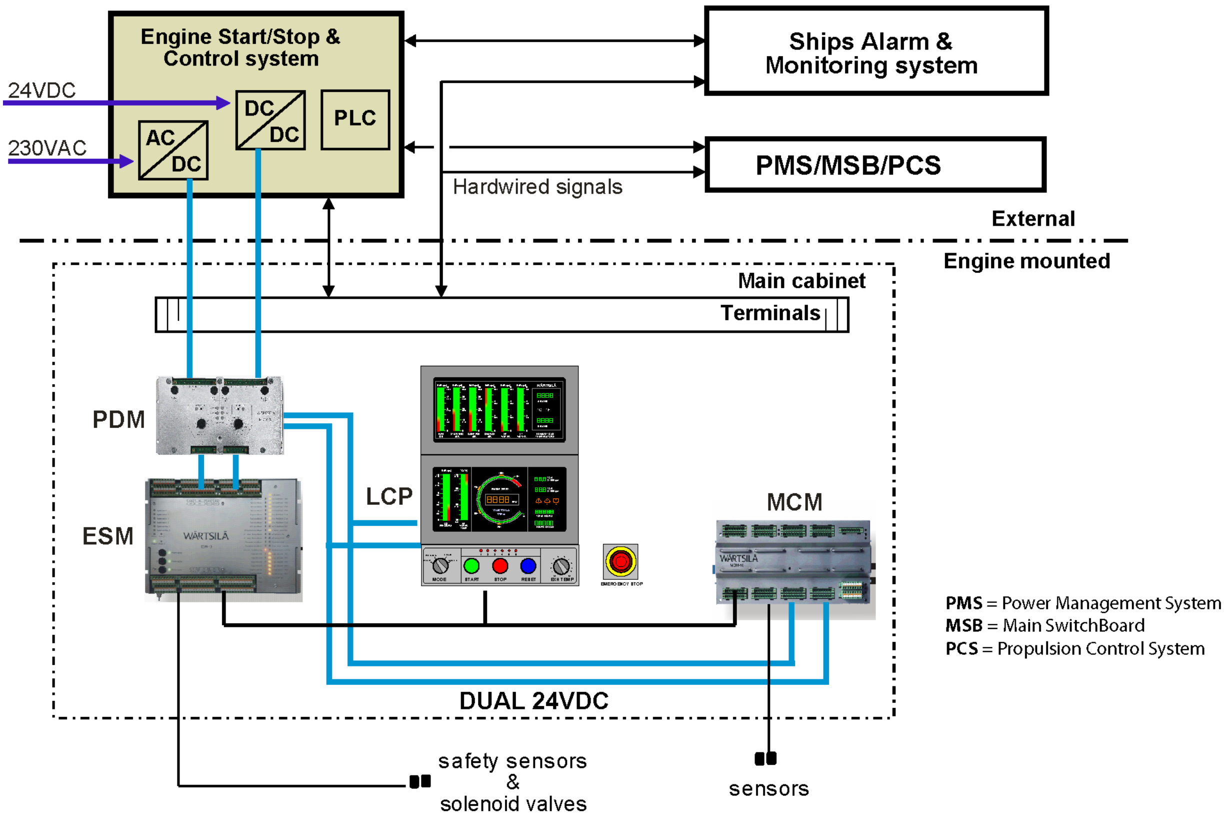
Wärtsilä Unified Controls – UNIC is a modular embedded automation system, which is available in three different versions. The basic functionality is the same in all versions, but the functionality can be easily expanded to cover different applications. UNIC C1 and UNIC C2 are applicable for engines with conventional fuel injection, whereas UNIC C3 additionally includes fuel injection control for engines with common rail fuel injection.

UNIC C1 has a completely hardwired signal interface with external systems, whereas UNIC C2 and C3 have hardwired interface for control functions and a bus communication interface for alarm and monitoring.

14.1 UNIC C1

The equipment on the engine included in UNIC C1 handles critical safety functions, some basic signal conversion and power distribution on the engine. The engine is equipped with push buttons for local operation and local display of the most important operating parameters. Speed control can also be integrated in the system on the engine. All terminals for signals to/from external systems are located in the main cabinet on the engine.

Figure 14.1 Architecture of UNIC C1



Equipment in the main cabinet on the engine:

MCM Main Control Module is used for speed/load control.

ESM Engine Safety Module handles fundamental engine safety, for example shutdown due to overspeed, low lubricating oil pressure, or oil mist in crankcase. The safety module is the interface to the shutdown devices on the engine for all other control equipment.

LCP Local Control Panel is equipped with push buttons and switches for local engine control, as well as a graphical panel with indication of the most important operating parameters.

PDM Power Distribution Module handles fusing, power distribution, earth fault monitoring and EMC filtration in the system. It provides two fully redundant 24 VDC supplies to all modules, sensors and control devices.

Equipment locally on the engine

- Sensors
- Solenoids
- Actuators

The above equipment is prewired to the main cabinet on the engine. The ingress protection class is IP54.

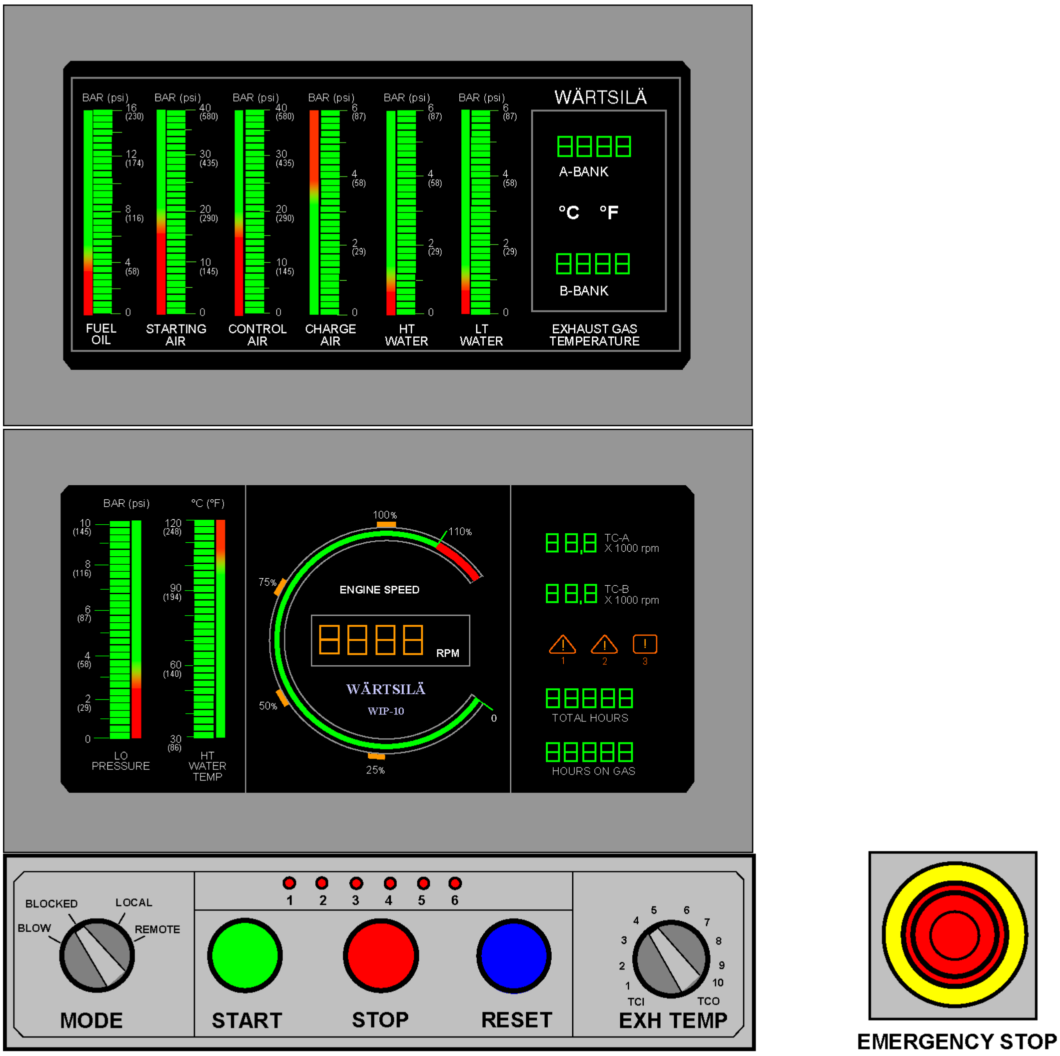
External equipment

Power unit

Two redundant power supply converters/isolators are installed in a steel sheet cabinet for bulkhead mounting, protection class IP44.

14.1.1 Local control panel (LCP)

Figure 14.2 Local control panel



Operational functions available at the LCP:

- Local start
- Local stop
- Local emergency stop
- Local shutdown reset
- Exhaust gas temperature selector switch

- Local mode selector switch with positions: blow, blocked, local and remote.
  - 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 inhibited.

Parameters indicated at the LCP

- Engine speed
- Turbocharger speed
- Running hours
- Fuel oil pressure
- Lubricating oil pressure
- Starting air pressure
- Control air pressure
- Charge air pressure
- LT cooling water pressure
- HT cooling water pressure
- HT cooling water temperature
- Exhaust gas temperature after each cylinder, before and after the turbocharger

14.1.2 Engine safety system

The engine safety system is based on hardwired logic with redundant design for safety-critical functions. 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 shutdown 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 outputs for engine speed and turbocharger speed
- Adjustable speed switches

14.1.3 Engine start/stop & control system

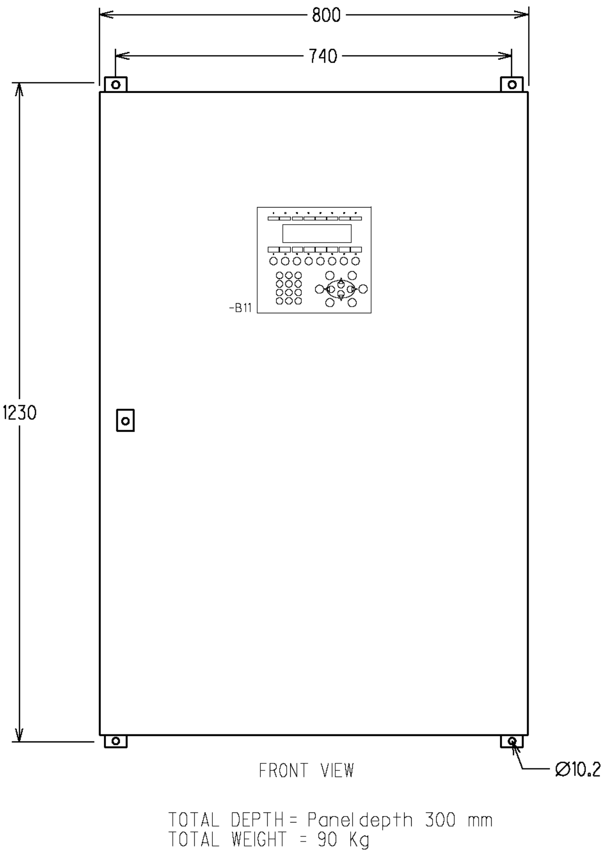
The main features of the engine start/stop & control system are:

- Steel sheet cabinet for bulkhead mounting, protection class IP44
- Programmable logic controller for the main functions:
  - Startblocking
  - Slowturning and start sequence
  - Control of charge air bypass and exhaust gas wastegate when applicable

- Control of pre-lubricating pump, cooling water pre-heater pump and standby pumps (when applicable) through external motor starters

- Display unit in the cabinet door showing the status of startblocking signals, shutdown reasons and control function parameters. Interface for adjustment of control parameters.
- Conversion to 24 VDC, isolation from other DC systems onboard, distribution of 2 x 24 VDC internally in the cabinet and to the engine mounted equipment, as well as bumpless switching between power supplies. At least one of the two incoming supplies must be connected to a UPS.
- Power supply from ship's system:
  - Supply 1: 230 VAC / abt. 400 W
  - Supply 2: 24 VDC / abt. 200 W

Figure 14.3 Front layout of the cabinet



14.1.4 Cabling and system overview

The following figure and table show typical system- and cable interface overview for the engine in mechanical propulsion and generating set applications.

Figure 14.4 UNIC C1 overview

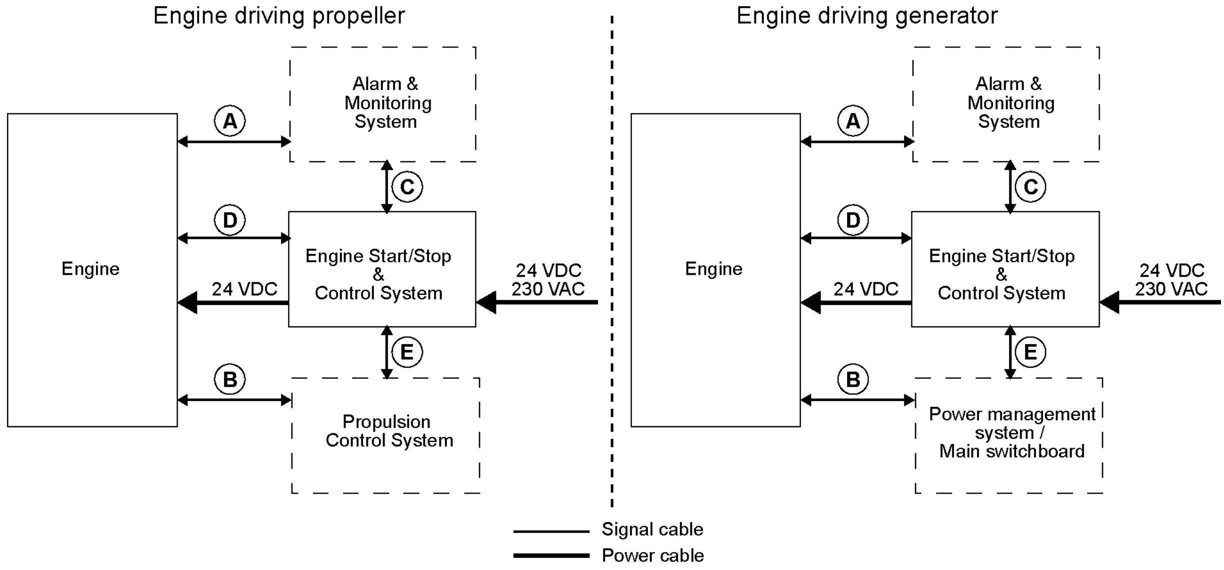


Table 14.1 Typical amount of cables for UNIC C1

Cable	From <=> To	Cable types (typical)
A	Engine <=> alarm & monitoring system	11 x 2 x 0.75 mm^2 11 x 2 x 0.75 mm^2 10 x 2 x 0.75 mm^2 32 x 0.75 mm^2 22 x 0.75 mm^2
B	Engine <=> propulsion control system Engine <=> power management system / main switchboard	1 x 2 x 0.75 mm^2 1 x 2 x 0.75 mm^2 1 x 2 x 0.75 mm^2 10 x 0.75 mm^2
C	Engine start/stop & control system <=> alarm & monitoring system	2 x 2 x 0.75 mm^2 7 x 0.75 mm^2
D	Engine <=> engine start/stop & control system	4 x 2.5 mm^2 (power supply) 27 x 0.75 mm^2 6 x 0.75 mm^2 4 x 1.5 mm^2 4 x 0.75 mm^2
E	Engine start/stop & control system <=> propulsion control system Engine start/stop & control system <=> power management system / main switchboard	14 x 0.75 mm^2

NOTE! Cable types and grouping of signals in different cables will differ depending on installation and cylinder configuration.

Power supply requirements are specified in section *Engine start/stop and control system*.

Figure 14.5 Signal overview (Main engine)

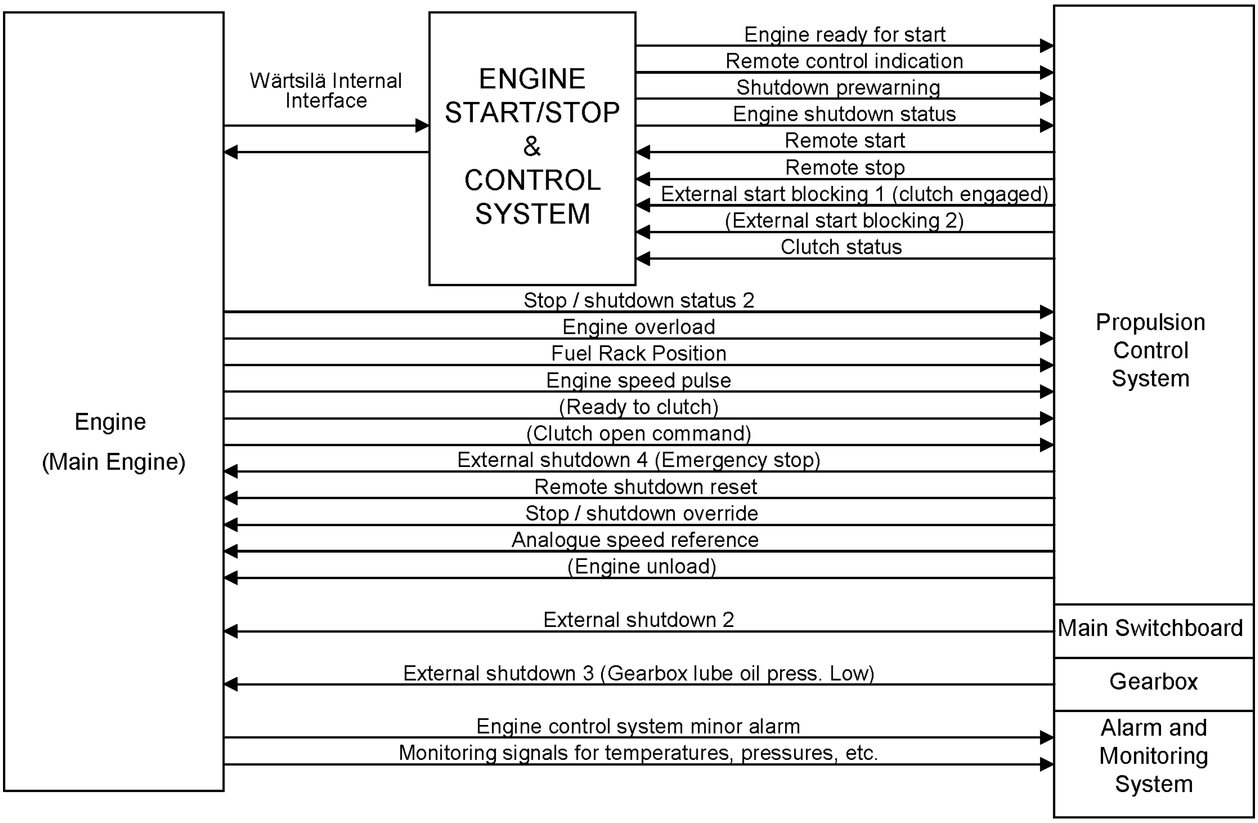
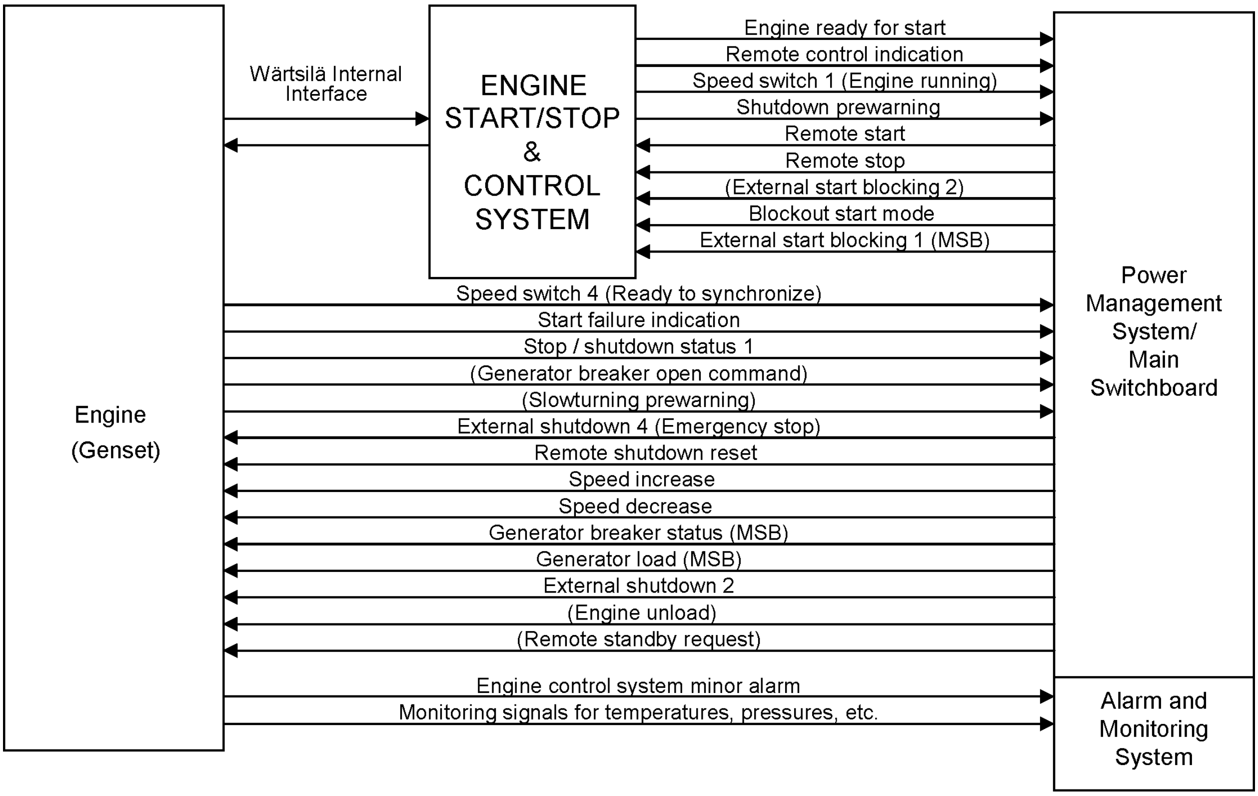


Figure 14.6 Signal overview (Generating set)



14.2 UNIC C2

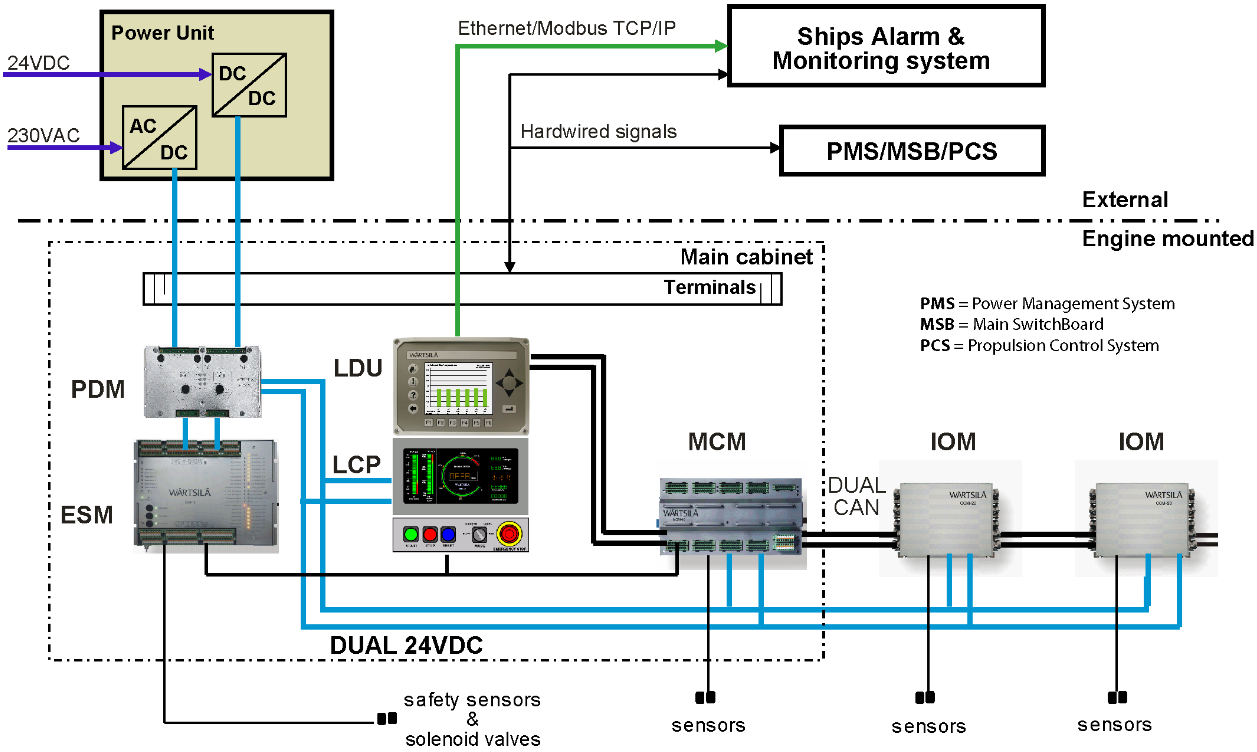
UNIC C2 is a fully embedded and distributed engine management system, which handles all control functions on the engine; for example start sequencing, start blocking, speed control, load sharing, normal stops and safety shutdowns.

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 an Modbus TCP connection to external systems.

Figure 14.7 Architecture of UNIC C2



Equipment in the main cabinet on the engine:

MCM Main Control Module handles all strategic control functions, for example start sequencing, start blocking and speed/load control. The module also supervises the fuel injection control on common rail engines.

ESM Engine Safety Module handles fundamental engine safety, for example shutdown due to overspeed or low lubricating oil pressure. The safety module is the interface to the shutdown devices on the engine for all other control equipment.

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 24 VDC supplies to all modules, sensors and control devices.

Equipment locally on the engine:

IOM Input/Output Module handles measurements and limited control functions in a specific area on the engine.

Sensors

Solenoids

Actuators

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

External equipment

Power unit

Two redundant power supply converters/isolators are installed in a steel sheet cabinet for bulkhead mounting, protection class IP44.

14.2.1 Local control panel and local display unit

Operational functions available at the LCP:

- Local start
- Local stop
- Local emergency stop
- Local shutdown reset
- Local mode selector switch with positions blow, blocked, local and remote

  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.

Figure 14.8 Local control panel and local display unit

14.2.2 Engine safety system

The engine safety system is based on hardwired logic with redundant design for safety-critical functions. 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 outputs for engine speed and turbocharger speed
- Adjustable speed switches

14.2.3 Power unit

A power unit is delivered with each engine for separate installation. The power unit supplies DC power to the electrical 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. 150 W
- Supply 2: 24 VDC / abt. 150 W.

14.2.4 Cabling and system overview

Figure 14.9 UNIC C2 overview

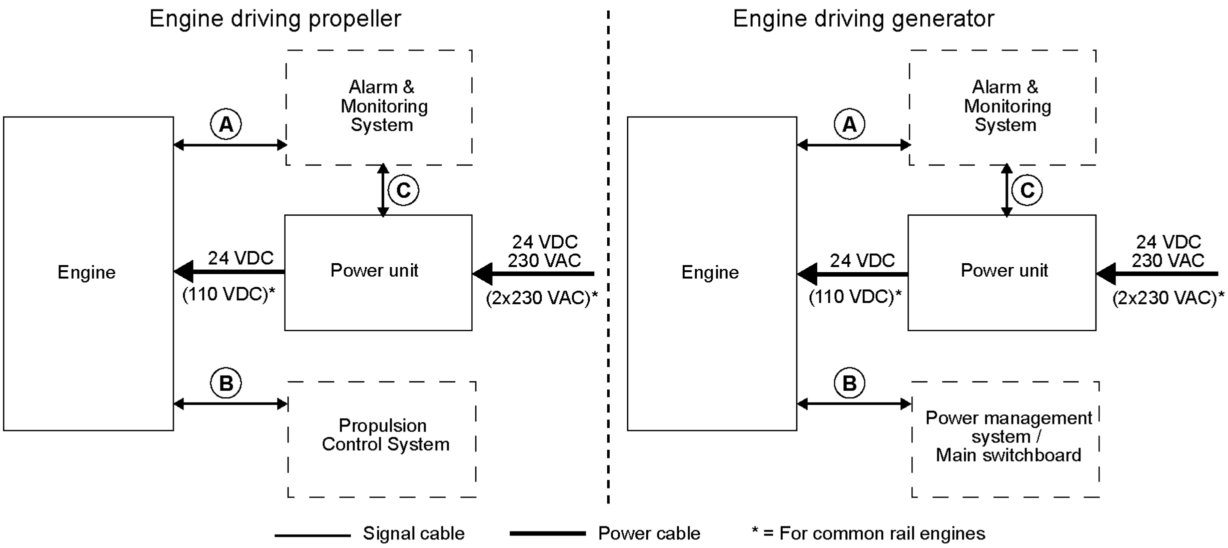


Table 14.2 Typical amount of cables for UNIC C2

Cable	From <=> To	Cable types (typical)
A	Engine <=> alarm & monitoring system	3 x 2 x 0.75 mm^2 1 x Ethernet CAT 5
B	Engine <=> propulsion control system Engine <=> power management system / main switchboard	1 x 2 x 0.75 mm^2 1 x 2 x 0.75 mm^2 1 x 2 x 0.75 mm^2 14 x 0.75 mm^2 14 x 0.75 mm^2
C	Power unit <=> alarm & monitoring system	2 x 0.75 mm^2
D	Engine <=> power unit	2 x 2.5 mm^2 (power supply) 2 x 2.5 mm^2 (power supply)

NOTE! Cable types and grouping of signals in different cables will differ depending on installation and cylinder configuration.

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

Figure 14.10 Signal overview (Main engine)

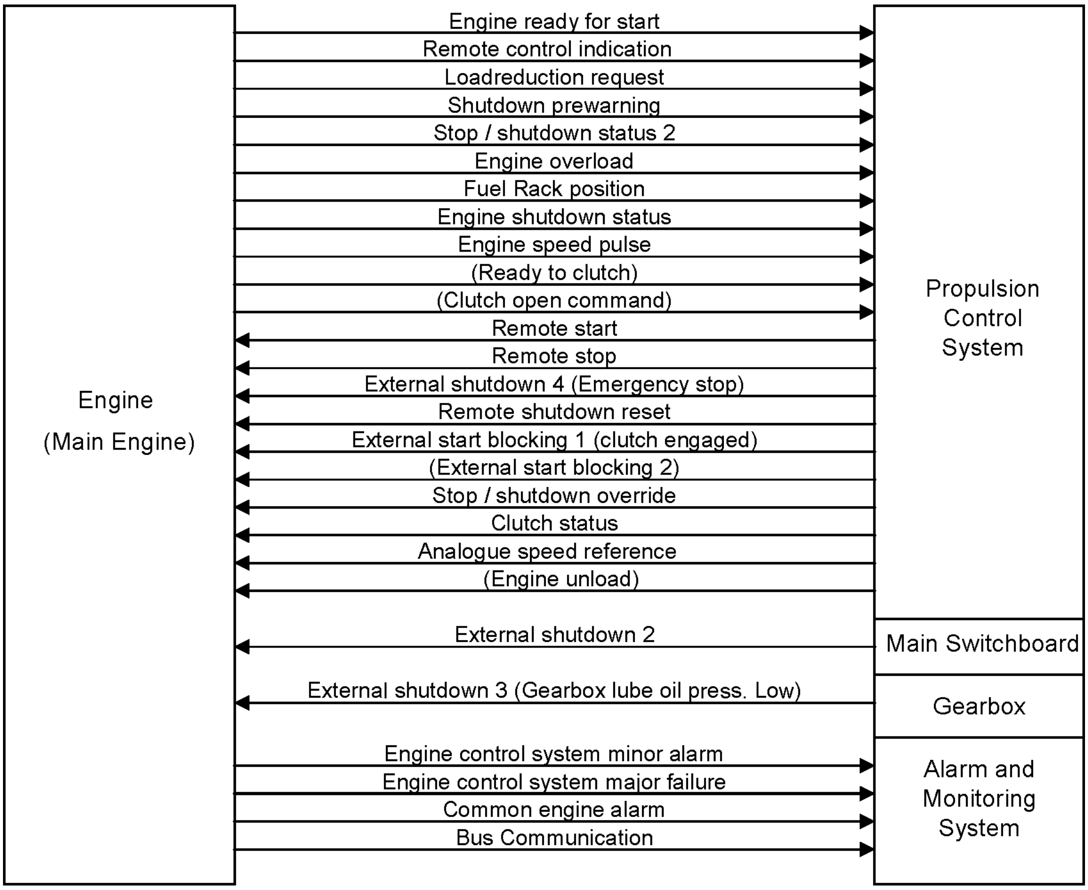
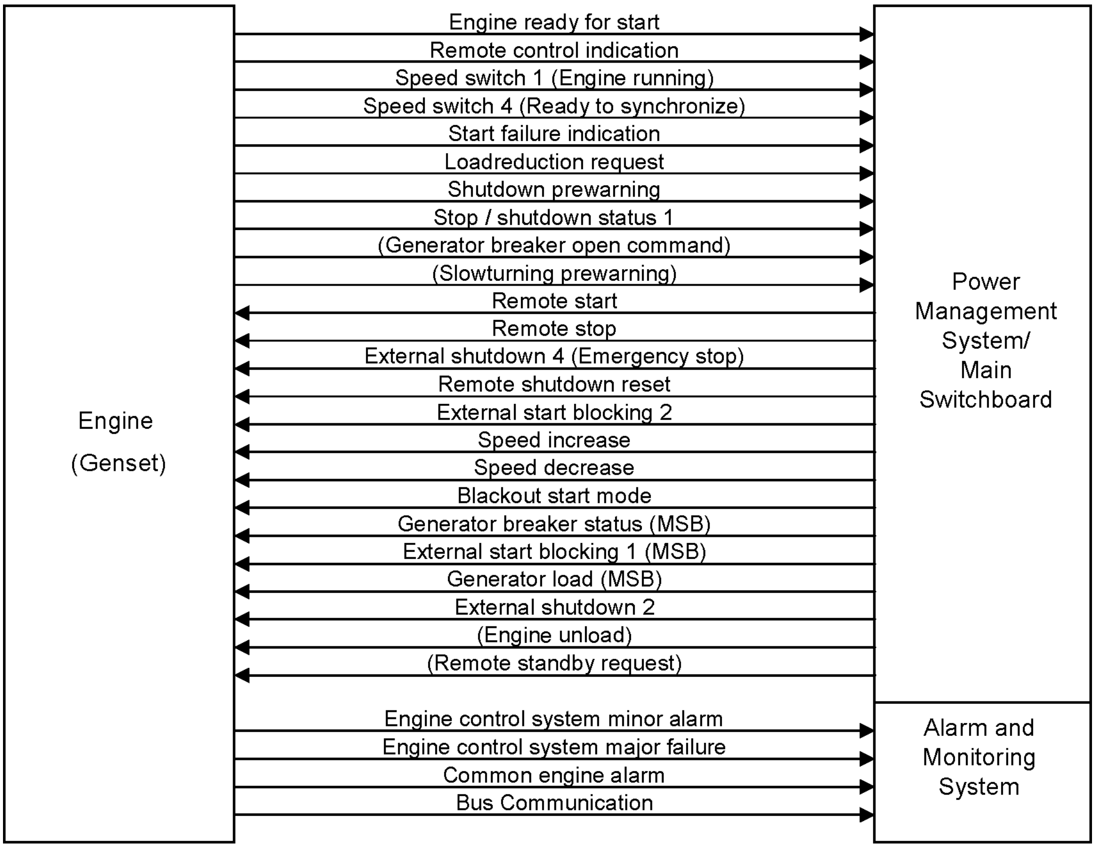


Figure 14.11 Signal overview (Generating set)



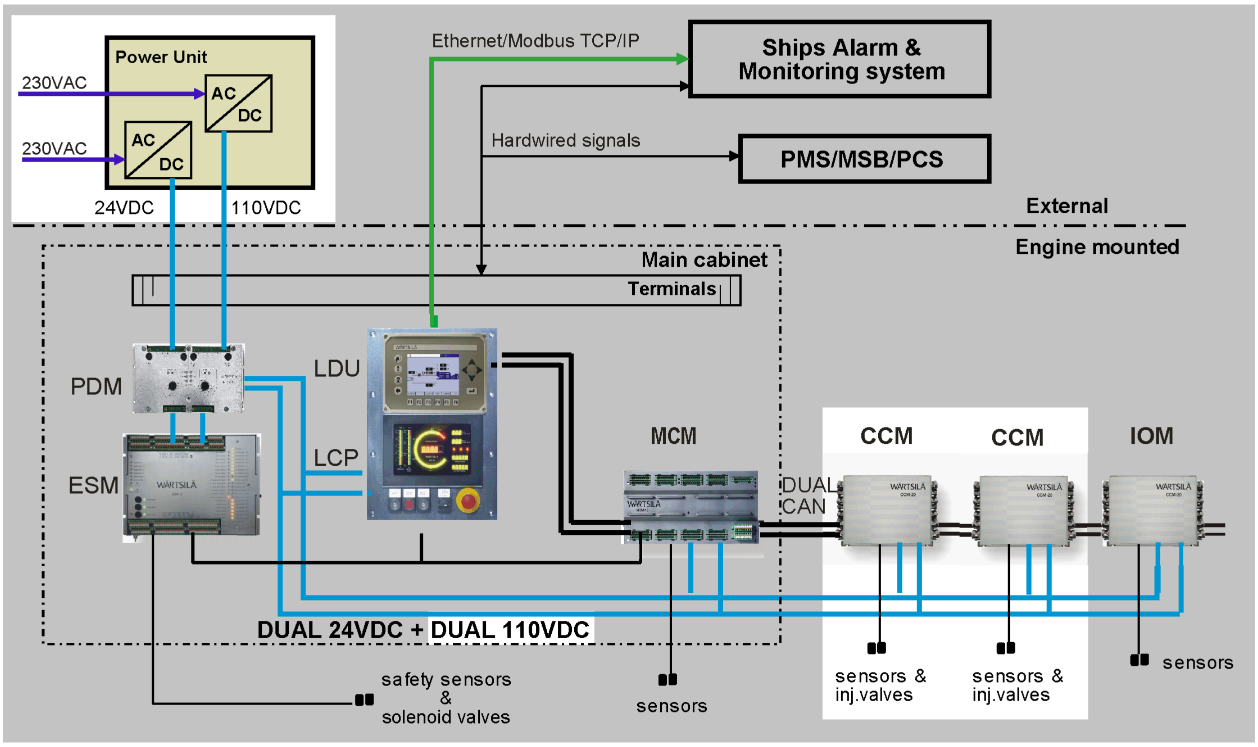
14.3 UNIC C3

The basic functionality is the same as in UNIC C2, but UNIC C3 additionally includes fuel injection control for engines with common rail fuel injection.

Differences compared to UNIC C2:

- Power supply from ship's system 2 x 230 VAC, each 600 W (no 24 VDC required).
- The power unit also supplies 2 x 110 VDC for the fuel injectors.
- Cylinder Control Modules (CCM) for fuel injection control.

Figure 14.12 Architecture of UNIC C3



14.4 Functions

14.4.1 Start

The engine is started by injecting compressed air directly into the cylinders. The solenoid controlling the master starting 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.

Injection of starting air 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).

The starting air system is equipped with a slow turning valve, which rotates the engine slowly without fuel injection for a few turns before start. Slow turning is not performed if the engine has been running max. 30 minutes earlier, or if slow turning is automatically performed every 30 minutes. Stand-by diesel generators should have automatic slow turning.

Startblockings and slow turning are handled by the programmable logic in the external cabinet with UNIC C1, and by the system on the engine (main control module) with UNIC C2 and C3.

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.

14.4.2 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
- Oil mist in crankcase
- 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.

14.4.3 Speed control

Main engines (mechanical propulsion)

The electronic speed control is integrated in the engine automation system. For single main engines with conventional fuel injection 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 propellershaft.

Mechanical back-up is not an option in installations with two engines connected to the same reduction gear.

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 of the electronic speed control 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*.

Diesel generators

The electronic speed control is integrated in the engine automation system. Engine driven hydraulic fuel rack actuators are used on engines with conventional fuel injection.

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.

14.5 Alarm and monitoring signals

The number of sensors and signals may vary depending on the application. The actual configuration of signals and the alarm levels are found in the project specific documentation supplied for all contracted projects.

The table below lists typical sensors and signals for ship's alarm and monitoring system. The signal type is indicated for UNIC C1, which has a completely hardwired signal interface. UNIC C2 and C3 transmit information over a Modbus communication link to the ship's alarm and monitoring system.

Table 14.3 Typical sensors and signals

Code	Description	I/O type	Signal type	Range
PT101	Fuel oil pressure, engine inlet	AI	4-20 mA	0-16 bar
TE101	Fuel oil temp., engine inlet	AI	PT100	0-160 °C
LS103A	Fuel oil leakage, injection pipe (A-bank)	DI	Pot. free	on/off
LS103B 1)	Fuel oil leakage, injection pipe (B-bank)	DI	Pot. free	on/off
LS108A	Fuel oil leakage, dirty fuel (A-bank)	DI	Pot. free	on/off
LS108B 1)	Fuel oil leakage, dirty fuel (B-bank)	DI	Pot. free	on/off
PT201	Lubricating oil pressure, engine inlet	AI	4-20 mA	0-10 bar
TE201	Lubricating oil temp., engine inlet	AI	PT100	0-160 °C
PT271	Lubricating oil pressure, TC A inlet	AI	4-20 mA	0-10 bar
TE272	Lubricating oil temp., TC A outlet	AI	PT100	0-160 °C
PT281 1)	Lubricating oil pressure, TC B inlet	AI	4-20 mA	0-10 bar
TE282 1)	Lubricating oil temp., TC B outlet	AI	PT100	0-160 °C
PT301	Starting air pressure	AI	4-20 mA	0-40 bar
PT311	Control air pressure	AI	4-20 mA	0-40 bar
PT401	HT water pressure, jacket inlet	AI	4-20 mA	0-6 bar
TE401	HT water temp., jacket inlet	AI	PT100	0-160 °C
TE402	HT water temp., jacket outlet A bank	AI	PT100	0-160 °C
TEZ402	HT water temp., jacket outlet A bank	AI	PT100	0-160 °C
TE432	HT water temp., HT CAC outlet	AI	PT100	0-160 °C
PT471	LT water pressure, CAC inlet	AI	4-20 mA	0-6 bar
TE471	LT water temp., LT CAC inlet	AI	PT100	0-160 °C
TE472	LT water temp., CAC outlet	AI	PT100	0-160 °C
TE5011A ... TE5091A	Exhaust gas temp., cylinder A1 outlet ... Exhaust gas temp., cylinder A9 outlet	AI	4-20 mA	0-750 °C
TE5011B 1) ... TE5091B	Exhaust gas temp., cylinder B1 outlet ... Exhaust gas temp., cylinder B9 outlet	AI	4-20 mA	0-750 °C
TE511	Exhaust gas temp., TC A inlet	AI	4-20 mA	0-750 °C
TE521 1)	Exhaust gas temp., TC B inlet	AI	4-20 mA	0-750 °C
TE517	Exhaust gas temp., TC A outlet	AI	4-20 mA	0-750 °C

Code	Description	I/O type	Signal type	Range
TE527 1)	Exhaust gas temp., TC B outlet	AI	4-20 mA	0-750 °C
PT601	Charge air pressure, CAC outlet	AI	4-20 mA	0-6 bar
TE601	Charge air temp. engine inlet	AI	PT100	0-160 °C
TE700 ... TE710	Main bearing 0 temp ... Main bearing 10 temp	AI	4-20 mA	0-250 °C
TE7011A ... TE7092B	Cylinder liner temp, 2 sensors/cylinder	AI	4-20 mA	0-250 °C
PT700	Crankcase pressure	AI	4-20 mA	0-10 mbar
NS700	Oil mist detector failure	DI	Pot. free	on/off
QS700	Oil mist in crankcase, alarm	DI	Pot. free	on/off
IS1741	Alarm, overspeed shutdown	DI	Pot. free	on/off
IS2011	Alarm, lub oil press. low shutdown	DI	Pot. free	on/off
IS7311	Alarm, red.gear lo press low shutdown	DI	Pot. free	on/off
IS7338	Alarm, oil mist in crankcase shutdown	DI	Pot. free	on/off
IS7305	Emergency stop	DI	Pot. free	on/off
NS881	Engine control system minor alarm	DI	Pot. free	on/off
IS7306	Alarm, shutdown override	DI	Pot. free	on/off
SI196	Engine speed	AI	4-20 mA	0-750 rpm
SI518	Turbocharger A speed	AI	4-20 mA	0-50000 rpm
SI528	Turbocharger B speed 1)	AI	4-20 mA	0-50000 rpm
IS875	Start failure	DI	Pot. free	on/off
	Power supply failure	DI	Pot. free	on/off
	Torsional vibration level	AI	4-20 mA	0-2 deg.

Note 1 V-engines only

14.6 Electrical consumers

14.6.1 Motor starters and operation of electrically driven pumps

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

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

Engine turning device (9N15)

The crankshaft can be slowly rotated with the turning device for maintenance purposes. The motor starter must be designed for reversible control of the motor. The electric motor ratings are listed in the table below.

Table 14.4 Electric motor ratings for engine turning device

Engine	Voltage [V]	Frequency [Hz]	Power [kW]	Current [A]
L38	3 x 400 / 440	50 / 60	2.2 / 2.6	5.0 / 5.3
V38	3 x 400 / 440	50 / 60	4.0 / 4.6	8.6 / 8.9

Pre-lubricating oil pump (2P02)

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.

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.

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.

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.

Circulating pump for preheater (4P04)

If the main cooling water pump (HT) is engine driven, 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.

Sea water pumps (4P11)

The pumps can be stopped when all engines are stopped, provided that cooling is not required for other equipment in the same circuit.

Lubricating oil separator (2N01)

Continuously in operation.

Feeder/booster unit (1N01)

Continuously in operation.

14.7 System requirements and guidelines for diesel-electric propulsion

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

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

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

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

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

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

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

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

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

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

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

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

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

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

15. Foundation

15.1 General

The main engines can be rigidly mounted to the foundation, either on steel or resin chocks, or resiliently mounted on rubber elements.

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.

15.2 Rigid mounting

15.2.1 Rigid mounting on steel chocks

The top plates of the engine girders are usually inclined outwards with regard to the centre line of the engine. The inclination of the supporting surface should be 1/100. The top plate should be designed so that the wedge-type chocks can easily be fitted into their positions.

If the top plate of the engine girder is placed in a fully horizontal position, a chock is welded to each point of support. The chocks should be welded around the periphery as well as through the holes drilled at regular intervals to avoid possible relative movement in the surface layer. After that the welded chocks are face-milled to an inclination of 1/100. The surfaces of the welded chocks should be big enough to fully cover the wedge-type chocks.

The size of the wedge-type chocks should be 165 x 360 mm for in-line 38 engines and 340 x 360 mm for V38 engines. The material may be cast iron or steel.

When fitting the chocks, the supporting surface of the top plate is planed by means of a grinding wheel and a face plate until an evenly distributed bearing surface of min. 80% is obtained. The chock should be fitted so that the distance between the bolt holes and the edges is equal at both sides.

The clearance hole in the chock and top plate should have a diameter about 2 mm bigger than the bolt diameter for all chocks, except those which are to be reamed and equipped with fitted bolts.

Side supports should be installed for all engines. There must be three supports on both sides. The side supports are to be welded to the top plate before aligning the engine and fitting the chocks. The side support wedges should be fitted when the engine has obtained its thermal operating condition.

The holding down bolts are usually through-bolts with lock nuts at the lower end and a normal nut at the upper end. Two Ø38m6 mm fitted bolts on each side of the engine are required for the L38 engines while one Ø45m6 mm fitted bolt on each side of the engine is required for the V38 engines. Clearance bolts are to be provided for the remaining holes.

The holes in the seating topplate for the fitted bolts for L38 must fulfil the tolerance Ø38H7 mm (which means that they should first be drilled to Ø37 mm and then reamed to their final size), while the ones for V38 must fulfil the tolerance Ø45H7 mm (which means that they should first be drilled to Ø44 mm and then reamed to their final size).

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

To avoid a gradual reduction of tightening tension due to among others, unevenness in threads, the bolt thread must fulfil tolerance 6g and the nut thread must fulfil tolerance 6H. In order to avoid extra bending stresses in the bolts, the contact face of the nut underneath the top plate should be counter bored. When tightening the bolts with a torque wrench, the equivalent stress in the bolts is allowed to be max. 90% of the material yield strength (in practice, without consideration of torsional stress, it is sufficient to tighten bolts to a tensile stress of about 50% of the material yield strength).

15.2.2 Rigid mounting on resin chocks

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

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

The recommended size of the resin chocks is about 500 x 160 mm for in-line 38 engines and about 600 x 300 mm for V38 engines. The total surface pressure on the resin must not exceed the maximum value, which depends on the type of resin and the requirements of the classification society. It is recommended to select a resin type, which has a type approval from the relevant classificationsociety for a total surface pressure of 5 N/mm^2 (a typical conservative value is $p_{tot} \leq 3.5\ N/mm^2$).

The clearance hole in the chock and top plate should have a diameter about 2 mm bigger than the bolt diameter for all chocks, except those which are to be reamed and equipped with fitted bolts.

The bolts must be made as tensile bolts with a reduced shank diameter to ensure a sufficient elongation, since the bolt force is limited to the permissible surface pressure on the resin. For a given bolt diameter the permissible bolt force is limited either by the strength of the bolt material (max. 90% equivalent stress), or by the maximum permissible surface pressure on the resin. The lower nuts should always be locked regardless of the bolt tension.

Figure 15.1 Foundation and fastening, rigidly mounted in-line 38, steel chocks (9603DT130b)

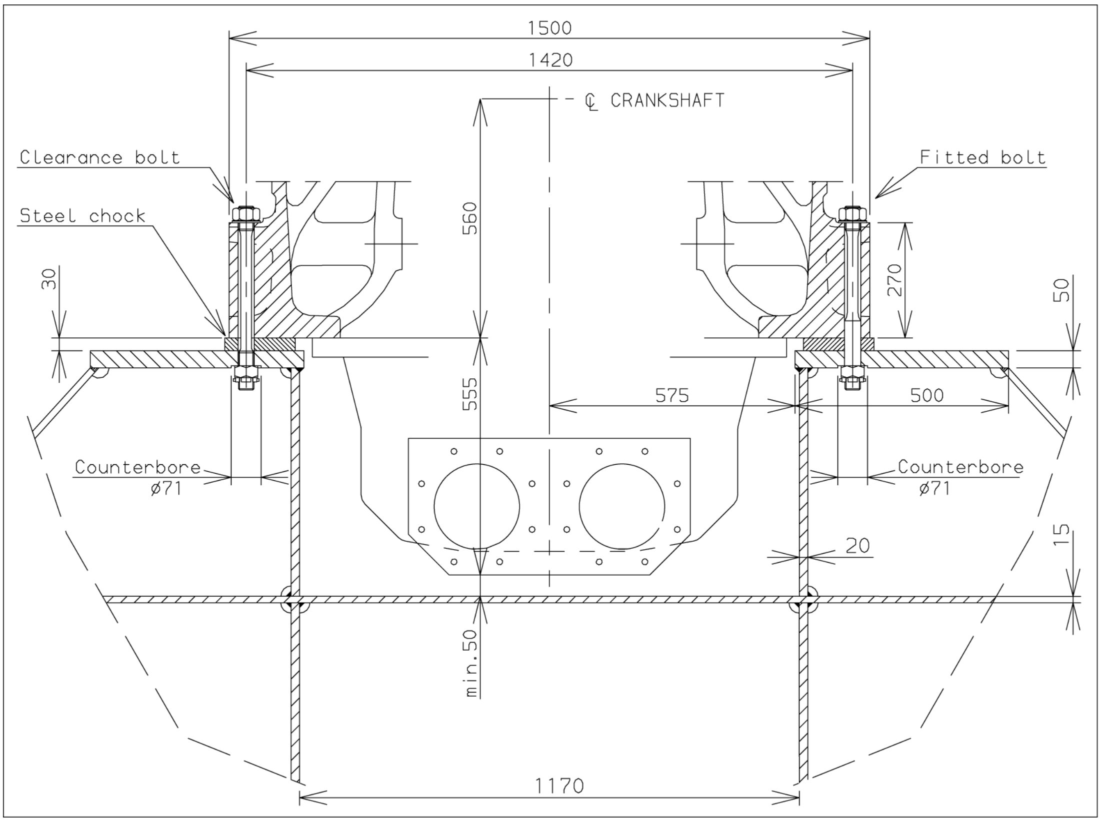


Figure 15.2 Foundation and fastening, rigidly mounted, V38, steel chocks (9603DT135b)

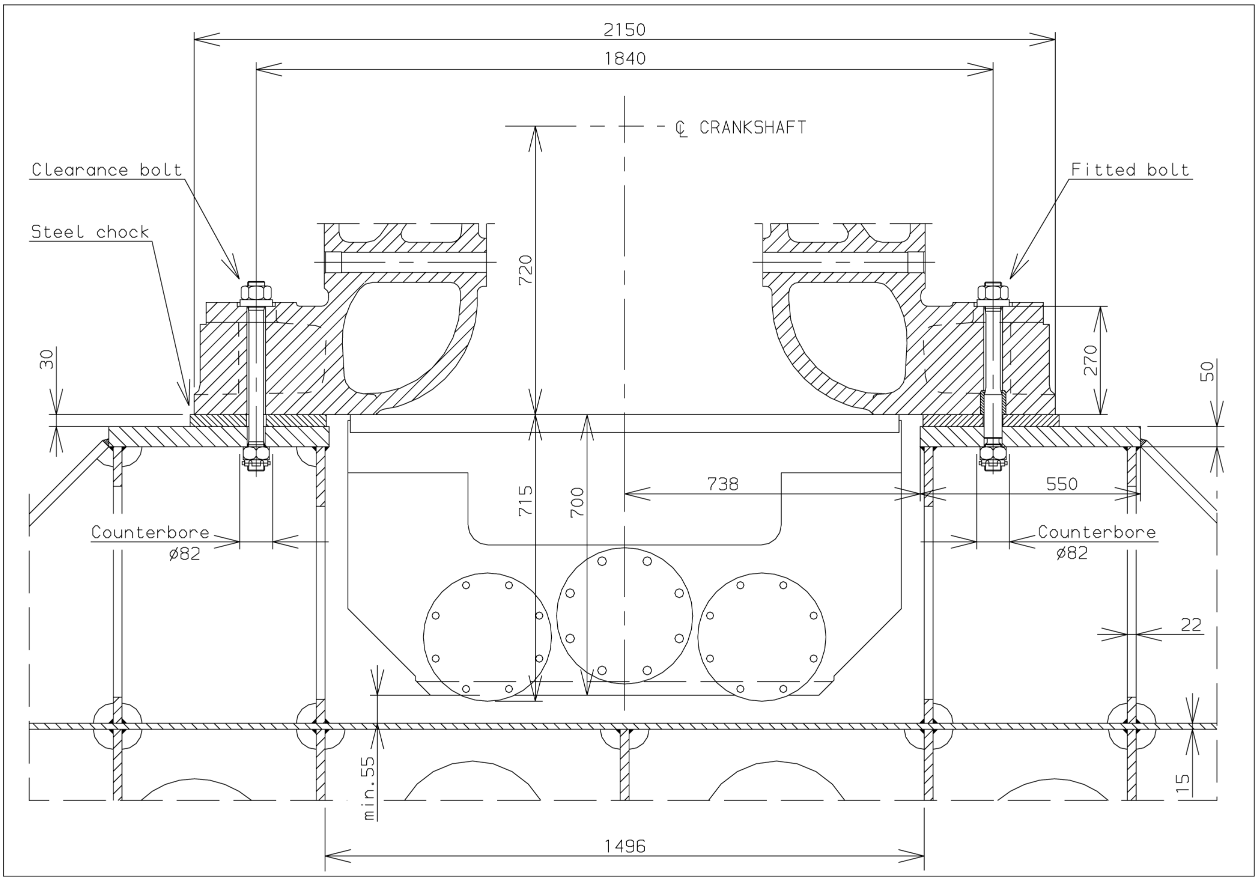


Figure 15.3 Foundation and fastening, rigidly mounted L38, resin chocks (9603DT103b)

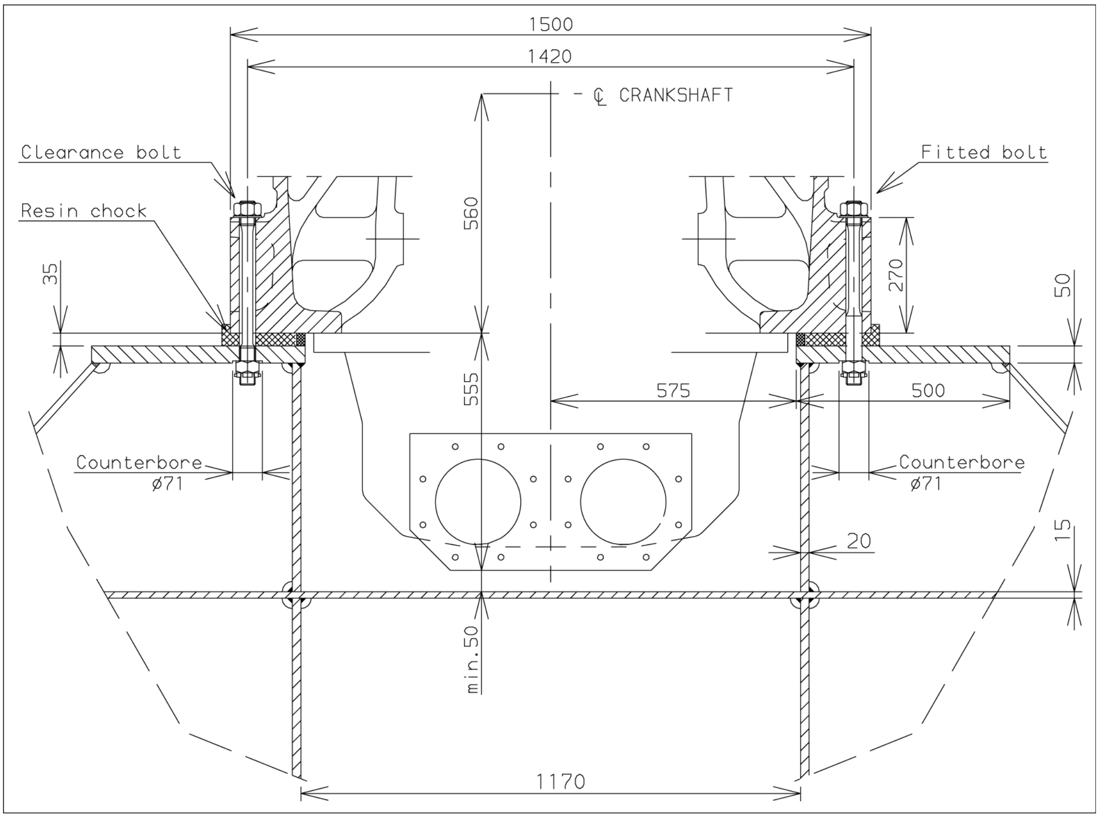
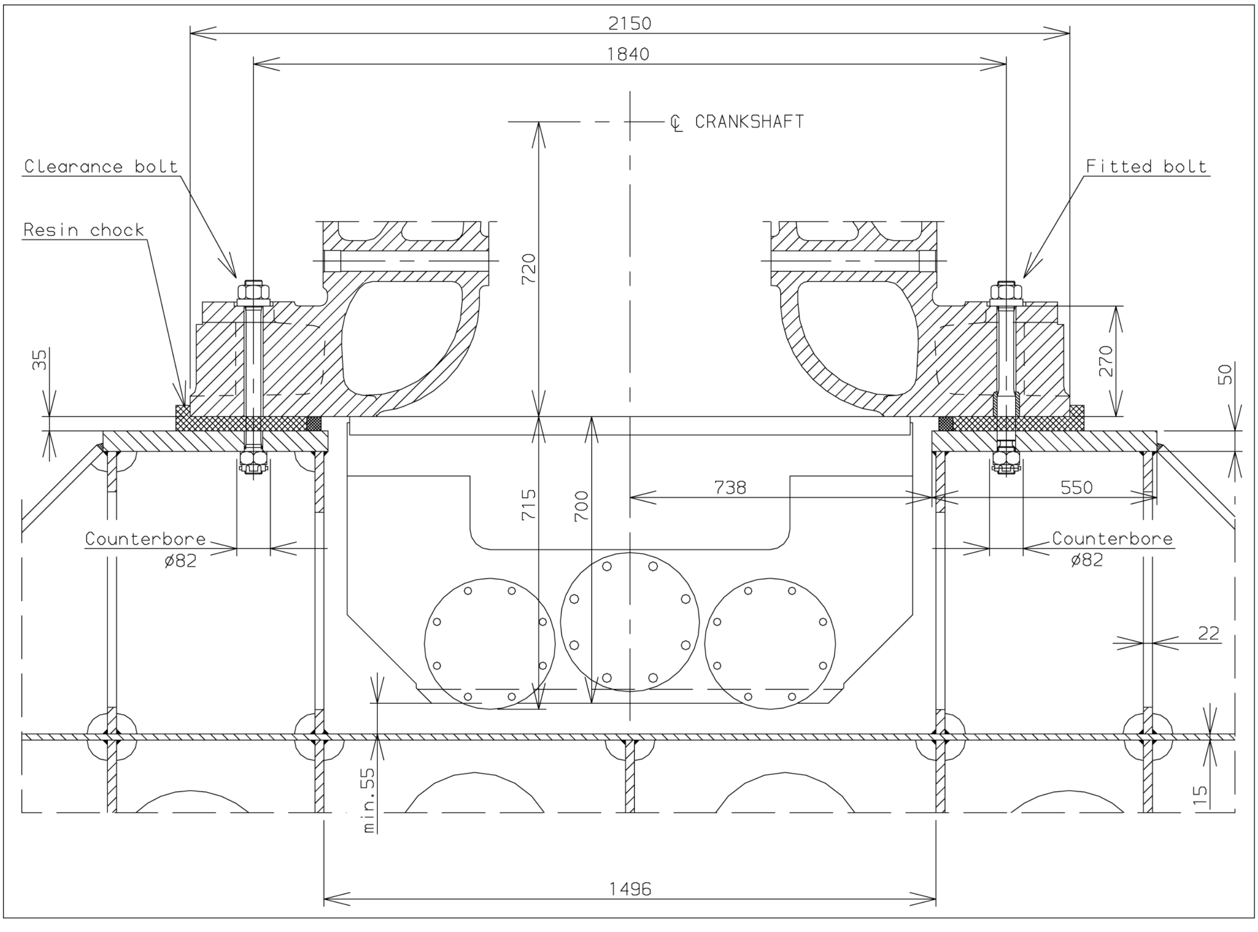


Figure 15.4 Foundation and fastening, rigidly mounted V38, resin chocks (9603DT134b)



15.2.3 Foundation and fastening, rigidly mounted in-line 38, steel / resin chocks

Figure 15.5 Clearance bolt, in-line 38 (9603DT122b)

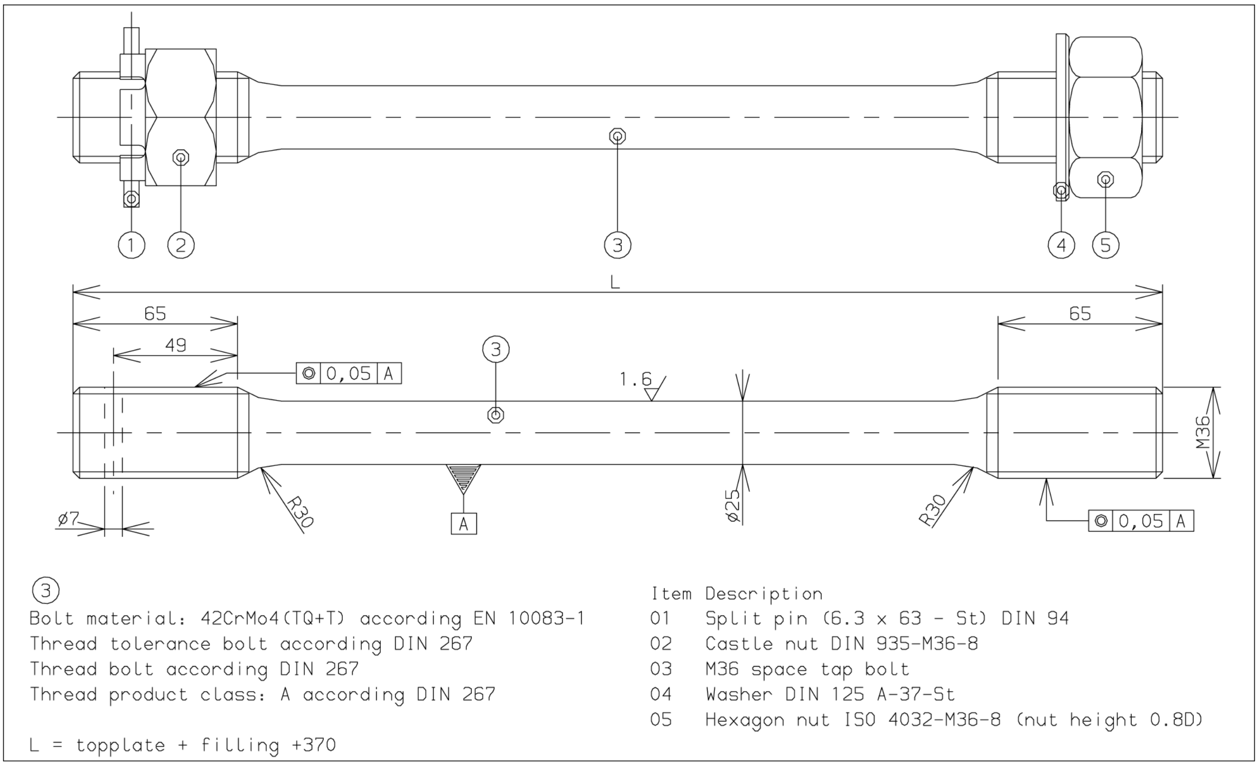
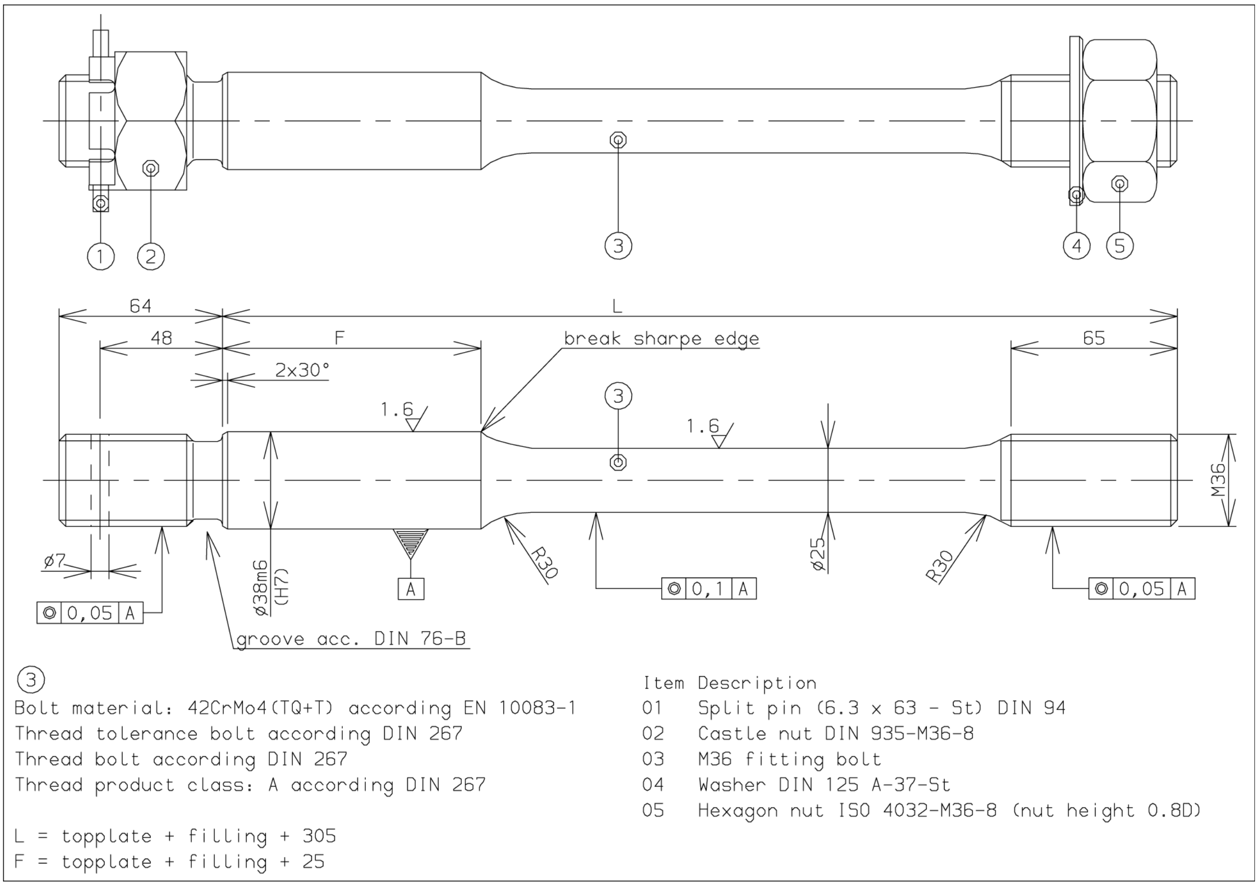


Figure 15.6 Fitted bolt, in-line 38 (9603DT123c)



15.2.4 Foundation and fastening, rigidly mounted in-line 38, steel chocks

Figure 15.7 Foundation design steel chocks (9603DT140b)

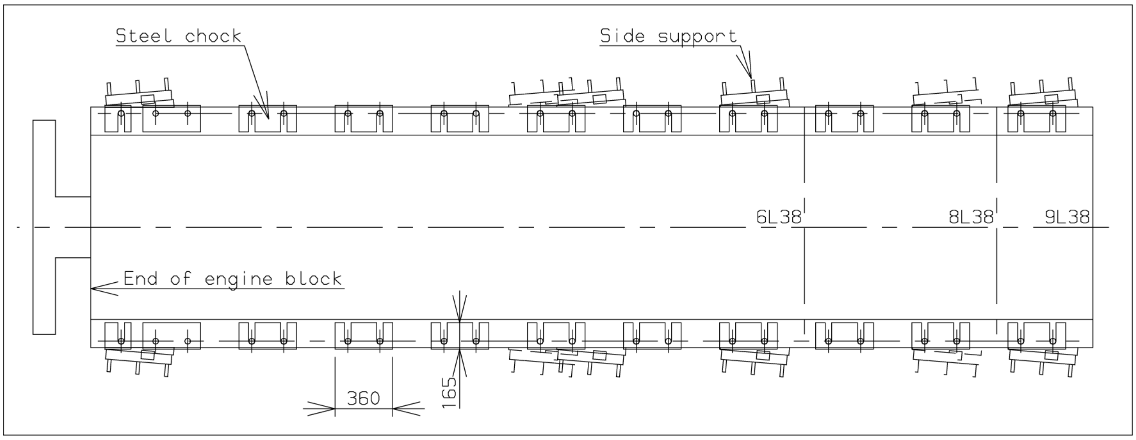
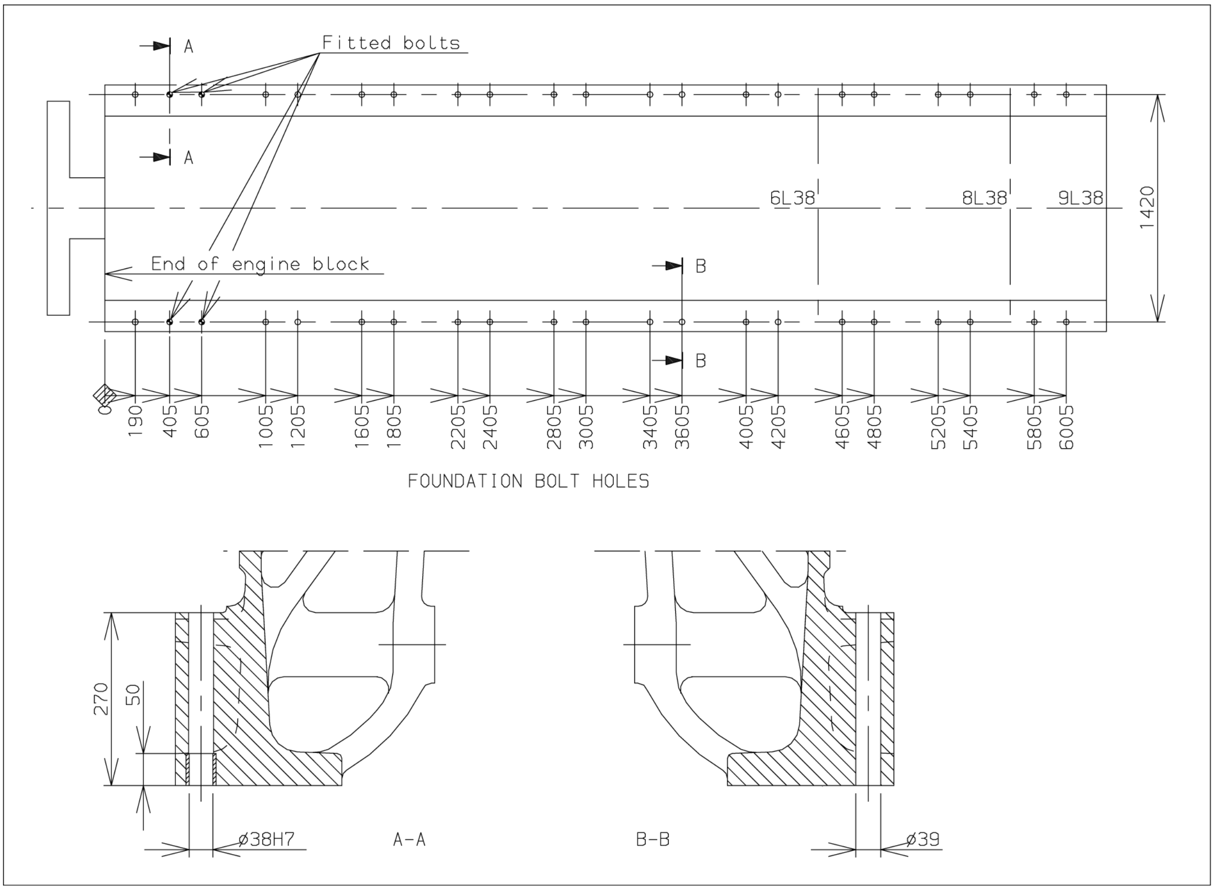


Figure 15.8 Foundation design / drilling plan (9603DT104b)



15.2.5 Foundation and fastening, rigidly mounted V38, steel / resin chocks

Figure 15.9 Clearance bolt, V38 (9603DT126b)

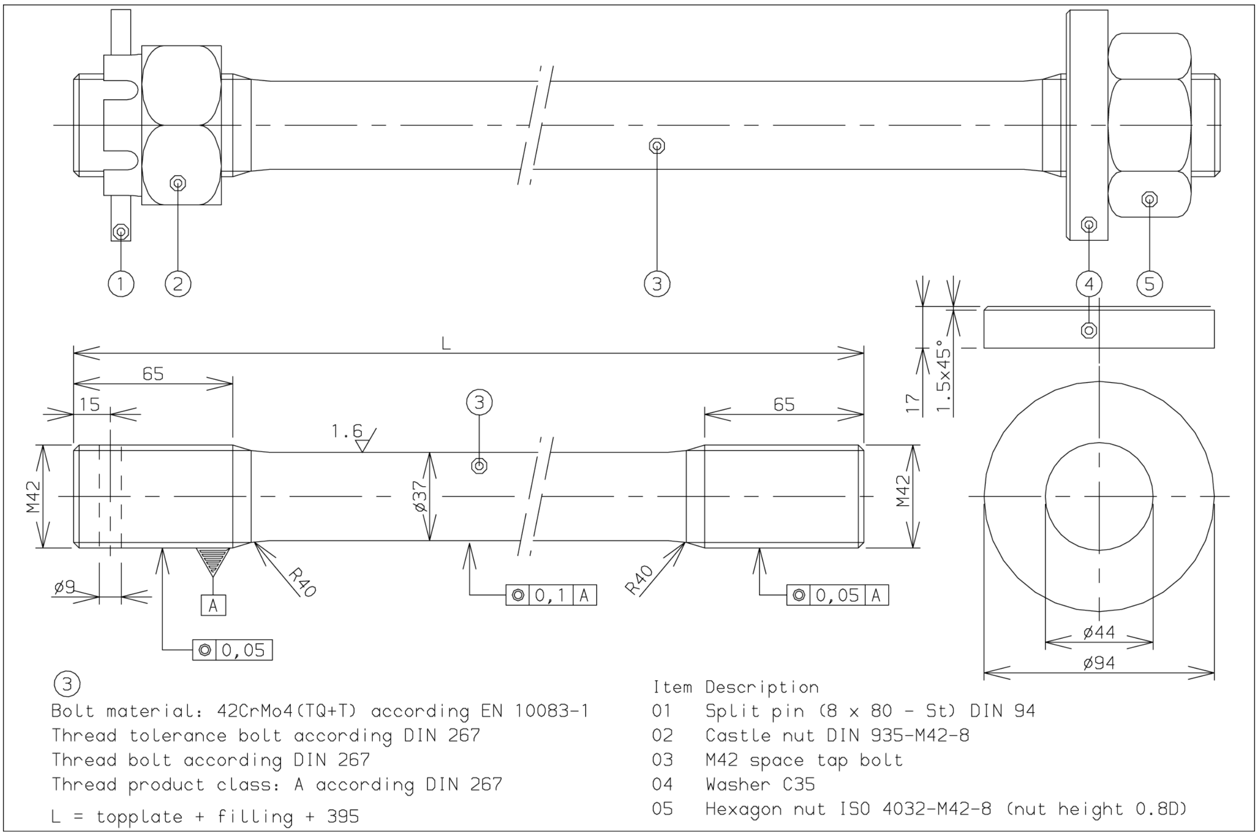
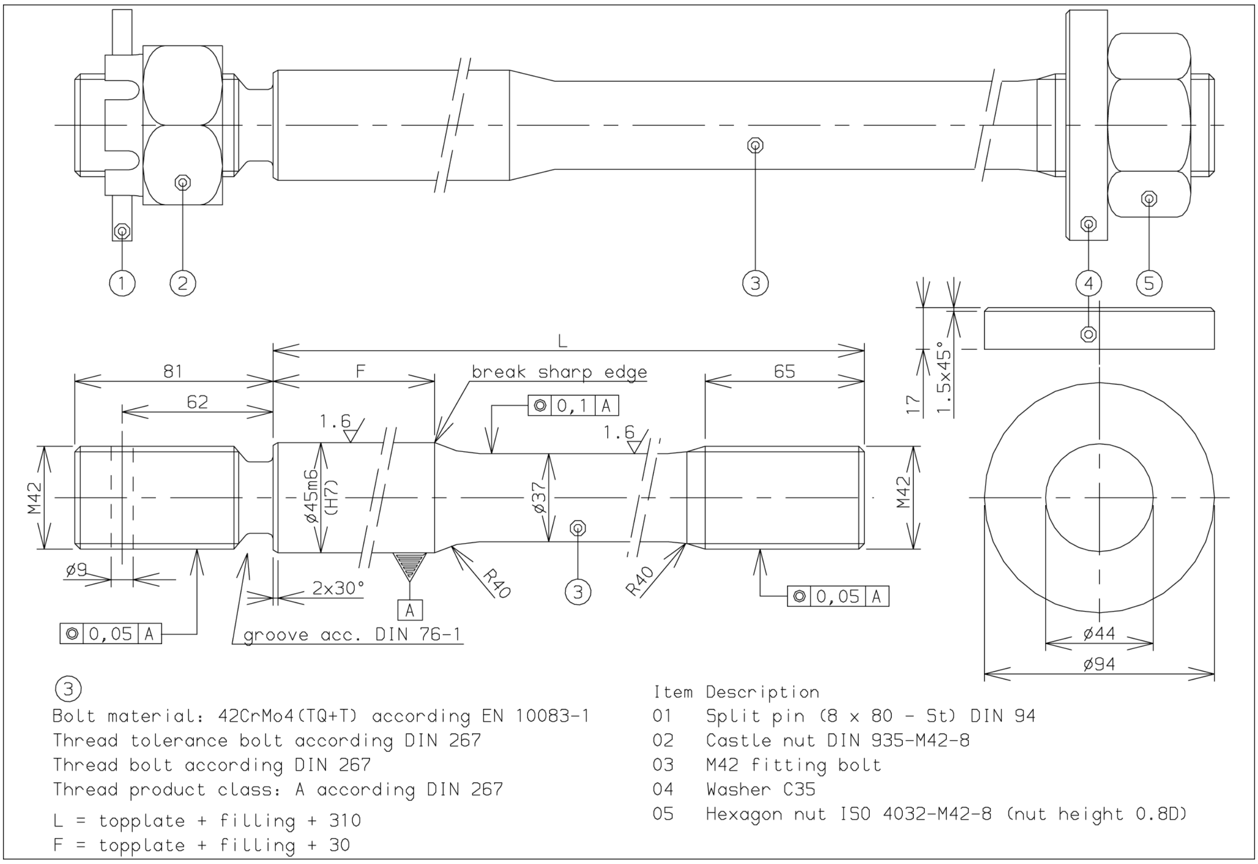


Figure 15.10 Fitted bolt, V38 (9603DT127c)



15.2.6 Foundation and fastening, rigidly mounted V38, steel chocks

Figure 15.11 Foundation design / steel chocks (9603DT139c)

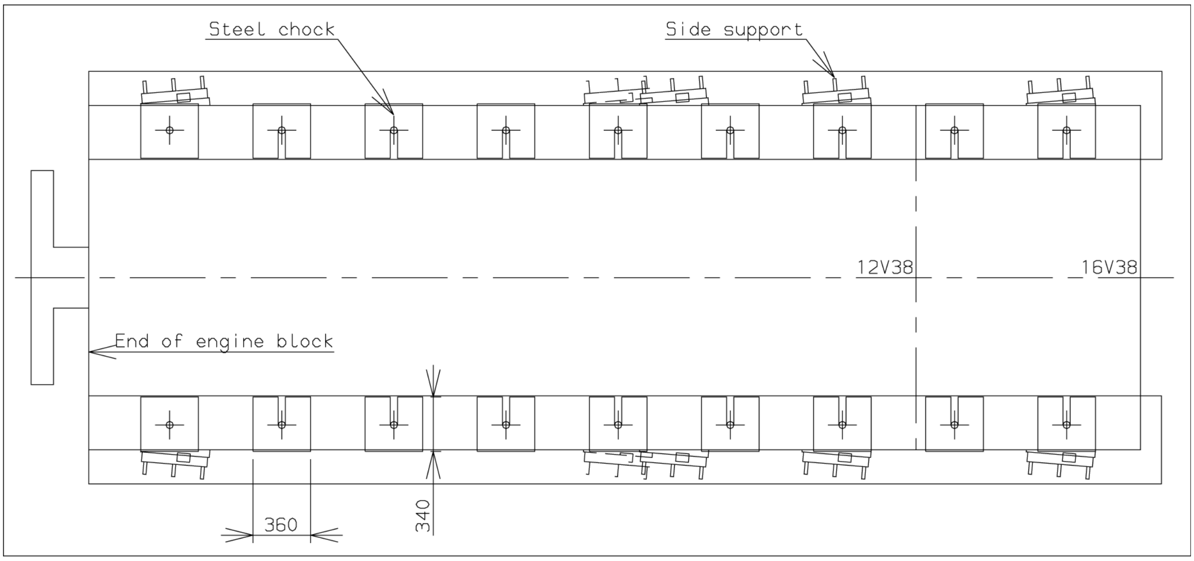
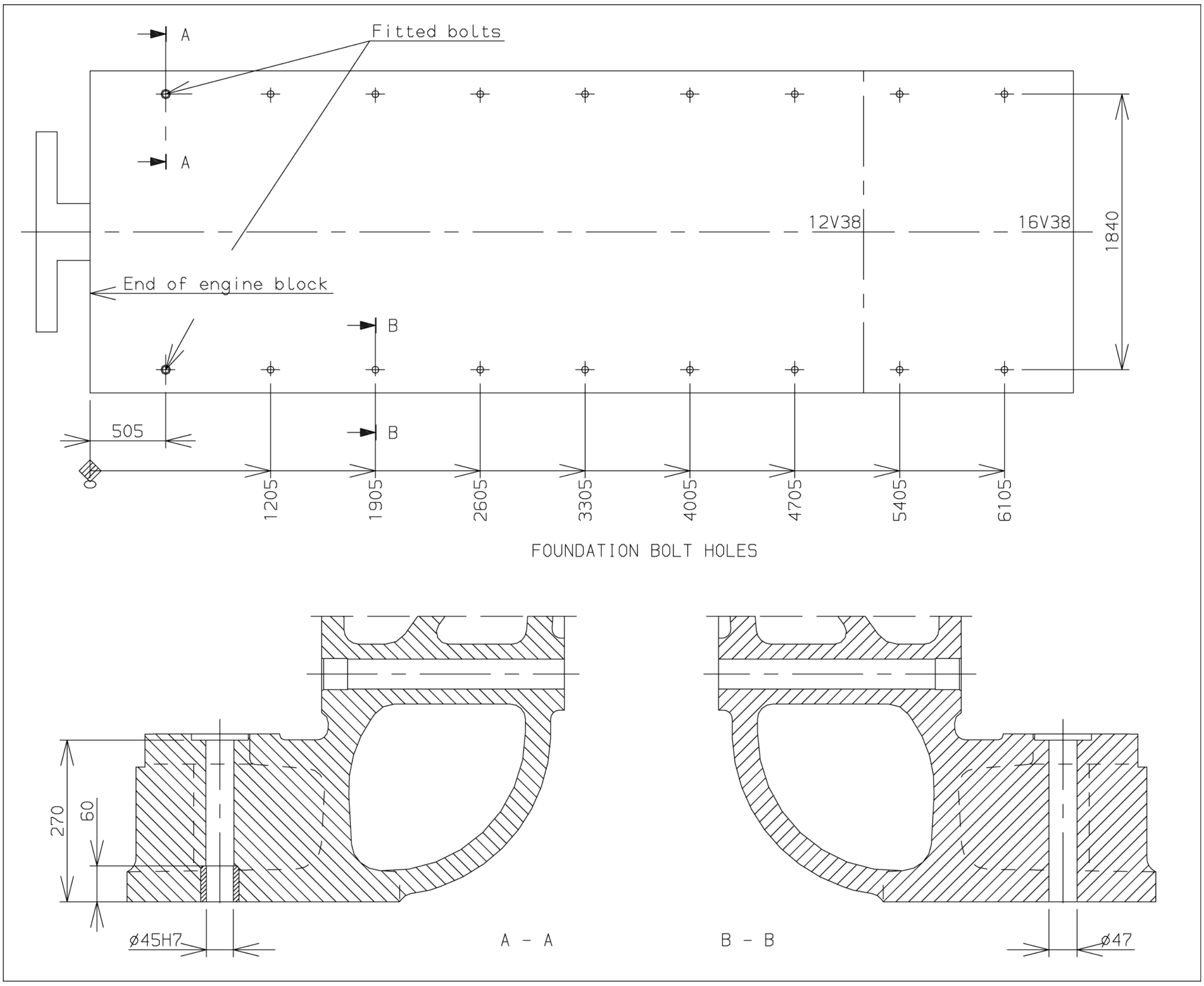


Figure 15.12 Foundation design / drilling plan (9603DT137c)



15.2.7 Seating and fastening, rigidly mounted in-line 38, resin chocks

Figure 15.13 Foundation design/resin chocks (9603DT131b)

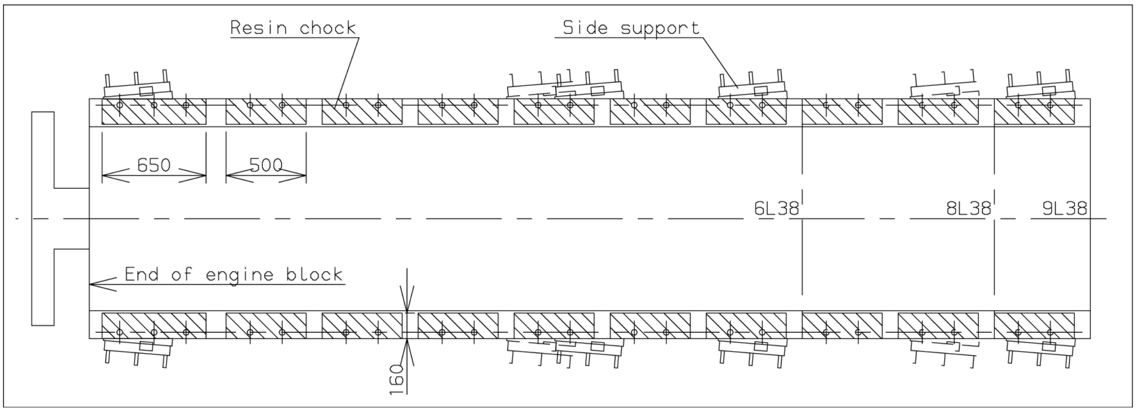
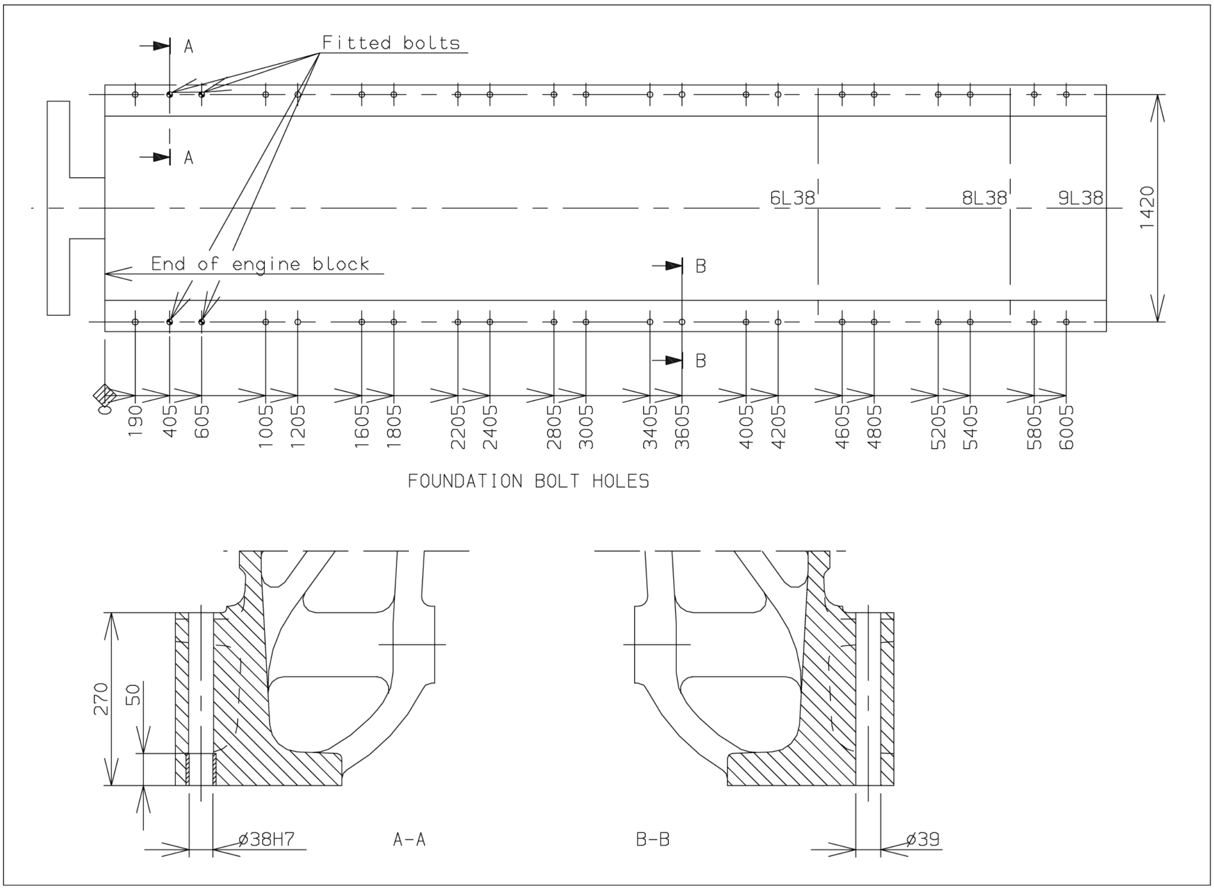


Figure 15.14 Foundation design/drilling plan (9603DT104b)



15.2.8 Seating and fastening, rigidly mounted V38, resin chocks

Figure 15.15 Foundation design/resin chocks (9603DT138c)

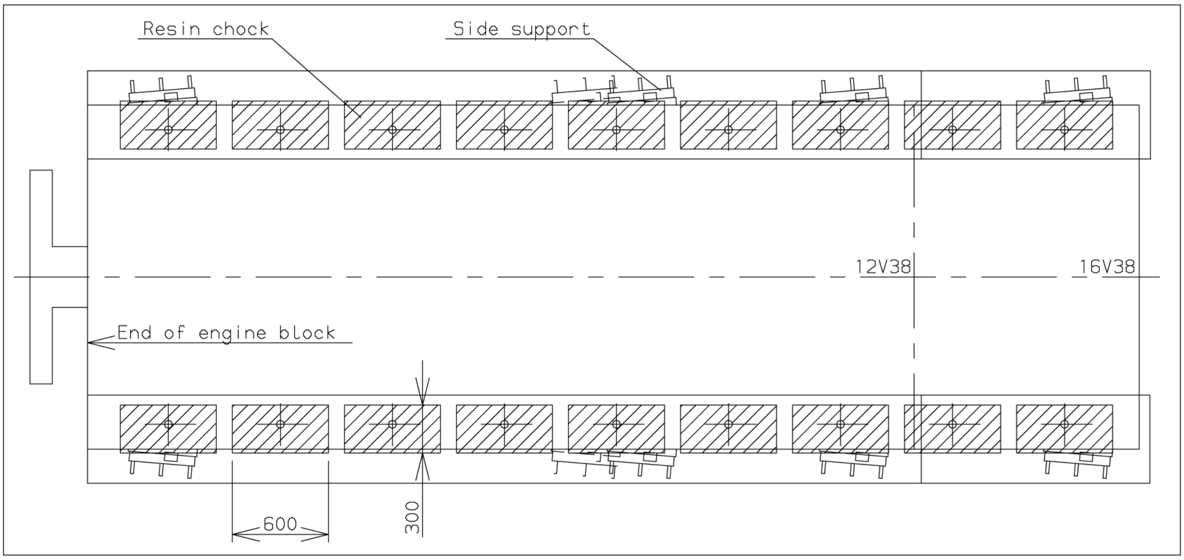
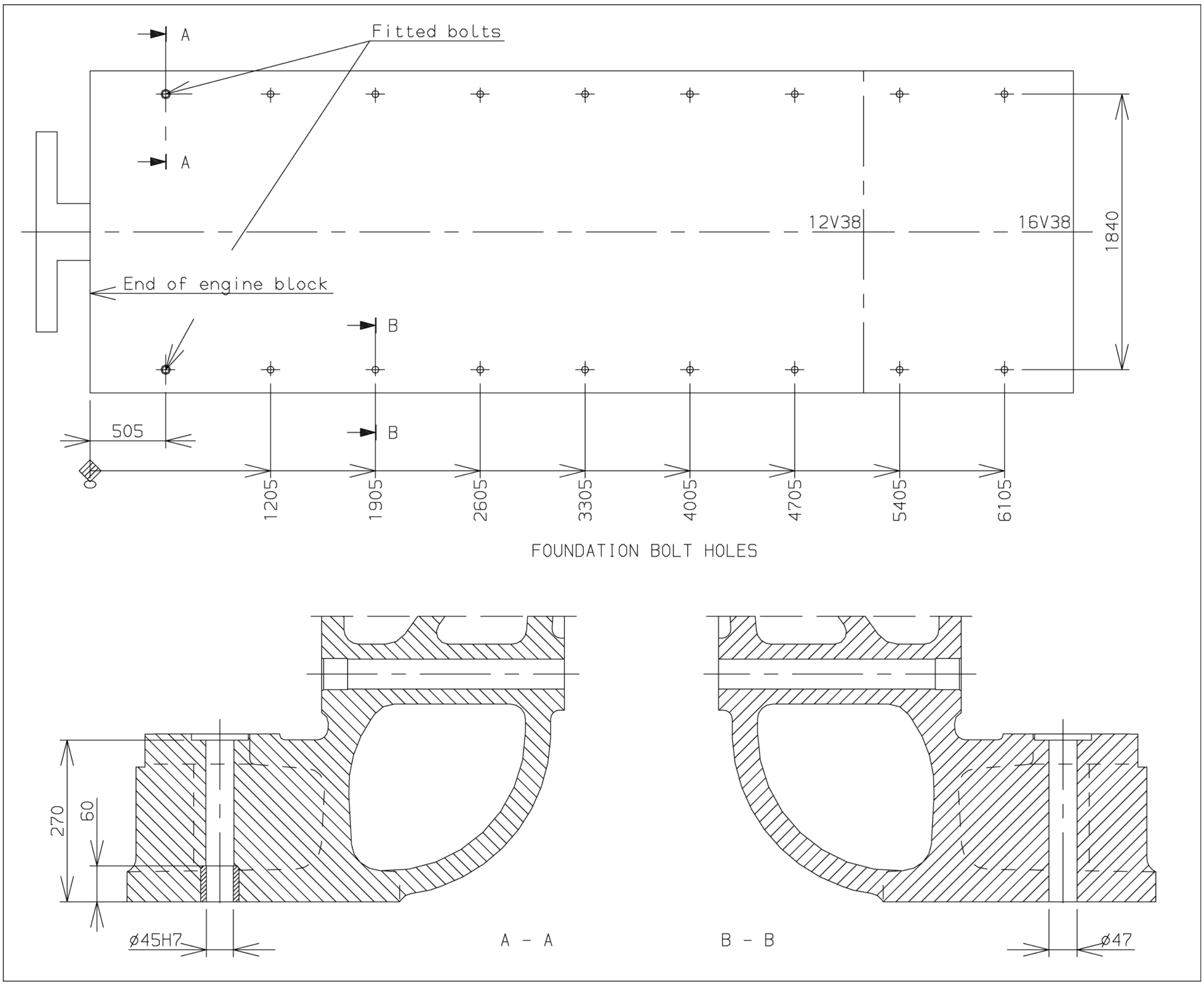
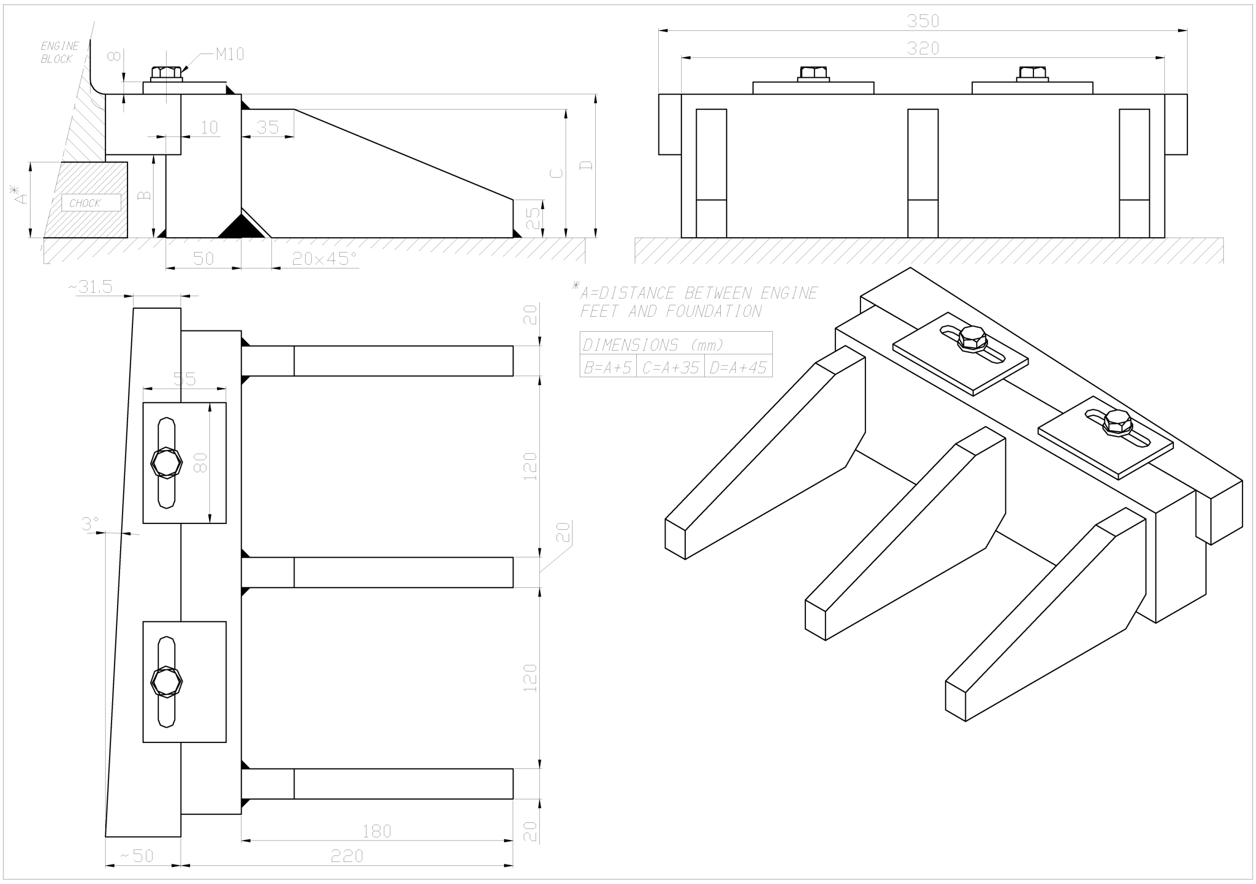


Figure 15.16 Foundation design/drilling plan (9603DT137c)



15.2.9 Foundation W38, side support

Figure 15.17 Recommended side support design, W38 (DAAE031949)



15.3 Resilient mounting

In order to reduce vibrations and structure borne noise, main engines may be resiliently mounted. The engine block is rigid, therefore no intermediate base-frame is necessary. The flexible elements are mounted in brackets that are bolted to the engine feet for in-line 38 engines and are mounted directly to the engine feet for V38 engines. The flexible elements are installed on steel strips which are installed on resin chocks on the foundation.

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

Due to the soft mounting the engine will move when passing resonance speeds at start and stop. Typical amplitudes are ±1 mm at the crankshaft centre and ± 5 mm at top of the engine. The torque reaction (at 600 rpm and 100% load) will cause a displacement of the engine of up to 1 mm at the crankshaft centre and 5 mm at the turbo charger outlet. Furthermore creep and thermal expansion of the rubber elements have to be considered when installing and aligning the engine.

Figure 15.18 Resiliently mounted main engine, in-line 38 engine (9603DT113b)

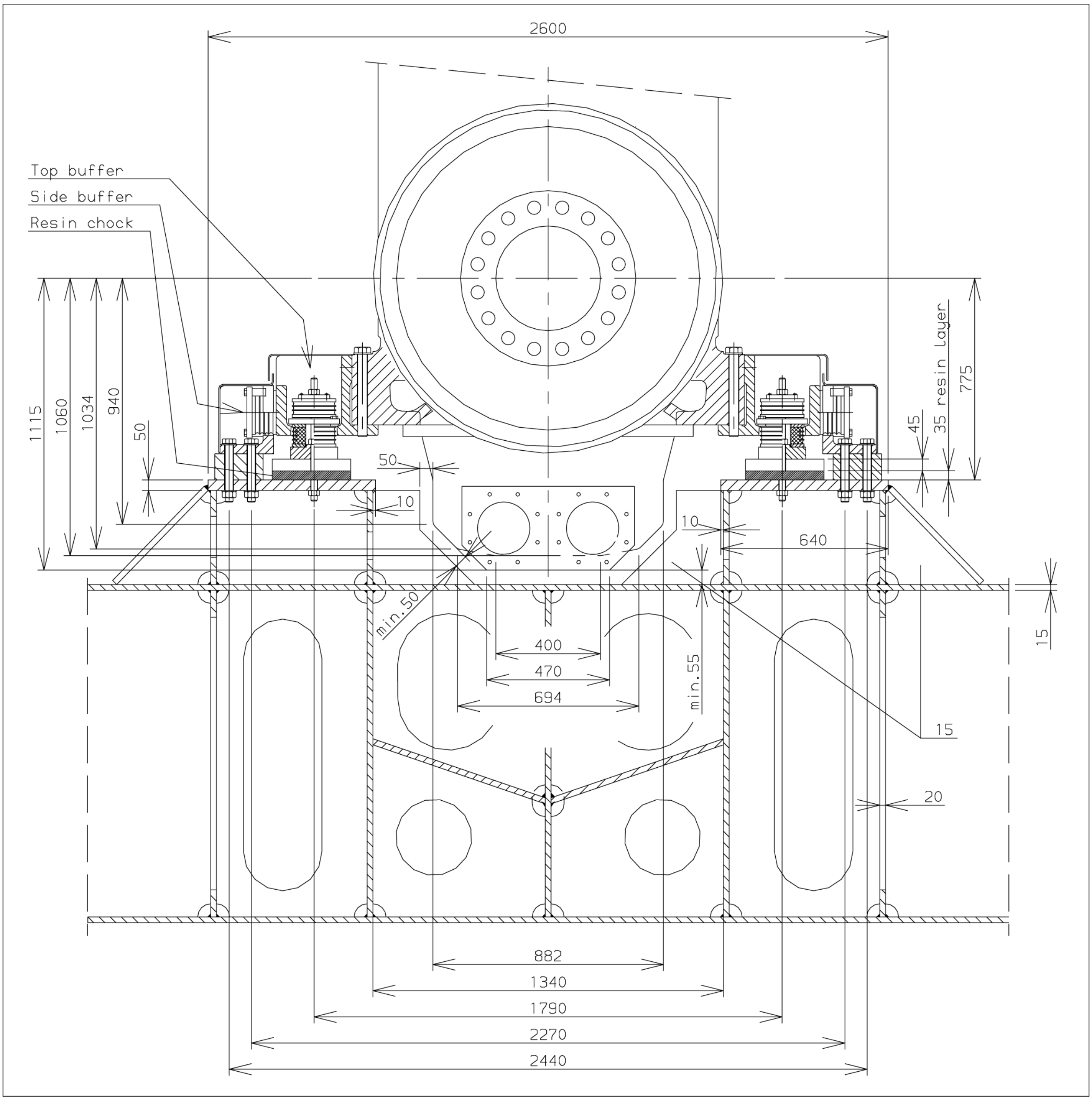
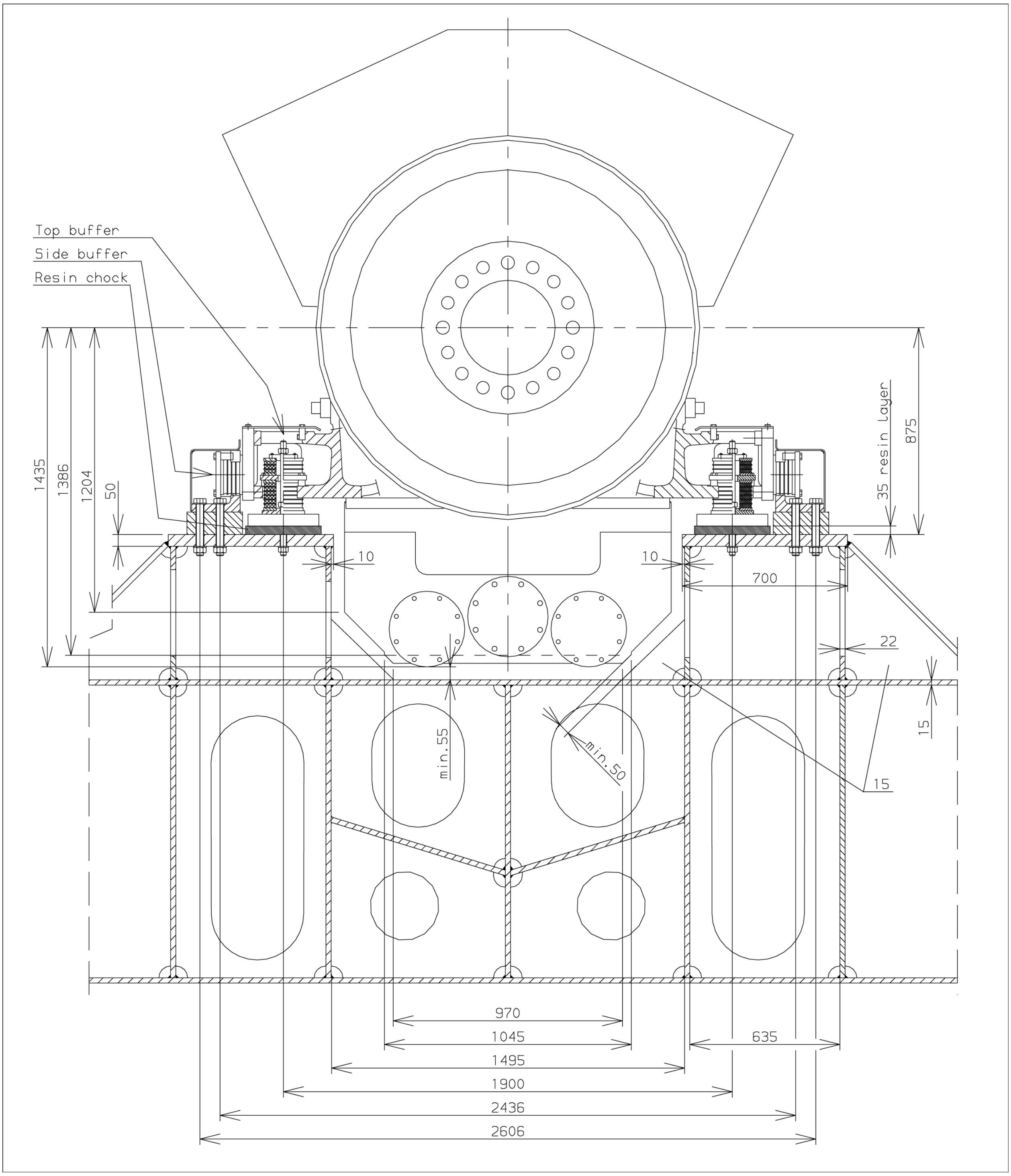


Figure 15.19 Resiliently mounted main engine, V-engine (9603DT107b)



15.3.1 Flexible pipe connections

When the engine is resiliently mounted, all connections must be flexible and no grating nor ladders may be fixed to the engine. Especially the connection to turbocharger must be arranged so that all the displacements can be absorbed.

When installing the flexible pipe connections, unnecessary bending or stretching should be avoided (see chapter 5). The piping outside the flexible connection must be well fixed and clamped to prevent vibrations, which could damage the flexible connection and increase structure borne noise.

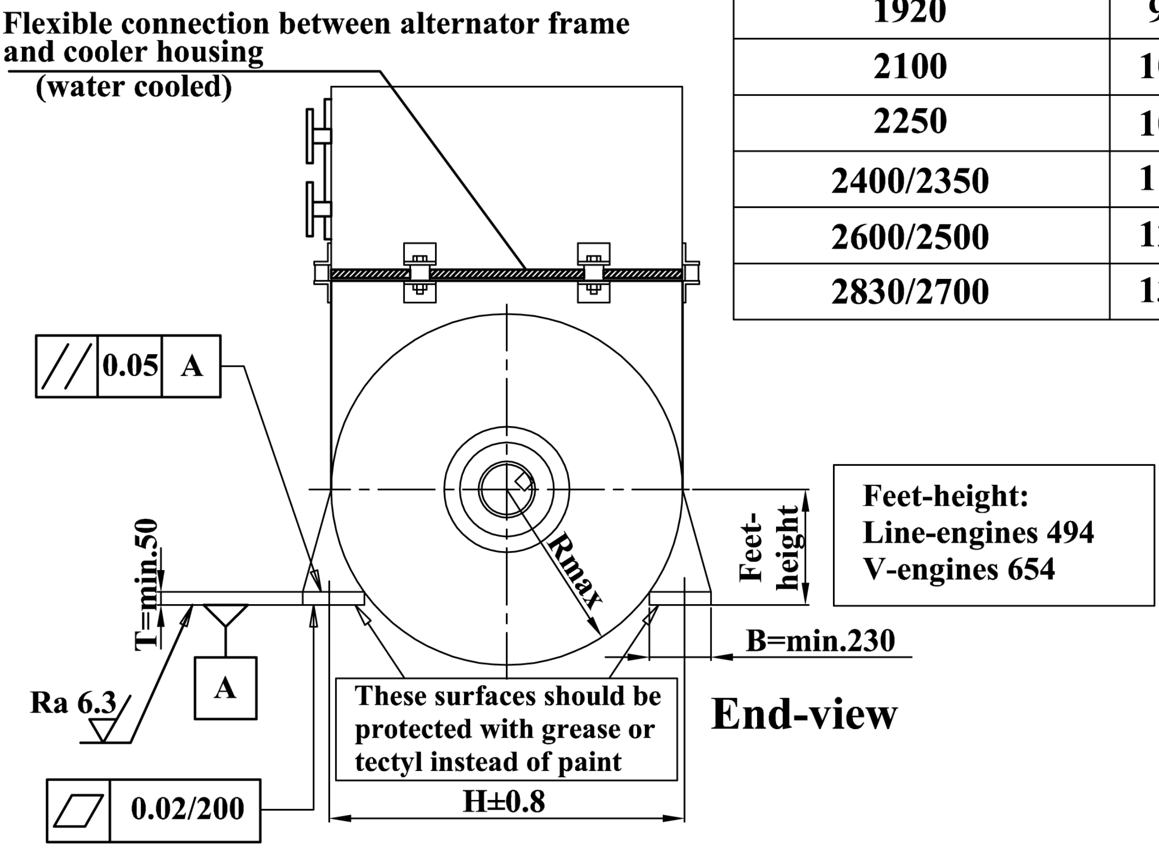
15.4 Mounting of generating sets

15.4.1 Generator feet design

The following directives should be followed for designing the generator feet, when Vibracon elements are used between generator and common baseframe.

Figure 15.20 Recommended generator feet design, W38 (9506DT706a)

H line-engine/V-engine	Rmax
1920	925
2100	1000
2250	1075
2400/2350	1150
2600/2500	1250
2830/2700	1350



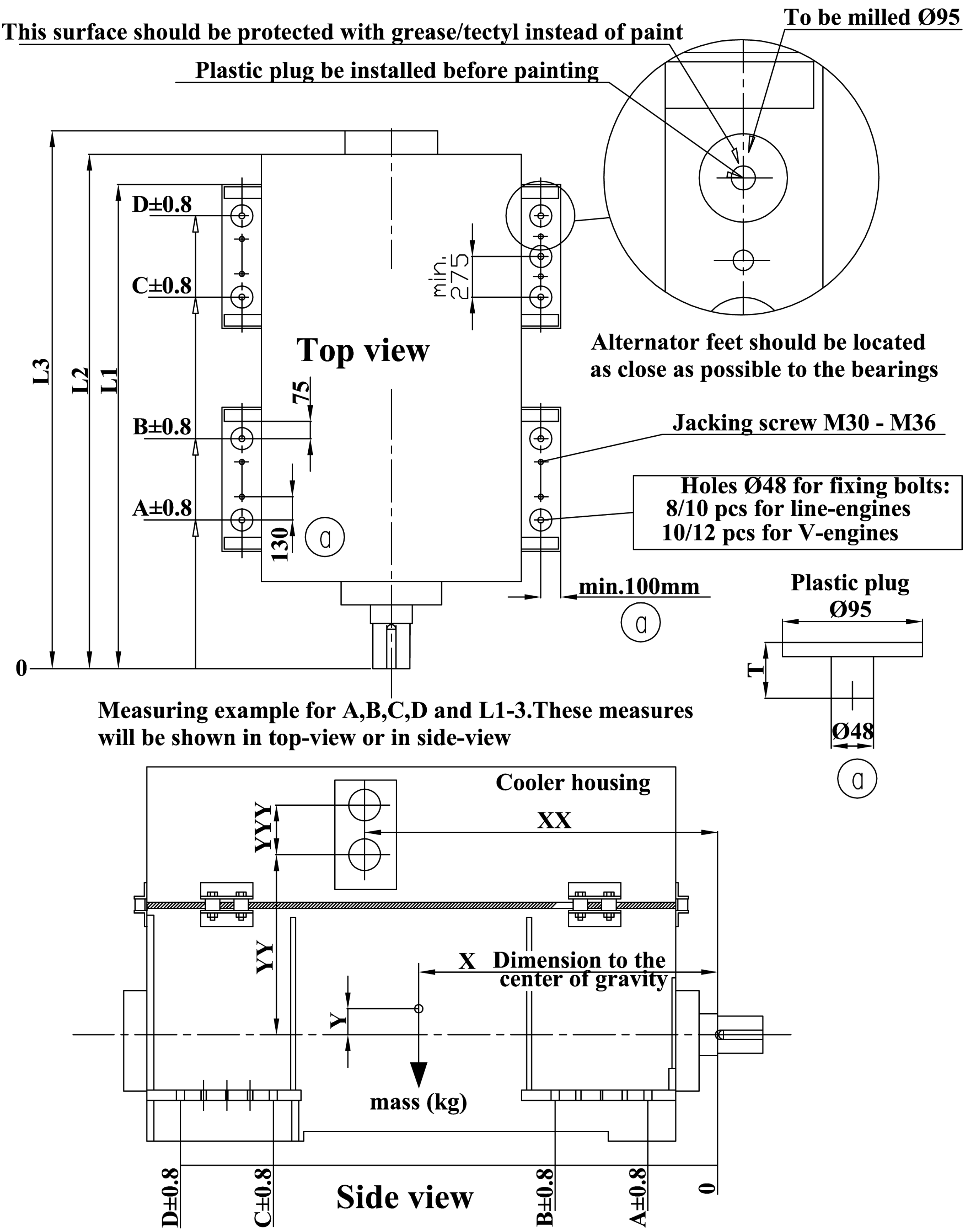


Figure 15.21 Recommended generator feet design, W38 (9506DT706a)

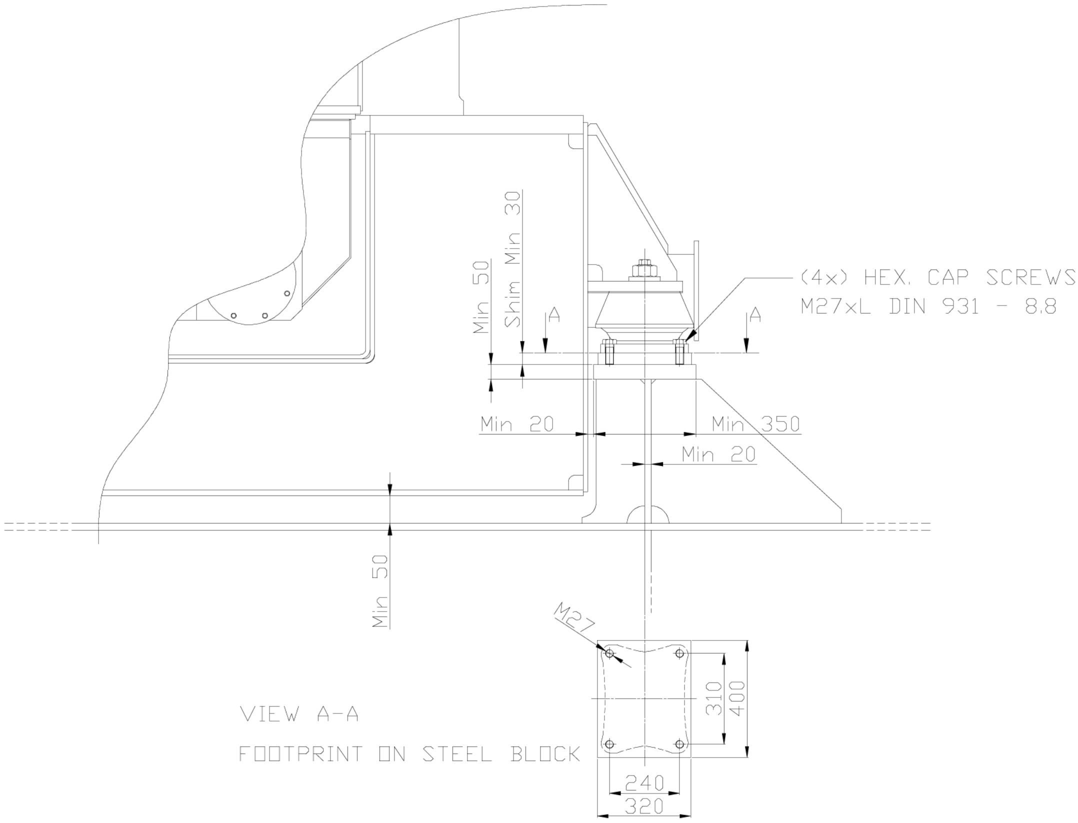
15.4.2 Resilient mounting

Generator sets, comprising engine and generator mounted on a common base frame, are always installed on resilient mounts in the ship. The resilient mounts reduce the structure born noise transmitted to the ship.

The typically used mounts are conical resilient mounts, which are designed to withstand both compression and shear loads. In addition the mounts are equipped with an internal buffer to limit the movements of the generating set due to ship motions. Hence, no additional side or end buffers are required. The rubber in the mounts is natural rubber and it must therefore be protected from oil, oily water and fuel.

Type, number and position of resilient mounts is shown in the project-specific generating set drawing.

Figure 15.22 Example of foundation design for generating set mounted on steel blocks



16. Vibration and noise

16.1 General

Dynamic external couples and forces caused by the engine are shown in tables 16.1 and 16.2. Due to manufacturing tolerances some variation of these values may occur.

The external forces for 6,8,12 and 16 cylinder-configuration are not significant. For the 9 cylinder configurations the external couples are shown in table 16.1

Natural frequencies of decks, bulkheads and other structures close to the excitation frequencies should be avoided. The double bottom should be stiff enough to avoid resonances especially with the rolling frequencies. On cargo ships, the frequency of the lowest hull girder vibration modes are generally far below the 1st excitation order. The higher modes are unlikely to be excited due to the absence of or low magnitude of the external couples, and the location of the engine in relation to nodes and anti nodes is therefore not so critical.

16.2 External free couples and forces acting on W38B

Figure 16.1 Definition of axis

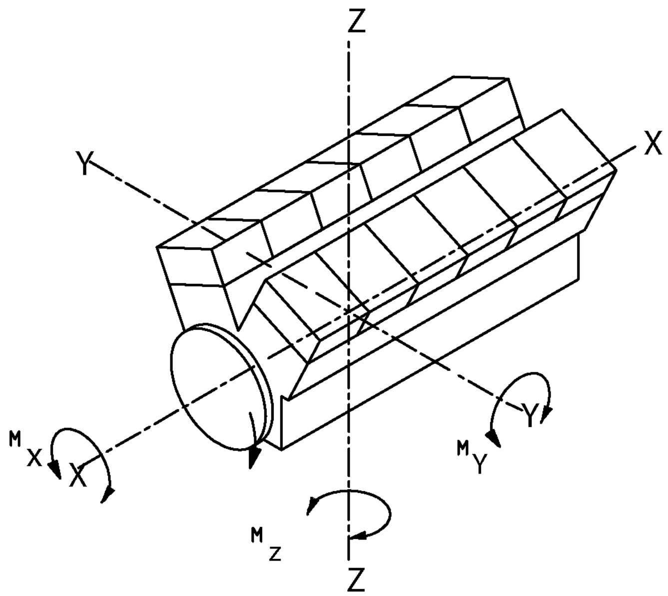


Table 16.1 External couples

Engine	Speed [rpm]	My [kNm] / frequency [Hz]		Mz [kNm] / frequency [Hz]	
9L38	600	77.6 / 10	43.5 / 20	73.9 / 10	

Table 16.2 External forces

Engine	Speed [rpm]	Fyz [kN] / frequency [Hz]
9L38	600	4.9 / 10

16.3 Torque variations

The torque variations are shown in table 16.3

In case of misfiring the maximum power and/or speed should be reduced as indicated on the torsional vibration calculation which is carried out for each individual installation. Under misfiring conditions higher torsional couples may be transmitted as indicated in the table 16.4 until the appropriate corrective action has been taken. This condition should be taken into account when carrying out the design calculations

Table 16.3 Torque variations

Engine	Speed [rpm]	Mx / frequency [kNm] / [Hz]	
6L38	600	62.0 / 30	33.9 / 60
8L38	600	106.9 / 40	16.2 / 80
9L38	600	100.5 / 45	10.9 / 90
12V38	600	32.1 / 30	58.7 / 60
16V38	600	37.1 / 40	30.5 / 80

Table 16.4 Misfiring couples

Speed [rpm]	Mx / frequency [kNm / Hz]			
600	23.1 / 5	20.4 / 10	16.6 / 15	12.7 / 20

The values are instructive and valid for all cylinder configurations.

16.4 Mass moments of inertia

These typical inertia values include the flexible coupling part connected to the flywheel and torsional vibration damper (without engine PTO shaft).

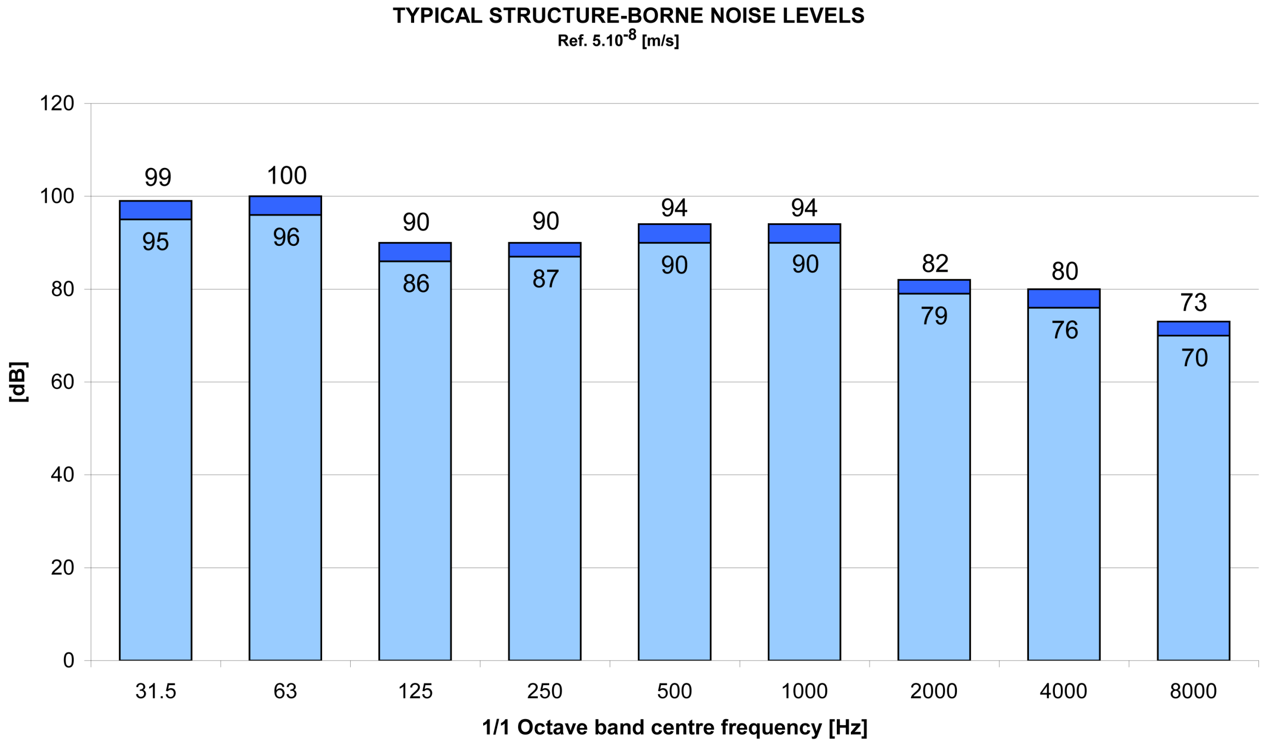
Table 16.5 Mass moments of inertia

Engine	Mass moments of inertia J [kgm^2]
6L38	850 - 1250
8L38	1000 - 1750
9L38	1450 - 1900
12V38	1600 - 2500
16V38	2000 - 3000

16.5 Structure borne noise

The expected vibration velocity level averaged over the four corners of the engine foundation flange in three perpendicular directions with reference level v_{ref} = 5.10^{-8} [m/s] per octave band with centre frequency in [Hz] is shown in the following figure.

Figure 16.2 Typical structure borne noise levels



16.6 Air borne noise

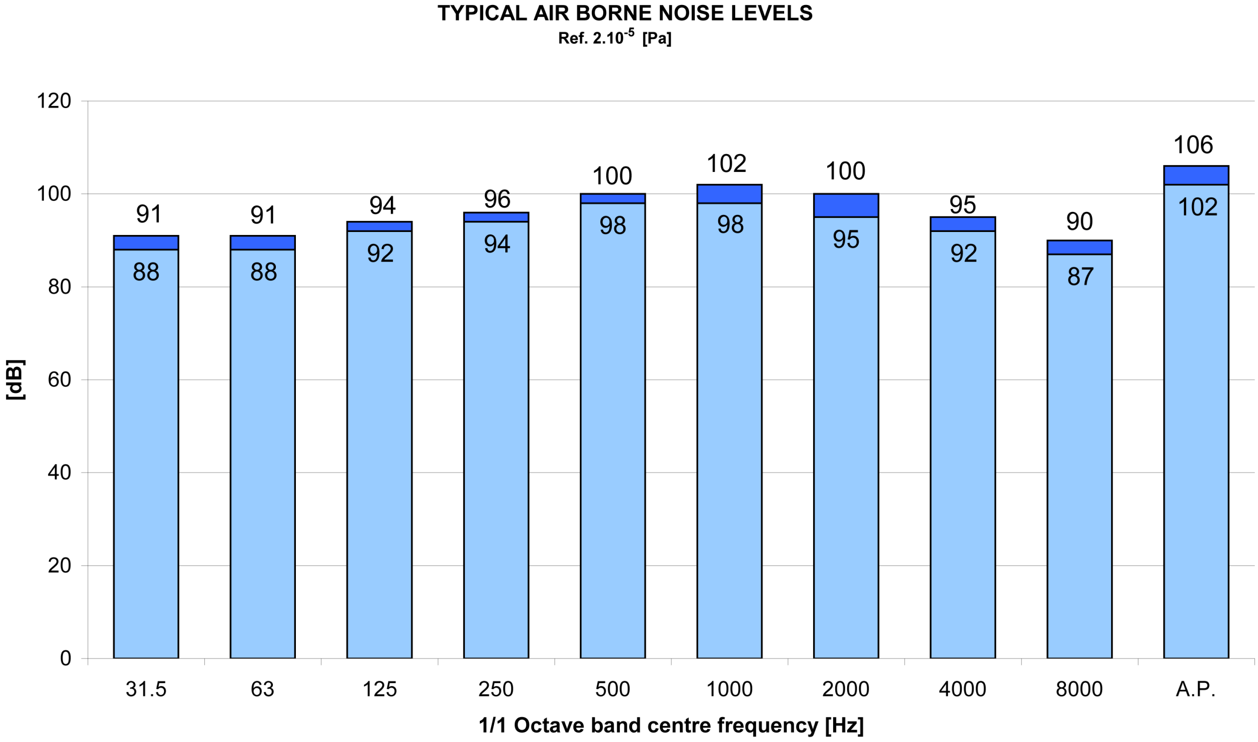
16.6.1 Engine surface radiated noise

The average octave band sound pressure levels represent free field conditions, and are based on measurements over at least 8 up to 14 points around tested engines corrected for the influence of reflected sound.

Measuring points are taken at cylinder height and overhead the cylinder heads at 1 metre from the engine reference surface. The average sound pressure are in dB ref. 2.10^{-5} Pa per octave band with centre frequency in Hz.

A-weighted 'All pass' (A.P.) levels are shown in the following figure.

Figure 16.3 Typical air-borne noise levels

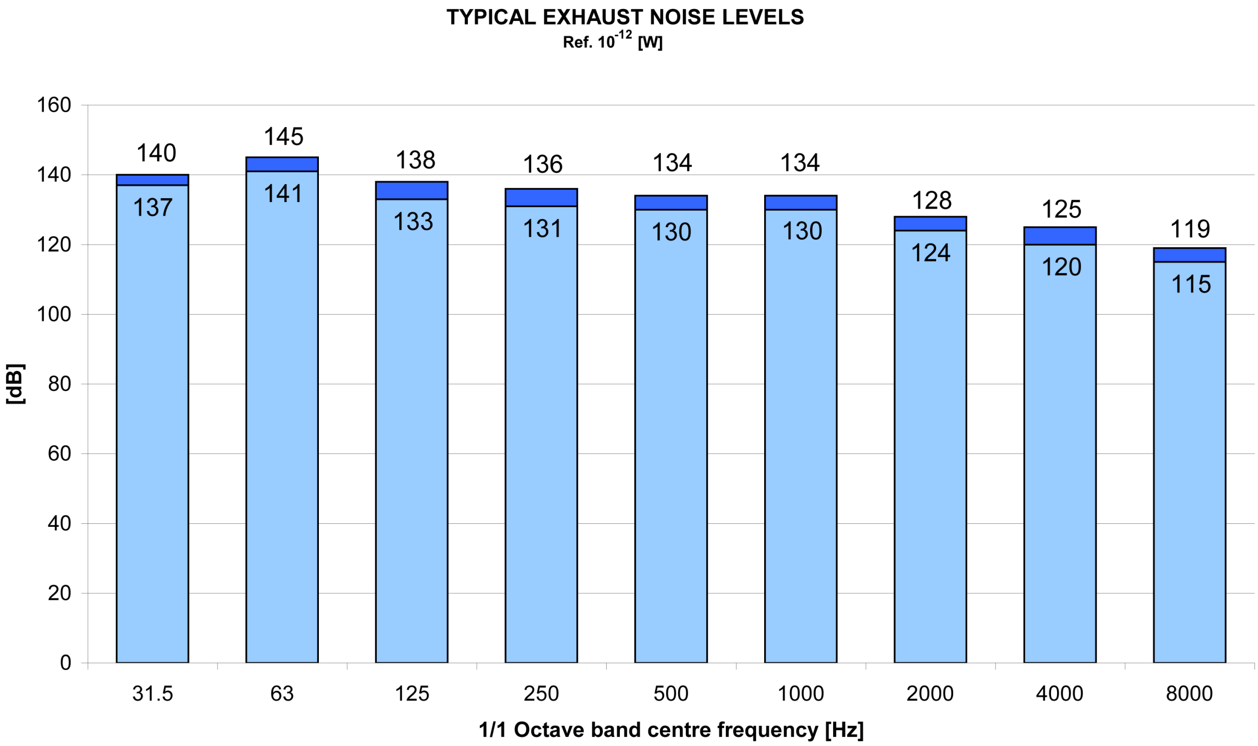


The noise level is measured in a test cell with a turbo air filter 1 m from the engine. 90% of the values measured on production engines are below the figures in the diagram.

16.7 Exhaust noise

The unsilenced exhaust noise of the opening directly downstream of the exhaust gas turbine in sound power levels in dB ref. 10^{-12} W per octave band with mid frequency in Hz is shown in the following figure.

Figure 16.4 Typical exhaust noise levels



17. Power transmission

17.1 Flexible coupling

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

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

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

17.2 Clutch

In 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.

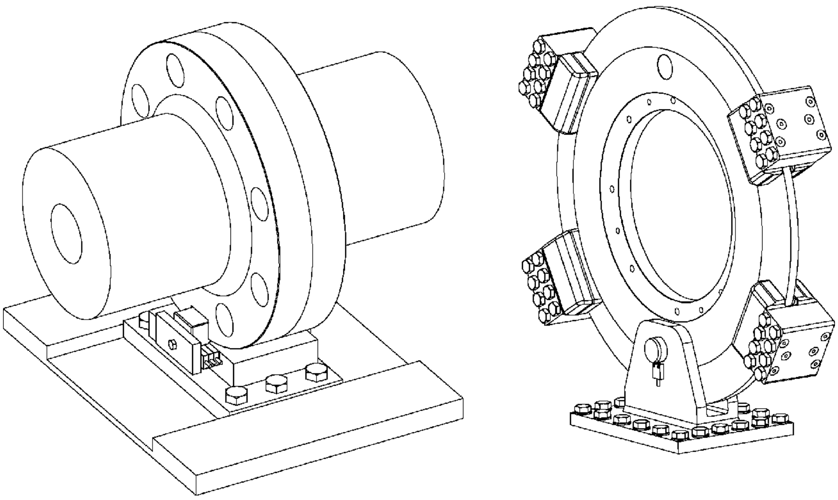
To permit maintenance of a stopped engine clutches must be installed in twin screw vessels which can operate on one shaft line only.

17.3 Shaft locking device

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.

Figure 17.1 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.

The weight of the coupling mounted on the PTO shaft, and the need for a support bearing is subject to special consideration, on a case-by-case basis. The support bearing is possible only for rigidly mounted engines.

17.5 Input data for torsional vibration calculations

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

Installation

- Classification
- Ice class
- Operating modes

Reduction gear

A mass elastic diagram showing:

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

Propeller and shafting

A mass-elastic diagram or propeller shaft drawing showing:

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

Main generator or shaft generator

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

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

Flexible coupling/clutch

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

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

Operational data

- Operational profile (load distribution over time)

- Clutch-in speed
- Power distribution between the different users
- Power speed curve of the load

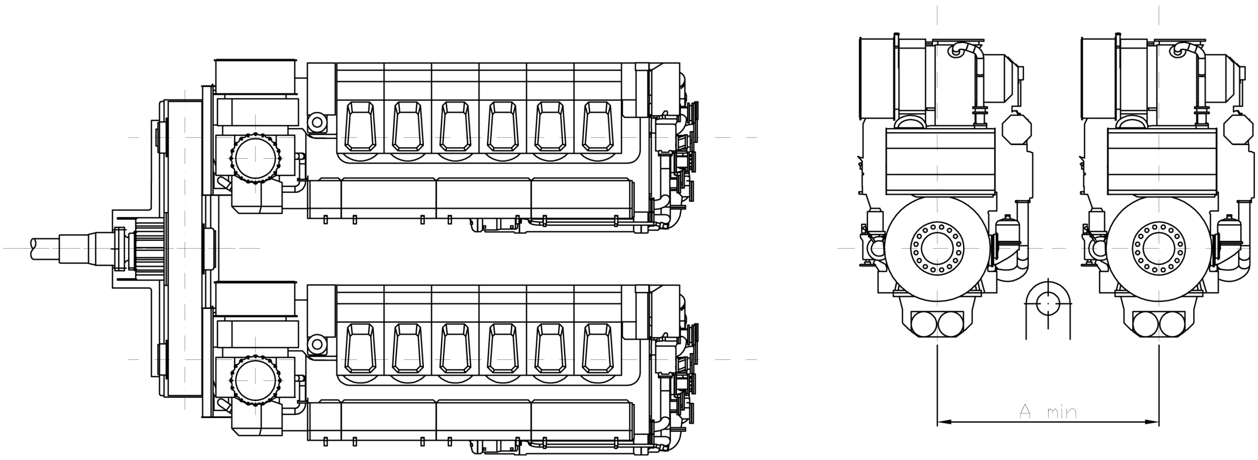
17.6 Turning gear

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

18. Engine room layout

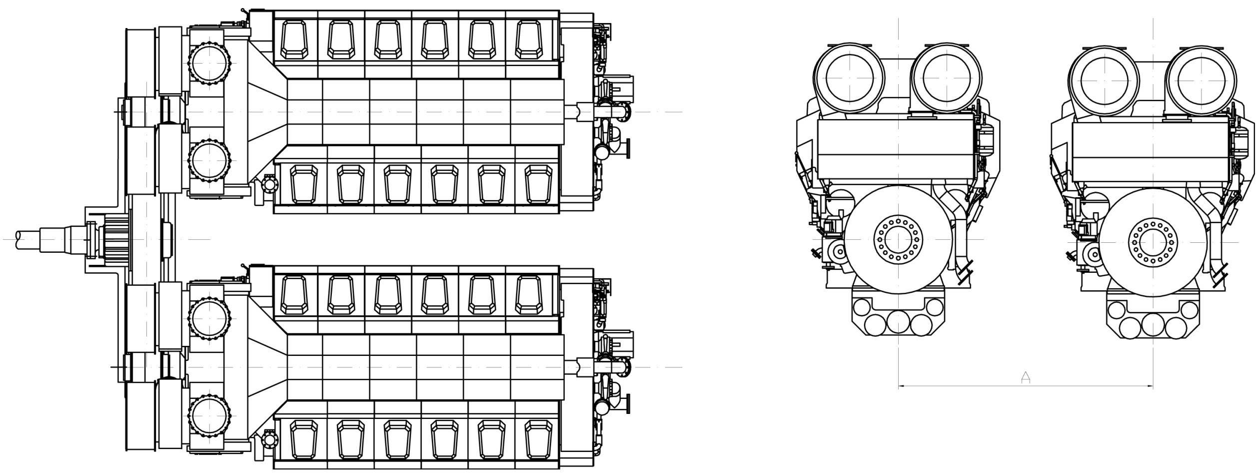
18.1 Crankshaft distances

Figure 18.1 Crankshaft centre distances, in-line engines (DAAE052816)



Engine Type	A min [mm]
W6L38	2800
W8L38	3010
W9L38	3010

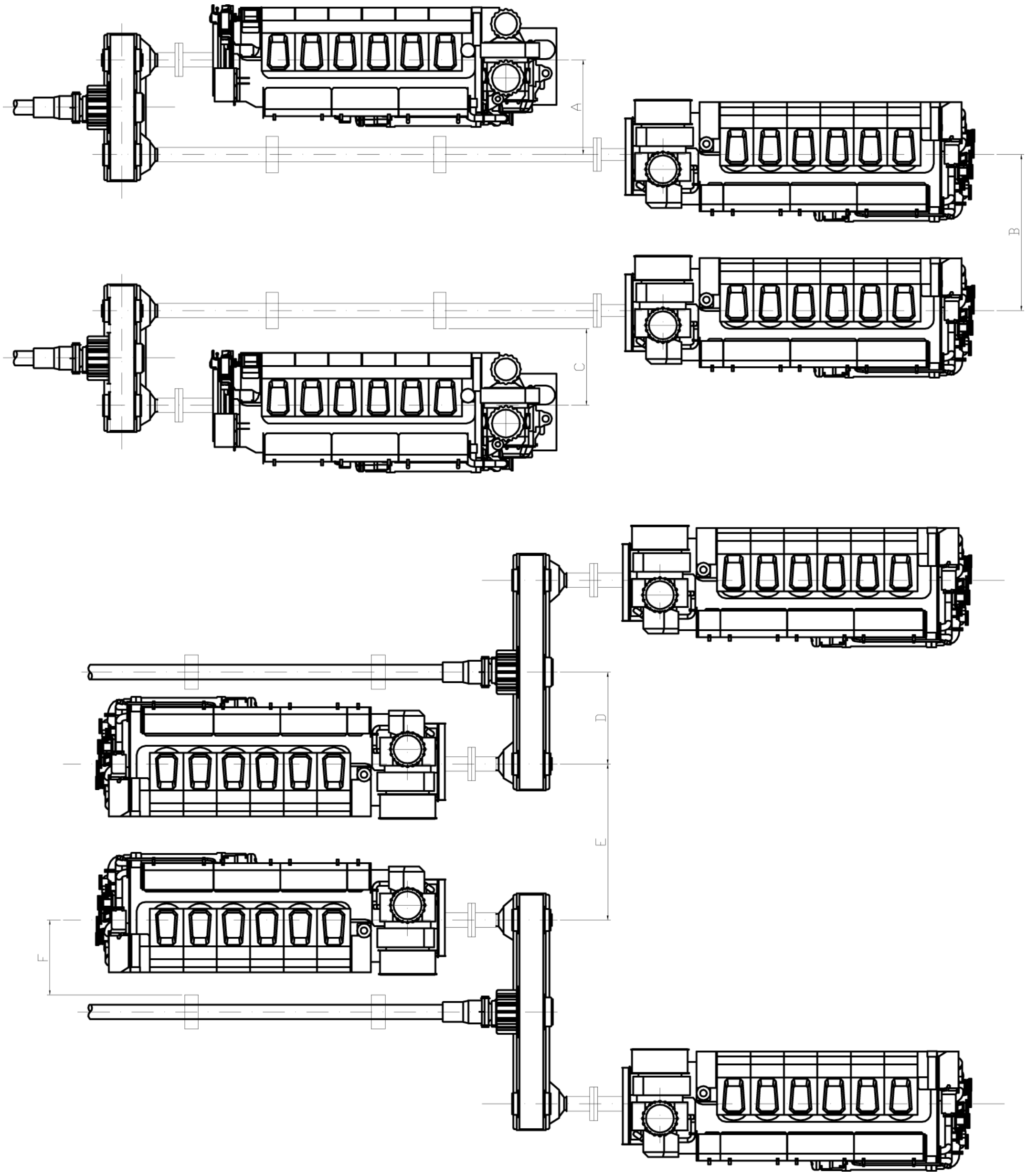
Figure 18.2 Crankshaft centre distances, V-engines (DAAE052817)



Engine Type	A min [mm]
W12V38	3800
W16V38	3800

18.2 Four-engine arrangements

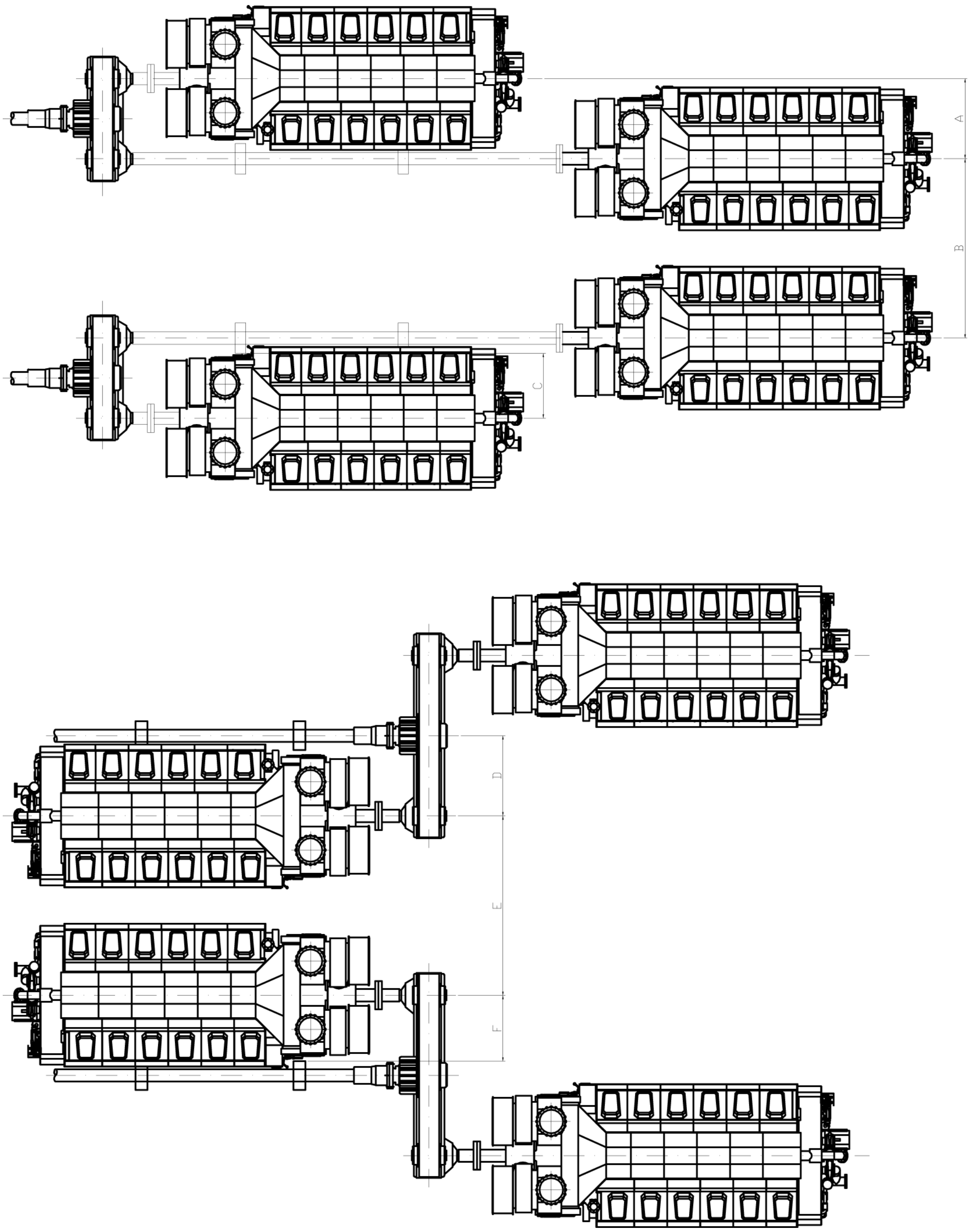
Figure 18.3 Main engine arrangement, 4 x in-line engines (DAAE052818)



Engine type	A min.* [mm]	B min. [mm]	C min.* [mm]	D min.* [mm]	E min. [mm]	F min. [mm]
6L38	1700	2800	1345	1650	2800	1345
8L38	1700	3010	1345	1650	3010	1345
9L38	1700	3010	1345	1650	3010	1345

* Depends on type of bearing block.

Figure 18.4 Main engine arrangement, 4 x V-engines (DAAE052886)



Engine type	A min.* [mm]	B min. [mm]	C min.* [mm]	D min.* [mm]	E min. [mm]	F min. [mm]
12V38	1700	3800	1300	1700	3800	1280
16V38	1700	3800	1300	1700	3800	1280

* Depends on type of bearing block.

18.3 Father and son arrangement

Figure 18.5 shows an example of an in-line and a V-engine as a father and son arrangement. The engines 8L38 and 12V38 are roughly equally long.

To minimize the crankshaft distance the operating side of the V38 should be towards the in-line engine, otherwise dismantling of the air cooler of the in-line engine will determine the required distance to avoid interference with the charge air cooler of the in-line engine.

When the operating side of the in-line 38 is towards the V-engine, the recommended platform height between the engines is as recommended for the in-line 38.

Figure 18.6 shows an example of father and son arrangement for an 8L and a 6L.

A configuration of father and son arrangement needs often a customize approach. Many parameters play a role; cylinder configurations, position turbocharger, position platforms, horizontal or vertical offset etc. Please contact Wärtsilä for addtional information.

Figure 18.5 Main engine arrangement, 8L38 + 12V38 (DAAE052819)

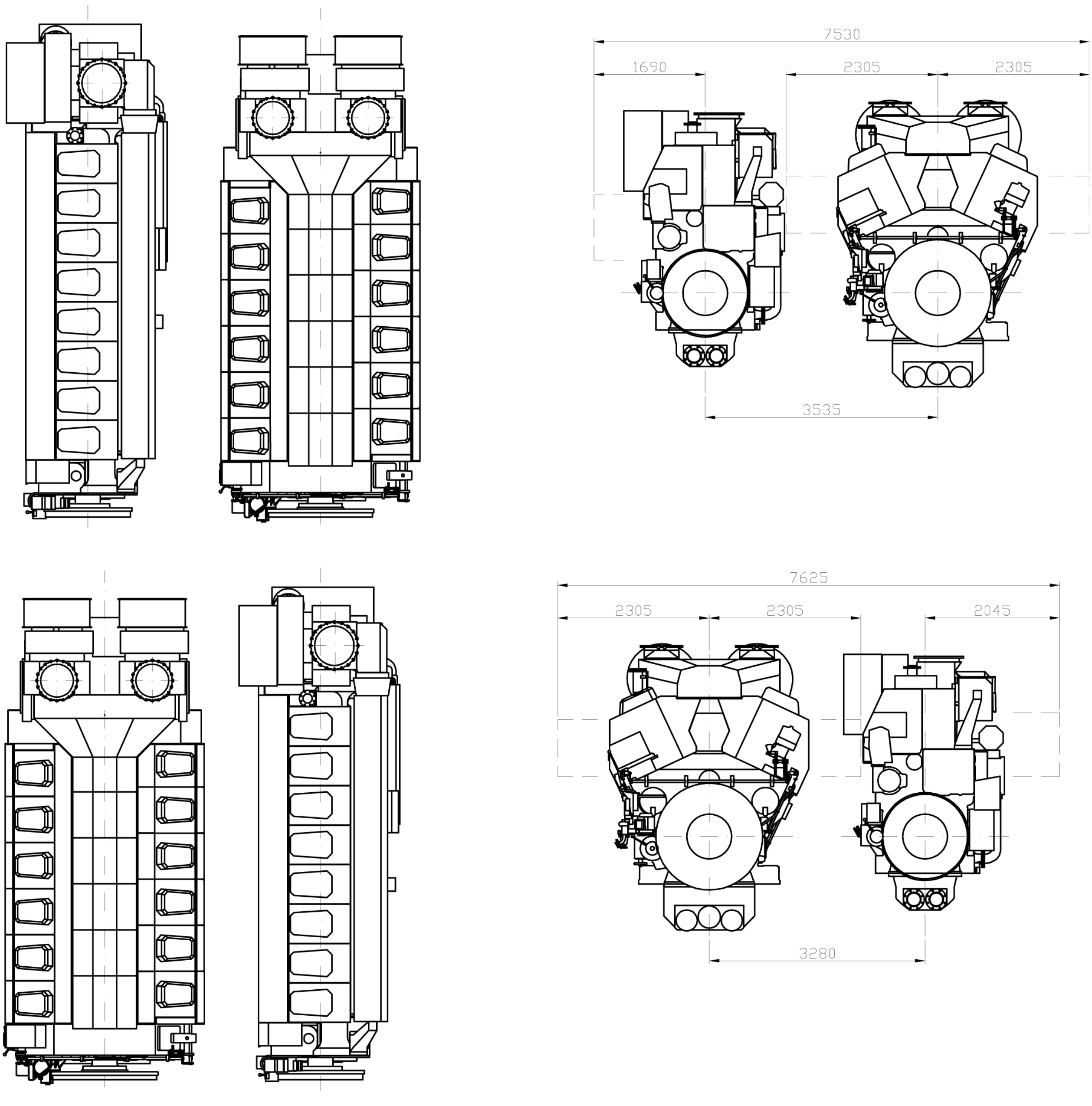
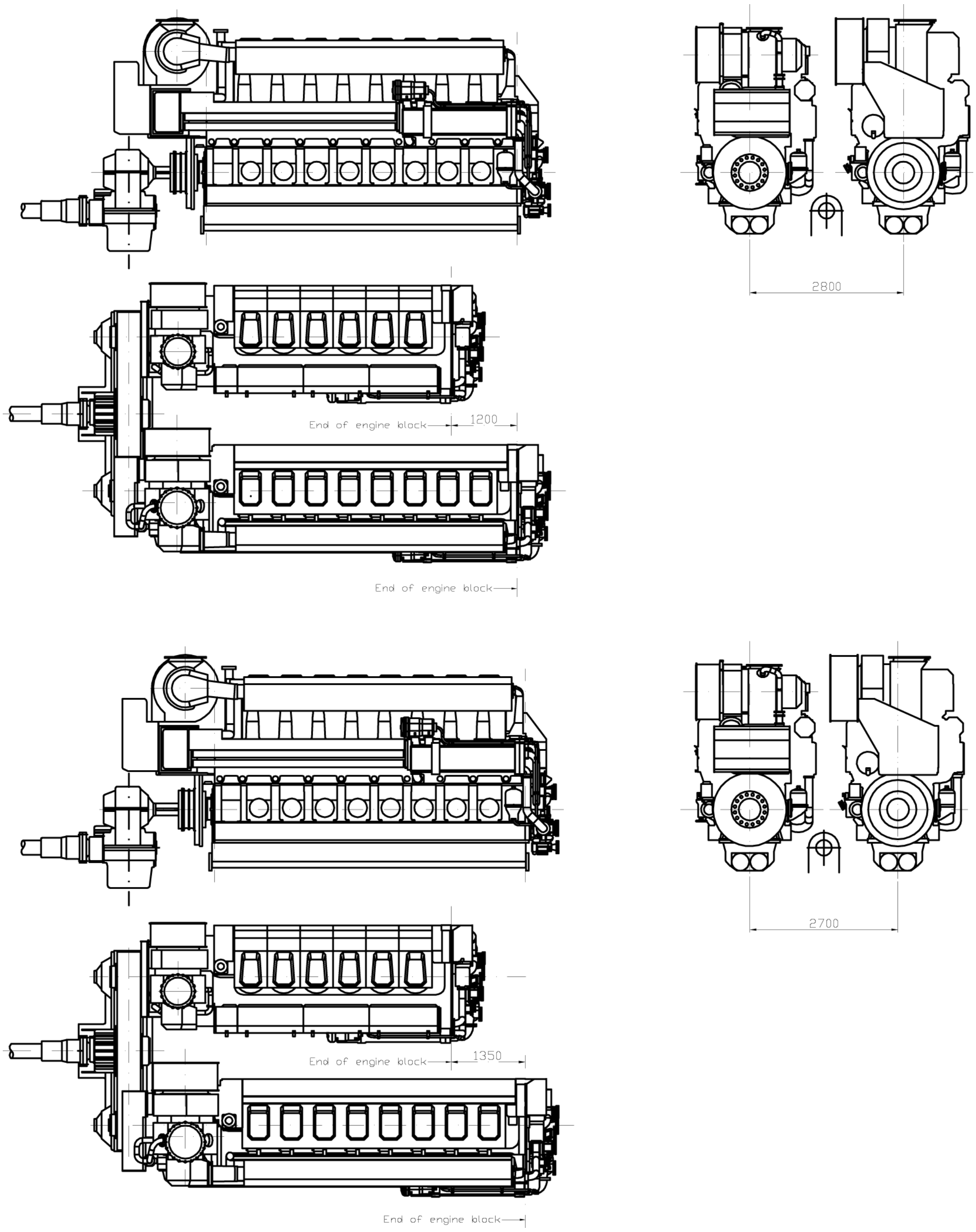


Figure 18.6 Main engine arrangement, 6L38 + 8L38 (DAAE052820)



18.4 Space requirements for maintenance

Figure 18.7 Service space requirements for In-line engines (DAAE033905a)

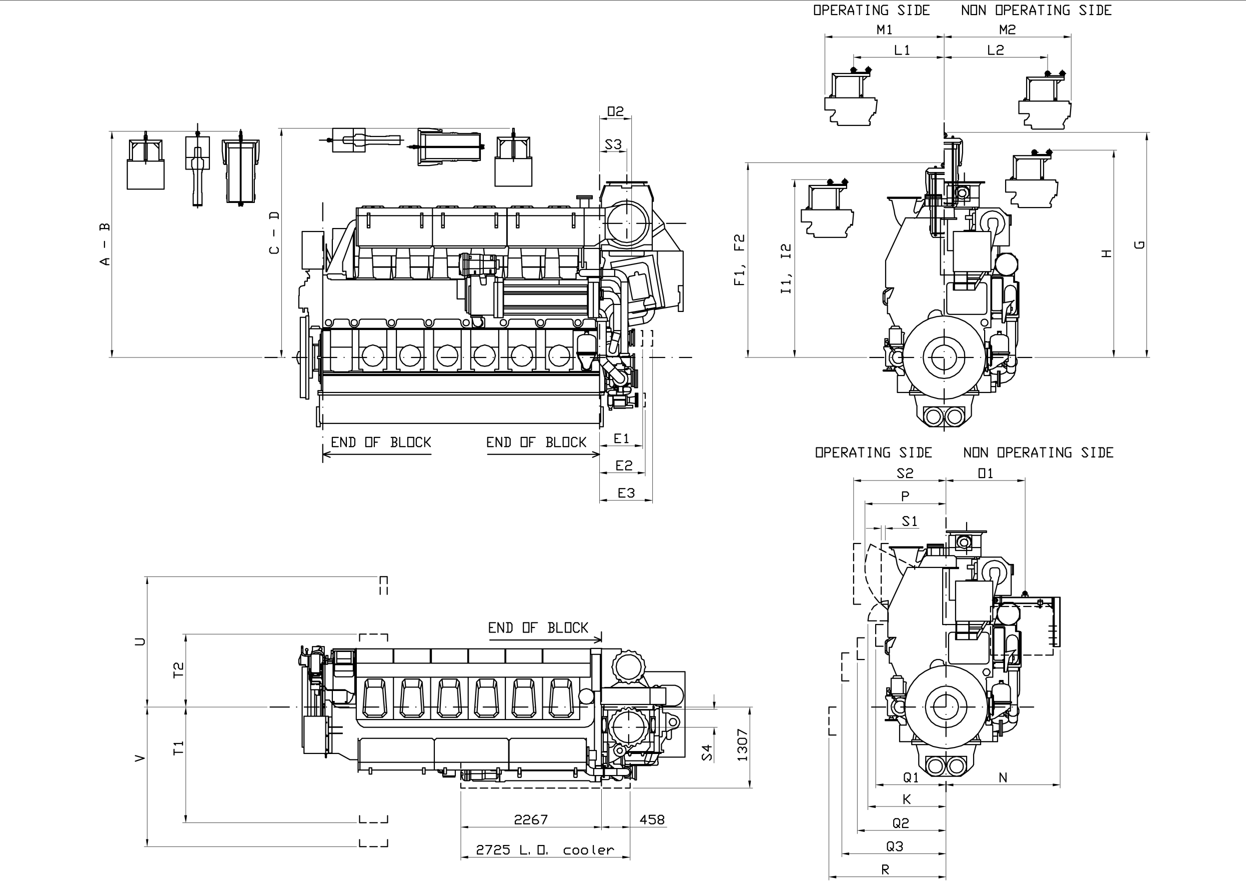


Figure 18.8 Service space requirements for In-line engines (DAAE029677b)

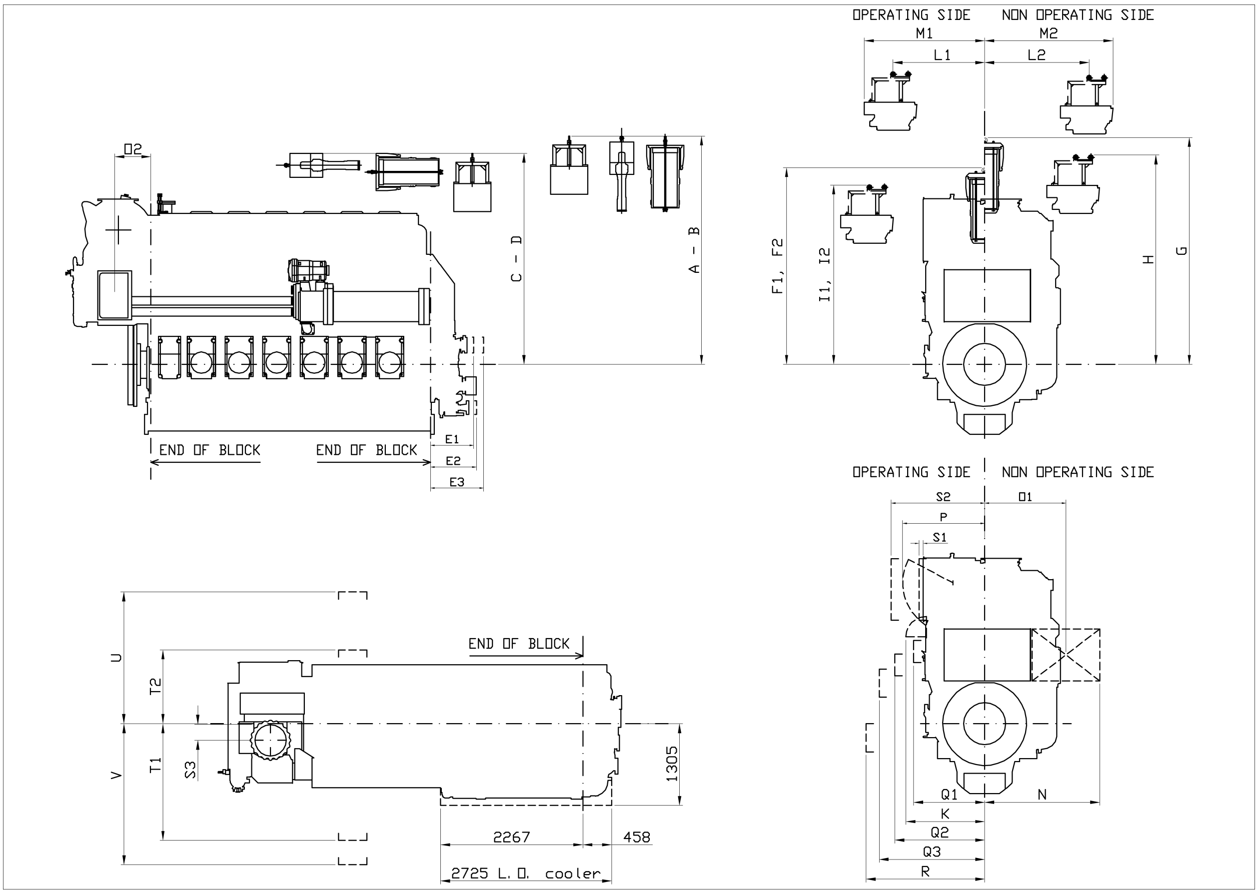


Table 18.1 Service space requirements for in-line engines

Dimensions [mm]:		6L	8L - 9L
A	Over cylinder head cover (vert. pos.)	3690	
B	Without cylinder head cover (vert. pos.)	3610	
C	Over cylinder head cover (hor. pos.)	3410	
D	Without cylinder head cover (hor. pos.)	3390	
E1	Dismounting space for HT Cooling water Pump	690	
E2	Dismounting space for Lubricating Oil Pump	733	
E3	Dismounting space for LT Cooling water Pump	850	
F1	Cyl. Liner towards engine operating side (over HP pipe, vert. pos.)	3140	
F2	Cyl. Liner towards engine operating side (HP pipes removed, vert. pos.)	2970	
G	Cyl. Liner towards non operating side (over insulation box, vert. pos.)	3620	
H	Cyl. Head towards non operating side (over insulation box, hor. pos.)	3340	
I1	Cyl. Head towards engine operating side (over HP pipe, hor. pos.)	2865	
I2	Cyl. Head towards engine operating side (HP pipe removed, hor. pos.)	2690	
K	Space required for stop lever	1255	
L1	Cyl head hook (operating side)	1460	
L2	Cyl head hook (non operating side)	1665	
M1	Maximum requested space for lowering cyl. head sideways (operating side)	1920	
M2	Maximum requested space for lowering cyl. head sideways (non operating side)	2045	
N	Dismounting space for charge air cooler (incl. tool)	1835	2045
O1	Recommended Charge Air Cooler lifting point	1270	1425
O2	Recommended Charge Air Cooler lifting point	513	666
P	Hot box covers opening	1330	

Dimensions [mm]:		6L	8L - 9L
Q1	Camshaft section (incl. tool)	1020	
Q2	Camshaft gearwheel (incl. tool)	1430	
Q3	Camshaft journal (incl. tool)	1680	
R	Intermediate gearwheel (incl. tool)	1690	
S1	TC Filter	120	140
S2	TC Cartridge	1320	1340
S3	Recommended TC lifting point	436	575
S4	Recommended TC lifting point	254	295
T1	Dismounting space for big end conn. rod, upper part (towards either side)	1335	
T2	Dismounting space for big end conn. rod, lower part (towards either side)	1175	
U	Dismounting space for side stud (to each side)	1345	
V	Dismounting space for main bearing cap (to either side)	2100	
Clearances for dismounting spaces are not considered; minimum recommended clearance 100 mm			

Figure 18.9 Service space requirements for V engines (DAAE029678b)

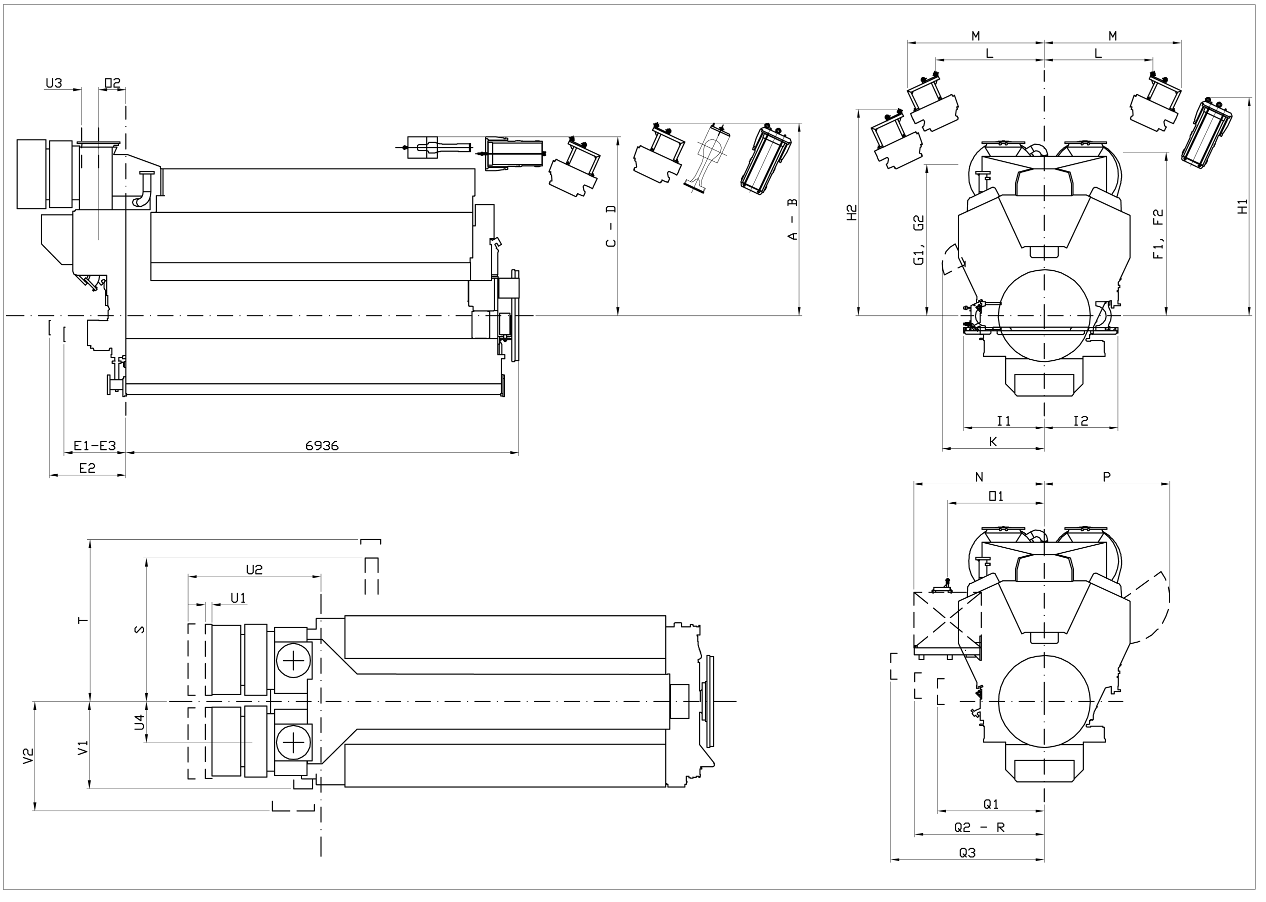


Figure 18.10 Service space requirements for V engines (DAAE033924a)

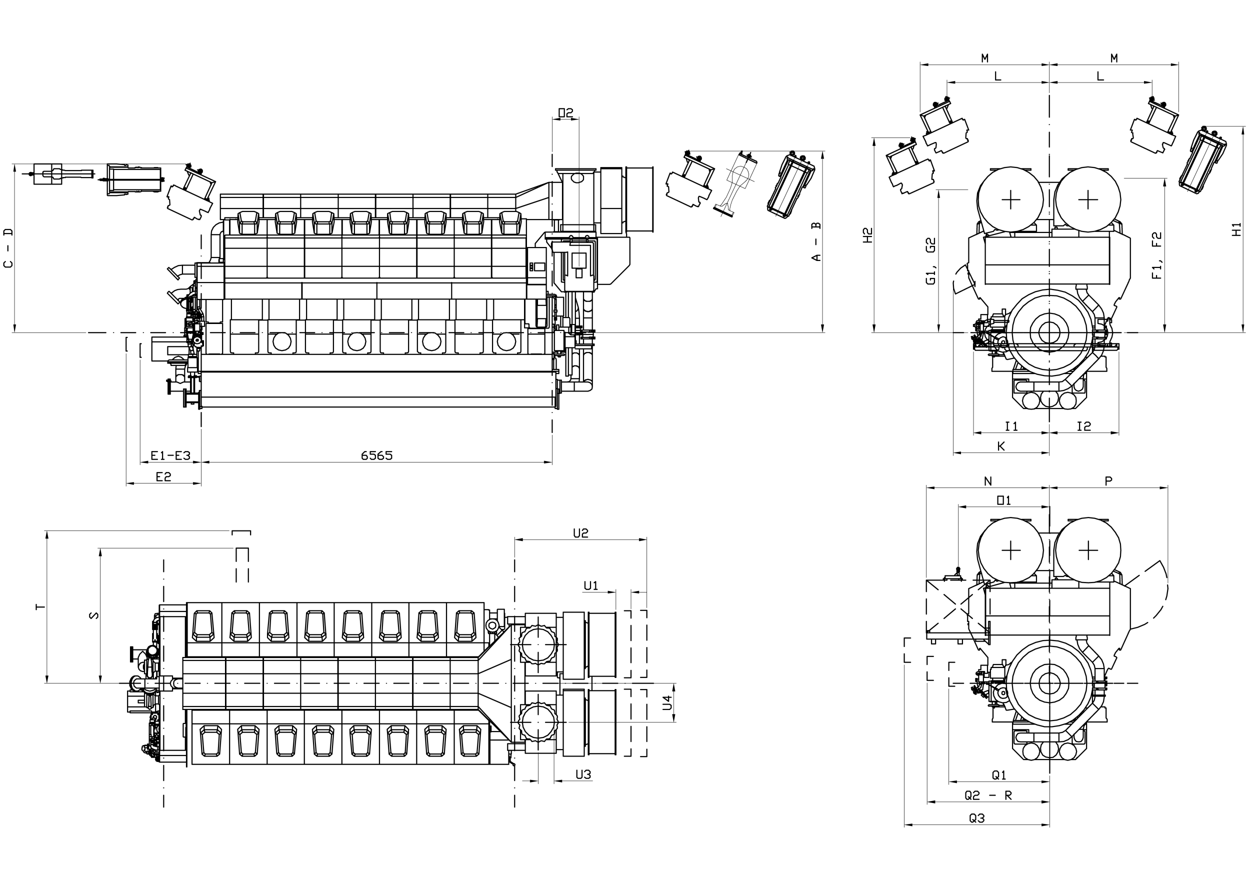


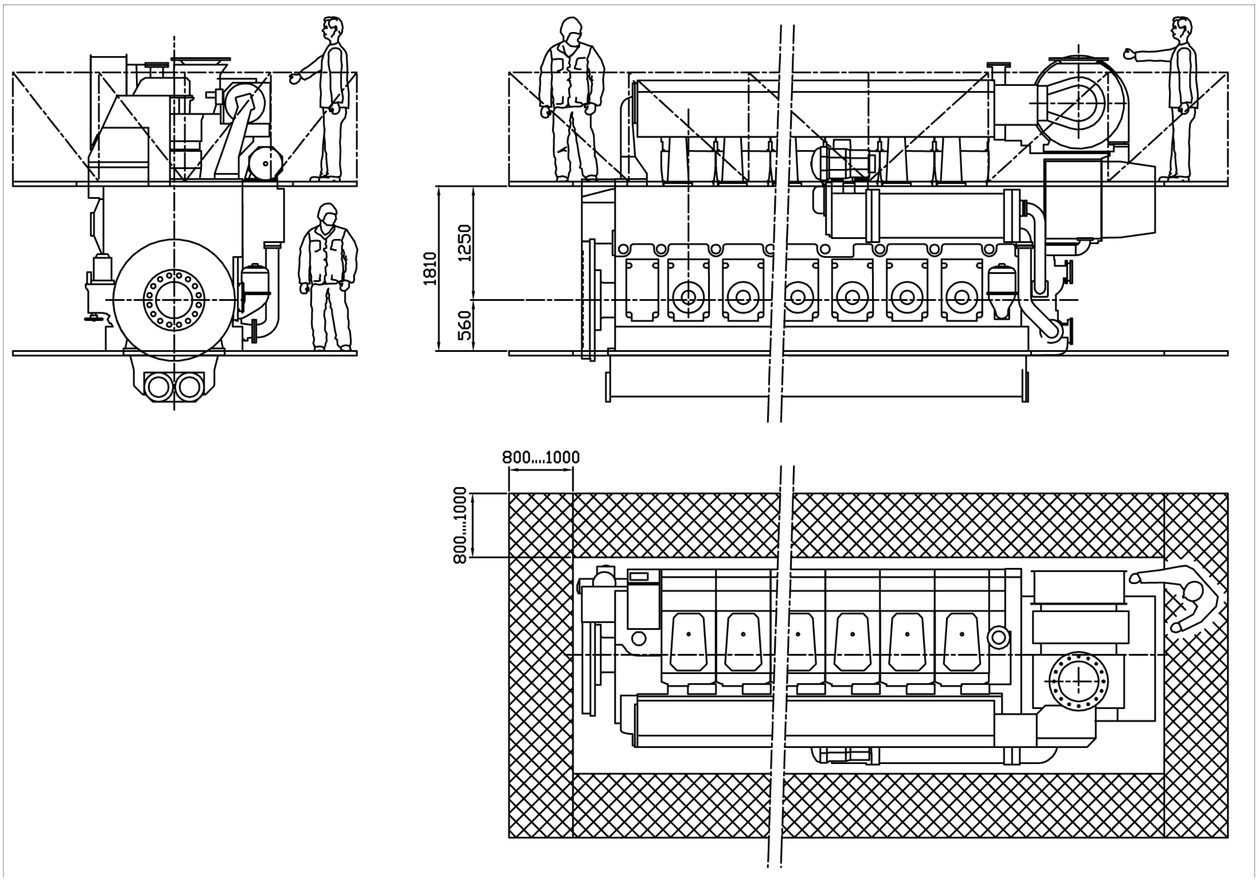
Table 18.2 Service space requirements for V engines

Dimensions [mm]:		12V	16V
A	Over cylinder head cover (vert. pos.)	3405	
B	Without cylinder head cover (vert. pos.)	3340	
C	Over cylinder head cover (hor. pos.)	3160	
D	Without cylinder head cover (hor. pos.)	3095	
E1	Dismounting space for HT Cooling water Pump	520	
E2	Dismounting space for Lubricating Oil Pump	810	
E3	Dismounting space for LT Cooling water Pump	520	
F1	Dismounting space for cylinder liner from both banks (over HP pipe, vert. pos.)	2885	
F2	Dismounting space for cylinder liner from both banks (HP pipes removed, vert. pos.)	2635	
G1	Dismounting space for cylinder head from both banks (over HP pipe, hor. pos.)	2675	
G2	Dismounting space for cylinder head from both banks (HP pipe removed, hor. pos.)	2425	
H1	Over insulation box, vert. pos.	3860	
H2	Over insulation box, hor. pos.	3650	
I1	Dismounting space for big end conn. rod, upper part (towards either side, out of engine block)	1425	
I2	Dismounting space for big end conn. rod, lower part (towards either side, out of engine block)	1300	
K	Space required for stop lever	1800	
L	Cylinder head hook (both side)	1920	
M	Maximum requested space for cyl. head side lowering (both side)	2420	
N	Dismounting space for charge air cooler incl. tool (both side)	2305	
O1	Recommended Charge Air Cooler lifting point	1710	
P	Hot box covers opening	2215	
Q1	Camshaft section incl. tool (both side)	1555	

Dimensions [mm]:		12V	16V
Q2	Camshaft gearwheel (incl. tool)	1975	
Q3	Camshaft journal incl. tool (both side)	2005	
R	Intermediate gearwheel incl. tool (both side)	1975	
S	Dismounting space for side stud (to each side, out of engine block)	1290	
T	Dismounting space for main bearing cap (to either side, out of engine block)	1450	
U1	TC filter (remmended +400 mm)	120	140
U2	TC cartridge	2120	2040
U3	Recommended lifting point for turbocharger	295	
U4	Recommended lifting point for turbocharger	724	
Clearances for dismounting spaces are not considered; minimum recommended clearance 100 mm			

18.5 Platforms

Figure 18.11 Maintenance platforms, in-line engine (DAAE057717)

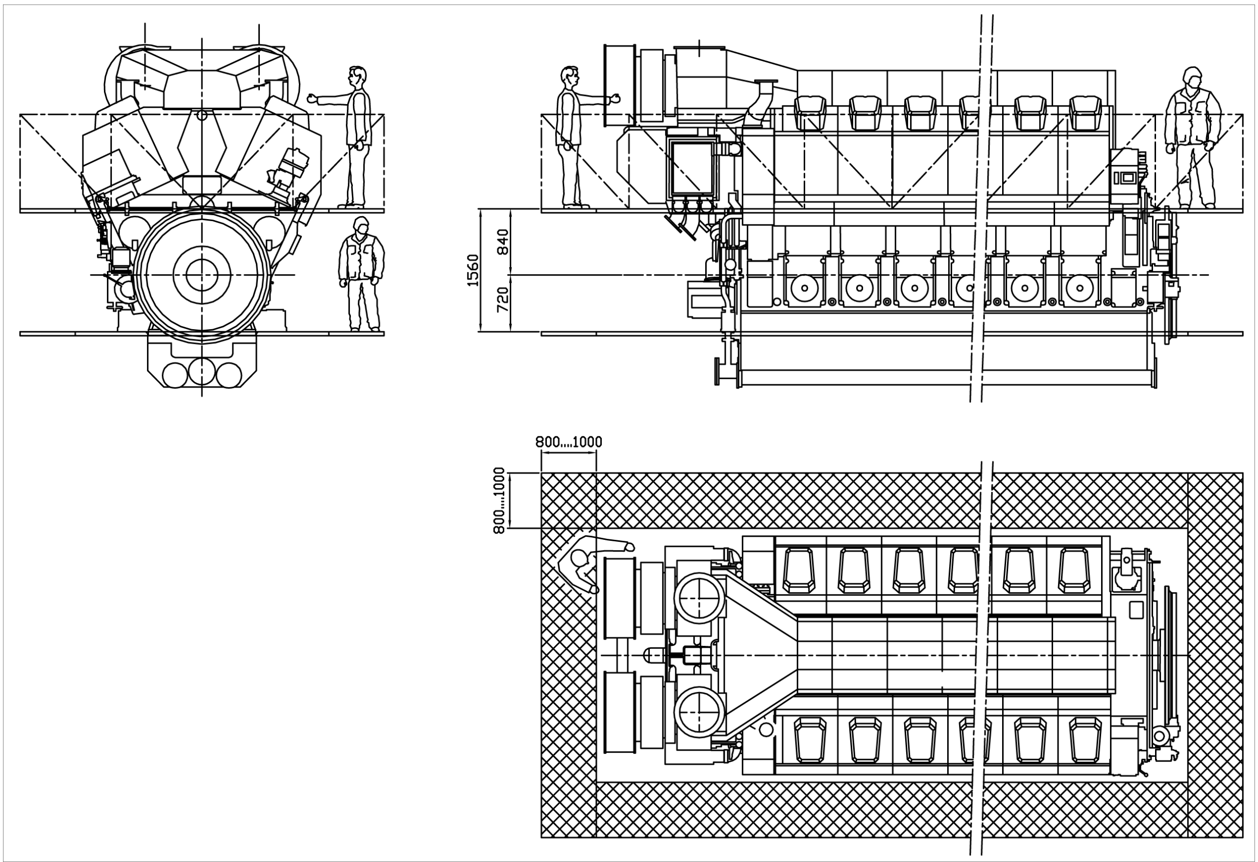


The upper platform should be removable for dismantling of the air cooler and for the maintenance crane to reach the lower level in front of the cranckcase doors.

Note!

- Platforms are not mounted on the engine.
- Sufficient distance should be kept between engine and platform (about 200 mm).

Figure 18.12 Maintenance platforms, V-engine (DAAE057719)



The upper platform should be removable for dismantling of the air cooler and for the maintenance crane to reach the lower level in front of the cranckcase doors.

Note!

- Platforms are not mounted on the engine.
- Sufficient distance should be kept between engine and platform (about 200 mm).

18.6 Engine room maintenance hatch

18.6.1 Engine room maintenance hatch, recommended minimum free opening for engine parts, charge air cooler and turbocharger.

Table 18.3 Recommended minimum free opening for engine parts, charge air cooler and turbocharger.

Engine type	Minimum size [m]
6L38	1.2 x 1.2
8L38	1.4 x 1.4
9L38	1.4 x 1.4
12V38	1.2 x 1.2
16V38	1.4 x 1.4

19. Transport dimensions and weights

Figure 19.1 Lifting of in-line engine (DAAE054668)

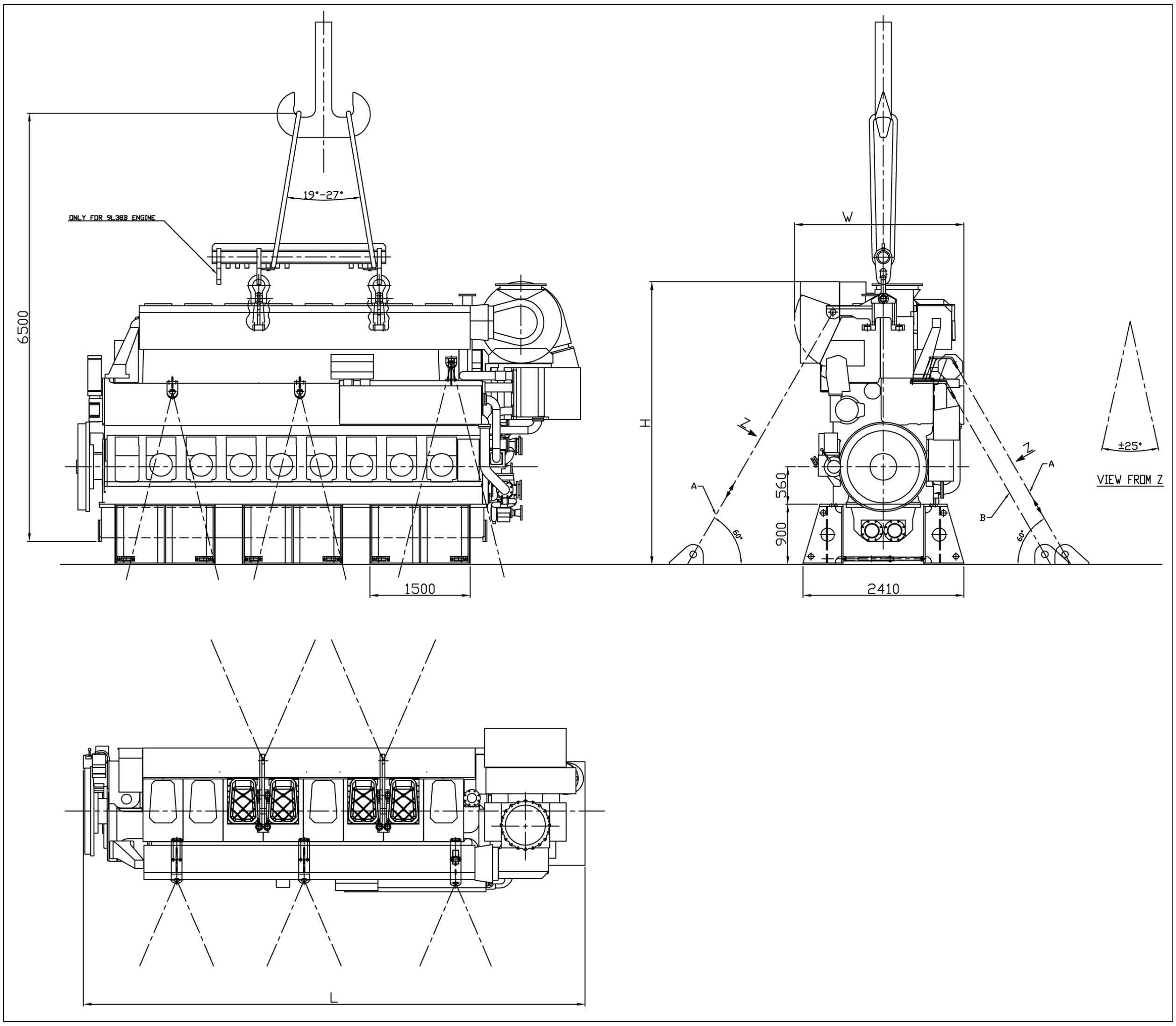


Table 19.1 Dimensions in-line engine

Engine type	T/C position	L [mm]	H [mm]	W [mm]	Weights [ton]			
					Engine	Flexible mounting	Support	Lifting tool
6L38	Free end	6220	4290	2190	51	4	0.7	0.5
6L38	Driving end	6345	4290	2190	51	4	0.7	0.5
8L38	Free end	7545	4230	2445	63	5.5	0.7	0.5
8L38	Driving end	7925	4280	2445	63	5.5	0.7	0.5
9L38	Free end	8145	4230	2445	72	6	0.7	0.5
9L38	Driving end	8525	4280	2445	72	6	0.7	0.5

Note: 5% tolerance on weights

Figure 19.2 Lifting of V-engine (DAAE054666)

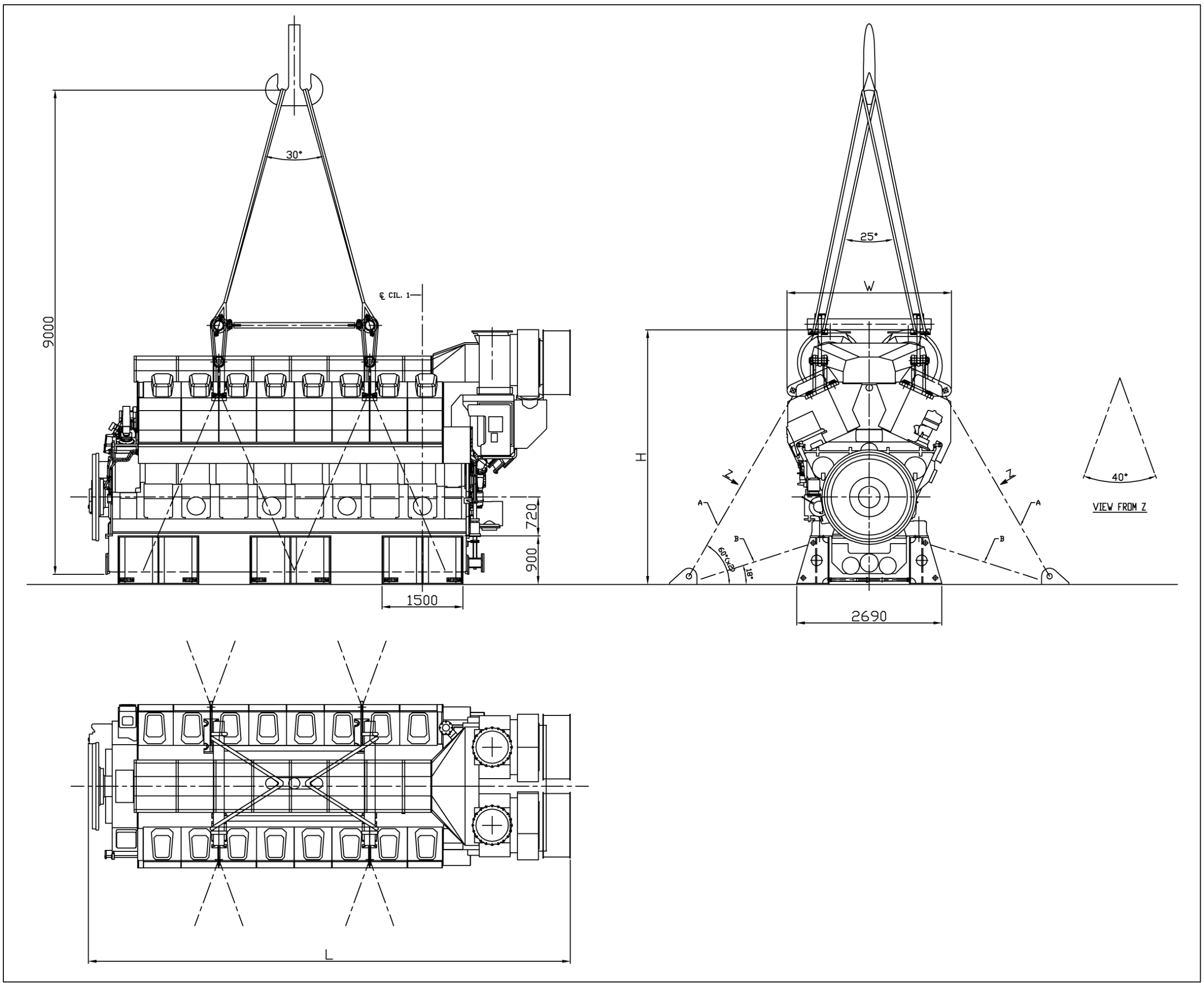


Table 19.2 Dimensions V-engine

Engine type	T/C position	L [mm]	H [mm]	W [mm]	Weights [ton]			
					Engine	Flexible mounting	Support	Lifting tool
12V38	Free end	7385	4550	3030	88	4	0.7	5.9
12V38	Driving end	7615	4550	3030	88	4	0.7	5.9
16V38	Free end	8945	4815	3030	110	4.5	0.7	5.9
16V38	Driving end	9130	4725	3030	110	4.5	0.7	5.9

Note: 5% tolerance on weights

19.1 Dimensions and weights of engine parts

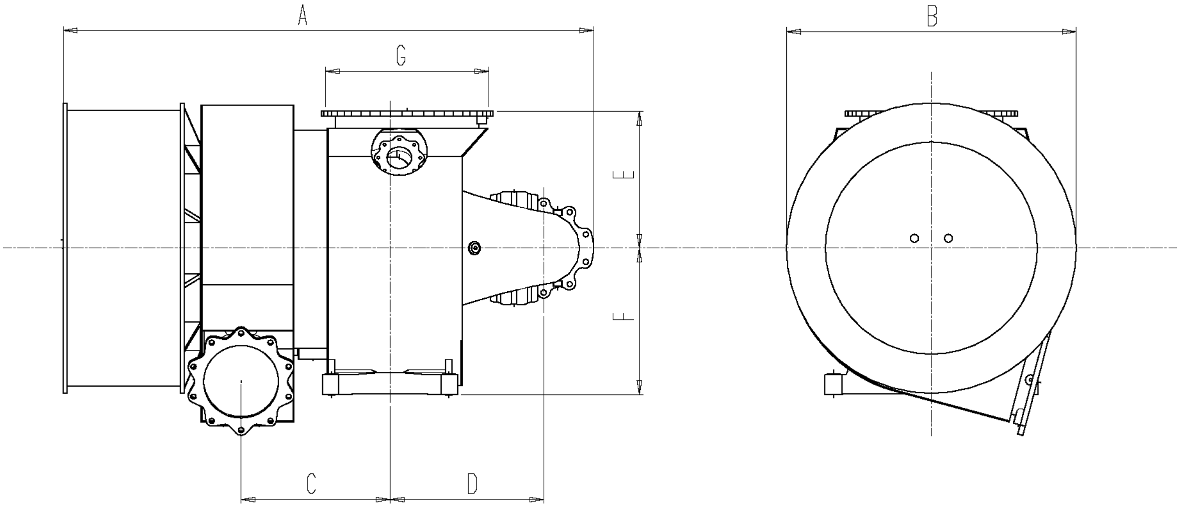


Figure 19.3 Turbocharger

Table 19.3 Dimensions turbocharger

Engine type	A [mm]	B [mm]	C [mm]	D [mm]	E [mm]	F [mm]	G [mm]	Mass T.C [kg]	Mass rotor block [kg]
6L38	1624	890	458	472	670	450	DN 500	1194	282
8L38	2246	1220	627	648	576	616	DN 600	2324	546
9L38	2246	1220	627	648	576	616	DN 600	2324	546
12V38	1574	1036	540	427	495	530	DN 500	1558	356
16V38	1875	1220	627	497	576	616	DN 600	2324	546

Note: For V-engines, the exhaust gas inlet is axial inlet instead of radial. For 8L FPP, T/C dimensions are equal to 12V.

Figure 19.4 Charge air cooler

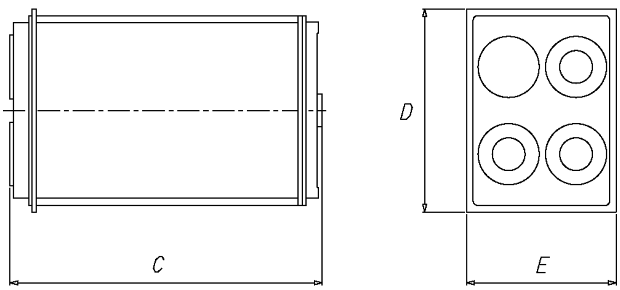
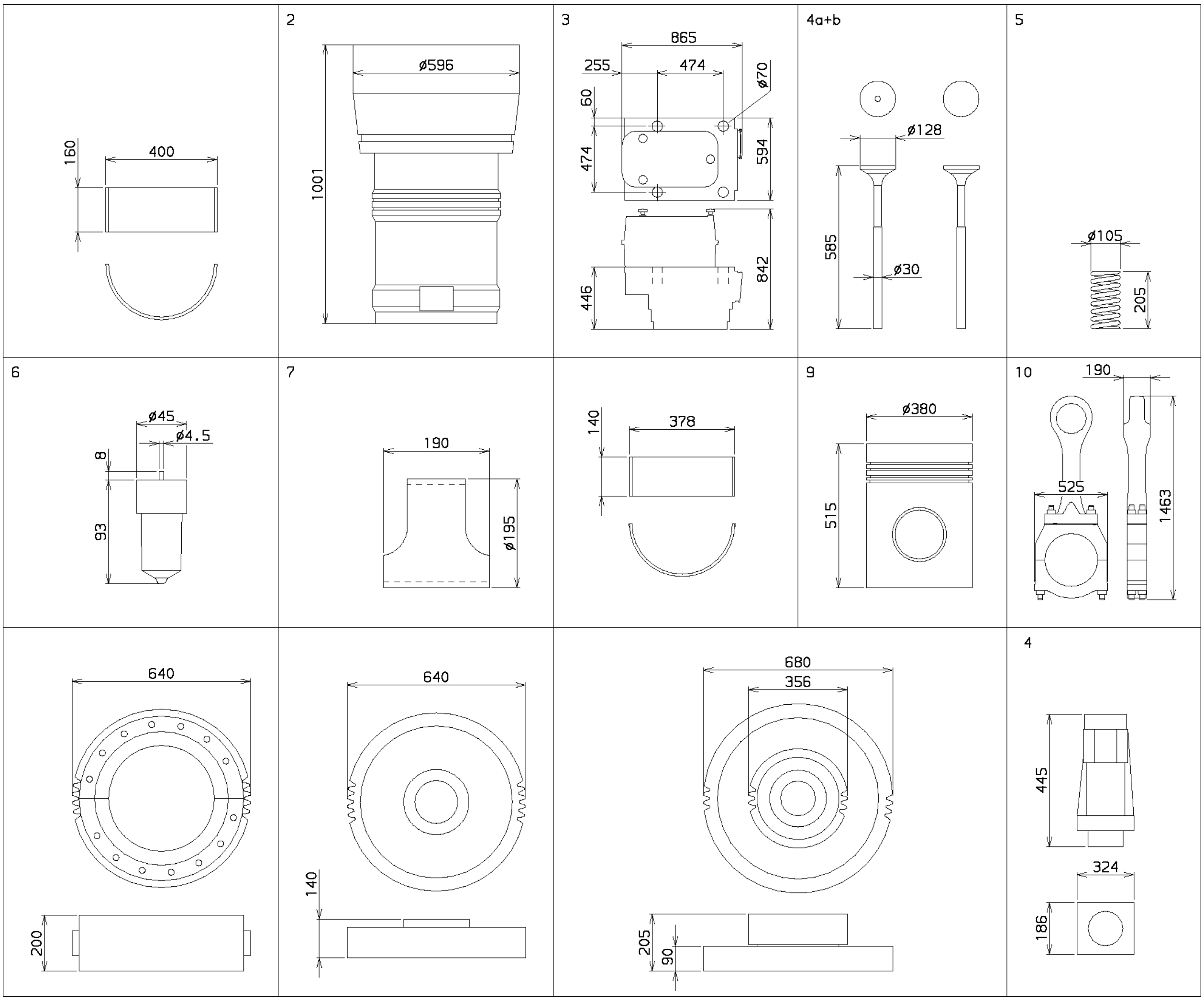


Table 19.4 Dimensions charge air cooler

Engine type	Amount	C [mm]	D [mm]	E [mm]	Mass [kg]
6L38	1	1010	850	610	600
8L38	1	1225	850	686	620
9L38	1	1225	850	686	620
12V38	2	1200	985	850	700
16V38	2	1200	985	850	750

Figure 19.5 Major spare parts (9604DT115d)



Note! Dimensions in [mm]

1)	Main bearing shell	7	kg	8)	Crank pin bearing shell	6	kg
2)	Cylinder liner	612	kg	9)	Piston + pin	190	kg
3)	Cylinder head	670	kg	10)	Connecting rod	305	kg
4a)	Inlet valve	6	kg	11)	Crankshaft gearwheel	219	kg
4b)	Outlet valve	6	kg	12)	Camshaft gearwheel	147	kg
5)	Valve spring in-out	3	kg	13a)	Intermediate gearwheel small	80	kg
6)	Fuel injector	1	kg	13b)	Intermediate gearwheel large	122	kg
7)	Piston pin bearing bush	6	kg	14)	Fuel pump	60	kg

20. Project guide attachments

This and other project guides can be accessed on the internet, from the Business Online Portal at www.wartsila.com. Project guides are available both in PDF and HTML 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 project guides on the Business Online Portal.

The attachments are not available in the printed version of the project guide.

21. ANNEX

21.1 Unit conversion tables

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

Table 21.1 Length conversion factors

Convert from	To	Multiply by
mm	in	0.0394
mm	ft	0.00328

Table 21.2 Mass conversion factors

Convert from	To	Multiply by
kg	lb	2.205
kg	oz	35.274

Table 21.3 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

Table 21.4 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

Table 21.5 Power conversion factors

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

Table 21.6 Moment of inertia and torque conversion factors

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

Table 21.7 Fuel consumption conversion factors

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

Table 21.8 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

Table 21.9 Temperature conversion factors

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

Table 21.10 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

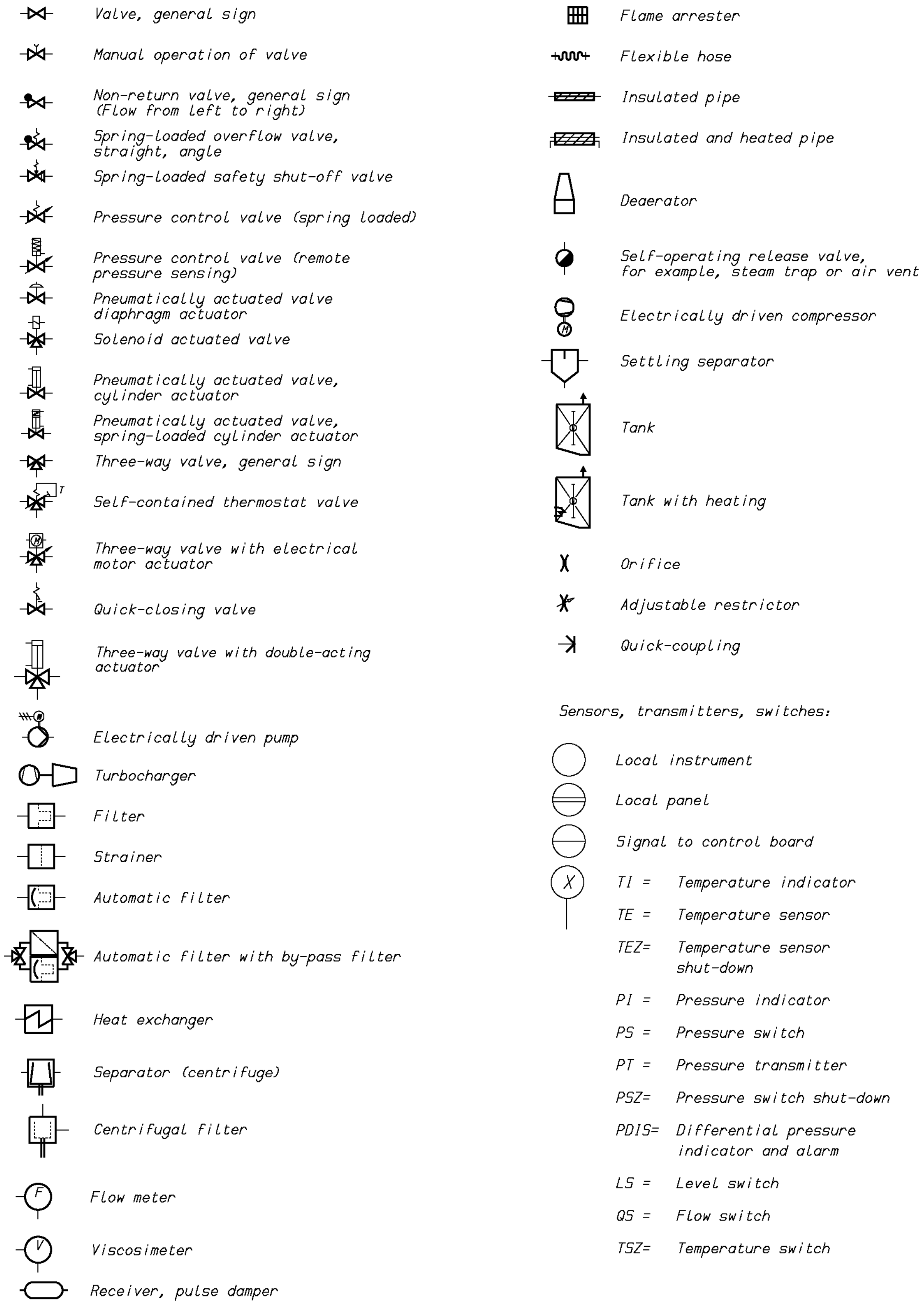
21.1.1 Prefix

Table 21.11 The most common prefix multipliers

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

21.2 Collection of drawing symbols used in drawings

Figure 21.1 List of symbols (DAAE000806c)



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