WÄRTSILÄ

WÄRTSILÄ 46

PROJECT GUIDE

Lib Version: a1395

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 3/2007 issue replaces all previous issues of the Wärtsilä 46 Project Guides.

Issue	Published	Updates
3/2007	12.3.2007	Chapter Exhaust emissions updated.
2/2007	20.2.2007	Minor changes in chapters Lubricating oil system and Turbocharger cleaning system, mass moments of inertia updated.
1/2007	18.1.2007	Sensors in internal system schemes updated, chapter Automation system updated.
2/2006	24.11.2006	Minor updates to chapters Fuel oil system and Cooling water system.
1/2006	17.11.2006	1155 kW/cyl output added, new chapter for common rail fuel injection, automation system chapter updated, numerous updates throughout the project guide.

Wärtsilä Ship Power

4-stroke, Business Support

Vaasa, March 2007

Table of Contents

1. General data and outputs

The Wärtsilä 46 is a 4-stroke, non-reversible, turbocharged and intercooled diesel engine with direct fuel injection.

Cylinder bore	460 mm
Stroke	580 mm
Piston displacement	96.4 l/cyl
Number of valves	2 inlet valves and 2 exhaust valves
Cylinder configuration	6, 8 and 9 in-line; 12, 16 and 18 in V-form
V-angle	45°
Direction of rotation	clockwise, counter-clockwise on request
Speed	500, 514 rpm
Mean piston speed	9.7, 9.9 m/s

1.1 Maximum continuous output

Table 1.1 Maximum continuous output at 500 rpm and 514 rpm

Engine type	975 kW/cyl		1050 kW/cyl		1155 kW/cyl	
	kW	hp	kW	hp	kW	hp
6L46	5 850	7 950	6 300	8 565	6 930	9 420
8L46	7 800	10 600	8 400	11 420	9 240	12 560
9L46	8 775	11 930	9 450	12 850	10 395	14 135
12V46	11 700	15 900	12 600	17 130	13 860	18 845
16V46	15 600	21 210	16 800	22 840	18 480	25 125
18V46 *	17 550	23 860	18 900	25 695	20 790	28 265

* 18V46 only for diesel-electric propulsion.

Nominal speed 500 rpm is recommended for mechanical propulsion engines.

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

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

where:

P_e = mean effective pressure [bar]

P = output per cylinder [kW]

n = engine speed [r/min]

D = cylinder diameter [mm]

L = length of piston stroke [mm]

c = operating cycle (4)

1.2 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 without engine driven pumps, operating in ambient conditions according to ISO 15550:2002 (E). The ISO standard reference conditions are:

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

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

1.3 Dimensions and weights

Figure 1.1 In-line engines (3V58E0537e)

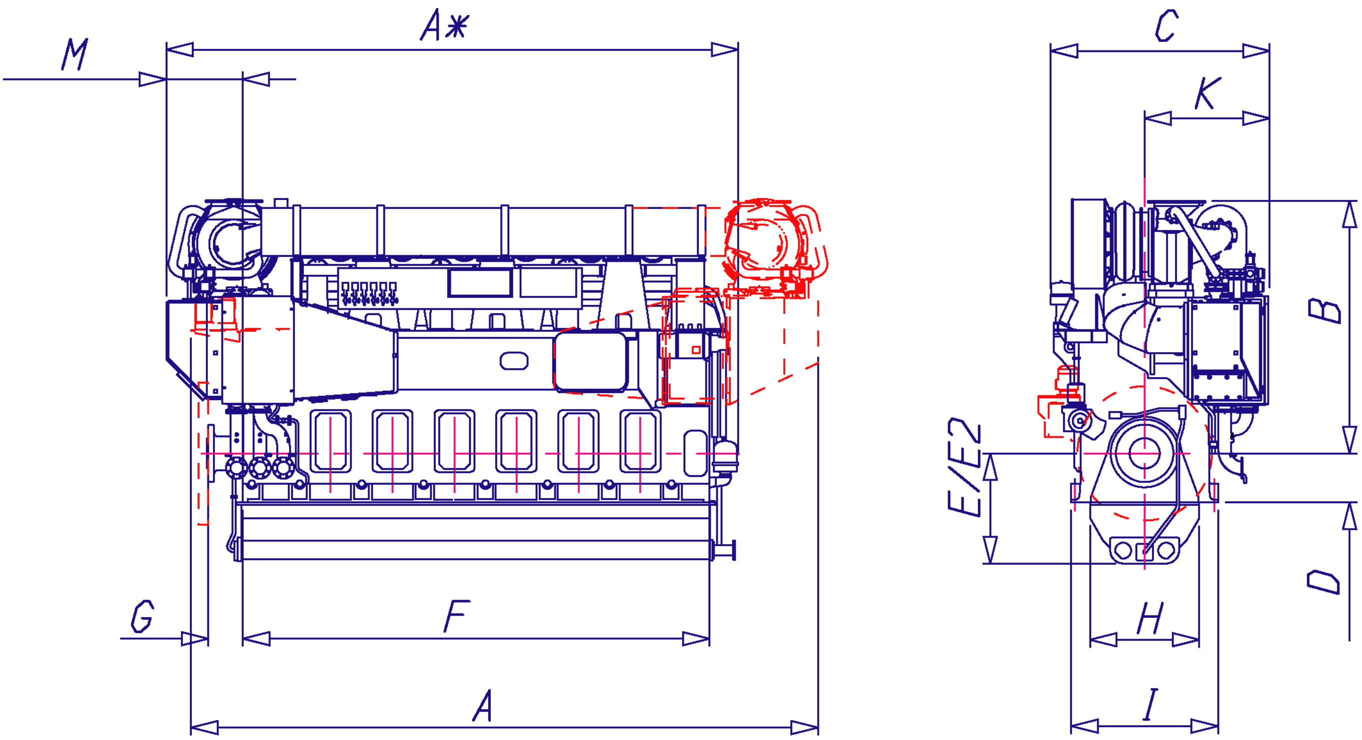


Table 1.2 Principal dimensions, in-line engines [mm]

Engine	kW/cyl	Turbo-charger	A*	A	B	C	D	E	E2	F	G	H	I	K	M	Weight [ton]
6L46	975 1050	NA 357	7820	8300	3680	2870	650	1460	1230	6170	460	1450	1940	1630	1010	93
	1155	TPL 73	7540	-	3350	2870	650	1460	1230	6170	460	1450	1940	1630	1010	94
8L46	975 1050	TPL 73	9390	10000	2950	2870	650	1460	1230	7810	460	1450	1940	1630	1280	116
	1155	TPL 77	9390	9930	3610	3270	650	1460	1230	7810	460	1450	1940	1870	1280	119
9L46	975 1050 1155	TPL 77	10250	10750	3610	3270	650	1460	1230	8630	460	1450	1940	1870	1280	133

* Turbocharger at flywheel end

For applications with restricted height a low sump can be specified (dimension E2 instead of E), however without hydraulic jacks under the main bearing caps.

Weights are dry weights (in metric tons) of rigidly mounted engines without flywheel and pumps.

Table 1.3 Additional weights [ton]:

Item	6L46	8L46	9L46
Flywheel	1...2	1...2	1...3
Resilient mounting parts on engine	4.4	5.1	5.5
Built-on pumps	2.0	2.0	2.0

Figure 1.2 V-engines (3V58E0538d)

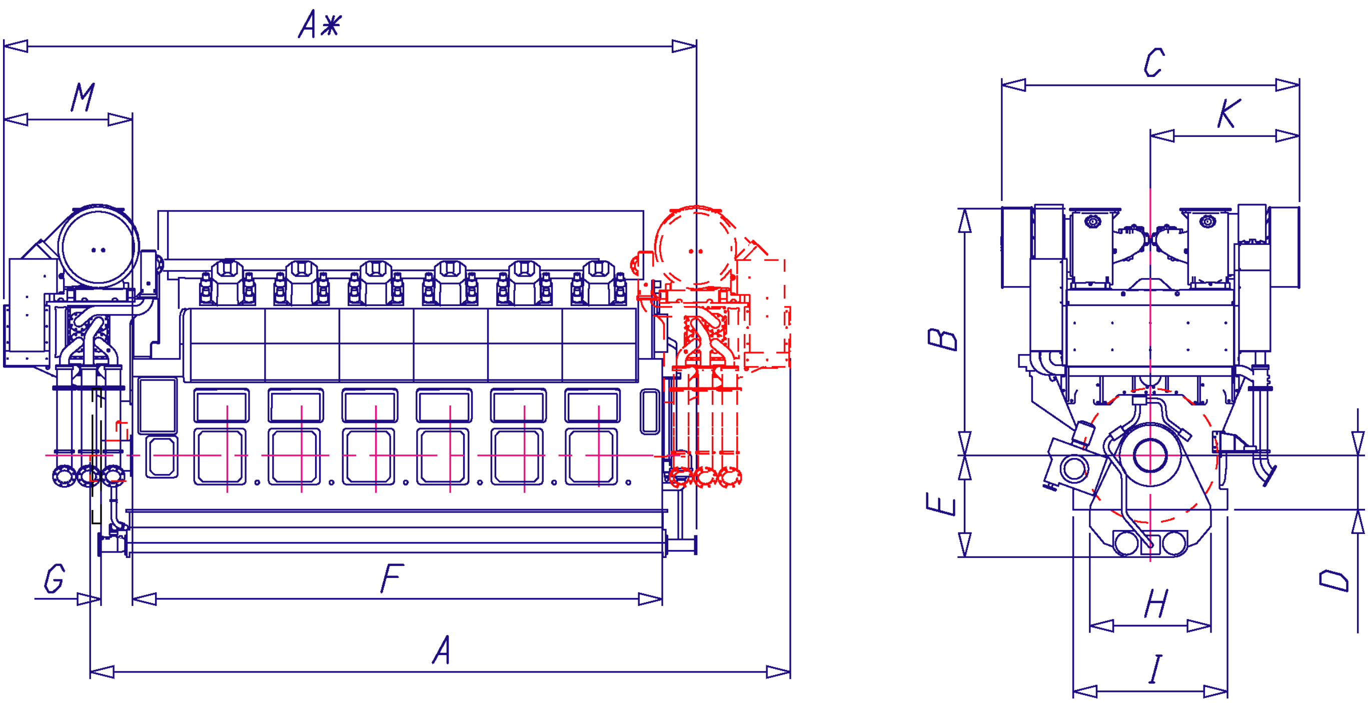


Table 1.4 Principal dimensions, V-engines [mm]

Engine	kW/cyl	Turbo-charger	A*	A	B	C	D	E	F	G	H	I	K	M	Weight [ton]
12V46	975 1050	NA 357	-	10320	4060	4520	800	1500	7850	460	1800	2290	2260	1900	170
	1155	TPL 73	10410	10260	3660	4540	800	1500	7850	460	1800	2290	2270	1900	172
16V46	975 1050	TPL 73	12460	-	3660	4420	800	1500	10050	460	1800	2290	2270	1900	217
	1155	TPL 77	-	12480	3990	5350	800	1500	10050	460	1800	2290	2680	1790	218
18V46	975 1050 1155	TPL 77	-	13670	3990	5350	800	1500	11150	460	1800	2290	2680	1790	241

* Turbocharger at flywheel end

Weights are dry weights (in metric tons) of rigidly mounted engines without flywheel and pumps.

Table 1.5 Additional weights [ton]:

Item	12V46	16V46	18V46
Flywheel	1...3	1...3	1...3
Resilient mounting parts on engine	5.6	6.9	7.7
Built-on pumps	2.4	2.4	2.4

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.

2.1.1 Controllable pitch propellers

Engines driving CP-propellers are commonly resiliently mounted, which restricts the available speed range. Inertia to be accelerated, clutch torque during engagement and directly driven pumps are other factors that may limit the speed range according to the diagrams, even though the engine is rigidly mounted.

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, 975 kW/cyl (DAAE041143)

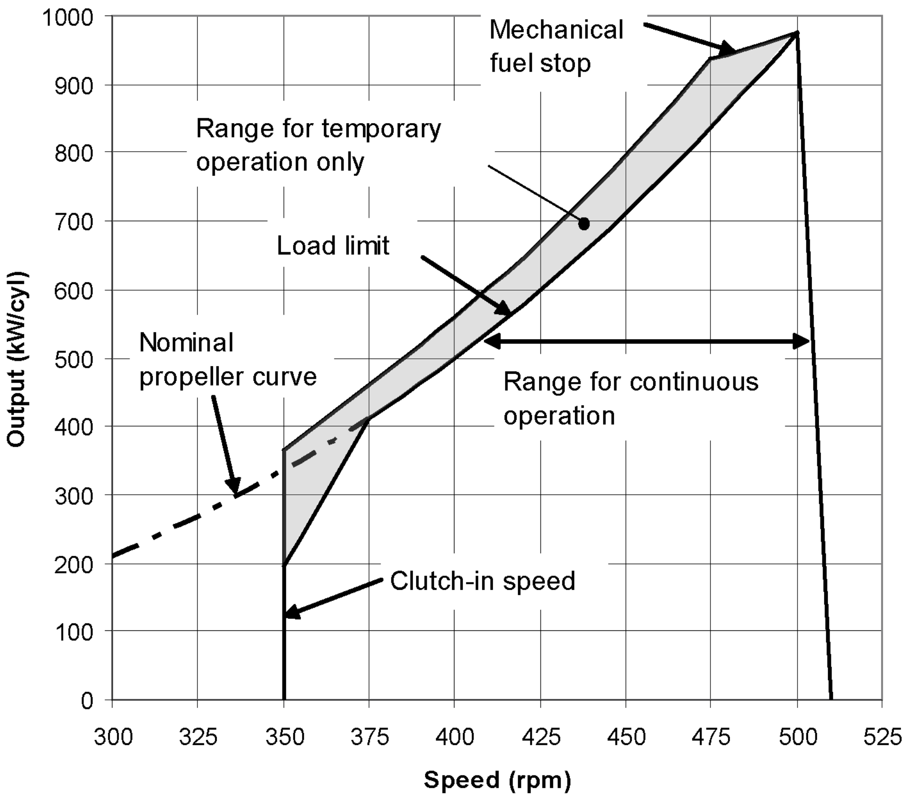


Figure 2.2 Operating field for CP-propeller, 1050 kW/cyl (DAAE041143)

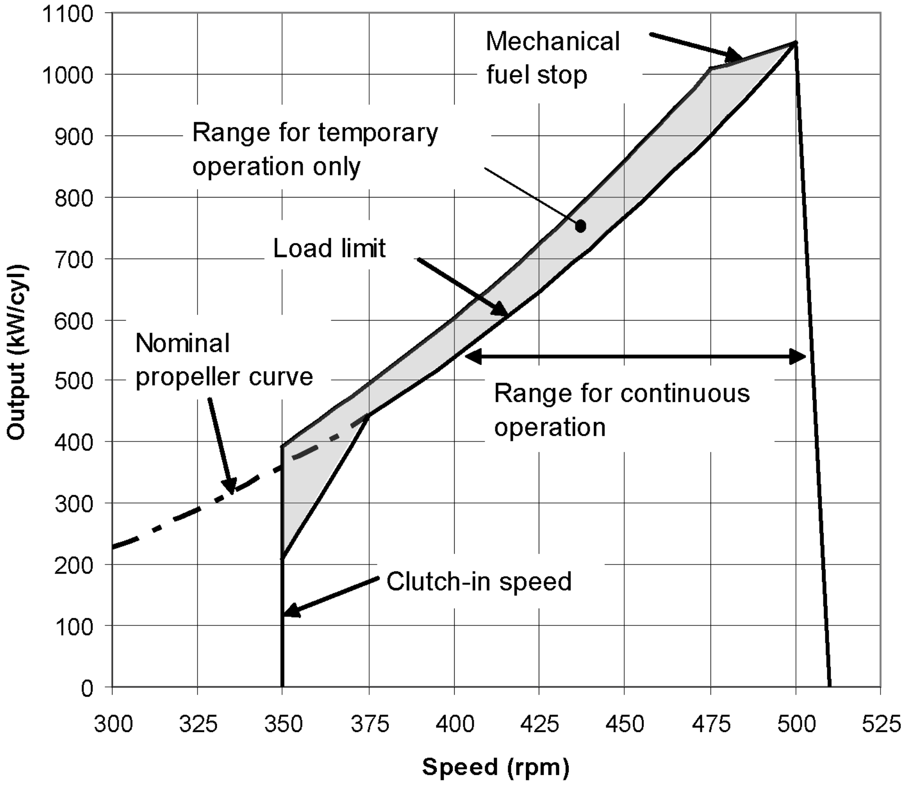
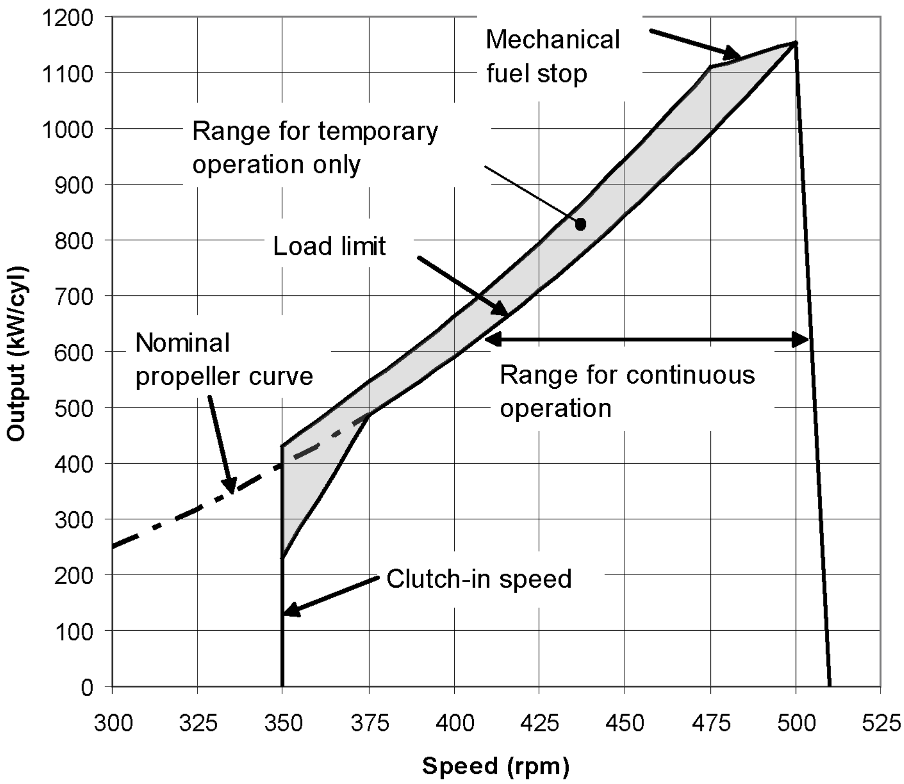


Figure 2.3 Operating field for CP-propeller, 1155 kW/cyl (DAAE041143)



2.1.2 Fixed pitch propellers

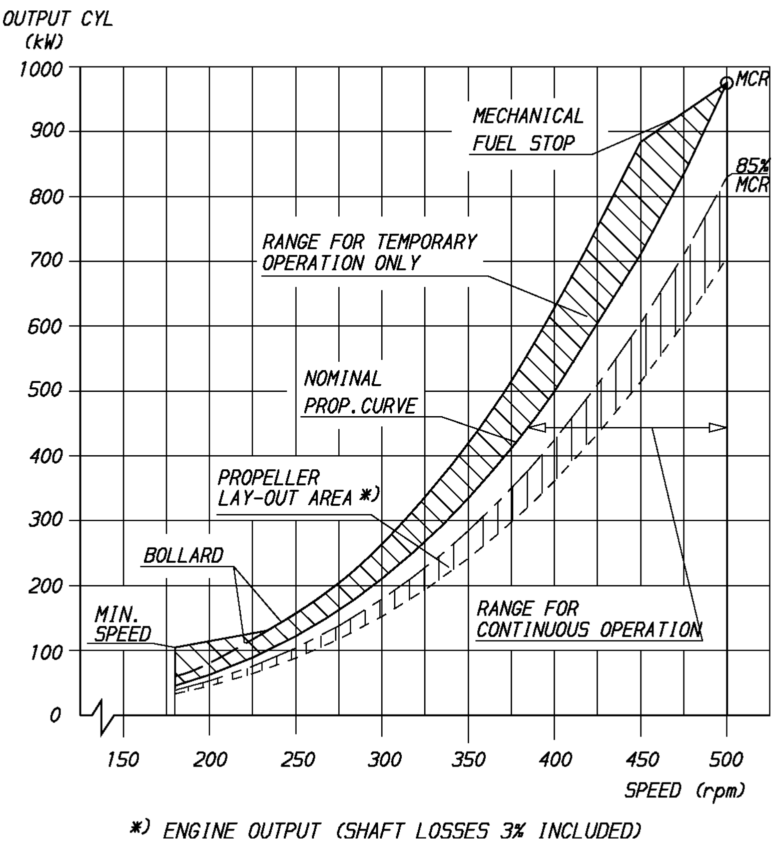
The thrust and power absorption of a given fixed pitch propeller is determined by the relation between ship speed and propeller revolution speed. The power absorption during acceleration, manoeuvring or towing is considerably higher than during free sailing for the same revolution speed. Increased ship 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 2.4 Operating field for FP-propeller, 975 kW/cyl (4V93L0757)



2.2 Loading capacity

2.2.1 Definitions and general requirements

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.

The load increase ramps presented in this document apply to all available outputs for Wärtsilä 46 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.

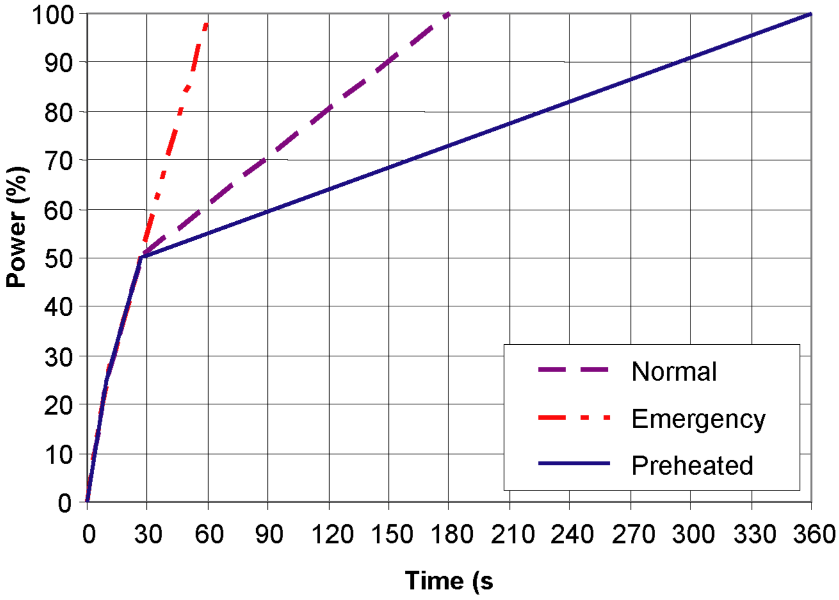
The ramp for normal loading applies to engines that have reached normal operating temperature.

Emergency loading may only be possible by activating an emergency load programme. The activation of this program should be indicated with a visual and audible alarm in the control room and on the command bridge.

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.

2.2.2 Mechanical propulsion, controllable pitch propeller (CPP)

Figure 2.5 Maximum recommended load increase rates for variable speed engines (DAAE041292)

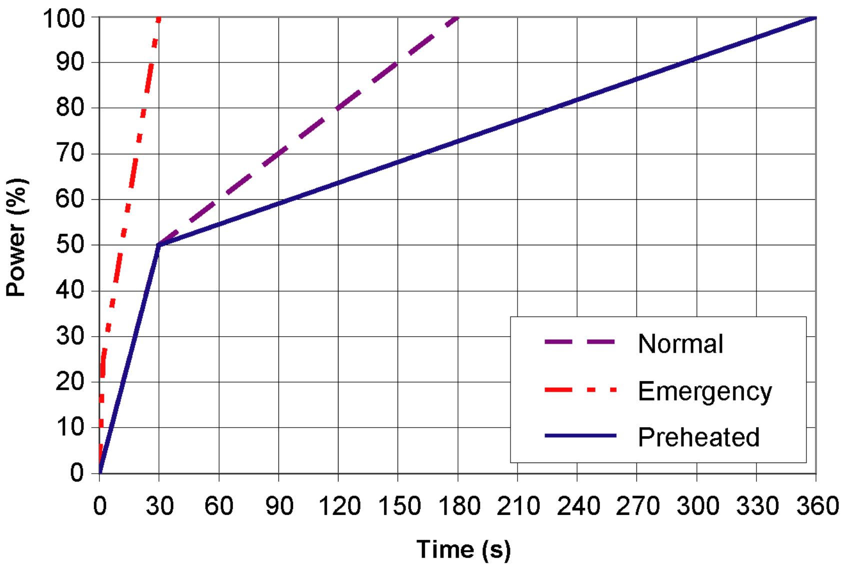


If minimum smoke during load increase is a major priority, slower loading rate than in the diagram can be necessary below 50% load.

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).

2.2.3 Diesel electric propulsion

Figure 2.6 Maximum recommended load increase rates for engines operating at nominal speed (DAAE041292)



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.

2.2.4 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

During prolonged low load operation in cold climate the two-stage charge air cooler is useful in heating the charge air by the HT-water. To prevent undercooling of the HT-water special provisions shall be made, e.g. by designing the preheating arrangement to heat the running engine. For operation at high load in cold climate the capacity of the wastegate arrangement is specified on a case-by-case basis.

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

2.4 Restrictions for low load operation and idling

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

Absolute idling (declutched main engine, unloaded generator):

- Max. 10 min. (recommended 3 - 5 min.), if the engine is to be stopped after the idling.
- Max. 6 hours, if the engine is to be loaded after the idling.

Operation at 5 - 20% load:

- Max. 100 hours' continuous operation. At intervals of 100 operating hours the engine must be loaded to min. 70% of the rated load.

Operation at higher than 20% load:

- No restrictions.

3. Technical data

3.1 Introduction

3.1.1 General

This chapter contains 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 “D-E”. The reason for this is that these engines are built to different specifications. Engines driving controllable-pitch propellers belong to the category “CPP” whether or not they have shaft generators (operated at constant speed).

The parameters of engines driving fixed-pitch propellers are as ”CPP”. However, all output stages and nominal speeds are not available for FPP-applications.

3.1.2 Ambient conditions

The basic heat balance (in the table) is given in the so-called ISO-conditions (25°C suction air and 25°C LT-water temperature). The heat balance is, however, affected by the ambient conditions. The effect of the charge air suction temperature can be seen in the figures below.

The recommended LT-water system is based on maintaining a constant charge air temperature to minimise condensate. The external cooling water system will maintain an engine inlet temperature close to 38°C. On part load, the LT-water thermostatic valve of the engine will by-pass a part of the LT-water to maintain the charge air temperature at a constant level. With this arrangement the heat balance in not affected by variations in the LT-water temperature.

Figure 3.1 Influence of suction air temperature

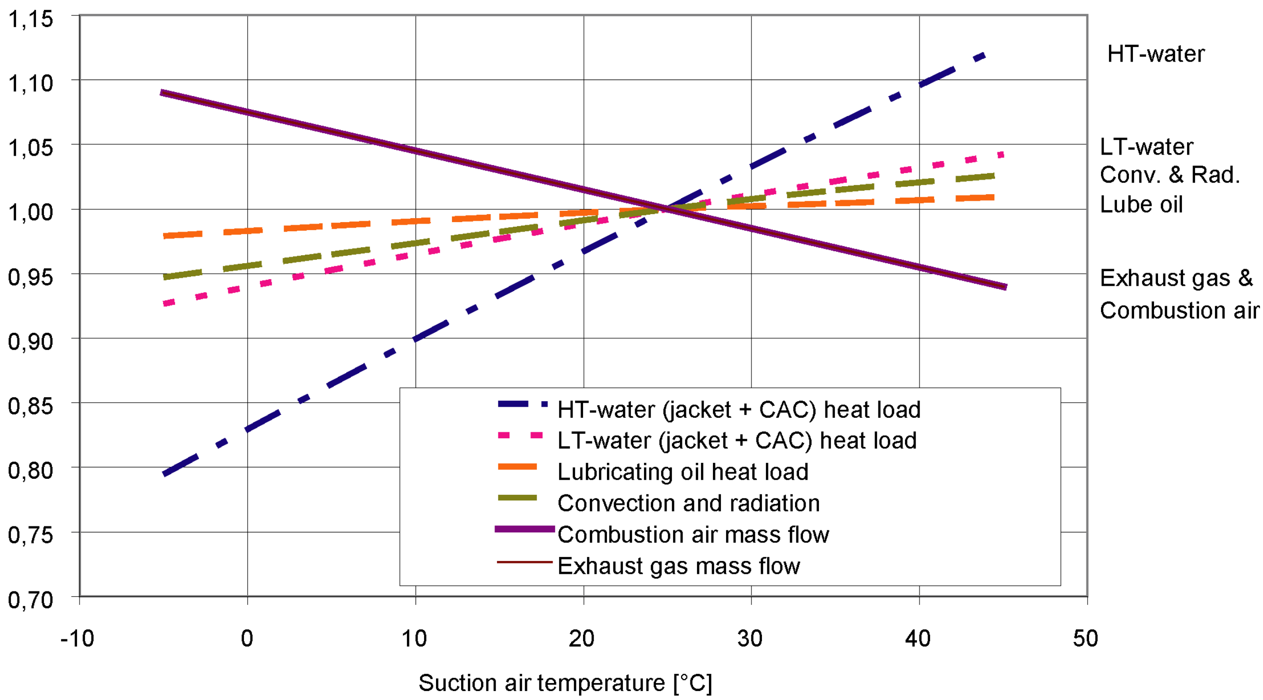
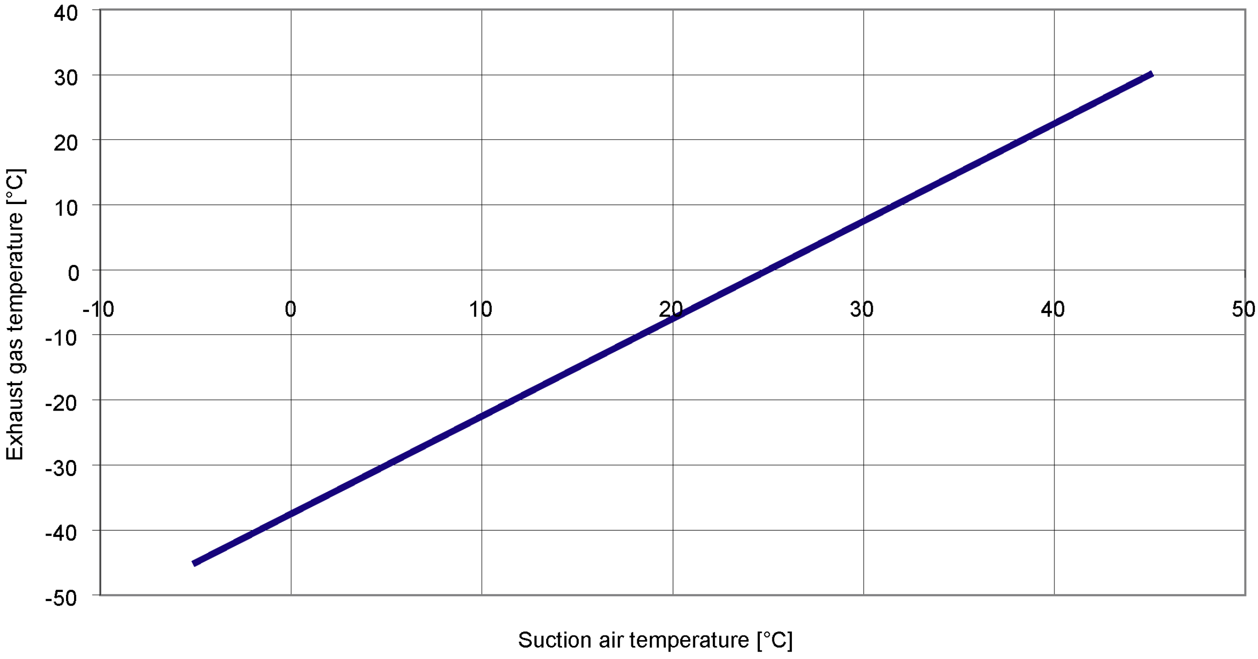


Figure 3.2 Influence of suction air temperature on exhaust gas temperature



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 an LT-water temperature of 38°C. Correction factors are obtained from the diagrams.

Example: The heat balance of a 6L46C engine (nominal speed 500 rpm, driving a CPP) in tropical conditions:

Table 3.1 Heat balance example

		Factor	ISO	Tropical
Suction air temperature	°C		25	45
HT-water total (jacket + CAC)	kW	1.13	1840	2073
Lubricating oil	kW	1.01	810	818
LT-water total (lubricating oil + CAC)	kW	1.04	1540	1605
Central cooler (HT+LT) total	kW	1.09	3380	3678
Convection and radiation	kW	1.03	240	247
Combustion air mass flow	kg/s	0.94	10.7	10.1
Exhaust gas mass flow	kg/s	0.94	11.0	10.3
Exhaust gas temperature	°C	+30	380	410

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 in ISO-conditions, representing average conditions reasonably well in many cases.

There are separate load-dependent exhaust gas and heat balance diagrams for variable speed engines operated at:

- Constant speed. This is a typical operating mode of a variable speed engine with a shaft generator.
- Variable speed. Operation along nominal propeller curve is assumed. If necessary, accurate figures when operating according to a combination curve can be obtained by interpolation from these two diagrams.

3.1.5 Engine driven pumps

The basic fuel consumption given in the technical data tables are without engine driven pumps. The increase in fuel consumption in g/kWh is given in the table below:

Table 3.2 Fuel consumption increase with engine driven pumps [g/kWh]

		Engine load [%]			
		50	**75**	**85**	**100**
Constant speed	Lubricating oil pump	4.0	3.0	2.5	2.0
	HT- & LT-pump total	2.0	1.6	1.3	1.0
Propeller law	Lubricating oil pump	2.0	2.0	2.0	2.0
	HT- & LT-pump total	1.0	1.0	1.0	1.0

3.2 Technical data tables

3.2.1 Wärtsilä 6L46

Wärtsilä 6L46		**ME**	**ME**	**DE**	**DE**	**ME**	**DE**	**DE**
Cylinder output	**kW**	**975**	**1050**	**1050**	**1050**	**1155**	**1155**	**1155**
Engine speed	**rpm**	**500**	**500**	**500**	**514**	**500**	**500**	**514**
Engine output	kW	5850	6300	6300	6300	6930	6930	6930
Mean effective pressure	MPa	2.43	2.61	2.61	2.54	2.88	2.88	2.8
Combustion air system (Note 1)								
Flow at 100% load	kg/s	10.3	10.7	10.7	10.9	12.2	12.2	12.4
Temperature at turbocharger intake, max.	°C	45	45	45	45	45	45	45
Temperature after air cooler (TE 601)	°C	40...70	40...70	40...70	40...70	40...70	40...70	40...70
Exhaust gas system (Note 2)								
Flow at 100% load	kg/s	10.6	11.0	11.0	11.2	12.5	12.5	12.7
Flow at 85% load	kg/s	9.1	10.1	10.3	10.5	11.5	11.7	11.9
Flow at 75% load	kg/s	7.7	8.6	9.5	9.7	10.0	10.9	11.1
Flow at 50% load	kg/s	5.2	5.5	6.8	7.0	6.5	9.0	9.2
Temp. after turbo, 100% load (TE 517)	°C	380	380	380	375	390	390	375
Temp. after turbo, 85% load (TE 517)	°C	320	315	310	305	320	315	310
Temp. after turbo, 75% load (TE 517)	°C	340	330	305	300	320	315	310
Temp. after turbo, 50% load, BP open (TE 517)	°C	395	380	320	315	360	280	275
Backpressure, max.	kPa	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pipe diameter, min.	mm	900	900	900	900	900	900	900
Calculated pipe diameter for 35 m/s	mm	842	858	858	863	922	922	918
Heat balance at 100% load (Note 3)								
Jacket water, HT-circuit	kW	630	650	650	650	700	700	700
Charge air, HT-circuit	kW	1000	1190	1190	1190	1425	1425	1425
Charge air, LT-circuit	kW	660	730	730	730	825	825	825
Lubricating oil, LT-circuit	kW	770	810	810	810	850	850	850
Radiation	kW	170	180	180	180	190	190	190
Fuel system (Note 4)								
Pressure before injection pumps (PT 101)	kPa	800...1000	800...1000	800...1000	800...1000	800...1000	800...1000	800...1000
Fuel flow to engine, approx.	m^3/h	4.6	5.0	5.0	5.0	5.7	5.7	5.7
HFO viscosity before engine	cSt	20...24	20...24	20...24	20...24	20...24	20...24	20...24
MDF viscosity, min.	cSt	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Max. HFO temperature before engine (TE 101)	°C	135	135	135	135	135	135	135
Clean leak fuel quantity, HFO at 100% load	kg/h	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Clean leak fuel quantity, MDF at 100% load	kg/h	22.5	22.5	22.5	22.5	22.5	22.5	22.5
Fuel consumption at 100% load	g/kWh	175	176	176	176	183	183	183
Fuel consumption at 85% load	g/kWh	170	170	172	172	178	179	179
Fuel consumption at 75% load	g/kWh	170	170	172	172	178	180	180
Fuel consumption at 50% load	g/kWh	175	174	176	176	182	188	188
Lubricating oil system								
Pressure before bearings, nom. (PT 201)	kPa	400	400	400	400	400	400	400
Pressure after pump, max.	kPa	800	800	800	800	800	800	800
Suction ability, including pipe loss, max.	kPa	40	40	40	40	40	40	40
Priming pressure, nom. (PT 201)	kPa	80	80	80	80	80	80	80
Temperature before bearings, nom. (TE 201)	°C	63	63	63	63	63	63	63
Temperature after engine, approx.	°C	78	78	78	78	78	78	78
Pump capacity (main), engine driven	m^3/h	157	157	149	153	157	149	153
Pump capacity (main), electrically driven	m^3/h	140	140	140	145	140	140	145
Oil flow through engine	m^3/h	120	120	120	120	120	120	120
Priming pump capacity	m^3/h	34	34	34	34	34	34	34
Oil volume in separate system oil tank	m^3	7.9	8.5	8.5	8.5	9.4	9.4	9.4
Oil consumption at 100% load	g/kWh	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Crankcase ventilation flow rate at full load	l/min	1300	1300	1300	1300	1300	1300	1300
Crankcase ventilation backpressure, max.	Pa	200	200	200	200	200	200	200
Oil volume in turning device	l	8.5...9.5	8.5...9.5	8.5...9.5	8.5...9.5	8.5...9.5	8.5...9.5	8.5...9.5
Oil volume in speed governor	l	1.9	1.9	1.9	1.9	1.9	1.9	1.9
High temperature cooling water system								
Pressure at engine, after pump, nom. (PT 401)	kPa	250 + static	250 + static	250 + static	250 + static	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 401)	kPa	480	480	480	480	480	480	480
Temperature before cylinders, approx. (TE 401)	°C	74	74	74	74	74	74	74

Wärtsilä 6L46		ME	ME	DE	DE	ME	DE	DE
Cylinder output	kW	975	1050	1050	1050	1155	1155	1155
Engine speed	rpm	500	500	500	514	500	500	514
Temperature after cylinders, approx. (TE 402)	°C	82	82	82	82	82	82	82
Temperature after charge air cooler, nom.	°C	91	91	91	91	91	91	91
Capacity of engine driven pump, nom.	m^3/h	135	135	135	135	135	135	135
Pressure drop over engine, total	kPa	70	70	70	70	70	70	70
Pressure drop in external system, max.	kPa	150	150	150	150	150	150	150
Pressure from expansion tank	kPa	70...150	70...150	70...150	70...150	70...150	70...150	70...150
Water volume in engine	m^3	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Low temperature cooling water system								
Pressure at engine, after pump, nom. (PT 451)	kPa	250	250	250	250	250	250	250
Pressure at engine, after pump, max. (PT 451)	kPa	440	440	440	440	440	440	440
Temperature before engine, max. (TE 451)	°C	38	38	38	38	38	38	38
Temperature before engine, min. (TE 451)	°C	25	25	25	25	25	25	25
Capacity of engine driven pump, nom.	m^3/h	135	135	135	135	135	135	135
Pressure drop over charge air cooler	kPa	30	30	30	30	30	30	30
Pressure drop in external system, max.	kPa	200	200	200	200	200	200	200
Pressure from expansion tank	kPa	70 ... 150	70 ... 150	70 ... 150	70 ... 150	70 ... 150	70 ... 150	70 ... 150
Starting air system								
Pressure, nom.	kPa	3000	3000	3000	3000	3000	3000	3000
Pressure at engine during start, min. (20°C)	kPa	1000	1000	1000	1000	1000	1000	1000
Pressure, max.	kPa	3000	3000	3000	3000	3000	3000	3000
Low pressure limit in air vessels	kPa	1800	1800	1800	1800	1800	1800	1800
Consumption per start at 20°C (manual)	Nm^3	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Consumption per start at 20°C, (with slowturn)	Nm^3	4.3	4.3	4.3	4.3	4.3	4.3	4.3

COMMON RAIL								
Fuel oil system								
Fuel flow to engine, approx.	m^3/h	3.5	3.7	3.7	3.7	4.3	4.3	4.3
MDF viscosity, min.	cSt	2	2	2	2	2	2	2
Clean leak fuel quantity, HFO at 100% load	kg/h	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Clean leak fuel quantity, MDF at 100% load	kg/h	11.3	11.3	11.3	11.3	11.3	11.3	11.3
Clean leak fuel quantity at stop, max.	l	11	11	11	11	11	11	11
Lubricating oil system								
Control oil flow, steady	l/min	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Control oil flow, max. momentary	l/min	110	110	110	110	110	110	110
Starting air system								
Consumption per start at 20°C (manual)	Nm^3	5.4	5.4	5.4	5.4	5.4	5.4	5.4
Consumption per start at 20°C, (with slowturn)	Nm^3	6.1	6.1	6.1	6.1	6.1	6.1	6.1

Notes:

Note 1 At ISO 3046-1 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Tolerance 5%.

Note 2 At ISO 3046-1 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 5% and temperature tolerance 15°C.

Note 3 At ISO3046-1 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Tolerance for cooling water heat 10%, tolerance for radiation heat 30%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers.

Note 4 According to ISO 3046/1, lower calorific value 42 700 kJ/kg, without engine driven pumps. Tolerance 5%. Load according to propeller law for mechanical propulsion engines (ME).

Subject to revision without notice.

3.2.2 Wärtsilä 8L46

Wärtsilä 8L46		ME	ME	DE	DE	ME	DE	DE
Cylinder output	**kW**	**975**	**1050**	**1050**	**1050**	**1155**	**1155**	**1155**
Engine speed	**rpm**	**500**	**500**	**500**	**514**	**500**	**500**	**514**
Engine output	kW	7800	8400	8400	8400	9240	9240	9240
Mean effective pressure	MPa	2.43	2.61	2.61	2.54	2.88	2.88	2.8
Combustion air system (Note 1)								
Flow at 100% load	kg/s	13.7	14.3	14.3	14.5	16.3	16.3	16.5
Temperature at turbocharger intake, max.	°C	45	45	45	45	45	45	45
Temperature after air cooler (TE 601)	°C	40...70	40...70	40...70	40...70	40...70	40...70	40...70
Exhaust gas system (Note 2)								
Flow at 100% load	kg/s	14.1	14.7	14.7	14.9	16.7	16.7	16.9
Flow at 85% load	kg/s	12.1	13.5	13.7	14.0	15.3	15.6	15.9
Flow at 75% load	kg/s	10.3	11.5	12.7	12.9	13.3	14.5	14.8
Flow at 50% load	kg/s	6.9	7.3	9.1	9.3	8.7	12.0	12.3
Temp. after turbo, 100% load (TE 517)	°C	380	380	380	375	390	390	375
Temp. after turbo, 85% load (TE 517)	°C	320	315	310	305	320	315	310
Temp. after turbo, 75% load (TE 517)	°C	340	330	305	300	320	315	310
Temp. after turbo, 50% load, BP open (TE 517)	°C	395	380	320	315	360	280	275
Backpressure, max.	kPa	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pipe diameter, min.	mm	1000	1000	1000	1000	1000	1000	1000
Calculated pipe diameter for 35 m/s	mm	971	992	992	995	1065	1065	1059
Heat balance at 100% load (Note 3)								
Jacket water, HT-circuit	kW	840	867	867	867	933	933	933
Charge air, HT-circuit	kW	1333	1587	1587	1587	1900	1900	1900
Charge air, LT-circuit	kW	880	973	973	973	1100	1100	1100
Lubricating oil, LT-circuit	kW	1027	1080	1080	1080	1133	1133	1133
Radiation	kW	210	220	220	220	240	240	240
Fuel system (Note 4)								
Pressure before injection pumps (PT 101)	kPa	800...1000	800...1000	800...1000	800...1000	800...1000	800...1000	800...1000
Fuel flow to engine, approx.	m^3/h	6.1	6.6	6.6	6.6	7.6	7.6	7.6
HFO viscosity before engine	cSt	20...24	20...24	20...24	20...24	20...24	20...24	20...24
MDF viscosity, min.	cSt	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Max. HFO temperature before engine (TE 101)	°C	135	135	135	135	135	135	135
Clean leak fuel quantity, HFO at 100% load	kg/h	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Clean leak fuel quantity, MDF at 100% load	kg/h	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Fuel consumption at 100% load	g/kWh	175	176	176	176	183	183	183
Fuel consumption at 85% load	g/kWh	170	170	172	172	178	179	179
Fuel consumption at 75% load	g/kWh	170	170	172	172	178	180	180
Fuel consumption at 50% load	g/kWh	176	174	176	176	182	188	188
Lubricating oil system								
Pressure before bearings, nom. (PT 201)	kPa	400	400	400	400	400	400	400
Pressure after pump, max.	kPa	800	800	800	800	800	800	800
Suction ability, including pipe loss, max.	kPa	40	40	40	40	40	40	40
Priming pressure, nom. (PT 201)	kPa	80	80	80	80	80	80	80
Temperature before bearings, nom. (TE 201)	°C	63	63	63	63	63	63	63
Temperature after engine, approx.	°C	78	78	78	78	78	78	78
Pump capacity (main), engine driven	m^3/h	198	198	149	153	198	149	153
Pump capacity (main), electrically driven	m^3/h	145	145	145	145	145	145	145
Oil flow through engine	m^3/h	115	115	115	115	115	115	115
Priming pump capacity	m^3/h	45	45	45	45	45	45	45
Oil volume in separate system oil tank	m^3	10.5	11.3	11.3	11.3	12.5	12.5	12.5
Oil consumption at 100% load	g/kWh	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Crankcase ventilation flow rate at full load	l/min	1500	1500	1500	1500	1800	1800	1800
Crankcase ventilation backpressure, max.	Pa	200	200	200	200	200	200	200
Oil volume in turning device	l	8.5...9.5	8.5...9.5	8.5...9.5	8.5...9.5	8.5...9.5	8.5...9.5	8.5...9.5
Oil volume in speed governor	l	1.9	1.9	1.9	1.9	1.9	1.9	1.9
High temperature cooling water system								
Pressure at engine, after pump, nom. (PT 401)	kPa	250 + static	250 + static	250 + static	250 + static	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 401)	kPa	480	480	480	480	480	480	480
Temperature before cylinders, approx. (TE 401)	°C	74	74	74	74	74	74	74
Temperature after cylinders, approx. (TE 402)	°C	82	82	82	82	82	82	82
Temperature after charge air cooler, nom.	°C	91	91	91	91	91	91	91
Capacity of engine driven pump, nom.	m^3/h	180	180	180	180	180	180	180

Wärtsilä 8L46		ME	ME	DE	DE	ME	DE	DE
Cylinder output	**kW**	**975**	**1050**	**1050**	**1050**	**1155**	**1155**	**1155**
Engine speed	**rpm**	**500**	**500**	**500**	**514**	**500**	**500**	**514**
Pressure drop over engine, total	kPa	70	70	70	70	70	70	70
Pressure drop in external system, max.	kPa	150	150	150	150	150	150	150
Pressure from expansion tank	kPa	70...150	70...150	70...150	70...150	70...150	70...150	70...150
Water volume in engine	m³	1.35	1.35	1.35	1.35	1.35	1.35	1.35
Low temperature cooling water system								
Pressure at engine, after pump, nom. (PT 451)	kPa	250	250	250	250	250	250	250
Pressure at engine, after pump, max. (PT 451)	kPa	440	440	440	440	440	440	440
Temperature before engine, max. (TE 451)	°C	38	38	38	38	38	38	38
Temperature before engine, min. (TE 451)	°C	25	25	25	25	25	25	25
Capacity of engine driven pump, nom.	m³/h	180	180	180	180	180	180	180
Pressure drop over charge air cooler	kPa	30	30	30	30	30	30	30
Pressure drop in external system, max.	kPa	200	200	200	200	200	200	200
Pressure from expansion tank	kPa	70 ... 150	70 ... 150	70 ... 150	70 ... 150	70 ... 150	70 ... 150	70 ... 150
Starting air system								
Pressure, nom.	kPa	3000	3000	3000	3000	3000	3000	3000
Pressure at engine during start, min. (20°C)	kPa	1000	1000	1000	1000	1000	1000	1000
Pressure, max.	kPa	3000	3000	3000	3000	3000	3000	3000
Low pressure limit in air vessels	kPa	1800	1800	1800	1800	1800	1800	1800
Consumption per start at 20°C (manual)	Nm³	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Consumption per start at 20°C, (with slowturn)	Nm³	5.8	5.8	5.8	5.8	5.8	5.8	5.8

COMMON RAIL								
Fuel oil system								
Fuel flow to engine, approx.	m³/h	4.6	5.0	5.0	5.0	5.7	5.7	5.7
MDF viscosity, min.	cSt	2	2	2	2	2	2	2
Clean leak fuel quantity, HFO at 100% load	kg/h	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Clean leak fuel quantity, MDF at 100% load	kg/h	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Clean leak fuel quantity at stop, max.	l	15	15	15	15	15	15	15
Lubricating oil system								
Control oil flow, steady	l/min	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Control oil flow, max. momentary	l/min	110	110	110	110	110	110	110
Starting air system								
Consumption per start at 20°C (manual)	Nm³	7.2	7.2	7.2	7.2	7.2	7.2	7.2
Consumption per start at 20°C, (with slowturn)	Nm³	8.2	8.2	8.2	8.2	8.2	8.2	8.2

Notes:

Note 1 At ISO 3046-1 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Tolerance 5%.

Note 2 At ISO 3046-1 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 5% and temperature tolerance 15°C.

Note 3 At ISO3046-1 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Tolerance for cooling water heat 10%, tolerance for radiation heat 30%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers.

Note 4 According to ISO 3046/1, lower calorific value 42 700 kJ/kg, without engine driven pumps. Tolerance 5%. Load according to propeller law for mechanical propulsion engines (ME).

Subject to revision without notice.

3.2.3 Wärtsilä 9L46

Wärtsilä 9L46		ME	ME	DE	DE	ME	DE	DE
Cylinder output	**kW**	**975**	**1050**	**1050**	**1050**	**1155**	**1155**	**1155**
Engine speed	**rpm**	**500**	**500**	**500**	**514**	**500**	**500**	**514**
Engine output	kW	8775	9450	9450	9450	10395	10395	10395
Mean effective pressure	MPa	2.43	2.61	2.61	2.54	2.88	2.88	2.8
Combustion air system (Note 1)								
Flow at 100% load	kg/s	15.5	16.1	16.1	16.4	18.3	18.3	18.6
Temperature at turbocharger intake, max.	°C	45	45	45	45	45	45	45
Temperature after air cooler (TE 601)	°C	40...70	40...70	40...70	40...70	40...70	40...70	40...70
Exhaust gas system (Note 2)								
Flow at 100% load	kg/s	15.9	16.5	16.5	16.8	18.8	18.8	19.1
Flow at 85% load	kg/s	13.7	15.2	15.5	15.8	17.3	17.6	17.9
Flow at 75% load	kg/s	11.6	12.9	14.3	14.6	15.0	16.4	16.7
Flow at 50% load	kg/s	7.8	8.3	10.2	10.5	9.8	13.5	13.8
Temp. after turbo, 100% load (TE 517)	°C	380	380	380	375	390	390	375
Temp. after turbo, 85% load (TE 517)	°C	320	315	310	305	320	315	310
Temp. after turbo, 75% load (TE 517)	°C	340	330	305	300	320	315	310
Temp. after turbo, 50% load, BP open (TE 517)	°C	395	380	320	315	360	280	275
Backpressure, max.	kPa	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pipe diameter, min.	mm	1100	1100	1100	1100	1100	1100	1100
Calculated pipe diameter for 35 m/s	mm	1032	1051	1051	1056	1130	1130	1126
Heat balance at 100% load (Note 3)								
Jacket water, HT-circuit	kW	945	975	975	975	1050	1050	1050
Charge air, HT-circuit	kW	1500	1785	1785	1785	2136	2138	2138
Charge air, LT-circuit	kW	990	1095	1095	1095	1238	1238	1238
Lubricating oil, LT-circuit	kW	1155	1215	1215	1215	1275	1275	1275
Radiation	kW	230	240	240	240	260	260	260
Fuel system (Note 4)								
Pressure before injection pumps (PT 101)	kPa	800...1000	800...1000	800...1000	800...1000	800...1000	800...1000	800...1000
Fuel flow to engine, approx.	m^3/h	6.9	7.5	7.5	7.5	8.6	8.6	8.6
HFO viscosity before engine	cSt	20...24	20...24	20...24	20...24	20...24	20...24	20...24
MDF viscosity, min.	cSt	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Max. HFO temperature before engine (TE 101)	°C	135	135	135	135	135	135	135
Clean leak fuel quantity, HFO at 100% load	kg/h	6.8	6.8	6.8	6.8	6.8	6.8	6.8
Clean leak fuel quantity, MDF at 100% load	kg/h	34.0	34.0	34.0	34.0	34.0	34.0	34.0
Fuel consumption at 100% load	g/kWh	175	176	176	176	183	183	183
Fuel consumption at 85% load	g/kWh	170	170	172	172	178	179	179
Fuel consumption at 75% load	g/kWh	170	170	172	172	178	180	180
Fuel consumption at 50% load	g/kWh	175	174	176	176	182	188	188
Lubricating oil system								
Pressure before bearings, nom. (PT 201)	kPa	400	400	400	400	400	400	400
Pressure after pump, max.	kPa	800	800	800	800	800	800	800
Suction ability, including pipe loss, max.	kPa	40	40	40	40	40	40	40
Priming pressure, nom. (PT 201)	kPa	80	80	80	80	80	80	80
Temperature before bearings, nom. (TE 201)	°C	63	63	63	63	63	63	63
Temperature after engine, approx.	°C	78	78	78	78	78	78	78
Pump capacity (main), engine driven	m^3/h	198	198	157	162	198	157	162
Pump capacity (main), electrically driven	m^3/h	160	160	160	160	160	160	160
Oil flow through engine	m^3/h	130	130	130	130	130	130	130
Priming pump capacity	m^3/h	51	51	51	51	51	51	51
Oil volume in separate system oil tank	m^3	11.8	12.8	12.8	12.8	14.0	14.0	14.0
Oil consumption at 100% load	g/kWh	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Crankcase ventilation flow rate at full load	l/min	1900	1900	1900	1900	1900	1900	1900
Crankcase ventilation backpressure, max.	Pa	200	200	200	200	200	200	200
Oil volume in turning device	l	68...70	68...70	68...70	68...70	68...70	68...70	68...70
Oil volume in speed governor	l	1.9	1.9	1.9	1.9	1.9	1.9	1.9
High temperature cooling water system								
Pressure at engine, after pump, nom. (PT 401)	kPa	250 + static	250 + static	250 + static	250 + static	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 401)	kPa	480	480	480	480	480	480	480
Temperature before cylinders, approx. (TE 401)	°C	74	74	74	74	74	74	74
Temperature after cylinders, approx. (TE 402)	°C	82	82	82	82	82	82	82
Temperature after charge air cooler, nom.	°C	91	91	91	91	91	91	91
Capacity of engine driven pump, nom.	m^3/h	200	200	200	200	200	200	200

Wärtsilä 9L46		ME	ME	DE	DE	ME	DE	DE
Cylinder output	**kW**	**975**	**1050**	**1050**	**1050**	**1155**	**1155**	**1155**
Engine speed	**rpm**	**500**	**500**	**500**	**514**	**500**	**500**	**514**
Pressure drop over engine, total	kPa	70	70	70	70	70	70	70
Pressure drop in external system, max.	kPa	150	150	150	150	150	150	150
Pressure from expansion tank	kPa	70...150	70...150	70...150	70...150	70...150	70...150	70...150
Water volume in engine	m^3	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Low temperature cooling water system								
Pressure at engine, after pump, nom. (PT 451)	kPa	250	250	250	250	250	250	250
Pressure at engine, after pump, max. (PT 451)	kPa	440	440	440	440	440	440	440
Temperature before engine, max. (TE 451)	°C	38	38	38	38	38	38	38
Temperature before engine, min. (TE 451)	°C	25	25	25	25	25	25	25
Capacity of engine driven pump, nom.	m^3/h	200	200	200	200	200	200	200
Pressure drop over charge air cooler	kPa	30	30	30	30	30	30	30
Pressure drop in external system, max.	kPa	200	200	200	200	200	200	200
Pressure from expansion tank	kPa	70 ... 150	70 ... 150	70 ... 150	70 ... 150	70 ... 150	70 ... 150	70 ... 150
Starting air system								
Pressure, nom.	kPa	3000	3000	3000	3000	3000	3000	3000
Pressure at engine during start, min. (20°C)	kPa	1000	1000	1000	1000	1000	1000	1000
Pressure, max.	kPa	3000	3000	3000	3000	3000	3000	3000
Low pressure limit in air vessels	kPa	1800	1800	1800	1800	1800	1800	1800
Consumption per start at 20°C (manual)	Nm^3	5.4	5.4	5.4	5.4	5.4	5.4	5.4
Consumption per start at 20°C, (with slowturn)	Nm^3	6.5	6.5	6.5	6.5	6.5	6.5	6.5

COMMON RAIL								
Fuel oil system								
Fuel flow to engine, approx.	m^3/h	5.2	5.6	5.6	5.6	6.4	6.4	6.4
MDF viscosity, min.	cSt	2	2	2	2	2	2	2
Clean leak fuel quantity, HFO at 100% load	kg/h	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Clean leak fuel quantity, MDF at 100% load	kg/h	17.0	17.0	17.0	17.0	17.0	17.0	17.0
Clean leak fuel quantity at stop, max.	l	17	17	17	17	17	17	17
Lubricating oil system								
Control oil flow, steady	l/min	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Control oil flow, max. momentary	l/min	110	110	110	110	110	110	110
Starting air system								
Consumption per start at 20°C (manual)	Nm^3	8.1	8.1	8.1	8.1	8.1	8.1	8.1
Consumption per start at 20°C, (with slowturn)	Nm^3	9.2	9.2	9.2	9.2	9.2	9.2	9.2

Notes:

Note 1 At ISO 3046-1 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Tolerance 5%.

Note 2 At ISO 3046-1 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 5% and temperature tolerance 15°C.

Note 3 At ISO3046-1 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Tolerance for cooling water heat 10%, tolerance for radiation heat 30%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers.

Note 4 According to ISO 3046/1, lower calorific value 42 700 kJ/kg, without engine driven pumps. Tolerance 5%. Load according to propeller law for mechanical propulsion engines (ME).

Subject to revision without notice.

3.2.4 Wärtsilä 12V46

Wärtsilä 12V46		ME	ME	DE	DE	ME	DE	DE
Cylinder output	**kW**	**975**	**1050**	**1050**	**1050**	**1155**	**1155**	**1155**
Engine speed	**rpm**	**500**	**500**	**500**	**514**	**500**	**500**	**514**
Engine output	kW	11700	12600	12600	12600	13860	13860	13860
Mean effective pressure	MPa	2.43	2.61	2.61	2.54	2.88	2.88	2.8
Combustion air system (Note 1)								
Flow at 100% load	kg/s	20.6	21.4	21.4	21.8	24.3	24.3	24.8
Temperature at turbocharger intake, max.	°C	45	45	45	45	45	45	45
Temperature after air cooler (TE 601)	°C	40...70	40...70	40...70	40...70	40...70	40...70	40...70
Exhaust gas system (Note 2)								
Flow at 100% load	kg/s	21.2	22.0	22.0	22.4	25.0	25.0	25.4
Flow at 85% load	kg/s	18.2	19.9	20.6	21.0	23.0	23.4	23.8
Flow at 75% load	kg/s	15.4	17.6	18.9	19.2	20.0	21.8	22.2
Flow at 50% load	kg/s	10.4	10.7	13.6	13.8	13.0	18.0	18.4
Temp. after turbo, 100% load (TE 517)	°C	380	380	380	375	390	390	390
Temp. after turbo, 85% load (TE 517)	°C	320	321	310	305	320	315	310
Temp. after turbo, 75% load (TE 517)	°C	340	318	305	300	320	315	310
Temp. after turbo, 50% load, BP open (TE 517)	°C	395	371	320	315	360	280	275
Backpressure, max.	kPa	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pipe diameter, min.	mm	1200	1200	1200	1200	1200	1200	1200
Calculated pipe diameter for 35 m/s	mm	1191	1213	1213	1220	1303	1303	1314
Heat balance at 100% load (Note 3)								
Jacket water, HT-circuit	kW	1320	1420	1420	1420	1600	1600	1600
Charge air, HT-circuit	kW	2270	2640	2640	2640	3000	3000	3000
Charge air, LT-circuit	kW	1080	1190	1190	1190	1400	1400	1400
Lubricating oil, LT-circuit	kW	1380	1400	1400	1400	1500	1500	1500
Radiation	kW	280	295	295	295	320	320	320
Fuel system (Note 4)								
Pressure before injection pumps (PT 101)	kPa	800...1000	800...1000	800...1000	800...1000	800...1000	800...1000	800...1000
Fuel flow to engine, approx.	m^3/h	9.2	10.0	10.0	10.0	11.4	11.4	11.4
HFO viscosity before engine	cSt	20...24	20...24	20...24	20...24	20...24	20...24	20...24
MDF viscosity, min.	cSt	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Max. HFO temperature before engine (TE 101)	°C	135	135	135	135	135	135	135
Clean leak fuel quantity, HFO at 100% load	kg/h	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Clean leak fuel quantity, MDF at 100% load	kg/h	45.0	45.0	45.0	45.0	45.0	45.0	45.0
Fuel consumption at 100% load	g/kWh	175	176	176	176	183	183	183
Fuel consumption at 85% load	g/kWh	170	170	172	172	178	179	179
Fuel consumption at 75% load	g/kWh	170	170	172	172	178	180	180
Fuel consumption at 50% load	g/kWh	175	174	176	176	182	188	188
Lubricating oil system								
Pressure before bearings, nom. (PT 201)	kPa	400	400	400	400	400	400	400
Pressure after pump, max.	kPa	800	800	800	800	800	800	800
Suction ability, including pipe loss, max.	kPa	40	40	40	40	40	40	40
Priming pressure, nom. (PT 201)	kPa	80	80	80	80	80	80	80
Temperature before bearings, nom. (TE 201)	°C	63	63	63	63	63	63	63
Temperature after engine, approx.	°C	78	78	78	78	78	78	78
Pump capacity (main), engine driven	m^3/h	263	263	215	221	263	215	221
Pump capacity (main), electrically driven	m^3/h	210	210	210	210	210	210	210
Oil flow through engine	m^3/h	170	170	170	170	170	170	170
Priming pump capacity	m^3/h	65	65	65	65	65	65	65
Oil volume in separate system oil tank	m^3	15.8	17.0	17.0	17.0	18.7	18.7	18.7
Oil consumption at 100% load	g/kWh	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Crankcase ventilation flow rate at full load	l/min	1900	1900	1900	1900	1900	1900	1900
Crankcase ventilation backpressure, max.	Pa	200	200	200	200	200	200	200
Oil volume in turning device	l	68...70	68...70	68...70	68...70	68...70	68...70	68...70
Oil volume in speed governor	l	1.9	1.9	1.9	1.9	1.9	1.9	1.9
High temperature cooling water system								
Pressure at engine, after pump, nom. (PT 401)	kPa	250 + static	250 + static	250 + static	250 + static	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 401)	kPa	480	480	480	480	480	480	480
Temperature before cylinders, approx. (TE 401)	°C	74	74	74	74	74	74	74
Temperature after cylinders, approx. (TE 402)	°C	82	82	82	82	82	82	82
Temperature after charge air cooler, nom.	°C	91	91	91	91	91	91	91
Capacity of engine driven pump, nom.	m^3/h	270	270	270	270	270	270	270

Wärtsilä 12V46		ME	ME	DE	DE	ME	DE	DE
Cylinder output	**kW**	**975**	**1050**	**1050**	**1050**	**1155**	**1155**	**1155**
Engine speed	**rpm**	**500**	**500**	**500**	**514**	**500**	**500**	**514**
Pressure drop over engine, total	kPa	70	70	70	70	70	70	70
Pressure drop in external system, max.	kPa	150	150	150	150	150	150	150
Pressure from expansion tank	kPa	70...150	70...150	70...150	70...150	70...150	70...150	70...150
Water volume in engine	m^3	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Low temperature cooling water system								
Pressure at engine, after pump, nom. (PT 451)	kPa	250	250	250	250	250	250	250
Pressure at engine, after pump, max. (PT 451)	kPa	440	440	440	440	440	440	440
Temperature before engine, max. (TE 451)	°C	38	38	38	38	38	38	38
Temperature before engine, min. (TE 451)	°C	25	25	25	25	25	25	25
Capacity of engine driven pump, nom.	m^3/h	270	270	270	270	270	270	270
Pressure drop over charge air cooler	kPa	30	30	30	30	30	30	30
Pressure drop in external system, max.	kPa	200	200	200	200	200	200	200
Pressure from expansion tank	kPa	70 ... 150	70 ... 150	70 ... 150	70 ... 150	70 ... 150	70 ... 150	70 ... 150
Starting air system								
Pressure, nom.	kPa	3000	3000	3000	3000	3000	3000	3000
Pressure at engine during start, min. (20°C)	kPa	1000	1000	1000	1000	1000	1000	1000
Pressure, max.	kPa	3000	3000	3000	3000	3000	3000	3000
Low pressure limit in air vessels	kPa	1800	1800	1800	1800	1800	1800	1800
Consumption per start at 20°C (manual)	Nm^3	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Consumption per start at 20°C, (with slowturn)	Nm^3	7.2	7.2	7.2	7.2	7.2	7.2	7.2

COMMON RAIL								
Fuel oil system								
Fuel flow to engine, approx.	m^3/h	6.9	7.5	7.5	7.5	8.6	8.6	8.6
MDF viscosity, min.	cSt	2	2	2	2	2	2	2
Clean leak fuel quantity, HFO at 100% load	kg/h	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Clean leak fuel quantity, MDF at 100% load	kg/h	22.5	22.5	22.5	22.5	22.5	22.5	22.5
Clean leak fuel quantity at stop, max.	l	22	22	22	22	22	22	22
Lubricating oil system								
Control oil flow, steady	l/min	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Control oil flow, max. momentary	l/min	110	110	110	110	110	110	110
Starting air system								
Consumption per start at 20°C (manual)	Nm^3	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Consumption per start at 20°C, (with slowturn)	Nm^3	10.2	10.2	10.2	10.2	10.2	10.2	10.2

Notes:

Note 1 At ISO 3046-1 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Tolerance 5%.

Note 2 At ISO 3046-1 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 5% and temperature tolerance 15°C.

Note 3 At ISO3046-1 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Tolerance for cooling water heat 10%, tolerance for radiation heat 30%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers.

Note 4 According to ISO 3046/1, lower calorific value 42 700 kJ/kg, without engine driven pumps. Tolerance 5%. Load according to propeller law for mechanical propulsion engines (ME).

Subject to revision without notice.

3.2.5 Wärtsilä 16V46

Wärtsilä 16V46		ME	ME	DE	DE	ME	DE	DE
Cylinder output	**kW**	**975**	**1050**	**1050**	**1050**	**1155**	**1155**	**1155**
Engine speed	**rpm**	**500**	**500**	**500**	**514**	**500**	**500**	**514**
Engine output	kW	15600	16800	16800	16800	18480	18480	18480
Mean effective pressure	MPa	2.43	2.61	2.61	2.54	2.88	2.88	2.8
Combustion air system (Note 1)								
Flow at 100% load	kg/s	27.5	28.5	28.5	29.1	32.4	32.4	33.1
Temperature at turbocharger intake, max.	°C	45	45	45	45	45	45	45
Temperature after air cooler (TE 601)	°C	40...70	40...70	40...70	40...70	40...70	40...70	40...70
Exhaust gas system (Note 2)								
Flow at 100% load	kg/s	28.3	29.3	29.3	29.9	33.3	33.3	33.9
Flow at 85% load	kg/s	24.3	26.5	27.5	28.0	30.7	31.2	31.7
Flow at 75% load	kg/s	20.5	23.5	25.2	25.6	26.7	29.1	29.6
Flow at 50% load	kg/s	13.9	14.3	18.1	18.4	17.3	24.0	24.5
Temp. after turbo, 100% load (TE 517)	°C	380	380	380	375	390	390	390
Temp. after turbo, 85% load (TE 517)	°C	320	321	310	305	320	315	310
Temp. after turbo, 75% load (TE 517)	°C	340	318	305	300	320	315	310
Temp. after turbo, 50% load, BP open (TE 517)	°C	395	371	320	315	360	280	275
Backpressure, max.	kPa	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pipe diameter, min.	mm	1400	1400	1400	1400	1400	1400	1400
Calculated pipe diameter for 35 m/s	mm	1376	1400	1400	1409	1504	1504	1518
Heat balance at 100% load (Note 3)								
Jacket water, HT-circuit	kW	1760	1893	1893	1893	2133	2133	2133
Charge air, HT-circuit	kW	3027	3520	3520	3520	4000	4000	4000
Charge air, LT-circuit	kW	1440	1587	1587	1587	1867	1867	1867
Lubricating oil, LT-circuit	kW	1840	1867	1867	1867	2000	2000	2000
Radiation	kW	340	360	360	360	380	380	380
Fuel system (Note 4)								
Pressure before injection pumps (PT 101)	kPa	800...1000	800...1000	800...1000	800...1000	800...1000	800...1000	800...1000
Fuel flow to engine, approx.	m^3/h	12.3	13.3	13.3	13.3	15.3	15.3	15.3
HFO viscosity before engine	cSt	20...24	20...24	20...24	20...24	20...24	20...24	20...24
MDF viscosity, min.	cSt	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Max. HFO temperature before engine (TE 101)	°C	135	135	135	135	135	135	135
Clean leak fuel quantity, HFO at 100% load	kg/h	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Clean leak fuel quantity, MDF at 100% load	kg/h	60.0	60.0	60.0	60.0	60.0	60.0	60.0
Fuel consumption at 100% load	g/kWh	175	176	176	176	183	183	183
Fuel consumption at 85% load	g/kWh	170	170	172	172	178	179	179
Fuel consumption at 75% load	g/kWh	170	170	172	172	178	180	180
Fuel consumption at 50% load	g/kWh	175	174	176	176	182	188	188
Lubricating oil system								
Pressure before bearings, nom. (PT 201)	kPa	400	400	400	400	400	400	400
Pressure after pump, max.	kPa	800	800	800	800	800	800	800
Suction ability, including pipe loss, max.	kPa	40	40	40	40	40	40	40
Priming pressure, nom. (PT 201)	kPa	80	80	80	80	80	80	80
Temperature before bearings, nom. (TE 201)	°C	63	63	63	63	63	63	63
Temperature after engine, approx.	°C	78	78	78	78	78	78	78
Pump capacity (main), engine driven	m^3/h	279	279	263	272	279	263	272
Pump capacity (main), electrically driven	m^3/h	260	260	260	260	260	260	260
Oil flow through engine	m^3/h	230	230	230	230	230	230	230
Priming pump capacity	m^3/h	85	85	85	85	85	85	85
Oil volume in separate system oil tank	m^3	21.1	22.7	22.7	22.7	24.9	24.9	24.9
Oil consumption at 100% load	g/kWh	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Crankcase ventilation flow rate at full load	l/min	2300	2300	2300	2300	2600	2600	2600
Crankcase ventilation backpressure, max.	Pa	200	200	200	200	200	200	200
Oil volume in turning device	l	68...70	68...70	68...70	68...70	68...70	68...70	68...70
Oil volume in speed governor	l	1.9	1.9	1.9	1.9	1.9	1.9	1.9
High temperature cooling water system								
Pressure at engine, after pump, nom. (PT 401)	kPa	250 + static	250 + static	250 + static	250 + static	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 401)	kPa	480	480	480	480	480	480	480
Temperature before cylinders, approx. (TE 401)	°C	74	74	74	74	74	74	74
Temperature after cylinders, approx. (TE 402)	°C	82	82	82	82	82	82	82
Temperature after charge air cooler, nom.	°C	91	91	91	91	91	91	91
Capacity of engine driven pump, nom.	m^3/h	355	355	355	355	355	355	355

Wärtsilä 16V46		ME	ME	DE	DE	ME	DE	DE
Cylinder output	**kW**	**975**	**1050**	**1050**	**1050**	**1155**	**1155**	**1155**
Engine speed	**rpm**	**500**	**500**	**500**	**514**	**500**	**500**	**514**
Pressure drop over engine, total	kPa	70	70	70	70	70	70	70
Pressure drop in external system, max.	kPa	150	150	150	150	150	150	150
Pressure from expansion tank	kPa	70...150	70...150	70...150	70...150	70...150	70...150	70...150
Water volume in engine	m³	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Low temperature cooling water system								
Pressure at engine, after pump, nom. (PT 451)	kPa	250	250	250	250	250	250	250
Pressure at engine, after pump, max. (PT 451)	kPa	440	440	440	440	440	440	440
Temperature before engine, max. (TE 451)	°C	38	38	38	38	38	38	38
Temperature before engine, min. (TE 451)	°C	25	25	25	25	25	25	25
Capacity of engine driven pump, nom.	m³/h	355	355	355	355	355	355	355
Pressure drop over charge air cooler	kPa	30	30	30	30	30	30	30
Pressure drop in external system, max.	kPa	200	200	200	200	200	200	200
Pressure from expansion tank	kPa	70 ... 150	70 ... 150	70 ... 150	70 ... 150	70 ... 150	70 ... 150	70 ... 150
Starting air system								
Pressure, nom.	kPa	3000	3000	3000	3000	3000	3000	3000
Pressure at engine during start, min. (20°C)	kPa	1000	1000	1000	1000	1000	1000	1000
Pressure, max.	kPa	3000	3000	3000	3000	3000	3000	3000
Low pressure limit in air vessels	kPa	1800	1800	1800	1800	1800	1800	1800
Consumption per start at 20°C (manual)	Nm³	7.8	7.8	7.8	7.8	7.8	7.8	7.8
Consumption per start at 20°C, (with slowturn)	Nm³	9.4	9.4	9.4	9.4	9.4	9.4	9.4

COMMON RAIL								
Fuel oil system								
Fuel flow to engine, approx.	m³/h	9.2	10.0	10.0	10.0	11.4	11.4	11.4
MDF viscosity, min.	cSt	2	2	2	2	2	2	2
Clean leak fuel quantity, HFO at 100% load	kg/h	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Clean leak fuel quantity, MDF at 100% load	kg/h	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Clean leak fuel quantity at stop, max.	l	29	29	29	29	29	29	29
Lubricating oil system								
Control oil flow, steady	l/min	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Control oil flow, max. momentary	l/min	110	110	110	110	110	110	110
Starting air system								
Consumption per start at 20°C (manual)	Nm³	11.7	11.7	11.7	11.7	11.7	11.7	11.7
Consumption per start at 20°C, (with slowturn)	Nm³	13.3	13.3	13.3	13.3	13.3	13.3	13.3

Notes:

Note 1 At ISO 3046-1 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Tolerance 5%.

Note 2 At ISO 3046-1 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 5% and temperature tolerance 15°C.

Note 3 At ISO3046-1 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Tolerance for cooling water heat 10%, tolerance for radiation heat 30%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers.

Note 4 According to ISO 3046/1, lower calorific value 42 700 kJ/kg, without engine driven pumps. Tolerance 5%. Load according to propeller law for mechanical propulsion engines (ME).

Subject to revision without notice.

3.2.6 Wärtsilä 18V46

Wärtsilä 18V46		**DE**	**DE**
Cylinder output	**kW**	**1050**	**1050**
Engine speed	**rpm**	**500**	**514**
Engine output	kW	18900	18900
Mean effective pressure	MPa	2.61	2.54
Combustion air system (Note 1)			
Flow at 100% load	kg/s	32.1	32.7
Temperature at turbocharger intake, max.	°C	45	45
Temperature after air cooler (TE 601)	°C	40...70	40...70
Exhaust gas system (Note 2)			
Flow at 100% load	kg/s	33.0	33.6
Flow at 85% load	kg/s	30.9	31.5
Flow at 75% load	kg/s	28.4	28.8
Flow at 50% load	kg/s	20.4	20.7
Temp. after turbo, 100% load (TE 517)	°C	380	375
Temp. after turbo, 85% load (TE 517)	°C	310	305
Temp. after turbo, 75% load (TE 517)	°C	305	300
Temp. after turbo, 50% load, BP open (TE 517)	°C	320	315
Backpressure, max.	kPa	3.0	3.0
Pipe diameter, min.	mm	1500	1500
Calculated pipe diameter for 35 m/s	mm	1486	1494
Heat balance at 100% load (Note 3)			
Jacket water, HT-circuit	kW	2130	2130
Charge air, HT-circuit	kW	3960	3960
Charge air, LT-circuit	kW	1785	1785
Lubricating oil, LT-circuit	kW	2100	2100
Radiation	kW	390	390
Fuel system (Note 4)			
Pressure before injection pumps (PT 101)	kPa	800...1000	800...1000
Fuel flow to engine, approx.	m^3/h	15.0	15.0
HFO viscosity before engine	cSt	20...24	20...24
MDF viscosity, min.	cSt	2.8	2.8
Max. HFO temperature before engine (TE 101)	°C	135	135
Clean leak fuel quantity, HFO at 100% load	kg/h	13.6	13.6
Clean leak fuel quantity, MDF at 100% load	kg/h	68.0	68.0
Fuel consumption at 100% load	g/kWh	176	176
Fuel consumption at 85% load	g/kWh	172	172
Fuel consumption at 75% load	g/kWh	172	172
Fuel consumption at 50% load	g/kWh	176	176
Lubricating oil system			
Pressure before bearings, nom. (PT 201)	kPa	400	400
Pressure after pump, max.	kPa	800	800
Suction ability, including pipe loss, max.	kPa	40	40
Priming pressure, nom. (PT 201)	kPa	80	80
Temperature before bearings, nom. (TE 201)	°C	63	63
Temperature after engine, approx.	°C	78	78
Pump capacity (main), engine driven	m^3/h	279	287
Pump capacity (main), electrically driven	m^3/h	279	279
Oil flow through engine	m^3/h	260	260
Priming pump capacity	m^3/h	100	100
Oil volume in separate system oil tank	m^3	25.5	25.5
Oil consumption at 100% load	g/kWh	0.5	0.5
Crankcase ventilation flow rate at full load	l/min	2800	2800
Crankcase ventilation backpressure, max.	Pa	200	200
Oil volume in turning device	l	68...70	68...70
Oil volume in speed governor	l	1.9	1.9
High temperature cooling water system			
Pressure at engine, after pump, nom. (PT 401)	kPa	250 + static	250 + static
Pressure at engine, after pump, max. (PT 401)	kPa	480	480
Temperature before cylinders, approx. (TE 401)	°C	74	74
Temperature after cylinders, approx. (TE 402)	°C	82	82
Temperature after charge air cooler, nom.	°C	91	91
Capacity of engine driven pump, nom.	m^3/h	400	400

Wärtsilä 18V46		DE	DE
Cylinder output	**kW**	**1050**	**1050**
Engine speed	**rpm**	**500**	**514**
Pressure drop over engine, total	kPa	70	70
Pressure drop in external system, max.	kPa	150	150
Pressure from expansion tank	kPa	70...150	70...150
Water volume in engine	m³	2.6	2.6
Low temperature cooling water system			
Pressure at engine, after pump, nom. (PT 451)	kPa	250	250
Pressure at engine, after pump, max. (PT 451)	kPa	440	440
Temperature before engine, max. (TE 451)	°C	38	38
Temperature before engine, min. (TE 451)	°C	25	25
Capacity of engine driven pump, nom.	m³/h	400	400
Pressure drop over charge air cooler	kPa	30	30
Pressure drop in external system, max.	kPa	200	200
Pressure from expansion tank	kPa	70 ... 150	70 ... 150
Starting air system			
Pressure, nom.	kPa	3000	3000
Pressure at engine during start, min. (20°C)	kPa	1000	1000
Pressure, max.	kPa	3000	3000
Low pressure limit in air vessels	kPa	1800	1800
Consumption per start at 20°C (manual)	Nm³	9.0	9.0
Consumption per start at 20°C, (with slowturn)	Nm³	10.8	10.8

COMMON RAIL			
Fuel oil system			
Fuel flow to engine, approx.	m³/h	11.2	11.2
MDF viscosity, min.	cSt	2	2
Clean leak fuel quantity, HFO at 100% load	kg/h	6.8	6.8
Clean leak fuel quantity, MDF at 100% load	kg/h	34.0	34.0
Clean leak fuel quantity at stop, max.	l	33	33
Lubricating oil system			
Control oil flow, steady	l/min	9.0	9.0
Control oil flow, max. momentary	l/min	110	110
Starting air system			
Consumption per start at 20°C (manual)	Nm³	13.5	13.5
Consumption per start at 20°C, (with slowturn)	Nm³	15.3	15.3

Notes:

Note 1 At ISO 3046-1 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Tolerance 5%.

Note 2 At ISO 3046-1 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Flow tolerance 5% and temperature tolerance 15°C.

Note 3 At ISO3046-1 conditions (ambient air temperature 25°C, LT-water 25°C) and 100% load. Tolerance for cooling water heat 10%, tolerance for radiation heat 30%. Fouling factors and a margin to be taken into account when dimensioning heat exchangers.

Note 4 According to ISO 3046/1, lower calorific value 42 700 kJ/kg, without engine driven pumps. Tolerance 5%. Load according to propeller law for mechanical propulsion engines (ME).

Subject to revision without notice.

3.3 Exhaust gas and heat balance diagrams

The following load-dependent diagrams are included:

975 kW/cyl	Nominal rpm	rpm mode	Diagram
Exhaust gas flow	500	variable	*Figure 3.3*
Exhaust gas flow	500	constant	*Figure 3.4*
HT-water heat	500/514	constant	*Figure 3.5*
LT-water heat	500/514	constant	*Figure 3.6*

1050 kW/cyl	Nominal rpm	rpm mode	Diagram
Exhaust gas flow	500	variable	*Figure 3.7*
Exhaust gas flow	500	constant	*Figure 3.8*
HT-water heat	500/514	constant	*Figure 3.9*
LT-water heat	500/514	constant	*Figure 3.10*

1155 kW/cyl	Nominal rpm	rpm mode	Diagram
Exhaust gas flow	500	variable	*Figure 3.11*
Exhaust gas flow	500	constant	*Figure 3.12*
HT-water heat	500/514	constant	*Figure 3.13*
LT-water heat	500/514	constant	*Figure 3.14*

Exhaust gas temperature	Nominal rpm	rpm mode	Diagram
Exhaust gas temperature after turbine	500	variable	*Figure 3.15*
Exhaust gas temperature after turbine	500	constant	*Figure 3.16*

3.3.1 Wärtsilä 46, 975 kW/cyl (4V93E0376a)

Figure 3.3 Exhaust gas massflow, 500 rpm, variable speed

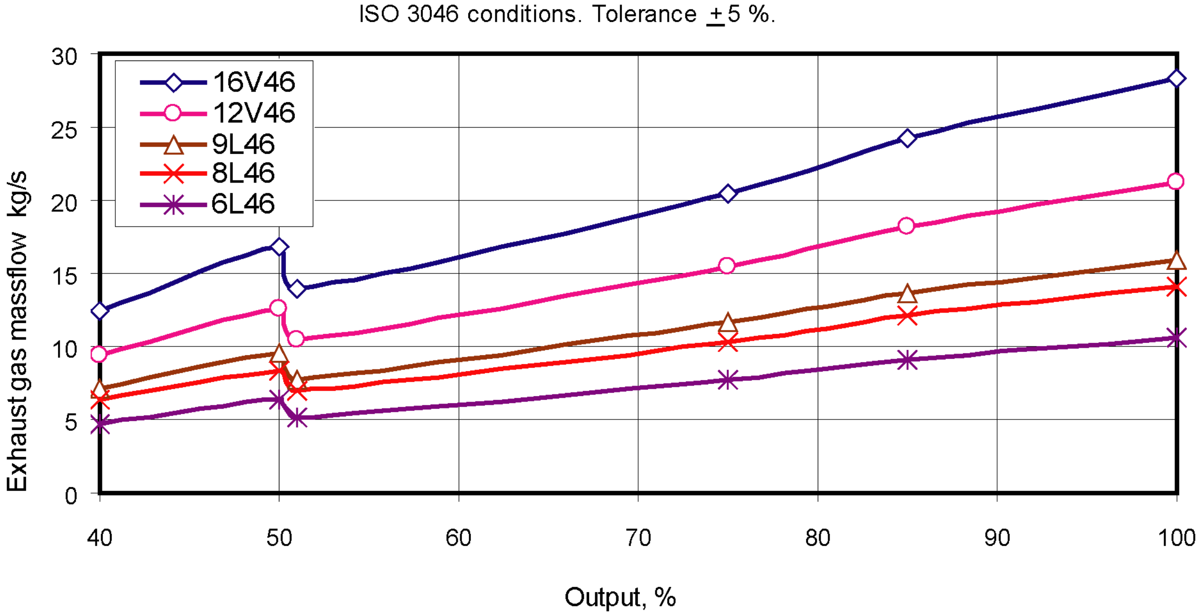


Figure 3.4 Exhaust gas massflow, 500 rpm, constant speed

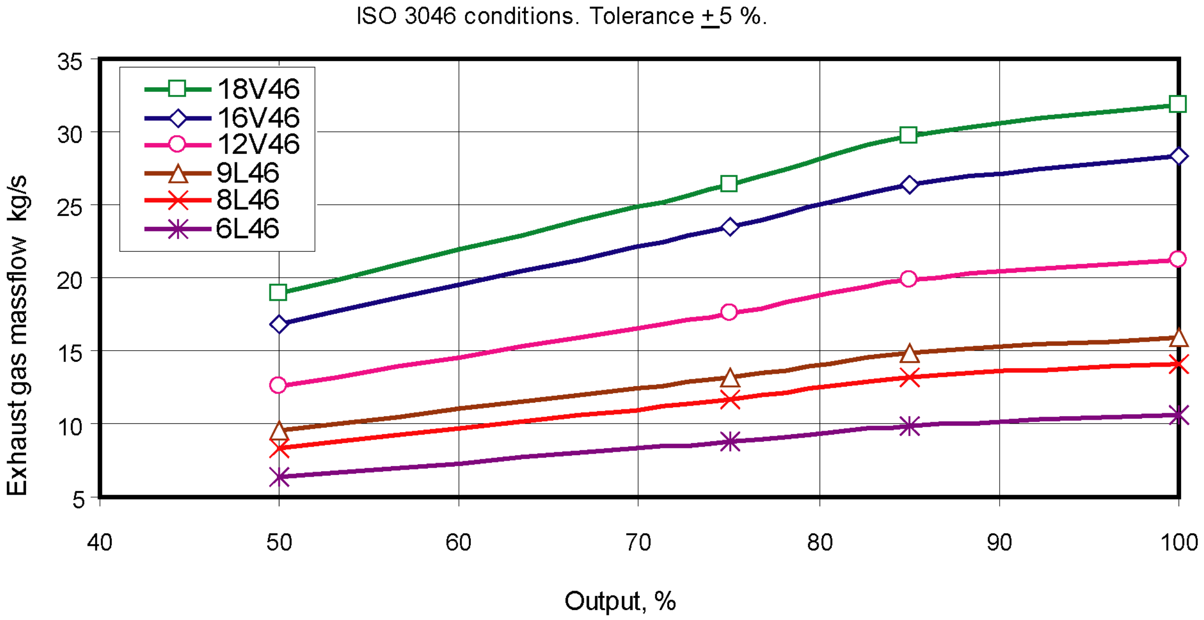


Figure 3.5 HT circuit (jacket + charge air cooler) heat dissipation, 500/514 rpm, constant speed

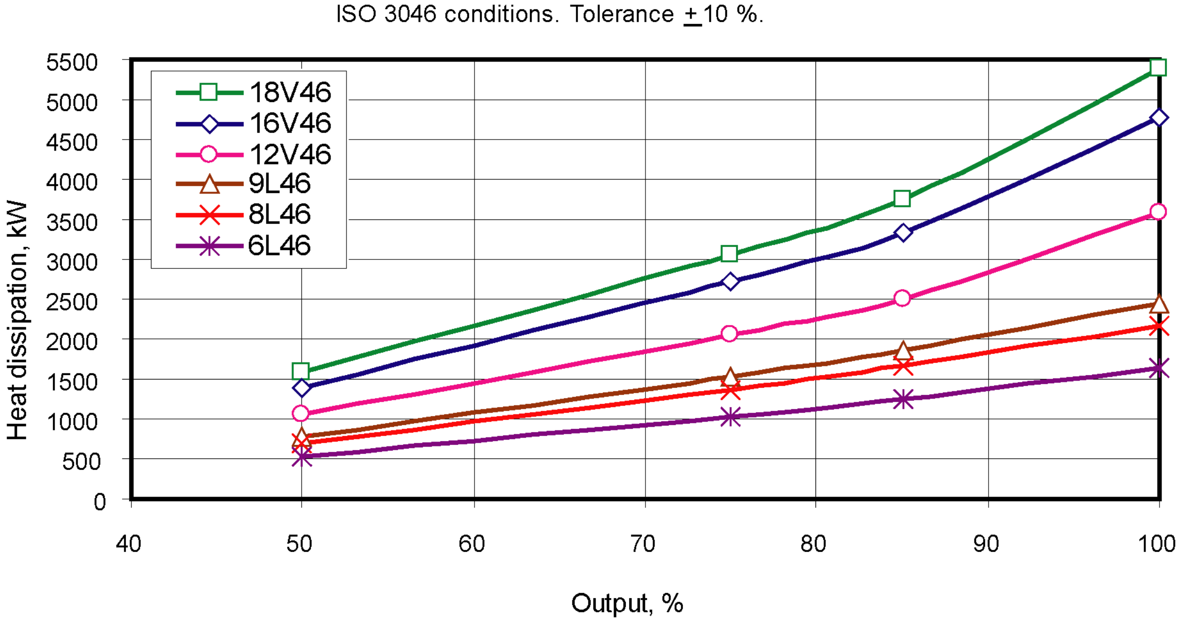
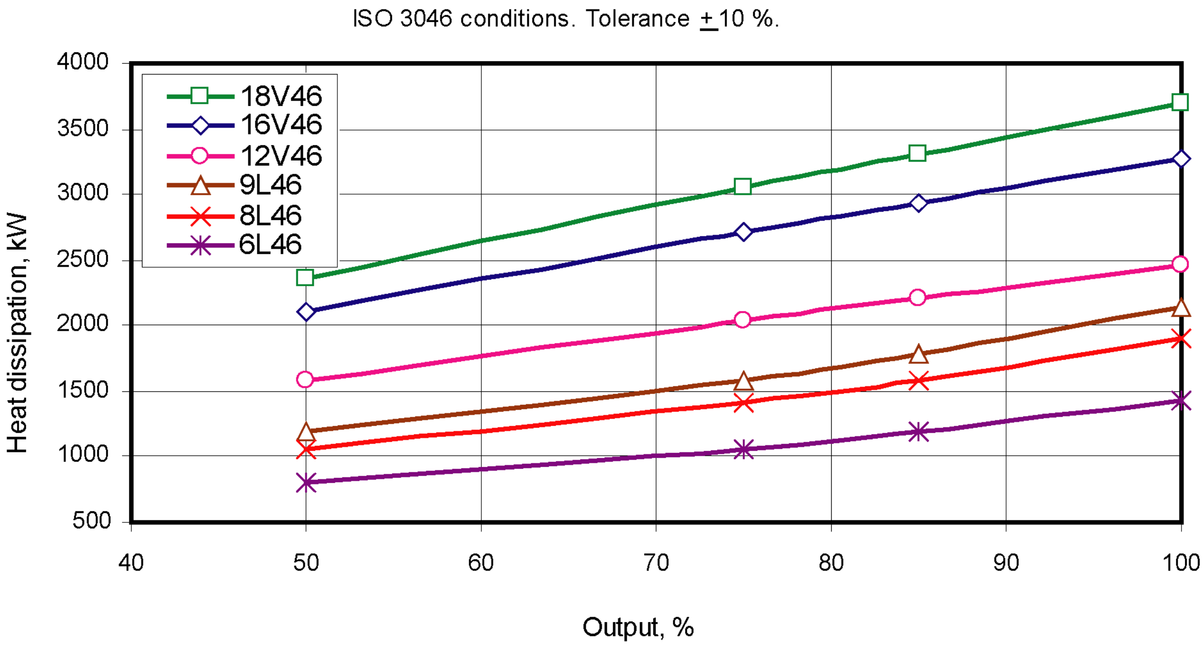


Figure 3.6 LT circuit (lubricating oil + charge air cooler) heat dissipation, 500/514 rpm, constant speed



3.3.2 Wärtsilä 46, 1050 kW/cyl (4V93E0378a)

Figure 3.7 Exhaust gas massflow, 500 rpm, variable speed

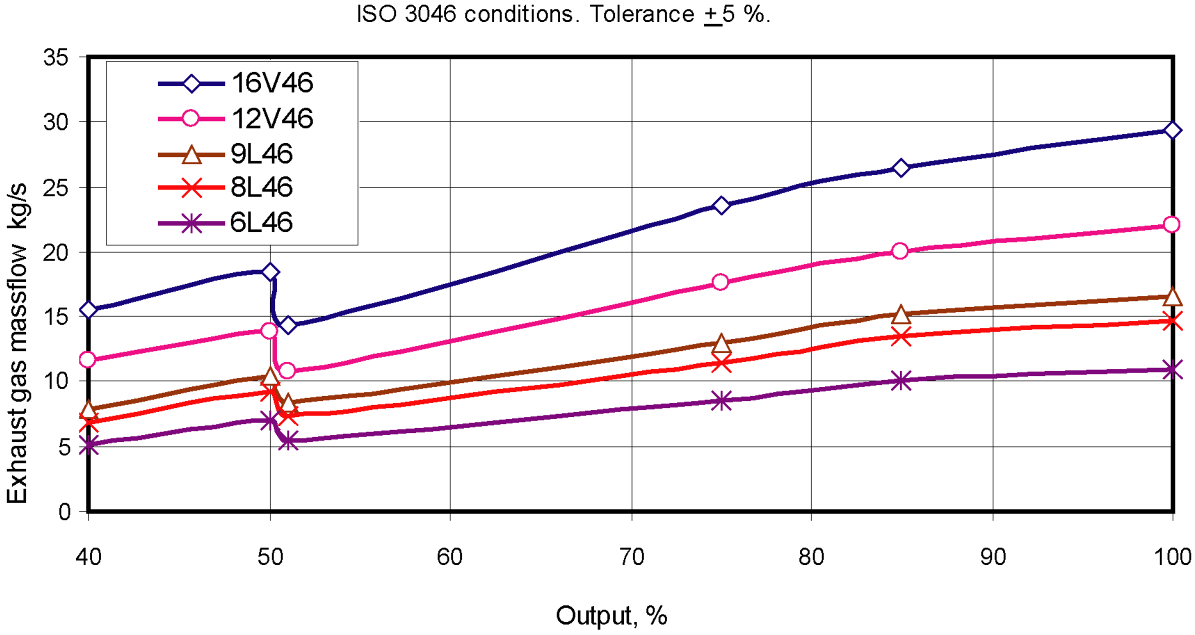


Figure 3.8 Exhaust gas massflow, 500 rpm, constant speed

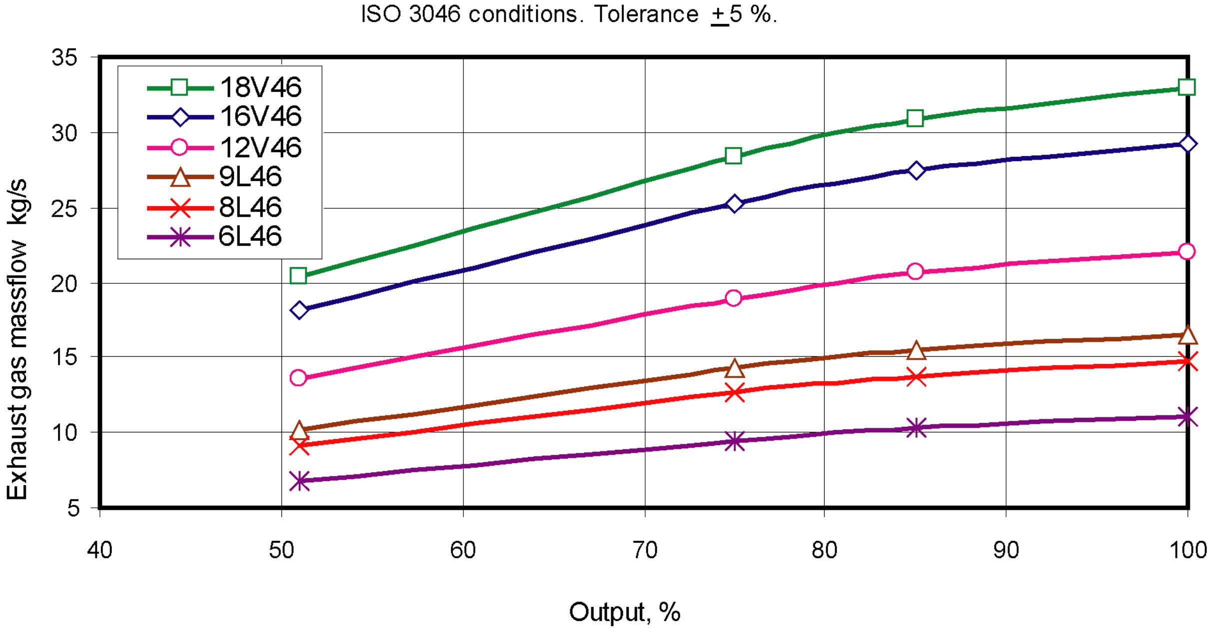


Figure 3.9 HT circuit (jacket + charge air cooler) heat dissipation, 500/514 rpm, constant speed

ISO 3046 conditions. Tolerance ±10 %.

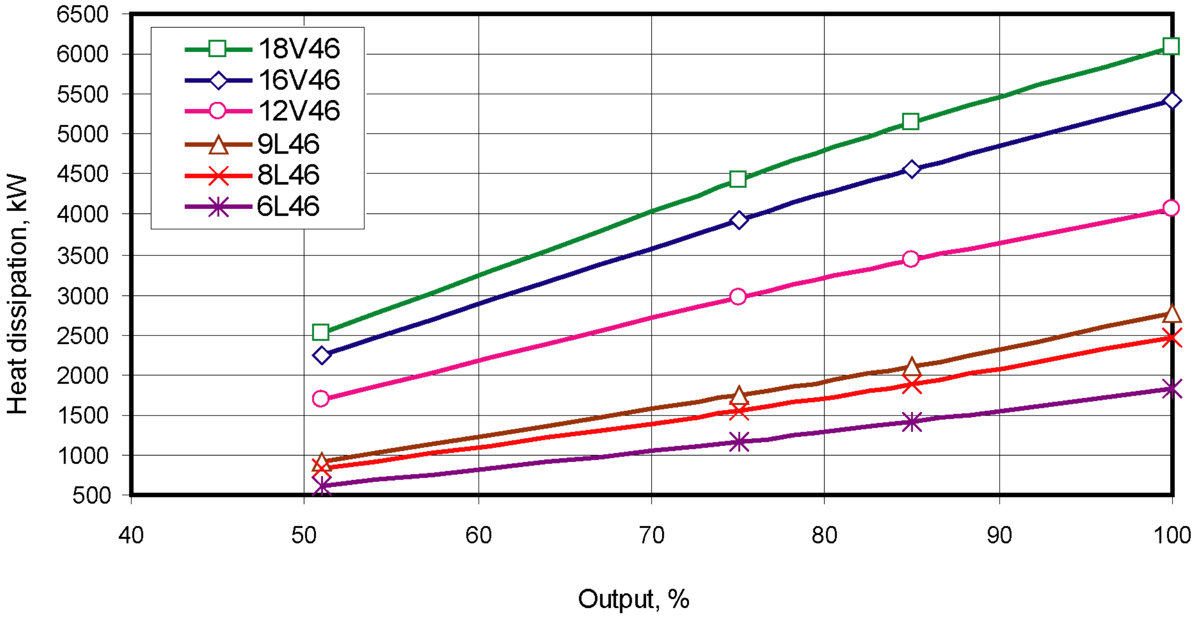
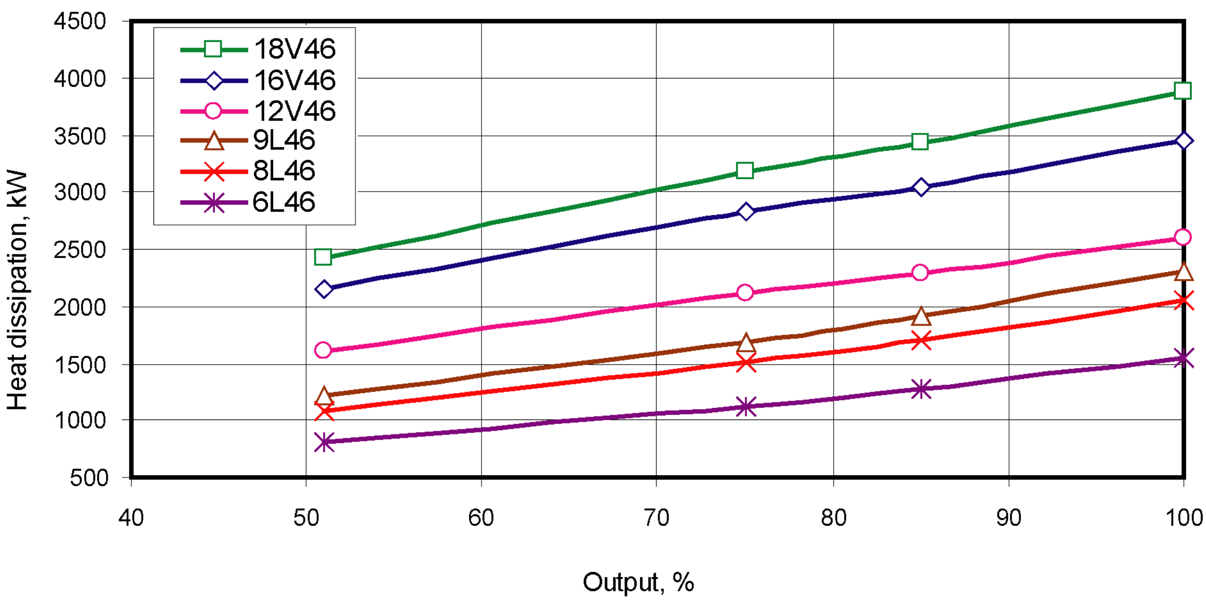


Figure 3.10 LT circuit (lubricating oil + charge air cooler) heat dissipation, 500/514 rpm, constant speed

ISO 3046 conditions. Tolerance ±10 %.



3.3.3 Wärtsilä 46, 1155 kW/cyl (DAAE041152)

Figure 3.11 Exhaust gas massflow, 500 rpm, variable speed

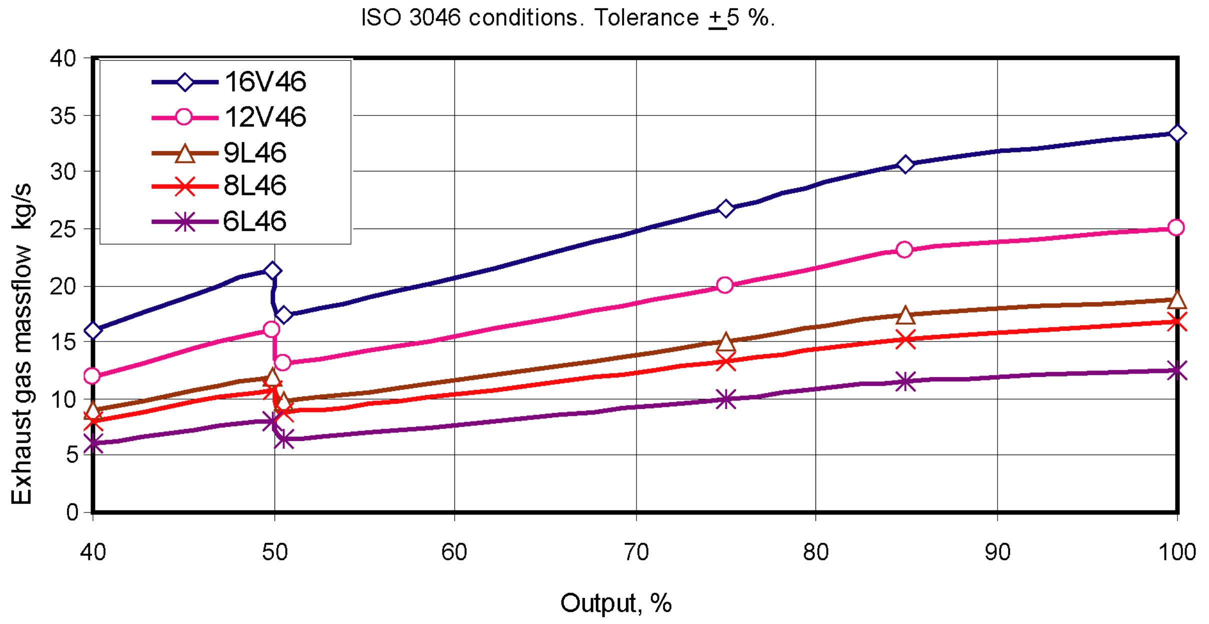


Figure 3.12 Exhaust gas massflow, 500 rpm, constant speed

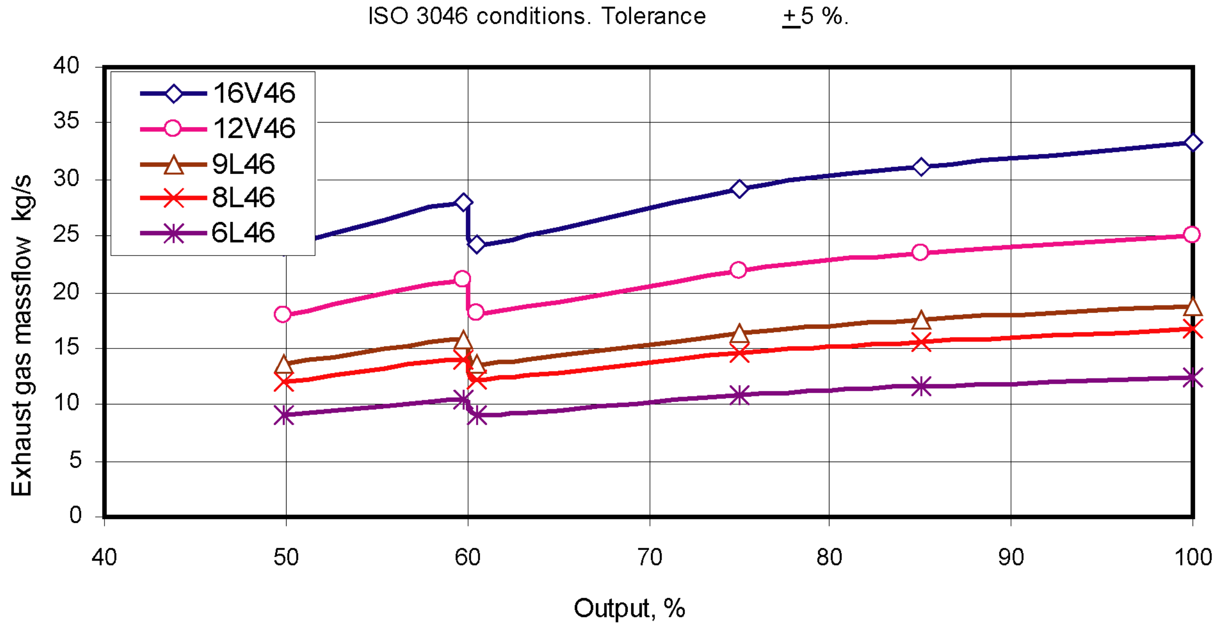


Figure 3.13 HT circuit (jacket + charge air cooler) heat dissipation, 500/514 rpm, constant speed

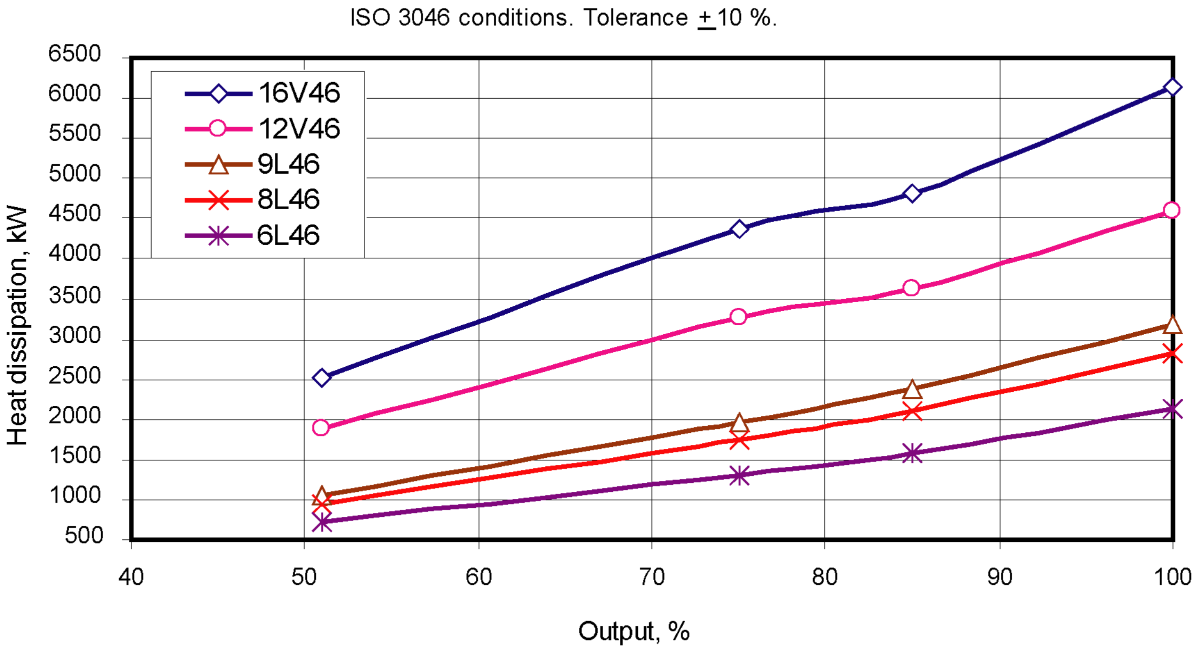
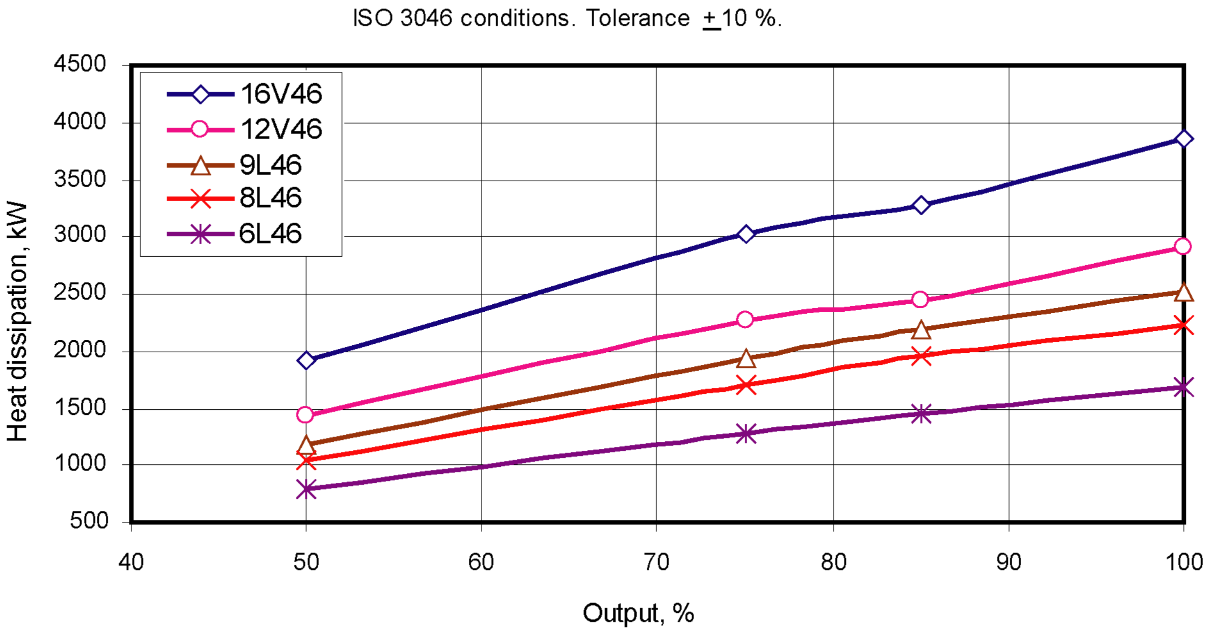


Figure 3.14 LT circuit (lubricating oil + charge air cooler) heat dissipation, 500/514 rpm, constant speed



3.3.4 Wärtsilä 46 exhaust gas temperature (DAAE041185)

Figure 3.15 Exhaust gas temperature after turbine, variable speed

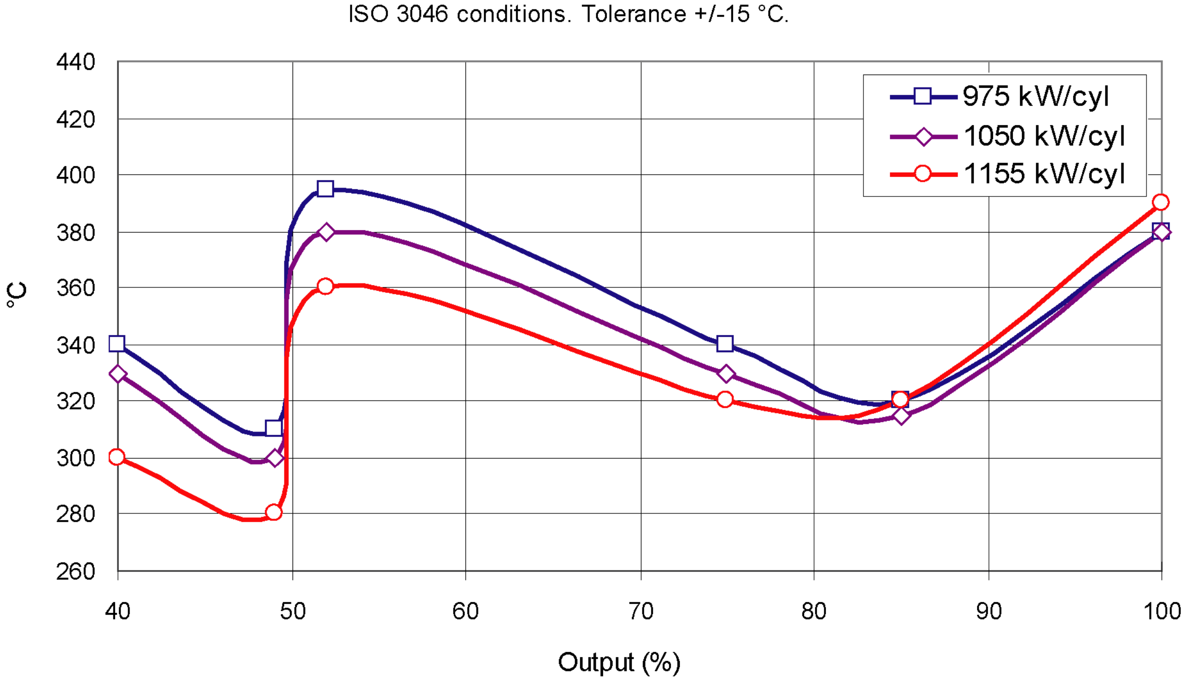
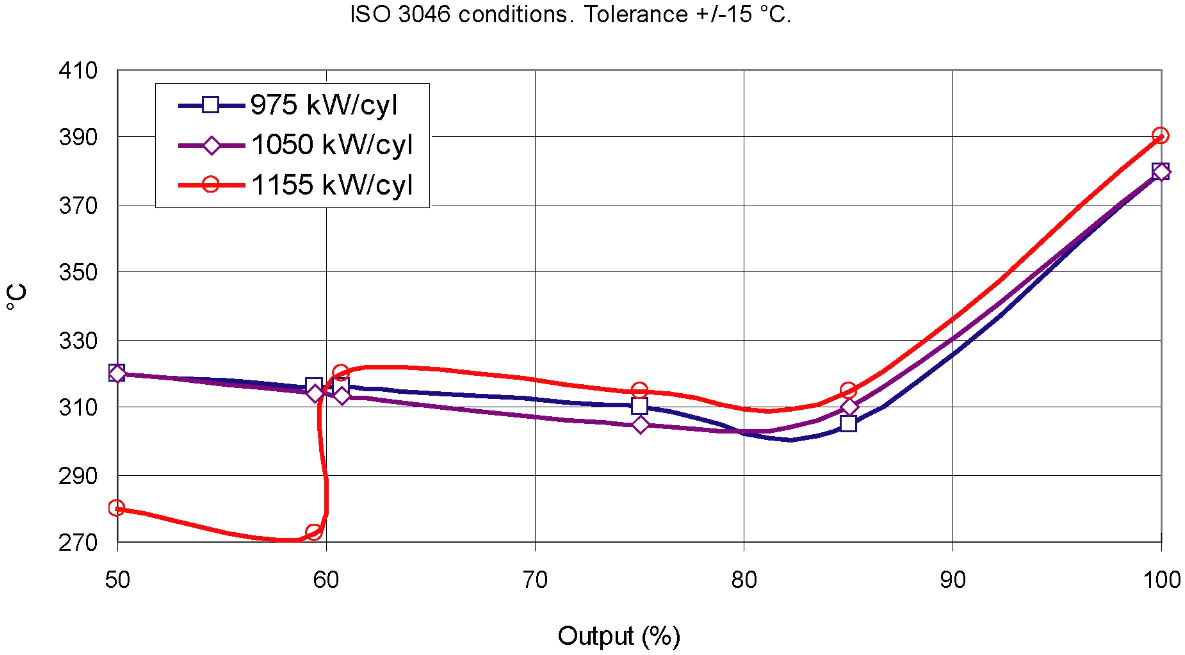
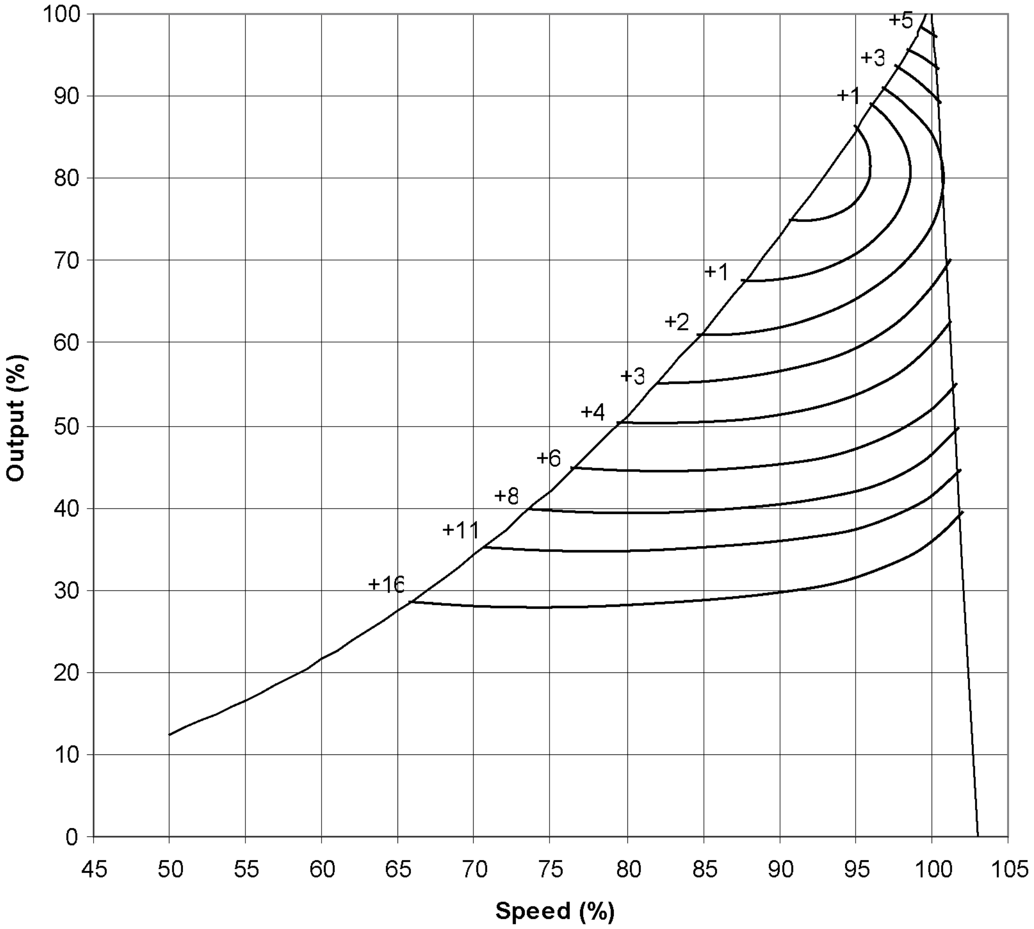


Figure 3.16 Exhaust gas temperature after turbine, constant speed



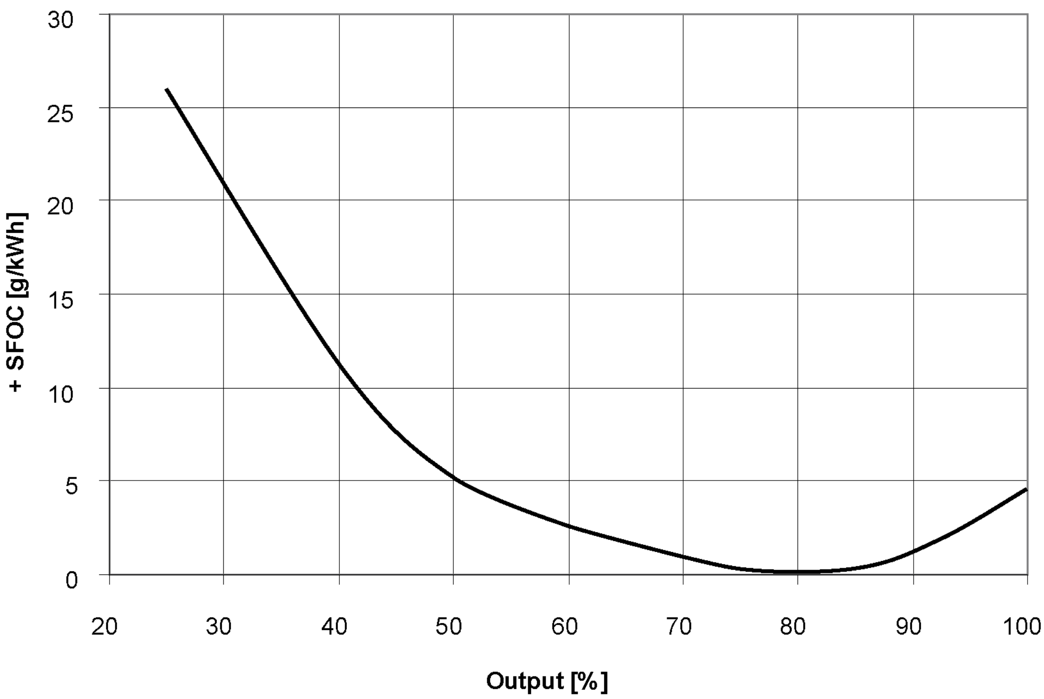
3.4 Specific fuel oil consumption curves

Figure 3.17 Typical specific fuel oil consumption, variable speed [g/kWh] (DAAE041227)



Average for 1050 and 1155 kW/cyl engines. The mussel diagram is very installation specific. For guidance only.

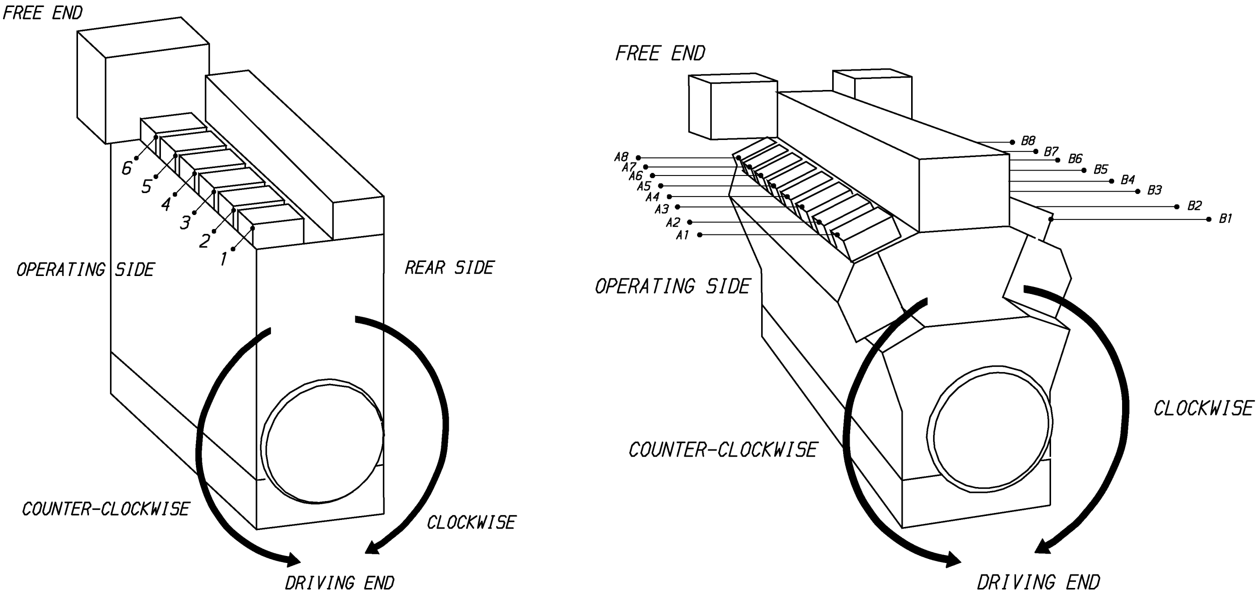
Figure 3.18 Typical specific fuel oil consumption curve, constant speed (DAAE041227)



4. Description of the engine

4.1 Definitions

Figure 4.1 In-line and V-engine definitions (1V93C0029 / 1V93C0028)



4.2 Main components and systems

Main dimensions and weights are presented in the chapter *General data and outputs*.

4.2.1 Engine block

The engine block is made of nodular cast iron in one piece for all cylinder numbers.

The engine block has been given a stiff and durable design to absorb internal forces and the engine can therefore also be resiliently mounted in propulsion systems not requiring any intermediate foundations.

The crankshaft is mounted in the engine block in an underslung way.

The main bearing caps, made of nodular cast iron, are fixed from below by two hydraulically tensioned screws. They are guided sideways by the engine block at the top as well as at the bottom. Hydraulically tensioned horizontal side screws support the main bearing caps.

Hydraulic jacks, supported in the oil sump, offer the possibility to lower and lift the main bearing caps for easy maintenance. Lubricating oil is led to the bearings and piston through the same jack. A combined flywheel/ thrust bearing is located at the driving end of the engine.

The oil sump, a light welded construction, is mounted on the engine block from below and sealed by O-rings. The oil sump is of dry sump type and includes the main distributing pipe for lubricating oil. The sump is drained at both ends to a separate system oil tank. For applications with restricted height a low sump can be specified, however without the hydraulic jacks.

4.2.2 Crankshaft

The crankshaft design is based on a reliability philosophy with very low bearing loads. High axial and torsional rigidity is achieved with a moderate bore to stroke ratio.

The crankshaft is forged in one piece. In the V-engines the connecting rods are arranged side-by-side on the same crank in order to obtain a high degree of standardisation between in-line and V-engines. For the same reason the diameters of the crank pins and journals are equal regardless of the engine size.

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

All crankshafts can be provided with torsional vibration dampers at the free end of the engine, if necessary. Full output can be taken off at either end of the engine.

4.2.3 Connecting rod

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

The connecting rod of alloy steel is forged and machined with round sections. The lower end is split horizontally to allow removal of piston and connecting rod through the cylinder liner. All connecting rod bolts are hydraulically tightened. The gudgeon pin bearing is of tri-metal type.

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

4.2.4 Main bearings and big end bearings

The big end bearings are of tri-metal type with steel back, lead bronze lining and a soft and thick running layer. Both tri-metal and bi-metal bearings are used as main bearings.

4.2.5 Cylinder liner

The centrifugally cast cylinder liner has a high and rigid collar to minimise deformations. A distortion-free liner bore in combination with wear resistant materials and good lubrication provide optimum running conditions for the piston and piston rings and reduces wear. The liner material is a special grey cast iron alloy developed for excellent wear resistance and high strength.

Accurate temperature control is achieved with precisely positioned longitudinal cooling water bores. To eliminate the risk of bore polishing, the liner is equipped with an anti-polishing ring.

The cooling water space between block and liner is sealed off by double O-rings.

4.2.6 Piston

The piston is of composite design with nodular cast iron skirt and steel crown.

The piston skirt is pressure lubricated, which ensures a controlled oil distribution to the cylinder liner under all operating conditions. Oil is fed to cooling gallery in the piston top through the connecting rod. The piston ring grooves are hardened for good wear resistance.

4.2.7 Piston rings

The piston ring set consists of two directional compression rings and one spring-loaded conformable oil scraper ring. All piston rings have a wear resistant chromium plating.

4.2.8 Cylinder head

A rigid box-like design ensures even circumferential contact pressure and permits high cylinder pressure. Only four hydraulically tightened cylinder head studs simplify the maintenance and enable optimisation of the inlet and outlet port flow characteristics.

The exhaust valve seats are water cooled and all valves are equipped with valve rotators. The seat faces of the inlet valves are Stellite-plated. In case the engine is specified for MDF operation only, also the exhaust valves are Stellite-plated. Engines that are intended for operation on HFO have Nimonic exhaust valves.

4.2.9 Camshaft and valve mechanism

The camshaft is built of single cylinder sections that are connected with separate bearing journals. The camshaft sections and the bearing journals are connected by means of flange connections, which makes it possible to remove single camshaft sections sideways. The camshaft sections are forged in one piece with integrated cams. The bearing housings are integrated in the engine block casting and thus completely closed. The bearings are installed and removed by means of a hydraulic tool. The camshaft covers, one for each cylinder, seal against the engine block with a closed sealing profile. The valve tappets are of piston type with a self-adjustment of roller against cam to give an even distribution of the contact pressure. Double valve springs ensure that the valve mechanism is dynamically stable.

4.2.10 Camshaft drive

The camshafts are driven by the crankshaft through a gear train. The gear wheel on the crankshaft and the gear wheel on the camshaft are connected to the shaft by means of a flange connection. The intermediate gear wheels are fixed together by means of a hydraulically tightened central bolt.

4.2.11 Fuel injection equipment

The Wärtsilä 46 engine is available with conventional fuel injection, or optionally with common rail fuel injection for smokeless operation also at low load. The entire fuel system is enclosed in a fully covered compartment for maximum safety. All leakages from injection valves, pumps and pipes are collected in a closed system.

Conventional fuel injection

The conventional fuel injection system has a separate injection pump for each cylinder. Rigid and distortion-free design of the injection pump permits injection pressures up to 1500 bar. A constant pressure relief valve in the injection pump maintains a residual pressure during all operating conditions to prevent cavitation erosion and ensure long intervals between overhauls. There is a drained and sealed-off compartment between the pump and the tappet to prevent leakage fuel from mixing with lubricating oil. Each pump is equipped with a pneumatic stop cylinder acting directly on the fuel rack.

The injection valve is designed to have a small heat absorbing surface facing the combustion space. Together with efficient heat transfer to the cooling water this eliminates the need for a separate nozzle temperature control system.

Common rail fuel injection

The common rail system comprises pressurizing fuel pumps, fuel accumulators and electronically controlled fuel injectors. The fuel pumps are driven by the camshaft and each pump and accumulator serve two cylinders. Adjacent accumulators are connected with small bore piping in order to reduce the risk of pulsation in the rail. The engine can operate with one or two fuel pumps disconnected, should this ever be necessary. A safety feature of the system is that there is no pressure on the injection nozzles between injections. All functions are controlled by the embedded control system on the engine. The main advantage of the common rail system is that the injection pressure can be kept at a sufficiently high level over the whole load range, which gives smokeless operation also at low load.

The electrically controlled fuel injectors are actuated using control oil. The control oil pump is engine driven and engine lubricating oil is used as control oil.

4.2.12 Exhaust pipes

The exhaust manifold is built up of separate cylinder sections forming a Single Pipe Exhaust (SPEX). V-engines have a separate exhaust manifold on each cylinder bank. The SPEX system has a relatively small volume and is optimised to utilize the pressure pulses without disturbing the cylinder scavenging. The exhaust pipes are made of a special nodular cast iron. The connections to the cylinder heads are of clamp ring type. The complete exhaust gas system is enclosed in an insulating box consisting of easily removable panels fitted to a resiliently mounted frame.

4.2.13 Lubricating oil system

The engine is equipped with dry oil sump.

The lubricating oil pump can be either engine driven or separate. The pump is located in the free end when it is built on the engine.

Filters, oil cooler, temperature control valve and pre-lubricating oil pump are to be installed in the external system.

All engines are delivered with start-up/running-in filters.

4.2.14 Cooling water system

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

The HT and LT cooling water pumps can be either engine driven or separate. The pumps are located in free end of the engine, if the engine is equipped with engine driven pumps.

Other equipment is to be installed in the external system.

4.2.15 Turbocharging and charge air cooling

The SPEX (Single Pipe Exhaust) turbocharging system is designed to combine the good part load performance of a pulse charging system with the simplicity and good high load efficiency of a constant pressure system. In order to further enhance part load performance and prevent excessive charge air pressure at high load, all engines are equipped with a wastegate on the exhaust side. The wastegate arrangement permits a part of the exhaust gas to discharge after the turbine in the turbocharger at high engine load.

In addition there is a by-pass valve to increase the flow through the turbocharger at low engine speed and low engine load. Part of the charge air is conducted directly into the exhaust gas manifold (without passing through the engine), which increases the speed of the turbocharger. The net effect is increased charge air pressure at low engine speed and low engine load, despite the apparent waste of air.

All engines are provided with devices for water cleaning of the turbine and the compressor. The cleaning is performed during operation of the engine.

In-line engines have a transversely installed turbocharger. The turbocharger can be located at either end of the engine and the exhaust gas outlet can be vertical, inclined or horizontal in the longitudinal direction of the engine. V-engines have transversely installed turbochargers as well, which permits inclined or horizontal exhaust gas outlets in longitudinal direction to minimise the required height above the engine. Also V-engines are available with the turbochargers at either end of the engine.

A two-stage charge air cooler is standard. Heat is absorbed with high temperature (HT) cooling water in the first stage, while low temperature (LT) cooling water is used for the final air cooling in the second stage. The engine has two separate cooling water circuits. The flow of LT cooling water through the charge air cooler is controlled to maintain a constant charge air temperature.

4.2.16 Automation system

Engines with conventional fuel injection are available with two different levels of automation. Automation level 1 has a completely hardwired signal interface with the external systems, whereas automation level 2 has hardwired interface for control functions and a bus communication interface for alarm and monitoring. Engines with common rail fuel injection are always equipped with automation system level 2, which in such case includes fuel injection control.

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

The major additional features of automation level 2 are: all necessary engine control functions are handled by the equipment on the engine, bus communication to external systems, a more comprehensive local display unit, and fuel injection control for common rail engines.

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

4.3 Humidification of charge air (Wetpac H)

The new NO_x reduction technology developed by Wärtsilä is named Wetpac H. The principle of Wetpac H is to introduce water with the intake air to reduce the combustion temperature and thereby the formation of NO_x. Pressurized water is injected directly after the compressor of the turbocharger. The high temperature of the compressed air evaporates the water, which enters the cylinders as steam. A water mist catcher prevents water in liquid state from entering the cylinders. The NO_x reduction is up to 50%, and the water consumption is about two times the fuel oil consumption. Wetpac H is available as an option for fuels with sulphur contents less than 1.5%.

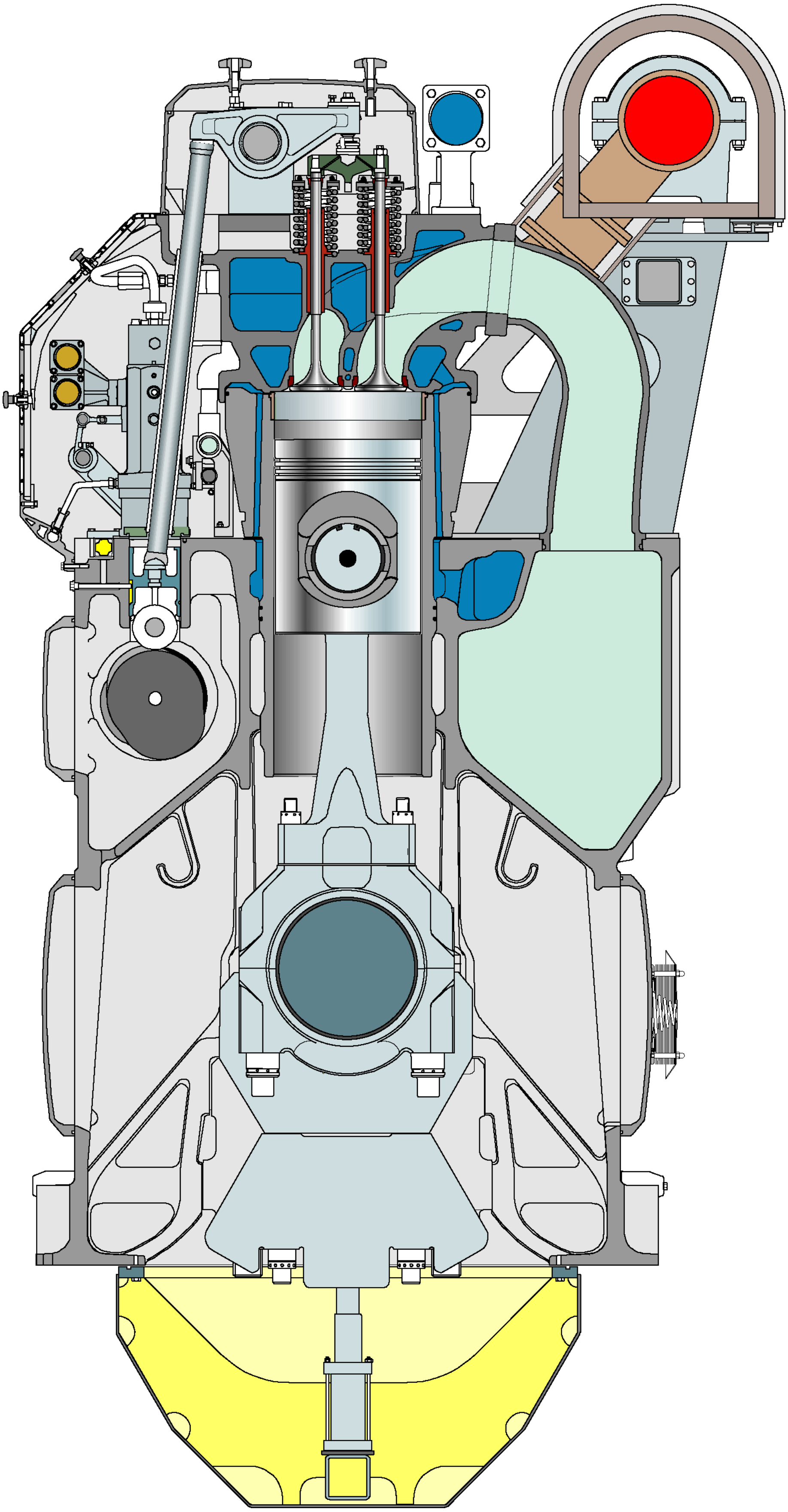
4.4 Direct water injection (DWI)

Water for Direct Water Injection is supplied from an external pump unit to a manifold in the hot-box, and further via a flow fuse to each injector. Fuel and water are injected through separate injectors. Excessive water is taken back to an external tank.

DWI reduces NO_x emissions typically by 50...60 % without adversely affecting the power output. Built-in safety features enable immediate water shut-off in the event of excessive water flow or water leakage. The water system is completely separate from the fuel system: if water shut-off should prove necessary, engine operation is not affected. The water-to-fuel ratio is typically within the range 0.4...0.7. Direct water injection is an option for low sulphur fuel (below 1.5%).

4.5 Cross section of the engine

Figure 4.2 Cross section of the in-line engine



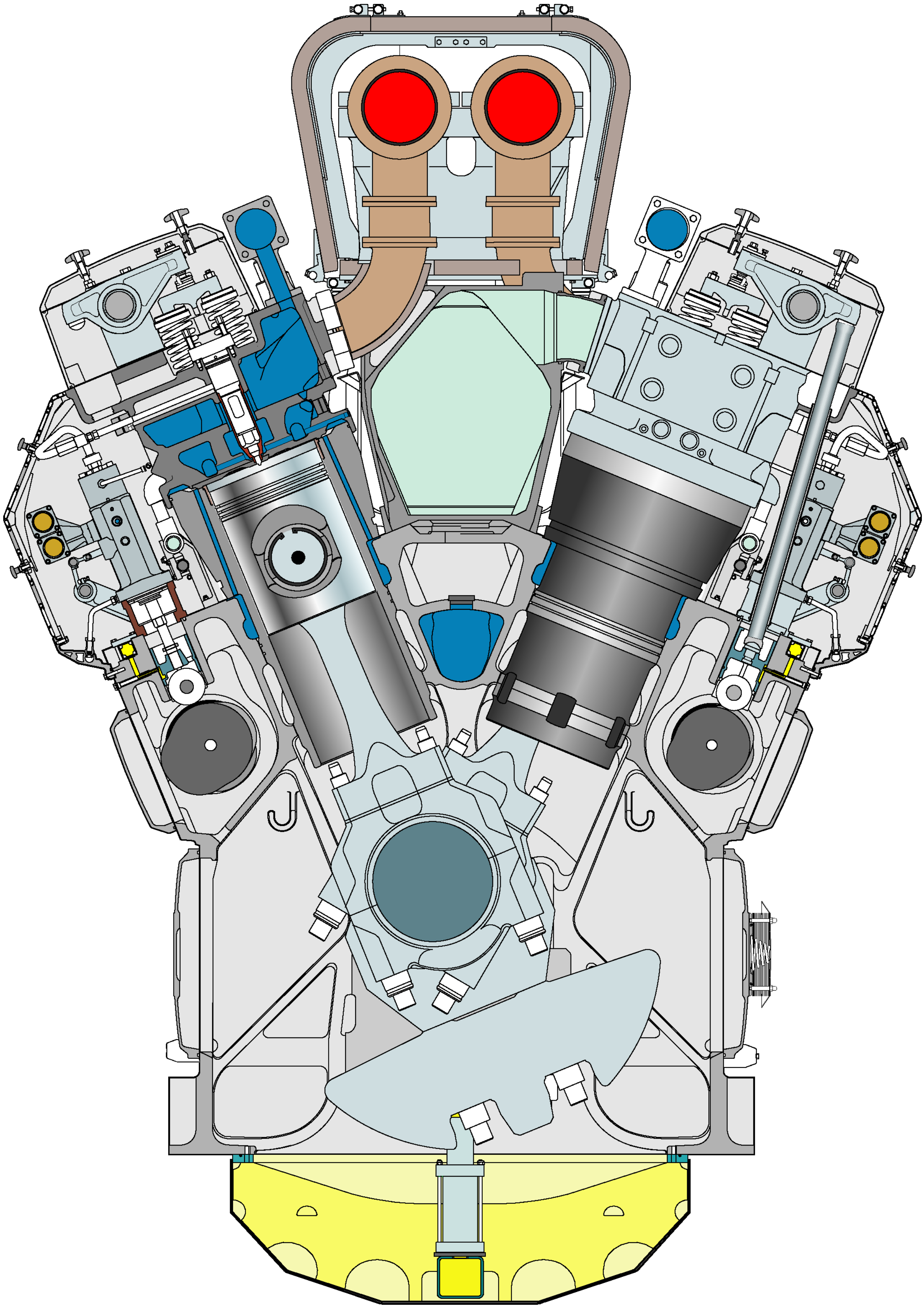


Figure 4.3 Cross section of the V-engine

4.6 Overhaul intervals and expected life times

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

Table 4.1 Time between inspection or overhaul [h] (4V92A0485b / 4V92A0498b)

Work description	HFO	MDO/LFO
Injector, testing	3000	3000
Injection pump	12000	12000
Cylinder head	12000	16000
Piston, liner	12000	16000
Piston crown/skirt, dismantling of one	12000	16000
Piston crown/skirt, dismantling of all	24000	32000
Big end bearing, inspection of one	12000	16000
Big end bearing, replacement of all	36000	36000
Main bearing, inspection of one	18000	18000
Main bearing, replacement of all	36000	36000
Camshaft bearing, inspection of one	36000	36000
Camshaft bearing, replacement of all	60000	60000
Turbocharger, mechanical cleaning	12000	12000
Turbocharger bearings, inspection	12000	12000
Charge air cooler cleaning	6000	6000

Table 4.2 Expected life times [h] (4V92A0485b / 4V92A0498b)

Component	HFO	MDO/LFO
Injection nozzles	6000	6000
Injection pump element	24000	24000
Inlet valve seat	36000	36000
Inlet valve, guide and rotator	24000	32000
Exhaust valve seat	36000	36000
Exhaust valve, guide and rotator	24000	32000
Cylinder head	60000	64000
Piston crown, including one reconditioning	36000	48000
Piston skirt	60000	64000
Piston rings	12000	16000
Cylinder liner	72000	96000
Antipolishing ring	12000	16000
Gudgeon pin	60000	64000
Gudgeon pin bearing	36000	36000
Big end bearing	36000	36000
Main bearing	36000	36000
Camshaft bearing	60000	60000
Turbocharger plain bearings	36000	36000
Charge air cooler	36000	48000
Rubber elements for flexible mounting	60000	60000

5. Piping design, treatment and installation

5.1 General

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.

5.2 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.

5.3 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

5.4 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) has to be selected.
- 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.

5.5 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

5.6 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

5.7 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.

5.8 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

5.8.1 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.

5.8.2 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.

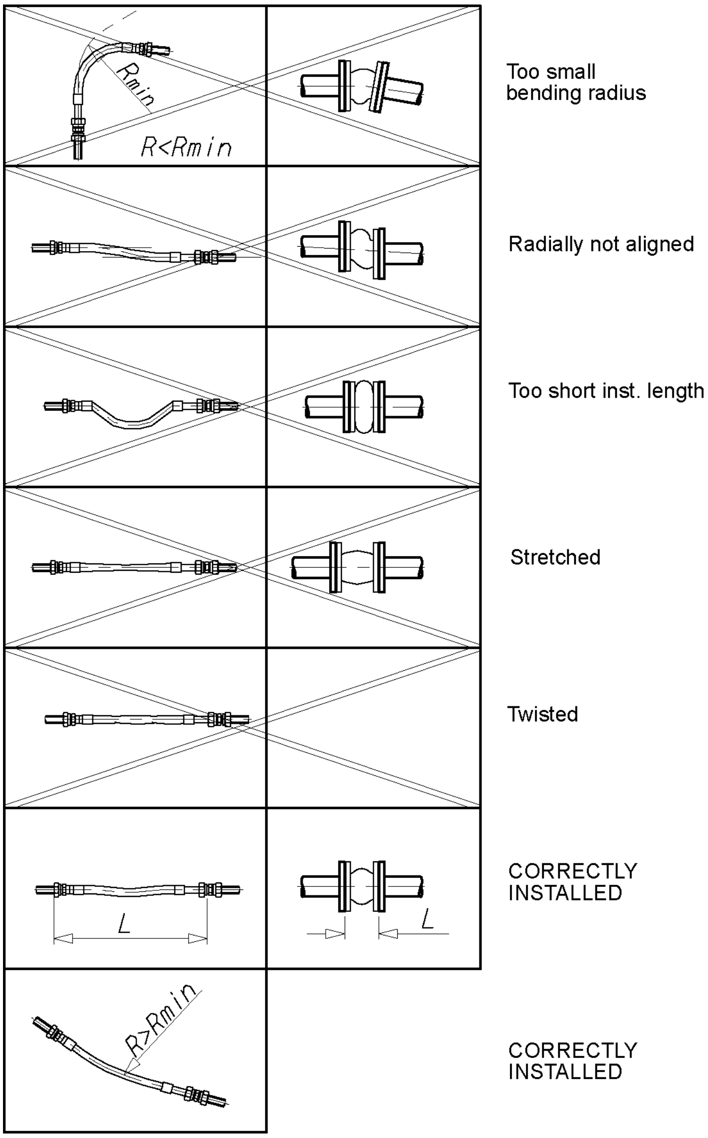
5.9 Flexible pipe connections

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)



5.10 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)

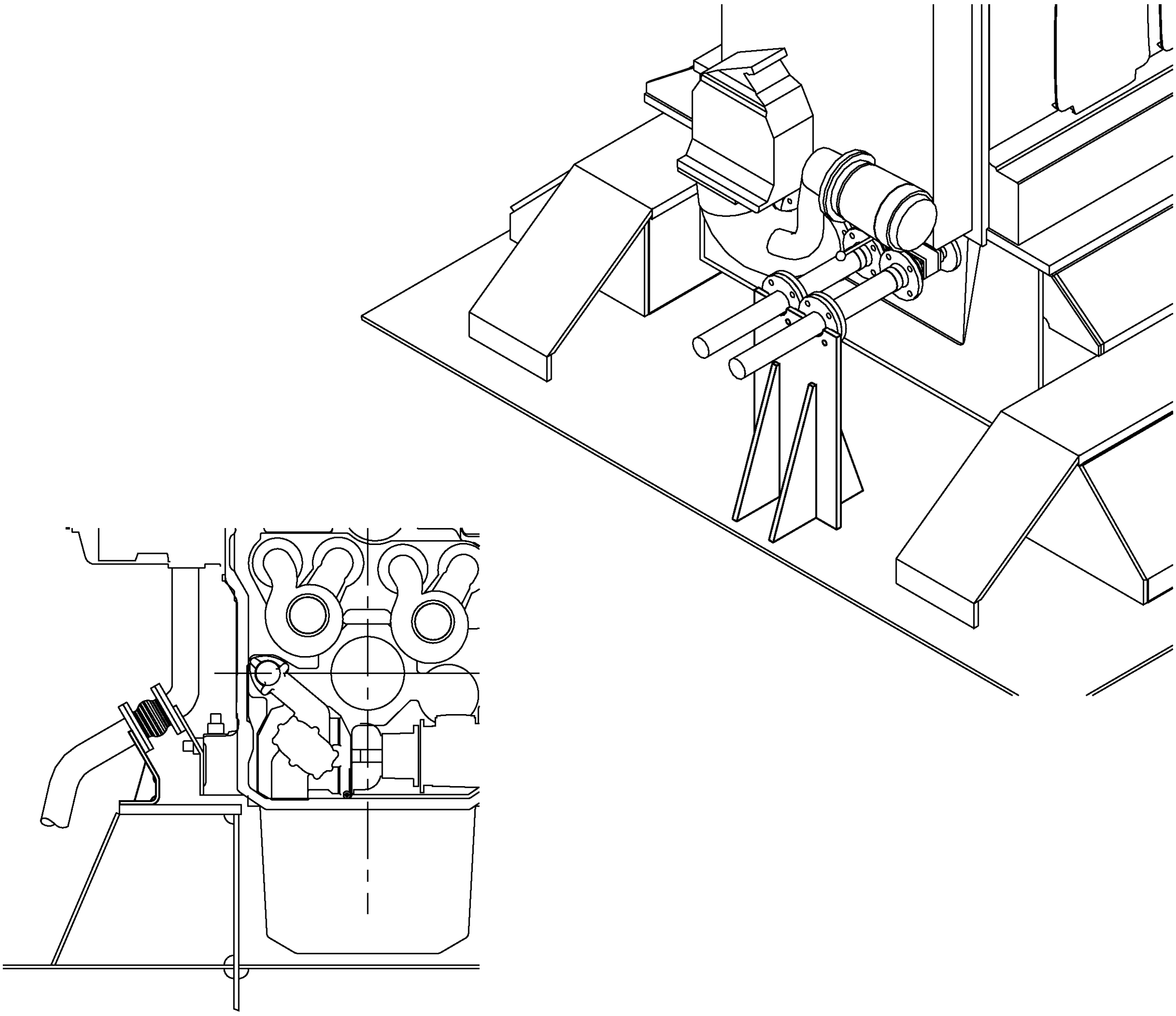
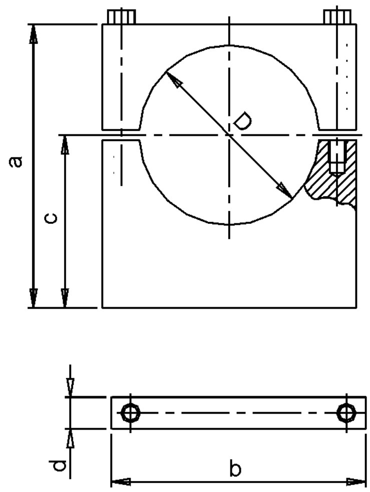


Figure 5.3 Pipe clamp for fixed support (4V61H0842)



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

d_u = Pipe outer diameter

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	2.8 / 2.0 [5]	2.8 / 2.0 [5]	2.8 / 2.0 [5]	2.8 / 2.0 [5]	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.

5) 2.8 cSt with conventional fuel injection system, 2.0 cSt with common rail fuel injection system

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	20±4	20±4	
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 are very good ignitors. Cracked residues delivered as bunkers may range from 840 to - in exceptional cases - above 900. Most bunkers remain in the max. 850 to 870 range at the moment.

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 blading 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.

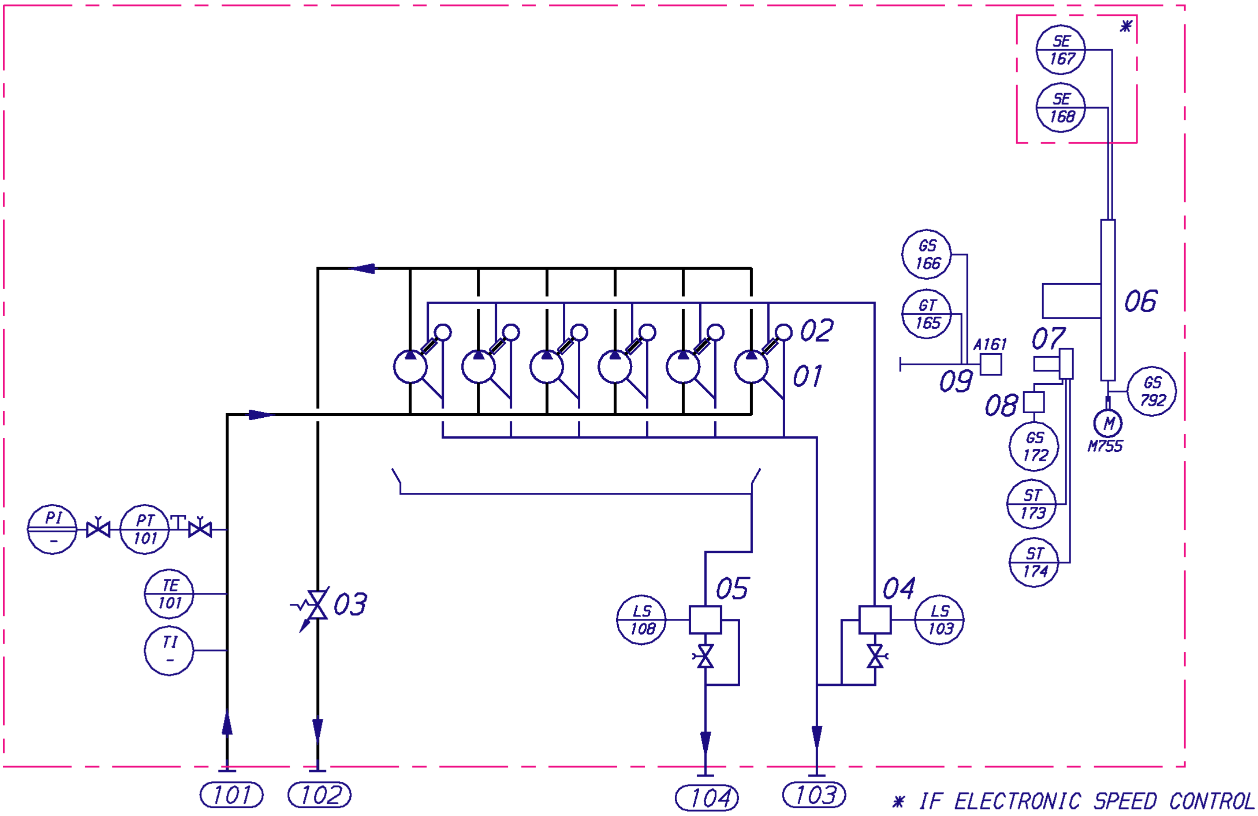
The limits above concerning HFO 2 also correspond to the demands of the following standards:

- 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 include any added substances or chemical waste, which jeopardizes the safety of installations or adversely affects the performance of the engines or is hamful to personnel or contributes overall to air pollution.

6.2 Internal fuel oil system

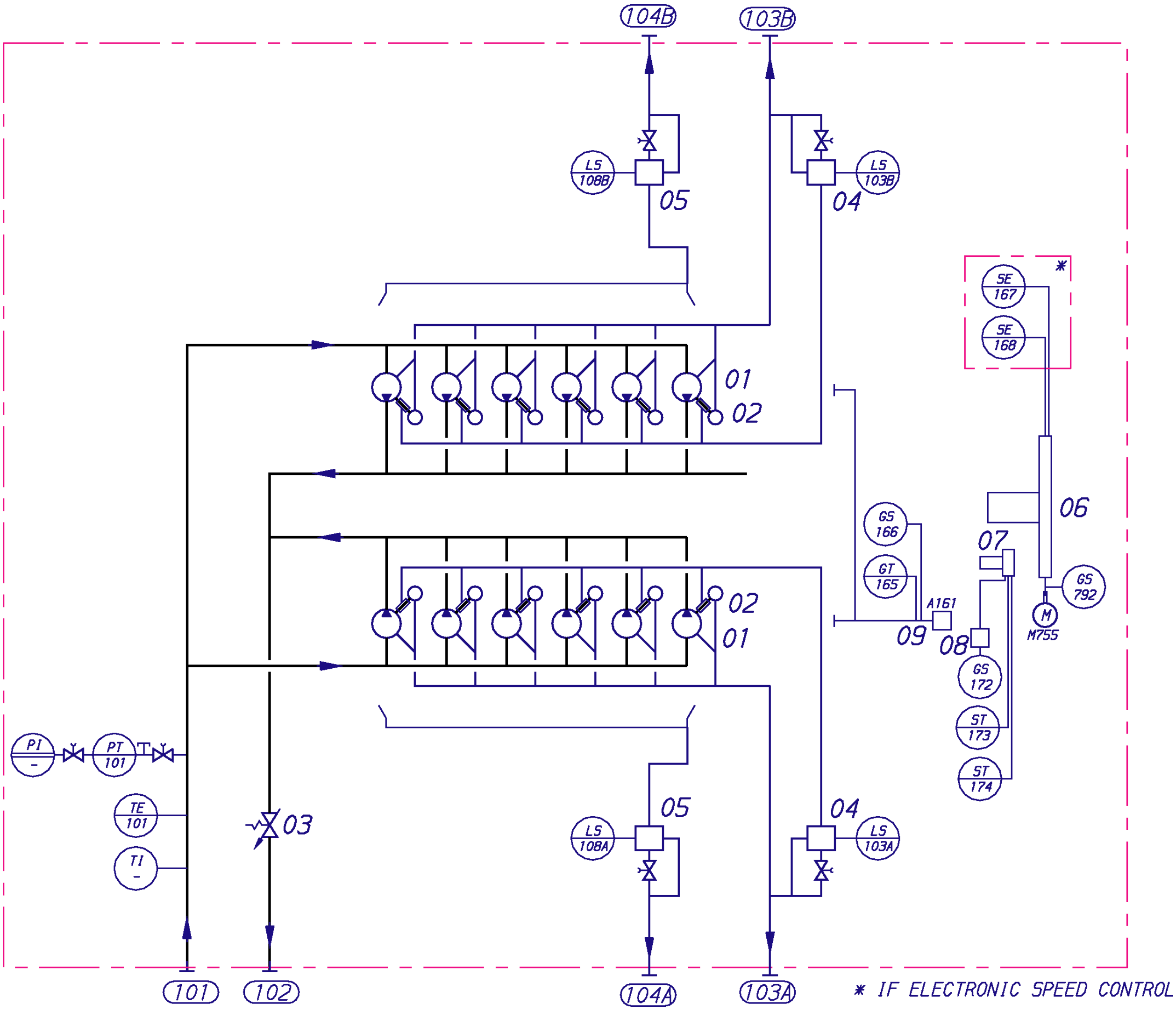
Figure 6.1 Internal fuel system, in-line engine (DAAE018492a)



System components		Sensors and indicators	
01	Injection pump	PT101	Fuel oil inlet pressure
02	Injection valve	TE101	Fuel oil inlet temperature
03	Pressure control valve	LS103	Clean fuel oil leakage level
04	Clean fuel oil leakage collector	LS108	Dirty fuel oil leakage level
05	Dirty fuel oil leakage collector	A161	Governor or actuator
06	Flywheel	GT165	Fuel rack position
07	Camshaft	GS166	Overload
08	Overspeed protection	GS172	Overspeed
09	Fuel rack	ST173	Engine speed
		ST174	Engine speed
PI	Manometer	M755	Electric motor for turning gear
TI	Thermometer	GS792	Turning gear engaged
		SE167	Engine speed
		SE168	Engine speed

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

Figure 6.2 Internal fuel system, V-engine (DAAE018493a)



System components		Sensors and indicators	
01	Injection pump	PT101	Fuel oil inlet pressure
02	Injection valve	TE101	Fuel oil inlet temperature
03	Pressure control valve	LS103A	Clean fuel oil leakage level, A-bank
04	Clean fuel oil leakage collector	LS103B	Clean fuel oil leakage level, B-bank
05	Dirty fuel oil leakage collector	LS108A	Dirty fuel oil leakage level, A-bank
06	Flywheel	LS108B	Dirty fuel oil leakage level, B-bank
07	Camshaft	A161	Governor or actuator
08	Overspeed protection	GT165	Fuel rack position
09	Fuel rack	GS166	Overload
		GS172	Overspeed
PI	Manometer	ST173	Engine speed
TI	Thermometer	ST174	Engine speed

System components	Sensors and indicators	
	M755	Electric motor for turning gear
	GS792	Turning gear engaged
	SE167	Engine speed
	SE168	Engine speed

Pipe connections		Size	Pressure class	Standard
101	Fuel inlet	DN32	PN40	ISO 7005-1
102	Fuel outlet	DN32	PN40	ISO 7005-1
103A	Leak fuel drain, clean fuel, A-bank	OD28		
103B	Leak fuel drain, clean fuel, B-bank	OD28		
104A	Leak fuel drain, dirty fuel, A-bank	OD48		
104B	Leak fuel drain, dirty fuel, B-bank	OD48		

The Wärtsilä 46 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*. 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.

The fuel pipe connections on the engine are smaller than the required pipe diameter on the installation side.

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 safety filter, 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

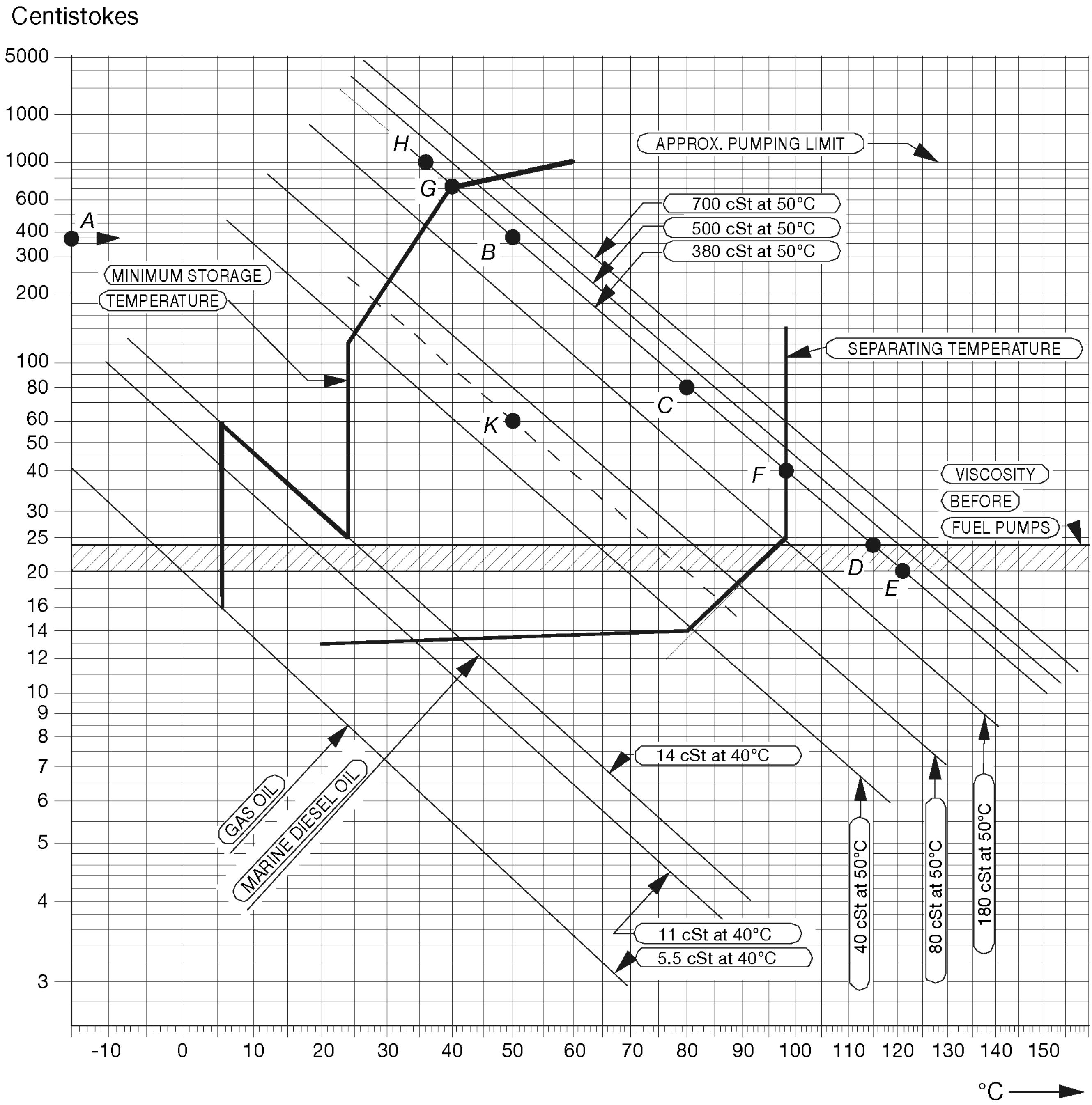
Heating is required for:

- 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 6.3 Fuel oil viscosity-temperature diagram for determining the pre-heating temperatures of fuel oils (DAAE012908)



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 - 121°C (D-E) before the fuel injection pumps, to 98°C (F) at the centrifuge 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 - 80°C, centrifuging 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.

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)

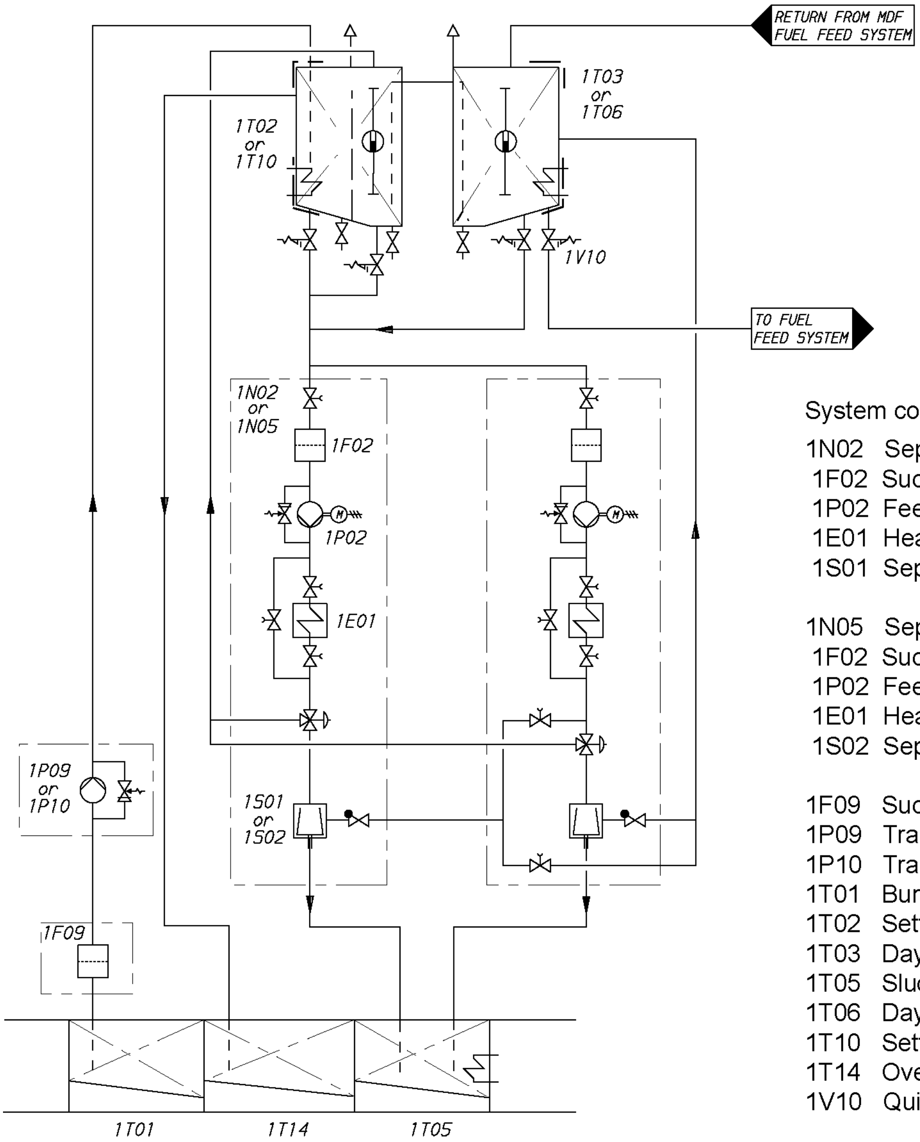
Separators are usually supplied as pre-assembled units designed by the separator manufacturer.

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 6.4 Fuel transfer and separating system (3V76F6626)



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)

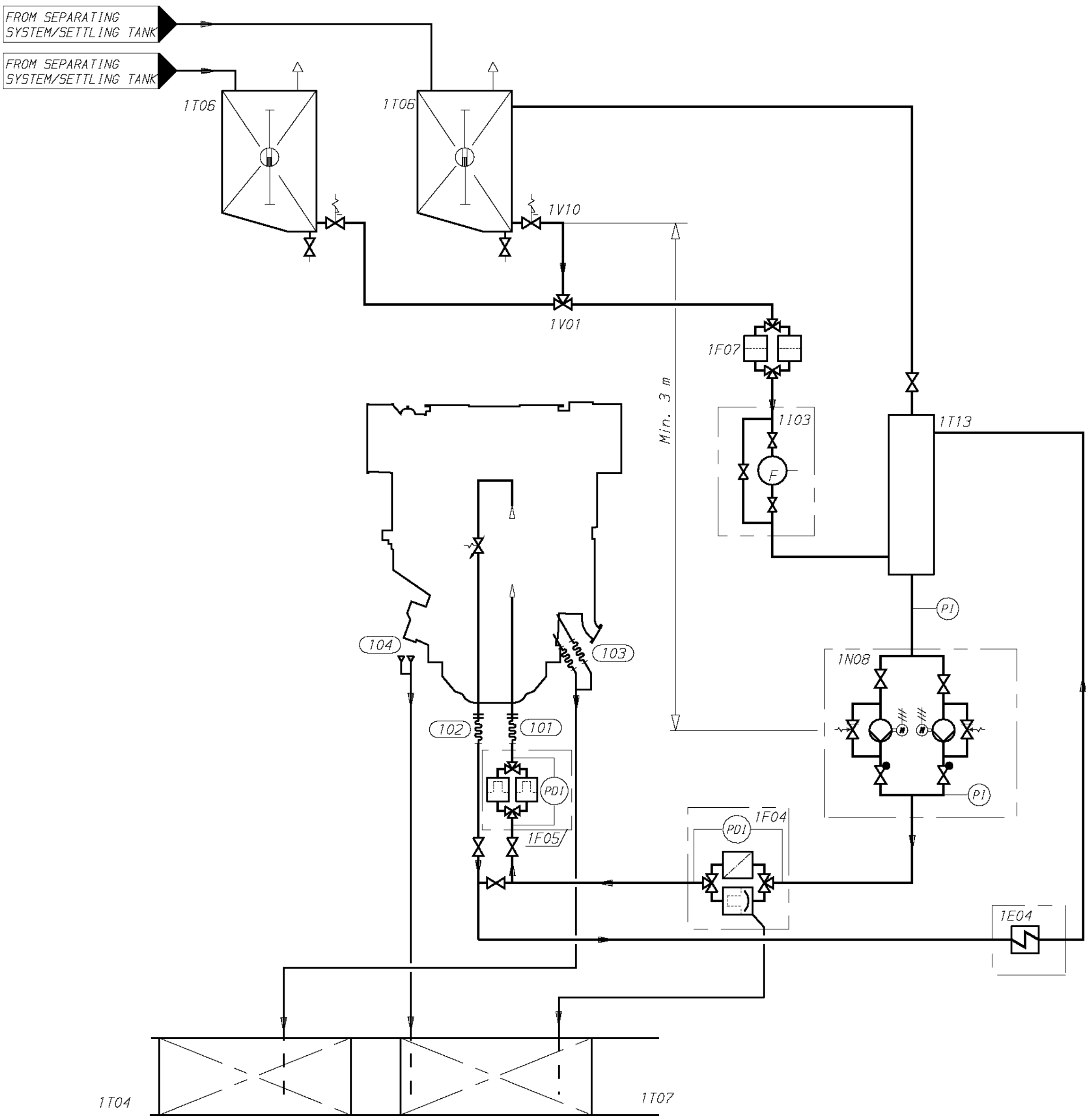
A separator for MDF is recommended also for for installations operating primarily on HFO. The MDF separator can be a smaller size dedicated MDF separator, or a stand-by HFO separator used for MDF.

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 6.5 Example of fuel oil system (MDF) (DAAE037642)



Size of the piping in the installation to be calculated case by case.

System components		Pipe connections	
1E04	Cooler (MDF)	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
1I03	Flow meter (MDF)		
1N08	Fuel feed pump unit (MDF)		
1T04	Leak fuel tank (clean fuel)		
1T06	Day tank (MDF)		
1T07	Leak fuel tank (dirty fuel)		
1T13	Return fuel tank		
1V01	Changeover valve		
1V10	Quick closing valve (fuel oil tank)		

* Flexible hoses are used on all engines (also rigidly mounted) to reduce pressure peaks.

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.

Circulation pump, MDF (1P03)

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

Design data:	
Capacity	4 x the total consumption of the connected engines and the flush quantity of a possible automatic filter
Design pressure	1.6 MPa (16 bar)
Max. pressure (safety valve)	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 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 volume of the return fuel tank should be about 60-150 litres.

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:	
- automatic filter	35 μm (absolute mesh size)
- insert filter	35 μm (absolute mesh size)
Maximum permitted pressure drops at 14 cSt:	
- clean filter	20 kPa (0.2 bar)
- alarm	80 kPa (0.8 bar)

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 data:	
Design temperature	50°C
Design flow	4 times the fuel consumption at full load
Design pressure	1.6 MPa (16 bar)
Fineness	37 µm (absolute mesh size)
Maximum permitted pressure drops at 14 cSt:	
- clean filter	20 kPa (0.2 bar)
- alarm	80 kPa (0.8 bar)

Pressure control valve, MDF (1V02)

The pressure control valve increases 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 2.8 cSt. When operating on MDF, the practical consequence is that the fuel oil inlet temperature must be kept below 45...50°C.

The heat transferred from the engine to the fuel circulating in the system is approximately 4 kW/cyl at full load and 0.5 kW/cyl at idle.

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.

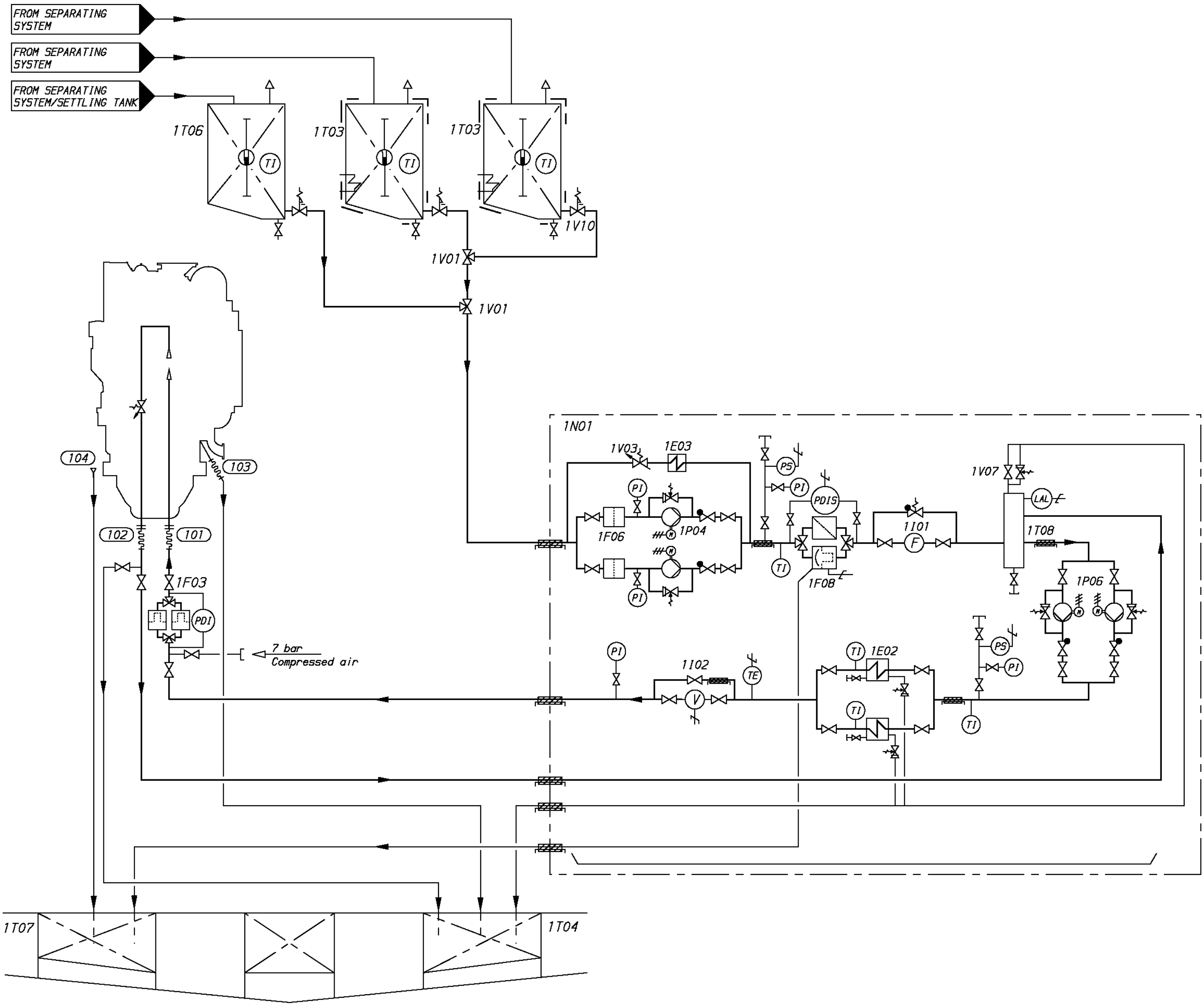
Black out start

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 6.6 Example of fuel oil system (HFO), single engine installation (3V76F6659)

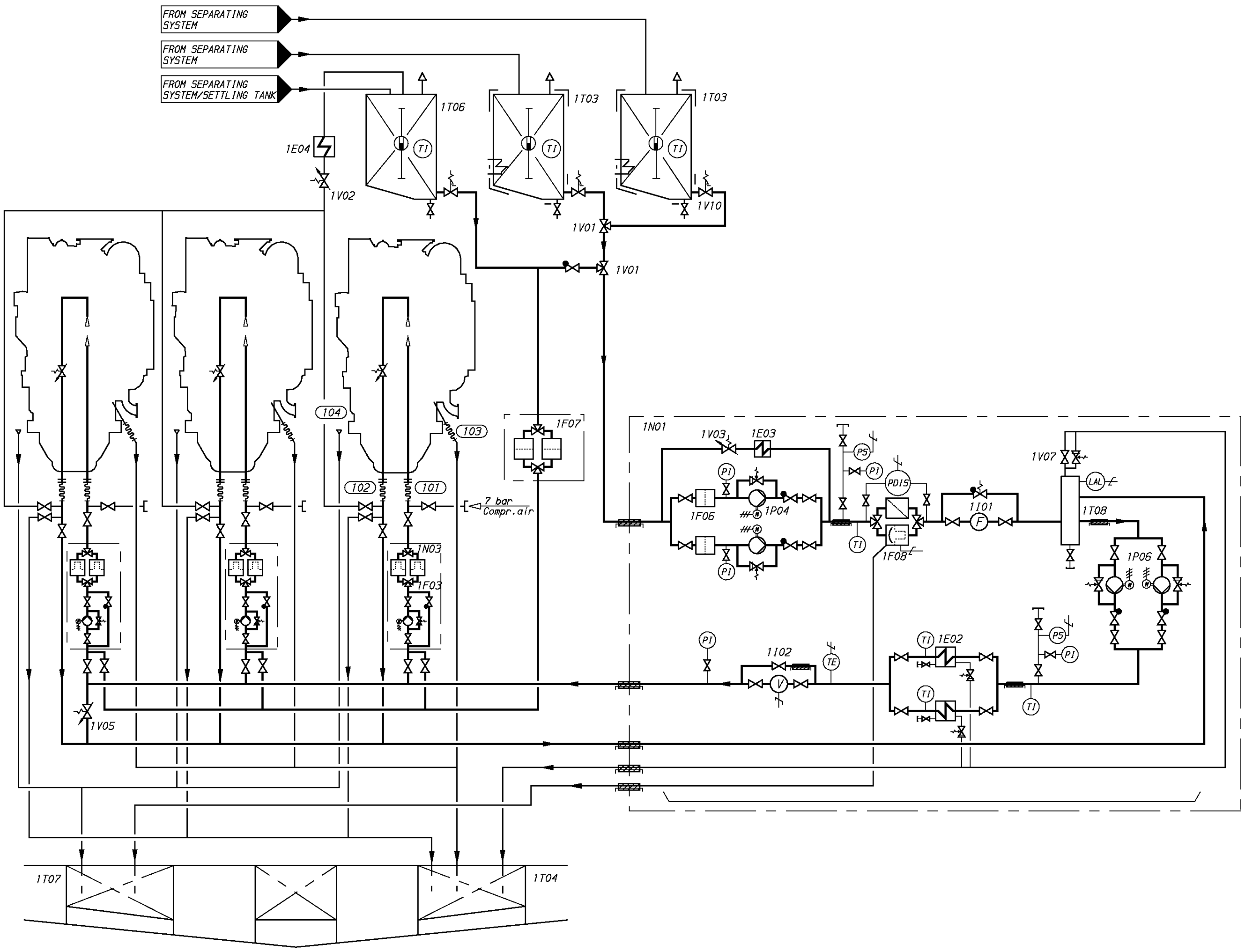


Size of the piping in the installation to be calculated case by case.

System components				Pipe connections	
1E02	Heater	1T03	Day tank (HFO)	101	Fuel inlet *
1E03	Cooler	1T04	Leak fuel tank, clean fuel	102	Fuel outlet *
1F03	Safety filter (HFO)	1T06	Day tank (MDF)	103	Leak fuel drain, clean fuel
1F06	Suction filter	1T07	Leak fuel tank, dirty fuel	104	Leak fuel drain, dirty fuel
1F08	Automatic filter	1T08	De-aeration tank		
1I01	Flow meter	1V01	Change-over valve		
1I02	Viscosity meter	1V03	Pressure control valve		
1N01	Feeder/booster unit	1V07	Venting valve		
1P04	Fuel feed pump	1V10	Quick closing valve		
1P06	Circulation pump				

* Flexible hoses are used on all engines (also rigidly mounted) to reduce pressure peaks.

Figure 6.7 Example of fuel oil system (HFO), multiple engine installation (DAAE037640)



Size of the piping in the installation to be calculated case by case.

System components				Pipe connections	
1E02	Heater	1P06	Circulation pump	101	Fuel inlet *
1E03	Cooler	1T03	Day tank (HFO)	102	Fuel outlet *
1E04	Cooler (MDF return line)	1T04	Leak fuel tank, clean fuel	103	Leak fuel drain, clean fuel
1F03	Safety filter (HFO)	1T06	Day tank (MDF)	104	Leak fuel drain, dirty fuel
1F06	Suction filter	1T07	Leak fuel tank, dirty fuel		
1F07	Suction strainer (MDF)	1T08	De-aeration tank		
1F08	Automatic filter	1V01	Changeover valve		
1I01	Flow meter	1V02	Pressure control valve (MDF)		
1I02	Viscosity meter	1V03	Pressure control valve		
1N01	Feeder/booster unit	1V05	Overflow valve (HFO/MDF)		
1N03	Pump and filter unit (HFO/MDF)	1V07	Venting valve		
1P04	Fuel feed pump	1V10	Quick closing valve		

* Flexible hoses are used on all engines (also rigidly mounted) to reduce pressure peaks.

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 feed 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 feed 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 should be at least 2.8 cSt and not drop below 2.0 cSt even during short transients.

Number of engines in the same system

When the fuel feed unit serves Wärtsilä 46 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 auiliary 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.

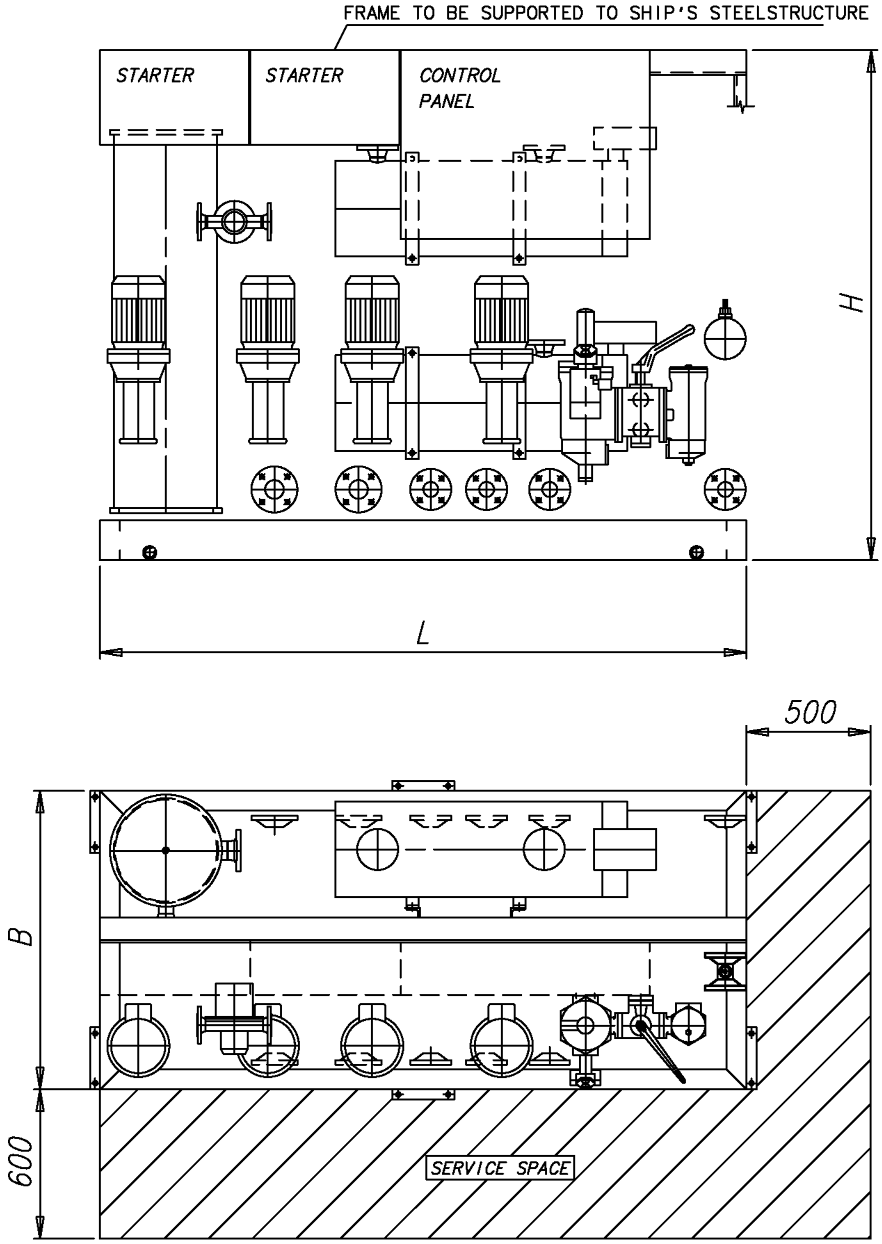
Fuel feed unit, HFO (1N01)

A completely assembled fuel feed 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 6.8 Fuel feed unit, example (DAAE006659)



	H	L	B
STEAM	1800	2500	1100
ELECTRICAL	2050	2600	1200

Feed pump, HFO (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
Design pressure	1.6 MPa (16 bar)
Max. pressure (safety valve)	0.7 MPa (7 bar)
Design temperature	100°C
Viscosity for dimensioning of electric motor	1000 cSt

Pressure control valve, HFO (1V03)

The pressure control valve in the fuel feed 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, HFO (1F08)

It is recommended to select an automatic filter with a manually cleaned filter in the bypass line. The filter should be installed 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 higher than 25 cSt/100°C
Design flow	Equal to feed pump capacity
Design pressure	1.6 MPa (16 bar)
Fineness:	
- automatic filter	35 μm (absolute mesh size)
- by-pass filter	35 μm (absolute mesh size)
Maximum permitted pressure drops at 14 cSt:	
- clean filter	20 kPa (0.2 bar)
- alarm	80 kPa (0.8 bar)

Flow meter, HFO (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 (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 about 60-150 l.

Circulation pump, HFO (1P06)

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

If the automatic filter is installed on the pressure side of this pump, then the flush quantity of the filter must be taken into account for this pump as well.

Design data:	
Capacity	4 x the total consumption of the connected engines

Design data:

Design pressure	1.6 MPa (16 bar)
Max. pressure (safety valve)	1.2 MPa (12 bar)
Design temperature	150°C
Viscosity for dimensioning of electric motor	500 cSt

Heater, HFO (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 (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)

Safety filter (1F03)

The fuel oil safety filter is a full flow duplex type filter with steel net. This filter must be installed as near the engine as possible. The filter should be equipped with a heating jacket. In multiple engine installations a common filter is preferred to separate filters for each engine, as it is important to ensure an even distribution of the flow.

The diameter of the pipe between the safety filter and the engine should be the same as between the fuel feed unit and the safety filter.

Design data:

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

Design data:

- alarm	80 kPa (0.8 bar)

Overflow valve, HFO (1V05)

In multiple engine installations an overflow valve should be installed between the feed line and the return line, if several engines are served by the same fuel feed unit. 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
Design pressure	1.6 MPa (16 bar)
Design temperature	150°C
Set-point (Δp)	0.3...0.6 MPa (3...6 bar)

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.

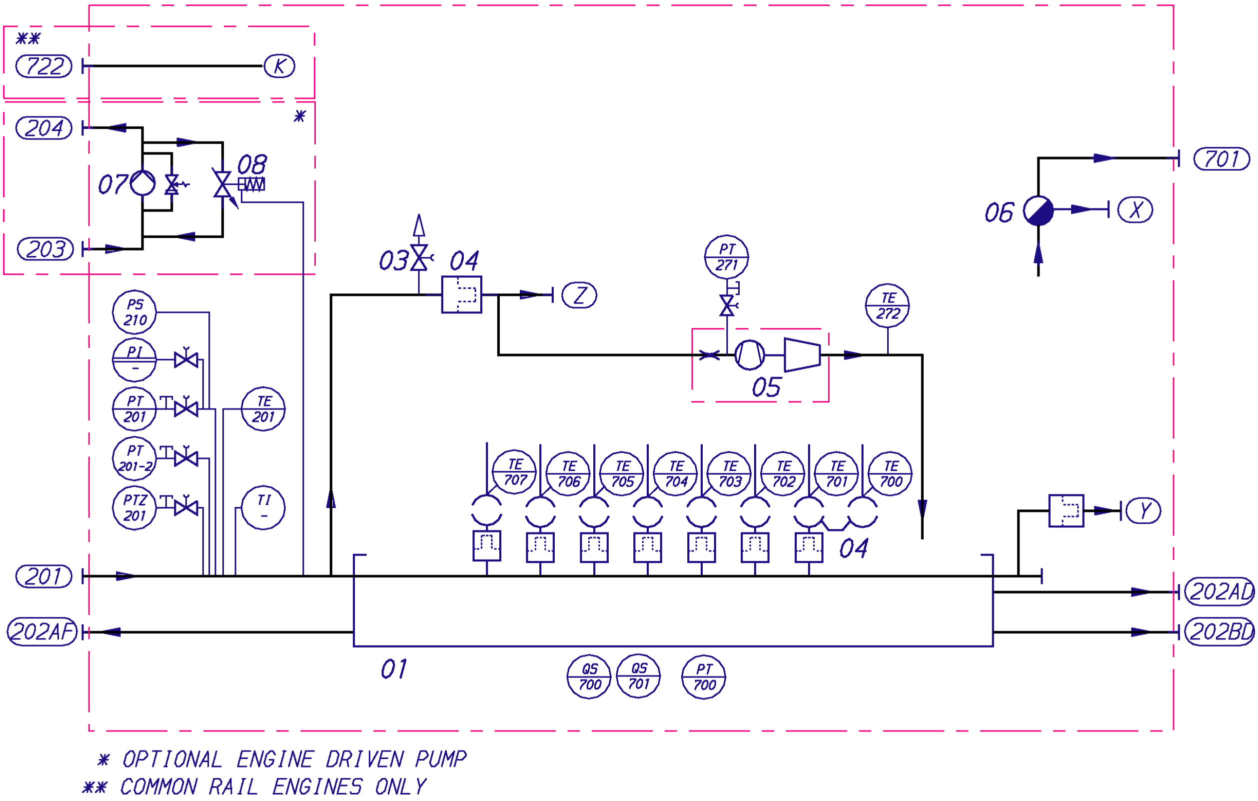
7.1.3 Oil in turning device

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 engines (DAAE018494b)



System components	
01	Oil sump
04	Running-in filter, to be removed after commissioning
05	Turbocharger
06	Crankcase breather
07	Lubricating oil main pump
08	Pressure control valve

Sensors and indicators	
PTZ201	Lubricating oil inlet pressure
PT201	Lubricating oil inlet pressure
PT201-2	Lubricating oil inlet pressure
TE201	Lubricating oil inlet temperature
PT271	Lubricating oil pressure before turbocharger
TE272	Lubricating oil temperature after turbocharger
PS210	Lubricating oil inlet pressure (stand-by)
QS700...	Oil mist in crankcase
PT700	Crankcase pressure
TE700...	Main bearing temperature

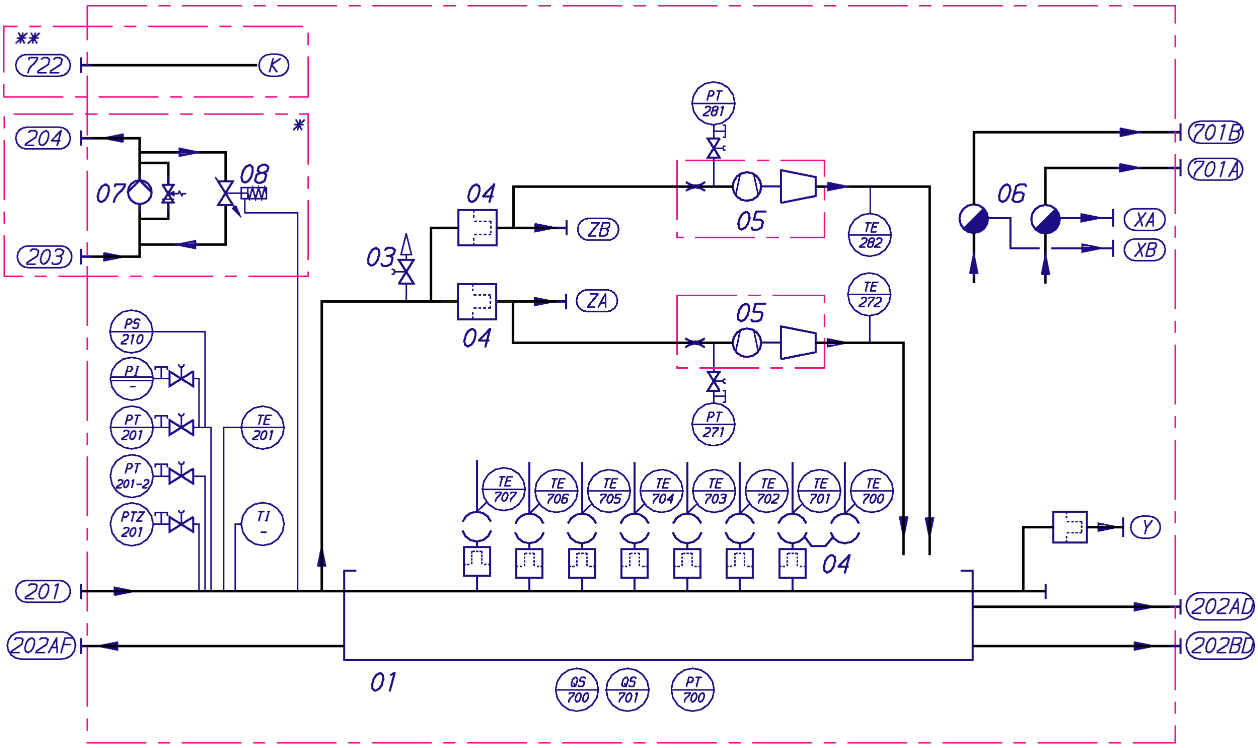
Pipe connections		Size	Pressure class	Standard
201	Lubricating oil inlet (to manifold)	DN125	PN16	ISO 7005-1
202AD	Lubricating oil outlet (from oil sump), D.E.	DN200	PN10	ISO 7005-1
202AF	Lubricating oil outlet (from oil sump), F.E.	DN200	PN10	ISO 7005-1
202BD	Lubricating oil outlet (from oil sump), D.E.	DN200	PN10	ISO 7005-1
203	Lubricating oil to engine driven pump	DN250 / DN300 [1)]	PN10	ISO 7005-1
204	Lubricating oil from engine driven pump	DN150 / DN200 [1)]	PN16 / PN10 [1)]	ISO 7005-1
224	Control oil to pressure control valve	M18 x 1.5		
701	Crankcase ventilation	OD114		
722	Control oil from external filter	DN25	PN40	ISO 7005-1
K	Control oil to common rail system			

[1)] 8L46, 9L46 variable speed

Pipe connections		Size	Pressure class	Standard
X	Crankcase breather drain to dirty leak fuel			
Y	Lubricating oil to intermediate gear wheels			
Z	Lubricating oil to valve gear, camshaft etc.			

[1)] 8L46, 9L46 variable speed

Figure 7.2 Internal lubricating oil system, V-engines (DAAE018495a)



System components	
01	Oil sump
04	Running-in filter, to be removed after commissioning
05	Turbocharger
06	Crankcase breather
07	Lubricating oil main pump
08	Pressure control valve

Sensors and indicators	
PTZ201	Lubricating oil inlet pressure
PT201	Lubricating oil inlet pressure
PT201-2	Lubricating oil inlet pressure
TE201	Lubricating oil inlet temperature
PT271	Lubricating oil pressure before turbocharger, A-bank
PT281	Lubricating oil pressure before turbocharger, B-bank
TE272	Lubricating oil temperature after turbocharger, A-bank
TE282	Lubricating oil temperature after turbocharger, B-bank
PS210	Lubricating oil inlet pressure (stand-by)
QS700...	Oil mist in crankcase
PT700	Crankcase pressure
TE700...	Main bearing temperature

Pipe connections		Size	Pressure class	Standard
201	Lubricating oil inlet (to manifold)	DN200	PN10	ISO 7005-1
202AD	Lubricating oil outlet (from oil sump), D.E.	DN250	PN10	ISO 7005-1
202AF	Lubricating oil outlet (from oil sump), F.E.	DN250	PN10	ISO 7005-1
202BD	Lubricating oil outlet (from oil sump), D.E.	DN250	PN10	ISO 7005-1
203	Lubricating oil to engine driven pump	DN300	PN10	ISO 7005-1

Pipe connections		Size	Pressure class	Standard
204	Lubricating oil from engine driven pump	DN200	PN10	ISO 7005-1
224	Control oil to pressure control valve	M18 x 1.5		
701A	Crankcase ventilation, A-bank	OD114		
701B	Crankcase ventilation, B-bank	OD114		
722	Control oil from external filter	DN25	PN40	ISO 7005-1
K	Control oil to common rail system			
XA	Crankcase breather drain to dirty leak fuel A-bank			
XB	Crankcase breather drain to dirty leak fuel, B-bank			
Y	Lubricating oil to intermediate gear wheels			
ZA	Lubricating oil to valve gear, camshaft etc. A-bank			
ZB	Lubricating oil to valve gear, camshaft etc. B-bank			

The Wärtsilä 46 engine is available with or without engine driven lubricating oil pump. Engine driven pump is however not possible in installations with a fixed pitch propeller connected to the engine.

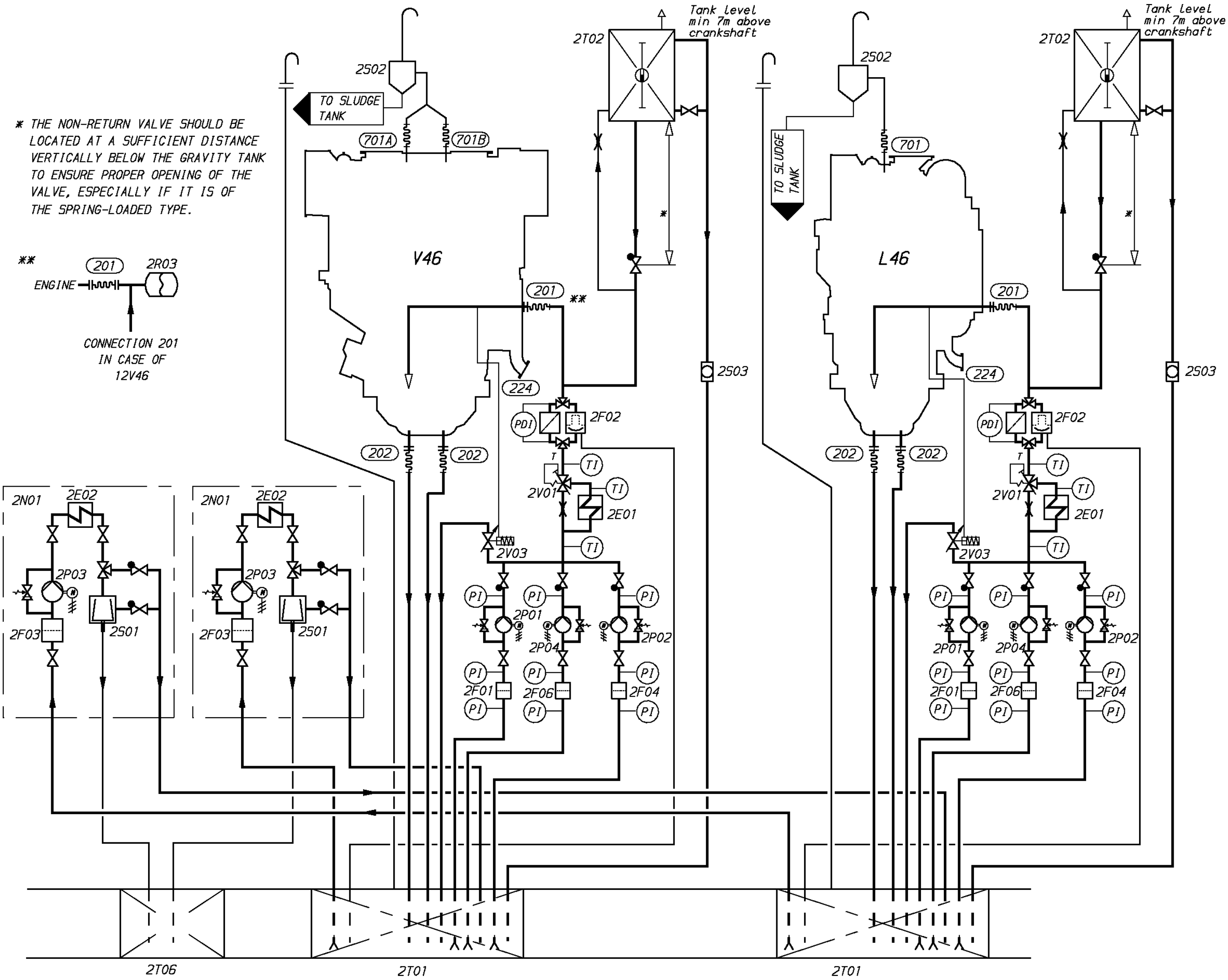
The engine driven lubricating oil pump is of screw type and it is equipped with a pressure control valve. Concerning suction height, flow rate and pressure of the engine driven pump, see *Technical data.*

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 6L46 and 12V46 engines. On other engines one outlet at the free end and both outlets at the driving end should be connected to the system oil tank.

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 Main engine external lubricating oil system, electrically driven pumps (3V76E4592a)



System components

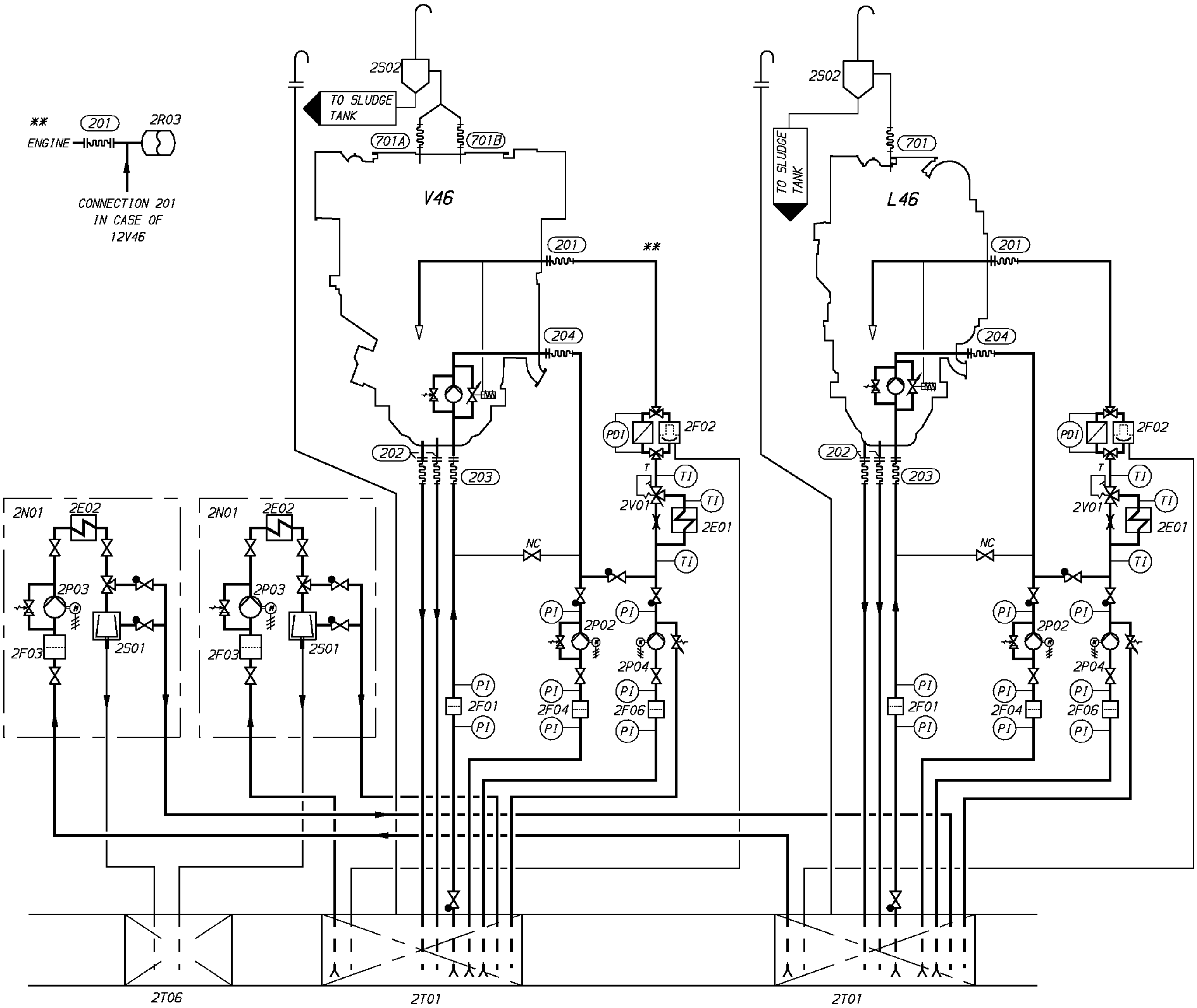
2E01	Lubricating oil cooler	2P04	Stand-by pump
2E02	Heater	2R03	Lubricating oil damper
2F01	Suction strainer	2S01	Separator
2F02	Automatic filter	2S02	Condensate trap
2F03	Suction filter	2S03	Sight glass
2F04	Suction strainer	2T01	System oil tank
2F06	Suction strainer	2T02	Gravity tank
2N01	Separator unit	2T06	Sludge tank
2P01	Main lubricating oil pump	2V01	Temperature control valve
2P02	Pre-lubricating oil pump	2V03	Pressure control valve
2P03	Separator pump		

Pipe connections

201	Lubricating oil inlet
202	Lubricating oil outlet *)
224	Control oil to pressure control valve
701	Crankcase air vent

*) Two outlets in each end are available

Figure 7.4 Main engine external lubricating oil system, engine driven pumps (3V76E4593a)



System components

2E01	Lubricating oil cooler	2F06	Suction strainer	2S01	Separator
2E02	Heater	2N01	Separator unit	2S02	Condensate trap
2F01	Suction strainer	2P02	Pre-lubricating oil pump	2T01	System oil tank
2F02	Automatic filter	2P03	Separator pump	2T06	Sludge tank
2F03	Suction filter	2P04	Stand-by pump	2V01	Temperature control valve
2F04	Suction strainer	2R03	Lubricating oil damper		

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

*) Two outlets in each end are available

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 designed by the separator manufacturer.

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 continuos 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.

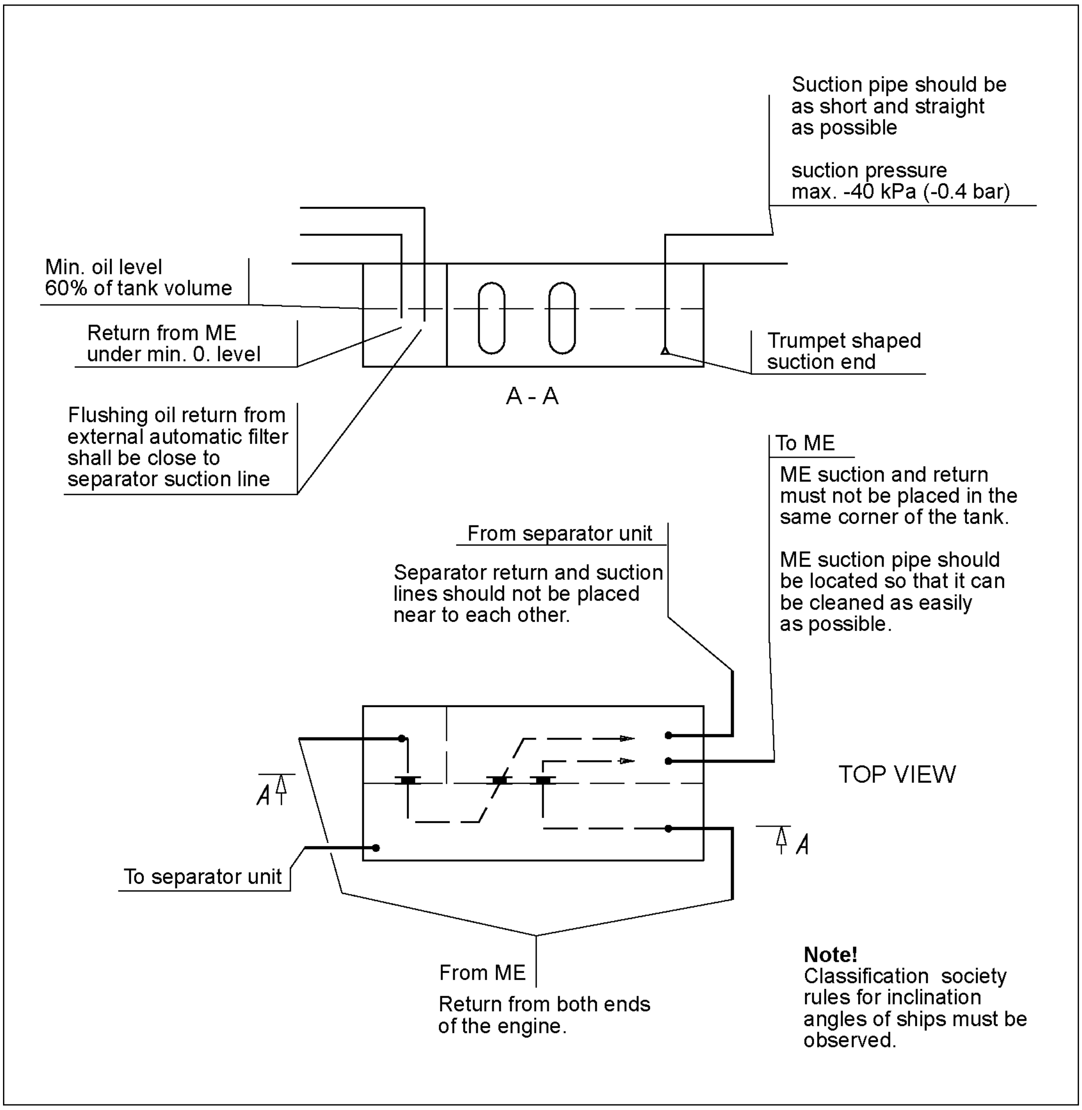
The suction pipe of the pump should have a trumpet shaped or conical inlet to minimise the pressure loss. For the same reason the suction pipe shall be as short and straight as possible and have a sufficient diameter. A pressure gauge shall be installed close to the inlet of the lubricating oil pump. 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 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 7.5 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 Gravity tank (2T02)

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

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

Engine type	**Tank volume [m³]**
6L46	1.0
8L46, 9L46, 12V46	2.0
16V46, 18V46	3.0

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

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

Design data:	
Fineness	0.5...1.0 mm

7.3.5 Lubricating oil pump (2P01, 2P04)

An electrically driven lubricating oil pump is required in fixed pitch propeller installations.

A lubricating oil pump of screw type is recommended. The pump must be provided with a safety valve.

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.

Design data:	
Capacity	see *Technical data*
Design pressure	1.0 MPa (10 bar)
Max. pressure (safety valve)	800 kPa (8 bar)
Design temperature	100°C
Viscosity for dimensioning the electric motor	500 cSt

Example of required power, oil temperature 40°C. The actual power requirement is determined by the type of pump and the flow resistance in the external system.

	6L46	**8L46**	**9L46**	**12V46**	**16V46**	**18V46**
Pump [kW]	45	45	50	65	80	90
Electric motor [kW]	55	55	55	75	90	110

7.3.6 Pre-lubricating oil pump (2P02)

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

Example of required power, oil temperature 40°C.

	6L46	8L46	9L46	12V46	16V46	18V46
Pump [kW]	5	6	8	8	11	12
Electric motor [kW]	7.5	7.5	11	11	15	15

Example of required power, oil temperature 20°C.

	6L46	8L46	9L46	12V46	16V46	18V46
Pump [kW]	11	14	17	18	25	26
Electric motor [kW]	15	15	18.5	22	30	30

7.3.7 Pressure control valve (2V03)

An external pressure control valve is required in installations with electrically driven lubricating oil pump. The surplus flow from the pressure control valve should be conducted back to the oil tank.

The control valve must have remote pressure sensing from connection 224 on the engine, if the electrically driven pump is the main lubricating oil pump. An adjustable control valve with direct pressure sensing is acceptable for stand-by pumps. (The control valve integrated in the engine driven lubricating oil pump does not control the pressure from the stand-by pump).

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	400 kPa (4 bar) at engine inlet

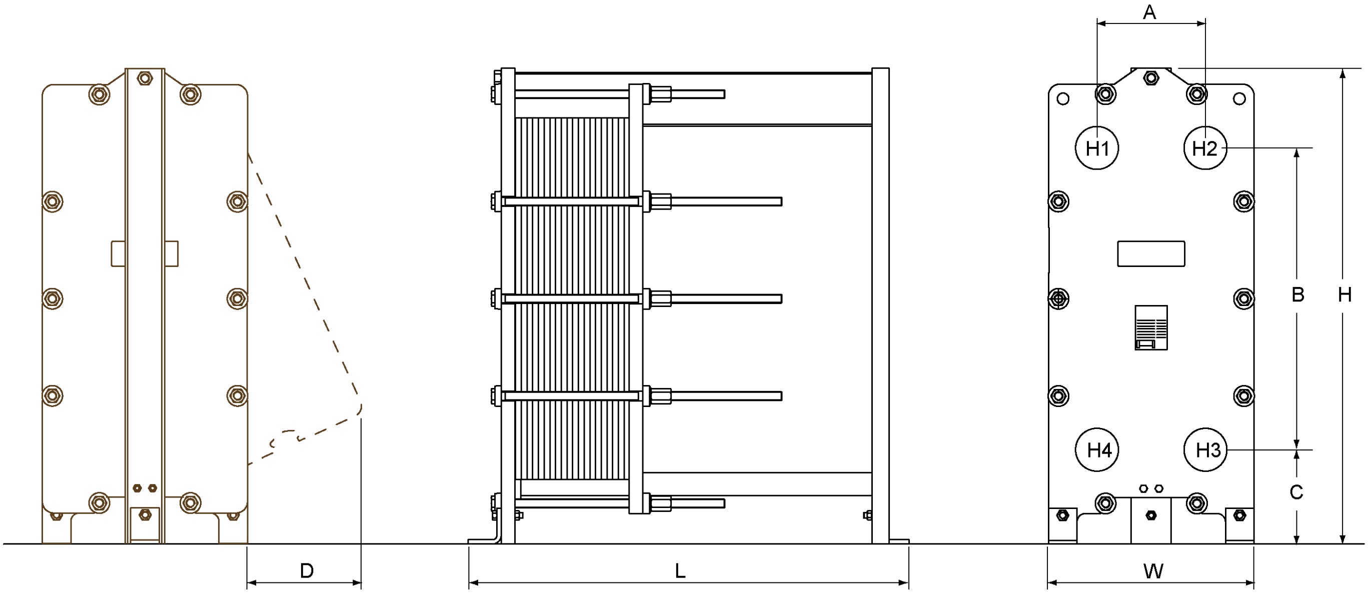
7.3.8 Lubricating oil cooler (2E01)

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

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

Design data:	
Oil flow through cooler	see *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 7.6 Main dimensions of the lubricating oil cooler



H1 = Lubricating oil inlet
H4 = Lubricating oil outlet
H3 = Water inlet
H2 = Water outlet

Engine	Weight, dry [kg]	Dimensions [mm]						
		H	W	L	A	B	C	D
W 6L46	1220	1675	720	1237	380	1057	330	300
W 8L46	1330	1675	720	1487	380	1057	330	300
W 9L46	1350	1675	720	1487	380	1057	330	300
W 12V46	1500	1675	720	1737	380	1057	330	300
W 16V46	1590	1675	720	1987	380	1057	330	300
W 18V46	2150	1937	877	1534	465	1290	330	400

NOTE! These dimensions are for guidance only.

7.3.9 Temperature control valve (2V01)

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

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

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

Design data:

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

7.3.10 Automatic filter (2F02)

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

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

Design data:

Oil viscosity	50 cSt (SAE 40, VI 95, 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)

7.3.11 Safety filter (2F05)

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

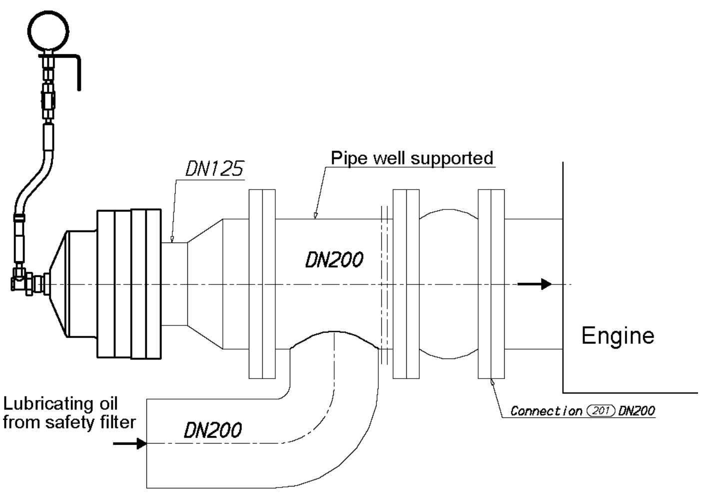
Design Data:

Oil viscosity	50 cSt (SAE 40, VI 95, 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)

7.3.12 Lubricating oil damper (2R03)

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

Figure 7.7 Lubricating oil damper arrangement to external piping (3V35L3112)



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.

V-engines are equipped with two ventilation pipes. It is permitted to join the pipes from the same engine.

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.

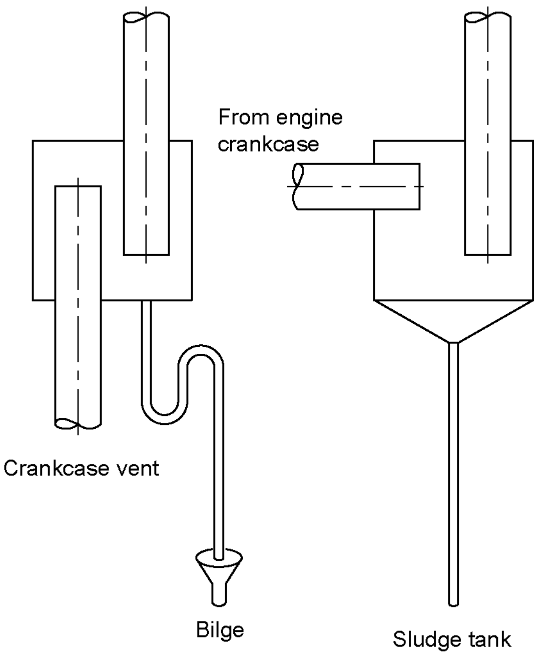
A condensate trap must be fitted on the vent pipe near the engine.

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 L46	DN100
W V46	DN125

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 (connection 201) 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 should be bypassed to prevent damage. It is also recommended to bypass the cooler.

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 filter 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 filter. 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 dry and clean from solid particles and oil.

8.1 Internal compressed air system

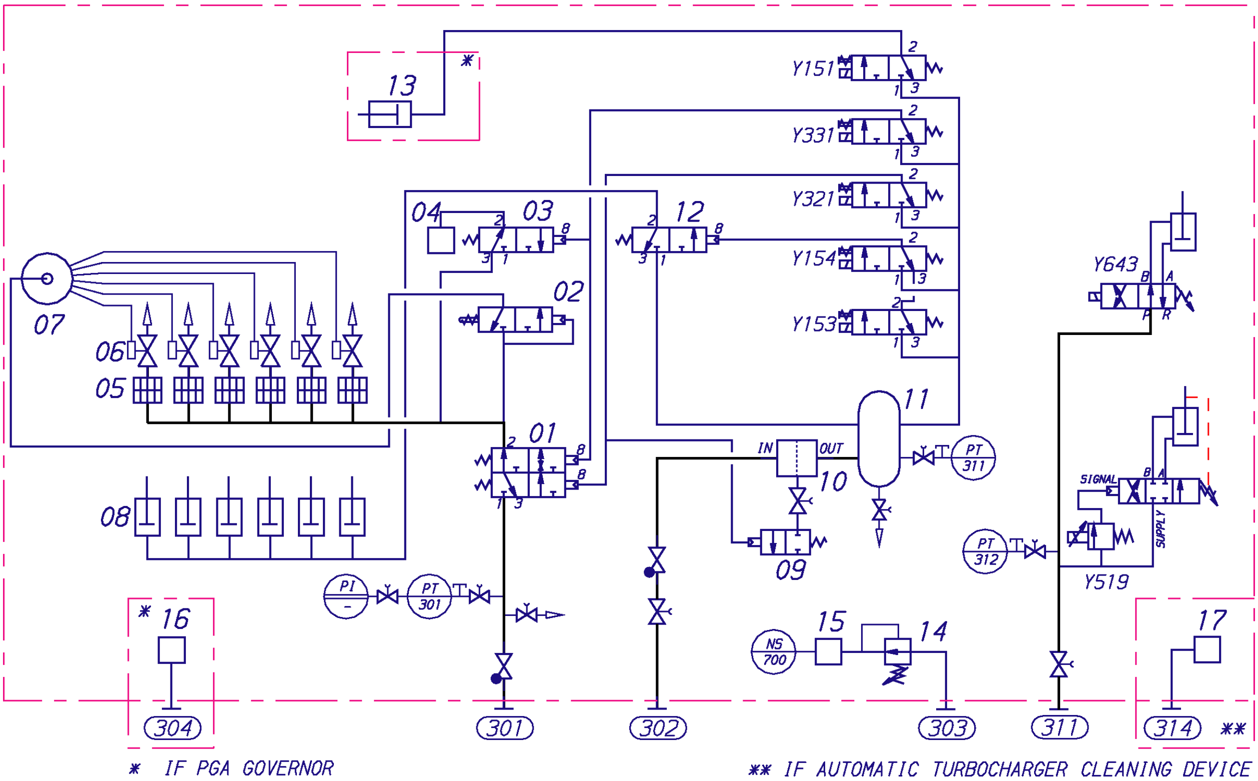
All engines are started by means of compressed air with a nominal pressure of 3 MPa (30 bar). The start is performed by direct injection of air into the cylinders through the starting air valves in the cylinder heads. The 12V-engines are provided with starting air valves for the cylinder on the A bank, 16V- and 18V-engines on both banks. The master starting valve is built on the engine and can be operated both manually and electrically.

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

In addition to the starting system, the compressed air system is also used for a number of control functions. There are separate connections to the external system for these functions.

To ensure correct operation of the engine the compressed air supply, high-pressure or low-pressure, must not be closed during operation.

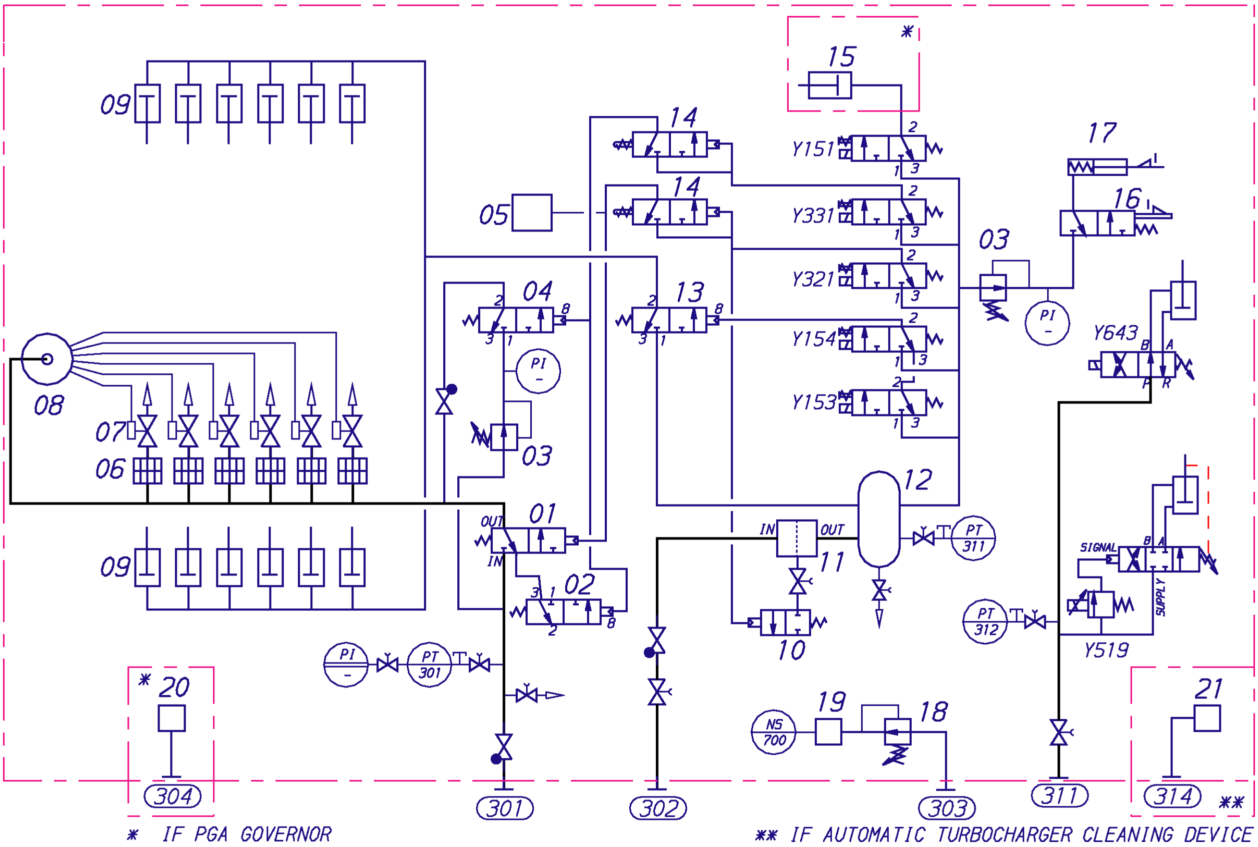
Figure 8.1 Internal compressed air system, in-line engines (DAAE018496a)



System components		Sensors and indicators	
01	Starting air master valve	Y151	Fuel limiting
02	Blocking valve, when turning gear engaged	Y153	Autostop
03	Shut-off valve	Y154	Emergency stop
04	Starting booster for speed governor	PT301	Starting air inlet pressure
05	Flame arrestor	PT311	Control air pressure
06	Starting air valve in cylinder head	PT312	Instrument air pressure
07	Starting air distributor	Y321	Starting
08	Pneumatic cylinder at each injection pump	Y331	Slow turning
09	Valve for automatic draining	Y519	I/P converter for waste gate valve
10	High pressure filter	Y643	By-pass valve
11	Air container	NS700	Oil mist detector failure
12	Stop valve		
13	Starting fuel limiter	PI	Manometer
14	Pressure control valve		
15	Oil mist detector		
16	Speed governor		
17	Turbocharger cleaning valves		

Pipe connections		Size	Pressure class	Standard
301	Starting air inlet, 3 MPa	DN50	PN40	ISO 7005-1
302	Control air inlet, 3 MPa	OD18		
303	Driving air to oil mist detector, 0.2 - 1.2 MPa	OD10		
304	Control air to speed governor	OD6		
311	Control air to by-pass/waste-gate valve, 0.4 - 0.8 MPa	OD8		
314	Air supply to compressor and turbine cleaning device (if TPL turbocharger) 0.4 - 0.8 MPa	G3/4		DIN ISO 228

Figure 8.2 Internal compressed air system, V-engines (DAAE018497a)



System components

01	Starting air master valve
02	Drain valve
03	Pressure control valve
04	Slow turning valve
05	Starting booster for speed governor
06	Flame arrestor
07	Starting air valve in cylinder head
08	Starting air distributor
09	Pneumatic cylinder at each injection pump
10	Valve for automatic draining
11	High pressure filter
12	Air container
13	Stop valve
14	Blocking valve, when turning gear engaged
15	Starting fuel limiter
16	Closing valve
17	Mechanical over-speed trip device
18	Pressure control valve
19	Oil mist detector
20	Speed governor
21	Turbocharger cleaning valves

Sensors and indicators

Y151	Fuel limiting
Y153	Autostop
Y154	Emergency stop
PT301	Starting air inlet pressure
PT311	Control air pressure
PT312	Instrument air pressure
Y321	Starting
Y331	Slow turning
Y519	I/P converter for waste gate valve
Y643	By-pass valve
NS700	Oil mist detector failure
PI	Manometer

Pipe connections		Size 12V	Size 16V, 18V	Pressure class	Standard
301	Starting air inlet, 3 MPa	DN50	2xDN50	PN40	ISO 7005-1
302	Control air inlet, 3 MPa	OD18	OD18		
303	Driving air to oil mist detector, 0.2 - 1.2 MPa	OD10	OD10		
304	Control air to speed governor (if PGA governor)	OD6	OD6		
311	Control air to by-pass/waste-gate valve, 0.4 - 0.8 MPa	OD8	OD8		
314	Air supply to compressor and turbine cleaning device (if TPL turbocharger) 0.4 - 0.8 MPa	G3/4	G3/4		DIN ISO 228

8.2 External compressed air system

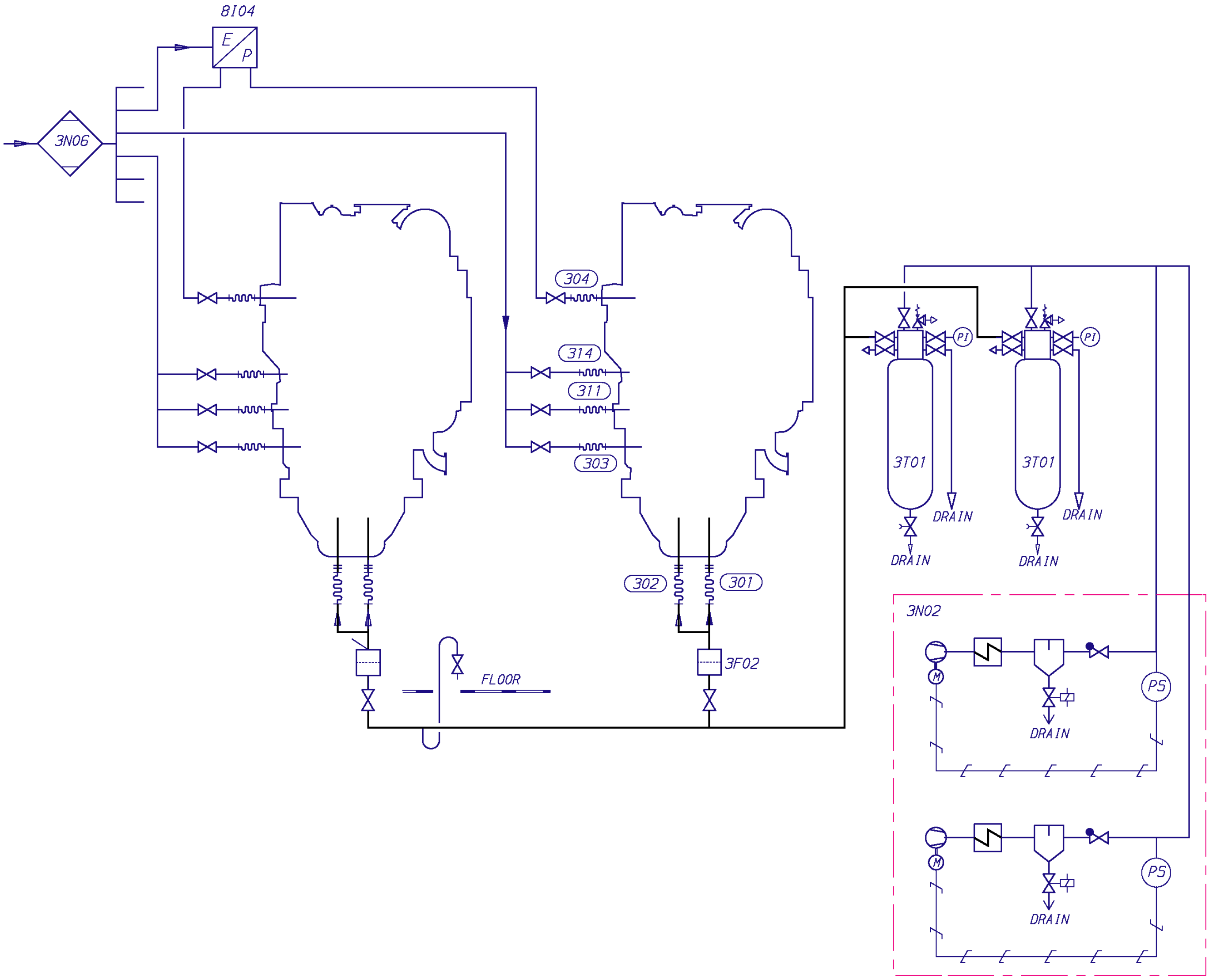
The design of the starting air system is partly determined by classification regulations. Most classification societies require that the total capacity is divided into two equally sized starting air receivers and starting air compressors.

Control air must be treated in an air dryer.

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

The requirements concerning multiple engine installations can be subject to special consideration by the classification society.

Figure 8.3 Example of external compressed air system (3V76H4165)



System components

3F02	Air filter (starting air inlet)	3T01	Starting air receiver
3N02	Starting air compressor unit	8I04	E/P converter
3N06	Air dryer unit		

Pipe connections

301	Starting air inlet
302	Control air inlet
303	Driving air to oil mist detector
304	Control air to speed governor (if PGA governor)
311	Control air to by-pass/waste-gate valve
314	Air supply to compressor and turbine cleaning device (if TPL turbocharger)

The recommended size for the piping is based on pressure losses in a piping with a length of 40 m.

Table 8.1 Recommended main starting air pipe size

Engine	Size
6L	DN65
8L, 9L	DN80
12V	DN80, starting air to A-bank
16V, 18V	DN100, starting air to A- and B-banks

8.2.1 Starting air compressor unit (3N02)

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

8.2.2 Oil and water separator (3S01)

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

8.2.3 Starting air receiver (3T01)

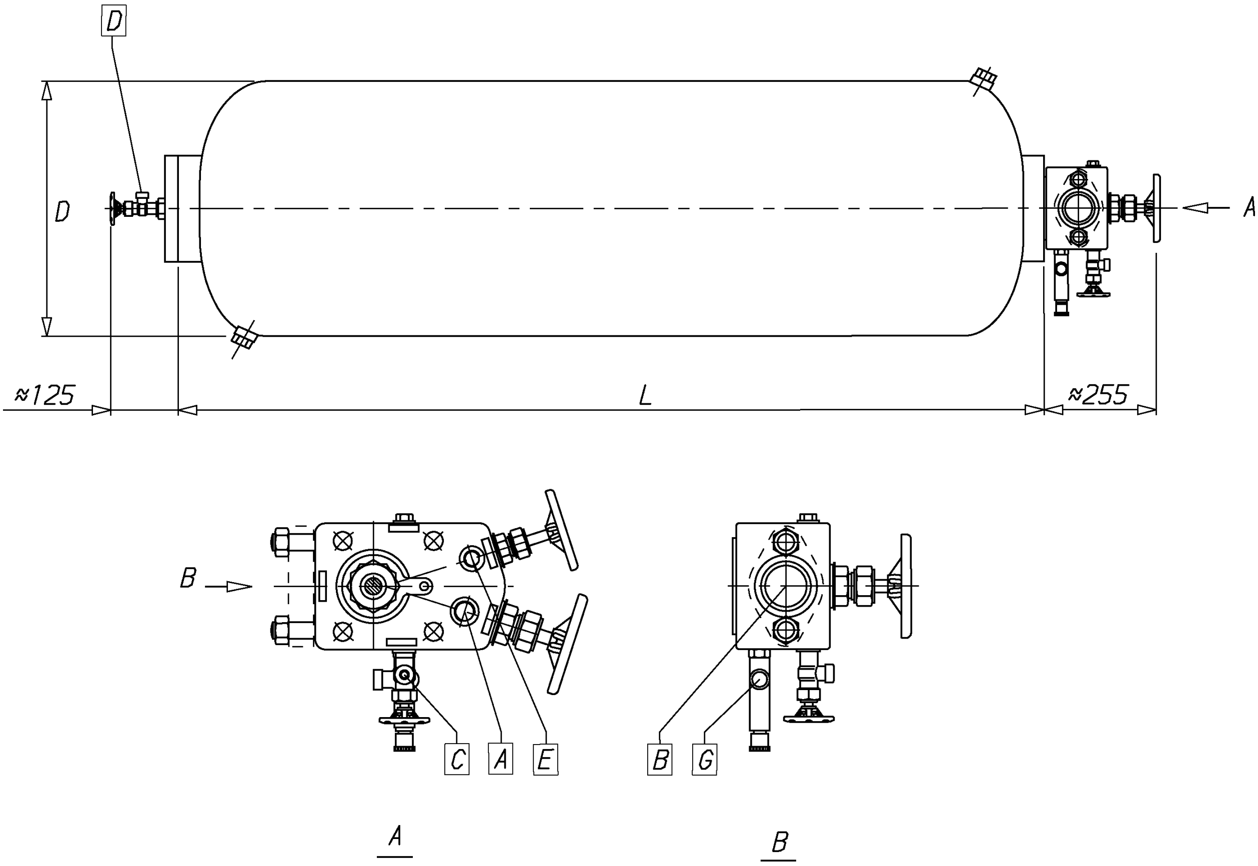
The starting air receivers should be dimensioned for a nominal pressure of 3 MPa.

The number and the capacity of the air receivers 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 receivers.

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

Figure 8.4 Starting air receiver (4V49A0019a)



Connections		Size
A	Inlet	R 3/4"
B	Outlet	Ø 50 mm
C	Pressure gauge	R 1/4"
D	Drain	R 1/4"
E	Auxiliary connection	R 1/2"
G	Safety valve	R 1/2"

Size [Litres]	Dimensions		Weight [kg]
	L [mm]	D [mm]	
500	3205	480	480
1000	3560	650	890
1500	3460	800	1090
2000	4610	800	1450

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 receiver 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 receiver volume [m^3]

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

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

n = required number of starts according to the classification society

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

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

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

8.2.4 Starting air filter (3F02)

Significant condense formation can occur after the water separator, especially in tropical conditions. Depending on the materials used, this can result in abrasive rust particles from the piping, fittings and receivers. It is therefore recommended to install a filter strainer in the external starting air system just before the engine.

The recommended mesh opening size is 400 microns. The open flow area of the straining element shall be at least 250% of the cross sectional area of the pipe, when it is related to the recommended pipe diameter.

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.

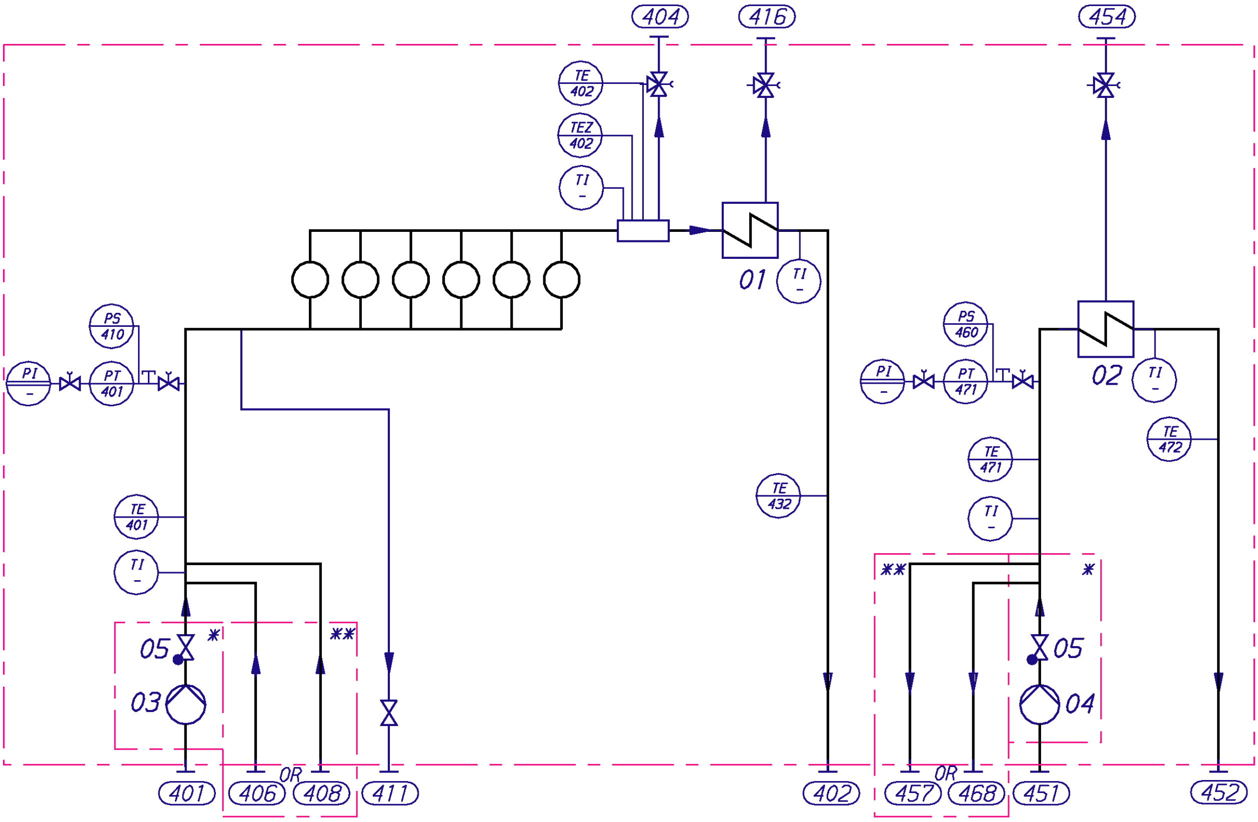
9.1.2 Glycol

Use of glycol in the cooling water is not recommended unless it is absolutely necessary. Starting from 10% glycol the engine is to be de-rated 0.67% per 1% glycol in the water. Max. 40% 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 engines (DAAE018498a)

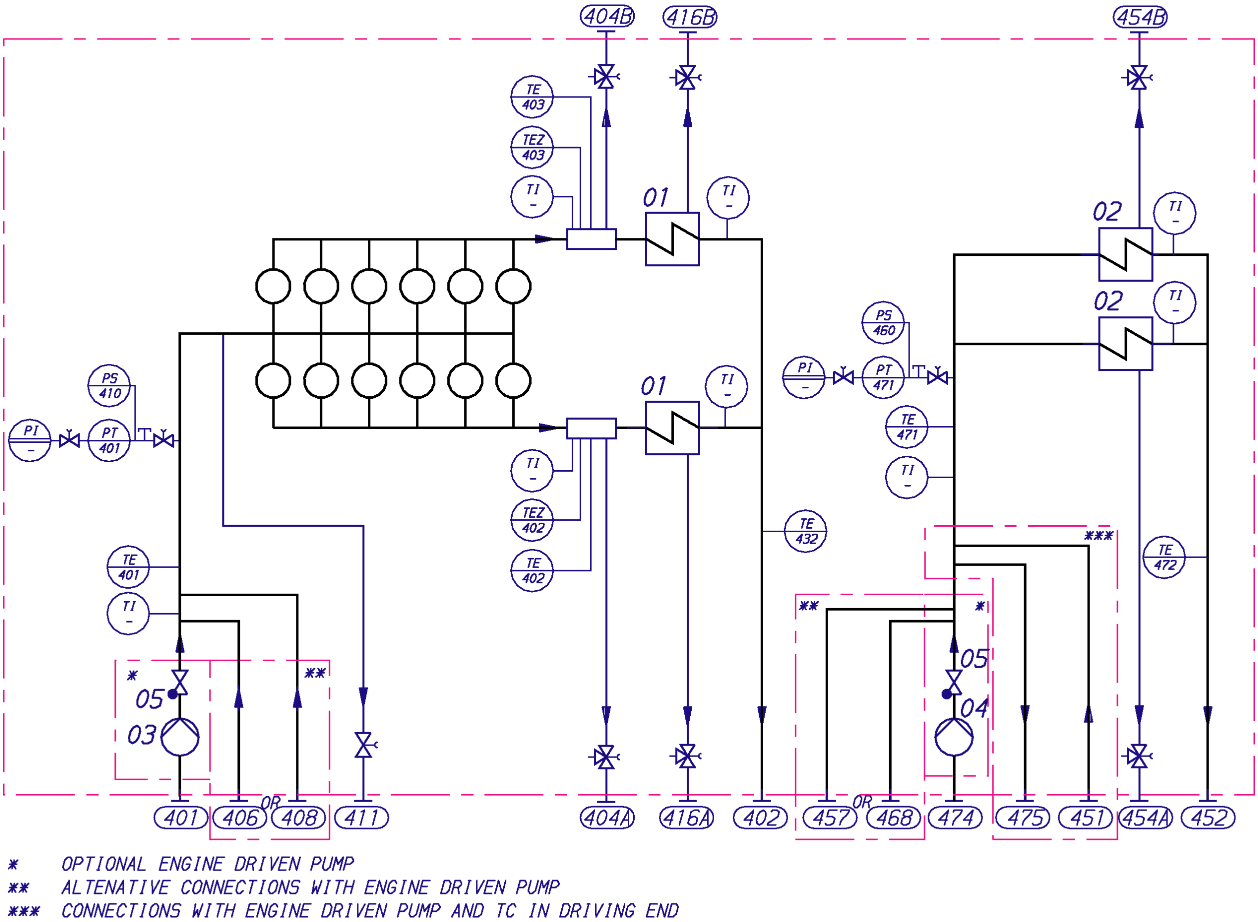


* OPTIONAL ENGINE DRIVEN PUMP
** ALTERNATIVE CONNECTIONS WITH ENGINE DRIVEN PUMP

System components		Pipe connections		Size	Pressure class	Standard
01	Charge air cooler (HT)	401	HT-water inlet	DN150	PN16	ISO 7005-1
02	Charge air cooler (LT)	402	HT-water outlet	DN150	PN16	ISO 7005-1
03	HT-water pump	404	HT-water air vent	OD12		
04	LT-water pump	406	Water from pre-heater to HT-circuit	DN40	PN40	ISO 7005-1
05	Non return valve	408	HT-water from stand-by pump	DN150		
		411	HT-water drain	OD48		
		416	HT-water air vent from air cooler	OD12		
		451	LT-water inlet	DN150	PN16	ISO 7005-1
PI	Manometer	452	LT-water outlet	DN150	PN16	ISO 7005-1
TI	Thermometer	454	LT-water air vent from air cooler	OD12		
		457	LT-water from stand-by pump	DN125	PN16	ISO 7005-1
		468	LT-water, air cooler by-pass	DN125	PN16	ISO 7005-1

Sensors and indicators			
PT401	HT-water inlet pressure	PS410	HT-water inlet pressure (if stand-by pump)
TE401	HT-water inlet temperature	PT471	LT-water inlet pressure
TE402	HT-water outlet temperature	TE471	LT-water inlet temperature
TEZ402	HT-water outlet temperature	TE472	LT-water outlet temperature
TE432	HT-water outlet temperature, CAC outlet	PS460	LT-water inlet pressure (if stand-by pump)

Figure 9.2 Internal cooling water system, V-engines (DAAE018499b)



System components		Pipe connections		Size	Pressure class	Standard
01	Charge air cooler (HT)	401	HT-water inlet	DN200	PN10	ISO 7005-1
02	Charge air cooler (LT)	402	HT-water outlet	DN200	PN10	ISO 7005-1
03	HT-water pump	404A	HT-water air vent, A-bank	OD12		
04	LT-water pump	404B	HT-water air vent, B-bank	OD12		
05	Non return valve	406	Water from pre-heater to HT-circuit	DN40	PN40	ISO 7005-1
		408	HT-water from stand-by pump	DN150	PN16	ISO 7005-1
		411	HT-water drain	OD48		
PI	Manometer	416A	HT-water air vent from air cooler, A-bank	OD12		
TI	Thermometer	416B	HT-water air vent from air cooler, B-bank	OD12		
		451	LT-water inlet	DN200	PN10	ISO 7005-1
		452	LT-water outlet	DN200	PN10	ISO 7005-1
		454A	LT-water air vent from air cooler, A-bank	OD12		
		454B	LT-water air vent from air cooler, B-bank	OD12		
		457	LT-water from stand-by pump	DN200	PN10	ISO 7005-1
		468	LT-water, air cooler by-pass	DN200	PN10	ISO 7005-1
		474	LT-water to engine drive pump	DN200	PN16	ISO 7005-1
		475	LT-water from engine drive pump	DN200	PN16	ISO 7005-1

Sensors and indicators

PT401	HT-water inlet pressure	TE432	HT-water outlet temperature, CAC outlet
TE401	HT-water inlet temperature	PS410	HT-water inlet pressure (if stand-by pump)
TE402	HT-water outlet temperature, A-bank	PT471	LT-water inlet pressure

Sensors and indicators

TE403	HT-water outlet temperature, B-bank	TE471	LT-water inlet temperature
TEZ402	HT-water outlet temperature, A-bank	TE472	LT-water outlet temperature (optional)
TEZ403	HT-water outlet temperature, B-bank	PS460	LT-water inlet pressure (if stand-by pump)

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

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

9.2.1 Engine driven circulating pumps

The LT and HT cooling water pumps can be either engine driven or separate electrically driven pumps. Engine driven pumps are located at the free end of the engine. Connections for stand-by pumps are available with engine driven pumps (option).

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 L46 at 500 rpm, HT- and LT-pumps (4V19L0332a)

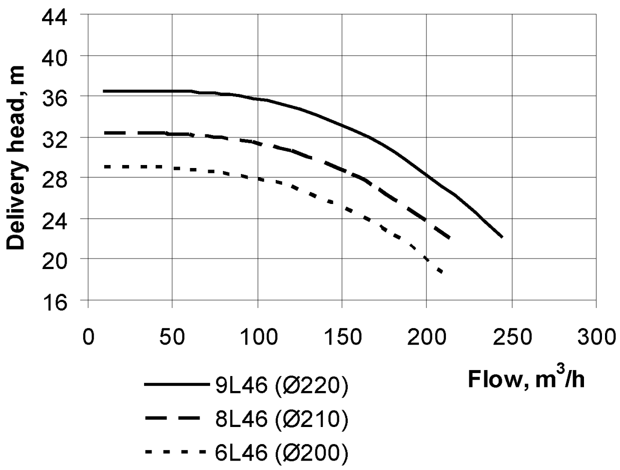


Figure 9.4 L46 at 514 rpm, HT- and LT-pumps (4V19L0332a)

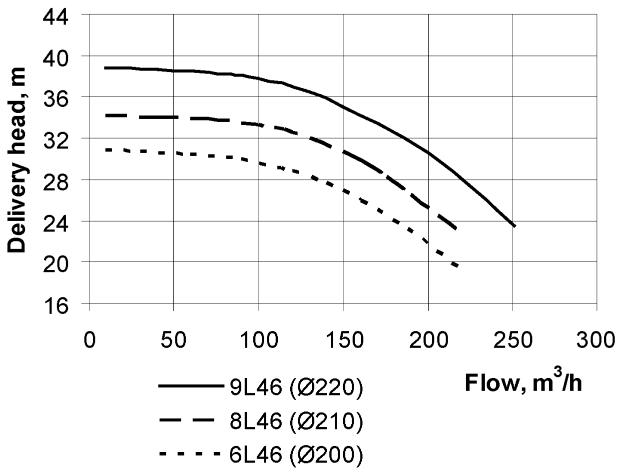


Figure 9.5 V46 at 500 rpm, HT- and LT-pumps (4V19L0333a)

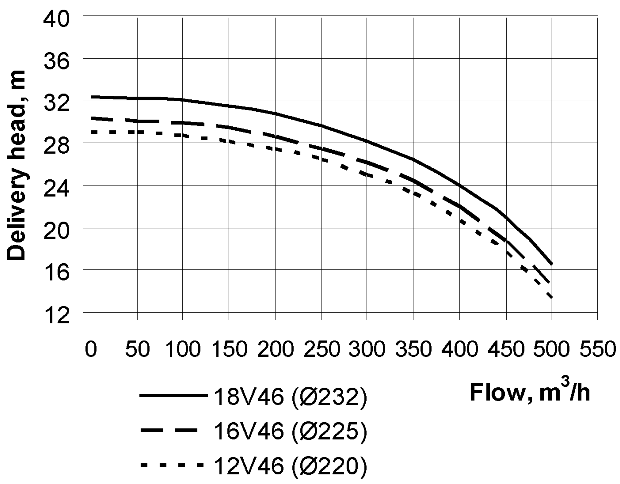
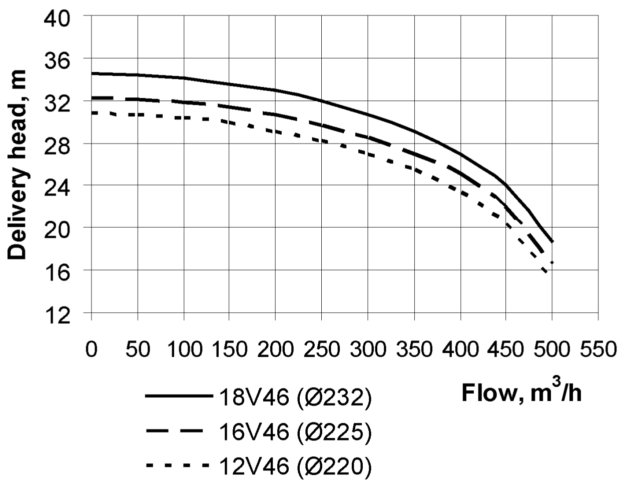
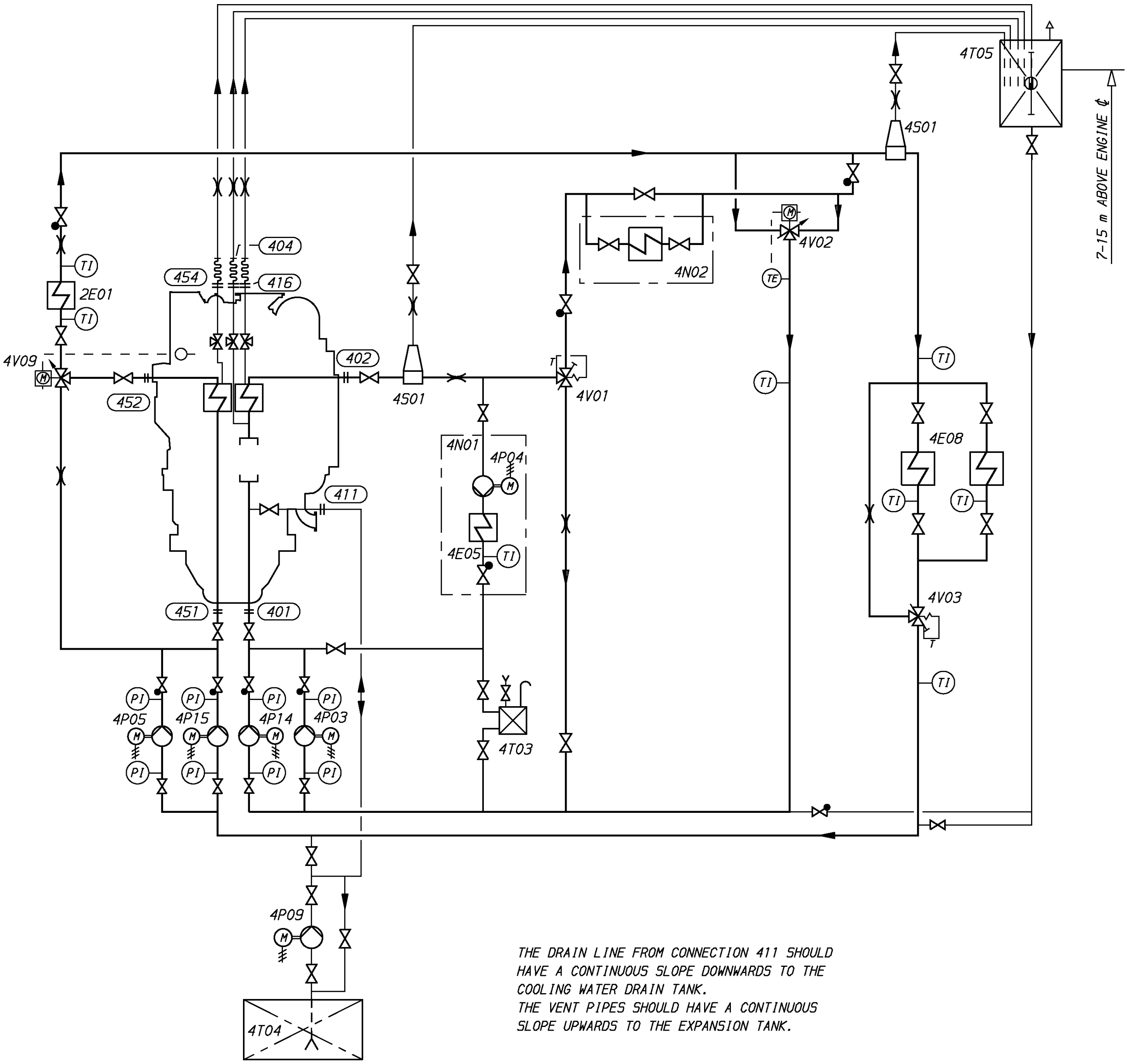


Figure 9.6 V46 at 514 rpm, HT- and LT-pumps (4V19L0333a)



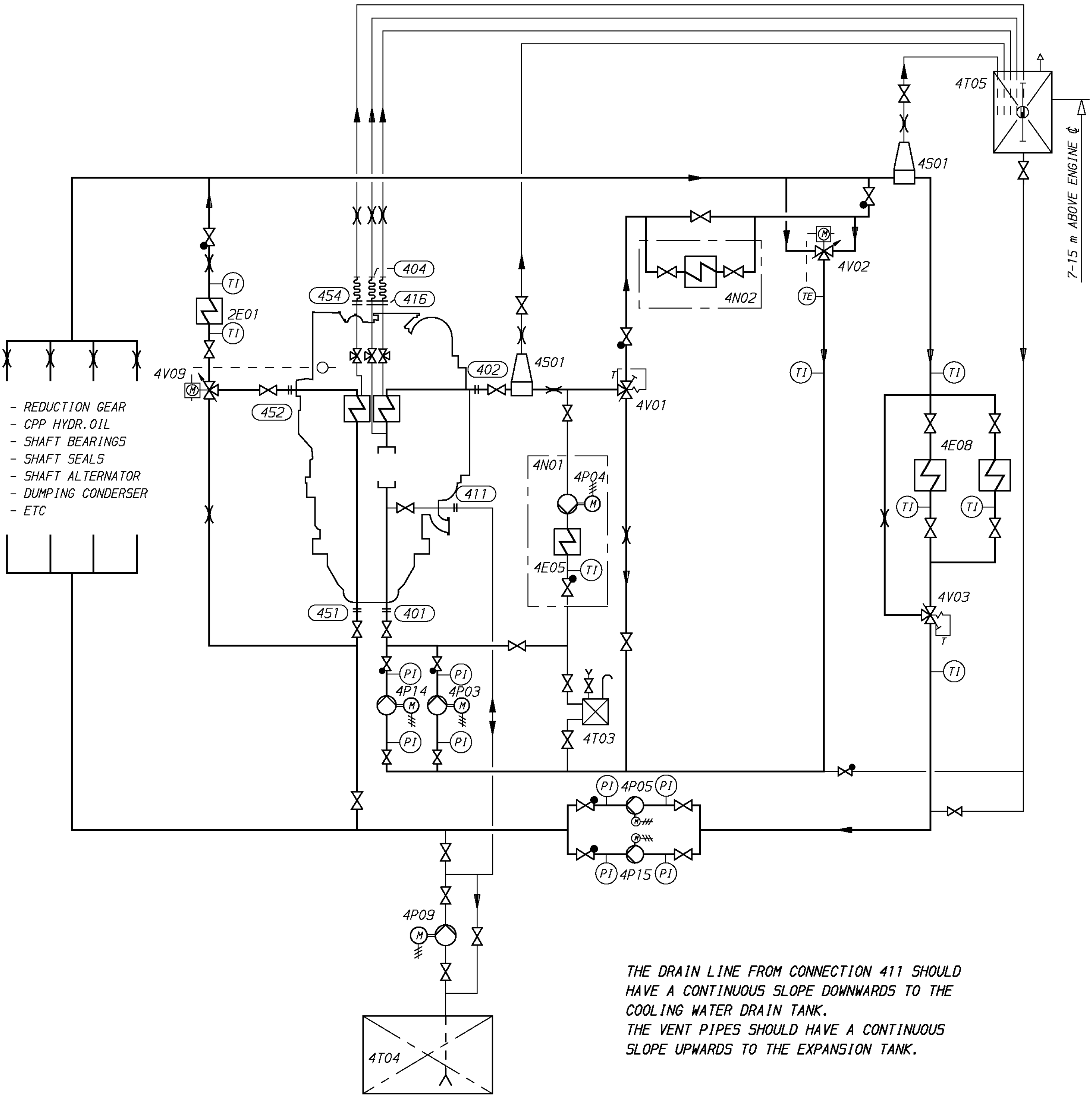
9.3 External cooling water system

Figure 9.7 External cooling water system example, 1 x Wärtsilä L46 without built-on pumps (3V76C5828)



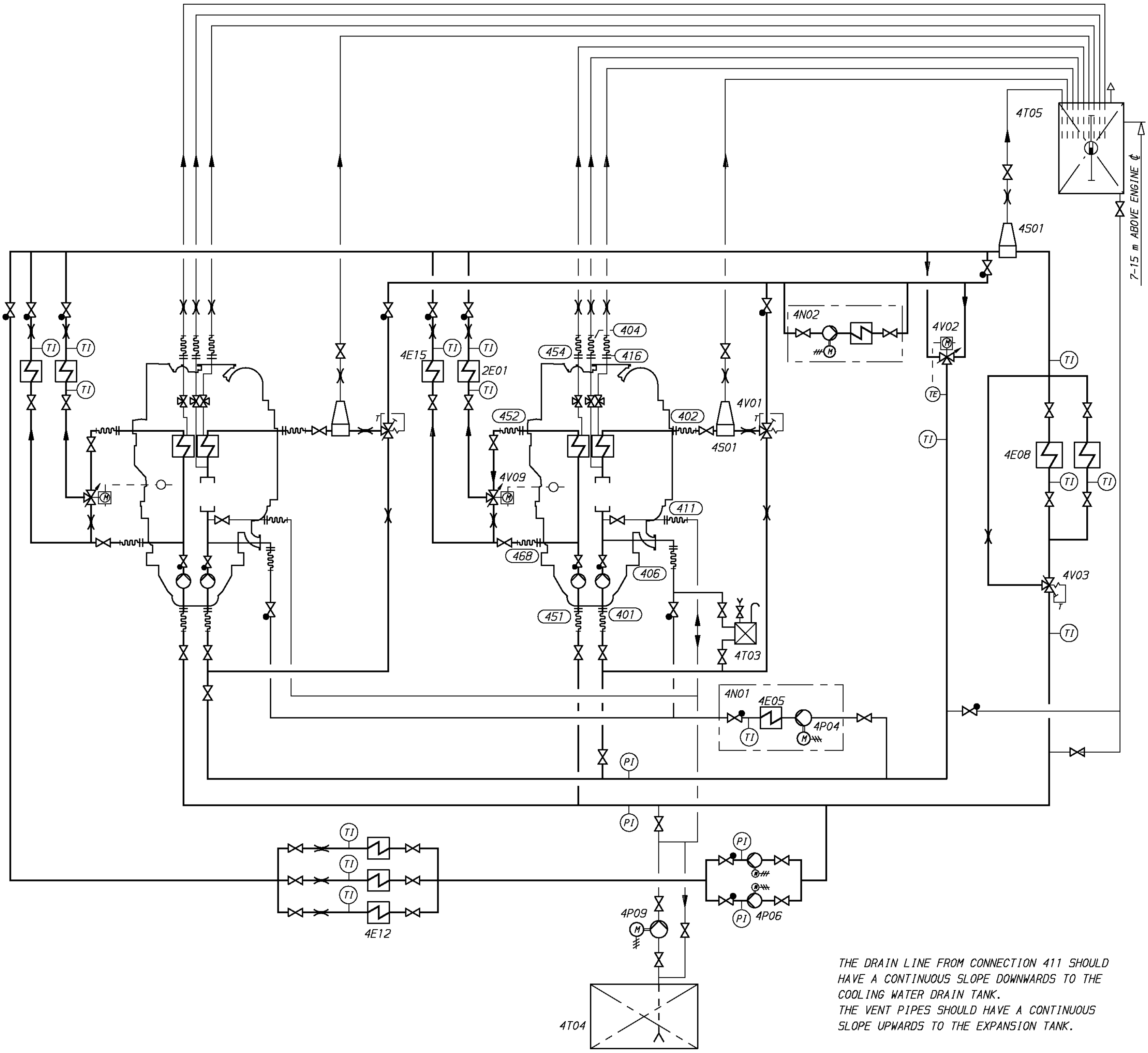
System components				Pipe connections	
2E01	Lubricating oil cooler	4P15	Circulating pump (LT)	401	HT-water inlet
4E05	Heater (pre-heating unit)	4S01	Air venting	402	HT-water outlet
4E08	Central cooler	4T03	Additive dosing tank	404	HT-water air vent
4N01	Pre-heating unit	4T04	Drain tank	411	HT-water drain
4N02	Evaporator unit	4T05	Expansion tank	416	HT-water air vent from air cooler
4P03	Stand-by pump (HT)	4V01	Temperature control valve (HT)	451	LT-water inlet
4P04	Circulating pump (pre-heating unit)	4V02	Temperature control valve (heat recovery)	452	LT-water outlet
4P05	Stand-by pump (LT)	4V03	Temperature control valve (LT)	454	LT-water air vent from air cooler
4P09	Transfer pump	4V09	Temperature control valve (charge air)		
4P14	Circulating pump (HT)				

Figure 9.8 External cooling water system example, Wärtsilä L46 without built-on pumps (3V76C5829)



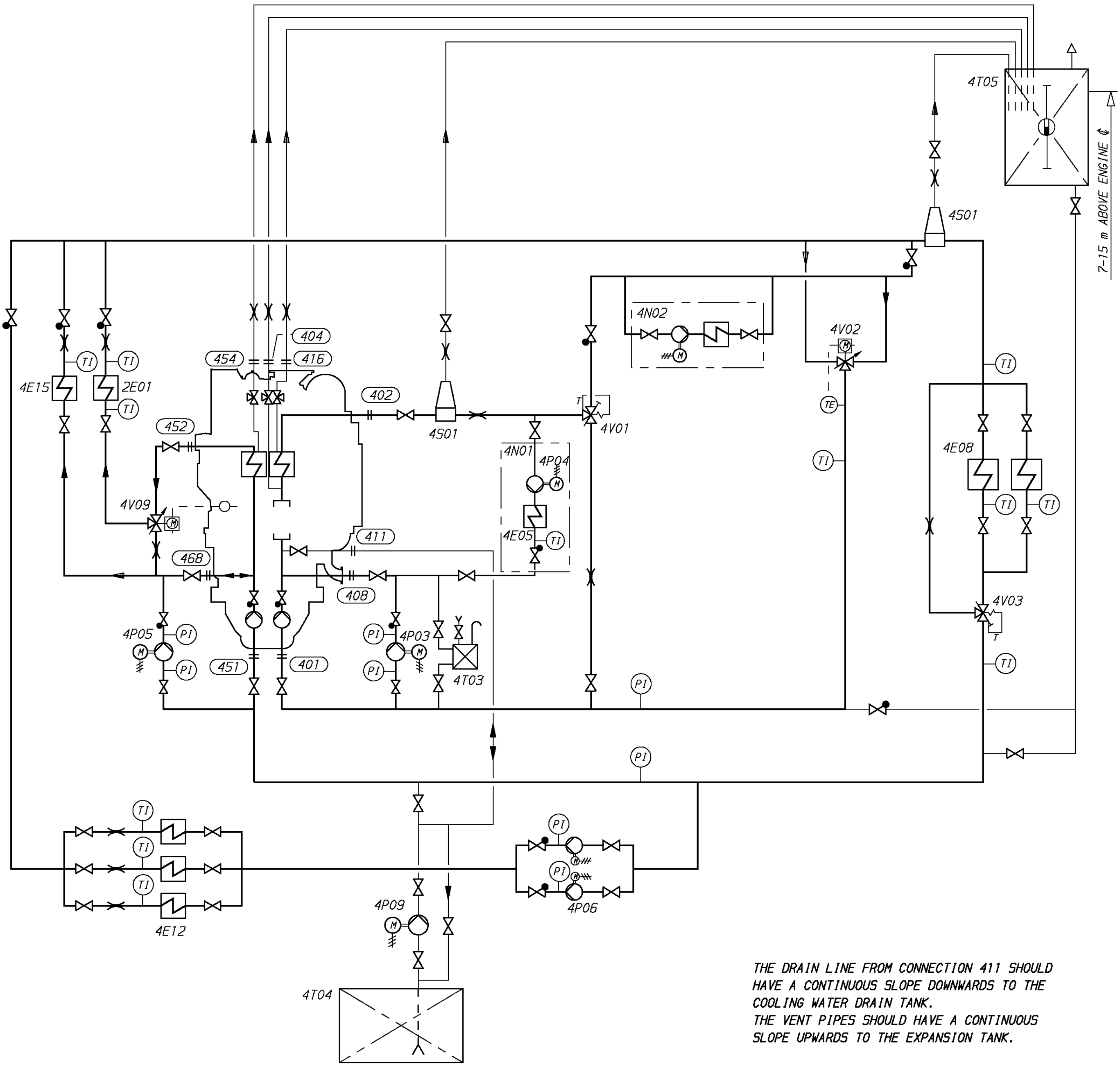
System components				Pipe connections	
2E01	Lubricating oil cooler	4P15	Circulating pump (LT)	401	HT-water inlet
4E05	Heater (pre-heating unit)	4S01	Air venting	402	HT-water outlet
4E08	Central cooler	4T03	Additive dosing tank	404	HT-water air vent
4N01	Pre-heating unit	4T04	Drain tank	411	HT-water drain
4N02	Evaporator unit	4T05	Expansion tank	416	HT-water air vent from air cooler
4P03	Stand-by pump (HT)	4V01	Temperature control valve (HT)	451	LT-water inlet
4P04	Circulating pump (pre-heating unit)	4V02	Temperature control valve (heat recovery)	452	LT-water outlet
4P05	Stand-by pump (LT)	4V03	Temperature control valve (LT)	454	LT-water air vent from air cooler
4P09	Transfer pump	4V09	Temperature control valve (charge air)		
4P14	Circulating pump (HT)				

Figure 9.9 External cooling water system example, 2 x Wärtsilä L46 with built-on pumps (2V76C5830)



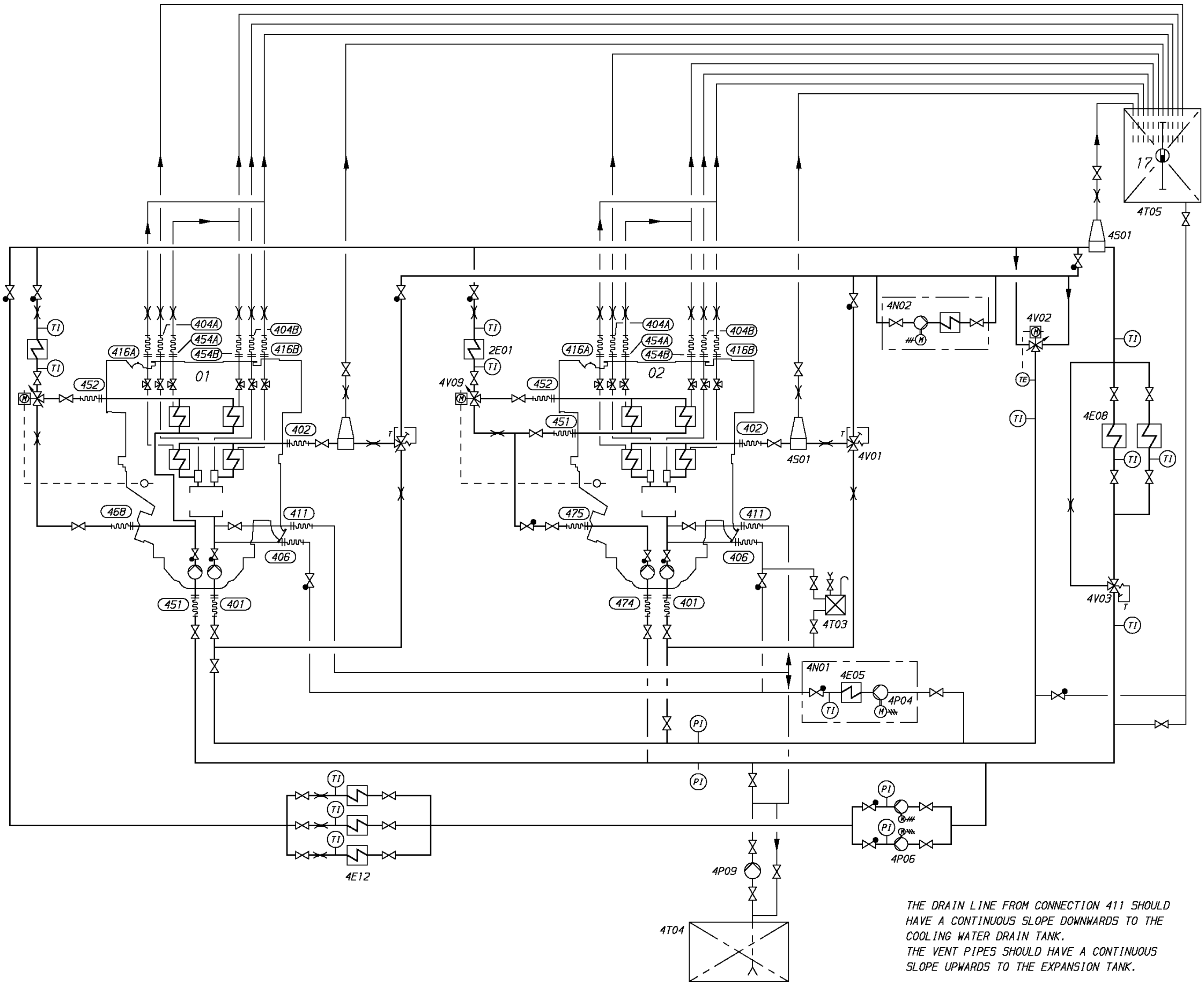
System components				Pipe connections	
2E01	Lubricating oil cooler	4P09	Transfer pump	401	HT-water inlet
4E05	Heater (pre-heating unit)	4S01	Air venting	402	HT-water outlet
4E08	Central cooler	4T03	Additive dosing tank	404	HT-water air vent
4E12	Cooler (installation parts)	4T04	Drain tank	406	Water from pre-heater to HT-circuit
4E15	Cooler (generator)	4T05	Expansion tank	411	HT-water drain
4N01	Pre-heating unit	4V01	Temperature control valve (HT)	416	HT-water air vent from air cooler
4N02	Evaporator unit	4V02	Temperature control valve (heat recovery)	451	LT-water inlet
4P04	Circulating pump (pre-heating unit)	4V03	Temperature control valve (LT)	452	LT-water outlet
4P06	Circulating pump	4V09	Temperature control valve (charge air)	454	LT-water air vent from air cooler
				468	LT-water, air cooler by-pass

Figure 9.10 External cooling water system example, 1 x Wärtsilä L46 with built-on pumps (3V76C5831)



System components				Pipe connections	
2E01	Lubricating oil cooler	4P06	Circulating pump	401	HT-water inlet
4E05	Heater (pre-heating unit)	4P09	Transfer pump	402	HT-water outlet
4E08	Central cooler	4S01	Air venting	404	HT-water air vent
4E12	Cooler (installation parts)	4T03	Additive dosing tank	408	HT-water from stand-by pump
4E15	Cooler (generator)	4T04	Drain tank	411	HT-water drain
4N01	Pre-heating unit	4T05	Expansion tank	416	HT-water air vent from air cooler
4N02	Evaporator unit	4V01	Temperature control valve (HT)	451	LT-water inlet
4P03	Stand-by pump (HT)	4V02	Temperature control valve (heat recovery)	452	LT-water outlet
4P04	Circulating pump (pre-heating unit)	4V03	Temperature control valve (LT)	454	LT-water air vent from air cooler
4P05	Stand-by pump (LT)	4V09	Temperature control valve (charge air)	468	LT-water, air cooler by-pass

Figure 9.11 External cooling water system example, 2 x Wärtsilä V46 with built-on pumps (2V76C5832)



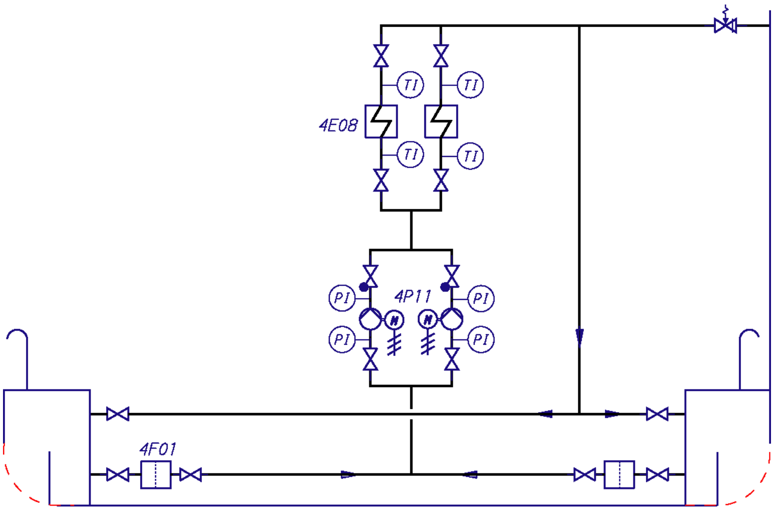
System components

01	Diesel engine Wärtsilä V46, TC in free end	4P09	Transfer pump
02	Diesel engine Wärtsilä V46, TC in driving end	4S01	Air venting
2E01	Lubricating oil cooler	4T03	Additive dosing tank
4E05	Heater (pre-heating unit)	4T04	Drain tank
4E08	Central cooler	4T05	Expansion tank
4E12	Cooler (installation parts)	4V01	Temperature control valve (HT)
4N01	Pre-heating unit	4V02	Temperature control valve (heat recovery)
4N02	Evaporator unit	4V03	Temperature control valve (LT)
4P04	Circulating pump (pre-heating unit)	4V09	Temperature control valve (charge air)
4P06	Circulating pump		

Pipe connections

401	HT-water inlet
402	HT-water outlet
404	HT-water air vent
406	Water from pre-heater to HT-circuit
411	HT-water drain
416	HT-water air vent from air cooler
451	LT-water inlet
452	LT-water outlet
454	LT-water air vent from air cooler
468	LT-water, air cooler by-pass (only with TC in free end)
474	LT-water to engine driven pump
475	LT-water from engine driven pump (only with TC in driving end)

Figure 9.12 Sea water system example (DAAE020523)



System components	
4E08	Central cooler
4F01	Suction strainer (sea water)
4P11	Circulating pump (sea water)

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

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

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

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

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

9.3.1 Electrically driven HT and LT circulating pumps (4P14, 4P15, 4P03, 4P05)

Electrically driven pumps should be of centrifugal type. Required capacities are stated in *Technical data*. If there are no engine driven pumps, then the delivery head can be matched to the actual resistance in the system. The total pressure before the engine may however not exceed the maximum value stated in *Technical data*.

HT pumps (4P14, 4P03)

There must be individual pumps for each engine in the HT circuit.

LT pumps (4P15, 4P05)

In the LT circuit several engines can share a common pump, also together with other equipment such as reduction gear, generator and compressors.

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

9.3.2 Sea water pump (4P11)

The 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.

9.3.3 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	91°C

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

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 38 °C, or lower if required by other equipment connected to the same circuit.

9.3.5 Charge air temperature control valve (4V09)

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

The set-point can be slightly different depending on the operating conditions (amount of condensation in the charger air cooler), but normally it is about 55 °C.

9.3.6 Temperature control valve for heat recovery (4V02)

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

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

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

9.3.7 Lubricating oil cooler (2E01)

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

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

9.3.8 Coolers for other equipment and MDF coolers

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

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

9.3.9 Fresh water central cooler (4E08)

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

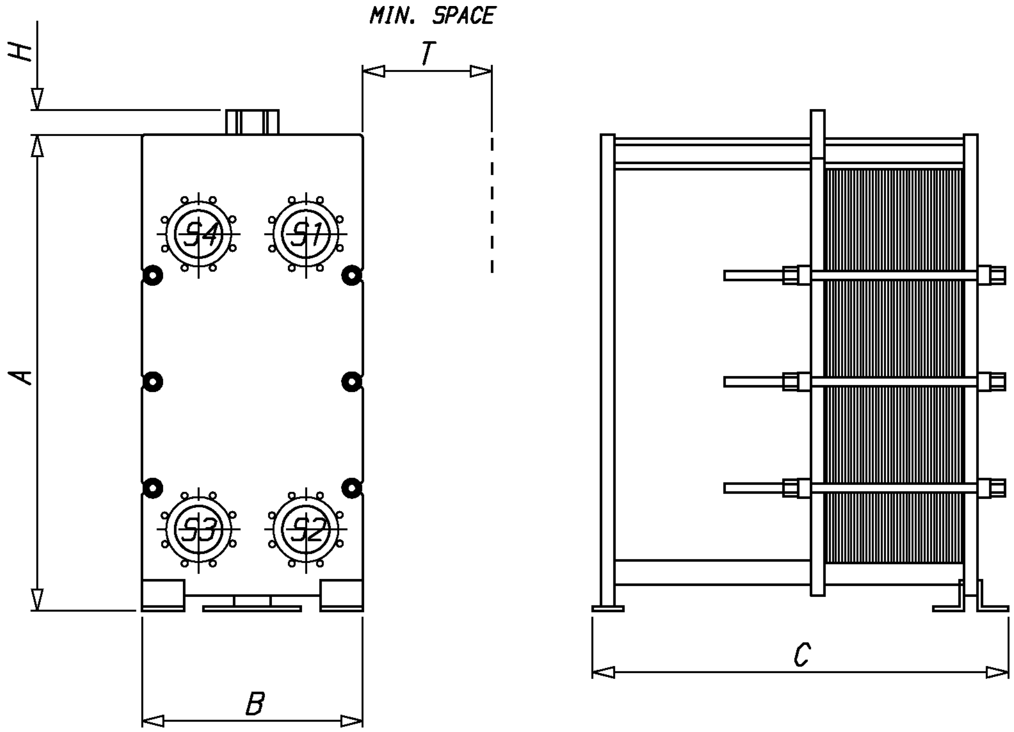
If the system layout is according to one of the example diagrams, then the flow capacity of the cooler should be equal to the total capacity of the LT circulating pumps in the circuit. The flow may be higher for other system layouts and should be calculated case by case.

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

Design data:

Fresh water flow	see chapter *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 9.13 Central cooler main dimensions (4V47F0004). Example for guidance only



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

9.3.10 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.

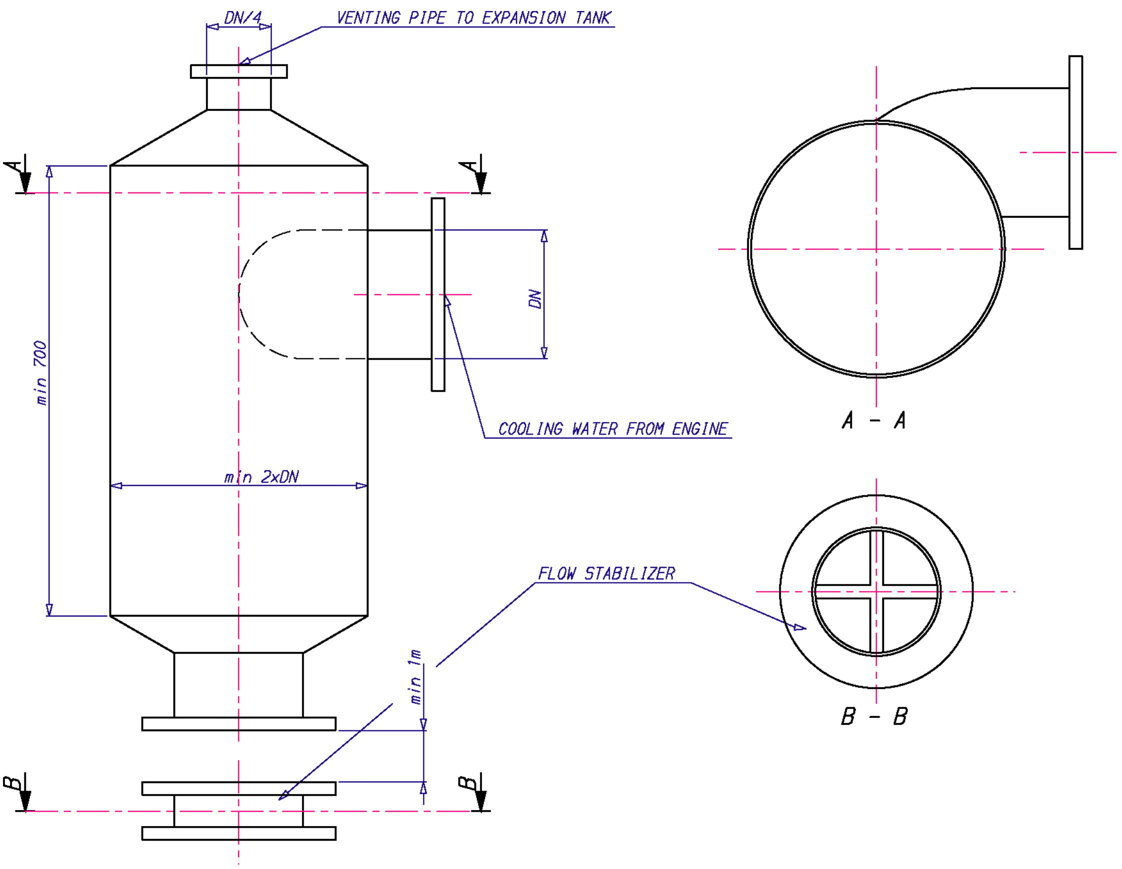
The vent pipes must be continuously rising.

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.

Figure 9.14 Example of air venting device (3V76C4757)



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 system

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 9.2 Minimum diameter of balance pipe

Nominal pipe size	Max. flow velocity (m/s)	Max. number of vent pipes with ø 5 mm orifice
DN 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 °C, preferably 70 °C. This is an absolute requirement for installations that are designed to operate on heavy fuel, but strongly recommended also for engines that operate exclusively on marine diesel fuel.

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

Heater (4E05)

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

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

The minimum required heating power is 12 kW/cyl, which makes it possible to warm up the engine from 20 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 6 kW/cyl is required to keep a hot engine warm.

Design data:	
Preheating temperature	min. 60°C
Required heating power	12 kW/cyl
Heating power to keep hot engine warm	6 kW/cyl

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

$$P = \frac{(t_1 - t_0)(m_{eng} \times 0.14 + V_{FW} \times 1.16)}{T} + k_{eng} \times n_{cyl}$$

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 = 3 kW
n_{cyl} =	Number of cylinders

The formula above should not be used for P < 10 kW/cyl.

Circulating pump for preheater (4P04)

Design data:	
Capacity	1.6 m^3/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 9.15 Example of preheating unit, electric (4V47K0045)

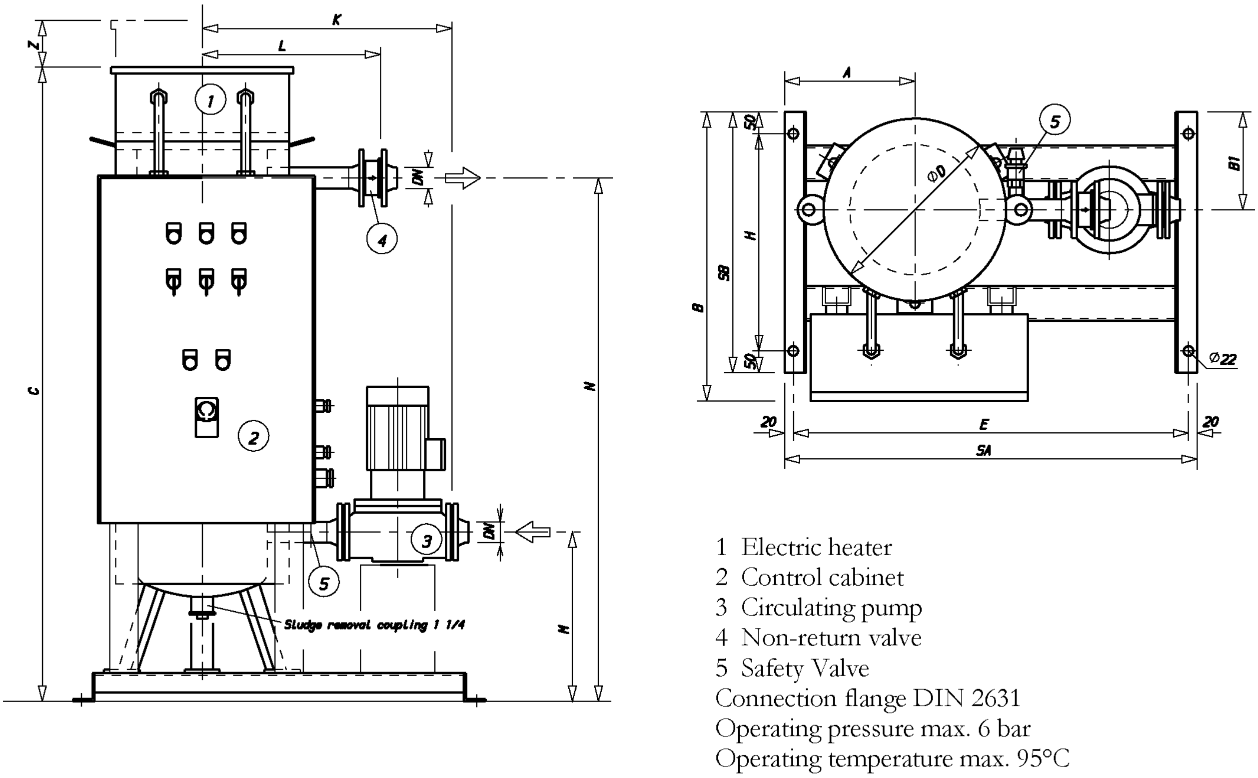
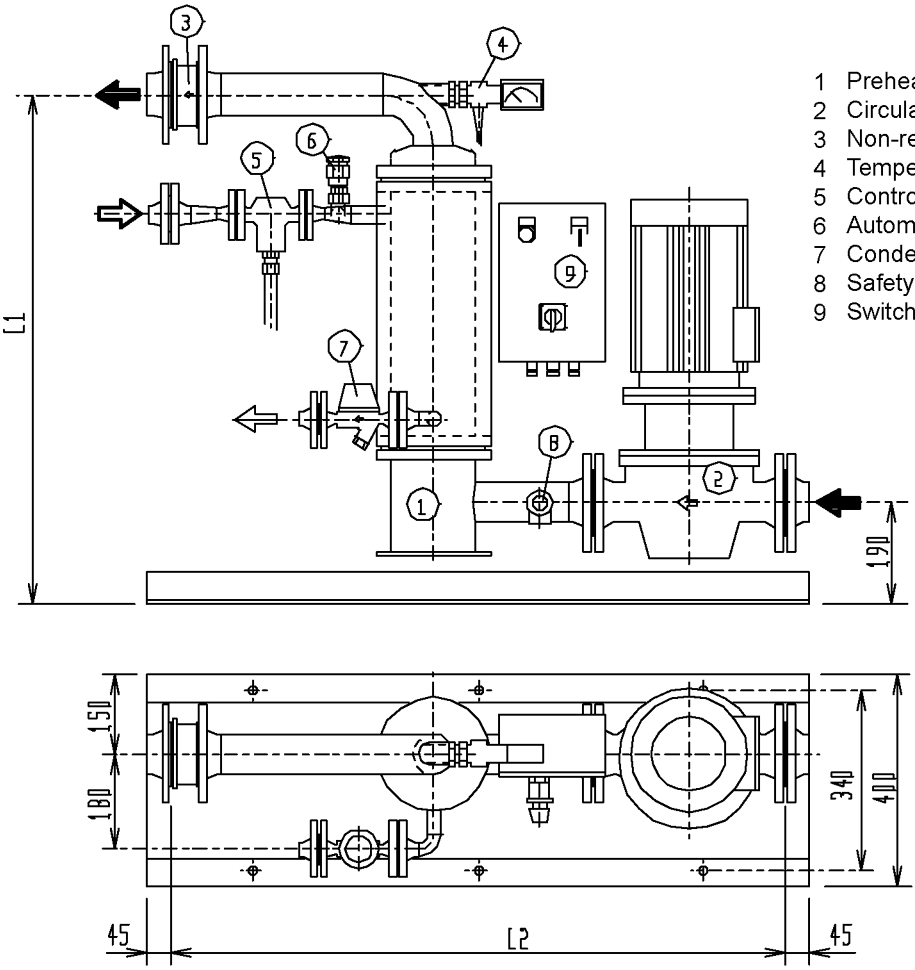


Table 9.3 Example of preheating unit

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

Figure 9.16 Example of preheating unit, steam



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

9.3.16 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*.

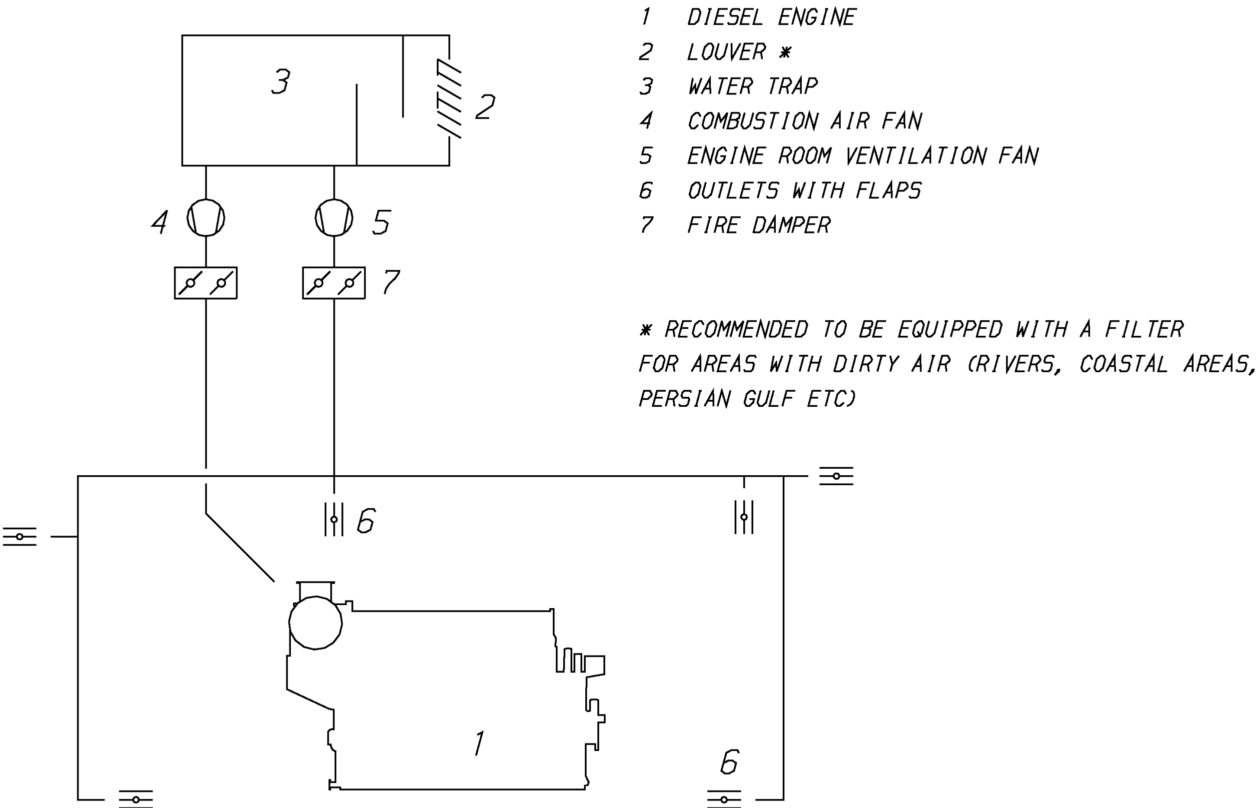
The engine room ventilation has to be provided by separate ventilation fans. These fans should preferably have two-speed electric motors (or variable speed). Thus flexible operation is possible, e.g. in port the capacity can be reduced during overhaul of the main engine when it is not preheated (and 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 an exit for the majority 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 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 a heating system 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 air required for combustion is taken from the engine room through a filter fitted 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.

As far as possible the air temperature at turbocharger inlet should be kept between 5 and 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 the 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 like other engines, gas turbines and boilers shall be served by dedicated combustion air ducts.

If necessary, the combustion air duct can be directly connected to the turbocharger with a flexible connection piece. To protect the turbocharger a filter must be built into the air duct. 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

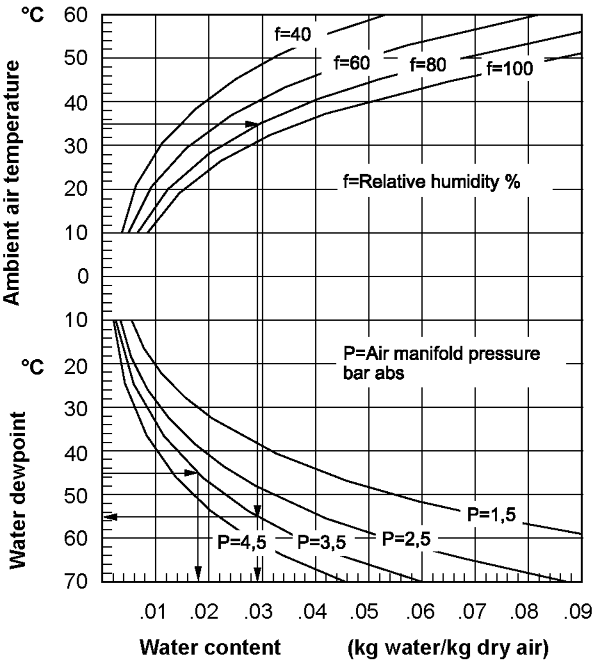
Air humidity may condense in the charge air cooler, especially in tropical conditions. The engine equipped with a small drain pipe from the charge air cooler for condensed water

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.

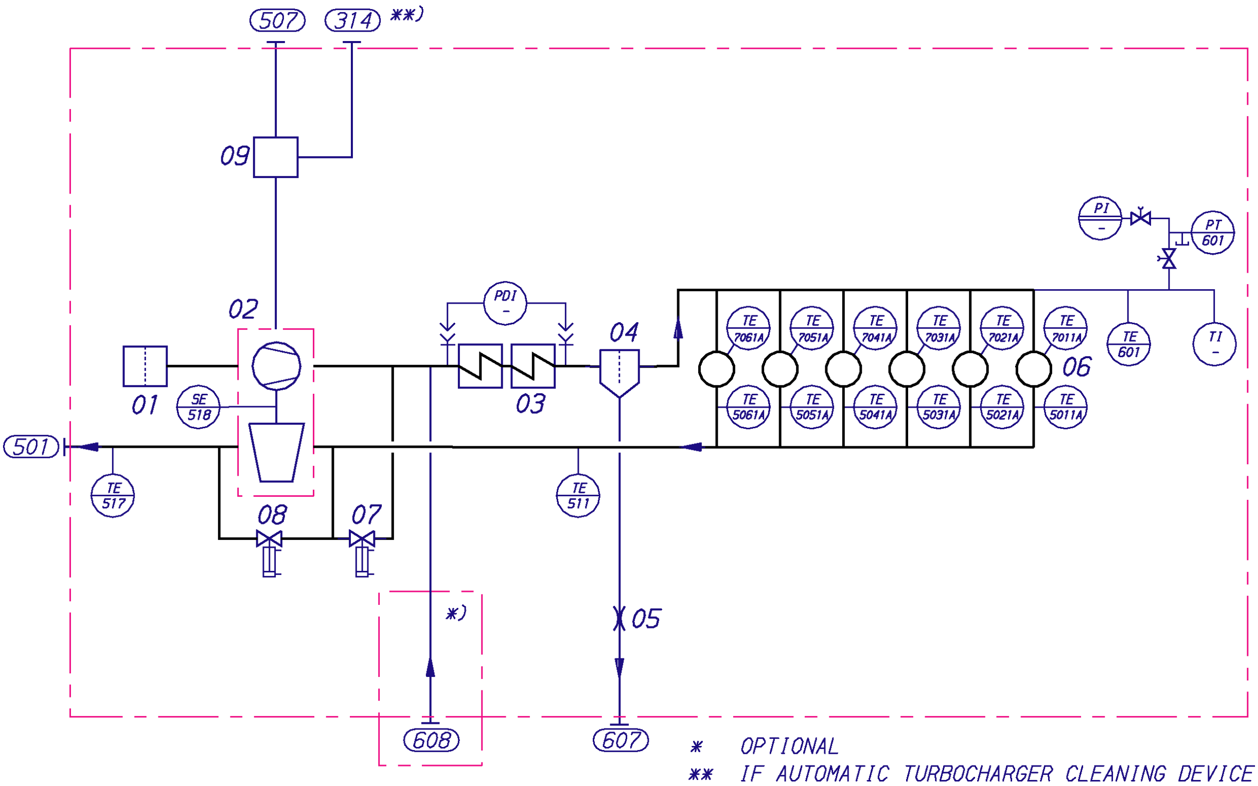
Figure 10.2 Condensation in charge air coolers



11. Exhaust gas system

11.1 Internal exhaust gas system

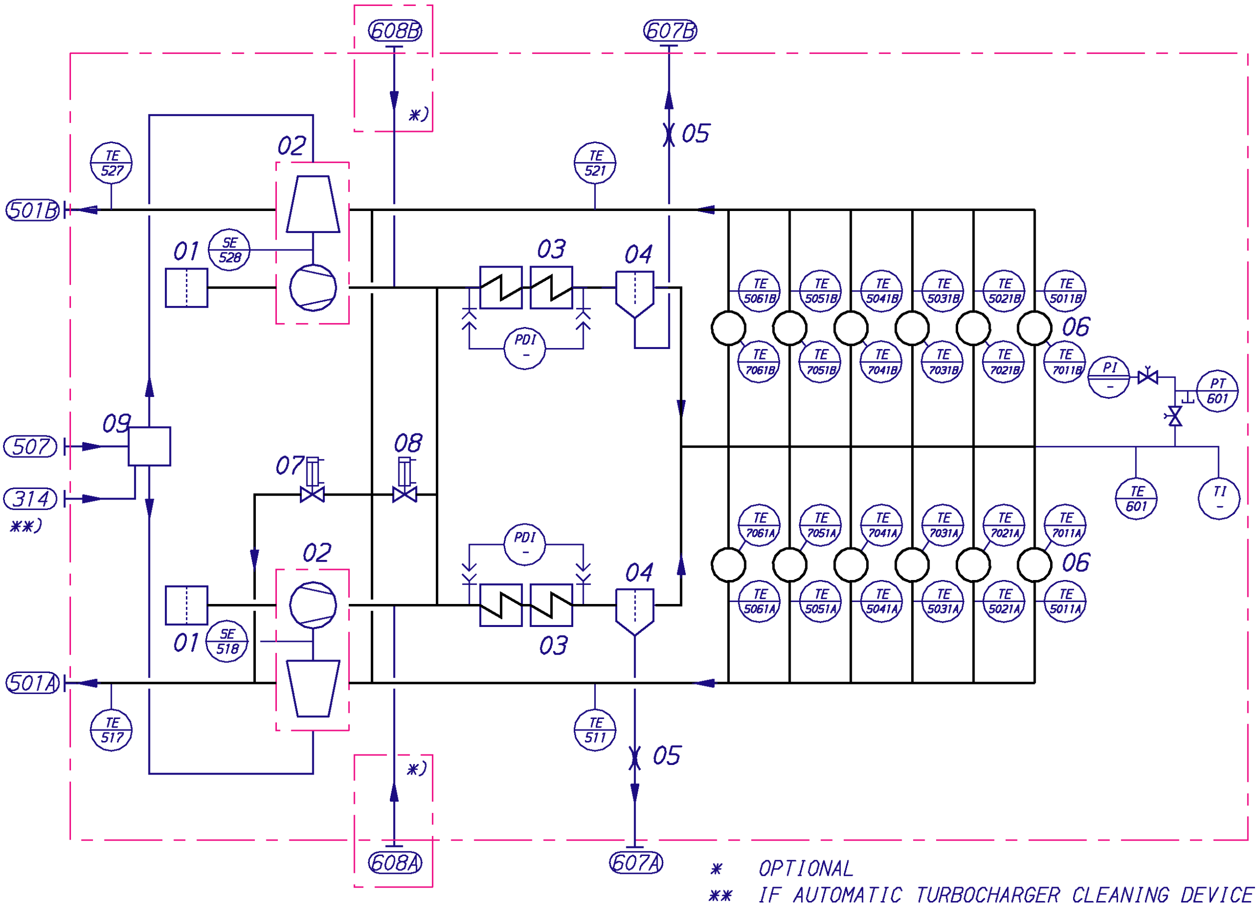
Figure 11.1 Charge air and exhaust gas system, in-line engines (DAAE018500)



System components		Sensors and indicators	
01	Air filter	TE5011A..	Exhaust gas temperature after each cylinder
02	Turbocharger	TE7011A..	Cylinder liner temperature
03	Charge air cooler	TE511	Exhaust gas temperature before turbine
04	Water separator	TE517	Exhaust gas temperature after turbine
05	Restrictor	SE518	Turbocharger speed
06	Cylinder	PT601	Charge air pressure after CAC
07	By-pass valve	TE601	Charge air temperature after CAC
08	Waste gate valve		
09	Turbocharger cleaning valves	PDI	Pressure difference manometer (portable)

Pipe connections		Size	Standard
314	Air supply to compressor and turbine cleaning device	G3/4	DIN ISO 228
501	Exhaust gas outlet	see *Section 11.2.2*	
507	Cleaning water to turbine and compressor	depends on cleaning device	
607	Condensate after air cooler	OD28	
608	Cleaning water to charge air cooler	OD10	

Figure 11.2 Charge air and exhaust gas system, V-engines (DAAE018501a)



System components	
01	Air filter
02	Turbocharger
03	Charge air cooler
04	Water separator
05	Restrictor
06	Cylinder
07	Waste gate valve
08	By-pass valve
09	Turbocharger cleaning valves

Sensors and indicators	
TE5011A..	Exhaust gas temperature after each cylinder
TE7011A..	Cylinder liner temperature
TE511	Exhaust gas temperature before turbine, A-bank
TE521	Exhaust gas temperature before turbine, B-bank
TE517	Exhaust gas temperature after turbine, A-bank
TE527	Exhaust gas temperature after turbine, B-bank
SE518	Turbocharger speed, A-bank
SE528	Turbocharger speed, B-bank
PT601	Charge air pressure after CAC
TE601	Charge air temperature after CAC
PDI	Pressure difference manometer (portable)

Pipe connections		Size	Standard
314	Air supply to compressor and turbine cleaning device	G3/4	DIN ISO 228
501A	Exhaust gas outlet, A-bank	see *Section 11.2.2*	
501B	Exhaust gas outlet, B-bank	see *Section 11.2.2*	
507	Cleaning water to turbine and compressor	depends on cleaning device	
607A	Condensate after air cooler, A-bank	OD28	
607B	Condensate after air cooler, B-bank	OD28	
608A	Cleaning water to charge air cooler, A-bank	OD10	
608B	Cleaning water to charge air cooler, B-bank	OD10	

11.2 Exhaust gas outlet

11.2.1 Exhaust gas outlet

Figure 11.3 Exhaust pipe connection, in-line engines (4V58F0036a)

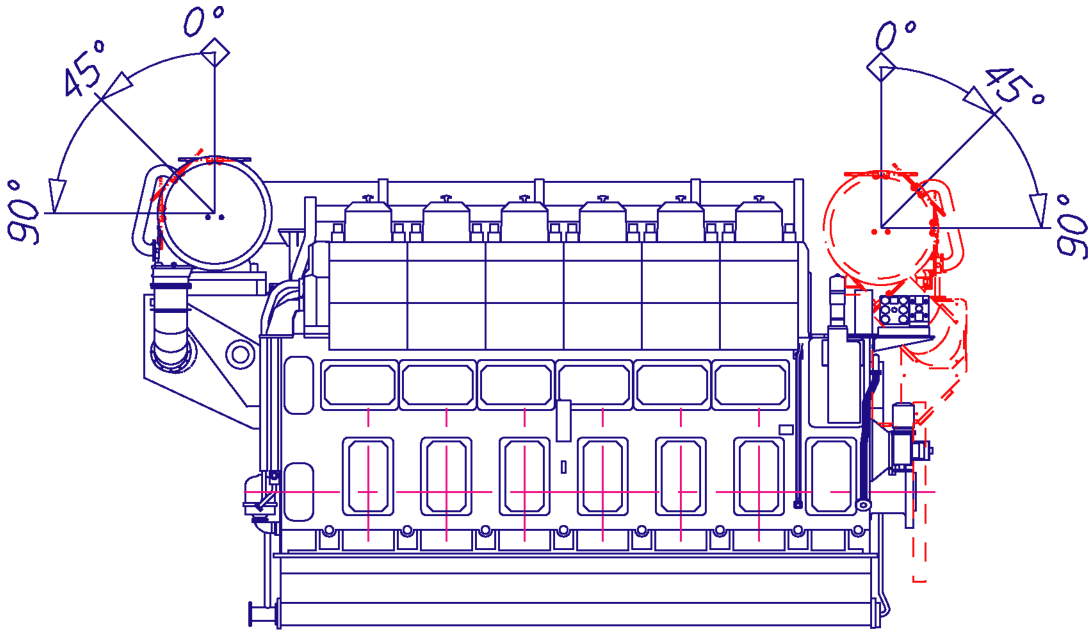
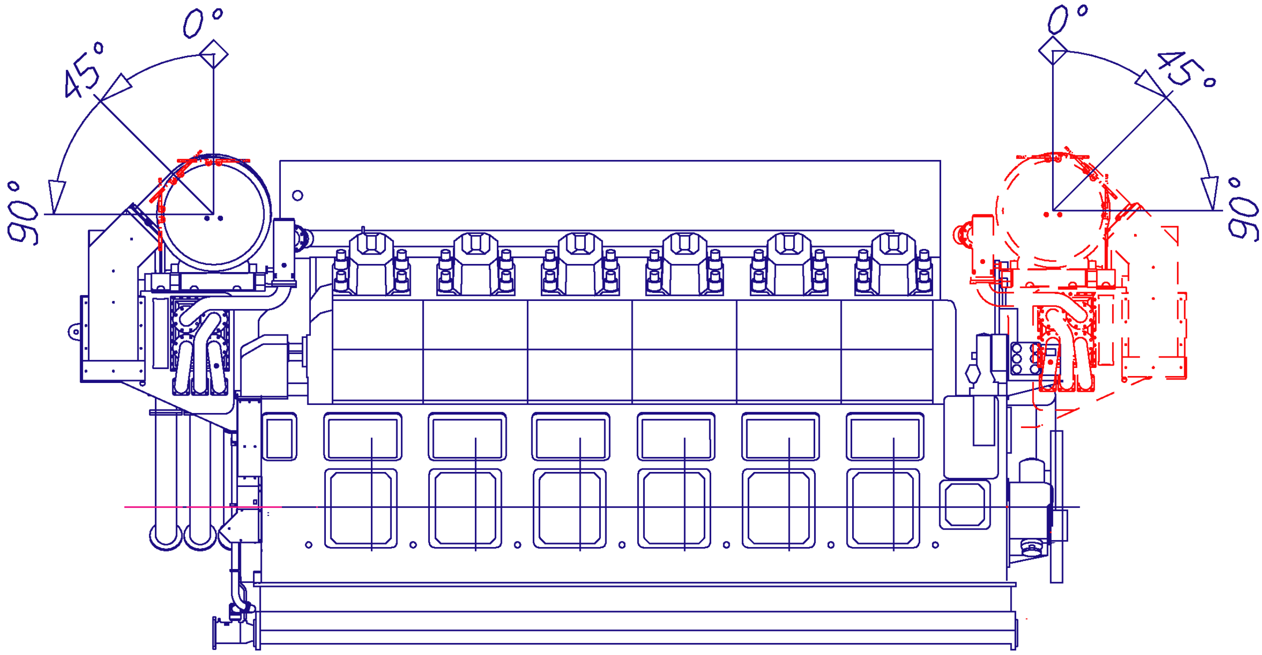


Figure 11.4 Exhaust pipe connection, V-engines (4V58F0037a)



11.2.2 Exhaust pipe, diameters and support

Figure 11.5 (4V76A2674a)

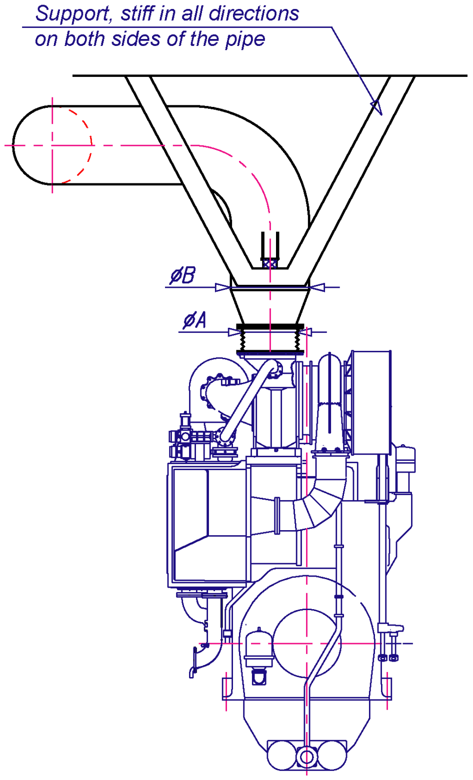


Figure 11.6 (4V76A2676a)

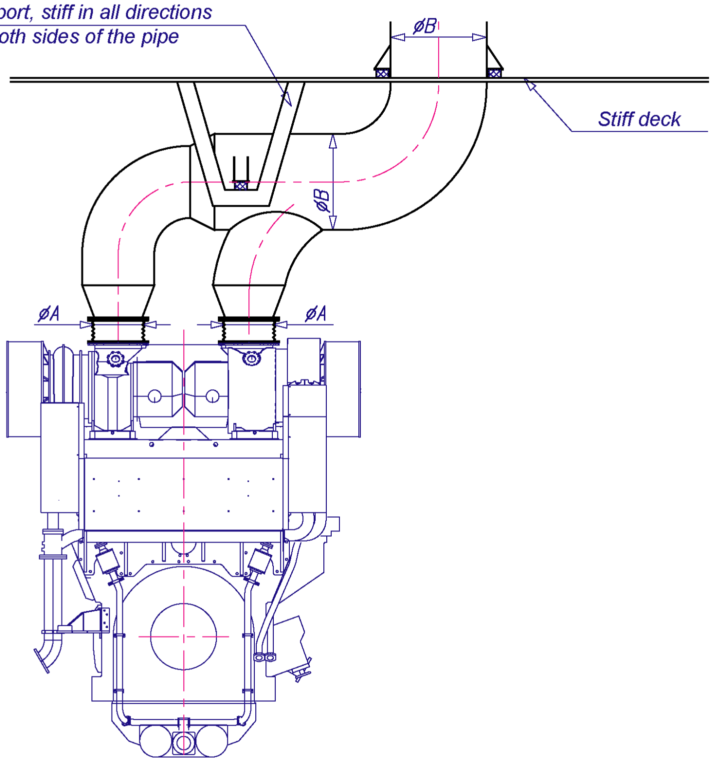


Figure 11.7 (4V76A2675a)

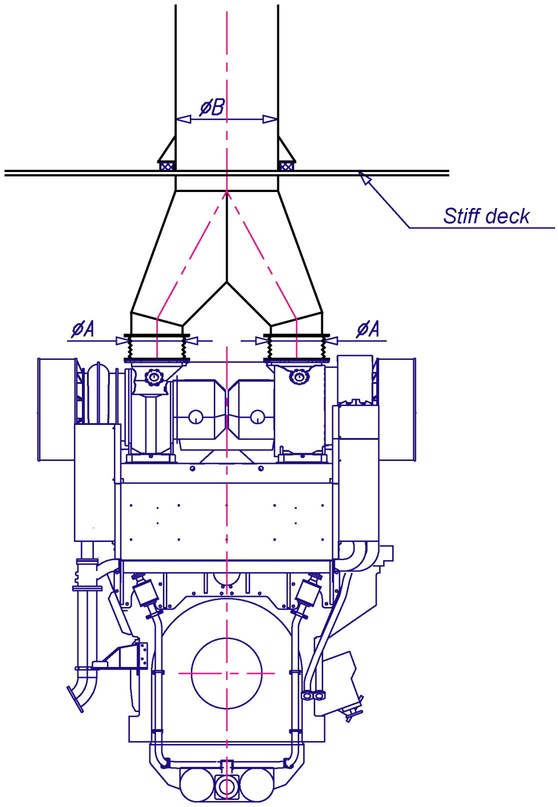


Table 11.1 Exhaust pipe dimensions

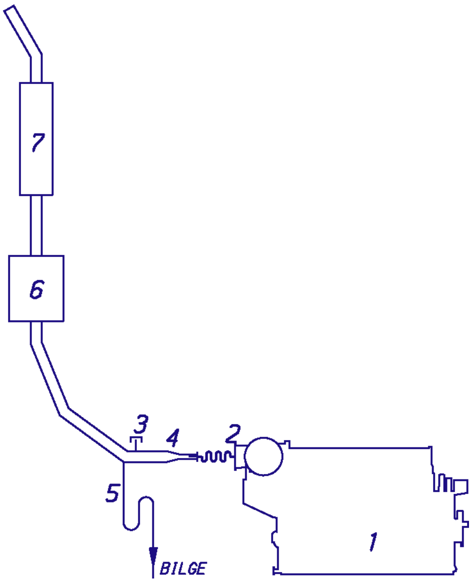
Engine	ØA [mm]		
	Na 357	TPL 73	TPL 77
6L46	450	600	-
8L46	-	600	700
9L46	-	-	700
12V46	2 x 450	2 x 600	-
16V46	-	2 x 600	2 x 700
18V46	-	-	2 x 700

11.3 General

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 11.8 External exhaust gas system



1 Diesel engine
2 Flexible bellows
3 Connection for measurement of back pressure
4 Transition piece
5 Drain with water trap, continuously open
6 Exhaust gas boiler
7 Silencer

11.4 Piping

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

The recommended flow velocity in the pipe is 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.

11.5 Supporting

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

Absolutely rigid mounting between the pipe and the support is recommended at the first fixing point after the turbocharger. Resilient mounts can be accepted for resiliently mounted engines with 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. decklevels, framewebs or specially constructed supports.

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

11.6 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.

11.7 Exhaust gas bellows (5H01, 5H03)

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

11.8 Selective Catalytic Reduction (11N03)

The exhaust gas piping must be straight at least 3...5 meters in front of 2 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.

11.9 Exhaust gas silencer (5R02)

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

When included in the scope of supply, the standard silencer is of the absorption type, equipped with a spark arrester. It is also provided with a soot collector and a condense drain, but it comes without mounting brackets and insulation. The silencer 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 11.9 Exhaust gas silencer

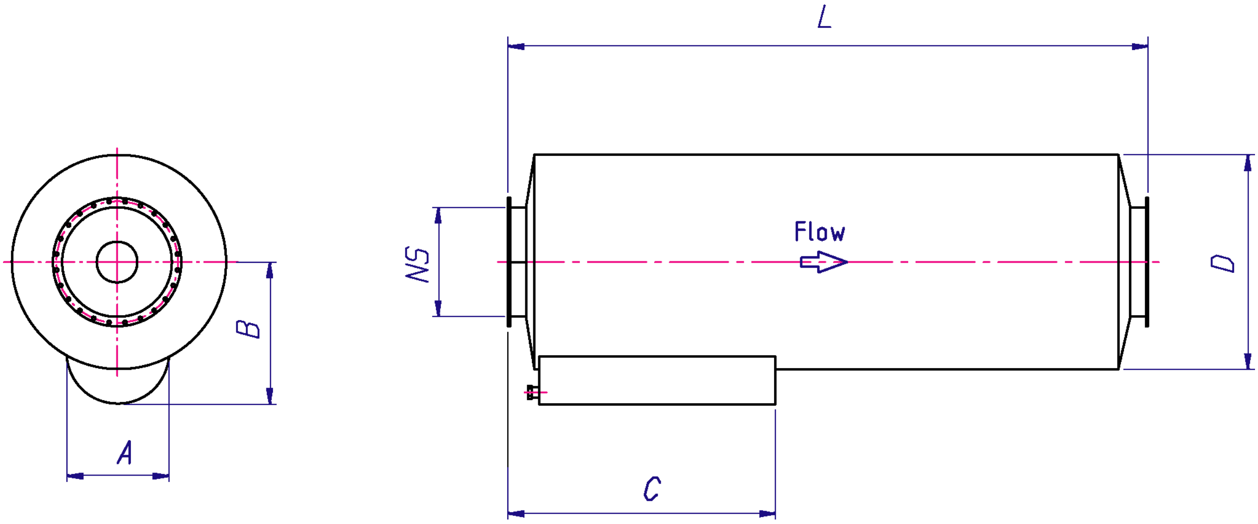


Table 11.2 Typical dimensions of exhaust gas silencers

				Attenuation:	25 dB(A)		35 dB(A)	
NS	**A [mm]**	**B [mm]**	**C [mm]**	**ØD [mm]**	**L [mm]**	**Weight [kg]**	**L [mm]**	**Weight [kg]**
900	860	1190	2240	1800	5360	2295	6870	2900
1000	870	1280	2340	1900	5880	2900	7620	3730
1200	900	1340	2650	2100	7000	4080	9000	5280
1400	950	1490	2680	2400	8165	5800	10165	7120
1500	1000	1540	2680	2500	8165	6180	10165	7650

Flanges: DIN 2501 except NS1500: DIN 86044

11.10 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.

12. Turbocharger cleaning

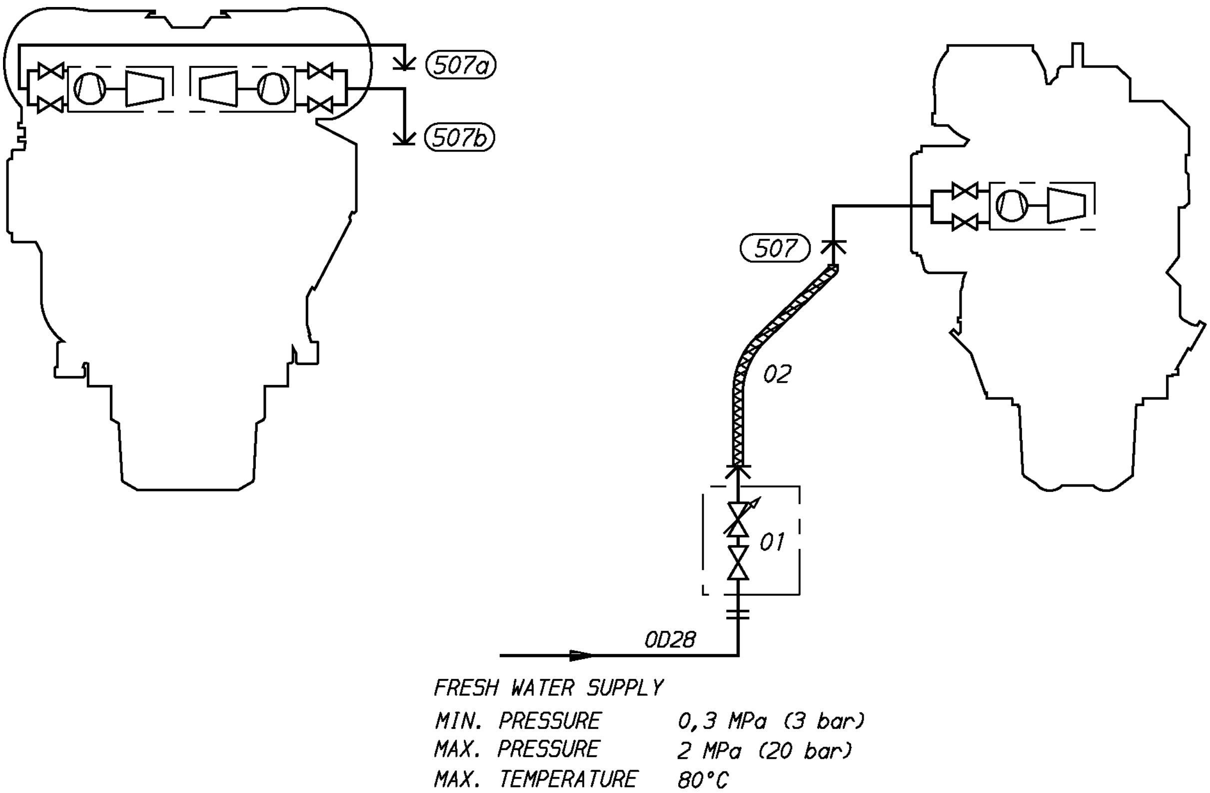
Regular water cleaning of the turbine and the compressor reduces the formation of deposits and extends the time between overhauls. Fresh water is injected into the turbocharger during operation. Additives, solvents or salt water must not be used and the cleaning instructions in the operation manual must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

12.1 Manually operated cleaning system

Engines equipped with Napier turbochargers are delivered with a flow adjustment device and manually operated valves. The flow adjustment device 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 flow adjustment device can be used for several engines.

The water supply must have a pressure of at least 0.3 MPa (3 bar) and the consumption is 35-70 l/min.

Figure 12.1 Turbocharger cleaning system, Napier turbochargers (4V76A2574).



System components		Pipe connections		Size
01	Shut-off and flow adjusting unit	507	Cleaning water to turbine and compressor	Quick coupling
02	Rubber hose, 10 m			

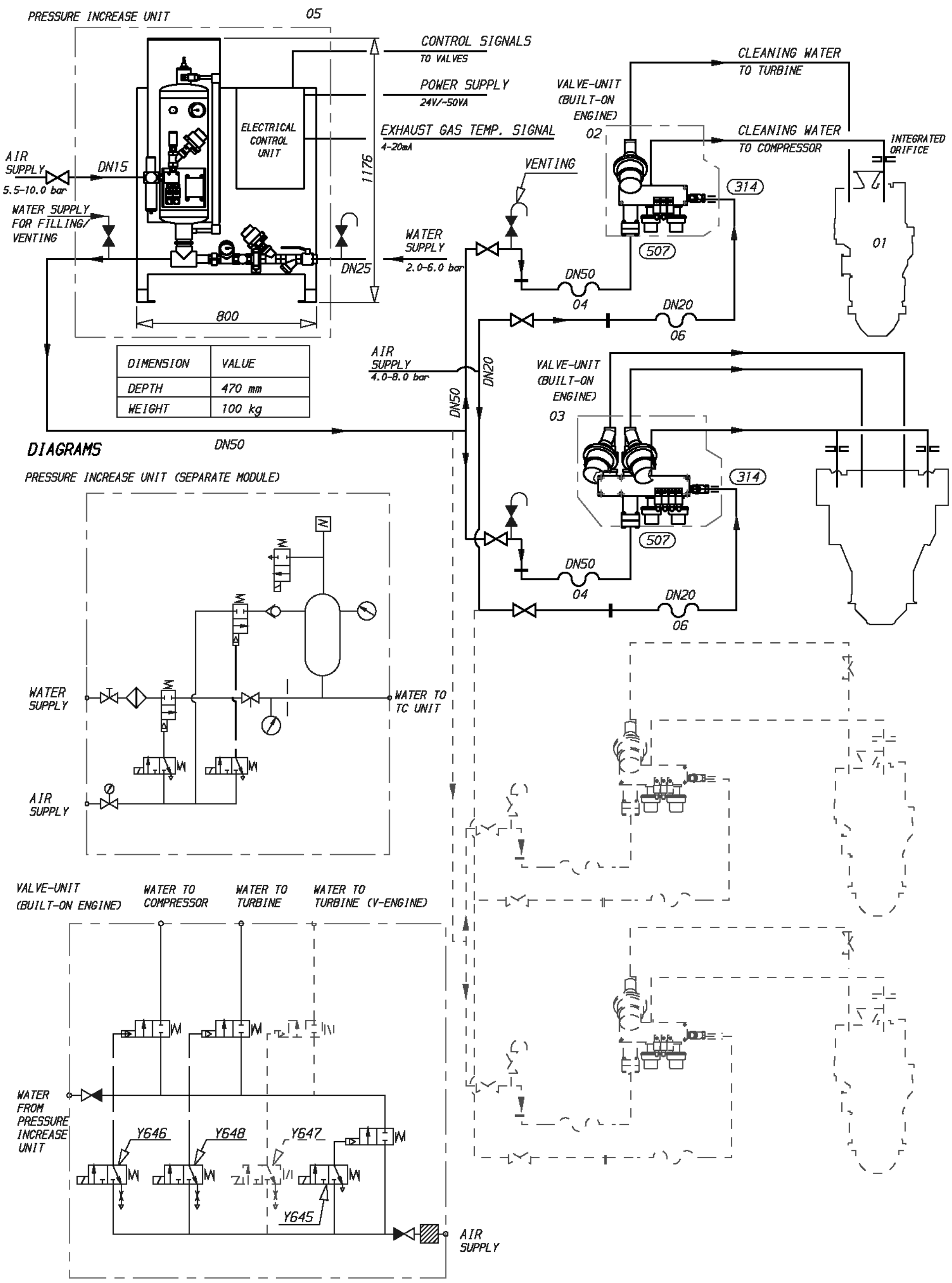
12.2 Automatic cleaning system

Engines with TPL turbochargers are delivered with an automatic cleaning system, which comprises a water feed unit and electrically actuated control valves on the engine. The water feed unit can serve 1-4 engines. The piping between the feed unit and the engines is permanent. Cleaning is started from the control panel on the feed unit and the cleaning sequence is then controlled automatically.

The water feed unit is to be installed as symmetrically as possible between the engines in multiple engine installations. It can be installed max. 1 m below or 7 m above the level of the engine feet. The piping between the feed unit and each engine should be as straight as possible and have a continuous slope as well as a venting valve at the highest position.

The water supply pressure must be 0.2...0.6 MPa (2...6 bar). Required flow is 40...55 l/min for in-line engines and 80...110 l/min for V-engines. The feed unit also needs compressed air at a pressure of 0.55...1.0 MPa (5.5...10 bar). The air consumption at the mentioned pressure is about 6 l/s during water injections. The control unit requires a 24V / 50 VA electric supply.

Figure 12.2 Automatic turbocharger cleaning system, TPL turbochargers (3V69E8155g).



Position

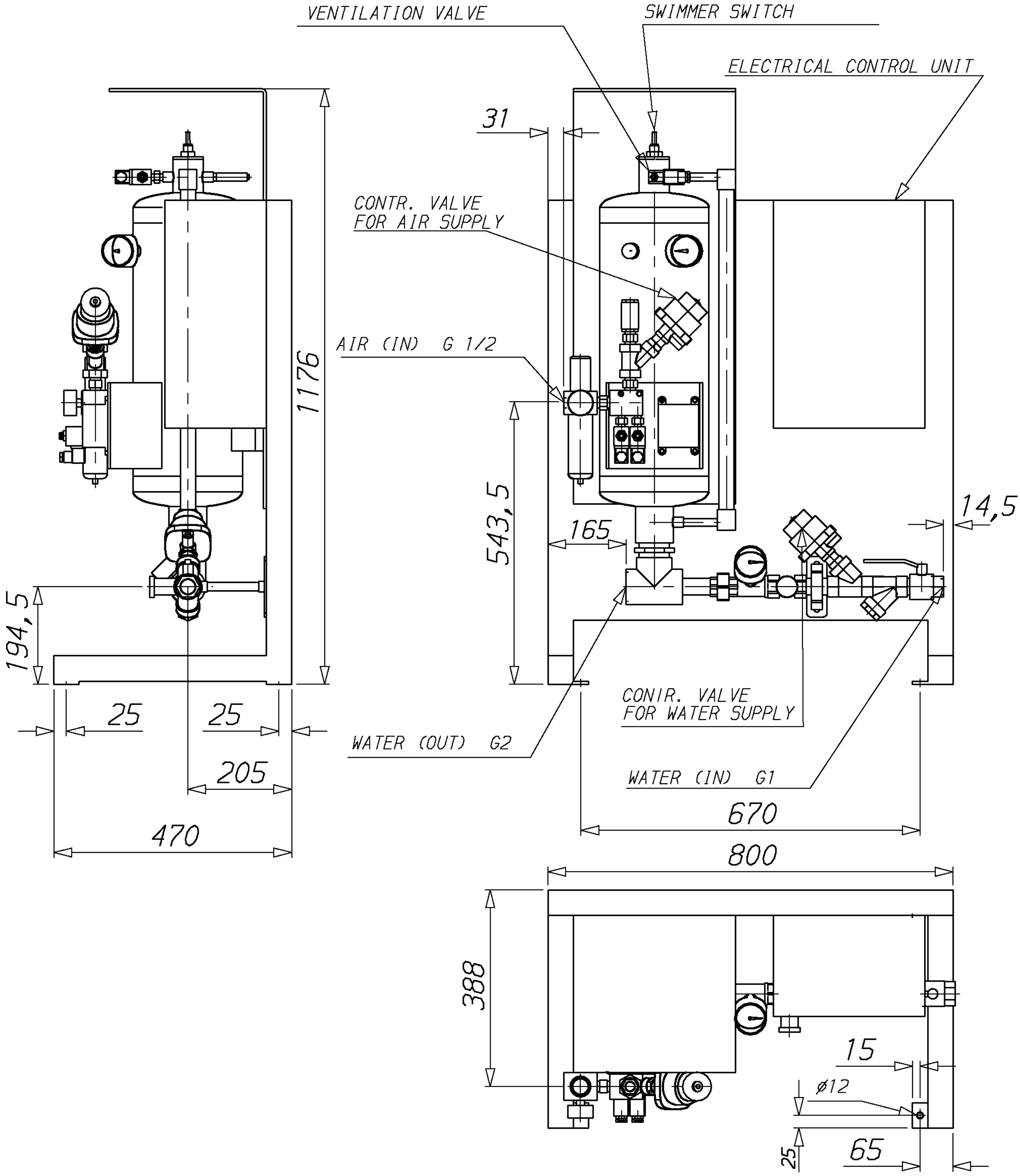
01	Diesel engine	05	Pressure increase unit **
02	Valve unit (in-line engine)	06	Rubber hose DN20 ***
03	Valve unit (V-engine)	314	Air supply for TC
04	Metal hose DN50 *	507	Cleaning water to TC

**) Metal hose length 1.3 m*

***) Max. pipeline length between pressure increase unit and turbocharger is 25 m. Pressure increase unit is allowed to be located max. 1 m below or 7 m above the engine feet.*

****) Rubber hose length 1.5 m*

Figure 12.3 Water feed unit (pressure increase unit) for automatic cleaning system (4V37C1579-2f).



Pipe connections	Size
Water inlet	G 1"
Air inlet	G 1/2"
Water outlet	G 2"

Water supply pressure 0.2...0.6 MPa (2...6 bar). Required flow 40...55 l/min for in-line engine and 80...110 l/min for V-engines.
Air pressure 0.55...1.0 MPa (5.5...10 bar). Air consumption 6 l/s during water injections.
Electric supply 24V / 50 VA.

13. Exhaust emissions

13.1 General

Exhaust emissions from the diesel engine mainly consist of nitrogen, oxygen and combustion products: 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 several legislations world wide limiting the amount of pollutants in the exhaust gas stream of an engine a ship can deliver in the atmosphere.

There are many emission control methods, depending on the aimed pollutant. They are mainly divided in two categories, primary methods are applied on the engine itself, secondary methods are applied on the exhaust gas stream.

13.2 Diesel engine exhaust components

In the following table the typical composition of the exhaust gas from diesel engines is shown.

Table 13.1 Typical exhaust gas composition

Main exhaust gas component	approx % by volume	approx g/kWh
NItrogen N2	74.0-76.0	5020-5160
Oxygen O2	11.6-12.6	900-980
Carbon Dioxide CO2	5.2-5.8	560-620
Steam H2O	5.9-8.6	260-370
Inert gases	0.9	75
Sulphur Oxides SOx	0.08	9.6-16.0
Nitrogen Oxides NOx	0.08-0.15	12.0
CO, THC and VOC	0.02-0.09	0.8-2.0

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 particulates.

In the actual legislation for marine engines CO_2 emission is not limited as it is the result of the combustion process of fossil fuels, although it is one of the main contributors to the greenhouse effect.

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. For this reason, at the present their emissions are not regulated by the Authorities.

13.2.1 Nitrogen oxides (NO_x)

The combustion process gives secondary products as Nitrogen oxides, in fact at high temperature the nitrogen, usually inert, can react with oxygen to form Nitric oxide (NO) and Nitrogen dioxide (NO_2), usually grouped together as NO_x emissions. Their amount is strictly related to the combustion temperature. Predominant oxide of nitrogen found inside the diesel engine cylinder is NO. It 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.

NOx contribute to acid rain, ozone and smog formation in the lower atmosphere especially in urban polluted areas and to over-fertilization of lakes and soil.

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).

SOx contribute to acid rains, potential detrimental effect on vegetation, human health and buildings. Anyhow, they are usually regarded as negligible at deep sea far from shore, because of the alkalinity of sea water, which neutralize the acid, and short transportation distances of SOx (10 - 100 km).

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.

Particulate Matter can affect human breathing system. The size of the particle is a main determinant of where in the respiratory tract the particle will come to rest when inhaled. Larger particles are generally filtered and do not cause problems, but Particulate Matter smaller than about 10 micrometres (PM10) can settle in the bronchi and lungs and cause health problems. Particles smaller than 2.5 micrometres (PM2.5) tend to penetrate into the gas-exchange regions of the lung.

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.

The need for non-visible smoke operation in the marine market has been boosted in recent years especially by the cruise ship industry. Since most harbours visited and routes operated by cruise ships are close to densely populated or environmentally sensitive areas the demand for non-visible smoke operation is considered to be increasingly important.

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.

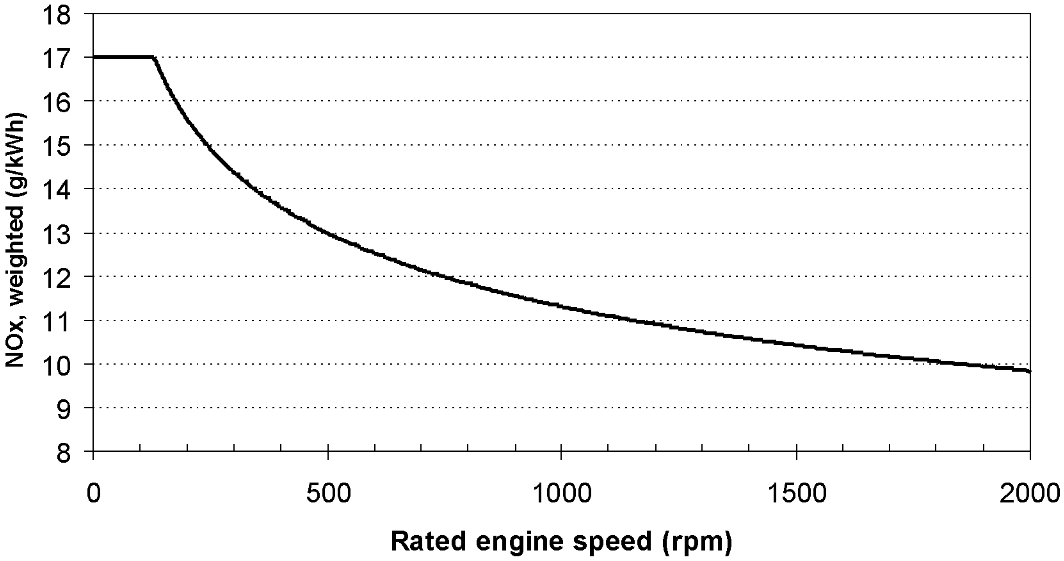
MARPOL Annex VI

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 46 with a rated speed of 500 rpm, the NO_x level is below 13.0 g/kWh and with 514 rpm the NOx level is below 12.9 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 13.2 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 46 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 weigth. 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 weigth. 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 Environmental Protection Agency (EPA)

The Environmental Protection Agency (EPA or sometimes USEPA) is an agency of the federal government of the United States charged with protecting human health and with safeguarding the natural environment: air, water, and land.

Background

Marine engines are classified in three categories, C1, C2, and C3, by their displacement, in liters per cylinder. C1 engines are the smallest (<5 L/cylinder), and typically run on on-road diesel. C2 engines are larger (5-30 L/cylinder) and can use a variety of marine diesel formulations, from ultra-low sulfur to biodiesel to marine gas oil, with each resulting in different profiles of NOx, SOx, and PM emissions. C3 engines (>30 L/cylinder) weight many tons and are at the core of the huge propulsion systems moving large oceangoing vessels. They generally burn high-sulphur residual fuel oil. While C3 engines are, worldwide, responsible for more pollution than C2 engines, the latter will be the target of recommendations. C2 engines power boats and ships that remain close to their local port while C3 engines are mostly found on non-US flag vessels.

Regulatory Acts

Emissions from marine diesel engines have been regulated through a number of rules - the first one issued in 1999 - applicable to different engine categories.

EPA issued new legislation concerning air emission legislation for US coastal shipping in early 2003 (table 2.7). These standards covers C3 category engines, i.e. new marine compression-ignition engines at or above 30 litres/cylinder (only to vessels flagged or registered in the USA). The rule establishes emission standards for marine engines virtually equivalent to the IMO MARPOL Annex VI limits.

Table 13.3 New EPA regulations from January 2003.

Category	Cylinder displacement Litres/cylinder	HC + NOx g/kWh	PM g/kWh	CO g/kWh	Implementation date
C1	displ. < 0.9	7.5	0.40	5.0	2005
	0.9 < displ. < 1.2	7.2	0.30	5.0	2004
	1.2 < displ. < 2.5	7.2	0.20	5.0	2004
	2.5 < displ. < 5.0	7.2	0.20	5.0	2007
C2	5.0 < displ. < 15.0	7.8	0.27	5.0	2007
	15 < displ. < 20.0 power < 3300 kW	8.7	0.50	5.0	2007
	15 < displ. < 20 power > 3300 kW	9.8	0.50	5.0	2007
	20.0 < displ. < 25.0	9.8	0.50	5.0	2007
	25.0 < displ. < 30.0	11.0	0.50	5.0	2007
C3	displ. > 30.0	IMO Limit	-	-	2007

13.3.3 Other Legislations

Several other local legislations are in force in particular regions: further information are mentioned in ECO Guide.

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 Direct Water Injection (DWI)

With DWI NO_x emissions can be reduced by up to 60%, depending on engine load and application. Typical NO_x levels with DWI on Wärtsilä engines are 4-6 g/kWh when operating on marine diesel fuel (MDF) and 5-7 g/kWh when operating on heavy fuel oil (HFO).

DWI is an option for fuels with sulphur contents less than 1.5%.

The high pressure water injection and the fuel injection are completely independent of each other. Fuel and water are injected through separate nozzles integrated in the same injector. The performance of the engine is thus unaffected whether the water injection system is in operation or not. The water injection typically ends before the fuel injection starts in order not to interfere with the fuel injection spray pattern and the combustion process.

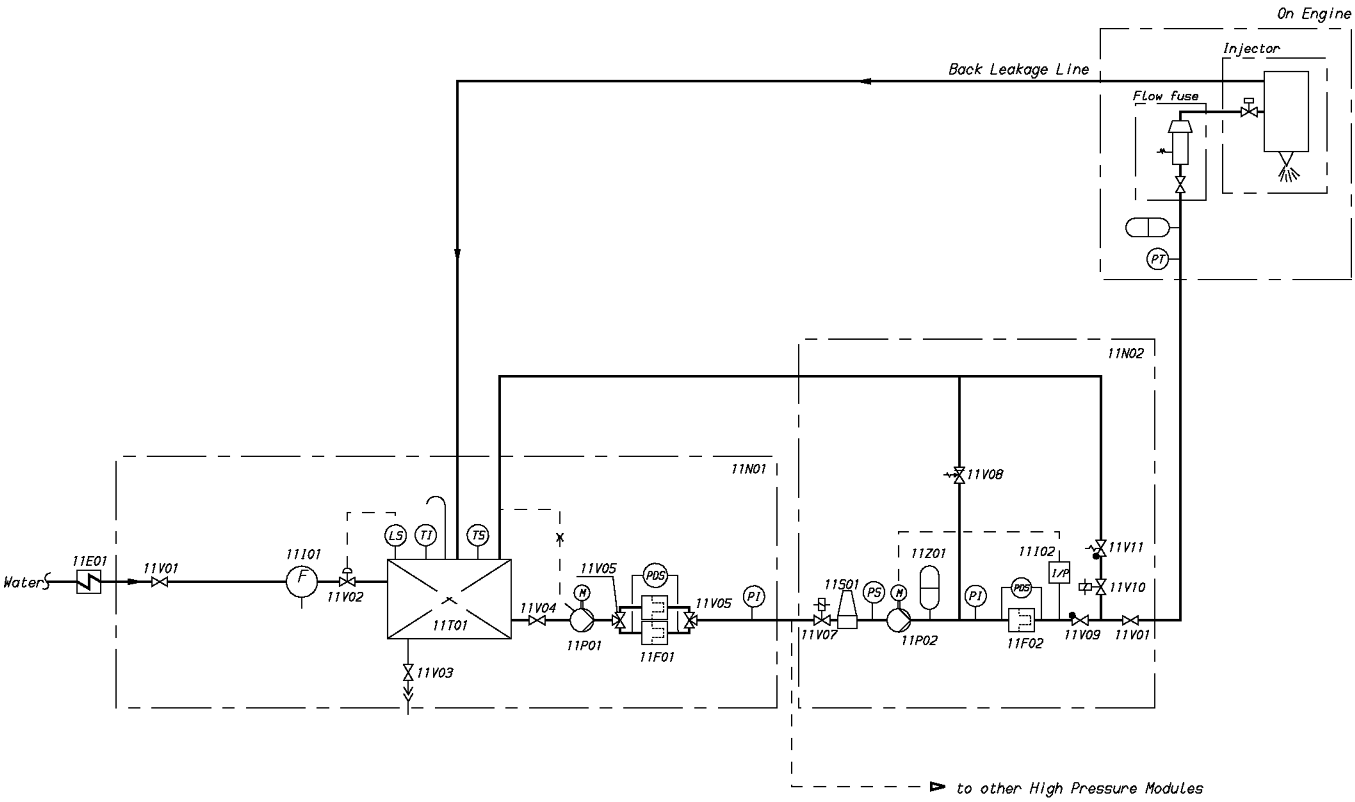
The injection of water is electronically controlled. A solenoid valve, which is mounted on the injector, opens on command from the control unit to let the high pressure water itself open and close the needle. On each cylinder, there is a flow fuse mounted as an essential safeguard against flooding of the engine cylinders. If the injection nozzle does not close properly, the water flow is physically blocked and the system is shut down. The transfer to “non-water” operational mode is automatic and instant.

The required pressure is generated using a piston pump. Excessive water is taken back to a small tank. The water used should be clean fresh water, for instance from the evaporator. The required water quality is as follows:

Table 13.4 Water quality requirements

Property	Unit	Maximum value
Chlorides	mg/l	80
SiO_2	mg/l	50
Particulates	mg/l	50

Figure 13.2 Typical P&ID for Direct Water Injection (3V27A0017c).



System components:

11N01	Low pressure water module	11N02	High pressure water module
11F01	Low-pressure filter	11F02	High-pressure filter
11I01	Flow meter	11I02	Frequency converter
11P01	Low-pressure pump	11P02	High-pressure pump
11T01	Water tank	11S01	Venting tank
11V01	Valve (manual operated)	11V07	Solenoid valve
11V02	Flow control valve	11V08	Safety valve
11V03	Drain valve	11V09	Non-return valve
11V04	Manual shut-off valve	11V10	Valve
11V05	Three way valve	11V11	Pressure control valve
		11Z01	Pressure damper
11E01	Heater (optional)		

The required investment (assuming that fresh water is available) consists of the special fuel injectors, one high pressure pump module, one low pressure pump module plus piping and electronic control system. When retrofitting, the cylinder heads have to be modified.

Required fresh water supply is typically more than half of the fuel oil consumption, i.e. 100-130 g/kWh (margin included). However, if the DWI system is used only in coastal or port areas, the water consumption has to be related to this.

When operating the DWI system the fuel oil consumption will increase with 2-3%.

13.4.2 Humidification of charge air (Wetpac H)

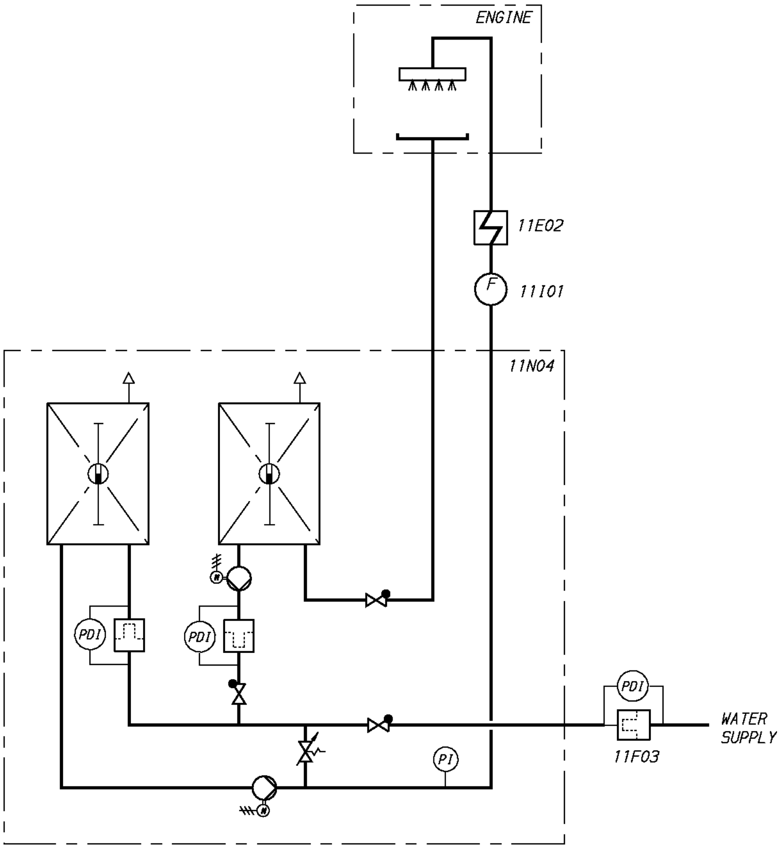
With Wetpac H NO_x emissions can be reduced up to 40%.

Wetpac H is an option for fuels with sulphur contents less than 1.5%.

Water is injected after the turbocharger, carried to the cylinders with the air and decreasing the maximum temperatures in the cylinders, thus reducing NO_x.

The Wetpac H system includes a pump unit and a control unit outside the engine and group(s) of spraying nozzles with solenoid valves built on the charge air duct. The pump unit should be placed somewhere close to the engine.

Figure 13.3 Internal scheme Wetpac H (DAAE039819)



Main components	
11N04	Humidification pump unit
11E02	Heater
11F03	Pre-filter
11I01	Flowmeter

The system is designed and built so that the amount of water injected can be adjusted and the Wetpac H system can also be shut off if necessary. In case of failure the system will automatically go in off-mode.

The amount of water needed varies with the load and with the NO_x level the operator wants to achieve. Typically the water amount needed is 1.5...2 times the engine fuel oil consumption for full NO_x reduction. The water used for Wetpac H has to be of very good quality, produced by evaporators or 2-stage reverse osmosis, see table *13.5 Water quality requirements*.

Please note that when Wetpac H is in operation the heat balance of the engine will change, always ask for project specific information.

Water used for Wetpac H has to fulfill the following requirements:

Table 13.5 Water quality requirements

Property	Unit	Maximum value
PH		6...8
Hardness	°dH	0.4
Chlorides as Cl	mg/l	5
Suspended solids	mg/l	5
Temperature before pump unit	°C	40

In order to achieve a safe operation of the Wetpac H system and the engine, water produced with a fresh water generator / distiller or a 2-stage reverse osmosis unit has to be used. The water must not be contaminated by oil, grease, surfactants or similar impurities. These kinds of impurities may cause blocking of the filters or other malfunctions in the Wetpac H system.

Table 13.6 Water consumption

Engine type	Water consumption [l/h]
W 6L46	1900
W 8L46	2600
W 9L46	2900
W 12V46	3900
W 16V46	5200

The water consumption is calculated at max NO_x reduction and 85% load of the engine.

13.4.3 Selective Catalytic Reduction (SCR)

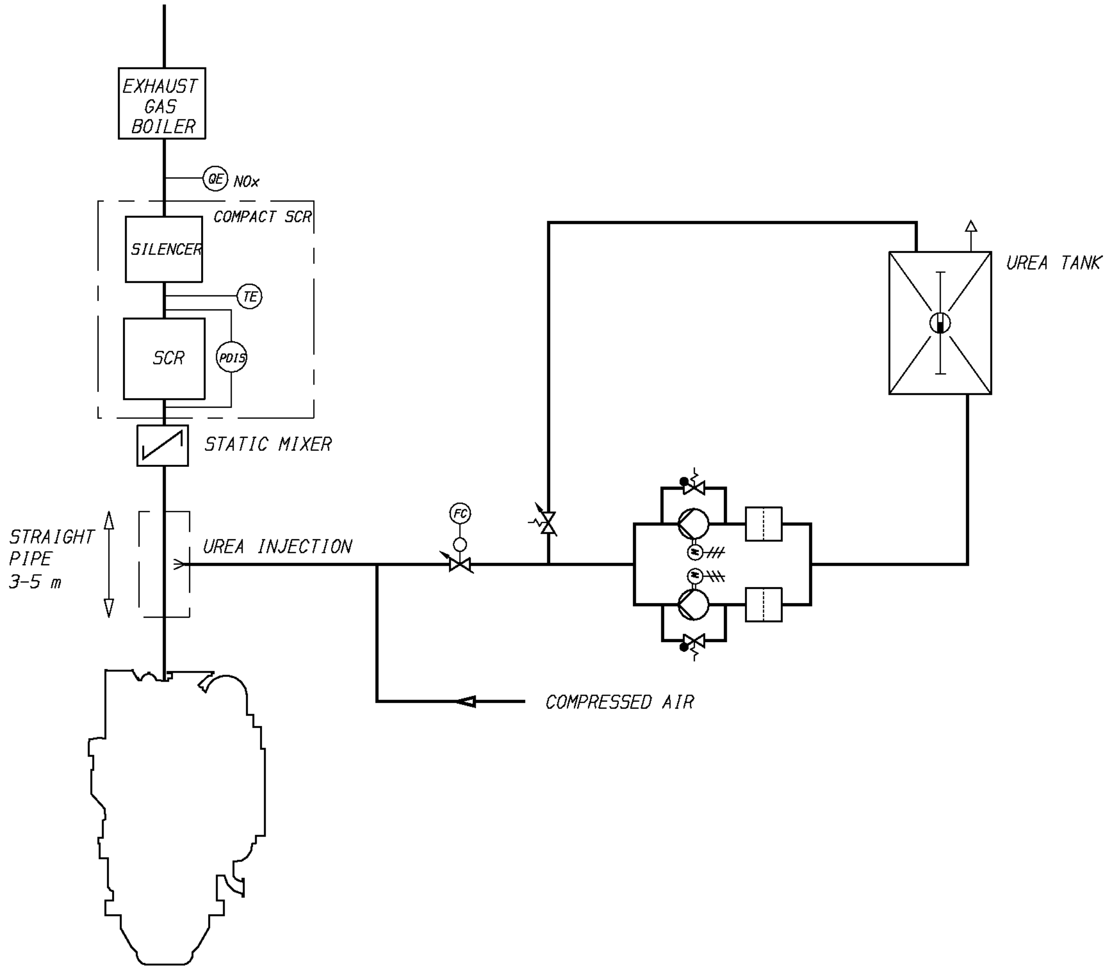
Selective Catalytic Reduction (SCR) is the only way to reach a NO_x reduction level of 85-95%.

The reducing agent, aqueous solution of urea (40 wt-%), is injected into the exhaust gas directly after the turbocharger. Urea decays immediately to ammonia (NH_3) and carbon dioxide. The mixture is passed through the catalyst where NO_x is converted to harmless nitrogen and water, which are normally found in the air that we breathe. 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 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.

Figure 13.4 Typical P&ID for Compact SCR (DAAE037524)



The disadvantages of the SCR are the large size and the relatively high installation and operation costs. To reduce the size, Wärtsilä has together with subsuppliers developed the Compact SCR, which is a combined silencer and SCR. The Compact SCR will require only a little more space than an ordinary silencer.

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 applied on all Wärtsilä engines, using the same architecture and components on all engine types.

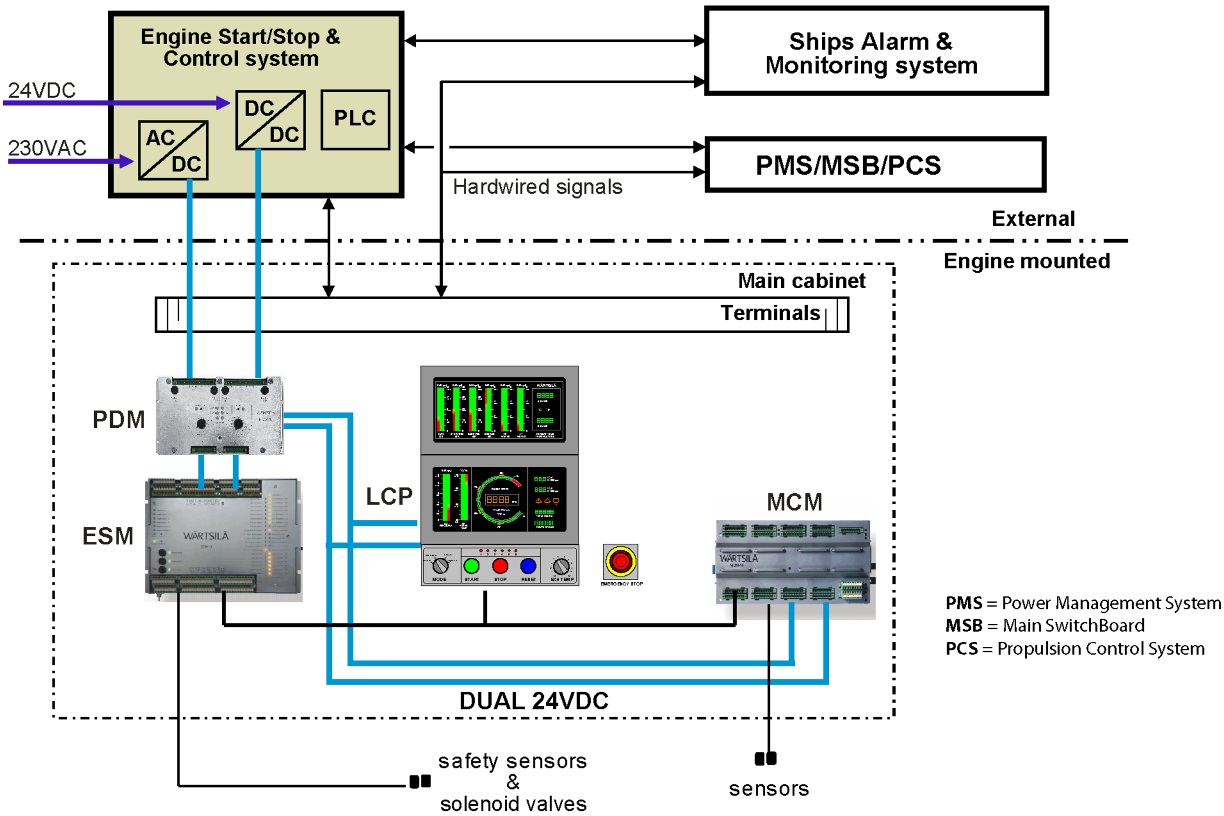
Engines with conventional fuel injection are available with two different levels of automation. Automation level 1 has a completely hardwired signal interface with external systems, whereas automation level 2 has hardwired interface for control functions and a bus communication interface for alarm and monitoring.

Engines with common rail fuel injection are always equipped with automation system level 2 as this is required for fuel injection control.

14.1 Automation system level 1

The equipment on the engine included in automation system level 1 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 automation system level 1



Equipment in the main cabinet on the engine:

MCM Main Control Module. In automation system level 1 this module is used for speed/load control (unless an external speed control unit is specified).

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. 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

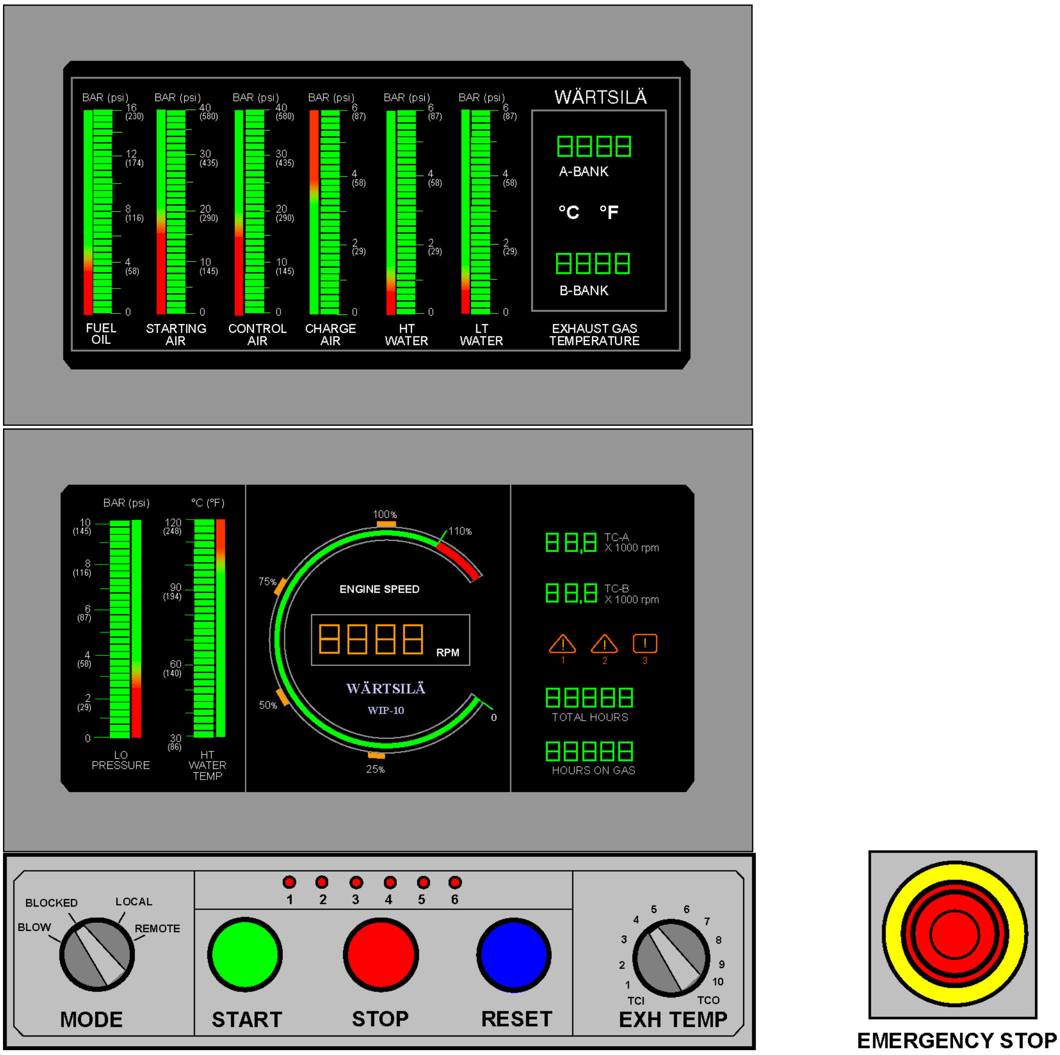
Start/stop & control system

The equipment listed below is mounted in a steel sheet cabinet for bulkhead mounting, protection class IP44.

- Programmable logic controller for start blockings, slow turning, wastegate control etc.
- Two redundant power supply converters/isolators
- Fuses and terminals
- External speed control unit, if applicable
- Display unit

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
- Hour counter
- 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 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

14.1.3 Engine start/stop & control system

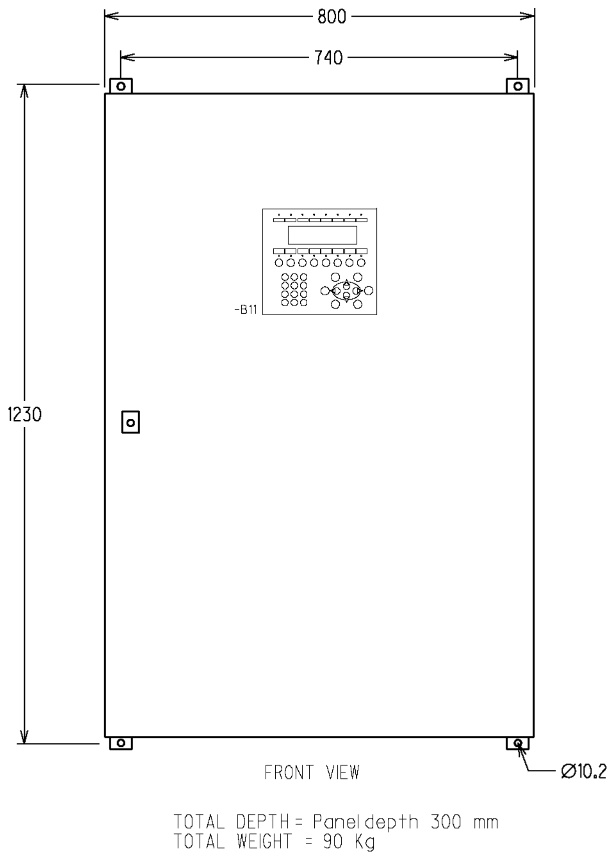
The main features of the engine start/stop & control system are:

- Steel sheet cabinet for bulkhead mounting, protection class IP44
- Programmable logic controller for the main functions:

- Start blocking
- Slowturning and start sequence
- Control of LT-thermostatic valve, charge air bypass and exhaust gas wastegate
- 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 UPS

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 Automation system level 1 overview

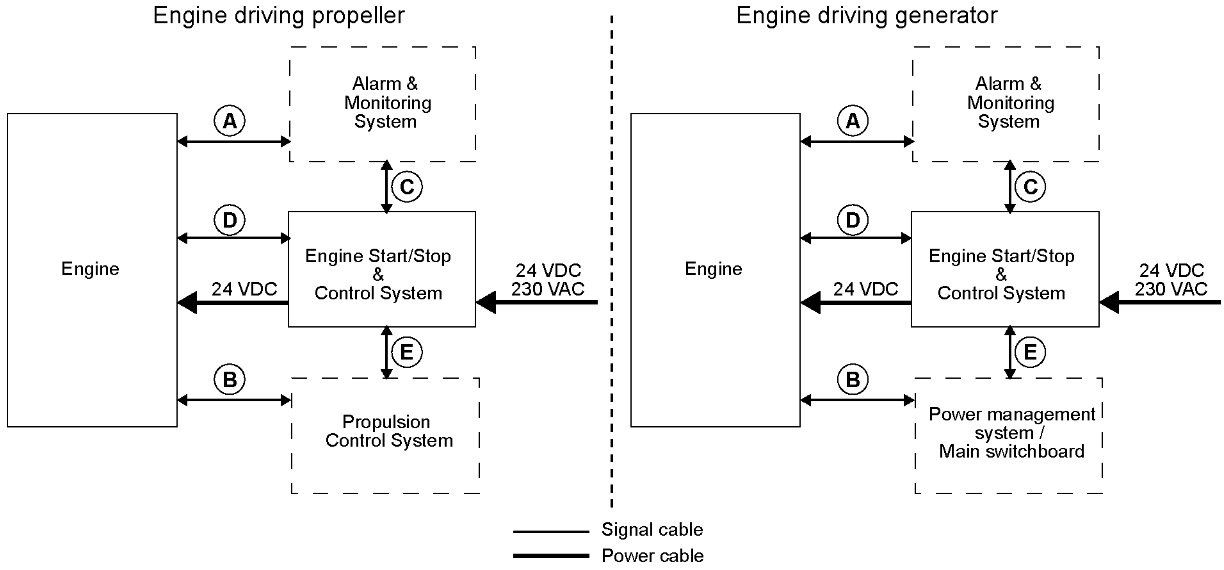


Table 14.1 Typical amount of cables of the automation system level 1

Cable	From <=> To	Cable types (typical)
A	Engine <=> alarm & monitoring system	18 x 2 x 0.75 mm^2 11 x 2 x 0.75 mm^2 9 x 2 x 0.75 mm^2 6 x 2 x 0.75 mm^2 4 x 2 x 0.75 mm^2 4 x 2 x 0.75 mm^2 21 x 0.75 mm^2 12 x 0.75 mm^2 10 x 0.75 mm^2
B	Engine <=> propulsion control system Engine <=> power management system / main switchboard	1 x 2 x 0.75 mm^2 10 x 0.75 mm^2 4 x 0.75 mm^2
C	Engine start/stop & control system <=> alarm & monitoring system	3 x 2 x 0.75 mm^2 22 x 0.75 mm^2
D	Engine <=> engine start/stop & control system	4 x 1.5 mm^2 (power supply) 12 x 2 x 0.75 mm^2 1 x 2 x 0.75 mm^2 26 x 0.75 mm^2 13 x 0.75 mm^2 6 x 1.5 mm^2 8 x 0.75 mm^2 3 x 1.5 mm^2
E	Engine start/stop & control system <=> propulsion control system Engine start/stop & control system <=> power management system / main switchboard	1 x 2 x 0.75 mm^2 14 x 0.75 mm^2 2 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)

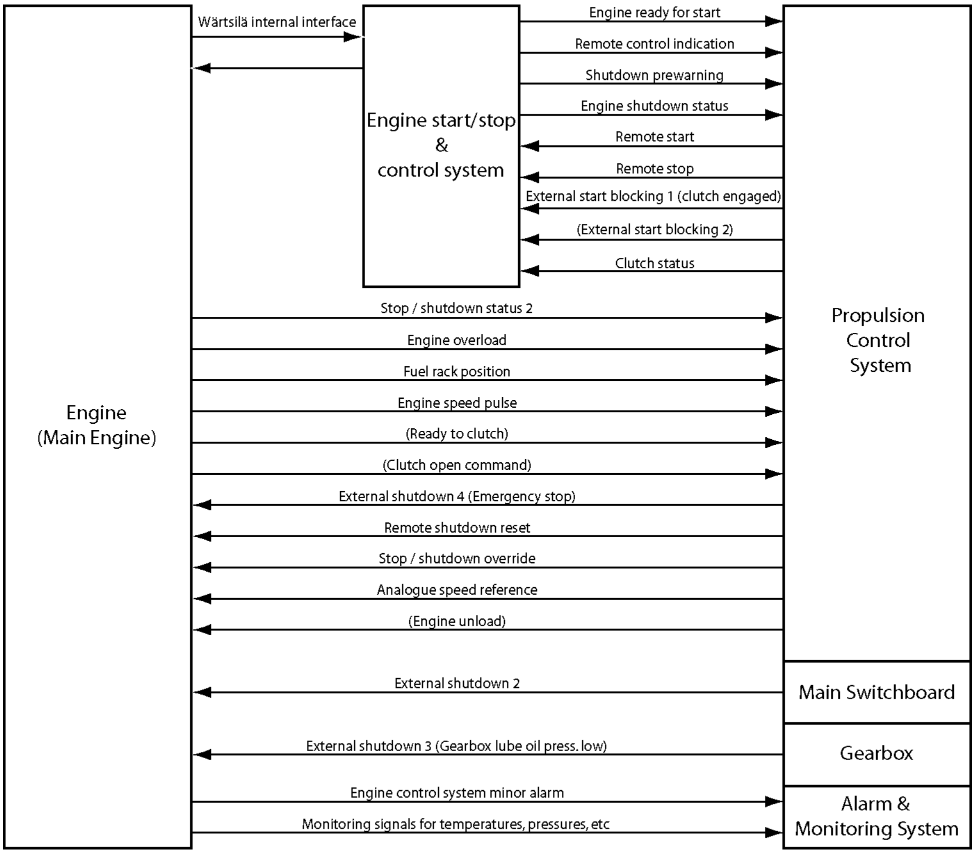
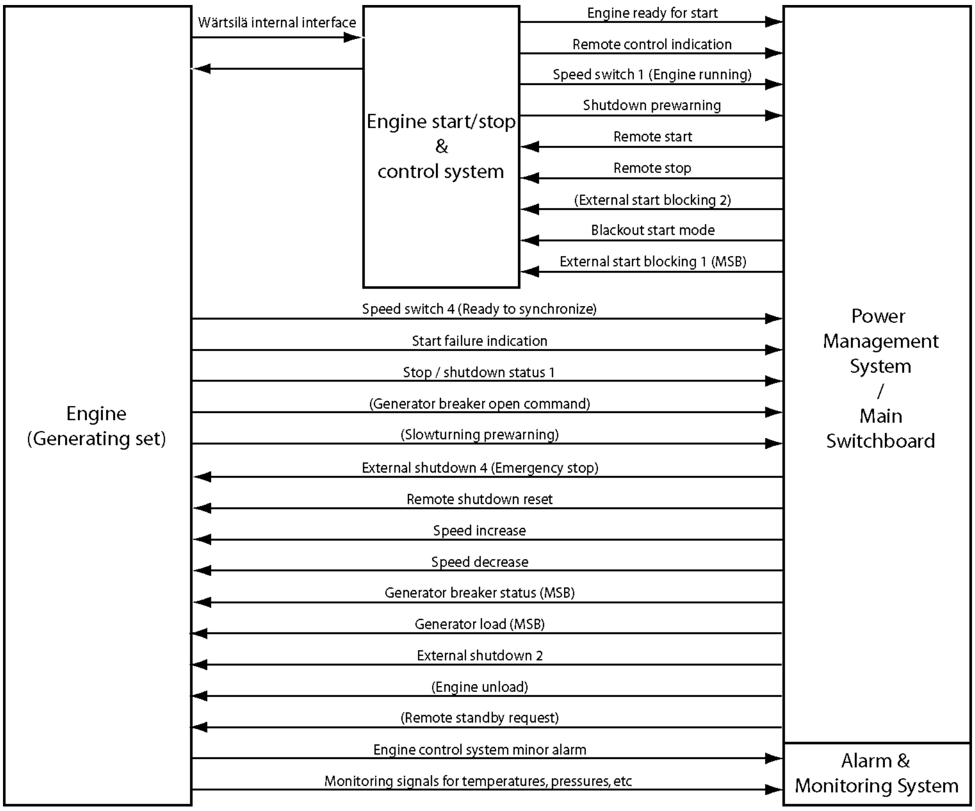


Figure 14.6 Signal overview (Generating set)



14.2 Automation system level 2

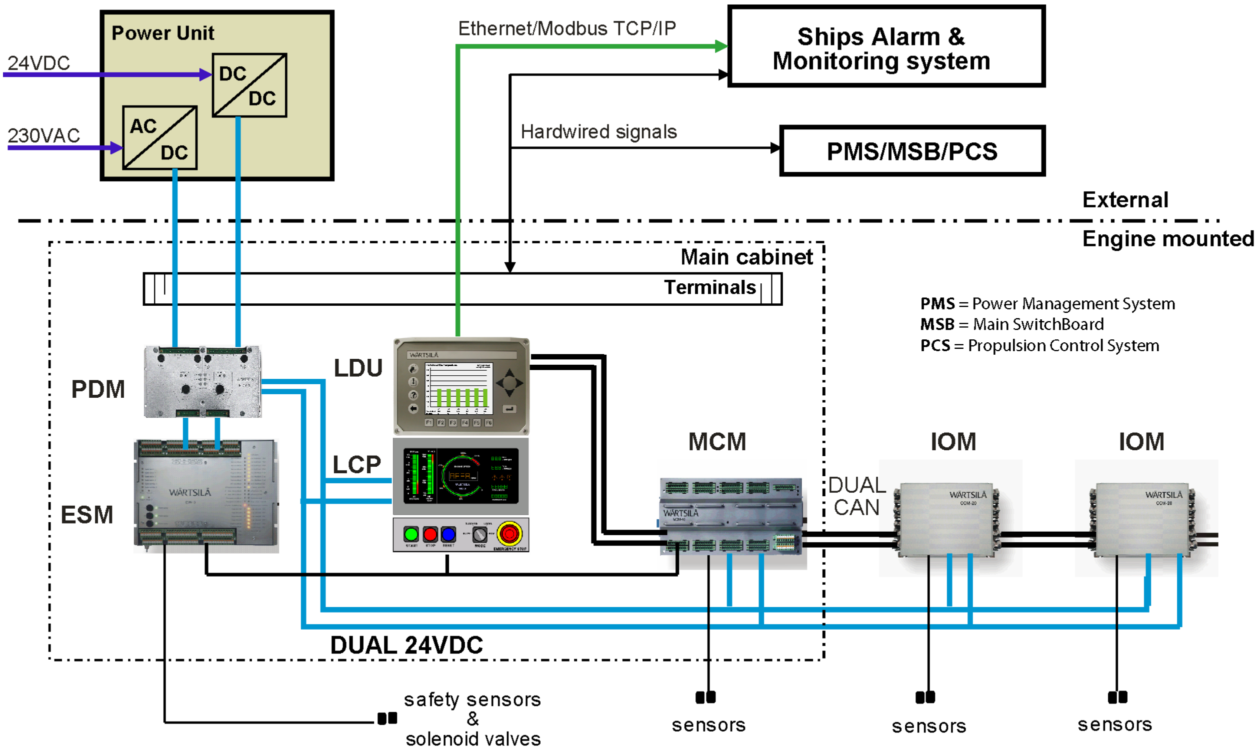
Automation system level 2 is a fully embedded and distributed engine management system. It handles all control functions on the engine; for example start sequencing, start blocking, speed control, load sharing, normal stops and safety shutdowns. On common rail engines it also includes fuel injection control.

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 Ethernet TCP/IP connection to external systems.

Figure 14.7 Architecture of automation system level 2



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.

IOM Input/Output Module. Handles measurements and controls locally at its engine position.

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. 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 Ethernet TCP/IP.

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. Common rail engines also have two redundant 110 VDC supplies for the injector drivers.

Equipment locally on the engine:

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

CCM Cylinder Control Module on common rail engines. Handles fuel injection control and cylinder related measurements, usually for three cylinders.

Sensors

Solenoids

Actuators

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

For common rail engines also the following modules are included:

PDM Power Distribution Module. Handles the fusing, power distribution and EMC filtration in the system. Two fully redundant supplies are arranged both for the valve drive supply (110 VDC) and module- and auxiliary supply (24 VDC) on the engine.

CCM Cylinder Control Module. Handles fuel injection control, and local measurements at the cylinders where it is used.

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 hour counter.
- 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 provides DC power to the electrical system on the engine and isolates the power supply from other DC systems onboard. The cabinet is designed for bulkhead mounting, protection degree IP44, max. ambient temperature 50 °C.

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

Power supply from ship's system for engines with conventional fuel injection:

- Supply 1: 230 VAC / abt. 150 W
- Supply 2: 24 VDC / abt. 150 W.

Power supply from ship's system for engines with common rail fuel injection:

- Supply 1: 230 VAC / abt. 600 W
- Supply 2: 230 VAC / abt. 600 W.

14.2.4 Cabling and system overview

Figure 14.9 Overview of automation system level 2

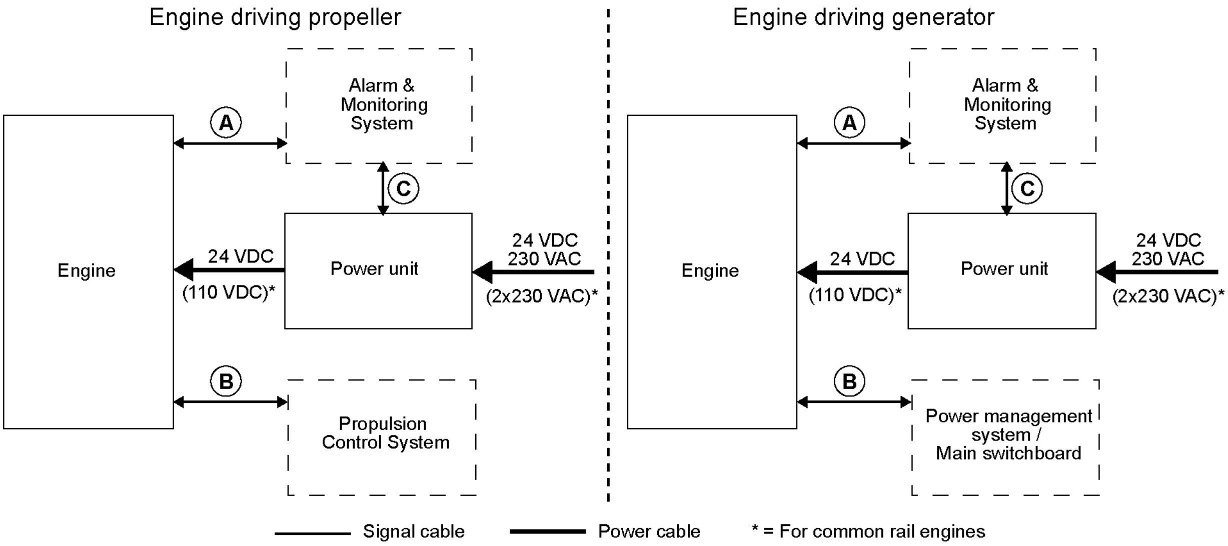


Table 14.2 Typical amount of cables of the automation system level 2

Cable	From <=> To	Cable types (typical)
A	Engine <=> alarm & monitoring system	3 x 2 x 0.75 mm^2 4 x 2 x 0.5 mm^2 (Ethernet)
B	Engine <=> propulsion control system Engine <=> power management system / main switchboard	1 x 2 x 0.75 mm^2 16 x 0.75 mm^2 14 x 0.75 mm^2 8 x 0.75 mm^2
C	Power unit <=> alarm & monitoring system	2 x 0.75 mm^2
D	Engine <=> power unit	2 x 1.5 mm^2 (power supply) 2 x 1.5 mm^2 (power supply) 2 x 1.5 mm^2 (power supply) (CR) 2 x 1.5 mm^2 (power supply) (CR)

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)

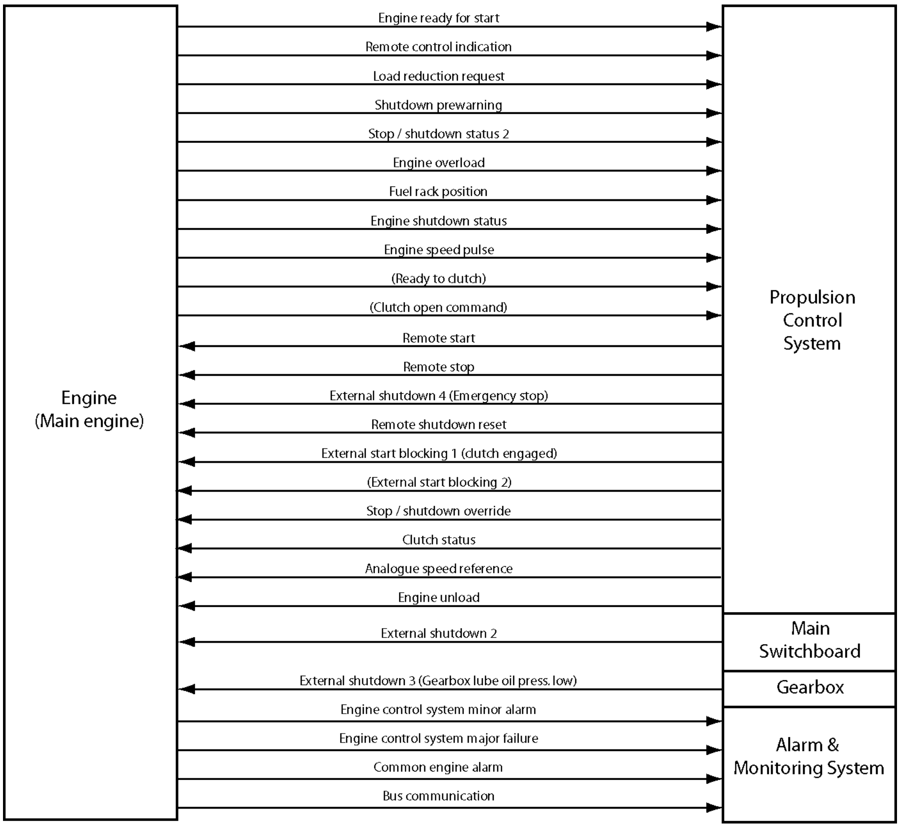
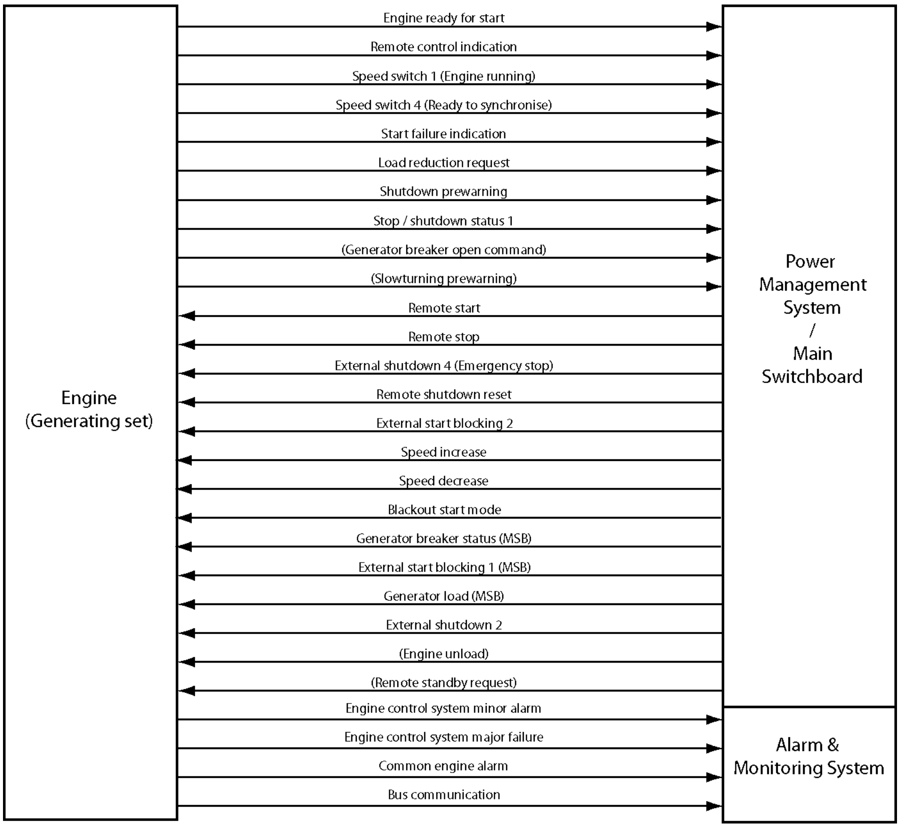


Figure 14.11 Signal overview (Generating set)



14.3 Functions

14.3.1 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.

Start blockings and slow turning are handled by the programmable logic in the external cabinet with automation level 1, and by the system on the engine (main control module) with automation level 2.

Start blockings

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.

14.3.2 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.

14.3.3 Speed control

Main engines (mechanical propulsion)

It is recommended to utilise the electronic speed control integrated in the engine automation system also in simpler applications. 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.

In installations with two engines connected to the same reduction gear, electronic speed control is mandatory, while mechanical back-up is not an option.

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 (normally for synchronising of shaft generators). If the engine is equipped with a mechanical-hydraulic governor as backup, the 4-20 mA speed setting from the propulsion control is converted to a pneumatic speed setting for the governor through an E/P converter. The E/P converter is installed separately from the engine.

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

Diesel generators are always equipped with electronic speed control. 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.

14.4 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 automation level 1, which has a completely hardwired signal interface. Automation level 2 transmits the 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

Code	Description	I/O type	Signal type	Range
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
PT312	Instrument air pressure	AI	4-20 mA	0-10 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
TE403	HT water temp., jacket outlet B bank	AI	PT100	0-160 °C
TEZ402	HT water temp., jacket outlet A bank	AI	PT100	0-160 °C
TEZ403	HT water temp., jacket outlet B 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
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	0-25000 rpm

Code	Description	I/O type	Signal type	Range
SI528	Turbocharger B speed 1)	AI	4-20 mA	0-25000 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

14.5 Electrical consumers

14.5.1 Motor starters

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. Oil temperature has a great impact on the required motor rating for a pre-lubricating oil pump for example.

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

Engine turning device

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]
6L46, 8L46	3 x 400/440	50/60	2.2/2.6	5
9L46, V46	3 x 400/440	50/60	5.5/6.4	12

14.5.2 Operation of electrically driven pumps

Pre-lubricating oil pump (2P02)

The pre-lubricating oil pump should 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.

Main pump, lubricating oil (if installed) (2P01)

The pump is in operation only when the engine is running. The pump shall be started no earlier than a few minutes before starting the engine and it must be stopped within a few minutes after stopping the engine.

Following a black-out, it is not permissible to start the engine before the pump is back in operation.

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.

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.

Main pump, HT cooling water (if installed) (4P14)

The pump shall be started before starting the engine. It should also be running for about 30 minutes after stopping the engine.

The cooling water pump must be restarted as quickly as possible, when restarting a diesel generator after a blackout.

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.

Main pump, LT cooling water (if installed) (4P15)

The pump shall be started before starting the engine. It can be stopped as soon as the engine is stopped, provided that there is no other equipment in the same circuit that requires cooling.

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.

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.

Fuel feed unit (1N01)

Continuously in operation.

14.6 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. Common Rail fuel injection system

The main advantage of the common rail system is that the injection pressure can be maintained at a sufficiently high level over the whole load range, which gives smokeless operation also at low load. Too rapid load increase will result in smoke formation due to air deficit in the same way as with any other engine.

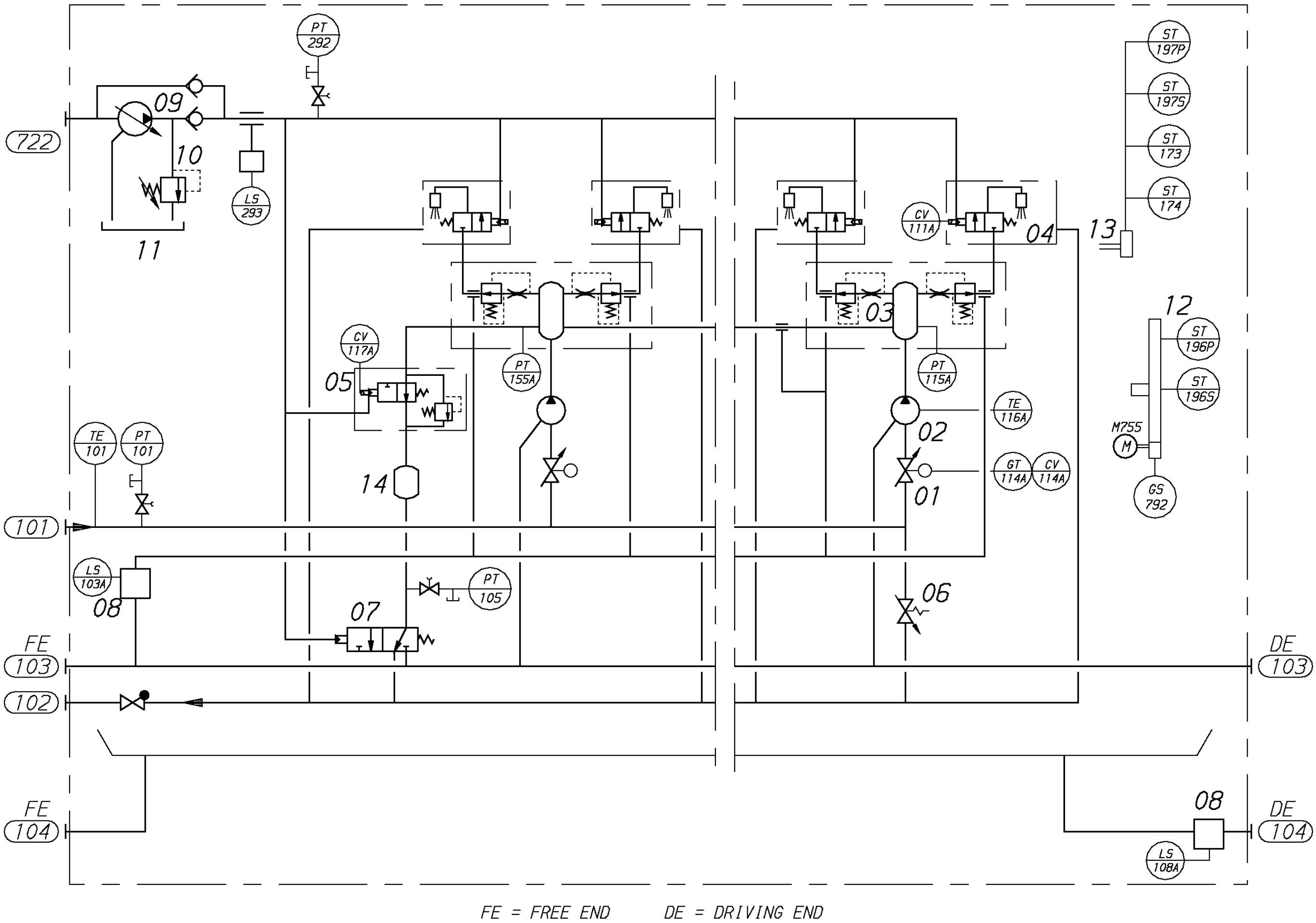
Electronically controlled fuel injection also offers certain flexibility to optimise the engine according to prevailing operating conditions and implement future developments in fuel injection control.

Differences from installation point of view compared to an engine with conventional fuel injection:

- Higher starting air consumption
- Fuel oil filters with finer mesh size
- Required fuel oil circulation factor is 3 instead of 4
- An amount of fuel is discharged into the clean leak fuel line at every stop
- Clean leak fuel connections always at both ends of the engine
- Pipe connection for control oil on the engine
- Control oil filter in the external system
- Automation system level 1 is not an option

15.1 Internal fuel system

Figure 15.1 Internal fuel oil system for common rail engines (DAAE037690)



System components

01	Flow control valve	08	Fuel oil leakage collector
02	High pressure pump	09	Control oil pump
03	Accumulator with flow fuses	10	Pressure relief valve
04	Fuel injector	11	Lubrication oil sump
05	Start and safety valve	12	Flywheel
06	Pressure control valve	13	Camshaft
07	3-way valve	14	Pressure damper

Sensors and indicators

PT101	Fuel oil inlet pressure	PT155A	Rail pressure, free end
TE101	Fuel oil inlet temperature	ST173	Engine speed
LS103	Clean fuel oil leakage level	ST174	Engine speed
LS108	Dirty fuel oil leakage level	ST196P	Engine speed / top dead centre
PT105	Fuel oil pressure, return flow valve	ST196S	Engine speed / top dead centre
CV111	Fuel injector control (111A...181A)	ST197P	Engine phase
CV117A	Start and safety valve	ST197S	Engine phase
GT114A	Flow control valve position (114A...1X4A)	PT292	Control oil pressure
CV114A	Flow control valve (114A...1X4A)	LS293	Control oil leakage

X = Fuel pump number

Sensors and indicators			
TE116A	High pressure pump temperature (116A...1X6A)	M755	Electric motor for turning gear
PT115A	Rail pressure, driving end	GS792	Turning gear engaged

X = Fuel pump number

Pipe connections		Size		
101	Fuel inlet	DN32	ISO 7005-1	PN40
102	Fuel outlet	DN32	ISO 7005-1	PN40
103	Leak fuel drain, clean fuel	OD28		
104	Leak fuel drain, dirty fuel	OD48		
722	Control oil from external filter	DN25	ISO 7005-1	PN40

The high-pressure fuel pumps are actuated by the camshaft and perform two pumping strokes per camshaft revolution. Each pump discharges into an accumulator, which primarily supplies fuel to two fuel injectors. The accumulators are connected with the common-rail pipe, which equalizes the pressure throughout the system. The rail pressure is controlled by regulating the fuel volume entering the pumps before each pumping stroke.

The fuel injector (injection valve), consists of a solenoid valve, a shuttle valve, and an injection nozzle. The fuel flow to the injection nozzle is controlled by the shuttle valve, which is actuated using control oil, and the control oil is in turn controlled by the solenoid valve. The control oil pump is engine driven and engine lubricating oil is used as control oil. An external filter with finer filtering than the normal lubricating oil filter is required for the control oil.

The shuttle valve controlling the injection nozzle has two key functions: it depressurizes the nozzle between injections and it provides crisp control of nozzle opening and closing. A single malfunction must not result in early fuel entry into the cylinder. The shuttle valve ensures that the fuel is cut off even though the nozzle would be leaking. The nozzle remains closed also in case the shuttle valve would get stuck half open.

A flow fuse at each injection pipe connection on the accumulator prevents injection of larger fuel quantity than the maximum permitted. If a flow fuse would close, it will remain closed until the pressure in the fuel rail drops below a preset level

At least one of the accumulators is equipped with a start and safety valve, which depressurizes the fuel rail when the engine is to be stopped, and permits fuel circulation through the rail when the engine is stopped. The control system opens the valve in case of excessive rail pressure. In addition there is an integrated mechanical safety valve that operates independently from the main valve. The safety valve discharges into a chamber, which dampens the pressure wave in the clean leak fuel line when the valve opens.

A pressure control valve between the fuel inlet and return lines maintains desired pressure before the high-pressure pumps.

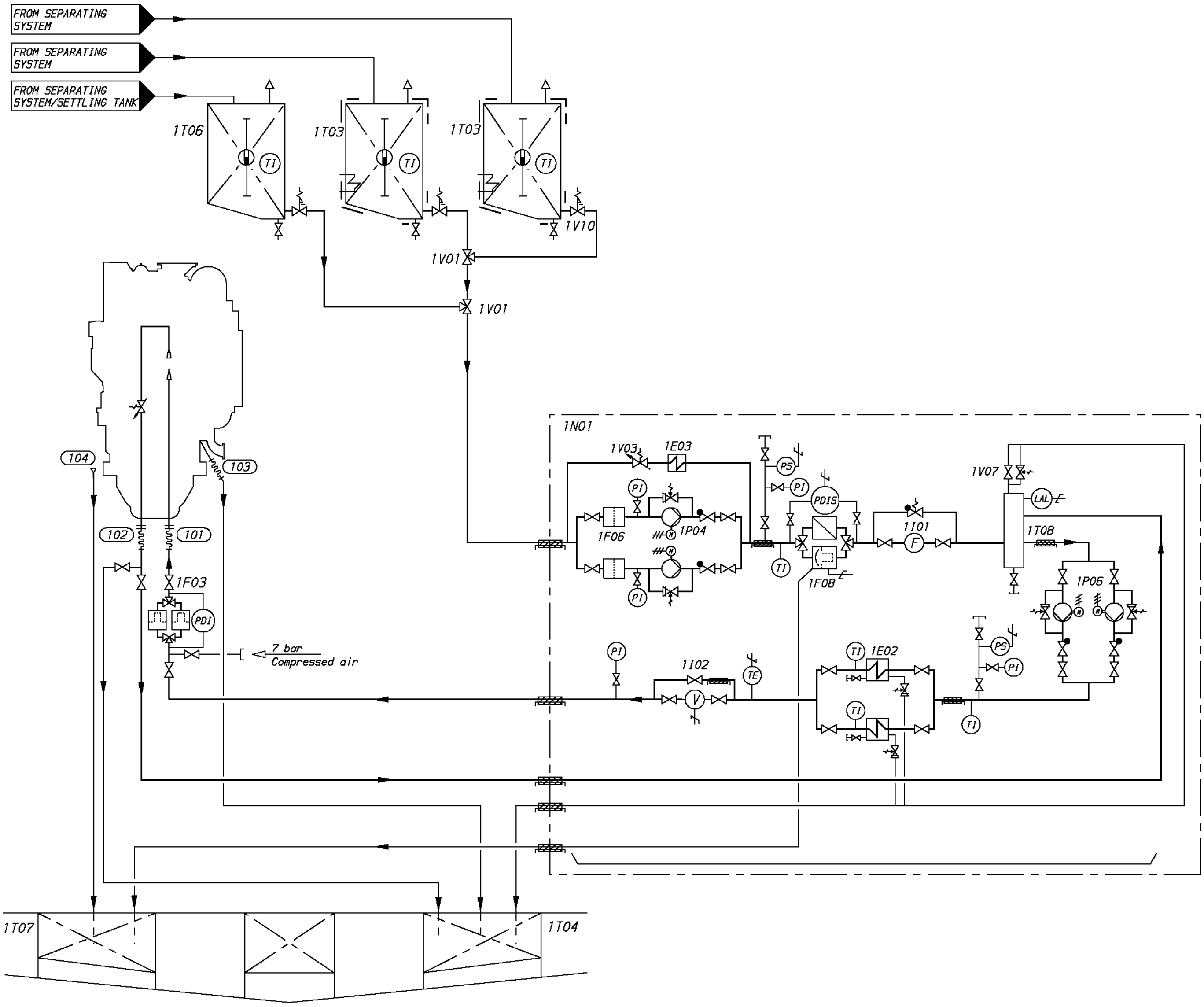
The engine has separate connections for clean leak fuel and dirty leak fuel. Clean leak fuel from high-pressure pumps can be reused without separation. The dirty leak fuel shall be led to a sludge tank. Both leak fuel types are drained from the engine by gravity. The fuel rail is depressurized by discharging fuel into the clean leak fuel line when the engine is to be stopped.

15.2 External fuel system

Circulation pumps, safety filters, fuel oil coolers (MDF), and control valves are to be dimensioned for a flow corresponding to at least three times the maximum fuel consumption. The fuel flow to the engine is stated in chapter Technical data for conventional engines and common rail engines separately.

Apart from finer mesh size in the automatic filter, the external fuel oil system can be designed and dimensioned following the same principles as for engines with conventional fuel injection.

Figure 15.2 Example of fuel oil system (HFO), single engine installation (3V76F6659)



Size of the piping in the installation to be calculated case by case.

System components				Pipe connections	
1E02	Heater	1T03	Day tank (HFO)	101	Fuel inlet *
1E03	Cooler	1T04	Leak fuel tank, clean fuel	102	Fuel outlet *
1F03	Safety filter	1T06	Day tank (MDF)	103	Leak fuel drain, clean fuel
1F06	Suction filter	1T07	Leak fuel tank, dirty fuel	104	Leak fuel drain, dirty fuel
1F08	Automatic filter	1T08	De-aeration tank		
1I01	Flow meter	1V01	Change-over valve		
1I02	Viscosity meter	1V03	Pressure control valve		
1N01	Feeder/booster unit	1V07	Venting valve		
1P04	Fuel feed pump	1V10	Quick closing valve		
1P06	Circulation pump				

* Flexible hoses are used on all engines (also rigidly mounted) to reduce pressure peaks.

15.2.1 Clean leak fuel system

At every engine stop a quantity of fuel will be discharged into the clean leak fuel line, when the fuel rail is depressurized. It is therefore very important that the external leak fuel system can accommodate this volume at all times. The maximum volume discharged at 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.

The leak fuel tank may not be located above the engine or pressurized (always applies). The leak fuel outlets at both ends of the engine must be connected to the external system.

15.2.2 Automatic filter, HFO (1F08)

It is recommended to select an automatic filter with a manually cleaned filter in the bypass line. The filter shall be installed between the feed pump and the de-aeration tank, and it shall 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 higher than 25 cSt/100°C
Design flow	Equal to feed pump capacity
Design pressure	1.6 MPa (16 bar)
Fineness:	
- automatic filter	10 μm (absolute mesh size)
- by-pass filter	25 μm (absolute mesh size)
Maximum permitted pressure drops at 14 cSt:	
- clean filter	30 kPa (0.3 bar)
- alarm	80 kPa (0.8 bar)

15.2.3 Circulation pump, HFO (1P06)

The purpose of this pump is to maintain the pressure stated in the chapter for *Technical data* at the high-pressure pumps on the engine. By circulating the fuel in the system it also maintains correct fuel viscosity, and keeps all components at operating temperature.

Design data:	
Capacity	3 x the total consumption of the connected engines
Design pressure	1.6 MPa (16 bar)
Max. pressure (safety valve)	1.2 MPa (12 bar)
Design temperature	150°C
Viscosity for dimensioning of electric motor	500 cSt

15.2.4 Safety filter (1F03)

The fuel oil safety filter is a full flow duplex type filter with steel net. This filter must be installed as near the engine as possible. The filter is to be equipped with a heating jacket. In multiple engine installations a common filter is preferred to separate filters for each engine, as it is important to ensure an even distribution of the flow.

The diameter of the pipe between the safety filter and the engine should be the same as between the fuel feed unit and the safety filter.

Design data:	
Fuel viscosity	according to fuel specification
Design temperature	150°C

Design data:

Design flow	Equal to circulation pump capacity
Design pressure	1.6 MPa (16 bar)
Fineness	25 μm (absolute mesh size)
Maximum permitted pressure drops at 14 cSt:	
- clean filter	20 kPa (0.2 bar)
- alarm	80 kPa (0.8 bar)

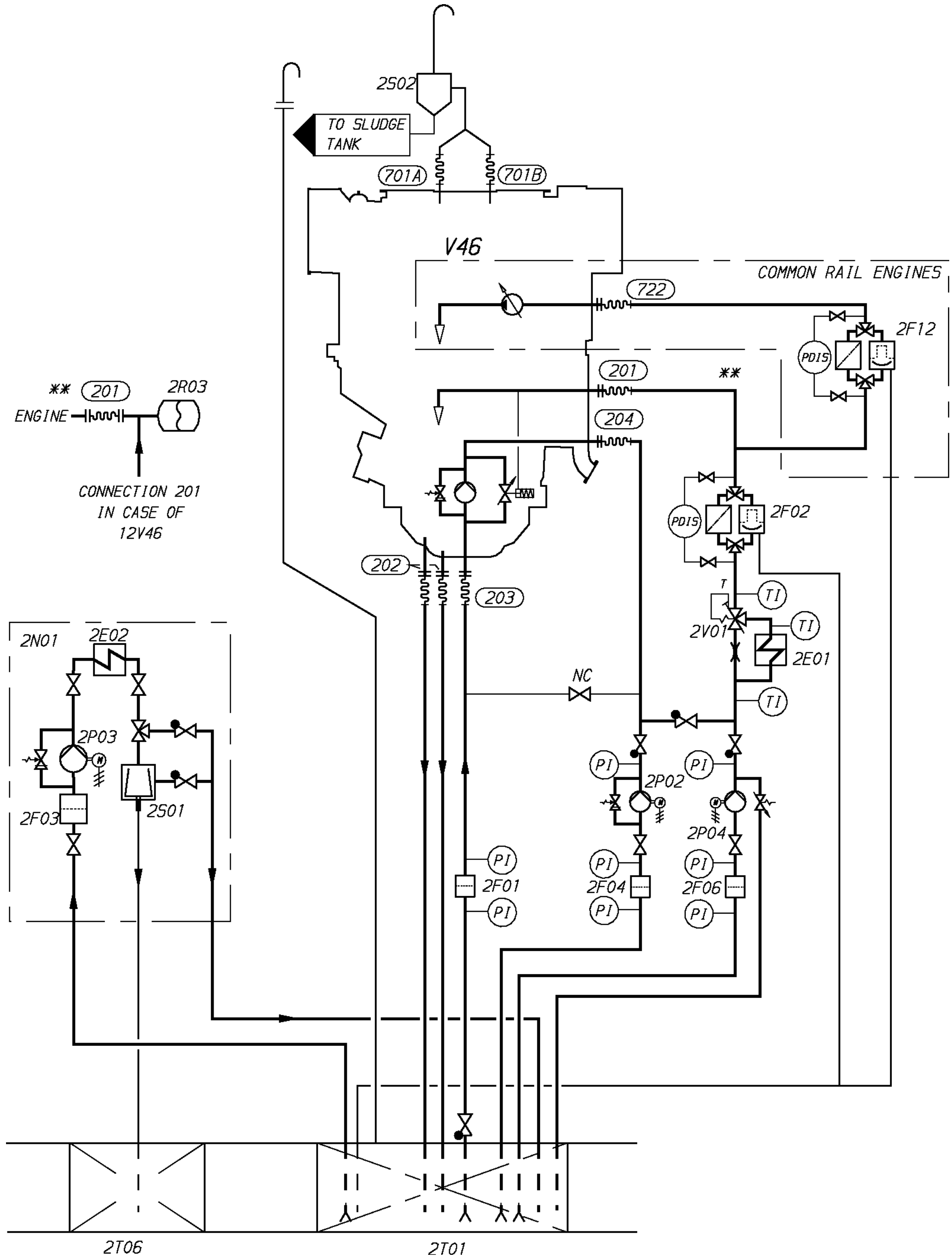
15.3 External lubricating oil system

Engine lubricating oil is used as control oil. A fine filter after the normal lubricating oil filter is required for the control oil to ensure flawless operation. The fine filter should be installed as close as possible to the engine.

The piping between the control oil filter and the control oil inlet on the engine (connection 722) must be flushed with very clean oil. It shall therefore be possible to install an additional flushing filter with finer mesh size next to the control oil filter. See also flushing instructions in chapter *Lubricating oil system*.

Apart from the control oil filter 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.

Figure 15.3 External lubricating oil system, common rail (DAAE037692)



System components

2E01	Lubricating oil cooler	2P02	Prelubricating oil pump
2E02	Heater	2P03	Separator pump
2F01	Suction strainer	2P04	Stand-by pump
2F02	Automatic filter (LO)	2R03	Lubricating oil damper
2F03	Suction filter	2S01	Separator
2F04	Suction strainer	2S02	Condensate trap
2F06	Suction strainer	2T01	System oil tank
2F12	Control oil automatic filter (LO)	2T06	Sludge tank
2N01	Separator unit	2V01	Temperature control valve

Pipe connection sizes		6L46	8L, 9L46 constant speed	8L, 9L46 variable speed	V46
201	Lubricating oil inlet	DN125	DN125	DN125	DN200
202	Lubricating oil outlet 1)	DN200	DN200	DN200	DN250
203	Lubricating oil to engine driven pump	DN250	DN250	DN300	DN300
204	Lubricating oil from engine driven pump	DN150	DN150	DN200	DN200
701	Crankcase air vent	ø114	ø114	ø114	2xø114
722	Control oil from external filter	DN25	DN25	DN25	DN25

1) Two outlets in each end are available

15.3.1 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* *)
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)
Maximum permitted pressure drops at 50 cSt:	
- clean filter	30 kPa (0.3 bar)
- alarm	80 kPa (0.8 bar)

*) 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).

15.4 Fuel injection control

The fuel injection control is handled by the automation system on the engine. Automation system level 2 is required for common rail engines. See description in chapter *Automation system*.

16. Foundation

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

16.1 Steel structure design

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

The foundation and the double bottom should be as stiff as possible in all directions to absorb the dynamic forces caused by the engine, reduction gear and thrust bearing.

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

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

16.2 Engine mounting

The mounting arrangement is similar for diesel electric installations and conventional propulsion.

16.2.1 Rigid mounting

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

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

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

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

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

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

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

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

The tool included in the standard set of engine tools is used for hydraulic tightening of the holding down bolts. The piston area of the tools is 72.7 cm^2 and the hydraulic tightening pressures mentioned in the following sections only apply when using this tool.

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

Steel chocks

The top plates of the engine girders are normally inclined outwards with regard to the centre line of the engine. The inclination of the supporting surface should be 1/100. The seating top plate should be designed so that the wedge-type steel chocks can easily be fitted into their positions. The wedge-type chocks also have an inclination of 1/100 to match the inclination of the seating. If the top plate of the engine girder is fully horizontal, a chock is welded to each point of support. The chocks should be welded around the periphery as well as through holes drilled for this purpose at regular intervals to avoid possible relative movement in the surface layer. The welded chocks are then face-milled to an inclination of 1/100. The surfaces of the welded chocks should be large enough to fully cover the wedge-type chocks.

The supporting surface of the the seating top plate should be machined so that a bearing surface of at least 75% is obtained. The chock should be fitted so that they are approximately equally inserted under the engine on both sides.

The size of the wedge type chocks should be 200x360 mm. The chocks should always cover two bolts, except the chock closest to the flywheel, which accomodates only one bolt. Steel is preferred, but cast iron chocks are also accepted.

The cutout in the chocks for the clearance bolts should be about 2 mm larger than the bolt diameter (M42). The maximum cut out area is 20%. Holes are to be drilled and reamed to the correct tolerance for the fitted bolts after the coupling alignment has been checked and the chocks have been lightly knocked into position.

The following hydraulic tightening pressure should be used with the supplied tightening tool, provided that the minimum bolt diameter is 35 mm and the material yield strength is at least 600 N/mm^2 (e.g. 42CrMo4): p_{hyd} = 70 MPa (700 bar)

Steel chocks with adjustable height

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

Resin chocks

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

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

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

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

For a given bolt diameter the permissible bolt tension is limited either by the strength of the bolt material (max. stress 80% of the yield strength), or by the maximum permissible surface pressure on the resin.

Assuming bolt dimensions and chock dimensions according to drawing 1V69L0082b and 1V69L0083c, the following hydraulic tightening pressures should be used with the supplied tightening tool, provided that the yield strength of the bolt material is at least 600 N/mm^2 (e.g. 42CrMo4):

- In-line engines, total surface pressure max. 4.5 N/mm^2: p_{hyd} = 33.5 MPa
- V-engines, total surface pressure max. 5 N/mm^2: p_{hyd} = 47.5 MPa

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

Figure 16.1 Seating and fastening, rigidly mounted in-line engine on steel chocks (1V69L1651a)

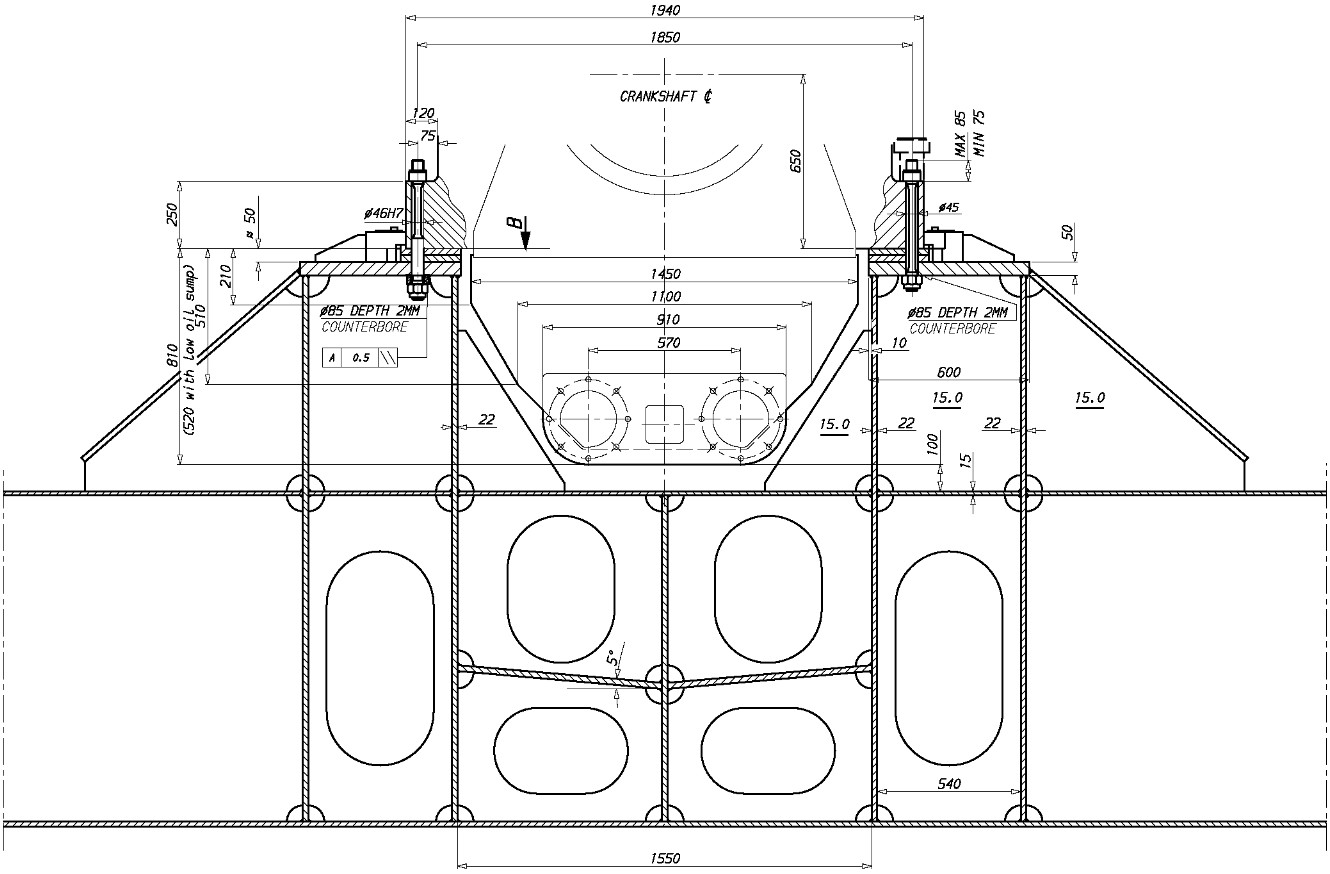


Figure 16.2 Seating and fastening, rigidly mounted V-engine on steel chocks (1V69L1659a)

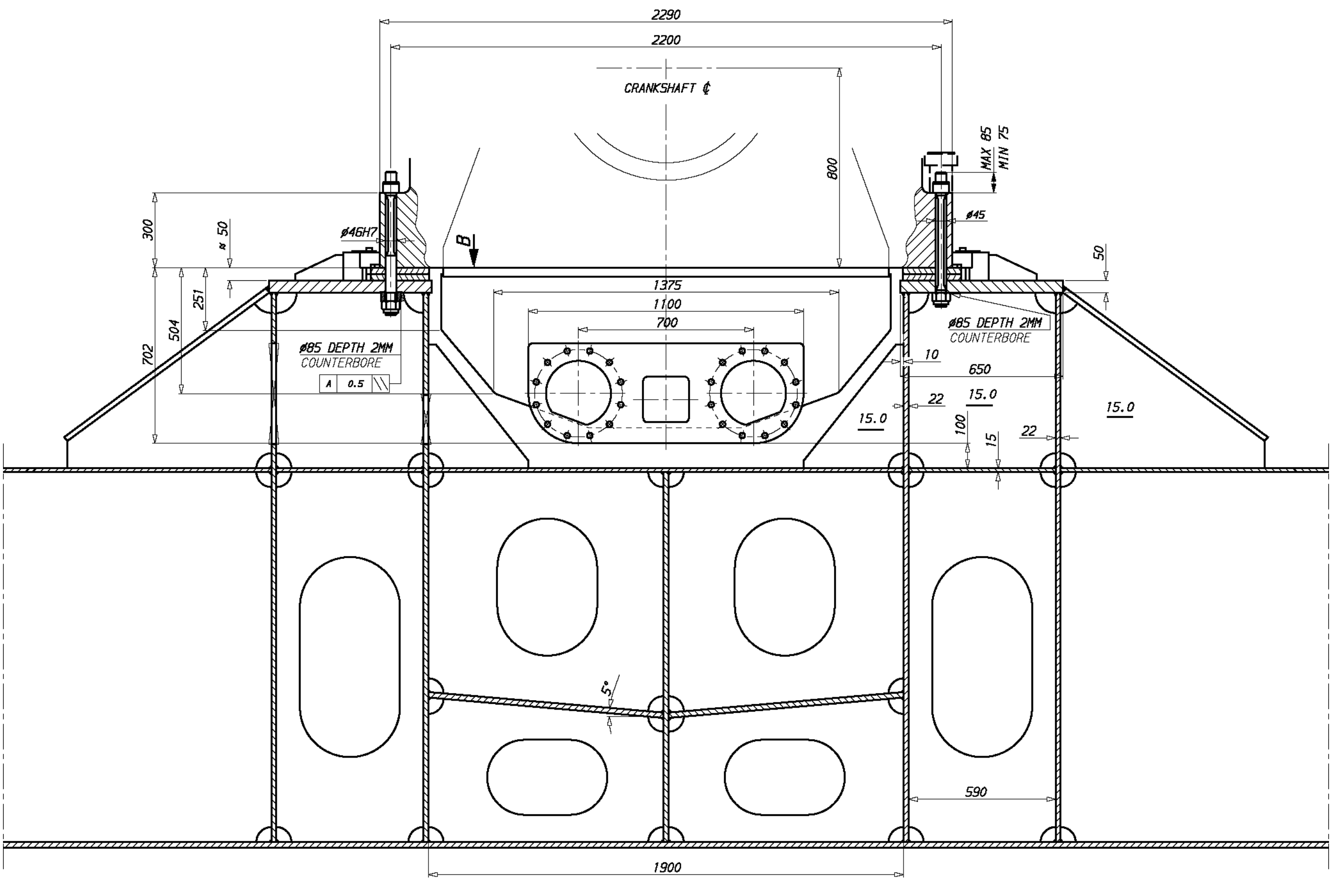


Figure 16.3 Seating and fastening, rigidly mounted in-line engine on steel chocks (1V69L1651a)

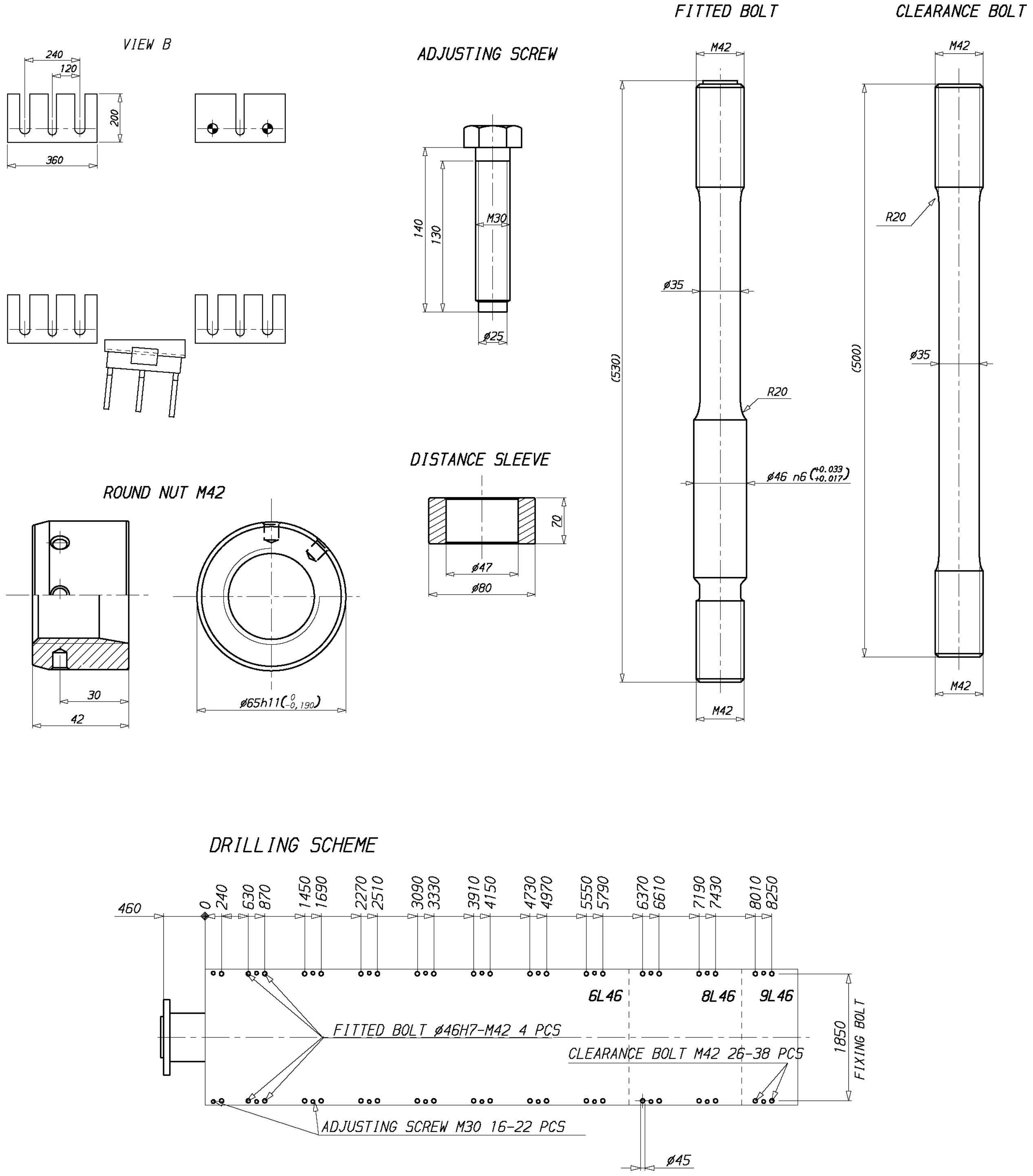


Figure 16.4 Seating and fastening, rigidly mounted V-engine on steel chocks (1V69L1659a)

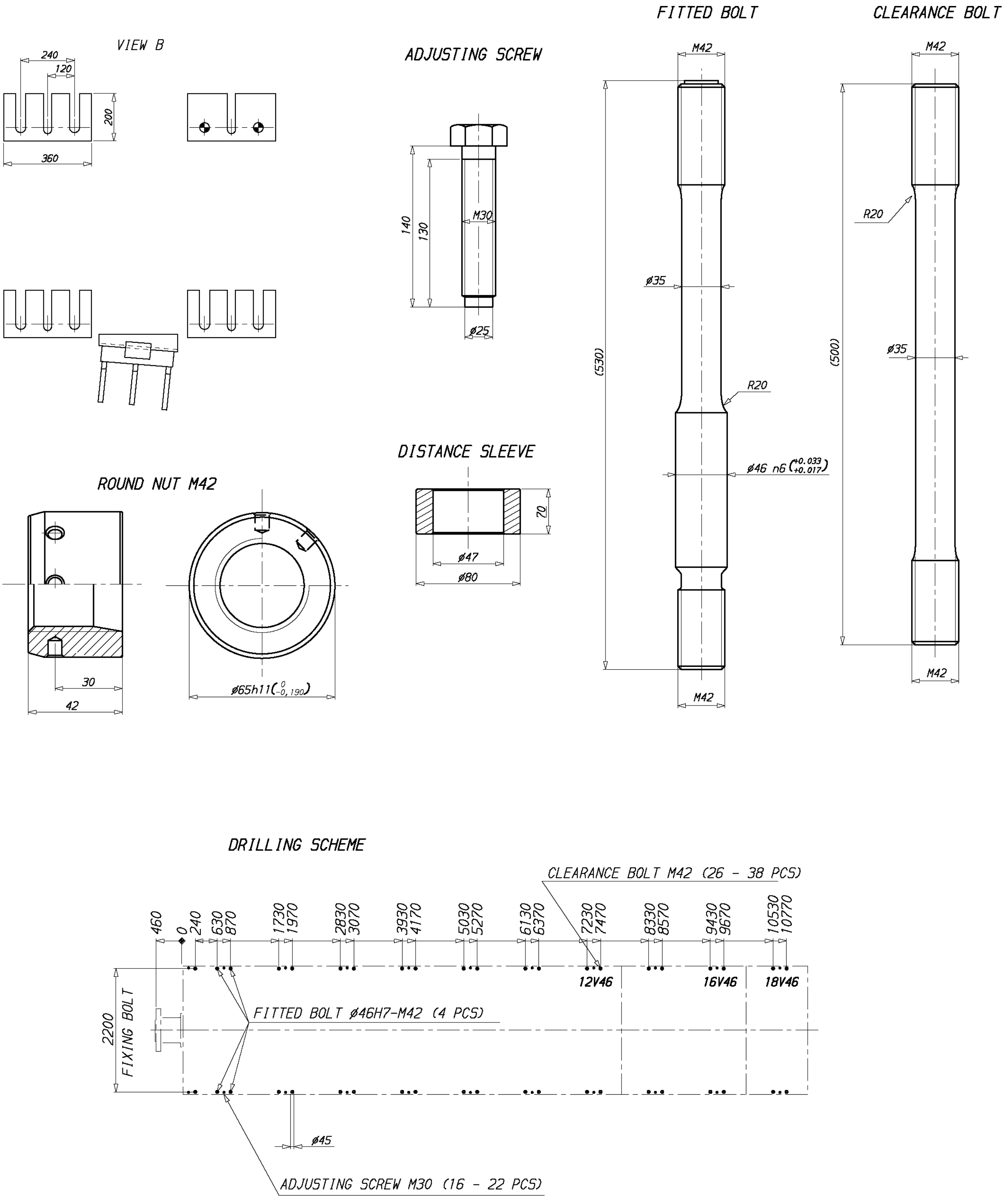


Figure 16.5 Seating and fastening, rigidly mounted in-line engine on resin chocks (1V69L0082c)

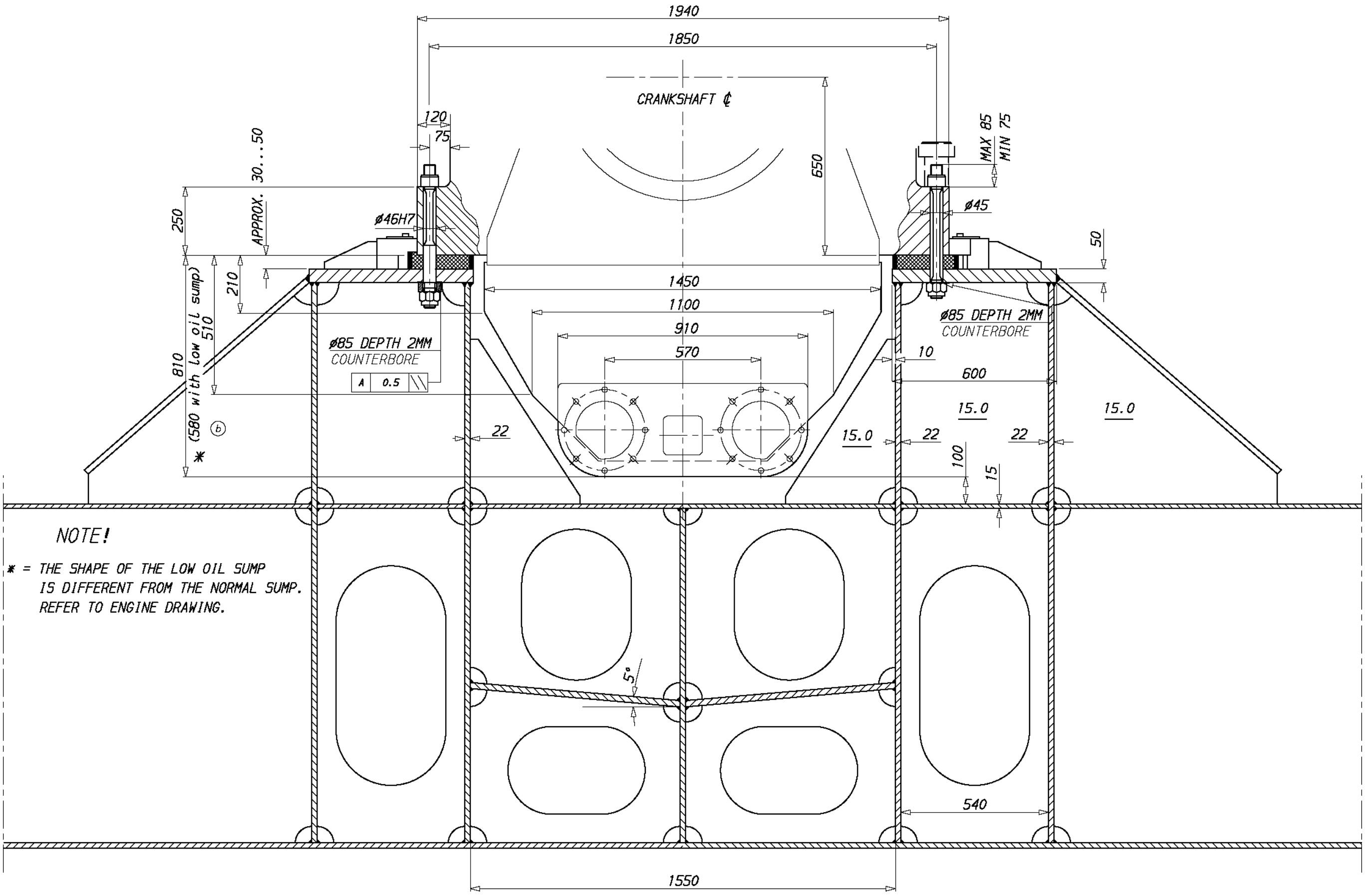


Figure 16.6 Seating and fastening, rigidly mounted V-engine on resin chocks (1V69L0083c)

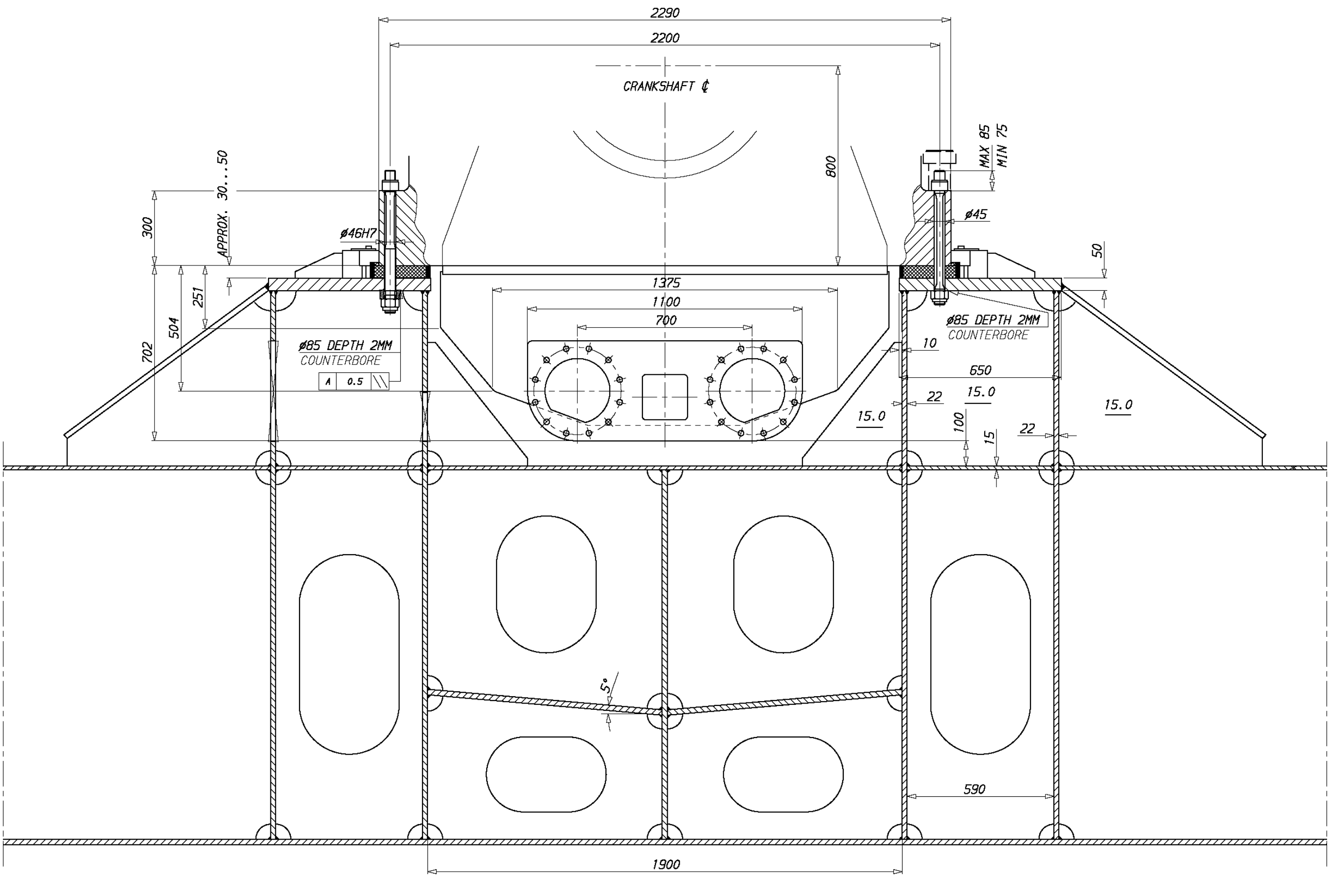


Figure 16.7 Seating and fastening, rigidly mounted in-line engine on resin chocks (1V69L0082c)

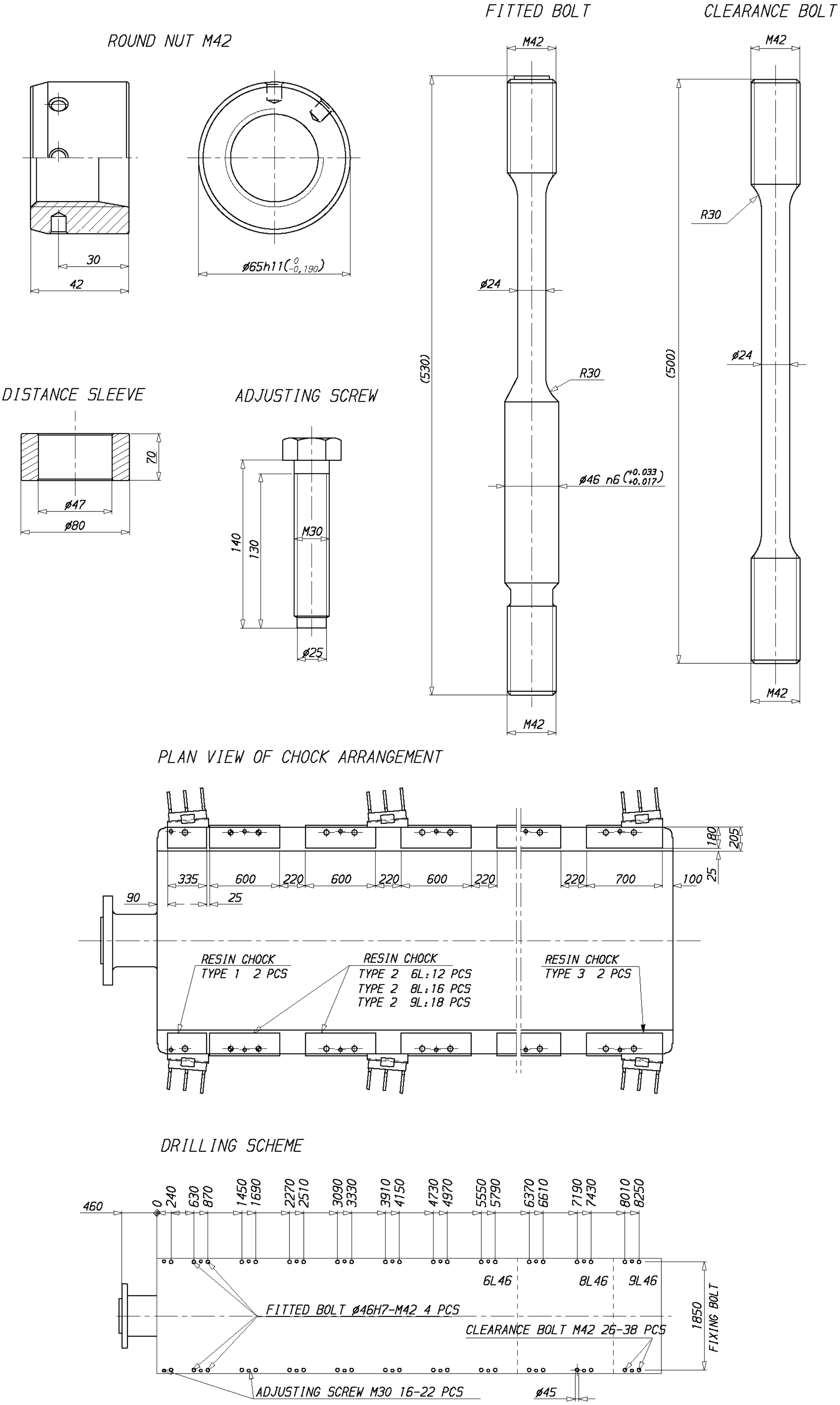
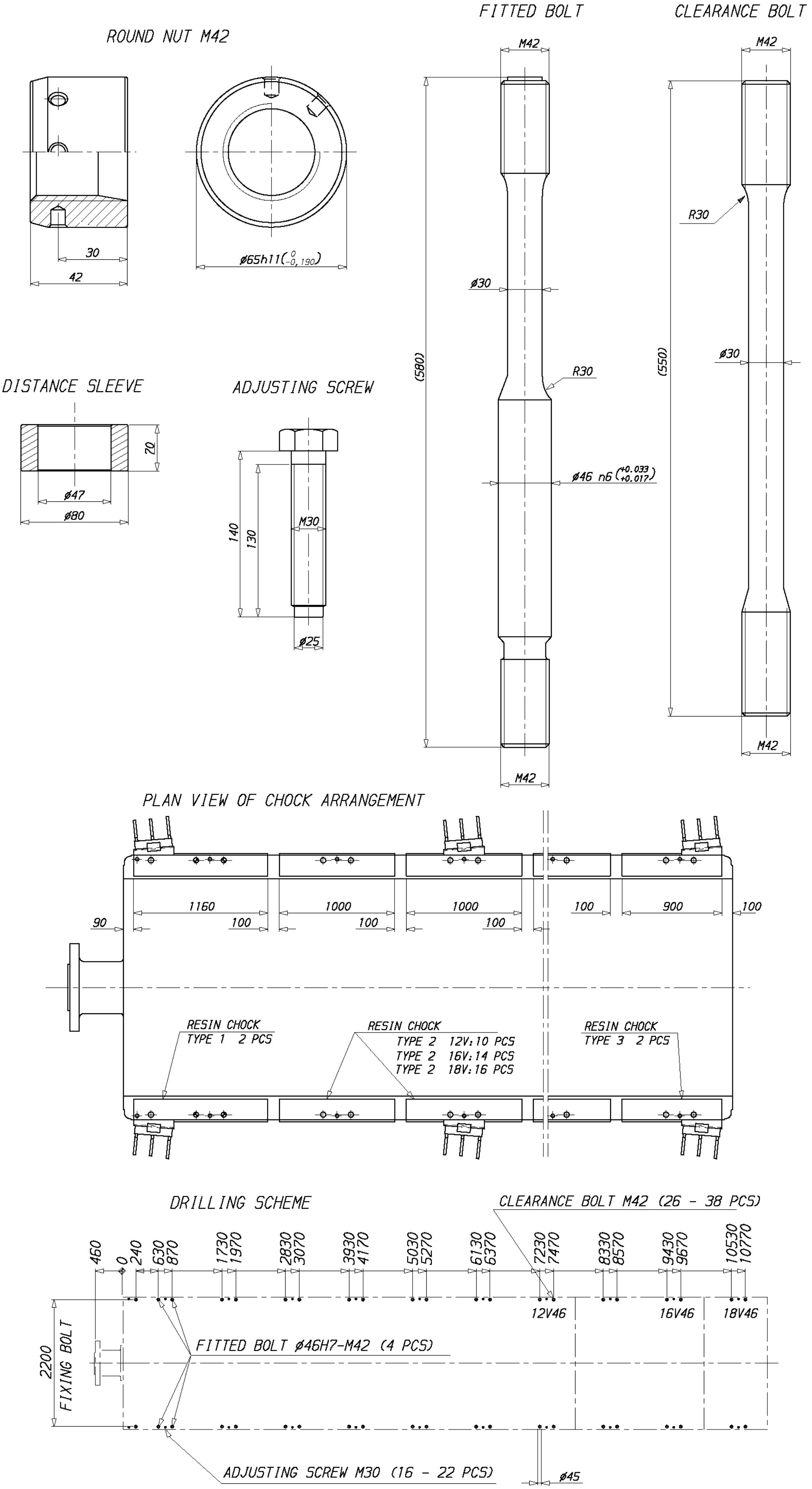


Figure 16.8 Seating and fastening, rigidly mounted V-engine on resin chocks (1V69L0083c)



16.2.2 Resilient mounting

In order to reduce vibrations and structure borne noise, engines can be resiliently mounted on rubber elements. The transmission of forces emitted by the engine is 10-20% when using resilient mounting. Typical structure borne noise levels can be found in chapter 17.

Cylindrical rubber elements are mounted in vertical position to a fixing rail, which is attached to the engine feet. Side and end buffers are used to limit the movements in horizontal direction. The brackets for the horizontal buffers are prefabricated and welded to the foundation. The rubber elements are protected against dripping and splashing with covers.

An advantage of vertical elements over V-type mounting is that alignment adjustments are considerably easier to perform.

Engines connected to a reduction gear must be aligned according to the propeller shaft. Steel chocks or shims are installed under rubber elements to achieve the desired vertical position. A machining tool is available from Wärtsilä for machining of the seating top plate under the steel chocks. The machining tool permits a maximum distance of 85 mm between the seating top plate and the fixing rail.

Displacement of the engine due to the torque reaction, thermal expansion and time dependent creep of the rubber elements are issues to consider, when determining the desired alignment during installation and selecting the bellows for the exhaust pipe connection. The transverse displacement due to the torque reaction can be up to 10 mm at the turbocharger outlet.

A speed range of 350-500 rpm is generally available for resiliently mounted engines.

Figure 16.9 Seating and fastening resiliently mounted in-line engine (2V69A0129c)

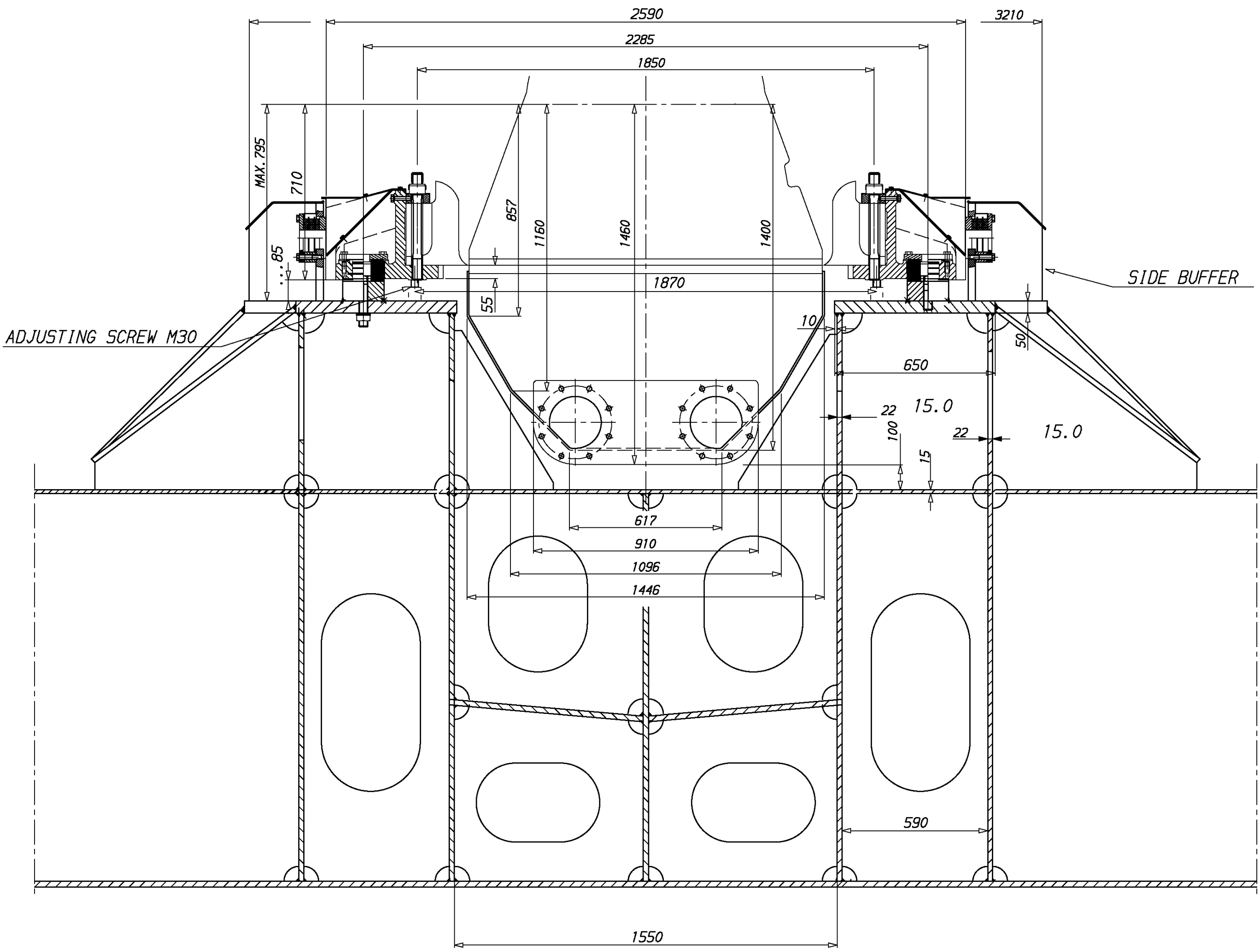
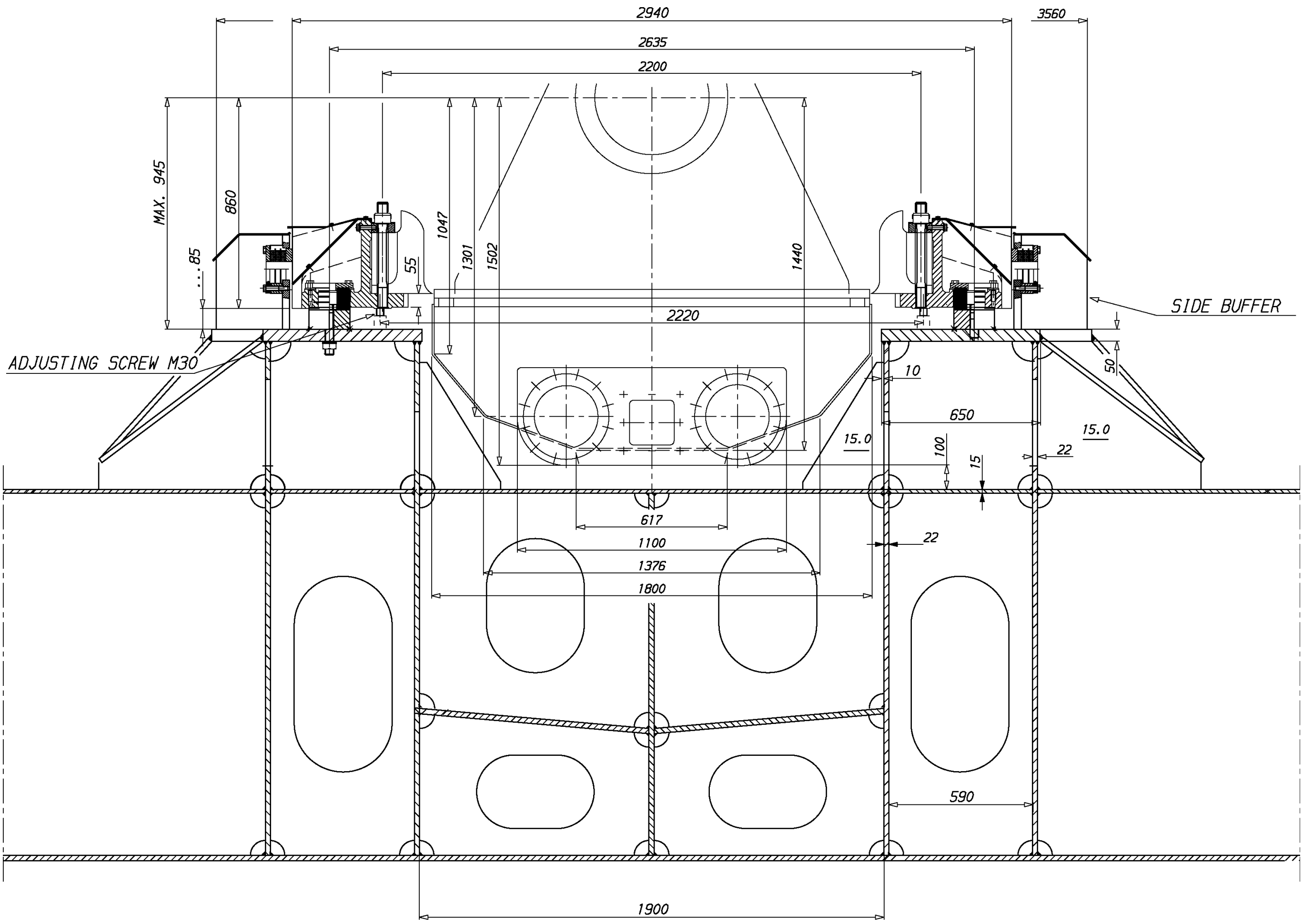


Figure 16.10 Seating and fastening flexibly mounted V-engine (2V69A0128c)



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 the turbocharger must be arranged so that the above mentioned displacements can be absorbed, without large forces on the turbocharger.

Proper fixing of pipes next to flexible pipe connections is not less important for resiliently mounted engines. See the chapter *Piping design, treatment and installation* for more detailed information.

17. Vibration and noise

17.1 General

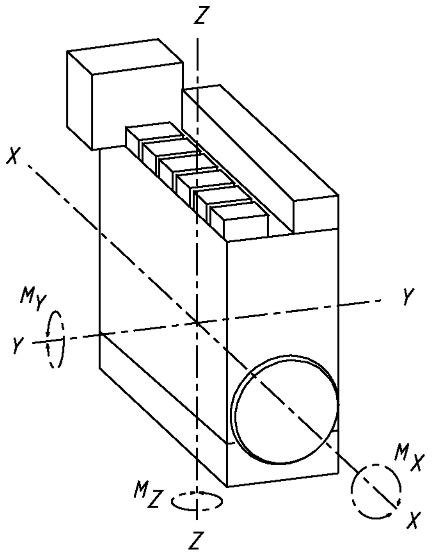
Resiliently mounted engines comply with the requirements of the following standards regarding vibration level on the engine:

6L and 12V46 engines	ISO 10816-6 Class 4
other cylinder numbers	ISO 10816-6 Class 5

Dynamic forces and moments caused by the engine appear from the tables. Due to manufacturing tolerances some variation of these values may occur.

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

Figure 17.1 Coordinate system of the external torques



17.2 External forces and couples

Some cylinder numbers have external couples. On cargo ships, the frequency of the lowest hull girder vibration modes are far below the 1st 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 antinodes is therefore not so critical.

On ships with narrow superstructures (like on container ships) the ship designer should avoid superstructure natural frequencies close to the excitation frequencies. A response analysis of the hull and the superstructure should be done. At the request of the customer, Wärtsilä can provide an estimation of first order forces transmitted through the elastic or rigid mounting.

External forces are zero for all cylinder numbers.

Table 17.1 External couples

Engine	Speed [rpm]	Frequency [Hz]	M_Y [kNm]	M_Z [kNm]	Frequency [Hz]	M_Y [kNm]	M_Z [kNm]	Frequency [Hz]	M_Y [kNm]	M_Z [kNm]
9L46	500	8.3	–	–	16.7	80.7	–	33.3	4.0	–
	514	8.6	–	–	17.1	85.3	–	34.3	4.2	–
18V46	500	8.3	293.8	293.8	16.7	141.4	58.6	33.3	–	4.1
	514	8.6	310.5	310.5	17.1	149.4	61.9	34.3	–	4.4
– couples are zero or insignificant										

17.3 Torque variations

Table 17.2 Torque variation, 975 kW/cyl

Engine	Speed [rpm]	Frequency [Hz]	M_X [kNm]	Frequency [Hz]	M_X [kNm]	Frequency [Hz]	M_X [kNm]
6L46	500	25.0	101.2	50.0	49.6	75.0	9.2
	514	25.7	94.0	51.4	50.0	77.1	9.6
6L46, idle	500	25.0	69.8	50.0	12.0	75.0	3.0
	514	25.7	75.8	51.4	12.1	77.1	3.0
8L46	500	33.3	167.9	66.7	21.6	100.0	3.6
	514	34.3	166.9	68.5	22.2	102.8	3.9
9L46	500	37.5	155.8	75.0	13.8	112.5	2.8
	514	38.6	155.9	77.1	14.4	115.7	3.0
12V46	500	25.0	77.4	50.0	70.2	75.0	17.1
	514	25.7	71.9	51.4	70.7	77.1	17.7
12V46, idle	500	25.0	53.4	50.0	17.0	75.0	5.6
	514	25.7	58.0	51.4	17.1	77.1	5.6
16V46	500	–	–	66.7	43.3	133.4	2.2
	514	–	–	68.5	44.4	137.0	2.5
18V46, alternating firing order	500	37.5	305.9	75.0	25.6	112.5	4.6
	514	38.6	306.1	77.1	26.6	115.6	5.0

– couples are zero or insignificant

Table 17.3 Torque variation, 1050 kW/cyl

Engine	Speed [rpm]	Frequency [Hz]	M_X [kNm]	Frequency [Hz]	M_X [kNm]	Frequency [Hz]	M_X [kNm]
6L46	500	25.0	113.3	50.0	55.6	75.0	12.0
	514	25.7	105.0	51.4	56.0	77.1	12.6
6L46, idle	500	25.0	69.8	50.0	12.0	75.0	3.0
	514	25.7	75.8	51.4	12.1	77.1	3.0
8L46	500	33.3	181.3	66.7	26.4	100.0	4.9
	514	34.3	179.5	68.5	27.2	102.8	5.3
9L46	500	37.5	169.1	75.0	18.0	112.5	3.5
	514	38.6	168.7	77.1	18.8	115.7	3.8
12V46	500	25.0	86.7	50.0	78.7	75.0	22.2
	514	25.7	80.4	51.4	79.2	77.1	23.2
12V46, idle	500	25.0	53.4	50.0	17.0	75.0	5.6
	514	25.7	58.0	51.4	17.1	77.1	5.6
16V46	500	–	–	66.7	52.8	133.4	2.6
	514	–	–	68.5	54.4	137.0	2.9
18V46, alternating firing order	500	37.5	332.0	75.0	33.3	112.5	5.7
	514	38.6	331.1	77.1	34.8	115.6	6.3

– couples are zero or insignificant

Table 17.4 Torque variation, 1155 kW/cyl

Engine	Speed [rpm]	Frequency [Hz]	M_X [kNm]	Frequency [Hz]	M_X [kNm]	Frequency [Hz]	M_X [kNm]
6L46	500	25.0	123.2	50.0	57.3	75.0	11.6
	514	25.7	117.2	51.4	57.3	77.1	11.6
6L46, idle	500	25.0	70.6	50.0	13.0	75.0	3.5
	514	25.7	77.1	51.4	13.0	77.1	3.5
8L46	500	33.3	190.5	66.7	26.3	100.0	4.2
	514	34.3	190.0	68.5	26.3	102.8	4.2
9L46	500	37.5	177.1	75.0	17.4	112.5	2.8
	514	38.6	177.1	77.1	17.4	115.7	2.8
12V46	500	25.0	94.3	50.0	81.1	75.0	21.5
	514	25.7	89.7	51.4	81.1	77.1	21.5
12V46, idle	500	25.0	54.0	50.0	18.4	75.0	6.4
	514	25.7	59.0	51.4	18.4	77.1	6.4
16V46	500	–	–	66.7	52.7	133.3	1.9
	514	–	–	68.5	52.7	137.1	1.9
18V46, alternating firing order	500	37.5	347.3	75.0	32.2	112.5	4.6
	514	38.6	347.3	77.1	32.2	115.6	4.6

– couples are zero or insignificant

17.4 Mass moments of inertia

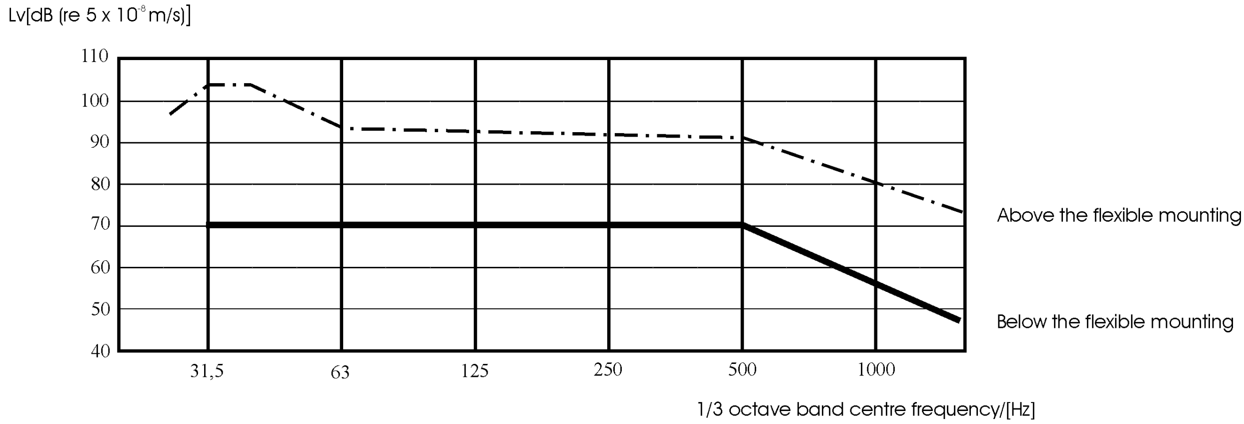
These typical inertia values include the flexible coupling part connected to the flywheel and torsional vibration damper, if needed.

Table 17.5 Mass moments of inertia

Polar mass moment of inertia J [kgm²]		
	Speed [rpm]	
Engine	**500**	**514**
6L46	3020	2900
8L46	3570	3540
9L46	4580	4580
12V46	5310	5310
16V46	7250	6790
18V46	8820	8820

17.5 Structure borne noise

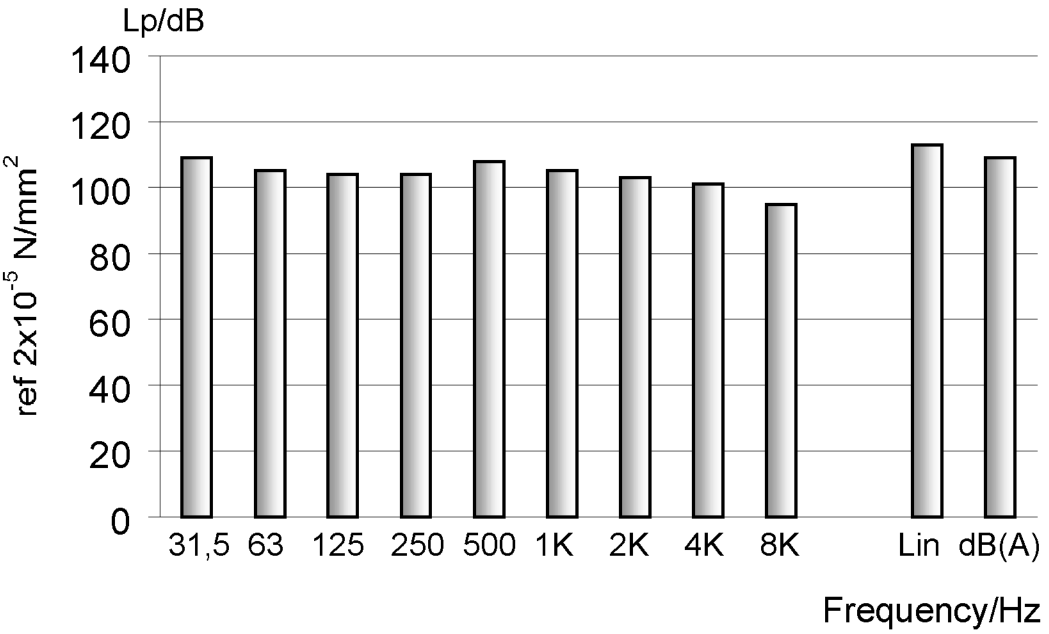
Figure 17.2 Typical structure borne noise levels (4V93F0089a)



17.6 Air borne noise

The airborne noise of the engine is measured as a sound power level according to ISO 9614-2. The results are presented with A-weighting in octave bands, reference level 1 pW.

Figure 17.3 Sound pressure levels of a Wärtsilä 46 engine (4V93F0090b)



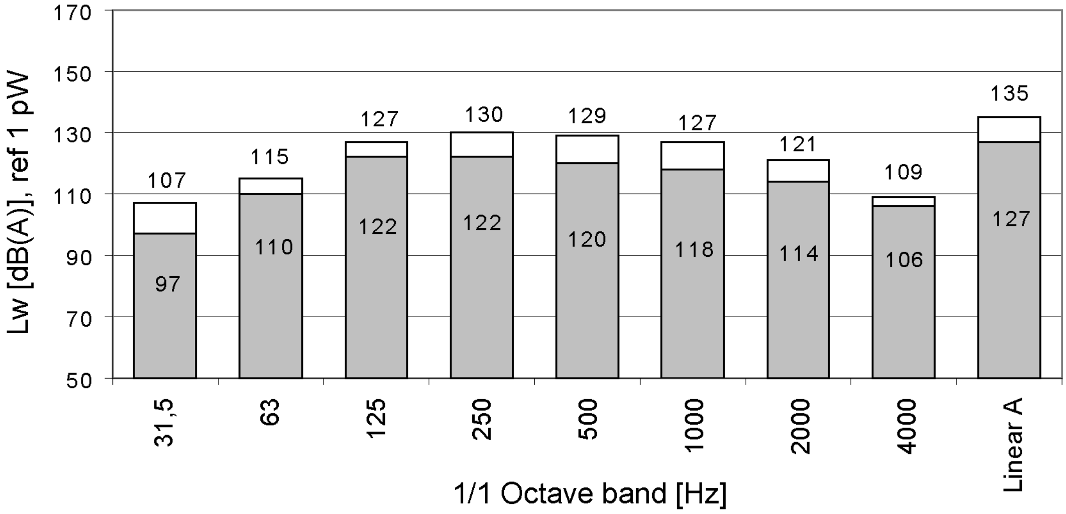
The noise level is measured in a test cell with a turbo air filter 1m from the engine. 90% of the values measured on production engines are under these figures.

17.7 Exhaust gas noise

The exhaust noise of the engines is measured as a sound power level according to ISO 9614-2. The results are presented with A-weighting in octave bands, reference level 1 pW.

The two values presented in the table below are as follows. The minimum value is the smallest sound power level recorded from the engines with different number of cylinders. (The values present the total sound power level of the engine, not individual points). The 90% level is such that 90% of all measured values are below this figure.

Figure 17.4 Exhaust gas noise



18. Power transmission

18.1 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.

18.2 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.

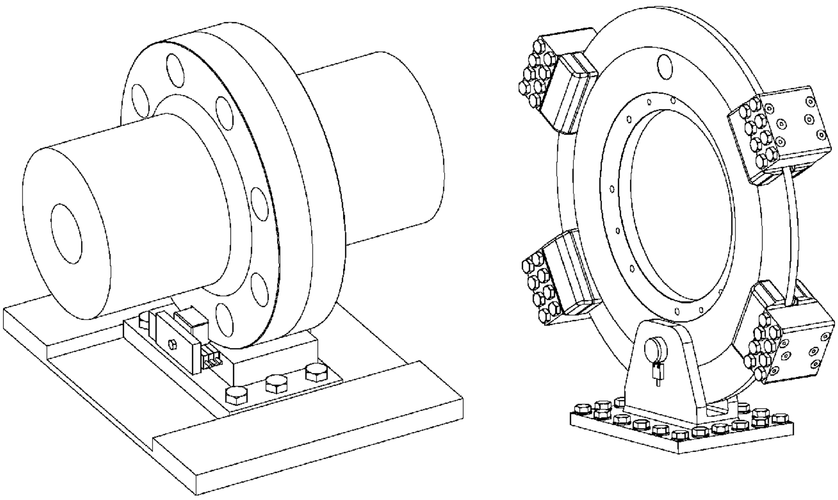
To permit maintenance of a stopped engine clutches must be installed in twin screw vessels which can operate on one shaft line only.

18.3 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 18.1 Shaft locking device and brake disc with calipers



18.4 Power-take-off from the free end

Full output is also available from the free end of the engine of all cylinder numbers of in-line and V engines.

This PTO cannot be provided together with built on pumps.

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

18.5 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

18.6 Turning gear

The engine is equipped with an electrically driven turning gear, capable of turning the propeller shaft line or generator in most installations. A turning gear with a capability of turning a higher external torque may be needed e.g. in installations as listed below, in which case consideration should be given to installing a separate turning gear e.g. on the reduction gear.

- Installations with a stern tube with a high friction torque
- Installations with a heavy ice-classed shaft line
- Installations with several engines connected to the same shaft line
- If the shaft line and a heavy generator are to be turned at the same time.

Table 18.1 Turning gear torque (4V48L0238)

Cylinder number	Type of turning gear	Max. torque at crankshaft [kNm]	Torque needed to turn the engine [kNm]	Additional torque available [kNm]
6L	LKV 145	18	12	6
8L	LKV 145	18	15	3
9L	LKV 250	75	17	58
12V	LKV 250	75	25	50
16V	LKV 250	75	35	40
18V	LKV 250	75	40	35

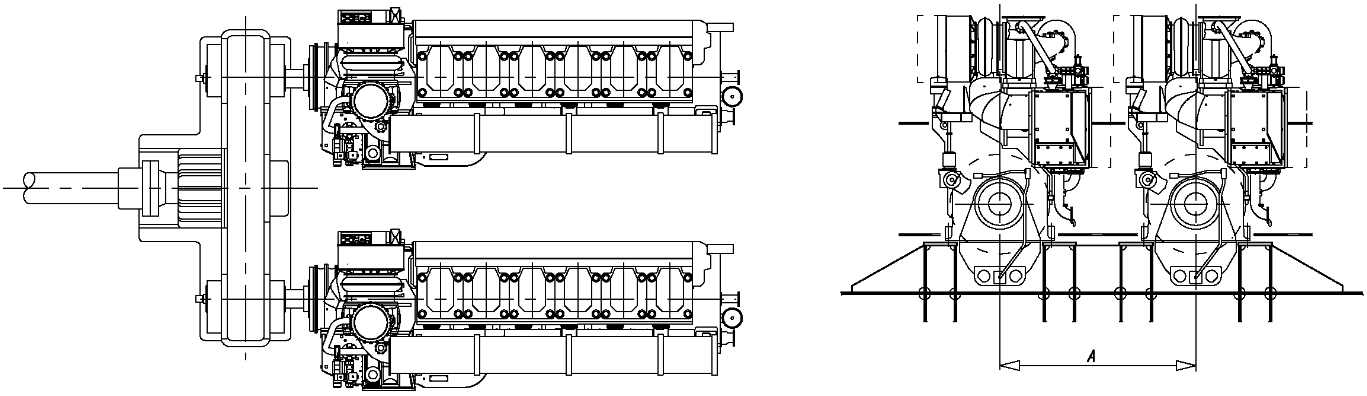
19. Engine room layout

19.1 Crankshaft distances

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

19.1.1 In-line engines

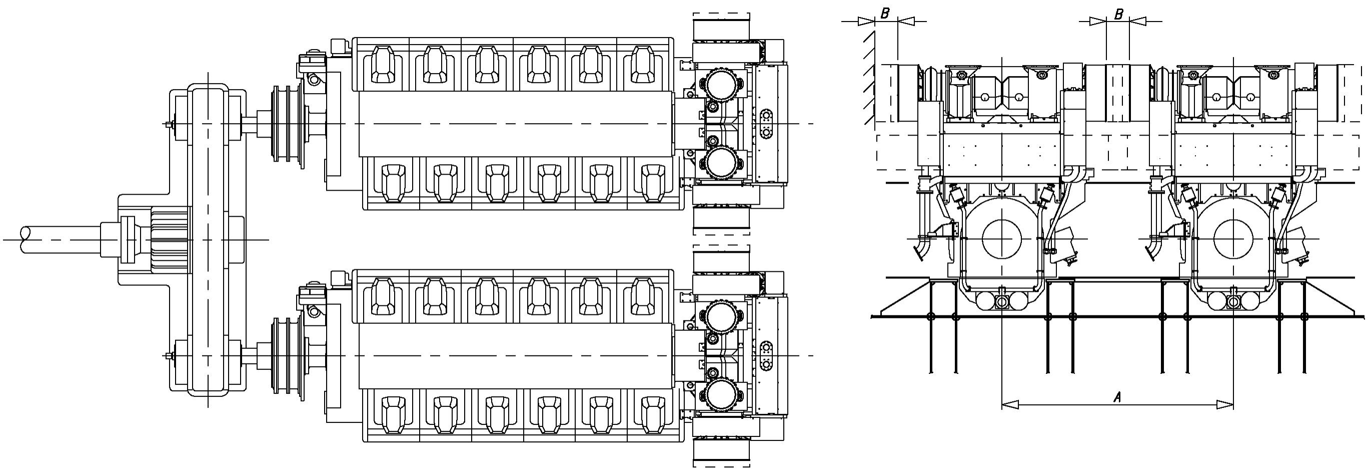
Figure 19.1 Crankshaft distances, in-line engines (3V69C0245a)



Engine type	A [mm]
Wärtsilä 6L46	3500
Wärtsilä 8L46	3700
Wärtsilä 9L46	3700

19.1.2 V-engines

Figure 19.2 Crankshaft distances, V-engines (3V69C0241b)



		Minimum		Recommended	
Engine type	Turbocharger	A [mm]	B [mm]	A [mm]	B [mm]
Wärtsilä 12V46	TPL 73	4700	200	4900	350
Wärtsilä 12V46	NA 357	4500	200	4500	500
Wärtsilä 16V46	TPL 73	4700	200	4900	500
Wärtsilä 16V46	TPL 77	5500	200	5800	500

19.1.3 Four-engine arrangements

Figure 19.3 Main engine arrangement, 4 x L46 (3V69C0238)

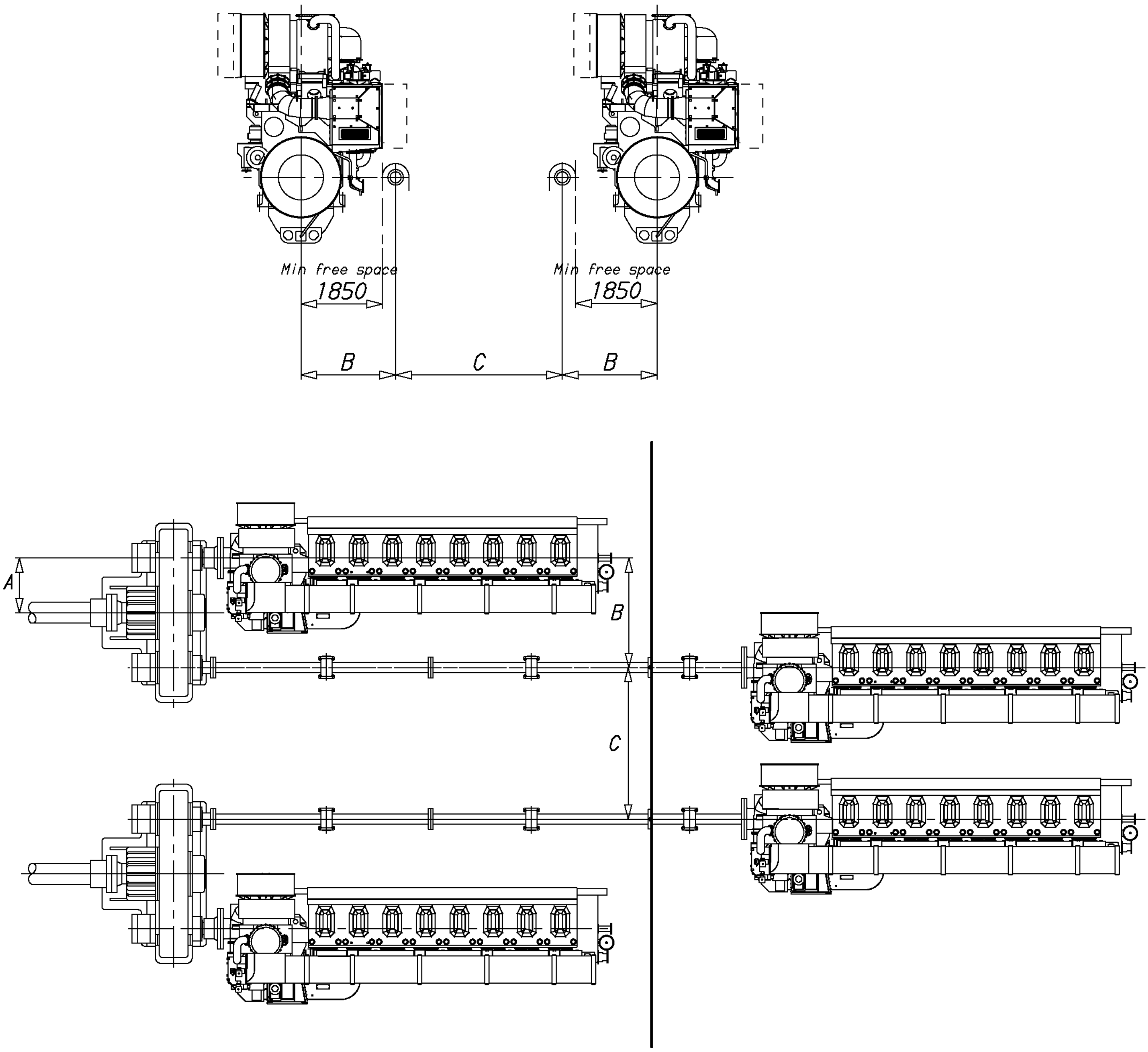


Table 19.1 Minimum distance between engines [mm]

Engine type	A	B	C
Wärtsilä 6L46	1050	2100	3500
Wärtsilä 8L46	1050	2100	3700
Wärtsilä 9L46	1050	2100	3700

Intermediate shaft diameter to be determined case by case.

Dismantling of big end bearing requires 1580 mm on one side and 2210 mm on the other side. Direction may be freely chosen.

Figure 19.4 Main engine arrangement, 4 x V46 (2V69C0243b)

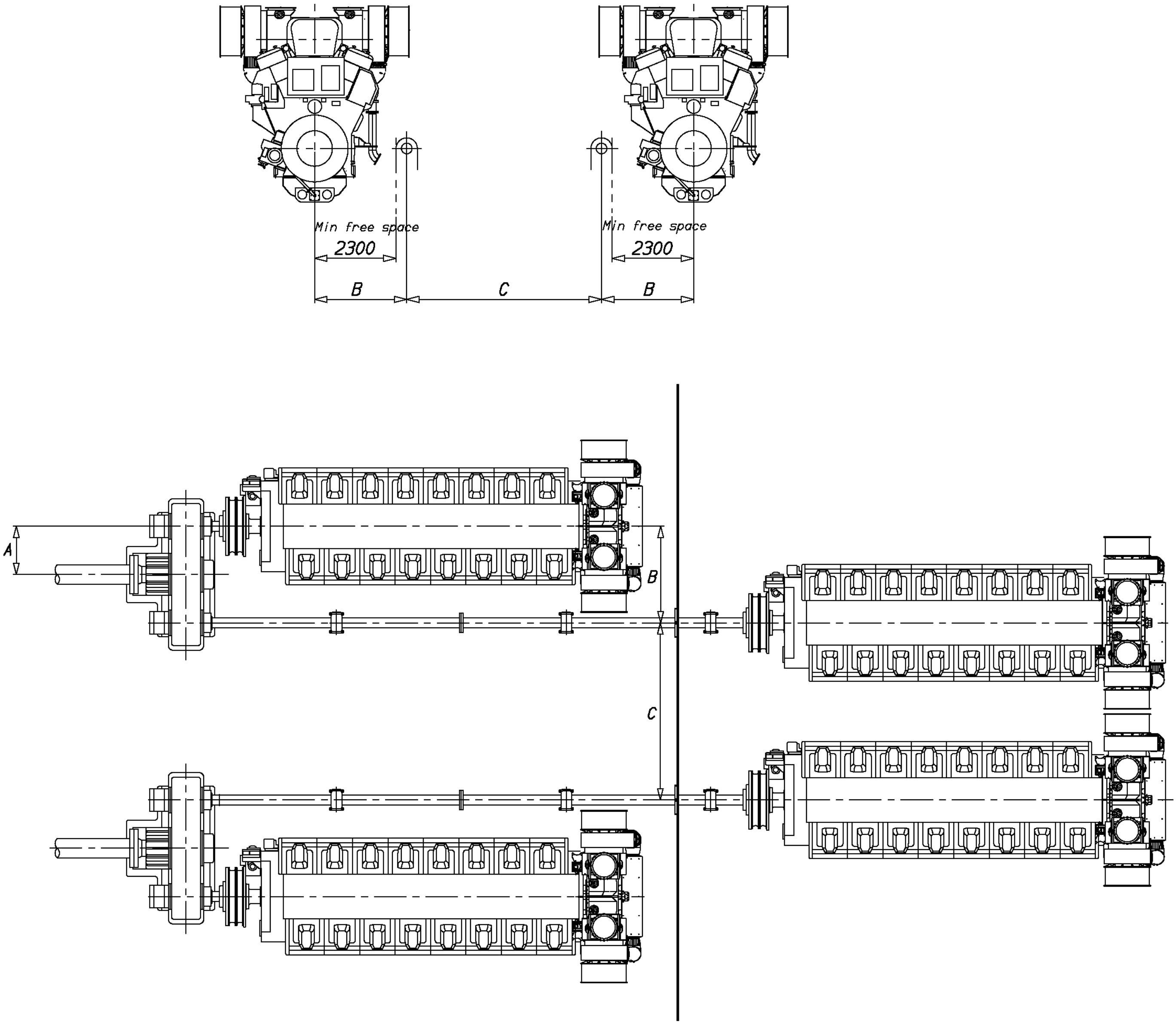


Table 19.2 Minimum distance between engines [mm]

Engine type	Turbocharger	A	B	C, min.	C, rec.
Wärtsilä 12V46	TPL 73	1300	2600	4700	4900
Wärtsilä 12V46	NA 357	1300	2600	4500	4500
Wärtsilä 16V46	TPL 73	1300	2600	4700	4900
Wärtsilä 16V46	TPL 77	1300	2600	5500	5800

Intermediate shaft diameter to be determined case by case.

Dismantling of big end bearing requires 2045 mm on one side and 2400 mm on the other side. Direction may be freely chosen.

Required crankshaft distance is 4500 mm if the turbochargers are in different ends (this is however not recommended in low engine rooms as the lifting arrangement becomes difficult).

Figure 19.5 Main engine arrangement, 4 x L46 (2V69C0232)

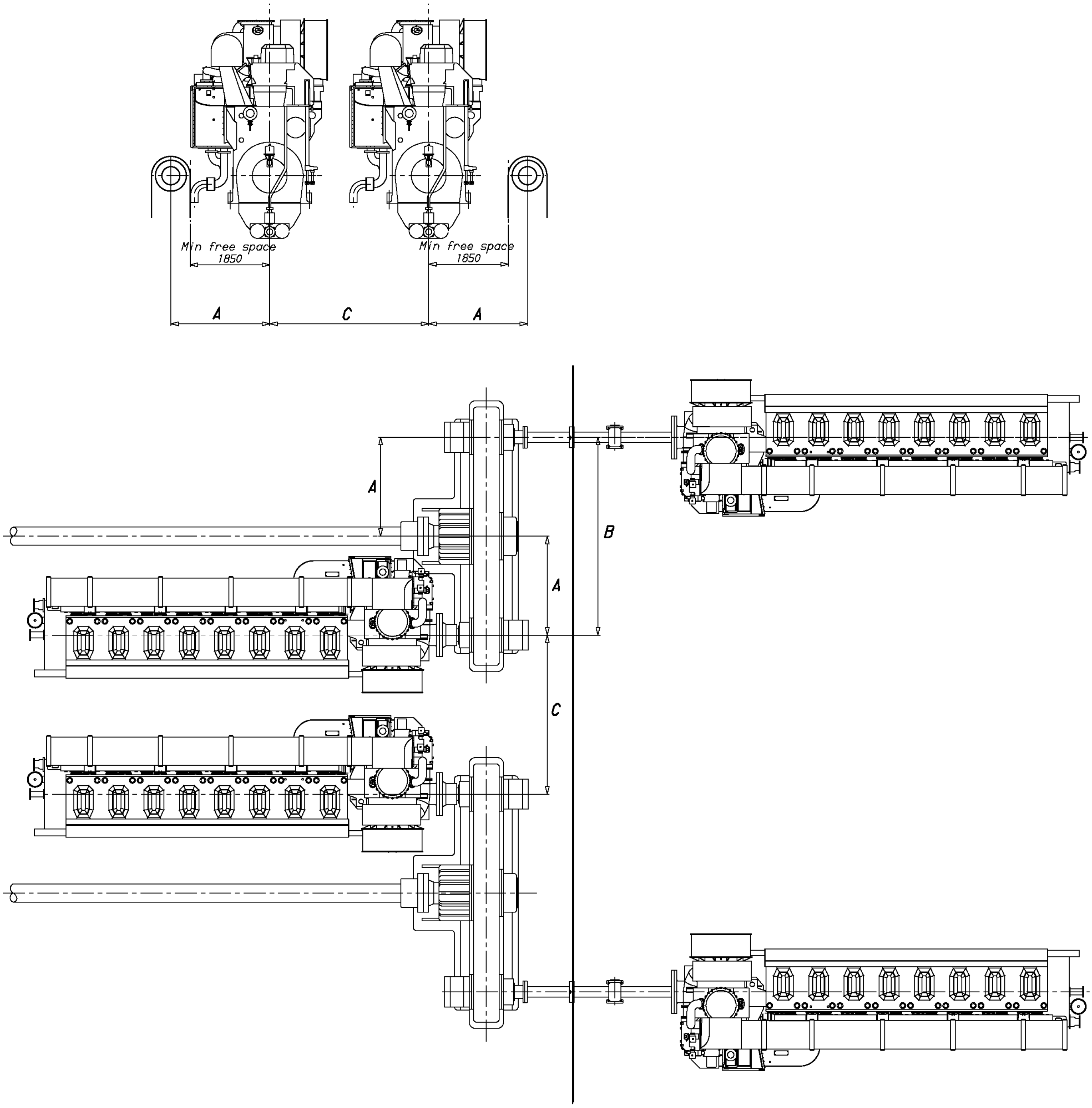


Table 19.3 Minimum distance between engines [mm]

Engine type	A	B	C
Wärtsilä 6L46	2300	4600	3500
Wärtsilä 8L46	2300	4600	3700
Wärtsilä 9L46	2300	4600	3700

Intermediate shaft diameter to be determined case by case.

Dismantling of big end bearing requires 1580 mm on one side and 2210 mm on the other side. Direction may be freely chosen.

Figure 19.6 Main engine arrangement, 4 x V46 (2V69C0242b)

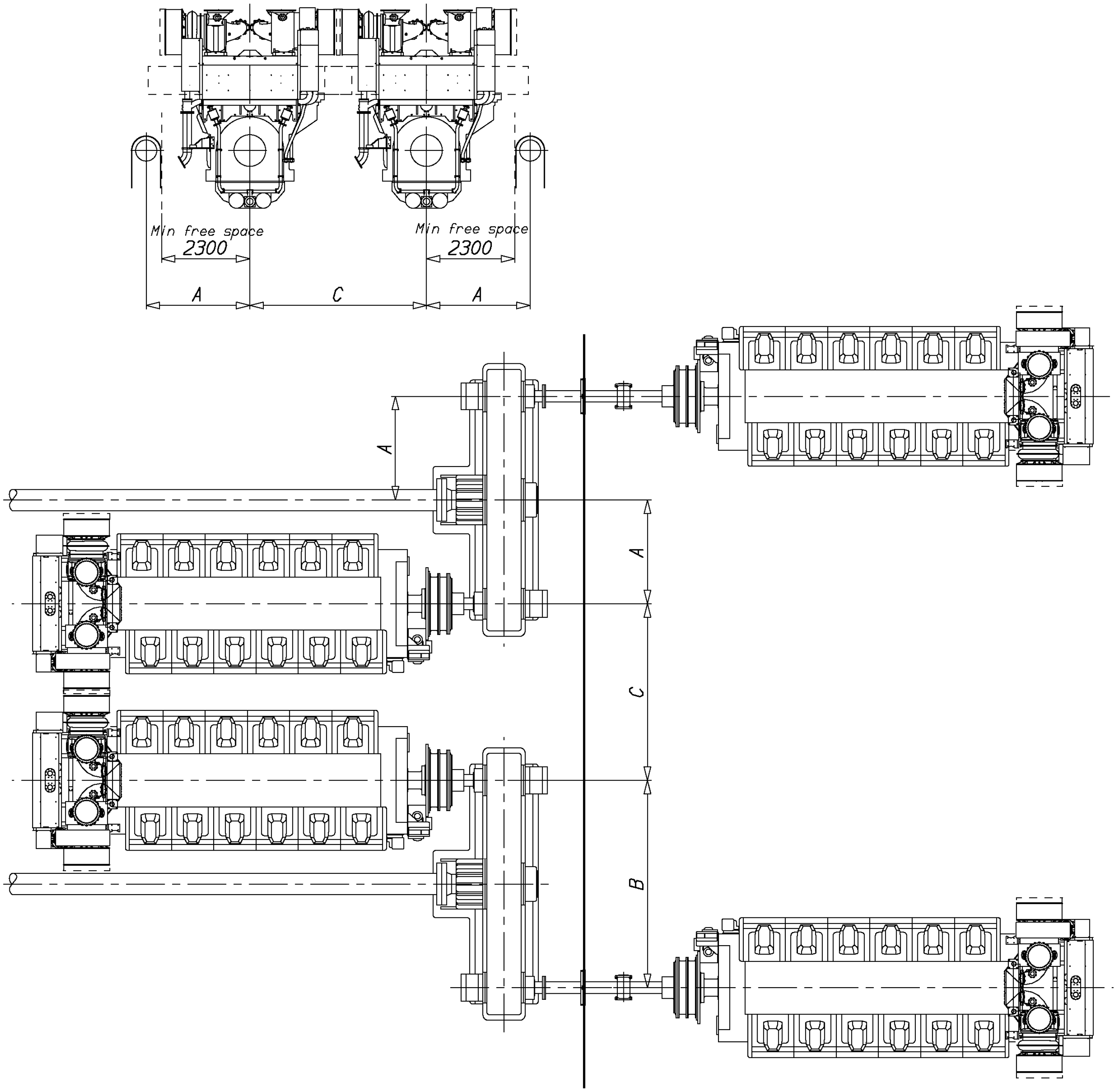


Table 19.4 Minimum distance between engines [mm]

Engine type	Turbocharger	A	B	C, min.	C, rec.
Wärtsilä 12V46	TPL 73	2700	5400	4700	4900
Wärtsilä 12V46	NA 357	2700	5400	4500	4500
Wärtsilä 16V46	TPL 73	2700	5400	4700	4900
Wärtsilä 16V46	TPL 77	2700	5400	5500	5800

Intermediate shaft diameter to be determined case by case.

Dismantling of big end bearing requires 2045 mm on one side and 2400 mm on the other side. Direction may be freely chosen.

Required crankshaft distance is 4500 mm if the turbochargers are in different ends (this is however not recommended in low engine rooms as the lifting arrangement becomes difficult).

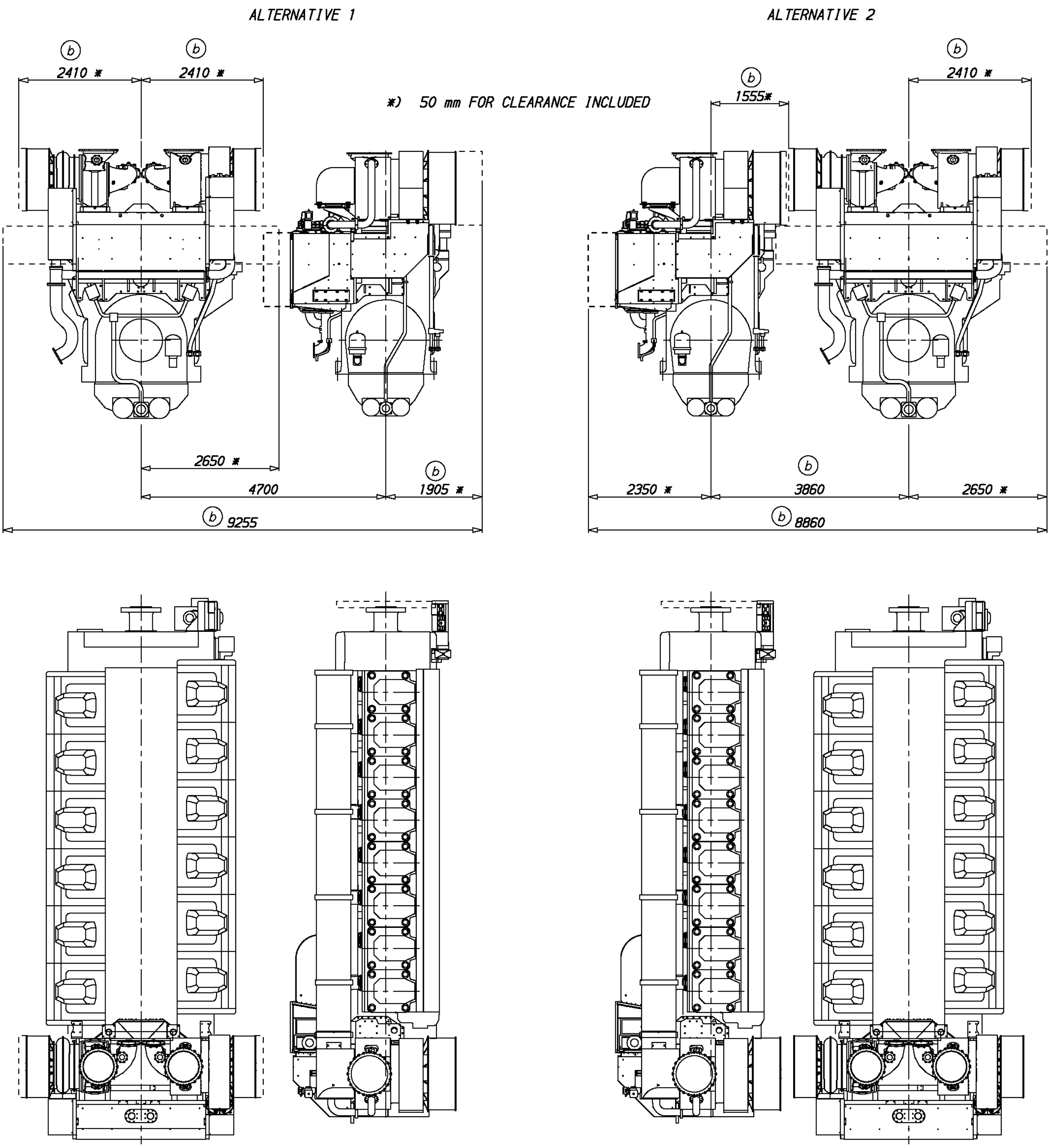
19.1.4 Father-and-son arrangement

Drawing 1V91B0616b shows an example of an in-line and a V-engine of the Wärtsilä 46 type connected to the same gearbox. In this case the engines (8L46 and 12V46) are roughly equally long, and therefore the turbochargers are close to each other.

To minimize the crankshaft distance the manoeuvring side of the L46 should be towards the V-engine, otherwise dismantling of the air cooler of the V-engine will determine the required distance to avoid interference with the charge air cooler of the in-line engine. If the engines are clearly of different length (other cylinder numbers than 8L46 and 12V46) the pattern is different.

When the manoeuvring side of the L46 is towards the V-engine, the recommended platform height between the engines is as recommended for the L46 (1450 mm above crankshaft). A platform height as recommended for the V46 (1200 mm above crankshaft) would interfere with the camshaft covers of the L46. In other words, this father-and-son arrangement has a slight ergonomic disadvantage, the platform being located 250 mm higher than recommended for the V-engine, assuming a reduction gear with a pure horizontal offset. This issue is different in case there is a vertical offset between the crankshafts.

Figure 19.7 Main engine arrangement, 12V46 + 8L46 (1V91B0616b)



19.2 Space requirements for maintenance

19.2.1 Working space around the engine

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

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

Figure 19.8 Service space requirement in-line engine (3V69C0192b)

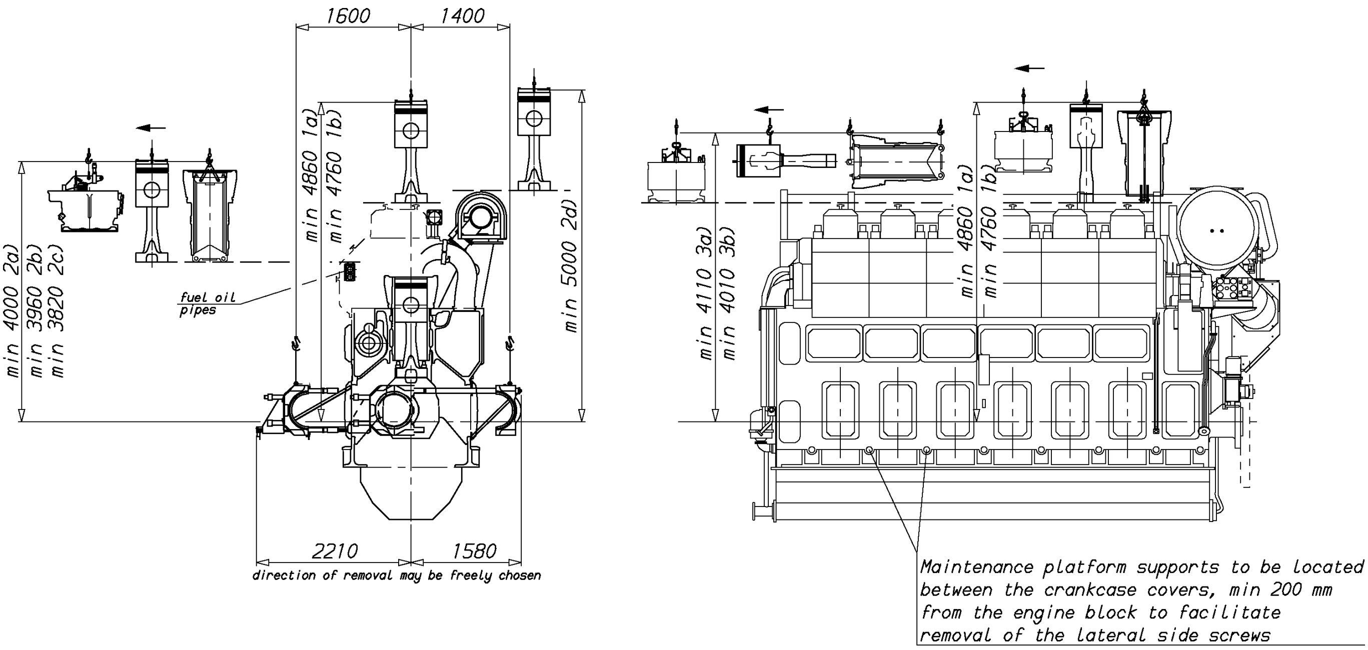
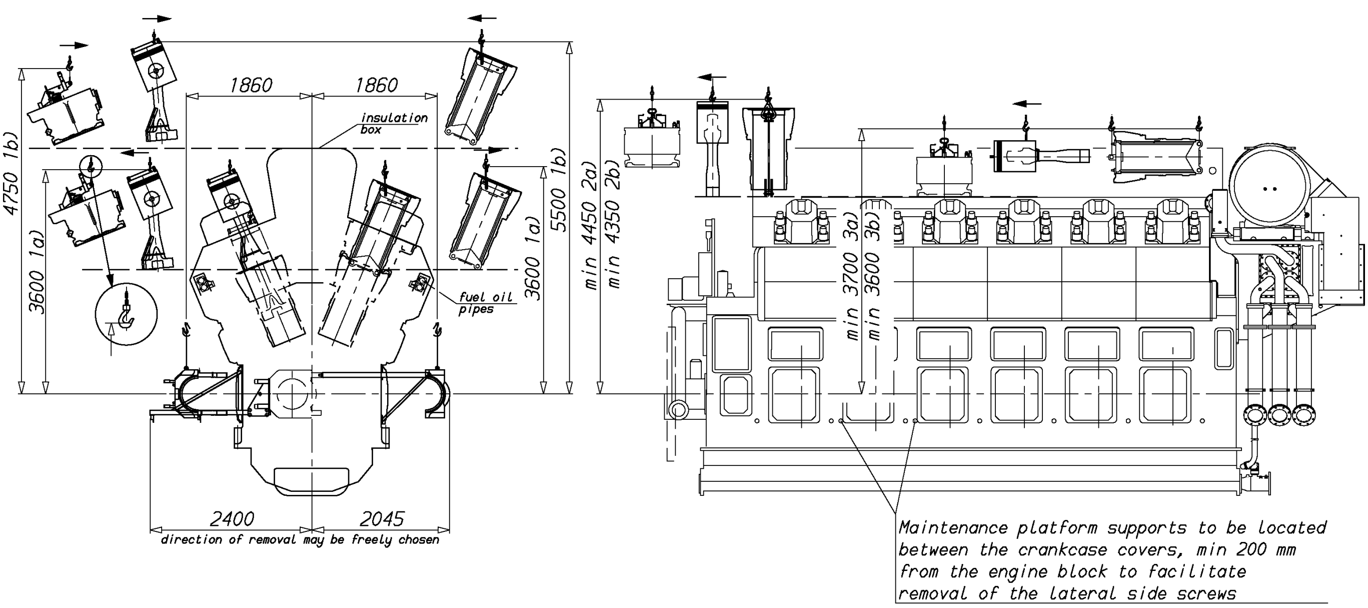


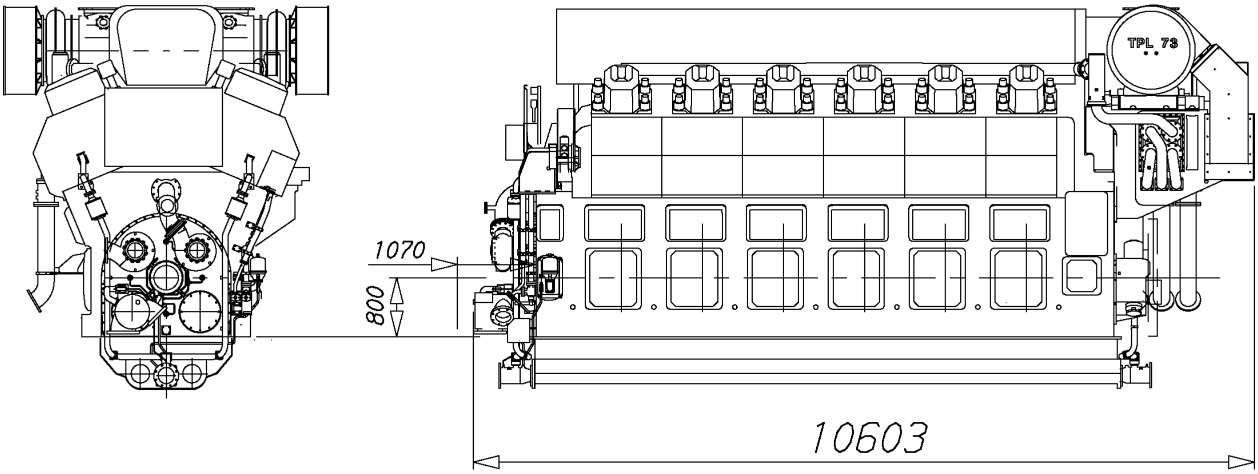
Figure 19.9 Service space requirement V-engine (3V69C0193b)



[All dimensions are in mm]

Minimum overhauling heights, in-line engines	Minimum overhauling heights, V-engines
1. Overhauling along the engine centerline (vertical position) a) over the valve gear covers b) valve gear covers removed	1. Overhauling sidewards (vertical position) a) over fuel oil pipes b) over insulation box
2. Overhauling sidewards (vertical position) a) over the fuel oil pipes b) cover of fuel oil pipes removed c) fuel oil pipes removed d) over insulation box	2. Overhauling along the engine centerline (vertical position) a) over the valve gear covers b) valve gear covers removed
3. Overhauling along the engine CL (horizontal position) a) over the valve gear covers b) valve gear covers removed	3. Overhauling along the engine CL (horizontal position) a) over the valve gear covers b) valve gear covers removed

Figure 19.10 Service space requirement for dismounting of lubricating oil pump



19.2.2 Engine room height and lifting equipment

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

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

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

Table 19.5 Recommended lifting capacity for overhead travelling crane

Engine parts including dismantled turbocharger	2.0 ton
Engine parts including complete TPL 73 turbocharger	2.5 ton
Engine parts including complete TPL 77 turbocharger	3.8 ton

Required crane hook height from deck

Required hook height vertically above floor level for storing and servicing engine parts (for V-engines some more space is needed if the component is lifted in inclined position):

	L46	V46
Above piston - connecting rod trestle	1850 mm	1900 mm
Above storage place for cylinder liner	1700 mm	1800 mm
Above cylinder head trestle (in workshop)	1650 mm	1650 mm

Required crane hook height from deck for different lifting positions of W46 main components (3V69C0228b).

Figure 19.11 Piston connecting rod assembly

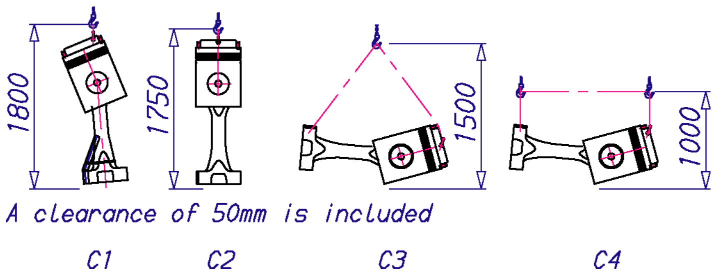


Figure 19.12 Cylinder liner

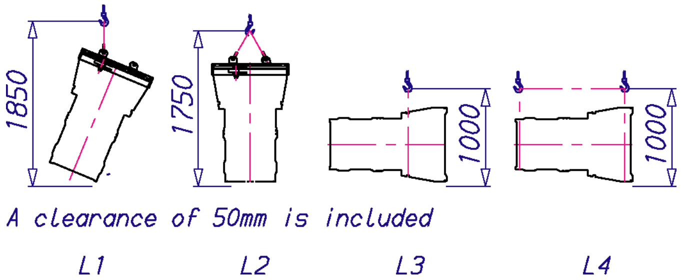
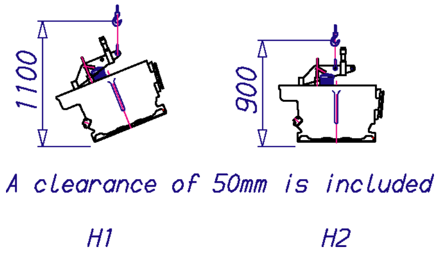


Figure 19.13 Cylinder head



Bridge crane for Wärtsilä L46

Figure 19.14 Space requirements for overhaul of main components (3V69C0248)

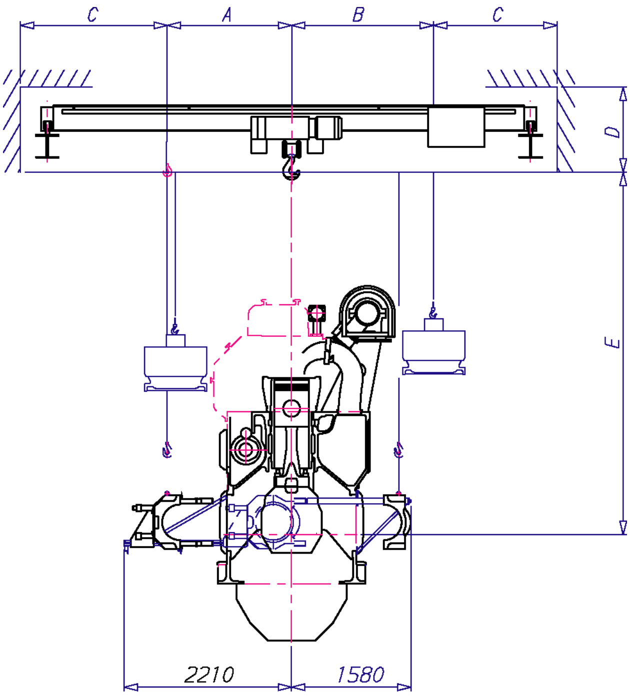


Table 19.6 Minimum transverse travel of hook for overhauling main parts of Wärtsilä L46 engines, operating side of engine

Operational requirement on the operating side of the engine	Reference No.	A [mm] (all engines)
For removing lower half of connecting rod big end [1]	TOS1	1400
For removing upper half of connecting rod big end [1]	TOS2	1600
For removing main parts pass hot-box or transporting longitudinally along operating side of engine	TOS3	1500
[1] Direction of removal can be freely chosen (see drawing 3V69C0248). The service platforms must be removable to allow crane access to the connecting rod big end halves.		

Table 19.7 Minimum transverse travel of hook for overhauling main parts of Wärtsilä L46 engines, rear side of engine

Operational requirement on the rear side of the engine	Reference No.	B [mm]	
		6L46	8L46 and 9L46
For removing lower half of connecting rod big end [1]	TRS1	1400	1400
For removing upper half of connecting rod big end [1]	TRS2	1600	1600
For lifting or lowering the charge air cooler from its housing [2]	TRS3	1600	1850
For lowering or transporting main parts pass insulation box	TRS4	1800	1800
For removing charge air cooler sideways [2]	TRS5	2000	2150
For lowering or transporting main parts pass charge air cooler housing	TRS6	2150	2300
[1] Direction of removal can be freely chosen (see drawing 3V69C0248). The service platforms must be removable to allow crane access to the connecting rod big end halves. [2] A vertical hook height of 4000 mm (E) is required for lifting the charge air cooler upwards to free it from its housing. Otherwise the cooler will have to be lowered or removed from its housing sideways.			

Table 19.8 Required hook height vertically above crankshaft when overhauling main parts along centerline of engine to landing area at non-turbocharger end of engine

Reference No.	AC1	AC2	AC3	AC4	AC5	AC6
Required hook height, E [mm]:	4860	4760 [1)]	4610	4510 [1)]	4110	4010 [1)]
Piston-conrod assembly	C2	C2	C3	C3	C4	C4
Cylinder liner	L2	L2	L3 (L4)	L3 (L4)	L3 (L4)	L3 (L4)
Cylinder head	H2	H2	H2	H2	H2	H2

1) The valve gear covers must be removed

Table 19.9 Required hook height vertically above crankshaft when overhauling main parts sideways to operating side of the engine

Reference No.	OS1	OS2	OS3	OS4
Required hook height, E [mm]:	4000	3960 [1)]	3820	3820 [2)]
Piston-conrod assembly	C2	C2	C3 (C4)	C2
Cylinder liner	L2	L2	L3 (L4)	L2
Cylinder head	H2	H2	H2	H2

1) The fuel pipe covers must be removed
2) The fuel pipes must be removed

Table 19.10 Required hook height vertically above crankshaft when overhauling main parts sideways to rear side of engine over exhaust manifold insulation box

Reference No.	RS1	RS2	RS3
Required hook height, E [mm]:	5000	4750	4250
Piston-conrod assembly	C2	C3	C4
Cylinder liner	L2	L3 (L4)	L3 (L4)
Cylinder head	H2	H2	H2

Table 19.11 Required hook height vertically above crankshaft for lifting charge air cooler

Operational requirement	**Reference No.**	**Required hook height, E [mm]**
For lifting the cooler over the exhaust manifold insulation box in vertical position	CD1	5200
For lifting the cooler over the exhaust manifold insulation box in horizontal position	CD2	4150
For removing the cooler straight up from its housing	CD3	4000

Figure 19.15 Requirement for longitudinal travel of hook for overhauling main parts, turbocharger at free end of the engine (3V58B2177)

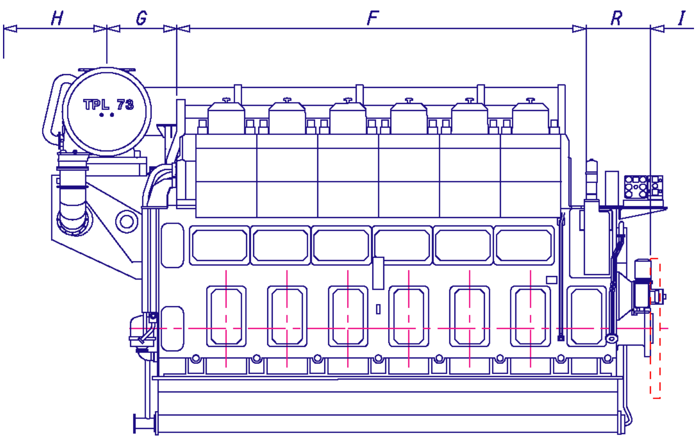


Table 19.12 Requirement for longitudinal travel of hook for overhauling main parts, turbocharger at free end [mm]

		6L46	8L46	9L46
R	Reference from crankshaft flange	850	850	850
F	Minimum longitudinal travel to cover cylinders, charge air cooler and camshaft driving end [1)]	5700	7350	8150
G	To cover turbocharger [2)]	850	850	850
H	To cover landing area at the free end of the engine [3)]	min. 1250	min. 1300	min. 1300
I	To cover flywheel, elastic coupling, gearbox, shaft generator or landing area at driving end of the engine	Depends on application, 100 to cover flywheel		

[1)] Landing area at either side of the engine
[2)] Exhaust pipes may limit the travel of the crane, separate lifting rail may be required
[3)] Travel of the crane is usually restricted by exhaust pipes

Figure 19.16 Requirement for longitudinal travel of hook for overhauling main parts, turbocharger at driving end of the engine (3V58B2178)

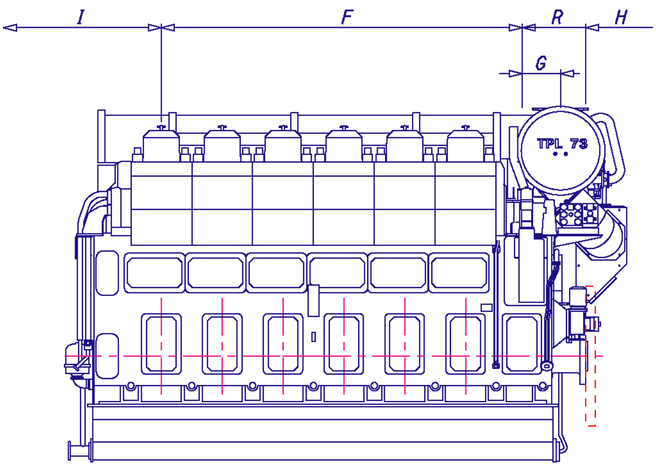


Table 19.13 Requirement for longitudinal travel of hook for overhauling main parts, turbocharger at driving end [mm]

		6L46	8L46	9L46
R	Reference from crankshaft flange	850	850	850
F	Minimum longitudinal travel to cover cylinders, charge air cooler and camshaft driving end [1)]	4950	6550	7400
G	To cover turbocharger [2)]	500	700	700
H	To cover flywheel, elastic coupling, gearbox, shaft generator or landing area at driving end of the engine. Required dimension depends on application; the dimension given here allows the hook to pass charge air manifold [3)]	650	850	850
I	To cover landing area for spares and tools at free end of the engine and to access built-on pumps	for pumps: min. 1150, for landing area: min. 1900		

[1)] Landing area at either side of the engine
[2)] Exhaust pipes may limit the travel of the crane, separate lifting rail may be required
[3)] Travel of the crane is usually restricted by exhaust pipes

Example 1: Lifting arrangements for multi-engine ferry or roro-ship

The engine room height is typically limited, especially on ferries and roro-ships.

Assumptions in this example:

- Mechanical single-prop driveline with two 8L46 engines
- Turbochargers at driving end of the engines
- Main parts overhauled to the operating side of engine and moved along the engine side to landing area at free end of the engines
- Turbochargers are covered with designated lifting rails with chain blocks on them
- Prime movers are covered with a single overhead traveling crane

Table 19.14 Approximate space reservations for one overhead travelling crane (example 1)

Vertically	Main deck girders, approx.	0.6 m
	Bridge crane, free height above hook, approx.	0.7 m
	Hook height vertically above crankshaft, OS1 1)	4.0 m
	From crankshaft center to oil sump bottom 2)	1.5 m
	Distance from oil sump to tanktop 3)	0.1 m
	Double bottom, approx.	1.8 m
	Total from base line to main deck, approx:	**8.7 m**
Transversely	Transverse travel of hook on operating side, TOS3 4)	1.5 m
	Transverse travel of hook on rear side, TRS5 5)	2.2 m
	Free width transversely beyond hook on each side	0.8 m (x2)
	Distance between crankshafts	3.7 m
	Transverse width between pillars/bulkheads etc, approx.	**9.0 m**
Longitudinally	To cover cylinders, charge air cooler and camshaft driving end	6.6 m
	To cover landing area	1.9 m
	Total longitudinal travel 6)	**8.5 m**

1) Lifting strategy OS1 can be followed; parts can be lifted in vertical position
2) An oil sump 230 mm lower is available as an option
3) If necessary, engine oil sump may be recessed into tanktop
4) Allows transportation of components along engine side (TOS3)
5) Allows removing charge air cooler sideways from its housing (TRS5)
6) Longitudinal travel of the crane should start at approx. 850 mm from flywheel flange towards the free end of the engine

Example 2: Lifting arrangements for single engine cargo ship

The engine room of cargo ship may be high in case it is located underneath the superstructure. Thus the height is not limiting dismantling procedures and transportation of engine components. To minimise the engine room length the landing area for components should be at the engine side rather than at the end of the engine. On single-engine ships it is important to arrange the bridge crane to cover the storage space for tools and spares needed for an emergency repair.

Assumptions in this example:

- Mechanical single prop driveline with single 9L46 engine
- Engine equipped with built-on pumps at the free end of the engine
- Turbocharger at the driving end of engine
- Main parts overhauled to landing area at operating side of the engine
- Turbocharger is covered with designated lifting rail with chain block on it
- Prime mover is covered with an overhead travelling crane

Table 19.15 Approximate space reservations for one overhead travelling crane (example 2)

Vertically	**Hook height vertically above crankshaft, OS1, CD1 1)**	**5.2 m**
Transversely	Transverse travel of hook on operating side of engine, TOS3 2) Transverse travel of hook on rear side of engine, TRS3 3) Free width transversely beyond hook on each side, approx. **Transverse free width between pillars/bulkheads, etc. approx.**	2.3 m 1.9 m 0.8 m (x2) **5.8 m**
Longitudinally	To cover cylinders, charge air cooler and camshaft driving end To cover built-on pumps **Total longitudinal travel 4)**	7.4 m 1.2 m **8.6 m**

1) Allows lifting charge air cooler from rear side of engine in vertical position over the exhaust manifold insulation box to the landing area at the operating side of the engine (CD1). For other components lifting strategy OS1 is applied; parts can be lifted in vertical position
2) Covers landing area on operating side (TOS3) of the engine, part of which acts as storage of emergency spare parts and tools. Assumed that next to the engine hot-box is 800 mm wide grating, unsuitable for landing heavy parts
3) Allows lifting charge air cooler from its housing (TRS3)
4) Longitudinal travel of the crane should start at approx. 850 mm from flywheel flange towards the free end of the engine

Bridge crane for Wärtsilä V46

Figure 19.17 Space requirement for overhaul of main components (3V69C0249)

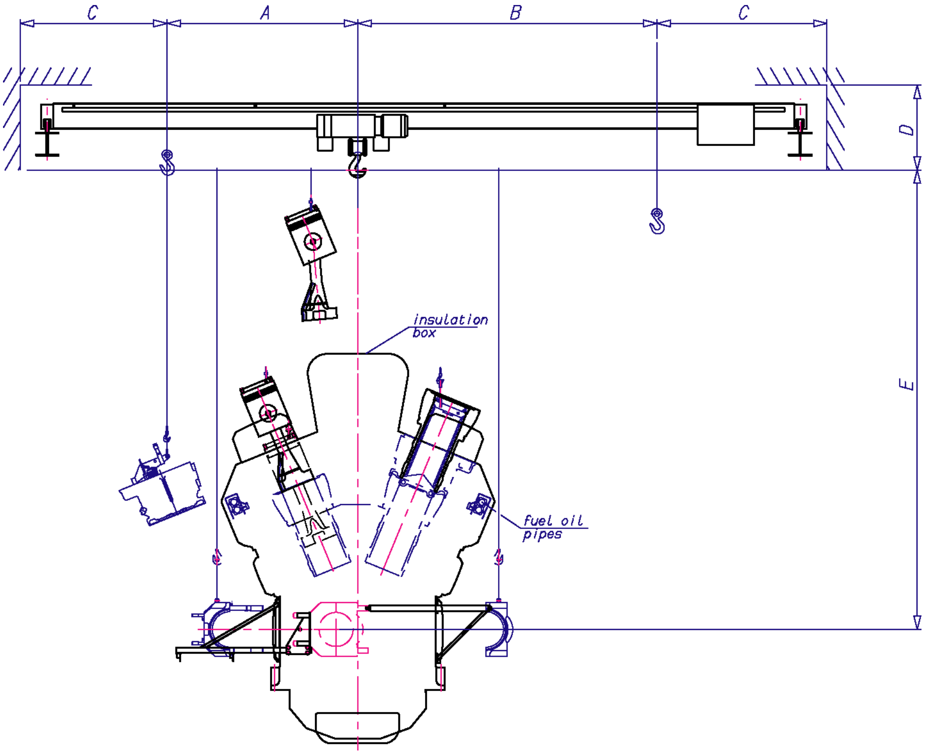


Table 19.16 Minimum transverse travel of hook for overhauling main parts of Wärtsilä V46 engines

Operational requirement on both sides of the engine	Reference No.	A and B [mm]	
		12V46	16V46 and 18V46
For removing connecting rod big end halves 1)	TT1	1860	1860
For removing charge air coolers	TT2	1990	2140
For lowering main parts pass hot box or transporting longitudinally along engine side	TT3	2250	2250
For dismantling turbochargers	TT4	2710	3180

1) Service platforms must be removable to access connecting rod big end halves with the crane

Table 19.17 Required hook height vertically above crankshaft when overhauling main parts longitudinally above cylinder bank to landing area at non-turbocharger end of engine [1)]

Reference No.	AC1	AC2	AC3	AC4	AC5	AC6
Required hook height, E [mm]:	4450	4350 [2)]	4100	4000 [2)]	3700	3600 [2,3)]
Piston-conrod assembly	C1	C1	C3	C3	C4	C4
Cylinder liner	L1	L1	L3 (L4)	L3 (L4)	L3 (L4)	L3 (L4)
Cylinder head	H1	H1	H1	H1	H1	H1

[1)] Hook travelling 1860 mm of the engine centerline
[2)] The valve gear covers must be removed
[3)] Minimum height of 3650 mm is required for the empty hook to travel over exhaust manifold insulation box

Table 19.18 Required hook height vertically above crankshaft when overhauling main parts sideways to the side of the engine

Reference No.	LS1
Required hook height, E [mm]:	3600 [1)]
Piston-conrod assembly	C1
Cylinder liner	L1
Cylinder head	H1

[1)] Care must be taken that the transverse beam of the crane has adequate clearance over exhaust manifold insulation box. Insulation box height (3650 mm from crankshaft) will also limit the transverse travel of the hook.

Table 19.19 Required hook height vertically above crankshaft when lifting main parts over exhaust manifold insulation box

Reference No.	NL1	NL2	NL3	NL4	NL5	NL6
Required hook height, E [mm]:	5500	5450	5400	5150	4750	4650
Piston-conrod assembly	C1	C1	C2	C3	C4	C4
Cylinder liner	L1	L2	L2	L3 (L4)	L3 (L4)	L3 (L4)
Cylinder head	H1	H1	H1	H1	H1	H2

Table 19.20 Required hook height vertically above crankshaft for lifting charge air cooler over exhaust manifold insulation box

Operational requirement	**Reference No.**	**Required hook height, E [mm]**	
		12V46	**16V46 and 18V46**
For lifting cooler in vertical position	CD1	5200	5300
For lifting cooler in horizontal position	CD2	4500	4550

Figure 19.18 Requirement for longitudinal travel of hook for overhauling main parts, turbocharger at free end of the engine (3V58B2175)

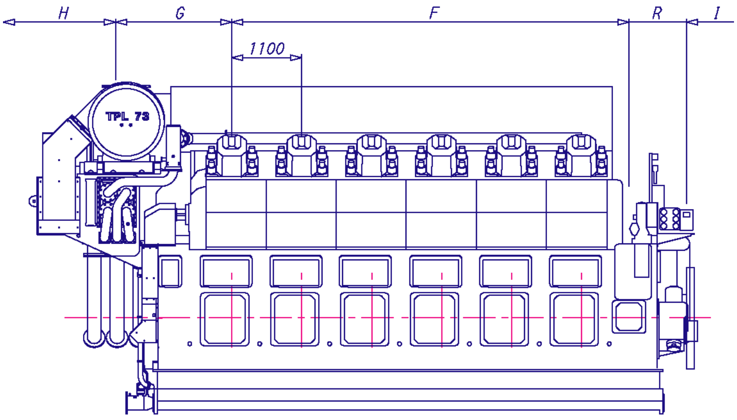


Table 19.21 Requirement for longitudinal travel of hook for overhauling main parts, turbocharger at free end [mm]

		12V46	16V46	18V46
R	Reference from crankshaft flange	920	920	920
F	Minimum longitudinal travel to cover cylinders and camshaft driving end [1)]	6500	8700	9800
G	To cover turbocharger and charge air coolers [2)]	1600	1600	1700
H	To cover landing area at the free end of the engine [3)]	min. 1700	min. 1700	min. 1700
I	To cover flywheel, elastic coupling, gearbox or shaft generator or landing area at driving end of the engine	Depends on application, 30 to cover flywheel		

[1)] Landing area at the side of the engine
[2)] Exhaust pipes may limit the travel of the crane, separate lifting rail may be required
[3)] Travel of the crane is usually restricted by exhaust pipes

Figure 19.19 Requirement for longitudinal travel of hook for overhauling main parts, turbocharger at driving end of the engine (3V58B2176)

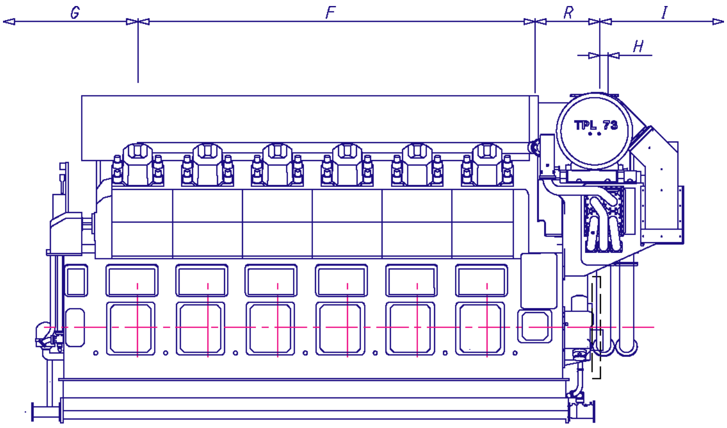


Table 19.22 Requirement for longitudinal travel of hook for overhauling main parts, turbocharger at driving end [mm]

		12V46	16V46	18V46
R	Reference from crankshaft flange	920	920	920
F	Minimum longitudinal travel to cover cylinders and camshaft driving end [1)]	6500	8700	9800
G	To cover landing area for spares and tools at free end of the engine and to access built-on pumps	for pumps min. 1150 for landing area min. 1900		
H	To cover turbocharger and charge air coolers [2)]	180	180	180
I	To access flywheel, elastic coupling, gearbox or shaft generator or landing area at driving end of the engine [3)]	Depends on application, 1480 for hook to pass charge air manifold		

[1)] Landing area at the side of the engine
[2)] Exhaust pipes may limit the travel of the crane, separate lifting rail may be required
[3)] Travel of the crane is usually restricted by exhaust pipes

Example 1: Multi-engine cruise ship

The engine room height is typically limited in this type of vessel. Ship's structures, e.g. pillars, often divide the engine room space. These force to use more than one overhead travelling crane to cover the engine room.

Assumptions in this example:

- Diesel-electric driveline with 12V46 engines
- Turbochargers at free end of the engines
- Main parts overhauled to the side of engine and moved along the engine side to landing area at driving end of the engines
- Turbochargers and charge air coolers are covered with designated lifting rails with chain blocks on them.

- Each engine is covered by own overhead travelling crane.

Table 19.23 Approximate space reservations for one overhead travelling crane (example 1)

Vertically	Main deck girders, approx. Bridge crane, free height above hook, approx. Hook height vertically above crankshaft, LS1 1) From crankshaft center to oil sump bottom Distance from oil sump to tanktop 2) Double bottom, approx. **Total from base line to main deck, approx:**	0.5 m 0.7 m 3.6 m 1.5 m 0.1 m 1.8 m **8.2 m**
Transversely	Transverse travel of hook on each side, TT3 3) Free width transversely beyond hook on each side **Transverse width between pillars/bulkheads etc, approx.**	2.3 m 0.8 m (x2) **6.2 m**
Longitudinally	To cover cylinders and camshaft driving end To cover flywheel, elastic coupling (and landing area, which is located on a deck above the coupling) **Total longitudinal travel 4)**	7.4 m 2.5 m **9.9 m**

1) Lifting strategy LS1 can be followed. Care must be taken that the transverse beam of the crane has adequate clearance over exhaust manifold insulation box.
2) If necessary, engine oil sump may be recessed into tanktop
3) Allows transportation along engine side (TT3)
4) Longitudinal travel of the crane should start at the centerline of cylinder B6

Example 2: Single engine cargo ship

The engine room may be high in case it is located underneath the superstructure. Thus the height is not limiting dismantling procedures and transportation of engine components. To minimise the engine room length the landing area for engine components should be at the engine side rather than at the end of the engine. On single engine ships it is important to arrange the bridge crane to cover the storage space for tools and spares needed for an emergency repair.

Assumptions in this example:

- Mechanical single prop driveline with single 16V46 engine
- Engine equipped with built-on pumps at the free end of the engine
- Turbochargers at the driving end of engine
- Main parts overhauled to landing areas at operating side of the engine
- Turbocharger and charge air cooler is covered with designated lifting rail with chain block on it
- Prime mover is covered with an overhead travelling crane.

Table 19.24 Approximate space reservations for one overhead travelling crane (example 2)

Vertically	**Hook height vertically above crankshaft, LS1, NL1 1)**	**5.5 m**
Transversely	Transverse travel of hook on operating side of engine, TT3 2) Transverse travel of hook on rear side of engine, TT1 3) Free width transversely beyond hook on each side, approx. **Transverse free width between pillars/bulkheads, etc. approx.**	3.1 m 1.9 m 0.8 m (x2) **6.6 m**
Longitudinally	To cover cylinders and camshaft driving end To cover built-on pumps **Total longitudinal travel 4)**	8.7 m 1.2 m **9.9 m**

1) Allows lifting parts from rear side of engine in vertical position over exhaust manifold insulation box. Lifting strategy LS1 is applied for cylinders in the operating side and NL1 for cylinders in the rear side of engine.
2) Covers landing area on operating side of the engine (TT3), part of which also acts as storage space of emergency spare parts. Assumed that next to engine hot box is 800 mm wide grating, unsuitable for landing heavy parts.
3) Allows lifting of connecting rod big end halves (TT1)
4) Longitudinal travel of the crane should start at approx. 920 mm from flywheel flange towards the free end of the engine

Lifting dimensions for turbochargers

Figure 19.20 Lifting arrangement for turbocharger overhauling, in-line engine (4V69C0252c)

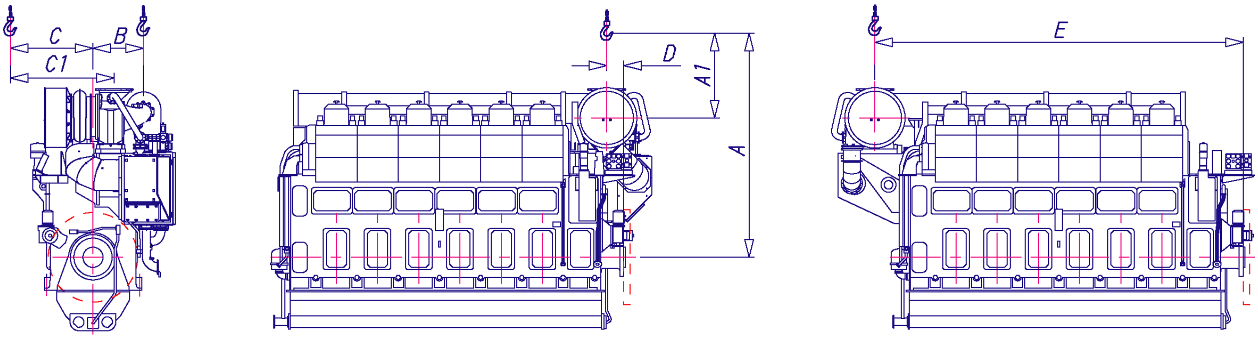


Table 19.25 Lifting arrangement for turbocharger overhauling, in-line engines [mm]

Engine	kW/cyl	Turbo-charger	A_{min}	$A1_{min}$	B_{min}	C_{min}	$C1_{min}$	D	E	Heaviest TC component weight [kg]	TC weight [kg]
6L46	975 1050	NA 357	4170	1400	1000	880	1300	370	7190	270	1460
	1155	TPL 73	4170	1400	1000	880	1300	330	7190	550	2280
8L46	975 1050	TPL 73	4170	1400	1000	880	1300	330	8960	550	2280
	1155	TPL 77	4470	1550	1000	1180	1500	150		890	3510
9L46	975 1050 1155	TPL 77	4470	1550	1000	1180	1500	150	9780	890	3510

Figure 19.21 Lifting arrangement for turbocharger overhauling, V-engine (4V69C0253b)

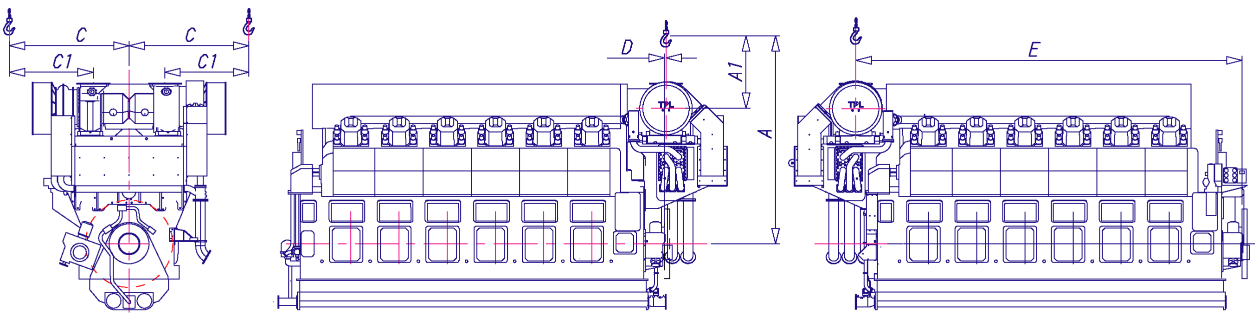


Table 19.26 Lifting arrangement for turbocharger overhauling, V-engines [mm]

Engine	kW/cyl	Turbo-charger	A_{min}	$A1_{min}$	B_{min}	C_{min}	$C1_{min}$	D	E	Heaviest TC component weight [kg]	TC weight [kg]
12V46	975 1050	NA 357	4490	1400	-	2120	1300	-	8820	270	1460
	1155	TPL 73	4490	1400	-	2120	1300	40	8810	550	2280
16V46	975 1050	TPL 73	4490	1400	-	2120	1300	40	11010	550	2280
	1155	TPL 77	4850	1550	-	2460	1500	140		890	3510
18V46	975 1050 1155	TPL 77	4850	1550	-	2460	1500	140	12210	890	3510

19.2.3 Platforms

In order to enable efficient maintenance work on the engine, it is advised to build the maintenance platforms on recommended elevations. The width of the platforms should be at minimum 800 mm to allow adequate working space. The surface of maintenance platforms should be of non-slippery material (grating or chequer plate). Also see *Project guide attachments* for approximate platform drawings (only available on-line).

Figure 19.22 Maintenance platforms, V-engine (3V69C0244)

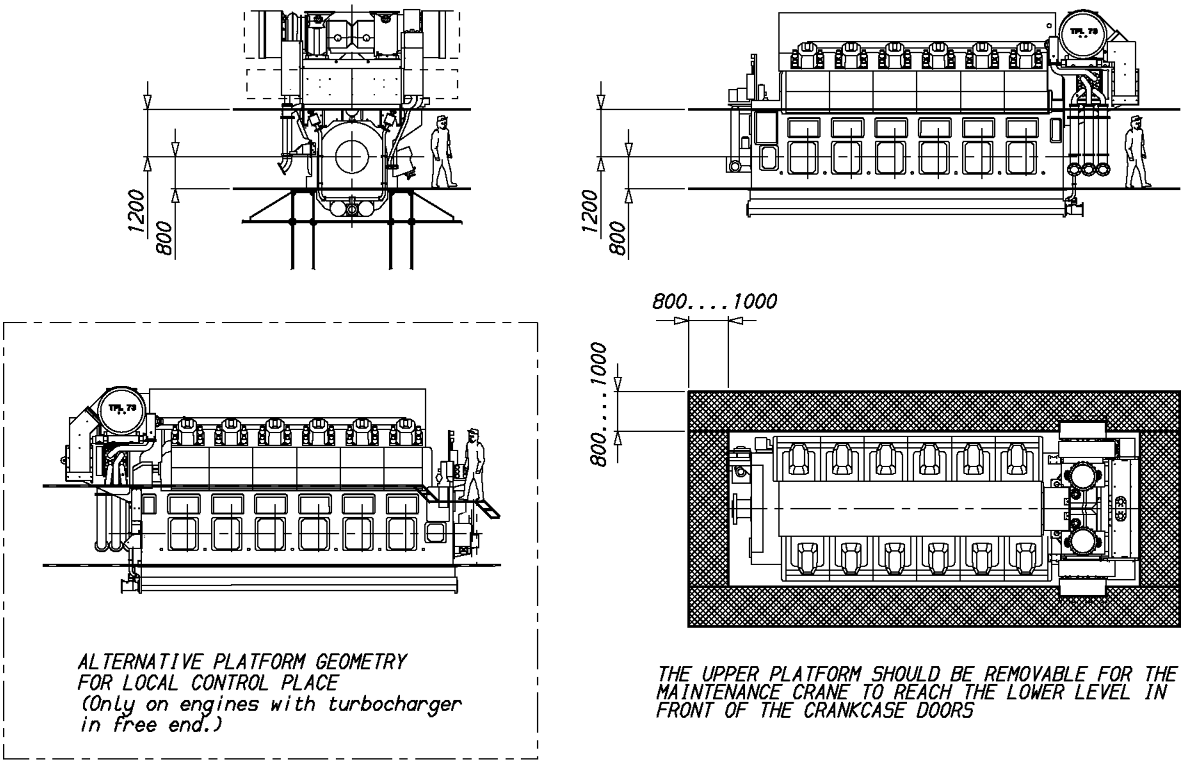
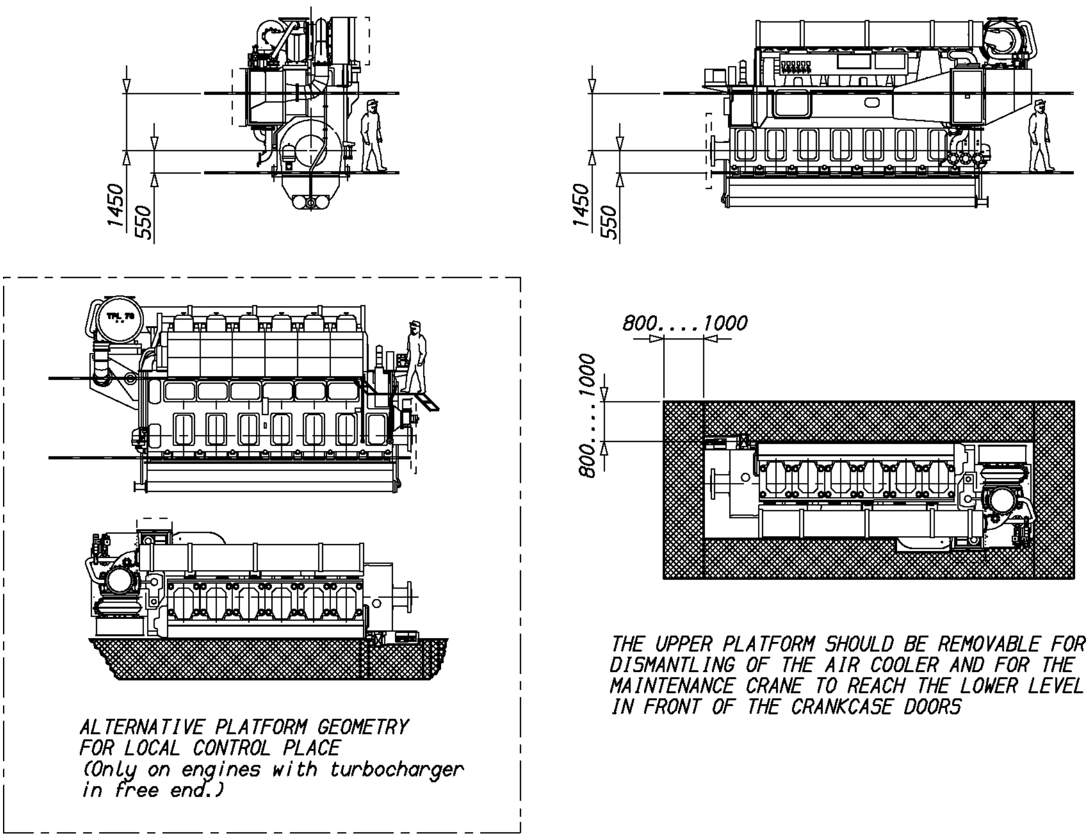


Figure 19.23 Maintenance platforms, in-line engine (3V69C0246)



19.3 Handling of spare parts and tools

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

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

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

19.4 Required deck area for service work

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

If parts must be transported further with trolley or pallet truck, the surface of the deck should be smooth enough to allow this. If transportation to final destination must be carried out using several lifting equipment, coverage areas of adjacent cranes should be as close as possible to each other.

Table 19.27 Required deck area for overhaul work

Piston - connecting rod assembly	2.5 m x 3 m
Cylinder head	2 m x 2 m

Required service area for overhauling both cylinder head and piston-connecting rod assembly (not at the same time) is approximately 8…10 m^2.

For overhauling more than one cylinder at a time, an additional area of about 4 m^2 per cylinder is required. This area is used for temporary storing of dismantled parts.

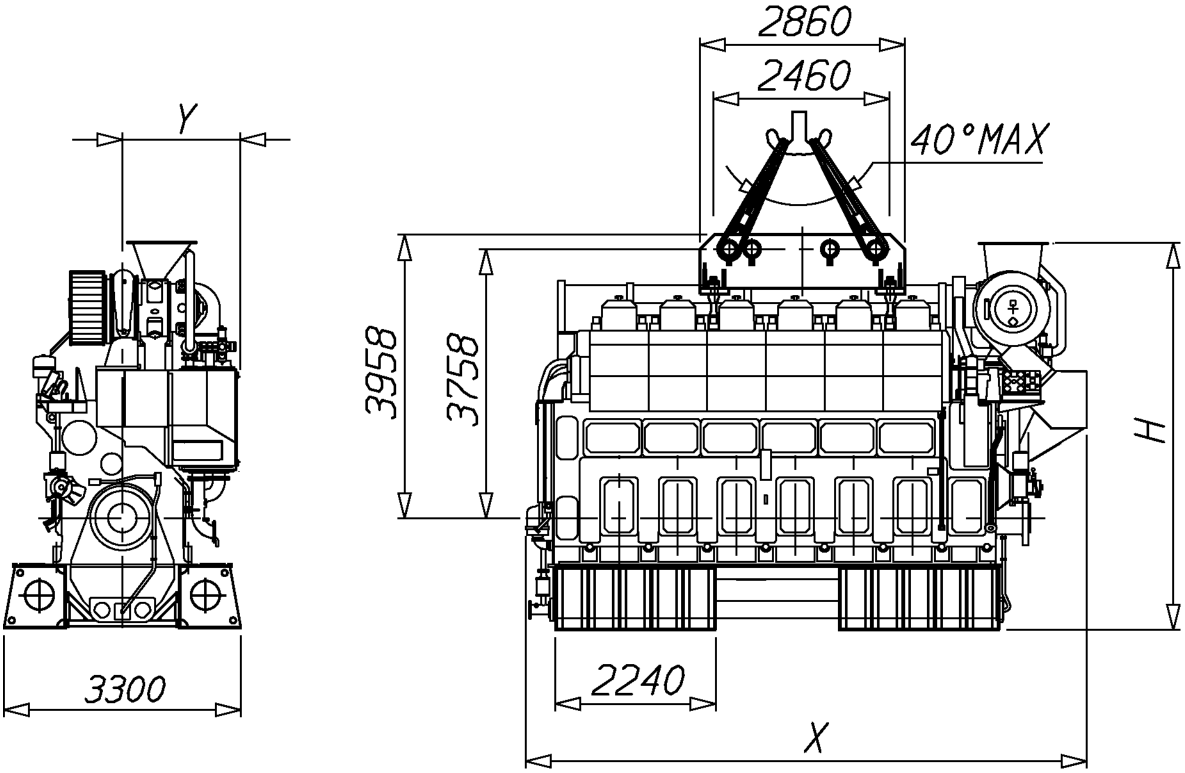
Table 19.28 Example of recommended service area for overhauling whole bank

	8L46	**12V46 one bank**
Service area for overhaul work of one cylinder	10 m^2	10 m^2
Storage area for dismantled parts (8L46 7 cylinders, 12V46 5 cylinders)	28 m^2	20 m^2
Total service area required	38 m^2	30 m^2

20. Transport dimensions and weights

20.1 Lifting of engines

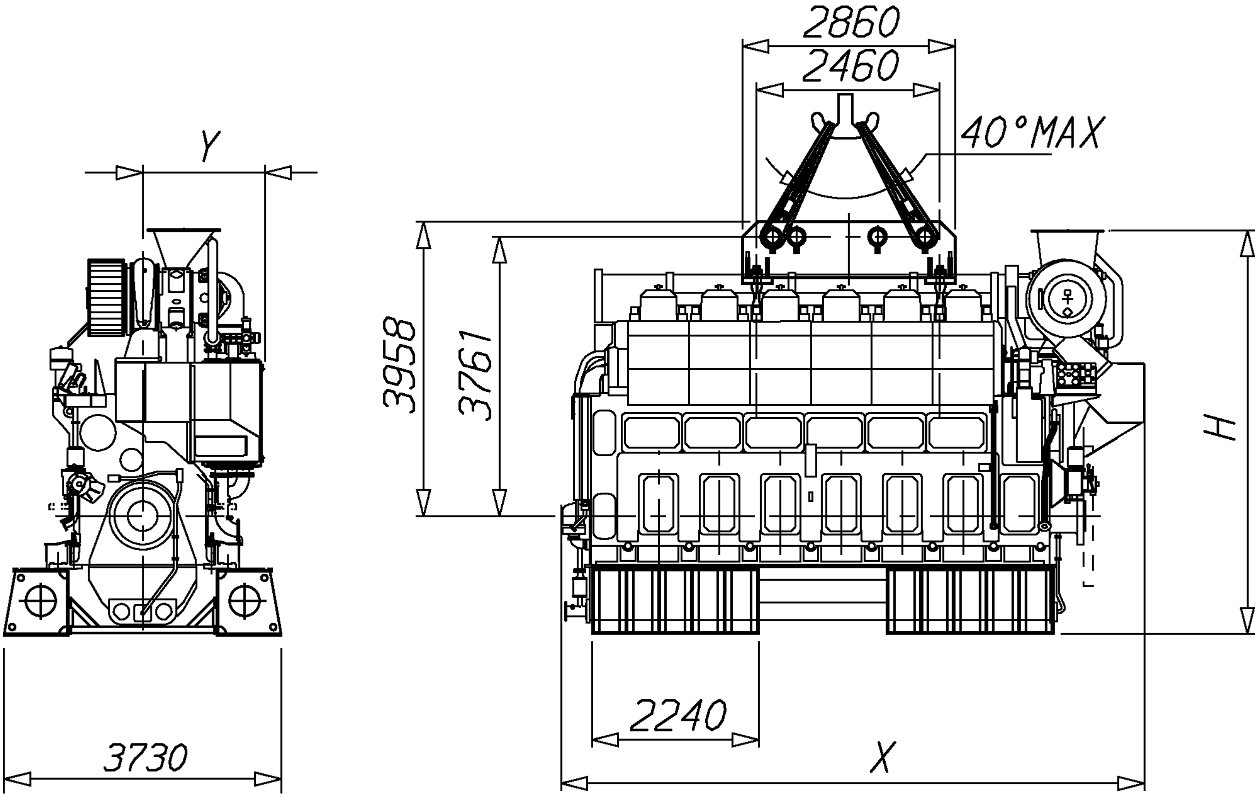
Figure 20.1 Lifting of rigidly mounted in-line engines (4V83D0212c)



Engine type	X [mm]	Y [mm]	H [mm]	Weights without flywheel [ton]			
				Engine	Lifting device	Transport cradle	Total weight
6L46	8290 1) 7815 2)	1650 1650	5510 5510	93.1 93.1	3.3 3.3	6.4 6.4	102.8 102.8
8L46	10005 1) 9455 2)	1860 1860	5510 5510	119.0 119.0	3.3 3.3	6.4 6.4	128.7 128.7
9L46	11015 1) 10275 2)	1860 1860	5675 5675	133.5 133.5	3.3 3.3	9.6 9.6	146.4 146.4

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

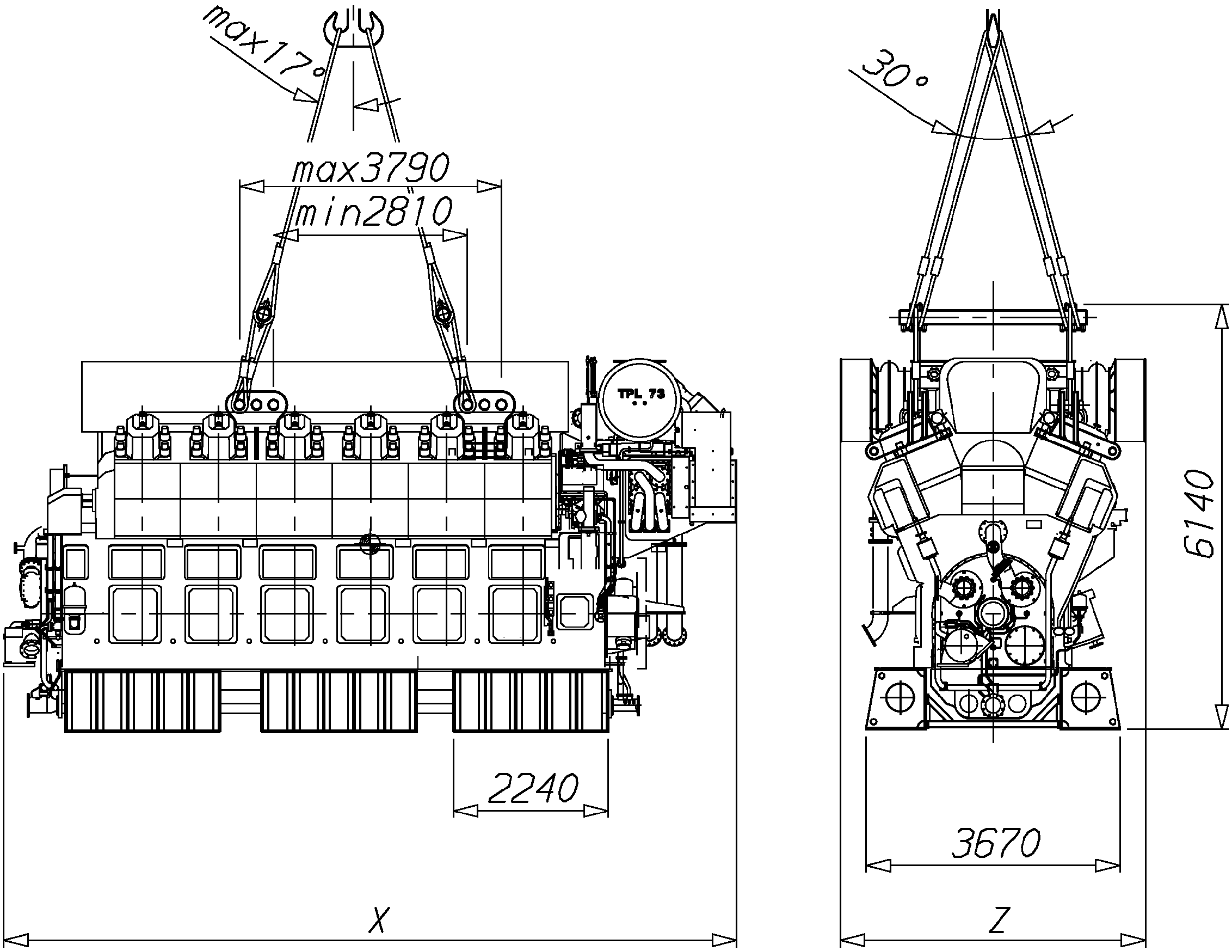
Figure 20.2 Lifting of resiliently mounted in-line engines (4V83D0211c)



Engine type	X [mm]	Y [mm]	H [mm]	Weights without flywheel [ton]				
				Engine	Fixing rails	Lifting device	Transport cradle	Total weight
6L46	8290 1) 7815 2)	1650 1650	5650 5650	93.1 93.1	4.0 4.0	3.3 3.3	6.4 6.4	106.8 106.8
8L46	10005 1) 9455 2)	1860 1860	5650 5650	119.0 119.0	4.7 4.7	3.3 3.3	6.4 6.4	133.4 133.4
9L46	11015 1) 10275 2)	1860 1860	5815 5815	133.5 133.5	5.0 5.0	3.3 3.3	9.6 9.6	151.4 151.4

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

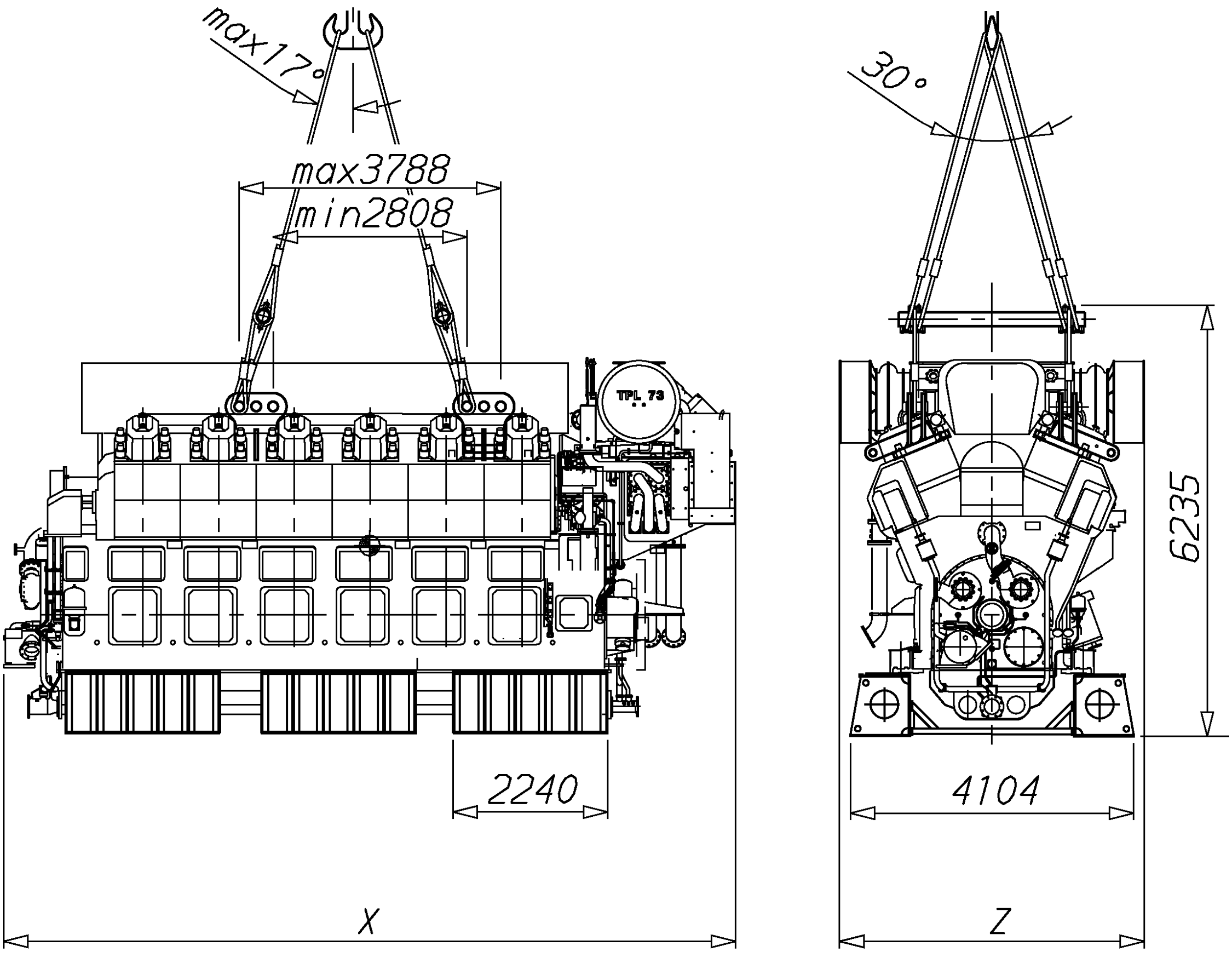
Figure 20.3 Lifting of rigidly mounted V-engines (4V83D0248c)



Engine type	X 1) [mm]	X 2) [mm]	Z [mm]	Weights without flywheel [ton]			
				Engine	Lifting device	Transport cradle	Total weight
12V46	10380	10600	4530	166	3.4	9.6	179
16V46	12580	12460	4530	211	3.4	9.6	224
18V46	13830	-	5350	237	3.4	9.6	250

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

Figure 20.4 Lifting of resiliently mounted V-engines (4V83D0249c)

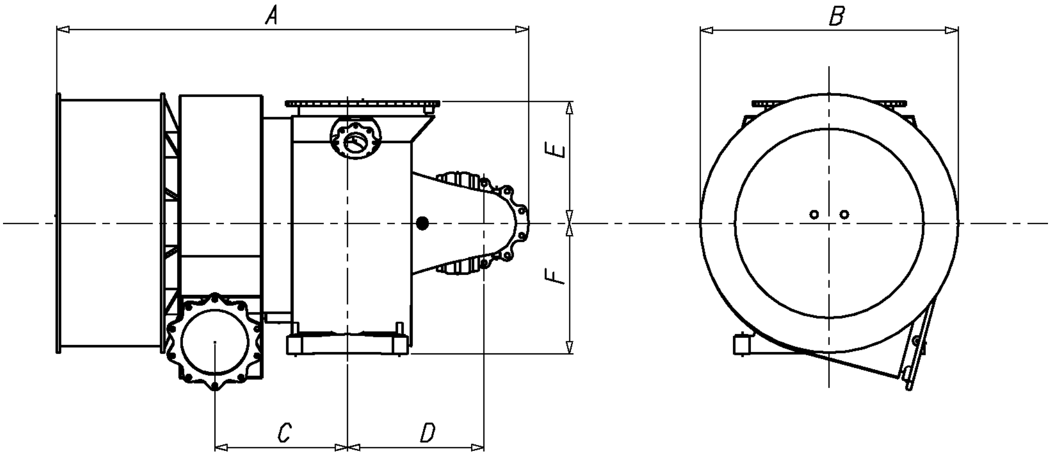


Engine type	X 1) [mm]	X 2) [mm]	Z [mm]	Weights without flywheel [ton]			
				Engine	Lifting device	Transport cradle	Total weight
12V46	10211	10601	4532	166.1	3.4	9.6	179.1
16V46	12300	12801	5350	213.9	3.4	9.6	226.9
18V46	13667	-	5957	237.0	3.4	9.6	250.0

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

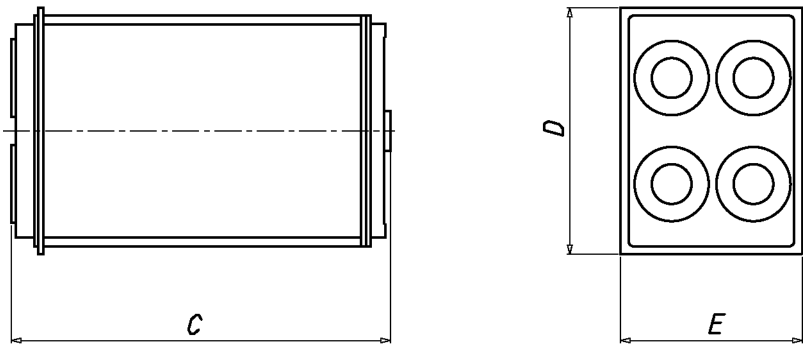
20.2 Engine components

Figure 20.5 Turbocharger (3V92L1224b)



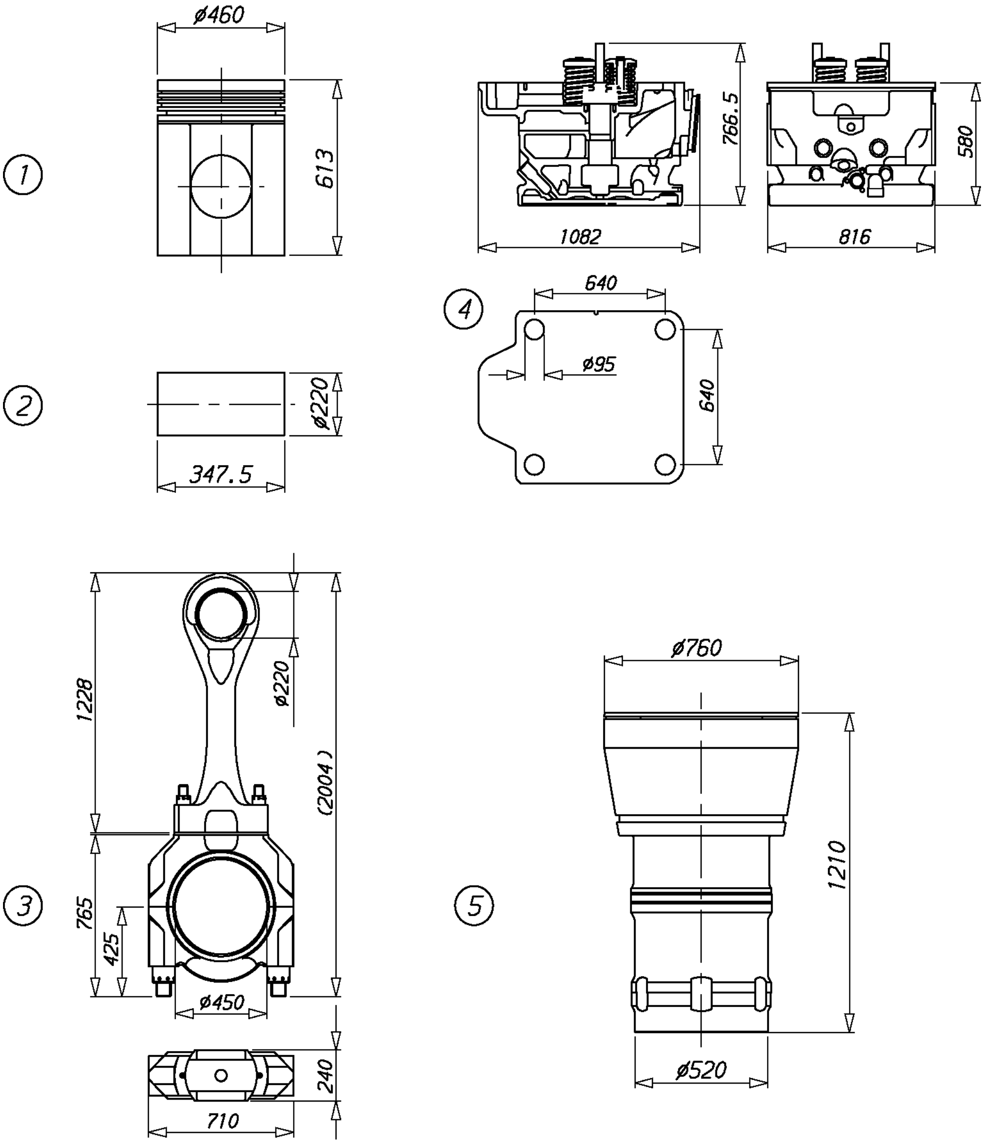
Engine type	Turbocharger	A [mm]	B [mm]	C [mm]	D [mm]	E [mm]	F [mm]	Weight, complete [kg]	Weight, rotor block cartridge [kg]
6L46, 12V46	NA 357	1874	1024	545	524	525	510	1460	270
6L46, 8L46 12V46, 16V46	TPL 73	2190	1200	630	650	580	620	2280	550
8L46, 9L46 16V46, 18V46	TPL 77	2650	1420	750	770	680	730	3510	870

Figure 20.6 Charge air cooler inserts (3V92L1063)



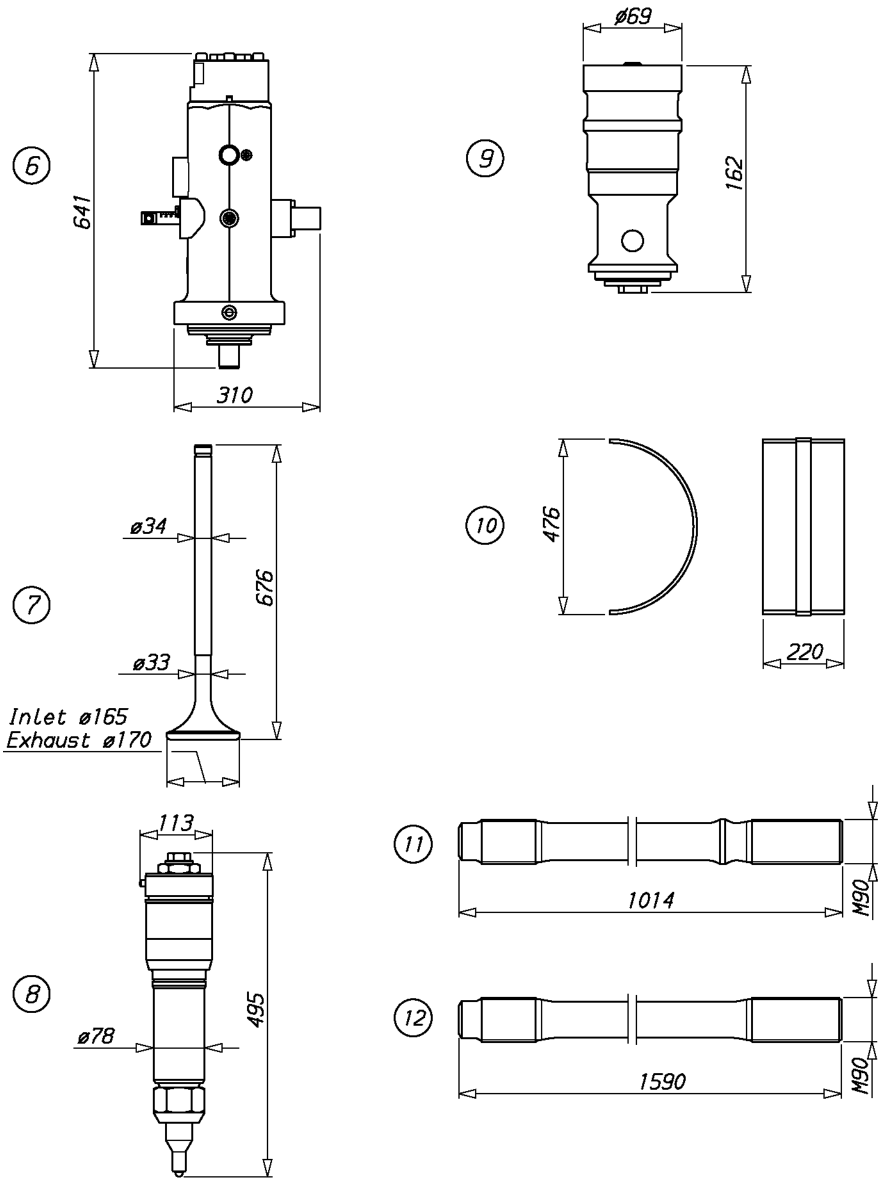
Engine type	C [mm]	D [mm]	E [mm]	Weight [kg]
6L46	1650	745	640	985
8L46	1650	955	640	1190
9L46	1650	955	640	1190
12V46	1330	790	615	610
16V46	1330	790	615	610
18V46	1430	930	685	830

Figure 20.7 Major spare parts (4V92L0929a)



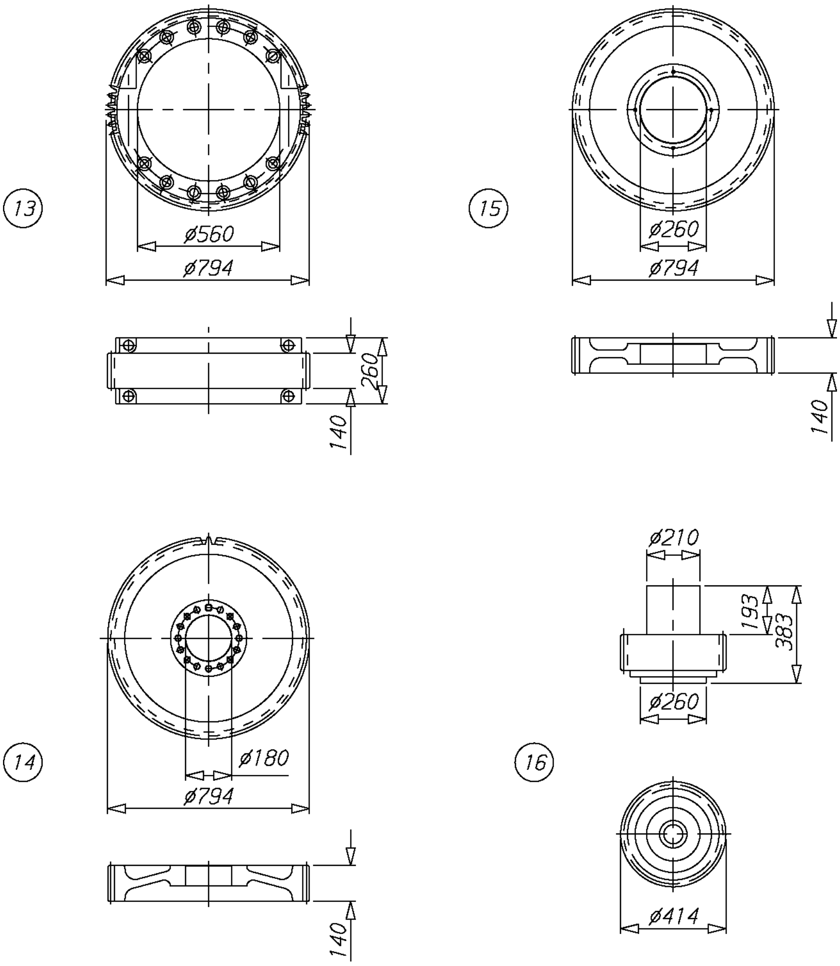
Item	Description	Weight [kg]
1.	Piston	207
2.	Gudgeon pin	103.5
3.	Connecting rod, upper part	278
	Connecting rod, lower part	360
4.	Cylinder head with valves	1250
5.	Cylinder liner	1120

Figure 20.8 Major spare parts (4V92L0930a)



Item	Description	Weight [kg]
6.	Injection pump	98
7.	Valve	10
8.	Injection valve	17
9.	Starting air valve	2.4
10.	Main bearing shell	12
11.	Main bearing screw	59
12.	Cylinder head screw	89

Figure 20.9 Major spare parts (4V92L0931a)



Item	Description	Weight [kg]
13.	Split gear wheel	360
14.	Camshaft gear wheel	685
15.	Bigger intermediate gear wheel	685
16.	Smaller intermediate gear wheel	550

21. Project guide attachments

Customers with a user account can download the latest version of this project guide and all attachments from www.wartsila.com. Drawings are available in PDF and DXF format, and in the near future also as 3D models. Consult your sales contact at Wärtsilä to obtain access rights and your own InfoBoard account.

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

22. ANNEX

22.1 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 22.1 Length conversion factors

Convert from	To	Multiply by
mm	in	0.0394
mm	ft	0.00328

Table 22.2 Mass conversion factors

Convert from	To	Multiply by
kg	lb	2.205
kg	oz	35.274

Table 22.3 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 22.4 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 22.5 Power conversion factors

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

Table 22.6 Moment of inertia and torque conversion factors

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

Table 22.7 Fuel consumption conversion factors

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

Table 22.8 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 22.9 Temperature conversion factors

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

Table 22.10 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

22.1.1 Prefix

Table 22.11 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}

22.2 Collection of drawing symbols used in drawings

Figure 22.1 List of symbols (DAAE000806b)

This page left intentionally blank

Wärtsilä Finland Oy
Ship Power
P.O Box 252
65101 Vaasa, Finland

Tel: +358 10 709 0000
Fax: +358 6 356 7188
www.wartsila.com

WÄRTSILÄ