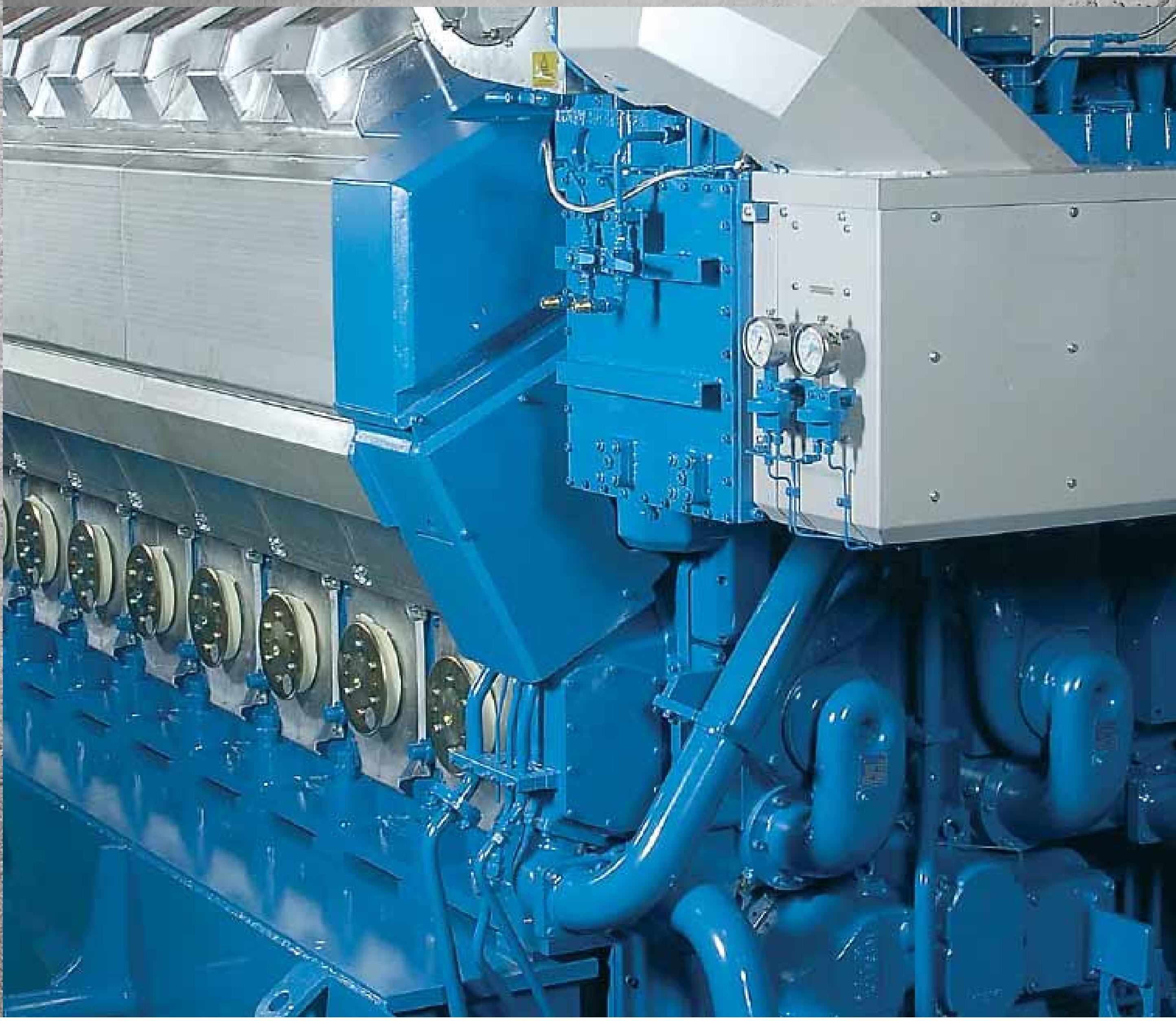
WÄRTSILÄ

WÄRTSILÄ Engines

WÄRTSILÄ 32 PRODUCT GUIDE



WÄRTSILÄ 32 – PRODUCT GUIDE

Introduction

This Product Guide provides data and system proposals for the early design phase of marine engine installations. For contracted projects specific instructions for planning the installation are always delivered. Any data and information herein is subject to revision without notice. This 1/2013 issue replaces all previous issues of the Wärtsilä 32 Project Guides.

Issue	Published	Updates
1/2013	14.08.2013	Product Guide Attachments updated (InfoBoard version). Other minor updates.
4/2012	06.07.2012	Product Guide Attachments updated (InfoBoard version). Chapters Compressed Air System and Exhaust Gas System updated.
3/2012	29.05.2012	Chapter Technical Data updated
2/2012	03.05.2012	Starting air consumption updated in chapter Technical Data
1/2012	17.04.2012	New engine outputs; 550 & 580 kW/cy added. Other minor updates throughout the project guide.

Wärtsilä, Ship Power Technology

Vaasa, August 2013

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1. Main Data and Outputs

The Wärtsilä 32 is a 4-stroke, non-reversible, turbocharged and intercooled diesel engine with direct fuel injection.

Cylinder bore .... 320 mm
Stroke .... 400 mm
Piston displacement .... 32.2 l/cylinder
Number of valves .... 2 inlet valves2 exhaust valves
Cylinder configuration .... 6, 7, 8 and 9 in-line12, 16 and 18 in V-form
V-angle .... 55°
Direction of rotation .... Clockwise, counterclockwise on request
Speed .... 720, 750 rpm
Mean piston speed .... 9.6, 10.0 m/s

1.1 Maximum continuous output

Table 1.1 Rating table for Wärtsilä 32

Cylinder configuration	Main engines	Generating sets			
	750 rpm	720 rpm		750 rpm	
	[kW]	Engine [kW]	Generator [kVA]	Engine [kW]	Generator [kVA]
W 6L32	3000 / 3480	2880 / 3300	3460 / 3960	3000 / 3480	3600 / 4180
W 7L32	3500	3360	4030	3500	4200
W 8L32	4000 / 4640	3840 / 4400	4610 / 5280	4000 / 4640	4800 / 5570
W 9L32	4500 / 5220	4320 / 4950	5180 / 5940	4500 / 5220	5400 / 6260
W 12V32	6000 / 6960	5760 / 6600	6910 / 7920	6000 / 6960	7200 / 8350
W 16V32	8000 / 9280	7680 / 8800	9220 / 10560	8000 / 9280	9600 / 11130
W 18V32	9000	8640	10370	9000	10800

The mean effective pressure Pe can be calculated as follows:

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

where:

Pe = mean effective pressure [bar]
P = output per cylinder [kW]
n = engine speed [r/min]
D = cylinder diameter [mm]
L = length of piston stroke [mm]
c = operating cycle (4)

1.2 Reference conditions

The output is available 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 Operation in inclined position

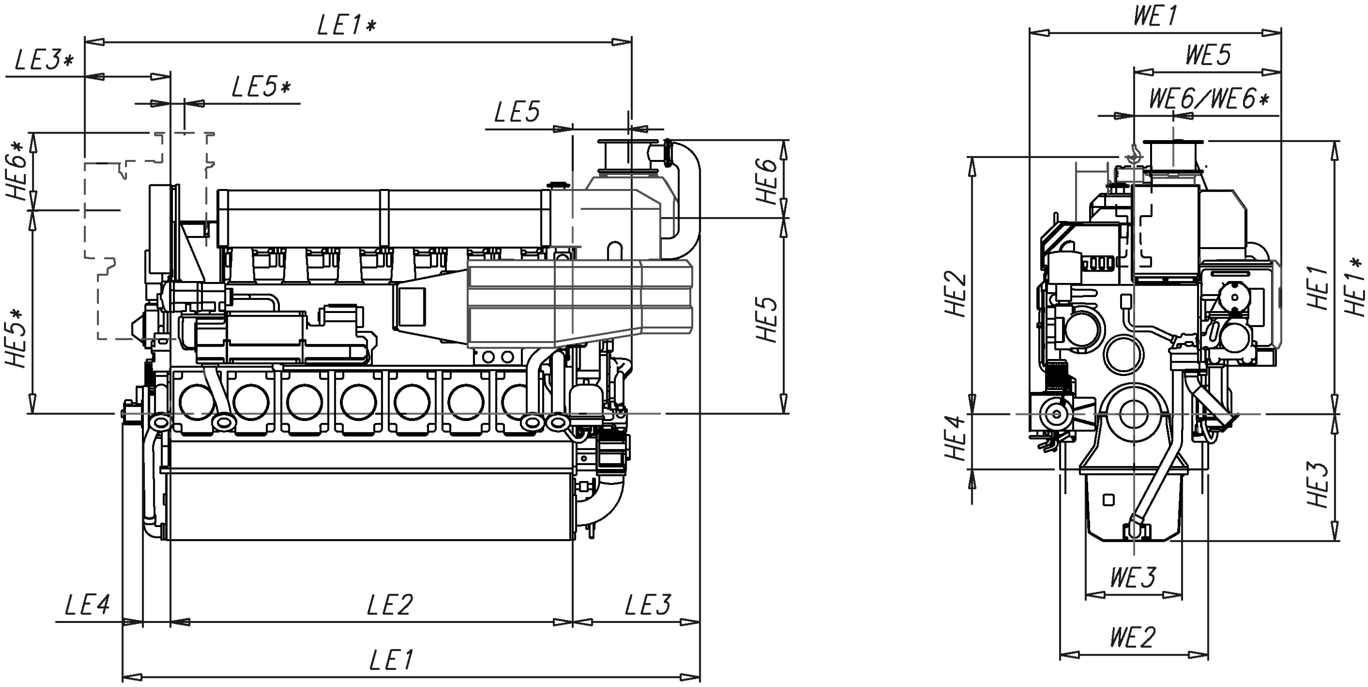
Max. inclination angles at which the engine will operate satisfactorily.

Transverse inclination, permanent (list) .... 15°
Transverse inclination, momentary (roll) .... 22.5°
Longitudinal inclination, permanent (trim) ...... 10°
Longitudinal inclination, momentary (pitch) .... 10°

1.4 Dimensions and weights

1.4.1 Main engines

Figure 1.1 In-line engines (DAAE030112)



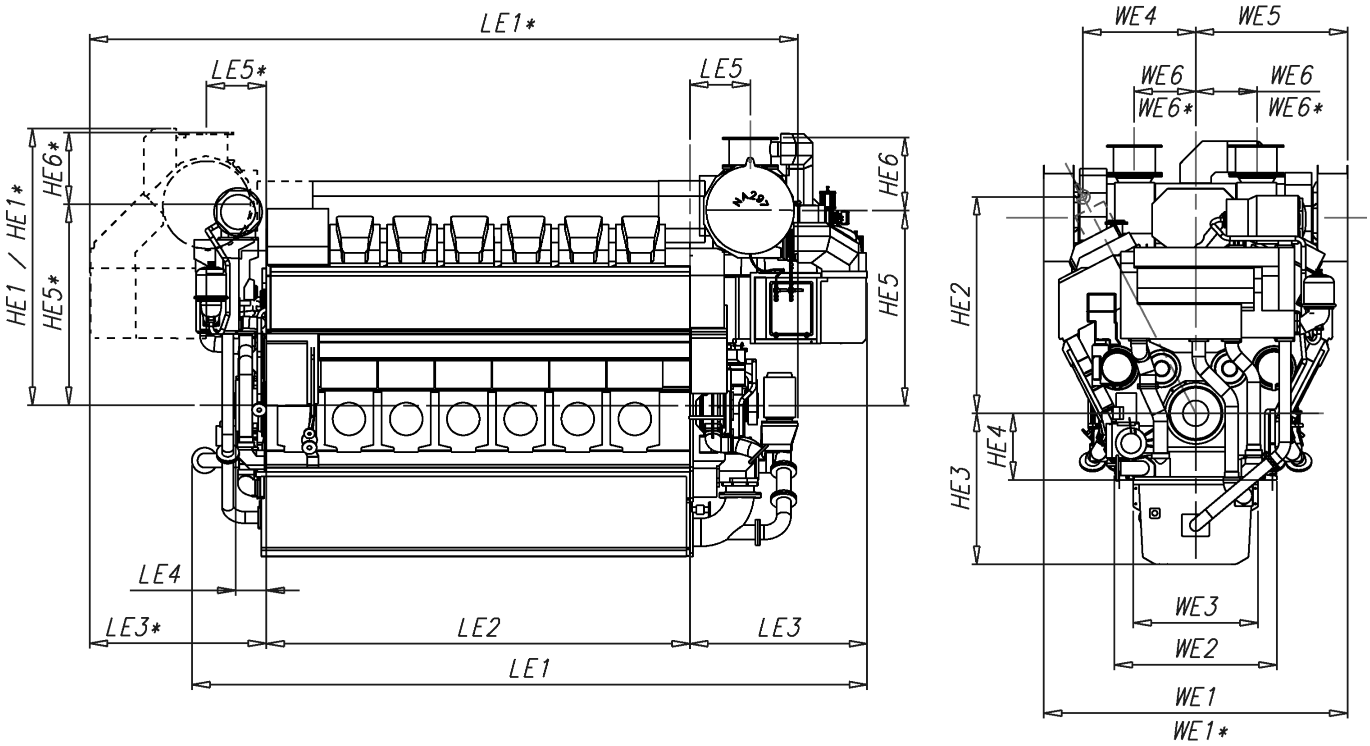
Engine	LE1*	LE1	HE1*	HE1	WE1	HE2	HE4	HE3	LE2	LE4	WE3	WE2
W 6L32	4980	5260	2560	2490	2305	2345	500	1155	3670	250	880	1350
W 7L32	5470	5750	2560	2490	2305	2345	500	1155	4160	250	880	1350
W 8L32	5960	6245	2360	2295	2305	2345	500	1155	4650	250	880	1350
W 9L32	6450	6730	2360	2295	2305	2345	500	1155	5140	250	880	1350

Engine	WE5	LE3*	LE3	HE5*	HE5	HE6*	HE6	WE6*	WE6	LE5*	LE5	Weight
W 6L32	1345	775	1150	1850	1780	710	710	660	360	130	505	33.5
W 7L32	1345	775	1150	1850	1780	710	710	660	360	130	505	39
W 8L32	1345	775	1150	1850	1780	420	420	660	360	130	505	43.5
W 9L32	1345	775	1150	1850	1780	420	420	660	360	130	505	47

* Turbocharger at flywheel end.

All dimensions in mm. Weight in metric tons with liquids (wet sump) but without flywheel.

Figure 1.2 V-engines (DAAE035123)



Engine	LE1*	LE1	HE1	HE1*	WE1	WE1*	HE2	HE4	HE3	LE2	LE4	WE3	WE2
W 12V32	6935	6615	2665	2715	3020	3020	2120	650	1475	4150	300	1220	1590
W 16V32	8060	7735	2430	2480	3020	3020	2120	650	1475	5270	300	1220	1590
W 18V32	8620	8295	2430	2480	3020	3020	2120	650	1475	5830	300	1220	1590

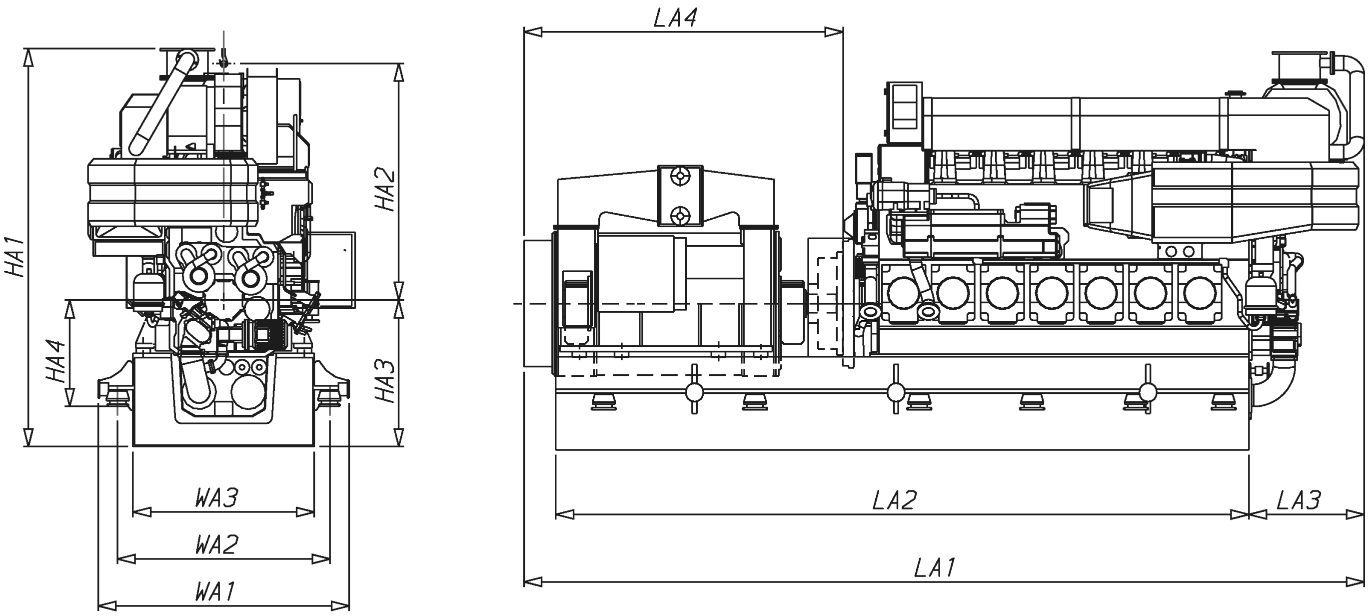
Engine	WE5	LE3*	LE3	WE4	HE5	HE5*	HE6	HE6*	WE6*	WE6	LE5*	LE5	Weight
W 12V32	1510	1735	1735	850	1915	1965	710	710	600	600	590	590	59
W 16V32	1510	1735	1735	850	1915	1965	420	420	600	600	590	590	74.5
W 18V32	1510	1735	1735	850	1915	1965	420	420	600	600	590	590	81.5

* Turbocharger at flywheel end.

All dimensions in mm. Weight in metric tons with liquids (wet sump) but without flywheel.

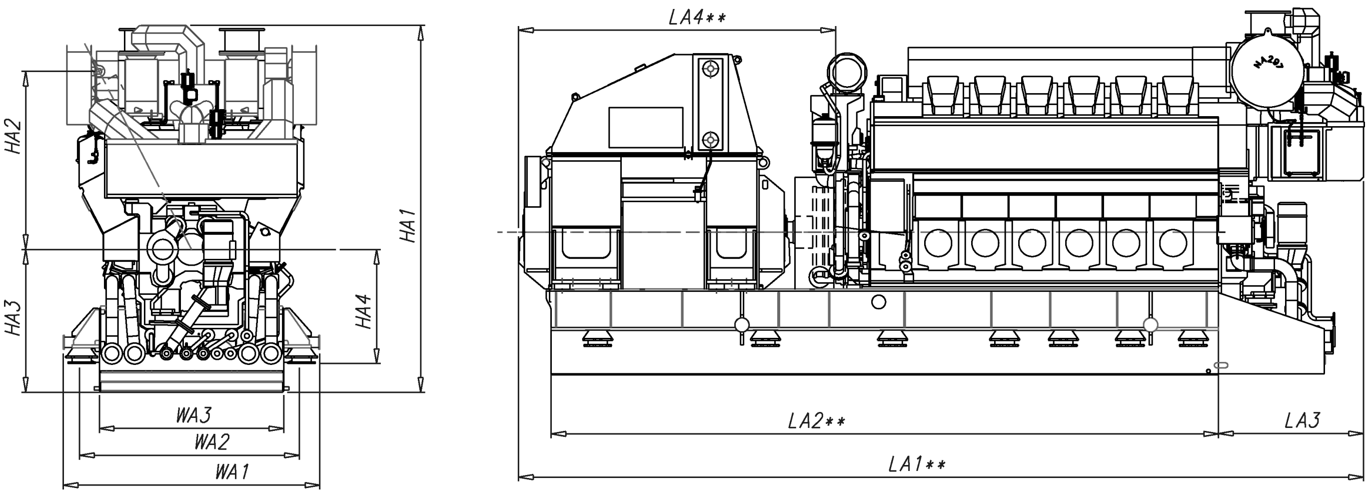
1.4.2 Generating sets

Figure 1.3 In-line engines (DAAE030093)



** Actual dimensions might vary based on power output and turbocharger maker.*

Figure 1.4 V-engines (DAAE039700)



** Actual dimensions might vary based on power output and turbocharger maker.*

Engine	LA1**	LA3	LA2**	LA4**	WA1	WA2	WA3	HA4	HA3	HA2	HA1	Weight**
W 6L32	8345	1150	6845	3160	2290	1910	1600	1046	1450	2345	3940	57
W 7L32	9215	1150	7515	3650	2690	2310	2000	1046	1650	2345	4140	69
W 8L32	9755	1150	7920	3710	2690	2310	2000	1046	1630	2345	3925	77
W 9L32	10475	1150	8850	3825	2890	2510	2200	1046	1630	2345	3925	84
W 12V32	10075	1735	7955	3775	3060	2620	2200	1375	1700	2120	4365	96
W 16V32	11175	1735	9020	3765	3060	2620	2200	1375	1850	2120	4280	121
W 18V32	11825	1735	9690	3875	3360	2920	2500	1375	1850	2120	4280	133

** Dependent on generator and flexible coupling.

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

2. Operating Ranges

2.1 Engine operating range

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

2.1.1 Controllable pitch propellers

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

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

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

Figure 2.1 Operating field for CP Propeller, 500 kW/cyl, 750 rpm

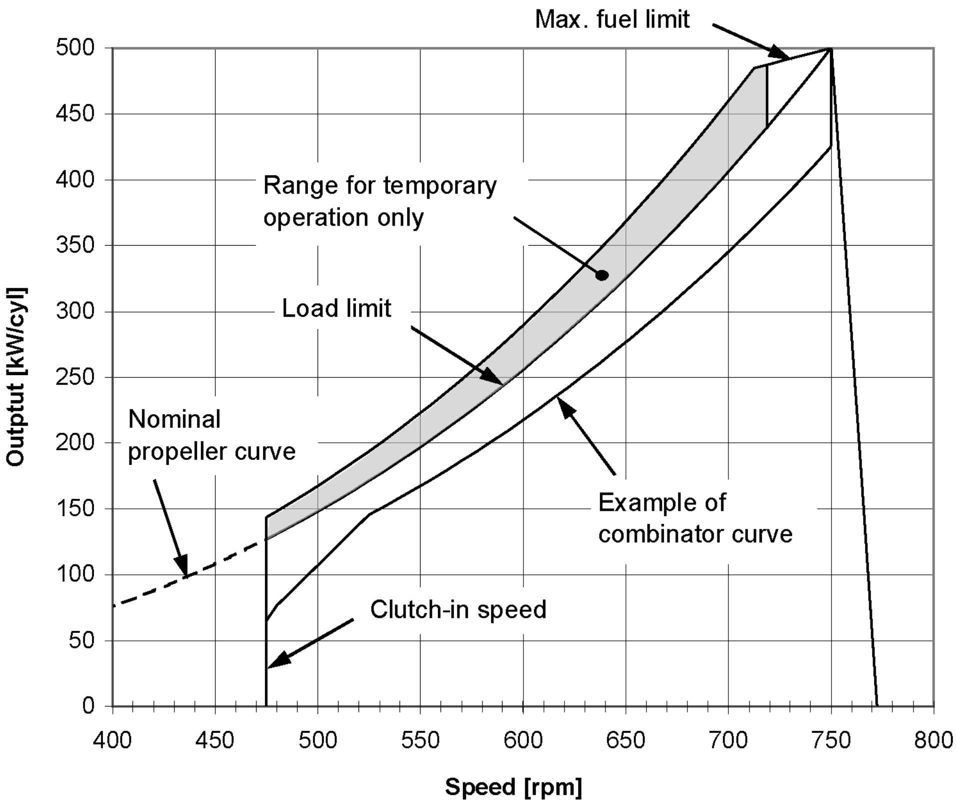
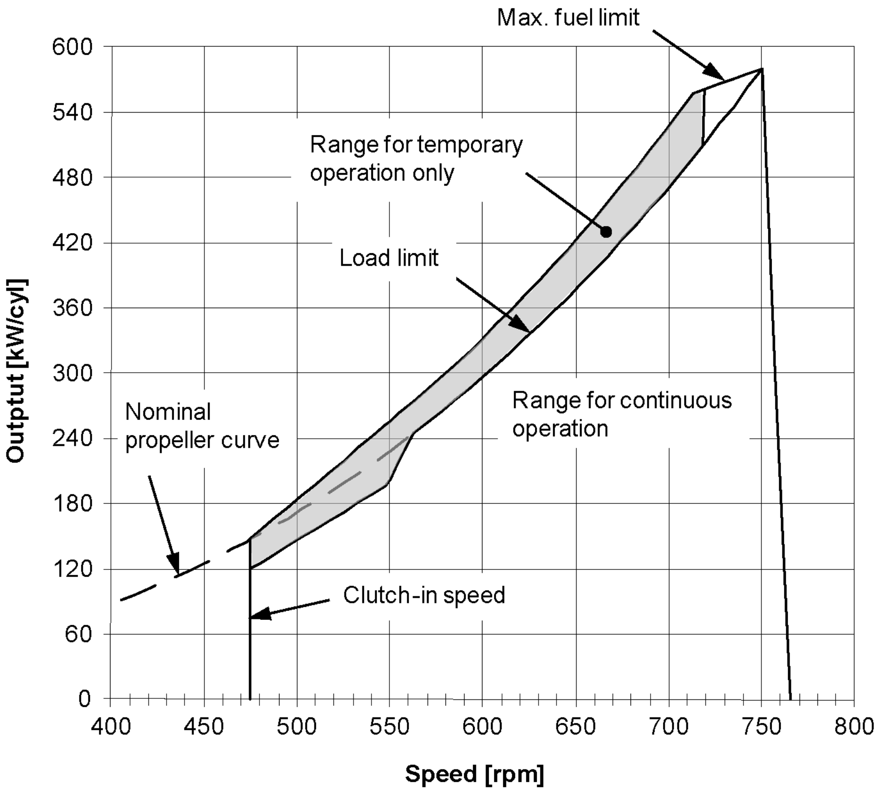


Figure 2.2 Operating field for CP Propeller, 580 kW/cyl, 750 rpm



2.1.2 Fixed pitch propellers

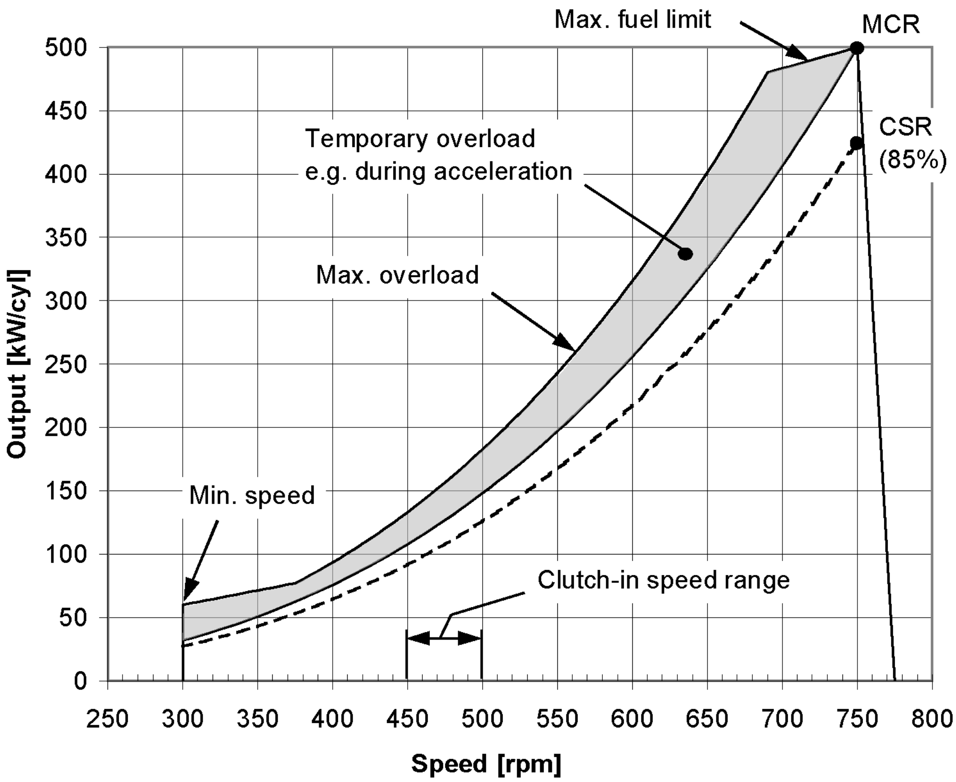
The thrust and power absorption of a given fixed pitch propeller is determined by the relation between ship speed and propeller revolution speed. The power absorption during acceleration, manoeuvring or towing is considerably higher than during free sailing for the same revolution speed. Increased ship 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 2.3 Operating field for FP Propeller, 500 kW/cyl), 750 rpm



2.1.3 Dredgers

Mechanically driven dredging pumps typically require a capability to operate with full torque down to 70% or 80% of nominal engine speed. This requirement results in significant de-rating of the engine.

2.2 Loading capacity

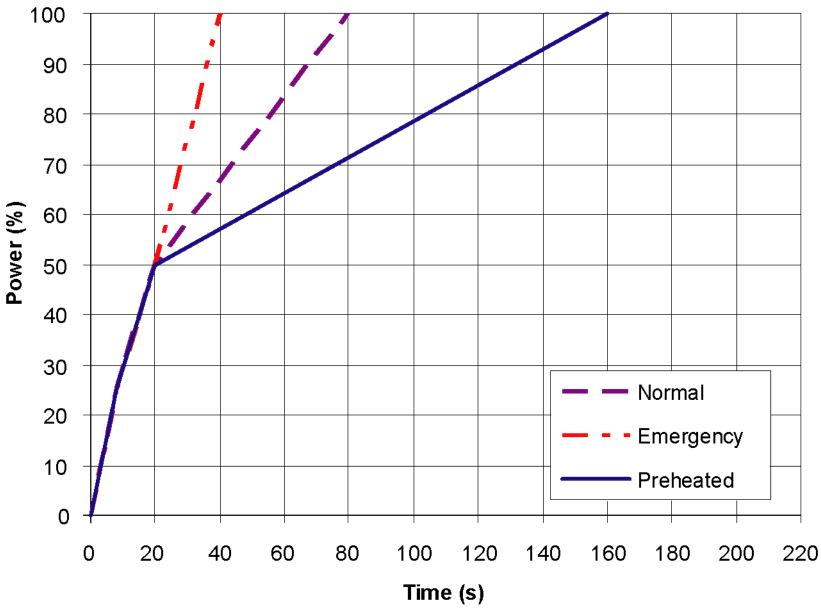
Controlled load increase is essential for highly supercharged diesel engines, because the turbocharger needs time to accelerate before it can deliver the required amount of air. A slower loading ramp than the maximum capability of the engine permits a more even temperature distribution in engine components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

The engine can be loaded immediately after start, provided that the engine is pre-heated to a HT-water temperature of 60…70ºC, and the lubricating oil temperature is min. 40 ºC.

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

2.2.1 Mechanical propulsion

Figure 2.4 Maximum recommended load increase rates for variable speed engines



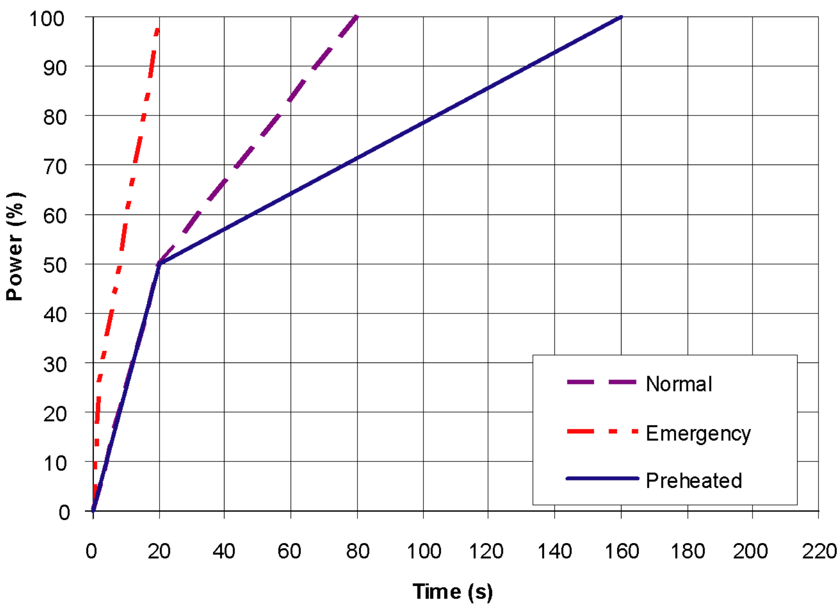
The propulsion control must include automatic limitation of the load increase rate. If the control system has only one load increase ramp, then the ramp for a preheated engine should be used. In tug applications the engines have usually reached normal operating temperature before the tug starts assisting.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

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

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

2.2.2 Diesel electric propulsion and auxiliary engines

Figure 2.5 Maximum recommended load increase rates for engines operating at nominal speed



In diesel electric installations loading ramps are implemented both in the propulsion control and in the power management system, or in the engine speed control in case isochronous load sharing is applied. If a ramp without knee-point is used, it should not achieve 100% load in shorter time than the ramp in the figure. When the load sharing is based on speed droop, the load increase rate of a recently connected generator is the sum of the load transfer performed by the power management system and the load increase performed by the propulsion control.

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

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

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

Maximum instant load steps (500 kW/cyl)

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

When electrical power is restored after a black-out, consumers are reconnected in groups, 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.

Maximum instant load steps (580 kW/cyl)

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. Maximum load steps are 0-30-65-100% MCR without air assist. Engines driving generators are prepared for air assist, see chapter *Compressed air system*. Sudden load steps equal to 33% MCR can be absorbed also at low load if air assist is used. The speed drop is less than 10% and the recovery time to within 1% of the steady state speed at the new load level is max. 5 seconds.

When electrical power is restored after a black-out, consumers are reconnected in groups, which may cause significant load steps. The engine must be allowed to recover for at least 10 seconds before applying the following load step, if the load is applied in maximum steps.

Start-up time

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

2.3 Operation at low load and idling

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

Absolute idling (declutched main engine, disconnected generator)

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

Operation below 20 % load on HFO or below 10 % load on MDF

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

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

- No restrictions.

2.4 Low air temperature

In cold conditions the following minimum inlet air temperatures apply:

- Starting + 5ºC
- Idling - 5ºC
- High load - 10ºC

If the engine is equipped with a two-stage charge air cooler, sustained operation between 0 and 40% load can require special provisions in cold conditions to prevent too low engine temperature.

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

3. Technical Data

3.1 Wärtsilä 6L32

Wärtsilä 6L32		AE/DE IMO Tier 2	AE/DE IMO Tier 2	ME IMO Tier 2	AE/DE IMO Tier 2	AE/DE IMO Tier 2	ME IMO Tier 2
Engine speed **Cylinder output**	**RPM** **kW/cyl**	**720** **480**	**750** **500**	**750** **500**	**720** **550**	**750** **580**	**750** **580**
Engine output	kW	2880	3000	3000	3300	3480	3480
Mean effective pressure	MPa	2.49	2.49	2.49	2.85	2.88	2.88
Combustion air system (Note 1)							
Flow at 100% load	kg/s	4.98	5.24	5.24	6.2	6.56	6.56
Temperature at turbocharger intake, max.	°C	45	45	45	45	45	45
Air temperature after air cooler (TE 601)	°C	55	55	55	55	55	55
Exhaust gas system (Note 2)							
Flow at 100% load	kg/s	5.13	5.4	5.4	6.38	6.75	6.75
Flow at 85% load	kg/s	4.88	5.14	4.96	5.53	5.99	5.92
Flow at 75% load	kg/s	4.4	4.65	4.43	4.86	5.23	5.16
Flow at 50% load	kg/s	3.1	3.26	3.71	3.41	3.69	4.05
Temperature after turbocharger, 100% load (TE 517)	°C	380	380	380	360	360	360
Temperature after turbocharger, 85% load (TE 517)	°C	328	325	336	340	335	335
Temperature after turbocharger, 75% load (TE 517)	°C	328	325	345	348	345	355
Temperature after turbocharger, 50% load (TE 517)	°C	352	345	315	380	380	340
Backpressure, max.	kPa	4.0	4.0	4.0	4.0	4.0	4.0
Calculated pipe diameter for 35m/s	mm	586	601	601	643	662	662
Heat balance (Note 3)							
Jacket water, HT-circuit	kW	488	510	510	452	480	480
Charge air, HT-circuit	kW	473	488	488	650	730	730
Charge air, LT-circuit	kW	375	398	398	420	440	440
Lubricating oil, LT-circuit	kW	361	390	390	421	432	432
Radiation	kW	110	110	110	110	110	110
Fuel system (Note 4)							
Pressure before injection pumps (PT 101)	kPa	700±50	700±50	700±50	700±50	700±50	700±50
Engine driven pump capacity (MDF only)	m³/h	4.3	4.5	4.5	4.3	4.5	4.5
Fuel flow to engine (without engine driven pump), approx.	m³/h	2.9	3.1	3.1	3.4	3.6	3.6
HFO viscosity before engine	cSt	16...24	16...24	16...24	16...24	16...24	16...24
HFO temperature before engine, max. (TE 101)	°C	140	140	140	140	140	140
MDF viscosity, min	cSt	2.0	2.0	2.0	2.0	2.0	2.0
MDF temperature before engine, max. (TE 101)	°C	45	45	45	45	45	45
Fuel consumption at 100% load	g/kWh	184	185	185	184	185	185
Fuel consumption at 85% load	g/kWh	181	182	181	181	182	181
Fuel consumption at 75% load	g/kWh	182	183	182	182	183	182
Fuel consumption at 50% load	g/kWh	193	193	191	193	193	191
Clean leak fuel quantity, MDF at 100% load	kg/h	11.1	11.6	11.6	12.7	13.5	13.5
Clean leak fuel quantity, HFO at 100% load	kg/h	2.2	2.3	2.3	2.5	2.7	2.7
Lubricating oil system							
Pressure before bearings, nom. (PT 201)	kPa	500	500	500	500	500	500
Suction ability main pump, including pipe loss, max.	kPa	30	30	30	30	30	30
Priming pressure, nom. (PT 201)	kPa	50	50	50	50	50	50
Suction ability priming pump, including pipe loss, max.	kPa	30	30	30	30	30	30
Temperature before bearings, nom. (TE 201)	°C	63	63	63	63	63	63
Temperature after engine, approx.	°C	78	78	78	78	78	78
Pump capacity (main), engine driven	m³/h	78	81	81	78	81	81
Pump capacity (main), stand-by	m³/h	67	70	70	67	70	70
Priming pump capacity, 50Hz/60Hz	m³/h	15.0 / 18.0	15.0 / 18.0	15.0 / 18.0	15.0 / 18.0	15.0 / 18.0	15.0 / 18.0
Oil volume, wet sump, nom.	m³	1.6	1.6	1.6	1.6	1.6	1.6
Oil volume in separate system oil tank, nom.	m³	3.9	4.1	4.1	4.5	4.7	4.7
Oil consumption (100% load), approx.	g/kWh	0.5	0.5	0.5	0.5	0.5	0.5
Crankcase ventilation flow rate at full load	l/min	990	990	990	1080	1080	1080
Crankcase ventilation backpressure, max.	kPa	0.4	0.4	0.4	0.4	0.4	0.4
Oil volume in turning device	liters	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	liters	1.9	1.9	1.9	1.9	1.9	1.9

Wärtsilä 6L32		AE/DE IMO Tier 2	AE/DE IMO Tier 2	ME IMO Tier 2	AE/DE IMO Tier 2	AE/DE IMO Tier 2	ME IMO Tier 2
Engine speed **Cylinder output**	**RPM** **kW/cyl**	**720** **480**	**750** **500**	**750** **500**	**720** **550**	**750** **580**	**750** **580**
Cooling water system							
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
Pressure at engine, after pump, max. (PT 401)	kPa	530	530	530	530	530	530
Temperature before cylinders, approx. (TE 401)	°C	85	85	85	77	77	77
HT-water out from engine, nom (TE402) (single stage CAC)	°C	96	96	96	96	96	96
HT-water out from engine, nom (TE432) (two stage CAC)	°C	96	96	96	96	96	96
Capacity of engine driven pump, nom.	m³/h	60	60	60	60	60	60
Pressure drop over engine, total (single stage CAC)	kPa	100	100	100	100	100	100
Pressure drop over engine, total (two stage CAC)	kPa	150	150	150	150	150	150
Pressure drop in external system, max.	kPa	60	60	60	60	60	60
Pressure from expansion tank	kPa	70...150	70...150	70...150	70...150	70...150	70...150
Water volume in engine	m³	0.41	0.41	0.41	0.41	0.41	0.41
Low temperature cooling water system							
Pressure at engine, after pump, nom. (PT 451)	kPa	250 + static	250 + static	250 + static	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 451)	kPa	530	530	530	530	530	530
Temperature before engine (TE 451)	°C	25 ... 38	25 ... 38	25 ... 38	25 ... 38	25 ... 38	25 ... 38
Capacity of engine driven pump, nom.	m³/h	60	60	60	60	60	60
Pressure drop over charge air cooler	kPa	35	35	35	35	35	35
Pressure drop over oil cooler	kPa	30	30	30	30	30	30
Pressure drop in external system, max.	kPa	60	60	60	60	60	60
Pressure from expansion tank	kPa	70 ... 150	70 ... 150	70 ... 150	70 ... 150	70 ... 150	70 ... 150
Starting air system (Note 5)							
Pressure, nom.	kPa	3000	3000	3000	3000	3000	3000
Pressure at engine during start, min. (20°C)	kPa	1500	1500	1500	1500	1500	1500
Pressure, max.	kPa	3000	3000	3000	3000	3000	3000
Low pressure limit in air vessels	kPa	1800	1800	1800	1800	1800	1800
Air consumption per start	Nm³	2.1	2.1	-	2.1	2.1	-
Air consumption per start without propeller shaft engaged	Nm³	-	-	2.1	-	-	2.1
Air consumption with automatic start and slowturning	Nm³	-	-	-	3.0	3.0	3.0
Air consumption per start with propeller shaft engaged	Nm³	-	-	3.4	-	-	3.4
Air consumption with automatic start and high inertia slowturning	Nm³	-	-	-	4.6	4.6	4.6

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 10°C.

Note 3 At ISO 3046-1 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, with engine driven pumps (two cooling water + one lubricating oil pumps). Tolerance 5%. Load according to propeller law for mechanical propulsion engines (ME).

Note 5 Automatic (remote or local) starting air consumption (average) per start, at 20°C for a specific long start impulse (DE/AUX: 2...3 sec, CPP/FPP: 4...6 sec) which is the shortest time required for a safe start.

ME = Engine driving propeller, variable speed

AE = Auxiliary engine driving generator

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

WÄRTSILÄ Engines

3.2 Wärtsilä 7L32

Wärtsilä 7L32		**AE/DE IMO Tier 2**	**AE/DE IMO Tier 2**	**ME IMO Tier 2**
Engine speed **Cylinder output**	**RPM** **kW/cyl**	**720** **480**	**750** **500**	**750** **500**
Engine output	kW	3360	3500	3500
Mean effective pressure	MPa	2.49	2.49	2.49
Combustion air system (Note 1)				
Flow at 100% load	kg/s	5.81	6.11	6.11
Temperature at turbocharger intake, max.	°C	45	45	45
Air temperature after air cooler (TE 601)	°C	55	55	55
Exhaust gas system (Note 2)				
Flow at 100% load	kg/s	5.99	6.3	6.3
Flow at 85% load	kg/s	5.69	5.99	5.78
Flow at 75% load	kg/s	5.13	5.43	5.16
Flow at 50% load	kg/s	3.62	3.81	4.33
Temperature after turbocharger, 100% load (TE 517)	°C	380	380	380
Temperature after turbocharger, 85% load (TE 517)	°C	328	325	336
Temperature after turbocharger, 75% load (TE 517)	°C	328	325	345
Temperature after turbocharger, 50% load (TE 517)	°C	352	345	315
Backpressure, max.	kPa	4.0	4.0	4.0
Calculated pipe diameter for 35m/s	mm	633	649	649
Heat balance (Note 3)				
Jacket water, HT-circuit	kW	569	595	595
Charge air, HT-circuit	kW	551	569	569
Charge air, LT-circuit	kW	438	464	464
Lubricating oil, LT-circuit	kW	421	455	455
Radiation	kW	120	120	120
Fuel system (Note 4)				
Pressure before injection pumps (PT 101)	kPa	700±50	700±50	700±50
Engine driven pump capacity (MDF only)	m³/h	4.3	4.5	4.5
Fuel flow to engine (without engine driven pump), approx.	m³/h	3.4	3.6	3.6
HFO viscosity before engine	cSt	16...24	16...24	16...24
HFO temperature before engine, max. (TE 101)	°C	140	140	140
MDF viscosity, min	cSt	2.0	2.0	2.0
MDF temperature before engine, max. (TE 101)	°C	45	45	45
Fuel consumption at 100% load	g/kWh	184	185	185
Fuel consumption at 85% load	g/kWh	181	182	181
Fuel consumption at 75% load	g/kWh	182	183	182
Fuel consumption at 50% load	g/kWh	193	193	191
Clean leak fuel quantity, MDF at 100% load	kg/h	13.0	13.6	13.6
Clean leak fuel quantity, HFO at 100% load	kg/h	2.6	2.7	2.7
Lubricating oil system				
Pressure before bearings, nom. (PT 201)	kPa	500	500	500
Suction ability main pump, including pipe loss, max.	kPa	30	30	30
Priming pressure, nom. (PT 201)	kPa	50	50	50
Suction ability priming pump, including pipe loss, max.	kPa	30	30	30
Temperature before bearings, nom. (TE 201)	°C	63	63	63
Temperature after engine, approx.	°C	78	78	78
Pump capacity (main), engine driven	m³/h	101	105	105
Pump capacity (main), stand-by	m³/h	78	82	82
Priming pump capacity, 50Hz/60Hz	m³/h	21.6 / 25.9	21.6 / 25.9	21.6 / 25.9
Oil volume, wet sump, nom.	m³	1.8	1.8	1.8
Oil volume in separate system oil tank, nom.	m³	4.5	4.7	4.7
Oil consumption (100% load), approx.	g/kWh	0.5	0.5	0.5
Crankcase ventilation flow rate at full load	l/min	1155	1155	1155
Crankcase ventilation backpressure, max.	kPa	0.4	0.4	0.4
Oil volume in turning device	liters	8.5...9.5	8.5...9.5	8.5...9.5
Oil volume in speed governor	liters	1.9	1.9	1.9
Cooling water system				
High temperature cooling water system				
Pressure at engine, after pump, nom. (PT 401)	kPa	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 401)	kPa	530	530	530

Wärtsilä 7L32		AE/DE IMO Tier 2	AE/DE IMO Tier 2	ME IMO Tier 2
Engine speed **Cylinder output**	**RPM** **kW/cyl**	**720** **480**	**750** **500**	**750** **500**
Temperature before cylinders, approx. (TE 401)	°C	85	85	85
HT-water out from engine, nom (TE402) (single stage CAC)	°C	96	96	96
HT-water out from engine, nom (TE432) (two stage CAC)	°C	96	96	96
Capacity of engine driven pump, nom.	m³/h	70	70	70
Pressure drop over engine, total (single stage CAC)	kPa	100	100	100
Pressure drop over engine, total (two stage CAC)	kPa	150	150	150
Pressure drop in external system, max.	kPa	60	60	60
Pressure from expansion tank	kPa	70...150	70...150	70...150
Water volume in engine	m³	0.46	0.46	0.46
Low temperature cooling water system				
Pressure at engine, after pump, nom. (PT 451)	kPa	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 451)	kPa	450	450	450
Temperature before engine (TE 451)	°C	25 ... 38	25 ... 38	25 ... 38
Capacity of engine driven pump, nom.	m³/h	70	70	70
Pressure drop over charge air cooler	kPa	35	35	35
Pressure drop over oil cooler	kPa	30	30	30
Pressure drop in external system, max.	kPa	60	60	60
Pressure from expansion tank	kPa	70 ... 150	70 ... 150	70 ... 150
Starting air system (Note 5)				
Pressure, nom.	kPa	3000	3000	3000
Pressure at engine during start, min. (20°C)	kPa	1500	1500	1500
Pressure, max.	kPa	3000	3000	3000
Low pressure limit in air vessels	kPa	1800	1800	1800
Air consumption per start	Nm³	2.4	2.4	-
Air consumption per start without propeller shaft engaged	Nm³	-	-	2.4
Air consumption per start with propeller shaft engaged	Nm³	-	-	3.8

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 10°C.

Note 3 At ISO 3046-1 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, with engine driven pumps (two cooling water + one lubricating oil pumps). Tolerance 5%. Load according to propeller law for mechanical propulsion engines (ME).

Note 5 Automatic (remote or local) starting air consumption (average) per start, at 20°C for a specific long start impulse (DE/AUX: 2...3 sec, CPP/FPP: 4...6 sec) which is the shortest time required for a safe start.

ME = Engine driving propeller, variable speed

AE = Auxiliary engine driving generator

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

3.3 Wärtsilä 8L32

Wärtsilä 8L32		AE/DE IMO Tier 2	AE/DE IMO Tier 2	ME IMO Tier 2	AE/DE IMO Tier 2	AE/DE IMO Tier 2	ME IMO Tier 2
Engine speed **Cylinder output**	**RPM** **kW/cyl**	**720** **480**	**750** **500**	**750** **500**	**720** **550**	**750** **580**	**750** **580**
Engine output	kW	3840	4000	4000	4400	4640	4640
Mean effective pressure	MPa	2.49	2.49	2.49	2.85	2.88	2.88
Combustion air system (Note 1)							
Flow at 100% load	kg/s	6.63	6.98	6.98	8.26	8.76	8.76
Temperature at turbocharger intake, max.	°C	45	45	45	45	45	45
Air temperature after air cooler (TE 601)	°C	55	55	55	55	55	55
Exhaust gas system (Note 2)							
Flow at 100% load	kg/s	6.84	7.2	7.2	8.5	9.01	9.01
Flow at 85% load	kg/s	6.51	6.85	6.61	7.38	7.98	7.98
Flow at 75% load	kg/s	5.86	6.2	5.9	6.48	6.98	6.98
Flow at 50% load	kg/s	4.14	4.35	4.95	4.54	4.92	4.92
Temperature after turbocharger, 100% load (TE 517)	°C	380	380	380	360	360	360
Temperature after turbocharger, 85% load (TE 517)	°C	328	325	336	340	335	335
Temperature after turbocharger, 75% load (TE 517)	°C	328	325	345	348	345	345
Temperature after turbocharger, 50% load (TE 517)	°C	352	345	315	380	380	380
Backpressure, max.	kPa	4.0	4.0	4.0	4.0	4.0	4.0
Calculated pipe diameter for 35m/s	mm	677	694	694	743	765	765
Heat balance (Note 3)							
Jacket water, HT-circuit	kW	650	680	680	603	640	640
Charge air, HT-circuit	kW	630	650	650	867	973	973
Charge air, LT-circuit	kW	500	530	530	560	587	587
Lubricating oil, LT-circuit	kW	481	520	520	562	576	576
Radiation	kW	140	140	140	147	147	147
Fuel system (Note 4)							
Pressure before injection pumps (PT 101)	kPa	700±50	700±50	700±50	700±50	700±50	700±50
Engine driven pump capacity (MDF only)	m³/h	5.4	5.6	5.6	5.4	5.6	5.6
Fuel flow to engine (without engine driven pump), approx.	m³/h	3.9	4.1	4.1	4.5	4.7	4.7
HFO viscosity before engine	cSt	16...24	16...24	16...24	16...24	16...24	16...24
HFO temperature before engine, max. (TE 101)	°C	140	140	140	140	140	140
MDF viscosity, min	cSt	2.0	2.0	2.0	2.0	2.0	2.0
MDF temperature before engine, max. (TE 101)	°C	45	45	45	45	45	45
Fuel consumption at 100% load	g/kWh	184	185	185	184	185	185
Fuel consumption at 85% load	g/kWh	181	182	181	181	182	182
Fuel consumption at 75% load	g/kWh	182	183	182	182	183	183
Fuel consumption at 50% load	g/kWh	193	193	191	193	193	193
Clean leak fuel quantity, MDF at 100% load	kg/h	14.8	15.5	15.5	17.0	18.0	18.0
Clean leak fuel quantity, HFO at 100% load	kg/h	3.0	3.1	3.1	3.4	3.6	3.6
Lubricating oil system							
Pressure before bearings, nom. (PT 201)	kPa	500	500	500	500	500	500
Suction ability main pump, including pipe loss, max.	kPa	30	30	30	30	30	30
Priming pressure, nom. (PT 201)	kPa	50	50	50	50	50	50
Suction ability priming pump, including pipe loss, max.	kPa	30	30	30	30	30	30
Temperature before bearings, nom. (TE 201)	°C	63	63	63	63	63	63
Temperature after engine, approx.	°C	79	79	79	79	79	79
Pump capacity (main), engine driven	m³/h	101	105	105	101	105	105
Pump capacity (main), stand-by	m³/h	91	95	95	91	95	95
Priming pump capacity, 50Hz/60Hz	m³/h	21.6 / 25.9	21.6 / 25.9	21.6 / 25.9	21.6 / 25.9	21.6 / 25.9	21.6 / 25.9
Oil volume, wet sump, nom.	m³	2.0	2.0	2.0	2.0	2.0	2.0
Oil volume in separate system oil tank, nom.	m³	5.2	5.4	5.4	5.9	6.3	6.3
Oil consumption (100% load), approx.	g/kWh	0.5	0.5	0.5	0.5	0.5	0.5
Crankcase ventilation flow rate at full load	l/min	1320	1320	1320	1440	1440	1440
Crankcase ventilation backpressure, max.	kPa	0.4	0.4	0.4	0.4	0.4	0.4
Oil volume in turning device	liters	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	liters	1.9	1.9	1.9	1.9	1.9	1.9
Cooling water system							
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
Pressure at engine, after pump, max. (PT 401)	kPa	530	530	530	530	530	530

Wärtsilä 8L32		AE/DE IMO Tier 2	AE/DE IMO Tier 2	ME IMO Tier 2	AE/DE IMO Tier 2	AE/DE IMO Tier 2	ME IMO Tier 2
Engine speed **Cylinder output**	**RPM** **kW/cyl**	**720** **480**	**750** **500**	**750** **500**	**720** **550**	**750** **580**	**750** **580**
Temperature before cylinders, approx. (TE 401)	°C	85	85	85	77	77	77
HT-water out from engine, nom (TE402) (single stage CAC)	°C	96	96	96	96	96	96
HT-water out from engine, nom (TE432) (two stage CAC)	°C	96	96	96	96	96	96
Capacity of engine driven pump, nom.	m³/h	75	75	80	75	75	75
Pressure drop over engine, total (single stage CAC)	kPa	100	100	100	100	100	100
Pressure drop over engine, total (two stage CAC)	kPa	150	150	150	150	150	150
Pressure drop in external system, max.	kPa	60	60	60	60	60	60
Pressure from expansion tank	kPa	70...150	70...150	70...150	70...150	70...150	70...150
Water volume in engine	m³	0.51	0.51	0.51	0.51	0.51	0.51
Low temperature cooling water system							
Pressure at engine, after pump, nom. (PT 451)	kPa	250 + static	250 + static	250 + static	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 451)	kPa	530	530	530	530	530	530
Temperature before engine (TE 451)	°C	25 ... 38	25 ... 38	25 ... 38	25 ... 38	25 ... 38	25 ... 38
Capacity of engine driven pump, nom.	m³/h	75	75	80	75	75	75
Pressure drop over charge air cooler	kPa	35	35	35	35	35	35
Pressure drop over oil cooler	kPa	30	30	30	30	30	30
Pressure drop in external system, max.	kPa	60	60	60	60	60	60
Pressure from expansion tank	kPa	70 ... 150	70 ... 150	70 ... 150	70 ... 150	70 ... 150	70 ... 150
Starting air system (Note 5)							
Pressure, nom.	kPa	3000	3000	3000	3000	3000	3000
Pressure at engine during start, min. (20°C)	kPa	1500	1500	1500	1500	1500	1500
Pressure, max.	kPa	3000	3000	3000	3000	3000	3000
Low pressure limit in air vessels	kPa	1800	1800	1800	1800	1800	1800
Air consumption per start	Nm³	2.7	2.7	-	2.7	2.7	-
Air consumption per start without propeller shaft engaged	Nm³	-	-	2.7	-	-	2.7
Air consumption with automatic start and slowturning	Nm³	-	-	-	4.5	4.5	4.5
Air consumption per start with propeller shaft engaged	Nm³	-	-	4.3	-	-	4.3
Air consumption with automatic start and high inertia slowturning	Nm³	-	-	-	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 10°C.

Note 3 At ISO 3046-1 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, with engine driven pumps (two cooling water + one lubricating oil pumps). Tolerance 5%. Load according to propeller law for mechanical propulsion engines (ME).

Note 5 Automatic (remote or local) starting air consumption (average) per start, at 20°C for a specific long start impulse (DE/AUX: 2...3 sec, CPP/FPP: 4...6 sec) which is the shortest time required for a safe start.

ME = Engine driving propeller, variable speed

AE = Auxiliary engine driving generator

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

3.4 Wärtsilä 9L32

Wärtsilä 9L32		AE/DE IMO Tier 2	AE/DE IMO Tier 2	ME IMO Tier 2	AE/DE IMO Tier 2	AE/DE IMO Tier 2	ME IMO Tier 2
Engine speed **Cylinder output**	**RPM** **kW/cyl**	**720** **480**	**750** **500**	**750** **500**	**720** **550**	**750** **580**	**750** **580**
Engine output	kW	4320	4500	4500	4950	5220	5220
Mean effective pressure	MPa	2.49	2.49	2.49	2.85	2.88	2.88
Combustion air system (Note 1)							
Flow at 100% load	kg/s	7.47	7.86	7.86	9.29	9.85	9.85
Temperature at turbocharger intake, max.	°C	45	45	45	45	45	45
Air temperature after air cooler (TE 601)	°C	55	55	55	55	55	55
Exhaust gas system (Note 2)							
Flow at 100% load	kg/s	7.7	8.1	8.1	9.56	10.13	10.13
Flow at 85% load	kg/s	7.32	7.71	7.44	8.3	8.89	8.88
Flow at 75% load	kg/s	6.59	6.98	6.64	7.29	7.85	7.75
Flow at 50% load	kg/s	4.65	4.89	5.57	5.11	5.53	6.08
Temperature after turbocharger, 100% load (TE 517)	°C	380	380	380	360	360	360
Temperature after turbocharger, 85% load (TE 517)	°C	328	325	336	340	335	335
Temperature after turbocharger, 75% load (TE 517)	°C	328	325	345	348	345	355
Temperature after turbocharger, 50% load (TE 517)	°C	352	345	315	380	380	340
Backpressure, max.	kPa	4.0	4.0	4.0	4.0	4.0	4.0
Calculated pipe diameter for 35m/s	mm	718	736	736	788	811	811
Heat balance (Note 3)							
Jacket water, HT-circuit	kW	731	765	765	678	720	720
Charge air, HT-circuit	kW	709	731	731	975	1095	1095
Charge air, LT-circuit	kW	563	596	596	630	660	660
Lubricating oil, LT-circuit	kW	541	585	585	632	648	648
Radiation	kW	160	160	160	165	165	165
Fuel system (Note 4)							
Pressure before injection pumps (PT 101)	kPa	700±50	700±50	700±50	700±50	700±50	700±50
Engine driven pump capacity (MDF only)	m³/h	5.4	5.6	5.6	5.4	5.6	5.6
Fuel flow to engine (without engine driven pump), approx.	m³/h	4.4	4.6	4.6	5.0	5.3	5.3
HFO viscosity before engine	cSt	16...24	16...24	16...24	16...24	16...24	16...24
HFO temperature before engine, max. (TE 101)	°C	140	140	140	140	140	140
MDF viscosity, min	cSt	2.0	2.0	2.0	2.0	2.0	2.0
MDF temperature before engine, max. (TE 101)	°C	45	45	45	45	45	45
Fuel consumption at 100% load	g/kWh	184	185	185	184	185	185
Fuel consumption at 85% load	g/kWh	181	182	181	181	182	181
Fuel consumption at 75% load	g/kWh	182	183	182	182	183	182
Fuel consumption at 50% load	g/kWh	193	193	191	193	193	191
Clean leak fuel quantity, MDF at 100% load	kg/h	16.7	17.5	17.5	19.1	20.3	20.3
Clean leak fuel quantity, HFO at 100% load	kg/h	3.3	3.5	3.5	3.8	4.1	4.1
Lubricating oil system							
Pressure before bearings, nom. (PT 201)	kPa	500	500	500	500	500	500
Suction ability main pump, including pipe loss, max.	kPa	30	30	30	30	30	30
Priming pressure, nom. (PT 201)	kPa	50	50	50	50	50	50
Suction ability priming pump, including pipe loss, max.	kPa	30	30	30	30	30	30
Temperature before bearings, nom. (TE 201)	°C	63	63	63	63	63	63
Temperature after engine, approx.	°C	79	79	79	79	79	79
Pump capacity (main), engine driven	m³/h	108	112	112	108	112	112
Pump capacity (main), stand-by	m³/h	96	100	100	96	100	100
Priming pump capacity, 50Hz/60Hz	m³/h	21.6 / 25.9	21.6 / 25.9	21.6 / 25.9	21.6 / 25.9	21.6 / 25.9	21.6 / 25.9
Oil volume, wet sump, nom.	m³	2.3	2.3	2.3	2.3	2.3	2.3
Oil volume in separate system oil tank, nom.	m³	5.8	6.1	6.1	6.7	7.0	7.0
Oil consumption (100% load), approx.	g/kWh	0.5	0.5	0.5	0.5	0.5	0.5
Crankcase ventilation flow rate at full load	l/min	1485	1485	1485	1620	1620	1620
Crankcase ventilation backpressure, max.	kPa	0.4	0.4	0.4	0.4	0.4	0.4
Oil volume in turning device	liters	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	liters	1.9	1.9	1.9	1.9	1.9	1.9
Cooling water system							
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
Pressure at engine, after pump, max. (PT 401)	kPa	530	530	530	530	530	530

Wärtsilä 9L32		AE/DE IMO Tier 2	AE/DE IMO Tier 2	ME IMO Tier 2	AE/DE IMO Tier 2	AE/DE IMO Tier 2	ME IMO Tier 2
Engine speed **Cylinder output**	**RPM** **kW/cyl**	**720** **480**	**750** **500**	**750** **500**	**720** **550**	**750** **580**	**750** **580**
Temperature before cylinders, approx. (TE 401)	°C	85	85	85	77	77	77
HT-water out from engine, nom (TE402) (single stage CAC)	°C	96	96	96	96	96	96
HT-water out from engine, nom (TE432) (two stage CAC)	°C	96	96	96	96	96	96
Capacity of engine driven pump, nom.	m³/h	85	85	85	85	85	85
Pressure drop over engine, total (single stage CAC)	kPa	100	100	100	100	100	100
Pressure drop over engine, total (two stage CAC)	kPa	150	150	150	150	150	150
Pressure drop in external system, max.	kPa	60	60	60	60	60	60
Pressure from expansion tank	kPa	70...150	70...150	70...150	70...150	70...150	70...150
Water volume in engine	m³	0.56	0.56	0.56	0.56	0.56	0.56
Low temperature cooling water system							
Pressure at engine, after pump, nom. (PT 451)	kPa	250 + static	250 + static	250 + static	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 451)	kPa	530	530	530	530	530	530
Temperature before engine (TE 451)	°C	25 ... 38	25 ... 38	25 ... 38	25 ... 38	25 ... 38	25 ... 38
Capacity of engine driven pump, nom.	m³/h	85	85	85	85	85	85
Pressure drop over charge air cooler	kPa	35	35	35	35	35	35
Pressure drop over oil cooler	kPa	30	30	30	30	30	30
Pressure drop in external system, max.	kPa	60	60	60	60	60	60
Pressure from expansion tank	kPa	70 ... 150	70 ... 150	70 ... 150	70 ... 150	70 ... 150	70 ... 150
Starting air system (Note 5)							
Pressure, nom.	kPa	3000	3000	3000	3000	3000	3000
Pressure at engine during start, min. (20°C)	kPa	1500	1500	1500	1500	1500	1500
Pressure, max.	kPa	3000	3000	3000	3000	3000	3000
Low pressure limit in air vessels	kPa	1800	1800	1800	1800	1800	1800
Air consumption per start	Nm³	2.7	2.7	-	2.7	2.7	-
Air consumption per start without propeller shaft engaged	Nm³	-	-	2.7	-	-	2.7
Air consumption with automatic start and slowturning	Nm³	-	-	-	4.5	4.5	4.5
Air consumption per start with propeller shaft engaged	Nm³	-	-	4.3	-	-	4.3
Air consumption with automatic start and high inertia slowturning	Nm³	-	-	-	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 10°C.

Note 3 At ISO 3046-1 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, with engine driven pumps (two cooling water + one lubricating oil pumps). Tolerance 5%. Load according to propeller law for mechanical propulsion engines (ME).

Note 5 Automatic (remote or local) starting air consumption (average) per start, at 20°C for a specific long start impulse (DE/AUX: 2...3 sec, CPP/FPP: 4...6 sec) which is the shortest time required for a safe start.

ME = Engine driving propeller, variable speed

AE = Auxiliary engine driving generator

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

3.5 Wärtsilä 12V32

Wärtsilä 12V32		AE/DE IMO Tier 2	AE/DE IMO Tier 2	ME IMO Tier 2	AE/DE IMO Tier 2	AE/DE IMO Tier 2	ME IMO Tier 2
Engine speed **Cylinder output**	**RPM** **kW/cyl**	**720** **480**	**750** **500**	**750** **500**	**720** **550**	**750** **580**	**750** **580**
Engine output	kW	5760	6000	6000	6600	6960	6960
Mean effective pressure	MPa	2.49	2.49	2.49	2.85	2.88	2.88
Combustion air system (Note 1)							
Flow at 100% load	kg/s	9.86	10.44	10.41	12.4	13.13	13.13
Temperature at turbocharger intake, max.	°C	45	45	45	45	45	45
Air temperature after air cooler (TE 601)	°C	55	55	55	55	55	55
Exhaust gas system (Note 2)							
Flow at 100% load	kg/s	10.17	10.76	10.76	12.75	13.5	13.5
Flow at 85% load	kg/s	9.65	10.2	9.92	11.06	11.97	11.83
Flow at 75% load	kg/s	8.7	9.23	8.7	9.72	10.46	10.32
Flow at 50% load	kg/s	6.3	6.53	7.43	6.81	7.37	8.1
Temperature after turbocharger, 100% load (TE 517)	°C	384	379	379	360	360	360
Temperature after turbocharger, 85% load (TE 517)	°C	331	325	331	340	335	335
Temperature after turbocharger, 75% load (TE 517)	°C	330	325	350	348	345	355
Temperature after turbocharger, 50% load (TE 517)	°C	354	345	317	380	380	340
Backpressure, max.	kPa	4.0	4.0	4.0	4.0	4.0	4.0
Calculated pipe diameter for 35m/s	mm	828	848	848	910	936	936
Heat balance (Note 3)							
Jacket water, HT-circuit	kW	949	1008	1008	904	960	960
Charge air, HT-circuit	kW	915	960	960	1300	1460	1460
Charge air, LT-circuit	kW	728	795	795	830	880	880
Lubricating oil, LT-circuit	kW	690	728	728	777	794	794
Radiation	kW	170	170	170	170	170	170
Fuel system (Note 4)							
Pressure before injection pumps (PT 101)	kPa	700±50	700±50	700±50	700±50	700±50	700±50
Fuel flow to engine, approx.	m³/h	5.8	6.1	6.1	6.6	7.0	7.0
HFO viscosity before engine	cSt	16...24	16...24	16...24	16...24	16...24	16...24
HFO temperature before engine, max. (TE 101)	°C	140	140	140	140	140	140
MDF viscosity, min	cSt	2.0	2.0	2.0	2.0	2.0	2.0
MDF temperature before engine, max. (TE 101)	°C	45	45	45	45	45	45
Fuel consumption at 100% load	g/kWh	182	183	183	182	183	183
Fuel consumption at 85% load	g/kWh	180	180	180	180	180	180
Fuel consumption at 75% load	g/kWh	180	181	180	180	181	180
Fuel consumption at 50% load	g/kWh	191	191	189	191	191	189
Clean leak fuel quantity, MDF at 100% load	kg/h	22.0	23.0	23.0	25.2	26.7	26.7
Clean leak fuel quantity, HFO at 100% load	kg/h	4.4	4.6	4.6	5.0	5.3	5.3
Lubricating oil system							
Pressure before bearings, nom. (PT 201)	kPa	500	500	500	500	500	500
Suction ability main pump, including pipe loss, max.	kPa	40	40	40	40	40	40
Priming pressure, nom. (PT 201)	kPa	50	50	50	50	50	50
Suction ability priming pump, including pipe loss, max.	kPa	35	35	35	35	35	35
Temperature before bearings, nom. (TE 201)	°C	63	63	63	63	63	63
Temperature after engine, approx.	°C	81	81	81	81	81	81
Pump capacity (main), engine driven	m³/h	124	129	129	124	129	129
Pump capacity (main), stand-by	m³/h	106	110	110	106	110	110
Priming pump capacity, 50Hz/60Hz	m³/h	38.0 / 45.9	38.0 / 45.9	38.0 / 45.9	38.0 / 45.9	38.0 / 45.9	38.0 / 45.9
Oil volume, wet sump, nom.	m³	3.0	3.0	3.0	3.0	3.0	3.0
Oil volume in separate system oil tank, nom.	m³	7.8	8.1	8.1	8.9	9.4	9.4
Oil consumption (100% load), approx.	g/kWh	0.5	0.5	0.5	0.5	0.5	0.5
Crankcase ventilation flow rate at full load	l/min	1980	1980	1980	2160	2160	2160
Crankcase ventilation backpressure, max.	kPa	0.4	0.4	0.4	0.4	0.4	0.4
Oil volume in turning device	liters	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	liters	1.9	1.9	1.9	1.9	1.9	1.9
Cooling water system							
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
Pressure at engine, after pump, max. (PT 401)	kPa	530	530	530	530	530	530
Temperature before cylinders, approx. (TE 401)	°C	85	85	85	77	77	77

Wärtsilä 12V32		AE/DE IMO Tier 2	AE/DE IMO Tier 2	ME IMO Tier 2	AE/DE IMO Tier 2	AE/DE IMO Tier 2	ME IMO Tier 2
Engine speed **Cylinder output**	**RPM** **kW/cyl**	**720** **480**	**750** **500**	**750** **500**	**720** **550**	**750** **580**	**750** **580**
HT-water out from engine, nom (TE432)	°C	96	96	96	96	96	96
Capacity of engine driven pump, nom.	m³/h	100	100	100	100	100	100
Pressure drop over engine, total	kPa	150	150	150	150	150	150
Pressure drop in external system, max.	kPa	60	60	60	60	60	60
Pressure from expansion tank	kPa	70...150	70...150	70...150	70...150	70...150	70...150
Water volume in engine	m³	0.74	0.74	0.74	0.74	0.74	0.74
Low temperature cooling water system							
Pressure at engine, after pump, nom. (PT 451)	kPa	250 + static	250 + static	250 + static	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 451)	kPa	530	530	530	530	530	530
Temperature before engine (TE 451)	°C	25 ... 38	25 ... 38	25 ... 38	25 ... 38	25 ... 38	25 ... 38
Capacity of engine driven pump, nom.	m³/h	100	100	100	100	100	100
Pressure drop over charge air cooler	kPa	35	35	35	35	35	35
Pressure drop over oil cooler	kPa	20	20	20	20	20	20
Pressure drop in external system, max.	kPa	60	60	60	60	60	60
Pressure from expansion tank	kPa	70 ... 150	70 ... 150	70 ... 150	70 ... 150	70 ... 150	70 ... 150
Starting air system (Note 5)							
Pressure, nom.	kPa	3000	3000	3000	3000	3000	3000
Pressure at engine during start, min. (20°C)	kPa	1500	1500	1500	1500	1500	1500
Pressure, max.	kPa	3000	3000	3000	3000	3000	3000
Low pressure limit in air vessels	kPa	1800	1800	1800	1800	1800	1800
Air consumption per start	Nm³	3.0	3.0	-	3.0	3.0	-
Air consumption per start without propeller shaft engaged	Nm³	-	-	3.0	-	-	3.0
Air consumption with automatic start and slowturning	Nm³	-	-	-	4.5	4.5	4.5
Air consumption per start with propeller shaft engaged	Nm³	-	-	4.8	-	-	4.8
Air consumption with automatic start and high inertia slowturning	Nm³	-	-	-	6.3	6.3	6.3

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 10°C.

Note 3 At ISO 3046-1 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, with engine driven pumps (two cooling water + one lubricating oil pumps). Tolerance 5%. Load according to propeller law for mechanical propulsion engines (ME).

Note 5 Automatic (remote or local) starting air consumption (average) per start, at 20°C for a specific long start impulse (DE/AUX: 2...3 sec, CPP/FPP: 4...6 sec) which is the shortest time required for a safe start.

ME = Engine driving propeller, variable speed

AE = Auxiliary engine driving generator

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

3.6 Wärtsilä 16V32

Wärtsilä 16V32		AE/DE IMO Tier 2	AE/DE IMO Tier 2	ME IMO Tier 2	AE/DE IMO Tier 2	AE/DE IMO Tier 2	ME IMO Tier 2
Engine speed **Cylinder output**	**RPM** **kW/cyl**	**720** **480**	**750** **500**	**750** **500**	**720** **550**	**750** **580**	**750** **580**
Engine output	kW	7680	8000	8000	8800	9280	9280
Mean effective pressure	MPa	2.49	2.49	2.49	2.85	2.88	2.88
Combustion air system (Note 1)							
Flow at 100% load	kg/s	13.16	13.92	13.87	16.53	17.52	17.52
Temperature at turbocharger intake, max.	°C	45	45	45	45	45	45
Air temperature after air cooler (TE 601)	°C	55	55	55	55	55	55
Exhaust gas system (Note 2)							
Flow at 100% load	kg/s	13.57	14.35	14.35	17.0	18.01	18.01
Flow at 85% load	kg/s	12.87	13.6	13.2	14.75	15.96	15.78
Flow at 75% load	kg/s	11.6	12.3	11.6	12.95	13.95	13.77
Flow at 50% load	kg/s	8.4	8.7	9.9	9.08	9.83	10.8
Temperature after turbocharger, 100% load (TE 517)	°C	384	379	379	360	360	360
Temperature after turbocharger, 85% load (TE 517)	°C	331	325	331	340	335	335
Temperature after turbocharger, 75% load (TE 517)	°C	330	325	350	348	345	355
Temperature after turbocharger, 50% load (TE 517)	°C	354	345	317	380	380	340
Backpressure, max.	kPa	4.0	4.0	4.0	4.0	4.0	4.0
Calculated pipe diameter for 35m/s	mm	956	979	979	1050	1081	1081
Heat balance (Note 3)							
Jacket water, HT-circuit	kW	1265	1344	1344	1205	1280	1280
Charge air, HT-circuit	kW	1220	1280	1280	1733	1947	1947
Charge air, LT-circuit	kW	970	1060	1060	1107	1173	1173
Lubricating oil, LT-circuit	kW	920	970	970	1035	1059	1059
Radiation	kW	230	230	230	227	227	227
Fuel system (Note 4)							
Pressure before injection pumps (PT 101)	kPa	700±50	700±50	700±50	700±50	700±50	700±50
Fuel flow to engine, approx.	m³/h	7.7	8.1	8.1	8.8	9.4	9.4
HFO viscosity before engine	cSt	16...24	16...24	16...24	16...24	16...24	16...24
HFO temperature before engine, max. (TE 101)	°C	140	140	140	140	140	140
MDF viscosity, min	cSt	2.0	2.0	2.0	2.0	2.0	2.0
MDF temperature before engine, max. (TE 101)	°C	45	45	45	45	45	45
Fuel consumption at 100% load	g/kWh	182	183	183	182	183	183
Fuel consumption at 85% load	g/kWh	180	180	180	180	180	180
Fuel consumption at 75% load	g/kWh	180	181	180	180	181	180
Fuel consumption at 50% load	g/kWh	191	191	189	191	191	189
Clean leak fuel quantity, MDF at 100% load	kg/h	29.3	30.7	30.7	33.6	35.6	35.6
Clean leak fuel quantity, HFO at 100% load	kg/h	5.9	6.1	6.1	6.7	7.1	7.1
Lubricating oil system							
Pressure before bearings, nom. (PT 201)	kPa	500	500	500	500	500	500
Suction ability main pump, including pipe loss, max.	kPa	40	40	40	40	40	40
Priming pressure, nom. (PT 201)	kPa	50	50	50	50	50	50
Suction ability priming pump, including pipe loss, max.	kPa	35	35	35	35	35	35
Temperature before bearings, nom. (TE 201)	°C	63	63	63	63	63	63
Temperature after engine, approx.	°C	81	81	81	81	81	81
Pump capacity (main), engine driven	m³/h	158	164	164	158	164	164
Pump capacity (main), stand-by	m³/h	130	135	135	130	135	135
Priming pump capacity, 50Hz/60Hz	m³/h	38.0 / 45.9	38.0 / 45.9	38.0 / 45.9	38.0 / 45.9	38.0 / 45.9	38.0 / 45.9
Oil volume, wet sump, nom.	m³	3.9	3.9	3.9	3.9	3.9	3.9
Oil volume in separate system oil tank, nom.	m³	10.4	10.8	10.8	11.9	12.5	12.5
Oil consumption (100% load), approx.	g/kWh	0.5	0.5	0.5	0.5	0.5	0.5
Crankcase ventilation flow rate at full load	l/min	2640	2640	2640	2880	2880	2880
Crankcase ventilation backpressure, max.	kPa	0.4	0.4	0.4	0.4	0.4	0.4
Oil volume in turning device	liters	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	liters	1.9	1.9	1.9	1.9	1.9	1.9
Cooling water system							
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
Pressure at engine, after pump, max. (PT 401)	kPa	530	530	530	530	530	530
Temperature before cylinders, approx. (TE 401)	°C	85	85	85	77	77	77

Wärtsilä 16V32		AE/DE IMO Tier 2	AE/DE IMO Tier 2	ME IMO Tier 2	AE/DE IMO Tier 2	AE/DE IMO Tier 2	ME IMO Tier 2
Engine speed **Cylinder output**	**RPM** **kW/cyl**	**720** **480**	**750** **500**	**750** **500**	**720** **550**	**750** **580**	**750** **580**
HT-water out from engine, nom (TE432)	°C	96	96	96	96	96	96
Capacity of engine driven pump, nom.	m³/h	140	140	140	140	140	140
Pressure drop over engine, total	kPa	150	150	150	150	150	150
Pressure drop in external system, max.	kPa	60	60	60	60	60	60
Pressure from expansion tank	kPa	70...150	70...150	70...150	70...150	70...150	70...150
Water volume in engine	m³	0.84	0.84	0.84	0.84	0.84	0.84
Low temperature cooling water system							
Pressure at engine, after pump, nom. (PT 451)	kPa	250 + static	250 + static	250 + static	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 451)	kPa	530	530	530	530	530	530
Temperature before engine (TE 451)	°C	25 ... 38	25 ... 38	25 ... 38	25 ... 38	25 ... 38	25 ... 38
Capacity of engine driven pump, nom.	m³/h	120	120	120	120	120	120
Pressure drop over charge air cooler	kPa	35	35	35	35	35	35
Pressure drop over oil cooler	kPa	20	20	20	20	20	20
Pressure drop in external system, max.	kPa	60	60	60	60	60	60
Pressure from expansion tank	kPa	70 ... 150	70 ... 150	70 ... 150	70 ... 150	70 ... 150	70 ... 150
Starting air system (Note 5)							
Pressure, nom.	kPa	3000	3000	3000	3000	3000	3000
Pressure at engine during start, min. (20°C)	kPa	1500	1500	1500	1500	1500	1500
Pressure, max.	kPa	3000	3000	3000	3000	3000	3000
Low pressure limit in air vessels	kPa	1800	1800	1800	1800	1800	1800
Air consumption per start	Nm³	3.6	3.6	-	3.6	3.6	-
Air consumption per start without propeller shaft engaged	Nm³	-	-	3.6	-	-	3.6
Air consumption with automatic start and slowturning	Nm³	-	-	-	5.6	5.6	5.6
Air consumption per start with propeller shaft engaged	Nm³	-	-	5.8	-	-	5.8
Air consumption with automatic start and high inertia slowturning	Nm³	-	-	-	7.8	7.8	7.8

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 10°C.

Note 3 At ISO 3046-1 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, with engine driven pumps (two cooling water + one lubricating oil pumps). Tolerance 5%. Load according to propeller law for mechanical propulsion engines (ME).

Note 5 Automatic (remote or local) starting air consumption (average) per start, at 20°C for a specific long start impulse (DE/AUX: 2...3 sec, CPP/FPP: 4...6 sec) which is the shortest time required for a safe start.

ME = Engine driving propeller, variable speed

AE = Auxiliary engine driving generator

DE = Diesel-Electric engine driving generator

Subject to revision without notice.

3.7 Wärtsilä 18V32

Wärtsilä 18V32		AE/DE IMO Tier 2	AE/DE IMO Tier 2	ME IMO Tier 2
Engine speed **Cylinder output**	**RPM** **kW/cyl**	**720** **480**	**750** **500**	**750** **500**
Engine output	kW	8640	9000	9000
Mean effective pressure	MPa	2.49	2.49	2.49
Combustion air system (Note 1)				
Flow at 100% load	kg/s	14.8	15.66	15.61
Temperature at turbocharger intake, max.	°C	45	45	45
Air temperature after air cooler (TE 601)	°C	55	55	55
Exhaust gas system (Note 2)				
Flow at 100% load	kg/s	15.26	16.14	16.14
Flow at 85% load	kg/s	14.48	15.3	14.87
Flow at 75% load	kg/s	13.05	13.84	13.05
Flow at 50% load	kg/s	9.45	9.79	11.14
Temperature after turbocharger, 100% load (TE 517)	°C	384	379	379
Temperature after turbocharger, 85% load (TE 517)	°C	331	325	331
Temperature after turbocharger, 75% load (TE 517)	°C	330	325	350
Temperature after turbocharger, 50% load (TE 517)	°C	354	345	317
Backpressure, max.	kPa	4.0	4.0	4.0
Calculated pipe diameter for 35m/s	mm	1014	1039	1039
Heat balance (Note 3)				
Jacket water, HT-circuit	kW	1423	1512	1512
Charge air, HT-circuit	kW	1373	1440	1440
Charge air, LT-circuit	kW	1091	1193	1193
Lubricating oil, LT-circuit	kW	1035	1091	1091
Radiation	kW	260	260	260
Fuel system (Note 4)				
Pressure before injection pumps (PT 101)	kPa	700±50	700±50	700±50
Fuel flow to engine, approx.	m³/h	8.7	9.1	9.1
HFO viscosity before engine	cSt	16...24	16...24	16...24
HFO temperature before engine, max. (TE 101)	°C	140	140	140
MDF viscosity, min	cSt	2.0	2.0	2.0
MDF temperature before engine, max. (TE 101)	°C	45	45	45
Fuel consumption at 100% load	g/kWh	182	183	183
Fuel consumption at 85% load	g/kWh	180	180	180
Fuel consumption at 75% load	g/kWh	180	181	180
Fuel consumption at 50% load	g/kWh	191	191	189
Clean leak fuel quantity, MDF at 100% load	kg/h	33.0	34.6	34.6
Clean leak fuel quantity, HFO at 100% load	kg/h	6.6	6.9	6.9
Lubricating oil system				
Pressure before bearings, nom. (PT 201)	kPa	500	500	500
Suction ability main pump, including pipe loss, max.	kPa	40	40	40
Priming pressure, nom. (PT 201)	kPa	50	50	50
Suction ability priming pump, including pipe loss, max.	kPa	35	35	35
Temperature before bearings, nom. (TE 201)	°C	63	63	63
Temperature after engine, approx.	°C	81	81	81
Pump capacity (main), engine driven	m³/h	158	164	164
Pump capacity (main), stand-by	m³/h	144	150	150
Priming pump capacity, 50Hz/60Hz	m³/h	38.0 / 45.9	38.0 / 45.9	38.0 / 45.9
Oil volume, wet sump, nom.	m³	4.3	4.3	4.3
Oil volume in separate system oil tank, nom.	m³	11.7	12.2	12.2
Oil consumption (100% load), approx.	g/kWh	0.5	0.5	0.5
Crankcase ventilation flow rate at full load	l/min	2970	2970	2970
Crankcase ventilation backpressure, max.	kPa	0.4	0.4	0.4
Oil volume in turning device	liters	8.5...9.5	8.5...9.5	8.5...9.5
Oil volume in speed governor	liters	1.9	1.9	1.9
Cooling water system				
High temperature cooling water system				
Pressure at engine, after pump, nom. (PT 401)	kPa	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 401)	kPa	530	530	530
Temperature before cylinders, approx. (TE 401)	°C	85	85	85

Wärtsilä 18V32		AE/DE IMO Tier 2	AE/DE IMO Tier 2	ME IMO Tier 2
Engine speed **Cylinder output**	**RPM** **kW/cyl**	**720** **480**	**750** **500**	**750** **500**
HT-water out from engine, nom (TE432)	°C	96	96	96
Capacity of engine driven pump, nom.	m³/h	160	160	150
Pressure drop over engine, total	kPa	150	150	150
Pressure drop in external system, max.	kPa	60	60	60
Pressure from expansion tank	kPa	70...150	70...150	70...150
Water volume in engine	m³	0.89	0.89	0.89
Low temperature cooling water system				
Pressure at engine, after pump, nom. (PT 451)	kPa	250 + static	250 + static	250 + static
Pressure at engine, after pump, max. (PT 451)	kPa	530	530	530
Temperature before engine (TE 451)	°C	25 ... 38	25 ... 38	25 ... 38
Capacity of engine driven pump, nom.	m³/h	130	130	150
Pressure drop over charge air cooler	kPa	35	35	35
Pressure drop over oil cooler	kPa	20	20	20
Pressure drop in external system, max.	kPa	60	60	60
Pressure from expansion tank	kPa	70 ... 150	70 ... 150	70 ... 150
Starting air system (Note 5)				
Pressure, nom.	kPa	3000	3000	3000
Pressure at engine during start, min. (20°C)	kPa	1500	1500	1500
Pressure, max.	kPa	3000	3000	3000
Low pressure limit in air vessels	kPa	1800	1800	1800
Air consumption per start	Nm³	4.0	4.0	-
Air consumption per start without propeller shaft engaged	Nm³	-	-	4.0
Air consumption per start with propeller shaft engaged	Nm³	-	-	6.4

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 10°C.

Note 3 At ISO 3046-1 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, with engine driven pumps (two cooling water + one lubricating oil pumps). Tolerance 5%. Load according to propeller law for mechanical propulsion engines (ME).

Note 5 Automatic (remote or local) starting air consumption (average) per start, at 20°C for a specific long start impulse (DE/AUX: 2...3 sec, CPP/FPP: 4...6 sec) which is the shortest time required for a safe start.

ME = Engine driving propeller, variable speed

AE = Auxiliary engine driving generator

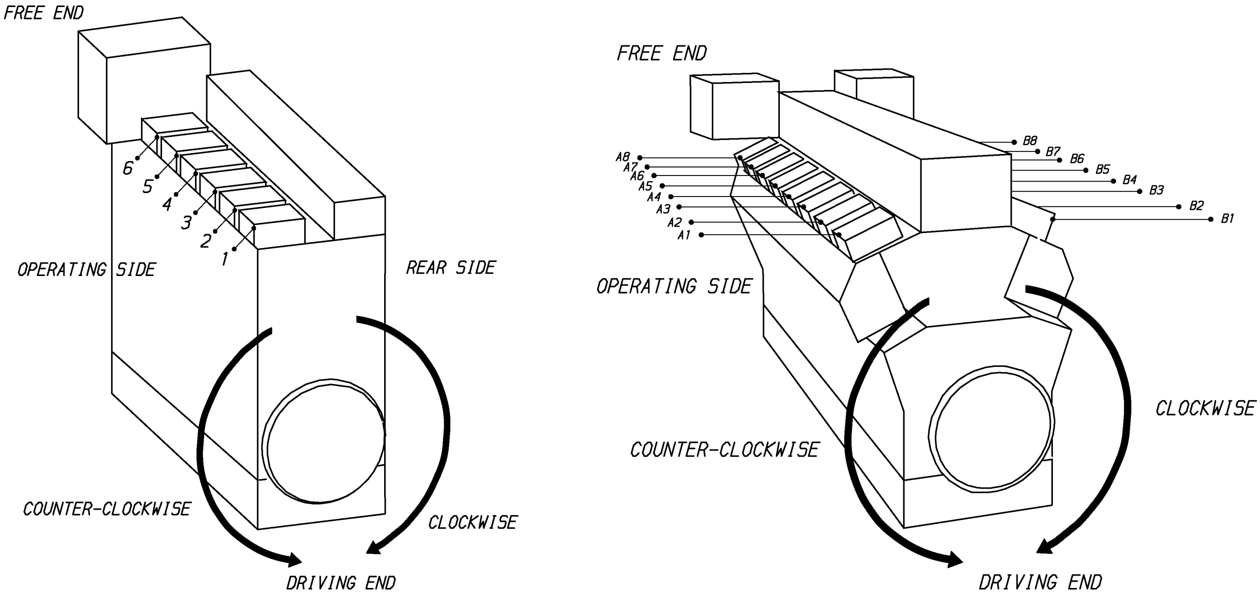
DE = Diesel-Electric engine driving generator

Subject to revision without notice.

4. Description of the Engine

4.1 Definitions

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



4.2 Main components and systems

The dimensions and weights of engines are shown in section *1.4 Dimensions and weights* .

4.2.1 Engine block

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

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

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

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

4.2.2 Crankshaft

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

The connecting rods, at the same crank in the V-engine, are arranged side-by-side in order to achieve standardisation between the in-line and V-engines.

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

4.2.3 Connecting rod

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

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

4.2.4 Main bearings and big end bearings

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

4.2.5 Cylinder liner

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

4.2.6 Piston

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

4.2.7 Piston rings

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

4.2.8 Cylinder head

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

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

The valve seat rings are made of specially alloyed cast iron with good wear resistance. The inlet valves as well as, in case of MDF installation, the exhaust valves have stellite-plated seat faces and chromium-plated stems. Engines for HFO operation have Nimonic exhaust valves.

All valves are equipped with valve rotators.

A “multi-duct” casting is fitted to the cylinder head. It connects the following media with the cylinder head:

- charge air from the air receiver
- exhaust gas to exhaust system
- cooling water from cylinder head to the return pipe

4.2.9 Camshaft and valve mechanism

The cams are integrated in the drop forged shaft material. The bearing journals are made in separate pieces, which are fitted, to the camshaft pieces by flange connections. The camshaft bearing housings are integrated in the engine block casting and are thus completely closed. The bearings are installed and removed by means of a hydraulic tool. The camshaft covers, one for each cylinder, seal against the engine block with a closed O-ring profile.

The valve tappets are of piston type with self-adjustment of roller against cam to give an even distribution of the contact pressure. The valve springs make the valve mechanism dynamically stable.

Variable Inlet valve Closure (VIC), which is available on IMO Tier 2 engines, offers flexibility to apply early inlet valve closure at high load for lowest NOx levels, while good part-load performance is ensured by adjusting the advance to zero at low load. The inlet valve closure can be adjusted up to 30° crank angle.

4.2.10 Camshaft drive

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

4.2.11 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 on main engines 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 one turbocharger and V-engines have one turbocharger per cylinder bank. For in-line engines and 12V32, the turbocharger(s) can be placed either at the driving end or at the free end. 16V32 and 18V32 have the turbochargers always placed at free end.

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

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.

4.2.12 Fuel injection equipment

The fuel injection equipment and system piping are located in a hotbox, providing maximum reliability and safety when using preheated heavy fuels. The fuel oil feed pipes are mounted directly to the injection pumps, using a specially designed connecting piece. The return pipe is integrated in the tappet housing.

Cooling of the nozzles by means of lubricating oil is standard for HFO-installations, while the nozzles for MDF-installations are non-cooled.

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

Setting the fuel rack to zero position stops the fuel injection. For emergencies the fuel rack of each injection pump is fitted with a stop cylinder. The fuel pump and pump bracket are adjusted in manufacturing to tight tolerances. This means that adjustments are not necessary after initial assembly.

The fuel injection pump design is a reliable mono-element type designed for injection pressures up to 2000 bar. The constant pressure relief valve system provides for optimum injection, which guarantees long intervals between overhauls. The injector holder is designed for easy maintenance.

4.2.13 Lubricating oil system

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

4.2.14 Cooling water system

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

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

4.2.15 Exhaust pipes

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

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

4.2.16 Automation system

Wärtsilä 32 is equipped with a modular embedded automation system, Wärtsilä Unified Controls - UNIC, which is available in two different versions. The basic functionality is the same in both versions, but the functionality can be easily expanded to cover different applications.

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

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

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

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

4.3 Cross section of the engine

Figure 4.2 Cross section of the in-line engine

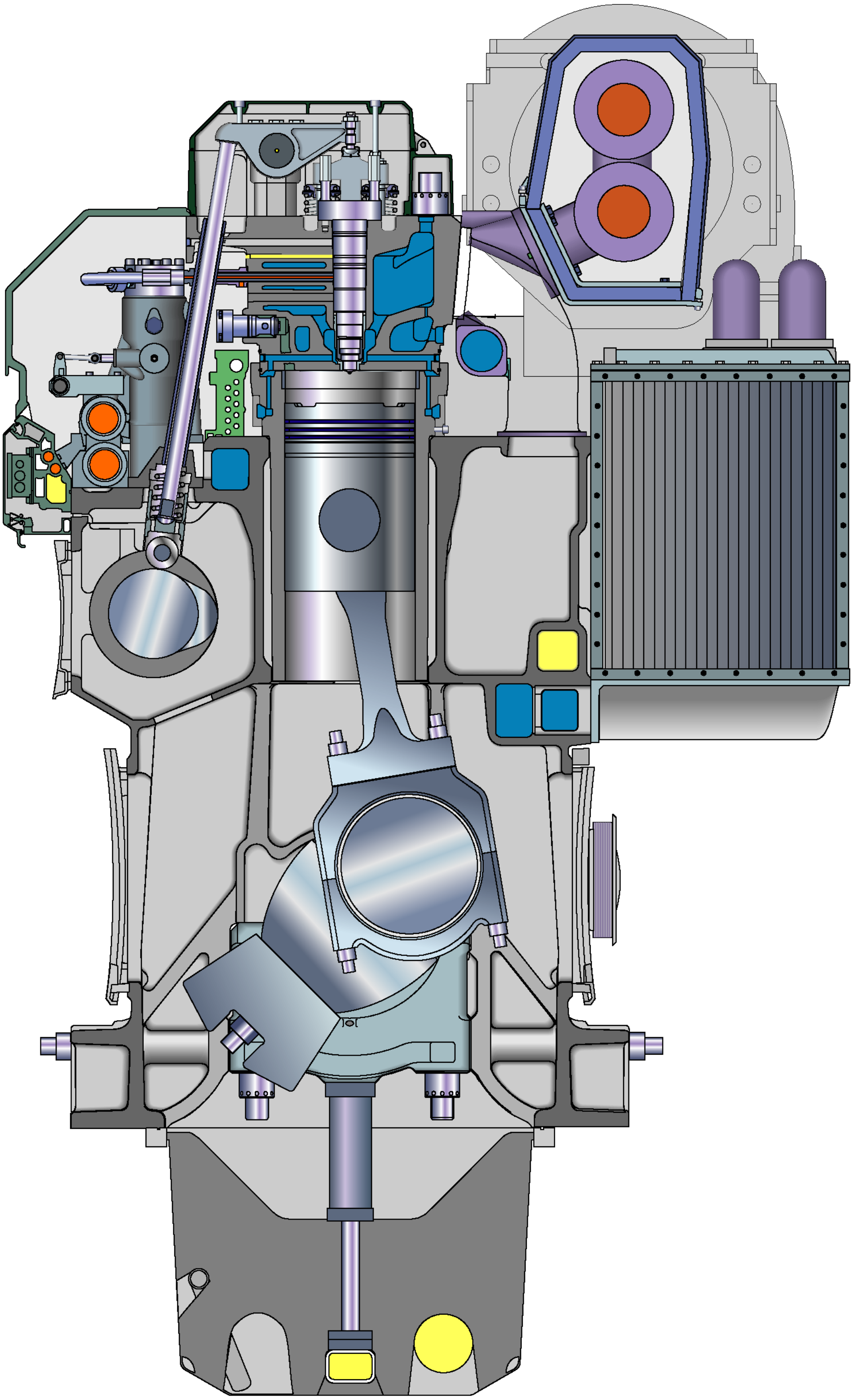
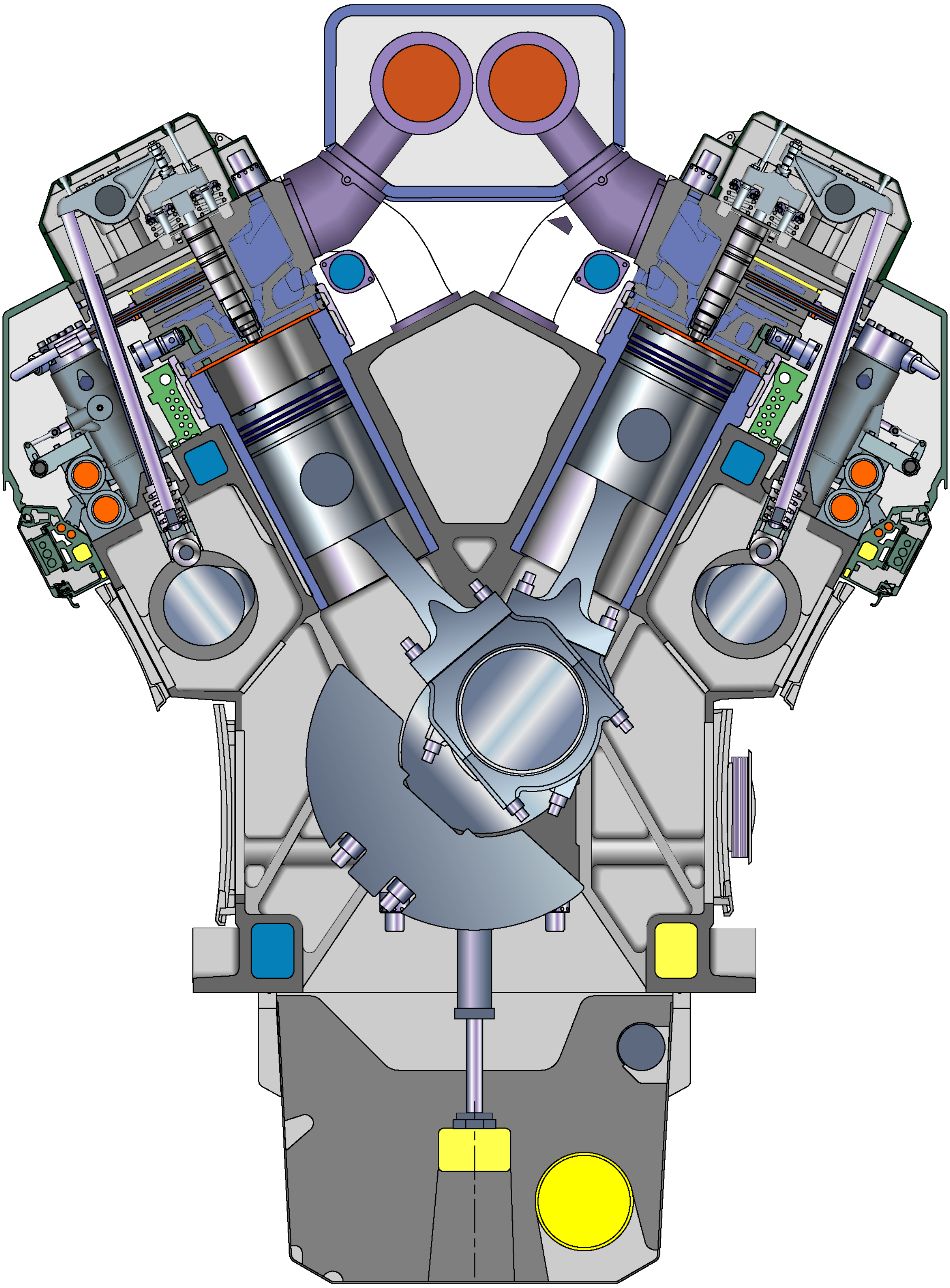


Figure 4.3 Cross section of the V-engine



4.4 Overhaul intervals and expected life times

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

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

Table 4.1 Time between overhauls and expected component lifetimes.

	HFO	MDF	HFO	MDF
	Time between overhauls (h)		Expected component lifetimes (h)	
Piston Piston rings	12000 - 20000 12000 - 20000	20000 - 24000 20000 - 24000	48000 - 60000 12000 - 20000	60000 - 100000 20000 - 24000
Cylinder liner Cylinder head	12000 - 20000 12000 - 20000	20000 - 24000 20000 - 24000	60000 - 100000 60000 - 100000	> 100000 > 100000
Inlet valve Exhaust valve	12000 - 20000 12000 - 20000	20000 - 24000 20000 - 24000	36000 - 40000 20000 - 32000	40000 - 48000 20000 - 40000
Injection valve nozzle Injection pump Injection pump element	2000 12000 	2000 12000 	4000 - 6000 24000	4000 - 6000 24000
Main bearing Big end bearing	24000 - 32000 12000 - 20000	24000 - 32000 20000 - 24000	48000 24000 - 32000	48000 24000 - 32000

5. Piping Design, Treatment and Installation

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

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

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

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

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

The following aspects shall be taken into consideration:

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

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

5.1 Pipe dimensions

When selecting the pipe dimensions, take into account:

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

Table 5.1 Recommended maximum velocities on pump delivery side for guidance

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

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

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

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

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

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

5.2 Trace heating

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

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

5.3 Pressure class

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

The pressure in the system can:

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

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

Example 1:

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

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

Example 2:

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

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

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

5.4 Pipe class

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

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

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

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

Table 5.2 Classes of piping systems as per DNV rules

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

5.5 Insulation

The following pipes shall be insulated:

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

Insulation is also recommended for:

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

5.6 Local gauges

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

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

5.7 Cleaning procedures

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

5.7.1 Cleanliness during pipe installation

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

Piping cleaning methods are summarised in table below:

Table 5.3 Pipe cleaning

System	Methods
Fuel 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

[1)] In case of carbon steel pipes

Methods applied during prefabrication of pipe spools

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

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

D = Pickling (not required for seamless precision tubes)

Methods applied after installation onboard

C = Purging with compressed air

F = Flushing

5.7.2 Pickling

Prefabricated pipe spools are pickled before installation onboard.

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

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

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

5.8 Flexible pipe connections

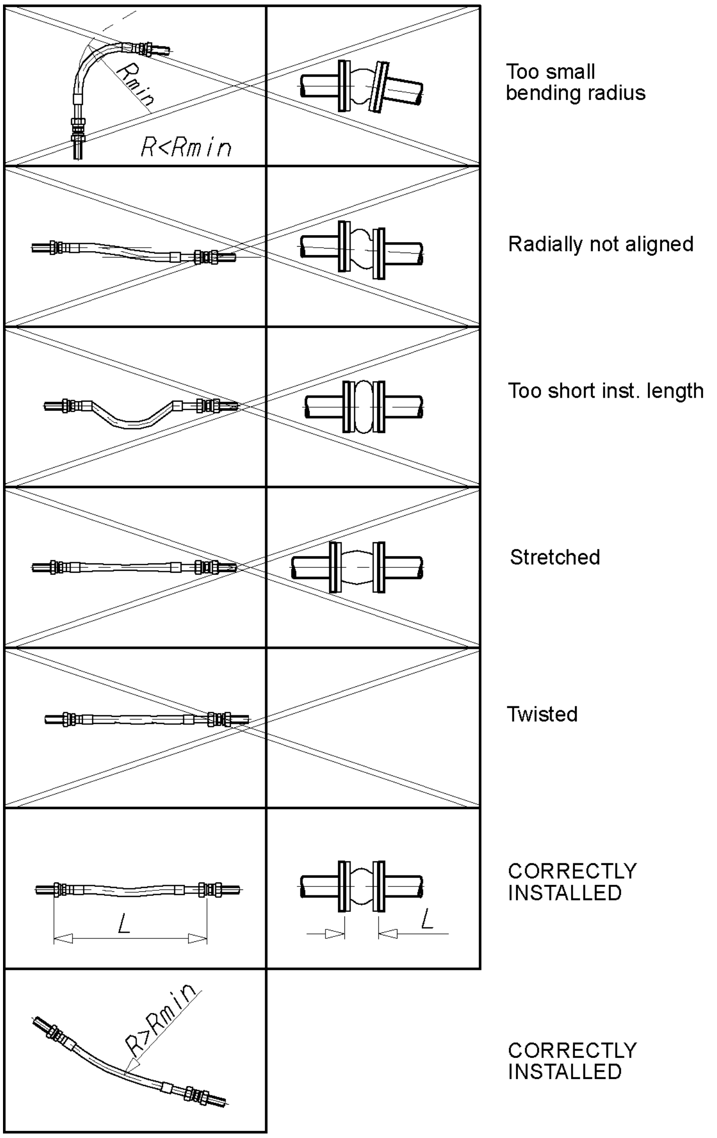
Pressurized flexible connections carrying flammable fluids or compressed air have to be type approved.

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

- Flexible pipe connections must not be twisted
- Installation length of flexible pipe connections must be correct
- Minimum bending radius must 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



5.9 Clamping of pipes

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

- Pipe clamps and supports next to the engine must be very rigid and welded to the steel structure of the foundation.
- The first support should be located as close as possible to the flexible connection. Next support should be 0.3-0.5 m from the first support.

- First three supports closest to the engine or generating set should be fixed supports. Where necessary, sliding supports can be used after these three fixed supports to allow thermal expansion of the pipe.
- Supports should never be welded directly to the pipe. Either pipe clamps or flange supports should be used for flexible connection.

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

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

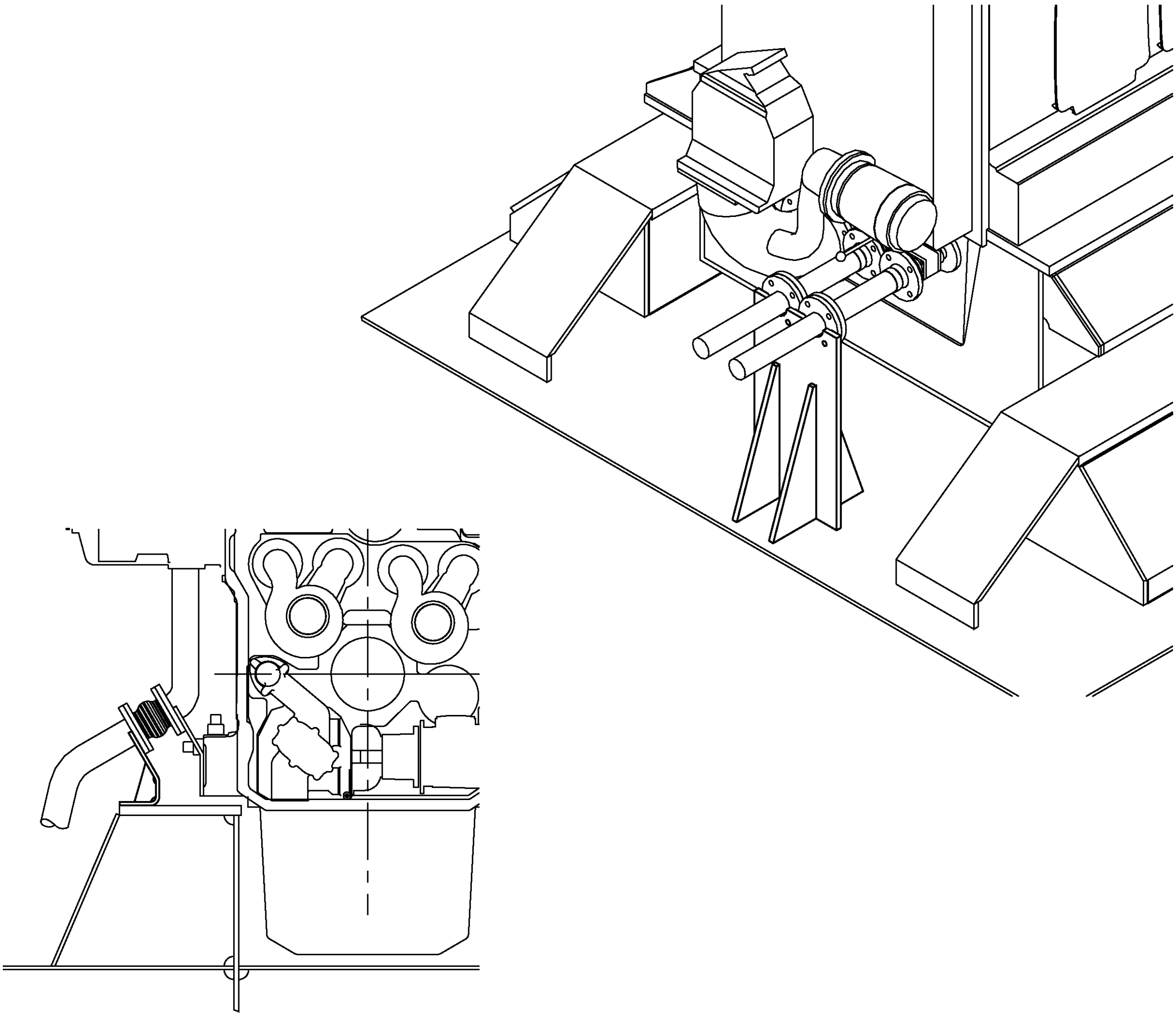
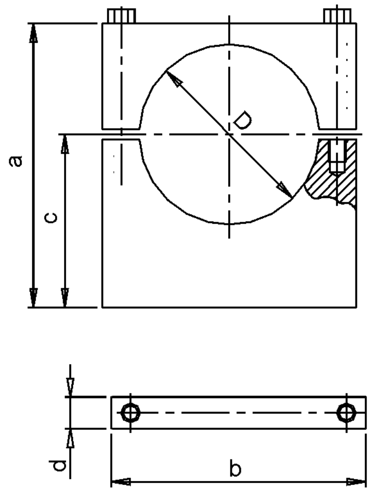


Figure 5.3 Pipe clamp for fixed support (4V61H0842)



DN	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 8217:2010 (E) standard. Observe that a few additional properties not included in the standard are listed in the tables. For maximum fuel temperature before the engine, see chapter "*Technical Data*".

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

6.1.1 Marine Diesel Fuel (MDF)

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

The distillate grades mentioned above can be described as follows:

- DMX: A fuel which is suitable for use at ambient temperatures down to -15°C without heating the fuel. Especially in merchant marine applications its use is restricted to lifeboat engines and certain emergency equipment due to the reduced flash point. The low flash point which is not meeting the SOLAS requirement can also prevent the use in other marine applications, unless the fuel system is built according to special requirements. Also the low viscosity (min. 1.4 cSt) can prevent the use in engines unless the fuel can be cooled down enough to meet the min. injection viscosity limit of the engine.
- DMA: A high quality distillate, generally designated as MGO (Marine Gas Oil).
- DMZ: A high quality distillate, generally designated as MGO (Marine Gas Oil). An alternative fuel grade for engines requiring a higher fuel viscosity than specified for DMA grade fuel.
- DMB: A general purpose fuel which may contain trace amounts of residual fuel and is intended for engines not specifically designed to burn residual fuels. It is generally designated as MDO (Marine Diesel Oil).

Table 6.1 MDF specifications

Property	Unit	ISO-F-DMA	ISO-F-DMZ	ISO-F-DMB	Test method ref.
Viscosity, before injection pumps, min. 1)	cSt	2.0	2.0	2.0	
Viscosity, before injection pumps, max. 1)	cSt	24	24	24	
Viscosity at 40°C, min.	cSt	2	3	2	
Viscosity at 40°C, max.	cSt	6	6	11	ISO 3104
Density at 15°C, max.	kg/m³	890	890	900	ISO 3675 or 12185
Cetane index, min.		40	40	35	ISO 4264
Sulphur, max.	% mass	1.5	1.5	2	ISO 8574 or 14596
Flash point, min.	°C	60	60	60	ISO 2719
Hydrogen sulfide. max. 2)	mg/kg	2	2	2	IP 570
Acid number, max.	mg KOH/g	0.5	0.5	0.5	ASTM D664
Total sediment by hot filtration, max.	% mass	—	—	0.1 3)	ISO 10307-1
Oxidation stability, max.	g/m³	25	25	25 4)	ISO 12205
Carbon residue: micro method on the 10% volume distillation residue max.	% mass	0.30	0.30	—	ISO 10370
Carbon residue: micro method, max.	% mass	—	—	0.30	ISO 10370
Pour point (upper) , winter quality, max. 5)	°C	-6	-6	0	ISO 3016

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

Remarks:

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

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

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

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

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

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

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

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

6.1.2 Heavy Fuel Oil (HFO)

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

Table 6.2 HFO specifications

Property	Unit	Limit HFO 1	Limit HFO 2	Test method ref.
Viscosity, before injection pumps 1)	cSt	16...24	16...24	
Viscosity at 50°C, max.	cSt	700	700	ISO 3104
Density at 15°C, max.	kg/m³	991 / 1010 2)	991 / 1010 2)	ISO 3675 or 12185
CCAI, max.3)		850	870	ISO 8217, Annex F
Sulphur, max. 4) 5)	% mass	Statutory requirements		ISO 8754 or 14596
Flash point, min.	°C	60	60	ISO 2719
Hydrogen sulfide, max. 6)	mg/kg	2	2	IP 570
Acid number, max.	mg KOH/g	2.5	2.5	ASTM D664
Total sediment aged, max.	% mass	0.1	0.1	ISO 10307-2
Carbon residue, micro method, max.	% mass	15	20	ISO 10370
Asphaltenes, max.1)	% mass	8	14	ASTM D 3279
Pour point (upper), max. 7)	°C	30	30	ISO 3016

Property	Unit	Limit HFO 1	Limit HFO 2	Test method ref.
Water, max.	% volume	0.5	0.5	ISO 3733 or ASTM D6304-C 1)
Water before engine, max.1)	% volume	0.3	0.3	ISO 3733 or ASTM D6304-C 1)
Ash, max.	% mass	0.05	0.15	ISO 6245 or LP1001 1)
Vanadium, max. 5)	mg/kg	100	450	ISO 14597 or IP 501 or IP 470
Sodium, max. 5)	mg/kg	50	100	IP 501 or IP 470
Sodium before engine, max.1) 5)	mg/kg	30	30	IP 501 or IP 470
Aluminium + Silicon, max.	mg/kg	30	60	ISO 10478 or IP 501 or IP 470
Aluminium + Silicon before engine, max.1)	mg/kg	15	15	ISO 10478 or IP 501 or IP 470
Used lubricating oil, calcium, max. 8)	mg/kg	30	30	IP 501 or IP 470
Used lubricating oil, zinc, max. 8)	mg/kg	15	15	IP 501 or IP 470
Used lubricating oil, phosphorus, max. 8)	mg/kg	15	15	IP 501 or IP 500

Remarks:

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

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

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

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

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

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

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

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

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

6.1.3 Liquid bio fuels

The engine can be operated on liquid bio fuels according to the specifications in tables "*6.3 Straight liquid bio fuel specification*" or "*6.4 Biodiesel specification based on EN 14214:2003 standard*". Liquid bio fuels have typically lower heating value than fossil fuels, the capacity of the fuel injection system must be checked for each installation.

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

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

Table 6.3 Straight liquid bio fuel specification

Property	Unit	Limit	Test method ref.
Viscosity at 40°C, max.1)	cSt	100	ISO 3104
Viscosity, before injection pumps, min.	cSt	2.0	
Viscosity, before injection pumps, max.	cSt	24	
Density at 15°C, max.	kg/m³	991	ISO 3675 or 12185
Ignition properties 2)			FIA test
Sulphur, max.	% mass	0.05	ISO 8574
Total sediment existent, max.	% mass	0.05	ISO 10307-1
Water before engine, max.	% volume	0.20	ISO 3733
Micro carbon residue, max.	% mass	0.50	ISO 10370
Ash, max.	% mass	0.05	ISO 6245 / LP1001
Phosphorus, max.	mg/kg	100	ISO 10478
Silicon, max.	mg/kg	15	ISO 10478
Alkali content (Na+K), max.	mg/kg	30	ISO 10478
Flash point (PMCC), min.	°C	60	ISO 2719
Cloud point, max.	°C	3)	ISO 3015
Cold filter plugging point, max.	°C	3)	IP 309
Copper strip corrosion (3h at 50°C), max.	Rating	1b	ASTM D130
Steel corrosion (24/72h at 20, 60 and 120°C), max.	Rating	No signs of corrosion	LP 2902
Acid number, max.	mg KOH/g	15.0	ASTM D664
Strong acid number, max.	mg KOH/g	0.0	ASTM D664
Iodine number, max.	g iodine / 100 g	120	ISO 3961
Synthetic polymers	% mass	Report 4)	LP 2401 ext. and LP 3402

Remarks:

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

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

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

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

Table 6.4 Biodiesel specification based on EN 14214:2003 standard

Property	Unit	Limit	Test method ref.
Viscosity at 40°C, min...max.	cSt	3.5...5	ISO 3104
Viscosity, before injection pumps, min.	cSt	2.0	
Density at 15°C, min...max.	kg/m^3	860...900	ISO 3675 / 12185
Cetane number, min.		51	ISO 5165
Sulphur, max.	mg/kg	10	ISO 20846 / 20884
Sulphated ash, max.	% mass	0.02	ISO 3987
Total contamination, max.	mg/kg	24	EN 12662
Water, max.	mg/kg	500	ISO 12937
Carbon residue (on 10% distillation residue), max.	% mass	0.30	ISO 10370
Phosphorus, max.	mg/kg	4	EN 14107
Group 1 metals (Na+K), max.	mg/kg	5	EN 14108 / 14109
Group 2 metals (Ca+Mg), max.	mg/kg	5	EN 14538
Flash point, min.	°C	101	ISO 2719A / 3679
Cold filter plugging point, max. [2)]	°C	-44...+5	EN 116
Oxidation stability at 110°C, min.	h	6	EN 14112
Copper strip corrosion (3h at 50°C), max.	Rating	Class 1	ISO 2160
Acid number, max.	mg KOH/g	0.5	EN 14104
Iodine number, max.	g iodine / 100 g	120	EN 14111
Ester content, min	% mass	96.5	EN 14103
Linolenic acid methyl ester, max.	% mass	12	EN 14103
Polyunsaturated methyl esters, max.	% mass	1	
Methanol content, max.	% mass	0.2	EN 14110
Monoglyceride content, max.	% mass	0.8	EN 14105
Diglyceride content, max.	% mass	0.2	EN 14105
Triglyceride content, max.	% mass	0.2	EN 14105
Free glycerol, max.	% mass	0.02	EN 14105 / 14106
Total glycerol, max.	% mass	0.25	EN 14105

Remarks:

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

6.1.4 Crude oil

The engine can be operated on crude oil, according to the specification below, without reduction in the rated output. Since crude oils exist in a wide range of qualities the crude oil feed system shall be designed on a case-by-case basis.

Table 6.5 Crude oil specification

Fuel property	Unit	Limit	Test method
Viscosity, before injection pumps, min.	cSt	2.0	
Viscosity, before injection pumps, max.	cSt	24.0	
Viscosity, max.	cSt/100°C cSt/50°C Redwood No.1 sec. at 100°F	55 700 7200	ISO 3104
Density, max.	kg/m³ at 15°C	991 /1010 1)	ISO 3675 or 12185
CCAI, max.		870	ISO 8217
Water before engine, max.	% volume	0.3	ISO 3733
Sulphur, max.	% mass	4.5	ISO 8754 or 14596
Ash, max.	% mass	0.15	ISO 6245
Vanadium, max.	mg/kg	600	ISO 14597 or IP 501 or 407
Sodium before engine, max.	mg/kg	30	ISO 10478
Aluminium + Silicon before engine, max.	mg/kg	15	ISO 10478 or IP 501 or 470
Calcium + Potassium + Magnesium before engine, max.	mg/kg	50	IP 501 or 500 for CA ISO 10478 for K and Mg
Carbon residue, max.	% mass	22	ISO 10370
Asphaltenes, max.	% mass	14	ASTM D 3279
Reid vapour pressure (RVP), max.	kPa at 37.8°C	65	ASTM D 323
Cloud point or Cold filter plugging point, max.	°C	60 2)	ISO 3015 IP 309
Total sediment potential, max.	% mass	0.1	ISO 10307-2
Hydrogen sulphide, max.	mg/kg	5	IP 399

Remarks:

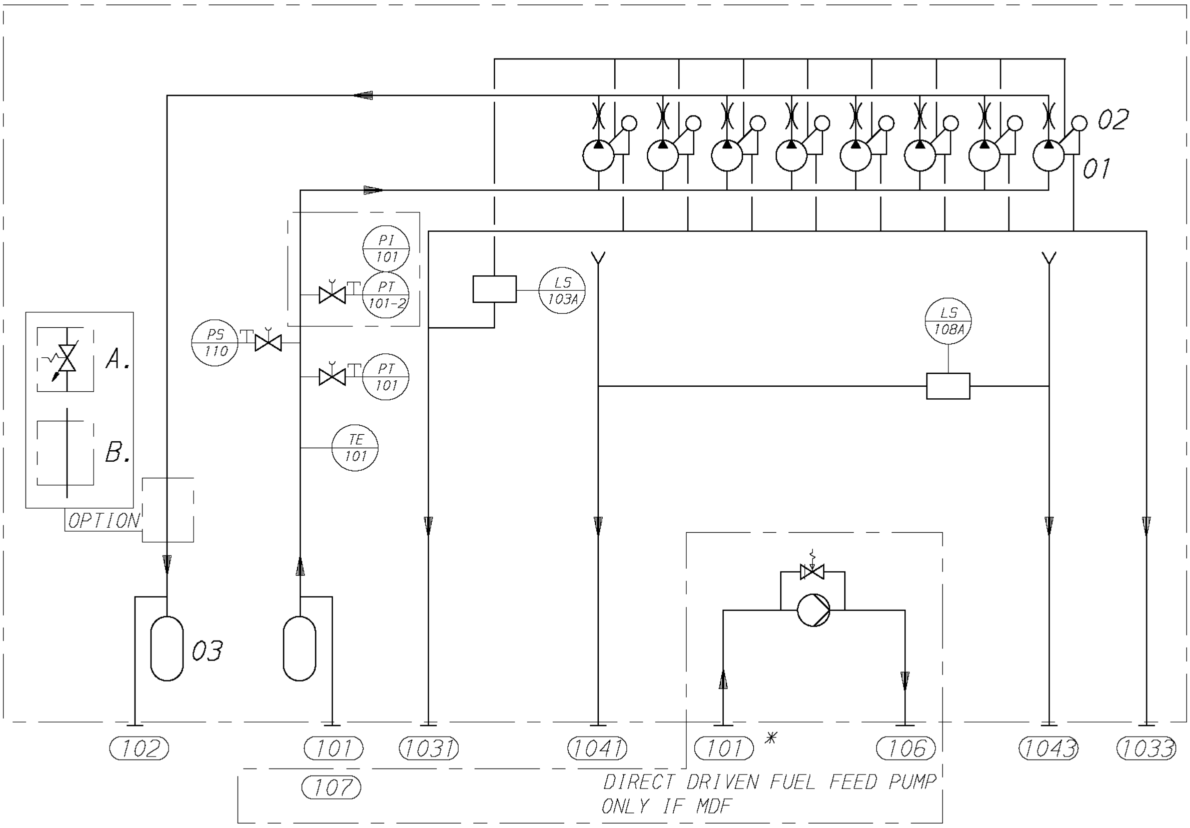
1) Max. 1010 kg/m³ at 15 °C, provided that the fuel treatment system can remove water and solids.

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

Lubricating oil, foreign substances or chemical waste, hazardous to the safety of the installation or detrimental to the performance of the engines, should not be contained in the fuel.

6.2 Internal fuel oil system

Figure 6.1 Internal fuel oil system, in-line engines (DAAE005307a)



System components:

01	Injection pump	Option A:	Pressure relief valve
02	Injection valve	Option B:	Without pressure relief valve
03	Pulse damper		

Sensors and indicators:

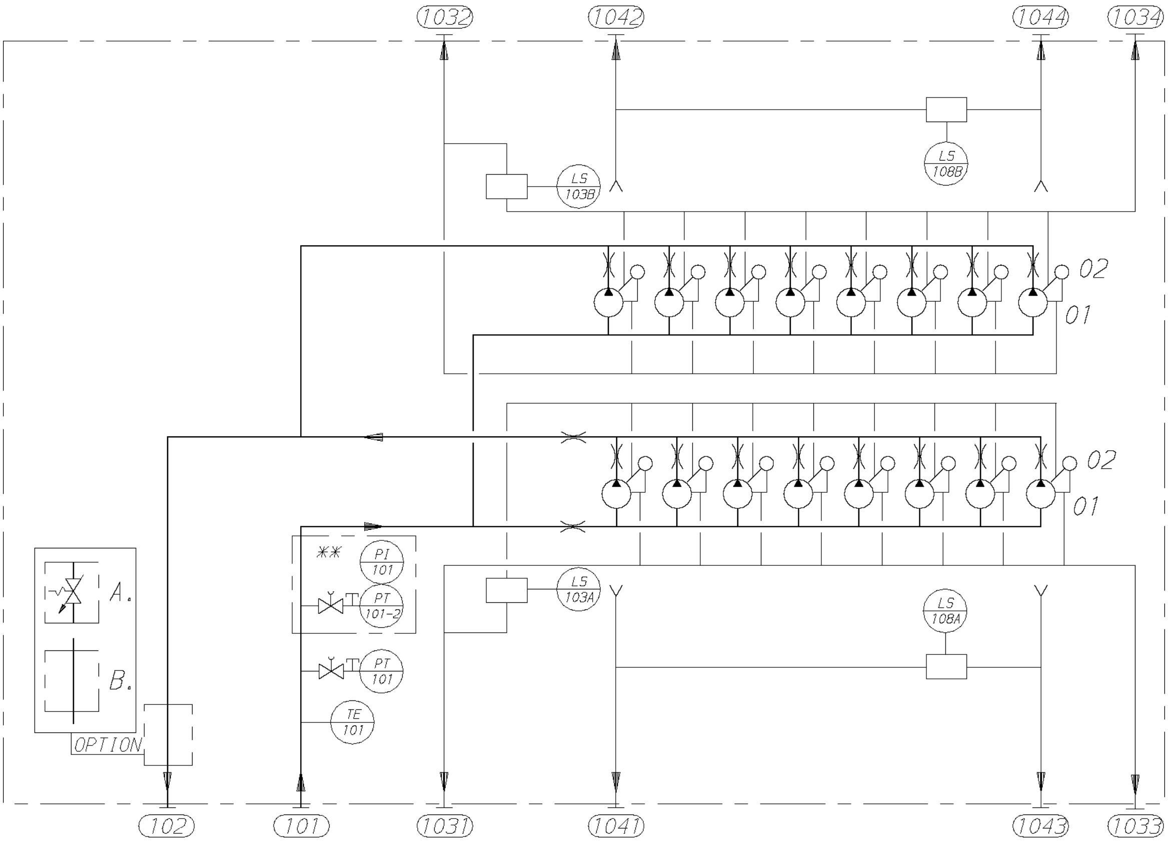
LS103A	Fuel oil leakage, injection pipe A-bank	PT101-2	Fuel oil pressure, engine inlet (if UNIC C1)
LS108A	Fuel oil leakage, dirty fuel A-bank	TE101	Fuel oil temperature, engine inlet
PS110	Fuel oil stand-by pump start (if stand-by)	PI101	Fuel oil pressure, engine inlet (if UNIC C1)
PT101	Fuel oil pressure, engine inlet		

Pipe connections:		Size	Pressure class	Standard
101	Fuel inlet	DN32 (DN40)*	PN40	ISO 7005-1
102	Fuel outlet	DN32	PN40	ISO 7005-1
1031	Clean fuel leakage, outlet	OD28		DIN 2353
1033	Clean fuel leakage, outlet	OD28		DIN 2353
1041	Dirty fuel leakage, outlet	OD18		DIN 2353
1043	Dirty fuel leakage, outlet	OD28		DIN 2353
106	Fuel to external filter	DN32	PN40	ISO 7005-1
107	Fuel from external filter	DN32	PN40	ISO 7005-1

Notes:

* DN40 if engine driven fuel feed pump

Figure 6.2 Internal fuel oil system, V-engines (DAAE005308c)



System components:

01	Injection pump	Option A:	Pressure relief valve
02	Injection valve	Option B:	Without pressure relief valve

Sensors and indicators:

LS103A,B	Fuel oil leakage, injection pipe A-, B-bank	PT101-2	Fuel oil pressure, engine inlet (if UNIC C1)
LS108A,B	Fuel oil leakage, dirty fuel A-, B-bank	TE101	Fuel oil temperature, engine inlet
PT101	Fuel oil pressure, engine inlet	PI101	Fuel oil pressure, engine inlet (if UNIC C1)

Pipe connections:		Size	Pressure class	Standard
101	Fuel inlet	DN32	PN40	ISO 7005-1
102	Fuel outlet	DN32	PN40	ISO 7005-1
1031,32	Clean fuel leakage, outlet	OD28		DIN 2353
1033,34	Clean fuel leakage, outlet	OD28		DIN 2353
1041,42	Dirty fuel leakage, outlet	OD18		DIN 2353
1043,44	Dirty fuel leakage, outlet	OD28		DIN 2353

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

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.

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

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

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

6.3.1 Fuel heating requirements HFO

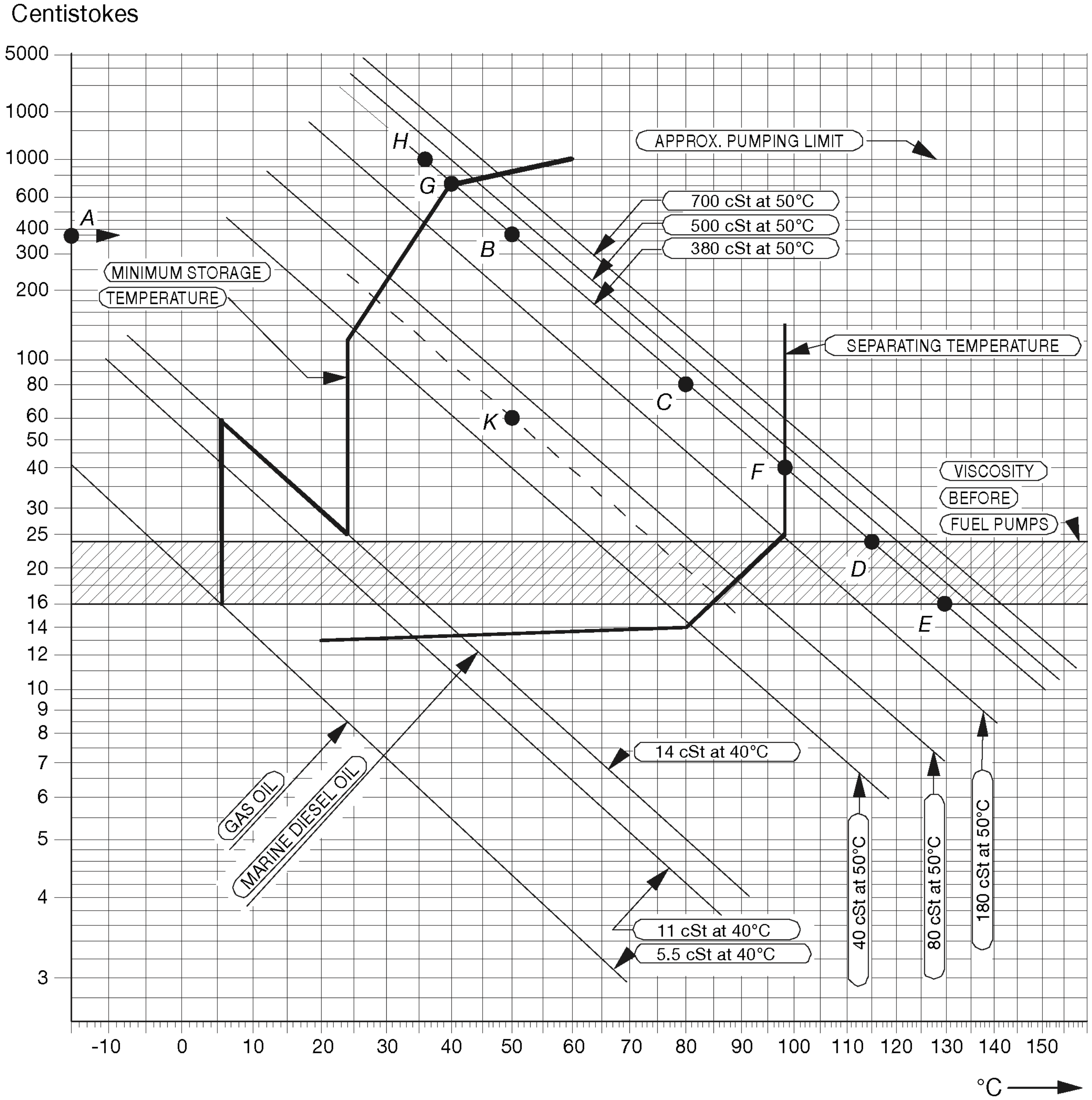
Heating is required for:

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

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

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

Figure 6.3 Fuel oil viscosity-temperature diagram for determining the pre-heating temperatures of fuel oils (4V92G0071b)



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

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

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

6.3.2 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

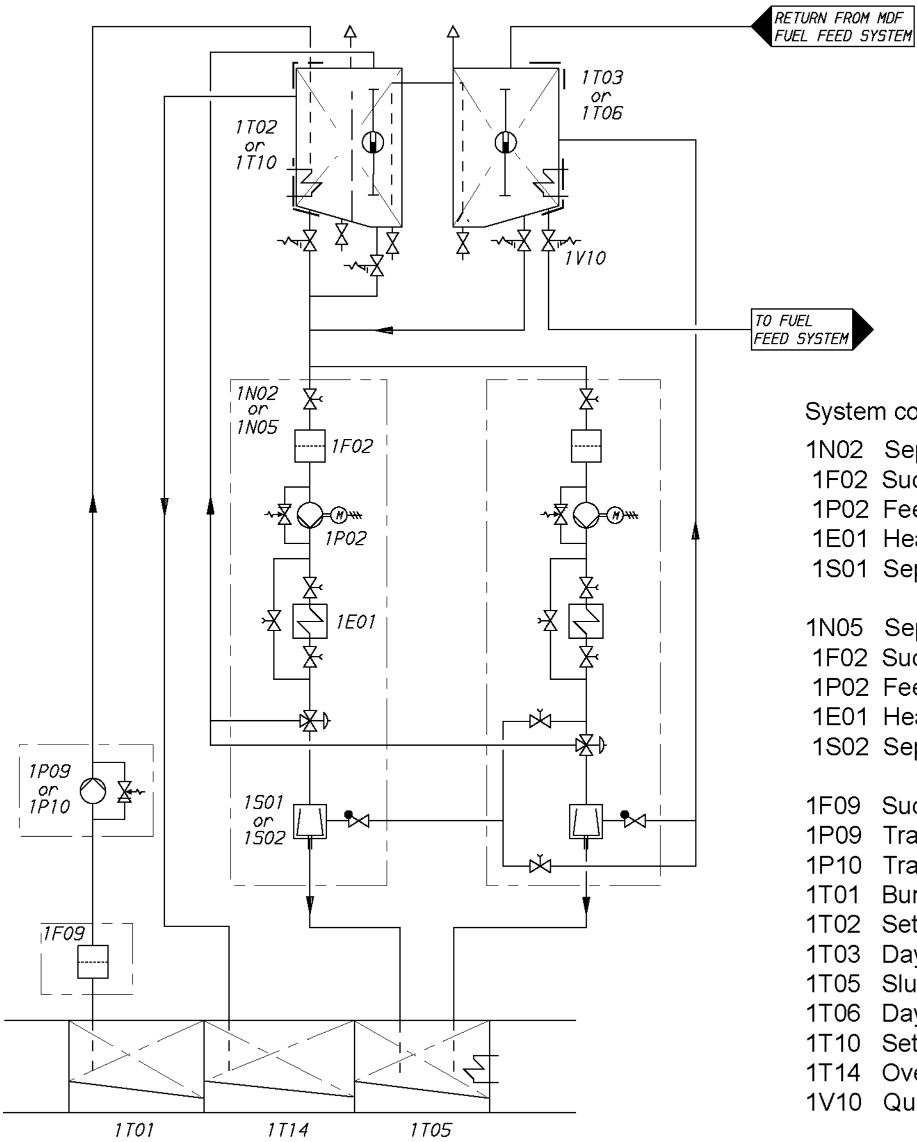
Separator unit (1N02/1N05)

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 (3V76F6626d)



System components:

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

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

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

Separator feed pumps (1P02)

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

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

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

Separator pre-heater (1E01)

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

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

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

The required minimum capacity of the heater is:

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

where:

P = heater capacity [kW]

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

ΔT = temperature rise in heater [°C]

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

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

Separator (1S01/1S02)

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

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

where:

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

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

ρ = density of the fuel [kg/m^3]

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

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

Sample valves must be placed before and after the separator.

MDF separator in HFO installations (1S02)

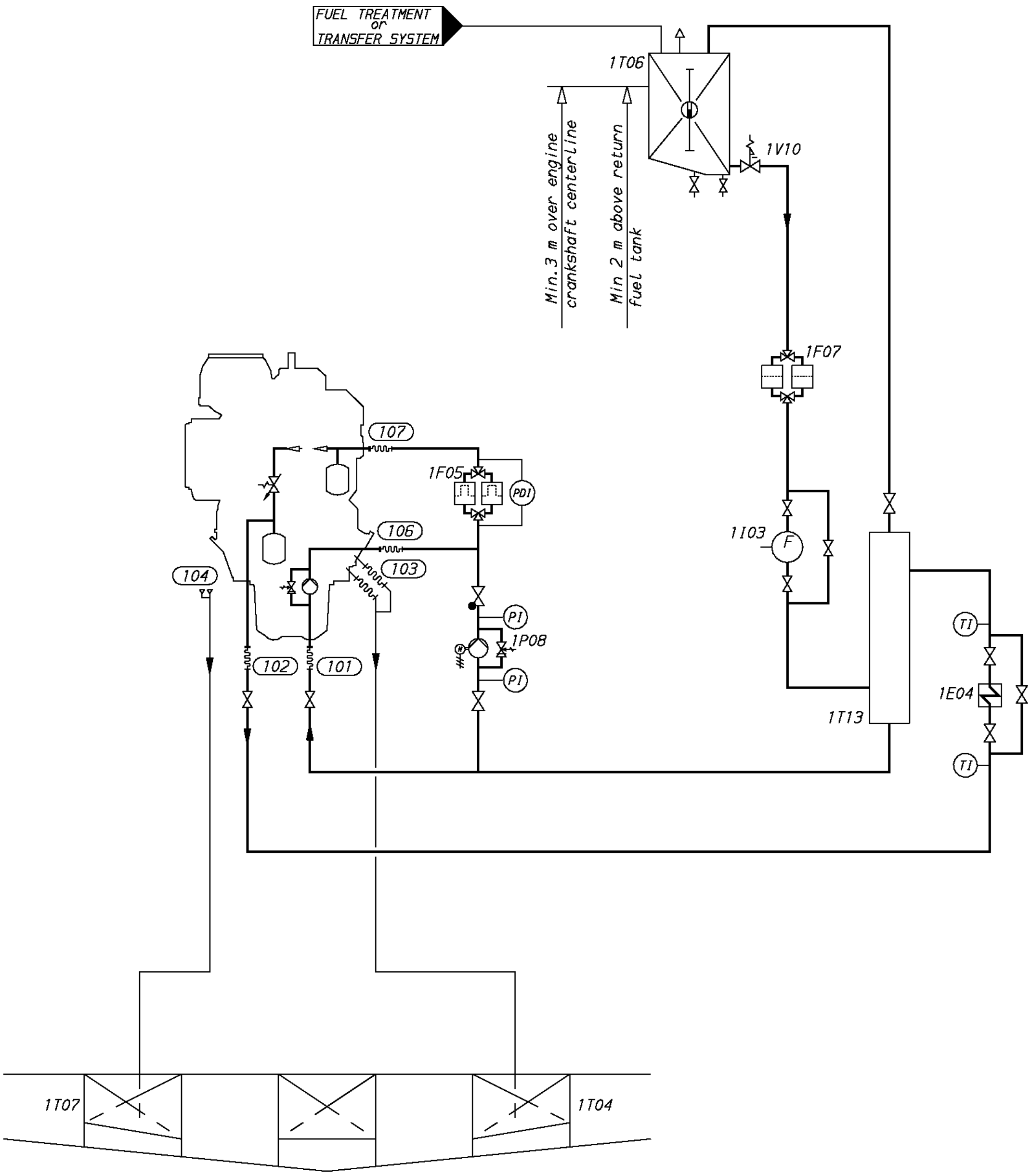
A separator for MDF is recommended also for installations operating primarily on HFO. The MDF separator can be a smaller size dedicated MDF separator, or a stand-by HFO separator used for MDF.

Sludge tank (1T05)

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

6.3.4 Fuel feed system - MDF installations

Figure 6.5 Typical example of fuel oil system (MDF) with engine driven pump (3V76F6629d)



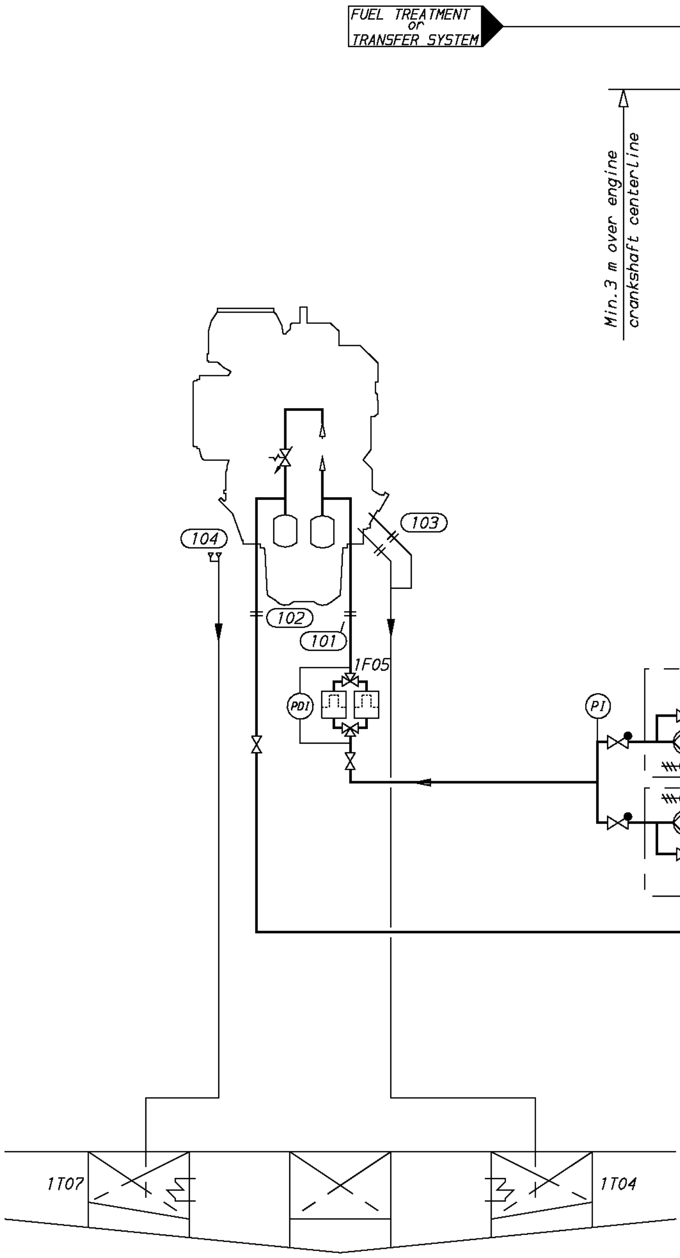
System components

1E04	Cooler (MDF)
1F05	Fine filter (MDF)
1F07	Suction strainer (MDF)
1I03	Flow meter (MDF)
1P08	Stand-by pump (MDF)
1T04	Leak fuel tank (clean fuel)
1T06	Day tank (MDF)
1T07	Leak fuel tank (dirty fuel)
1T13	Return fuel tank
1V10	Quick closing valve (fuel oil tank)

Pipe connections

101	Fuel inlet
102	Fuel outlet
103	Leak fuel drain, clean fuel
104	Leak fuel drain, dirty fuel
106	Fuel to external filter
107	Fuel from external filter

Figure 6.6 Typical example of fuel oil system (MDF) without engine driven pump (3V76F6116c)



System components		Pipe connections	
1E04	Cooler (MDF)	101	Fuel inlet
1F05	Fine filter (MDF)	102	Fuel outlet
1F07	Suction strainer (MDF)		
1I03	Flowmeter (MDF)	103	Leak fuel drain, clean fuel
1P03	Circulation pump (MDF)	104	Leak fuel drain, dirty fuel
1T04	Leak fuel tank (clean fuel)		
1T06	Day tank (MDF)		
1T07	Leak fuel tank (dirty fuel)		
1T13	Return fuel tank		
1V10	Quick closing valve (fuel oil tank)		

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

Circulation pump, MDF (1P03)

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

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

Stand-by pump, MDF (1P08)

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

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

Flow meter, MDF (1I03)

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

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

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

Fine filter, MDF (1F05)

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

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

Design data:	
Fuel viscosity	according to fuel specifications
Design temperature	50°C
Design flow	Larger than feed/circulation pump capacity

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

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

MDF cooler (1E04)

The fuel viscosity may not drop below the minimum value stated in *Technical data*. When operating on MDF, the practical consequence is that the fuel oil inlet temperature must be kept below 45°C. Very light fuel grades may require even lower temperature.

Sustained operation on MDF usually requires a fuel oil cooler. The cooler is to be installed in the return line after the engine(s). LT-water is normally used as cooling medium.

If MDF viscosity in day tank exceeds stated minimum viscosity limit then it is recommended to install an MDF cooler into the engine fuel supply line in order to have reliable viscosity control.

Design data:	
Heat to be dissipated	2.5 kW/cyl
Max. pressure drop, fuel oil	80 kPa (0.8 bar)
Max. pressure drop, water	60 kPa (0.6 bar)
Margin (heat rate, fouling)	min. 15%
Design temperature MDF/HFO installation	50/150°C

Return fuel tank (1T13)

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

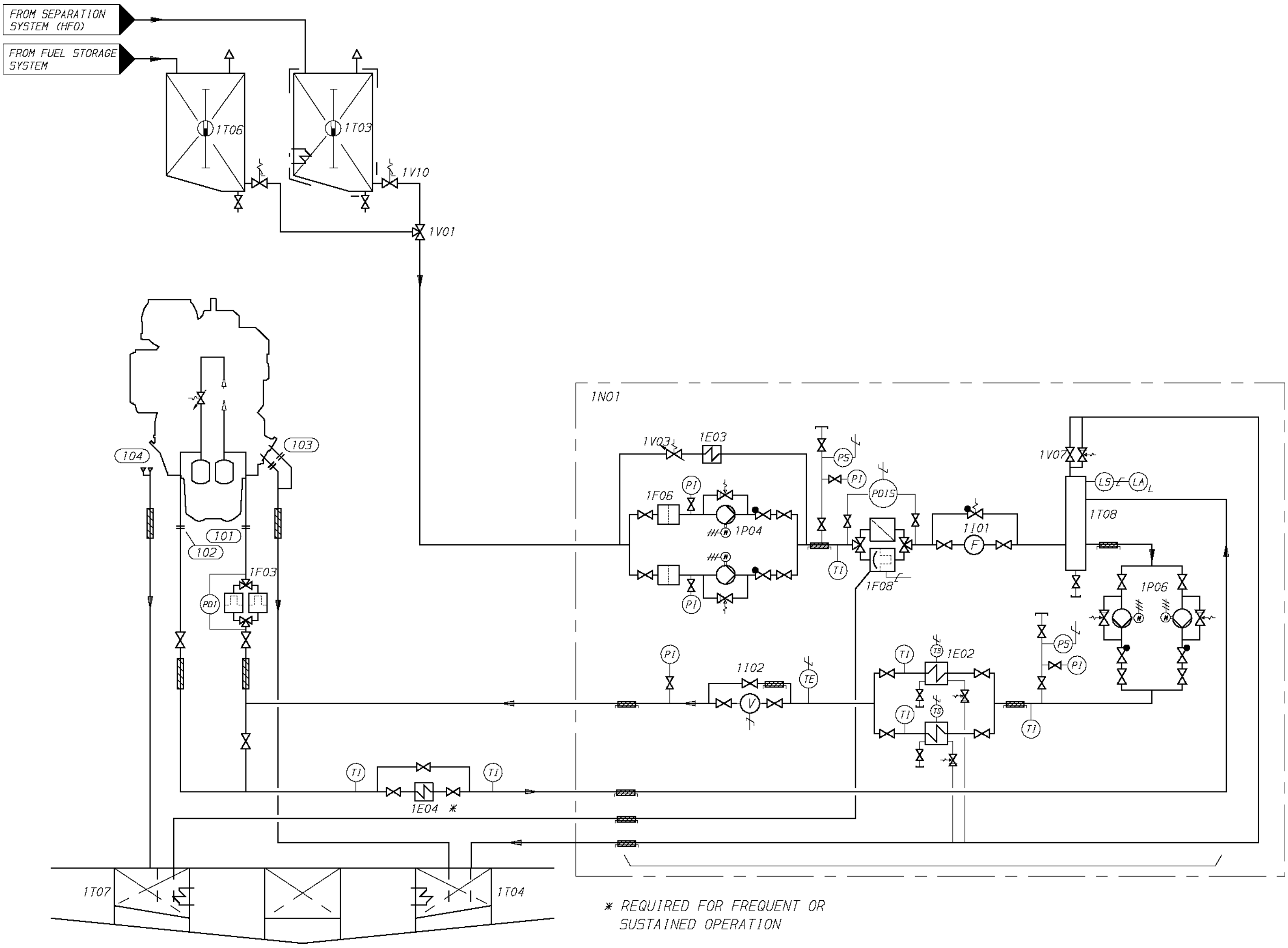
Black out start

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

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

6.3.5 Fuel feed system - HFO installations

Figure 6.7 Example of fuel oil system (HFO) single engine installation (3V76F6627b)



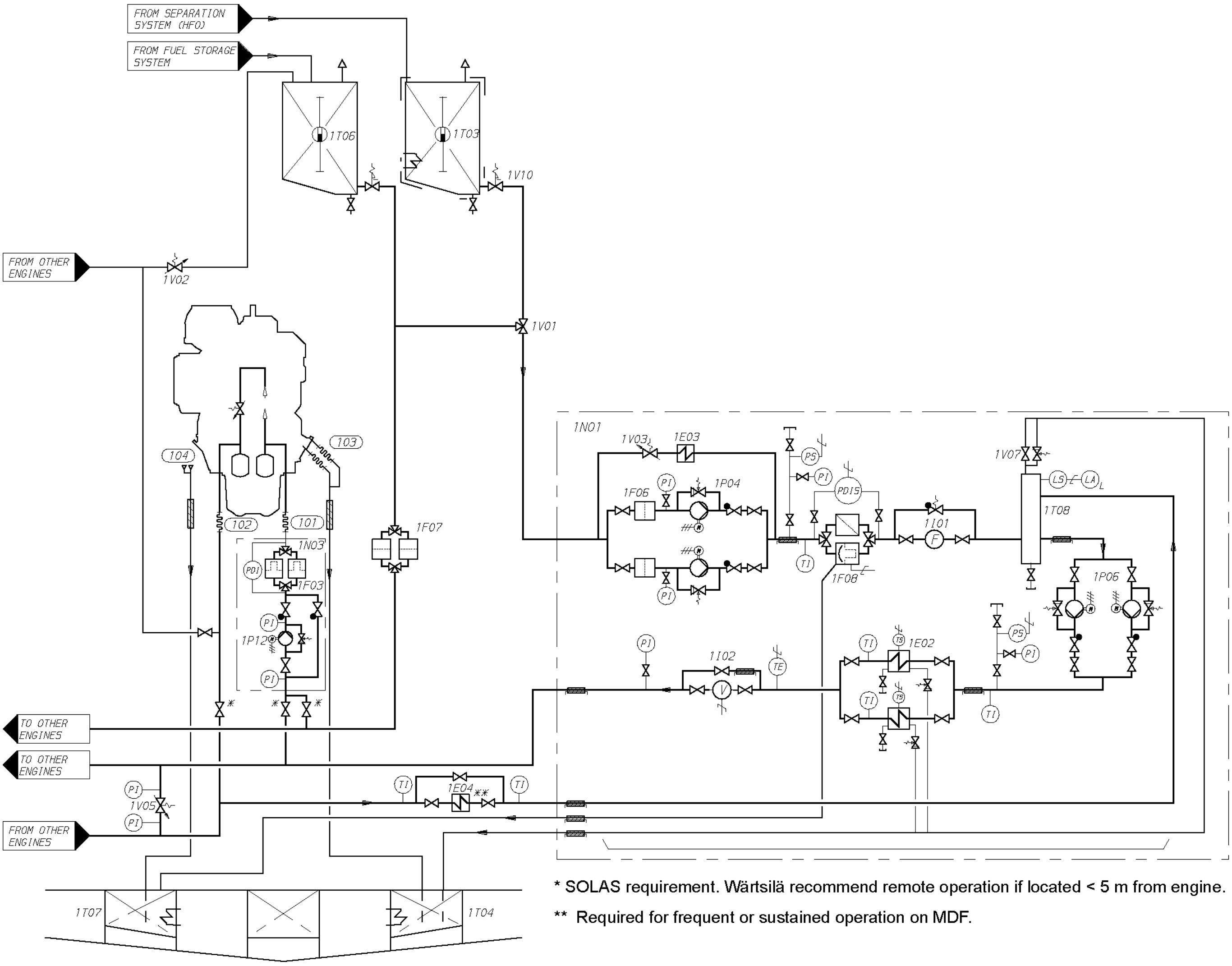
System components:

1E02	Heater (booster unit)	1P06	Circulation pump (booster unit)
1E03	Cooler (booster unit)	1T03	Day tank (HFO)
1E04	Cooler (MDF)	1T04	Leak fuel tank (clean fuel)
1F03	Safety filter (HFO)	1T06	Day tank (MDF)
1F06	Suction filter (booster unit)	1T07	Leak fuel tank (dirty fuel)
1F08	Automatic filter (booster unit)	1T08	De-aeration tank (booster unit)
1I01	Flow meter (booster unit)	1V01	Changeover valve
1I02	Viscosity meter (booster unit)	1V03	Pressure control valve (booster unit)
1N01	Feeder/booster unit	1V07	Venting valve (booster unit)
1P04	Fuel feed pump (booster unit)	1V10	Quick closing valve (fuel oil tank)

Pipe connections:

101	Fuel inlet	1031...34	Leak fuel drain, clean fuel
102	Fuel outlet	1041...44	Leak fuel drain, dirty fuel

Figure 6.8 Example of fuel oil system (HFO) multiple engine installation (3V76F6628d)



* SOLAS requirement. Wärtsilä recommend remote operation if located < 5 m from engine.

** Required for frequent or sustained operation on MDF.

System components:

1E02	Heater (booster unit)	1P12	Circulation pump (HFO/MDF)
1E03	Cooler (booster unit)	1T03	Day tank (HFO)
1E04	Cooler (MDF)	1T04	Leak fuel tank (clean fuel)
1F03	Safety filter (HFO)	1T06	Day tank (MDF)
1F06	Suction filter (booster unit)	1T07	Leak fuel tank (dirty fuel)
1F07	Suction strainer (MDF)	1T08	De-aeration tank (booster unit)
1F08	Automatic filter (booster unit)	1V01	Changeover valve
1I01	Flow meter (booster unit)	1V02	Pressure control valve (MDF)
1I02	Viscosity meter (booster unit)	1V03	Pressure control valve (booster unit)
1N01	Feeder/booster unit	1V05	Overflow valve (HFO/MDF)
1N03	Pump and filter unit (HFO/MDF)	1V07	Venting valve (booster unit)
1P04	Fuel feed pump (booster unit)	1V10	Quick closing valve (fuel oil tank)
1P06	Circulation pump (booster unit)		

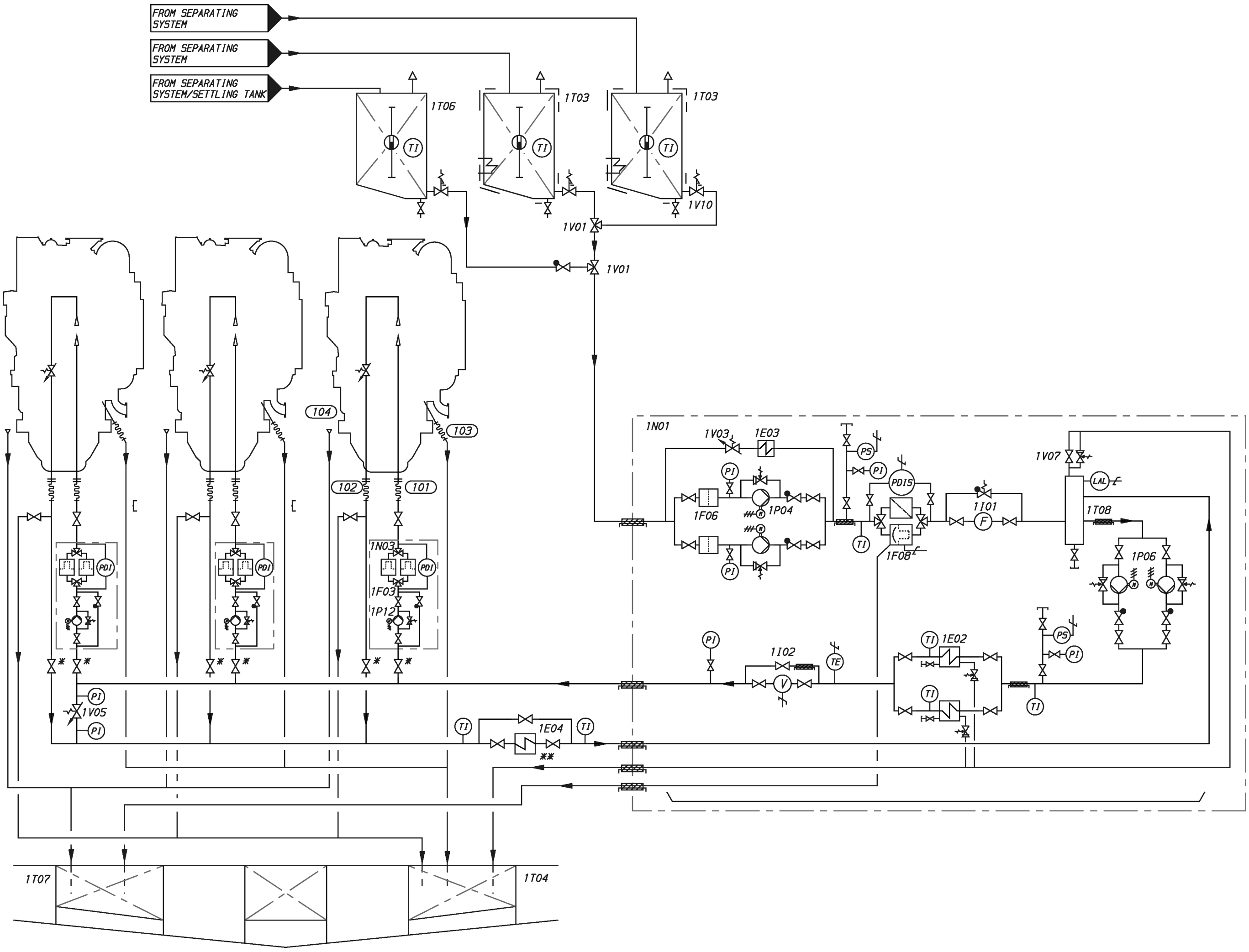
Pipe connections:

101	Fuel inlet	1031...34	Leak fuel drain, clean fuel

Pipe connections:

102	Fuel outlet	1041...44	Leak fuel drain, dirty fuel

Figure 6.9 Example of fuel oil system (HFO) multiple engine installation (DAAE057999C)



* SOLAS requirement. Wärtsilä recommend remote operation of located < 5m from engine.

** Required for frequent or sustained operation on MDF.

System components:

1E02	Heater (booster unit)	1P06	Circulation pump (booster unit)
1E03	Cooler (booster unit)	1P12	Circulation pump (HFO/MDF)
1E04	Cooler (MDF)	1T03	Day tank (HFO)
1F03	Safety filter (HFO)	1T04	Leak fuel tank (clean fuel)
1F06	Suction filter (booster unit)	1T06	Day tank (MDF)
1F07	Suction strainer (MDF)	1T07	Leak fuel tank (dirty fuel)
1F08	Automatic filter (booster unit)	1T08	De-aeration tank (booster unit)
1I01	Flow meter (booster unit)	1V01	Changeover valve
1I02	Viscosity meter (booster unit)	1V03	Pressure control valve (booster unit)
1N01	Feeder/booster unit	1V05	Overflow valve (HFO/MDF)
1N03	Pump and filter unit (HFO/MDF)	1V07	Venting valve (booster unit)
1P04	Fuel feed pump (booster unit)	1V10	Quick closing valve (fuel oil tank)

Pipe connections:

101	Fuel inlet	1031...34	Leak fuel drain, clean fuel
102	Fuel outlet	1041...44	Leak fuel drain, dirty fuel

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

Starting and stopping

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

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

Changeover from HFO to MDF

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

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

Number of engines in the same system

When the fuel feed unit serves Wärtsilä 32 engines only, maximum one engine should be connected to the same fuel feed circuit, unless individual circulating pumps before each engine are installed.

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

In addition the following guidelines apply:

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

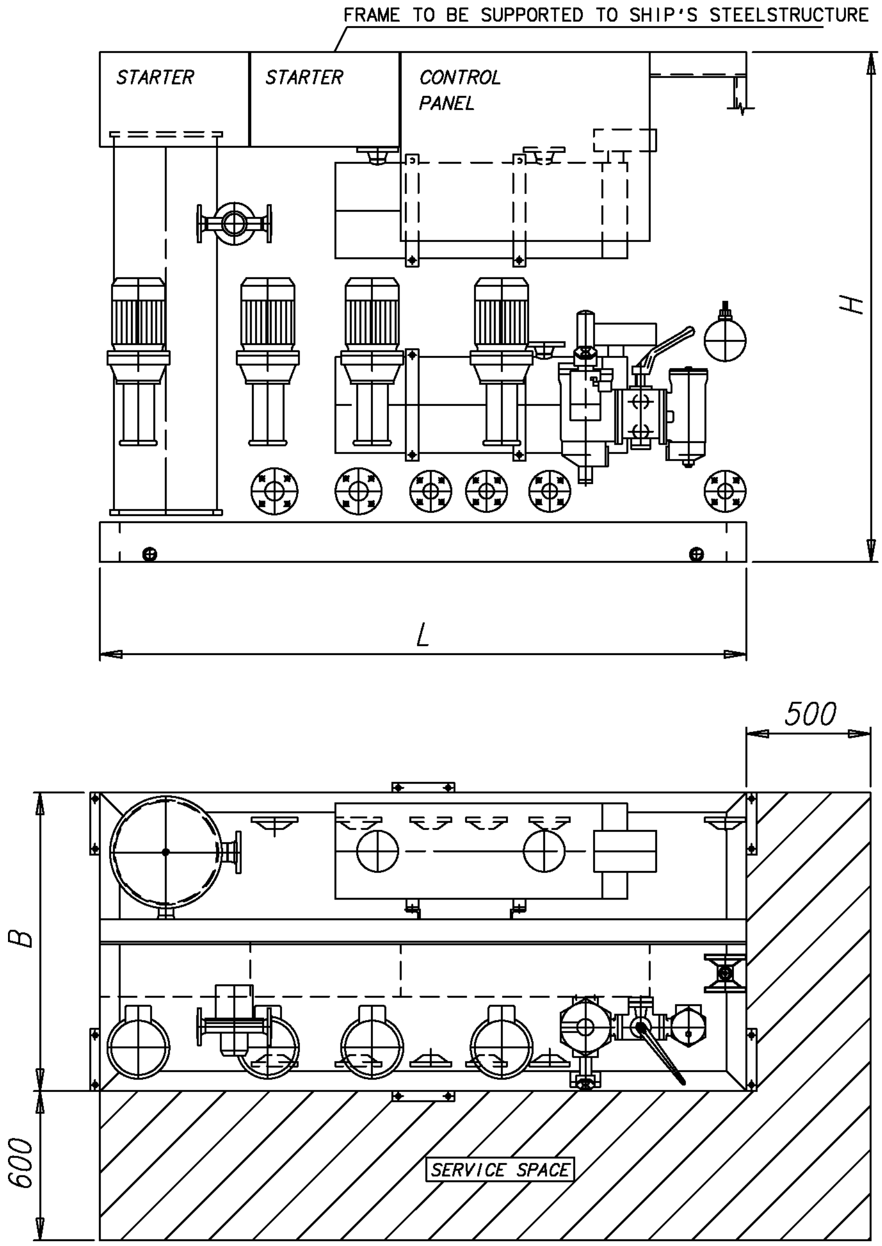
Feeder/booster unit (1N01)

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

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

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

Figure 6.10 Feeder/booster unit, example (DAAE006659)



	H	L	B
STEAM	1800	2500	1100
ELECTRICAL	2050	2600	1200

All dimensions in mm.

Fuel feed pump, booster unit (1P04)

The feed pump maintains the pressure in the fuel feed system. It is recommended to use a screw pump as feed pump. The capacity of the feed pump must be sufficient to prevent pressure drop during flushing of the automatic filter.

A suction strainer with a fineness of 0.5 mm should be installed before each pump. There must be a positive static pressure of about 30 kPa on the suction side of the pump.

Design data:

Capacity	Total consumption of the connected engines added with the flush quantity of the automatic filter (1F08)
Design pressure	1.6 MPa (16 bar)
Max. total pressure (safety valve)	0.7 MPa (7 bar)
Design temperature	100°C
Viscosity for dimensioning of electric motor	1000 cSt

Pressure control valve, booster unit (1V03)

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

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

Automatic filter, booster unit (1F08)

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

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

Flow meter, booster unit (1I01)

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

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

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

De-aeration tank, booster unit (1T08)

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

Circulation pump, booster unit (1P06)

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

When more than one engine is connected to the same feeder/booster unit, individual circulation pumps (1P12) must be installed before each engine.

Design data:

Capacity:	
- without circulation pumps (1P12)	5 x the total consumption of the connected engines
- with circulation pumps (1P12)	15% more than total capacity of all circulation pumps
Design pressure	1.6 MPa (16 bar)
Max. total pressure (safety valve)	1.0 MPa (10 bar)
Design temperature	150°C
Viscosity for dimensioning of electric motor	500 cSt

Heater, booster unit (1E02)

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

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

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

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

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

where:

P =	heater capacity (kW)
Q =	total fuel consumption at full output + 15% margin [l/h]
ΔT =	temperature rise in heater [°C]

Viscosimeter, booster unit (1I02)

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

Design data:

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

Pump and filter unit (1N03)

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

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

Circulation pump (1P12)

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

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

Design data:	
Capacity	5 x the fuel consumption of the engine
Design pressure	1.6 MPa (16 bar)
Max. total pressure (safety valve)	1.0 MPa (10 bar)
Design temperature	150°C
Pressure for dimensioning of electric motor (ΔP):	
- if MDF is fed directly from day tank	0.7 MPa (7 bar)
- if all fuel is fed through feeder/booster unit	0.3 MPa (3 bar)
Viscosity for dimensioning of electric motor	500 cSt

Safety filter (1F03)

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

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

Overflow valve, HFO (1V05)

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

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

Design data:	
Capacity	Equal to circulation pump (1P06)
Design pressure	1.6 MPa (16 bar)
Design temperature	150°C
Set-point (Δp)	0.2...0.7 MPa (2...7 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
D	CRUDE OIL (CRO)		30...55
F	LIQUID BIO FUEL (LBF)		10...20

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.

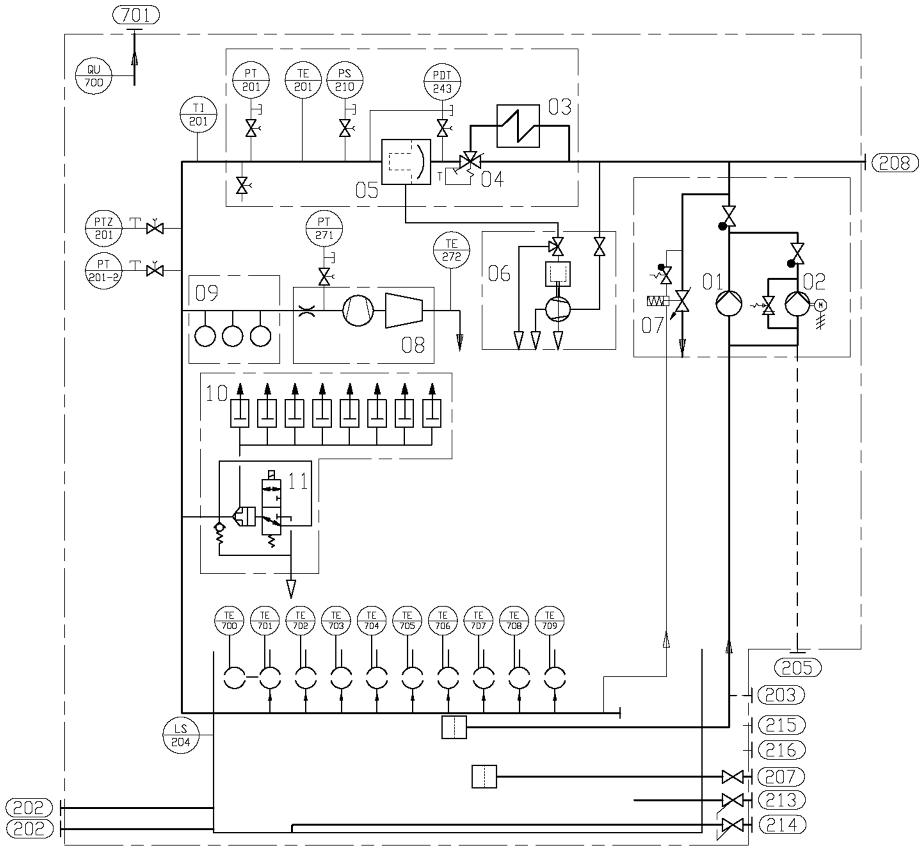
7.1.3 Oil in turning device

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 (DAAE005309d)



System components:

01	Lubricating oil main pump	07	Pressure control valve
02	Prelubricating oil pump	08	Turbocharger
03	Lubricating oil cooler	09	Camshaft bearings and cylinder head lubrication
04	Thermostatic valve	10	Guide block (if VIC)
05	Automatic filter	11	Control valve (if VIC)
06	Centrifugal filter		

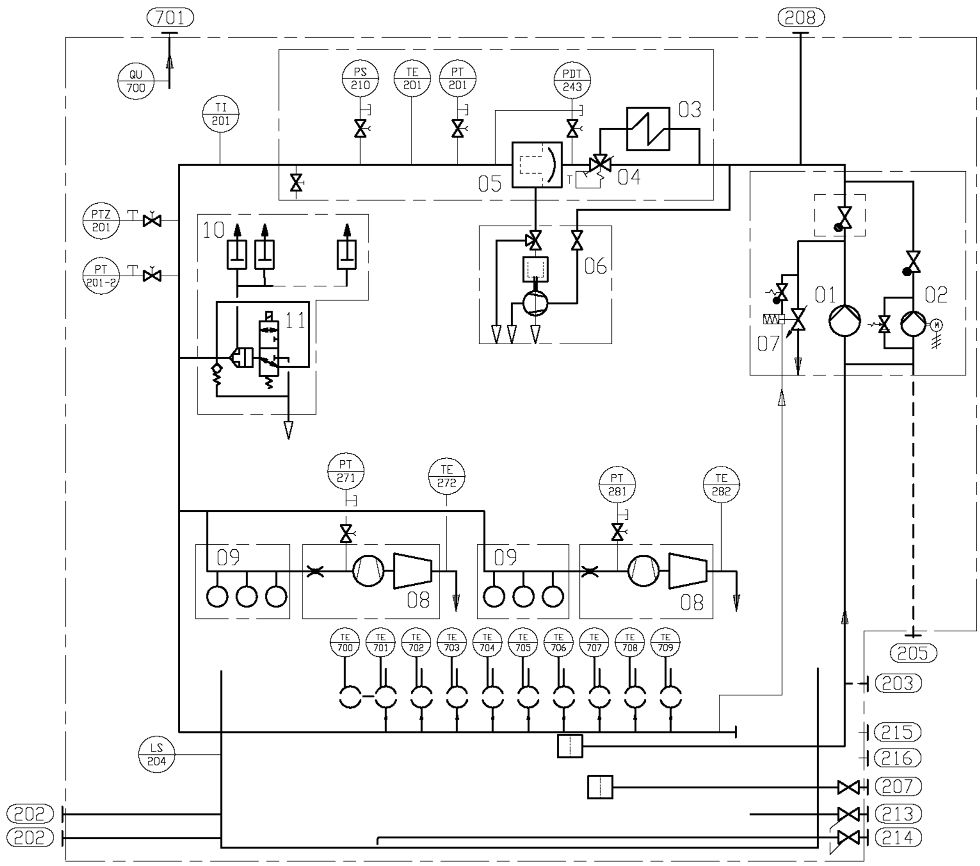
Sensors and indicators:

LS204	Lubricating oil low level, wet sump	PTZ201	Lubricating oil pressure, engine inlet
PDT243	Lubricating oil filter pressure difference	TE201	Lubricating oil temperature, engine inlet
PS210	Lubricating oil stand-by pump start (if stand-by)	TE272	Lubricating oil temperature, TC A outlet
PT201	Lubricating oil pressure, engine inlet	TE70_	Main bearing temperature
PT201-2	Lubricating oil pressure, engine inlet (if UNIC C1)	TI201	Lubricating oil temperature, engine inlet (if ME)
PT271	Lubricating oil pressure, TC A inlet (not if TPS61 turboc.)	QU700	Oil mist detector

Pipe connections:		Size	Pressure class	Standard
202	Lubricating oil outlet (dry sump)	DN150	PN16	ISO 7005-1
203	Lubricating oil to engine driven pump (dry sump)	DN200	PN16	ISO 7005-1
205	Lubricating oil to priming pump (dry sump)	DN80	PN16	ISO 7005-1

Pipe connections:		Size	Pressure class	Standard
207	Lubricating oil to el. driven pump (stand-by pump)	DN150	PN16	ISO 7005-1
208	Lubricating oil from el. driven pump (stand-by pump)	DN100	PN16	ISO 7005-1
213	Lubricating oil from separator and filling (wet sump)	DN40	PN40	ISO 7005-1
214	Lubricating oil to separator and drain (wet sump)	DN40	PN40	ISO 7005-1
215	Lubricating oil filling (wet sump)	DN40		ISO 7005-1
216	Lubricating oil drain (wet sump)	M22 x 1.5		
701	Crankcase ventilation	DN100	PN16	ISO 7005-1

Figure 7.2 Internal lubricating oil system, V-engines (DAAE005310d)



System components:

01	Lubricating oil main pump	07	Pressure control valve
02	Prelubricating oil pump	08	Turbocharger
03	Lubricating oil cooler	09	Camshaft bearings and cylinder head lubrication
04	Thermostatic valve	10	Guide block (if VIC)
05	Automatic filter	11	Control valve (if VIC)
06	Centrifugal filter		

Sensors and indicators:

LS204	Lubricating oil level, wet sump, low	PTZ201	Lubricating oil pressure, engine inlet
PDT243	Lubricating oil filter pressure difference	TE201	Lubricating oil temperature, engine inlet

Sensors and indicators:

PS210	Lubricating oil stand-by pump start (if stand-by)	TE272	Lubricating oil temperature, TC A outlet
PT201	Lubricating oil pressure, engine inlet	TE282	Lubricating oil temperature, TC B outlet
PT201-2	Lube oil pressure, engine inlet (if UNIC C1)	TE70_	Main bearing temperature
PT271	Lubricating oil pressure, TC A inlet (not if TPS61 turboc.)	TI201	Lubricating oil temperature, engine inlet (if ME)
PT281	Lubricating oil pressure, TC B inlet (not if TPS61 turboc.)	QU700	Oil mist detector

Pipe connections:		Size	Pressure class	Standard
202	Lubricating oil outlet (dry sump)	DN150	PN16	ISO 7005-1
203	Lubricating oil to engine driven pump (dry sump)	DN250	PN16	ISO 7005-1
205	Lubricating oil to priming pump (dry sump)	DN125	PN16	ISO 7005-1
207	Lubricating oil to el. driven pump (stand-by pump)	DN200	PN16	ISO 7005-1
208	Lubricating oil from el. driven pump (stand-by pump)	DN125	PN16	ISO 7005-1
213	Lubricating oil from separator and filling (wet sump)	DN40	PN40	ISO 7005-1
214	Lubricating oil to separator and drain (wet sump)	DN40	PN40	ISO 7005-1
215	Lubricating oil filling (wet sump)	DN40		ISO 7005-1
216	Lubricating oil drain (wet sump)	M22 x 1.5		
701	Crankcase ventilation	DN125	PN16	ISO 7005-1

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

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

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

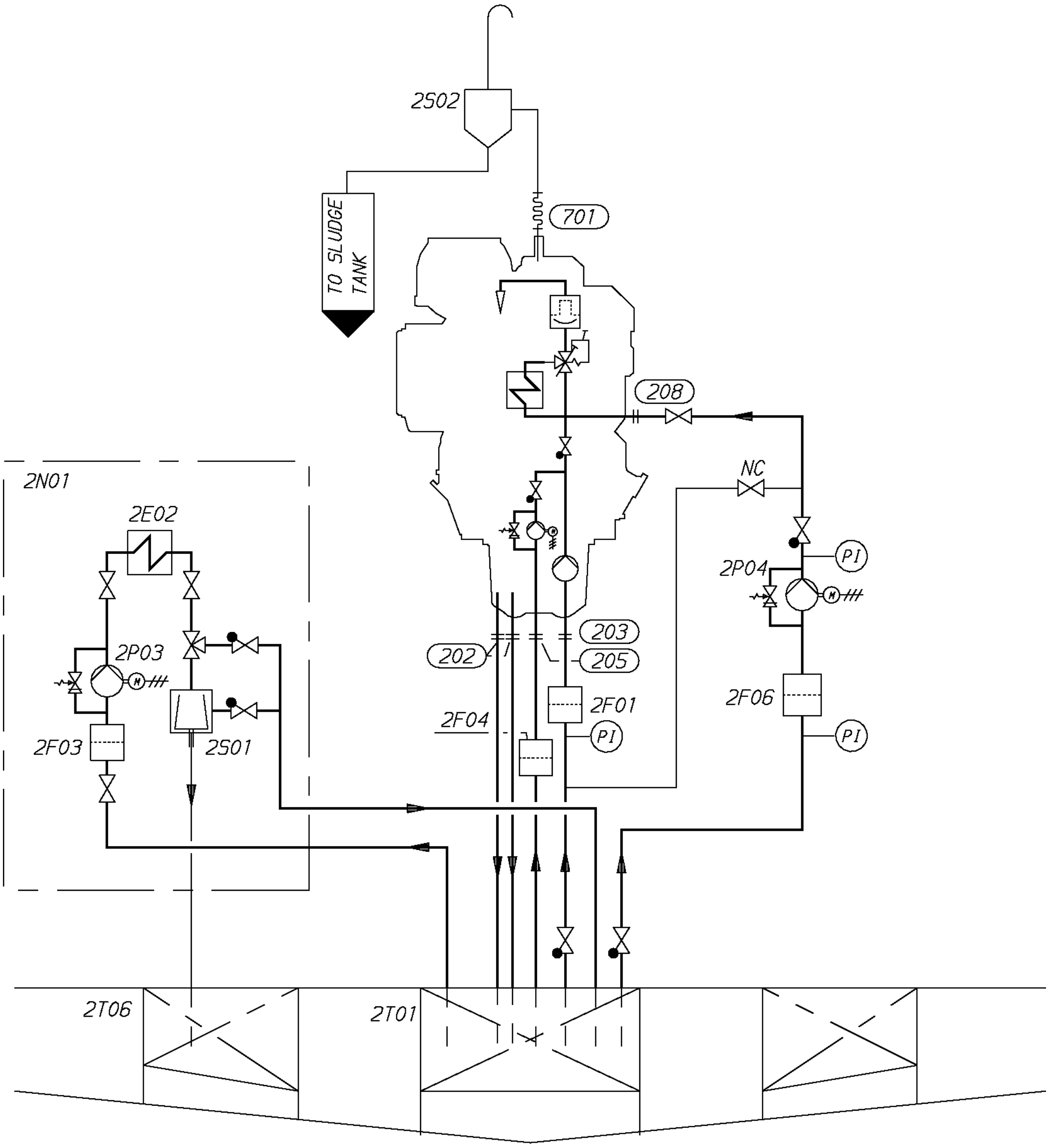
The lubricating oil module built on the engine consists of the lubricating oil cooler, thermostatic valve and automatic filter.

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

All dry sump engines are delivered with a running-in filter before each main bearing. These filters are to be removed after commissioning.

7.3 External lubricating oil system

Figure 7.3 Lubricating oil system, main engines (3V76E4562b)



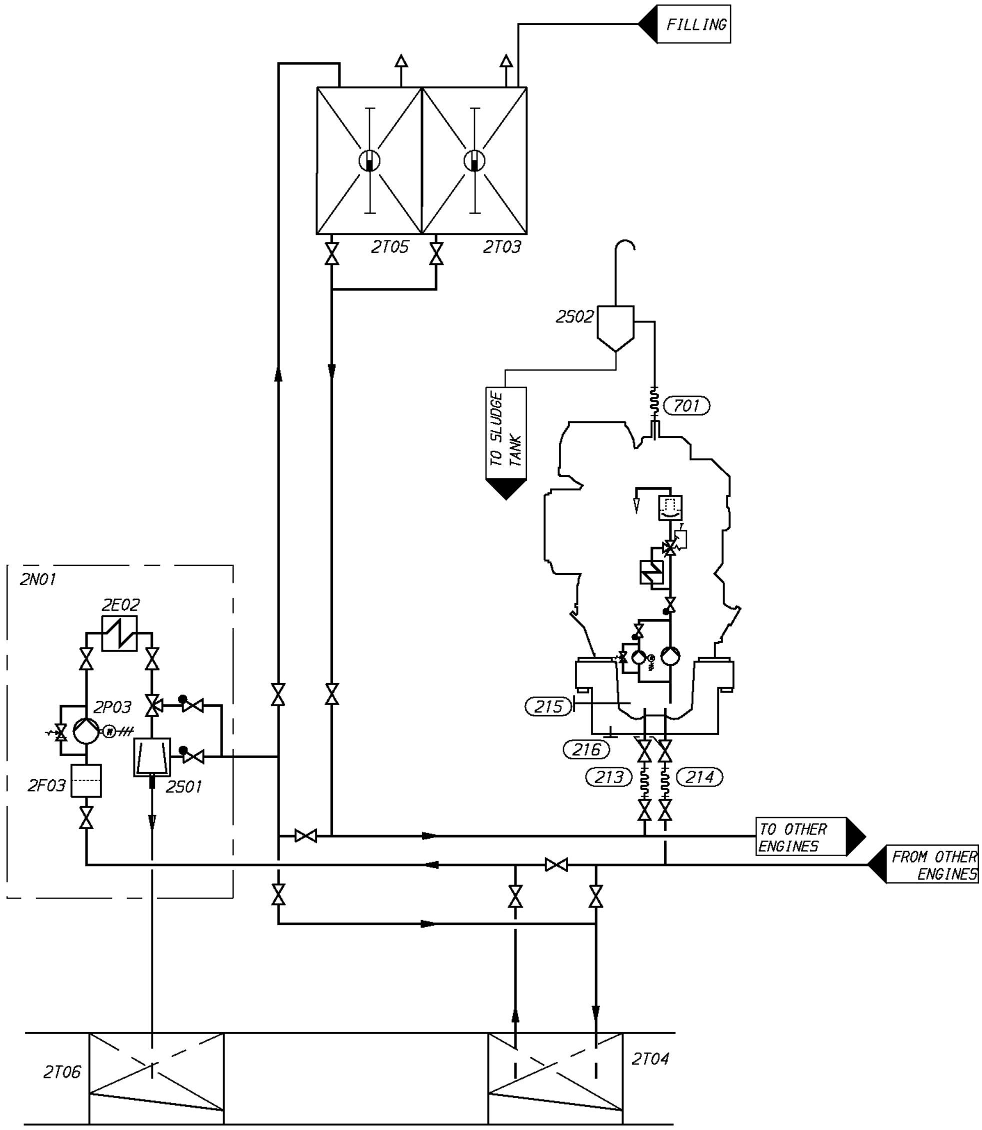
System components:

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

Pipe connections:

202	Lubricating oil outlet
203	Lubricating oil to engine driven pump
205	Lubricating oil to priming pump
208	Lubricating oil from electric driven pump
701	Crankcase air vent

Figure 7.4 Lubricating oil system, auxiliary engines (3V76E4563a)



System components:

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

Pipe connections:

213	Lubricating oil from separator and filling
214	Lubricating oil to separator and drain
215	Lubricating oil filling
216	Lubricating oil drain
701	Crankcase air vent

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.

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

Separators are usually supplied as pre-assembled units.

Typically lubricating oil separator units are equipped with:

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

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

Separator feed pump (2P03)

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

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

Separator preheater (2E02)

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

Recommended oil temperature after the heater is 95°C.

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

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

Separator (2S01)

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

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

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

where:

Q = volume flow [l/h]

P = engine output [kW]

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

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

Sludge tank (2T06)

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

Renovating oil tank (2T04)

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

Renovated oil tank (2T05)

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

7.3.2 System oil tank (2T01)

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

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

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

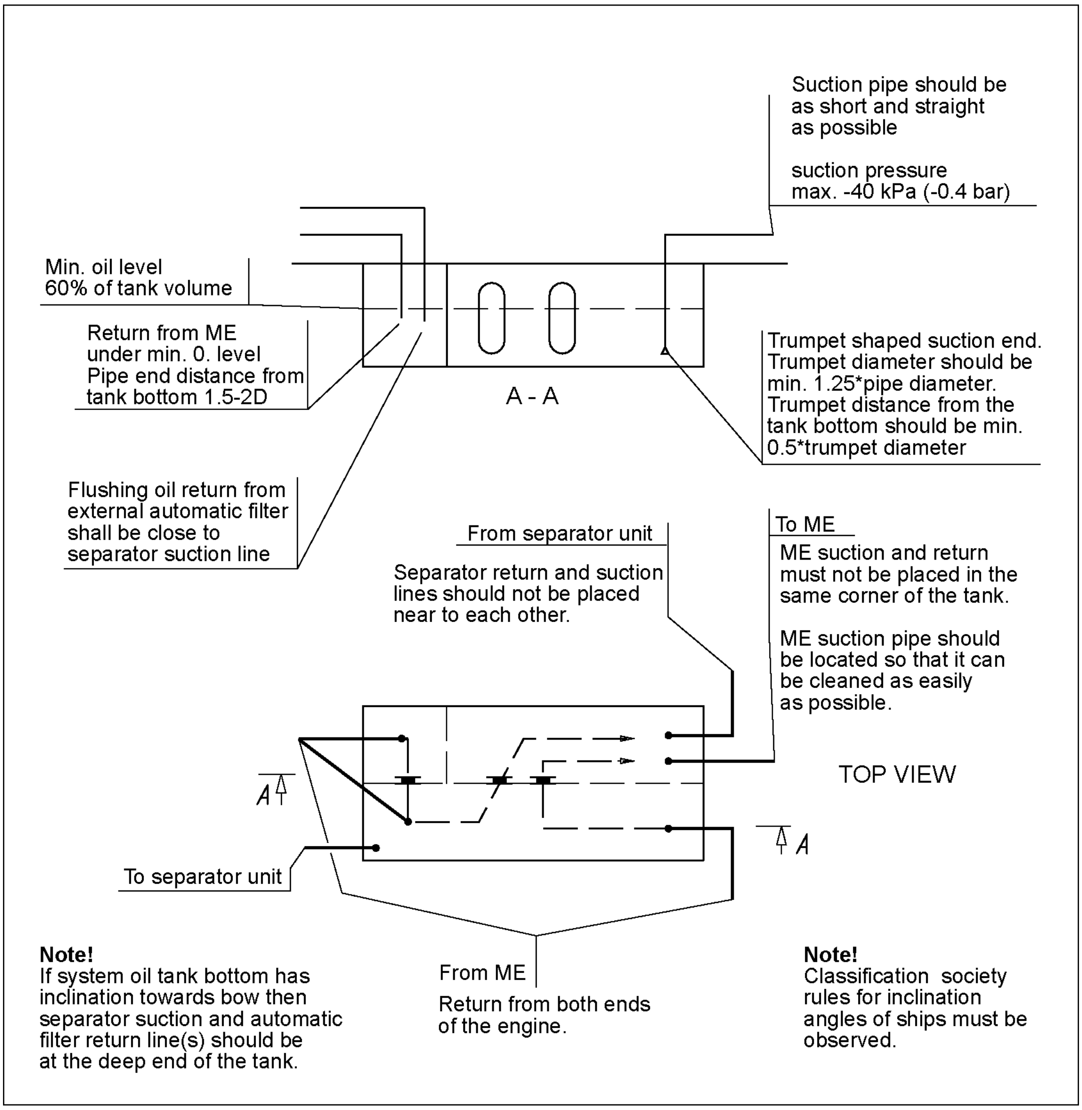
The suction pipe of the pump should have a trumpet shaped or conical inlet to minimise the pressure loss. For the same reason the suction pipe shall be as short and straight as possible and have a sufficient diameter. A pressure gauge shall be installed close to the inlet of the lubricating oil pump.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

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

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

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

Figure 7.5 Example of system oil tank arrangement (DAAE007020e)



Design data:

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

7.3.3 New oil tank (2T03)

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

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

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

Design data:

Fineness	0.5...1.0 mm

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

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

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

7.4 Crankcase ventilation system

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

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

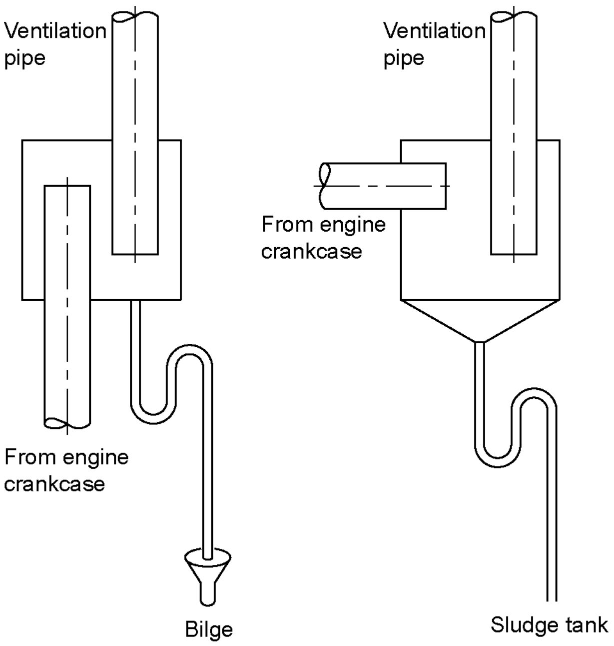
The diameter of the pipe shall be large enough to avoid excessive back pressure. Other possible equipment in the piping must also be designed and dimensioned to avoid excessive flow resistance.

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

The connection between engine and pipe is to be flexible.

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

Figure 7.6 Condensate trap (DAAE032780)



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

W L32: DN100
W V32: DN125

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

7.5 Flushing instructions

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

7.5.1 Piping and equipment built on the engine

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

7.5.2 External oil system

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

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

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

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

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

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

7.5.3 Type of flushing oil

Viscosity

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

Flushing with engine oil

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

Flushing with low viscosity flushing oil

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

Lubricating oil sample

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

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

8. Compressed Air System

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

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

8.1 Instrument air quality

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

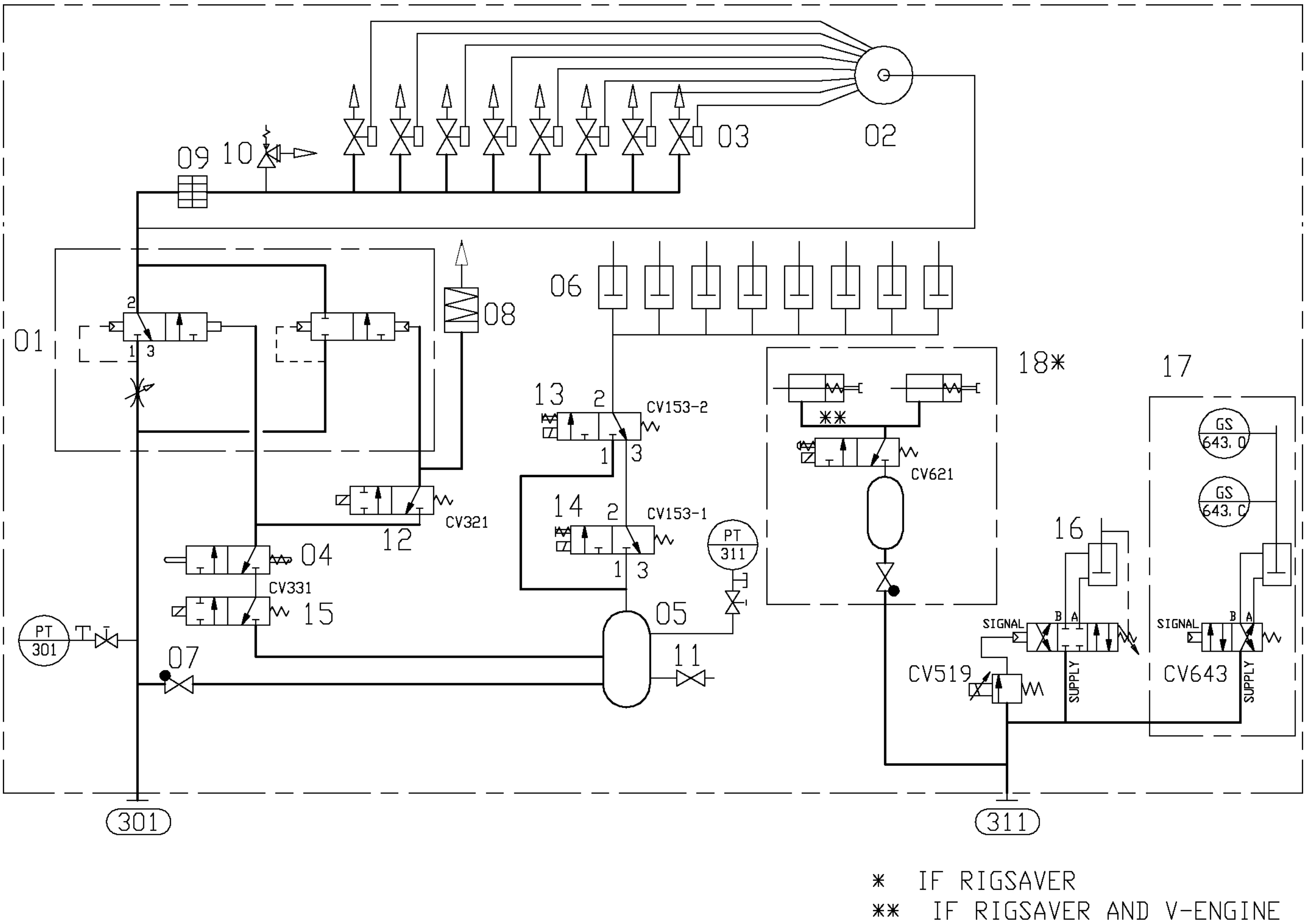
Instrument air specification:	
Design pressure	1 MPa (10 bar)
Nominal pressure	0.7 MPa (7 bar)
Dew point temperature	+3°C
Max. oil content	1 mg/m^3
Max. particle size	3 µm

8.2 Internal compressed air system

All engines, independent of cylinder number, are started by means of compressed air with a nominal pressure of 3 MPa (30 bar). The start is performed by direct injection of air into the cylinders through the starting air valves in the cylinder heads. The 12V-engines are provided with starting air valves for the cylinder on both cylinder banks, 16V- and 18V-engines on A bank only. The main starting valve, is operated by an pneumatically operated solenoid valve for local (button in the control cabinet), remote or automatic start.

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

Figure 8.1 Internal starting air system, in-line engines (DAAE005311C)



System components:

01	Main starting air valve	10	Safety valve
02	Starting air distributor	11	Drain valve
03	Starting air valve in cylinder head	12	Start solenoid valve
04	Blocking valve of turning gear	13	Stop solenoid valve
05	Air container	14	Stop solenoid valve
06	Pneumatic stop cylinder at each injection pump	15	Slow turning solenoid valve
07	Non return valve	16	Wastegate valve
08	Starting booster for speed governor	17	By-pass valve
09	Flame arrester	18	Charge air shut off valve (if rigsaver)

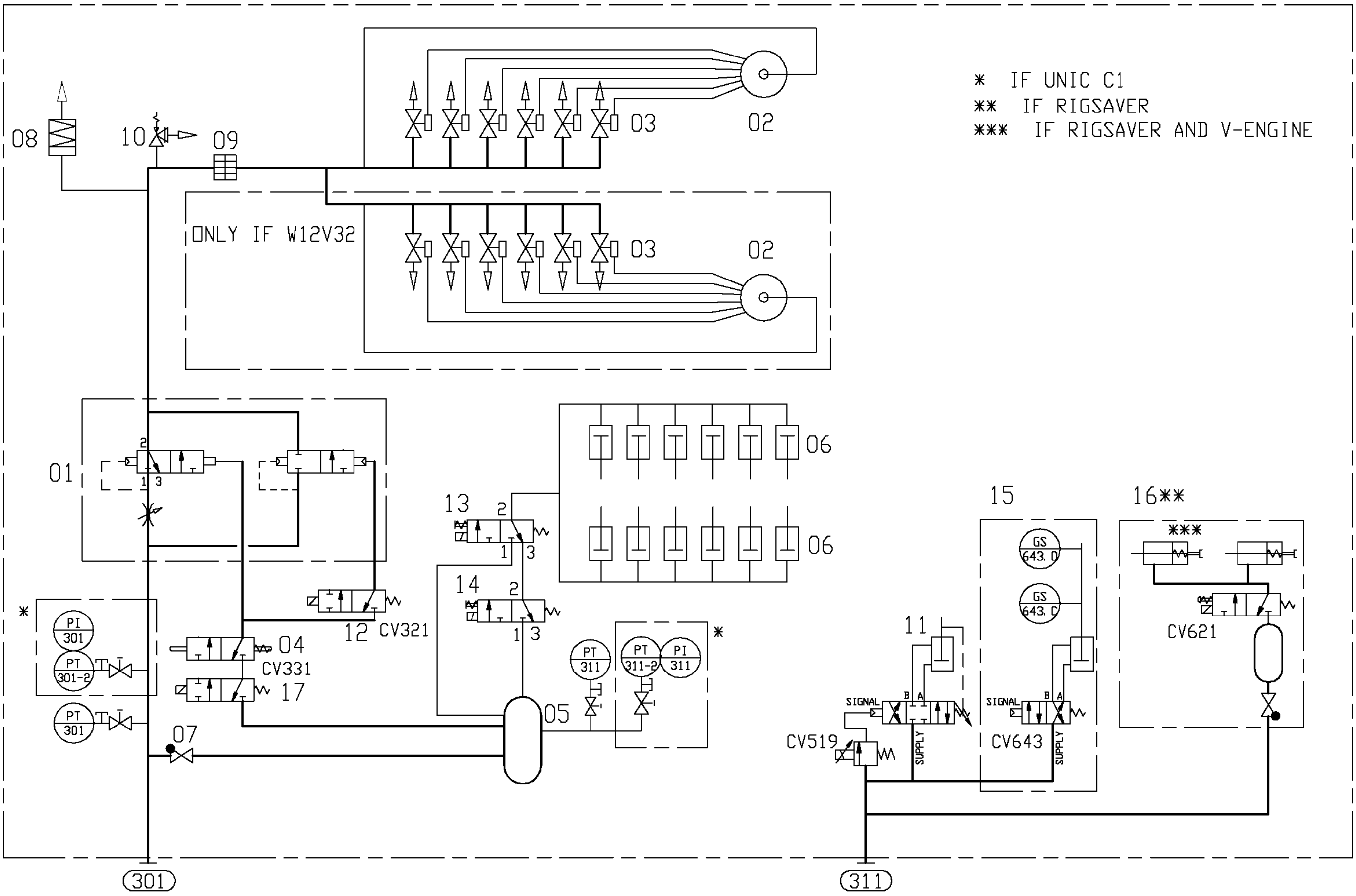
Sensors and indicators:

CV153-1	Stop / shutdown solenoid valve	CV519	I/P converter for wastegate valve
CV153-2	Stop / shutdown solenoid valve 2	CV621	Charge air shut-off valve control
CV321	Start solenoid valve	CV643	Charge air by-pass valve
CV331	Slow turning solenoid valve	GS643.O	Charge air by-pass valve position open
PT301	Starting air pressure engine inlet	GS643.C	Charge air by-pass valve position close

Sensors and indicators:	
PT311	Control air pressure

Pipe connections:		Size	Pressure class	Standard
301	Starting air inlet	DN32	PN40	ISO 7005-1
311	Control air to waste gate valve	OD8		DIN 2353

Figure 8.2 Internal starting air system, V-engines (DAAE082194A)



System components:

01	Main starting air valve	10	Safety valve
02	Starting air distributor	11	Wastegate valve
03	Starting air valve in cylinder head	12	Start solenoid valve CV321
04	Blocking valve, when turning gear engaged	13	Stop solenoid valve 153-1
05	Air container	14	Stop solenoid valve 153-2
06	Pneumatic stop cylinder at each injection pump	15	By-pass valve
07	Non return valve	16	Charge air shut off valve (if rigsaver)
08	Starting booster for speed governor	17	Start solenoid valve CV331
09	Flame arrestor		

Sensors and indicators:

PT301	Starting air pressure, engine inlet	CV331	Slow turning solenoid valve
PT301-2	Starting air pressure, engine inlet (if UNIC C1)	CV519	I/P converter for wastegate valve
PT311	Control air pressure	CV621	Charge air shut-off valve control
PT311-2	Control air pressure (if UNIC C1)	CV643	Charge air by-pass valve
PI301	Starting air pressure, engine inlet (if UNIC C1)	GS643.O	Charge air by-pass valve position open
PI311	Control air pressure (if UNIC C1)	GS643.C	Charge air by-pass valve position close

Sensors and indicators:	
CV321	Starting solenoid valve

Pipe connections:		Size	Pressure class	Standard
301	Starting air inlet	DN32	PN40	ISO 7005-1
311	Control air to waste gate valve	OD10		DIN 2353

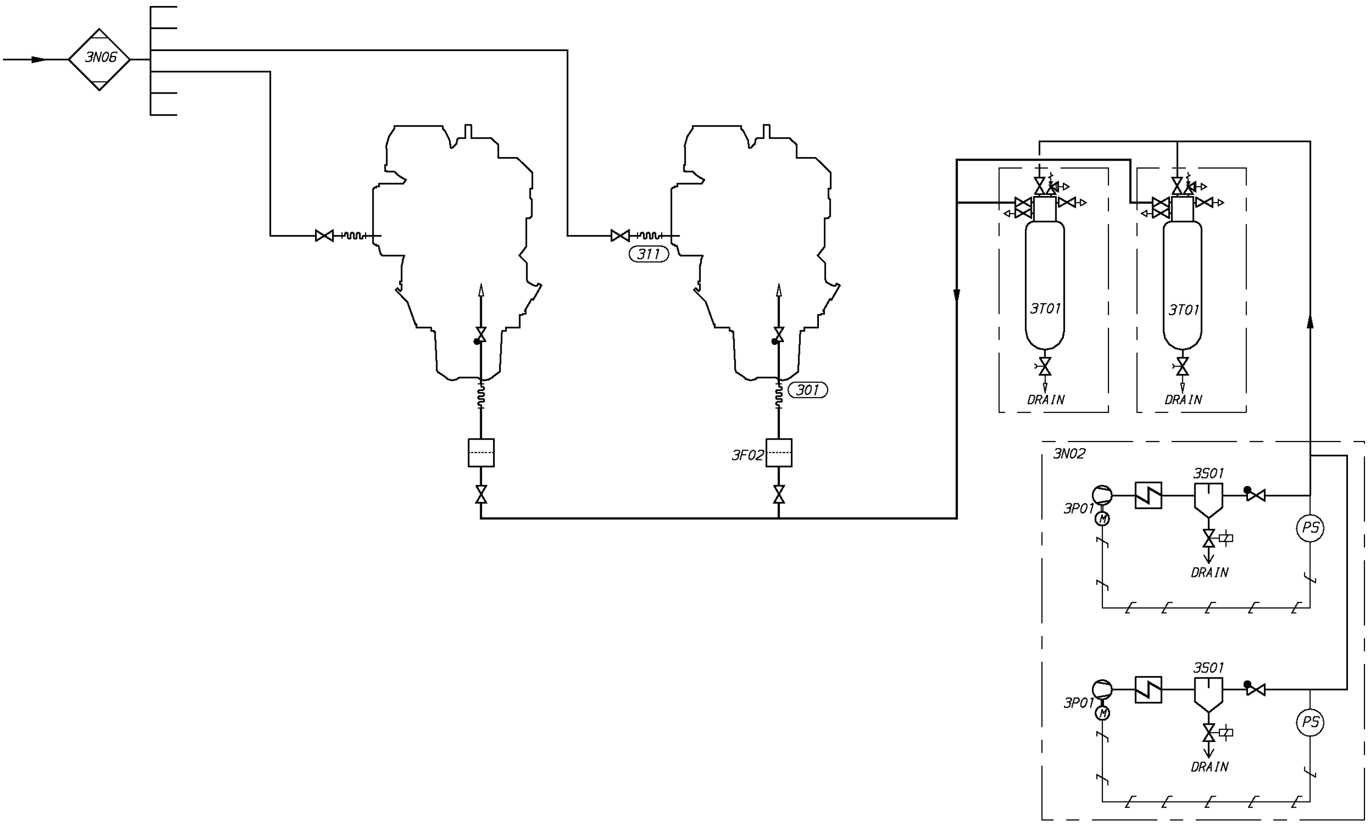
8.3 External compressed air system

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

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

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

Figure 8.3 External starting air system (3V76H4142d)



System components:		Pipe connections:	
3F02	Air filter (starting air inlet)	301	Starting air inlet
3N02	Starting air compressor unit	311	Control air to wastegate valve
3N06	Air dryer unit		
3P01	Compressor (starting air compressor unit)		
3S01	Separator (starting air compressor unit)		
3T01	Starting air vessel		

8.3.1 Starting air compressor unit (3N02)

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

8.3.2 Oil and water separator (3S01)

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

8.3.3 Starting air vessel (3T01)

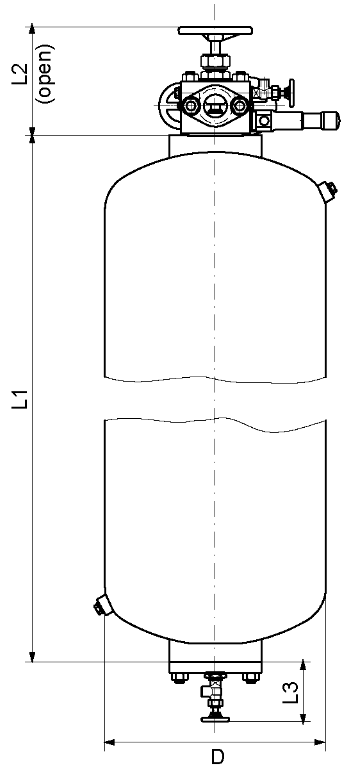
The starting air vessels should be dimensioned for a nominal pressure of 3 MPa.

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

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

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

Figure 8.4 Starting air vessel



Size [Litres]	Dimensions [mm]				Weight [kg]
	L1	L2 1)	L3 1)	D	
250	1767	243	110	480	274
500	3204	243	133	480	450
710	2740	255	133	650	625
1000	3560	255	133	650	810
1250	2930	255	133	800	980

1) Dimensions are approximate.

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

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

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

where:

V_R = total starting air vessel volume [m³]

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

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

n = required number of starts according to the classification society

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

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

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

8.3.4 Starting air filter (3F02)

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

An Y-type strainer can be used with a stainless steel screen and mesh size 400 µm. The pressure drop should not exceed 20 kPa (0.2 bar) for the engine specific starting air consumption under a time span of 4 seconds.

9. Cooling Water System

9.1 Water quality

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

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

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

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

9.1.1 Corrosion inhibitors

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

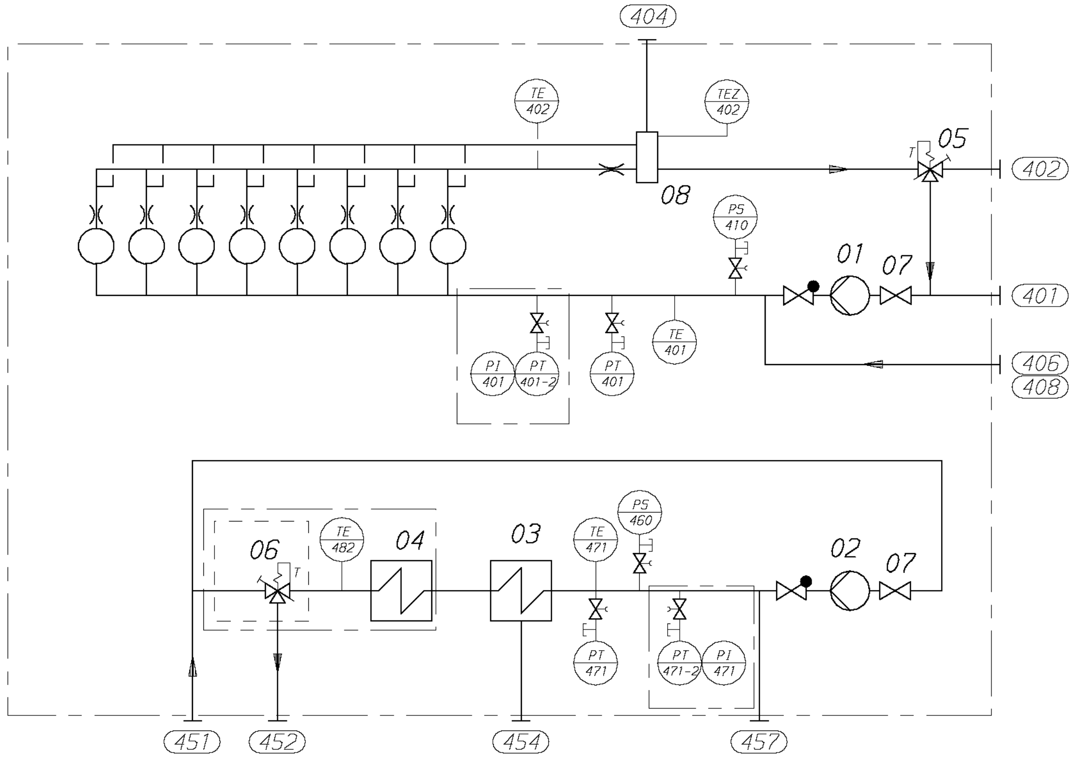
9.1.2 Glycol

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

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

9.2 Internal cooling water system

Figure 9.1 Internal cooling water system, single stage air cooler, in-line engines (DAAE005312a)



System components:

01	HT-cooling water pump	05	HT-thermostatic valve
02	LT-cooling water pump	06	LT-thermostatic valve (as an option in external system)
03	Charge air cooler	07	Shut-off valve
04	Lubricating oil cooler	08	Connection piece

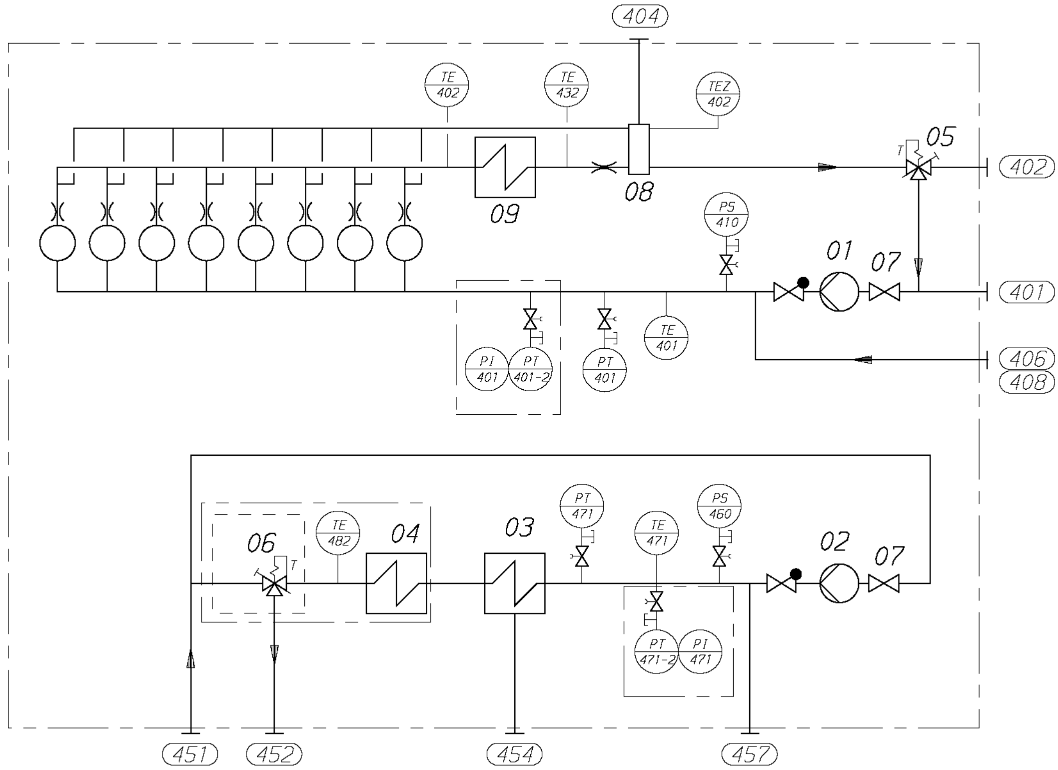
Sensors and indicators:

PS410	HT-water stand-by pump start	PI401	HT-water pressure, engine inlet (if UNIC C1)
PT401	HT-water pressure, engine inlet	PT471	LT-water pressure, CAC inlet
PT401-2	HT-water pressure, engine inlet (if UNIC C1)	PT471-2	LT-water pressure, CAC inlet (if UNIC C1)
TE401	HT-water temperature, engine inlet	TE471	LT-water temperature, CAC inlet
TE402	HT-water temperature, engine outlet	TE482	LT-water temperature, LOC inlet
TEZ402	HT-water temperature, engine outlet	PS460	LT-water stand-by pump start
		PI471	LT-water pressure, CAC inlet (if UNIC C1)

Pipe connections:		Size	Pressure class	Standard
401	HT-water inlet	DN100	PN16	ISO 7005-1
402	HT-water outlet	DN100	PN16	ISO 7005-1
404	HT-water air vent	OD12		DIN 2353
406	Water from preheater to HT-circuit	OD28		DIN 2353
408	HT-water from stand-by pump	DN100	PN16	ISO 7005-1

Pipe connections:		Size	Pressure class	Standard
451	LT-water inlet	DN100	PN16	ISO 7005-1
452	LT-water outlet	DN100	PN16	ISO 7005-1
454	LT-water air vent from air cooler	OD12		DIN 2353
457	LT-water from stand-by pump	DN100	PN16	ISO 7005-1

Figure 9.2 Internal cooling water system, two stage air cooler, in-line engines (DAAE005313a)



System components:

01	HT-cooling water pump	06	LT-thermostatic valve (optionally in the external system)
02	LT-cooling water pump	07	Shut-off valve
03	Charge air cooler (LT)	08	Connection piece
04	Lubricating oil cooler	09	Charge air cooler (HT)
05	HT-thermostatic valve		

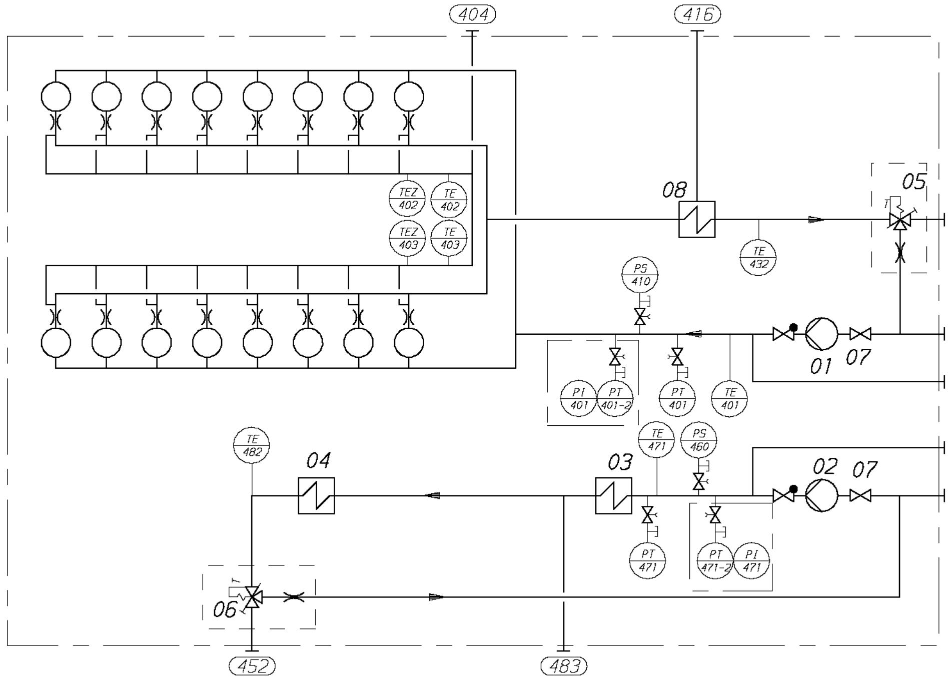
Sensors and indicators:

PS410	HT-water stand-by pump start	PI401	HT-water pressure, engine inlet (if UNIC C1)
PT401	HT-water pressure, engine inlet	PT471	LT-water pressure, CAC inlet
PT401-2	HT-water pressure, engine inlet (if UNIC C1)	PT471-2	LT-water pressure, CAC inlet (if UNIC C1)
TE401	HT-water temperature, engine inlet	TE471	LT-water temperature, CAC inlet
TE402	HT-water temperature, engine outlet	TE482	LT-water temperature, LOC inlet
TE432	HT-water temperature, CAC outlet	PS460	LT-water stand-by pump start
TEZ402	HT-water temperature, engine outlet	PI471	LT-water pressure, CAC inlet (if UNIC C1)

Pipe connections:		Size	Pressure class	Standard
401	HT-water inlet	DN100	PN16	ISO 7005-1
402	HT-water outlet	DN100	PN16	ISO 7005-1
404	HT-water air vent	OD12		DIN 2353
406	Water from preheater to HT-circuit	OD28		DIN 2353
408	HT-water from stand-by pump	DN100	PN16	ISO 7005-1

Pipe connections:		Size	Pressure class	Standard
451	LT-water inlet	DN100	PN16	ISO 7005-1
452	LT-water outlet	DN100	PN16	ISO 7005-1
454	LT-water air vent from air cooler	OD12		DIN 2353
457	LT-water from stand-by pump	DN100	PN16	ISO 7005-1

Figure 9.3 Internal cooling water system, V-engines (DAAE005314b)



System components:

01	HT-cooling water pump	05	HT-thermostatic valve (optionally in the external system)
02	LT-cooling water pump	06	LT-thermostatic valve (optionally in the external system)
03	Charge air cooler (LT)	07	Shut-off valve
04	Lubricating oil cooler	08	Charge air cooler (HT)

Sensors and indicators:

PS410	HT-water stand-by pump start	PI401	HT-water pressure, engine inlet (if UNIC C1)
PT401	HT-water pressure, engine inlet	PT471	LT-water pressure, CAC inlet
PT401-2	HT-water pressure, engine inlet (if UNIC C1)	PT471-2	LT-water pressure, CAC inlet (if UNIC C1)
TE401	HT-water temperature, engine inlet	TE471	LT-water temperature, CAC inlet
TE402	HT-water temperature, engine outlet	TE482	LT-water temperature, LOC inlet
TE432	HT-water temperature, CAC outlet	PS460	LT-water stand-by pump start
TEZ402	HT-water temperature, engine outlet	PI471	LT-water pressure, CAC inlet (if UNIC C1)

Pipe connections:		Size	Pressure class	Standard
401	HT-water inlet	DN125	PN16	ISO 7005-1
402	HT-water outlet	DN125	PN16	ISO 7005-1
404	HT-water air vent	OD12		DIN 2353
406	Water from preheater to HT-circuit	DN32	PN40	ISO 7005-1
408	HT-water from stand-by pump	DN125	PN16	ISO 7005-1
416	HT-water airvent from aircooler	OD12		DIN 2353
451	LT-water inlet	DN125	PN16	ISO 7005-1

Pipe connections:		Size	Pressure class	Standard
452	LT-water outlet	DN125	PN16	ISO 7005-1
457	LT-water from stand-by pump	DN125	PN16	ISO 7005-1
483	LT water air vent from air cooler	OD12		DIN 2353

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, if the engine is equipped with a two-stage charge air cooler. V-engines are equipped with a two-stage charge air cooler, while in-line engines have a single-stage charge air cooler.

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

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

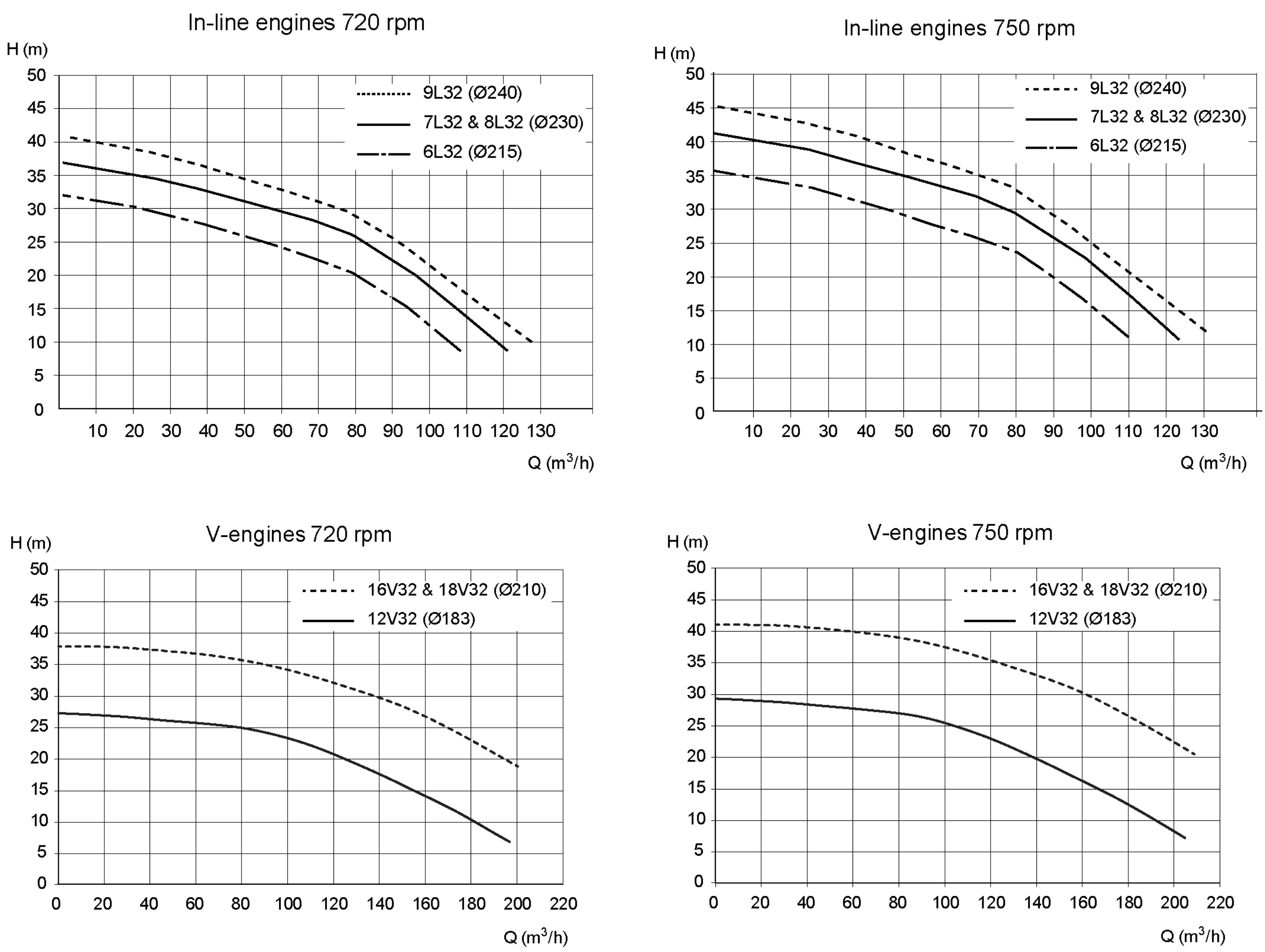
Temperature control valves regulate the temperature of the water out from the engine, by circulating some water back to the cooling water pump inlet. The HT temperature control valve is always mounted on the engine, while the LT temperature control valve can be either on the engine or separate. In installations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

9.2.1 Engine driven circulating pumps

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

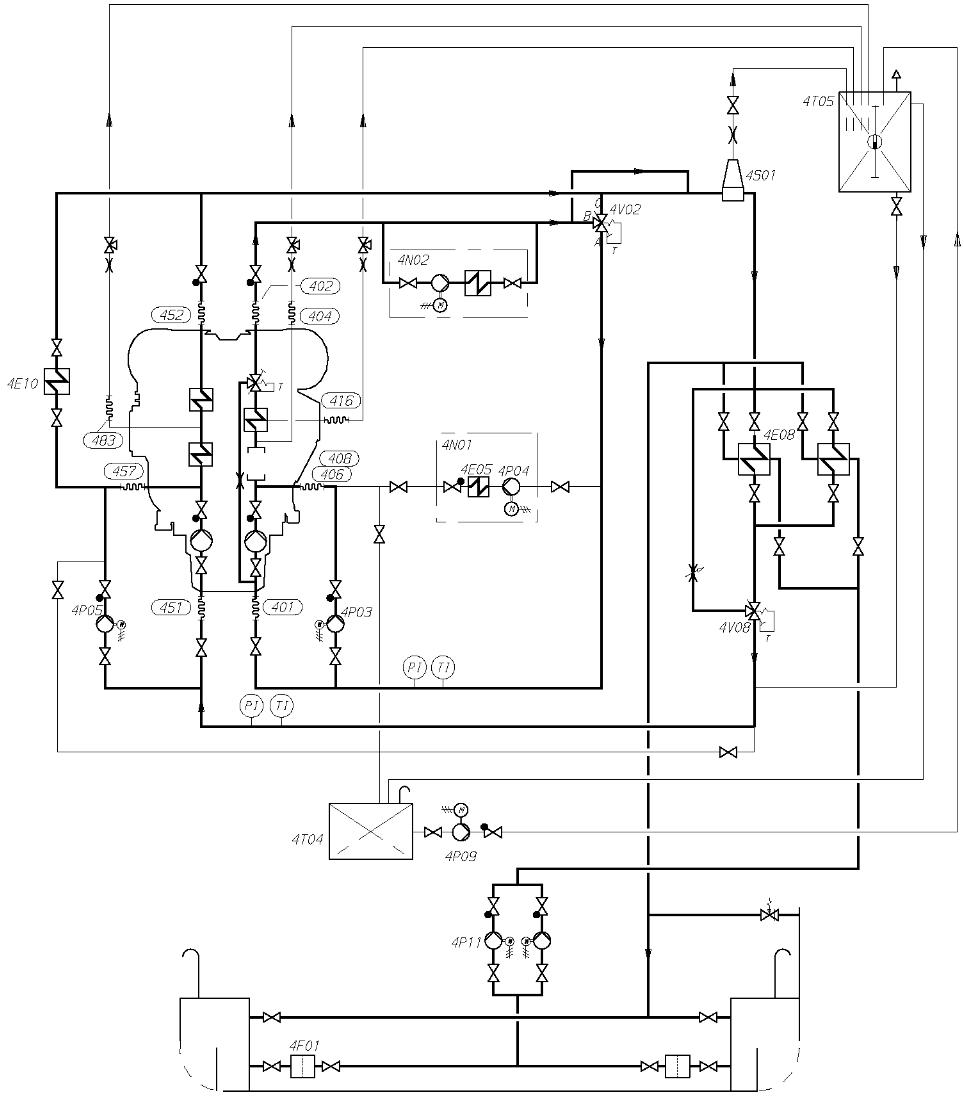
Pump curves for engine driven pumps are shown in the diagrams. The nominal pressure and capacity can be found in the chapter *Technical data*.

Figure 9.4 Pump curves for engine driven HT- and LT- water pumps (4V19L0240C, DAAF022986, DAAF022987, DAAF022998, DAAF022999)



9.3 External cooling water system

Figure 9.5 Example diagram for single main engine (MDF) (3V76C5775b)



System components:

4E05	Heater (preheating unit)	4P05	Stand-by pump (LT)
4E08	Central cooler	4P09	Transfer pump
4E10	Cooler (reduction gear)	4P11	Circulating pump (sea water)
4F01	Suction strainer (sea water)	4S01	Air venting
4N01	Preheating unit	4T04	Drain tank
4N02	Evaporator unit	4T05	Expansion tank
4P03	Stand-by pump (HT)	4V02	Temperature control valve (heat recovery)
4P04	Circulating pump (preheater)	4V08	Temperature control valve (central cooler)

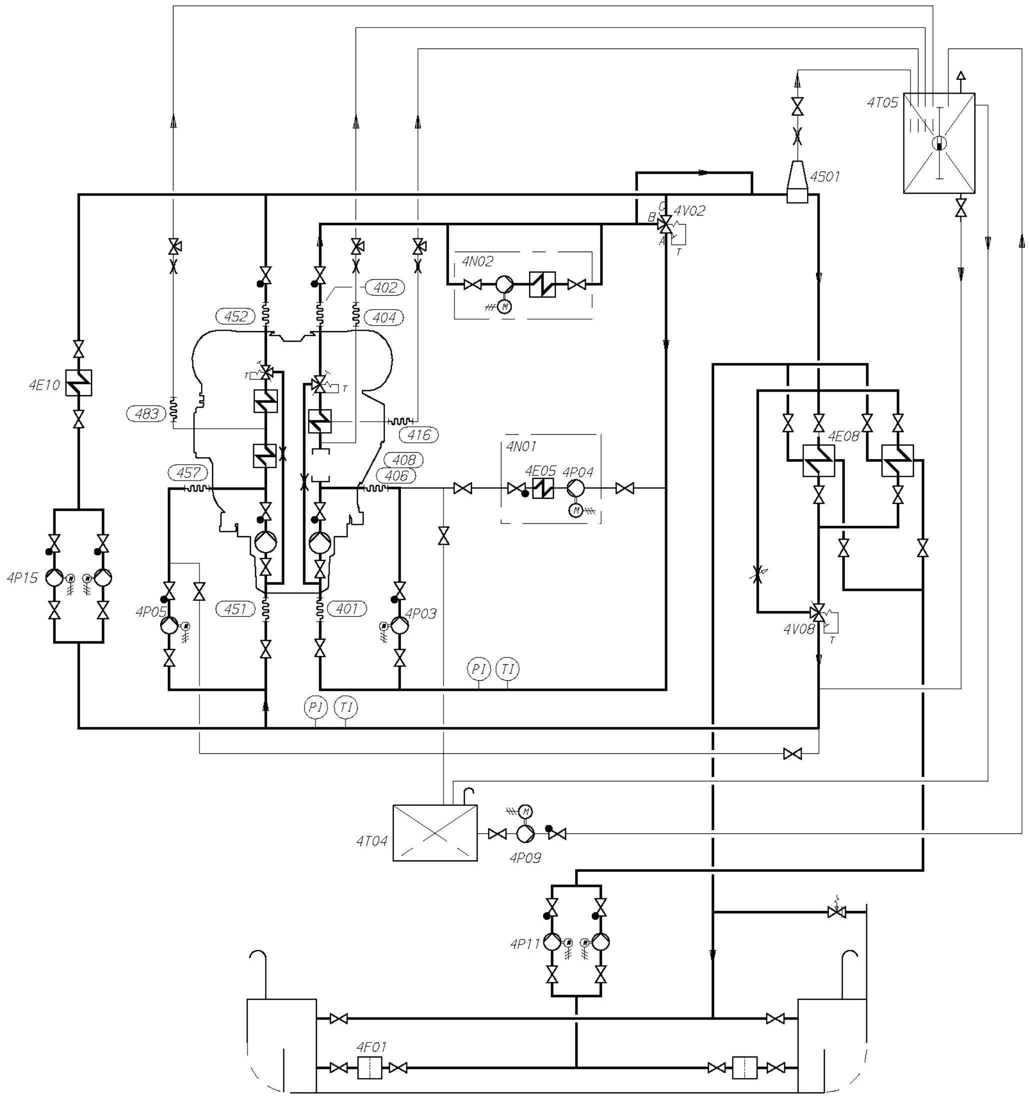
Pipe connections:

401	HT-water inlet	416	HT-water airvent from air cooler
402	HT-water	451	LT-water inlet
404	HT-water air vent	452	LT-water outlet
406	Water from preheater to HT-circuit	457	LT-water from stand-by pump

Pipe connections:

408	HT-water from stand-by pump	483	LT-water air vent

Figure 9.6 Example diagram for single main engine (HFO), reduction gear fresh water cooled (3V76C5262b)



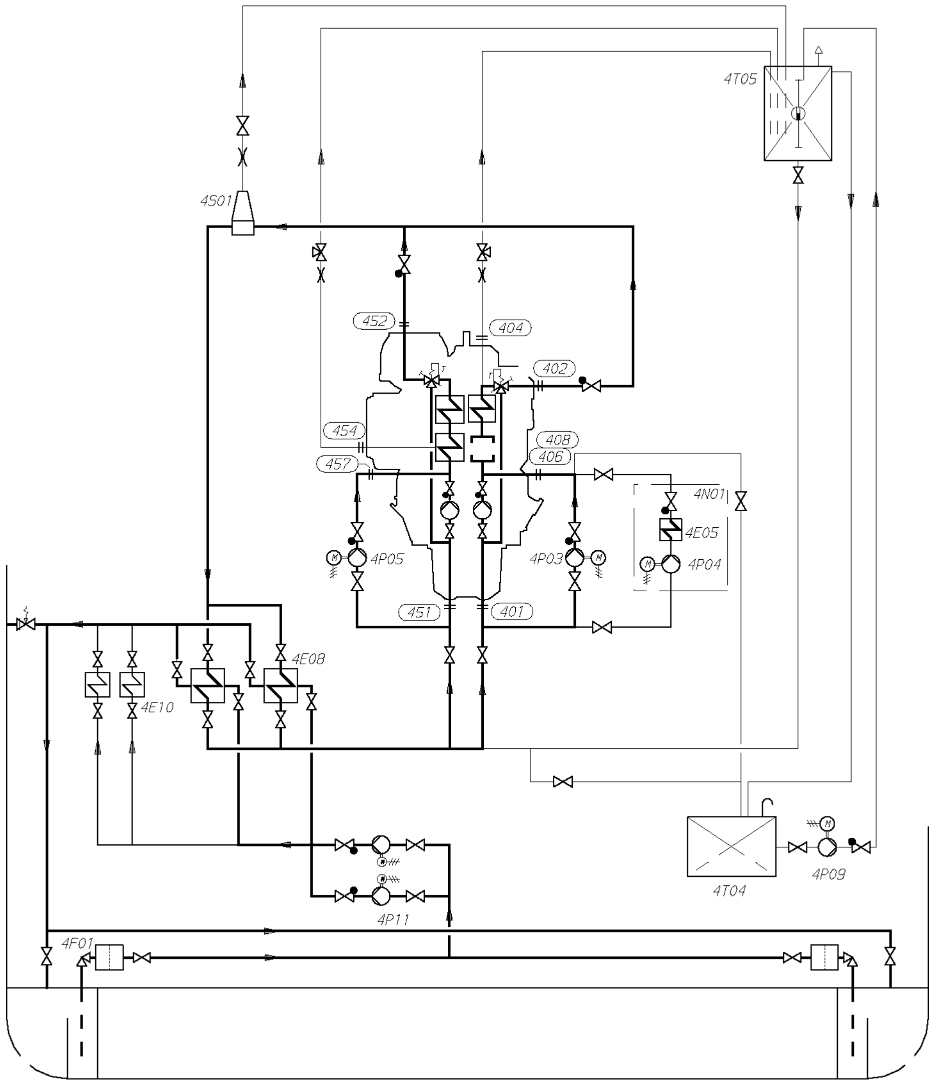
System components:

4E05	Heater (preheating unit)	4P09	Transfer pump
4E08	Central cooler	4P11	Circulating pump (sea water)
4E10	Cooler (reduction gear)	4P15	Circulating pump (LT)
4F01	Suction strainer (sea water)	4S01	Air venting
4N01	Preheating unit	4T04	Drain tank
4N02	Evaporator unit	4T05	Expansion tank
4P03	Stand-by pump (HT)	4V02	Temperature control valve (heat recovery)
4P04	Circulating pump (preheater)	4V08	Temperature control valve (central cooler)
4P05	Stand-by pump (LT)		

Pipe connections:

401	HT-water inlet	416	HT-water airvent from air cooler
402	HT-water outlet	451	LT-water inlet
404	HT-water air vent	452	LT-water outlet
406	Water from preheater to HT-circuit	457	LT-water from stand-by pump
408	HT-water from stand-by pump	483	LT-water air vent

Figure 9.7 Example diagram for single main engine (HFO) reduction gear sea water cooled (3V76C5791a)



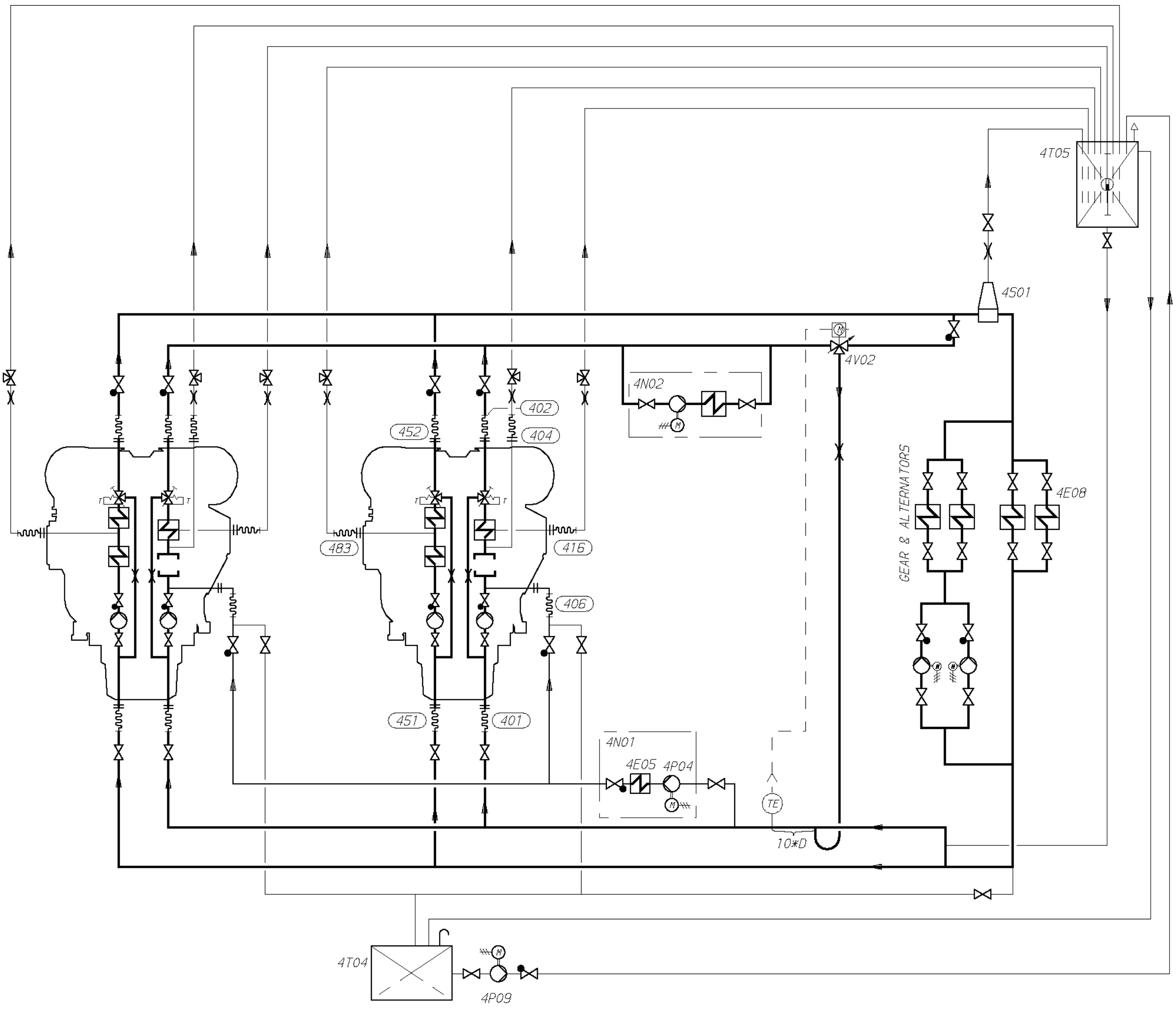
System components:

4E05	Heater (preheater)	4P05	Stand-by pump (LT)
4E08	Central cooler	4P09	Transfer pump
4E10	Cooler (reduction gear)	4P11	Circulating pump (sea water)
4F01	Suction strainer (sea water)	4S01	Air venting
4N01	Preheating unit	4T04	Drain tank
4P03	Stand-by pump (HT)	4T05	Expansion tank
4P04	Circulating pump (preheater)		

Pipe connections:

401	HT-water inlet	451	LT-water inlet
402	HT-water outlet	452	LT-water outlet
404	HT-water air vent	454	LT-water air venting from air cooler
406	Water from preheater to HT-circuit	457	LT-water from stand-by pump
408	HT-water from stand-by pump		

Figure 9.8 Example diagram for multiple main engines (3V76C5263b)



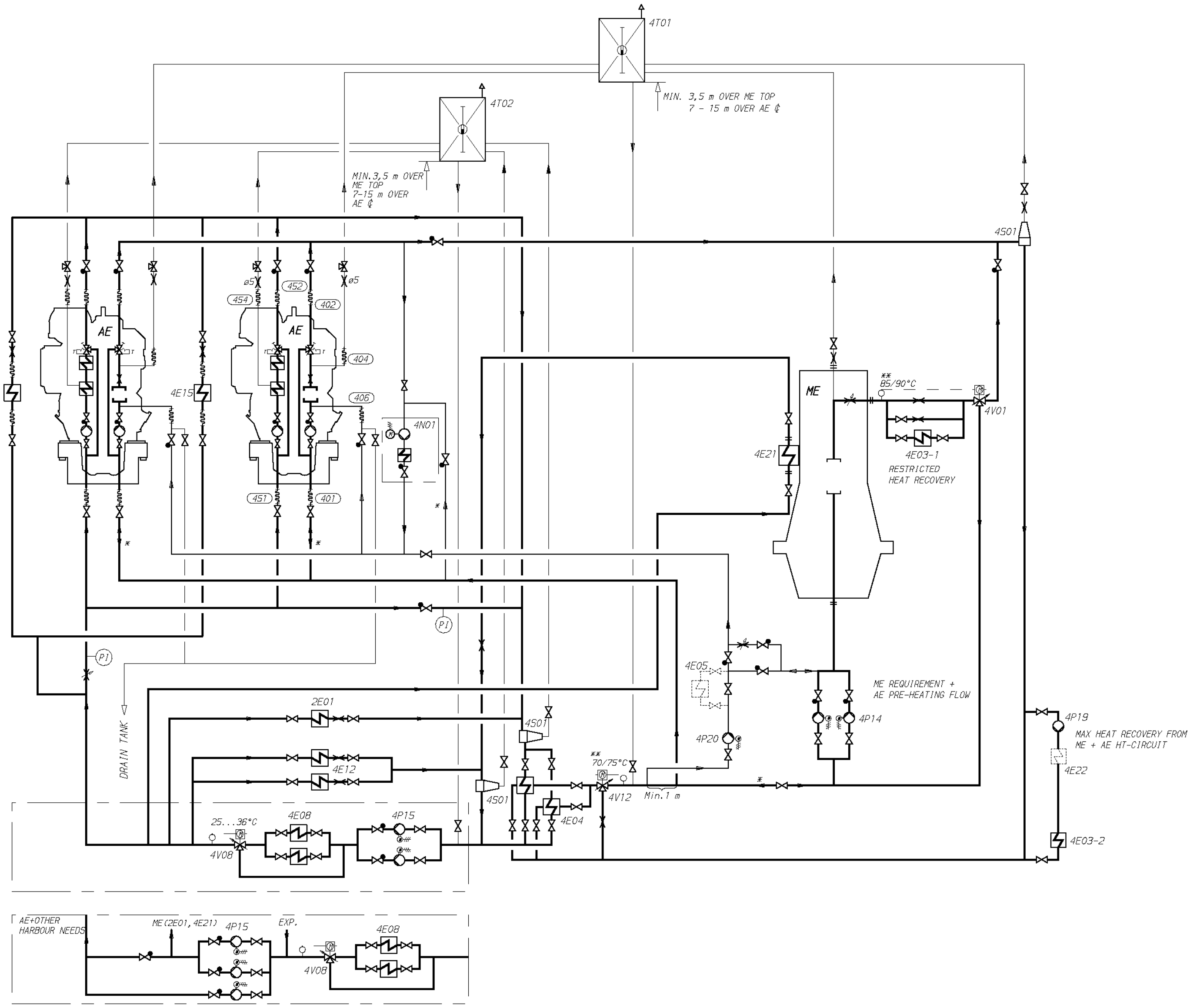
System components:

4E05	Heater (preheater)	4P09	Transfer pump
4E08	Central cooler	4S01	Air venting
4N01	Preheating unit	4T04	Drain tank
4N02	Evaporator unit	4T05	Expansion tank
4P04	Circulating pump (preheater)	4V02	Temperature control valve (heat recovery)

Pipe connections:

401	HT-water inlet	416	HT-water airvent from air cooler
402	HT-water outlet	451	LT-water inlet
404	HT-water air vent	452	LT-water outlet
406	Water from preheater to HT-circuit	483	LT-water air vent

Figure 9.9 Example diagram for common auxiliary engines and a low speed main engine with spilt LT and HT circuit (DAAE026913)



Notes:

* Preheating

** Depending of Main engine type

The preheating unit (4N01) is needed for preheating before start of first auxiliary engine AE, if the heater (4E05) is not installed.

The pump (4P04) is used for preheating of stopped main engine and auxiliary engine with heat from running auxiliary engine.

The pump (4P14) preheats stopped auxiliary engine when main engine is running.

The heater (4E05) is only needed if the heat from the running auxiliary engine is not sufficient for preheating the main engine, e.g. in extreme winter conditions

It is not necessary to open/close valve when switching on the preheating of main engine or auxiliary engine.

The LT-circulating pump 4P15 can alternatively be mounted after the central coolers 4E08 and thermostatic valve 4V08 which gives possibility to use a smaller pump in harbour without clousing valves to main engine.

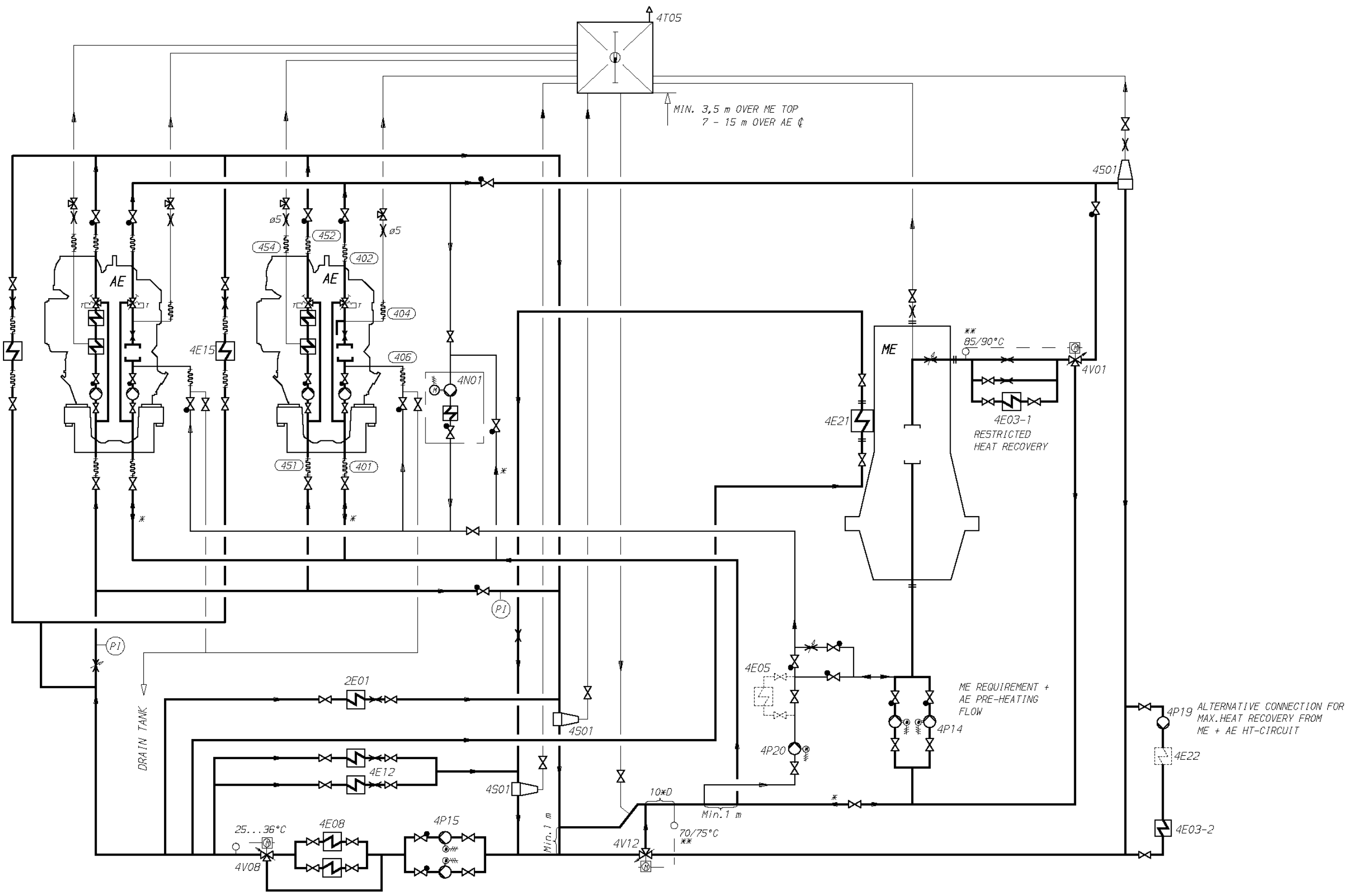
System components:

2E01	Lubricating oil cooler	4P14	Circulating pump (HT)
4E03-1	Heat recovery (evaporator) ME	4P15	Circulating pump (LT)
4E03-2	Heat recovery (evaporator) ME + AE	4P19	Circulating pump (evaporator)
4E04	Raw water cooler (HT)	4P20	Circulating pump (preheating HT)
4E05	Heater (preheater), optional	4S01	Air venting
4E08	Central cooler	4T01	Expansion tank (HT)
4E12	Cooler (installation parts)	4T02	Expansion tank (LT)
4E15	Cooler (generator), optional	4V01	Temperature control valve (HT)
4E21	Cooler (scavenge air)	4V03	Temperature control valve (LT)
4E22	Heater (booster), optional	4V12	Temperature control valve (heat recovery and preheating)
4N01	Preheating unit		

Pipe connections:

401	HT-water inlet	451	LT-water inlet
402	HT-water outlet	452	LT-water outlet
404	HT-water air vent	454	LT-water air vent from air cooler
406	Water from preheater to HT-circuit		

Figure 9.10 Example diagram for common auxiliary engines and a low speed main engine with mixed LT and HT circuit (DAAE026912)



Notes:

* Preheating flow

** Depending of ME type

The preheating unit (4N01) is needed for preheating before start of first auxiliary engine AE, if heater (4E05) is not installed.

The pump (4P04) is used for preheating of stopped main engine ME and auxiliary engine AE with heat from running auxiliary engine.

The pump (4P14) preheats the stopped auxiliary engine AE when main engine ME is running.

The heater (4E05) is only needed if the heat from the running auxiliary engine is not sufficient for preheating the main engine, e.g. in extreme winter conditions

It is not necessary to open/close valve when switching on the preheating of main engine or auxiliary engine.

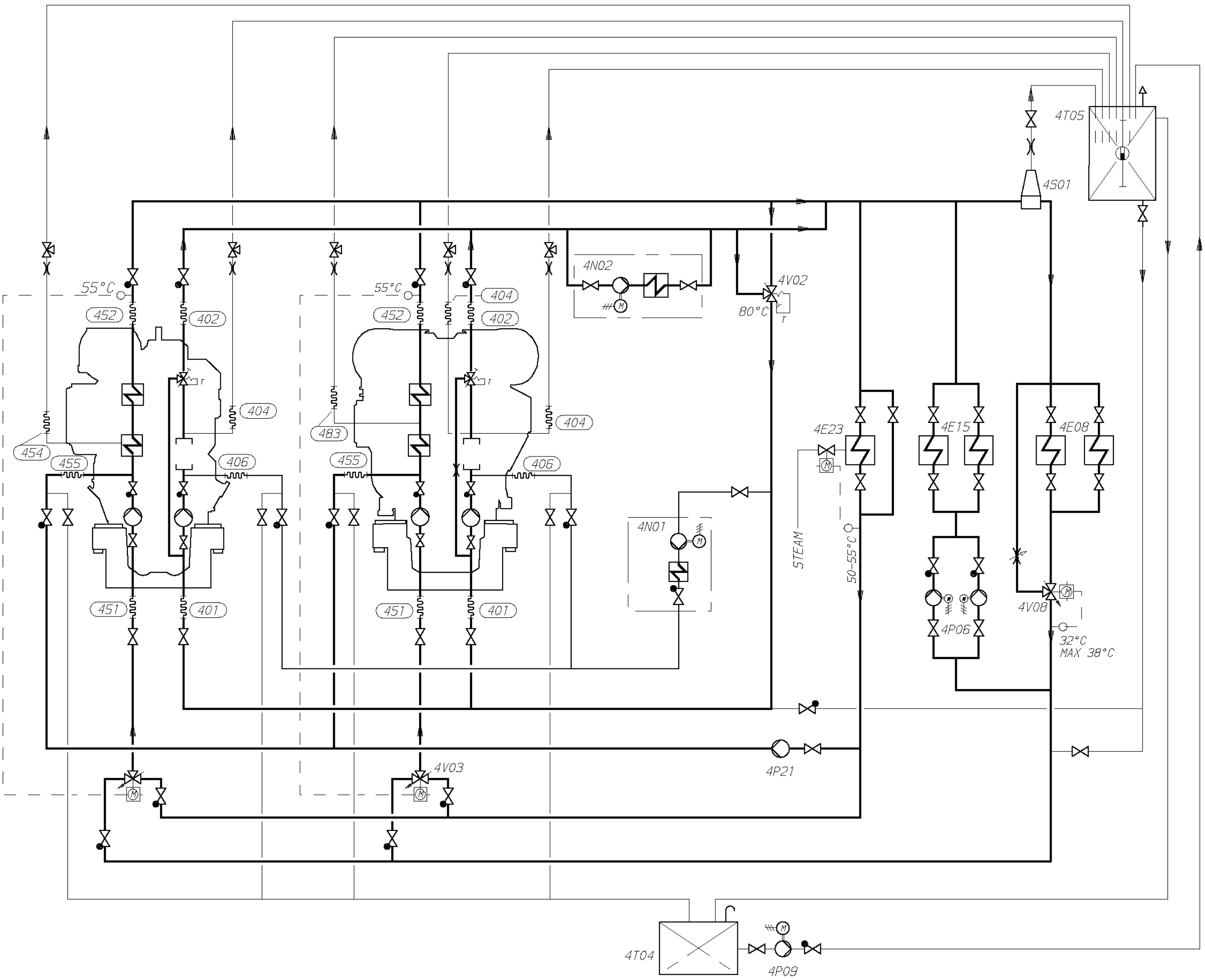
System components:

2E01	Lubriating oil cooler	4P14	Circulating pump (HT)
4E03-1	Heat recovery (evaporator) ME	4P15	Circulating pump (LT)
4E03-2	Heat recovery (evaporator) ME + AE	4P19	Circulating pump (evaporator)
4E05	Heater (preheater), optional	4P20	Circulating pump (preheating HT)
4E08	Central cooler	4S01	Air venting
4E12	Cooler (installation parts)	4T05	Expansion tank
4E15	Cooler (generator)	4V01	Temperature control valve (HT)
4E21	Cooler (scavenge air)	4V08	Temperature control valve (central cooler)
4E22	Heater (booster), optional	4V12	Temperature control valve (heat recovery and preheating)
4N01	Preheating unit		

Pipe connections:

401	HT-water inlet	451	LT-water inlet
402	HT-water outlet	452	LT-water outlet
404	HT-water air vent	454	LT-water air vent from air cooler
406	Water from preheater to HT-circuit		

Figure 9.11 Example diagram for arctic conditions (DAAE027131)



System components:

4E08	Central cooler	4P21	Circulating pump (preheating LT)
4E15	Cooler (generator)	4S01	Air venting
4E23	Heater (LT)	4T04	Drain tank
4N01	Preheating unit	4T05	Expansion tank
4N02	Evaporator unit	4V02	Temperature control valve (heat recovery)
4P06	Circulating pump	4V03	Temperature control valve (LT)
4P09	Transfer pump	4V08	Temperature control valve (central cooler)

Pipe connections:

401	HT-water inlet	451	LT-water inlet
402	HT-water outlet	452	LT-water outlet
404	HT-water air vent	454	LT-water air vent from air cooler
406	Water from preheater to HT-circuit	455	Water from preheater to LT-circuit
		483	LT-water air vent

Note: Charge air cooler is only in the LT-circuit. Heat energy from lubricating oil is used for heating charge air at low load.

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

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

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

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

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

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

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

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

9.3.2 Sea water pump (4P11)

The 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)

External HT temperature control valve is an option for V-engines.

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	96°C

9.3.4 Temperature control valve for central cooler (4V08)

When it is desired to utilize the engine driven LT-pump for cooling of external equipment, e.g. a reduction or a generator, there must be a common LT temperature control valve in the external system, instead of an individual valve for each engine. The common LT temperature control valve is installed after the central cooler and controls the temperature of the water before the engine and the external equipment, by partly bypassing the central cooler. The valve can be either direct acting or electrically actuated.

The set-point of the temperature control valve 4V08 is 38 °C in the type of system described above.

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

9.3.5 Temperature control valve for heat recovery (4V02)

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

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

9.3.6 Coolers for other equipment and MDF coolers

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

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

9.3.7 Fresh water central cooler (4E08)

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

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

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

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

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

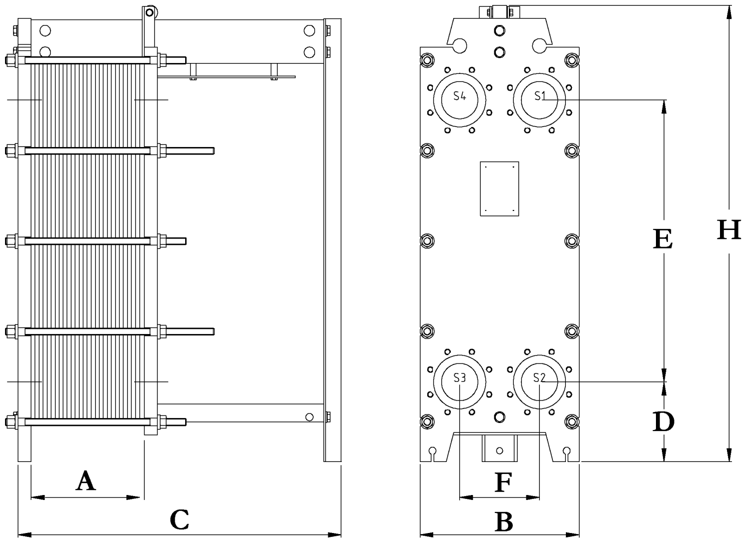
where:

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

Design data:

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

Figure 9.12 Main dimensions of the central cooler.



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

Engine type	P [kW]	Weight [kg]	Dimension [mm]						
			A	B	C	D	E	F	H
1 x 6L32	1641	820	193	690	817	330	1057	380	1675
1 x 7L32	1914	830	227	690	817	330	1057	380	1675
1 x 8L32	2189	860	262	690	817	330	1057	380	1675
1 x 9L32	2462	880	296	690	817	330	1057	380	1675
1 x 12V32	3170	890	331	690	817	330	1057	380	1675
1 x 16V32	4227	960	448	690	817	330	1057	380	1675
1 x 18V32	4755	1000	524	690	817	330	1057	380	1730

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

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

9.3.8 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.

9.3.9 Air venting

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

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

The vent pipes must be continuously rising.

9.3.10 Expansion tank (4T05)

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

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

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

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

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

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

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

Table 9.1 Minimum diameter of balance pipe

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

9.3.11 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.

9.3.12 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 5 kW/cyl, which makes it possible to warm up the engine from 20 °C to 60...70 °C in 10-15 hours. The required heating power for shorter heating time can be estimated with the formula below. About 2 kW/cyl is required to keep a hot engine warm.

Design data:	
Preheating temperature	min. 60°C
Required heating power	5 kW/cyl
Heating power to keep hot engine warm	2 kW/cyl

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

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

where:

P =	Preheater output [kW]
T_1 =	Preheating temperature = 60...70 °C
T_0 =	Ambient temperature [°C]
m_{eng} =	Engine weight [ton]
V_{LO} =	Lubricating oil volume [m^3] (wet sump engines only)
V_{FW} =	HT water volume [m^3]
t =	Preheating time [h]
k_{eng} =	Engine specific coefficient = 1 kW
n_{cyl} =	Number of cylinders

The formula above should not be used for	$P < 3.5$ kW/cyl

Circulation pump for preheater (4P04)

Design data:	
Capacity	0.4 m^3/h per cylinder
Delivery pressure	80...100 kPa (0.8...1.0 bar)

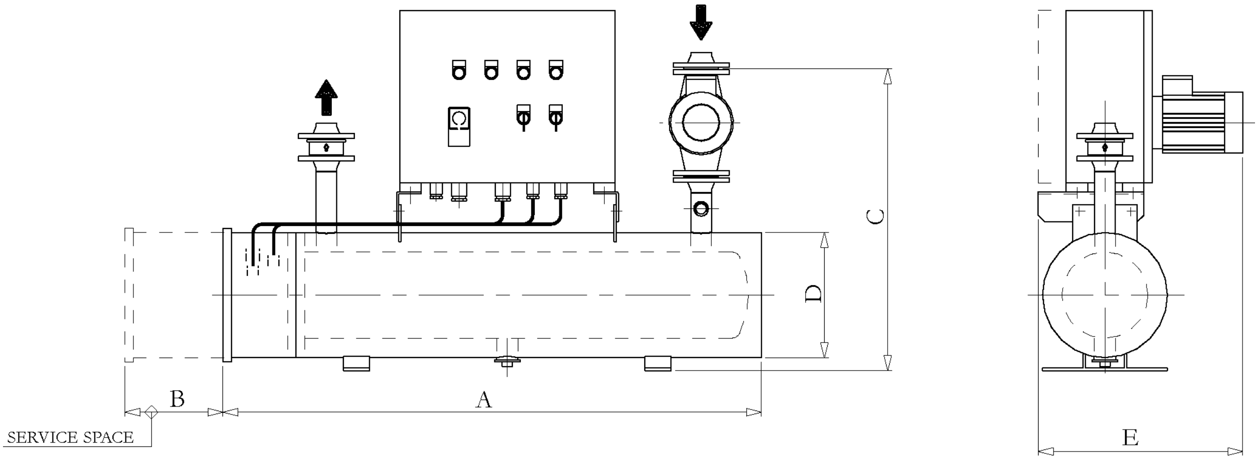
Preheating unit (4N01)

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 9.13 Preheating unit, electric (3V60L0562C).



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

9.3.13 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.

9.3.14 Thermometers and pressure gauges

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

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

10. Combustion Air System

10.1 Engine room ventilation

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

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

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

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

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

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

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

The amount of air required for ventilation is then calculated using the formula:

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

where:

qv = air flow [m³/s]

Φ = total heat emission to be evacuated [kW]

ρ = air density 1.13 kg/m³

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

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

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

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

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

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

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

Figure 10.1 Engine room ventilation, turbocharger with air filter (DAAE092651)

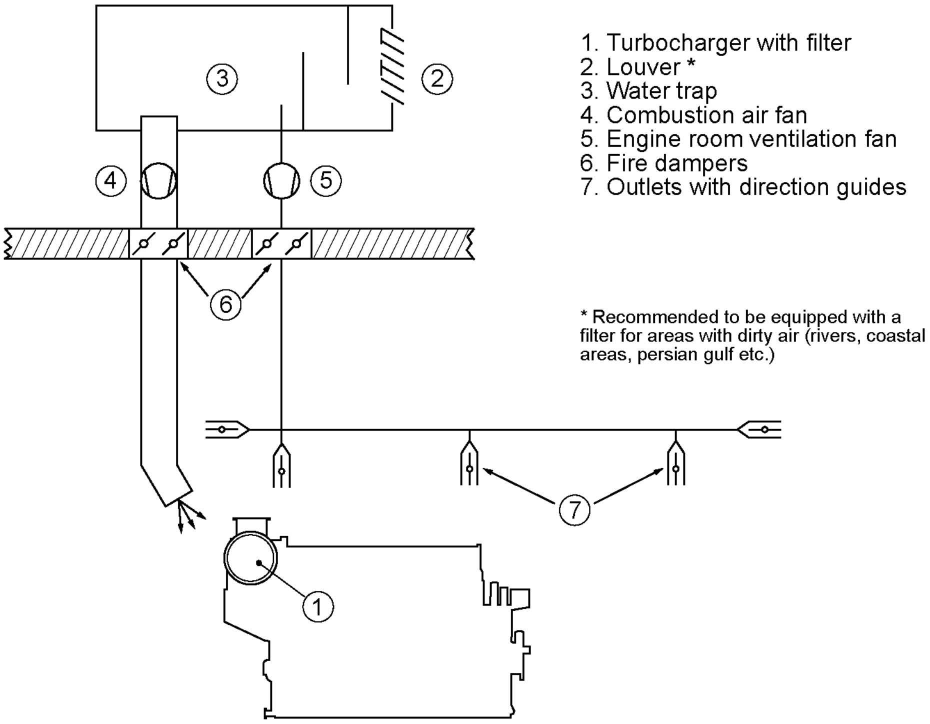
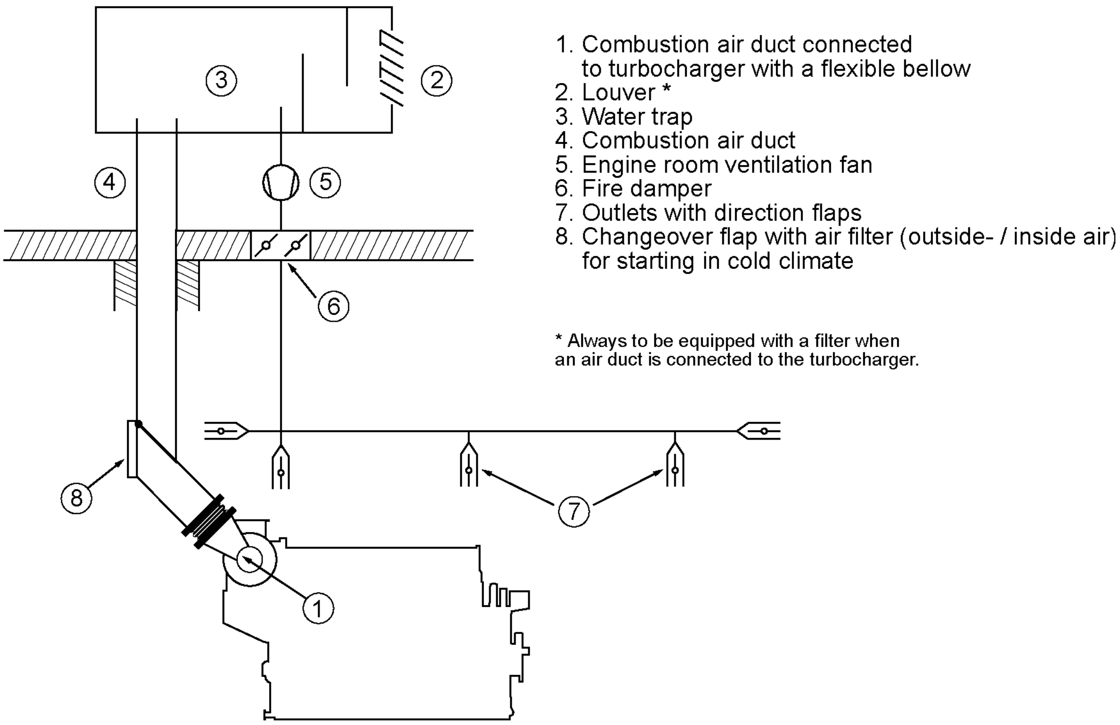


Figure 10.2 Engine room ventilation, air duct connected to the turbocharger (DAAE092652A)



10.2 Combustion air system design

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

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

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

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

where:

q_c = combustion air volume flow [m³/s]

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

ρ = air density 1.15 kg/m³

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

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

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

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

For very cold conditions 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 Charge air shut-off valve, "rigsaver" (optional)

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

10.2.2 Condensation in charge air coolers

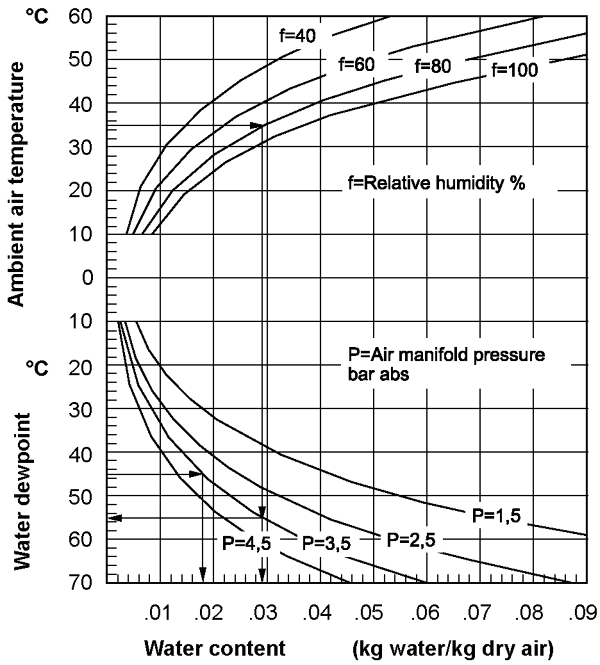
Air humidity may condense in the charge air cooler, especially in tropical conditions. The engine equipped with a small drain pipe from the charge air cooler for condensed water.

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

Example, according to the diagram:

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

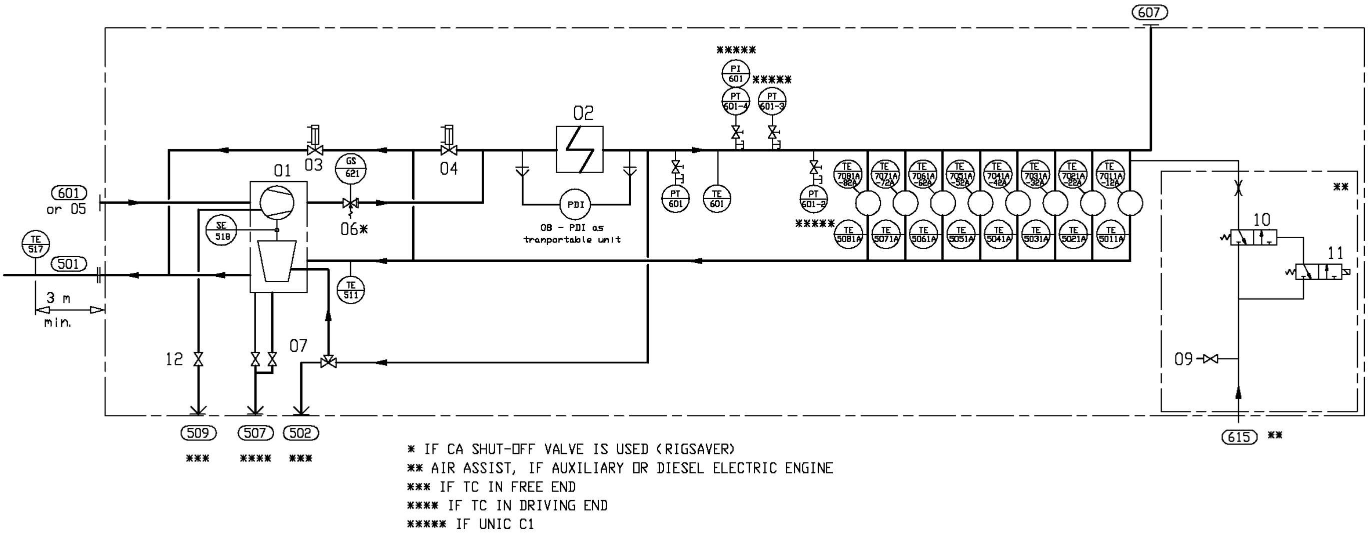
Figure 10.3 Condensation in charge air coolers



11. Exhaust Gas System

11.1 Internal exhaust gas system

Figure 11.1 Internal system, in-line engines (DAAE005315D)



System components:

01	Turbocharger	07	Turbocharger cleaning device
02	Charge air cooler	08	Pressure difference over CAC as transportable unit
03	Wastegate valve	09	Drain valve
04	By-pass valve (only mech propulsion or pump drive)	10	Air assist valve
05	Air filter (Engine without suction branch, 601)	11	3/2 solenoid valve
06	CA shut-off valve (rigsaver)	12	Compressor cleaning valve

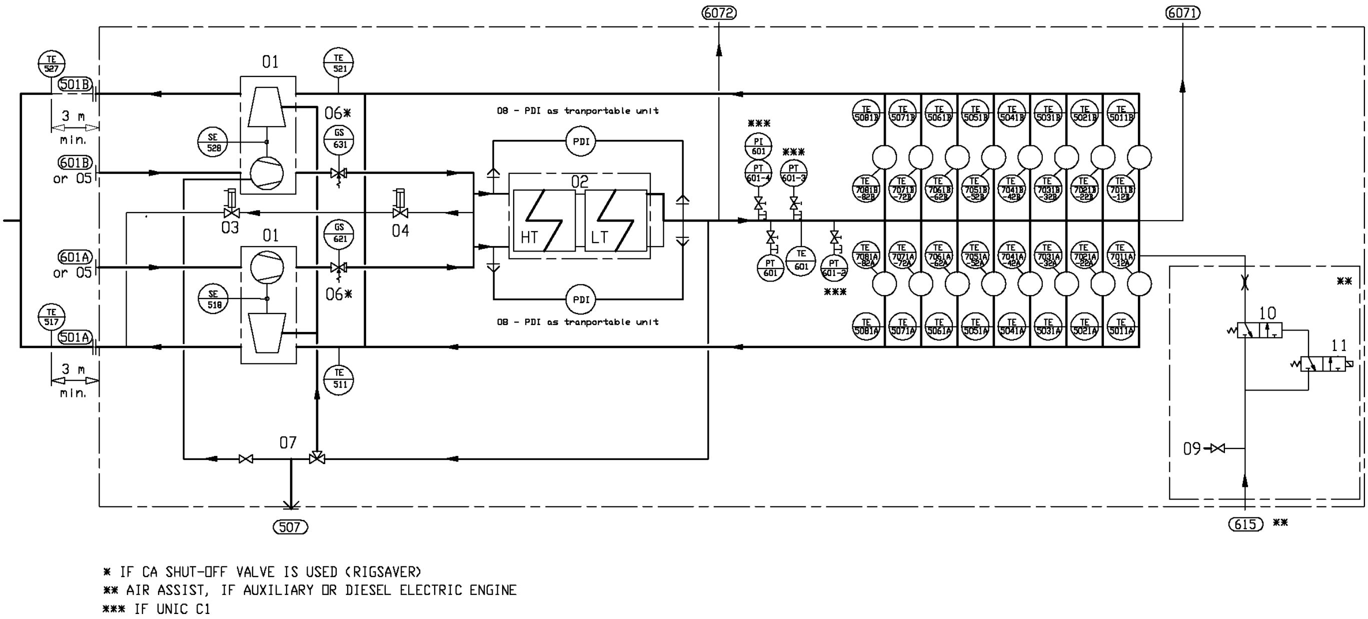
Sensors and indicators:

GS621	CA shut-off valve position, A-bank (if used)	TE511	Exhaust gas temp, TC A inlet
PT601	Charge air pressure, engine inlet	TE517	Exhaust gas temp, TC A outlet
PT601-2	Charge air pressure, for LCP display (if UNIC C1)	TE50#1A	Exhaust gas temperature, after cylinder A
PT601-3	Charge air pressure, for waste gate control (if UNIC C1)	TE601	Charge air temperature, engine inlet
PT601-4	Charge air pressure, engine inlet (if UNIC C1)	TE70#1A	Cylinder liner temperature, sensor 1 (option)
PI601	Charge air pressure, engine inlet	TE70#2A	Cylinder liner temperature, sensor 2 (option)
SE518	Turbocharger A speed		

Pipe connections:		W6L32 NA298	W6L32 A150	8-9L32 A155
501	Exhaust gas outlet	DN400 PN6	DN500 PN6	DN450 PN6
502	Cleaning water to turbine	QUICK COUPLING	QUICK COUPLING	QUICK COUPLING

Pipe connections:		W6L32 NA298	W6L32 A150	8-9L32 A155
507	Cleaning water to turbine and compressor	QUICK COUPLING	QUICK COUPLING	QUICK COUPLING
509	Cleaning water to compressor	QUICK COUPLING	QUICK COUPLING	QUICK COUPLING
607	Condensate water from air receiver	OD08	OD08	OD08
615	Air inlet to air assist system	OD28	OD28	OD28

Figure 11.2 Internal system, V-engines (DAAE005316D)



System components:

01	Turbocharger	07	Turbocharger cleaning device
02	Charge air cooler	08	Pressure difference over CAC as transportable unit
03	Wastegate valve	09	Drain valve
04	By-pass valve (only mech propulsion or pump drive)	10	Air assist valve
05	Air filter (Engine without suction branch, 601)	11	3/2 solenoid valve
06	CA shut-off valve (rigsaver)		

Sensors and indicators:

GS621	Charge air shut-off valve position, A-bank (if used)	TE511	Exhaust gas temperature, TC A inlet
GS631	Charge air shut-off valve position, B-bank (if used)	TE517	Exhaust gas temperature, TC A outlet
PT601	Charge air pressure, engine inlet	TE521	Exhaust gas temperature, TC B inlet
PT601-2	Charge air pressure, for LCP display (if UNIC C1)	TE527	Exhaust gas temperature, TC B outlet
PT601-3	Charge air pressure, for waste gate valve (if UNIC C1)	TE50#1A/B	Exhaust gas temperature, after cyl A/B
PT601-4	Charge air pressure, engine inlet (if UNIC C1)	TE601	Charge air temperature, engine inlet
PI601	Charge air pressure, engine inlet	TE70#1A/B	Cylinder liner temperature, sensor 1 (option)
SE518	Turbocharger A speed	TE70#2A/B	Cylinder liner temperature, sensor 2 (option)
SE528	Turbocharger B speed		

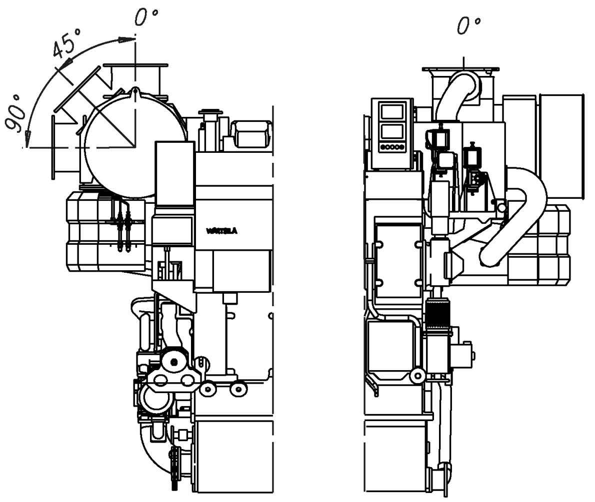
Pipe connections:		12V32 NA298	16V32 NA358
501	Exhaust gas outlet	DN400 PN6	DN500 PN6
507	Cleaning water to turbine and compressor	QUICK COUPLING	QUICK COUPLING

Pipe connections:		12V32 NA298	16V32 NA358
601	Air inlet to turbochargers	DN400 PN6	DN500 PN6
615	Air inlet to air assist system	OD28	OD28
6071	Condensate water from air receiver	OD12	OD12
6072	Condensate water from charge air cooler	OD18	OD18

11.2 Exhaust gas outlet

Figure 11.3 Exhaust pipe connections (DAAE059232b)

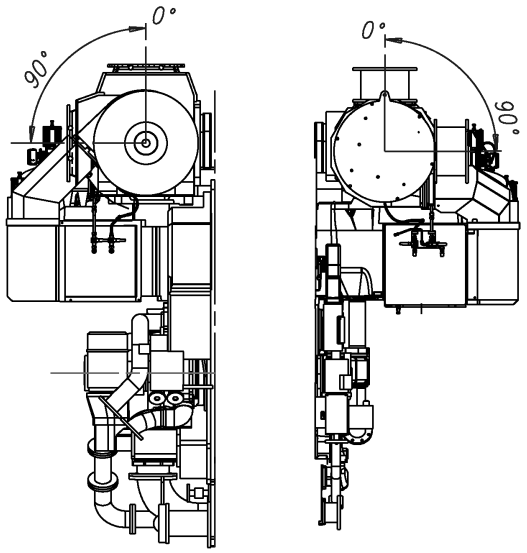
In-line engine



TC at free end   TC at flywheel end

Engine	[kW]	TC type	TC location	
			Free end	Driving end
W 6L32	3000	NA297, TPS61	0°, 45°, 90°	0°
W 6L32	3480	NA298	0°,45°,90°	-
W 7L32	3500	NA297	0°, 45°, 90°	0°
W 8L32	4000	NA307, TPL67	0°, 45°, 90°	0°
W 9L32	4500	TPL67	0°, 45°, 90°	0°

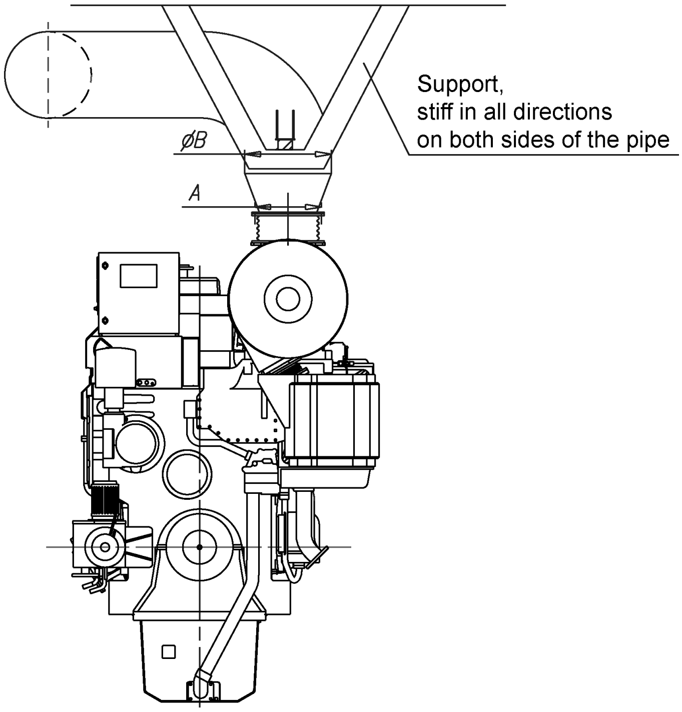
V-engine



TC at free end   TC at flywheel end

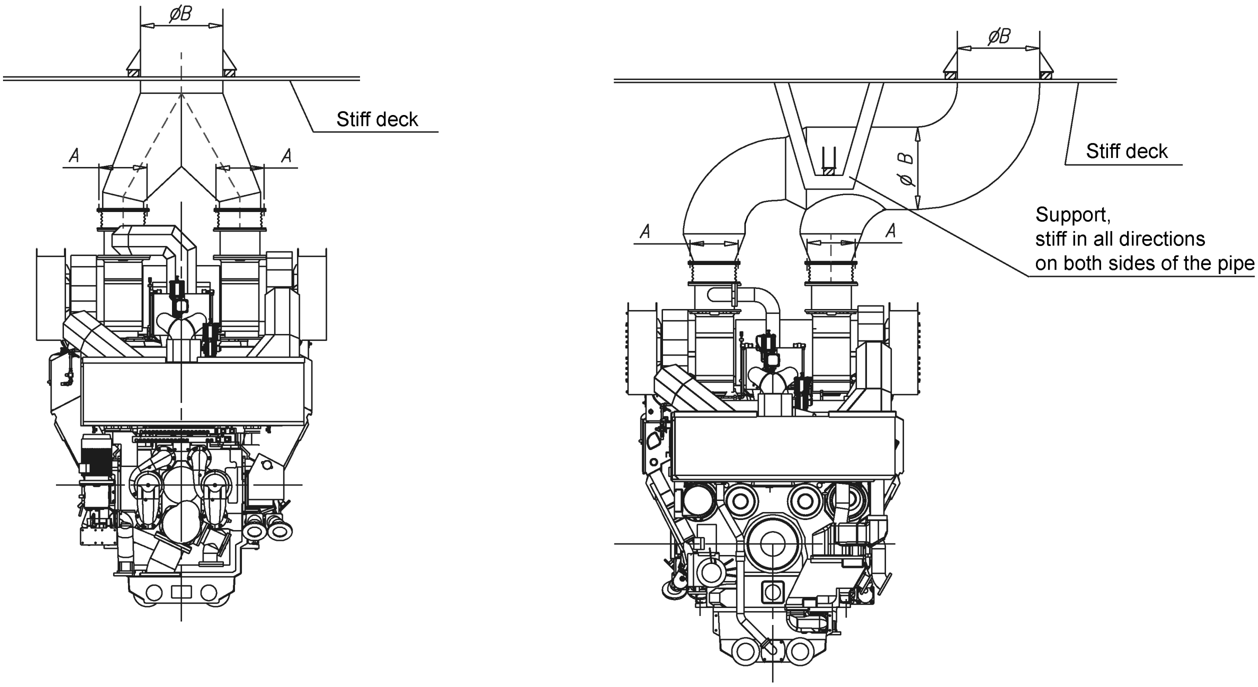
Engine	[kW]	TC type	TC location	
			Free end	Driving end
W 12V32	6000	NA297 TPS61	0° 0°	0° -
W 12V32	6960	NA298	0°	-
W 16V32	8000	NA307 TPL67 TPL67 with shut-off valve	0°, 90° 0°, 90° 0°	0°, 90° - -
W 18V32	9000	TPL67 TPL67 with shut-off valve	0°, 90° 0°	- -

Figure 11.4 Exhaust pipe, diameters and support (DAAE057875C)



Engine	TC type	ØA [mm]	ØB [mm]
W 6L32	NA297	DN400	600
	TPS61	DN350	600
	NA298	DN400	600
	A150	DN500	600
W 7L32	NA297	DN400	700
	TPS61	DN350	700
W 8L32	NA307	DN400	700
	TPL67	DN500	700
	NA358	DN500	700
	A155	DN450	700
W 9L32	TPL67	DN500	800
	NA358	DN500	800
	A155	DN450	800

Figure 11.5 Exhaust pipe, diameters and support (DAAE057873C, -74b)



Engine	TC type	ØA [mm]	ØB [mm]
W 12V32	NA297	2 x DN400	900
	TPS61	1 x DN600	900
	NA358	2 x DN400	900

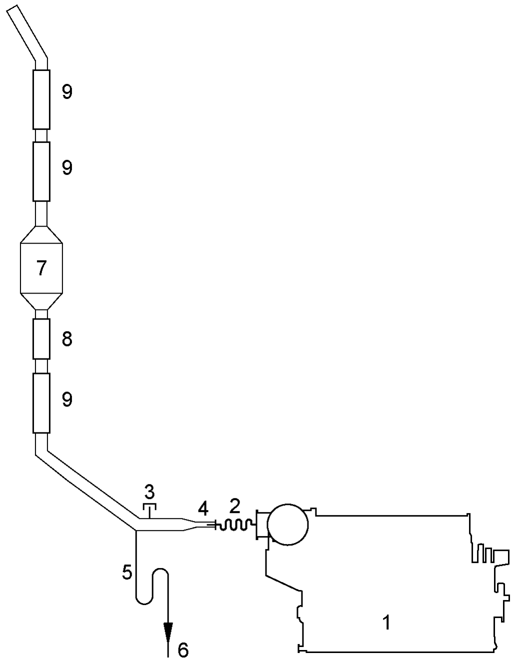
Engine	TC type	ØA [mm]	ØB [mm]
W 16V32	NA307	2 x DN400	1000
	TPL67	2 x DN500	1000
	NA358	2 x DN500	1000
W 18V32	TPL67	2 x DN500	1000

11.3 External exhaust gas system

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

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

Figure 11.6 External exhaust gas system



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

11.3.1 Piping

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

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

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

Where:

v = gas velocity [m/s]

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

Where:

T = exhaust gas temperature [°C]

D = exhaust gas pipe diameter [m]

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

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

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

11.3.2 Supporting

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

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

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

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

11.3.3 Back pressure

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

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

11.3.4 Exhaust gas bellows (5H01, 5H03)

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

11.3.5 SCR-unit (11N03)

The exhaust gas piping must be straight at least 3...5 meters in front of the SCR unit. If both an exhaust gas boiler and a SCR unit will be installed, then the exhaust gas boiler shall be installed after the SCR. Arrangements must be made to ensure that water cannot spill down into the SCR, when the exhaust boiler is cleaned with water.

11.3.6 Exhaust gas boiler

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

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

11.3.7 Exhaust gas silencers

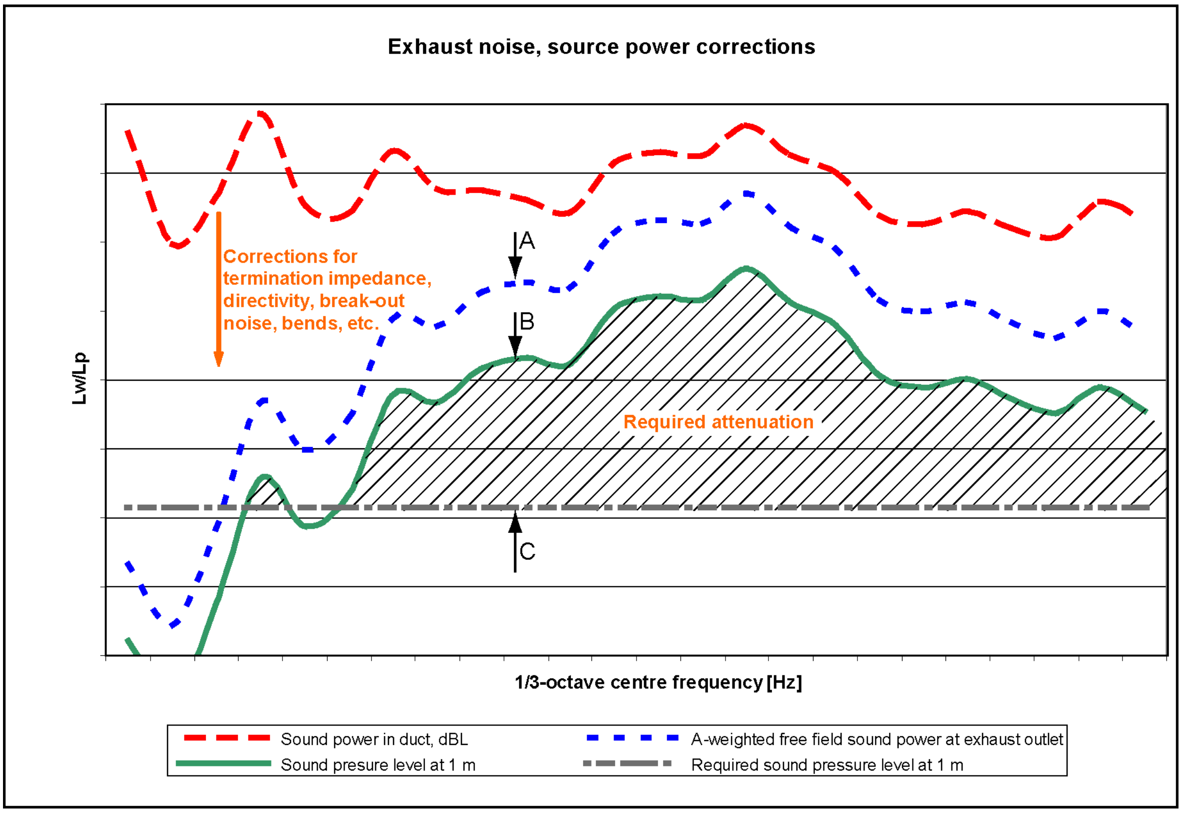
The exhaust gas silencing can be accomplished either by the patented Compact Silencer System (CSS) technology or by the conventional exhaust gas silencer.

Exhaust noise

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

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

Figure 11.7 Exhaust noise, source power corrections

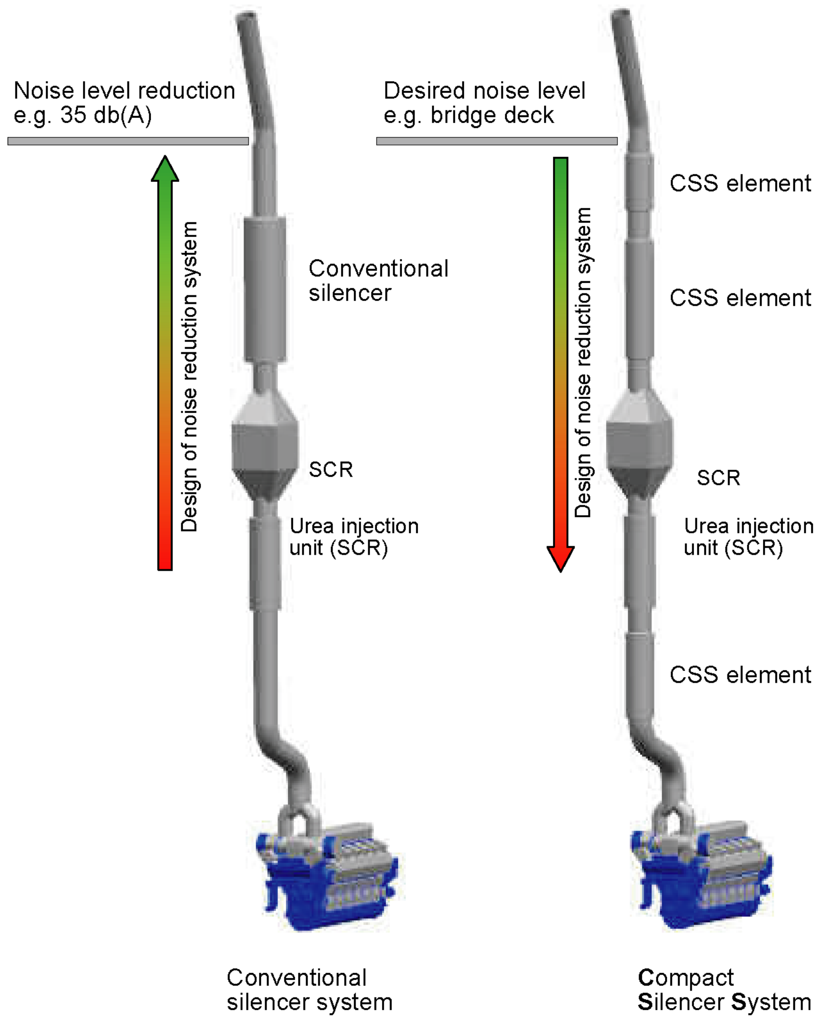


The conventional silencer is able to reduce the sound level in a certain area of the frequency spectrum. CSS is designed to cover the whole frequency spectrum.

Silencer system comparison

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

Figure 11.8 Silencer system comparison



Compact silencer system (5N02)

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

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

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

Conventional exhaust gas silencer (5R02)

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

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

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

Figure 11.9 Exhaust gas silencer (3V49E0142c)

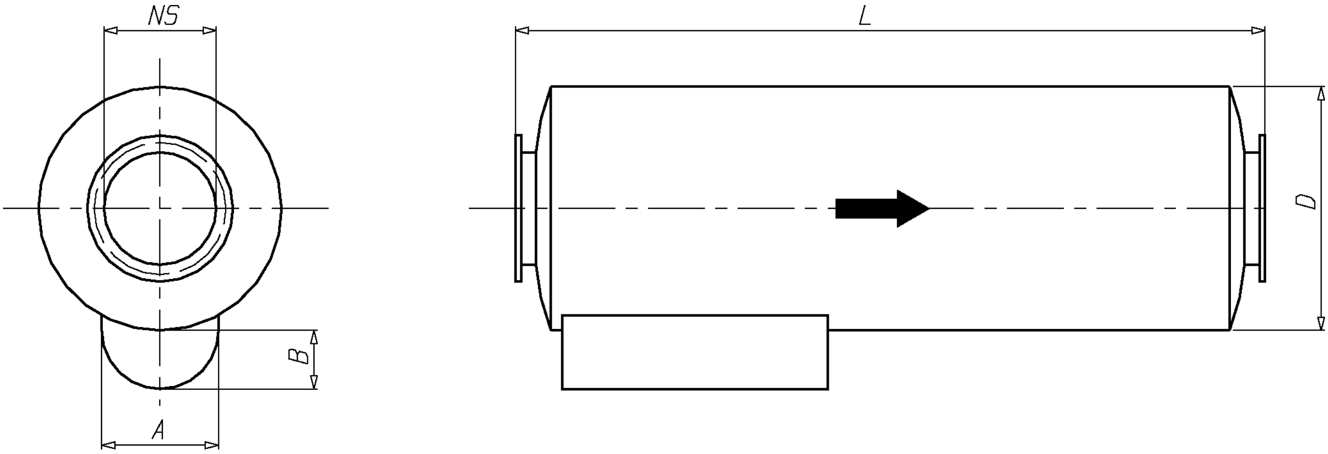


Table 11.1 Typical dimensions of exhaust gas silencers

NS	D	A	B	Attenuation: 25 dB(A)		Attenuation: 35 dB(A)	
				L	Weight [kg]	L	Weight [kg]
600	1300	635	260	4010	980	5260	1310
700	1500	745	270	4550	1470	6050	1910
800	1700	840	280	4840	1930	6340	2490
900	1800	860	290	5360	2295	6870	2900
1000	1900	870	330	5880	2900	7620	3730
Flanges: DIN 2501							

12. Turbocharger Cleaning

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

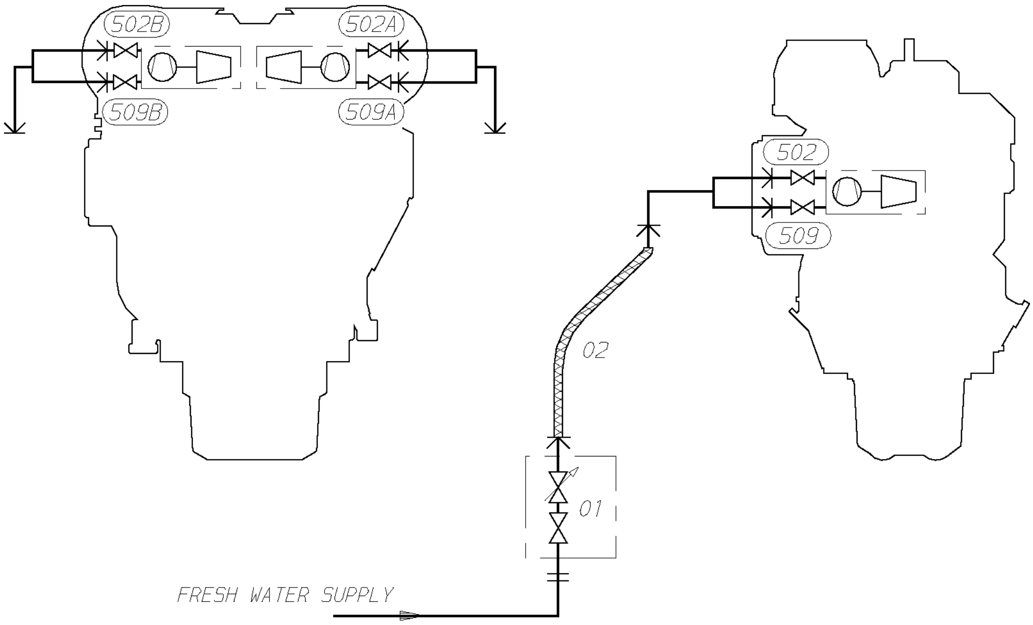
12.1 Turbine cleaning system

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

Water supply:	
Fresh water	
Min. pressure	0.3 MPa (3 bar)
Max. pressure	2 MPa (20 bar)
Max. temperature	80 °C
Flow	15-30 l/min (depending on cylinder configuration)

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

Figure 12.1 Turbocharger cleaning system (4V76A2937a)



System components		Pipe connections		Size
01	Dosing unit with shut-off valve	502	Cleaning water to turbine	OD18
02	Rubber hose	509	Cleaning water to compressor	OD18

12.2 Compressor cleaning system

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

13. Exhaust Emissions

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

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

13.1 Diesel engine exhaust components

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

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

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

13.1.1 Nitrogen oxides (NO_x)

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

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

13.1.2 Sulphur Oxides (SO_x)

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

13.1.3 Particulate Matter (PM)

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

13.1.4 Smoke

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

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

13.2 Marine exhaust emissions legislation

13.2.1 International Maritime Organization (IMO)

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

MARPOL Annex VI - Air Pollution

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

Nitrogen Oxides, NO_X Emissions

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

EIAPP Certification

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

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

Table 13.1 ISO 8178 test cycles

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

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

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

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

Engine family/group

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

Technical file

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

IMO NOx emission standards

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

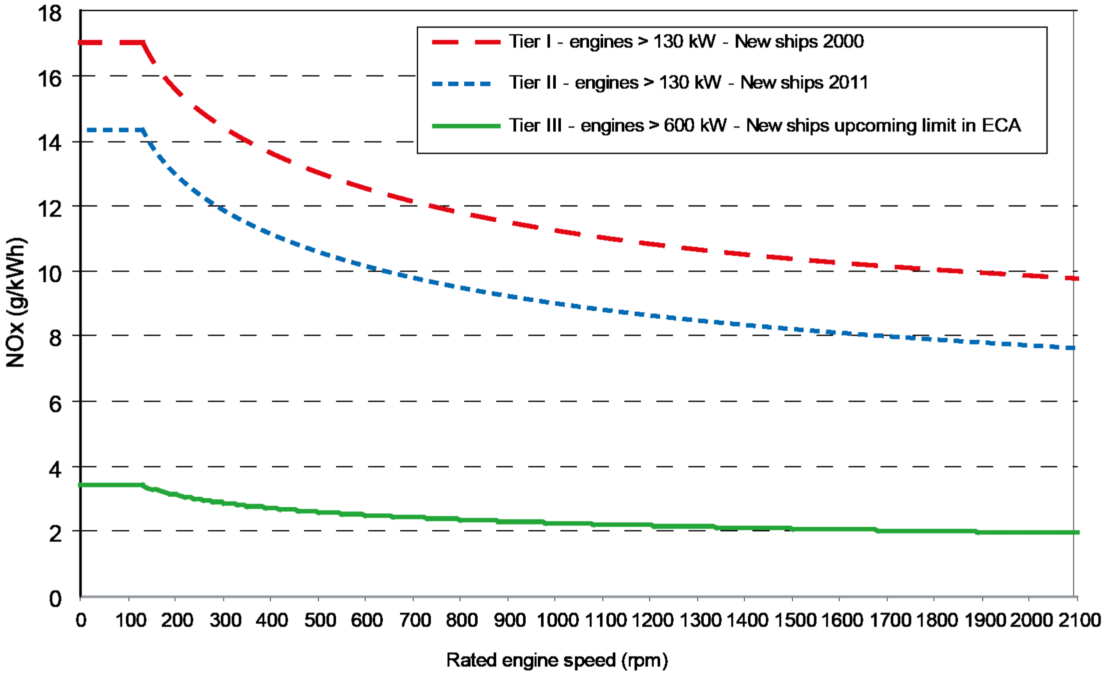
The Marpol Annex VI and the NO_x Technical Code were then undertaken a review with the intention to further reduce emissions from ships. In the IMO MEPC meeting in April 2008 proposals for IMO Tier 2 and IMO Tier 3 NOx emission standards were agreed. Final adoption for IMO Tier 2 and Tier 3 was taken by IMO/MEPC 58 in October 2008.

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

The IMO Tier 3 NO_x emission standard effective date is not finalized. The Tier 3 standard will apply in designated emission control areas (ECA). The ECA areas are to be defined by the IMO. So far, the North American ECA and the US Caribbean Sea ECA has been defined. The IMO Tier 2 NO_x emission standard will apply outside the Tier 3 designated areas. The Tier 3 NO_x emission standard is not applicable to recreational ships < 24 m and for ships with combined propulsion power < 750 kW subject to satisfactory demonstration to Administration that the ship cannot meet Tier 3.

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

Figure 13.1 IMO NO_x emission limits



IMO Tier 1 NO_x emission standard

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

The IMO Tier 1 NO_x limit is defined as follows:

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

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

IMO Tier 2 NO_x emission standard (new ships 2011)

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

The IMO Tier 2 NO_x limit is defined as follows:

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

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

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

The IMO Tier 3 NO_x emission standard has not yet entered into force. When it enter into force, it will apply for new marine diesel engines > 130 kW, when operating inside a designated emission control area (ECA).

The IMO Tier 3 NO_x limit is defined as follows:

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

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

Sulphur Oxides, SO_x emissions

Marpol Annex VI has set a maximum global fuel sulphur limit of currently 3,5% (from 1.1.2012) in weight for any fuel used on board a ship. Annex VI also contains provisions allowing for special SOx Emission Control Areas (SECA) to be established with more stringent controls on sulphur emissions. In a "SOx Emission Control Area", which currently comprises the Baltic Sea, the North Sea, the English Channel and the area outside North America (200 nautical miles), the sulphur content of fuel oil used onboard a ship must currently not exceed 1% in weight. On january1, 2014, the US Caribbean Sea SECA will become effective.

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

Table 13.2 Fuel sulphur caps

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

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

13.2.2 Other Legislations

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

13.3 Methods to reduce exhaust emissions

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

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

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

14. Automation System

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

14.1 UNIC C2

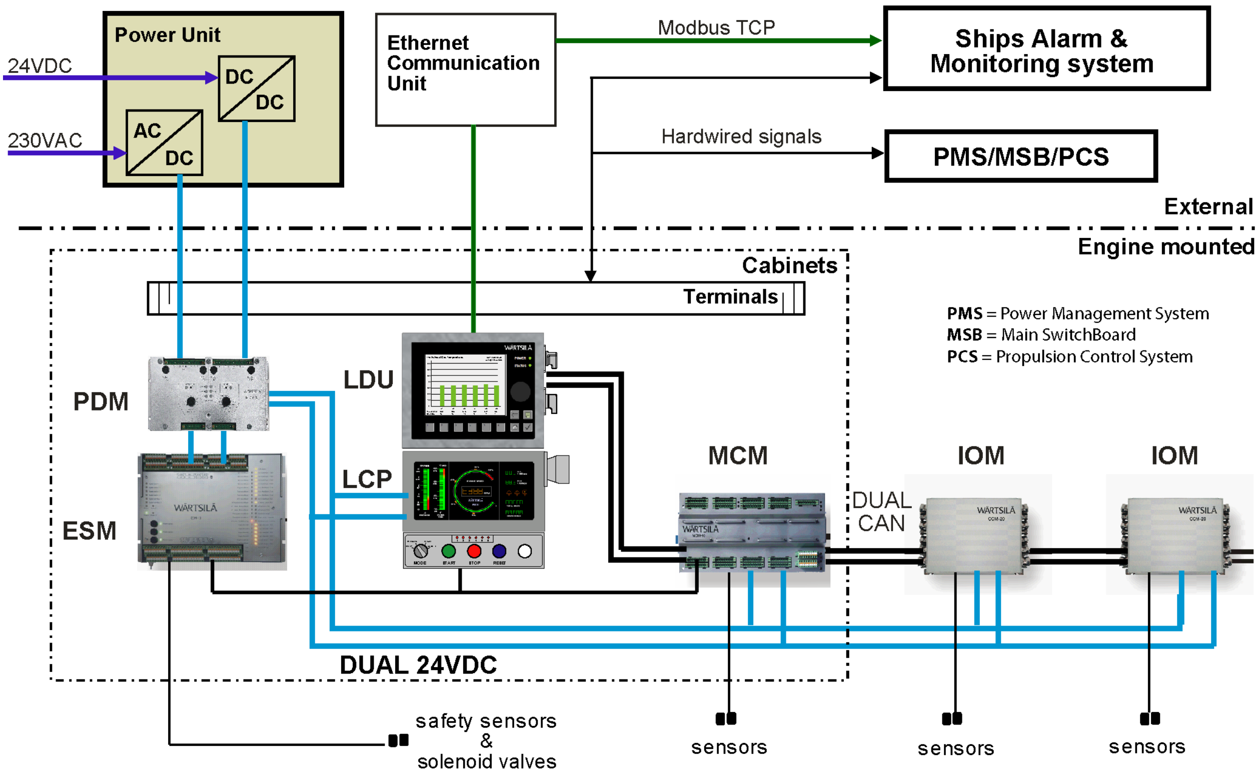
UNIC C2 is a fully embedded and distributed engine management system, which handles all control functions on the engine; for example start sequencing, start blocking, speed control, load sharing, normal stops and safety shutdowns.

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

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

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

Figure 14.1 Architecture of UNIC C2



Short explanation of the modules used in the system:

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

ESM Engine Safety Module handles fundamental engine safety, for example shutdown due to overspeed or low lubricating oil pressure. The safety module is the interface to the shutdown devices and backup instruments.

LCP Local Control Panel is equipped with push buttons and switches for local engine control, as well as indication of running hours and safety-critical operating parameters.

LDU Local Display Unit offers a set of menus for retrieval and graphical display of operating data, calculated data and event history. The module also handles communication with external systems over Modbus TCP.

PDM	Power Distribution Module handles fusing, power distribution, earth fault monitoring and EMC filtration in the system. It provides two fully redundant 24 VDC supplies to all modules, sensors and control devices.
IOM	Input/Output Module handles measurements and limited control functions in a specific area on the engine.
CCM	Cylinder Control Module. Handles fuel injection control, and local measurements at the cylinders where it is used.

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

14.1.1 External equipment

Power unit

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

Ethernet communication unit

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

14.1.2 Local control panel and local display unit

Operational functions available at the LCP:

- Local start
- Local stop
- Local emergency speed setting selectors (mechanical propulsion):
  - Normal / emergency mode
  - Decrease / Increase speed
- Local emergency stop
- Local shutdown reset
- Local mode selector switch with positions blow, blocked, local and remote

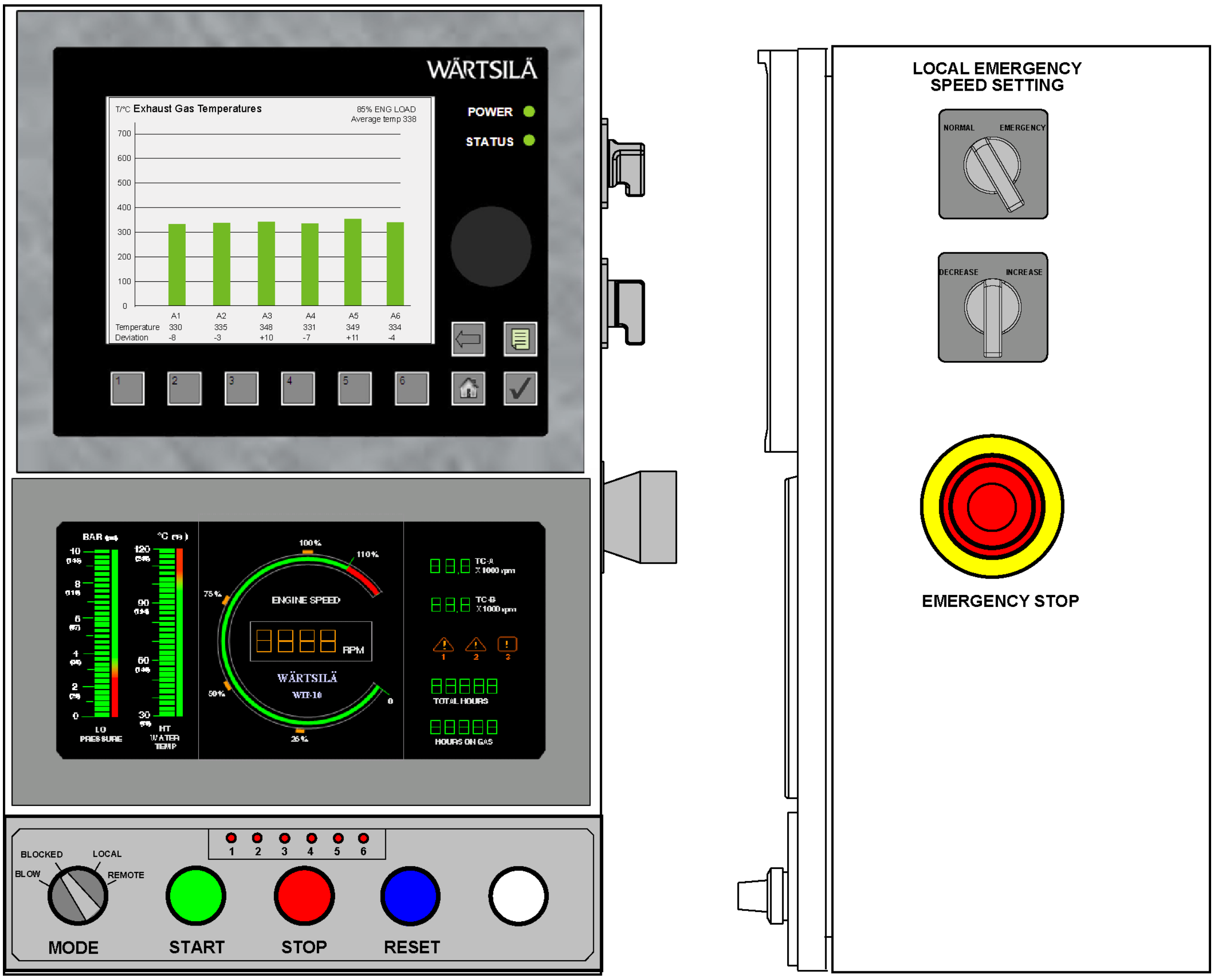
  Positions:
  - Local: Engine start and stop can be done only at the local control panel
  - Remote: Engine can be started and stopped only remotely
  - Blow: In this position it is possible to perform a “blow” (an engine rotation check with indicator valves open and disabled fuel injection) by the start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

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

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

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

Figure 14.2 Local control panel and local display unit



14.1.3 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

14.1.4 Power unit

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

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

Power supply from ship's system:

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

14.1.5 Cabling and system overview

Figure 14.3 UNIC C2 overview

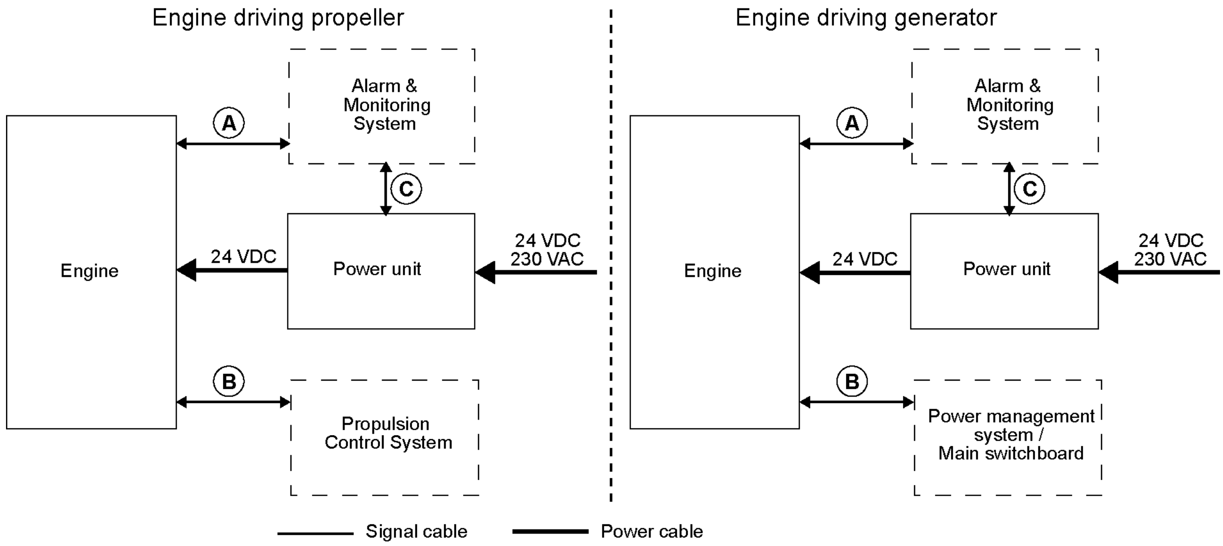


Table 14.1 Typical amount of cables

Cable	From <=> To	Cable types (typical)
A	Engine <=> Integrated Automation System	3 x 2 x 0.75 mm^2 1 x Ethernet CAT 5
B	Engine <=> Propulsion Control System Engine <=> Power Management System / Main Switchboard	1 x 2 x 0.75 mm^2 1 x 2 x 0.75 mm^2 1 x 2 x 0.75 mm^2 14 x 0.75 mm^2 14 x 0.75 mm^2
C	Power unit <=> Integrated Automation System	2 x 0.75 mm^2
D	Engine <=> Power Unit	2 x 2.5 mm^2 (power supply) 2 x 2.5 mm^2 (power supply)

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

* Dimension of the power supply cables depends on the cable length.

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

Figure 14.4 Signal overview (Main engine)

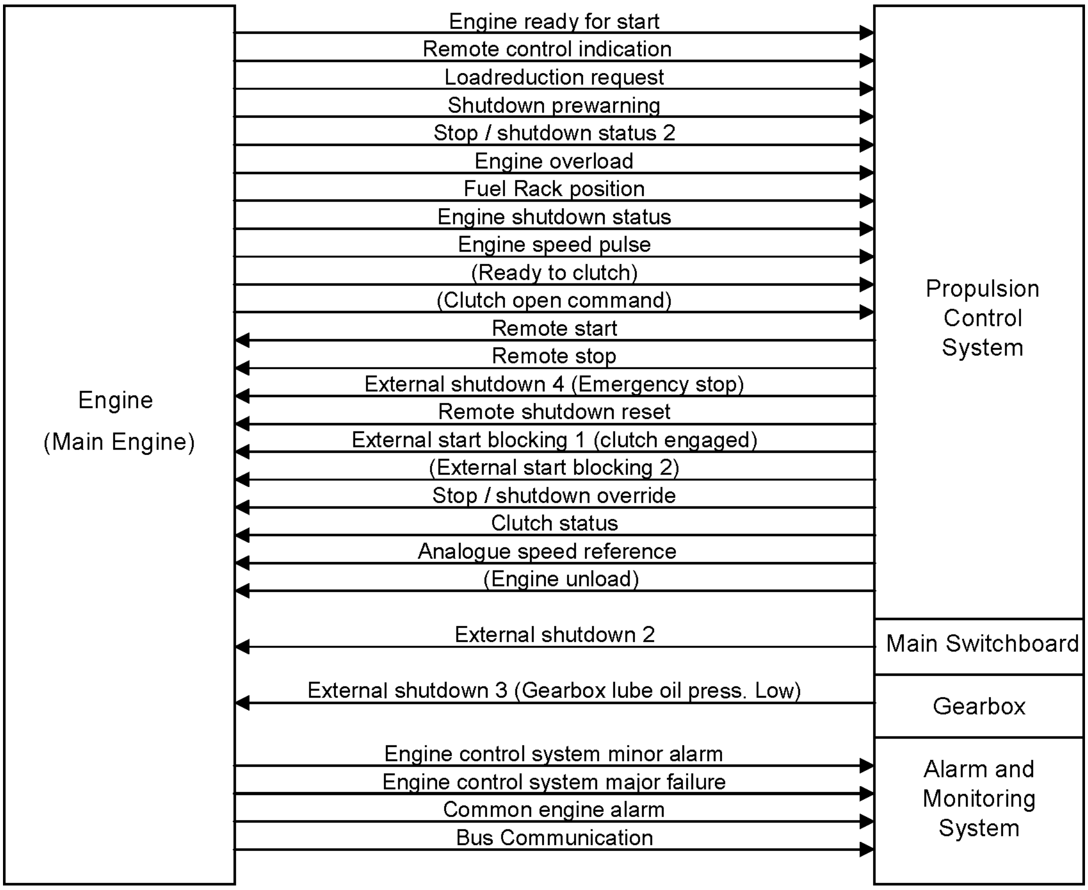
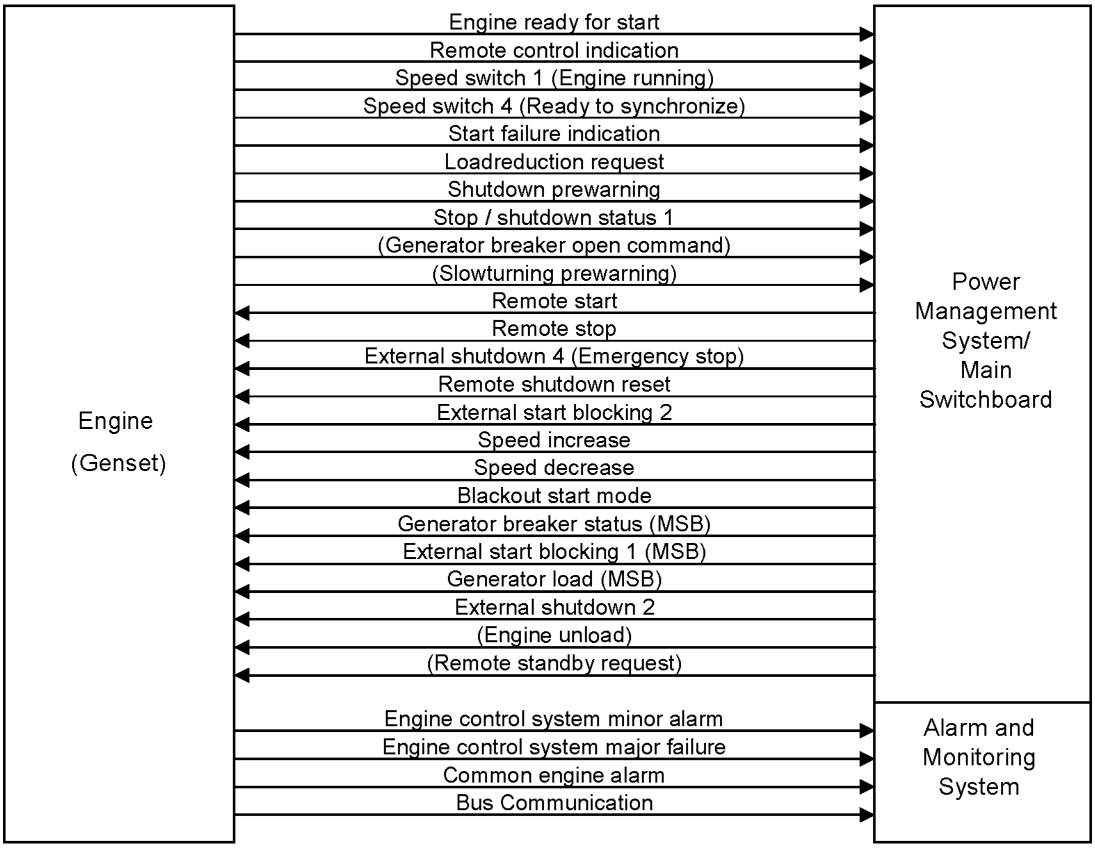


Figure 14.5 Signal overview (Generating set)



14.2 Functions

14.2.1 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).

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

Startblockings

Starting is inhibited by the following functions:

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

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

14.2.2 Stop and shutdown

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

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

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

Typical shutdown functions are:

- Lubricating oil pressure low
- Overspeed
- 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.

14.2.3 Speed control

Main engines (mechanical propulsion)

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

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

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

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

Generating sets

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

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

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

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

14.3 Alarm and monitoring signals

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 for ship's alarm and monitoring system, which are transmitted over a Modbus communication link.

Table 14.2 Typical sensors

Code	Description	Range
PT101	Fuel oil pressure, engine inlet	0-16 bar
TE101	Fuel oil temp., engine inlet	0-160 °C
LS103A	Fuel oil leakage, injection pipe (A-bank)	on/off
LS103B 1)	Fuel oil leakage, injection pipe (B-bank)	on/off
LS108A	Fuel oil leakage, dirty fuel (A-bank)	on/off
LS108B 1)	Fuel oil leakage, dirty fuel (B-bank)	on/off
PT201	Lub. oil pressure, engine inlet	0-10 bar
TE201	Lub. oil temp., engine inlet	0-160 °C
LS204	Lube oil low level, wet sump	on/off
PDT243	Lube oil filter pressure difference	0-2 bar
PT271	Lube oil pressure, TC A inlet	0-10 bar
TE272	Lube oil temp., TC A outlet	0-160 °C
PT281 1)	Lube oil pressure, TC B inlet	0-10 bar
TE282 1)	Lube oil temp., TC B outlet	0-160 °C
PT301	Starting air pressure	0-40 bar
PT311	Control air pressure	0-40 bar

Code	Description	Range
PT401	HT water pressure, jacket inlet	0-6 bar
TE401	HT water temp., jacket inlet	0-160 °C
TE402	HT water temp., jacket outlet	0-160 °C
TEZ402	HT water temp., jacket outlet	0-160 °C
TE432	HT water temp., HT CAC outlet	0-160 °C
PT471	LT water pressure, CAC inlet	0-6 bar
TE471	LT water temp., LT CAC inlet	0-160 °C
TE482	LT water temp., LOC outlet	0-160 °C
TE5011A ... TE5091A	Exhaust gas temp., cylinder A1 outlet ... Exhaust gas temp., cylinder A9 outlet	0-750 °C
TE5011B [1)] ... TE5091B	Exhaust gas temp., cylinder B1 outlet ... Exhaust gas temp., cylinder B9 outlet	0-750 °C
TE511	Exhaust gas temp., TC A inlet	0-750 °C
TE521 [1)]	Exhaust gas temp., TC B inlet	0-750 °C
TE517	Exhaust gas temp., TC A outlet	0-750 °C
TE527 [1)]	Exhaust gas temp., TC B outlet	0-750 °C
PT601	Charge air pressure, CAC outlet	0-6 bar
TE601	Charge air temp. engine inlet	0-160 °C
TE700 ... TE710	Main bearing 0 temp ... Main bearing 10 temp	0-250 °C
PT700	Crankcase pressure	-25 ... 25 mbar
NS700	Oil mist detector failure	on/off
QS700	Oil mist in crankcase, alarm	on/off
IS1741	Alarm, overspeed shutdown	on/off
IS2011	Alarm, lub oil press. low shutdown	on/off
IS7311	Alarm, red.gear lo press low shutdown	on/off
IS7338	Alarm, oil mist in crankcase shutdown	on/off
IS7305	Emergency stop	on/off
NS881	Engine control system minor alarm	on/off
IS7306	Alarm, shutdown override	on/off
SI196	Engine speed	0-1200 rpm
SI518	Turbocharger A speed	0-50000 rpm
SI528	Turbocharger B speed [1)]	0-50000 rpm
IS875	Start failure	on/off
	Power supply failure	on/off

Note 1 V-engines only

14.4 Electrical consumers

14.4.1 Motor starters and operation of electrically driven pumps

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

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

Engine turning device (9N15)

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

Table 14.3 Electric motor ratings for engine turning device

Engine type	Voltage [V]	Frequency [Hz]	Power [kW]	Current [A]
Wärtsilä 32	3 x 400 / 440	50 / 60	2.2 / 2.6	5.0 / 5.3

Pre-lubricating oil pump

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

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

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

Table 14.4 Electric motor ratings for pre-lubricating pump

Engine type	Voltage [V]	Frequency [Hz]	Power [kW]	Current [A]
in-line engines	3 x 400	50	7.5	14.0
	3 x 440	60	8.6	14.6
V-engines	3 x 400	50	15.5	29.0
	3 x 440	60	18.0	30.5

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

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

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

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

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

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

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

Circulating pump for preheater (4P04)

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

Sea water pumps (4P11)

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

Lubricating oil separator (2N01)

Continuously in operation.

Feeder/booster unit (1N01)

Continuously in operation.

15. Foundation

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

15.1 Steel structure design

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

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

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

15.2 Mounting of main engines

15.2.1 Rigid mounting

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

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

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

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

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

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

Resin chocks

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

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

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

Steel chocks

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

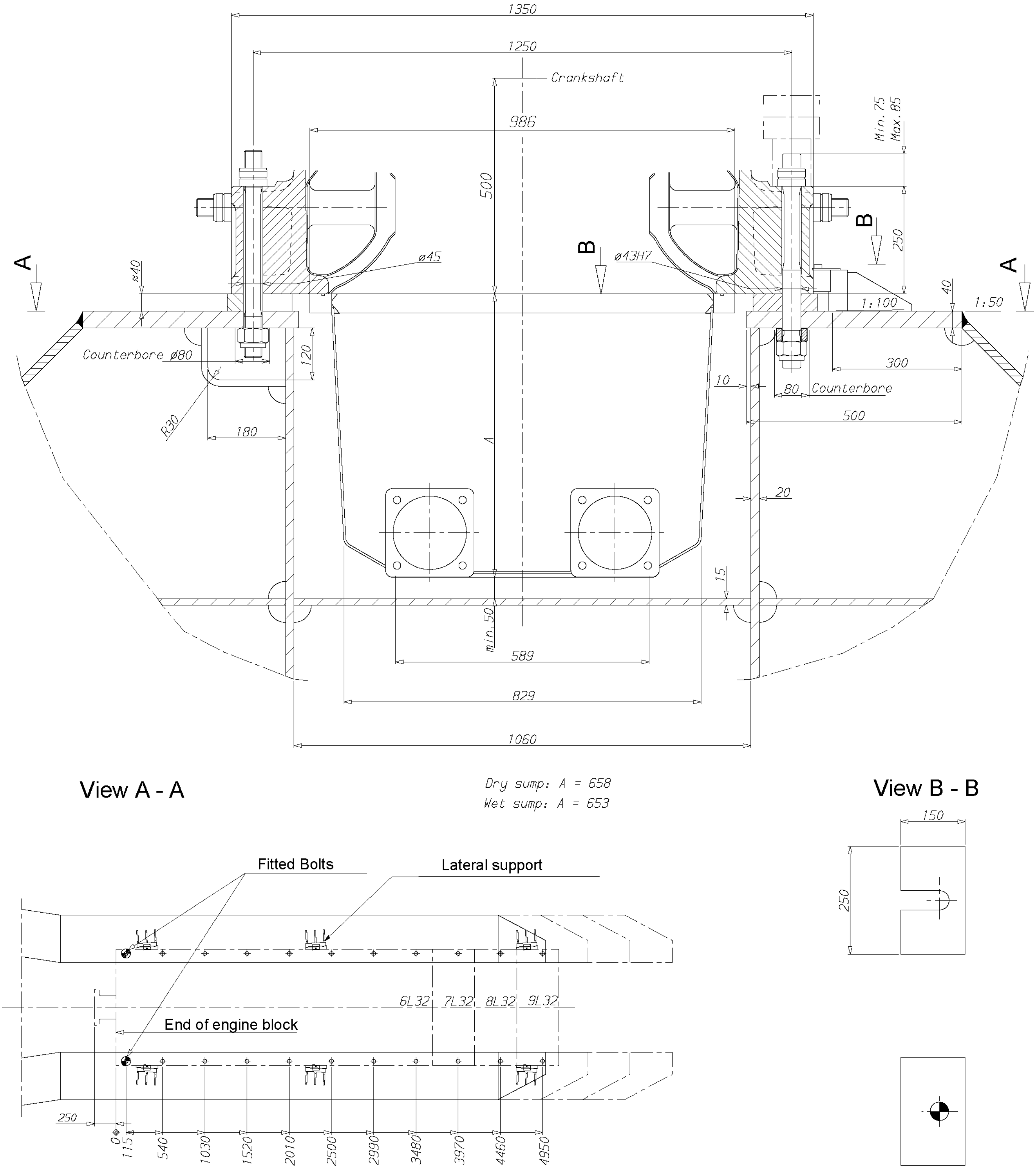
Recommended chock dimensions are 250 x 200 mm and the chocks must have an inclination of 1:100, inwards with regard to the engine centre line. The cut-out in the chocks for the clearance bolts shall be 44 mm (M42 bolts), while the hole in the chocks for the fitted bolts shall be drilled and reamed to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

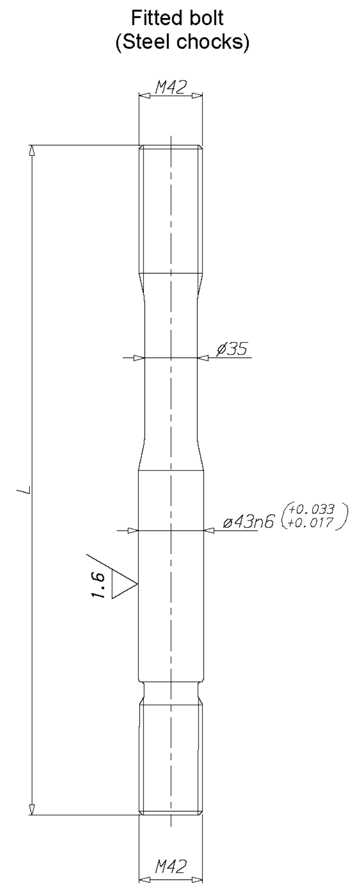
The design of the holding down bolts is shown the foundation drawings. The bolts are designed as tensile bolts with a reduced shank diameter to achieve a large elongation, which improves the safety against loosening of the nuts.

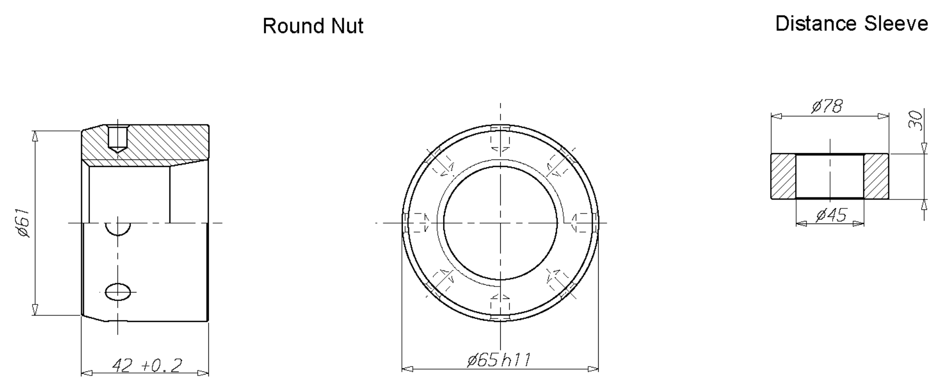
Steel chocks with adjustable height

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.

Figure 15.1 Main engine seating and fastening, in-line engines, steel chocks (1V69A0144f)

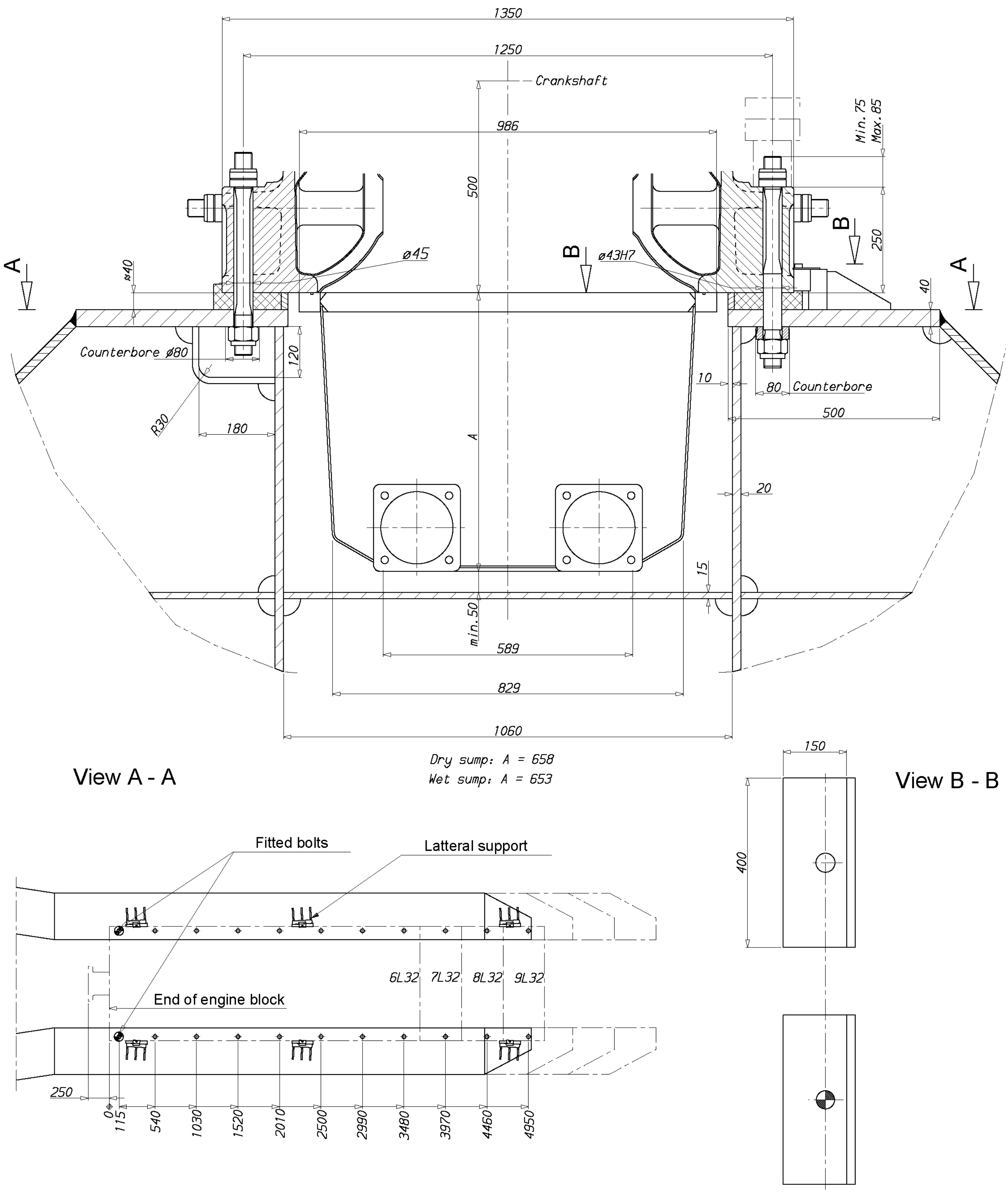




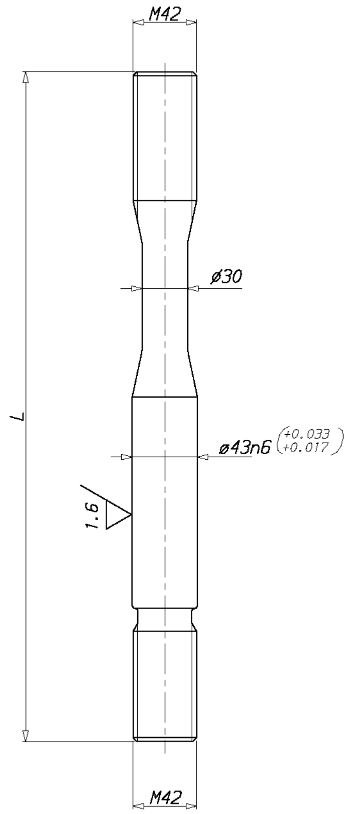


Number of pieces per engine				
	W 6L32	**W 7L32**	**W 8L32**	**W 9L32**
Fitted bolt	2	2	2	2
Clearance bolt	14	16	18	20
Round nut	16	18	20	22
Lock nut	16	18	20	22
Distance sleeve	2	2	2	2
Lateral support	4	4	4	6
Chocks	16	18	20	22

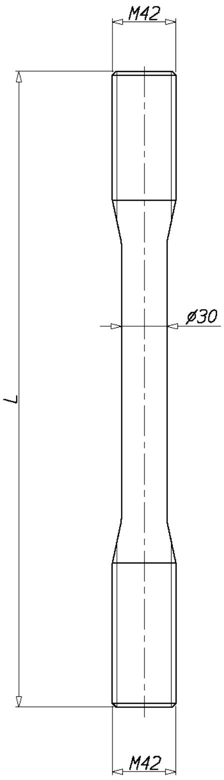
Figure 15.2 Main engine seating and fastening, in-line engines, resin chocks (1V69A0140f)



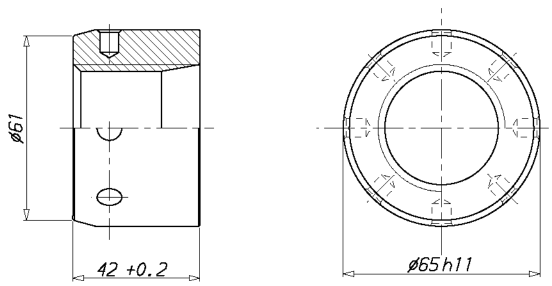
Fitted bolt
(Resin chocks)



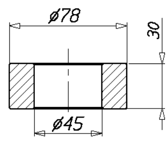
Clearance bolt
(Resin chocks)



Round Nut

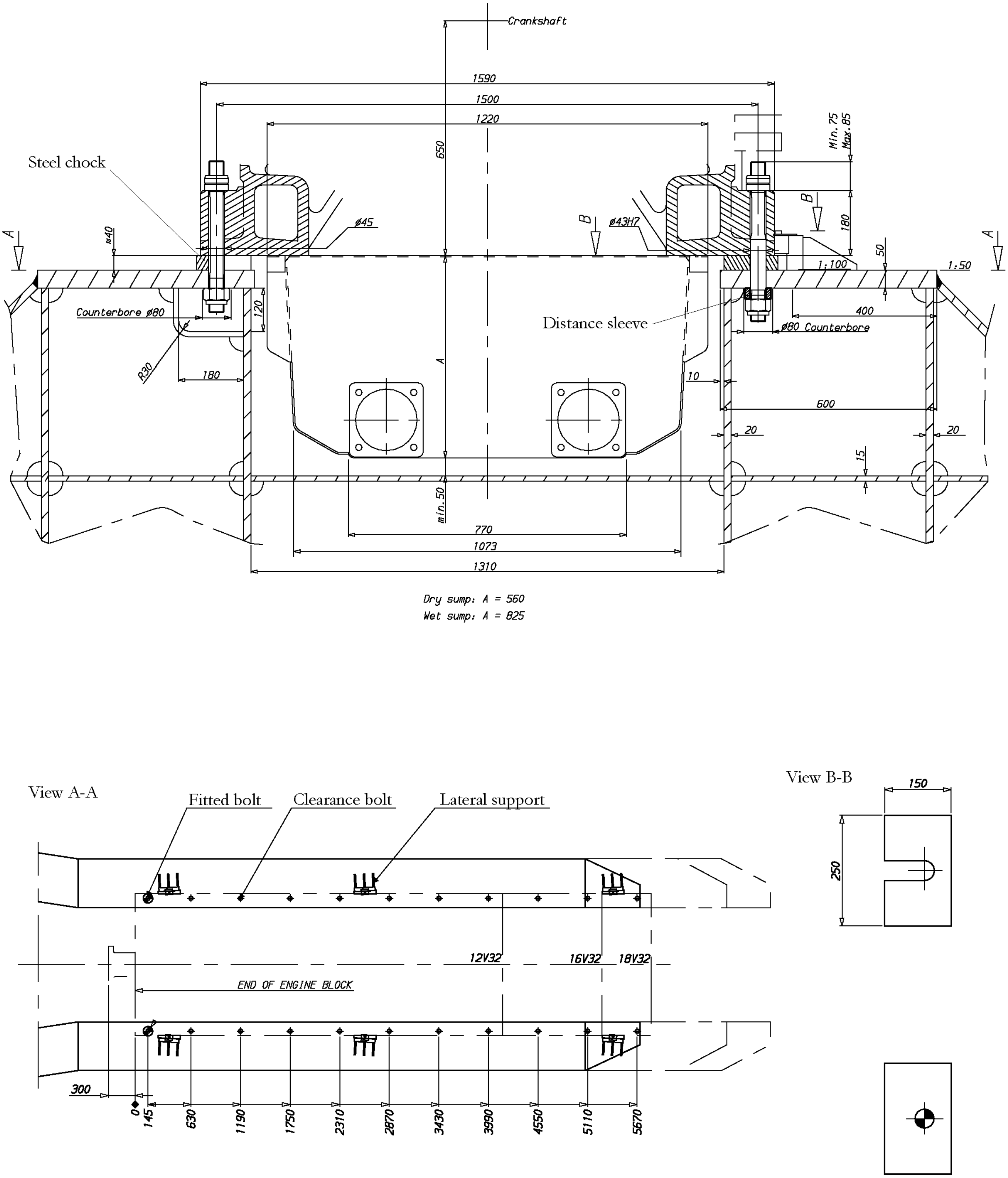


Distance sleeve

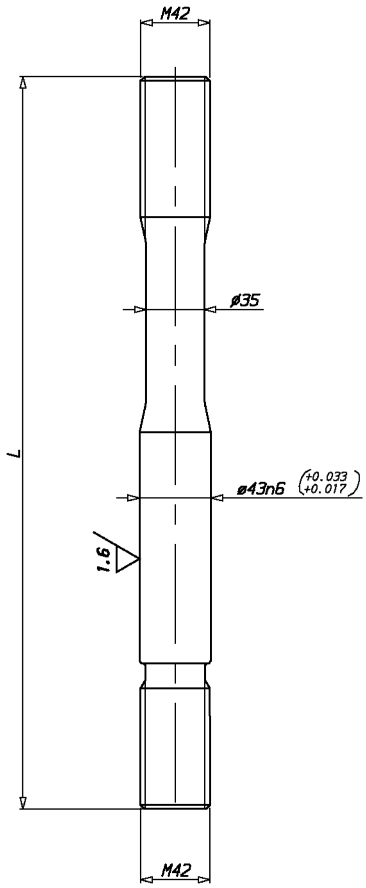


Number of pieces per engine				
	W 6L32	**W 7L32**	**W 8L32**	**W 9L32**
Fitted bolt	2	2	2	2
Clearance bolt	14	16	18	20
Round nut	16	18	20	22
Lock nut	16	18	20	22
Distance sleeve	2	2	2	2
Lateral support	4	4	4	6
Chocks	16	18	20	22

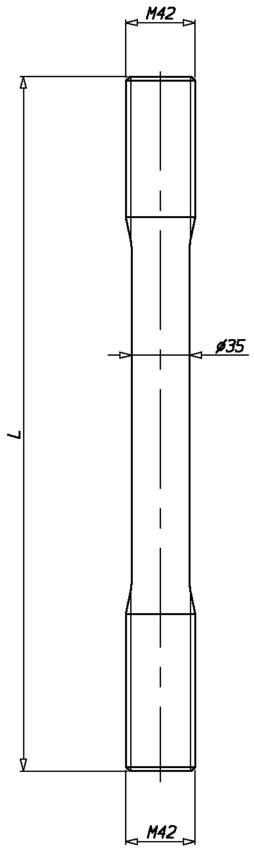
Figure 15.3 Main engine seating and fastening, V-engines, steel chocks (1V69A0145f)



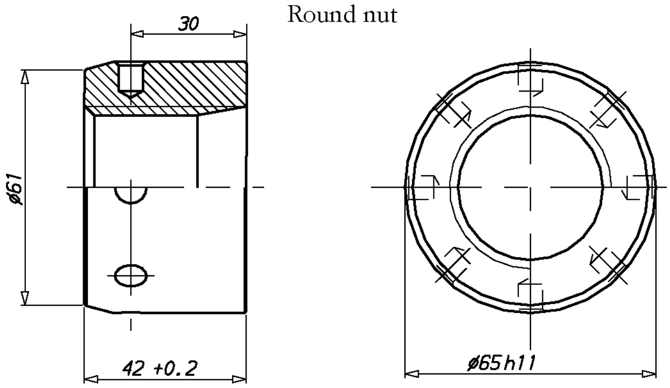
Fitted bolt
(steel chock)



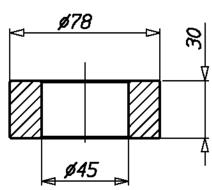
Clearance bolt
(steel chock)



Round nut

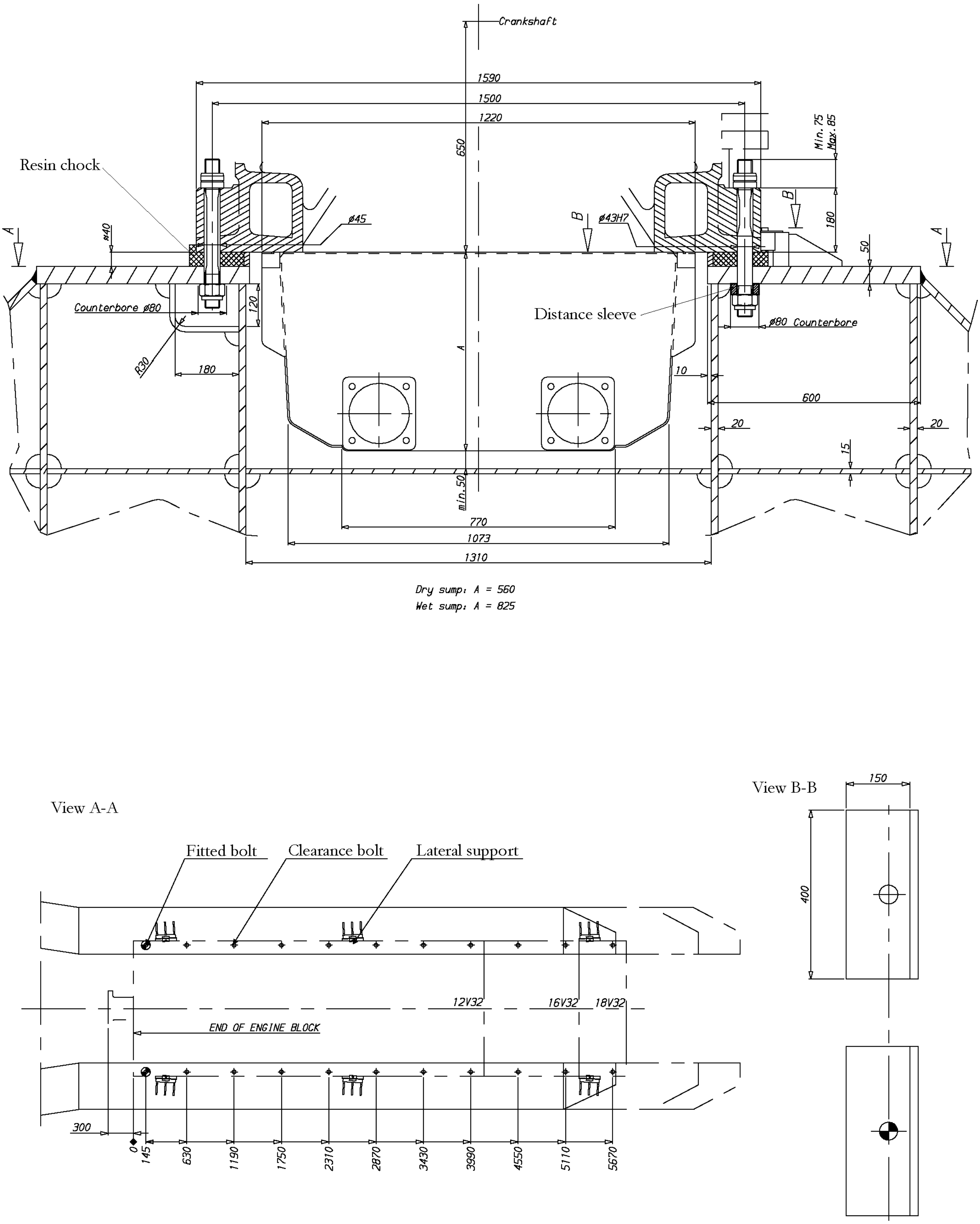


Distance sleeve

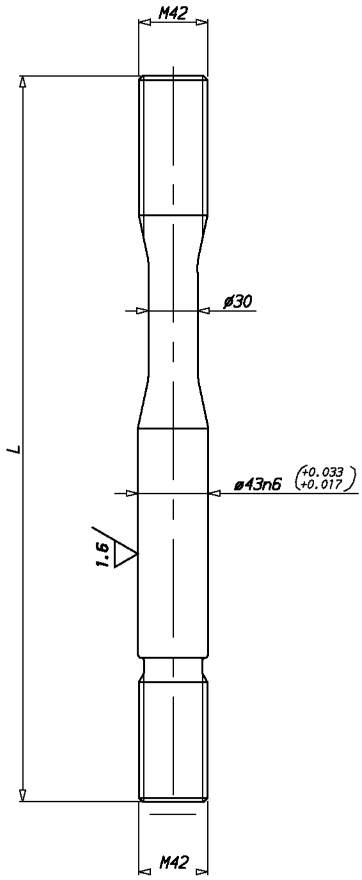


Number of pieces per engine			
	W 12V32	W 16V32	W 18V32
Fitted bolt	2	2	2
Clearance bolt	14	18	20
Round nut	16	20	22
Lock nut	16	20	22
Distance sleeve	2	2	2
Lateral support	4	4	6
Chocks	16	20	22

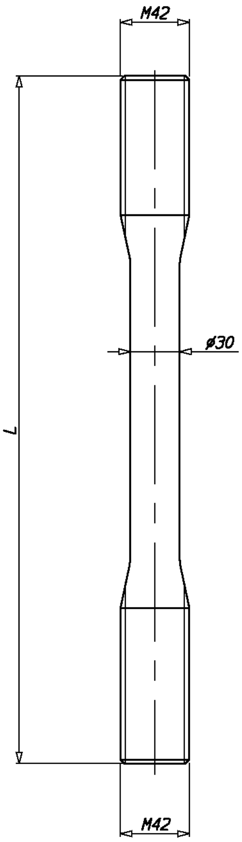
Figure 15.4 Main engine seating and fastening, V engines, resin chocks (1V69A0146g)



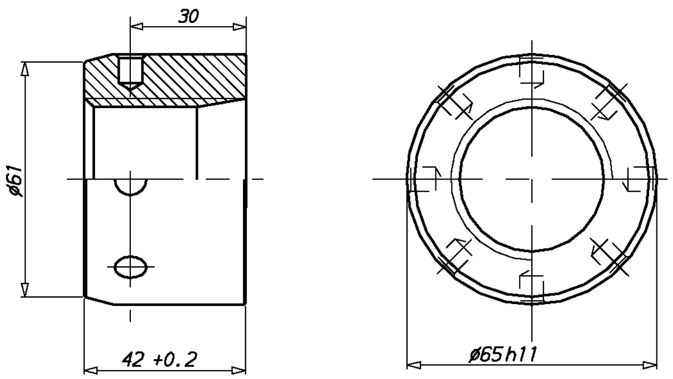
Fitted bolt
(resin chock)



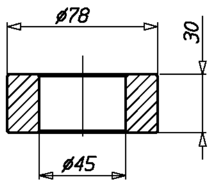
Clearance bolt
(resin chock)



Round nut



Distance sleeve



Number of pieces per engine			
	W 12V32	W 16V32	W 18V32
Fitted bolt	2	2	2
Clearance bolt	14	18	20
Round nut	16	20	22
Lock nut	16	20	22
Distance sleeve	2	2	2
Lateral support	4	4	6
Chocks	16	20	22

15.2.2 Resilient mounting

In order to reduce vibrations and structure borne noise, main engines can be resiliently mounted on rubber elements. The transmission of forces emitted by the engine is 10-20% when using resilient mounting. For resiliently mounted engines a speed range of 500-750 rpm is generally available, but cylinder configuration 18V is limited to constant speed operation (750 rpm) and resilient mounting is not available for 7L32.

Two different mounting arrangements are applied. Cylinder configurations 6L, 8L, 12V and 16V are mounted on conical rubber mounts, which are similar to the mounts used under generating sets. The mounts are fastened directly to the engine feet with a hydraulically tightened bolt. To enable drilling of holes in the foundation after final alignment adjustments the mount is fastened to an intermediate steel plate, which is fixed to the foundation with one bolt. The hole in the foundation for this bolt can be drilled through the engine foot. A resin chock is cast under the intermediate steel plate.

Cylinder configurations 9L and 18V are mounted on cylindrical rubber elements. These rubber elements are mounted to steel plates in groups, forming eight units. These units, or resilient elements, each consist of an upper steel plate that is fastened directly to the engine feet, rubber elements and a lower steel plate that is fastened to the foundation. The holes in the foundation for the fastening bolts can be drilled through the holes in the engine feet, when the engine is finally aligned to the reduction gear. The resilient elements are compressed to the calculated height under load by using M30 bolts through the engine feet and distance pieces between the two steel plates. Resin chocks are then cast under the resilient elements. Shims are provided for installation between the engine feet and the resilient elements to facilitate alignment adjustments in vertical direction. Steel chocks must be used under the side and end buffers located at each corner if the engine.

Figure 15.5 Principle of resilient mounting, W6L32 and W8L32 (DAAE048811)

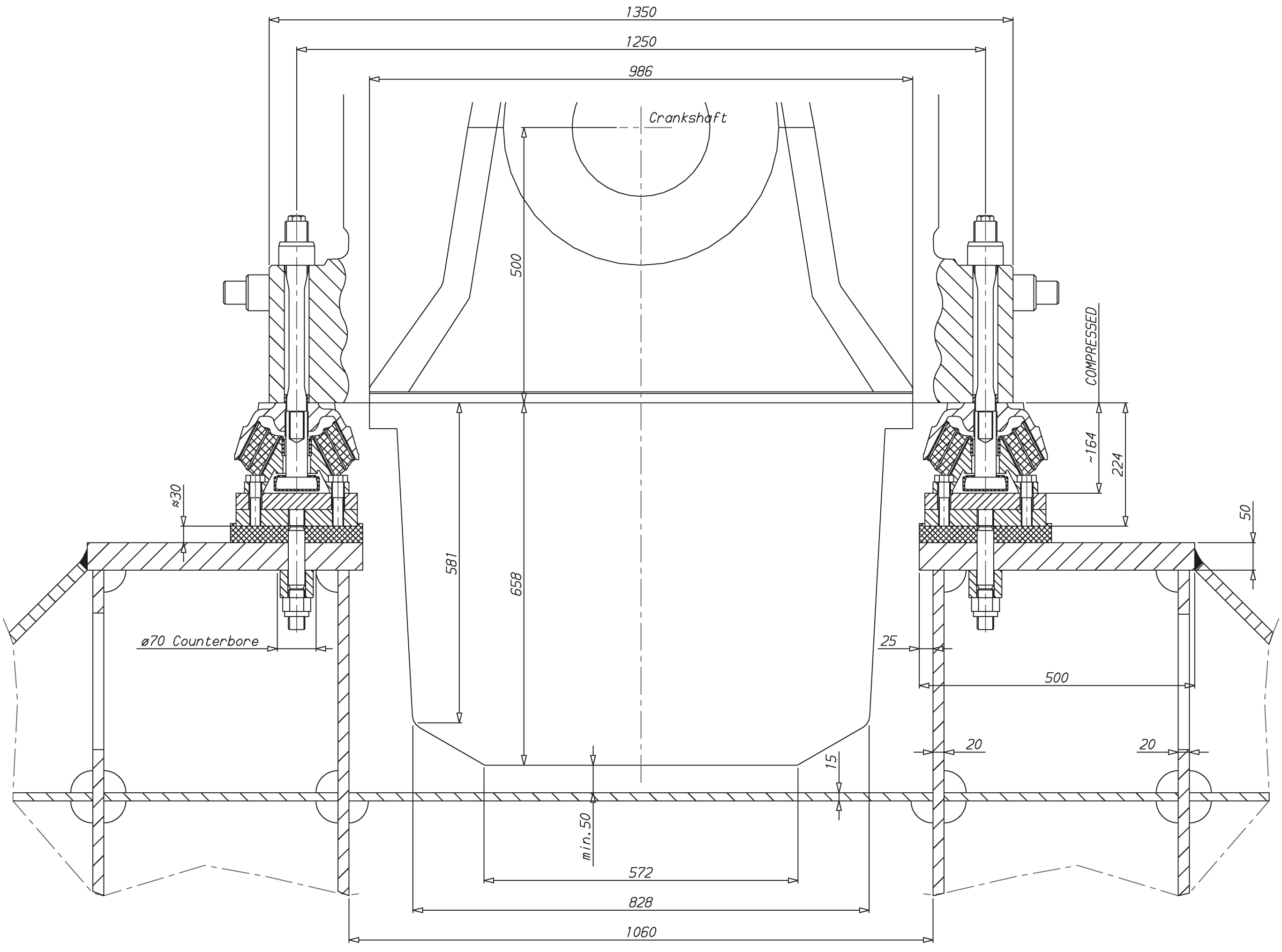


Figure 15.6 Principle of resilient mounting, W9L32 (2V69A0247a)

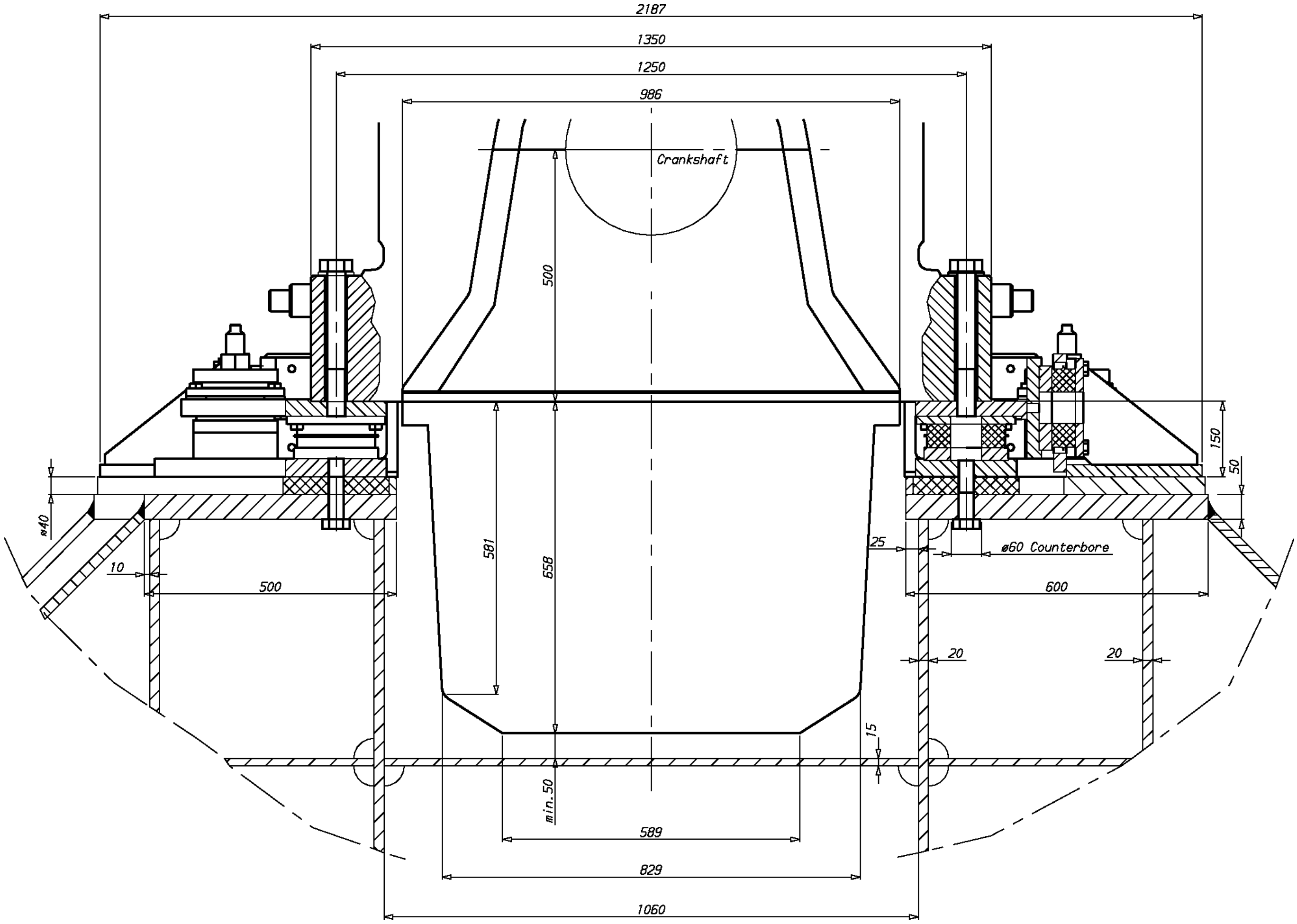


Figure 15.7 Principle of resilient mounting, W12V32 and W16V32 (DAAE041111A)

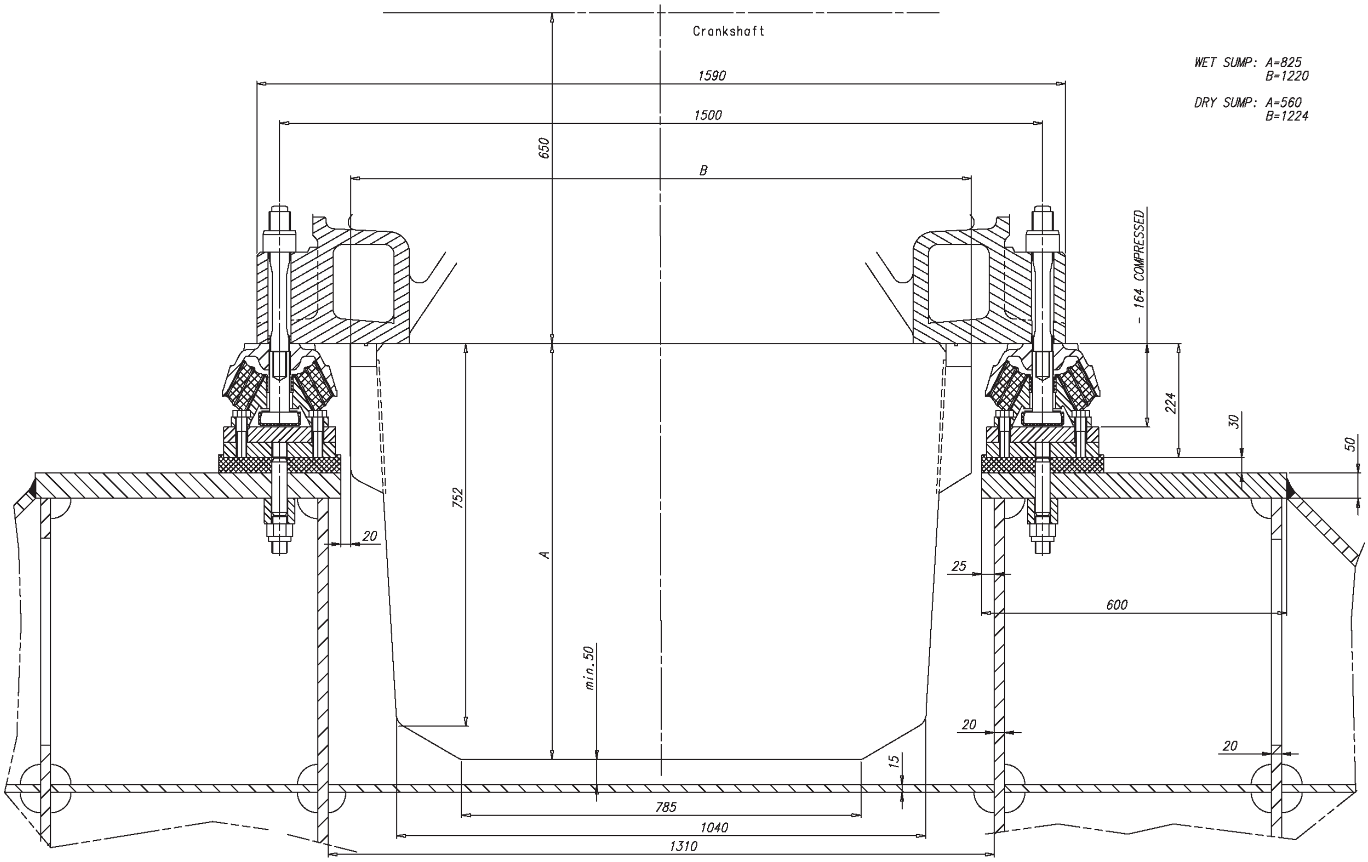
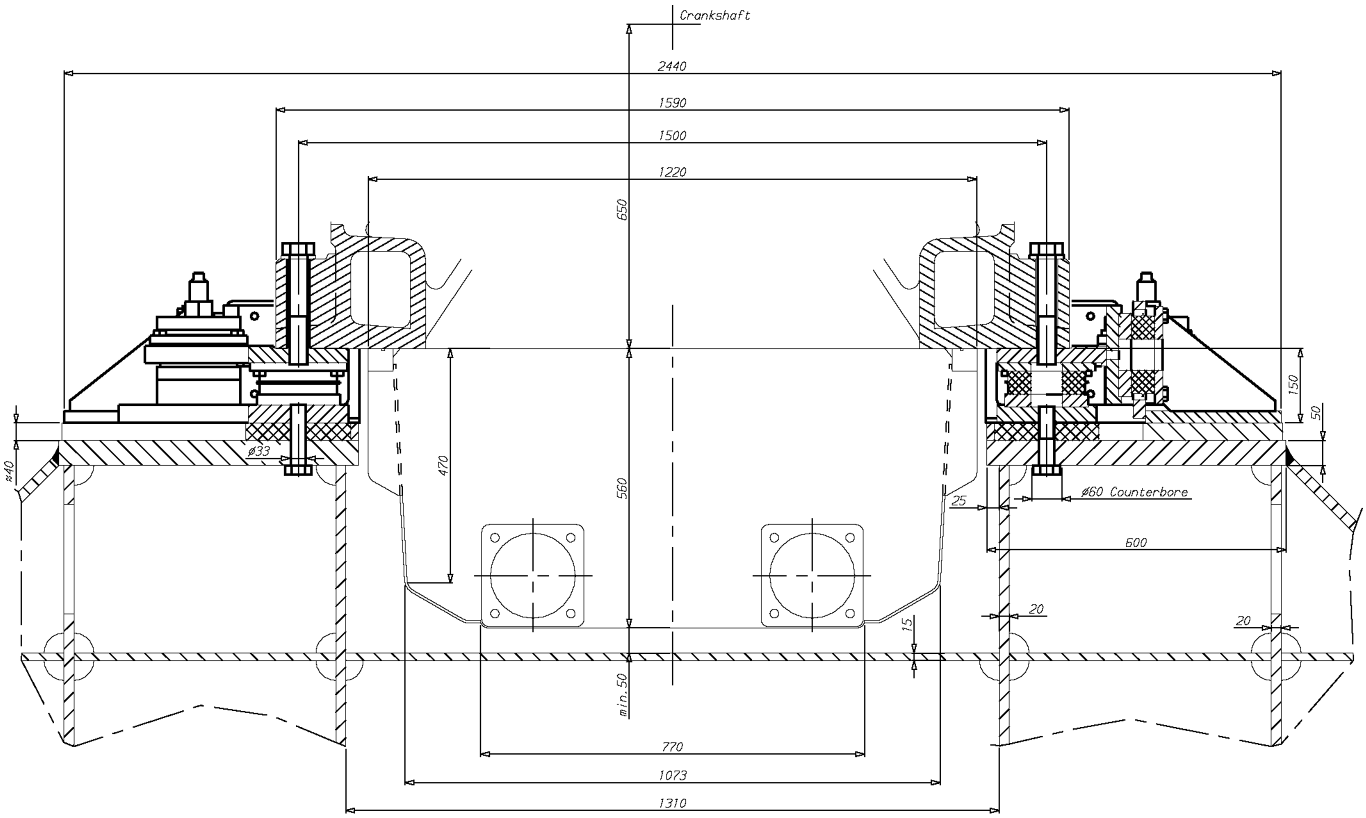


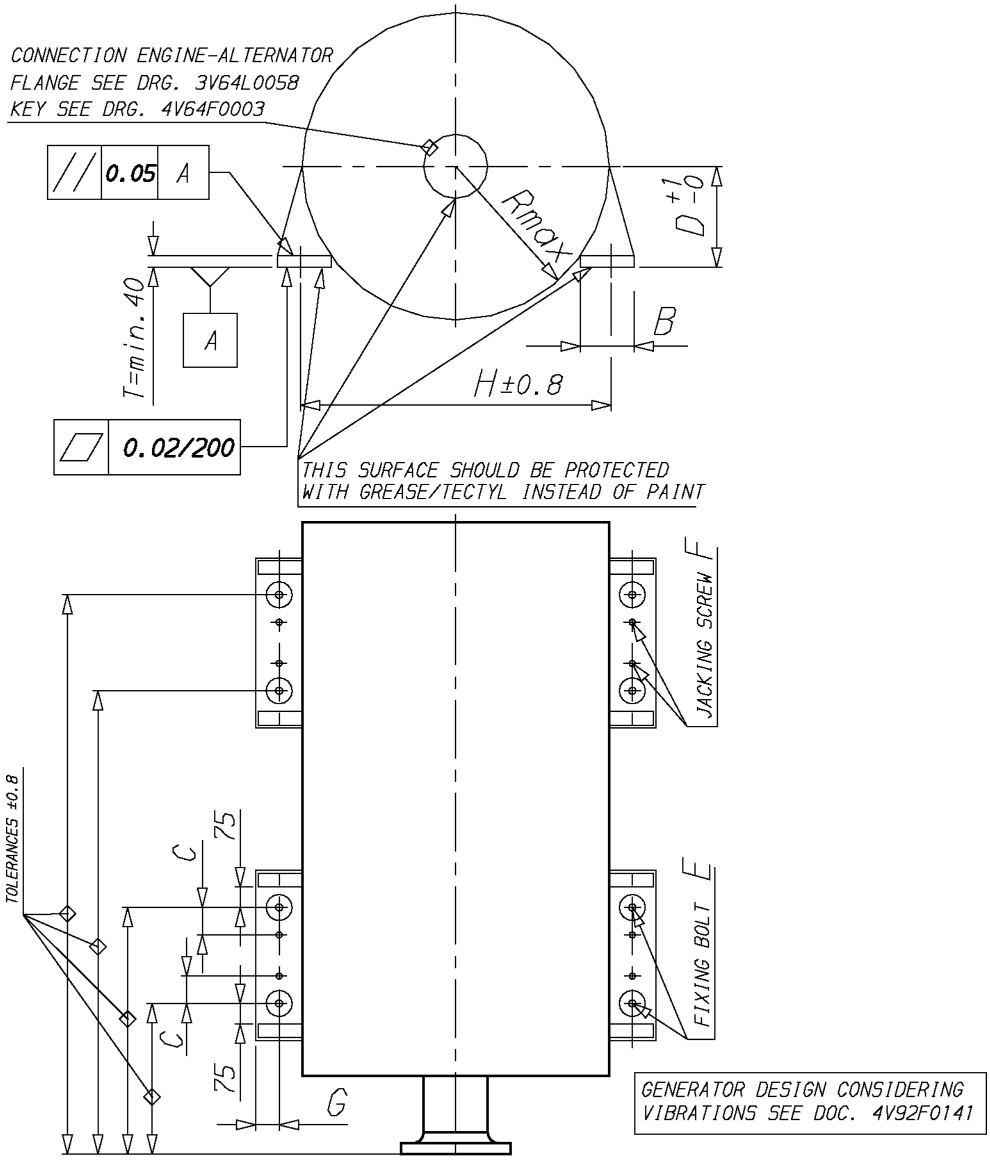
Figure 15.8 Principle of resilient mounting, W18V32 (2V69A0248a)



15.3 Mounting of generating sets

15.3.1 Generator feet design

Figure 15.9 Distance between fixing bolts on generator (4V92F0143b)



H [mm]	W 6L32 Rmax [mm]	W 7L32 Rmax [mm]	W 8L32 Rmax [mm]	W 9L32 Rmax [mm]	W 12V32 Rmax [mm]	W 16V32 Rmax [mm]	W 18V32 Rmax [mm]
1400	715	-	-	-	-	-	-
1600	810	810	810	810	-	-	-
1800	-	905	905	905	985	985	985
1950	-	980	980	980	1045	1045	1045
2200	-	-	-	1090	-	-	1155

Engine	G [mm]	F	E [mm]	D [mm]	C [mm]	B [mm]
W L32	85	M24 or M27	Ø35	475	100	170
W V32	100	M30	Ø48	615	130	200

15.3.2 Resilient mounting

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

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

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

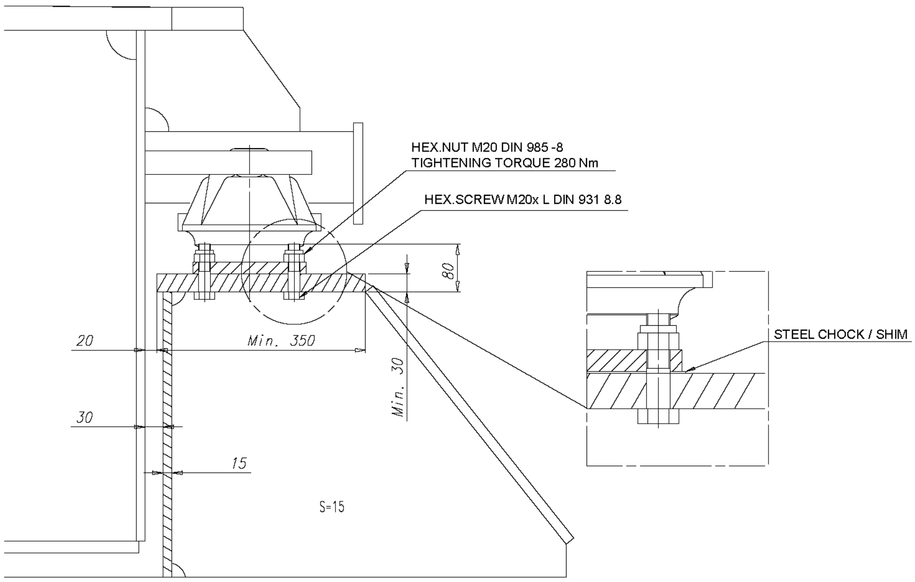
NOTE! To avoid induced oscillation of the generating set, the following data must be sent by the shipyard to Wärtsilä at the design stage:

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

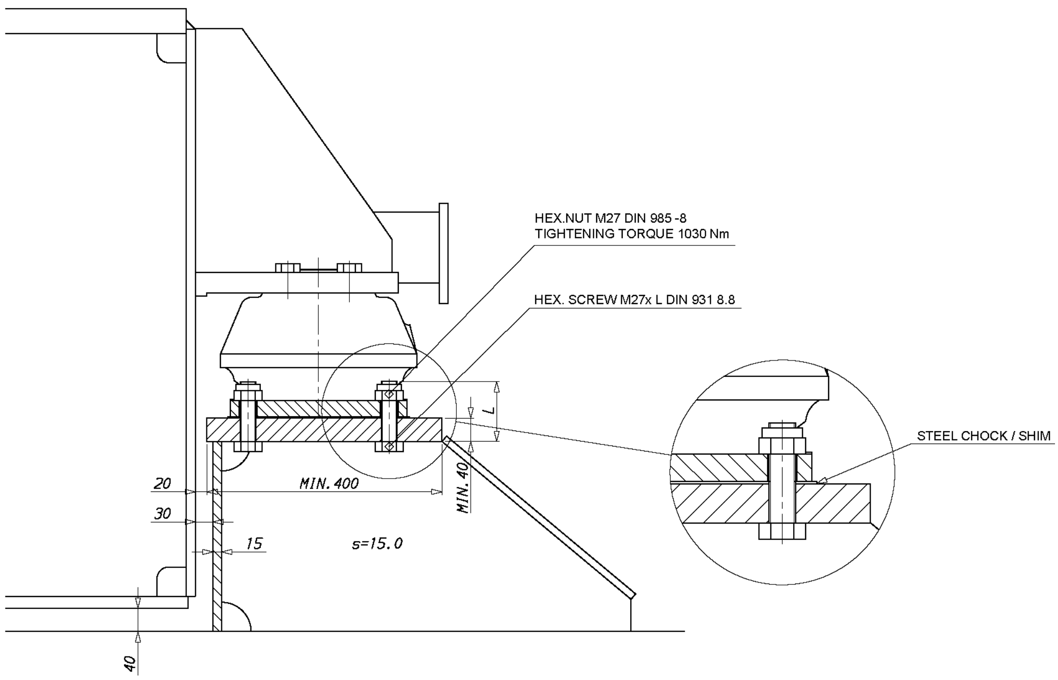
The selected number of mounts and their final position is shown in the generating set drawing.

Figure 15.10 Recommended design of the generating set seating (3V46L0295d, DAAE020067a)

In-line engines



V-engines



Rubber mounts

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

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

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

The transmission of forces emitted by the engine is 10 -20% when using conical mounts. For the foundation design, see drawing 3V46L0295 (in-line engines) and 3V46L0294 (V-engines).

Figure 15.11 Rubber mount, In-line engines (DAAE004230c)

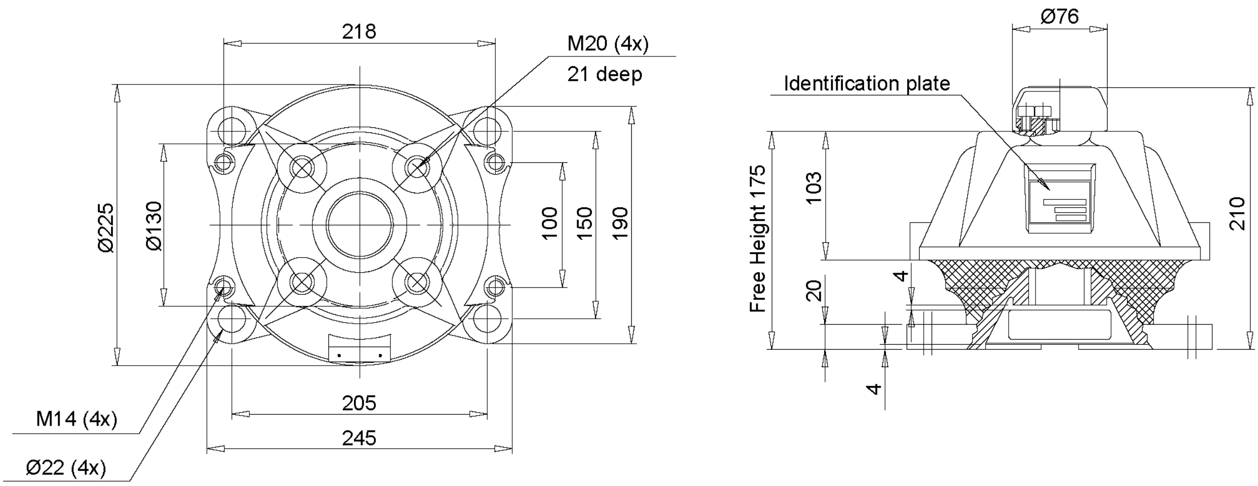
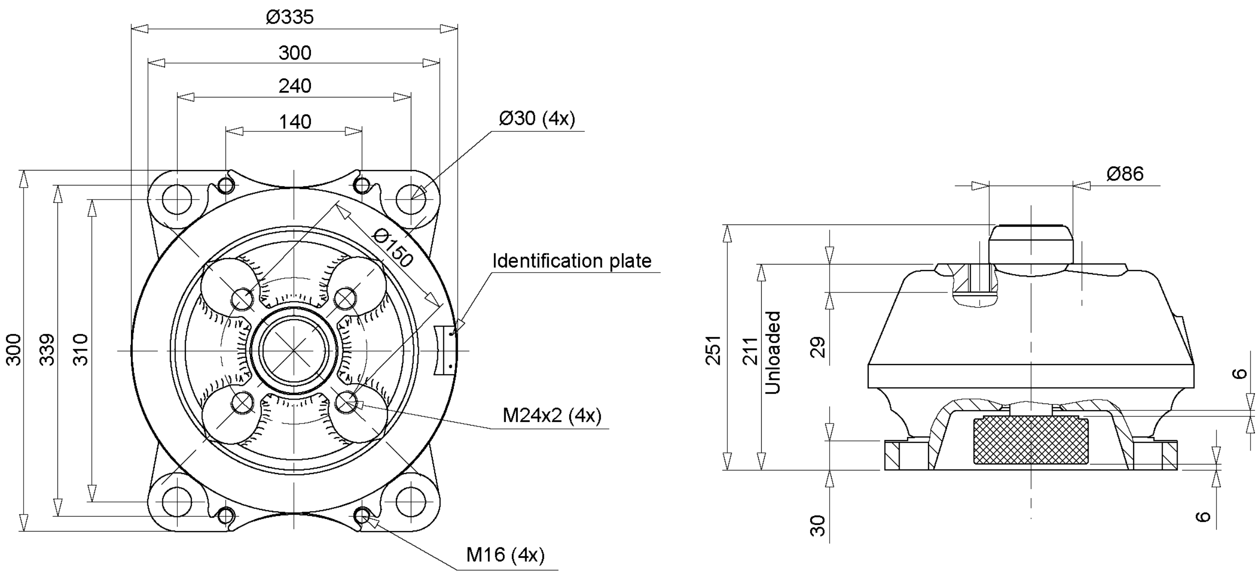


Figure 15.12 Rubber mount, V-engines (DAAE018766b)



15.4 Flexible pipe connections

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

16. Vibration and Noise

Wärtsilä 32 generating sets comply with vibration levels according to ISO 8528-9. Main engines comply with vibration levels according to ISO 10816-6 Class 5.

16.1 External forces and couples

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

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

Figure 16.1 Coordinate system

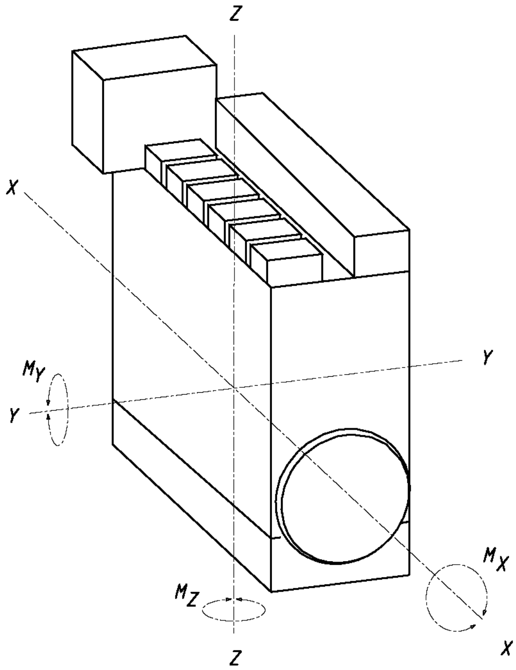


Table 16.1 External forces and couples

Engine	Speed	Fre-quency	M_Y	M_Z	Fre-quency	M_Y	M_Z	Fre-quency	F_Y	F_Z
	[rpm]	[Hz]	[kNm]	[kNm]	[Hz]	[kNm]	[kNm]	[Hz]	[kN]	[kN]
W 7L32	720 750	12 12.5	12.7 13.7	12.7 13.7	24 25	23 25	– –	– –	– –	– –
W 8L32	720 750	– –	– –	– –	– –	– –	– –	48 50	– –	5.3 5.7
W 9L32	720 750	12 12.5	44 47	44 47	24 25	26 28	– –	– –	– –	– –
W 16V32	720 750	– –	– –	– –	– –	– –	– –	48 50	4.6 4.9	3.2 3.5
W 18V32	720 750	12 12.5	57 62	57 62	24 25	30 32	22 24	– –	– –	– –

– couples are zero or insignificant.

16.2 Torque variations

Table 16.2 Torque variation at 100% load for 480 & 500 kW/cyl

Engine	Speed [rpm]	Frequency [Hz]	M_X [kNm]	Frequency [Hz]	M_X [kNm]	Frequency [Hz]	M_X [kNm]
W 6L32	720 750	36 37.5	32 29	72 75	18 18	108 112.5	2.9 3.0
W 7L32	720 750	42 43.8	69 68	84 87.5	12 12	126 131	1.1 1.1
W 8L32	720 750	48 50	59 59	96 100	7.4 7.5	144 150	0.3 0.4
W 9L32	720 750	54 56.2	55 55	108 112.5	4.4 4.5	– –	– –
W 12V32	720 750	36 37.5	8.4 7.5	72 75	34 34	108 112.5	2.2 2.3
W 16V32	720 750	48 50	40 40	96 100	11 11	144 150	0.5 0.6
W 18V32	720 750	54 56.2	61 61	108 112.5	3.3 3.4	– –	– –

Table 16.3 Torque variation at 100% load for 550 & 580 kW/cyl

Engine	Speed [rpm]	Frequency [Hz]	M_X [kNm]	Frequency [Hz]	M_X [kNm]	Frequency [Hz]	M_X [kNm]
W 6L32	720 750	36 37.5	46 43	72 75	21 21	108 113	3 3
W 8L32	720 750	48 50	73 73	96 100	9 9	144 150	1 1
W 9L32	720 750	54 56.3	66 66	108 113	5 5	216 169	1 1
W 12V32	720 750	36 37.5	12 11	72 75	41 41	108 113	3 3
W 16V32	720 750	48 50	50 50	96 100	14 14	144 150	1 1

Table 16.4 Torque variation at 0% load

Engine	Speed [rpm]	Frequency [Hz]	M_X [kNm]	Frequency [Hz]	M_X [kNm]	Frequency [Hz]	M_X [kNm]
W 6L32	720 750	36 37.5	25 29	72 75	5.2 5.2	108 112.5	1.4 1.4
W 7L32	720 750	42 43.8	16 16	84 87.5	3.9 3.9	126 131	0.9 0.9
W 8L32	720 750	48 50	11 10	96 100	2.9 3.0	144 150	0.5 0.6
W 9L32	720 750	54 56.2	14 14	108 112.5	2.1 2.2	– –	– –
W 12V32	720 750	36 37.5	6.6 7.5	72 75	10 10	108 112.5	1.1 1.1
W 16V32	720 750	48 50	7.4 7.2	96 100	4.5 4.5	144 150	0.9 1.0

Engine	Speed	Frequency	M_X	Frequency	M_X	Frequency	M_X
	[rpm]	[Hz]	[kNm]	[Hz]	[kNm]	[Hz]	[kNm]
W 18V32	720 750	54 56.2	16 16	108 112.5	1.6 1.7	– –	– –

16.3 Mass moments of inertia

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

Engine	J [kgm²]
W 6L32	500...560
W 7L32	520...600
W 8L32	520...650
W 9L32	650...690
W 12V32	730...810
W 16V32	830...900
W 18V32	980...1010

16.4 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-weighing in octave bands, reference level 1 pW. Two values are given; a minimum value and a 90% value. The minimum value is the lowest measured noise level. The 90% value indicates that 90% of all measured noise levels are below this value.

Figure 16.2 Typical sound power level for engine noise, W L32

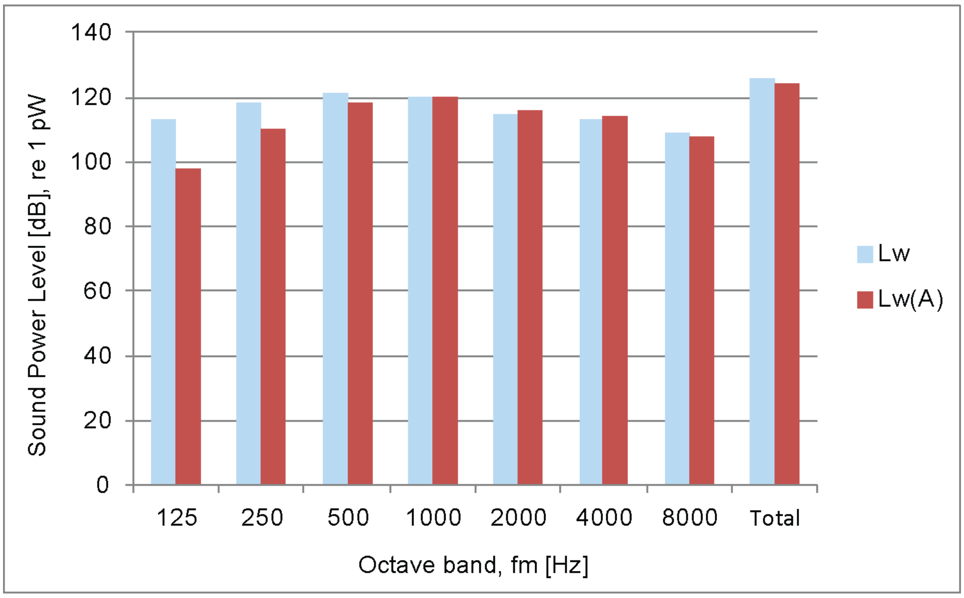
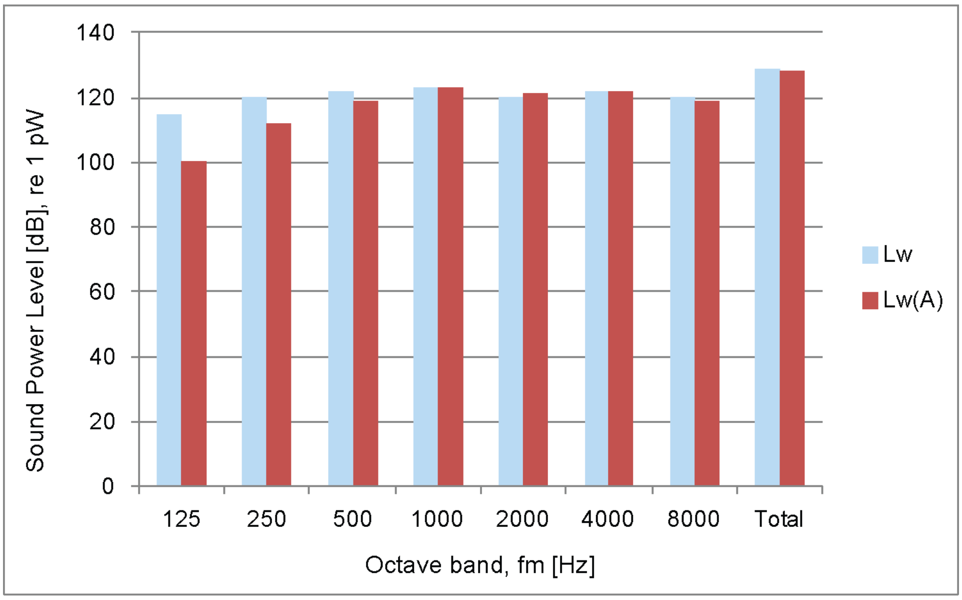


Figure 16.3 Typical sound power level for engine noise, W V32



16.5 Exhaust noise

Figure 16.4 Typical sound power level for exhaust noise, W L32

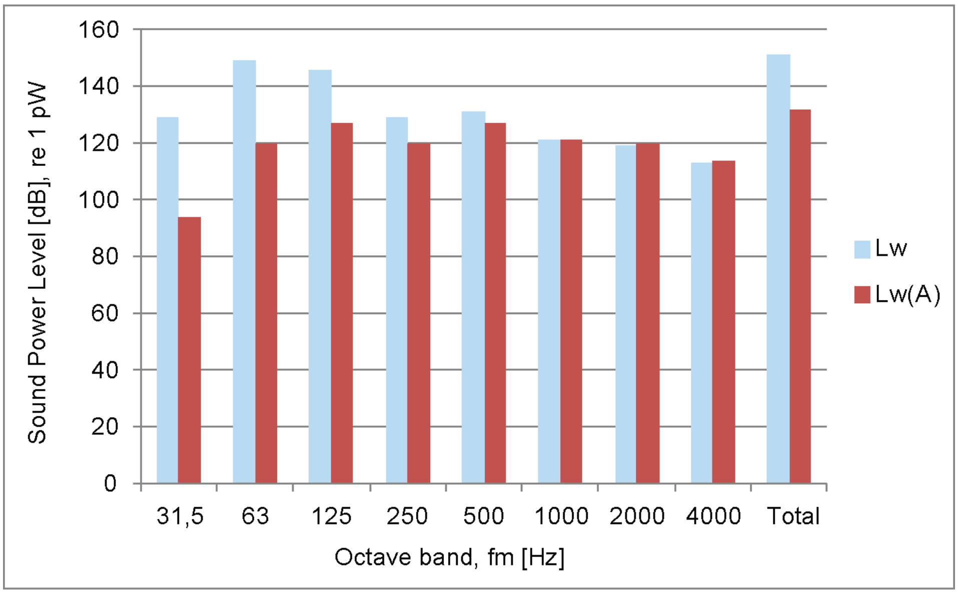
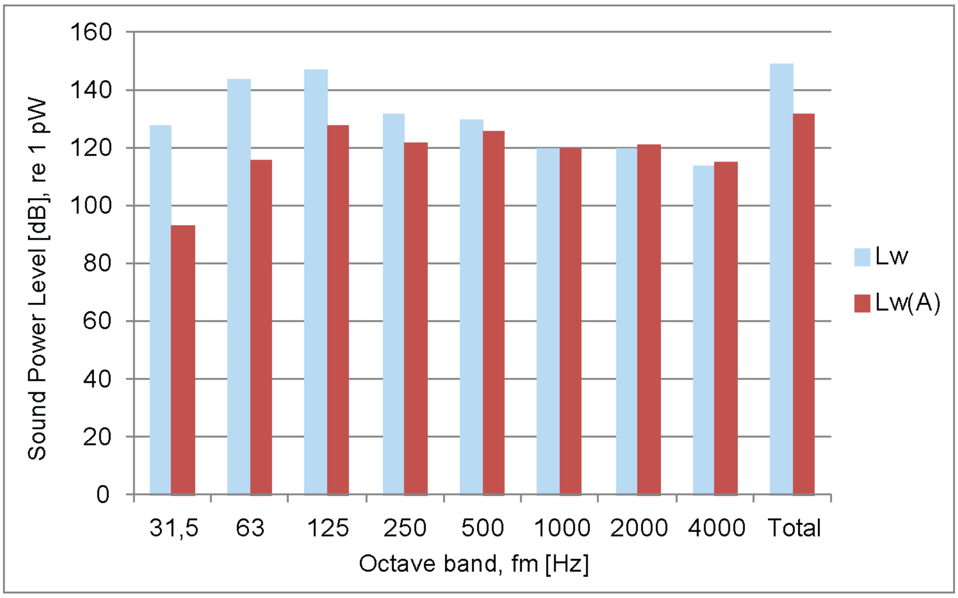


Figure 16.5 Typical sound power level for exhaust noise, W V32



17. Power Transmission

17.1 Flexible coupling

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

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

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

17.1.1 Connection to generator

Figure 17.1 Connection engine-generator (3V64L0058c)

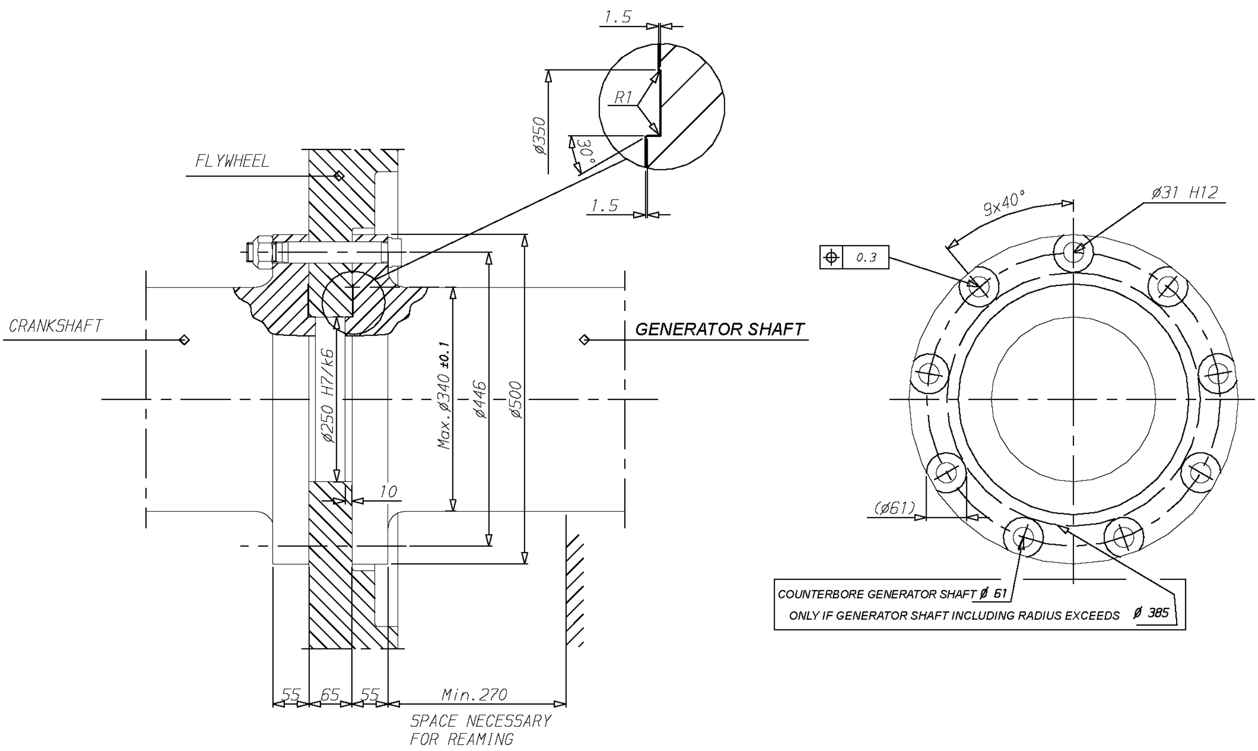
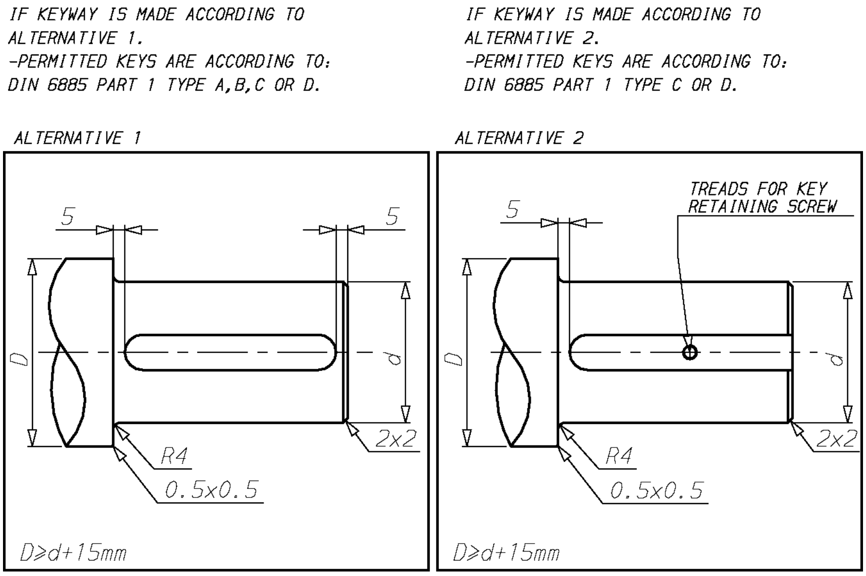


Figure 17.2 Directives for generator end design (4V64F0003a)



17.2 Clutch

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

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

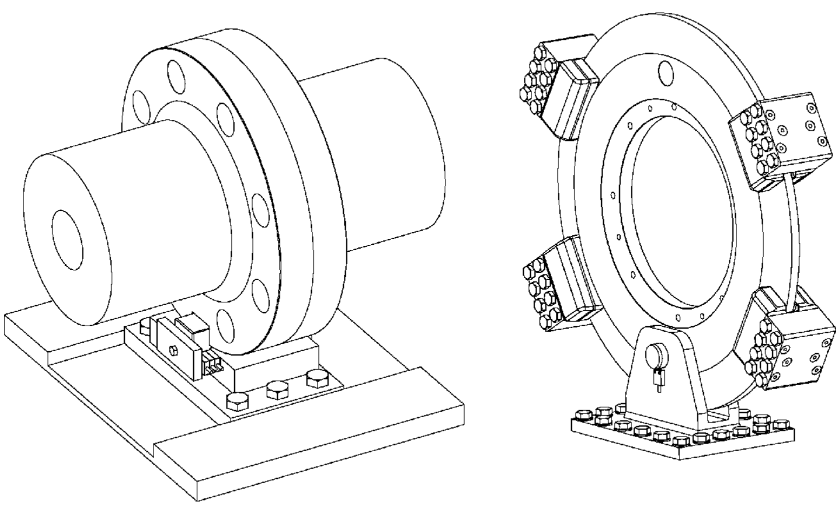
To permit maintenance of a stopped engine clutches must be installed in twin screw vessels which can operate on one shaft line only.

17.3 Shaft locking device

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

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

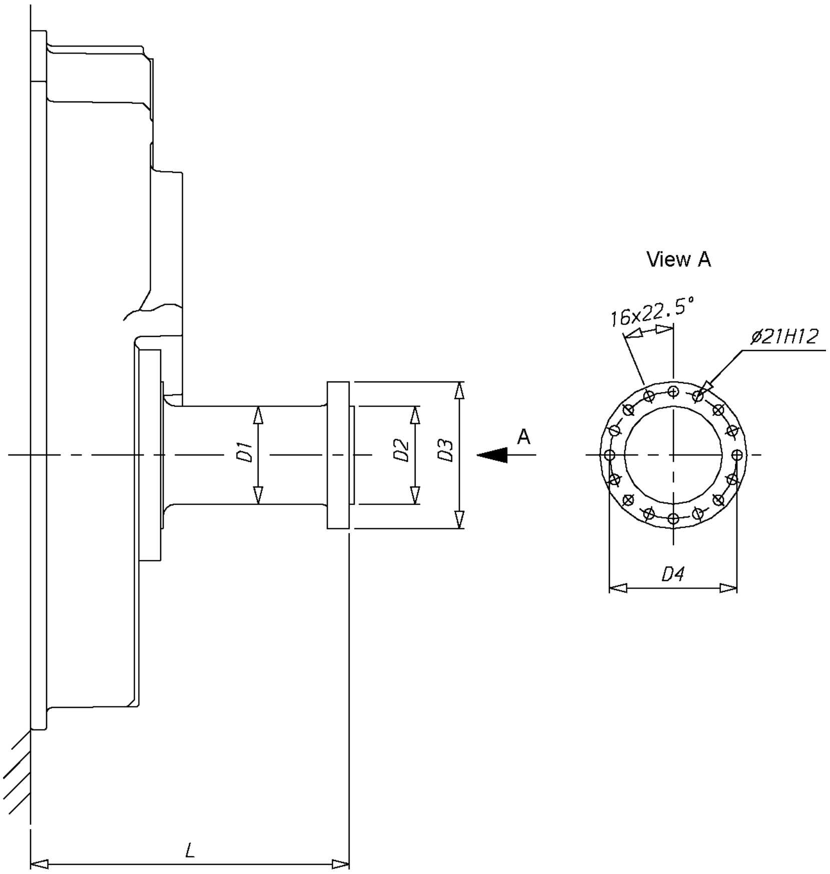
Figure 17.3 Shaft locking device and brake disc with calipers



17.4 Power-take-off from the free end

The engine power can be taken from both ends of the engine. For in-line engines full engine power is also available at the free end of the engine. On V-engines the engine power at free end must be verified according to the torsional vibration calculations.

Figure 17.4 Power take off at free end (4V62L1260a)



Engine	Rating 1) [kW]	D1 [mm]	D2 [mm]	D3 [mm]	D4 [mm]	L [mm]	PTO shaft connected to
In-line engines	4500	200	200	300	260	650	extension shaft with support bearing
	4500	200	200	300	260	700	flexible coupling, max weight at distance L = 900 kg
V-engines	5000	200	200	300	260	800	extension shaft with support bearing
	3500	200	200	300	260	1070	flexible coupling, max weight at distance L = 390 kg

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

17.5 Input data for torsional vibration calculations

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

Installation

- Classification
- Ice class
- Operating modes

Reduction gear

A mass elastic diagram showing:

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

Propeller and shafting

A mass-elastic diagram or propeller shaft drawing showing:

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

Main generator or shaft generator

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

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

Flexible coupling/clutch

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

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

Operational data

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

17.6 Turning gear

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

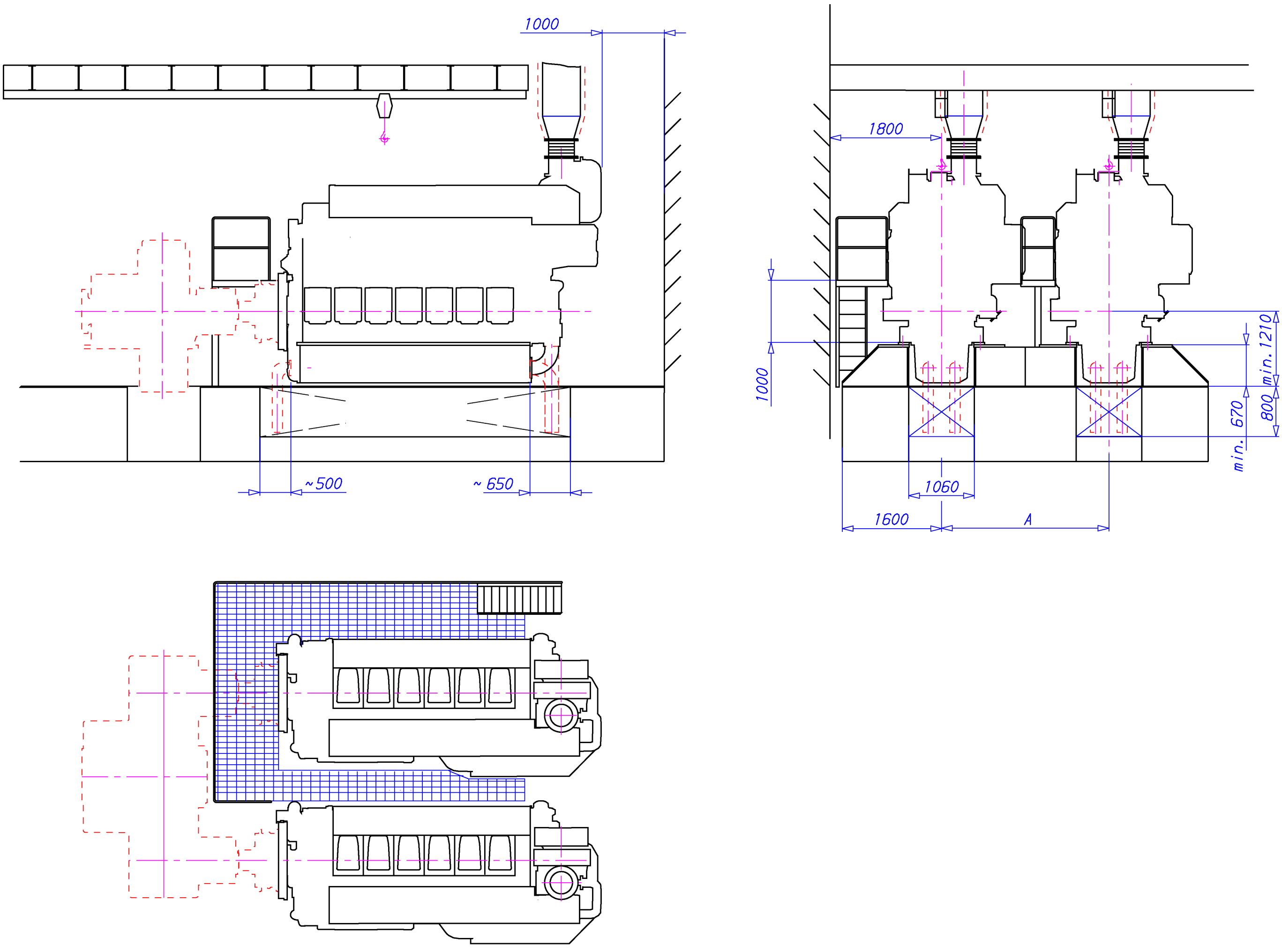
18. Engine Room Layout

18.1 Crankshaft distances

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

18.1.1 Main engines

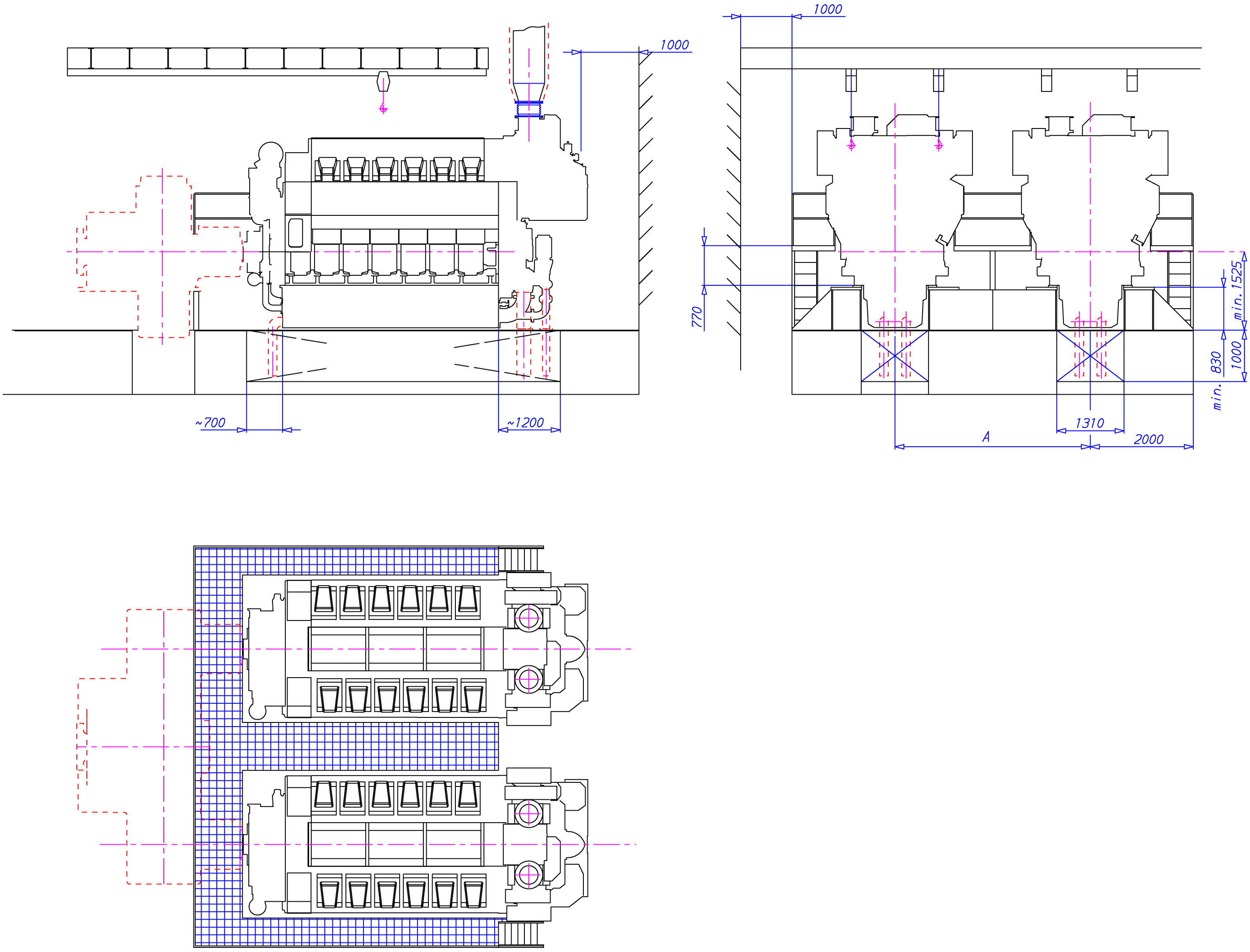
Figure 18.1 In-line engines, turbocharger in free end (DAAE041961)



Engine	A
W 6L32	2700
W 7L32	2700
W 8L32	2700
W 9L32	2700

All dimensions in mm.

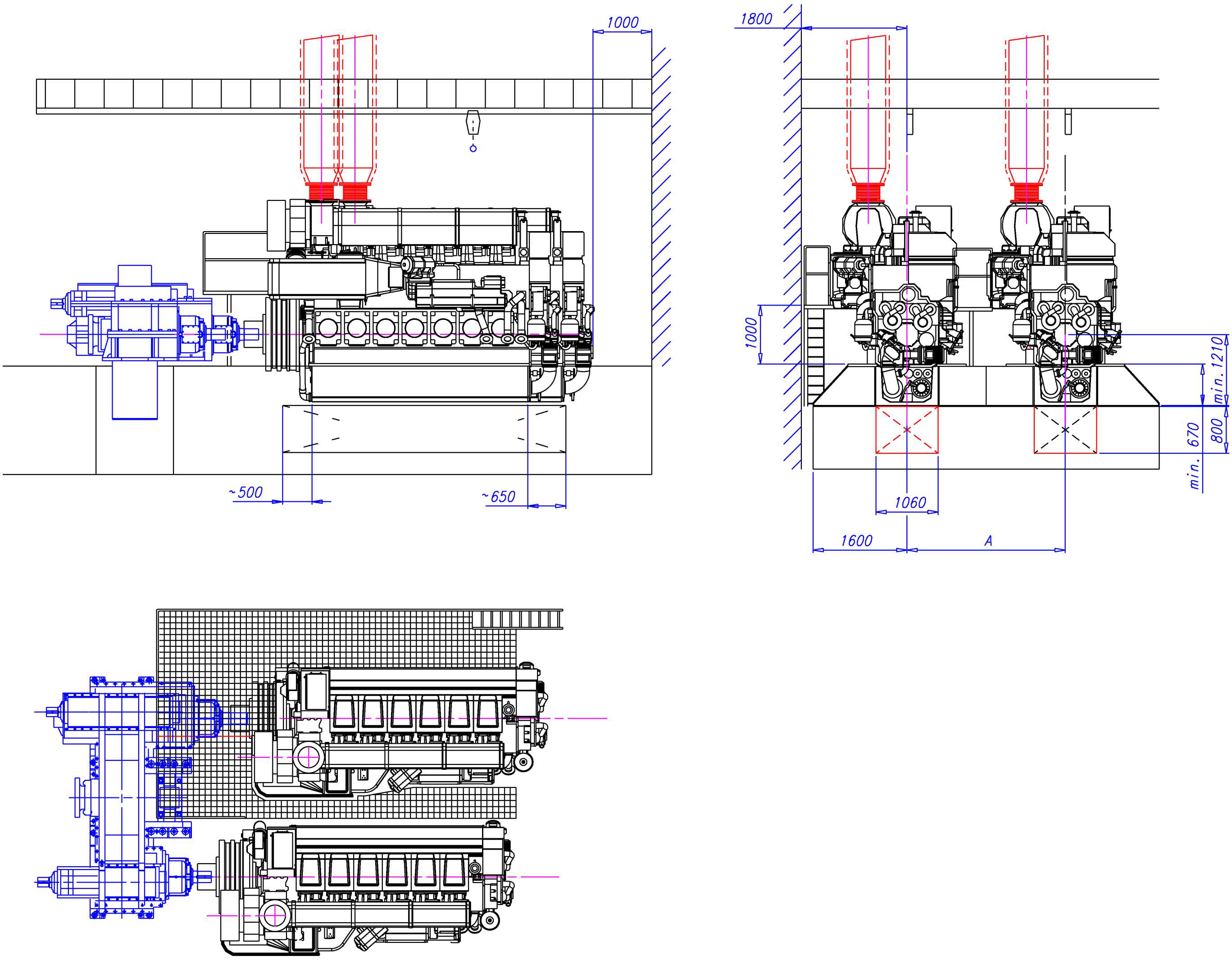
Figure 18.2 V engines, turbocharger in free end (DAAE042488a)



Engine	A
V-engine with filter/ silencer on turbochar-ger	3700
V-engine with suction branches	3800

All dimensions in mm.

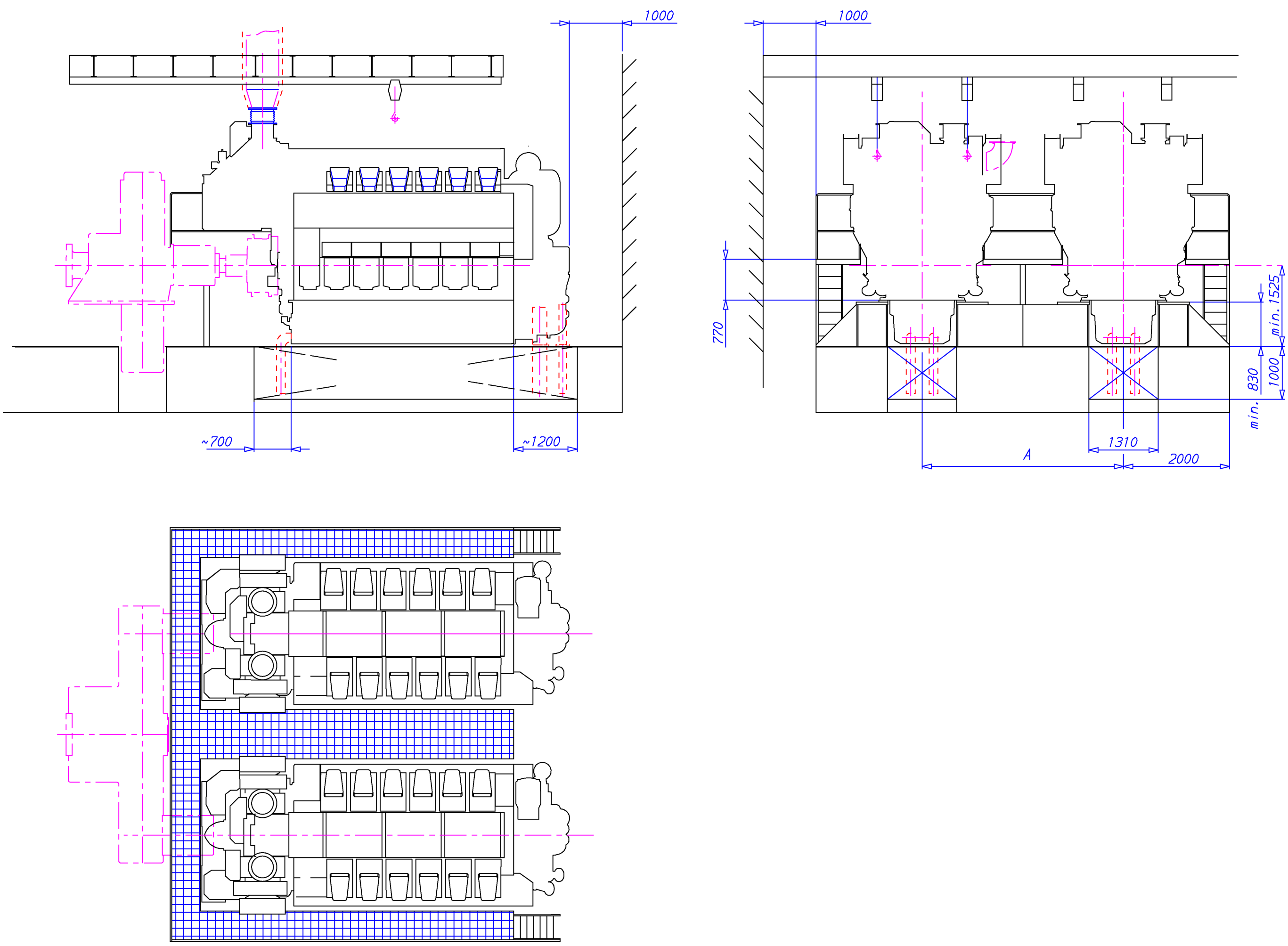
Figure 18.3 In-line engines, turbocharger in driving end (DAAE030105a)



Engine	A
W 6L32	2700
W 7L32	2700
W 8L32	2700
W 9L32	2700

All dimensions in mm.

Figure 18.4 V engines, turbocharger in driving end (DAAE053931)

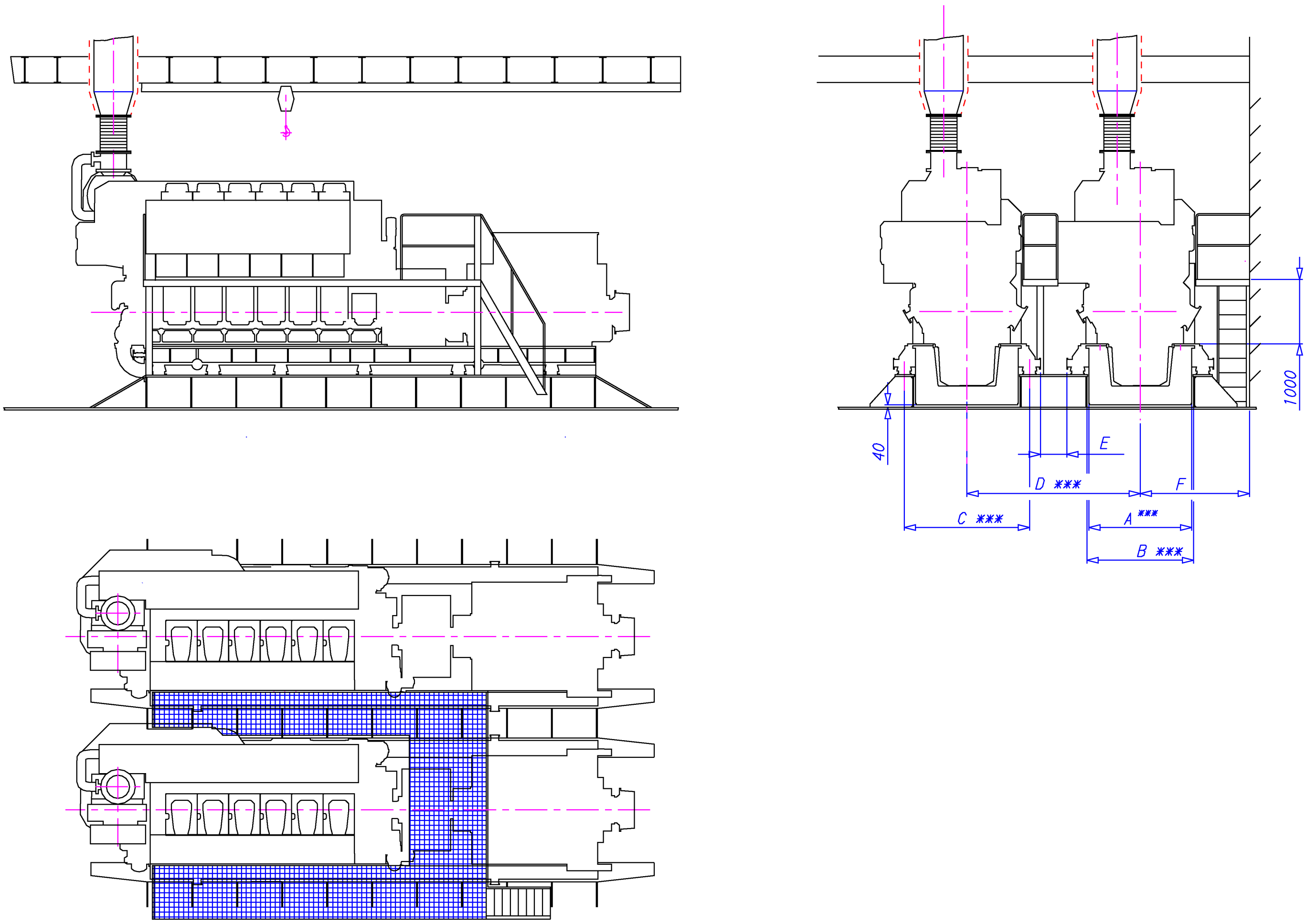


Engine	A
V-engine with filter/ silencer on turbocharger	3700
V-engine with suction branches	3800

All dimensions in mm.

18.1.2 Generating sets

Figure 18.5 In-line engines, turbocharger in free end (DAAE041218)

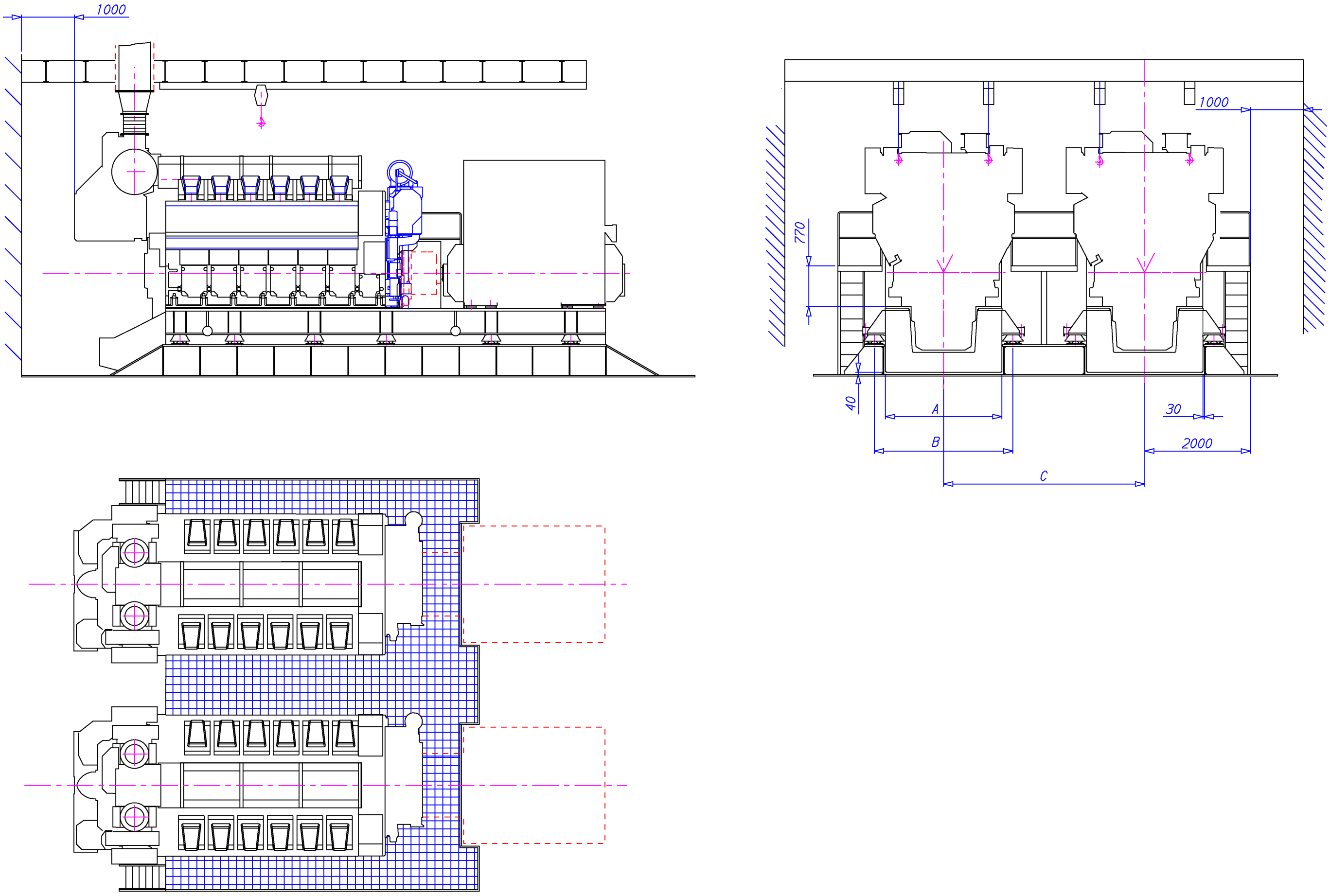


Engine	A ***	B ***	C ***	D ***	E	F
W 6L32	1600	1660	1910	2700	410	1700
W 7L32	2000	2060	2310	2800	110	1900
W 8L32	2000	2060	2310	2800	110	1900
W 9L32	2200	2260	2510	3000	110	2000

All dimensions in mm.

*** Dependent on generator type.

Figure 18.6 V-engines, turbocharger in free end (DAAE040884)



Engine	A	B	C
W 12V32	2200	2620	Min. 3800
W 16V32	2200	2620	Min. 3800
W 18V32	2500	2920	Min. 3800

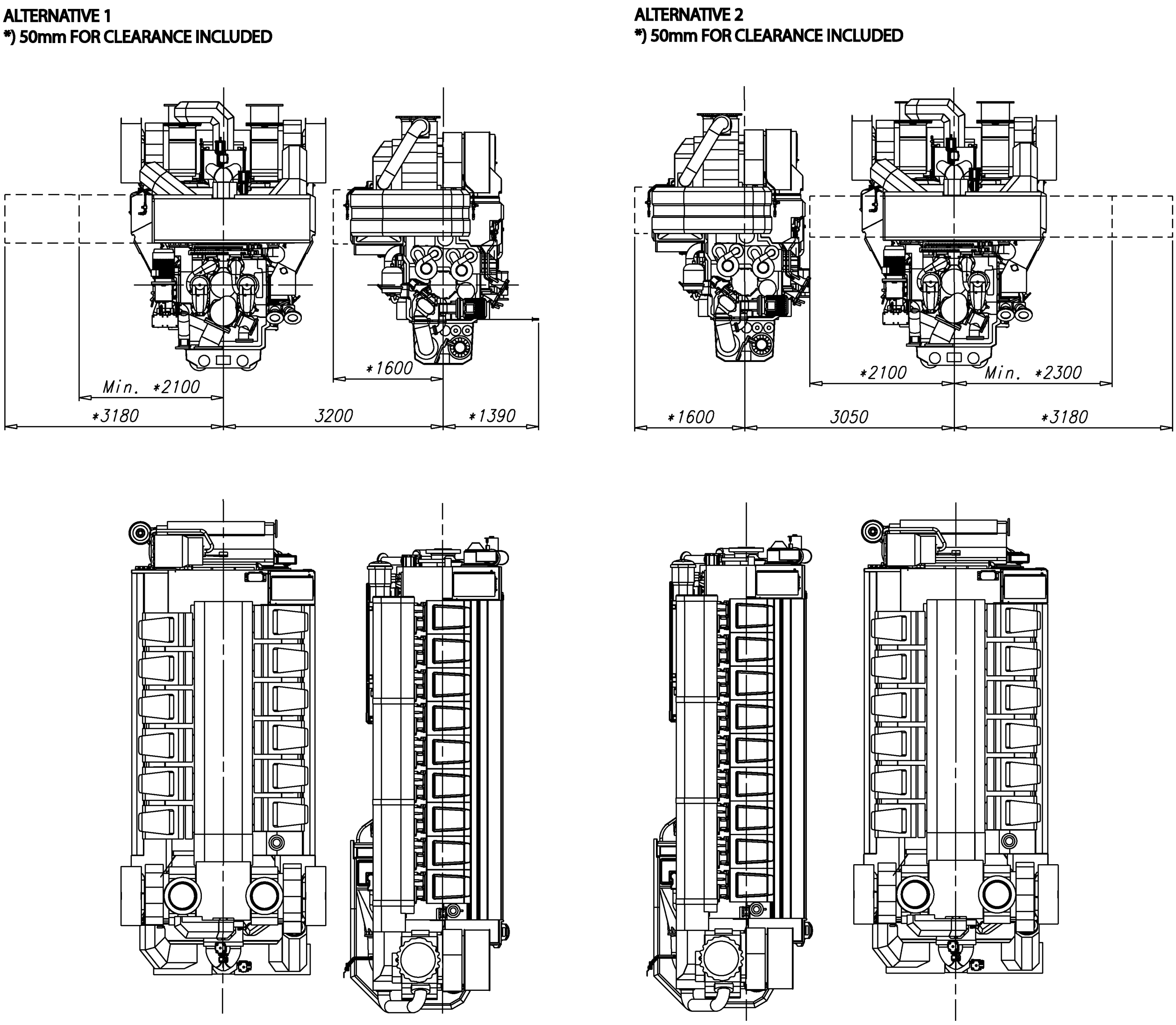
All dimensions in mm.

18.1.3 Father-and-son arrangement

When connecting two engines of different type and/or size to the same reduction gear the minimum crankshaft distance has to be evaluated case by case. However, some general guidelines can be given:

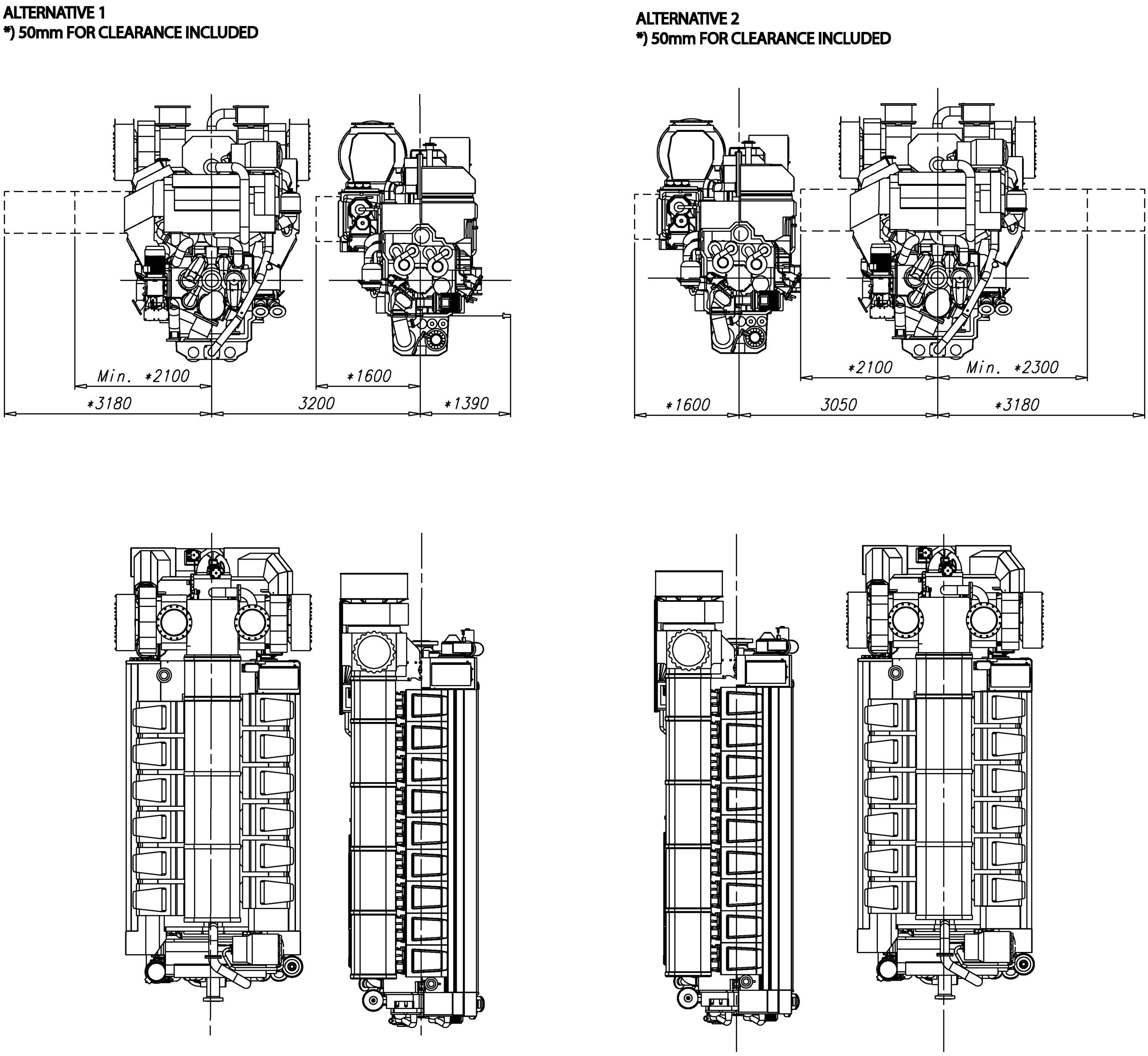
- It is essential to check that all engine components can be dismounted. The most critical are usually turbochargers and charge air coolers.
- When using a combination of in-line and v-engine, the operating side of in-line engine should face the v-engine in order to minimise the distance between crankshafts.
- Special care has to be taken checking the maintenance platform elevation between the engines to avoid structures that obstruct maintenance.

Figure 18.7 Example of father-and-son arrangement, 9L32 + 12V32, TC in free end (DAAE040264a)



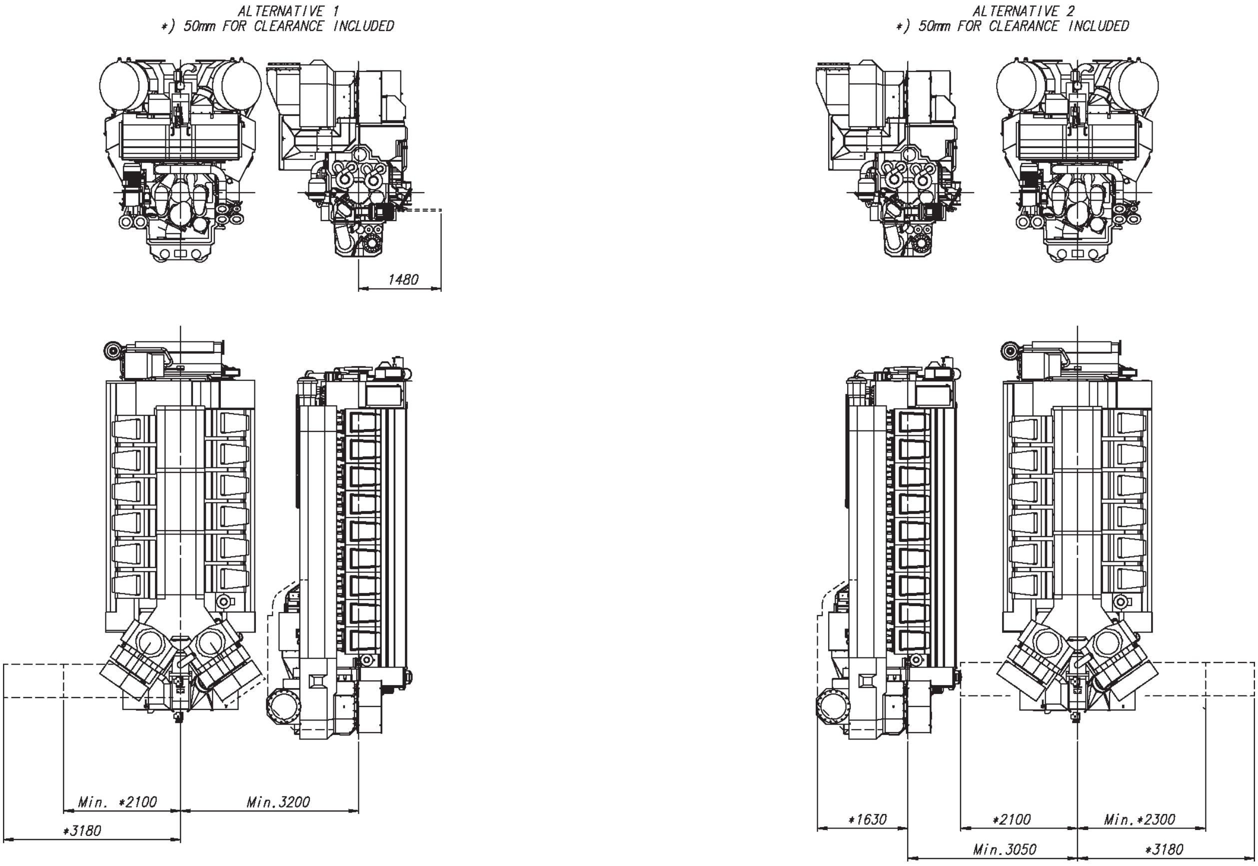
All dimensions in mm.

Figure 18.8 Example of father-and-son arrangement, 9L32 + 12V32, TC in flywheel end (DAAE057212)



All dimensions in mm.

Figure 18.9 Example of father-and-son arrangement, 9L32 + 12V32 (580 kW/cyl), TC in free end (DAAF033143)



All dimensions in mm.

18.1.4 Distance from adjacent intermediate/propeller shaft

Some machinery arrangements feature an intermediate shaft or propeller shaft running adjacent to engine. To allow adequate space for engine inspections and maintenance there has to be sufficient free space between the intermediate/propeller shaft and the engine. To enable safe working conditions the shaft has to be covered. It must be noticed that also dimensions of this cover have to be taken into account when determining the shaft distances in order to fulfil the requirement for minimum free space between the shaft and the engine.

Figure 18.10 Main engine arrangement, in-line engines (DAAE059183)

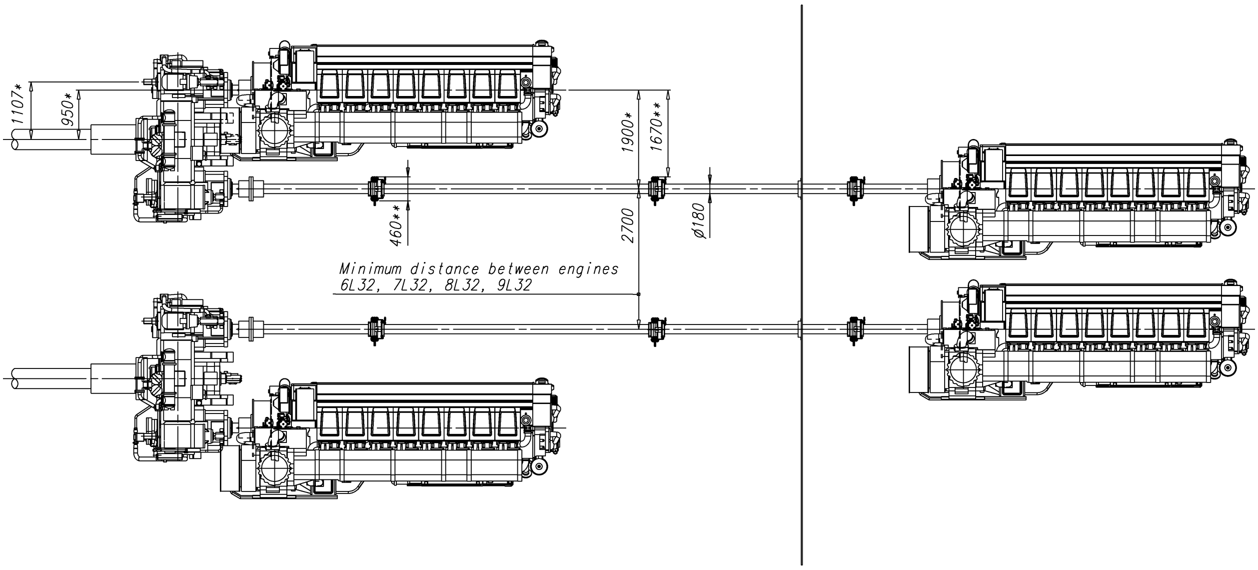
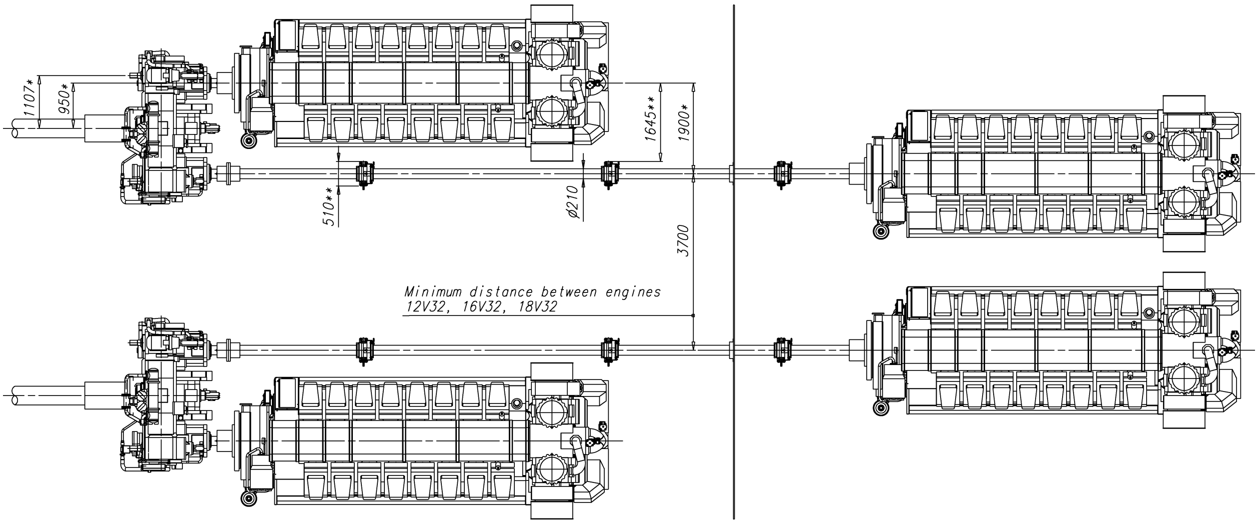


Figure 18.11 Main engine arrangement, V-engines (DAAE059181)



Notes:

All dimensions in mm.

Intermediate shaft diameter to be determined case by case

* Depending on type of gearbox

** Depending on type of shaft bearing

Figure 18.12 Main engine arrangement, in-line engines (DAAE059178)

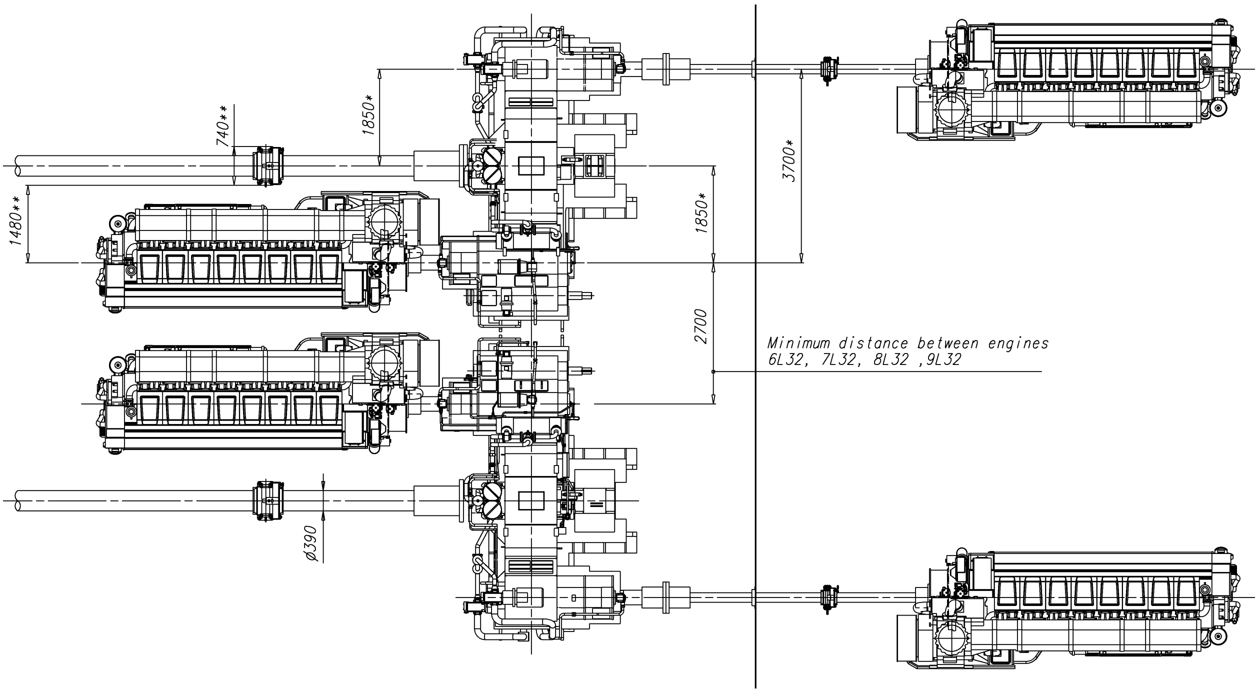
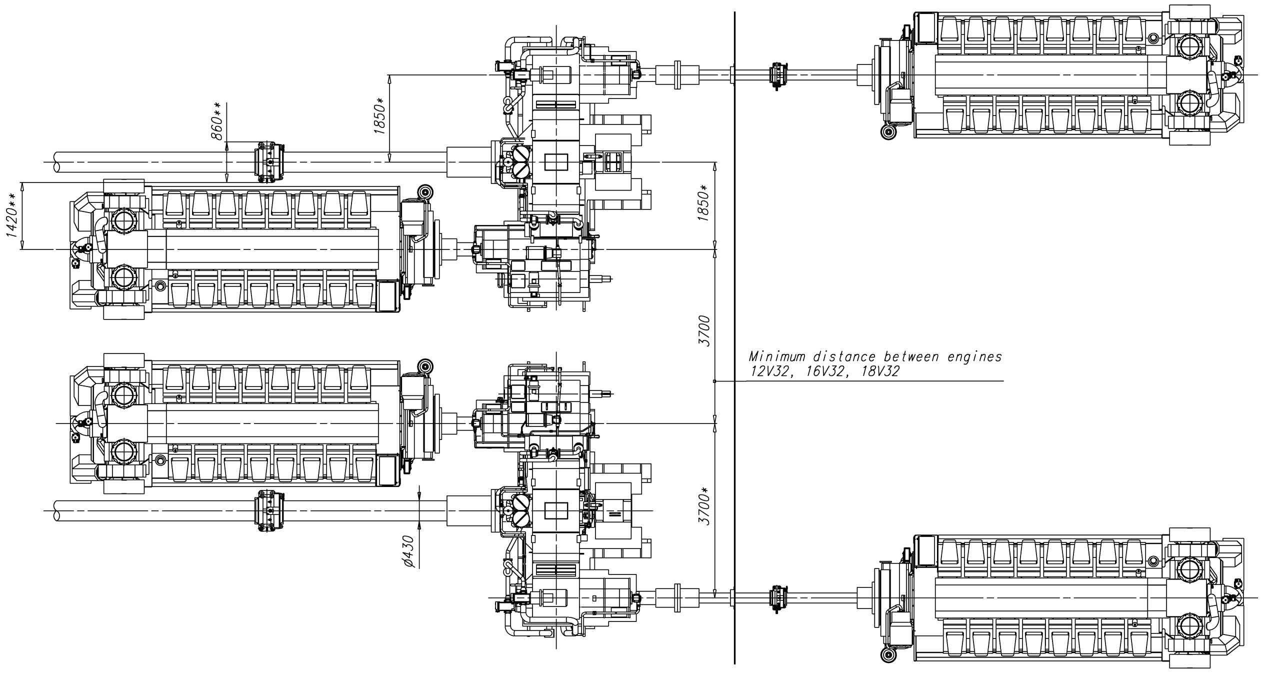


Figure 18.13 Main engine arrangement, V-engines (DAAE059176)



Notes:
All dimensions in mm.
Intermediate shaft diameter to be determined case by case
* Depending on type of gearbox
** Depending on type of shaft bearing

18.2 Space requirements for maintenance

18.2.1 Working space around the engine

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

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

18.2.2 Engine room height and lifting equipment

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

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

18.2.3 Maintenance platforms

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

18.3 Transportation and storage of spare parts and tools

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

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

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

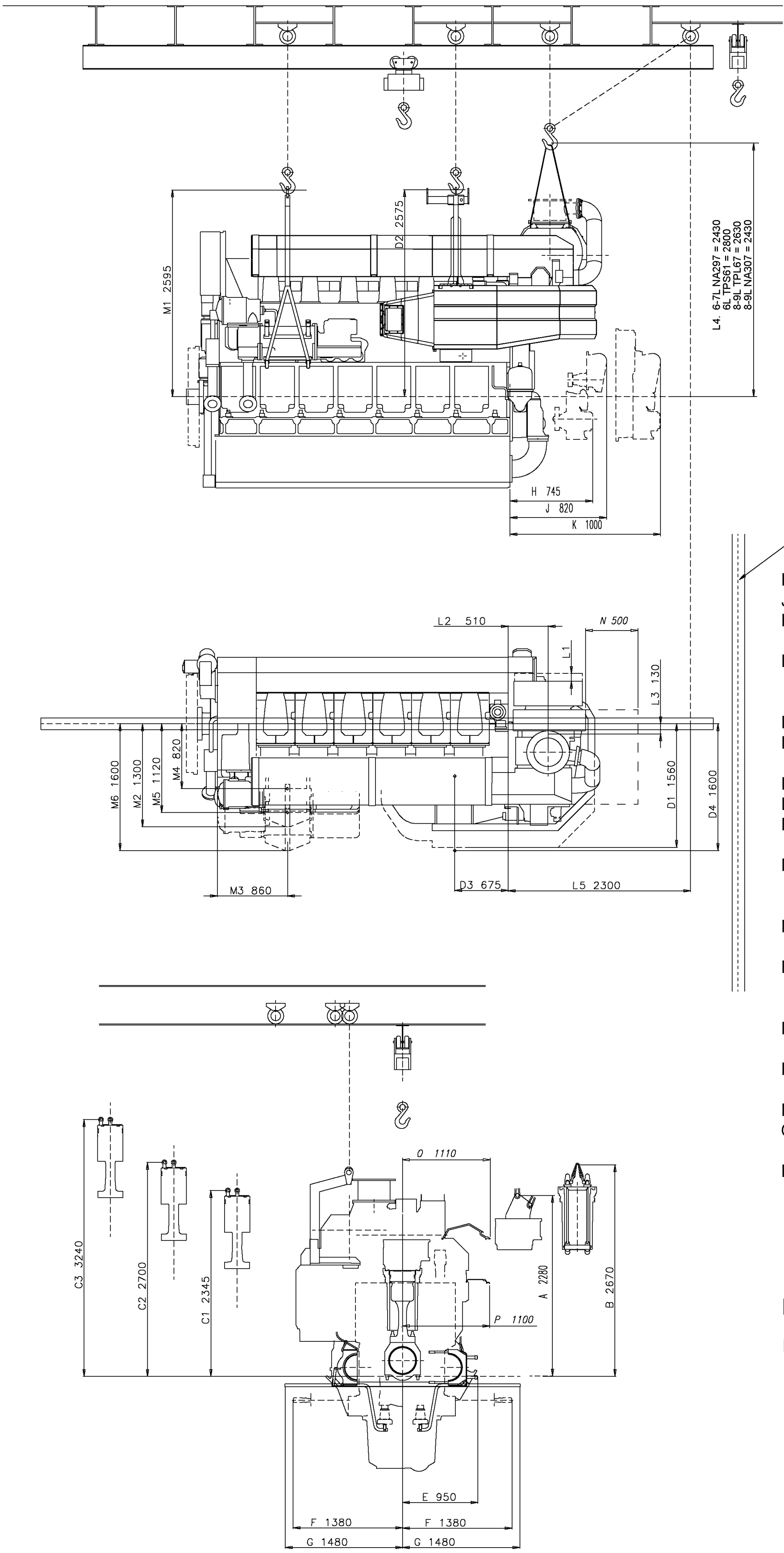
On single main engine installations it is important to store heavy engine parts close to the engine to make overhaul as quick as possible in an emergency situation.

18.4 Required deck area for service work

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

18.4.1 Service space requirement for the in-line engine

Figure 18.14 Service space requirement (500 kW/cyl), turbocharger in free end (DAAE030158F)



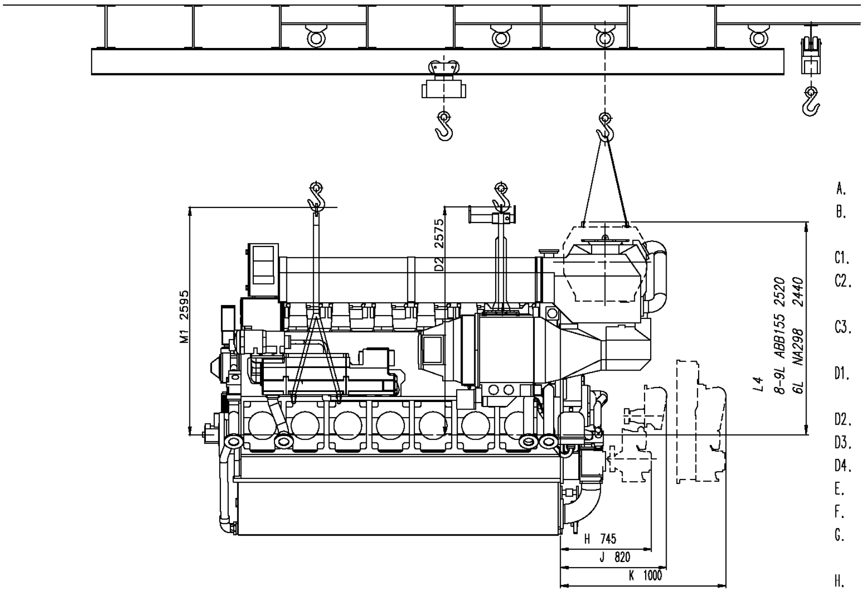
A. Height needed for overhauling cylinder head
B. Height needed for transporting cylinder liner freely over injection pump
C1. Height needed for overhauling piston and connecting rod
C2. Height needed for transporting piston and connecting rod freely over adjacent cylinder head covers
C3. Height needed for transporting piston and connecting rod freely over exhaust gas insulation box
D1. Width needed for dismantling charge air cooler and air inlet box sideways by using lifting tool
D2. Height of the lifting eye for the charge air cooler lifting tool
D3. Recommended lifting point for charge air cooler lifting tool
D4. Recommended lifting point for charge air cooler lifting tool
E. Width needed for dismantling connecting rod big end bearing
F. Width needed for removing main bearing side screw
G. Width of lifting tool for hydraulic cylinder / main bearing nuts

H. Distance needed to dismantle lubricating oil pump
J. Distance needed to dismantle water pumps
K. Distance needed to dismantle pump cover with fitted pumps
L1. The recommended axial clearance for dismantling and assembly of silencers is 500 mm, minimum clearance is 6L-7L32 100 mm and 8-9L32 180 mm
L2. Recommended lifting point for the turbocharger
L3. Recommended lifting point sideways for the turbocharger
L4. Height needed for dismantling the turbocharger
L5. Recommended lifting point for the turbocharger
M1. Height of the lifting eye for the lubricating oil module lifting tool
M2. Minimum width needed dismantling lubricating oil module (lubricating oil module is lowered down directly)
M3. Recommended lifting point for dismantling lubricating oil module
M4. Recommended lifting point for dismantling lubricating oil module (lubricating oil module is lowered down directly)
M5. Recommended lifting point for dismantling lubricating oil module (to pass the insulation box)
M6. Width needed dismantling lubricating oil module (to pass the insulation box)
N. Service space for dismantling of T/C insulation
O. Space necessary for opening the side cover upper part
P. Space necessary for opening the side cover lower part

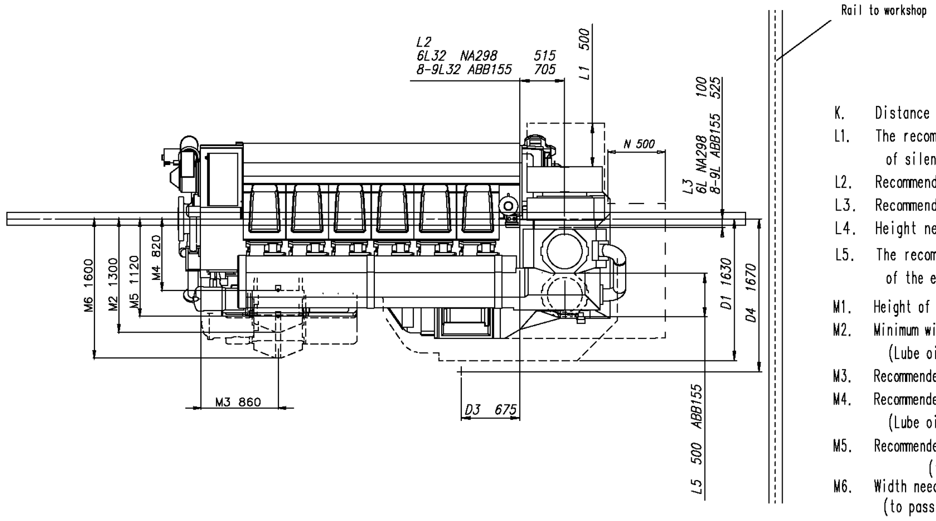
[All dimensions in mm]

Dimensions include 20mm clearance

Figure 18.15 Service space requirement (580 kW/cyl), turbocharger in free end (DAAF023936A)



A. Height needed for overhauling cylinder head
B. Height needed for transporting cylinder liner freely over injection pump
C1. Height needed for overhauling piston and connecting rod
C2. Height needed for transporting piston and connecting rod freely over adjacent cylinder head covers
C3. Height needed for transporting piston and connecting rod freely over exhaust gas insulation box
D1. Width needed for dismantling charge air cooler and air inlet box sideways by using lifting tool
D2. Height of the lifting eye for the charge air cooler lifting tool
D3. Recommended lifting point for charge air cooler lifting tool
D4. Recommended lifting point for charge air cooler lifting tool
E. Width needed for dismantling connecting rod big end bearing
F. Width needed for removing main bearing side screw
G. width of lifting tool for hydraulic cylinder / main bearing nuts
H. Distance needed to dismantle lube oil pump
J. Distance needed to dismantle water pumps



K. Distance needed to dismantle pump cover with fitted pumps
L1. The recommended axial clearance for dismantling and assembly of silencers is 500mm, (minimum clearance is 120mm NA298 and 100mm ABB155)
L2. Recommended lifting point for the turbocharger
L3. Recommended lifting point sideways for the turbocharger
L4. Height needed for dismantling the turbocharger
L5. The recommended axial clearance for dismantling and assembly of the exhaust gas-outlet casing is 500mm, minimun 100mm (ABB155)
M1. Height of the lifting eye for the lube oil module lifting tool
M2. Minimum width needed dismantling lube oil module (Lube oil module is lowered down directly)
M3. Recommended lifting point for dismantling lube oil module
M4. Recommended lifting point for dismantling lube oil module (Lube oil module is lowered down directly)
M5. Recommended lifting point for dismantling lube oil module (to pass the insulation box)
M6. Width needed dismantling lube oil module (to pass the insulation box)
N. Service space for dismantling of T/C insulation
O. Space necessary for opening the side cover upper part
P. Space necessary for opening the side cover lower part

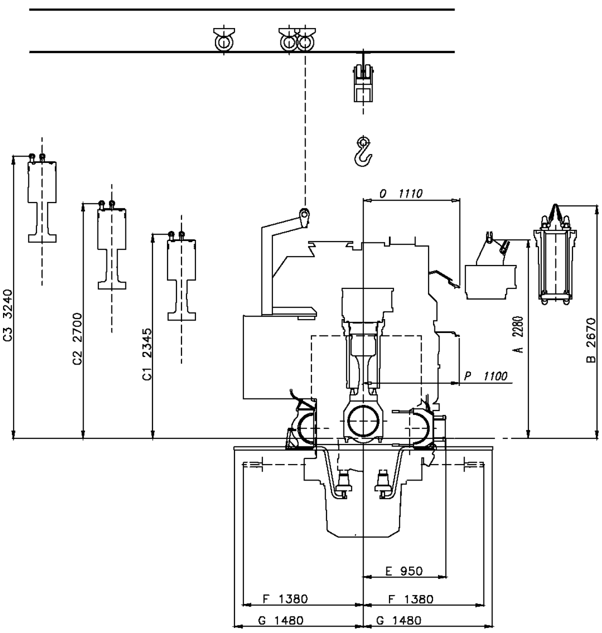
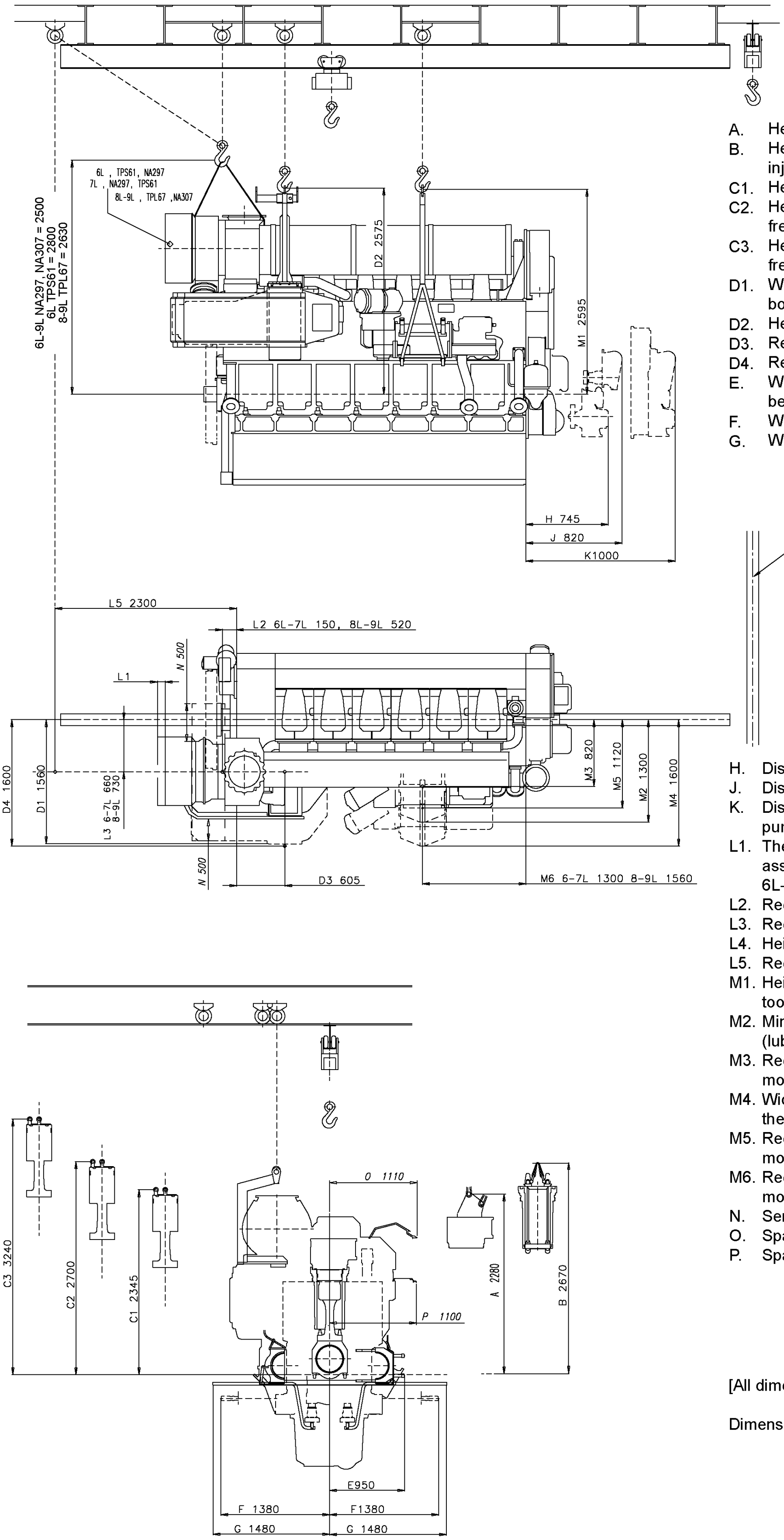


Figure 18.16 Service space requirement, turbocharger in driving end (DAAE030104d)



A. Height needed for overhauling cylinder head
B. Height needed for transporting cylinder liner freely over injection pump
C1. Height needed for overhauling piston and connecting rod
C2. Height needed for transporting piston and connecting rod freely over adjacent cylinder head covers
C3. Height needed for transporting piston and connecting rod freely over exhaust gas insulation box
D1. Width needed for dismanling charge air cooler and air inlet box sideways by using lifting tool
D2. Height of the lifting eye for the charge air cooler lifting tool
D3. Recommended lifting point for charge air cooler lifting tool
D4. Recommended lifting point for charge air cooler lifting tool
E. Width needed for dismantling connecting rod big end bearing
F. Width needed for removing main bearing side screw
G. Width of lifting tool for hydraulic cylinder / main bearing

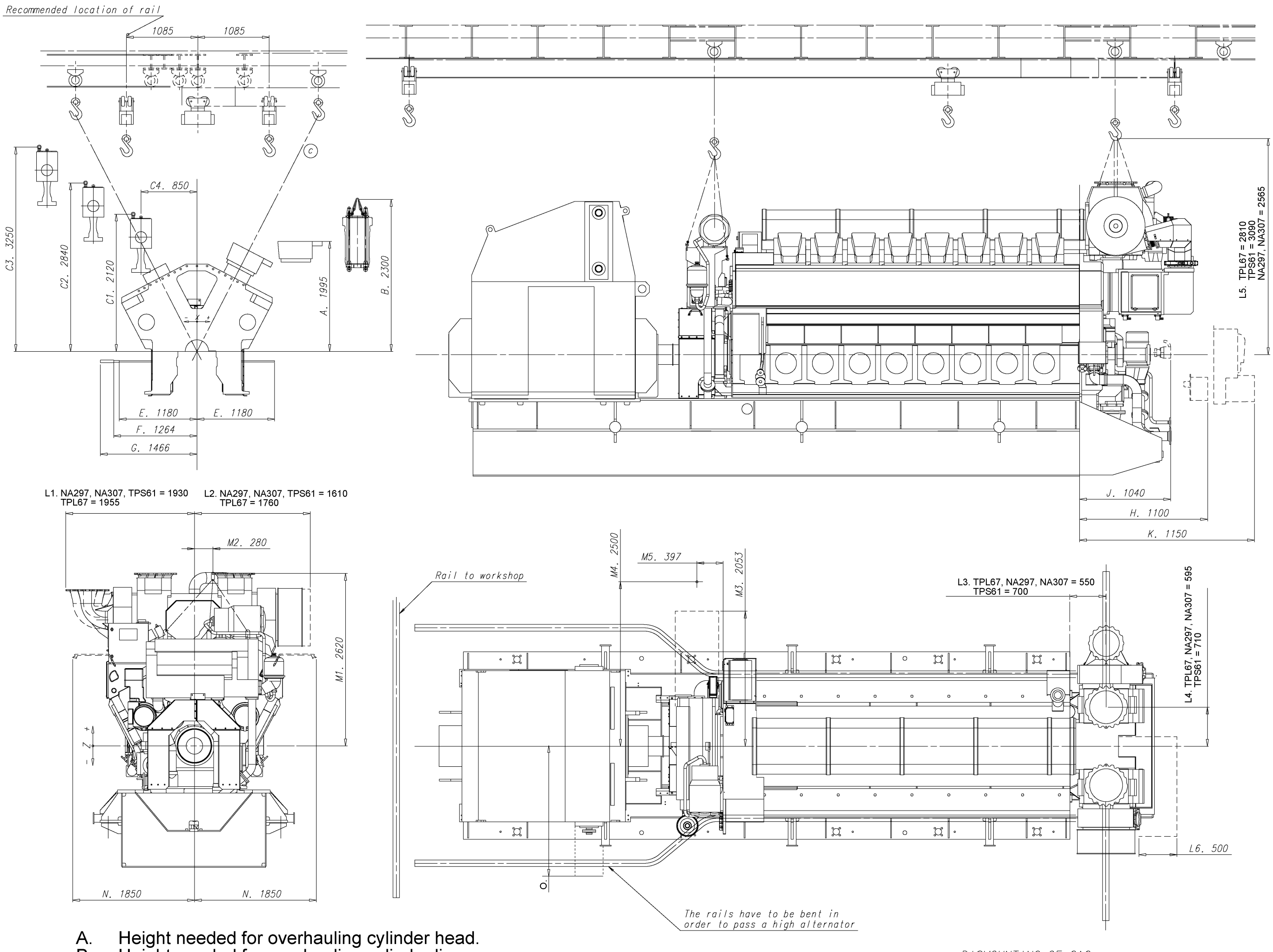
H. Distance needed to dismantle lubricating oil pump
J. Distance needed to dismantle water pumps
K. Distance needed to dismantle pump cover with fitted pumps
L1. The recommended axial clearence for dismantling and assembly of silencers is 500 mm, minimum clearence is 6L-7L 100 mm and 8L-9L 120 mm
L2. Recommended lifting point for the turbocharger
L3. Recommended lifting point sideways for the turbocharger
L4. Height needed for dismantling the turbocharger
L5. Recommended lifting point for the turbocharger
M1. Height of the lifting eye for the lubricating oil module lifting tool
M2. Minimum width needed dismantling lubricating oil module (lubricating oil module is lowered down directly)
M3. Recommended lifting point for dismantling lubricatin oil module (lubricating oil module is lowered down directly)
M4. Width needed dismantling lubricatin oil module (to pass the insulation box)
M5. Recommended lifting point for dismantling lubricating oil module (to pass the insulation box)
M6. Recommended lifting point for dismantling lubricating oil module
N. Service space for dismantling of T/C insulation
O. Space necessary for opening the side cover upper part
P. Space necessary for opening the side cover lower part

[All dimensions in mm]

Dimensions include 20mm clearance

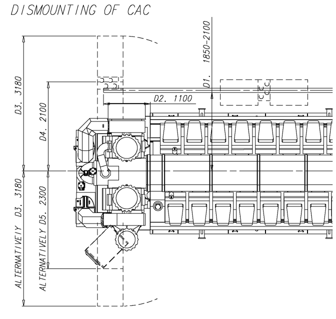
18.4.2 Service space requirement for the V-engine

Figure 18.17 Service space requirement, turbocharger in free end (DAAE041142H)



A. Height needed for overhauling cylinder head.
B. Height needed for overhauling cylinder liner.
C1. Height needed for overhauling piston and connecting rod.
C2. Height needed for transporting piston and connecting rod freely over adjacent cylinder head covers.
C3. Height needed for transporting piston and connecting rod freely over exhaust gas insulation box.
C4. Width needed for transporting piston and connecting rod.
E. Width needed for removing main bearing side screw.
F. Width needed for dismantling connecting rod big end gearing.
G. Width of lifting tool for hydraulic cylinder/main bearing nuts.
H. Distance needed to dismantle LO pump.
J. Distance needed to dismantle water pumps.
K. Distance needed to dismantle pump cover with fitted pumps.
L1. The recommended axial clearance for dismantling and assembly of silencers is 500mm, min clearance is 110mm for TPS61, NA297 and NA307. 120mm for TPL67. The given dimension for L1 includes the minimum maintenance space.
L2. The recommended axial clearance for dismantling and assembly of suction branches is 500mm, min clearance is 110mm for TPS61, NA297 and NA307. 120mm for TPL67. The given dimension for L2 includes the minimum maintenance space.
L3. Recommended lifting point for the TC.
L4. Recommended lifting point sideways for the TC.
L5. Height needed for dismantling the TC.
L6. Recommended space needed for dismantle insulation, minimum space is 330mm.
M1. Height of LO module lifting tool eye.
M2. Width of LO module lifting tool eye.
M3. Width needed for dismantling LO module insert.
M4. Recommended lifting point for LO module insert.
M5. Recommended lifting point for LO module insert.
N. Space necessary for opening the side cover
O. Service space for generator cooler, depending on generator type

DISMOUNTING OF CAC

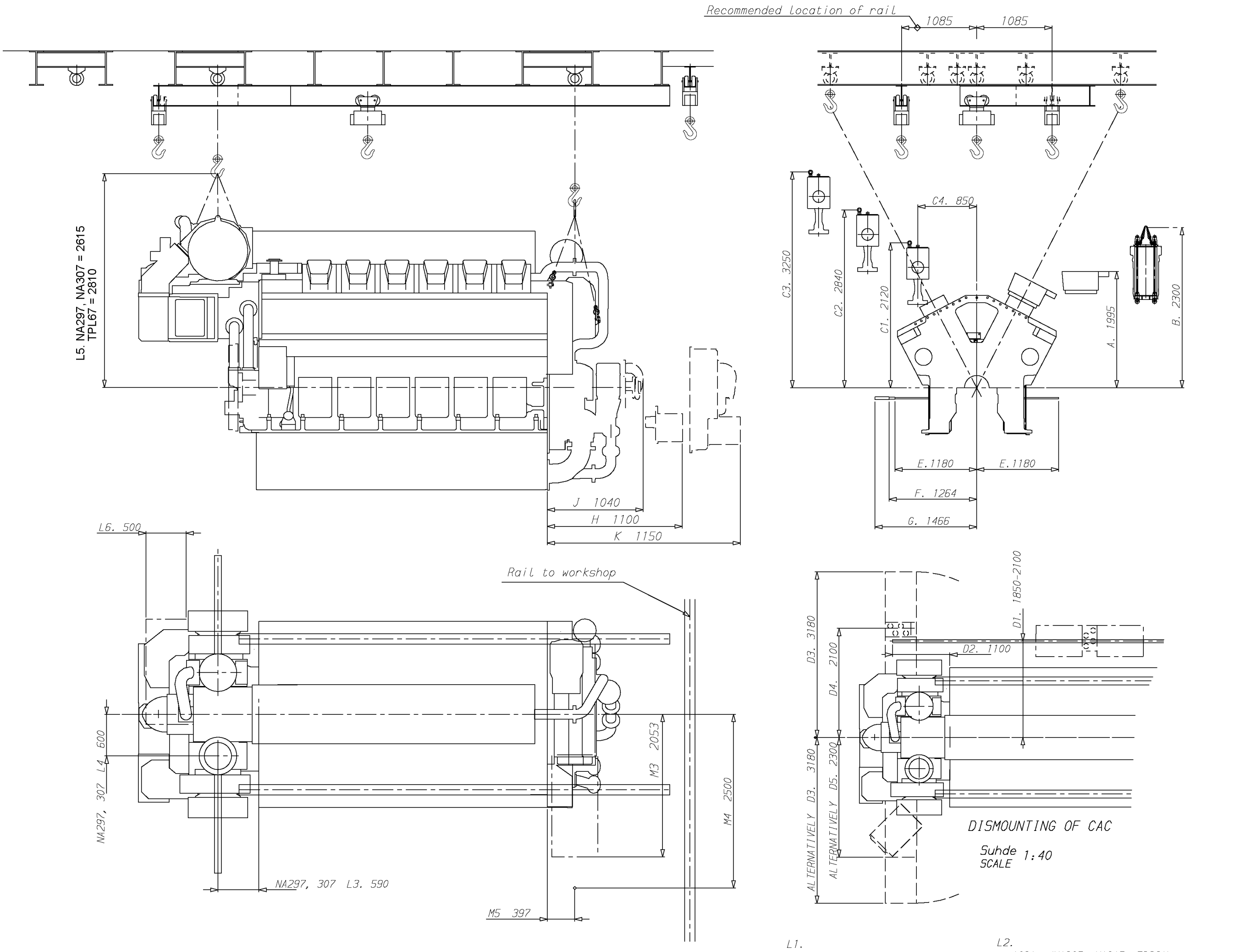


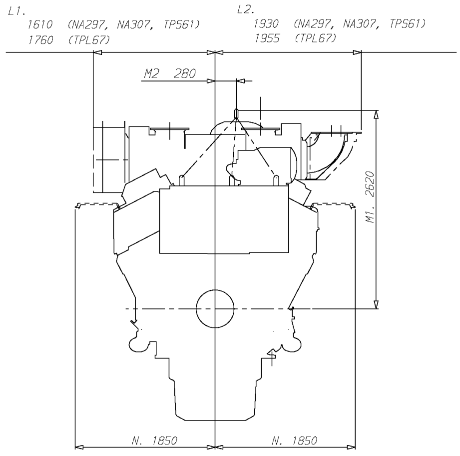
D1. Recommended location of rail for removing the CAC, either on A- or B-bank.
D2. Recommended location of starting point for the rails.
D3. Width needed for dismantling the whole CAC, either from A- or B-bank. (advantage: CAC can be pressure tested before assembly)
D4. Minimum width needed for dismantling CAC from B-bank when CAC is divided into 3 parts before turning 90°. (pressure test when mounted)
D5. Minimum width needed for dismantling CAC from A-bank when CAC is divided into 3 parts before turning. (pressure test when mounted)

[All dimensions in mm]

** Actual dimensions might vary based on power output and turbocharger maker.*

Figure 18.18 Service space requirement, turbocharger in driving end (DAAE033769c)





A. Height needed for overhauling cylinder head.
B. Height needed for transporting cylinder liner.
C1. Height needed for overhauling piston and connecting rod.
C2. Height needed for transporting piston and connecting rod freely over adjacent cylinder head covers.
C3. Height needed for transporting piston and connecting rod freely over exhaust gas insulation box.
C4. Width needed for transporting piston and connecting rod.
D1. Recommended location of rail for removing the CAC, either on A- or B-bank.
D2. Recommended location of starting point for rails.
D3. Width needed for dismantling the whole CAC, either on A- or B-bank.
D4. Minimum width needed for dismantling CAC from A-bank when CAC is divided into 3 parts before turning 90 degrees.
D5. Minimum width needed for dismantling CAC from B-bank when CAC is divided into 3 parts before turning.
E. Width needed for removing main bearing side screw.
F. Width needed for dismantling connecting rod big end bearing.
G. Width of lifting tool for hydraulic cylinder/main bearing nuts.
H. Distance needed to dismantle LO pump.
J. Distance needed to dismantle water pumps.
K. Distance needed to dismantle pump cover with fitted pumps.
L1. The recommended axial clearance for dismantling and assembly of silencers is 500mm, min clearance=110mm for TPS61, NA297 and NA307. 120mm for TPL67. The given dimension for L1 includes the minimum maintenance space.
L2. The recommended axial clearance for dismantling and assembly of suction branches is 500mm, min clearance =110mm for TPS61, NA297 and NA307. 120mm for TPL67. The given dimension for L2 includes the minimum maintenance space.
L3. Recommended lifting point for the TC.
L4. Recommended lifting point sideways for the TC.
L5. Height needed for dismantling the TC.
L6. Recommended space needed for dismantle insulation, minimum space is 330mm.

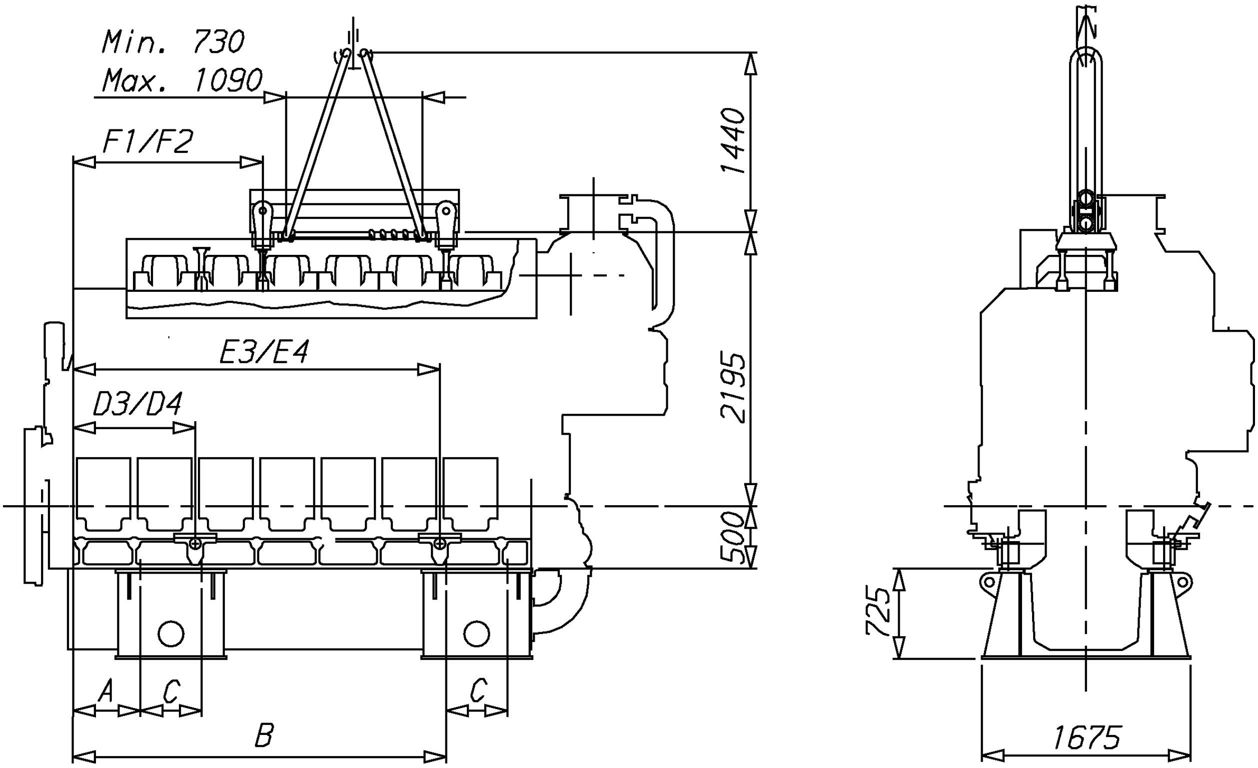
All dimensions in mm.
Dimensions include 20mm clearance

M1. Height of the LO module lifting tool eye.
M2. Width of the LO module lifting tool eye.
M3. Width needed for dismantling LO module insert.
M4. Recommended lifting point for dismantling the LO module.
M5. Recommended lifting point for dismantling the LO module.
N. Space necessary for opening side cover

19. Transport Dimensions and Weights

19.1 Lifting of main engines

Figure 19.1 Lifting of main engines, in-line engines (2V83D0253e)



All dimensions in mm.

Transport bracket weight = 890 kg.

Engine	A	B	C	F1*	F2*	D3*	D4*	E3*	E4*
W 6L32	540	2990	490	1520	1030	980	980	2940	2940
W 7L32	540	3480	490	1520	1520	490	980	2940	3430
W 8L32	540	3970	490	2010	1520	490	980	3430	3920
W 9L32	540	4460	490	2010	1520	490	980	3920	4410

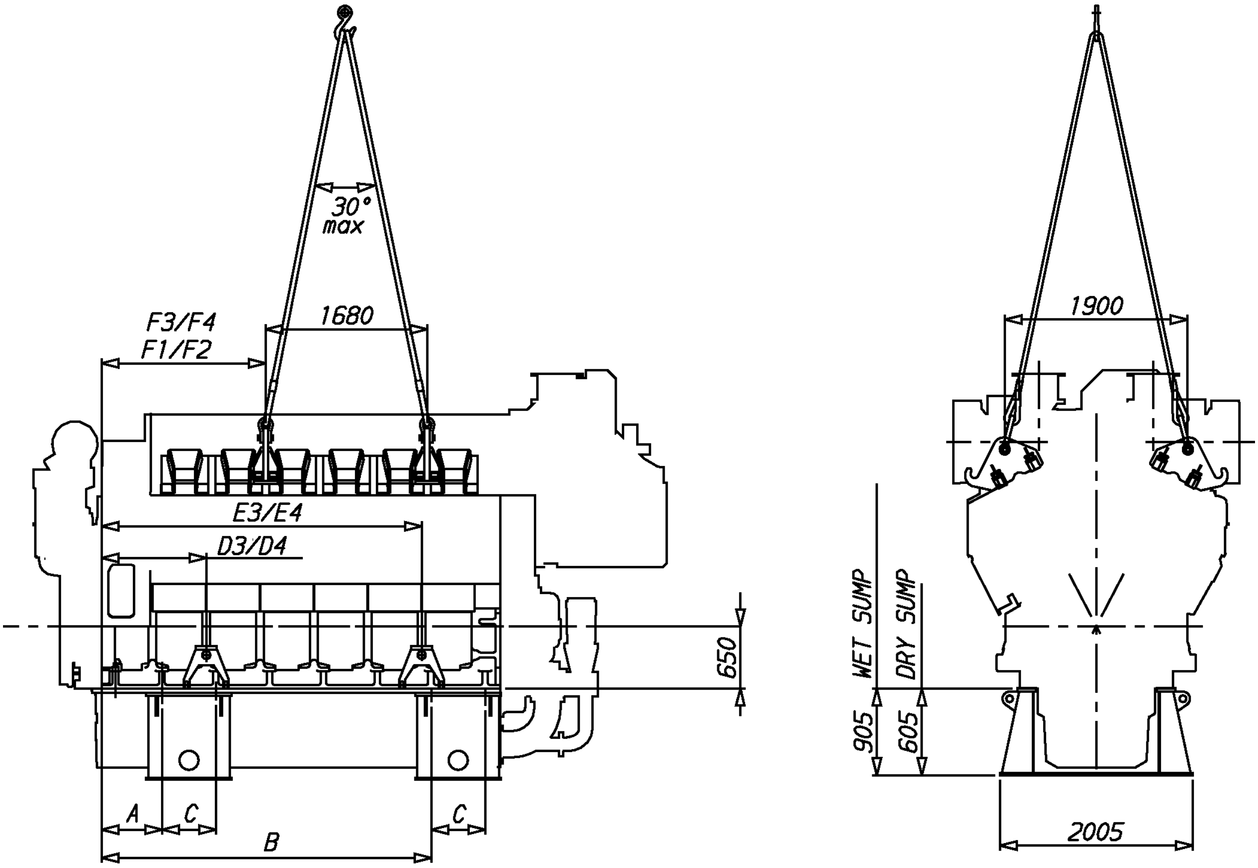
* 1 = Turbocharger in free end

2 = Turbocharger in driving end

3 = Rear side (B-bank)

4 = Operating side (A-bank)

Figure 19.2 Lifting of main engines, V-engines (2V83D0253e)



All dimensions in mm.

Transport bracket weight = 935 kg.

Engine	A	B	C	D3	D4	E3, E4	F1, F4	F1, F3	F2, F4	F2, F3
W 12V32	630	3430	560	1090	530	3330	1594	1706	1034	1146
W 16V32	630	4550	560	1090	530	4450	2154	2266	1594	1706
W 18V32	630	5110	560	1090	530	5010	2154	2266	-	-

* 1 = Turbocharger in free end
2 = Turbocharger in driving end
3 = Rear side (B-bank)
4 = Operating side (A-bank)

19.2 Lifting of generating sets

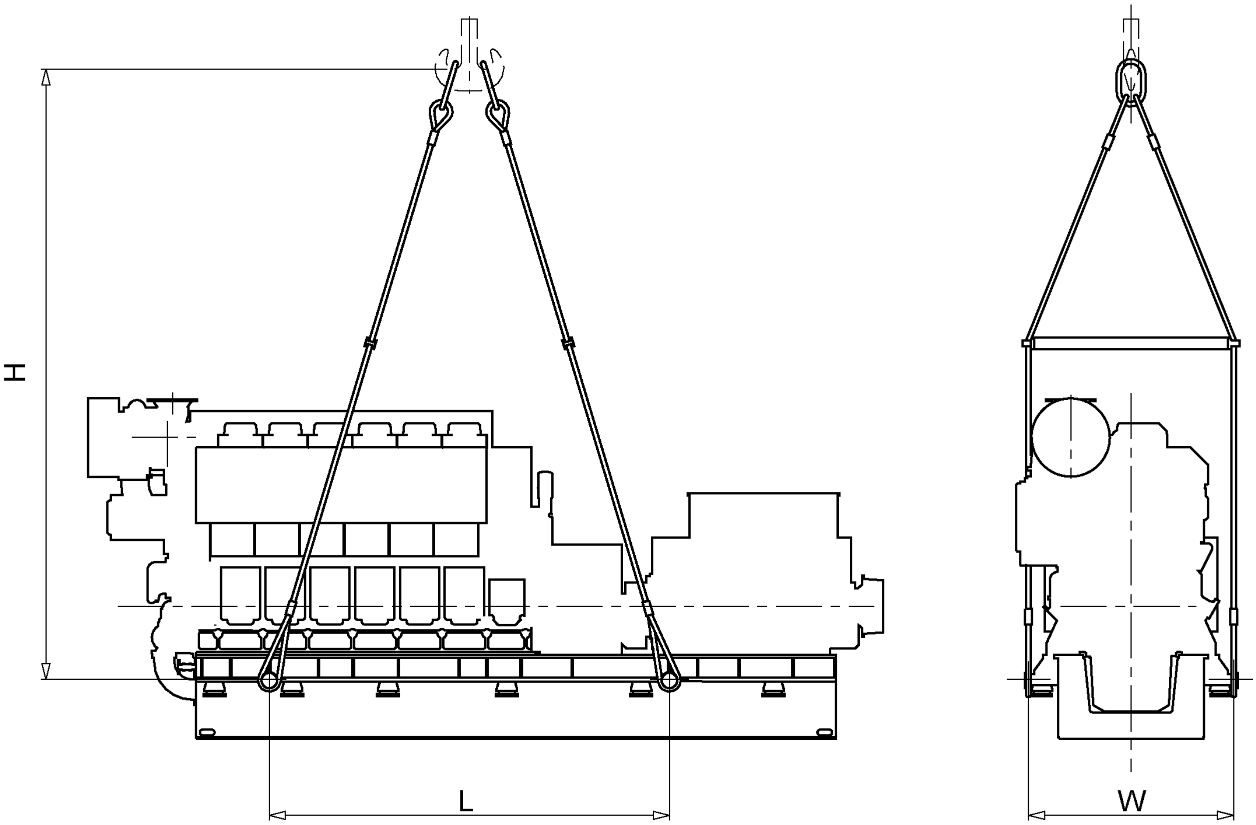


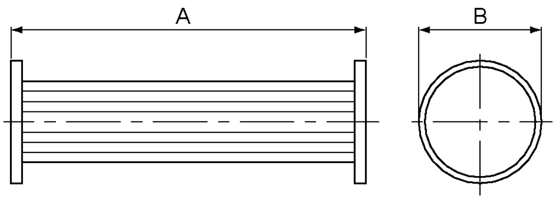
Figure 19.3 Lifting of generating sets (3V83D0251b, -252a)

Engine	H [mm]	L [mm]	W [mm]
W L32	6550...6900	3700...6000	2245...2845
W V32	8000...8480	4500...6500	2975...3275

19.3 Engine components

Table 19.1 Turbocharger and cooler inserts (2V92L1099C)

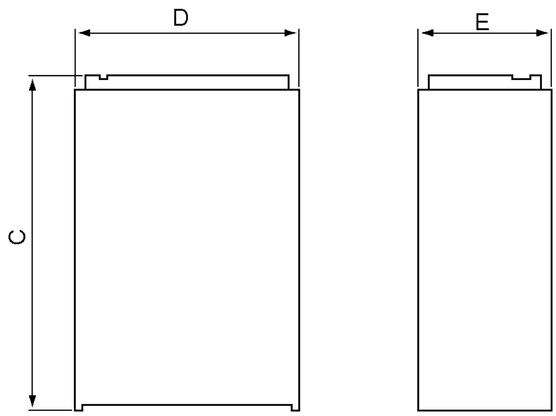
Lubricating oil cooler insert



Engine	Weight [kg] *	Dimensions [mm]	
		A *	B
W 6L32	87	730	369.4
W 7L32	87	730	369.4
W 8L32	110	1220	369.4
W 9L32	110	1220	369.4
W 12V32	250	1338	479.4
W 16V32	250	1338	479.4
W 18V32	250	1338	479.4

** Depends on the cylinder output.*

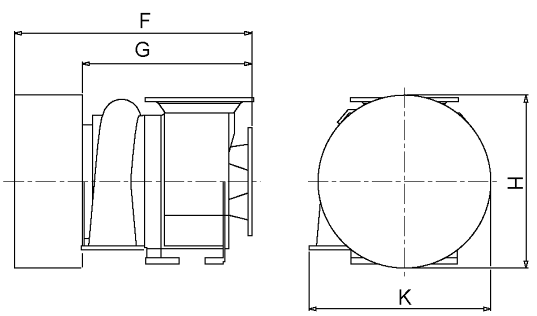
Charge air cooler insert



Engine	Weight [kg]	Dimensions [mm]		
		C *	D *	E *
W 6L32	450	963	630	400
W 7L32	450	963	630	400
W 8L32	500	963	710	436
W 9L32	500	963	710	436
W 12V32	850	1896	630	400
W 16V32	950	2056	630	600
W 18V32	950	2056	630	600

** Depends on the cylinder output.*

Turbocharger



Engine	Dimensions [mm]									
	Napier					ABB				
	F	G	H	K	Weight [kg]	F	G	H	K	Weight [kg]
W 6L32	1500	1185	1150	935	900	1530	1190	905	845	600
W 7L32	1500	1185	1150	935	900	-	-	-	-	-
W 8L32	1500	1185	1150	935	900	1625	1260	1275	1030	1200
W 9L32	-	-	-	-	-	1625	1260	1275	1030	1200
W 12V32	1500	1185	995	1045	2x900	1120	780	905	880	2x550
W 16V32	1500	1185	995	1045	2x900	1625	1260	1150	1050	2x1200
W 18V32	-	-	-	-	-	1625	1260	1150	1050	2x1200

Figure 19.4 Major spare parts (500 kW/cyl), (1V92L1098B)

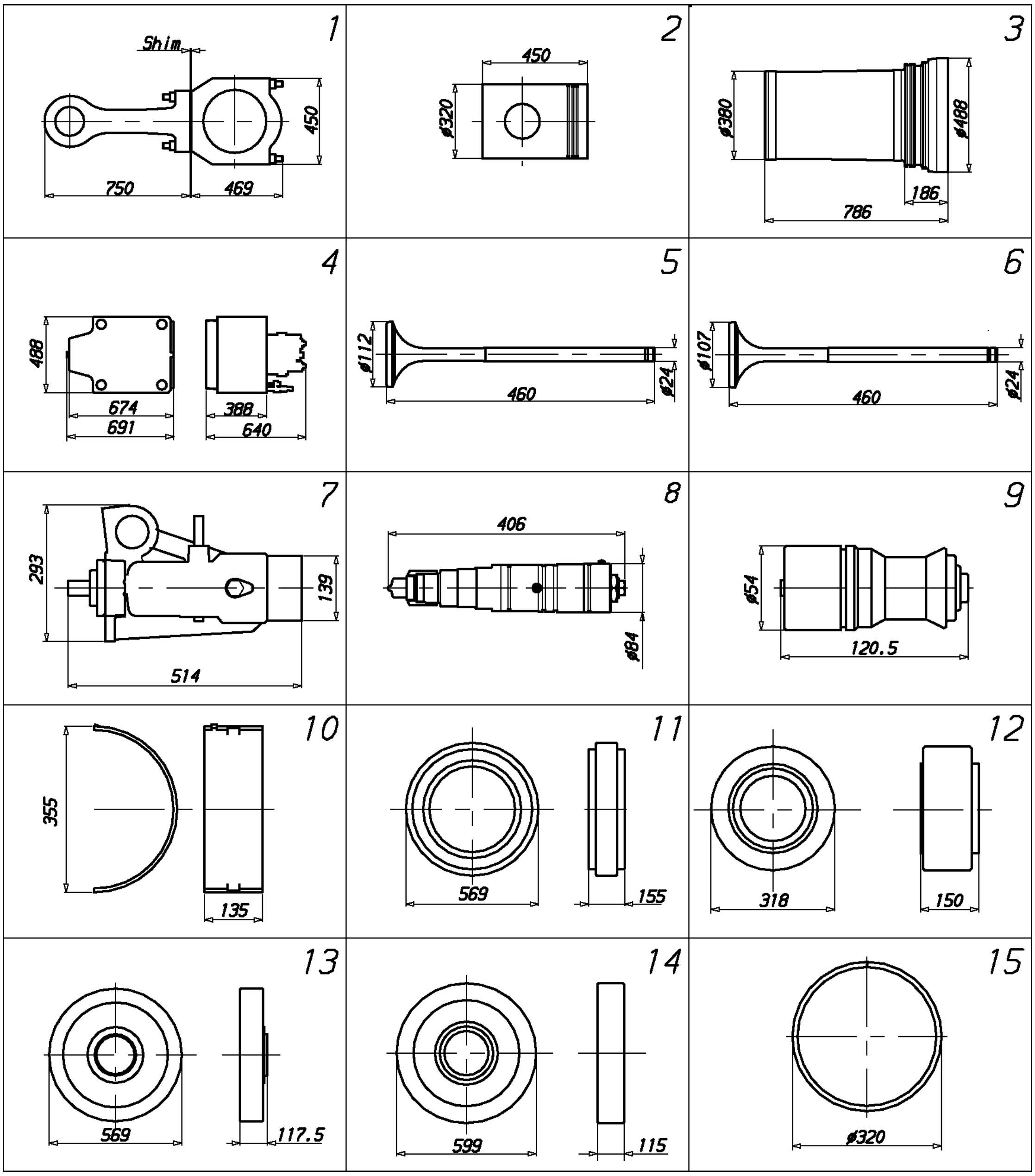


Table 19.2 Weights for 1V92L1098B

Item no	Description	Weight [kg]	Item No	Description	Weight [kg]
1	Connecting rod	153.5	9	Starting valve	1.0
2	Piston	82.0	10	Main bearing shell	8.5
3	Cylinder liner	253.0	11	Split gear wheel	127.0
4	Cylinder head	410.0	12	Small intermediate gear	31.0
5	Inlet valve	3.0	13	Large intermediate gear	156.0
6	Exhaust valve	2.8	14	Camshaft gear wheel	103.0
7	Injection pump	37.0	15	Piston ring set	1.5
8	Injection valve	12.0		Piston ring	0.5

Figure 19.5 Major spare parts (580 kW/cyl), (DAAF049715A)

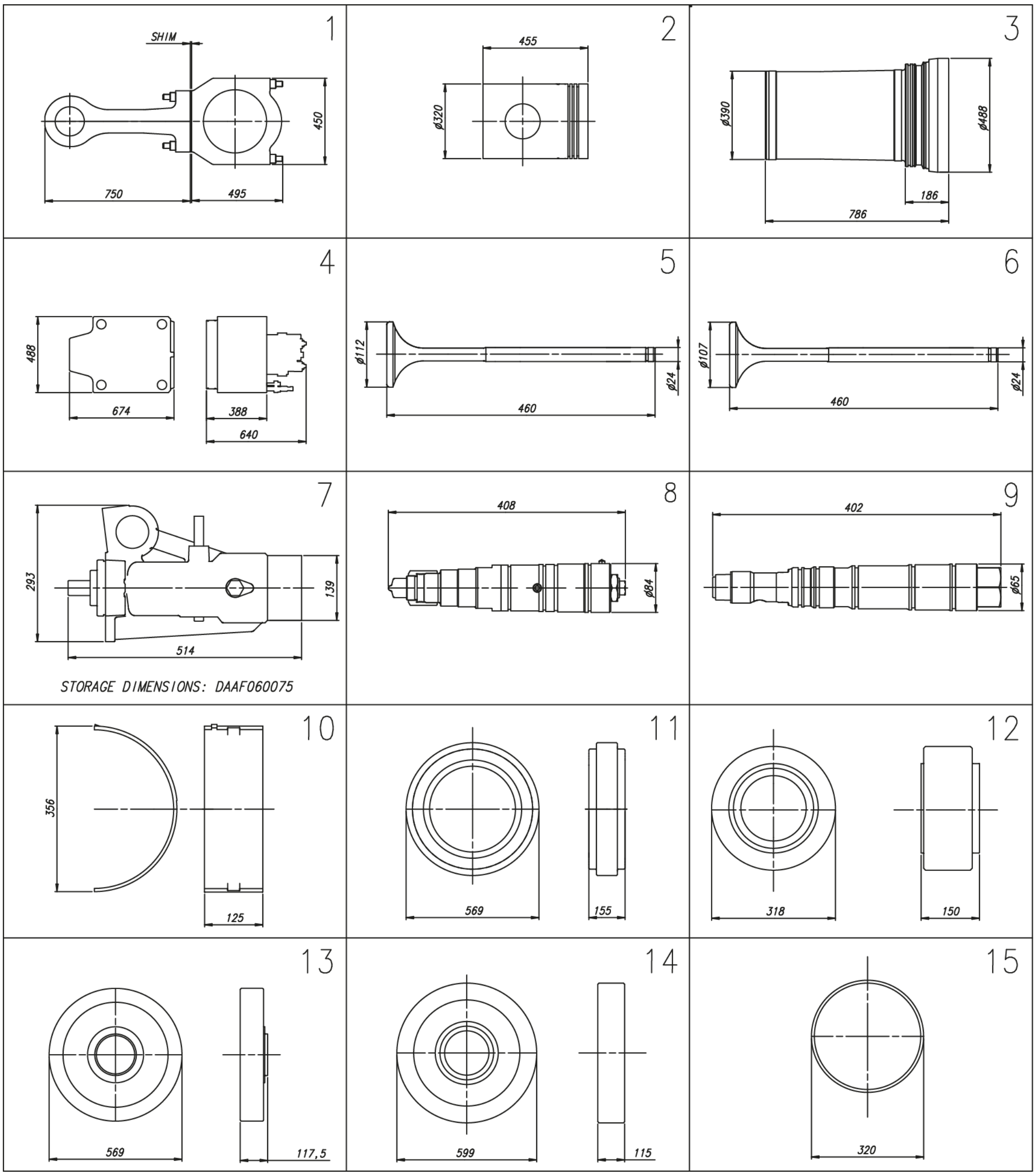


Table 19.3 Weights for DAAF049715A

Item no	Description	Weight [kg]	Item No	Description	Weight [kg]
1	Connecting rod	157.0	9	Starting valve	6.4
2	Piston	82.0	10	Main bearing shell	7.3
3	Cylinder liner	239.0	11	Split gear wheel	121.0
4	Cylinder head	382.0	12	Small intermediate gear	49.0
5	Inlet valve	3.0	13	Large intermediate gear	113.0
6	Exhaust valve	3.0	14	Camshaft gear wheel	132.0
7	Injection pump	50.0	15	Piston ring set	1.5
8	Injection valve	9.4			

20. Product Guide Attachments

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

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

21. ANNEX

21.1 Unit conversion tables

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

Table 21.1 Length conversion factors

Convert from	To	Multiply by
mm	in	0.0394
mm	ft	0.00328

Table 21.2 Mass conversion factors

Convert from	To	Multiply by
kg	lb	2.205
kg	oz	35.274

Table 21.3 Pressure conversion factors

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

Table 21.4 Volume conversion factors

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

Table 21.5 Power conversion factors

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

Table 21.6 Moment of inertia and torque conversion factors

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

Table 21.7 Fuel consumption conversion factors

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

Table 21.8 Flow conversion factors

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

Table 21.9 Temperature conversion factors

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

Table 21.10 Density conversion factors

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

21.1.1 Prefix

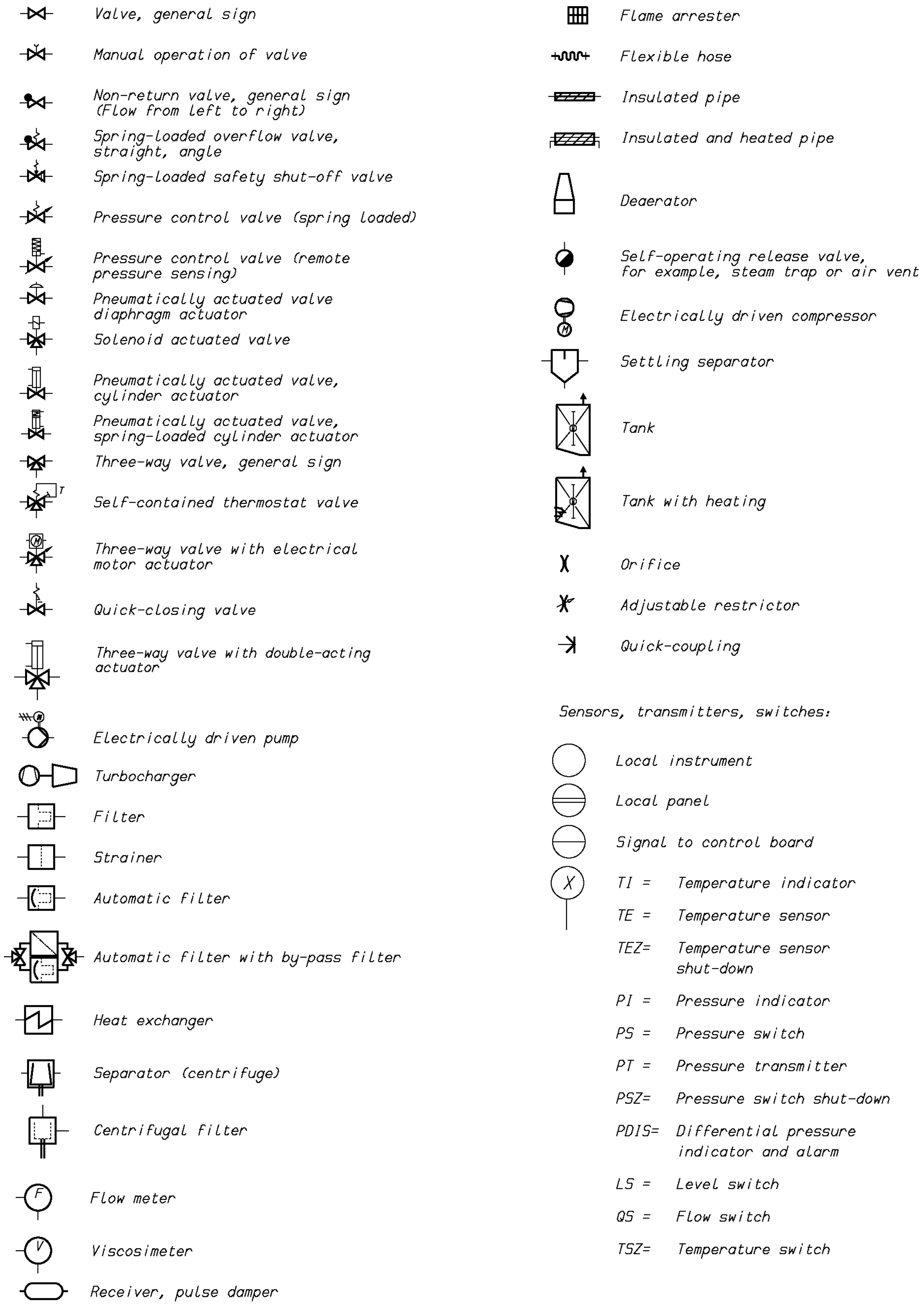
Table 21.11 The most common prefix multipliers

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

Name	Symbol	Factor	Name	Symbol	Factor
kilo	k	10^3			

21.2 Collection of drawing symbols used in drawings

Figure 21.1 List of symbols (DAAE000806c)



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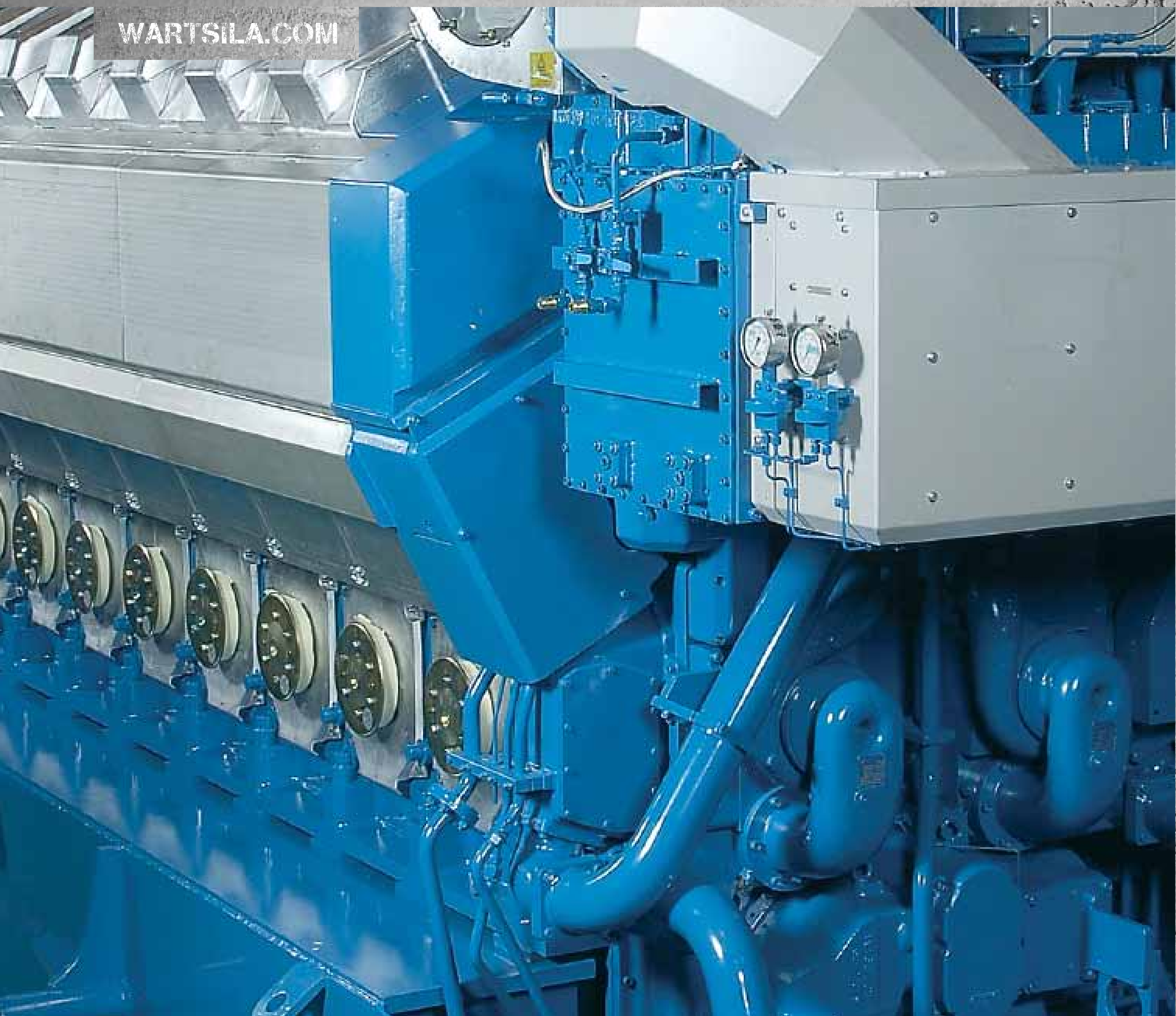

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