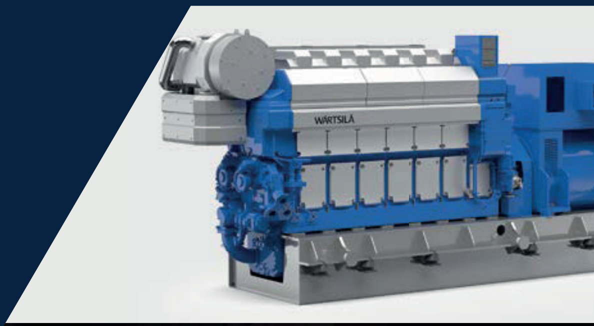
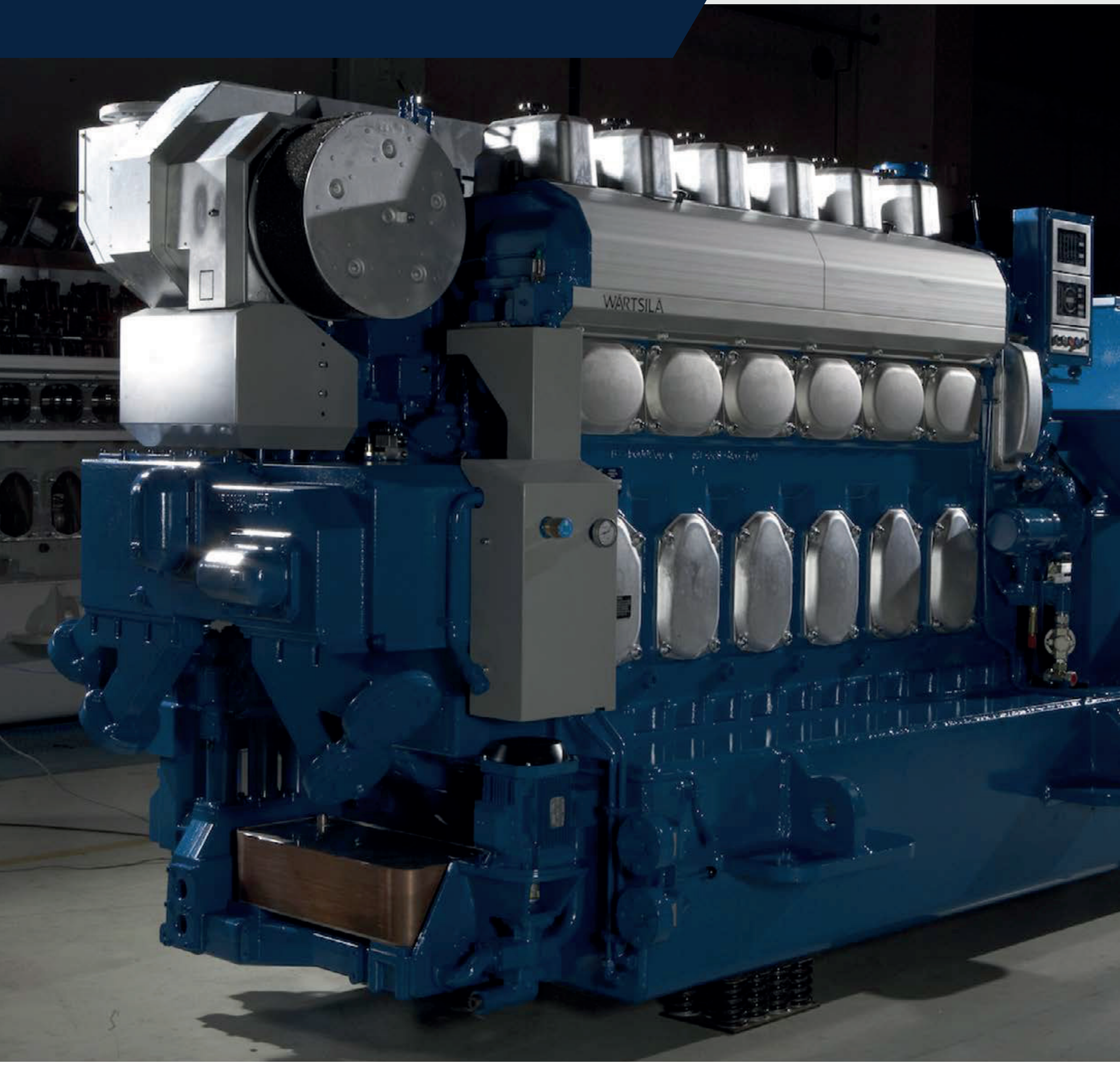
WÄRTSILÄ

WÄRTSILÄ Engines

Wärtsilä Auxpac

PRODUCT GUIDE





1. Main Data and Outputs

1.1 Wärtsilä Auxpac – reliable and cost-efficient power generation

The WÄRTSILÄ® Auxpac is a generating set designed for auxiliary power generation in commercial type vessels. It is a pre-commissioned standard package that ensures the availability of electrical power in sufficient quantity as and when it is needed.

Wärtsilä Auxpac is designed to provide:

- Easy installation
- Easy operation
- Low operation costs

The Wärtsilä Auxpac's are the ideal choice for Container vessels, Bulk carriers, General cargo vessels and Tankers.

1.2 Technical main data and definitions

1.2.1 Genset designation

The genset designation is as follows:

1000W 6 L20

Engine type [WA16, WA20]

No. of Cylinders [4, 5, 6, 7, 8, 9]

Output [kWe]

1.2.2 Engine main data

Wärtsilä Auxpac is a 4-stroke, non-reversible, turbocharged and intercooled diesel engines with direct fuel injection.

Part No.	Cylinder bore	Stroke	Piston displacement	Number of valves	Cylinder configuration	Direction of rotation	Speed	Mean piston speed
WA16	160 mm	250 mm	5.0 l/cyl	2 inlet valves 2 exhaust valves	5, 6 and 7 in-line	Clockwise, CCW on request	1000, 1200 rpm	8.3, 10 m/s

Part No.	Cylinder bore	Stroke	Piston displacement	Number of valves	Cylinder configuration	Direction of rotation	Speed	Mean piston speed
WA20	200 mm	280 mm	8.8 l/cyl	2 inlet valves 2 exhaust valves	4, 6, 8 and 9 in-line	Clockwise, CCW on request	900, 1000 rpm	8.4, 9.3 m/s

1.2.3 Maximum continuous output

Table 1-1 Rating table for Wärtsilä Auxpac 16

1000 rpm / 50 Hz					1200 rpm / 60 Hz			
Type	Output [kWe]	Voltage [V]	Generator		Type	Output [kWe]	Voltage [V]	Generator
455W5L16	455	400	Leroy Somer		525W5L16	525	450	Leroy Somer
545W6L16	545	400	Leroy Somer		630W6L16	660	450	Leroy Somer
635W7L16	635	400	Leroy Somer		735W7L16	735	450	Leroy Somer

Table 1-2 Rating table for Wärtsilä Auxpac 20

900 rpm / 60 Hz					1000 rpm / 50 Hz			
Type	Output [kWe]	Voltage [V]	Generator		Type	Output [kWe]	Voltage [V]	Generator
520W4L20	520	450	Fenxi		520W4L20	520	400	Fenxi
645W4L20	645	450	Fenxi		670W4L20	670	400	Fenxi
760W6L20	760	450	Fenxi		790W6L20	790	400	Fenxi
875W6L20	875	450	Fenxi		860W6L20	860	400	Fenxi
975W6L20	975	450	Fenxi		1000W6L20	1000	400	Fenxi
1040W6L20	1050	450	Fenxi		1140W6L20	1140	400	Fenxi
1200W8L20	1200	450	Fenxi		1350W8L20	1350	400	Fenxi
1300W8L20	1300	450	Fenxi		1550W9L20	1550	400	Fenxi
1400W8L20	1400	450	Fenxi		1700W9L20	1700	400	Fenxi
1600W9L20	1600	450	Fenxi					

Maximum fuel rack position is mechanically limited to 110% continuous output.

1.3 Reference conditions

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

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

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

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

1.4 Principal dimensions and weights

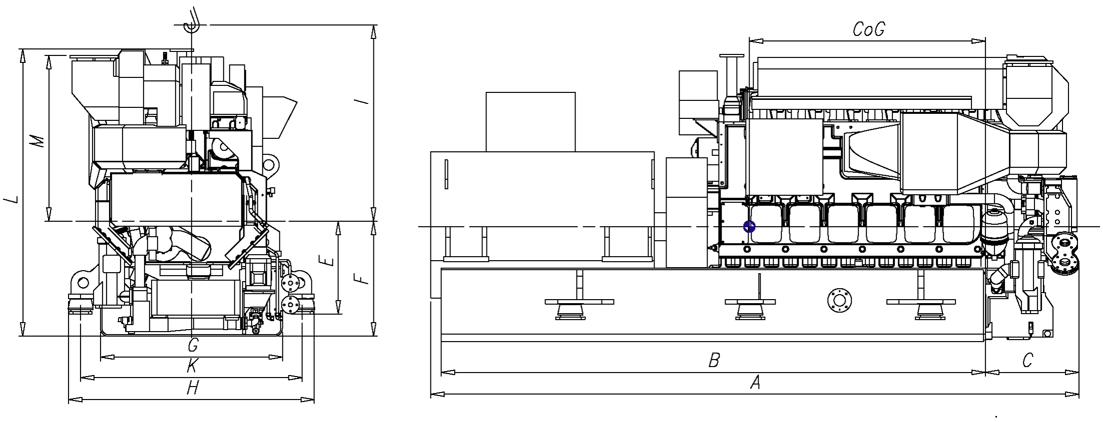


Fig 1-1 Wärtsilä Auxpac dimensions (DAAE026184E, DAAF367387)

Table 1-3 Wärtsilä Auxpac 16, 1200 rpm / 60Hz

Type	A	B	C	E	F	G	H	I	K	L	M	CoG	Weight Wet	Weight Dry
525W5L16	4530	3700	535	692	745	804	1294	1471	1114	1955	1188		10.3	9.8
630W6L16	4787	3953	535	692	745	804	1294	1471	1114	1955	1188	1558	11.3	10.8
735W7L16	5050	4220	535	692	745	804	1294	1471	1114	1955	1188		12.3	11.8

Table 1-4 Wärtsilä Auxpac 16, 1000 rpm / 50Hz

Type	A	B	C	E	F	G	H	I	K	L	M	CoG	Weight Wet	Weight Dry
455W5L16	4530	3700	535	692	745	804	1294	1471	1114	1955	1188		10.3	9.8
545W6L16	4787	3953	535	692	745	804	1294	1471	1114	1955	1188	1558	11.3	10.8
635W7L16	5050	4220	535	692	745	804	1294	1471	1114	1955	1188		12.3	11.8

Table 1-5 Wärtsilä Auxpac 20, 900 rpm / 60Hz

	Type	A	B	C	E	F	G	H	I	K	L	M
Antifriction bearing	520W4L20	4634	3600	732	725	900	1420	1920	1800	1730	2248	1207
	685W4L20	4764	3725	732	725	900	1420	1920	1800	1730	2248	1207
	760W6L20	5274	4250	732	725	900	1420	1920	1800	1730	2248	1297
	875W6L20	5274	4250	732	725	900	1420	1920	1800	1730	2248	1297
	975W6L20	5274	4250	732	725	900	1420	1920	1800	1730	2248	1297
	1040W6L20	5274	4250	732	725	900	1420	1920	1800	1730	2248	1297
	1200W8L20	6144	5100	732	725	1025	1420	1920	1800	1730	2462	1390
	1300W8L20	6144	5100	732	725	1025	1420	1920	1800	1730	2462	1390
	1400W8L20	6119	5050	732	725	1025	1570	2070	1800	1880	2462	1390
	1600W9L20	6837	5750	732	725	1025	1570	2070	1800	1880	2462	1390

Table 1-6 Wärtsilä Auxpac 20, 900 rpm / 60Hz

	Type	Air cooled generator			Water cooled generator		
		CoG	Weight Wet	Weight Dry	CoG	Weight wet	Weight dry
Antifriction bearing	520W4L20	1355	13.5	13.1	1408	13960	13530
	685W4L20	1447	14.2	13.8	1498	14604	14174
	760W6L20	1781	17.3	16.7	1835	17828	17268
	875W6L20	1781	17.3	16.7	1835	17828	17268
	975W6L20	1817	17.9	17.3	1868	18258	17698
	1040W6L20	1817	17.9	17.3	1868	18258	17698
	1200W8L20	2201	21.9	20.5	2273	22391	21051
	1300W8L20	2201	21.9	20.5	2273	22391	21051
	1400W8L20	2311	24.5	22.4	2381	24981	23381
	1600W9L20	2677	25.5	24.0	2735	25844	24344

Table 1-7 Wärtsilä Auxpac 20, 900 rpm / 60Hz

	Type	A	B	C	E	F	G	H	I	K	L	M	Air cooled generator		
													CoG	Weight wet	Weight dry
Sleeve bearing	645W4L20	4764	3725	732	725	900	1420	1920	1800	1730	2248	1207	1429	14.2	13.8
	875W6L20	5274	4250	732	725	900	1420	1920	1800	1730	2248	1297	1781	17.3	16.7

Table 1-8 Wärtsilä Auxpac 20, 1000 rpm / 50Hz

	Type	A	B	C	E	F	G	H	I	K	L	M
Antifriction bearing	520W4L20	4407	3600	732	725	900	1420	1920	1800	1730	2248	1207
	670W4L20	4407	3600	732	725	900	1420	1920	1800	1730	2248	1207
	790W6L20	5007	4200	732	725	900	1420	1920	1800	1730	2248	1299
	860W6L20	5137	4350	732	725	900	1420	1920	1800	1730	2248	1299
	1000W6L20	5212	4370	732	725	900	1420	1920	1800	1730	2248	1299
	1140W6L20	5212	4370	732	725	900	1420	1920	1800	1730	2248	1299
	1350W8L20	5932	5100	732	725	1025	1420	1920	1800	1730	2373	1299
	1550W9L20	6567	5700	732	725	1025	1570	2070	1800	1880	2455	1390
	1700W9L20	6647	5800	732	725	1025	1570	2070	1800	1880	2455	1390

Table 1-9 Wärtsilä Auxpac 20, Fenxi 1000 rpm / 50Hz

	Type	Air cooled generator			Water cooled generator		
		CoG	Weight Wet	Weight Dry	CoG	Weight Wet	Weight Dry
Antifriction bearing	520W4L20	1340	13.5	12.9	1394	14.0	13.4
	670W4L20	1329	13.4	12.8	1394	14.0	13.4
	790W6L20	1687	16.3	15.8	1750	16.9	16.4
	860W6L20	1752	16.8	16.2	1822	17.5	16.9
	1000W6L20	1864	17.8	17.2	1903	18.4	17.9
	1140W6L20	1892	18.1	17.5	1920	18.6	18.1
	1350W8L20	2200	22.1	20.6	2256	22.6	21.3
	1550W9L20	2632	25.3	23.8	2679	25.9	24.4
	1700W9L20	2675	25.6	24.1	2744	26.5	25.0

Dimensions in mm. Weight in tons.

Weight including resilient elements. Tolerance = ± 3%

2. Operating Conditions

2.1 Loading capacity

2.1.1 Loading rate

The loading rate of a highly turbocharged diesel engine must be controlled, because the turbocharger needs time to accelerate before it can deliver the required amount of air. Class rules regarding load acceptance capability stipulate what the generating set must be capable of in an unexpected situation, but in normal operation the loading rate should be slower, about 60 seconds from zero to full load for W20 and W26 based auxpacs and 80 seconds for W32 based auxpacs. The generating set can be loaded immediately after start, provided that the engine is pre-heated to a HT-water temperature of 60…70ºC.

2.1.2 Maximum instant load step

The automation system and the operation of the plant must prevent excessive load steps. The fastest and smoothest loading from 0% to 100% is achieved with gradual load increase in small increments. The maximum instant load application is 33% MCR. However, if the engine is not equipped with Variable Inlet valve Closure (VIC), the maximum instant load application is limited to 25% MCR for the following generating sets: 645W4L20 (900 rpm/60 Hz), 975W6L20 (900 rpm/60 Hz), 1000W6L20 (1000 rpm/50 Hz), 1350W8L20 (1000 rpm/50 Hz), 1550W9L20 (1000 rpm/50 Hz).

2.1.3 Overload capacity

All generating sets are capable of producing 110% power in service. The overload capacity is a power reserve for transients and emergency situations. Overload may not be planned for in the normal operation of the plant, or otherwise utilised on a routine basis.

2.2 Operation at low load and idling

The generating set 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. The following recommendations apply:

2.2.1 Absolute idling (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.

2.2.2 Operation at < 20 % load on HFO or < 10 % on MDF

Maximum 100 hours continuous operation. At intervals of 100 operating hours the genset must be loaded to minimum 70 % of the rated load.

2.2.3 Operation at > 20 % load on HFO or > 10 % on MDF

No restrictions.

3.2 Wärtsilä Auxpac, 50 Hz

3.2.1 Wärtsilä Auxpac 16, 1000 rpm / 50 Hz

Wärtsilä Auxpac		**455W5L16 / 50 Hz**	**545W6L16 / 50 Hz**	**635W7L16 / 50 Hz**
database id, temp info to be removed		**2145**	**2089**	**2147**
Engine speed	rpm	1000	1000	1000
Engine output	kW	475	570	665
Mean effective pressure	MPa	2.27	2.27	2.27
IMO compliance		IMO Tier 2	IMO Tier 2	IMO Tier 2
Combustion air system				
Flow of air at 100% load	kg/s	0.9	1.08	1.26
Temperature at turbocharger intake, max	°C	45	45	45
Temperature after air cooler (TE 601)	°C	25...38	25...38	25...38
Exhaust gas system (Note 1)				
Flow at 100% load	kg/s	0.92	1.1	1.28
Flow at 85% load	kg/s	0.78	0.94	1.1
Temp. after turbocharger at 100% load (TE 517)	°C	349	349	349
Temp. after turbocharger at 85% load (TE 517)	°C	340	340	340
Backpressure, max.	kPa	4.0	4.0	4.0
Calculated exhaust diameter for 35 m/s	mm	242	265	286
Heat balance at 100% load (Note 2)				
Jacket water	kW	95	126	133
Charge air (LT-circuit)	kW	160	198	224
Lubricating oil	kW	75	84	105
Radiation, etc	kW	13	15	18
Fuel system (Note 3)				
Pressure before injection pumps (PT 101)	kPa	700±50	700±50	700±50
Pressure before injection pumps, unifuel system	kPa	1000±50	1000±50	1000±50
HFO viscosity before injection pumps	cSt	16...24	16...24	16...24
HFO viscosity before injection pumps, unifuel system	cSt	12...24	12...24	12...24
Max. HFO temperature before engine (TE 101)	°C	140	140	140
MDF viscosity, min.	cSt	1.8	1.8	1.8
Max. MDF temperature before engine (TE 101)	°C	60	60	60
Fuel consumption at 100% load	g/kWh	187.6	190.0	187.6
Fuel consumption at 85% load	g/kWh	188.6	191.5	188.6
Fuel consumption at 75% load	g/kWh	191.4	194.3	191.4
Fuel consumption at 50% load	g/kWh	203.8	208.0	203.8
Clean leak fuel quantity, MDF at 100% load	kg/h	1.7	2.0	2.4
Clean leak fuel quantity, HFO at 100% load	kg/h	0.3	0.4	0.5
Lubricating oil system				
Pressure before engine, nom. (PT 201)	kPa	450	450	450
Priming pressure, nom. (PT 201)	kPa	200	200	200

Wärtsilä Auxpac		455W5L16 / 50 Hz	545W6L16 / 50 Hz	635W7L16 / 50 Hz
database id, temp info to be removed		**2145**	**2089**	**2147**
Temperature before bearings, nom. (TE 201)	°C	66	66	66
Temperature after engine, about	°C	80	80	80
Pump capacity (main), engine driven	m³/h	18	21	25
Priming pump capacity	m³/h	4.5	4.5	4.5
Filter fineness, mesh size	mi-crons	25	25	25
Oil consumption at 100% load, about	g/kWh	0.6	0.6	0.6
Crankcase ventilation flow rate at full load	l/min	460	552	644
Crankcase ventilation backpressure, max.	kPa	0.4	0.4	0.4
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	320	320	320
Temperature before cylinders, approx. (TE 401)	°C	85	85	85
Temperature after engine, nom.	°C	90	90	90
Capacity of engine driven pump, nom.	m³/h	15.0	18.0	21.0
Pressure drop over engine	kPa	70	70	70
Pressure drop in external system, max.	kPa	120	120	120
Pressure from expansion tank	kPa	70...150	70...150	70...150
Engine water volume	m³	0.08	0.09	0.1
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	320	320	320
Temperature before engine (TE 451)	°C	25...38	25...38	25...38
Capacity of engine driven pump, nom.	m³/h	18.0	22.0	26.0
Pressure drop over charge air cooler	kPa	30	30	30
Pressure drop over thermostatic valve	kPa	30	30	30
Pressure drop over oil cooler	kPa	50	50	50
Pressure drop in the external system, max.	kPa	120	120	120
Pressure from expansion tank	kPa	70...150	70...150	70...150
Starting air system				
Pressure, nom.	kPa	3000	3000	3000
Pressure, max	kPa	3000	3000	3000
Pressure, min	kPa	1800	1800	1800
Starting air consumption, start (successful)	Nm³	0.6	0.6	0.6
Generator data (Note 4)				
Generator brand		Leroy Somer	Leroy Somer	Leroy Somer
Frequency	Hz	50	50	50
Rated output	kVa	594	594	831
Voltage	V	400	400	400
Rated current	A	857	857	1199
Power factor		0.8	0.8	0.8
CT/Ratio		1000/1A 10VA CL0.5	1250/1A 10VA CL0.5	1250/1A 10VA CL0.5
Temperature rise		F	F	F
Insulation class		H	H	H

Wärtsilä Auxpac		455W5L16 / 50 Hz	545W6L16 / 50 Hz	635W7L16 / 50 Hz
database id, temp info to be removed		**2145**	**2089**	**2147**
Td'	s	0.123	0.121	0.123
Td''	s	0.019	0.019	0.02
Ta	s	0.036	0.041	0.047
Heat dissipation of air cooled generator	kW	24	24	32

Notes:

Note 1 At an ambient temperature of 25°C.

Note 2 ISO-optimized engine at ambient conditions according to ISO 15550. With engine driven pumps. Fuel net caloric value: 42700 kJ/kg. Radiation includes generator cooling power.

Note 3 According to ISO 15550, lower calorofic value 42 700 kJ/kg at constant engine speed, with engine driven pumps (two cooling water + one lubricating oil). Tolerance 5%.

Note 4 Acc. to IEC 34.

Subject to revision without notice.

3.2.2 Wärtsilä Auxpac 20, 1000 rpm / 50 Hz

Wärtsilä Auxpac		520W4L20 / 50 Hz	670W4L20 / 50 Hz	790W6L20 / 50 Hz
database id, temp info to be removed		**1600**	**1601**	**1602**
Engine speed	rpm	1000	1000	1000
Engine output	kW	548	705	832
Mean effective pressure	MPa	1.87	2.41	1.89
IMO compliance		IMO Tier 2	IMO Tier 2	IMO Tier 2
Combustion air system (Note 1)				
Flow of air at 100% load	kg/s	1.17	1.44	1.78
Temperature at turbocharger intake, max	°C	45	45	45
Temperature after air cooler (TE 601)	°C	50...70	50...70	50...70
Exhaust gas system (Note 2)				
Flow at 100% load	kg/s	1.2	1.48	1.83
Flow at 85% load	kg/s	1.04	1.29	1.59
Temp. after turbocharger at 100% load (TE 517)	°C	338	337	322
Temp. after turbocharger at 85% load (TE 517)	°C	346	335	330
Backpressure, max.	kPa	5.0	5.0	5.0
Calculated exhaust diameter for 35 m/s	mm	274	304	334
Heat balance at 100% load (Note 3)				
Jacket water	kW	133	155	201
Charge air (LT-circuit)	kW	138	222	215
Lubricating oil	kW	100	114	136
Radiation, etc	kW	33	33	49
Fuel system (Note 4)				
Pressure before injection pumps (PT 101)	kPa	700±50	700±50	700±50
Pressure before injection pumps, unifuel system	kPa	1000±50	1000±50	1000±50
HFO viscosity before injection pumps	cSt	16...24	16...24	16...24
HFO viscosity before injection pumps, unifuel system	cSt	12...24	12...24	12...24
Max. HFO temperature before engine (TE 101)	°C	140	140	140
MDF viscosity, min.	cSt	1.8	1.8	1.8
Max. MDF temperature before engine (TE 101)	°C	45	45	45
Fuel consumption at 100% load	g/kWh	200.1	196.3	192.7
Fuel consumption at 85% load	g/kWh	204.9	198.2	195.6
Fuel consumption at 75% load	g/kWh	209.7	200.6	197.8
Fuel consumption at 50% load	g/kWh	224.2	211.9	209.0
Clean leak fuel quantity, HFO at 100% load	kg/h	0.5	0.6	0.7
Lubricating oil system				
Pressure before engine, nom. (PT 201)	kPa	450	450	450
Priming pressure, nom. (PT 201)	kPa	80	80	80
Temperature before bearings, nom. (TE 201)	°C	66	66	66
Temperature after engine, about	°C	78	78	78

Wärtsilä Auxpac		520W4L20 / 50 Hz	670W4L20 / 50 Hz	790W6L20 / 50 Hz
database id, temp info to be removed		**1600**	**1601**	**1602**
Pump capacity (main), engine driven	m³/h	28	28	35
Priming pump capacity	m³/h	8.6	8.6	8.6
Oil volume, nom.	m³	0.64	0.64	0.76
Filter fineness, mesh size	mi-crons	25	25	25
Oil consumption at 100% load, about	g/kWh	0.5	0.5	0.5
Crankcase ventilation flow rate at full load	l/min	520	520	780
Crankcase ventilation backpressure, max.	kPa	0.4	0.4	0.4
High temperature cooling water system				
Pressure at engine, after pump, nom. (PT 401)	kPa	200 + static	200 + static	200 + static
Pressure at engine, after pump, max. (PT 401)	kPa	500	500	500
Temperature before cylinders, approx. (TE 401)	°C	83	83	83
Temperature after engine, nom.	°C	91	91	91
Capacity of engine driven pump, nom.	m³/h	20.0	20.0	30.0
Pressure drop over engine	kPa	90	90	90
Pressure drop in external system, max.	kPa	120	120	120
Pressure from expansion tank	kPa	70...150	70...150	70...150
Engine water volume	m³	0.08	0.08	0.105
Low temperature cooling water system				
Pressure at engine, after pump, nom. (PT 451)	kPa	200 + static	200 + static	200 + static
Pressure at engine, after pump, max. (PT 451)	kPa	500	500	500
Temperature before engine (TE 451)	°C	25...38	25...38	25...38
Capacity of engine driven pump, nom.	m³/h	24.0	24.0	36.0
Pressure drop over charge air cooler	kPa	30	30	30
Pressure drop over thermostatic valve	kPa	30	30	30
Pressure drop over oil cooler	kPa	30	30	30
Pressure drop in the external system, max.	kPa	120	120	120
Pressure from expansion tank	kPa	70...150	70...150	70...150
Starting air system				
Pressure, nom.	kPa	3000	3000	3000
Pressure, max	kPa	3000	3000	3000
Pressure, min	kPa	1800	1800	1800
Starting air consumption, start (successful)	Nm³	1.2	1.2	1.2
Generator data (Note 5)				
Generator brand		Fenxi	Fenxi	Fenxi
Frequency	Hz	50	50	50
Rated output	kVa	651	838	988
Voltage	V	400	400	400
Rated current	A	940	1210	1426
Power factor		0.8	0.8	0.8
CT/Ratio		1500/5 5P10, 20 VA	2000/5 5P10, 20 VA	2000/5 5P10, 20 VA
Temperature rise		F	F	F
Insulation class		F	F	F

Wärtsilä Auxpac		520W4L20 / 50 Hz	670W4L20 / 50 Hz	790W6L20 / 50 Hz
database id, temp info to be removed		**1600**	**1601**	**1602**
Xd (Unsaturated)	p.u	3.22	4.16	4.12
X'd (Saturated)	p.u	0.14	0.17	0.17
X"d (Saturated)	p.u	0.08	0.09	0.09
Td'	s	0.054	0.054	0.053
Td''	s	0.003	0.003	0.003
Ta	s	0.015	0.015	0.019
Heat dissipation of air cooled generator	kW	32	47	51

Notes:

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

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

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

Note 4 At ambient conditions according to ISO 15550. Lower calorific value 42 700 kJ/kg. With engine driven pumps (two cooling water + one lubricating oil pump). Tolerance 5%.

Note 5 Acc. to IEC 34.

Subject to revision without notice.

Wärtsilä Auxpac		860W6L20 / 50 Hz	1000W6L20 / 50 Hz	1140W6L20 / 50 Hz
database id, temp info to be removed		**1603**	**1612**	**1613**
Engine speed	rpm	1000	1000	1000
Engine output	kW	905	1053	1200
Mean effective pressure	MPa	2.06	2.39	2.73
IMO compliance		IMO Tier 2	IMO Tier 2	IMO Tier 2
Combustion air system (Note 1)				
Flow of air at 100% load	kg/s	1.92	2.17	2.31
Temperature at turbocharger intake, max	°C	45	45	45
Temperature after air cooler (TE 601)	°C	50...70	50...70	50...70
Exhaust gas system (Note 2)				
Flow at 100% load	kg/s	1.97	2.23	2.38
Flow at 85% load	kg/s	1.71	1.95	2.18
Temp. after turbocharger at 100% load (TE 517)	°C	320	321	355
Temp. after turbocharger at 85% load (TE 517)	°C	326	320	320
Backpressure, max.	kPa	5.0	5.0	5.0
Calculated exhaust diameter for 35 m/s	mm	346	368	391
Heat balance at 100% load (Note 3)				
Jacket water	kW	212	231	250
Charge air (LT-circuit)	kW	253	333	405
Lubricating oil	kW	141	153	170
Radiation, etc	kW	49	49	49
Fuel system (Note 4)				
Pressure before injection pumps (PT 101)	kPa	700±50	700±50	700±50
Pressure before injection pumps, unifuel system	kPa	1000±50	1000±50	1000±50
HFO viscosity before injection pumps	cSt	16...24	16...24	16...24
HFO viscosity before injection pumps, unifuel system	cSt	12...24	12...24	12...24
Max. HFO temperature before engine (TE 101)	°C	140	140	140
MDF viscosity, min.	cSt	1.8	1.8	1.8
Max. MDF temperature before engine (TE 101)	°C	45	45	45
Fuel consumption at 100% load	g/kWh	191.6	191.6	194.9
Fuel consumption at 85% load	g/kWh	194.0	191.8	191.6
Fuel consumption at 75% load	g/kWh	196.3	193.7	191.8
Fuel consumption at 50% load	g/kWh	207.1	203.3	198.5
Clean leak fuel quantity, HFO at 100% load	kg/h	0.7	0.8	1.0
Lubricating oil system				
Pressure before engine, nom. (PT 201)	kPa	450	450	450
Priming pressure, nom. (PT 201)	kPa	80	80	80
Temperature before bearings, nom. (TE 201)	°C	66	66	66
Temperature after engine, about	°C	78	78	78
Pump capacity (main), engine driven	m³/h	35	35	35

Wärtsilä Auxpac		860W6L20 / 50 Hz	1000W6L20 / 50 Hz	1140W6L20 / 50 Hz
database id, temp info to be removed		**1603**	**1612**	**1613**
Priming pump capacity	m³/h	8.6	8.6	8.6
Oil volume, nom.	m³	0.76	0.76	0.76
Filter fineness, mesh size	microns	25	25	25
Oil consumption at 100% load, about	g/kWh	0.5	0.5	0.5
Crankcase ventilation flow rate at full load	l/min	780	780	780
Crankcase ventilation backpressure, max.	kPa	0.4	0.4	0.4
High temperature cooling water system				
Pressure at engine, after pump, nom. (PT 401)	kPa	200 + static	200 + static	200 + static
Pressure at engine, after pump, max. (PT 401)	kPa	500	500	500
Temperature before cylinders, approx. (TE 401)	°C	83	83	83
Temperature after engine, nom.	°C	91	91	91
Capacity of engine driven pump, nom.	m³/h	30.0	30.0	30.0
Pressure drop over engine	kPa	90	90	90
Pressure drop in external system, max.	kPa	120	120	120
Pressure from expansion tank	kPa	70...150	70...150	70...150
Engine water volume	m³	0.105	0.105	0.105
Low temperature cooling water system				
Pressure at engine, after pump, nom. (PT 451)	kPa	200 + static	200 + static	200 + static
Pressure at engine, after pump, max. (PT 451)	kPa	500	500	500
Temperature before engine (TE 451)	°C	25...38	25...38	25...38
Capacity of engine driven pump, nom.	m³/h	36.0	36.0	36.0
Pressure drop over charge air cooler	kPa	30	30	30
Pressure drop over thermostatic valve	kPa	30	30	30
Pressure drop over oil cooler	kPa	30	30	30
Pressure drop in the external system, max.	kPa	120	120	120
Pressure from expansion tank	kPa	70...150	70...150	70...150
Starting air system				
Pressure, nom.	kPa	3000	3000	3000
Pressure, max	kPa	3000	3000	3000
Pressure, min	kPa	1800	1800	1800
Starting air consumption, start (successful)	Nm³	1.2	1.2	1.2
Generator data (Note 5)				
Generator brand		Fenxi	Fenxi	Fenxi
Frequency	Hz	50	50	50
Rated output	kVa	1075	1250	1425
Voltage	V	400	400	400
Rated current	A	1552	1804	2057
Power factor		0.8	0.8	0.8
CT/Ratio		2000/5 5P10, 20 VA	2500/5 5P10, 20 VA	3000/5 5P10, 20 VA
Temperature rise		F	F	F

Wärtsilä Auxpac		**860W6L20 / 50 Hz**	**1000W6L20 / 50 Hz**	**1140W6L20 / 50 Hz**
database id, temp info to be removed		**1603**	**1612**	**1613**
Insulation class		F	F	F
Xd (Unsaturated)	p.u	3.57	3.83	4.1
X'd (Saturated)	p.u	0.13	0.17	0.18
X"d (Saturated)	p.u	0.07	0.09	0.1
Td'	s	0.051	0.068	0.068
Td''	s	0.003	0.003	0.003
Ta	s	0.015	0.021	0.024
Heat dissipation of air cooled generator	kW	51	58	64

Notes:

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

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

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

Note 4 At ambient conditions according to ISO 15550. Lower calorific value 42 700 kJ/kg. With engine driven pumps (two cooling water + one lubricating oil pump). Tolerance 5%.

Note 5 Acc. to IEC 34.

Subject to revision without notice.

Wärtsilä Auxpac		1350W8L20 / 50 Hz	1550W9L20 / 50 Hz	1700W9L20 / 50 Hz
database id, temp info to be removed		**1614**	**1615**	**1616**
Engine speed	rpm	1000	1000	1000
Engine output	kW	1421	1632	1790
Mean effective pressure	MPa	2.42	2.47	2.71
IMO compliance		IMO Tier 2	IMO Tier 2	IMO Tier 2
Combustion air system (Note 1)				
Flow of air at 100% load	kg/s	2.89	3.35	2.45
Temperature at turbocharger intake, max	°C	45	45	45
Temperature after air cooler (TE 601)	°C	50...70	50...70	50...70
Exhaust gas system (Note 2)				
Flow at 100% load	kg/s	2.97	3.44	3.55
Flow at 85% load	kg/s	2.58	3.0	3.25
Temp. after turbocharger at 100% load (TE 517)	°C	337	323	355
Temp. after turbocharger at 85% load (TE 517)	°C	335	319	320
Backpressure, max.	kPa	5.0	5.0	5.0
Calculated exhaust diameter for 35 m/s	mm	431	458	478
Heat balance at 100% load (Note 3)				
Jacket water	kW	309	354	373
Charge air (LT-circuit)	kW	448	523	607
Lubricating oil	kW	232	260	269
Radiation, etc	kW	66	74	74
Fuel system (Note 4)				
Pressure before injection pumps (PT 101)	kPa	700±50	700±50	700±50
Pressure before injection pumps, unifuel system	kPa	1000±50	1000±50	1000±50
HFO viscosity before injection pumps	cSt	16...24	16...24	16...24
HFO viscosity before injection pumps, unifuel system	cSt	12...24	12...24	12...24
Max. HFO temperature before engine (TE 101)	°C	140	140	140
MDF viscosity, min.	cSt	1.8	1.8	1.8
Max. MDF temperature before engine (TE 101)	°C	45	45	45
Fuel consumption at 100% load	g/kWh	195.4	192.8	195.4
Fuel consumption at 85% load	g/kWh	192.5	192.7	192.5
Fuel consumption at 75% load	g/kWh	193.5	194.4	193.0
Fuel consumption at 50% load	g/kWh	202.3	203.3	200.4
Clean leak fuel quantity, HFO at 100% load	kg/h	1.2	1.3	1.5
Lubricating oil system				
Pressure before engine, nom. (PT 201)	kPa	450	450	450
Priming pressure, nom. (PT 201)	kPa	80	80	80
Temperature before bearings, nom. (TE 201)	°C	66	66	66
Temperature after engine, about	°C	78	78	78
Pump capacity (main), engine driven	m³/h	50	50	50

Wärtsilä Auxpac		1350W8L20 / 50 Hz	1550W9L20 / 50 Hz	1700W9L20 / 50 Hz
database id, temp info to be removed		**1614**	**1615**	**1616**
Priming pump capacity	m³/h	8.6	8.6	8.6
Oil volume, nom.	m³	1.31	1.58	1.58
Filter fineness, mesh size	mi-crons	25	25	25
Oil consumption at 100% load, about	g/kWh	0.5	0.5	0.5
Crankcase ventilation flow rate at full load	l/min	1040	1170	1170
Crankcase ventilation backpressure, max.	kPa	0.4	0.4	0.4
High temperature cooling water system				
Pressure at engine, after pump, nom. (PT 401)	kPa	200 + static	200 + static	200 + static
Pressure at engine, after pump, max. (PT 401)	kPa	500	500	500
Temperature before cylinders, approx. (TE 401)	°C	83	83	83
Temperature after engine, nom.	°C	91	91	91
Capacity of engine driven pump, nom.	m³/h	40.0	45.0	45.0
Pressure drop over engine	kPa	90	90	90
Pressure drop in external system, max.	kPa	120	120	120
Pressure from expansion tank	kPa	70...150	70...150	70...150
Engine water volume	m³	0.13	0.14	0.14
Low temperature cooling water system				
Pressure at engine, after pump, nom. (PT 451)	kPa	200 + static	200 + static	200 + static
Pressure at engine, after pump, max. (PT 451)	kPa	500	500	500
Temperature before engine (TE 451)	°C	25...38	25...38	25...38
Capacity of engine driven pump, nom.	m³/h	48.0	54.0	54.0
Pressure drop over charge air cooler	kPa	30	30	30
Pressure drop over thermostatic valve	kPa	30	30	30
Pressure drop over oil cooler	kPa	30	30	30
Pressure drop in the external system, max.	kPa	120	120	120
Pressure from expansion tank	kPa	70...150	70...150	70...150
Starting air system				
Pressure, nom.	kPa	3000	3000	3000
Pressure, max	kPa	3000	3000	3000
Pressure, min	kPa	1800	1800	1800
Starting air consumption, start (successful)	Nm³	1.2	1.2	1.2
Generator data (Note 5)				
Generator brand		Fenxi	Fenxi	Fenxi
Frequency	Hz	50	50	50
Rated output	kVa	1688	1938	2125
Voltage	V	400	400	400
Rated current	A	2436	2797	3067
Power factor		0.8	0.8	0.8
CT/Ratio		3000/5 5P10, 20 VA	4000/5 5P10, 20 VA	4000/5 5P10, 20 VA
Temperature rise		F	F	F

Wärtsilä Auxpac		1350W8L20 / 50 Hz	1550W9L20 / 50 Hz	1700W9L20 / 50 Hz
database id, temp info to be removed		**1614**	**1615**	**1616**
Insulation class		F	F	F
Xd (Unsaturated)	p.u	4.39	3.15	3.03
X'd (Saturated)	p.u	0.17	0.19	0.19
X"d (Saturated)	p.u	0.08	0.13	0.12
Td'	s	0.066	0.3541	0.36
Td''	s	0.003	0.0443	0.045
Ta	s	0.02	0.06	0.05
Heat dissipation of air cooled generator	kW	73	78	82

Notes:

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

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

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

Note 4 At ambient conditions according to ISO 15550. Lower calorific value 42 700 kJ/kg. With engine driven pumps (two cooling water + one lubricating oil pump). Tolerance 5%.

Note 5 Acc. to IEC 34.

Subject to revision without notice.

4. Description of the Auxpac Generating Set

4.1 Engine main components

The engine is designed to fulfil the requirements of the classification societies, SOLAS, and IMO.

4.1.1 Engine block

The engine block is an one piece nodular cast iron component with integrated oil and water channels for WA16 and WA20. The engine block is of stiff and durable design to absorb internal forces.

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

4.1.2 Crankshaft

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

4.1.3 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.

W20 engines have a diagonally split connecting rod which allows for pulling the connecting rod through the cylinder liner.

4.1.4 Main bearings and big end bearings

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

4.1.5 Cylinder liner

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

4.1.6 Piston

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

4.1.7 Piston rings

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

4.1.8 Cylinder head

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

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

All valves are equipped with valve rotators.

4.1.9 Camshaft and valve mechanism

There is one cam piece for each cylinder with separate bearing pieces in between. The drop forged completely hardened camshaft pieces have fixed cams. The camshaft bearing housings are integrated in the engine block casting and are thus completely closed. The camshaft covers, one for each cylinder, seal against the engine block with a closed O-ring profile.

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

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

4.1.10 Camshaft drive

The camshaft is driven by the crankshaft through a gear train.

4.1.11 Fuel injection equipment

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

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

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

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

4.1.12 Turbo charging and charge air cooling

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

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

4.1.13 Charge air wastegate

The charge air wastegate is used to reduce the charge air pressure by bleeding air from the charge air system. The air is blown out into the engine room.

4.1.14 Exhaust pipes

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

4.2 Common base frame

The common base frame is a welded steel frame on which the engine and generator are fixed. The common base frame is resiliently mounted to the ship's foundation.

4.3 Generator

Auxpac generating sets are equipped with brushless synchronous generators of marine type. The generators are available as air cooled (standard) with a protection degree of IP 23, or as water cooled with a protection degree of IP 44. The generators have built-in automatic voltage regulators.

The generators are designed and manufactured with a temperature rise of class F and a isolation level of class F or H. See chapter "*Technical Data*" for details.

4.4 Overhaul intervals and expected component lifetimes

Presented overhaul intervals and lifetimes are for guidance only. Actual figures depend on service conditions.

HFO1 fuel allows for longer overhaul intervals than HFO2, for relevant components. The tables are based on HFO2 specification. Contact Wärtsilä for details.

Table 4-1 Time between overhauls and expected component lifetimes, WA16

Component	HFO	MDF	HFO	MDF
	Time between overhauls (h)		Expected comp. lifetimes (h)	
Piston	12000	24000	48000	72000
Piston rings			12000	24000
Cylinder liner	12000	24000	36000	72000
Cylinder head	12000	24000		
Inlet valve	12000	24000	36000	48000
Exhaust valve	12000	24000	24000	24000
Injection valve body	24000	24000		
Injection nozzle			6000	6000
Injection pump housing	24000	24000	100000	100000
Injection pump element			12000	24000
Main bearing			24000	36000
Turbocharger bearings	12000	12000	24000	24000
Turbocharger compressor wheel	12000	12000	48000	48000
Turbocharger turbine wheel	12000	12000	48000	48000

Table 4-2 Time between overhauls and expected component lifetimes, WA20

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

5. Fuel Oil System

5.1 Acceptable fuel characteristics

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

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

5.1.1 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 5-1 MDF specifications

Property	Unit	ISO-F-DMA	ISO-F-DMZ	ISO-F-DMB	Test method ref.
Viscosity, before injection pumps, min. 1)	cSt	WA16: 1.8 WA20: 1.8	WA16: 1.8 WA20: 1.8	WA16: 1.8 WA20: 1.8	
Viscosity, before injection pumps, max. 1)	cSt	24	24	24	
Viscosity at 40°C, min.	cSt	2	3	2	
Viscosity at 40°C, max.	cSt	6	6	11	ISO 3104
Density at 15°C, max.	kg/m³	890	890	900	ISO 3675 or 12185
Cetane index, min.		40	40	35	ISO 4264
Sulphur, max.	% mass	1.5	1.5	2	ISO 8574 or 14596
Flash point, min.	°C	60	60	60	ISO 2719
Hydrogen sulfide. max. 2)	mg/kg	2	2	2	IP 570
Acid number, max.	mg KOH/g	0.5	0.5	0.5	ASTM D664
Total sediment by hot filtration, max.	% mass	—	—	0.1 3)	ISO 10307-1
Oxidation stability, max.	g/m³	25	25	25 4)	ISO 12205
Carbon residue: micro method on the 10% volume distillation residue max.	% mass	0.30	0.30	—	ISO 10370
Carbon residue: micro method, max.	% mass	—	—	0.30	ISO 10370
Pour point (upper) , winter quality, max. 5)	°C	-6	-6	0	ISO 3016

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

Remarks:

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

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

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

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

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

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

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

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

5.1.2 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 5-2 HFO specifications

Property	Unit	Limit HFO 1	Limit HFO 2	Test method ref.
Viscosity, before injection pumps 1)	cSt	WA16: 16...24 WA20: 16...24	WA16: 16...24 WA20: 16...24	
Viscosity at 50°C, max.	cSt	700	700	ISO 3104
Density at 15°C, max.	kg/m³	991 / 1010 2)	991 / 1010 2)	ISO 3675 or 12185
CCAI, max.3)		850	870	ISO 8217, Annex F
Sulphur, max. 4) 5)	% mass	Statutory requirements		ISO 8754 or 14596
Flash point, min.	°C	60	60	ISO 2719
Hydrogen sulfide, max. 6)	mg/kg	2	2	IP 570
Acid number, max.	mg KOH/g	2.5	2.5	ASTM D664
Total sediment aged, max.	% mass	0.1	0.1	ISO 10307-2
Carbon residue, micro method, max.	% mass	15	20	ISO 10370
Asphaltenes, max.1)	% mass	8	14	ASTM D 3279
Pour point (upper), max. 7)	°C	30	30	ISO 3016
Water, max.	% volume	0.5	0.5	ISO 3733 or ASTM D6304-C 1)
Water before engine, max.1)	% volume	0.3	0.3	ISO 3733 or ASTM D6304-C 1)
Ash, max.	% mass	0.05	0.15	ISO 6245 or LP1001 1)
Vanadium, max. 5)	mg/kg	100	450	ISO 14597 or IP 501 or IP 470
Sodium, max. 5)	mg/kg	50	100	IP 501 or IP 470
Sodium before engine, max.1) 5)	mg/kg	30	30	IP 501 or IP 470
Aluminium + Silicon, max.	mg/kg	30	60	ISO 10478 or IP 501 or IP 470
Aluminium + Silicon before engine, max.1)	mg/kg	15	15	ISO 10478 or IP 501 or IP 470
Used lubricating oil, calcium, max. 8)	mg/kg	30	30	IP 501 or IP 470
Used lubricating oil, zinc, max. 8)	mg/kg	15	15	IP 501 or IP 470
Used lubricating oil, phosphorus, max. 8)	mg/kg	15	15	IP 501 or IP 500

Remarks:

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

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

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

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

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

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

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

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

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

5.2 Internal fuel system

5.2.1 Internal fuel oil system, WA16

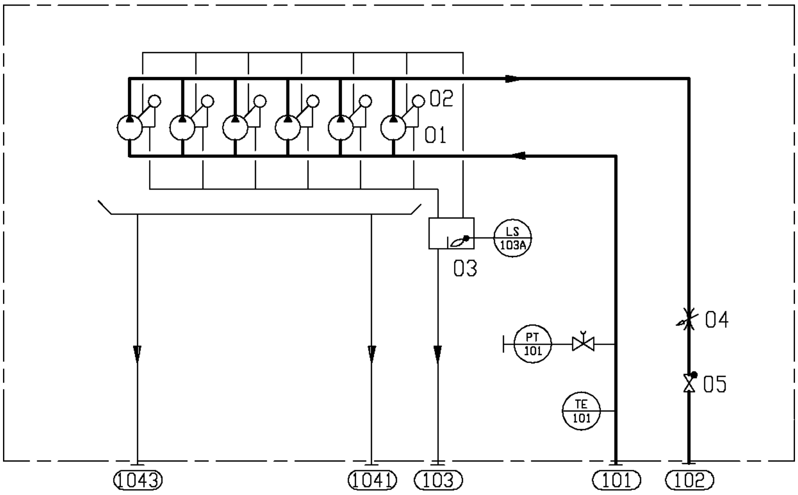


Fig 5-1 Internal fuel oil system, WA16 (DAAF062359A)

System components:			
01	Injection pump	04	Adjustable throttle valve
02	Injection valve	05	Non-return valve
03	Level alarm for leak fuel oil		

Sensors and indicators:	
PT101	Fuel oil inlet pressure
TE101	Fuel oil inlet temperature
LS103A	Fuel oil leakage, injection pipe

Pipe connections:		Size
101	Fuel inlet	OD18
102	Fuel outlet	OD18
103	Leak fuel drain, clean fuel	OD18
1041	Leak fuel drain, dirty fuel	OD12
1043	Leak fuel drain, dirty fuel	OD12

5.2.2 Internal fuel oil system, WA20

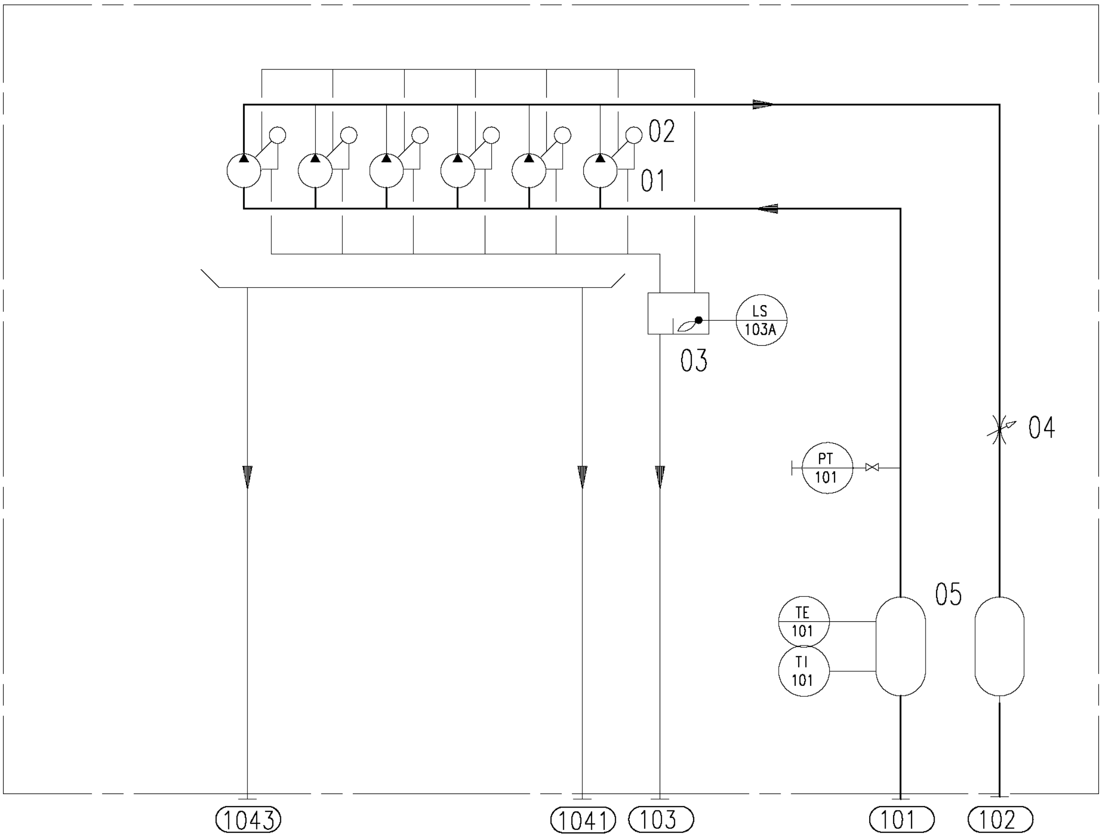


Fig 5-2 Internal fuel oil system, WA20 (DAAE010153D)

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

Sensors and indicators:	
PT101	Fuel oil inlet pressure
TE101	Fuel oil temperature, engine inlet
TI101	Fuel oil temperature, engine inlet
LS103A	Fuel oil leakage, injection pipe

Pipe connections:		Size	Standard
101	Fuel inlet	OD18	DIN 2353
102	Fuel outlet	OD18	DIN 2353
103	Leak fuel drain, clean fuel	OD18	DIN 2353
1041	Leak fuel drain, dirty fuel	OD18	DIN 2353
1043	Leak fuel drain, dirty fuel	OD18	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.

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

5.2.3 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.

5.3 External fuel system

5.3.1 External fuel oil system (MDF), WA16

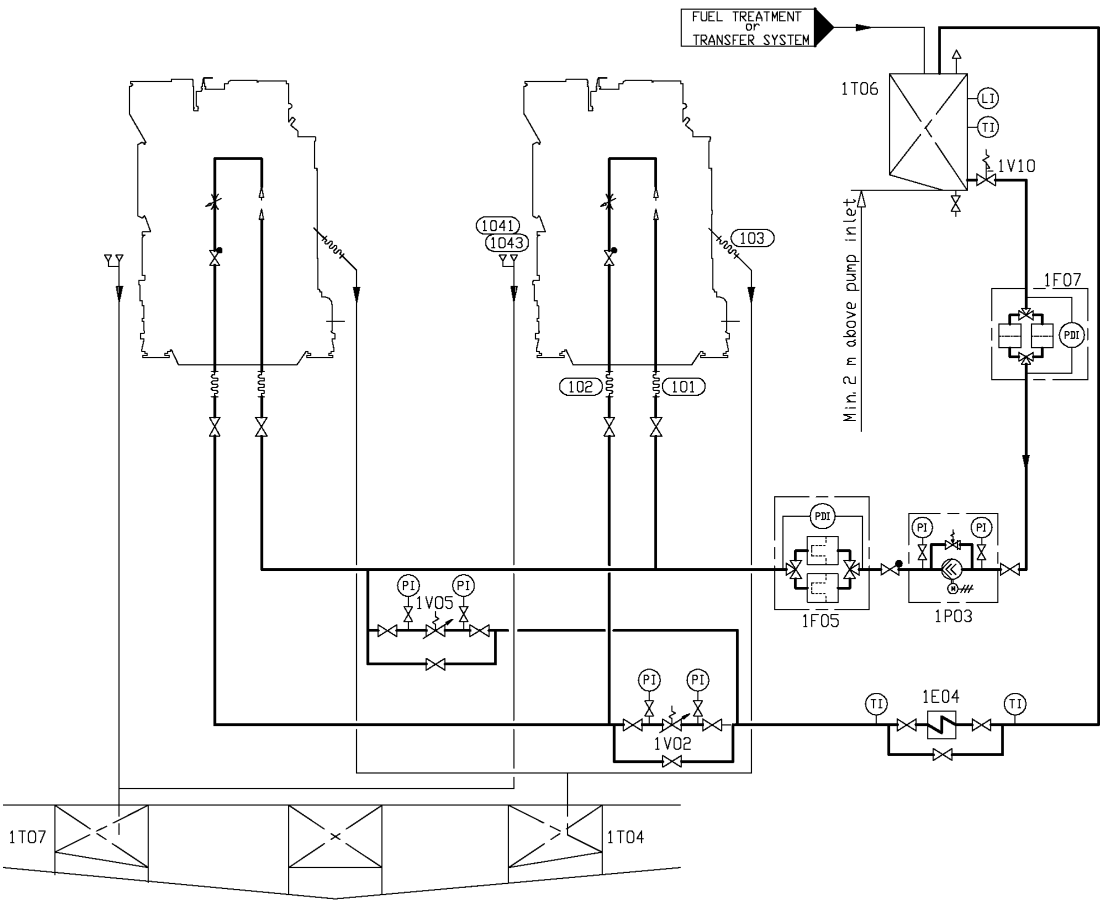


Fig 5-3 **External fuel oil system (MDF), WA16 (DAAF062360A)**

Pos	Part	Pos	Part
1E04	Cooler (MDF)	1T06	Day tank (MDF)
1F05	Fine filter (MDF)	1T07	Leak fuel tank (Dirty fuel)

Pos	Part	Pos	Part
1F07	Suction strainer (MDF)	1V02	Pressure control valve (MDF)
1P03	Circulation pump (MDF)	1V05	Overflow valve (MDF)
1T04	Leak fuel tank (Clean fuel)	1V10	Quick closing valve (FO tank)

Pipe connections:		Size
101	Fuel inlet	OD18
102	Fuel outlet	OD18
103	Leak fuel drain, clean fuel	OD18
1041	Leak fuel drain, dirty fuel	OD12
1043	Leak fuel drain, dirty fuel	OD12

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.

5.3.2 Fuel heating requirements HFO

Heating is required for:

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

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

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

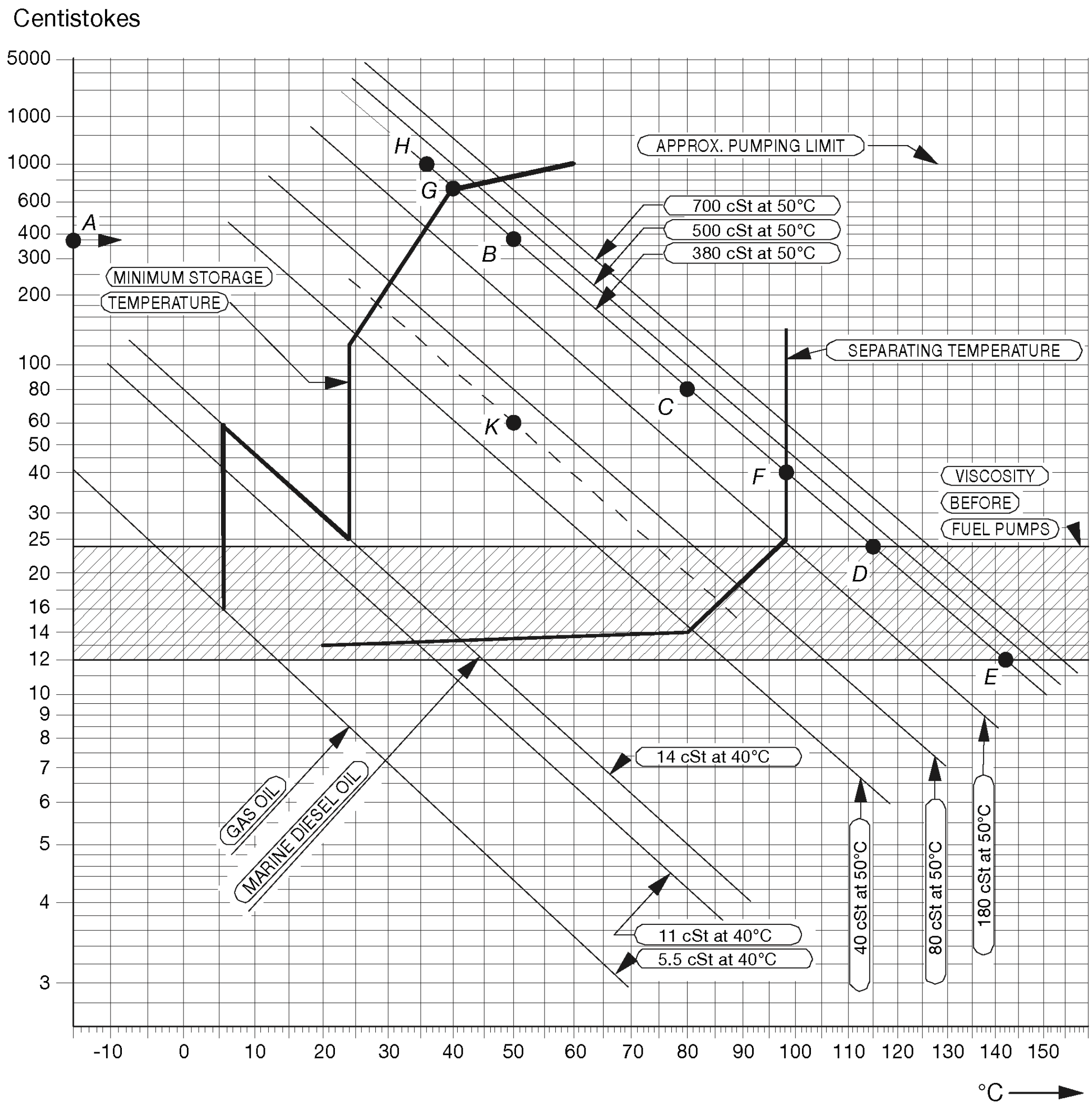


Fig 5-4 **Fuel oil viscosity-temperature diagram for determining the pre-heating temperatures of fuel oils (DAAE016379a)**

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 preheated to 115-150°C (D-E) before the fuel injection pumps, to 98°C (F) at the centrifuge and to minimum 40°C (G) in the storage tanks. The fuel oil may not be pumpable below 36°C (H).

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

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

5.3.3 Fuel tanks

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

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

Separate settling tanks for HFO and MDF are recommended.

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

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

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

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

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

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

Settling tanks may not be used instead of day tanks.

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.

5.3.3.3 Leak fuel tank, clean fuel (1T04)

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

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

5.3.3.4 Leak fuel tank, dirty fuel (1T07)

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

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

5.3.4 Fuel treatment

5.3.4.1 Separation

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

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

All recommendations from the separator manufacturer must be closely followed.

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

Separator mode of operation

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

Separators with monitoring of cleaned fuel (without gravity disc) operating on a continuous basis can handle fuels with densities exceeding 991 kg/m3 at 15°C. In this case the main and stand-by separators should be run in parallel.

When separators with gravity disc are used, then each stand-by separator should be operated in series with another separator, so that the first separator acts as a purifier and the second as clarifier. This arrangement can be used for fuels with a density of max. 991 kg/m3 at 15°C. The separators must be of the same size.

Separation efficiency

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

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

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

where:

n = separation efficiency [%]

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

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

5.3.4.2 Separator unit (1N02/1N05)

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

Typically separator modules are equipped with:

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

- Sludge pump
- Control cabinets including motor starters and monitoring

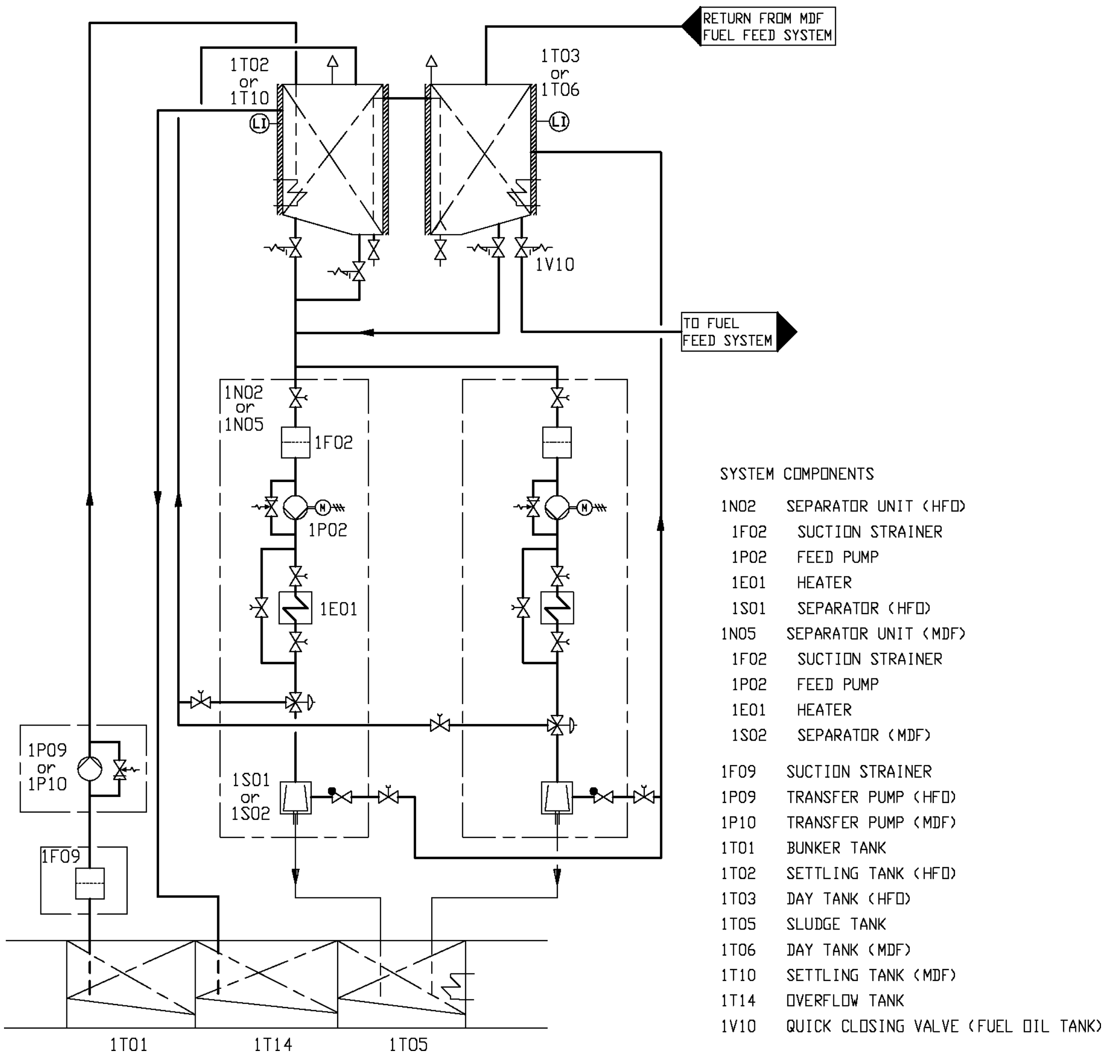


Fig 5-5 **Fuel transfer and separating system (V76F6626F)**

5.3.4.3 Separator feed pumps (1P02)

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

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

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

5.3.4.4 Separator pre-heater (1E01)

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

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

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

The required minimum capacity of the heater is:

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

where:

P = heater capacity [kW]

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

ΔT = temperature rise in heater [°C]

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

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

5.3.4.5 Separator (1S01/1S02)

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

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

where:

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

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

ρ = density of the fuel [kg/m^3]

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

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

Sample valves must be placed before and after the separator.

5.3.4.6 MDF separator in HFO installations (1S02)

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

5.3.4.7 Sludge tank (1T05)

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

5.3.5 Fuel feed system – HFO installation

5.3.5.1 External fuel system, WA16 with two gensets

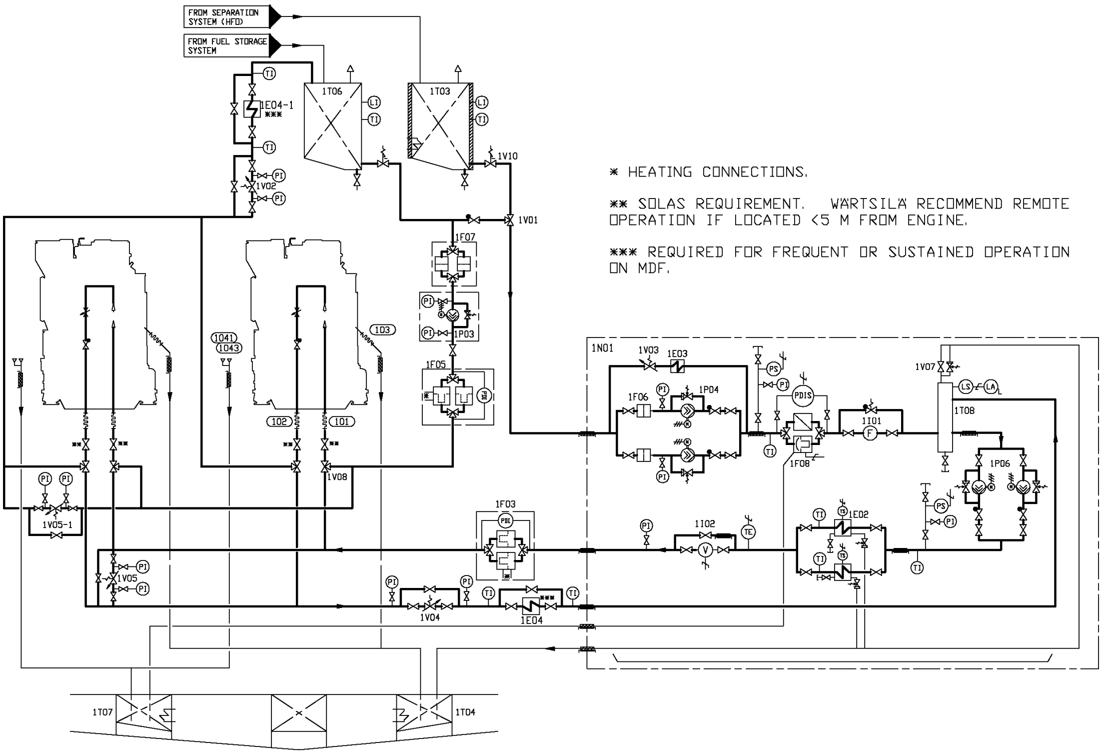


Fig 5-6 External fuel system, WA16, two gensets (DAAF062361A)

System components:			
1E02	Heater (booster unit)	1T03	Day tank (HFO)
1E03	Cooler (booster unit)	1T04	Leak fuel tank (clean fuel)
IE04	Cooler (HFO)	1T06	Day tank (MDF)
IE04-1	Cooler (MDF)	1T07	Leak fuel tank (dirty fuel)
1F03	Safety filter (HFO)	1T08	De-aeration tank (booster unit)
1F05	Fine filter (MDF)	1V01	Change-over valve
1F06	Suction filter (booster unit)	1V02	Pressure control valve (MDF)
1F07	Suction strainer (MDF)	1V03	Pressure control valve (booster unit)
1F08	Automatic filter (booster unit)	1V04	Pressure control valve (HFO)
1I01	Flowmeter (booster unit)	1V05	Overflow valve (HFO/MDF)
1I02	Viscosimeter (booster unit)	1V05-1	Overflow valve (HFO/MDF)
1N01	Feeder / Booster unit	1V07	Venting valve (booster unit)
1P03	Circulation pump (MDF)	1V08	Change-over valve
1P04	Fuel feed pump (booster unit)	1V10	Quick closing valve (Fuel oil tank)
1P06	Day tank (MDF)		

Pipe connections		Size	Pipe connections		Size
101	Fuel inlet	OD18	1041	Leak fuel drain, dirty fuel	OD12
102	Fuel outlet	OD18	1043	Leak fuel drain, dirty fuel	OD12
103	Leak fuel drain, clean fuel	OD18			

5.3.5.2 External fuel system WA20 with HFO and two gensets

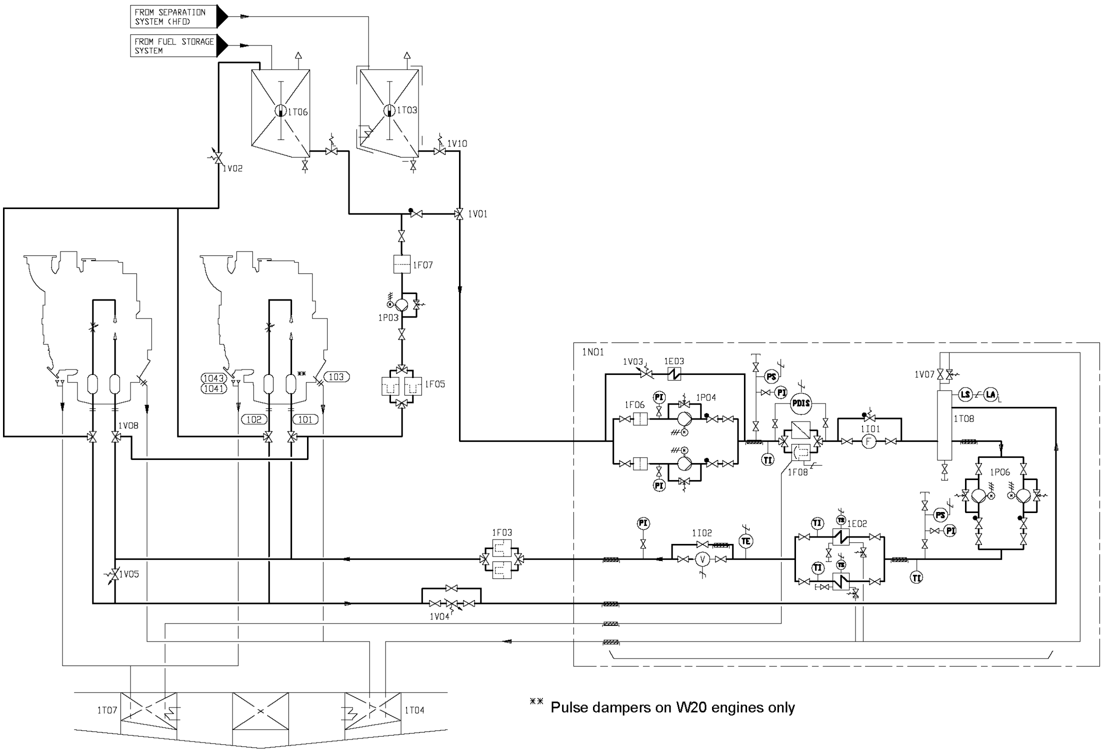


Fig 5-7 External fuel system, HFO, two gensets (DAAE003609d)

System components:			
1E02	Heater (booster unit)	1T03	Day tank (HFO)
1E03	Cooler (booster unit)	1T04	Leak fuel tank (clean fuel)
1F03	Safety filter (HFO)	1T06	Day tank (MDF)
1F05	Fine filter (MDF)	1T07	Leak fuel tank (dirty fuel)
1F06	Suction filter (booster unit)	1T08	De-aeration tank (booster unit)
1F07	Suction strainer (MDF)	1V01	Change-over valve
1F08	Automatic filter (booster unit)	1V02	Pressure control valve (MDF)
1I01	Flowmeter (booster unit)	1V03	Pressure control valve (booster unit)
1I02	Viscosimeter (booster unit)	1V04	Pressure control valve (HFO)
1N01	Feeder / Booster unit	1V05	Overflow valve (HFO)
1P03	Circulation pump (MDF)	1V07	Venting valve (booster unit)
1P04	Fuel feed pump (booster unit)	1V08	Change-over valve
1P06	Day tank (MDF)		

Pipe connections			
101	Fuel inlet	1041	Leak fuel drain, dirty fuel, free end
102	Fuel outlet	1043	Leak fuel drain, dirty fuel, fw end
103	Leak fuel drain, clean fuel		

5.3.5.3 Unifuel system, main and auxiliary engines

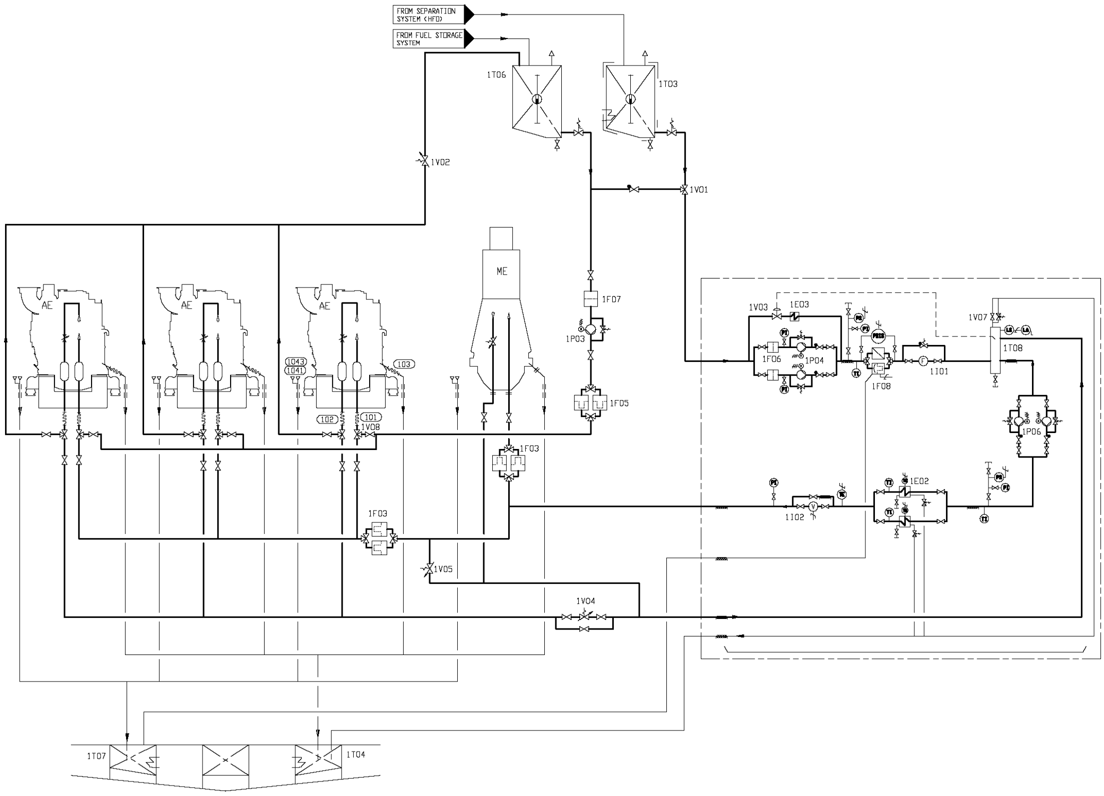


Fig 5-8 Unifuel system, main and auxiliary engines (DAAE006120f)

System components		Pipe connections	
1E02	Heater (booster unit)	101	Fuel inlet
1E03	Cooler (booster unit)	102	Fuel outlet
1F03	Safety filter (HFO)	103	Leak fuel drain, clean fuel
1F05	Fine filter (MDF)	1041	Leak fuel drain, dirty fuel, free end
1F06	Suction filter (booster unit)	1043	Leak fuel drain, dirty fuel, fw end
1F07	Suction strainer (MDF)		
1F08	Automatic filter (booster unit)		
1I01	Flow meter (booster unit)		
1I02	Viscosity meter (booster unit)		
1P03	Circulation pump (MDF)		
1P04	Fuel feed pump (booster unit)		
1P06	Circulation pump (booster unit)		
1T03	Day tank (HFO)		
1T04	Leak fuel tank (clean fuel)		
1T06	Day tank (MDF)		
1T07	Leak fuel tank (dirty fuel)		
1T08	De-aeration tank (booster unit)		
1V01	Change-over valve		
1V02	Pressure control valve (MDF)		
1V03	Pressure control valve (booster unit)		
1V04	Pressure control valve (HFO)		
1V05	Overflow valve (HFO)		
1V07	Venting valve (booster unit)		
1V08	Change-over valve		

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).

5.3.5.4 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.

5.3.5.5 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*.

5.3.5.6 Number of engines in the same system

It is recommended that separate fuel feed systems are installed for main engine and generating sets. Thus problems with flow distribution, temperature or pressure control related to large variations in fuel consumption depending on whether the main engine is running or not can be avoided.

If anyhow a common fuel feed system is required for a 2-stroke main engine and the auxpac generating sets, the fuel system can be designed as a unifuel system. Unifuel means that the fuel to the auxpac generating sets and the 2-stroke main engine is fed by a common fuel feed system. This requires that a higher pressure before injection pumps is accepted, see *Technical data*.

When the fuel feed unit serves auxpac generating sets only, maximum three auxpac generating sets should be connected to the same fuel feed circuit. In a unifuel system maximum one main engine and three auxpac generating sets should be connected to the same fuel feed circuit.

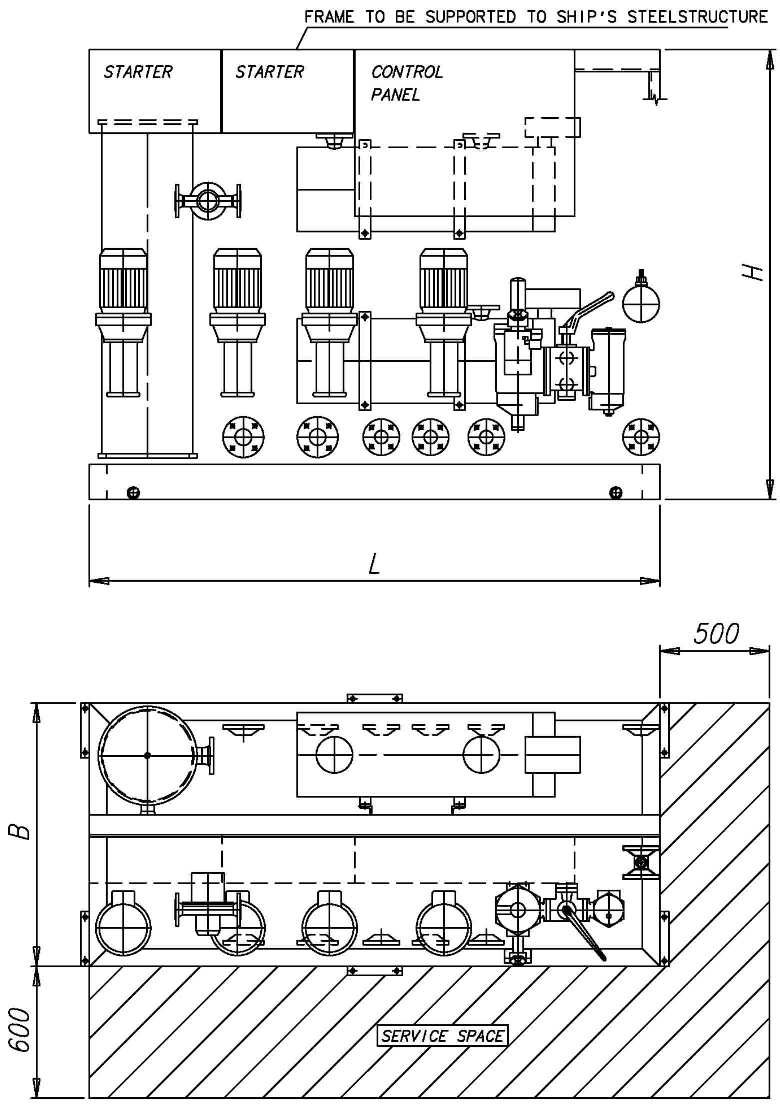
5.3.5.7 Feeder/booster unit (1N01)

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 temperature sensor for emergency control of the heaters

- One control cabinet including starters for pumps
- One alarm panel

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



	H	L	B
STEAM	1800	2500	1100
ELECTRICAL	2050	2600	1200

All dimensions in mm.

Fig 5-9 Feeder/booster unit, example (DAAE006659)

Fuel feed pump, booster unit (1P04)

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

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

Design data:

Capacity	Total consumption of the connected engines added with the flush quantity of the automatic filter (1F08) and 15% margin.
Design pressure	1.6 MPa (16 bar)

Max. total pressure (safety valve)	0.7 MPa (7 bar)
Design temperature	100°C
Viscosity for dimensioning of electric motor	1000 cSt

Pressure control valve, booster unit (1V03)

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

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

Automatic filter, booster unit (1F08)

It is recommended to 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.

Design data:

Capacity	W20 engines: 5 x the total consumption of the connected engines W26 engines: 6 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)
Max. total pressure (safety valve) unifuel installations	1.2 MPa (12 bar)
Design temperature	150°C
Viscosity for dimensioning of electric motor	500 cSt

Heater, booster unit (1E02)

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

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

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

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

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

where:

P = heater capacity (kW)

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

ΔT = temperature rise in heater [°C]

Viscosimeter, booster unit (1I02)

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

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

5.3.5.8 Safety filter (1F03)

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

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

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

5.3.5.9 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)	Auxpac gensets: 0.1...0.2 MPa (1...2 bar) Unifuel system: 0.2...0.7 MPa (2...7 bar)

5.3.5.10 Pressure control valve (1V04)

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

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

5.3.6 Fuel feed system – MDF installation

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.

5.3.6.1 Circulation pump, MDF (1P03)

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

Design data:

Capacity	W20 engines: 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

5.3.6.2 Fine filter, MDF (1F05)

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

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

Design data:

Fuel viscosity	according to fuel specifications
Design temperature	50°C
Design flow	Larger than feed/circulation pump capacity
Design pressure	1.6 MPa (16 bar)
Fineness	25 µm (absolute mesh size)

Maximum permitted pressure drops at 14 cSt:

- clean filter	20 kPa (0.2 bar)

- alarm	80 kPa (0.8 bar)

5.3.6.3 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)

5.3.6.4 MDF cooler (1E04)

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

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

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

Design data:	
Heat to be dissipated	WA20: 1 kW/cyl
Max. pressure drop, fuel oil	80 kPa (0.8 bar)
Max. pressure drop, water	60 kPa (0.6 bar)
Margin (heat rate, fouling)	min. 15%
Design temperature MDF/HFO installation	50/150°C

5.3.6.5 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

5.3.7 Flushing

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

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

6. Lubricating Oil System

6.1 Lubricating oil requirements

6.1.1 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 6-1 Fuel standards and lubricating oil requirements

Category	Fuel standard		Lubricating oil BN
A	ASTM D 975-01, BS MA 100: 1996 CIMAC 2003 ISO8217: 2012(E)	GRADE NO. 1-D, 2-D, 4-D DMX, DMA, DMB DX, DA, DB ISO-F-DMX, DMB	10...30
B	ASTM D 975-01 BS MA 100: 1996 CIMAC 2003 ISO 8217: 2012(E)	GRADE NO. 1-D, 2-D, 4-D DMX, DMA, DMB DX, DA, DB ISO-F-DMX - DMB	15...30
C	ASTM D 975-01, ASTM D 396-04, BS MA 100: 1996 CIMAC 2003 ISO 8217: 2012(E)	GRADE NO. 4-D GRADE NO. 5-6 DMC, RMA10-RMK55 DC, A30-K700 RMA10-RMK 700	30...55

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

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 validated by Wärtsilä, if the engine still under warranty.

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

6.2 Internal lubricating oil system

6.2.1 Internal lubricating oil system, WA16

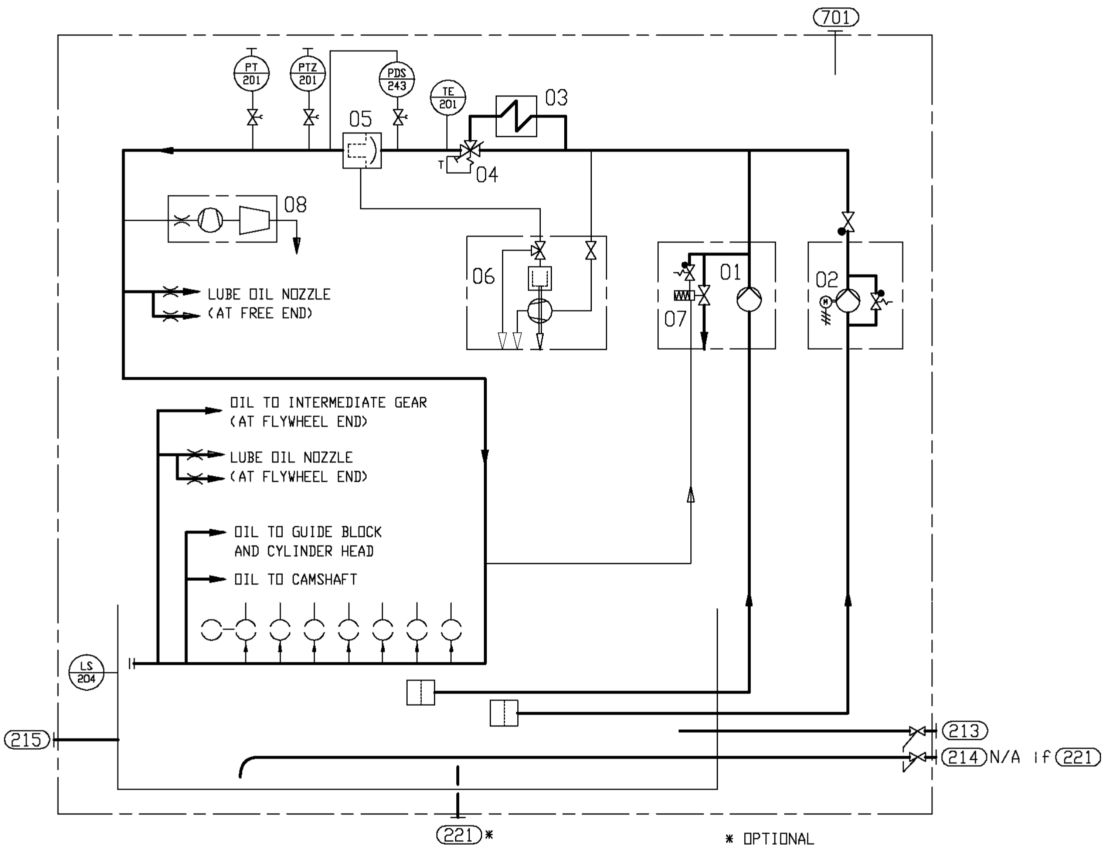


Fig 6-1 Internal lubricating oil system, WA16 (DAAF062362A)

System components:					
01	Lubricating oil main pump	04	Thermostatic valve	07	Pressure control valve
02	Prelubricating oil pump	05	Automatic filter	08	Turbocharger
03	Lubricating oil cooler	06	Centrifugal filter		

Sensors and indicators:			
PT201	Lube oil pressure, engine inlet	TE201	Lube oil temperature, engine inlet
PTZ201	Lube oil pressure, engine inlet	LS204	Lube oil low level, wet sump
PDS243	Lubricating oil filter difference pressure		

Pipe connections		Size
213	Lubricating oil from separator and filling	DN32
214	Lubricating oil to separator and drain	DN32
215	Lubricating oil filling	M52*1.5
221	Lubricating oil overflow (Replaced conn 214 if used)	DN32
701	Crankcase air vent	DN65

6.2.2 Internal lubricating oil system, WA20

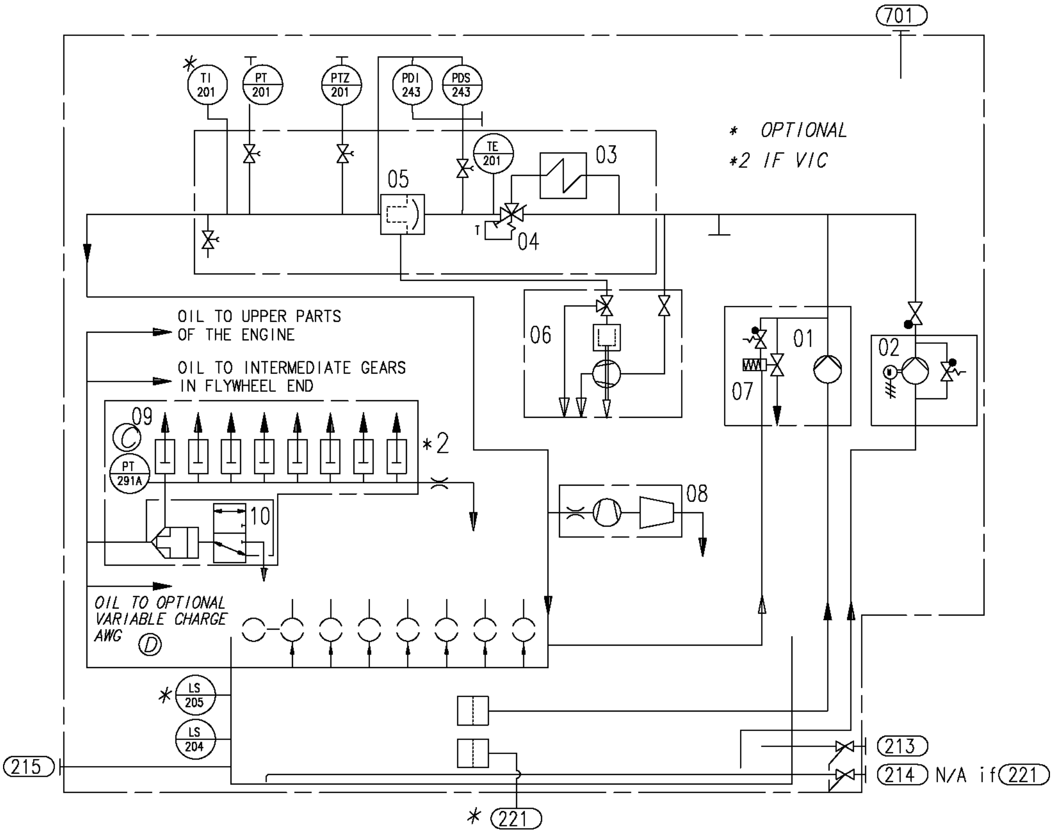


Fig 6-2 **Internal lubricating oil system, WA20 (DAAE010160D)**

System components:					
01	Lubricating oil main pump	04	Thermostatic valve	07	Pressure control valve
02	Prelubricating oil pump	05	Automatic filter	08	Turbocharger
03	Lubricating oil cooler	06	Centrifugal filter	09	Guide block (*2)
				10	Control valve (*2)

Sensors and indicators:			
PT201	Lubricating oil pressure before bearings	TE201	Lube oil temp. before bearings
PTZ201	Low lubricating oil pressure, back-up	TI201	Lube oil temp. before bearings (*)
PDI243	Lubricating oil filter difference pressure	LS204	Lubricating oil low level, oil sump
PDS243	Lubricating oil filter difference pressure	LS205	Lubricating oil high level, oil sump (*)

Pipe connections		Size
213	Lubricating oil from separator and filling	DN32
214	Lubricating oil to separator and drain	DN32
215	Lubricating oil filling	M48*2
221	Lubricating oil overflow	DN65
701	Crankcase air vent	DN65

6.3 External lubricating oil system

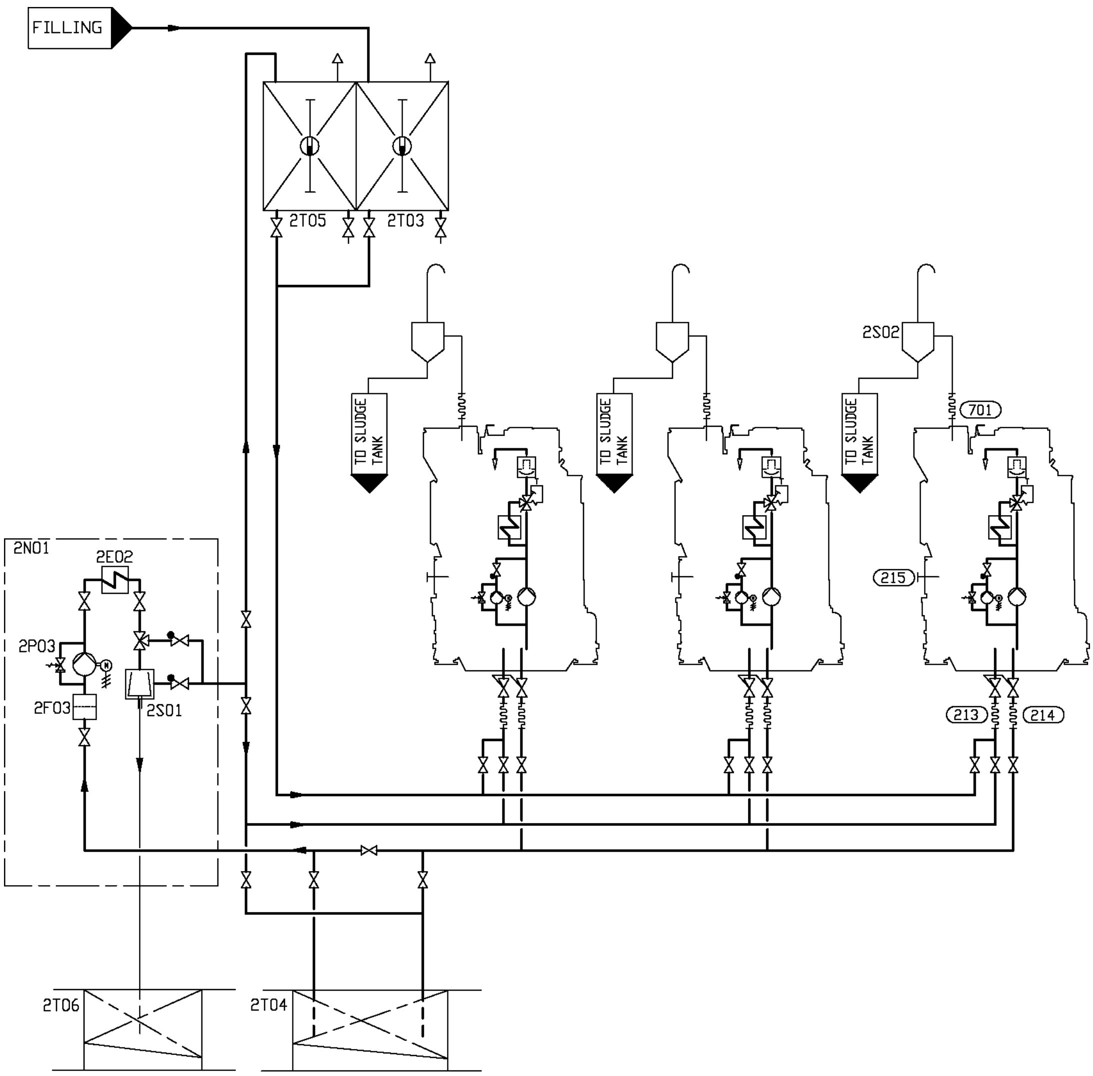


Fig 6-3 External lubricating oil system, WA16 (DAAF062363)

System components		Pipe connections		Size
2E02	Heater (Separator unit)	213	LO from separator and filling	DN32
2F03	Suction filter (Separator unit)	215	LO filling	DN32
2N01	Separator unit	221	LO overflow	M52*1.5
2P03	Separator pump (Separator unit)	701	Crankcase air vent	DN65
2S01	Separator			
2S02	Condensate trap			
2T03	New oil tank			
2T06	Sludge tank			
2T08	Used oil tank			

6.3.1 External lubricating oil system, overflow system

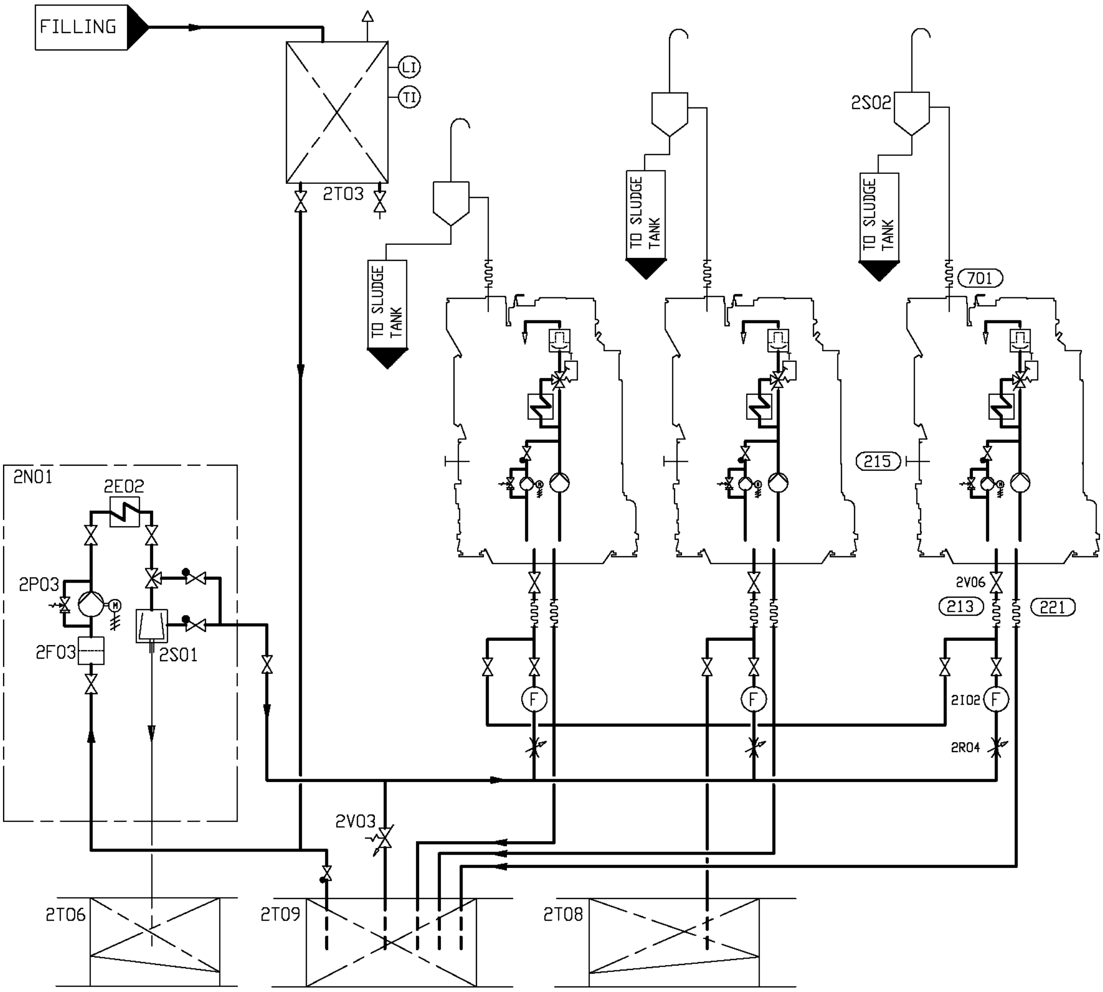


Fig 6-4 External lubricating oil system for WA16, overflow system (DAAF062364A)

System components		Pipe connections		Size
2E02	Heater (Separator unit)	213	Lubrication oil from separator and filling	DN32
2F03	Suction filter (Separator unit)	215	Lubrication oil filling	M52*1.5
2I02	Flow indicator	221	Lubrication oil overflow	DN32
2N01	Separator unit	701	Crankcase air vent	DN65
2P03	Separator pump (Separator unit)			
2R04	Orifice (adjustable)			
2S01	Separator			
2S02	Condensate trap			
2T03	New oil tank			
2T06	Sludge tank			
2T08	Used oil tank			
2T09	Overflow oil tank			
2V03	Pressure control valve			
2V06	Shut-off valve			

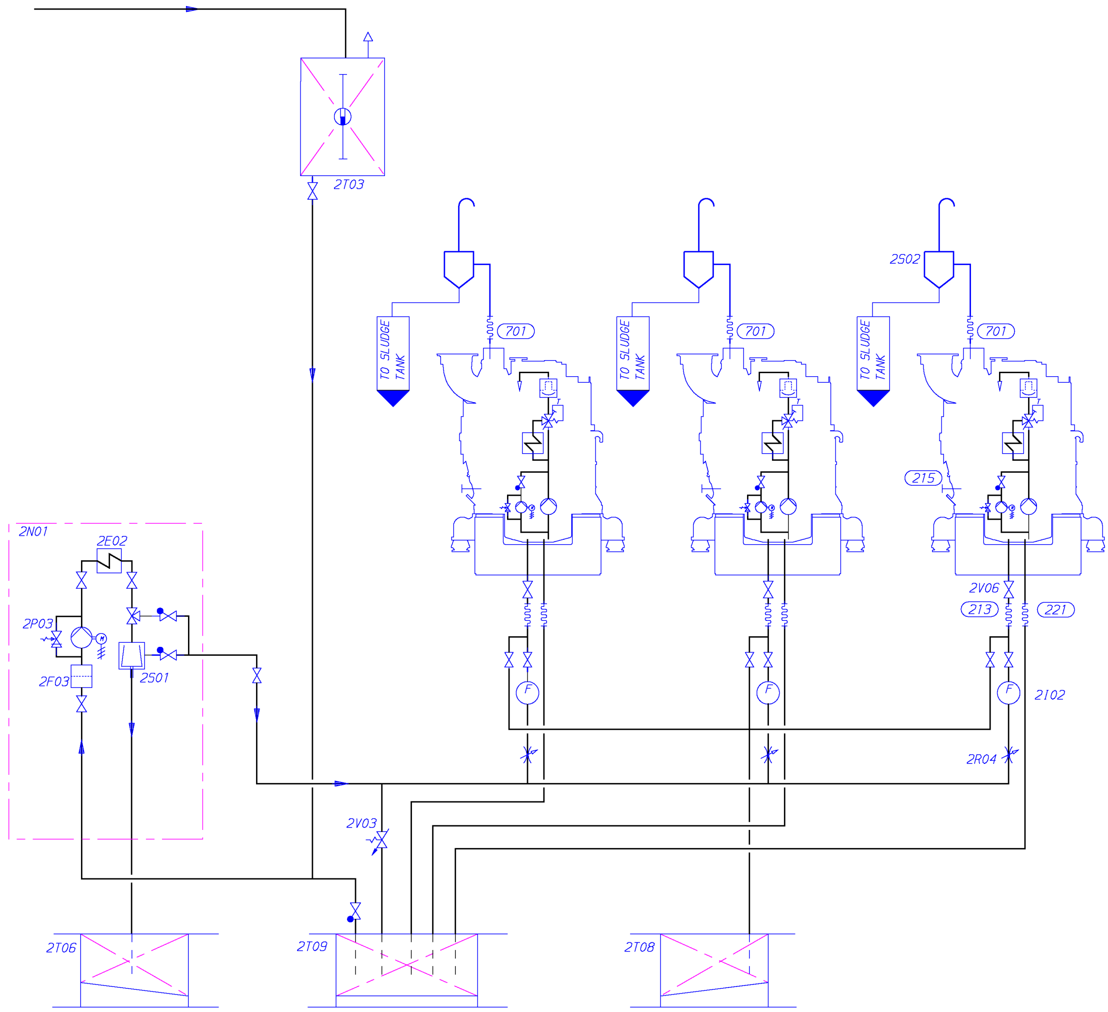


Fig 6-5 External lubricating oil system WA20, overflow system (DAAE052029)

System components		Pipe connections	
2E02	Heater (Separator unit)	213	Lubrication oil from separator and filling
2F03	Suction filter (Separator unit)	215	Lubrication oil filling
2I02	Flow indicator	221	Lubrication oil overflow
2N01	Separator unit	701	Crankcase air vent
2P03	Separator pump (Separator unit)		
2R04	Orifice (adjustable)		
2S01	Separator		
2S02	Condensate trap		
2T03	New oil tank		
2T06	Sludge tank		
2T08	Used oil tank		
2T09	Overflow oil tank		
2V03	Pressure control valve		
2V06	Shut-off valve		

6.3.2 External lubricating oil system, intermittent direct separation

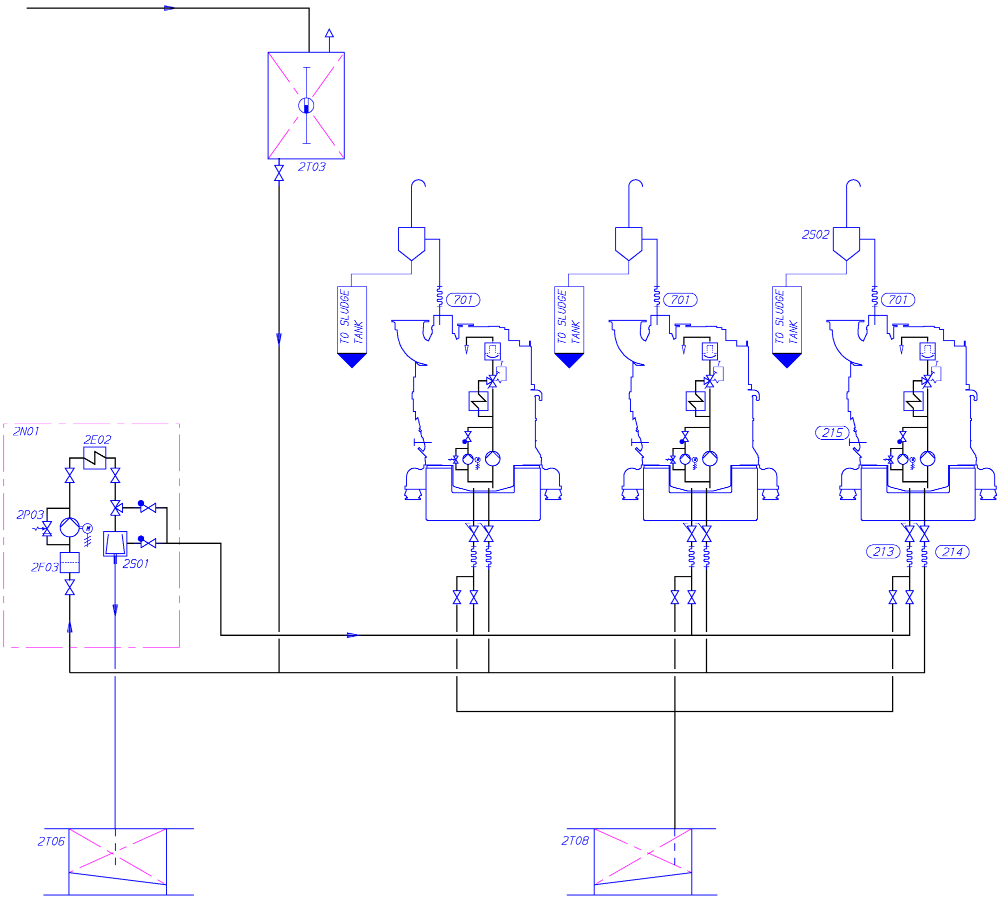


Fig 6-6 External lubricating oil system, intermittent direct separation (DAAE052030a)

System components		Pipe connections	
2E02	Heater (Separator unit)	213	Lubrication oil from separator and filling
2F03	Suction filter (Separator unit)	214	Lubrication oil to separator and drain
2N01	Separator unit	215	Lubrication oil filling
2P03	Separator pump (Separator unit)	701	Crankcase air vent
2S01	Separator		
2S02	Condensate trap		
2T03	New oil tank		
2T06	Sludge tank		
2T08	Used oil tank		

6.3.3 Separation system

6.3.3.1 Separator unit (2N01)

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

Separators are usually supplied as pre-assembled units.

Typically lubricating oil separator units are equipped with:

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

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

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 = 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.

6.3.3.2 Renovating oil tank (2T04)

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

6.3.3.3 Renovated oil tank (2T05)

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

6.3.4 New oil tank (2T03)

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

6.4 Crankcase ventilation system

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

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

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

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

The connection between engine and pipe is to be flexible.

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

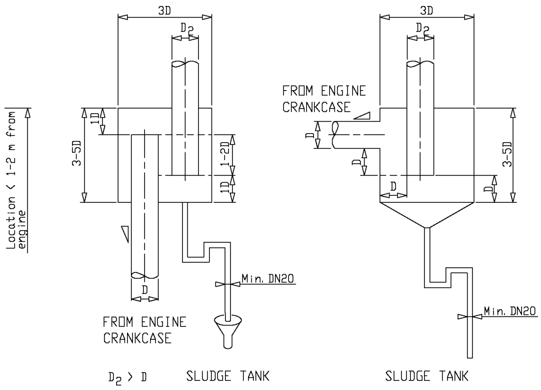


Fig 6-7 **Condensate trap (DAAE032780B)**

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

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

6.5 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).

6.5.1 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.

6.5.2 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.

6.5.3 Type of flushing oil

6.5.3.1 Viscosity

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

6.5.3.2 Flushing with engine oil

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

6.5.3.3 Flushing with low viscosity flushing oil

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

6.5.3.4 Lubricating oil sample

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

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

7. 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.

7.1 Internal starting air system

The engine is equipped with a pneumatic starting motor driving the engine through a gear rim on the flywheel. The nominal starting air pressure is 3 MPa (30 bar). For WA16 and WA20 engines the starting air pressure is reduced to proper pressure with a pressure regulator mounted on the engine.

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

To ensure correct operation of the engine the compressed air supply must not be closed during operation.

7.1.1 Internal starting air system, WA16

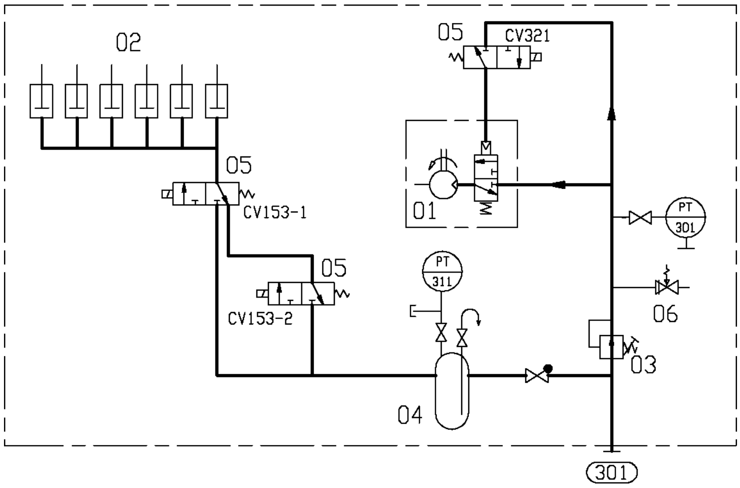


Fig 7-1 **Internal starting air system, WA16 (DAAF062365A)**

System components:					
01	Turbine starter	03	Pressure regulator	05	Solenoid valve
02	Pneumatic cylinder at each inj pump	04	Air container	06	Safety valve

Sensors and indicators:			
PT301	Starting air pressure, engine inlet	CV153-2	Stop/shutdown solenoid valve
PT311	Control air pressure	CV321	Start solenoid valve
CV153-1	Stop/shutdown solenoid valve		

Pipe connections		**Size**
301	Starting air inlet	OD28

7.1.2 Internal starting air system, WA20

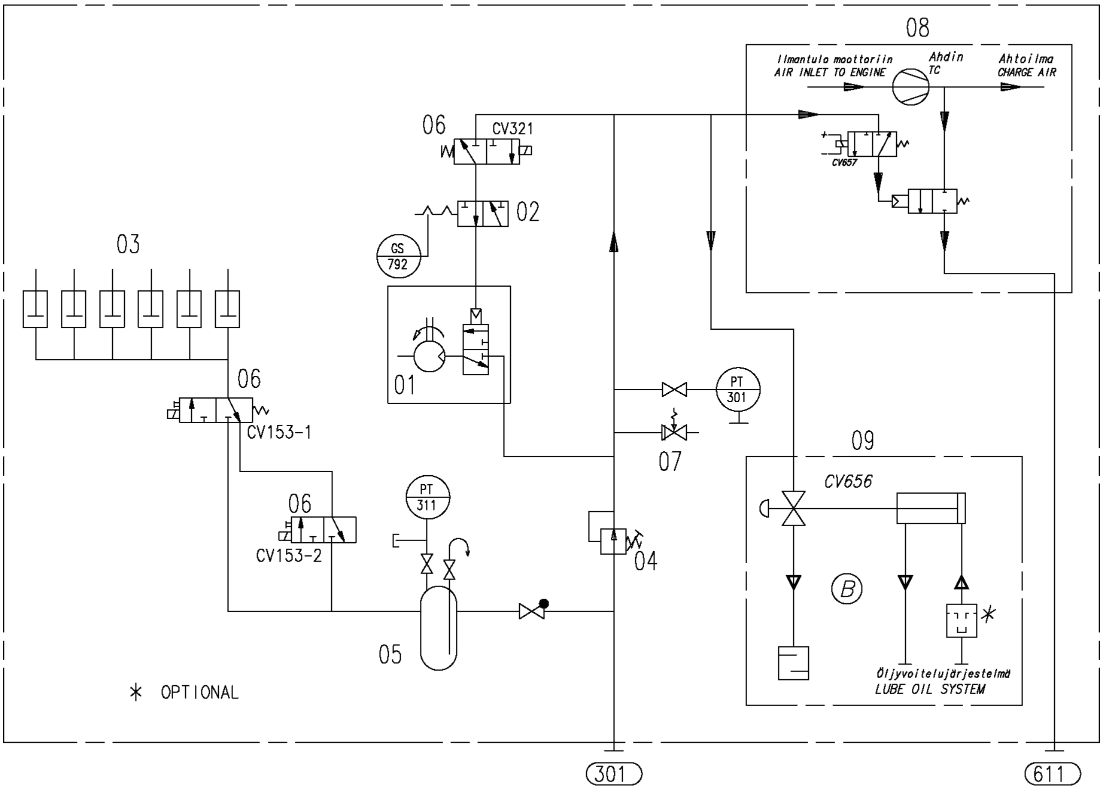


Fig 7-2 Internal starting air system, WA20 (DAAE010155B)

System components:			
01	Turbine starter	05	Air container
02	Blocking valve, turning gear engaged	06	Solenoid valve
03	Pneumatic cylinder at each injection pump	07	Safety valve
04	Pressure regulator	08	Charge air waste gate (if VIC)

Sensors and indicators:			
PT301	Starting air pressure, engine inlet	CV153-2	Stop/shutdown solenoid valve
PT311	Control air pressure	CV321	Start solenoid valve
GS792	Turning gear engaged	CV657	Charge air limiter (if VIC)
CV153-1	Stop/shutdown solenoid valve		

Pipe connections		Size
301	Starting air inlet	OD28
611	Charge air wastegate outlet (if VIC)	OD28

7.2 External starting 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.

A typical starting air system is a common system for the auxiliary engines and the main engine(s).

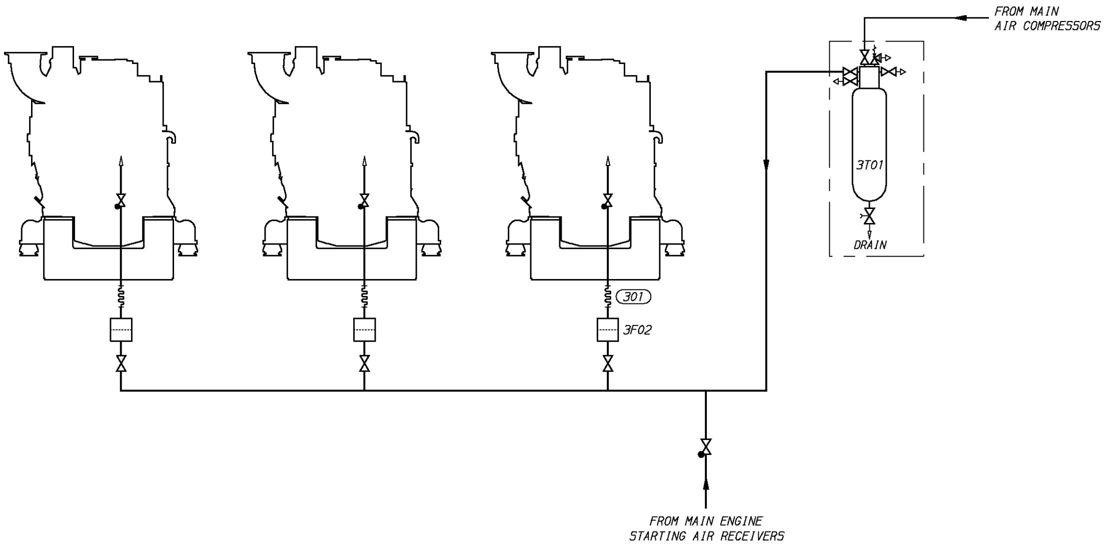


Fig 7-3 Common external starting air system (DAAE007205d)

The auxiliary engines can also have a separate starting air system.

7.2.1 Starting air compressor unit (3N02)

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

7.2.2 Oil and water separator (3S01)

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

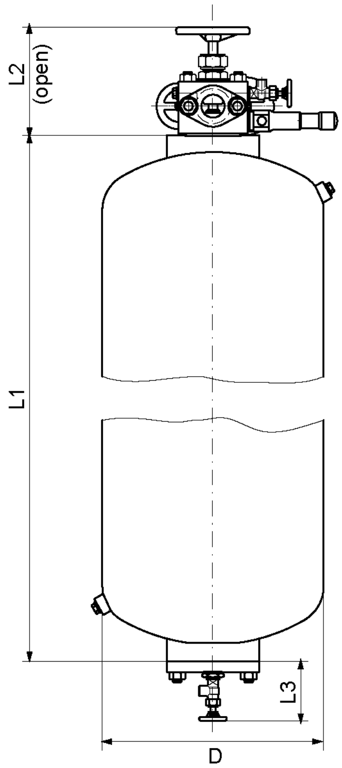
7.2.3 Starting air vessel (3T01)

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

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

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

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



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

[1] Dimensions are approximate.

Fig 7-4 Starting air vessel

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

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

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

where:

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

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

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

n = required number of starts according to the classification society

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

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

NOTE

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

7.2.4 Air filter, starting air inlet (3F02)

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

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

The starting air filter is mandatory for W20 engines.

8. Cooling Water System

8.1 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.

8.1.1 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.

8.1.2 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. 60% glycol is permitted.

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

8.2 Internal cooling water system

8.2.1 Internal cooling water system, WA16, separate HT and LT

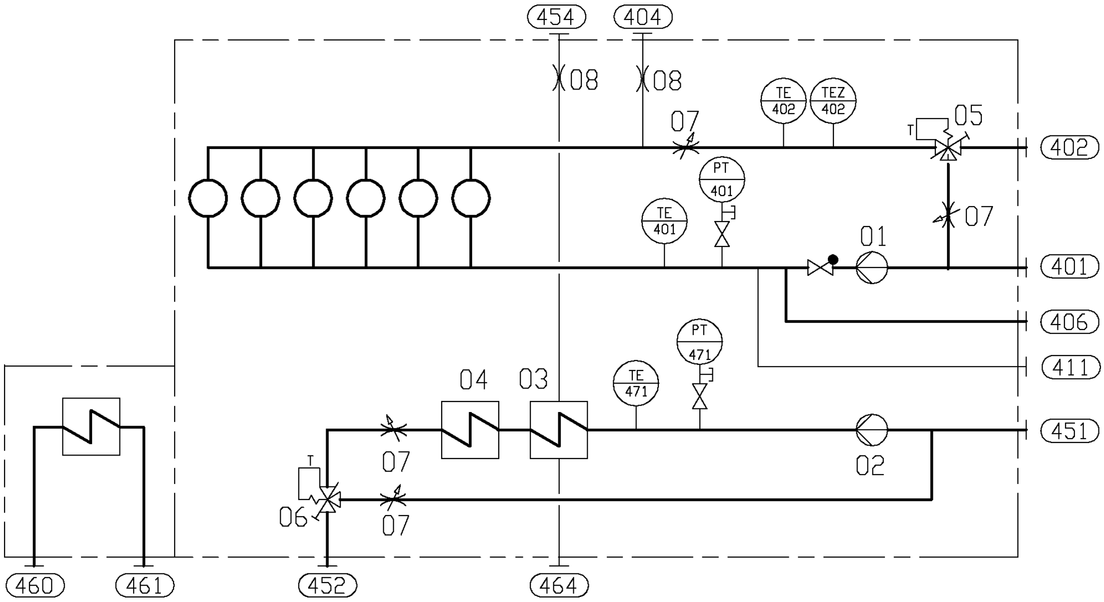


Fig 8-1 **Internal cooling water system, WA16, separate HT and LT (DAAF062367A)**

System components:					
01	HT-cooling water pump	04	Lubricating oil cooler	07	Adjustable orifice
02	LT-cooling water pump	05	HT-thermostatic valve	08	Orifice
03	Charge air cooler	06	LT-thermostatic valve		

Sensors and indicators:			
PT401	HT-water pressure before cylinder jackets	TE402	HT-water temp. after cylinder jackets
PT471	LT-water pressure before CAC	TEZ402	HT-water temp. after cylinder jackets
TE401	HT-water temp. before cylinder jackets	TE471	LT-water temp. before CAC

Pipe connections		Size
401	HT-water inlet	DN65
402	HT-water outlet	DN65
404	HT-water air vent	OD12
406	Water from preheater to HT-circuit	M33*2
411	HT-water drain	M16*1.5
451	LT-water inlet	DN65
452	LT-water outlet	DN65
454	LT water air vent from charge air cooler	OD12
460	LT-water to generator (if water cooled generator)	-
461	LT-water from generator (if water cooled generator)	-
464	LT-water drain	M16*1.5

8.2.2 Internal cooling water system, WA20, separate HT and LT

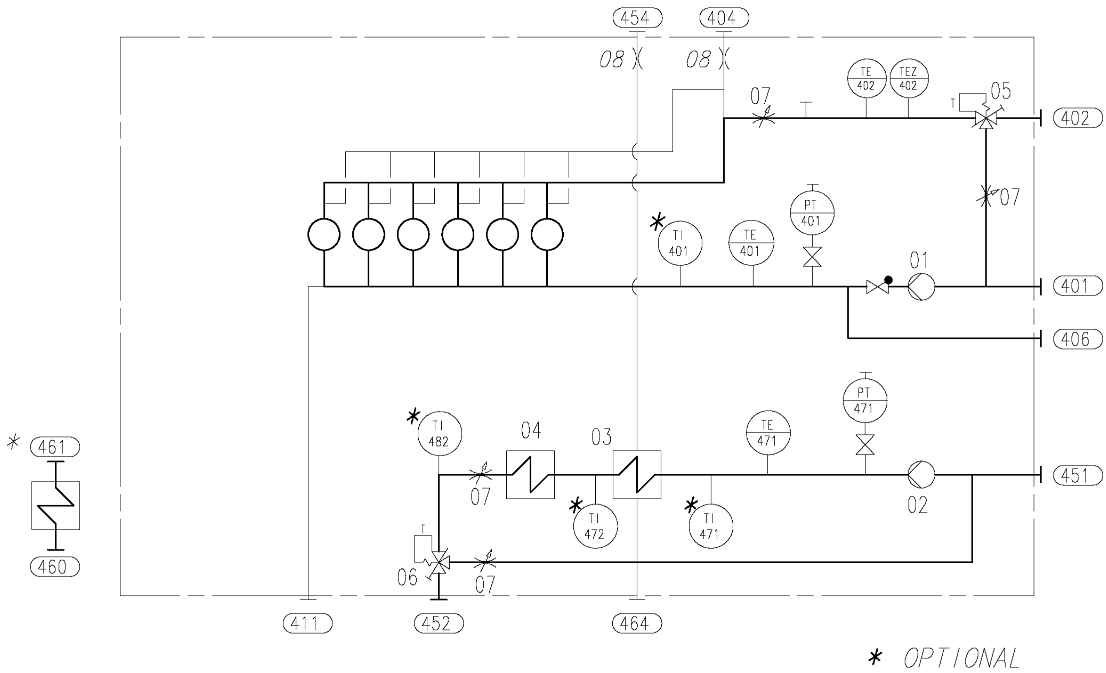


Fig 8-2 Internal cooling water system, WA20, separate HT and LT (DAAE010162G)

System components:					
01	HT-cooling water pump	04	Lubricating oil cooler	07	Adjustable orifice
02	LT-cooling water pump	05	HT-thermostatic valve	08	Orifice
03	Charge air cooler	06	LT-thermostatic valve		

Sensors and indicators:			
PT401	HT-water pressure before cylinder jackets	TEZ402	HT-water temp. after cylinder jackets
PT471	LT-water pressure before CAC	TE471	LT-water temp. before CAC
TE401	HT-water temp. before cylinder jackets	TI471	LT-water temp. before CAC (optional)
TI401	HT-water temp. before cylinder jackets (optional)	TI472	LT-water temp. after CAC (optional)
TE402	HT-water temp. after cylinder jackets	TI482	LT-water temp. after cooler (optional)

Pipe connections		Size
401	HT-water inlet	DN65
402	HT-water outlet	DN65
404	HT-water air vent	OD12
406	Water from preheater to HT-circuit	OD28
411	HT-water drain	M18*1.5
451	LT-water inlet	DN80
452	LT-water outlet	DN80
454	LT-water air vent from air cooler	OD12
460	LT-water to generator (if water cooled generator)	DN50
461	LT-water from generator (if water cooled generator)	DN50
464	LT-water drain	M18*1.5

The cooling water system comprises a low-temperature (LT) circuit and a high-temperature (HT) circuit. The LT-circuit includes the LT-charge air cooler and lubricating oil cooler while the HT-circuit includes jacket and cylinder head cooling. As option LT and HT can be internally connected together for WA20 gensets.

The outlet temperatures of the LT and the HT circuits are controlled by thermostatic valves.

8.2.3 Internal cooling water system, WA20, combined HT and LT

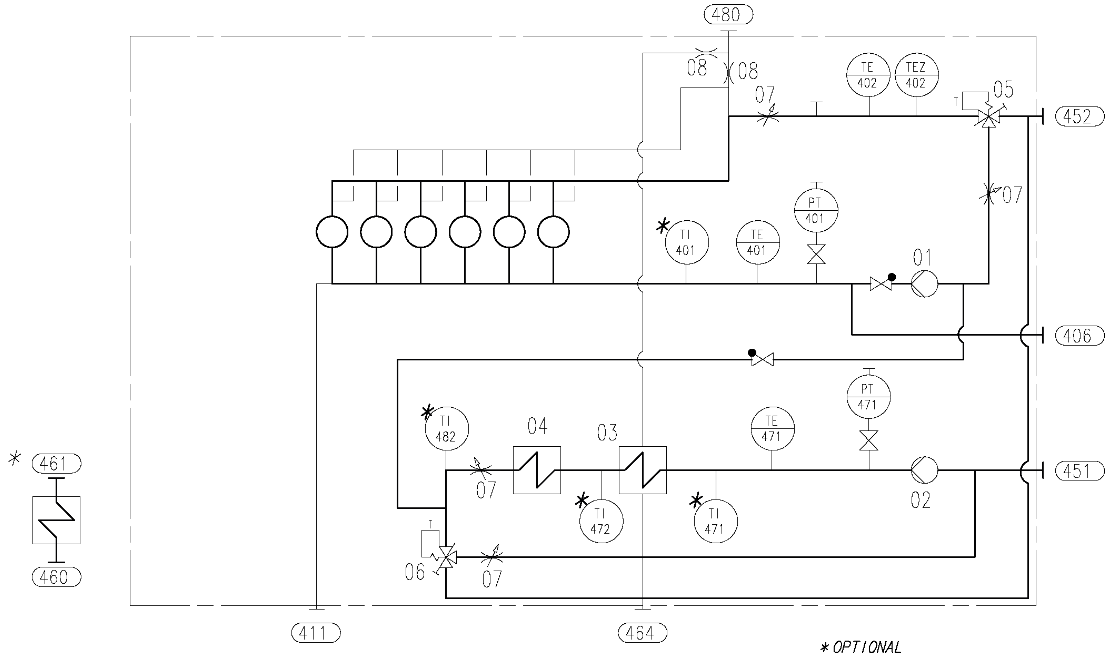


Fig 8-3 Internal cooling water system, WA20, combined HT and LT (DAAE010159G)

System components:					
01	HT-cooling water pump	04	Lubricating oil cooler	07	Adjustable orifice
02	LT-cooling water pump	05	HT-thermostatic valve	08	Orifice
03	Charge air cooler	06	LT-thermostatic valve		

Sensors and indicators:			
PT401	HT-water pressure before cylinder jackets	TEZ402	HT-water temp. after cylinder jackets
PT471	LT-water pressure before CAC	TE471	LT-water temp. before CAC
TE401	HT-water temp. before cylinder jackets	TI471	LT-water temp. before CAC (optional)
TI401	HT-water temp. before cylinder jackets (optional)	TI472	LT-water temp. after CAC (optional)
TE402	HT-water temp. after cylinder jackets	TI482	LT-water temp. after cooler (optional)

Pipe connections		Size	Pressure class	Size
406	Water from preheater to HT-circuit	OD28		DIN 2353
411	HT-water drain	M18*1.5		
451	LT-water inlet	DN80	PN16	ISO 7005-1
452	LT-water outlet	DN80	PN16	ISO 7005-1
460	LT-water to generator (if water cooled generator)	DN50	PN40	ISO 7005-1
461	LT-water from generator (if water cooled generator)	DN50	PN40	ISO 7005-1
464	LT-water drain	M18*1.5		
480	Cooling water vent	OD12		DIN 2353

8.2.4 Charge air cooler

The charge air cooler is of the monoblock type.

8.2.5 Lubricating oil cooler

The lubricating oil cooler is cooled by fresh water and connected in series with the charge air cooler.

8.2.6 Engine driven circulating water pumps

The LT and HT circuit circulating pumps are engine driven.

The HT and LT water pump impeller diameters and corresponding pump curves are presented in the following table and figures.

For the nominal capacities (required flow) see chapter "*Technical data*".

Table 8-1 Impeller diameters of engine driven HT & LT pumps

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

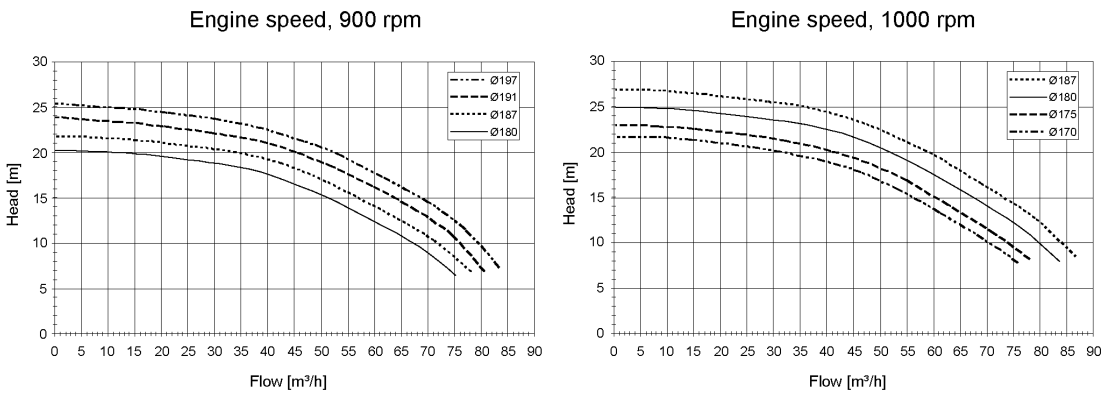


Fig 8-4 W20 engine HT & LT-water pump curves

8.2.7 Thermostatic valve LT-circuit

The self-actuating thermostatic valve controls the water outlet temperature from the lubricating oil cooler.

Set point (W20): .... 49°C (43...54°C)

8.2.8 Thermostatic valve HT-circuit

The self-actuating thermostatic valve controls the engine outlet temperature.

Set point: .... 91°C (87...98°C)

8.3 External cooling water system

There are a numerous ways to design the freshwater (FW) circuit. This guide presents four proposals.

External fresh water piping should be designed to minimize the flow resistance. Galvanized pipes should not be used in the fresh water circuits.

The pipe connections are listed in section "*Internal cooling water system*".

8.3.1 Cooling water system, separate system for auxiliary engines, without heat recovery

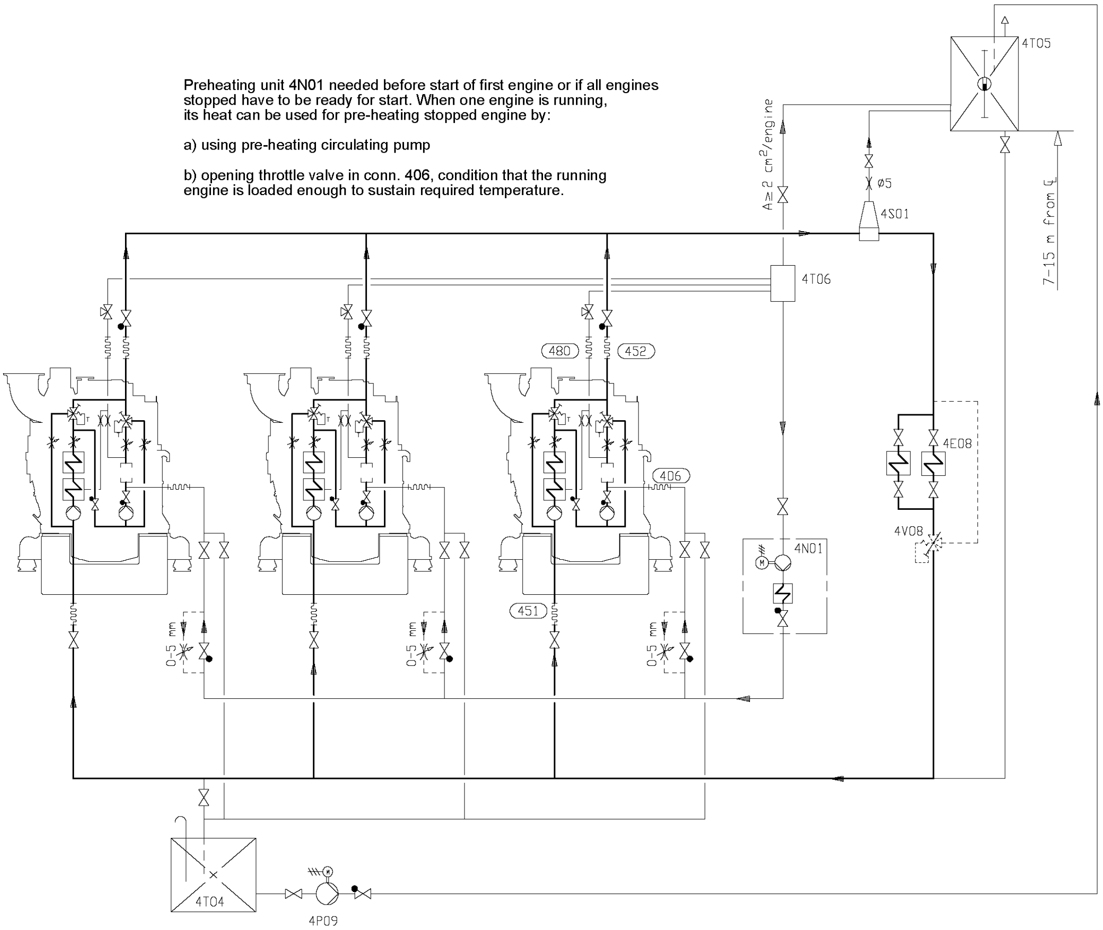


Fig 8-5 **Cooling water system, separate system for auxiliary engines, without heat recovery (DAAE028083b)**

System components			
4E08	Central cooler	4T04	Drain tank
4N01	Preheating unit	4T05	Expansion tank
4P09	Transfer pump	4T06	Air vent collecting tank
4S01	Air venting	4V08	Temperature control valve (Optional)

8.3.2 Cooling water system, separate system for auxiliary engines, with evaporator

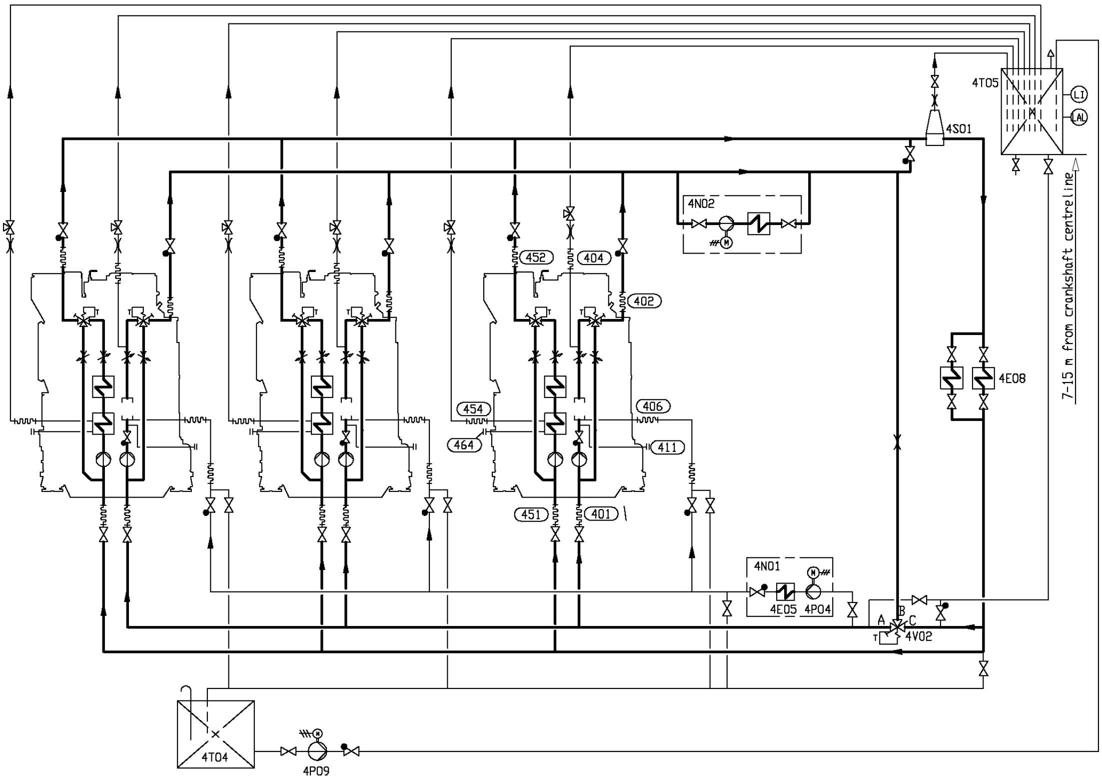


Fig 8-6 Cooling water system, separate system for WA16 engines, with evaporator (DAAF062368A)

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

Pos	Pipe connections	Size
401	HT-water inlet	DN65
402	HT-water outlet	DN65
404	HT-air vent	OD12
406	Water from preheater to HT-circuit	M33*2
411	HT-water drain	M16*1.5
451	LT-water inlet	DN65
452	LT-water outlet	DN65
454	LT-water air vent from CAC	OD12
464	LT-water drain	M16*1.5

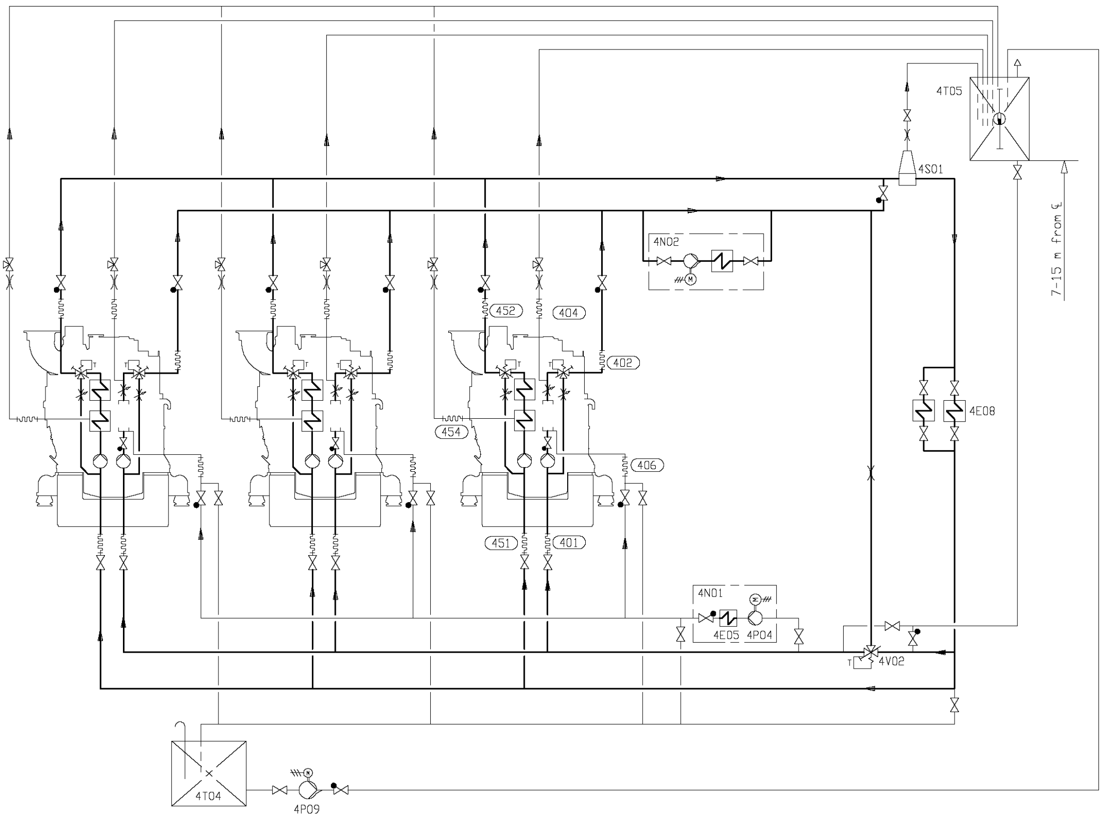


Fig 8-7 **Cooling water system, separate system for auxiliary engines, with evaporator (DAAF062369A)**

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

Pos	Pipe connections	Size
401	HT-water inlet	DN65
402	HT-water outlet	DN65
404	HT-air vent	OD12
406	Water from preheater to HT-circuit	M33*2
411	HT-water drain	M16*1.5
451	LT-water inlet	DN65
452	LT-water outlet	DN65
454	LT-water air vent from CAC	OD12
464	LT-water drain	M16*1.5

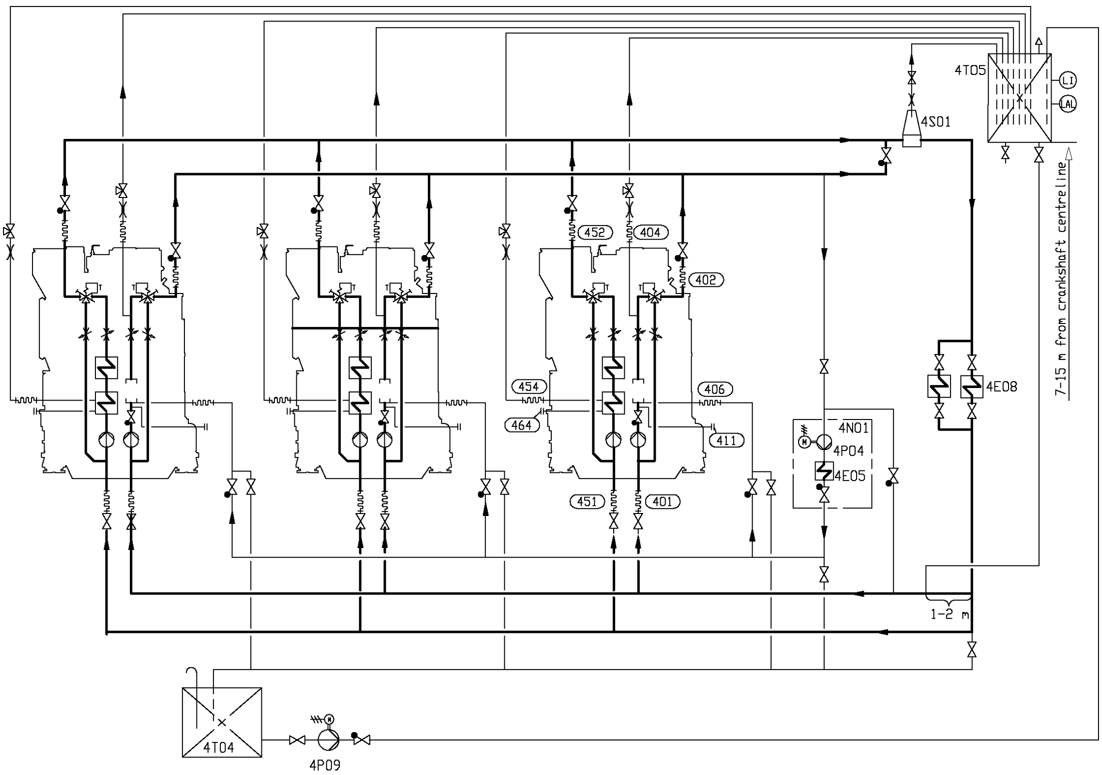


Fig 8-8 **Cooling water system, separate system for WA16 engines, without evaporator (DAAF062370A)**

System components			
4E05	Heater (Preheating unit)	4P09	Transfer pump
4E08	Central cooler	4S01	Air venting
4N01	Preheating unit	4T04	Drain tank
4P04	Circulating pump (Preheating unit)	4T05	Expansion tank

Pos	Pipe connections	Size
401	HT-water inlet	DN65
402	HT-water outlet	DN65
404	HT-air vent	OD12
406	Water from preheater to HT-circuit	M33*2
411	HT-water drain	M16*1.5
451	LT-water inlet	DN65
452	LT-water outlet	DN65
454	LT-water air vent from CAC	OD12
464	LT-water drain	M16*1.5

Figures 8-9 and *8-10* shows common cooling water circuits for auxiliary engines and slow speed main engines.

Features to note are:

- LT-water supply from electric driven LT-pump (flow to auxiliary engine circuit adjusted by throttle valve)
- Main engine can be pre-heated with running auxiliary engine
- Generator cooling possible from the electric driven pump

- HT-water from return line of LT circuit before central cooler (*Figure 8-10* only)

8.3.3 Cooling water system, common for ME and AE

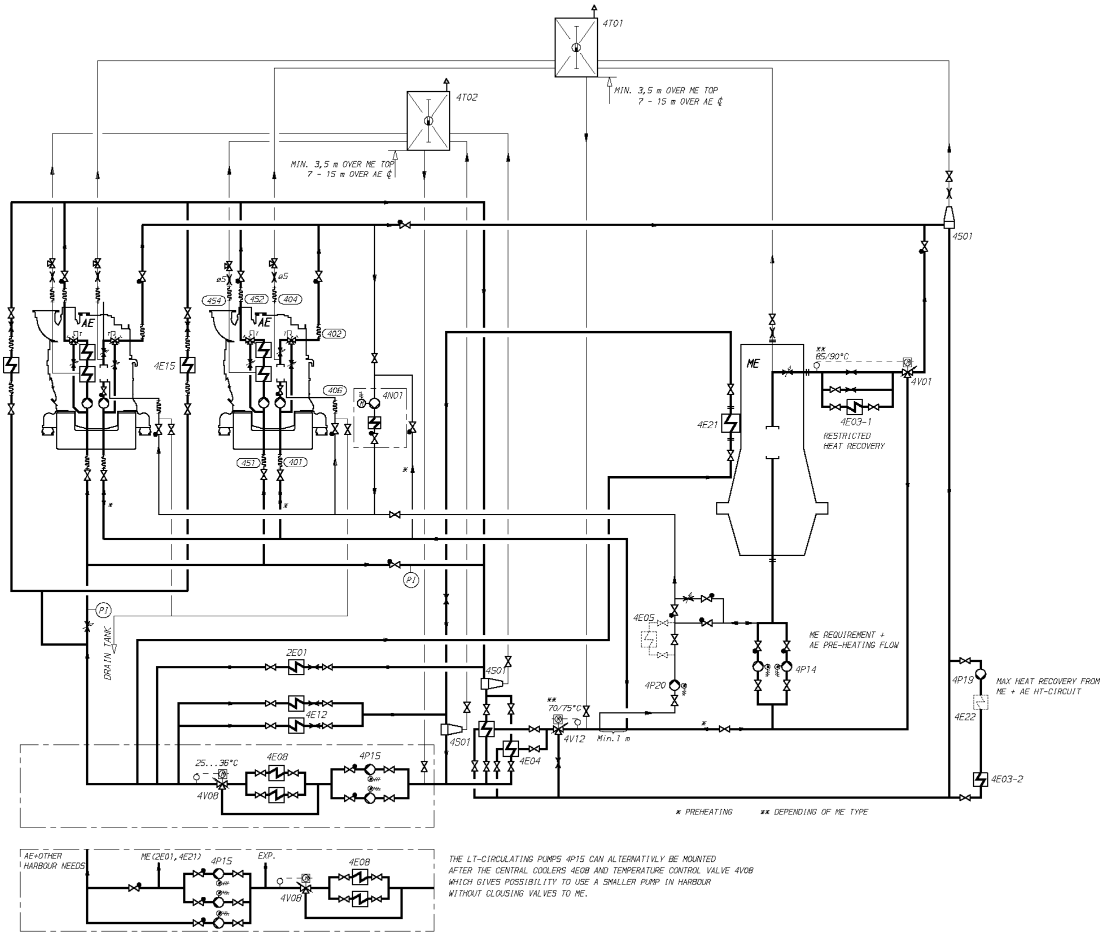


Fig 8-9 Cooling water system, common for ME and AE, split LT- and HT-circuit, common heat recovery and preheating for ME and AE (DAAE030654A)

System components			
2E01	Lubrication oil cooler	4P14	Circulating pump (HT)
4E03-1	Heat recovery (Evaporator) ME	4P15	Circulating pump (LT)
4E03-2	Heat recovery (Evaporator) ME+AE	4P19	Circulating pump (Evaporator)
4E04	Raw water cooler (HT)	4P20	Circulating pump (Preheating HT)
4E05	Heater (Preheater) Optional	4S01	Air venting
4E08	Central cooler	4T01	Expansion tank (HT)
4E12	Cooler (Installation parts)	4T02	Expansion tank (LT)
4E15	Cooler (Generator) Optional	4V01	Temperature control valve (HT)
4E21	Cooler (Scavenge air)	4V08	Temperature control valve (LT)
4E22	Heater (Booster) Optional	4V12	Temperature control valve (Heat recovery and preheating)
4N01	Preheating unit		

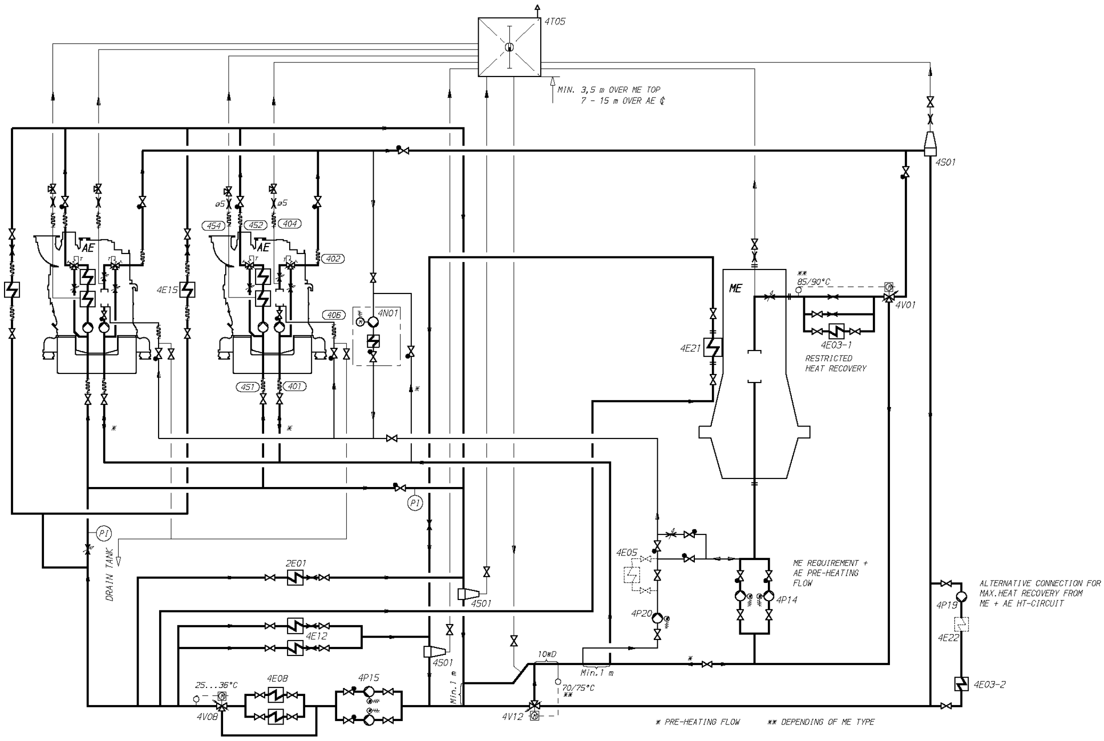


Fig 8-10 **Cooling water system, common for ME and AE, mixed LT- and HT-circuit, common heat recovery and preheating for ME and AE (DAAE030653A)**

System components			
2E01	Lubrication oil cooler	4P14	Circulating pump (HT)
4E03-1	Heat recovery (Evaporator) ME	4P15	Circulating pump (LT)
4E03-2	Heat recovery (Evaporator) ME+AE	4P19	Circulating pump (Evaporator)
4E05	Heater (Preheater) Optional	4P20	Circulating pump (Preheating HT)
4E08	Central cooler	4S01	Air venting
4E12	Cooler (Installation parts)	4T05	Expansion tank
4E15	Cooler (Generator) Optional	4V01	Temperature control valve (HT)
4E21	Cooler (Scavenge air)	4V08	Temperature control valve (central cooler)
4E22	Heater (Booster) Optional	4V12	Temperature control valve (heat recovery and preheating)
4N01	Preheating unit		

8.3.4 Cooling water system, connected to a central LT system with circulating pump

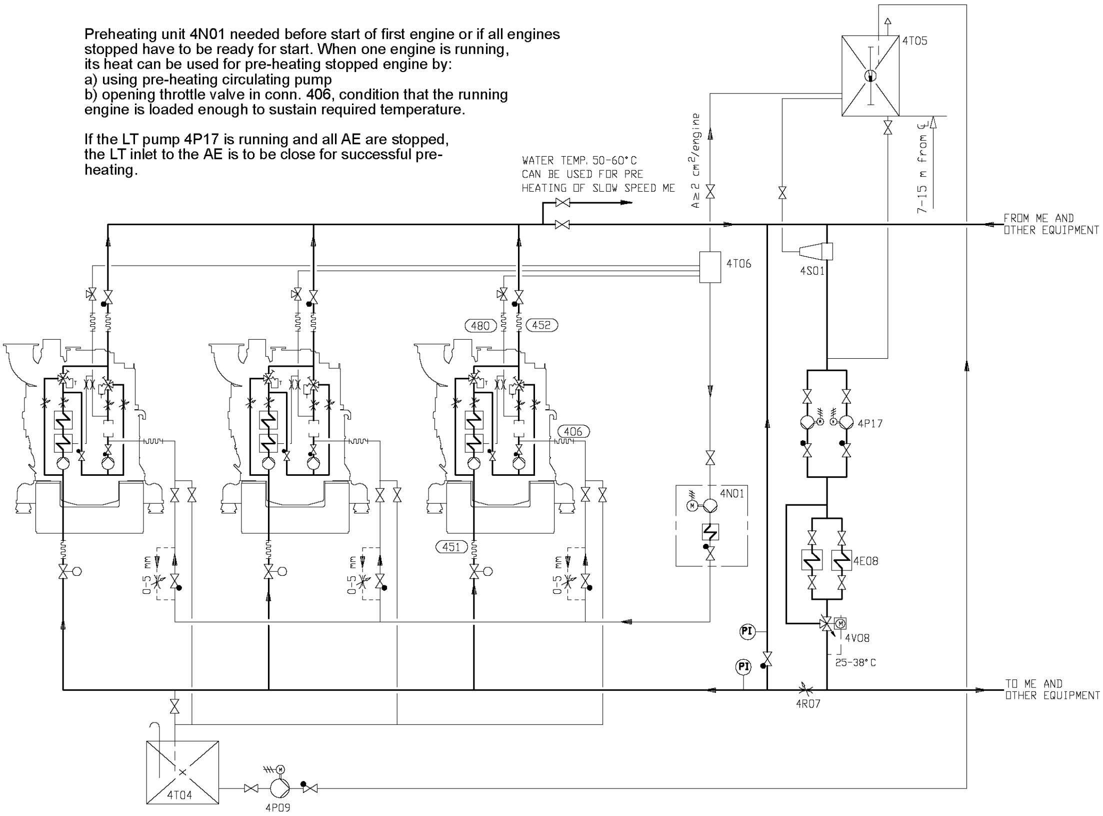


Fig 8-11 Cooling water system, connected to a central LT system with circulating pump, without heat recovery (DAAE028652b)

System components				
4E08	Central cooler	4S01	Air venting	
4N01	Preheating unit	4T04	Drain tank	
4P09	Transfer pump	4T05	Expansion tank	
4P17	Circulating pump (HT/LT)	4T06	Air vent collecting tank	
4R07	Adjustable throttle valve (LT-water)	4V08	Temperature control valve (Optional)	

8.3.5 Ships for cold conditions

Ships (with ice class) designed for cold sea-water should have temperature regulation with a re-circulation back to the sea chest to melt ice and slush, to avoid clogging and to increase the sea-water temperature enhancing temperature regulation of the LT-water.

8.3.6 Fresh water central cooler (4E08)

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

If the system layout is according to one of the example diagrams (except *Figure 8-7*), then the flow capacity of the cooler should be equal to the total capacity of the parallel connected LT circulating pumps in the circuit. The flow may be higher for other system layouts (e.g. *Figure 8-7)* and should be calculated case by case.

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

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

In case where 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:

where:

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

Note that in a parallel system usually the full LT pump capacity goes to the cooler whereas most HT water is re-circulated on the enigne. The HT flow from the engine depends on the engine load (HT heat flow) and the temperature of the replacement water.

In a system with LT and HT circuits in series as well as for engine internally combined system is the flow to the coolers equals the LT pump capacity.

8.3.7 Expansion tank (4T05)

An expansion tank compensates for volume changes due to thermal expansion of the coolant, serves for venting of the circuits and provides a static pressure for the cooling water circulating pumps.

Design data:

Static pressure required:	70 - 150 kPa (0.7 - 1.5 bar)
Volume	min. 10% of the system

The vent pipes should enter the tank below the water level to prevent oxidation.

The tank should be equipped so that it is possible to dose water treatment agents.

The expansion tank is to be provided with inspection devices.

8.3.8 Air venting

To evacuate entrained air from the cooling water circuits the following air vent pipes should be installed:

1. **Connection 404**
2. **Connection 454**
3. **High point(s) in the CW circuit**

Vent pipes should be throttled by about Ø5 mm orifices to avoid excessive circulation through the expansion tank and relevant loss of recoverable heat and static pressure.

Vent pipes of each engine should be drawn separately and continuously rising to the expansion tank or to an air vent collecting tank (for engine with built on combined HT-LT system).

8.3.9 Balance pipe

The balance pipe down from the expansion tank must be dimenisioned 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 8-2 Balance pipe from the expansion tank

Size	Velocity, max [m/s]	Max number of air vent with orifice Ø5
DN32	1.1	3
DN40	1.2	6
DN50	1.3	10
DN65	1.4	17

8.3.10 Throttles

Throttles (orifices) are recommended at all by-pass lines to ensure balanced operating conditions for temperature control valves.

8.3.11 Waste heat recovery

The waste heat of the HT-circuit may be used for fresh water production, central heating, tank heating etc. In such cases the piping system should be provided with a temperature control valve to avoid unnecessary cooling. With this arrangement the HT-water flow and the recoverable heat can be increased.

8.3.12 Drain tank

It is recommended to provide a drain tank to which the engines and coolers can be drained for maintenance so that the water and cooling water treatment can be collected and reused. Most of the cooling water in the engine can be recovered from the HT-circuit, whereas the amount of water in the LT-circuit is small.

8.3.13 Pre-heating

Engines started and stopped on heavy fuel and all engines on which high load will be applied immediately after start have to be pre-heated as close to the actual operating temperature as possible, or minimum 60°C. If the HT-cooling water temperature cannot be kept at 60°C or higher, load application should follow the graph below. Starting and loading the generating set at HT-water temperatures below 40°C is not recommended. Based on how the system is designed, heat from running engines can be used for pre-heating.

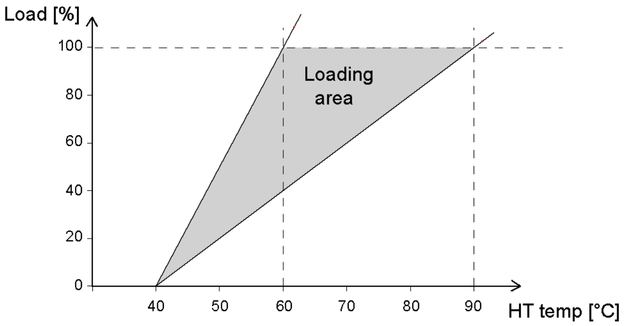


Fig 8-12 Load application on a cold generating set (20AP0703)

8.3.13.1 Heater (4E05)

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

It is recommended to heat the HT-water to a temperature near the normal operating temperature, however minimum 60°C. The heating power determines the required time to heat up the engine from cold condition.

Design data:	
Preheating temperature	min. 60°C
Heating power to keep hot engine warm	WA20: 1.0 kW/cyl

Required heating power to heat up the engine to 60°C, see formula below:

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

where:	
P =	Preheater output [kW]
T_1 =	Preheating temperature = 60°C
T_0 =	Ambient temperature [°C]
m_{eng} =	Engine weight [ton]
V_{LO} =	Lubricating oil volume [m^3]
V_{FW} =	HT-water volume [m^3]

where:	
t =	Preheating time [h]
k_{eng} =	Engine specific coefficient
n_{cyl} =	Number of cylinders

Engine specific coefficient: WA20: 0.5 kW

8.3.13.2 Circulating pump for preheater (4P04)

Design data:	
Capacity	WA20: 0.3 m^3/h per cylinder
Delivery pressure	80 kPa (0.8 bar) (1.2 bar for Auxpac with built on combined HT-LT system)

8.3.13.3 Pre-heating unit (4N01)

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

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

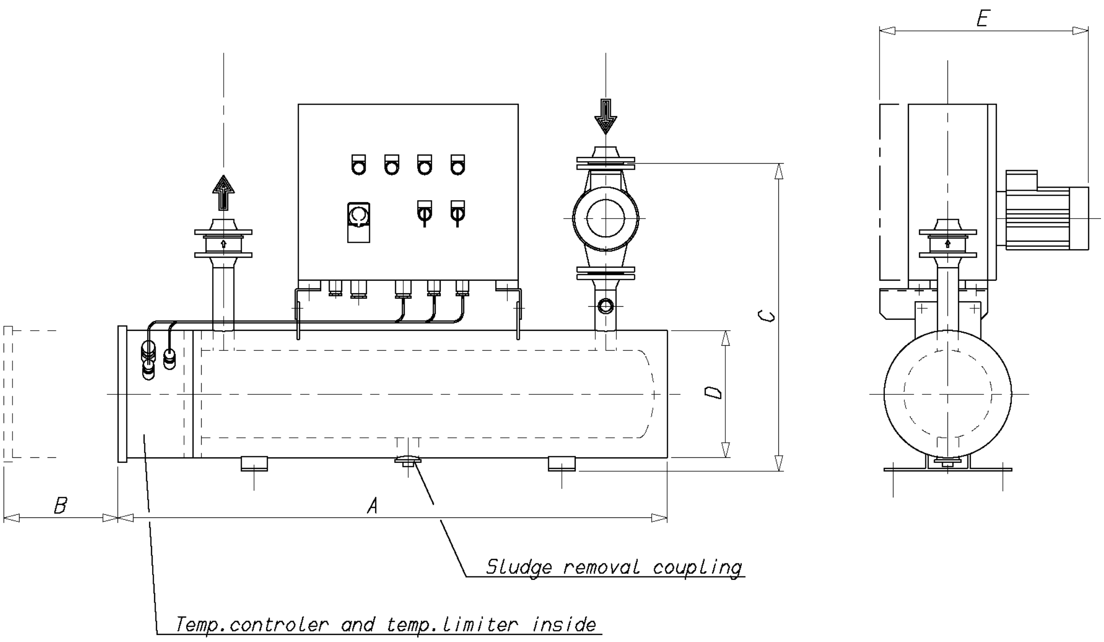


Fig 8-13 Preheating unit, electric (3V60L0653a)

Heater capacity [kW]	Pump capacity [m^3/h]	Weight [kg]	Pipe connections Inlet / Outlet	Dimensions [mm]				
				A	B	C	D	E
7.5	3	75	DN40	1050	720	610	190	425
12	3	93	DN40	1050	550	660	240	450
15	3	93	DN40	1050	720	660	240	450
18	3	95	DN40	1250	900	660	240	450

9. Combustion Air System

9.1 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.

9.2 Combustion air system design

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

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

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

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

where:

q_c = combustion air volume flow [m³/s]

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

ρ = air density 1.15 kg/m³

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

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

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

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

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

9.2.1 Condensation in charge air coolers

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

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

Example, according to the diagram:

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

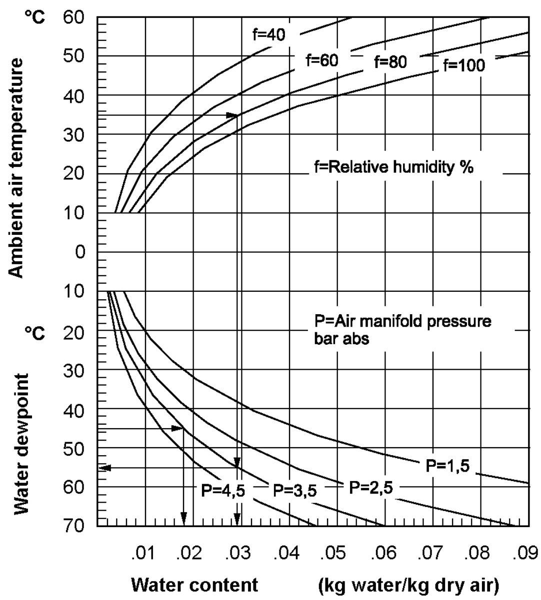


Fig 9-1 Condensation in charge air coolers

10. Exhaust Gas System

10.1 Internal air and exhaust gas system

10.1.1 Internal charge air and exhaust gas system, WA16

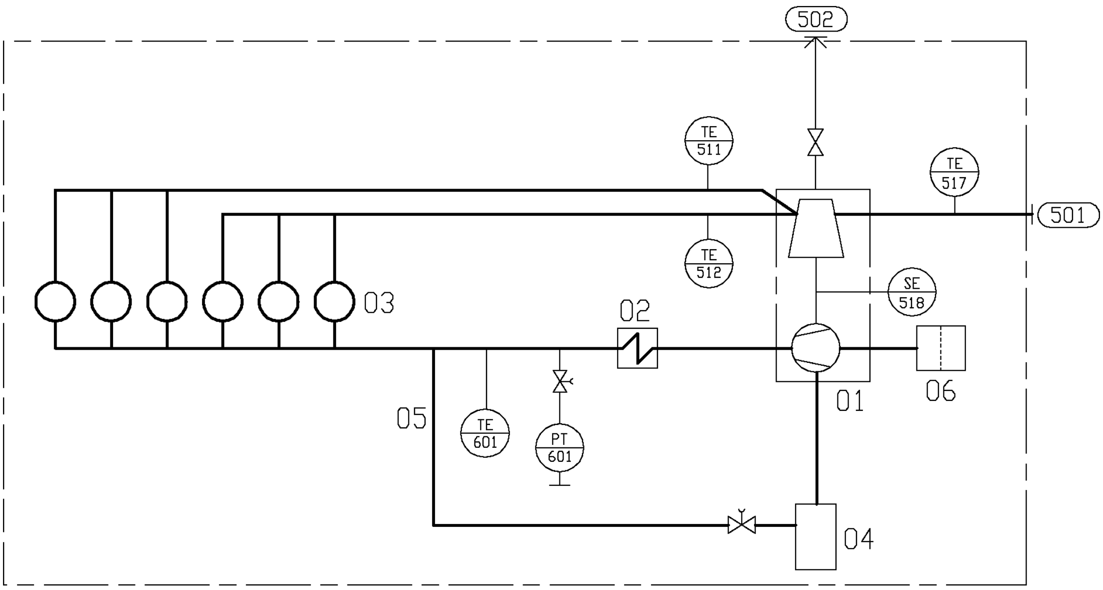


Fig 10-1 Internal charge air and exhaust gas system, WA16 (DAAF062371A)

System components:			
01	Turbocharger	04	Water container
02	Charge air cooler	05	Pressure from air duct
03	Cylinders	06	Air filter

Sensors and indicators			
TE511	Exhaust gas temperature TC A inlet	TE601	Charge air temperature, engine inlet
TE512	Exhaust gas temperature TC A inlet	PT601	Charge air pressure, engine inlet
TE517	Exhaust gas temperature TC A outlet	SE518	Turbocharger speed

Pipe connections	
501	Exhaust gas outlet
502	Cleaning water to turbine

10.1.2 Internal charge air and exhaust gas system, WA20

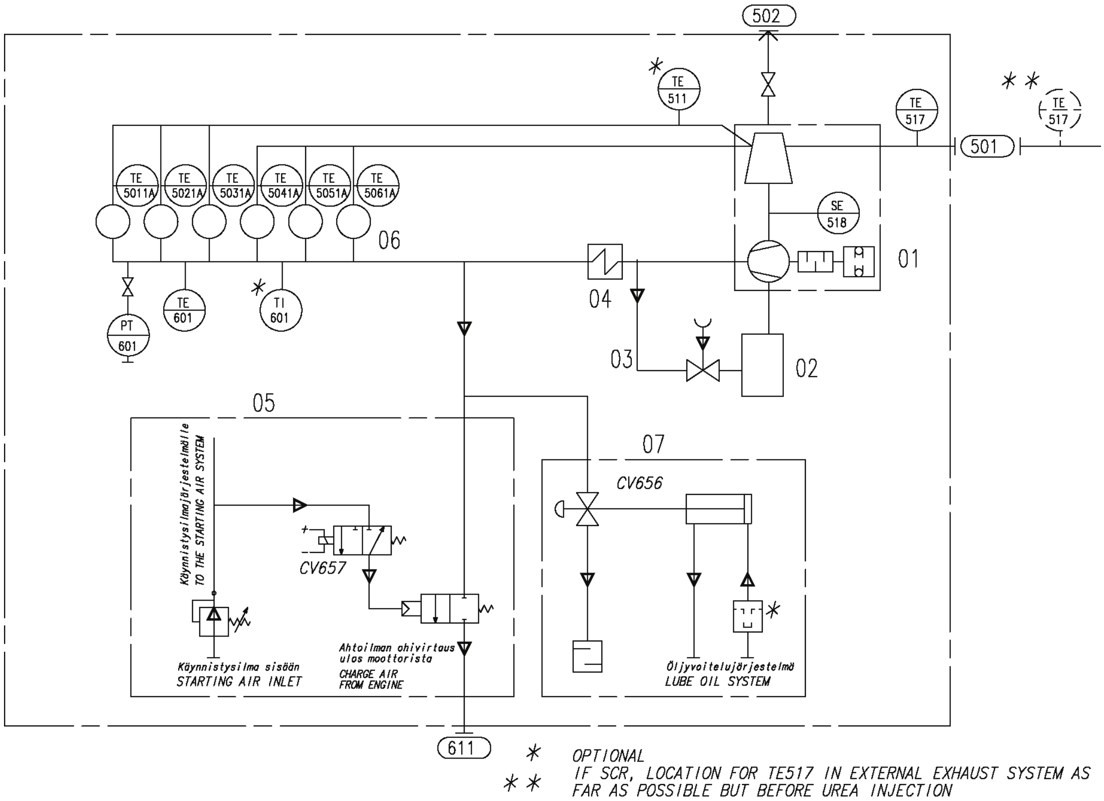


Fig 10-2 Internal charge air and exhaust gas system, WA20 (DAAE010154D)

System components:			
01	Turbocharger	05	Charge air wastegate, only on WA20D4
02	Water container	06	Cylinders
03	Pressure from air duct	07	Variable charge air waste gate (optional)
04	Charge air cooler		

Sensors and indicators			
TE501xA	Exhaust gas temperature after each cylinder	TI601	Charge air temperature after CAC (optional)
TE511	Exhaust gas temperature before turbine (optional)	PT601	Charge air pressure after CAC
TE517	Exhaust gas temperature after turbine	SE518	Turbocharger speed
TE601	Charge air temperature after CAC	CV657	Charge air limiter (if VIC)

Pipe connections		Size
501	Exhaust gas outlet	see section "*Exhaust gas outlet*"
502	Cleaning water to turbine	Quick connection
611	Charge air wastegate outlet (if VIC)	OD28

10.2 Exhaust gas outlet

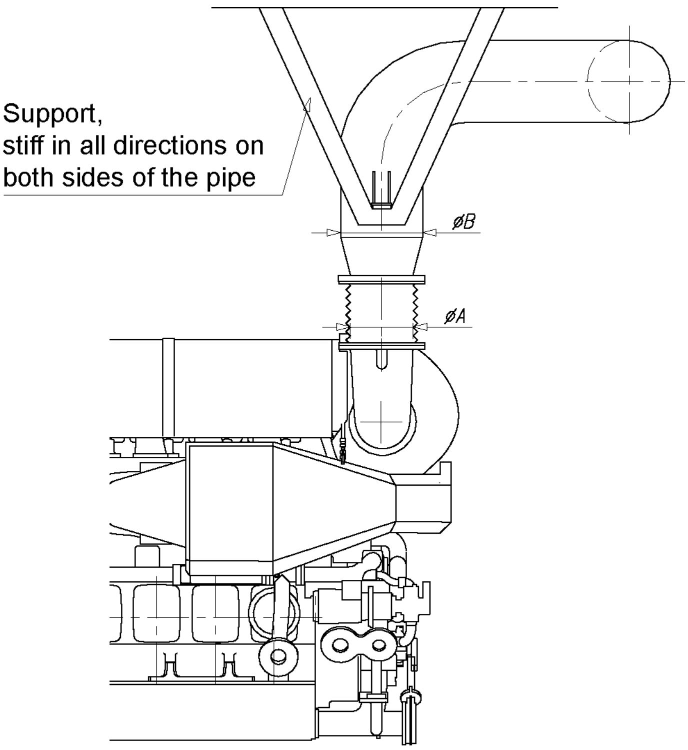


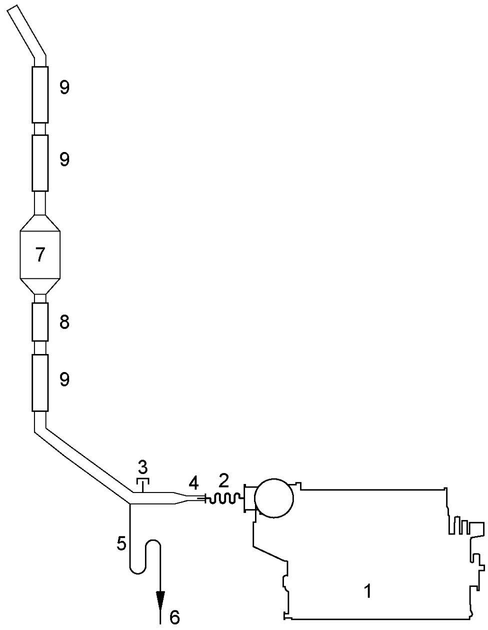
Fig 10-3 Exhaust pipe, diameters and support (DAAE011697A)

Engine	ØA [mm]	ØB [mm]
4L20	DN200	250, 300
6L20	DN250	300, 350
8L20	DN300	400
9L20	DN300	450

10.3 External exhaust gas system

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

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



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

Fig 10-4 External exhaust gas system

10.3.1 Piping

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

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

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

where:

v = gas velocity [m/s]

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

T = exhaust gas temperature [°C]

D = exhaust gas pipe diameter [m]

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

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

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

10.3.2 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.

10.3.3 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.

10.3.4 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.

10.3.5 SCR-unit (11N14)

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

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

10.3.6 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.

10.3.7 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.

10.3.7.1 Exhaust noise

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

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

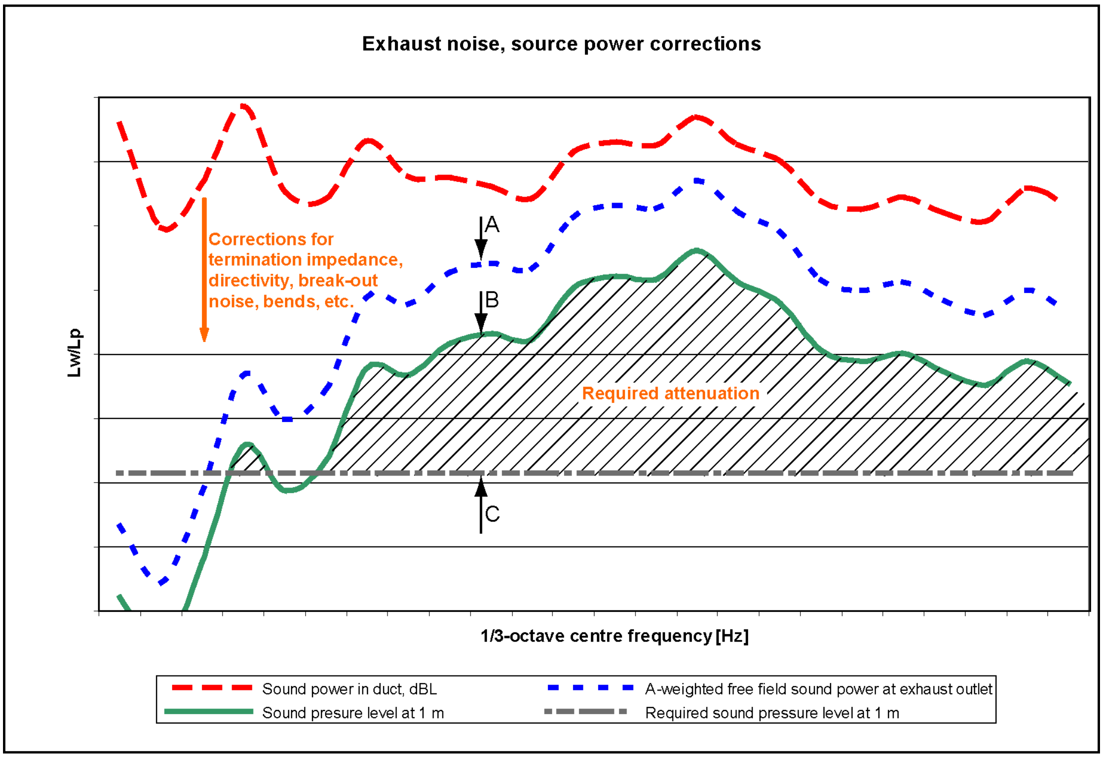


Fig 10-5 Exhaust noise, source power corrections

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.

10.3.7.2 Silencer system comparison

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

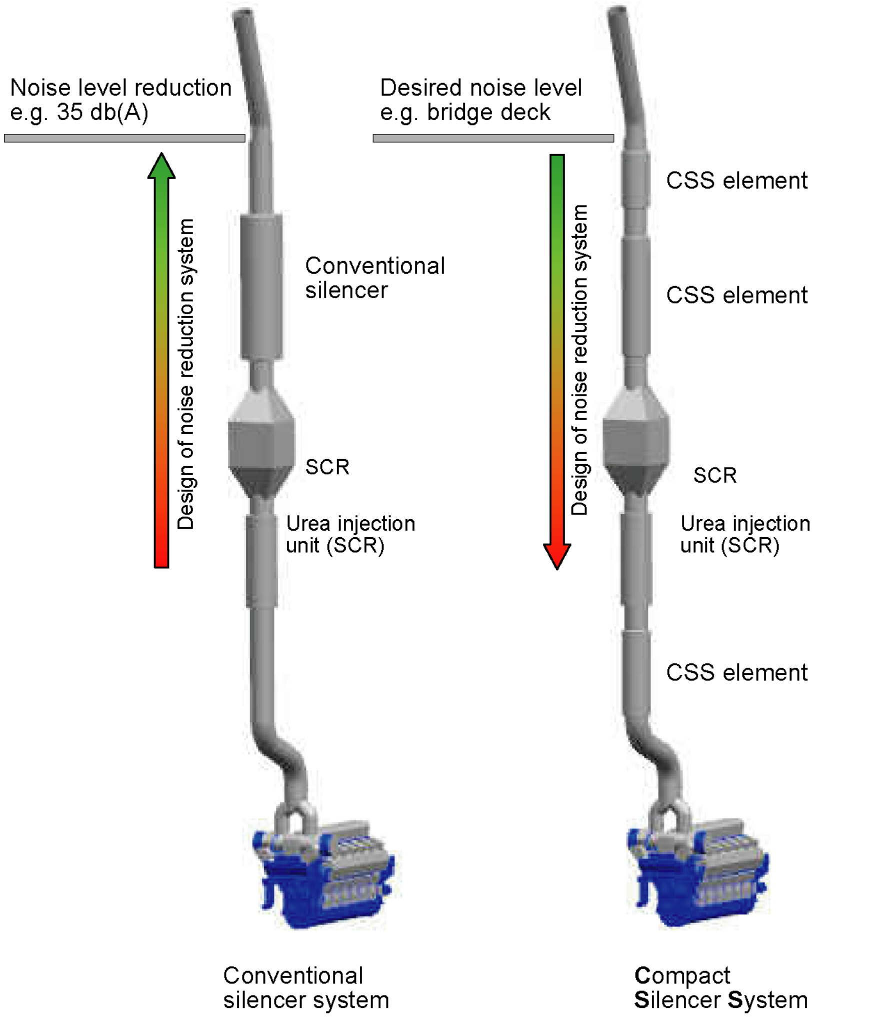


Fig 10-6 Silencer system comparison

10.3.7.3 Compact silencer system (5N02)

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

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

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

10.3.7.4 Conventional exhaust gas silencer (5R02)

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

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

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

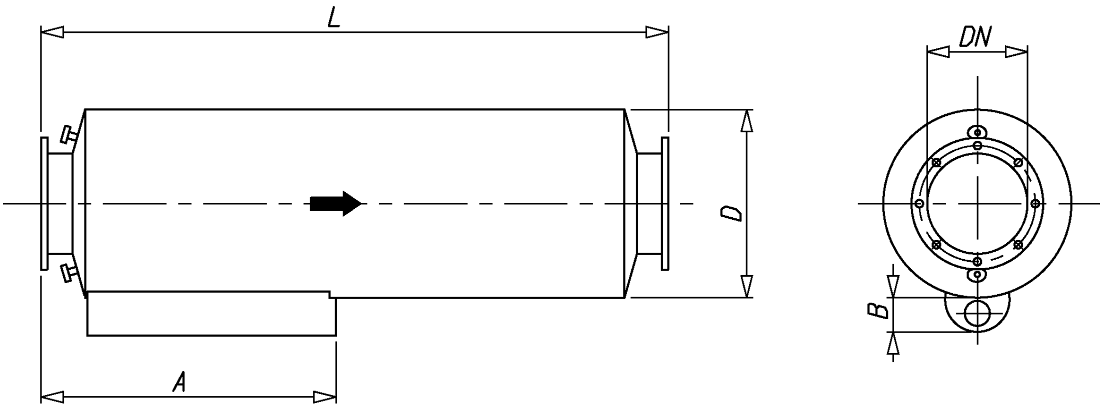


Fig 10-7 Exhaust gas silencer (4V49E0137b)

Table 10-1 Typical dimensions of exhaust gas silencers

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

11. 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.

11.1 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	W20 engines: 6-10 l/min (depending on cylinder configuration)

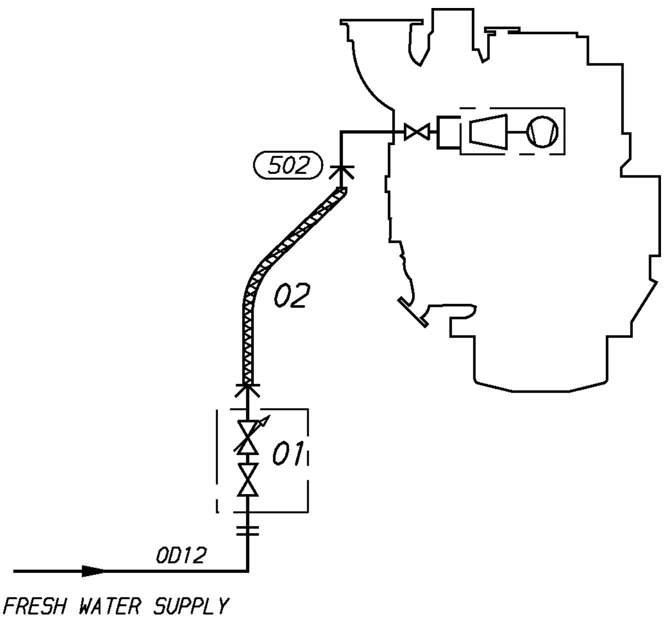


Fig 11-1 Turbine cleaning system (DAAE003884)

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

11.2 Compressor cleaning system

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

12. 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.

12.1 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.

12.1.1 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.

12.1.2 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).

12.1.3 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.

12.1.4 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.

12.2 Marine exhaust emissions legislation

12.2.1 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.

12.2.1.1 MARPOL Annex VI - Air Pollution

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

Nitrogen Oxides, NO_x Emissions

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

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 12-1 ISO 8178 test cycles

D2: Constant-speed auxiliary engine application	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: Constant-speed main propulsion application including diesel-electric drive and all controllable-pitch propeller installations	Speed (%)	100	100	100	100
	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 later undertaken a review with the intention to further reduce emissions from ships and a final adoption for IMO Tier 2 and Tier 3 standards were taken in October 2008.

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

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

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

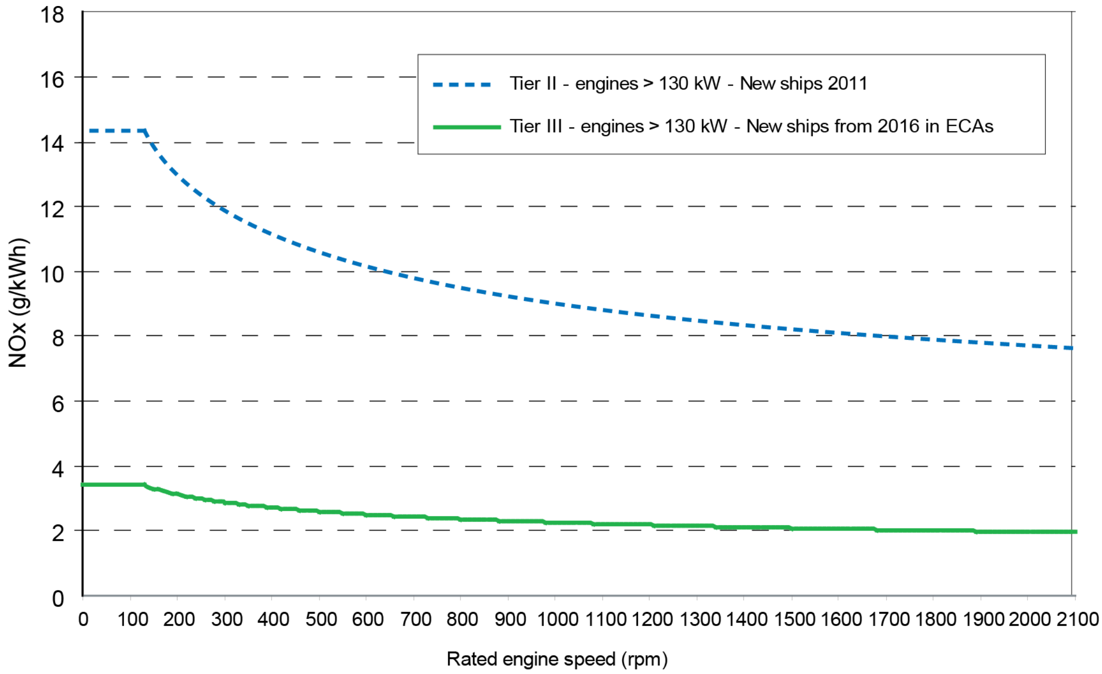


Fig 12-1 **IMO NO_x emission limits**

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] $= 44 \times rpm^{-0.23}$ 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. The IMO Tier 2 NOx level is met by engine internal methods.

IMO Tier 3 NO_x emission standard (new ships from 2016 in ECAs)

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

The IMO Tier 3 NO_x limit is defined as follows:

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

The IMO Tier 3 NO_x emission level corresponds to an 80% reduction from the IMO Tier 2 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 for diesel engines to reach the NOx reduction needed for the IMO Tier 3 standard.

If the Wärtsilä NOx Reducer SCR system is installed together with the engine, the engine + SCR installation complies with the maximum permissible NOx emission according to the IMO Tier 3 NOx emission standard and the Tier 3 EIAPP certificate will be delivered for the complete installation.

NOTE

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

Sulphur Oxides, SO_x emissions

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

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

Table 12-2 Fuel sulphur caps

Fuel sulphur cap	Area	Date of implementation
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.

12.2.2 Other Legislations

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

12.3 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.

13. Automation system

13.1 Automation System, WA16

13.1.1 Engine automation system

The engine is equipped with a fully embedded and distributed engine management system, which handles all control functions on the engine; for example start sequencing, start blocking, speed control, 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 serial connection to external systems.

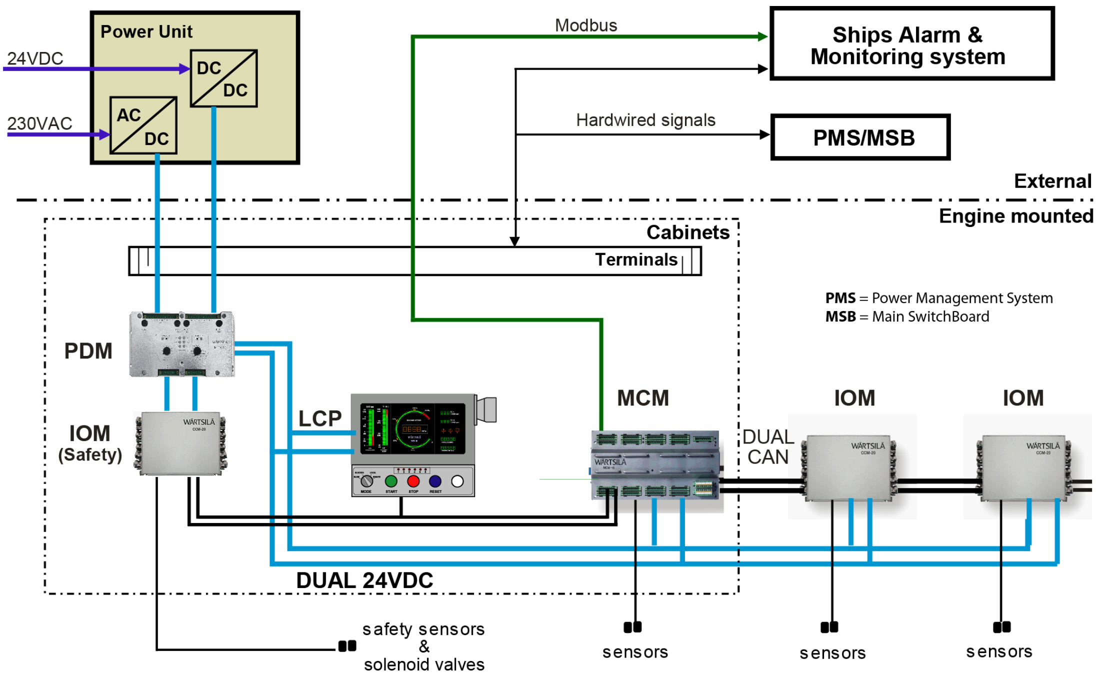


Fig 13-1 Architecture of Engine Automation System

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.

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

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

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.

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

13.1.1.1 Local control panel

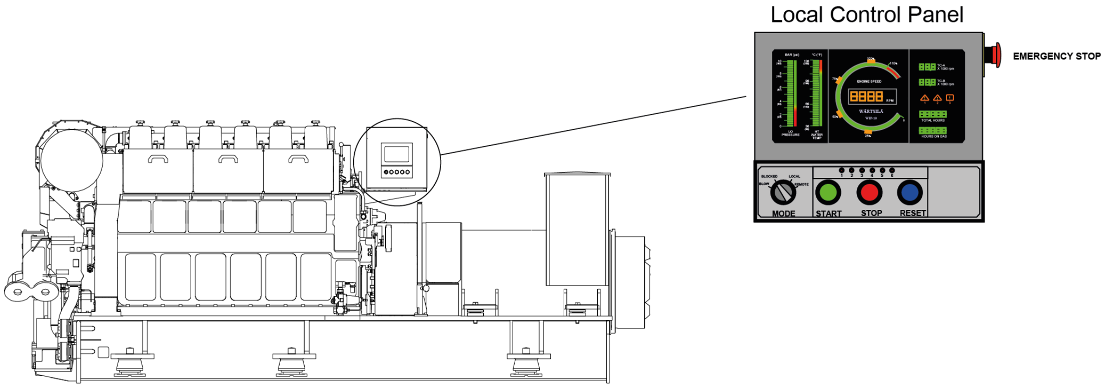


Fig 13-2 Connecting box and Local control panel

Operational functions available at the LCP:

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

  Positions:

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

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

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

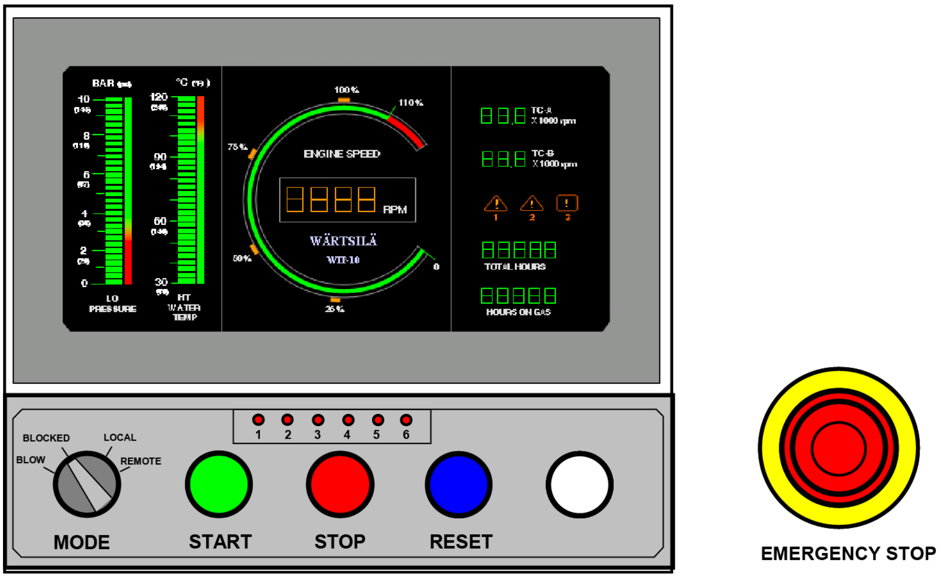


Fig 13-3 Local control panel

13.1.1.2 Engine safety system

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

Main features:

- Redundant design for power supply
- Fault detection on sensors, solenoids and wires
- Shutdown latching and reset

13.1.1.3 Power unit

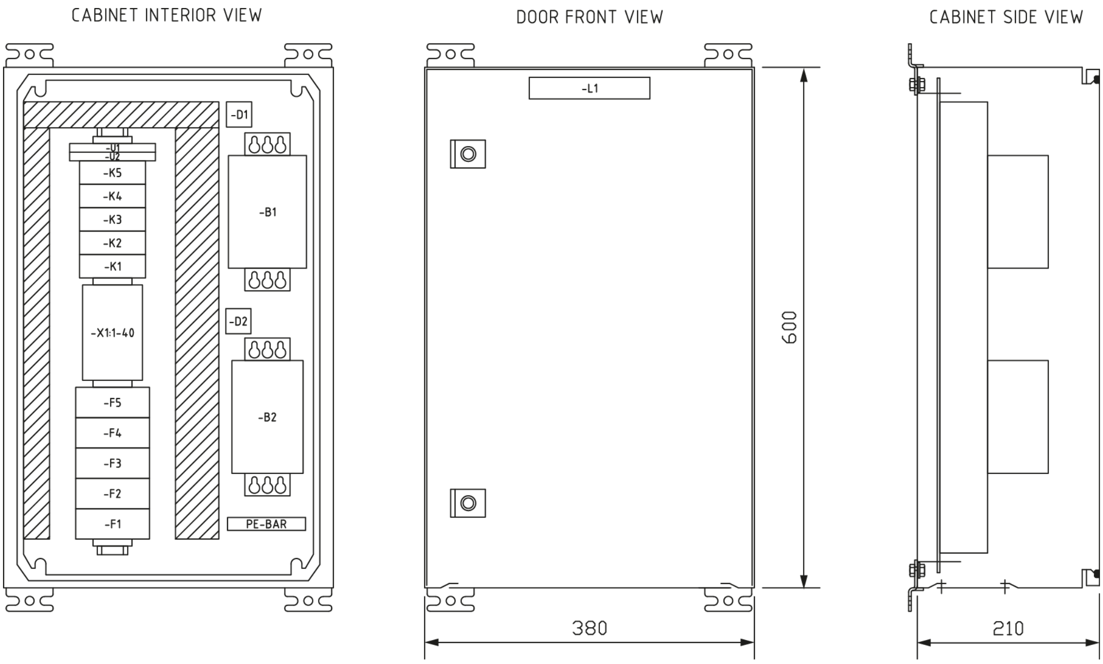


Fig 13-4 Standard power unit (DBAC145268)

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

Power supply from ship's system:

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

13.1.1.4 Cabling and system overview

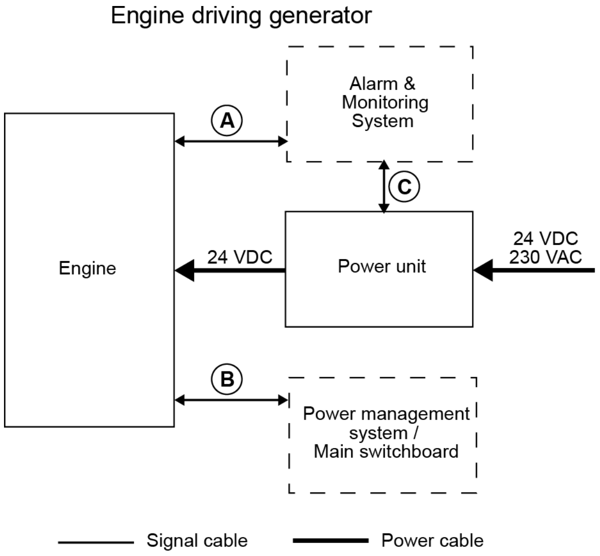


Fig 13-5 Overview

Table 13-1 Typical amount of cables

Cable	From <=> To	Cable types (typical)
A	Engine <=> Integrated Automation System	3 x 2 x 0.75 mm² 2 x 0.75 mm² (RS485)
B	Engine <=> Power Management System / Main Switch-board	1 x 2 x 0.75 mm² 1 x 2 x 0.75 mm² 1 x 2 x 0.75 mm² 10 x 0.75 mm² 10 x 0.75 mm²
C	Power unit <=> Integrated Automation System	2 x 0.75 mm²
D	Engine <=> Power Unit	2 x 2.5 mm² (power supply) 2 x 2.5 mm² (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*.

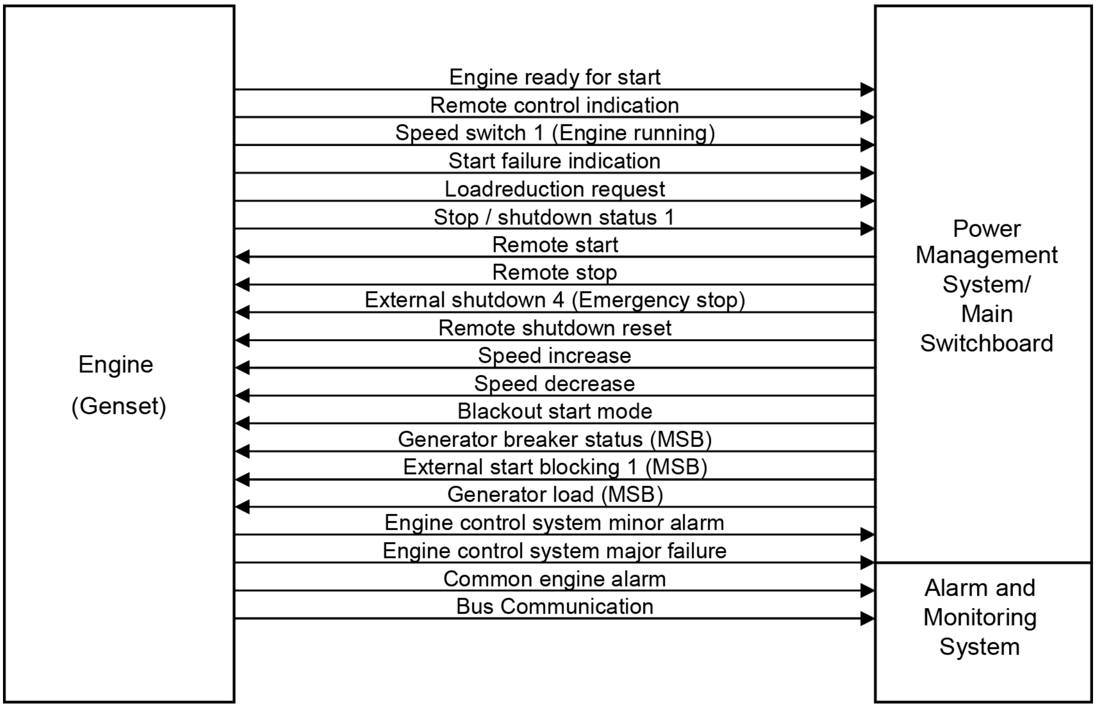


Fig 13-6 Signal overview

13.1.2 Functions

13.1.2.1 Start

The engine is equipped with a pneumatic starting motor driving the engine through a gear rim on the flywheel. The start can be initiated either locally with the start button, or by the remote start command. 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.

Startblockings are handled by the system on the engine.

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
- 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.

13.1.2.2 Stop and shutdown

Normal stop is initiated either locally with the stop button, or by the remote stop command. The control devices on the engine are held in stop position 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 an external command.

Typical shutdown functions are:

- Lubricating oil pressure low
- Overspeed
- HT cooling water temp high

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

13.1.2.3 Speed control

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

The load sharing is be based on traditional speed droop.

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%.

13.1.3 Alarm and monitoring signals

Regarding sensors on the engine, please see the internal P&I diagrams for Auxpac 16 in this product guide. The actual configuration of signals and the alarm levels are found in the project specific documentation supplied for all contracted projects.

13.1.4 Electrical consumers

13.1.4.1 Motor starters and operation of electrically driven pumps

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

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

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 13-2 Electric motor ratings for pre-lubricating pump

Engine type	Voltage [V]	Frequency [Hz]	Power [kW]	Current [A]
Auxpac 16	3 x 400	50	2.9	
	3 x 440	60	3.5	

Circulating pump for preheater (4P04)

The cooling water 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.

13.2 Automation System, WA20

13.2.1 System overview

The Auxpac automation system consists of a built-on control system for control of the running parameters, monitoring of the safety sensors and automatic safety operations.

13.2.2 Automation system scope

The engine mounted equipment mainly consists of :

- Main control unit (MCM) for control of starting and stopping sequences and speed control of the generating set.
- Engine safety module (ESM) for measuring of engine speed and turbocharger speed and for activation of automatic safety shutdowns (over speed, low lubricating oil pressure and high HT cooling water temperature. The ESM also performs wire break monitoring for the safety system signals.
- Electric actuator for control of fuel rack position.
- Solenoids
- Sensors and switches for the ships alarm and monitoring system. The sensors are pre-wired to a connection box on the generating set.
- Indicators for generating set speed, turbocharger speed and running hours.
- Local indications (bar graphs) for engine main parameters.
- Control mode switch Blow / Blocked / Local / Remote
- Emergency stop button
- Local start button
- Local stop button
- Shutdown reset button

13.2.3 Power supply

The power supply requirement for the Auxpac generating sets is 24 VDC, 5A at steady state, and up to 20A for peaks (5 sec). UPS backed power supply is recommended. The control system is designed so that a redundant power supply system can be adopted.

13.2.4 Safety System

The safety system is an independent system continuously monitoring the required parameters for safe operation and performing shutdown of the generating set if the operating parameters exceed preset limits. The parameters monitored are:

- Overspeed
- Low lubricating oil pressure
- High HT cooling water temperature
- Emergency stop button

13.2.5 Start and stop system

The generating set is equipped with a built-on start and stop system for control of starting and stopping sequences as well as start blocking functions.

13.2.5.1 Start blocking

Starting is inhibited by the following functions:

- Turning device engaged.
- Pre-lubricating pressure low. Starting is allowed within 30 minutes after the pressure has dropped below the set point of 50 kPa.
- Engine start blocking selector switch turned into “Blocked” position
- Engine running
- Stop signal to engine activated (safety shut-down, emergency stop, normal stop)
- Stop lever in stop position

13.2.6 Speed control

The generating sets are provided with a built-on electronic speed control system and an actuator. The system is designed for maximum reliability and optimum performance.

The speed measuring is performed with redundant speed pick-ups and failure of one speed pick-up will not cause interference in the operation.

The speed control system has an integrated start fuel limiter for minimising smoke emission during the acceleration period when starting an engine.

The dynamic response can be adjusted and optimised for the particular installation.

The speed control is set up for speed droop control mode operation and the speed droop is factory adjusted for 4% at rated load. This is to ensure proper load sharing between paralleling units. To compensate for the speed decrease of the plant when the load increases, and vice versa when the load decreases, the ship should have a load sharing system with an outer (cascade) loop to correct for the frequency drift.

13.2.7 Sensors and signals

13.2.7.1 Local instrumentation

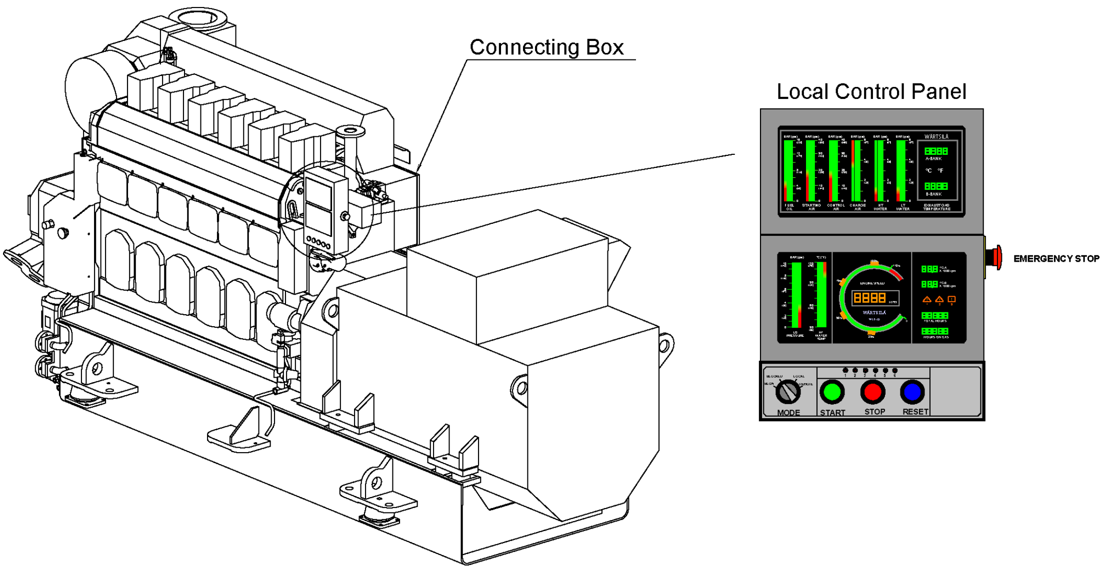


Fig 13-7 Connecting box and Local control panel

Thermometers

The generating set is as standard equipped with a bar graph type thermometer for HT cooling water temperature mounted in the local control box.

Pressure gauges

The generating set is as standard equipped with the following bar graph type pressure gauges:

- Fuel pressure
- Lubricating oil pressure
- Starting air pressure
- Control air pressure
- HT cooling water pressure
- LT cooling water pressure
- Charge air pressure

Indication of rpm

The generating sets are equipped with local indication for engine speed and turbocharger speed.

Generating set instrumentation

The generating sets are equipped with instrumentation for safety shutdowns and monitoring of various parameters.

Table 13-3 Engine to alarm system

Code	Description	I/O type	Signal type	Range	Alarm set-point	Delay	Note
PT101	Fuel Oil Pressure, Engine inlet	AI	4-20 mA	0-16 bar	< 4	5 s	
TE101	Fuel Oil Temperature, Engine inlet	AI	PT100	0-160°C			
LS103A	Fuel Oil Leakage, Injection Pipe	DI	Pot. free	on/off	OPEN	5 s	
PT201	Lubricating Oil Pressure, Engine inlet	AI	4-20 mA	0-10 bar	< 3	5 s	BL
TE201	Lubricating Oil Temperature, Engine inlet	AI	PT100	0-160°C	> 75	5 s	
PDS243	Lubricating Oil Filter Pressure Difference	DI	Pot. free	on/off	OPEN	5 s	Setpoint in sensor >1.5 bar
LS204	Lubricating oil low level, oil sump	DI	Pot. free	on/off	OPEN	5 s	
LS205	Lubricating oil high level, oil sump	DI	Pot. free	on/off	OPEN	5 s	Optional
PT301	Starting Air Pressure, Engine inlet	AI	4-20 mA	0-16 bar	< 7 > 15	15/5 s	
PT311	Control Air Pressure, Engine inlet	AI	4-20 mA	0-40 bar	< 16	5 s	
PT401	HT Water Pressure, Jacket inlet	AI	4-20 mA	0-6 bar	< 2	5 s	BL
TE401	HT Water Temperature, Jacket inlet	AI	PT100	0-160°C	< 60	5 s	
TE402	HT Water Temperature, Engine outlet	AI	PT100	0-160°C	> 105	5 s	

Code	Description	I/O type	Signal type	Range	Alarm set-point	Delay	Note
PT471	LT Water Pressure, CAC inlet	AI	4-20 mA	0-6 bar	< 2	2 s	BL
TE471	LT Water Temperature, CAC inlet	AI	PT100	0-160°C	> 55	5 s	
TE5011A-TE50X1A	Exhaust Gas Temperature, Cylinder X outlet	AI	4-20 mA	0-750°C	> 480	10 s	One sensor / cylinder. See Note 1)
TE517	Exhaust Gas Temperature, TC outlet	AI	4-20 mA	0-750°C	> 450	2 s	
PT601	Charge Air Pressure, Engine inlet	AI	4-20 mA	0-6 bar	> 3.7	25 s	
TE601	Charge Air Temperature, Engine inlet	AI	PT100	0-160°C	> 70	5 s	
ST173	Engine Speed	AI	4-20 mA	0-1200 rpm			
SE518	Turbo speed	AI	4-20 mA	0-75000 rpm	See table *13-4*	5 s	
IS875	Start Failure	DI	Pot. free	on/off	OPEN	2 s	
IS1741/ IS1742	Overspeed, shutdown	DI	Pot. free	on/off	OPEN	2 s	Setpoint in ESM: >115%
IS4011	HT-Water Temperature High, Shutdown	DI	Pot. free	on/off	OPEN	2 s	Setpoint in ESM: >110°C
IS2011	Lubricating Oil Pressure Low, Shutdown	DI	Pot. free	on/off	OPEN	2 s	Setpoint in ESM: <2.0bar
NS161	Actuator major failure, Shutdown	DI	Pot. free	on/off	OPEN	2 s	
IS7305	Emergency Stop	DI	Pot. free	on/off	OPEN	2 s	
NS881	Engine Control System Minor Alarm	DI	Pot. free	on/off	OPEN	2 s	
NS718	ESM failure	DI	Pot. free	on/off	OPEN	2 s	
NS7799-1	PDM System Supply Earth Fault	DI	Pot. free	on/off	OPEN	2 s	
NS7800-1	PDM System Supply Failure	DI	Pot. free	on/off	OPEN	2 s	
NS869	WIP Failure	DI	Pot. free	on/off	OPEN	2 s	
OS820/ NS886	Engine Control System Major Failure	DI	Pot. free	on/off	OPEN	2 s	
IS780	Alarm Blocking	DI	Pot. free	on/off	CLOSED	2 s	Blocking all alarms marked with BL

Table 13-4 Alarm setpoint for SE518 Turbo speed

Engine	TC speed high alarm
4L20	60850 rpm

Engine	TC speed high alarm
6L20	48000 rpm
8L20	41500 rpm
9L20	41500 rpm

Table 13-5 Generator to alarm system

Code	Description	I/O type	Signal type	Range	Alarm set-point	Delay	Note
TE7501	Bearing Temperature, DE	AI	PT100	0-160°C	> 85	2 s	If two bear-ing
TE7502	Bearing Temperature, NDE	AI	PT100	0-160°C	> 85	2 s	
TE7503	Winding Temperature, L1	AI	PT100	0-160°C	> 155	2 s	
TE7504	Winding Temperature, L2	AI	PT100	0-160°C	> 155	2 s	
TE7505	Winding Temperature, L3	AI	PT100	0-160°C	> 155	2 s	
TE75??	Air Temperature, Cooler Inlet	AI	PT100	0-160°C	> 75	2 s	If water cooled
LS7506	Cooling Water Leakage 1	DI	Pot. free	on/off	OPEN	2 s	If water cooled

Note 1) Alarm when exhaust gas temperature deviation >±100°C/>±50°C from average when average temperature is 250/450°C. Deviation alarm to be blocked when average temperature <250°C.

13.2.8 Control of auxiliary equipment

13.2.8.1 Pre-lubricating oil pump

The engine is equipped with an electric pre-lubricating pump.

The pre-lubricating pump is used for filling of the lubricating oil system, pre-lubricate a stopped engine before start and for pre-heating by circulating warm lubricating oil. The colder the engine is, the earlier the pump should be started before the engine is started.

The pump may also be run continuously when the engine is stopped and must run in multiple engine installations when other engines are running.

To ensure continuous pre-lubrication of a stopped engine, automatic starting and stopping of the pre-lubricating pump is recommended. This can be achieved using the pre-lubricating oil pump control output in the engine control system.

The generating sets can be supplied (option) with a pre-lubrication pump starter box. The starter is of bulkhead mount type with a starter contactor, overload protection and control system for the pump. The starters have indicating lights for power on, pump running and pump failure as well as a control switch for automatic or manual operation. The starter box can control pre-lubrication pumps of up to 4 generating sets.

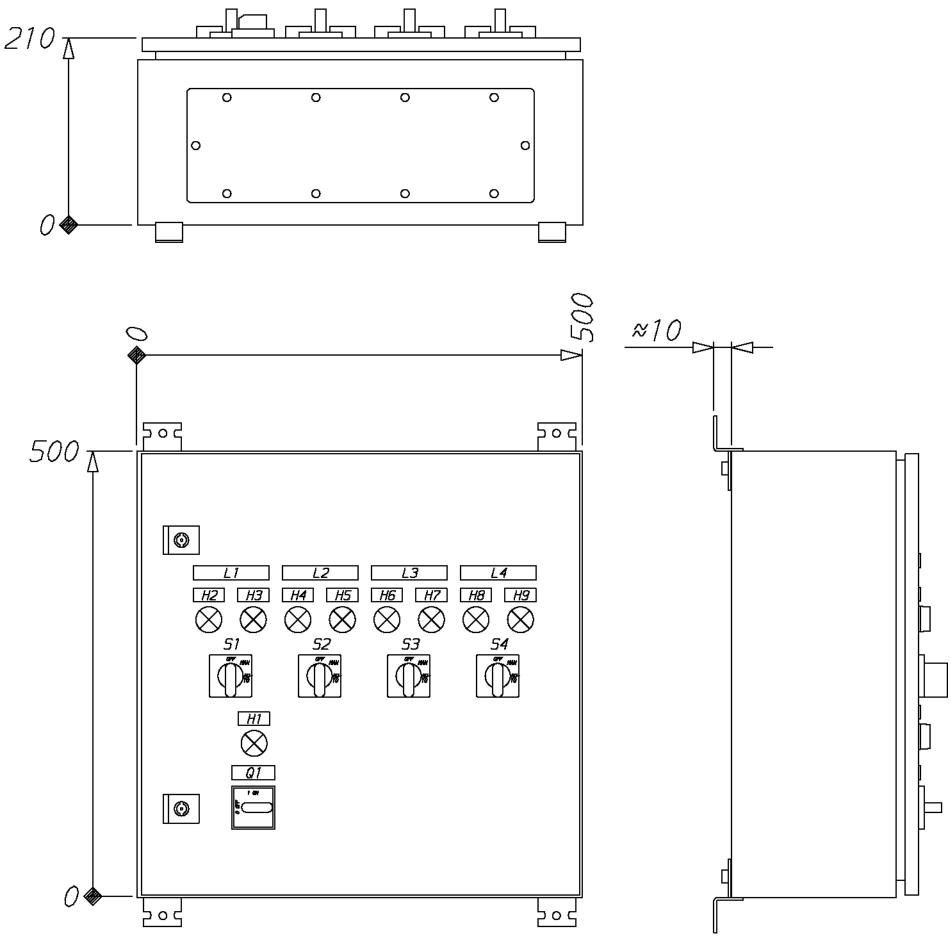


Fig 13-8 Pre-lubricating pump starter (DAAE005967A)

Technical data of pre-lubrication pumps:

WA20
400V / 50Hz 3.0kW, In = 6.0A

WA20
440V / 60Hz 3.7kW In = 6.2A

13.2.8.2 Cooling water pre-heater and circulation pump

Pre-heating is done by an electric or steam pre-heater with a required heating power depending of the engine type. The temperature control of the pre-heater should be made automatic with a control thermostat. The heater and the circulation pump should be controlled from the pre-heater control output in the engine control system. For pre-heating unit see section "*Pre-heating*" in chapter "*Cooling Water System*".

14. Generator

Auxpac generating sets are equipped with a brushless synchronous generator for marine environment. The generators are designed, built and tested according to the requirements of the marine classification societies and IEC 60034. The generators are built with a top mounted terminal box, air inlet filters and instrumentation according to table "*Generator to alarm system*" in chapter "*Automation System*".

14.1 Connection of main cables

The main power cables from the main switch gear to the generator are connected in the generator terminal box. The cable outlet can be on either side of the generator and it is directed downwards at an approximately 45°. The generator is as standard deliverd without cable glands. The glands can be supplied as an option.The terminal box has one copper bar for each phase. The copper bars are equipped with pre-drilled holes for the connection of cables.

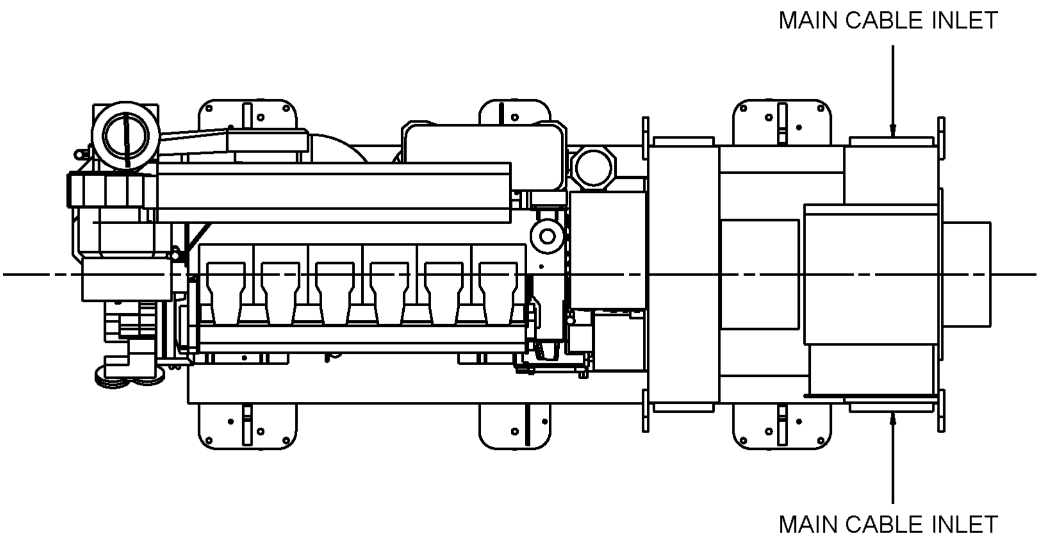


Fig 14-1 Connection of main cables (DAAE007153)

NOTE! Cable inlet on one side only

14.2 Anti condensation heater

The generators have internal heaters for avoiding condensation inside the generator. The heaters should be energised when the generating set is not running. The control of the heaters should be from the “ engine running “ signal. The rating of the heaters is according to the table.

Table 14-1 Heater size

Generating set output	Heater size	Heater voltage
1350 kWe	315 W	220 VAC
> 1950 kW		

14.3 Current transformers

The generators can be pre-installed with current transformers(CT's) for differential protection of the generator windings. All CT’s have a secondary current of 5A or 1A and have a fixed current ratio according to the enclosed table. The accuracy class of the CT´s 5P10 and max burden is 20 VA.

Table 14-2 Current transformers

900 rpm / 60 Hz		1000 rpm / 50 Hz	
Type	**Ct Ratio at 450V**	**Type**	**Ct Ratio at 400V**
520W4L20	1500/5 or 1500/1	520W4L20	1500/5 or 1500/1
645W4L20	1500/5 or 1500/1	670W4L20	2000/5 or 2000/1
760W6L20	1500/5 or 1500/1	790W6L20	2000/5 or 2000/1
875W6L20	2000/5 or 2000/1	860W6L20	2000/5 or 2000/1
975W6L20	2000/5 or 2000/1	1000W6L20	2500/5 or 2500/1
1050W6L20	2500/5 or 2500/1	1140W6L20	3000/5 or 3000/1
1200W8L20	2500/5 or 2500/1	1350W8L20	3000/5 or 3000/1
1400W8L20	3000/5 or 3000/1	1550W9L20	4000/5 or 4000/1
1600W9L20	4000/5 or 4000/1	1700W9L20	4000/5 or 4000/1

14.4 Generator cooling

14.4.1 Air cooled generators

The standard method of cooling is air cooling. With air cooling the excess heat from the generator is led out to the engine room.

The amount of heat radiated to the engine room from the generator of each generating set type can be found in the chapter Technical data.

14.4.2 Water cooled generators

The generators can optionally be installed with a built-on top mounted air to water cooler. The air circulates in a closed loop inside the generator and excess heat is transferred through the heat exchanger to the cooling water circuit.

14.5 Automatic voltage regulator (A.V.R)

The generators are equipped with a electronic automatic voltage regulator which is mounted inside the generator. The AVR uses voltage droop for basic reactive loadsharing. The droop is factory set to 3.5% at rated load.

14.5.1 Remote voltage setting

The generators are supplied with a possibility of setting the voltage remotely. The setting range is ±5% of the rated voltage of the generator.

The remote setting potentiometer is to be mounted in the main switchboard at each generator breaker section.

15. Foundation

15.1 Mounting of generating sets

Generating sets, comprising engine and generator mounted on a common base plate, are 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.

15.1.1 Seating

The seating for the common base plate must be rigid enough to carry the load from the generating set. The recommended seating design is shown in the figure below.

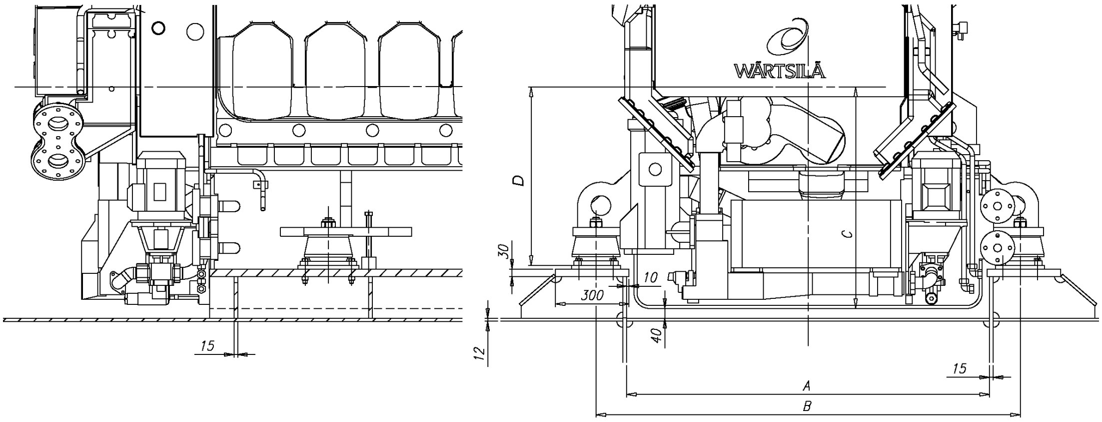


Fig 15-1 Recommended design of the generating set seating (DAAE028099B / DAAE048324)

900 rpm / 60 Hz [Dimensions in mm]					1000 rpm / 50 Hz [Dimensions in mm]				
Type	A	B	C	D 1)	Type	A	B	C	D 1)
520W4L20	1480	1730	900	725	520W4L20	1480	1730	900	725
645W4L20	1480	1730	900	725	670W4L20	1480	1730	900	725
760W6L20	1480	1730	900	725	790W6L20	1480	1730	900	725
875W6L20	1480	1730	900	725	860W6L20	1480	1730	900	725
975W6L20	1480	1730	900	725	1000W6L20	1480	1730	900	725
1050W6L20	1480	1730	900	725	1140W6L20	1480	1730	900	725
1200W8L20	1480	1730	1025	725	1350W8L20	1480	1730	1025	725
1400W8L20	1630	1880	1025	725	1550W9L20	1630	1880	1025	725
1600W9L20	1630	1880	1025	725	1700W9L20	1630	1880	1025	725
1800W6L26	1510	1750	1120	920	1950W6L26	1510	1750	1120	920
2100W8L26	1660	1910	1200	920	2250W8L26	1660	1910	1200	920
2400W8L26	1660	1910	1200	920	2550W9L26	1660	1910	1200	920
2700W9L26	1660	1910	1200	920	2850W9L26	1660	1910	1200	920

1) Approximate value for compressed mounts

15.1.2 Rubber mounts

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

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

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

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

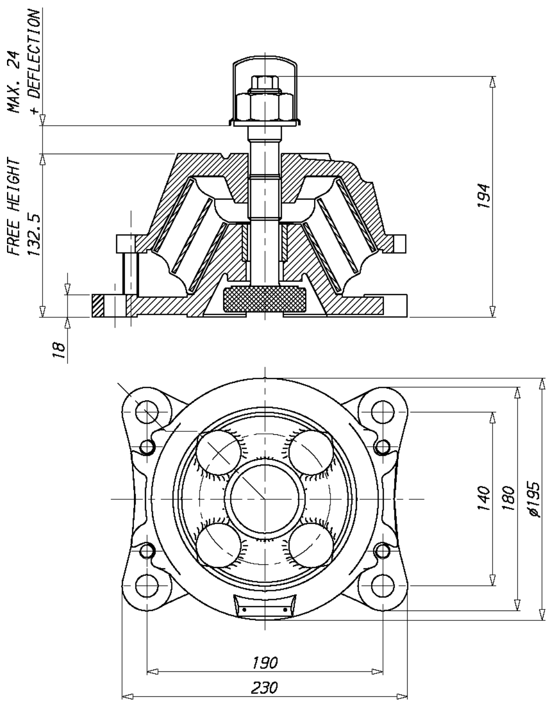


Fig 15-2 Rubber mounts W20

15.2 Flexible pipe connections

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

16. Vibration and Noise

Wärtsilä Auxpac gensets comply with vibration levels according to ISO 8528-9.

16.1 Structure borne noise

Typical structure borne noise levels above and below the resilient mounts are presented as vibration velocity in dB, reference 1x10^{-6} mm/s, per octave band.

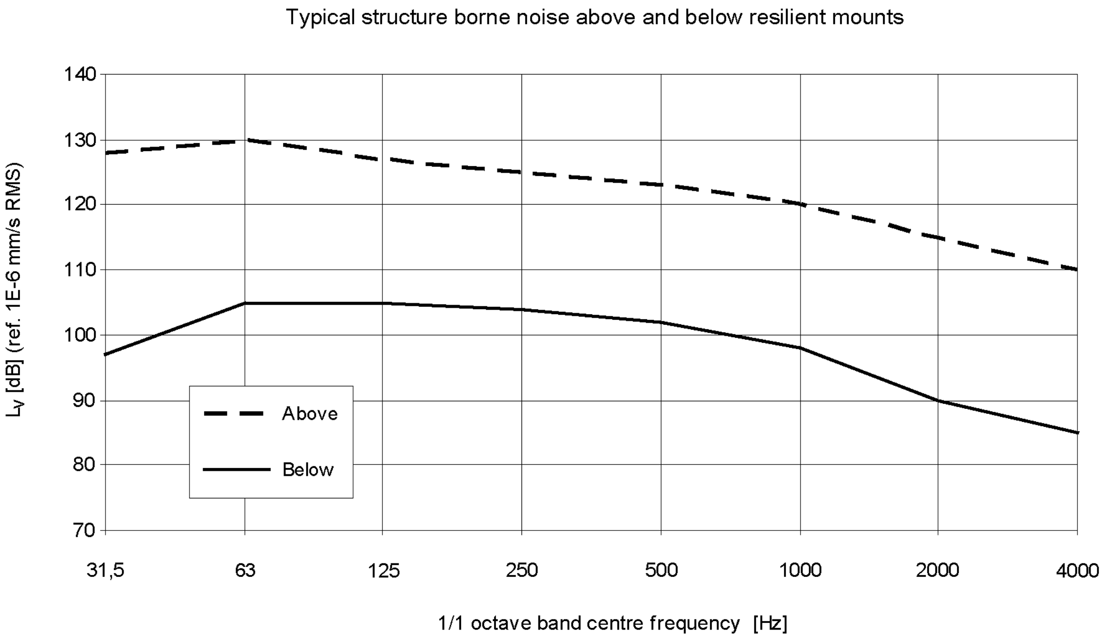


Fig 16-1 **Structure borne noise levels, WA20**

16.2 Air borne noise

Typical air borne noise is presented as sound power level in dB, reference 1x10^{-12} W, per octave band.

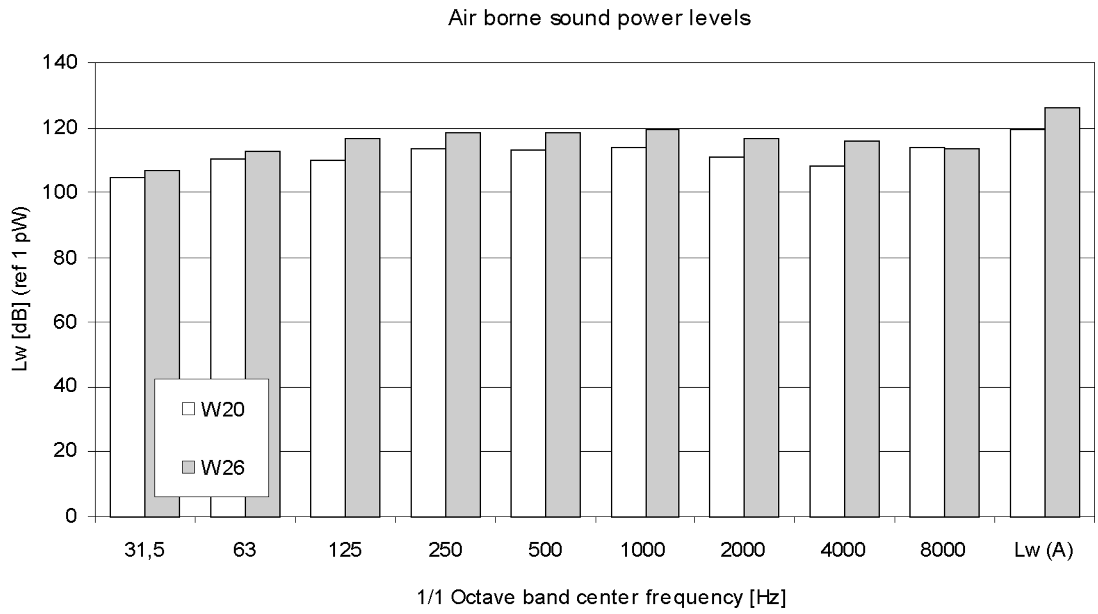


Fig 16-2 Air borne noise, WA20

Note for Lw(A):

Corresponding sound pressure level in a typical engine room is lower than 110 dB(A) when reverberation time is 1.5 second.

17. Engine Room Layout

17.1 Crankshaft distances

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

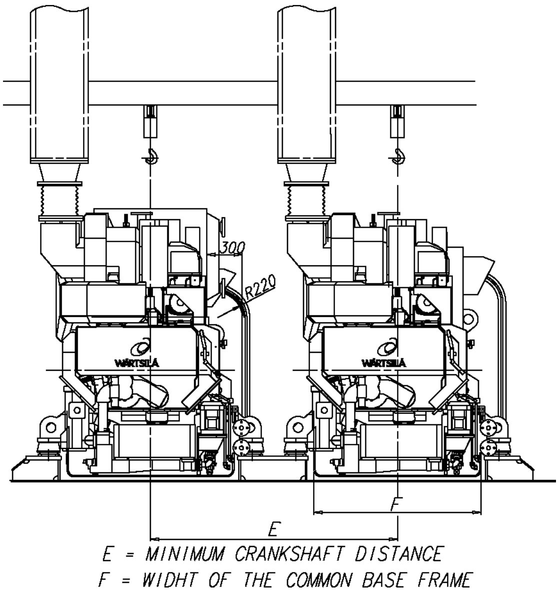


Fig 17-1 Engine room arrangement, generating sets (DAAE028722D / DAAE048494 / DAAE041961)

Engine	Air cooled generator		Water cooled generator	
	E	F	E	F
5L16	1324	1092	-	-
6L16	1324	1092	-	-
7L16	1324	1092	-	-

Engine	Air cooled generator		Water cooled generator	
	E	F	E	F
4L20	2020	1420	2500	1420
6L20	2020	1420	2600	1420
1200W8L20 1350W8L20	2020	1420	2600	1420
1400W8L20	2170	1570	3200	1570
9L20	2170	1570	3200	1570

17.2 Space requirements for maintenance

17.2.1 Working space reservation

It is recommended to reserve about one meter of free working space around the generating set.

No obstructions should be built in way of:

- Crankcase and camshaft covers
- Camshaft withdrawal space
- Engine driven pump service space
- Charge air cooler withdrawal space
- Piston overhauling height
- Turbocharger maintenance space
- Electrical junction box door

Free route for hauling parts to and from engine to be foreseen. A minimum of 1000mm free space around the genset is recommended.

See chapter "*Transport Dimensions and Weights*" for dimensions of maintenance items.

17.2.2 Lifting equipment

Engine maintenance is best served by a gantry crane.

When a gantry crane is not installed the minimum lifting requirements are:

- Longitudinal lifting rail and tackle above cylinders – rec. SWL 1000 kg
- Transverse lifting rail (in the sense of TC axis) and tackle for turbocharger overhaul, 1000 kg.

17.2.3 Maintenance platforms

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

NOTE

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

17.3 Handling of spare parts and tools

Transportation arrangement from engine room to storage and to workshop has to be prepared for heavy engine components. This can be done with several chain blocks on rails or alternatively utilising a pallet truck or a 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 the 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 from excessive vibration.

17.4 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 or the whole engine at time. Service area should be plain steel deck dimensioned to carry the weight of engine parts.

17.4.1 Service space requirements, WA16

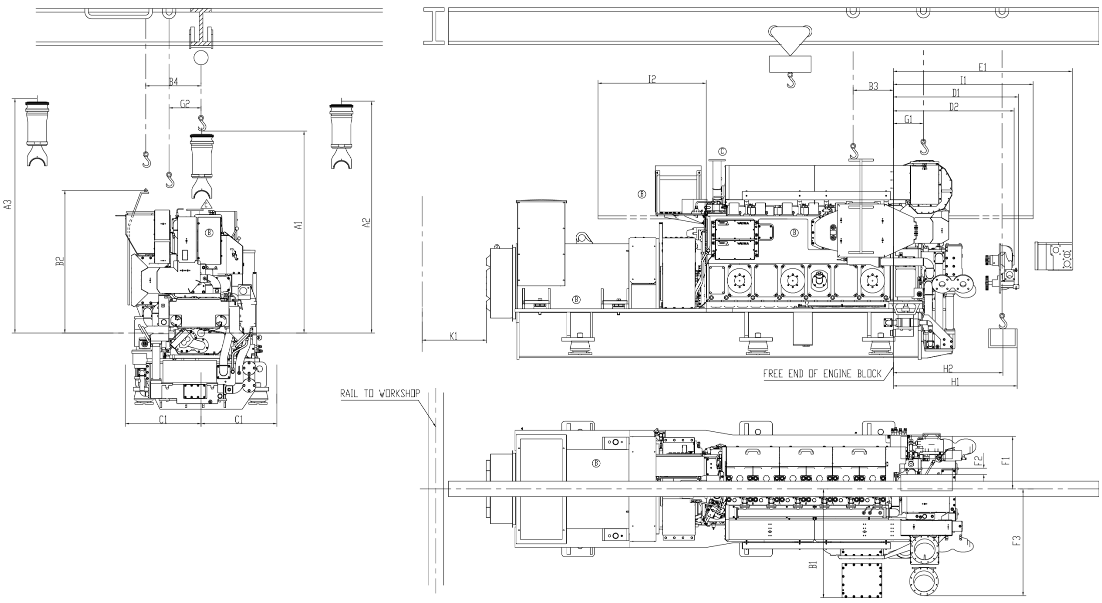


Fig 17-2 Service spaces, WA16 (DAAT000976C)

Service space in mm		5L16	6L16	7L16
A1	Height needed for overhauling piston and connecting rod	1480		
A2	Height needed for transporting piston and conn rod freely over adjacent cylinder head covers	1830		
A3	Height needed for transporting piston and conneting freely over exhaust gas insulation box	1830		
B1	Width needed for dismantling charge air cooler and air inlet box by using lifting tool	960		
B2	Height of the lifting eye for the charge air cooler lifting tool	1500		
B3	Recommended lifting point for charge air cooler lifting tool	310		360
B4	Recommended lifting point for charge air cooler lifting tool	480		
C1	Width needed for removing main bearing side screw	500		
D1	Distance needed for dismantle lubricating oil pump	850		
D2	Distance needed for dismantle water pump	570		
E1	Distance needed for dismantle water box cover	1100		
F1	The recommended axial clearance for dismantling and assembly of silencers	560		650
F2	Minimal axial clearance for dismantling and assembly of silencers	100		
F3	Recommended distance for dismantling the gas outlet elbow	770		900
G1	Recommended lifting point for the turbocharger	310		
G2	Recommended lifting point sideways for turbocharger	280		
H1	Distance needed for dismantling lubricating oil plate cooler	1050		
H2	Recommended lifting point for dismantling lubricating oil plate cooler	900		
I1	Camshaft overhaul distance (free end)	650	910	1170
I2	Camshaft overhaul distance (flywheel end)	930	1190	1450
K1	Service space for generator	500		

17.4.2 Service space requirements, WA20

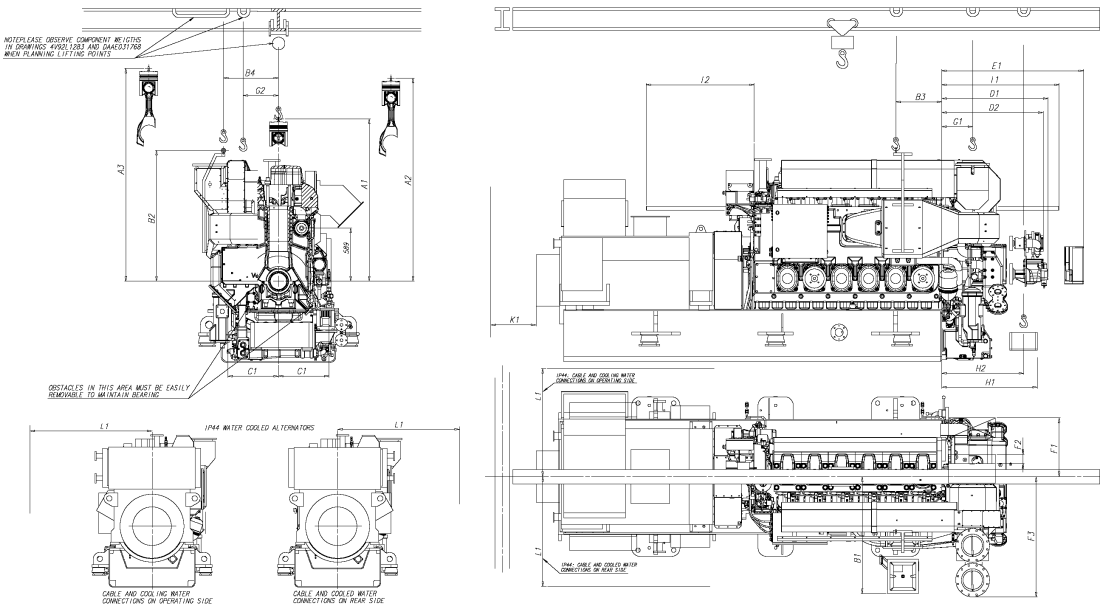


Fig 17-3 Service spaces, WA20 (DAAE031777B)

Service space in mm		4L20	6L20	8L20	9L20
A1	Height needed for overhauling piston and connecting rod	1800			
A2	Height needed to transport piston and conn rod freely over adjacent cyl head covers	2300			
A3	Height needed to transport piston and conn freely over exh gas insulation box	2230	2300	2400	
B1	Width needed for dismantling charge air cooler and air inlet box by using lifting tool	1200			
B2	Height of the lifting eye for the charge air cooler lifting tool	1580			
B3	Recommended lifting point for charge air cooler lifting tool	260	550		
B4	Recommended lifting point for charge air cooler lifting tool	560			
C1	Width needed for removing main bearing side screw	560			
D1	Distance needed for dismantle lubricating oil pump	1145			
D2	Distance needed for dismantle water pump	935			
E1	Distance needed for dismantle water box cover	750			
F1	The recommended axial clearance for dismantling and assembly of silencers	590	650	750	
F2	Minimal axial clearance for dismantling and assembly of silencers	100			
F3	Recommended distance for dismantling the gas outlet elbow	890	990	1120	
G1	Recommended lifting point for the turbocharger	350			
G2	Recommended lifting point sideways for turbocharger	320			
H1	Distance needed for dismantling lubricating oil plate cooler	1050			
H2	Recommended lifting point for dismantling lubricating oil plate cooler	900			
I1	Camshaft overhaul distance (free end)	700	1000	1300	
I2	Camshaft overhaul distance (flywheel end)	700	1000	1300	
K1	Service space for generator	500			
L1	Service space required water cooled generator	1840	1900		

18. Transport Dimensions and Weights

18.1 Lifting of WA16 genset

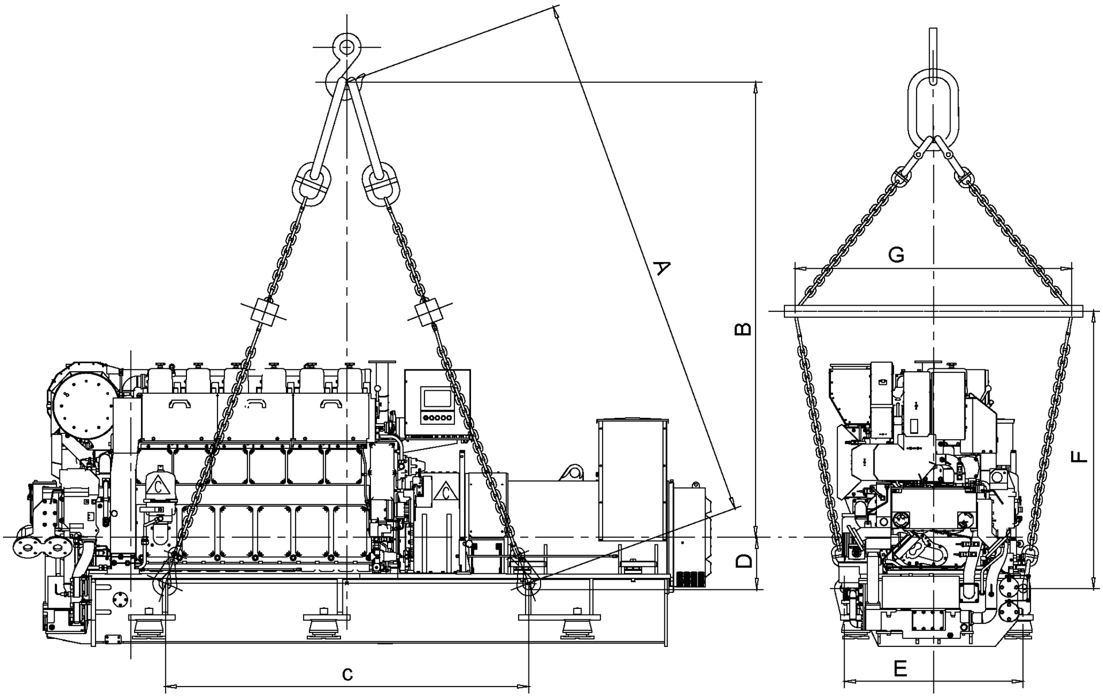


Fig 18-1 Lifting of generating set (DAAT003152C)

Table 18-1 Dimensions and weights

Engine	A [mm]	B [mm]	C [mm]	D [mm]	E [mm]	F [mm]	Weight [tons]
5L16	3900	3310	2680	350	1144	1900	9.8
6L16	3900	3260	2940	350	1144	1900	10.8
7L16	3900	3200	3200	350	1144	1900	11.8

18.2 Lifting of WA20 genset

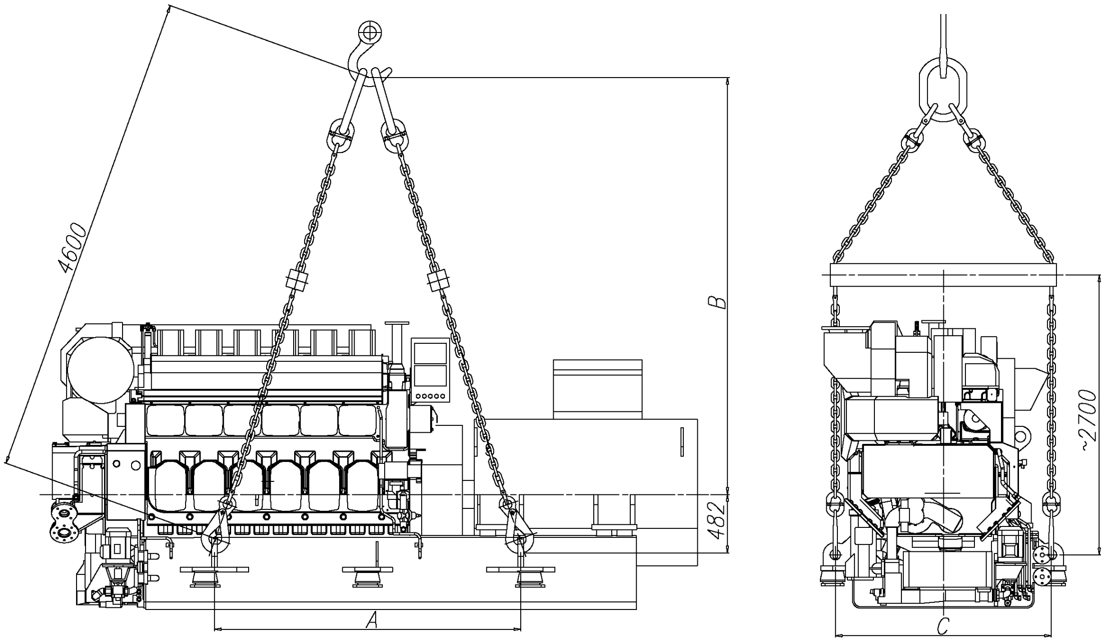


Fig 18-2 Lifting of generating set (DAAE028691D)

Type	900 rpm / 60 Hz				1000 rpm / 50 Hz				
	A		B	C	Type	A		B	C
	Air cooled	Water cooled				Air cooled	Water cooled		
520W4L20	2065	2065	4000	1690	520W4L20	2025	2025	4000	1690
645W4L20	2255	2255	4000	1690	670W4L20	2025	2025	4000	1690
760W6L20	2665	2665	3900	1690	790W6L20	2415	2415	3900	1690
875W6L20	2665	2665	3900	1690	860W6L20	2435	2435	3900	1690
975W6L20	2665	2665	3900	1690	1000W6L20	2705	2705	3900	1690
1050W6L20	2705	2705	3900	1690	1140W6L20	2705	2705	3900	1690
1200W8L20	3325	3325	3800	1690	1350W8L20	3305	3305	3800	1690
1400W8L20	3015	3015	3800	1840	1550W9L20	3405	3405	3800	1840
1600W9L20	3405	3405	3800	1840	1700W9L20	3455	3455	3800	1840

Dimensions in mm.

18.3 Major parts dimensions and weights

18.3.1 Turbocharger and cooler inserts

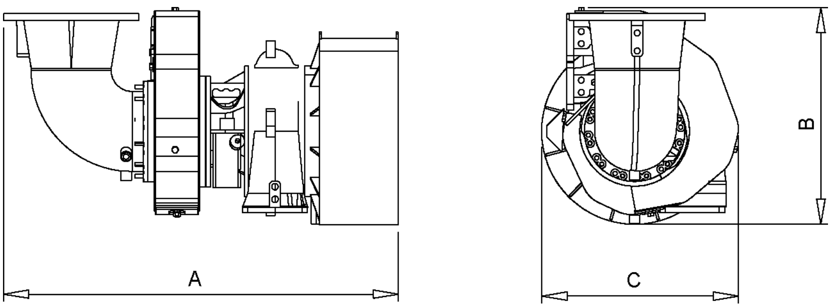


Fig 18-3 Turbocharger

Engine	A [mm]	B [mm]	C [mm]	Weight [kg]
4L20	936	536	478	160
6L20	1096	603	546	226
8L20	1357	716	666	368
9L20	1357	716	666	368

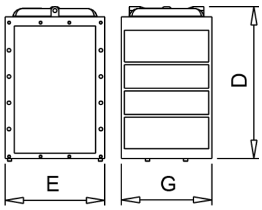


Fig 18-4 Charge air cooler

Engine	D [mm]	E [mm]	G [mm]	Weight [kg]
4L20	568	340	285	126
6L20	578	380	345	152
8L20	578	380	345	156
9L20	578	380	345	159

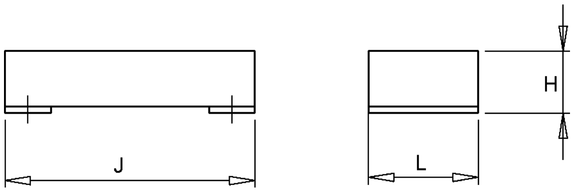


Fig 18-5 Lubricating oil cooler

Engine	H [mm]	J [mm]	L [mm]	Weight [kg]
4L20	147	694	304	45
6L20	206	694	304	59
8L20	288	694	304	80
9L20	317	694	304	86

18.3.2 Other engine parts

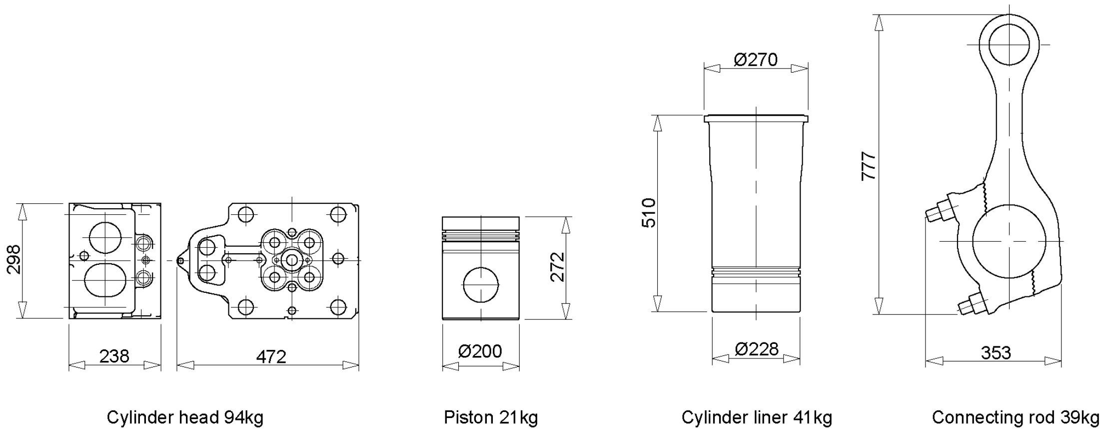


Fig 18-6 Major spare parts, WA20

19. 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.

20. ANNEX

20.1 Unit conversion tables

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

Length conversion factors

Convert from	To	Multiply by
mm	in	0.0394
mm	ft	0.00328

Mass conversion factors

Convert from	To	Multiply by
kg	lb	2.205
kg	oz	35.274

Pressure conversion factors

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

Volume conversion factors

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

Power conversion

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

Moment of inertia and torque conversion factors

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

Fuel consumption conversion factors

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

Flow conversion factors

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

Temperature conversion factors

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

Density conversion factors

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

20.1.1 Prefix

Table 20-1 The most common prefix multipliers

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

20.2 Collection of drawing symbols used in drawings

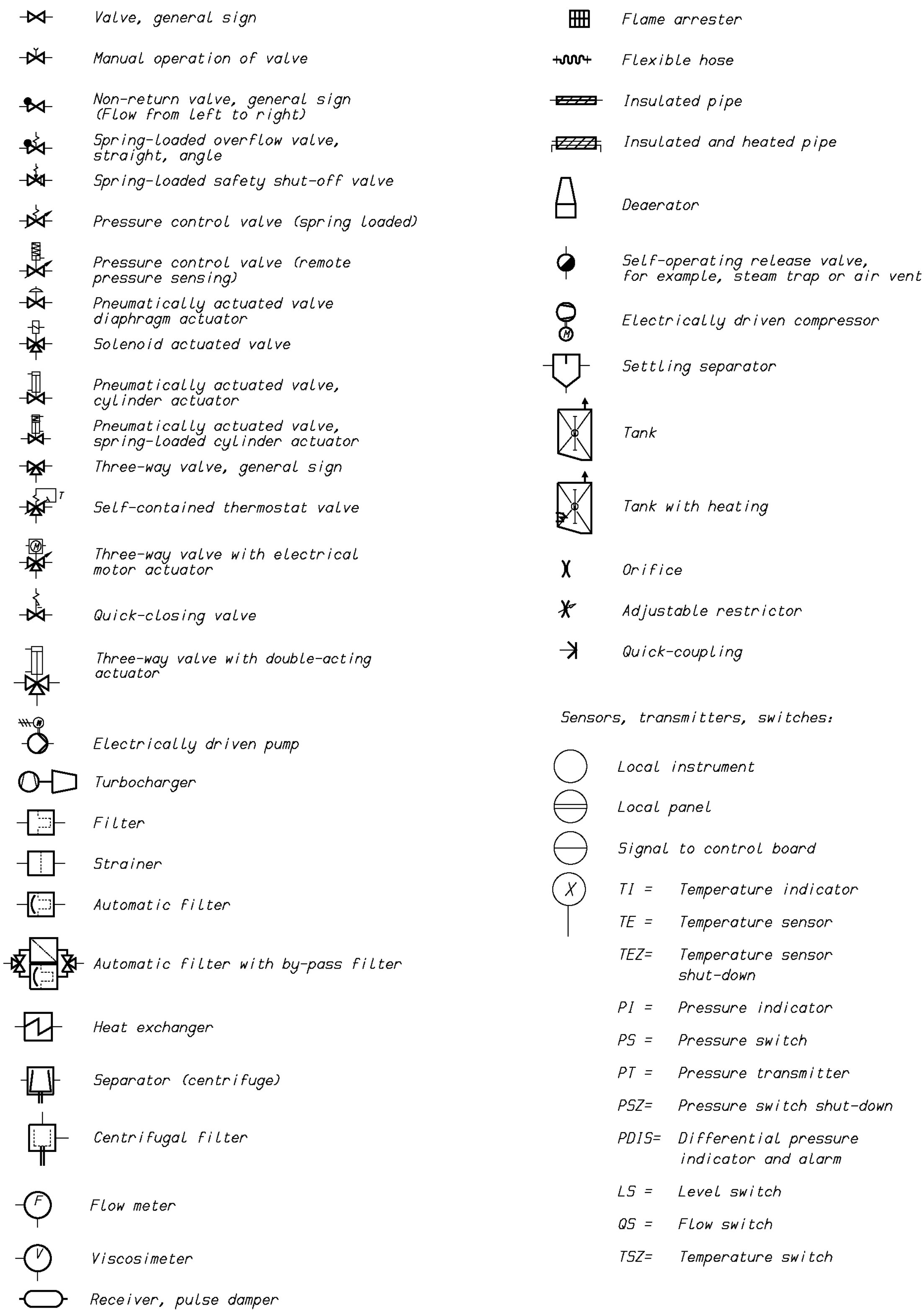
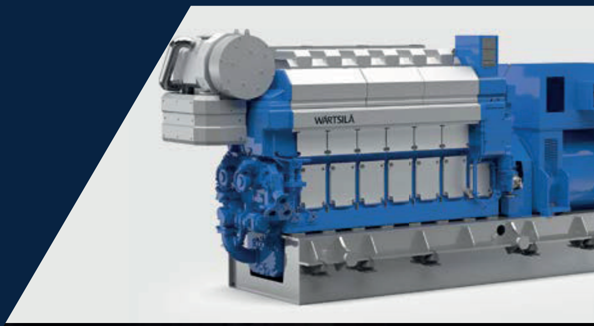


Fig 20-1 **List of symbols (DAAE000806c)**

WÄRTSILÄ



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