

# Wärtsilä 20

PRODUCT GUIDE



## © Copyright by WÄRTSILÄ FINLAND OY

All rights reserved. No part of this booklet may be reproduced or copied in any form or by any means (electronic, mechanical, graphic, photocopying, recording, taping or other information retrieval systems) without the prior written permission of the copyright owner.

THIS PUBLICATION IS DESIGNED TO PROVIDE AN ACCURATE AND AUTHORITATIVE INFORMATION WITH REGARD TO THE SUBJECT-MATTER COVERED AS WAS AVAILABLE AT THE TIME OF PRINTING. HOWEVER, THE PUBLICATION DEALS WITH COMPLICATED TECHNICAL MATTERS SUITED ONLY FOR SPECIALISTS IN THE AREA, AND THE DESIGN OF THE SUBJECT-PRODUCTS IS SUBJECT TO REGULAR IMPROVEMENTS, MODIFICATIONS AND CHANGES. CONSEQUENTLY, THE PUBLISHER AND COPYRIGHT OWNER OF THIS PUBLICATION CAN NOT ACCEPT ANY RESPONSIBILITY OR LIABILITY FOR ANY EVENTUAL ERRORS OR OMISSIONS IN THIS BOOKLET OR FOR DISCREPANCIES ARISING FROM THE FEATURES OF ANY ACTUAL ITEM IN THE RESPECTIVE PRODUCT BEING DIFFERENT FROM THOSE SHOWN IN THIS PUBLICATION. THE PUBLISHER AND COPYRIGHT OWNER SHALL UNDER NO CIRCUMSTANCES BE HELD LIABLE FOR ANY FINANCIAL CONSEQUENTIAL DAMAGES OR OTHER LOSS, OR ANY OTHER DAMAGE OR INJURY, SUFFERED BY ANY PARTY MAKING USE OF THIS PUBLICATION OR THE INFORMATION CONTAINED HEREIN.

# Introduction

This Product Guide provides data and system proposals for the early design phase of marine engine installations. For contracted projects specific instructions for planning the installation are always delivered. Any data and information herein is subject to revision without notice. This 2/2023 issue replaces all previous issues of the Wärtsilä 20 Project Guides.

Issue	Published	Updates
2/2023	20.09.2023	Principle Dimensions and weights drawing format updated. Other minor updates throughout the product guide.
1/2023	27.06.2023	Chapter Automation updated. Other minor updates throughout the product guide.
1/2021	15.08.2021	Operating field updated, other minor updates throughout the product guide.
1/2020	15.06.2020	Chapter Automation updated (UNIC 6 - series). Other minor updates throughout the product guide.
1/2019	12.07.2019	Technical data section updated, UNIC C1 added in Chapter Automation. Other minor updates throughout the product guide.
1/2018	7.11.2018	Technical data section updated (e.g. SCR, 1200 rpm and HFO Optimized engines added). Other minor updates throughout the product guide.
1/2017	14.02.2017	Technical data section updated. Other minor updates throughout the product guide.
1/2016	06.09.2016	Technical data section updated
1/2015	14.10.2015	Numerous updates throughout the product guide
1/2013	19.04.2013	Chapters Fuel Oil System and Lubrication Oil System updated with low sulphur operation, several other updates throughout the product guide.

Wärtsilä, Marine Business

Vaasa, September 2023

This page intentionally left blank

# Table of contents

<b>1. Main Data and Outputs</b> .....	<b>1-1</b>
1.1 Technical main data .....	1-1
1.2 Maximum continuous output .....	1-1
1.3 Reference conditions .....	1-3
1.4 Operation in inclined position .....	1-3
1.5 Principal dimensions and weights .....	1-4
<b>2. Operating Ranges</b> .....	<b>2-1</b>
2.1 Engine operating modes .....	2-1
2.2 Engine operating range .....	2-1
2.3 Loading capacity .....	2-11
2.4 Low load operation .....	2-15
2.5 SCR Operation .....	2-15
2.6 Low air temperature .....	2-15
<b>3. Technical Data</b> .....	<b>3-1</b>
3.1 Introduction .....	3-1
<b>4. Description of the Engine</b> .....	<b>4-1</b>
4.1 Definitions .....	4-1
4.2 Main components and systems .....	4-1
4.3 Cross section of the engine .....	4-4
4.4 Time between inspection or Overhaul & Expected Life Time .....	4-5
4.5 Engine storage .....	4-5
<b>5. Piping Design, Treatment and Installation</b> .....	<b>5-1</b>
5.1 Pipe dimensions .....	5-1
5.2 Trace heating .....	5-2
5.3 Pressure class .....	5-2
5.4 Pipe class .....	5-3
5.5 Insulation .....	5-3
5.6 Local gauges .....	5-4
5.7 Cleaning procedures .....	5-4
5.8 Flexible pipe connections .....	5-5
5.9 Clamping of pipes .....	5-7
<b>6. Fuel Oil System</b> .....	<b>6-1</b>
6.1 Acceptable fuel characteristics .....	6-1
6.2 External fuel oil system .....	6-18
<b>7. Lubricating Oil System</b> .....	<b>7-1</b>
7.1 Lubricating oil requirements .....	7-1
7.2 External lubricating oil system .....	7-3
7.3 Crankcase ventilation system .....	7-9
7.4 Flushing instructions .....	7-11
<b>8. Compressed Air System</b> .....	<b>8-1</b>
8.1 External compressed air system .....	8-1
<b>9. Cooling Water System</b> .....	<b>9-1</b>
9.1 Water quality .....	9-1
9.2 External cooling water system .....	9-4

<b>10. Combustion Air System</b> .....	<b>10-1</b>
10.1 Engine room ventilation .....	10-1
10.2 Combustion air system design .....	10-3
<b>11. Exhaust Gas System</b> .....	<b>11-1</b>
11.1 Temperature sensor location after Turbocharger .....	11-1
11.2 Exhaust gas outlet .....	11-2
11.3 External exhaust gas system .....	11-4
<b>12. Turbocharger Cleaning</b> .....	<b>12-1</b>
12.1 Turbine cleaning system .....	12-1
12.2 Compressor cleaning .....	12-2
<b>13. Exhaust Emissions</b> .....	<b>13-1</b>
13.1 Diesel engine exhaust components .....	13-1
13.2 Marine exhaust emissions legislation .....	13-2
13.3 Methods to reduce exhaust emissions .....	13-2
<b>14. Automation System</b> .....	<b>14-1</b>
14.1 W20 UNIC .....	14-1
<b>15. Foundation</b> .....	<b>15-1</b>
15.1 Steel structure design .....	15-1
15.2 Mounting of main engines .....	15-1
15.3 Mounting of generating sets .....	15-6
15.4 Flexible pipe connections .....	15-8
<b>16. Vibration and Noise</b> .....	<b>16-1</b>
16.1 External forces & couples .....	16-1
16.2 Mass moments of inertia .....	16-5
16.3 Structure borne noise .....	16-5
16.4 Air borne noise .....	16-6
16.5 Exhaust noise .....	16-7
<b>17. Power Transmission</b> .....	<b>17-1</b>
17.1 Flexible coupling .....	17-1
17.2 Clutch .....	17-2
17.3 Shaft locking device .....	17-2
17.4 Power-take-off from the free end .....	17-3
17.5 Input data for Torsional Vibration Calculation .....	17-4
17.6 Turning gear .....	17-6
<b>18. Engine Room Layout</b> .....	<b>18-1</b>
18.1 Crankshaft distances .....	18-1
18.2 Space requirements for maintenance .....	18-2
18.3 Transportation and storage of spare parts and tools .....	18-3
18.4 Required deck area for service work .....	18-3
<b>19. Transport Dimensions and Weights</b> .....	<b>19-1</b>
19.1 Lifting of engines .....	19-1
19.2 Engine components .....	19-3
<b>20. Product Guide Attachments</b> .....	<b>20-1</b>
<b>21. ANNEX</b> .....	<b>21-1</b>
21.1 Unit conversion tables .....	21-1
21.2 Collection of drawing symbols used in drawings .....	21-2

# 1. Main Data and Outputs

## 1.1 Technical main data

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

Cylinder bore .....	200 mm
Stroke .....	280 mm
Piston displacement .....	8.8 l/cyl
Number of valves .....	2 inlet valves and 2 exhaust valves
Cylinder configuration .....	4, 6, 8, 9, in-line
Direction of rotation .....	Clockwise, counterclockwise on request
Speed .....	900, 1000, 1200 rpm
Mean piston speed .....	8.4, 9.3, 11,2 m/s

## 1.2 Maximum continuous output

### 1.2.1 Rated output

The engine is available in 1200 and 1000 rpm versions for propeller propulsion and for electric propulsion 1200, 1000 and 900 rpm.

#### 1.2.1.1 Diesel electric propulsion, constant speed

Table 1-1 Output tables (kW)

Engine	1200 rpm	1000 rpm	900 rpm
4L20	-	800	740
6L20	1320	1200	1110
8L20	1760	1600	1480
9L20	1980	1800	1665

Outputs are given in kW at flywheel, including or excluding engine driven pumps, ISO 15550 - 2002 (E) conditions.

### 1.2.1.2 Mechanical controllable pitch propeller propulsion, variable speed

Table 1-2 Output tables (kW)

Engine	1200 rpm	1000 rpm
4L20	-	800
6L20	1320	1200
8L20	1760	1600
9L20	1980	1800

Outputs are given in kW at flywheel, including or excluding engine driven pumps, ISO 15550 - 2002 (E) conditions.

### 1.2.2 Rated Output - Auxiliary Engines

Table 1-3 Output tables (kW)

Engine	1200 rpm	1000 rpm	900 rpm
4L20	-	800	740
6L20	1320	1200	1110
8L20	1760	1600	1480
9L20	1980	1800	1665

Outputs are given in kW at flywheel, including or excluding engine driven pumps, ISO 15550 - 2002 (E) conditions.

The mean effective pressure  $p_e$  can be calculated as follows:

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

where:

$P_e$  = Mean effective pressure [bar]

$P$  = Output per cylinder [kW]

$n$  = Engine speed [r/min]

$D$  = Cylinder diameter [mm]

$L$  = Length of piston stroke [mm]

$c$  = Operating cycle (4)

## 1.3 Reference conditions

The output is available up to 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 available by using [Engine Online Configurator](#) available at Wärtsilä.com. The stated specific fuel oil consumption applies to engines with engine driven pumps, operating in ambient conditions according to ISO 15550:2016 (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 15550:2016 (E).

## 1.4 Operation in inclined position

The engine is designed to ensure proper engine operation at inclination positions, specified under IACS M46.2 (1982), (Rev.1 June 2002), (Rev.2 Dec 2018) - Main and auxiliary machinery.

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

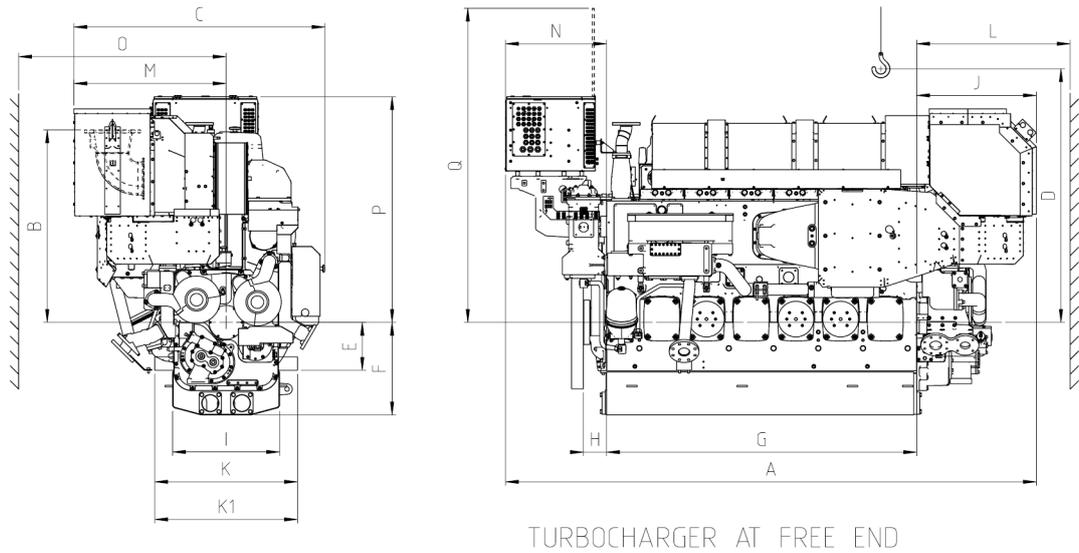
- Permanent athwart ship inclinations (list) 15°
- Temporary athwart ship inclinations (roll) 22.5°
- Permanent fore-and-aft inclinations (trim) 5°
- Temporary fore and aft inclinations (pitch) 7.5°

Inclination in all directions requires special arrangements.

### NOTE

- Athwartships and fore-end-aft inclinations may occur simultaneously
- Inclination angles are applicable ONLY to marine main and auxiliary machinery engines. Emergency power installations are not currently available
- If inclination exceeds some of the above mentioned IACS requirements, a special arrangement might be needed.

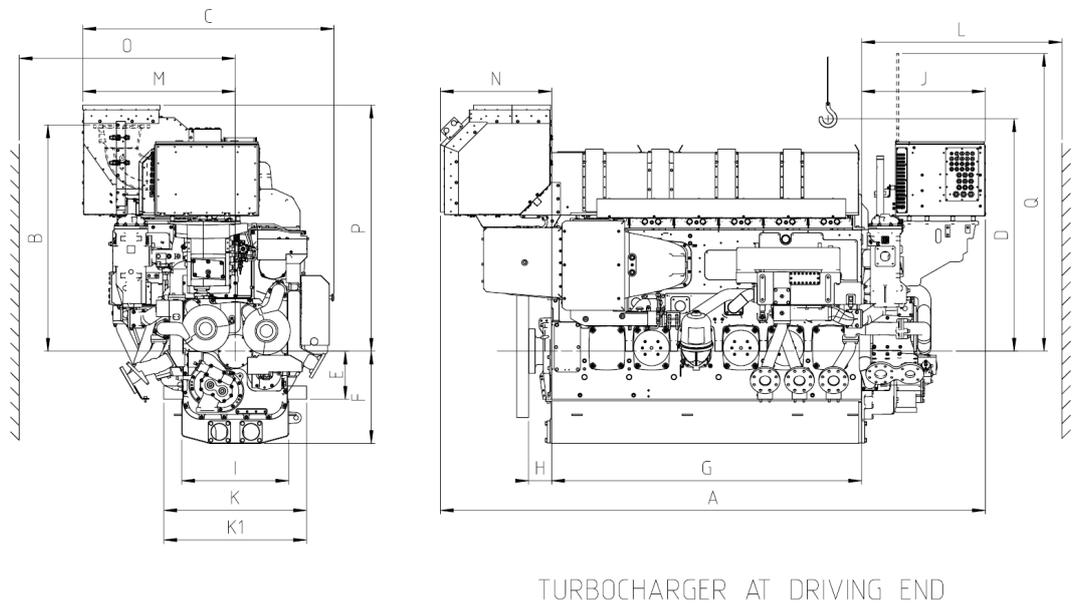
# 1.5 Principal dimensions and weights



TURBOCHARGER AT FREE END

Engine	A	B	C	D	E	F	G	H	I	J	K	K1	L	M	N	O	900/1000 rpm		1200 RPM	
																	O	P	O	P
4L20	2960	1168	1817 Cl 1584	1800	325	725	1480	155	718	803	980	114.0	700	920	680	1200	1320	1522	2119	
6L20	3560	1297	1830 Cl 1584	1800	325	824 D1 824 D2 824	2080	155	718	803	980	114.0	1000	1021	680	1200	1320	1522	2119	
8L20	4242	1390	1811 Cl 1817	1800	325	824 D1 824 D2 824	2680	155	718	885	980	114.0	1300	1153	680	1200	1320	1522	2119	
9L20	4542	1390	1811 Cl 1817	1800	325	824 D1 824 D2 824	2680	155	718	885	980	114.0	1300	1153	680	1200	1320	1522	2119	

**Fig 1-1 Main Engines (DAAE060842E-1)**



TURBOCHARGER AT DRIVING END

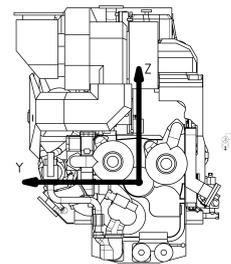
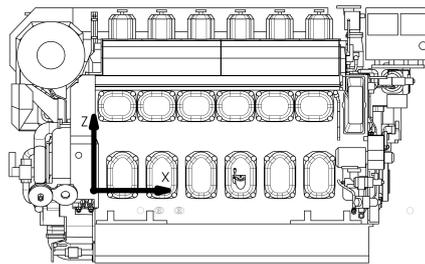
Engine	A	B	C	D	E	F	G	H	I	J	K	K1	L	M	N	O	900/1000 rpm		1200 rpm	
																	O	P	O	P
6L20	3656	1528	1831 Cl 1686	1800	325	824 D1 824 D2 824	2080	155	718	830	980	114.0	1000	1023	746	1200	1320	1662	2012	
8L20	4339	1614	1814 Cl 1814	1800	325	824 D1 824 D2 824	2680	155	718	830	980	114.0	1300	1196	829	1200	1320	1728	2012	
9L20	4639	1614	1814 Cl 1814	1800	325	824 D1 824 D2 824	2980	155	718	830	980	114.0	1300	1196	829	1200	1320	1728	2012	

**Fig 1-2 Main Engines (DAAE060842E-2)**

A	TOTAL LENGTH OF THE ENGINE
B	HEIGHT FROM THE CRANKSHAFT CENTERLINE TO THE EXHAUST GAS OUTLET
C	TOTAL WIDTH OF THE ENGINE
D	MINIMUM HEIGHT WHEN REMOVING A PISTON
E	HEIGHT FROM THE CRANKSHAFT CENTERLINE TO THE ENGINE FEET
F	DIMENSION FROM THE CRANKSHAFT CENTERLINE TO THE BOTTOM OF OIL SUMP
G	LENGTH OF THE ENGINE BLOCK
H	DIMENSION FROM THE END OF THE ENGINE BLOCK TO MOUNTING FACE FOR FLYWHEEL
I	WIDTH OF THE OIL SUMP
J	FROM ENGINE BLOCK TO THE OUTERMOST FREE END
K	WIDTH OF THE ENGINE AT THE ENGINE FEET, FIXED MOUNTING
K1	WIDTH OF THE ENGINE AT THE ENGINE FEET, FLEXIBLE MOUNTING
L	CAMSHAFT OVERHAUL DISTANCE
M	DIMENSION FROM CENTER OF CRANKSHAFT TO OUTERMOST PART ON BACK SIDE OF ENGINE
N	FROM ENGINE BLOCK TO THE OUTMOST PART AT THE FLYWHEEL END
O	CHARGE AIR COOLER OVERHAUL DISTANCE
P	CRANKSHAFT CENTER TO TOP OF ENGINE
Q	CRANKSHAFT CENTER TO CONNECTION BOX DOOR

- 1) Auxiliary engine (normal sump)
- 2) Main engine (deep sump)
- 3) HFO fuel
- 4) LFO fuel

Fig 1-3 Main Engines (DAAE060842E table)



Unic C1 / Unic C2 AUTOMATION SYSTEM

Moottori-tyyppi ENGINE TYPE	Turboahdin sijainti TURBOCHARGER LOCATION	Kuvapaino DRY WEIGHT kg (average)	Nesteden massa WEIGHT OF LIQUIDS Öljy + jäähdytysvesi OIL + COOLING WATER kg (approx.)	Massakeskipiste CENTRE OF GRAVITY			
				X (mm)	Y (mm)	Z (mm)	
4L20LF	Free end	6600	With dry sump, running condition Wet sump	100 400	632	77	341
6L20LF	Free end	8100	With dry sump, running condition Wet sump	135 465	900	76	341
6L20LD	Driving end	8500	Deep sump	645	987	78	341
8L20LF	Free end	10300	With dry sump, running condition Wet sump	145 585	1186	76	341
8L20LD	Driving end	10400	Deep sump	825	1329	77	341
9L20LF	Free end	11100	With dry sump, running condition Wet sump	165 660	1333	70	341
9L20LD	Driving end	10900	Deep sump	925	1480	83	341

Weights are approx. and should be used only for guidance. Weights may vary due to the following reasons:

- Turbocharger type / brand
- Turbocharger with silencer or suction air pipe
- Oil sump type to wet or deep
- Pre-lubrication pump electric motor type
- With / without engine driven fuel pump
- Casting variations

Estimated tolerance for the weight: +2.5%

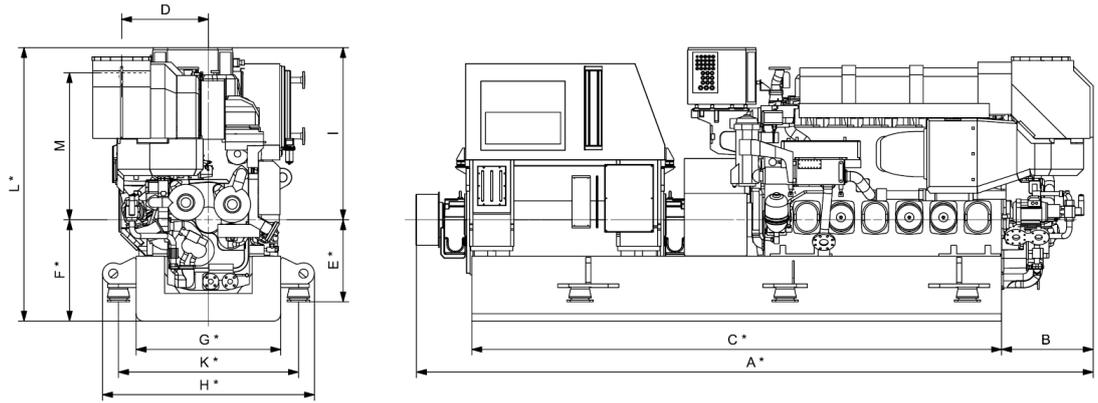
\*Values from old FEM analyses

\*\*Values calculated from engines with Unic C2 automation system

\*\* UNIC 6-SERIES AUTOMATION SYSTEM

Moottori-tyyppi ENGINE TYPE	Turboahdin sijainti TURBOCHARGER LOCATION	Kuvapaino DRY WEIGHT kg (average)	Nesteden massa WEIGHT OF LIQUIDS Öljy + jäähdytysvesi OIL + COOLING WATER kg (approx.)	Massakeskipiste CENTRE OF GRAVITY			
				X (mm)	Y (mm)	Z (mm)	
4L20LF	Free end	6800	With dry sump, running condition Wet sump	100 400	658	77	352
6L20LF	Free end	8300	With dry sump, running condition Wet sump	115 465	926	77	350
6L20LD	Driving end	8700	Deep sump	645	966	82	348
8L20LF	Free end	10500	With dry sump, running condition Wet sump	145 585	1211	77	348
8L20LD	Driving end	10600	Deep sump	825	1307	80	347
9L20LF	Free end	11300	With dry sump, running condition Wet sump	165 660	1358	71	348
9L20LD	Driving end	11100	Deep sump	925	1457	83	346

Fig 1-4 Engine Weight & Center of Gravity (V92E0066H)



ENGINE TYPE	A*	B	C*	D*	E*	F*	G*	H*	I	K*	L*	M	WEIGHT (ton)*
4L20	5000	803	4000	695	725	895	1270 1420	1860 1960	1522	1580 1730	2417	1207	15,0
6L20	5800	803	4600	762	725	895	1270 1420	1960 2090	1522	1580 1730	2417	1298	18,0
8L20	6700	885	5400	863	725	1025	1420 1570	2010 2110	1522	1730 1880	2547	1390	23,0
9L20	7000	885	5700	863	725	1025	1420 1570	2010 2110	1522	1730 1880	2547	1390	25,0

\* DEPENDENT ON GENERATOR TYPE AND SIZE:  
 -WIDTH  
 -LENGTH  
 -HEIGHT  
 -WEIGHT (air or water cooled)

**Fig 1-5 Generating sets (DAAF599197)**

**NOTE**

Generating set dimensions (DAAF599197) shown above are for reference ONLY.



Most current **2D** drawings and **3D** models of Engines and Gensets are available at [www.wartsila.com](http://www.wartsila.com) and all dimensions and weights shown above are for reference only.

## 2. Operating Ranges

### 2.1 Engine operating modes

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

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

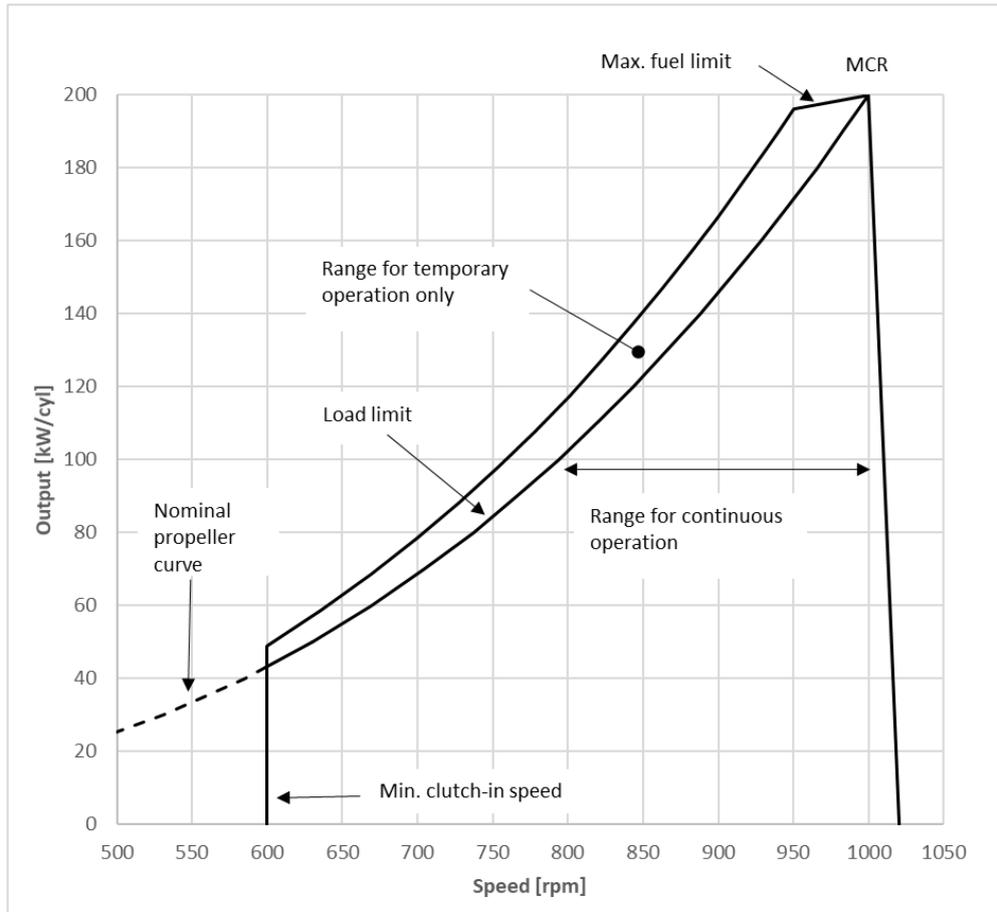
### 2.2 Engine operating range

Running below nominal speed the load must be limited according to the diagrams in this chapter in order to maintain engine operating parameters within acceptable limits. Minimum speed is indicated in the diagram, but project specific limitations may apply.

#### 2.2.1 Controllable pitch propellers

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

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

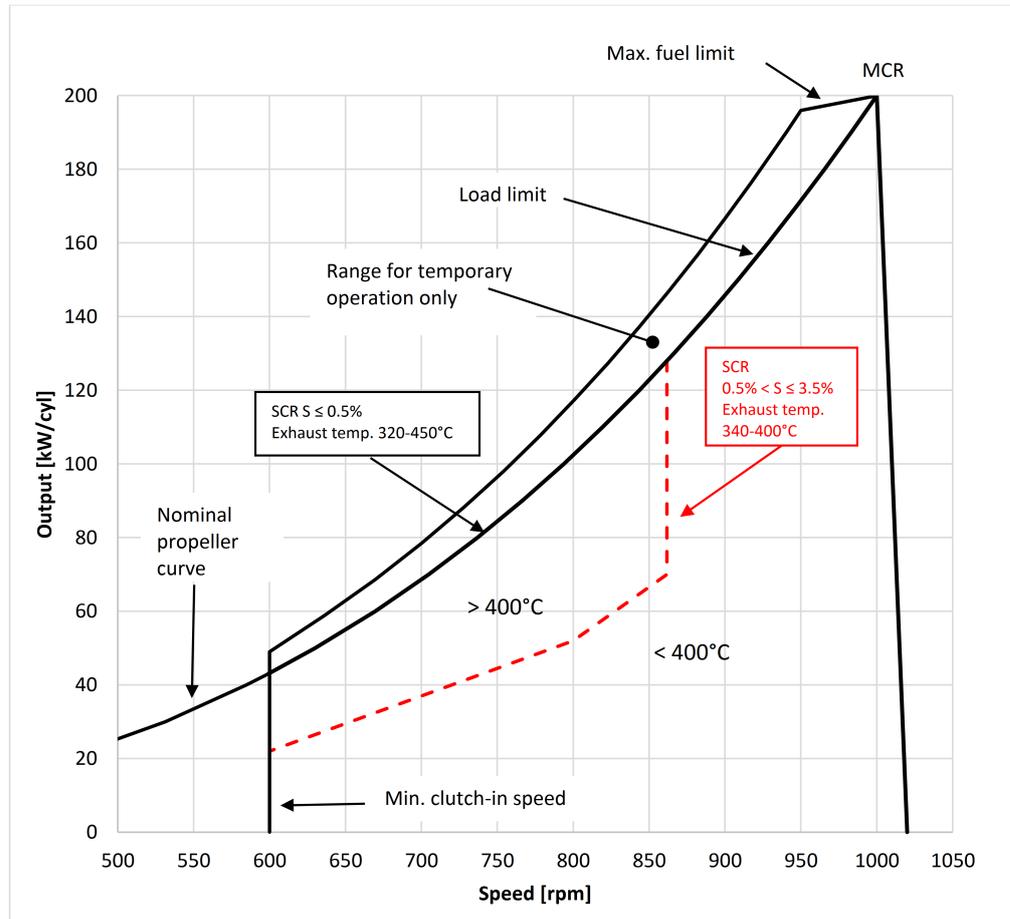


Rated output = 200 kW/cyl at 1000 rpm  
MCR = Maximum Continuous Rating

**Fig 2-1 Operating field - CP Propeller 1000 rpm, no restriction on sulphur content if without SCR, or S<0.5% with SCR (DAAF007339D)**

Wärtsilä 20 **6L and 9L** 1000rpm

Operating field for CPP SCR with sulphur content  $0,5\% < S \leq 3,5\%$  and  $S \leq 0,5\%$   
 Allowed for SCR W20 at  $0 - +45\text{ }^\circ\text{C}$  suction air temperature.

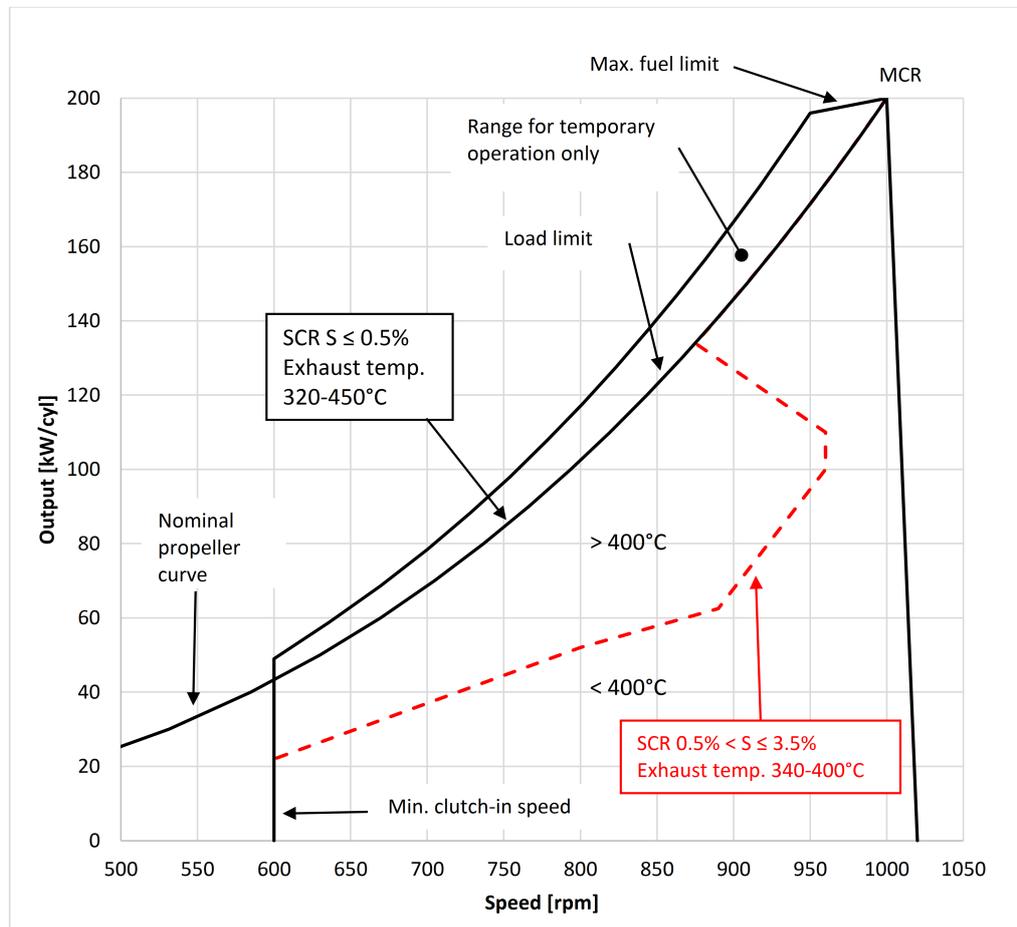


Rated output = 200 kW/cyl at 1000 rpm  
 MCR = Maximum Continuous Rating  
 SCR = Selective Catalytic Reduction

**Fig 2-2 Operating field - CP Propeller 1000 rpm SCR with sulphur content  $0,5\% < S \leq 3,5\%$  and  $S \leq 0,5\%$  (DAAF360481E - 1)**

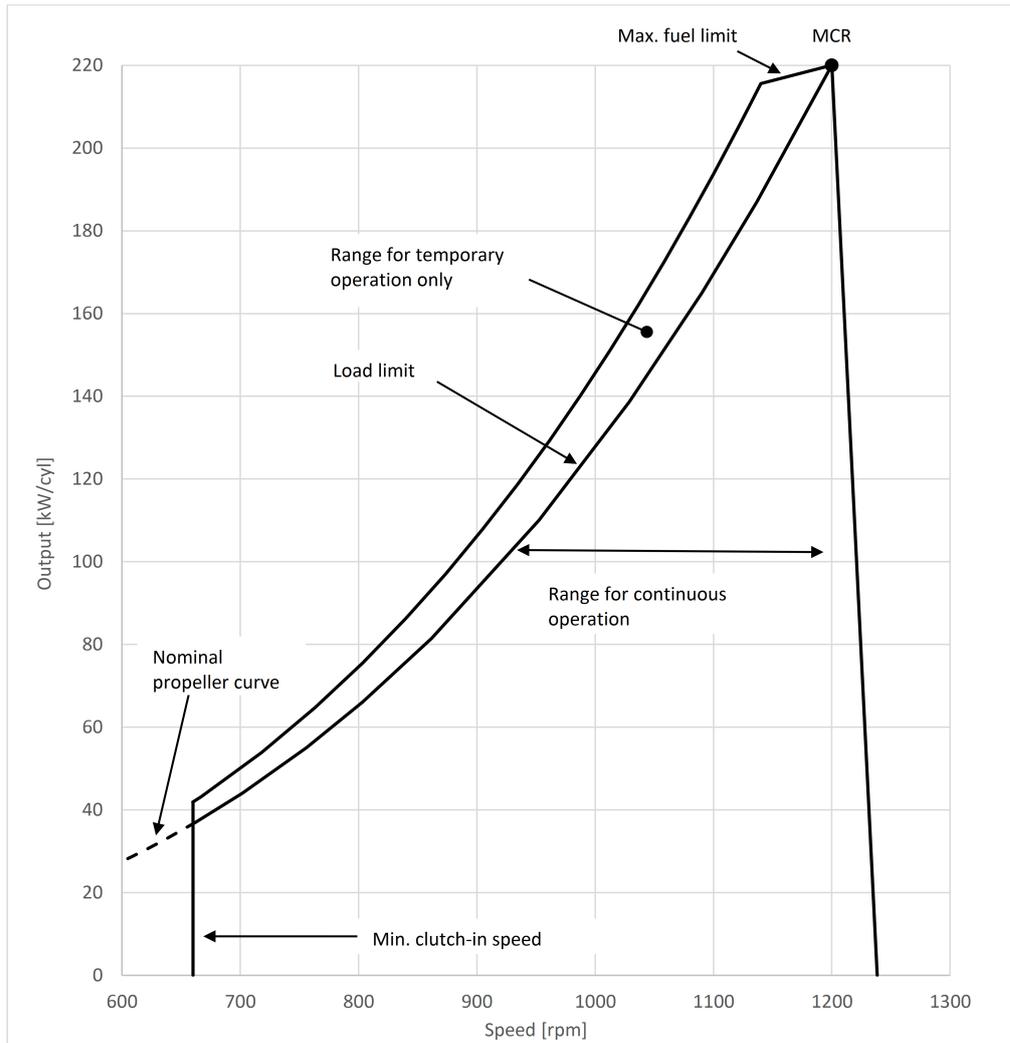
Wärtsilä 20 **4L and 8L** 1000rpm

Operating field for CPP SCR with sulphur content  $0,5\% < S \leq 3,5\%$  and  $S \leq 0,5\%$   
 Allowed for SCR W20 at 0 - +45 °C suction air temperature.



Rated output = 200 kW/cyl at 1000 rpm  
 MCR = Maximum Continuous Rating  
 SCR = Selective Catalytic Reduction

**Fig 2-3 Operating field - CP Propeller 1000 rpm SCR with sulphur content  $0,5\% < S \leq 3,5\%$  and  $S \leq 0,5\%$  (DAAF360481E - 2)**



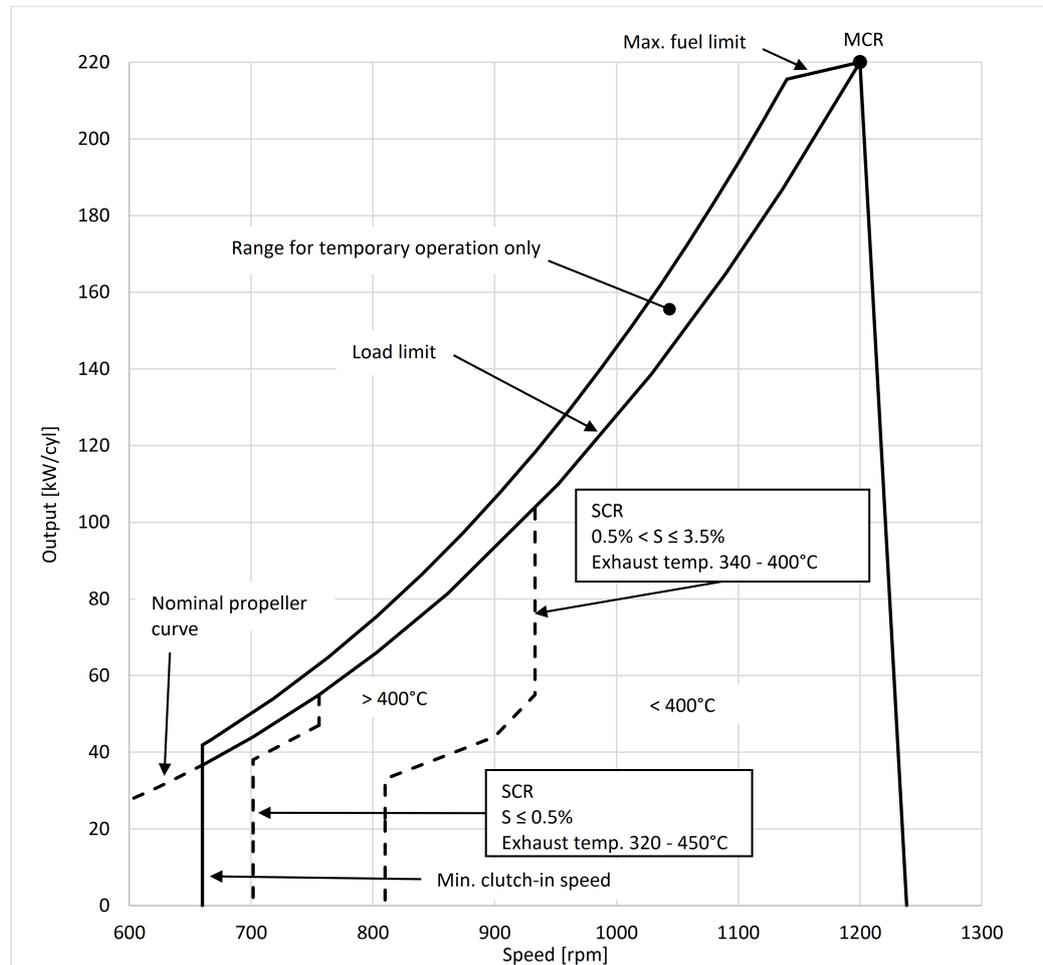
Rated output = 220 kW/cyl at 1200 rpm  
 MCR = Maximum Continuous Rating

**Fig 2-4 Operating field - CP Propeller 1200 rpm (DAAF437248B)**

Wärtsilä 20, 1200rpm

Operating field for CPP SCR with sulphur content  $S \leq 0,5\%$  and  $0,5\% < S \leq 3,5\%$

Allowed for SCR W20 at  $-25 - +45\text{ }^{\circ}\text{C}$  suction air temperature.



Rated output = 220 kW/cyl at 1200 rpm  
MCR = Maximum Continuous Rating  
SCR = Selective Catalytic Reduction

**Fig 2-5 Operating field - CP Propeller 1200 rpm SCR with sulphur content  $0,5\% < S \leq 3,5\%$  and  $S \leq 0,5\%$  (DAAF424192C)**

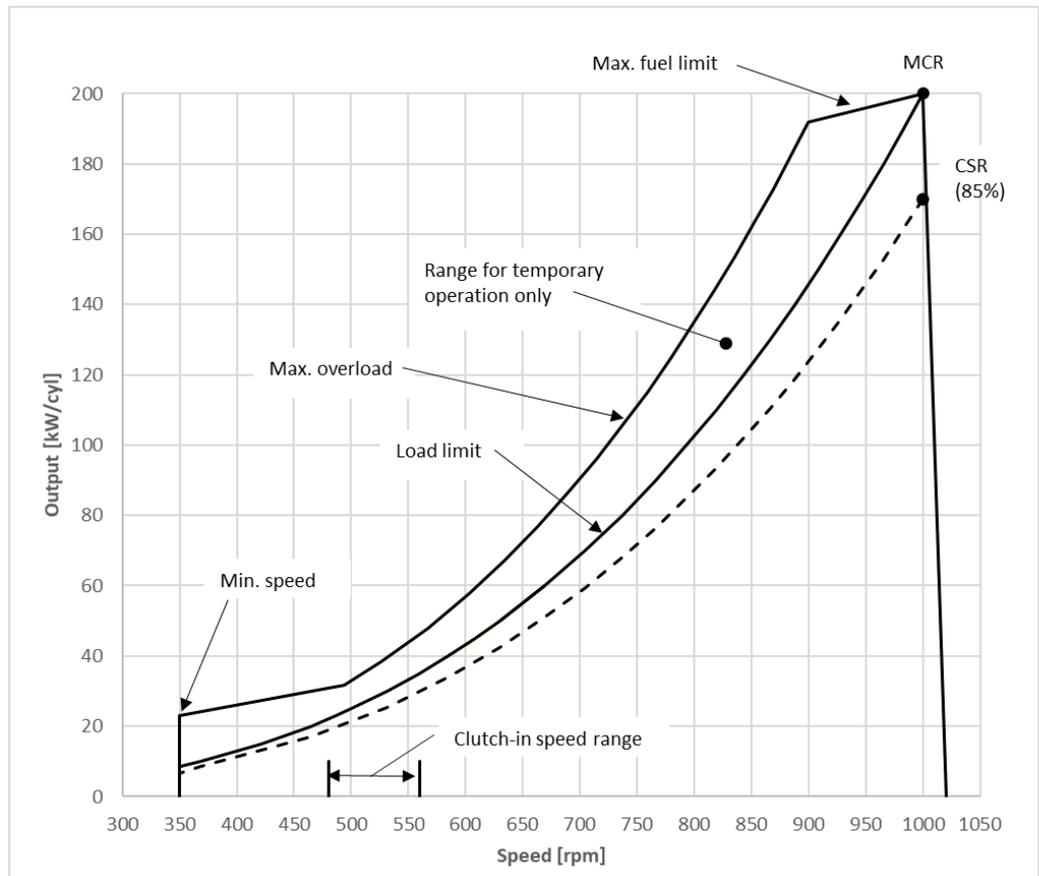
## 2.2.2 Fixed pitch propellers

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

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

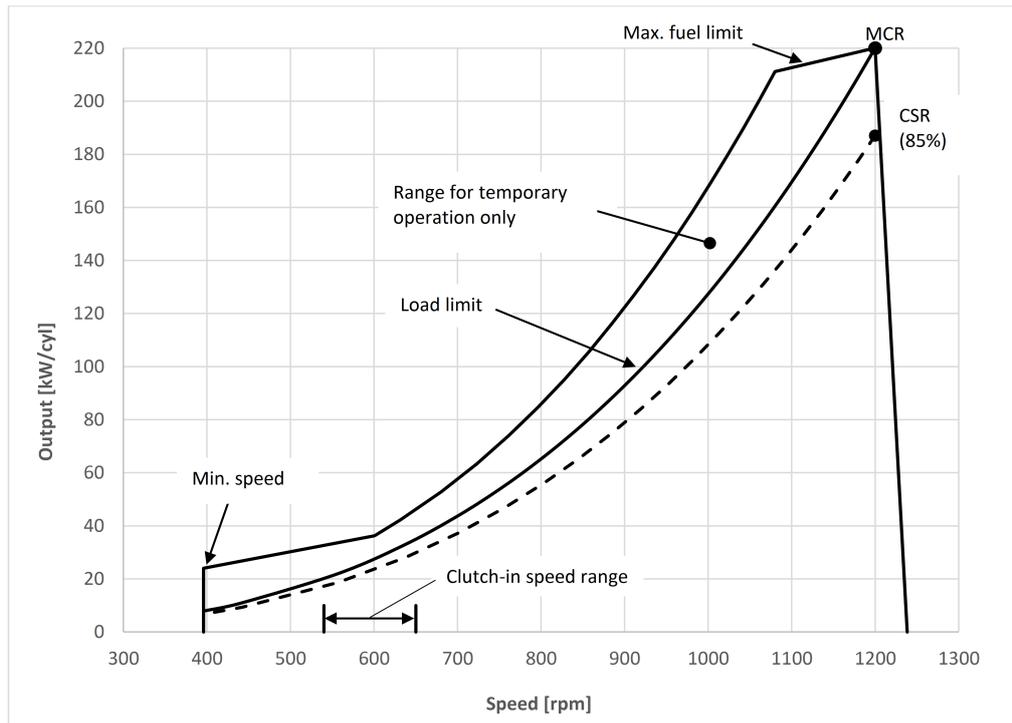
If the vessel is intended for towing, the propeller is dimensioned to absorb 95% of the engine power at nominal engine speed in bollard pull or towing condition. It is allowed to increase the engine speed to 101.7% in order to reach 100% MCR during bollard pull.

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



Rated output = 200 kW/cyl at 1000 rpm  
 MCR = Maximum Continuous Rating  
 CSR = Continuous Service Rating

**Fig 2-6 Operating field - FP Propeller 1000 rpm, rated output 200 kW/cyl (DAAF007340D)**



Rated output = 220 kW/cyl at 1200 rpm  
MCR = Maximum Continuous Rating  
CSR = Continuous Service Rating

**Fig 2-7 Operating field - FP Propeller 1200 rpm, rated output 220 kW/cyl (DAAF437249B)**

MCR = Maximum Continuous Rating

CSR = Continuous Service Rating

### 2.2.2.1 FP propellers in twin screw vessels

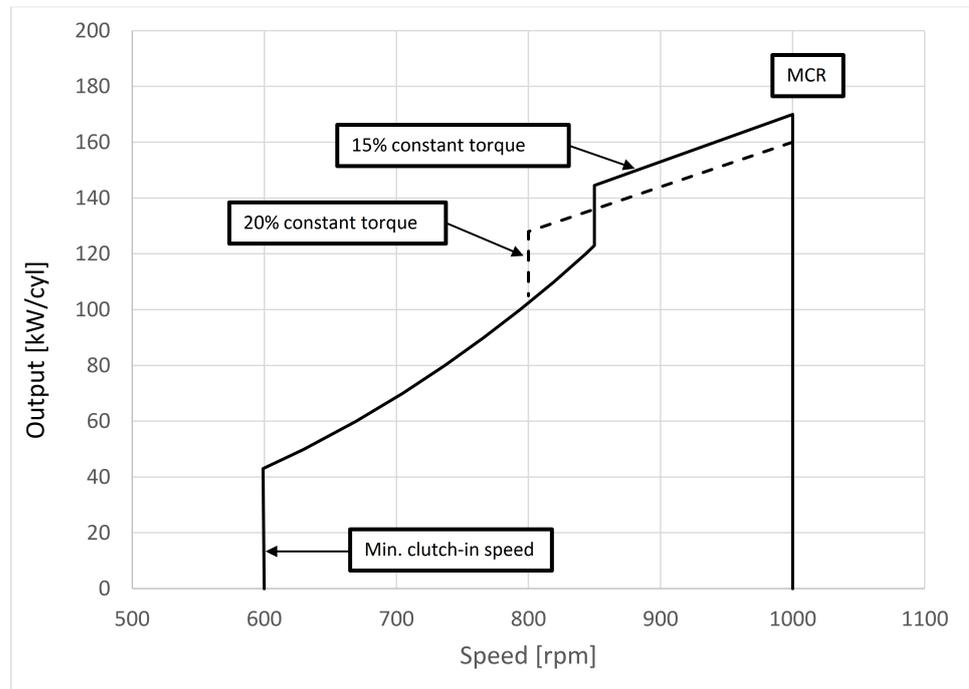
Requirements regarding manoeuvring response and acceleration, as well as overload with one engine out of operation must be very carefully evaluated if the vessel is designed for free sailing, in particular if open propellers are applied. If the bollard pull curve significantly exceeds the maximum overload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

### 2.2.3 Dredgers

Mechanically driven dredging pumps typically require a capability to operate with full torque down to 80% or 85% of nominal engine speed. This requirement results in significant de-rating of the engine.

**W20 Pump drive 1000rpm operating field**

Allowed for W20 at +45°C suction air temperature.

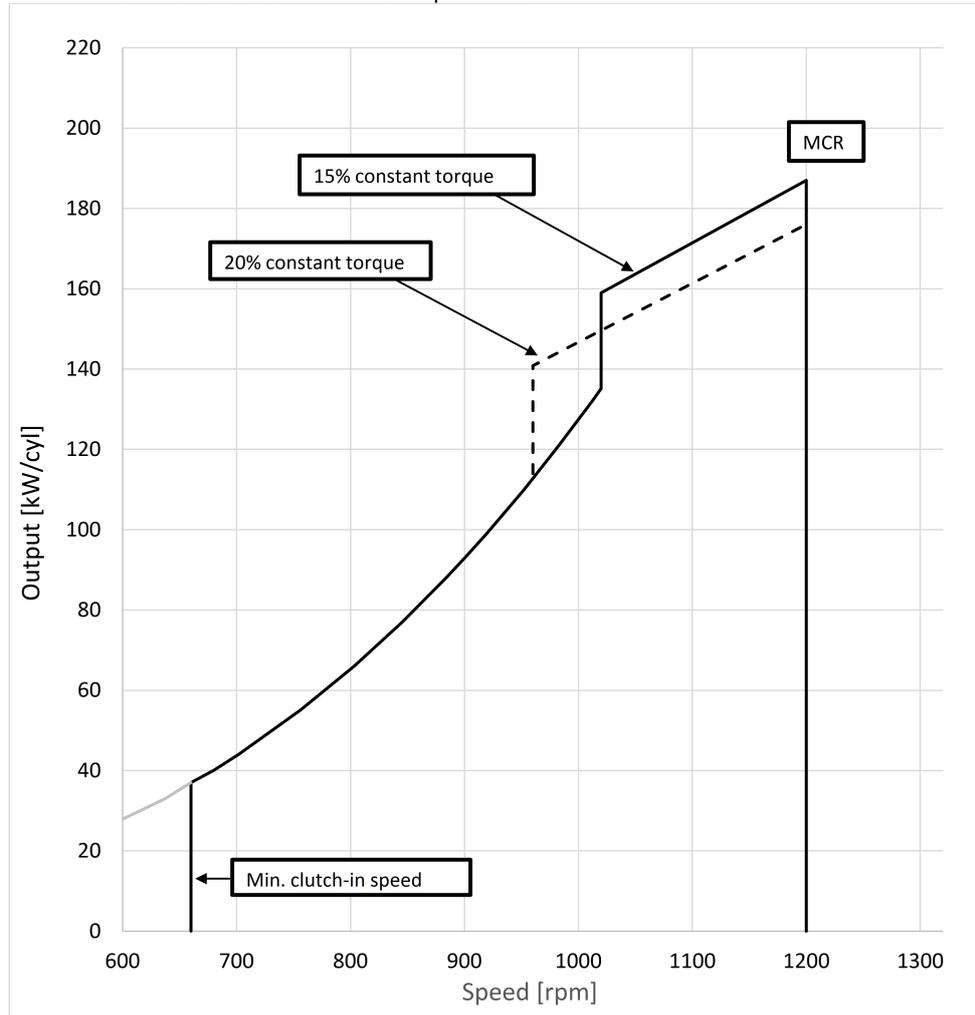


Rated outputs = 170 kW/cyl at 15% constant torque and 160 kW/cyl at 20% constant torque  
 MCR = Maximum Continuous Rating

**Fig 2-8 Operating field - Pump Drive, 1000rpm (DAAF481715)**

**W20 Pump drive 1200rpm operating field**

Allowed for W20 at +45°C suction air temperature.

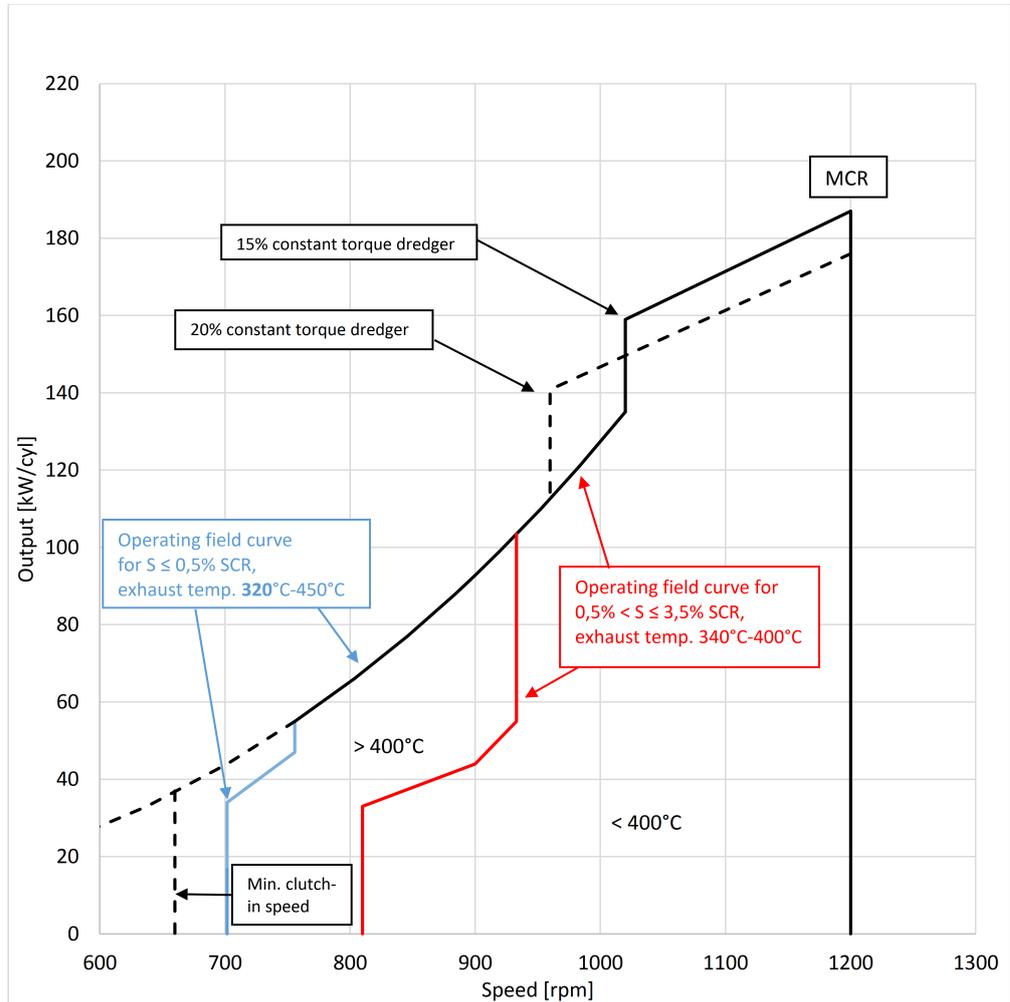


Rated outputs = 187 kW/cyl at 15% constant torque and 176 kW/cyl at 20% constant torque  
 MCR = Maximum Continuous Rating

**Fig 2-9 Operating field - Pump Drive, 1200rpm (DAAF481713)**

Wärtsilä 20 Dredger, 1200rpm  
 Operating field for SCR with sulphur content  $S \leq 0,5\%$  and  $0,5\% < S \leq 3,5\%$

Allowed for SCR at 0 - +45 °C suction air temperature.



Rated outputs = 187 kW/cyl at 15% constant torque and 176 kW/cyl at 20% constant torque  
 MCR = Maximum Continuous Rating  
 SCR = Selective Catalytic Reduction

**Fig 2-10 Operating field - Pump Drive, 1200 rpm SCR with sulphur content  $0,5\% < S \leq 3,5\%$  and  $S \leq 0,5\%$  (DAAF481714B)**

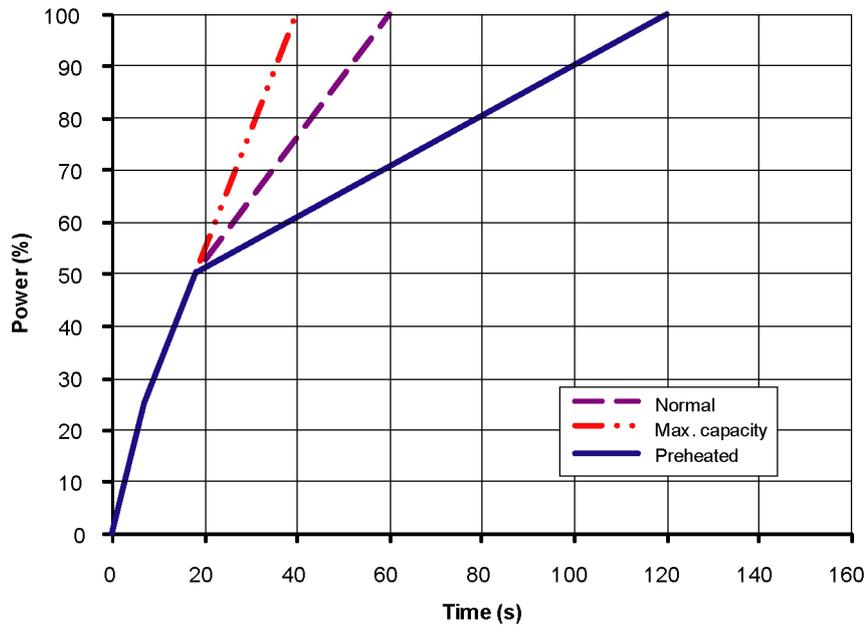
## 2.3 Loading capacity

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

The engine can be loaded immediately after start, provided that the engine is pre-heated to a HT-water temperature of 60...70°C, and the lubricating oil temperature of 30...40 °C.

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

## 2.3.1 Mechanical propulsion



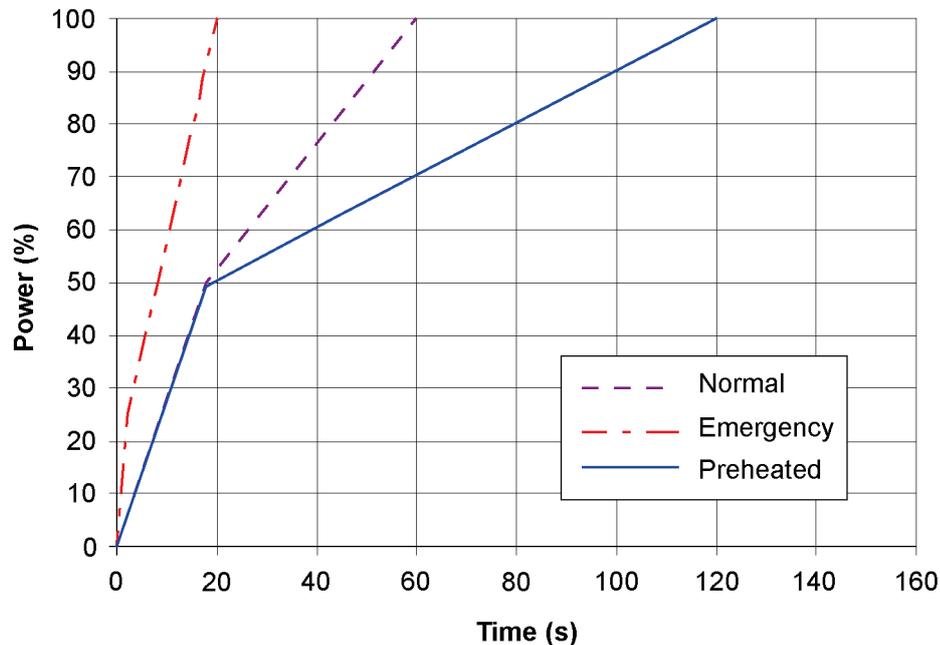
**Fig 2-11 Maximum recommended load increase rates for variable speed engines**

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

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

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

## 2.3.2 Diesel electric propulsion and auxiliary engines



**Fig 2-12 Maximum recommended load increase rates for engines operating at nominal speed**

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

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

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

### NOTE

According to classification rules, all engines driving generators must be able to take 110% load, 110% output can be utilised for as long as it takes to bring the system back to a safe state with a power demand below 100%.

Overload may never be used on a routine basis, or planned for in the operation of the plant. It is a power reserve for extreme situations.

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

### 2.3.2.1 Maximum instant load steps

The electrical system must be designed so that tripping of breakers can be safely handled. This requires that the engines are protected from load steps exceeding their maximum load

acceptance capability. The maximum permissible load step is 33% MCR for an engine without SCR and 25% MCR if the engine is equipped with an SCR. The resulting speed drop is less than 10% and the recovery time to within 1% of the steady state speed at the new load level is max. 5 seconds.

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

### Maximum load steps, DME and AUX engines

#### Instant Load Application

- Maximum load step according to figure below (0 – 33 – 66 – 100 %)
- Maximum transient speed decrease of 10 % of rated speed
- Steady-state frequency band  $\pm 1.0$  %
- Steady-state recovery time  $\leq 5$  sec.
- Time between load steps  $\geq 10$  sec., however the max. load limit specified in the graph below should not be exceeded

#### Engine unloading

- Instant load rejection 100 % - 0 %
- Maximum transient speed increase of 10 % of the rated speed
- Steady-state frequency band  $\pm 1.0$  %
- Steady-state recovery time  $\leq 5$  sec.

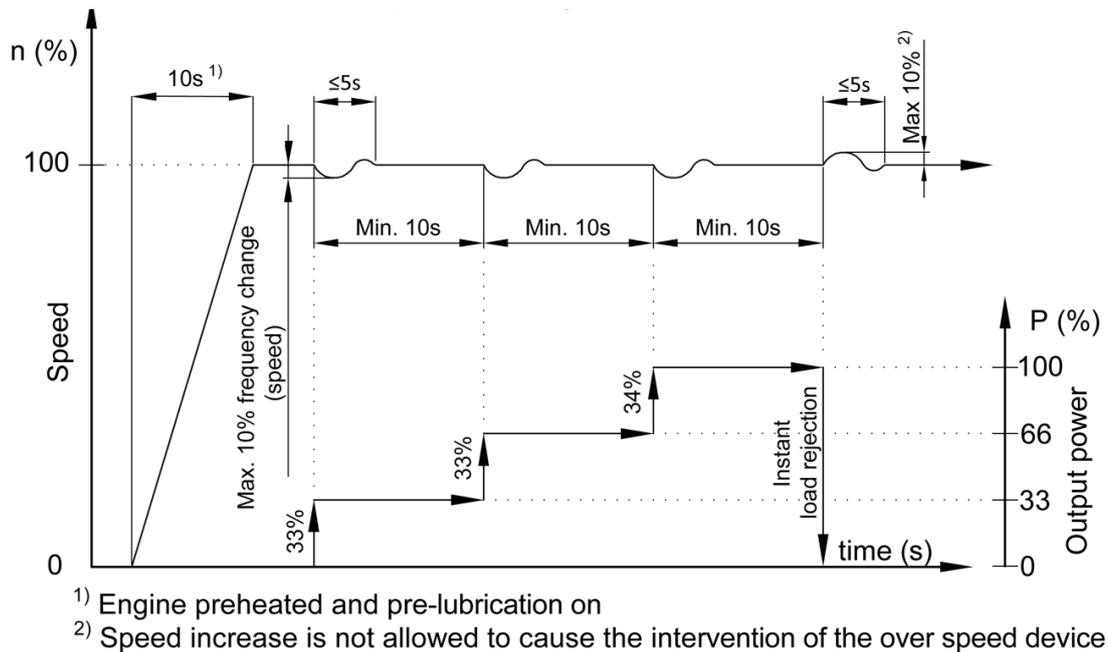


Fig 2-13 Load steps, Tier II and China Stage II with SCR-optimization

### 2.3.2.2 Start-up

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

## 2.4 Low load operation

Operating and stopping the engine with the following limits for low load operations:

### Absolute idling (disconnected generator)

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

### Operation below 44 kW/cyl <sup>1)</sup> load on HFO or below 22 kW/cyl <sup>2)</sup> load on LFO

- Maximum 100 hours continuous operation. At intervals of 100 operating hours the engine must be loaded to minimum 70 % of the rated output for one hour before continuing with low-load operation or shutting down

### Operation at or above 44 kW/cyl <sup>1)</sup> load on HFO or at or above 22 kW/cyl <sup>2)</sup> load on LFO

- No restrictions

<sup>1)</sup> 20 % from 220 kW/cyl

<sup>2)</sup> 10 % from 220 kW/cyl

NOTE
The engine can be started and stopped on HFO provided that the engine and the fuel system are pre-heated to operating temperature.

## 2.5 SCR Operation

SCR operation on sustained low load/ idling might need special attention from the operator. Please contact Wärtsilä for further details.

## 2.6 Low air temperature

Depending on the setup down to -45°C.

For further guidelines, see chapter [Combustion air system design](#).

This page intentionally left blank

## 3. Technical Data

### 3.1 Introduction

Real-time product information including all technical data can be found by using [Engine Online Configurator](#) available through Wärtsilä's website. Please check online for the most up to date technical data.

<b>NOTE</b>
Fuel consumptions in SCR operation guaranteed only when using Wärtsilä SCR unit.

<b>NOTE</b>
For proper operation of the Wärtsilä Nitrogen Oxide Reducer (NOR) systems, the exhaust temperature after the engine needs to be kept within a certain temperature window. Minimum target temperature are 320°C or 340°C (with liquid fuel) depending of sulphur content. Please consult your sales contact at Wärtsilä for more information about SCR Operation.

This page intentionally left blank

## 4. Description of the Engine

### 4.1 Definitions

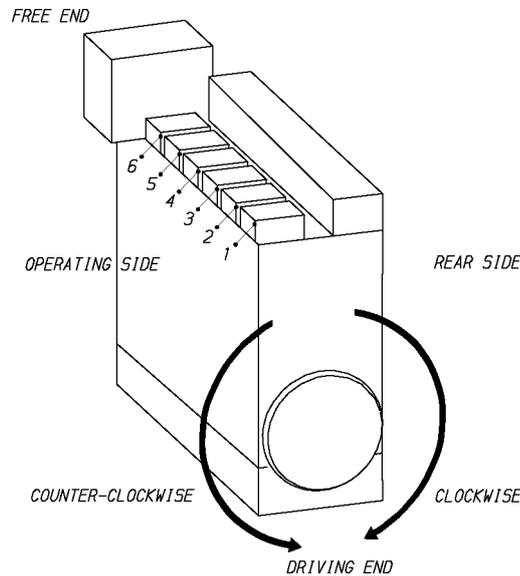


Fig 4-1 In-line engine definitions (V93C0029)

## 4.2 Main components and systems

### 4.2.1 Engine block

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

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

### 4.2.2 Crankshaft

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

### 4.2.3 Connecting rod

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

### 4.2.4 Main bearings and big end bearings

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

### 4.2.5 Cylinder liner

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

## 4.2.6 Piston

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

## 4.2.7 Piston rings

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

## 4.2.8 Cylinder head

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

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

All valves are equipped with valve rotators.

## 4.2.9 Camshaft and valve mechanism

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

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

Variable Inlet valve Closure (VIC), which is available on IMO Tier 2 engines, offers flexibility to apply early inlet valve closure at high load for lowest NO<sub>x</sub> levels, while good part-load performance is ensured by adjusting the advance to zero at low load.

## 4.2.10 Camshaft drive

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

## 4.2.11 Fuel injection equipment

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

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

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

The injection valve is centrally located in the cylinder head and the fuel is admitted sideways through a high pressure connection screwed in the nozzle holder. The injection pipe between

the injection pump and the high pressure connection is well protected inside the hot box. The high pressure side of the injection system is completely separated from the hot parts of the exhaust gas components.

#### **4.2.12 Turbocharging and charge air cooling**

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

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

#### **4.2.13 Charge air waste gate**

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

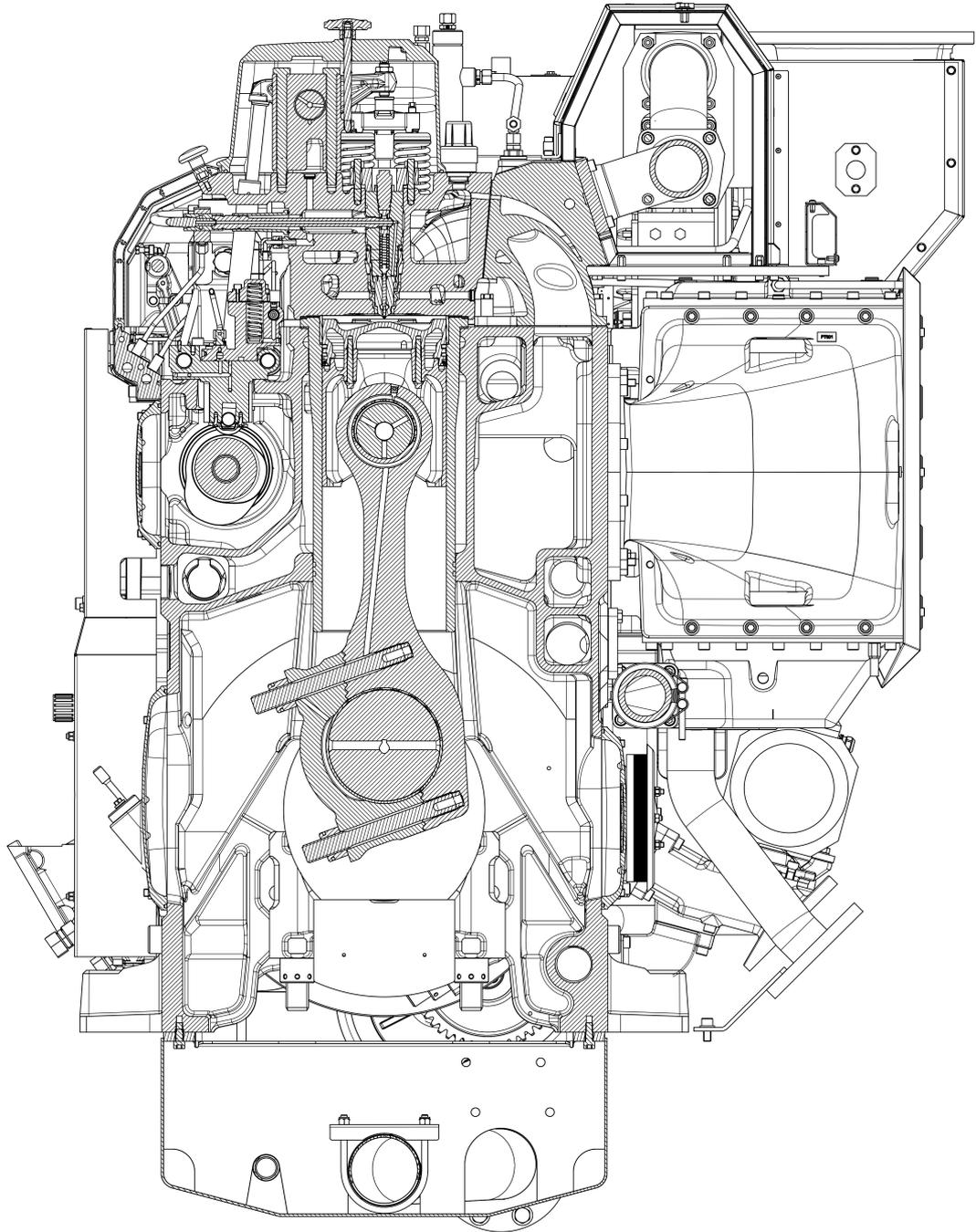
#### **4.2.14 Exhaust pipes**

The exhaust pipes are made of special heat resistant nodular cast iron alloy. The complete exhaust system is enclosed in an insulating box made of insulated sandwich steel sheets, easily removable. Mineral wool is used as insulating material.

#### **4.2.15 Wärtsilä Unified Controls - UNIC**

The Wärtsilä 20 engine is equipped with a UNIC electronic control system. For more information, please refer to chapter Automation System.

## 4.3 Cross section of the engine



**Fig 4-2** Cross sections of the engine (DAAF476083)

## 4.4 Time between inspection or Overhaul & Expected Life Time

### NOTE

- Achieved life times very much depend on the operating conditions, average loading of the engine, fuel quality used, fuel handling systems, performance of maintenance etc
- Expected lifetime is different depending on HFO1 or HFO2 used. For detailed information of HFO1 and HFO2 qualities, please see [6.1.3.1](#).

**Table 4-1 Time Between Overhaul and Expected Life Time**

Component	Time between inspection or overhaul (h)		Expected life time (h)	
	HFO1/ HFO2 <sup>1)</sup>	LFO	HFO1/ HFO2 <sup>1)</sup>	LFO
Piston	14000/ 10000	20000	48000/ 42000	60000
Piston rings	14000/ 10000	20000	14000/ 10000	20000
Cylinder liner	14000/ 10000	20000	60000/ 48000	80000
Cylinder head	14000/ 10000	20000	56000/ 50000	60000
Inlet valve	14000/ 10000	20000	42000/ 30000	48000
Exhaust valve	14000/ 10000	20000	28000 / 20000	40000
Main bearing	14000/ 10000	20000	48000/ 42000	60000
Big end bearing	14000/ 10000	20000	20000/ 20000	20000
Injection valve nozzle	4000/ 4000	4000	4000/ 4000	4000
High Pressure fuel pump	14000/ 10000	20000	28000/ 20000	28000

### NOTE

1) For detailed information of HFO1 and HFO2 qualities, please see chapter [Heavy Fuel Oil \(HFO\)](#).

### NOTE

Turbocharger lifetime for W20 Dredger applications are 25000 hours for Constant Speed engines and 50000 hours for Constant Torque engines.

## 4.5 Engine storage

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

This page intentionally left blank

## 5. Piping Design, Treatment and Installation

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

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

### **NOTICE**

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

### **NOTICE**

The external fuel system must not contaminate the engine's fuel with zinc. For example, galvanized surfaces or surfaces painted with paints containing zinc must not be in contact with the engine fuel. Zinc in the fuel system could lead to e.g. clogged injectors and operational problems.

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

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

**The following aspects shall be taken into consideration:**

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

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

### 5.1 Pipe dimensions

**When selecting the pipe dimensions, take into account:**

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

**Table 5-1 Recommended maximum velocities on pump delivery side for guidance**

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

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

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

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

## 5.2 Trace heating

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

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

## 5.3 Pressure class

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

**The pressure in the system can:**

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

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

**Example 1:**

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

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

**Example 2:**

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

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

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

## 5.4 Pipe class

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

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

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

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

**Table 5-2 Classes of piping systems as per DNV rules**

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

## 5.5 Insulation

The following pipes shall be insulated:

- All trace heated pipes
- Exhaust gas pipes

- Exposed parts of pipes with temperature > 60°C

**Insulation is also recommended for:**

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

## 5.6 Local gauges

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

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

## 5.7 Cleaning procedures

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

### 5.7.1 Cleanliness during pipe installation

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

Piping cleaning methods are summarised in table below:

**Table 5-3 Pipe cleaning**

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

1) In case of carbon steel pipes

#### **Methods applied during prefabrication of pipe spools**

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

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

*D = Pickling (not required for seamless precision tubes)*

#### **Methods applied after installation onboard**

*C = Purging with compressed air*

*F = Flushing*

## 5.7.2 Fuel oil pipes

Before start up of the engines, all the external piping between the day tanks and the engines must be flushed in order to remove any foreign particles such as welding slag.

Disconnect all the fuel pipes at the engine inlet and outlet. Install a temporary pipe or hose to connect the supply line to the return line, bypassing the engine. The pump used for flushing should have high enough capacity to ensure highly turbulent flow, minimum same as the max nominal flow. Heaters, automatic filters and the viscosimeter should be bypassed to prevent damage caused by debris in the piping. The automatic fuel filter must not be used as flushing filter.

The pump used should be protected by a suction strainer. During this time the welds in the fuel piping should be gently knocked at with a hammer to release slag and the filter inspected and carefully cleaned at regular intervals.

The cleanliness should be minimum ISO 4406 © 20/18/15, or NAS 1638 code 9. A measurement certificate shows required cleanliness has been reached there is still risk that impurities may occur after a time of operation.

<b>NOTICE</b>
The engine must not be connected during flushing.

## 5.7.3 Lubricating oil pipes

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 external oil sump/tank or via engine sump if this is advantageous. Cleanliness of the oil sump shall be verified after completed flushing and is acceptable when the cleanliness has reached a level in accordance with ISO 4406 © 21/19/15, or NAS 1638 code 10. All pipes connected to the engine, the engine wet sump or to the external engine wise oil tank shall be flushed. Oil used for filling shall have a cleanliness of ISO 4406 © 21/19/15, or NAS 1638 code 10.

<b>NOTICE</b>
The engine must not be connected during flushing.

## 5.7.4 Pickling

Prefabricated pipe spools are pickled before installation onboard.

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

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

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

## 5.8 Flexible pipe connections

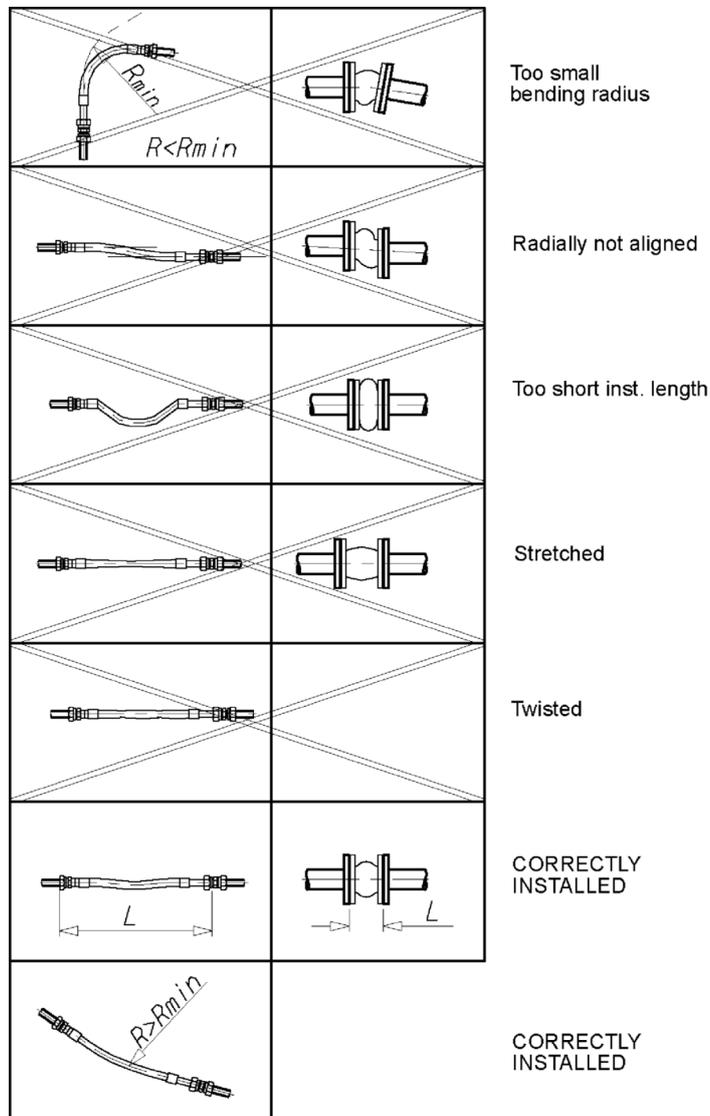
All external pipes must be precisely aligned to the fitting or the flange of the engine to minimize causing external forces to the engine connection.

Adding adapter pieces to the connection between the flexible pipe and engine, which are not validated by Wärtsilä are forbidden. Observe that the pipe clamp for the pipe outside the flexible connection must be very rigid and welded to the steel structure of the foundation to prevent vibrations and external forces to the connection, which could damage the flexible connections

and transmit noise. The support must be close to the flexible connection. Most problems with bursting of the flexible connection originate from poor clamping.

Proper installation of pipe connections between engines and ship's piping to be ensured.

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



**Fig 5-1 Flexible hoses**

**NOTICE**

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

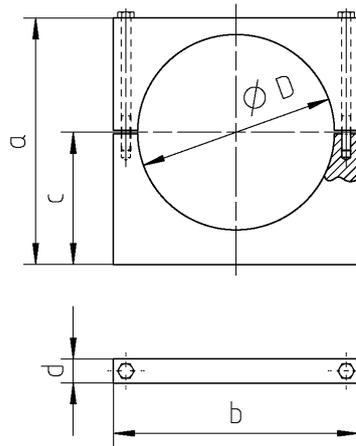
## 5.9 Clamping of pipes

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

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

A typical pipe clamp for a fixed support is shown in Figure 5-2. Pipe clamps must be made of steel; plastic clamps or similar may not be used.

## SUPPORTS AFTER FLEXIBLE BELLOW (FIXED) DN 25-300)



DN	$d_u$ mm	D mm	a mm	b mm	c mm	d mm	BOLTS
25	33.7	35	150	80	120	25	M10x50
32	42.4	43	150	75	120	25	M10x50
40	48.3	48	154.5	100	115	25	M12x60
50	60.3	61	185	100	145	25	M12x60
65	76.1	76.5	191	115	145	25	M12x70
80	88.9	90	220	140	150	30	M12x90
100	114.3	114.5	196	170	121	25	M12x100
125	139.7	140	217	200	132	30	M16x120
150	168.3	170	237	240	132	30	M16x140
200	219.1	220	295	290	160	30	M16x160
250	273.0	274	355	350	190	30	M16x200
Ⓐ 300	323.9	325	410	405	220	40	M16x220

$d_u$  = Pipe outer diameter

**Fig 5-2 Pipe clamp for fixed support (V61H0842A)**

## 6. Fuel Oil System

### 6.1 Acceptable fuel characteristics

The fuel specifications are based on the ISO 8217:2017 (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, please refer to technical data which can be found by accessing [Engine Online Configurator](#) available through Wärtsilä's website.

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

#### 6.1.1 Light Fuel Oil (LFO)

The fuel specification is based on the ISO 8217:2017(E) standard and covers the fuel grades ISO-F-DMX, DMA, DFA, DMZ, DFZ, DMB and DFB. These fuel grades are referred to as Light Fuel Oil (LFO).

The distillate grades mentioned above can be described as follows:

- **DMX:** A fuel quality which is suitable for use at ambient temperatures down to  $-15\text{ °C}$  without heating the fuel. Especially in merchant marine applications its use is restricted to lifeboat engines and certain emergency equipment due to 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 MGO (Marine Gas Oil) in the marine field.
- **DFA:** A similar quality distillate fuel compared to DMA category fuels but a presence of max. 7,0% v/v of Fatty acid methyl ester (FAME) is allowed.
- **DMZ:** A high quality distillate, generally designated MGO (Marine Gas Oil) in the marine field. An alternative fuel grade for engines requiring a higher fuel viscosity than specified for DMA grade fuel.
- **DFZ:** A similar quality distillate fuel compared to DMZ category fuels but a presence of max. 7,0% v/v of Fatty acid methyl ester (FAME) is allowed.
- **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.
- **DFB:** A similar quality distillate fuel compared to DMB category fuels but a presence of max. 7,0% v/v of Fatty acid methyl ester (FAME) is allowed.

##### 6.1.1.1 Table Light fuel oils

**Table 6-1 Distillate fuel specifications**

Characteristics	Unit	Lim- it	Category ISO-F						Test meth- od(s) and ref- erences
			DMX	DMA	DFA	DMZ	DFZ	DMB	
Kinematic viscosity at 40 °C i)	mm <sup>2</sup> /s a)	Max	5,500	6,000		6,000		11,00	ISO 3104
		Min	1,400 <sup>1)</sup>	2,000		3,000		2,000	

**Table 6-1 Distillate fuel specifications (continued)**

Characteristics	Unit	Limit	Category ISO-F						Test method(s) and references	
			DMX	DMA	DFA	DMZ	DFZ	DVB		DFB
Density at 15 °C	kg/m <sup>3</sup>	Max	-	890,0	890,0	900,0			ISO 3675 or ISO 12185	
Cetane index		Min	45	40	40	35			ISO 4264	
Sulphur <sup>b, k)</sup>	% m/m	Max	1,00	1,00	1,00	1,50			ISO 8754 or ISO 14596, ASTM D4294	
Flash point	°C	Min	43,0 <sup>l)</sup>	60,0	60,0	60,0			ISO 2719	
Hydrogen sulfide	mg/kg	Max	2,00	2,00	2,00	2,00			IP 570	
Acid number	mg KOH/g	Max	0,5	0,5	0,5	0,5			ASTM D664	
Total sediment by hot filtration	% m/m	Max	-	-	-	0,10 <sup>c)</sup>			ISO 10307-1	
Oxidation stability	g/m <sup>3</sup>	Max	25	25	25	25 <sup>d)</sup>			ISO 12205	
Fatty acid methyl ester (FAME) <sup>e)</sup>	% v/v	Max	-	-	7,0	-	7,0	-	7,0	ASTM D7963 or IP 579
Carbon residue - Micro method on 10% distillation residue	% m/m	Max	0,30	0,30	0,30	-			ISO 10370	
Carbon residue - Micro method	% m/m	Max	-	-	-	0,30			ISO 10370	
Cloud point <sup>f)</sup>	winter	°C	Max	-16	Report	Report	-		ISO 3015	
	summer			-16	-	-	-			
Cold filter plugging point <sup>f)</sup>	winter	°C	Max	-	Report	Report	-		IP 309 or IP 612	
	summer			-	-	-	-			
Pour point <sup>f)</sup>	winter	°C	Max	-	-6	-6	0		ISO 3016	
	summer			-	0	0	6			
Appearance		-	Clear and bright <sup>g)</sup>				c)		-	
Water	% v/v	Max	-	-	-	0,30 <sup>c)</sup>			ISO 3733 or ASTM D6304-C <sup>m)</sup>	
Ash	% m/m	Max	0,010	0,010	0,010	0,010			ISO 6245	
Lubricity, corr. wear scar diam. <sup>h)</sup>	µm	Max	520	520	520	520 <sup>d)</sup>			ISO 12156-1	

**NOTICE**

- a)  $1 \text{ mm}^2/\text{s} = 1 \text{ cSt}$ .
- b) Notwithstanding the limits given, the purchaser shall define the maximum sulphur content in accordance with relevant statutory limitations.
- c) If the sample is not clear and bright, the total sediment by hot filtration and water tests shall be required.
- d) If the sample is not clear and bright, the Oxidation stability and Lubricity tests cannot be undertaken and therefore, compliance with this limit cannot be shown.
- e) See ISO 8217:2017(E) standard for details.
- f) Pour point cannot guarantee operability for all ships in all climates. The purchaser should confirm that the cold flow characteristics (pour point, cloud point, cold filter clogging point) are suitable for ship's design and intended voyage.
- g) If the sample is dyed and not transparent, see ISO 8217:2017(E) standard for details related to water analysis limits and test methods.
- h) The requirement is applicable to fuels with a sulphur content below 500 mg/kg (0,050 % m/m).
- Additional notes not included in the ISO 8217:2017(E) standard:**
- i) Low min. viscosity of 1,400  $\text{mm}^2/\text{s}$  can prevent the use ISO-F-DMX category fuels in Wärtsilä® 4-stroke engines unless a fuel can be cooled down enough to meet the specified min. injection viscosity limit.
- j) Allowed kinematic viscosity before the injection pumps for this engine type is 1,8 - 24  $\text{mm}^2/\text{s}$ .
- k) There doesn't exist any minimum sulphur content limit for Wärtsilä® 4-stroke diesel engines and also the use of Ultra Low Sulphur Diesel (ULSD) is allowed provided that the fuel quality fulfils other specified properties.
- l) Low flash point of min. 43 °C can prevent the use ISO-F-DMX category fuels in Wärtsilä® engines in marine applications unless the ship's fuel system is built according to special requirements allowing the use or that the fuel supplier is able to guarantee that flash point of the delivered fuel batch is above 60 °C being a requirement of SOLAS and classification societies.
- m) Alternative test method.

## 6.1.2 Operation on 0,10 % m/m residual sulphur fuels (ULSFO RM) for SECA areas

Due to the tightened sulphur emission legislation being valid since 01.01.2015 in the specified SECA areas many new max. 0,10 % m/m sulphur content fuels have entered the market. Some of these fuels are not pure distillate fuels, but contain new refinery streams, like hydrocracker bottoms or can also be blends of distillate and residual fuels. The new 0,10 % m/m sulphur fuels are also called as Ultra Low Sulphur Fuel Oils (ULSFO) or “hybrid” fuels, since those can contain properties of both distillate and residual fuels. In the existing ISO 8217:2017(E) standard the fuels are classed as RMA 10, RMB 30 or RMD 80, if not fulfilling the DM grade category requirements, though from their properties point of view this is generally not an optimum approach.

These fuels can be used in the Wärtsilä 20 engine type, but special attention shall be paid to optimum operating conditions. See also Services Instruction WS02Q312.

Characteristics	Unit	RMA 10	RMB 30	RMD 80	Test method reference
Kinematic viscosity bef. inj. pumps <sup>c)</sup>	mm <sup>2</sup> /s a)	6,0 - 24	6,0 - 24	6,0 - 24	-
Kinematic viscosity at 50 °C, max.	mm <sup>2</sup> /s a)	10,00	30,00	80,00	ISO 3104
Density at 15 °C, max.	kg/m <sup>3</sup>	920,0	960,0	975,0	ISO 3675 or ISO 12185
CCAI, max. <sup>e)</sup>	-	850	860	860	ISO 8217, Annex F
Sulphur, max. <sup>b)</sup>	% m/m	0,10	0,10	0,10	ISO 8574 or ISO 14596
Flash point, min.	°C	60,0	60,0	60,0	ISO 2719
Hydrogen sulfide, max.	mg/kg	2,00	2,00	2,00	IP 570
Acid number, max.	mg KOH/g	2,5	2,5	2,5	ASTM D664
Total sediment existent, max.	% m/m	0,10	0,10	0,10	ISO 10307-2
Carbon residue, micro method, max.	% m/m	2,50	10,00	14,00	ISO 10370
Asphaltenes, max. <sup>c)</sup>	% m/m	1,5	6,0	8,0	ASTM D3279
Pour point (upper), max., winter quality <sup>d)</sup>	°C	0	0	30	ISO 3016
Pour point (upper), max., summer quality <sup>d)</sup>	°C	6	6	30	ISO 3016
Water max.	% v/v	0,30	0,50	0,50	ISO 3733 or ASTM D6304-C <sup>c)</sup>
Water bef. engine, max. <sup>c)</sup>	% v/v	0,30	0,30	0,30	ISO 3733 or ASTM D6304-C <sup>c)</sup>
Ash, max.	% m/m	0,040	0,070	0,070	ISO 6245 or LP1001 <sup>c, h)</sup>
Vanadium, max. <sup>f)</sup>	mg/kg	50	150	150	IP 501, IP 470 or ISO 14597
Sodium, max. <sup>f)</sup>	mg/kg	50	100	100	IP 501 or IP 470
Sodium bef. engine, max. <sup>c, f)</sup>	mg/kg	30	30	30	IP 501 or IP 470

(continued)

Characteristics	Unit	RMA 10	RMB 30	RMD 80	Test method reference
Aluminium + Silicon, max.	mg/kg	25	40	40	IP 501, IP 470 or ISO 10478
Aluminium + Silicon bef. engine, max. <sup>c)</sup>	mg/kg	15	15	15	IP 501, IP 470 or ISO 10478
Used lubricating oil: <sup>g)</sup> - Calcium, max.	mg/kg	30	30	30	IP 501 or IP 470
- Zinc, max.	mg/kg	15	15	15	IP 501 or IP 470
- Phosphorus, max.	mg/kg	15	15	15	IP 501 or IP 500

**NOTE**

**a)** 1 mm<sup>2</sup>/s = 1 cSt.

**b)** The purchaser shall define the maximum sulphur content in accordance with relevant statutory limitations.

**c)** Additional properties specified by the engine manufacturer, which are not included in the ISO 8217:2017(E) standard.

**d)** Purchasers shall ensure that this pour point is suitable for the equipment on board / at the plant, especially if the ship operates / plant is located in cold climates.

**e)** Straight run residues show CCAI values in the 770 to 840 range and are very good ignitors. Cracked residues delivered as bunkers may range from 840 to – in exceptional cases – above 900. Most bunkers remain in the max. 850 to 870 range at the moment. CCAI value cannot always be considered as an accurate tool to determine fuels' ignition properties, especially concerning fuels originating from modern and more complex refinery processes.

**f)** Sodium contributes to hot corrosion on 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, but 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.

**g)** 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 OR
- Calcium > 30 mg/kg and phosphorus > 15 mg/kg

**h)** Ashing temperatures can vary when different test methods are used having an influence on the test result.

## 6.1.3 Heavy Fuel Oil (HFO)

Residual fuel grades are referred to as HFO (Heavy Fuel Oil). The fuel specification HFO 2 is based on the ISO 8217:2017(E) standard and 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.

### 6.1.3.1 Table Heavy fuel oils

**Table 6-2 Residual fuel specifications**

Characteristics	Unit	Limit HFO 1	Limit HFO 2	Test method reference
Kinematic viscosity bef. inj. pumps <sup>d)</sup>	mm <sup>2</sup> /s <sup>b)</sup>	20 ± 4	20 ± 4	-
Kinematic viscosity at 50 °C, max.	mm <sup>2</sup> /s <sup>b)</sup>	700,0	700,0	ISO 3104
Density at 15 °C, max.	kg/m <sup>3</sup>	991,0 / 1010,0 <sup>a)</sup>	991,0 / 1010,0 <sup>a)</sup>	ISO 3675 or ISO 12185
CCAI, max. <sup>f)</sup>	-	850	870	ISO 8217, Annex F
Sulphur, max. <sup>c, g)</sup>	%m/m	Statutory requirements or max. 3,50 % m/m <sup>c)</sup>		ISO 8754 or ISO 14596
Flash point, min.	°C	60,0	60,0	ISO 2719
Hydrogen sulfide, max.	mg/kg	2,00	2,00	IP 570
Acid number, max.	mg KOH/g	2,5	2,5	ASTM D664
Total sediment aged, max.	%m/m	0,10	0,10	ISO 10307-2
Carbon residue, micro method, max.	%m/m	15,00	20,00	ISO 10370
Asphaltenes, max. <sup>d)</sup>	%m/m	8,0	14,0	ASTM D3279
Pour point (upper), max. <sup>e)</sup>	°C	30	30	ISO 3016
Water, max. <sup>d)</sup>	%V/V	0,50	0,50	ISO 3733 or ASTM D6304-C <sup>d)</sup>
Water before engine, max. <sup>d)</sup>	%V/V	0,30	0,30	ISO 3733 or ASTM D6304-C <sup>d)</sup>
Ash, max.	%m/m	0,050	0,150	ISO 6245 or LP1001 <sup>d, i)</sup>
Vanadium, max. <sup>g)</sup>	mg/kg	100	450	IP 501, IP 470 or ISO 14597
Sodium, max. <sup>g)</sup>	mg/kg	50	100	IP 501 or IP 470
Sodium before engine, max. <sup>d, g)</sup>	mg/kg	30	30	IP 501 or IP 470
Aluminium + Silicon, max. <sup>d)</sup>	mg/kg	30	60	IP 501, IP 470 or ISO 10478
Aluminium + Silicon before engine, max. <sup>d)</sup>	mg/kg	15	15	IP 501, IP 470 or ISO 10478
Used lubricating oil <sup>h)</sup>				
- Calcium, max.	mg/kg	30	30	IP 501 or IP 470
- Zinc, max.	mg/kg	15	15	IP 501 or IP 470
- Phosphorus, max.	mg/kg	15	15	IP 501 or IP 500

**NOTICE**

- a)** Max. 1010 kg/m<sup>3</sup> at 15 °C, provided the fuel treatment system can reduce water and solids (sediment, sodium, aluminium, silicon) before engine to the specified levels.
- b)** 1 mm<sup>2</sup>/s = 1 cSt.
- c)** The purchaser shall define the maximum sulphur content in accordance with relevant statutory limitations. However, the use of fuels with sulphur content higher than 3,50 % m/m is also possible. Please contact Wärtsilä for further evaluation.
- d)** Additional properties specified by the engine manufacturer, which are not included in the ISO 8217:2017(E) standard.
- e)** Purchasers shall ensure that this pour point is suitable for the equipment on board / at the plant, especially if the ship operates / plant is located in cold climates.
- f)** Straight run residues show CCAI values in the 770 to 840 range and are very good ignitors. Cracked residues delivered as bunkers may range from 840 to – in exceptional cases – above 900. Most bunkers remain in the max. 850 to 870 range at the moment. CCAI value cannot always be considered as an accurate tool to determine fuels' ignition properties, especially concerning fuels originating from modern and more complex refinery processes.
- g)** Sodium contributes to hot corrosion on 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, but 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.
- h)** 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 OR
  - Calcium > 30 mg/kg and phosphorus > 15 mg/kg
- i)** The ashing temperatures can vary when different test methods are used having an influence on the test result.

**6.1.4****Biofuel oils****Liquid biofuel characteristics and specifications**

The Wärtsilä engines are designed and developed for continuous operation on liquid biofuel (LBF) qualities with the properties included in the Tables [SVO and PVO](#), [FAME](#), [B10 table](#), [B20 table](#) and [B30 table](#) and [Paraffinic diesel fuels from synthesis and hydrotreatment](#). For the Straight Vegetable Oils (SVO) and Pure Vegetable Oils (PVO) operation included in Table [SVO and PVO](#) dedicated kits are required.

Liquid biofuels included in the Tables [SVO and PVO](#), [FAME](#), have typically lower heating value (LHV) than fossil fuels, while the capacity of fuel injection system influencing on guaranteed engine output must be checked case by case. Concerning biodiesel blends included in tables [B10 table](#), [B20 table](#) and [B30 table](#) the influence of LHV is however not significant.

**NOTICE**

Liquid biofuels included in the Table [Paraffinic diesel fuels from synthesis and hydrotreatment](#) have a low density, why the capacity of fuel injection system influencing on guaranteed engine output must be checked case by case. Their flash point can based on specifications be also lower than 60 °C required for marine applications by SOLAS and Classification societies, which may prevent the use.

**NOTICE**

Fuel injection system is not validated for Straight and Pure Vegetable oils ([SVO and PVO](#)) qualities. Wärtsilä have to cover possible FIE warranty cost. Depending on FIE equipment, field follow up / validation may be required.

**NOTICE**

The use of liquid bio fuels qualities included in the table [SVO and PVO](#), [FAME](#), [B10 table](#), [B20 table](#) and [B30 table](#) needs to be validated by contacting Wärtsilä.

Acceptable storage period for liquid biofuels excluding products which belong to the category being presented in [Paraffinic diesel fuels from synthesis and hydrotreatment](#) can be significantly shorter than storage period specified for fossil fuels. Some biodiesel manufacturers are referring to max. one month storage period. After that acidity starts to increase leading to faster oxidation rate of the fuel.

Blending of different fuel qualities:

Straight Vegetable Oils (SVO) and Pure Vegetable Oils (PVO) (table [SVO and PVO](#)) must not be mixed with fossil fuels, but have to be used as such.

Mixing of Straight Vegetable Oils (SVO) and Pure Vegetable Oils (PVO) (table [SVO and PVO](#)) and distillate fuel will increase the risk of cavitation in the fuel system, since the required fuel temperature before engine is normally 80 - 90 °C. At this temperature light fractions of distillate fuel have already started to evaporate.

The use of residual fuel requires much higher operating temperature than the use of Straight Vegetable Oils (SVO) and Pure Vegetable Oils (PVO), i.e. normally above 100 °C in order to achieve a proper fuel injection viscosity. Thus mixing of Straight Vegetable Oils (SVO) and Pure Vegetable Oils (PVO) (table [SVO and PVO](#)) with residual fuel will increase the risk of biofuel component polymerization due to elevated temperature.

Liquid biofuel qualities presented in the table [FAME](#), and table [Paraffinic diesel fuels from synthesis and hydrotreatment](#) can be mixed with fossil distillate fuel and residual fuel with various ratios. Fossil fuel being used as a blending component has to fulfil Wärtsilä's distillate and residual fuel specification based on the ISO 8217:2017(E) standard. Depending on the bio component type its quality has to meet either the EN 14214:2012 standard included in the table [FAME](#), or the EN 15940:2016 standard included in the table [Paraffinic diesel fuels from synthesis and hydrotreatment](#). For biodiesel blend B10 there also exists an EN 16734 standard and for B20 & B30 blends an EN 16709 standard respectively. Biodiesel blend quality has to fulfil the requirements included in those two standards

Required fuel temperatures:

Straight Vegetable Oils (SVO) and Pure Vegetable Oils (PVO) (table [SVO and PVO](#)) temperature before an engine is an utmost important operating parameter. Too low temperature will cause solidification of fatty acids leading to clogging of filters, plug formation in the fuel system and even to fuel injection equipment component breakdowns. Too high fuel temperature will increase the risk of polymerization and formation of gummy deposits, especially in the presence of oxygen.

When operating on Straight Vegetable Oils (SVO) and Pure Vegetable Oils (PVO) (table [SVO and PVO](#)), it is utmost important to maintain a proper fuel temperature before fuel injection pumps in order to ensure safe operation of the engine and fuel system. The recommended fuel operating temperature depends on both the liquid biofuel quality and the degree of processing. E.g. many palm oil qualities require ~ 80 - 90 °C fuel temperature in order to achieve an expected lifetime of fuel injection equipment and to avoid fuel filter clogging. Some refined palm oil qualities are however behaving acceptably also at lower, ~ 70 - 75 °C operating temperature. For other types of Straight Vegetable Oils (SVO) and Pure Vegetable Oils (PVO) the temperature requirement can be slightly different and must be confirmed before the use.

For fuel qualities included in the table [FAME](#), [B10 table](#), [B20 table](#) and [B30 table](#) and [Paraffinic diesel fuels from synthesis and hydrotreatment](#), fuel temperature before fuel injection pumps is limited to max. 45 °C. If residual fuel is used as a blending component together with HVO or biodiesel, fuel injection viscosity and injection temperature requirements being valid for residual fuels have to be followed.

### 6.1.4.1 Straight Vegetable Oils (SVO) and Pure Vegetable Oils (PVO)

The specification included in the table below is valid for crude and refined liquid biofuels, like palm oil, coconut oil, copra oil, rape seed oil, jatropha oil, fish oil, etc.

**Table 6-3 Liquid biofuel specification for Straight Vegetable Oils (SVO) and Pure Vegetable Oils (PVO) (residual fuel substitutes)**

Property	Unit	Limit	Test method reference
Viscosity, max.	mm <sup>2</sup> /s @ 50 °C mm <sup>2</sup> /s @ 80 °C	70 <sup>1)</sup> 15 <sup>1)</sup>	ISO 3104
Injection viscosity, min.	mm <sup>2</sup> /s	1.8 <sup>2)</sup>	ISO 3104
Injection viscosity, max.	mm <sup>2</sup> /s	24	ISO 3104
Density, max.	kg/m <sup>3</sup> @ 15 °C	940	ISO 3675 or ISO 12185
Ignition properties <sup>3)</sup>		<sup>3)</sup>	FIA-100 FCA test
Sulphur, max.	% m/m	0.05	ISO 8754
Total sediment existent, max.	% m/m	0.05	ISO 10307-1
Water, max. before engine	% v/v	0.20	ISO 3733
Micro carbon residue, max.	% m/m	0.50	ISO 10370
Ash, max.	% m/m	0.05	ISO 6245 / LP1001 <sup>4)</sup>
Phosphorus, max.	mg/kg	100	ISO 10478
Silicon, max.	mg/kg	15	ISO 10478
Alkali content (Na+K), max.	mg/kg	30	ISO 10478
Flash point (PMCC), min.	°C	60	ISO 2719
Cloud point, max.	°C	<sup>5)</sup>	ISO 3015
Cold filter plugging point, max.	°C	<sup>5)</sup>	IP 309
Copper strip corrosion (3 hrs @ 50 °C), max.	Rating	1b	ASTM D130
Steel corrosion (24 / 72 hours @ 20, 60 and 120 °C), max.	Rating	No signs of corrosion	LP 2902
Oxidation stability @ 110 °C, min.	h	17.0 <sup>6)</sup>	EN 14112
Acid number, max.	mg KOH/g	15.0	ASTM D664
Strong acid number, max.	mg KOH/g	0.0	ASTM D664
Iodine number, max.	g iodine /100 g	120 <sup>7)</sup>	ISO 3961

**Table 6-3 Liquid biofuel specification for Straight Vegetable Oils (SVO) and Pure Vegetable Oils (PVO) (residual fuel substitutes) (continued)**

Property	Unit	Limit	Test method reference
Synthetic polymers	% m/m	Report <sup>8)</sup>	LP 2501

**NOTICE**

- 1) If injection viscosity of max. 24 cSt cannot be achieved with an unheated fuel, fuel system has to be equipped with a heater ( $\text{mm}^2/\text{s} = \text{cSt}$ ).
- 2) Min. viscosity limit at engine inlet in running conditions ( $\text{mm}^2/\text{s} = \text{cSt}$ ).
- 3) Ignition properties have to be equal to or better than the requirements for fossil fuels, i.e., CI min. 35 for LFO and CCAI max. 870 for HFO.
- 4) Ashing temperatures can vary when different test methods are used having an influence on the test result.
- 5) Cloud point and cold filter plugging point have to be at least 10 °C below fuel injection temperature and the temperature in the whole fuel system has to be min. 10 – 15 °C higher than cloud point and cold filter plugging point.
- 6) A lower oxidation stability value down to min. 10 hours can be considered acceptable if other fuel properties, like cloud point, cold filter plugging point and viscosity support that. This needs to be decided case-by-case.
- 7) Iodine number of soybean oil is somewhat higher, up to ~ 140, which is acceptable for specific that biofuel quality.
- 8) Biofuels originating from food industry can contain synthetic polymers, like e.g. styrene, propene and ethylene used in packing material. Such compounds can cause filter clogging and shall thus not be present in biofuels.

**NOTICE**

If Selective Catalyst Reduction or oxidation catalyst needs to be used the specification included in the table above does not apply, but the fuel quality requirements have to be discussed separately. The specification does not take into consideration Particulate Matter emission limits.

**NOTICE**

When analysing the energy content (Higher and Lower Heating Value) of Straight Vegetable Oils (SVO) and Pure Vegetable Oils (PVO) the calculation method included in the ISO 8217 standard can't be used, but the analysis has to be made by following the ASTM D240 standard.

**NOTICE**

The use of liquid biofuel oils fulfilling the table above requirements always require a NSR to be made.

### 6.1.4.2 Fatty acid methyl ester (FAME) / Biodiesel

Renewable refined liquid biofuels which are manufactured by using transesterification processes, can contain both vegetable and / or animal based feedstock and do normally show out very good physical and chemical properties. These fuels can be used provided that the specification included in the table below is fulfilled. International standards ASTM D 6751-20 or EN 14214:2012 (E) are typically used for specifying biodiesel quality. Further, for biodiesel blend

B10 there exists an EN 16734 standard and for B20 & B30 blends an EN 16709 standard respectively. Biodiesel blend quality has to fulfil the requirements included in those two standards. The requirements of B10, B20 and B30 are included in the Table [B10 table](#), [B20 table](#) and [B30 table](#).

**Table 6-4 Fatty acid methyl ester (FAME) / Biodiesel specification based on the EN 14214:2012 standard**

Property	Unit	Limit	Test method reference
Viscosity, min. - max.	mm <sup>2</sup> /s @ 40 °C	3.5 - 5.0	EN ISO 3104
Injection viscosity, min.	mm <sup>2</sup> /s	1.8 <sup>1)</sup>	EN ISO 3104
Density, min. - max.	kg/m <sup>3</sup> @ 15 °C	860 - 900	EN ISO 3675 / 12185
Cetane number, min.	-	51.0	EN ISO 5165
Sulphur content, max.	mg/kg	10.0	EN ISO 20846 / 20884 / 13032
Sulphated ash content, max.	% m/m	0.02	ISO 3987
Total contamination, max.	mg/kg	24	EN 12662
Water content, max.	mg/kg	500	EN ISO 12937
Phosphorus content, max.	mg/kg	4.0	EN 14107
Group I metals (Na + K) content, max.	mg/kg	5.0	EN 14108 / EN 14109 / 14538
Group II metals (Ca + Mg) content, max.	mg/kg	5.0	EN 14538
Flash point, min.	°C	101	EN ISO 2719A / 3679
Cold filter plugging point, max. (climate dependent requirement)	°C	-20 → +5 <sup>2)</sup>	EN 116
Oxidation stability @ 110 °C, min.	h	8.0	EN 14112
Copper strip corrosion (3 hrs @ 50 °C), max.	Rating	Class 1	EN ISO 2160
Acid value, max.	mg KOH/g	0.50	EN 14104
Iodine value, max.	g iodine/100 g	120	EN 14111 / 16300
FAME content, min.	% m/m	96.5	EN 14103
Linolenic acid methyl ester, max.	% m/m	12.0	EN 14103
Polyunsaturated ( ≥ 4 double bonds) methyl esters, max.	% m/m	1.00	EN 15779
Methanol content, max.	% m/m	0.20	EN 14110
Monoglyceride content, max.	% m/m	0.70	EN 14105
Diglyceride content, max.	% m/m	0.20	EN 14105
Triglyceride content, max.	% m/m	0.20	EN 14105
Free glycerol, max.	% m/m	0.02	EN 14105 / EN 14106
Total glycerol, max.	% m/m	0.25	EN 14105

**NOTICE**

1) Min. limit at engine inlet in running conditions ( $\text{mm}^2/\text{s} = \text{cSt}$ ).

2) Cold flow properties of renewable biodiesel can vary based on the geographical location and also based on the feedstock properties, which issues must be taken into account when designing the fuel system. For arctic climates even lower CFPP values down to  $-44\text{ }^\circ\text{C}$  are specified.

**NOTICE**

When analysing the energy content (Higher and Lower Heating Value) of Biodiesel the calculation method included in the ISO 8217 standard can't be used, but the analysis has to be made by following the ASTM D240 standard.

**NOTICE**

The use of liquid biofuel oils fulfilling the table above requirements always require a NSR to be made.

### 6.1.4.3 Automotive B10 diesel fuel

**Table 6-5 Automotive B10 diesel fuel – Requirements and test methods based on the EN 16734:2016 standard**

Property	Unit	Limit	Test method reference
Viscosity, min - max.	$\text{mm}^2/\text{s}$ @ 40 $^\circ\text{C}$	2.000 - 4.500	EN ISO 3104
Injection viscosity, min.	$\text{mm}^2/\text{s}$	1.8 <sup>1)</sup>	EN ISO 3104
Density, min - max.	$\text{kg}/\text{m}^3$ @ 15 $^\circ\text{C}$	820 - 845	EN ISO 3675
Sulphur content, max.	$\text{mg}/\text{kg}$	10.0	EN ISO 20846 / 20884 / 13032
Ash content, max.	% m/m	0.01	EN ISO 6245
Total contamination, max.	$\text{mg}/\text{kg}$	24	EN 12662
Water content, max.	% m/m	0.02	EN ISO 12937
Manganese content, max.	$\text{mg}/\text{l}$	2.0	EN 16576
Cold filter plugging point, max. (climate dependent requirement)	$^\circ\text{C}$	-20 -> +5 <sup>2)</sup>	EN 116 / 16329
Flash point, min.	$^\circ\text{C}$	55 <sup>3)</sup>	EN ISO 2719
Oxidation stability, min.	h	20.0	EN 15751
Oxidation stability, max.	$\text{g}/\text{m}^3$	25	EN 12205
Polycyclic aromatic hydrocarbons, max.	% m/m	8.0	EN 12916
Carbon residue (on 10% distillation residue), max.	% m/m	0.3	EN ISO 10370
Copper strip corrosion (3 hrs @ 50 $^\circ\text{C}$ ), max.	Rating	Class 1	EN ISO 2160
Lubricity, wear scar diameter at 60 oC, max.	$\mu\text{m}$	460	EN ISO 12156-1
Distillation			EN ISO 3405 / 3924

**Table 6-5 Automotive B10 diesel fuel – Requirements and test methods based on the EN 16734:2016 standard (continued)**

Property	Unit	Limit	Test method reference
- % v/v recovered at 250 °C, max.	% v/v	< 65	
- % v/v recovered at 350°C, min	% v/v	85	
- 95% v/v recovered at, max.	°C	360	
FAME content, min.	% v/v	10.0	EN 14078

**NOTICE**

- 1) Min. limit at engine inlet in running conditions (mm<sup>2</sup>/s = cSt).
- 2) Cold flow properties of renewable biodiesel can vary based on the geographical location and also based on the feedstock properties, which issues must be taken into account when designing the fuel system. For arctic climates even lower CFPP values down to -44 °C are specified.
- 3) The use in marine applications is allowed provided that a fuel supplier can guarantee min. flash point of 60 °C.

**NOTICE**

The use of liquid biofuel oils fulfilling the table above requirements always require a NSR to be made.

**6.1.4.4 High FAME diesel fuel (B20)****Table 6-6 High FAME diesel fuel (B20) – Requirements and test methods based on the EN 16709:2015 standard**

Property	Unit	Limit	Test method reference
Viscosity, min - max.	mm <sup>2</sup> /s @ 40 °C	2.000 - 4.620	EN ISO 3104
Injection viscosity, min.	mm <sup>2</sup> /s	1.8 <sup>1)</sup>	EN ISO 3104
Density, min - max.	kg/m <sup>3</sup> @ 15 °C	820 - 860	EN ISO 3675
Cetane number, min.	-	51.0	EN ISO 5165, EN 15195 / 16144 / 16715 / 16906
Sulphur content, max.	mg/kg	10.0	EN ISO 20846 / 20884 / 13032
Ash content, max.	% m/m	0.01	EN ISO 6245
Total contamination, max.	mg/kg	24	EN 12662
Water content, max.	% m/m	0.026	EN ISO 12937
Manganese content, max.	mg/l	2.0	EN 16576
Cold filter plugging point, max. (climate dependent requirement)	°C	-20 -> +5 <sup>2)</sup>	EN 116 / 16329

**Table 6-6 High FAME diesel fuel (B20) – Requirements and test methods based on the EN 16709:2015 standard (continued)**

Property	Unit	Limit	Test method reference
Flash point, min.	°C	55 <sup>3)</sup>	EN ISO 2719
Oxidation stability, min.	h	20.0	EN 15751
Polycyclic aromatic hydrocarbons, max.	% m/m	8.0	EN 12916
FAME content, min.	% v/v	14.0 - 20.0	EN 14078
Distillation			EN ISO 3405 / 3924
- % v/v recovered at 250 °C, max.	% v/v	< 65	
- % v/v recovered at 350°C, min	% v/v	85	
- 95% v/v recovered at, max.	°C	360	

**NOTICE**

1) Min. limit at engine inlet in running conditions ( $\text{mm}^2/\text{s} = \text{cSt}$ ).

2) Cold flow properties of renewable biodiesel can vary based on the geographical location and also based on the feedstock properties, which issues must be taken into account when designing the fuel system. For arctic climates even lower CFPP values down to  $-44\text{ °C}$  are specified.

3) The use in marine applications is allowed provided that a fuel supplier can guarantee min. flash point of  $60\text{ °C}$ .

**NOTICE**

The use of liquid biofuel oils fulfilling the table above requirements always require a NSR to be made.

**6.1.4.5 High FAME diesel fuel (B30)****Table 6-7 High FAME diesel fuel (B30) – Requirements and test methods based on the EN 16709:2015 standard**

Property	Unit	Limit	Test method reference
Viscosity, min - max.	$\text{mm}^2/\text{s}$ @ 40 °C	2.000 - 4.620	EN ISO 3104
Injection viscosity, min.	$\text{mm}^2/\text{s}$	1.8 <sup>1)</sup>	EN ISO 3104
Density, min - max.	$\text{kg}/\text{m}^3$ @ 15 °C	825 - 865	EN ISO 3675
Cetane number, min.	-	51.0	EN ISO 5165, EN 15195 / 16144 / 16715 / 16906
Sulphur content, max.	mg/kg	10.0	EN ISO 20846 / 20884 / 13032
Ash content, max.	% m/m	0.01	EN ISO 6245
Total contamination, max.	mg/kg	24	EN 12662

**Table 6-7 High FAME diesel fuel (B30) – Requirements and test methods based on the EN 16709:2015 standard (continued)**

Property	Unit	Limit	Test method reference
Water content, max.	% m/m	0.029	EN ISO 12937
Manganese content, max.	mg/l	2.0	EN 16576
Cold filter plugging point, max. (climate dependent requirement)	°C	-20 -> +5 <sup>2)</sup>	EN 116 / 16329
Flash point, min.	°C	55 <sup>3)</sup>	EN ISO 2719
Oxidation stability, min.	h	20.0	EN 15751
Polycyclic aromatic hydrocarbons, max.	% m/m	8.0	EN 12916
FAME content, min. - max.	% v/v	24.0 - 30.0	EN 14078
Distillation			EN ISO 3405 / 3924
- % v/v recovered at 250 °C, max.	% v/v	< 65	
- % v/v recovered at 350°C, min	% v/v	85	
- 95% v/v recovered at, max.	°C	360	

**NOTICE**

- 1) Min. limit at engine inlet in running conditions ( $\text{mm}^2/\text{s} = \text{cSt}$ ).
- 2) Cold flow properties of renewable biodiesel can vary based on the geographical location and also based on the feedstock properties, which issues must be taken into account when designing the fuel system. For arctic climates even lower CFPP values down to -44 °C are specified.
- 3) The use in marine applications is allowed provided that a fuel supplier can guarantee min. flash point of 60 °C.

**NOTICE**

The use of liquid biofuel oils fulfilling the table above requirements always require a NSR to be made.

### 6.1.4.6 Paraffinic diesel fuels from synthesis and hydrotreatment

Paraffinic renewable distillate fuels originating from synthesis or hydrotreatment are high quality distillate fuels and their composition and physical & chemical properties do differ from transesterified biodiesel. The quality of paraffinic diesel shall meet the EN 15940:2016 Class A requirements included in the table below. For arctic or severe winter climates additional or more stringent requirements are set concerning cold filter plugging point, cloud point, viscosity and distillation properties.

**Table 6-8 Requirements for paraffinic diesel from synthesis or hydrotreatment based on the EN 15940:2016 standard**

Property	Unit	Limit	Test method reference
Viscosity, min. - max.	mm <sup>2</sup> /s @ 40 °C	2.0 - 4.5	EN ISO 3104
Injection viscosity, min.	mm <sup>2</sup> /s	1.8 <sup>1)</sup>	EN ISO 3104
Density, min. - max.	kg/m <sup>3</sup> @ 15 °C	765 - 800 <sup>2)</sup>	EN ISO 3675 / 12185
Cetane number, min.	-	70.0	EN 15195 / EN ISO 5165
Sulphur content, max.	mg/kg	5.0	EN ISO 20846 / 20884
Ash content, max.	% m/m	0.010	EN ISO 6245
Total contamination, max.	mg/kg	24	EN 12662
Water content, max.	mg/kg	200	EN ISO 12937
Total aromatics, max.	% m/m	1.1	EN 12916
Carbon residue on 10% distillation residue, max.	% m/m	0.30	EN ISO 10370
Lubricity, max.	µm	460	EN ISO 12156-1
Flash point, min.	°C	55 <sup>3)</sup>	EN ISO 2719
Cold filter plugging point, max. (climate dependent requirement)	°C	-20 → +5 <sup>4)</sup>	EN 116 / 16329
Oxidation stability, max. Oxidation stability, min.	g/m <sup>3</sup> h	25 20 <sup>5)</sup>	EN ISO 12205 EN 15751
Copper strip corrosion (3 hrs @ 50 °C), max.	Rating	Class 1	EN ISO 2160
Distillation			EN ISO 3405 / 3924
% v/v recovered @ 250 °C, max.	% v/v	65	
% v/v recovered @ 350 °C, min.	% v/v	85	
95 % v/v recovered at, max.	°C	360	
Distillation % v/v recovered @ 250 °C, max. % v/v recovered @ 350 °C, min. 95 % v/v recovered at, max.	% v/v % v/v °C	65 85 360	EN ISO 3405 / 3924
FAME content, max.	% v/v	7.0	EN 14078

**NOTICE**

- 1) Min. limit at engine inlet in running conditions ( $\text{mm}^2/\text{s} = \text{cSt}$ ).
- 2) Due to low density the guaranteed engine output of pure hydrotreated fuel / GTL has to be confirmed case by case.
- 3) The use in marine applications is allowed provided that a fuel supplier can guarantee min. flash point of  $60\text{ }^\circ\text{C}$ .
- 4) Cold flow properties of renewable biodiesel can vary based on the geographical location and also based on the feedstock properties, which issues must be taken into account when designing the fuel system. For arctic or severe winter climates even lower CFPP values down to  $-44\text{ }^\circ\text{C}$  are specified.
- 5) Additional requirement if the fuel contains  $> 2.0\%$  v/v of FAME.

**NOTICE**

When analysing the energy content (Higher and Lower Heating Value) of paraffinic diesel the calculation method included in the ISO 8217 standard can't be used, but the analysis has to be made by following the ASTM D240 standard.

## 6.2 External fuel oil system

The design of the external fuel system may vary from installation to installation but every system shall be designed to provide the engine with fuel oil of correct flow, pressure, viscosity and degree of purity. Temperature control is required to maintain stable and correct viscosity of the fuel before the injection pumps (please refer to [Engine Online Configurator](#) available through Wärtsilä website for details). Sufficient circulation through every engine connected to the same circuit must be ensured in all operating conditions.

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

The external fuel system must not contaminate the engine's fuel with zinc. For example, galvanized surfaces or surfaces painted with paints containing zinc must not be in contact with engine fuel. Zinc in the fuel system could lead to e.g. clogged injectors and operational problems.

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.

### NOTICE

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.

### NOTE

- Recommended maximum number of engines connected in parallel to the same fuel feed system is three
- Separate fuel feed circuits are recommended for each propeller shaft (two engine installations); in four engine installations so that one engine from each shaft is fed from the same circuit
- Main and auxiliary engines are recommended to be connected to separate circuits

### 6.2.1 Low sulphur operation

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

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

### 6.2.2 Definitions Filtration term used

• **Beta value  $\beta_{xx}$  ISO 16889, and Efficiency  $\epsilon_{xx}$** : scientific measurement of filter effectiveness. Numerical result on a given filter variates, depending on test method used, and on dust size distribution used during measurements.

- **Beta value  $\beta_{xx} = YY$**  : ISO name with ISO 16889 internationally standardised test method. Scientific repeatability below 25 micron  $\beta_{xx} = 75$ , but weaker repeatability for filter mesh bigger than 25..45 microns. Example:  $\beta_{20} = 75$  means “ultipass test, with standardised dust (ISO MTD dust): every 75 particles 20 micron ISO dust sent, one passes.”
- **Efficiency  $\epsilon_{xx} = YY\%$**  : Old terminology, mathematically same meaning as Beta-value, but not any ISO standardised test method, and not necessarily with ISO MTD dust. Hence sometimes used for particles larger than 25..45 micron. Example:  $\epsilon_{20} = 98,7\%$  means “undefined test method, undefined dust: every 75 particles 20 micron non-ISO dust sent, one passes, which is 98,7% stopped.”
- **mesh size**: opening of the mesh (surface filtration), and often used as commercial name at purchase. Only approximately related to Efficiency and Beta-value. Insufficient to compare two filters from two suppliers. Good to compare two meshes of same filter model from same supplier. Totally different than micron absolute, that is always much bigger size in micron.  
e.g. a real example: 30 micron mesh size = approx. 50 micron  $\beta_{50} = 75$
- **abs. mesh (sphere passing mesh)**: it is a more accurate mesh size definition than above. It also specifies the measurement method (with spherical particles, passing /not passing through). On a given filter, it can have a different micron value than the commercial “mesh size”
- **XX micron, absolute**: it defines the real grade of filtration only when it is followed by Beta-value or Efficiency. Example: many suppliers intend it as  $\beta_{xx} = 75$  ISO 16889 similar to old efficiency  $\epsilon_{xx} = 98,7\%$ , or as  $\beta_{xx} = 200$  ISO 16889 (was  $\epsilon_{xx} = 99,9\%$ ), but some suppliers intend it as  $\beta_{xx} = 2$  ISO 16889 (was  $\epsilon_{xx} = 50\%$ )
- **XX micron, nominal**: commercial name of that mesh, at purchase. Not really related to filtration capability, especially when comparing different suppliers. Typically, a totally different value than XX micron, absolute e.g. a real example: 10 micron nominal ( $\epsilon_{10} = 60\%$ ) = approx. 60 micron absolute  $\beta_{60} = 75$  ISO 16889

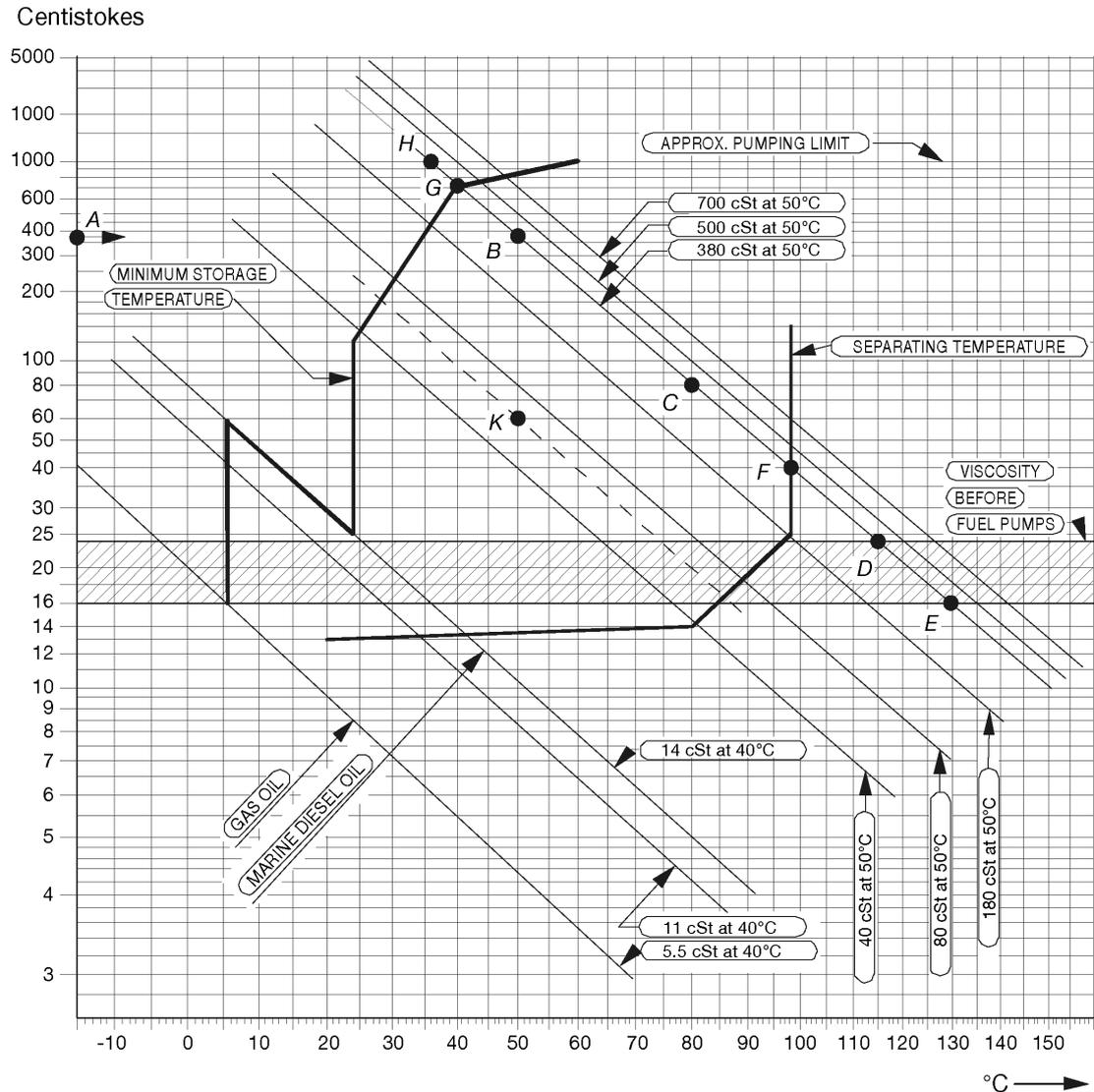
### 6.2.3 Fuel heating requirements HFO

Heating is required for:

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

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

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



**Fig 6-1 Fuel oil viscosity-temperature diagram for determining the pre-heating temperatures of fuel oils (V92G0071b)**

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

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

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

## 6.2.4 Fuel tanks

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

### 6.2.4.1 Settling tank, HFO (1T02) and LFO (1T10)

Separate settling tanks for HFO and LFO are recommended.

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

To ensure sufficient time for settling (water and sediment separation), the capacity of each tank should be sufficient for min. 24 hours operation at maximum fuel consumption. The tanks should be provided with internal baffles to achieve efficient settling and have a sloped bottom for proper draining. The temperature in HFO settling tanks should be maintained between 50°C and 70°C, which requires heating coils and insulation of the tank. Usually LFO settling tanks do not need heating or insulation, but the tank temperature should be in the range 20...40°C.

#### **6.2.4.2 Day tank, HFO (1T03) and LFO (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 LFO. The capacity of the LFO tank should ensure fuel supply for 8 hours. Settling tanks may not be used instead of day tanks.

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

The day tank must be designed so that accumulation of sludge near the suction pipe is prevented and the bottom of the tank should be sloped to ensure efficient draining. HFO day tanks shall be provided with heating coils and insulation. It is recommended that the viscosity is kept below 140 cSt in the day tanks. Due to risk of wax formation, fuels with a viscosity lower than 50 cSt at 50°C must be kept at a temperature higher than the viscosity would require. Continuous separation is nowadays common practice, which means that the HFO day tank temperature normally remains above 90°C. The temperature in the LFO 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 LFO from a gravity tank is foreseen, then the tank must be located at least 15 m above the engine crankshaft.

#### **6.2.4.3 Starting tank, LFO (1T09)**

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

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

#### **6.2.4.4 Leak fuel tank, clean fuel (1T04)**

Clean leak fuel is drained by gravity from the engine. The fuel should be collected in a separate clean leak fuel tank, from where it can be pumped to the day tank and reused without separation. The pipes from the engine to the clean leak fuel tank should be arranged continuously sloping.

The tank and the pipes must be heated and insulated, unless the installation is designed for operation on LFO only.

In HFO installations the change over valve for leak fuel (1V13) is needed to avoid mixing of the LFO and HFO clean leak fuel. When operating the engines in LFO, the clean LFO leak fuel shall be directed to the LFO clean leak fuel tank. Thereby the LFO can be pumped back to the LFO day tank (1T06).

When switching over from HFO to LFO the valve 1V13 shall direct the fuel to the HFO leak fuel tank long time enough to ensure that no HFO is entering the LFO clean leak fuel tank.

Refer to section "*Fuel feed system - HFO installations*" for an example of the external HFO fuel oil system.

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

### 6.2.4.5 Leak fuel tank, dirty fuel (1T07)

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

Dirty leak fuel shall be led to a sludge tank.

The tank and the pipes must be heated and insulated, unless the installation is designed for operation exclusively on LFO.

### 6.2.4.6 Bunker tank (1T01)

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

## 6.2.5 Fuel treatment

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

#### Separator mode of operation

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

Separators with monitoring of cleaned fuel (without gravity disc) operating on a continuous basis can handle fuels with densities exceeding 991 kg/m<sup>3</sup> at 15°C. In this case the main and stand-by separators should be run in parallel.

When separators with gravity disc are used, then each stand-by separator should be operated in series with another separator, so that the first separator acts as a purifier and the second as clarifier. This arrangement can be used for fuels with a density of max. 991 kg/m<sup>3</sup> 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<sub>out</sub> = number of test particles in cleaned test oil

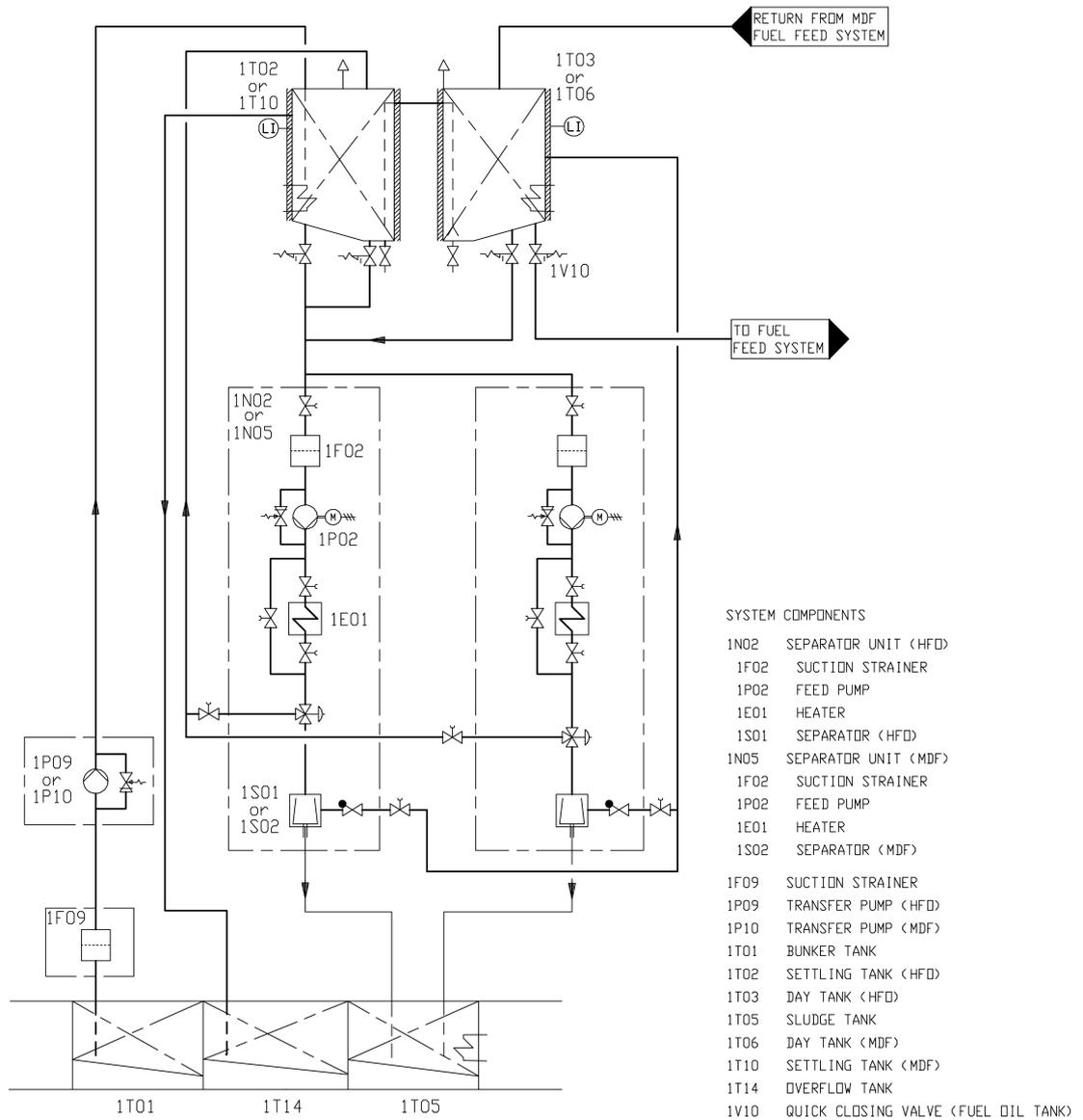
C<sub>in</sub> = number of test particles in test oil before separator

### 6.2.5.2 Separator unit (1N02/1N05)

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

Typically separator modules are equipped with:

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



**Fig 6-2 Fuel transfer and separating system (V76F6626G)**

### 6.2.5.3 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	LFO
Design pressure	0.5 MPa (5 bar)	0.5 MPa (5 bar)
Design temperature	100°C	50°C
Viscosity for dimensioning electric motor	1000 cSt	100 cSt

### 6.2.5.4 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  $\pm 2^{\circ}\text{C}$ .

Recommended fuel temperature after the heater depends on the viscosity, but it is typically  $98^{\circ}\text{C}$  for HFO and  $20\text{...}40^{\circ}\text{C}$  for LFO. The optimum operating temperature is defined by the separator 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]

$\Delta T$  = temperature rise in heater [ $^{\circ}\text{C}$ ]

For heavy fuels  $\Delta T = 48^{\circ}\text{C}$  can be used, i.e. a settling tank temperature of  $50^{\circ}\text{C}$ . Fuels having a viscosity higher than 5 cSt at  $50^{\circ}\text{C}$  require pre-heating before the separator.

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

### 6.2.5.5 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:

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

where:

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

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

$\rho$  = density of the fuel [ $\text{kg}/\text{m}^3$ ]

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

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

Sample valves must be placed before and after the separator.

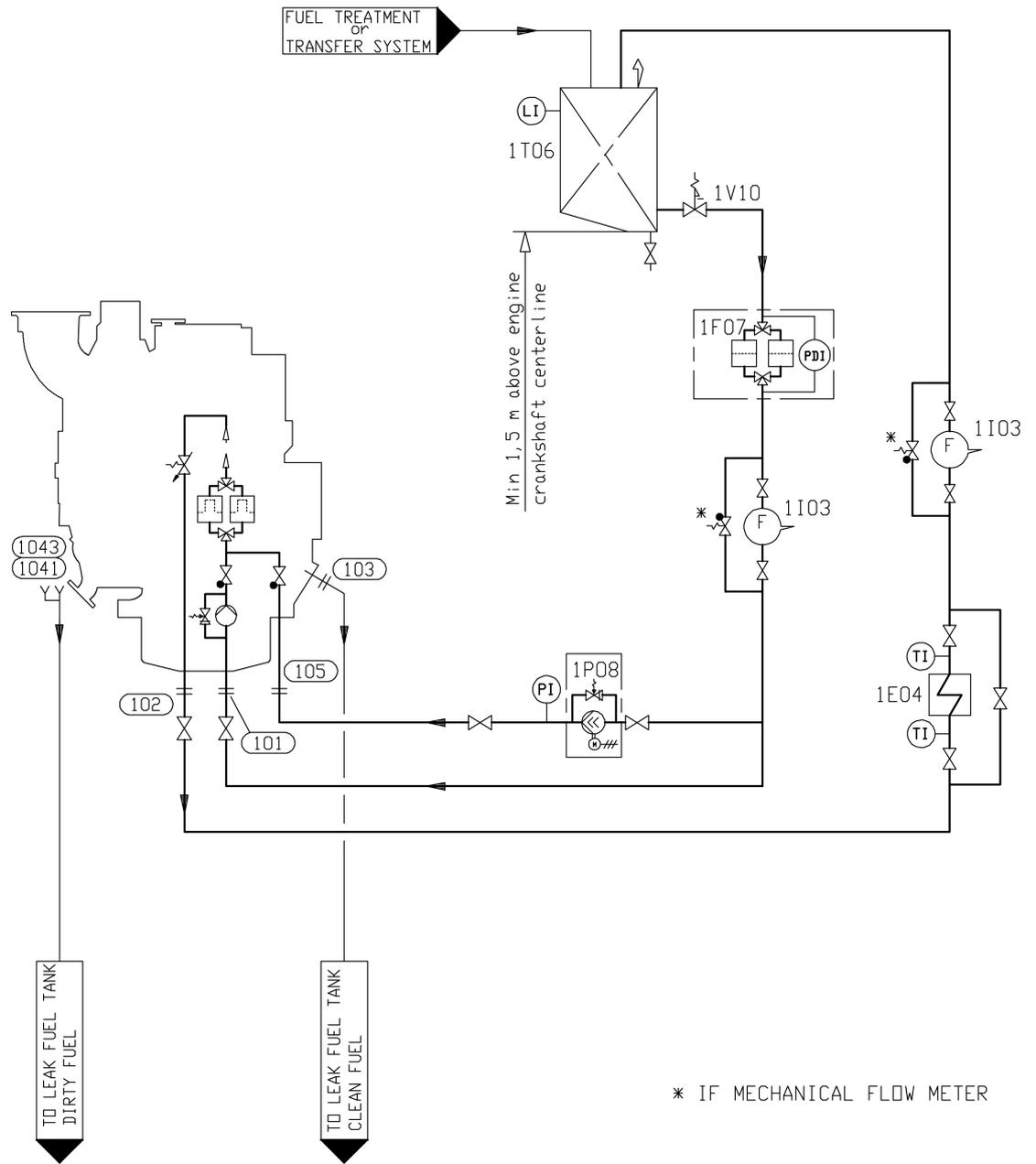
### **6.2.5.6 LFO separator in HFO installations (1S02)**

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

### **6.2.5.7 Sludge tank (1T05)**

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

## 6.2.6 Fuel feed system - LFO installations



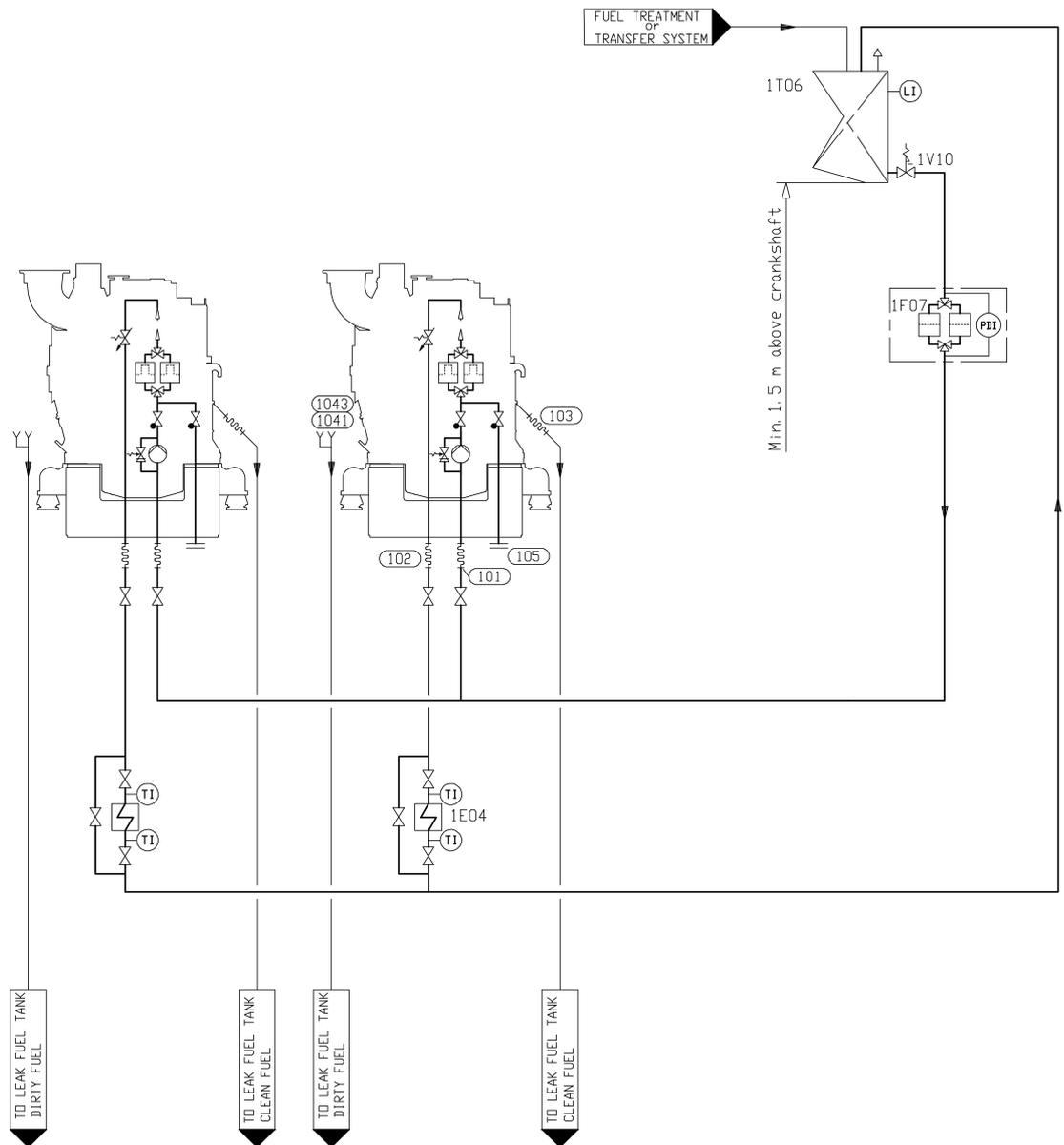
**Fig 6-3 Fuel feed system, single main engine (DAAE003608E)**

System components			
1E04	Cooler (LFO)	1P08	Standby pump (LFO)
1F07	Suction strainer (LFO)	1T06	Day tank (LFO)
1I03	Flow meter (LFO)	1V10	Quick closing valve (Fuel Oil Tank)

Pipe connections		Size
101	Fuel inlet	OD28
102	Fuel outlet	OD28
103	Leak fuel drain, clean fuel	OD18

(continued)

<b>Pipe connections</b>		<b>Size</b>
1041	Leak fuel drain, dirty fuel free end	OD22
1043	Leak fuel drain, dirty fuel FW-end	OD18
105	Fuel stand-by connection	OD22



**Fig 6-4 Fuel feed system, multiple engines (DAAF064961A)**

System components			
1E04	Cooler (LFO)	1T06	Day tank (LFO)
1F07	Suction strainer (LFO)	1V10	Quick closing valve (Fuel Oil Tank)

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

If the engines are to be operated on LFO 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 LFO part of a HFO fuel oil system.

### 6.2.6.1 Circulation pump, LFO (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 without circulation pumps (1P12)	please refer to <a href="#">Engine Online Configurator</a> available through Wärtsilä website
Capacity with circulation pumps (1P12)	15% more than total capacity of all 1P12 circulation pumps
Design pressure	1.6 MPa (16 bar)
Max. total pressure (safety valve)	1.0 MPa (10 bar)
Nominal pressure	please refer to <a href="#">Engine Online Configurator</a> available through Wärtsilä website
Design temperature	50°C
Viscosity for dimensioning of electric motor	90 cSt

### 6.2.6.2 Stand-by pump, LFO (1P08)

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

**Design data:**

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

### 6.2.6.3 Flow meter, LFO (1I03)

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

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

### 6.2.6.4 Fine filter or Safety filter, LFO (1F05)

The fuel oil fine filter (safety 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 (safety 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	34 µm (absolute mesh size) ( $\beta_{34} = 2$ , $\beta_{50} = 75$ , ISO16889)

Maximum permitted pressure drops at 14 cSt:

- clean filter	20 kPa (0.2 bar)
- alarm	80 kPa (0.8 bar)

### 6.2.6.5 LFO cooler (1E04)

The fuel viscosity may not drop below the minimum value stated in [Engine Online Configurator](#) available through Wärtsilä website. When operating on LFO, 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 LFO 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 LFO viscosity in day tank drops below stated minimum viscosity limit then it is recommended to install a LFO cooler into the engine fuel supply line in order to have reliable viscosity control.

**Design data:**

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

### 6.2.6.6 Return fuel tank (1T13)

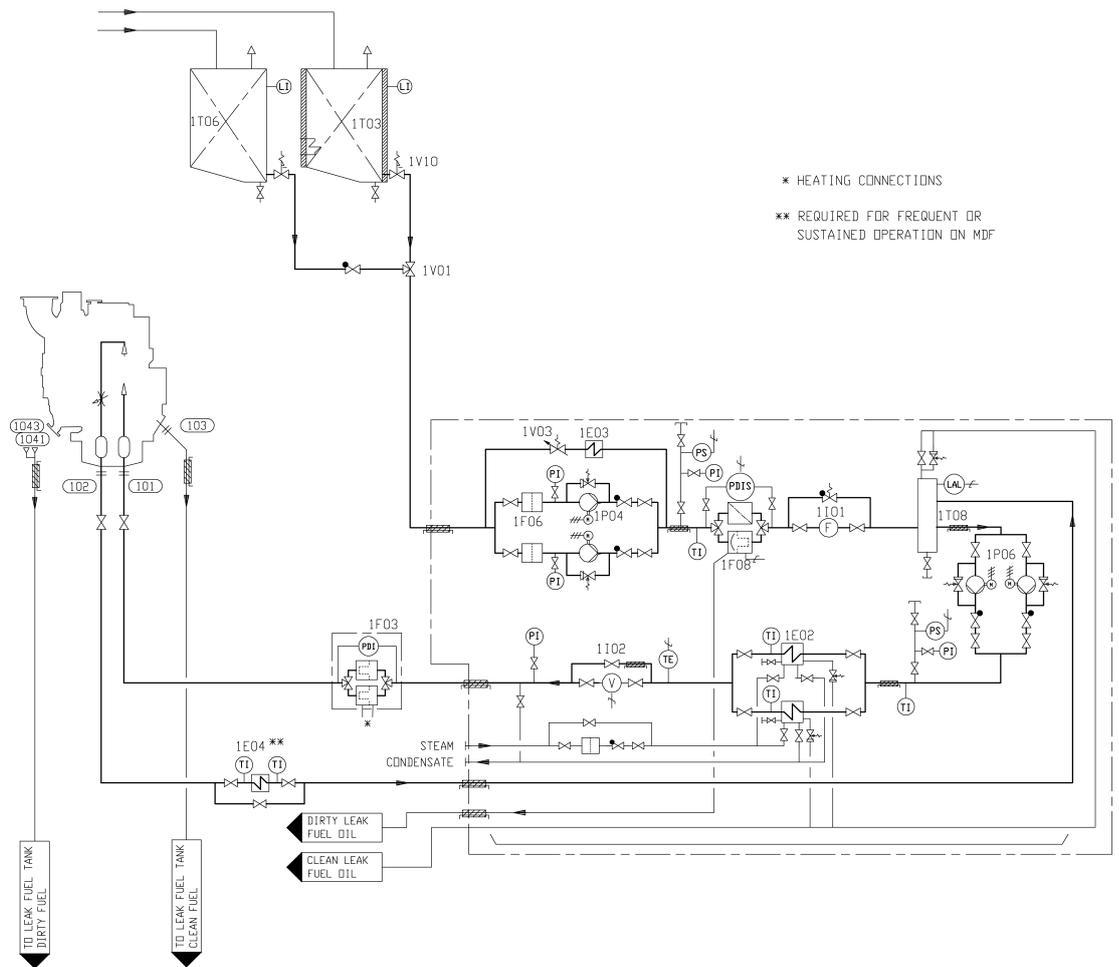
The return fuel tank shall be equipped with a vent valve needed for the vent pipe to the LFO day tank. The volume of the return fuel tank should be at least 100 l.

### **6.2.6.7 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. Engines without engine driven fuel feed pump can reach sufficient fuel pressure to enable black out start by means of:

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

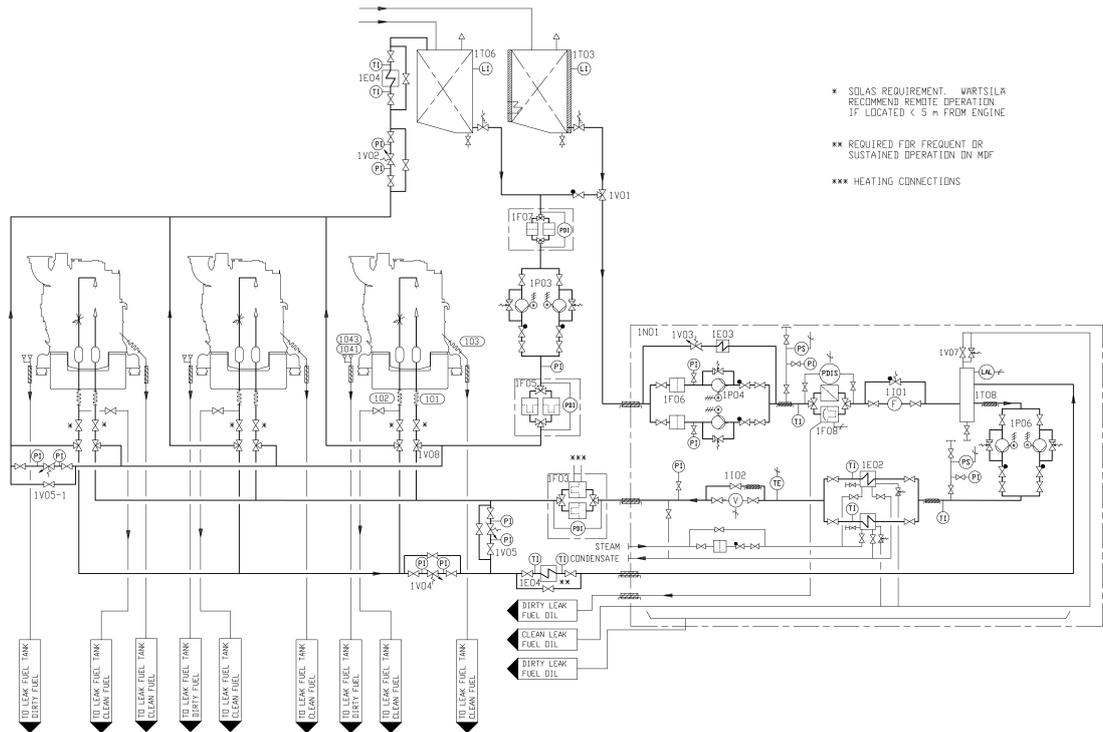
## 6.2.7 Fuel feed system - HFO installations



**Fig 6-5 Fuel oil system (HFO), single main engine (DAAF437836)**

System components			
1E02	Heater (booster unit)	1P06	Circulation pump (booster unit)
1E03	Cooler (booster unit)	1T03	Day tank (HFO)
1E04	Cooler (LFO)	1T06	Day tank (LFO)
1F03	Safety filter (HFO)	1T08	De-aeration tank (booster unit)
1F06	Suction filter (booster unit)	1V01	Change over valve
1F08	Automatic filter (booster unit)	1V03	Pressure control valve (booster unit)
1I01	Flow meter (booster unit)		
1I02	Viscosity meter (booster unit)		
1P04	Fuel feed pump (booster unit)		

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



**Fig 6-6 Example of fuel oil system (HFO), multiple engine installation (V76F6656H)**

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

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

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

### 6.2.7.1 Starting and stopping

The engine can be started and stopped on HFO provided that the engine and the fuel system are pre-heated to operating temperature. The fuel must be continuously circulated also through a stopped engine in order to maintain the operating temperature. Changeover to LFO 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 LFO.

### 6.2.7.2 Changeover from HFO to LFO

The control sequence and the equipment for changing fuel during operation must ensure a smooth change in fuel temperature and viscosity. When LFO 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 LFO, then the fuel change should be performed with the HFO feeder/booster unit before switching over to the LFO circulating pumps. As mentioned earlier, sustained operation on LFO usually requires a fuel oil cooler. The viscosity at the engine shall not drop below the minimum limit stated in [Engine Online Configurator](#) available through Wärtsilä website.

### 6.2.7.3 Changeover to low sulphur fuel

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

### 6.2.7.4 Number of engines in the same system

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

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

**In addition the following guidelines apply:**

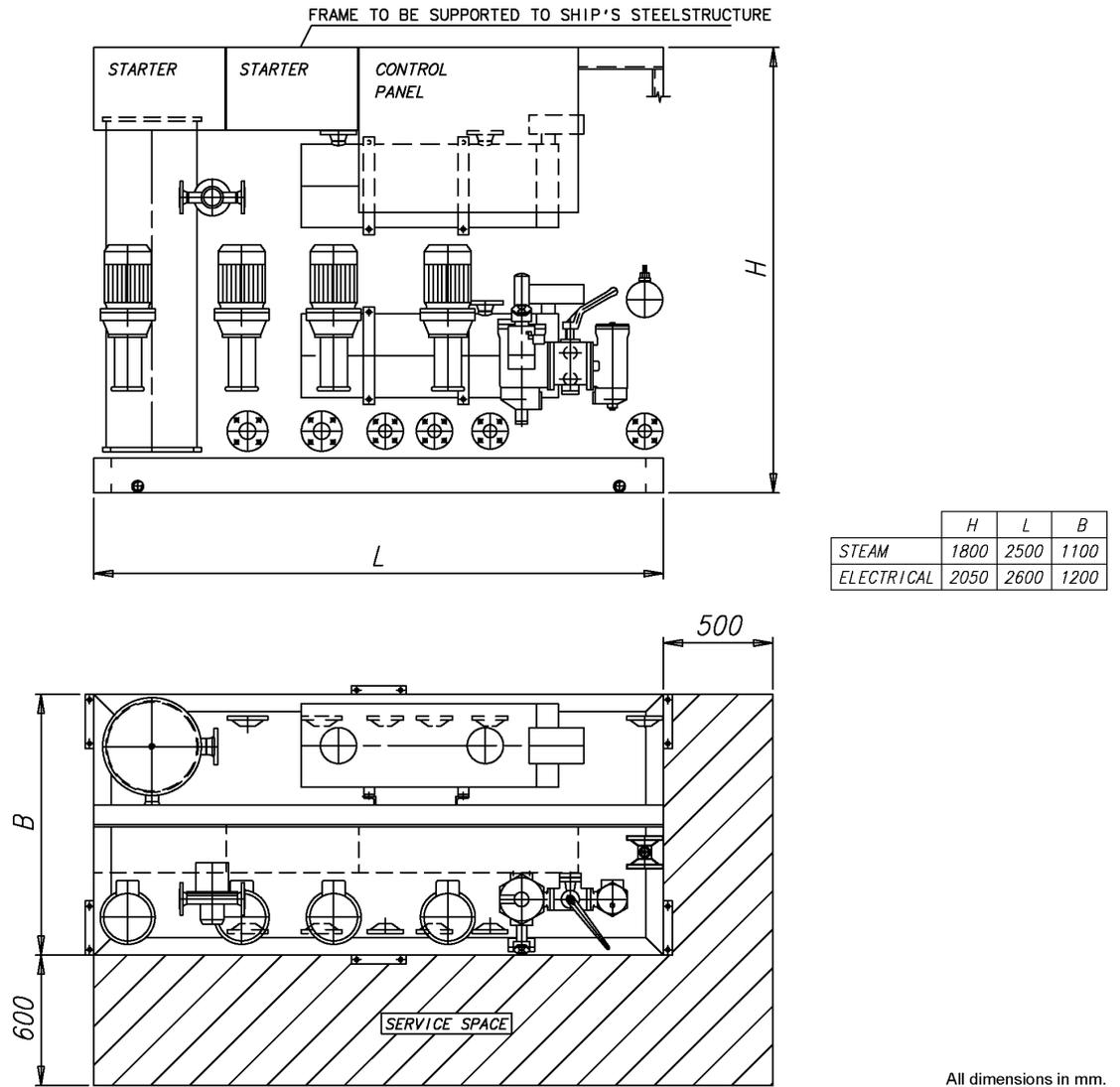
- Twin screw vessels with two engines should have a separate fuel feed circuit for each propeller shaft.
- Twin screw vessels with four engines should have the engines on the same shaft connected to different fuel feed circuits. One engine from each shaft can be connected to the same circuit.

**6.2.7.5 Feeder/booster unit (1N01)**

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

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



**Fig 6-7 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 stand-by 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 LFO.

#### 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 (or fuel main filter)	34 µm absolute ( $\beta_{34} = 2$ , $\beta_{50} = 75$ , ISO 16889)
- stand-by filter	34 µm absolute ( $\beta_{34} = 2$ , $\beta_{50} = 75$ , ISO 16889)
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 [Engine Online Configurator](#) available through Wärtsilä website. By circulating the fuel in the system it also maintains correct viscosity, and keeps the piping and the injection pumps at operating temperature. When more than one engine is connected to the same feeder/booster unit, individual circulation pumps (1P12) must be installed before each engine.

#### Design data:

Capacity without circulation pumps (1P12)	please refer to <a href="#">Engine Online Configurator</a> available through Wärtsilä website
Capacity with circulation pumps (1P12)	15% more than total capacity of all 1P12 circulation pumps
Design pressure	1.6 MPa (16 bar)
Max. total pressure (safety valve)	1.0 MPa (10 bar)
Design temperature	150°C
Viscosity for dimensioning of electric motor	500 cSt

### Heater, booster unit (1E02)

The heater must be able to maintain a fuel viscosity of 14 cSt at maximum fuel consumption, with fuel of the specified grade and a given day tank temperature (required viscosity at injection pumps stated in [Engine Online Configurator available through Wärtsilä website](#)). 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<sup>2</sup>.

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)

**6.2.7.6 Pump and filter unit (1N03)**

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

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

**Circulation pump (1P12)**

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

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

**Design data:**

Capacity	please refer to <a href="#">Engine Online Configurator</a> available through Wärtsilä website
Design pressure	1.6 MPa (16 bar)
Design temperature	150°C
Pressure for dimensioning of electric motor ( $\Delta P$ ):	
- if all fuel is fed through feeder/booster unit	0.3 MPa (3 bar)
Viscosity for dimensioning of electric motor	500 cSt

**6.2.7.7 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:**

(continued)

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	34 µm (absolute mesh size) ( $\beta_{34} = 2$ , $\beta_{50} = 75$ , ISO16889)
Maximum permitted pressure drops at 14 cSt:	
- clean filter	20 kPa (0.2 bar)
- alarm	80 kPa (0.8 bar)

### 6.2.7.8 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 ( $\Delta p$ )	0.1...0.2 MPa (1...2 bar)

### 6.2.7.9 Pressure control valve (1V04)

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

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

## 6.2.8 Flushing

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

The fuel pipes at the engine (connections 101 and 102) are disconnected and the supply and return lines are connected with a temporary pipe or hose on the installation side. All filter inserts

are removed, except in the flushing filter of course. The automatic filter and the viscosimeter should be bypassed to prevent damage.

The fineness of the flushing filter should be 35 µm or finer.

# 7. Lubricating Oil System

## 7.1 Lubricating oil requirements

### 7.1.1 Engine lubricating oil

The lubricating oil must be of viscosity class SAE 40 and have a viscosity index (VI) of minimum 95. The lubricating oil alkalinity (BN) is tied to the fuel grade, the required lubricating oil alkalinity in distillate fuel / liquid bio fuel operation is tied to the fuel quality as stated in the table hereafter. BN is an abbreviation of Base Number. The value indicates milligrams KOH per gram of oil.

**Table 7-1 Fuel standards and lubricating oil requirements**

Category	Fuel standard		Lubricating oil BN	Fuel S content, [% m/m]
A	ASTM D 975-17, ISO 8217:2017(E)	GRADE NO. 1-D, 2-D, 4-D ISO-F-DMX -> DMB, DFA ->DFB	10...20 21 - 30 *)	< 0.40
B	ASTM D 975-17 ISO 8217:2017(E)	GRADE NO. 1-D, 2-D, 4-D ISO-F-DMX -> DMB, DFA ->DFB	15...20 (10 - 14) ** (21 - 30) *)	0.40 - 1,50
C	ASTM D 975-17, ASTM D 396-17, ISO 8217:2017(E)	GRADE NO. 4-D GRADE NO. 5-6 RMA 10 - RMK 700 (incl. also max. 0,50 % m/m S VLSFO RM)	30...55	≤ 3.5 or statutory require- ments ***)
D	ISO 8217:2017(E)	RMA 10 - RMK 700 (ULSFO RM)	20	≤ 0.10
E	CRUDE OIL (GRO)		30...55	≤ 4.50
F	LIQUID BIO FUEL (LBF)	HVO ****), Biodiesel (FAME) *****), SVO & PVO *****)	10...15 (20)	< 0.05

### **NOTICE**

\*) Though the use of BN 21 – 30 lubricating oils is allowed in distillate fuel operation, there is no technical reason for that but a lower BN level shown in the above table is well enough.

\*\*\*) BN 10 – 14 lubricating oils cannot be recommended in the first place when operating on > 0,40 % m/m sulphur distillate fuels due to shortened oil change interval resulting from BN depletion.

\*\*\*\*) Sulphur content can be also higher than 3,50 % m/m

\*\*\*\*\*) Hydrotreated Vegetable Oil (HVO)

\*\*\*\*\*) Fatty Acid Methyl Ester (FAME).

\*\*\*\*\*) The use of Straight Vegetable Oil (SVO) & Pure Vegetable Oil (PVO) is not allowed in the W46F engine type

In case a low sulphur (S max. 0,4 % m/m) distillate fuel is used, it's recommended to use a lubricating oil with BN of 10 – 15.

It is recommended to use in the first place BN 50 - 55 lubricants when operating on residual fuel. This recommendation is valid especially for engines having wet lubricating oil sump and using residual fuel with sulphur content above 2,0 % mass. BN 40 lubricants can be used when operating on residual fuel as well if experience shows that the lubricating oil BN equilibrium remains at an acceptable level.

In residual fuel operation BN 30 lubricants are recommended to be used only in special cases, like e.g. such as installations equipped with an SCR catalyst. Lower BN products eventually have a positive influence on cleanliness of the SCR catalyst. With BN 30 oils lubricating oil

change intervals may be rather short, but lower total operating costs may be achieved because of better plant availability provided that the maintenance intervals of the SCR catalyst can be increased.

If both distillate fuel and residual fuel are used in turn as fuel, lubricating oil quality has to be chosen according to instructions being valid for residual fuel operation, i.e. BN 30 is the minimum.

Optimum BN in this kind of operation depends on the length of operating periods on both fuel qualities as well as of sulphur content of fuels in question. Thus in particular cases BN 40 or even higher BN lubricating oils should be used.

If Ultra Low Sulphur Fuel Oils (ULSFO) with sulphur content of max. 0,10 % m/m being classed as residual fuels are used, the use of BN 20 lubricating oil is allowed.

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 is still under warranty.

An updated list of validated lubricating oils is supplied for every installation. Please refer to Service Bulletin WS15S475.

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 is still under warranty.

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

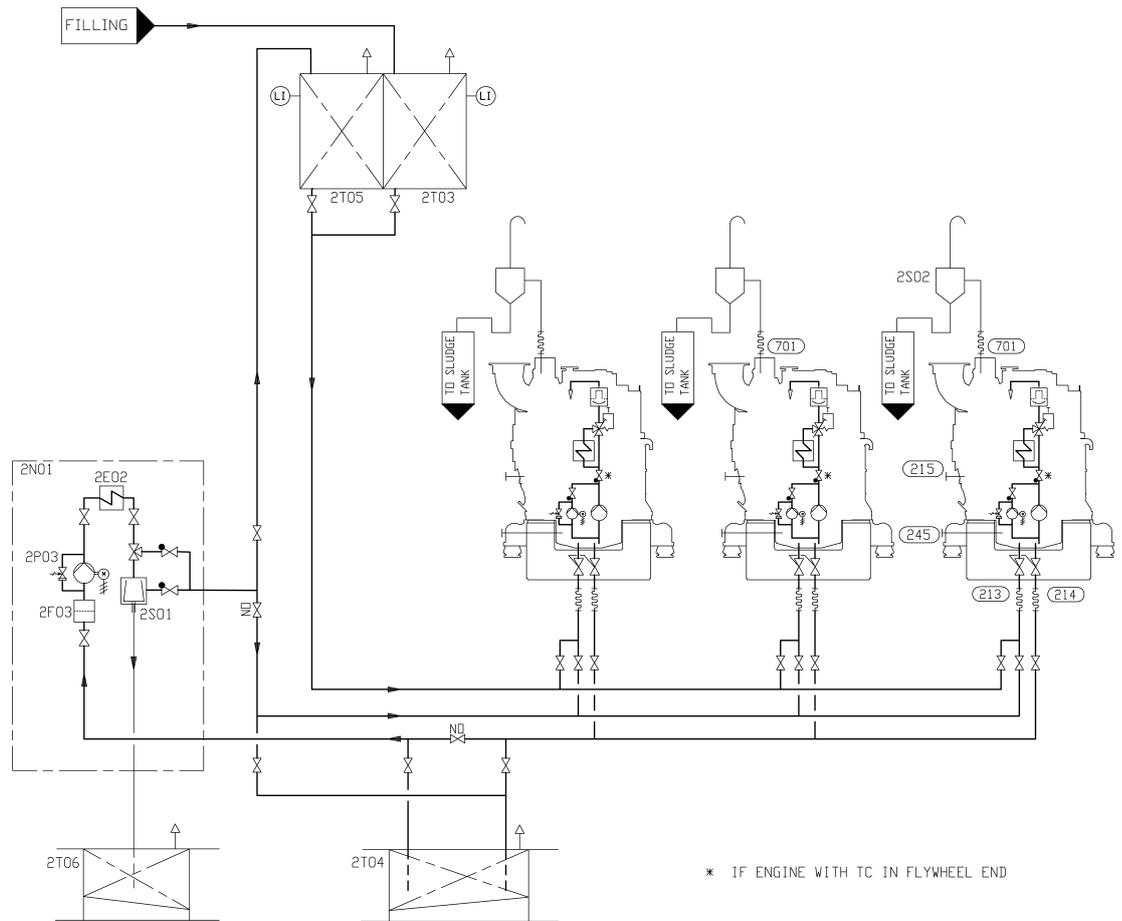
## 7.1.2 Oil in speed governor or actuator

An oil of viscosity class SAE 30 or SAE 40 is suitable and usually the same oil can be used as in the engine. Turbocharger oil can also be used in the governor. At cold ambient conditions it may be necessary to use a multigrade oil (e.g. SAE 5W-40) for better governor response during start-up. Oil change interval: 2000 service hours.

<b>NOTICE</b>
Monograde engine oils, multigrade oils or turbocharger oils etc. are not compatible with each other and shall not be mixed. Thus it's important to drain and flush with the new oil both the governor and booster properly if changing the oil quality.

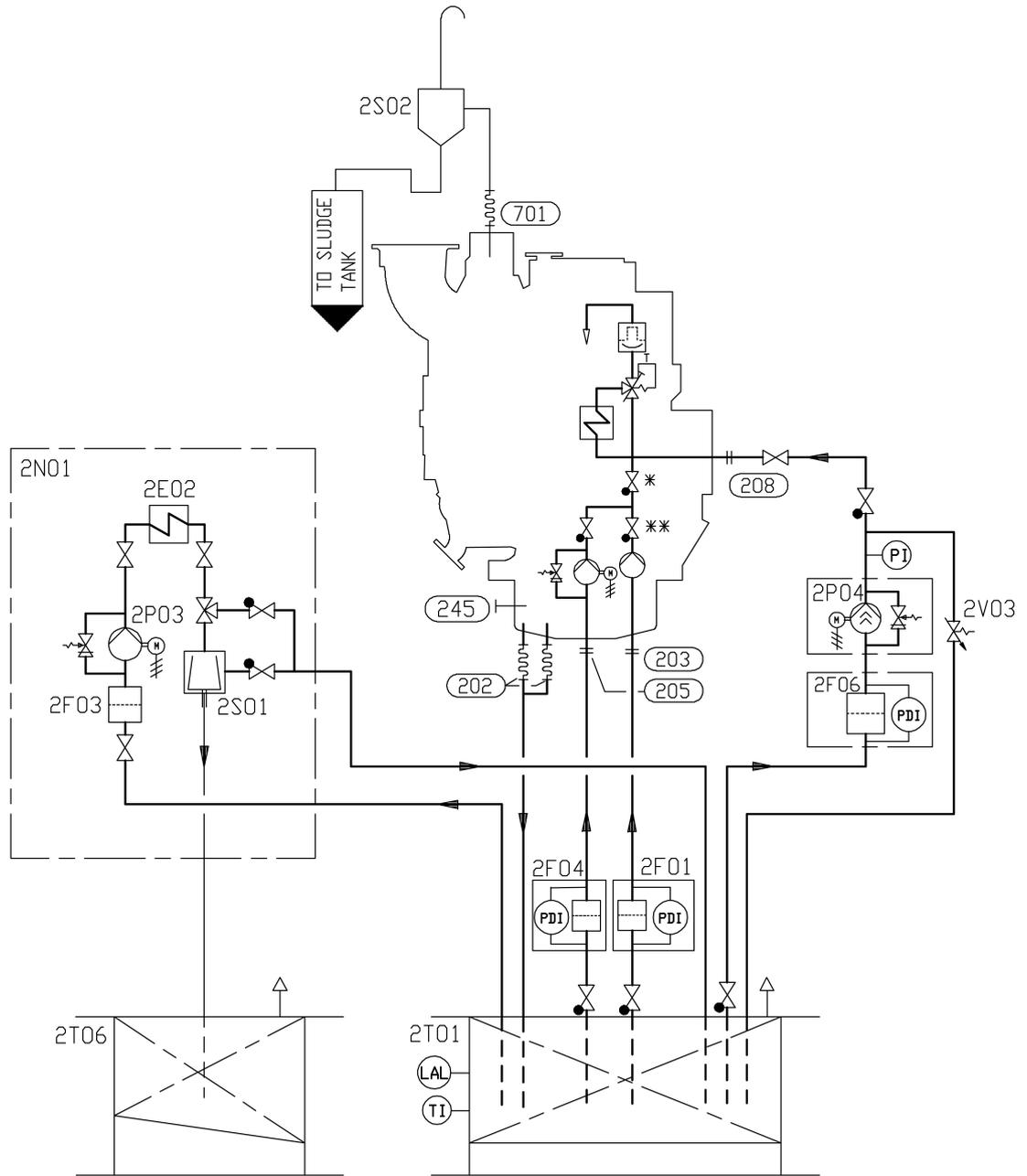
<b>NOTICE</b>
No oil in digital electric actuator, please contact Wärtsilä for further details.

## 7.2 External lubricating oil system



**Fig 7-1 Lubricating oil system, auxiliary engines (V76E4590F)**

System components		Pipe connections		Size
2E02	Heater (Separator unit)	213	Lubricating oil from separator and filling	DN32
2F03	Suction filter (Separator unit)	214	Lubricating oil to separator and drain	DN32
2N01	Separator unit	215	Lubricating oil filling	M48*2
2P03	Separator pump (Separator unit)	245	Priming pump lubrication drain	M12
2S01	Separator	701	Crankcase air vent	DN65
2S02	Condensate trap			
2T03	New oil tank			
2T04	Renovating oil tank			
2T05	Renovated oil tank			
2T06	Sludge tank			



\* IF ENGINE WITH TC IN FLYWHEEL END

\*\* IF STAND-BY PUMP & ENGINE WITH TC IN FREE END

**Fig 7-2 Lubricating oil system, single main engine (V76E4591H)**

System components		Pipe connections		Size
2E02	Heater (Separator unit)	202	Lubricating oil outlet (from oil sump)	DN100
2F01	Suction strainer (Main lubricating oil pump)	203	Lubricating oil to engine driven pump	DN100
2F03	Suction filter (Separator unit)	205	Lubricating oil to priming pump	DN32
2F04	Suction strainer (Prelubricating oil pump)	208	Lubricating oil from electric driven pump	DN80
2F06	Suction strainer (Stand-by pump)	245	Priming pump lubrication drain	M12
2N01	Separator unit	701	Crankcase air vent	DN65
2P03	Separator pump (Separator unit)			
2P04	Stand-by pump			

(continued)

System components		Pipe connections		Size
2S01	Separator			
2S02	Condensate trap			
2T01	System oil tank			
2T06	Sludge tank			
2V03	Pressure control valve			

## 7.2.1 Separation system

### 7.2.1.1 Separator unit (2N01)

As a method of external lubricating oil treatment, the requirement depends on fuel type. Engines operating on HFO should have dedicated lubricating oil separator and the separators shall be dimensioned for continuous separating. If the installation is designed to operate on LFO only, the use of lubricating oil separator or similar device maintaining oil cleanliness is recommended.

A lube oil separator is required, as oil by-pass treatment device, for engines running on fuels classified as worse than ISO-F-DMB.

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.

It shall be considered that, while the engine is stopped in stand-by mode without LT water circulation, the separator unit may be heating up the total amount of lubricating oil in the oil tank to a value higher than the nominal one required at engine inlet, after lube oil cooler (please refer to [Engine Online Configurator](#) available through Wärtsilä website). Higher oil temperatures at engine inlet than the nominal, may be creating higher component wear and in worst conditions damages to the equipment and generate alarm signal at engine start, or even a load reduction request to PMS.

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 LFO

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

### Sludge tank (2T06)

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

#### 7.2.1.2 Renovating oil tank (2T04)

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

#### 7.2.1.3 Renovated oil tank (2T05)

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

### 7.2.2 System oil tank (2T01)

Recommended oil tank volume is stated in [Engine Online Configurator](#) available through Wärtsilä website.

The system oil tank is usually located beneath the engine foundation. The tank may not protrude under the reduction gear or generator, and it must also be symmetrical in transverse direction under the engine. The location must further be such that the lubricating oil is not cooled down below normal operating temperature. Suction height is especially important with engine driven lubricating oil pump. Losses in strainers etc. add to the geometric suction height. Maximum suction ability of the pump is stated in [Engine Online Configurator](#) available through Wärtsilä website.

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

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

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

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

It must be possible to raise the oil temperature in the tank after a long stop. In cold conditions it can be necessary to have heating coils in the oil tank in order to ensure pumpability. The separator heater can normally be used to raise the oil temperature once the oil is pumpable.

Further heat can be transferred to the oil from the preheated engine, provided that the oil viscosity and thus the power consumption of the pre-lubricating oil pump does not exceed the capacity of the electric motor.

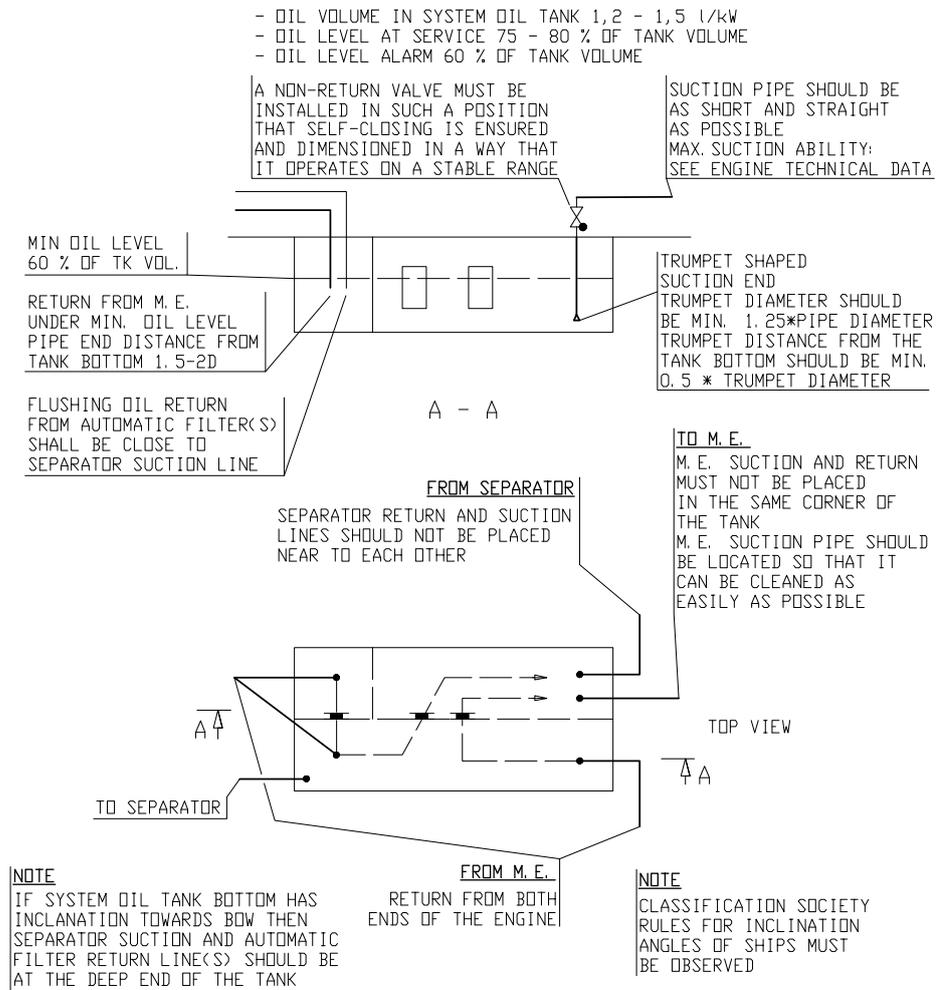


Fig 7-3 Example of system oil tank arrangement (DAAE007020G)

### 7.2.3 New oil tank (2T03)

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

### 7.2.4 Suction strainers (2F01, 2F04, 2F06)

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

**Design data:**

Fineness	0.5...1.0 mm
----------	--------------

### 7.2.5 Lubricating oil pump, stand-by (2P04)

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

**Design data:**

Capacity	please refer to <a href="#">Engine Online Configuration</a> or available through Wärtsilä website
Design pressure, max	0.8 MPa (8 bar)
Design temperature, max.	100°C
Lubricating oil viscosity	SAE 40
Viscosity for dimensioning the electric motor	500 mm <sup>2</sup> /s (cSt)

## 7.3 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.

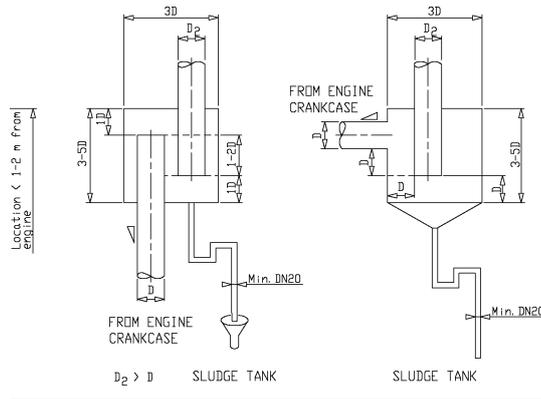
The diameter of the pipe shall be large enough to avoid excessive back pressure. Other possible equipment in the piping must also be designed and dimensioned to avoid excessive flow resistance.

A condensate trap and a drain must be provided for the vent pipe near the engine.

The connection between engine and pipe is to be flexible. It is very important that the crankcase ventilation pipe is properly fixed to a support rigid in all directions directly after the flexible hose from crankcase ventilation outlet, extra mass on the oil mist detector must be avoided. There should be a fixing point on both sides of the pipe at the support. Absolutely rigid mounting between the pipe and the support is recommended. The supporting must allow thermal expansion and ship's structural deflections.

**Design data:**

Flow	please refer to <a href="#">Engine Online Configurator</a> available through Wärtsilä website
Crankcase pressure, max.	please refer to <a href="#">Engine Online Configurator</a> available through Wärtsilä website
Temperature	80°C



**Fig 7-4 Condensate trap (DAAE032780B)**

The size of the ventilation pipe (D<sub>2</sub>) out from the condensate trap should be 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.

## 7.4 Flushing instructions

Flushing instructions in this Product Guide are for guidance only. For contracted projects, please refer to Installation Planning Instructions (IPI) for the fineness of the flushing filter and other project specific instructions.

### 7.4.1 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). Cleanliness of the external system shall be verified after completed flushing and is acceptable when the cleanliness has reached a level in accordance with ISO 4406 © 21/19/15, or NAS 1638 code 10. All pipes connected to the engine, the engine wet sump or to the external engine wise oil tank shall be flushed. Oil used for filling shall have a cleanliness of ISO 4406 © 21/19/15, or NAS 1638 code 10.

<b>NOTICE</b>
The engine must not be connected during flushing.

### 7.4.2 External oil system

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

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

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

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

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

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

### 7.4.3 Type of flushing oil

#### 7.4.3.1 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 85°C or by using a separate flushing oil which has an ideal viscosity in ambient temperature.

#### 7.4.3.2 Flushing with engine oil

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

### **7.4.3.3 Flushing with low viscosity flushing oil**

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

### **7.4.3.4 Lubricating oil sample**

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

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

# 8. Compressed Air System

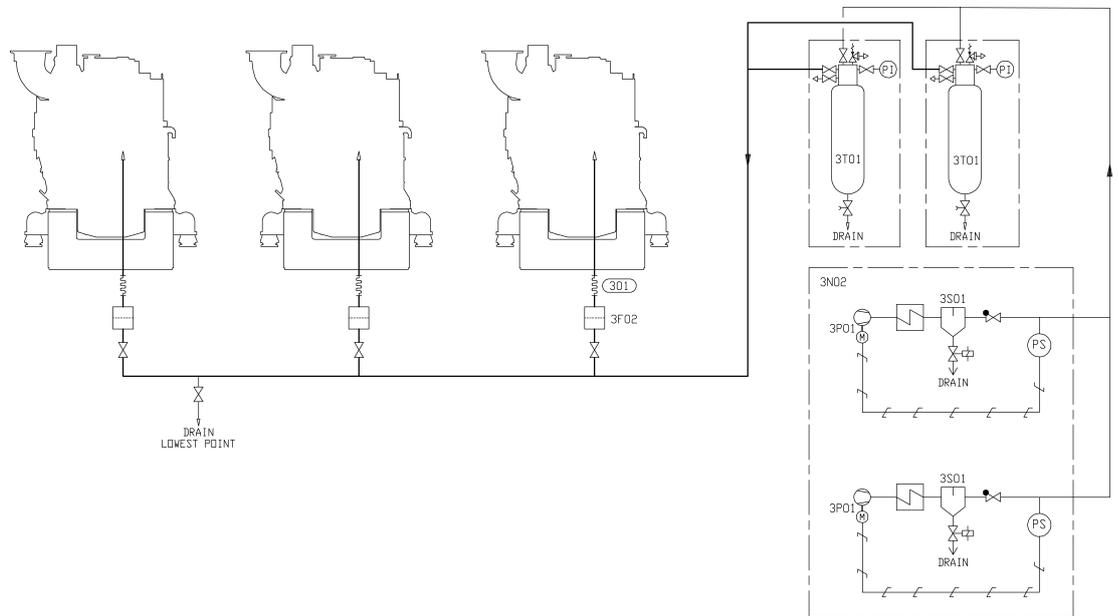
Compressed air is used to start engines and to provide actuating energy for safety and control devices. The use of starting air for other purposes is limited by the classification regulations.

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

## 8.1 External compressed air system

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

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



**Fig 8-1 External starting air system (DAAE007204I)**

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

Pipe connections		Size
301	Starting air inlet	OD28

### 8.1.1 Starting air compressor unit (3N02)

At least two starting air compressors must be installed. It is recommended that the compressors are capable of filling the starting air vessel from minimum (1.8 MPa) to maximum pressure in

15...30 minutes. For exact determination of the minimum capacity, the rules of the classification societies must be followed.

### 8.1.2 Oil and water separator (3S01)

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

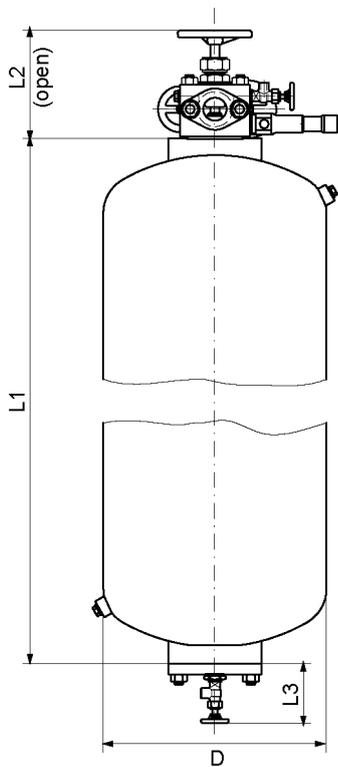
### 8.1.3 Starting air vessel (3T01)

The starting air vessels should be dimensioned for a nominal pressure of 3000 kPa (g).

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 <sup>1)</sup>	L3 <sup>1)</sup>	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

<sup>1)</sup> Dimensions are approximate.

**Fig 8-2 Starting air vessel**

The starting air consumption stated in [Engine Online Configurator](#) (available through Wärtsilä website) 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 take twice the air consumption of a successful start. 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<sup>3</sup>]

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

$V_E$  = air consumption per start [Nm<sup>3</sup>] please refer to [Engine Online Configurator](#) available through Wärtsilä website

$n$  = required number of starts according to the classification society

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

$p_{Rmin}$  = minimum starting air pressure = please refer to [Engine Online Configurator](#) available through Wärtsilä website

<b>NOTICE</b>
---------------

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

### 8.1.4 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 200 (75 µm). The pressure drop should not exceed 20 kPa (0.2 bar) for the engine specific starting air consumption under a time span of 4 seconds.

The starting air filter is mandatory for Wärtsilä 20 engines.

This page intentionally left blank

# 9. Cooling Water System

## 9.1 Water quality

Raw water quality to be used in the closed cooling water circuits of engines has to meet the following specification.

Property .....	Unit	Limits for chemical use
pH <sup>1)</sup> .....	-	6,5 – 8,5
Hardness .....	°dH	max. 10
Chlorides as Cl <sup>1)</sup> .....	mg/l	max. 80
Sulphates as SO <sub>4</sub> .....	mg/l	max. 150
Silica as SiO <sub>2</sub> .....	mg/l	max. 100

Use of raw water produced with an evaporator as well as a good quality tap water will normally ensure that an acceptable raw water quality requirement is fulfilled, but e.g. sea water and rain water are unsuitable raw water qualities.

1) If a Reverse Osmosis (RO) process is used, min. limit for pH is 6,0 based on the RO process operational principle. The use of water originating from RO process further presumes that a max. content of 80 mg/l for chloride content is achieved.

### 9.1.1 Corrosion inhibitors

The use of validated cooling water additives is mandatory, failing to follow this requirement will void any agreed engine warranty. An updated list of validated products is supplied for every installation and it can also be found in the Instruction manual of the engine, together with dosage and further instructions.

### 9.1.2 Validated cooling water additives

Manufacturer	Additive name	Additive type
Alm International S.A.	Diaprosim RD11 (RD11M)	Sodium nitrite + borate
S.A. Artec N.V.	Havoline XLI	Organic Acid Technology
Drew Marine	Liquidewt Maxigard	Sodium nitrite + borate Sodium nitrite + borate
Chevron (Texaco + Caltex)	Delo XLI Corrosion Inhibitor Concentrate (supersedes Havoline XLI) XL Corrosion Inhibitor Concentrate	Organic Acid Technology Organic Acid Technology
Korves Oy	Pekar J	Organic Acid Technology
Kuwait Petroleum (Danmark) AS	Q8 Corrosion Inhibitor Long-Life	Organic Acid Technology
Marine Care B.V.	Caretreat 2 Diesel	Sodium nitrite + borate
Maritech AB	Marisol CW	Sodium nitrite + borate

(continued)

Manufacturer	Additive name	Additive type
Motul	HD Cool Power Ultra	Organic Acid Technology
Nalco Chemical Company	TRAC102 TRAC118 Nalcool 2000	Sodium nitrite + borate Sodium nitrite + borate Sodium nitrite + borate
Shell	Shipcare Cooling Water Treat	Sodium nitrite + borate
Solenis	Drewgard 4109	Sodium nitrite + borate
Suez Water Technologies & Solutions	CorrShield NT4293 CorrShield NT4200	CorrShield NT4293 CorrShield NT4200
Total	WT Supra	Organic Acid Technology
Vecom Marine Alliance B.V.	Cool Treat NCLT	Sodium nitrite + borate
Wilhelmsen Chemicals AS	Dieselguard NB Rocor NB liquid Cooltreat AL Engine Water Treatment 9-108 Nalfleet 2000	Sodium nitrite + borate Sodium nitrite + borate Organic Acid Technology Sodium nitrite + borate Sodium nitrite + borate

In order to prevent corrosion in the cooling water system, the instructions of right dosage and concentration of active corrosion inhibitors should always be followed. Please contact Wärtsilä for details.

### 9.1.3 Glycol

If a freezing risk exists, glycol needs to be added to cooling water. However, in case there is no freezing risk, the use of glycol in cooling water shall be avoided due to its detrimental effect on heat transfer. Since glycol alone does not protect the engine and cooling water system against corrosion, additionally a validated cooling water additive must always be used. All validated cooling water additives are compatible with glycol.

Ready-to-use mixtures of commercial coolant brands containing both glycol and corrosion inhibitors are not allowed to use. Those are typically designed to be used as strong (~ 30 –) 50% / 50 (~ 70) % mixtures. However, in Wärtsilä engines normally a much lower glycol amount is adequate to protect the cooling water system against freezing. The outcome of decreasing the glycol amount is that simultaneously also the concentration of corrosion inhibitors will decrease to too low level resulting in an increased risk of corrosion.

The amount of glycol in closed cooling water system shall always be minimized since heat transfer of water containing glycol has deteriorated significantly. The engine may therefore be subject to additional output derating when using glycol in the cooling water, please contact Wärtsilä for details.

Instead of ready-to-use glycol-corrosion inhibitor mixtures a pure commercially available monopropylene glycol (MPG) or monoethyleneglycol (MEG) has to be used when a freezing risk exists. So called industrial quality of both glycol types is allowed to use, but MPG is considered to be a more environmentally friendly alternative.

### 9.1.4 Wärtsilä Water Conditioner Unit (WWCU)

As an alternative to the validated cooling water additives, Wärtsilä Water Conditioner Unit (WWCU) can also be used to treat cooling water of engines' closed water circuits. WWCU is based on the Enwamatic EMM cooling water treatment system, but it includes a number of new features based on Wärtsilä design. The WWCU protects an engine from corrosion without

a need to use any chemicals. It acts as a side stream filtration and water treatment unit and includes the following functions:

- corrosion protection
- scale control
- filtration
- control of bacterial growth and air separation

The WWCU can be a sensible alternative for the installations in which environmentally friendly solutions are appreciated or even required by authorities.

The WWCU cannot be used if simultaneously ready-to-use mixtures of commercial coolant brands containing both glycol and corrosion inhibitors are used in the cooling water system. If protection against freezing is needed, the equipment can on the other hand be used together with pure monopropylene glycol (MPG) or monoethylene glycol (MEG). The WWCU must be installed so that the cooling water inlet temperature to the unit does not exceed 109 °C and that the inlet pressure does not exceed 10 bar (abs.).

Due to a severe corrosion risk WWCU can't be used in the cooling water systems containing aluminium or aluminium alloys as a construction material. The reason for the above mentioned ban is that in the cooling water systems equipped with the WWCU pH of cooling water can be above 9 and at that pH range corrosion rate of aluminium / aluminium alloys starts to increase significantly.

One WWCU unit has to be installed to each separate cooling water circuit and the right type must be chosen according to the water volume of each cooling water system.

The WWCU must be backflushed regularly in order to remove deposits from the bottom of the unit. In case of new installation even daily backflushing is needed, but the backflush interval can be extended when a stable situation in the cooling water system is achieved.

A typical backflush interval in a stabilized cooling water system is estimated to be from one week to one month depending on water quality and added make-up water amount. Further, it is important to follow continuously functioning of the WWCU. Frequent operation of an engine will intensify the circulation rate of cooling water through the WWCU.

If WWCU is installed to the engines having already been in service and in which chemical cooling water treatment has been used, the cooling water system has to be drained and possible deposits (grease, rust, other impurities) need to be removed from the system prior to the start of using WWCU. If flushing of the cooling water system does not result in an adequate cleanliness, additionally a chemical cleaning has to be done. Major cooling water additive suppliers are able to offer suitable cleaning chemicals.

If an engine will not be in service for longer periods, water circulation in the closed cooling water circuit will be slow and a special attention has to be paid to that corrosion of the system will not occur.

The list of the WWCU types along with the specified cooling water system volumes are included in the table below.

<b>WWCU type</b>	<b>Specified water system volume (m<sup>3</sup>)</b>
WWCU F1	0 - 7
WWCU F2	0 - 20
WWCU F3	0 - 40

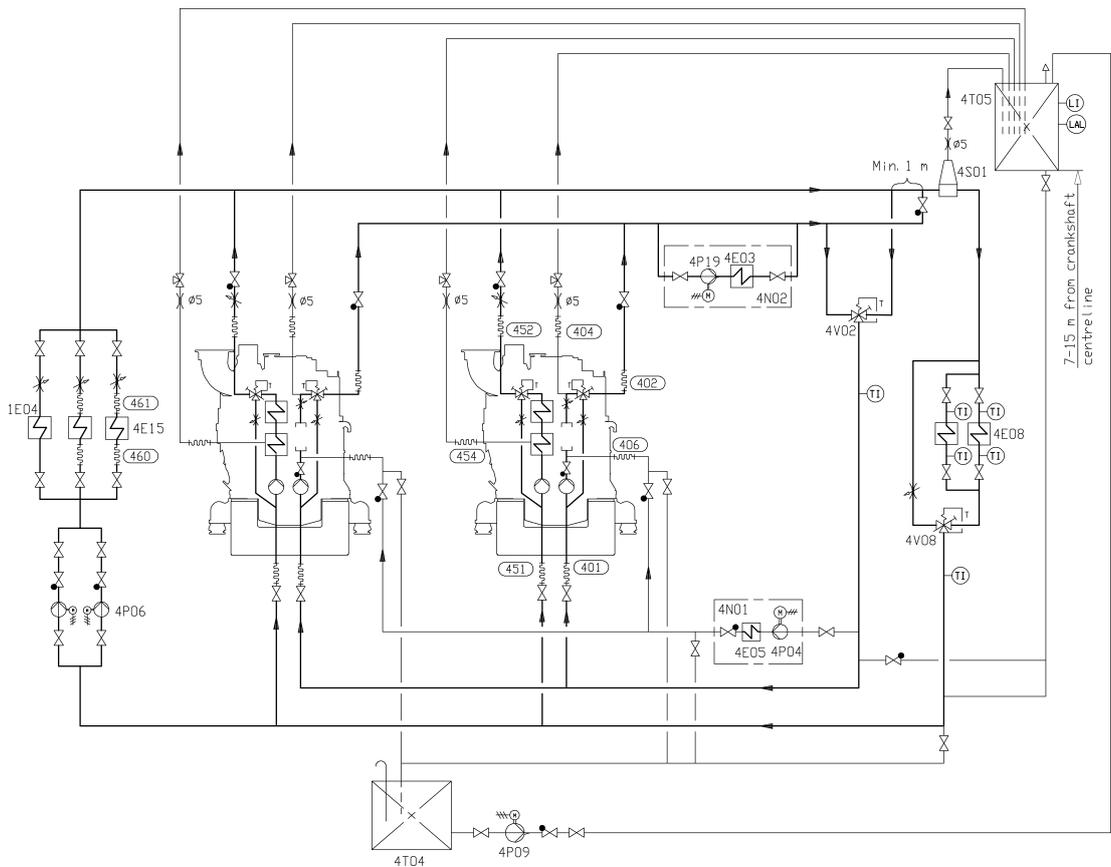
The use of pipes having galvanized inner surfaces is not allowed in the cooling water system.

## 9.2 External cooling water system

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

The external system shall be designed so that flows, pressures and temperatures are close to the nominal values in *Engine Online Configurator* available through *Wärtsilä website* and the cooling water is properly de-aerated.

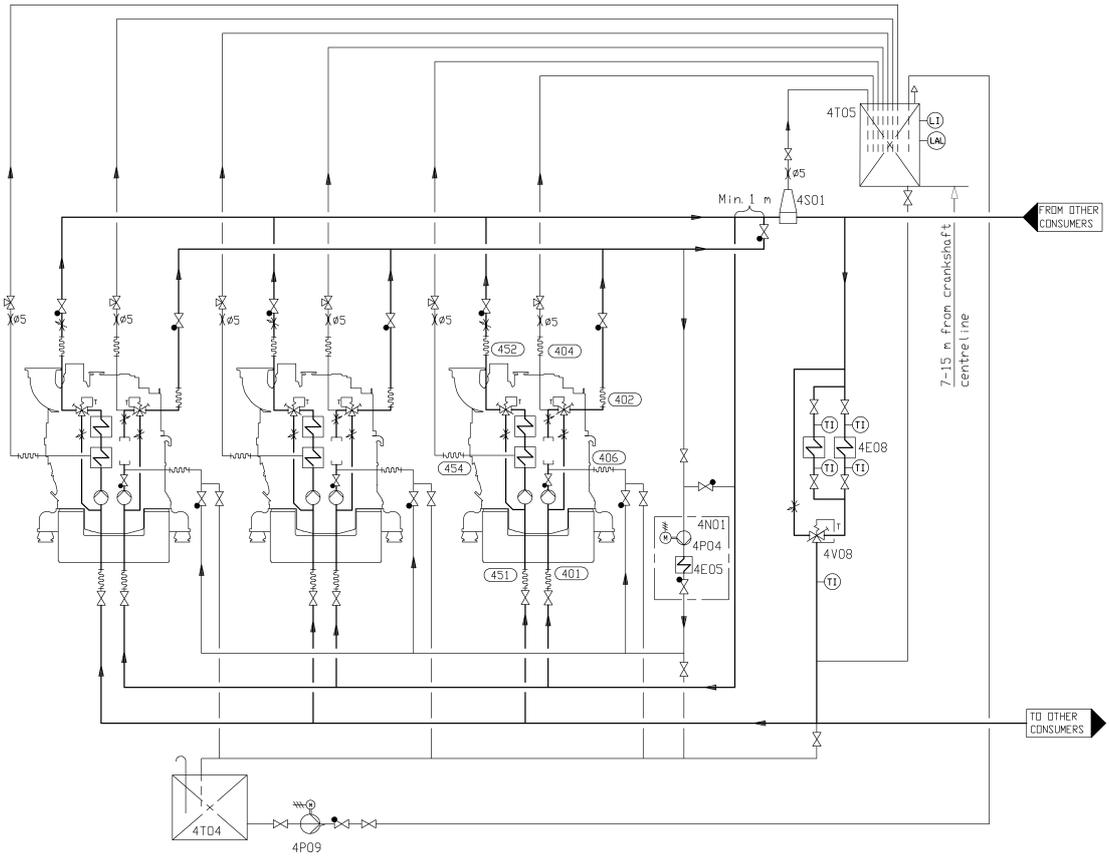
Pipes with galvanized inner surfaces are not allowed in the fresh water cooling system. Some cooling water additives react with zinc, forming harmful sludge. Zinc also becomes nobler than iron at elevated temperatures, which causes severe corrosion of engine components.



**Fig 9-1 Cooling water system, HFO engines with heat recovery (DAAF068123B)**

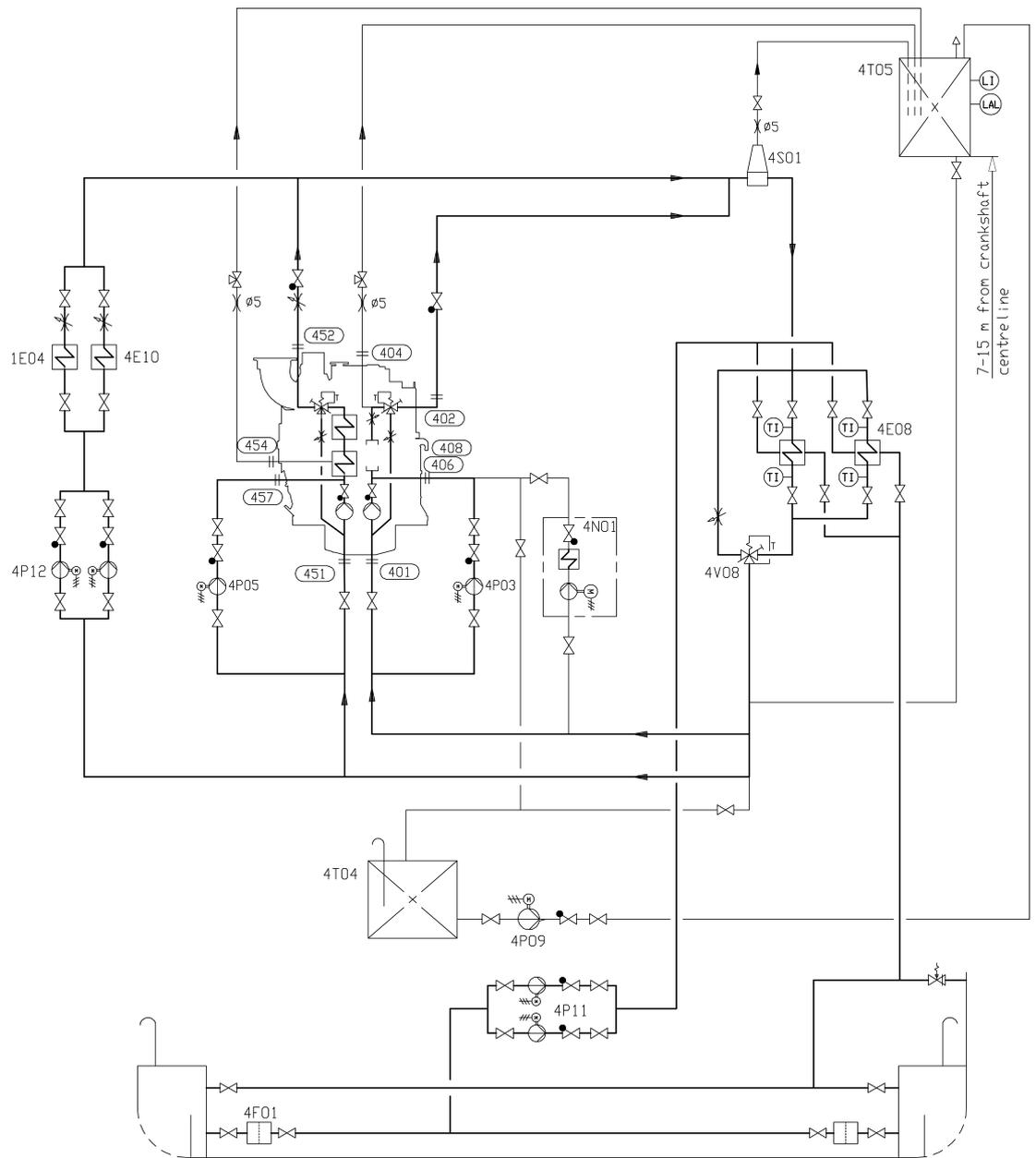
System components:			
1E04	Cooler (LFO)	4P06	Circulating pump
4E03	Heat recovery (Evaporator)	4P09	Transfer pump
4E05	Heater (Preheater)	4P19	Circulating pump (Evaporator)
4E08	Central cooler	4S01	Air venting
4E15	Cooler (Generator)	4T04	Drain tank
4N01	Preheating unit	4T05	Expansion tank
4N02	Evaporator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

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



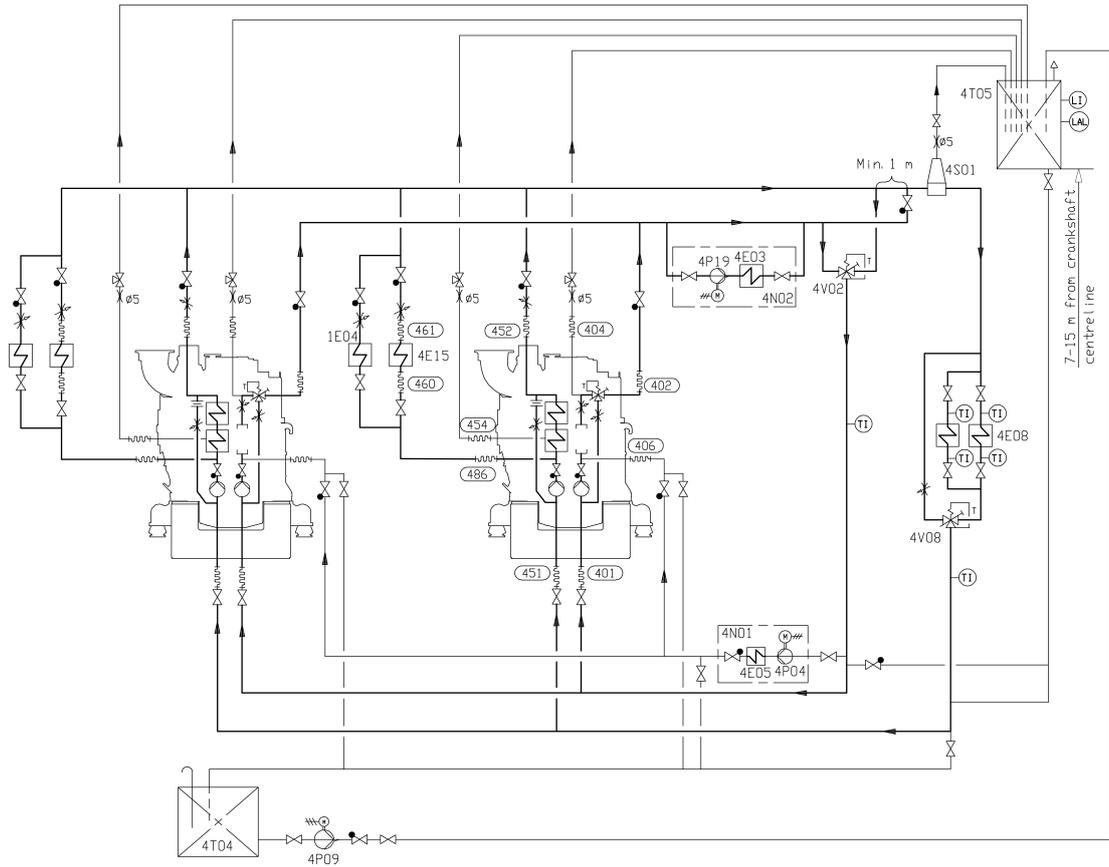
**Fig 9-2 Cooling water system, auxiliary engines operating on HFO and LFO without heat recovery (V76C5823D)**

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



**Fig 9-3 Cooling water system, single main engine (V76C5825D)**

System components:			
1E04	Cooler (LFO)	4P09	Transfer pump
4E08	Central cooler	4P11	Circulating pump (Sea water)
4E10	Cooler (Reduction gear)	4P12	Circulating pump
4F01	Suction strainer (Sea water)	4S01	Air venting
4N01	Preheating unit	4T04	Drain tank
4P03	Stand-by pump (HT)	4T05	Expansion tank
4P05	Stand-by pump (LT)	4V08	Temperature control valve (Central cooler)
Pipe connections are listed in section "Internal cooling water system".			



**Fig 9-4 Cooling water system, LFO engines with heat recovery (V76C5827D)**

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

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

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

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

### 9.2.1 Stand-by circulation pumps (4P03, 4P05)

Stand-by pumps should be of centrifugal type and electrically driven. Required capacities and delivery pressures can be found in [Engine Online Configurator](#) available through [Wärtsilä website](#).

<b>NOTICE</b>
Stand-by pumps may be considered as backup rather than actual spare pumps.

### 9.2.2 Sea water pump (4P11)

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

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

### 9.2.3 Temperature control valve for central cooler (4V08)

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

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

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

### 9.2.4 Fresh water central cooler (4E08)

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

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

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

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

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

where:

q = total fresh water flow [m<sup>3</sup>/h]

(continued)

$q_{LT}$  = nominal LT pump capacity[m<sup>3</sup>/h]

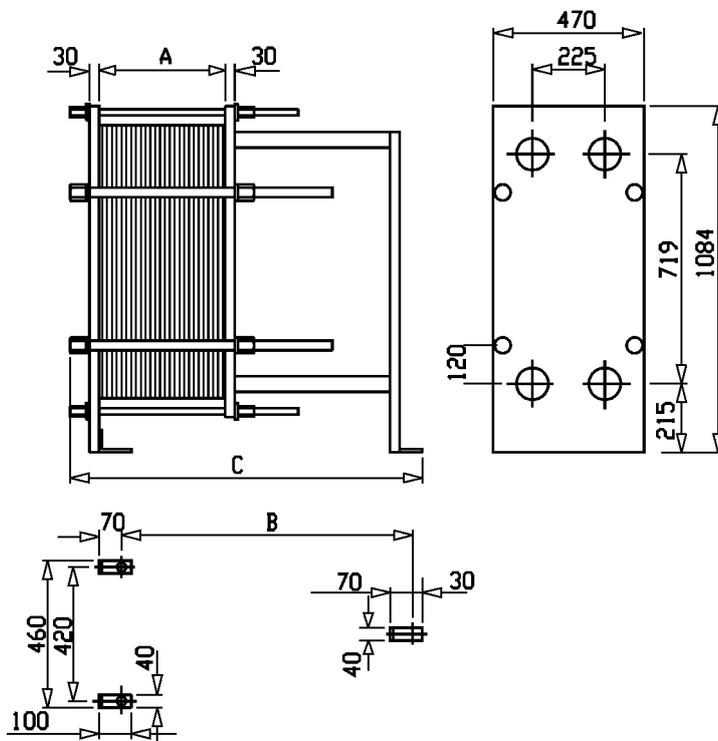
$\Phi$  = heat dissipated to HT water [kW]

$T_{out}$  = HT water temperature after engine ( 91°C)

$T_{in}$  = HT water temperature after cooler (38°C)

**Design data:**

Fresh water flow	please refer to <a href="#">Engine Online Configurator</a> available through Wärtsilä website
Heat to be dissipated	please refer to <a href="#">Engine Online Configurator</a> available through Wärtsilä website
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
Fresh water temperature after HT cooler	max. 83 °C
Margin (heat rate, fouling)	15%



**Fig 9-5 Central cooler, main dimensions (V47E0188b)**

Engine type	[rpm]	Cooling water			Sea water			Dimension [mm]			Weight [kg]	
		Flow [m <sup>3</sup> /h]	T <sub>cw, in</sub> [°C]	T <sub>cw, out</sub> [°C]	Flow [m <sup>3</sup> /h]	T <sub>sw, in</sub> [°C]	T <sub>sw, out</sub> [°C]	A	B	C	Dry	Wet
W4L20	1000	27	54.3	38	36	32	44.3	106	505	695	275	298
W6L20	1000	40	53.3	38	53	32	43.5	150	655	845	288	321
W8L20	1000	53	53.6	38	71	32	43.8	198	655	845	298	341
W9L20	1000	59	53.7	38	80	32	43.8	221	905	1095	305	354

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

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

## 9.2.5 Waste heat recovery

The waste heat in the HT cooling water can be used for hot water consumers, absorption chillers, potable water production, AC system heating, stand-by engines preheating and generating electricity through e.g., an ORC (Organic Rankine Cycle). The system should in such case be provided with a temperature control valve to avoid unnecessary cooling, as shown in the example diagrams. With this arrangement the HT water flow through the heat recovery can be increased.

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

To maximize heat recovery and functionality, it is recommended for all valves installed on the LT and HT line, to have max 0.5% volumetric leakage. For electrical actuated valves, full stroke speed must be max. 65 seconds and dead band max. 1%.

## 9.2.6 Air venting

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

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

The vent pipes must be continuously rising.

## 9.2.7 Expansion tank (4T05)

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

### Design data:

Pressure from the expansion tank at pump inlet 70 - 150 kPa (0.7...1.5 bar)

Volume min. 10% of the total system volume

**NOTICE**

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

Concerning the water volume in the engine, please refer to [Engine Online Configurator](#) available through Wärtsilä website.

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

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

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

**Table 9-1 Minimum diameter of balance pipe**

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

## 9.2.8 Drain tank (4T04)

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

Concerning the water volume in the engine, please refer to [Engine Online Configurator](#) available through Wärtsilä website. The water volume in the LT circuit of the engine is small.

## 9.2.9 HT preheating

The cooling water circulating through the cylinders must be preheated to at least 50 °C, preferably 70 °C.

This is an absolute requirement for installations that are designed to operate on heavy fuel, but strongly recommended also for engines that operate exclusively on marine diesel fuel.

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

### 9.2.9.1 HT heater (4E05)

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

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

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

**Design data:**

Preheating temperature	min. 50°C for starts at LFO; min 70°C for startings at HFO
Required heating power	2 kW/cyl
Heating power to keep hot engine warm	1 kW/cyl

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

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

**where:**

P =	Preheater output [kW]
T <sub>1</sub> =	Preheating temperature = 60...70 °C
T <sub>0</sub> =	Ambient temperature [°C]
m <sub>eng</sub> =	Engine weight [tonne]
V <sub>LO</sub> =	Lubricating oil volume [m <sup>3</sup> ] (wet sump engines only)
V <sub>FW</sub> =	HT water volume [m <sup>3</sup> ]
t =	Preheating time [h]
k <sub>eng</sub> =	Engine specific coefficient = 0.5 kW
n <sub>cyl</sub> =	Number of cylinders

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

### 9.2.9.2 Circulation pump for HT preheater (4P04)

**Design data:**

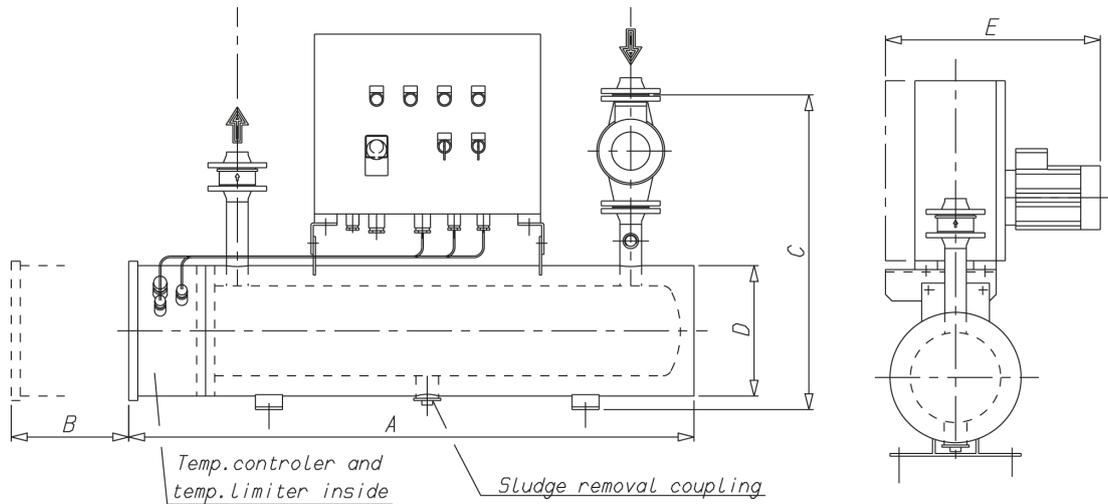
Capacity	0.3 m <sup>3</sup> /h per cylinder
Delivery pressure	80...100 kPa (0.8...1.0 bar)

### 9.2.9.3 Preheating unit (4N01)

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

- Electric or steam heaters
- Circulating pump
- Control cabinet for heaters and pump
- Set of thermometers

- Non-return valve
- Safety valve



**Fig 9-6 Preheating unit, electric (V60L0653A)**

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

## 9.2.10 Throttles

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

## 9.2.11 Thermometers and pressure gauges

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

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

## 10. Combustion Air System

### 10.1 Engine room ventilation

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

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

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

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

The amount of air required for ventilation is calculated from the total heat emission  $\Phi$  to evacuate. To determine  $\Phi$ , 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:**

$Q_v$  = air flow [m<sup>3</sup>/s]

$\Phi$  = total heat emission to be evacuated [kW]

$\rho$  = air density 1.13 kg/m<sup>3</sup>

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

$\Delta T$  = temperature rise in the engine room [°C]

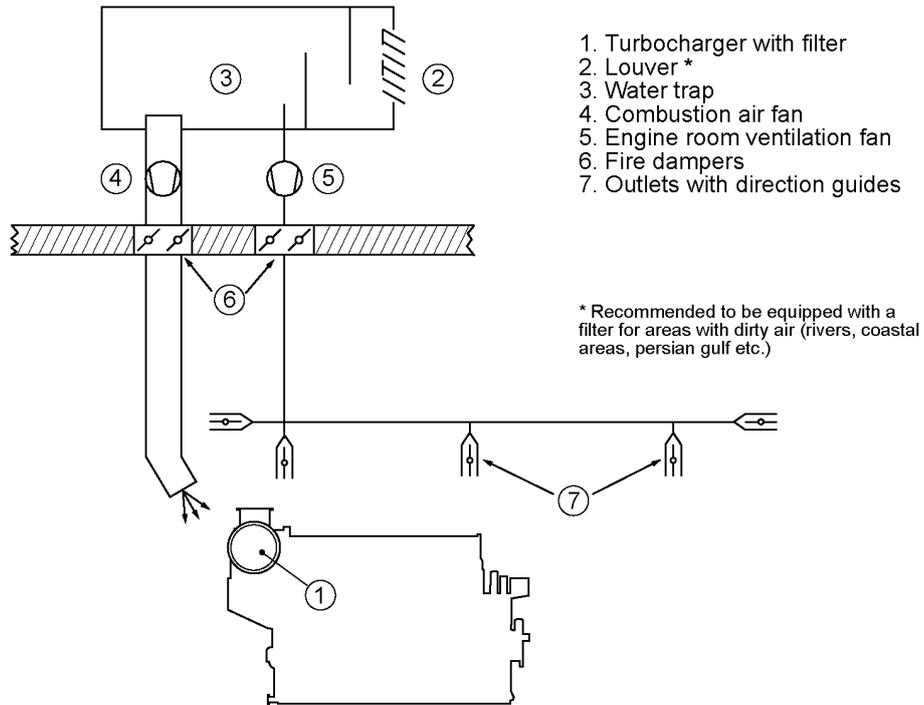
The heat emitted by the engine is listed in [Engine Online Configurator](#) available through Wärtsilä website.

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

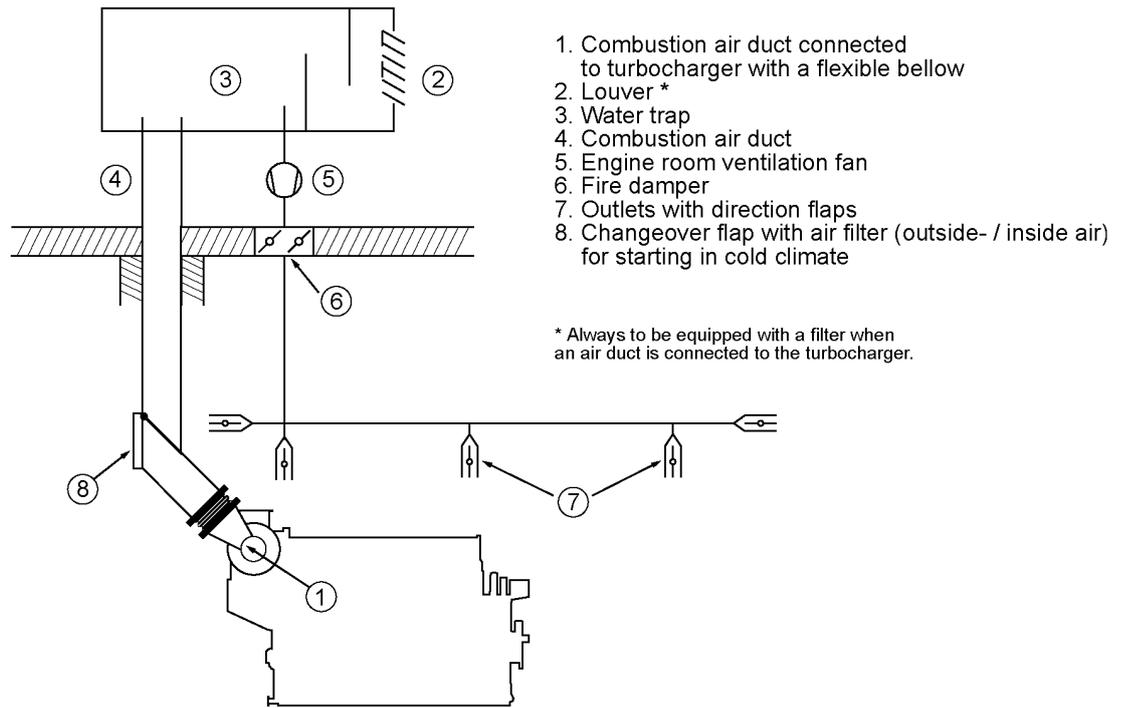
The ventilation air is to be equally distributed in the engine room considering air flows from points of delivery towards the exits. This is usually done so that the funnel serves as exit for most of the air. To avoid stagnant air, extractors can be used.

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

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



**Fig 10-1 Engine room ventilation, turbocharger with air filter (DAAE092651)**



**Fig 10-2 Engine room ventilation, air duct connected to the turbocharger (DAAE092652A)**

## 10.2 Combustion air system design

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

For the required amount of combustion air, please refer to [Engine Online Configurator](#) available through Wärtsilä website.

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 [Engine Online Configurator](#) available through Wärtsilä website 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 [m<sup>3</sup>/s]

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

$\rho$  = air density 1.15 kg/m<sup>3</sup>

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

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

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

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

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

### 10.2.1 Charge air shut-off valve (optional)

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

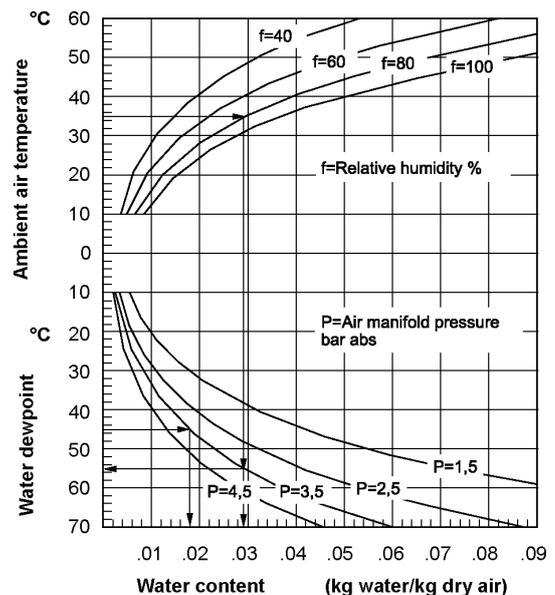
### 10.2.2 Condensation in charge air coolers

Air humidity may condense in the charge air cooler and in the engine block air receiver. Especially in tropical conditions amount of condense water can be remarkable. To remove the condense water from the charge air system, engines are equipped with two water drain holes. One at the bottom of charge air cooler and another one at the engine block air receiver. To reduce engine room noise level, these drain holes are equipped with silencers. Possible clogging of these drains / silencers needs to be monitored every second day or after every 50 running hours. Replace silencer(s) when needed.

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

**Example, according to the diagram:**

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



**Fig 10-3 Condensation in charge air coolers**

## 11. Exhaust Gas System

### 11.1 Temperature sensor location after Turbocharger

For measuring the exhaust gases after the turbocharger, the engine is delivered with temperature sensor TE517. The sensor is located at the exhaust gas bend, which is mounted on the turbocharger. Measuring results from this sensor is used to alarm / trigger load reduction, if exhaust gasses are abnormal high. It is also used in exhaust gas temperature (t6) control functionality in the SCR installations.

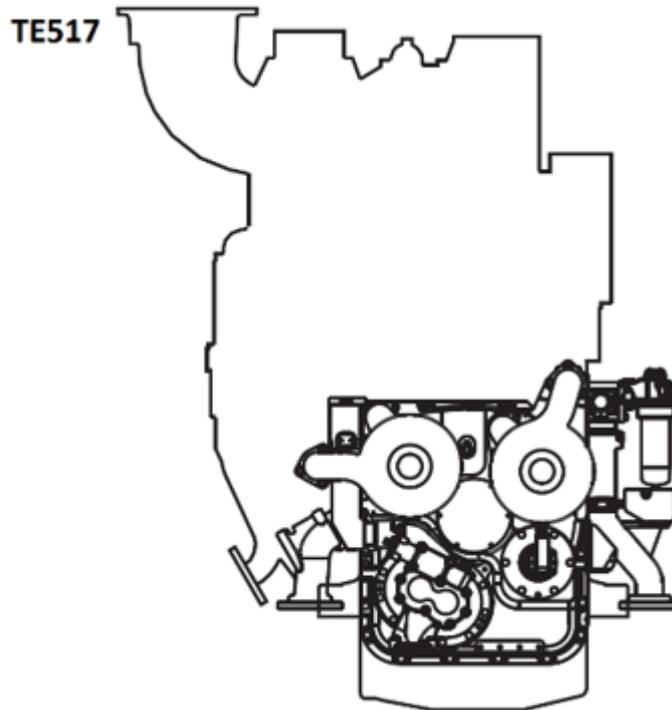


Fig 11-1 TE517 sensor location on turbocharger bend curve

#### To be noted in SCR installations

When urea injection is activated, urea water liquid and compressed air, which are colder than exhaust gasses, are mixed into the hot exhaust gasses in the mixing and injection unit. This endothermic reaction, which happens before SCR reactor, drops the exhaust gas temperature from the engine t6 set point with approx. 5-10 °C. This means that exhaust gas temperature just before the SCR reactor inlet is approx. 5-10 °C lower than temperature at TE517. Temperature drop is load and exhaust gas flow dependent. Largest temperature drop affect can therefore be seen on low engine loads, where urea injection ratio is higher compared to the decreased exhaust gas flow.

The exothermic chemical reaction that is taking place inside the SCR reactor, increases the exhaust gas temperature with approx. 10 °C. The exhaust gas temperature at SCR outlet is therefore approx. the same as at TE517 sensor location.

When urea is not injected, its cooling affect before catalyst elements is not seen. This means that SCR inlet and outlet temperatures should be even.

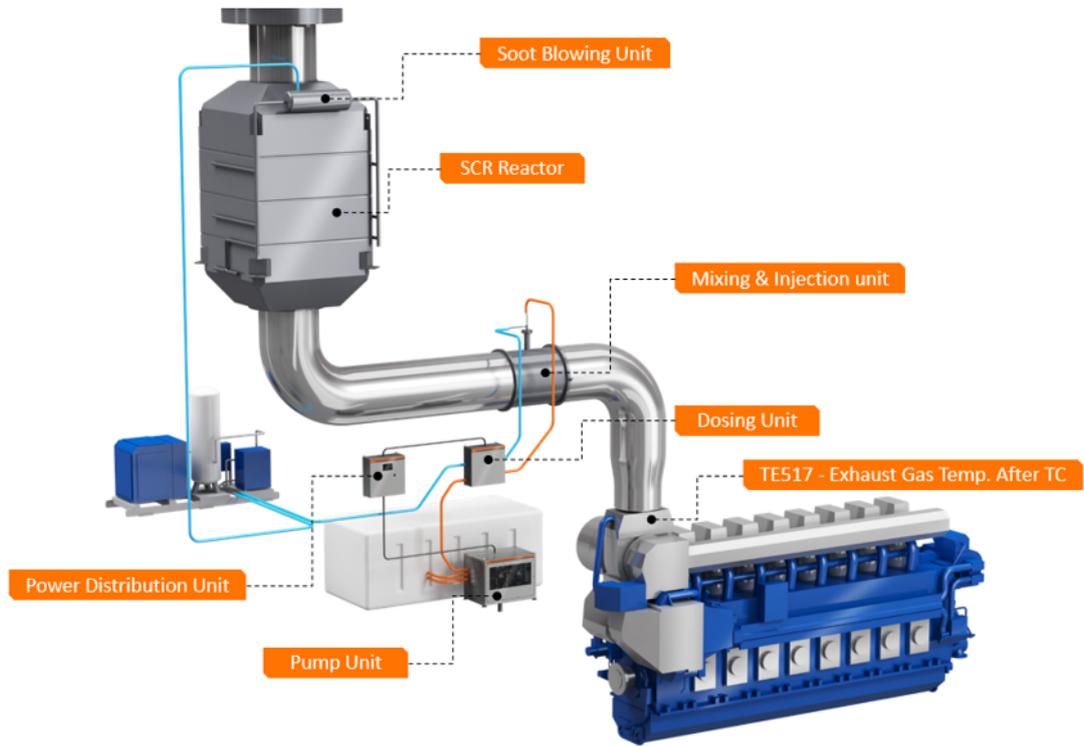


Fig 11-2 Principle layout of SCR (Wärtsilä NOR)

## 11.2 Exhaust gas outlet

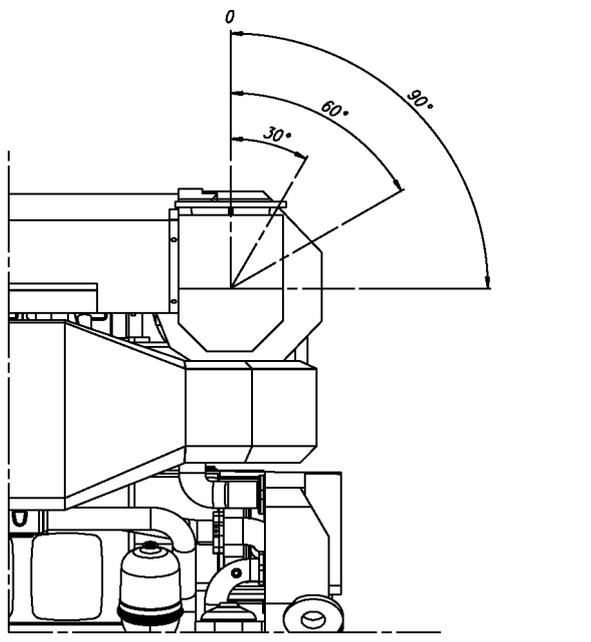
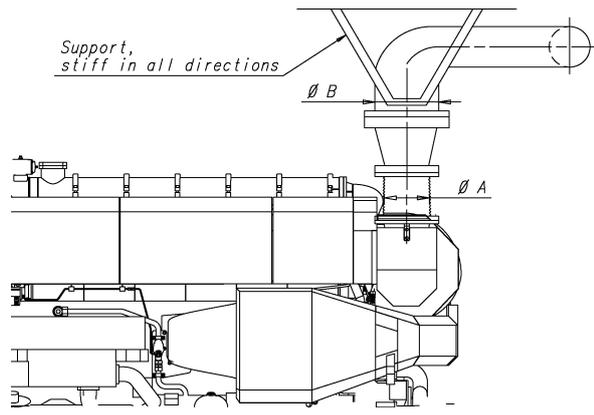


Fig 11-3 Exhaust pipe connections (DAAE066842)

Engine	TC in free end	TC in driving end
W 4L20	0°, 30°, 60°, 90°	-
W 6L20	0°, 30°, 60°, 90°	0°, 30°, 60°, 90°
W 8L20	0°, 30°, 60°, 90°	0°, 30°, 60°, 90°
W 9L20	0°, 30°, 60°, 90°	0°, 30°, 60°, 90°



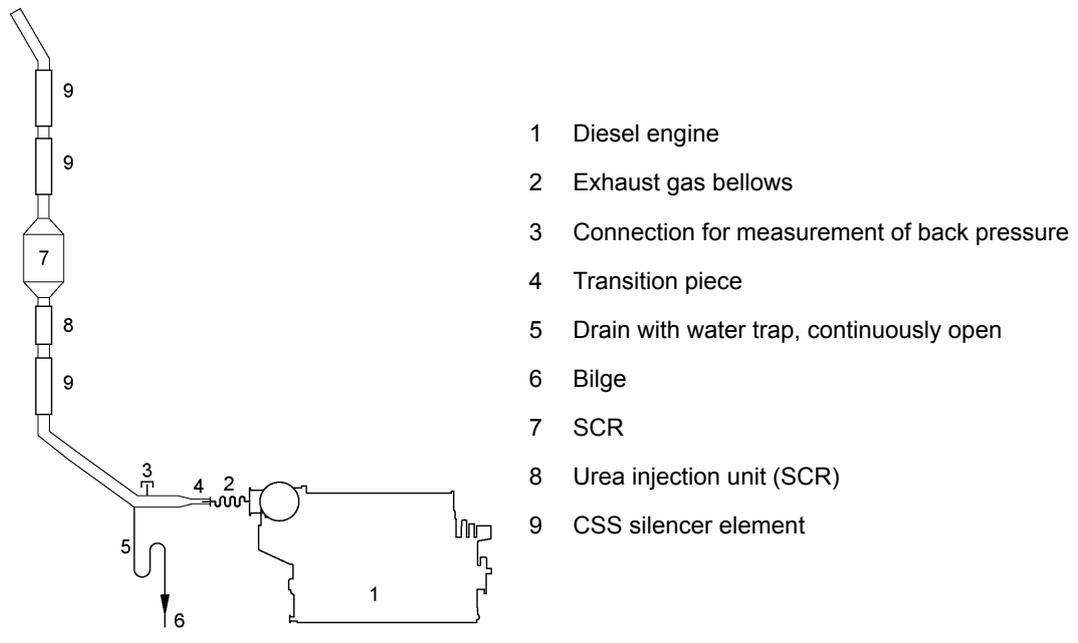
Engine	ØA [mm]	ØB [mm]
W 4L20	200	300
W 6L20	250	350 - 400
W 8L20	300	400 - 450
W 9L20	300	450

**Fig 11-4 Exhaust pipe, diameters and support (DAAF014083)**

## 11.3 External exhaust gas system

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

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



**Fig 11-5 External exhaust gas system**

### 11.3.1 Piping

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

The recommended flow velocity in the pipe is maximum 35...40 m/s at full output. If there are many resistance factors in the piping, or the pipe is very long, then the flow velocity needs to be lower. The exhaust gas mass flow given in [Engine Online Configurator](#) available through Wärtsilä website can be translated to velocity using the formula:

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

where:

v = gas velocity [m/s]

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

T = exhaust gas temperature [°C]

D = exhaust gas pipe diameter [m]

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

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

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

### 11.3.2 Supporting

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

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

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

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

### 11.3.3 Back pressure

The maximum permissible exhaust gas back pressure is stated in [Engine Online Configurator](#) available through Wärtsilä website. 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 [Engine Online Configurator](#) available through Wärtsilä website may be used for the calculation.

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

### 11.3.4 Exhaust gas bellows (5H01, 5H03)

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

### 11.3.5 SCR-unit (11N14)

The SCR-unit requires special arrangement on the engine in order to keep the exhaust gas temperature and backpressure into SCR-unit working range. The exhaust gas piping must be straight at least 3..5 meters in front of the SCR unit. If both an exhaust gas boiler and a SCR unit will be installed, then the exhaust gas boiler shall be installed after the SCR. Arrangements

must be made to ensure that water cannot spill down into the SCR, when the exhaust boiler is cleaned with water.

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

### **11.3.6 Exhaust gas boiler**

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

For dimensioning the boiler, the exhaust gas quantities and temperatures given in [Engine Online Configurator](#) available through Wärtsilä website.

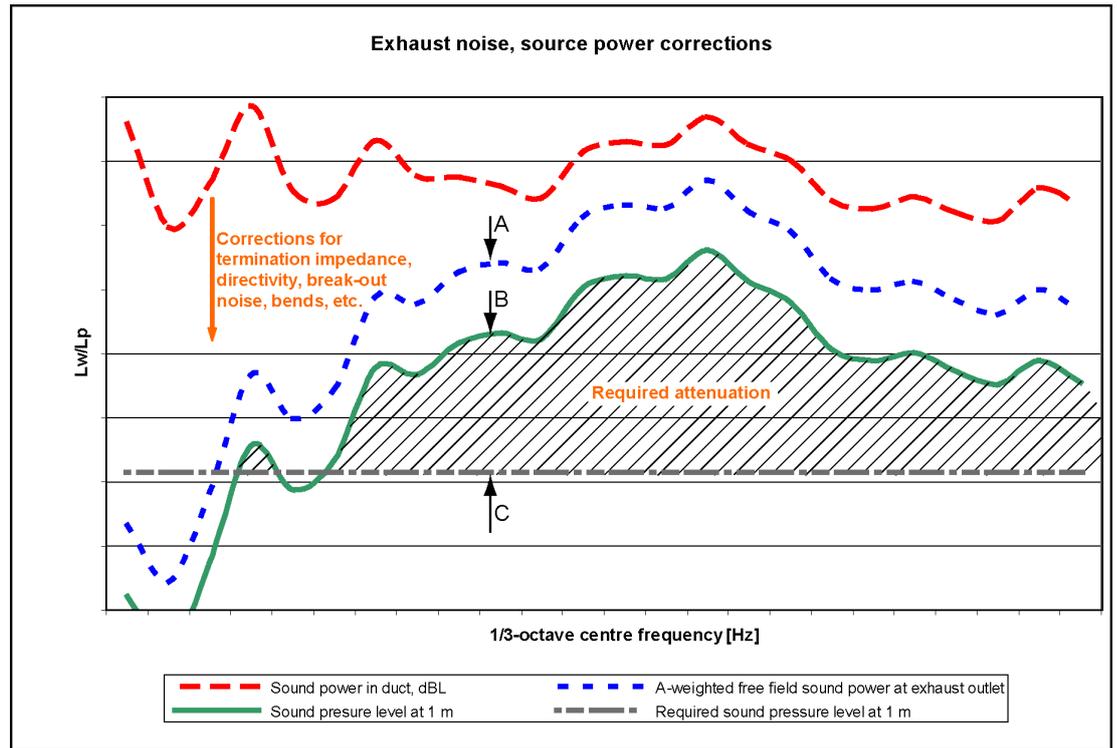
### 11.3.7 Exhaust gas silencers

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

#### 11.3.7.1 Exhaust noise

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

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



**Fig 11-6 Exhaust noise, source power corrections**

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

### 11.3.7.2 Silencer system comparison

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

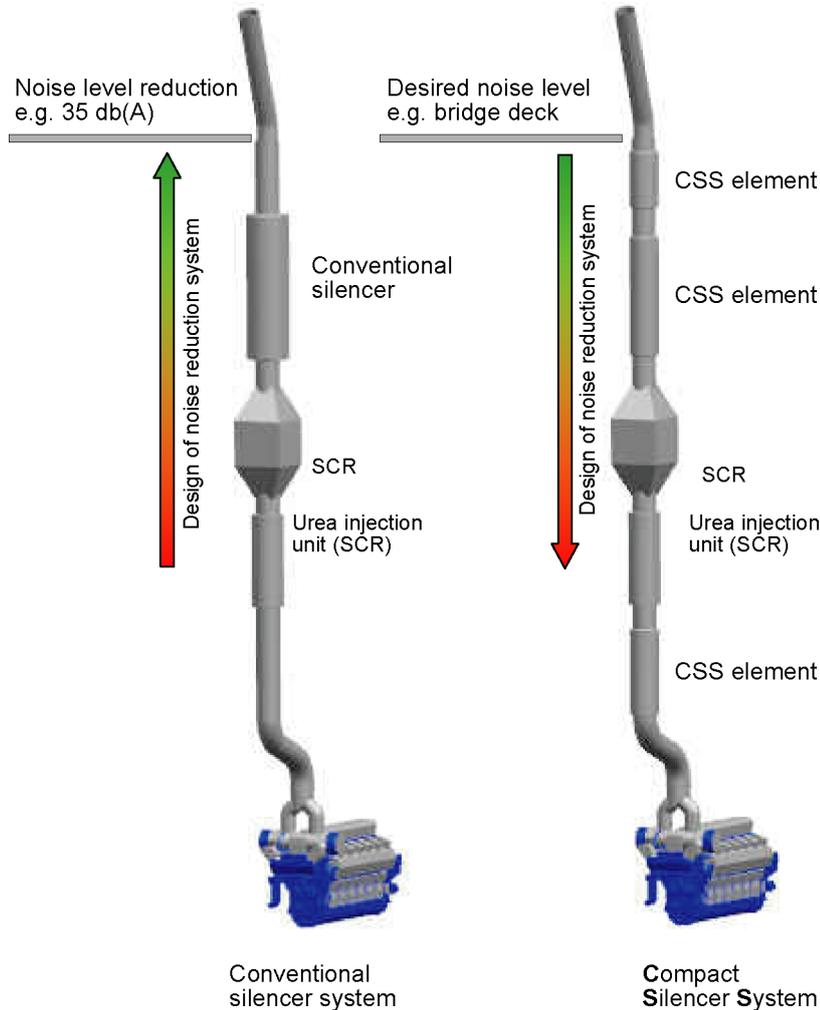


Fig 11-7 Silencer system comparison

### 11.3.7.3 Compact silencer system (5N02)

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

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

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

### 11.3.7.4 Conventional exhaust gas silencer (5R02)

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

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

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

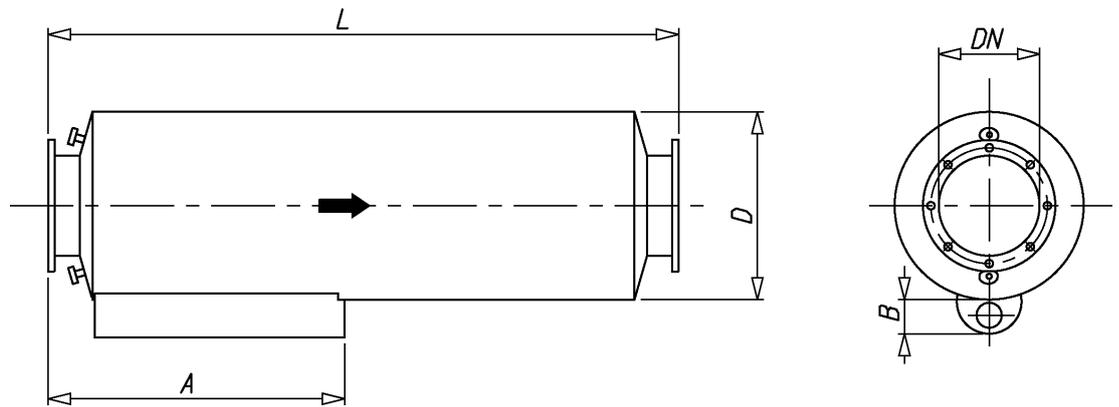


Fig 11-8 Exhaust gas silencer (V49E0137B)

Table 11-1 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

This page intentionally left blank

# 12. Turbocharger Cleaning

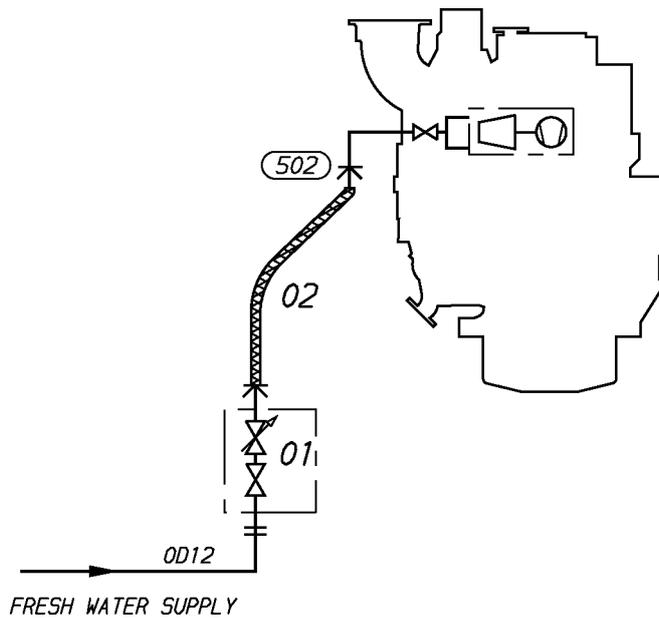
Regular water cleaning of the turbine and the compressor reduces the formation of deposits and extends the time between overhauls. Fresh water is injected into the turbocharger during operation. Additives, solvents or salt water must not be used and the cleaning instructions, as outlined in the Engine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

## 12.1 Turbine cleaning system

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

**Water supply:**

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



**Fig 12-1 Turbine cleaning system (DAAE003884)**

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

## 12.2 Compressor cleaning

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

### 12.2.1 Compressor cleaning

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

**Water supply:**

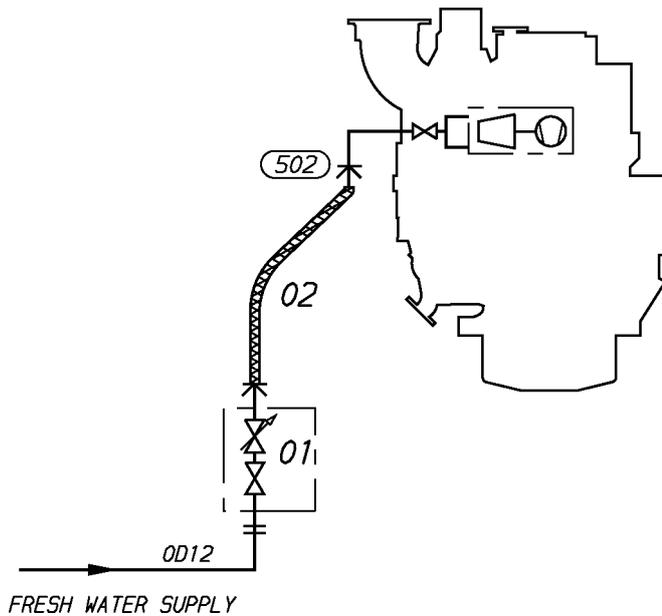
Fresh water

Min. pressure 0.3 MPa (3 bar)

Max. pressure 2 MPa (20 bar)

Max. temperature 80 °C

Flow 6-10 l/min (depending on cylinder configuration)



**Fig 12-2 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			

**NOTE**

If the turbocharger suction air is below +5 °C, washing is not possible.

## 13. Exhaust Emissions

Exhaust emissions from the diesel engine mainly consist of nitrogen, oxygen and combustion products like carbon dioxide (CO<sub>2</sub>), water vapour and minor quantities of carbon monoxide (CO), sulphur oxides (SO<sub>x</sub>), nitrogen oxides (NO<sub>x</sub>), partially reacted and non-combusted hydrocarbons (HC) and particulate matter (PM).

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

### 13.1 Diesel engine exhaust components

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

CO<sub>2</sub> 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<sub>2</sub>, hence their quantity in the exhaust gas stream are very low.

#### 13.1.1 Nitrogen oxides (NO<sub>x</sub>)

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<sub>2</sub>), which are usually grouped together as NO<sub>x</sub> 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<sub>2</sub>. The amount of NO<sub>2</sub> emissions is approximately 5 % of total NO<sub>x</sub> emissions.

#### 13.1.2 Sulphur Oxides (SO<sub>x</sub>)

Sulphur oxides (SO<sub>x</sub>) 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<sub>2</sub>). A small fraction of SO<sub>2</sub> may be further oxidized to sulphur trioxide (SO<sub>3</sub>).

#### 13.1.3 Particulate Matter (PM)

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

#### 13.1.4 Smoke

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

Smoke can be black, blue, white, yellow or brown in appearance. Black smoke is mainly comprised of carbon particulates (soot). Blue smoke indicates the presence of the products of

the incomplete combustion of the fuel or lubricating oil. White smoke is usually condensed water vapour. Yellow smoke is caused by NO<sub>x</sub> emissions. When the exhaust gas is cooled significantly prior to discharge to the atmosphere, the condensed NO<sub>2</sub> component can have a brown appearance.

## **13.2 Marine exhaust emissions legislation**

### **13.2.1 International Maritime Organization (IMO)**

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

The IMO Tier 3 NO<sub>x</sub> emission standard has entered into force from year 2016. It applies for new marine diesel engines that:

- Are > 130 kW
- Installed in ships which keel laying date is 1.1.2016 or later
- Operating inside the North American ECA and the US Caribbean Sea ECA

From 1.1.2021 onwards Baltic sea and North sea will be included in to IMO Tier 3 NO<sub>x</sub> requirements.

### **13.2.2 Other Legislations**

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

## **13.3 Methods to reduce exhaust emissions**

All standard Wärtsilä engines meet the NO<sub>x</sub> 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 NO<sub>x</sub> 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.

# 14. Automation System

## 14.1 W20 UNIC

Wärtsilä Unified Controls - UNIC is a fully embedded and distributed engine management system, which handles all control functions on the engine.

The distributed modules communicate over an internal communication bus.

The power supply to each module is physically doubled on the engine for full redundancy.

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

### 14.1.1 Technical data and system overview

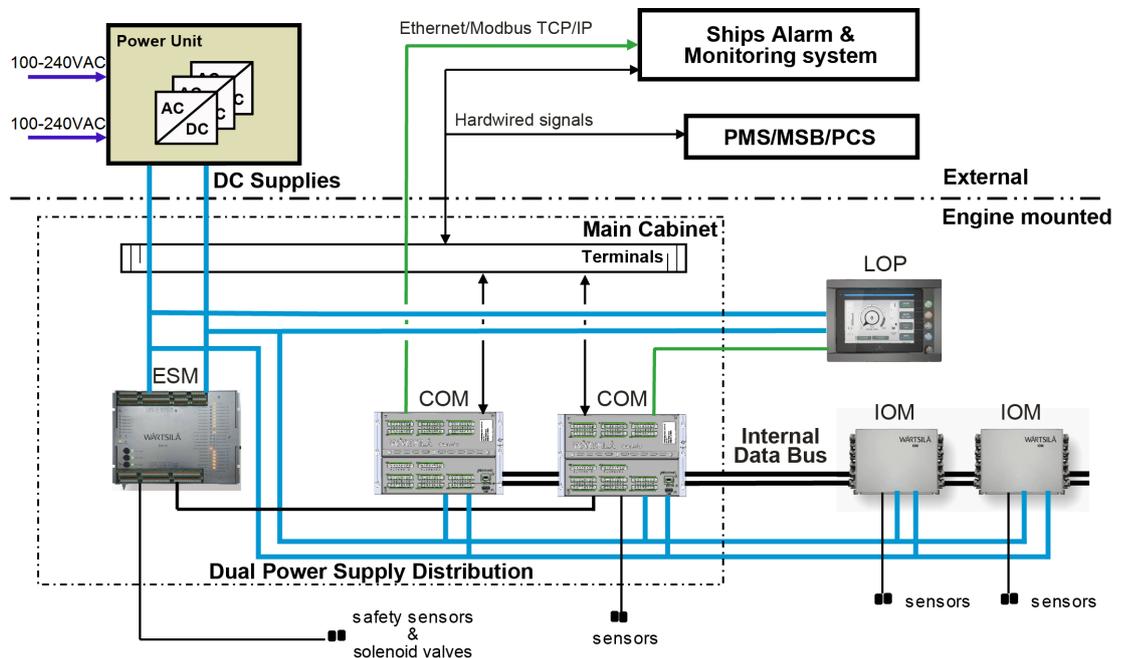
#### 14.1.1.1 Ingress protection

The ingress protection class of the system is IP54.

#### 14.1.1.2 Ambient temp for automation system

The automation system on the engine allows for an ambient engine room temperature up to 55°C.

Single components such as electronic modules have a temperature rating not less than 70°C.



**Fig 14-1 Architecture of UNIC**

Short explanation of the modules used in the system:

**COM** Communication Module. Handles strategic control functions (such as start/stop sequencing and speed/load control, i.e. "speed governing") of the engine. The communication modules handle engine internal and external communication, as well as hardwired external interfaces.

(continued)

<b>LOP</b>	The LOP (local operator panel) shows all engine measurements (e.g. temperatures and pressures) and provides various engine status indications as well as an event history.
<b>IOM</b>	Input/Output Module handles measurements and limited control functions in a specific area on the engine.
<b>ESM</b>	Engine Safety Module handles fundamental engine safety, for example shutdown due to overspeed or low lubricating oil pressure.

The above equipment and instrumentation are prewired on the engine.

### 14.1.1.3 Local operator panel

The Local operator panel (LOP) consist of a display unit (LDU) with touch screen as well as an emergency stop button built on the engine.

The local operator panel shows all engine measurements (e.g. temperatures and pressures) and provides various engine status indications as well as an event history

The following control functions are available:

- Local/remote control selection
- Local start & stop
- Shutdown reset
- Local emergency speed setting (mechanical propulsion)
- Local emergency stop



Fig 14-2 Local operator panel

### 14.1.1.4 Engine safety system

The engine safety module handles fundamental safety functions, for example overspeed protection.

Main features:

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

### 14.1.1.5 Power unit

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

The power unit contains redundant power converters, each converter dimensioned for 100% load. At least one of the two incoming supplies must be connected to a UPS. The power unit supplies the automation system on the engine with necessary DC voltages.

Power supply from ship's system:

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

### 14.1.1.6 Cabling and system overview

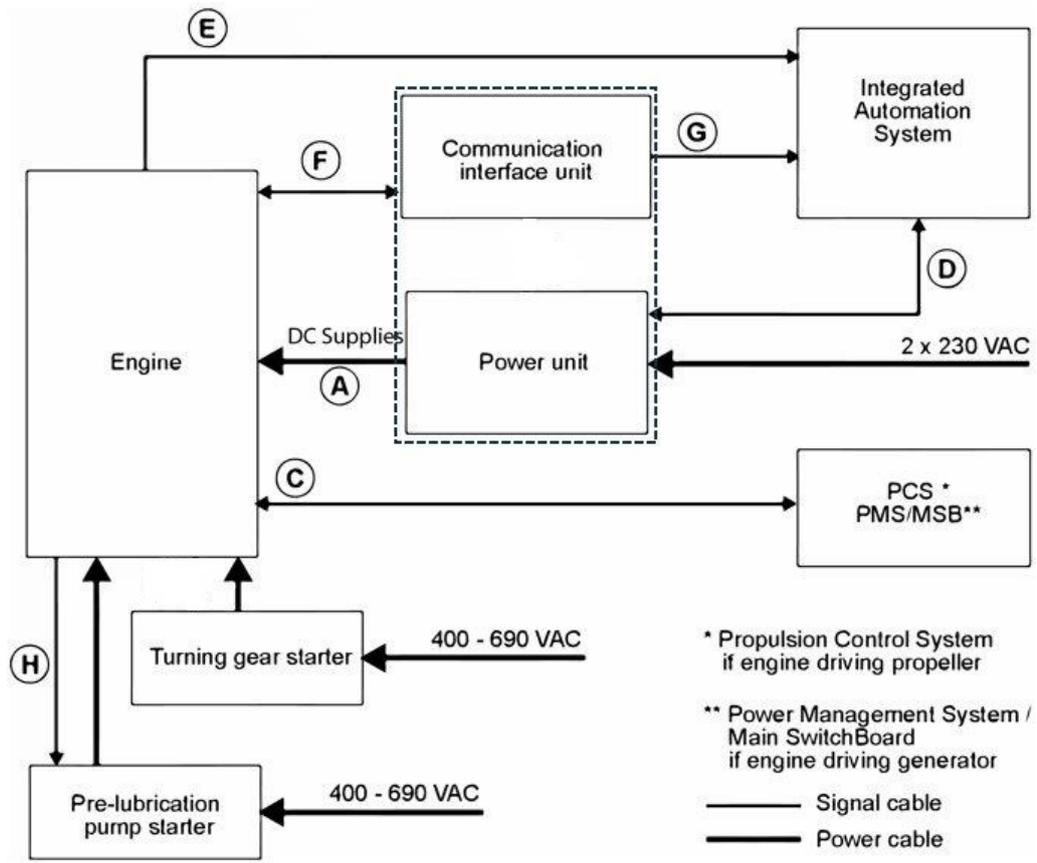


Fig 14-3 UNIC overview

Table 14-1 Typical amount of cables

Cable	From <=> To	Cable types (typical)
A	Engine <=> Power Unit	2 x 4 mm <sup>2</sup> (power supply) * 2 x 4 mm <sup>2</sup> (power supply) *
C	Engine <=> Propulsion Control System Engine <=> Power Management System / Main Switch-board	1 x 2 x 0.75 mm <sup>2</sup> 1 x 2 x 0.75 mm <sup>2</sup> 1 x 2 x 0.75 mm <sup>2</sup> 24 x 0.75 mm <sup>2</sup> 24 x 0.75 mm <sup>2</sup>
D	Power unit <=> Integrated Automation System	2 x 0.75 mm <sup>2</sup>
E	Engine <=> Integrated Automation System	3 x 2 x 0.75 mm <sup>2</sup>
F	Engine => Power Unit	1 x Ethernet CAT 5
G	Power Unit => Integrated automation system	1 x Ethernet CAT 5

**Table 14-1 Typical amount of cables (continued)**

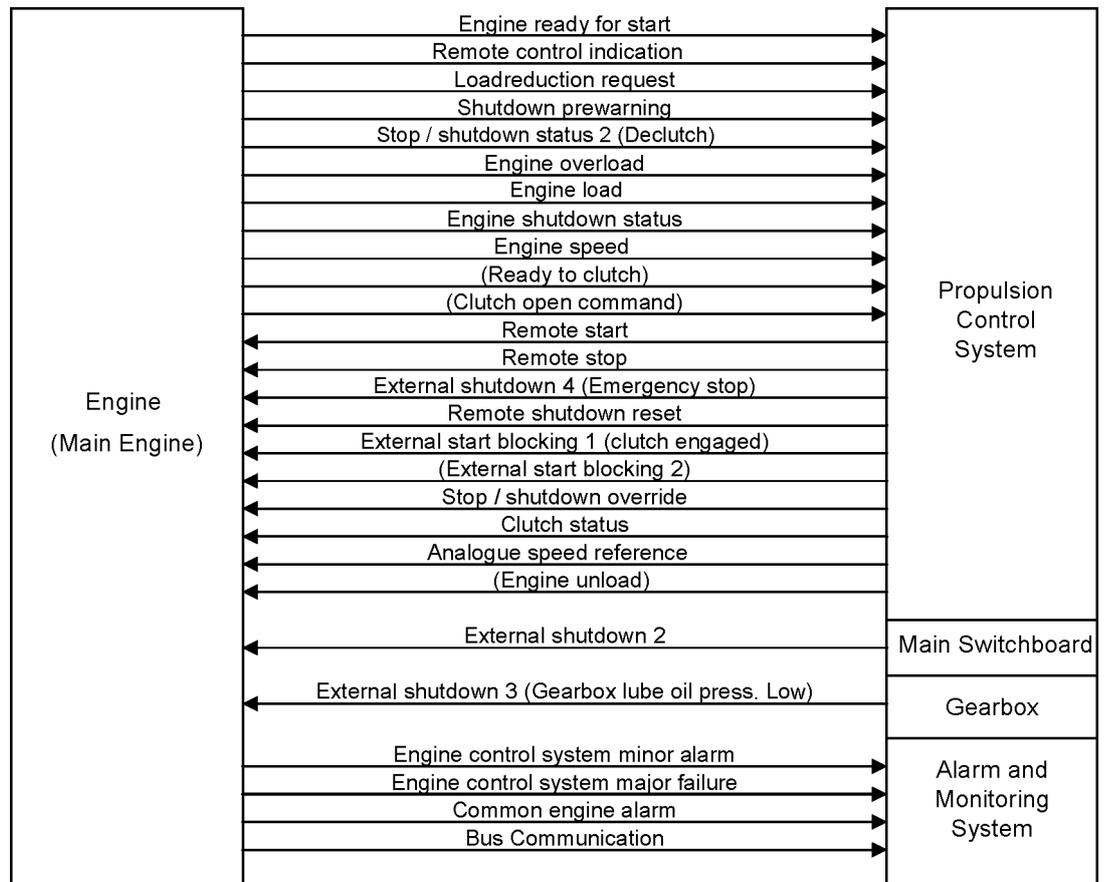
Cable	From <=> To	Cable types (typical)
H	Engine => Pre-lubrication pump starter	2 x 0.75 mm <sup>2</sup>

**NOTICE**

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

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

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



**Fig 14-4 Typical signal overview (Main engine)**

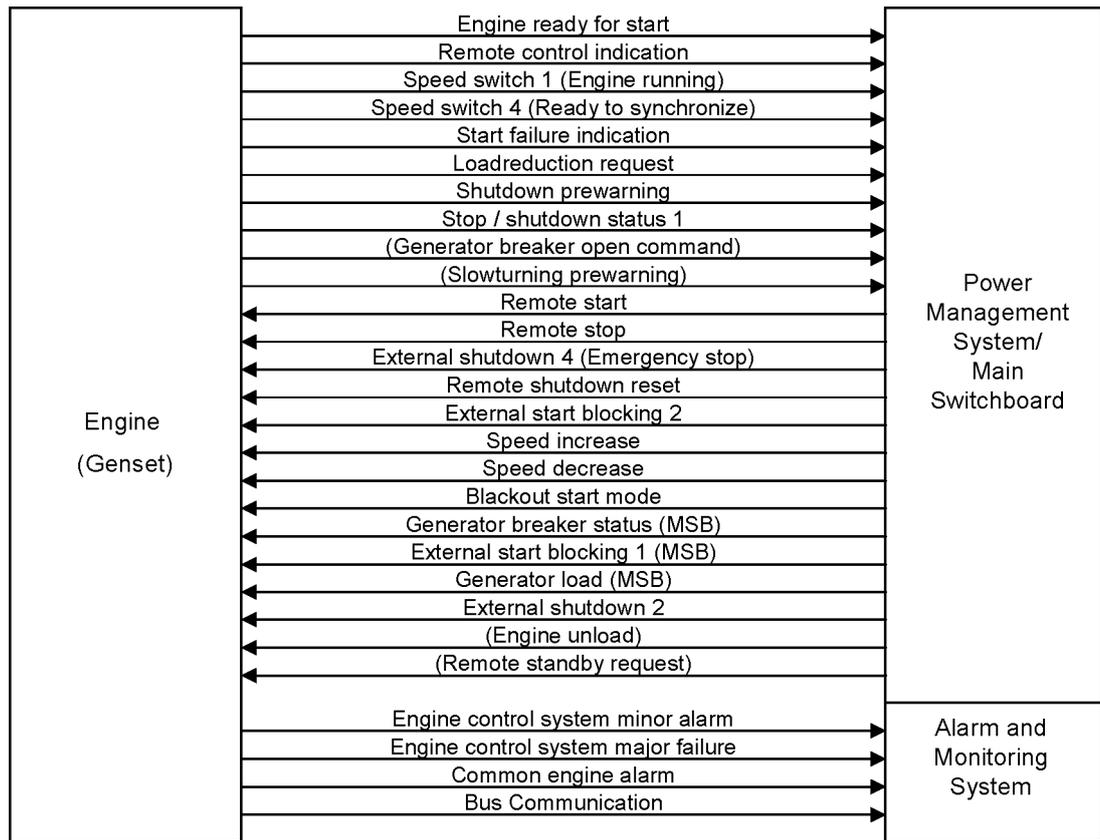


Fig 14-5 Typical signal overview (Generating set)

## 14.1.2 Functions

### 14.1.2.1 Start

The engine is started by compressed air driven turbine motor.

The engine can be started locally, or remotely if applicable for the installation e.g. from the power management system or control room. In an emergency situation it is also possible to operate the starting air valve manually.

Starting is blocked both pneumatically and electrically when the turning gear is engaged.

#### Start blocking

Starting is inhibited by the following functions:

- Turning device engaged
- Pre-lubricating pressure low (override if black-out input is high and within last 30 minutes after the pressure has dropped below the set point)
- Stop signal to engine active (safety shut-down, emergency stop, normal stop)
- External start blocking active

### 14.1.2.2 Stop, shutdown and emergency stop

#### Stop mode

Before stopping the engine, the control system shall first unload the engine slowly (if the engine is loaded), and after that open the generator breaker and send a stop signal to the engine.

### Shutdown mode

Shutdown mode is initiated automatically as a response to abnormal measurement signals.

In shutdown mode the clutch/generator breaker is opened immediately without unloading. The actions following a shutdown are similar to normal engine stop.

Shutdown mode must be reset by the operator and the reason for shutdown must be investigated and corrected before re-start.

### Emergency stop mode

The sequence of engine stopping in emergency stop mode is similar to shutdown mode.

Emergency stop is the fastest way of manually shutting down the engine. In case the emergency stop push-button is pressed, the button is automatically locked in pressed position.

To return to normal operation the push button must be pulled out and alarms acknowledged by pushing reset either locally or remotely.

## 14.1.2.3 Speed control

### Main engines (mechanical propulsion)

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

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

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

### Generating sets

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

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

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

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

## 14.1.3 Alarm and monitoring signals

Regarding sensors on the engine, the actual configuration of signals and the alarm levels are found in the project specific documentation supplied for all contracted projects.

## 14.1.4 Electrical consumers

### 14.1.4.1 Motor starters and operation of electrically driven pumps

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

#### Pre-lubricating oil pump

The pre-lubricating oil pump must always be running when the engine is stopped. 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.

Electric motor ratings are listed in the table below.

**Table 14-2 Electric motor ratings for pre-lubricating pump**

Engine type	Voltage [V]	Frequency [Hz]	Power [kW]	Current [A]
Wärtsilä 20	3 x 208 - 690	50 / 60	2.9 - 3.7	3 - 11.3

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

The engine control system starts the pump automatically via a motor starter, if the lubricating oil pressure drops below a preset level when the engine is running.

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

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

The engine control system starts the pump automatically via a motor starter, if the cooling water pressure drops below a preset level when the engine is running.

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

The engine control system starts the pump automatically via a motor starter, if the cooling water pressure drops below a preset level when the engine is running.

#### Circulating pump for preheater (4P04)

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

## 14.1.5 System requirements and guidelines for diesel-electric propulsion

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

1. The load increase program must limit the load increase rate during ship acceleration and load transfer between gensets according to the curves in chapter [Loading Capacity](#).

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

The load increase rate of a recently connected generator is the sum of the load transfer performed by the power management system and the load increase performed by the propulsion control.

2. Rapid loading according to the "emergency" curve in chapter [Loading Capacity](#) may only be possible by activating an emergency function, which generates visual and audible alarms in the control room and on the bridge.

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

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

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

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

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

7. In speed droop mode all generators take an equal share of increased system load, regardless of any difference in initial load. The control system (Power Management System) should monitor the generator load and reduce the system load, if the generator load exceeds 100%.

8. The system should monitor the network frequency and reduce the load, if the network frequency tends to drop excessively.

This page intentionally left blank

## 15. Foundation

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

### 15.1 Steel structure design

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

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

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

### 15.2 Mounting of main engines

#### 15.2.1 Rigid mounting

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

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

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

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

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

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

### 15.2.1.1 Resin chocks

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

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

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

### 15.2.1.2 Steel chocks

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

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

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

### 15.2.1.3 Steel chocks with adjustable height

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

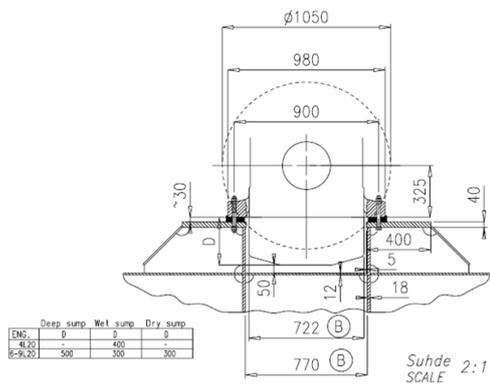
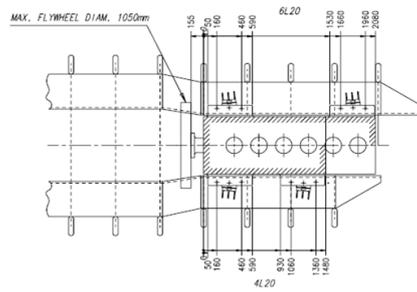
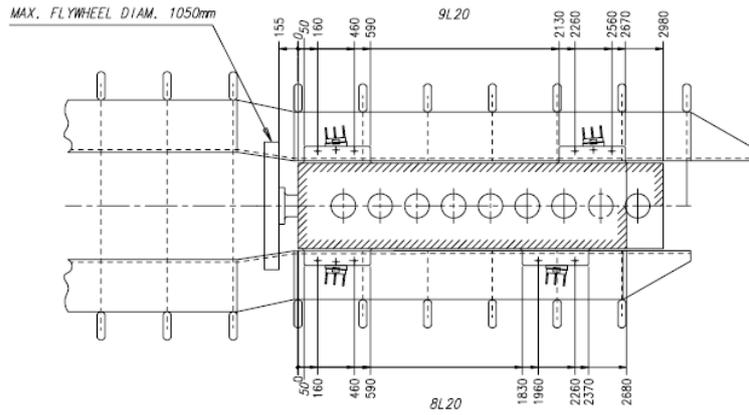
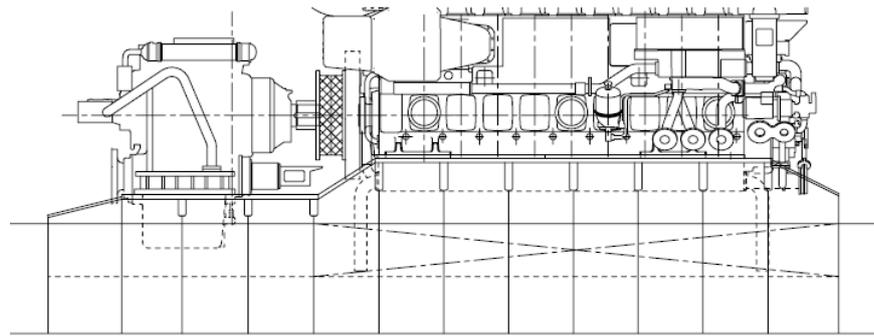
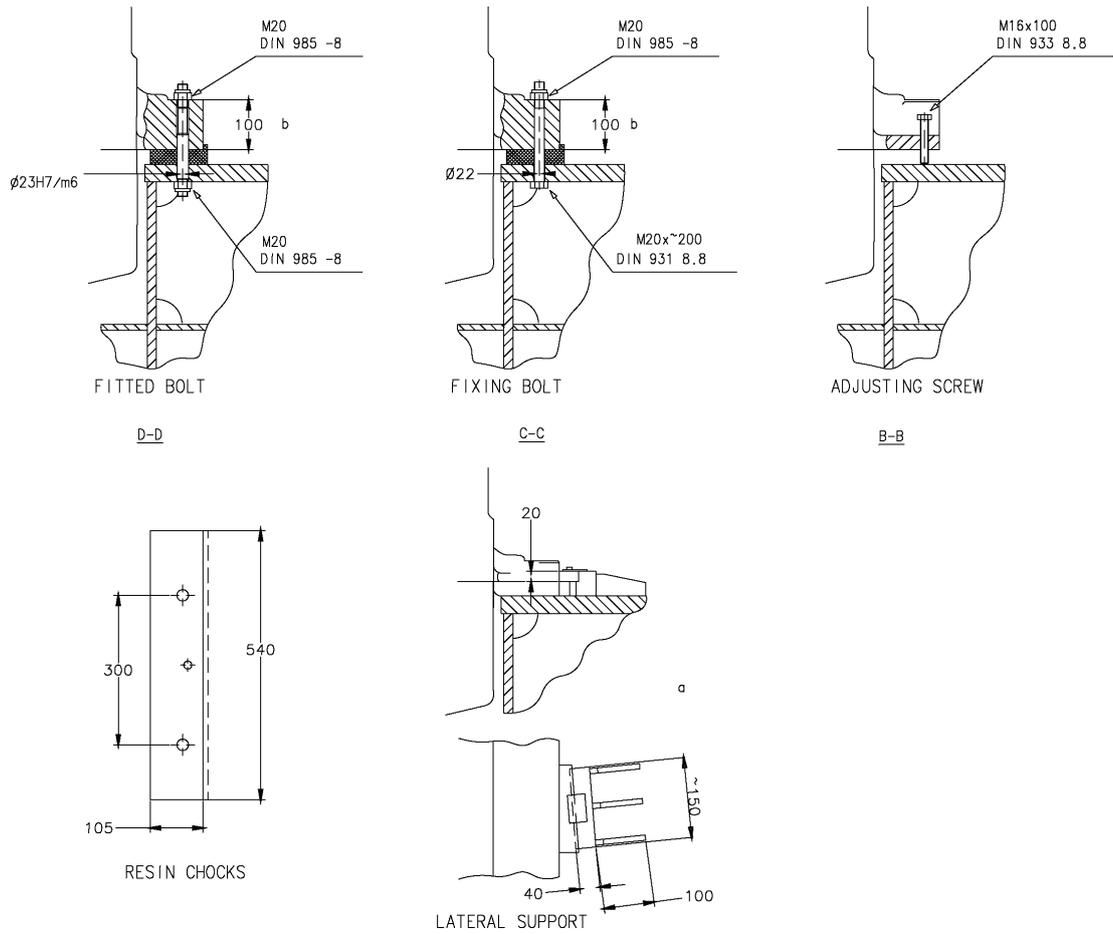


Fig 15-1 Main engine seating, view from above (DAAE017514B)



**Fig 15-2 Chocking of main engines (V69A0238C)**

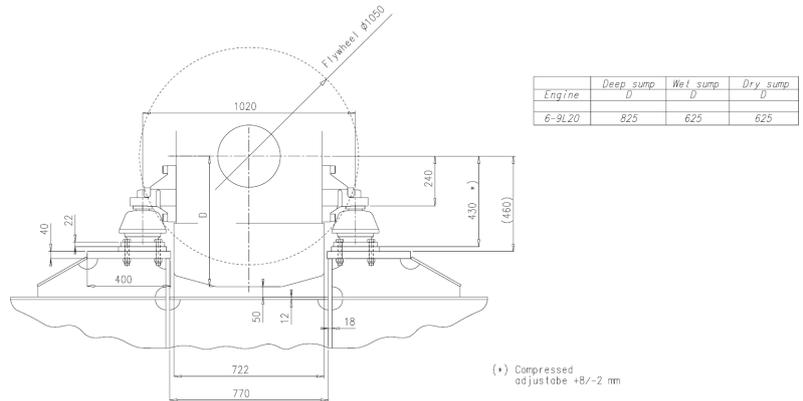
## 15.2.2 Resilient mounting

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

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

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

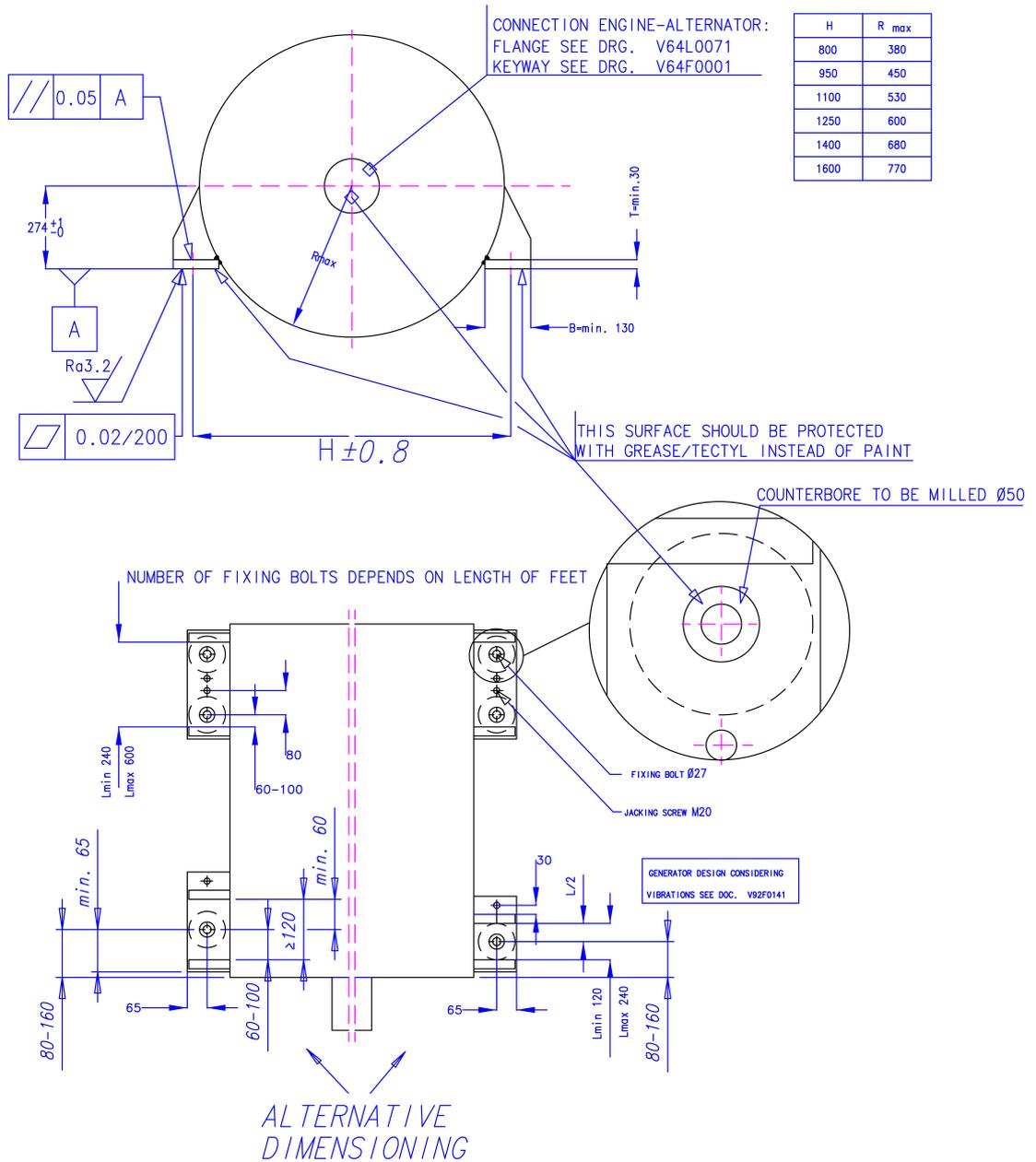
Resilient mounting is not available for W 4L20 engines.



**Fig 15-3 Resilient mounting (DAAE003263B)**

## 15.3 Mounting of generating sets

### 15.3.1 Generator feet design



**Fig 15-4** Instructions for designing the feet of the generator and the distance between its holding down bolt (V92F0134E)

### 15.3.2 Resilient mounting

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

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

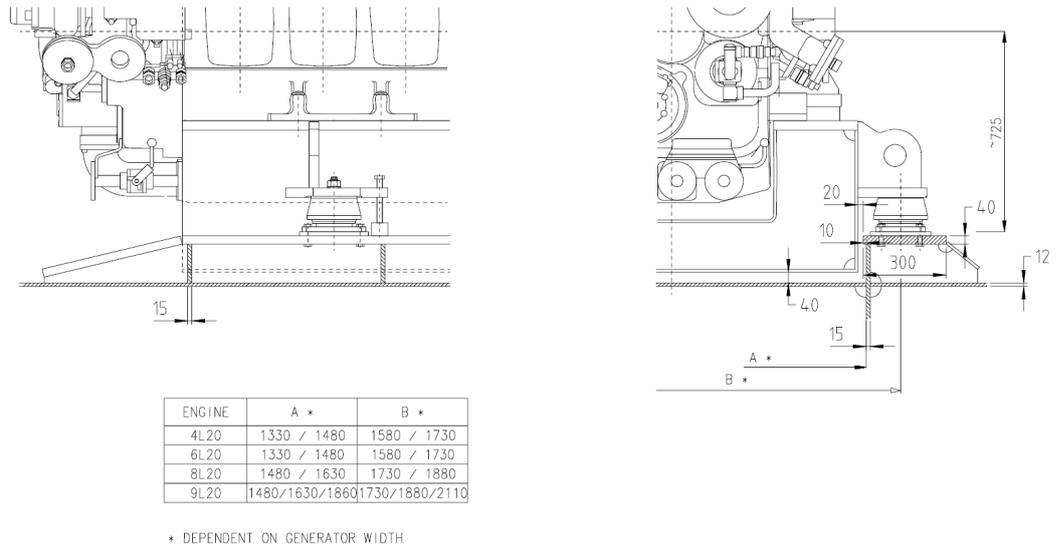
The number of mounts and their location is calculated to avoid resonance with excitations from the generating set engine, the main engine and the propeller.

**NOTE**

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

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

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



**Fig 15-5 Recommended design of the generating set seating (V46L0720H)**

\* *Dependent on generator width*

### 15.3.3 Rubber mounts

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

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

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

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

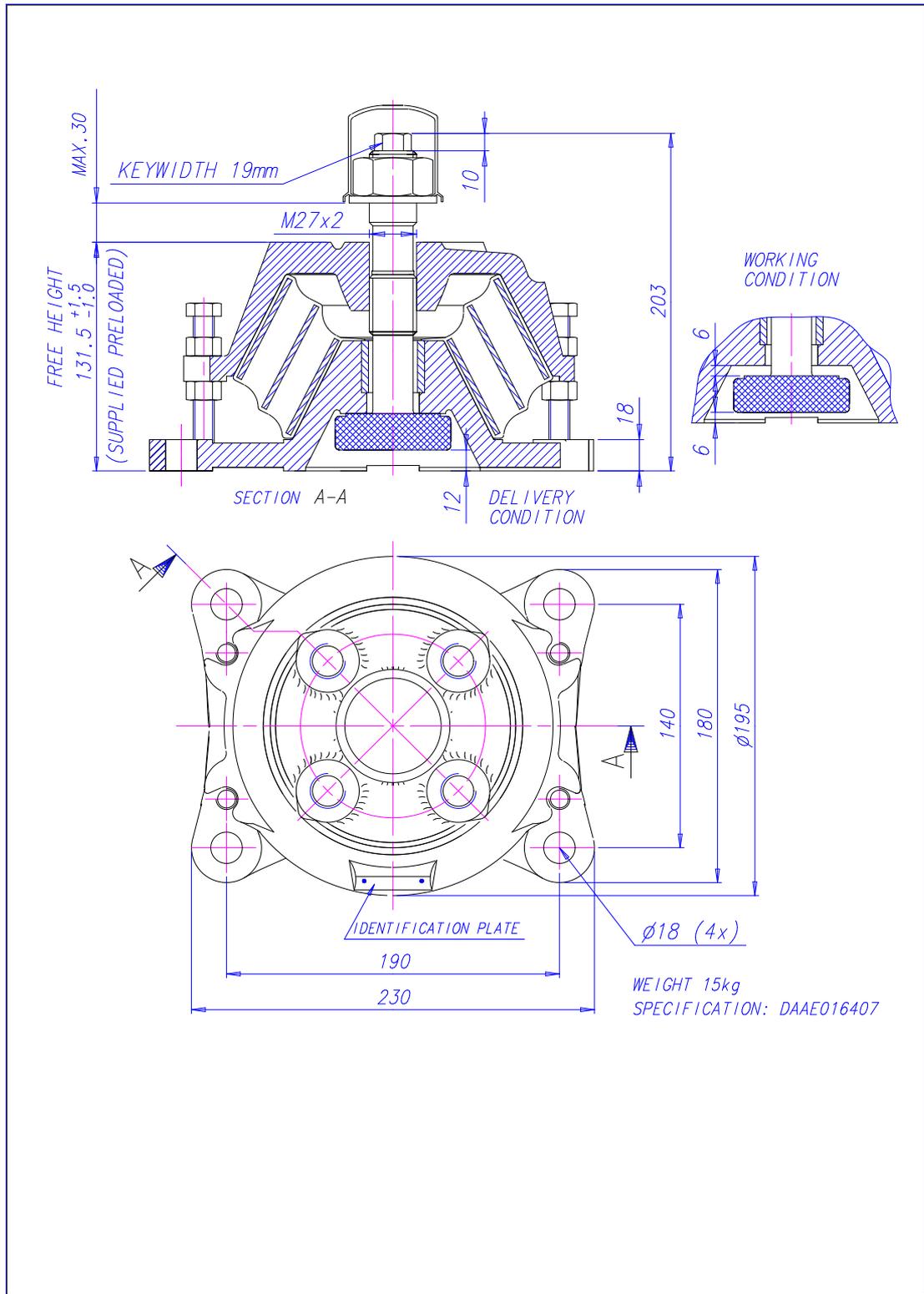


Fig 15-6 Rubber mounts (DAAE016408C)

## 15.4 Flexible pipe connections

When the engine or the generating set is resiliently installed, all connections must be flexible and no grating nor ladders may be fixed to the generating set. When installing the flexible pipe connections, unnecessary bending or stretching should be avoided. The external pipe must be precisely aligned to the fitting or flange on the engine. It is very important that the pipe

clamps for the pipe outside the flexible connection must be very rigid and welded to the steel structure of the foundation to prevent vibrations, which could damage the flexible connection.

This page intentionally left blank

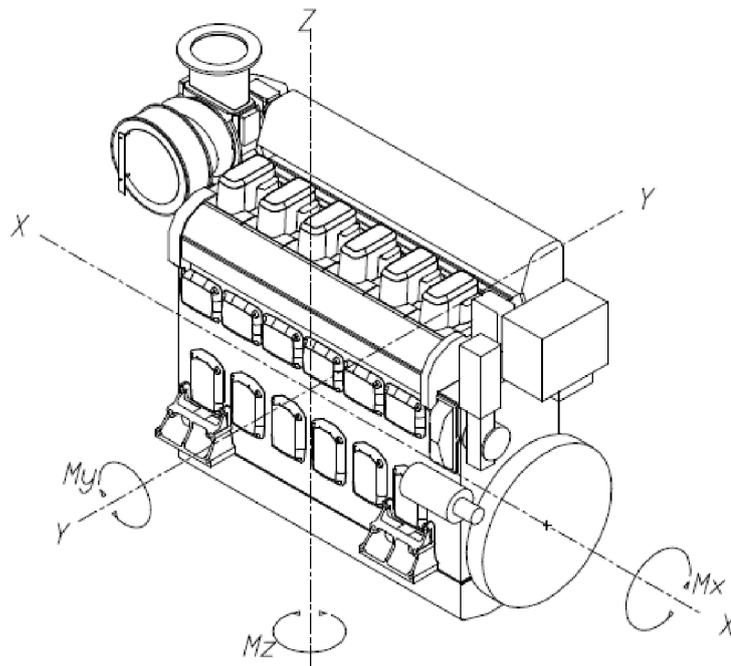
# 16. Vibration and Noise

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

## 16.1 External forces & couples

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

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



**Fig 16-1 External forces & couples**

### External forces

$F_z = 0, F_y = 0$  for all others than 4 and 8 cylinder engines.

**Table 16-1 External forces**

Engine	Speed [RPM]	Freq. [Hz]	$F_y$ [kN]	Freq. [Hz]	$F_z$ [kN]
4L20	900	30	--	30	--
		60	--	60	1
		--	--	--	--
	1000	33.3	--	33.3	--
		67	--	67	1
		--	--	--	--

**Table 16-1 External forces (continued)**

Engine	Speed [RPM]	Freq. [Hz]	F <sub>y</sub> [kN]	Freq. [Hz]	F <sub>z</sub> [kN]
8L20	900	60	--	60	2
		--	--	--	--
		--	--	--	--
	1000	67	--	67	3
		--	--	--	--
		--	--	--	--
	1200	80	--	80	4
		--	--	--	--
		--	--	--	--

-- couples and forces = zero or insignificant.

**External couples**

$M_z = 0$ ,  $M_y = 0$  for all others than 9 cylinder engines.

**Table 16-2 External couples**

Engine	Speed [RPM]	Freq. [Hz]	$M_y$ [kNm]	Freq. [Hz]	$M_z$ [kNm]
9L20	720	12	4.4	12	4.4
		24	3	--	--
		48	0.3	--	--
	750	12.5	4.7	12.5	4.7
		25	3.3	--	--
		50	0.3	--	--
	900	15	7.0	15	7.0
		30	4.8	--	--
		60	0.4	--	--
	1000	17	8	17	8
		33	6	33	--
		67	1	67	--
	1200	20	12	20	12
		40	8	40	--
		80	1	80	--

-- couples and forces = zero or insignificant.

**Table 16-3 Torque variations at 100% load**

Engine	Speed [RPM]	Freq. [Hz]	M <sub>x</sub> [kNm]	Freq. [Hz]	M <sub>x</sub> [kNm]	Freq. [Hz]	M <sub>x</sub> [kNm]
4L20	900	30	9.9	60	9.8	90	3.5
	1000	33.3	6.6	67	9.6	100	3.5
6L20	900	45	15.4	90	5.2	135	0.4
	1000	50	10	100	5	150	1
	1200	60	6	120	5	180	1
8L20	900	60	19.6	120	1.5	180	0.5
	1000	67	17	133	2	--	--
	1200	80	16	160	2	--	--
9L20	900	67.5	17.8	135	0.6	203	0.4
	1000	75	16	150	1	--	--
	1200	90	16	180	1	--	--

-- couples and forces = zero or insignificant.

900 rpm, 185 kW/cyl

1000 rpm, 200 kW/cyl

1200 rpm, 220 kW/cyl

**Table 16-4 Torque variations at 0% load**

Engine	Speed [RPM]	Freq. [Hz]	M <sub>x</sub> [kNm]	Freq. [Hz]	M <sub>x</sub> [kNm]	Freq. [Hz]	M <sub>x</sub> [kNm]
4L20	720	24	4.8	48	1.6	72	0.8
	750	25	5.6	50	1.5	75	0.8
	900	30	10	60	1.4	90	0.9
	1000	33.3	13	66.7	1.3	100	0.9
6L20	720	36	1.4	72	1.2	108	0.3
	750	37.5	1.9	75	1.2	112.5	0.3
	900	45	4.7	90	1.3	135	0.4
	1000	50	6	100	1	150	--
	1200	60	11	120	1	180	--
8L20	720	48	3.1	96	0.7	--	--
	750	50	3.1	100	0.7	--	--
	900	60	2.8	120	0.7	--	--
	1000	67	3	133	1	--	--
	1200	80	2	160	1	--	--
9L20	720	54	3.5	108	0.5	--	--
	750	56.3	3.5	112.5	0.5	--	--
	900	67.5	3.6	135	0.5	--	--
	1000	75	4	150	1	--	--
	1200	90	4	180	1	--	--

-- couples and forces = zero or insignificant.

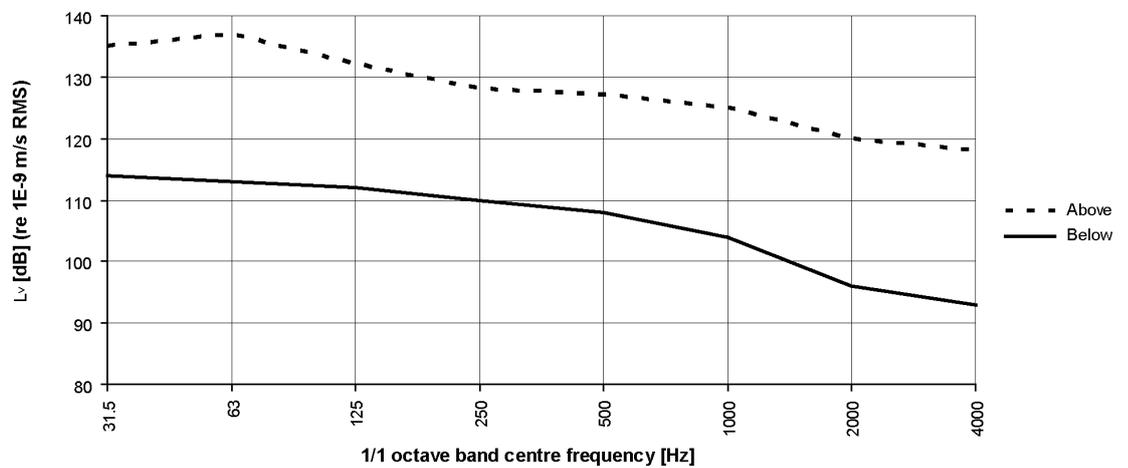
## 16.2 Mass moments of inertia

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

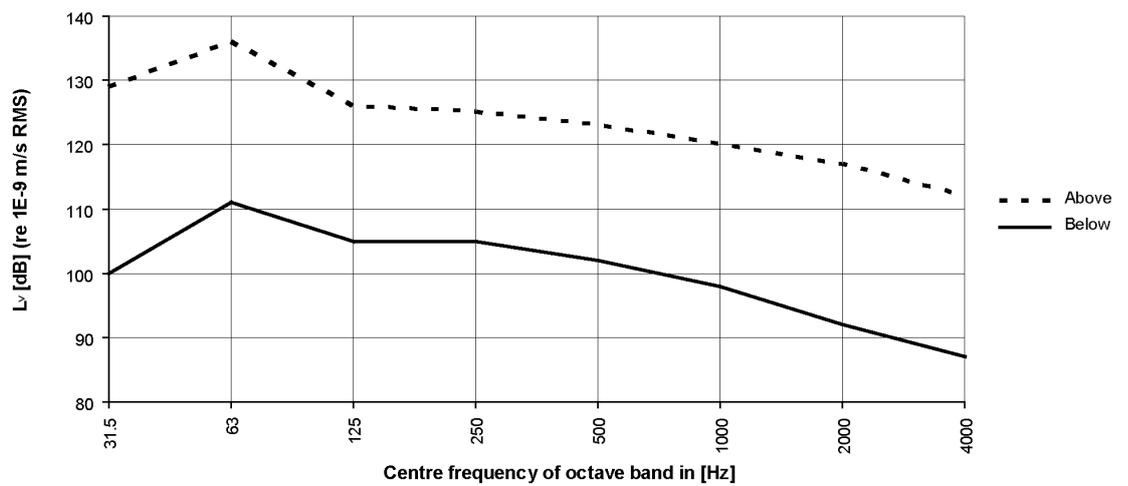
Engine	J [kgm <sup>2</sup> ]
W 4L20	90...120
W 6L20	90...150
W 8L20	110...160
W 9L20	100...170

## 16.3 Structure borne noise

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



**Fig 16-2 Main engines, typical structure borne noise levels above and below resilient mounts (DAAB814306)**



**Fig 16-3 Generating sets, typical structure borne noise levels above and below resilient mounts (DBAB120103)**

## 16.4 Air borne noise

The airborne noise of the engines is measured as sound power level based on ISO 9614-2. The results represent typical engine A-weighted sound power level at full load and nominal speed.

**Table 16-5 W20\_900 & 1000 rpm Engine A-weighted Sound Power Level in Octave Frequency Band [dB, ref. 1pW]**

[Hz]	125	250	500	1000	2000	4000	8000	Total
4L	93	101	105	110	109	108	109	116
6L	98	103	109	113	112	110	114	119
8L	102	104	107	112	112	111	112	118
9L	99	104	110	113	112	113	113	119

**Table 16-6 W20\_1200rpm Engine A-weighted Sound Power Level in Octave Frequency Band [dB, ref. 1pW]**

[Hz]	125	250	500	1000	2000	4000	8000	Total
6L	91	100	110	115	115	112	107	120
8L	86	99	109	114	113	115	106	120
9L	99	106	111	114	114	116	112	121

## 16.5 Exhaust noise

The results represent typical exhaust sound power level measured after turbocharger outlet in duct line with 0,5m diameter and exhaust temperature approximately 350 Celsius at engine full load and nominal speed.

**Table 16-7 W20\_900 & 1000 rpm Exhaust Gas Sound Power Level in Octave Frequency Band [dB, ref. 1pW]**

[Hz]	32	63	125	250	500	1000	2000	4000	Total
4L	149	145	139	140	139	133	119	109	152
6L	138	148	144	136	134	127	119	110	150
8L	139	147	148	144	143	131	116	109	152
9L	134	145	131	128	127	124	117	115	146

The results represent typical exhaust sound power level measured after turbocharger outlet in duct line with 0,5m diameter and exhaust temperature approximately 300 Celsius at engine full load and nominal speed.

**Table 16-8 W20\_1200rpm Exhaust Gas Sound Power Level in Octave Frequency Band [dB, ref. 1pW]**

[Hz]	32	63	125	250	500	1000	2000	4000	Total
6L	135	146	146	145	147	129	121	113	152
8L	135	142	143	136	139	122	118	112	147
9L	142	152	151	141	132	123	116	114	155

This page intentionally left blank

# 17. Power Transmission

## 17.1 Flexible coupling

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

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

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

### 17.1.1 Connection to generator

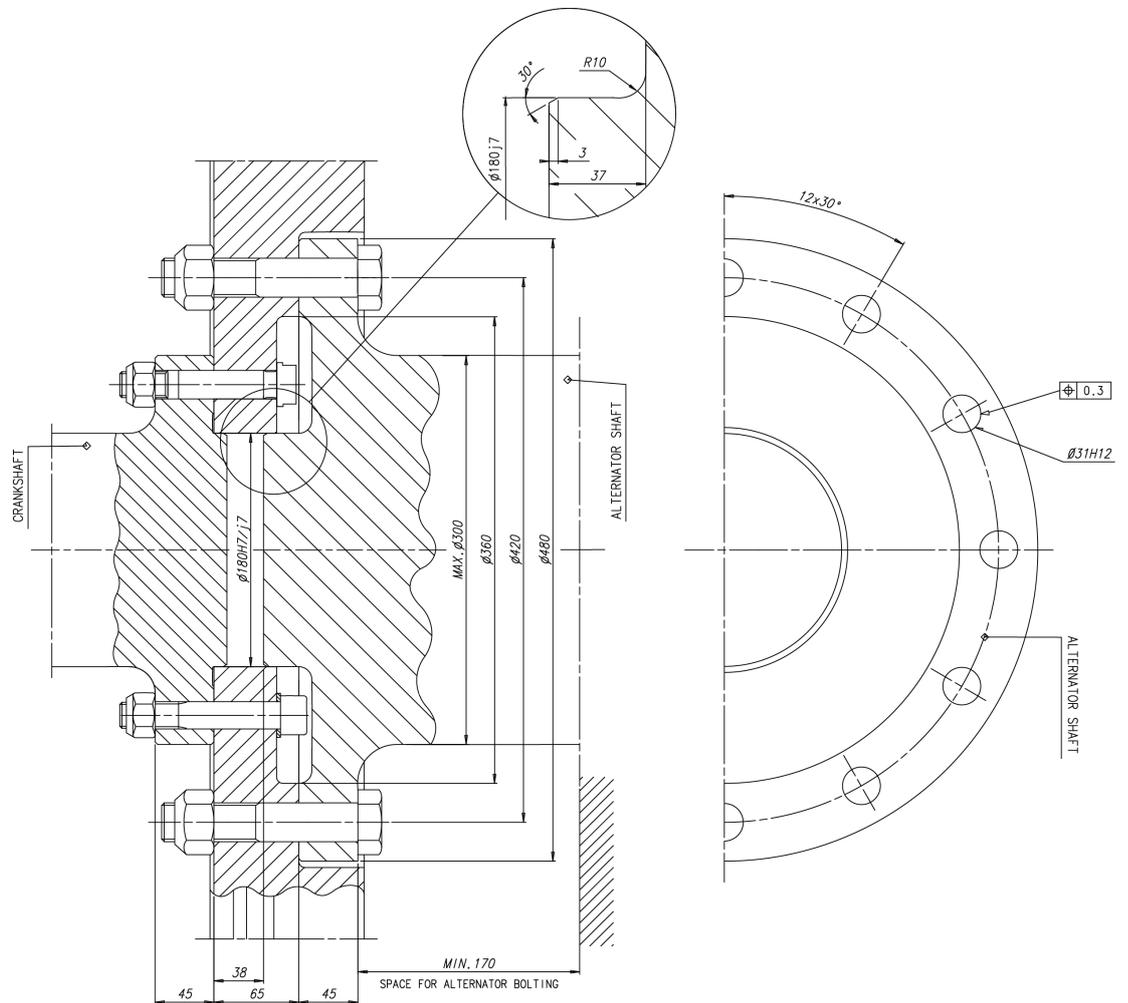
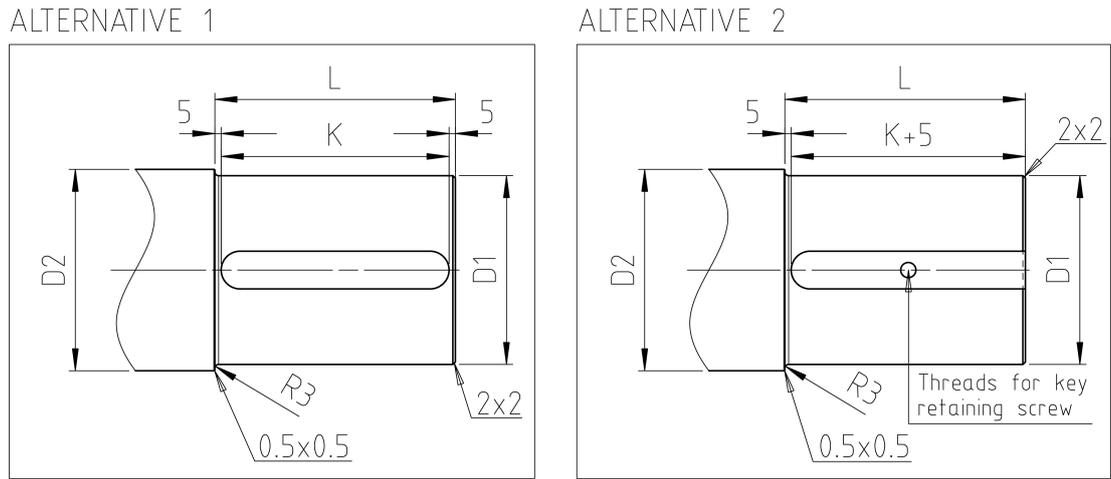


Fig 17-1 Connection engine/single bearing generator (V64L0071B)



**Fig 17-2 Connection engine/two-bearing generator (V64F0001C)**

Engine	Dimensions [mm]			
	D <sub>1</sub>	L	K	min D
W 4L20	120	150	140	130
W 6L20	150	190	180	160
W 8L20	150	190	180	160
W 9L20	150	190	180	160

## 17.2 Clutch

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

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

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

## 17.3 Shaft locking device

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

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

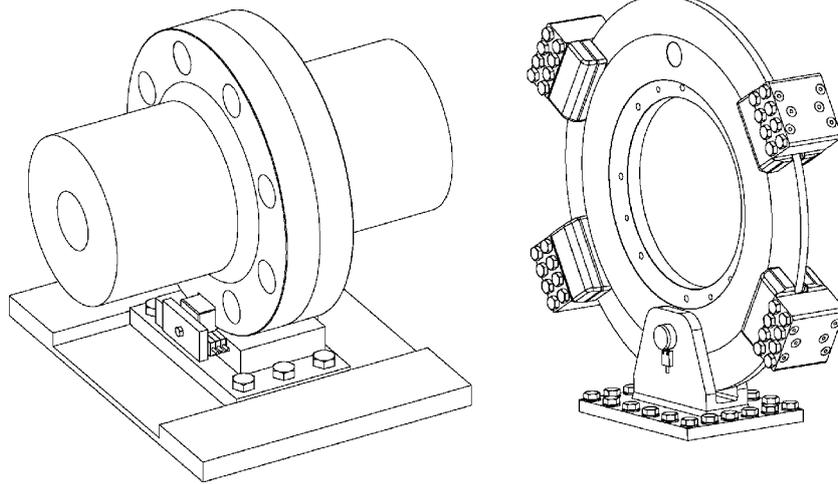


Fig 17-3 Shaft locking device and brake disc with calipers

## 17.4 Power-take-off from the free end

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

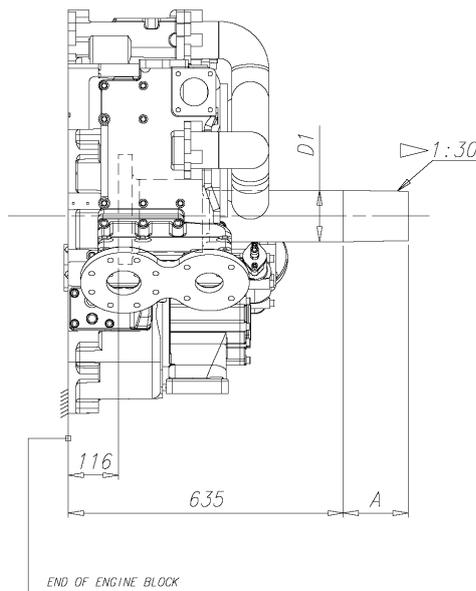


Fig 17-4 PTO alternative 1 (DAAE079074A)

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

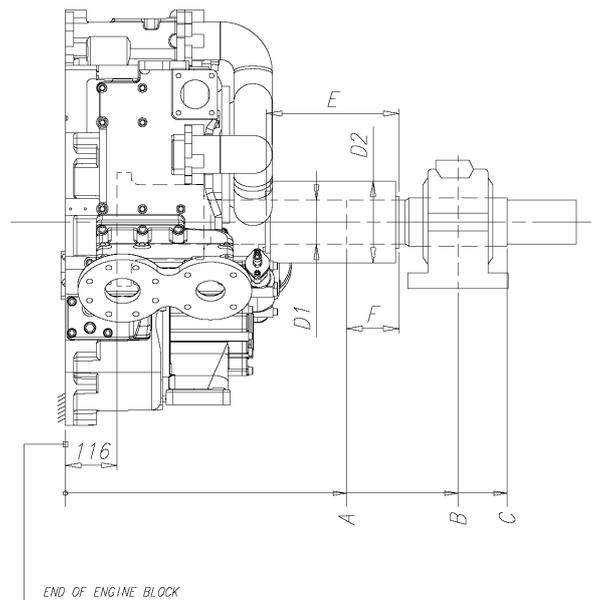


Fig 17-5 PTO alternative 2 (DAAE079045)

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

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

External support bearing is not possible for resiliently mounted engines.

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

## 17.5 Input data for Torsional Vibration Calculation

The torsional vibration calculation (TVC) is performed for each installation according to classification requirements. For this purpose, the following project specific exact data of all components included in the shaft system are required.

### General and operational data

- Classification society (leading class, in case of dual class)
- Class notations (especially in case of Ice, Polar, Redundant Propulsion)
- List of all operating modes (including for navigation in ice, if applicable)
- Power distribution between the different consumers for every operating mode
- Power Vs Speed curve for every consumer
- GA drawing or layout illustrating propulsion machinery arrangements

### Gearbox

- Mass elastic diagram showing:
  - All clutching possibilities (especially in case of multiple clutches)
  - Dimensions of all shafts
  - Mass moment of inertia of all rotating parts including shafts and flanges
  - Torsional stiffness of shafts between rotating masses
  - Gear ratios
  - Drawing number (including revision)
- GA drawing or other type of drawing showing:
  - Input and output interface details (type/dimensions details, material and yield strength, surface roughness)
    - In case of cylindrical shaft interface: fillet radius at step diameter and keyway standard
  - Material of shafts including minimum tensile strength
  - Drawing number (including revision)

### Propeller and shafting

- Mass-elastic diagram or propeller shaft drawing showing:
  - Mass moment of inertia of all rotating parts including the rotating part of the OD-box, SKF couplings and rotating parts of the bearings
  - Mass moment of inertia of the propeller in water for all operating modes (as minimum full/zero pitch)
  - Torsional stiffness or dimensions of the shafts
  - Drawing number (including revision)
- Drawing or data sheet with:
  - Propeller power consumption for all operating modes (as minimum full/zero pitch)
  - Number of propeller blades
  - Material of the shafts including minimum tensile strength

- In case of Ice class notation: propeller outer diameter, outer diameter of the propeller hub, propeller pitch at bollard pull condition
- In case of cardan shafts: joint inclination angle and mass moment of inertia of every single part (joints and shaft)
- Drawing number (including revision)

**Shaft generator or main generator**

- Technical data sheet with at least:
  - Nominal power and speed
  - Information if variable or constant speed operation
  - In case of variable speed, Power Vs Speed curve
  - Number of pole pairs
  - Bearing external load capabilities (axial and radial)
- Outline drawing with:
  - input interface details (type/dimensions details, material and yield strength, surface roughness)
    - In case of cylindrical shaft interface: fillet radius at step diameter and keyway standard
  - Bearing axial clearance (minimum and maximum values)
  - Drawing number (including revision)
- Mass-elastic diagram or the generator shaft drawing showing:
  - Mass moment of inertia of all rotating parts and total inertia value of the rotor, including the shaft
  - Torsional stiffness or dimensions of the shaft
  - Material of the shaft including minimum tensile strength
  - Drawing number of the diagram or drawing
- For shaft generator (connected to gearbox)
  - In case of PTI function, Power Vs Speed curve
  - In case of booster function, Power Vs Speed curve
- For main generator (connected to engine)
  - Electrical data: reactances and time constants

**Flexible coupling/clutch**

- Customer preferred coupling brand, if any
- Brand selection restrictions due to possible international export regulations
- Specific dimensional requirements (for example length)
- If coupling is in customer scope of supply, the following data of it must be informed:
  - Mass moment of inertia of all parts of the coupling
  - Number of flexible elements
  - Torsional stiffness per element
  - Dynamic magnification or relative damping
  - Nominal torque, permissible vibratory torque and permissible power loss
  - Drawing of the coupling showing interface details, maker, type and drawing number

**Other components:**

- In case of electric motor
  - Nominal power and speed
  - Power Vs Speed curve
  - Outline drawing with:
    - input interface details (type/dimensions details, material and yield strength, surface roughness)
      - In case of cylindrical shaft interface: fillet radius at step diameter and keyway standard
    - Drawing number (including revision)
  - Mass-elastic diagram or the motor shaft drawing showing:
    - Mass moment of inertia of all rotating parts and total inertia value of the rotor, including the shaft
    - Torsional stiffness or dimensions of the shaft
    - Material of the shaft including minimum tensile strength
    - Drawing number of the diagram or drawing
- In case of pump:
  - Nominal power and speed
  - Power Vs Speed curve
  - Information if variable or constant speed operation
  - Outline drawing with:
    - input interface details (type/dimensions details, material and yield strength, surface roughness)
      - In case of cylindrical shaft interface: fillet radius at step diameter and keyway standard
    - Drawing number (including revision)
  - Mass-elastic diagram or the impeller shaft drawing showing:
    - Mass moment of inertia of all rotating parts and total inertia value of the impeller, including the shaft
    - Torsional stiffness or dimensions of the shaft
    - Material of the shaft including minimum tensile strength
    - Drawing number of the diagram or drawing
  - Number of impeller blades
  - Torsional excitations (especially in case of dredging pump)

## 17.6 Turning gear

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

<b>NOTICE</b>
---------------

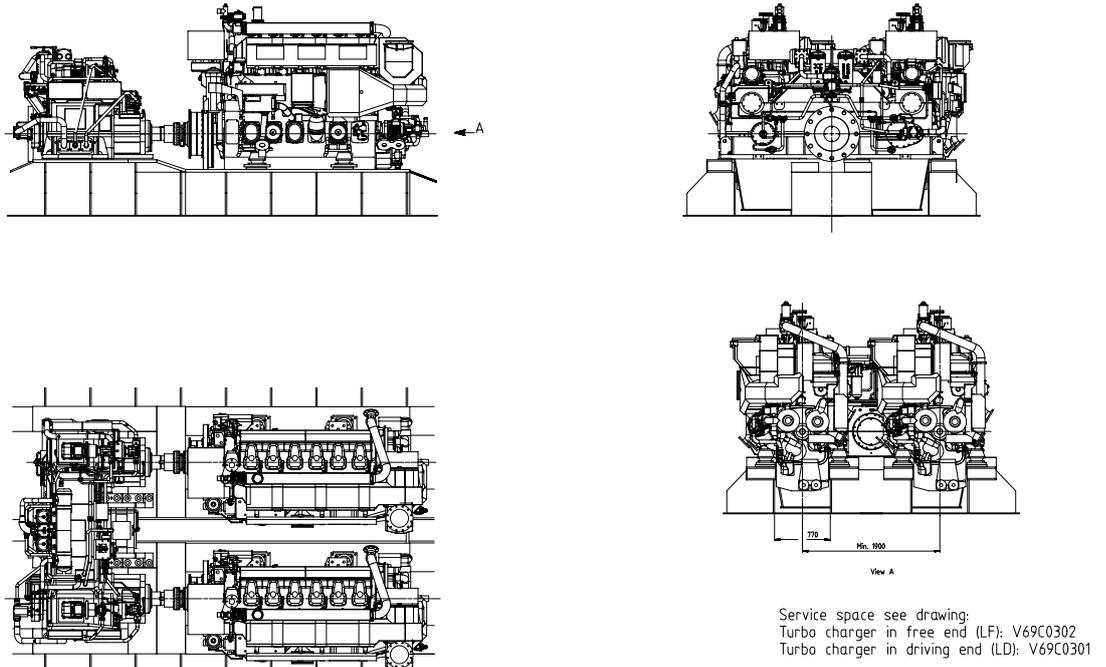
Interlock test of turning gear is to be performed when installed.
---

# 18. Engine Room Layout

## 18.1 Crankshaft distances

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

### 18.1.1 Main engines

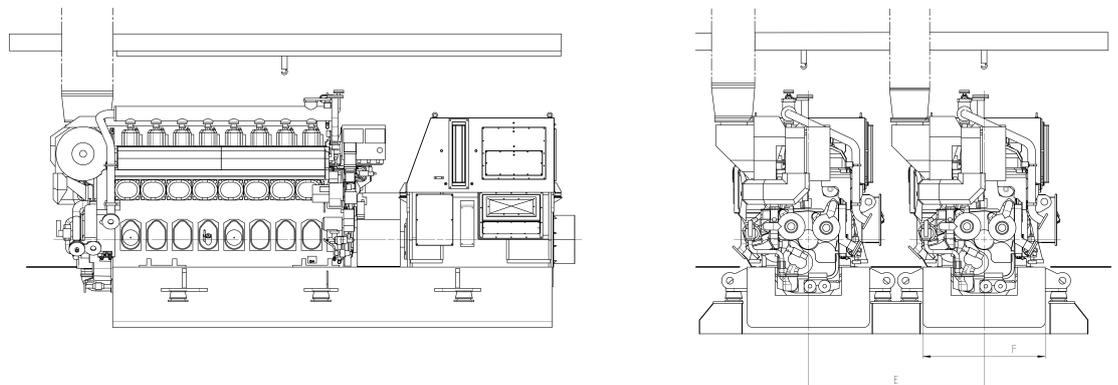


**Fig 18-1 Crankshaft distances main engines (DAAF017589A)**

**NOTE**

Please refer to [Service Space Requirement](#) for details.

### 18.1.2 Generating sets



**Fig 18-2 Crankshaft distances generating sets (DAAE007434D)**

**Table 18-1 Standard genset**

Engine type	E*	F
W 4L20	1970 / 2040	1270 / 1420
W 6L20	1970 / 2040 / 2170	1270 / 1420 / 1570
W 8L20	2040 / 2170 / 2250	1420 / 1570 / 1700
W 9L20	2040 / 2200 / 2400	1420 / 1570 / 1700

**Table 18-2 Double flexible installed genset**

Engine type	E*	F
W 6L20	2450	1350
W 8L20	2450	1350
W 9L20	2450	1350

E = MIN. DISTANCE BETWEEN ENGINES DEPENDENT ON COMMON BASE PLATE

F = WIDTH OF THE COMMON BASE PLATE DEPENDENT ON WIDTH OF THE ALTERNATOR

\* In case of extra wide lifting lugs needed, 230mm should be added to dimension E. Depending on final generator selection

\* Dimension E should be checked at all times with each project specific configuration due to generator service space

All dimensions in mm.

## 18.2 Space requirements for maintenance

### 18.2.1 Working space reservation

It is recommended to reserve about one meter of free working space.

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.

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

## 18.2.2 Engine room height and lifting equipment

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

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

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

## 18.2.3 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

## 18.3 Transportation and storage of spare parts and tools

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

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

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

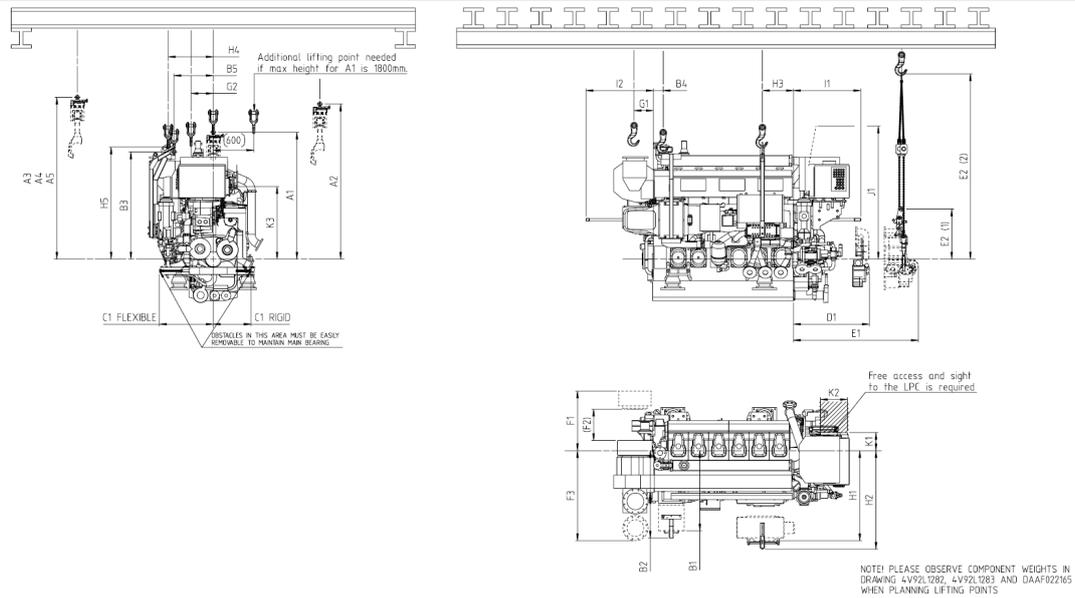
On single main engine (SME) installations it is important to store heavy engine parts close to the engine to make overhaul as quick as possible in an emergency situation.

## 18.4 Required deck area for service work

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

## 18.4.1 Service space requirement

### 18.4.1.1 Service space for engines with turbocharger in driving end



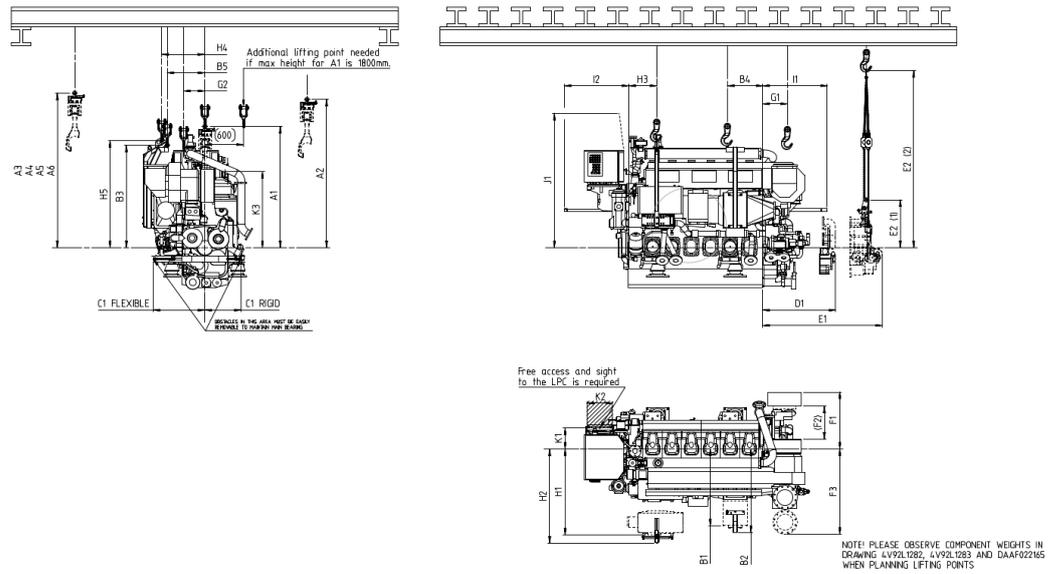
TC in driving end

Service space in (mm)	6L	8L	9L
A1. Height for overhauling piston and connecting rod		3000	
A2. Height for transporting piston and connecting rod freely over adjacent cylinder head covers		2300	
A3. Height for transporting piston and connecting rod freely over exhaust gas insulation box	2300	2400	2400
A4. Height needed for transporting piston and connecting rod freely over APC exhaust gas insulation box (SOLA)	-	-	2720
A5. Height for transporting piston and connecting rod freely over gas manifold for WRODP		2470	
B1. Width for dismantling charge air cooler and/or inlet box		1200	
B2. Width for dismantling charge air cooler and/or inlet box sideways by using lifting tool		1310	
B3. Height of the lifting eye for the charge air cooler lifting tool		1400	
B4. Recommended lifting point for charge air cooler lifting tool		390 / 3P = 270	
B5. Recommended lifting point for charge air cooler lifting tool		380	
C1. Removal of main bearing side screw, flange / rigid mounting		800 / 560	
D1. Distance needed for dismantling lube oil and water pumps		635	
E1. Distance needed for dismantling pump cover with fitted pumps		With P10, length = 575 without P10, 650	
E2. Height of the lifting eye for the pump cover with fitted pumps, with lifting tool 1 / alternative lifting tool 2		750 / 2770	
FL. The recommended axial clearance for dismantling and assembly of silencers	650	710	710
F2) Minimum axial clearance		100	
G3. Recommended distance for dismantling the gas outlet elbow	990	1150	1170
G1. Recommended lifting point for the turbocharger		300	
G2. Recommended lifting point sideways for the turbocharger		345	
H1. Width for dismantling lubricating oil module and/or plate cooler		1250	
H2. Width for dismantling lube oil module with lifting tool		1480	
H3. Recommended lifting point for dismantling lubricating oil module and/or plate cooler		1445	
H4. Recommended lifting point sideways for dismantling lubricating oil module and/or plate cooler		1045	
H5. Height of lifting eye for dismantling lube oil module with lifting tool		1075	
I1. Camshaft screw overhaul distance (flywheel end)	1000	1000	1000
I2. Camshaft screw overhaul distance (free end)	1300	1400	1400
J1. Space necessary for access to connecting box		2050	
K1. Distance to LCP (Local Control Panel)		270	
K2. Width of LCP		450	
K3. Distance to LCP		150	

NOTE!  
It is sufficient if one of I1 or I2 are fulfilled.

Fig 18-3 Service space for engines with turbocharger in driving end (V69C0301H)

### 18.4.1.2 Service space for engines with turbocharger in free end



TC in free end

Service space in [mm]		4L	6L	8L	9L
A1.	Height for overhauling piston and connecting rod	1800			
A2.	Height for transporting piston and connecting rod freely over adjacent cylinder head covers	2300			
A3.	Height for transporting piston and connecting rod freely over exhaust gas insulation box	2230	2300	2400	2400
A4.	Height needed for transporting piston and connecting rod freely over 60°C exhaust gas insulation box (SOLAS)	-	-	-	2720
A5.	Height for transporting piston and connecting rod freely over exhaust gas insulation box for W20 with UNIC 6-series.	2320	2320	2420	2420
A6.	Height for transporting piston and connecting rod freely over gas manifold for W20DF	-	-	2470	
B1.	Width for dismantling charge air cooler and air inlet box	1200			
B2.	Width for dismantling charge air cooler and air inlet box sideways by using lifting tool	1310			
B3.	Height of the lifting eye for the charge air cooler lifting tool	1600			
B4.	Recommended lifting point for charge air cooler lifting tool	260	550 / DF=4.30		
B5.	Recommended lifting point for charge air cooler lifting tool	585			
C1.	Removal of main bearing side screw, flexible / rigid mounting	800 / 560			
D1.	Distance needed for dismantling lube oil and water pump	635			
E1.	Distance needed for dismantling pump cover with fitted pumps	With PTO, length + 515 Without PTO: 650			
E2.	Height of the lifting eye for the pump cover with fitted pumps, with lifting tool 1 / alternative lifting tool 2	750 / 2770			
F1.	The recommended axial clearance for dismantling and assembly of silencers	590	650	750	750
(F2.)	Minimum axial clearance	100			
F3.	Recommended distance for dismantling the gas outlet elbow	890	990	1120	1120
G1.	Recommended lifting point for the turbocharger	350			
G2.	Recommended lifting point sideways for the turbocharger	320			
H1.	Width for dismantling lubricating oil module and/or plate cooler	1250			
H2.	Width for dismantling lube oil module with lifting tool	1480			
H3.	Recommended lifting point for dismantling lubricating oil module and/or plate cooler	445			
H4.	Recommended lifting point sideways for dismantling lubricating oil module and/or plate cooler	1045			
H5.	Height of lifting eye for dismantling lube oil module with lifting tool	1675			
I1.	Camshaft screw overhaul distance (free end)	700	1000	1300	1600
I2.	Camshaft screw overhaul distance (flywheel end)	1000	1300	1600	1600
J1.	Space necessary for access to connecting box	2100			
K1.	Distance to LCP (Local Control Panel)	300			
K2.	Width of LCP	360			
K3.	Distance to LCP	1200			

NOTE!  
It is sufficient if one of I1 or I2 are fulfilled.

Fig 18-4 Service space for engines with turbocharger in free end (V69C03021)

### 18.4.1.3 Service space for generating sets

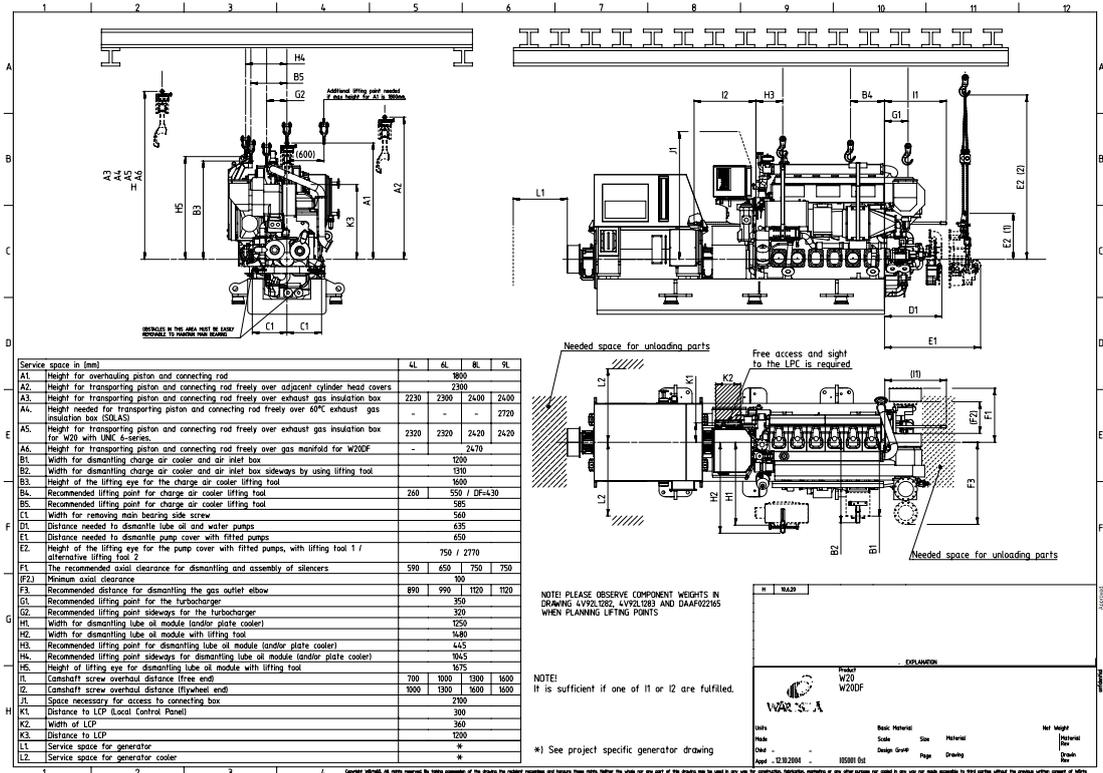


Fig 18-5 Service space for generating sets (DAAE006367H)

Service spaces in mm		4L	6L	8L	9L
A1	Height for overhauling piston and connecting rod	1800			
A2	Height for transporting piston and connecting rod freely over adjacent cylinder head covers	2300			
A3	Height for transporting piston and connecting rod freely over exhaust gas insulation box	2230	2300	2400	2400
A4	Height needed for transporting piston and connecting rod freely over 60°C exhaust gas insulation box (SOLAS)	-	-	-	2720
B1	Width for dismantling charge air cooler and air inlet box	1200			
B2	Width for dismantling charge air cooler and air inlet box sideways by using lifting tool	1310			
B3	Height of the lifting eye for the charge air cooler lifting tool	1600			
B4	Recommended lifting point for charge air cooler lifting tool	260	550		
B5	Recommended lifting point for charge air cooler lifting tool	585			
C1	width for removing main bearing side screw	560			
D1	Distance needed to dismantle lube oil and water pumps	635			
E1	Distance needed to dismantle pump cover with fitted pumps	650			
E2	Height of the lifting eye for the pump cover with fitted pumps, with lifting tool 1/ alternative lifting tool 2	750 / 2770			
F1	The recommended axial clearance for dismantling and assembly of silencers	590	650	750	750

(continued)

Service spaces in mm		4L	6L	8L	9L
F2	Minimum axial clearance	100			
F3	Recommended distance for dismantling the gas outlet elbow	890	990	1120	1120
G1	Recommended lifting point for the turbocharger	350			
G2	Recommended lifting point sideways for the turbocharger	320			
H1	Width for dismantling lubricating oil module and/or plate cooler	1250			
H2	Width for dismantling lubricating oil module with lifting tool	1480			
H3	Recommended lifting point for dismantling lubricating oil module and/or plate cooler	445			
H4	Recommended lifting point sideways for dismantling lube oil module and/or plate cooler	1045			
H5	Height of lifting eye for dismantling lube oil module with lifting tool	1670			
I1	Camshaft overhaul distance (free end)	700	1000	1300	1600
I2	Camshaft overhaul distance (flywheel end)	700	1000	1300	1600
J3	Space necessary for access to connecting box	2120			
K1	Service space for generator	500			

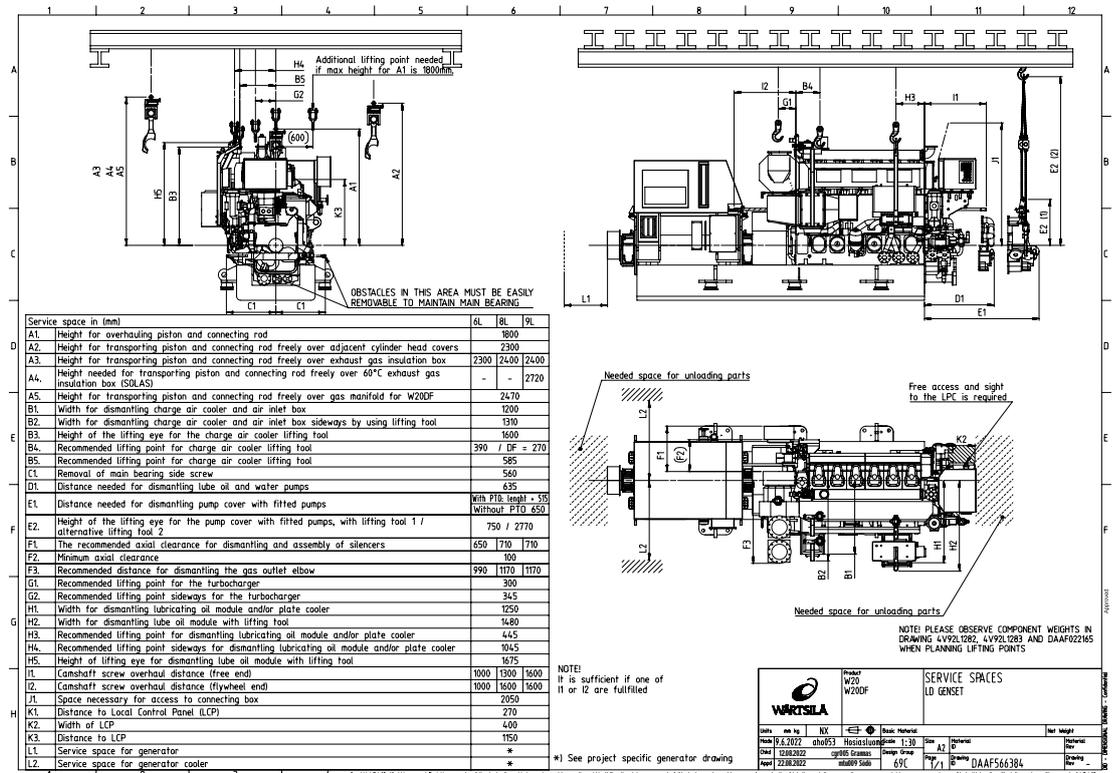


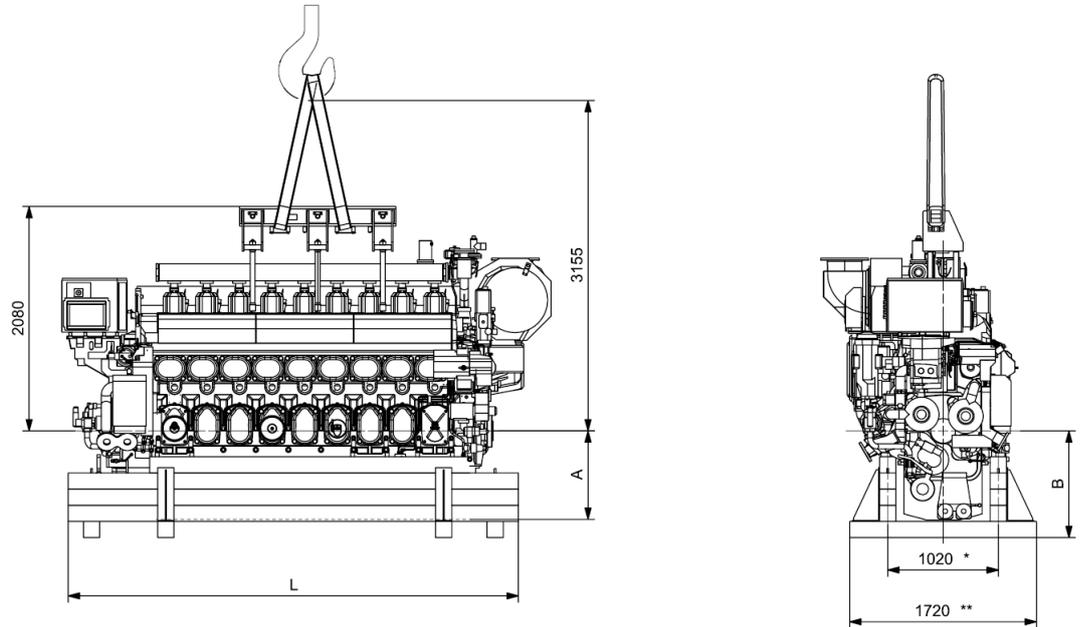
Fig 18-6 Service space for generating sets with turbocharger at driving end (DAAF566384)

**NOTE**

It is sufficient if one of I1 or I2 are fulfilled.

# 19. Transport Dimensions and Weights

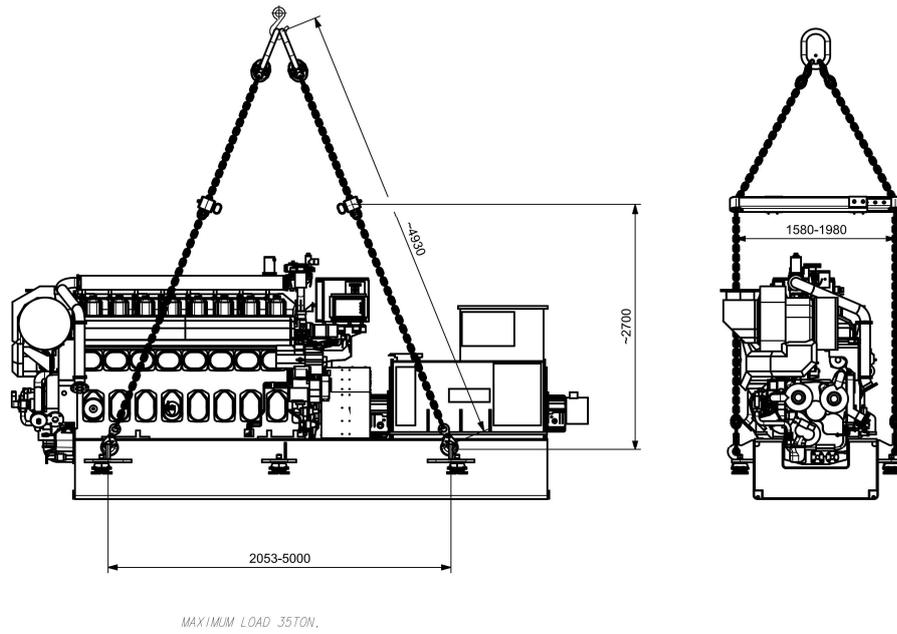
## 19.1 Lifting of engines



ENGINE TYPE	L	Dry sump A	Wet sump A	Dry sump B	Wet sump B
6L20	3200	624	824	600	675
8L20	3500	624	824	600	675
9L20	4150	624	824	600	675

\*) 900 FOR FIXED MOUNTED ENGINE  
 \*\*) 1600 FOR FIXED MOUNTED ENGINE

Fig 19-1 Lifting of main engines (DAAF016244A)



**Fig 19-2 Lifting of generating sets (DAAF016285B)**

## 19.2 Engine components

### 19.2.1 Turbocharger and cooler inserts (DAAE031768D)

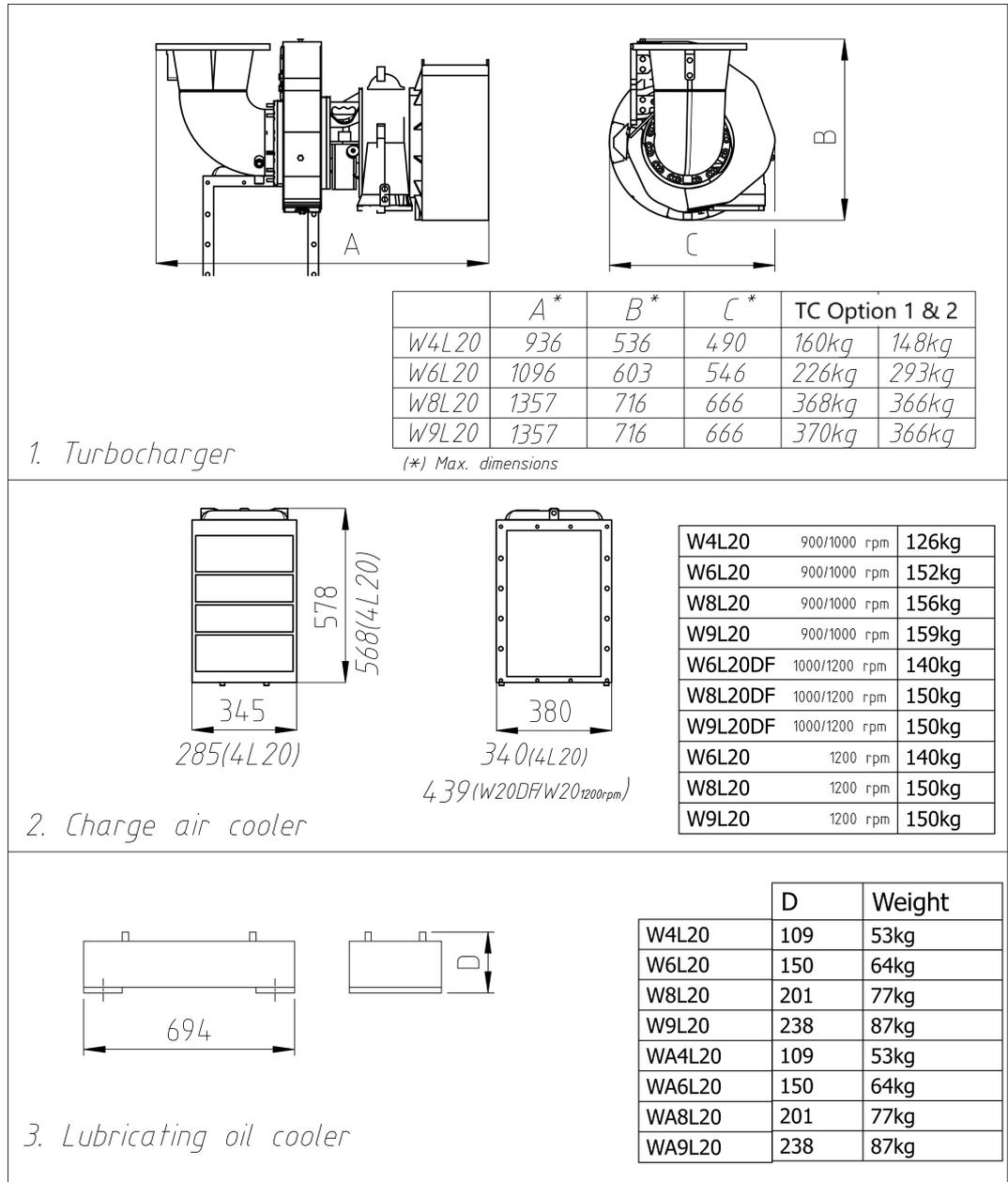
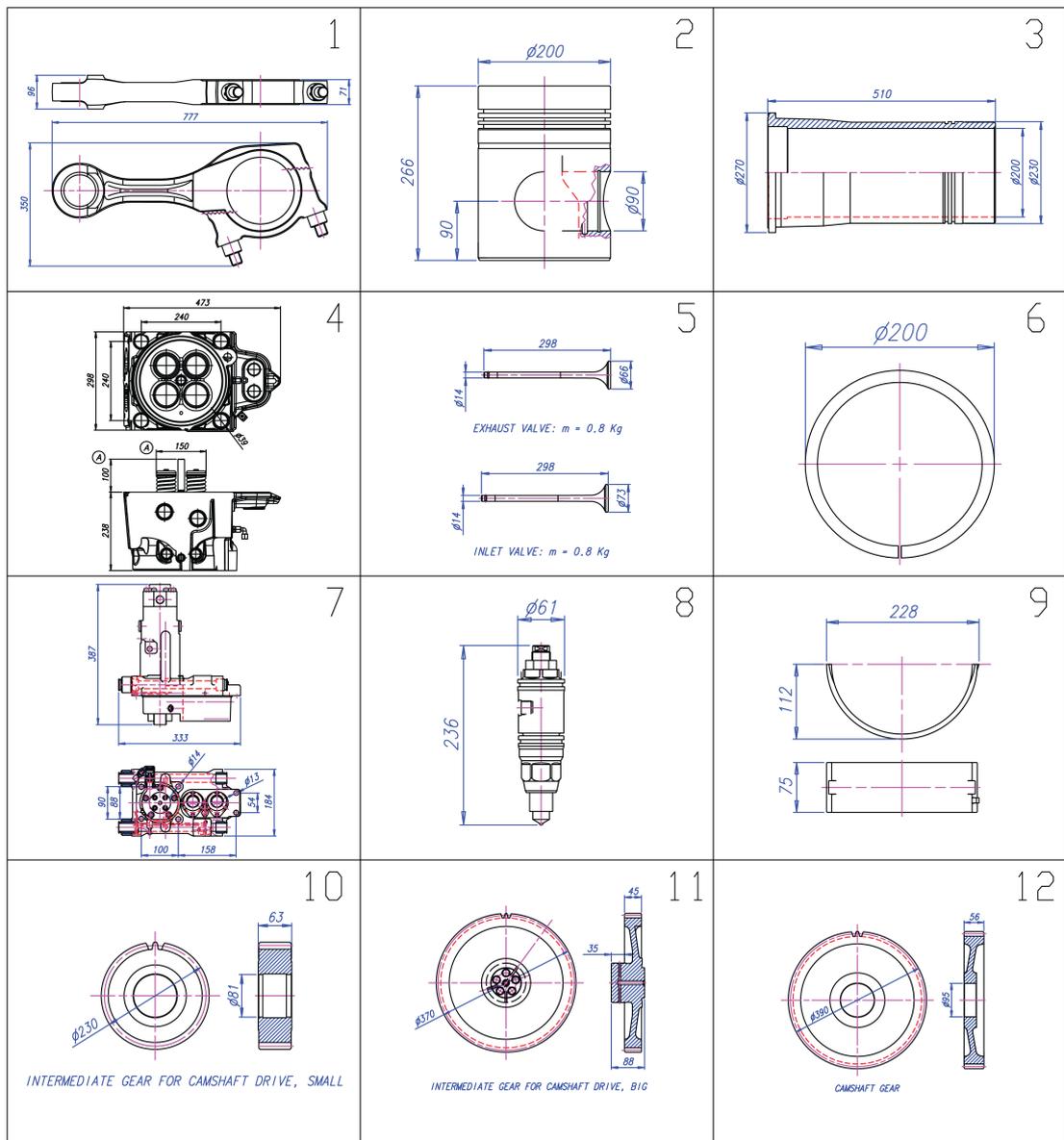


Fig 19-3 Turbocharger and cooler (DAAE031768D)

## 19.2.2 Major spare parts (V92L1275A)



Item	Weight (kg)	Item	Weight (kg)
1 Connecting rod	39	7 Injection pump	27
2 Piston	21	8 Injection valve	3.2
3 Cylinder liner	41	9 Main bearing shell	1.4
4 Cylinder head	94	10 Smaller intermediate gear	11.4
5 Valve	0.8	11 Bigger intermediate gear	23.5
6 Piston ring	0.2	12 Camshaft drive gear	25

## 20. Product Guide Attachments

This and all other product guides can be accessed on the internet, at [www.wartsila.com](http://www.wartsila.com). Product guides are available both in web and PDF format. Engine outline drawings are available not only in [2D](#) drawings (in PDF, DXF format), but also in [3D](#) models. Please consult your sales contact at Wärtsilä for more information.

Engine outline drawings are not available in the printed version of this product guide.

This page intentionally left blank

# 21. ANNEX

## 21.1 Unit conversion tables

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

*Length conversion factors*

Convert from	To	Multiply by
mm	in	0.0394
mm	ft	0.00328

*Mass conversion factors*

Convert from	To	Multiply by
kg	lb	2.205
kg	oz	35.274

*Pressure conversion factors*

Convert from	To	Multiply by
kPa	psi (lbf/in <sup>2</sup> )	0.145
kPa	lbf/ft <sup>2</sup>	20.885
kPa	inch H <sub>2</sub> O	4.015
kPa	foot H <sub>2</sub> O	0.335
kPa	mm H <sub>2</sub> O	101.972
kPa	bar	0.01

*Volume conversion factors*

Convert from	To	Multiply by
m <sup>3</sup>	in <sup>3</sup>	61023.744
m <sup>3</sup>	ft <sup>3</sup>	35.315
m <sup>3</sup>	Imperial gallon	219.969
m <sup>3</sup>	US gallon	264.172
m <sup>3</sup>	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 <sup>2</sup>	lbf ft <sup>2</sup>	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 <sup>3</sup> /h (liquid)	US gallon/min	4.403
m <sup>3</sup> /h (gas)	ft <sup>3</sup> /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 <sup>3</sup>	lb/US gallon	0.00834
kg/m <sup>3</sup>	lb/Imperial gallon	0.01002
kg/m <sup>3</sup>	lb/ft <sup>3</sup>	0.0624

### 21.1.1 Prefix

**Table 21-1 The most common prefix multipliers**

Name	Symbol	Factor	Name	Symbol	Factor	Name	Symbol	Factor
tera	T	10 <sup>12</sup>	kilo	k	10 <sup>3</sup>	nano	n	10 <sup>-9</sup>
giga	G	10 <sup>9</sup>	milli	m	10 <sup>-3</sup>			
mega	M	10 <sup>6</sup>	micro	μ	10 <sup>-6</sup>			

# 21.2 Collection of drawing symbols used in drawings

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
1 2101		Valve (general)	10 X2113		Check valve globe type	17 X2131		Control valve with electric motor actuator
2 X8068		Valve, globe type	11 X8078		Swing check valve (Form 1)	18 X2103		Two-way valve with solenoid actuator
3 X8071		Valve, ball type	12 X8165		Swing check valve (Form 2)	19		Two-way valve with double-acting cylinder actuator (pneumatic)
4 X8074		Valve, gate type	13 X2124		Safety valve, spring loaded, globe type	20 X2104		Two-way valve with electric motor actuator
5 X8075		Valve, butterfly type (Form 1)	14 X1021		Manual operation of valve	21 X2101		Two-way valve with diaphragm actuator (pneumatic)
6 X8075		Valve, butterfly type (Form 2)	15 X2001		Weight-loaded safety valve defained in open position after operation	22		Two-way control valve with diaphragm actuator (pneumatic)
7 X8076		Valve, needle type	16 X2134		Float-operated control valve	23 X2002		Spring-loaded safety two-way valve with automatic return after operation
8 X8087		Valve, control type, continuously operated						
9 X8077		Check valve (general). (Two-way non-return valve; flow from left to right)						

Fig 21-1 List of symbols (DAAF406507A - 1)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
24		Manually operated control valve	33 X8070		Valve, three way globe type	40		Three-way control valve with diaphragm actuator
25 X2112		Combinated non-return valve and manually actuated stop valve. Flow from left to right	34 X8073		Valve, three way ball type	41		Self-operating pressure reducing three-way control valve
26		Spring-loaded non-return valve. Flow from left to right	35		Three-way control valve with electrical motor actuator	42		Self-operating thermostatic three-way control valve
27 X2133		Self-operating pressure reducing control valve	36 X2103		Three-way valve with solenoid actuator	43		Self-contained thermostatic valve
28		Pressure control valve (spring loaded)	37 X2107		Three-way valve with double-acting cylinder actuator (pneumatic)	44 Z102		Valve, angle type (general)
29		Pressure control valve (remote pressure sensing)	38		Three-way valve with electric motor actuator	45 X8069		Valve, angle globe type
30		Pneumatically actuated valve, spring-loaded cylinder actuator	39 X2102		Three-way valve with diaphragm actuator			
31		Quick-closing valve						
32 2103		Valve, three way type (general)						

Fig 21-2 List of symbols (DAAF406507A - 2)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
46 X8072		Valve, angle ball type	55 772		Orifice plate	62		Valve 3/2 Pneum/Pneum
47 X2125		Safety valve, spring loaded, globe angle type	56 X2182		Shuttle valve with "AND-function"	63		Valve 3/2 Pneum/Spring
48		Weight loaded angled valve defined in open position after operation	57		Valve 2/2 Pneum/Pneum	64		Valve 3/2 Solenoid/Spring
49		Spring-loaded safety angled valve with automatic return after operation	58		Valve 2/2 Pneum/Spring	65		Valve 3/2 Lever/Spring
50		Non-return angled two-way valve. Flow from left to right	59		Valve 2/2 Solenoid/Spring	66		Valve 3/2 Manual/Spring
51		Non-return angled two-way valve hand operating. Flow from left to right	60		Valve 2/2 Lever/Spring	67		Valve 3/2 Pneum/Pneum
52 2181		Self-operating release valve (steam trap)	61		Valve 2/2 Manual/Spring			
53 X2212		Adjustable restrictor (valve)						
54 2031		Restrictor						

Fig 21-3 List of symbols (DAAF406507A - 3)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
68		Valve 3/2 Pneum/Spring	77		Electrically driven compressor	84 X8079		Heat exchanger (general), condenser
69		Valve 3/2 Solenoid/Spring	78 2302		Compressor, vacuum pump (general)	85 X2674		Pneumatic-air lubricator
70		Valve 3/2 Lever/Spring	79 2301		Pump, liquid type (general)	86 X8111		Cooling tower, dry with induced draught
71		Valve 3/2 Manual/Spring	80 2401		Hydraulic pump	87 2521		Cooling tower (general) (Deaerator)
72		Turbogenerator	81		Manual hydraulic pump	88 2040		Funnel
73		Turbogenerator with gear transmission	82 X2071		Boiler feedwater vessel with deaerator	89		Trough or drip tray with drain funnel
74		Turbocharger	83 2501		Heating or cooling coil			
75 C0082		Electric motor (general)						
76		Electrically driven pump						

Fig 21-4 List of symbols (DAAF406507A - 4)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
90 517		Flanged dummy cover (Blind flange pair)	99 564		Quick-release coupling element of female type	106		Air vent + flame arrester
91 511		Flanged connection	100 563		Quick-release coupling element of male type	107 2036		Flame arrester
92 518		End cap	101 X411		Hose	108 X322		Pipeline with thermal insulation
93 514		Screwed joint	102 532		Expansion sleeve	109 X8174		Piping, heated or cooled and insulated
94 516		Reducer	103 533		Compensator (Expansion bellows)	110 X2619		High speed centrifuge (separator)
95		Joint with change of pipe dimension, pipe reducer eccentric	104 2038		Siphon	111 X2614		Centrifuge with perforated shell (Centrifugal filter)
96 565		Quick-release coupling element which fits into another coupling element of the same type	105 2039		Vent (outlet to the atmosphere for steam/gas)			
97 567		Quick-release coupling element of female type with automatic closing when decoupled						
98 566		Quick-release coupling element of male type with automatic closing when decoupled						

Fig 21-5 List of symbols (DAAF406507A - 5)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
112 X8116		Liquid filter (general)	121 X8123		Screening device, sieve, strainer, general	128 X2069		Vessel with dished ends and heating / cooling jacket
113 X8117		Liquid filter, bag, candle or cartridge type	122 X8031		Gravity separator, settling chamber	129 2033		Silencer
114		Automatic filter with by-pass filter	123 X2618		Separator, cyclone type	130 2034		Viewing glass
115 X8019		Suction filter	124 X8090		Strainer	131		Receiver, pulse damper
116 X8119		Liquid rotary filter, drum or disc type	125 2073		Pressure vessel with diaphragm for example expansion vessel	132		Indicating measuring instrument D - Pressure - 001 E - Temperature 010 M - Humidity - 002 F - Flow rate - 003
117		Duplex filter	126 2062		Pressure or vacuum vessel	133		Local instrument
118		Candle filter with rotating drum with by-pass	127 301		Tank, vessel			
119 X8122		Gas filter (general)						
120 X8022		Gas filter, bag, candle or cartridge type						

Fig 21-6 List of symbols (DAAF406507A - 6)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
134		Local panel	141 X1032		Automatic operation of valve with two stable positions open and close	148 X2233		Pilot-operated non-return valve, opened by pilot pressure against return spring
135		Signal to control board	142 2006		Bearing	149 X2192		Single-stage pressure-relief valve
136		TI = Temperature indicator TE = Temperature sensor TEZ = Temperature sensor shut-down FI = Pressure indicator PS = Pressure switch PT = Pressure transmitter FSZ = Pressure switch shut-down PDIS = Differential pressure indicator and alarm LS = Level switch OS = Flow switch TSZ = Temperature switch	143 X8080		Rupture disc	150 X2199		Pressure-reducing valve
137 X2122		Overflow safety valve	144 513		Clamped flange coupling	151 X2180		Shuttle valve with OR-function 1
138 X1048		Flow rate indication	145 C0100		Coupling	152 X2180		Shuttle valve with OR-function 2
139 X1056		Recording of flow rate with summation of volume	146 X2231		Spring-loaded non-return valve			
140 X1036		Automatic operation of valve with infinite number of stable positions	147 X2232		Pilot-operated non-return valve, closed by pilot pressure			

Fig 21-7 List of symbols (DAAF406507A - 7)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
153 2113		L-bore in a three-way valve	162 2126		Valve disc or butterfly type	169 X2125		Angled, globe-type, spring-loaded vacuum valve operating when pressure p lower than set value
154 2114		T-bore in a three-way valve	163 X2114		Swing-type non-return valve	170		Angled, globe-type, spring-loaded vacuum valve operating when pressure p higher than set value
155 2104		Four-way valve	164 X2115		Spring-loaded ball-type non-return valve	171 2123		Valve Plug Type
156		four-way valve globe type	165		Spring-loaded globe-type non-return valve	172		Manual operation of Three-way valve
157		four-way valve ball type	166 X2121		Safety valve which opens when pressure p higher than set value			
158		L-bore in a four-way valve	167 X2121		Pipe break valve which closes when flow rate q is higher than set value			
159		T-bore in a four-way valve	168 X2124		Globe type spring-loaded safety valve operating when pressure p higher than set value			
160 2115		Double L-bore in a four-way valve						
161 2127		Piston type; plunger type						

Fig 21-8 List of symbols (DAAF406507A - 8)

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
173		Valve body 2 position 2-3-4 port	182		3-2 Valve 1	189		4-3 Valve open 2
174		Valve body 2 position 5 port	183		3-2 Valve 2	190		4-3 Valve empty 1
175		Valve body 3 position 2-3-4 port	184		4-2 Valve 1	191		4-3 Valve empty 2
176		Valve body 3 position 5 port	185		4-2 Valve 2	192		5-3 Valve open 1
177		Valve body 4 position 2-3-4 port	186		5-2 Valve 1	193		5-3 Valve open 2
178		Valve body 4 position 5 port	187		5-2 Valve 2	194		5-3 Valve empty 1
179		2-2 Valve arrow up	188		4-3 Valve open 1	195		5-3 Valve empty 2
180		2-2 Valve arrow down						
181		2-2 Valve both arrows						

**Fig 21-9 List of symbols (DAAF406507A - 9)**

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
196		2-port closed	205		4-port crossed	212		5-port closed
197		2-port single arrow	206		4-port tandem single arrow	213		5-port arrows same direction
198		2-port double arrow	207		4-port tandem double arrow	214		5-port arrows opposite direction
199		3-port single arrow	208		4-port crossover single arrow	215		5-port crossover arrows same
200		3-port double arrow	209		4-port crossover double arrow	216		5-port crossover opposite arrows
201		3-port crossover single arrow	210		4-port open	217		5-port crossover arrows same up
202		3-port crossover double arrow	211		4-port semi-connected			
203		4-port						
204		4-port closed						

**Fig 21-10 List of symbols (DAAF406507A - 10)**

INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617			INTERNATIONAL STANDARD ISO 10628 and ISO 14617		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
218		Spring for valve	227		Pedal for valve	234		Single acting cylinder with spring (1)
219		Spring for valve variable	228		Electrical actuation for valve	235		Single acting cylinder with spring (2)
220 711		Plunger for valve	229		Electrical actuation for valve variable	236 724		Double acting cylinder
221		Plunger for valve variable	230		Pilot operation for valve			
222		Roller for valve	231		Exhaust port for valve			
223		Roller for valve variable	232 723		Single acting cylinder			
224		Manual override for valve	233		Double ended cylinder			
225		Pull / push button for valve						
226		Lever for valve						

**Fig 21-11 List of symbols (DAAF406507A - 11)**

Wärtsilä specific symbols for P&I diagrams			Wärtsilä specific symbols for P&I diagrams			Wärtsilä specific symbols for P&I diagrams		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
238		Cam profile 1	247		Water tank	254		Bearing upper and lower
239		Flywheel	248		Description arrow for flow in one direction	255		L-engine
240		Gear wheel	249		Description arrow for flow in both directions	256		V-engine
241		Spray nozzle	250		Line jump	257		square heat exchanger
242		Leak collector	251		Arrow for flow	258		Starting air valve for cylinder head
243		Oil sump	252		Starting air distributor	259		External connection
244		Dipstick 1	253		Starting air distributor 2	260		Automatic filter
245		Dipstick 2						
246		Cylinder						

**Fig 21-12 List of symbols (DAAF406507A - 12)**

Wärtsilä specific symbols for P&I diagrams			Wärtsilä specific symbols for P&I diagrams			Wärtsilä specific symbols for P&I diagrams		
POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION	POS Reg. No.	SYMBOL	DESCRIPTION
261		Separator	270		Booster for valve mechanism	277		
262		Separator with filter	271			278		
263		Filtter	272			279		
264		Flexible double wall pipe	273			280		
265		Cartridge valve with spring	274			281		
266		Cartridge valve	275			282		
267		Revision mark	276					
268		PT sensor with gauge valve						
269		Hydraulic wastegate valve						

**Fig 21-13 List of symbols (DAAF406507A - 13)**



Wärtsilä is a global leader in complete lifecycle power solutions for the marine and energy markets. By emphasising technological innovation and total efficiency, Wärtsilä maximises the environmental and economic performance of the vessels and power plants of its customers.

[www.wartsila.com](http://www.wartsila.com)

