WÄRTSILÄ **RT-flex84T-D**

Marine Installation Manual

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This issue of this Marine Installation Manual (MIM) is the fourth edition covering the Wärtsilä 5–9RT-flex84T-D two-stroke marine diesel engines.

This manual covers the Wärtsilä RT-flex84T-D engines with the following MCR:

– Power per cylinder	4200 kW	5715 bhp
– Speed	76 rpm	
– Mean effective pressure at R1	19.0 bar	

- All data are related to engines compliant with **IMO-2000 regulations Tier II.**
- The engine performance data (BSFC, BSEF and tEaT) and other data can be obtained from the winGTD-program, which can be downloaded from our Licensee Portal.
- The engine performance data (rating R1) refer to **winGTD version 3.1.2**
- This Marine Installation Manual is complete within itself, no additional documentation is necessary.

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Abbreviations

ALM	Alarm
AMS	Attended machinery space
BFO	Bunker fuel oil
BN	Base Number
BSEF	Brake specific exhaust gas flow
BSFC	Brake specific fuel consumption
CCAI	Calculated Carbon Aromaticity Index
CCR	Conradson carbon
CCW	Cylinder cooling water
CMCR	Contract maximum continuous rating (Rx)
CO	Cost-optimised
CPP	Controllable pitch propeller
CSR	Continuous service rating (NOR, NCR)
cSt	centi-Stoke (kinematic viscosity)
DAH	Differential pressure alarm, high
DENIS	Diesel engine control and optimizing specification
EM	Engine margin
EO	Efficiency-optimised
FCM	Flex control module
FPP	Fixed pitch propeller
FQS	Fuel quality setting
FW	Fresh water
GEA	Scavenge air cooler (GEA manufacture)
HFO	Heavy fuel oil
HT	High temperature
IMO	International Maritime Organisation
IND	Indication
IPDLC	Integrated power-dependent liner cooling
ISO	International Standard Organisation
kW	Kilowatt
kWe	Kilowatt electrical
kWh	Kilowatt hour
LAH	Level alarm, high
LAL	Level alarm, low
LCV	Lower calorific value
LI	Level indicator
LR	Light running margin
LSL	Level switch, low
LT	Low temperature
LLT	Low-Load Tuning
M	Torque
MAPEX	Monitoring and maintenance performance enhancement with expert knowledge
M_{1H}	External moment 1st order horizontal
M_{1V}	External moment 1st order vertical
M_{2V}	External moment 2nd order vertical
MCR	Maximum continuous rating (R1)
MDO	Marine diesel oil
mep	Mean effective pressure
MHI	Mitsubishi Heavy Industries
MIM	Marine installation manual
MMI	Man–machine interface
N, n	Speed of rotation
NAS	National Aerospace Standard
NCR	Nominal continuous rating
NOR	Nominal operation rating
OM	Operational margin
OPI	Operator interface
P	Power
PAL	Pressure alarm, low
PI	Pressure indicator
PLS	Pulse Lubricating System (cylinder liner)
ppm	Parts per million
PRU	Power related unbalance
PTO	Power take off
RCS	Remote control system
RW1	Redwood seconds No. 1 (kinematic viscosity)
SAC	Scavenge air cooler
SAE	Society of Automotive Engineers
S/G	Shaft generator
SHD	Shut down
SIB	Shipyard interface box
SLD	Slow down
SM	Sea margin
SSU	Saybolt second universal
SU	Supply unit
SW	Sea-water
TBO	Time between overhauls
TC	Turbocharger
TI	Temperature indicator
tEaT	Temperature of exhaust gas after turbine
UMS	Unattended machinery space
VI	Viscosity index
WCH	Wärtsilä Switzerland
WECS	Wärtsilä Engine Control System
WHR	Waste heat recovery
winGTD	General Technical Data program
ΔM	Torque variation

A. Introduction

The **Wärtsilä RT-flex system** represents a major step forward in the technology of large diesel engines:
Common rail injection – fully suitable for heavy fuel oil operation.

The **M**arine **I**nstallation **M**anual (MIM) is for use by project and design personnel. Each chapter contains detailed information required by design engineers and naval architects enabling them to optimize plant items and machinery space, and to carry out installation design work.
This book is only distributed to persons dealing with this engine.

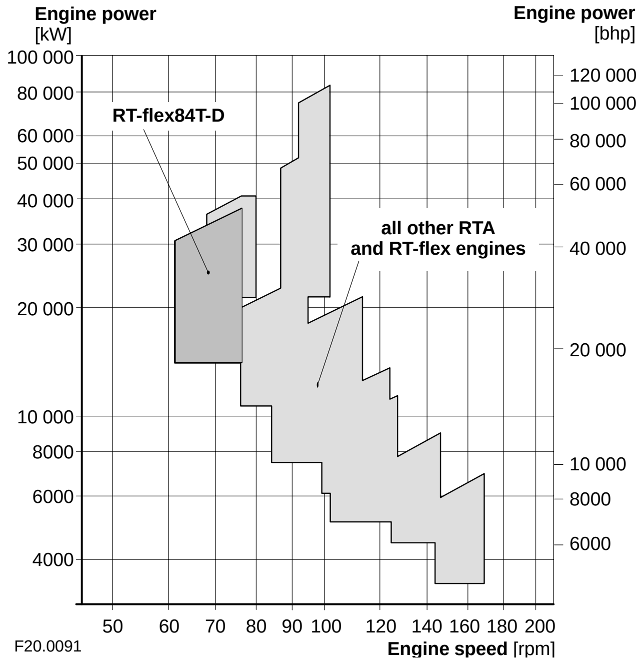

Fig. A1 Power/speed range of all IMO-2000 regulation compatible RTA and RT-flex engines

This manual provides the information required for the layout of marine propulsion plants. It is not to be considered as a specification. The build specification is subject to the laws of the legislative body of the country of registration and the rules of the classification society selected by the owners.
Its content is subject to the understanding that any data and information herein have been prepared with care and to the best of our knowledge. We do not, however, assume any liability with regard to unforeseen variations in accuracy thereof or for any consequences arising therefrom.

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A1 Primary engine data

Engine		Wärtsilä RT-flex84T-D			
Bore x stroke [mm]		**840 x 3150**			
Speed [rpm]		**76**	**76**	**61**	**61**
Engine power (MCR)					
Cylinder	**Power**	**R1**	**R2**	**R3**	**R4**
5	[kW] *[bhp]*	21 000 *28 575*	14 700 *20 000*	16 850 *22 900*	14 700 *20 000*
6	[kW] *[bhp]*	25 200 *34 290*	17 640 *24 000*	20 220 *27 480*	17 640 *24 000*
7	[kW] *[bhp]*	29 400 *40 005*	20 580 *28 000*	23 590 *32 060*	20 580 *28 000*
8	[kW] *[bhp]*	33 600 *45 720*	23 520 *32 000*	26 960 *36 640*	23 520 *32 000*
9	[kW] *[bhp]*	37 800 *51 435*	26 460 *36 000*	30 330 *41 220*	26 460 *36 000*
Brake specific fuel consumption (BSFC)					
100 %	[g/kWh]	171	165	171	167
mep	[bar]	19.0	13.3	19.0	16.6
Lubricating oil consumption (for fully run-in engines under normal operating conditions)					
System oil		approximately 9 kg/cyl per day			
Cylinder oil *1)	Pulse Lubricating System (PLS)	guide feed rate 0.7 g/kWh			
	Conventional cyl. lub. system *2)	0.9 – 1.3 g/kWh			

Remark: *1) Data for guidance only, it may have to be increased as the actual cylinder lubricating oil consumption in service is dependent on operational factors.
*2) Conventional lub. oil system (CLU-3) is available as an option.

Table A1 Primary engine data of Wärtsilä RT-flex84T-D

All brake specific fuel consumptions (BSFC) are quoted for fuel of lower calorific value 42.7 MJ/kg (10200 kcal/kg). All other reference conditions refer to ISO standard (ISO 3046-1). The figures for BSFC are given with a tolerance of +5 %.

The values of power in **kilowatt** (kW) and fuel consumption in **g/kWh** are the **standard** figures, and discrepancies occur between these and the corresponding brake horsepower (bhp) values owing to the rounding of numbers.

To determine the power and BSFC figures accurately in bhp and g/bhph respectively, the standard kW-based figures have to be converted by factor 1.36.

A2 Tuning options

With the introduction of the Wärtsilä RT-flex engines, a major step in the development of marine 2-stroke engine was taken. After the successful introduction of Delta Tuning, Wärtsilä Switzerland Ltd is taking this development even further by introducing Low-Load Tuning.

A2.1 Delta Tuning

Delta Tuning makes it possible to further reduce the specific fuel oil consumption while still complying with all existing emission legislation. Moreover, this is achieved only by changing software parameters and without having to modify a single engine part. Delta Tuning option needs to be specified at a very early stage in the project.

In realising Delta Tuning, the flexibility of the RT-flex system in terms of free selection of injection and exhaust valve control parameters, specifically variable injection timing (VIT) and variable exhaust closing (VEC) is utilised for reducing the brake specific fuel consumption (BSFC) in the part load range below 90 % load.

Due to the trade-off between BSFC and NO_x emissions, the associated increase in NO_x emissions at part load must then be compensated by a corresponding decrease in the full load NO_x emissions. Hence, there is also a slight increase in full load BSFC, in order to maintain compliance of the engine with the IMO NO_x regulations.

The concept is based on tailoring the firing pressure and firing ratio for maximum efficiency in the range up to 90 % load and then reducing them again towards full load. In this process, the same design-related limitations with respect to these two quantities are applied as in the specification of the Standard Tuning.

The reliability of the engine is by no means impaired by the application of Delta Tuning since all existing limitations to mechanical stresses and thermal load are observed.

A2.2 Low-Load Tuning (LLT)

The complete flexibility in engine setting that is an integral feature of the RT-flex common-rail system, enables fuel injection pressures and timing to be freely set at all loads. It is employed in special tuning regimes to optimize brake specific fuel consumption (BSFC) at individual engine loads.

This concept was first applied in Delta Tuning, which reduced BSFC for Wärtsilä RT-flex engines in the operating range below 90 % engine load. The concept has now been extended to Low-Load Tuning, which provides the lowest possible BSFC in the operating range of 40 to 70 % engine load. With Low-Load Tuning, RT-flex engines can be operated continuously and reliably at any load in the range of 30 to 100 %.

The Low-Load Tuning concept is based on the combination of a specifically designed turbocharging system setup and appropriately adjusted engine parameters related to fuel injection and exhaust valve control.

The reduced part-load BSFC in Low-Load Tuning is achieved by optimizing the turbocharger match for part-load operation. This is done by increasing the combustion pressure at less than 75 % load through an increased scavenge air pressure and a higher air flow (waste gate closed), and by blowing off part of the exhaust gas flow (waste gate open) at engine loads above 85 %.
The higher scavenge air pressure at part-load automatically results in lower thermal load and better combustion over the entire part-load range.

Low-Load Tuning requires the fitting of an exhaust gas waste gate (a pneumatically-operated valve, see figure A2) on the exhaust gas receiver before the turbocharger turbine. Exhaust gas blown off through the waste gate is by-passed to the main exhaust uptake. The waste gate is opened at engine loads above 85 % to protect the turbocharger and the engine from overload.

A Wärtsilä RT-flex engine with Low-Load Tuning complies with the IMO Tier II regulations for NOx emissions.

The engine parameters controlling the fuel injection and exhaust valve operational characteristic have to be selected appropriately in order to allow realizing the full potential of the concept while ensuring compliance with the applicable NO_x limit value. On the one hand, these parameters have to be specified in such a way that the transition between the bypass-closed and bypass-opened operating ranges can be realized as smooth as possible. On the other hand, higher scavenge air pressure trendwise increases NO_x emissions also need to be adjusted appropriately for compensating this increase.

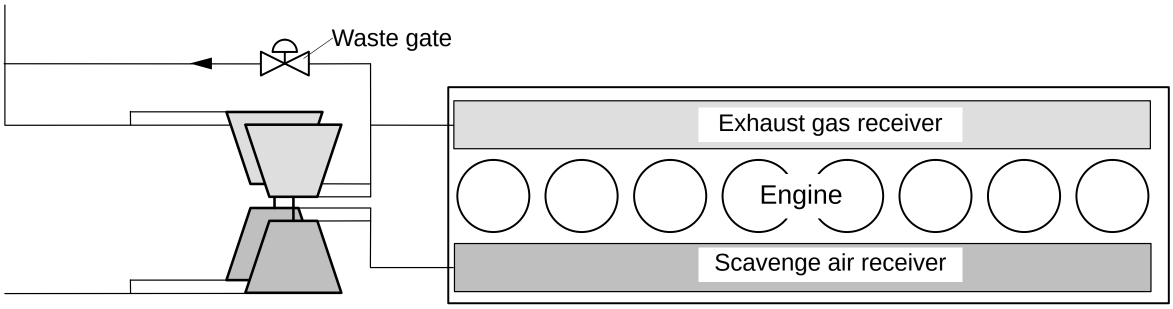


Fig. A2 Schematic functional principle of Low-Load Tuning

A2.3 Further aspects of engine tuning options

Tuning for de-rated engines:

For various reasons, the margin against the IMO NO_x limit decreases for de-rated engines. Delta Tuning and Low-load Tuning thus holds the highest benefits for engines rated close to R1. With the de-rating, the effect diminishes and, in fact, Delta Tuning and Low-load Tuning are not applicable in the entire field (see figure A3).

Effect on engine dynamics:

The application of Delta Tuning or Low-Load Tuning have an influence on the harmonic gas excitations and, as a consequence, the torsional and axial vibrations of the installation. Hence, the corresponding calculations have to be carried out with the correct data in order to be able to apply appropriate countermeasures, if necessary.

Project specification for RT-flex engines:

Although Delta Tuning is realised in such a way that it could almost be considered a pushbutton option, its selection as well as the selection of LLT have an effect on other aspects of engine and system design as well.
Therefore the tuning option to be applied to RT-flex engines needs to be specified at a very early stage in the project:

– The calculations of the torsional and axial vibrations of the installation have to be performed using the correct data.

– The layout of the ancillary systems has to be based on the correct specifications.

– In order to prepare the software for the RT-flex system control, the parameters also have to be known in due time before commissioning of the engine.

A. Introduction

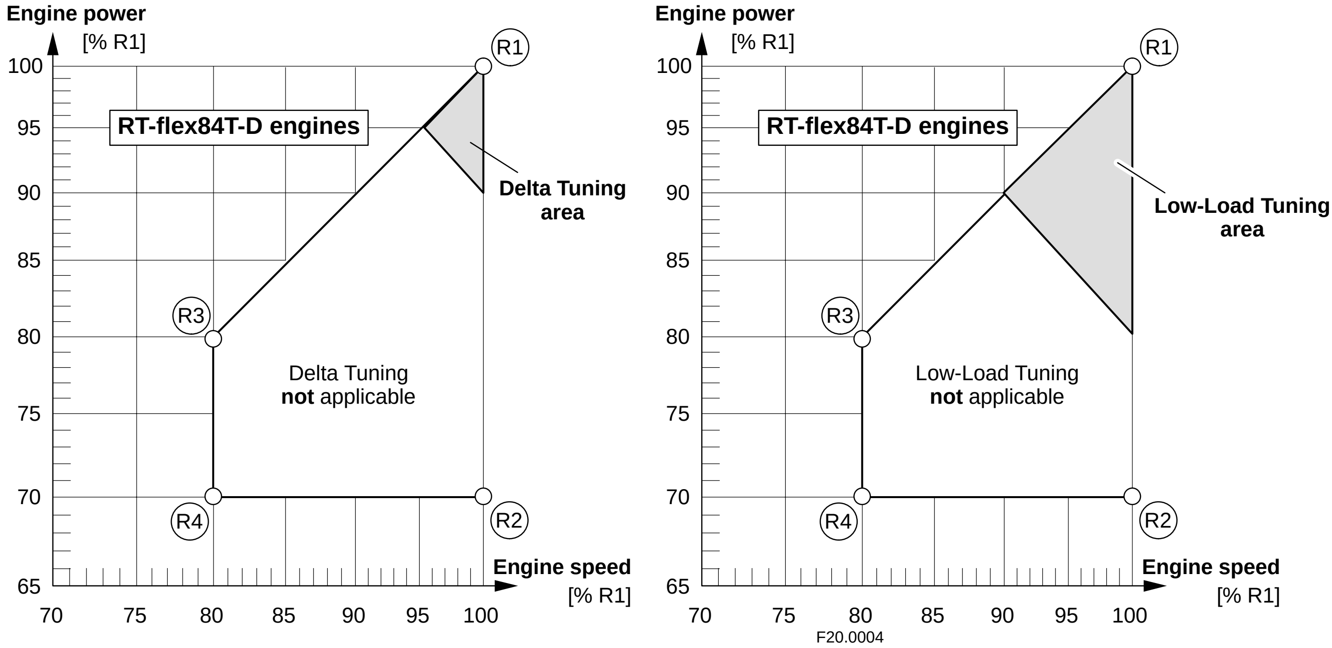


Fig. A3 Layout fields for Delta Tuning and Low-Load Tuning

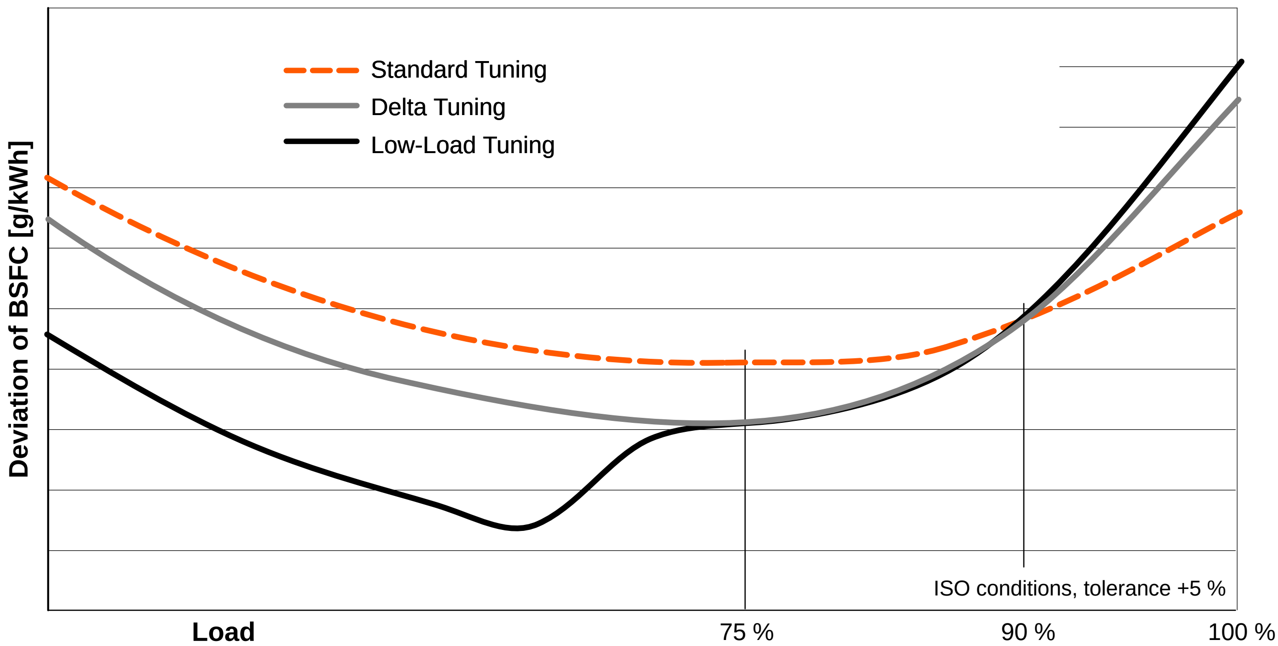


Fig. A4 BSFC deviation for Delta Tuning and Low-Load Tuning compared with Standard Tuning

Data for brake specific fuel consumption (BSFC) in table A1 and data in table F1 refer to Standard Tuning. Data for Delta Tuning and Low-Load Tuning can be obtained from the winGTD (see figure C10).

B. Engine description

B1 Engine description

The **Wärtsilä RT-flex84T-D** engine is a camshaft-less low-speed, direct-reversible, two-stroke engine, fully electronically controlled.
The Wärtsilä RT-flex84T-D is designed for running on a wide range of fuels from **m**arine **d**iesel **o**il (MDO) to **h**eavy **f**uel **o**ils (HFO) of different qualities.

Main features:

Bore	840 mm
Stroke	3150 mm
Number of cylinders	5 to 9

Main parameters (R1):

Power (MCR)	4200 kW/cyl
Speed (MCR)	76 rpm
Mean effect. press.	19 bar
Mean piston speed	8.0 m/s

The Wärtsilä RT-flex84T-D is available with 5 to 9 cylinders rated at 4200 kW/cyl to provide a maximum output of 37 800 kW for the 9-cylinder engine (primary engine data on table A1).

Overall sizes of engines	5 cyl.	9 cyl.
Length [m]	9.70	16.70
Height [m]	13.65	13.65
Dry weight [t]	740	1260

The design of the Wärtsilä RT-flex84T-D includes the well-proven features of the RTA engines like the bore-cooling principle for the pistons, cylinder liners, cylinder covers and exhaust valve seats.

The RT-flex system (figure B3)

The classic RTA configuration of fuel injection pumps and valve drives with the camshaft and its gear train is replaced by a compact set of supply pumps in the supply unit and the common rail with the integrated electronic **W**ärtsilä **e**ngine **c**ontrol **s**ystem WECS-9520.

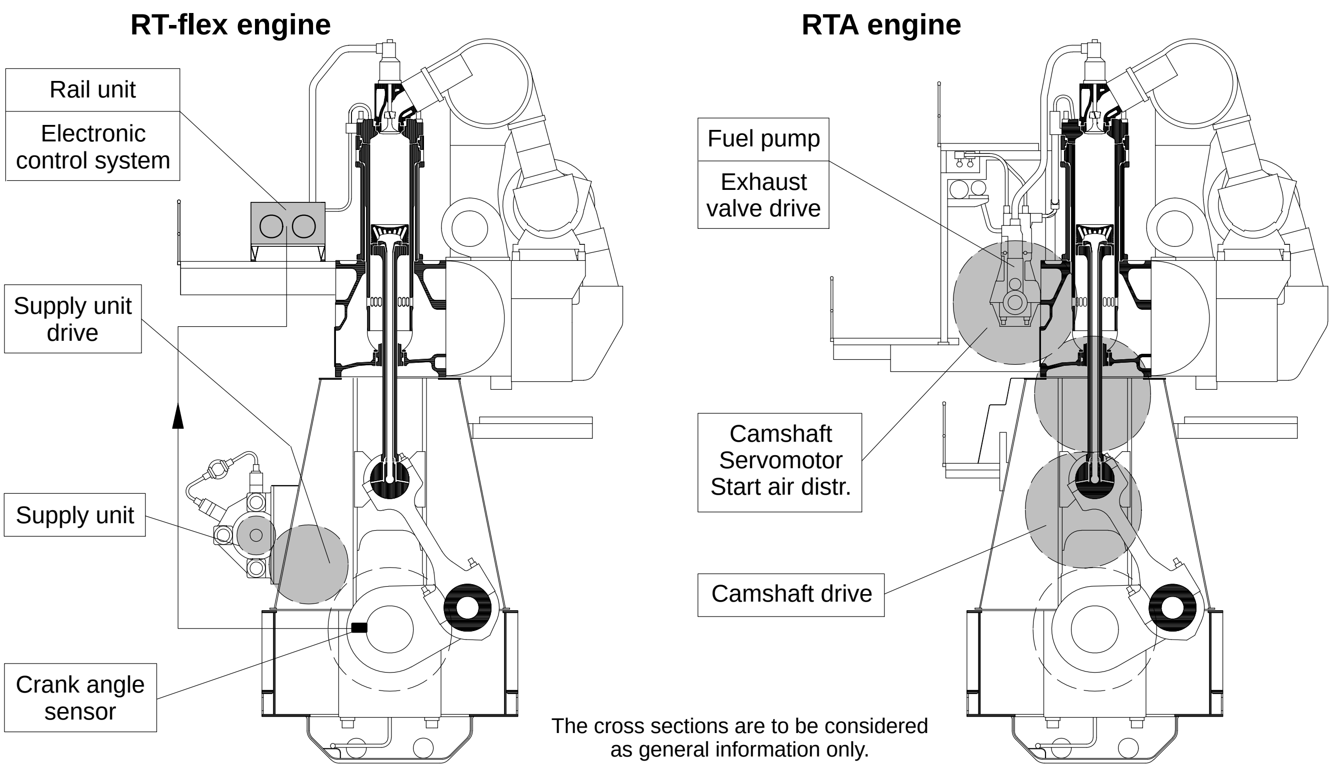


Fig. B1 Comparison of Wärtsilä RTA engines and RT-flex engines.

B. Engine description

All key engine functions like fuel injection, exhaust valve drives, engine starting and cylinder lubrication are fully under electronic control. The timing of the fuel injection, its volumetric and various injection patterns are regulated and controlled by the WECS-9520 control system.

Engine installation and operation

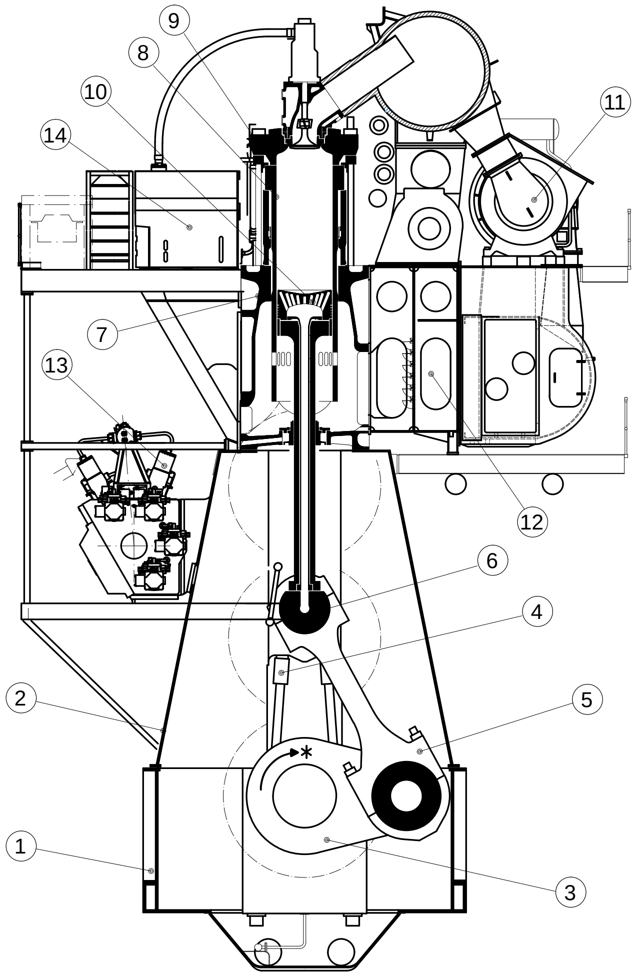
Compared with the RTA engines, the RT-flex has no additional or particular requirements for the engine installation and shipboard operation.
The engine outline dimensions and foundation, the installation, the key engine parameters, the integration into ship automation and other interfaces of the RT-flex are identical with the RTA engines.

The major benefits of the RT-flex system are:

- Adaptation to different operating modes.
- Adaptation to different fuels.
- Delta Tuning, as an optional application, for reduced brake specific fuel consumption (BSFC) in the part-load range below 90 %.
- Another optional application is Low-Load Tuning, which provides the lowest possible BSFC in the operating range of 40 to 70 % engine load.
- Optimised fuel consumption.
- Precise speed regulation, in particular at very slow steaming (adequate lubricating of propeller shaft bearings must be provided).
- Smokeless mode for slow steaming.
- Benefits in terms of operating costs, maintenance requirement and compliance with emissions regulations.
- Slight reduction of engine mass, compared to RTA engines.

Common design features of RTA and RT-flex engines:

1 Welded bedplate with integrated thrust bearings and large surface main bearing shells.



* Direction of rotation: clockwise as standard (viewed from the propeller towards the engine).

This cross section is considered as a general information only.

Fig. B2 Cross section of a typical Wärtsilä RT-flex engine

2 Sturdy engine structure with low stresses and high stiffness comprising A-shaped fabricated double-wall columns and cylinder blocks attached to the bedplate by pre-tensioned vertical tie rods.

3 Semi-built crankshaft.

4 Main bearing cap jack bolts for easier assembly and disassembly of white-metalled shell bearings.

5 White-metaled type bottom-end bearings.

6 Crosshead with crosshead pin and single-piece white metal large surface bearings. Elevated pressure hydrostatic lubrication.

7 Single cast-iron jackets bolted together to form a rigid cylinder block.

8 Special grey cast-iron, bore-cooled cylinder liners with load dependent cylinder lubrication and cooling.

9 Solid forged or steel cast, bore-cooled cylinder cover with bolted-on exhaust valve cage containing Nimonic 80A exhaust valve.

10 Oil-cooled pistons with bore-cooled crowns and short piston skirts.

11 Constant-pressure turbocharging system comprising exhaust gas turbochargers and auxiliary blowers for low-load operation. Turbochargers: ABB TPL or Mitsubishi MET.

12 Uniflow scavenging system comprising scavenge air receiver and non-return flaps.

The RT-flex key parts:

13 Supply unit: High-efficiency fuel pumps feeding the 1000 bar fuel manifold.

14 Rail unit (Common rail): Both, common rail injection and exhaust valve actuation are controlled by quick acting solenoid valves (Wärtsilä Rail Valve LP-1).

15 Electronic engine control WECS-9520 for monitoring and controlling the key engine functions.

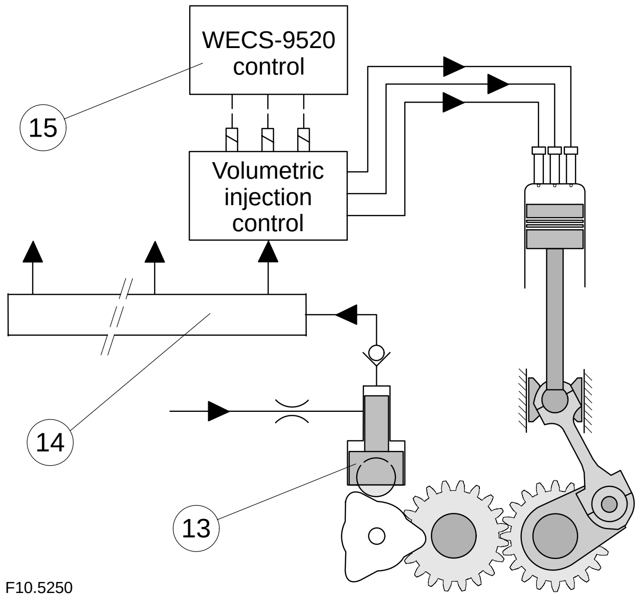


Fig. B3 Wärtsilä RT-flex system comprising supply unit , common rail, electronic engine control system WECS-9520.

B2 Engine numbering and designation

The engine components are numbered from the driving end to the free end as shown in the figure below.

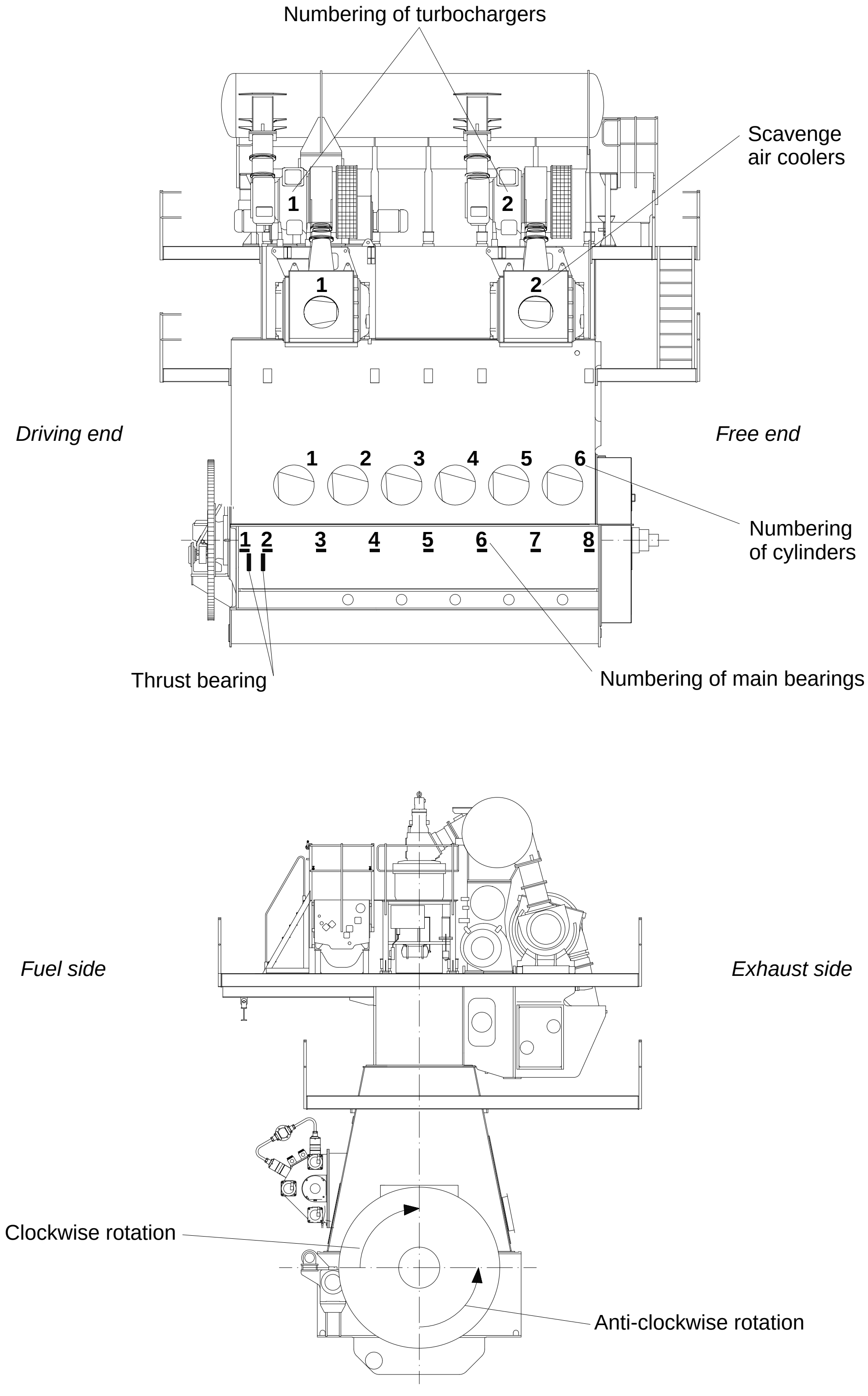


Fig. B4 Engine numbering and designation

C. General engine data

C1 Engine rating field and load range

Selecting a suitable main engine to meet the power demands of a given project involves proper tuning in respect of load range and influence of operating conditions which are likely to prevail throughout the entire life of the ship. This chapter explains the main principles in selecting a Wärtsilä 2-stroke marine diesel engine.

Every engine has a rating field within which the combination of power and speed (= rating) can be selected. Contrary to the 'rating field', the 'load range' is the admissible area of operation once the CMCR has been determined.

In order to define the required **c**ontract **m**aximum **c**ontinuous **r**ating (CMCR), various parameters need to be considered such as propulsive power, propeller efficiency, operational flexibility, power and speed margins, possibility of a main-engine driven generator, and the ship's trading patterns.

Selecting the most suitable engine is vital to achieving an efficient cost/benefit response to a specific transport requirement.

C1.1 Rating field

The rating field shown in figure C1 is the area of power and engine speed. In this area the contract maximum continuous rating of an engine can be positioned individually to give the desired combination of propulsive power and rotational speed. Engines within this rating field will be tuned for maximum firing pressure and best efficiency. Experience over the last years has shown that engines are ordered with CMCR-points in the upper part of the rating field only.

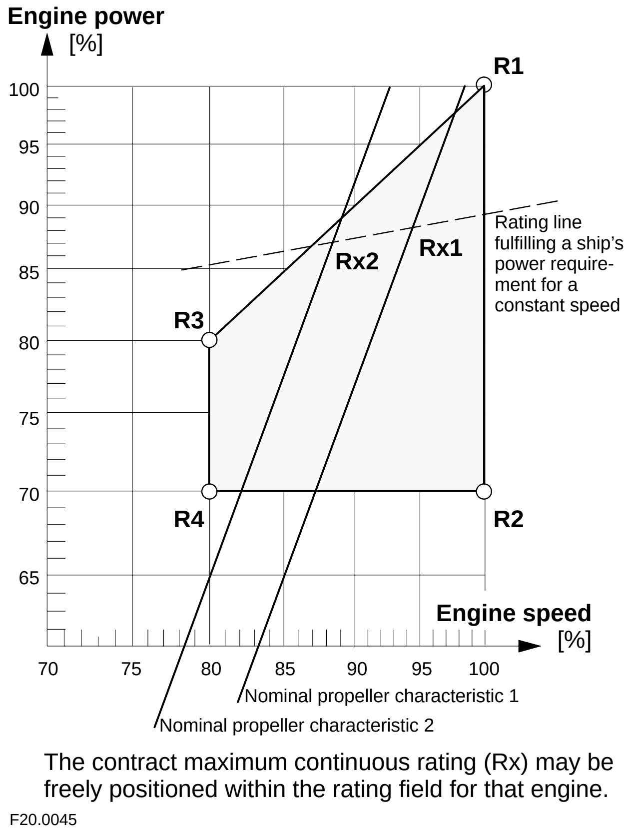


Fig. C1 Rating field of the Wärtsilä RT-flex84T-D engine.

The engine speed is given on the horizontal axis and the engine power on the vertical axis of the rating field. Both are expressed as a percentage (%) of the respective engine's nominal R1 parameters.

Percentage values are being used so that the same diagram can be applied to various engine models. The scales are logarithmic so that exponential curves, such as propeller characteristics (cubic power) and **m**ean **e**ffective **p**ressure (mep) curves (first power), are straight lines.

The rating field serves to determine the specific fuel oil consumption, exhaust gas flow and temperature, fuel injection parameters, turbocharger and scavenge air cooler specifications for a given engine.

Calculations for specific fuel consumption, exhaust gas flow and temperature after turbine are explained in further chapters.

C1.1.1 Rating points R1, R2, R3 and R4

The rating points (R1, R2, R3 and R4) for the Wärtsilä RT-flex engines are the corner points of the engine rating field (figure C1).

The point **R1** represents the nominal **m**aximum **c**ontinuous **r**ating (MCR). It is the maximum power/speed combination which is available for a particular engine.

The point **R2** defines 100 % speed, and 70 % power of R1.

The point **R3** defines 80 % speed and 80 % power of R1.

The connection **R1**–**R3** is the nominal 100 % line of constant mean effective pressure of R1.

The point **R4** defines 80 % speed and 70 % power of R1.

The connection line **R2**–**R4** is the line of 70 % power between 80 and 100 % speed of R1.

Rating points Rx can be selected within the entire rating field to meet the requirements of each particular project. Such rating points require specific engine adaptations.

C1.1.2 Influence of propeller revolutions on the power requirement

At constant ship speed and for a given propeller type, lower propeller revolutions combined with a larger propeller diameter increase the total propulsive efficiency. Less power is needed to propel the vessel at a given speed.

The relative change of required power in function of the propeller revolutions can be approximated by the following relation:

$$Px_2/Px_1 = (N_2/N_1)^{\alpha}$$

Px_j = Propulsive power at propeller revolution N_j.
N_j = Propeller speed corresponding with propulsive power Px_j.
α = 0.15 for tankers and general cargo ships up to 10 000 dwt.
= 0.20 for tankers, bulkcarriers from 10 000 dwt to 30 000 dwt.
= 0.25 for tankers, bulkcarriers larger than 30 000 dwt.
= 0.17 for reefers and container ships up to 3000 TEU.
= 0.22 for container ships larger than 3000 TEU.

This relation is used in the engine selection procedure to compare different engine alternatives and to select optimum propeller revolutions within the selected engine rating field.

Usually, the selected propeller revolution depends on the maximum permissible propeller diameter. The maximum propeller diameter is often determined by operational requirements such as:
- Design draught and ballast draught limitations.
- Class recommendations concerning propeller/hull clearance (pressure impulse induced by the propeller on the hull).

The selection of main engine in combination with the optimum propeller (efficiency) is an iterative procedure where also commercial considerations (engine and propeller prices) play a great role.

According to the above approximation, when a required power/speed combination is known – for example point Rx1 as shown in figure C1 – a CMCR-line can be drawn which fulfils the ship's power requirement for a constant speed. The slope of this line depends on the ship's characteristics (coefficient α). Any other point on this line represents a new power/speed combination, for example Rx2, and requires a specific propeller adaptation.

C1.2 Load range

The load range diagram shown in figure C2 defines the power/speed limits for the operation of the engine. Percentage values are given as explained in section C1.1.1, in practice absolute figures might be used for a specific installation project.

C1.2.1 Propeller curves

In order to establish the proper location of propeller curves, it is necessary to know the ship's speed to power response.

The propeller curve without sea margin is for a ship with a new and clean hull in calm water and weather, often referred to as 'trial condition'.

The propeller curves can be determined by using full scale trial results of similar ships, algorithms developed by maritime research institutes or model tank results. Furthermore, it is necessary to define the maximum reasonable diameter of the propeller which can be fitted to the ship. With this information and by applying propeller series such as the 'Wageningen', 'SSPA' (Swedish Maritime Research Association), 'MAU' (Modified AU), etc., the power/speed relationships can be established and characteristics developed.

The relation between absorbed power and rotational speed for a fixed-pitch propeller can be approximated by the following cubic relation:

$$P_2/P_1 = \left(N_2/N_1\right)^3$$

in which

P_i = propeller power

N_i = propeller speed

The propeller curve without sea margin is often called the 'light running curve'. The nominal propeller characteristic is a cubic curve through the CMCR-point. (For additional information, refer to section C1.2.4 'light running margin'.)

C1.2.2 Sea trial power

The sea trial power must be specified. Figure C2 shows the sea trial power to be the power required for point 'B' on the propeller curve. Often and alternatively the power required for point 'A' on the propeller curve is referred to as 'sea trial power'.

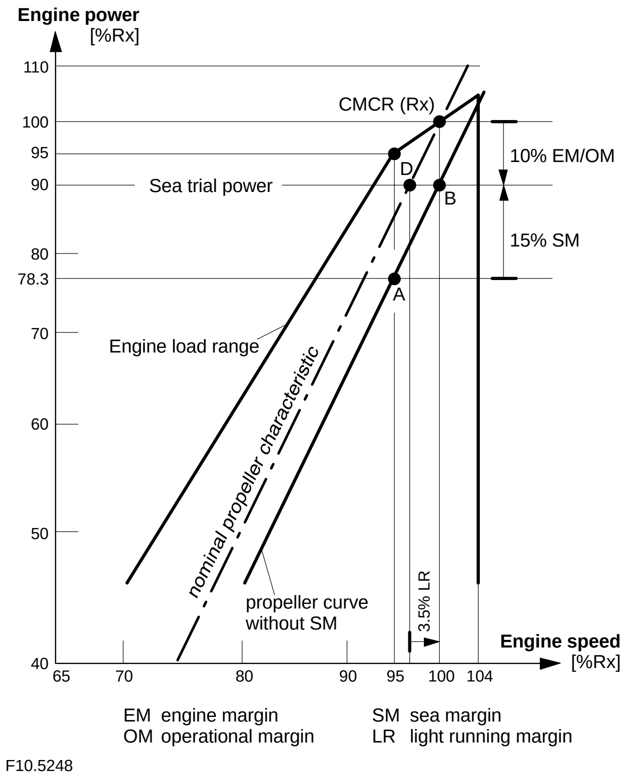


Fig. C2 Load range limits of an engine corresponding to a specific rating point Rx

C1.2.3 Sea margin (SM)

The increase in power to maintain a given ship's speed achieved in calm weather (point '**A**' in figure C2) and under average service condition (point '**D**'), is defined as the 'sea margin'. This margin can vary depending on owner's and charterer's expectations, routes, season and schedules of the ship. The location of the reference point '**A**' and the magnitude of the sea margin are determined between the shipbuilder and the owner. They form part of the newbuilding contract.

With the help of effective antifouling paints, drydocking intervals have been prolonged up to 4 or 5 years. Therefore, it is still realistic to provide an average sea margin of about 15 % of the sea trial power, refer to figure C2, unless as mentioned above, the actual ship type and service route dictate otherwise.

C1.2.4 Light running margin (LR)

The sea trial performance (curve '**a**') in figure C3 should allow for a 4 to 7 % light running of the propeller when compared to the nominal propeller characteristic (the example in figure C3 shows a light running margin of 5 %). This margin provides a sufficient torque reserve whenever full power must be attained under unfavourable conditions. Normally, the propeller is hydrodynamically optimized for a point '**B**'. The trial speed found for '**A**' is equal to the service speed at '**D**' stipulated in the contract at 90 % of CMCR.

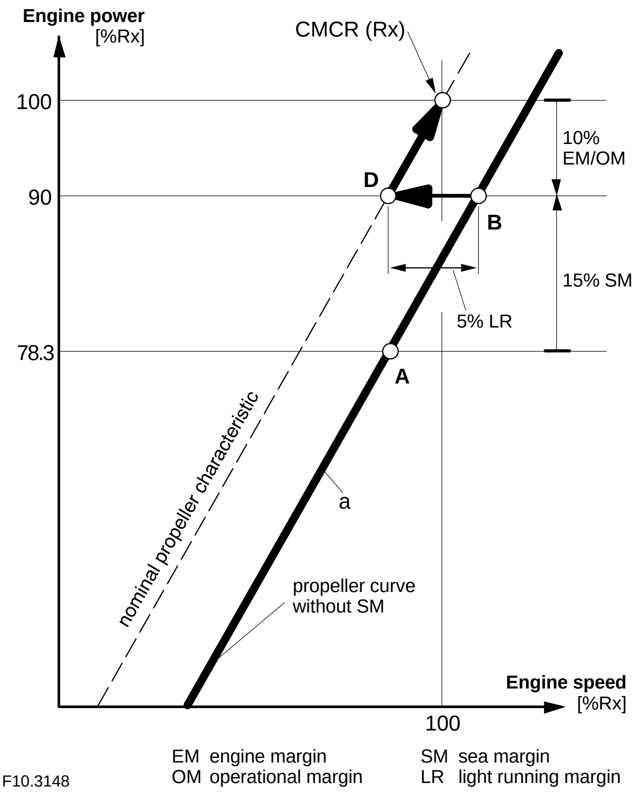


Fig. C3 Load diagram for a specific engine showing the corresponding power and speed margins

The recommended light running margin originates from past experience. It varies with specific ship designs, speeds, drydocking intervals, and trade routes.

Please note: it is the shipbuilder's responsibility to determine the light running margin large enough so that, at all service conditions, the load range limits on the left side of nominal propeller characteristic line are not reached (see section C1.2.6 and figure C4).

Assuming, for example, the following:

- Drydocking intervals of the ship 5 years.
- Time between overhauls of the engine 2 years or more.
- Full service speed must be attainable, without surpassing the torque limit, under less favourable conditions and without exceeding 100 % mep.

Therefore the 'light running margin' required will be 5 to 6 %. This is the sum of the following factors:

1. **1.5–2 %** influence of wind and weather with an adverse effect on the intake water flow of the propeller. Difference between Beaufort 2 sea trial condition and Beaufort 4–5 average service condition. For vessels with a pronounced wind sensitivity, i.e. containerships or car carriers this value will be exceeded.
2. **1.5**–**2 %** increase of ship's resistance and mean effective wake brought about by:
   - Rippling of hull (frame to frame).
   - Fouling of local, damaged areas, i.e. boot top and bottom of the hull.
   - Formation of roughness under paint.
   - Influence on wake formation due to small changes in trim and immersion of bulbous bow, particularly in the ballast condition.
3. **1 %** frictional losses due to increase of propeller blade roughness and consequent drop in efficiency, e.g. aluminium bronze propellers:
   - New: surface roughness = 12 microns.
   - Aged: rough surface but no fouling = 40 microns.

4. **1 %** deterioration in engine efficiency such as:
   - Fouling of scavenge air coolers.
   - Fouling of turbochargers.
   - Condition of piston rings.
   - Fuel injection system (condition and/or timing).
   - Increase of back pressure due to fouling of the exhaust gas boiler, etc.

C1.2.5 Engine margin (EM) or operational margin (OM)

Most owners specify the contractual ship's loaded service speed at 85 to 90 % of the contract maximum continuous rating. The remaining 10 to 15 % power can then be utilized to catch up with delays in schedule or for the timing of drydocking intervals. This margin is usually deducted from the CMCR. Therefore, the 100 % power line is found by dividing the power at point '**D**' by 0.85 to 0.90. The graphic approach to find the level of CMCR is illustrated in figures C2 and C3.

In the examples two current methods are shown. Figure C2 presents the method of fixing point '**B**' and CMCR at 100 % speed thus obtaining automatically a light running margin **B**–**D** of 3.5 per cent. Figures C3 and C5 show the method of plotting the light running margin from point '**B**' to point '**D**' or '**D**′' (in our example 5 %) and then along the nominal propeller characteristic to obtain the CMCR-point. In the examples, the engine power at point '**B**' was chosen to be at 90 % and 85 % respectively.

C1.2.5.1 Continuous service rating (CSR=NOR=NCR)

Point '**A**' represents power and speed of a ship operating at contractual speed in calm seas with a new clean hull and propeller. On the other hand, the same ship at the same speed requires a power/speed combination according to point '**D**', shown in figure C4, under service condition with aged hull and average weather. '**D**' is then the CSR-point.

C1.2.5.2 Contract maximum continuous rating (CMCR = Rx)

By dividing, in our example, the CSR (point D) by 0.90, the 100 % power level is obtained and an operational margin of 10 % is provided (see figure C4). The found point Rx, also designated as CMCR, can be selected freely within the rating field defined by the four corner points R1, R2, R3 and R4 (see figure C1).

C1.2.6 Load range limits

Once an engine is optimized at CMCR (Rx), the working range of the engine is limited by the following border lines, refer to figure C4:

Line ① is a constant mep or torque line through CMCR from 100 % speed and power down to 95 % power and speed.

Line ② is the **overload limit.** It is a constant mep line reaching from 100 % power and 93.8 % speed to 110 % power and 103.2 % speed. The latter one is the point of intersection between the nominal propeller characteristic and 110 % power.

Line (3) is the 104 % speed limit where an engine can run continuously. For Rx with reduced speed ($N_{CMCR} \le 0.98\ N_{MCR}$) this limit can be extended to 106 %, however, the specified torsional vibration limits must not be exceeded.

Line (4) is the **overspeed limit**. The overspeed range between 104 (106) and 108 % speed is only permissible during sea trials if needed to demonstrate the ship's speed at CMCR power with a light running propeller in the presence of authorized representatives of the engine builder. However, the specified torsional vibration limits must not be exceeded.

Line (5) represents the admissible torque limit and reaches from 95 % power and speed to 45 % power and 70 speed. This represents a curve defined by the equation:

$$P_2/P_1 = (N_2/N_1)^{2.45}$$

When approaching line (5), the engine will increasingly suffer from lack of scavenge air and its consequences. **The area formed by lines (1), (3) and (5) represents the range within which the engine should be operated. The area limited by the nominal propeller characteristic, 100 % power and line (3) is recommended for continuous operation.** The area between the nominal propeller characteristic and line (5) has to be reserved for acceleration, shallow water and normal operational flexibility.

Line (6) is defined by the equation:

$$P_2/P_1 = (N_2/N_1)^{2.45}$$

through 100 % power and 93.8 % speed and is the maximum torque limit in transient conditions.

The area above line (1) is the **overload range**. It is only allowed to operate engines in that range for a maximum duration of one hour during sea trials in the presence of authorized representatives of the engine builder.

The area between lines (5) and (6) and constant torque line (dark area of fig. C4) should only be used for transient conditions, i.e. during fast acceleration. This range is called '**service range with operational time limit**'.

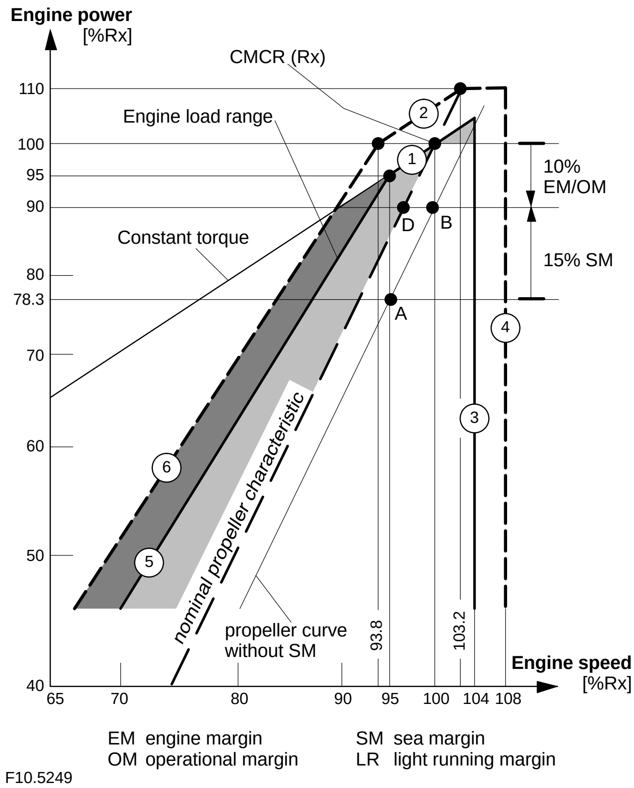


Fig. C4 Load range limits, with the load diagram of an engine corresponding to a specific rating point Rx

C1.2.7 Load range with main-engine driven generator

The load range diagram with main-engine driven generator, whether it is a **s**haft **g**enerator (S/G) mounted on the intermediate shaft or driven through a **p**ower **t**ake **o**ff gear (PTO), is shown by curve '**c**' in figure C5. This curve is not parallel to the propeller characteristic without main-engine driven generator due to the addition of a constant generator power over most of the engine load. In the example of figure C5, the main-engine driven generator is assumed to absorb 5 per cent of the nominal engine power.

The CMCR-point is, of course, selected by taking into account the max. power of the generator.

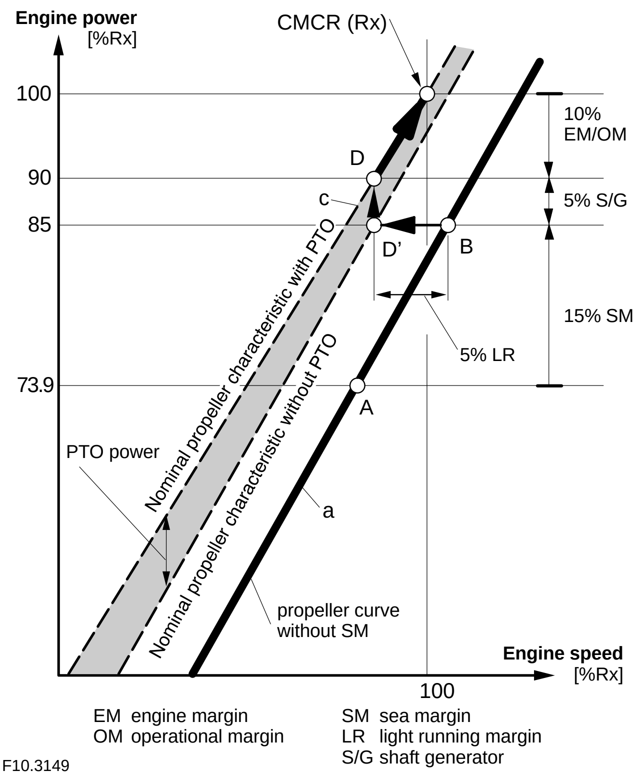


Fig. C5 Load range diagram for an engine equipped with a main-engine driven generator, whether it is a shaft generator or a PTO-driven generator

C2 Engine data

The engine can be operated in the ambient condition range between **reference conditions** and **design (tropical) conditions.**

C2.1 Reference conditions

The engine performance data, like **BSFC, BSEF** and **tEaT** and others are based on **reference conditions**. They are specified in ISO Standard 15550 (core standard) and for marine application in ISO Standard 3046 (satellite standard) as follows:

- Air temperature before blower 25 °C
- Engine room ambient air temp. 25 °C
- Coolant temp. before SAC 25 °C for SW
- Coolant temp. before SAC 29 °C for FW
- Barometric pressure 1000 mbar
- Relative air humidity 30 %

C2.2 Design conditions

The capacities of ancillaries are specified according to ISO Standard 3046-1 (clause 11.4) following the International Association of Classification Societies (IACS) and are defined as design conditions:

- Air temperature before blower 45 °C
- Engine ambient air temp. 45 °C
- Coolant temp. before SAC 32 °C for SW
- Coolant temp. before SAC 36 °C for FW
- Barometric pressure 1000 mbar.
- Relative air humidity 60 %

C2.3 Ancillary system design parameters

The layout of the ancillary systems of the engine bases on the performance of its specified rating point Rx (CMCR). The given design parameters must be considered in the plant design to ensure a proper function of the engine and its ancillary systems.

- Cylinder water outlet temp. 90 °C
- Oil temperature before engine 45 °C
- Exhaust gas back pressure at rated power (Rx) 30 mbar

The engine power is independent from ambient conditions. The cylinder water outlet temperature and the oil temperature before engine are system-internally controlled and have to remain at the specified level.

C2.4 Engine performance data

The calculation of the performance data **BSFC, BSEF** and **tEaT** for any engine power and tuning (e.g. Low-Load Tuning, Delta Tuning) will be done with the help of the **winGTD** program which can be downloaded from our Licensee Portal.

If needed we offer a computerized information service to analyze the engine’s heat balance and determine main system data for any rating point within the engine rating field.
For details of this service please refer to section F1.2.2, ‘Questionnaire for engine data’.
The downlodad of the winGTD program is explained in section C7.1.

C. General engine data

C3 Turbocharger and scavenge air cooler

The selections of turbochargers covering the types ABB TPL, MHI MET are shown in figures C7 and C8. The selection of scavenge air coolers follows the demand of the selected turbochargers.

The data can be calculated directly by the winGTD-program (see section C7.2). Parameters and details of the scavenge air coolers (SAC) are shown in table C1 and figure C6, weights of turbochargers in table C2.

Fresh water: Single-stage scavenge air coolers							
Cooler	Design water flow	Design air flow	design pressure drop		Water content	Insert	
	[kg/s]	[kg/s]	Water [bar]	Air [Pa]	[dm^3]	Dimensions [mm]	Mass [kg]
SAC241	70.8	37.8	1.5	2000	approx. 560	2490x1738x790	3890
SAC247	70.6	55.0	1.5	2500	approx. 680	2809x1738x885	4190

Table C1 Scavenge air cooler parameters

ABB	**Type**	–	TPL80-B11 TPL80-B12	TPL85-B14
	Mass [kg]	–	6010	10520
MHI (Mitsubishi)	**Type**	MET66MA	MET71MA	MET83MA
	Mass [kg]	6250	7120	11100

Table C2 Turbocharger weights

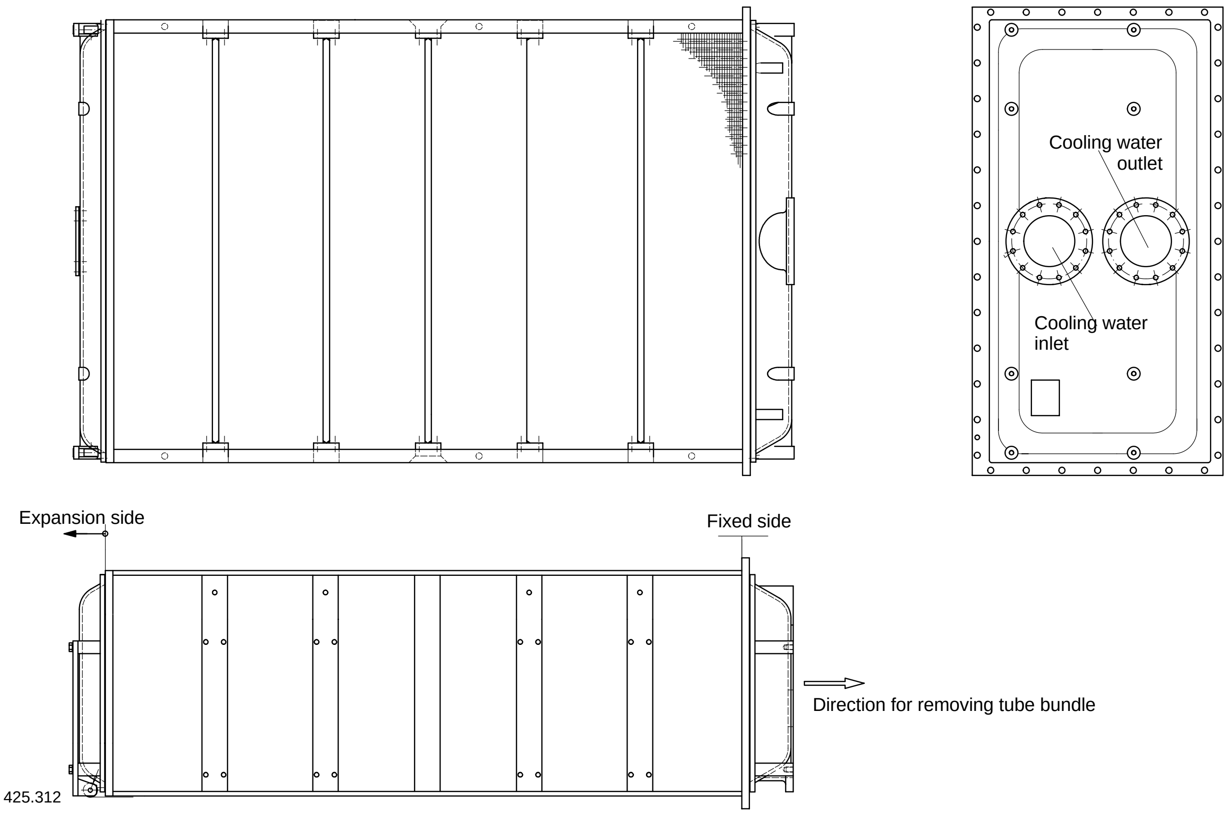


Fig. C6 Scavenge air cooler outline

C3.1 Turbocharger and scavenge air cooler selection

The SAC and TC selection for the engines RT-flex84T-D is given in the layout fields in figures C7 to C8.

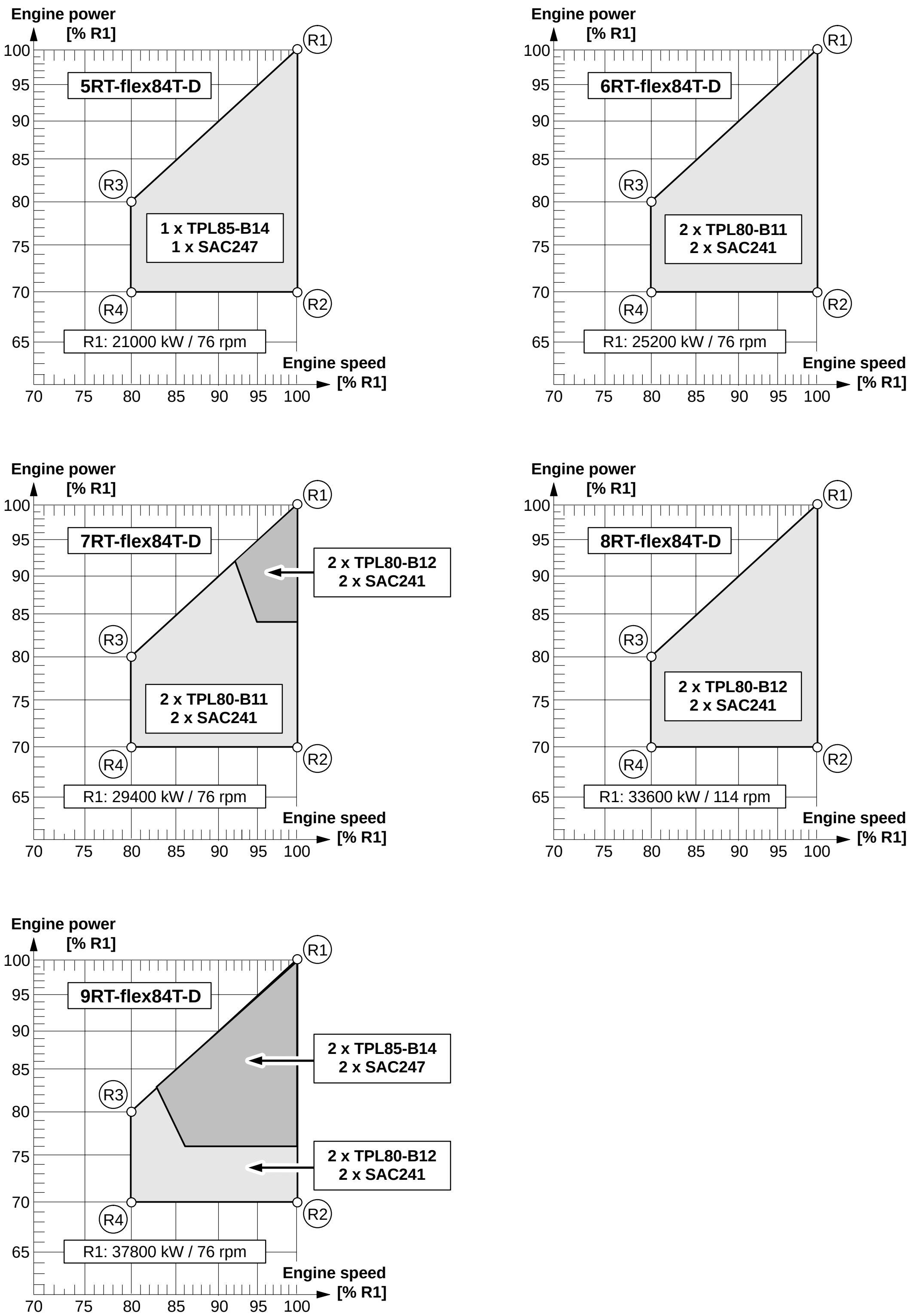


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Fig. C7 Turbocharger and scavenge air cooler selection (**ABB TPL** turbochargers)

C. General engine data

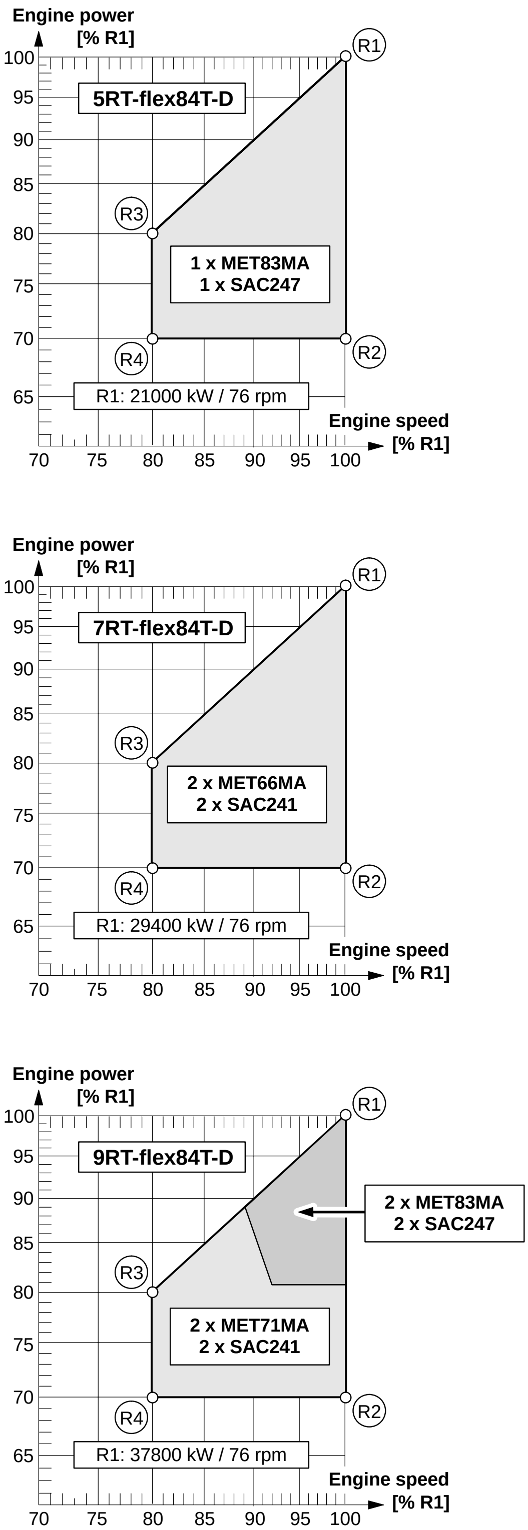

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Fig. C8 Turbocharger and scavenge air cooler selection (**MHI MET** turbochargers)

C4 Auxiliary blower

For manoeuvring and operating at low powers, electrically driven auxiliary blowers must be used to provide sufficient combustion air.
Table C3 shows the number of blowers required.

Number of cylinders	5	6	7	8	9
Number of auxiliary air blowers required	2	2	2	2	2

Table C3 Number of auxiliary blowers per engine

C5 Electrical power requirement of the engine

Electrical power consumers	Supply voltage	Power requirement [kW] referring to numbers of cylinders				
		5	**6**	**7**	**8**	**9**
Auxiliary blowers *1) (estimated values)	440 V / 60 Hz	2 x 63	2 x 80	2 x 99	2 x 99	2 x 124
Turning gear	400 V / 50 Hz / 1000 rpm	9.2			12.5	
	440 V / 60 Hz / 1200 rpm	11			15	
Cylinder lubrication CLU-3 *2)	400/440 V / 50/60 Hz	1.5				
Control oil pumps	400/440 V / 50/60 Hz	2 x 25				
Servo automatic filter *2)	400/440 V / 50/60 Hz	0.1				
WECS power supply, box E85 *2)	230 VAC / 50/60 Hz	1.4	1.6	1.8	2.0	2.2
Propulsion control system	24 V DC UPS	acc. to maker specifications				
Additional monitoring devices (e.g. oil mist detector etc.)	acc. to maker specifications	acc. to maker specifications				

Remark: *1) Minimal installed electric motor power (shaft) is indicated. The *actual* electric power requirement depends on the size, type and voltage/frequency of the installed electric motor. Direct starting or Star-Delta starting to be specified when ordering.
*2) Two redundant power supplies from different feeder panels required; indicated power for each power supply.

Table C4 Electrical power consumers

C6 Pressure and temperature ranges

Table C5 (on the next page) represents a summary of the required pressure and temperature ranges at continuous service rating (CSR). The gauge pressures are measured about **7.5 m** above the crankshaft centre line. The pump delivery head is obtained by adding the pressure losses in the piping system, filters, coolers, valves, etc., and the vertical level pressure difference between pump suction and pressure gauge to the values in the table on the next page.

C. General engine data

Medium	System	Location of measurement	Gauge pressure limit values [bar]		Temperature limit values [°C]		
			Min	Max	Min	Max	Diff
Fresh water	Cylinder cooling	Inlet	4.5	5.5	65	–	max 15
		Outlet each cylinder	–	–	85	95	
	LT circuit (single-stage SAC)	Inlet cooler	2.0	4.0	25	36	* 1)
		Outlet cooler	–	–	–	80	
Lubricating oil (high pressure)	Crosshead bearing oil	Inlet	10.0	12.0	40	50	
Lubricating oil (low pressure)	Servo oil	Servo oil pump inlet	1.7	5.0	–	–	–
	Main bearing oil	Supply	2.7	4.5	40	50	–
		Outlet	–	–	–	–	–
	Piston cooling oil	Inlet	2.7	4.5	40	50	max 30
		Outlet	–	–	–	80	
	Thrust bearing pads	Pads AHEAD	–	–	–	75	–
	Torsional vibration damper (if steel spring damper is used)	Supply	–	–	–	–	–
		Inlet casing	1.0	–	–	–	–
	Integrated axial vibration damper (detuner)	Supply	2.7	4.5	–	–	–
		Damp. chamber	1.7	–	–	–	–
	Turbocharger bearing oil (ABB TPL on engine lub. oil system)	Inlet	1.0	–	–	–	–
		Outlet	–	–	–	110	–
	Turbocharger bearing oil (ABB TPL with separate lub. oil system)	Inlet	1.3	–	–	–	–
		Outlet	–	–	–	120	–
	Turbocharger bearing oil (MHI MET)	Inlet	0.7	–	–	–	–
		Outlet	–	–	–	85	–
Fuel oil	Booster (supply unit)	Inlet	7.0 *2)	10.0 *3)	–	150	–
	After retaining valve (supply unit)	Return	3.0	5.0	–	–	–
Scavenge air	Intake from engine room (pressure drop, max)	Air filter / Silencer	max 10 mbar		–	–	–
	Intake from outside (pressure drop, max)	Ducting and filter	max 20 mbar		–	–	–
	Cooling (pressure drop)	New SAC	max 30 mbar		–	–	–
		Fouled SAC	max 50 mbar		–	–	–
Air	Starting air	Engine inlet	–	25 or 30	–	–	–
	Control air	Engine inlet	6.0	7.5	–	–	–
			normal 6.5				
	Air spring air for exhaust valve	Main distributor	6.0	7.5	–	–	–
			normal 6.5		–	–	–
Exhaust gas	Exhaust gas	After each cylinder	–	–	–	515	Devi-ation ±50 *4)
		Before each TC	–	–	–	515	–
	Manifold after turbocharger	Design maximum	30 mbar		–	–	–
		Fouled maximum	50 mbar		–	–	–

Remark:
*1) The water flow has to be within the prescribed limits.
*2) At 100 % engine power.
*3) At stand-by condition; during commissioning of the fuel oils system the fuel oil pressure is adjusted to 10 bar.
*4) Max deviation of the temperature among the cylinders

Table C5 Pressure and temperature ranges

C7 General Technical Data – winGTD

The purpose of this program is to calculate the heat balance of a Wärtsilä two-stroke diesel engine for a given project. Various cooling circuits can be taken in account, temperatures and flow rates can be manipulated on line for finding the most suitable cooling system.
This software is intended to provide the information required for the project work of marine propulsion plants. Its content is subject to the understanding that any data and information herein have been prepared with care and to the best of our knowledge. We do not, however, assume any liability with regard to unforeseen variations in accuracy thereof or for any consequences arising therefrom.

C7.1 Availability of winGTD

The winGTD is available:

– as download from our Licensee Portal.

C7.1.1 Download from Licensee Portal

1. Open the 'Licensee Portal' and go to: 'Project Tools & Documents' – 'winGTD'.
2. Click the link and follow the instructions.

The amendments and how the current version differs from previous versions are explaineded on the Licensee Portal.
Furthermore this information is contained in the winGTD program itself. Menu:
'Help' – 'version information'.

C7.2 Using winGTD

C7.2.1 Start

After starting winGTD by double-clicking winGTD icon, click on 'Start new Project' button on 'Welcome' screen and specify desired engine type in appearing window (fig. C9):

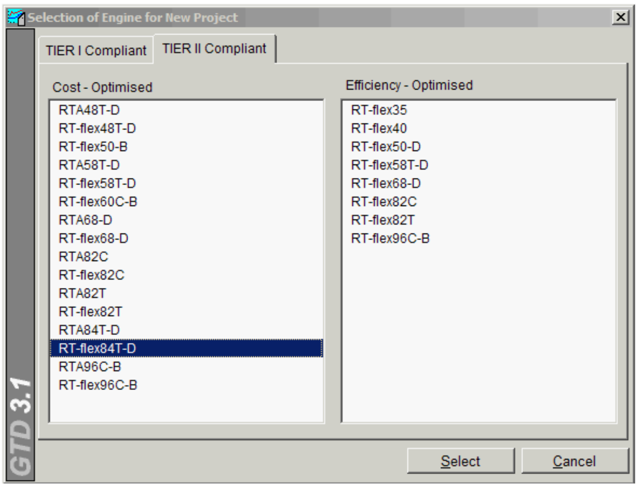


Fig. C9 winGTD: Selection of engine window

Double-click on selected engine type or click the 'Select' button to access the main window (fig. C10).
Select the particular engine according to the number of cylinders (eg. 7RTflex-84T-D).

C7.2.2 Data input

In the main window (fig. C10) enter the desired power and speed to specify the engine rating. The rating point must be within the rating field. The shaft power can either be expressed in units of kW or bhp.

C. General engine data

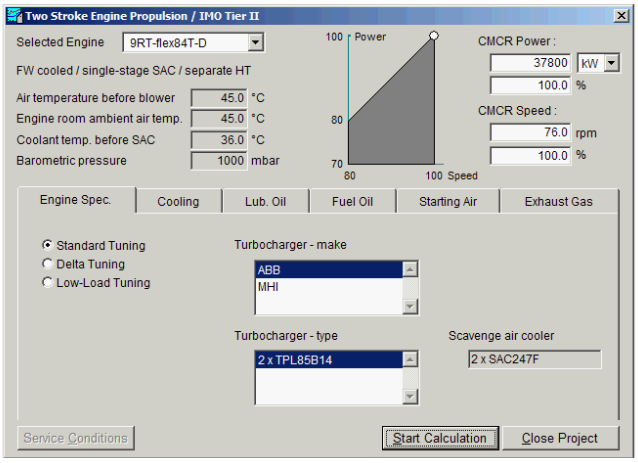


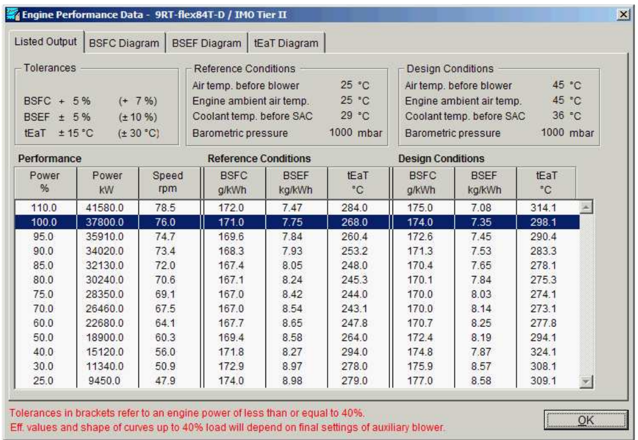
Fig. C10 winGTD: Main window

Further input parameters can be entered in sub-panels to be accessed by clicking on tabs 'Engine Spec.' (eg. for turbocharger selection), 'Cooling', 'Lub. Oil', 'Fuel Oil', 'Starting Air' or 'Exhaust Gas' relating to the relevant ancillary systems.

C7.2.3 Output results

Clicking the 'Start Calculation' button (fig. C10) initiates the calculation with the chosen data to determine the temperatures, flows of lubricating oil and cooling water quantities.
Firstly the 'Engine performance data' window (fig. C11) is displayed on the screen.
To see further results, click the appropriate button in the tool bar or click the 'Show results' menu option in the menu bar.

To print the results click the button or click the button for export to a ASCII file, both in the tool bar.



Performance			Reference Conditions			Design Conditions		
Power %	Power kW	Speed rpm	BSFC g/kWh	BSEF kg/kWh	tEaT °C	BSFC g/kWh	BSEF kg/kWh	tEaT °C
110.0	41580.0	78.5	172.0	7.47	284.0	175.0	7.08	314.1
100.0	37800.0	76.0	171.0	7.75	268.0	174.0	7.35	298.1
95.0	35910.0	74.7	169.6	7.84	260.4	172.6	7.45	290.4
90.0	34020.0	73.4	168.3	7.93	253.2	171.3	7.53	283.3
85.0	32130.0	72.0	167.4	8.05	248.0	170.4	7.65	278.1
80.0	30240.0	70.6	167.1	8.24	245.3	170.1	7.84	275.3
75.0	28350.0	69.1	167.0	8.42	244.0	170.0	8.03	274.1
70.0	26460.0	67.5	167.0	8.54	243.1	170.0	8.14	273.1
60.0	22680.0	64.1	167.7	8.65	247.8	170.7	8.25	277.8
50.0	18900.0	60.3	169.4	8.58	264.0	172.4	8.19	294.1
40.0	15120.0	56.0	171.8	8.27	294.0	174.8	7.87	324.1
30.0	11340.0	50.9	172.9	8.97	278.0	175.9	8.57	308.1
25.0	9450.0	47.9	174.0	8.98	279.0	177.0	8.58	309.1

Fig. C11 winGTD: General technical data

C7.2.4 Service conditions

Click the button 'Service Conditions' in the main window (fig. C10) to access the option window (fig. C12) and enter any ambient condition data deviating from design conditions.

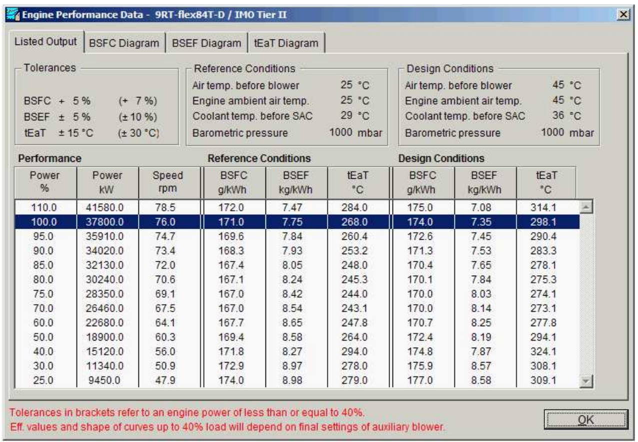


Fig. C12 winGTD: Two-stroke engine propulsion

The calculation is carried out with all the relevant design parameters (pump sizes etc.) of the ancillaries set at design conditions.

C7.2.5 Saving a project

To save all data belonging to your project choose 'Save as...' from the 'File' menu. A windows 'Save as...' dialogue box appears.

Type a project name (winGTD proposes a three-character suffix based on the program you have selected) and choose a directory location for the project.
Once you have specified a project name and selected the desired drive and directory, click the 'Save' button to save your project data.

D. Engine dynamics

D1 Vibration aspects

As a leading designer and licensor we are concerned that satisfactory vibration levels are obtained with our engine installations. The assessment and reduction of vibration is subject to continuing research. Therefore, we have developed extensive computer software, analytical procedures and measuring techniques to deal with this subject.

For successful design, the vibration behaviour needs to be calculated over the whole operating range of the engine and propulsion system. The following vibration types and their causes are to be considered:

- External mass forces and moments.
- Lateral engine vibration.
- Longitudinal engine vibration.
- Torsional vibration of the shafting.
- Axial vibration of the shafting.

D1.1 External forces and moments

In the design of the Wärtsilä RT-flex84T-D engine free mass forces are eliminated and unbalanced external moments of first, second and fourth order are minimized. However, five- and six-cylinder engines generate second order unbalanced vertical moments of a magnitude greater than those encountered with higher numbers of cylinders. Depending on the ship's design, the moments of fourth order have to be considered too.

Under unfavourable conditions, depending on hull structure, type, distribution of cargo and location of the main engine, the unbalanced moments of first, second and fourth order may cause unacceptable vibrations throughout the ship and thus call for countermeasures.

Figure D1 shows the external forces and moments acting on the engine.

External forces and moments due to the reciprocating and rotating masses (see table D1):

F_{1V}: resulting first order vertical force.
F_{1H}: resulting first order horizontal force.
F_{2V}: resulting second order vertical force.
F_{4V}: resulting fourth order vertical force.
M_{1V}: first order vertical mass moment.
M_{1H}: first order horizontal mass moment.
M_{2V}: second order vertical mass moment.
M_{4V}: fourth order vertical mass moment.

All Wärtsilä RT-flex84T-D engines have no free mass forces.

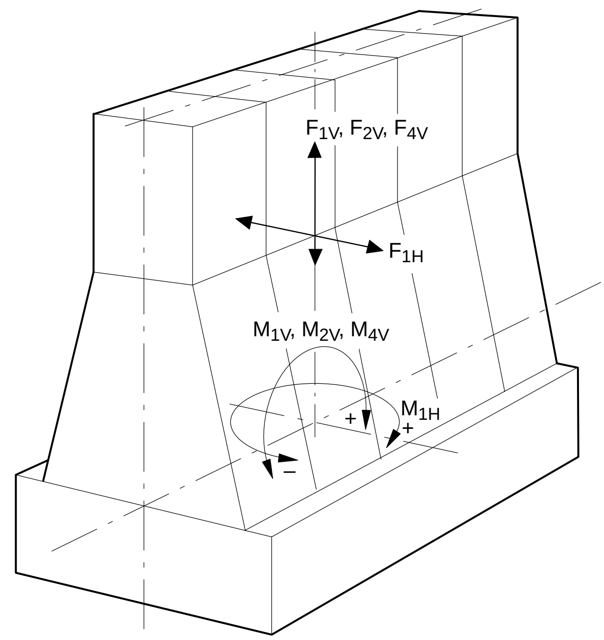


Fig. D1 External forces and moments

D1.1.1 Balancing free first order moments

Standard counterweights fitted to the ends of the crankshaft reduce the first order mass moments to acceptable limits. However, in special cases non-standard counterweights can be used to reduce either M_{1V} or M_{1H}, if needed.

D1.1.2 Balancing free second order moments

The second order vertical moment (M_{2V}) is higher on five- and six-cylinder engines compared with 7–9-cylinder engines; the second order vertical moment being negligible for the 7–9-cylinder engines. Since no engine-fitted 2nd order balancer is available, Wärtsilä Switzerland Ltd. recommends for five- and six-cylinder engines to install an electrically driven compensator on the ship's structure (figure D2) to reduce the effects of the second order moments to acceptable values.

If no experience is available from a sister ship, it is advisable to establish at the design stage, what form the ship's vibration will be. Table D1 assists in determining the effect of installing the Wärtsilä 5RT-flex84T-D and 6RT-flex84T-D engines.

However, when the ship's vibration pattern is not known at the early stage, an external electrically compensator can be installed later, should disturbing vibrations occur; provision should be made for this countermeasure.
Such a compensator is usually installed in the steering compartment, as shown in figure D2. It is tuned to the engine operating speed and controlled accordingly.

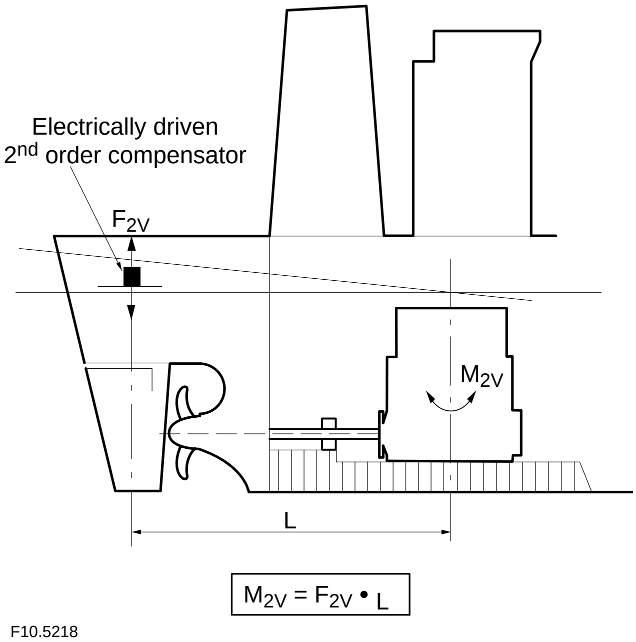


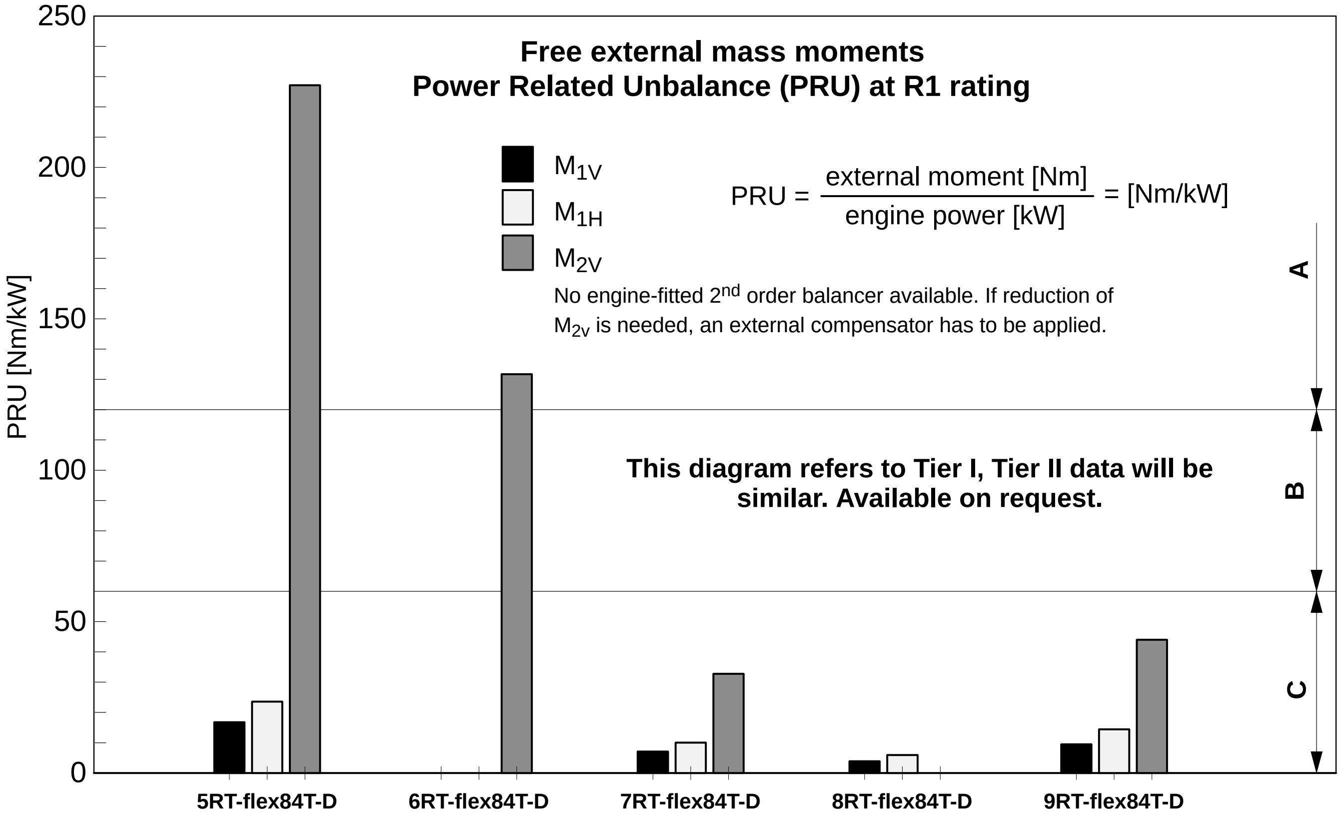
Fig. D2 Locating electrically driven compensator

Suppliers of electrically driven compensators	
Gertsen & Olufsen AS Savsvinget 4 DK-2970 Hørsholm Denmark	 Tel. +45 45 76 36 00 Fax +45 45 76 17 79 www.gertsen-olufsen.dk
Nishishiba Electric Co., Ltd Shin Osaka Iida Bldg. 5th Floor 1-5-33, Nishimiyahara, Yodogawa-ku Osaka 532-0004 Japan	 Tel. +81 6 6397 3461 Tel. +81 6 6397 3475 www.nishishiba.co.jp

D. Engine dynamics

D1.1.3 Power related unbalance (PRU)

The so-called Power Related Unbalance (PRU) values can be used to evaluate if there is a risk that free external mass moments of 1st and 2nd order may cause unacceptable hull vibrations, see figure D3.



A-range: balancing countermeasure is likely needed.
B-range: balancing countermeasure is unlikely needed.
C-range: balancing countermeasure is not relevant.

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Fig. D3 Free external mass moments

The external moments M_1 and M_2 given in table D1 are related to R1 speed. For other engine speeds, the corresponding external moments are calculated with the following formula:

$$M_{Rx} = M_{R1} \quad (n_{Rx}/n_{R1})^2$$

D1.2 Lateral engine vibration (rocking)

The lateral components of the forces acting on the crosshead induce lateral rocking depending on the number of cylinders and firing order. These forces may be transmitted to the engine-room bottom structure. From there hull resonance or local vibrations in the engine room may be excited.

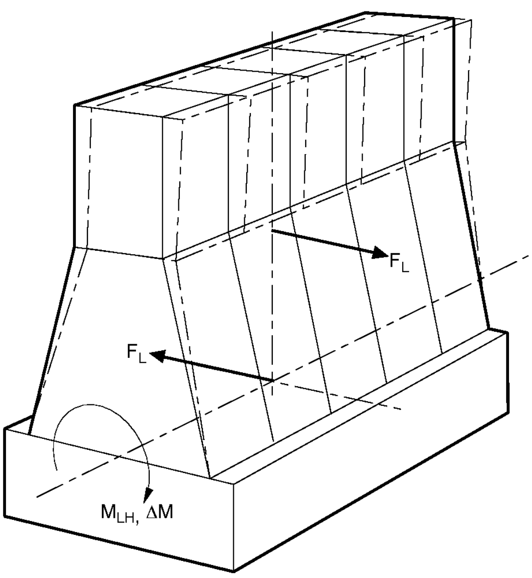
There are two different modes of lateral engine vibration, the so-called '**H-type**' and '**X-type**', please refer to figure D4.

The 'H-type' lateral vibrations are characterized by a deformation where the driving and free end side of the engine top vibrate in phase as a result of the lateral guide force F_L and the lateral H-type moment. The torque variation (ΔM) is the reaction moment to M_{LH}.

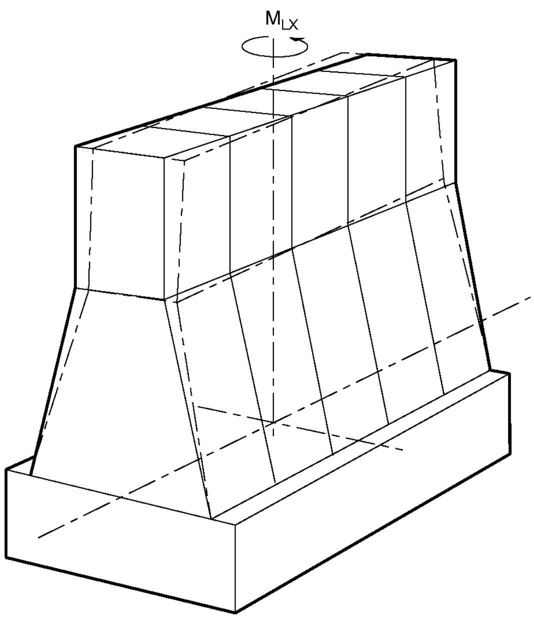
The 'X-type' lateral vibrations are caused by the resulting lateral guide force moment M_{LX}. The driving- and free-end side of the engine top vibrate in counterphase.

Table D1 gives the values of resulting lateral guide forces and moments of the relevant orders.

The amplitudes of the vibrations transmitted to the hull depend on the design of the engine seating, frame stiffness and exhaust pipe connections. As the amplitude of the vibrations cannot be predicted with absolute accuracy, the support to the ship's structure and space for installation of lateral stays should be considered in the early design stages of the engine-room structure. Please refer to tables D2 to D4, countermeasures for dynamic effects.



F_L resulting guide force
M_{LH} resulting lateral H-type moment



M_{LX} resulting lateral X-type moment

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Fig. D4 External forces and moments

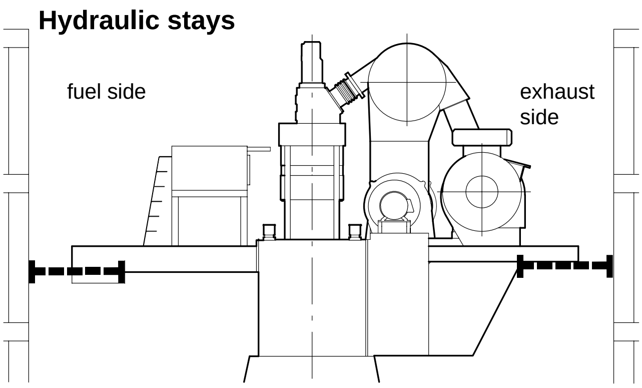
D. Engine dynamics

D1.2.1 Reduction of lateral vibration

D1.2.1.1 Engine stays

Fitting of lateral stays between the upper platform level and the hull reduces transmitted vibration and lateral rocking (see figures D5 and D6). Two stay types can be considered:

- Hydraulic stays: installed on the exhaust and on the fuel side of the engine (lateral).
- Friction stays:
  installed on the engine exhaust side (lateral),
  installed at the free end (longitudinal).



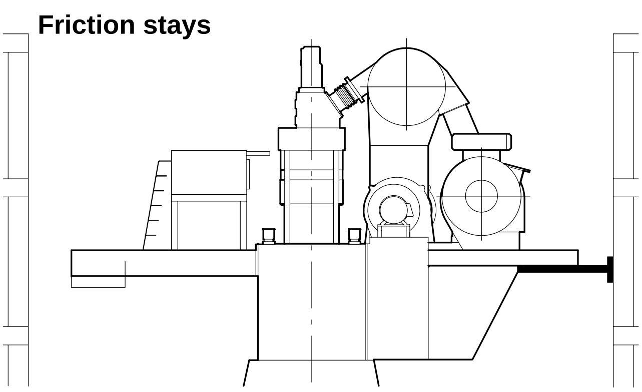


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Fig. D5 General arrangement of lateral stays

Table D3 shows where countermeasures for lateral and longitudinal rocking are needed.
For installation data concerning lateral engine stays, please refer to section H8.

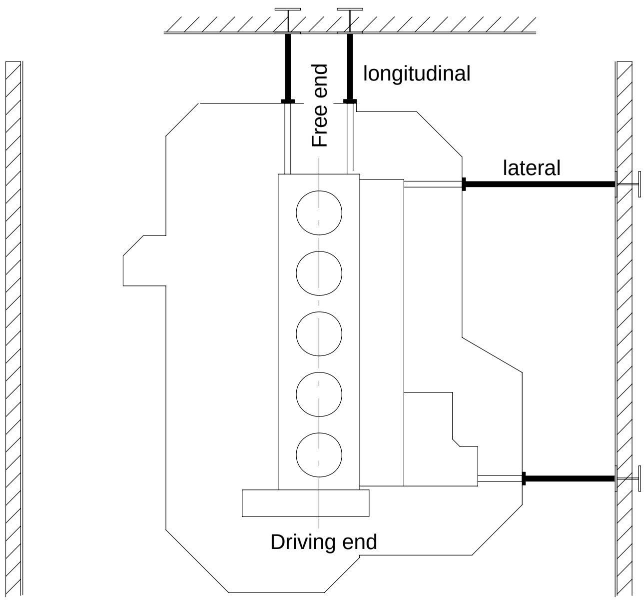

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Fig. D6 General arrangement of friction stays

D1.2.1.2 Electrically driven compensator

If for some reason it is not possible to install lateral stays, an electrically driven compensator can be installed which is able to reduce the lateral engine vibrations and their effect on the ship's superstructure. It is important to note that only one harmonic excitation can be compensated at a time and in the case of an 'X-type' vibration mode, two compensators, one fitted at each end of the engine top are necessary.

D1.3 Longitudinal engine vibration (pitching)

In some cases with **five-cylinder** Wärtsilä RT-flex engines, specially those coupled to very stiff intermediate and propeller shafts, the engine foundation can be excited at a frequency close to the full load speed range resonance, leading to increased axial (longitudinal) vibration at the engine top and as a result of this to vibrations in the ship's superstructure (refer to section D1.5 'Axial vibration'). In order to prevent this vibration, stiffness of the double-bottom structure should be as high as possible.

D1.4 Torsional vibration

Torsional vibrations are generated by gas and inertia forces as well as by the irregularity of the propeller torque. It does not cause hull vibration (except in very rare cases) and is not perceptible in service, but causes additional dynamic stresses in the shafting.

The shafting system comprising crankshaft, propulsion shafting, propeller, engine running gear, flexible couplings and **p**ower **t**ake **o**ff (PTO), as any system capable of vibrating, has resonant frequencies.

If any source generates excitation at the resonant frequencies the torsional loads in the system reach maximum values. These torsional loads have to be limited, if possible by design, i.e., optimizing shaft diameters and flywheel inertia. If the resonance still remains dangerous, its frequency range (critical speed) has to be passed through rapidly (barred-speed range) provided that the corresponding limits for this transient condition are not exceeded, otherwise other appropriate countermeasures have to be taken.

The amplitudes and frequencies of torsional vibration must be calculated at the design stage for every engine installation. The calculation normally requires approval from the relevant classification society and may require verification by measurement on board ship during sea trials. All data required for torsional vibration calculations should be made available to the engine supplier at an early design stage (see section D3 'Order forms for vibration calculations').

D1.4.1 Reduction of torsional vibration

Excessive torsional vibration can be reduced, shifted or even avoided by installing a heavy flywheel at the driving end and/or a tuning wheel at the free end or a torsional vibration damper at the free end of the crankshaft. Such dampers reduce the level of torsional stresses by absorbing a part of their energy. Where low energy torsional vibrations have to be reduced, a viscous damper, can be installed, please refer to figure D7. In some cases the torsional vibration calculation shows that an additional oil-spray cooling for the viscous damper is needed. In these cases the layout has to be in accordance with the recommendations of the damper manufacturer and our design department.

For high energy vibrations, i.e., for higher additional torque levels that can occur with five- and six-cylinder engines, a spring damper, with its higher damping effect may have to be considered, please refer to figure D8. This damper has to be supplied with oil from the engine's lubricating oil system, and depending on the torsional vibration energy to be absorbed can dissipate up to approximately **100 kW** energy (depends on number of cylinders). The oil flow to the damper should be approximately **10 to 20 m^3/h**, but an accurate value will be given after the results of the torsional vibration calculation are known.

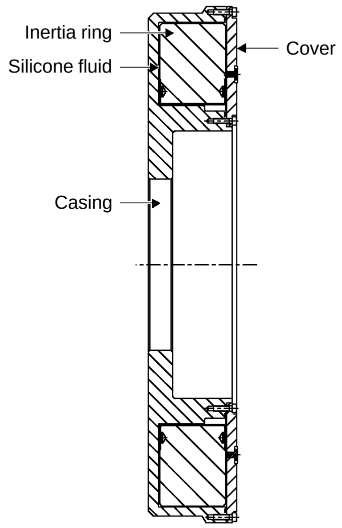

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Fig. D7 Vibration damper (Viscous type)

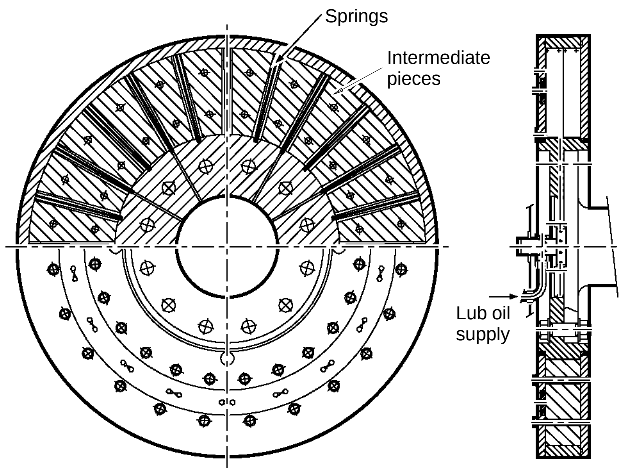

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Fig. D8 Vibration damper (Geislinger type)

D1.5 Axial vibration

The shafting system formed by the crankshaft and propulsion shafting, is able to vibrate in the axial direction, the basic principle being the same as described in section D1.4 ‘Torsional vibration’. The system, made up of masses and elasticities, will feature several resonant frequencies. These will result in axial vibration causing excessive stresses in the crankshaft if no countermeasures are taken. Strong axial vibration of the shafting can also lead to excessive axial (or longitudinal) vibration of the engine, particularly at its upper part.

The axial vibrations of installations depend mainly on the dynamical axial system of the crankshaft, the mass of the torsional damper, free-end gear (if any) and flywheel fitted to the crankshaft. Additionally, there can be a considerable influence of the torsional vibrations to the axial vibrations. This influence is called the coupling effect of the torsional vibrations.

It is recommended that axial vibration calculations are carried out at the same time as the torsional vibration calculation. In order to consider the coupling effect of the torsional vibrations to the axial vibrations, it is necessary to use a suitable coupled axial vibration calculation method.

D1.5.1 Reduction of axial vibration

In order to limit the influence of the axial excitations and reduce the level of vibration, all RT-flex84T-D engines are equipped as standard with an integrated axial damper mounted at the free end of the crankshaft, please refer to figure D9.

The axial damper sufficiently reduces the axial vibrations in the crankshaft to acceptable values. No excessive axial vibrations should occur on either the crankshaft nor the upper part of the engine.

The effect of the axial damper can be adjusted by an adjusting throttle. However, the setting of the adjusting throttle is preset by the engine builder and there is normally no need to change the setting.
The integrated axial damper does not affect the external dimensions of the engine. It is connected to the main lubricating oil circuit.
An integrated monitoring system continuously checks the correct operation of the axial damper.

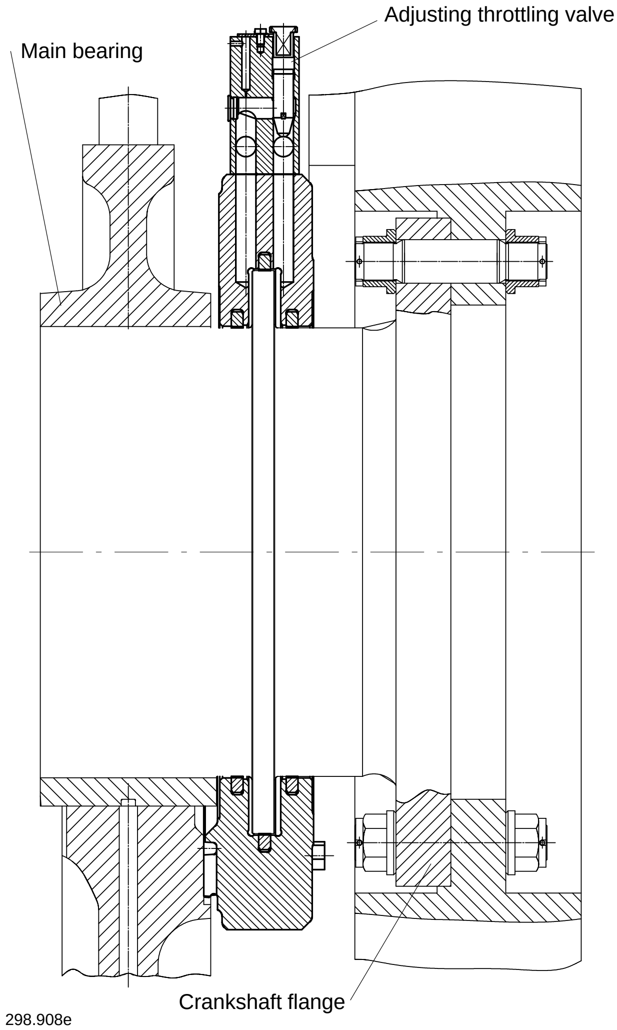


Fig. D9 Axial damper (detuner)

D1.6 Hull vibration

The hull and accommodation area are susceptible to vibration caused by the propeller, machinery and sea conditions. Controlling hull vibration is achieved by a number of different means and may require fitting mass moment compensators, lateral stays, torsional damper and axial damper. Avoiding disturbing hull vibration requires a close co-operation between the propeller manufacturer, naval architect, shipyard and engine builder. To enable Wärtsilä Switzerland Ltd to provide the most accurate information and advice on protecting the installation and vessel from the effects of plant vibration, please complete the order forms as given in section D3 and send it to the address given.

D1.7 External forces and moments

Please note: Data in table D1 refer to Tier I. Tier II data will be similar. Available on request.

Engine: Wärtsilä RT-flex84T-D	Number of cylinders	5	6	7	8	9
Rating R1: 4200 kW/cyl. at 76 rpm	Engine power kW	**21 000**	**25 200**	**29 400**	**33 600**	**37 800**
Massmoments / Forces						
Free forces						
F_{1V}	[±kN]	0	0	0	0	0
F_{1H}	[±kN]	0	0	0	0	0
F_{2V}	[±kN]	0	0	0	0	0
F_{4V}	[±kN]	0	0	0	0	0
External moments *1)						
M_{1V}	[±kNm]	353	0	209	131	359
M_{1H}	[±kNm]	495	0	296	200	547
M_{2V}	[±kNm]	4771	3319	963	0	1667
M_{4V}	[±kNm]	27	208	591	240	335
Lateral H-moments M_{LH} *2) *3)						
Order 1	[±kNm]	0	0	0	0	0
Order 2	[±kNm]	0	0	0	0	0
Order 3	[±kNm]	0	0	0	0	0
Order 4	[±kNm]	0	0	0	0	0
Order 5	[±kNm]	3058	0	0	0	0
Order 6	[±kNm]	0	2254	0	0	0
Order 7	[±kNm]	0	0	1719	0	0
Order 8	[±kNm]	0	0	0	1116	0
Order 9	[±kNm]	0	0	0	0	646
Order 10	[±kNm]	174	0	0	0	0
Order 11	[±kNm]	0	0	0	0	0
Order 12	[±kNm]	0	69	0	0	0
Lateral X-moments M_{LX} *3)						
Order 1	[±kNm]	352	0	209	137	376
Order 2	[±kNm]	229	160	46	0	80
Order 3	[±kNm]	514	929	1016	1482	1788
Order 4	[±kNm]	124	955	2714	1103	1537
Order 5	[±kNm]	0	0	199	2841	1103
Order 6	[±kNm]	49	0	29	0	1891
Order 7	[±kNm]	376	0	0	13	131
Order 8	[±kNm]	201	140	11	0	19
Order 9	[±kNm]	9	178	20	3	0
Order 10	[±kNm]	0	38	107	0	5
Order 11	[±kNm]	2	0	46	67	8
Order 12	[±kNm]	19	0	4	15	67
Torque variation (Synthesis value)	[±kNm]	3149	2297	1735	1113	655

Remarks: *1) The external moments M_1 and M_2 are related to R1 speed. For other engine speeds the corresponding external moments are calculated with the relation: $\mathbf{M_{Rx} = M_{R1} \cdot (n_{Rx}/n_{R1})^2}$.
No engine-fitted 2nd order balancer available. If reduction on M_{2V} is needed, an external compensator has to be applied.
*2) The resulting lateral guide force can be calculated as follows: $\mathbf{F_L = M_{LH} \cdot 0.204}$ **[kN].**
*3) The values for other engine ratings are available on request.
— Crankshaft type: forged.

Table D1 External forces and moments

D1.8 Summary of countermeasures for dynamic effects

The following tables indicate where special attention is to be given to dynamic effects and the counter-measures required to reduce them.

External mass moments

Number of cylinders	2nd order compensator	*2)
5–6	balancing countermeasure is likely needed *1)	A
7–9	balancing countermeasure is not relevant	C

Remarks: *1) No engine-fitted 2nd order balancer available.
If reduction on M_{2v} is needed, an external compensator has to be applied.
*2) Refer also to figure D3

Table D2 Countermeasures for external mass moments

Lateral and longitudinal rocking

Number of cylinders	Lateral stays	Longitudinal stays
5	A	B
6	B	C
7	C	C
8	A	C
9	B	C

Remarks: A: The countermeasure indicated is needed.
B: The countermeasure indicated may be needed and provision for the corresponding countermeasure is recommended.
C: The countermeasure indicated is not needed.

Table D3 Countermeasures for lateral and longitudinal rocking

Torsional vibration & axial vibration

Where installations incorporate PTO arrangements further investigation is required and Wärtsilä Switzerland Ltd, Winterthur, should be contacted.

Number of cylinders	Torsional vibrations	Axial vibrations
5–9	Detailed calculations have to be carried out for every installation, countermeasures to be selected accordingly (shaft diameter, critical or barred speed range, flywheel, tuning wheel, damper).	An integrated axial damper is fitted as standard to reduce the axial vibration in the crankshaft. However, the effect of the coupled axial vibration to the propulsion shafting components should be checked by calculation.

Table D4 Countermeasures for torsional & axial vibration

D2 System dynamics

A modern propulsion plant with the RT-flex engine may include a main-engine driven generator. This element is connected by clutches, gears, shafts and elastic couplings. Under transient conditions large perturbations, due to changing the operating point, loading or unloading generators, engaging or disengaging a clutch, cause instantaneous dynamic behaviour which weakens after a certain time (or transient). Usually the transfer from one operating point to another is supervised by a control system in order to allow the plant to adapt safely and rapidly to the new operating point (engine speed control and propeller speed control).

Simulation is an opportune method for analysing the dynamic behaviour of a system subject to large perturbations or transient conditions. Mathematical models of several system components such as clutches and couplings have been determined and programmed as library blocks to be used with a simulation program. With this program it is possible to check, for example, if an elastic coupling will be overloaded during engine start, or to optimize a clutch coupling characteristic (engine speed before clutching, slipping time, etc.), or to adjust the speed control parameters.

This kind of study should be requested at an early stage in the project if some special specification regarding speed deviation and recovery time, or any special speed and load setting programs have to be fulfilled.

Wärtsilä Switzerland Ltd would like to assist if you have any questions or problems relating to the dynamics of RT-flex engines. Please describe the situation and send or fax the completed relevant order form given in the next section D3. We will provide an answer as soon as possible.

D3 Order forms for vibration calculations and simulation

For system dynamics and vibration analysis, please send or fax a copy of the completed relevant forms to the following address:

Wärtsilä Switzerland Ltd
Dept. 10189
'Engine and System Dynamics'
PO Box 414
CH-8401 Winterthur
Switzerland
Fax: +41-52-262 07 25

Minimum required data needed for provisional calculation are highlighted in the forms (tables D5 to D8) as follows:

D3.1 Marine installation Torsional Vibration Calculation

Client Information	Name:			Phone:		
	Order Date:			Order deadline:		
Project	Project name:					
	Shipyard:			Hull No.:		
	Classification society:					
Engine	Engine type:					
	Engine power:		kW	Engine speed:		rpm
	Rotation:	clockwise ☐ anti-clockwise ☐		Engine tuning (RT-flex):	Standard ☐	DeltaTuning ☐
	Barred speed range accepted:	Y ☐ N ☐		if yes, in which speed range:		rpm
Shafting						
	Intermediate shaft diameter:		mm	Propeller shaft diameter:		mm
	Intermediate shaft length:		mm	Propeller shaft length:		mm
	Intermediate shaft UTS:		N/mm^2	Propeller shaft UTS:		N/mm^2
		If possible, a drawing or sketch of the propulsion shafting should be enclosed. In case the installation consists of a CP-Propeller, a detailed drawing of the oil-distribution shaft is needed.				
Propeller						
	Type:	FP ☐ CP ☐		Number of blades:	4 ☐ 5 ☐ 6 ☐	
	Diameter:		m	Mass:		kg
	Mean pitch:		m	Expanded area blade ratio:		
	Inertia in air:		kgm^2	Inertia with entr. water*:		kgm^2
		*In case of a CP-Propeller, the inertia in water for full pitch has to be given and if possible, the inertia of the entrained water depending on the pitch to be enclosed.				
PTO	Type:	Free end gear (RTA) ☐	Tunnel gear ☐	Camshaft gear (RTA) ☐	Shaft generator ☐	
PTO-Gear	Manufacturer:					
		Detailed drawings with the gearwheel inertias and gear ratios to be enclosed.				
PTO-Clutches/Elastic couplings						
		The arrangement and the type of couplings to be enclosed.				
PTO-Generator	Manufacturer:			Service speed range:		rpm
	Generator speed:		rpm	Rated voltage:		V
	Rated apparent power:		kVA	Grid frequency:		Hz
	Rotor inertia:		kgm^2	Power factor cos φ:		
	Frequency control system:	No ☐	Thyristor ☐	Constant speed gear ☐		
		If possible, drawing of generator shaft to be enclosed				

(grey field) Minimum required data needed for provisional calculation.

Table D5 Marine installation Torsional Vibration Calculation

D3.2 Testbed installation Torsional Vibration Calculation

Client Information	Name:			Phone:	
	Order Date:			Order deadline:	
Project	Project name:				
	Shipyard:			Hull No.:	
	Classification society:				
Engine	Engine type:				
	Engine power:		kW	Engine speed:	rpm
	Rotation:	clockwise ☐	anti-clockwise ☐	Engine tuning (RT-flex):	Standard ☐ DeltaTuning ☐
	Flywheel inertia:		kgm^2	Front disc inertia:	kgm^2
	TV damper type / designation:			TV damper manufacturer:	
		Details of the dynamic characteristics of TV damper to be enclosed if already known.			
Shafting					
	Intermediate shaft diameter:		mm	Intermediate shaft length:	mm
	Intermediate shaft UTS:		N/mm^2	Propeller shaft UTS:	N/mm^2
		A drawing or sketch of the propulsion shafting should be enclosed.			
Water brake					
	Type:			Manufacturer:	
	Inertia of rotor with entr. water:		kgm^2	Drw.No.:	
	Elasticity of brake shaft:		rad/Nm (between flange and rotor)		
PTO	Type:	Free end gear ☐	Camshaft gear ☐		
PTO-Gear	Manufacturer:				
		Detailed drawings with the gearwheel inertias and gear ratios to be enclosed.			
PTO-Clutches/Elastic couplings					
		The arrangement and the type of couplings to be enclosed.			
PT-Generator	Manufacturer:			Service speed range:	rpm
	Generator speed:		rpm		
	Rotor inertia:		kgm^2	Rotor mass:	kg
		If possible, drawing of generator shaft to be enclosed			

Minimum required data needed for provisional calculation.

Table D6 Testbed installation Torsional Vibration Calculation

D3.3 Marine installation Coupled Axial Vibration Calculation

Client Information	Name:			Phone:	
	Order Date:			Order deadline:	
Project	Project name:				
	Shipyard:			Hull No.:	
	Classification society:				
Engine	Engine type:				
	Engine power:		kW	Engine speed:	rpm
	Rotation:	clockwise ☐ anti-clockwise ☐		Engine tuning (RT-flex):	Standard ☐ DeltaTuning ☐
	Flywheel inertia:		kgm^2	Flywheel mass:	kg
	Front disc inertia:		kgm^2	Front disc mass:	kg
	TV damper type / designation:			TV damper manufacturer:	
		Details of the dynamic characteristics of TV damper to be enclosed if already known.			
Shafting					
	Intermediate shaft diameter:		mm	Propeller shaft diameter:	mm
	Intermediate shaft length:		mm	Propeller shaft length:	mm
	Intermediate shaft UTS:		N/mm^2	Propeller shaft UTS:	N/mm^2
		If possible, a drawing or sketch of the propulsion shafting should be enclosed. In case the installation consists of a CP-Propeller, a detailed drawing of the oil-distribution shaft is needed			
Propeller					
	Type:	FP ☐ CP ☐		Number of blades:	4 ☐ 5 ☐ 6 ☐
	Diameter:		m		
	Mean pitch:		m	Expanded area blade ratio:	
	Inertia in air:		kgm^2	Mass in air:	kg
	Inertia with entr. water*:		kgm^2	Mass with entrained water:	kg
		*In case of a CP-Propeller, the inertia in water for full pitch has to be given and if possible, the inertia of the entrained water depending on the pitch to be enclosed.			
PTO	Type:	Free end gear (RTA) ☐ Tunnel gear ☐		Camshaft gear (RTA) ☐	Shaft generator ☐
PTO-Gear	Manufacturer:				
		Detailed drawings with the gearwheel inertias and gear ratios to be enclosed.			
PTO-Clutches/Elastic couplings					
		The arrangement and the type of couplings to be enclosed.			
PTO-Generator	Manufacturer:			Service speed range:	rpm
	Generator speed:		rpm		
	Rotor inertia:		kgm^2	Rotor mass:	kg
		If possible, drawing of generator shaft to be enclosed			

Table D7 Marine installation Coupled Axial Vibration Calculation

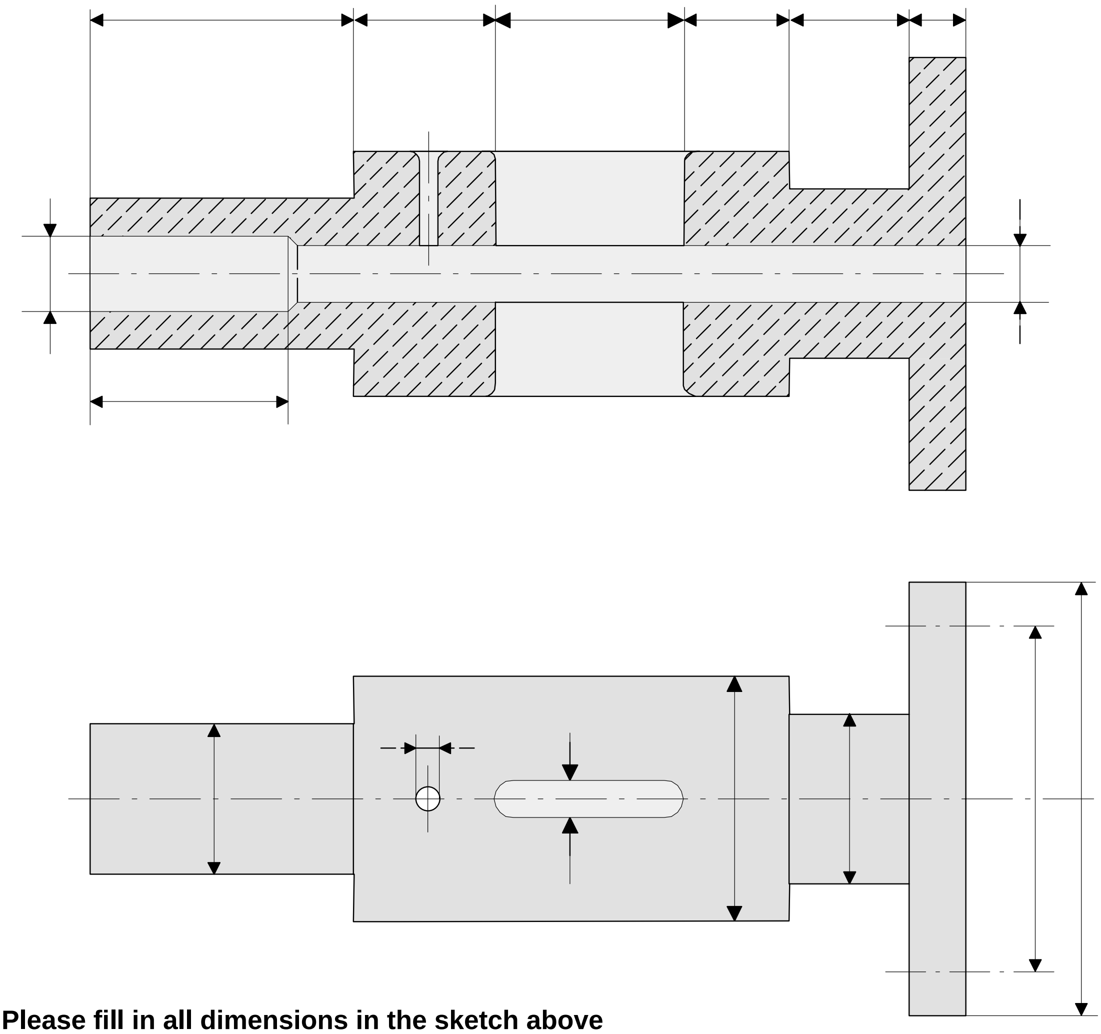
D3.4 Marine installation Bending Vibration & Alignment Calculation

Client Information	Name:			Phone:		
	Order Date:			Order deadline:		
Project	Project name:					
	Shipyard:			Hull No.:		
	Classification society:					
Engine	Engine type:					
	Engine power:		kW	Engine speed:		rpm
	Rotation:	clockwise ☐ anti-clockwise ☐		Engine tuning (RT-flex):	Standard ☐	DeltaTuning ☐
	Flywheel inertia:		kgm^2	Flywheel mass:		kg
	Front disc inertia:		kgm^2	Front disc mass:		kg
	TV damper type / designation:			TV damper manufacturer:		
		Details of the dynamic characteristics of TV damper to be enclosed if already known.				
Shafting						
	Intermediate shaft diameter:		mm	Propeller shaft diameter:		mm
	Intermediate shaft length:		mm	Propeller shaft length:		mm
	Intermediate shaft UTS:		N/mm^2	Propeller shaft UTS:		N/mm^2
		A drawing or sketch of the propulsion shafting should be enclosed. In case the installation consists of a CP-Propeller, a detailed drawing of the oil-distribution shaft is needed				
Propeller	Type:	FP ☐ CP ☐		Number of blades:	4 ☐ 5 ☐ 6 ☐	
	Diameter:		m			
	Mean pitch:		m	Expanded area blade ratio:		
	Inertia in air:		kgm^2	Mass in air:		kg
	Inertia with entr. water*:		kgm^2	Mass with entrained water:		kg
PTO	Type:	Free end gear (RTA) ☐	Tunnel gear ☐	Camshaft gear (RTA) ☐	Shaft generator ☐	
PTO-Gear	Manufacturer:					
		Detailed drawings with the gearwheel inertias, masses and gear ratios to be enclosed.				
PTO-Clutches/Elastic couplings						
		The arrangement and the type of couplings to be enclosed.				
PTO-Generator	Manufacturer:			Service speed range:		rpm
	Generator speed:		rpm			
	Rotor inertia:		kgm^2	Rotor mass:		Kg
Shaft bearings	Type:					
	Stiffness horizontal:		N/m	Stiffness vertical:		N/m
	Sterntube stiffn. horiz.:		N/m	Sterntube stiffn. vertical:		N/m

Table D8 Marine installation Bending Vibration Calculation

D. Engine dynamics

D3.5 Required information of OD-shafts for TVC



Please fill in all dimensions in the sketch above

Project name : ______________________

Shipyard : ______________________

Hull number : ______________________

Manufacturer of OD-shaft : ______________________

OD-shaft type : ______________________

UTS [N/mm^2] : ______________________

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Fig. D10 OD-shafts for TVC

E. Auxiliary power generation

E1 General information

This chapter covers a number of auxiliary power arrangements for consideration. However, if your requirements are not fulfilled, please contact our representative or consult Wärtsilä Switzerland Ltd, Winterthur, directly. Our aim is to provide flexibility in power management, reduce overall fuel consumption and maintain uni-fuel operation.

The sea load demand for refrigeration compressors, engine and deck ancillaries, machinery space auxiliaries and hotel load can be met by using a main-engine driven generator, by a steam-turbine driven generator utilising waste heat from the engine exhaust gas, or simply by auxiliary generator sets.

The waste heat option is a practical proposition for high powered engines employed on long voyages. The electrical power required when loading and discharging cannot be met with a main-engine driven generator or with the waste heat recovery system, and for vessels employed on comparatively short voyages the waste heat system is not viable. Stand-by diesel generator sets **(Wärtsilä GenSets)**, burning heavy fuel oil or marine diesel oil, available for use in port, when manoeuvring or at anchor, provide the flexibility required when the main engine power cannot be utilised.

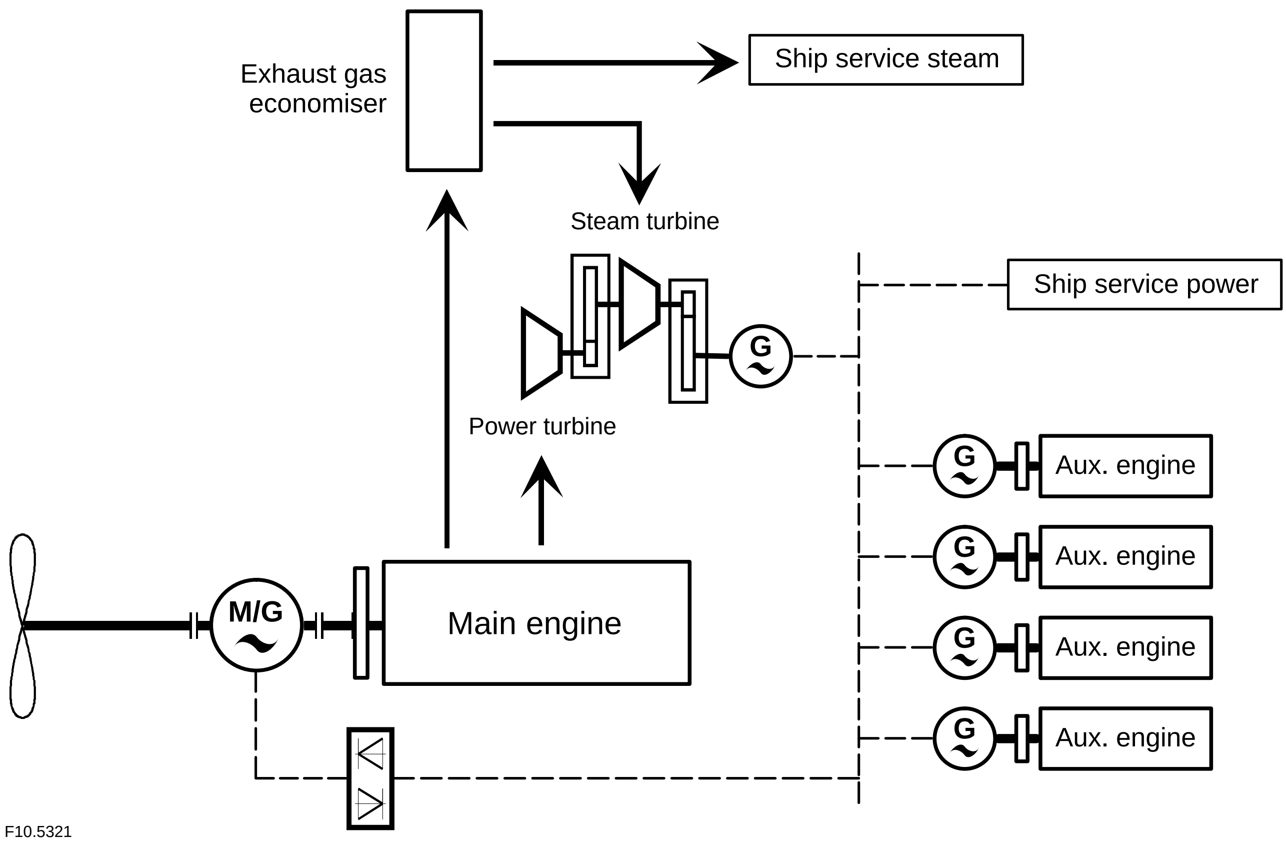

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Fig. E1 Heat recovery, typical system layout

E1.1 System description and layout

Although initial installation costs for a heat recovery plant are relatively high, these are recovered by fuel savings if maximum use is made of the steam output, i.e., electrical power and domestics, space heating, heating of tank, fuel and water.

E2 Waste heat recovery

Before any decision can be made about installing a waste heat recovery system (see figure E1) the steam and electrical power available from the exhaust gas is to be established.

For more information see chapter J 'winGTD – the General Technical Data'.

E3 Power take off (PTO)

Main-engine driven generators are an attractive option when consideration is given to simplicity of operation and low maintenance costs. The generator is driven through a tunnel PTO gear with frequency control provided by thyristor invertors or constant-speed gears.

The tunnel gear is mounted at the intermediate propeller shaft. Positioning the PTO gear in that area of the ship depends upon the amount of space available.

E3.1 Arrangements of PTO

Figure E2 illustrates various arrangements for PTO with generator. If your particular requirements are not covered, please do not hesitate to contact our representative or Wärtsilä Switzerland Ltd, Winterthur, directly.

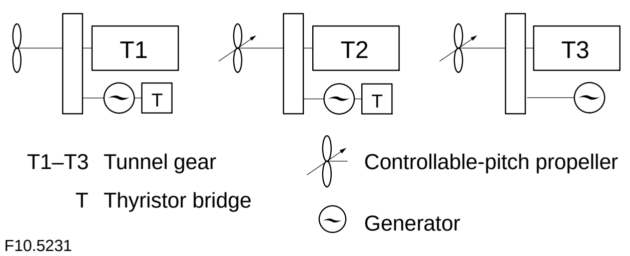

Fig. E2 Tunnel PTO gear

E3.2 PTO power and speed

PTO tunnel gear with generator	
Generator speed [rpm]	1000, 1200, 1500, 1800
Power [kWe]	700 1200 1800 *1)

Remark: *1) Higher powers on request

Table E1 PTO power and speed

Another alternative is a shaft generator.

F. Ancillary systems

F1 General information

Sizing engine ancillary systems, i.e. fresh water cooling, lubricating oil, fuel oil, etc., depends on the contract maximum engine power. If the expected system design is out of the scope of this manual please contact our representative or Wärtsilä Switzerland Ltd, Winterthur, directly.

The winGTD-program enables all engine and system data at any Rx rating within the engine rating field to be obtained.

However, for convenience or final confirmation when optimizing the plant, **Wärtsilä Switzerland Ltd** provide a computerized calculation service. Please complete in full the questionnaire on the next page to enable us to supply the necessary data.

F1.1 Part-load data

The engine part-load data can be determined with the help of the winGTD-program which is available on request.

F1.2 Engine system data

The data contained in table F1 are applicable to the nominal maximum continuous rating (R1) of each five- to nine-cylinder engine and are suitable for estimating the size of ancillary equipment.
These data refer to engines with the following conditions/features:

– At design (tropical) conditions.
– Standard Tuning
– Central fresh water cooling system with single-stage scavenge air cooler (SAC) and *separate* HT circuit.
– ABB TPL turbochargers.
– Turbochargers lubricated from the engine’s lubricating system.

Furthermore, the following data are obtainable from the winGTD-program or on request at WCH:

– Data for engines fitted with Mitsubishi MET MA turbochargers.
– Derating and part-load performance data.
– Data for Delta Tuning.
– Data for Low-Load Tuning.

F1.2.1 R1 data for central fresh water cooling system (single-stage, separate HT)

Engine equipped with ABB TPL turbochargers

for Mitsubishi turbochargers use data from the winGTD program (see section C7.2).

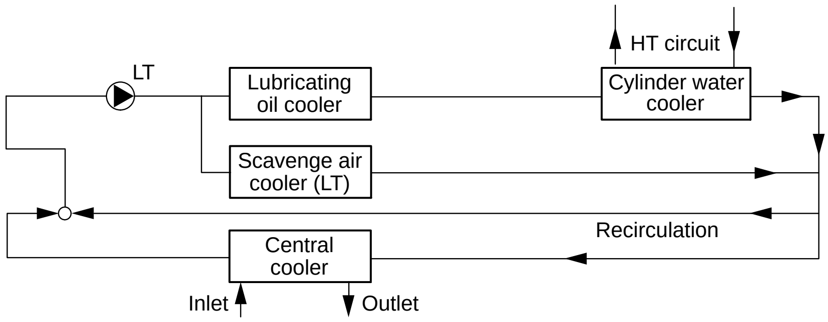

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Fig. F1 Central fresh water cooling system with single-stage SAC and separate HT circuit

RT-flex84T-D	Number of cylinders	–	**5**	**6**	**7**	**8**	**9**
R1 data	Engine power	kW	**21 000**	**25 200**	**29 400**	**33 600**	**37 800**
Speed: 76 rpm	Turbochargers	–	**1 x**	**2 x**	**2 x**	**2 x**	**2 x**
	Type ABB	–	**TPL85-B14**	**TPL80-B11**	**TPL80-B12**	**TPL80-B12**	**TPL85-B14**
Cyl. water cooler (HT)	heat dissip.	kW	3467	3998	4768	5544	6178
Fresh water flow (HT)		m^3/h	153	176	210	244	272
Fresh water temp. (HT)	cooler in/out	°C	90.0/73.0	90.0/73.0	90.0/73.0	90.0/73.0	90.0/73.0
Fresh water flow (LT)		m^3/h	204	245	283	321	370
Fresh water temp. (LT)	cooler in/out	°C	46.0/60.7	46.0/60.1	46.0/60.6	46.0/60.9	46.0/60.5
Mean log. temperature difference		°C	26.5	26.8	26.6	26.4	26.7
Cylinder cooling (HT)	heat dissipation	kW	3467	3998	4768	5544	6178
Fresh water flow		m^3/h	180	207	247	288	320
Fresh water temperature	engine in/out	°C	73.0/90.0	73.0/90.0	73.0/90.0	73.0/90.0	73.0/90.0
Scavenge air cooler (LT)	heat dissip.	kW	7753	9408	10941	12464	13991
Fresh water flow (LT)		m^3/h	254	510	510	510	508
Fresh water temperature	cooler in/out	°C	36.0/62.4	36.0/52.0	36.0/54.6	36.0/57.2	36.0/59.9
Scavenge air	mass flow	kg/h	153048	183658	214267	244877	275486
Lubricating oil cooler	heat dissip. *1)	kW	2353	2826	3267	3711	4267
Oil flow *1)		m^3/h	306	355	400	445	495
Oil temperature	cooler n/out	°C	60.7/45.0	61.2/45.0	61.6/45.0	62.0/45.0	62.5/45.0
Fresh water flow		m^3/h	204	245	283	321	370
Fresh water temperature	cooler in/out	°C	36.0/46.0	36.0/46.0	36.0/46.0	36.0/46.0	36.0/46.0
Mean log. temperature difference		°C	11.6	11.8	12.0	12.2	12.4
Central cooler	heat dissipation	kW	13572	16232	18976	21718	24435
Fresh water flow (LT)		m^3/h	458	755	793	831	878
Fresh water temperature	cooler in/out	°C	61.7/36.0	54.6/36.0	56.7/36.0	58.6/36.0	60.1/36.0
Sea-water flow		m^3/h	662	792	926	1059	1192
Sea-water temperature	cooler in/out	°C	32.0/50.0	32.0/50.0	32.0/50.0	32.0/50.0	32.0/50.0
Mean log. temperature difference		°C	7.2	4.3	5.2	6.0	6.6
Exhaust gas	heat dissipation *2)	kW	5623	6747	7872	8996	10121
Mass flow		kg/h	154406	185287	216168	247050	277931
Temperature after turbine		°C	298	298	298	298	298
Engine radiation		kW	183	214	244	275	305
Starting air *3)	at design pressure	bar	30	30	30	30	30
Bottle (2 units)	capacity each	m^3	10.5	12.0	13.7	15.7	17.6
Air compressor (2 units)	capacity each	m^3/h	320	360	410	470	530

Pump capacities / delivery head *4)	**m^3/h**	**bar**	**m^3/h**	**bar**	**m^3/h**	**bar**	**m^3/h**	**bar**	**m^3/h**	**bar**
Lubricating oil	306	5.6	355	5.6	400	5.6	445	5.6	495	5.6
Crosshead lubricating oil	50	8.4	60	8.4	70	8.4	80	8.4	90	8.4
High temperature circuit (cylinder cooling)	180	3.0	207	3.0	247	3.0	288	3.0	320	3.0
Low temperature circuit	458	2.7	755	2.7	793	2.7	831	2.7	878	2.7
Fuel oil booster	9.5	7.0	11.3	7.0	13.2	7.0	15.1	7.0	17.0	7.0
Fuel oil feed	5.3	5.0	6.3	5.0	7.4	5.0	8.4	5.0	9.5	5.0
Sea-water	662	2.2	792	2.2	926	2.2	1059	2.2	1192	2.2

Remark:
*1) Excluding heat and oil flow for damper and PTO gear.
*2) Available heat for boiler with gas outlet temperature 170˚C and temperature drop 5˚C from turbine to boiler.
*3) For 12 starts and refilling time 1 hour, when J_{Rel} = 2.0 (see section F2.4)
*4) Pressure difference across pump (final delivery head must be according to the actual piping layout).

Table F1 R1 data for central fresh water cooling system with single-stage SAC and separate HT circuit

F1.2.2 Questionnaire for engine data

In order to obtain computerized engine performance data and optimized ancillary system data, please send completed copy of this questionnaire to:

Wärtsilä Switzerland Ltd
Dept. 10189
PO Box 414,
CH-8401 Winterthur, Switzerland.
Fax No. +41 52 212 49 17

Client specification

Company:____________________

Name:____________________

Address:____________________

Department:____________________

Country:____________________

Telephone:____________________

Telefax:____________________

Telex:____________________

E-mail:____________________

Date of contact:____________________

Project specification

Project number:____________________

Shipowner, country:____________________

Shipyard, country:____________________

Project manager:____________________

Wärtsilä representative:____________________

Engine specification

Number of cylinders: _______RT-flex84T-D

PTO:	○ Yes	☐ No (continue to ‘Rating point’ below)		
(see PTO options in table E1)				
Max. PTO [kW]	○ 700	○ 1200	○ 1800	○ __________
Constant-speed output:	○ Yes	☐ No (continue to ‘Rating point’ below)		
Speed [rpm]:	○ 1000	○ 1200	○ 1500	○ 1800

Rating point (CMCR = Rx)

Power:_______kW

Speed:_______rpm

Cooling system specification

☐ Central fresh water cooling with single-stage scavenge air cooler and separate HT circuit

Calculations are based on an operating mode according to propeller law and design (tropical) conditions.

F2 Piping systems

All pipework systems and fittings are to conform to the requirements laid down by the legislative council of the vessel's country of registration and the classification society selected by the owners. They are to be designed and installed to accommodate the quantities, velocities, flow rates and contents identified in this manual, set to work in accordance with the build specification as approved by the classification society and protected at all times from ingress of foreign bodies. **All pipework systems are to be flushed and proved clean prior to commissioning**. For flushing the lubricating oil system, please follow the instructions in section F2.2.9, and for flushing the fuel oil system follow the instructions in section F2.3.6.

Note:

The pipe connections on the engine are supplied with blind mating flanges, except for the turbocharger exhaust gas outlet. Screw connections are supplied complete.

F2.1 Cooling water and pre-heating systems

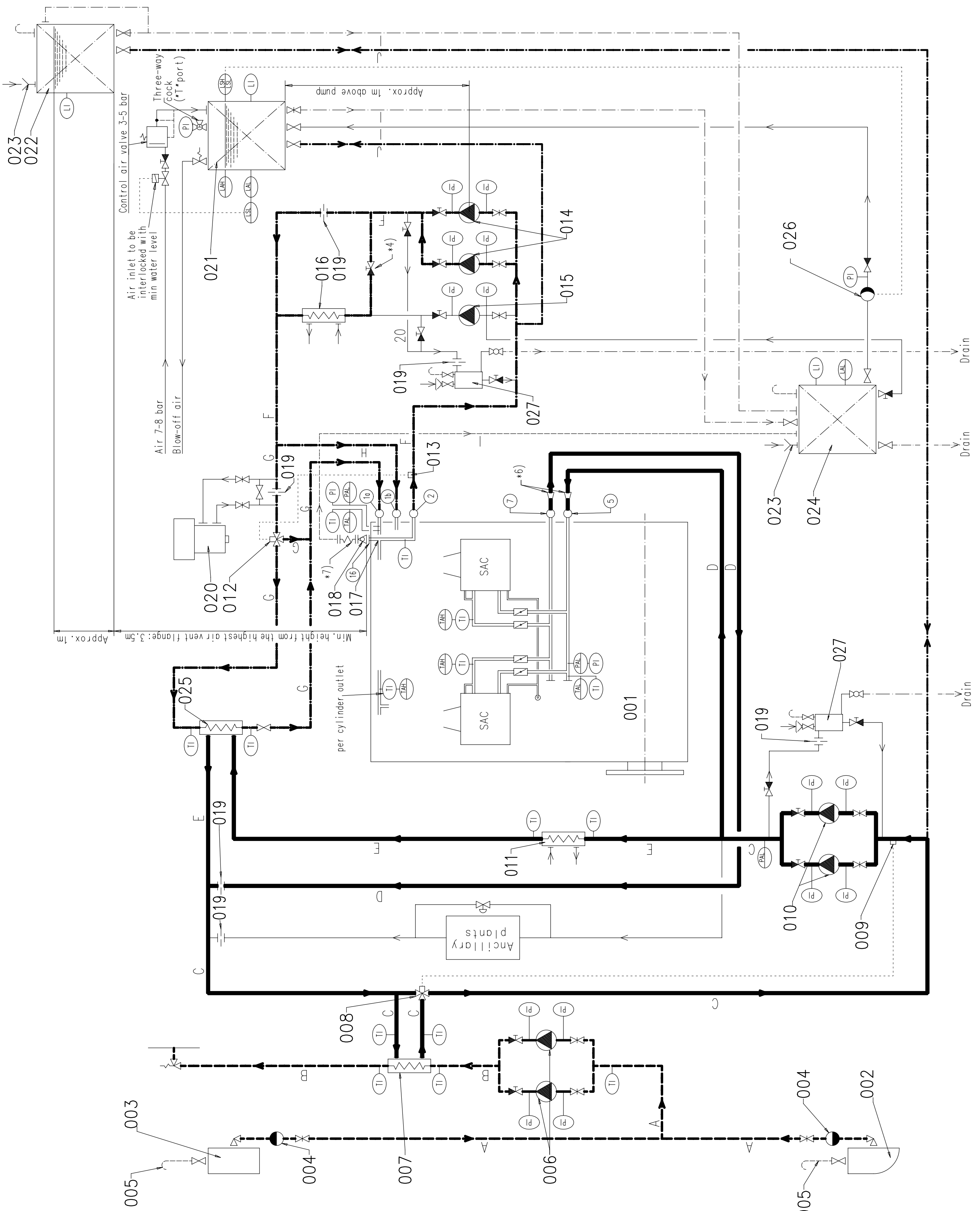
The cooling system of the RT-flex84T-D engine runs on the following standard layout:

– Central fresh water cooling system with single-stage scavenge air cooler and separate HT circuit (see fig. F2).

F2.1.1 Central freshwater cooling system

The central cooling system comprises a high temperature freshwater circuit for the cylinder cooler, a low temperature freshwater circuit for the scavenge air cooler, lubricating oil cooler and a sea water line for the central cooler(s) as shown in figure F2. It reduces the amount of seawater pipework and its attendant problems and provides for improved cooling control. Optimizing central freshwater cooling results in lower overall running costs when compared with the conventional seawater cooling system.
As the cylinder cooling water system of the RT-flex84T-D engine is pressurized, both high- and low-temperature circuits must be totally separated. This means that the high temperature circuit has its own cooler: the cylinder cooler. The cooling medium for this cooler is, however, freshwater from the low temperature circuit.

F. Ancillary systems



Note: For legend see table F2

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Fig. F2 Central fresh water cooling system: layout for single-stage scavenge air cooler

001 Main engine RT-flex84T-D
002 Low sea chest *1)
003 High sea chest
004 seawater strainer
005 Air vent (air vent pipe or equal venting system acc. to shipyard's design)
006 seawater circulating pump
007 Central seawater cooler *10)
008 Automatic temperature control valve for LT circuit
009 Temperature sensor of regulating system, min. temp. of SAC inlet: 25 °C
010 Fresh water pump for LT circuit
011 Lubricating oil cooler *10)
012 Automatic temperature control valve for HT circuit
013 Temperature sensor of regulating system, constant temp. at engine outlet
014 Cylinder cooling water pump for HT circuit
015 Pre-heating circulating pump (optional), capacity 10 % from pump 014 *8)
016 Heater for main engine (HT circuit) *10)
017 Air vent pipe (piping on engine)
018 Automatic float vent valve (on engine)
019 Throttling disc *2)
020 Fresh water generator
021 Buffer unit for HT circuit, see figure F4
022 Cooling water expansion tank for LT circuit, see figure F3
023 Filling pipe / inlet chemical treatment *3)
024 Cylinder cooling water feed & drain tank (or feed tank only)
025 Cylinder cooling water cooler *10)
026 Supply pump, automatic level control (0.5 m^3/h at 7 bar)
027 Chemical treatment refill unit *9)

1a Cylinder cooling water inlet
1b Cylinder cooling water inlet by-pass (approx. 15 % of tot. CW flow)
2 Cylinder cooling water outlet
5 Scavenge air cooler, cooling water inlet *5)
7 Scavenge air cooler, cooling water outlet *5)
16 Cylinder cooling water air vent

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seawater pipes
LT fresh water pipes
HT fresh water pipes
Balance pipes
freshwater drain pipes
Air vent pipes
Pipes on engine / pipe connections

Remarks:

*1) If requested, two low sea chests are applicable.
*2) When using a valve, lock in proper position to avoid mishandling.
*3) Other designs like hinged covers, etc. are also possible.
*4) Only when pos. 015 is installed.
*5) The inlet and outlet pipes to SAC have to be designed to allow for engine thermal expansion, or expansion parts have to be fitted.
*6) If required.
*7) Depending on vibration, a flexible hose connection may be recommendable.
*8) For guidance only, final layout according to actual engine pre-heating requirements.
*9) Capacity according to the chemical treatment requirements. Other designs are also possible.
*10) All heat exchangersequipped with air-vents and draains.
— Air vent pipes and drain valves where necessary.
— Air vent and drain pipes must be fully functional at all inclination angles of the ship at which the engine must be operational.

Number of cylinders				5	6	7	8	9
Main engine RT-flex84T-D	**(R1)**	power	kW	21 000	25 200	29 400	33 600	37 800
		speed	rpm	76				
Buffer unit for HT circuit		cap.	m^3	0.8	0.8	1.2	1.2	1.2
Cylinder cooling water feed tank (singly)	min.	cap.	m^3	1.5	1.5	1.5	1.5	1.5
CCW feed and drain tank (combined)	min.	cap.	m^3	5	5	7	7	7
Cooling water expansion tank (LT)		cap.	m^3	depending on ancillary plants				
Nominal pipe diameter		A	DN	To be determined by shipyard. Suitable for main engine and ancillary plants.				
		B	DN					
		C	DN					
All pipe diameters are valid for R1-rated engines and laid out for flows given in section F1.2 'Engine system data'. For pipe diameters if Rx-rated pump capacities are used, please refer to section F4 'Pipe size and flow details'		D	DN	200	200	200	200	200
		E	DN	150	200	200	200	300
		F	DN	150	200	200	200	200
		G	DN	150	150	200	200	200
		H	DN	65	80	80	80	100
		I	DN	25	25	25	25	25
		J	DN	65	65	65	80	80

Table F2 Central fresh water cooling system: data to layout for single-stage scavenge air cooler

F2.1.1.1 Central fresh water cooling system components

The following description of the components refers to figure F2 (central freshwater cooling system with single-stage scavenge air cooler).

Low-temperature circuit (LT):

– **seawater strainer** (pos. 004)
Simplex or duplex to be fitted at each sea chest and arranged to enable manual cleaning without interrupting flow. The strainer perforations are to be sized (not more than 6 mm) to prevent passage of large particles and debris damaging the pumps and impairing heat transfer across the coolers.

– **seawater pump** (pos. 006)
  - Pump type: centrifugal
  - Pump capacity: refer to table F1, the given seawater flow capacity covers the need of the engine only and is to be within a tolerance of 0 to +10 %.
  - Delivery head: the final delivery head is determined by the layout of the system and is to ensure that the inlet pressure to the scavenge air coolers is within the range of the summarized data in table C5.

– **Central cooler** (pos. 007)
  - Cooler type: plate or tubular
  - Cooling medium: seawater
  - Cooled medium: fresh water
  - Heat dissipation: refer to table F1
  - Margin for fouling: 10 to 15 % to be added
  - Fresh water flow: refer to table F1
  - seawater flow: refer to table F1
  - Temperatures: refer to table F1

– **Temperature control** (pos. 008)
The central fresh water cooling system is to be capable of maintaining the inlet temperature to the scavenge air cooler at 25 °C minimum to 36 °C maximum and for all seawater temperatures to a maximum of 32 °C by recirculation and the use of an automatic temperature control valve.

– **Fresh water pumps for LT circuit** (pos. 010)
  - Pump type: centrifugal
  - Pump capacity: refer to table F1
  - The given capacity of fresh water flow covers the need of the engine only and is to be within a tolerance of 0 % to +10 %.
  - Delivery head: the final delivery head is determined by the layout of the system and is to ensure that the inlet pressure to the scavenge air coolers is within the range of the summarized data.

High-temperature circuit (HT):

– **Cylinder cooling water pump**
The values for the delivery head and capacity required for selection of the centrifugal pumps for the cylinder cooling water system (one on stand-by) are given in F1.
The delivery head has to be determined according to the total pressure losses (resistance) of the actual arrangement of the piping installation, as for a non-pressurized system.
The system pressure (p_{ei}) at the engine inlet will be:

$$p_{ei} = p_p + p_{st} - d_p - \frac{h}{10.2} \text{ [bar]}$$

where :
– p_p : pump delivery head [bar]
– p_{st}: static pressure at pump inlet [bar]
– d_p: pressure losses [bar] between pump outlet and engine inlet
– h : height difference [m] between pump outlet and engine inlet.

The pressure (p_{ei}), related to liner top, has to be:
Minimum = 4.5 bar
Maximum = 5.5 bar

A centrifugal pump with a steep head/capacity curve is to be given preference. As opposed to a flat head/capacity curve, a steep head/capacity curve results in smaller variation in flow capacity when the head varies. The differential pressure at the pump varies markedly with the flow capacity, so that the reading of the pump pressure gauges give relatively accurate indication of the actual flow.

– **Buffer unit** (021)
  The required static water pressure at the pump inlet is obtained by the use of a buffer unit shown in in figure F4 which an air cushion with constant and controlled pressure is maintained. The buffer unit acts as volume-compensating device, the water volume can expand or contract without altering the system pressure. In case the cooling water pumps should stop due to power failure, the cooling system remains pressurized thus avoiding vapour formation in the system.
  The initial filling of the buffer unit should be just above the low level alarm, i.e. at approx. 30 % of its total capacity. The large air cushion, available in the buffer unit can so partly compensate the expansion or contraction of the water volume without bringing the control air pressure unit into operation. In this way, continuous operation of this unit is avoided. Figure F4 shows, as example only, a possible design for the buffer unit. The final design must meet the requirements of the concerned classification societies. The working pressure indicated on this figure can vary, depending on the location of the main water pumps with regard to the engine cooling water inlet. The recommended buffer unit capacities for the RT-flex84T-D are indicated in figure F4. The buffer unit contains the following main equipment:
  - A control air pressure unit (DN15, pressure range adjustable 3–5 bar), which reduces the supply air pressure (7 bar, filtered air) to the required static pressure and automatically maintains it constant.
  - A solenoid valve, fitted upstream of the control air pressure unit, interlocks the air inlet with the min. water level in the buffer unit.
  - A relief valve DN25, adjusted to approx. 5.5 bar.
  - High and low level switch to control the supply pump. The low level switch is set at approx. 35 % of the total content of the buffer unit. The difference between the high and low level should correspond to a volume of approx. 150 l.
  - Low and high level alarm. The low level is set at approx. 30 % of the total capacity of the buffer unit.

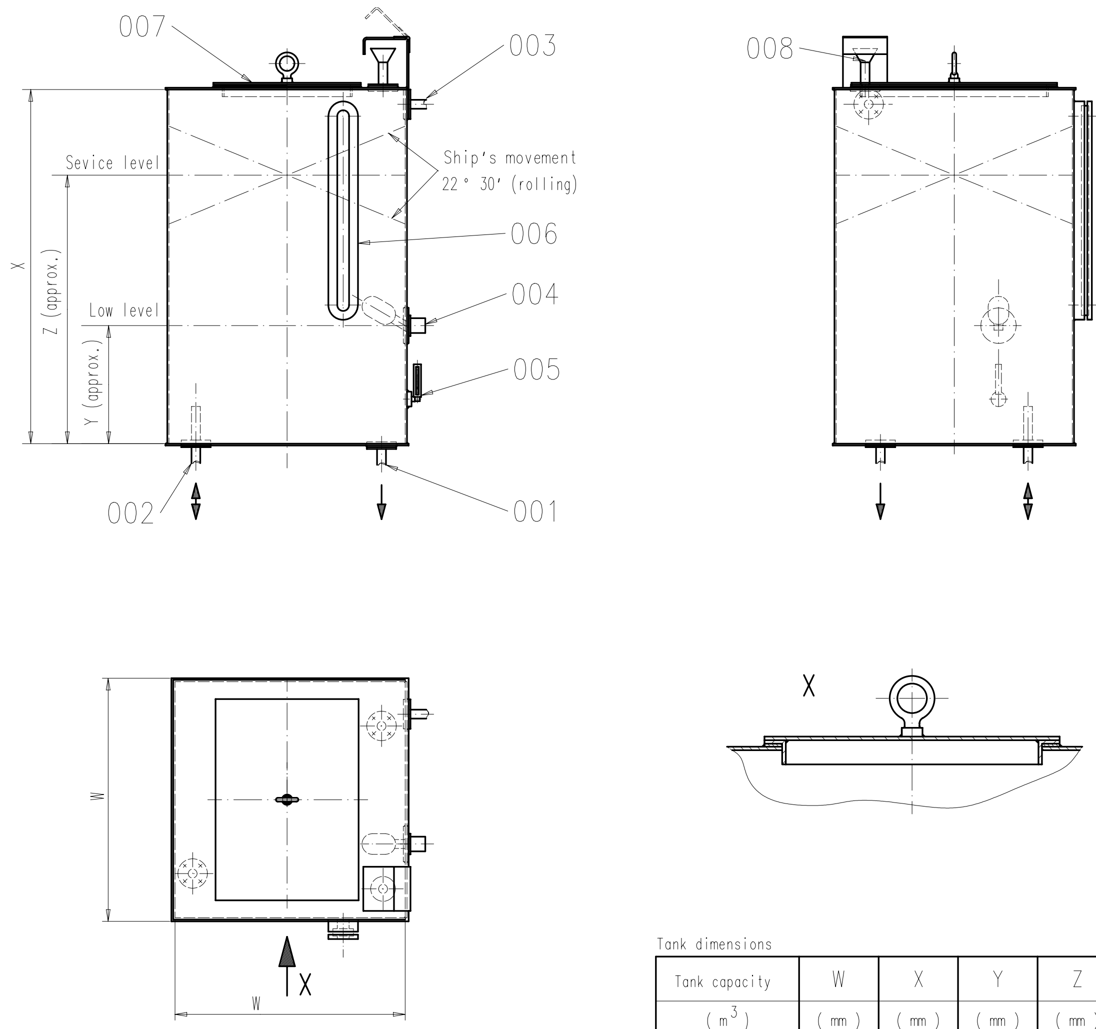
  The compensation pipe should be led by the shortest route close to the pump suction. With the buffer unit close to the cooling water pumps, a module including all main components of the cooling system can easily be realized.
  The pipe sizes and tank capacities are given in table F2.

– **Cylinder water cooler** (025)
  - Cooler type: tubular or plate
  - Heat dissipation: refer to table F1.
  - Margin for fouling: 10 % to 15 % to be added
  - Flow rates: refer to table F1.
  - Temperature ranges: refer to table F1.

  The cylinder cooler should be selected to remove the total heat transferred from the engine to the cooling water, whatever the capacity of the freshwater generator may be. To determine the cooler capacity, please refer to heat dissipation in table F1.

– **Supply pump** (026)
  A positive displacement supply pump with a capacity of 0.5 m^3/h, 7 bar, is provided to replace the leakage water losses in the cylinder cooling water system. This pump is automatically controlled by the water level in the buffer unit (021) as described under paragraph headed ‘Buffer unit’. It would be also advisable to monitor the running period of the supply pump. A monitoring of the pump running period will warn when the running period exceeds a preset value, indicating unusual water losses in the system. Spare parts for the supply pump must be available according to classification societies’ requirements.

– **Automatic temperature control valve**
Electric or electro/pneumatic actuated three-way type (butterfly valves are not adequate) having a linear characteristic.
- Design pressure: 10 bar
- Test pressure: refer to the specification laid down by the classification society.
- Pressure drop across valve: max. 0.5 bar
- Controller: proportional plus integral (PI); also known as proportional plus reset for steady state error of max. ±2 °C and transient condition error of max. ±4 °C.
- Temperature sensor:
  according to the control valve manufacturers specification fitted in the engine outlet pipe.



Tank dimensions

Tank capacity	W	X	Y	Z
(m^3)	(mm)	(mm)	(mm)	(mm)
0.5	800	800	330	640
0.75	800	1200	500	960
1.0	800	1600	670	1280
1.25	1000	1250	530	1000
1.5	1000	1500	630	1200
1.75	1000	1750	730	1400
2.0	1000	2000	830	1600

001 Drain
002 Balance pipe from LT circuit
003 Overflow / air vent
004 Low level alarm
005 Thermometer
006 Level indicator *1)
007 Inspection cover *2)
008 Filling pipe / inlet chemical treatment *2)

Remarks:
*1) Level indicator can be omitted if an alternative is fitted.
*2) Other designs (like hinged covers etc) are also possible.
*3) Depending on actual ancillary plants. LT tank capacity to be increased accordingly.
— Required tank capacity depends on number of cylinders and ancillary plants.

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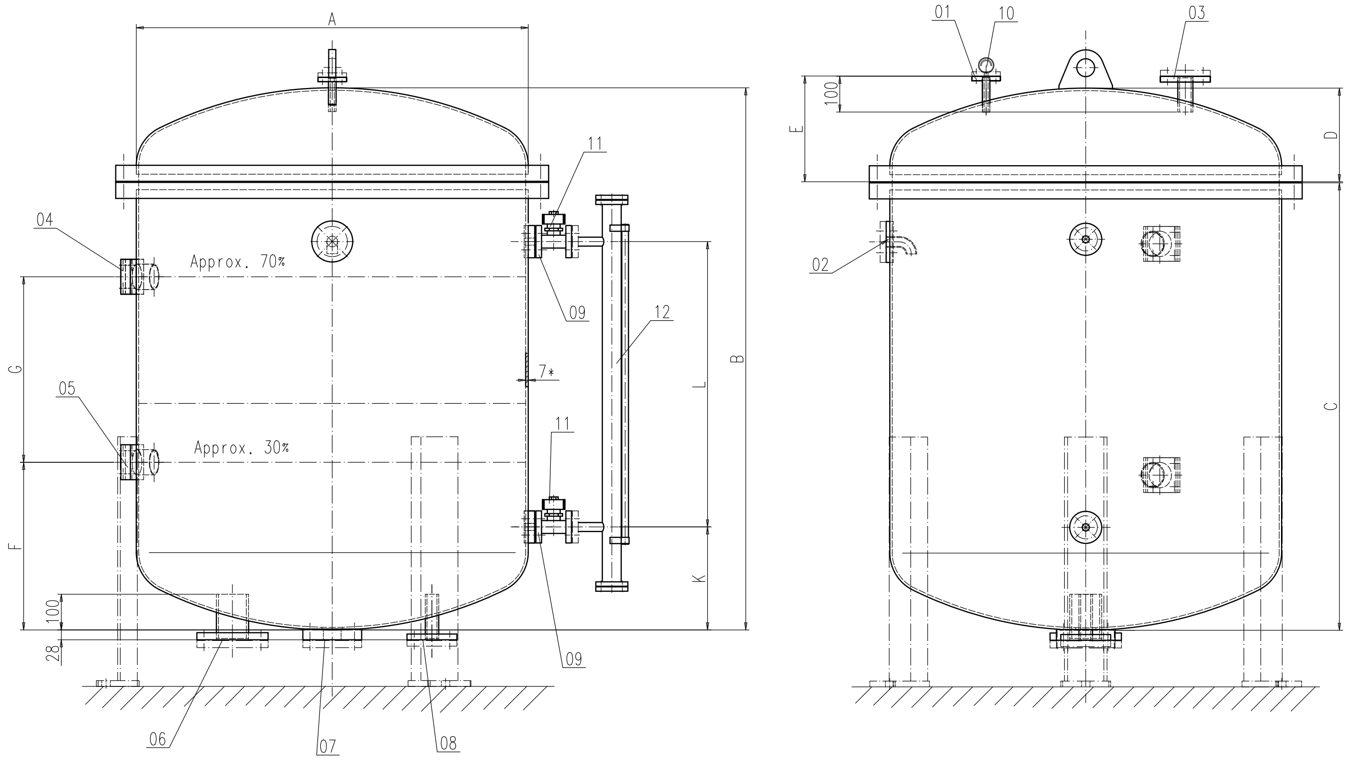
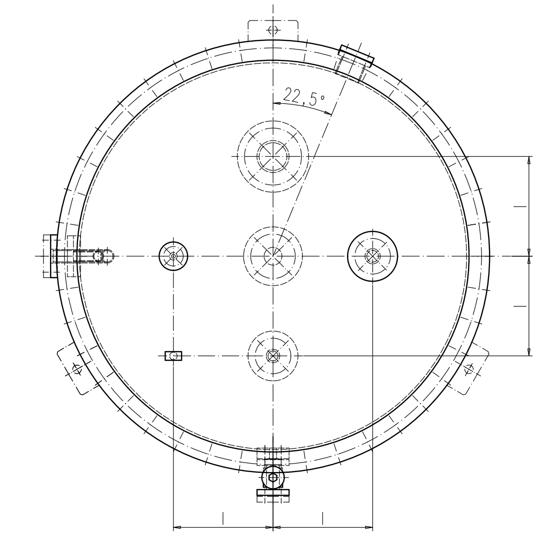
Fig. F3 Central cooling water system expansion tank (LT circuit)

F. Ancillary systems





Connections for:

01 Compressed air supply 3-5 bar, DN15 with blank flange
02 Pressure indicator, DN25 with blank flange
03 Safety and relief valve adjustment 5,5 bar DN32 with blank flange
04 Level alarm high, with blank flange
05 Level alarm low, with blank flange
06 Compensation, DN80 with blank flange
07 Drain, DN50 with blank flange
08 Feed, DN32 with blank flange
09 Flanges for level indicator
10 Pressure indicator
11 Valve for level indicator
12 Level indicator with level switch high / low

Capacity	A	B	C	D	E	F	G	H	I	K	L
800l	ø900	1430	1205	222	250	455	520	600	250	250	800
1200l	ø1100	1520	1255	262	300	470	520	650	280	290	800

Working pressure : 5 bar
* Wall thickness and test pressure : according to relevant classification society/rules
Service temperature : max. 95°C

245.626c

Fig. F4 Buffer unit for cylinder cooling water system

F2.1.2 General recommendations for design

The number of valves in the system is to be kept to a minimum in order to reduce the risk of incorrect setting.

Valves are to be locked in the set position and labelled to eliminate incorrect handling.

The possibility of manual interference of the cooling water flow in the various branches of the cylinder cooling water system is to be avoided by installing and setting throttling discs at the commissioning stage and not by adjusting the valves.

Under normal operation of the cylinder cooling water system the pump delivery head and the total flow rate are to remain constant even when the fresh water generator is started up or shut down.

The cylinder cooling water system is to be totally separated from steam systems. Under no circumstances are there to be any possibilities of steam entering the cylinder cooling water system, e.g. via a fresh water generator.

The installation of equipment affecting the controlled temperature of the cylinder cooling water is to be examined carefully before being added. Uncontrolled increases or decreases in cylinder cooling water temperature may lead to thermal shock of the engine components and scuffing of the pistons. Thermal shock is to be avoided and the temperature gradient of the cooling water when starting and shutting down additional equipment is not to exceed two degrees per minute at the engine inlet.

The design pressure and temperature of all the component pipes, valves, expansion tank, fittings, etc., are to meet the requirements of the classification society.

F2.1.3 Cooling water treatment

Correct treatment of the cooling fresh water is essential for safe engine operation. Only totally demineralized water or condensate must be used. In the event of an emergency tap water may be used for a limited period but afterwards the entire cylinder cooling water system is to be drained off, flushed, and recharged with demineralized water.

Recommended parameters for raw water

- min. pH 6.5
- max. 10 °dH
  (corresponds to 180 mg/l $CaCO_3$) *1)
- max. 80 mg/l chloride
- max. 150 mg/l sulphates

*1) In case of higher values the water is to be softened.

In addition, the water used must be treated with a suitable corrosion inhibitor to prevent corrosive attack, sludge formation and scale deposits, refer to the chemical supply companies for details. Monitoring the level of the corrosion inhibitor and water softness is very important to prevent down-times due to component failures resulting from corrosion or impaired heat transfer. No internally galvanized steel pipes should be used in connection with treated fresh water, since most corrosion inhibitors have a nitrite base. Nitrites attack the zinc lining of galvanized piping and create sludge.

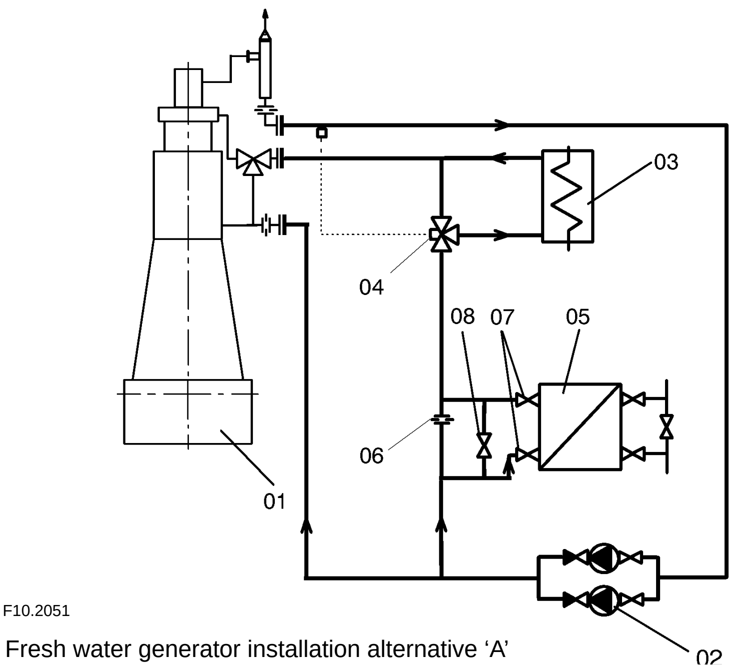
F2.1.4 Fresh water generator

A fresh water generator, utilizing heat from the cylinder cooling system to distil seawater, can be used to meet the demand for washing and potable water. The capacity of the fresh water generator is limited by the amount of heat available which in turn is dependant on the service power rating of the engine. It is important at the design stage to ensure there are sufficient safeguards to protect the main engine from thermal shock when the fresh water generator is started. To reduce such risk, the use of valves, e.g., butterfly valves at the fresh water generator inlet and in the bypass line, which are linked and actuated with a large reduction ratio, will be of advantage. The following installations are given as examples and we recommend that the fresh water generator valves (7 and 8) be operated by progressive servomotors and a warning sign be displayed on the fresh water generator to remind engine-room personnel of the possibilities of thermal shocking if automatic start up is overridden.

WARNING!
Avoid thermal shock to your main engine. The fresh water generator inlet and outlet valves to be opened and closed slowly and progressively.

It is important that the bypass with valve (08) has the same pressure drop as the freshwater generator.
This must be open when the freshwater generator is not in operation and closed when the freshwater generator is operating. To avoid wrong manipulation we recommend to interlock valves 07 and 08.
Figures F5 and F6 ‘Freshwater generator installation alternative’ provide two systems designed to utilize in ‘A’ up to **50** % of available heat and ‘B’ up to 85 % of available heat.

Alternative A
Freshwater generators with an evaporator heat requirement not in excess of **50** % of the heat available to be dissipated from the cylinder cooling water at full load (CMCR) and only for use at engine loads above **50** %, can be connected in series as shown in figure F5. The throttling disc (06) serves to correct the water flow rate if the pressure drop in the cooling circuit is less than that in the freshwater generator circuit. It is to be adjusted so that the cylinder cooling water pressure at the engine inlet is maintained within the pressure range of the summarized data in table C5 when the freshwater generator is started up and shut down.



01 Main engine
02 Cylinder cooling water pump
03 Cylinder cooling water cooler
04 Automatic temperature control valve
05 Freshwater generator
06 Throttling disc
07 Freshwater valves
08 Freshwater generator by-pass valve

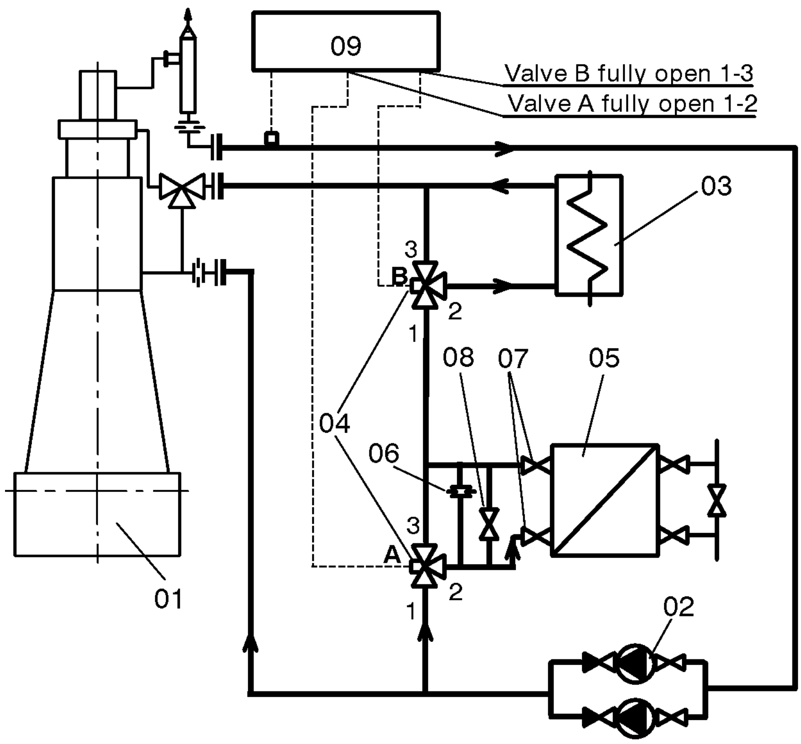
Fig. F5 Fresh water generator installation alternative ‘A’

Alternative B

A freshwater generator with an evaporator heat requirement not in excess of 85 % of the heat available to be dissipated from the cylinder cooling water at full load (CMCR), can be connected in series as shown in figure F6 . This arrangement requires the provision of an additional automatic temperature control valve (04A) connected in cascade control with the cylinder cooling water cooler temperature control valve (04B), and controlled by the step controller (09) sensing the outlet cylinder cooling water temperature from the engine. If the engine cylinder cooling water outlet temperature is falling below the set point, the valve (04A) reduces the flow of cylinder cooling water to the freshwater generator to compensate. A part of the cylinder cooling water is then routed directly to the engine inlet connection until the normal temperature is attained. This means that the freshwater generator can be kept in continuous operation, although the generated freshwater volume decreases due to the reduced flow of hot water to the evaporator

When the freshwater generator cannot dissipate all the heat in the cylinder cooling water, the valve (04A) is fully opened across connections 1 and 2 and a valve travel limit switch changes the regulation of the cylinder cooling water temperature to temperature control valve (04B). This in turn passes water to the cylinder cooling water cooler (03) to maintain the engine cylinder water outlet at the required temperature. If in this condition the engine cylinder cooling water temperature falls below the set point and the cooler (03) is fully bypassed, the valve (04B) is fully opened across connections 1 and 3 and a valve travel limit switch transfers regulation of the cylinder cooling water temperature back to temperature control valve (04A).

As an alternative to a single step controller (09) two controllers can be installed, one for each valve, making sure that there is a 3 °C difference in the set point between (04A) and (04B) to avoid both controllers acting at the same time.



01 Main engine
02 Cylinder cooling water pump
03 Cylinder cooling water cooler
04 Automatic temperature control valve
05 Freshwater generator
06 Throttling disc
07 Freshwater valves
08 Freshwater generator by-pass valve
09 Controller

F10.2050

Fig. F6 Fresh water generator installation alternative ‘B’

The quantity of **f**resh **w**ater (FW) produced by a single-effect vacuum (flash) evaporator can be estimated for guidance purposes as follows:

$$\text{FW produced in t/day} = 32 \cdot 10^{-3} \cdot Q_{FW}$$

where Q_{FW} is the available heat in kW from the cylinder cooling water, estimated from the derating table in section F1.2.

Example for alternative 'A'

7RT-flex84T-D – R1 specification of 29 400 kW at 76 rpm fitted with central cooling system and single-stage scavenge air cooler. The available heat (from table F1) is 4768 kW. Alternative 'A' utilizes up to 50 per cent of the available heat therefore there is 2384 kW of heat available. Substitute this value in the equation:

FW produced in t/day = constant · available heat

$$\text{FW produced in t/day} = 32 \cdot 10^{-3} \cdot 2384$$

FW produced in **t/day = 76**

Example for alternative 'B'

7RT-flex84T-D – R1 specification of 29 400 kW at 76 rpm fitted with central cooling system and single-stage scavenge air cooler. The available heat (from table F1) is 4768 kW. Alternative 'B' utilizes up to 85 per cent of the available heat therefore there is 4052 kW of heat available. Substitute this value in the equation:

FW produced in t/day = constant · available heat

$$\text{FW produced in t/day} = 32 \cdot 10^{-3} \cdot 4052$$

FW produced in **t/day = 130**

For more information a **"Concept Guidance"** showing installation options for freshwater generators is available; please ask WCH.
The indicated values for evaporator heat requirement and load in alternative A and B (i.e. 50 % and 85 % respectively) are only applicable if there are **no additional heat consumers** installed (e.g. feed water pre-heater for waste heat recovery, etc.).

F2.1.5 Pre-heating

To prevent corrosive liner wear when not in service or during short stays in port, it is important that the main engine is kept warm. Warming-through can be provided by a dedicated heater as shown in figure F2 'Central fresh water cooling system', using boiler raised steam or hot water from the diesel auxiliaries, or by direct circulation from the diesel auxiliaries.

If the main cylinder water pump is to be used to circulate water through the engine during warming up, the heater is to be arranged parallel with the cylinder water system and on / off control provided by a dedicated temperature sensor on the cylinder water outlet from the engine. The flow through the heater is set by throttling discs, and not by valves, to assure flow through the heater.

If the requirement is for a separate pre-heating pump, a small unit of 5 % or 10 % of the main pump capacity and an additional non-return valve between the cylinder cooling water pump and the heater are to be installed (please compare the values of pos 015 in tables F2 and F1). In addition, the pumps are to be electrically interlocked to prevent two pumps running at the same time.

Before starting and operating the engine, a temperature of 60 °C at the cylinder cooling water outlet of the main engine is recommended. If the engine is to be started below the recommended temperature, engine power is not to exceed 80 % of CMCR until the water temperature has reached 60 °C.

To estimate the heater power capacity required to achieve 60 °C, the heating-up time and the engine ambient temperature are the most important parameters. They are plotted on the graph shown in figure F7 to arrive at the required capacity per cylinder; this figure is multiplied by the number of cylinders to give the total heater capacity required.

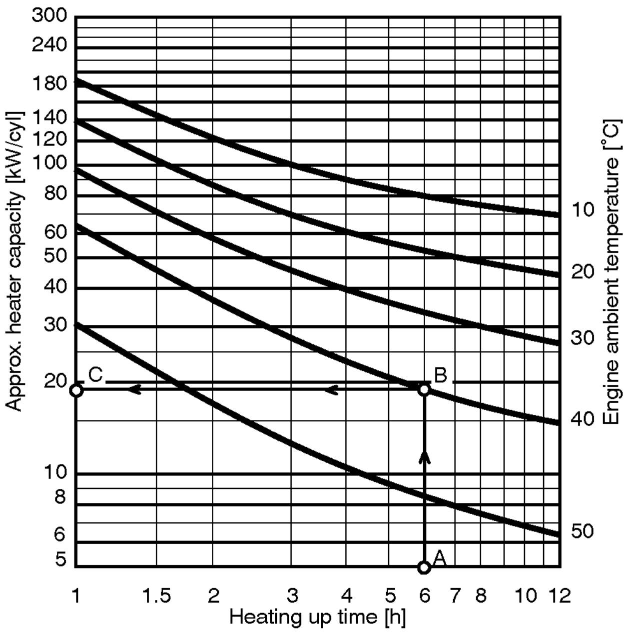


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Fig. F7 Pre-heating power requirement

Example for 7RT-flex84T-D

– Estimated heating-up time: 6 h.
– Engine ambient temperature: 40 °C.
– Required engine temperature: 60 °C.
  From the graph in figure F7:
  - the approximate amount of heat per cylinder is 19 kW.
  - heater capacity required is
    7 · 19 kW = 133 kW.

If the requirement for warming up is from the cooling water system of the diesel auxiliaries, it is essential that the amount of heat available at normal load is sufficient to warm the main engine. If the main and auxiliary engines have a cooling water system which can be cross-connected, it is important to ensure that any pressure drop across the main engine, when the cross-connection is made, does not affect the cooling water pressure required by the auxiliaries. If the cooling water systems are separate then a dedicated heat exchanger is required to transfer the heat to the main cylinder water system.

F2.2 Lubricating oil systems

Engine lubrication is achieved using two separate systems, the main lubricating system, including turbochargers, and the cylinder lubricating system.

F2.2.1 Lubricating oil systems for turbochargers

The ABB TPL and Mitsubishi MET turbochargers feature journal bearings which are lubricated from the engine's lubricating system.
As an option, a separate lubricating system (fig. F10 and F11) which only serves the turbochargers can be supplied. For more information please contact WCH.
For lubricating oil of turbochargers equipped with separate lub. oil systems, the recommendations given by the supplier must be observed.

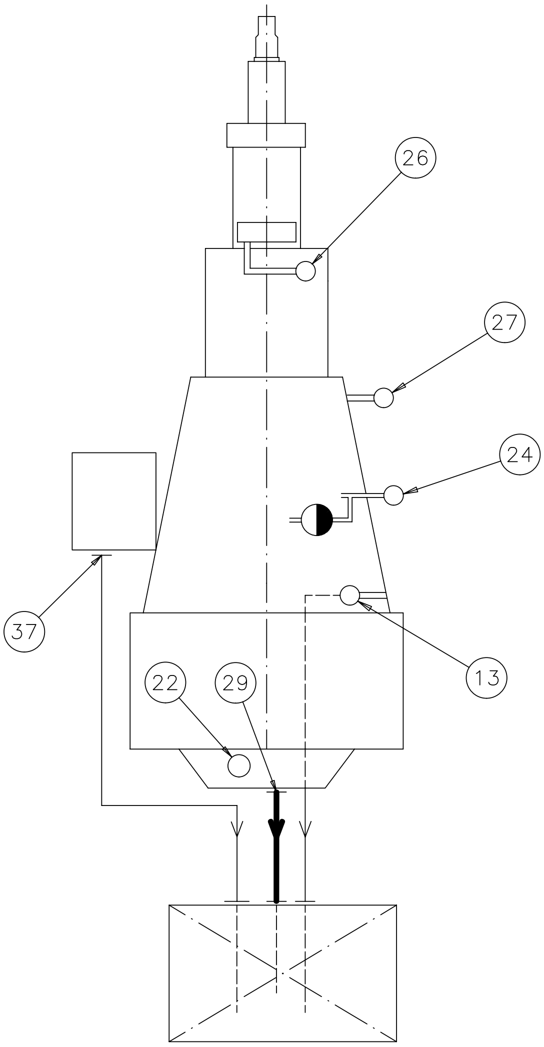
F2.2.2 Main lubricating oil system

Specifications for the engine lubrication that need to be met are shown in figure F8.
The main lubricating system for the engine lubrication, as shown in figure F9, comprises a combined low- and high-pressure system supplied from the lubricating oil drain tank. The low-pressure circuit supplies the main bearings, including turbochargers. The high-pressure circuit supplies the crosshead bearings and the connecting rod bottom-end bearings

The main bearing oil is also used to cool the piston crown, to lubricate and cool the torsional damper and the axial damper (detuner), and to feed the high-pressure circuit.
A schematic arrangement of the lubricating oil system on the engine is shown in figure F12.

F. Ancillary systems

Specifications for the engine lubrication that need to be met



13	Flushing oil outlet pipe - automatic filter
22	Lubricating oil drain from bedplate horizontal - FOR TESTBED ONLY! Not connected.
24	Lubricating oil inlet - Lubricating oil temperature: 40–50°C - Lubricating oil pressure 2.7–4.5 bar - Lubricating oil volume flow according to winGTD spec - Lubricating oil cleanliness: filtered by 50 micron absolute (sphere passing mesh) filter
26	Cylinder lubricating oil inlet - Cylinder lubricating oil temperature: 40^{+10}_{-5} °C - Cylinder lubricating oil static pressure: 0.4 bar
27	Crosshead lubricating oil inlet - Lubricating oil temperature: 40–50°C - Lubricating oil pressure 10.0–12.0 bar - Lubricating oil volume flow according to winGTD spec - Lubricating oil cleanliness: filtered by 50 micron absolute (sphere passing mesh) filter
29	Lubricating oil drain from bedplate vertical - Drain to lubricating oil drain tank: drain pipe positions to be clarified between shipyard and engine manufacturer
37	Leakage servo oil pipe from supply unit - Drain to lubricating oil drain tank: drain pipe positions to be clarified between shipyard and engine manufacturer

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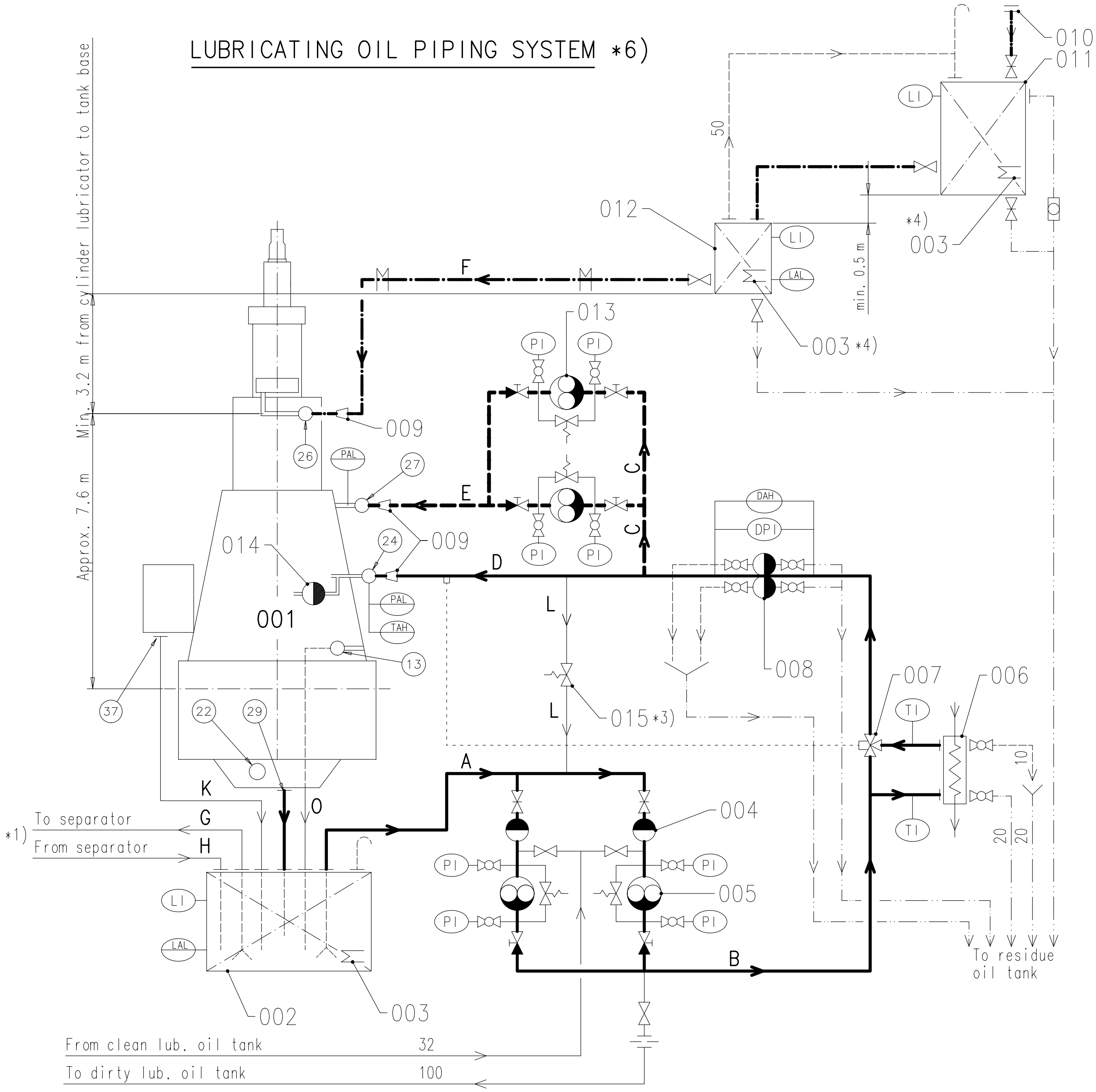
Fig. F8 Connections and specifications for the engine lubrication



Bearing lub. oil pipes
Crosshead lub. oil pipes
Cylinder lub. oil pipes
Cylinder lub. oil pipes, trace heated and insulated
Pipes on engine / pipe connections
Transfer/dirty lub. oil pipes
Overflow/drain pipes
Air vent pipes

Note: For legend see table F3

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Remarks:

*1) The pipe diameters for the lub. oil separator are sized according to the effective throughput capacity of the separator and according to the separator's manufacturer recomendations.

*3) The by-pass line with the pressure control valve can be omitted if the main lubricating oil pumps have a built-in pressure control and safety valve or if centrifugal pumps are used.

*4) Optional heating coil.

*6) Alternative executions are possible.

— Air vent pipes and drain valves where necessary.

— Air vent and drain pipes must be fully functional at all inclination angles of the ship at which the engine must be operational.

Fig. F9 Lubricating oil system

F. Ancillary systems

001 Main engine RT-flex84T-D
002 Lubricating oil drain tank
003 Heating coil
004 Suction filter
005 Lubricating oil pump *5)
006 Lubricating oil cooler
007 Automatic temperature control valve; constant temp. at engine inlet: 45 °C
008 Lubricating oil filter
009 Reduction piece (only when required)
010 Deck connection
011 Cylinder lubricating oil storage tank *2)
012 Cylinder lubricating oil service tank
013 Crosshead lubricating oil pump
014 Automatic oil filter (on the engine)
015 Pressure control valve
13 Flushing oil outlet pipe, automatic filter
22 Lubricating oil drain from bedplate, horizontal, for testbed only
24 Lubricating oil inlet
26 Cylinder lubricating oil inlet
27 Crosshead lub. oil inlet
29 Lubricating oil drain from bedplate, vertical
37 Servo oil leakage pipe supply unit

Remarks:
– All tank and pump capacities as well as the pipe diameters are layout including the integrated TC lubrication, but excluding any possibly installed damper and PTO gears. In case of damper and/or PTO gear installation or separated TC lubrication, the capacities need to be adopted accordingly. for selecting the appropriate pipe diameters, please refer to “Fluid velocities and flow rates: recommended values for pipework of diesel plants”.
*2) Alternatively, the cylinder oil can be fed directly from the storage tank by gravity to the lubricators. If this arrangement is preferred, the storage tank is to be located at the same height as requested for the service tank and the feed pipe to the lubricators is provided with a flow meter. This pressure loss resulting from the flowmeter has to be compensated by increasing the min. height from cylinder lubricator to the tank base and/or the pipe diameter, accordingly.
*5) The lub. oil pumps (pos. 005) and the crosshead lub oil pumps (pos. 013) are to be interlocked so that the crosshead lub. oil pumps never can run alone.

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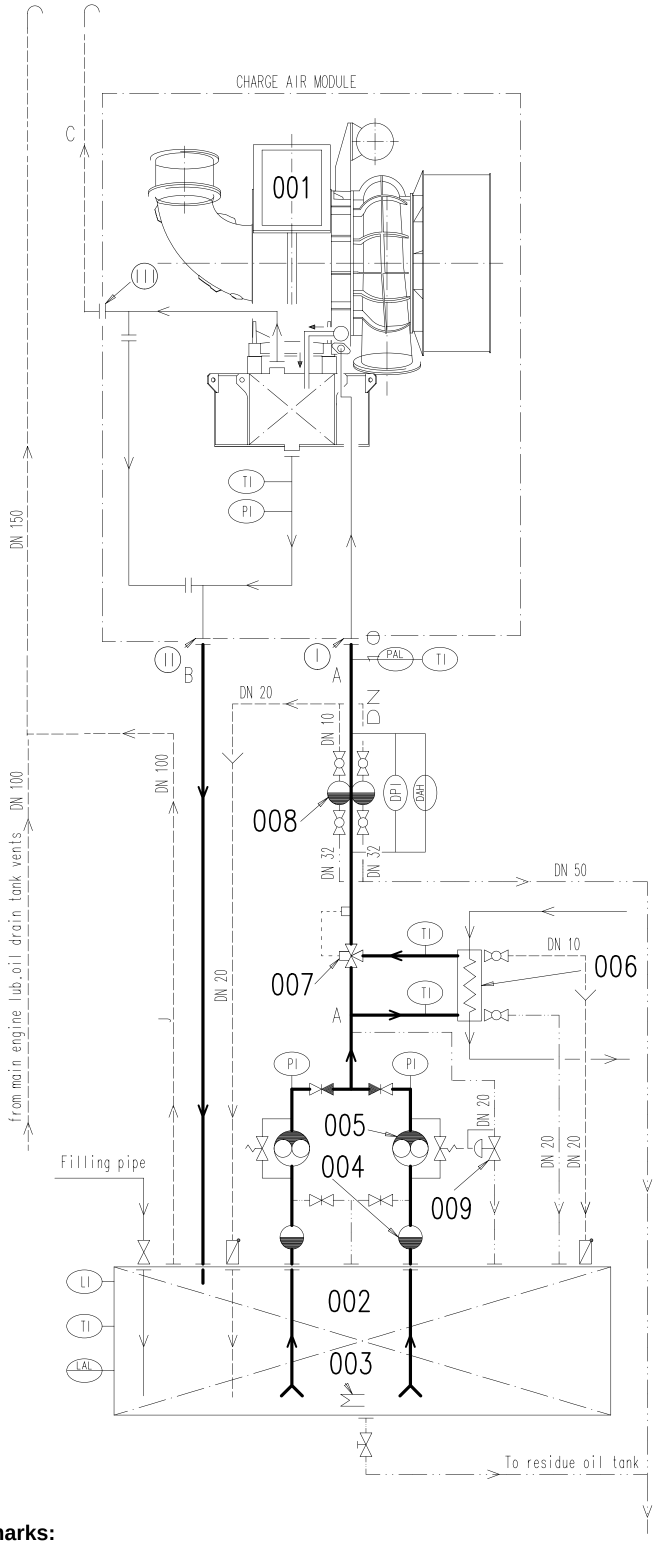
Number of cylinders			5	6	7	8	9
Main engine RT-flex84T-D (R1)	power	kW	21 000	25 200	29 400	33 600	37 800
	speed	rpm	76				
Lub. oil drain tank	cap.	m^3	For capacities see figure F23				
Cylinder lub. oil storage tank	cap.	m^3	based on a consumption of approx. 0.7 g/kWh (pulse)				
Cylinder lub. oil service tank	cap.	m^3	0.8	0.9	1.0	1.2	1.3
Nominal pipe diameter	A	DN	300	350	350	350	400
	B	DN	250	300	300	300	300
	C	DN	150	150	150	150	200
	D	DN	250	250	250	300	300
All pipe diameters are valid for R1-rated engines and laid out for flows given in section F1.2 ‘Engine system data’.	E	DN	125	125	125	150	150
	F	DN	40	40	40	40	40
For pipe diameters if Rx-rated pump capacities are used, please refer to section F4 ‘Pipe size and flow details’.	G	DN	40	50	50	50	50
	H	DN	32	40	40	40	40
	K	DN	100	100	100	100	100
	L	DN	50	65	65	80	80
	O	DN	25	25	25	25	25

Remarks:
– All capacities and given diameters are valid for the engines excl. oil flow for damper and PTO-gear.
– The pipe diameters for the lub. oil separator are sized acc. to the effective throughput capacity of the separator and acc. to the manufacturers recommendations for the separator.

Table F3 Lubricating oil system: referring legend, remarks and data



TPL85-B			
Lub.oil tank	min. residual capacity	m^3	1,0
	total capacity	m^3	*1)
Lub.oil pump *2)	capacity	m^3/h	Refer to winGTD
	capacity	l/min	
	*3) delivery	bar	4,0
	min. pre-lubrication time	min	5,0
	min. post-lubrication time	min	7,0
Blow-By	capacity	m^3/h	*4)
	capacity	l/min	
Nominal pipe diameter	A	DN	65
	A	dia mm	ø 76,1x2,9
	B	DN	100
	B	dia mm	ø 114,3x3,6
	C	DN	80
	C	dia mm	ø 88,9x3,2

Data for other turbochargers available on request.

001 Turbocharger ABB TPL
002 Lubricating oil drain tank
003 Heating coil
004 Suction filter
005 Lubricating oil pump
006 Lubricating oil cooler
007 Automatic temperature control valve
008 Lubricating oil filter
009 Pressure regulating and safety valve

I Lubricating oil inlet *5)
II Lubricating oil outlet *5)
III Air vent *5)

Bearing lub. oil pipes
Transfer/dirty lub. oil pipes
Overflow/drain pipes
Air vent pipes
Pipes on engine / pipe connections

Remarks:

*1) Total lub. oil tank capacity is 15 % higher.
*2) For pump capacity, temperatures and oil viscosity, please refer to the winGTD program.
*3) Delivery head must be according to the actual piping layout.
*4) For corresponding data, please refer to manufacturer of turbocharger.
*5) See engine pipe connection plans in section F5 for the numbering of pipe connections.
— Air vent and drain pipes must be fully functional at all inclination angles of the ship at which the engine must be operational.

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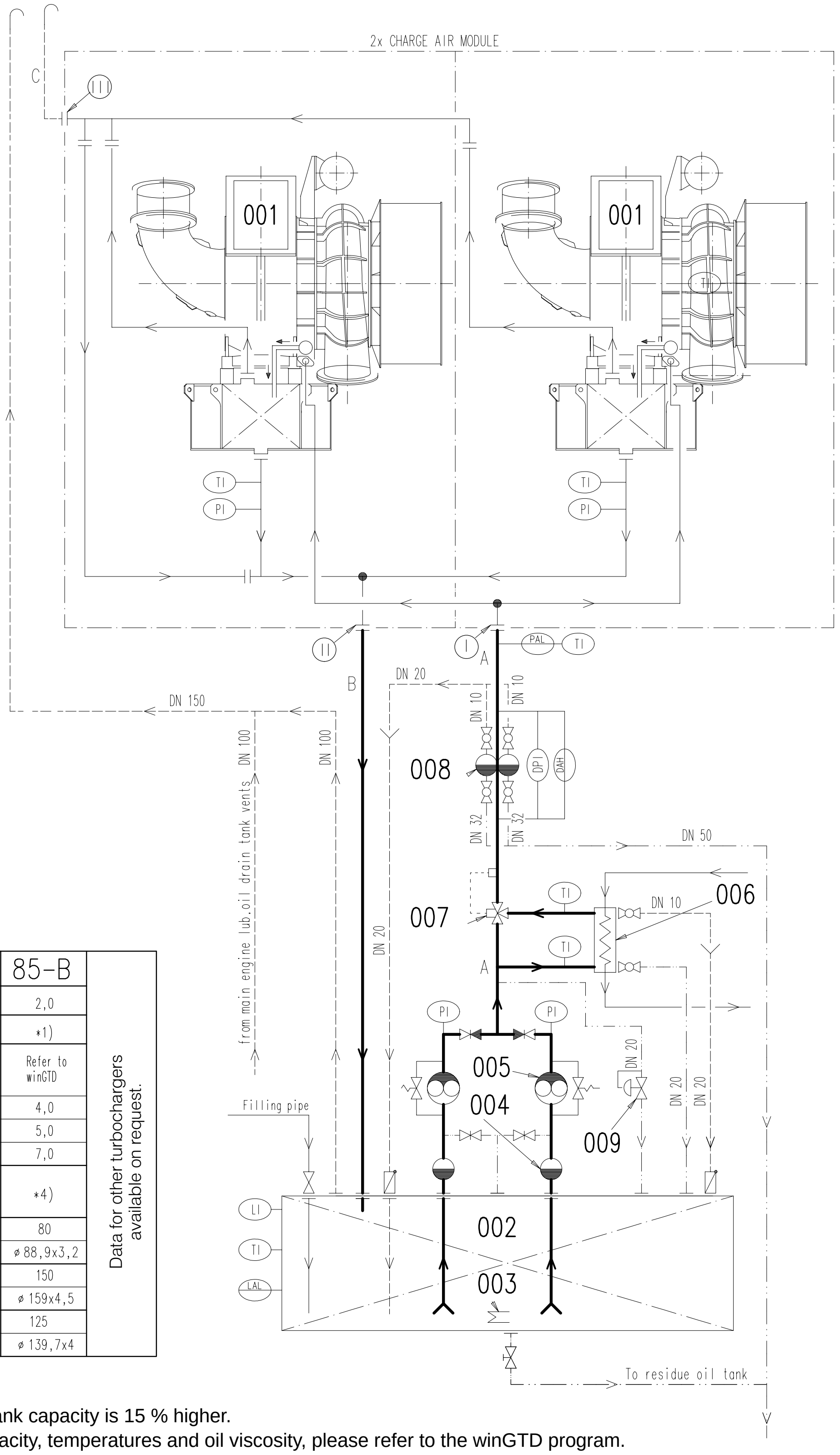
Fig. F10 Lubricating oil system for 1 x ABB-TPL85-B turbochargers

F. Ancillary systems



- Bearing lub. oil pipes
- Transfer/dirty lub. oil pipes
- Overflow/drain pipes
- Air vent pipes
- Pipes on engine / pipe connections

001 Turbocharger ABB TPL
002 Lubricating oil tank
003 Heating coil
004 Suction filter
005 Lubricating oil pump
006 Lubricating oil cooler
007 Automatic temperature control valve
008 Lubricating oil filter
009 Pressure regulating valve
I Lubricating oil inlet *5)
II Lubricating oil outlet *5)
III Air vent *5)

2x TPL			80-B	85-B	Data for other turbochargers available on request.
Lub.oil tank	min. residual capacity	m^3	1,5	2,0	
	total capacity	m^3	*1)	*1)	
Lub.oil pump *2)	capacity	m^3/h	Refer to winGTD	Refer to winGTD	
	capacity	l/min			
	*3) delivery	bar	4,0	4,0	
	min. pre-lubrication time	min	5,0	5,0	
	min. post-lubrication time	min	5,5	7,0	
Blow-By	capacity	m^3/h	*4)	*4)	
	capacity	l/min			
Nominal pipe diameter	A	DN	65	80	
	A	dia mm	ø 76,1x2,9	ø 88,9x3,2	
	B	DN	100	150	
	B	dia mm	ø 114,3x3,6	ø 159x4,5	
	C	DN	100	125	
	C	dia mm	ø 114,3x3,6	ø 139,7x4	

Remarks:

*1) Total lub. oil tank capacity is 15 % higher.
*2) For pump capacity, temperatures and oil viscosity, please refer to the winGTD program.
*3) Delivery head must be according to the actual piping layout.
*4) For corresponding data, please refer to manufacturer of turbocharger.
*5) See engine pipe connection plans in section F5 for the numbering of pipe connections.
— Air vent and drain pipes must be fully functional at all inclination angles of the ship at which the engine must be operational.

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246.701c

Fig. F11 Lubricating oil system for 2 x ABB-TPL80-B/85-B turbochargers

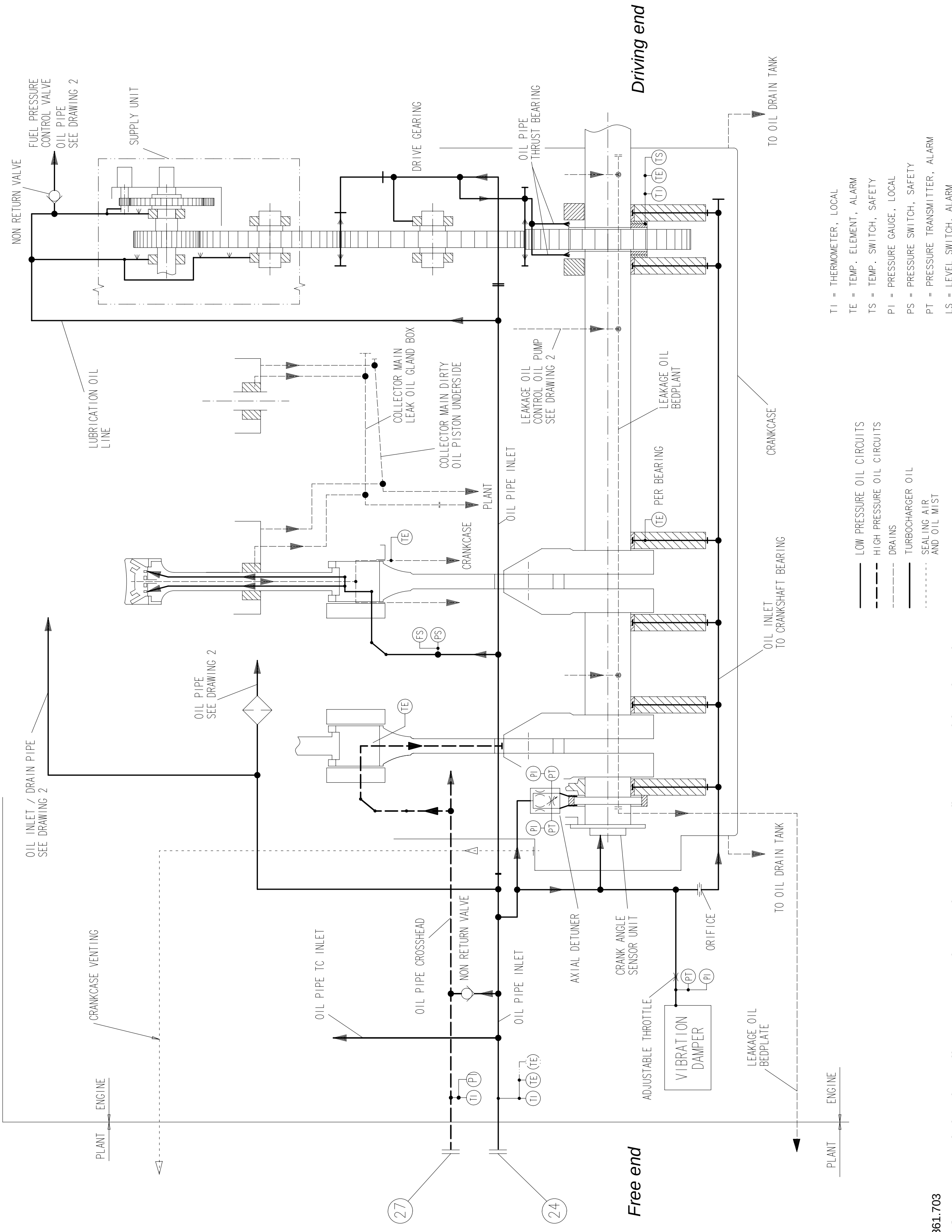

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Fig. F12 Lubricating oil system on the engines 5–7RT-flex84T-D (drawing 1)

F. Ancillary systems

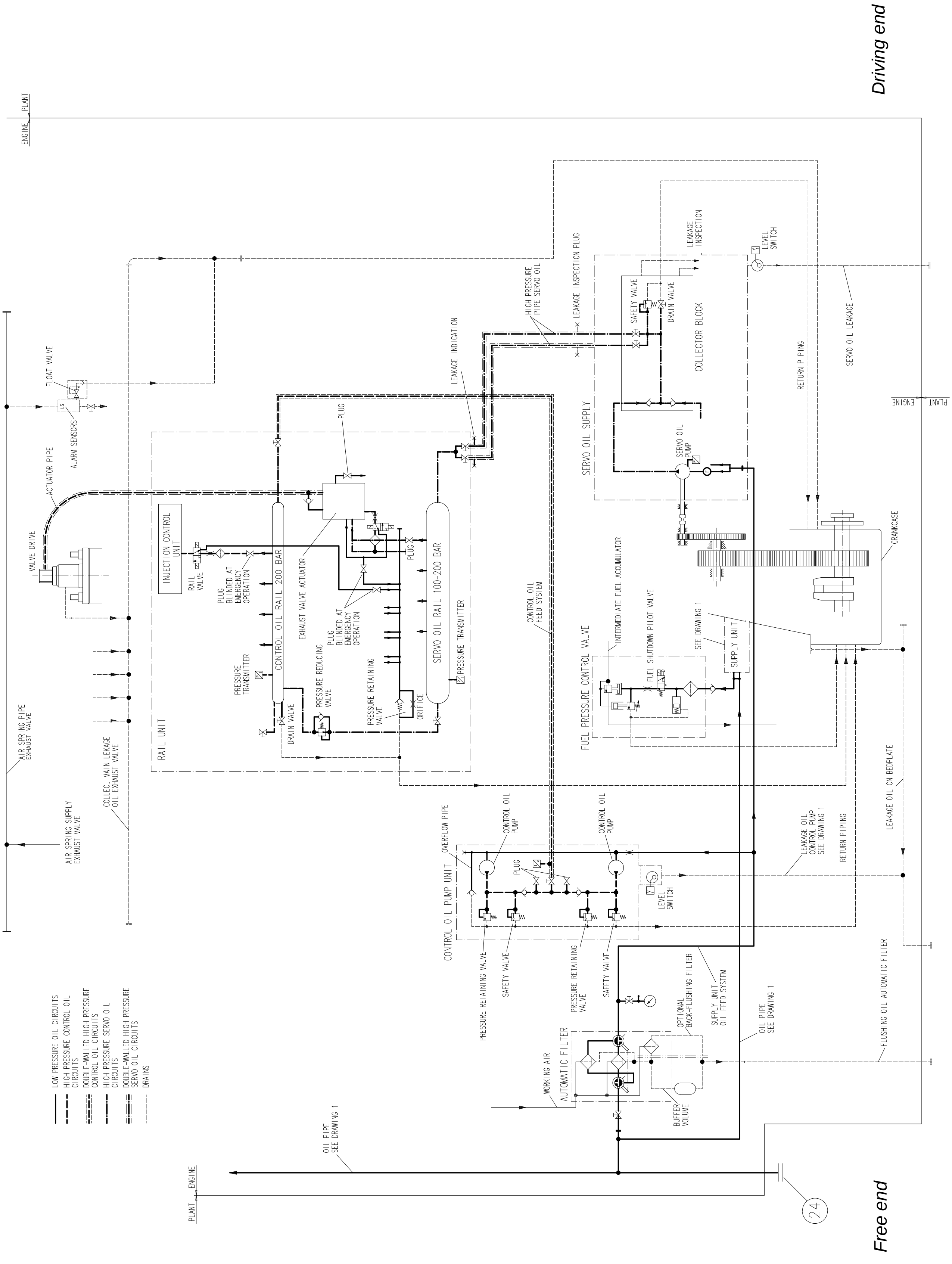

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Fig. F13 Lubricating oil system on the engine (drawing 2)

F2.2.3 Main lubricating oil system components

– **Low-pressure pump (main lub. oil)**
  - Positive displacement screw pumps having built-in overpressure relief valves or centrifugal pumps.
  - Pump capacity for positive displacement pump: refer to table F1, the given flow rate is to be within a tolerance of 0 % to +10 % plus the back-flushing flow of the automatic filter, if any.
  - Pump capacity for centrifugal pump: refer to table F1, the given flow rate is to be within a tolerance of –10 % to +10 % plus the back-flushing flow of the automatic filter, if any.
  - Delivery head: see table F1. The final delivery head to be determined is subject to the actual piping layout.
  - Working temperature: 60 °C
  - Oil type: SAE30, 50 cSt at working temperature, maximum viscosity to be allowed for when sizing the pump motor is 400 cSt.

– **Lubricating oil cooler**
  - Oil flow: refer to table F1
  - Type: plate or tubular
  - Cooling medium: fresh water or seawater
  - Heat dissipation: refer to table F1
  - Margin for fouling: 10 % to 15 % to be added
  - Oil viscosity at cooler inlet: 50 cSt at 60 °C
  - Oil temperature at inlet: approx. 60 °C
  - Oil temperature at outlet: 45 °C
  - Working pressure oil side: 6 bar
  - Working pressure water side: approx. 3 bar
  - Cooling water flow: refer to table F1.
  - Cooling water temperature:
    Fresh water 36 °C.

– **Lubricating oil full flow filters**
  - Type: change-over duplex filter designed for in-service cleaning, with differential-pressure gauge and high differential-pressure alarm contacts. **Alternatively**:
  - Type: automatic back-flushing filter with differential pressure gauge and high differential-pressure alarm contacts. Designed to clean itself automatically using reverse flow or compressed air techniques. The drain from the filter is to be sized and fitted to allow free flow into the residue oil tank. The output required by the main lubricating oil pump to ‘back flushing’ the filter without interrupting the flow is to be taken into account when estimating the pump capacity.
  - Test pressure: specified by classification society
  - Working pressure: 6 bar
  - Working viscosity: 95 cSt, at working temperature
  - Oil flow: refer to table F1, main lubricating oil capacity
  - Diff. pressure, clean filter: 0.2 bar max
  - Diff. pressure, dirty filter: 0.6 bar max
  - Diff. pressure, alarm: 0.8 bar max
  - Bursting pressure of filter inserts: min. 8 bar (= differential pressure across the filter inserts)
  - Filter material: stainless steel mesh
  - Mesh size: sphere passing max. 0.05 mm

– **High-pressure pump (crosshead lub. oil)**
  - Pump type: positive displacement screw or gear types having built-in overpressure relief valves.
  - Pump capacity: refer to table F1, the given flow rate is to be within a tolerance of 0 % to +10 %.
  - Delivery head: see table F1
  - Working temperature: approx. 45 °C
  - Oil type: SAE 30, 95 cSt

  (at working temperature, maximum viscosity to be allowed for when sizing the pump motor is 400 cSt).

F2.2.4 Cylinder lubricating oil system

Cylinder liner lubrication is carried out by a separate system included in figure F9 ‘Lubricating oil system’, working on the once-through principle using a high-alkaline oil of SAE 50 grade fed to the surface of the liner through hydraulically actuated quills. The oil supply rate is adjustable and metered to suit the age and running condition of the piston rings and liners. The arrangement of service tank (012) and storage tank (011) (figure F9) can be changed by locating the storage tank in place of the service tank. If this arrangement is preferred, the storage tank is to be located at the same height as a service tank to provide the necessary head and be of similar design ensuring a sloping tank floor. Refer to table A1 ‘Primary engine data’ for the cylinder lubricating oil consumption.

F2.2.5 Lubricating oil maintenance and treatment

It is very important to keep the engine lubricating oil as clean as possible. Water and solid contaminants held in suspension are to be removed using centrifugal separators operating in by-pass to the engine lubricating system as shown in figure F14 ‘Lubricating oil treatment and transfer’. Great care and attention has to be paid to the separators and filters to ensure that they work correctly. The separators are to be set up as purifiers and to be completely isolated from the fuel oil treatment systems, there is to be no possibility of cross-contamination.

F2.2.5.1 Lubricating oil separator

– Separator type: self-cleaning purifier
– **Minimum throughput capacity**
  0.140 · CMCR [litres/hour], CMCR in kW
– Example:
  7RT-flex84T-D with CMCR at R1: 29 400 kW
  Minimum throughput capacity
  0.140 · 29 400 = **4116 litres/hour**
– Rated separator capacity: the rated or nominal capacity of the separator is to be according to the recommendations of the separator manufacturer
– Separation temperature: 90–95 °C
  Please refer to manufacturer’s instructions.

F2.2.6 Lubricating oil requirements

The products listed in table F6 ‘Lubricating oils’ were selected in co-operation with the oil suppliers and are considered the appropriate lubricants in their respective product lines for the application indicated. Wärtsilä Switzerland Ltd does not accept any liability for the quality of the supplied lubricating oil or its performance in actual service.

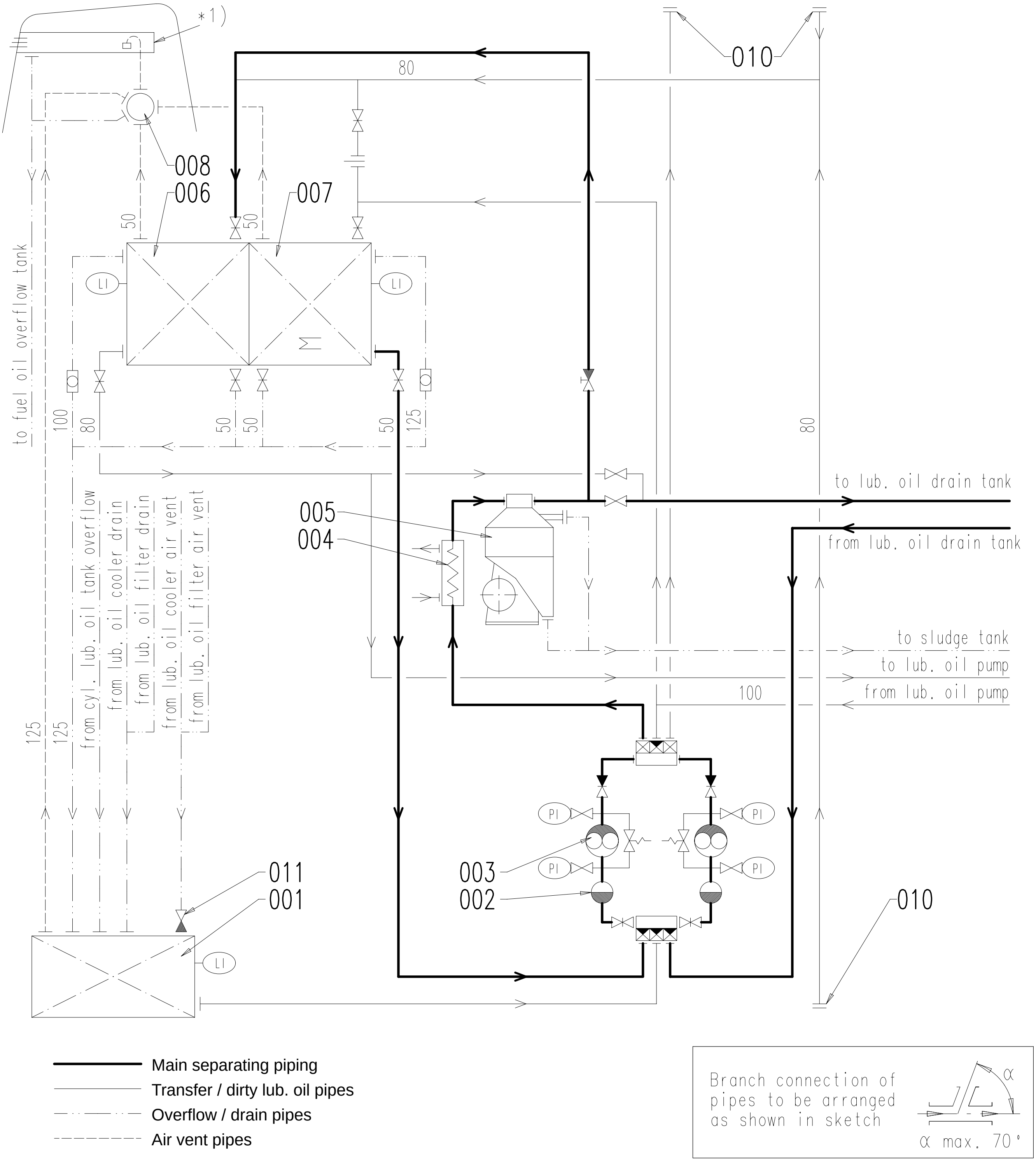
In addition to the oils shown in the mentioned list, there are other brands which might be suitable for the use in Wärtsilä two-stroke diesel engines. Information concerning such brands may be obtained on request from Wärtsilä Switzerland Ltd, Winterthur.

For the Wärtsilä RT-flex84T-D engines which are designed with oil-cooled pistons, the crankcase oils typically used as **system oil** have the following properties (see also table F5, ‘Global brands of lubricating oils’):

- SAE 30
- Minimum BN of 5 detergent properties
- Load carrying performance of the FZG gear machine method IP 334/90:
  FZG failure load stage 11
- Good thermal stability
- Antifoam properties
- Good demulsifying performance.

The cylinders in the engines are lubricated by a separate system, working on the once-through principle, i.e. fresh lubricating oil is directly fed into the cylinders to provide lubrication for the liners, pistons and piston rings.

For normal operating conditions, a high-alkaline marine cylinder oil of the SAE 50 viscosity grade with a minimum kinematic viscosity of 18.5 cSt at 100 °C is recommended. The alkalinity of the oil is indicated by its Base Number (BN).



Remarks:

*1) Vent chamber in funnel.

— Air vent pipes and drain valves where necessary.

— Air vent and drain pipes must be fully functional at all inclination angles of the ship at which the engine must be operational.

— Pipe diameters to be designed according to shipyard's practice considering component manufacturers recommendations.

Note:

For legend and tank capacities see table F4.

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Fig. F14 Lubricating oil treatment and transfer system

F. Ancillary systems

001 Residue oil tank
002 Suction filter
003 Lubricating oil pump (one for transfer and separator service, one for separator service)
004 Lubricating oil heater with relief valve and temperature control
005 Self-cleaning centrifugal separator
006 Clean lubricating oil tank
007 Dirty lubricating oil tank
008 Air vent manifold
010 Deck connection
011 Float non return valve

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			Number of cylinders	5	6	7	8	9
Main engine RT-flex84T-D	**(R1)**	power	kW	21 000	25 200	29 400	33 600	37 800
		speed	rpm	76				
Dirty lubricating oil tank *1)		cap.	m^3	39	45	51	58	64
Clean lubricating oil tank *1)		cap.	m^3	39	45	51	58	64
Residue oil tank		cap.	m^3	depending on ship's requirement				

Remarks: *1) Capacities are valid for R1-rated engines and serve as an example. The capacities can be proportionally reduced to actual CMCR.

Table F4 Lubricating oil treatment and transfer system data

Servo oil filter back flushing

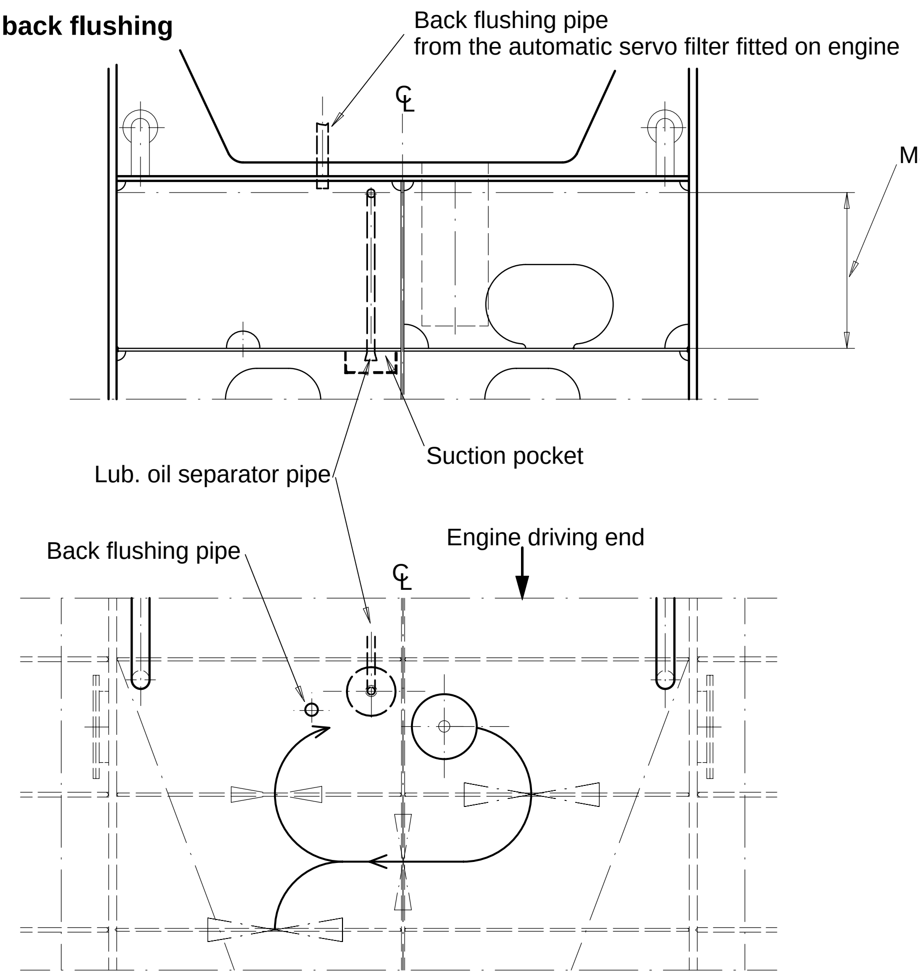

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Fig. F15 Lubricating oil treatment details

F2.2.7 List of lubricating oils

The application of the lubricants listed in tables F5 and F6 must be in compliance with the Wärtsilä general lubricating oil requirements and recommendations.

The supplying oil company undertakes all responsibility for the performance of the oil in service to *the exclusion of any liability* of Wärtsilä Switzerland Ltd.

<table>
<tr><th colspan="4">Global brands of lubricating oils</th></tr>
<tr><th>Oil Supplier</th><th>System oil</th><th>Cylinder oil *a)
fuel with more than 1.5% sulphur
recommended oils of BN 70–80</th><th>Cylinder oil *b)
fuel with less than 1.5% sulphur
recommended oils of BN 40</th></tr>
<tr><td>BP</td><td>Energol OE-HT 30</td><td>Energol CLO 50M</td><td>Energol CL-DX 405
Energol CL 505 *c)</td></tr>
<tr><td>Castrol</td><td>CDX 30</td><td>Cyltech 80 AW
Cyltech 70</td><td>Cyltech 40 SX
Cyltech 50 S *c)</td></tr>
<tr><td>Chevron (FAMM, Texaco, Caltex)</td><td>Veritas 800 Marine 30</td><td>Taro Special HT 70</td><td>Taro Special HT LS 40</td></tr>
<tr><td>ExxonMobil</td><td>Mobilgard 300
Exxmar XA</td><td>Mobilgard 570
Exxmar X 70</td><td>Mobilgard L 540</td></tr>
<tr><td rowspan="2">Total</td><td rowspan="2">Atlanta Marine D 3005</td><td>Talusia HR 70</td><td>Talusia LS 40</td></tr>
<tr><td colspan="2">Talusia Universal *d)</td></tr>
<tr><td>Shell</td><td>Melina S30
Melina 30</td><td>Alexia 50 *1)</td><td>Alexia LS *1)</td></tr>
<tr><td colspan="4">Above mentioned cylinder lubricating oils – except those marked with *1) – have passed the Wärtsilä Switzerland “LOQuS” quality requirements (Lubricating Oil Qualitiy Survey), including global product consistency.
*1) These cylinder lubricants were not tested with LOQuS. 2009-11-09</td></tr>
</table>

Remarks:
- *a) Between 1.5% and 2.0% sulphur in fuel, also BN 40 can be used without problems.
- *b) Between 1.0% and 1.5% sulphur in fuel, also BN 70 can be used, but only for a short period with a low feed rate.
- *c) This BN 50 cylinder lubricant ca be used up to 3.0% sulphur in the fuel.
- *d) This BN 57 cylinder lubricant ca be used over the whole fuel sulphur range.

Table F5 Global brands of lubricating oils

Local brands of lubricating oils			
Oil Supplier	**System oil**	**Cylinder oil** *a) fuel with **more than 1.5%** sulphur recommended oils of **BN 70–80**	**Cylinder oil** *b) fuel with **less than 1.5%** sulphur recommended oils of **BN 40**
AGIP 19th Mai 2005	Cladium 50	Punica 570 *1)	—
Bardahl 17th March 2009	—	Naval 50	—
Chevron 18th September 2003	Doro AR	Taro Special 70 *2)	—
FL Selenia 10th October 2006	MESYS 3006	MECO 5070	—
Gdanska 14th November 1995	—	Marinol RG 7050 *2)	—
SeaLub Alliance 25th February 2009	GulfSea SuperBear 3008	GulfSea Cylcare DCA5070H	—
IOC 7th June 2006	Servo Marine 0530	Servo Marine 7050	—
Mexicana de Lubricantes 22nd August 2008	—	Marinelub 7050 *2)	—
NOC 10th December 2008	Marine S30	Marine C705	—
Pertamina 1st October 2009	Medripal 307	Medripal 570	
Petrobras 6th December 2006	Marbrax CAD-308	Marbrax CID-57	Marbrax CID-54-AP Marbrax CID-55 *c)
PetroChina 26th February 2008	KunLun DCC3008	KunLun DCA 5070H	—
SK 3rd April 2007	Supermar AS	Supermar Cyl 70 plus	—

*1) Limited to bore size of 62 cm.
*2) Limited to engines built before 1995.

2009-11-09

Remarks:
*a) Between 1.5% and 2.0% sulphur in fuel, also BN 40 can be used without problems.
*b) Between 1.0% and 1.5% sulphur in fuel, also BN 70 can be used, but only for a short period with a low feed rate.
*c) This BN 50 cylinder lubricant ca be used up to 3.0% sulphur in the fuel.

Table F6 Local brands of lubricating oils

F2.2.8 Lubricating oil drain tank

The engine is designed to operate with a dry sump, the oil returns from the bearings, flows to the bottom of the crankcase and through strainers into the lubricating oil drain tank. The drain connections from the crankcase to the drain tank are arranged vertically as shown in figures F16 and F22. There is to maintain adequate drainage under sea conditions resulting in pitching and rolling.
Table F8 gives the minimum angles of inclination at which the engine is to remain fully operational.

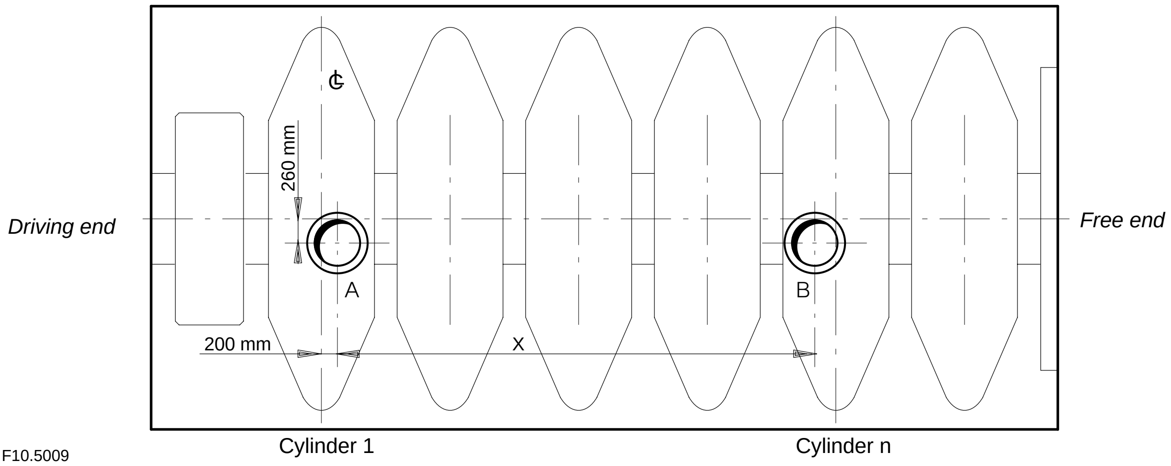


Fig. F16 Arrangement of vertical lubricating oil drains

Vertical lubricating oil drains to drain tank					
Number of cylinders	**5**	**6**	**7**	**8**	**9**
Necessary drains	2	3	3	3	4

Note: The arrangement of lubricating oil drains is to comply with the relevant classification society rules.

Table F7 Number of vertical lubricating oil drains

Figures F18 to F22 show the double-bottom arrangements for the drain tank when *vertical* drains are fitted and the position of the air vents and external pipe connections. For details of vertical drain connection see figure F17.

The drain tank is to be located beneath the engine and equipped with the following:

- Depth sounding pipe
- Pipe connections for lubricating oil purifiers
- Heating coil adjacent to pump suction
- Air vents with flame protection

Arrangements with *horizontal* drains are available on request.

All the drain pipes from the crankcase to the drain tank are to be taken as low as possible below the free surface of the oil to prevent aeration and foaming and remain below the oil surface at all times.

This is a requirement of the classification societies and strict attention is to be paid to this specification.

The amount of lubricating oil required for an initial charge of the drain tank is indicated in figure F22. The total tank size is normally 5–10 % greater than the amount of lubricating oil required for an initial filling

Classification societies	American Bureau of Shipping 2007	Bureau Veritas 2006	China Classification Society 2002	Croatian Register of Shipping –	Det Norske Veritas 2005	Germanischer Lloyd 2006
Main and aux. engine						
Abbreviations	4/1/1/7.9	C/1/1/2.4			4/1/3/B 200	2/1.1/C.1
Heel to each side	15°	15°	15°		15°	15°
Rolling to each side	±22.5°	±22.5°	±22.5°		±22.5°	±22.5°
Trim by the head 1*)	5°	5°	5°		5°	5°
Trim by the stern 1*)	5°	5°	5°		5°	5°
Pitching	±7.5°	±7.5°	±7.5°		±7.5°	±7.5°
Emergency sets						
Abbreviation	4/1/1/7.9	C/1/1/2.4			4/1/3/B 200	2/1.1/C.1
Heel to each side	22.5°	22.5°	22.5°		22.5°	22.5°
Rolling to each side	±22.5°	±22.5°	±22.5°		±22.5°	±22.5°
Trim	10°	10°	10°		10°	10°
Pitching	±10°	±10°	±10°		±10°	±10°
Electrical installation						
Abbreviation	4/1/1/7.9	C/1/1/2.4			4/8/3/B 100	2/1.1/C.1
Heel to each side	22.5°	22.5°	15°		15°	22.5°
Rolling to each side	±22.5°	±22.5°	±22.5°		±22.5°	±22.5°
Trim	10°	10°	5°		5°	10°
Pitching	±10°	±10°	±7.5°		±7.5°	±10°

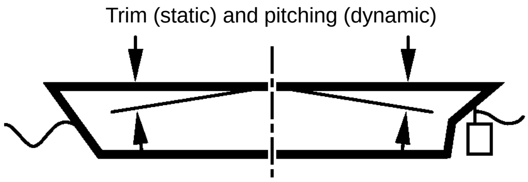
Classification societies	Korean Register of Shipping 2007	Lloyd's Register of Shipping 2006	Nippon Kaiji Koykai 2005	Polski Rejestr Statkow 2004	Registro Italiano Navale 2007	Russian Maritime Register of Shipping 2003
Main and aux. engine						
Abbreviations		5/1/3.6	D/1.3	VI-1.6	C/1/1/2.4	VII-2.3
Heel to each side	15°	15°	15°	15°	15°	15°
Rolling to each side	±22.5°	±22.5°	±22.5°	±22.5°	±22.5°	±22.5°
Trim by the head 1*)	5°	5°	5°	5°	5°	5°
Trim by the stern 1*)	5°	5°	5°	5°	5°	5°
Pitching	±7.5°	±7.5°	±7.5°	±7.5°	±7.5°	±7.5°
Emergency sets						
Abbreviation		5/1/3.6	D/1.3	VI-1.6	C/1/1/2.4	VII-2.3
Heel to each side	22.5°	22.5°	22.5°	22.5°	22.5°	22.5°
Rolling to each side	±22.5°	±22.5°	±22.5°	±22.5°	±22.5°	±22.5°
Trim	10°	10°	10°	10°	10°	10°
Pitching	±10°	±10°	±10°	±10°	±10°	±10°
Electrical installation						
Abbreviation		6/2/1.9	H/1.1.7	VIII-2.1.2.2	C/2/2/1.6	XI-2.1.2.2
Heel to each side		15°	15°	15°	15°	15°
Rolling to each side		±22.5°	±22.5°	±22.5°	±22.5°	±22.5°
Trim		5°	5°	5°	5°	5°
Pitching		7.5°	±7.5°	±10°	±7.5°	±10°

1*) Where the ship's length exceeds 100 m, the fore-and-aft static angle of inclination may be taken as:

$$\frac{500}{L} \text{ degrees}$$

where L = length of ship in metres

Athwartships and fore-and-aft inclinations may occur simultaneously.



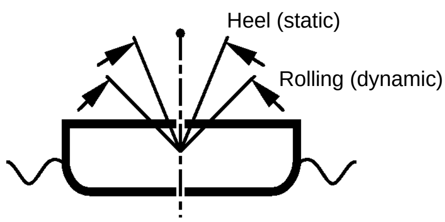
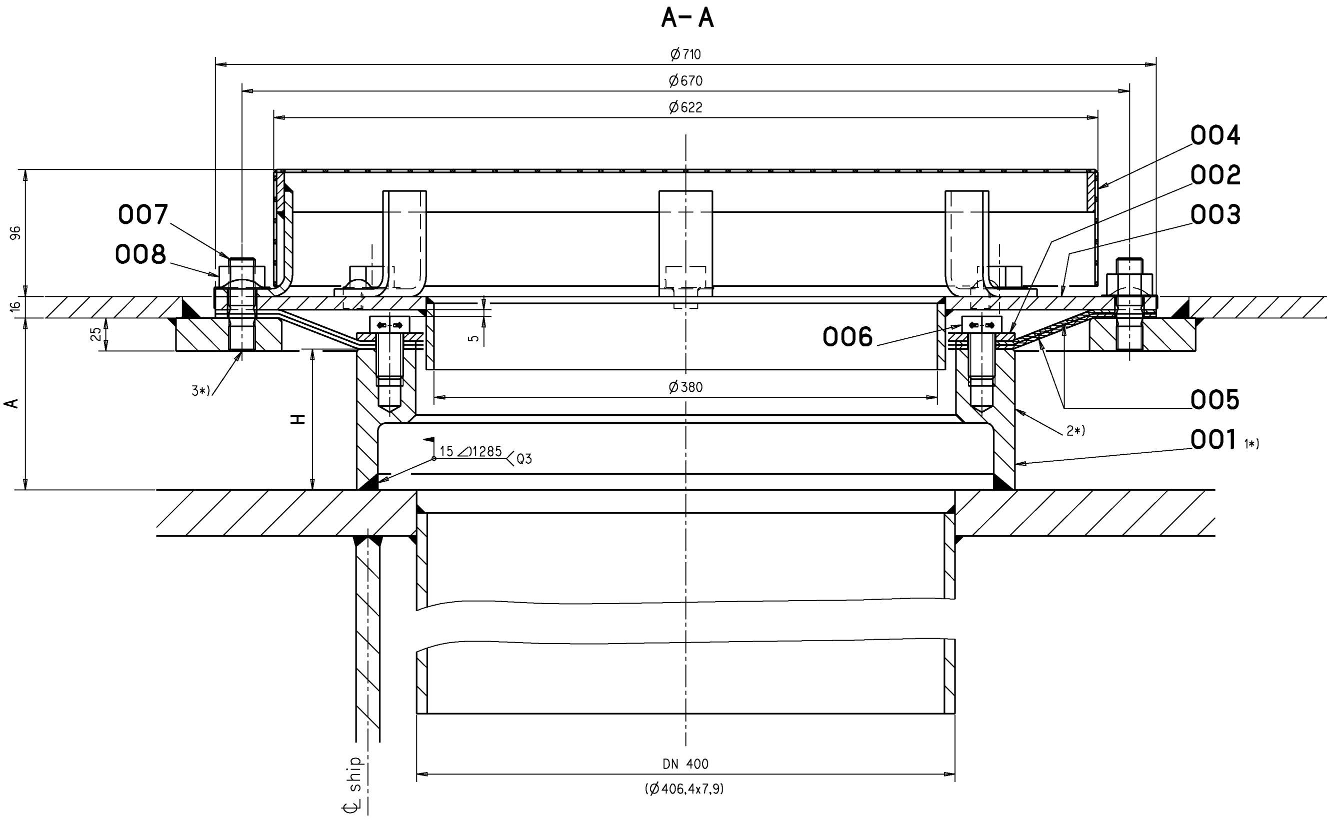


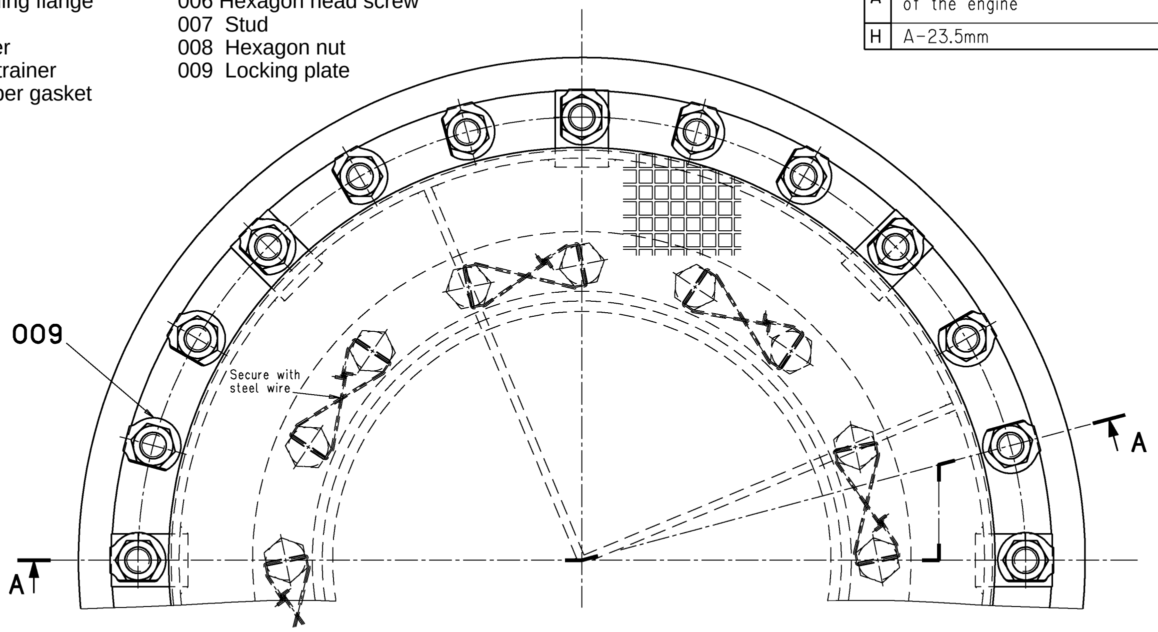
Table F8 Minimum inclination angles at which the engine is to remain fully operational

F. Ancillary systems



001 Welding flange
002 Ring
003 Cover
004 Oil strainer
005 Rubber gasket
006 Hexagon head screw
007 Stud
008 Hexagon nut
009 Locking plate

A	To be measured after alignment of the engine
H	A–23.5mm



Remark: *1) To be aligned after engine is in final position.
*2) Item 001, 002, 005 and 006 to be pre-assembled prior to alignment. After alignment the pos. 001 (flange) can be welded in place.
*3) Driven in oil tight with jointing compound.
– Items 001 to 009 are to be delivered by the shipyard.

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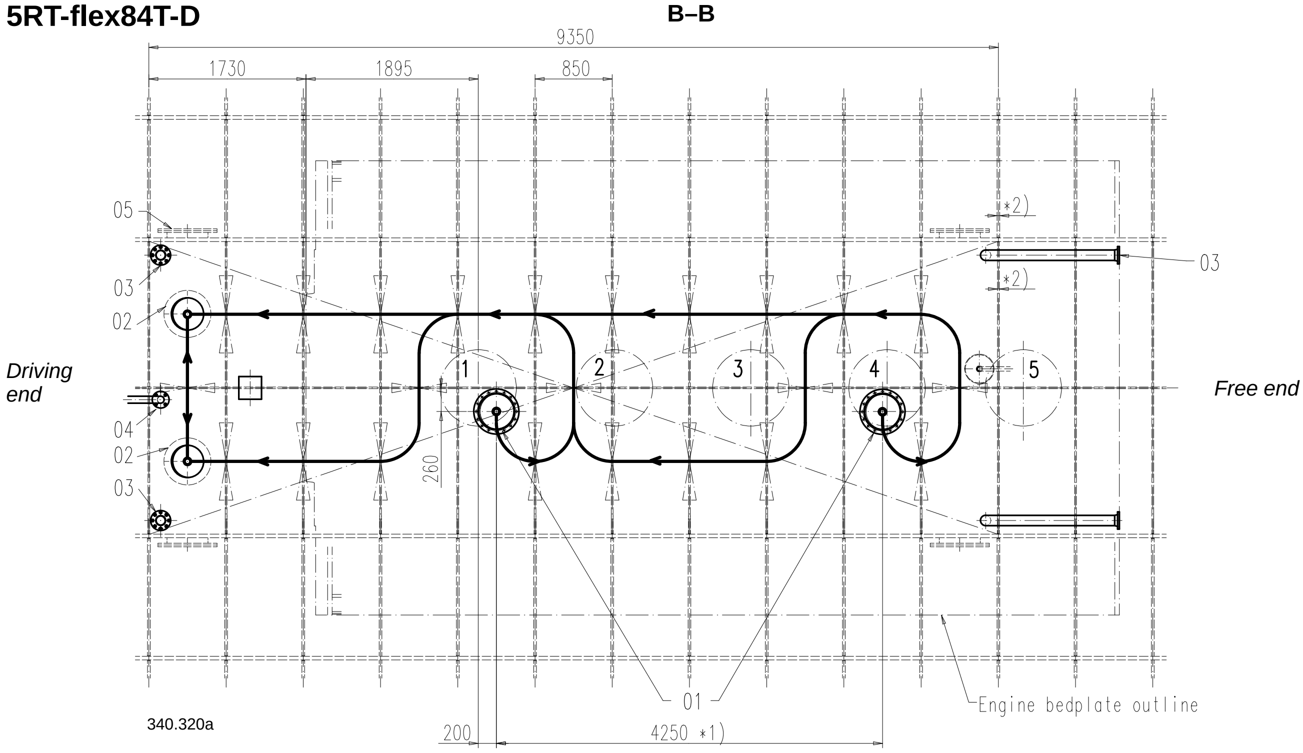
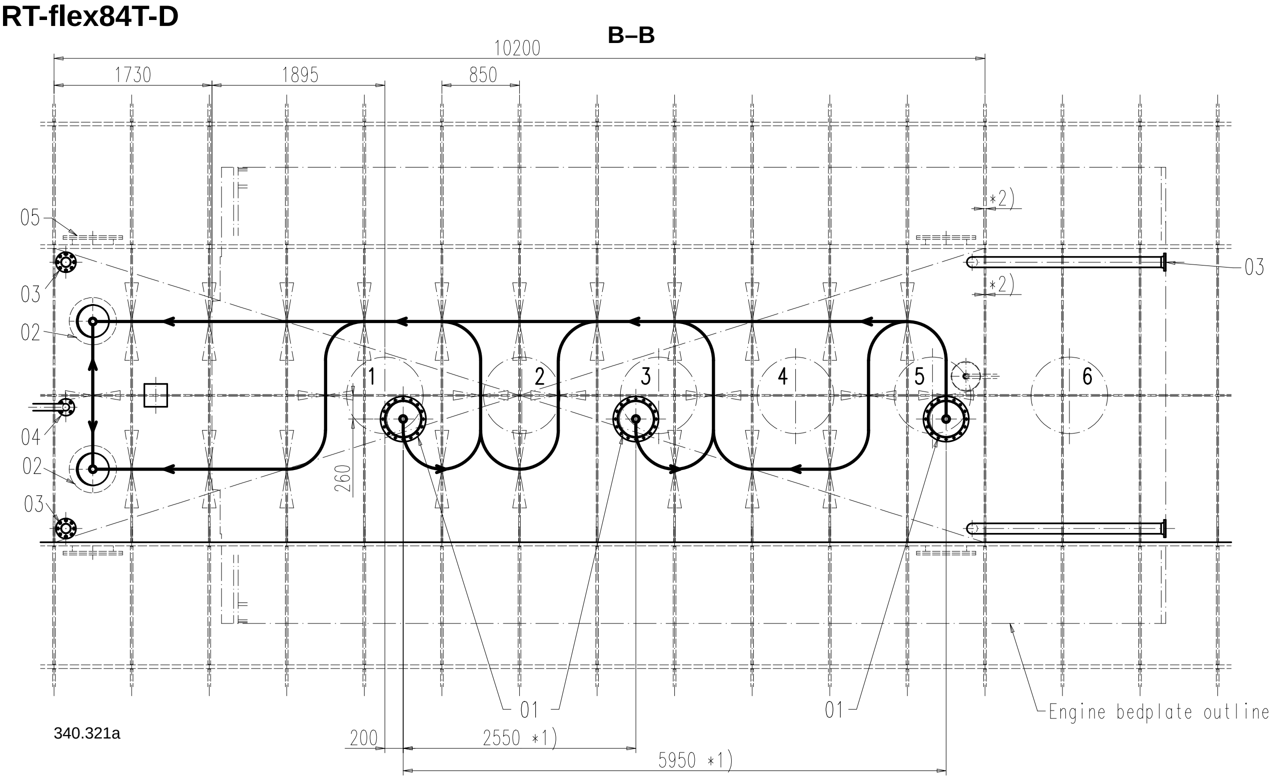
Fig. F17 Vertical drain connection details

F. Ancillary systems

5RT-flex84T-D



6RT-flex84T-D



01 Vertical oil drain
02 Lub. oil suction pipes
03 Air vent DN 100
04 Lub. oil separator delivery pipe
05 Man hole

Remarks:

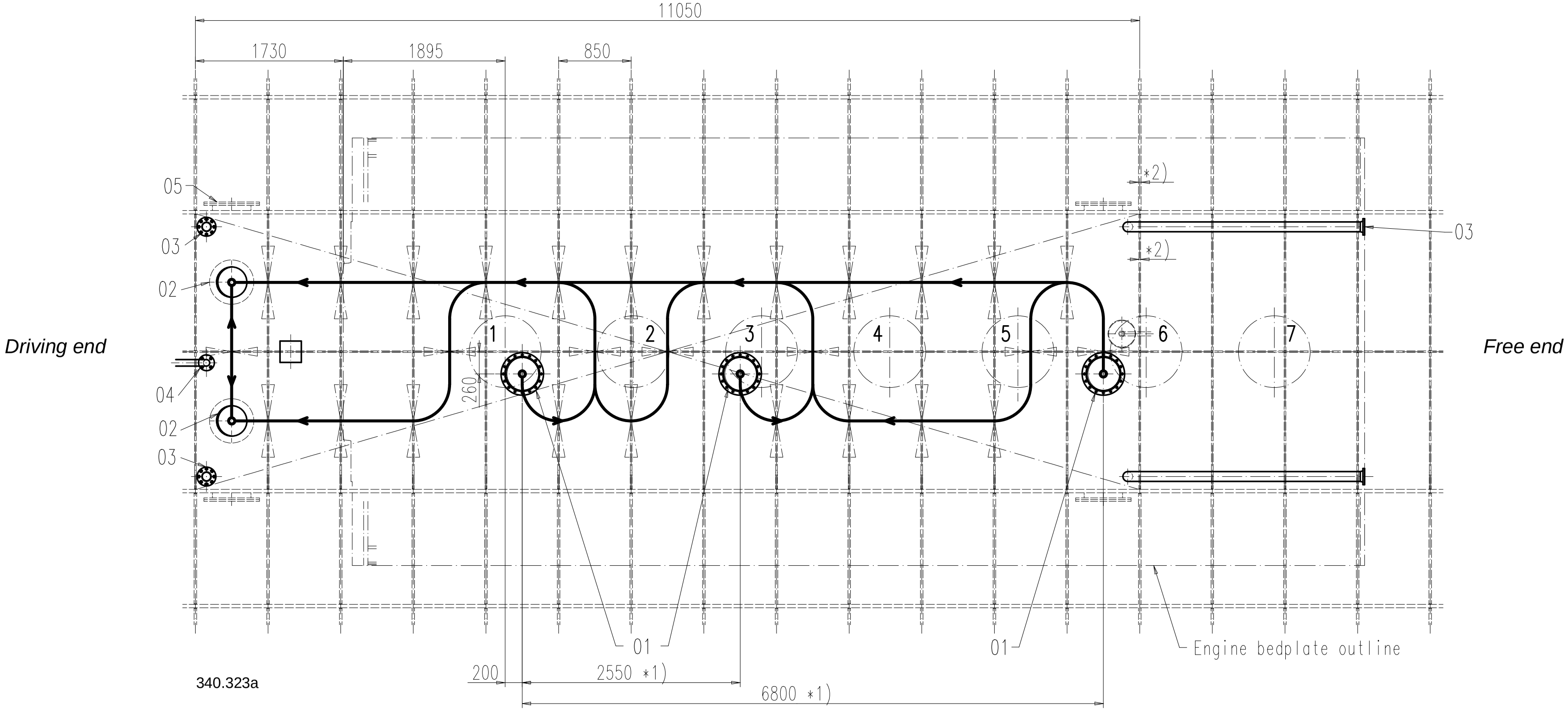
*1) Proposal, final position has to be determined by the shipyard in accordance with the engine builder.

*2) Plate thickness, refer to figure H14.

Fig. F18 Layout of vertical oil drains for 5RT-flex84T-D and 6RT-flex84T-D

7RT-flex84T-D

B–B



01 Vertical oil drain
02 Lub. oil suction pipes
03 Air vent DN 100
04 Lub. oil separator delivery pipe
05 Man hole

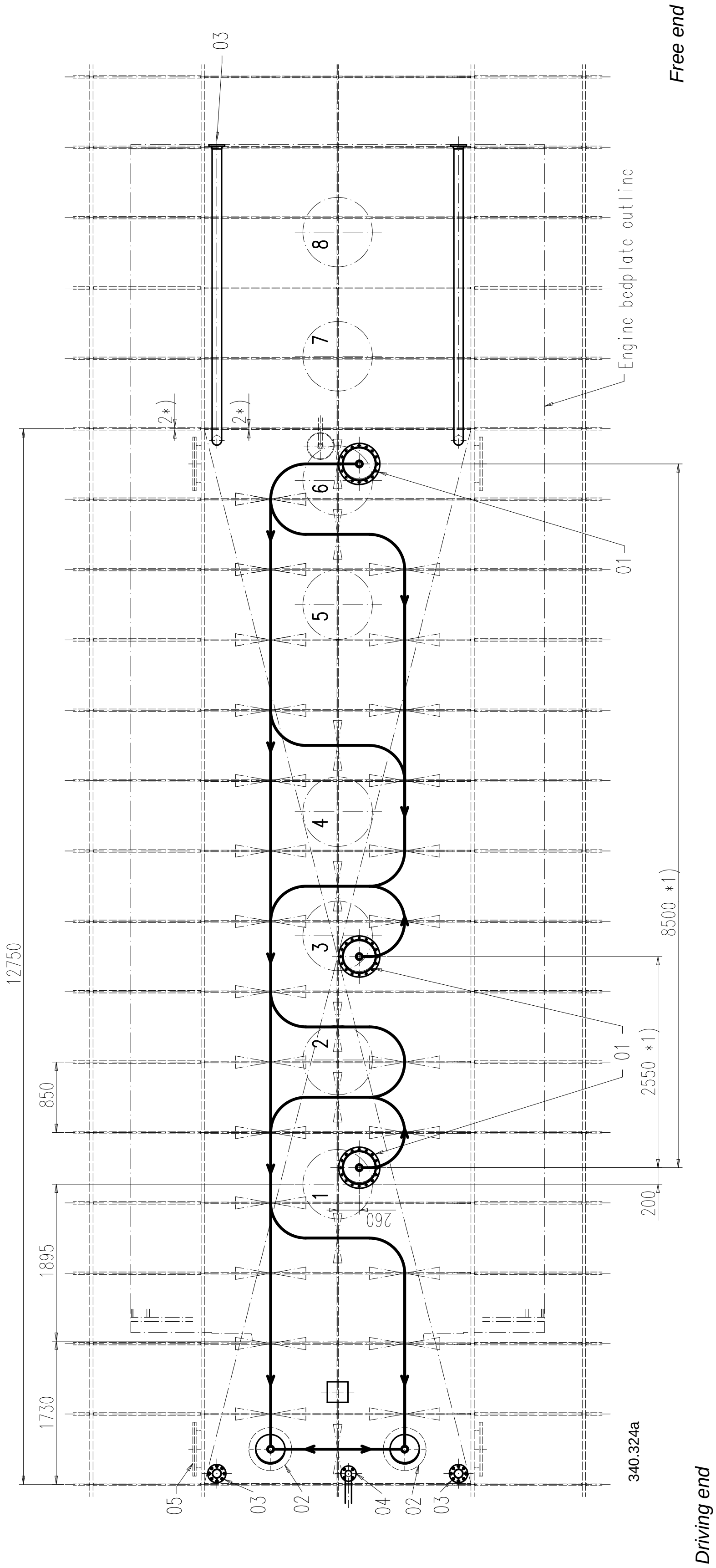
Remarks:
*1) Proposal, final position has to be determined by the shipyard in accordance with the engine builder.
*2) Plate thickness, refer to figure H14.

Fig. F19 Layout of vertical oil drains for 7RT-flex84T-D

F. Ancillary systems

8RT-flex84T-D

B–B



01 Vertical oil drain
02 Lub. oil suction pipes
03 Air vent DN 100
04 Lub. oil separator delivery pipe
05 Man hole

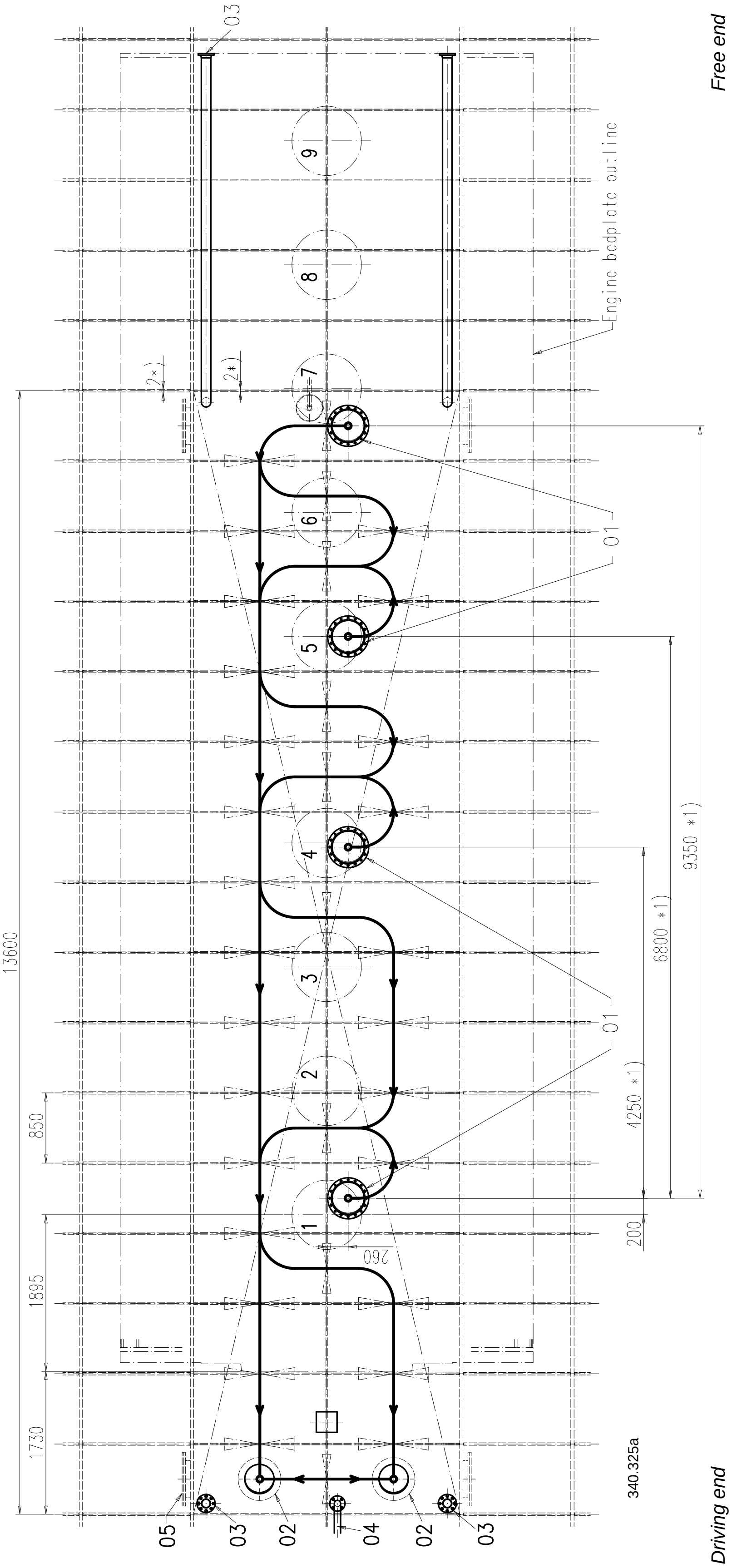
Remarks:
*1) Proposal, final position has to be determined by the shipyard in accordance with the engine builder.
*2) Plate thickness, refer to figure H14.

Fig. F20 Layout of vertical oil drains for 8RT-flex84T-D

F. Ancillary systems

9RT-flex84T-D

B–B

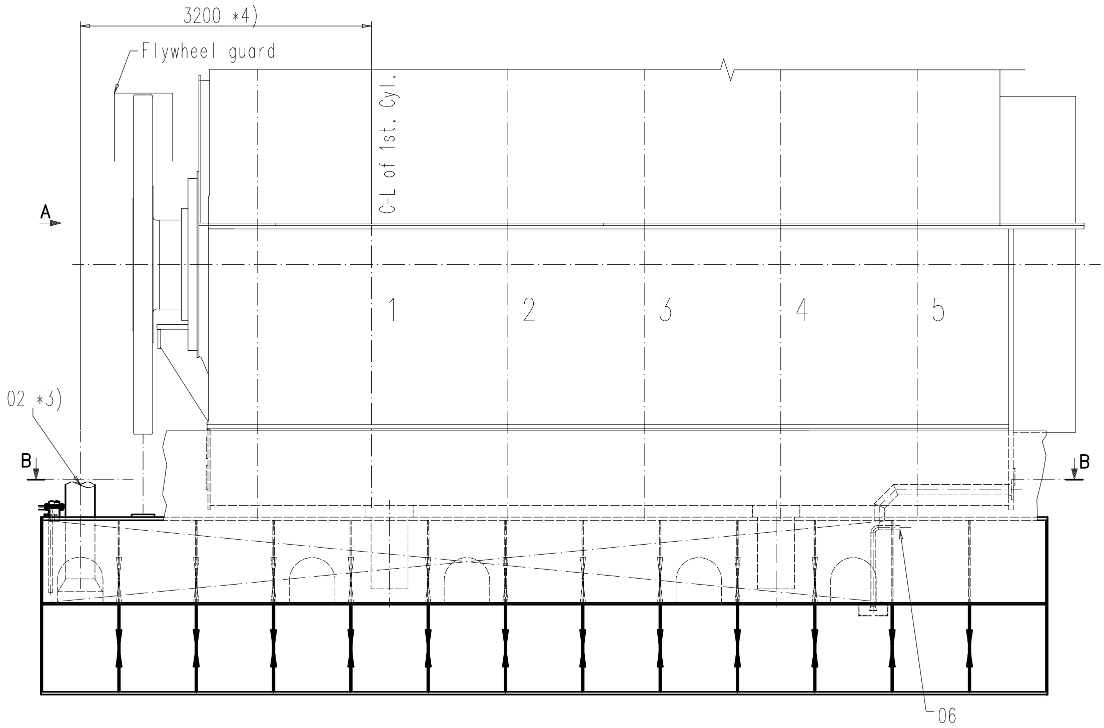


Remarks:
*1) Proposal, final position has to be determined by the shipyard in accordance with the engine builder.
*2) Plate thickness, refer to figure H14.

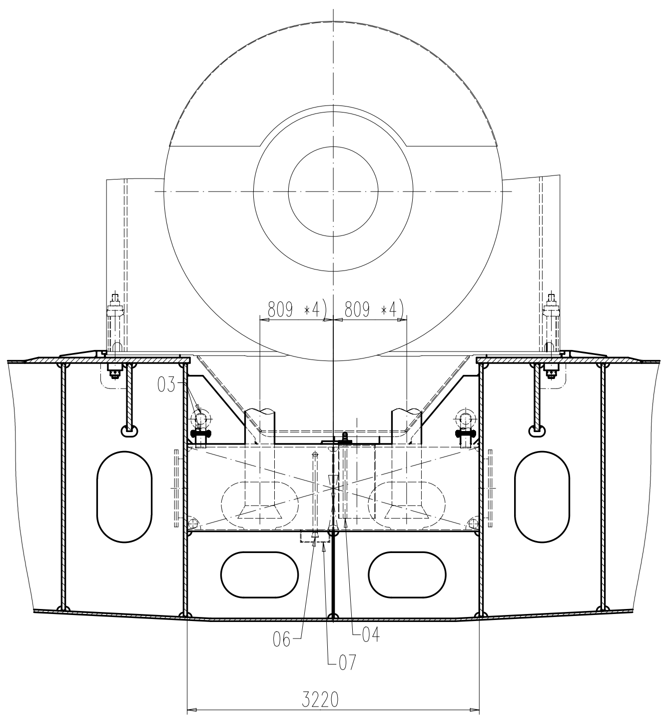
01 Vertical oil drain
02 Lub. oil suction pipes
03 Air vent DN 100
04 Lub. oil separator delivery pipe
05 Man hole

Fig. F21 Layout of vertical oil drains for 9RT-flex84T-D

F. Ancillary systems



A
(Driving end)



Remarks:

*3) Dimension (DN) according to fig. F9, table F3 'Lubricating oil system'.

*4) Proposal, dimension depends upon the size of the flywheel guard and oil pumps. Final dimension to be determined by shipyard.

– The final layout of the drain tank has to comply with the rules of the relevant classification society.

02 Lub. oil suction pipes
03 Air vent DN 100
04 Lub. oil separator delivery pipe
06 Lub. oil separator suction pipe
07 Suction pocket

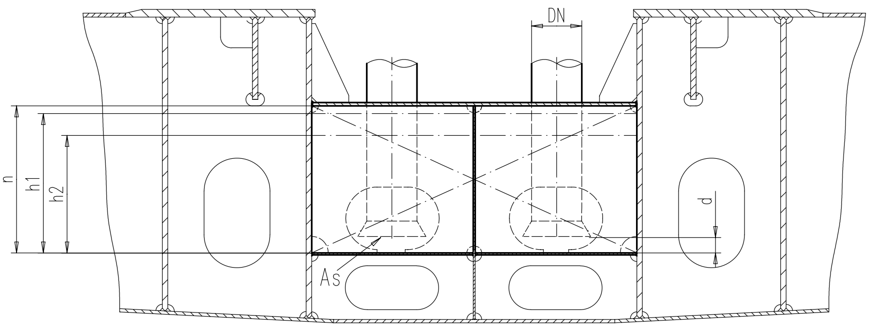
340.320a
340.321a
340.323a
340.324a
340.325a

Fig. F22 Lubricating oil drain tank, vertical oil drains.

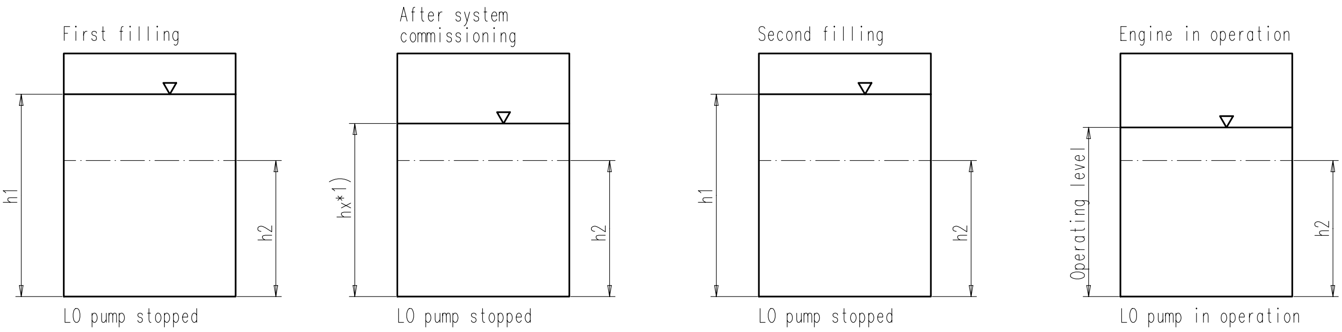
Lubricating oil tank: dimensioning guide-lines and filling process

Dimensioning guide-lines and capacities for tank design

No. of cylinders			5	6	7	8	9
h	Recommended total tank height	(mm)	900	1040	1100	1080	1140
	Recommended total tank volume: 105%	(m3)	27	34	39	44	50
h1	Recommended filling level	(mm)	860	970	1040	1020	1100
	Recommended volume: 100%	(m3)	26	32	37	42	48
h2	Low level alarm	(mm)	*2)				
	volume	(m3)					
Vr	Min. retention volume *3)	(m3)	15	18	20	22	25
d	Distance between suction pipe and bottom of tank	(mm)	*4)				
As	Suction Area		min. 1.5x suction pipe area (DN)				



Filling process of lubricating oil tank



REMARKS:

*1) Level after filling of external system. Volume and level in the lub. oil drain tank depend on capacity of pipes, coolers, filters, etc. The oil volume in tank contains a part of the oil quantity, which drains back, when the pumps are stopped.

*2) The low level alarm (h2) has to be positioned in such a way that a proper pump suction is ensured under the conditions defined by classification societies.

Minimum inclination angles comply with the rules of classification societies: see table F8.

Additionally this level has to be above or equal to the minimum retention volume (Vr) for M/E operation.

*3) Min. retention volume when engine in operation.

*4) Distance (d) between the suction pipe inlet of the main lub. oil pumps and the drain tank bottom has to be in accordance with the requirements of pump manufacturer. As guideline the following formula can be applied: d = DN/4 + 40, d = min. 80 mm.

420.361

Fig. F23 Dimensioning guide-lines and filling process of the lubricating oil drain tank

F2.2.9 Flushing the lubricating oil system

This instruction describes the flushing procedure for the *external* lubricating oil system (on the plant). The flushing of the *internal* lubricating oil system (on the engine) is under the responsibility of the engine builder and should be already done. If flushing of the internal lubricating oil system is required, please consult the “Instruction for Flushing of Lub. Oil and Fuel Oil System” and “Instruction for Flushing for Common Rail System” provided by the engine builder.

A correct manufacturing of the pipes avoids the presence of scales, slag and spelter. It is a fact that the expense for special welding methods, e.g. inert gas welding, is worthwhile when considering the costs of an extensive flushing procedure or the grinding and cleaning work if using normal electric arc welding or welding with electrodes. However, a thorough cleaning of the pipes before mounting is a must.

The pipes of the entire lubricating oil system on the plant side are to be flushed separately.

It is absolutely essential to ensure that the lubricating oil systems are clear of all foreign matter before circulating oil through the engine. A systematic approach is to be adopted prior to commissioning when the engine, pipework, filters, heat exchangers, pumps, valves and other components are flushed. They have to be proved absolutely clear of any dirt by observation and physical inspection. The engine crankcase and lubricating oil drain tank are to be inspected and cleaned by hand to remove all residual build-debris. Special attention is to be given to very small loose particles of welding matter such as spelter and slag.

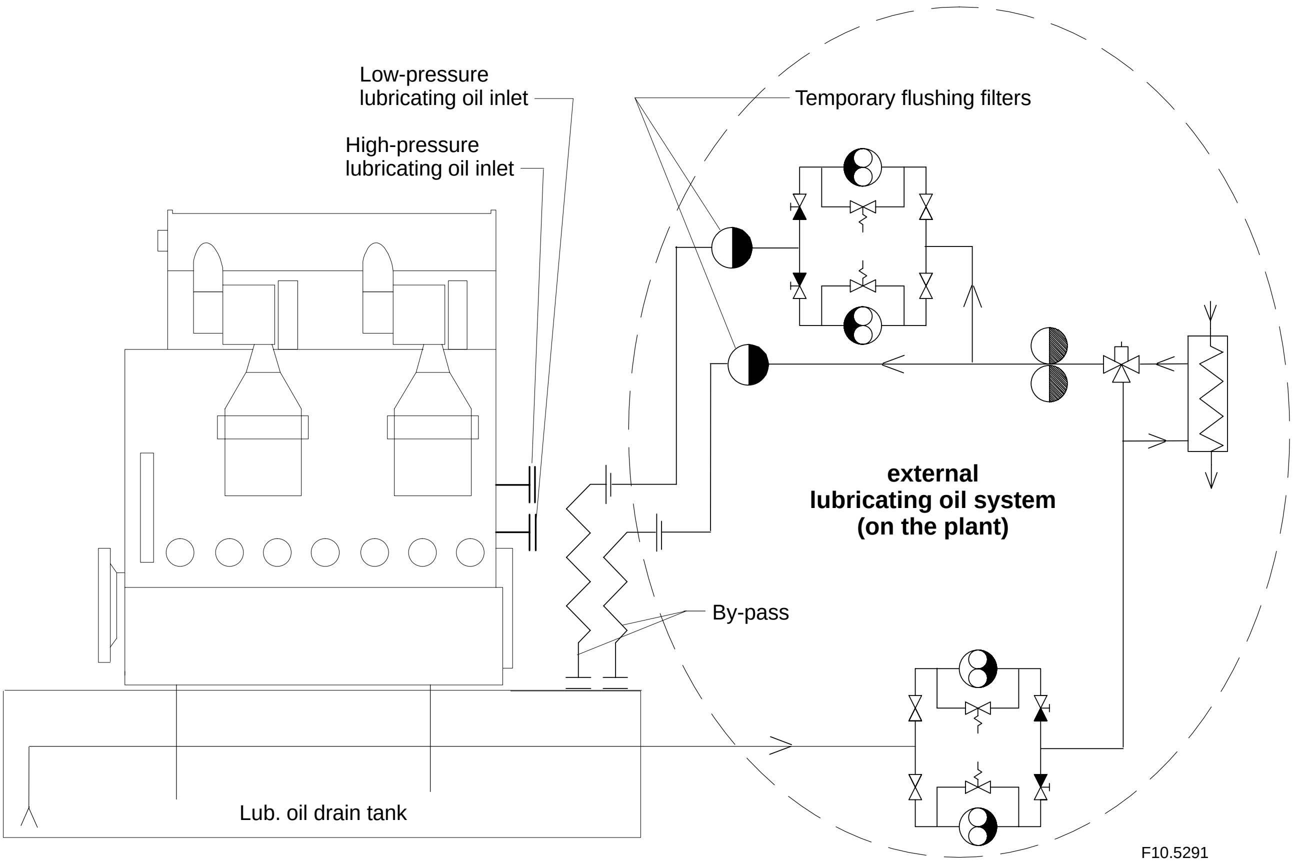


Fig. F24 Flushing the lubricating oil system

F2.2.9.1 Preparation before flushing

1. Lead the lubricating oil connections immediately before the engine straight back into the lubricating oil drain tank by means of hoses or pipes, see fig. F24.
2. Immediately before the engine, in the discharge pipes from the low-pressure and high-pressure lubricating oil pumps (figure F24), install temporary filters with a mesh size (sphere passing) of max. 0.030 mm (30 μm) and equipped with magnetic elements.
   Instead of filter inserts of stainless steel mesh, disposable cartridges with a nominal grade of filtration of 0.020 mm (20 μm) can also be used.
   The surface loading of the temporary filters should be 1–2 l/cm^{2}h. Alternatively, the plant lubricating oil filters can be used under the condition that the filter inserts are of mesh size of max. 0.030 mm (30 μm) and magnetic elements are used during flushing. After flushing, the filter inserts are to be replaced by the original ones and the filter housing is to be cleaned.
   In the final step of flushing, it is advisable to fit filter bag made of cotton or synthetic fabric of mesh size 0.040 to 0.050 mm (40 to 50 μm) to the end of the hoses or pipes, in order to facilitate checking the cleanliness of the system.
3. If the **engine is supplied to the ship in subassemblies** proceed as follows:
   - Blank off each of the main bearing lubricating oil supply pipes at the main bearings in such a way that absolutely no oil can enter the bearing but oil can escape between pipe and blank piece.
   - Blank off each of the crosshead lubrication linkage in that way, that absolutely no oil can enter the bearing but oil can escape between linkage and blank piece.
   - Blank off the oil supply of the axial damper in that way that absolutely no oil can enter the damper but oil can escape between pipe and blank piece.
   - Disconnect and blank off all oil supply pipes to the camshaft, intermediate gears and reversing gear.

F2.2.9.2 Flushing external lubricating oil system

1. Fill the lubricating oil drain tank with sufficient oil to cover the pump suction and heat it up to approximately 60 °C using temporary immersion heaters or the heating coil of the drain tank.
2. Circulate the oil in the drain tank using the lubricating oil separator(s) and their preheater(s) to maintain the flushing temperature to improve oil cleanliness. Operate the separator(s) until all the flushing procedures are completed.
3. Fully open all system valves.
4. Remove the crankcase round covers at the exhaust side and open the crankcase on the fuel side: good ventilation is to be provided to avoid condensation.
5. Flush the system by starting the low- and high-pressure lubricating oil pumps, the main and stand-by pumps are to be alternatively operated. Before starting the pumps, the oil cooler(s) might be by-passed at the beginning of the flushing procedure.
   Circulate the oil through the pumps and hose connections back to the drain tank. Observe the suction and discharge pressures carefully. Do not let the pumps run hot. Observe also the pressure drop through the filters.
6. During the flushing procedure, the pipes are to be periodically tapped to help loosen any foreign matter that may be present. If available, vibrators are to be used.
   All pipes used during the engine operation must be flushed, including by-pass lines and the oil cooler(s).
   Drain the dirt of all equipment's (oil cooler(s), suction filters, etc.) where dirt can accumulate.

7. Inspect and clean the filters in the lubricating oil system periodically.
   Flushing is to be continued until filter bags remain clean and no residues can be found in the filters; no metallic particles adhere to the magnetic filter inserts and no residues are detected in the bottom of the filter housing.
   One method to judge the oil cleanliness is described under section the F2.2.9.5.
   When the system proves clean, remove any filter bags and connect the low- and high-pressure oil supply pipes to the engine.

F2.2.9.3 Flushing within the engine

Flushing the engine at the shipyard (after flushing the external lub. oil system) is a safety measure and is recommended because even if the external lub. oil system appears clean, there could be pockets with contamination. **If the engine is supplied to the ship in sub-assemblies, the re-assembled engine has to be flushed.** If there is no need of flushing the engine, follow directly the steps described under section F2.2.9.4.

1. Start up the low- and high- pressure lubricating oil pumps and flush through the engine for at least another 8 hours.
2. Inspect and clean the filter in the lubricating oil system periodically.
   Flushing is to be continued until the filters are absolutely clean:
   - No metallic particles adhere to the magnetic inserts and no residues are detected in the bottom of the filter housing.
   - When the lubricating oil system proves clean, remove all blank pieces and temporary flushing filters.
   - To judge the oil cleanliness, refer to the section F2.2.9.5.
3. **Re-assembly of the lub. oil system**
   - Drain the oil from the distribution pipe to the main bearings.
   - Inspect the inside of the pipes for eventual deposits. If clean, re-fit all oil pipes.
   - Make sure that all screwed connections are tight and secured.
   - Inspect the bottom of the crankcase and clean it if necessary.

Any pipe-connecting piece, which was not flushed before, must be cleaned separately.

F2.2.9.4 Commissioning of lubricating oil system

1. Remove the inspection cover of the thrust bearing in main bearing girder #2.
2. Circulate the low- and high-pressure system for approximately two hours under normal operating pressure and temperature.
3. Observe the oil flow on all bearings, spray nozzles and any other engine components (e.g. dampers) for proper oil flow.
4. The turning gear is to be engaged to turn the engine from time to time.
5. Check and clean the filters periodically.
6. To flush the by-pass line between the low- and high-pressure system on the engine, the regulating valve for adjusting the oil pressure to the main bearings must be throttled temporarily. During flushing the by-pass, the high-pressure lubricating oil pump is to be stopped.
7. Carry out an inspection of the crankcase before refitting all the crankcase doors.

F2.2.9.5 Lubricating oil cleanliness

There are several criteria to judge if the lubrication oil is sufficiently clean. One of those criteria is defined by the NAS method. The NAS method counts particles of different sizes and gives an **upper limit** of particles of each size. For further information, please refer to the “Annual Book of ASTM Standards”.

NAS 1638 cleanliness classes are explained in table F9.

NAS 1638 classes		Contamination (particles per 100 ml)				
Particle size in micron		5–15	15–25	25–50	50–100	>100
Classes	14	4096000	729600	129600	23040	4096
	13	2048000	364800	64800	11520	2048
	12	1024000	182400	32400	5760	1024
	11	512000	91200	16200	2880	512
	10	256000	45600	8100	1440	256
	9	128000	22800	4050	720	128
	8	64000	11400	2025	360	64
	7	32000	5700	1012	180	32
	6	16000	2850	506	90	16
	5	8000	1425	253	45	8
	4	4000	712	126	22	4
	3	2000	356	63	11	2
	2	1000	178	32	6	1
	1	500	89	16	3	1
	0	250	44	8	2	0
	00	125	22	4	1	0

Table F9 NAS 1638 cleanliness classes

Recommended limits in NAS 1638 classes
The lubricating oil can be considered as clean, if the oil contamination is within the following NAS classes:

Particle size in micron	5–15	15–25	25–50	50–100	>100
Class	13	11	10	8	3

Example:
Class 10 means that the number of particles between 25 and 50 µm should be not higher than 8100 per 100 ml oil.

Sampling position:
The oil sample should be taken in the main oil supply lines (low- and high-pressure lines) before the temporary flushing filters.

F2.2.9.6 Cylinder oil supply system

It is absolutely essential to ensure that the cylinder oil system is clear of all foreign matter before connecting to the engine in order to safeguard the engine and assure proper operation.
The storage and service tank are to be inspected and cleaned by hand to remove all residual build-debris, special attention is to be given to very small loose particles of welding matter such as spelter and slag.
The complete piping, from the storage tank to the engine connection, has to be inspected and cleaned accordingly.

F2.3 Fuel oil systems

A number of systems external to the engine are required to maintain heavy fuel oil and marine diesel oil in the quality required for efficient and reliable combustion.

F2.3.1 Fuel oil requirements

The values in the column Bunker limit (RMK700) (table F10) indicate the minimum quality of heavy fuel as bunkered, i.e. as supplied to the ship or installation. Good operating results have been achieved with all commercially available fuels within ISO8217 limits. However, using of fuel with lower density, ash and carbon residue content can be expected to have a positive influence on overhaul periods, by improving combustion, wear and exhaust gas composition.
The fuel oil as bunkered must be processed before it enters the engine. For the design of the fuel treatment plant, the relevant Wärtsilä recommendations have to be followed. The minimum centrifuge capacity is 1.2 x CMCR x BSFC / 1000 (litres/hour), which corresponds to 0.21 l/kW. The fuel oil treatment has to reduce catalyst fines and water to engine inlet limits.
According to ISO8217 it is forbidden to add foreign substances or chemical waste to the fuel, because of the hazards for the ship crew, machineries and environment. Testing for foreign substances like acids, solvents and monomers with titrimetric, infrared and chromatographic tests is not standard but recommended – because of the high likelihood of damage these substances can cause to fuel treatment, fuel pumps, fuel injection and piston running components.

Parameter	Unit	Bunker limit ISO 8217: 2005 class F, RMK700	Test method *1)	Required fuel quality Engine inlet
Density at 15 °C	[kg/m^3]	max. 1010 *2)	ISO 3675/12185	max. 1010
Kinematic viscosity at 50 °C	[mm^2/s (cSt)]	– 700	ISO 3104	13–17 –
Carbon residue	[m/m (%)]	max. 22	ISO 10370	max. 22
Sulphur	[m/m (%)]	max. 4.5	ISO 8754/14596	max. 4.5
Ash	[m/m (%)]	max. 0.15	ISO 6245	max. 0.15
Vanadium	[mg/kg (ppm)]	max. 600	ISO 14597/IP501/470	max. 600
Sodium	[mg/kg (ppm)]	–	AAS	max. 30
Aluminium plus Silicon	[mg/kg (ppm)]	max. 80	ISO 10478/IP501/470	max. 15
Total sediment, potential	[m/m (%)]	max. 0.10	ISO 10307-2	max. 0.10
Water	[v/v (%)]	max. 0.5	ISO 3733	max. 0.2
Flash point	[°C]	min. 60	ISO 2719	min. 60
Pour point	[°C]	max. 30	ISO 3016	max. 30

Remark: *1) ISO standards can be obtained from the ISO Central Secretariat, Geneva, Switzerland (www.iso.ch).
*2) Limited to max. 991 kg/m^3 (ISO-F-RMH700), if the fuel treatment plant (Alcap centrifuge) cannot remove water from high density fuel oil (excludes RMK grades).
– The fuel shall be free from used lube oil, a homogeneous blend with no added substance or chemical waste (ISO8217:2005–5–1).

Table F10 Fuel oil requirements

Viscosity

The **recommended viscosity range** at engine inlet is: 13–17 cSt (mm2/s). The preheating temperature to reach 15 cSt is usually reported in bunker reports, but can also be estimated from the approximate viscosity/temperature chart in the engine instruction manual. Standard 380 cSt fuel (at 50 °C) must be preheated t o about 130 °C.

The maximum viscosity of the bunkered fuel that can be used in an installation depends on the heating and fuel preparation facilities available (see viscosity/temperature chart in figure F25). The throughput and the temperature of the fuel going through the centrifuges must be adjusted in relation to the viscosity to achieve a good separation. Heating the fuel above 150 °C to reach the recommended viscosity at engine inlet is not recommended because the fuel may start to decompose and deposit.

Carbon residue, asphaltenes sediment

The content of asphaltenes and related aromatic heavy fuel components is indicated by the carbon residue. These substances have high energy content, but high levels can however impair the combustion quality of the fuel oil, promoting increased wear and fouling of engine components. At least up to 14 % asphaltenes should be no problem.

The sediment potential is an indication for fuel stability. Asphaltenes must be kept solubilised to prevent problems of sludge formation in centrifugal separators, filters and on the tank bottom. Especially the addition of paraffinic distillates could cause the asphaltenes to settle out. To minimise compatibility risks, care must be taken to avoid mixing bunkers from different suppliers and sources in storage tanks on board, onboard test kits are available to assess this risk.

Sulphur

The alkalinity of the cylinder lubricating oil, i.e. the base number (BN), should be selected with regard to the sulphur level of the fuel oil. When using a heavy fuel oil containing less than 1 % sulphur a low BN cylinder lubricant has to be used.

Ash and trace metals

Fuel oils with low contents of ash are preferable. Especially vanadium and sodium tend to promote mechanical wear, high temperature corrosion and the formation of deposits in the turbocharger and on the exhaust valve. Sodium compounds depress the melting point of vanadium oxide and sulphate salts, especially when the vanadium to sodium ratio is 3:1. High sodium levels (as well as lithium and potassium) at engine inlet can cause fouling of turbocharger components. The effect of high temperature corrosion and the formation of deposits can be counteracted by the application of ash modifiers.

Aluminium, silicon

Aluminium and silicon in the fuel oil are regarded as an indication of the presence of catalytic fines (cat fines), porcelain-like round particles used in petroleum refining. They cause high abrasive wear to piston rings and cylinder liners, over a prolonged time period when embedded in the ring and liner surface. The most dangerous are cat fines with a diameter 10 to 20 microns, which corresponds to common clearances and oil film thickness.

Cat fines tend to be attracted to water droplets and are very difficult to remove from the fuel oil, even more so when used lube oil is present. Practical experience has shown that with proper treatment in the fuel oil separator the aluminium and silicon content of 80 mg/kg can be reduced to 15 mg/kg, which is considered as just tolerable. For efficient separation, a fuel temperature as close as possible to 98 °C is recommended. With more than 40 ppm cat fines in the bunkered fuel, reduced throughput in the separator is recommended.

Cat fines can accumulate in the sediment of the fuel tank from previous bunkers, and be mixed into the fuel when the sediment is churned up in bad weather. For this reason all fuels should be assumed to contain cat fines, even if this is not apparent from the fuel oil analysis, making continuous and efficient centrifugation of paramount importance.

Water

The water content of the fuel oil must be reduced by centrifuging and by the use of proper draining arrangements on the settling and service tanks. A thorough removal of water is strongly recommended, to ensure homogenous injection and to reduce the content of hydrophilic cat fines and sodium in the fuel oil. Sodium is not a natural oil component but marine fuel oil is often contaminated with sea water containing sodium. 1.0 % sea water in the fuel oil corresponds to 100ppm sodium.

Flash point

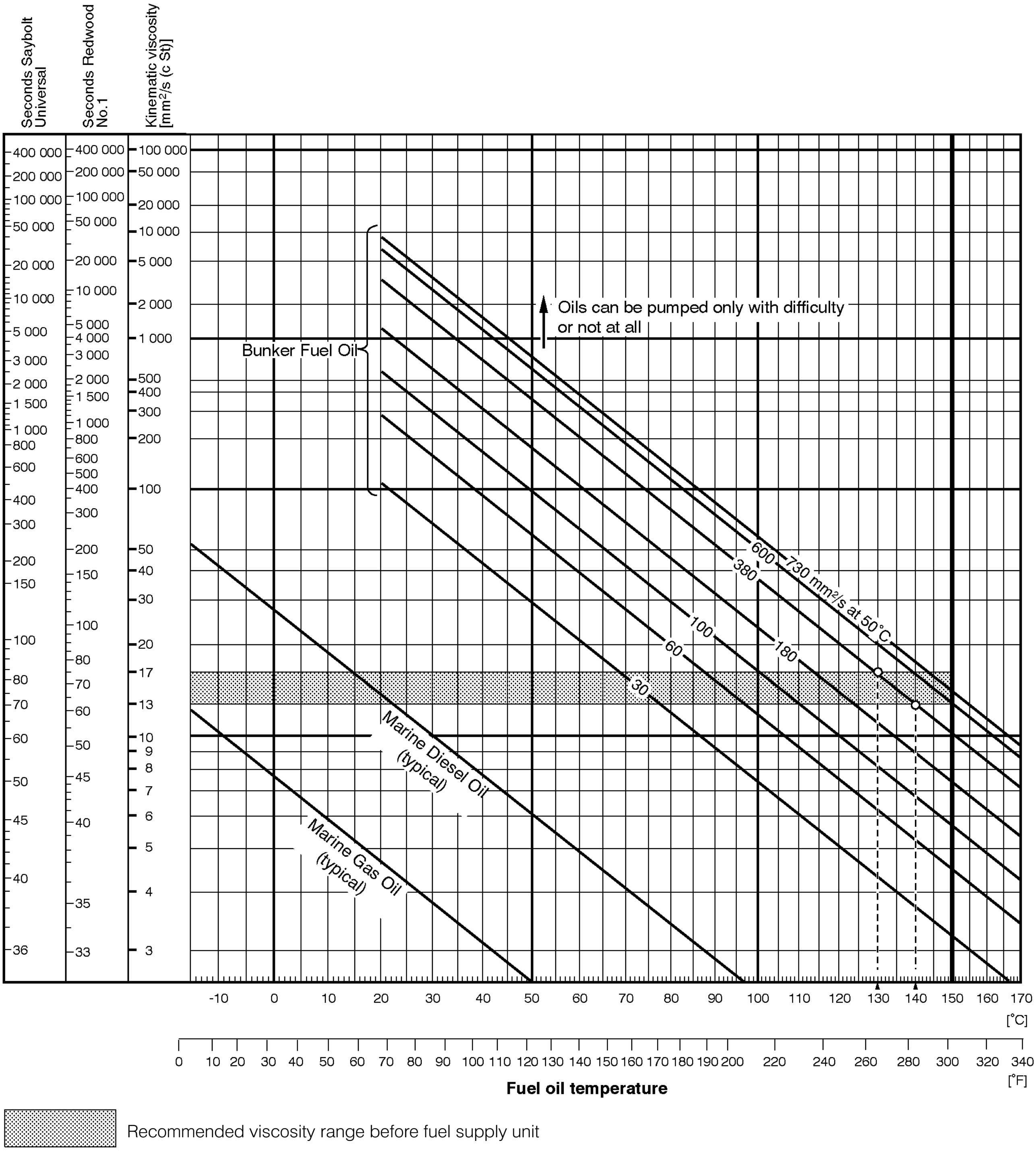
This is a legal requirement with regard to the fire hazards of petroleum based fuels.

Pour point

The lowest operating temperature of the fuel should be kept about **5–10 C above the pour point** to secure easy pumping.

Ignition quality

Contaminants, unstable fuels and incorrect injection (temperature, timing, nozzle wear) are the main reasons for incomplete or improper combustion. Some fuels cause more combustion problems by nature. These can possibly be detected by looking at the unnatural ratio between viscosity and density (CCAI), and with combustion analyzing equipment like FIA tests.



Example:

To obtain the recommended viscosity before the fuel supply unit, fuel oil of 380 mm^2/s (cSt) at 50 °C must be heated up to 130 – 140 °C.

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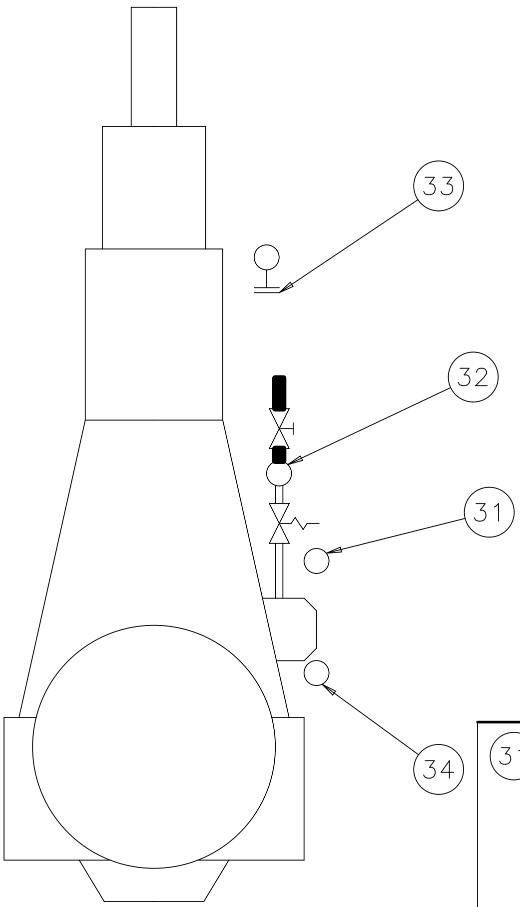
Fig. F25 Typical viscosity / temperature diagram

F. Ancillary systems

Specifications for the engine fuel oil system that need to be met



31	Fuel oil inlet - Inlet pressure: stopped engine 10 bar running engine 7 bar - Viscosity for HFO: 13–17 cSt - Min. viscosity MGO/MDO: min. 2 cSt - Filter: max. 34 micron absolute (sphere passing mesh) filter - Volume flow: according to WinGTD
32	Fuel oil outlet - Led back to mixing tank
33	Fuel leakage pipe rail unit (dirty) - Connected to sludge tank
34	Fuel leakage pipe rail unit/supply unit (clean) - Connected to fuel oil overflow tank

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Fig. F26 Connections and specifications for the engine lubrication system

Fuel oil system main circuit

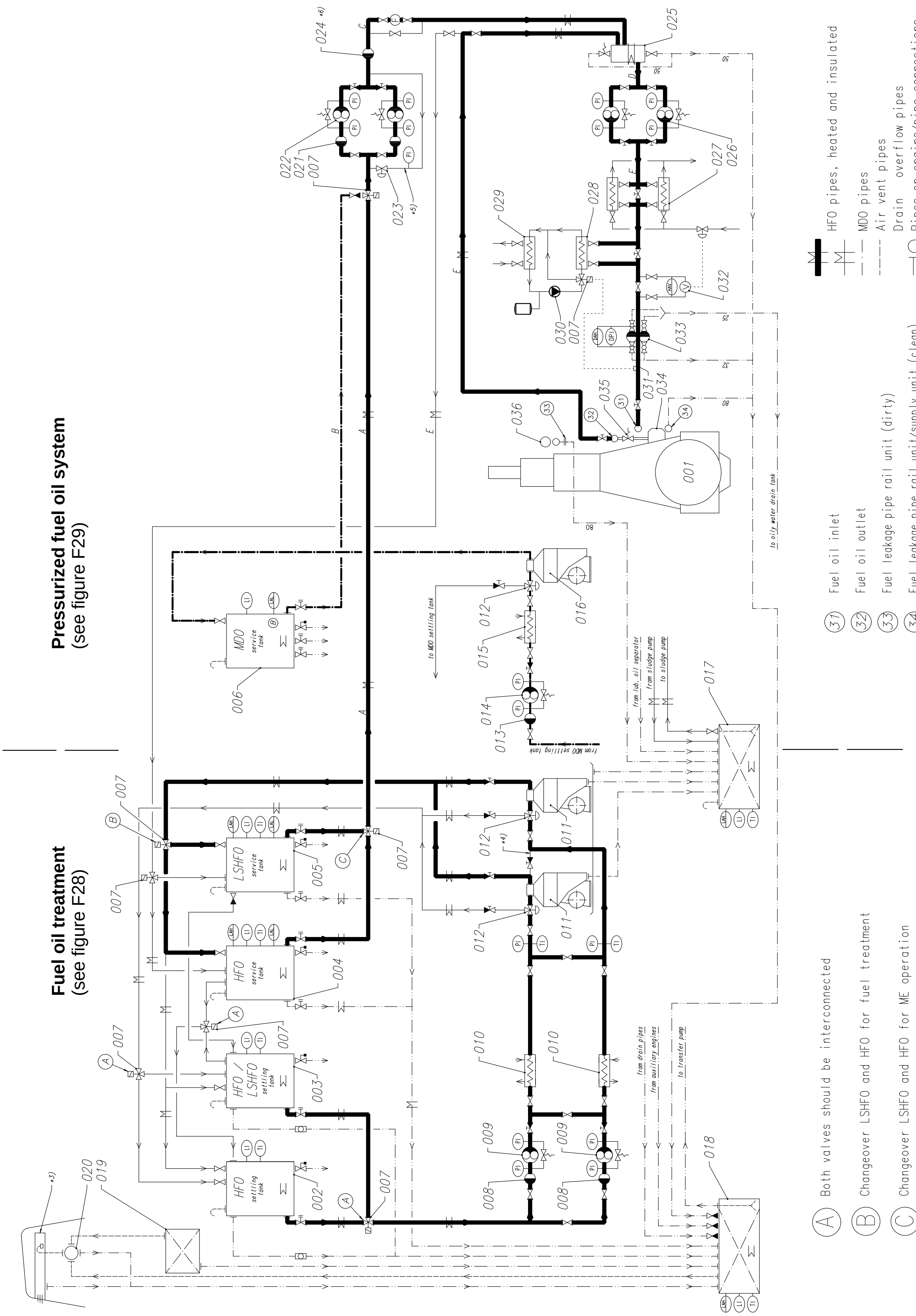

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Fig. F27 Fuel oil system main circuit

Note:
For legend and additional information refer to table F11.

F. Ancillary systems

001 Main engine RT-flex84T-D
002 HFO settling tank, heated and insulated
003 HFO/LSHFO settling tank, heated and insulated
004 HFO service tank, heated and insulated
005 LSHFO service tank, heated and insulated
006 MDO service tank
007 Three way valve, mnaually or remotely operated
008 Suction filter
009 HFO/LSHFO separator supply pump, with safety valve *1)
010 HFO pre-heater
011 Self-cleaning HFO/LSHFO separator *2)
012 Three-way valve, diaphragm operated
013 suction filter
014 MDO separator supply pump, with safety valve *1)
015 MDO pre-heater
016 Self-cleaning MDO separator *2)
017 Sludge tank
018 Fuel oil overflow tank
019 Air vent collector
020 Air vent manifold
021 Fuel oil suction filter, heated (trace heating acceptable)
022 Fuel oil feed pump
023 Pressure regulating valve
024 Automatic self-cleaning filter, heated (trace heating accepted)
025 Mixing unit, heated and insulated (according to sparate drawing)
026 Fuel oil booster pump
027 Endheater
028 FW - fuel oil cooler (cooler-chiller unit)
029 Chiller (cooler-chiller unit)
030 Fresh water circulating pump (cooler-chiller unit)
031 Temperature sensor
032 Viscosimeter
033 Fuel oil filter (trace heating acceptable)
034 Fuel supply unit
035 Pressure retaining valve
036 Fuel rail unit

Possible arrangements

1.) HFO : 1 settling tank, 1 service tank
LSHFO: 1 settling tank, 1 service tank
MDO : 1 settling tank, 1 service tank

2.) HFO : 2 settling tanks, 1 service tank
LSHFO: 2 settling tanks, 1 service tank
MDO : 1 settling tank, 1 service tank

3.) HFO & LSFO combined: 2 settling tanks
HFO : 1 service tank
LSHFO: 1 service tank
MDO : 1 settling tank, 1 service tank

Remarks

*1) Pump may be omitted if integrated in separator
*2) Separator capacity related to viscosity in accordance with instructions of separator manufacturer.
*3) Vent chamber in funnel
*4) Connection pipe optional
*5) The return pipe may also be led to the HFO service tank.
*6) Optional

- Feed pumps (pos.023) shall be installed below MDO and HFO service tanks.
- All heaters to be fitted with thermometers, relief valves, drains and drip trays.
- Steam tracers on main engine are laid out for 7 bar saturated steam.
- Air vent and drain pipes must be fully functional at all inclination angles of the ship at which the engine must be operational.

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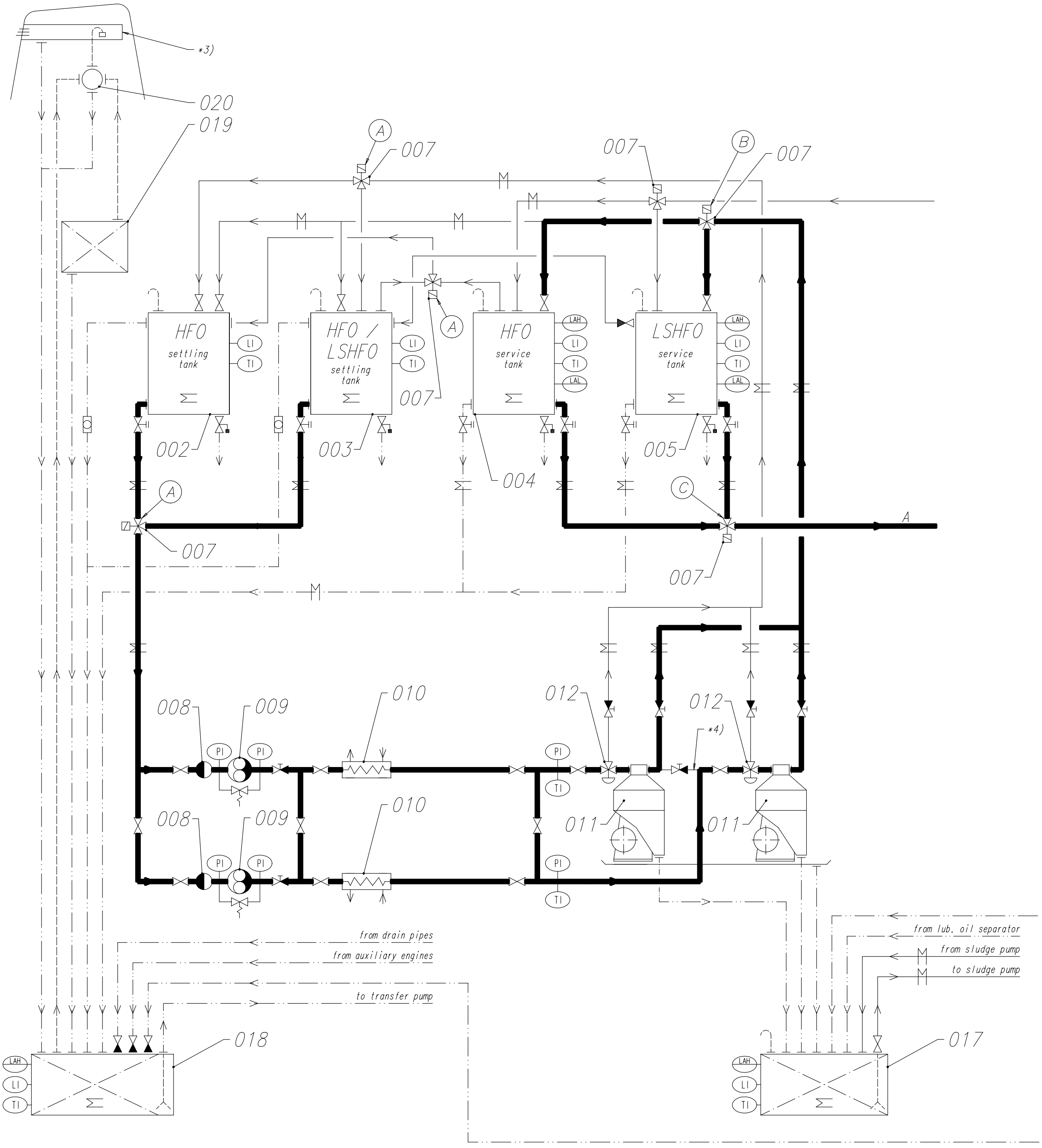
		Number of cylinders	**5**	**6**	**7**	**8**	**9**
Main engine RT-flex82T	power	kW	21 000	25 200	29 400	33 600	37 800
	speed	rpm	76				
Mixing unit	cap.	litre	acc. to figure F31				
Heavy fuel oil settling tank *1)	capacity	m^3					
Heavy fuel oil service tank *1)	cap.	m^3					
Marine diesel oil service tank *2)	cap.	m^3					
Sludge tank approx. 10 % from service tank *3)	cap.	m^3					
Nominal pipe diameter	A	DN	65	65	80	80	80
	B	DN	50	50	50	65	65
Nominal pipe diameter	C	DN	50	65	65	65	65
Nominal pipe diameter	D	DN	80	100	100	100	100
Nominal pipe diameter	E	DN	65	80	80	80	80

Remarks: *1) based on 8 hours running time with HFO at MCR (kW)
*2) based on 8 hours running time with MDO at MCR (kW)
*3) Capacity depends upon contamination of fuel oil and ship owner requirements.

Table F11 Heavy fuel oil treatment and tank system data

F2.3.2 Fuel oil treatment

Figure F28 'Heavy fuel oil treatment and tank layout' is a schematic diagram of a fuel oil treatment plant and the following paragraphs are for consideration before designing a system.



Note: For legend and additional information to this layout refer to table F11.

Fig. F28 Heavy fuel oil treatment and tank system layout

F2.3.2.1 Settling tanks

Gravitational settling of water and sediment from modern heavy fuel oils is an extremely slow process due to the small difference in densities. The settling process is a function of the fuel surface area of the tank to the viscosity, temperature and density difference, heated large surface area tanks enable better separation than heated small surface area tanks.

F2.3.2.2 Service tanks

Most of the service tank design features are similar to the settling tank, having a self-closing sludge cock, level monitoring device and remote closing discharge valves to the separator(s) and engine systems. The service tank is to be equipped with a drain valve arrangement at its lowest point, an overflow to the overflow tank and recirculating pipework to the settling tank. The recirculation pipe reaches to the lower part of the service tank to guide water which may be present in the fuel after the separators (eg due to condensation or coil leakage) into the settling tank. A pipe to the separators should be provided to re-clean the fuel in case of dirty water contamination. This line should be connected just above the drain valve at the service tank bottom.

The fuel is cleaned either from the settling tank to the service tank or recirculating the service tank. Ideally when the main engine is operating at CMCR, the fuel oil separator(s) should be able to maintain a flow from the settling tank to the service tank with a continual overflow back to the settling tank. The sludge cock is to be operated at regular intervals to observe the presence of water, an important indication to the condition of the separator(s) and heating coils.

Diesel oil service tanks are similar to the heavy oil service tanks with the exception possibly of tank heating, although this may be incorporated for vessels constantly trading in cold climates.

F2.3.2.3 Centrifugal separators

- Separator type – self-cleaning:

It is advisable to use fuel oil separators without gravity discs to meet the process requirements of the marine diesel oil and 730 cSt heavy fuel oils. These separators are self-adjusting and do not require gravity discs to be changed for different fuel densities. The manufacturers claim extended periods between overhaul and greatly improved reliability, enabling unattended onboard operation. The minimum effective throughput capacity of the separators required is determined by the following example. The nominal separator capacity and the installation are to comply with the recommendations of the separator manufacturer.

- Throughput capacity
  = 1.2 · CMCR · BSFC / 1000 [litres / hour]
  CMCR in kW
- Example:
  7RT-flex84T-D with – CMCR: 29 400 kW
  – BSFC: 171 g/kWh
  Throughput = 1.2 · 29 400 · 171 / 1000
  Throughput = **6033 litres/hour**

– **Separator arrangement**

- Separator without gravity disc:
  One of the main features of these self-adjusting separators is that only a single unit is required. This unit operates as a combined purifier/clarifier. However, as it is usual to install a stand-by separator as a back-up, it is of advantage to use this separator to improve the separation result. For the arrangement of the separators, parallel or in series, please refer to the manufacturer's instructions.

- Separator with gravity disc:
  These types are running in series with the fuel being purified in one and clarified in the other, two separators are required. The clarifier improves the separation result and acts as a safety device in case that the purifier is not properly adjusted. It is important when processing heavy fuel oils that strict adherence is made to the separator manufacturer's recommendations. If using these separators it will be advantageous to install an extra separator for marine diesel oil only in order to avoid the changing of gravity discs when switching from HFO to MDO separation.

The **m**arine **d**iesel **o**il (MDO) separator capacity can be estimated using the same formula.

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:

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

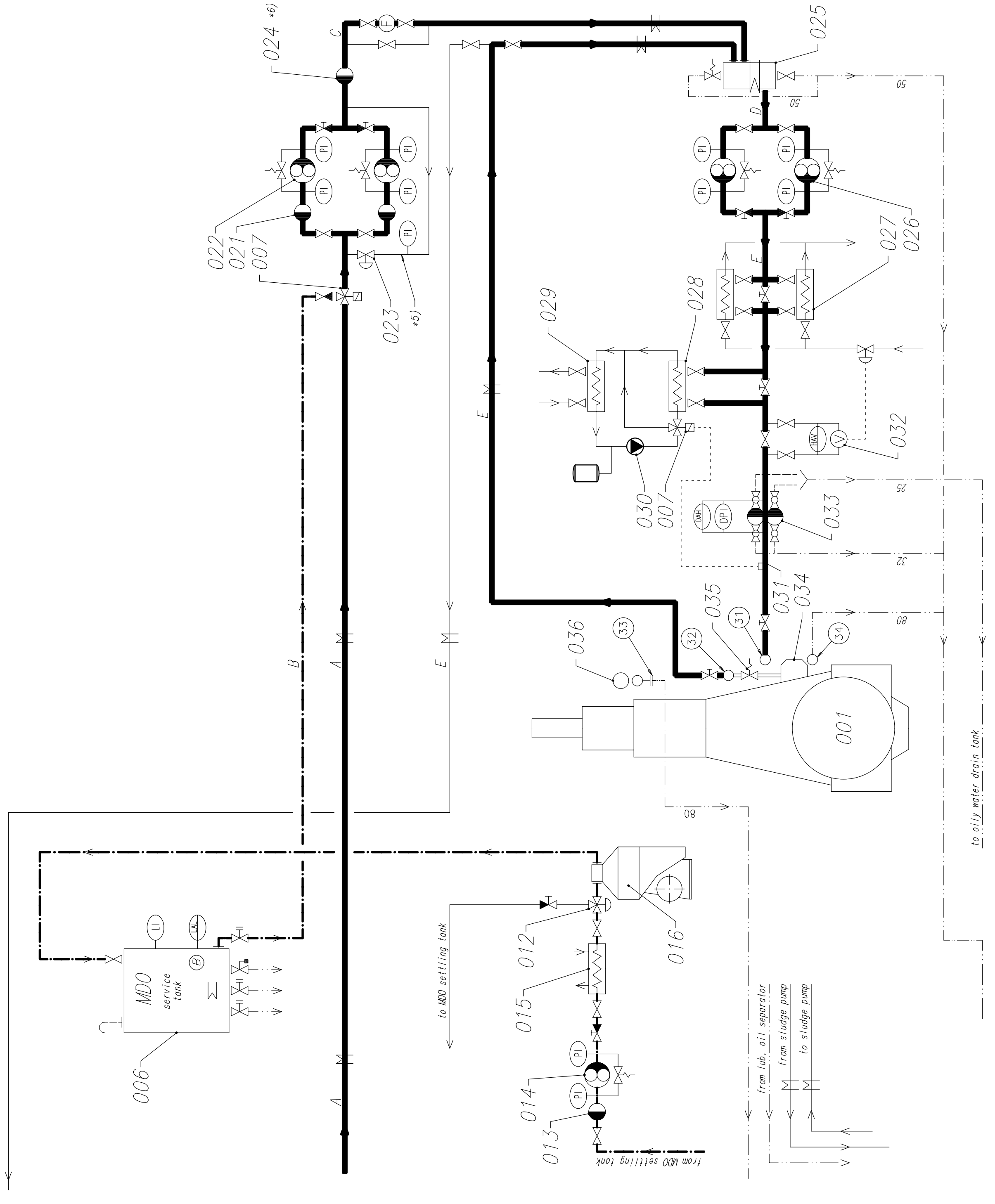
where:

n	separation efficiency [%]
C_{out}	number of test particles in cleaned test oil
C_{in}	number of test particles in test oil before separator

F2.3.3 Pressurized fuel oil system

Referring to figure F29 and table F11, the fuel from the heated heavy fuel oil service tank or the unheated diesel oil service tank passes through the three-way valve (007), filter (008), and is transferred to the mixing unit (025) by the low-pressure feed pump (022). The high pressure booster pump (026) transfers the fuel through the endheater (027), viscosimeter (032) and filter (033) to the fuel supply unit (034). Circulation is maintained via pipework back to the mixing unit which equalizes the temperature between hotter oil returning from the engine and the cooler oil from the service tank. The pressure regulating valve (035) controls the delivery of the low-pressure feed pump and ensures that the discharge pressure is 1 bar above the evaporation pressure in order to prevent entrained water from flashing off into steam. When the engine is running on marine diesel oil the steam heaters and viscosimeter are only required prior to changing over to heavy oil or immediately after changing from heavy to diesel when there is still heavy oil in the system.

F. Ancillary systems



Note:
For additional information to this layout refer to table F11.

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Fig. F29 Pressurized fuel oil system

F2.3.4 Fuel oil system on the engine

Figure F30 is a schematic arrangement of the fuel oil system mounted on the engine. The quantity of fuel oil delivered to the supply pumps (supply unit) by the booster pump installed in the plant is greater than the amount actually required, with the excess fuel being recirculated via the mixing unit, please refer to section F2.3.3 ‘Pressurized fuel oil system’.

When commissioning the fuel system with the engine at stand-by, the fuel pressure at the inlet of the supply unit is to be set at 10 bar, to result in a pressure of minimum 7 bar when the engine is running at 100 % load.

F. Ancillary systems

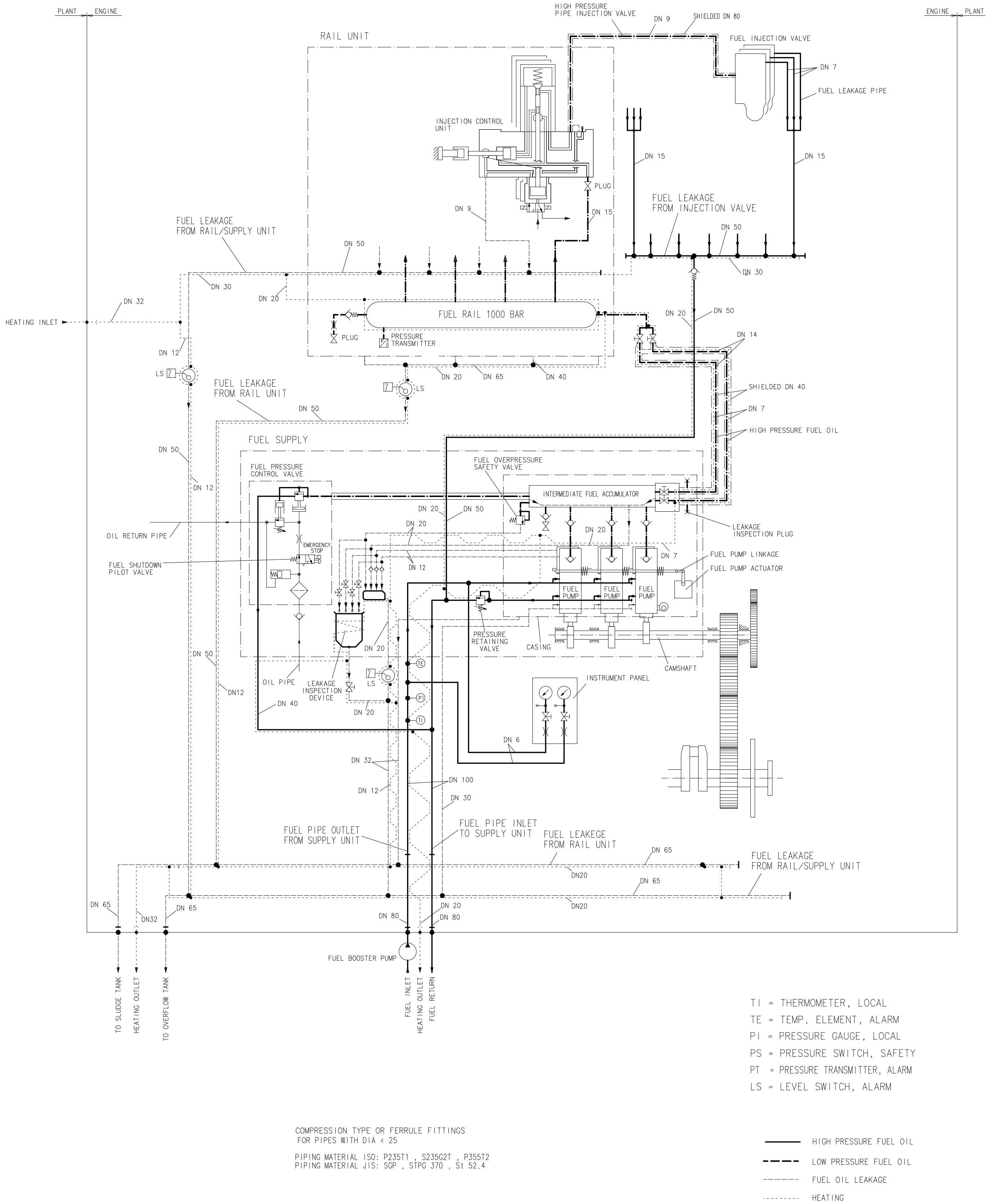

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Fig. F30 Fuel oil system on the engines 5–7RT-flex84T-D

F2.3.5 Heavy fuel oil system components

Fuel oil feed pump

- Pump type: positive displacement screw type with built-in overpressure relief valve.
- Pump capacity: refer to table F1.
  the given capacity is to be within a tolerance of 0 to +20 %.
- Fuel type: marine diesel oil and heavy fuel oil, up to 730 cSt at 50 °C.
- Working temperature: ambient to 90 °C.
- Delivery pressure: the delivery pressure is to take into account the system pressure drop and prevent entrained water from flashing off into steam by ensuring the pressure in the mixing unit is at least 1 bar above the water vapour pressure and not lower than 3 bar. The water vapour pressure is a result of the system temperature and pressure for a given fuel type. Heavier oils need more heat and higher temperatures to maintain them at the correct viscosity than lighter oils, refer to the formula and example below:
  Delivery gauge pressure
  $= p_v + 1 + \Delta p_1 + \Delta p_2$ [bar]

where:

p_v = water vapour gauge pressure at the required system temperature [bar] (see viscosity/temperature diagram fig. F25).
Δp_1 = maximum pressure losses between the feed pumps and the mixing unit [bar].
Δp_2 = maximum pressure change difference across the pressure regulating valve of the feed system between minimum and maximum flow.
Refer to 'Pressure regulating valve' next.

Example

HFO of 730 cSt at 50 °C

- Required system temperature:
  approx. 145 °C
- Water vapour gauge pressure at 145 °C
  $p_v = 3.2$ bar
- Pressure losses between feed pump and mixing unit: $\Delta p_1 = 0.5$ bar
- Pressure change difference across the pressure regulating valve: $\Delta p_2 = 0.6$ bar
- Substituting these values in the formula:
- Delivery pressure $= 3.2 + 1 + 0.5 + 0.6$
  $= 5.3$ bar

Electric motor

- The electric motor driving the fuel oil feed pumps shall be sized large enough for the power absorbed by the pump at maximum pressure head (difference between inlet and outlet pressure), maximum fuel oil viscosity (600 cSt) and the required flow.

Pressure regulating valve

- The pressure regulating valve maintains the inlet pressure to the booster system practically constant irrespective of the actual amount of fuel consumed by the main engine and auxiliaries. It should have a flat steady state characteristic across the fuel oil recirculation flow range.
- Valve type: self- or pilot-operated which senses the upstream pressure to be maintained through an external line. It is to be pneumatically or direct hydraulically actuated with an additional manual control for emergency operation. When using a pneumatic type, use a combined spring type to close the valve in case of air supply failure.
- Fuel oil viscosity: 100 cSt, at working temp. (HFO 730 cSt at 50 °C).
- Maximum capacity: refer to feed pump capacity in table F1.

- Minimum capacity: approximately 20 % of that of the feed pump.
- Service pressure: max. 10 bar
- Pressure setting range: 2–6 bar
- Inlet pressure change: ≤ 0.8 bar,
  between 20 % and 100 % flow (upstream pressure build-up over the valve capacity; between the minimum and maximum flow capacity).
- Working temperature: ambient to 90 °C

Mixing unit

- Due to the small amount of fuel consumed there is only need of a small mixing unit. It is recommended that the tank contains no more than approx. 100 litres. This is to avoid the change over from HFO to MDO or visa versa taking too long.
- The mixing unit equalizes the temperature between the hotter fuel oil returning from the engine and the cooler fuel oil from the day tank, particularly when changing over from heavy fuel oil to marine diesel oil and vice versa.
- Type: cylindrical steel fabricated pressure vessel as shown in figure F31.
- Capacity: see figure F31.
- Dimensions: see figure F31.
- Service pressure: 10 bar
- Test pressure: according to the classification society.
- Working temperature: ambient up to 150 °C.

High-pressure booster pump

- Pump type: positive displacement screw type with built-in overpressure relief valve.
- Pump capacity: refer to table F1, the given flow rate is to be within an allowable tolerance of 0 to +20 %.
- Inlet pressure up to 6 bar
- Delivery head: see table F1, final delivery pressure according to the actual piping layout.
- Working temperature: ambient up to 150 °C

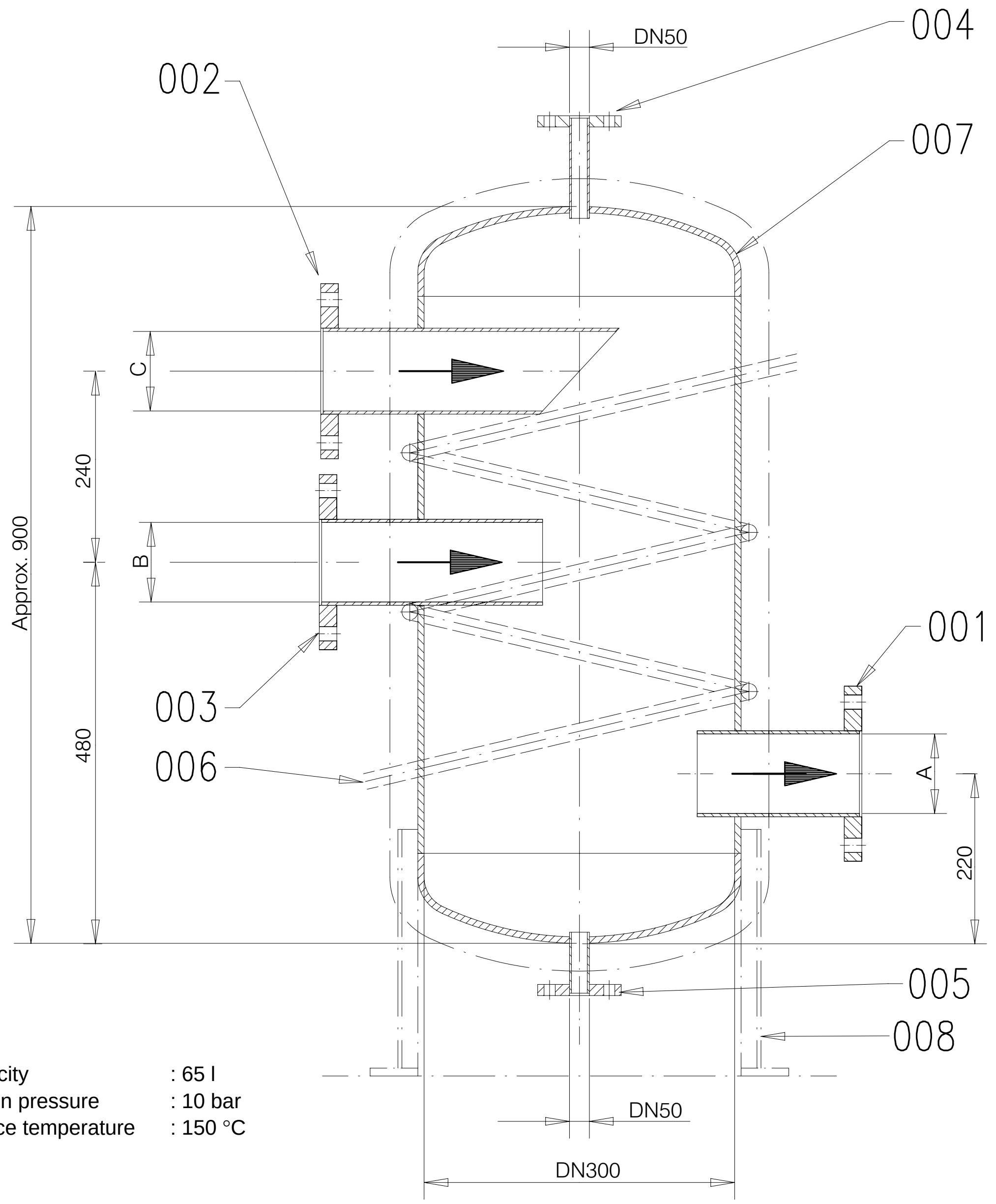
Electric motor (booster pump)
Refer to the remarks for electric motor for the feed pumps (anterior page).

Fuel oil endheater

- Heater type: steam, electric or thermal oil, tubular or plate type heat exchanger suitable for heavy oils to 730 cSt at 50 °C.
- Working pressure: max. 12 bar,
  pulsating on fuel oil side.
- Working temperature: ambient up to 150 °C, outlet temperature on fuel oil side.
- Heating capacity [kW]:
  $= 0.75 \cdot 10^{-6} \cdot \mathrm{CMCR} \cdot \mathrm{BSFC} \cdot (T_1 - T_2)$
- Consumption of saturated steam at 7 bar gauge pressure [kg/h]:
  $= 1.32 \cdot 10^{-6} \cdot \mathrm{CMCR} \cdot \mathrm{BSFC} \cdot (T_1 - T_2)$
- where:

  BSFC is the brake specific fuel consumption at the **c**ontract **m**aximum **c**ontinuous **r**ating (CMCR).
  T_1 is the temperature of the fuel oil at the viscosimeter.
  T_2 is the temperature of the fuel oil from the service tank.
- Example: 7RT-flex84T-D with CMCR at R1: 29 400 kW at 76 rpm,
  BSFC of 171 g/kWh,
  using 730 cSt fuel,
  at a system temperature of 145 °C (T_1),
  assuming the heavy fuel oil service tank is kept at a steady temperature of 65 °C (T_2).
  Heater capacity required:
  $= 0.75 \cdot 10^{-6} \cdot 29\,400 \cdot 171 \cdot (145 - 65)$
  = 245 kW
  Consumption of saturated steam at 7 bar gauge pressure:
  $= 1.32 \cdot 10^{-6} \cdot 29\,400 \cdot 171 \cdot (145 - 65)$
  = 431 kg/h

The viscosimeter monitors the fuel viscosity prior to the supply unit and transmits signals to the heater controls to maintain this viscosity by regulating the fuel temperature after the endheater.



Capacity : 65 l
Design pressure : 10 bar
Service temperature : 150 °C

001 Outlet
002 Inlet, return pipe
003 Inlet, from feed pump
004 Vent
005 Drain
006 Heating coil
007 Insulation
008 Mounting brackets *1)

Remarks:

*1) Mounting brackets for fixation on floor plate. The mixing unit must not be fitted unsupported!

— Configuration and dimension of the mixing unit have to comply with the relevant classification societies/rules.

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Fig. F31 Fuel oil system mixing unit

Number of cylinders			5	6	7	8	9
Nominal pipe diameter	**A**	DN	80	100	100	100	100
	B	DN	50	65	65	65	65
	C	DN	65	80	80	80	80

Table F12 Fuel oil system mixing unit: nominal pipe diameters for connections A, B, C

F2.3.5.1 Fuel oil filter

A mesh size of maximum **34** microns (sphere passing mesh) is the absolute minimum requirement for the fuel oil filter. This specified filtration grade conforms to a high reliability and optimal cleaning efficiency of the centrifugal separators (see the note on the next page).

Arrangement before the supply unit

Figure F32 A: High temperature (booster circuit). This filter is extremely important to protect the supply unit and is to be installed as close as possible to the inlet of the supply unit. The absolute minimum requirements are met by using either one of the following filters: duplex filter or automatic back-flushing filter.

Filter type:

Change-over duplex (full flow)
Heatable designed for in-service cleaning, fitted with differential pressure gauge and high differential pressure alarm contacts.

or

Automatic back-flushing filter
Heated, with differential pressure gauge and differential pressure alarm contacts. Designed for automatic in-service cleaning, continuous or discontinuous back-flushing, using filtered fuel oil or compressed air techniques.

Further specifications/properties of the filters:

- Working viscosity: 13–17 cSt.
- Flow rate: booster pump capacity, refer to table F1. The given capacities cover the needs of the engine only.
  If an automatic back-flushing filter type is installed, the feed and booster pump capacities must be increased by the quantity needed for the back-flushing of the filter.
- Service pressure: max. 12 bar at filter inlet.
- Test pressure: specified by classification society.
- Permitted differential pressure at 17 cSt: clean filter: max. 0.2 bar, dirty filter: 0.6 bar, alarm setting: max. 0.8 bar.
- Minimum bursting pressure of filter insert: max. 8 bar differential across filter.
- Working temperature: ambient up to 150 °C.
- Mesh size: max. **0.034** mm, sphere passing mesh.
- Filter insert material: stainless steel mesh (CrNiMo).

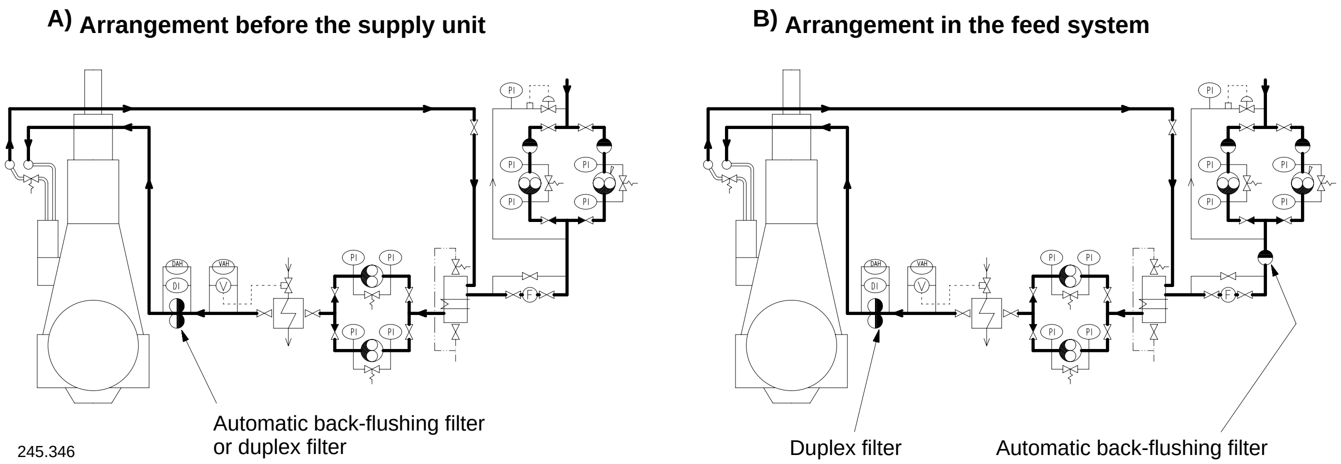


Fig. F32 Filter arrangements

Arrangement in the feed system

Figure F32 B: If the requirement is for an automatic back-flushing filter, it is best to fit it on the low-temperature side in the discharge from the feed pumps. Locating the filter at this point reduces the risk of clogging due to asphaltene coagulation.

Back-flushing filter

- Working viscosity: 100 cSt, for HFO of 730 cSt at 50 °C.
- Flow rate: feed pump capacity, refer to table F1. The given capacities cover the needs of the engine only.
  The feed pump capacity must be increased by the quantity needed for the back-flushing of the filter.
- Service pressure at filter inlet, after feed pumps: 10 bar
- Test pressure: specified by classification society.
- Permitted differential pressure at 100 cSt:
  clean filter: max. 0.2 bar,
  dirty filter: 0.6 bar,
  alarm setting: max. 0.8 bar.
- Minimum bursting pressure of filter insert: max. 8 bar differential across filter.
- Working temperature: ambient up to 90 °C.
- Mesh size: max. 0.034 mm (34 μm), sphere passing mesh.
- Filter insert material: stainless steel mesh (CrNiMo).

Duplex filter

- The installation of the automatic back-flushing filter in the low-temperature side does not replace the need for a duplex filter fitted immediately before the supply unit.
- The same technical data as specified for the arrangement before the supply unit are applied.
  The filter mesh size (sphere passing) in this case is max. **0.06** mm

Note:
Cat fines may, for various reasons, be present in the fuel when entering the engine. Excessive piston ring and cylinder liner wear on all cylinders is often caused by cat fines in the fuel oil. It is obvious that other exposed parts e.g. fuel pumps, fuel injection valves, piston rod and piston rod stuffing boxes will be also damaged if a high content of cat fines is present in the fuel oil.
The use of an automatic self-cleaning filter with a mesh size of 10 microns installed on the low-temperature side of the pressurized fuel oil system will additionally protect the engine from serious damages by removing cat fines which may have passed through the separator(s). This filter will also indicate changes in the separator efficiency and/or in the fuel quality.
Such an additional investment should especially be considered where, due to the ship's trading route, the risk of bunkering fuel with a high cat fines content is prevalent.

F2.3.6 Flushing the fuel oil system

This instruction describes the flushing procedure for the *external* fuel oil system (on the plant). The flushing of the *internal* fuel oil system (on the engine) is under the responsibility of the engine builder and should be already done. If flushing of the internal fuel oil system is indicated, please consult the “Instruction for Flushing of Lub. Oil and Fuel Oil System” and “Instruction for Flushing for Common Rail System” provided by the engine bulder.

A correct manufacturing of the pipes avoids the presence of scales, slag and spelter. It is a fact that the expense for special welding methods, e.g. inert gas welding, is worthwhile when considering the costs of an extensive flushing procedure or the grinding and cleaning work if using normal electric arc welding or welding with electrodes. A thorough cleaning of the pipes before mounting is a must.

It is absolutely essential to ensure that the fuel oil systems are clear of all foreign matter before circulating fuel oil through to the engine. A systematic approach is to be adopted prior to commissioning when the tanks, pipework, filters, end-heaters, pumps, valves and other components are flushed and proved clear by observation and physical inspection. All fuel oil tanks are to be inspected and cleaned by hand to remove all residuals build-debris; special attention is to be paid to very small loose particles of welding matter such as spelter and slag.

The pipes of the entire fuel oil system on the plant side are to be flushed separately.

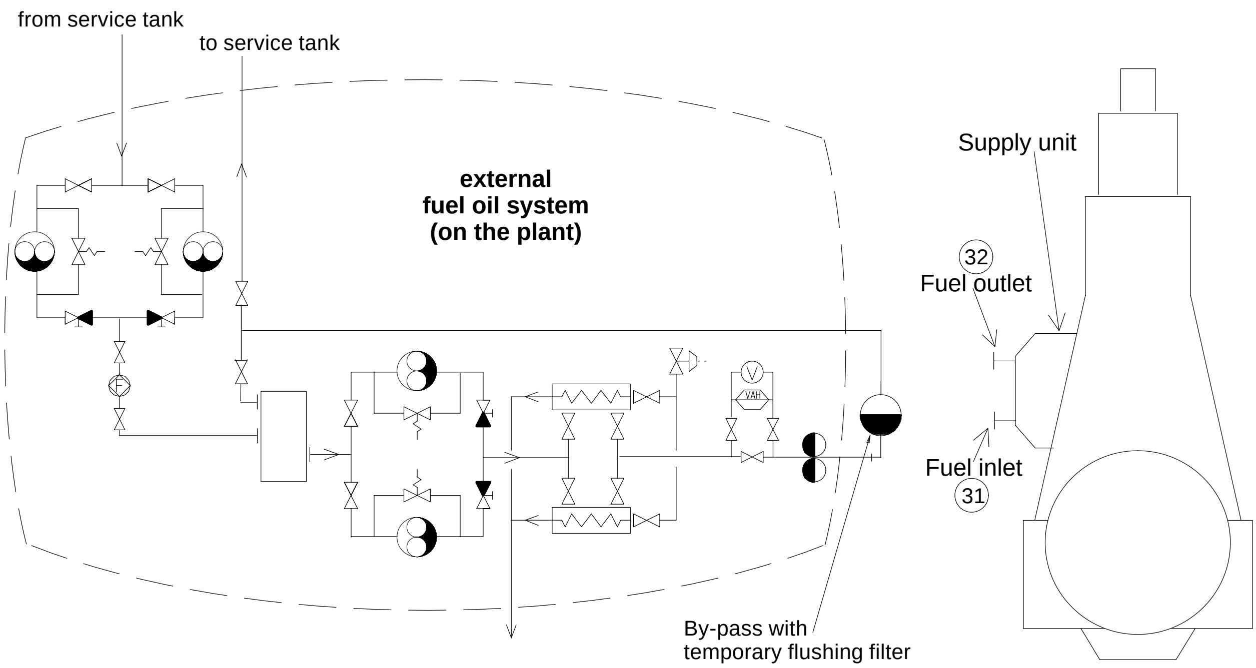


Fig. F33 Fuel oil system flushing

F2.3.6.1 Preparation before flushing

1. By-pass the fuel oil connections immediately before the supply unit by means of temporary hoses or pipes as shown in figure F33.
2. Install in the by-pass line a temporary filter with a mesh size (sphere passing mesh) of max. 0.03 mm (30 µm) and equipped with magnetic elements.
   Alternatively, the plant fuel oil duplex filter, if available, can be used under the condition that the filter inserts are of mesh size (sphere passing mesh) of max. 0.03 mm (30 µm). After flushing the filter, inserts are to be replaced by the original ones and the filter housing to be cleaned.

F2.3.6.2 Flushing procedure

1. Fill the service tank with sufficient marine diesel oil (MDO).
2. Circulate the MDO in the service tank using the separator(s) and pre-heater(s) to maintain the cleanliness and the MDO temperature at approximately 30°C. Operate the separator(s) until the flushing procedure is completed.
3. Circulate the MDO through the whole fuel oil system back to the service tank by running the feed and booster pump.
   Both pumps (feed and booster pump) must be in operation to ensure a correct fuel oil circulation through the whole fuel oil system. As the capacity of the booster pump(s) is higher than the one of the feed pump(s), part of the fuel returns, via the mixing tank, directly to the booster pump.
   The fuel must circulate freely in the return pipe to the service tank and from the feed pump to the mixing unit.
   The main and stand-by pumps are to be alternatively operated. Observe the suction and discharge pressure carefully; do not let run the pumps hot. Observe the pressure drop through the filters too.
4. During the flushing procedure, the pipes are to be periodically tapped to help loosen any foreign matter that may be present. If available, vibrators are to be used.
   All pipes used during the engine operation must be flushed, including by-pass lines.
   Inspect and clean all filters in the fuel oil system periodically.
   Drain the dirt of all equipments (mixing unit, endheater, etc.) where dirt can accumulate.

Flushing is to be continued until absolutely no residues can be found in the filters:
No metallic particles adhere to the magnetic inserts and no residues are detected in the bottom of the filter housing.

When the fuel oil system proves clean, the temporary flushing equipment can be removed and the engine connected to the fuel oil system.

F2.4 Starting and control air systems

Compressed air is required for engine starting, engine control, exhaust valve air springs, washing plant for the scavenge air coolers and general services.

F2.4.1 System layout

The starting and control air system shown in figure F34 is valid for five- to nine-cylinder engines and comprises two air compressors, two air receivers and systems of pipework and valves connected to the engine starting air manifold.

F2.4.2 Capacities of air compressor and receiver

The capacity of the air compressor and receiver depends on the total inertia (J_{Tot}) of the rotating parts of the propulsion system too.

- Total inertia = engine inertia + shafting and propeller inertia => (J_{Tot}) = (J_{Eng}) + (J_{S+P}).
- Propeller inertia includes the part of entrained water.
- Engine inertia (J_{Eng}) see table F13.
- Relative inertia $J_{Rel} = J_{Tot} / J_{Eng}$.

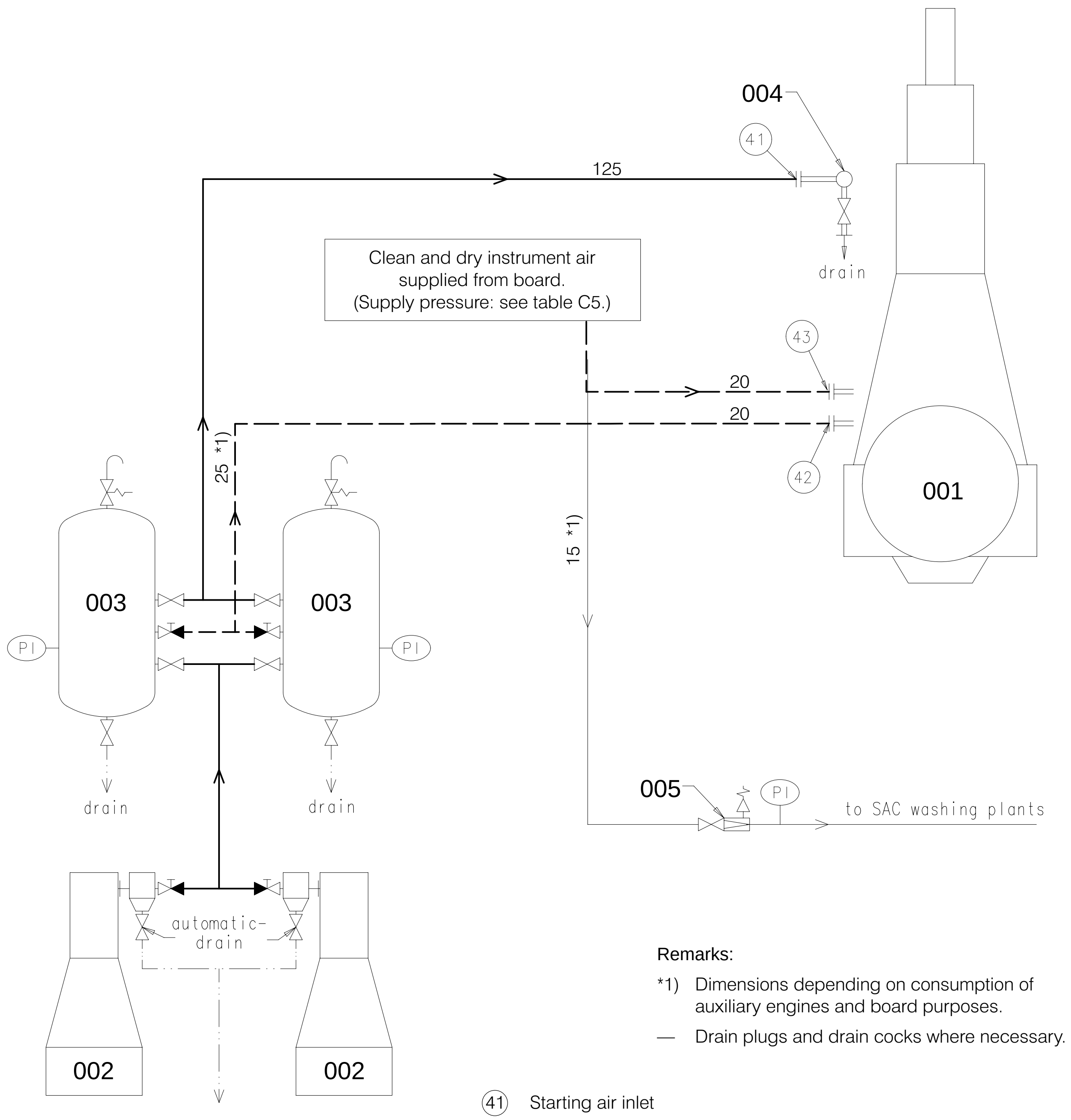
The air receiver and compressor capacities of table F13 refer to a relative inertia, **(J_{Rel} = 2.0).** For other values than 2.0, the air receiver and compressor capacities have to be calculated with the winGTD program. It provides the capacity of the air compressor and receiver for relative inertia values (J_{Rel}).
Table F13 outlines the basic requirements for a system similar to figure F34 ‘Starting and control air system’ for maximum engine rating.
Our winGTD program (available on the Licensee Portal) enables to optimise the capacities of the compressors and air receivers for the **c**ontract **m**aximum **c**ontinuous **r**ating (CMCR).

Starting air	Air receivers	Air compressors	J_{Eng} *2)
Number of starts requested by the classification societies for reversible engines	12 *1)	12 *1)	
Standard pressure	Max. air pressure 30 [bar] *3)	Free air delivery at 30 [bar] *3)	
No. of cylinders	Number x volume [m^3]	Number x capacity [Nm^3/h]	[kgm^2]
5	2 x 10.5	2 x 320	245 300
6	2 x 12.0	2 x 360	281 800
7	2 x 13.7	2 x 410	327 000
8	2 x 15.7	2 x 470	391 900
9	2 x 17.6	2 x 530	439 500

Remark: *1) 12 consecutive starts of the main engine, alternating between ahead and astern.
*2) Data given for engines without damper and front disc on crankshaft but included smallest flywheel.
*3) Data for air pressure of 25 bar are available on winGTD.

Table F13 Air receiver and air compressor capacities

F. Ancillary systems



41 Starting air inlet
42 Control air inlet, in case of board supply failure
43 Control air inlet (for control system and air spring)

001 Main engine RT-flex84T-D
002 Starting air compressor, 25/30 bar
003 Starting air receiver, 25/30 bar
004 Distribution pipe with automatic starting air shut-off valve
005 Pressure reducing valve, from 25/30 to 8 bar

Starting air feed pipes
Control air pipes
Ancillary equipment pipes
Drain pipes
Pipes on engine / pipe connections

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Fig. F34 Starting and control air system

F2.4.3 Starting and control air system specification

Starting air compressors

- Type: water cooled two stage with intercooler and oil / water separator. The discharge air temperature is not to exceed 90 °C and the air supply to the compressors is to be as clean as possible without oil vapour.
- Capacity: refer to table F13.
- Delivery gauge pressure: 30 or 25 bar.

Starting air receivers

- Type: fabricated steel pressure vessels having domed ends and integral pipe fittings for isolating valves, automatic drain valves, pressure reading instruments and pressure relief valves.
- Capacity: refer to table F13.
- Working gauge pressure: 30 or 25 bar.

F2.4.3.1 Control air system supply

The control air is supplied from the board instrument air supply system (see figure F34) providing air at 7–8 bar gauge pressure. The air quality should comply with the compressed air purity class:
2-4-2 according to ISO 8573-1 (2007-02-01).

(Capacity Nm^3/h)		Number of cylinders				
		5	**6**	**7**	**8**	**9**
Control system	up to	21.0	21.0	21.0	21.0	21.0
Exhaust valve air spring		12.0	14.4	16.8	19.2	21.6
Total		**33.0**	**35.4**	**37.8**	**40.2**	**42.6**

Table F14 Control air capacities

F2.4.4 General service and working air

General service and working air for driving air powered tools and assisting in the cleaning of scavenge air coolers is provided by the reducing valve (item 005, figure F34). The valve is to reduce 25 or 30 bar to 7–8 bar. Consumers other than engine starting and control are to be taken into account when final selection of compressor capacity and pipe dimensions is to be made.

F2.5 Leakage collection system and washing devices

Figure F35 'Leakage collection and washing system layout' is suitable for the whole engine series, with the same pipe sizes independent of the number of cylinders. Dirty oil collected from the piston underside is led under pressure of approximately 2.8 bar to the sludge oil trap (002) and then to the sludge oil tank (004). The purpose of the sludge oil trap is to retain the large amount of solid parts which may be contained in the dirty oil and to reduce the pressure by means of an orifice or throttling disc (003) fitted at its outlet so that the sludge oil tank (004) is under atmospheric pressure. The sludge oil trap is shown in figure F36. The dirty oil from the piston rod stuffing box, which consists of waste system oil, cylinder oil, metallic particles and small amounts of combustion products, is led directly to the sludge tank. Condensate from scavenge air is formed when the vessel is operating in a humid climate and is to be continually drained from the scavenge air receiver to avoid excessive piston ring and liner wear. As a guide, the largest amount of this condensate which is to be dealt with under extremely humid conditions is indicated on the system layout data (table F15).

001	Main engine RT-flex84T-D
002	Sludge oil trap (for details, see figure F36)
003	Throttling disc
004	Sludge or appropriate tank, available capacity approx. 2m^3
005	Throttling disc
006	Air vent manifold
007	Scavenge air cooler washing plant *1)
008	Turbocharger compressor washing plant *1)
009	Turbocharger turbine washing plant *1)
010	Turbocharger turbine dry cleaning plant (optional) *1)
011	Condensate drain units
012	Venting unit
11	Oily water drain from charge air receiver
12	Cylinder and scavenge air cooler, cooling water drain pipe
14	Washing water inlet TC/SAC *3)
15	Collector main condensate water from SAC
19	Condensate water from water separator and SAC *2)
20	Washing water outlet from SAC
21	Oil system TC venting
23	Common dirty oil drain from engine
25	Dirty oil from piston underside
28	Dirty oil from piston rod stuffing box
30	Venting pipe crankcase
40	Working air inlet SAC washing plant *3)

Remarks:

*1) One unit per turbocharger

*2) Depending on the relative air humidity and temperature before and after the scavenge air cooler condensate may be knocked out. Under extreme ambient conditions a maximum condensate quantity of up to 0.16 kg/kW/h may be produced.

*3) At free end or at driving end.

— Please note: For Mitsubishi MET turbochargers only DRY CLEANING method applies.

Washing water pipes
Dirty oil drain pipes
Compressed air pipes
Air vent pipes
Drain & overflow pipes
Pipes on engine / pipe connections

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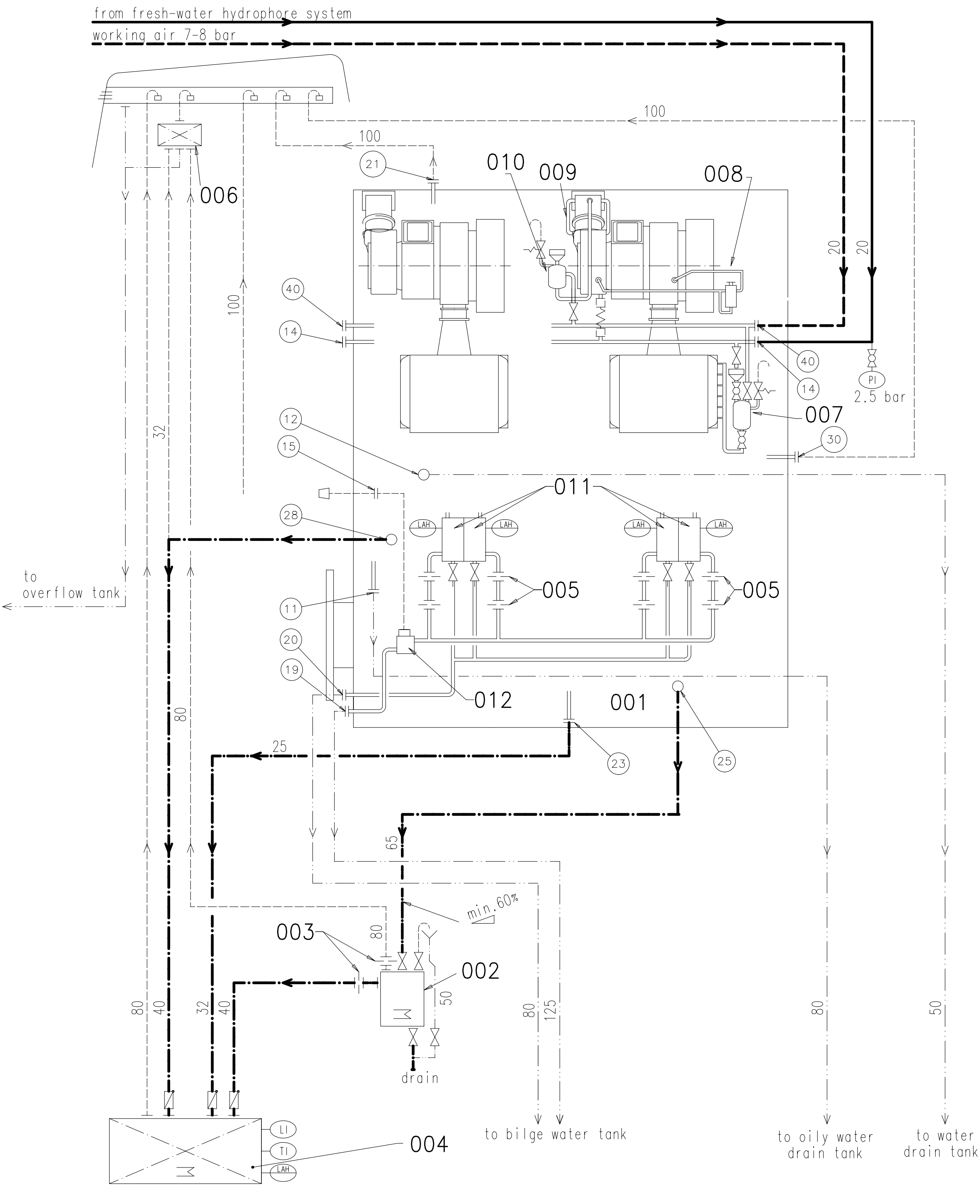
Table F15 Leakage collection and washing system

F. Ancillary systems



Note: Refer to table F15 for additional information and legend to this layout.

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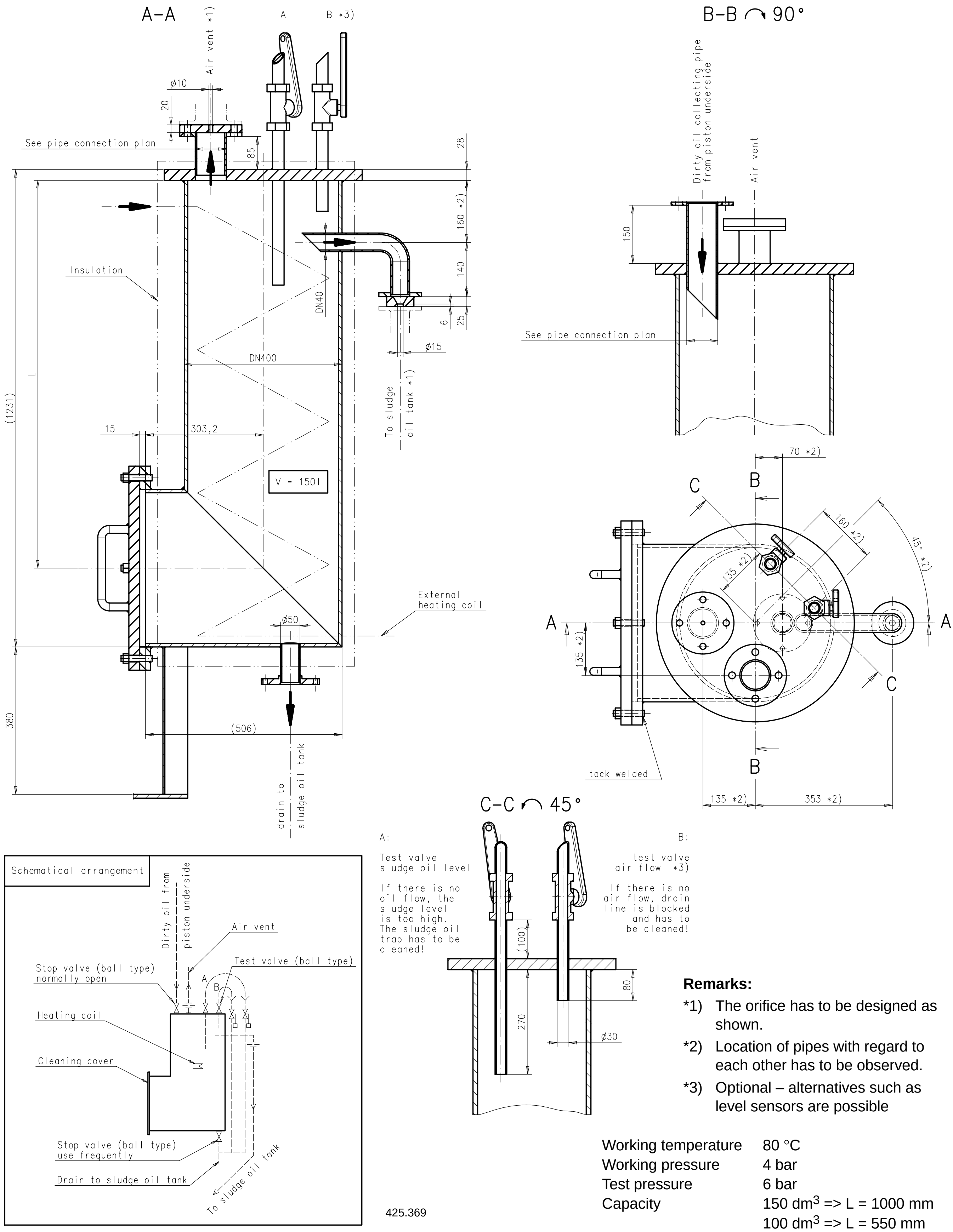
Fig. F35 Leakage collection and washing system

F. Ancillary systems



Remarks:

*1) The orifice has to be designed as shown.

*2) Location of pipes with regard to each other has to be observed.

*3) Optional – alternatives such as level sensors are possible

Working temperature	80 °C
Working pressure	4 bar
Test pressure	6 bar
Capacity	150 dm^3 => L = 1000 mm
	100 dm^3 => L = 550 mm

Fig. F36 Sludge oil trap

F. Ancillary systems

Engine exhaust uptakes can be drained automatically using a system as shown in figure F37.

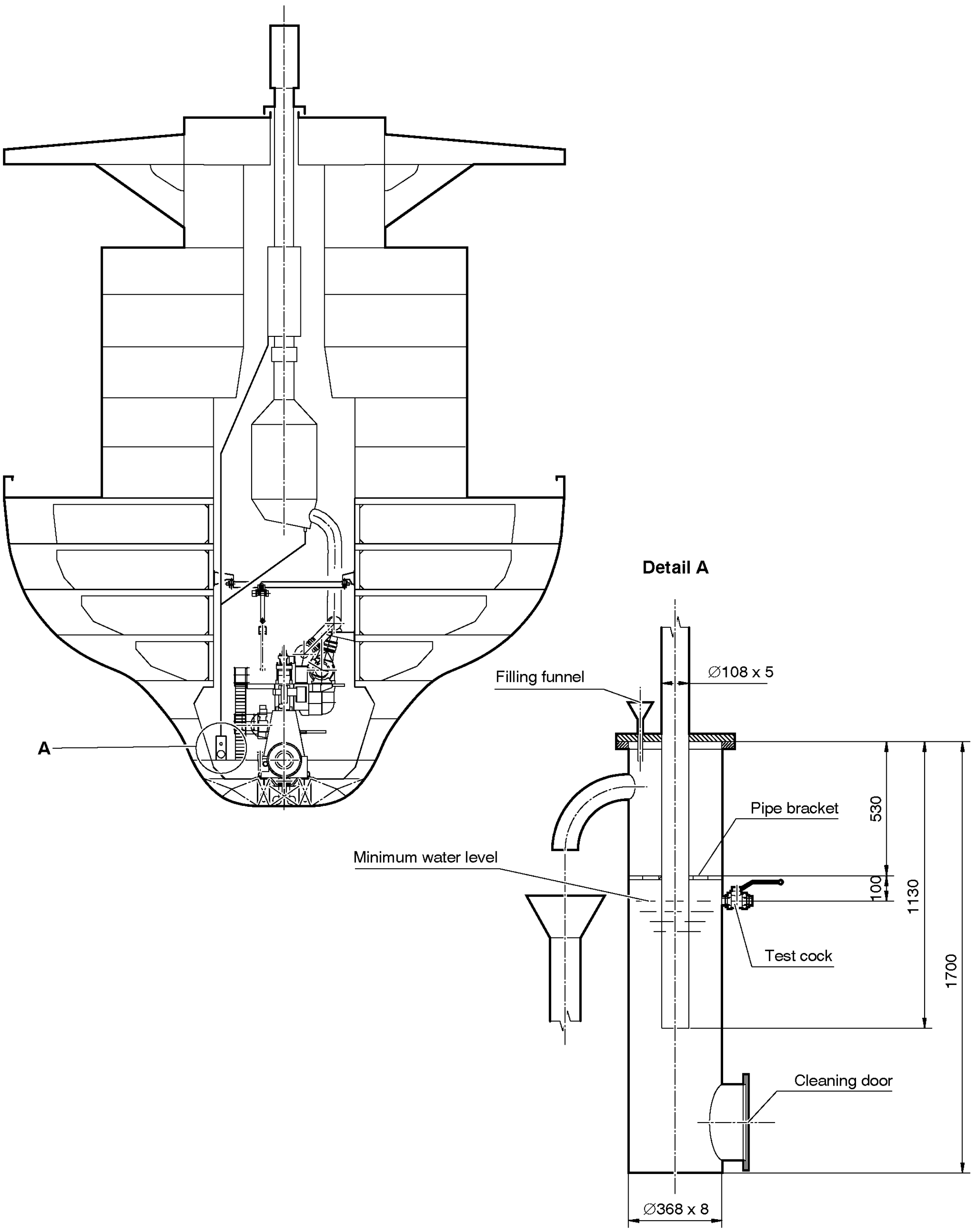


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Fig. F37 Arrangement of automatic water drain

F2.6 Exhaust gas system

To optimize the exhaust gas systems, please refer to the following calculations. The calculations based on figure F38 'Determination of exhaust pipe diameter', figure F39 'Estimation of exhaust gas density' and figure F40 'Estimation of exhaust pipe diameter' are given as an example only:

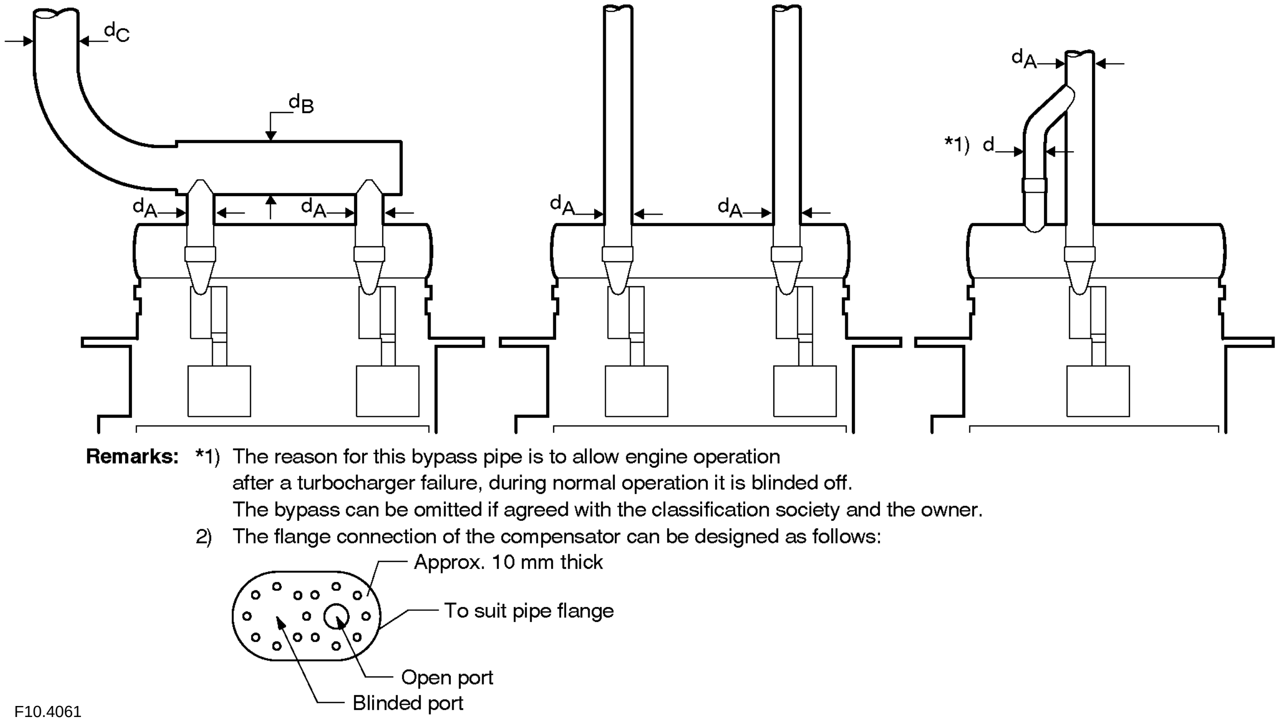


Fig. F38 Determination of exhaust pipe diameter

Example:

Estimation of exhaust gas pipe diameters for Wärtsilä 7RT-flex84T-D, CMCR (R1) specified and for design (tropical) conditions:

Power (R1) = 29 400 kW
Speed (R1) = 76 rpm

Recommended gas velocities:
Pipe A: WA = 40 m/s
Pipe B: WB = 25 m/s
Pipe C: WC = 35 m/s

1) Exhaust gas mass flow: 216 168 kg/h (according to table F1)

2) Exhaust gas temperature: 298 °C (according to table F1)

3) Exhaust gas density (assumed back pressure on turbine outlet Δp = 30 mbar (figure F39):

$$\rho_{EXH} = \frac{P}{RT} = 0.627 \text{ kg/m}^3$$

4) Number of turbochargers (according to figure C7):

n_{TC} = 2

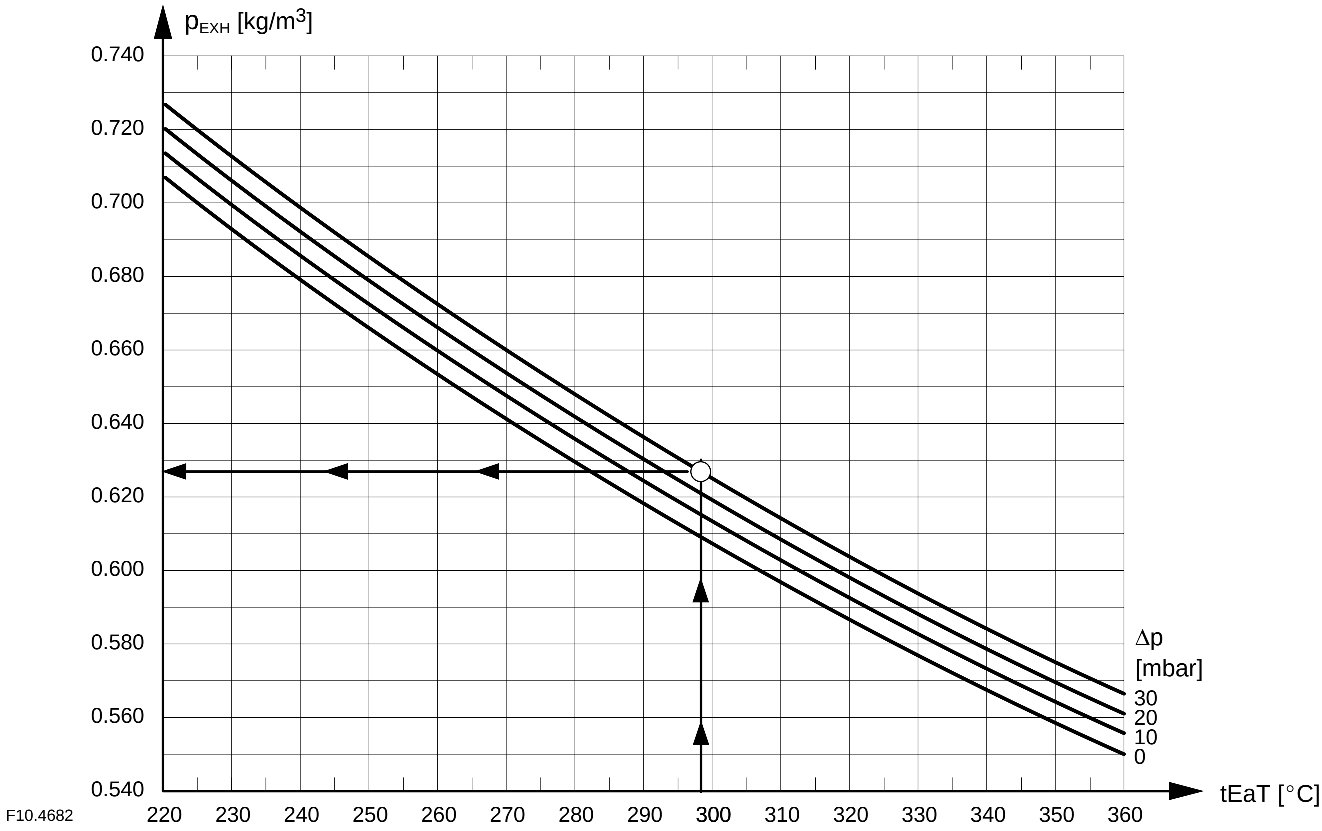


Fig. F39 Estimation of exhaust gas density

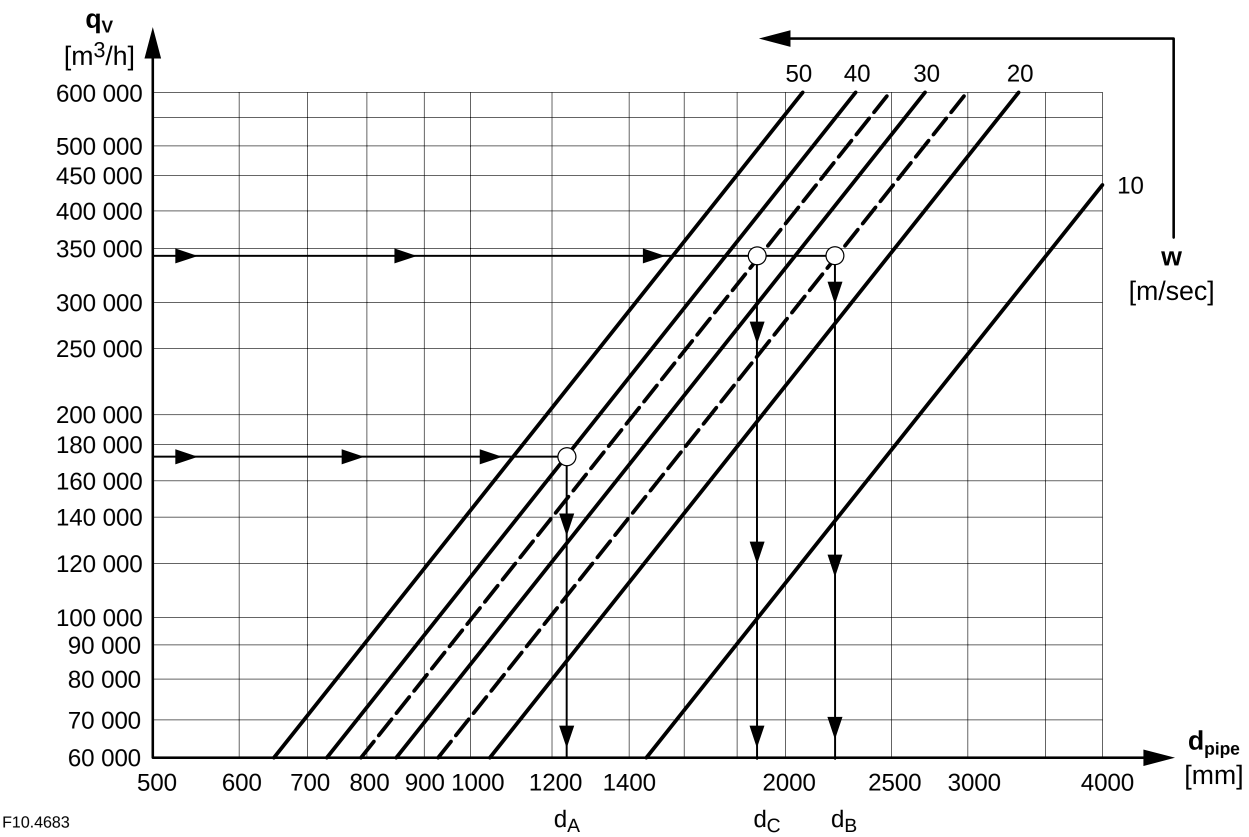


Fig. F40 Estimation of exhaust pipe diameters

5) Exhaust gas volume flow:

Pipe A:

$$q_{VA} = \frac{q_m}{\rho_{EXH} \cdot n_{TC}} = \frac{216\,168}{0.627 \cdot 2} = 172\,383\ m^3/h$$

Pipes B and C:

$$q_{VB} = q_{VC} = \frac{q_m}{\rho_{EXH}} = \frac{216\,168}{0.627} = 344\,766\ m^3/h$$

6) Exhaust pipe diameters:

Pipe diameters are
(approx. according to figure F40):

d_A = 1260 mm

d_B = 2270 mm

d_C = 1860 mm

or calculated:

$$d_{pipe} = 18.81 \cdot \sqrt{\frac{q_V}{w_{pipe}}}\ [mm]$$

7) Select the calculated or the next larger diameter available, for example:

d_A = **1250 mm**

d_B = **2250 mm**

d_C = **1840 mm**

Check the back pressure drop of the whole exhaust gas system (not to exceed 30 mbar).

R = gas constant = 268.4 J/kg°K
T = absolute temperature [°K]
P = barometer pressure [N/m^2]

F2.7 Air vents

The air vent pipes of the ancillary systems must be fully functional at all inclination angles of the ship at which the engine must be operational. This is normally achieved if the vent pipes have a continuous, uninterrupted inclination of 5 % minimum. Such an arrangement enables the vapour to separate into its air and fluid components, discharging the air to atmosphere and returning the fluid to its source.

F2.8 Engine-room ventilation

The engine-room ventilation is to conform to the requirements specified by the legislative council of the vessel's country of registration and the classification society selected by the ship owners. Calculation methods for the air flow required for combustion and air flow required to keep the machinery spaces cool are given in the international standard ISO 8861 'Shipbuilding – Engine-room ventilation in diesel engined ships; Design requirements and basis of calculations'.

Based on ISO 8861, the radiated heat, required air flow and power for the layout of the engine-room ventilation can be obtained from the winGTD program, see section C7.

The final layout of the engine-room ventilation is, however, at the discretion of the shipyard.

Figure F41 is a typical arrangement for direct suction of combustion air.

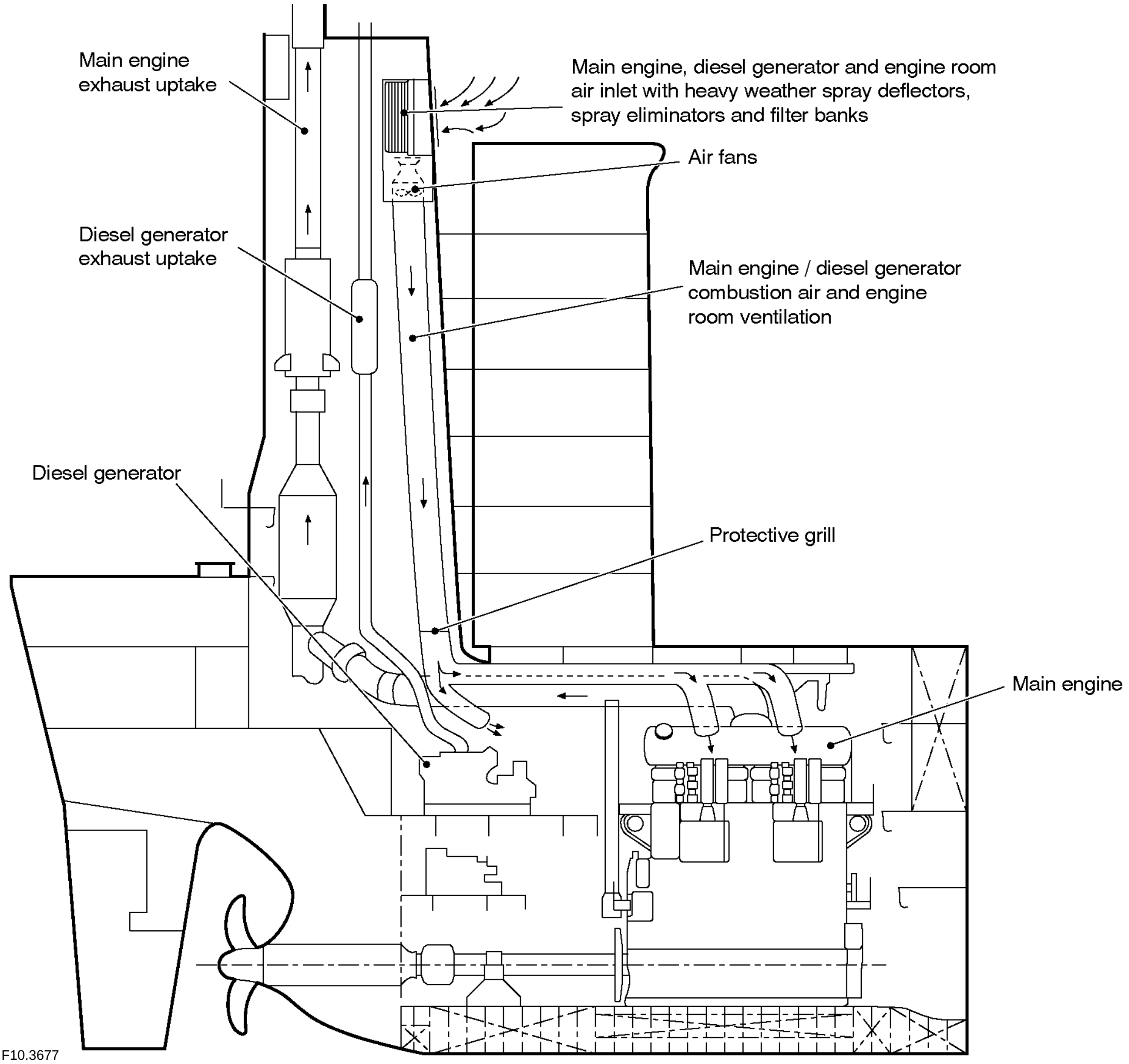


Fig. F41 Direct suction of combustion air – main and auxiliary engine

F3 Ambient temperature consideration

F3.1 Engine air inlet – Operating temperatures from 45 °C to 5 °C

Due to the high compression ratio, the diesel engine RT-flex84T-D does not require any special measures, such as pre-heating the air at low temperatures, even when operating on heavy fuel oil at part load, idling and starting up. The only condition which must be fulfilled is that the water inlet temperature to the scavenge air cooler must not be lower than 25 °C.

This means that:

- When combustion air is drawn directly from the engine room, no pre-heating of the combustion air is necessary.
- When the combustion air is ducted in from outside the engine room and the air suction temperature does not fall below 5 °C, no measures have to be taken.

The central fresh water cooling system permits the recovery of the engine's dissipated heat and maintains the required scavenge air temperature after the scavenge air cooler by recirculating part of the warm water through the low-temperature system.

F3.1.1 Scavenge air system – arctic conditions at operating temperatures below 5 °C

Under arctic conditions the ambient air temperatures can meet levels below –50 °C. If the combustion air is drawn directly from outside, these engines may operate over a wide range of ambient air temperatures between arctic condition and tropical (design) condition (45 °C).

To avoid the need of a more expensive combustion air preheater, a system has been developed that enables the engine to operate directly with cold air from outside.

If the air inlet temperature drops below 5 °C, the air density in the cylinders increases to such an extent that the maximum permissible cylinder pressure is exceeded. This can be compensated by blowing off a certain mass of the scavenge air through a blow-off device as shown in figure F42.

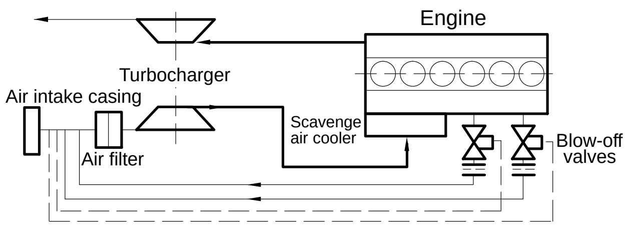


Fig. F42 Scavenge air system for arctic conditions

There are up to three blow-off valves fitted on the scavenge air receiver. In the event that the air inlet temperature to the turbocharger is below +5 °C the first blow-off valve vents. For each actuated blow-off valve, a higher suction air temperature is simulated by reducing the scavenge air pressure and thus the air density. The second blow-off valve vents automatically as required to maintain the desired relationship between scavenge and firing pressures. Figure F43 shows the effect of the blow-off valves to the air flow, the exhaust gas temperature after turbine and the firing pressure.

F. Ancillary systems

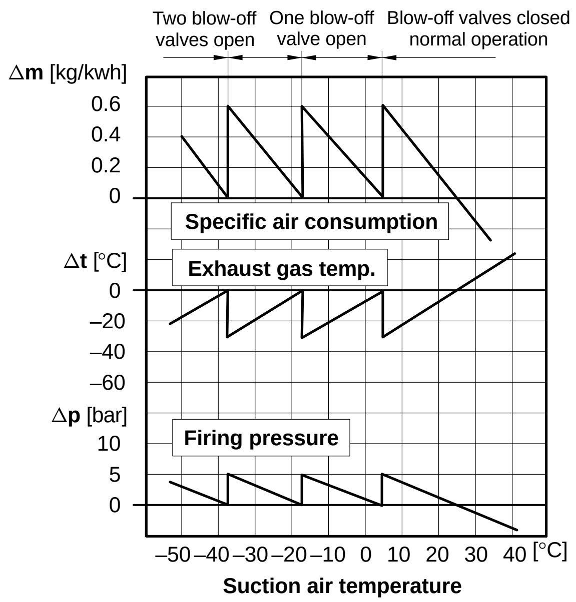


Fig. F43 Blow-off effect under arctic conditions

Control of the blow-off valves is effected by means of a signal generated by the temperature sensors in the inlet piping. Care is to be taken that no foreign particles in the form of ice gain access to the turbocharger compressor in any way, because they could lead to its destruction. Reduction of the pipe's cross sectional area by snow is also to be prevented.

The scavenge air cooling water inlet temperature is to be maintained at a minimum of 25 °C. This means that the scavenge air cooling water will have to be pre-heated in the case of low power operation. The required heat is obtained from the lubricating oil cooler and the engine cylinder cooling.

F3.2 Air filtration

In the event that the air supply to the machinery spaces has a high dust content in excess of 0.5 mg/m^3 which can be the case on ships trading in coastal waters, desert areas or transporting dust-creating cargoes, there is a higher risk of increased wear to the piston rings and cylinder liners.

The normal air filters fitted to the turbochargers are intended mainly as silencers and not to protect the engine against dust.

The necessity for the installation of a dust filter and the choice of filter type depends mainly on the concentration and composition of the dust in the suction air.

Where the suction air is expected to have a dust content of 0.5 mg/m^3 or more, the engine must be protected by filtering this air before entering the engine, e.g., on coastal vessels or vessels frequenting ports having high atmospheric dust or sand content.

Marine installations have seldom had special air filters installed until now. Stationary plants on the other hand, very often have air filters fitted to protect the diesel engine.

The installation of a filtration unit for the air supply to the diesel engines and general machinery spaces on vessels regularly transporting dust-creating cargoes such as iron ore and bauxite, is highly recommended.

The following table F16 and figure F44 show how the various types of filter are to be applied.

Normal Most frequent particle sizes	**Atmospheric dust concentration**		
	Normal shipboard requirement Short period < 5 % of running time, < 0.5 mg/m^3	Alternatives necessary for very special circumstances	
		frequently to permanently ≥ 0.5 mg/m^3	permanently > 0.5 mg/m^3
> 5 µm	Standard turbocharger filter sufficient	Oil wetted or roller screen filter	Inertial separator and oil wetted filter
< 5 µm	Standard turbocharger filter sufficient	Oil wetted or panel filter	Inertial separator and oil wetted filter
Valid for	the vast majority of installations	These may likely apply to only a very few extreme cases. For example: ships carrying bauxite or similar dusty cargoes or ships routinely trading along desert coasts.	

Table F16 Guidance for air filtration

F. Ancillary systems

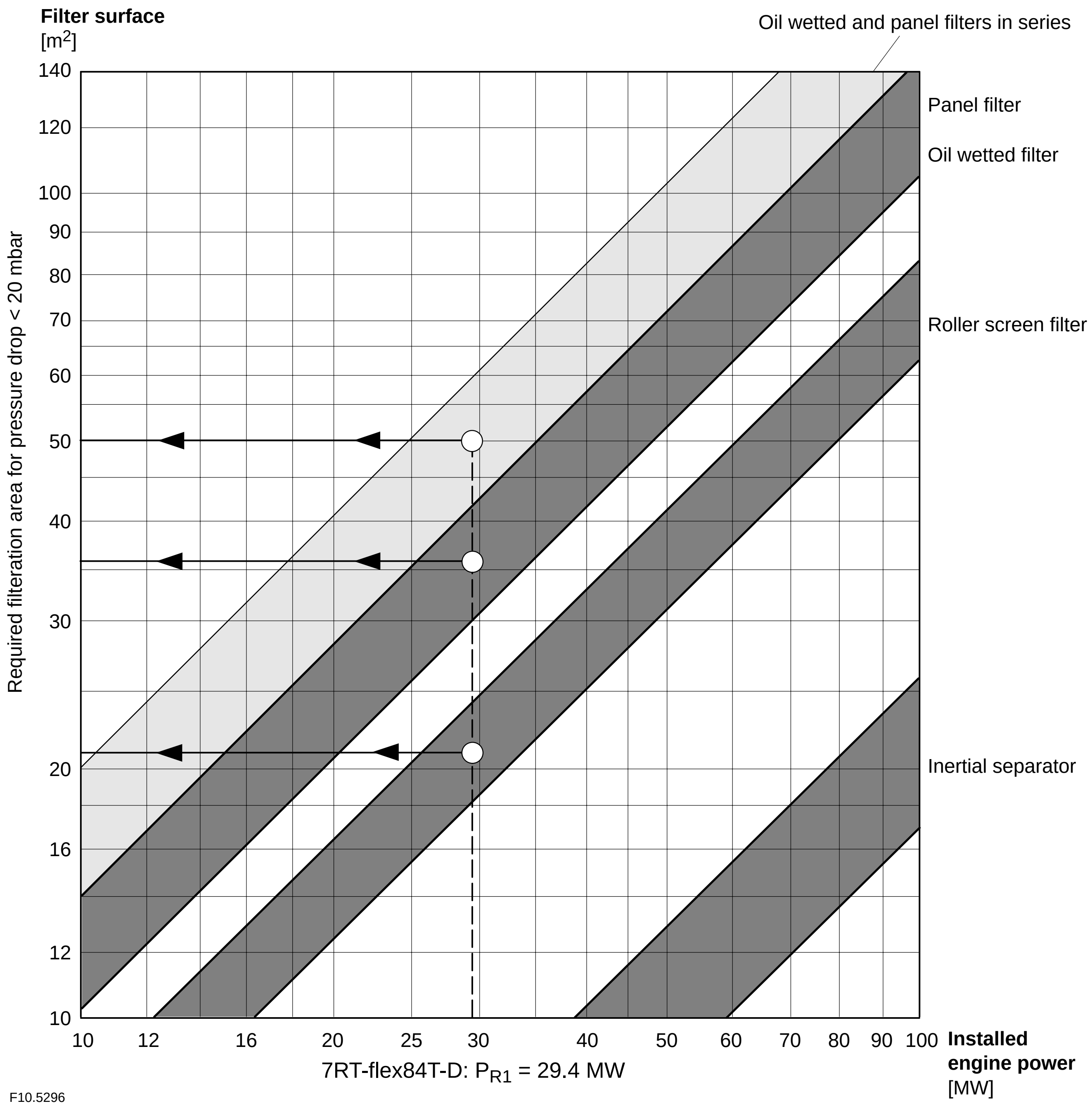


Fig. F44 Air filter size

F4 Pipe size and flow details

F4.1 Pipe velocities

The velocities given in table F17 are for guidance only. They have been selected with due regard to friction losses and corrosion. Increased velocity figures to those stated may be acceptable when short piping runs, water properties and ambient temperature, are taken into consideration.

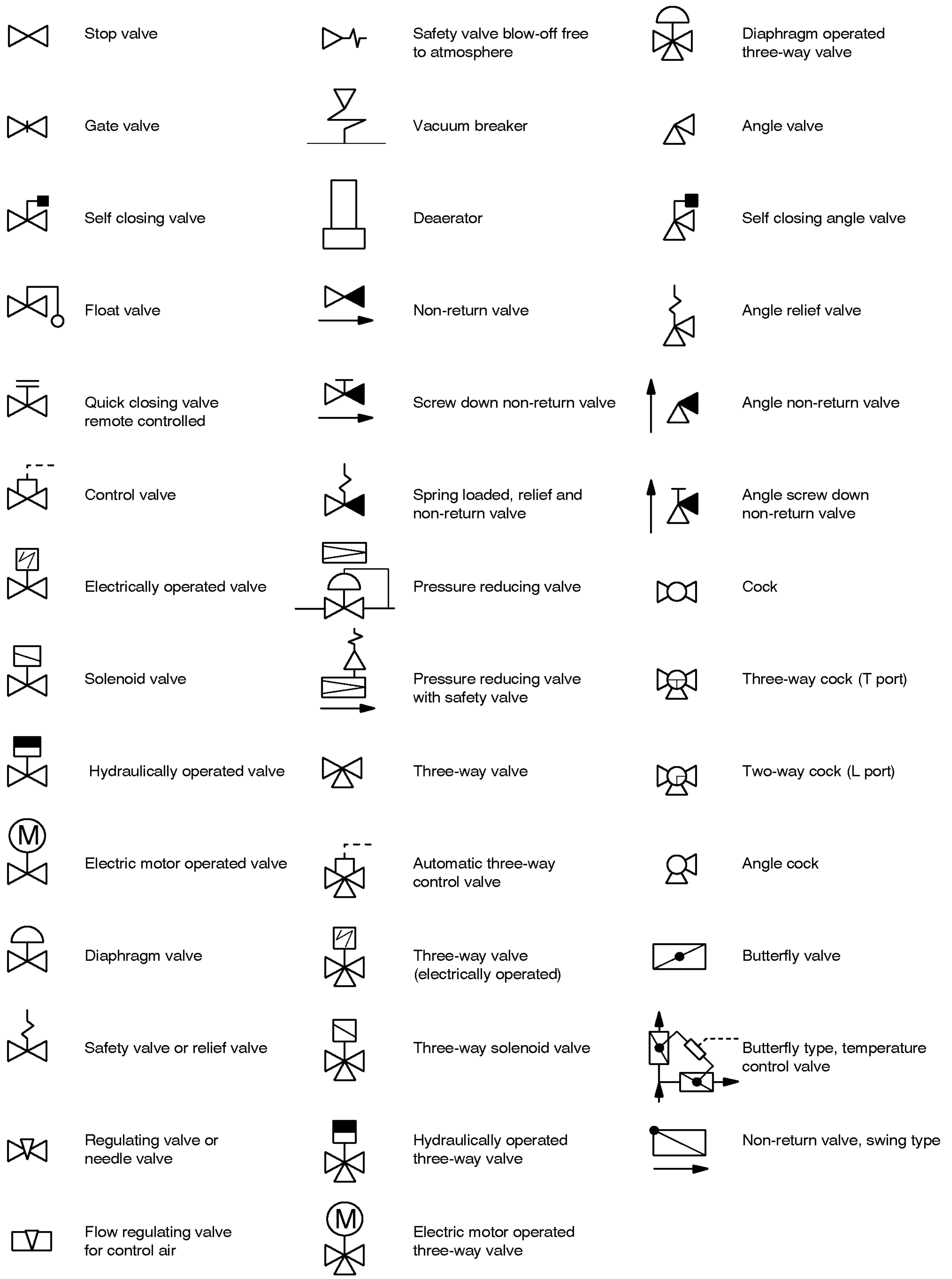
Nominal pipe diameter	Medium / Pipe material / pump-side	Sea-water, steel galvanized: suction	Sea-water, steel galvanized: delivery	Fresh water, mild steel: suction	Fresh water, mild steel: delivery	Lubricating oil, mild steel: suction	Lubricating oil, mild steel: delivery	Marine diesel oil, mild steel: suction	Marine diesel oil, mild steel: delivery	Heavy fuel oil, mild steel: suction	Heavy fuel oil, mild steel: delivery
32	[m/sec]	1.0	1.4	1.5	1.5	0.6	1.0	0.9	1.1	0.5	0.6
	$[m^3/h]$	2.9	4.1	4.3	4.3	1.7	2.9	2.6	3.2	1.4	1.7
40	[m/sec]	1.2	1.6	1.7	1.7	0.7	1.2	1.0	1.2	0.5	0.7
	$[m^3/h]$	5.4	7.2	7.7	7.7	3.2	5.4	4.5	5.4	2.3	3.2
50	[m/sec]	1.3	1.8	1.9	1.9	0.8	1.4	1.1	1.3	0.5	0.8
	$[m^3/h]$	9.2	12.5	13.5	13.5	5.7	10	7.8	9.2	3.5	5.7
65	[m/sec]	1.5	2.0	2.1	2.1	0.8	1.5	1.2	1.4	0.6	0.9
	$[m^3/h]$	18	24	25	25	9.6	18	14.5	16.5	7.2	11
80	[m/sec]	1.6	2.1	2.2	2.2	0.9	1.6	1.3	1.5	0.6	1.0
	$[m^3/h]$	29	38	40	40	16.5	29	23.5	27	11	18
100	[m/sec]	1.8	2.2	2.3	2.3	0.9	1.6	1.4	1.6	0.7	1.2
	$[m^3/h]$	51	62	65	65	26	45	40	45	20	34
125	[m/sec]	2.0	2.3	2.4	2.5	1.1	1.7	1.5	1.7	0.8	1.4
	$[m^3/h]$	88	102	106	110	49	75	66	75	35	62
150	[m/sec]	2.2	2.4	2.5	2.6	1.3	1.8	1.5	1.8	0.9	1.6
	$[m^3/h]$	140	153	159	165	83	115	95	115	57	108
200	[m/sec]	2.3	2.5	2.6	2.7	1.3	1.8		—		—
	$[m^3/h]$	260	283	294	305	147	204				
Aluminium brass	[m/sec]	2.6									
	$[m^3/h]$	294									
250	[m/sec]	2.5	2.6	2.7	2.7	1.3	1.9		—		—
	$[m^3/h]$	442	460	477	477	230	336				
Aluminium brass	[m/sec]	2.7									
	$[m^3/h]$	477									
300	[m/sec]	2.6	2.6	2.7	2.7	1.3	1.9		—		—
	$[m^3/h]$	662	662	687	687	331	484				
Aluminium brass	[m/sec]	2.8									
	$[m^3/h]$	713									
350	[m/sec]	2.6	2.6	2.7	2.7	1.4	2		—		—
	$[m^3/h]$	900	900	935	935	485	693				
Aluminium brass	[m/sec]	2.8									
	$[m^3/h]$	970									
400	[m/sec]	2.6	2.6	2.7	2.7	1.4	2		—		—
	$[m^3/h]$	1176	1222	1222	1222	633	905				
Aluminium brass	[m/sec]	2.8									
	$[m^3/h]$	1267									
450	[m/sec]	2.6	2.7	2.7	2.7	1.4	2		—		—
	$[m^3/h]$	1489	1546	1546	1546	802	1145				
Aluminium brass	[m/sec]	2.9									
	$[m^3/h]$	1660									
500	[m/sec]	2.6	2.7	2.7	2.7	1.5	2.1		—		—
	$[m^3/h]$	1838	1909	1909	1909	1060	1484				
Aluminium brass	[m/sec]	2.9									
	$[m^3/h]$	2050									

Note: The velocities given in the above table are guidance figures only. National standards can also be applied.

Table F17 Recommended fluid velocities and flow rates for pipework

F. Ancillary systems

F4.2 Piping symbols



F10.1910

Fig. F45 Piping symbols 1

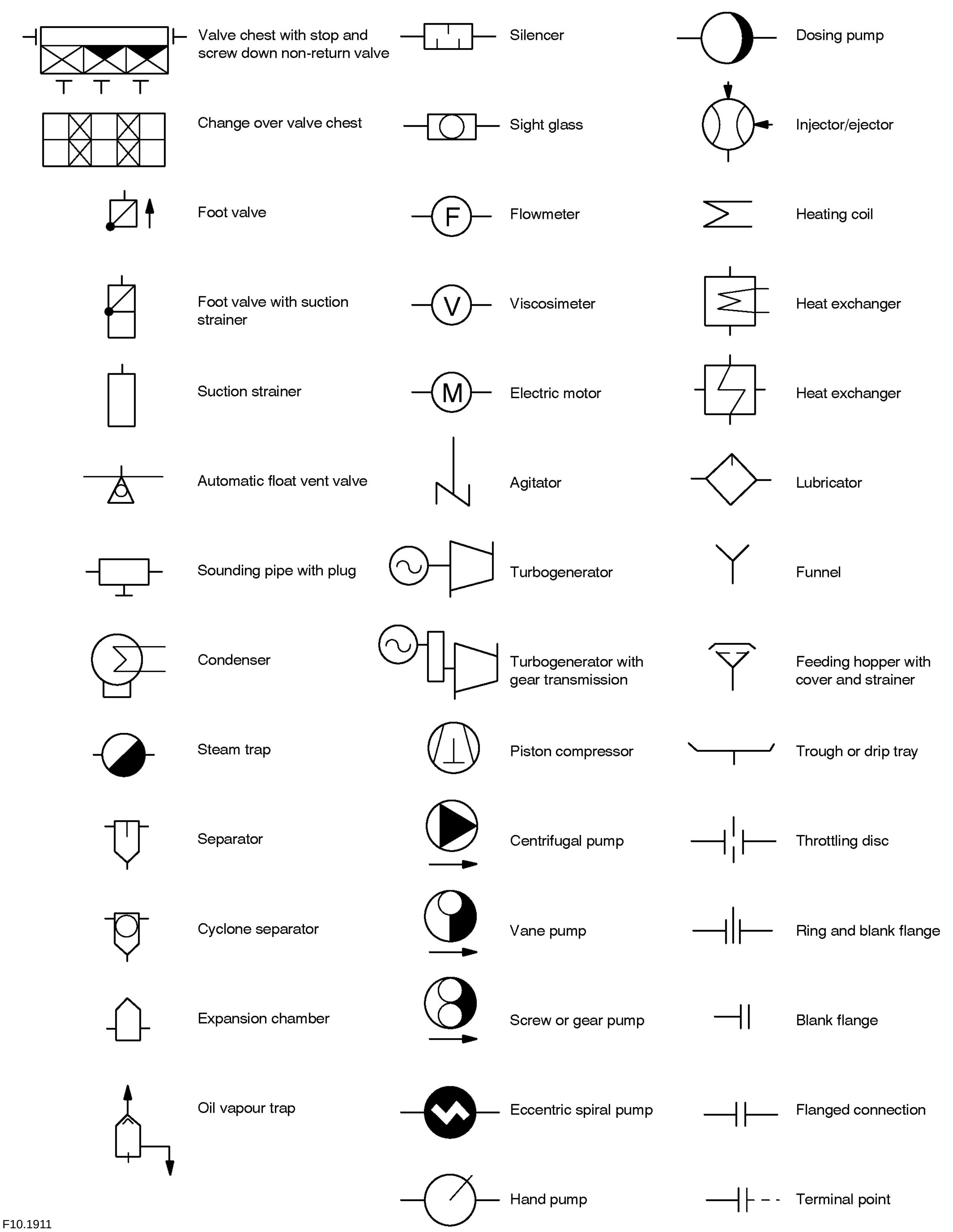


Fig. F46 Piping symbols 2

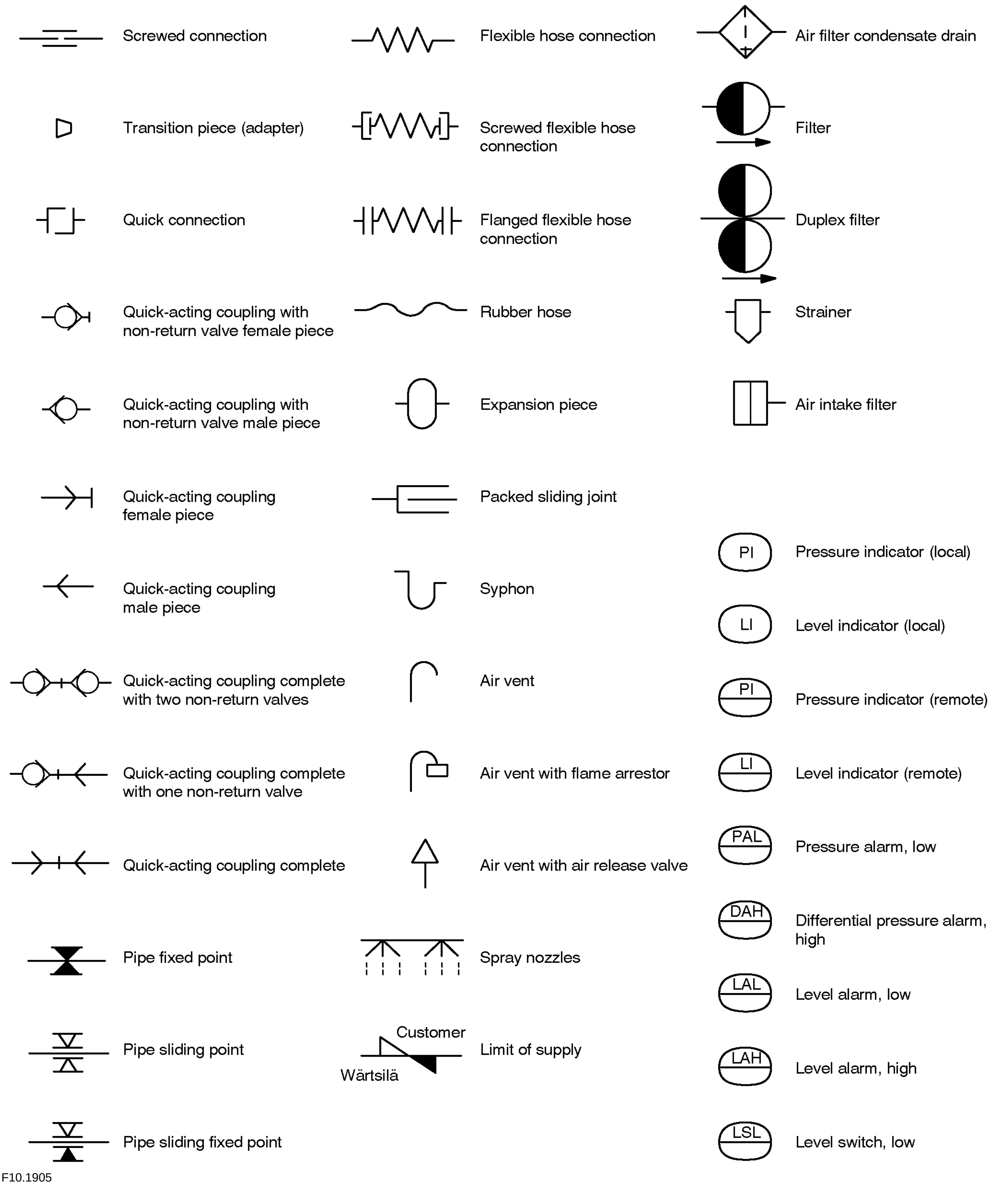
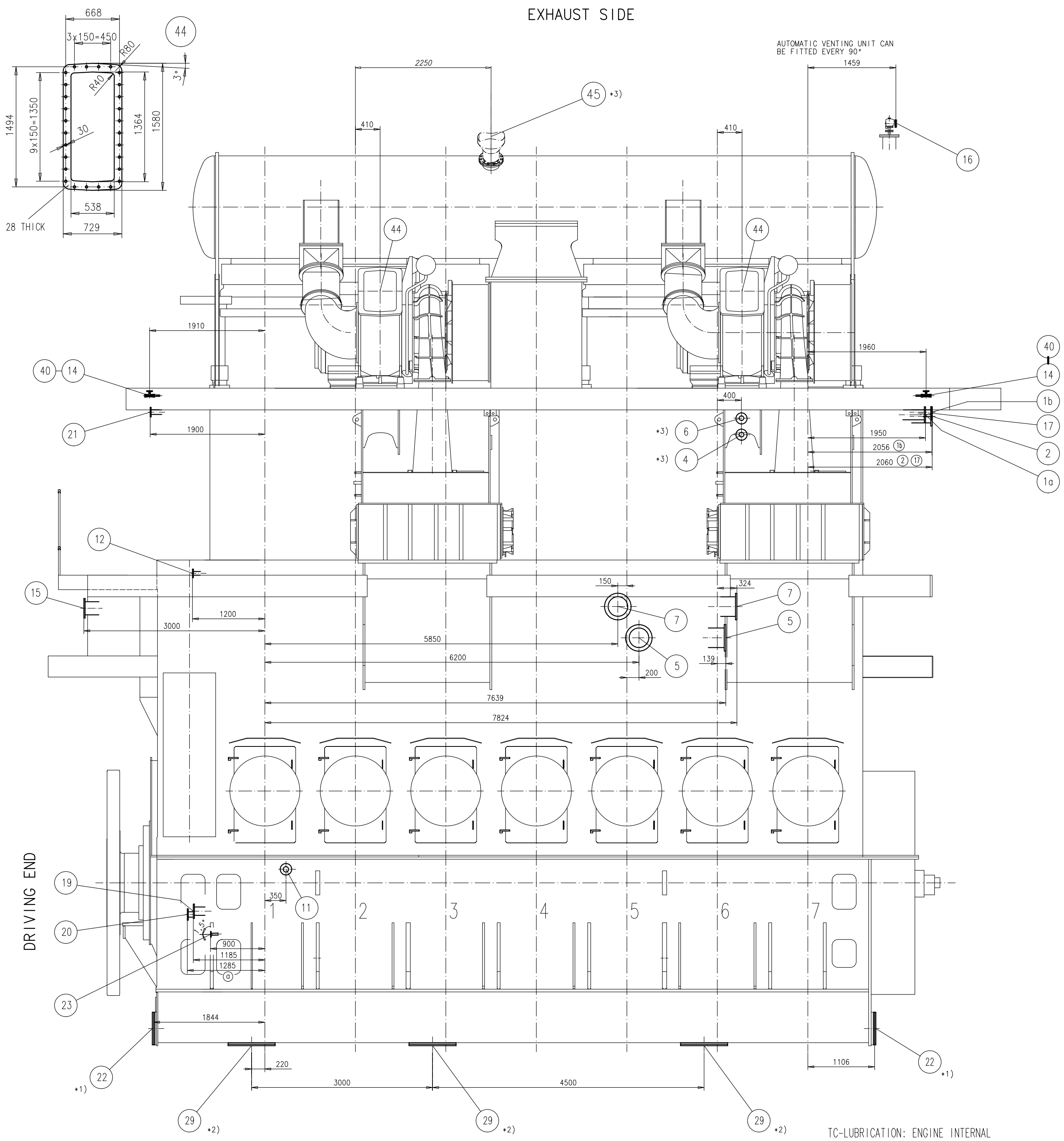


Fig. F47 Piping symbols 3

F5 Engine pipe connections

The following selection of the pipe connection plans doesn't cover all available executions of the RT-flex84T-D engines.

The drawings of other configurations (number of cylinders, number and type of turbochargers) are available on request.

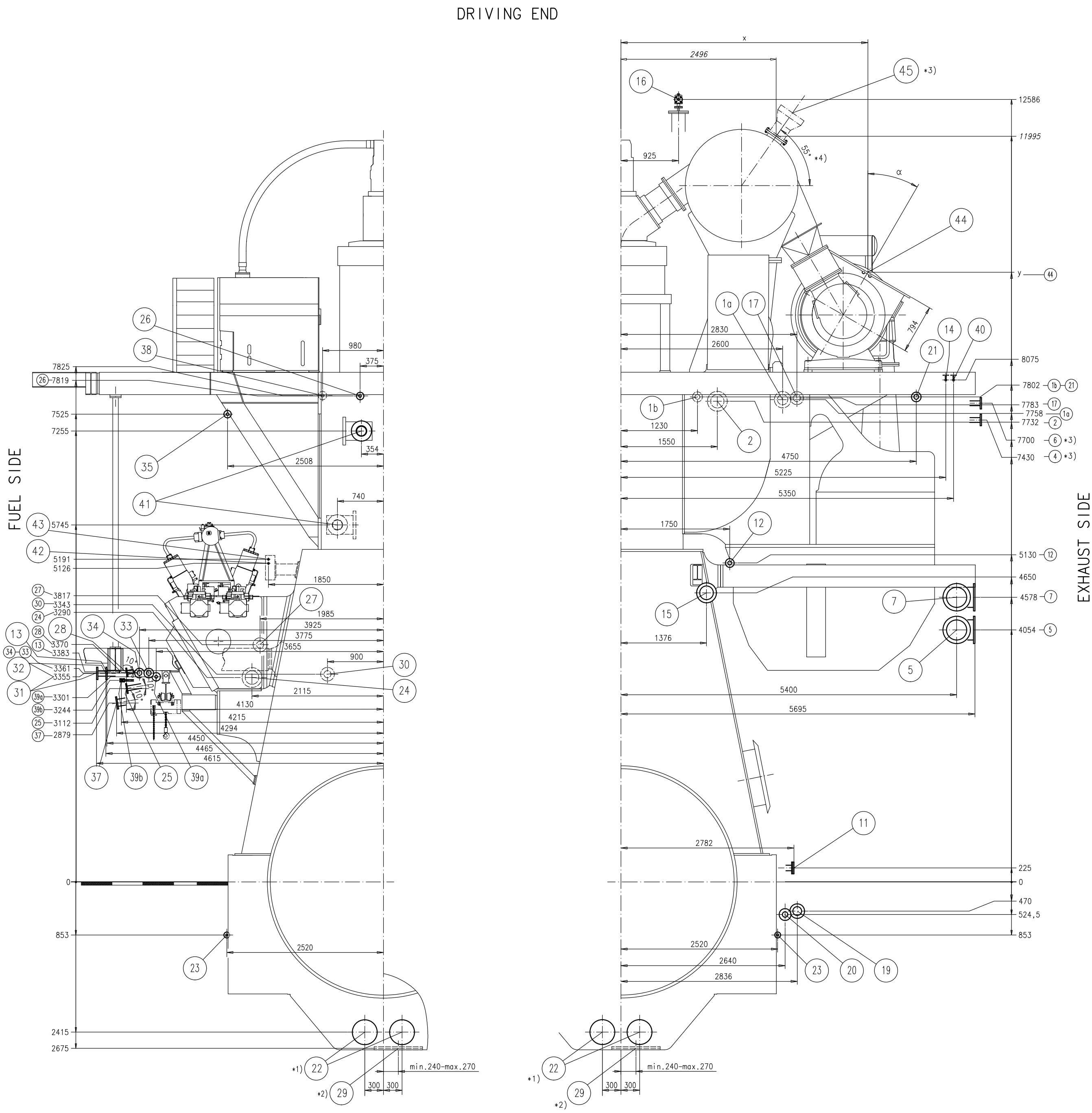


DAAD013153 – ISO drawing

Note: for details see figure F51

Fig. F48 Pipe connection plan for 7RT-flex84T-D engine with 2 x ABB TPL80-B turbochargers

F. Ancillary systems



GAS OUTLET POSITION	x	y
15°	3781	9887
30°	3973	9807
45°	4137	9681

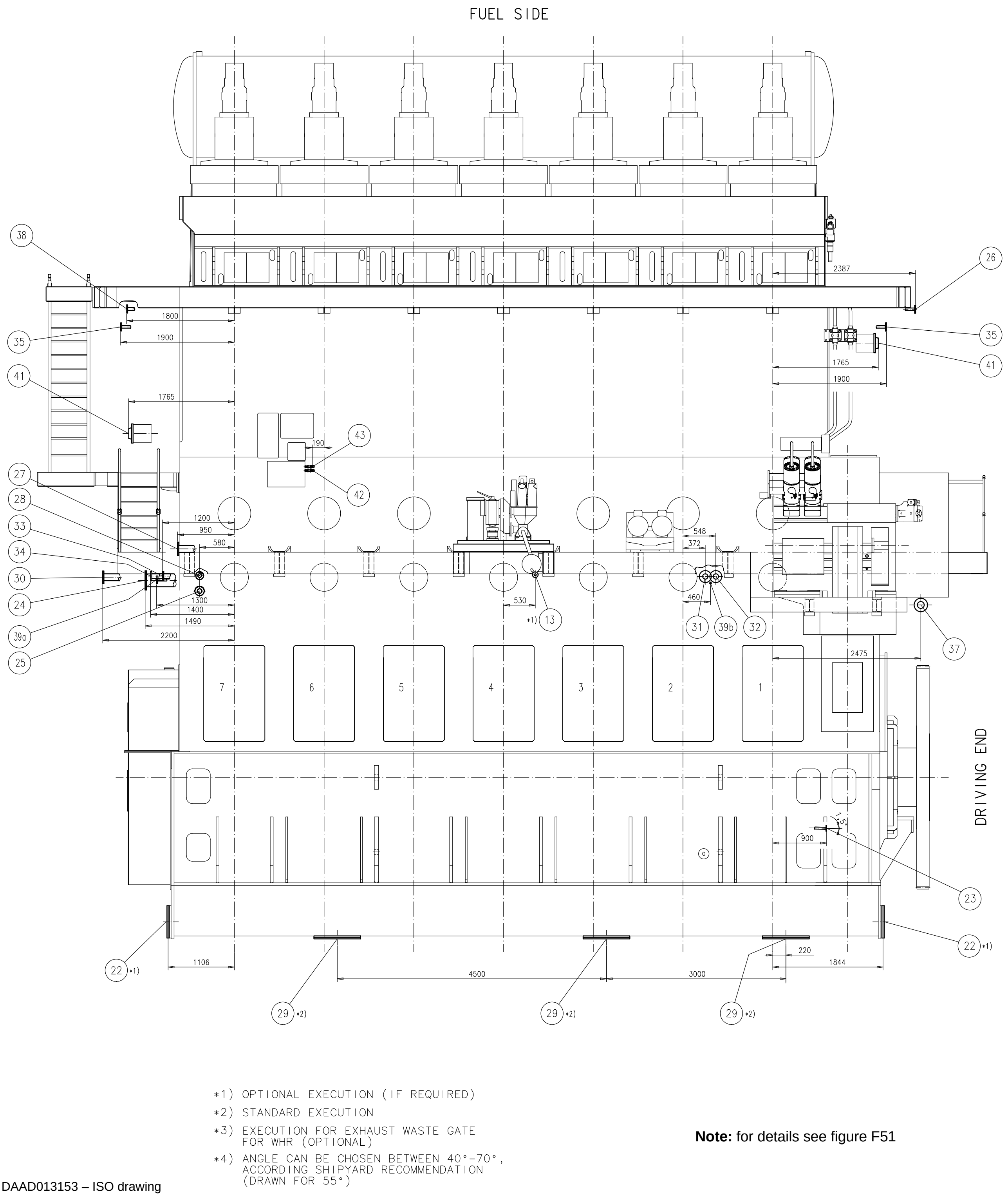
THE PIPE CONNECTIONS ON THE ENGINE ARE SUPPLIED WITH MATING FLANGES BLIND, WITH EXCEPTION OF THE TURBO-CHARGER EXHAUST GAS OUTLET, BLIND FLANGES TO BE DRILLED TO MATCH PIPE DIA SUPPLIED BY THE SHIPYARD.

*1) OPTIONAL EXECUTION (IF REQUIRED)
*2) STANDARD EXECUTION
*3) EXECUTION FOR EXHAUST WASTE GATE FOR WHR (OPTIONAL)
*4) ANGLE CAN BE CHOSEN BETWEEN 40°-70°, ACCORDING SHIPYARD RECOMMENDATION (DRAWN FOR 55°)

DAAD013153 – ISO drawing

Note: for details see figure F51

Fig. F49 Pipe connection plan for 7RT-flex84T-D engine with 2 x ABB TPL80-B turbochargers



Note: for details see figure F51

DAAD013153 – ISO drawing

Fig. F50 Pipe connection plan for 7RT-flex84T-D engine with 2 x ABB TPL80-B turbochargers

DAAD013153 – ISO drawing

Note	No.	Flange	Designation	DN	Ko.Gr. / KO.GR.	Freies Ende / FREE END	Antriebseite / DRIVING END	Abgasseite / EXHAUST SIDE	Brennstoffseite / FUEL SIDE
	1a	8x ø 18; 265; 225	Zylinderkuehlwasserleitung Eintritt / CYLINDER COOLING WATER PIPE INLET	DN150	8301	X			
	1b	4x ø 14; 160; 130	Kuehlwasserleitung Zylindereinsatz Eintritt / COOLING WATER PIPE CYLINDER LINER INLET	DN65	8305	X			
	2	8x ø 18; 320; 280	Zylinderkuehlwasserleitung Austritt / CYLINDER COOLING WATER PIPE OUTLET	DN200	8310	X			
	3								
*3)	4	8x ø 18; 185; 145	SLK Leitung Kuehlwasser Eintritt 1. Stufe / SAC PIPE COOLING WATER INLET 1. STAGE	DN65 PN40	8335			X	
	5	12x ø 22; 440; 395	SLK Leitung Kuehlwasser Eintritt / SAC PIPE COOLING WATER INLET	DN300	8335	X		X	
*3)	6	8x ø 18; 185; 145	SLK Leitung Kuehlwasser Austritt und Entlueftung 1. Stufe / SAC PIPE COOLING WATER OUTLET AND AIR VENT 1. STAGE	DN65 PN40	8335			X	
	7	12x ø 22; 440; 395	SLK Leitung Kuehlwasser Austritt / SAC PIPE COOLING WATER OUTLET	DN300	8335	X		X	
	8								
	9								
	10								
	11	4x ø 18; 190; 150	Sammelltg. oeliges Wasser Receiver / COLLECTOR MAIN OILY WATER RECEIVER	DN80	8352		X		
	12	4x ø 14; 140; 110	Kuehlwasser Entleerungsleitung / COOLING WATER DRAIN PIPE	DN50	8313			X	
*1)	13	4x ø 11; 100; 75	Spueloelableitung Automatikfilter / FLUSHING OIL OUTLET PIPE AUTOMATIC FILTER	DN25	8445				X
	14	ø25x2	Wasser-/Luftltg. Reinigungsanlage TL und SLK (Wasseranschluss) / WATER-/AIR PIPE CLEANING PLANT TC AND SAC (WATER CONNECTION)	DN20	8338	X	X		
	15	8x ø 18; 320; 280	Sammelleitung Kondenswasser SLK Entlueftung / COLLEC. MAIN CONDENSATE WATER SAC VENTING	DN200	8357		X		
	16	4x ø 18; 125; 90	Zylinderkuehlwasserleitung Entlueftung / CYLINDER COOLING WATER PIPE OUTLET VENTING	DN25	8310	X			
	17	4x ø 18; 210; 170	Oelsystem TL Entlueftung / OIL SYSTEM TC VENTING	DN100	8429	X			
	18								
	19	8x ø 18; 240; 200	Sammelleitung Kondenswasser SLK / COLLEC. MAIN CONDENSATE WATER SAC	DN125	8357		X		
	20	4x ø 18; 190; 150	Sammelleitung Kondenswasser SLK Waschwasser Austritt / COLLEC. MAIN CONDENSATE WATER SAC WASHING WATER OUTLET	DN80	8357		X		
	21	4x ø 14; 160; 130	Waschanlage TL Schmutzwasser Asutritt / WASHING PLANT TC DIRTY WATER OUTLET	DN65	8354		X		
*1)	22	16xM20; 540; 495	Grundplatte Oelablauf (Horizontal) / BEDPLATE OIL DRAIN (HORIZONTAL)	DN350	1110	X	X		
	23	4x ø 11; 100; 75	Sammelleitung Leckoel Grundplatte / COLLECTOR MAIN LEAKAGE OIL BEDPLATE	DN25	8463		X		
	24	8x ø 18; 320; 280	Oelleitung Eintritt / OIL PIPE INLET	DN200	8406	X			
	25	4x ø 14; 160; 130	Schmutzoel von Kolben-Unterseite / DIRTY OIL FROM PISTON UNDERSIDE	DN65	8487				X
	26	4x ø 14; 120; 90	Zylinderschmieroelleitung Eintritt / CYL. LUBRICATING OIL PIPE INLET	DN32	7206	X			
	27	8x ø 18; 220; 180	Oelleitung Kreuzkopf Eintritt / OIL PIPE CROSSHEAD INLET	DN100 PN16	8455	X			
	28	4x ø 14; 130; 100	Sammelleitung Leckoel Stopfbuechse / COLLEC. MAIN LEAKAGE OIL GLAND BOX	DN40	8488				X
*2)	29	24xM20; 780; 670	Grundplatte Oelablauf (Vertikal) / BEDPLATE OIL DRAIN (VERTICAL)	DN600	1110				
	30	4x ø 18; 210; 170	Entlueftungsleitung Kurbelgehaeuse / VENTING PIPE CRANKCASE	DN100	8608	X			
	31	8x ø 18; 200; 160	Brennstoff Eintritt / FUEL OIL INLET	DN80 PN16	8705				X
	32	8x ø 18; 200; 160	Brennstoff Austritt / FUEL OIL OUTLET	DN80 PN16	8705				X
	33	4x ø 14; 160; 130	Leckbrennstoffleitung Rail Unit (schmutzig) / FUEL LEAKAGE PIPE RAIL UNIT (DIRTY)	DN65	8740	X			
	34	4x ø 14; 160; 130	Leckbrennstoffleitung Rail Unit/ Versorgungseinheit (sauber) / FUEL LEAKAGE PIPE RAIL UNIT/ SUPPLY UNIT (CLEAN)	DN65	8744	X			
	35	4x ø 14; 120; 90	Feuerloeschleitung / FIRE EXTINGUISHING PIPE	DN32	8830	X	X		
	36								
	37	4x ø 18; 210; 170	Leckservooelltg. Versorgungseinheit / SERVO OIL LEAKAGE PIPE SUPPLY UNIT	DN100	8451				X
	38	4x ø 18; 140; 110	Heizltg. Brennstoff Eintritt / HEAT PIPING FUEL INLET	DN32 PN16	8810	X			
	39a	4x ø 18; 140; 110	Heizltg. Austritt fuer Leckbrennstoff / HEAT PIPING OUTLET FOR FUEL LEAKAGE	DN32 PN16	8810	X			
	39b	ø 25x2	Heizltg. Austritt Fuer Brennstoff Ein- und Austritt / HEAT PIPING OUTLET FOR FUEL IN/OUTLET	DN20 PN16	8810				X
	40	ø 25x2	Wasser-/Luftltg. //Reinigungsanlage TL und SLK (Luftanschluss) / WATER-/AIR PIPE CLEANING PLANT TC AND SAC (AIR CONNECTION)	DN20	8338	X	X		
	41	12xø26; 320; 275; ø168,3x4,5	Anlassluft Eintritt / STARTING AIR INLET; 4.5 159-529 Q2 WIG+E(4) Luftspalt=3 ± 0.5 AIR GAP	DN150 PN30	8605	X	or X		
	42	ø 15x1,5	Steuerluftversorgung 30 bar: A2 / CONTROL AIR SUPPLY	DN12	4605 4606				X
	43	ø 15x1,5	Steuerluftversorgung 8 bar: A1 / CONTROL AIR SUPPLY	DN12	4605 4606				X
	44	see fig. F48	Turbolader Gasaustritt / TURBOCHARGER GAS OUTLET		6506 6509			X	
*3)	45	12x ø22; 395; 350	Abgas-Abblaseventil Austritt / EXHAUST WASTE GATE OUTLET	DN250 PN10	8135			X	

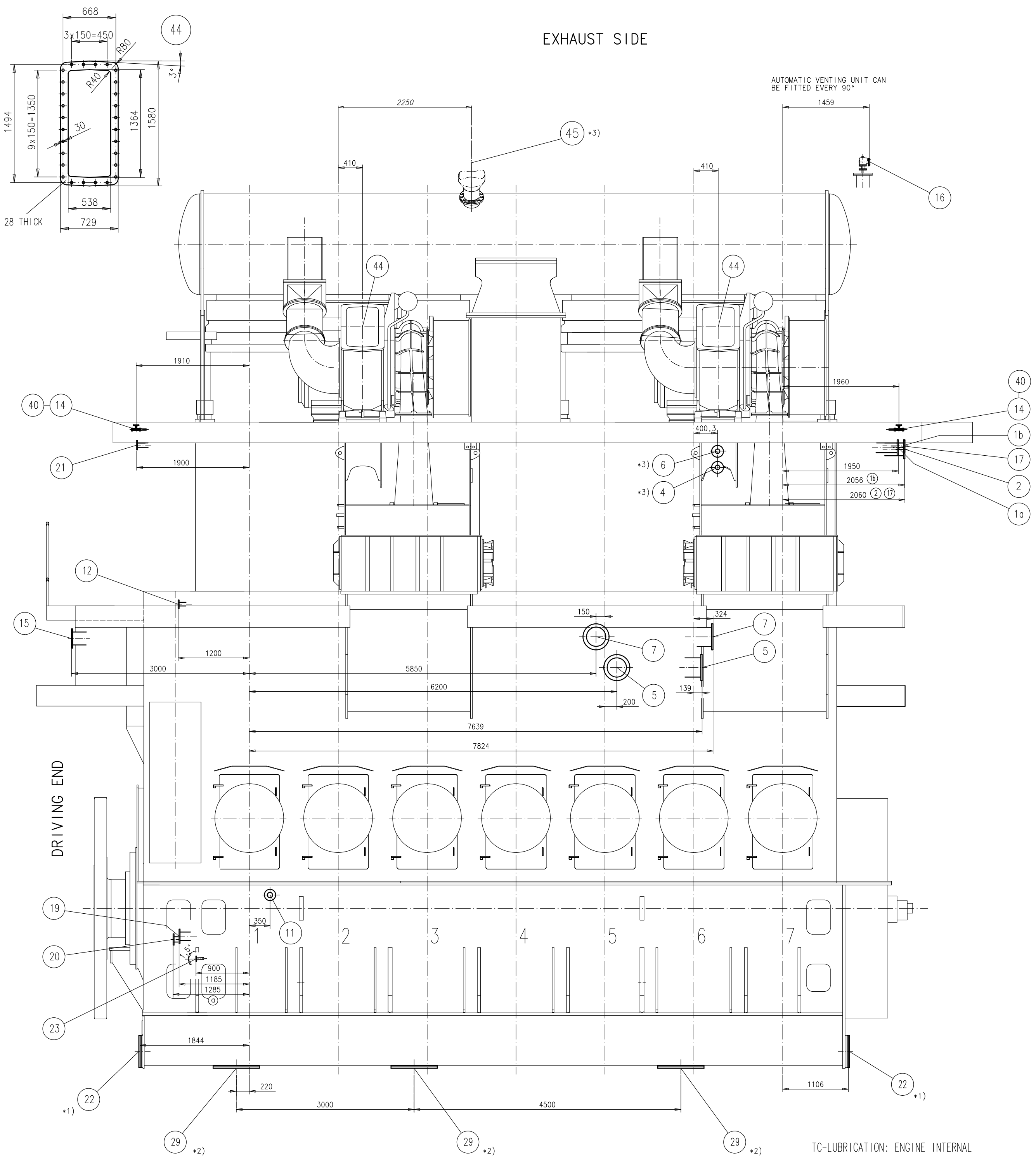
*1) OPTIONAL EXECUTION (IF REQUIRED)

*2) STANDARD EXECUTION

*3) EXECUTION FOR EXHAUST WASTE GATE FOR WHR (OPTIONAL)

*4) ANGLE CAN BE CHOSEN BETWEEN 40°-70°, ACCORDING SHIPYARD RECOMMENDATION (DRAWN FOR 55°)

Fig. F51 Pipe connection details for 7RT-flex84T-D engine with 2 x ABB TPL80-B

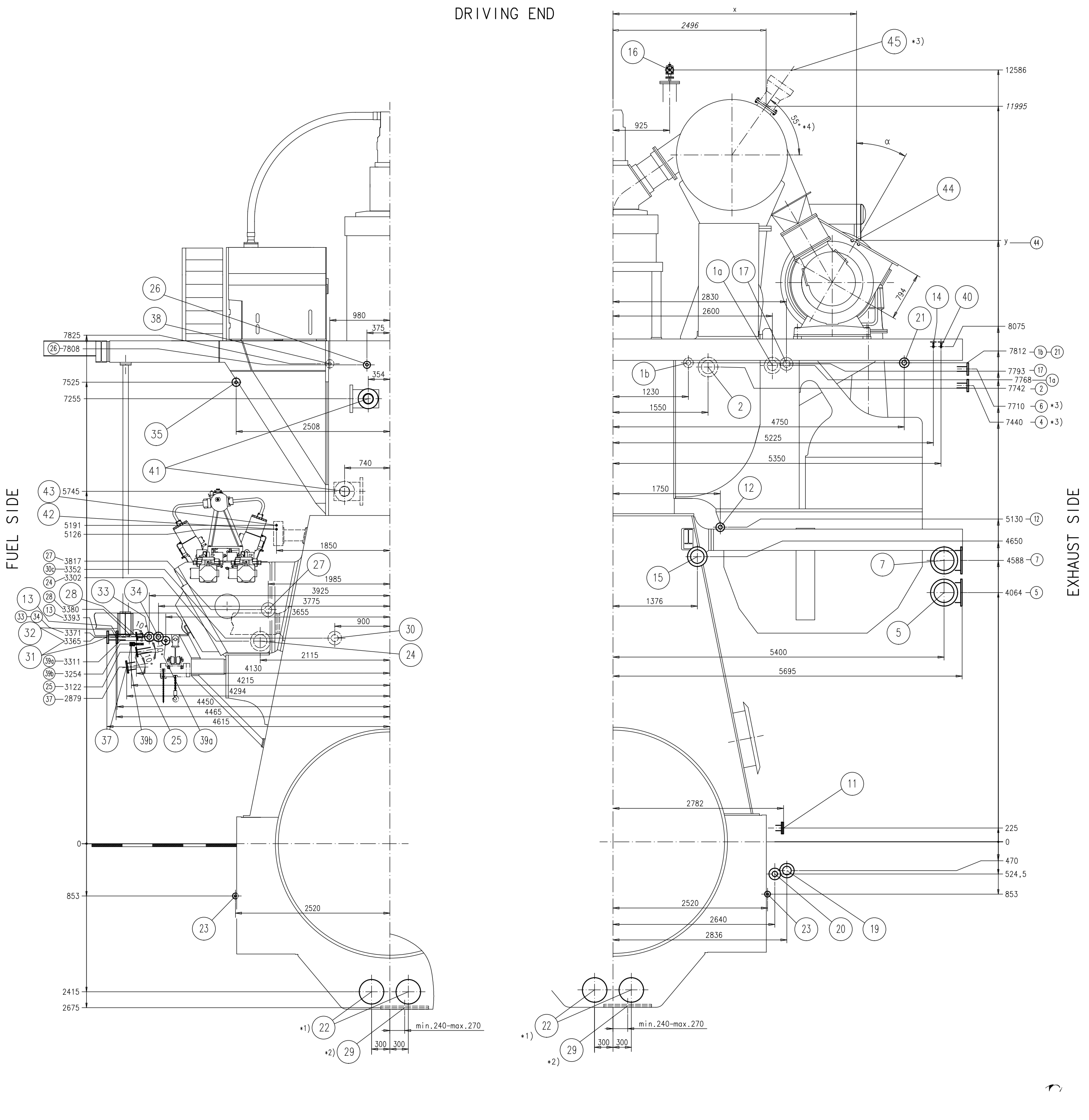


DAAD013154 – JIS drawing

Note: for details see figure F55

Fig. F52 Pipe connection plan for 7RT-flex84T-D engine with 2 x ABB TPL80-B turbochargers

F. Ancillary systems



GAS OUTLET POSITION	x	y
15°	3781	9887
30°	3973	9807
45°	4137	9681

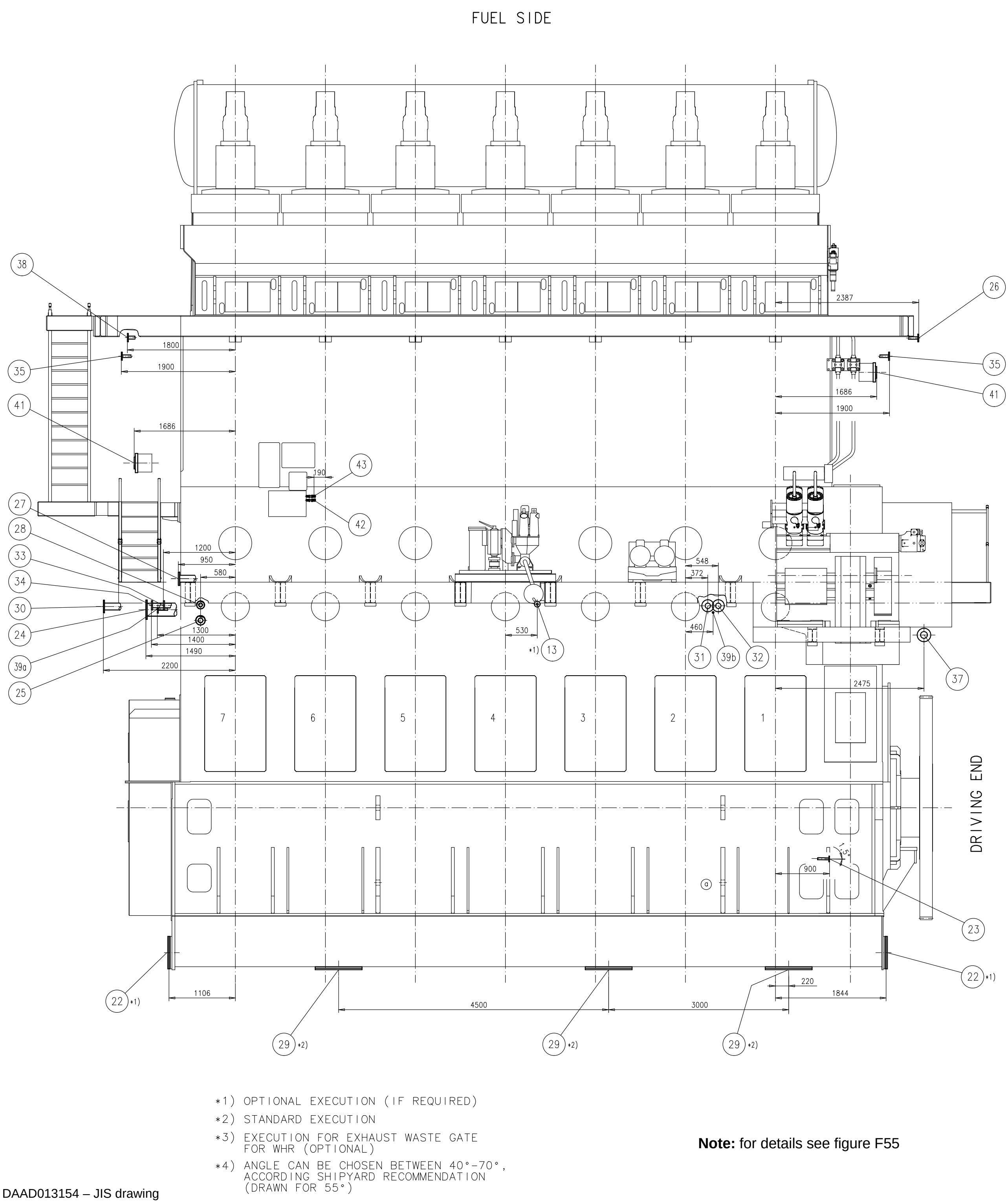
THE PIPE CONNECTIONS ON THE ENGINE ARE SUPPLIED WITH MATING FLANGES BLIND, WITH EXCEPTION OF THE TURBO-CHARGER EXHAUST GAS OUTLET, BLIND FLANGES TO BE DRILLED TO MATCH PIPE DIA SUPPLIED BY THE SHIPYARD.

*1) OPTIONAL EXECUTION (IF REQUIRED)
*2) STANDARD EXECUTION
*3) EXECUTION FOR EXHAUST WASTE GATE FOR WHR (OPTIONAL)
*4) ANGLE CAN BE CHOSEN BETWEEN 40°-70°, ACCORDING SHIPYARD RECOMMENDATION (DRAWN FOR 55°)

DAAD013154 – JIS drawing

Note: for details see figure F55

Fig. F53 Pipe connection plan for 7RT-flex84T-D engine with 2 x ABB TPL80-B turbochargers



Note: for details see figure F55

DAAD013154 – JIS drawing

Fig. F54 Pipe connection plan for 7RT-flex84T-D engine with 2 x ABB TPL80-B turbochargers

F. Ancillary systems

DAAD013154 – JIS drawing

No.	Flange	Description	DN	Ko.Gr. KO.GR.	Freies Ende FREE END	Antriebseite DRIVING END	Abgasseite EXHAUST SIDE	Brennstoffseite FUEL SIDE
1a	8x ø 19; 265; 230	Zylinderkuehlwasserleitung Eintritt / CYLINDER COOLING WATER PIPE INLET	DN150	8301	X			
1b	4x ø 15; 155; 130	Kuehlwasserleitung Zylindereinsatz Eintritt / COOLING WATER PIPE CYLINDER LINER INLET	DN65	8305	X			
2	8x ø 23; 320; 280	Zylinderkuehlwasserleitung Austritt / CYLINDER COOLING WATER PIPE OUTLET	DN200	8310	X			
3								
*3) 4	8x ø 23; 200; 160	SLK Leitung Kuehlwasser Eintritt 1. Stufe / SAC PIPE COOLING WATER INLET 1. STAGE	DN65 PN30	8335			X	
5	12x ø 23; 430; 390	SLK Leitung Kuehlwasser Eintritt / SAC PIPE COOLING WATER INLET	DN300	8335	X		X	
*3) 6	8x ø 23; 200; 160	SLK Leitung Kuehlwasser Austritt und Entlueftung 1. Stufe / SAC PIPE COOLING WATER OUTLET AND AIR VENT 1. STAGE	DN65 PN30	8335			X	
7	12x ø 23; 430; 390	SLK Leitung Kuehlwasser Austritt / SAC PIPE COOLING WATER OUTLET	DN300	8335	X		X	
8								
9								
10								
11	4x ø 15; 130; 105	Sammelltg. oeliges Wasser Receiver / COLLECTOR MAIN OILY WATER RECEIVER	DN80	8352			X	
12	4x ø 15; 130; 105	Kuehlwasser Entleerungsleitung / COOLING WATER DRAIN PIPE	DN50	8313			X	
*1) 13	4x ø 12; 95; 75	Spueloelableitung Automatikfilter / FLUSHING OIL OUTLET PIPE AUTOMATIC FILTER	DN25	8445				X
14	ø25x2	Wasser-/Luftltg. Reinigungsanlage zu Turbolader und SLK / WATER-/AIR PIPE CLEANING PLANT TO TURBOCHARGER AND SAC	DN20	8338	X	X		
15	8x ø 23; 320; 280	Sammelleitung Kondenswasser SLK Entlueftung / COLLEC. MAIN CONDENSATE WATER SAC VENTING	DN200	8357		X		
16	4x ø 19; 125; 90	Zylinderkuehlwasserleitung Entlueftung / CYLINDER COOLING WATER PIPE OUTLET VENTING	DN25	8310	X			
17	4x ø 15; 155; 130	Oelsystem TL Eintritt / OIL SYSTEM TC INLET	DN65	8429	X			
18	8x ø 23; 320; 280	Oelsystem TL Austritt / OIL SYSTEM TC OUTLET	DN150	8429	X			
19	8x ø 19; 235; 200	Sammelleitung Kondenswasser SLK / COLLEC. MAIN CONDENSATE WATER SAC	DN125	8357		X		
20	4x ø 19; 180; 145	Sammelleitung Kondenswasser SLK Waschwasser Austritt / COLLEC. MAIN CONDENSATE WATER SAC WASHING WATER OUTLET	DN80	8357		X		
21								
*1) 22	16xM20; 540; 495	Grundplatte Oelablauf (Horizontal) / BEDPLATE OIL DRAIN (HORIZONTAL)	DN350	1110	X	X		
23	4x ø 12; 95; 75	Sammelleitung Leckoel Grundplatte / COLLECTOR MAIN LEAKAGE OIL BEDPLATE	DN25	8463		X		
24	12x ø 23; 385; 345	Oelleitung Eintritt / OIL PIPE INLET	DN200	8406	X			

No.	Flange	Description	DN	Ko.Gr. KO.GR.	Freies Ende FREE END	Antriebseite DRIVING END	Abgasseite EXHAUST SIDE	Brennstoffseite FUEL SIDE
25	4x ø 15; 155; 130	Schmutzoel von Kolben-Unterseite / DIRTY OIL FROM PISTON UNDERSIDE	DN65	8487				X
26	4x ø 15; 115; 90	Zylinderschmieroelleitung Eintritt / CYL. LUBRICATING OIL PIPE INLET	DN32	8475	X			
27	8x ø 23; 225; 185	Oelleitung Kreuzkopf Eintritt / OIL PIPE CROSSHEAD INLET	DN100 PN16	8455	X			
28	4x ø 15; 120; 95	Sammelleitung Leckoel Stopfbuechse / COLLEC. MAIN LEAKAGE OIL GLAND BOX	DN40	8488				X
*2) 29	24xM20; 780; 670	Grundplatte Oelablauf (Vertikal) / BEDPLATE OIL DRAIN (VERTICAL)	DN600	1110				
30	8x ø 19; 200; 165	Entlueftungsleitung Kurbelgehaeuse / VENTING PIPE CRANKCASE	DN100	8466	X			
31	8x ø 23; 200; 160; ø 89,1x5,5; 4 280 Q2 WIG; 3,5 280 Q2 WIG	Brennstoff Eintritt SU / FUEL OIL INLET SU	DN80 PN16	8705				X
32	8x ø 23; 200; 160; ø 89,1x5,5; 4 280 Q2 WIG; 3,5 280 Q2 WIG	Brennstoff Austritt SU / FUEL OIL OUTLET SU	DN80 PN16	8705				X
33	4x ø 15; 155; 130	Leckbrennstoffleitung Rail Unit (schmutzig) / FUEL LEAKAGE PIPE RAIL UNIT (DIRTY)	DN65	8740	X			
34	4x ø 15; 155; 130	Leckbrennstoffleitung Rail Unit/ Versorgungseinheit (sauber) / FUEL LEAKAGE PIPE RAIL UNIT/ SUPPLY UNIT (CLEAN)	DN65	8744	X			
35	4x ø 19; 135; 100	Feuerloeschleitung / FIRE EXTINGUISHING PIPE	DN32 PN10	8830	X	X		
36								
37	8x ø 19; 200; 165	Leckservooelltg. Versorgungseinheit / SERVO OIL LEAKAGE PIPE SUPPLY UNIT	DN100	8451				X
38	4x ø 19; 135; 100	Heizltg. Brennstoff Eintritt / HEAT PIPING FUEL INLET	DN32 PN16	8810	X			
39a	4x ø 19; 135; 100	Heizltg. Austritt fuer Leckbrennstoff / HEAT PIPING OUTLET FOR FUEL LEAKAGE	DN32 PN16	8810	X			
39b	ø25x2	Heizltg. Austritt Fuer Brennstoff Ein- und Austritt / HEAT PIPING OUTLET FOR FUEL IN/OUTLET	DN20 PN16	8810				X
40	ø 25x2	Wasser-/Luftltg. //Reinigungsanlage (Luftanschluss) / WATER-/AIR PIPE CLEANING PLANT (AIR CONNECTION)	DN20	8338	X	X		
41	12x ø 27; 325; 275; ø 165,2x7,1; 6 519 Q2 WIG; 5 519 Q2 WIG	Anlassluftltg. Eintritt / STARTING AIR PIPET INLET	DN150 PN30	8605	X or	X		
42	ø 15x1,5	Steuerluftversorgung 30 bar: A2 / CONTROL AIR SUPPLY	DN12	4605 4606				X
43	ø 15x1,5	Steuerluftversorgung 8 bar: A1 / CONTROL AIR SUPPLY	DN12	4605 4606				X
44	see fig. F52	Turbolader Gasaustritt / TURBOCHARGER GAS OUTLET		6506 6509			X	
*3) 45	12x ø22; 395; 350	Abgas-Abblaseventil Austritt / EXHAUST WASTE GATE OUTLET	DN250 PN10	8135			X	

*1) OPTIONAL EXECUTION (IF REQUIRED)
*2) STANDARD EXECUTION
*3) EXECUTION FOR EXHAUST WASTE GATE FOR WHR (OPTIONAL)
*4) ANGLE CAN BE CHOSEN BETWEEN 40°–70°, ACCORDING SHIPYARD RECOMMENDATION (DRAWN FOR 55°)

Fig. F55 Pipe connection details for 7RT-flex84T-D engine with 2 x ABB TPL80-B

G. Automation and controls

G1 Introduction

Developments in Engine Management & Automation (EMA) at Wärtsilä Switzerland Ltd are focussed on the latest trends in ship automation that tends to always higher integration levels.

The standard electrical interface, designated DENIS-9520 (**D**iesel **E**ngine Co**N**trol and opt**I**mizing **S**pecification), assures a perfect match with approved remote control systems, while the WECS-9520 (**W**ärtsilä **E**ngine **C**ontrol **S**ystem) takes care of all RT-flex specific control functions. Computer based tools under the designation of the product family MAPEX (**M**onitoring and m**A**intenance **P**erformance **E**nhancement with e**X**pert knowledge) enable ship-owners and operators to improve the operating economy of their diesel engines.

All those systems provide data bus connection to the ship automation to make specific data available wherever required and facilitate installation.

Complete ship automation systems provided by one of the leading suppliers approved by Wärtsilä Switzerland offer the degree of integration demanded in modern shipbuilding while being perfectly adapted to the engine's requirements.

Applying a single supplier strategy for the entire ship automation shows many other advantages in terms of full responsibility, ease in operation and maintenance.

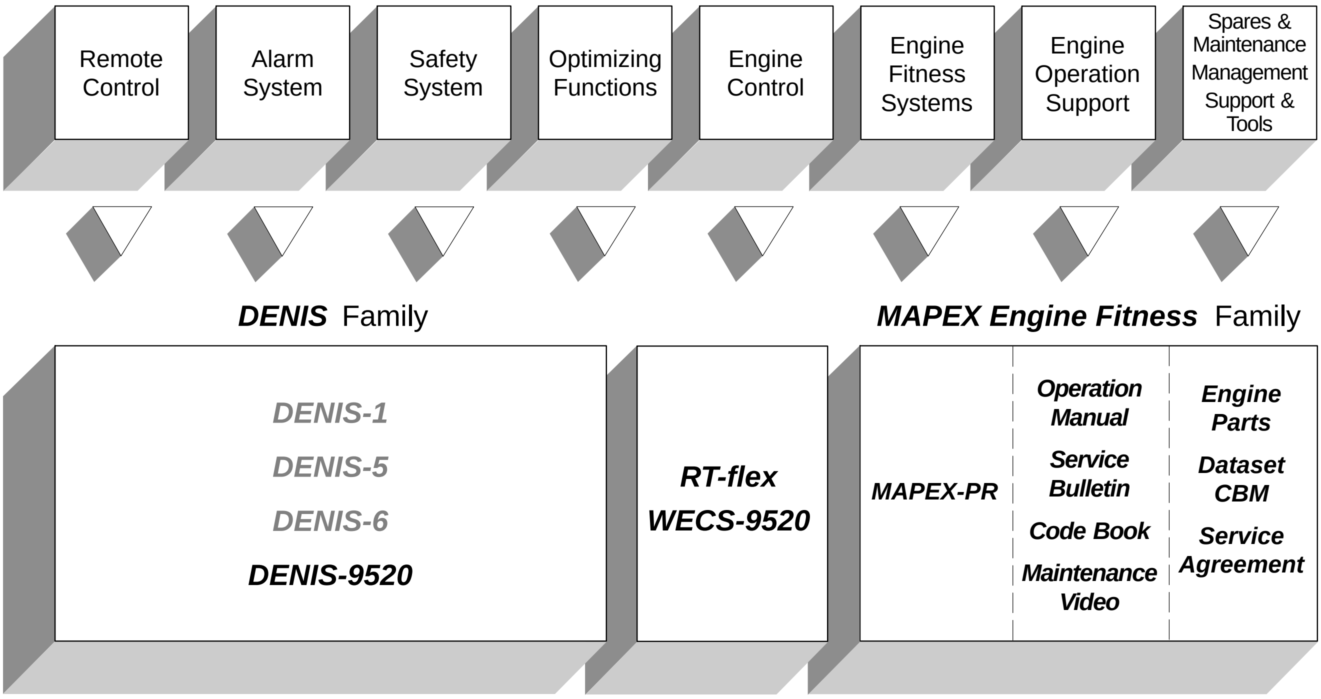


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Fig. G1 EMA concept comprising DENIS, WECS and MAPEX modules

RT-flex automation layout

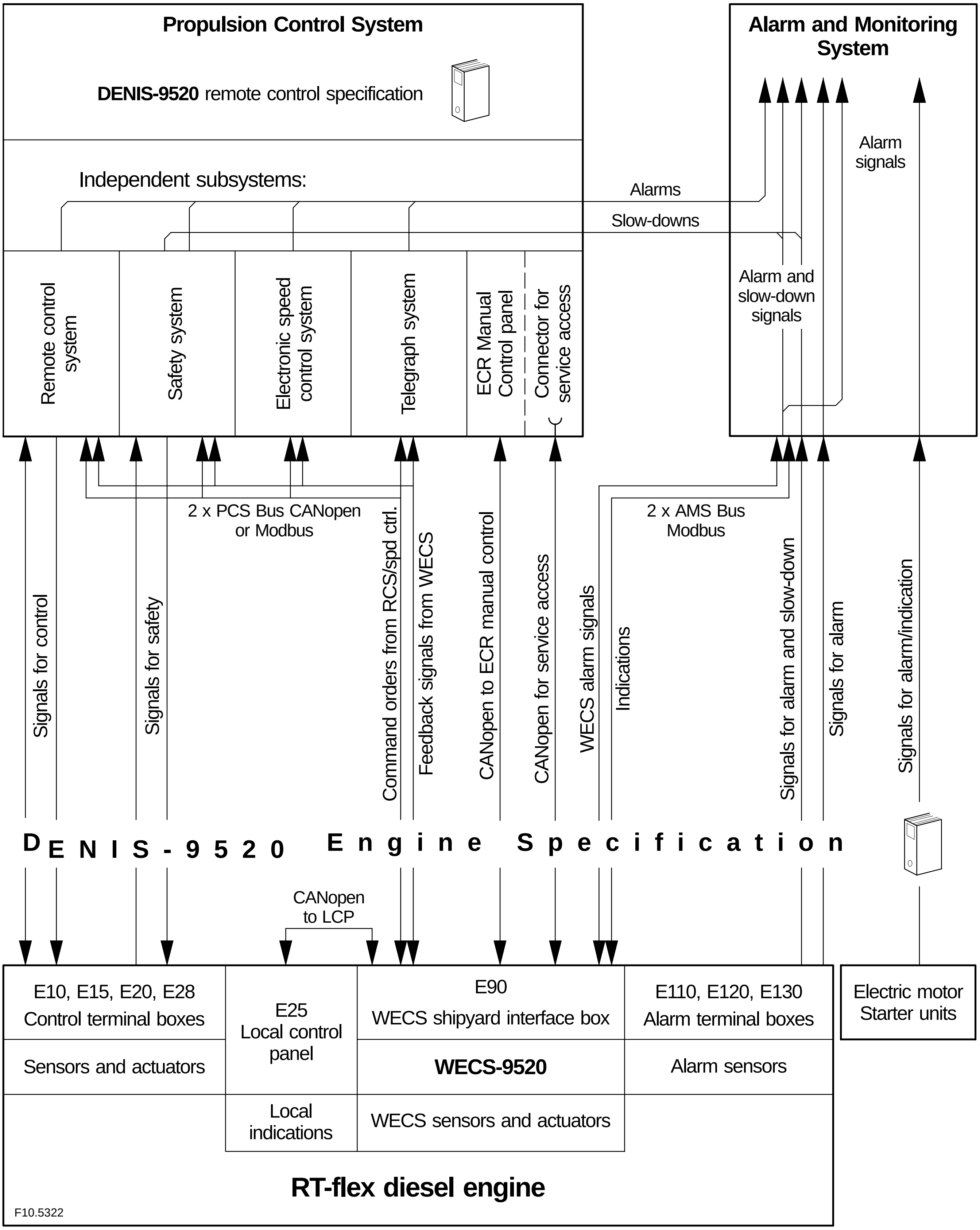

Fig. G2 RT-flex automation layout

G1.1 DENIS

The DENIS family contains specifications for the engine management systems of all modern types of Wärtsilä two-stroke marine diesel engines. The diesel engine interface specification applicable for all current types of RT-flex engines is DENIS-9520.

G1.2 WECS

Under the designation of WECS-9520 Wärtsilä Switzerland provides a computerised control system for all RT-flex functions. As such it is a component of the RT-flex system and includes all necessary interfaces to the engine as well as to the remote control and electronic speed control system.

With the same well proven engine control functions like the previous WECS-9500 it enhances the integration into the ship management system by providing data bus communication to all external systems.

G1.3 MAPEX

The products of the MAPEX family are designed to improve the engine's efficiency through better management and planning and save money by making available the knowledge of our engine management specialists.

For the further description of the MAPEX products please refer to section G4.

G2 DENIS-9520

G2.1 General

The concept of DENIS-9520 meets the requirements of increased flexibility and higher integration in modern ship automation and provides the following advantages for ship-owners, shipyards and engine builders:

- **Clear interface definition**
  The well defined and documented interface results in a clear separation of the responsibilities between engine builder and automation supplier.
  It allows that authorised suppliers adapt their systems to Wärtsilä RT-flex engines with reduced engineering effort.
  The clear signal exchange simplifies troubleshooting.
- **Approved propulsion control systems**
  Propulsion control systems including remote control, speed control, safety and telegraph systems are available from suppliers approved by Wärtsilä Switzerland Ltd. This cooperation ensures that these systems fully comply with the specifications of the engine designer.
- **Easy integration in ship management system**
  Providing data bus communication between WECS, the propulsion control and the vessel's alarm and monitoring system facilitates an easy integration of the various systems. The existing man–machine interface (MMI) of the vessel's automation can therefore handle also the additional MMI functions attributed to the WECS.
- **Ship automation from one supplier – Integrated solution**
  Automation suppliers approved by Wärtsilä Switzerland Ltd can handle all ship board automation tasks. Complete automation systems from one supplier show advantages like easier engineering, standardisation, easier operation, less training, fewer spare parts, etc.

The WECS-9520 is well suited to support this integrated automation concept by providing redundant data bus lines that deliver all necessary information for propulsion control, alarm / monitoring system and man–machine interface. The MMI of the WECS-9520 can provide additional features when using such an integrated solution.

- **Ship automation from different suppliers – Split solution**
  In the case that propulsion control and alarm / monitoring systems are from different suppliers the WECS-9520 supports also such a split solution by providing two separate redundant data bus lines one each for propulsion control and alarm / monitoring system. MMI functions are then also split within propulsion control and alarm / monitoring system.

DENIS-9520 describes the signal interface between the RT-flex engine including its flex engine control system (WECS) and the ship automation.

The DENIS specification does not include any hardware. It summarises all the data exchanged and defines the control functions required by the engine.

The DENIS specification is presented in two sets of documents:

- **DENIS engine specification**
  This file contains the specification of the signal interface on the engine and is made accessible to engine builders and shipyards. It consists basically of the control diagram of the engine, the signal list including a minimum of functional requirements and gives all information related to the electrical wiring on the engine. It lists also the necessary alarm and display functions to be realised in the vessel's alarm and monitoring system.
  The DENIS-9520 engine specification covers the engine-built components for control, alarm and indication.
  With the replacement of previous camshaft-controlled function by the WECS-9520, the engine built control components are reduced to a minimum.
  Instrumentation is based on the conventional RTA engine with RT-flex-specific components added.
- **DENIS remote control specification**
  This file contains the detailed functional specification of the remote control system.
  The intellectual property on this remote control specification remains with Wärtsilä Switzerland Ltd. Therefore this file is licensed to remote control partners of Wärtsilä Switzerland Ltd, only. These companies offer systems, built completely according to the engine designer's specifications, tested and approved by Wärtsilä Switzerland Ltd.

G2.2 Propulsion control system

The propulsion control system is divided into the following sub-systems:

- Remote control system.
- Safety system.
- Electronic speed control system.
- Telegraph system.

Safety system and telegraph system work independently and are fully operative even with the remote control system out of order.

G2.2.1 Approved propulsion control systems

Wärtsilä Switzerland Ltd has an agreement concerning the development, production, sales and servicing of remote control, electronic speed control and safety systems for their Wärtsilä RT-flex engines with each of the following leading marine automation suppliers. All approved propulsion control systems listed below contain the same functionality specified by Wärtsilä.

Supplier / Company	Remote Control System	Electronic Speed Control System
Kongsberg Marine Kongsberg Maritime AS P.O. Box 1009 km.sales@kongsberg.com N-3194 Horten Tel. +47 81 57 37 00 Norway Fax +47 850 28 028	**AutoChief C20**	**DGS C20**
NABTESCO Corporation NABTESCO corp., Marine Control Systems Company 1617-1, Fukuyoshi-dai 1-chome Nishi-ku Kobe, 651-22413 Tel. +81 78 967 5361 Japan Fax +81 78 967 5362	**M-800-III**	**MG-800 FLEX**
SAM Electronics GmbH / Lyngsø Marine SAM Electronics GmbH Behringstrasse 120 D-22763 Hamburg Tel. +49-40 88 25 0 Germany Fax +49-40 88 25 4116 Lyngsø Marine AS 2, Lyngsø Allé DK-2970 Hørsholm Tel. +45 45 16 62 00 Denmark Fax +45 45 16 62 62	**DMS2100i**	**EGS2000RTf**

Table G1 Suppliers of remote control systems and electronic speed control systrems

Modern remote control systems consist of electronic modules and operator panels for display and order input for engine control room and bridge. The different items normally communicate via serial bus connections. The engine signals described in the DENIS-9520 specification are usually connected via the terminal boxes on the engine to the electronic modules placed in the engine control room.

These electronic modules are in most cases built to be located either inside the ECR console or in a separate cabinet to be located in the ECR. The operator panels are to be inserted in the ECR console's surface.

Kongsberg Maritime has designed the electronic modules of the AutoChief C20 propulsion control system in a way that they can be mounted directly on the main engine. In this case the electronic modules for remote control, safety and speed control system are located in the same boxes used as terminal boxes for any other propulsion control system.

This facilitates to commission and test the complete propulsion control system already at the engine maker's testbed. The wiring at the shipyard is then limited to a few power cables and bus communication wires whereas the conventional arrangement requires more cables between the terminal boxes on the engine and the electronic modules of the remote control system in the engine control room.

These boxes with the electronic modules are part of the propulsion control system scope of supply and shall be delivered to the engine builder for mounting on the engine.

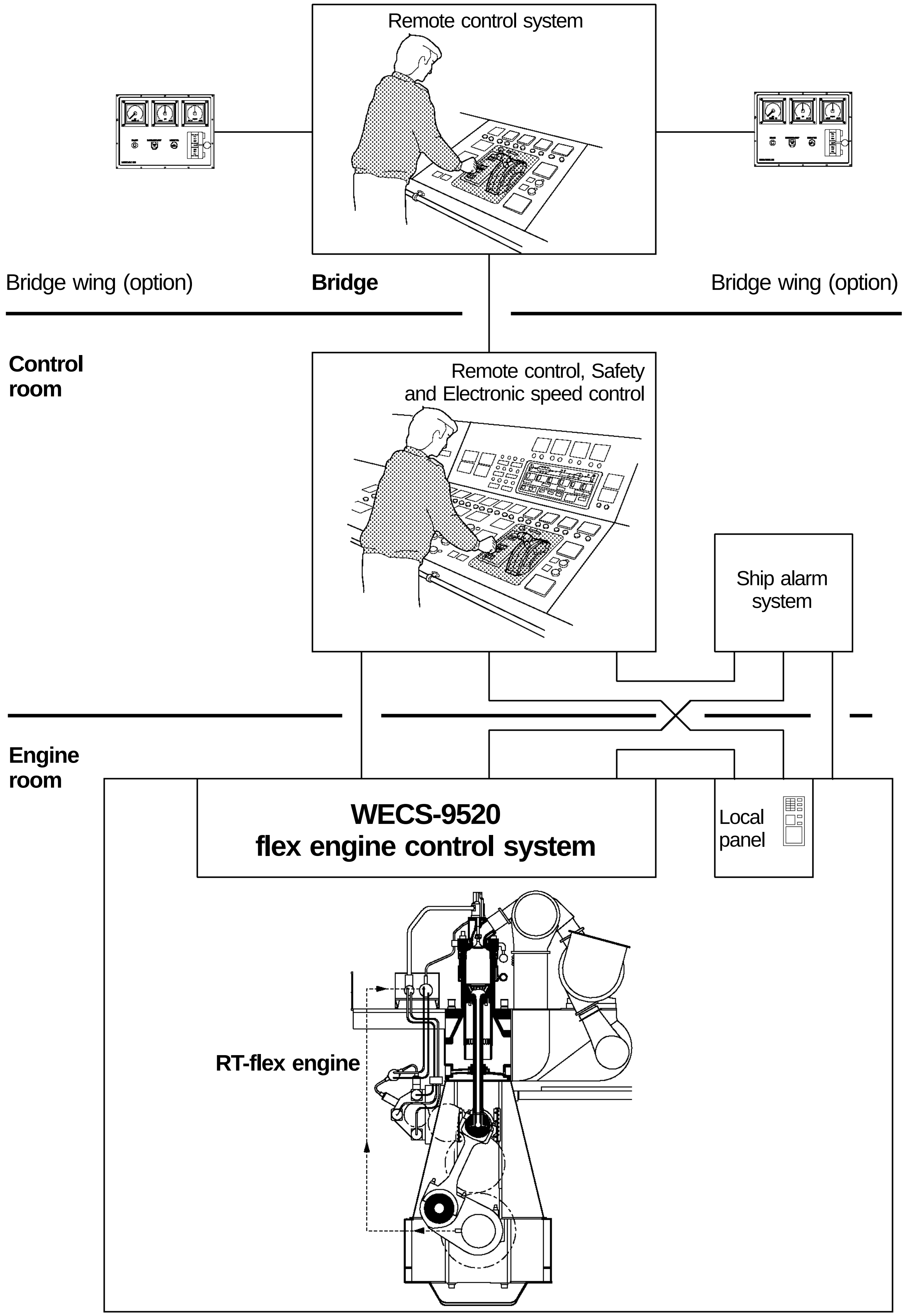

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Fig. G3 DENIS-9520 remote control system layout

G2.2.2 Functions of the propulsion control system

Approved propulsion control systems comprise the following independent sub-systems:

Remote control system
Main functions:

- Start, stop, reversing.
- Cylinder pre-/post-lubrication.
- Automatic slow turning.
- Auxiliary blower control.
- Control transfer.
- Speed setting.
- Automatic speed programme.
- Load-dependent cylinder lubrication (Pulse Lubricating System).

Indications:
The remote control system is delivered with control panels for local, control room and bridge control, including all necessary order input elements and indications e.g. push buttons/switches and indication lamps or alternatively a respective display.

The following instruments for remote indication in the control room are specified in the DENIS-9520 standard as a minimum:

- Starting air pressure.
- Engine speed.
- Revolution counter.
- Running hour counter.
- Load indicator.
- Turbocharger speed.
- Scavenge air pressure in air receiver.

The following instruments for remote indication on the bridge are specified in the DENIS-9520 standard as a minimum:

- Starting air pressure.
- Engine speed.

In addition to those indications, common for RTA and RT-flex engines, the remote control system applied to the RT-flex engine includes display of the most important values of the flex engine control system (WECS) like fuel pressure, servo oil pressure etc.

Electronic speed control system

- Keeps engine speed at the set point given by the remote control system.
- Sends fuel command to the WECS-9520.
- Limits fuel amount in function of charge air and measured speed for proper engine protection.

Wärtsilä Switzerland has always requested that remote control systems and speed control systems of the same supplier are applied, in order to avoid compatibility problems and increased engineering efforts.

Traditionally the electronic speed control system was considered as a part of the main engine and was therefore usually delivered together with the engine.

With the introduction of WECS-9520 and DENIS-9520, the electronic speed control system is assigned to the propulsion control system and therefore shall be delivered together with the corresponding remote control system and further components of the propulsion control package by the party responsible for the complete propulsion control system, i.e. in most cases the shipyard.

The details regarding system layout, mechanical dimensions of components as well as the information regarding electrical connections has to be taken from the technical documentation of the respective supplier.

Safety system
Main functions:

- Emergency stop functions.
- Overspeed protection.
- Automatic shut-down functions.
- Automatic slow-down functions.

Telegraph system

- Order communication between different control locations.

ECR manual control panel

A manual control panel delivered together with the propulsion control system and fitted in the ECR console allows to operate the engine manually and independently from the remote control system. The functions of the ECR manual control are equal to the control function on the local control panel at the engine side.

Local manual control

Local manual control of the engine is performed from a control panel located on the engine. This panel includes elements for manual order input and indication for safety system, telegraph system and WECS-9520.

The local control box with the local manual control panel is included in the package delivered by approved remote control system suppliers.

Options

- Bridge wing control.
- Order recorder.

G2.2.3 Recommended manoeuvring characteristics

Recommended values for the manoeuvring positions are given in figure G4.

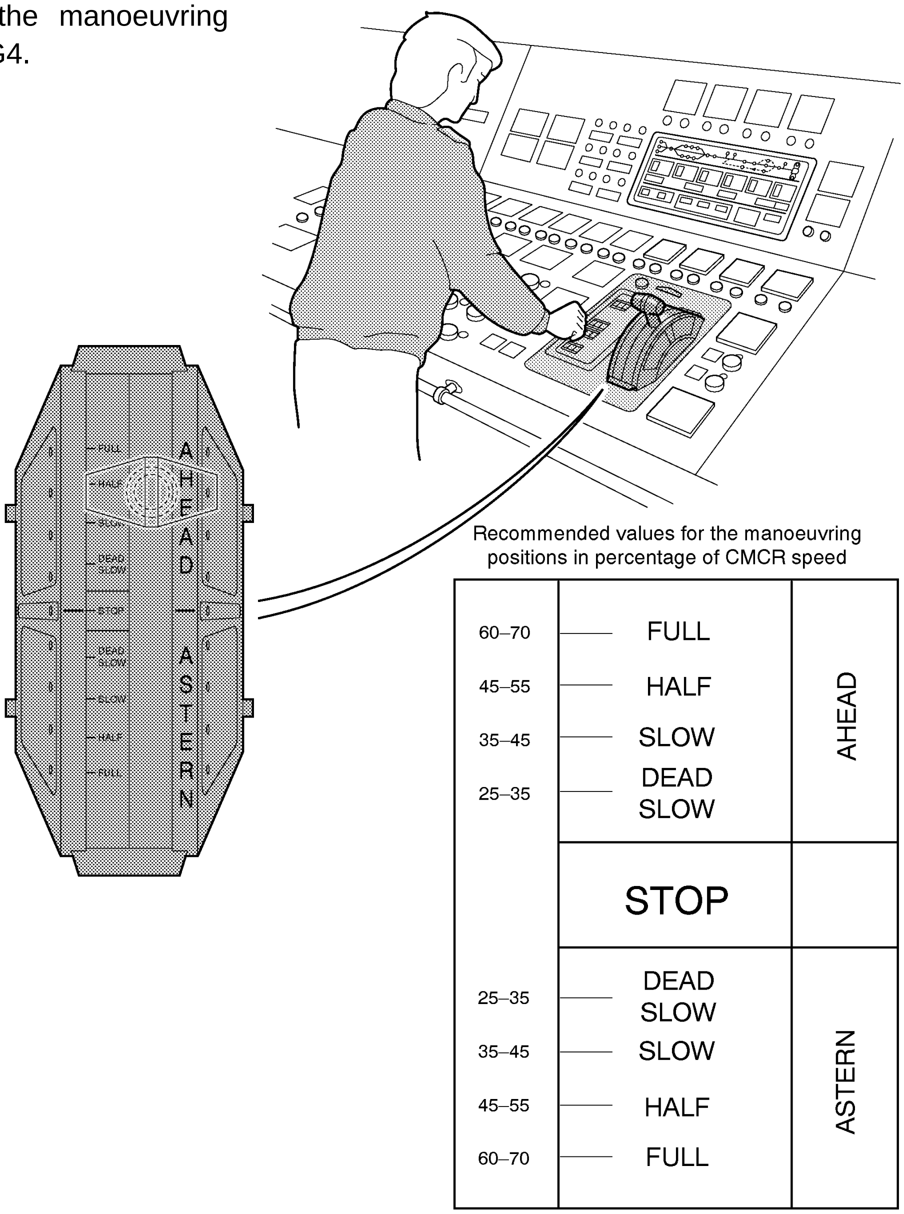

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Fig. G4 Recommended manoeuvring characteristics

G2.3 Interface to alarm and monitoring systems

G2.3.1 General layout – Operator interface OPI

On a conventional RTA engine, hardwired signals from alarm sensors mounted to the engine had to be connected to the vessel's alarm and monitoring system.
On a RT-flex engine, basically the same alarm sensors are available. Additional sensors with hardwired connection are fitted to monitor RT-flex specific circuits of the engine.
In addition to that, the flex engine control system (WECS) provides alarm values and analogue indications via data bus connection to the ship's alarm and monitoring system as part of the operator interface of the RT-flex engine.
Connection from the WECS-9520 to the engine automation can be made in two ways (refer to figure G5).

Integrated solution

Propulsion control system and alarm / monitoring system from same supplier:
This allows to connect both propulsion control system and alarm / monitoring system through one redundant bus line only (CANopen or Modbus, depending on automation maker) to the WECS-9520.

With this integrated solution an extended presentation of relevant parameters is possible as well as a comfortable access to changeable user parameters taking full profit of the graphical user interface functions available in the alarm and monitoring system.

A further step in integration is possible when using a DataChief C20 alarm and monitoring system of Kongsberg Maritime. In this case also all the conventional sensors and the additional flex sensors can be connected via data bus lines. The design allows that the data acquisition units are mounted directly on the engine in the same boxes used as terminal boxes for any other alarm and monitoring system.
These boxes which are part of the alarm and monitoring system usually provided by the shipyard have to be delivered to the engine builder for mounting to the engine and connection of the sensors.
Commissioning and testing of the complete set of alarm signals already at the engine maker's testbed is thus facilitated and the wiring at the shipyard is limited to a few power cables and bus communication.

Split solution

Propulsion control system and alarm / monitoring system from different suppliers:
The propulsion control system is connected through one redundant bus line (CANopen or Modbus, depending on automation maker) to the WECS.
For the separate alarm and monitoring system an additional redundant Modbus connection is available.
Also the operator interface is then split in this case:

- Changing of parameters accessible to the operator and display of parameters relevant for the engine operation is included in the remote control system.
- The alarm / monitoring system has to include:
  - Display of some flex system indications, like e.g. fuel pressure, servo oil pressure etc.
  - Display of the flex system alarms provided by the WECS.
- WCH provides modbus lists specifying the display values and alarm conditions as part of the DENIS engine specification.

Requirements for any alarm and monitoring system to be applied in a split solution:

- Possibility to read values from a redundant Modbus line according to standard Modbus RTU protocol.
- Ability to display analogue flex system values (typically 20 values) and add alarm values provided from WECS to the standard alarm list (100–200 alarms depending on engine type and number of cylinders).

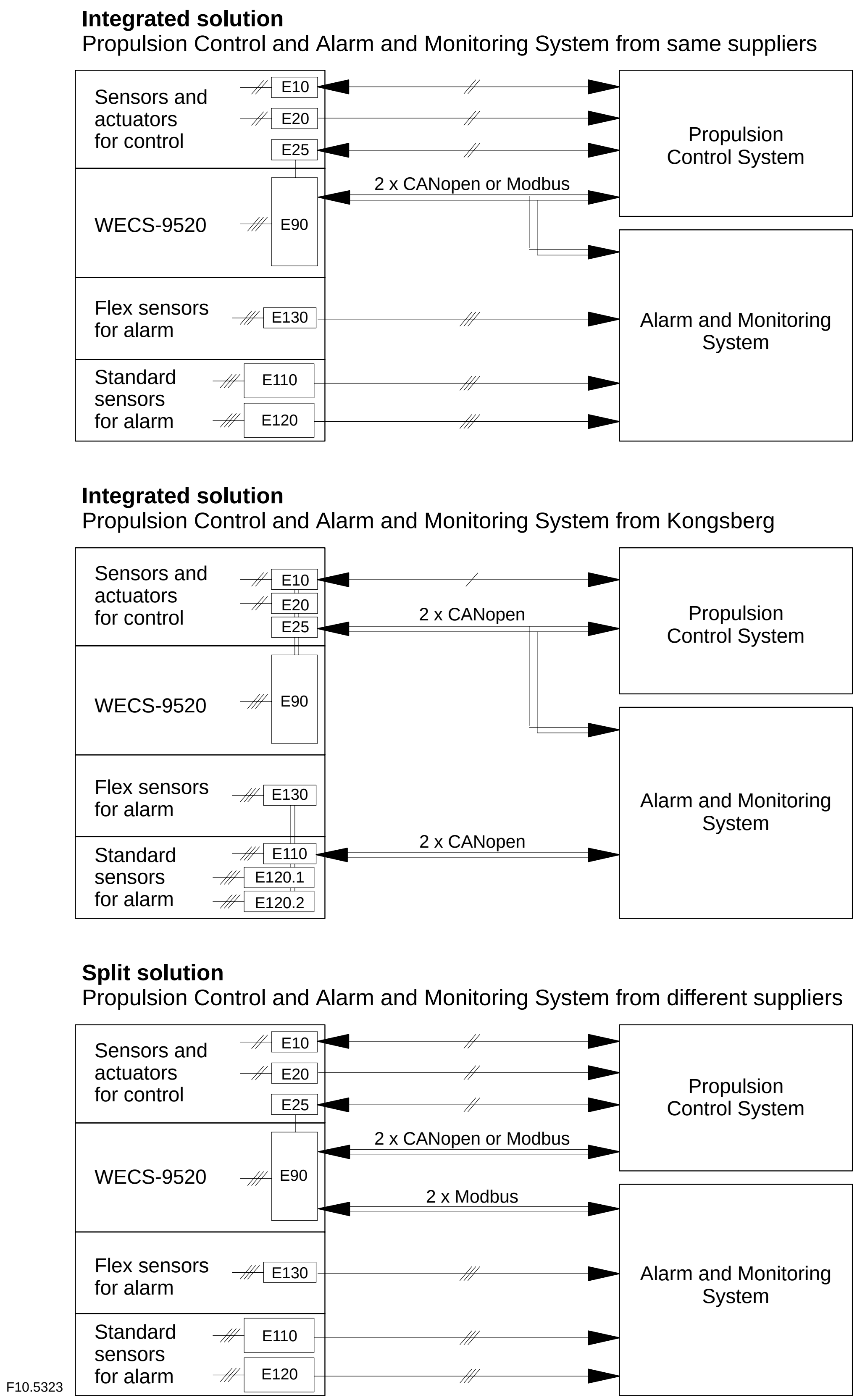

Fig. G5 Integrated/split solution

G2.3.2 Alarm sensors and safety functions

The classification societies require different alarm and safety functions, depending on the class of the vessel and its degree of automation.
These requirements are listed together with a set of sensors defined by Wärtsilä Switzerland Ltd in tables G2 to G3 “Alarm and safety functions of Wärtsilä RT-flex84T-D marine diesel engines”.

The time delays for the slow-down and shut-down functions given in tables G2 to G3 are maximum values. They may be reduced at any time according to operational requirements. When decreasing the values for the slow-down delay times, the delay times for the respective shut-down functions are to be adjusted accordingly.
The delay values are not to be increased without written consent of Wärtsilä Switzerland Ltd.

Included in the standard scope of supply are the minimum of safety sensors as required by WCH for attended machinery space (AMS). If the option of unattended machinery space (UMS) has been selected the respective sensors have to be added according to the requirements issued by Wärtsilä Switzerland Ltd. There are also some additional sensors defined for the monitoring of flex system specific engine circuits.

The exact extent of delivery of alarm and safety sensors has to cover the requirements of the respective classification society, Wärtsilä Switzerland Ltd, the shipyard and the owner.

The sensors delivered with the engine are basically connected to terminal boxes mounted on the engine. Signal processing has to be performed in a separate alarm and monitoring system usually provided by the shipyard.

Alarm and safety functions for RT-flex84T-D engines				Values				min. WCH requirements			Request of classification societies for UMS ■ = Additional request to UMS for AMS ▲ = Request for AMS only											
Medium	Physical unit	Location	Signal No.	Function	Level	Setting	max. allowable time delay [sec.]	for AMS	add. to AMS for UMS	add. flex signals	IACS	ABS	BV	CCS	DNV	GL	KR	LR	MRS	NK	PRS	RINA
Cylinder cooling water	Pressure	Engine inlet	PT1101A	ALM	L	4.5 bar	0		●		●	●	●	●	●	●	●	●	●	●	●	●
				SLD	L	4.3 bar	60	●			●	●	●	●	●	●	●	●	●	●	●	●
			PS1101S	SHD	L	4.0 bar	60	●								●						
	Temp.	Engine inlet	TE1111A	ALM	L	65 °C	0		●							●						●
		Outlet each cylinder	TE1121–29A	ALM	H	95 °C	0		●		●	●	●	■	●	●	●	●	●	●	●	●
				SLD	H	97 °C	60		●		●	●	●	●	●	●	●	●	●	●	●	●
Scavenge air cooling water	Pressure	Inlet cooler	PT1361A	ALM	L	2.0 bar	0		●													
fresh water, single-stage	Temp.	Inlet cooler	TE1371A	ALM	L	25 °C	0		●													
		Outlet cooler	TE1381–82A	ALM	H	80 °C	0		●													
Main bearing oil	Pressure	Supply	PT2001A	ALM	L	2.7 bar	0		●		●	●	●	●	●	●	●	●	●	●	●	●
				SLD	L	2.5 bar	60	●			●			●		●				●	●	
			PS2002S	SHD	L	2.0 bar	10	●			●	●	●	●	●	●	●	●	●	●	●	●
	Temp.	Supply	TE2011A	ALM	H	50 °C	0		●		●	●	●	●	●	●	●	●	●	●	●	●
				SLD	H	55 °C	60		●			●	●	●		●			●		●	●
Crosshead bearing oil	Pressure	Supply	PT2021A	ALM	L	10 bar	0		●					●		●						
			*1)	SLD	L	9 bar	60	●								●						
Servo oil	Pressure	Pump inlet	PT2051A	ALM	L	1.7 bar	0	●														
	Flow	Pump inlet	FS2061–63A	ALM	L	no flow	0	●														
	Failure	Automat. filter	XS2053A	ALM	F	–	0	●														
Oil leakage monitoring	Level	Supply unit	LS2055A	ALM	H	max.	0	●														
for Pulse Lubricating System only	Pressure	Free/driv. end	PT2041/42A	ALM	L	40 bar	3	●														
			*2)	ALM	H	70 bar	3	●														
	Leakage	Free/driv. end	PT2046/47A	ALM	H	10 bar	0	●														
Control oil leakage monitoring	Pressure	Supply unit	PT2083A	ALM	H	50 bar	0			●												
	Level	Supply unit	LS2085A	ALM	H	max.	0			●												
Thrust/Main bearing oil	Temp.	Outlet	TE2101–11A	ALM	H	65 °C	0				●	A	A	A	A	A	A	A	A	A	A	A
				SLD	H	70 °C	0									A						
Thrust bearing pads	Temp.	Fore/Aft side	TE4521/22A	ALM	H	75 °C	0		●		●	●	●	●	●	●	●	●	●	●	●	●
				SLD	H	80 °C	60		●		●	●	●	●	●					●	●	
		Fore/Aft side	TE4526/27A	ALM	H	75 °C	0															
	*3)			SLD	H	80 °C	60															
		Fore side	TS4521S	SHD	H	90 °C	60				●	●		●							●	
		Aft side	TS4522S	SHD	H	90 °C	60															
Crank bearing oil	Temp.	Outlet	TE2201–09A	ALM	H	65 °C	0				●	A	A	A	A	A	A	A	A	A	A	A
				SLD	H	70 °C	0							●		A						
Crosshead bearing oil	Temp.	Outlet	TE2301–09A	ALM	H	65 °C	0				●	A	A	A	A	A	A	A	A	A	A	A
				SLD	H	70 °C	0							●		A						
Oil mist concentration	Concen- tration	Crankcase	AS2401A	ALM	H	–	0	●			●	B	B	B	B	B	B	B	B	B	B	B
			AS2401S	SLD	H	–	60	●			●	B	B	B	B	B	B	B	B	B	B	B
	Failure	Detection unit	XS2411A	ALM	F	–	0	●								●						
Piston cooling oil	Temp.	Outlet each cylinder	TE2501–09A	ALM	H	80 °C	0		●		●	●	●	●	●	●	●	●	●	●	●	●
				SLD	H	85 °C	60		●		●	●	●	●	●	●	●	●	●	●	●	●
	Flow	Inlet each cylinder	FS2521–29S	SHD	L	no flow	15	●						●		●						
	Diff.press.		PS2541–49S	SHD	H	0.3 bar	15	●						●								

Table G2 Alarm and safety functions of Wärtsilä RT-flex84T-D marine diesel engines

Alarm and safety functions for RT-flex84T-D engines					Values			min. WCH requirements			Request of classification societies for UMS ■ = Additional request to UMS for AMS ▲ = Request for AMS only											
Medium	Physical unit	Location	Signal No.	Function	Level	Setting	max. allowable time delay [sec.]	for AMS	add. to AMS for UMS	add. flex signals	IACS	ABS	BV	CCS	DNV	GL	KR	LR	MRS	NK	PRS	RINA
Turbocharger bearing oil	Pressure	Inlet each TC	PT2611–12A	ALM	L	1.0 bar	5		●					■		●					●	
ME bearing oil supply			*4)	SLD	L	0.8 bar	60		●													
ABB TPL		Inlet each TC	PS2611–12S	SHD	L	0.6 bar	5	●														
	Temp.	Outlet TC	TE2601–02A	ALM	H	110 °C	0		●					▲		●					●	
				SLD	H	120 °C	60	●														
ME bearing oil supply	Pressure	Inlet each TC	PT2611–12A	ALM	L	0.7 bar	5		●					■		●					●	
				SLD	L	0.6 bar	60		●													
MHI MET		Inlet each TC	PS2611–12S	SHD	L	0.4 bar	5	●														
	Temp.	Outlet TC	TE2601–02A	ALM	H	85 °C	0		●					▲		●					●	
				SLD	H	90 °C	60	●														
Separate TC lub. oil supply	Pressure	Inlet each TC	PT2611–12A	ALM	L	1.3 bar	5		●					■		●					●	
			*4)	SLD	L	1.1 bar	60		●													
ABB TPL		Inlet each TC	PS2611–12S	SHD	L	0.9 bar	5	●														
	Temp.	Outlet TC	TE2601–02A	ALM	H	120 °C	0		●					▲		●					●	
				SLD	H	130 °C	60	●														
Additional requirement when separate TC lub. oil supply	Temp.	Inlet TC ABB TPL	TE2621A	ALM	H	80 °C	0		●											●		
				SLD	H	85 °C	60		●										●		●	
		Inlet TC MHI MET	TE2621A	ALM	H	60 °C	0		●											●		
				SLD	H	65 °C	60		●										●		●	
Geislinger damper oil	Pressure	Casing inlet	PT2711A	ALM	L	1.0 bar	0		●													
Axial damper (detuner) oil	Pressure	Damp. chamber aft side	PT2721A	ALM	L	1.7 bar	60		●													
		Damp. chamber fore side	PT2722A	ALM	L	1.7 bar	60		●													
Cylinder lubricating oil	Flow	Cylinder inlet	FS3101–09A	ALM	L	no flow	30		●		●	●	●	●	●	●	●	●	●	●	●	●
for conventional lubricating syst. CLU-3	*5)		FS3100S	SLD	L	no flow	60	●			●	●	●	●		●			●	●	●	●
	Flow	Cylinder inlet	FE3101–09A	ALM	L	no flow	30		●		●	●	●	●	●	●	●	●	●	●	●	●
	*5)			SLD	L	no flow	60	●			●	●	●			●			●			●
for pulse lub. syst. only	Diff.press.	Oil filter	PS3121A	ALM	H	0.5 bar	0	●														
for lub. syst. CLU-3	Level	Cyl.lub.oil pump	LS3125A	ALM	L	min.	–	●														
Fuel oil *6)	Temp.	Fuel pump outlet	TE3431–34A	ALM	D	–30 °C	30			●												
	Viscosity	Before supply unit		ALM	H	17 cST	0		●		D	D	D	D	D	D	D	D	D	D	D	D
				ALM	L	13 cST	0		●		●	●	●	●	●	●	●	●	●	●	●	●
	Temp.	Before supply unit	TE3411A *7)	ALM	H	50–160°C	0		●							C						
				ALM	L	20–130°C	0		●		C	C	C	C	C	C	C	C	C	C	C	C
	Pressure		PT3421A	ALM	L	7 bar	0		●		●	●	●	●	●	●	●	●	●	●	●	●
Leakage	Level	Supply unit	LS3426A	ALM	H	max.	0			●		●	●	●	●	●	●	●	●	●	●	●
		Rail unit	LS3444–45A	ALM	H	max.	0			●												
		Fuel pipe	LS3446–47A	ALM	H	max.	0			●												
Exhaust gas	Temp.	After each cylinder	TT3701–09A	ALM	H	515 °C	0		●		●	●	●	●	●	●	E	E	●	●	●	●
				ALM	D	± 50 °C	0		●		●	●	●	●	●	●	F	F	●	●	●	●
				SLD	H	530 °C	60		●		●	●	●	●	●	●	●	G		●	●	G
				SLD	D	± 70 °C	60		●							●		H			●	●
	Temp.	Before each turbocharger	TT3721–22A	ALM	H	515 °C	0				●			●		●				●	●	●
				SLD	H	530 °C	60															H
		After each turbocharger	TT3731–32A	ALM	H	480 °C	0				●			●		●		●		●	●	
				SLD	H	500 °C	60								●							

Table G3 Alarm and safety functions of Wärtsilä RT-flex84T-D marine diesel engines

G. Automation and controls

Alarm and safety functions for RT-flex84T-D engines				Values				min. WCH requirements			Request of classification societies for UMS ■ = Additional request to UMS for AMS ▲ = Request for AMS only											
Medium	Physical unit	Location	Signal No.	Function	Level	Setting	max. allowable time delay [sec.]	for AMS	add. to AMSfor UMS	add. flex signals	IACS	ABS	BV	CCS	DNV	GL	KR	LR	MRS	NK	PRS	RINA
Scavenge air	Temp.	After each cooler	TE4031–32A	ALM	L	25 °C	0		●			I				I	●		○	●	●	I
			*8)	ALM	H	60 °C	0		●			●		I		●	●		○	●	●	●
				SLD	H	70 °C	60							I								
	Temp.	Each piston underside	TE4081–89A	ALM	H	80 °C	0		●		●	●	●	K	●	●	●	●	●	●	●	●
				SLD	H	120 °C	60		●		●	●	●	K	●	●	●	●		●	●	●
Condensation water *9)	Level	Water separ-ator	LS4071–72A	ALM	H	max.	0		●		●	K	●	●		K				●		K
				SLD	H	max.	60		●													
		Before water separator	LS4075–76A	ALM	H	max.	0		●		●	K	●	●		K				●		K
				SLD	H	max.	60		●													
Starting air	Pressure	Engine inlet	PT4301C	ALM	L	12.0 bar	0		●		●	●	●	●	●	●	●	●	●	●	●	●
Air spring air	Pressure	Distributor	PT4341A	ALM	H	7.5 bar	0		●		●											
				ALM	L	5.5 bar	0	●			●			●								
				SLD	L	5.0 bar	60	●			●											
			PS4341S	SHD	LL	4.5 bar	0	●			●											
Leakage oil	Level	Exh.valve air	LS4351A	ALM	H	max.	0	●			●											
Control air normal supply	Pressure	Engine inlet	PT4401A	ALM	L	6.0 bar	0		●		●	●	●	●	●	●	●	●	●	●	●	●
stand-by supply	Pressure	Engine inlet	PT4411A	ALM	L	5.5 bar	0		●					●								
	Pressure	Engine inlet	PT4421A	ALM	L	5.0 bar	0		●					●		●						
Fuel actuator	Failure	Supply unit	XS5046–47A	ALM	F	–	–			●												
WECS-9520 control system	Pwr. fail	Pwr. sup. box	XS5056A	ALM	F	–	–			●												
Pulse Lubricating system	Pwr. fail	Pwr. sup. box	XS5058A	ALM	F	–	–	●								●						
Engine Overspeed	Speed	Crankshaft	ST5111–12S	SHD	H	110 %	0	●			●	●	●	●	●	●	●	●	●	●	●	●
Turbocharger Overspeed	Speed	TC casing	ST5501–02A	ALM	H	*10)	–								●							

Classification societies:

IACS	International Association of Classification Societies
ABS	American Bureau of Shipping
BV	Bureau Veritas
CCS	Chinese Classification Society
DNV	Det Norske Veritas
GL	Germanischer Lloyd
KR	Korean Register
LR	Lloyd's Register
MRS	Maritime Register of Shipping (Russia)
NK	Nippon Kaiji Kyokai
PRS	Polski Rejestr Statkow
RINA	Registro Italiano Navale

Signals for Geislinger damper, PTO coupling, electric speed control and turbocharger vibration apply only if respective equipment is used.

Remarks:

*1) ALM and SLD have to be suppressed at low load.

*2) PT2042A and PT2047A only for 8&9 cylinder engines.

*3) Temperature of the bearing pads is measured.
Optional sensors are: TE4522A, TE4526/27A, TS4522S.

*4) The indicated alarm and slow-down values are minimum settings allowed by the TC maker. In order to achieve an earlier warning, the ALM and SLD values may be increased up to 0.4 bar below the minimum effective pressure measured within the entire engine operation range. The final ALM/SLD setting shall be determined during commissioning / sea trial of the vessel.

*5) Signals FE3101–09A and LS3125A for cylinder lubrication type VOGEL,
signals FS3101–09A and FS3100S for cylinder lubrication type JENSEN.

*6) Deviation from median: Acts as "no flow" detection.

*7) ALM values depending on fuel viscosity.

*8) For water separators made from plastic material the sensor must be placed right after the separator.

*9) Alternatively, low temperature alarm **or** condensation water high level alarm.

*10) ALM value depending on turbocharger type.
Optional SLD for turbocharger available on customers request.

Function:
- ALM: alarm
- SLD: slow down
- SHD: shut down

Level:
- D: deviation
- F: failure
- H: high
- L: low

Request of classification societies:
- ● Request for UMS
- ○ Recommendation for UMS
- ■ Additional request to UMS for AMS
- ▲ Request for AMS only
- UMS Unattended machinery space
- AMS Attended machinery space

- A or B are requested alternatively
- C or D are requested alternatively
- E or F are requested alternatively
- G or H are requested alternatively
- I or K are requested alternatively

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Table G4 Alarm and safety functions of Wärtsilä RT-flex84T-D marine diesel engines

G3 WECS-9520 – RT-flex engine control system

G3.1 WECS-9520 – System layout

WECS-9520 covers RT-flex functions related to the engine as a whole (e.g. common rail pressure control, servo oil pressure control) as well as the cylinder specific RT-flex functions (e.g. control of volumetric injection, exhaust valve and start valves).

The WECS-9520 consists of the following components:

- 1 control box E95.n per cylinder, including one FCM-20 each, performing cylinder control and common control functions.
- 1 shipyard interface box (SIB) E90 providing all external connections. E90 includes one FCM-20 “online spare module”.
- 1 Power supply box E85.

The control boxes E95.n and the shipyard interface box E90 are incorporated in the rail unit. The power supply box E85 is supplied loose for mounting in the engine room.

G3.2 WECS-9520 – External 230 VAC power supply

The external 230 VAC power supply for WECS-9520 according to the engine designer’s standard must include two fully redundant 230 VAC power supplies. One 230 VAC power supply line #1 must be fed from the main switch board and one 230 VAC power supply line #2 must be fed from the emergency switchboard.
Alternative arrangements of the WECS-9520 power supply are within the responsibility of the shipyard. In this case the redundancy level of the external power supply shall be in line with the redundant power supply concept of WECS-9520.
For power consumption see table C4.

G3.3 Online spare module

With WECS-9520 WCH introduces an unique feature for automatic loading application software and parameter settings when replacing a flex control module (FCM-20). This includes the mounting of a so called “online spare module” in the shipyard interface box E90.

With the automatic software loading procedure built into the WECS-9520 it is possible to replace any FCM-20 by any spare module available on board without prior downloading of any data.

When installing an new FCM-20 into a WECS-9520 it will be automatically detected as a new module and receive all necessary application data from the other modules of the WECS-9520.

As the download of the respective data may take some time WCH has found an ultimate arrangement to provide immediate functioning of an FCM-20 after replacement: The online spare module FCM-20. An additional FCM-20 numbered #00 is always fitted in the shipyard interface box E90 ready to be used as spare with all application data already loaded. In case that a FCM-20 needs to be replaced this FCM20 #00 spare is taken as spare and allows full functionality immediately after replacement. An additional FCM-20 from the stock is then to be placed in the E90 as new online spare module. This module will download all necessary data from the other modules within a certain time without compromising engine operation.

G3.4 Communication to external systems

With WECS-9520, direct hard wired connection to external systems is limited to a minimum.

WECS-9520 provides data bus connections to propulsion control system and ship alarm / monitoring system. It also provides data bus connection to the local manual control panel on the engine and to the ECR manual control panel of the RT-flex engine.

With the WECS-9520 the man–machine interface (MMI) also referred to as operator interface (OPI) of the main engine and the WECS-9520 engine control system is integrated in the ship automation in either the integrated or split solution an described in section G2.3.1.

In the standard configuration the WECS-9520 provides the following external connections:

- 2 redundant CANopen lines intended for the connection of the remote control system.
- 2 redundant Modbus lines as an alternative connection of the remote control system.
- 2 redundant Modbus connections for the ship's alarm and monitoring system in the split solution.
- 1 CANopen line for connection of the local manual control panel.
- 1 CANopen line for connection of the ECR manual control panel.
- 1 CAN bus connection to a plug on the back-up panel of the remote control system foreseen for the connection of a notebook of a service engineer.

The use of the bus connection on the WECS-9520 with the different approved system makers is as follows:

Kongsberg Maritime

- **Integrated solution**
  Propulsion control system AutoChief C20 and alarm / monitoring system DataChief C20:
  Connection of two CANopen lines only. The propulsion control system with remote control, safety system and electronic speed control system is connected directly to the CANopen lines while the data to the alarm and monitoring system is routed through CAN couplers from the same two CANopen lines.
- **Split solution**
  Propulsion control system AutoChief C20 with an alarm and monitoring system of any other maker:
  The propulsion control system with remote control, safety system and electronic speed control system is connected to the two redundant CANopen lines.
  The alarm and monitoring system is to be connected to the additionally provided two redundant Modbus lines.

SAM Electronic / Lyngsø Marine

- **Integrated solution**
  Propulsion control system DMS2100i and alarm / monitoring system UMS2100:
  Connection of two Modbus lines only. The propulsion control system with remote control, safety system and electronic speed control system is connected directly to the Modbus lines while the data to the alarm and monitoring system is routed through the propulsion control system.
- **Split solution**
  Propulsion control system DMS2100i with an alarm and monitoring system of any other maker:
  The propulsion control system with remote control, safety system and electronic speed control system is connected to the two redundant Modbus lines provided for remote control.
  The alarm and monitoring system is to be connected to the additionally provided two redundant Modbus lines.

Nabtesco

- **Split solution**
  Nabtesco propulsion control system M-800-III with an alarm and monitoring system of any other maker:
  The propulsion control system with remote control, safety system and electronic speed control system is connected to the two redundant CANopen lines provided for remote control.
  The alarm and monitoring system is to be connected to the additionally provided two redundant Modbus lines.

G3.5 Cabling notes

The Remote Control System (PCS) and Alarm & Monitoring System (AMS) supplier is to provide a detailed wiring diagram for a specific plant showing the actual cabling, cable routing and intermediate terminals.

Screened cables are to be used where indicated in the cable lists and wiring diagrams.

Wärtsilä Switzerland Ltd recommends that cables carrying different current levels are routed separately through two cable ducts being at least 0.5 m apart and identified as follows:

- **High level signals**
  (denoted as **H** in wiring diagrams):
  Signals with considerable current level, e.g. solenoid valves and power supplies.
- **Low level signals**
  (denoted as **L** in wiring diagrams):
  Signals with minimal current level, e.g. switches, analogue signals, temperature signals.

Data signal cables

For the data bus cables connecting the PCS to the WECS it is mandatory to use cables that fulfil the following specifications:

- Screened twisted pair with 0.5 mm^2 to 1 mm^2 cable core section.
- Specific impedance of 120 Ω (± 15 %).

Note: Standard Cat5 cables usually do not fulfil these requirements!

Wiring principles

- Switches:
  Generally 2 cores per switch are required but in some cases a common supply may be used.
- PT 100 Sensors:
  The engine wiring should be done as 3 core cabling. The shipyard wiring can be done as 3 or 4 connection. The use of at least 3 core cabling is recommended.
- Thermocouples:
  Thermocouples are connected to the engine mounted terminal boxes by 2 core compensating cables, where they are connected to a converter that supplies a 4–20 mA signal. For the shipyard connections, compensating cables or reference temperature measurement in the terminal box are to be applied. It is madatory that screened cables are used in all cases between engine mounted terminal boxes and the AMS.

G4 MAPEX Engine Fitness Family

An intelligent engine management system also needs to include functions such as the monitoring of specific engine parameters, analysing data, and managing maintenance and spare parts purchasing activities. Many of these functions involve specific and complex engine knowledge and are most appropriately handled directly by the engine designer.

Wärtsilä Switzerland Ltd provides a full range of equipment for carrying out these functions, called the MAPEX Engine Fitness Family. MAPEX, or '**M**onitoring and m**A**intenance **P**erformance **E**nhancement with e**X**pert knowledge', encompasses the following principles:

- Improved engine performance through reduced down time.
- Monitoring of critical engine data, and intelligent analysis of that data.
- Advanced planning of maintenance work.
- Management support for spare parts and for maintenance.
- Access on board ship to the knowledge of experts.
- Reduced costs and improved efficiency.

The MAPEX Engine Fitness Family currently comprises one system: MAPEX-PR.

Further members of the MAPEX Engine Fitness Family are also envisaged.

In each case special emphasis has been placed on user friendliness and ease of installation.

For further information regarding products of the MAPEX Engine Fitness Family contact your WCH sales representative.

G4.1 Mapex-PR (Piston-running Reliability)

MAPEX-PR continuously monitors the piston-running behaviour on large-bore Wärtsilä two-stroke diesel engines with an alarm if adverse conditions should appear.
For example, an alarm is signalled if, among other criteria, the local temperature on the liner is abnormally high due to piston-ring scuffing or inadequate ring sealing.

The measured data are stored in an electronic unit and can be viewed on a personal computer. Preferably an industrial-PC installed in an ideally suited control box. All data and charts can be printed and copied to other storage media.

The following data are monitored over fixed periods of 1, 4.5, 24, 400 or variable engine running hours and displayed graphically:

- Liner wall temperature (two sensor per cylinder).
- Cylinder cooling water temperature inlet and outlet.
- Scavenge air temperature after each cooler.
- Engine speed.
- Engine load indicator position.
- Alarms.

The following alarms can be connected to the ship's alarm system to inform the engineers about any unexpected situation:

- High friction on one or both side of the cylinder liner.
- Deviation of temperature on one or both sides of the cylinder.
- Average temperature of the engine.
- Cooling water fluctuation.
- Scavenge air temperature.
- System alarm for: System failure.

Together with the "normal" Manual, Wärtsilä Switzerland Ltd delivers also a digital version, which will be installed together with the software MAPEX-MD

Customers benefit of MAPEX-PR

Thanks to the MAPEX-PR alarming system you are able to detect an abnormal behaviour of the piston-running without opening the engine. So you can save your engine from major damage and therefore increase the availability of your vessel's main propulsion system.

MAPEX-PR is the tool to check the piston-running behaviour.

MAPEX-PR

- Alarms if the liner wall temperature shows high piston-ring friction.
- Checks the hot spots of the diesel engine.
- Is an on-line display for piston-ring and nozzle performance.
- Is capable to detect malfunctions such as blow by and adhesive wear.
- Informs if thermal overload should occur on the cylinder liner.
- Is your round-the-clock watchful eye.

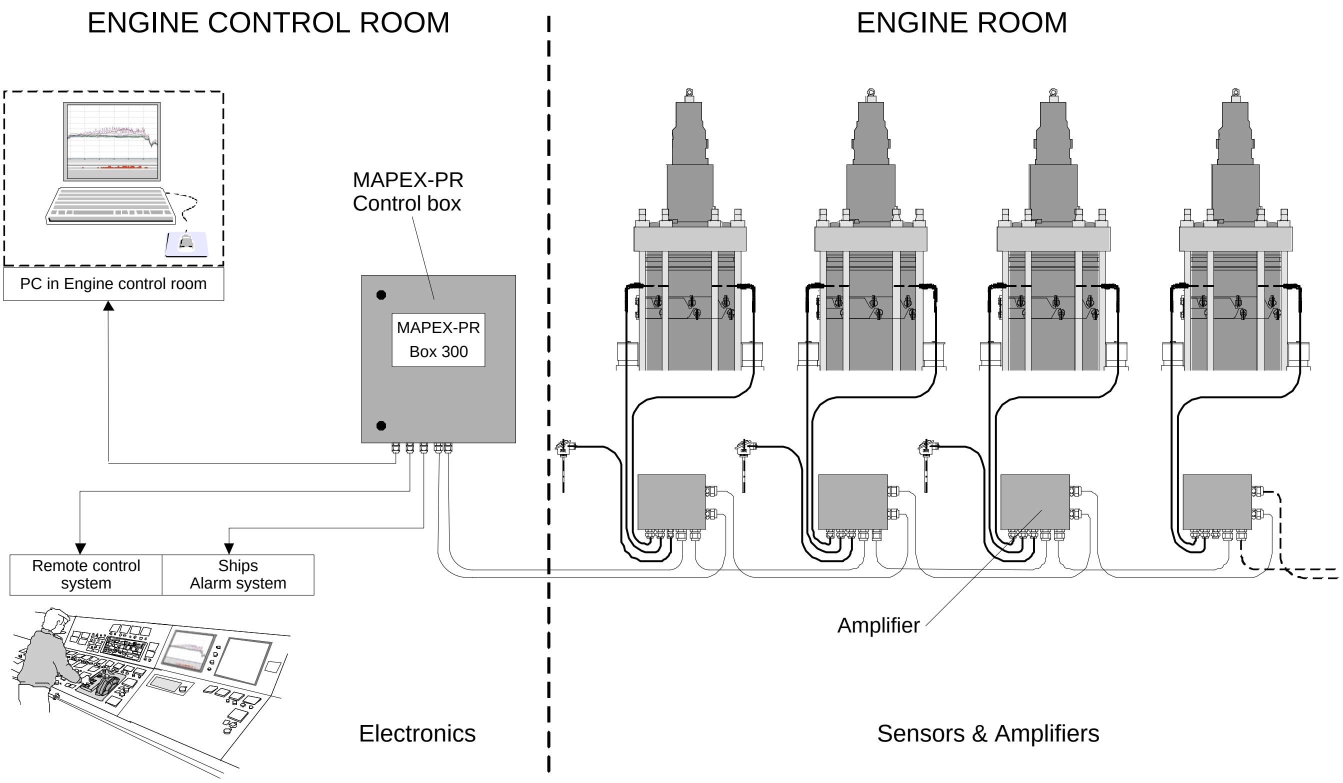


Fig. G6 MAPEX-PR – System overview

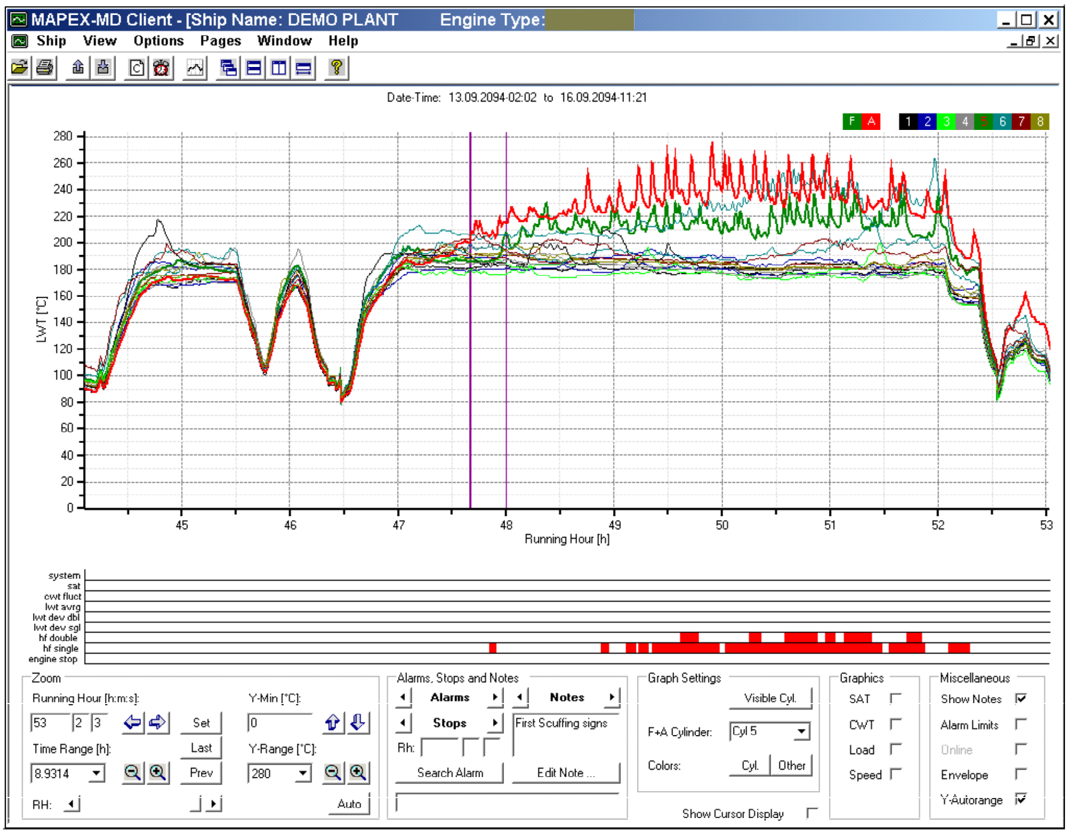


Fig. G7 MAPEX-MD – Visualization software

H. General installation aspects

H1 Introduction

The purpose of this chapter is to provide information to assist planning and installation of the engine. It is for guidance only and does not supersede current instructions. If there are details of engine installation not covered by this manual please contact Wärtsilä Switzerland Ltd, Winterthur, directly or our representative.

H2 Dimensions and masses

H2.1 Engine

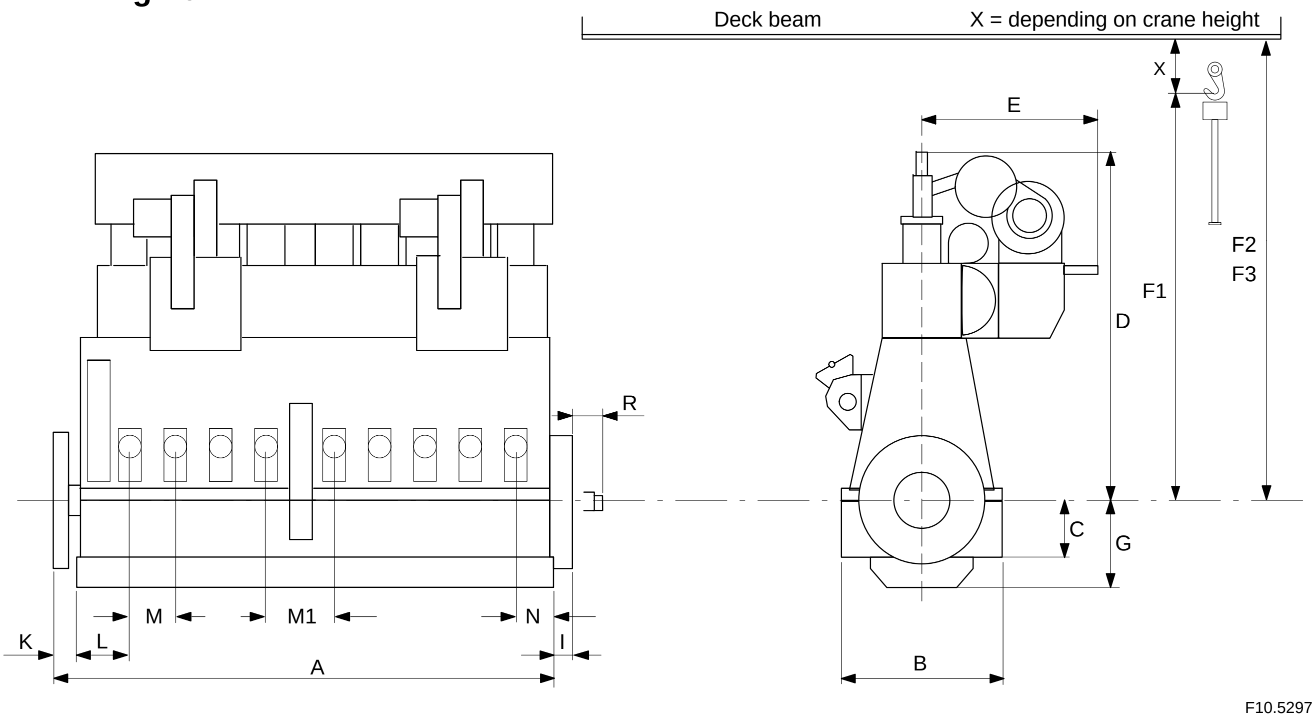


Fig. H1 Engine dimensions

Number of cylinders		5	6	7	8	9
Dimensions in mm with a tolerance of approx. ± 10 mm	A	9695	11 195	12 695	15 195	16 695
	B	5000				
	C	1800				
	D	11 933				
	E	5700				
	F1	14 500				
	F2	on request				
	F3	on request				
	G	2700				
	I	698				
	K	805				
	L	1815				
	M	1500				
	M1	2500				
	N	1075				
	R	660				
Net engine mass (without oil/water)	[tonnes]	740	870	990	1140	1260
Minimum crane capacity	[tonnes]	9.5				

Remarks:
E: Engines with turbochargers ABB TPL80
F1: Min. height to crane hook for vertical removal.
F2: Min. height to deck beam for vertical removal using a double-jib (special) crane.
F3: Min. height to deck beam for tilted piston removal using a double-jib (special) crane.
For removal with reduced minimum height, please contact WCH. In any case, vertical reemoval should be preferred.
M, M1: M = Cylinder distance; M1 for engines with middle drive (8 and 9 cylinders).
R Housing with crank angle sensor; space for removal included.

Table H1 Engine dimensions

H2.2 Dimensions and masses of main components

Table H2 contains the net component masses and dimension of the engine, calculated according to nominal dimensions.

Number of cylinders				5	6	7	8	9
Bedplate including bearing girders		length	[m]	9.05	10.93	12.43	DE 8.11 FE 6.83	DE 8.11 FE 8.33
		mass	[t]	88.28	94.6	105.1	DE 70.6 FE 55.9	DE 70.6 FE 66.4
Crankshaft		length	[m]	10.07	11.57	13.07	DE 8.37 FE 7.20	DE 8.37 FE 8.70
		mass	[t]	140.2	163.9	187.7	DE 133.4 FE 119.3	DE 133.4 FE 146.9
Flywheel	max.	mass	[t]	25.2	25.2	25.2	25.2	25.2
	min.	mass	[t]	6.23	4.5	5.29	4.94	5.6
Engine frame, complete (mono block)		length	[m]	8.80	10.30	11.80	DE 6.68 FE 6.66	DE 6.68 FE 8.16
		mass	[t]	81.34	93.56	105.18	DE 60.60 FE 60.50	DE 60.60 FE 73.05
Tie rod		length	[m]	10.6	10.6	10.6	10.6	10.6
		mass	[t]	1.88	1.88	1.88	1.88	1.88
Cylinder block, complete with studs		height	[m]	5.12	5.12	5.12	5.12	5.12
		mass	[t]	89.8	106.7	123.6	151.9	168.8
Cylinder liner		height	[m]	3.64	3.64	3.64	3.64	3.64
		mass	[t]	7.1	7.1	7.1	7.1	7.1
Cylinder cover, complete incl. starting and fuel valve and incl. upper ring of water guide jacket		height	[m]	2.46	2.46	2.46	2.46	2.46
		mass	[t]	7.5	7.5	7.5	7.5	7.5
Connecting rod, complete		length	[m]	4.53	4.53	4.53	4.53	4.53
		mass	[t]	5.92	5.92	5.92	5.92	5.92
Crosshead, complete with guide shoes		length	[m]	1.2	1.2	1.2	1.2	1.2
		mass	[t]	4.55	4.55	4.55	4.55	4.55
Piston, complete with rod		length	[m]	4.65	4.65	4.65	4.65	4.65
		mass	[t]	4.18	4.18	4.18	4.18	4.18
Scavenge air receiver, complete with valves and covers		length	[m]		9.22	11.05	DE 6.01 FE 7.02	DE 6.01 FE 8.52
	max.	mass	[t]		18.66	21.50	DE 12.45 FE 14.93	DE 12.45 FE 17.30
Exhaust valve, complete		height	[m]	2.1	2.1	2.1	2.1	2.1
		mass	[t]	1.93	1.93	1.93	1.93	1.93
Rail unit		length	[m]			11.55		
		mass	[t]			9.0		
Supply unit		length	[m]					
		mass	[t]			0.93		

Note: **DE:** refers to section on driving end
FE: refers to section on free end

Remark: For engine dimensions and masses see table H1.
For turbocharger and scavenge air cooler masses see tables C1 and C2.

Table H2 Dimensions and masses of main components

H2.3 Thermal expansion at the turbocharger expansion joint

Before expansion pieces, enabling connections between the engine and external engine services, are to be made it is important to take into account the thermal expansion of the engine. The expansions are defined as follows (see also fig. H2):

- Transverse expansion (X)
  Distance from crankshaft centerline to the centre of gas outlet flange
- Vertical expansion (Y)
  Distance from bottom edge of the bedplate to the centre of gas outlet flange
- Longitudinal expansion (Z)
  Distance from engine bedplate aft edge to the centre of gas outlet flange

Table H3 shows the figures of the expected thermal expansion from ambient temperature (T = 20 °C) to service temperature.

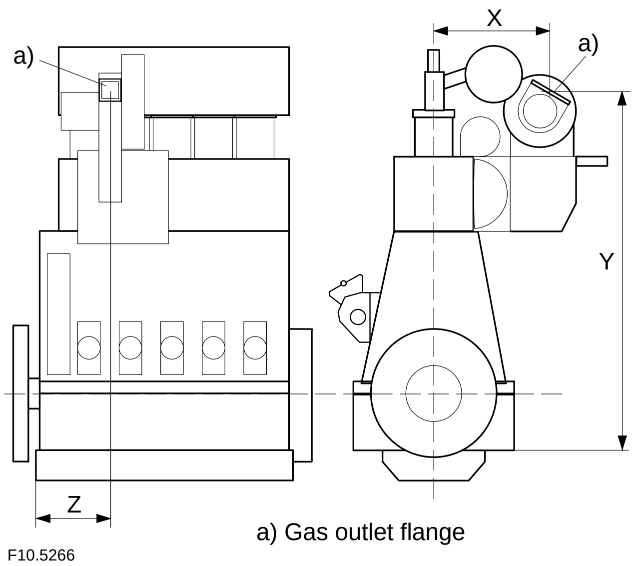


Fig. H2 Thermal expansion, dimensions X, Y, Z

Cylinder No.	**5**	**6**	**7**	**8**	**9**
Turbocharger type Turbocharger location	1× TPL85 (TC No 1)	2× TPL80 (TC No 2)	2× TPL80 (TC No 2)	2× TPL80 (TC No 2)	2× TPL85 (TC No 2)
Distance X [mm] **Thermal expansion Δx** [mm]	on request	3973 **1.6**	3973 **1.6**	on request	on request
Distance Y [mm] **Thermal expansion Δy** [mm]	on request	9807 **3.9**	9807 **3.9**	on request	on request
Distance Z [mm] **Thermal exansion Δz** [mm]	on request	8087 **3.1**	10225 **4.1**	on request	on request

Remark: For details of engine pipe connections refer to section F5.

Table H3 Expected thermal expansion figures at turbocharger gas outlet

H2.4 Contents of fluid in the engine

System fluid		Number of cylinders				
		5	6	7	8	9
Cylinder cooling water	[kg]	2220	2670	3110	3550	4000
Lubricating oil	[kg]	2900	3400	4000	4600	5100
Water in scavenge air cooler(s) *1)	[kg]	680	1120	1120	1120	1360
Total of water and oil in engine *2)	[kg]	5800	7190	8230	9270	10460

Remark: *1) The given water content is approximate.
*2) These quantities include engine piping except piping of scavenge air cooling.

Table H4 Fluid quantities in the engine

H2.5 Space requirements and dismantling heights

H2.5.1 Crane requirements

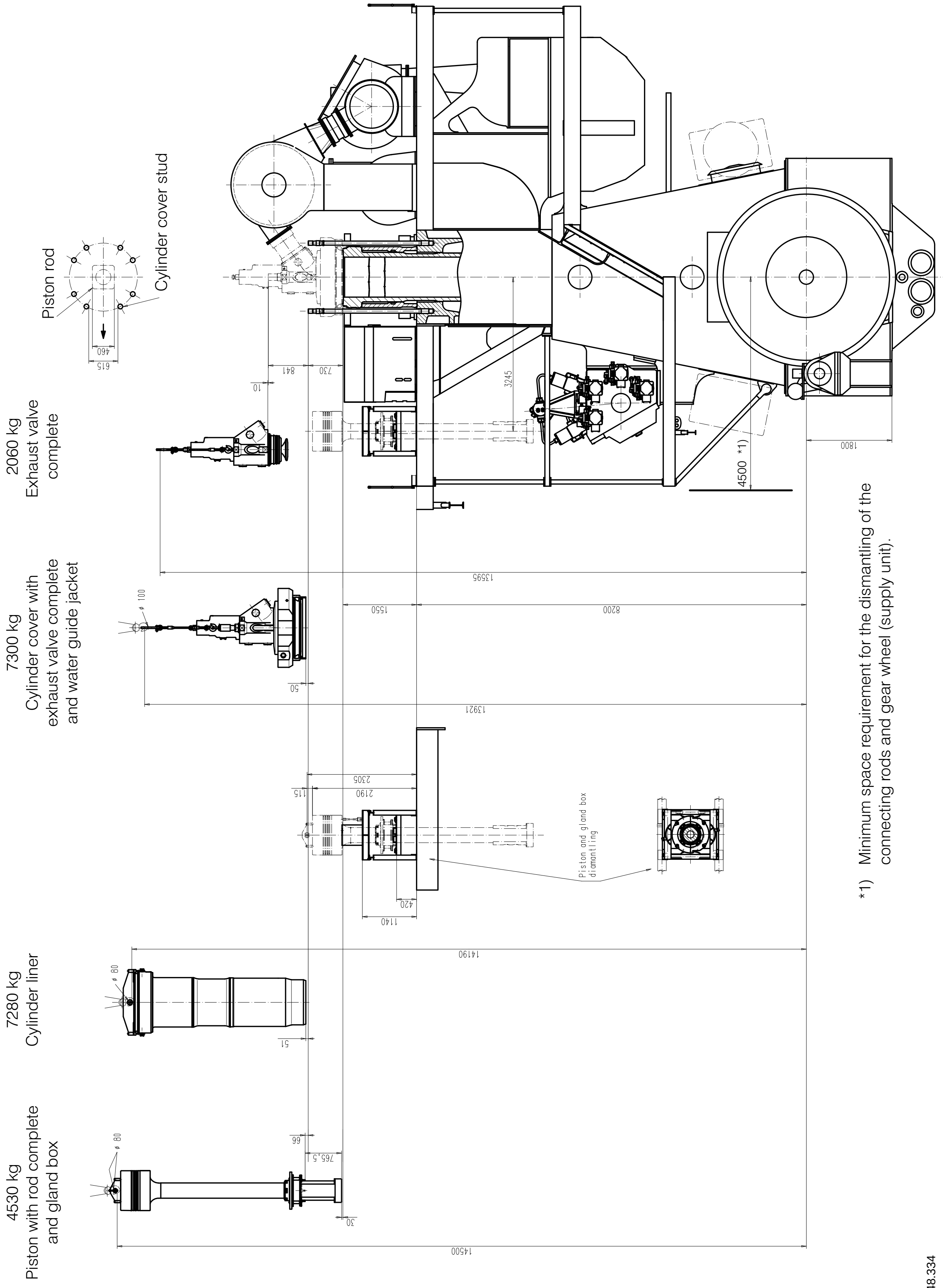
- An overhead travelling crane, of **9.5** metric tonnes minimum, is to be provided for normal engine maintenance.
- The crane is to conform to the requirements of the classification society.

As a general guide Wärtsilä Switzerland Ltd recommend a two-speed hoist with pendent control, being able to select high or low speed, i.e., high 6.0 m/minute, and low 0.6–1.5 m/minute.

H2.5.2 Piston dismantling heights

Figure H3 shows the dismantling height for vertical piston lifting. For the possibility of reducing the standard piston dismantling height applying special tools and/or tilted piston position please ask WCH. These dimensions are for guidance only and may vary depending on the crane dimension, handling tools and dismantling tolerances.
This dimensions are absolutely not binding.
However, please contact Wärtsilä Switzerland Ltd Winterthur or any of its representatives if these values cannot be maintained, or more detailed information is required.

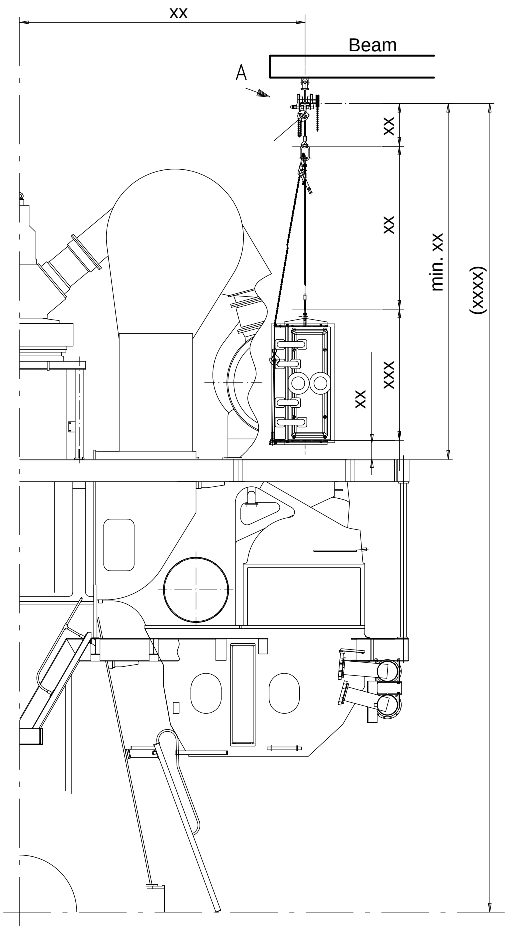
H. General installation aspects



348.334

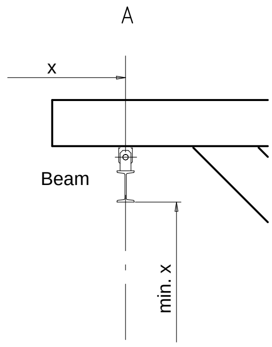
Fig. H3 Space requirements and dismantling heights for vertical piston lifting

H2.5.3 Dismantling of scavenge air cooler



In order to facilitate the dismantling of the scavenge air coolers, an adequate lifting facility may be foreseen as shown in figure H4.

The adequate drawing is still not available.



F10.xxxx

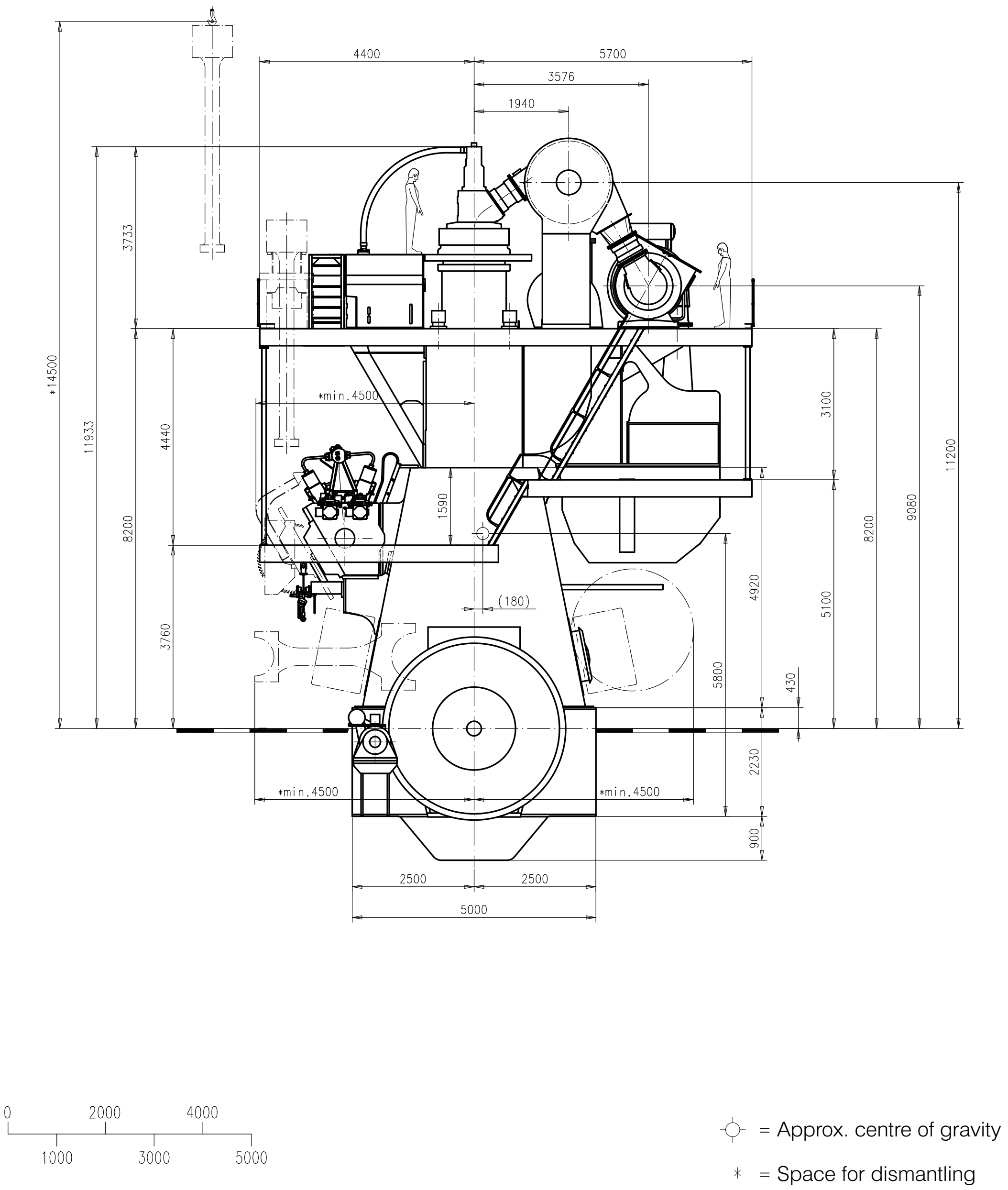
Fig. H4 Dismantling of SAC

H3 Outlines of Wärtsilä RT-flex84T-D engines

The following engine outline illustrations are produced to scale. They represent engine arrangements with ABB TPL and MHI MET turbochargers.

This selection doesn't cover all variations of the RT-flex84T-D engines. The drawings of other combinations (number of cylinders, number and type of turbochargers) are available on request.

View to driving end

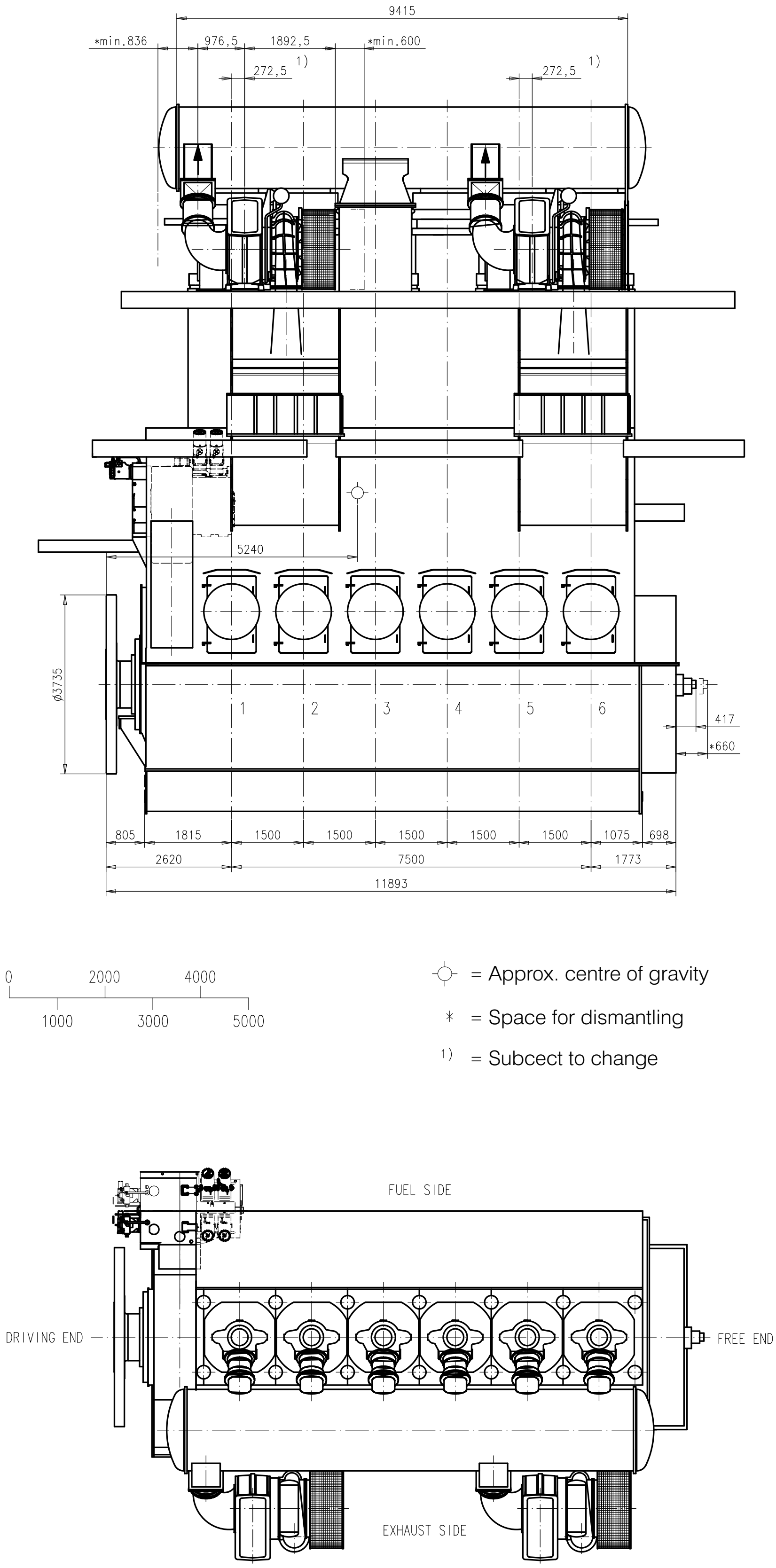


347.643a

Fig. H5 End elevation of Wärtsilä 6RT-flex84T-D engines with ABB TPL80-B turbochargers

H. General installation aspects

Exhaust side

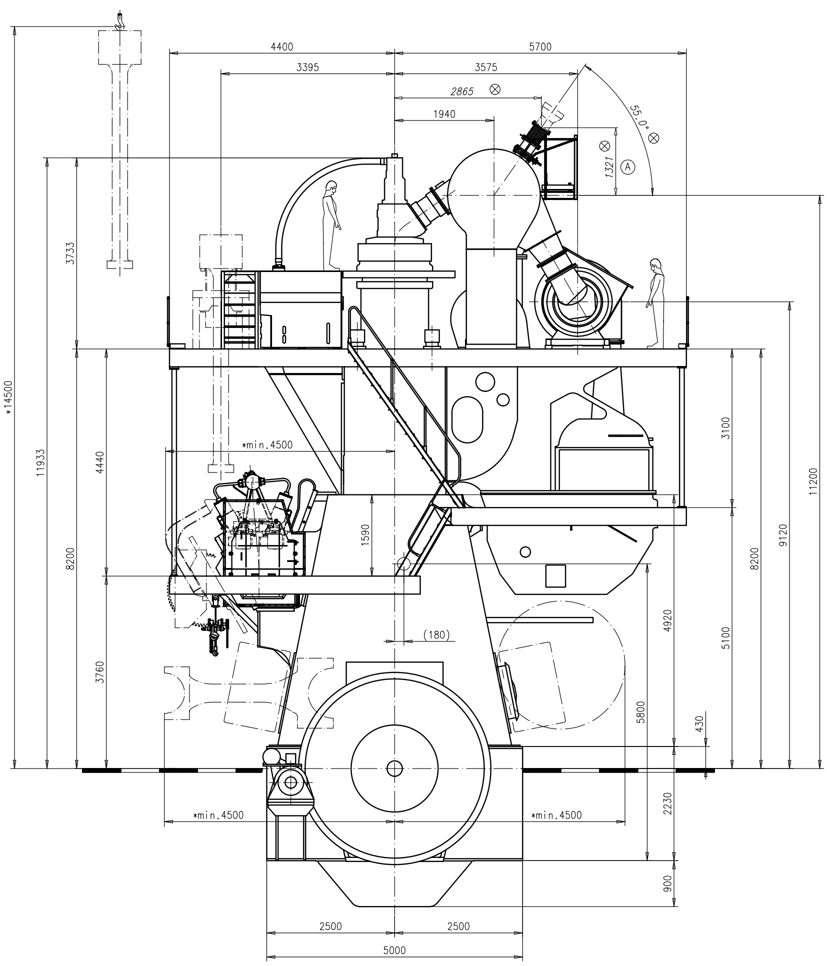


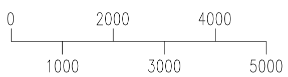
347.643a

Fig. H6 Side elevation and top view of Wärtsilä 6RT-flex84T-D engines with 2 x ABB TPL80-B turbochargers

H. General installation aspects

View to driving end





= Approx. centre of gravity

* = Space for dismantling

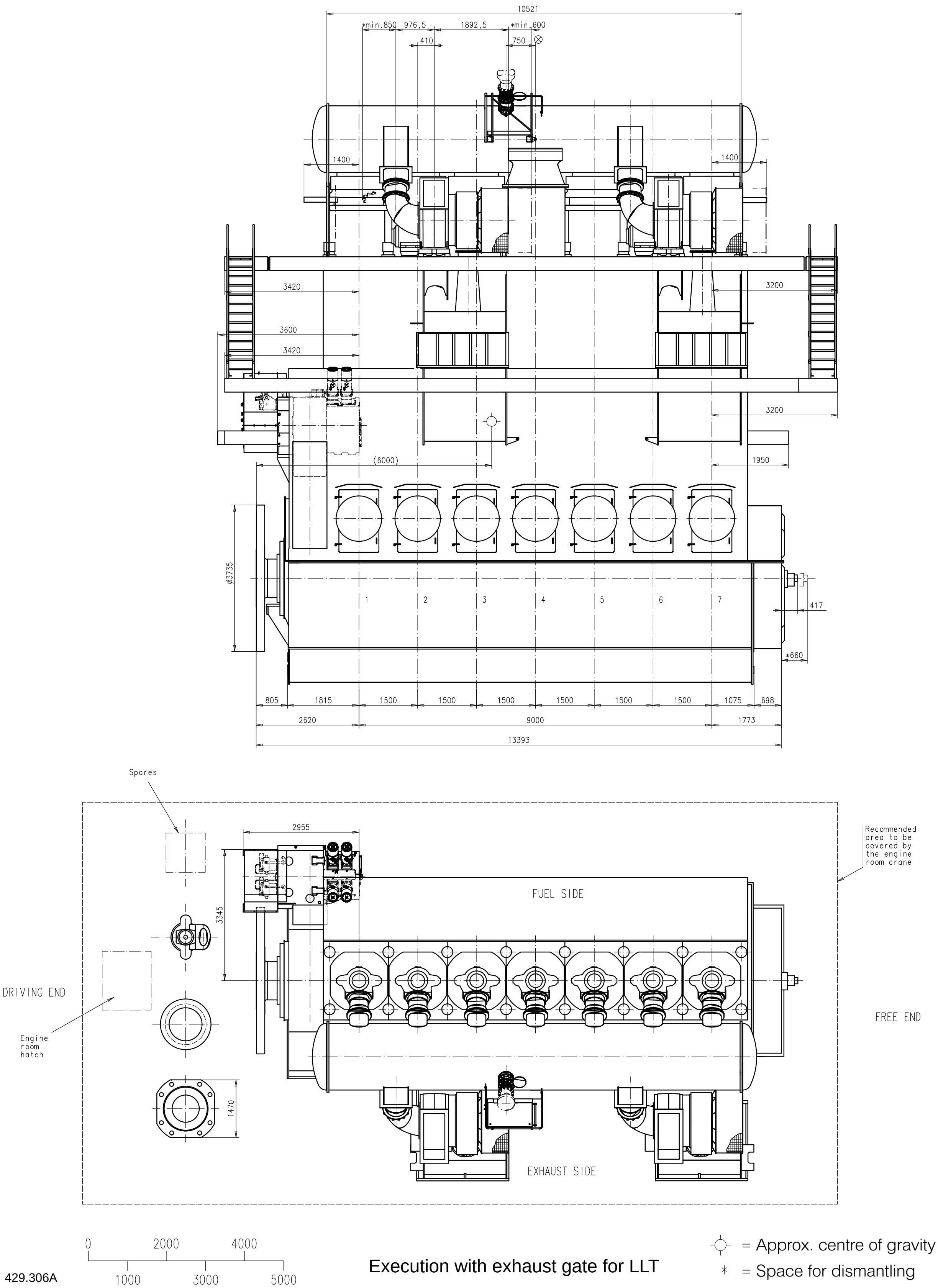
Execution with exhaust gate for LLT

429.306A

Fig. H7 End elevation of Wärtsilä 7RT-flex84T-D engines with ABB TPL80-B turbochargers

H. General installation aspects

Exhaust side



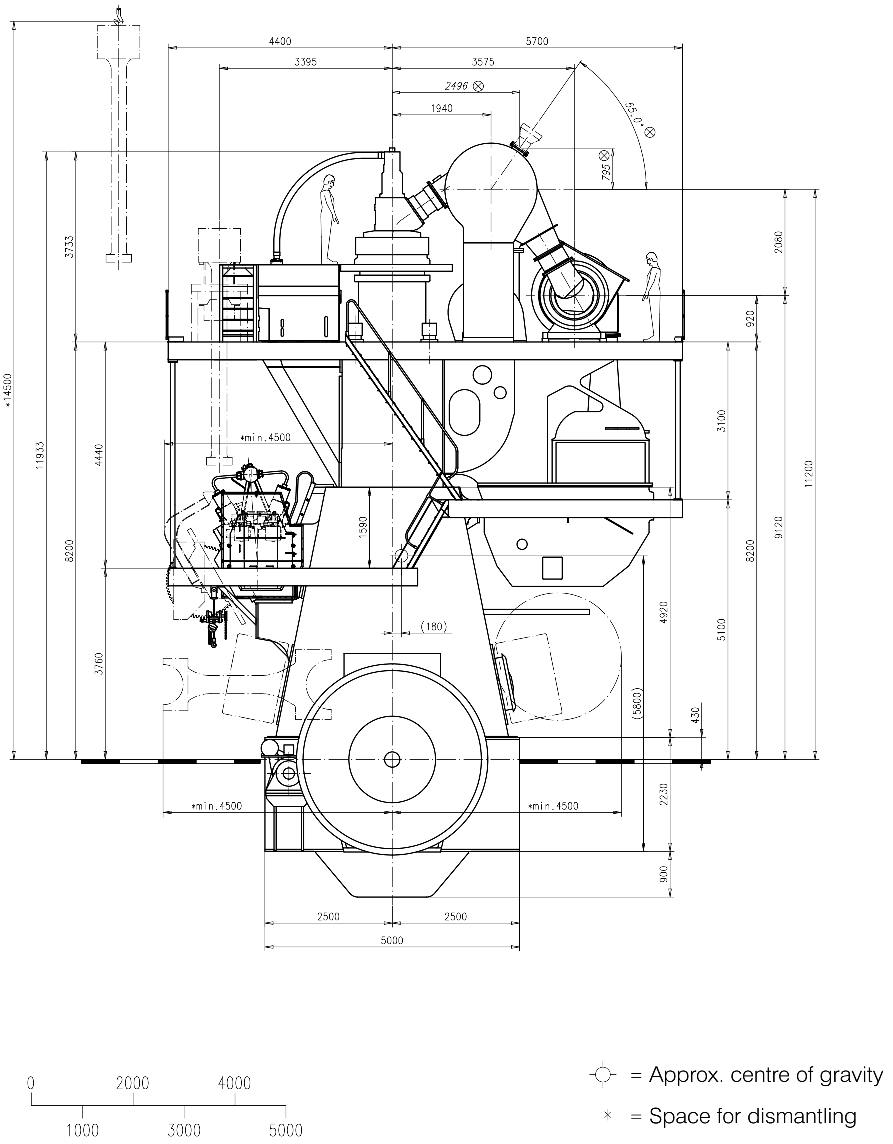
429.306A

Execution with exhaust gate for LLT

Fig. H8 Side elevation and top view of Wärtsilä 7RT-flex84T-D engines with 2 x ABB TPL80-B turbochargers

H. General installation aspects

View to driving end



Execution with exhaust gate for WHR

DAAD012031

Fig. H9 End elevation of Wärtsilä 7RT-flex84T-D engines with ABB TPL80-B turbochargers

9

H. General installation aspects

Exhaust side

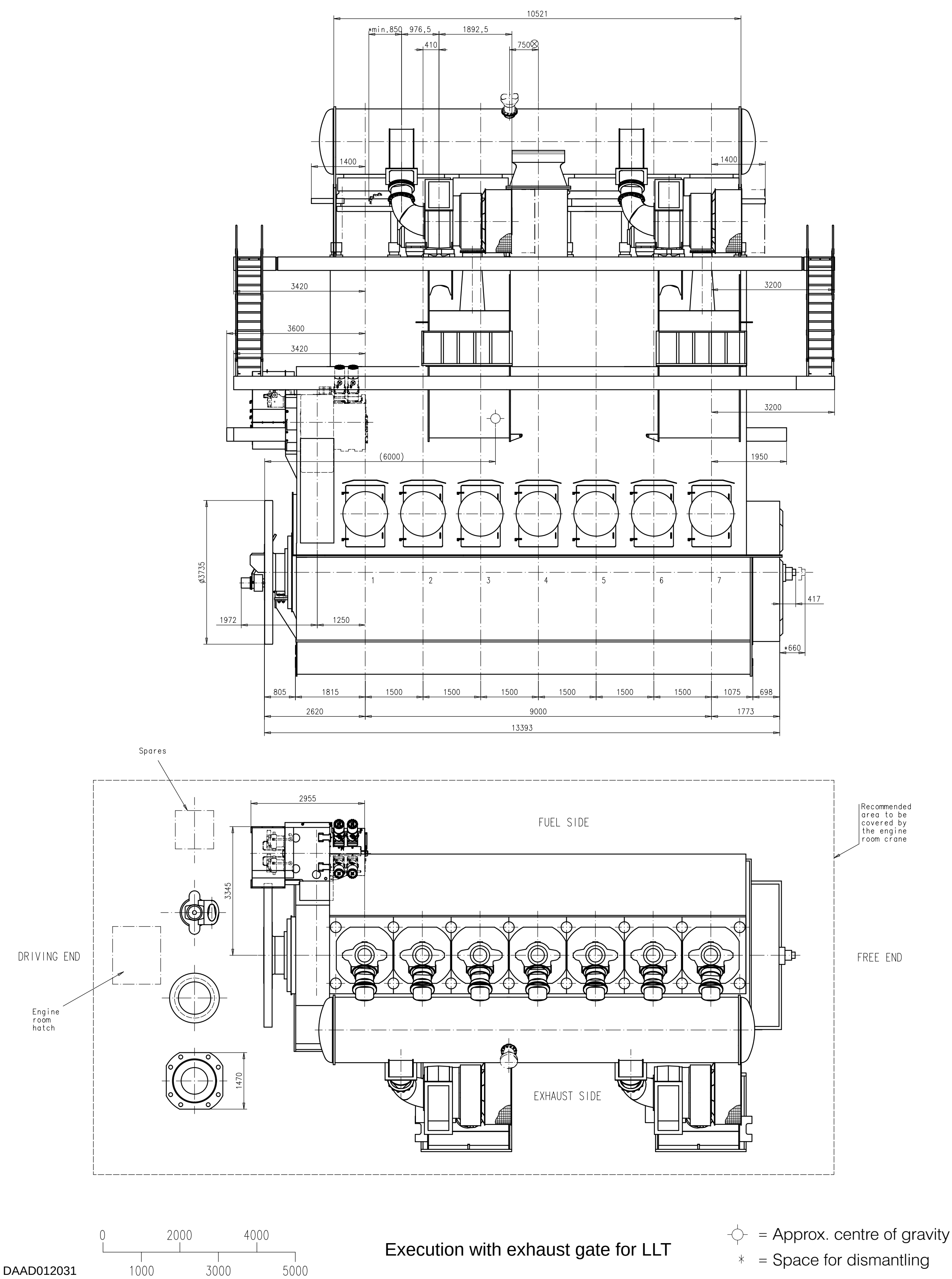


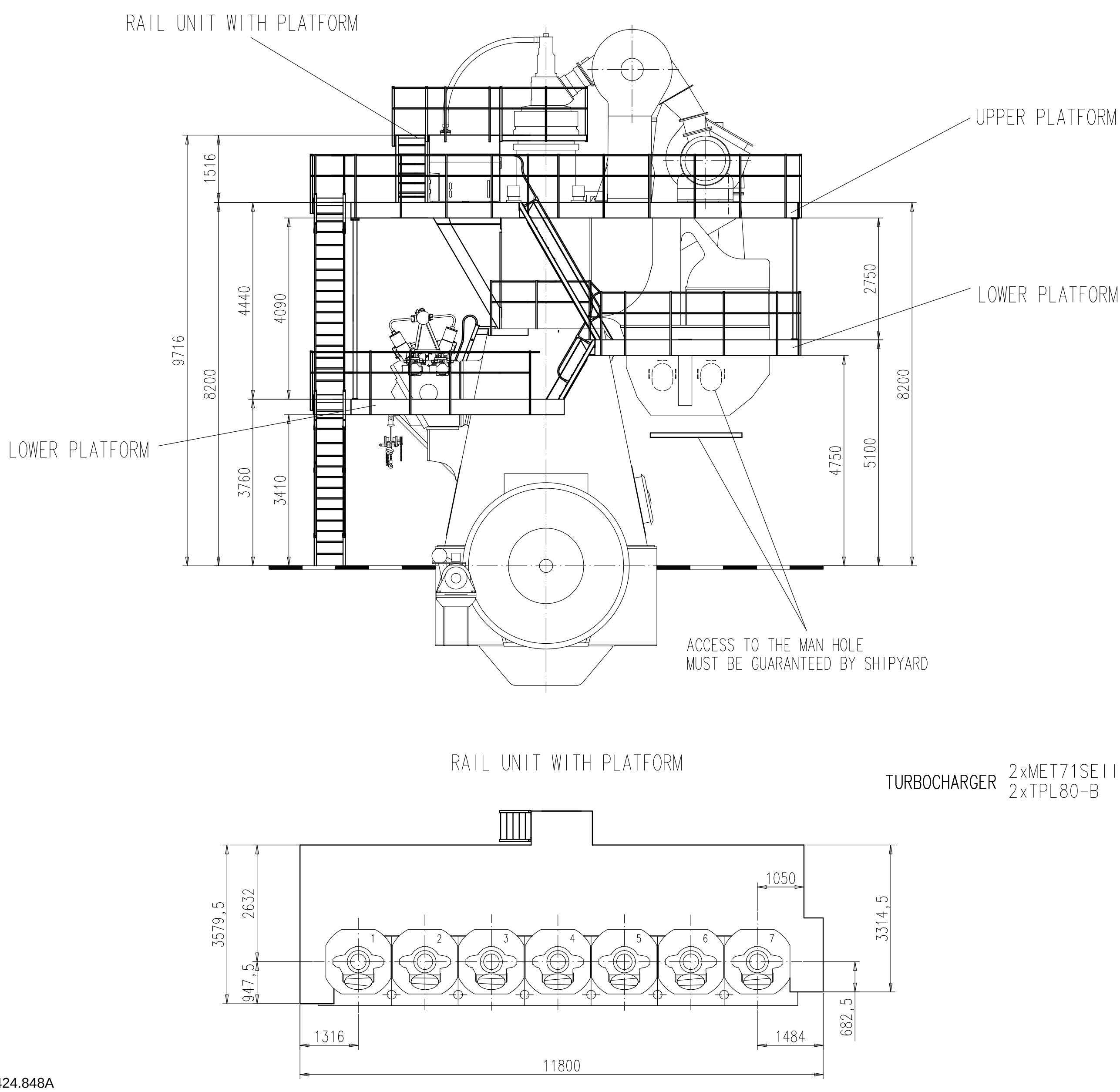
Fig. H10 Side elevation and top view of Wärtsilä 7RT-flex84T-D engines with 2 x ABB TPL80-B turbochargers

H4 Platform arrangements

The following platform outline illustrations represent engine arrangements with ABB TPL and MHI MET turbochargers. This selection of outlines doesn't cover all variations of the RT-flex84T-D engines.

The drawings of other combinations (number of cylinders, number and type of turbochargers) and drawings of platform details are available on request.

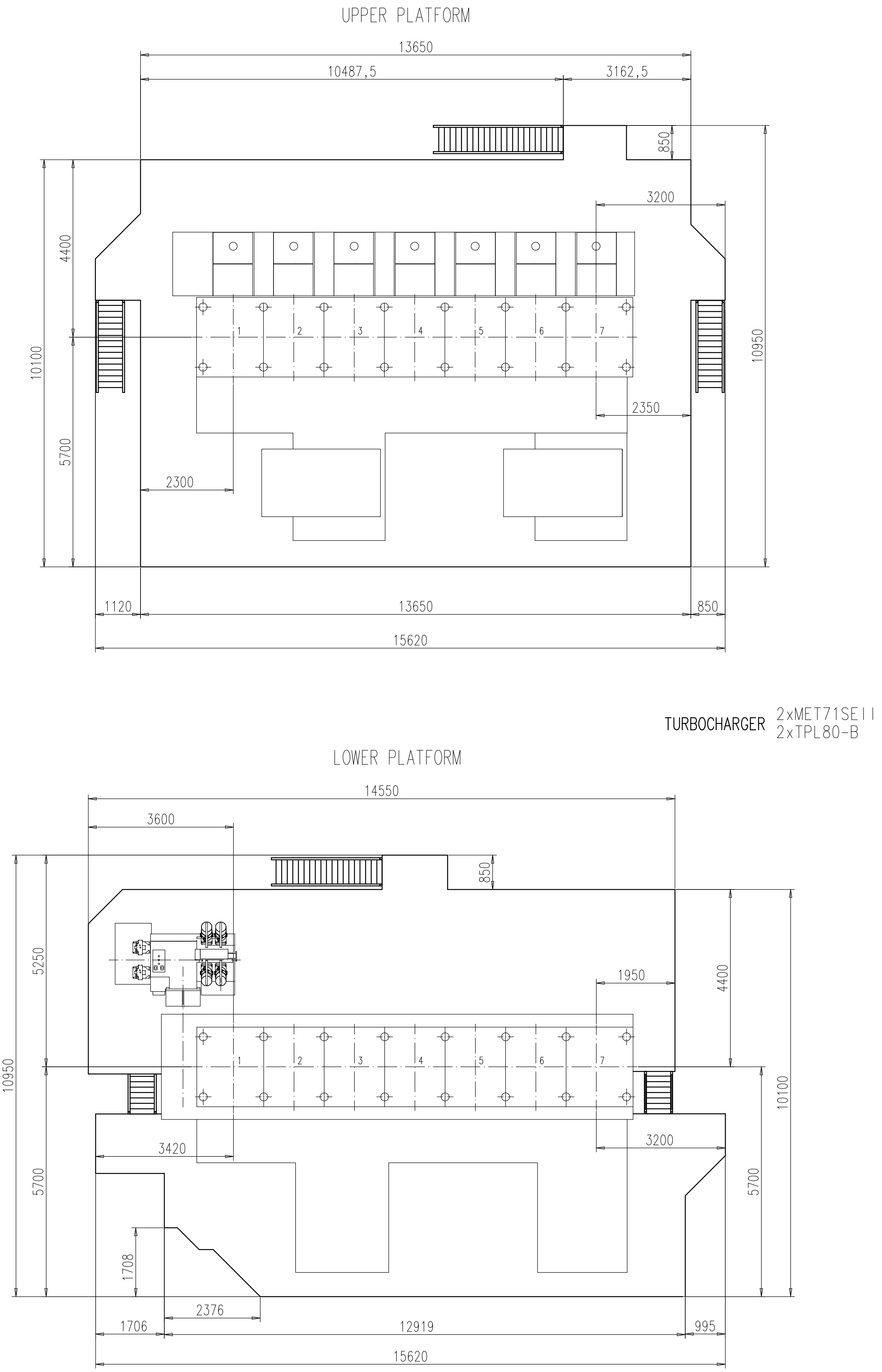
View to driving end



424.848A

Fig. H11 Platform arrangements for 7RT-flex84T-D engines

H. General installation aspects



424.848A

Fig. H12 Platform arrangements for 7RT-flex84T-D engines

H5 Engine seating with epoxy resin chocks

The engine seating is integral with the double-bottom structure and is to be of sufficient strength to support the weight of the engine, transmit the propeller thrust, withstand external moments and stresses related to propeller and engine resonance.
The longitudinal beams situated under the engine are to extend forward of the engine-room bulkhead by at least half the length of the engine and aft as far as possible.

The maximum allowable rake for these engines is 3° to the horizontal.

Before any engine seating work can be performed make sure that the engine is aligned with the intermediate propeller shaft as described in section L3.

Apart from the normal, conventional engine holding-down studs used to fasten the engine to the tank top plate, a different design is to be applied for the propeller thrust transmission. The propeller thrust is transmitted from the engine thrust bearing to the bedplate and to the tank top plate which is part of the ship's structure by means of the **thrust sleeves** located adjacent to the engine thrust bearing.

H5.1 Fitting

The thrust sleeve is fitted in the bottom plate of the engine bedplate and cast in the tank top plate. The diameter of the flame-cut or drilled hole for the thrust sleeve in the tank top is larger than the diameter of the sleeve to allow engine alignment without remachining of the hole. The sleeve in the tank top plate hole is then fixed with epoxy resin material as used for the chocks. The engine holding-down stud is inserted in the sleeve and tightened in the same way as the normal studs. This hydraulically tightened holding-down stud is of the same design as the normal holding-down stud used to fasten the engine to the tank top. Drilling and reaming of the holes in the engine bedplate is carried out by the engine manufacturer. The thrust sleeves with the final tolerance and the holding-down studs are supplied by the shipyard.

H5.2 Drilling of the holes in the tank top plate

The holes for the thrust sleeves must be drilled or flame-cut in the tank top plate **before setting the engine in position**. These holes are prepared while observing the dimensions given on the drawing **'Chocking and drilling plan for engine seating with epoxy resin chocks'**. The holes for the normal holding-down studs can be drilled or flame-cut either before or after setting the engine in position.

H5.3 Chock thickness

Since the chock thickness cannot be precisely determined before engine alignment is finalized, the standard design of the holding-down stud, thrust sleeve and conical washer allows for the application of chock thicknesses from **25 up to 60 mm**. To avoid additional machining of the sleeve to adjust its length, the conical washer is provided with a larger bore compared to the sleeve's external diameter. The sleeve can protrude beyond the top plate more or less, the space in the washer allows for this variable. At the project stage, if chock thicknesses are foreseen to be **more than 60 mm or less than 25 mm**, the length of the thrust sleeve and its corresponding holding-down stud as well as the length of the normal holding-down stud must be adapted accordingly. **Please note:** In any case, if the minimum thickness is less than 25 mm, the epoxy resin supplier must be consulted.

H5.4 Pouring of the epoxy resin chocks

H5.4.1 Conditions before pouring

- Engine fully aligned.
- All side stoppers welded in place, wedges not fitted.
- **Studs with thrust sleeves** (see figure H15): Thrust sleeves and their accompanying holding-down studs inserted into the corresponding holes with the nuts slightly tightened by hand. All bushes and sponge rubber sealings fixed correctly under the tank top plate. Contact surface washer to top plate smeared with gasket sealant.
- **Normal holding-down studs** (see figure H15): Sponge rubber plugs or similar inserted into bedplate where normal studs are applied.

H5.4.2 Pouring

Epoxy resin material for the thrust sleeve holes is identical to that used for the chocks. The epoxy resin material applied for the chocking of the engine has to fulfill the following requirements:

- Approved by the major classification societies
- The following material properties are met:

Properties	Standard	Values
Ultimate compression strength	ASTM D-695	min. 130 MPa
Compression yield point	ASTM D-695	min. 100 MPa
Compressive modulus of elasticity	ASTM D-695	min. 3100 MPa
Deformation under load Load 550 N / 70 °C Load 1100 N / 70 °C	ASTM D-621	max. 0.10 % max. 0.15 %
Curing shrinkage	ASTM D-2566	max. 0.15 %
Coefficient of thermal expansion (0–60 K)	ASTM D-696	max. $50 \cdot 10^{-6}$ 1/K
Coefficient of friction	normal	min. 0.3

Table H5 Required properties of epoxy resin material

Pouring of the epoxy resin chocks together with its preparatory work must be carried out either by experts of the epoxy resin manufacturers or by their representatives. Their instructions must be strictly observed. In particular, no yard work on the engine foundation may proceed before completion of the curing period of the epoxy resin chocks.

H5.4.3 Tightening the holding-down studs

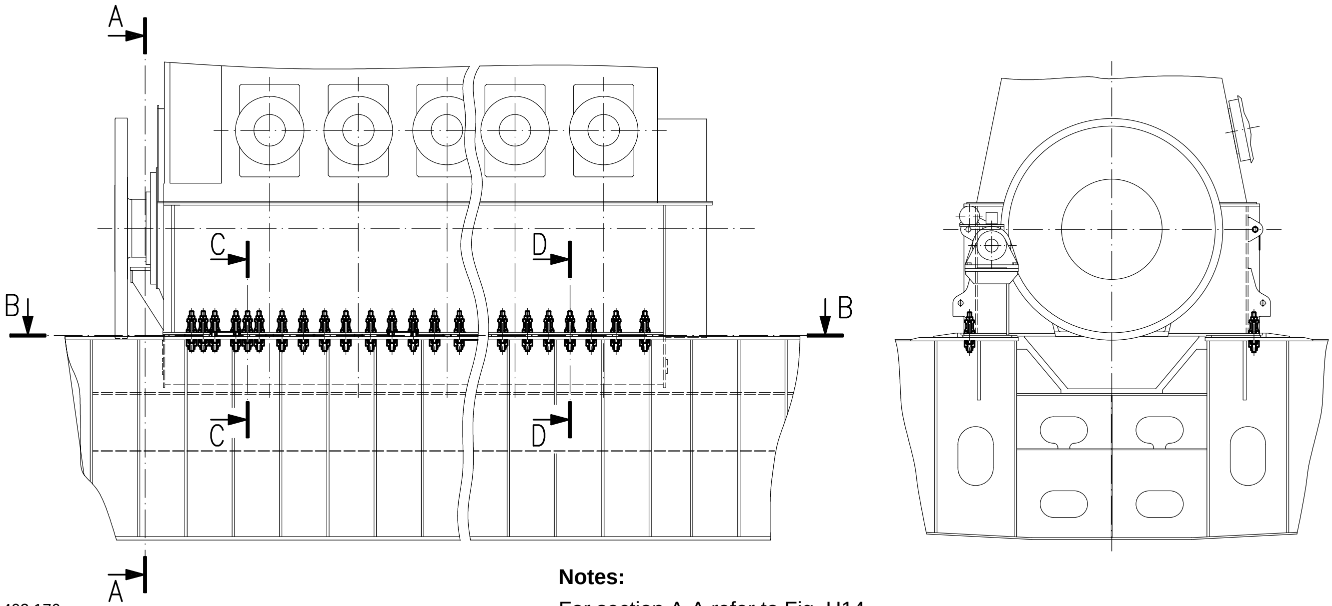
The instructions of the epoxy resin manufacturers or their representatives concerning the curing period must be strictly observed before any work on the engine foundation may proceed.
On completion of the curing period the supporting devices, i.e. jacking screws, jacking wedges, etc., must be removed before the holding-down studs are tightened.
All engine holding-down studs are tightened by means of a hydraulic pre-tensioning jack. The tightening procedure begins at the driving end and continues alternating from side to side in the direction of the engine free end.
After tightening all engine holding-down studs, fit the side stopper wedges.

Pre-tension force per stud F_V [kN] *1)	650
Hydraulic tightening pressure p [bar]	1000
Code number of hydraulic pre-tensioning jack *2)	94145

Remark: *1) Including an efficiency loss during tightening process. For guidance only.
*2) The hydraulic pre-tensioning jack is part of the engine builder's standard tool kit (see section J2).

Table H6 Tightening pressure

H5.5 Engine foundation



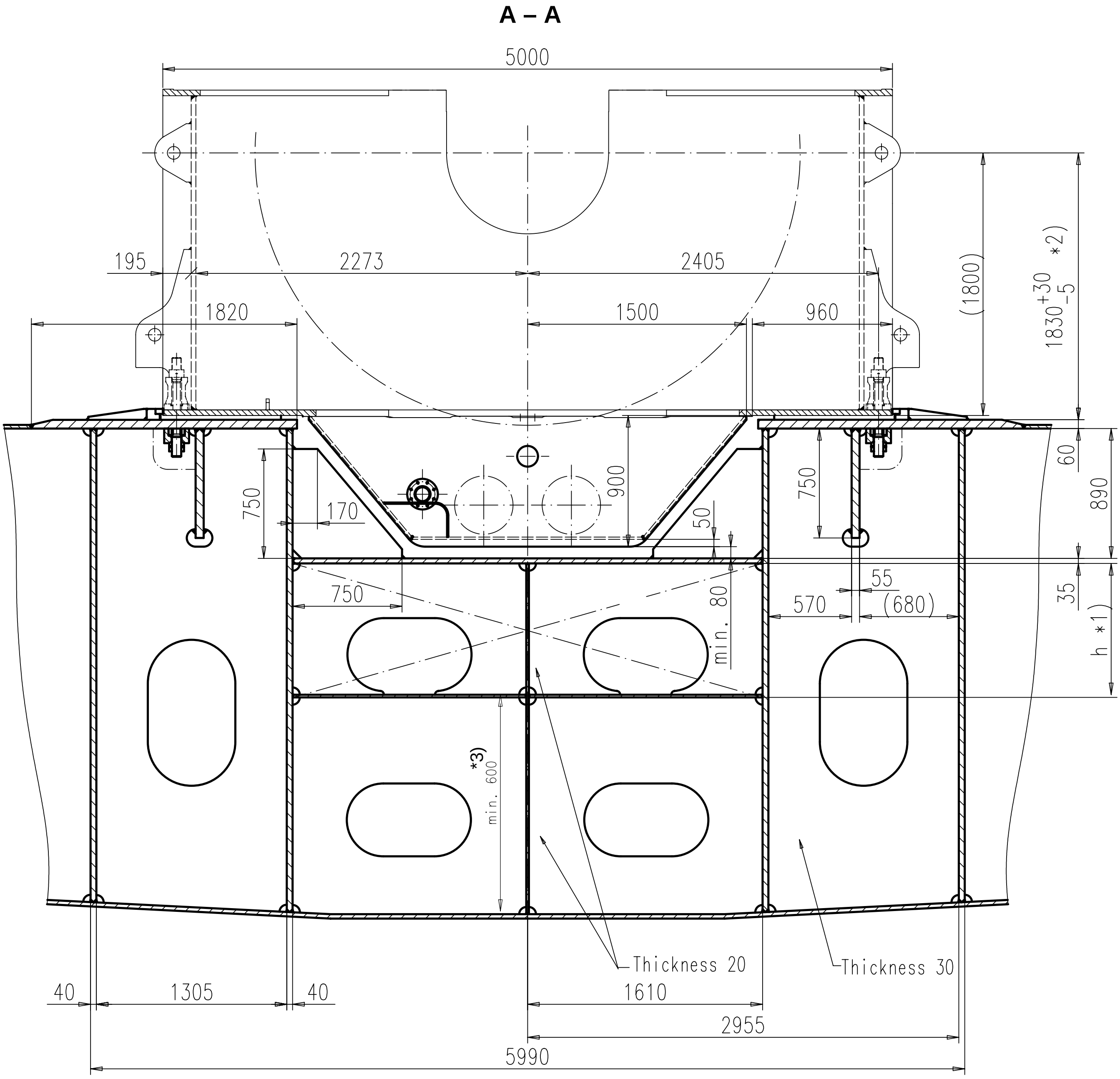
402.176c
402.177c
402.178c
402.179c
402.180c

Notes:

For section A-A refer to Fig. H14.
For section B-B refer to Fig. H23 to Fig. H26.
For view on C-C and D-D refer to Fig. H15.

Fig. H13 Engine seating and foundation overview

H. General installation aspects



Remarks:

*1) Final height h to be determined by shipyard.
For dimensions and layout of lub. oil drain tank see figure F23.

*2) Chock thickness (30 +30/–5 mm) to be determined by the shipyard.

*3) Final distances according to appropriate rules.

— This is a typical example, other foundation arrangements may be possible.

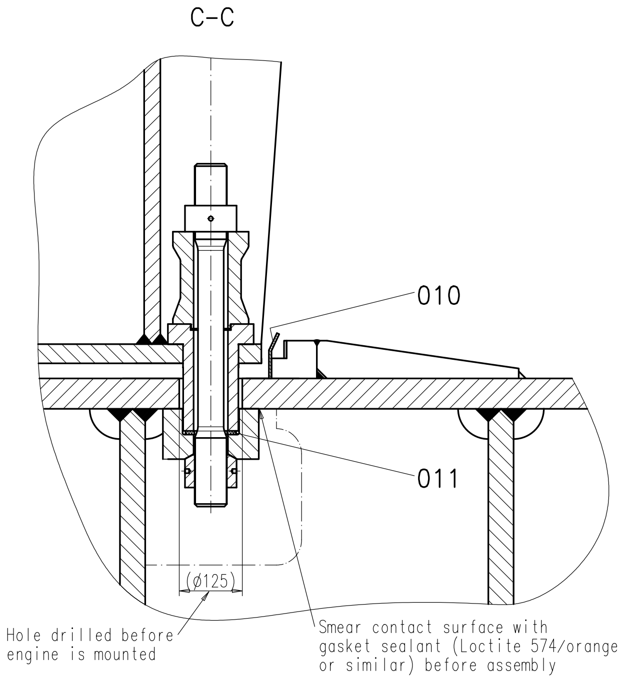
402.176c
402.177c
402.178c
402.179c
402.180c

Fig. H14 Engine seating (foundation) with epoxy resin chocks

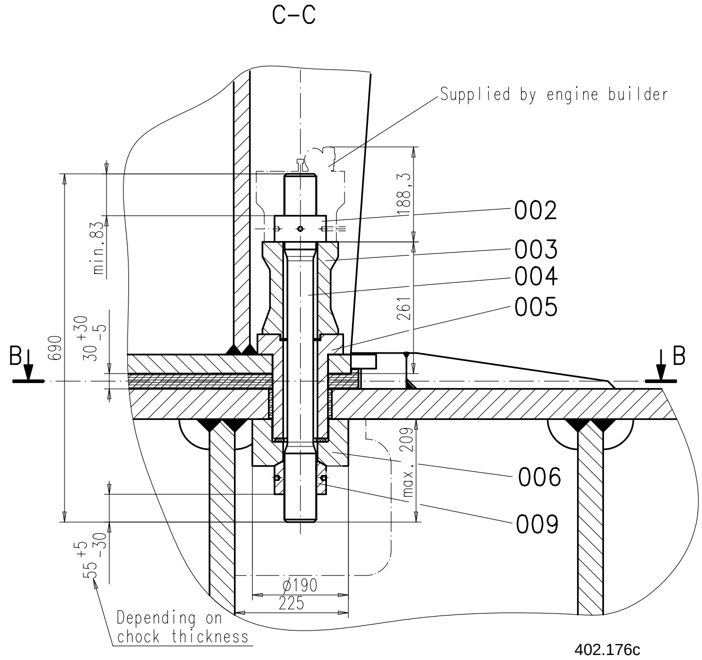
H5.6 Engine holding-down studs

Stud with thrust sleeve

Arrangement before pouring the epoxy resin chocks



Arrangement after pouring the epoxy resin chocks

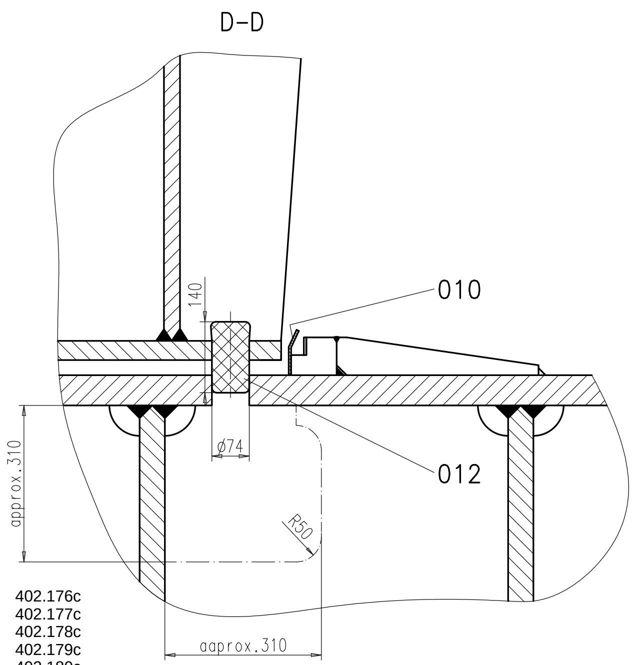


402.176c
402.177c
402.178c
402.179c
402.180c

Note: For parts list see table H7.

Normal holding-down stud

Arrangement before pouring the epoxy resin chocks



402.176c
402.177c
402.178c
402.179c
402.180c

Arrangement after pouring the epoxy resin chocks

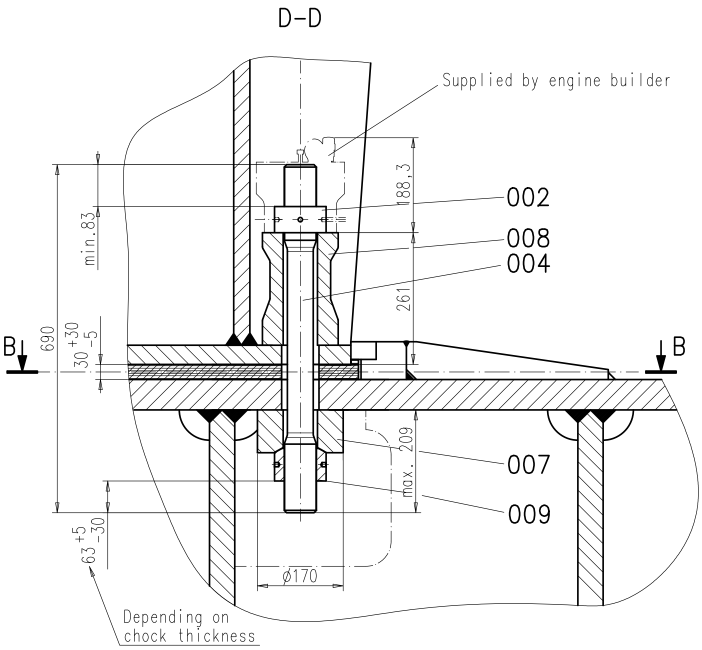
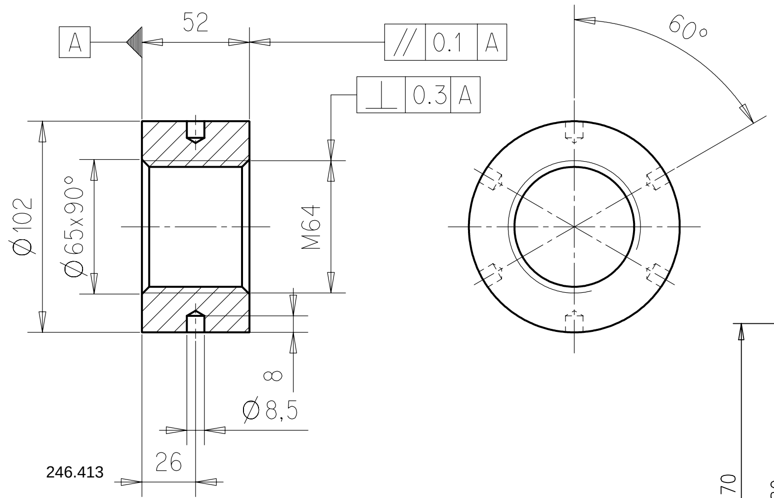


Fig. H15 Cross section of holding-down studs and epoxy resin chocks

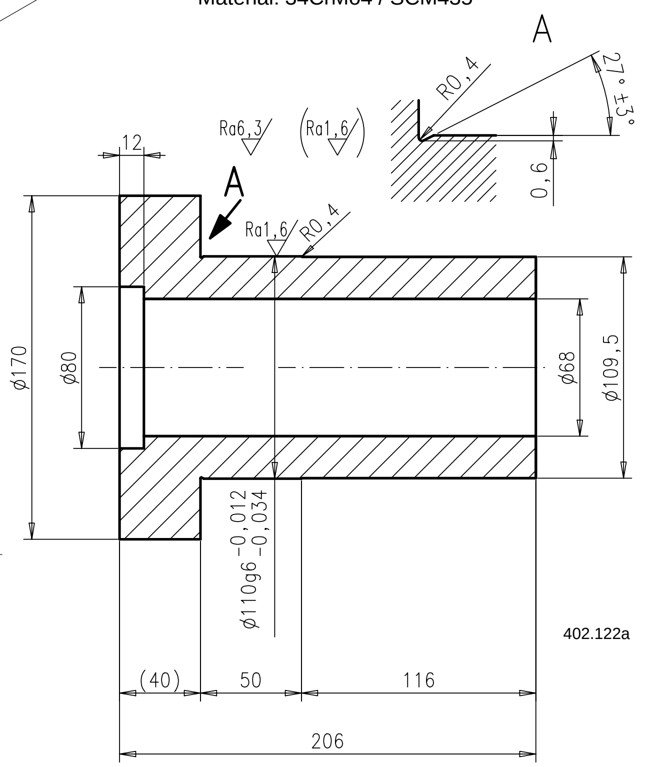
Number of cylinders		5	6	7	8	9	
Item	**Description**	**Execution with thrust sleeves**					**Remarks**
002	Round nut M64	52	60	68	82	90	These parts cover a standardized chock thickness of 25 mm up to 60 mm.
003	Bush	10	12	12	14	16	
004	Elastic bolt M64	52	60	68	82	90	
005	Thrust sleeve	10	12	12	14	16	
006	Conical socket	10	12	12	14	16	
007	Conical socket	42	48	56	68	74	
008	Bush	42	48	56	68	74	
009	Spherical round nut M64	52	60	68	82	90	
010	Sealing piece	for chock geometry see figures H23 to H26					Material and design determined by shipyard.
011	Joint disc	10	12	12	14	16	
012	Pin (rubber)	42	48	56	68	74	

Table H7 Parts list for engine seating with epoxy resin chocks

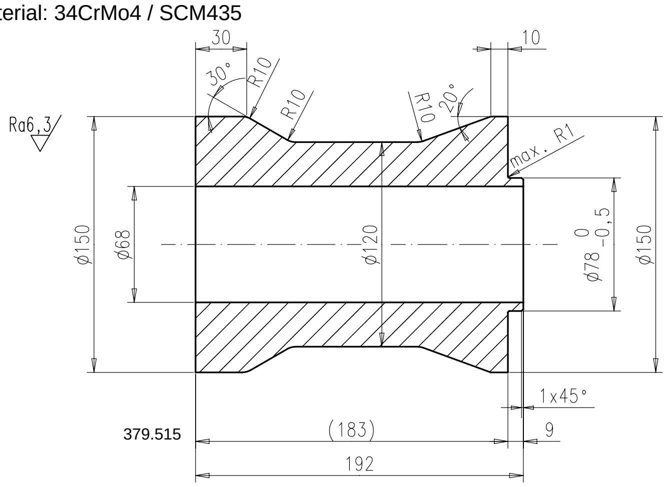
002 Round nut
Material: 34CrMo4 / SCM435



005 Thrust sleeve
Material: 34CrMo4 / SCM435



003 Sleeve
Material: 34CrMo4 / SCM435

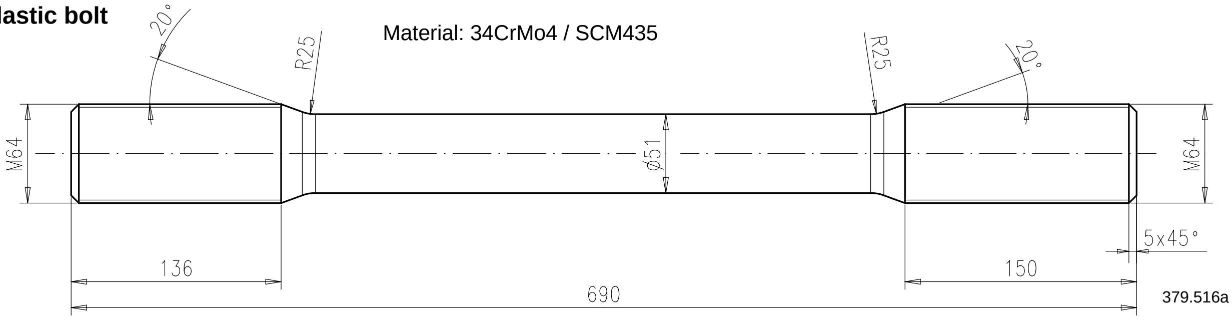


Note: For all item numbers refer to figure H15 and parts list, table H7.
These drawings are not drawn to scale.

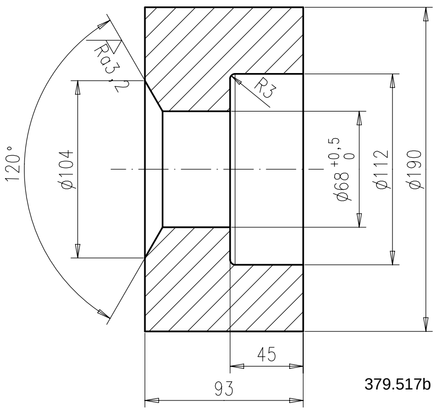
Fig. H16 Sleeves and nuts for engine holding-down studs

004 Elastic bolt

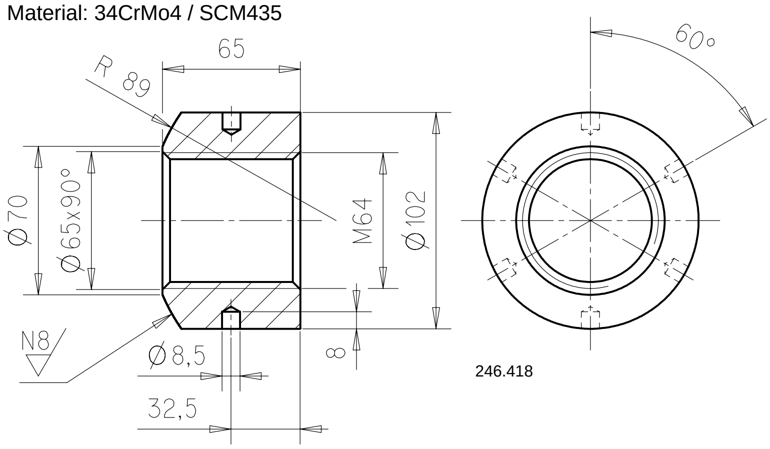
Material: 34CrMo4 / SCM435



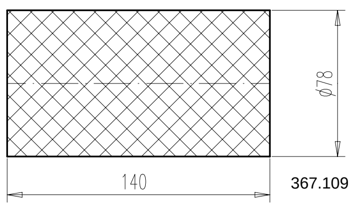
006 Conical socket
Material: 34CrMo4 / SCM435



009 Spherical round nut
Material: 34CrMo4 / SCM435

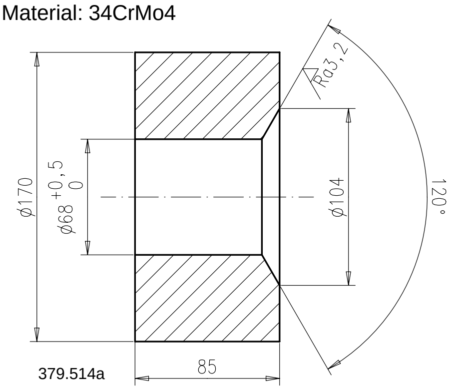


012 Pin (rubber)

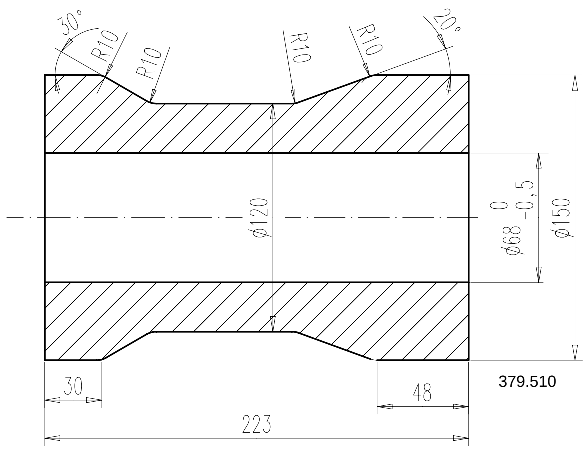


007 Conical socket
Material: 34CrMo4

Note: For all item numbers refer to figure H15 and parts list, table H7.
These drawings are not drawn to scale.

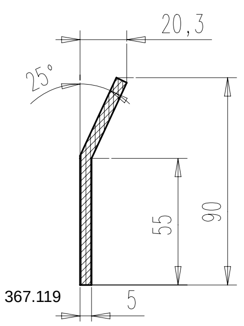


008 Bush
Material: 34CrMo4 / SCM435



011 Joint disc
Material: Rubber 750

010 Damming plate



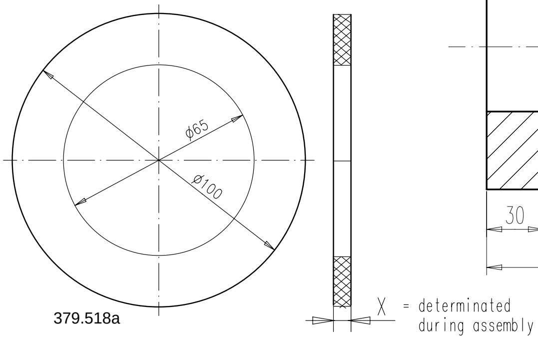
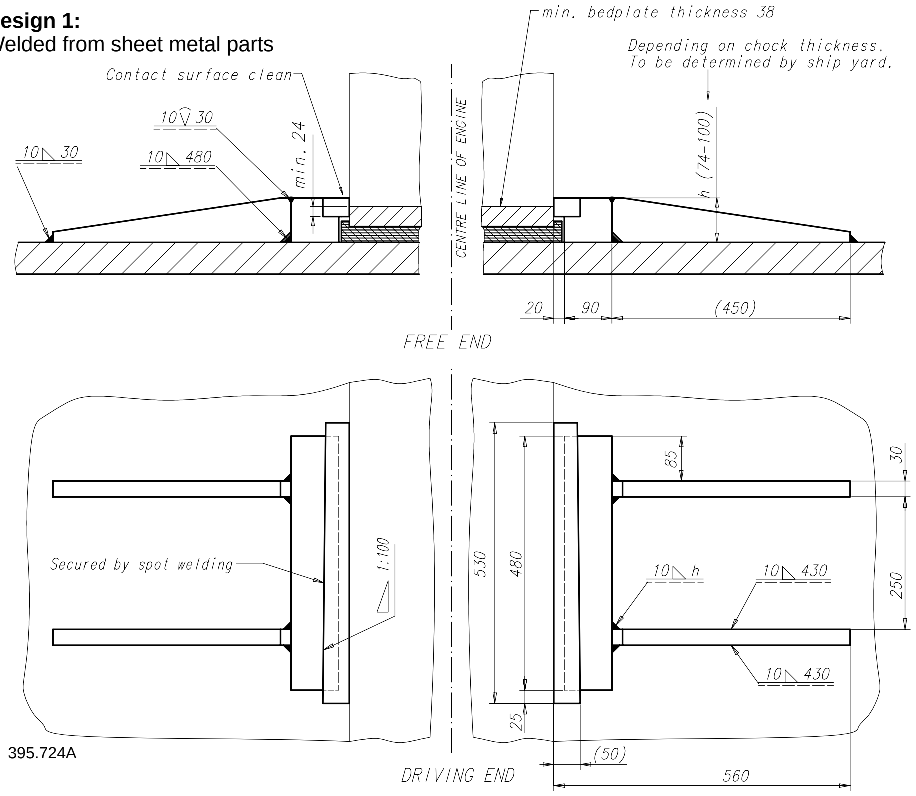


Fig. H17 Sleeves and nuts for engine holding-down studs

H5.7 Engine seating side stoppers

Design 1:
Welded from sheet metal parts



Design 2:
Laser or flame cut from a thick plate

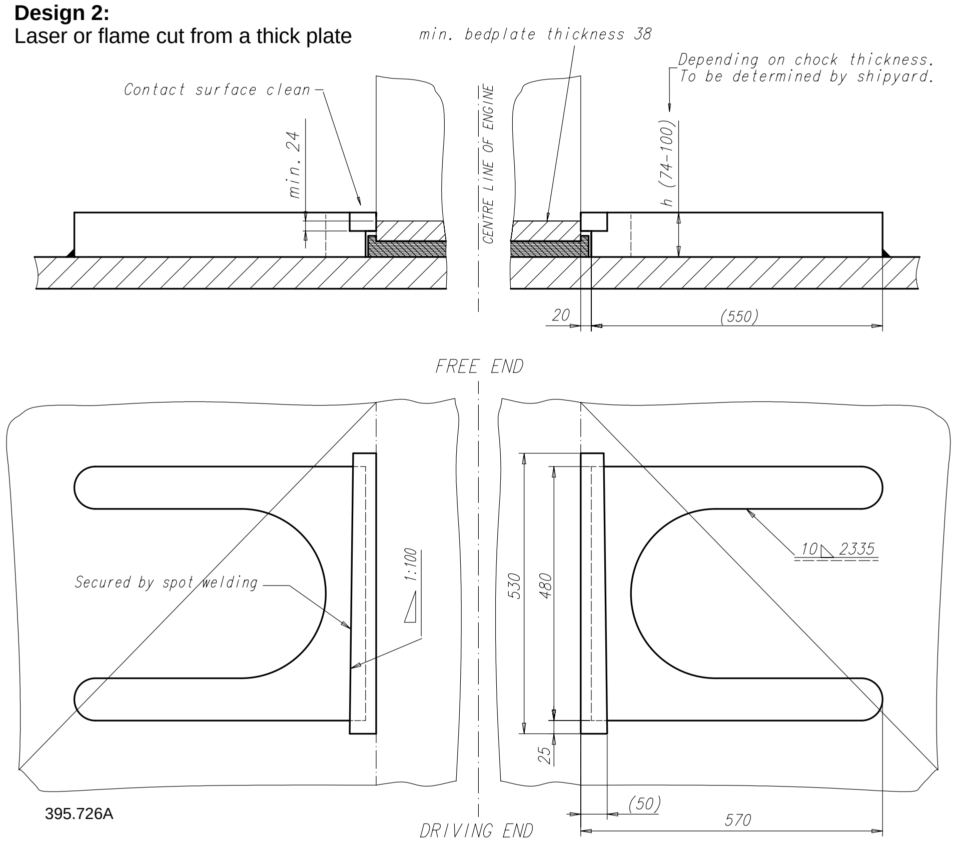


Fig. H18 Engine seating side stoppers

Fitting of the side stoppers

*1) Weld the stoppers in place when the engine is aligned.

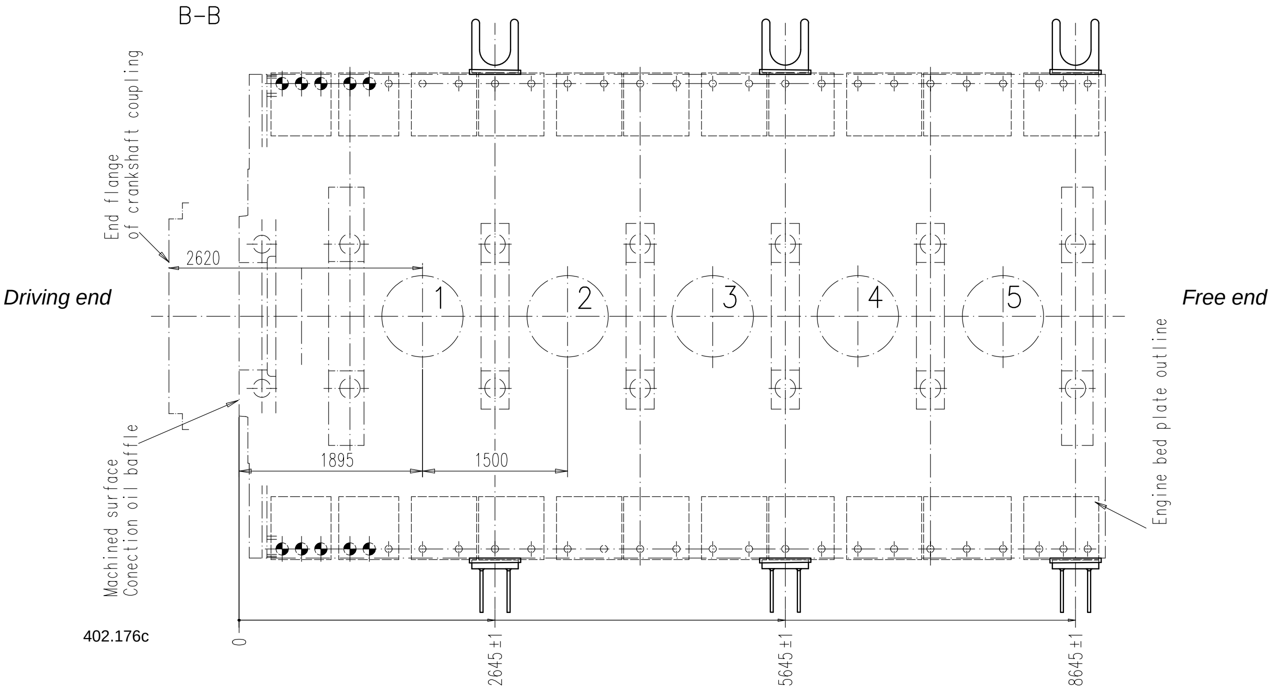
*2) Fit the wedges when the engine holding-down bolts are tightened.

Number of cylinders	Number of side stoppers
5	3 x 2
6	4 x 2
7	4 x 2
8	5 x 2
9	6 x 2

Note:

For the arrangement and number of side stoppers refer to figures H19 through H22.

5RT-flex84T-D



6RT-flex84T-D

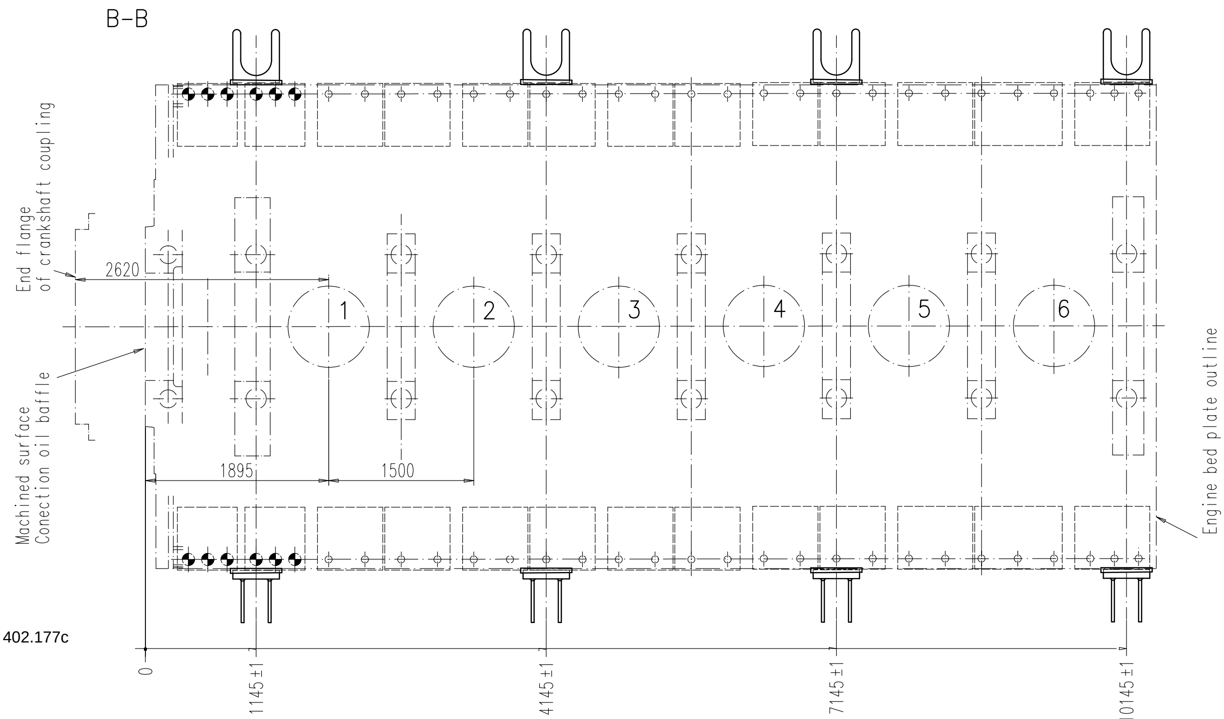
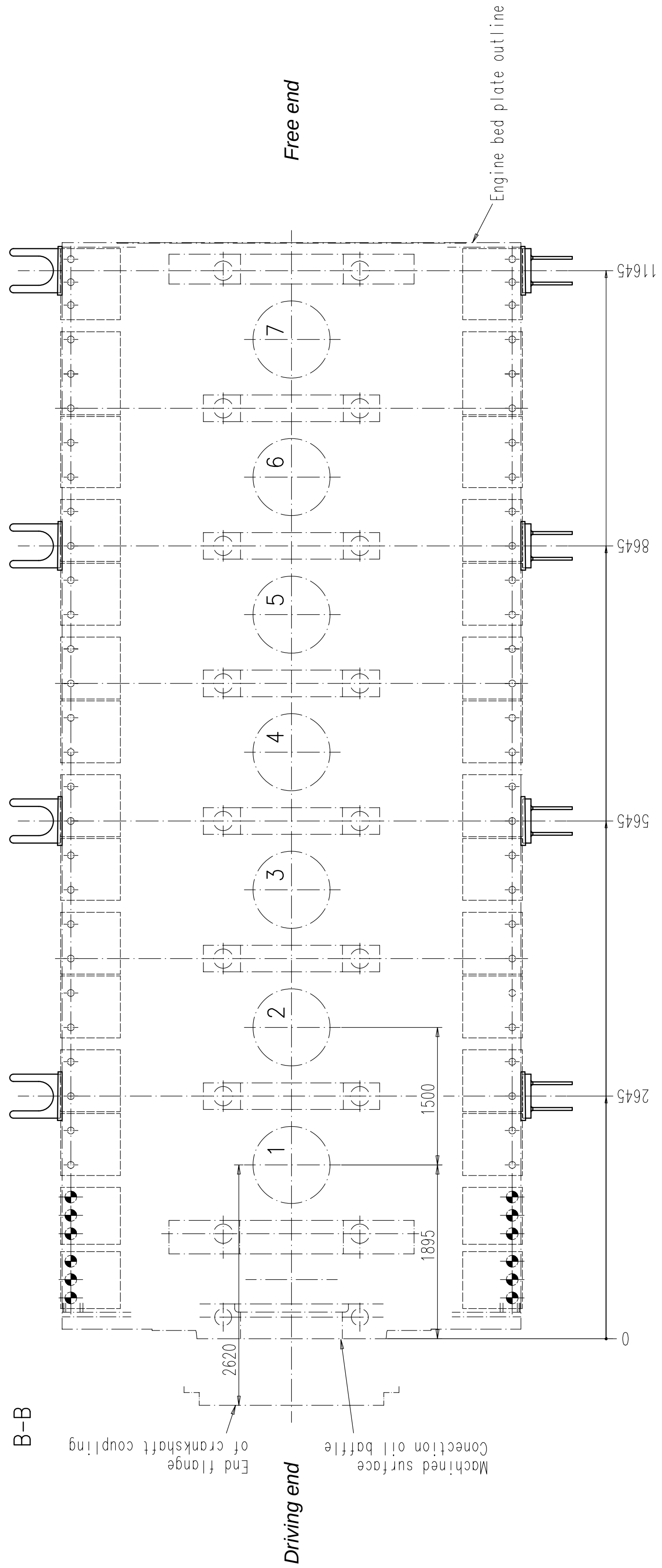


Fig. H19 5&6RT-flex84T-D engine side stopper arrangement (flame-cut or welded type)

H. General installation aspects

7RT-flex84T-D



402.178c

Fig. H20 7RT-flex84T-D engine side stopper arrangement (flame-cut or welded type)

8RT-flex84T-D

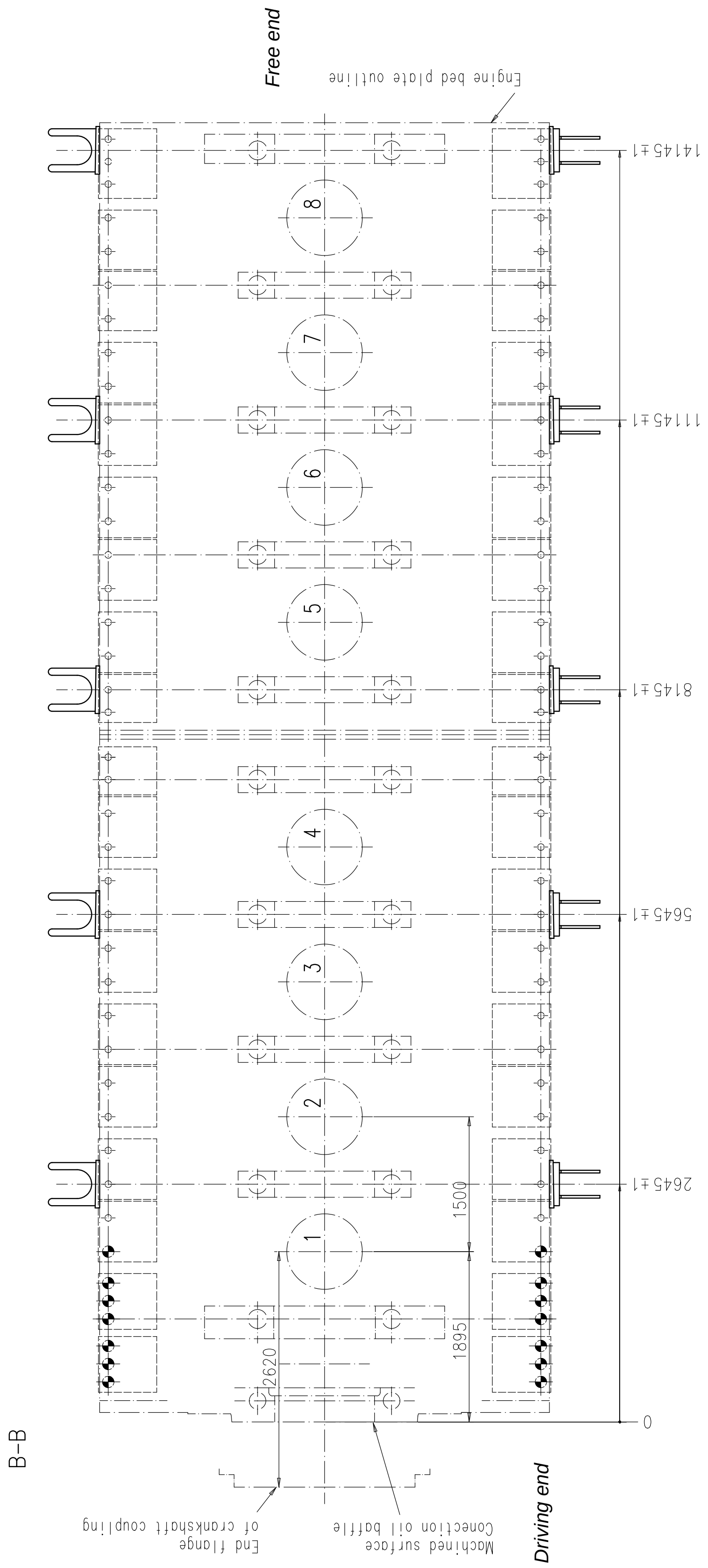


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Fig. H21 8RT-flex84T-D engine side stopper arrangement (flame-cut or welded type)

H. General installation aspects

9RT-flex84T-D

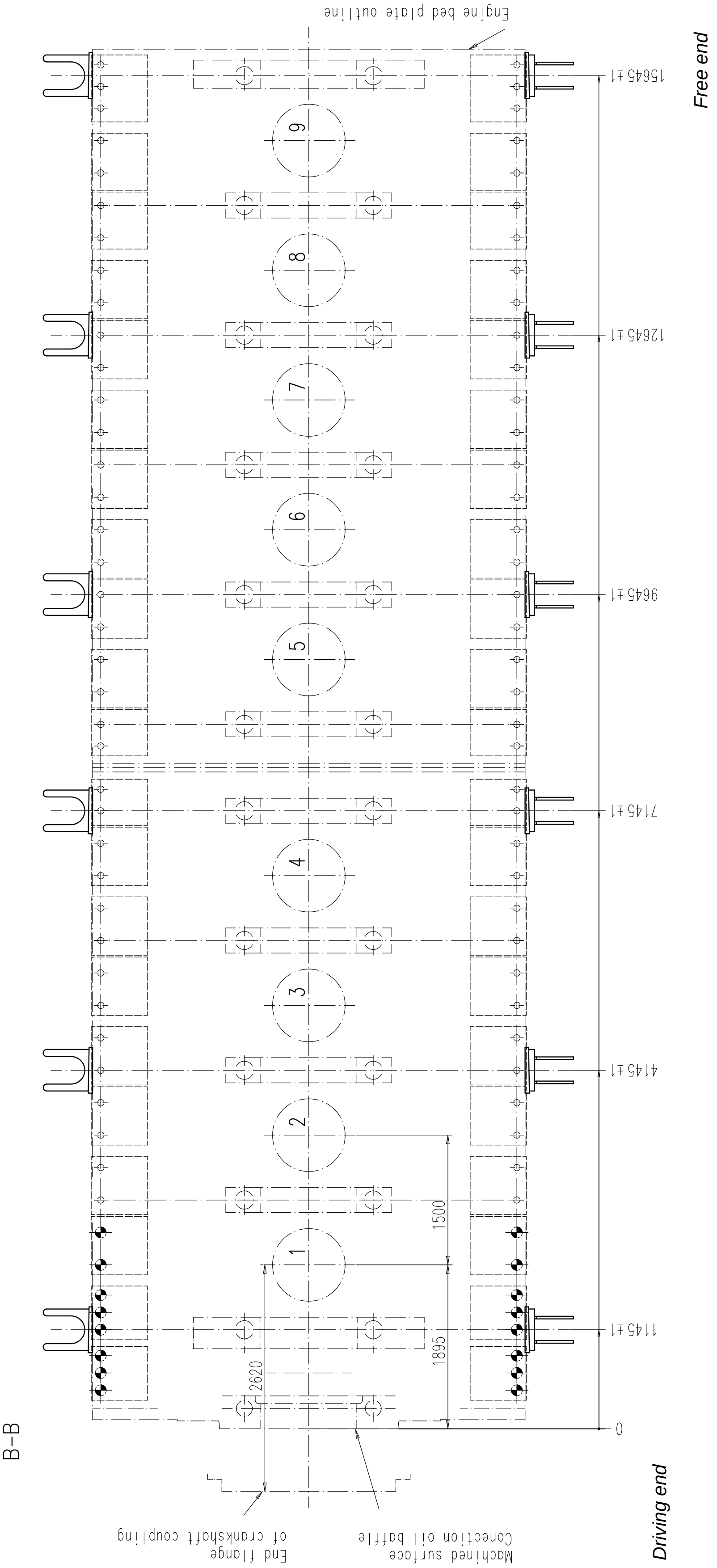

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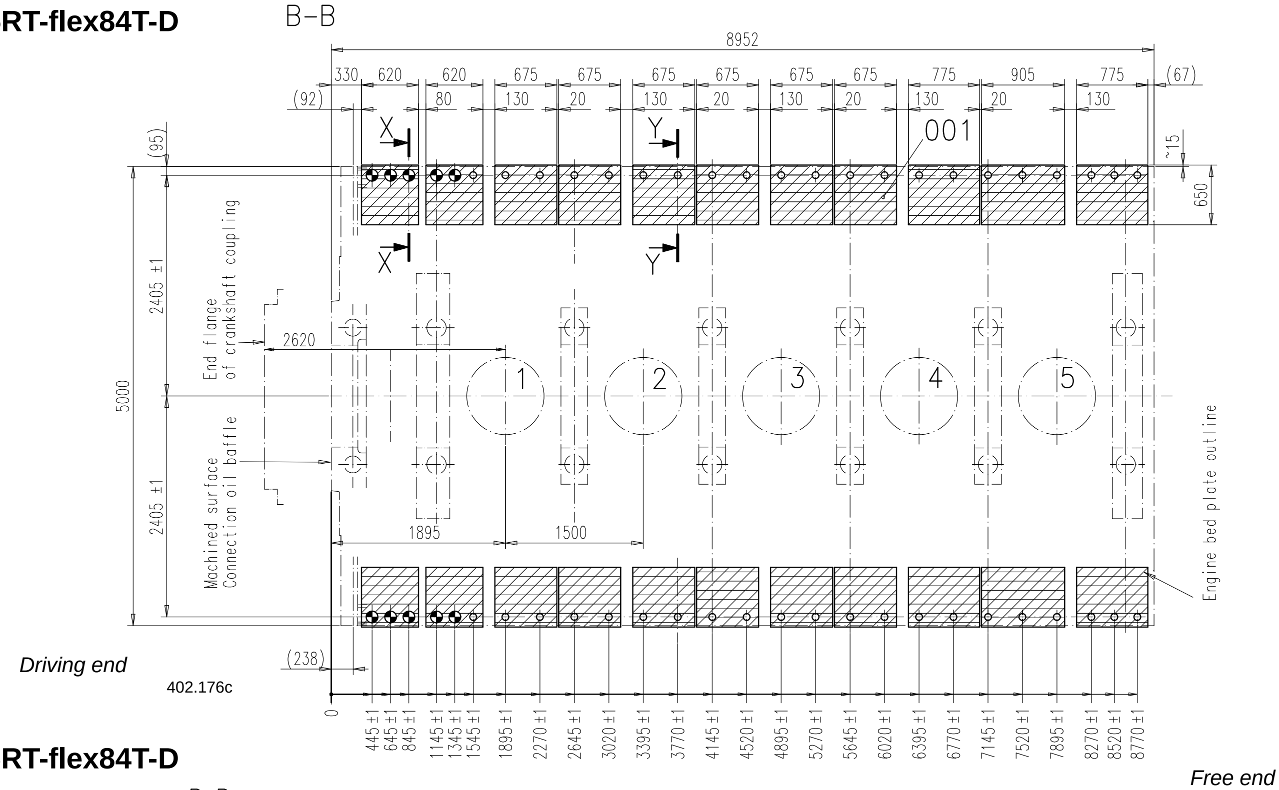
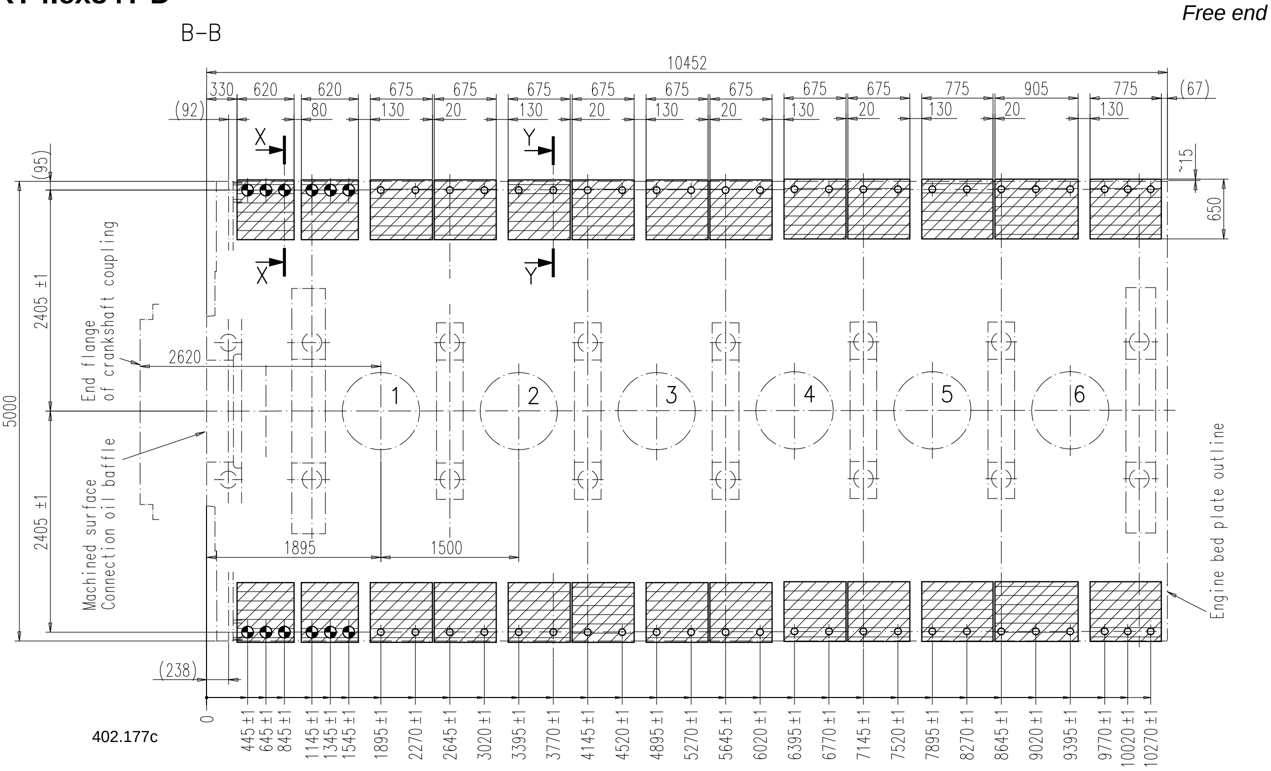
Fig. H22 9RT-flex84T-D engine side stopper arrangement (flame-cut or welded type)

H5.8 Chocking and drilling plan

5RT-flex84T-D



6RT-flex84T-D

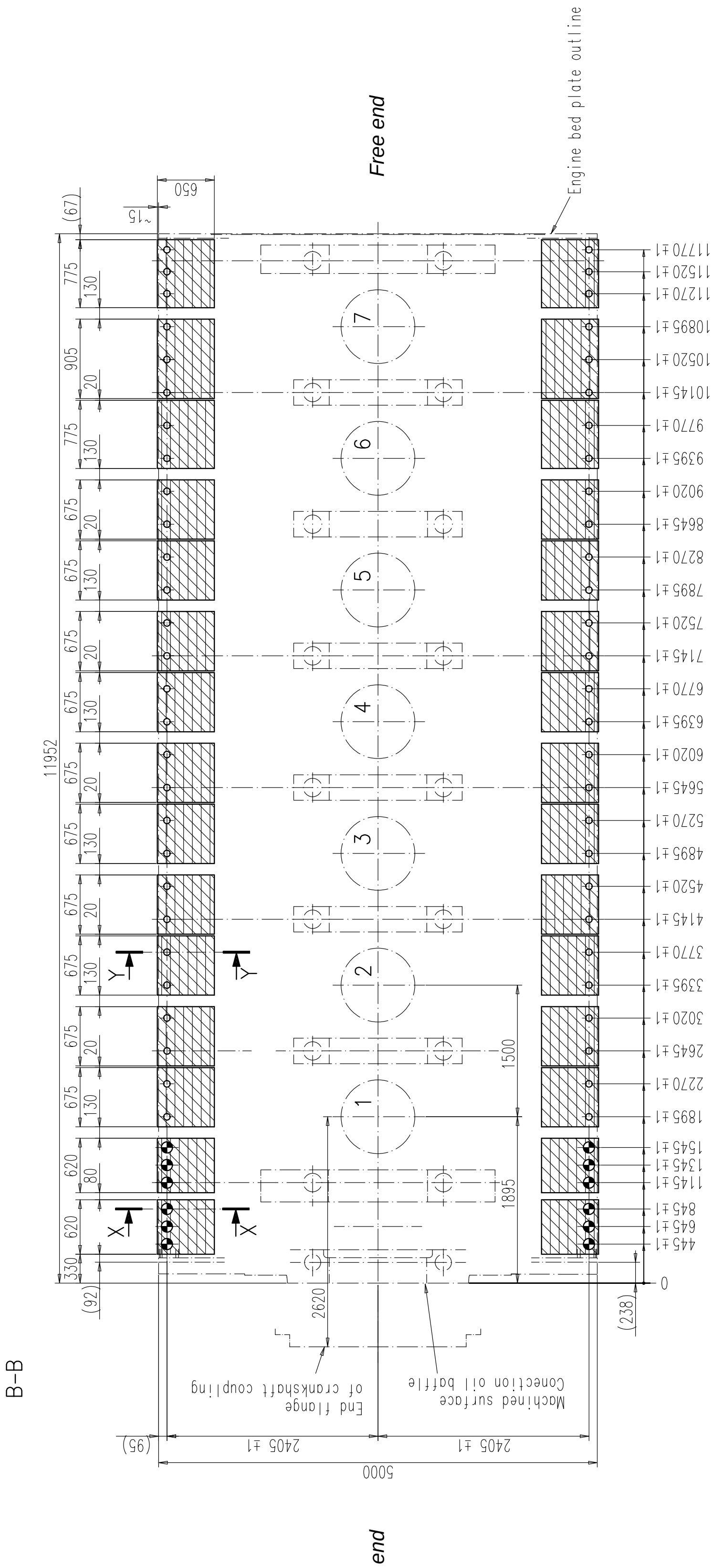


Note:
Plan view **B–B**, refer to Fig. H13.
For dertais of holes X and Y and chocks refer to figure H27 and tables H8 and H9.

Fig. H23 5&6RT-flex84T-D chocking and drilling plan for engine seating with epoxy resin chocks

H. General installation aspects

7RT-flex84T-D

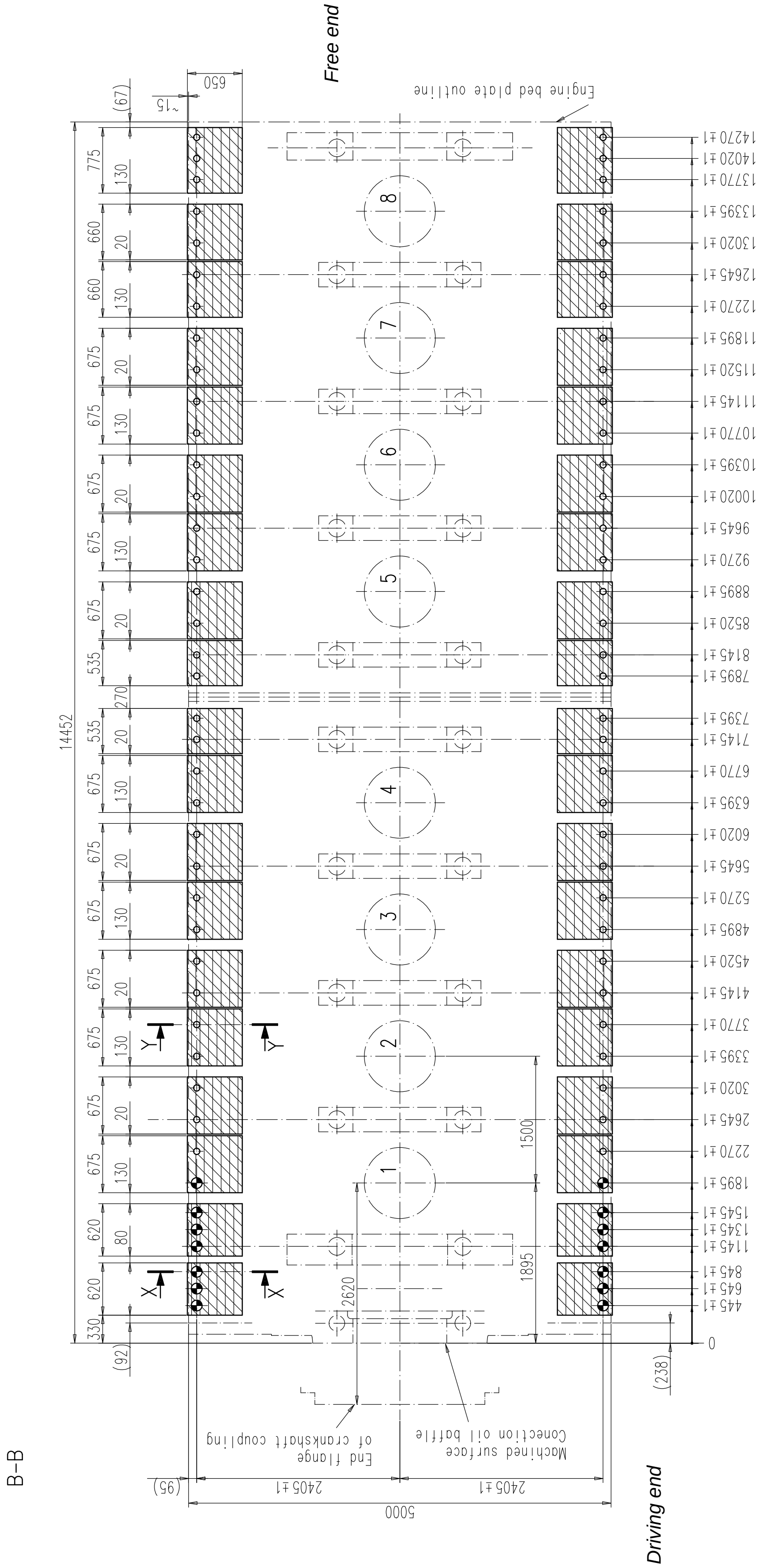


Note:
Plan view **B–B**, refer to Fig. H13.
For dertais of holes X and Y and chocks refer to figure H27 and tables H8 and H9.

402.178c

Fig. H24 7RT-flex84T-D chocking and drilling plan for engine seating with epoxy resin chocks

8RT-flex84T-D



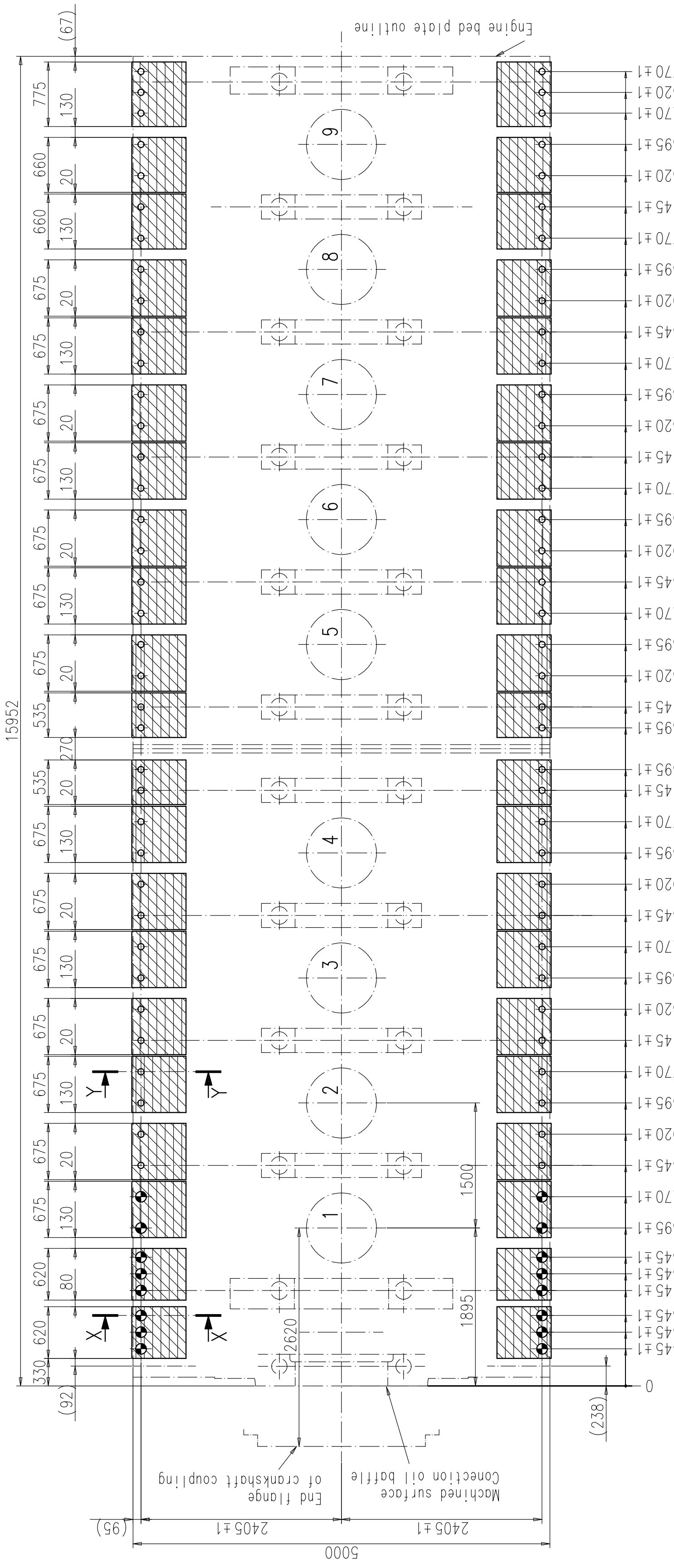
402.179c

Fig. H25 8RT-flex84T-D chocking and drilling plan for engine seating with epoxy resin chocks

H. General installation aspects

9RT-flex84T-D

B–B



Note:
Plan view **B–B**, refer to Fig. H13.
For dertais of holes X and Y and chocks refer to figure H27 and tables H8 and H9.

402.180c

Fig. H26 9RT-flex84T-D chocking and drilling plan for engine seating with epoxy resin chocks

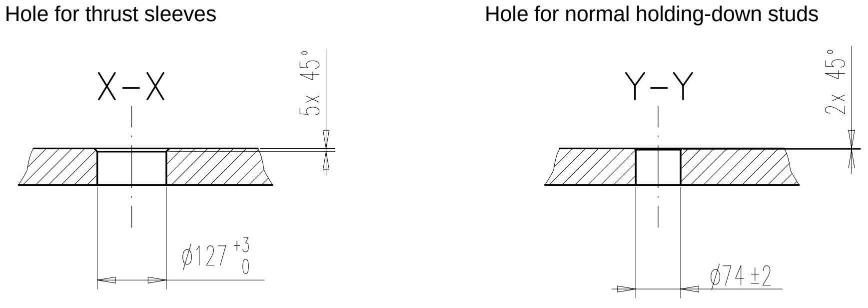
Dimensions of epoxy resin chocks *1)					
Number of cylinders	**Max. permanent mean surface pressure of chock** *2)	**Total chock length per side**	**Total net chocking area**	**Required quantity of epoxy resin material (related to chock thickness)**	
				min. 25 mm)	max. (60 mm)
	(N/mm²)	(mm)	(cm²)	(dm³)	
Execution with thrust sleeves					
5	5	7 745	97 452	252	601
6		9 095	114 465	296	706
7		10 445	131 652	340	812
8		12 505	157 622	407	972
9		13 855	174 634	451	1 077

Remark: *1) For the layout is taken into consideration:
– A max. permissible static load of 0.8 N/mm^2.
– Engine mass (incl. net engine mass, vibration damper, flywheel, water, and oil).
– Engine holding down studs fully tightened according to fitting instructions.
*2) The max. permissible mean surface pressure of the epoxy resin chocks has to be determined by the shipyard in accordance with the classification society/rules.

Table H8 Details and dimensions of epoxy resin chocks

Number of cylinders	**Total number of holes**	**Holes for thrust sleeves (X–X)**		**Holes for holding-down studs (Y–Y)**	
		No.	(diameter in mm)	No.	diameter in mm)
5	52	10	127^{+3}_{-0}	42	74 ± 2
6	60	12		48	
7	68	12		56	
8	82	14		68	
9	90	16		74	

Table H9 Number and diameter of holes drilled into top plate



402.176c
402.177c
402.178c
402.179c
402.180c

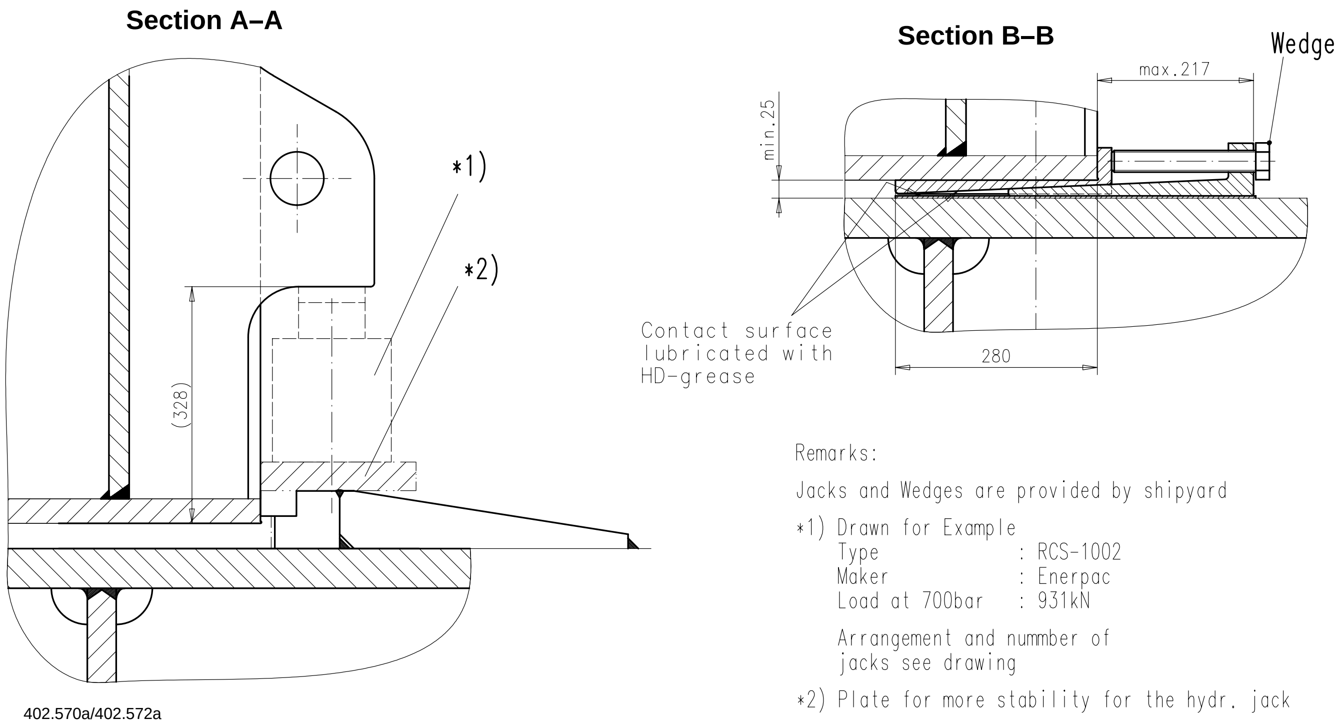
Fig. H27 Drilling plan details: holes for thrust sleeves and normal holding-down studs

H. General installation aspects

H5.9 Engine alignment tools

Arrangement for **pre-alignment with hydraulic jack**

Arrangement for **final alignment with wedge**



Note: Section A–A and B–B refer to figures H29 and H30.

Fig. H28 Alignment with hydraulic jacks and wedges

Tool	5 cyl.	6 cyl.	7 cyl.	8 cyl.	9 cyl.
Hydraulic jack		12	14		
Wedge		14	16		

Table H10 Number of hydraulic jacks and wedges

H5.9.1 Position of engine alignment tools

5RT-flex84T-D

Drawing for 5 cyl. engine available on request

Note: for cross section A–A and B–B see Fig. H28

Hydraulic jack

6RT-flex84T-D

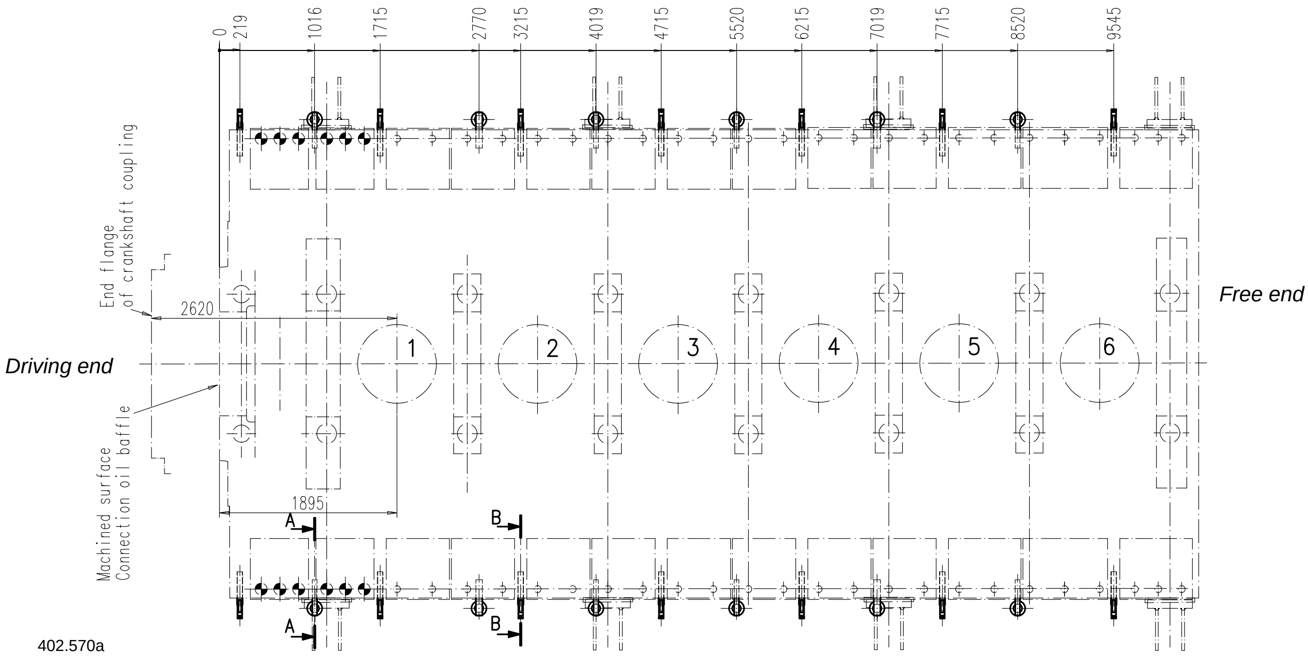
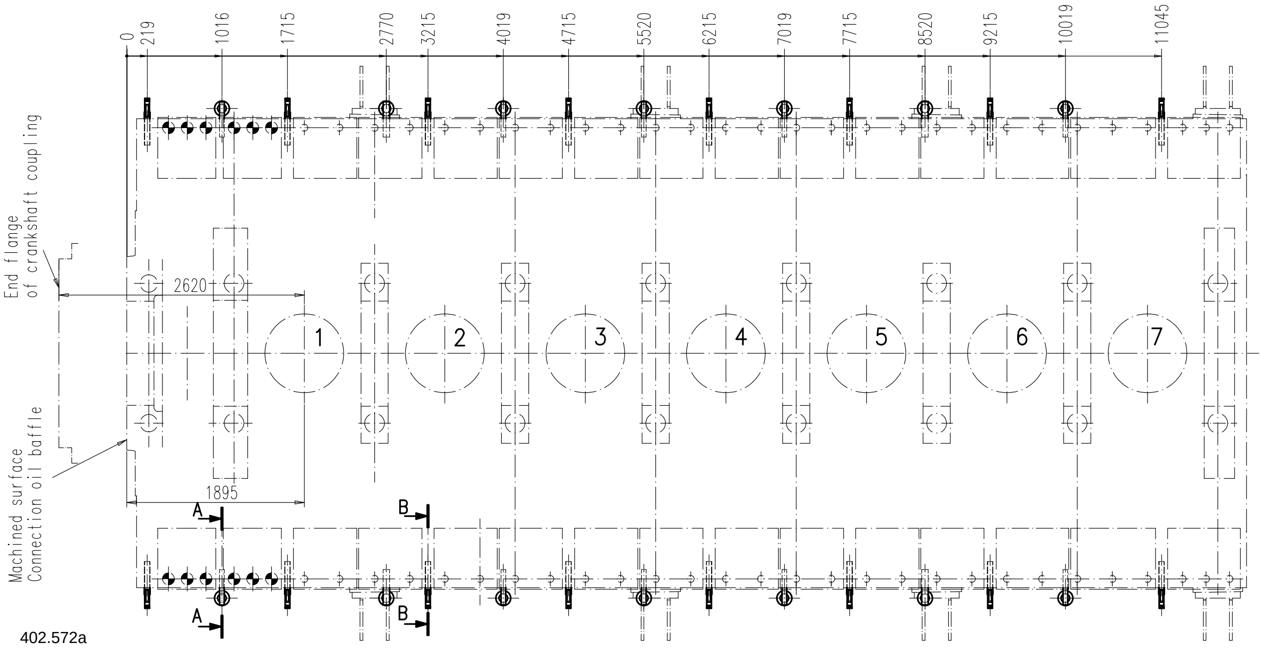


Fig. H29 Position of engine alignment tools for 5&6RT-flex84T-D

H. General installation aspects

7RT-flex84T-D



Note: for cross section A–A and B–B see Fig. H28

Hydraulic jack

Drawing for 8 cyl. engine available on request

Fig. H30 Position of engine alignment tools for 7&8RT-flex84T-D

Drawing for 9 cyl. engine available on request

Fig. H31 Position of engine alignment tools for 9RT-flex84T-D

H6 Engine coupling

Figure H32 gives a dimensioned cross-section of the engine coupling showing the arrangement of the fitted bolts, details of the nuts, and table H11 gives the quantity.

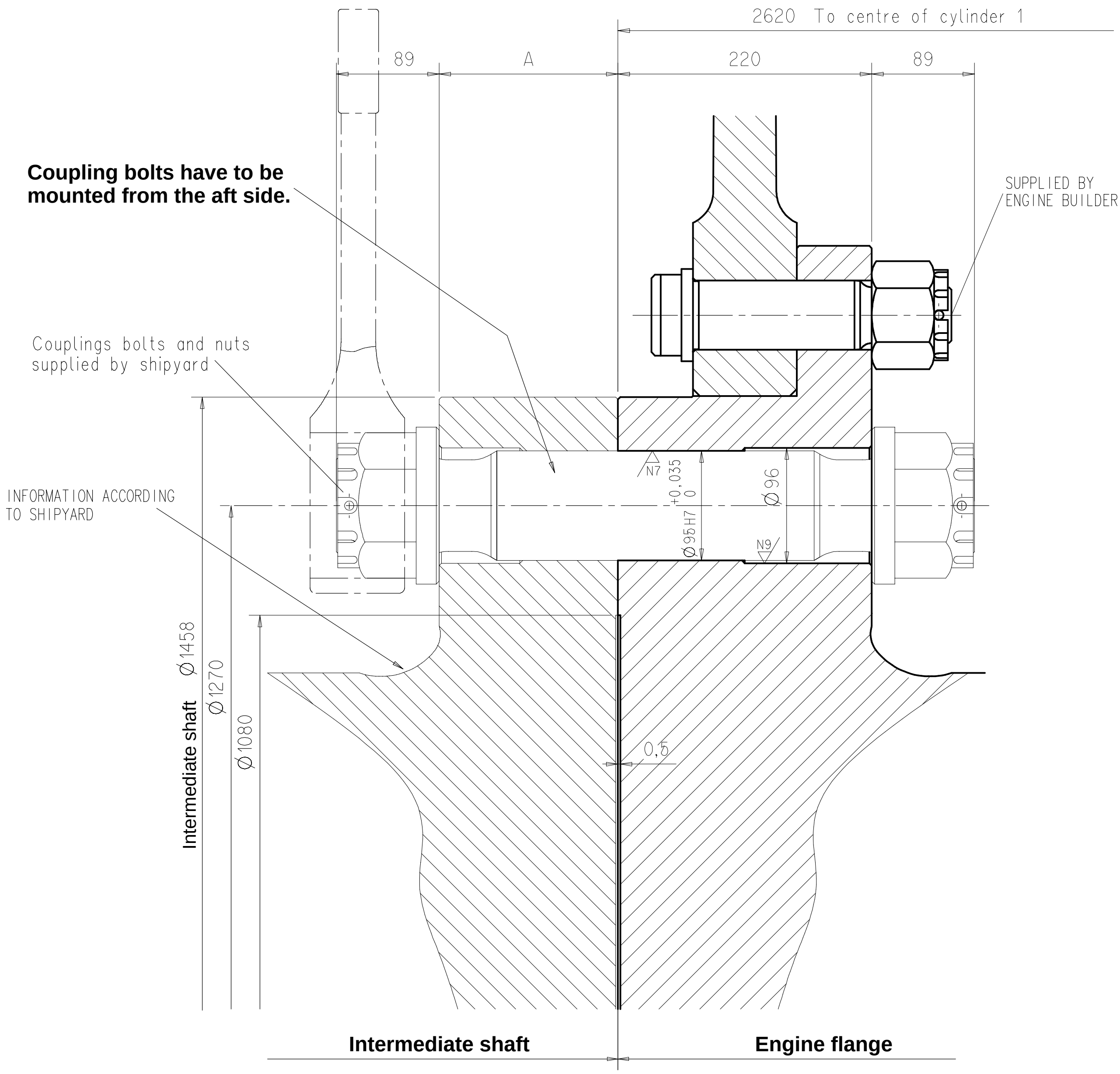
H6.1 Fitting coupling bolts

Drilling and reaming of the engine and shaft couplings is to be carried out using a computer numerically controlled drilling machine or accurately centred jig and great care is to be taken in matching and machining mating flanges together. Fitted bolt hole tolerances are to be H7 and fitted bolts are to be available for inserting in the holes on completion of reaming. Each fitted bolt is to be stamped with its position in the coupling with the same mark stamped adjacent to the hole.

In the event of pitch circle error leading to misalignment of bolt holes it is important to remedy the situation by joint cylindrical reaming an oversize hole and fitting an individually machined fitted bolt. Fitted bolts are to locate with a slight interference fit but not requiring heavy hammer blows. If there is any doubt that a fitted bolt is too slack or too tight refer to the classification society surveyor and a representative of the engine builder.

To tighten the coupling bolts it is important to work methodically, taking up the threads on opposite bolts to hand tight followed by sequential torque tightening. Mark each bolt head in turn, 1, 2, 3, etc., and tighten opposite nuts in turn to an angle of 55° making sure the bolt head is securely held and unable to rotate with the nut. Castellated nuts are to be locked according to the requirements of class with either locking wire or split pins. Use feeler gauges during the tightening process to ensure the coupling faces are properly mated with no clearance.

H. General installation aspects



270.801c

Dimension A = flange thickness of intermediate shaft

Fig. H32 Engine coupling fitted bolt arrangement

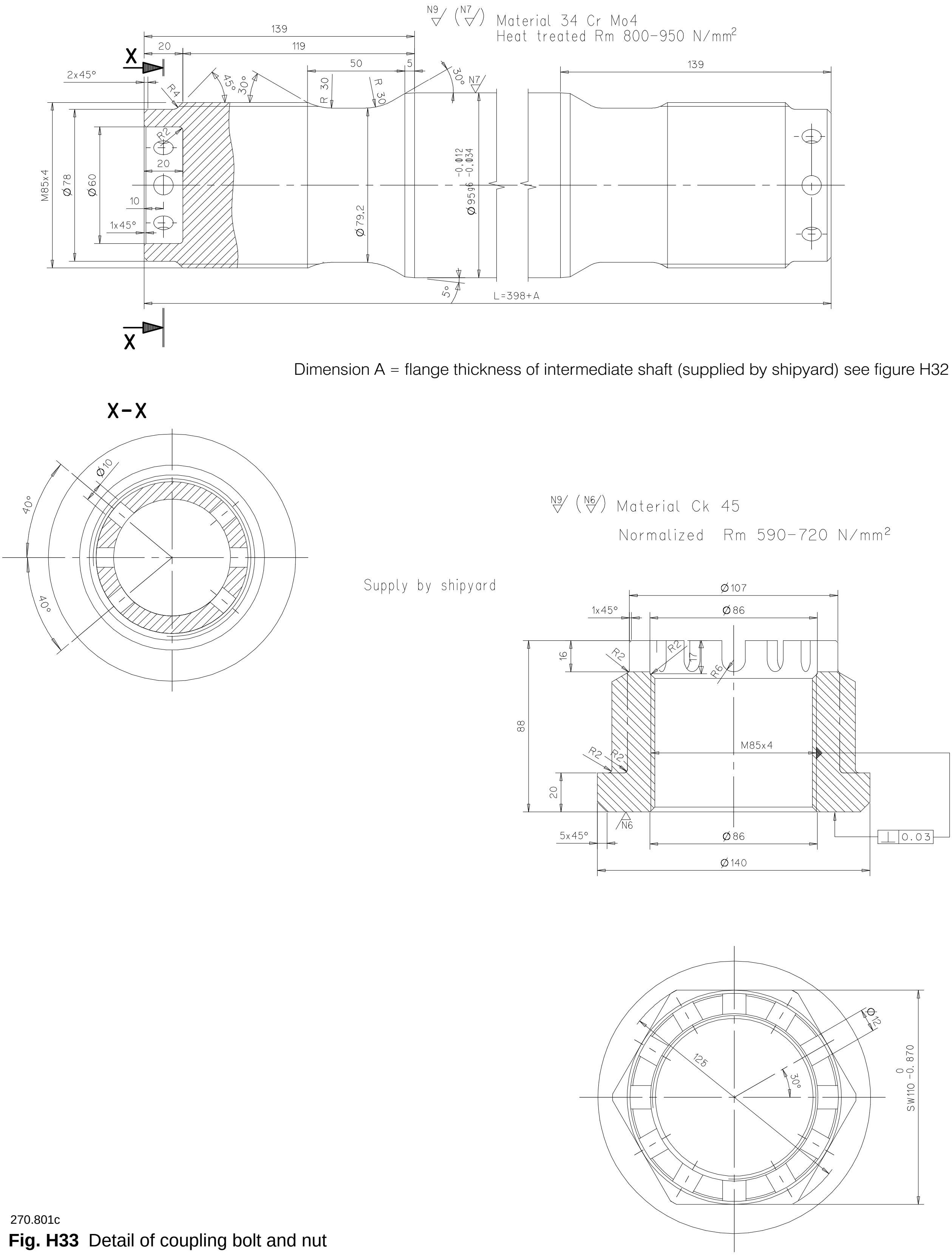
Number of cylinders	**5**	**6**	**7**	**8**	**9**
Number of fitted bolts	16	18	18	18	22

Note: The number of fitted bolts shown above is the minimum number recommended by Wärtsilä Switzerland Ltd.

Table H11 Quantity of engine coupling fitted bolts

H. General installation aspects

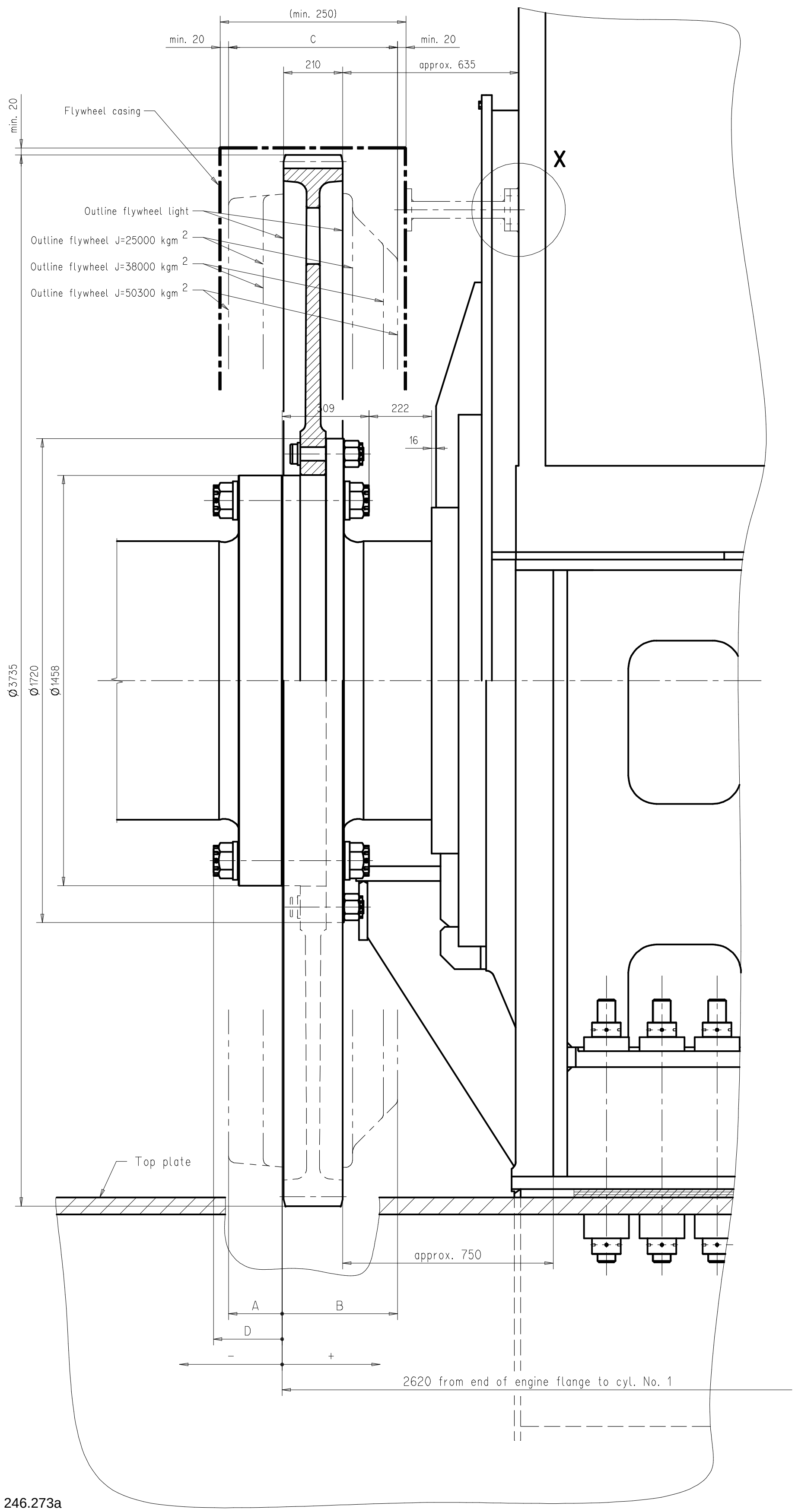
Recommended design of bolts and nuts for crankshaft coupling

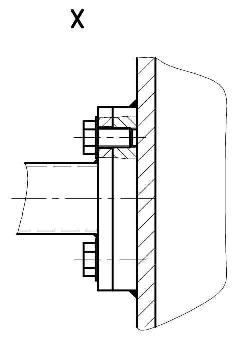


270.801c

Fig. H33 Detail of coupling bolt and nut

H. General installation aspects





Remarks:

If the flywheel casing shall be mounted onto the engine body, use preferably column wall or engine bedplate as attachment surface.
Do not drill threads or holes into the engine body. Use welded-on steel plates for bolting as shown in detail X.

The clearance between flywheel casing and any rotating part must be not less than 20 mm.

Dimensions in mm

Flywheel type	Cyls.	A	B	C	D
light	5	5	210	205	To be determined by shipyard
	6	5	215	210	
	7	5	167	162	
	8	5	151	146	
	9	5	181	176	
J=25000 kgm^2	5	−67	250	317	
	6	5	250	245	
	7	−22	250	272	
	8	−5	250	255	
	9	−36	250	286	
J=38000 kgm^2	5	−67	360	427	
	6	5	360	355	
	7	−22	360	382	
	8	−5	360	365	
	9	−36	360	396	
J=50300 kgm^2	5	−190	410	600	
	6	−190	410	600	
	7	−190	410	600	
	8	−190	410	600	
	9	−190	410	600	

246.273a

Fig. H34 Engine coupling and flywheel casing.

H7 Engine earthing

Electric current flows when a potential difference exists between two materials. The creation of a potential difference is associated with ‘thermoelectric’ by the application of heat, ‘tribo-electric’ between interactive surfaces, ‘electrochemical’ when an electrolytic solution exists and ‘electromagnetic induction’ when a conducting material passes through a magnetic field. Tracking or leakage currents are created in machinery by any of the above means and if they are not adequately directed to earth, can result in component failures, in some case fires and interference with control and monitoring instrumentation.

H7.1 Preventive action

Earthing brushes in contact with slip-rings and the chassis bonded by braided copper wire are common forms of protecting electric machines. Where operating loads and voltages are comparatively low then the supply is isolated from the machine by an ‘isolating transformer’, often the case with hand held power tools. The build specification dictates the earthing procedure to be followed and the classification society is to approve the final installation.

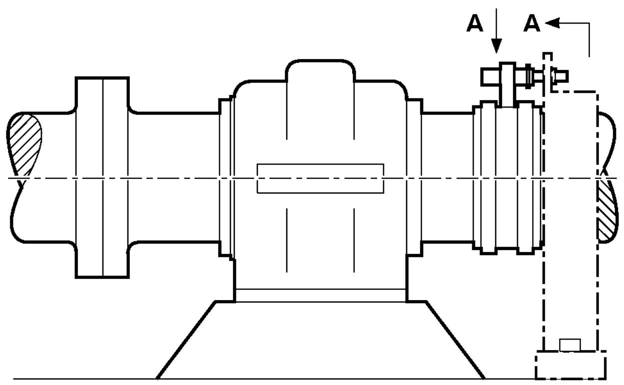
On vessels with star-wound alternators the neutral is considered to be earth and electrical devices are protected by automatic fuses. Ensure instrument wiring meets the building and classification society specifications and is shielded and isolated to prevent induced signal errors and short circuits. In certain cases large items of machinery are isolated from their foundations and couplings are isolated to prevent current flow, e.g., when electric motors are connected to a common gear box.

Retrospective fitting of earthing devices is not uncommon but due consideration is to be given at the design stage to adequate shielding of control equipment and earthing protection where tracking and leakage currents are expected. Magnetic induction and polarisation are to be avoided and degaussing equipment incorporated if there is likely to be a problem.

H7.2 Earthing slip-rings

Figures H35 and H36 show a typical shaft earthing system. The slip-ring (1) is supplied as matched halves to suit the shaft and secured by two tension bands (2) using clamps (12). The slip-ring mating faces are finished flush and butt jointed with solder. The brushes (4) are housed in the twin holder (3) clamped to a stainless steel spindle (6) and there is a monitoring brush (11) in a single holder (10) clamped to an insulated spindle (9). Both spindles are attached to the mounting bracket (8). The electric cables are connected as shown in figure H37 with the optional voltmeter. This instrument is at the discretion of the owner but it is useful to observe that the potential to earth does not rise above 100 mV.

Differing combinations of conducting material are available for the construction of the slip-rings however, alloys with a high silver content are found to be efficient and hard wearing.



Typical earthing arrangement for the main shaft

F10.4354

Fig. H35 Shaft earthing arrangement

Wärtsilä recommend installing a shaft earthing device on the intermediate shafting as illustrated in figure H36.

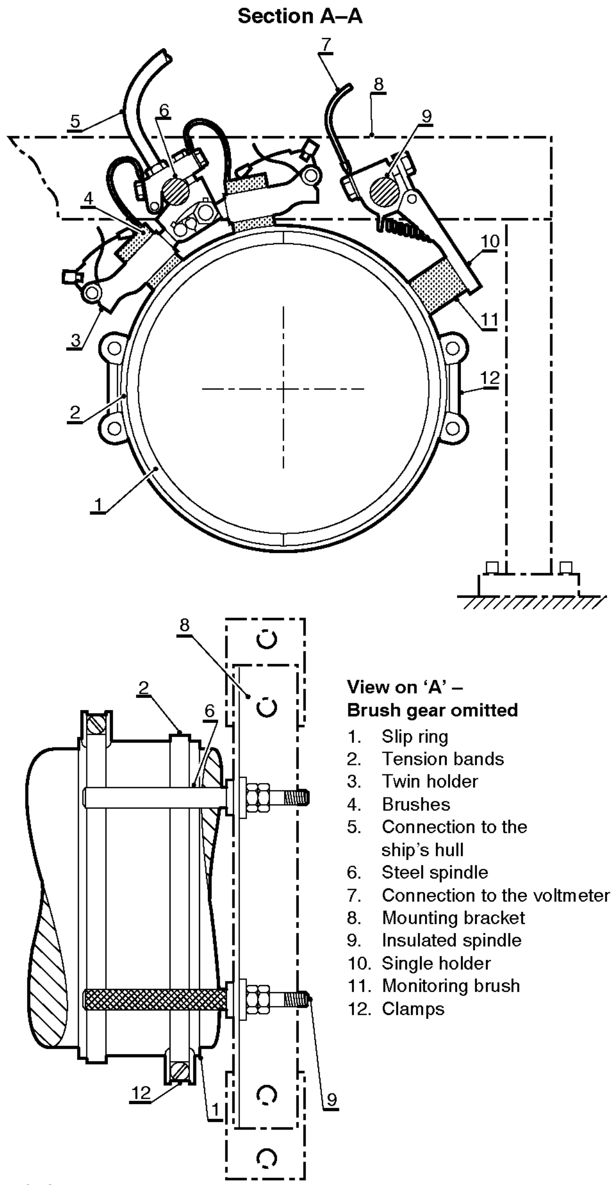


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Fig. H36 Shaft earthing slip-ring arrangement

H. General installation aspects

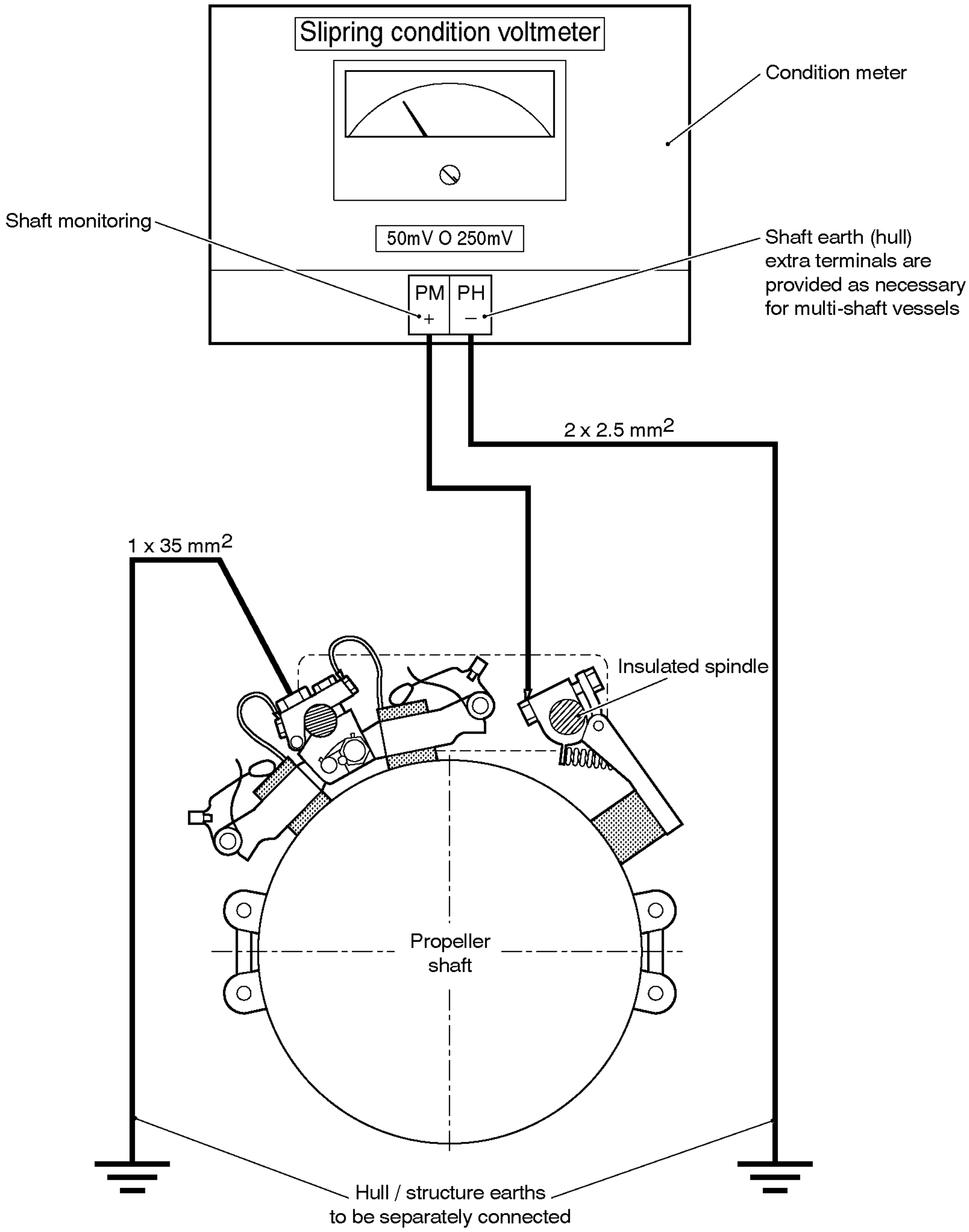

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Fig. H37 Shaft earthing with condition monitoring facility

H8 Engine stays

Ship vibrations and engine rocking caused by the engine behaviour (as described in chapter D 'Engine dynamics') are reduced by fitting longitudinal and lateral stays. The **five-cylinder** engines are liable to strong crankshaft axial vibrations throughout the full load speed range, leading to excessive axial and longitudinal vibration at the engine top. Lateral components of forces acting on the crossheads result in pulsating lateral forces and side to side or lateral rocking of the engine. This lateral rocking may be transmitted through the engine-room bottom structure to excite localized vibration or hull resonance.
In some installations with five-cylinder engines, especially those coupled to very stiff intermediate and propeller shafts, the engine foundation can be excited at a frequency close to the full load speed range resonance. This leads to increased axial (longitudinal) vibrations at the engine top and as a result, to vibrations in the ship's structure.

Fitting stays between the engine and the hull reduces the engine vibrations and the vibration transmission to the ship's structure.

H8.1 Stays arrangement

Table D3 'Countermeasures for lateral and longitudinal rocking' indicates in which cases the installation of lateral stays are to be considered.

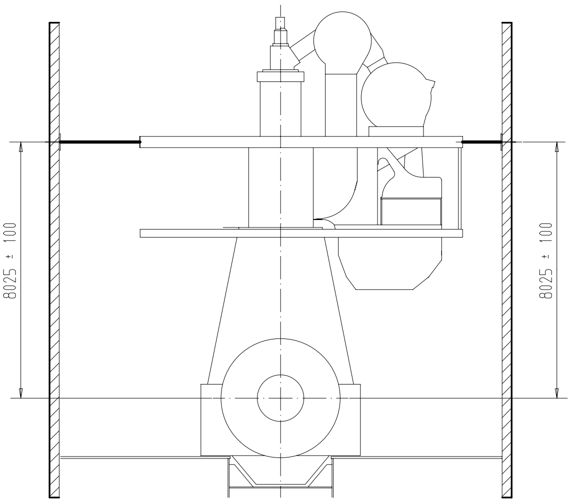
H8.1.1 Installation of lateral stays

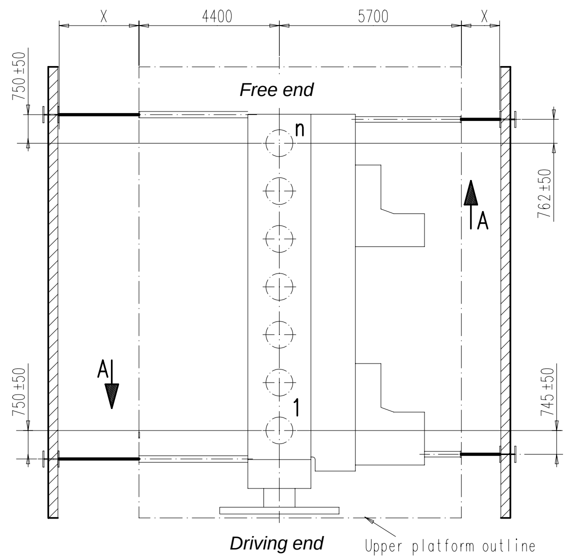
Two stay types can be considered:
– *Hydraulic stays*:
  two by two installed on the exhaust and on the fuel side of the engine,
– *Friction stays*:
  two stays installed on the engine exhaust side.

H8.1.2 Longitudinal stays

For the 5RT-flex84T-D engine there is a requirement for the installation of longitudinal stays (see table D3).

H. General installation aspects





Requirements for ship side attachment point

Max. force acting on ship's hull (per stay)	$F_{max.}$	(kN)	320
Minimum stiffness	$k_{min.}$	(N/m)	0.5×10^9
Permissible deflection per 100 kN	$Def_{max.}$	(mm)	0.2

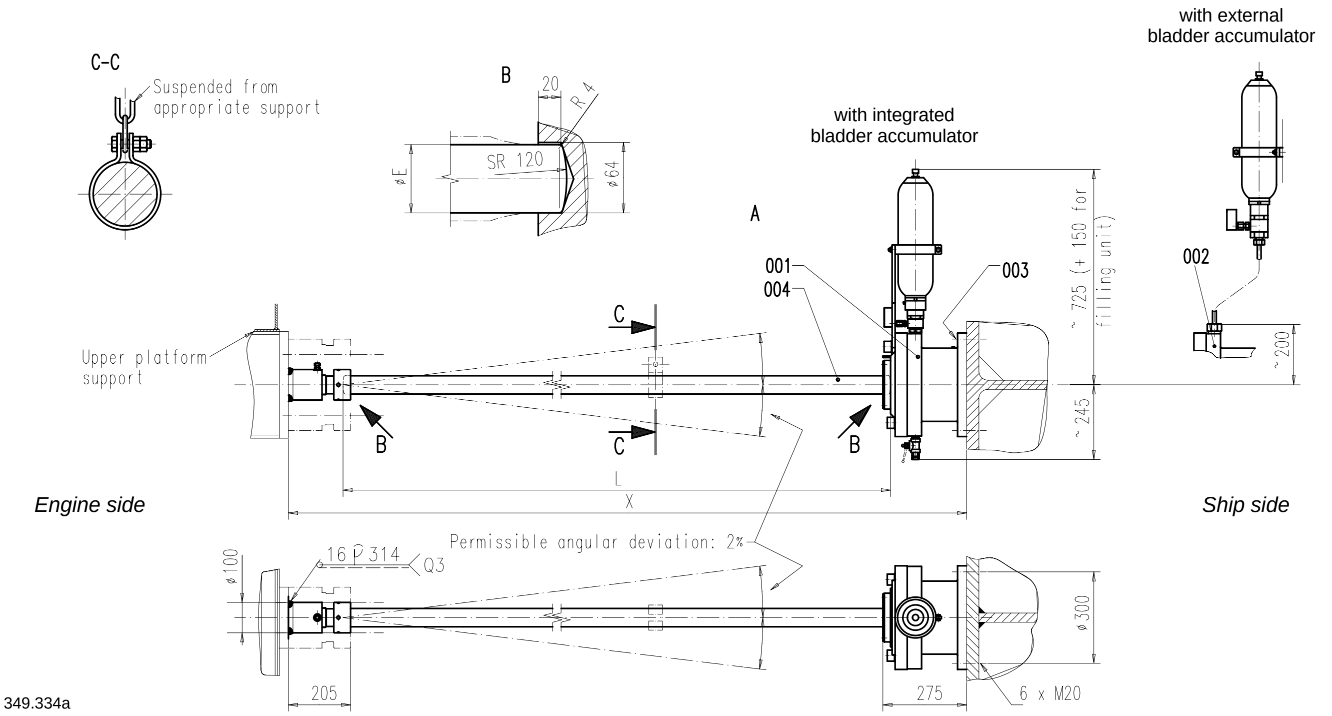
Dimensions of pos. 004

L	ø E
(mm)	(mm)
up to 1500	60
1501 to 2200	75
2201 to 2800	90

001 Hydraulic cylinder
002 Hydraulic cylinder
003 Hex head screw M20x60
004 Roundbar

Notes:

- X = clear width between engine and ship side
  L = length of the roundbar.
- When determining X and L observe:
  $X_{min.}$ = 550 mm, L = X – 430 mm



349.334a

Fig. H38 Lateral stay details – hydraulic type

Drawing available on request.

Fig. H39 Lateral stay details – friction type

H9 Fire protection

In areas such as under-piston spaces and scavenge air receiver, fire may develop. The engine is fitted with a piping system which leads the fire extinguishing agent into the mentioned areas.
In the drawings of section F5 “Engine pipe connections” the relevant connection is indicated.
The final arrangement of the fire extinguishing system is to be submitted for approval to the relevant classification society, where such protection is required.

H9.1 Extinguishing agents

Various extinguishing agents can be considered for fire fighting purposes. Their selection is made either by shipbuilder or shipowner in compliance with the rules of the classification society involved. Table H12 gives the recommended quantity of 45 kg bottles of CO_2 for each engine.

Steam as an alternative fire extinguishing medium is permissible for the scavenge air spaces of the piston underside but may cause corrosion if countermeasures are not taken immediately after its use.

These countermeasures comprise:

- Opening scavenge spaces and removing oil and carbon deposits.
- Drying all unpainted surfaces and applying rust protection (i.e. lubricating oil).

Note:

Steam is not suitable for fire extinguishing under-piston spaces as it may result in damage to vital parts such as the crankshaft. If steam is used for the scavenge spaces at piston underside, a water trap is recommended to be installed at each entry to the engine and assurance obtained that steam shut-off valves are tight when not in use.

Extinguishing medium	Piston underside at bottom dead centre including common section of cylinder jacket		Bottle	Recommended total number of fire extinguishing bottles Number of cylinders				
	Volume [m^3/cyl.]	**Mass** [kg/cyl.]	**Size** [kg]	**5**	**6**	**7**	**8**	**9**
Carbon-dioxide	11	40	45	3	4	5	5	6

Table H12 Recommended quantities of fire extinguishing medium

I. Engine emissions

I1 Exhaust gas emissions

I1.1 IMO-2000 regulations

The International Maritime Organisation (IMO) is the specialized agency of the United Nations (UN) dealing with technical aspects of shipping. For more information see http://www.imo.org.

I1.1.1 Establishment of emission limits for ships

In 1973, agreement on the establishment of an International Convention for the Prevention of Pollution from ships was reached. It was modified in 1978 and is now known as **MARPOL 73/78**.
The **Annex VI** to MARPOL 73/78 entered into force in 2005 and contains regulations limiting or prohibiting certain types of emissions from ships, including limitations with respect to the allowed air pollution. Following the entry into force of the annex, a review process was started resuling in an amended Annex IV which was adopted by the IMO in October 2008 and entered into force in July 2010. This amended Annex IV includes provisions for the further development of the emissions regulations up to 2020.

I1.1.2 Regulation regarding NO_X emissions of diesel engines

Regulation 13 of Annex IV specifies a limit for the nitrogen oxide (NO_X) emissions of engines installed on ships, which has a direct implication on propulsion engine design. Depending on the rated speed of the engine and the date of keel laying of the vessel, the weighted average NO_X emission of that engine must not exceed the maximum allowable value as indicated by the respective curves in the following diagram.

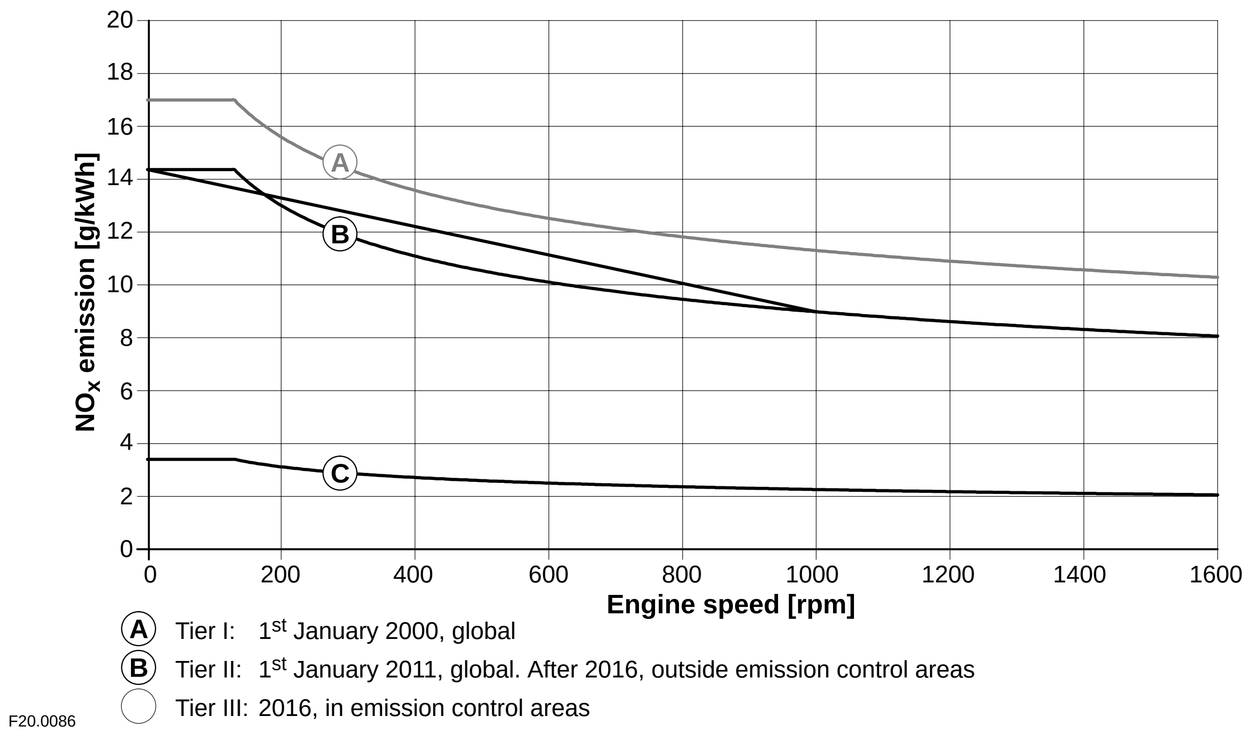


Fig. I1 Speed dependent maximum average NO_X emissions by engines

The rules and procedures for demonstrating and verifying compliance with this regulation are laid down in the **NO_X Technical code** which is part of Annex VI and is largely based on the latest revision of ISO 8178.

I1.2 Measures for compliance with the IMO regulation

The rating field of the Wärtsilä RT-flex84T-D is divided into two areas as shown in figure I2 and comprises the following measures:

I1.2.1 Low NO_x Tuning

In the upper part of the rating field (figure I2) the IMO regulation is fulfilled by the use of the Low NO_x Tuning concept. Low NO_x Tuning includes well tested measures, which lead to lowest disadvantage in engine costs and fuel consumption while maintaining the high reliability levels of pre-IMO tuned engines.

I1.2.2 Extended measures

In the lower part of the rating field, fulfilling the IMO NO_x regulation requires the application of extended measures. For further information please do not hesitate to contact one of our offices.

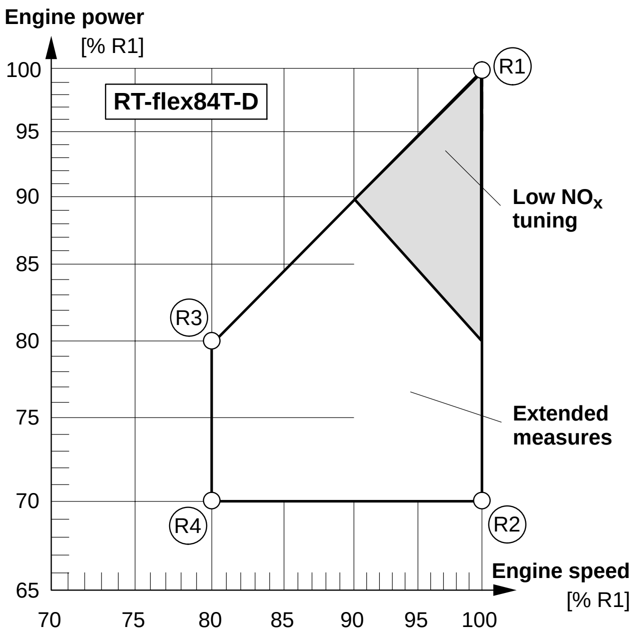


Fig. I2 Wärtsilä RT-flex84T-D: compliance with IMO regulations

I. Engine emissions

I2 Engine noise

It is very important to protect the ship's crew/passengers from the effects of machinery space noise. Therefore the scavenge air ducts and the exhaust duct system (both expansion joints of gas outlet and gas inlet of turbocharger) should be equipped with the standard insulation, and the turbocharger with the standard intake silencer.

I2.1 Engine surface sound pressure level

Figure I3 shows the average air borne noise level, measured at 1m distance and at nominal MCR. Near to the turbocharger (air intake) the maximum measured noise level will normally be about 3–5 dB(A) higher than the average noise level of the engine.

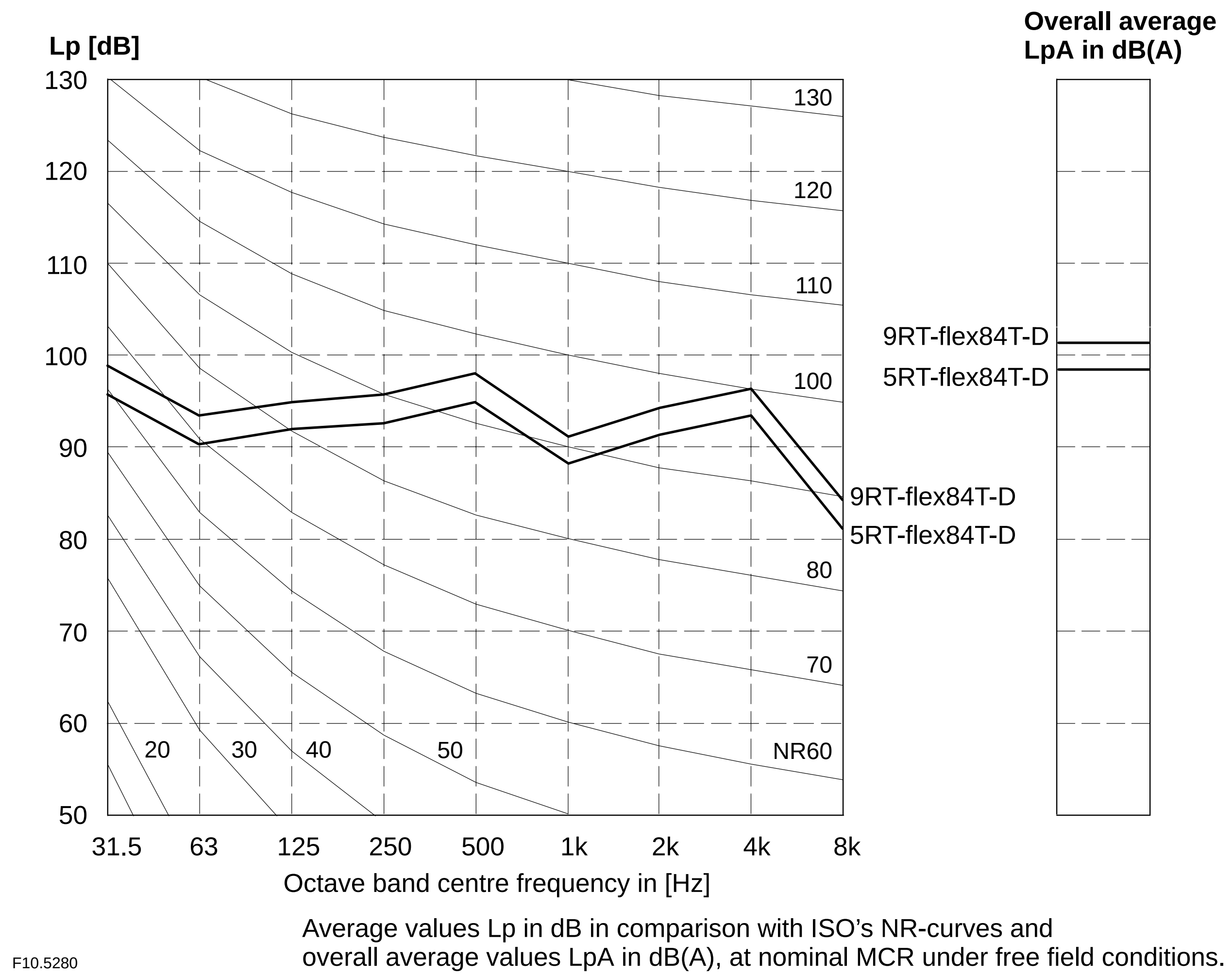


Fig. I3 Engine sound pressure level at 1 m distance

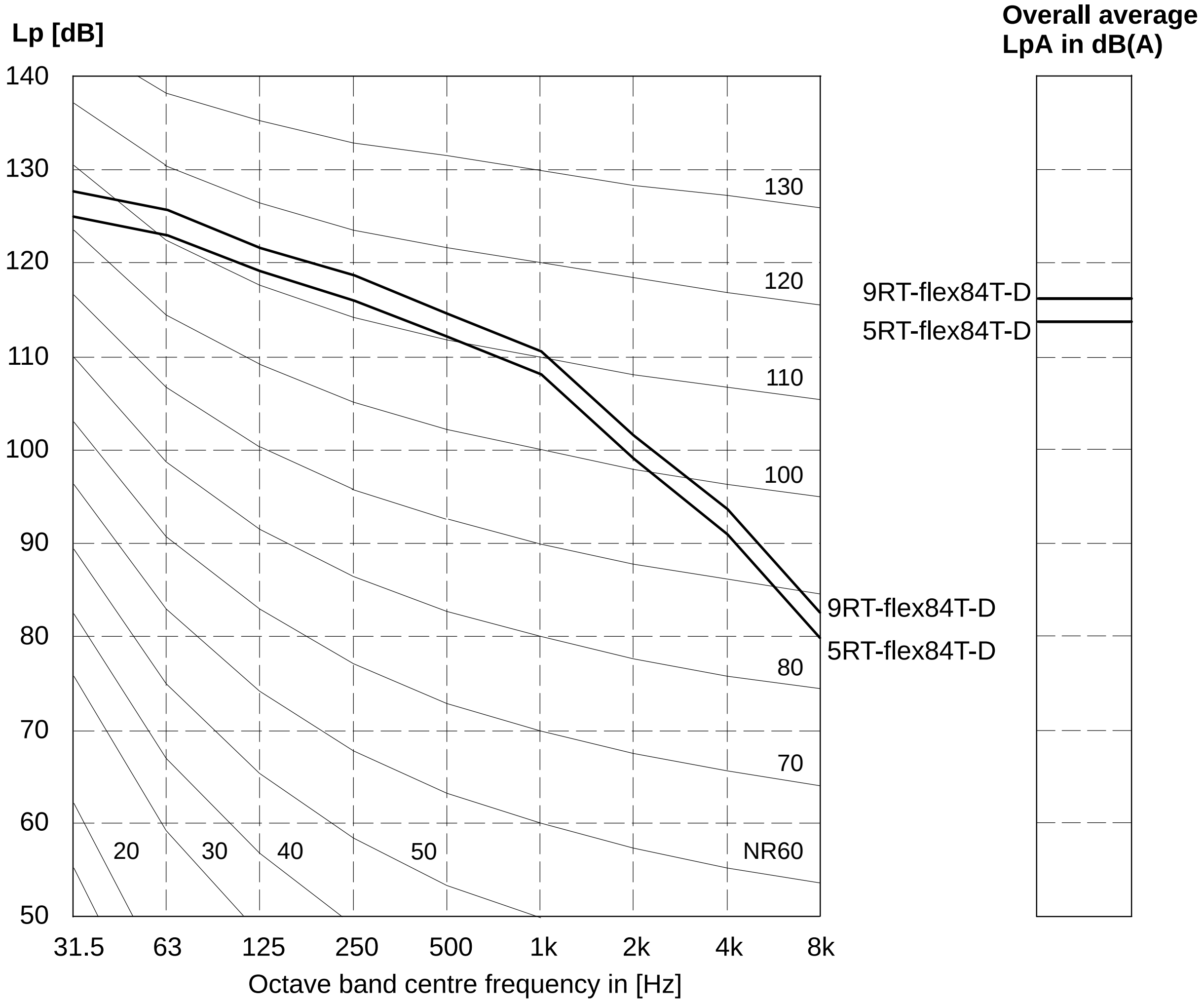
I2.2 Engine exhaust sound pressure level at funnel top

The sound pressure level from the engine exhaust gas system without boiler and silencer – given in figure I4 – is related to:

- a distance of one metre from the edge of the exhaust gas pipe opening (uptake)
- an angle of 30° to the gas flow direction
- nominal MCR

Each doubling of the distances reduces the noise level for about 6dB.

Depending on the actual noise level allowed on the bridge wing – which is normally maximum 60–70 dB(A) – a simple flow silencer of the absorption type may be necessary and placed after the exhaust gas boiler.
The silencer is dimensioned for a gas velocity of approximately 35 m/s with a pressure loss of approx. 2 mbar at specified MCR.



Average values Lp in dB in comparison with ISO's NR-curves and overall average values LpA in dB(A), at nominal MCR; at 1m distance from the edge of the exhaust gas pipe opening at an angle of 30° to the gas flow. Exhaust gas system without boiler and silencer.

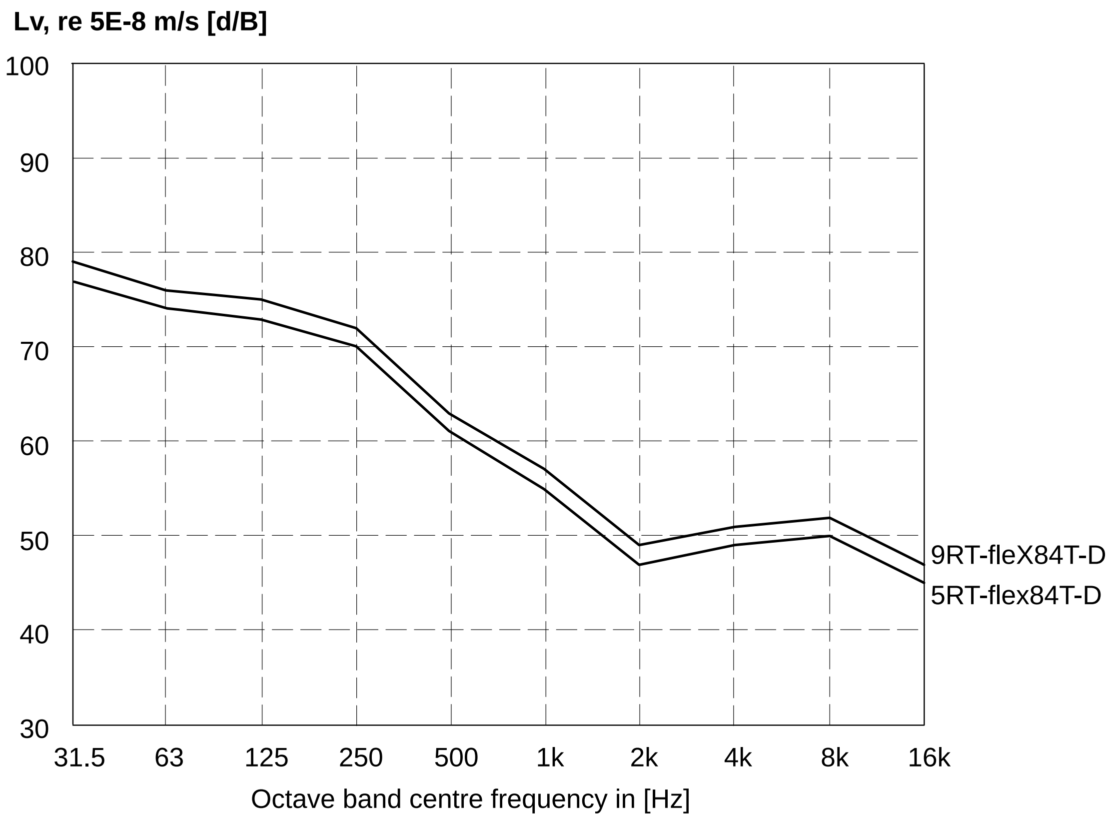
Fig. I4 Engine exhaust gas sound pressure level at funnel top

I. Engine emissions

I2.3 Engine structure borne noise

The vibrational energy is propagated via engine structure, bedplate flanges and engine foundation to the ship's structure which starts to vibrate, and thus emits noise.

The sound pressure levels in the accommodations can be estimated with the aid of standard empirical formulas and the vibration velocity levels given in figure I5.



Structure borne noise level Lv in dB at nominal MCR.

Fig. I5 Structure borne noise level at engine feet vertical

J. Tools

J1 Introduction

This chapter illustrates tools available for the running and maintenance of the main engine. It identifies their individual masses and dimensions to assist in the design and layout of the engine-room workshop and tool storage facilities.

The tools may not be part of the engine supply but they may be purchased separately and certain items may be removed or added depending on the requirements of the shipyard or operator. Therefore, we recommend a check is made of the extent of delivery before starting the detail design of workshop and storage spaces.

Please also note that the tools may differ from the illustrations in this book depending on the source of supply.

For tools with a mass of more than 25 kg, the mass is normally indicated.

Chapter J is organised as follows:

– **Standard tools (J2)**
  Tools and devices required for routine maintenance operations on the engine.

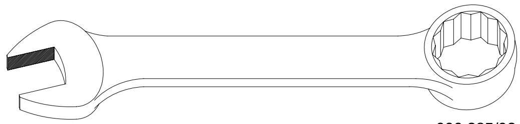
– **Recommended special tools (J3)**
  Additional tools recommended by Wärtsilä Switzerland Ltd, which will allow certain maintenance operations to be carried out more efficiently than with the use of standard tools.

– **Special tools, available on loan (J4)**
  Initially loaned for transportation and erection of the engine. They are returned to the engine manufacturer after completion of engine erection.

– **Storage proposal (J5)**
  Examples of tool panel arrangements and convenient locations for mounting the panels adjacent to the engine.

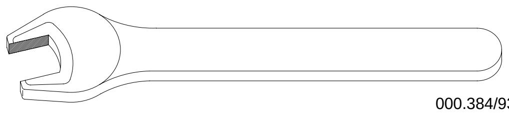
J2 Standard tools

<u>94000</u>	**Combination wrenches**
94000–36	2 Pieces AF36
94000–41	2 Pieces AF41
94000–46	2 Pieces AF46
94000–50	2 Pieces AF50
94000–55	2 Pieces AF55
94000–60	2 Pieces AF60



000.385/93

<u>94001</u>	**Open end wrenches**
94001–65	1 Piece AF65
94001–70	1 Piece AF70
94001–75	1 Piece AF75
94001–80	1 Piece AF80
94001–85	1 Piece AF85
94001–95	1 Piece AF95
94001–110	1 Piece AF110



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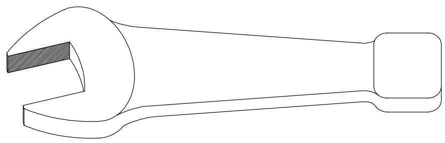
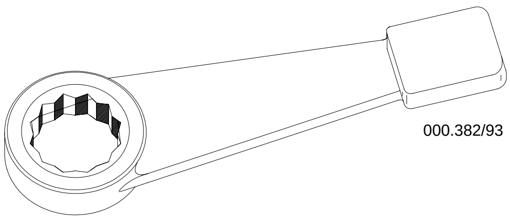
	Slugging open end wrenches
94001a–145	1 Piece AF145
94001a–160	1 Piece AF160



93.7463

<u>94002</u>	**Ring slugging wrenches**
94002–27	1 Piece AF27
94002–30	1 Piece AF30
94002–32	1 Piece AF32
94002–36	1 Piece AF36
94002–41	1 Piece AF41
94002–46	1 Piece AF46
94002–50	1 Piece AF50
94002–55	1 Piece AF55
94002–60	1 Piece AF60
94002–65	1 Piece AF65
94002–70	1 Piece AF70
94002–75	1 Piece AF75
94002–80	1 Piece AF80
94002–85	1 Piece AF85
94002–95	1 Piece AF95
94002–110	1 Piece AF110
94002–145	1 Piece AF145
94002–155	1 Piece AF155



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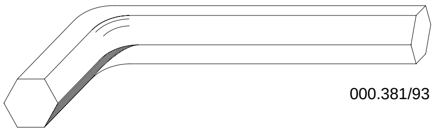
J. Tools

<u>94003</u> **Allen keys**
94003–17 1 Piece AF17
94003–19 1 Piece AF19
94003–22 1 Piece AF22
94003–24 1 Piece AF24
94003–27 1 Piece AF27



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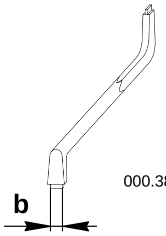
<u>94004</u> **Angle screwdrivers**
94004–10 1 Piece . . . . . b = 10 mm
94004–12 1 Piece . . . . . b = 12 mm
94004–25 1 Piece . . . . . b = 25 mm



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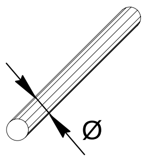
<u>94005</u> **Rods**
for pre-tensioning jacks
94005–8 3 Pieces . . . . Ø 8 mm
94005–10 3 Pieces . . . . Ø 10 mm
94005–14 3 Pieces . . . . $Ø_1$ 14 mm
94005–14.6 3 Pieces . . . . Ø 14.6 mm
94005–20 3 Pieces . . . . Ø 20 mm



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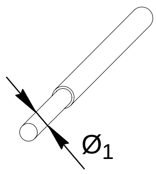

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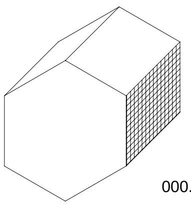
<u>94006</u> **Socket head keys**
94006–11 1 Piece AF11
94006–12 1 Piece AF12
94006–14 1 Piece AF14
94006–17 1 Piece AF17
94006–19 1 Piece AF19
94006–27 1 Piece AF27
94006–32 1 Piece AF32
94006–36 1 Piece AF36
94006–41 1 Piece AF41
94006–50 1 Piece AF50
94006–60 1 Piece AF60



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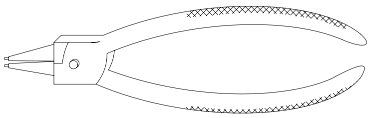
<u>94007</u> **Tongs**
94007–C8 1 Piece . . . . . Type C 8
94007–C19 1 Piece . . . . . Type C 19
94007–C40 1 Piece . . . . . Type C 40



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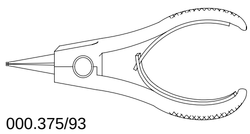
94007–A10 1 Piece . . . . . Type A 10
94007–A19 1 Piece . . . . . Type A 19
94007–A40 1 Piece . . . . . Type A 40

94007–A41 1 Piece . . . . . Type A 41



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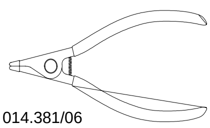
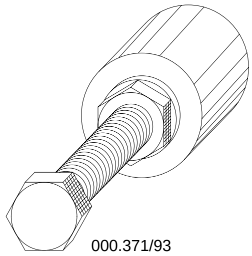


014.381/06

<u>94008</u> **Withdrawing gears**
for taper & cylindrical dowels and pins

94008–M4 1 Piece M4
94008–M5 1 Piece M5
94008–M6 1 Piece M6
94008–M8 1 Piece M8
94008–M10 1 Piece M10
94008–M12 1 Piece M12
94008–M16 1 Piece M16
94008–M20 1 Piece M20



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<u>94009</u> **Grip screws**

94009–M4 2 Pieces M4x150
94009–M5 2 Pieces M5x150
94009–M6 2 Pieces M6x150
94009–M8 2 Pieces M8x150
94009–M10 2 Pieces M10x150

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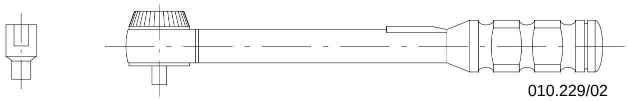
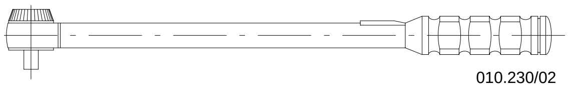
<u>94010</u> **1** **Torque spanner ¼”**
(Range of adjustment 2–25 Nm)
94010a Adapter piece $^3/_8$”–½”



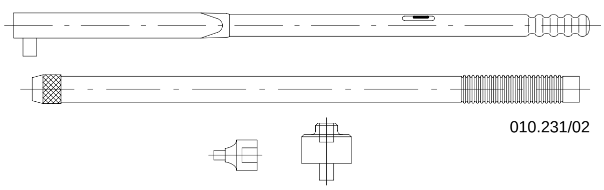
010.229/02

94011 **1** **Torque spanner ½”**
(Range of adjustment 20–200 Nm)



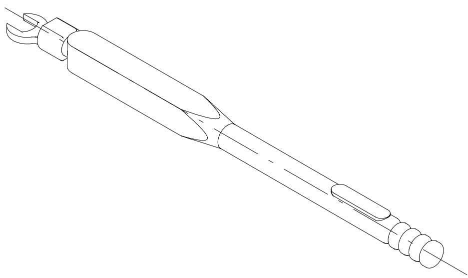
010.230/02

<u>94012</u> **1** **Torque spanner ¾”**
(Range of adjustment 140–760 Nm)
with extension tube and tool box
94012a adapter piece ¾” – ½”,
94012b shell type ratchet ¾” – ¾”



010.231/02

Torque spanner
<u>94013</u> **1** (Range of adjustment 8–40 Nm)
94013a **1** (Range of adjustment 20–120 Nm)
with open end spanner inserts:
94013–24 AF24
94013–27 AF27
94013–30 AF30

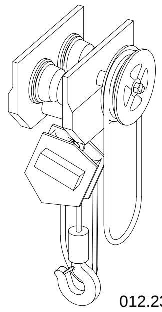


013.558/05

<u>94013b</u> **2** **Torque spanners**
(Range of adjustment 140–620 Nm)
with open end spanner inserts:
94013–24 AF24
94013–27 AF27
94013–32 AF32
94013–36 AF36
94013–46 AF46
94013–50 AF50
94013–55 AF55

J. Tools

94017b **2 Spur-geared chain blocks**
(WLL 5000 kg)
94017a **1 Spur-geared chain block**
(WLL 3000 kg)
94017c **2 Spur-geared chain blocks**
(WLL 1000 kg)



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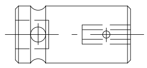
94022 **1 Adapter piece $^3/_8$"–¼"**
94022a **1 Socket wrench insert**
AF3
94022b **1 Socket wrench inserts ¾"**



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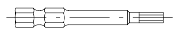
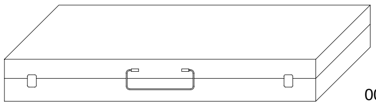


<u>**94025**</u> **1 Tool box with socket wrench set ½"**



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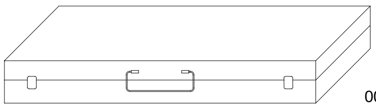
<u>**94026**</u> **1 Tool box with hex. head drivers ½"**



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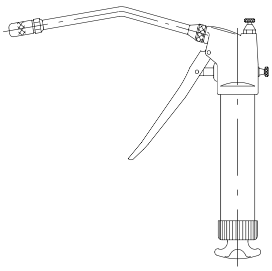
94032 **1 High pressure grease gun**
for lubricating grease nipples on
fuel pump regulating linkage



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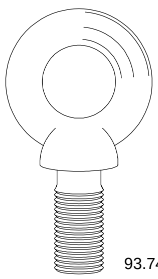
<u>**94045**</u> **Eye bolts**
94045–M10 8 Pieces M10
94045–M12 8 Pieces M12
94045–M16 8 Pieces M16
94045–M20 8 Pieces M20
94045–M24 8 Pieces M24
94045–M30 8 Pieces M30
94045–M36 8 Pieces M36
94045–M42 8 Pieces M42
94045–M48 4 Pieces M48
94045–M56 2 Pieces M56



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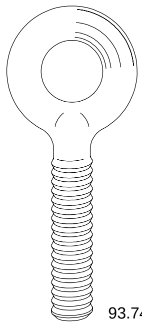
Eye screw
<u>**94045a–M16**</u> 6 Pieces M16x145



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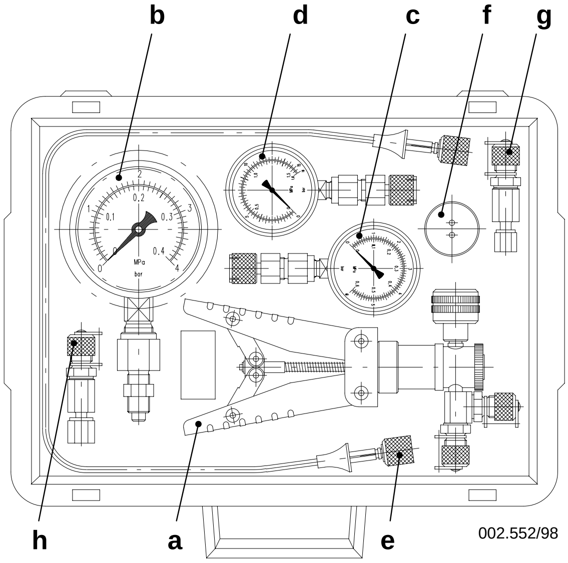
J. Tools

94050 **1 Tool for pressure measurement**
for pneumatic elements

94050a	1	Compressed air pump
94050b	1	Pressure gauge 0–4 bar
94050c	1	Pressure gauge 0–6 bar
94050d	1	Pressure gauge 0–16 bar
94050e	2	HP hoses
94050f	1	Adjusting tool
94050g	1	Measuring connection M12x1
94050h	1	Measuring connection M14x1

Mass: 3.7 kg



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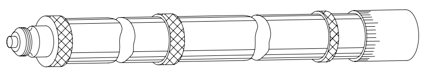
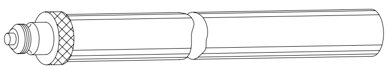
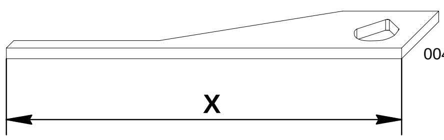
94101 **1 Inside micrometer**
with case
(Measuring range 50–1010 mm)


000.366/93

94101a **2 Extensions**
Length of 480 mm


000.365/93

94107 **1 Assembly template**
for positioning locating dowel pins
in main bearing shell
X = 260 mm



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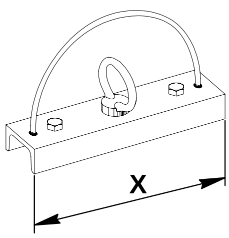
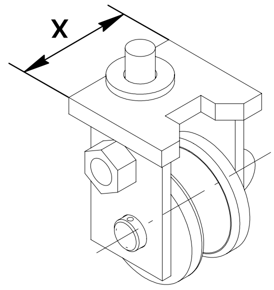
94116 **1 Lifting tool**
for removal and fitting of
main bearing shell
X = 290 mm



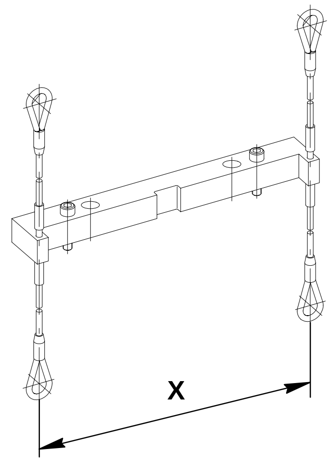
008.541/01

J. Tools

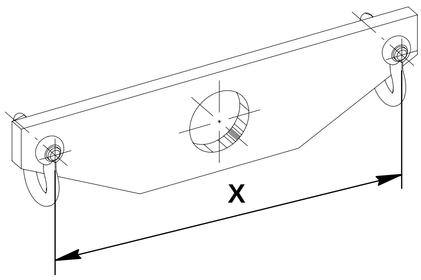


94117 2 **Roller supports**
for removal of main bearing
with screws M30x60 and washers ∅68 mm
X =140 mm, Mass: 11 kg
(max. lifting capacity 900 kg)

94118 1 **Turning-out device**
for removal and fitting of
main bearing shell
X = 330 mm, Mass: 4 kg

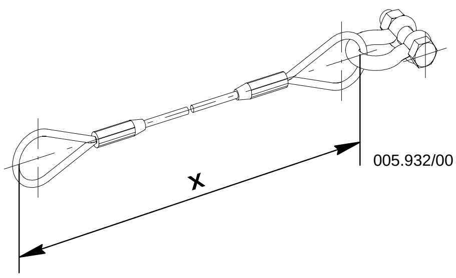


94119 1 **Lifting yoke**
for removal and fitting of
main bearing shell
X = 460 mm



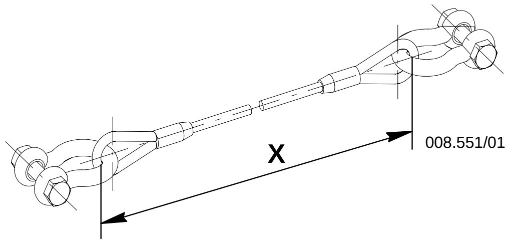
Rope (∅ 9 mm)
with shackle(s) for removal and fitting
of main bearing cover and shell

94120b	2 Pieces . . x = 300mm
94120c	1 Piece . . . x = 1200mm
94120d	1 Piece . . . x = 1500mm
94120e	1 Piece . . . x = 1800mm
94120f	1 Piece . . . x = 2000mm
94120g	1 Piece . . . x = 2300mm
94120i	1 Piece . . . x = 2800mm
94120k	1 Piece . . . x = 3000mm
94120l	1 Piece . . . x = 3500mm
94120m	1 Piece . . . x = 4000mm

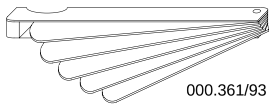


Rope (∅ 9 mm)
with two shackles for removal and fitting
of main bearing cover and shell

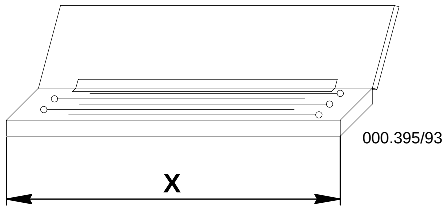
94120q 1 Piece x = 1000mm



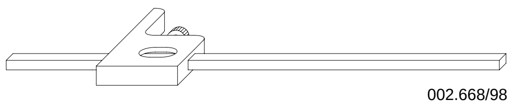
94122 1 Feeler gauge



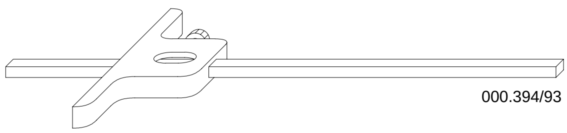
94123 1 Special feeler gauge
for main bearing
X = 620 mm



94124 1 Depth gauge
measuring range 250 mm

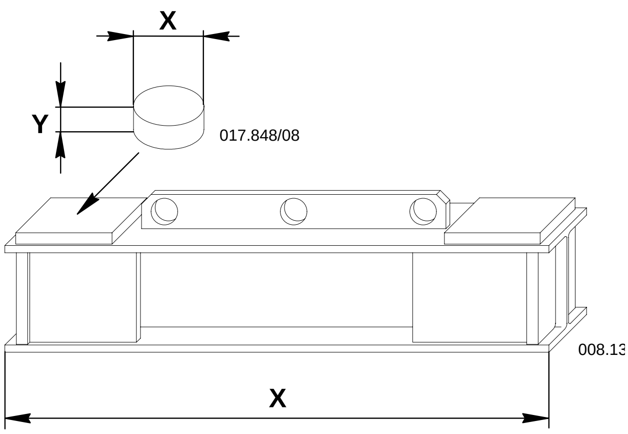


94126 1 Depth gauge
measuring range 700 mm



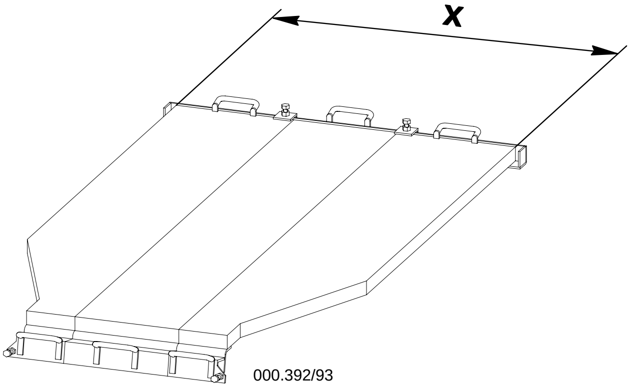
94141 1 Support
for lifting crankshaft for
removal of main bearing shells
X =1300 mm, Mass: approx. 264 kg

94141a 2 Ground plates
X = ∅ 240 mm
Y = 70 mm

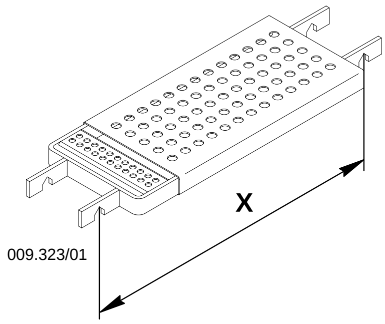


J. Tools

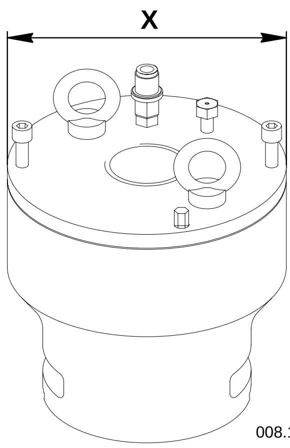
94142 **2** **Working platforms**
consisting of three grids each
X = 1030 mm
Mass: approx. 123 kg



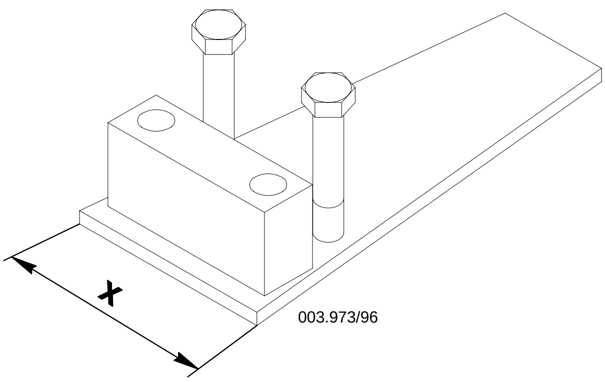
94143 **3** **Working supports**
X = 920–1170 mm
Mass: approx. 4 kg/unit



94145 **1** **Pre-tensioning jack**
for foundation bolts,
including a metal box
X = 170 mm
Mass: approx. 14 kg

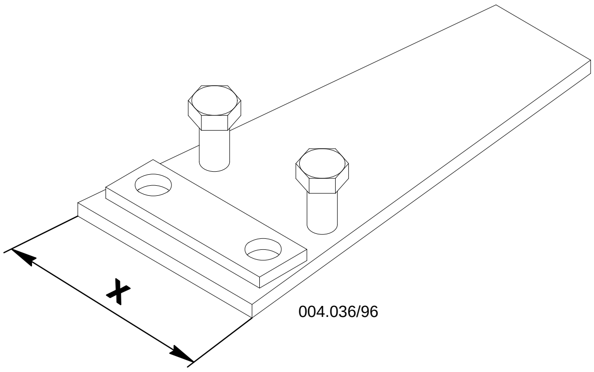


94155 **1** **Turning-out device**
with screws
for turning out thrust bearing pads
(with 1-part gear wheel)
X = 268 mm
Mass: approx. 26 kg

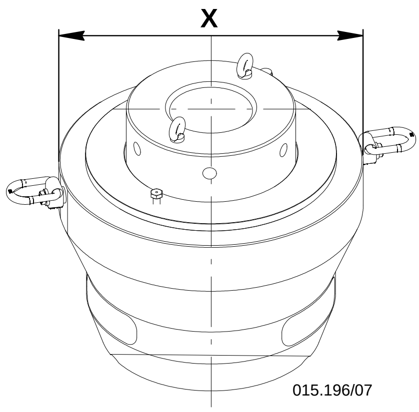


J. Tools

94155a 1 Turning-out device
with screws
for turning out thrust bearing pads
(with 2-part gear wheel)
X = 268 mm
Mass: approx. 15.8 kg



94180 2 Hydraulic pre-tensioning jacks
for tie rods,
including a metal box
X = 440 mm
Mass: approx. 191 kg



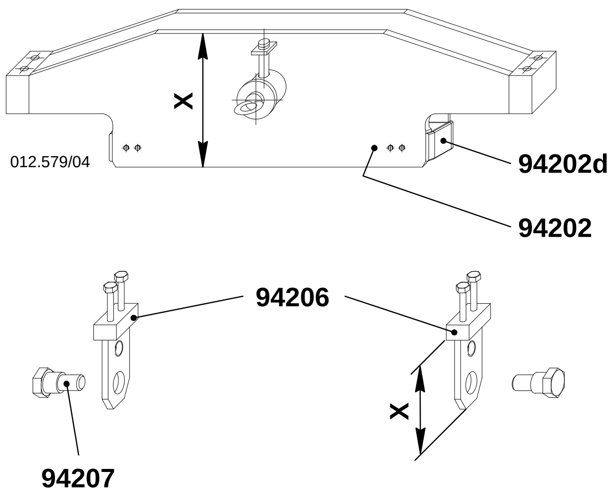
94201 1 Device
for fitting/transporting a cylinder liner
Mass: approx. 203 kg
consisting of:

94202 1 Lifting gear
X = 350 mm

94202d 2 Distance plates
with 8 screws M12x50 and nuts

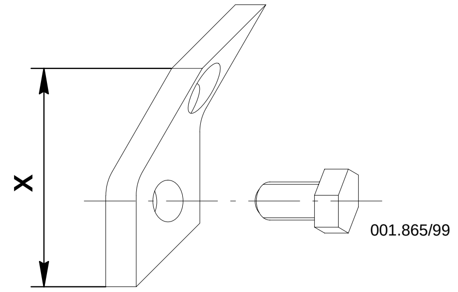
94206 2 Suspension straps
with 2 screws each
X = 225 mm

94207 2 Special screws M42

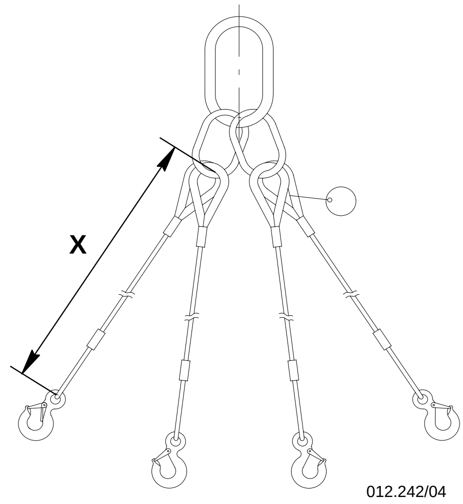


J. Tools

94208 4 Suspension straps
with screws M16x25
for removal and fitting of an
antipolishing ring
X = 101 mm

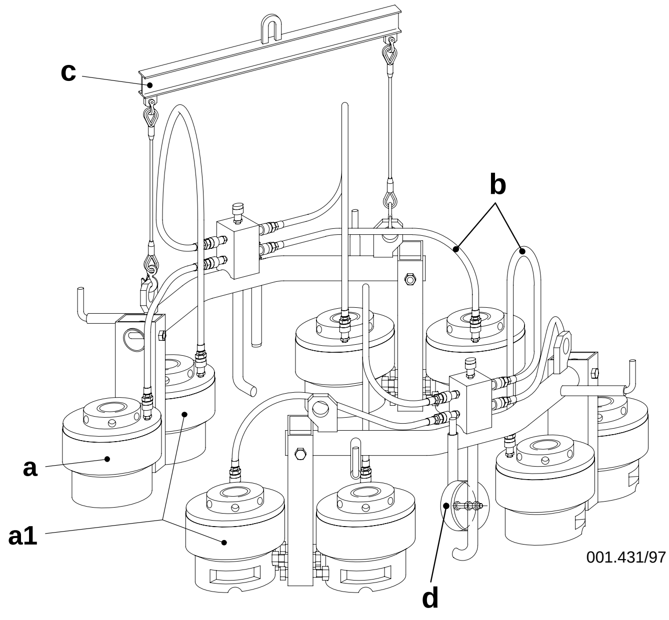


94209 1 Lifting hook
for removal and fitting of the
antipolishing ring
X = 1000 mm

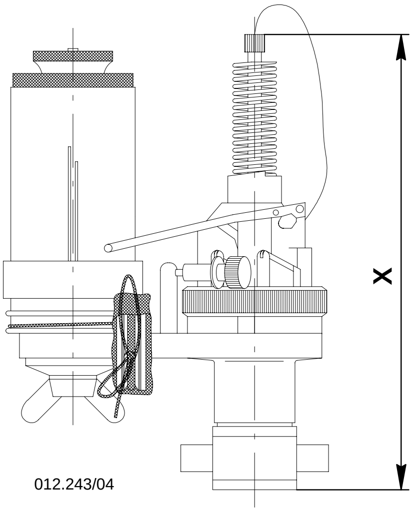


94215 1 Hydraulic tensioning device
with connecting elements
for cylinder cover studs,
consisting of:
a = 4 pre-tensioning jack LEFT
a1 = 4 pre-tensioning jack RIGHT
b = High pressure hoses,
900 mm long
c = Suspension device
d = 2 piston reset devices

Mass: approx. 645 kg

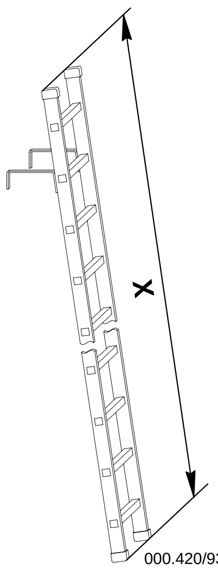


94219 1 Cylinder pressure measuring tool (indicator),
including a wooden box
X = 165 mm



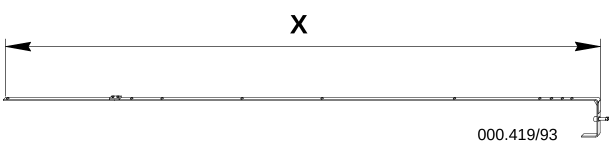
012.243/04

94224 1 Ladder
for measuring cylinder liner bore
X = 3600 mm
Mass: approx. 6 kg



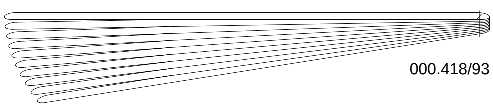
000.420/93

94225 1 Measuring gauge
for measuring cylinder liner bore
(accessory for it:
inside micrometer tool 94101)
X = 3636 mm



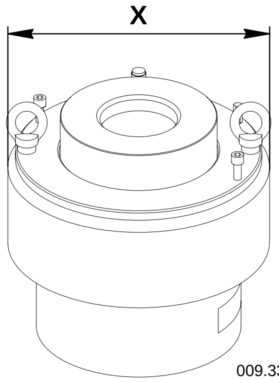
000.419/93

94238 1 Feeler gauge (10-part)
for checking bearing clearances
Leaf length = 600 mm

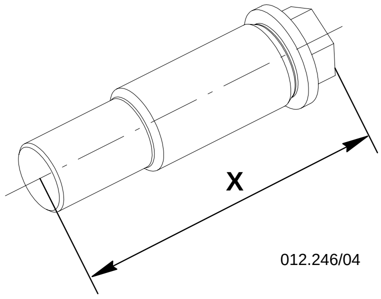


000.418/93

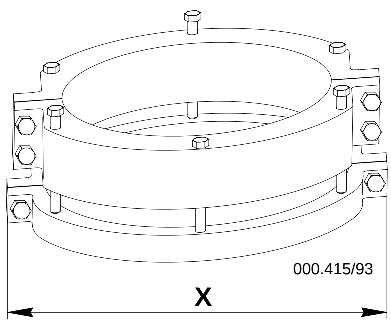
J. Tools



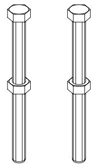
94252 2 Pre-tensioning jacks
for exhaust valve cage
X = 325 mm
Mass: approx. 100 kg



94259 2 Retaining screws
for exhaust valve
X = 80 mm

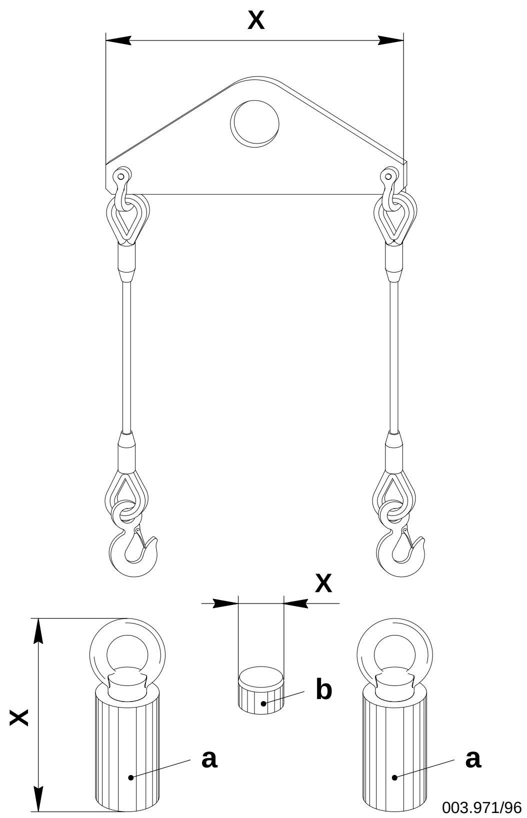


94261 1 Valve seat fitting and extracting device
X = 745 mm
Mass: approx. 130 kg



94263 2 Jack screws
to guide bush
for exhaust valve M16x180

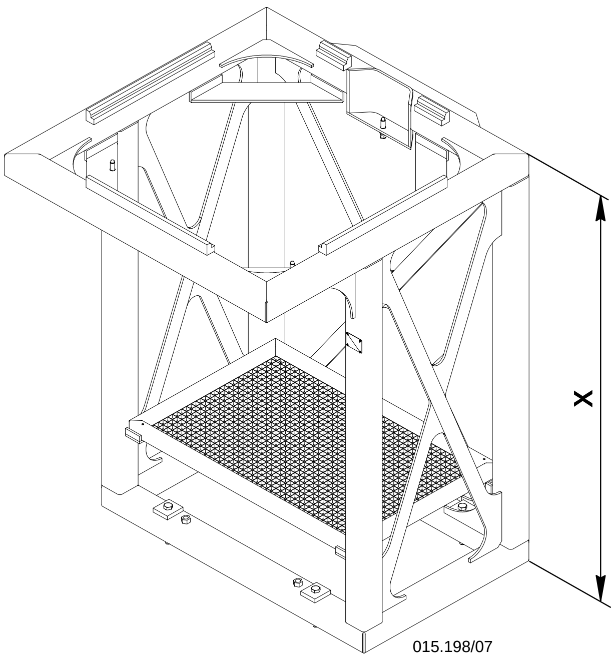
J. Tools



94265 1 Suspension device
for cylinder cover and exhaust valve cage
X = 980 mm
further:
a = 2 Special eye nuts
X = 356 mm

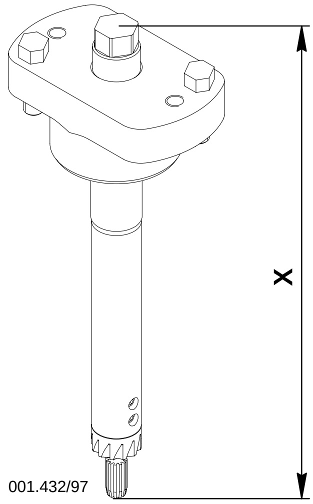
b = 3 Protection caps
X = 100 mm
Mass: approx. 124 kg

94266 1 Cradle
for removal and fitting of water guide jacket
X = 2306 mm

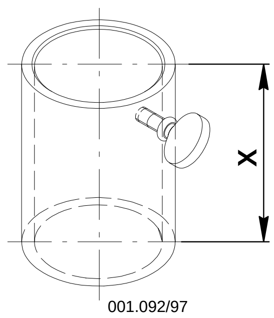


J. Tools

94270 1 Device
for overhauling injection valve seat in cylinder cover
X = 484 mm
Mass: approx. 11.8 kg



94271 Protection cap
for fuel nozzle
(1 piece each nozzle)
X = 110 mm

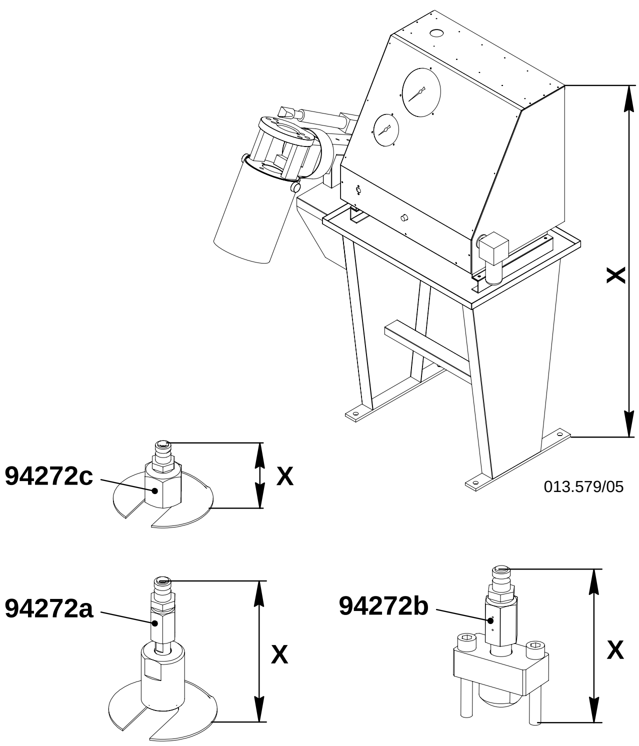


94272 1 OBEL test bench
for setting and testing of:
– injection valve
– relief valve (cylinder cover)
– relief valve (intermediate fuel accu.)
X = 1458 mm
including:

94272a 1 Valve holder
for checking and adjusting relief valve
X = 149 mm

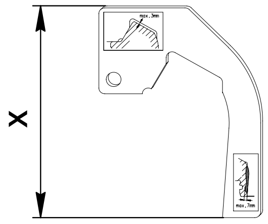
94272b 1 Connecting piece
for adjusting the injection valve
X = 124 mm

94272c 1 Valve holder
for checking relief valve to cylinder cover
X = 68 mm



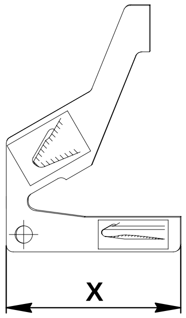
J. Tools

1 **Gauge**
for checking wear on exhaust valve seat
X = 210 mm



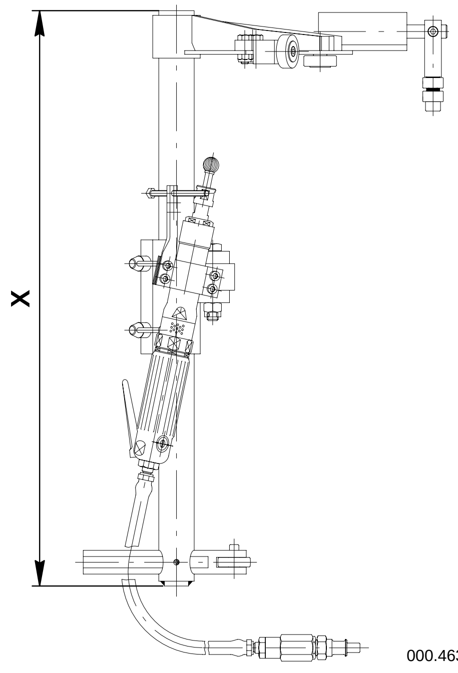
002.563/98

94292 1 **Gauge**
for checking wear on disc of exhaust valve spindle
X = 262 mm



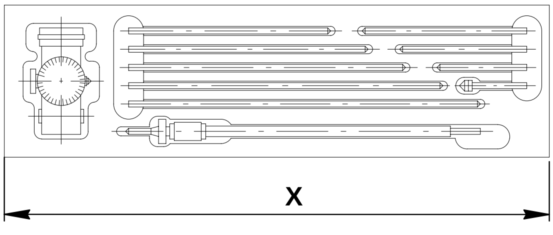
004.061/96

94299 1 **Grinding device**
for removing a built-up wear ridge at top of cylinder liner running surface
X = approx. 600 mm
Mass: approx. 14.6 kg



000.463/93

94305 1 **Crankshaft checking equipment**
for measuring crank deflection
(in wooden box)
X = 364 mm

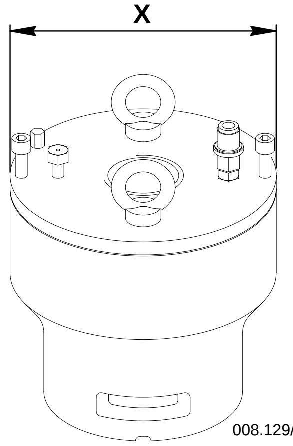


000.412/93

J. Tools

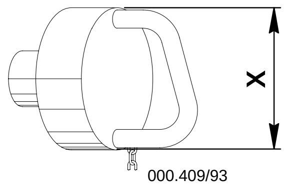
94314 2 Pre-tensioning jacks
for tensioning connecting rod studs to bottom end bearing, including a metal box
X = 270 mm
Mass: approx. 47 kg

94315 2
Pre-tensioning jacks
for tensioning connecting rod studs to top end bearing, including a metal box
X = 230 mm
Mass: approx. 32 kg



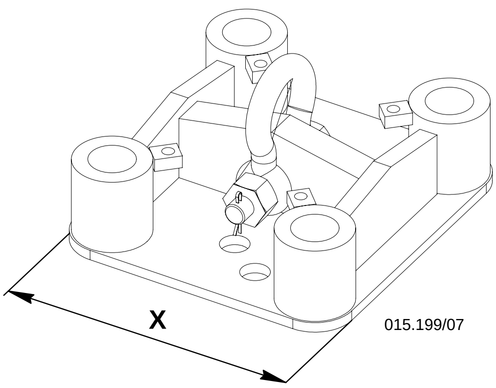
008.129/96

94323 4 Retaining pins
to prop up crosshead guide shoes when removing or fitting a connecting rod or a crosshead
X = 125 mm



000.409/93

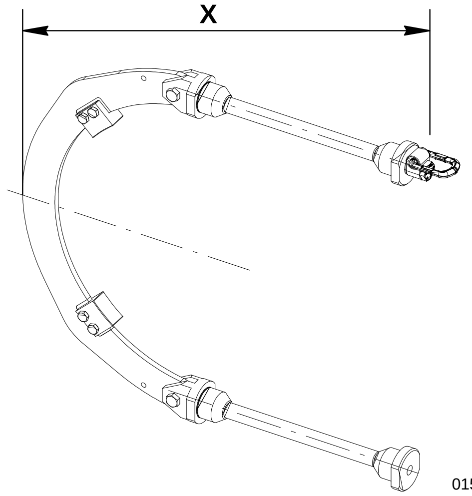
94324 1 Cover and lifting plate
(incl. shackle) to crosshead
X = 450 mm
(max. lifting capacity 11 600 kg)
Mass: approx. 105 kg



015.199/07

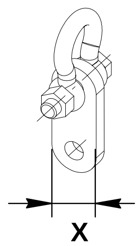
J. Tools

94331 **1** **Holder**
for removal and fitting of a connecting rod,
including: 4 Nut pieces
2 Lifting lugs
X = 1446 mm



015.200/07

94331a **1** **Connecting element with shackle**
X = 70 mm
(max. lifting capacity 11 600 kg)

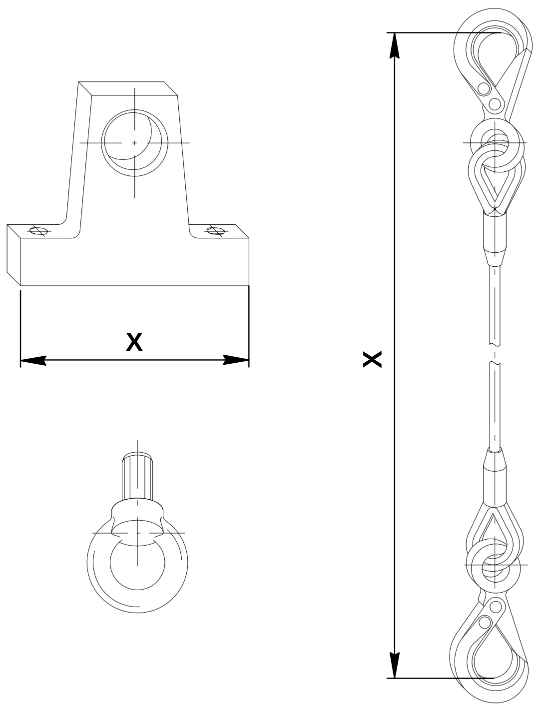


94333 **1** **Lifting device**
to piston for removal of top end bearing cover,
Mass: approx. 33 kg
consisting of:

94333a **2**
Suspension straps
X = 240 mm

94333b **2**
Wire ropes with hooks
X = 1856 mm

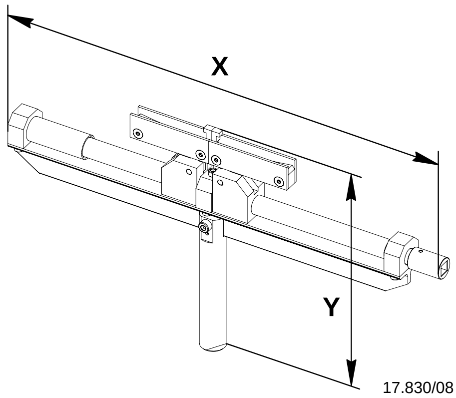
94333c **2**
Eye bolts M30



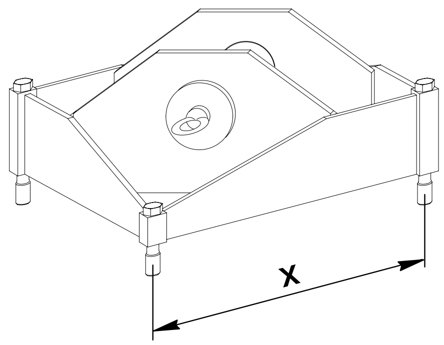
001.314/97

J. Tools

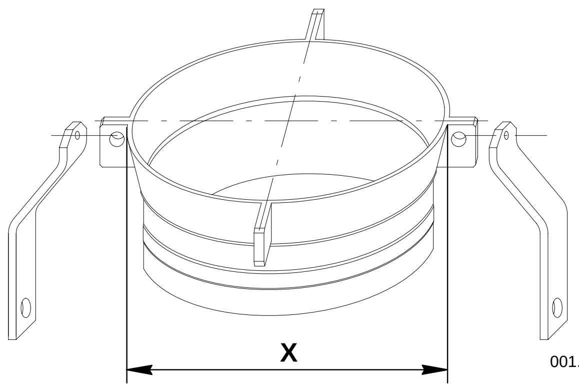
94338 1 Piston ring tensioning device
X = 500 mm
Y = 303.5 mm



94341 1 Piston suspension device
X = 467 mm
Mass: approx. 57 kg

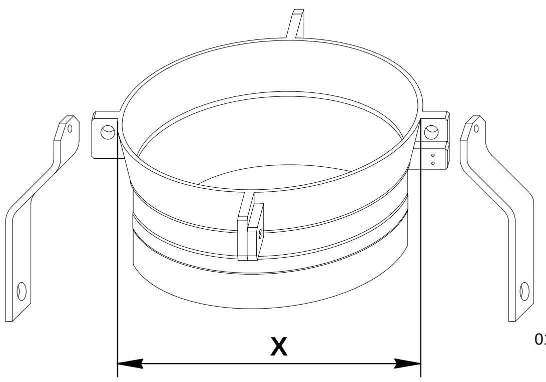


94342a 1 Insertion funnel
for fitting the piston
X = 945 mm
lincluding:
2 Holders
2 Screws M16x35
2 Screws M42x60
Mass: approx. 81 kg

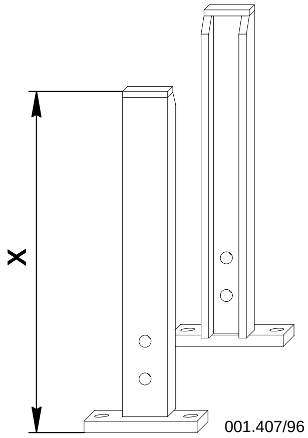


94342b 1 Insertion funnel (2-part)
for fitting the piston with restricted height to crane hook

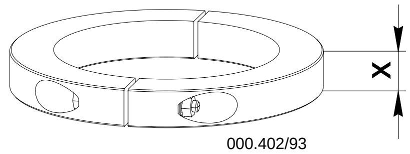
including: 2 Holders
2 Screws M16 x 35
2 Screws M42 x 60
2 Fitted screws M8 x 55
X = 945 mm
Mass: approx. 81 kg



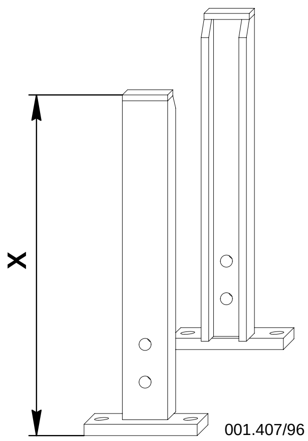
94345 2 Distance holder
for removal and fitting of piston rod
gland and piston
X = 500 mm



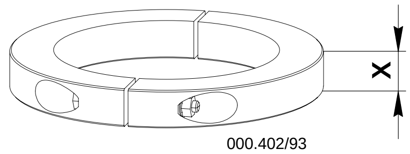
94345b 1 Clamp ring
for 94345a
X = 75 mm



94345 2 Distance holder
for removal and fitting of piston rod
gland and piston
X = 500 mm

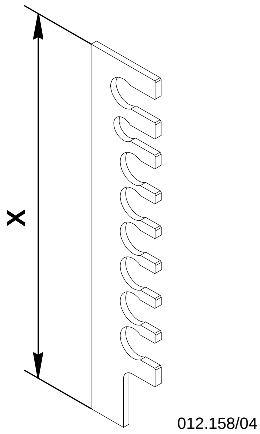


94345b 1 Clamp ring
for 94345a
X = 75 mm
Mass: approx. 5.4 kg

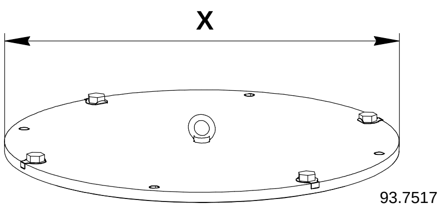


J. Tools

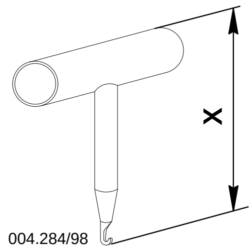
94345c 1 Gauge
for fitting scraper rings
X = 386 mm



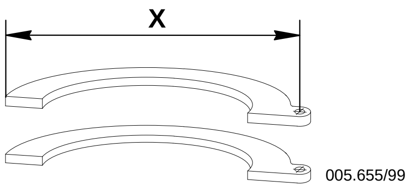
94345d 1 Cover plate
for covering bore of piston rod gland in cylinder jacket (when piston and gland are removed)
X = 762 mm



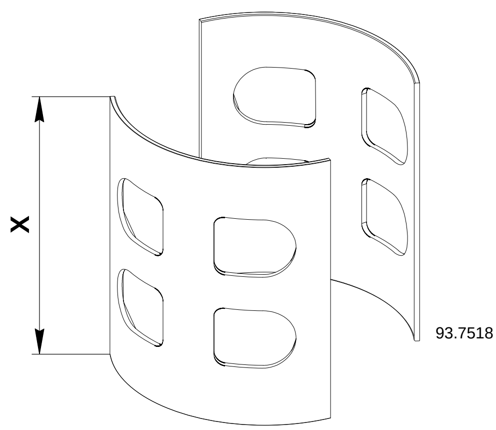
94345e 2 Assembly tools
for tensioning springs to piston rod gland
X = 160 mm



94345f 4 Distance pieces
for fitting rings to upper gland group, 2 pieces each 11 and 19 mm
X = 405 mm

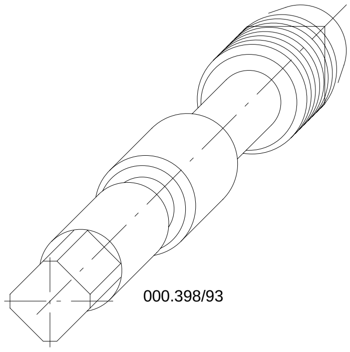


94347 1 Propping device
consisting of 2 segments for changing compression shims
X = 540 mm
Mass: approx. 35 kg

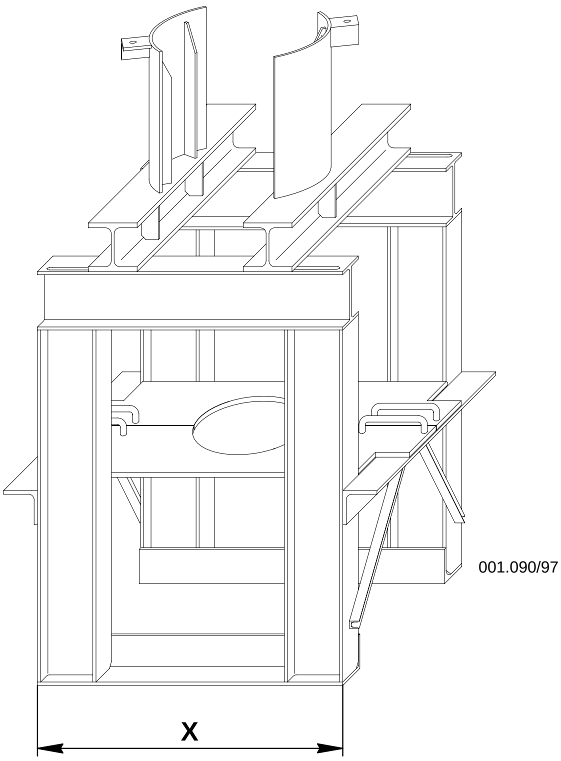


J. Tools

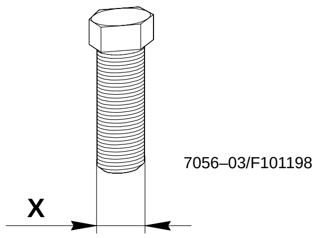
94348 1 Tap M24
for cleaning carbon deposits in threaded holes of piston crown



94350 2 Devices
for supporting piston and removal of piston rod gland
X = 1210 mm
Mass: approx. 418 kg

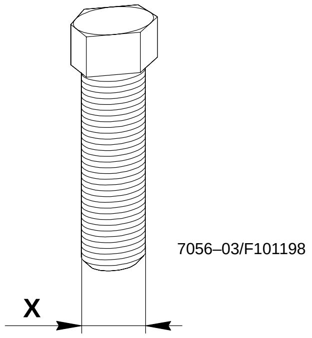


94363 2 Jacking screws
for separating piston crown from piston skirt
X = M20

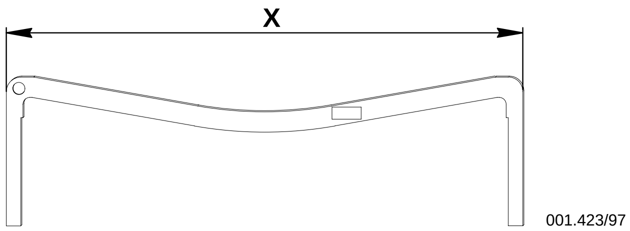


J. Tools

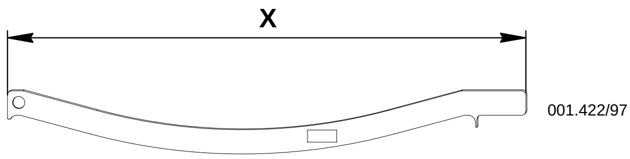
94364 **2** **Jacking screws**
for separating piston skirt from piston rod
X = M24



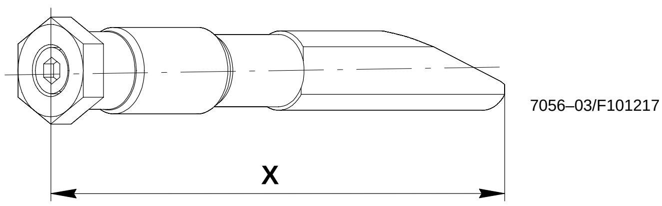
94366 **1** **Template**
for shape of top of piston crown
X = 892 mm



94366a **1** **Template**
for shape of top of piston crown
(for use with piston in situ)
X = 986 mm



94410 **Adjusting devices**
for alignment of intermediate wheel
3 pieces for 5–7 cylinder engines
6 pieces for 8–10 cylinder engines
X = 270 mm



94410a **Adjusting devices**
3 pieces for 5–7 cylinder engines
X = 230 mm

94412 1 Tightening device
(supplied only for engine equipped with 2-part gear wheel on crankshaft) consisting of:
Mass: approx. 27 kg

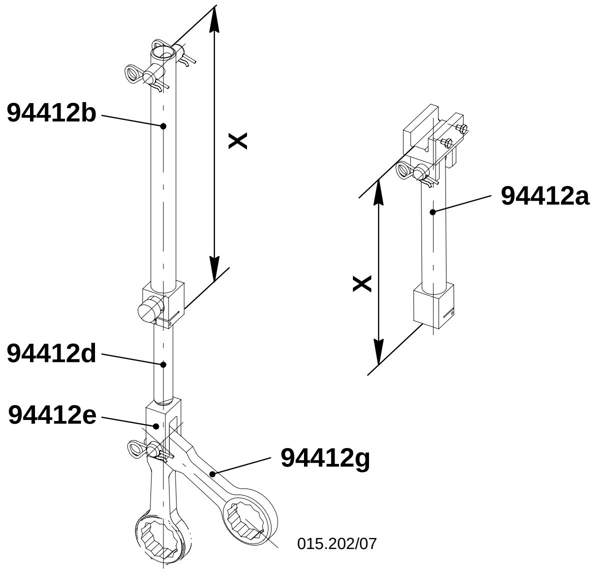
94412a 1
Clamping fork
(for 5–7 cylinder engines)
X = 485 mm

94412b 1
Support
(for 5–10 cylinder engines)
X = 640 mm

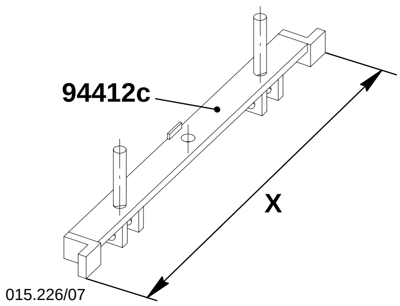
94412d 1
Hydraulic ram 44.8 kN
ENERPAC RC-57

94412e 1
Forked piece

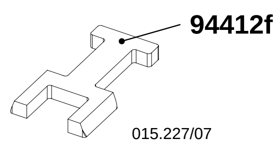
94412g
Impact ring spanners AF 75



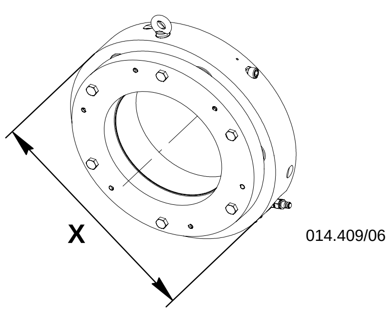
94412c 1 Retaining device
with screw M30x50
X = 1090 mm



94412f 1 Holding wrench AF 75

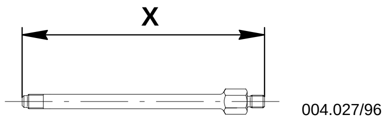


94424 1 Hydr. jacking tool
for removing & fitting fuel cams with conical bush, including 6 screws M16x180
X = 540 mm

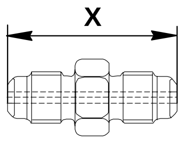


J. Tools

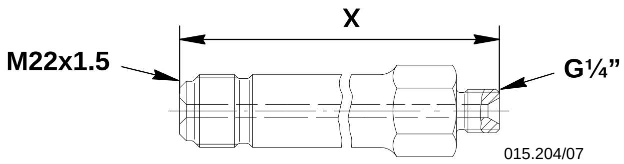
94426 **1** **Connection piece**
for repositioning the driving wheel of servo oil pumps
X = 247 mm



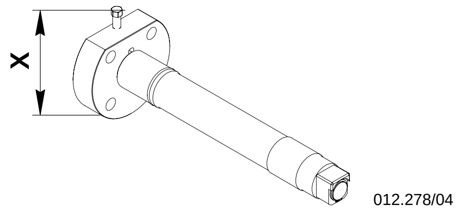
94426a **1** **Adapter piece**
for removing and fitting 2-part fuel cam
X = 45 mm



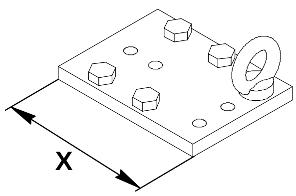
94427 **1** **Connection piece**
for removing and fitting
of jack bolts to main bearing
X = 198 mm



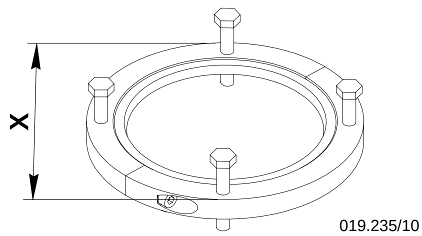
94430 **4** **Devices (roller lifting tools)**
for cutting out & in of fuel pump(s)
X = 116 mm



94435 **1** **Lifting plate**
for removal and fitting of Dynex servo oil pump
X = 190 mm
(max. lifting capacity 280 kg)

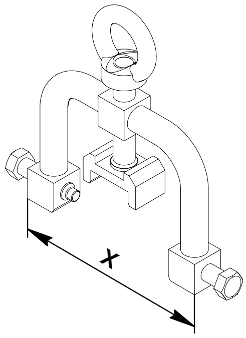


94550 **1** **2-part clamping ring**
for removal of non-return valve to fuel pump with 4 screws M10x60
X = 210 mm



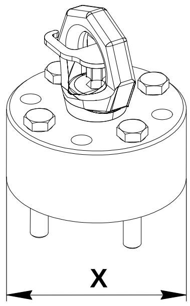
J. Tools

94551 **1** **Fitting & dismantling device**
for removal and fitting of guide pin to fuel pump
X = 304 mm



008.762/00

94552 **1** **Cover**
with head screws M12x70
for removal and fitting of a fuel pump
X = 120 mm

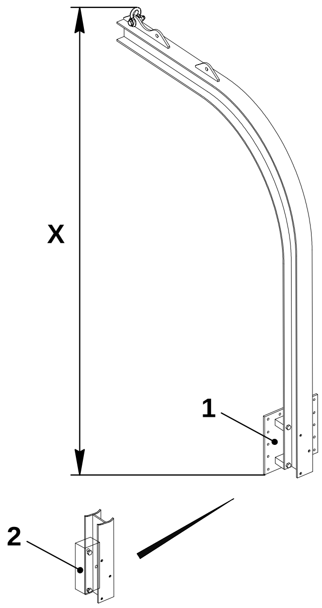


012.280/04

94553b **1** **Lifting support**
for removal and fitting of cover and bearing covers to supply unit, including:

1 **Flange (1)**
with 4 screws M16x35

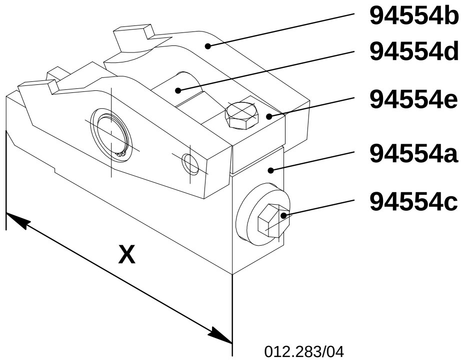
1 **Distance plate (2)**
with 4 screws M16x110
X = 2383 mm
(max. lifting capacity 540 kg)



014.386/06

94554 **1** **Fork lever**
for lifting camshaft consisting of:

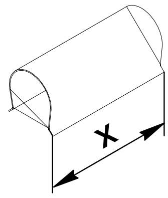
94554a **Face plate**
94554b **Rocker arm**
94554c **Nut**
94554d **Bolt with circlip**
94554e **Web with screw**
X = 329 mm



012.283/04

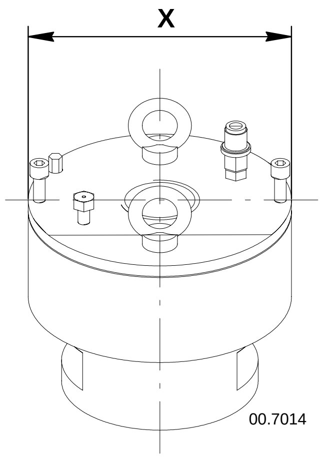
J. Tools

94555 **Spacers**
for cutting out of individual fuel pumps,
depending on number of cylinders:
4 pieces for 6–7 cylinder engines
6 pieces for 8–10 cylinder engines
X = 95 mm



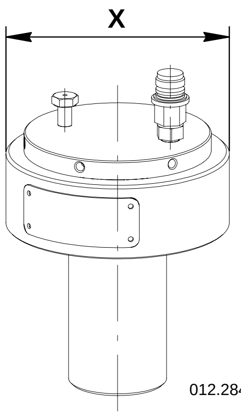
008.764/01

94556 **2** **Pre-tensioning jacks**
for waisted bolts to intermediate wheel
bearing of supply unit,
including a metal box
X = 195 mm



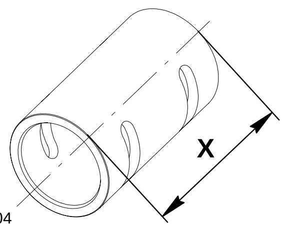
00.7014

94557 **2** **Pre-tensioning jacks**
for gear wheel and waisted bolts to
camshaft bearing,
including a metal box
X = 155 mm



012.284/04

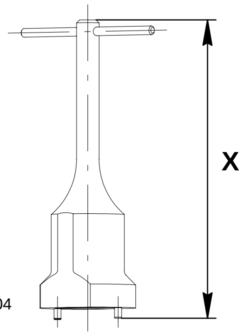
94558 **2** **Sleeves**
X = 166 mm



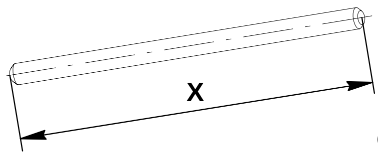
012.285/04

J. Tools

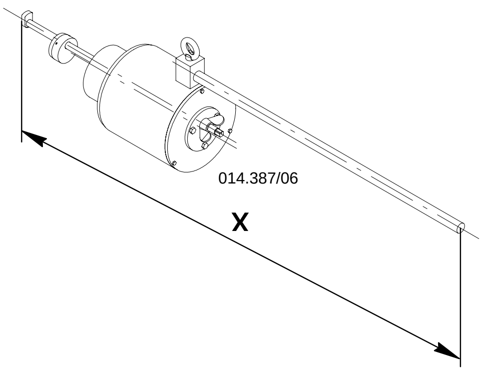
94559 1 Socket wrench
X = 206 mm



94560 2 Round bars Ø 6 mm
X = 100 mm



94561 1 Device
for removal and fitting of pinion to supply unit
X = 1376 mm

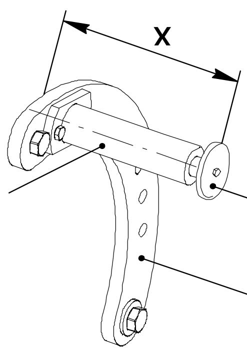


94562 1 Cam adjusting gear
X = 194 mm
consisting of:

94562a 1 Angle rail
including: 2 Fitted bolts M16x40
1 Washer
(there are appropriate tools depending on number of cylinders)

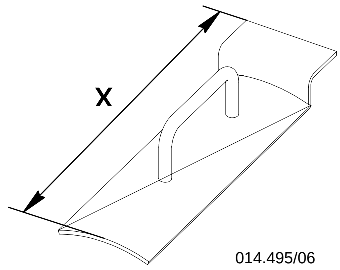
94562e 1 Guide tube

94562f 1 Positioning unit

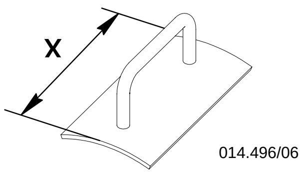


J. Tools

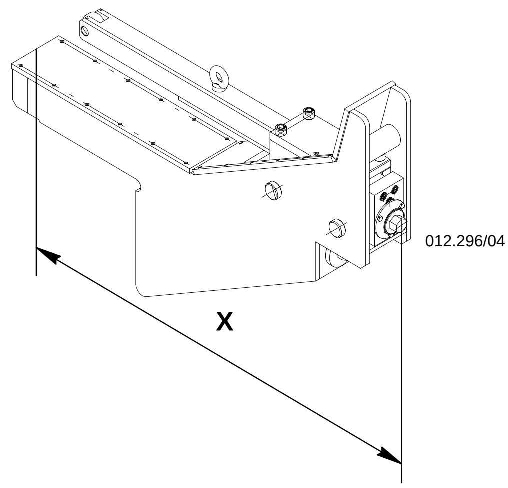
94563 1 Distance holder
for setting fuel cam No. 1
X = 365 mm



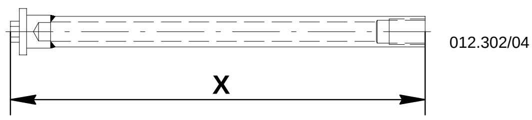
94563a 1 Distance holder
for setting fuel cams No. 2
X = 200 mm



94566 2 Supports
for removal and fitting of camshaft
X = 1097 mm

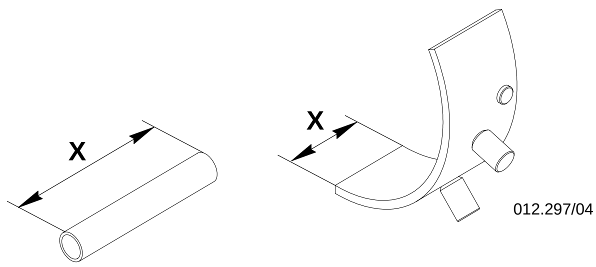


94566a 2 Tension nuts
to supports 94566
X = 692 mm



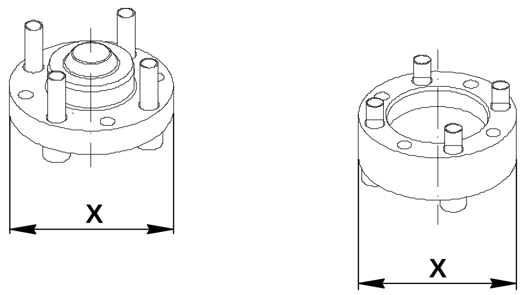
94567 1 Assembly template
for removal and fitting of bearing shells to supply unit
X = 100 mm
including:

94567a 1 Pipe
X = 200 mm

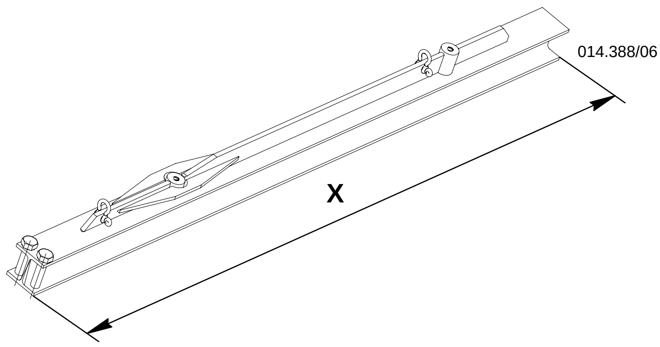


94569 2 Blank flanges
to fuel pump
with screws M12x55 mm
X = 110 mm

94569a 2 Blank flanges
to intermediate fuel accumulator
with screws M12x50 mm
X = 110 mm

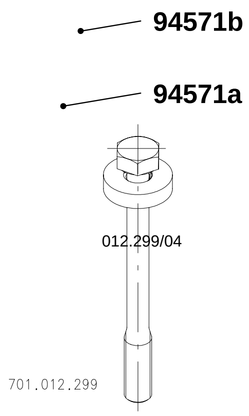


94571 1 Rail
for removal and fitting of intermediate wheel to supply unit,
including: 2 Shackles
(Lifting capacity 1500 kg)
4 Screws M30x130
X = 2565 mm



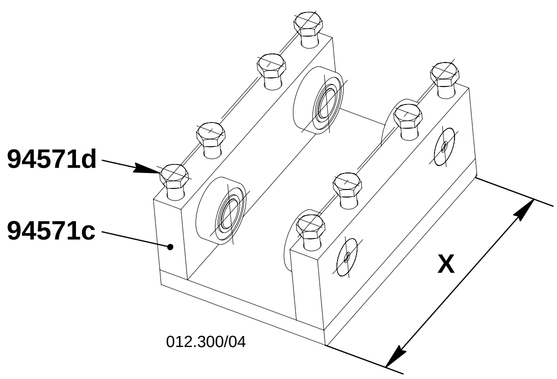
94571a 2 Screws M20x200

94571b 2 Washers



94571c 1 Carriage
to rail 94571
X = 280 mm

94571d 8 Screws M16x130

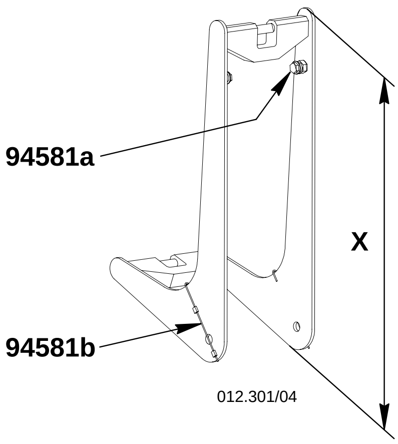


J. Tools

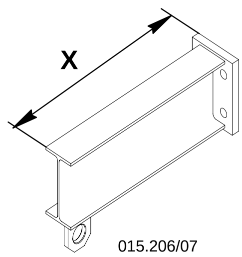
94581 1 Assembly tool
for removal and fitting of fuel pump
X = 905 mm
(max. lifting capacity 450 kg)
including:

94581a 2 Guide screws

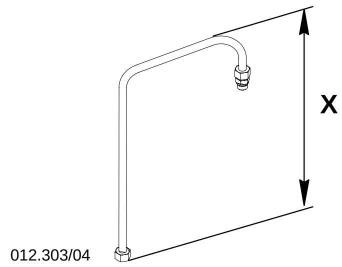
94581b 2 Steel wires



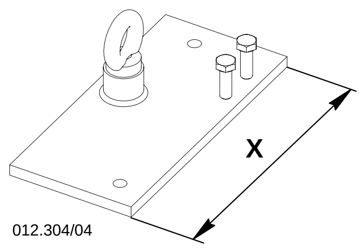
94582 1 Support
for removal and fitting of fuel pump
X = 640 mm



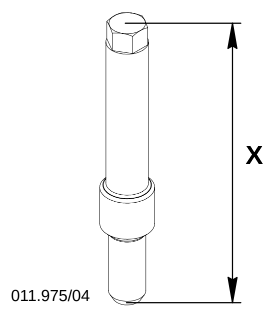
94583 1 Pipe
for pressure built-up in fuel rail during commissioning
X = 632.5 mm



94584 1 Lifting plate
for removal and fitting of injection control unit,
including 2 screws M12x30
X = 300 mm
(max. lifting capacity 330 kg)

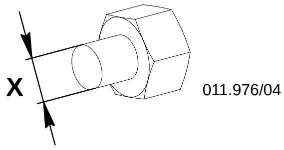


94585 2 Screw plugs
for fuel rail
X = 220 mm

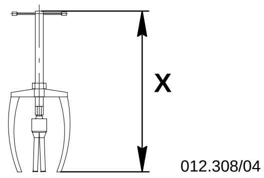


J. Tools

94587 8 Nuts with conical plugs
for servo oil return
X = 20 mm

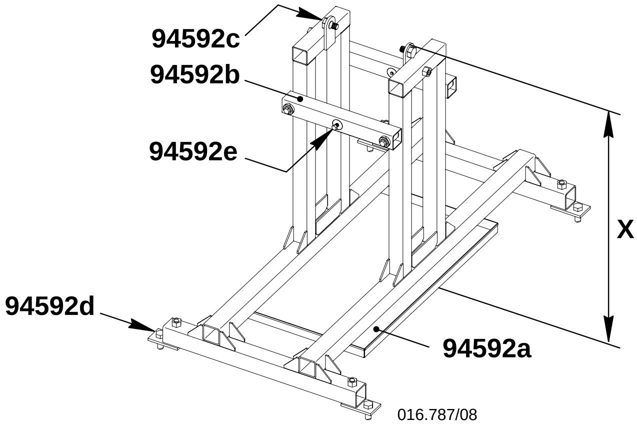


94589 2 Withdrawing tools
for removing lip seal from injection control unit
X = 310 mm & 638 mm



94592 1 Fitting and dismantling device
for fuel pump
X = 1029 mm
Mass approx. 89 kg
consisting of:

94592a 1 Oil trough
94592b 1 Limiter
with 4 screws M12x100 and washers
94592c 2 Screws
94592d 4 Screws (M20x50)
94592e 2 Screws (M12x90)



94593 1 Assembling device
for assembling fuel pump
consisting of:

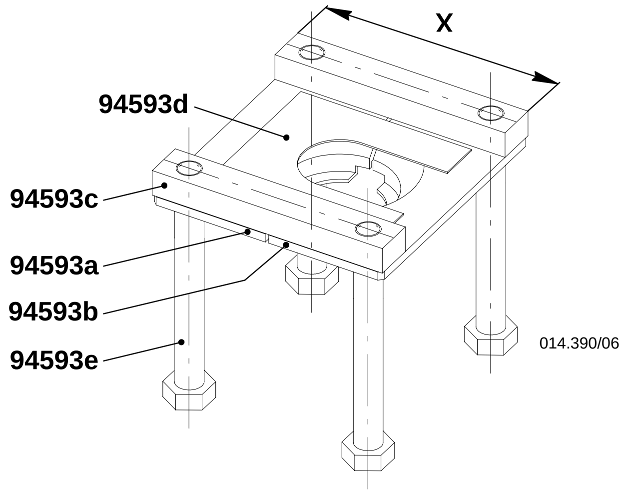
94593a 1 Tool half

94593b 1 Tool half

94593c 2 Flat bars
X = 270 mm

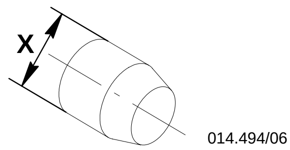
94593d 1 Metal sheet

94593e 4 Screws M30x260



94597 1 Mandrel
for fitting seal into lower spring carrier and lower housing of fuel pump
X = 70 mm

94597a 1 Mandrel
for fitting seal into lower spring carrier
X = 40 mm

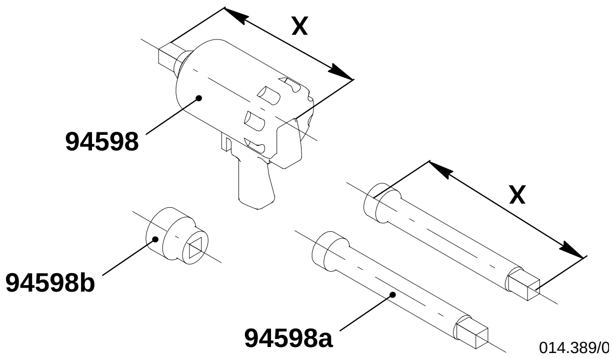


J. Tools

94598 **1** **Impact wrench**
for loosening and tightening fuel pump on supply unit
X = 256 mm

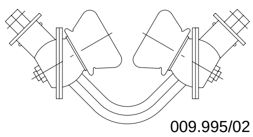
94598a **2** **Extension 1”**
X = 330 mm

94598b **1** **Socket spanner insert 1”**
AF 46 mm

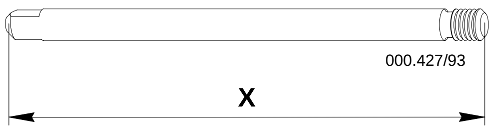


94651 **1** **Dismantling device**
for auxiliary blower
consisting of:

94651c **1** **Trolley**



94652 **2** **Centring studs**
for removal and fitting of electric motor on auxiliary blower
X = 615 mm



In case of a turbocharger breakdown, engines with 2 turbochargers TPL 80

94653 **2** **Covers to gas inlet housing and exhaust manifold**
X = 672 mm

94653 **1** **Cover for air connection**
X = 628 mm

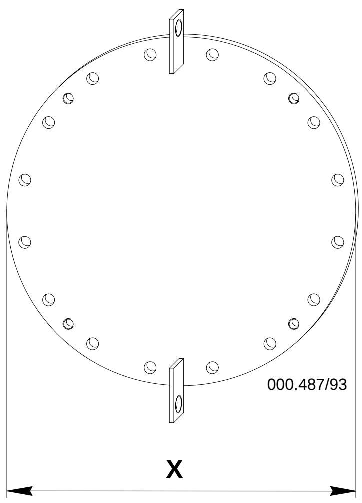
In case of a turbocharger breakdown, engines with 2 turbochargers MET 71S

94653 **2**

Covers to gas inlet housing and exhaust manifold
X = 665 mm

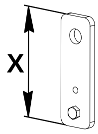
94653 **1**

Cover for air connection
X = 580 mm

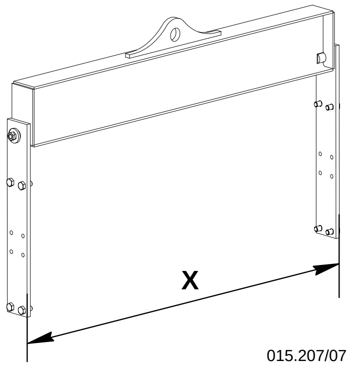


94660 **1** **Lifting device**
for removal and fitting of
scavenge air cooler,
including 8 screws M20x45
depending on type of scavenge air
cooler
X =1426 – 1776 mm

94660a **2**
Lifting plates
for removal and fitting of
SAC with cooler pre-stage only
X = 300 mm

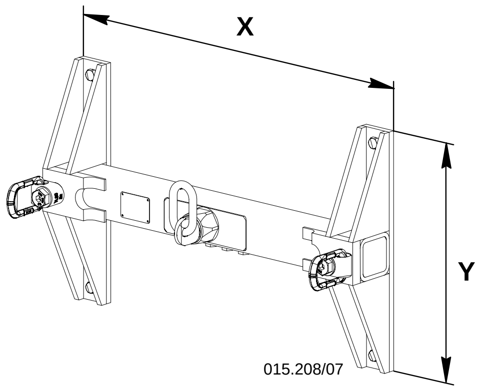


017.895/08



015.207/07

94663a **2** **Lifting devices**
for removal and fitting of
scavenge air cooler,
including 4 screws M20x40



015.208/07

6 cylinder engines with
turbochargers TPL 77–B or MET 66S
and SACs GEA 150/38/24/6
X = 900 mm
Y = 700 mm

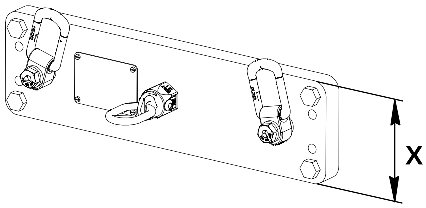
7 cylinder engines with
turbochargers TPL 80–B or MET 71S
and SACs GEA 190/48/24/4
X = 1140 mm
Y = 700 mm

6, 8, 9 cylinder engines with
TPL 80–B or MET 66S; 71S
and SACs GEA 190/48/24/64
X = 1140 mm
Y = 700 mm

5, 6, 8, 9 cylinder engines with
turbochargers TPL 85–B or MET 83S
and SACs GEA 240/48/24 (4+20) or
GEA 4–Nsv–S120–34N253
X = 1140 mm
Y = 560 mm

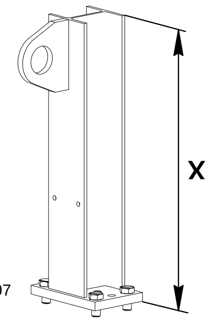
J. Tools

94663b 2 Lifting devices
for removal and fitting of
SAC with cooler pre-stage only
including 4 screws M16x40
X = 540 mm
(WLL = 1000 kg)



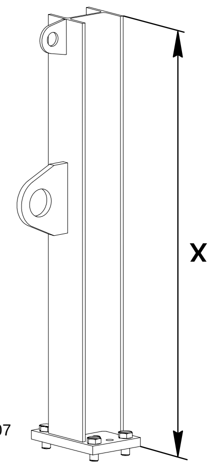
017.895/08

94663d 1 Support
for removal and fitting of scavenge air cooler,
including 4 screws M24x45
X = 809 mm



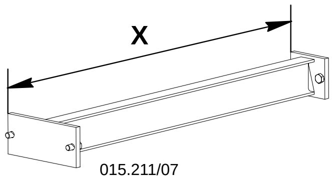
015.209/07

94663g 1 Support
for removal and fitting of scavenge air cooler and cooler pre-stage,
including 4 screws M24x45
(for SAC with cooler pre-stage only)
X = 1217 mm



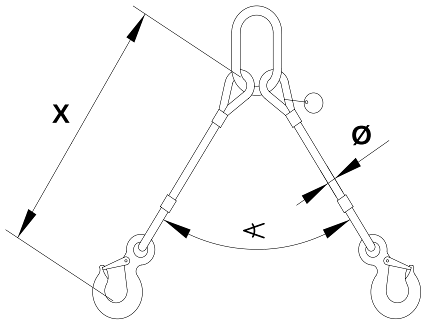
015.210/07

94663h 1 Bracket
for fitting of scavenge air cooler,
including 4 screws M16x35
X = 1107 mm



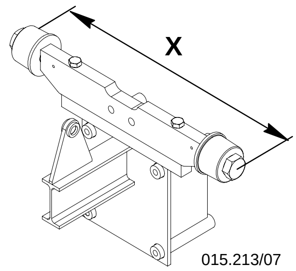
015.211/07

94666 1 Wire rope sling Ø 24 mm
for removal and fitting of scavenge air cooler
X = 743 mm
(max. lifting capacity 5000 kg at ∡ 0–60°)



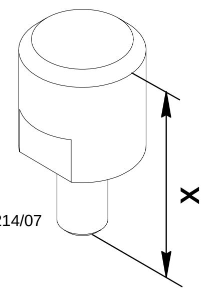
015.212/07

94667 1 Carriage
for removal and fitting
of water separator,
including 4 screws M12x180
X = 641 mm
(max. lifting capacity 430 kg)



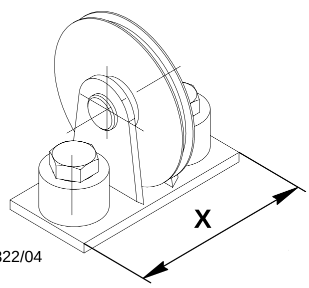
015.213/07

94667a 2 Stops
for removal and fitting of water separator
X = 87 mm



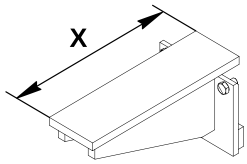
015.214/07

94668 1 Pulley device
for removal and fitting of water separator,
including 2 screws M30x55
X = 230 mm



012.322/04

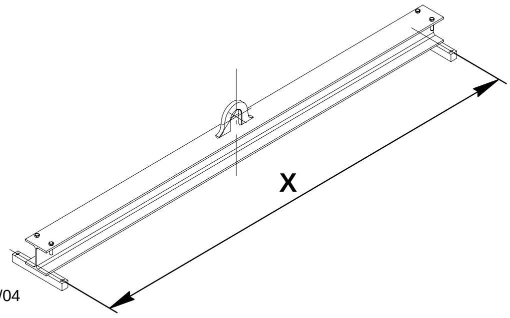
94669 1 Support
for removal and fitting of water separator,
including 2 screws M16x30
X = 440 mm



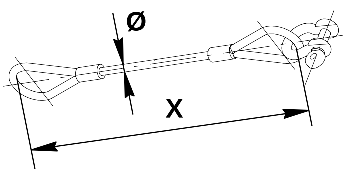
012.323/04

J. Tools

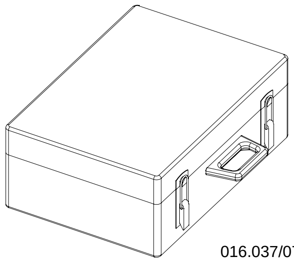
94672 1 Lifting device
for removal and fitting of water separator,
including 4 screws M12x50
X = 1966 mm
(max. lifting capacity 850 kg)



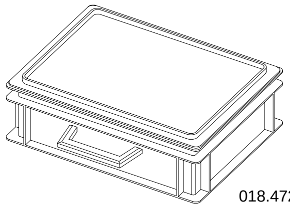
94673 1 Wire rope sling Ø 8 mm with shackle
for removal and fitting of water separator
X = 3410 mm
(max. lifting capacity 600 kg)



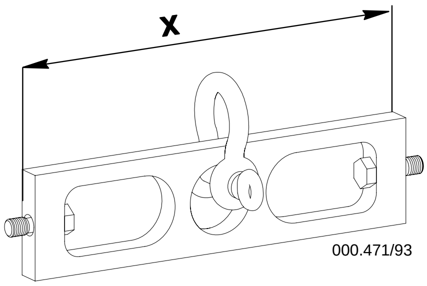
94720 1 Case (for CLU4)
consisting of:
measurement set complete for checking / refilling of hydraulic accumulator



94720c 1 Case (for CLU4–C)
consisting of:
measurement set complete for checking / refilling of hydraulic accumulator

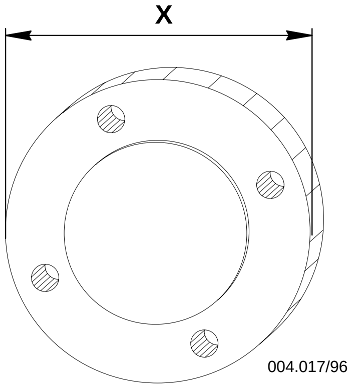


94811 2 Lifting lugs
(incl. 2 shackles) for removal and fitting expansion piece to exhaust valve cage
X = 445 mm

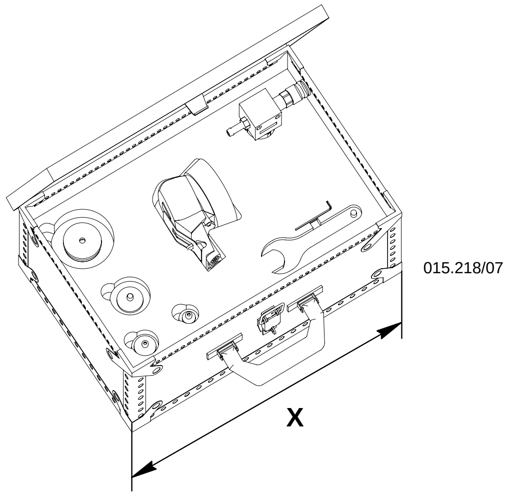


J. Tools

94831 1 Blank flange
for blanking off starting air pipe during emergency operation
X = 280 mm
Mass: approx. 11.5 kg



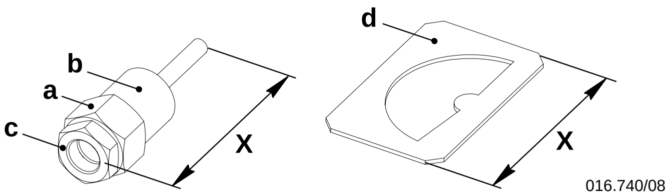
94835 1 Tool box with grinding machine
for regrinding of sealing surfaces, including User Manual
X = 450 mm



94870 1 Regrinding device
for sealing surfaces on fuel pressure piping (8733–1)
X = 106 mm
consisting of:

94870a 1 Screw-on sleeve (AF 36)
94870b 1 Grinding tool with countersunk screw M6
94870c 1 Lock nut M20x1.5 (AF 30)

94870d 1 Template
X = 50 mm

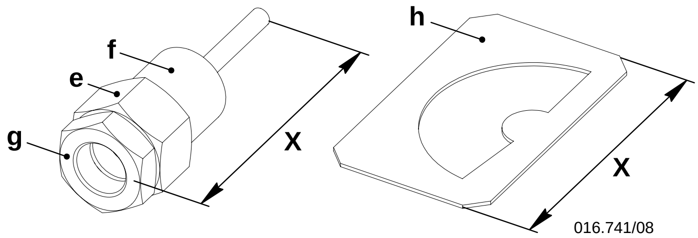


J. Tools

94870 1 Regrinding device
for sealing surfaces on fuel pressure piping (8752–1)
X = 158.5 mm
consisting of:

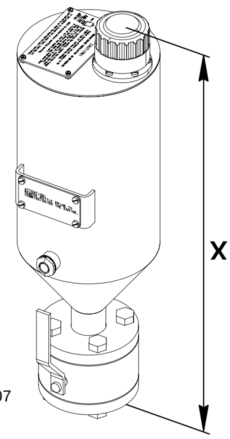
94870e 1 Screw-on sleeve (AF 55)
94870f 1 Grinding tool with countersunk screw M8
94870g 1 Lock nut M33x2 (AF 55)

94870h 1 Template
X = 80 mm



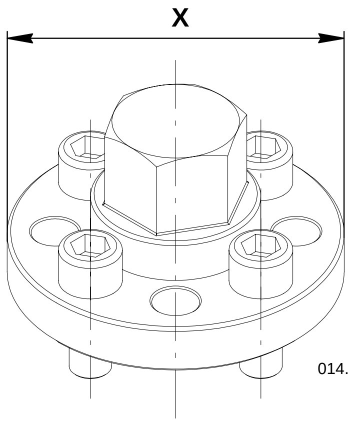
016.741/08

94844 1 Lubricating device
to supply unit
X = 604 mm



015.219/07

94874 1 Tightening device
for loosening and tightening connection piece on injection control unit, including 4 screws M12x30
X = 95 mm

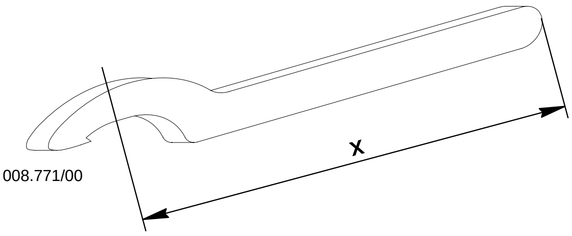


014.408/06

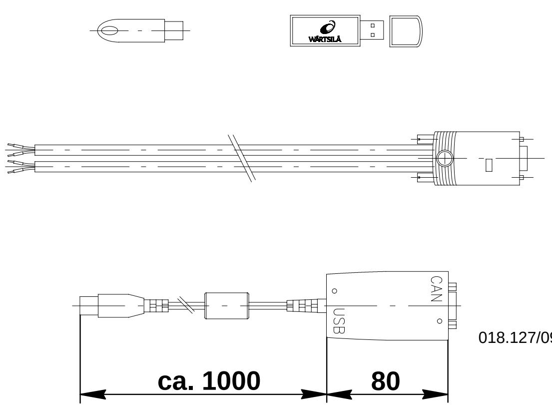
J. Tools

94924 **1** **Hook spanner**
for crank angle sensor
X = 205 mm

94925 **1** **Hook spanner**
for crank angle sensor
X = 242 mm



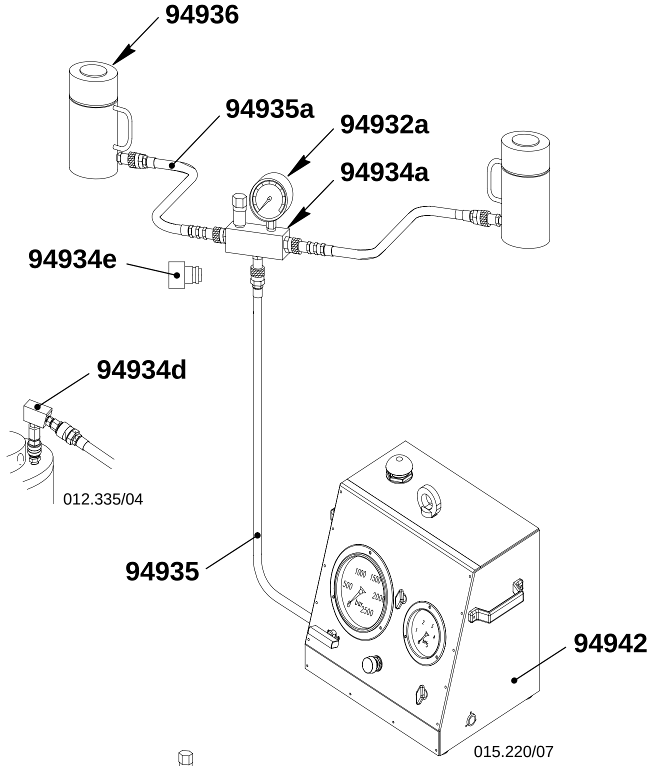
94930 **1** **SW-download package**
to WECS–9520 for flexView operator
consisting of:
2 USB–key (colour: blue)
1 USB–memory stick
1 CAN cable (ca. 10 m)
1 UBS to CAN adapter
1 Connection diagram
1 Requirements

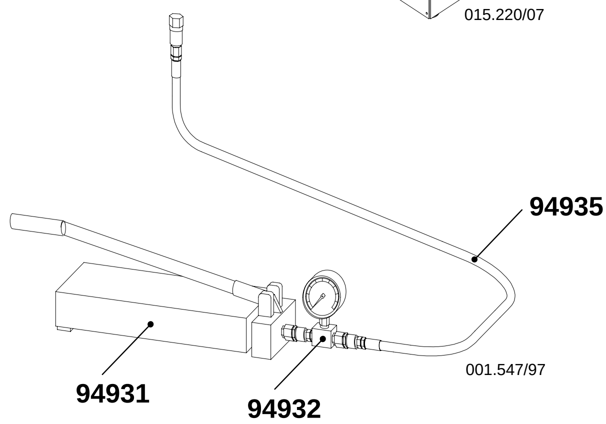


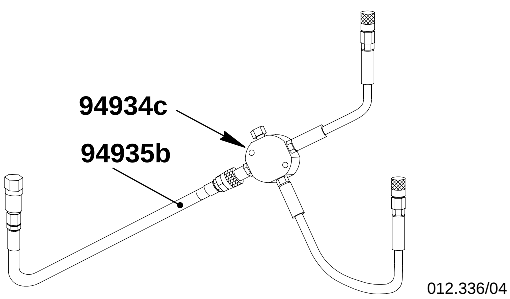
J. Tools

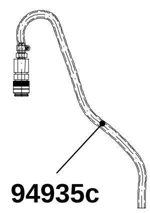
Hydraulic parts and pump

94931	1	**HP oil pump** working pressure max. 2500 bar
94932	1	**Pressure gauge** ∅ 100 mm working pressure 0–2500 bar connecting branch G½”
94932a	1	**Pressure gauge** ∅ 100 mm working pressure 0–1600 bar connecting branch G½”
94934a	1	**Hydr. distributor**
94934c	2	**Connection blocks**
94934d	2	**Connecting elements**
94934e	1	**Plug piece**
94935	3	**HP hoses** working pressure max. 2500 bar length approx. 1800 mm
94935a	2	**HP hoses** working pressure max. 1800 bar length approx. 1800 mm
94935b	4	**HP hoses** working pressure max. 1800 bar length approx. 700 mm
94935c	1	**Oil pipe drain** for set-up of pre-tensioning jacks lenght = 2000 mm
94936	2	**Hydraulic jacks 1000 kN (100t)**
94942	1	**Hydraulic unit**









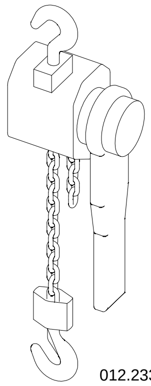
J3 Recommended special tools

94016 **2** **Manual rachets**
(max. lifting capacity 750 kg)

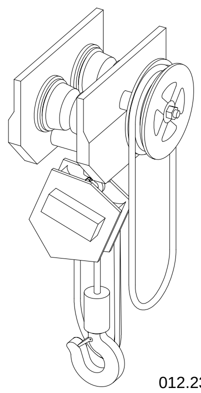
94016a **2** **Manual rachets**
(max. lifting capacity 1500 kg)

94016b **2** **Manual rachets**
(max. lifting capacity 3000 kg)

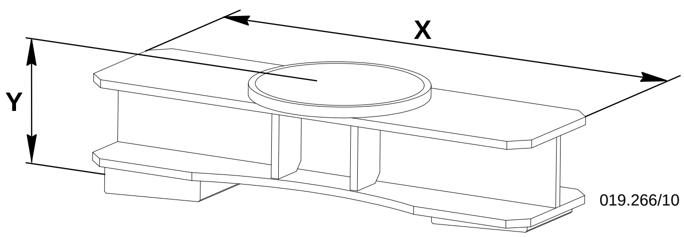
94016c **2** **Manual rachets**
(max. lifting capacity 6000 kg)


012.233/04

94017b **1** **Spur-geared chain block**
Lifting capacity 5000 kg

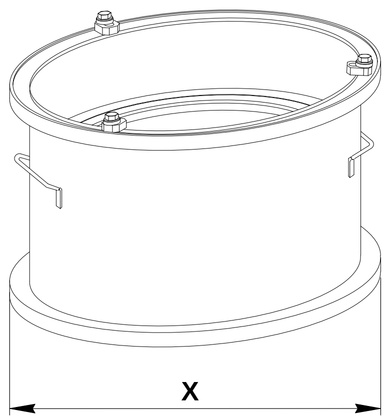

012.232/04

94203a **2** **Brackets**
(with reduced height Y)
for removing a cylinder liner
X = 550 mm
Y = 145 mm
Mass: approx. 52 kg



019.266/10

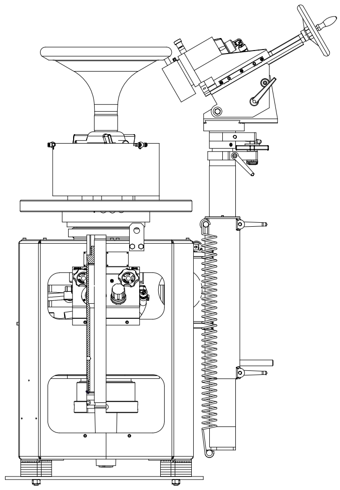
94262 **1** **Valve protector**
(only to be applied for transporting a complete exhaust valve)
X = 710 mm
Mass: approx. 89 kg

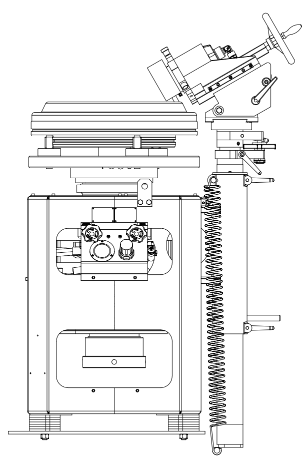


000.414/93

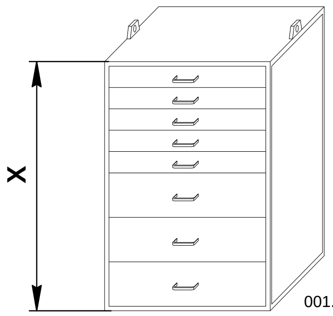
J. Tools

94291 1 Valve grinding device complete
for valve spindle and valve seat
Mass: approx. 497 kg


016.774/08

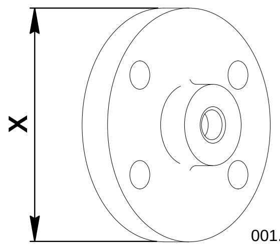

016.773/08

94300 1 Tool cupboard
X = 1120 mm



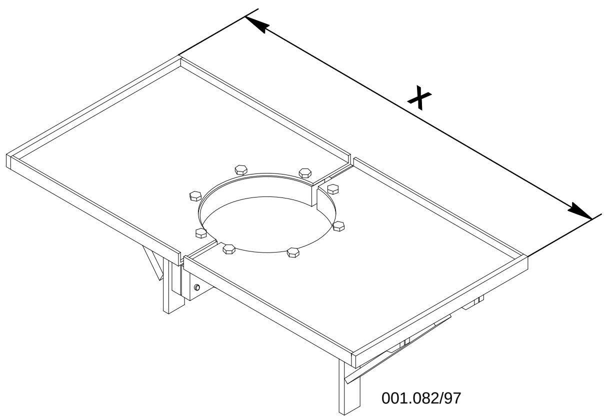
001.412/96

94336 1 Connecting flange
for pre-lubrication of top and bottom end bearings
X = 155 mm



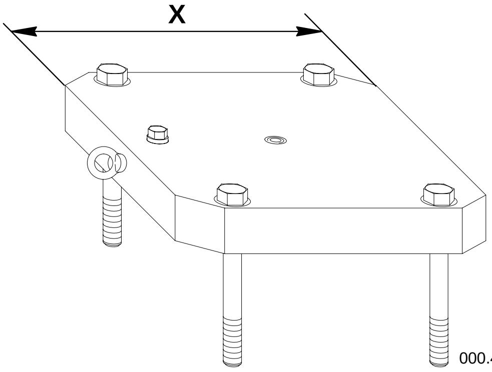
001.411/96

94344 1 Dismantling device
for removal of piston rod gland downwards
X = 1180 mm
Mass: approx. 45 kg



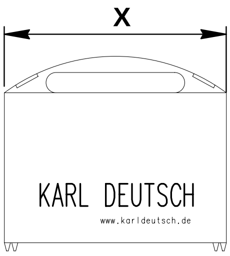
001.082/97

J. Tools



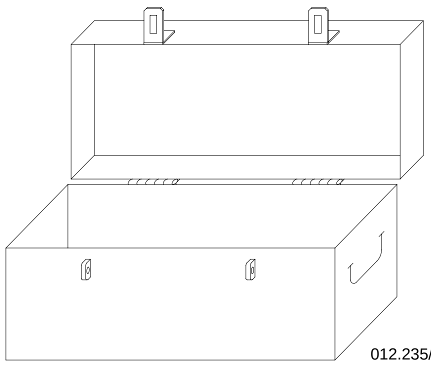
000.461/93

94349 1 Pressure testing device
for piston
X = 340 mm
Mass: approx. 65 kg



014.527/06

94356 1 Equipment case
with instruments
for measuring chrome layers
X = 280 mm

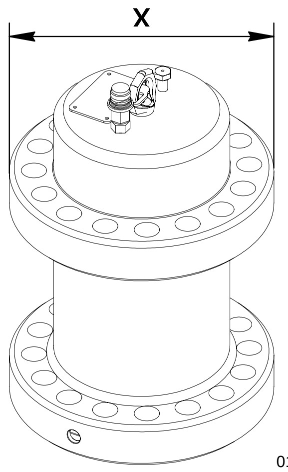

012.235/04

94481 1 Metal box
for storage of spare filter cartridges

Remark: Dimensions are depending on size of parts to be accommodated inside.

J. Tools

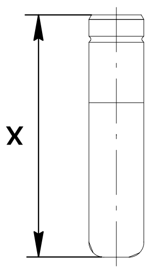
94595 1 Jack
for removal of a jammed fuel pump plunger (with <u>12-hole</u> pump cover)
X = 270 mm



014.499/06

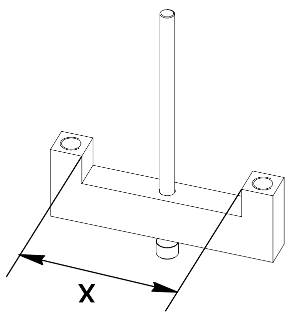
94595b 1 Short tappet
to jack 94595(a)
X = 222 mm

94595c 1 Long tappet
to jack 94595(a)
X = 344 mm



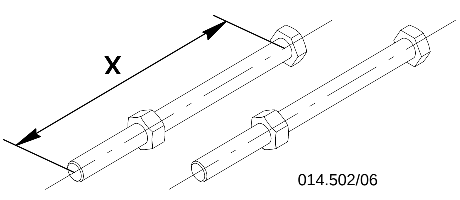
014.500/06

94595d 1 Piston reset tool
to jack 94595(a)
X = 173 mm (with <u>12-hole</u> pump cover)



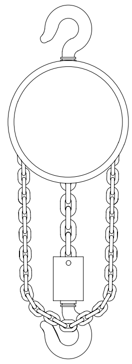
014.501/06

94595e 2 Screws M30
with nuts
X = 400 mm



014.502/06

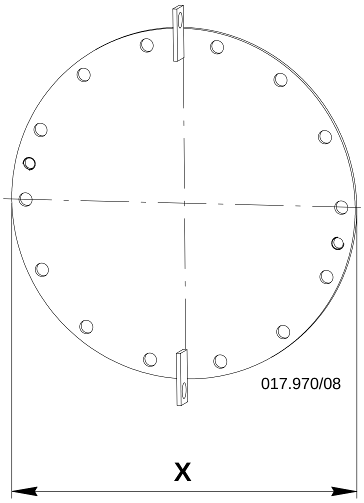
94650 1 Spur-geared chain block
for removing and fitting of electric motor on auxiliary blower
carrying capacity 2000 kg
Mass: approx. 17 kg



000.460/93

94655 1 In case of a turbocharger breakdown (turbocharger with suction pipe)

Cover
for air outlet casing
X = 630 mm (for TPL 80)
X = 580 mm (for MET 71S)

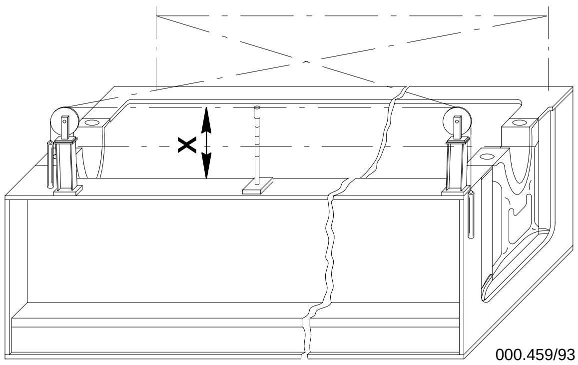


017.970/08

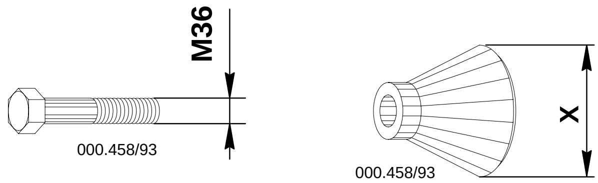
J. Tools

J4 Special tools, obtainable on loan

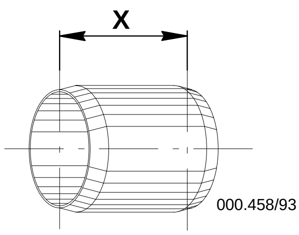
94105 1 Measuring apparatus
for leveling bedplate
consisting of:
4 Supports
4 Weights with wire
1 Measuring underlay
X = 1680 mm
Mass: approx. 172 kg



94174 4 Thread protectors
to upper threads of tie rods, when fitting a cylinder jacket
X = 160 mm
Mass: approx. 8.8 kg

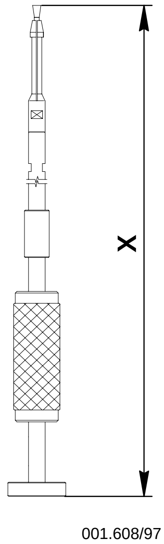


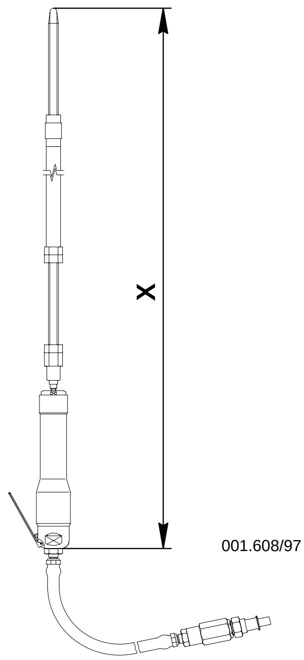
94177 1 Thread protector
to lower thread of tie rod
X = 170 mm



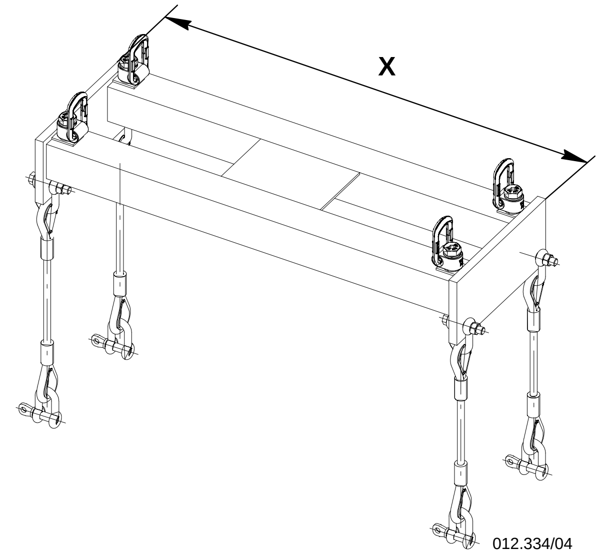
94211 1 Fitting device
for insulation tubes
X = 706 mm
Mass: approx. 3.2 kg

94212 1
Extractor
for insulation tubes
X = 890 mm
Mass: approx. 5.2 kg



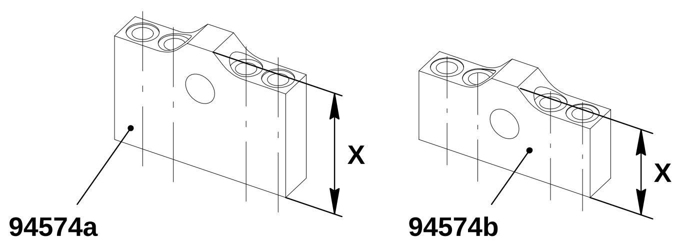


94574 1 Lifting tool complete
for transporting a complete supply unit,
5 & 7 Cyl. engines
X = 1565 mm
(max. lifting capacity 24 000 kg)
consisting of:



94574a 1 Holder
with head screws M20x180
X = 176 mm

94574b 3 Holders
with head screws M20x130
X = 125 mm



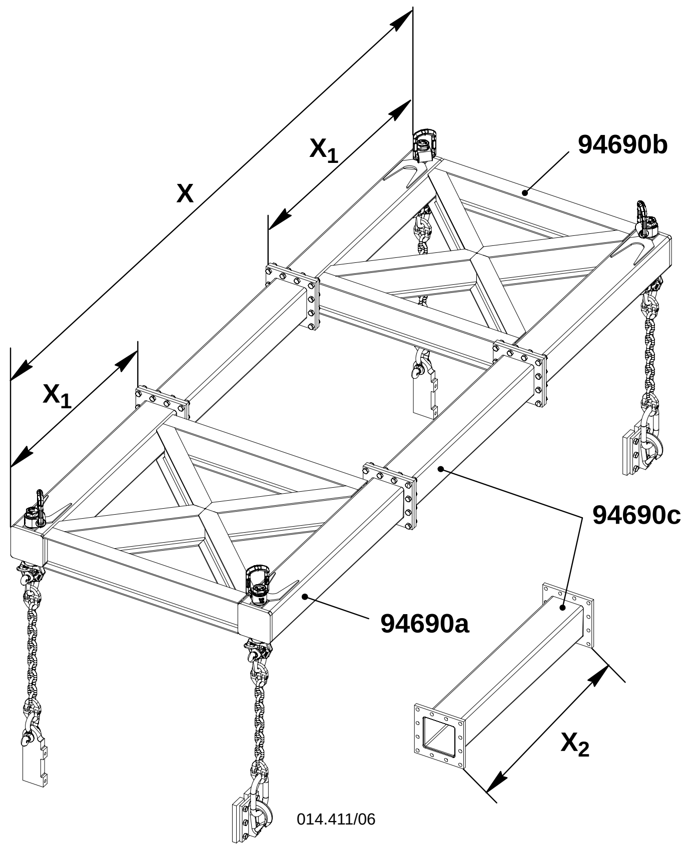
94691 1 Transport tool
for 7 Cyl. rail unit module
(max. lifting capacity 24 000 kg)
X = 6140 mm
consisting of:

94690a 1 Lifting element
X_1 = 1750 mm

94690b 1 Lifting element
X_1 = 1750 mm

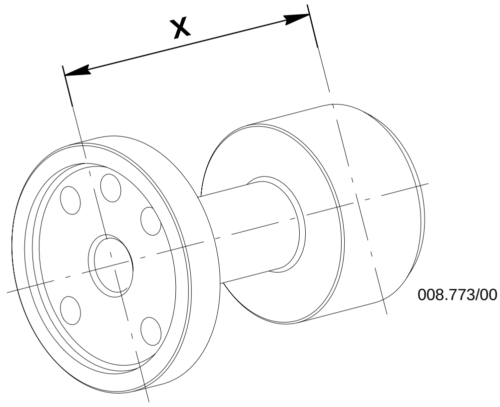
94690c 1 Bracket
X_2 = 2640 mm

incl. 48 screws M24x80 and nuts



J. Tools

94922 **1** **Alignment tool**
for crank angle sensor
X = 172 mm



J5 Storage proposal

The following proposals are a guide and intended to assist the shipyard in deciding where and how to locate the main-engine tools. The quantity and actual layout of the tool panels may have to be agreed between the shipyard and the ship owner and their location depends on the design and layout of the engine room, however tool panels should be easily accessible, located in clean, well ventilated and dry areas with the tools protected against rust. It is advisable to create tool inventories to enable engine-room staff to keep a proper check of the condition and location of the tools.

The extent of the supplies and services is determined exclusively by the relevant supply contract.

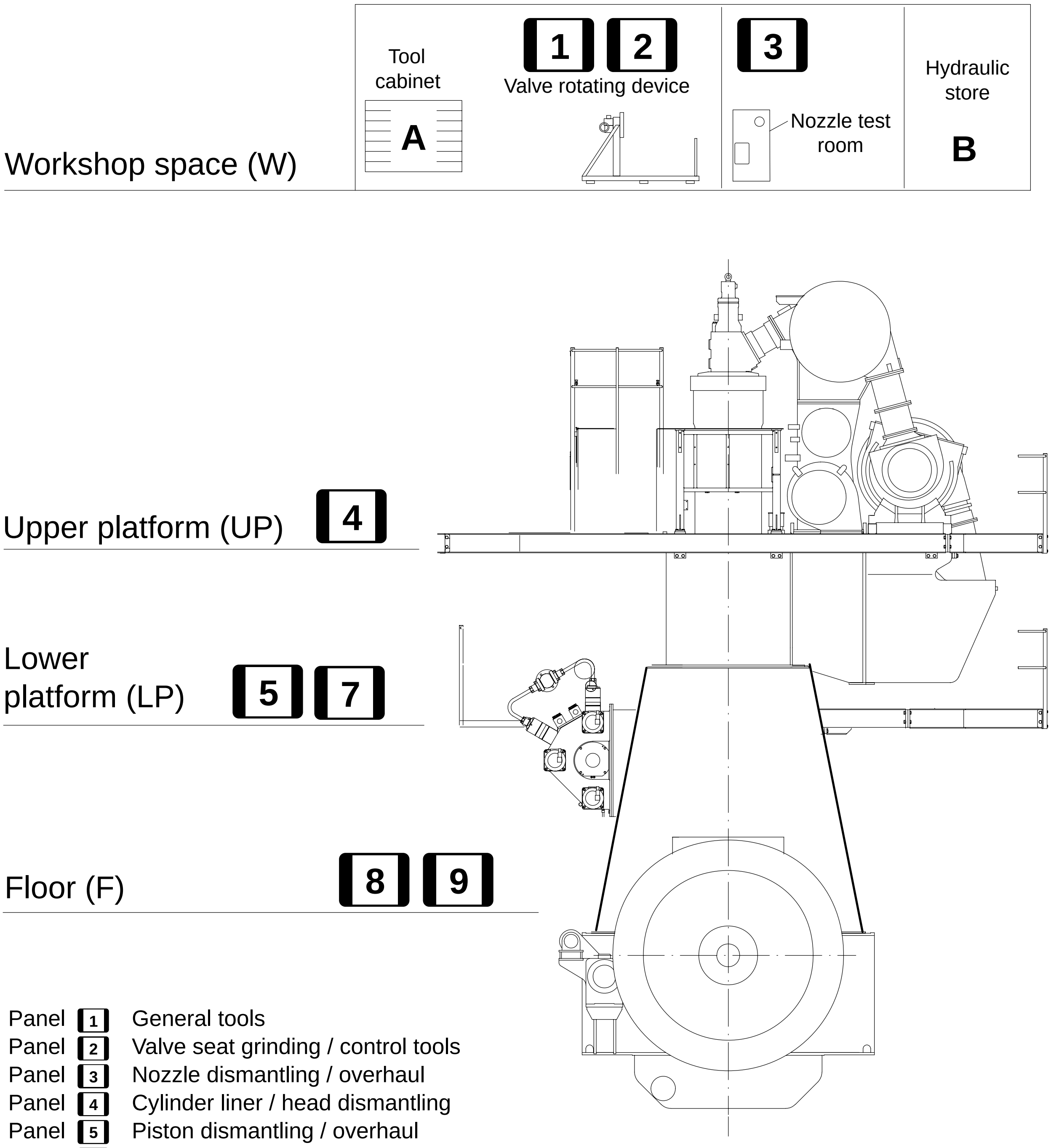
The figure shown on the right is an artists impression of a convenient solution to storing tool panels.

F10.5093

Fig. J1 Tool panel storage arrangement

J. Tools

J5.1 Tool panels

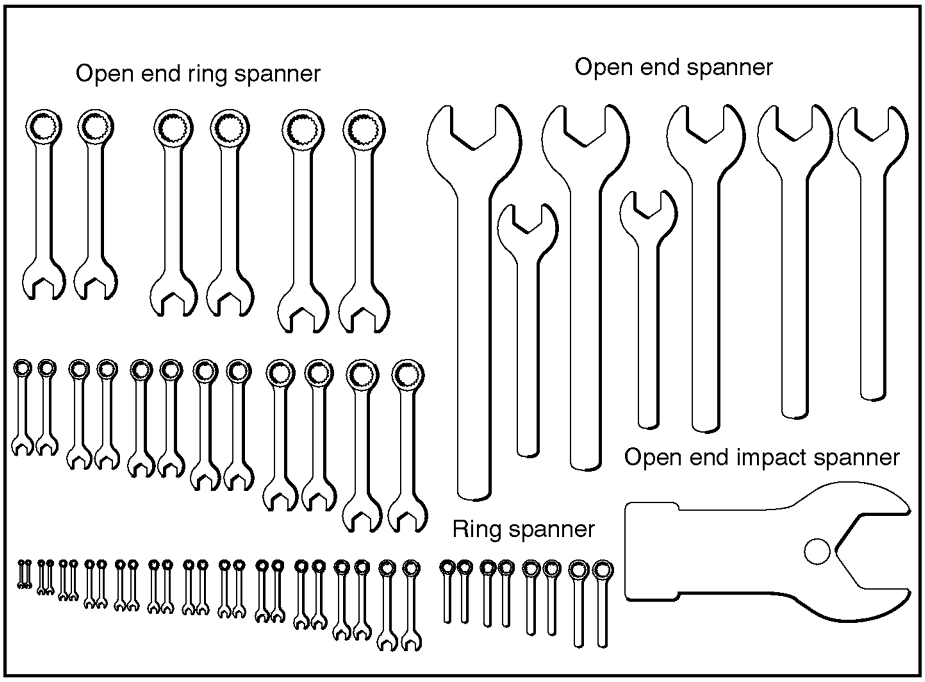


Panel 1 General tools
Panel 2 Valve seat grinding / control tools
Panel 3 Nozzle dismantling / overhaul
Panel 4 Cylinder liner / head dismantling
Panel 5 Piston dismantling / overhaul
Panel 7 Piston / various tools
Panel 8 Crankcase tools
Panel 9 Gear drive dismantling / control
A Tool cabinet
B Hydraulic tools and fittings

F10.5288

Fig. J2 Tool panel location

Panel 1
(typical)



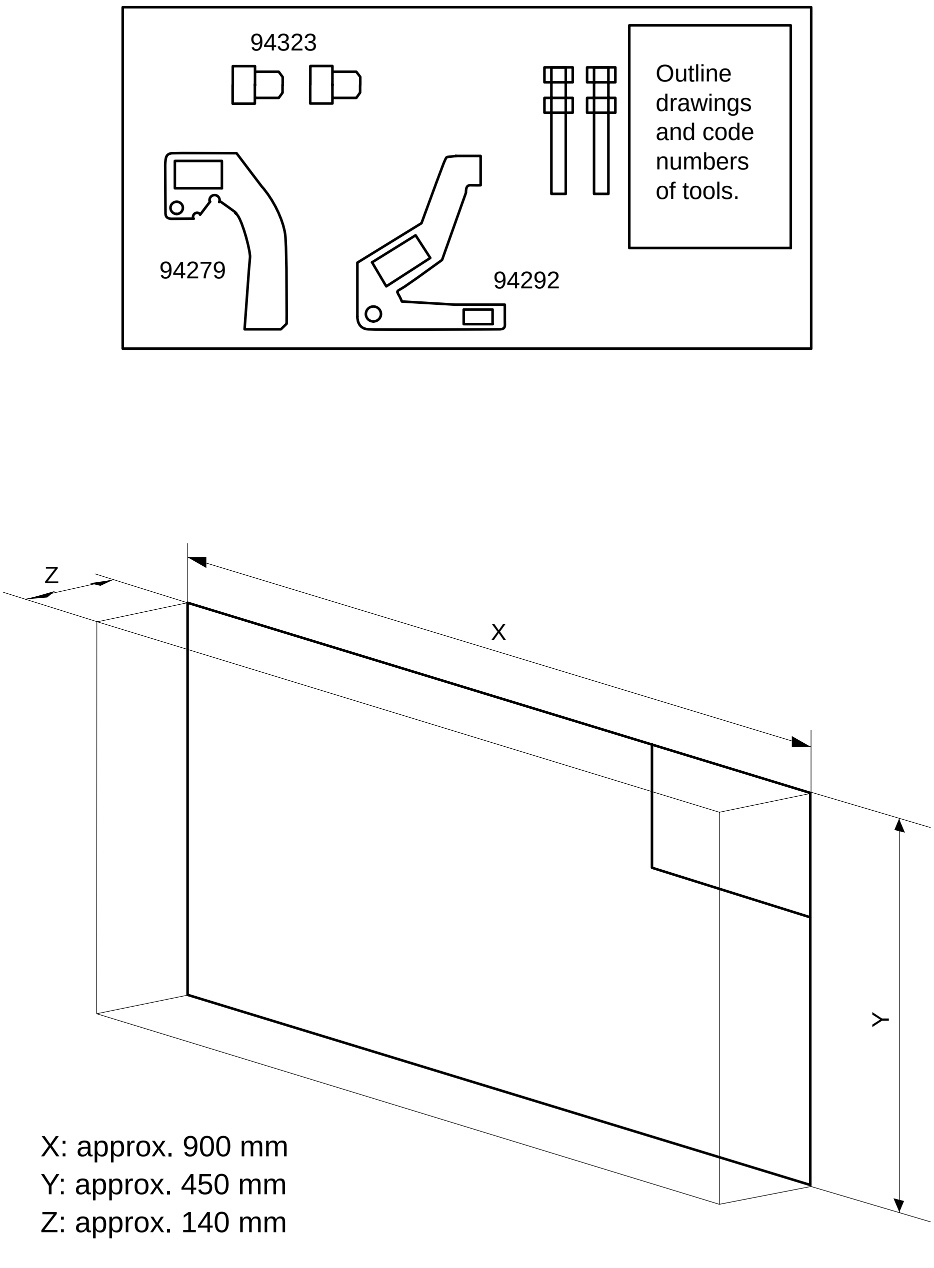
Design number and arrangement of panels
for general tools in the workshop according to
shipbuilder's or owner's practice.
(Not available from Wärtsilä Switzerland Ltd)

F10.3389

Fig. J3 Tool panel 1: General tools

J. Tools

Panel 2



Dimensions and arrangement of tools in this panel are to be determined according to shipbuilder’s or owner’s practice.
This panel is considered as a propsal only! There is no liability for completeness.

F10.5095

Fig. J4 Tool panel 2: for valve seat grinding / control tools

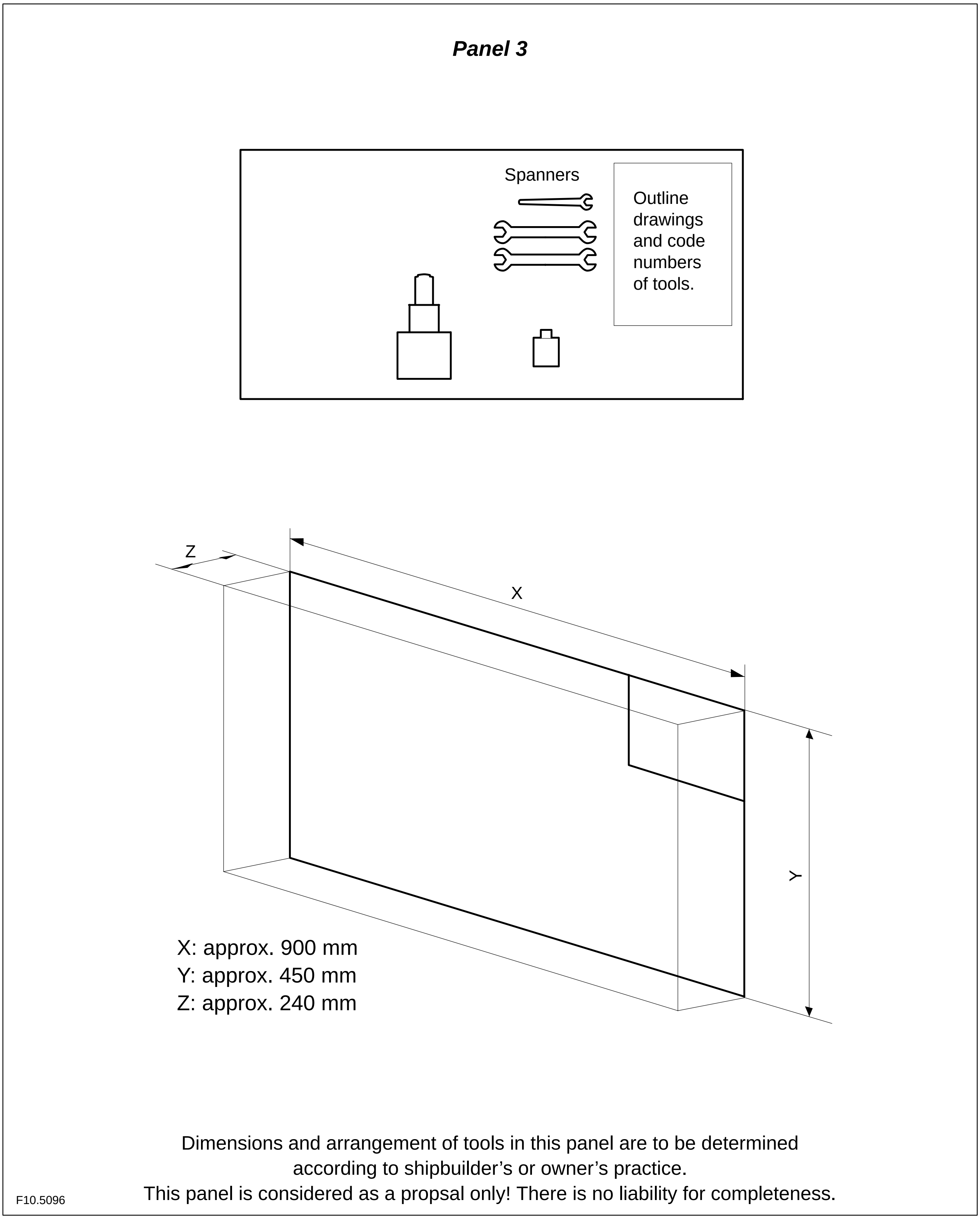


Fig. J5 Tool panel 3: for nozzle dismantling / overhaul

J. Tools

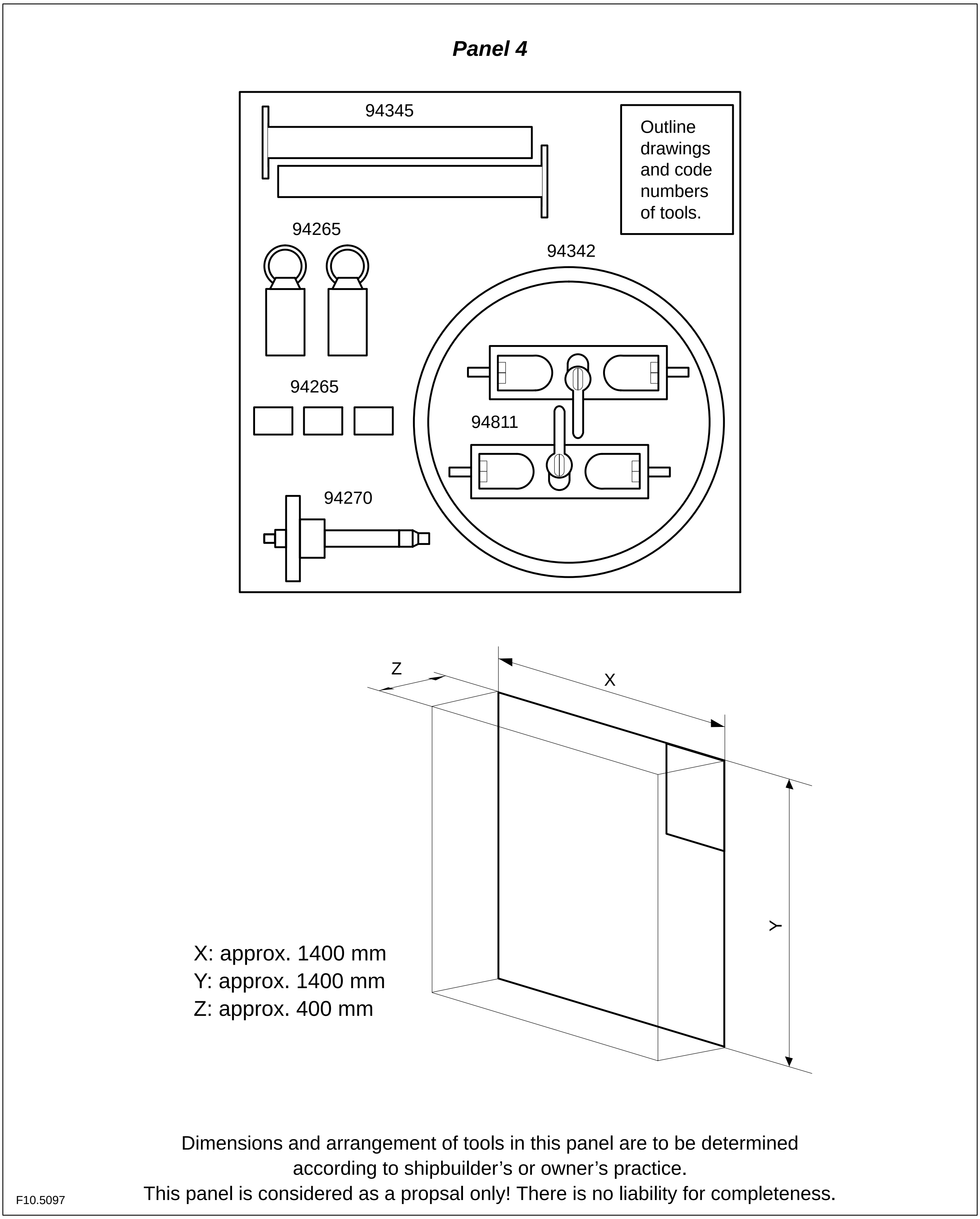
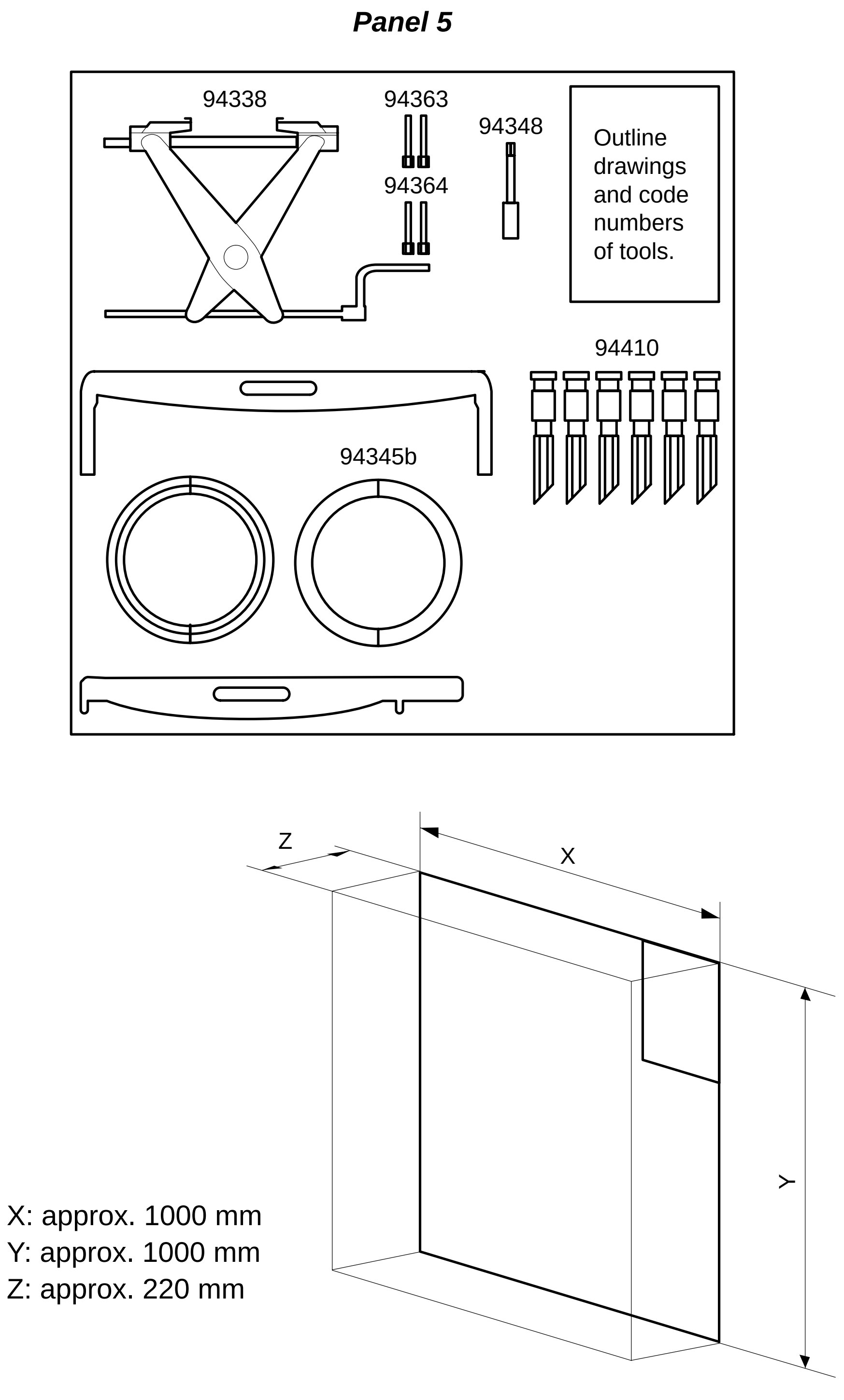


Fig. J6 Tool panel 4: for cylinder liner / head dismantling

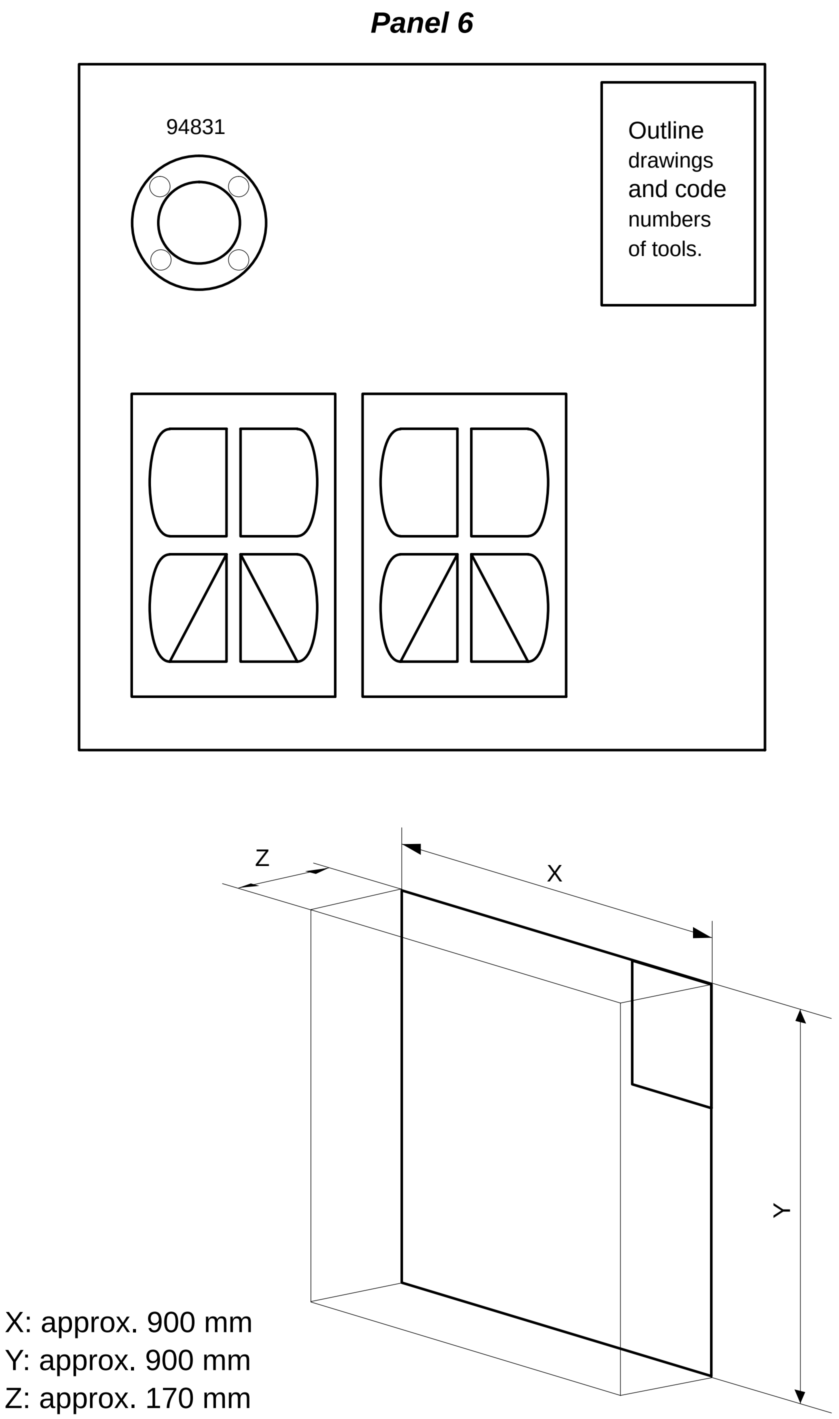


Dimensions and arrangement of tools in this panel are to be determined according to shipbuilder's or owner's practice.
This panel is considered as a propsal only! There is no liability for completeness.

F10.5108

Fig. J7 Tool panel 5: for piston dismantling / overhaul

J. Tools



Dimensions and arrangement of tools in this panel are to be determined according to shipbuilder’s or owner’s practice.
This panel is considered as a propsal only! There is no liability for completeness.

F10.5100

Fig. J8 Tool panel 6: for piston / various tools

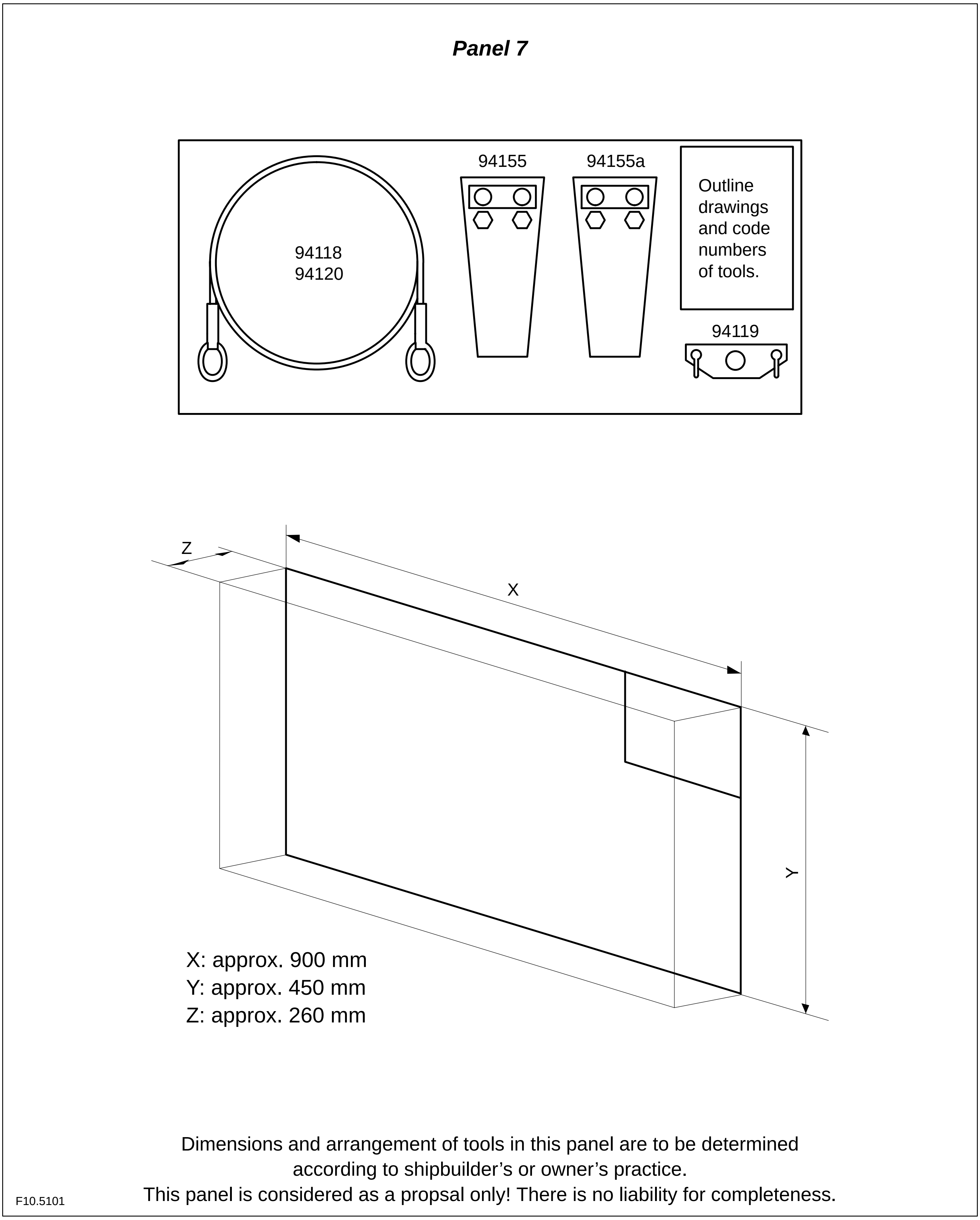


Fig. J9 Tool panel 7: Crankcase tools

J. Tools

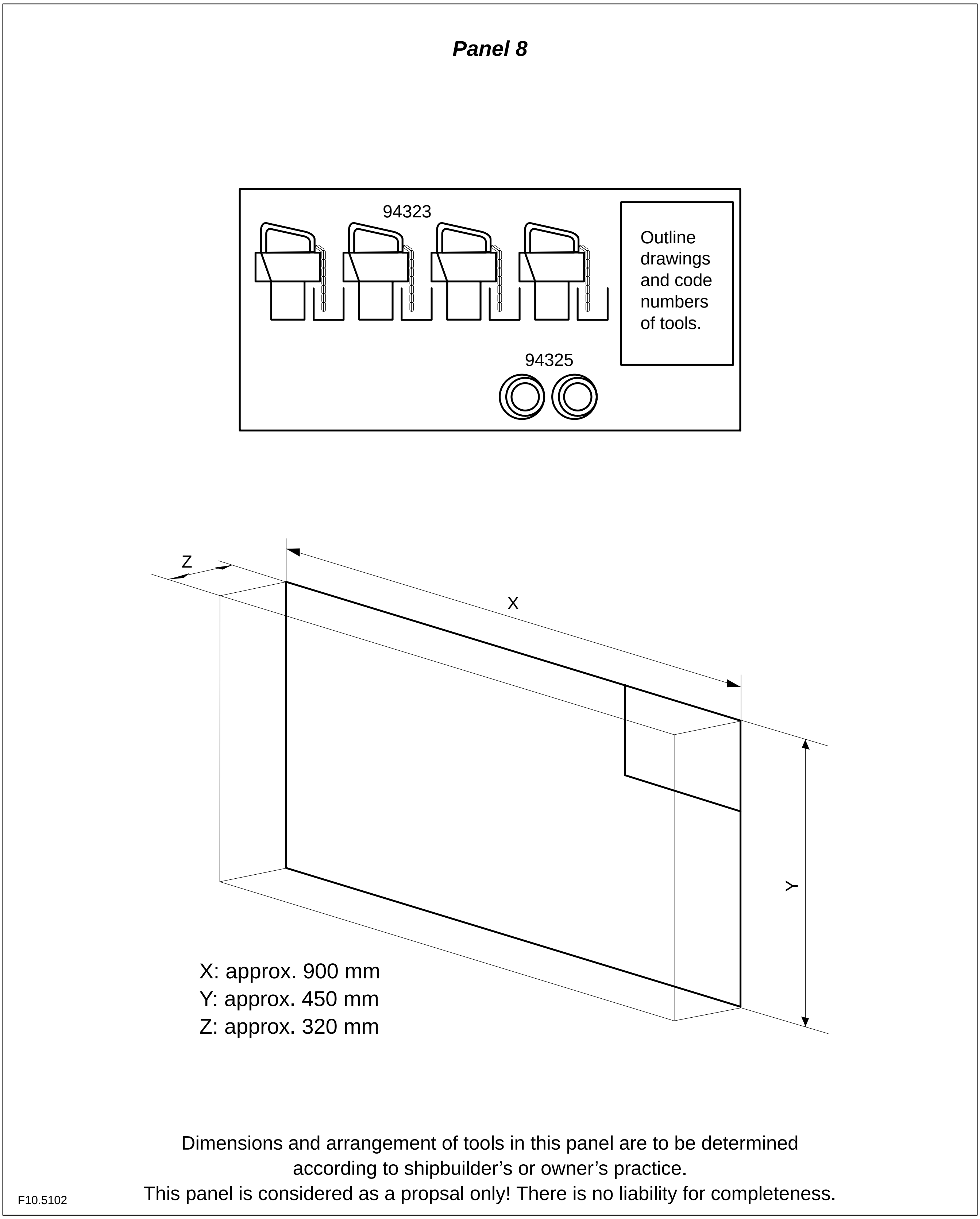


Fig. J10 Tool panel 8: for gear drive dismantling / control

K. Spare parts

K1 Introduction

This chapter illustrates spare parts required for running and maintenance of the main engine. For details of the spare parts required for the auxiliary and ancillary equipment refer to manufacturer’s documentation. The items identified in the “List of spare parts” in section K2 comprise the minimum spare parts recommended by the International Association of Classification Societies (IACS).

The spare parts may not be part of the engine supply but they may be ordered separately and certain items may be deleted or added depending on the requirements of the shipyard or operator. Therefore we recommend that the extent of delivery is determined before designing the storage facilities.

Illustrations are provided for some spare parts (in section K3) giving an aid for designing the storage facilities.
The mass and size of spare parts assist the designer to estimate the total additional mass to be carried.

Section K4 describes the storage of spare parts and the **protection against corrosion**.

K2 List of spare parts

This list is intended for single engined installation. In multi-engine installation the required spare parts are only necessary for one engine.

Column IACS:
Minimum spare parts recommended by the International Association of Classification Societies (IACS Rec. No. 26, 1990).

Columns „Additional parts“:
Spare parts recommended by WCH (Wärtsilä Switzerland Ltd) for 10’000 to 30‘000 hrs of operation which can be supplied at an extra price. These spare parts are recommended in addition to the IACS ones. Each column is to be considered for itself, e.g. „Column 20’000 hrs“ already contains the parts listed in „Column 10’000 hrs“.
For the following Classification Societies, IACS spare parts are considered as a requirement:
CCS, GL, KR, NK, RS
and the following ones as a recommendation:
ABS, BV, DNV, LR, PRS, RINA.
The statement made in brackets, for e.g. (2 per main bearing), is an information giving the number of parts per bearing or per cylinder, or per valve, etc., actually fitted in the engine. It is not necessarily the number of spare parts supplied.

K. Spare parts

Item	Spare parts	Code No.	Supply per ship	Additional parts to IACS Recommended by WCH for		
			IACS	Zero to 10’000 hrs	Zero to 20’000 hrs	Zero to 30’000 hrs
				N = number of cylinders		
Main bearing	Main bearing shell, lower half	BF 11340	1			
	Main bearing cover, white metal lined	BF 11365	1			
(fig. K1)	Jack bolt for main bearing, complete *(2 per main bearing)*	BF 11380	2			
	Main bearing cover, driving end, white metal lined *(1 per engine)*	BF 11370	1			
	Elastic stud for main bearing *(2 per main bearing)*	BF 11320	2			
	Round nut for elastic stud *(2 per bearing)*	BF 11321	2			
Thrust bearing	Thrust pad for one side of thrust bearing *(set of 7 pads per thrust bearing)*	BF 12241 **and / or**	1 set			
(fig. K3)	Depending on direction of rotation and propeller *(FPP or CPP)*	BF 12242	1 set			
Cylinder liner	**For conventional lubricating system**					
	Cylinder linerwith lower ports, complete *(without joint ring and O-ring)*	BF 21242	1			
	Filling piece	BF 21245	1			
(fig. K4)	Joint ring and O-rings *(set for 1 cyl. liner)*	BF 21270	1 set		$^{1}/_{3}$•N sets	$^{1}/_{2}$•N sets
	Insulation bandage, complete	BF 21290	1			
	Water guide jacket *(1 per cyl. liner)*	BF 21300				1
	or					
	For PULSE lubricating system					
	Cylinder linerwith lower ports, complete *(without joint ring and O-ring)*	BF 21241	1			
	Joint ring and O-rings *(set for 1 cyl. liner)*	BF 21270	1 set		$^{1}/_{3}$•N sets	$^{1}/_{2}$•N sets
	Insulation bandage, complete	BF 21280	1			
	Water guide jacket *(1 per cyl. liner)*	BF 21300				1
Lubricating quill	**For conventional lubricating system**					
	Lubricating quill, complete, with accumulator *(16 per cyl. liner)*	BF 21360	16			8
(fig. K5)	Diaphragm for accumulator *(1 per accumulator)*	BF 21368	16	16	16	16
	Gasket for lubricating quill *(2 per lubr. quill)*	BF 21390	32	32	32	32
	O-ring *(2 per lubr. quill)*	BF 21392	32			
	Progressive block distributor	BF 21450		2	2	2
	Piston distr. f. exh. valve shaft *(1 per cyl. liner)*	BF 21451		1	1	1
	or					
	For PULSE lubricating system					
	Seal	BF 21389	8	8	8	8
	O-ring	BF 21382	16	16	16	16
	Non-return valve	BF 21376	1	1	1	1

K. Spare parts

Item	Spare parts	Code No.	Supply per ship	Additional parts to IACS Recommended by WCH for		
			IACS	Zero to 10'000 hrs	Zero to 20'000 hrs	Zero to 30'000 hrs
			N = number of cylinders			
Cylinder cover	Cylinder cover, complete, without valves	BF 27103	1			
	Elastic stud for cyl. cover *(8 per cyl. cover)*	BF 21075	4			
(fig. K6)	Nut for elastic stud *(8 per cyl. cover)*	BF 21076	4			
	2 O-rings *(set for one cyl. cover)*	BF 27155		1•N sets	2•N sets	2•N sets
Valves for Cylinder cover	Injection valve, complete *(3 per cyl.)*	BF 27200	3•N+3			
Injection valve	Nozzle body with needle *(1 per valve)*	BF 27242	1•N			
(fig. K7)	Atomizer *(1 per valve)*	BF 27244	1•N	3•N	6•N	9•N
	Small parts *(set for 1 valve)*	BF 27250	1•N sets	3•N sets	6•N sets	9•N sets
	Dowel pin for nozzle holder	BF 27202	1•N		1•N	
	Dowel pin for atomizer *(1 per valve)*	BF 27243	1•N	3•N	6•N	9•N
Starting air valve	Starting air valve, complete *(1 per cyl. cover)*	BF 27280	2			
(fig. K8)	O-ring to BF 27281	BF 27302	1			
	Joint ring to BF 27281	BF 27306	1			
	Small parts *(set for 1 valve)*	BF 27350		1 set	2 sets	3 sets
Exhaust valve	Exhaust valve, complete, with valve drive *(1 per cyl. cover)* **(applies for ABS, BV, CRS, DNV, GL, LR, PRS, RMRS)**	BF 27500 **or**	2			
(fig. K9)	Exhaust valve, complete, with valve drive *(1 per cyl. cover)* **(applies for CCS, KR, NK, RINA)**	BF 27500	3			
	Valve seat *(1 per valve)*	BF 27516				1
	Valve spindle with rotation wing *(1 per valve)*	BF 27600				1
	Small parts to exhaust valve *(set for 1 valve)*	BF 27660	1 set	2 sets	2 sets	N sets
Relief valve	**Depending on class requirement**					
(fig. K10)	Relief valve, complete *(1 per cyl. cover)*	BF 27465	2			
	Joint ring	BF 27460	1			
Indicator valve	Indicator valve, complete *(1 per cyl. cover)*	BF 27435	2			
(fig. K11)	Indicator valve (cock) *(1 per cyl. cover)*	BF 27446		¼•N	½•N	N
	Joint ring *(1 per indicator valve)*	BF 27454		¼•N	½•N	N
Piston (fig. K13)	Piston, complete, with piston head, skirt, piston rod, screws, etc. *(without piston rings)*	BF 34000	1			
	Piston head	BF 34060				1
	Piston skirt	BF 34090				1
	Piston riing (top)	BF 34425 **and**	2		2•N	2•N
	Piston riing	BF 34426	6		6•N	12•N
	Small parts *(set for 1 piston)*	BF 34260			1 set	½•N sets

K. Spare parts

Item	Spare parts	Code No.	Supply per ship	Additional parts to IACS Recommended by WCH for		
			IACS	Zero to 10'000 hrs	Zero to 20'000 hrs	Zero to 30'000 hrs
				N = number of cylinders		
Connecting rod bearings	Bearing cover for top end bearing white metal lined	BF 33120	1			
	Bearing shell for top end bearing lower half,	BF 33150	1			
(fig. K12)	Bearing half for bottom end bearing, white metal lined	BF 33090	1			
	Bearing shell for bottom end bearing	BF 33100	1			
	Elastic stud to bottom end bearing *(2 per bearing)*	BF 33001	2			
	Nut for elastic stud to bottom end bearing	BF 33005	2			
	Elastic stud to top end bearing *(4 per bearing)*	BF 33003	4			
	Nut for elastic stud to top end bearing	BF 33006	4			
Piston cooling and crosshead lubrication	Upper and lower lever with bush and pin, complete, without support and connection piece *(set for 1 cylinder)*	BF 36145	1 set			
Gland box on Piston rod	Gland box piston rod, complete, incl. casing in 2-parts	BF 23150	1			
(fig. K15)	Tension springs *(set for 1 gland)*	BF 23161 **and** BF 23162			½•N set ½•N set	1•N sets 1•N sets
	Scraper- and joint rings *(set for 1 gland)*	BF 23180			1•N sets	2•N sets
	O-ring and locking plates *(set for 1 gland)*	BF 23185			1•N sets	2•N sets
Scavenge air receiver	Flap	BF 64220	4		4	8
Cylinder lubrication	**For conventional lubricating system** Cylinder lubricating pump, elements including driving electro motor and gear	BF 96350	1 set			
(fig. K17)	**For PULSE lubricating system**	**or**		according to manufacturer		
	Cylinder lubricating system components incl. bedplate, pump block accu., etc.	BF 72302	1			
	O-rings for bedplate	BF 96375	1			
Hydraulic pipe to exhaust valve	Hydraulic pipe, complete	BF 84650	1			
	O-ring *(set for one hydr. pipe)*	BF 84662		4		
	Gasket	BF 84663		2		
	Gasket	BF 84679		2		

K. Spare parts

Item	Spare parts	Code No.	Supply per ship	Additional parts to IACS Recommended by WCH for		
			IACS	Zero to 10'000 hrs	Zero to 20'000 hrs	Zero to 30'000 hrs
				N = number of cylinders		
High-pressure pipe to Rail unit (Servo oil)	**for 6-, 7-cylinder engines**					
	Oil piping	BF 84475	1			
	Oil piping	BF 84476	1			
	Oil piping	BF 84477	1			
	Oil piping	BF 84478	1			
	Claw	BF 84494	8			
	O-ring	BF 84503	8			
	O-ring	BF 84504	8			
	Oil piping	BF 84482	1			
	O-ring	BF 84501	1			
	O-ring	BF 84527	1			
High-pressure pipe to Rail unit (Fuel)	**for 6-, 7-cylinder engines**					
	Fuel pressure epipe	BF 87670	1			
	Fuel pressure epipe	BF 87671	1			
	Fuel pressure epipe	BF 87672	1			
	Fuel pressure epipe	BF 87673	1			
	Claw	BF 87688	8			
	Thrust ring	BF 87689	8			
	O-ring	BF 87694	8			
	O-ring	BF 87695	8			
High-pressure pipe to injection valve (Fuel)	**for fuel pressure pipe (Standard design)**					
	Fuel pressure epipe to injection valve	BF 87330	1			
	(one of each shape)	BF 87335	1			
	Fuel pressure epipe to injection valve	BF 87340	1			
	Claw	BF 87350	6			
	Thrust ring	BF 87351	6			
	O-ring	BF 87357	6			
	O-ring	BF 87358	6			
		or				
High-pressure pipe to injection valve (Fuel)	**for fuel pressure pipe (star tube design)**					
	Fuel pressure epipe to injection valve	BF 87380	1			
	(one of each shape)	BF 87381	1			
	Fuel pressure epipe to injection valve	BF 87382	1			
	Claw	BF 87350	6			
	Thrust ring	BF 87351	6			
	O-ring	BF 87358	6			
	O-ring	BF 87385	6			

K. Spare parts

Item	Spare parts	Code No.	Supply per ship	Additional parts to IACS Recommended by WCH for		
			IACS	Zero to 10'000 hrs	Zero to 20'000 hrs	Zero to 30'000 hrs
			N = number of cylinders			
Turbocharger	1 set of spare parts *(according to turbocharger supplier)* Locking device *(incl. in turbocharger supply)* Blanking device *(incl. in WCH standard tool set)*		1 set 1 1			
Exhaust pipe (fig. K18)	Expansion piece after exhaust valve Expansion piece before turbocharger for TPL 80-B Expansion piece before turbocharger for MET 71SE Expansion piece before turbocharger for MET 83SE	BF 81390 BF 65093 or BF 65090 or BF 65094	(1) **for GL only** (1) **for GL only** (1) **for GL only** (1) **for GL only**			1 1 1 1
Tools	Standard tools as listed in the Maintenance Manual		1 set			
Engine control system	Spare parts for engine control system to DENIS-9520 *(pressure switches, solenoid valves, valves, O-rings, etc.)* Spare parts for alarm system to DENIS-9520 *(switches, transmitters, sensors, etc.)*.	BF 96320 BF 96330		1 set 1 set	1 set 1 set	1 set 1 set
Indicating instruments	Thermometers, pressure gauges and switches. (*These instruments are fitted on the engine.)*			1 of each type	1 of each type	1 of each type
Flex system Electr. modules	Flex control module FCM-20 Power supply 240AC/24DC/5A Power supply 240AC/24DC/20A WECS-9520 spare parts box, complete **and** **For PULSE lubricating system** Control unit ALM-20, incl. set of resistors and plugs	BF 93609 BF 93695 BF 93696 BF 96200 BF 93751	1 1 1	1(*) 1(*) 1(*)	1(*) 1(*) 1(*)	1(*) 1(*) 1(*)
Crank angle sensor unit	Shaft encoder drive, complete Shaft encoder, complete (box) Elastic screw Lever with parallel pin Compression spring Fixing screw	BF 92260 BF 92265 BF 92231 BF 92241 BF 92243 BF 92251	1 1 1 1 2 1	1(*)		

K. Spare parts

Item	Spare parts	Code No.	Supply per ship	Additional parts to IACS Recommended by WCH for		
			IACS	Zero to 10'000 hrs	Zero to 20'000 hrs	Zero to 30'000 hrs
				N = number of cylinders		
Flex system						
Sensors, actuators and valves	Pressure transmitter 250 bar	BF 56071	1			
	Pressure transmitter 1200 bar	BF 55635	1			
	Rail valve complete *(box)*	BF 55754		4(*)	4(*)	4(*)
	Proximity sensor PNP	BF 46282	1			
	5/2-solenoid valve for starting air valve	BF 27310	1			
	3/2-way solenoid valve for press. ctrl valve	BF 87584		1(*)		
	FQ-sensor with connecting element *(box)*	BF 55762		1(*)	1(*)	1(*)
	Fuel pump actuator	BF 58054		1(*)	1(*)	1(*)
Supply unit	**For 6-, 7-cyl. engines**					
	Pinion	BF 55480		1(*)		
	Shaft	BF 55479	1			
	Bearing bush	BF 55542		1 pair(*)		
	Relief valve	BF 87470	2			
	Fuel pressure valve, complete	BF 87545	1			
	Non-return valve, complete	BF 87450		1(*)		
	Pressure control valve	BF 87560	1			
	Shut-off valve, complete	BF 87505	1			
	O-ring for shutoff valve BF 87505	BF 87513	1			
		and				
	Valve complete *(collectot block)*	BF 84530	1			
	O-ring for valve BF 84530	BF 87533	1			
	Relief valve complete *(to distributor block)*	BF 84517	1			
	Fuel pump plumger complete	BF 55600	1	1(*)		
	Fuel pump complete, with plunger	BF 55300				
	Set of O-rings and sealing rings	BF 55608	1 set	1(*)		
	Fuel cam	BF 55468		1(*)		
	Camshaft upper bearing shell half	BF 55435		1(*)		
	Camshaft lowerbearing shell half	BF 55478		1(*)		
Automatic filter	Filter inserts	BF 84461		7(*)		
	Set of O-rings	BF 84462		1 set(*)		

Item	Spare parts	Code No.	Supply per ship	Additional parts to IACS Recommended by WCH for		
			IACS	Zero to 10'000 hrs	Zero to 20'000 hrs	Zero to 30'000 hrs
				N = number of cylinders		
Flex system						
Rail unit	Lip seal	BF 55617	1			
	Lip seal	BF 55758	2			
	Injection control unit *(complete)*	BF 55764	1			
		or				
	Injection control unit *(complete)*	BF 55763	1			
	Lip seal (for inj. ctrl unit)	BF 55758		1(*)		
	Pressure reducing valve 50 bar *(control oil supply – free end)*	BF 55782	1			
	Non-return valve *(fuel)*	BF 55628		1(*)		
	Exhgaust valve actuator, complete	BF 56120	1			
	Set O-rings *(to exh. valve drive)*	BF 56170		1 set(*)		
	Flexible hose *(control oil supply to ICU)*	BF 55775	1			
	Flexible hose, complete with non-return valve *(control oil supply to ICU)*	BF 56013	1			
		and				
	For engines with PULSE lubricating system					
	Servo oil pipe, complete	BF 56181	1			

Table K1 List of spare parts 373.101D

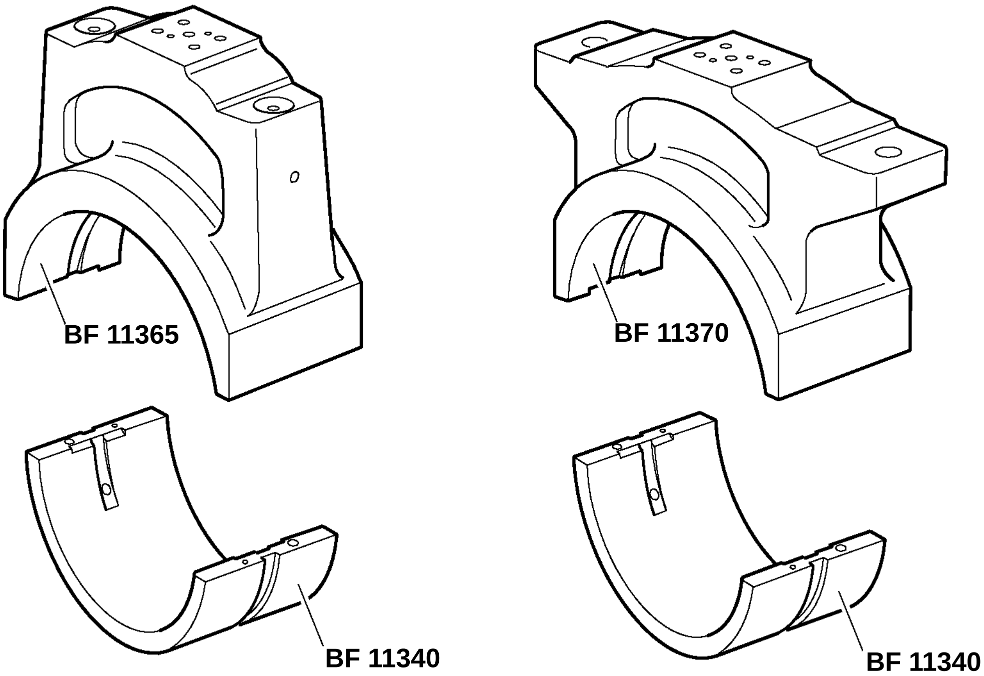
Examples:
Fuel injection valve, spare parts for 20'000 hours operation for a 7RT-flex84T-D.

		IACS		20'000 hrs	
Fuel injection valve complete	BF 27200	3 • N+3	= (3 • 7)+3 = 24 pcs	————	
Nozzle body with needle	BF 27242	1 • N	= 1 • 7 = 7 pcs	————	
Atomizer	BF 27244	1 • N	= 1 • 7 = 7 pcs	6 • N	= 6 • 7 = 42 pcs
Small parts	BF 27250	1 • N sets	= 1 • 7 = 7 sets	6 • N sets	= 6 • 7 = 42 sets
Dowel pin for nozzle body	BF 27202	1 • N	= 1 • 7 = 7 pcs	1 • N	= 1 • 7 = 7 pcs
Dowel pin for atomizer	BF 27243	1 • N	= 1 • 7 = 7 pcs	6 • N	= 6 • 7 = 42 pcs

Remarks:
The columns "Recommended bei WCH" for 10'000/20'000/30'000 hrs for items WECS-9520. Supply unit and rail unit are not complete yet as same are depending on experience.
The numbers stated in column "IACS" and marked with (*) have to be regarded as items by WCH to be kept on board for increased availability.

K. Spare parts

K3 Illustrations, masses and weights of spare parts



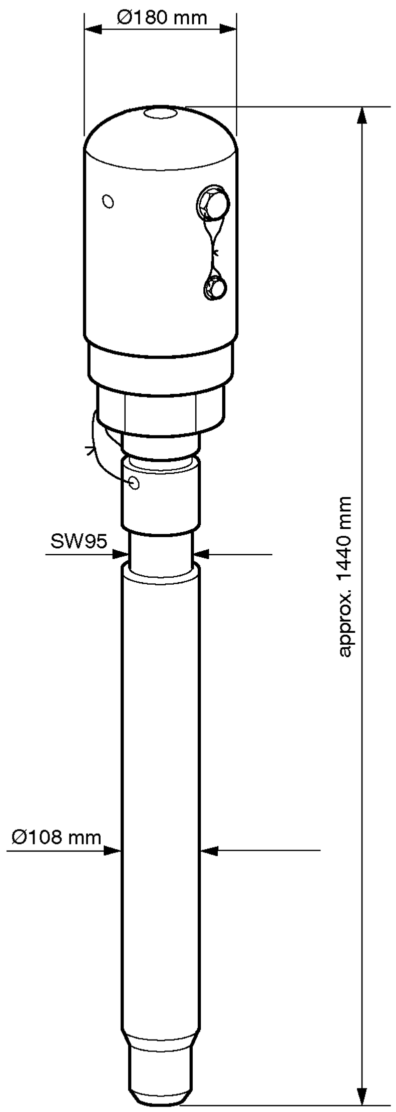
7056–03/F100714
(270.24qd)

Code No.	Description	Mass [kg]	Size [mm]
BF 11340	Main bearing shell lower half	295	1110 x 550 x 290
BF 11365	Main bearing cover	770	805 x 1110 x 360
BF 11370	Main bearing cover, at driving end only	768	805 x 1360 x 360

Fig. K1 Main bearing

K. Spare parts

BF 11380

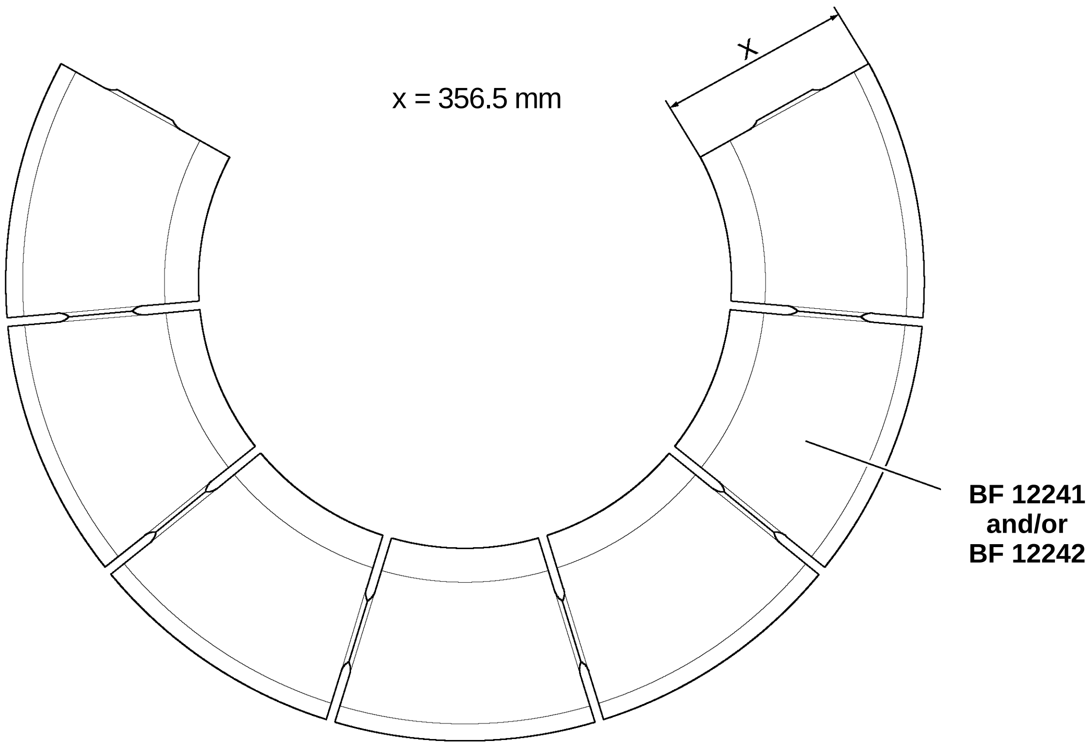


(297.574a)

Code No.	**Description**	**Mass** [kg]	**Size** [mm]
BF 11380	Jack bolt complete, for main bearing (BF 11365)	142	length approx. 1440

Fig. K2 Jack bolt

K. Spare parts

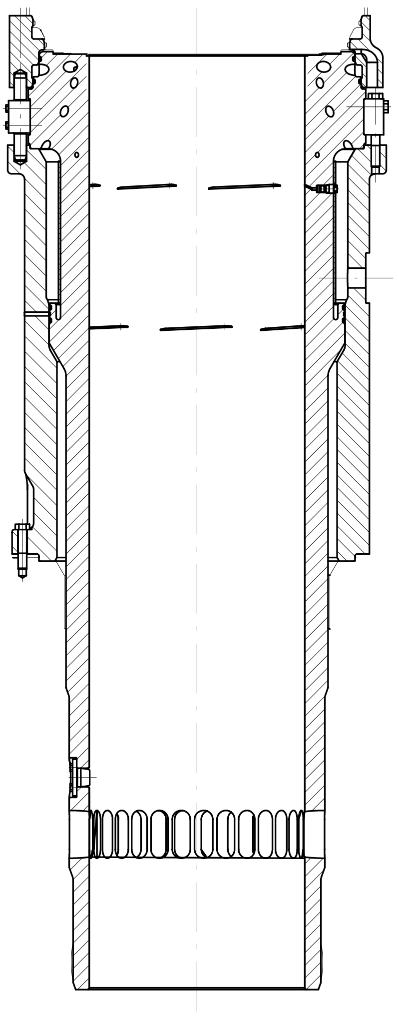


F10.4968
(355.012a)

Code No.	Description	Mass [kg]	Size [mm]
BF 12241 and/or BF 12242	Thrust pads (set of 7) (depending on rotation of engine)	156	each pad 356.5 x 491 x 145

Fig. K3 Thrust bearing pads

BF 21242

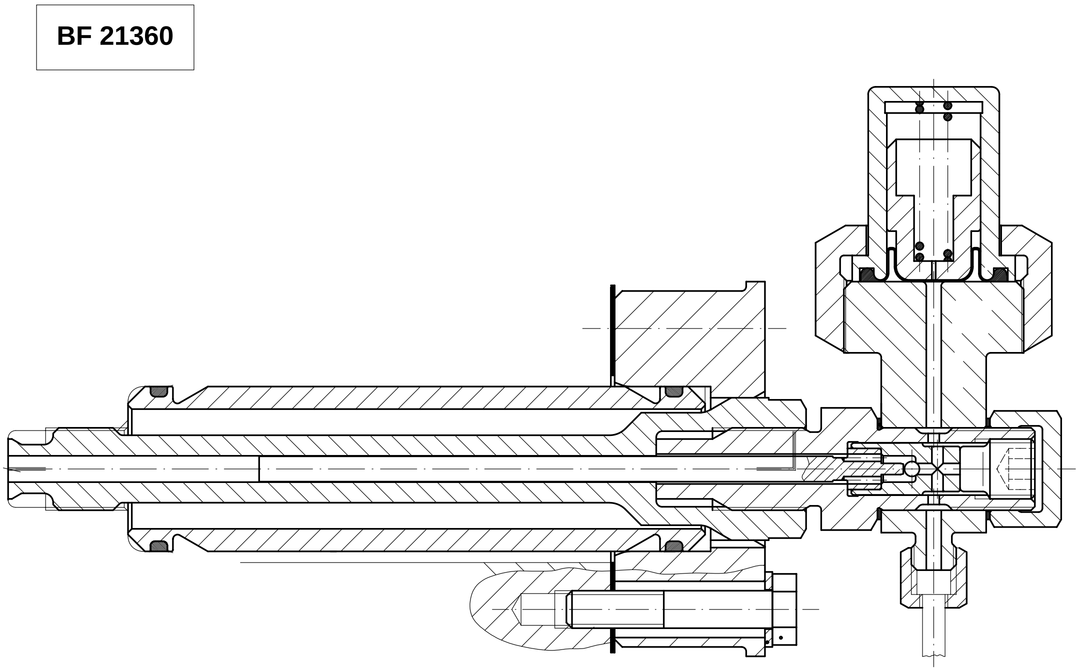


010.677/03
(389.313)

Code No.	Description	Mass [kg]	Size [mm]
BF 21242	Cylinder liner (without joint ring and O-rings)	7318	∅ 1290 x 3640
BF 21300	Water guide jacket	503	∅ 1458 x 277

Fig. K4 Cylinder liner

K. Spare parts



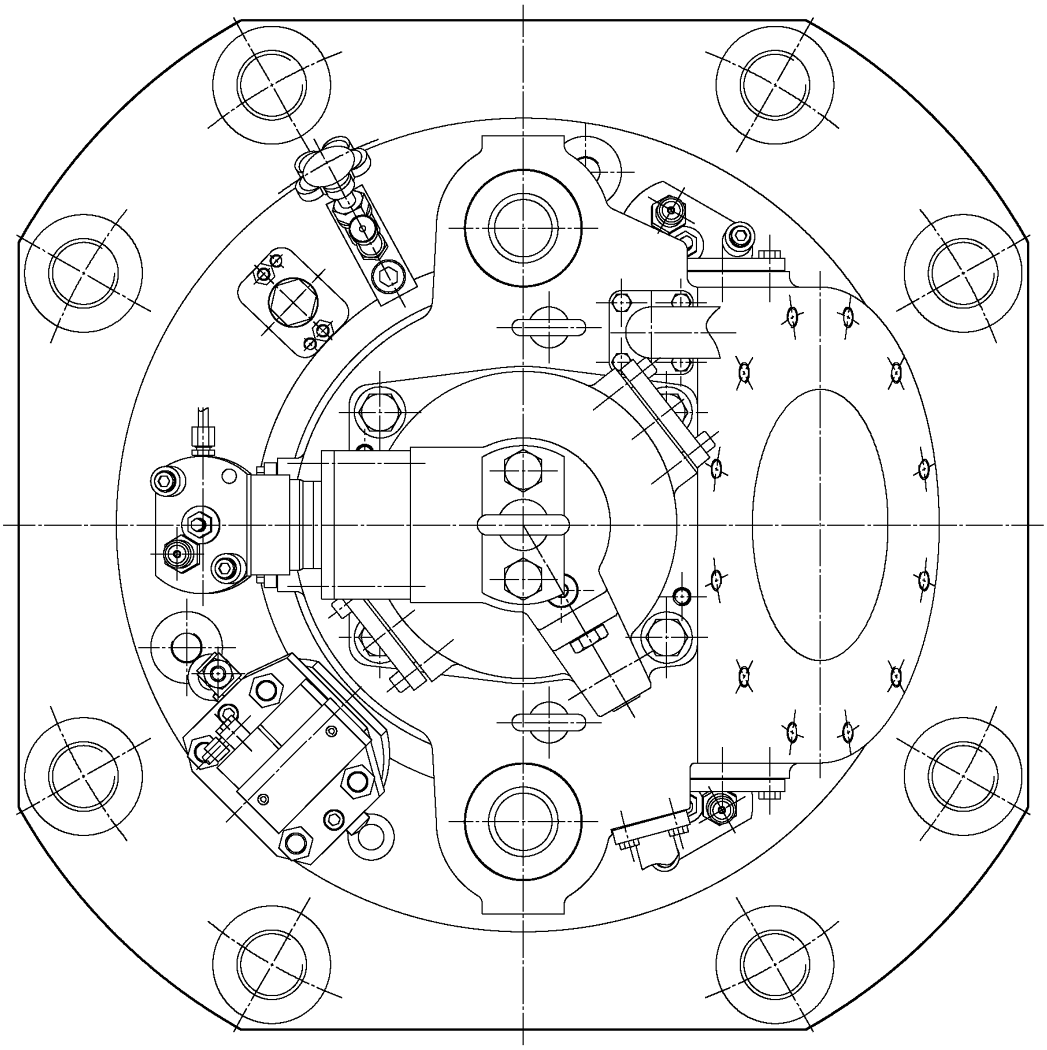
222.010b

Code No.	Description	Mass [kg]	Size [mm]
BF 21360	Cylinder lubricating quill with accumulator, complete for one cylinder	4.8	each 129 x 281 x 100

Fig. K5 Lubrication quill with accumulator (conventional lubricating system)

K. Spare parts

BF 27103

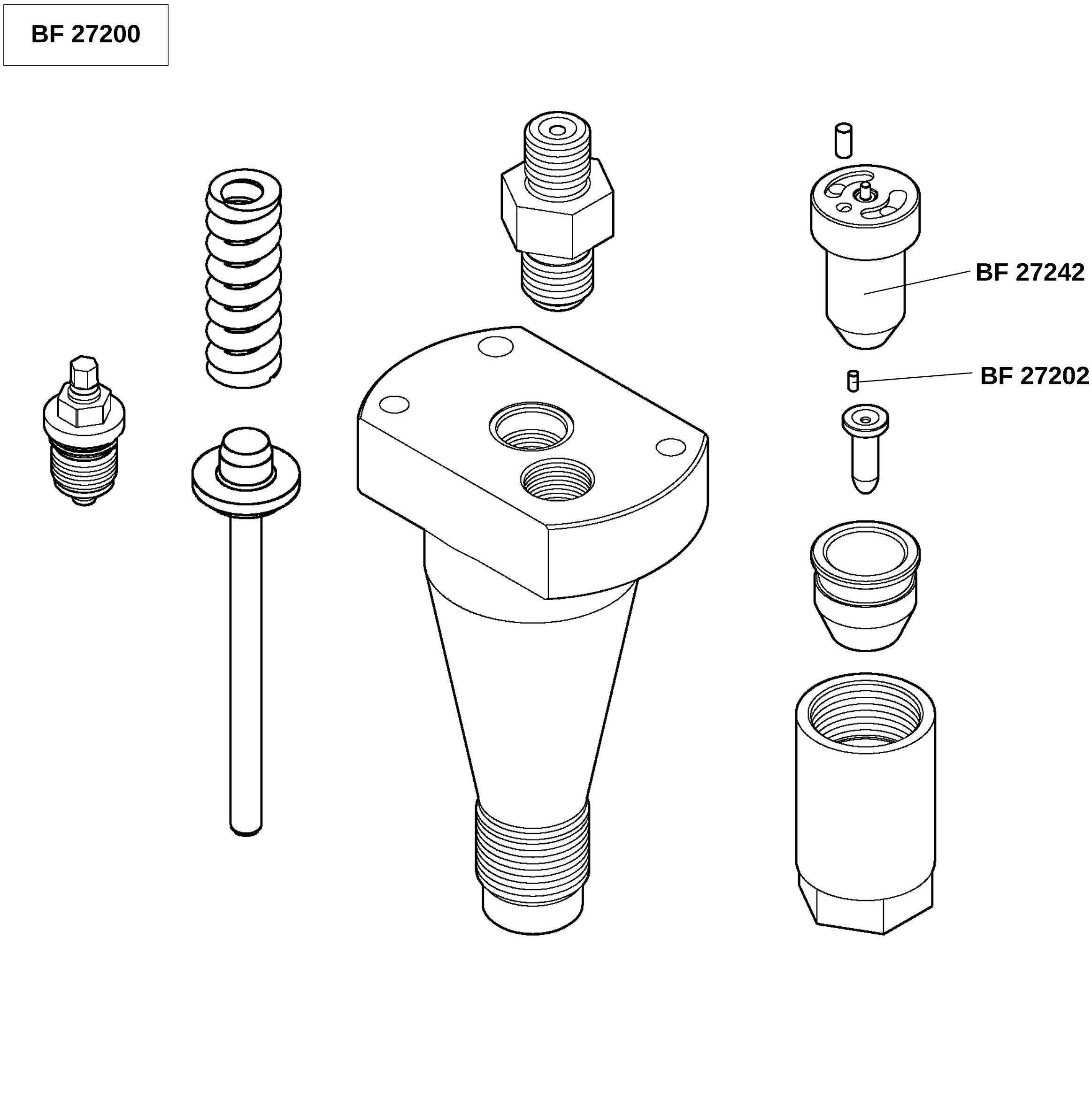


F10.4974
(317.303a)

Code No.	Description	Mass [kg]	Size [mm]
BF 27103	Cylinder cover, complete, but without valves	approx. 4900	1470 x 1470 x 570

Fig. K6 Cylinder cover

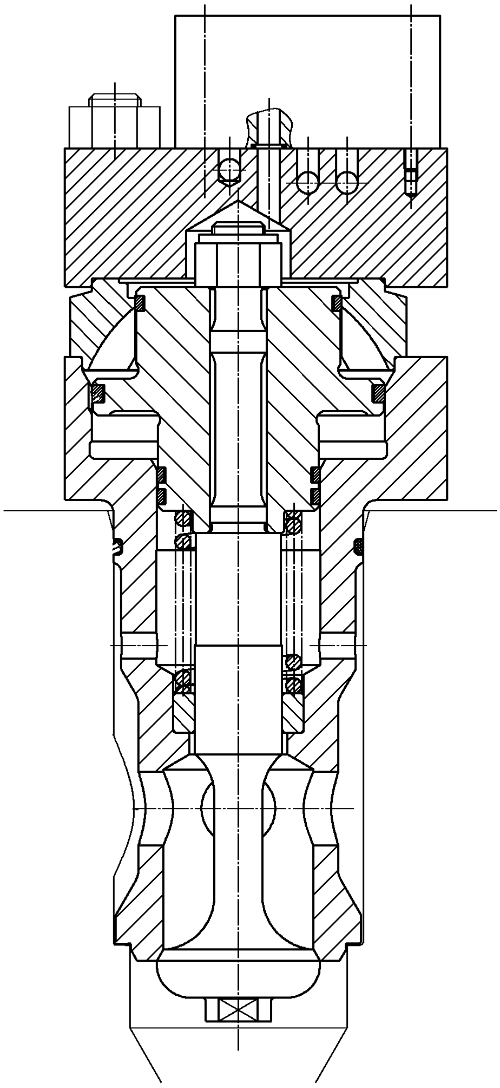
K. Spare parts



Code No.	Description	Mass [kg]	Size [mm]
BF 27200	Fuel injection valve, complete, adjustable with a collar nut	approx. 24	535 x 176 x 124
BF 27202	Dowel pin for nozzle holder	—	—
BF 27242	Nozzle body with needle (1 per valve)	0.8	—

Fig. K7 Fuel injection valve

BF 27280



F10.4980

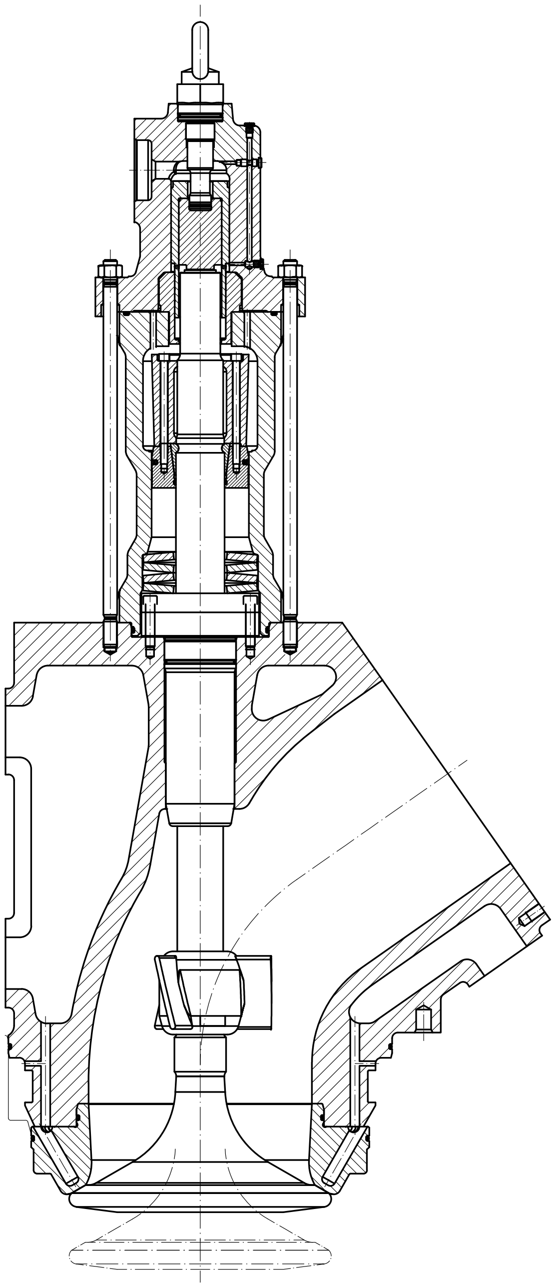
(348.891b)

Code No.	Description	Mass [kg]	Size [mm]
BF 27280	Starting air valve, complete	81	approx. 559 x 270 x 190

Fig. K8 Starting air valve

K. Spare parts

BF 27500

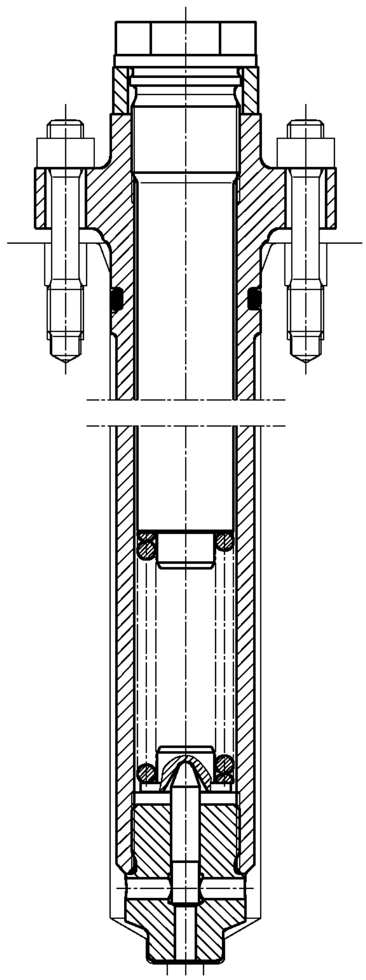


352.802c

Code No.	Description	Mass [kg]	Size [mm]
BF 27500	Exhaust valve, complete	—	—
BF 27600	Valve spindle with rotation wings	1750	∅400 x 1644

Fig. K9 Exhaust valve

BF 27465



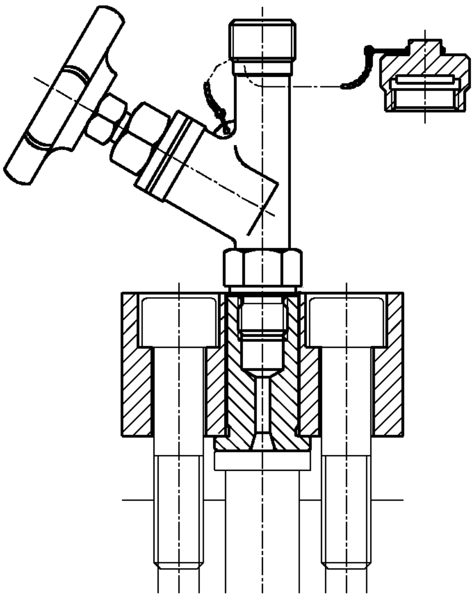
317.278a

Code No.	Description	Mass [kg]	Size [mm]
BF 27465	Relief valve, complete	5.4	397 x 100 x 60

Fig. K10 Relief valve

K. Spare parts

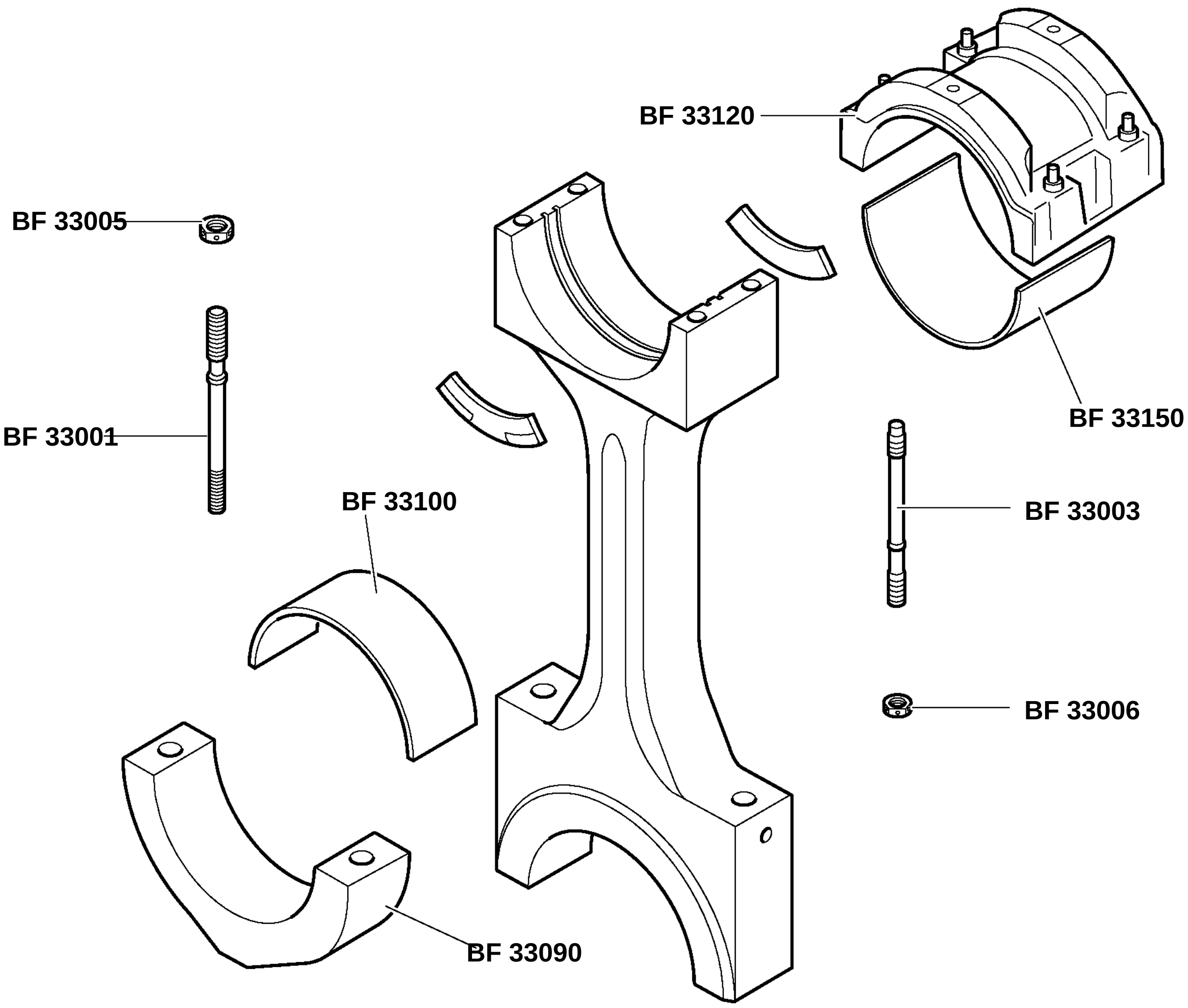
BF 27435



F10.5044

Code No.	Description	Mass [kg]	Size [mm]
BF 27435	Indicator valve, complete	2.42	175 x 114 x 105

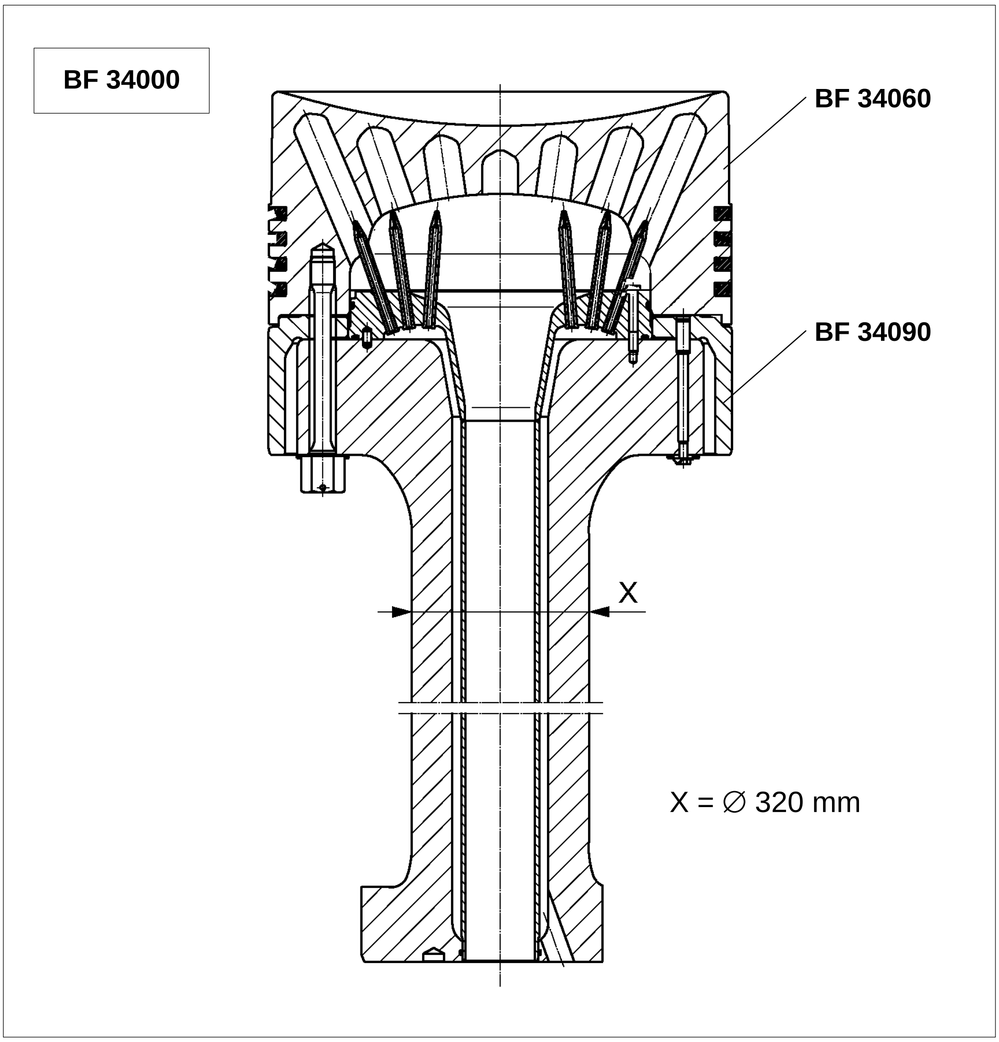
Fig. K11 Indicator valve (cock)



Code No.	Description	Mass [kg]	Size [mm]
BF 33003	Elastic stud for top-end bearing	25.5	∅78.5 x 875
BF 33006	Nut for elastic stud	3.1	M76 x 6
BF 33001	Elastic stud for bottom-end bearing	60	∅100 x 1102
BF 33005	Round nut for elastic stud to bottom-end bearing	5.8	M100 x 6
BF 33090	Lower bearing half for bottom-end bearing, white metal lined	653	1350 x 705 x 240
BF 33100	Shell for bottom-end bearing, upper half	82	346 x 1020 x 263
BF 33120	Bearing cover for top-end bearing, white metal lined	624	1030 x 530 x 780
BF 33150	Bearing shell, lower half, for top-end bearing	130	826 x 775 x 206

Fig. K12 Connecting rod bearings

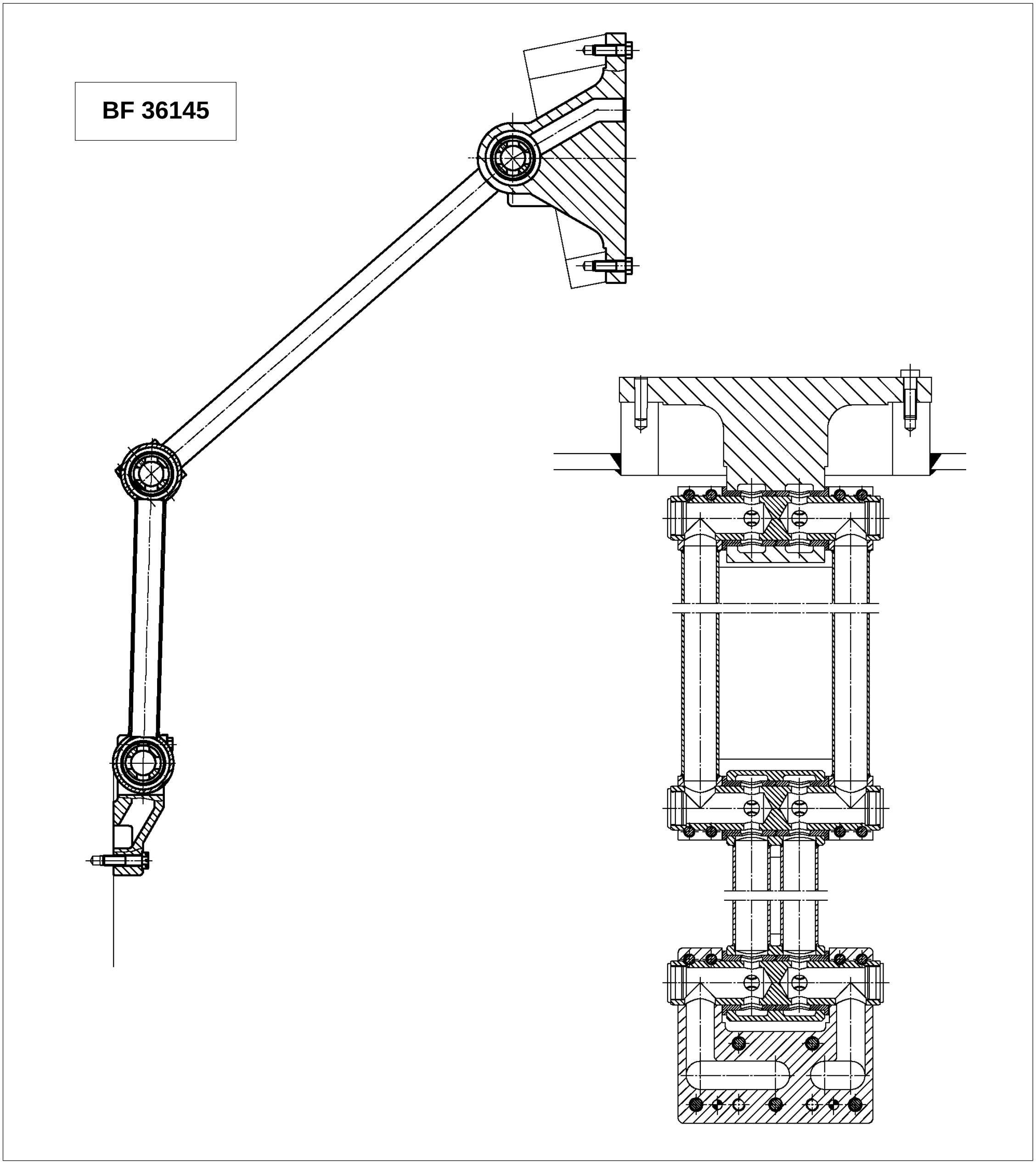
K. Spare parts



F10.4996

Code No.	Description	Mass [kg]	Size [mm]
BF 34000	Piston, complete with head, skirt, piston rod, studs and nuts (without piston rings)	4142	∅840 x 4645
BF 34060	Piston head	1056	∅840 x 420
BF 34090	Piston skirt	199	∅840 x 240

Fig. K13 Piston

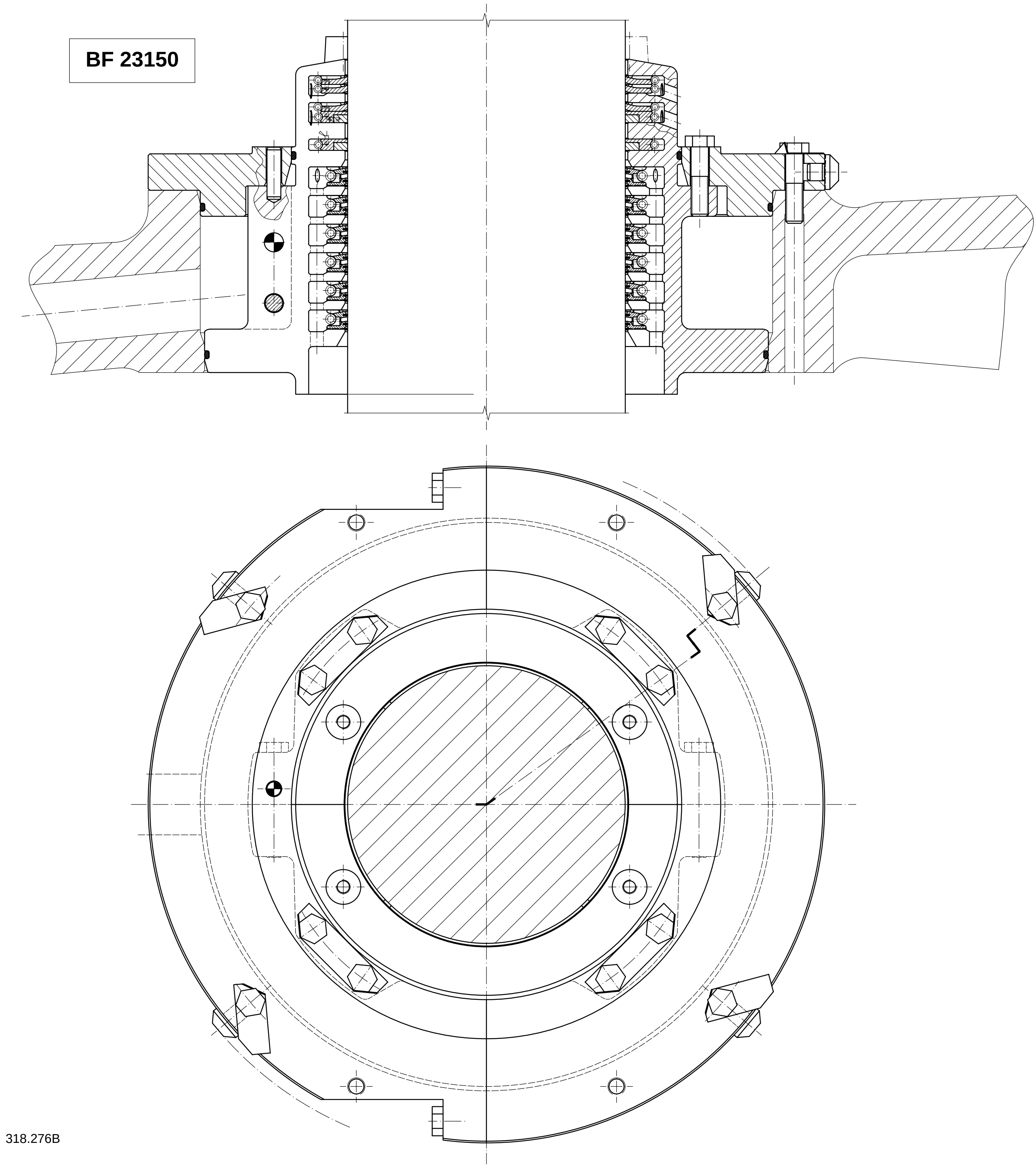


F10.4993

Code No.	Description	Mass [kg]	Size [mm]
BF 36145	Articulated levers with bush and pin (complete) without support and connection piece	196	—

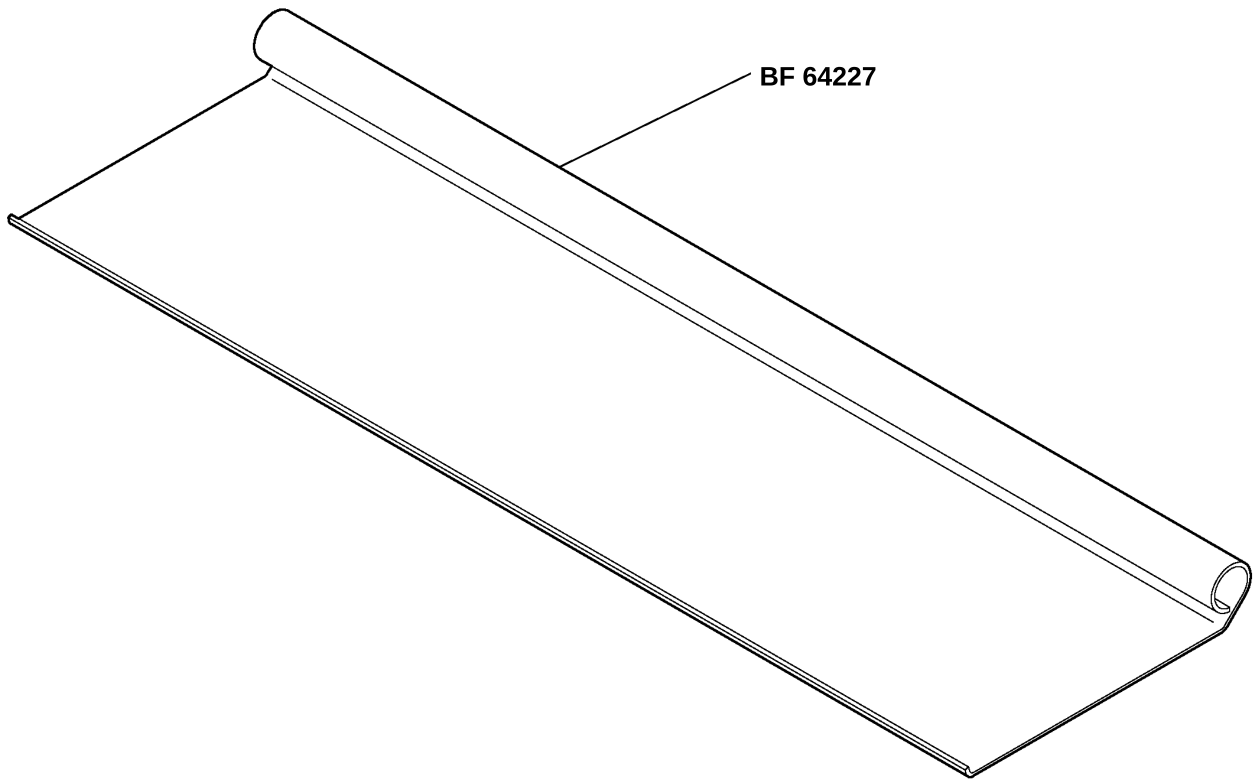
Fig. K14 Piston cooling and crosshead lubricating linkage

K. Spare parts



Code No.	Description	Mass [kg]	Size [mm]
BF 23150	Piston-rod gland box, complete incl. casing in 2 parts	356	∅780 x 386

Fig. K15 Gland box piston rod

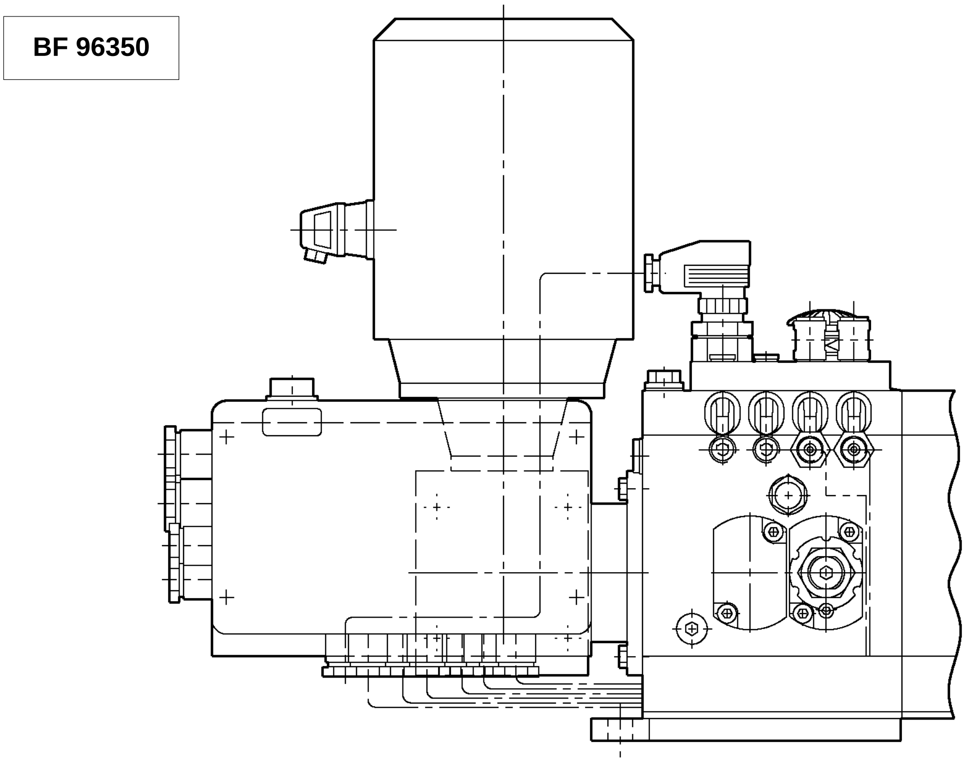


F10.5012

Code No.	Description	Mass [kg]	Size [mm]
BF 64220	Flap	2	554 x 156 x 2

Fig. K16 Flap for scavenging air receiver

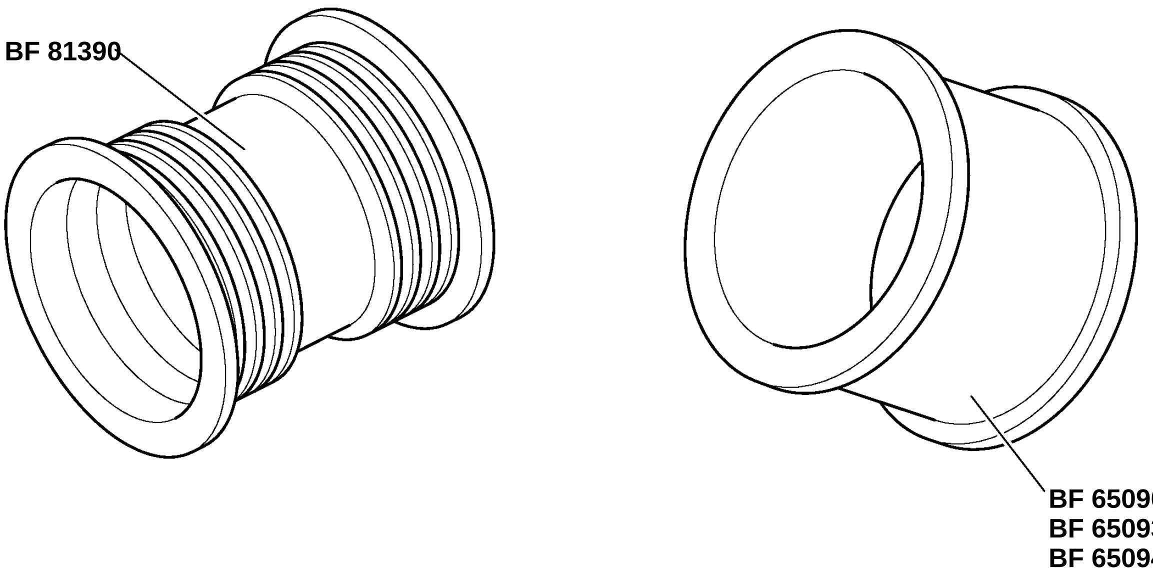
K. Spare parts



F10.5002

Code No.	Description	Mass [kg]	Size [mm]
BF 96350	Spare parts for cylinder lubrication pump (incl. driving electro motor and gear)	—	—

Fig. K17 Cylinder lubricating pump and drive



F10.5014

Code No.	Description	Mass [kg]	Size [mm]
BF 81390	Expansion piece after exhaust valve	107	∅630 x 495
BF 65090 or BF 65093 or BF 65094	Expansion piece before turbocharger	depends on type of turbocharger	

Fig. K18 Expansion piece of exhaust system

K4 Storage on board

K4.1 Protection against corrosion

It is essential that spare parts are previously preserved against corrosion by the manufacturer or provider to be protected during shipping. Before storage on board, the spare parts have to be checked for adequate preservation.

To achieve a long-term protection, spare parts and components with an insufficient preservation have to be treated as follows:

- Large components should be treated with Valvoline Tectyl 506 or a suitable equivalent.
- Smaller components, with the exception of electronic equipment, can be wrapped in a corrosive-protective paper i.e., Vapour Phase Inhibitor.
  Note: When using corrosive-protective paper, care must be taken not to tear the paper as the protective qualities of the paper will be lost.
- White metal and bearing surfaces should be protected with 'Emballit' alum or a suitable equivalent.
- Electronic components should be vacuum packed in 'Alfo' sheets using 1000 g of a suitable drying agent for each cubic metre content.

K4.2 Storage and security

Examples of ways to secure and protect spare parts safely and allow ease of access by the engine-room staff are given below (see also figures K19 to K22).

- The size and weight of each component is to be noted prior to storage, to ensure that the safest and most space-efficient method is adopted.
- All components are to be mounted within easy access of the engine, ensuring machinery space walkways are kept clear.
- Large components are to be mounted below suitable overhead lifting gear.
- The weights of large components are to be painted on, or, adjacent to the component.
- Suitable lifting eyes and shackles are to be provided.
- All components must be firmly secured to prevent any movement.
- Metal to metal contact is to be avoided during storage of any component.
- All open ports, adapters, pipes, etc., are to be sealed to prevent the ingress of foreign particles.
- Any provisions for mounting spare parts on the engine should be fully utilised.

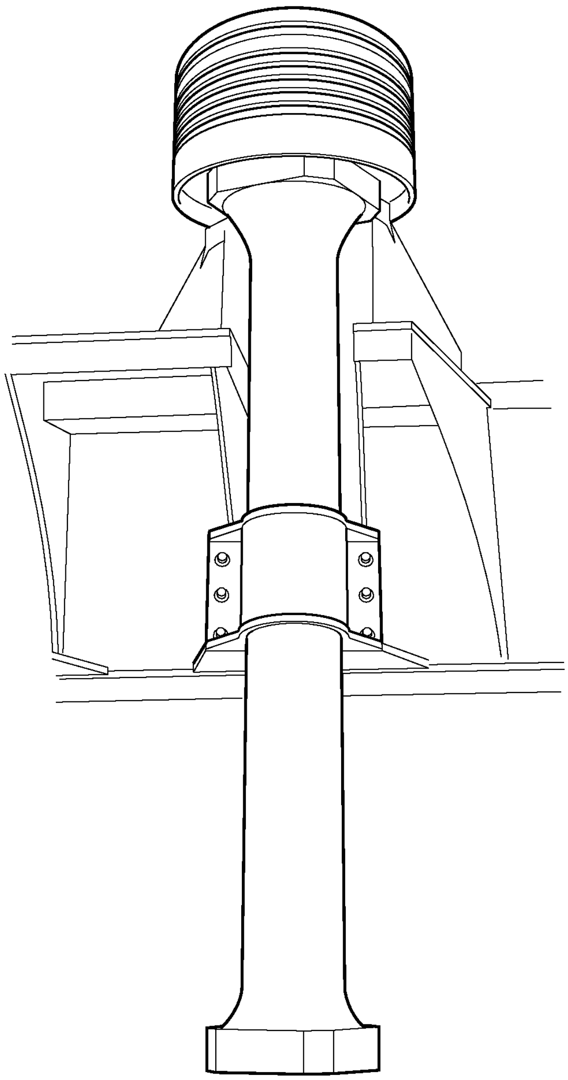
K4.2.1 Turbocharger spare parts

Turbocharger spare parts are to be suitably protected against corrosion and contained within their own spare parts box.

Bearing assemblies are supplied packed in sealed metal containers to protect them from the environment. Bearing assemblies must only be removed from metal containers when they are actually required.

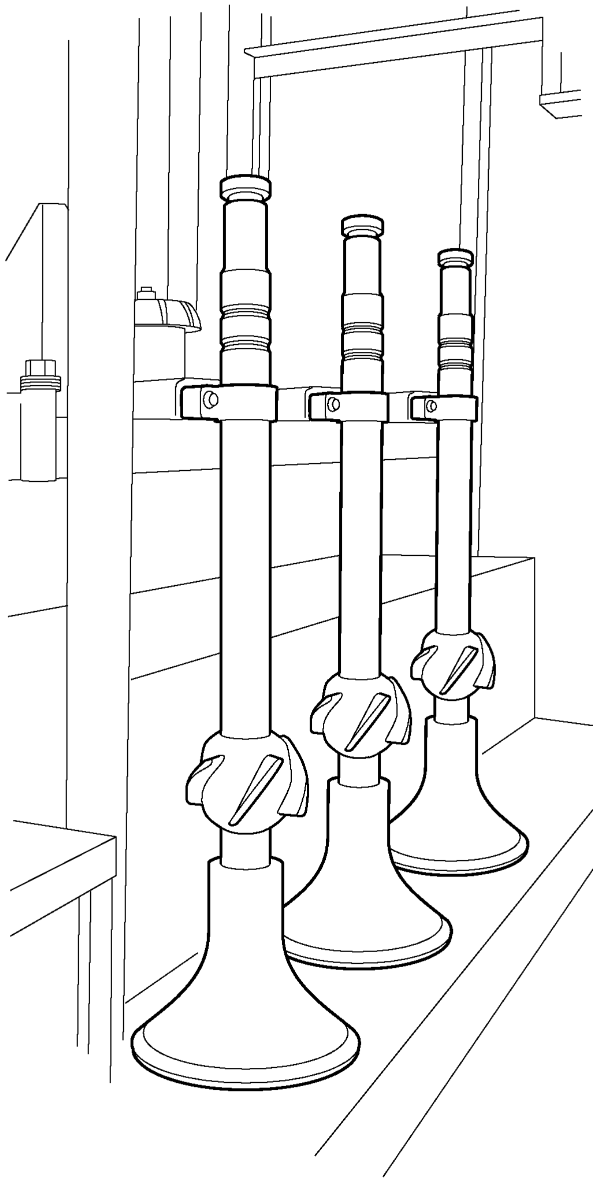
All turbocharger spare parts used, are to be replaced, to ensure the spares kit is complete.

K4.2.2 Secured spare parts



F10.2800

Fig. K19 Securing spare piston and rod



F10.2801

Fig. K20 Securing spare exhaust valves

K. Spare parts

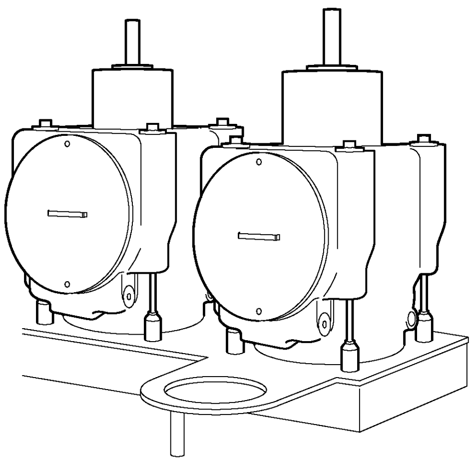


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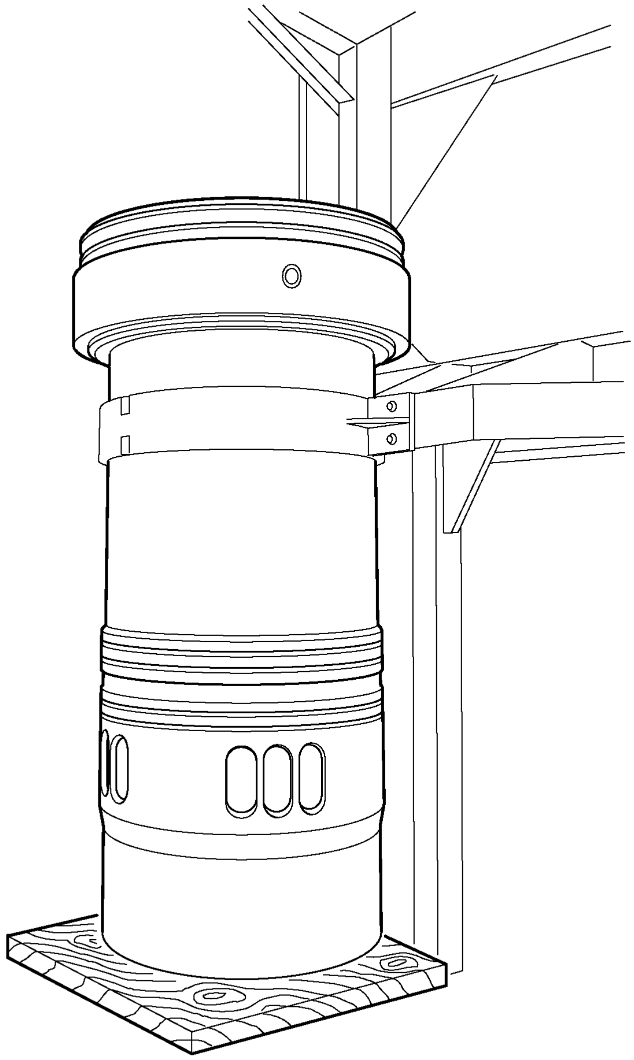
Fig. K21 Securing spare exhaust valve cages without hydraulic actuator



F10.2803

Fig. K22 Securing spare cylinder liner

L. Engine dispatch and installation

L1 Dismantling pattern

Engines are transported as complete or part assemblies and protected against corrosion by rust preventing oils, **v**apour **p**hase **i**nhibitor papers (VPI) and wooden crates lined with jute reinforced bituminous paper.

L1.1 Treatment against corrosion

Engine interior

For engines to be transported as complete assemblies we recommend for internal surfaces the use of rust preventing oils as listed below. It is not necessary to remove them before the engine goes into operation.

- Valvoline Tectyl 873
- Shell Ensis Engine Oil SAE 40/30
- Exxon Rust-Ban 623
- Mobil Mobilarma 524
- Caltex / Chevron Preservative Oil SAE 30.

For the transport of complete engines, dehumidifiers are to be enclosed in the scavenge space and the crankcase.

Engine exterior

One coat of Valvoline Tectyl 506 or similar product to be applied to all machined parts not protected by paint. It is to guarantee protection for at least six months from the effects of weather and remain intact until shortly before the engine goes into operation.

Bearing and cylinder lubricating oil systems

On completion of the engine shop trial the main and cylinder lubricating oil systems are to be drained completely and refilled with Valvoline Tectyl 873 or similar product and circulated for at least an hour with the engine being slowly rotated by the turning gear. At the same time, the cylinder lubricators must be rotated as well.

After that, the crossheads and main bearings are to be lubricated, please refer to the maintenance manual, group 3 ‘Connecting rod and connecting rod bearing’.

Spraycoating with rust preventing oil

Internal parts not sufficiently covered by the rust preventing oil during circulation are to be spray coated. These include the fuel pump pushrods, springs, plungers, rollers and cams, piston rods above, inside and below the stuffing box, scavenge valves and dry parts of the cylinder liners. The liners can be accessed and sprayed through the scavenge ports.

Pipework

All open ended pipework is to be sealed by plugs or blank flanges to eliminate ingress of foreign bodies and circulation of air.

Turbocharger in place

Drain the turbine and compressor end oil and spraycoat the bearings while turning the rotor by hand. Fit blank flanges to the air inlet and gas outlet sides.

Cylinder cooling water system

During engine shop trials, usually a cooling water treated with corrosion inhibitors is used. Corrosion-protective inhibitors are only effective as long as the correctly treated water is in contact with the metal surface to be protected. Once the cooling water has been drained off, further treatment against corrosive attack is absolutely essential.
Therefore a suitable corrosion protection has to be carried out by applying rust preventing oil as mentioned in section L1.1 under ‘Engine interior’

An alternative may be the admixture of a so-called 'soluble oil' to the cooling water to protect the engine cooling water system. The concentration must be maintained at levels between 0.5 to 0.8 per cent by volume. On completion of the trials and prior to shipping, the circulating cooling water through the engine cooling water system is to be maintained at a pH value between 7 and 9 and the soluble oil inhibitor level increased to 1 per cent by volume. The cylinder temperature is not to exceed 90°C and circulation is to continue for at least three hours allowing time for the soluble oil inhibitor to coat the internal surfaces.

We recommend using the following soluble oil inhibitors:

- BP Fedaro
- Castrol Solvex WT3
- Chevron Soluble Oil T1
- Exxon / Esso Kutwell 40
- Mobil Mobilmet 120
- Shell Dromus BX
- Texaco Soluble Oil C, CX.

For long time conservation of engines please ask for the specification from the engine manufacturer or Wärtsilä Switzerland Ltd.

L1.2 Engine dismantling

Engines transported as part assemblies are to be systematically disassembled and cleaned using dry cloths. Each item is to be clearly identified with 'paint ball' pen, similar indelible marker ink, or figure and letter stamps and protected from damage by careful crating and corrosion protected by rust preventing oils or paper.

It is very important that bearings and running gear are clearly marked cylinder by cylinder to ensure correct reassembly and eliminate the possibility of parts from one cylinder unit being fitted to another by mistake. Refer to section B2 of this manual for details of the engine numbering.

Use a paint brush to apply highly viscous rust preventing oil to the piston and connecting rods, crosshead guides, gear wheels, camshaft and rollers. Air powered spray guns to be used only if the air is absolutely free of water.

Crankshaft and crosshead pins are to be protected with an anti-corrosive coating of Tectyl 506 or similar product.

L. Engine dispatch and installation

L1.3 Engine dispatch

Engines transported as complete assemblies are lifted using special tools and lifting gears.

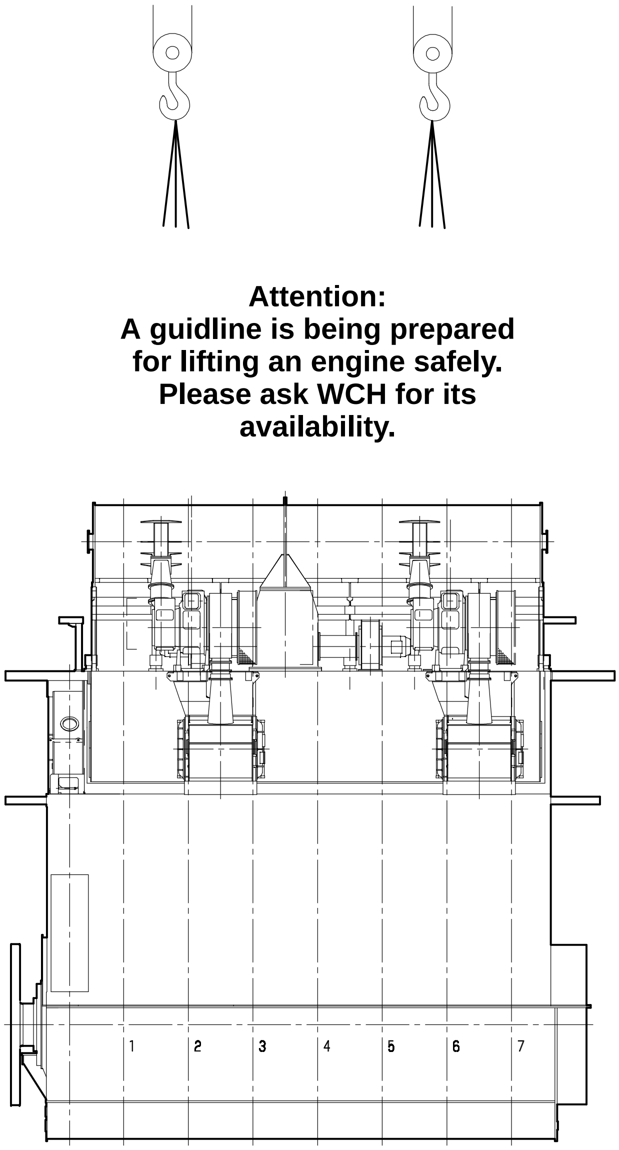


Fig. L1 Lifting a complete engine

L2 Engine installation on board

The alignment and chocking of the engine should be carried out in accordance with our recommendations and is subject to test and inspection by the relevant classification society. Each stage of the engine mounting is to be checked by qualified personnel and measurements cross-checked with the design figures. The responsible parties (e. g. shipyard) are to advise the representative of the engine builder or Wärtsilä Switzerland Ltd directly in case of any discrepancies.
Engines may be installed as complete units or assembled from sub-assemblies in the vessel, which may be afloat, in dry dock, or on the slipway.
After the engine re-assembly is completed, the engine alignment can be done with either jacking screws or wedges.

L2.1 Removing rust preventing oils

Rust preventing oils applied to the internal parts of an assembled engine do not contain thickening agents of wax or bitumen. These oils have similar properties as the engine lubricating oils, will wash off easily and mix without causing harm to the engine or its systems.
Rust preventing oils of the wax-type applied to exposed surfaces of the engine components do contain thickening agents of wax or bitumen forming an anti-corrosion coating when applied, which has to be washed off using a proprietary ‘Cold Cleaner’. It is not sufficient to use gas oil, kerosene or white spirit on its own as solvents; they are to be mixed with 2 to 3 parts of a ‘Cold Cleaner’ such as ‘Magnusol’, ‘Agitol’ or ‘Emultan’.

L2.2 Installation and assembly of sub-assemblies

When the engine seating has been approved, the bedplate is lowered onto blocks placed between the chocking points. The thickness of the blocks depends on the final alignment of the engine.
Engine bedplates comprise fabricated sections with drilled holes to allow the passing of the holding-down bolts and tapped holes for the jacking screws for engine alignment.

Proceed with preliminary alignment of bedplate to position the engine coupling flange to the intermediate shaft coupling flange. Ensure that the gap between both flanges is close to the calculated figures and that both flanges are exactly parallel on the horizontal plane (max. deviation 0.05 mm). In the vertical plane, the engine coupling flange is to be set 0.4 to 0.6 mm higher than the calculated figures, because less effort is required to lower the engine than to raise it for alignment.
Place bearing caps in position, install turning gear and check that crankshaft deflections are as recorded on the “Engine Assembly Records”.

To check bedplate level in longitudinal and diagonal direction a taut-wire measuring device is available on request. Compare the readings with those recorded at the works. Optical devices, lasers or water pots can also be used.

L. Engine dispatch and installation

All final dimensions are to be witnessed by the representatives of the engine builder and the classification society. They are to be recorded on appropriate log sheets. Crankshaft deflections at this stage are to correspond with the values recorded at works. Secure temporarily the bedplate against unexpected movement.
Continue engine assembly by mounting the columns, cylinder blocks, running gears and scavenge air receiver but ensure that the bearing caps are loose before tensioning the tie rods.
Make periodic checks of the crankshaft deflections to observe and correct any possible engine distortions. Careful adjustments of the wedges or of the jacking screws are necessary to re-establish the preliminary alignment setting. Once the engine assembly is completed, the final alignment is carried out with the vessel afloat, according to section L3.

L2.3 Installing a complete engine

In the event that the engine is shipped in part deliveries and assembled at the shipyard prior to installation in the vessel, the shipyard is to undertake the assembly work in accordance with the requirements of a representative of the engine builder and the classification society. The engine mounting is to be carried out systematically and measurement readings taken and recorded on appropriate log sheets, and to be compared for correctness with the data of the ‘ “Engine Assembly Records”, completed after test run in the works of manufacturer. Strict attention is to be paid to the removal of anti-corrosion coatings and the subsequent application of rust preventing oil where required.

For lifting details of the engine refer to section. L1.3.

The engine is to be lowered onto blocks placed between the chocking points. The alignment tools are to be clean and ready for use. Set the blocks so that the engine is slightly higher than the final position, because less effort is required to lower the engine than to raise it for alignment.

For movements in the horizontal plane, both in lateral or longitudinal directions, the shipyard is to construct appropriate anchor points for the use of hydraulic jacks. Such movements have to be carried out with great care to avoid stresses and distortions to the bedplate. Regular crankshaft deflection readings have to be taken to observe the effects and any noticed deviations have to be rectified immediately.

L2.4 Installing an engine from assembled sub-assemblies

Sub-assemblies of the engine may be assembled ashore prior to installation in the ship. One such assembly may comprise bedplate, main and thrust bearings, crankshaft, turning gear, and flywheel. The placing on blocks and alignment to shafting is analogue to the description in section L2.2.

L2.5 Engine installation with ship on slipway

Installing complete or partially assembled engines into ships under construction on an inclined slipway is possible when careful attention is paid to the following:

1. Consider the ship’s inclination when lifting and lowering the engine or large engine parts into the ship.
2. Tie rods to be centred and exactly perpendicular to the bedplate before tightening.
3. Fit temporary side, fore and aft stoppers to prevent the engine moving during launching.
4. Attach additional temporary stays at the upper platform level to steady the engine during launching.

L3 Shafting alignment

A new instruction manual is being prepared. Please ask WCH for its availability.

M. Appendix

M1 SI dimensions for internal combustion engines

Symbol	Definition	SI-Units	Other units
I,L	Length	m, mm, µm	
A	Area	m^2, mm^2, cm^2	
V	Volume	m^3, dm^3, l, cm^3	
m	Mass	kg, t, g	
ρ	Density	kg/m^3, g/cm^3, kg/dm^3	
Z, W	Section modulus	m^3	
I_a, I_p	Second moment of area	m^4	
I, J	Moment of inertia (radius)	kgm^2	
α, β, γ, δ, φ	Angle	rad, °	
t	Time	s, d, h, min	
f, v	Frequency	Hz, 1/s	
v, c, w, u	Velocity	m/s, km/h	Kn
N, n	Rotational frequency	1/s, 1/min	rpm
a	Acceleration	m/s^2	
ω	Angular velocity	rad/s	
α	Angular acceleration	rad/s^2	
q_m	Mass flow rate	kg/s	
q_v	Volume flow rate	m^3/s	
p	Momentum	Nm	
L	Angular momentum	Nsm	
F	Force	N, MN, kN	
p	Pressure	N/m^2, bar, mbar, kPa	1 bar = 100 kPa, 100 mmWG = 1 kPa
σ, τ	Stress	N/m^2, N/mm^2	
E	Modulus of elasticity	N/m^2, N/mm^2	
W, E, A, Q	Energy, work, quantity of heat	J, MJ, kJ, kWh	
P	Power	W, kW, MW	
M, T	Torque moment of force	Nm	
η	Dynamic viscosity	Ns/m^2	
ν	Kinematic viscosity	m^2/s	cSt, RW1
γ, σ	Surface tension	N/m	
T, Θ, t, θ	Temperature	K, °C	
ΔT, ΔΘ, ...	Temperature interval	K, °C	
α	Linear expansion coefficient	1/K	
C, S	Heat capacity, entropy	J/K	
c	Specific heat capacity	J/(kgK)	
λ	Thermal conductivity	W/(mK)	
K	Coefficient of heat transfer	$W/(m^2K)$	
e	Net calorific value	J/kg, J/m^3	
$L_{(LIN)TOT}$	Total LIN noise pressure level	dB	
$L_{(A)TOT}$	Total A noise pressure level	dB	
L_{OKT}	Average spatial noise level over octave band	dB	
U	Voltage	V	
I	Current	A	
BSFC	Brake specific fuel consumption	kg/J, kg/(kWh), g/(kWh)	

T10.3544

M2 Approximate conversion factors

Length

1 in		=	25.4 mm
1 ft	= 12 in	=	304.8 mm
1 yd	= 3 feet	=	914.4 mm
1 statute mile	= 1760 yds	=	1609.3 m
1 nautical mile	= 6080 feet	=	1853 m

Mass

1 oz		=	0.0283 kg
1 lb	= 16 oz	=	0.4536 kg
1 long ton		=	1016.1 kg
1 short ton		=	907.2 kg
1 tonne		=	1000 kg

Area

1 in^2		=	6.45 cm^2
1 ft^2		=	929 cm^2
1 yd^2		=	0.836 m^2
1 acre		=	4047 m^2
1 sq mile (of land)	640 acres	=	2.59 km^2

Volume

1 in^3		=	16.4 cm^3
1 ft^3		=	0.0283 m^3
1 yd^3		=	0.7645 m^3

Volume (fluids)

1 Imp. pint		=	0.568 l
1 U.S. pint		=	0.473 l
1 Imp. quart		=	1.136 l
1 U.S. quart		=	0.946 l
1 Imp. gal		=	4.546 l
1 U.S. gal		=	3.785 l
1 Imp. barrel	= 36 Imp. gal	=	163.66 l
1 barrel petroleum	= 42 US. gal	=	158.98 l

Force

1 lbf (pound force)	=	4.45 N

Pressure

1 psi (lb/sq in)	=	6.899 kPa (0.0689 bar)

Velocity

1 mph	=	1.609 km/h
1 knot	=	1.853 km/h

Acceleration

1 mphps	=	0.447 m/s^2

Temperature

1 °C	=	0.55 · (°F -32)

Energy

1 BTU	=	1.06 kJ
1 kcal	=	4.186 kJ

Power

1 kW	=	1.36 bhp
1 kW	=	860 kcal/h

M3 Reference to other Wärtsilä Ltd publications

For further publications please visit our homepage **http:/www.wartsila.com**
or contact your local **Wärtsilä representative**
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