MARINE INSTALLATION MANUAL

WÄRTSILÄ Engines

Marine Installation Manual

Wärtsilä X40
Issue December 2012

WÄRTSILÄ

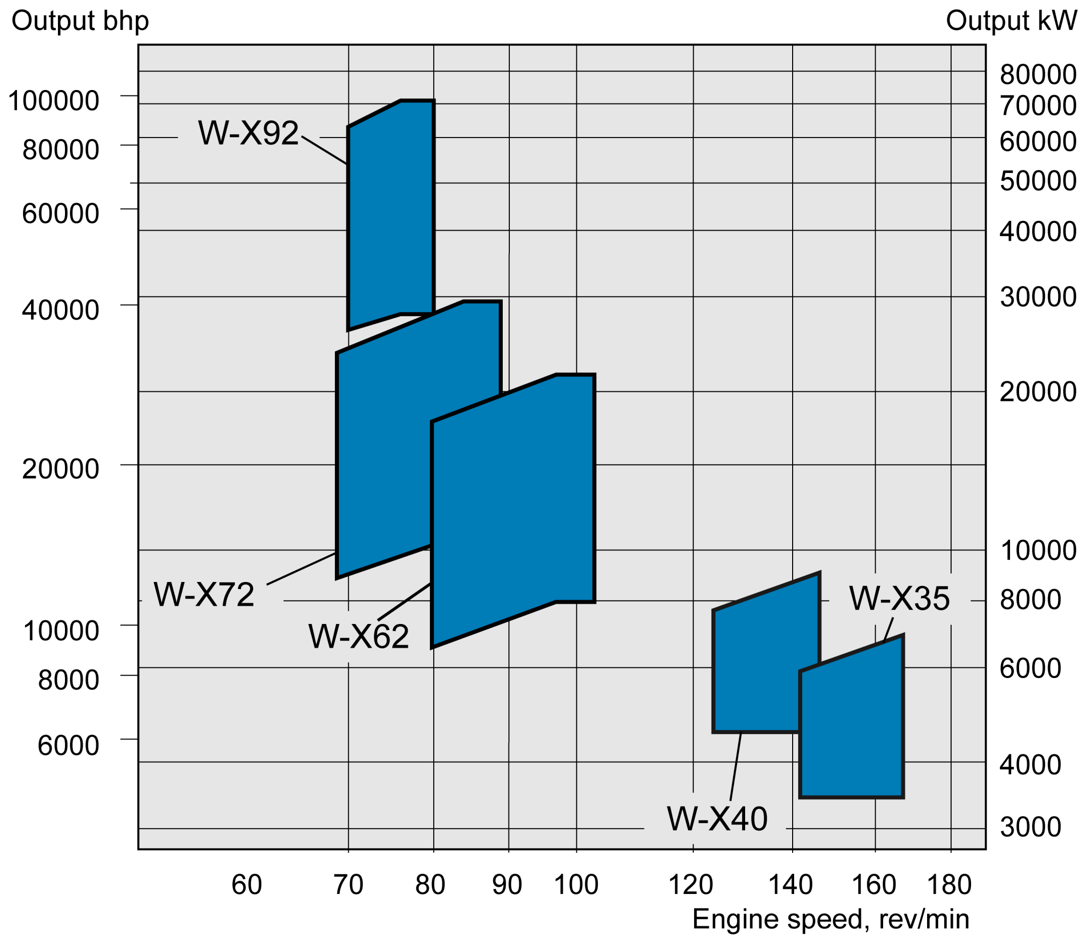
Preface

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 Marine Installation Manual is for use by project and design personnel. Each chapter contains detailed information for design engineers and naval architects, enabling them to optimize plant items and machinery space, and to carry out installation design work.

This manual is only designed for persons dealing with this engine.



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.

Attention is drawn to the following:

- All data are related to engines compliant with **IMO-2000 regulations Tier II**.
- The engine performance data (rating R1) refer to *winGTD and netGTD*.
- The engine performance data (BSFC, BSEF and tEaT) and other data can be obtained from the *winGTD and netGTD*. The winGTD can be downloaded from our Licensee Portal. The netGTD is accessible on internet using the following address: *http://www.wartsila.com/en/marine-solutions/products/netGTD*

Wärtsilä Switzerland Ltd.
Product Information
Zürcherstrasse 12
PO Box 414
CH-8401 Winterthur
Switzerland
Tel: +41 52 262 07 14
Fax: +41 52 262 07 18
http://www.wartsila.com
WCH.MIM@wartsila.com

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1. Engine Characteristics

The Wärtsilä X40 (W-X40) engine is a camshaftless low-speed, direct-reversible, two-stroke engine, fully electronically controlled, featuring common rail injection.

The W-X40 is designed for running on a wide range of fuels from marine diesel oil (MDO) to heavy fuel oils (HFO) of different qualities.

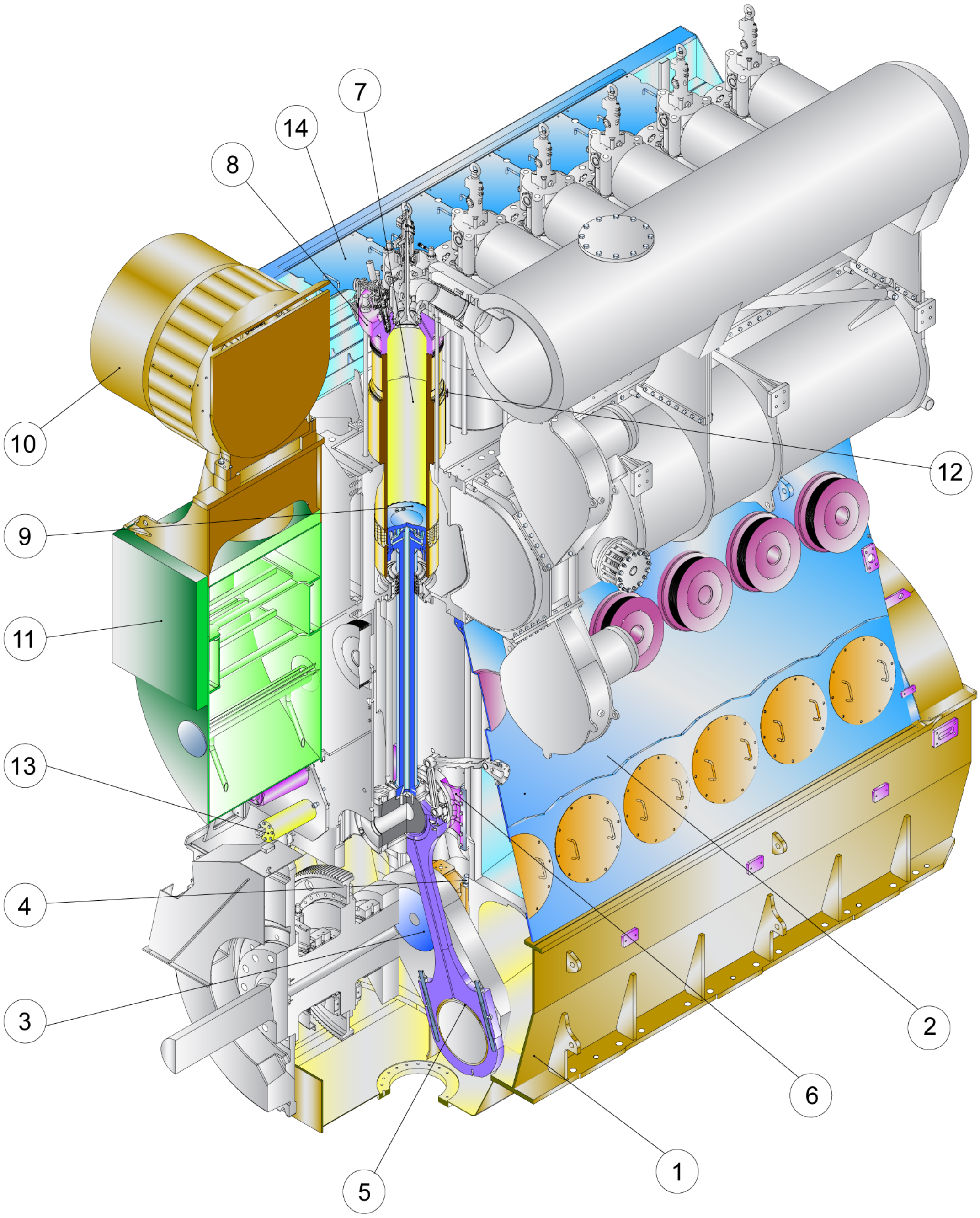

Figure 1.1: Cross section

1	Bedplate	6	Crosshead	11	Scavenging system
2	Column	7	Cylinder liner	12	Pulse Lubricating System
3	Crankshaft	8	Cylinder cover	13	Supply unit
4	Main bearing elastic studs	9	Piston	14	Rail unit (Common rail)
5	Bottom-end bearings	10	Turbocharging system		

1.1 Primary engine data

Bore x stroke: 400 x 1,770 [mm]				
No. of cyl.	**R1**	**R2**	**R3**	**R4**
Power [kW]				
5	5,675	4,550	4,825	4,550
6	6,810	5,460	5,790	5,460
7	7,945	6,370	6,755	6,370
8	9,080	7,280	7,720	7,280
Speed rpm				
All	146	146	124	124
Brake specific fuel consumption (BSFC) [g/kWh] Load 100%				
All	175	169	175	173
mep [bar]				
All	21.0	16.8	21.0	19.8
Lubricating oil consumption (for fully run-in engines under normal operating conditions)				
System oil	approximately 2.8 kg/cyl per day			
Cylinder oil 1)	Guide feed rate 0.6 g/kWh			

Table 1.1: Primary engine data

NOTICE

1) The guide feed rate shown is for new engines equipped with Pulse Jet cylinder lubrication system. This allows important savings in engine operating costs. Engines with different lubricating systems might require a higher feed rate.

All brake specific fuel consumption (BSFC) data are quoted for fuel of lower calorific value 42.7 MJ/kg [10,200 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 **standard** figures..

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 (see also *winGTD and netGTD*).

1.2 Tuning options

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

1.2.1 Delta Tuning

Delta Tuning allows further reduction of the specific fuel oil consumption while still complying with all existing emission legislation. This is achieved by changing software parameters without modifying any engine parts. The Delta Tuning option needs to be specified at a very early stage of 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 used to reduce the brake specific fuel consumption (BSFC) in the part load range of less than 90% load.

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

NOTICE

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.

1.2.2 Low-Load Tuning (LLT)

The complete flexibility in engine setting, which 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 reduces BSFC for Wärtsilä RT-flex engines in the operating range of less than 90% engine load.

The concept has now been extended to Low-Load Tuning, which provides the lowest possible BSFC in the operating range of 40-70% engine load.

With Low-Load Tuning, RT-flex engines can be operated continuously and reliably at any load in the range of 30-100%.

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 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 *1.2*) 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 to allow realizing the full potential of the concept while ensuring compliance with the applicable NOx 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, a higher scavenge air pressure trendwise increases NOx emissions – hence, for achieving the same weighted average value over the test cycle, the parameters also need to be adjusted appropriately for compensating this increase.

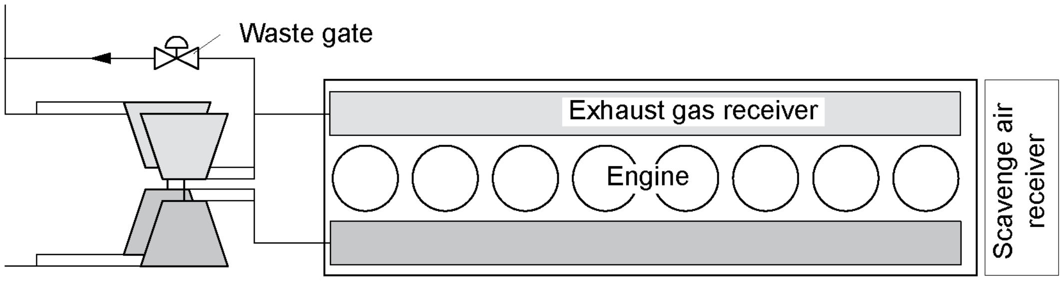

Figure 1.2: Schematic functional principle of Low-Load Tuning

1.2.3 Further aspects of engine tuning options

Tuning for de-rated engines:

For various reasons, the margin against the IMO NOx limit decreases for de-rated engines. Delta Tuning and Low-load Tuning thus holds the highest benefits for engines rated close to R1. Although with the de-rating the effect diminishes, Delta Tuning and Low-Load Tuning are applicable in the entire field (see figure *1.4*).

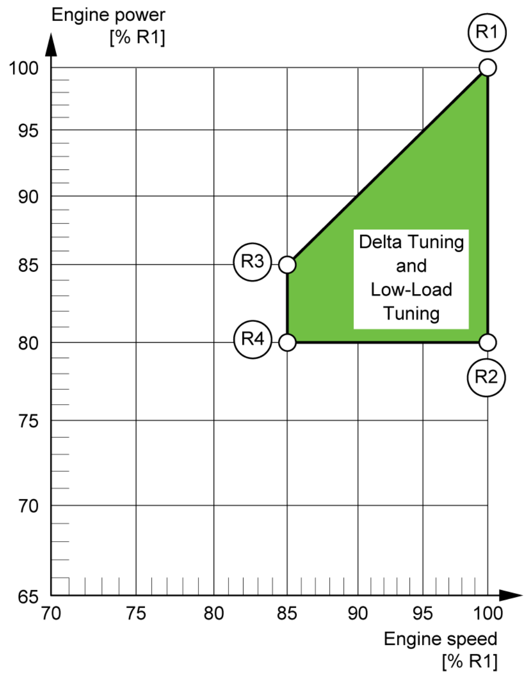

Figure 1.3: Delta Tuning and Low-load Tuning area

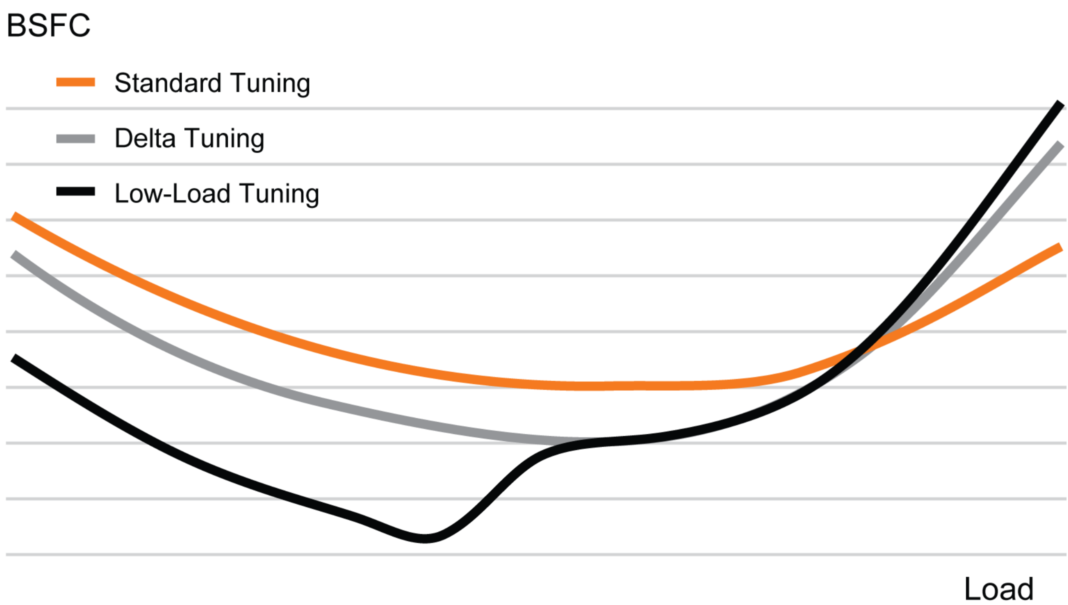

Figure 1.4: Typical BSFC curves to illustrate Standard Tuning, Delta Tuning and Low-Load Tuning

Effect on engine dynamics:

The application of Delta Tuning or Low-Load Tuning has 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 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 also have an effect on other aspects of engine and system design.

Therefore the tuning option to be applied on 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.
- 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.

Data for brake specific fuel consumption (BSFC) in section *Primary engine data* refer to Standard Tuning. Data for Delta Tuning and Low-Load Tuning can be obtained from the *winGTD and netGTD*.

1.3 Main features and parameters:

Bore .... 400 mm
Stroke .... 1,770 mm
Number of cylinders .... 5 to 8

Main parameters (R1):

Power (MCR) .... 1,135 kW/cyl
Speed (MCR) .... 146 rpm
Mean effect. press. .... 21.0 bar
Mean piston speed .... 8.6 m/s

1.3.1 Design features:

- Welded bedplate with integrated thrust bearings and main bearings designed as large thin-shell white metal bearings
- Sturdy engine structure with stiff thin-wall box type columns and cast iron cylinder blocks attached to the bedplate by pre-tensioned vertical tie rods
- Welded bedplate with integrated thrust bearings and main bearings designed as large thin-shell white metal bearings
- Semi-built crankshaft
- Main bearing jack bolts for easier assembly and disassembly of white metal shell bearings
- Thin-shell white metal bottom-end bearings
- Crosshead with crosshead pin and single-piece large white-metal surface bearings lubricated by the engine lubricating system
- Rigid cast iron cylinder monoblock
- Special grey-cast iron cylinder liners, water cooled, and with load dependent cylinder lubrication
- Cylinder cover of high-grade material with a bolted exhaust valve cage containing a Nimonic 80A exhaust valve
- Piston with crown cooled by combined jetshaker oil cooling
- Constant-pressure turbocharging system comprising high-efficiency turbochargers and auxiliary blowers for low-load operation
- Latest piston running concept for excellent piston running and extended TBO up to 5 years
- Pulse Lubricating System for high-efficiency cylinder lubrication
- Supply unit: high-efficiency fuel pumps feeding the 1000 bar fuel manifold
- Rail unit (common rail): both common rail injection and exhaust valve actuation are controlled by quick acting solenoid valves
- Electronic engine control UNIC for monitoring and controlling the key engine functions

The W-X40 is available with 5 to 8 cylinders rated at 1,135 kW/cyl to provide a maximum output of 9,080 kW for the 8-cylinder engine (see section *1.1 Primary engine data*).

No. cyl.	Overall sizes of engines		
	Length [mm]	Piston dismantling height (crank center – crane hook) [mm]	Dry weight [t]
5	5,107	7,700	109
6	5,807		125
7	6,507		140
8	7,207		153

Table 1.2: Overall sizes of engine

1.4 The RT-flex system

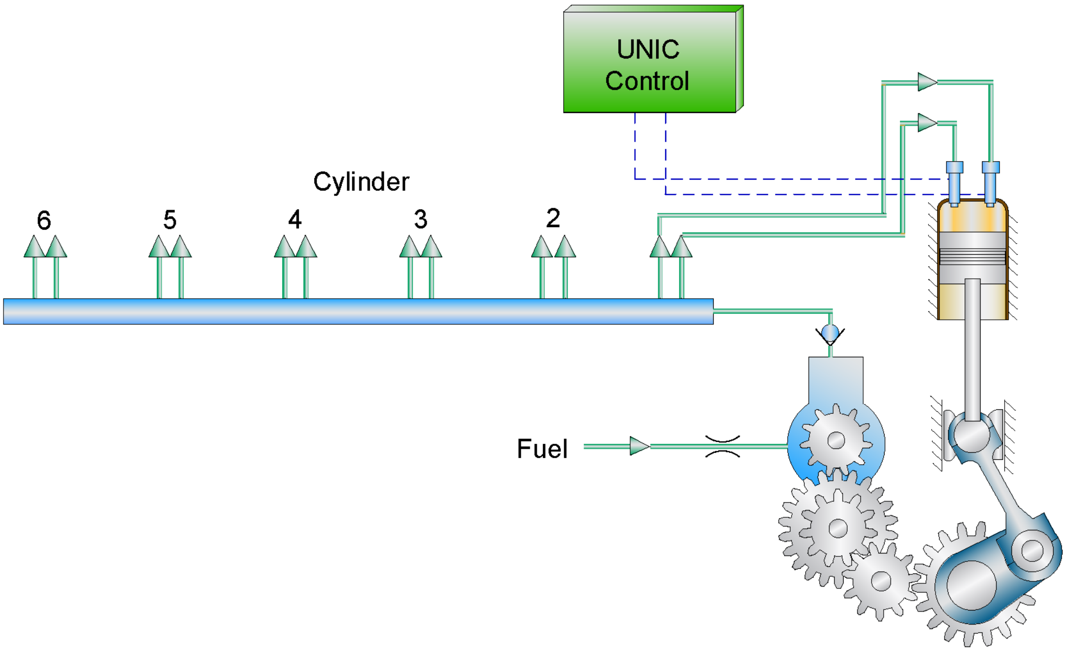

Figure 1.5: RT-flex key parts

All key engine functions such as 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 UNIC control system.

1.4.1 The major benefits of the RT-flex system are:

- Adaptation to different operating modes
- Adaptation to different fuels
- Optimised part-load operation
- Optimised fuel consumption
- Precise speed regulation, in particular at very slow steaming
- Smokeless mode for slow steaming
- Benefits in terms of operating costs, maintenance requirement and compliance with emissions regulations

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2. Engine Data

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

2.1 Reference conditions

The engine performance data, like **BSFC**, **BSEF**, **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	29°C for FW
Barometric pressure	1000 mbar
Relative air humidity	30%

2.2 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 room ambient air temp.	45°C
Coolant temp. before SAC	36°C for FW
Barometric pressure	1000 mbar
Relative air humidity	60%

2.3 Ancillary system design parameters

The layout of the ancillary systems of the engine is based on the rated performance (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. .... 85°C
Oil temperature before engine .... 45°C
Exhaust gas back pressure at rated power (Rx) ...... 30 mbar

The engine power is independent of 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.

2.4 Engine performance data

The calculation of the performance data **BSFC**, **BSEF** and **tEaT** for any engine power is done with the help of the *winGTD and netGTD*. Data for Delta Tuning and Low-Load Tuning are available on the *winGTD and netGTD*. 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 layout field.

2.5 Turbocharger and scavenge air cooler

The SAC and TC selection is given in *winGTD and netGTD*. Parameters and details of the scavenge air coolers are shown in section *2.5.1*.

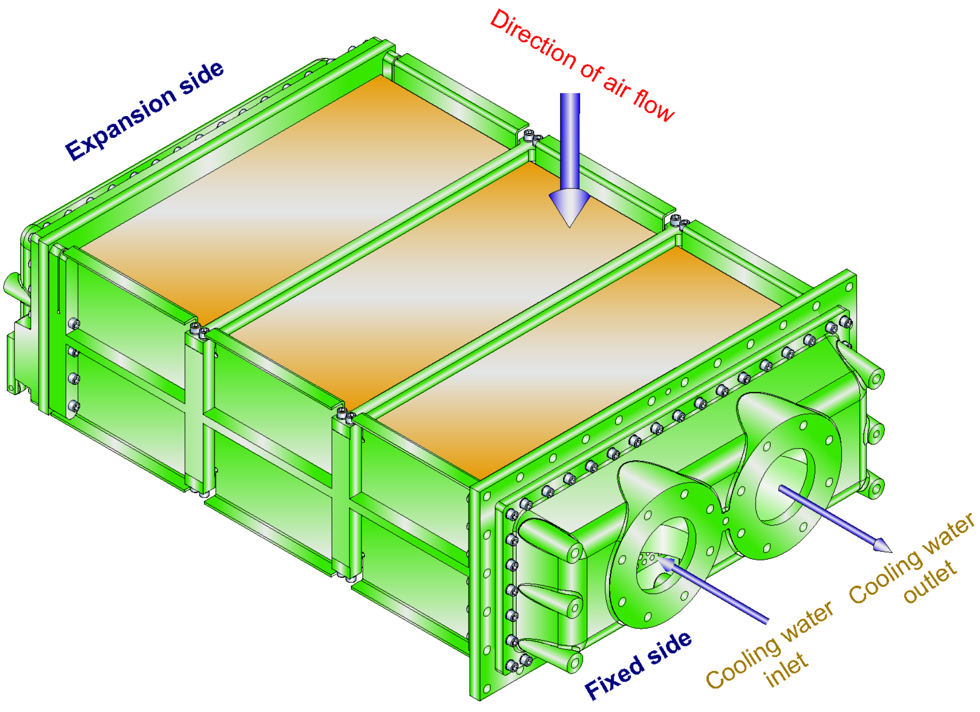

Figure 2.1: Scavenge air cooler

2.5.1 SAC parameters and turbocharger weights

SAC parameters and turbocharger weights

Scavenge air cooler parameters									
No. cyl.	Cooler	Qty	Design flow		Pressure drop (at design flow)		Water content [litres]	Insert	
			Water [kg/s]	Air [kg/s]	Water [bar]	Air [Pa]		Dimension [mm]	Mass [kg]
	Fresh water cooled / single-stage SAC / separate HT								
5	SAC283F	1	43.1	15.6	1.0	2,000	110	1420 x 1135 x 370	740
6	SAC283F	1	43.1	15.6	1.0	2,000	110	1420 x 1135 x 370	740
7	SAC285F	1	43.1	20.3	1.0	2,000	145	1820 x 1135 x 370	950
8	SAC285F	1	43.1	20.3	1.0	2,000	145	1820 x 1135 x 370	950

Table 2.1: Scavenge air cooler parameters

No. cyl.	ABB			MHI		
	Type	Qty	Mass [kg]	Type	Qty	Mass [kg]
5	A165-L34	1	2,000	MET42MB	1	1,600
6	A165-L35	1	2,000	MET53MB	1	4,100
7	A170-L34	1	3,000	MET53MB	1	4,100
8	A170-L35	1	3,000	MET53MB	1	4,100

Table 2.2: Turbocharger weights

2.5.2 Air filtration

In the event that the air supply to the machinery spaces has a dust content exceeding 0.5 mg/m^3, which can be the case for ships trading in coastal waters, desert areas or transporting dust creating cargoes, there is a risk of increased wear to the piston rings and cylinder liners. The normal air filters fitted to the turbochargers are intended mainly as silencers but not to protect the engine against dust.

The necessity for installing 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.

Wärtsilä Switzerland Ltd. advises to install a filtration unit for the air supplies to the diesel engines and general machinery spaces on vessels regularly transporting dust creating cargoes, such as iron ore and bauxite.

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

Table 2.3: Guidance for air filtration

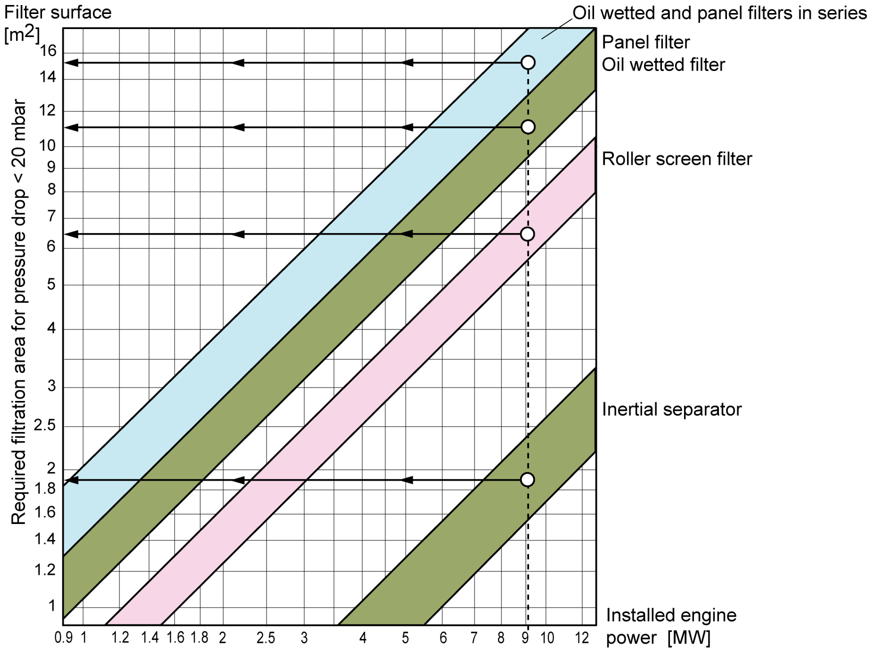

Figure 2.2: Air filter size (example for 8-cyl. engine)

2.6 Auxiliary blower

For manoeuvring and operating at low powers, electrically driven auxiliary blowers must be used to provide sufficient combustion air.

The following table shows the number of blowers required.

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

Table 2.4: Number of auxiliary blowers

2.7 Electrical power requirement

	No. cyl.	Supply voltage	Power requirement
Auxiliary blowers *1)	5	440 V	2 x 20 kW (60 Hz)
	6		2 x 20 kW (60 Hz)
	7		2 x 26 kW (60 Hz)
	8		2 x 26 kW (60 Hz)
Turning gear	5	440 V	1.8
	6		1.8
	7		1.8
	8		1.8
Propulsion control system		24 VDC UPS	acc. to maker's specifications
Additional monitoring devices (e.g. oil mist detector, etc.)		acc. to maker's specifications	

Table 2.5: Electrical power requirement

NOTICE

*1) Minimal 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.

2.8 Pressure and temperatures ranges

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

System	Location of measurement	Gauge pressure limit values [bar]		Temperature limit values [°C]		
		Min.	Max.	Min.	Max.	Diff.
Freshwater						
Cylinder cooling	Inlet	2.0	4.0	65	-	max. 15
	Outlet each cyl.	-	-	80	90	
SAC LT circuit (single-stage SAC)	Inlet cooler	2.0	4.0	25	36	*1)
	Outlet cooler	-	-	-	80	
Fuel oil						
Booster (injection pump)	Inlet	7.0 *2)	10.0 *3)	-	150	-
After pressure retaining valve	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		-	-	-
Lubricating oil						
Servo oil	Servo oil pump inlet	3.8	4.8	-	-	-
Main bearing oil	Supply	3.8	4.8	40	50	
	Outlet	-	-	-	-	-
Piston cooling oil	Inlet	3.8	4.8	40	50	max. 30
	Outlet	-	-	-	80	
Thrust bearing pads	Pads AHEAD	-	-	-	75	-
Torsional vibration damper (in case of steel spring damper)	Supply	3.8	4.8	-	-	-
	Inlet casing	1.0	-	-	-	-
Integrated axial vibration damper (detuner)	Supply	3.8	4.8	-	-	-
	Damp. chamber	1.7	-	-	-	-
TC bearing oil (on engine lub. oil system) ABB A100-L	Inlet	1.0	2.5	-	-	-
	Outlet	-	-	-	110	-
TC bearing oil (with separate lub. oil system) ABB A100-L	Inlet	1.3	2.5		85	
	Outlet	-	-		130	
TC bearing oil MHI MET MB	Inlet	0.7	1.5	-	-	-
	Outlet	-	-	-	85	-

System	Location of measurement	Gauge pressure limit values [bar]		Temperature limit values [°C]		
		Min.	Max.	Min.	Max.	Diff.
Air						
Starting air	Engine inlet	12	25/30	-	-	-
Control air	Engine inlet (engine internal)	6.0	7.5	-	-	-
		normal 6.5				
Air spring air for exh. valve	Main distributor (engine internal)	6.0	7.5	-	-	-
		normal 6.5				
Exhaust gas						
Receiver	After each cylinder	-	-	-	515	Dev. ±50 *4)
	Before each TC	-	-	-	515	-
Manifold after turbocharger	Design maximum	30 mbar		-	-	-
	Fouled maximum	50 mbar			-	-

Table 2.6: Pressure and temperature ranges

NOTICE

*1) The water flow has to be within the prescribed limits.

*2) At 100% engine power.

*3) In stand-by condition; during commissioning of the fuel oil system the fuel oil pressure is adjusted to 10 bar.

*4) Maximum temperature deviation among the cylinders.

Servo oil pump inlet: the minimum pressure can be 0.8 bar lower than indicated due to the specified maximum allowable pressure difference over fine filter.

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3. Engine Rating 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 contract maximum continuous rating (CMCR) has been determined. To define the 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.

3.1 Rating field

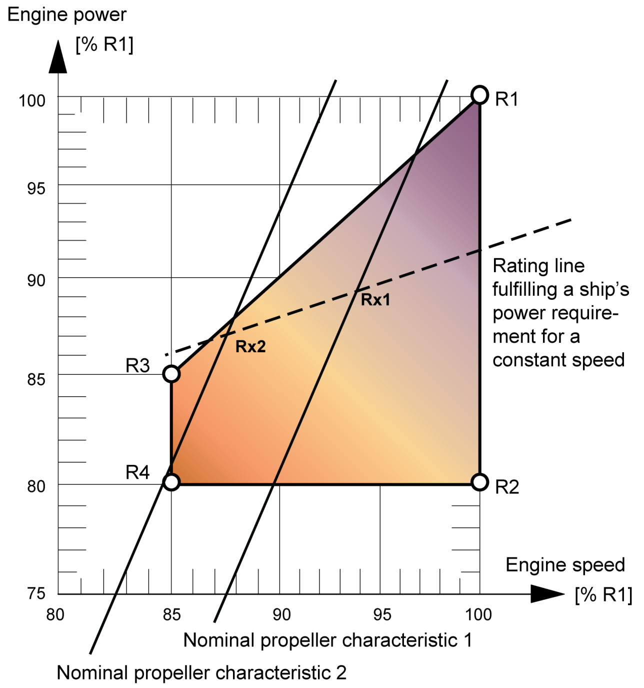

Figure 3.1: Rating field

The rating field shown in fig. *3.1* 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 wanted 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.

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 mean effective pressure (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.

- The rating points (R1, R2, R3 and R4) are the corner points of the engine rating field.
- The point R1 represents the nominal maximum continuous rating (MCR). It is the maximum power/speed combination which is available for a particular engine.
- The point R2 defines 100% speed and 80% power of R1.
- The point R3 defines 85% speed and 85% power of R1.
- The connection R1 - R3 is the nominal 100% line of the constant mean effective pressure of R1.
- The point R4 defines 85% speed and 80% power of R1.
- The connection line R2-R4 is the line of 80% power between 85% 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.

3.1.1 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: $\mathbf{Px_2/Px_1 = (N_2/N_1)^{\alpha}}$.

(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 and bulk carriers from 10,000 dwt to 30,000 dwt
- 0.25 for tankers and bulk carriers 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 chosen engine rating field. Usually, the selected 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 on the hull by the propeller)

The selection of a 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 - 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.

3.2 Load range

The load range diagram shown in figure *3.2* defines the power/speed limits for the operation of the engine. Percentage values are given as explained in section *3.1*; in practice absolute figures might be used for a specific installation project.

3.2.1 Propeller curves

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 (see *3.2.3*) is, for a ship with a new and clean hull in calm water and weather, often referred to as 'trial condition'.

The curves can be determined by using full-scale trial results from 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:
$\mathbf{P_2/P_1 = (N_2/N_1)^3}$ (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 characteristic is a cubic curve through the CMCR-point. (For additional information, refer to section *3.2.4*).

3.2.2 Sea trial power

The sea trial power must be specified. Figure *3.2* 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 curve is referred to as ‘sea trial power’.

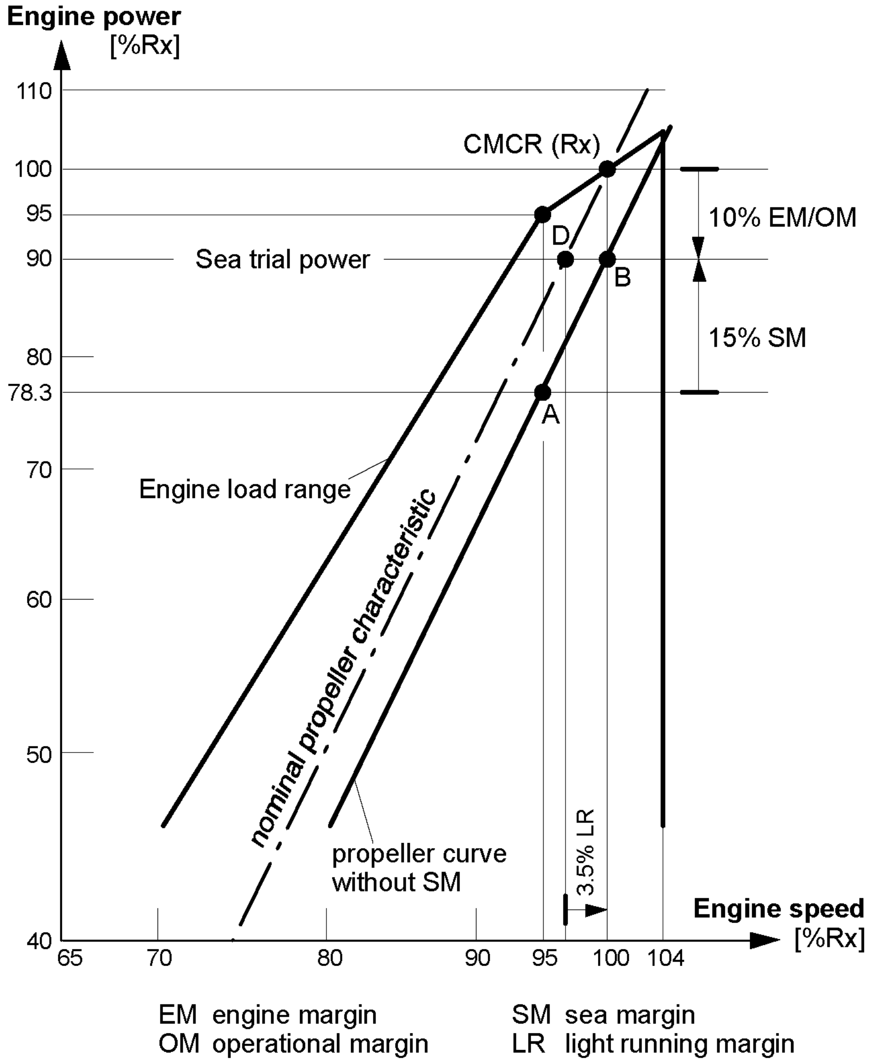

Figure 3.2: Load range limits of an engine corresponding to a specific rating point Rx

3.2.3 Sea margin (SM)

The increase in power to maintain a given ship’s speed achieved in calm weather (point A in figure *3.2*) 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 are part of the new building contract.

With the help of effective antifouling paints, dry-docking intervals have been prolonged 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 Fig. *3.2*), unless, as mentioned above, the actual ship type and service route dictate otherwise.

3.2.4 Light running margin (LR)

The sea trial performance (curve ‘a’) in figure *3.3* should allow for a 4-7% light running of the propeller when compared to the nominal characteristic (the example in figure *3.3* 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 optimised 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.

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

NOTICE

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 the nominal propeller characteristic line are not reached (see section *3.2.6* and Fig. *3.4*).

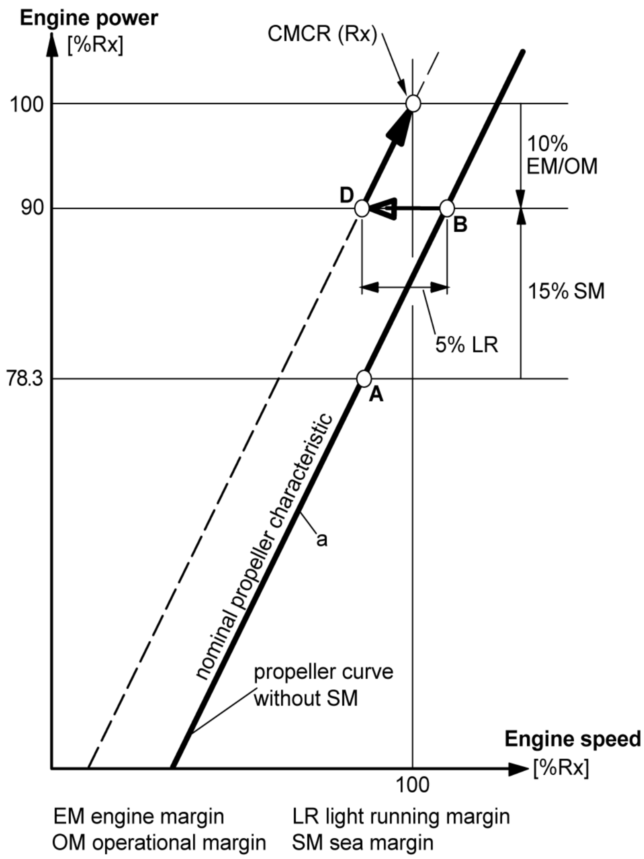

Figure 3.3: Load diagram for a specific engine, showing the corresponding power and speed margins

Assuming, for example, the following:

- Dry-docking 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 favorable conditions and without exceeding 100% mep

Therefore the required ‘light running margin’ will be between 5 and 6%.

This is the sum of the following factors:

- **1.5-2%** influence of wind and weather with 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.
- **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 ballast condition
- **1%** frictional losses due to increase in propeller blade roughness and consequent drop in efficiency, e.g. aluminium bronze propellers:
  - New: surface roughness = 12 micron
  - Aged: rough surface but no fouling = 40 micron
- **1%** deterioration in engine efficiency such as:
  - Fouling of scavenge air coolers
  - Fouling of turbochargers
  - Condition of piston rings
  - Fuel injection system (condition and timing)
  - Increase of back pressure due to fouling of the exhaust gas boiler, etc.

3.2.5 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 10-15% power can then be used to catch up with delays in schedule or for the timing of dry-docking intervals. This margin is usually deducted from the CMCR. Therefore, the 100% power line is found by dividing the power at point D by 0.85-0.90. The graphic approach to find the level of CMCR is illustrated in figures *3.2* and *3.3*.

In the examples two current methods are shown. Figure *3.2* presents the method of fixing point B and CMCR at 100% speed, thus obtaining automatically a light running margin B-D of 3.5%. Figures *3.3* and *3.5* 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.

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 same speed under service condition with aged hull and average weather requires a power/speed combination according to point D, as shown in figure *3.4*. In that case D is the CSR-point.

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 Fig. *3.4*). 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 the figure in section *3.1*).

3.2.6 Load range limits

Once an engine is optimised at CMCR (Rx), the working range of the engine is limited by the following border lines; refer to Fig. *3.4*:

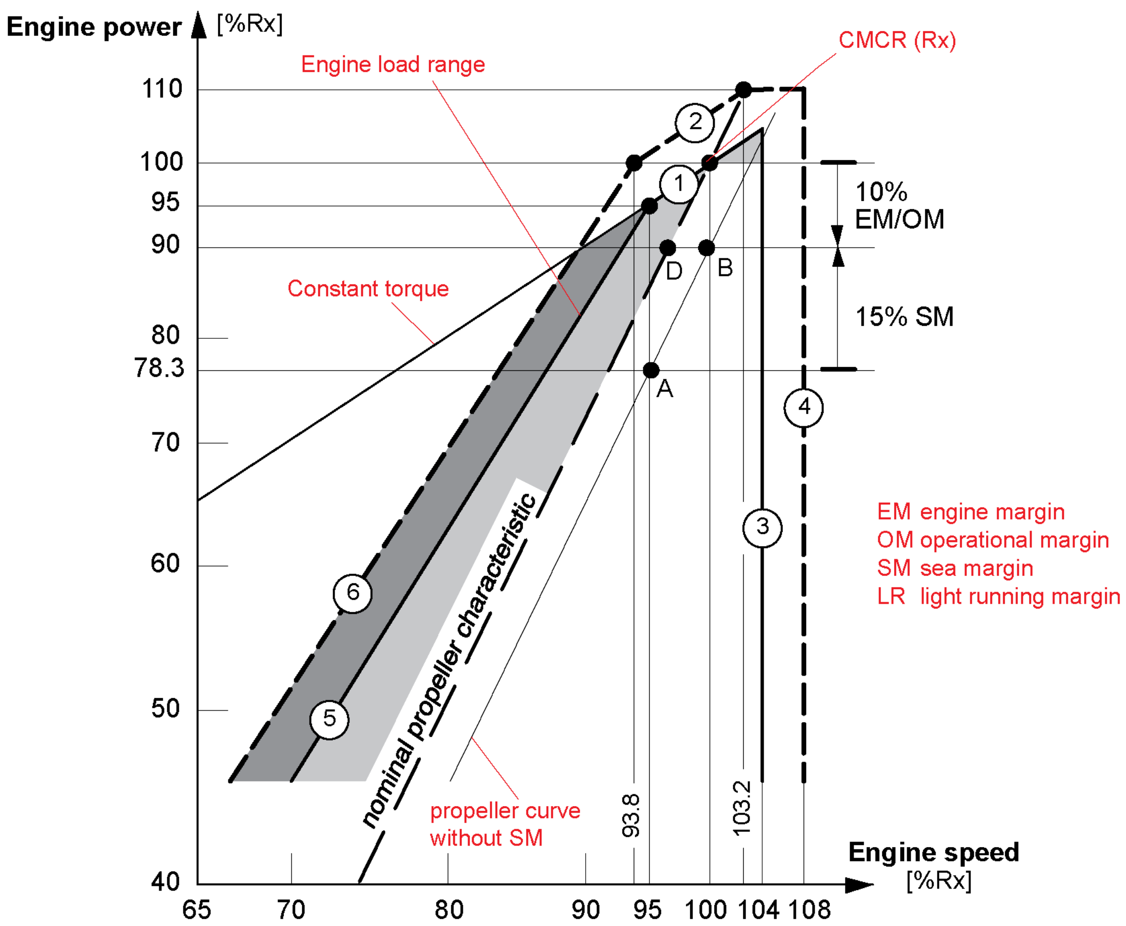

Figure 3.4: Load range limits with load diagram of an engine corresponding to a specific rating point Rx

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 ($N_{CMCR} \leq 0.98\ N_{MCR}$) 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, in the presence of authorised representatives of the engine builder, the ship's speed at CMCR power with a light running propeller. 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: $\mathbf{P_2/P_1 = (N_2/N_1)^{2.45}}$.
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: $\mathbf{P_2/P_1 = (N_2/N_1)^{2.45}}$ 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. *3.4*) should only be used for transient conditions, i.e. during fast acceleration. This range is called 'service range with operational time limit'.

3.2.7 Load range with main-engine driven generator

The load range with main-engine driven generator, whether it is a shaft generator (S/G) mounted on the intermediate shaft or driven through a power take-off gear (PTO), is shown by curve 'c' in figure *3.5*. 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 *3.5*, the main-engine driven generator is assumed to absorb 5% of the nominal engine power.

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

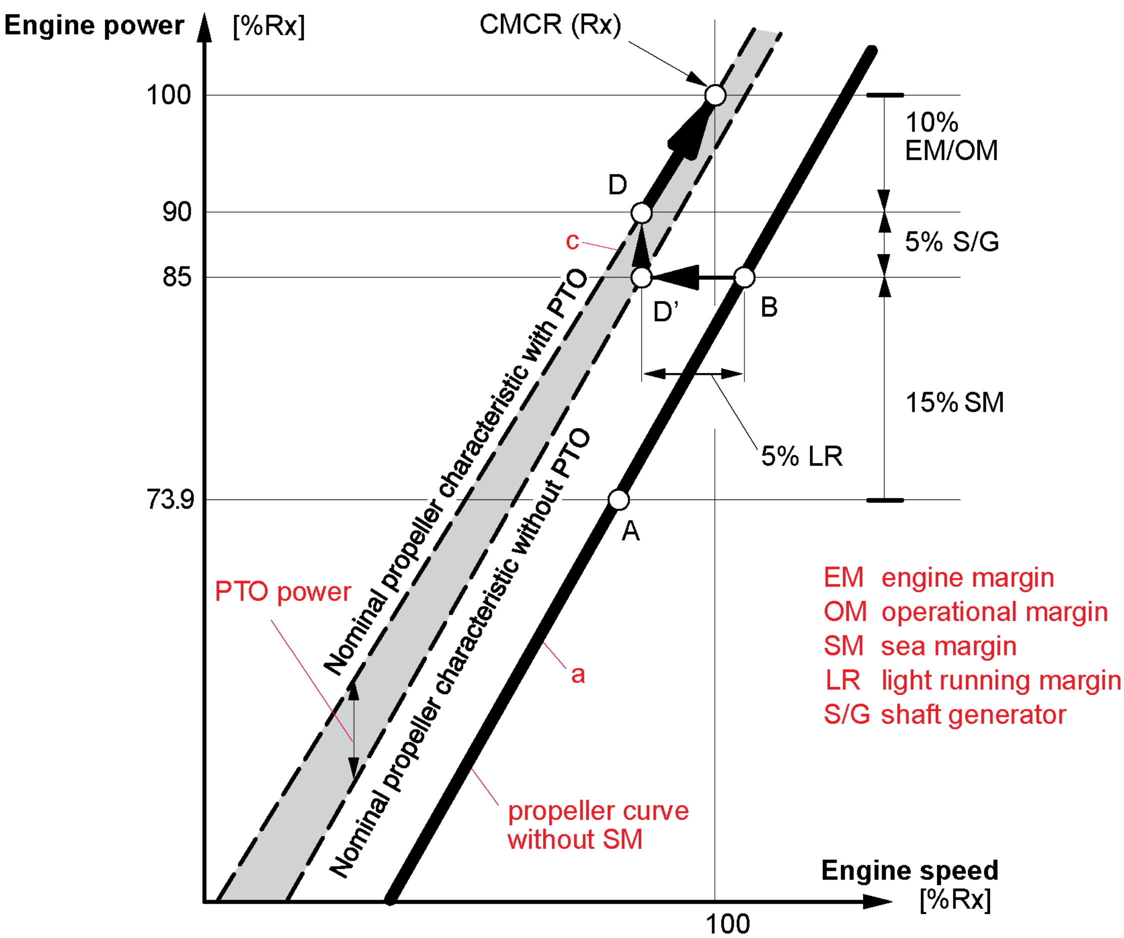

Figure 3.5: Load range diagram of an engine equipped with a main-engine driven generator

3.3 Load range limit with controllable pitch propeller

For the controllable pitch propeller (CPP) load range limit consult *winGTD and netGTD*.

After starting, the engine is operated at an idle speed of up to 70% of the rated engine speed with zero pitch. From idle running the pitch is to be increased with constant engine speed up to at least point E, the intersection with line 6.

Line **5** ...... is the upper load limit and corresponds to the admissible torque limit as defined in section *3.2.1* and shown in figure *3.2*.
The area formed between 70% speed and 100% speed and between lines 5 and 6 represents the area within which the engine with CPP has to be operated.

Line **6** ...... is the lower load limit between 70% speed and 100% speed, with such a pitch position that at 100% speed a minimum power of 37% is reached, point F. It is defined by the following equation: $\mathbf{P_2/P_1 = (N_2/N_1)^3}$
Along line **8** the power increase from 37% (point F) to 100% (CMCR) at 100% speed is the constant speed mode for shaft generator operation, covering electrical sea load with constant frequency.

Line **7** ...... represents a typical combinator curve for variable speed mode.

Manoeuvring at nominal speed with low or zero pitch is not allowed. Thus installations with main-engine driven generators must be equipped with a frequency converter when electric power is to be provided (e.g. to thrusters) at a constant frequency during manoeuvring. Alternatively, power from auxiliary engines may be used for this purpose.

For test purposes, the engine may be run at rated speed and low load during a one-time period of 15 minutes on the testbed (e.g. NOx measurements) and 30 minutes during dock trials (e.g. shaft generator adjustment) in the presence of authorized representatives of the engine builder. Further requests must be agreed by Wärtsilä Switzerland Ltd.

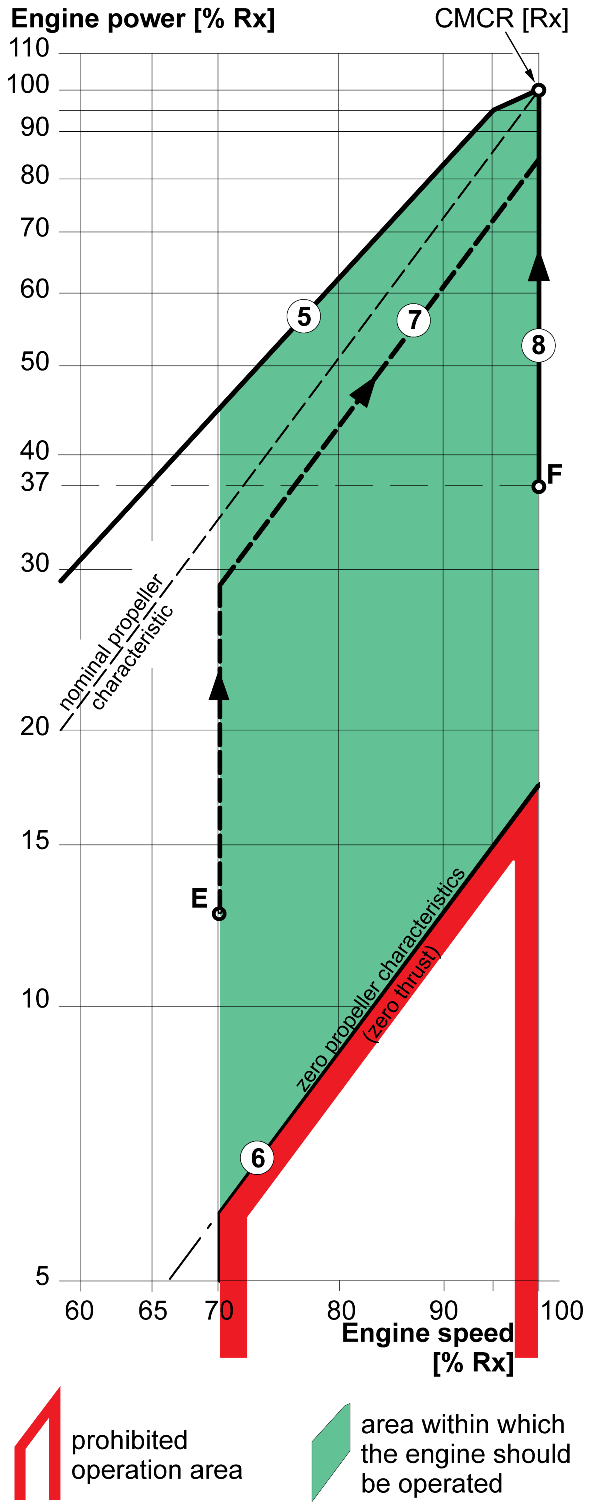

Figure 3.6: Load range diagram for CPP

3.4 Requirements for control system with CPP

Wärtsilä Switzerland Ltd. advises to include CPP control functions in an engine remote control system from an approved supplier. This ensures, amongst others, that the requirements of the engine builder are strictly followed.

The following operating modes shall be included in the control system:

- Combinator mode 1

  Combinator mode for operation without shaft generator. Any combinator curve including a suitable light running margin may be set within the permissible operating area, typically line **7**.

- Combinator mode 2

  Optional mode used in connection with shaft generators. During manoeuvring, the combinator curve follows line **6**. At sea the engine is operated between point F and 100% power (line **8**) at constant speed.

For manual and emergency operation, separate set points for speed and pitch are usually provided. At any location allowing such operation, a warning plate must be placed with the following text:

⚠ WARNING

Engine must not be operated continuously with a pitch lower than xx% at any engine speed above xx rpm.

- The values (xx) are to be defined according to the installation data.
- The rpm value normally corresponds to 70% of CMCR speed, and the pitch to approximately 60% of the pitch required for rated power.
- In addition, an alarm has to be provided in either the main-engine safety system or the vessel's alarm and monitoring system, in case the engine is operated for more than 3 minutes in the prohibited operation area. If the engine is operated for more than 5 minutes in the prohibited operation area, the engine speed must be reduced to idle speed (less than 70% speed).

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4. winGTD and netGTD

The purpose of these programs 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 online for finding the most suitable cooling system.

This these programs 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.

The **winGTD** is available as download from our Licensee Portal.

1 Open the Licensee Portal and go to:

- 'Project Tools & Documents'
- 'winGTD'

2 Click on the link and follow the instructions

The **netGTD** is accessible on internet using the following address:

http://www.wartsila.com/en/marine-solutions/products/netGTD

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5. Engine Dynamics

As a leading designer and licensor we are concerned that vibrations are minimised 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.

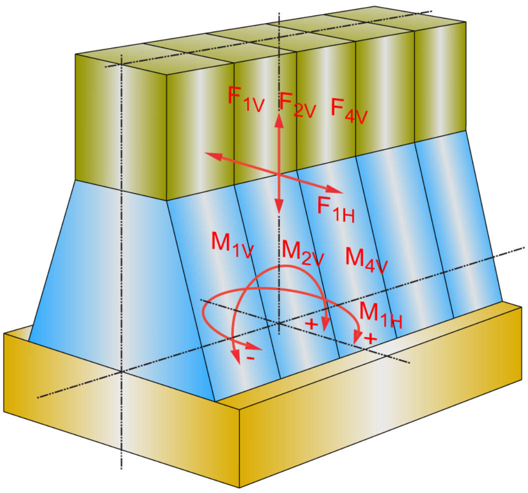
For successful design, the vibration behaviour needs to be calculated over the whole operating range of the engine and propulsion system. The following vibration types and their causes are to be considered:

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

5.1 External forces and moments

In the design of the engine, free mass forces are eliminated and unbalanced external moments of first, second and fourth order are minimized. However, 5 and 6-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 *5.1* shows the external forces and moments acting on the engine. External forces and moments due to the reciprocating and rotating masses see section *5.1.1*.



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

Figure 5.1: External forces and moments

5.1.1 External forces and moments

Mass moments / Forces at R1 / Standard Tuning						
Cylinder number			5	6	7	8
Engine Power [kW] / 146 rpm			5,675	6,810	7,945	9,080
Free mass forces [±kN]		F_{1V}	0	0	0	0
		F_{1H}	0	0	0	0
		F_{2V}	0	0	0	0
		F_{4V}	0	0	0	0
External mass moments *1) [±kNm]		M_{1V}	55	0	117	111
		M_{1H}	48	0	55	96
		M_{2V}	613	426	124	0
		M_{4V}	4	30	84	34
Lateral H-moments M_{LH} [±kNm]	Order	1	0	0	0	0
		2	0	0	0	0
		3	0	0	0	0
		4	0	0	0	0
		5	448	0	0	0
		6	0	325	0	0
		7	0	0	249	0
		8	0	0	0	185
		9	0	0	0	0
		10	38	0	0	0
		11	0	0	0	0
		12	0	12	0	0
Lateral X-moments M_{LX} [±kNm]	Order	1	45	0	27	90
		2	24	16	5	0
		3	55	99	108	138
		4	15	115	327	133
		5	0	0	26	325
		6	6	0	4	0
		7	45	0	0	8
		8	30	21	2	0
		9	1	27	3	3
		10	0	7	19	0
		11	1	0	11	15
		12	2	0	0	2
Torque variation	[±kNm]		457	327	251	186

Table 5.1: Mass moments and forces

NOTICE

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

- The resulting lateral guide force can be calculated as follows: $\mathbf{F_L = M_{LH} \times 0.376}$ **[kN]**.

- The values for other engine ratings and engine tunings are available on request.

- Crankshaft type: FCV1 / full crank pin.

5.1.2 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}.

5.1.3 Balancing free second order moments

The second order vertical moment (M_{2V}) is higher on 5-cylinder engines compared with 6-8-cylinder engines, the second order vertical moment being negligible for the 6-8-cylinder engines.

Since no engine-fitted second order balancer is available, Wärtsilä Switzerland Ltd. recommends for 5-cylinder engines to install an electrically driven compensator on the ship's structure (Fig. *5.2*) to reduce the effects of 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 kind the ship's vibration will be. Section *5.1.1* assists in determining the effect of installing the 5-cylinder engines. However, when the ship's vibration pattern is not known at an early stage, an external electrically driven 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 *5.2*. It is tuned to the engine operating speed and controlled accordingly.

Suppliers of electrically driven compensators

Gersten & 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 lida Bldg.
5th Floor
1-5-33, Nishimiyahara,
Yodogawa-ku Osaka
532-0004 Japan

Tel. +81 6 6397 3461
Fax +81 6 6397 3475
www.nishishiba.co.jp

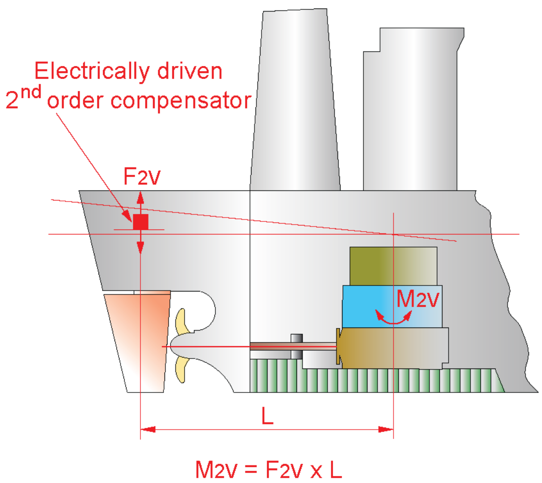


Figure 5.2: Locating electrically driven compensator

5.1.4 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 first and second order cause unacceptable hull vibrations.

The external mass moments M_1 and M_2 given in section *5.1* are related to R1 speed. For other engine speeds, the corresponding external mass moments are calculated with the following formula:
$M_{Rx} = M_{R1} \times (n_{Rx}/n_{R1})^2$

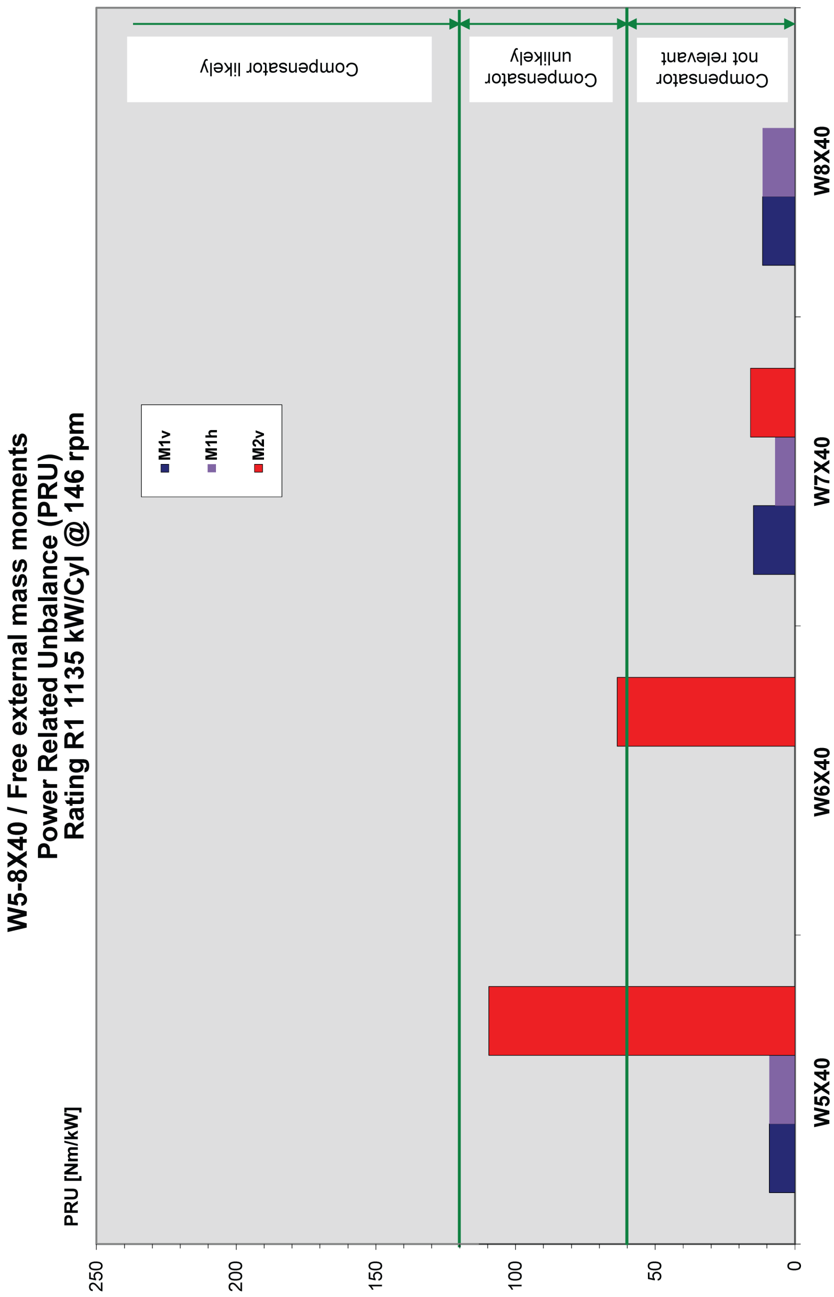


Figure 5.3: Power related unbalance (PRU)

5.2 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’; refer to Fig. *5.4*.

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.

The table in section *5.1* 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.

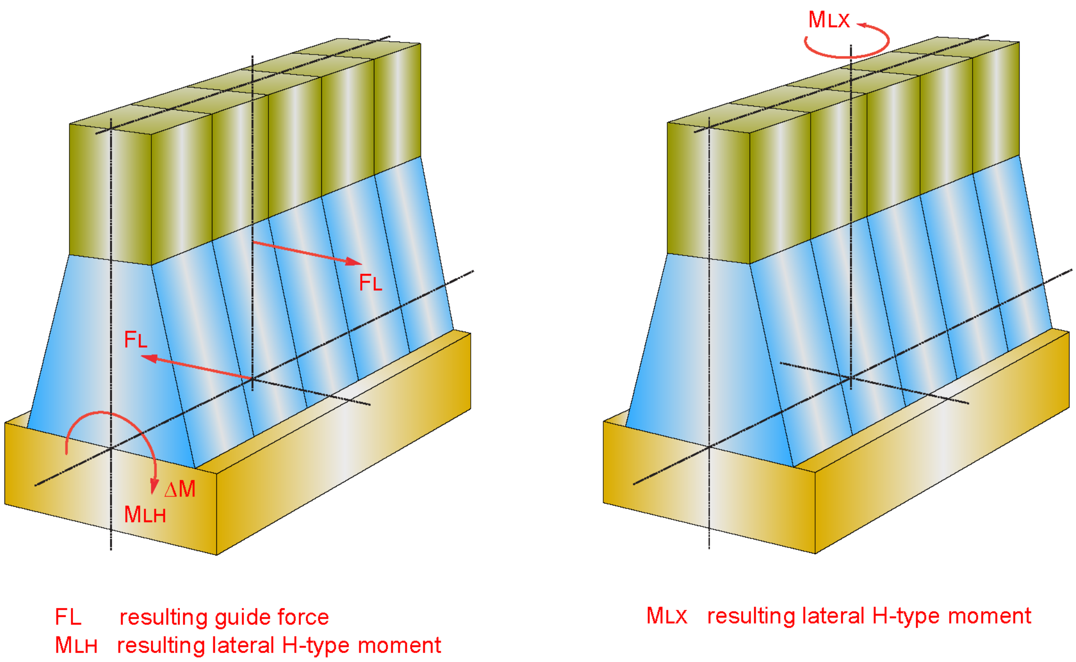


Figure 5.4: External forces and moments

5.3 Reduction of lateral vibration

5.3.1 Engine stays

Fitting of lateral stays between the upper platform level and the hull reduces transmitted vibration and lateral rocking. Two stay types can be considered:

Hydraulic stays:

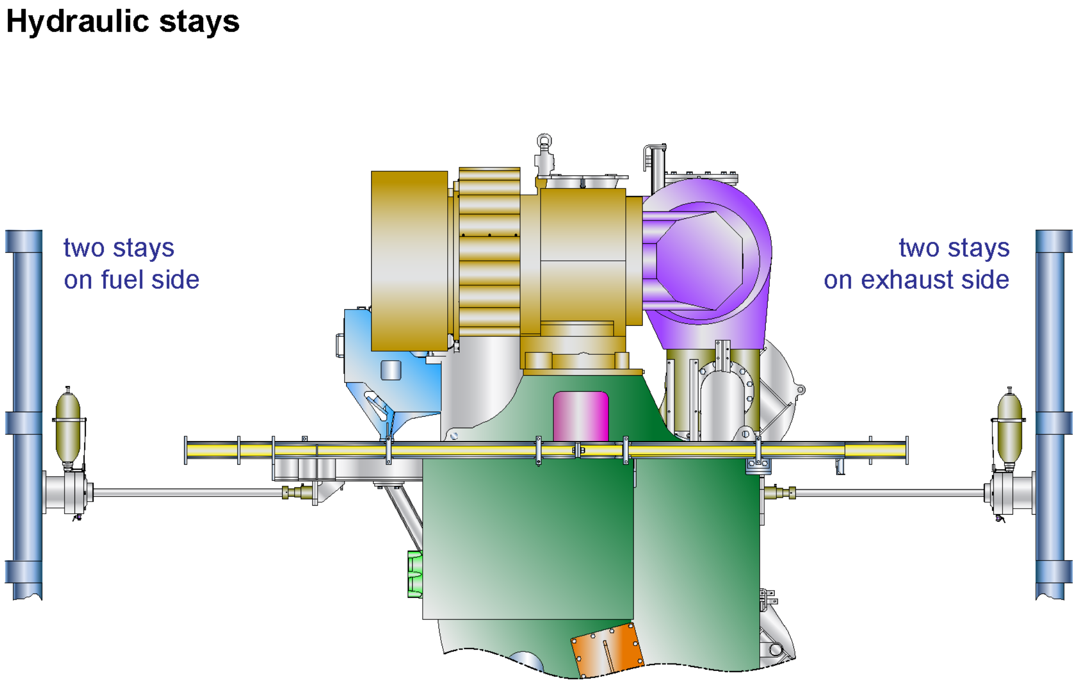


Figure 5.5: General arrangement of lateral stays (hydraulic)

Friction stays:

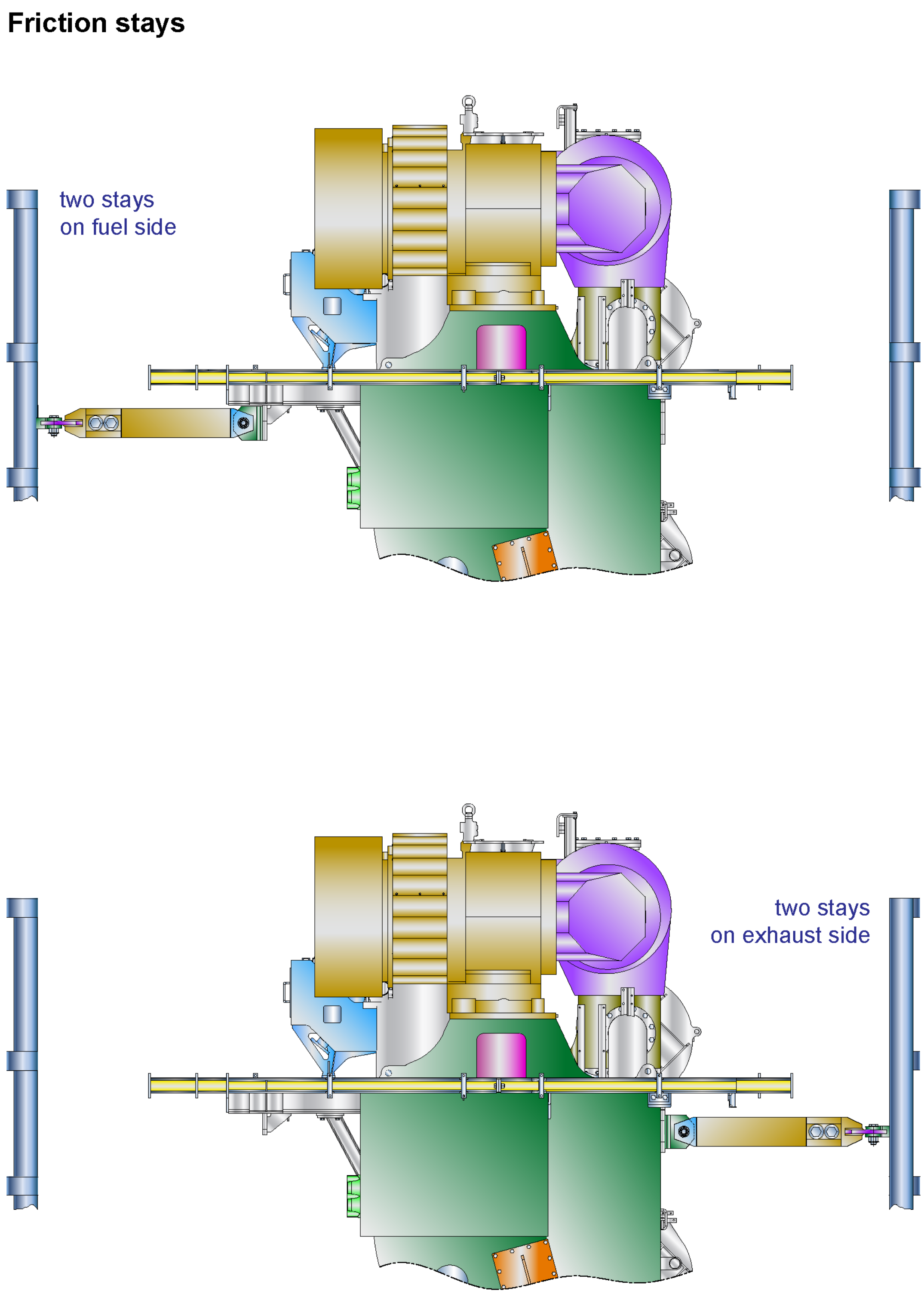


Figure 5.6: General arrangement of lateral stays (friction)

5.3.2 Electrically driven compensator

If for some reason it is not possible to fit lateral stays, an electrically driven compensator can be installed, which reduces the lateral engine vibrations and their effect on the ship's superstructure.

It has to be noted that only one harmonic excitation can be compensated at a time, and in case of an 'X-type' vibration mode, two compensators, one fitted at each end of the engine top, are necessary.

5.4 Longitudinal engine vibration (pitching)

In some cases with 5-cylinder 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 *5.6*). To prevent such vibration, the stiffness of the double-bottom structure should be as strong as possible.

5.5 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 power take-off (PTO), as any system capable of vibrating, has resonant frequencies.

If any source generates excitation at resonant frequencies, the torsional loads in the system reach maximum values. These torsional loads have to be limited, if possible by design, e.g. 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 by 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 *5.10*).

5.5.1 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 part of the energy. Where low energy torsional vibrations have to be reduced, a viscous damper can be installed; refer to Fig. *5.7*. In some cases the torsional vibration calculation shows that an additional oil-spray cooling for the viscous damper is needed. In such cases the layout has to be in accordance with the recommendations of the damper manufacturer and our design department.

For high energy vibrations, e.g. for higher additional torque levels that can occur with 5 and 6-cylinder engines, a spring damper with its higher damping effect may have to be considered; refer to Fig. *5.8*. This damper has to be supplied with oil from the engine's lubricating oil system. Depending on the torsional vibration energy to be absorbed, it can dissipate up to 30 kW energy (depends on number of cylinders).

The oil flow to the damper should be 5 to 8 m^3/h, but an accurate value will be given after the results of the torsional vibration calculation are known.

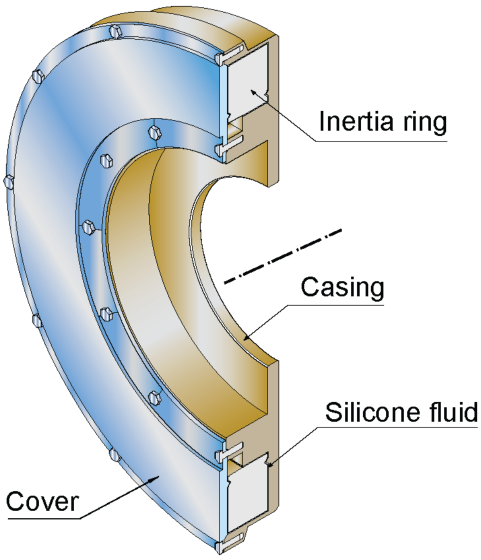


Figure 5.7: Vibration damper (viscous type)

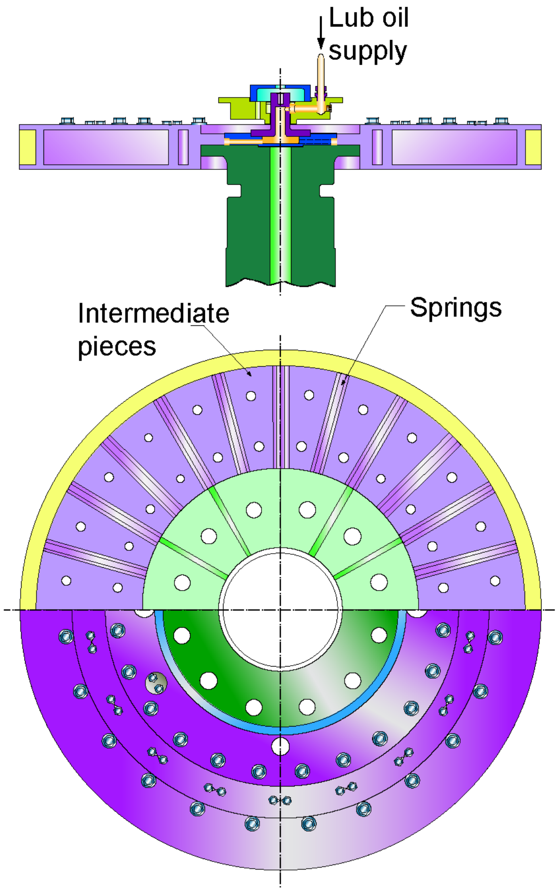


Figure 5.8: Vibration damper (Geislinger type)

5.6 Axial vibration

The shafting system, formed by the crankshaft and propulsion shafting, can vibrate in axial direction, the basic principle being the same as described in section *5.5*. 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 mainly depend 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, axial vibrations can be considerably influenced by torsional vibrations. This influence is called 'coupling effect of torsional vibrations'.

It is recommended to carry out axial vibration calculations at the same time as the torsional vibration calculation. To consider the coupling effect of the torsional vibrations on the axial vibrations, it is necessary to use a suitable coupled axial vibration calculation method.

5.6.1 Reduction of axial vibration

To limit the influence of axial excitations and reduce the level of vibration, the standard W-X40 engine is equipped with an integrated axial damper mounted at the free end of the crankshaft.

The axial damper reduces the axial vibrations in the crankshaft to acceptable values. No excessive axial vibrations should then occur, neither in the crankshaft, nor in the upper part of the engine.

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.

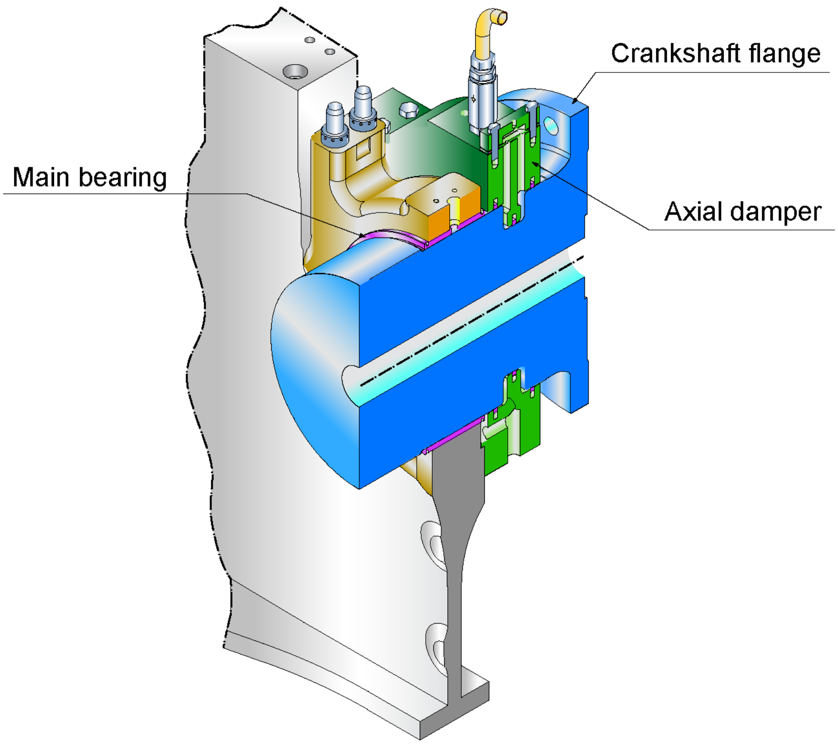


Figure 5.9: Example of an axial damper (detuner)

5.7 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 cooperation 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, complete the order forms as given in section *5.10* and send it to the address given.

5.8 Summary of countermeasures for dynamic effects

The following table indicates where special attention is to be given to dynamic effects and the countermeasures required to reduce them. Where installations incorporate PTO arrangements, further investigation is required, and Wärtsilä Switzerland Ltd. should be contacted.

5.8.1 External mass moments

No. cyl.	2^{nd} order compensator
5	Balancing countermeasure is unlikely to be needed 1)
6	Balancing countermeasure is unlikely to be needed 1)
7	Balancing countermeasure is not relevant
8	Balancing countermeasure is not relevant

Table 5.2: Countermeasures for external mass moments

NOTICE

1) No engine-fitted 2^{nd} order balancer available. If reduction on M_{2v} is needed, an external 2^{nd} order compensator has to be applied.

5.8.2 Lateral and longitudinal rocking

No. cyl.	Lateral stays	Longitudinal stays
5	A	B
6	B	C
7	B	C
8	A	C

Table 5.3: Countermeasures for lateral and longitudinal rocking

NOTICE

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.

5.8.3 Torsional and axial vibrations

No. cyl.	Torsional vibrations	Axial vibrations
5 to 8	Detailed calculations have to be carried out for every installation, countermeasures to be selected accordingly (shaft diameters, critical or barred speed range, flywheel, tuning wheel, TV 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 on the propulsion shafting components should be checked by calculation.

Table 5.4: Countermeasures for torsional and axial vibration

5.9 System dynamics

A modern propulsion plant may include a main-engine driven generator. This element is connected by clutches, gears, shafts and elastic couplings. Under transient conditions heavy 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 is transient). Usually the transfer from one operating point to another is monitored by a control system 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 heavy 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. This program allows 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 of 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 the engine. Please describe the situation and send or fax the completed relevant order form given in the next section *5.10*. We will provide an answer as soon as possible.

5.10 Order forms for vibration calculations and simulation

For system dynamics and vibration analysis the following forms are available on the Licensee Portal. They can be filled in and submitted directly to Wärtsilä Switzerland Ltd.

Marine installation: Torsional Vibration Calculation	PDF available on request
Testbed installation: Torsional Vibration Calculation	
Marine installation: Coupled Axial Vibration Calculation	
Marine installation: Whirling/Bending Vibration Calculation	

If you have no access to the Licensee Portal, order these forms from Wärtsilä Switzerland Ltd. Send a PDF or fax a copy of the completed relevant forms to the following address:

Wärtsilä Switzerland Ltd.
Dept. 10189 *'Engine and System Dynamics'*
Zürcherstrasse 12
PO Box 414
CH-8401 Winterthur
eMail: dynamics.ch@wartsila.com
Fax: +41-52-262 07 25

6. Auxiliary Power Generation

This chapter covers a number of auxiliary power arrangements for consideration. However, if your requirements are not fulfilled, contact our representative or consult **Wärtsilä Switzerland Ltd.** 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, a steamturbine driven generator using waste heat from the engine exhaust gas, or simply by applying 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 required flexibility when the main-engine power cannot be used.

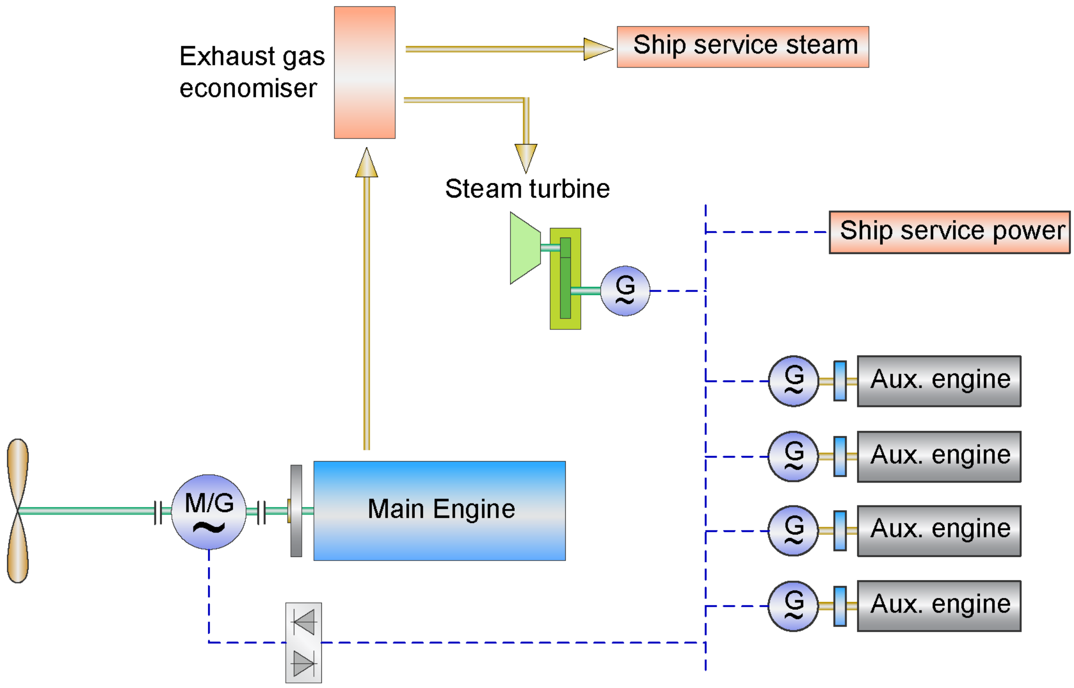


Figure 6.1: Heat recovery, typical system layout

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.

6.1 Waste heat recovery

Before any decision can be made on installing a waste heat recovery system (see Fig. *6.1*) the steam and electrical power available from the exhaust gas is to be established.

For more information see chapter *winGTD and netGTD*.

6.2 Power take-off (PTO)

Main-engine driven generators are an advantageous option when consideration is given to the simplicity of operation and low maintenance costs. The generator is driven by a tunnel PTO gear with frequencey control provided by thyristor invertors or constant-speed gears. The tunnel gear is mounted on the intermediate propeller shaft. Positioning the PTO gear in that area of the ship depends upon the available space.

6.2.1 PTO power and speed

PTO tunnel gear with generator	
Generator speed (rpm)	1000, 1200, 1500, 1800
Power (kWe)	700, 1200, 1800

Table 6.1: PTO power and speed

Free end PTO is available on request.

An alternative is a shaft generator.

7. Ancillary Systems

Sizing engine ancillary systems, i.e. freshwater 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, contact our representative or Wärtsilä Switzerland Ltd. directly.

The *winGTD and netGTD* enable 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.

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 before commissioning.**

The data given in section *7.1* are applicable to the nominal maximum continuous rating R1 of the 5 to 8-cylinder engines and 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 freshwater cooling system with single-stage scavenge air cooler (SAC) and integrated HT circuit
- ABB A100-L turbochargers
- Turbochargers lubricated from the engine's lubricating system

Furthermore the following data are obtainable from the *winGTD and netGTD* or on request from Wärtsilä Switzerland Ltd.:

- Data for engines fitted with MHI MET MB turbochargers
- Derating and part-load performance data
- Data for Delta Tuning
- Data for Low-Load Tuning

7.1 Data for central freshwater cooling system (integrated HT)

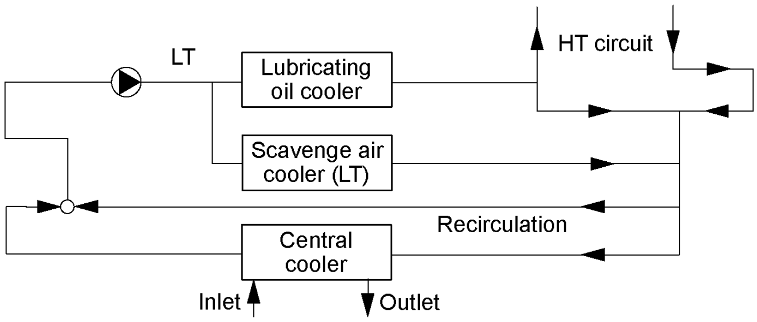


Figure 7.1: Central freshwater cooling system with integrated HT circuit

7.1.1 Data for central freshwater cooling system

Number of cylinders		**5**	**6**	**7**	**8**
Speed R1	rpm	**146**			
Engine power R1	kW	5,675	6,810	7,945	9,080
Turbochargers	-				
Type ABB	-	1 A165-L34	1 A165-L35	1 A170-L34	1 A170-L35
Cylinder cooling (HT)					
Heat dissipation	kW	856	1,057	1,228	1,431
Freshwater flow	m³/h	50	62	72	84
Freshwater temp. engine in / out	°C	70 / 85	70 / 85	70 / 85	70 / 85
Scavenge air cooler (LT)					
Heat dissipation	kW	2,315	2,767	3,237	3,687
Freshwater flow	m³/h	155	155	155	155
Freshwater temp. cooler in / out	°C	36 / 49	36 / 51	36 / 54	36 / 57
Scavenge air mass flow	t/h	41	50	58	66
Lubricating oil cooler					
Heat dissipation	kW	520	617	725	823
Oil flow *1)	m³/h	112	127	142	158
Oil temp. cooler in / out	°C	54 / 45	55 / 45	55 / 45	56 / 45
Water flow	m³/h	45	53	63	71
Water temp. cooler in / out	°C	36 / 46	36 / 46	36 / 46	36 / 46
Mean log temp. difference	°C	9	9	9	9

Number of cylinders		5		6		7		8	
Central cooler									
Heat dissipation	kW	3,691		4,442		5,190		5,941	
Freshwater flow	m³/h	200		208		218		226	
Freshwater temp. cooler in / out	°C	52 / 36		54 / 36		57 / 36		59 / 36	
Seawater flow	m³/h	180		217		253		290	
Seawater temp. cooler in / out	°C	32 / 50		32 / 50		32 / 50		32 / 50	
Mean log temp. difference	°C	3		4		5		6	
Exhaust gas									
Heat dissipation *2)	kW	1,270		1,524		1,779		2,033	
Mass flow	t/h	41.9		50.2		58.6		67.0	
Temp. after turbine	°C	277		277		277		277	
Engine radiation									
Radiation	kW	61		70		79		87	
Starting air *3)									
Bottles (2 units), pressure	bar	30		30		30		30	
Bottles (2 units), capacity each	m³	2.0		2.0		2.5		2.5	
Air compressors (2 units), capacity each	m³/h	60		60		75		75	
Pumps / delivery head *4)									
		m³/h	**bar**	**m³/h**	**bar**	**m³/h**	**bar**	**m³/h**	**bar**
Lubricating oil		112	6.2	127	6.2	142	6.2	158	6.2
High-temp. circuit		50	2.5	62	2.5	72	2.5	84	2.5
Low-temp. circuit		200	2.0	208	2.0	218	2.0	226	2.0
Fuel oil booster		1.6	7.0	2.0	7.0	2.3	7.0	2.6	7.0
Fuel oil feed		1.4	4.0	1.7	4.0	2.0	4.0	2.3	4.0
Seawater		180	2.2	217	2.2	253	2.2	290	2.2

Table 7.1: Data for central freshwater cooling system

NOTICE

*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 of 5°C from turbine to boiler.

*3) For 12 starts and refilling time 1 hour, when J_{rel} = 2.0 (see section *11.2 Starting and control air system specification*).

*4) Pressure difference across pump (final delivery head must be according to the actual piping layout).

8. Cooling Water System

The cooling system runs on either one of the following standard layouts:

1. Central freshwater cooling system with single-stage scavenge air cooler and **integrated** HT circuit
2. Central freshwater cooling system with single-stage scavenge air cooler and **separate** HT circuit.

⚠ WARNING

For all relevant and prevailing information consult the drawings in section 'Drawings' at the end of this chapter.

As freshwater is the standard cooling medium of the scavenge air cooler(s), this involves the use of a central freshwater cooling system.

The central freshwater cooling system comprises ‘low-temperature’ (LT) and ‘high-temperature’ (HT) circuits. Freshwater cooling systems reduce the amount of seawater pipework and its attendant problems and provide for improved cooling control. Optimizing central freshwater cooling results in lower overall running costs compared to the conventional seawater cooling system.

8.1 Central freshwater cooling system components

The high-temperature circuit may also be completely separated from the low-temperature circuit. In this case the high-temperature circuit has its own cooler with freshwater from the low-temperature circuit as cooling medium. The necessary data for this arrangement can be obtained from the *winGTD and netGTD*.

8.1.1 Low-temperature circuit

Seawater strainer	
Simplex or duplex to be fitted at each sea chest and arranged to enable manual cleaning without interrupting the flow. The strainer perforations are to be sized (no more than 6 mm) to prevent passage of large particles and debris damaging the pumps and impairing heat transfer across the coolers.	
Seawater strainer	
Pump type:	centrifugal
Pump capacity:	refer to table *7.1 Data for central freshwater cooling system (integrated HT)*; 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:	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 section *2.8 Pressure and temperatures ranges*
Central cooler	
Cooler type:	plate or tubular
Cooling medium:	seawater
Cooled medium:	freshwater
Heat dissipation:	refer to table *7.1*
Margin for fouling:	10-15% to be added
Freshwater flow:	refer to table *7.1*
Seawater flow:	refer to table *7.1*
Temperatures:	refer to table *7.1*
Temperature control	
The central freshwater cooling system is to be capable of maintaining the inlet temperature to the scavenge air cooler between 25°C and 36°C.	
Freshwater pumps for LT circuit	
Pump type:	centrifugal
Pump capacity:	refer to table *7.1 Data for central freshwater cooling system (integrated HT)*; the given capacity of freshwater 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

Table 8.1: Low-temperature circuit

8.1.2 High-temperature circuit

HT cooling water pump	
Pump type:	centrifugal, with a steep headcurve is to be given preference. As a guide, the minimum advisable curve steepness can be defined as follows: • For a pressure increase from 100% to 107%, the pump capacity should not decrease by more than 10%.
Pump capacity:	refer to section *7.1* The flow capacity is to be within a tolerance of -10 to +20%.
Delivery head:	determined by system layout
Working temperature:	95°C
Pump delivery head (p_p)	
The required delivery head can be calculated as follows: • $\geq$ system pressure losses ($\Sigma\Delta p$) • $\geq$ required pressure at engine inlet (p_0) • + pressure drop between pump inlet and engine inlet (d_p) • - constant (h / 10.2) • $p_p \geq \Sigma\Delta p \geq p_0 - h / 10.2 + d_p$ [bar]. The system pressure losses ($\Sigma\Delta p$) are the pressure drop across the system components and pipework and the pressure drop across the engine. The pump delivery head (p_p) depends on the height of the expansion tank, the pressure drop between pump outlet and engine inlet (d_p), and the required pressure at engine inlet (p_0). The constant is given as the difference in height between the expansion tank and the engine inlet (h) divided by 10.2.	
Expansion tank	
The expansion tank is to be fitted at least 3.5m above the highest engine air vent flange to ensure that the required static head is applied to the cylinder cooling water system. It is to be connected by a balance pipe, to replenish system losses, using the shortest route to the cylinder cooling water pump suction, making sure that pipe runs are as straight as possible without sharp bends. The cylinder cooling water system air vents are to be routed through the bottom of the expansion tank with the open end below the minimum water level.	
Automatic temp. control valve	
Electrically or electro-pneumatically actuated three-way type (butterfly valves are not adequate) having a linear characteristic	
Design pressure:	5 bar
Test pressure:	refer to the specification laid down by the classification society
Press. 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
Temp. sensor:	according to the control valve manufacturer's specification, fitted in the engine outlet pipe

Table 8.2: High-temperature circuit

⚠WARNING

The illustrations below do not necessarily represent the actual configuration or the stage of development, nor the type of your engine.

For all relevant and prevailing information consult the drawings in section 'Drawings' at the end of this chapter.

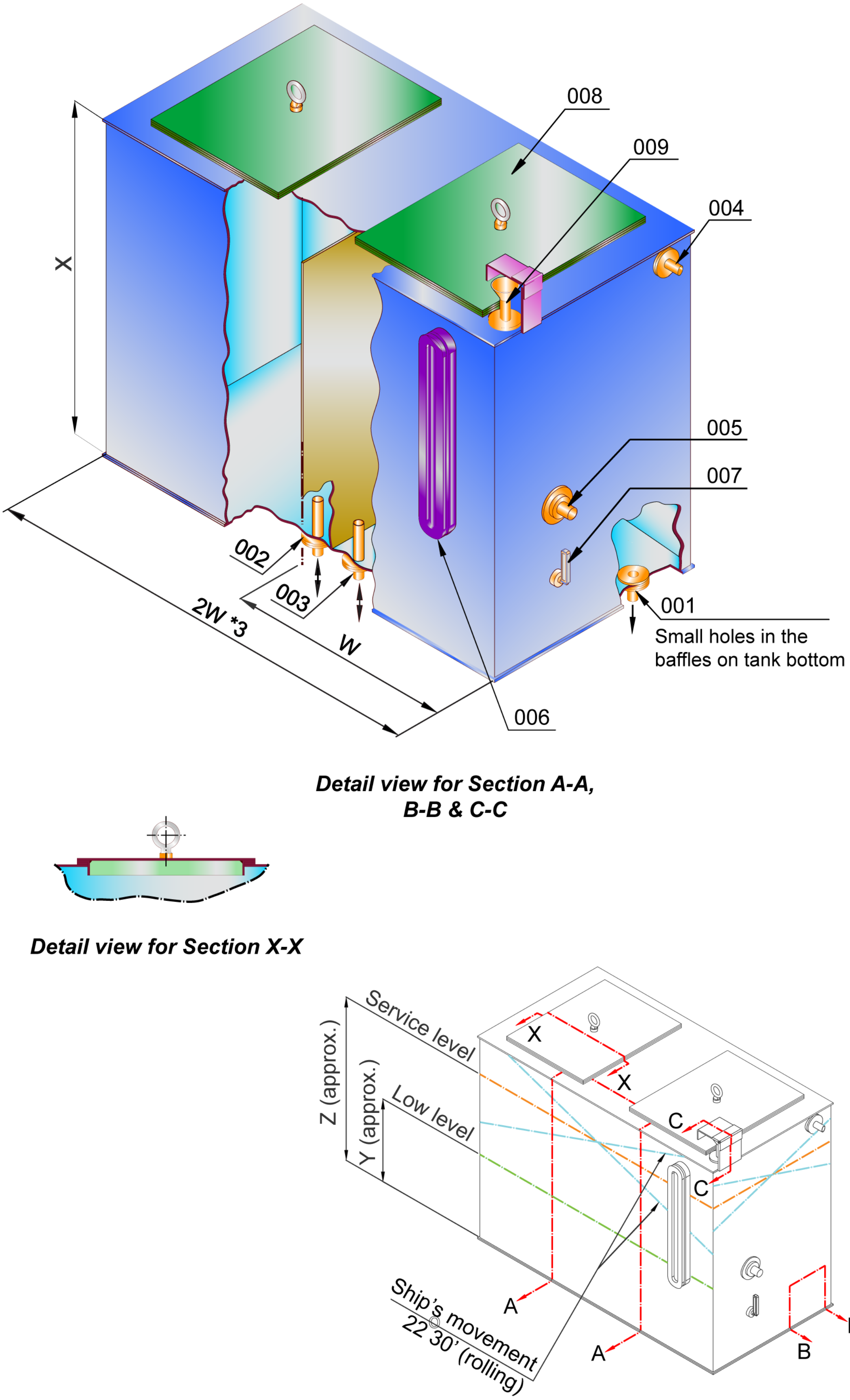


Figure 8.1: Central cooling water system, expansion tank

001	Drain	006	Level indicator *1)
002	Balance pipe from HT circuit	007	Thermometer
003	Balance pipe from LT circuit	008	Inspection cover *2)
004	Overflow / air vent	009	Filling pipe / inlet chemical treatment *2)
005	Low level alarm		

NOTICE

*1) Level indicator can be omitted if an alternative is fitted.

*2) Other designs (like hinged covers, etc.) are possible.

*3) Depending on actual ancillary plants. LT tank capacity to be increased accordingly.

Total capacity *3) (m^3)	W	X	Y	Z
1.0	800	800	330	640
1.5	800	1,200	500	960
2.0	800	1,600	670	1,280
2.5	1,000	1,250	530	1,000
3.0	1,000	1,500	630	1,200
3.5	1,000	1,750	730	1,400
4.0	1,000	2,000	830	1,600

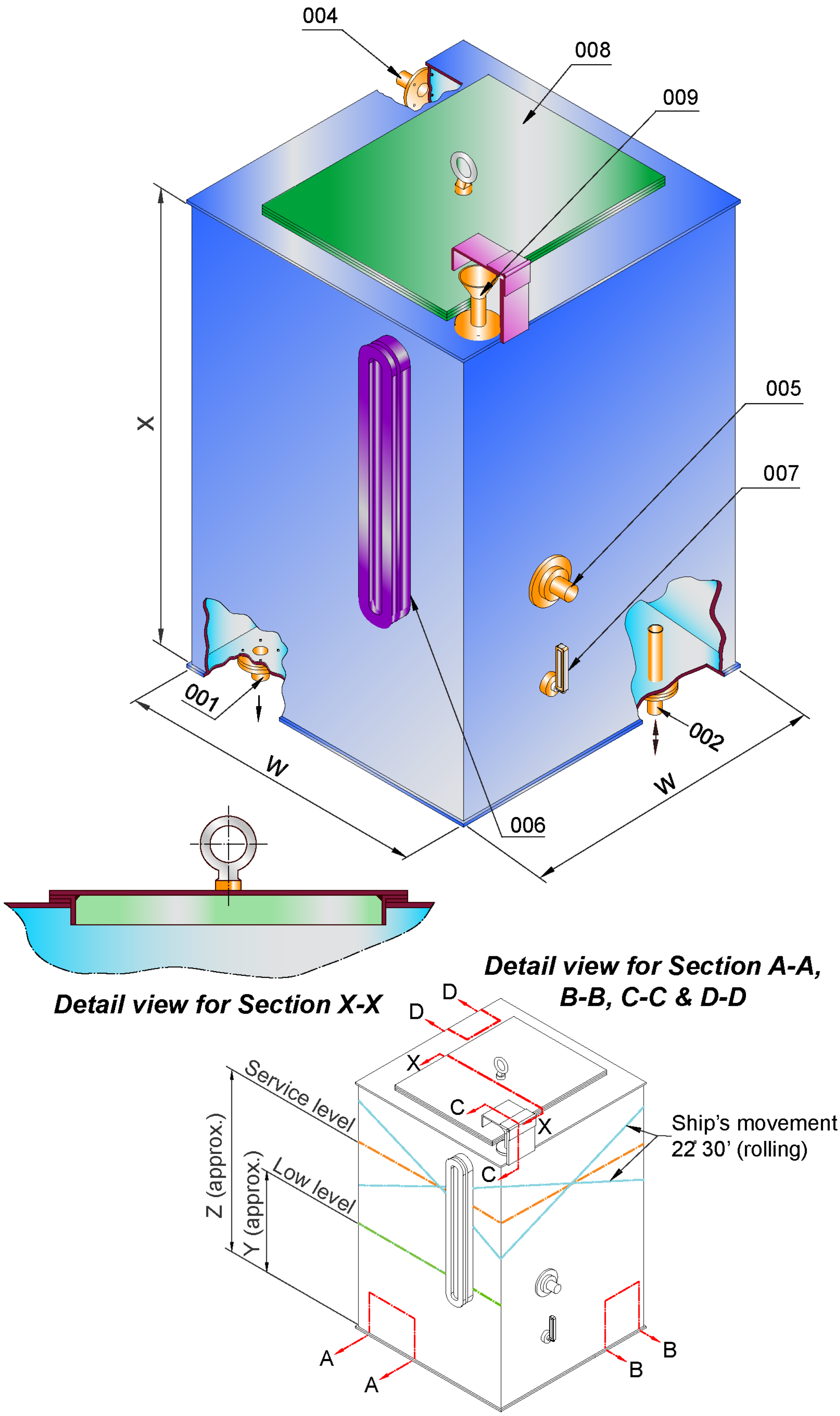


Figure 8.2: Central cooling water system, expansion tank (HT circuit)

001	Drain from HT circuit	006	Level indicator *1)
002	Balance pipe from circuit	007	Thermometer
		008	Inspection cover *2)
004	Overflow / air vent	009	Filling pipe / inlet chemical treatment *2)
005	Low level alarm		

NOTICE

*1) Level indicator can be omitted if an alternative is fitted.

*2) Other designs (like hinged covers, etc.) are possible.

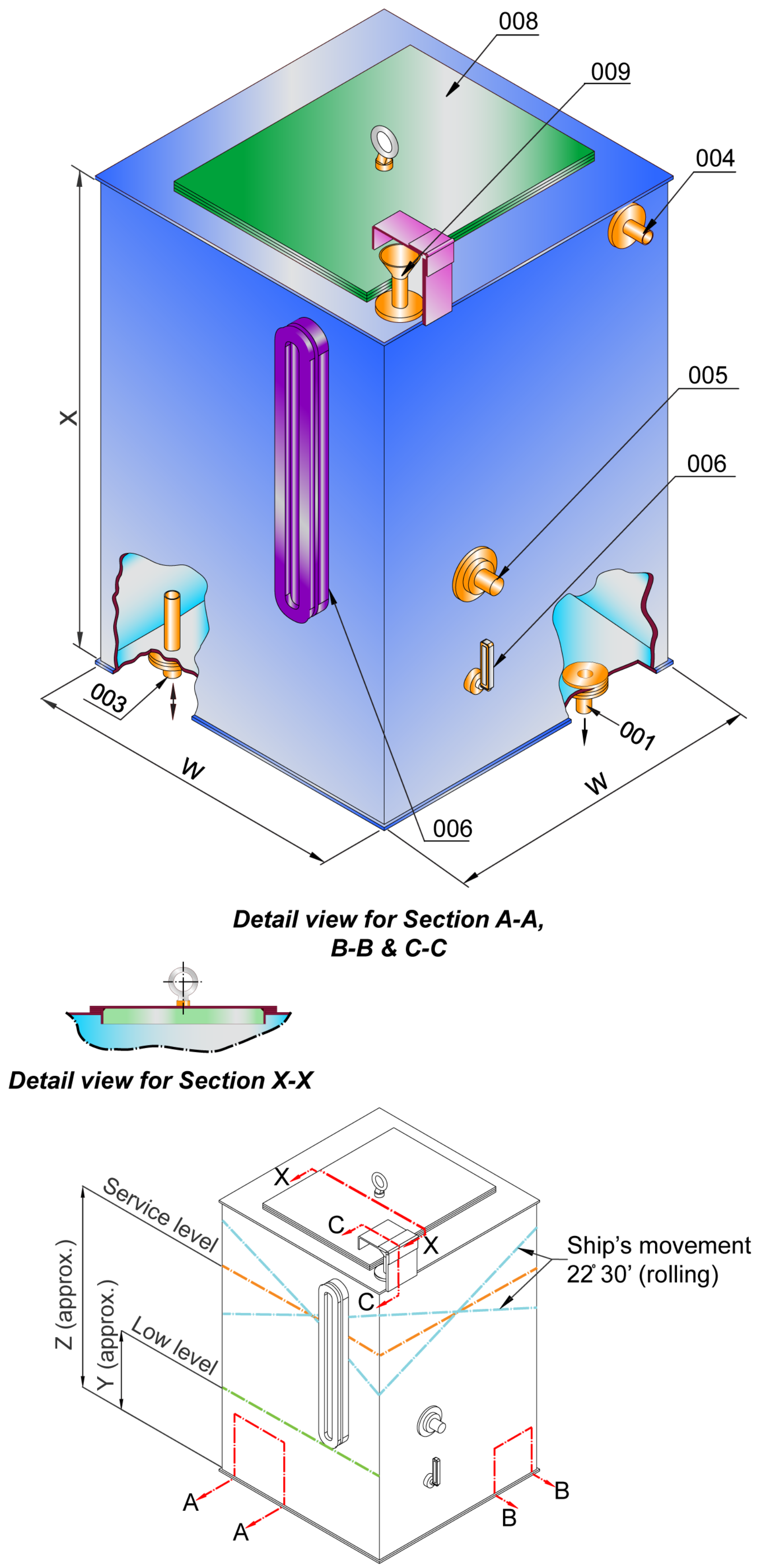


Figure 8.3: Central cooling water system, expansion tank (LT circuit)

001	Drain from LT circuit	006	Level indicator *1)
		007	Thermometer
003	Balance pipe from circuit	008	Inspection cover *2)
004	Overflow / air vent	009	Filling pipe / inlet chemical treatment *2)
005	Low level alarm		

NOTICE

*1) Level indicator can be omitted if an alternative is fitted.

*2) Other designs (like hinged covers, etc.) are possible.

8.2 General recommendations for design

The number of valves in the system is to be kept to a minimum 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 with the cooling water flow in the different branches of the cylinder cooling water system is to be avoided by installing and setting throttling discs at the commissioning stage, but 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 freshwater generator is started up or shut down.

The cylinder cooling water system is to be totally separated from steam systems. Under no circumstances must there be any possibility of steam entering the cylinder cooling water system, e.g. via a freshwater 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 parts such as pipes, valves, expansion tank, fittings, etc. are to meet the requirements of the classification society.

8.2.1 Cooling water treatment

Correct treatment of the cooling freshwater 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. dH .... 10°dH (corresponds to 180 mg/l $CaCO_3$) *1)
max. chloride ...... 80 mg/l
max. sulphates .... 150 mg/l

NOTICE

*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. (For details refer to the chemical supply companies.) Monitoring the level of the corrosion inhibitor and water softness is essential 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 freshwater, since most corrosion inhibitors have a nitrite base. Nitrites attack the zinc lining of galvanized piping and create sludge.

8.3 Freshwater generator

A freshwater generator, using 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 freshwater generator is limited by the amount of heat available, which in turn is dependent on the service power rating of the engine. It is crucial at the design stage to ensure that there are sufficient safeguards to protect the main engine from thermal shock when the freshwater generator is started. To reduce such risk, the use of valves, e.g. butterfly valves at the freshwater 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 freshwater generator valves (7 and 8) be operated by progressive servomotors and a warning sign be displayed on the freshwater generator to remind engine room personnel of the possibility of thermal shocking if automatic start-up is overridden.

⚠ WARNING

Avoid thermal shock to your main engine. The freshwater generator inlet and outlet valves to be opened and closed slowly and progressively.

The bypass with valve (8) must have the same pressure drop as the freshwater generator. The valve must be open when the freshwater generator is not in operation and closed when the freshwater generator is operating. To avoid any wrong manipulation we recommend to interlock valves 7 and 8.

Figures *8.4* and *8.5* provide two systems designed to use up to 50% of available heat (alternative 'A') and up to 85% of available heat (alternative 'B').

8.3.1 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 *8.4*. The throttling disc (6) 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 *2.8 Pressure and temperatures ranges* when the freshwater generator is started up and shut down.

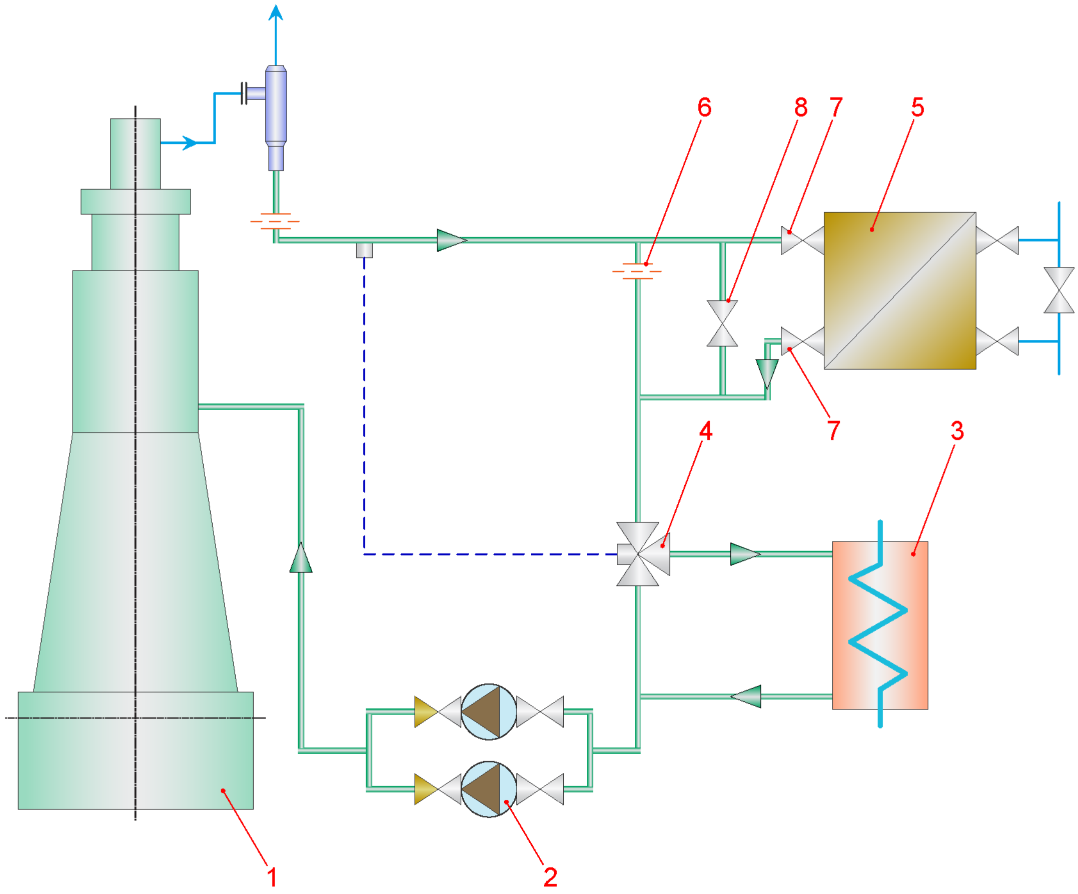


Figure 8.4: Freshwater generator installation, alternative 'A'

1	Main engine	5	Freshwater generator
2	Cylinder cooling water pump	6	Throttling disc
3	Cylinder cooling water cooler	7	Freshwater valves
4	Automatic temperature control valve	8	Freshwater generator by-pass valve

Example

8-cyl. engine - R1 specification with 9,080 kW at 146 rpm

The available heat (from section *7.1.1 Data for central freshwater cooling system*) is 1,431 kW. Alternative ‘A’ uses up to 50% of the available heat, hence 715 kW of heat is available. Substitute this value in the equation:

- FW produced in t/day = constant x available heat
- FW produced in t/day = 32 x 10^{-3} x 715
- FW produced in t/day = 23

8.3.2 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 *8.5*. This arrangement requires the provision of an additional automatic temperature control valve (4A), connected in cascade control with the cylinder cooling water cooler temperature control valve (4B), and controlled by the step controller (9) sensing the outlet cylinder cooling water temperature from the engine. If the cylinder cooling water outlet temperature is falling below the set point, valve (4A) reduces the flow of cylinder cooling water to the freshwater generator for compensation. A part of the cylinder cooling water is then routed directly to the cooling water pumps (2) 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, valve (4A) is fully opened across connections 1 and 2, and a valve travel limit switch changes the regulation of cylinder cooling water temperature over to temperature control valve (4B). This in turn passes water to the cylinder cooling water cooler (3) to maintain the cylinder water outlet at the required temperature. If in this condition the cylinder cooling water temperature falls below the set point and the cooler (3) is fully by-passed, valve (4B) is fully opened across connections 2 and 1, and a valve travel limit switch transfers the regulation of cylinder cooling water temperature back to temperature control valve (4A). As an alternative to the single-step controller (9), two controllers can be installed, one for each valve, making sure that there is a 3°C difference in the set point between (4A) and (4B) to avoid both controllers acting at the same time.

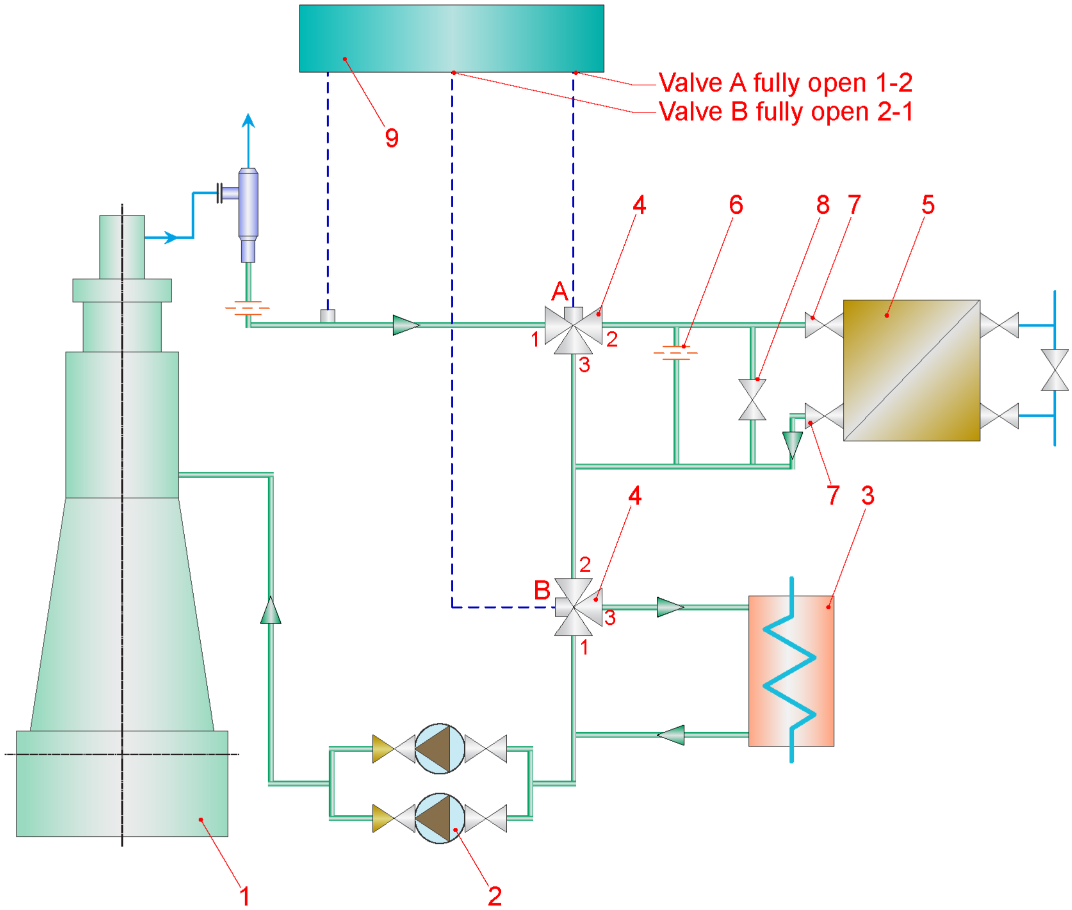


Figure 8.5: Freshwater generator installation, alternative 'B'

1	Main engine	6	Throttling disc
2	Cylinder cooling water pump	7	Cylinder water valve
3	Cylinder cooling water cooler	8	Freshwater generator by-pass valve
4	Automatic temperature control valve	9	Controller
5	Freshwater generator		

The quantity of freshwater produced by a single-effect vacuum (flash) evaporator can be estimated for guidance purposes as follows:

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

  where Q_{FW} is the heat in kW available from the cylinder cooling water, estimated from the derating table *7.1 Data for central freshwater cooling system (integrated HT)*

Example

8-cyl. engine - R1 specification with 9,080 kW at 146 rpm fitted with central cooling system and single-stage scavenge air cooler

The available heat (from table *7.1 Data for central freshwater cooling system (integrated HT)*) is 1,431 kW. Alternative ‘B’ uses up to 85% of the available heat, hence 1,216 kW of heat is available. Substitute this value in the equation:

- FW produced in t/day = constant x available heat
- FW produced in t/day = $32 \times 10^{-3} \times 1{,}216$
- FW produced in t/day = 39

NOTICE

The indicated values for evaporator heat requirement and load in alternatives '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.).

8.4 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, 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 is to be provided by a dedicated temperature sensor at the cylinder water outlet of the engine. The flow through the heater is set by throttling discs, but not by valves, to assure flow through the heater.

If the requirement is for a separate pre-heating pump, a small unit of 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. 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 has 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 the target temperature of 60°C, the engine ambient temperature and the heating-up time are the key parameters.

If the requirement for warming-up is from the cooling water systems 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 has to be ensured 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.

8.5 Drawings

PAAD060175	Central cooling water system with single-stage SAC and separated HT-circuit
PAAD060174	Central cooling water system with single-stage SAC and integrated HT-circuit

Quantity PAAD060175 (Net Weight 0.001)	Quantity PAAD060174 (Net Weight 0.001)	SEQ NO	Material ID	Material Name Dimension/Occ.Dimension	Standard or Drawing	Basic Material Material Standard	Weight GR./NET
1	1	003	107.429.532.500	CONCEPT GUIDANCE	107.429.532		0.001
-	1	002	PAAD060180	CENTRAL COOLING WATER SYSTEM	DAAD020443		0.001
1	-	001	PAAD060179	CENTRAL COOLING WATER SYSTEM	DAAD020442		0.001

SEE TABLE PER ENGINE

Approved

Free space for lic.

Q-Code XXXXX

Standard ISO JIS

Main Drw. H

Modif. | Number | Drawn date | Number | Drawn date | Number | Drawn date | Number | Drawn date

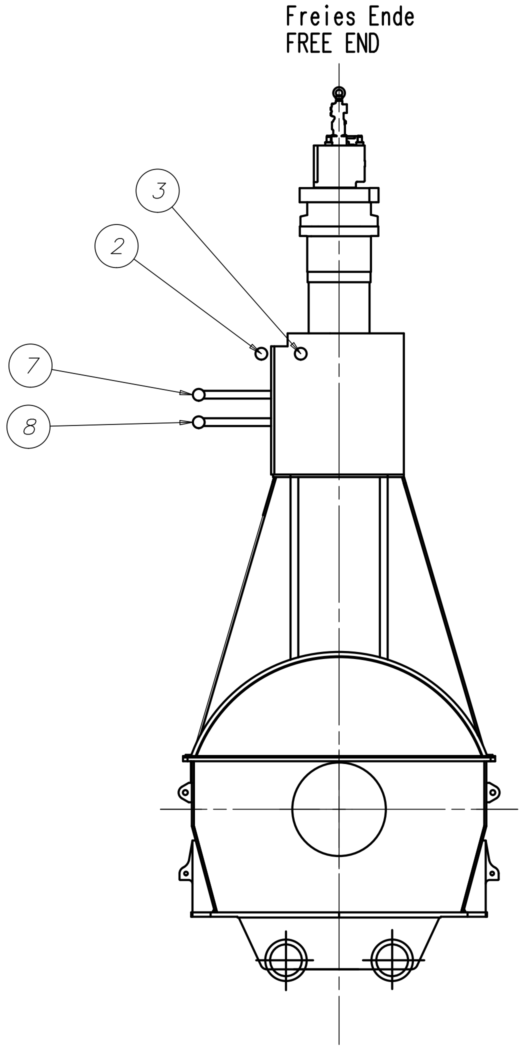
WÄRTSILÄ

Product: W5-8X40

COOLING WATER SYSTEMS
INSTALLATION DRAWINGS
Kuehlwassersystem

Units mm kg	IDE		Basic Material		Net Weight
SURFACE PROTECTION SEE GROUP 0344	Made	08.09.2011 lmux02 L.Müller	Scale –	Size A3 / Page 1/1	Material ID
TOLERANCING PRINCIPLE ISO8015	Chkd	04.10.2011 wwr001 Wroblewski	Design Group 9721	Drawing ID DAAD020444	Rev. –
GENERAL TOLERANCES ACCORDING TO ISO2768-mK	Appd	04.10.2011 dst009 Stroedecke			

DID - DIMENSIONAL DRAWING - Confidential



Specifications that need to be met:

No.	Specification
2	cylinder cooling water inlet - Cooling water pressure 2.0-4.0 bar - Cooling water volume flow according to winGTD spec. - FW has to be treated
3	cylinder cooling water outlet - Cooling water temperature 80-90°C - FW has to be treated
7	SAC LT cooling water inlet - Cooling water pressure 2.0-4.0 bar - Cooling water temperature 25-36° C - Cooling water volume flow according to winGTD spec. - FW has to be treated
8	SAC LT cooling water outlet -Cooling water volume flow according to winGTD spec. adjusted by orifice in outlet pipe on plant

QTY	SEQ NO	Material ID	Material Name	Dimension/Occ.Dimension	Standard or Drawing	Basic Material Material Standard	Weight GR./NET
1	002	107.413.098.500	EXPANSION TANK		107.413.098		0.001

Approved

Free space for lic.

Q-Code XXXXX | Main Drw.

Standard ISO JIS

Modif.	Number	Drawn date	Number	Drawn date	Number	Drawn date	Number	Drawn date

WÄRTSILÄ

Product W5-8X40

CENTRAL COOLING WATER SYSTEM
INTEGRATED HT-CIRCUIT
Zentralkuehlwassersystem

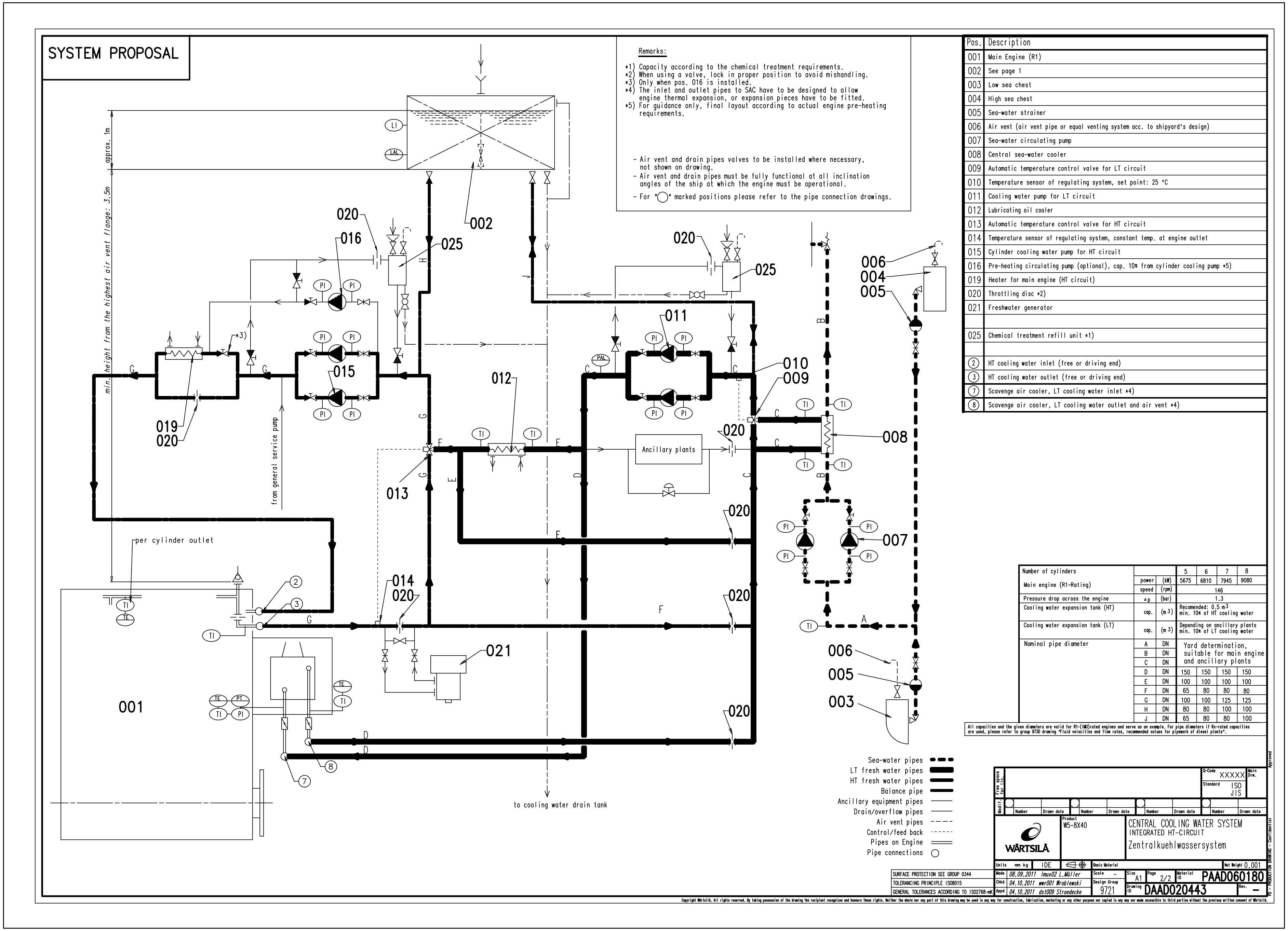
Units mm kg | IDE | Basic Material | Net Weight 0.001

SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK

Made	08.09.2011	lmux02 L.Müller
Chkd	04.10.2011	wwr001 Wroblewski
Appd	04.10.2011	dst009 Stroedecke

Scale - | Design Group 9721 | Size A3 | Page 1/2 | Material ID PAAD060180 | Drawing ID DAAD020443 | Rev. -

PD - PRODUCTION DRAWING - Confidential


SYSTEM PROPOSAL
Remarks:
*1) Capacity according to the chemical treatment requirements.
*2) When using a valve, lock in proper position to avoid mishandling.
*3) Only when pos. 016 is installed.
*4) The inlet and outlet pipes to SAC have to be designed to allow engine thermal expansion, or expansion pieces have to be fitted.
*5) For guidance only, final layout according to actual engine pre-heating requirements.
- Air vent and drain pipes valves to be installed where necessary, not shown on drawing.
- Air vent and drain pipes must be fully functional at all inclination angles of the ship at which the engine must be operational.
- For "◯" marked positions please refer to the pipe connection drawings.
Pos. Description
001 Main Engine (R1)
002 See page 1
003 Low sea chest
004 High sea chest
005 Sea-water strainer
006 Air vent (air vent pipe or equal venting system acc. to shipyard's design)
007 Sea-water circulating pump
008 Central sea-water cooler
009 Automatic temperature control valve for LT circuit
010 Temperature sensor of regulating system, set point: 25 °C
011 Cooling water pump for LT circuit
012 Lubricating oil cooler
013 Automatic temperature control valve for HT circuit
014 Temperature sensor of regulating system, constant temp. at engine outlet
015 Cylinder cooling water pump for HT circuit
016 Pre-heating circulating pump (optional), cap. 10% from cylinder cooling pump *5)
019 Heater for main engine (HT circuit)
020 Throttling disc *2)
021 Freshwater generator
025 Chemical treatment refill unit *1)
2 HT cooling water inlet (free or driving end)
3 HT cooling water outlet (free or driving end)
7 Scavenge air cooler, LT cooling water inlet *4)
8 Scavenge air cooler, LT cooling water outlet and air vent *4)
min. height from the highest air vent flange: 3.5m
approx. 1m
from general service pump
per cylinder outlet
to cooling water drain tank
Ancillary plants
Number of cylinders | 5 | 6 | 7 | 8
Main engine (R1-Rating) power (kW) | 5675 | 6810 | 7945 | 9080
speed (rpm) | 146
Pressure drop across the engine Δp (bar) | 1.3
Cooling water expansion tank (HT) cap. (m3) | Recomended: 0.5 m3 min. 10% of HT cooling water
Cooling water expansion tank (LT) cap. (m3) | Depending on ancillary plants min. 10% of LT cooling water
Nominal pipe diameter A DN / B DN / C DN | Yard determination, suitable for main engine and ancillary plants
D DN | 150 | 150 | 150 | 150
E DN | 100 | 100 | 100 | 100
F DN | 65 | 80 | 80 | 80
G DN | 100 | 100 | 125 | 125
H DN | 80 | 80 | 100 | 100
J DN | 65 | 80 | 80 | 100
All capacities and the given diameters are valid for R1-(IMO)rated engines and serve as an example. For pipe diameters if Rx-rated capacities are used, please refer to group 9730 drawing "Fluid velocities and flow rates, recommended values for pipework of diesel plants".
Sea-water pipes
LT fresh water pipes
HT fresh water pipes
Balance pipe
Ancillary equipment pipes
Drain/overflow pipes
Air vent pipes
Control/feed back
Pipes on Engine
Pipe connections
WÄRTSILÄ
Product W5-8X40
CENTRAL COOLING WATER SYSTEM
INTEGRATED HT-CIRCUIT
Zentralkuehlwassersystem
Q-Code XXXXX
Standard ISO JIS
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
08.09.2011 lmux02 L.Müller
04.10.2011 wwr001 Wroblewski
04.10.2011 ds1009 Stroedecke
Design Group 9721
Size A1
Page 2/2
Material ID PAAD060180
Drawing ID DAAD020443
Net Weight 0.001

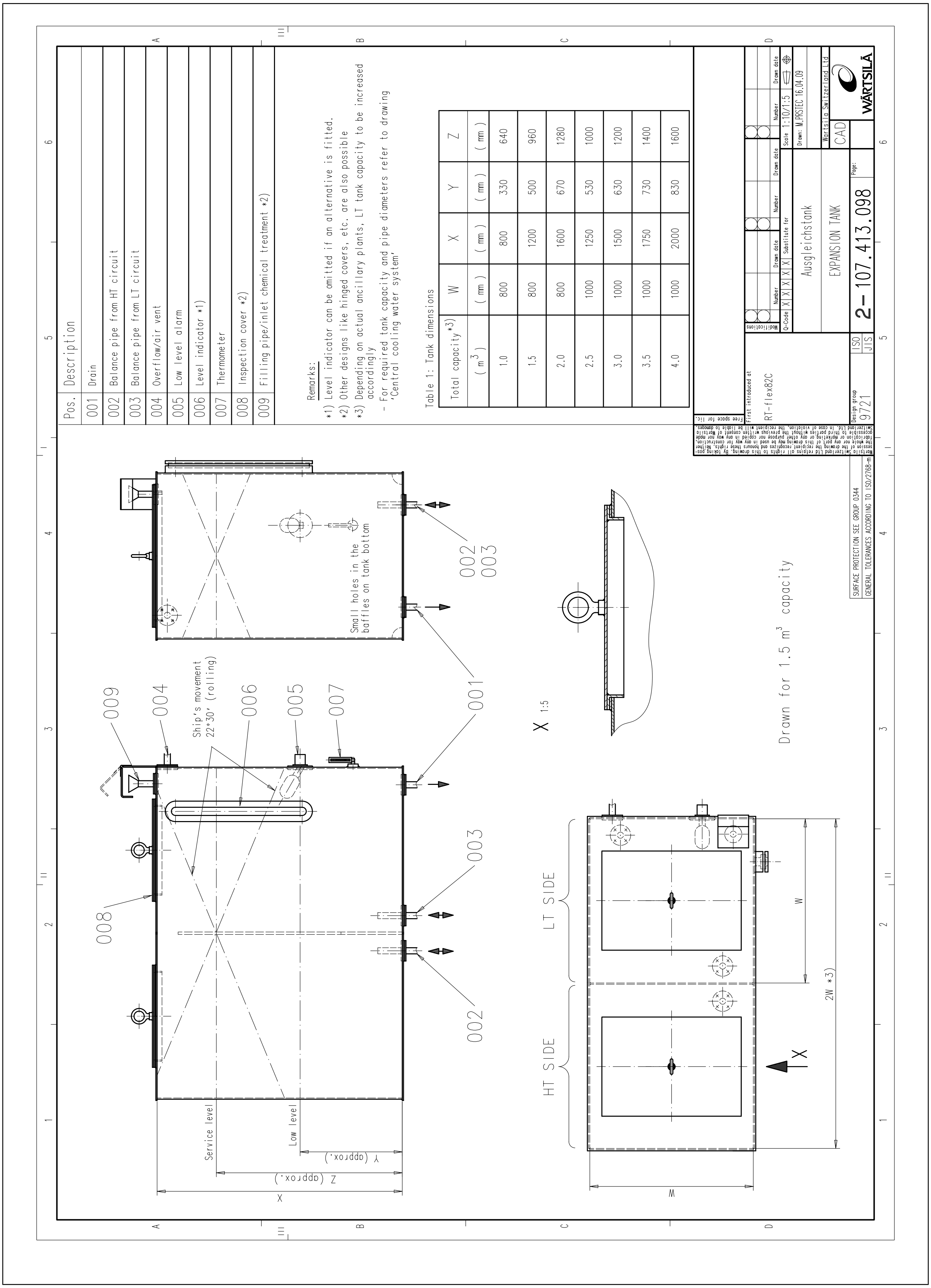
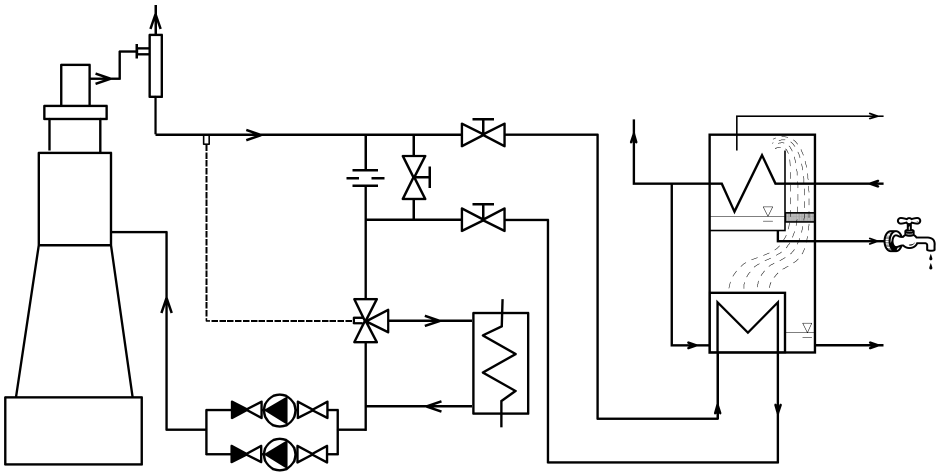


Table 1: Tank dimensions

Total capacity *3) (m^3)	W (mm)	X (mm)	Y (mm)	Z (mm)
1.0	800	800	330	640
1.5	800	1200	500	960
2.0	800	1600	670	1280
2.5	1000	1250	530	1000
3.0	1000	1500	630	1200
3.5	1000	1750	730	1400
4.0	1000	2000	830	1600

System Engineering Concept Guidance

Fresh water generators: installation options



Valid for RTA and RT-flex engines

-	7-77.309	17.12.09							Replaced by:
									Substitute for: 4-107.245.874, 4-107.245.868

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Index:

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Introduction

Production of fresh water on board of sea going vessels is a well-established requirement. However, nowadays a trend to install fresh water generators (FWG) with larger capacities can be seen. Most fresh water generators work according to the operating principle of distillation by utilising part of the engine waste heat. For very high water production, heat-independent fresh water generators are also employed, as described in section 4 on page 15.

This Concept Guidance assists in designing the installation which fits best to the fresh water demand while ensuring safe main engine operation. A simple formula in the following section titles allows calculating directly the possible fresh water production corresponding to the installed engine power in kilowatt [kW]. However, this simple formula is only applicable as a first estimation. The final possible water production depends on different factors, mainly on the available waste heat of the engines concerned and the heat demand of the chosen FWG type.

The available heat from the high temperature (HT) cooling water circuit depends on the main engine load[1] and the ambient conditions. At lower engine load and in colder ambient conditions the available heat decreases. The fresh water generator's heat requirement also depends on the ambient conditions, mainly on sea-water (SW) temperature: in colder ambient conditions the heat requirement increases. Therefore the FWG design has also to be determined in accordance with the vessel's operational profile.

In case of any doubt, please do not hesitate to contact Wärtsilä Switzerland.

If other high-temperature cooling water heat consumers are to be installed, the total heat requirement of all heat consumers has to be considered.

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[1] And auxiliary engine load for installations as described in sections 2.3 (p. 9) and 2.4 (p. 10).

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The system drawings in this Concept Guidance show only installations with separated HT cooling water circuits, i.e. the HT and the LT cooling water circuits are separated by the HT cooling water cooler (HTC). However, this Guidance is also valid for installations with an integrated HT cooling water circuit. In integrated HT cooling water systems, LT cooling water is mixed to the HT circuit to maintain the required temperature at the engine inlet.

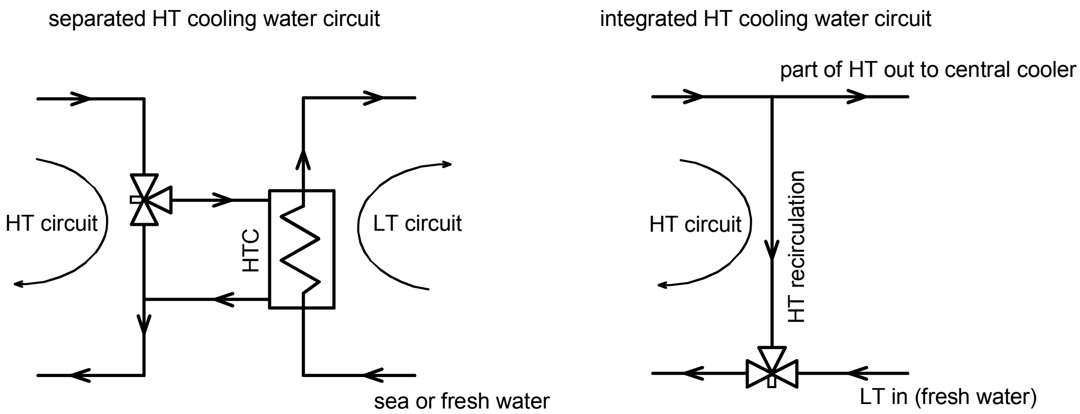

Fig. 1: The two principal types of cooling water systems

1 Safe engine operation

To avoid any negative impact of FWG operation on the engine, a few basic principles have to be observed:

- Avoid thermal shock to the engine. The fresh water generator inlet and outlet butterfly valves for the HT water are to be opened and closed slowly and progressively. They should be actuated manually with a large reduction ratio or preferably by a progressive servomotor with timer control. If the valves are manually operated, a conspicuous warning notice has to be positioned next to them. Please keep in mind that 50% to 100% of the cooling function may be taken over by the FWG, depending on the FWG design and the main engine load.
- Keep the water flow to the main engine always constant. Therefore do not install any stop valve in the main water flow to control the water flow.

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2 Single-stage fresh water generator

On board cargo vessels the fresh water is usually produced by evaporating sea water under vacuum conditions. The most common installation is a single-stage FWG. Different designs are possible, basically divided between those with tube or plate heat exchangers. However, the working principles are the same. Sea water is pre-heated by condensing the vapour in the FWG and heated by HT cooling water. About one third of the sea water evaporates. The vapour flows through the so-called demister which separates water droplets from the vapour. In the sea-water cooled condenser the vapour condensates as so-called distillate. The distillate is pumped to the storage tank. The non-evaporated two thirds of the sea water are removed as brine and pumped overboard. To obtain the vacuum in the FWG, the air has to be removed by an ejector.

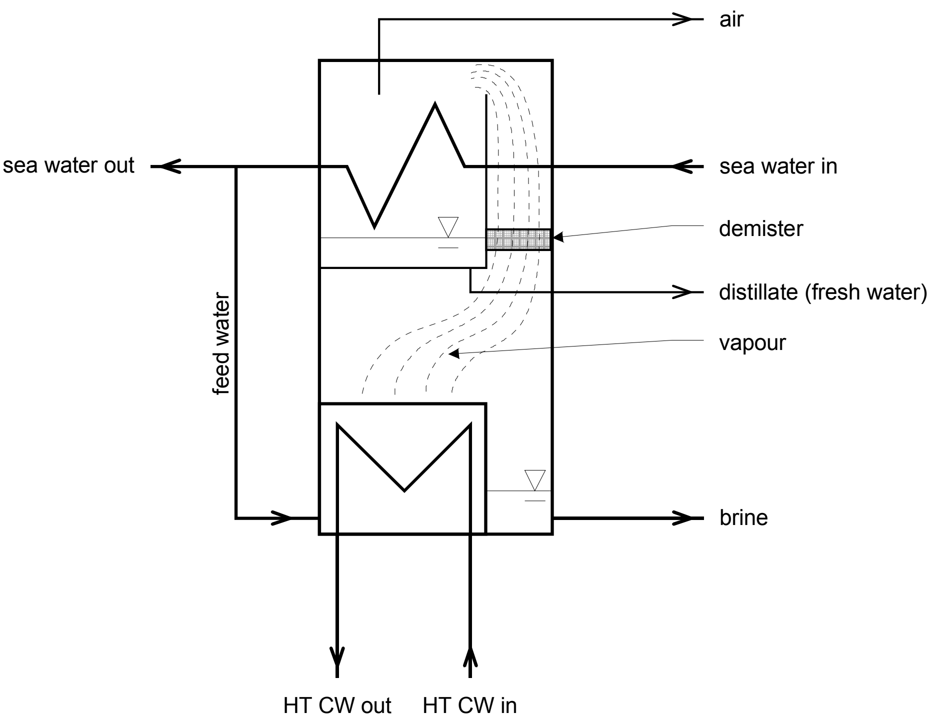

Fig. 2: General flow diagram of a single-stage evaporator

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2.1 Standard installation (single-stage FWG): up to about 2.2 x 10^{-3} x CMCR [m^3/day] fresh water production. Installation alternative ‘A’

The standard installation integrates the fresh water generator directly into the HT circuit. The FWG works as an additional cooler, but without any control valve, i.e. at a constant water flow and heat requirement. Therefore the FWG can only be operated at engine loads with sufficient heat dissipation from the HT cooling water to avoid cooling down the engine.

The FWG can be designed to utilise up to 40% of the maximum available HT cooling water heat dissipation at 100% CMCR for the RTA52U-B, RTA62U-B, RTA72U-B and RTA84C engines and up to 50% for the other RTA and RT-flex engines. To ensure that still sufficient heat is available to cover the FWG need, the FWG must not be operated at engine loads lower than 50% CMCR. However, in cold environments the FWG heat demand increases, but the engine heat dissipation decreases, i.e. the FWG has then to be operated at higher engine loads.

The possible fresh water production depending on the available heat can be calculated with the following formula:

FW produced in m^3/day = 32 x 10^{-3} x Q_{FW}.

Q_{FW} is the available heat in kW from the cylinder cooling water, i.e. 40% and 50% respectively of the cylinder cooling water heat dissipation at 100% CMCR.

-					

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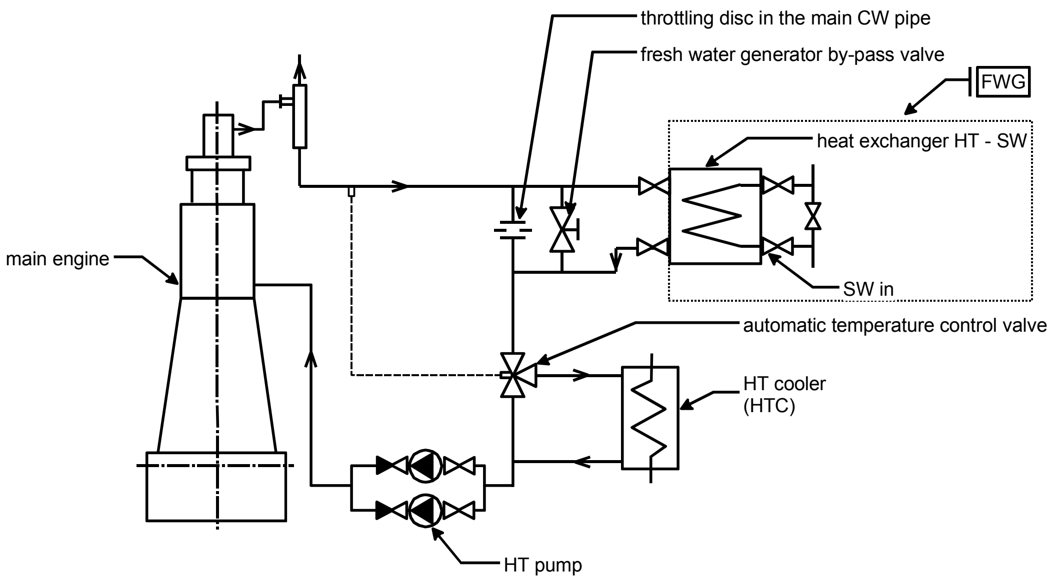

Fig. 3: Standard installation: MIM fresh water generator installation alternative 'A'

As described in section 1 (Safe engine operation) on page 4, **the cooling water flow to the engine has always to be kept constant**. For this purpose an FWG by-pass line has to be installed: when the FWG is running, the cooling water is distributed to the FWG and to the main cooling water pipe by the throttling disc; when the FWG is shut down, the water is distributed to the FWG by-pass pipe and to the main cooling water pipe. The water flow across the FWG during its operation is equal to that through the by-pass pipe when the FWG is shut down. The by-pass line has to be designed accordingly.

The purpose of the throttling disc in the main cooling water pipe is to adjust the pressure loss through this pipe to the pressure loss across the FWG at its nominal heating water flow.

2.2 Optimised installation (single-stage FWG): up to about 3.7 x 10^{-3} x CMCR [m^3/day] fresh water production. Installation alternative 'B'

For higher fresh water demands, it is possible to install an FWG which is designed to utilise up to 85% of the maximum available heat dissipation at 100% CMCR. To protect the engine against excessive cooling in cases where insufficient heat is available, the water flow to the FWG is reduced by a temperature control valve (CVA). During FWG operation, the FWG operates as the main HT cooling water cooler (HTC). Only if the engine HT cooling water heat dissipation is higher than the heat demand of the FWG, does the HTC take the remaining heat.

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The FWG installation, with the by-pass pipes, is similar to that of the standard installation (installation alternative 'A'). The FWG is integrated between the additional control valve (CVA) and the HTC control valve (CVB).

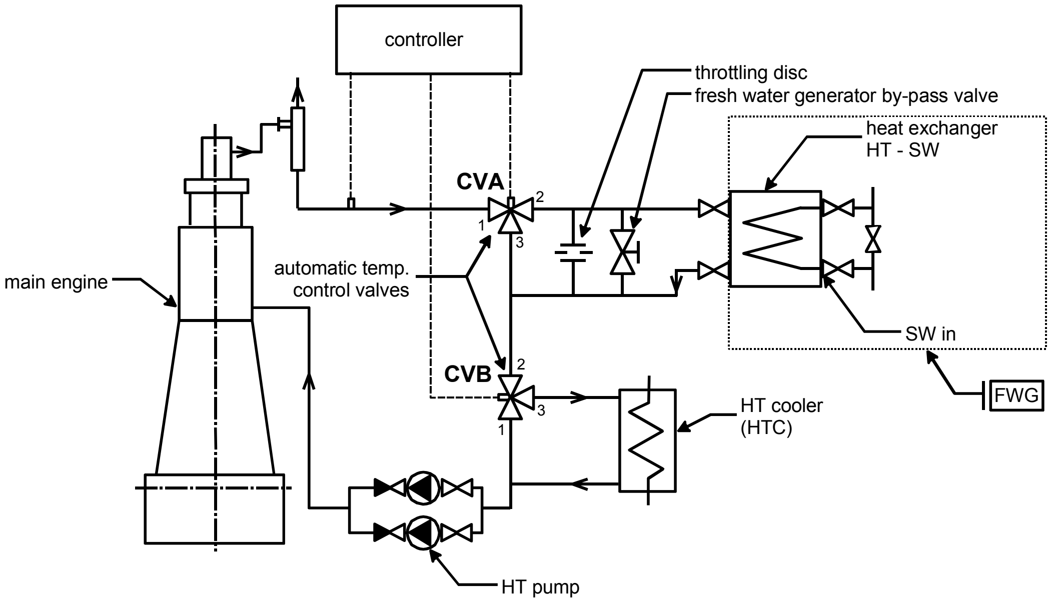

Fig. 4: Optimised installation: MIM fresh water generator installation alternative 'B'

Both temperature control valves CVA and CVB are either controlled by:

– One controller which detects the opening position of the main temperature control valve CVA. Control valve CVB opens only if control valve CVA is already fully open in order to take the remaining heat dissipation.

Or:

– Two separate temperature controllers with different temperature set points to avoid both controllers acting at the same time. The set point of temperature control valve CVB is adjusted 3 C higher than the set point of temperature control valve CVA: control valve CVB will only open if the cooling capacity of the FWG is not sufficient.

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2.3 Installation, utilising main and auxiliary engine heat dissipation (single stage FWG): 3.7×10^{-3} x CMCR (ME) + 5.3×10^{-3} x base load (AE) [m^3/day] fresh water production

A newly-developed system integrating the heat dissipation of the auxiliary engines into the HT system of the main engine is described below.

The FWG capacity can be specified by taking into account the additional continuous heat available from the auxiliary engines at base load.

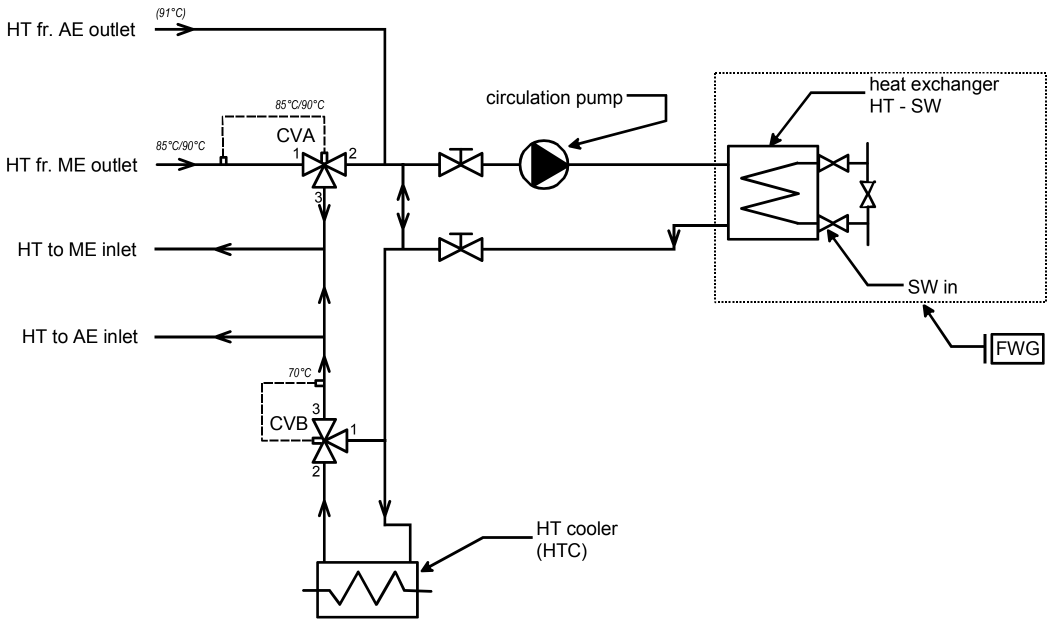

Fig. 5: Installation option utilising ME and AE cylinder cooling water waste heat

A circulation pump ensures a constant water flow to the FWG, independent of main and auxiliary engines' load, but at different temperature levels. Depending on the opening position of temperature control valve CVA, part of the flow recirculates through the by-pass line between the FWG inlet and outlet.

Control valve CVA maintains the cooling water temperature constant (85°C or 90°C[2]) at the main engine outlet. When the whole available heat cannot be dissipated by the FWG, the remaining heat is dissipated in the HT cooler.

[2] For RTA/RT-flex84T and RTA/RT-flex96C series only

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Control valve CVB maintains the temperature of the cooled HT cooling water at 70°C. If the cooling water temperature after the control valve CVB falls below 70°C, the FWG circulation pump has to be stopped.

The 70°C warm cooling water can directly be used for pre-heating the stopped auxiliary engines respectively the stopped main engine.

Applying of an integrated HT cooling water circuit is also possible. The HT cooler has to be replaced by adding LT cooling water at the connection No. 2 of temperature control valve CVB.

Other advantages of this installation, besides the greater fresh water production potential, are:

- Pre-heating of the ME from the AE is possible when in port.
- Pre-heating of the AE from the running ME is possible.
- Only a small pre-heater for one AE is required (not shown in above schematic drawing).

For further information on this installation please contact Wärtsilä Switzerland.

2.4 Installation with booster heater (single-stage FWG): maximum possible fresh water production depending on the additional booster heater capacity

To increase the available heat for the FWG, also during lower part-load operation of the main engine and in colder ambient conditions, it is possible to install a booster heater. The heater may be operated with steam or thermal oil heated by the exhaust gas boiler, enabling another source of waste heat to be used for the fresh water production.

The booster heater can be integrated in the systems as described in section 2.2 on page 7 and section 2.3 on page 9.

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Booster heater integrated in the system of installation alternative 'B'

A circulation pump provides a constant water flow to the FWG according to the FWG demand. When the available waste heat from the main engine is not sufficient, control valve CVA provides less HT cooling water to the FWG. In this case the circulation pump recirculates part of the flow of the cooled water through the by-pass line between the FWG inlet and outlet. The booster heater ensures a constant FWG operating temperature.

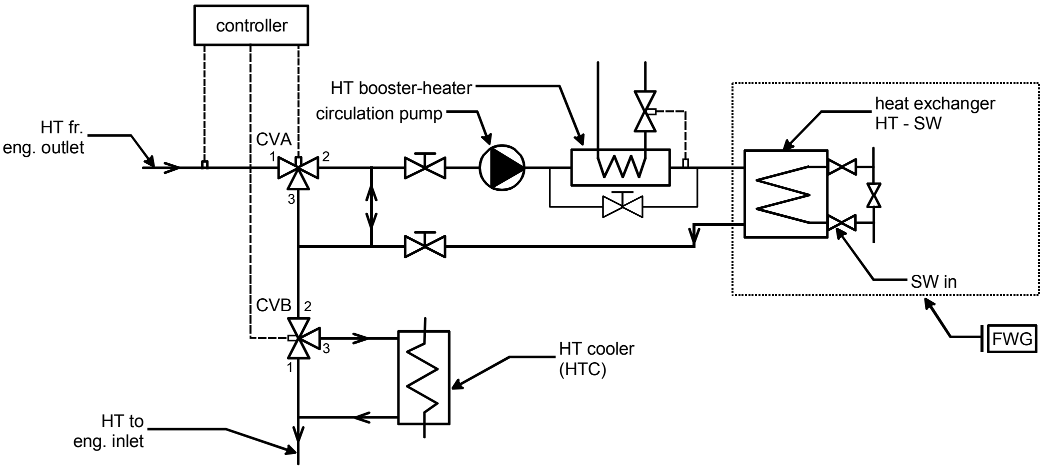

Fig. 6: Booster heater integrated in the MIM installation alternative 'B'

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Booster heater integrated in the system of section 2.3

In the system described in section 2.3 on page 9, a booster heater is integrated after the circulation pump. This ensures that the FWG is always operated at a constant temperature. For an optimum recovery of the HT cooling water heat it is recommended that the FWG outlet temperature be kept at about the same level as the outlet temperature after control valve CVB, i.e. 70°C. Therefore the booster heater should be controlled by the FWG outlet temperature.

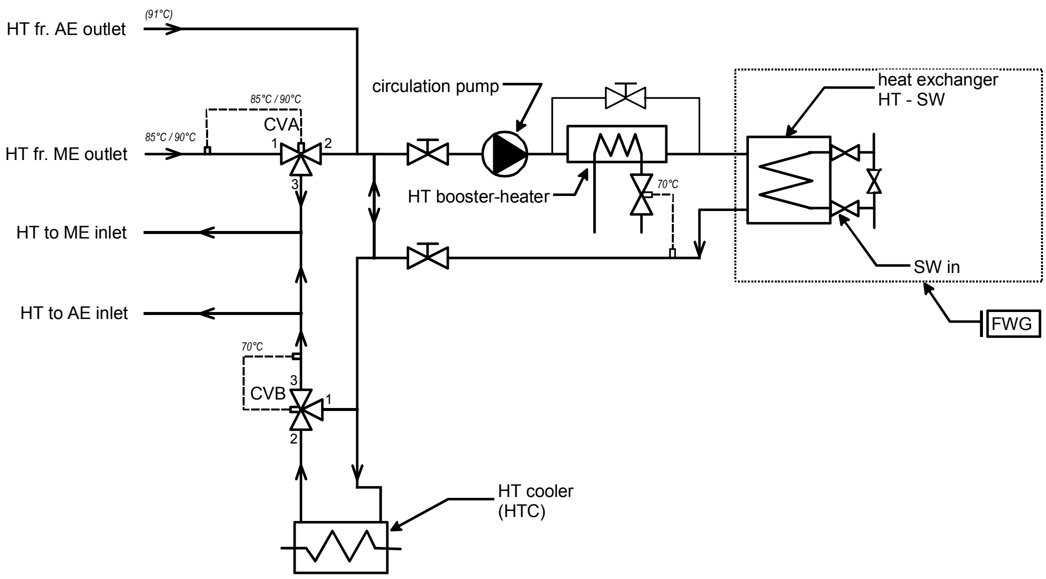

Fig. 7: Booster heater integrated in the ME and AE cylinder cooling water waste heat utilising system

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3 Multi-effect and multi-stage FWG: a multiple of the single-stage FWG installations

To increase the possible water production with a given amount of (waste) heat, it is possible to install fresh water generators which utilise the available heat several times. The basic principal behind the higher water production of these FWG is a better reutilisation of the latent vapour condensation heat.

3.1 Multi-effect evaporation FWG installations:

The single-stage FWG installations as described in section 2.1 to 2.4 can be replaced by a multi-effect evaporation FWG.

The multi-effect distillers (MED or MEP) utilise the latent vapour heat of the previous stage for evaporation in the following stage, i.e. the vapour condenser is cooled by heating up the sea water of the following stage.

Depending on the number of stages, it is possible to produce a multiple amount of fresh water compared to a single-stage FWG installation with the same heat input.

The figure below (Fig. 8) shows the working principle of a multi-effect evaporation FWG with five stages as an example.

For further information on this FWG type, please contact your FWG maker.

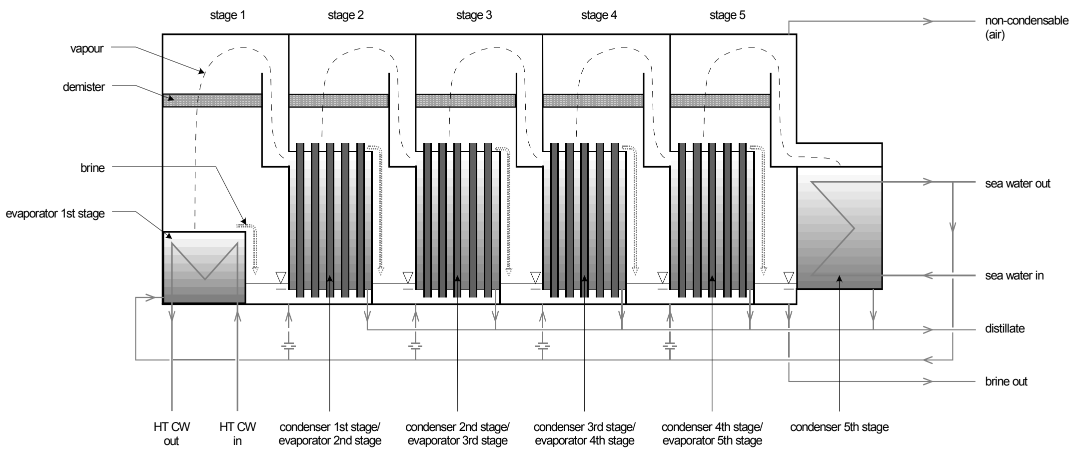

Fig. 8: Principal flow diagram of a multi-stage FWG

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3.2 Multi-stage flash FWG: a multiple of the single-stage FWG installations

The multi-stage flash (MSF) FWG type also re-uses a significantly higher amount of the condensation heat compared to the single-stage FWG. The main difference compared to the multi-effect FWG is that the total heat transfer to the sea water takes place before the sea water enters the FWG. First the sea water is heated by the vapour condensation heat, beginning from the last stage up to the first one. Thus the sea water gets already 70-80% (depending on number of stages) of the total required heat. The remaining required heat is provided by the HT cooling water and/or by a booster heater. After the final heating-up, the sea water has got enough latent heat for the multi-evaporation stages, i.e. the sea water inlet temperature is on a higher level compared to the other FWG (nearly HT cooling water outlet temperature).

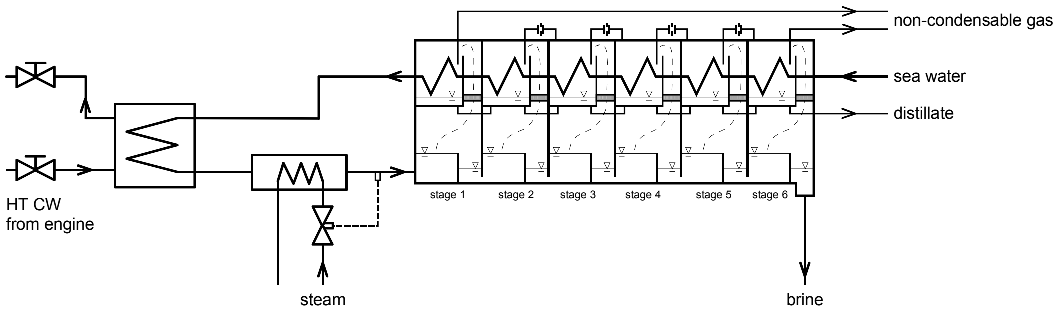

Fig. 9: Principal flow diagram of a multi-stage flash evaporator

The heated sea water enters the evaporation chambers from one stage to the next. The absolute pressure from the first stage to the last one is steadily decreased in a way that the sea water enters the chambers at a temperature level which is about 7°C higher than its boiling temperature. This leads to a spontaneous controlled evaporation of the superheated sea water. The sea water (brine) cools down due to the evaporation chill and flows to the next chamber with again a lower pressure inside. The process goes on until the sea water has passed the last chamber.

For further information on this FWG type, please contact your FWG maker.

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The following drawing shows an example for the system integration:

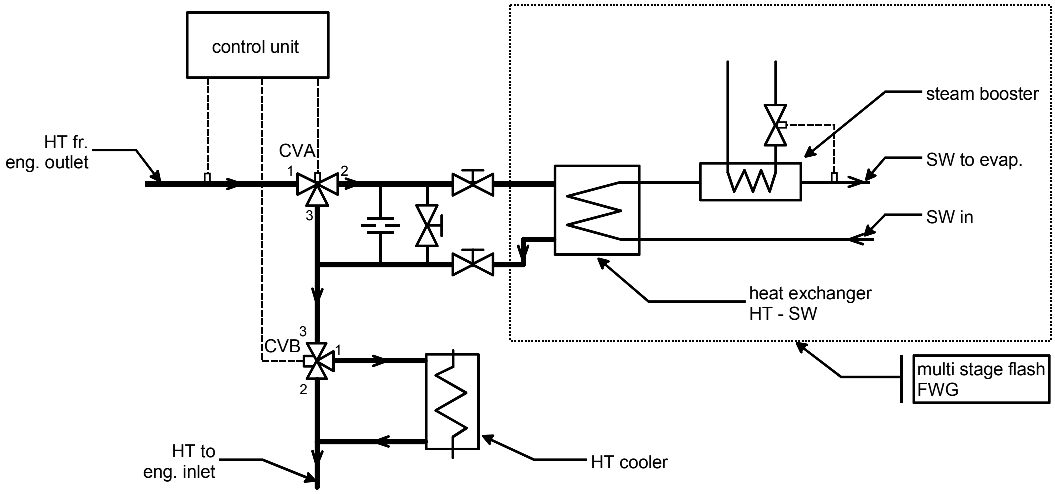

Fig. 10: Multi-stage flash evaporator system integration

4 Heat-independent installations

The following FWG types are normally only applied if the available heat is absolutely insufficient. They are mentioned here for information only.

Reverse osmosis

Sea water is forced at high pressure (about 60-70 bar) to pass through an extremely fine semi-permeable filter membrane known as the diaphragm. The filter membrane is permeable to water, but only very limited to salt. The pump therefore presses water without salt through the membrane.

Owing to the different salt concentrations on both membrane sides, an osmotic pressure builds up, which tries to balance the salt concentrations on both sides of the membrane by pressing back the saltless water to the salty side. Therefore a pump pressure higher than the osmotic pressure is required. According to an FGW maker's data, about 10 kWh of electrical energy is required for 1 m^3 fresh water production.

About 20% of the supplied sea water permeates saltless to the fresh water side of the membrane.

For further information on this FWG type, please contact your FWG maker.

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Vacuum vapour compression

The vacuum vapour compression (VVC) FWG consists of only one heat exchanger. The sea water on one side of the heat exchanger is heated by the heat of condensation of the mechanically compressed vapour, which is produced by partial evaporation of the sea water. This heat exchanger operation principle is comparable to the heat exchangers in the multi-effect FWG, except for its first stage.

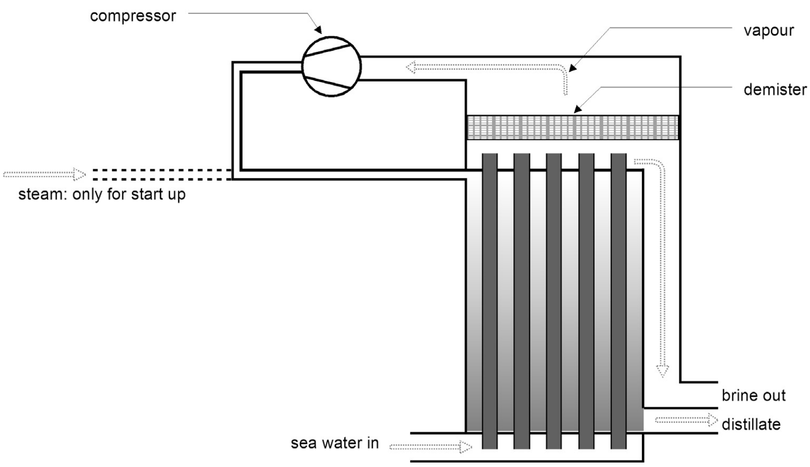

Fig. 11: Principal flow diagram of a vacuum vapour compression FWG.

A mechanical compressor extracts the water vapour from the evaporation chamber, creating a vacuum which is required for sea water evaporation at a low temperature level. The compressed vapour flows from the compressor to the heat exchanger and condenses. According to an FGW maker's data, about 25 kWh of electrical energy is required for 1 m^3 fresh water production.

Another installation option is "thermo compression" instead of mechanical compression. Steam flows at high velocity through an ejector, creating the required vacuum for sea water evaporation, like the compressor in the mechanical installation, and draws through the created vapour. The steam-vapour mixture flows to the condenser side of the heat exchanger. The reduced steam velocity at this side increases the static pressure, and the steam condenses in the heat exchanger, heating the sea water in the evaporation chamber. The boiler feed water cannot be treated with the usual chemicals, owing to the mixing of vapour and steam.

For further information on this FWG type, please contact your FWG maker.

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5 Abbreviations

AE	auxiliary engine
CCW	cylinder cooling water
CMCR	contracted maximum continuous rating
CW	cooling water
FW	fresh water
FWG	fresh water generator

FWG types:

MED	multi-effect distiller (tube type)
MEP	multi-effect distiller (plate type)
MSF	multi-stage flash
RO	reverse osmosis
VVC	vacuum vapour compression

HT	high temperature
HTC	high temperature cooling water cooler
LT	low temperature
ME	main engine
MIM	marine installation manual
SW	sea water

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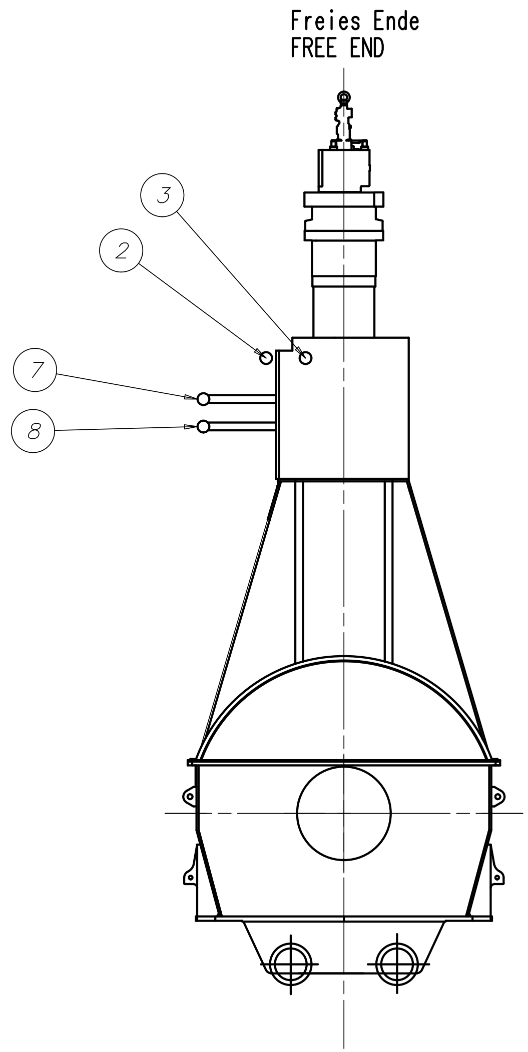

Specifications that need to be met:

2	cylinder cooling water inlet - Cooling water pressure 2.0-4.0 bar - Cooling water volume flow according to winGTD spec. - FW has to be treated
3	cylinder cooling water outlet - Cooling water temperature 80-90°C - FW has to be treated
7	SAC LT cooling water inlet - Cooling water pressure 2.0-4.0 bar - Cooling water temperature 25-36° C - Cooling water volume flow according to winGTD spec. - FW has to be treated
8	SAC LT cooling water outlet -Cooling water volume flow according to winGTD spec. adjusted by orifice in outlet pipe on plant

QTY	SEQ NO	Material ID	Material Name	Dimension/Occ.Dimension	Standard or Drawing	Basic Material Material Standard	Weight GR./NET
1	018	107.245.419.500	EXPANSION TANK		107.245.419		0.001
1	017	107.413.097.500	EXPANSION TANK		107.413.097		0.001

Approved

Free space for lic.

Q-Code XXXXX | Standard ISO JIS | Main Drw.

Modif. | Number | Drawn date | Number | Drawn date | Number | Drawn date | Number | Drawn date

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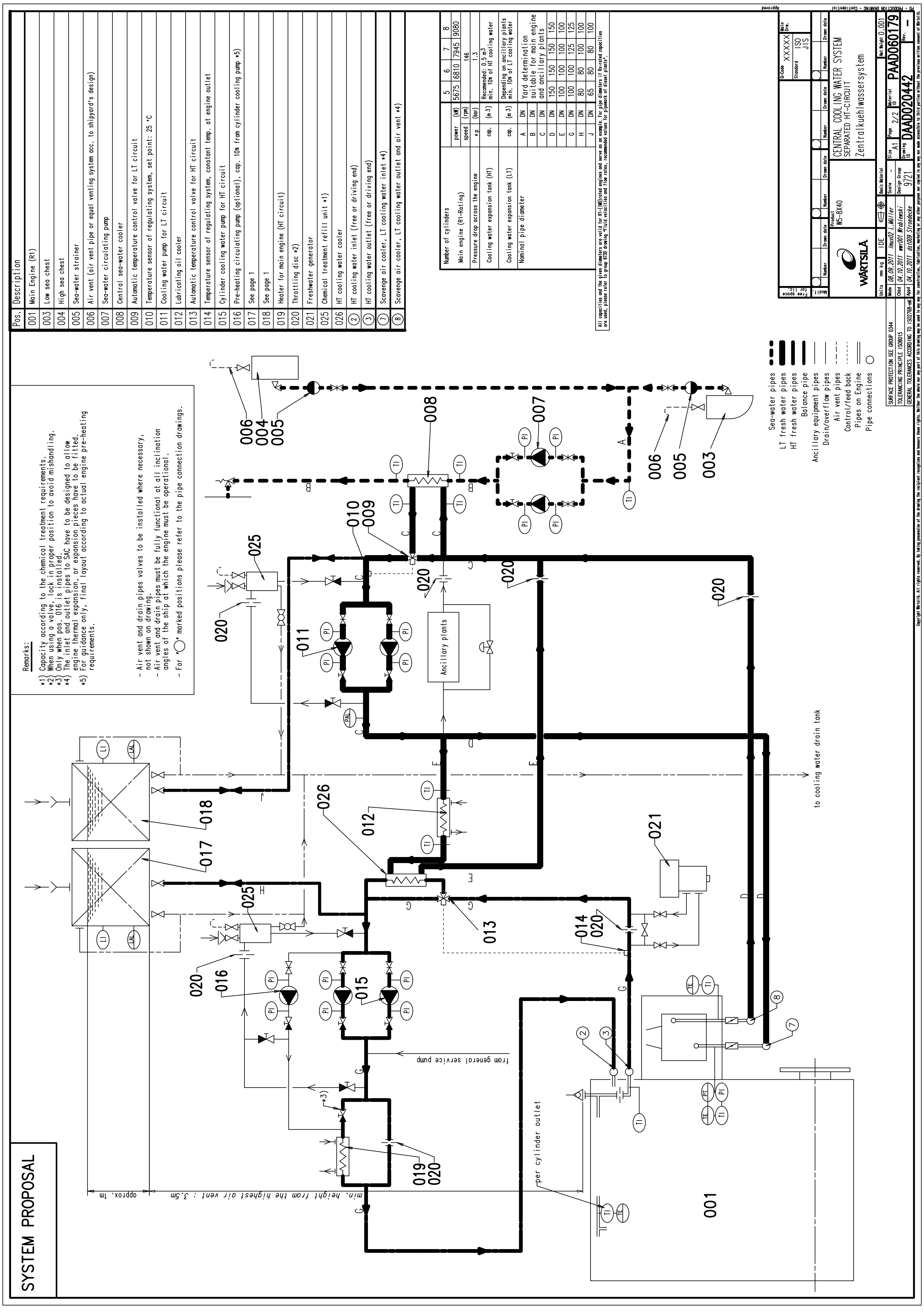
Product W5-8X40

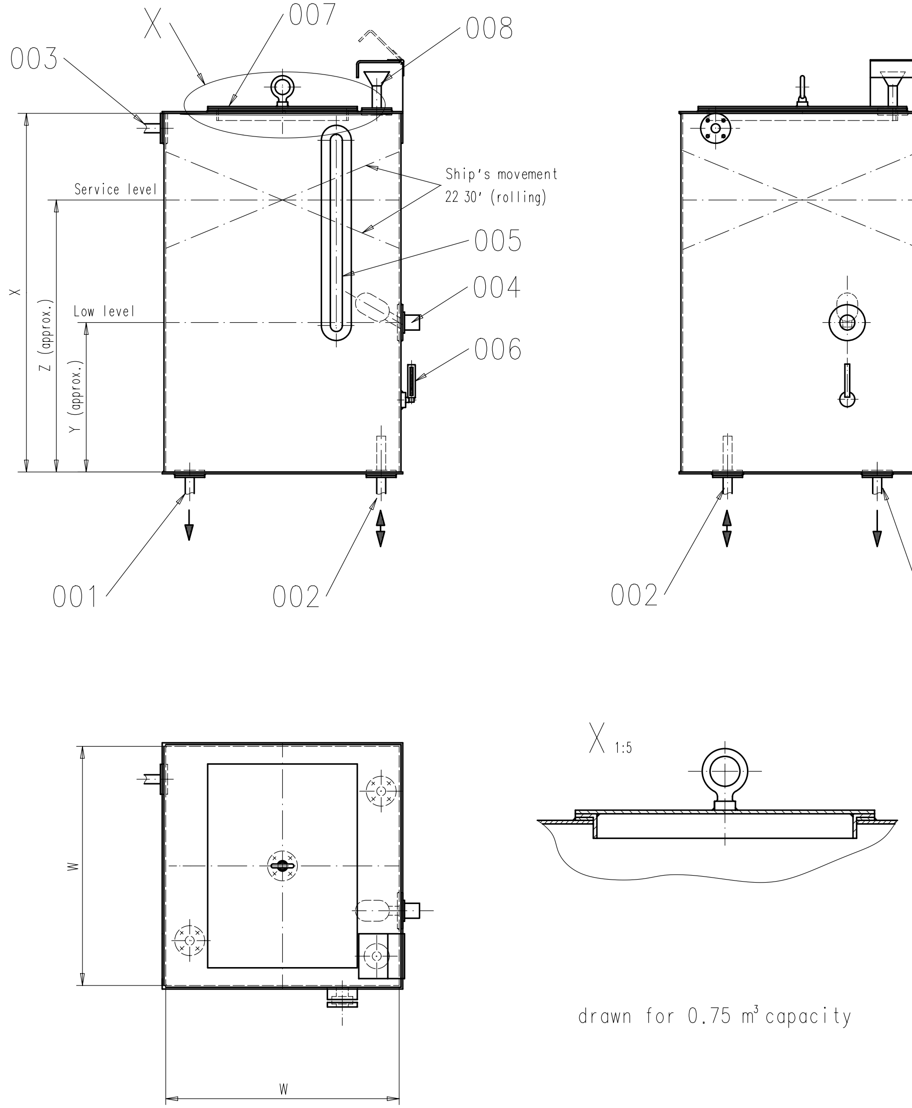
CENTRAL COOLING WATER SYSTEM
SEPARATED HT-CIRCUIT
Zentralkuehlwassersystem

SURFACE PROTECTION SEE GROUP 0344	Units mm kg	IDE
TOLERANCING PRINCIPLE ISO8015	Made	08.09.2011 lmux02 L.Müller
GENERAL TOLERANCES ACCORDING TO ISO2768-mK	Chkd	04.10.2011 wwr001 Wroblewski
	Appd	04.10.2011 dst009 Stroedecke

Basic Material | Net Weight 0.001
Scale - | Size A3 | Page 1/2 | Material ID PAAD060179
Design Group 9721 | Drawing ID DAAD020442 | Rev. -

PD - PRODUCTION DRAWING - Confidential


SYSTEM PROPOSAL
Remarks:
*1) Capacity according to the chemical treatment requirements.
*2) When using a valve, lock in proper position to avoid mishandling.
*3) Only when pos. 016 is installed.
*4) The inlet and outlet pipes to SAC have to be designed to allow engine thermal expansion, or expansion pieces have to be fitted.
*5) For guidance only, final layout according to actual engine pre-heating requirements.
- Air vent and drain pipes valves to be installed where necessary, not shown on drawing.
- Air vent and drain pipes must be fully functional at all inclination angles of the ship at which the engine must be operational.
- For "◯" marked positions please refer to the pipe connection drawings.
Pos. Description
001 Main Engine (R1)
003 Low sea chest
004 High sea chest
005 Sea-water strainer
006 Air vent (air vent pipe or equal venting system acc. to shipyard's design)
007 Sea-water circulating pump
008 Central sea-water cooler
009 Automatic temperature control valve for LT circuit
010 Temperature sensor of regulating system, set point: 25 °C
011 Cooling water pump for LT circuit
012 Lubricating oil cooler
013 Automatic temperature control valve for HT circuit
014 Temperature sensor of regulating system, constant temp. at engine outlet
015 Cylinder cooling water pump for HT circuit
016 Pre-heating circulating pump (optional), cap. 10% from cylinder cooling pump *5)
017 See page 1
018 See page 1
019 Heater for main engine (HT circuit)
020 Throttling disc *2)
021 Freshwater generator
025 Chemical treatment refill unit *1)
026 HT cooling water cooler
2 HT cooling water inlet (free or driving end)
3 HT cooling water outlet (free or driving end)
7 Scavenge air cooler, LT cooling water inlet *4)
8 Scavenge air cooler, LT cooling water outlet and air vent *4)
Number of cylinders 5 6 7 8
Main engine (R1-Rating) power (kW) 5675 6810 7945 9080
speed (rpm) 146
Pressure drop across the engine Δp (bar) 1.3
Cooling water expansion tank (HT) cap. (m3) Recomended: 0,5 m3 min. 10% of HT cooling water
Cooling water expansion tank (LT) cap. (m3) Depending on ancillary plants min. 10% of LT cooling water
Nominal pipe diameter A DN Yard determination suitable for main engine and ancillary plants
B DN
C DN
D DN 150 150 150 150
E DN 100 100 100 100
G DN 100 100 125 125
H DN 80 80 100 100
J DN 65 80 80 100
All capacities and the given diameters are valid for R1-rated engines and serve as an example. For pipe diameters if Rx-rated capacities are used, please refer to group 9730 drawing "Fluid velocities and flow rates, recommended values for pipework of diesel plants".
approx. 1m
min. height from the highest air vent : 3,5m
from general service pump
per cylinder outlet
Ancillary plants
to cooling water drain tank
Sea-water pipes
LT fresh water pipes
HT fresh water pipes
Balance pipe
Ancillary equipment pipes
Drain/overflow pipes
Air vent pipes
Control/feed back
Pipes on Engine
Pipe connections
WÄRTSILÄ
Product W5-8X40
CENTRAL COOLING WATER SYSTEM
SEPARATED HT-CIRCUIT
Zentralkuehlwassersystem
Q-Code XXXXX
Standard ISO JIS
Units mm kg IDE
Size A1 Page 2/2
Design Group 9721
Material ID PAAD060179
Drawing ID DAAD020442
Net Weight 0.001
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
Made 08.09.2011 lmux02 L.Müller
Chkd 04.10.2011 wwr001 Wroblewski
Appd 04.10.2011 ds1009 Stroedecke



Pos.	Description
001	Drain from HT circuit
002	Balance pipe from HT circuit
003	Overflow/air vent
004	Low level alarm
005	Level indicator *1)
006	Thermometer
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

- For reapacity and pipe diameters refer to drawing 'Central cooling water system' and 'Jacket cooling water system'

Table 1: Tank dimensions

HT 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

SURFACE PROTECTION SEE GROUP 0344
GENERAL TOLERANCES ACCORDING TO ISO/2768-m

Free space for lic.

First introduced at RT-flex82C

Modifications | Number | Drawn date | Number | Drawn date | Number | Drawn date

Q-Code X X X X X | Substitute for | Scale 1:10/1:5

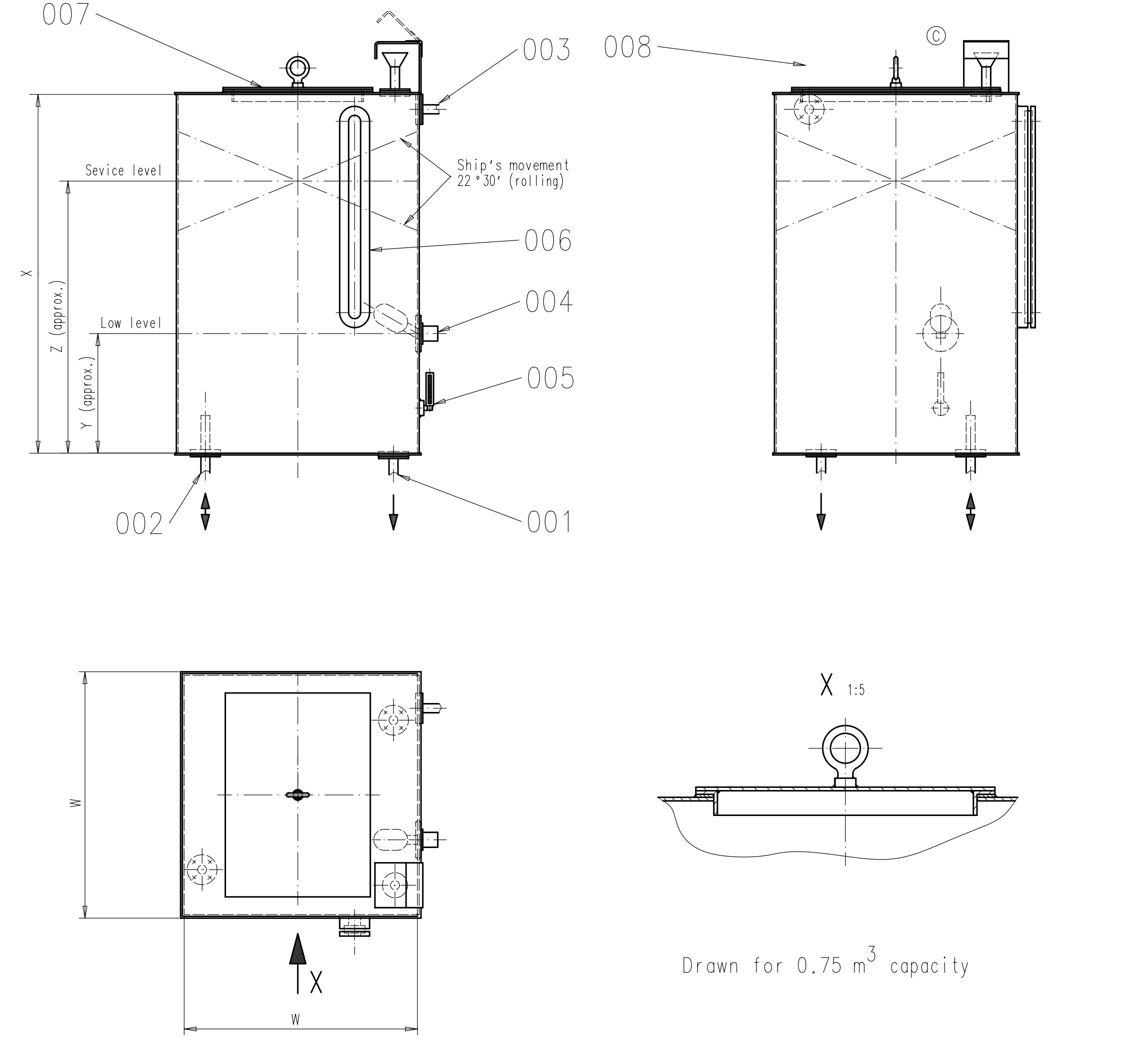
Drawn: M.PRSTEC 16.04.09

Ausgleichstank
Zentralkuehlwassersystem HT circuit
EXPANSION TANK
CENTRAL COOLING WATER HT CIRCUIT

Wärtsilä Switzerland Ltd
CAD

Design group 9721 | ISO JIS | 2- 107.413.097 | Page:

WÄRTSILÄ



Pos.	Description
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)
009	

Remarks:

*1) Level indicator can be omitted if an alternative is fitted.
*2) Other designs like hinged covers, etc. are also possible

- For required tank capacity and pipe diameters refer to drawing 'Central cooling water system'

Table 1: Tank dimensions

LT 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

Approved
Free space for lic.
Q-Code XXXXX Main Drw.
Standard ISO JIS

Modif.	Number	Drawn date		Number	Drawn date		Number	Drawn date		Number	Drawn date
A	7-14.356	11.06.1997	B	7-37.090	26.09.2005	C	EAA083145	14.09.2011			

WÄRTSILÄ
Product: RTMOT RT-flex
EXPANSION TANK
CENTRAL COOLING WATER LT CIRCUIT
Ausgleichstank
Zentralkuehlwassersystem LT

SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK

Units mm kg | IDE | Basic Material | Net Weight 0.001
Made 11.06.1997 T.LANDERT | Scale 1:10 | Size A2 | Page 1/1 | Material ID 107.245.419.500
Chkd | Design Group 9721 | Drawing ID 107.245.419 | Rev. C
Appd 16.06.1997 wdms2 Administrator

DID - DIMENSIONAL DRAWING - Confidential

9. Lubricating Oil Systems

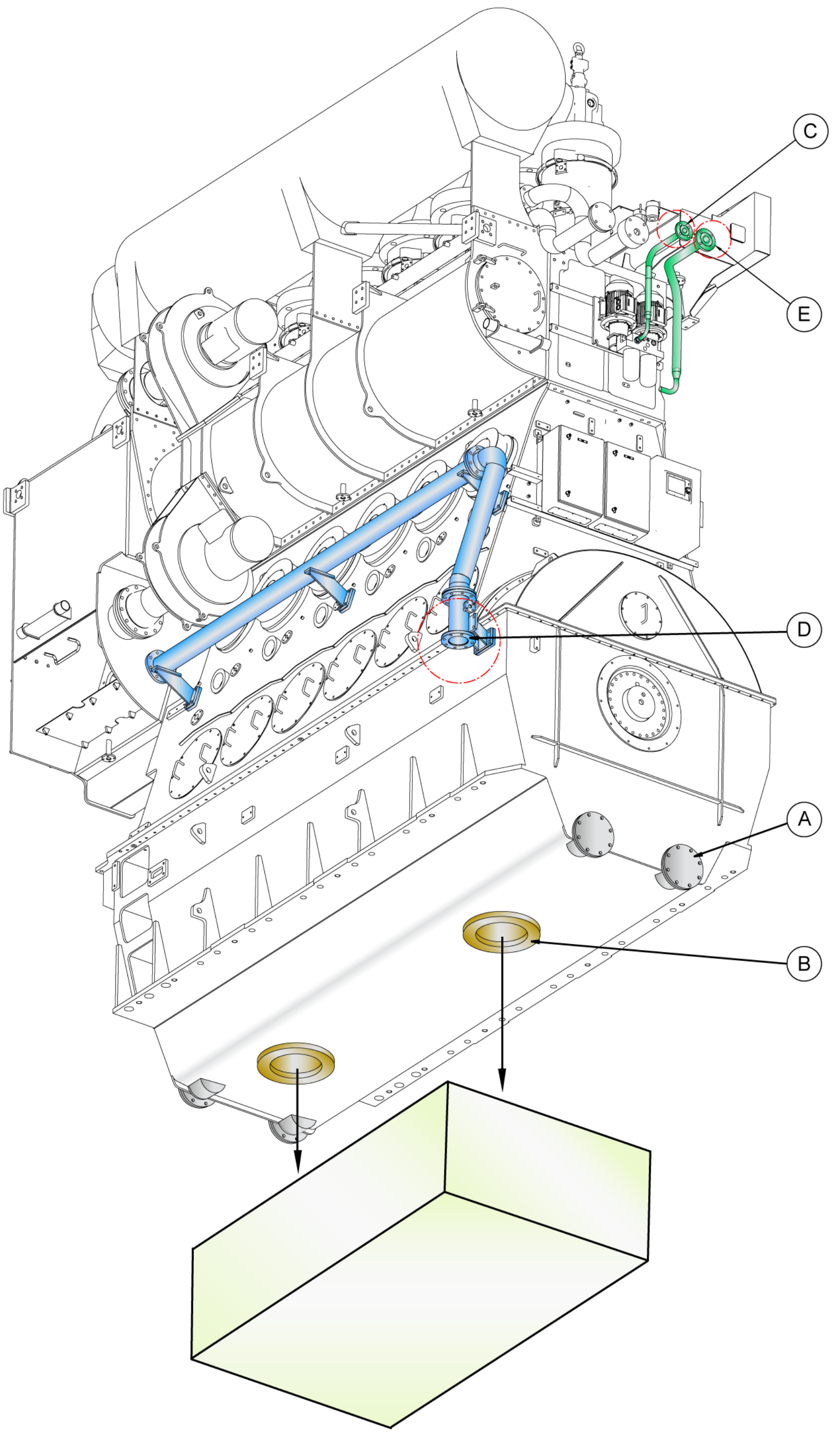


Figure 9.1: Pipe connections on the engine for the lubricating oil systems

A	Lubricating oil drain from bedplate horizontal (optional) • **FOR TESTBED ONLY! Not connected.**
B	Lubricating oil drain from bedplate vertical • Drain to lubricating oil drain tank: drain pipe positions to be clarified between shipyard and engine manufacturer
C	Cylinder lubricating oil outlet
D	Lubricating oil inlet
E	Cylinder lubricating oil inlet

9.1 Lubricating oil systems for turbochargers

For lubricating oil of turbochargers equipped with separate lub. oil systems, the recommendations given by the supplier must be observed.

9.2 Main lubricating oil system

⚠WARNING

For all relevant and prevailing information consult the drawings in section 'Drawings' at the end of this chapter.

Lubrication of the main bearings, thrust bearings, bottom-end bearings, crosshead bearings, together with piston cooling, is carried out by the main lubricating oil system. The main bearing oil is also used to cool the piston crown as well as to lubricate and cool the torsional damper and the axial damper (detuner).

The consumption of system oil is given in chapter *1.1 Primary engine data*.

9.3 Main lubricating oil system components

9.3.1 Lubricating oil pump

Positive displacement screw pumps with built-in overpressure relief valves, or centrifugal pumps (pump capacity see table *7.1 Data for central freshwater cooling system (integrated HT)*)

Positive displacement screw pump:	Refer to table *7.1*. The given flow rate is to be within a tolerance of 0 to +10% plus back-flushing flow of automatic filter, if any.
Centrifugal pump:	Refer to table *7.1*. The given flow rate is to be within a tolerance of -10 to +10% plus back-flushing flow of automatic filter, if any.
Delivery head:	(See also table *7.1*.) 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 of pump motor is 400 cSt

9.3.2 Lubricating oil cooler

Oil flow:	refer to table *7.1*
Type:	plate or tubular
Cooling medium:	freshwater or seawater
Heat dissipation:	refer to table *7.1*
Margin for fouling:	10-15% 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 press. oil side:	6 bar
Working press. water side:	approx. 3 bar
Cooling water flow:	refer to table *7.1*
Cooling water temperature:	freshwater 36°C

9.3.3 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
Test pressure:	specified by classification society
Working pressure:	6 bar
Working viscosity:	95 cSt, at working temperature
Oil flow:	refer to table *7.1*
Diff. pressure, clean filter:	max. 0.2 bar
Diff. pressure, dirty filter:	max. 0.6 bar
Diff. pressure, alarm:	max. 0.8 bar
Filter inserts bursting press.:	min. 8 bar (= differential pressure across the filter inserts)
Filter material:	stainless steel mesh
Mesh size:	sphere passing max. 0.034 mm

NOTICE

*** Alternatively:** 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-flush' the filter without interrupting the flow is to be taken into account when estimating the pump capacity.

9.4 Cylinder lubricating oil system

Cylinder lubrication is carried out by a separate system, working on the once-through principle normally using a high-alkaline oil of SAE 50 grade. The cylinder lubricating oil is fed to the surface of the cylinder liner by a hydraulically actuated dosage pump through quills in the cylinder liner. 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 and storage tank 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 the service tank to provide the necessary head. Furthermore, it has to be of similar design, ensuring a sloping tank floor. For cylinder lubricating oil consumption refer to section *1.1 Primary engine data*.

9.5 Lubricating oil maintenance and treatment

It is essential that the engine lubricating oil is kept as clean as possible. Water and solid contaminants held in suspension are to be removed using centrifugal separators which operate in bypass to the engine lubricating system. Great care has to be taken of the separators and filters to ensure that they work correctly. The separators are to be set up as purifiers and completely isolated from the fuel oil treatment systems; there must be no possibility of cross-contamination.

9.5.1 Lubricating oil separator

Separator type: .... self-cleaning purifier

Min. throughput capacity [l/h]: ... 0.140 x CMCR = [litres/hour], CMCR in kW
For example 8-cyl. engine with CMCR at R1: 9,080 kW:
0.140 x 9,080 = 1,271 l/h.

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; refer to manufacturer's instructions.

9.6 Lubricating oil requirements

The products listed in section *9.6.1* were selected in co-operation with the oil suppliers and in their respective product lines are considered as appropriate lubricants 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 use in Wärtsilä two-stroke diesel engines. Information concerning such brands may be obtained on request from Wärtsilä Switzerland Ltd.

For normal operating conditions, a high-alkaline marine cylinder oil of 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).

For the W-X40 engines designed with oil-cooled pistons, the crankcase oils typically used as system oil have the following properties (see also section *9.6.1*):

- Minimum BN of 5.0 mgKOH/g and detergent properties
- Load carrying performance in FZG gear machine test method A/8, 3/90 according to ISO 14635-1, failure load stage 11 as a minimum [1)]
- Good thermal stability
- Antifoam properties
- Good demulsifying performance

1) The FZG gear machines located at the FZG Institute, Munich/Germany shall be the reference test apparatus and will be used in the event of any uncertainty about test repeatability and reproducibility.

9.6.1 List of lubricating oils

Global brands of lubricating oils

Oil Supplier	System Oil	Cylinder Oil *a)	Cylinder Oil *b)
		Recommended for fuel with sulphur content > 1.5%	*Recommended for fuel with sulphur content < 1.5%*
BP	Energol OE-HT 30	Energol CLO 50M	Energol CL-DX 405 Energol CL 505 *c)
Castrol	CDX 30	Cyltech 80 AW Cyltech 70	Cyltech 40 SX Cyltech 50 S *c)
Chevron (FAMM, Texaco, Caltex)	Veritas 800 Marine 30	Taro Special HT 70	Taro Special HT LS 40
ExxonMobil	Mobilgard 300 Exxmar XA	Mobilgard 570 Exxmar X 70 Mobilgard XN5744E *d)	Mobilgard L 540
Total	Atlanta Marine D 3005	Talusia HR 70	Talusia LS 40
		Talusia Universal *e)	
Shell	Melina S30 Melina 30	Alexia 50	Alexia LS

Table 9.1: Global brands of lubricating oils

NOTICE

*a) With a sulphur content in the fuel between 1.5 and 2.0%, BN 40 can also be used.

*b) With a sulphur content in the fuel between 1.0 and 1.5%, BN 70 can be used only for a short period with low feed rate.

*c) This BN 50 cylinder lubricant can be used with up to 3.0% sulphur content in the fuel.

*d) This BN 60 cylinder oil is approved for a sulphur content in the fuel between 1.5 and 4.0%.

*e) This BN 57 cylinder lubricant can be used over the whole sulphur content range.

Local brands of lubricating oils

Oil Supplier	System Oil	Cylinder Oil *a)	Cylinder Oil *b)
		Recommended for fuel with sulphur content > 1.5%	*Recommended for fuel with sulphur content < 1.5%*
AGIP	Cladium 50	Punica 570	
Bardahl		Naval 50	
FL Selenia	MESYS 3006	MECO 5070	
LUKOIL	Navigo 6 SO	Navigo 70	MCL
SeaLub Alliance	GulfSea SuperBear 3008	GulfSea Cylcare DCA5070H	
IOC	Servo Marine 0530	Servo Marine 7050	
JX Nippon Oil & Energy Corporation (NOC)	Marine S30	Marine C705	
Pertamina	Medripal 307	Medripal 570	
Petrobras	Marbrax CAD-308	Marbrax CID-57	Marbrax CID-54-AP Marbrax CID-55 *c)
PetroChina	KunLun DCC3008	KunLun DCA 5070H	
SK	Supermar AS	Supermar Cyl 70 plus	
*1 Limited to bore size of 62 cm			

Table 9.2: Local brands of lubricating oils

NOTICE

The application 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.

9.7 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. There is to maintain adequate drainage under sea conditions resulting in pitching and rolling. Section *9.7.2* gives the minimum angles of inclination at which the engine is to remain fully operational.

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

The classification societies require that all drain pipes from the crankcase to the drain tank are taken as low as possible below the free surface of the oil to prevent aeration and foaming; they have to remain below the oil surface at all times. Strict attention has to be paid to this specification. The amount of lubricating oil required for an initial charge of the drain tank is indicated in fig. *9.5*. The total tank size is normally 5-10% greater than the amount of lubricating oil required for an initial filling (see fig. *9.5*).

9.7.1 Arrangement of vertical lubricating oil drains

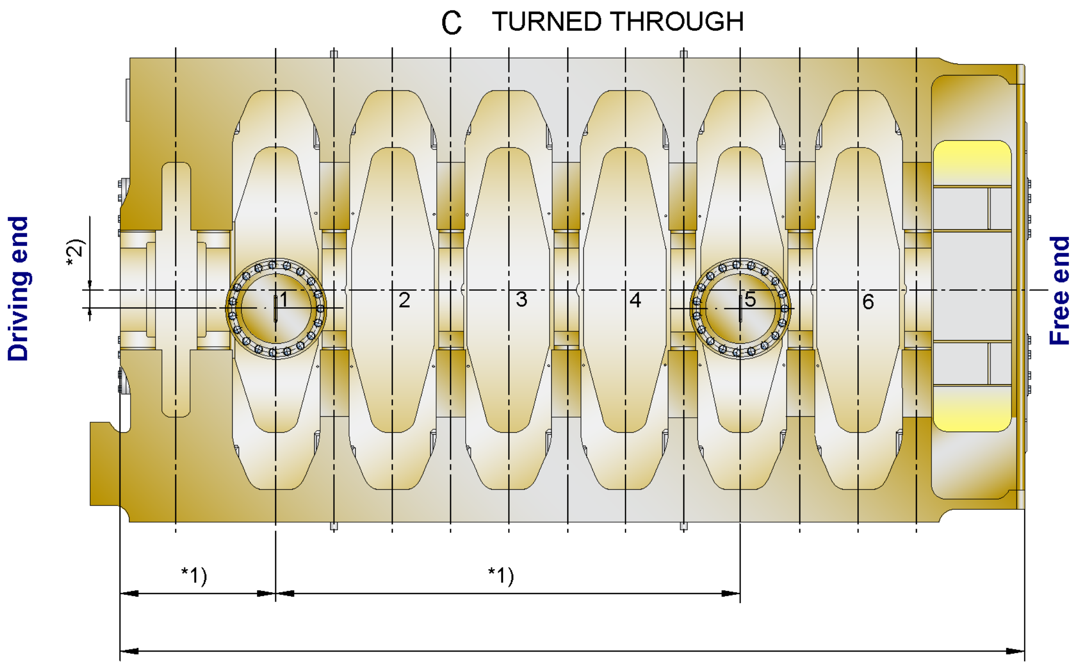


Figure 9.2: Arrangement of vertical lubricating oil drains for the 6 cylinders

NOTICE

*1) Proposal to determine final position in accordance with shipyard.

*2) Alternatively the oil drains may also be arranged symmetrically on port/fuel pump side.

⚠ WARNING

The illustration above does not necessarily represent the actual configuration or the stage of development, nor the type of your engine. For all relevant and prevailing information consult the drawings a the end of this chapter.

9.7.2 Min. inclination angles at which the engine is to remain fully operational

	Classification societies					
	American Bureau of Shipping	**Bureau Veritas**	**China Classification Society**	**Croatian Register of Shipping**	**Det Norske Veritas**	**Germanischer Lloyd**
	2007	**2006**	**2002**	**-**	**2005**	**2006**
Main and aux. engine						
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	15°	15°	15°		15°	15°
Rolling to each side	±22.5°	±22.5°	±22.5°		±22.5°	±22.5°
Trim by the head *)	5°	5°	5°		5°	5°
Trim by the stern *)	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°

Table 9.3: Minimum inclination angles at which the engine is to remain fully operational (1)

	Classification societies					
	Korean Register of Shipping	**Lloyd's Register of Shipping**	**Nippon Kaiji Koykai**	**Polski Rejestr Statkow**	**Registro Italiano Navale**	**Russian Maritime Register of Shipping**
	2007	**2006**	**2005**	**2004**	**2007**	**2003**
Main and aux. engine						
Abbreviation		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 *)	5°	5°	5°	5°	5°	5°
Trim by the stern *)	5°	5°	5°	5°	5°	5°
Pitching	±7.5°	±7.5°	±7.5°	±7.5°	±7.5°	±7.5°

	Classification societies					
	Korean Register of Shipping	Lloyd's Register of Shipping	Nippon Kaiji Koykai	Polski Rejestr Statkow	Registro Italiano Navale	Russian Maritime Register of Shipping
	2007	2006	2005	2004	2007	2003
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°

Table 9.4: Minimum inclination angles at which the engine is to remain fully operational (2)

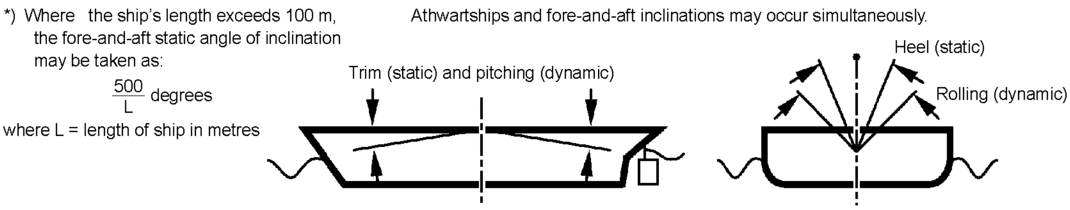


Figure 9.3: Minimum inclination angles at which the engine is to remain fully operational

Vertical lubricating oil drains to drain tank	
No Cyl.	**Necessary drains**
5	2
6	2
7	2
8	2
The arrangement of lubricating oil drains is to comply with the relevant classification society rules.	

Table 9.5: Vertical lubricating oil drains to drain tank

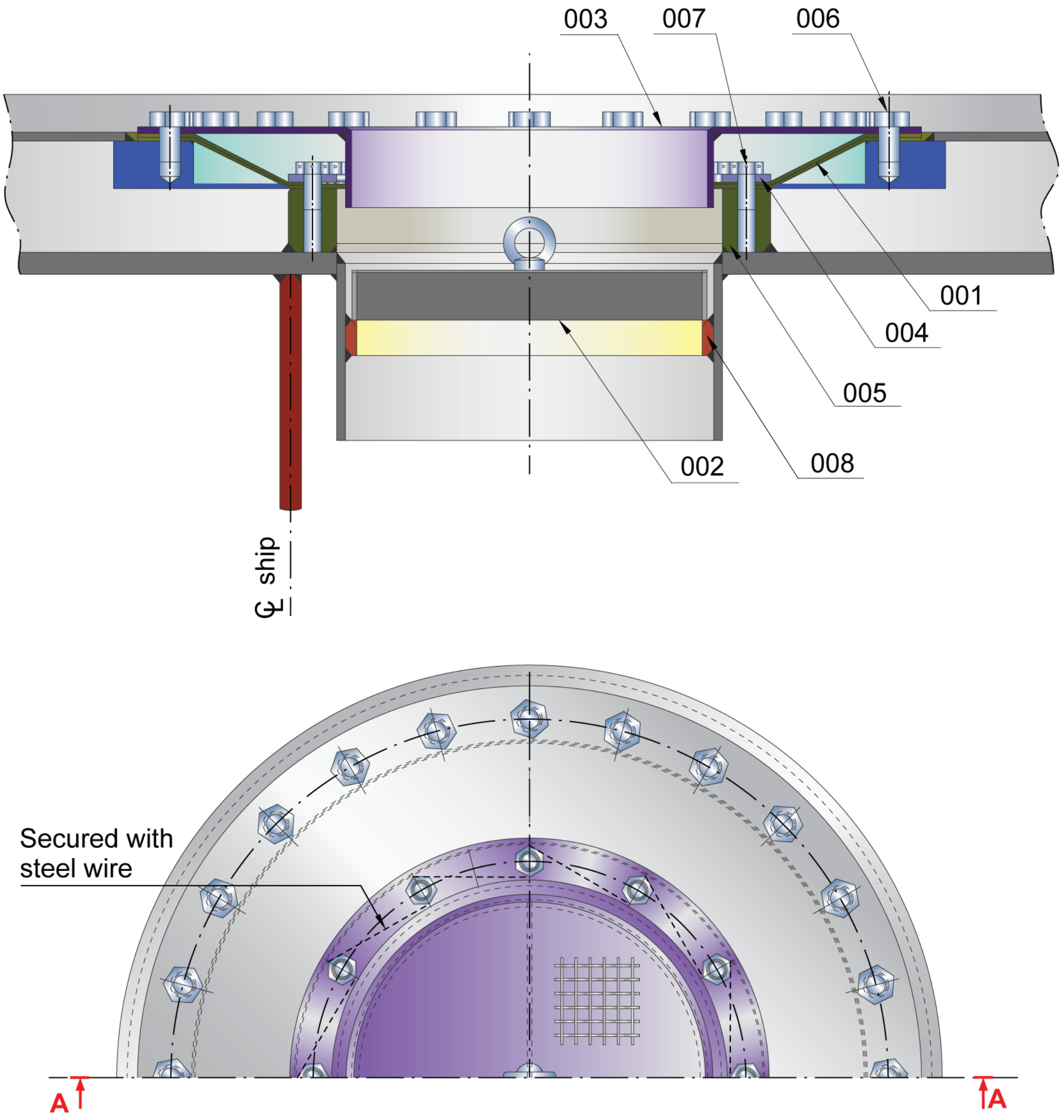


Figure 9.4: Example of an accepted vertical drain connection

001	Rubber gasket	005	Welding flange
002	Oil strainer	006	Hexagon head screw
003	Cover	007	Hexagon head screw
004	Ring	008	Support ring

⚠ WARNING

For all relevant and prevailing information consult the drawings in section 'Drawings' at the end of this chapter.

9.7.3 Dimensioning guide-lines and filling process

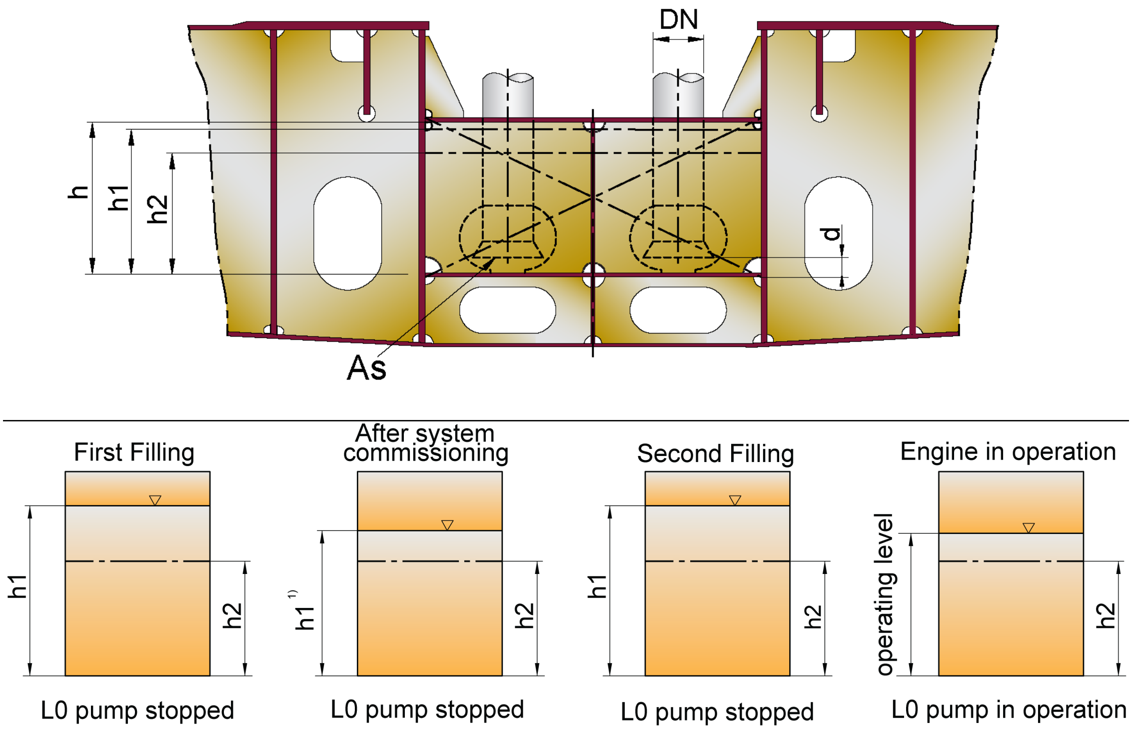


Figure 9.5: Filling process of lubricating oil tank

⚠WARNING

For all relevant and prevailing information consult the drawings in section 'Drawings' at the end of this chapter.

NOTICE

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 part of the oil quantity which drains back when the pumps are stopped.

9.8 Drawings

REMARKS:
Drawings for engine execution
with vertical drains

Net Weight: 0.001

Quantity PER ENGINE	SEQ NO	Material ID	Material Name	Dimension/Occ.Dimension	Standard or Drawing	Basic Material Material Standard	Weight GR./NET
1	004	PAAD060502	LUBRICATING OIL DRAIN TANK		DAAD020532		0.001
1	003	107.341.455.500	INSTRUCTION FOR FLUSHING		107.341.455		0.001
1	002	PAAD060891	LUBRICATING OIL DRAIN TANK		DAAD020633		0.001
1	001	PAAD060601	LUBRICATING OIL SYSTEM		DAAD020556		0.001

Material ID: PAAD060911

Free space for lic.

Q-Code XXXXX
Standard ISO JIS
Main Drw. H
Approved

Modif.	Number	Drawn date	Number	Drawn date	Number	Drawn date	Number	Drawn date

WÄRTSILÄ

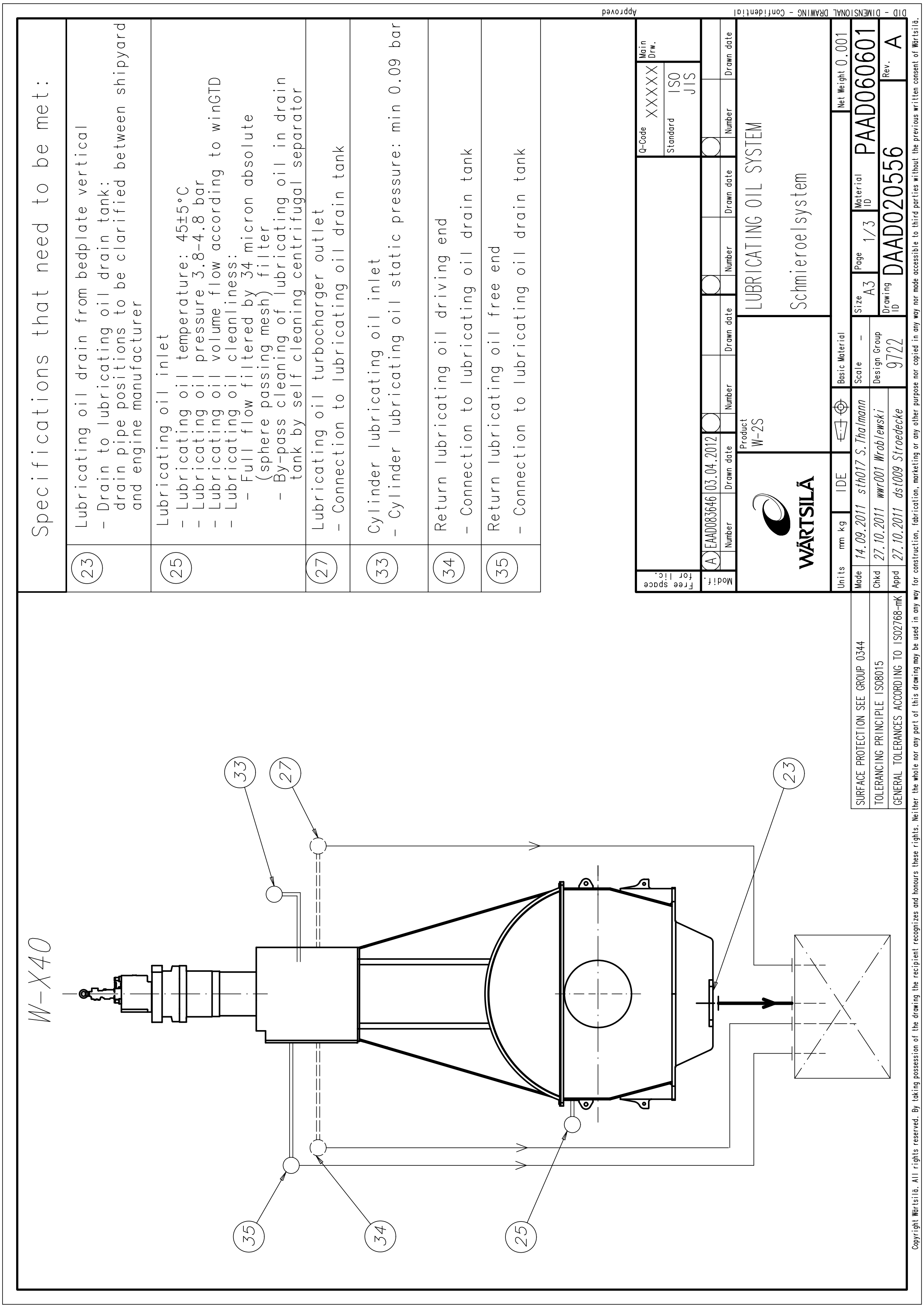
Product: W6X40

LUBRICATING OIL SYSTEM
WITH VERTICAL DRAINS
Schmieroelsystem

Units mm kg	IDE	Basic Material	Net Weight
Made	16.09.2011 sth017 S.Thalmann	Scale –	Size A3 / Page 1/1 / Material ID
Chkd	27.10.2011 wwr001 Wroblewski	Design Group 9722	Drawing ID DAAD020638 / Rev. –
Appd	27.10.2011 dst009 Stroedecke		

SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK

DID - DIMENSIONAL DRAWING - Confidential


Specifications that need to be met:
23 Lubricating oil drain from bedplate vertical
- Drain to lubricating oil drain tank:
drain pipe positions to be clarified between shipyard
and engine manufacturer
25 Lubricating oil inlet
- Lubricating oil temperature: 45±5°C
- Lubricating oil pressure 3.8-4.8 bar
- Lubricating oil volume flow according to winGTD
- Lubricating oil cleanliness:
- Full flow filtered by 34 micron absolute
(sphere passing mesh) filter
- By-pass cleaning of lubricating oil in drain
tank by self cleaning centrifugal separator
27 Lubricating oil turbocharger outlet
- Connection to lubricating oil drain tank
33 Cylinder lubricating oil inlet
- Cylinder lubricating oil static pressure: min 0.09 bar
34 Return lubricating oil driving end
- Connection to lubricating oil drain tank
35 Return lubricating oil free end
- Connection to lubricating oil drain tank
W-X40
23
25
27
33
34
35
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
Units mm kg IDE
Made 14.09.2011 sth017 S.Thalmann
Chkd 27.10.2011 wwr001 Wroblewski
Appd 27.10.2011 ds1009 Stroedecke
A EAAD083646 03.04.2012
WÄRTSILÄ
Product W-2S
LUBRICATING OIL SYSTEM
Schmieroelsystem
Basic Material
Scale -
Design Group 9722
Size A3
Page 1/3
Drawing ID DAAD020556
Material ID PAAD060601
Net Weight 0.001
Rev. A
Q-Code XXXXX
Standard ISO JIS
Main Drw.
DID - DIMENSIONAL DRAWING - Confidential
Approved
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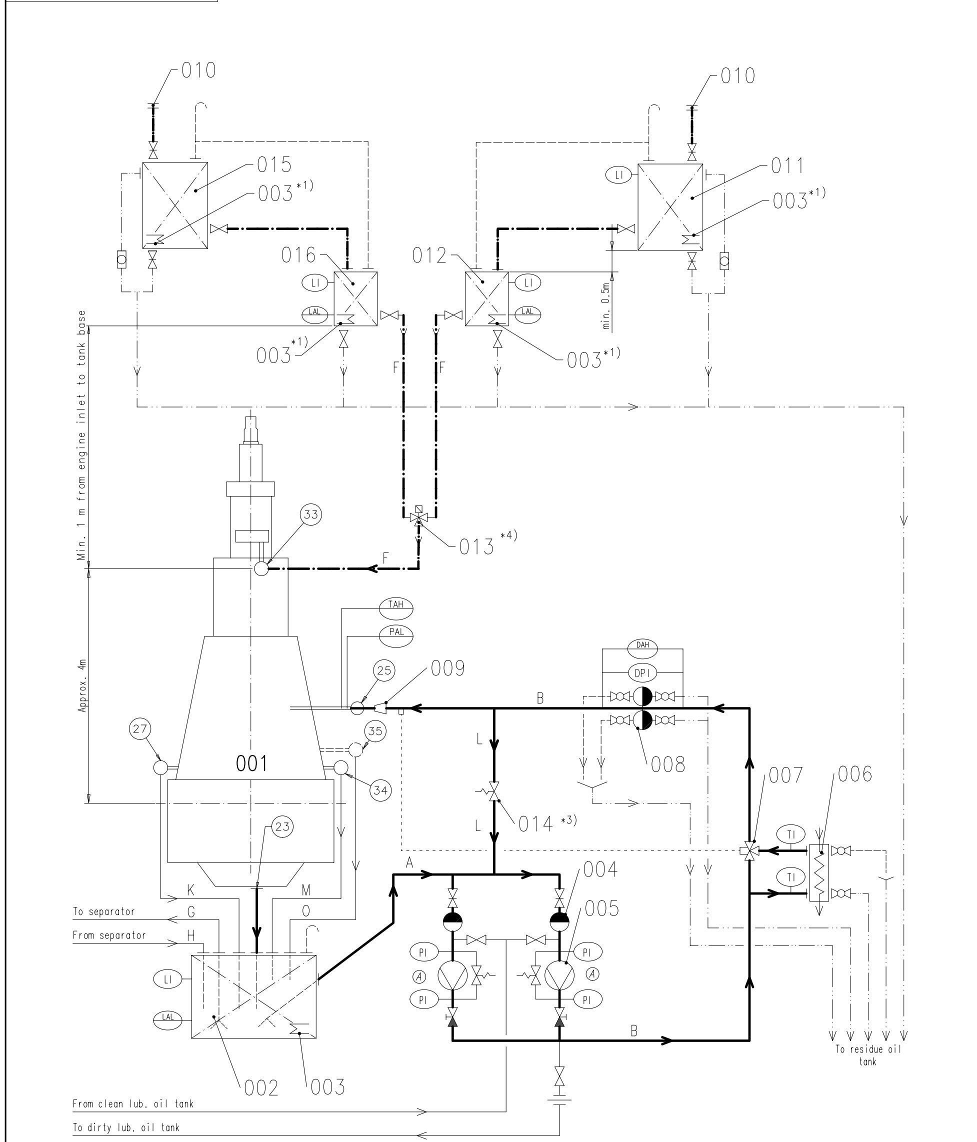
SYSTEM PROPOSAL



Number of cylinders			5	6	7	8
Main engine (R1-Rating)	power	(kW)	5675	6810	7945	9080
	speed	(rpm)	146			
Lub. oil drain tank		(m³)	For capacities refer to drawing 'Lub. oil drain tank'			
Main lub. oil pump	capacity	(m³/h)	see winGTD			
Cylinder lub. oil storage tank	capacity	(m³)	Based on a guide feed rate of 0.6g/kWh			
Cylinder lub. oil service tank	capacity	(m³)	0.5	0.5	0.6	0.6
Crosshead lub. oil pump	capacity	(m³/h)	see winGTD			
Nominal pipe diameter	A	DN	200	200	200	250
	B	DN	150	200	200	200
	F	DN	40	40	40	40
	G		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 recommendations			
	H					
	K	DN	65	65	65	65
	L	DN	50	50	65	65
	M	DN	65	65	65	65
	O	DN	65	65	65	65

Pos.	Description
001	Main engine (R1-Rating)
002	Lubricating oil drain tank
003	Heating coil
004	Suction filter
005	Lubricating oil pump
006	Lubricating oil cooler
007	Autom. temperature control valve, constant temp. at engine inlet: 45 °C
008	Lubricating oil filter
009	Reduction piece
010	Deck connection
011	Low BN cylinder lubricating oil storage tank *2)
012	Low BN cylinder lubricating oil service tank
013	Three-way valve, manually or remotely operated
014	Pressure control valve
015	High BN cylinder lubricating oil storage tank *2)
016	High BN cylinder lubricating oil service tank
(23)	Lubricating oil drain from bedplate vertical
(25)	Lubricating oil inlet
(27)	Lubricating oil turbocharger outlet
(33)	Cylinder lubricating oil inlet
(34)	OReturn lubricating oil driving end
(35)	Return lubricating oil free end

Remarks:

- All tank an pump capacities as well as the pipe diameters are dimensioned for R1 rated engines including the integrated turbo charger lubrication, but excluding any possibly installed damper and PTO gears. In case of damper and/or PTO gear installation or separated turbo charger lubrication, the capacities need to be adapted accordingly. For selecting the appropriate pipe diameters, please refer to drawing 'fluid velocities and flow rates: recommended values for pipework of diesel plants'.

*1) Optional heating coil

*2) Alternatively, the cylinder lub. 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 flowmeter.

(A) *3) The by-pass line with the pressure control valve can be omitted if one of the following conditions is fulfilled:
- The main lubricating oil pumps have built-in pressure control and safety valves.
- The pump capacity is adjusted according to the lubricating oil pressure at the engine inlet, e.g. by frequency controlled pump speed adjustment.

(A) *4) The three-way valve has to be fitted as close as possible to the engine inlet. The reason is that the oil volume after the change-over valve has to be kept small in order to allow a swift change-over between the different BN cylinder oils.

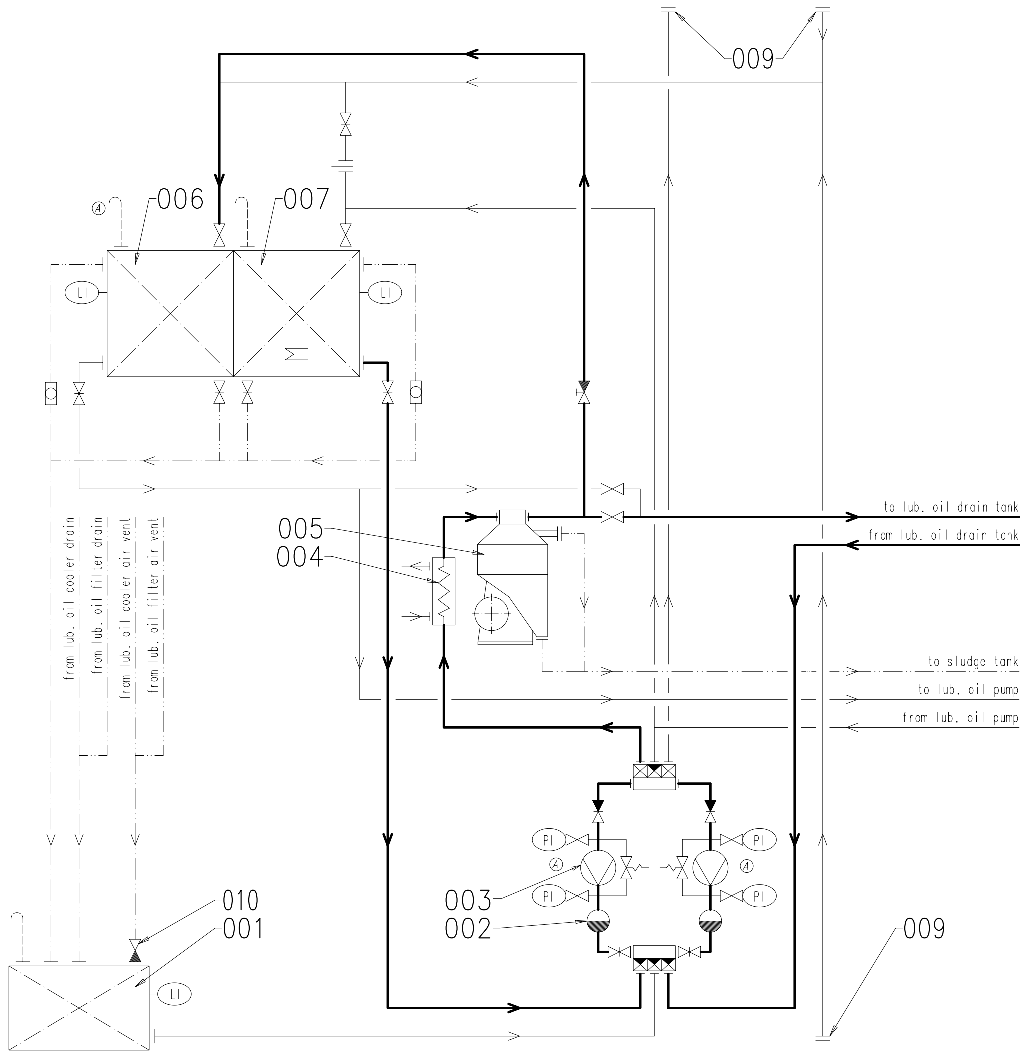
- Air vent pipes and drain valves where necessary
- Air vent and drain pipes must be fully functional at all inclinations of the ship at which the engine must be operational.
- For "◯" marked positions please refer to the pipe connection drawings.

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

Q-Code	XXXXX
Standard	ISO JIS
Modif.	(A) EAA0083646 03.04.2012
Product	W-25
Title	LUBRICATING OIL SYSTEM / Schmieroelsystem
Units	mm kg IDE
Net Weight	0,001
Made	14.09.2011 sth017 S.Thalmann
Chkd	27.10.2011 wwr001 Wroblewski
Appd	27.10.2011 ds1009 Stroedecke
Scale	–
Design Group	9722
Size	A1
Page	2/3
Material ID	PAAD060601
Drawing ID	DAAD020556
Rev.	A

SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK

SYSTEM PROPOSAL



Pos.	Description	
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 cenntrifugal separator	
006	Clean lubricating oil tank	
007	Dirty lubricating oil tank	
009	Deck connection	
010	Float non return valve	

Number of cylinders			5	6	7	8
Main engine (R1)	power	(kW)	5675	6810	7945	9080
	speed	(rpm)	146			
Dirty lubricating oil tank *1)	capacity	(m^3)	8.2	9.8	11.5	13
Clean lubricating oil tank *1)	capacity	(m^3)	8.2	9.8	11.5	13
Residue oil tank	capacity	(m^3)	Depending on ship's requirements			

Remark:

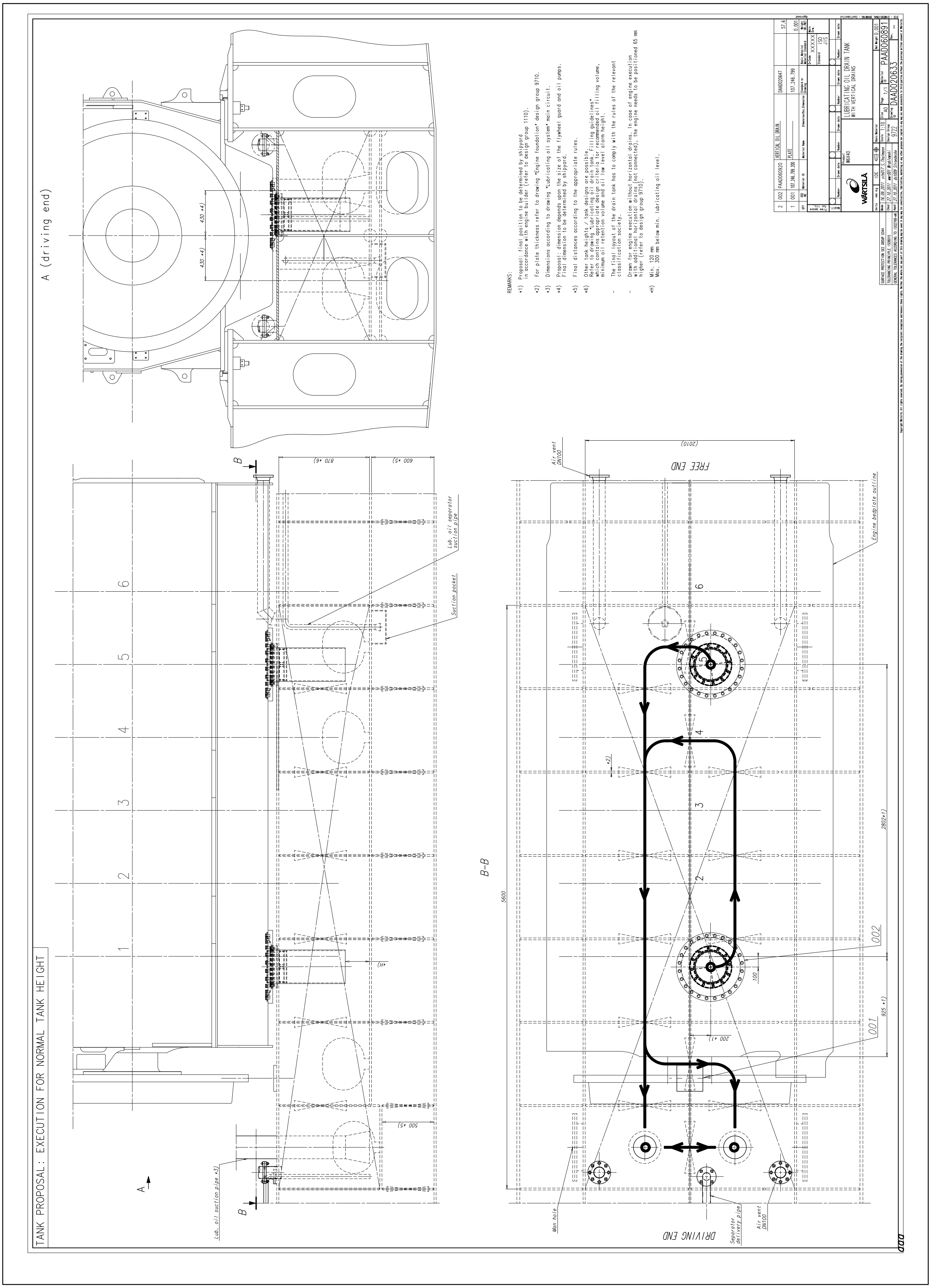
*1) The capacity can be proportionally reduced to actual CMCR

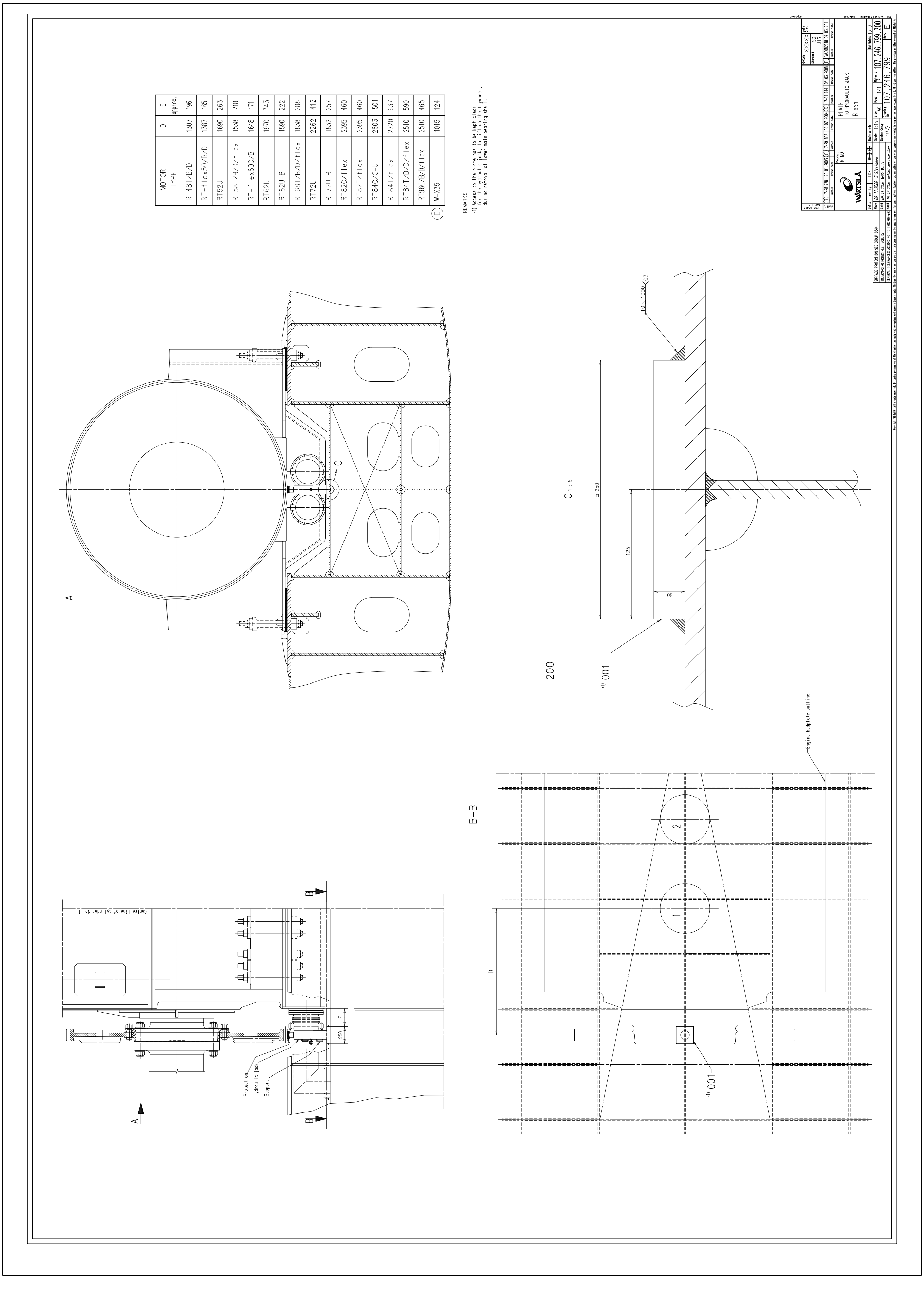
- Air vent pipes and drain valves where necessary.
- Air vent and drain pipes must be fully functional at all inclination angles of the ship at which the engine must be operational.
- Pipe diameters to be desinged according to shipyards practice component manufactures recommendations.

Main separating piping
Transfer/dirty lub. oil pipes
Drain & overflow pipes
Air vent pipes

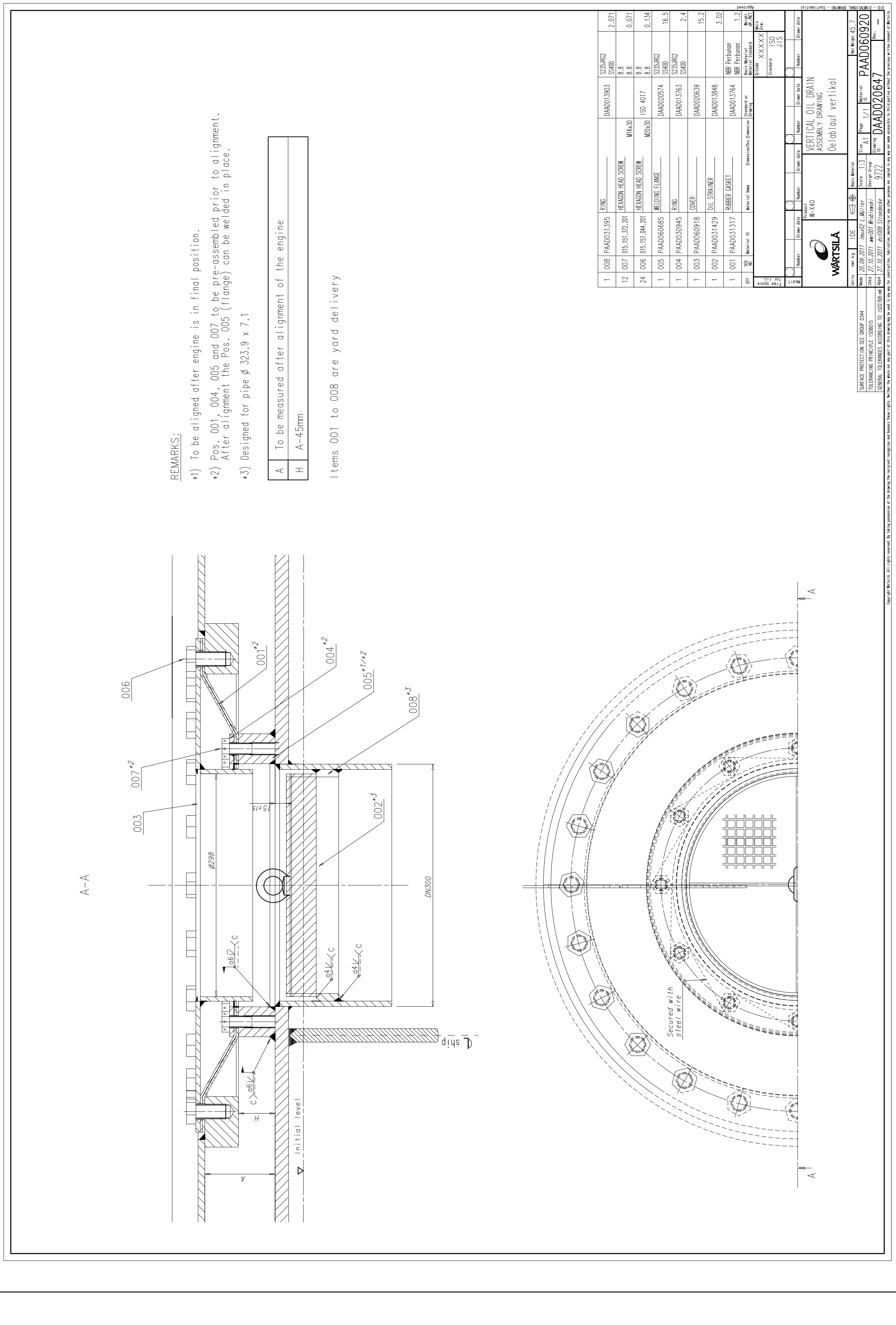
Q-Code	XXXXX
Standard	ISO JIS
Modif.	A EAA083646 03.04.2012
Product	W-2S
Title	LUBRICATING OIL SYSTEM / Schmieroelsystem
Units	mm kg
Made	14.09.2011 sth017 S.Thalmann
Chkd	27.10.2011 wwr001 Wroblewski
Appd	27.10.2011 ds1009 Stroedecke
Scale	-
Design Group	9722
Size	A1
Page	3/3
Material ID	PAAD060601
Drawing ID	DAAD020556
Rev.	A
Net Weight	0.001

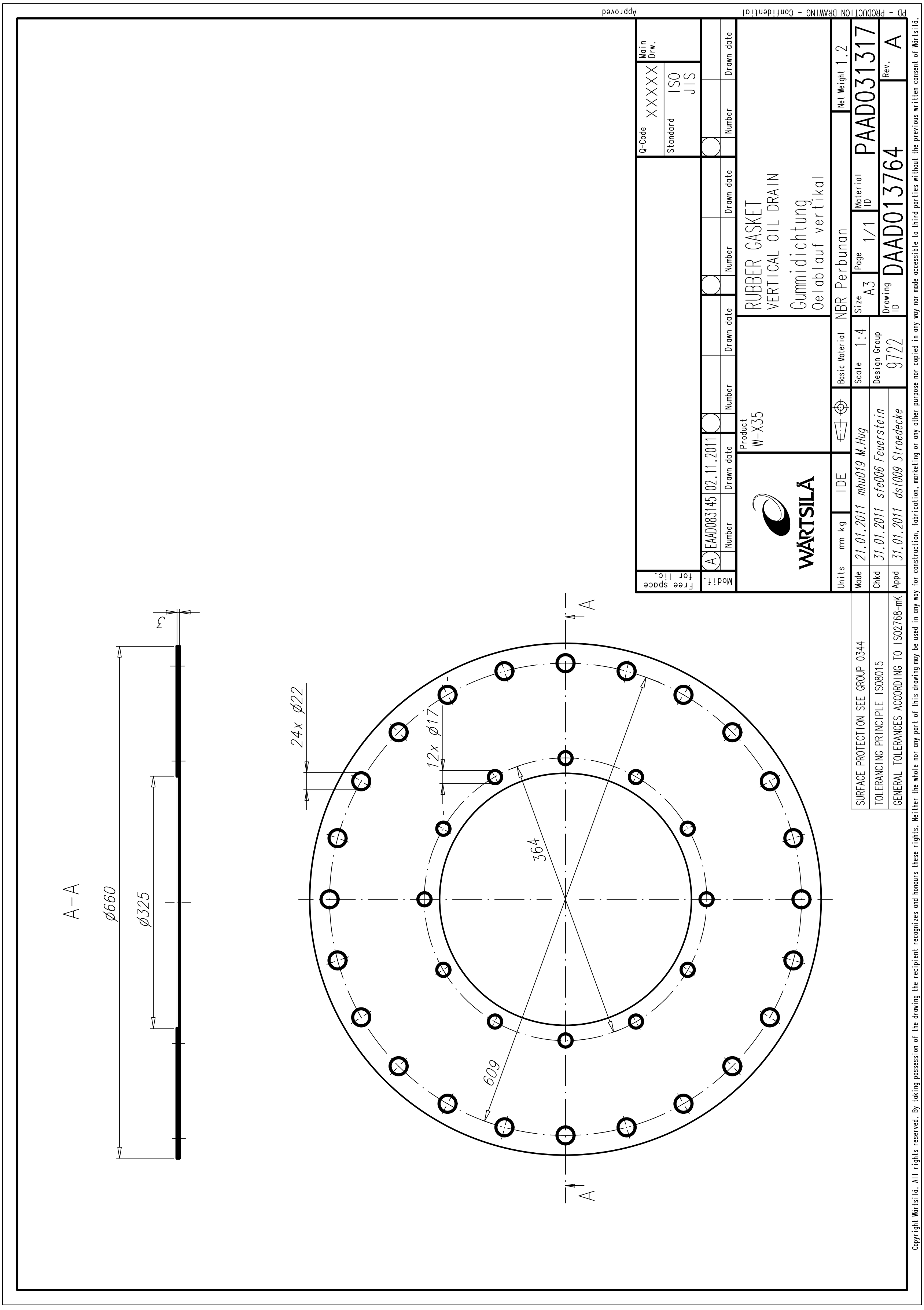
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK


TANK PROPOSAL: EXECUTION FOR NORMAL TANK HEIGHT
A (driving end)
B-B
FREE END
DRIVING END
Engine bedplate outline
Suction pocket
Lub. oil separator suction pipe
Lub. oil suction pipe
Man hole
Separator delivery pipe
Air vent DN100
LUBRICATING OIL DRAIN TANK WITH VERTICAL DRAINS



MOTOR TYPE	D	E approx.
RT48T/B/D	1307	196
RT-flex50/B/D	1387	165
RT52U	1690	263
RT58T/B/D/flex	1538	218
RT-flex60C/B	1648	171
RT62U	1970	343
RT62U-B	1590	222
RT68T/B/D/flex	1838	288
RT72U	2262	412
RT72U-B	1832	257
RT82C/flex	2395	460
RT82T/flex	2395	460
RT84C/C-U	2603	501
RT84T/flex	2720	637
RT84T/B/D/flex	2510	590
RT96C/B/D/flex	2510	465
(E) W-X35	1015	124


A-A
003
007*2
006
001*2
004*2
005*1/*2
008*3
002*3
Ø298
15±15
DN300
Initial level
ship
Secured with steel wire
REMARKS:
*1) To be aligned after engine is in final position.
*2) Pos. 001, 004, 005 and 007 to be pre-assembled prior to alignment. After alignment the Pos. 005 (flange) can be welded in place.
*3) Designed for pipe Ø 323.9 x 7.1
A To be measured after alignment of the engine
H A-45mm
Items 001 to 008 are yard delivery
1 008 PAAD031395 RING DAAD013903 S235JRG2 SS400 2.071
12 007 015.151.372.201 HEXAGON HEAD SCREW M16x30 8.8 8.8 0.071
24 006 015.151.044.201 HEXAGON HEAD SCREW M20x30 ISO 4017 8.8 8.8 0.134
1 005 PAAD060685 WELDING FLANGE DAAD020574 S235JRG2 SS400 16.5
1 004 PAAD030945 RING DAAD013763 S235JRG2 SS400 2.4
1 003 PAAD060918 COVER DAAD020639 15.2
1 002 PAAD031429 OIL STRAINER DAAD013848 3.02
1 001 PAAD031317 RUBBER GASKET DAAD013764 NBR Perbunan NBR Perbunan 1.2
WÄRTSILÄ
Product W-X40
VERTICAL OIL DRAIN
ASSEMBLY DRAWING
Oelablauf vertikal
Net Weight 45.7
Scale 1:3
Size A1
Page 1/1
Material ID PAAD060920
Drawing ID DAAD020647
Design Group 9722
20.09.2011 lmux02 L.Müller
27.10.2011 wwr001 Wroblewski
27.10.2011 ds1009 Stroedecke
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK


A-A
ø660
ø325
3
24x ø22
12x ø17
364
609
A
A
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
Units mm kg
IDE
Made 21.01.2011 mhu019 M.Hug
Chkd 31.01.2011 sfe006 Feuerstein
Appd 31.01.2011 dst009 Stroedecke
WÄRTSILÄ
Product W-X35
Basic Material NBR Perbunan
Scale 1:4
Size A3
Page 1/1
Design Group 9722
Drawing ID DAAD013764
Material ID PAAD031317
Rev. A
Net Weight 1.2
RUBBER GASKET
VERTICAL OIL DRAIN
Gummidichtung
Oelablauf vertikal
Modif.
A EAAD083145 02.11.2011
Number
Drawn date
Free space for lic.
Q-Code XXXXX
Standard ISO JIS
Main Drw.
Approved
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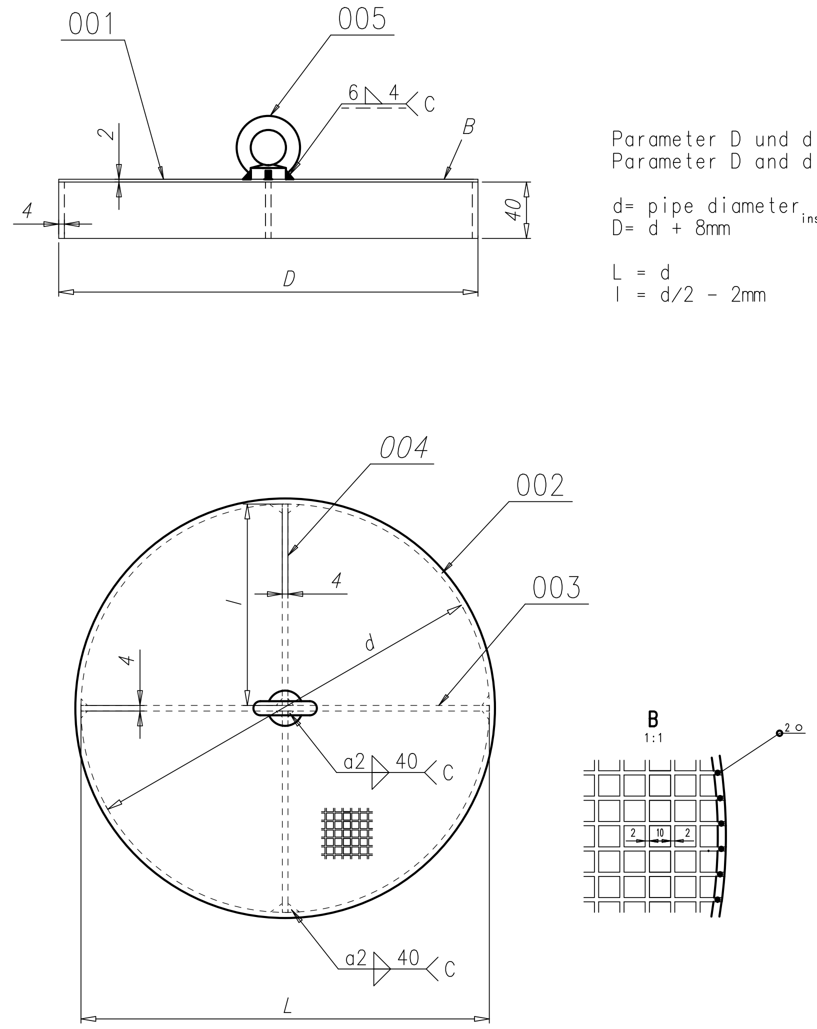

Parameter D und d abhängig vom inneren Rohr Durchmesser (DN300) im Schmieroel Ablauftank
Parameter D and d relateded to inner pipe diameter (DN300) inside of drain tank

d= pipe $diameter_{inside}$ - 20mmm
D= d + 8mm

L = d
l = d/2 - 2mm

QTY	SEQ NO	Material ID	Material Name	Dimension/Occ.Dimension	Standard or Drawing	Basic Material Material Standard	Weight GR./NET
1	005	015.201.531.730	EYE NUT	M10	DIN 582	C15	0.09
2	004	PAAD031427	FLAT BAR	40x4xl	DAAD013848	S235JRG2	0.17
1	003	PAAD031426	FLAT BAR	40x4xL	DAAD013848	S235JRG2	0.36
1	002	PAAD031396	RING		DAAD013964	S235JRG2	1.15
1	001	PAAD031425	PERFORATED SHEET	2xD	DAAD013848	S235JRG2	1.08

Approved

Free space for lic.	Q-Code XXXXX	Main Drw.
	Standard ISO	

Modif.	Number	Drawn date	Number	Drawn date	Number	Drawn date	Number	Drawn date

WÄRTSILÄ

Product W-X35

OIL STRAINER
VERTICAL OIL DRAIN
Oelsieb
Oelablauf vertikal

SURFACE PROTECTION SEE GROUP 0344	Units mm kg	IDE	Basic Material / Net Weight 3.02
TOLERANCING PRINCIPLE ISO8015	Made 27.01.2011 mhu019 M.Hug	Scale 1:3	Size A3 / Page 1/1 / Material ID PAAD031429
GENERAL TOLERANCES ACCORDING TO ISO2768-mK	Chkd 31.01.2011 sfe006 Feuerstein	Design Group 9722	Drawing ID DAAD013848 / Rev. –
	Appd 31.01.2011 dst009 Stroedecke		

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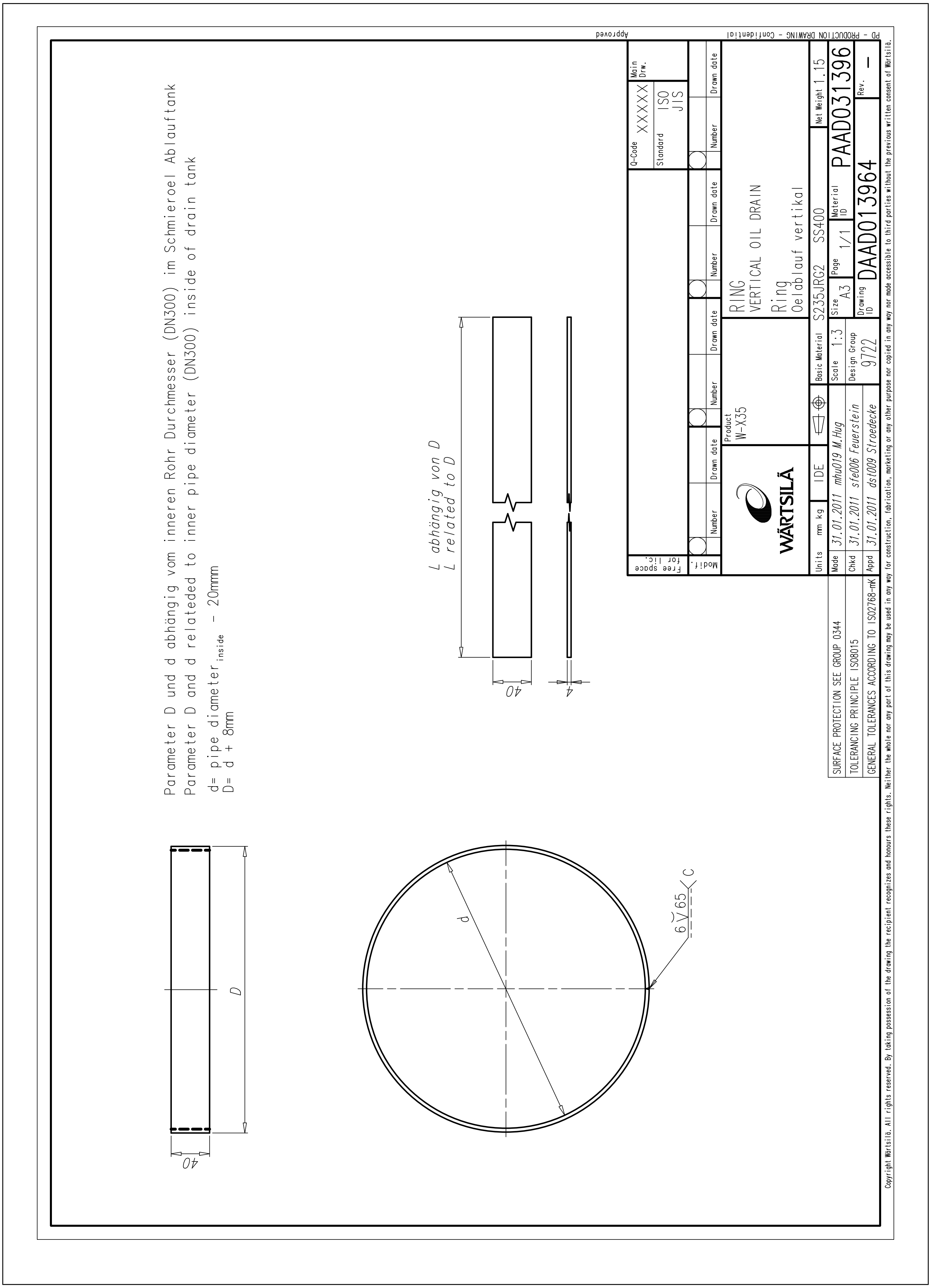
Parameter D und d abhängig vom inneren Rohr Durchmesser (DN300) im Schmieroel Ablauftank
Parameter D and d relateded to inner pipe diameter (DN300) inside of drain tank
d= pipe diameter inside - 20mmm
D= d + 8mm
L abhängig von D
L related to D
40
4
D
d
40
6 V 65 C
Approved
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Free space for lic.
Modif.
Number
Drawn date
Q-Code XXXXX
Standard ISO JIS
Main Drw.
Product W-X35
RING
VERTICAL OIL DRAIN
Ring
Oelablauf vertikal
Units mm kg
IDE
Basic Material S235JRG2 SS400
Net Weight 1.15
Scale 1:3
Size A3
Page 1/1
Material ID PAAD031396
Design Group 9722
Drawing ID DAAD013964
Rev. -
Made 31.01.2011 mhu019 M.Hug
Chkd 31.01.2011 sfe006 Feuerstein
Appd 31.01.2011 ds1009 Stroedecke
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
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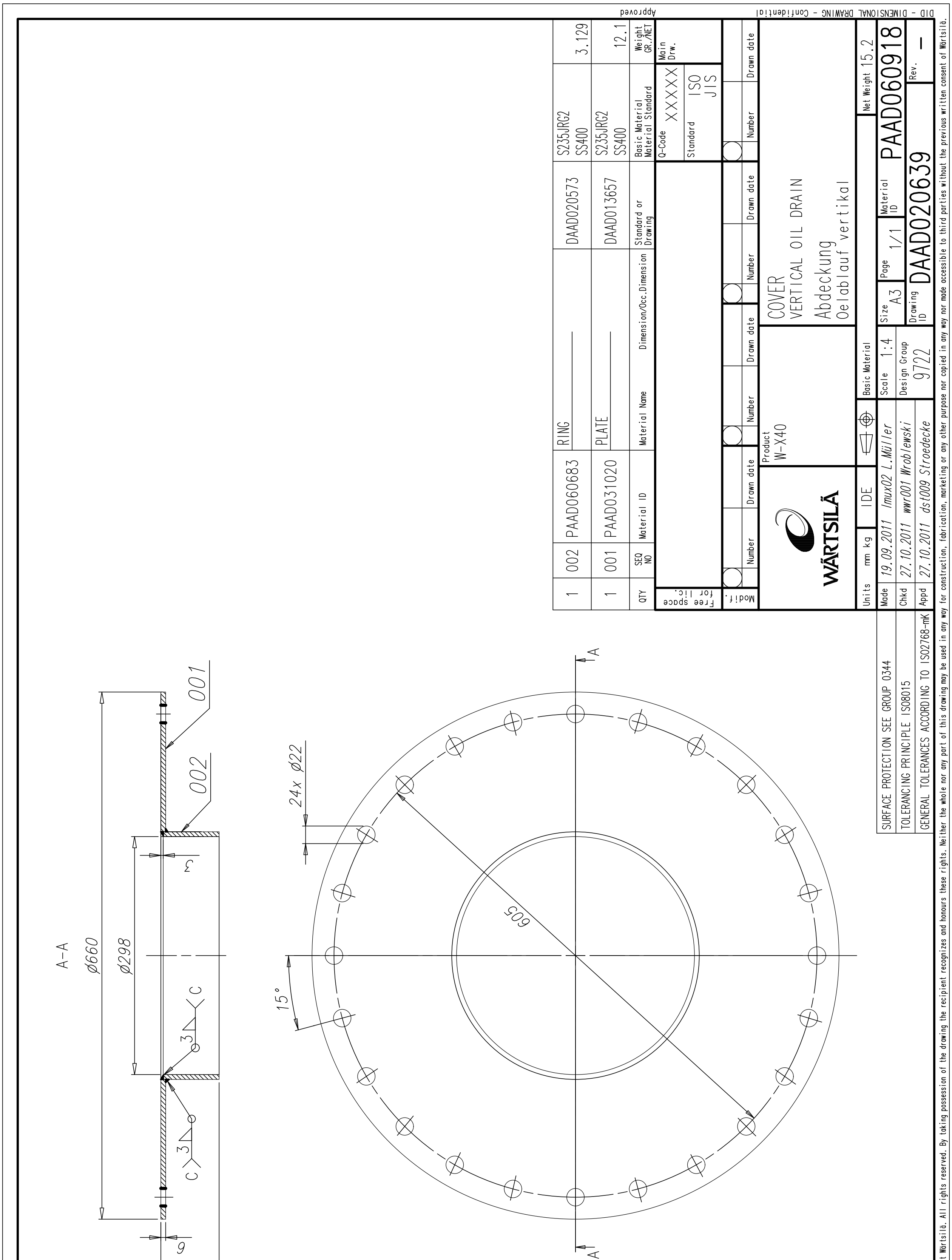

A-A
Ø660
Ø298
24x Ø22
605
15°
73
6
5
001
002
1 | 002 | PAAD060683 | RING | DAAD020573 | S235JRG2 SS400 | 3.129
1 | 001 | PAAD031020 | PLATE | DAAD013657 | S235JRG2 SS400 | 12.1
QTY | SEQ NO | Material ID | Material Name | Dimension/Occ.Dimension | Standard or Drawing | Basic Material Material Standard | Weight GR./NET
Q-Code XXXXX
Standard ISO JIS
Product W-X40
COVER
VERTICAL OIL DRAIN
Abdeckung
Oelablauf vertikal
Units mm kg
Made 19.09.2011 lmux02 L.Müller
Chkd 27.10.2011 wwr001 Wroblewski
Appd 27.10.2011 ds1009 Stroedecke
Scale 1:4
Size A3
Page 1/1
Design Group 9722
Drawing ID DAAD020639
Material ID PAAD060918
Net Weight 15.2
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
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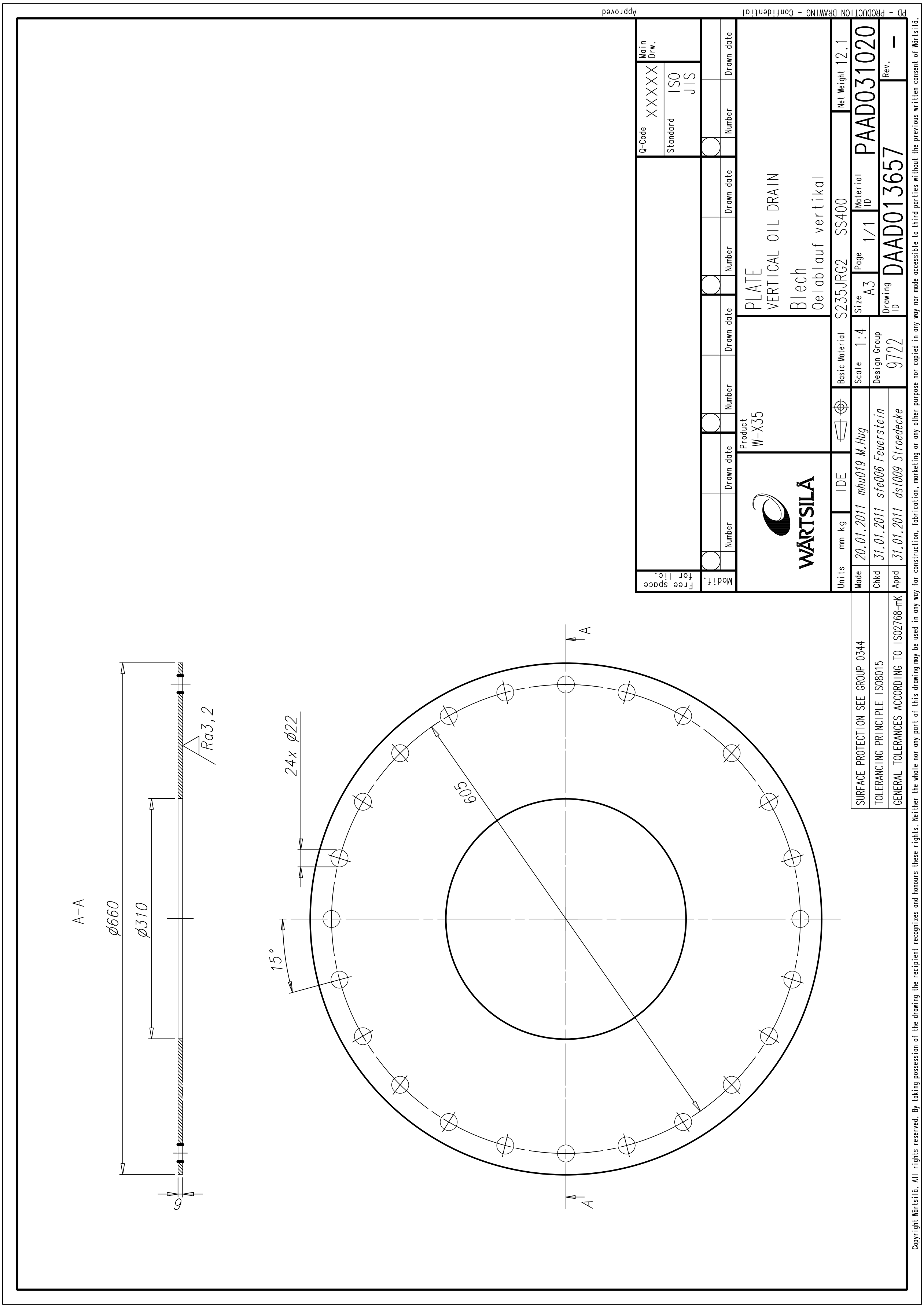
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Approved
Q-Code XXXXX
Main Drw.
Standard ISO JIS
Free space for lic.
Modif.
Number
Drawn date
Product W-X35
PLATE
VERTICAL OIL DRAIN
Blech
Oelablauf vertikal
WÄRTSILÄ
Units mm kg
IDE
Basic Material S235JRG2 SS400
Net Weight 12.1
Scale 1:4
Size A3
Page 1/1
Material ID PAAD031020
Made 20.01.2011 mhu019 M.Hug
Chkd 31.01.2011 sfe006 Feuerstein
Appd 31.01.2011 ds1009 Stroedecke
Design Group 9722
Drawing ID DAAD013657
Rev. –
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
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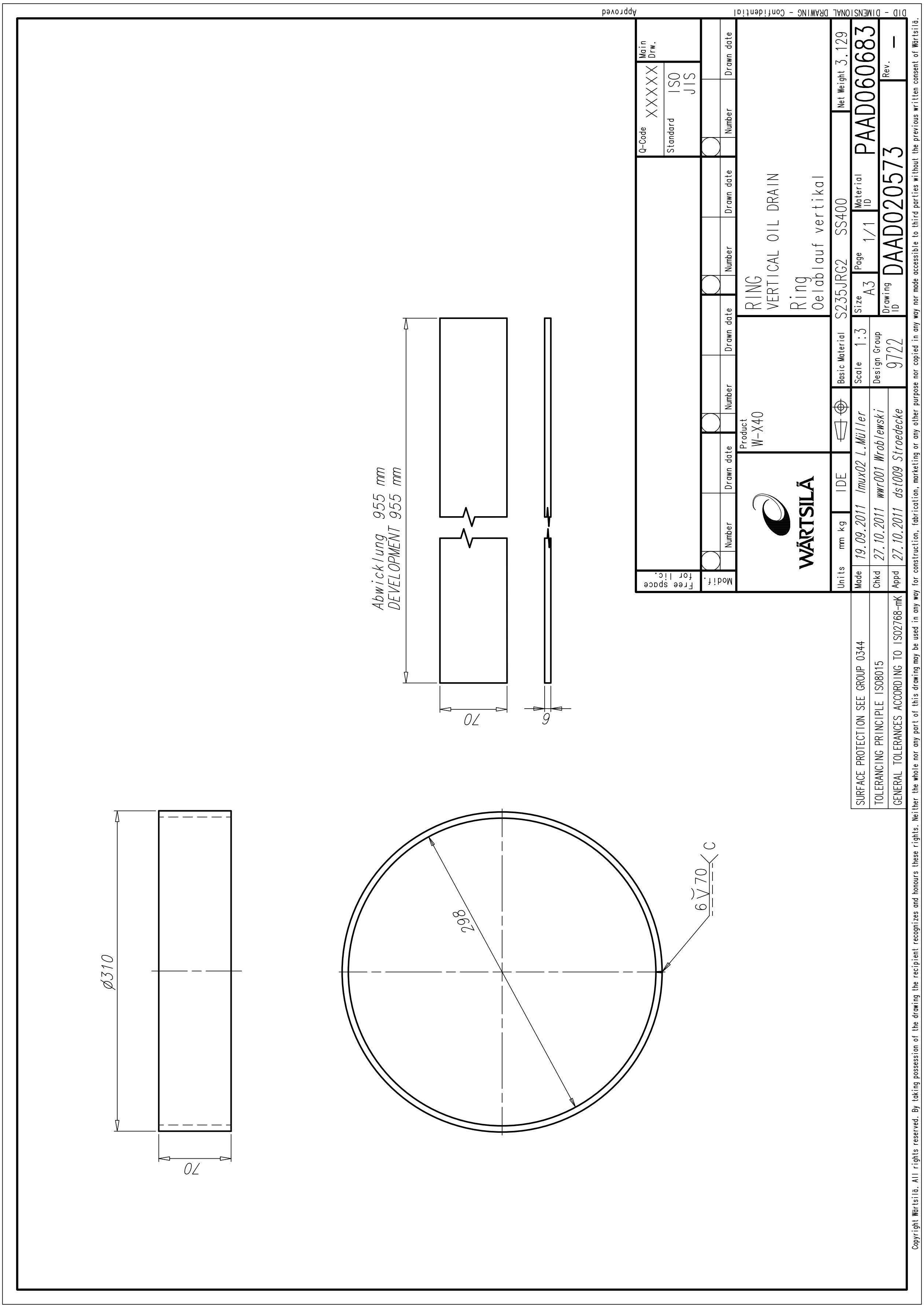
A-A
Ø660
Ø310
Ra3,2
9
24x Ø22
605
15°
A


DID - DIMENSIONAL DRAWING - Confidential
Approved
Q-Code XXXXX
Main Drw.
Standard ISO JIS
Free space for lic.
Modif.
Number
Drawn date
Product W-X40
WÄRTSILÄ
RING
VERTICAL OIL DRAIN
Ring
Oelablauf vertikal
Units mm kg
IDE
Basic Material S235JRG2 SS400
Net Weight 3.129
Made 19.09.2011 lmux02 L.Müller
Scale 1:3
Size A3
Page 1/1
Material ID PAAD060683
Chkd 27.10.2011 wwr001 Wroblewski
Design Group 9722
Drawing ID DAAD020573
Rev. –
Appd 27.10.2011 ds1009 Stroedecke
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
Abwicklung 955 mm
DEVELOPMENT 955 mm
70
6
298
6 70 C
Ø310
70
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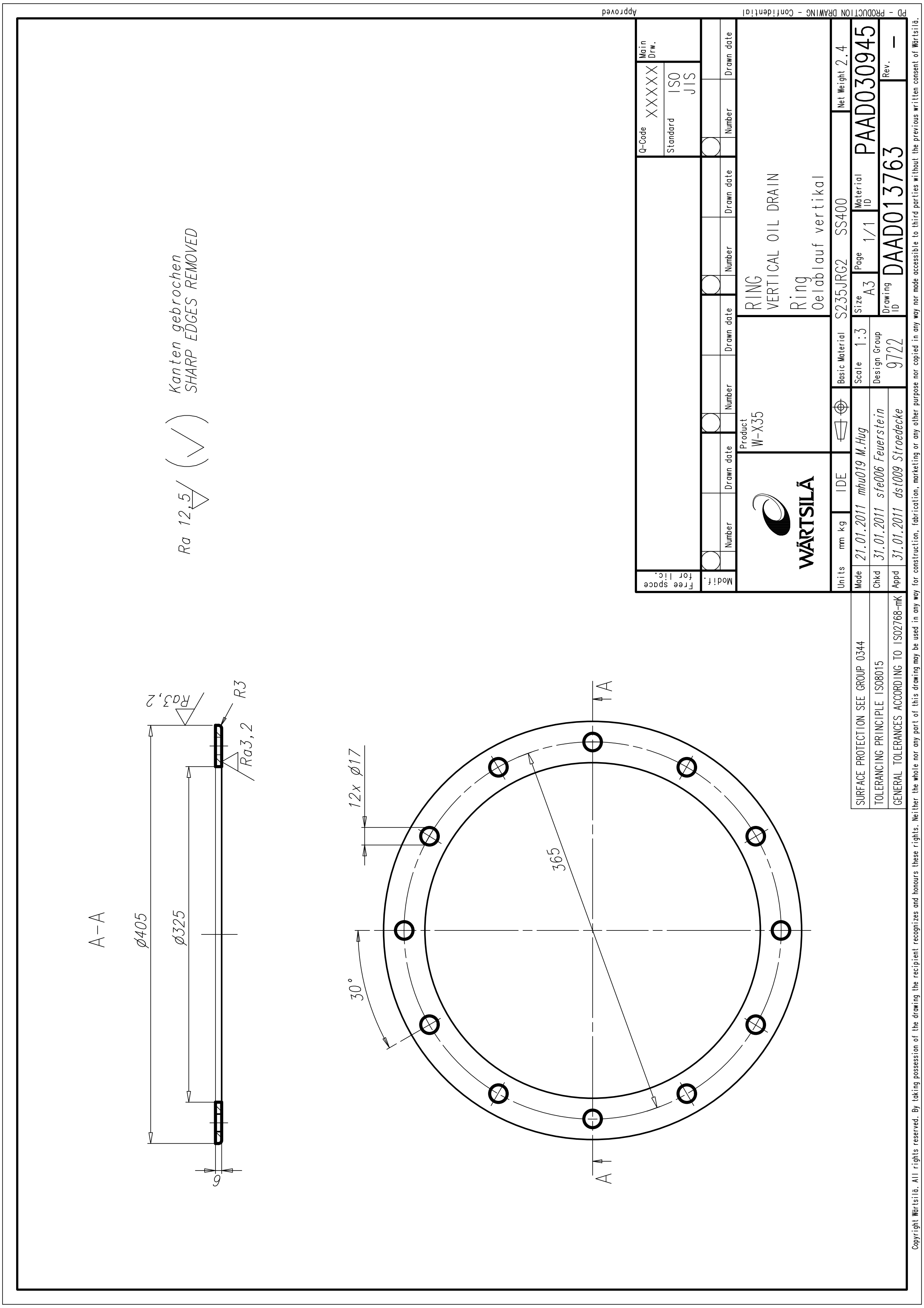
Ra 12.5
Kanten gebrochen
SHARP EDGES REMOVED
A-A
Ø405
Ø325
Ra3,2
R3
6
12x Ø17
365
30°
A
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
Product
W-X35
RING
VERTICAL OIL DRAIN
Ring
Oelablauf vertikal
Basic Material S235JRG2 SS400
Net Weight 2.4
Units mm kg IDE
Made 21.01.2011 mhu019 M.Hug
Chkd 31.01.2011 sfe006 Feuerstein
Appd 31.01.2011 ds1009 Stroedecke
Scale 1:3
Size A3
Page 1/1
Material ID PAAD030945
Design Group 9722
Drawing ID DAAD013763
Rev. –
Q-Code XXXXX
Standard ISO JIS
Main Drw.
Free space for lic.
Modif.
Number
Drawn date
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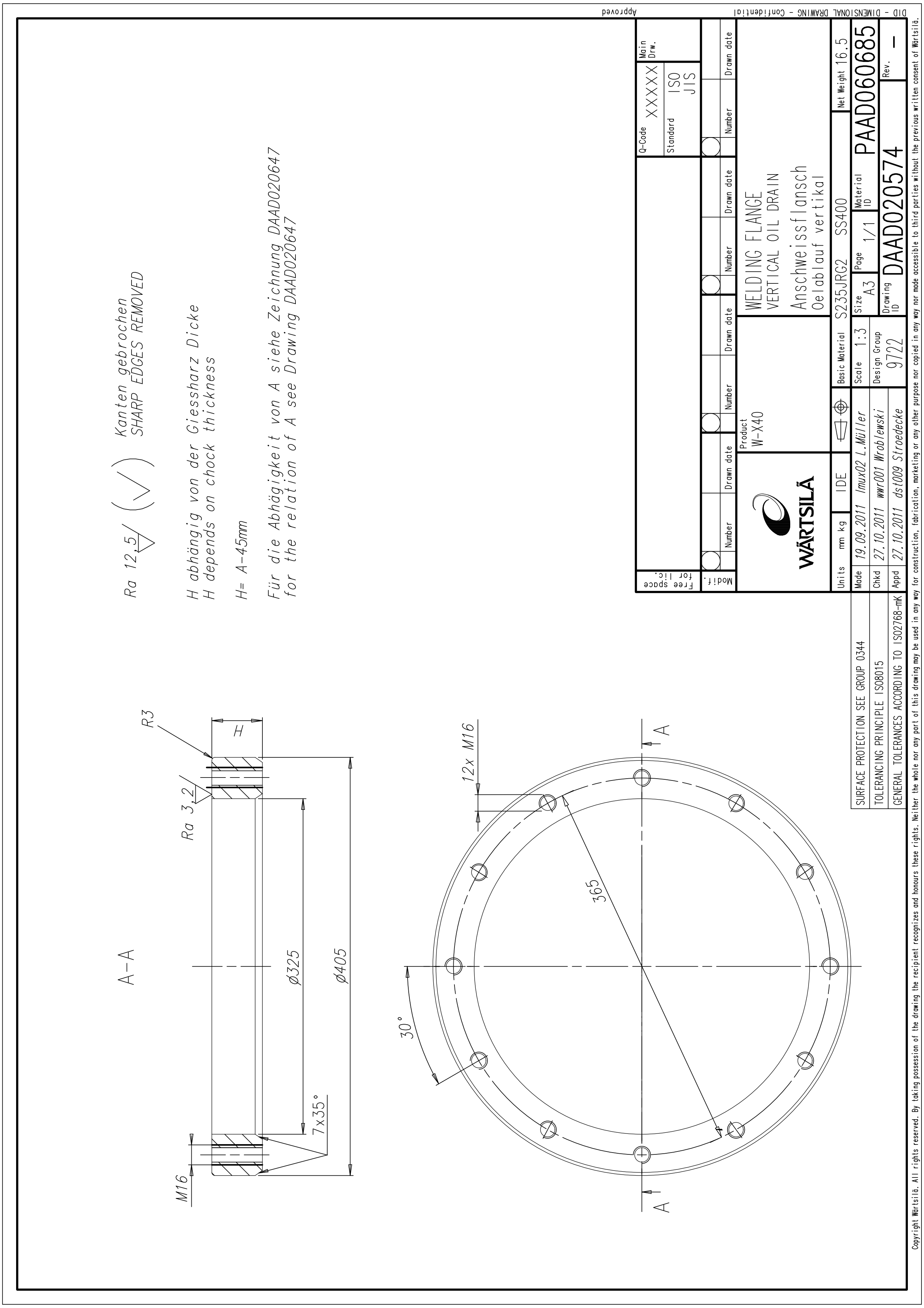
A-A
Ra 3,2
R3
H
M16
7x35°
Ø325
Ø405
12x M16
365
30°
A
A
Ra 12,5
Kanten gebrochen
SHARP EDGES REMOVED
H abhängig von der Giessharz Dicke
H depends on chock thickness
H= A-45mm
Für die Abhägigkeit von A siehe Zeichnung DAAD020647
for the relation of A see Drawing DAAD020647
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
Units mm kg
IDE
Made 19.09.2011 lmux02 L.Müller
Chkd 27.10.2011 wwr001 Wroblewski
Appd 27.10.2011 ds1009 Stroedecke
Product W-X40
WELDING FLANGE
VERTICAL OIL DRAIN
Anschweissflansch
Oelablauf vertikal
Basic Material S235JRG2 SS400
Scale 1:3
Size A3
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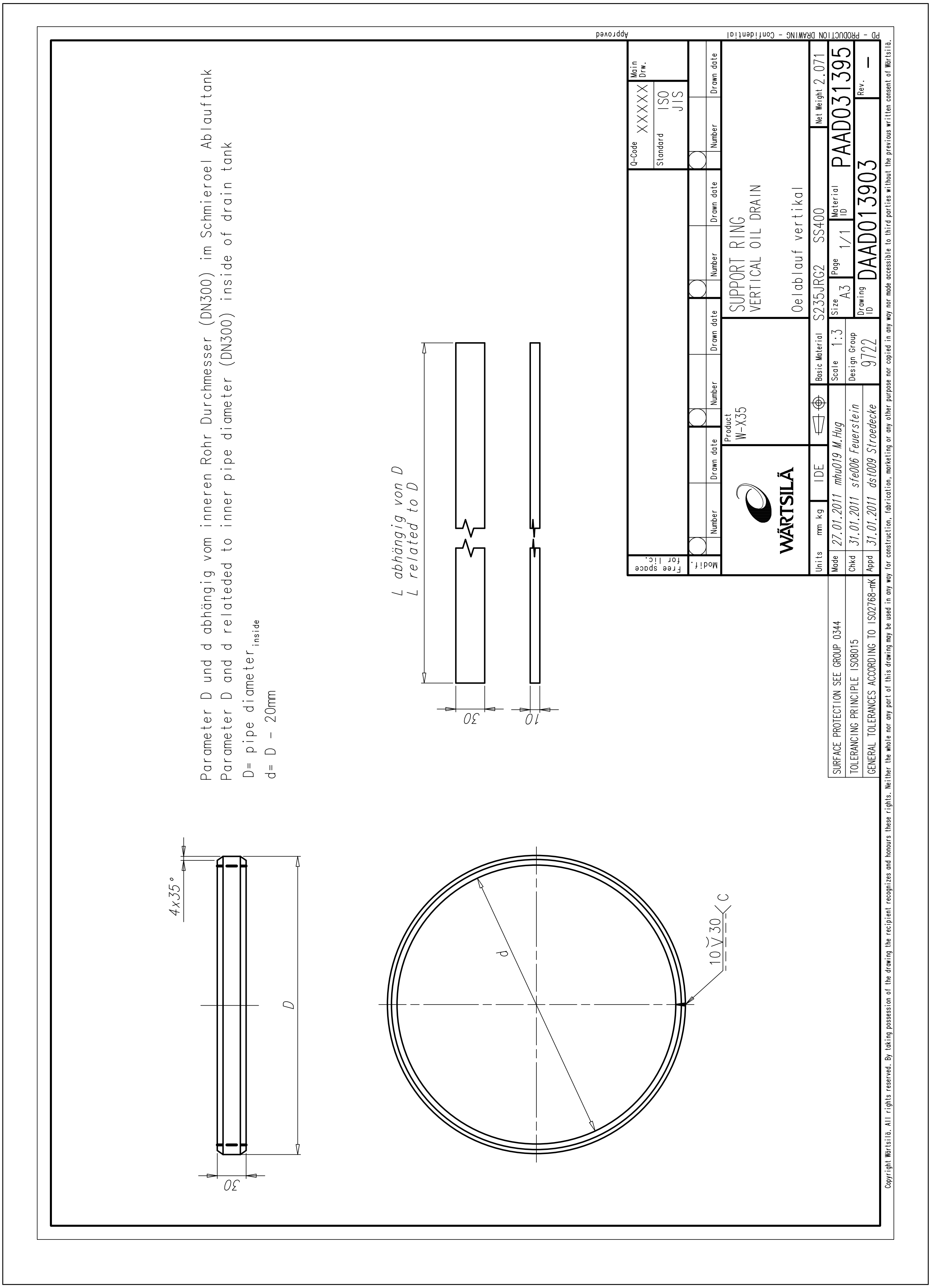
Parameter D und d abhängig vom inneren Rohr Durchmesser (DN300) im Schmieroel Ablauftank
Parameter D and d relateded to inner pipe diameter (DN300) inside of drain tank
D= pipe diameter inside
d= D - 20mm
L abhängig von D
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30
10
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SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
Units mm kg
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Made 27.01.2011 mhu019 M.Hug
Chkd 31.01.2011 sfe006 Feuerstein
Appd 31.01.2011 ds1009 Stroedecke
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Product W-X35
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1 Flushing the lubricating oil system

1.1 Introduction

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 lubricating oil systems are clear of all foreign matter before circulating oil through to the engine. A systematic approach is to be adopted prior to commissioning when the engine, pipe work, filters, heat exchangers, pumps, valves and other components are flushed and are 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.

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

1.2 Preparation before flushing

1. Led the lubricating oil connections immediately before the engine straight back into the lubricating oil drain tank by means of hoses or pipes see the figure.
2. Immediately before the engine, in the discharge pipes from the low-pressure and high-pressure lubricating oil pumps, install temporary filters with a mesh size (sphere passing) of max. 0.03 mm and equipped with magnetic elements. 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. 0.03 mm 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 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 sub-assemblies** 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 respectively blank off all oil supply pipes to the supply unit, rail unit and the gear train.

1.3 Flushing external lubricating oil system

1. Fill the lubricating oil drain tank with sufficient oil to cover the pump suction and heat it up using temporary immersion heaters or the heating coil of the drain tank to approximately 40-60 °C.
2. Circulate the oil in the drain tank using the lubricating oil separators(s) and their pre-heater(s) to maintain the flushing temperature to improve oil cleanliness. Operate the separators(s) until all the flushing procedures are completed.
3. All system valves are to be fully open.
4. Good ventilation is to be provided to avoid condensation. At the exhaust side, the crankcase round covers are to be removed and on the fuel pump side the crankcase doors must be opened.
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 bypassed 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 the pressure drop through the filters, too.

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WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTFL Drawn: S. Stylianou 13.04.04 Verif: M. Lüthi 13.04.04	**INSTRUCTIONS FOR FLUSHING** THE LUBRICATING OIL SYSTEM **4-107.341.455**	**Group 9722** **1/3**

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Release: 22.07.03 12.05.2009

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 and; no metallic particles adhere to the magnetic filter inserts and no residues are detected in the bottom of the filter housing. When the system proves clean, remove any filter bags and connect the low- and high-pressure oil supply pipes to the engine.

1.4 Flushing within the engine

Only in the case of **engines supplied to the ship in sub-assemblies**.

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.
3. **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.
   Any pipe-connecting piece, which was not flushed before, must be clean separately.
   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.

1.5 Circulation of lubricating oil

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 component such as dampers for proper oil flow.
4. The turning gear is to be engaged to turn the engine from time to time. Carry out an inspection of the crankcase before refitting all the crankcase doors.
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 bypass, the high-pressure lubricating oil pump is to be stopped.

1.6 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 daily 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.

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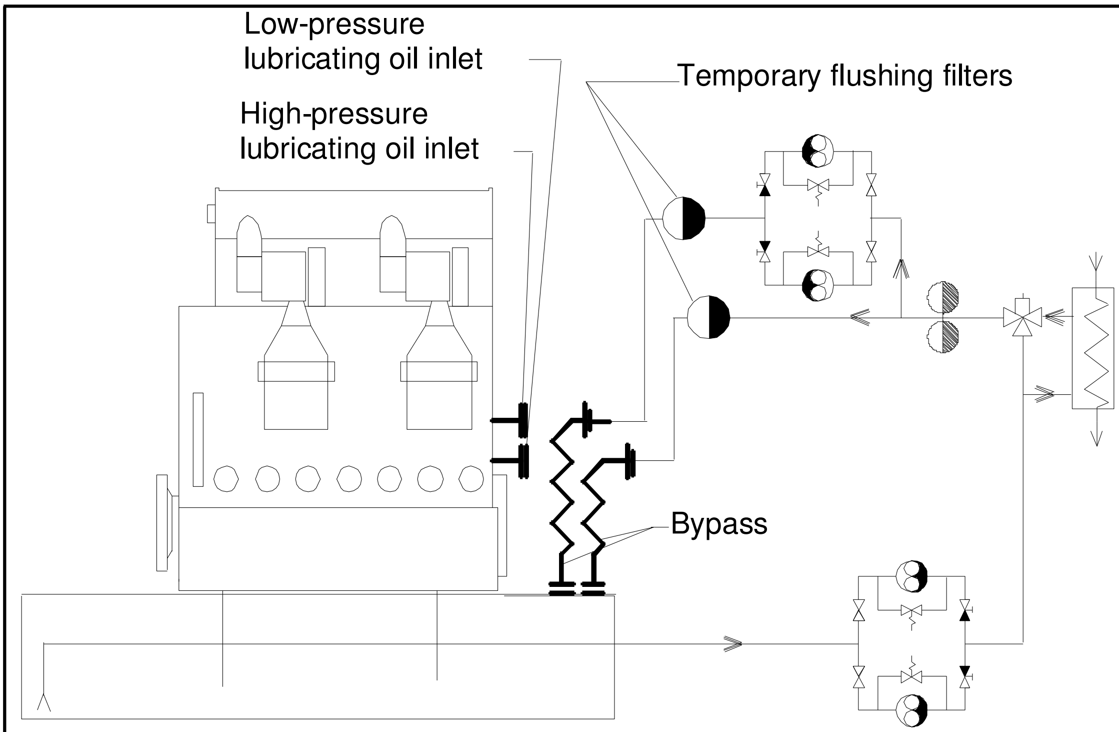

NAS 1638 classes		Contamination (particles per 100 ml)				
Particle size in micron		5-15	15-25	25-50	50-100	>100
Classes	14	4096000	729600	129600	23040	4096
	13	2048000	364800	64800	11520	2048
	12	1024000	182400	32400	5760	1024
	11	512000	91200	16200	2880	512
	10	256000	45600	8100	1440	256
	9	128000	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

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

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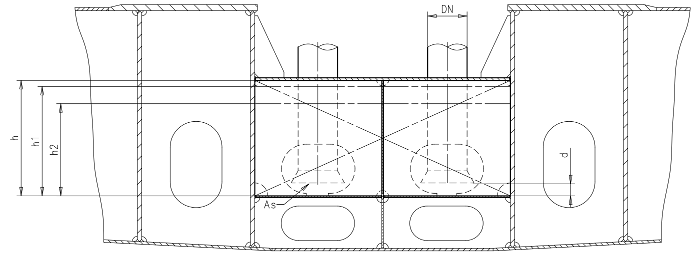
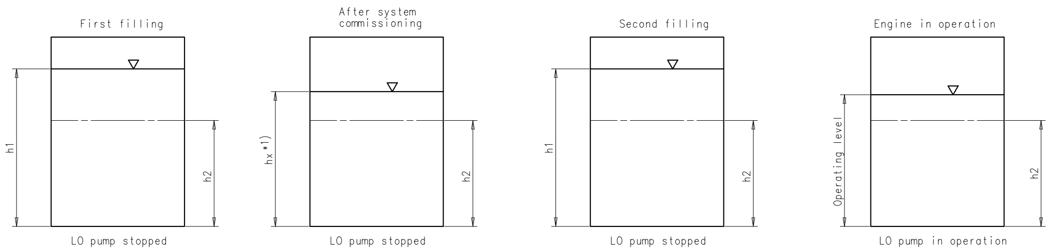
Specifications for engine LO drain tank that need to be meet:



Dimensioning guidelines and capacities for tank design

	No. of cylinders		5	6	7	8
h	Recommended total tank height	(mm)	according to installation requirements			
	Recommended total tank volume: 105%	(m3)	8.2	9.8	11.5	13
h1	Recommended filling level	(mm)	according to installation requirements			
	Recommended volume: 100%	(m3)	7.8	9.3	10.9	12.4
h2	Low level alarm	(mm)	*2)			
	volume	(m3)				
Vr	Min. retention volume *3)	(m3)	5.6	6.4	7.2	7.9
d	Distance between suction pipe and bottom of tank	(mm)	*4)			
As	Suction Area		min. 1.5x suction pipe area (DN)			

L.O. DRAIN TANK - FILLING PROCESS



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:

Heel to each side	15°
Rooling to each side	±22.5
Trim	500/L, max. 5° L: ship length in meter Example L = 250 m Trim = 500/250 = 2°
Pitching	± 7.5°

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.

Q-Code XXXXX | Standard ISO JIS | Product W-X40 | LUBRICATING OIL DRAIN TANK FILLING GUIDELINES | WÄRTSILÄ

Units mm kg | IDE | Net Weight 0.001
Made 13.09.2011 sth017 S.Thalmann | Scale 1:25 | Size A1 | Page 1/1 | Material ID PAAD060502
Chkd 27.10.2011 wwr001 Wroblewski | Design Group 9722 | Drawing ID DAAD020532 | Rev. –
Appd 27.10.2011 ds1009 Stroedecke

SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK

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10. Fuel Oil System

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.

10.1 Fuel oil requirements

In the folowing table the values in the column 'Bunker limit' indicate the minimum quality of heavy fuel as supplied to the installation. Good operating results have been achieved with all commercialised fuels within ISO 8217 limits. However, using fuel with lower density, ash and carbon residue content can 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.

ISO 8217 excludes adding 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**	Test method *1)	Fuel quality (engine inlet)
Density at 15°C	kg/m³	max. 1010 *2)	ISO 3675/12185	max. 1010
Kinematic viscosity at 50°C	mm²/s (cSt)	max. 700	ISO 3104	13-20
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 + 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

** ISO 8217:2005, class F, RMK700

*1) ISO standards can be obtained from the ISO Central Secretariat, Geneva, Switzerland (www.iso.ch).

*2) Limited to max. 991 kg/m3 (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 lubricating oil, a homogeneous blend with no added substance or chemical waste (ISO8217:2005-5-1).

10.1.1 Viscosity (see figure *10.1*)

The recommended viscosity range at engine inlet is **13-20 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 to 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. To achieve a good separation, the throughput and the temperature of the fuel going through the centrifuges must be adjusted in relation to the viscosity. 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.

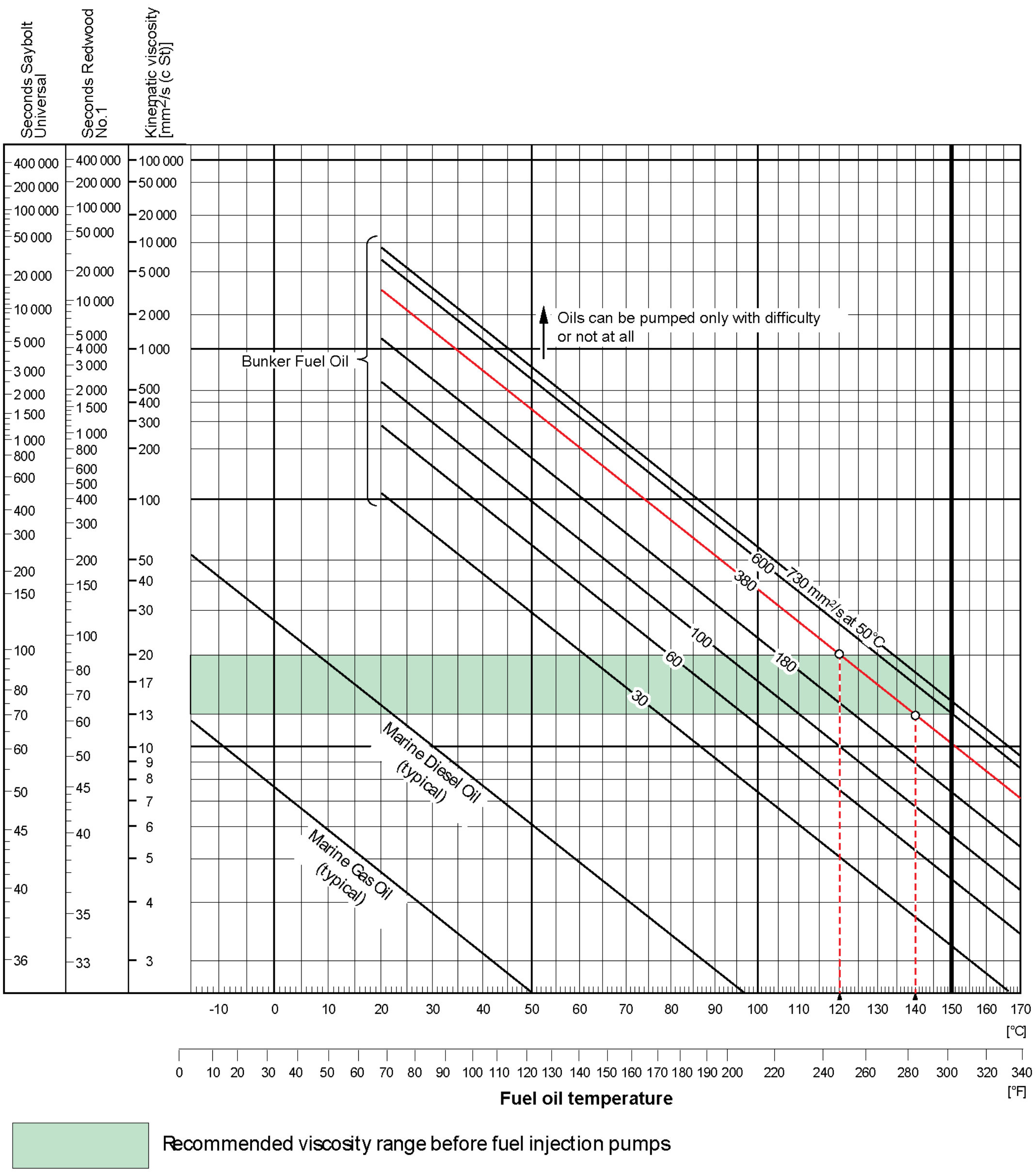


Figure 10.1: Typical viscosity / temperature diagram

Example:
To obtain the recommended viscosity before the fuel engine inlet, fuel oil of 380 mm^2/s (cSt) at 50°C must be heated up to 120-140°C.

10.1.2 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 impair the combustion quality of the fuel oil, promoting increased wear and fouling of engine components. An asphaltene content of up to 14% 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 and filters as well as on the tank bottom. Especially the addition of paraffinic distillates could cause the asphaltenes to settle out. To minimise compatibility risks, mixing bunkers from different suppliers and sources in storage tanks on board must be avoided. Onboard test kits are available to assess this risk.

10.1.3 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.

10.1.4 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.

10.1.5 Aluminium, silicon

Aluminium and silicon in the fuel oil are regarded as an indication of catalytic fines (cat fines), i.e. 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 of 10-20 micron, 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 lub. 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 a paramount importance.

10.1.6 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 seawater containing sodium. A content of 1.0% seawater in the fuel oil corresponds to 100 ppm sodium.

10.1.7 Flash point

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

10.1.8 Pour point

The operating temperature of the fuel has to be kept 5-10°C above the pour point to secure easy pumping.

10.1.9 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 by using combustion analyzing equipment like FIA tests.

10.2 Fuel oil treatment

10.2.1 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.

10.2.2 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 (e.g. due to condensation or coil leakage) into the settling tank. A pipe to the separators should be provided to reclean 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, a significant indication for the condition of the separator(s) and heating coils.

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

10.2.3 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 required minimum effective throughput capacity of the separators is determined as shown in the following example. The nominal separator capacity and the installation are to comply with the recommendations of the separator manufacturer.

Throughput capacity = ... 1.2 x CMCR x BSFC / 1000 [litres/hour]

Example: .... 8-cyl. engine with CMCR R1:

- CMCR: 9,080 kW
- BSFC: 175 g/kWh

Throughput = 1.2 x 9,080 x 175 (see table *1.1 Primary engine data*) / 1000 = 1,907 litres/hour

The marine diesel oil (MDO) separator capacity can be estimated using the same formula.

Separator without gravity disc:

One of the main features of the 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 standby separator as a back-up, it is of advantage to use the separator to improve the separation result. For the arrangement of the separators, parallel or in series, 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; thus two separators are required. The clarifier improves the separation result and acts as a safety device in case the purifier is not properly adjusted. When processing heavy fuel oils it is indispensable to strictly adhere to the separator manufacturer's instructions. If using these separators it will be advantageous to install an extra separator for marine diesel oil, only to avoid the changing of gravity discs when changing over from HFO to MDO separation.

Separation efficiency

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

- $n = 100 \cdot (1 - C_{out}/C_{in})$

  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

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).

10.3 Heavy fuel oil system components

10.3.1 Fuel oil feed pump

Pump type: .... positive displacement screw pump with built-in overpressure relief valve

Pump capacity: .... refer to table *7.1*; 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 that the pressure in the mixing unit is at least 1 bar above the water vapour pressure and no 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 following formula and example:
Delivery gauge pressure = $p_v + 1 + \Delta p_1 + \Delta p_2$ [bar]

NOTICE

p_v = ... water vapour gauge pressure at the required system temperature [bar] (see viscosity/ temperature diagram fig. *10.1*)

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 *10.3.2*

Example

HFO of 730 cSt at 50°C

Required system temperature: .... approx. 145°C

Water vapour gauge pressure at 145°C: .... pv = 3.2 bar

Press. losses betw. feed pump and mixing unit: ..... Δp1 = 0.5 bar

Pressure change difference across the pressure regulating valve: .... Δp2 = 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.

10.3.2 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 the 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 *7.1*
Minimum capacity:	approx. 20% of that of the feed pump
Service pressure:	max. 10 bar
Pressure setting range:	2-6 bar
Inlet pressure change:	$\leq$ 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

10.3.3 Mixing unit

Due to the small amount of fuel consumed, only a small mixing unit is required. It is recommended that the tank contains no more than approx. 100 litres. This is to avoid the changeover from HFO to MDO or vice 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 service 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 *10.2*
Capacity:	see figure *10.2*
Dimensions:	see figure *10.2*
Service pressure:	10 bar
Test pressure:	according to the classification society
Working temperature:	ambient to 150°C

10.3.4 High-pressure booster pump

Pump type:	positive displacement screw pump with built-in overpressure relief valve
Pump capacity:	refer to table *7.1 Data for central freshwater cooling system (integrated HT)*; the given flow rate is to be within a tolerance of 0 to +20%
Inlet pressure	up to 6 bar
Delivery head:	see also table *7.1 Data for central freshwater cooling system (integrated HT)*; final delivery pressure according to the actual piping layout
Working temperature:	ambient to 150°C

Electric motor (booster pump)

Refer to the remarks for electric motor for the feed pumps.

10.3.5 Fuel oil end heater

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

where:

- BSFC is the brake specific fuel consumption at the contract maximum continuous rating (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.

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

⚠ WARNING

For all relevant and prevailing information consult the drawings in section 'Drawings' at the end of this chapter.

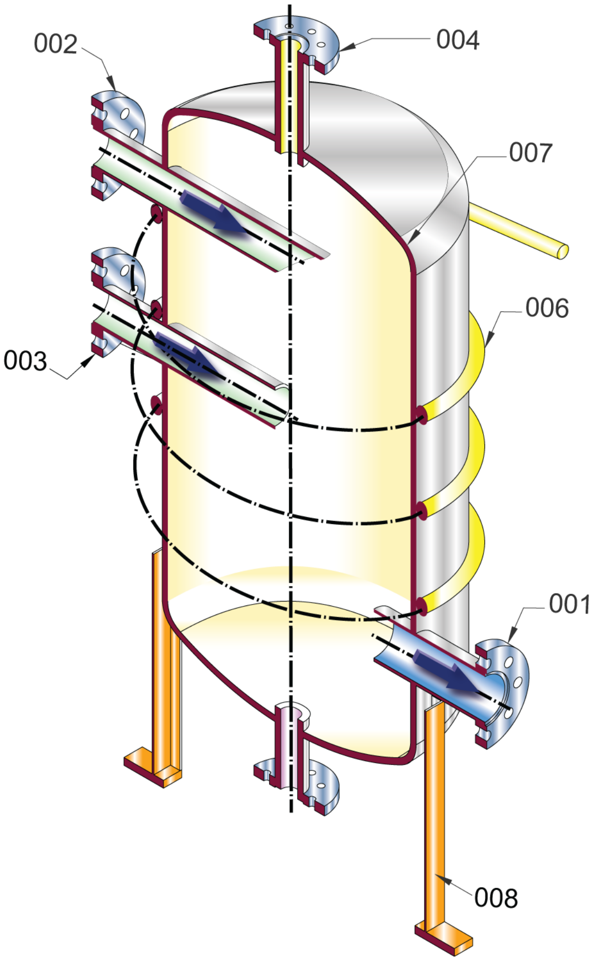


Figure 10.2: Fuel oil system mixing unit

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

NOTICE

Configuration and dimensioning of the mixing unit have to comply with the relevant classification society/rules.

*1) Mounting brackets for fixation on floor plate. The mixing unit must not, under any circumstances, be fitted unsupported.

10.3.6 Fuel oil filter

A mesh size of max. 10 micron (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.

Wärtsilä Switzerland Ltd. highly recommends the following filter arrangement:

Arrangement in the feed system (A)

Figure *10.3*, A): 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 *7.1 Data for central freshwater cooling system (integrated HT)*. 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 press. at filter inlet, after feed pumps:	10 bar
Test pressure:	specified by classification society
Permitted differential press. at 100 cSt:	• clean filter: max. 0.2 bar • dirty filter: 0.6 bar • alarm setting: max. 0.8 bar
Min. bursting press. of filter insert:	max. 8 bar differential across filter
Working temperature:	ambient to 90°C
Mesh size:	max. 10 micron, sphere passing mesh
Filter insert material:	stainless steel mesh (CrNiMo)

Duplex filter

- The installation of the automatic back-flushing filter on the low-temperature side does not replace the need for a duplex filter fitted immediately before the supply unit.
- The same technical data are applied as specified for the arrangement before the supply unit. The filter mesh size (sphere passing) in this case is max. 0.060 mm (60 μm).

NOTICE

For various reasons cat fines may be present in the fuel entering the engine. They often cause excessive piston ring and cylinder liner wear. It is obvious that other exposed parts, e.g. fuel pumps, fuel injection valves, piston rod and piston rod stuffing boxes, will also be damaged if the fuel oil shows a high content of cat fines.

As an alternative, the following arrangement is possible:

Arrangement before engine inlet (B)

Figure *10.3*, B): High-temperature (booster circuit).

This filter is most 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 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: .... 13-20 cSt

Flow rate: .... Booster pump capacity, refer to table *7.1 Data for central freshwater cooling system (integrated HT)*. 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 back-flushing of the filter.

Service pressure: .... max. 12 bar at filter inlet

Test pressure: .... specified by classification society

Permitted differential press. at 20 cSt: ....

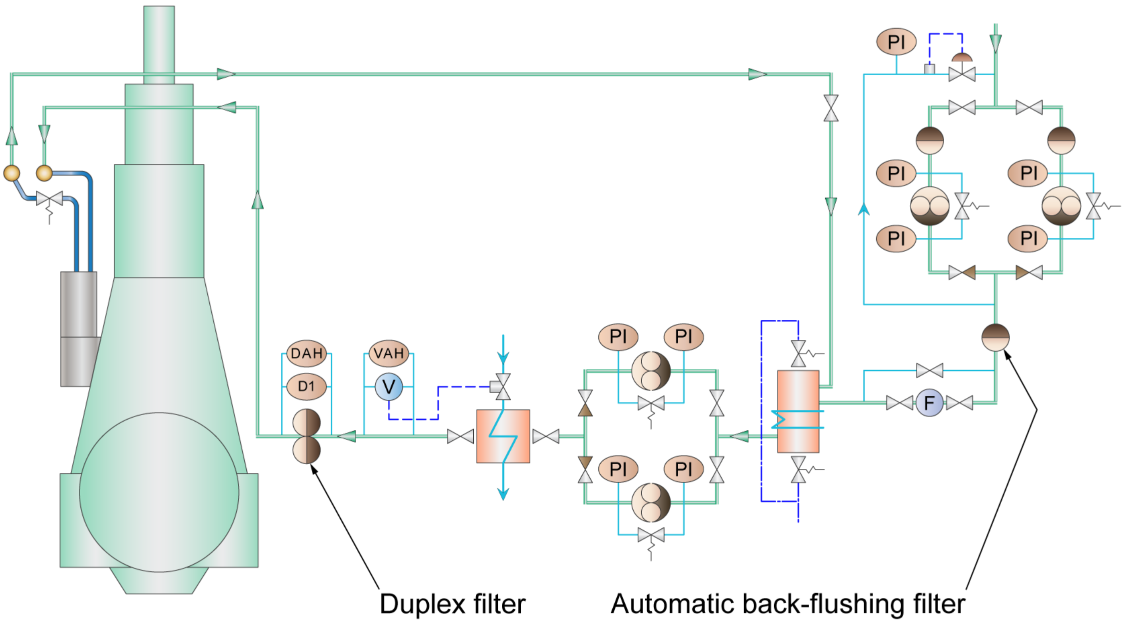
- clean filter: max. 0.2 bar
- dirty filter: 0.6 bar
- alarm setting: max. 0.8 bar

Min. bursting press. of filter insert: .... max. 8 bar differential across filter

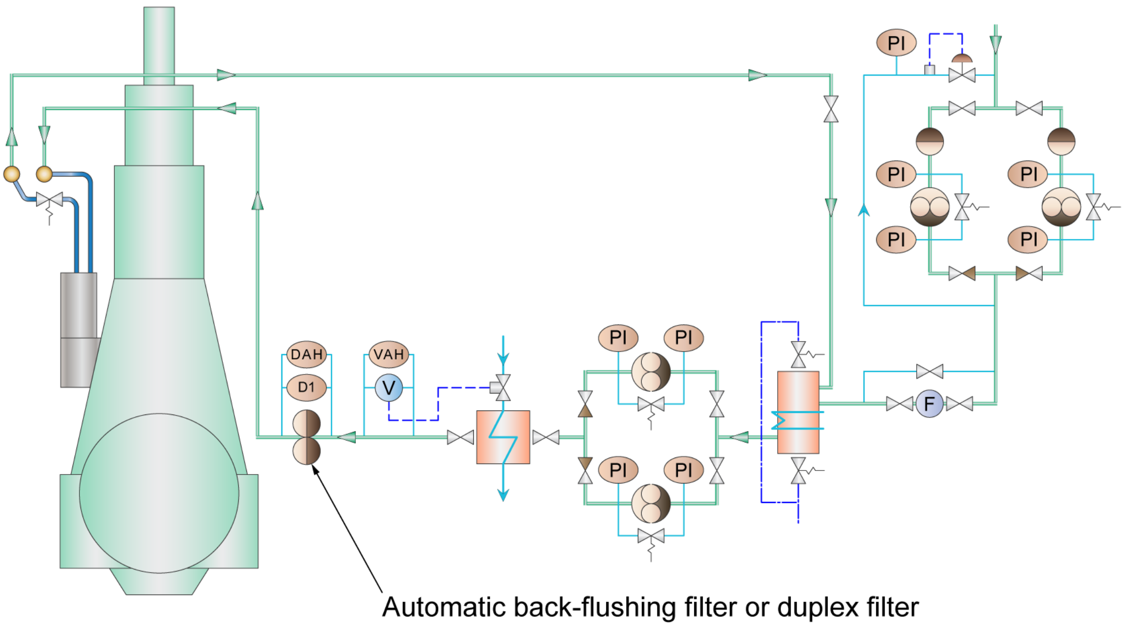
Working temperature: .... ambient up to 150°C

Mesh size: .... max. 10 μm, sphere passing mesh

Filter insert material: .... stainless steel mesh (CrNiMo)



A) Back-flushing filter arrangement in the feed system



B) Back-flushing or duplex filter arrangement before engine inlet

Figure 10.3: Filter arrangements

10.4 Drawings

Net Weight 0.004

Quantity PER ENGINE	SEQ NO	Material ID	Material Name	Dimension/Occ.Dimension	Standard or Drawing	Basic Material Material Standard	Weight GR./NET
1	004	107.428.377.500	DISTILLATE FUELS		107.428.377		0.001
1	003	107.341.454.500	INSTRUCTION FOR FLUSHING		107.341.454		0.001
1	002	PAAD059949	MIXING UNIT		DAAD020383		0.001
1	001	PAAD059948	FUEL OIL SYSTEM		DAAD020382		0.001

Approved

Material ID PAAD059953

Free space for lic.

Q-Code XXXXX

Main Drw. H

Standard ISO JIS

Modif.	Number	Drawn date	Number	Drawn date	Number	Drawn date	Number	Drawn date

WÄRTSILÄ

Product W5-8X40

FUEL OIL SYSTEM

Brennstoffsystem

Units mm kg IDE

Basic Material

Net Weight

SURFACE PROTECTION SEE GROUP 0344	Made	08.09.2011 lmux02 L.Müller
TOLERANCING PRINCIPLE ISO8015	Chkd	10.10.2011 wwr001 Wroblewski
GENERAL TOLERANCES ACCORDING TO ISO2768-mK	Appd	10.10.2011 dst009 Stroedecke

Scale –

Design Group 9723

Size A3

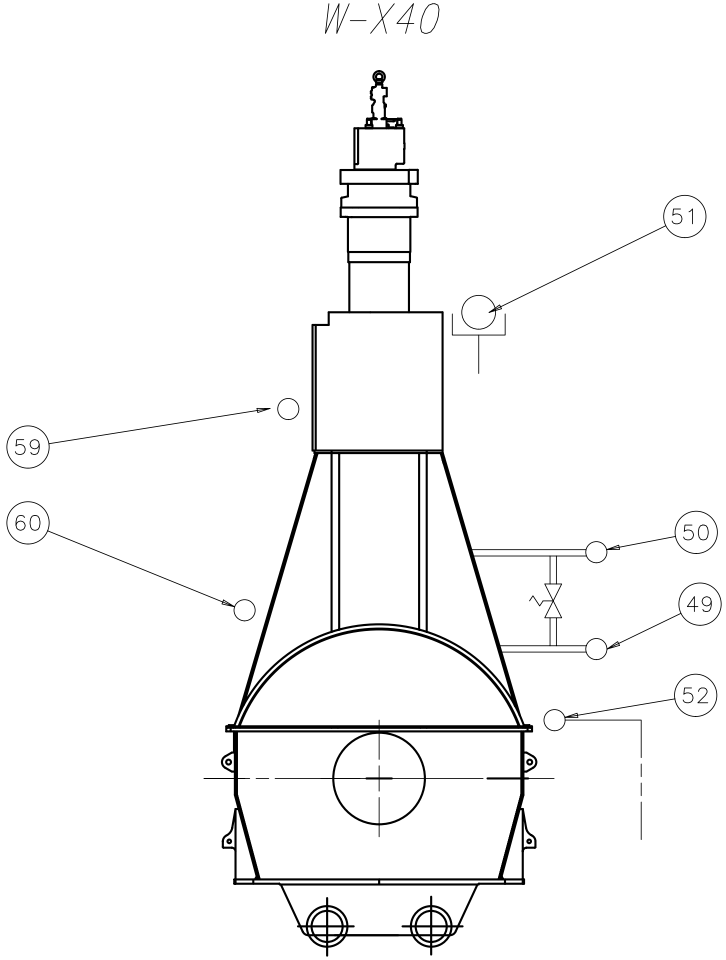
Page 1/1

Material ID

Drawing ID DAAD020384

Rev. –

DID - DIMENSIONAL DRAWING - Confidential



Specifications that need to be met:

49	**Fuel oil inlet** - At least one fuel oil filter unit close to the engine inlet. - Fuel oil quality at engine inlet according to specification in Marine Installation Manual(MIM) - Inlet pressure: stopped engine 10 bar; running engine 7-10 bar - Viscosity for HFO: 13-20 cSt - Viscosity MGO/MDO: 2-20 cSt - Max. temperature gradient during FO change-over: 2°C/min - Filtration: one filter unit with max. 10 micron absolute in the fuel oil system (sphere passing mesh) - Volume flow: according to WinGTD
50	**Fuel oil outlet** - Normal operation condition: Returning to mixing tank. - Fuel oil changeover while engine not in service: Returning to service tank.
51	**Fuel leakage rail unit (dirty)** - Free flow by gravity to sludge oil or appropriate tank, (not for re-use) pipe insulated and heated up (50-95C°)
52	**Fuel leakage pipe (clean)** - Free flow by gravity to fuel oil overflow tank, pipe insulated and heated up (50-95C°), no additional valve in drain, beside swing check valve at tank inlet.
59	**Fuel oil trace heating, inlet** - Connected to steam or thermal oil supply
60	**Fuel oil trace heating, outlet** - Connected to condensate manifold or thermal oil return

Free space for lic. | Q-Code XXXXX | Main Drw. | Standard ISO JIS | Approved

Modif.	Number	Drawn date	Number	Drawn date	Number	Drawn date	Number	Drawn date
A	EAAD083822	15.05.2012						

WÄRTSILÄ

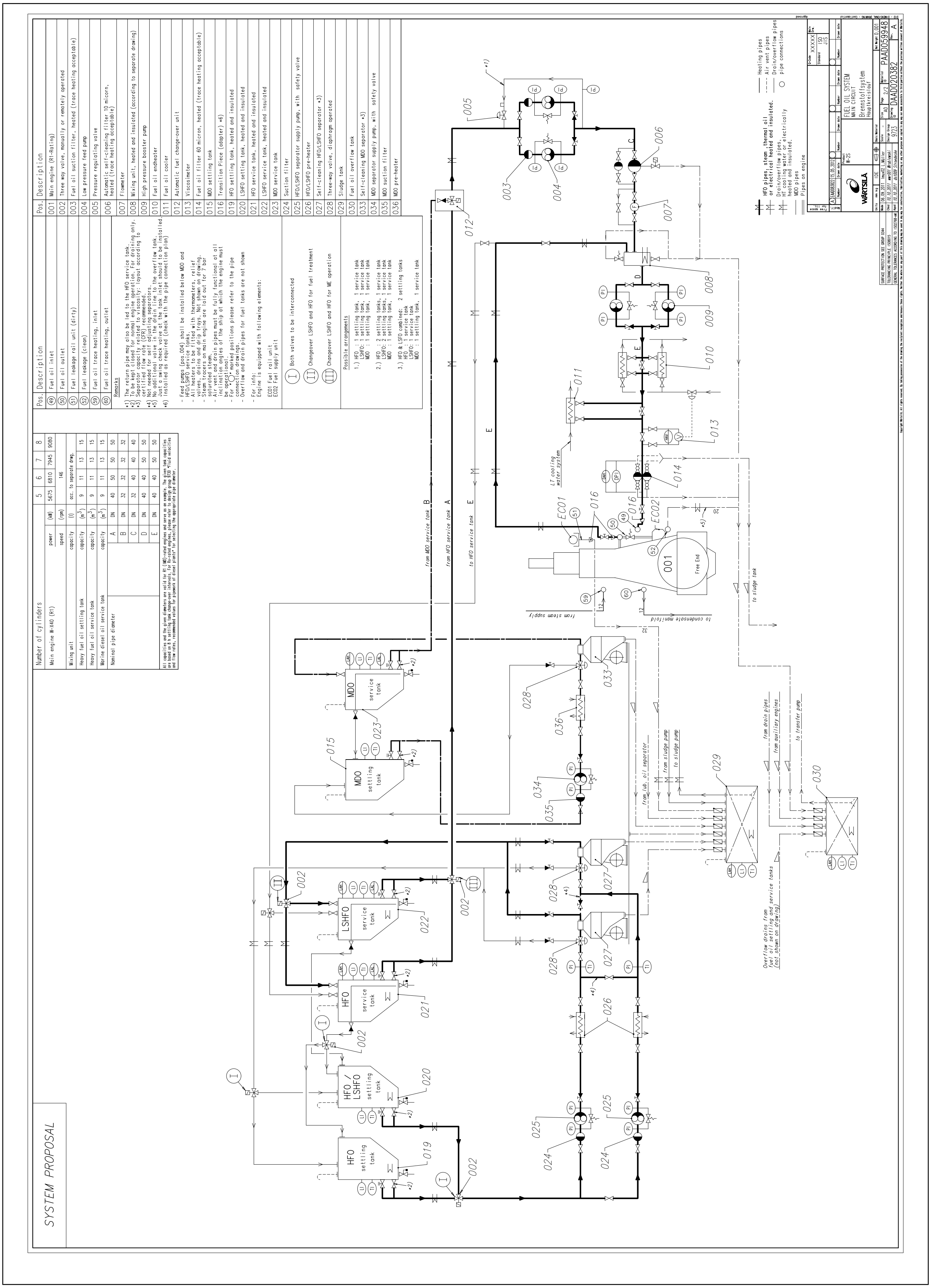
Product: W-2S

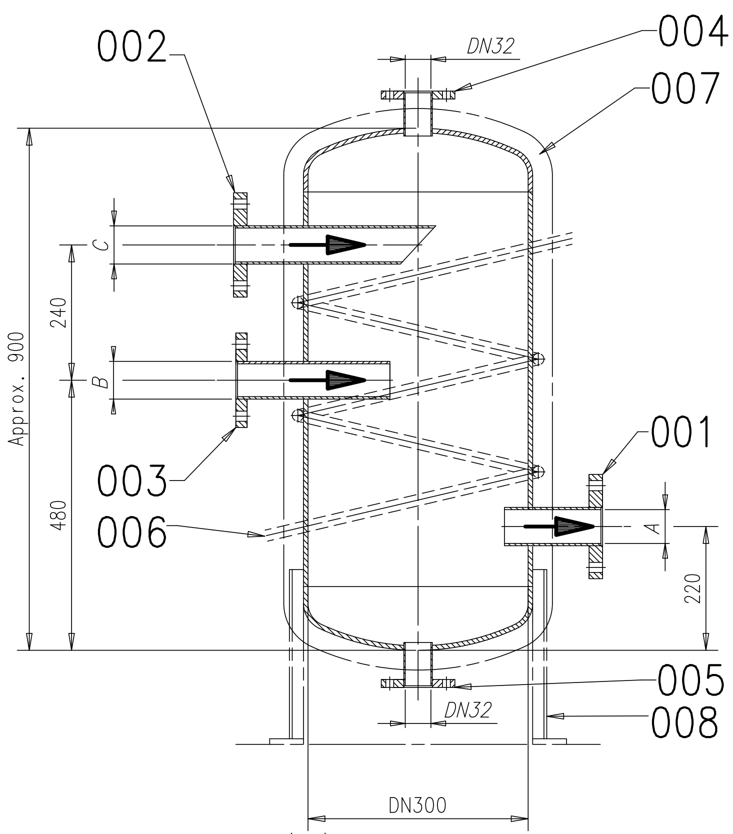
FUEL OIL SYSTEM
MAIN CIRCUIT
Brennstoffsystem
Hauptkreislauf

Units mm kg	IDE	Basic Material	Net Weight 0.001
Made 06.09.2011 lmux02 L.Müller	Scale -	Size A3	Page 1/2
Chkd 10.10.2011 wwr001 Wroblewski	Design Group 9723	Material ID PAAD059948	
Appd 10.10.2011 dst009 Stroedecke		Drawing ID DAAD020382	Rev. A

SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK

DID - DIMENSIONAL DRAWING - Confidential


SYSTEM PROPOSAL
Pos. Description
001 Main engine (R1-Rating)
002 Three way valve, manually or remotely operated
003 Fuel oil suction filter, heated (trace heating acceptable)
004 Low pressure feed pump
005 Pressure regulating valve
006 Automatic self-cleaning filter 10 micorn, heated (trace heating acceptable)
007 Flowmeter
008 Mixing unit, heated and insulated (according to separate drawing)
009 High pressure booster pump
010 Fuel oil endheater
011 Fuel oil cooler
012 Automatic fuel change-over unit
013 Viscosimeter
014 Fuel oil filter 60 micron, heated (trace heating acceptable)
015 MDO settling tank
016 Transition Piece (adapter) *6)
019 HFO settling tank, heated and insulated
020 LSHFO setting tank, heated and insulated
021 HFO service tank, heated and insulated
022 LSHFO service tank, heated and insulated
023 MDO service tank
024 Suction filter
025 HFO/LSHFO separator supply pump, with safety valve
026 HFO/LSHFO pre-heater
027 Self-cleaning HFO/LSHFO separator *3)
028 Three-way valve, diaphragm operated
029 Sludge tank
030 Fuel oil overflow tank
033 Self-cleaning MDO separator *3)
034 MDO separator supply pump, with safety valve
035 MDO suction filter
036 MDO pre-heater
Pos. Description
49 Fuel oil inlet
50 Fuel oil outlet
51 Fuel leakage rail unit (dirty)
52 Fuel leakage (clean)
59 Fuel oil trace heating, inlet
60 Fuel oil trace heating, outlet
Remarks
*1) The return pipe may also be led to the HFO service tank.
*2) To be kept closed for normal engine operation. For draining only.
*3) Separator capacity related to viscosity: layout according to certified flow rate (CFR) recommended.
*4) Not needed for self adjusting separators.
*5) No additional valve in the drain line to the overflow tank. Just a swing check valve at the tank inlet should to be installed.
*6) Installed as required (check with the pipe connection plan)
Number of cylinders 5 6 7 8
5675 6810 7945 9080
146
acc. to separate drwg.
HFO service tank
MDO service tank
LT cooling water system
from steam supply
to condensate manifold
to sludge tank
Free End



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

Remarks:

- Configuration and dimensioning of the mixing unit have to comply with the relevant classification society/rules.

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

*2) Shown on drawing.

Nominal pipe diameters (DN)

No. of cyls.	A	B	C	
	DN	DN	DN	
5	40	32	40	
6	40	40	40	*2)
7	50	40	50	
8	50	40	50	

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

SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK

Free space for lic. | Q-Code XXXXX | Standard ISO JIS | Main Drw. | Approved

Modif. | Number | Drawn date | Number | Drawn date | Number | Drawn date | Number | Drawn date

WÄRTSILÄ | Product: RT-Engine | MIXING UNIT TO FUEL OIL SYSTEM

Units mm kg | IDE | Basic Material | Net Weight 0.001

Made 08.09.2011 lmux02 L.Müller | Scale 1:5 | Size A3 | Page 1/1 | Material ID PAAD059949
Chkd 10.10.2011 wwr001 Wroblewski | Design Group 9723 | Drawing ID DAAD020383 | Rev. –
Appd 10.10.2011 dst009 Stroedecke

DID - DIMENSIONAL DRAWING - Confidential

1 Flushing the fuel oil system

1.1 Introduction

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, pipe work, 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.

1.2 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 the figure.
2. Install in the by-pass line a temporary filter with a mesh size (sphere passing mesh) of max. 0.03 mm 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. After flushing the filter, inserts are to be replaced by the original ones and the filter housing to be cleaned.

1.3 Flushing procedure

1. Fill the daily tank with sufficient marine diesel oil (MDO).
2. Circulate the MDO in the daily 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 daily 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 daily 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, end heater, 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.

		Replaced by:	PC
		Substitute for:	
WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTFL Drawn: S. Stylianou 13.04.04 Verif: M. Lüthi 13.04.04	INSTRUCTIONS FOR FLUSHING THE FUEL OIL SYSTEM 4-107.341.454	Group 9723 1/2

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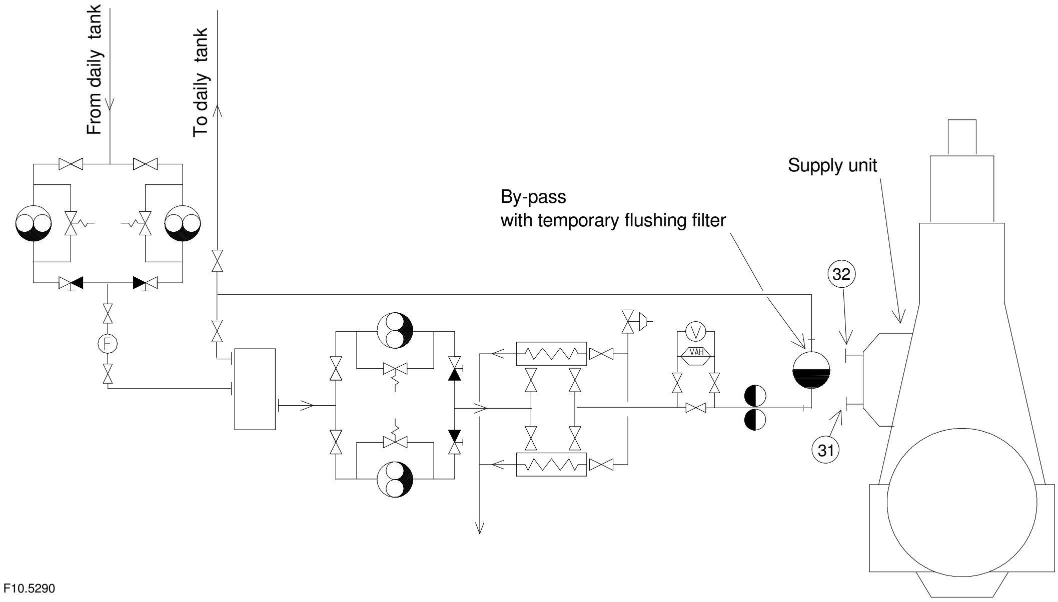
Release: 22.07.03 14.04.2004



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WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTFL Drawn: S. Stylianou 13.04.04 Verif.: M. Lüthi 13.04.04	**INSTRUCTIONS FOR FLUSHING** THE FUEL OIL SYSTEM **4-107.341.454**	**Group 9723** **2/2**

ISO-Basic Document Nr.X-107.XXX.XXX / 12.02.96 / Rev. 1.0
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System Engineering Concept Guidance

OPERATION ON DISTILLATE FUELS - IMPACT ON THE INSTALLATION

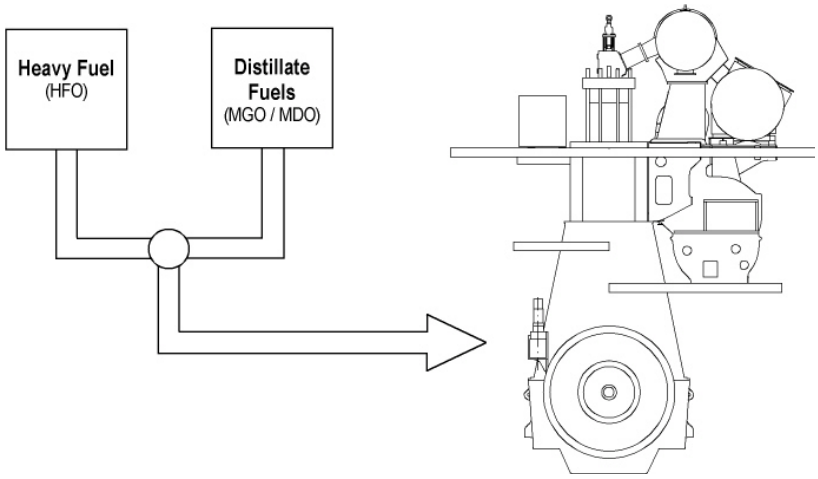

Table of contents:

Q-Code	X	X	X	X	X					
-	77-747	08.01.10								Replaced by:
										Substitute for:

WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTMOT	**Distillate Fuels** Installation Aspects	Group **9723**
	Drawn: M. Lüthi 20.11.09 Verif:: C. Van Gijssel 30.11.09	**4-107.428.377**	**1 / 15**

1. Introduction

Current and foreseen marine fuel legislation is limited to prescribing the maximum sulphur content of marine fuel oils or to reduce the sulphur in the exhaust gas with alternative methods equivalently.
The availability of fuels with various sulphur levels is not yet fully clear. However, as the demand for sulphur content in the fuel is reduced below 0.5%, the possibility of distillate fuel increases.
According to ISO 8217 standard, distillate fuels are categorised as DMX, DMA (also called MGO) and DMB (often called MDO). DMX is emergency fuel with a lower flashpoint, coming with additional storage precautions. Due to the low flash point, this fuel would not normally be used in marine diesel engines: DMA and DMB being the most common distillate fuels.
Wärtsilä Switzerland allows for its engines to be operated on all fuels supplied under the ISO 8217 standard.
This guide line is to mainly give information about the impact on the installation side, when using distillate fuels according to ISO 8217 standard. It is valid for RT-flex and RTA engines.

2. Fuel oil viscosity

The current recommendation for fuel viscosity at the fuel injector is 13 to 17cSt when operating on HFO. However, this viscosity level cannot be met with MDO and MGO unless the fuel is cooled down to very low temperatures.
Experience has however shown that viscosities for grades DMA and DMB distillate fuels have no adverse affect on the operation of the fuel system components: a nominal lower viscosity level of 2 cSt at the fuel pump is recommended.
To achieve this level a cooler may be required depending on the actual temperature of the distillate fuel delivered to the engine.
Table 1, page 9, shows the ISO 8217 standard. As example, the viscosity of the DMA grade as a function of the temperature is shown in figure 2, page 10.

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3. Fuel oil system

A complete fuel oil system including the fuel oil treatment with a tank arrangement for various fuel oil qualities and the pressurised system is shown in figure 3, page 11.
The tank arrangement shown in this enclosure is one possibility among several others.
Further possible tank arrangements, as example:

1)	HFO	1 settling tank	+ 1 service tank
	LSHFO	1 settling tank	+ 1 service tank
	DO	1 settling tank	+ 1 service tank
2)	HFO	2 settling tanks	+ 1 service tank
	LSHFO	2 settling tanks	+ 1 service tank
	DO	1 settling tank	+ 1 service tank
3)	HFO & LSFO combined	2 settling tanks	
	HFO	1 service tank	
	LSHFO	1 service tank	
	DO	1 settling tank	+ 1 service tank

Remark concerning the fuel oil pumps

The feed and booster pump capacities should be specified for the lower fuel oil viscosity, which normally corresponds to the MDO grade (7 - 11 cSt at 40°C). With lower fuel viscosities, the nominal pump capacities will decrease, therefore this has to be considered when determining the capacities of the feed and booster pumps.
Furthermore, the lower lubricating capacity of distillate fuels with low viscosity compared to HFO may influence the lifetime of the feed and booster pumps, especially when operating long periods with these fuels. Therefore, the advice of the pump manufacturers should be sought regarding pump performance when operating with distillate fuels.

-					

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3.1 Pressurised fuel oil system

The main difference to the standard pressurised fuel oil system is the adding of a cooler, as shown in figure 4, page 13, to cool down the DO depending on the used viscosity grade.

3.1.1 Cooler position

The cooler-chiller unit should be located before the viscosimeter with the sensor to control the fuel temperature located close to the engine inlet.
Other locations, as for example in the fuel engine return line, are not recommended. The advantage of locating the cooler close to the engine inlet is to reduce as far as possible the reaction time of the fuel temperature control as it is done with fuel end heater, which is also located in the fuel delivery line to the engine.

3.1.2 Cooler principle

There are two possible cooling principles:

- Direct cooling: where the heat exchange directly occurs between the distillate fuel and the refrigerant (refrigerant – fuel).
- The indirect-cooling: Where the refrigerant cools down fresh water (FW), which in turns cools down the distillate fuel (refrigerant – FW / FW – distillate fuel), as shown in figure 4.

The double heat exchanger arrangement is favoured basically in the event of fuel or refrigerant leakages; therefore direct cooling seems to be not accepted by the classification societies. However, shipyards should approach class for their advice / rules regarding direct cooling systems.
Seawater as coolant is, of course, not recommended at all.

3.1.3 Cooler heat dissipation

The cooler heat dissipation (Q) is determined by the following formula:

$$\mathbf{Q =}\ m * cp * DT[kW]$$

Where:	m	mass of the distillate fuel passing the cooler [kg/s]
	cp	specific heat capacity of the distillate fuel [kJ/kg °C]
	cp	2.0 – 2.2 kJ/kg °C
	DT	T1’ – T2
	T1’	temperature at the cooler inlet [°C]
	T2	temperature at the cooler outlet [°C]

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The temperature (T1') results from the mixing of the fuel part returning from the engine (temperature Tr) and the distillate fuel supply to the engine (temperature T1); the distillate fuel amount corresponding to the actual fuel consumption, see below figure.
The temperature difference (Tr – T2) corresponds to the fuel temperature increase across the engine injection system.

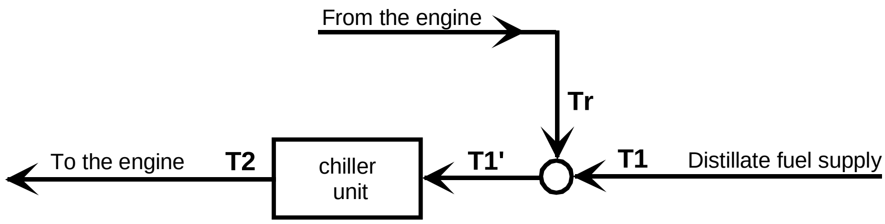


Figure 1

The below formulae allow to determine the required heat dissipation **at 100% engine load** by taking into account the temperature increase across the engine.

For RT-flex engines

$$Q = \frac{[\ BSFC * P * (DT + 6)\ ]}{1.42 * 10^6}$$

For RTA engines

$$Q = \frac{[\ BSFC * P * (DT + 12)\ ]}{1.42 * 10^6}$$

Where:		
	Q	Cooler heat dissipation at 100% engine load
	BSFC	Specific fuel consumption at design conditions and 100% engine load [g/kWh]
	P	Engine power at 100% CMCR [kW]
	DT	T1 – T2
	T1	Temperature of the distillate fuel supply [°C]
	T2	Distillate fuel temperature required at engine inlet [°C]

-					

WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTMOT	Distillate Fuels Installation Aspects	Group 9723
	Drawn: M. Lüthi 20.11.09 / Verif:: C. Van Gijssel 30.11.09	4-107.428.377	5 / 15

At 100% engine load, the temperature at the cooler inlet (= mixing temperature T1') can simply be determined by the following formulae:

For RT-flex engines

T1' = $0.455 * T1 + 0.545 * T2 + 2.73$ **[C°]**

For RTA engines

T1' = $0.455 * T1 + 0.545 * T2 + 5.46$ **[C°]**

Example with RT-flex engine

7RT-flex82T

P = 31640 kW, BSFC = 170 g/kWh (design conditions)
Distillate fuel: DMA, viscosity 1.5 cSt at 40°C, supply temperature T1 = 45°C,
to reach a viscosity of 2 cSt, DMA is to be cooled down from 45°C to 22°C
⇨ chosen T2 = 20°C

Q = $\frac{[\ 170 * 31640 * ((45 - 20) + 6)\ ]}{1.42 * 10^6} = 117kW \Rightarrow 120kW$

T1' = $0.455 * 45 + 0.545 * 20 + 2.73 = 34.1\,°C$

Example with RTA engine

12RTA96C-B

P = 68640 kW, BSFC = 180 g/kWh (design conditions)
Distillate fuel: DMA, viscosity 1.5 cSt at 40°C, supply temperature T1 = 35°C,
to reach a viscosity of 2 cSt, DMA is to be cooled down from 45°C to 22°C
⇨ chosen T2 = 20°C

Q = $\frac{[\ 180 * 68640 * ((35 - 20) + 12)\ ]}{1.42 * 10^6} = 235kW$

T1' = $0.455 * 35 + 0.545 * 20 + 5.46 = 32.3\,°C$

WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTMOT Drawn: M. Lüthi 20.11.09 Verif:: C. Van Gijssel 30.11.09	Distillate Fuels Installation Aspects		Group 9723
		4-107.428.377		6 / 15

4. Fuel change-over procedure (Refer to figure 3)
Changing over from diesel oil (DO) to heavy fuel oil (HFO) and vice versa

The change-over of the main engine operating mode HFO / DO or vice versa occurs through the three-way valve installed in the suction line from the HFO and DO tank (see figure 4, position 01).
When changing from one fuel to another however, thermal shock to the engine fuel injection system (injection pumps, piping, etc.) has to be prevented. Sudden temperature changes may lead to seizing of the fuel pump plungers; this may affect the manoeuvrability of the ship, or result in fuel pipe leakage with the risk of fire.
Not only the temperature increase when changing over from DO to HFO is important, but also the temperature decrease when changing over from HFO to DO.
The experience gained so far shows that the use of change-over valves (01) with time delay (e.g.: 10’ duration from 100% on HFO to 100% DO), and acting therefore as mixing valves, has not been very successful. This is due to the fact that to mix both fuels properly, the HFO and DO pressures at the valve inlet must be equal, which, in practice, is hardly feasible.

A metering device gradually mixing DO and HFO to obtain the required temperature gradient could be foreseen. However, such a metering device will require additional components (pumps, mixing valve, etc.) to the existing fuel oil circuit and is considered as not necessary.

4.1 Change-over from DO to HFO

The fuel viscosity is controlled by the viscosimeter and the increase in the fuel temperature itself can be manually or automatically controlled. Depending on the viscosimeter type, a temperature ramp (gradient) can be set to automatically control the change in temperature. The maximum temperature gradient must not exceed 15 °C/min.
The engine load must not exceed 75% of CMCR until the change-over procedure is finalised and the required HFO viscosity (13 to 17 cSt) is reached. The trace heating on the engine and installation side must be turned on at the same time when changing over.
The change-over procedure itself is detailed in the relevant engine operating manual.

4.2 Change-over from HFO to DO

In this case, the temperature change cannot be influenced by the viscosimeter, but by the fuel volume available in the fuel system (as well as by the involved steel mass of the fuel system).
The mixing unit (04) serves to equalise the fuel oil temperature between the hot surplus heavy fuel oil returning from the engine and the heavy fuel oil from the service tank. It also provides an additional fuel volume, which limits the temperature gradients when changing over from HFO to DO or vice versa.

-					

WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTMOT Drawn: M. Lüthi 20.11.09 Verif:: C. Van Gijssel 30.11.09	**Distillate Fuels** Installation Aspects **4-107.428.377**	Group **9723** **7 / 15**

A large capacity of the mixing unit will be of advantage in further reducing the temperature gradient. This will however increase the period for which both fuels are present together, and consequently the risk of compatibility problems may increase.
The pipe diameters are normally dictated by the fluid velocity, however, the use of larger pipe diameters as required for the fuel oil pressurised circuit will be of advantage too, e.g. DN80 instead of DN65
A suggested measure to reduce the temperature difference between both fuels before changing over is to increase the DO temperature in the service tank. Such a measure should be considered with caution: the flash point of distillate fuels being rather low, e.g. 60°C for DMA grade. Further, this measure can be considered as a waste of energy: on one hand the DO is pre-heated and on the other hand is cooled down again to reach the required viscosity before entering the engine.
Figure 5, page 14, shows, as example, the progression trend of the fuel temperature as a function of the time for various engine loads by switching the change-over valves (01) from HFO to DO without any time delay. The highest temperature drop resulting in the highest temperature gradient takes place just after the change-over as it can be seen on this enclosure.

The engine load must be lower than 50% CMCR until the change-over procedure is finalised and until the required DO viscosity (≥ 2 cSt) is reached. After a short period following the change-over from HFO to DO, the trace heating on the engine and installation side must be shut off. The change-over procedure itself is detailed in the relevant engine operating manual.

5. Cylinder oil lubrication

For operation on fuel with a sulphur content lower than 1.5%, the cylinder oil feed rate should be low and have 40BN. This is in order to prevent build-up of deposits, originating from un-neutralized hard calcium carbonate deposits.
Prior to changing over to distillate fuels the cylinder oil should be switched over to allow for the higher BN oil to be flushed through. The time for this to be achieved depends on the layout of the piping system, and in particular the volume. The use of low BN oil with a fuel with higher sulphur content during this relatively short change-over period will not have an adverse effect on the liner wear rates.

6. Cylinder oil lubricating system

Figure 6, page 15, shows an arrangement of the cylinder lubricating system with two storage (01) and service tanks (02) for operation with high and low BN. The change-over from one oil quality to another occurs by means of the three-way valve (04), which is to be fitted as close as possible to the engine inlet, to avoid a too long time delay in the oil delivery due to the oil volumes contained in the supply pipes when changing over.

-			
WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTMOT Drawn: M. Lüthi 20.11.09 Verif:: C. Van Gijssel 30.11.09	Distillate Fuels Installation Aspects 4-107.428.377	Group 9723 8 / 15

7. Enclosures

ISO 8217 Fuel Standard - Marine Distillate Fuels

Parameter	Unit	Limit	DMX	DMA	DMB	DMC
Density at 15 °C	kg/m³	Max	-	890	900	920
Viscosity at 40 ° C	mm²/s	Max	5.5	6	11	14
Viscosity at 40 °C	mm²/s	Min	1.4	1.5	-	-
Micro Carbon Residue at 10% Residue	% m/m	Max	0.3	0.3	-	-
Micro Carbon Residue	% m/m	Max	-	-	0.3	2.5
Water	% V/V	Max	-	-	0.3	0.3
Sulphur [c]	% (m/m)	Max	1	1.5	2	2
Total Sediment Existent	% m/m	Max	-	-	0.1	0.1
Ash	% m/m	Max	0.01	0.01	0.01	0.05
Vanadium	mg/kg	Max	-	-	-	100
Aluminium + Silicon	mg/kg	Max	-	-	-	25
Flash point	°C	Min	43	60	60	60
Pour point, Summer	°C	Max	-	0	6	6
Pour point, Winter	°C	Max	-	-6	0	0
Cloud point	°C	Max	-16	-	-	-
Calculated Cetane Index		Min	45	40	35	-
Appearance			Clear & Bright		-	-
Zinc [d]	mg/kg	Max	-		-	15
Phosphorus [d]	mg/kg	Max	-		-	15
Calcium [d]	mg/kg	Max	-		-	30
c	A sulphur limit of 1.5% m/m will apply in SOx Emission Control Areas designated by the International Maritime Organization, when its relevant Protocol comes into force. There may be local variations.					
d	The Fuel shall be free of ULO. A Fuel is considered to be free of ULO if one or more of the elements are below the limits. All three elements shall exceed the limits before deemed to contain ULO.					

Source: ISO 8217 Third Edition 2005-11-01
Petroleum products - Fuels (class F) - Specifications of marine fuels

Table 1

WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTMOT	**Distillate Fuels** Installation Aspects	Group **9723**
	Drawn: M. Lüthi 20.11.09 Verif:: C. Van Gijssel 30.11.09	**4-107.428.377**	**9 / 15**

DMA (MGO) viscosity as a function of the temperature

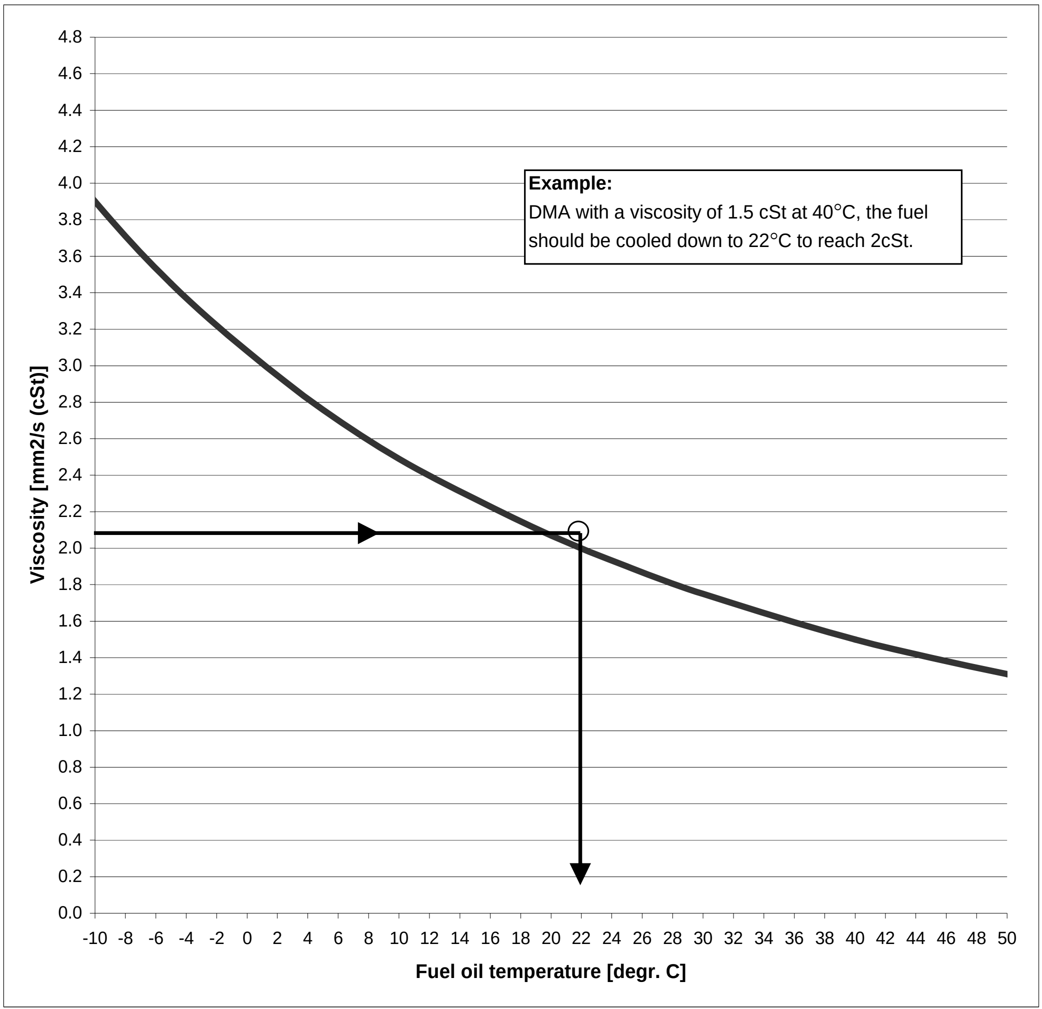
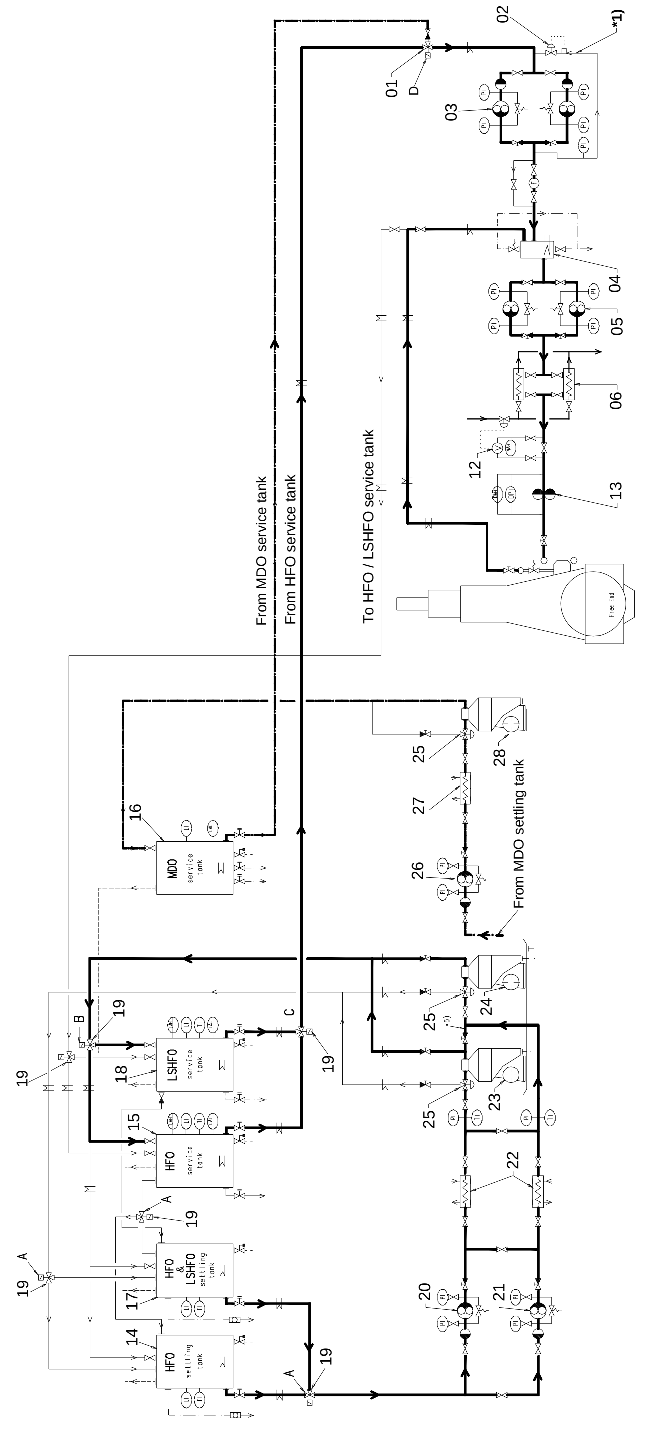


Figure 2

-					

WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTMOT	**Distillate Fuels** Installation Aspects	Group **9723**
	Drawn: M. Lüthi 20.11.09 Verif:: C. Van Gijssel 30.11.09	**4-107.428.377**	**10 / 15**

Fuel oil system



A These 3 change-over valves should be interconnected
B Change-over LSHFO and HFO for fuel treatment
C Change-over LSHFO and HFO for ME operation
D Change-over LSHFO/HFO and MDO for ME operation

Figure 3

For legend and additional information refer to table 2

WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTMOT	Distillate Fuels Installation Aspects		Group 9723
	Drawn: M. Lüthi 20.11.09 Verif:: C. Van Gijssel 30.11.09	4-107.428.377		11 / 15

Fuel oil system

01	Three-way valve, manually or remotely operated
02	Pressure regulating valve
03	Low pressure feed pump
04	Mixing unit, heated and insulated
05	High pressure booster pump
06	Fuel end-heater
[…]	
12	Viscosimeter
13	Fuel oil filter, heated
14	HFO settling tank, heated and insulated
15	HFO service tank, heated and insulated
16	MDO service tank
17	LSHFO settling tank, heated and insulated
18	LSHFO service tank, heated and insulated
19	Three-way valve, manually or remotely operated
20	HFO/LSHFO separator supply pump, with safety valve *2)
21	HFO/LSHFO separator supply pump, with safety valve *2)
22	HFO/LSHFO pre-heater
23	Self-cleaning HFO/LSHFO separator *3)
24	Self-cleaning HFO/LSHFO separator *3)
25	Three-way valve, diaphragm operated
26	MDO separator supply pump, with safety valve *2)
27	MDO pre-heater
28	Self-cleaning MDO separator

Table 2

Remarks:

*1) The return pipe may also be led to the HFO service tank.

*2) Pump may be omitted, if integrated in separator.

*3) Separator capacity related to viscosity in accordance with the instructions of the separator manufacturer.

WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTMOT Drawn: M. Lüthi 20.11.09 Verif:: C. Van Gijssel 30.11.09	**Distillate Fuels** Installation Aspects **4-107.428.377**	Group **9723** **12 / 15**

Pressurised fuel oil system

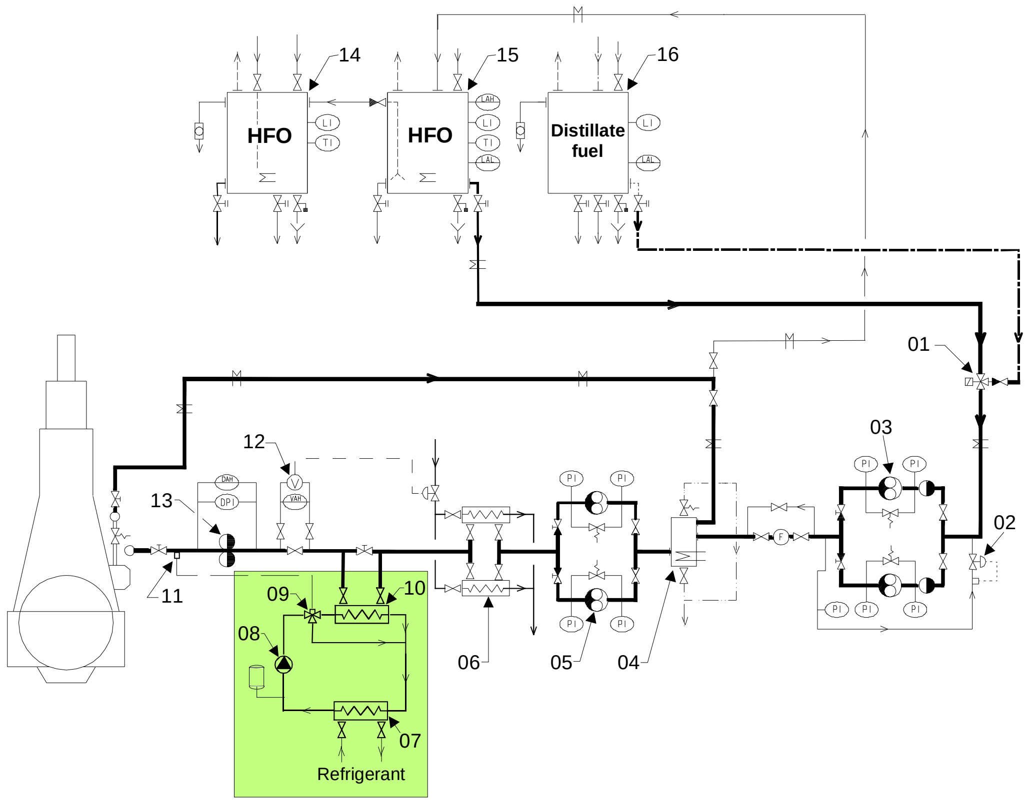


Figure 4

01	Three-way valve, manually or remotely operated	11	Temperature sensor
02	Pressure regulating valve	12	Viscosimeter
03	Low pressure feed pump	13	Fuel oil filter
04	Mixing unit	14	HFO settling tank
05	High pressure booster pump	15	HFO service tank
06	Fuel end heater	16	Distillate fuel service tank
07	Chiller (cooler-chiller unit)		
08	Fresh water circulating pump (cooler-chiller unit)		
09	Temperature control valve (cooler-chiller unit)		
10	FW – fuel oil cooler (cooler-chiller unit)		

WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTMOT Drawn: M. Lüthi 20.11.09 Verif:: C. Van Gijssel 30.11.09	**Distillate Fuels** Installation Aspects **4-107.428.377**	Group **9723** **13 / 15**

Fuel oil temperature at the engine inlet as a function of the time when changing over at once from HFO to DO

HFO temperature 145°C

DO temperature 35 °C

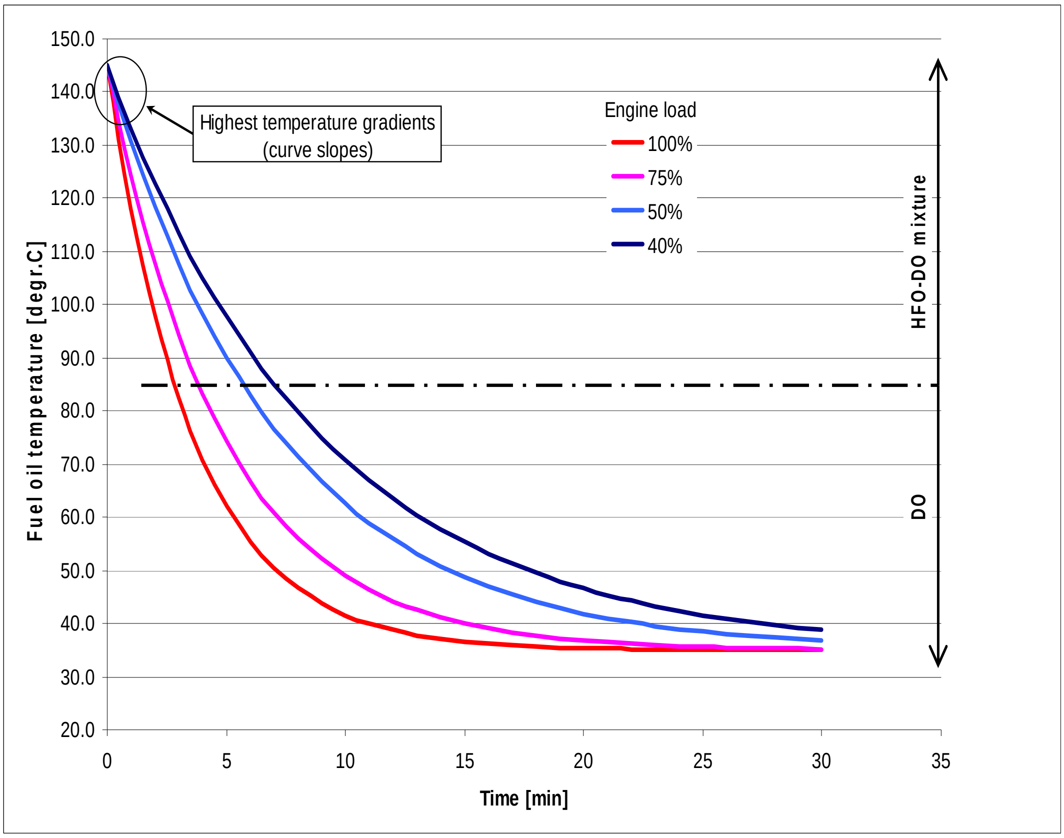


Figure 5

WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTMOT Drawn: M. Lüthi 20.11.09 Verif:: C. Van Gijssel 30.11.09	Distillate Fuels Installation Aspects	4-107.428.377	Group 9723 14 / 15

Cylinder lubricating system

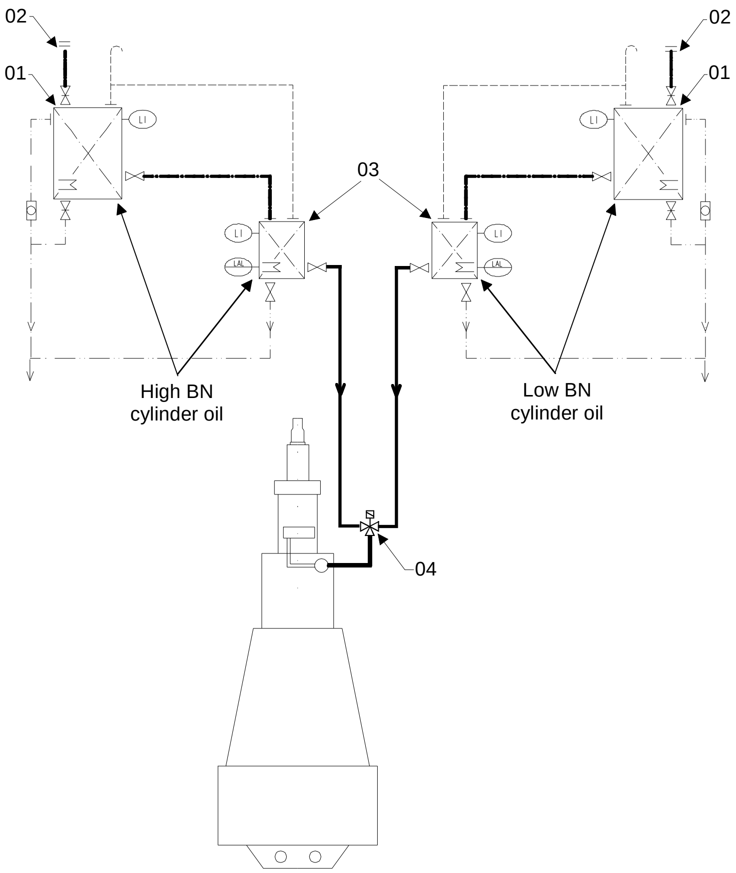


Figure 6

01 Cylinder lubricating oil storage tanks
02 Deck connection
03 Cylinder lubricating oil service tanks
04 Three-way valve, manually or remotely operated

WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTMOT	**Distillate Fuels** Installation Aspects	Group **9723**
	Drawn: M. Lüthi 20.11.09 Verif:: C. Van Gijssel 30.11.09	**4-107.428.377**	**15 / 15**

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11. 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.The starting and control air system shown in figure *11.1* comprises two air compressors, two air receivers, and systems of pipework and valves connected to the engine starting air manifold.

For all relevant and prevailing information consult the drawings in section 'Drawings' at the end of this chapter.

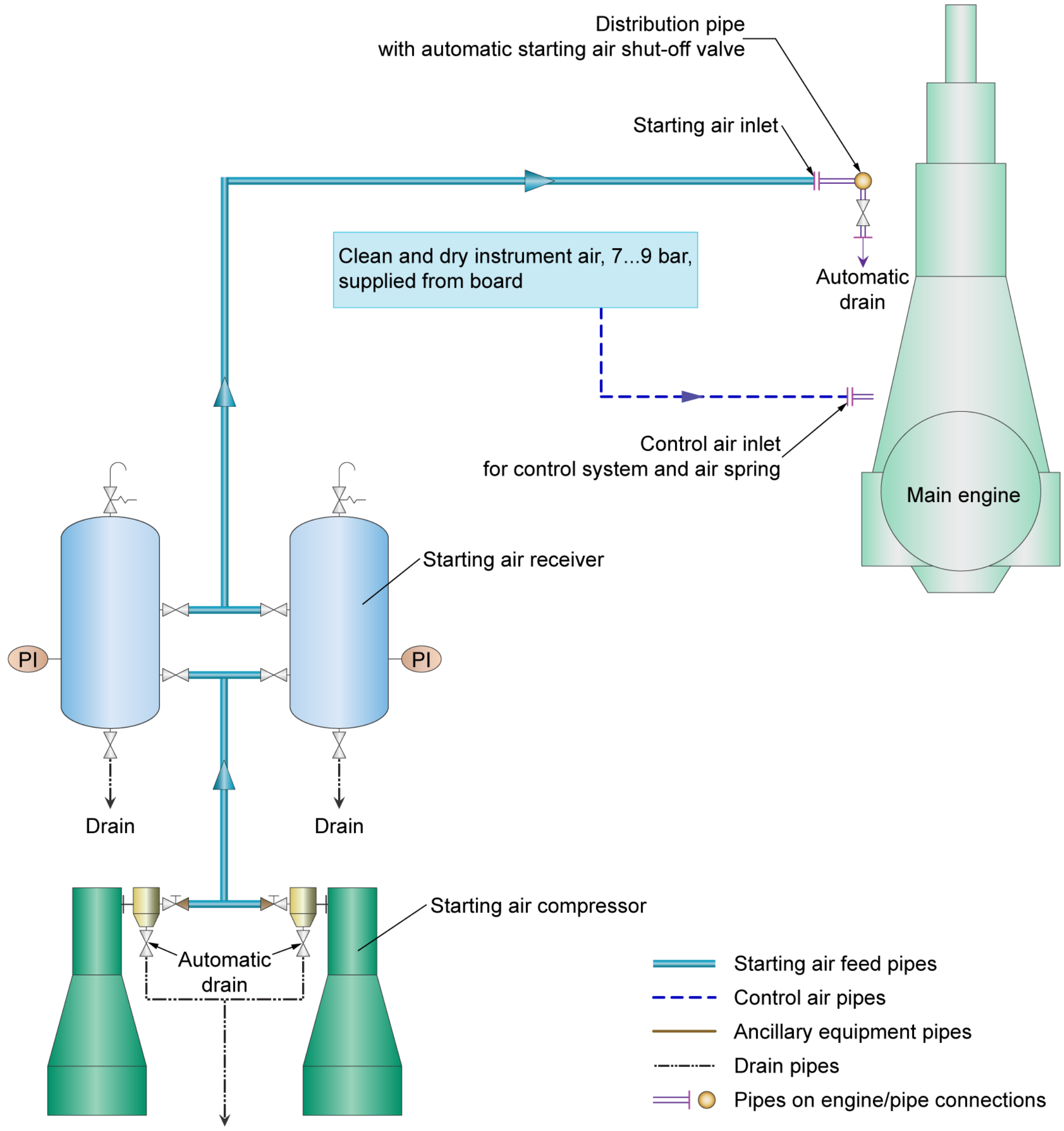


Figure 11.1: Starting and control air system

11.1 Capacities of air compressor and receiver

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

- 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 section *11.1.1*
- Relative inertia $J_{Rel} = J_{Tot} / J_{Eng}$

The air receiver and compressor capacities of section *11.1.1* 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 and netGTD*. It provides data on the capacity of air compressor and receiver for relative inertia values (J_{Rel}).

Section *11.1.1* outlines the basic requirements for a system similar to figure *11.1* for maximum engine rating. The *winGTD and netGTD* enable to optimise the capacities of the compressors and air receivers for the contract maximum continuous rating (CMCR).

11.1.1 Air receiver and air compressor capacities

Starting air			J_{Eng} *2)
No. cyl.	Air receivers	Air compressors	
	Number of starts requested by the classification societies for reversible engines: 12 *1)		
	Max. air pressure: 30 bar	Free air delivery at: 30 bar	
	Number x volume *3) [m³]	Number x capacity *3) [Nm³/h]	[kgm²]
5	2 x 2.0	2 x 60	11,002
6	2 x 2.0	2 x 60	12,704
7	2 x 2.5	2 x 75	14,606
8	2 x 2.5	2 x 75	16,688

Table 11.1: Air receiver and air compressor capacities

NOTICE

*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 smallest flywheel included.

*3) Data for air pressure of 25 bar are available on winGTD and netGTD.

11.2 Starting and control air system specification

11.2.1 Starting air compressors

Generally: .... 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 section *11.1.1*

Delivery gauge pressure: .... 30 bar

11.2.2 Starting air receivers

Type: .... fabricated steel pressure vessels having domed ends and integrated pipe fittings for isolating valves, automatic drain valves, pressure reading instruments and pressure relief valves

Capacity: .... refer to section *11.1.1*

Working gauge pressure: .... 30 bar

11.2.3 Control air system supply

The control air is supplied from the board instrument air supply system (see figure *11.1*) providing air at 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)

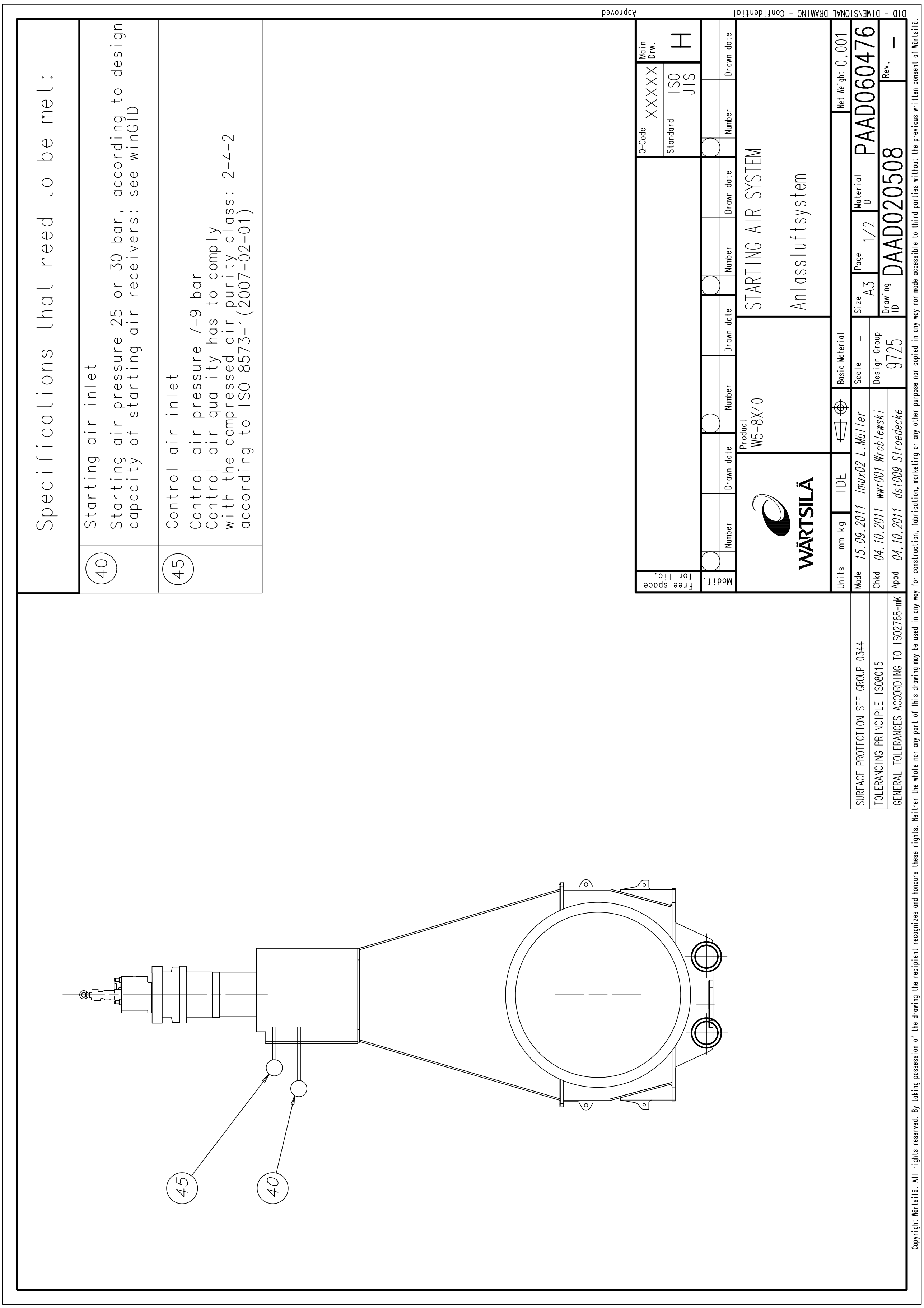
Control air capacities

No. of cyl.	Capacity [Nm³/h]		
	Control system up to	Exhaust valve air spring	Total
5	21.0	12.0	**33.0**
6	21.0	14.4	**35.4**
7	21.0	16.8	**37.8**
8	21.0	19.2	**40.2**

11.3 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 also provided by the board instrument air supply system.

11.4 Drawings


Specifications that need to be met:
40 Starting air inlet
Starting air pressure 25 or 30 bar, according to design capacity of starting air receivers: see winGTD
45 Control air inlet
Control air pressure 7-9 bar
Control air quality has to comply with the compressed air purity class: 2-4-2 according to ISO 8573-1(2007-02-01)
45
40
Approved
DID - DIMENSIONAL DRAWING - Confidential
Q-Code XXXXX
Main Drw. H
Standard ISO JIS
Free space for lic.
Modif. Number Drawn date
STARTING AIR SYSTEM
Anlassluftsystem
Product W5-8X40
WÄRTSILÄ
Units mm kg IDE
Basic Material
Net Weight 0.001
Made 15.09.2011 lmux02 L.Müller
Chkd 04.10.2011 wwr001 Wroblewski
Appd 04.10.2011 dst009 Stroedecke
Scale -
Size A3
Page 1/2
Material ID PAAD060476
Design Group 9725
Drawing ID DAAD020508
Rev. -
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
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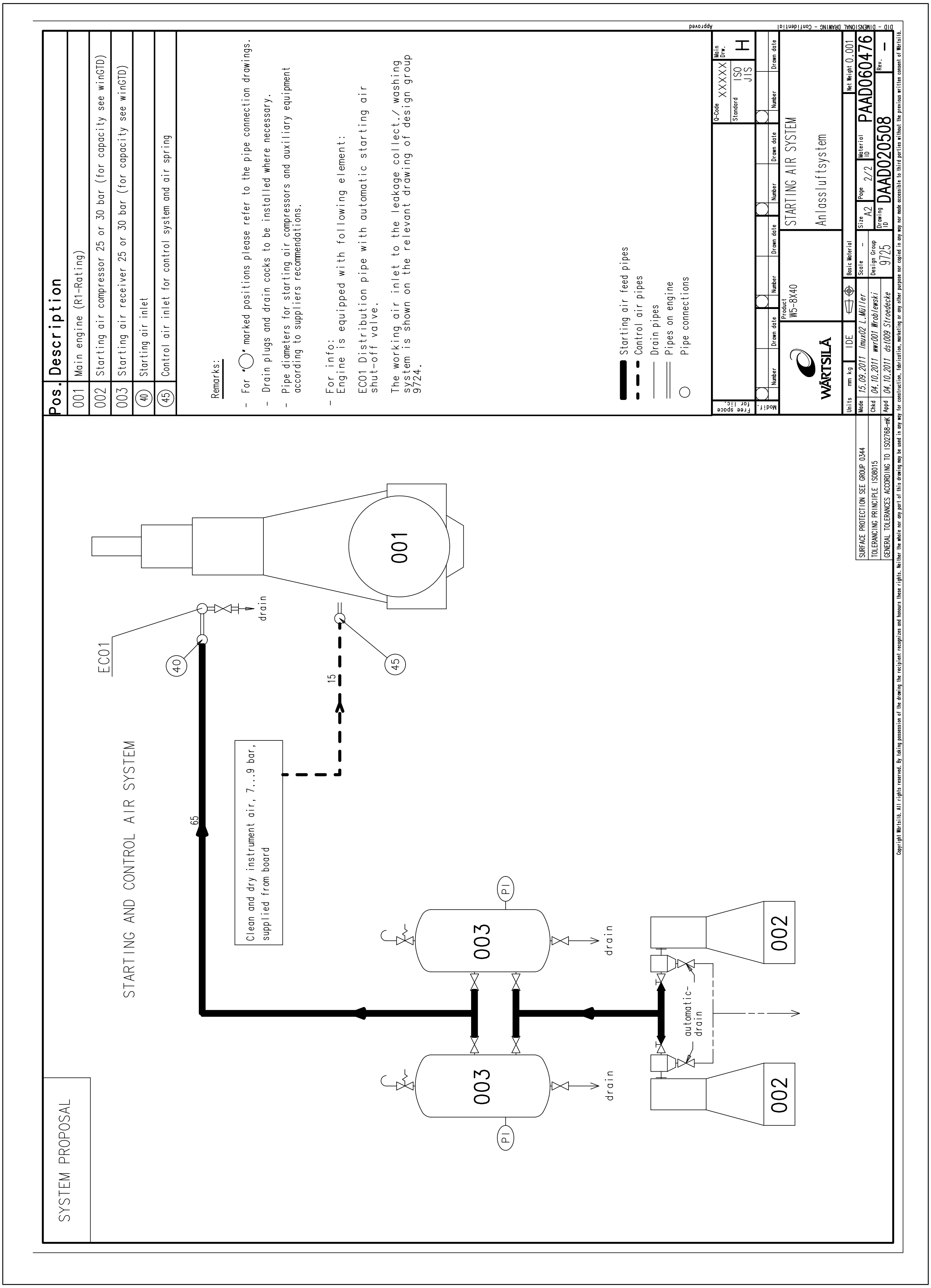
SYSTEM PROPOSAL
STARTING AND CONTROL AIR SYSTEM
Pos. Description
001 Main engine (R1-Rating)
002 Starting air compressor 25 or 30 bar (for capacity see winGTD)
003 Starting air receiver 25 or 30 bar (for capacity see winGTD)
40 Starting air inlet
45 Control air inlet for control system and air spring
Remarks:
- For marked positions please refer to the pipe connection drawings.
- Drain plugs and drain cocks to be installed where necessary.
- Pipe diameters for starting air compressors and auxiliary equipment according to suppliers recommendations.
- For info:
Engine is equipped with following element:
EC01 Distribution pipe with automatic starting air shut-off valve.
The working air inlet to the leakage collect./ washing system is shown on the relevant drawing of design group 9724.
Starting air feed pipes
Control air pipes
Drain pipes
Pipes on engine
Pipe connections
Clean and dry instrument air, 7...9 bar, supplied from board
EC01
drain
65
15
PI
automatic-drain
STARTING AIR SYSTEM
Anlassluftsystem
Product W5-8X40
WÄRTSILÄ
PAAD060476
DAAD020508
9725
A2
2/2
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
15.09.2011 lmux02 L.Müller
04.10.2011 wwr001 Wroblewski
04.10.2011 ds1009 Stroedecke

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12. Leakage Collection System

Dirty oil collected from the piston underside is led under a pressure of approximately 2.8 bar to the sludge oil trap and then to the sludge oil tank. The purpose of the sludge oil trap is to retain the large amount of solid parts contained in the dirty oil and to reduce the pressure by means of an orifice or throttling disc fitted at its outlet, so that the sludge oil tank is under atmospheric pressure. 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.

⚠WARNING

For all relevant and prevailing information consult the drawings in section 'Drawings' at the end of this chapter.

12.1 Sludge oil trap

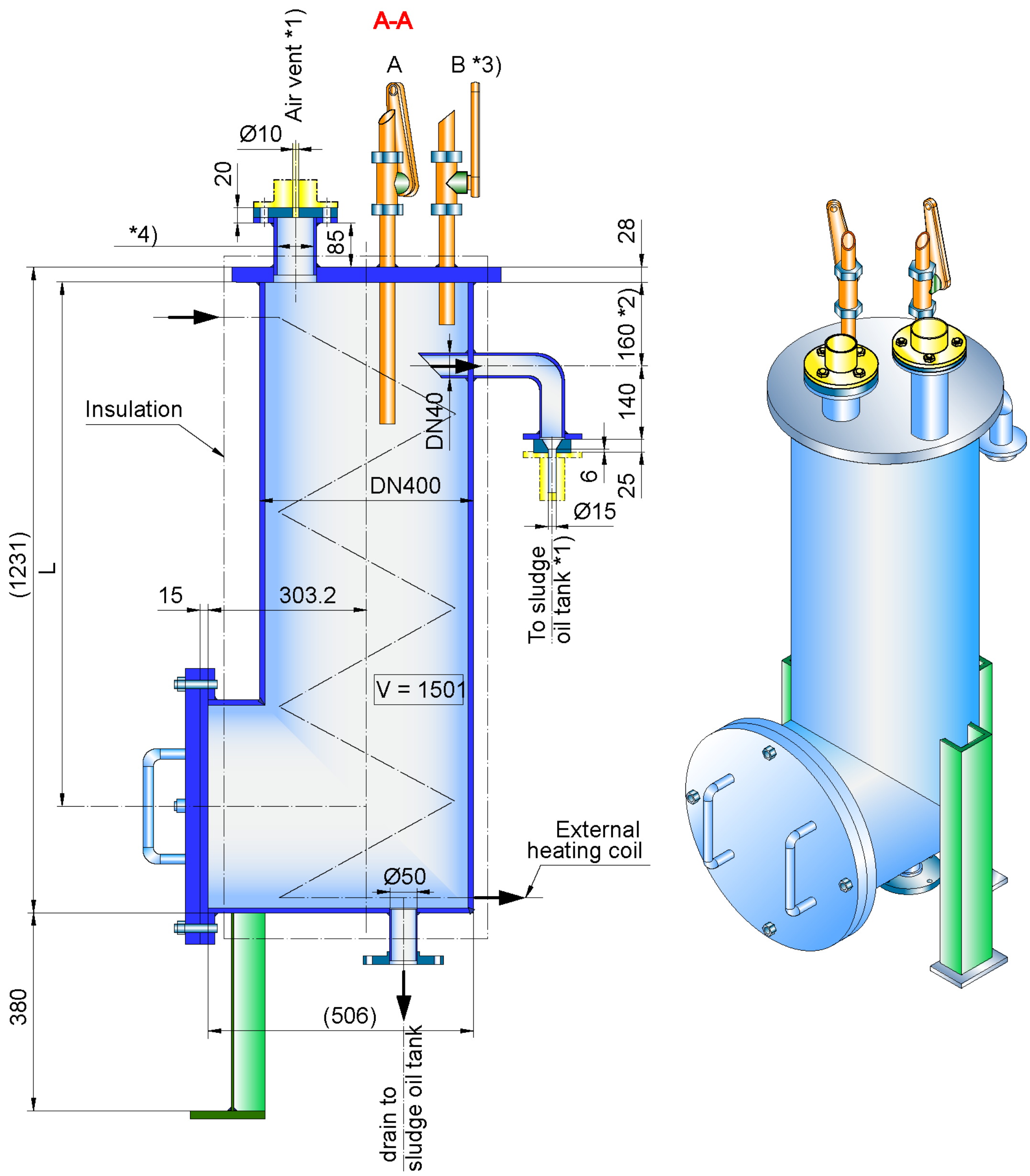


Figure 12.1: Sludge oil trap

NOTICE

*1) Orifice to be as shown.

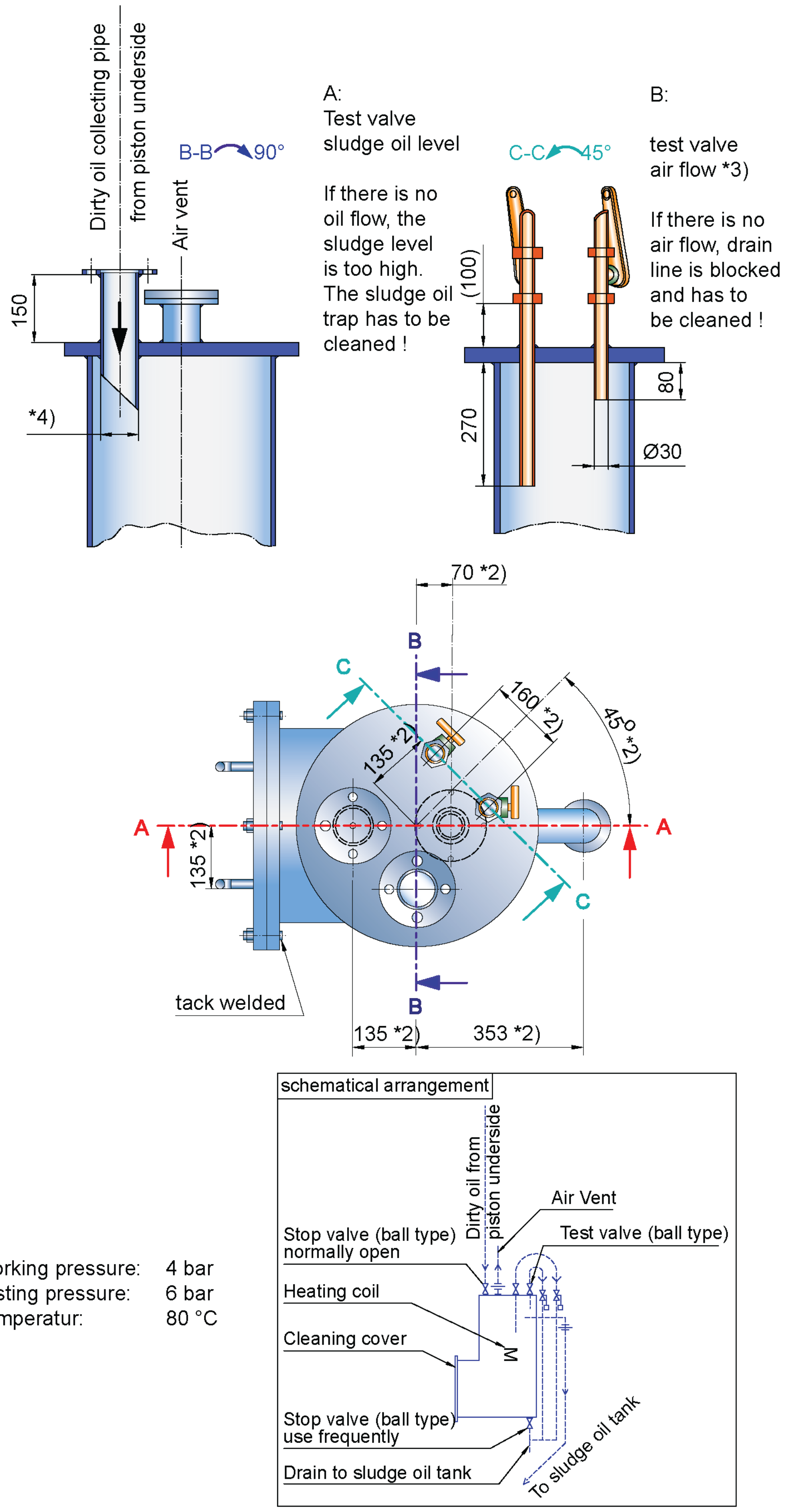
*2) Observe location of pipes with regard to each other.

*3) Optional - Alternatives, such as level sensors, are possible

*4) diametre =

L = 550 mm

Capacity = 100 l



Working pressure:	4 bar
Testing pressure:	6 bar
Temperatur:	80 °C

Figure 12.2: Sludge oil trap

Engine exhaust uptakes can be drained automatically using a system as shown in figure *12.3*.

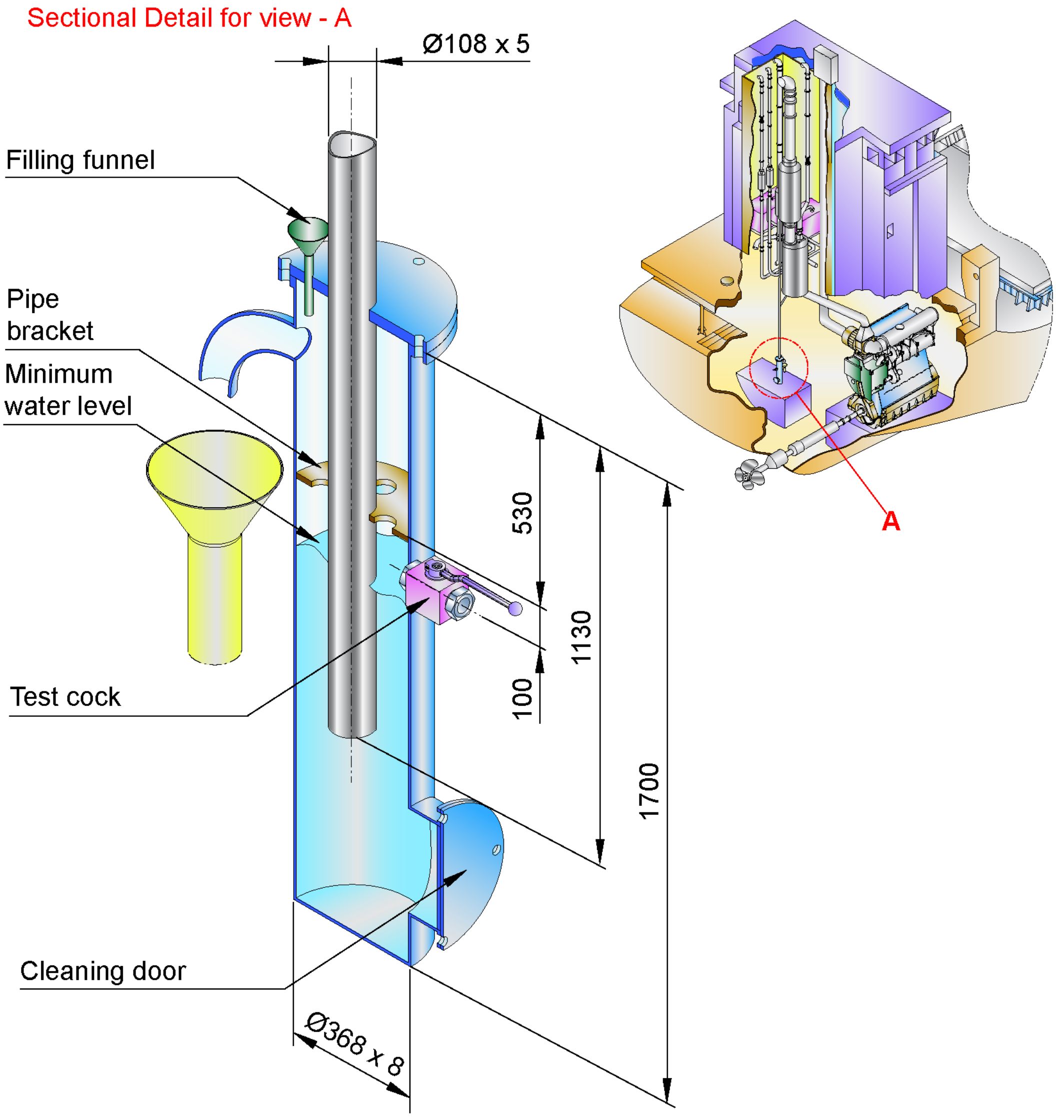


Figure 12.3: Arrangement of automatic water drain

⚠ WARNING

For all relevant and prevailing information consult the drawings in section 'Drawings' at the end of this chapter.

12.2 Air vents

The air vent pipes of the ancillary systems have to 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 an uninterrupted inclination of min. 5%.

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.

12.3 Drawings

Net Weight
0.001

Quantity	SEQ NO	Material ID	Material Name	Dimension/Occ.Dimension	Standard or Drawing	Basic Material Material Standard	Weight GR./NET
1	002	107.425.369.500	SLUDGE OIL TRAP		107.425.369		0.001
1	001	PAAD060489	LEAKAGE COLLECTION/WASHING SYS.		DAAD020518		0.001

PER ENGINE

Approved

Material ID: PAAD060490

Free space for lic.

Q-Code XXXXX

Standard ISO JIS

Main Drw. H

Modif.		Number	Drawn date		Number	Drawn date		Number	Drawn date		Number	Drawn date

WÄRTSILÄ

Product: W5-8X40

LEAKAGE COLLECTION/WASHING SYS.
SYSTEM DIAGRAM

Units mm kg | IDE | Basic Material | Net Weight

SURFACE PROTECTION SEE GROUP 0344	Made	15.09.2011 lmux02 L.Müller	Scale 1:1
TOLERANCING PRINCIPLE ISO8015	Chkd	04.10.2011 wwr001 Wroblewski	Design Group 9724
GENERAL TOLERANCES ACCORDING TO ISO2768-mK	Appd	04.10.2011 dst009 Stroedecke	

Size A3 | Page 1/1 | Material ID

Drawing ID DAAD020519 | Rev. –

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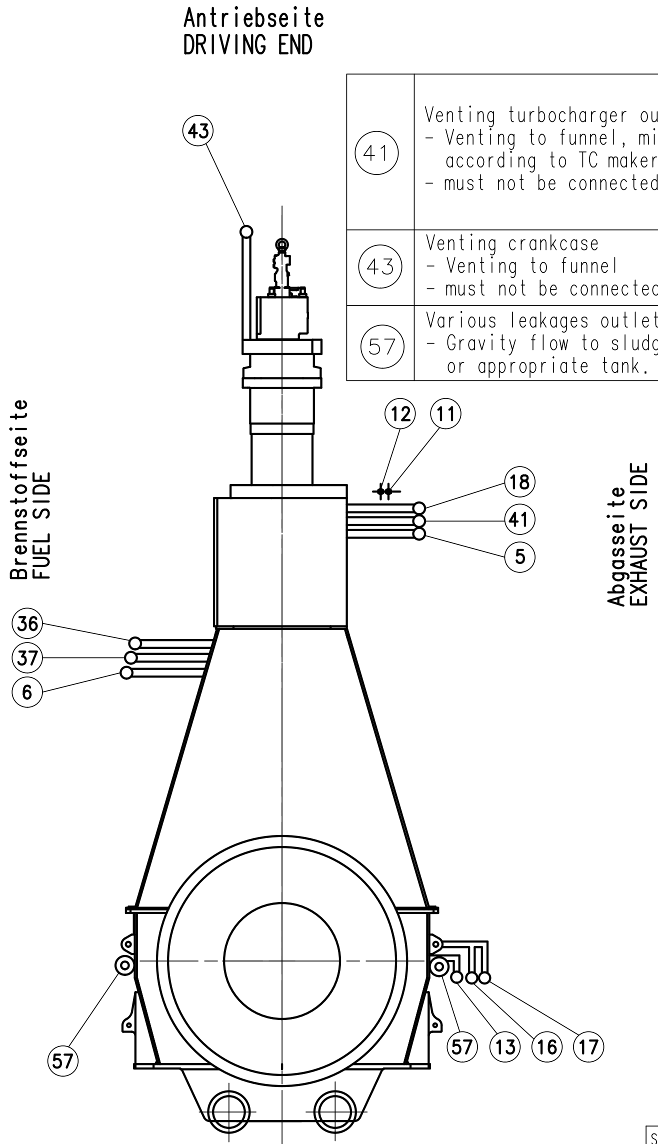


41	Venting turbocharger outlet - Venting to funnel, minimum inclination according to TC maker's spec. - must not be connected to other venting pipes.
43	Venting crankcase - Venting to funnel - must not be connected to other venting pipes.
57	Various leakages outlet - Gravity flow to sludge or appropriate tank.

Specifications that need to be met:

5	Cylinder cooling water drain outlet - Gravity flow to cooling water drain or appropirate tank.
6	SAC drain outlet - Gravity flow to cooling water drain or appropriate tank.
11	Washing water inlet SAC - From fresh water hydrophore system.
12	Air for cleaning plants TC and SAC, inlet. - Working air 6-9 bar.
13	Oily water from scavenge air receiver - Gravity flow to oily water or appropriate tank.
16	SAC condensate water - Gravity flow to bilge water or appropriate tank.
17	SAC washing water outlet - Gravity flow to bilge water tank chemical cleaning or appropriate tank.
18	SAC venting - Free flow venting.
36	Dirty oil piston underside outlet - Flow with SAC pressure to sludge oil trap or appropriate arrangement.
37	Leakage oil stuffing box outlet - Gravity flow to sludge or appropriate tank.

Free space for lic. | Q-Code XXXXX | Main Drw. | Standard ISO JIS

Modif. | Number | Drawn date | Number | Drawn date | Number | Drawn date | Number | Drawn date

WÄRTSILÄ | Product W5-8X40 | LEAKAGE COLLECTION/WASHING SYS. SYSTEM DIAGRAM

Units mm kg | IDE | Basic Material | Net Weight 0.001

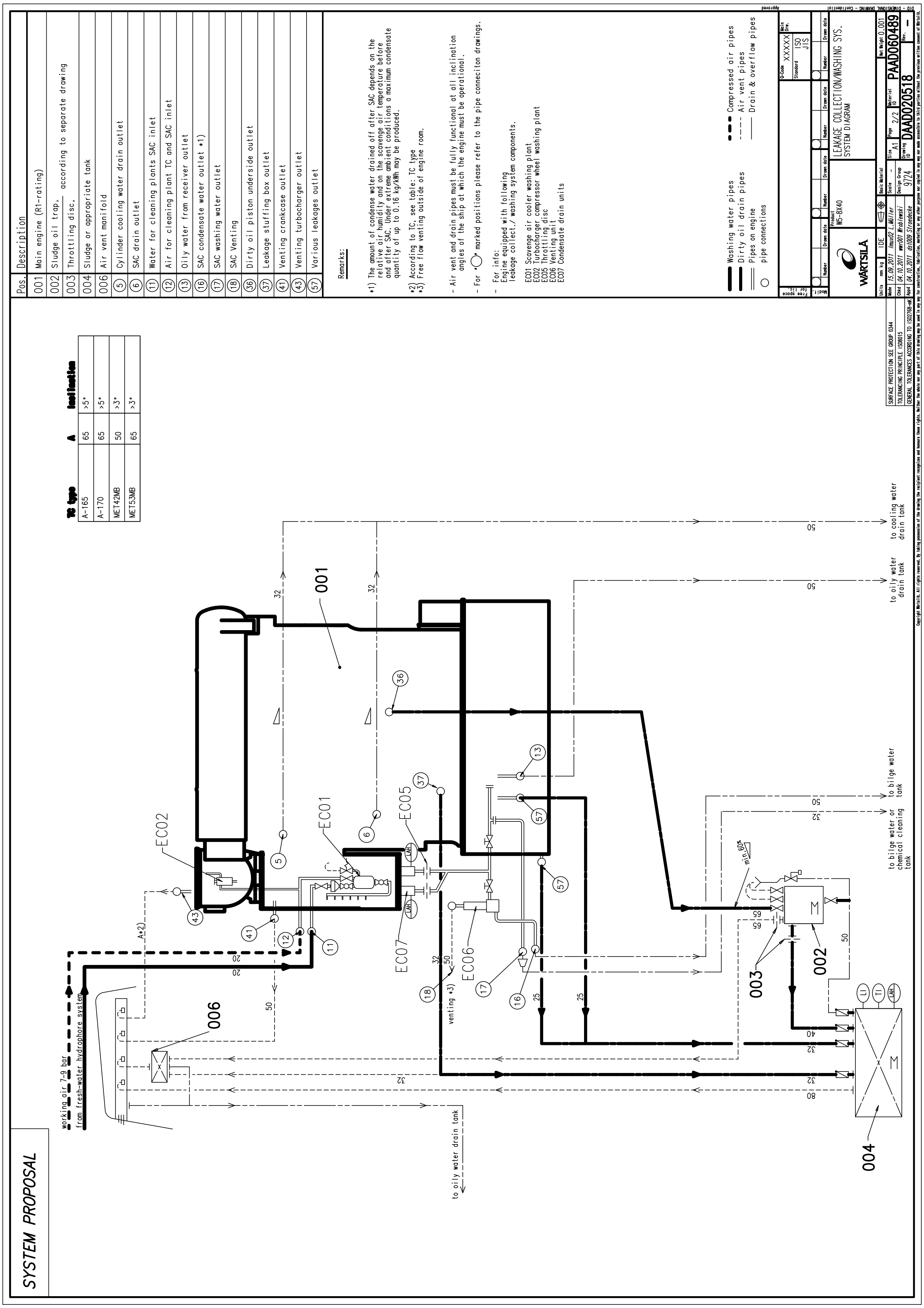
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK

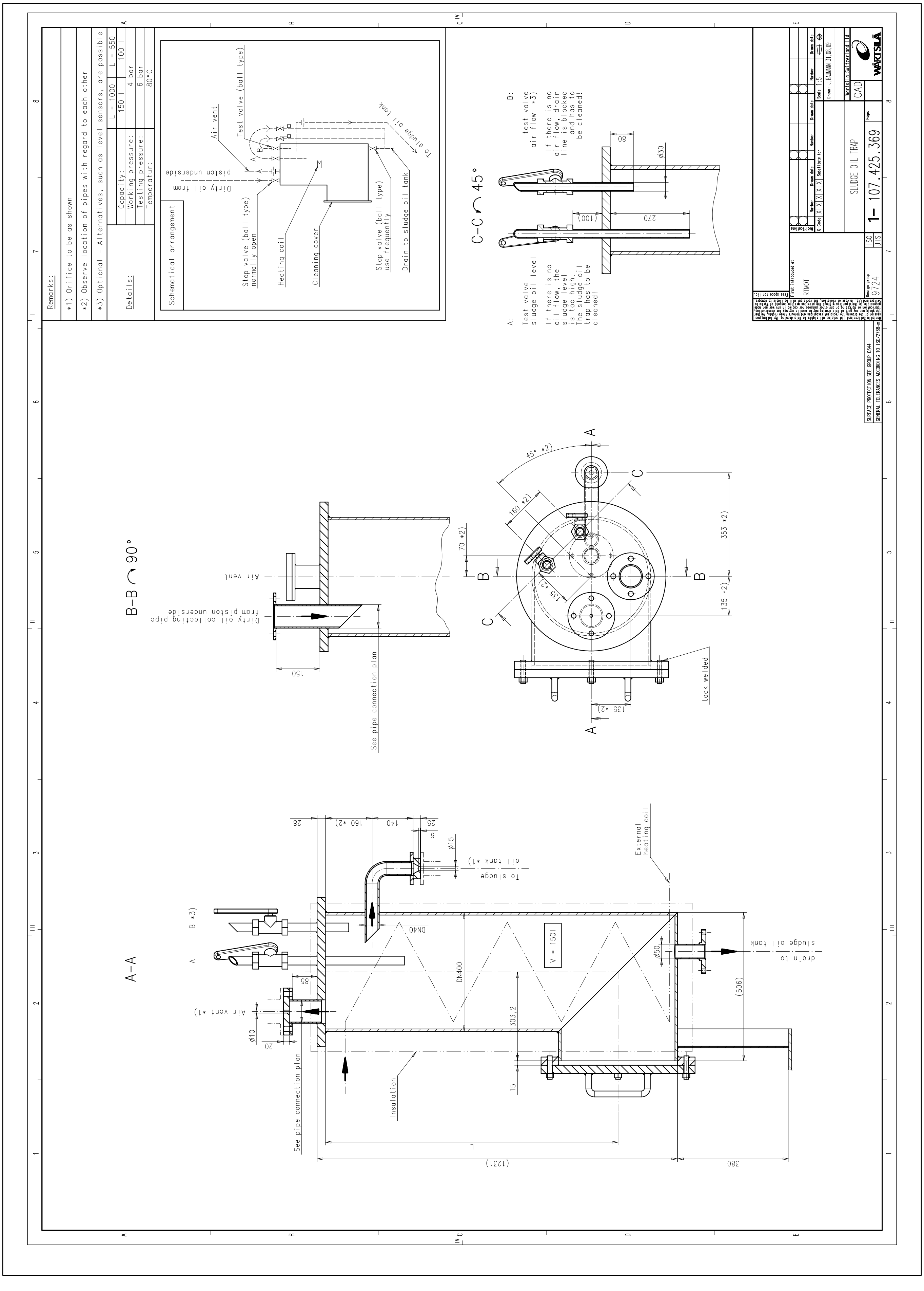
Made	15.09.2011	lmux02	L.Müller
Chkd	04.10.2011	wwr001	Wroblewski
Appd	04.10.2011	dst009	Stroedecke

Scale - | Design Group 9724 | Size A3 | Page 1/2 | Material ID PAAD060489 | Drawing ID DAAD020518 | Rev. -

Approved

DID - DIMENSIONAL DRAWING - Confidential


SYSTEM PROPOSAL
Pos. Description
001 Main engine (R1-rating)
002 Sludge oil trap, according to separate drawing
003 Throttling disc, according to separate drawing
004 Sludge or appropriate tank
006 Air vent manifold
5 Cylinder cooling water drain outlet
6 SAC drain outlet
11 Water for cleaning plants SAC inlet
12 Air for cleaning plant TC and SAC inlet
13 Oily water from receiver outlet
16 SAC condensate water outlet *1)
17 SAC washing water outlet
18 SAC Venting
36 Dirty oil piston underside outlet
37 Leakage stuffing box outlet
41 Venting crankcase outlet
43 Venting turbocharger outlet
57 Various leakages outlet
Remarks:
*1) The amount of condense water drained off after SAC depends on the relative air humidity and on the scavenge air temperature before and after SAC. Under extreme ambient conditions a maximum condensate quantity of up to 0.16 kg/kWh may be produced.
*2) According to TC, see table: TC type
*3) Free flow venting outside of engine room.
- Air vent and drain pipes must be fully functional at all inclination angles of the ship at which the engine must be operational.
- For * marked positions please refer to the pipe conneciton drawings.
- For info:
Engine equipped with following leakage collect./ washing system components.
EC01 Scavenge air cooler washing plant
EC02 Turbocharger compressor wheel washing plant
EC05 Throttling disc
EC06 Venting unit
EC07 Condensate drain units
Washing water pipes
Dirty oil drain pipes
Pipes on engine
pipe connections
Compressed air pipes
Air vent pipes
Drain & overflow pipes
TC type | A | Inclination
A-165 | 65 | >5°
A-170 | 65 | >5°
MET42MB | 50 | >3°
MET53MB | 65 | >3°
working air 7-9 bar
from fresh-water hydrophore system
to oily water drain tank
to cooling water drain tank
to oily water drain tank
to bilge water tank
to bilge water or chemical cleaning tank
venting *3)
min.60°
LEAKAGE COLLECTION/WASHING SYS.
SYSTEM DIAGRAM
W5-BX40
WÄRTSILÄ
DAAD020518
PAAD060489
9724


Remarks:
*1) Orifice to be as shown
*2) Observe location of pipes with regard to each other
*3) Optional - Alternatives, such as level sensors, are possible
Details:
Capacity: L = 1000 150 l L = 550 100 l
Working pressure: 4 bar
Testing pressure: 6 bar
Temperatur: 80°C
Schematical arrangement
Air vent
Test valve (ball type)
Dirty oil from piston underside
To sludge oil tank
Stop valve (ball type) normally open
Heating coil
Cleaning cover
Stop valve (ball type) use frequently
Drain to sludge oil tank
C-C 45°
A: Test valve sludge oil level
If there is no oil flow, the sludge level is too high. The sludge oil trap has to be cleaned!
B: test valve air flow *3)
If there is no air flow, drain line is blocked and has to be cleaned!
B-B 90°
Air vent
Dirty oil collecting pipe from piston underside
See pipe connection plan
tack welded
A-A
Air vent *1)
To sludge oil tank *1)
External heating coil
drain to sludge oil tank
Insulation
V = 150l
SLUDGE OIL TRAP
1- 107.425.369
WÄRTSILÄ

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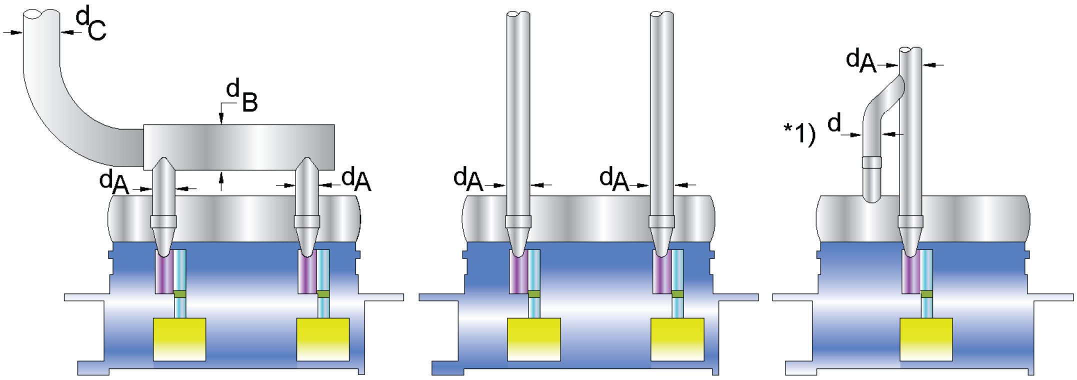
13. Exhaust Gas System

The following gas velocities are indicated as a guideline for an optimised exhaust gas system.



Remarks: *1) The reason for this bypass pipe is to allow engine operation after a turbocharger failure, during normal operation it is blinded off. The bypass can be omitted if agreed with the classification society and the owner.

2) The flange connection of the compensator can be designed as follows:

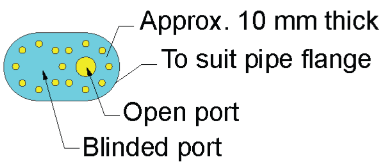


Figure 13.1: Determination of exhaust pipe diameter

13.1 Recommended gas velocities:

Pipe A .... 40 m/s

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

13.2 Exhaust gas pipe diameters

Refer to *winGTD and netGTD*.

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14. 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 shipowners. Calculation methods for the air flows required for combustion and keeping 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 and netGTD* on the Licensee Portal.

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

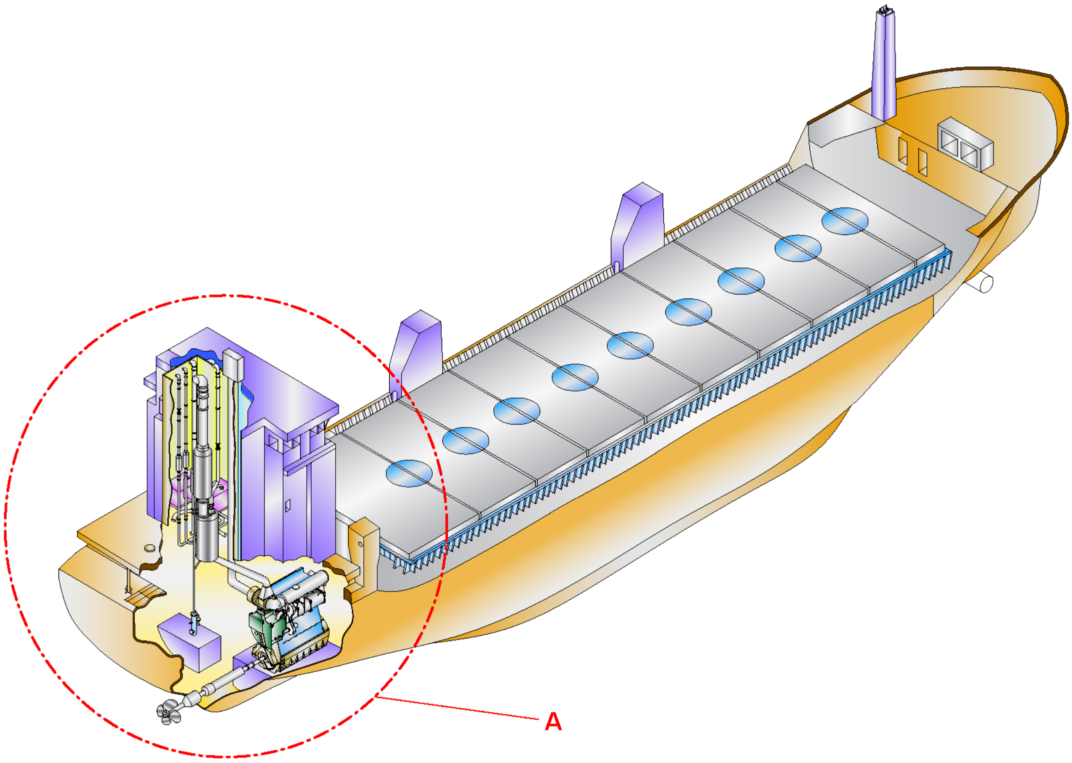

Figure 14.1: Direct suction of combustion air - main and auxiliary engine

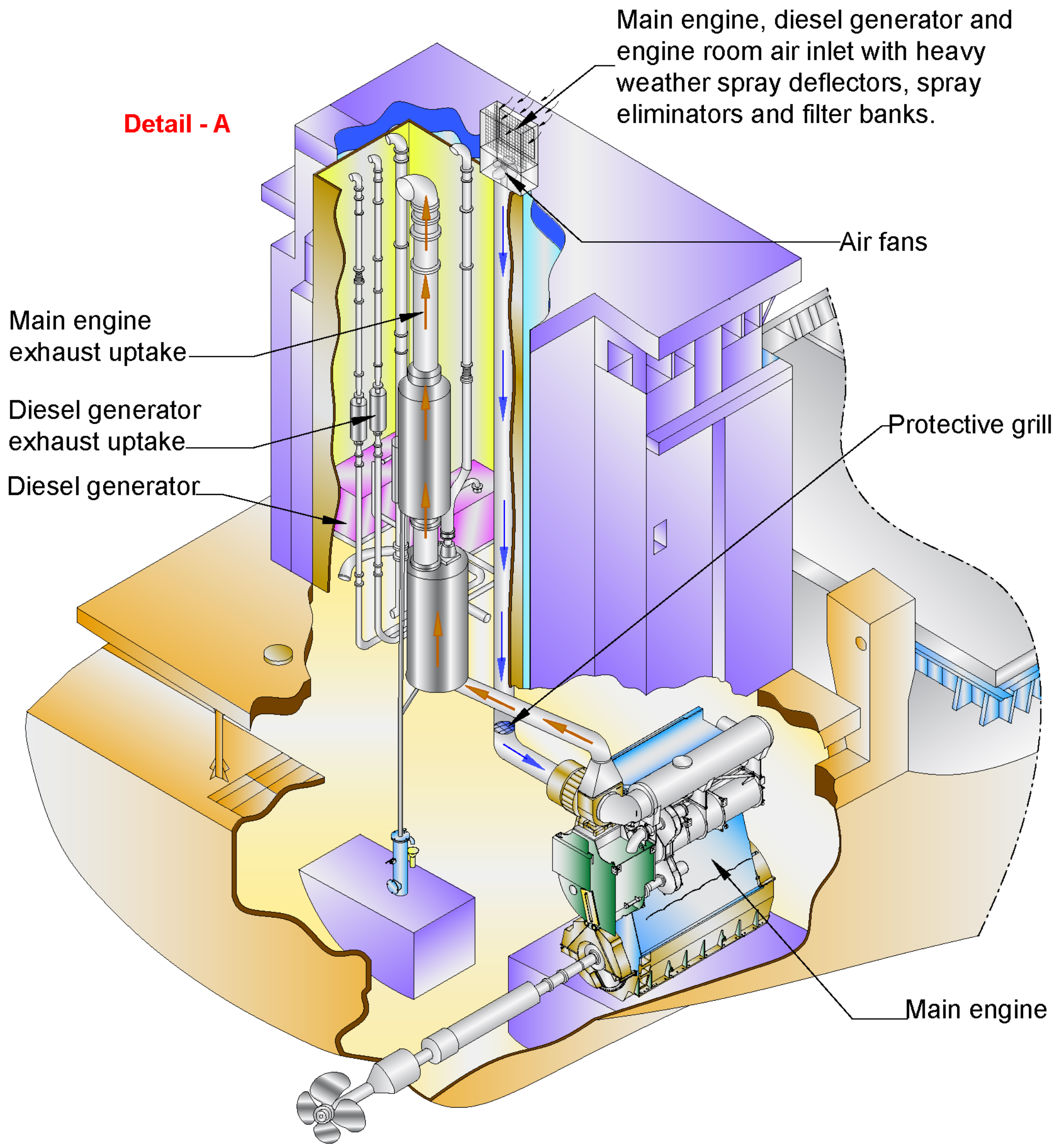

Figure 14.2: Direct suction of combustion air - main and auxiliary engine

14.1 Engine air inlet - Operating temperatures of 45 to 5°C

Due to the high compression ratio, the W-X40 engine 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 is not lower than 25°C.

This means:

- When the 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 freshwater cooling system allows recovering the heat dissipated from the engine and maintains the required scavenge air temperature after the scavenge air cooler by recirculating part of the warm water through the low-temperature system.

14.1.1 Arctic conditions at operating temperatures of less than 5°C

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

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

If the air inlet temperature drops to less than 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 amount of the scavenge air through a blow-off device as shown in figure *14.3*.

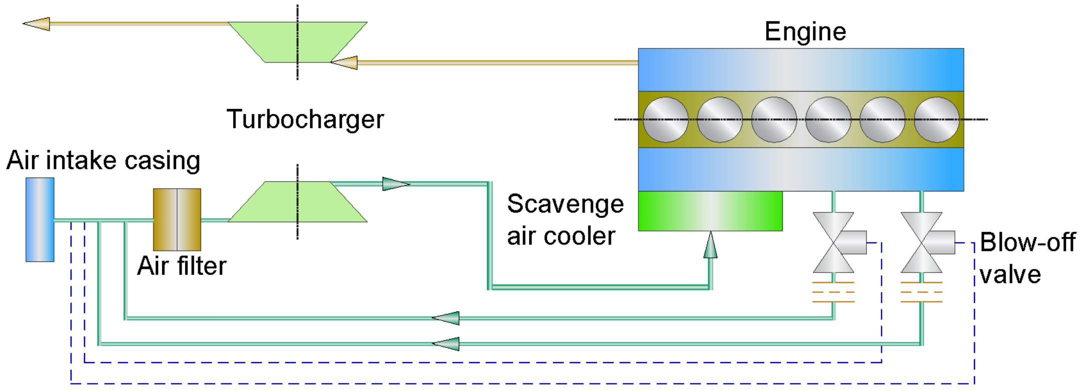

Figure 14.3: Scavenge air system for arctic conditions

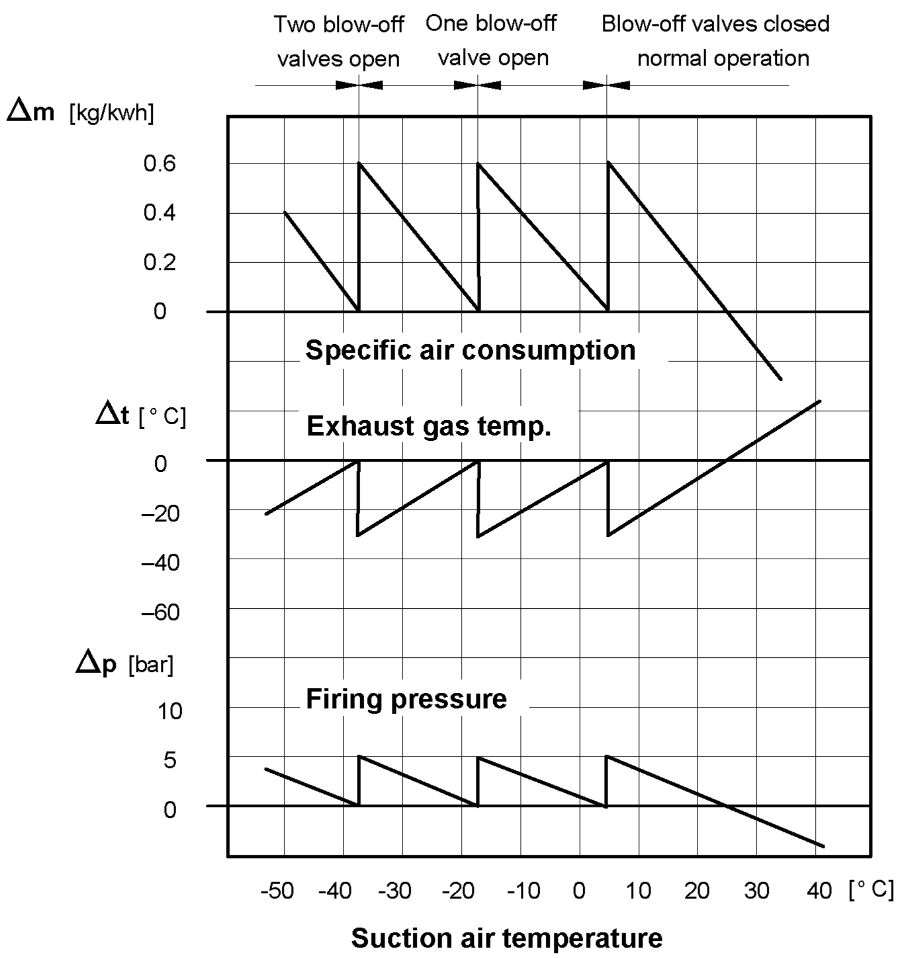

Figure 14.4: Blow-off effect under arctic conditions

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 less than +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 wanted relationship between scavenge and firing pressures. Figure *14.4* shows the effect of the blow-off valves on the air flow, the exhaust gas temperature after turbine and the firing pressure.

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.

NOTICE

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

15. Pipe Sizes and Flow Details

15.1 Pipe velocities

The velocities given in table *Recommended fluid velocities and flow rates for pipework* are for guidance only. They have been selected with due regard to friction losses and corrosion. Higher velocities compared with those stated may be acceptable when short piping runs, water properties and ambient temperature are taken into consideration.

Nominal pipe diameter	Medium	Seawater		Freshwater		Lubricating oil		Marine diesel oil		Heavy fuel oil	
	Pipe material	steel galvanized		mild steel		mild steel		mild steel		mild steel	
	pumpside	suction	delivery	suction	delivery	suction	delivery	suction	delivery	suction	delivery
32	[m/sec]	1.0	1.4	1.5	1.5	0.6	1.0	0.9	1.1	0.5	0.6
	[m³/h]	3.5	4.9	5.2	5.2	2.1	3.5	3.1	3.8	1.7	2.1
40	[m/sec]	1.2	1.6	1.7	1.7	0.7	1.2	1.0	1.2	0.5	0.7
	[m³/h]	5.7	7.6	8.1	8.1	3.3	5.7	4.7	5.7	2.4	3.3
50	[m/sec]	1.3	1.8	1.9	1.9	0.8	1.4	1.1	1.3	0.5	0.8
	[m³/h]	9.5	14.0	14.8	14.8	6.2	10.9	8.6	10.1	3.9	6.2
65	[m/sec]	1.5	2.0	2.1	2.1	0.8	1.5	1.2	1.4	0.6	0.9
	[m³/h]	16.7	22.0	23.3	23.3	8.9	16.7	13.3	15.6	6.7	10.0
80	[m/sec]	1.6	2.1	2.2	2.2	0.9	1.6	1.3	1.5	0.6	1.0
	[m³/h]	27.5	36.1	37.8	37.8	15.5	27.5	22.3	25.8	10.3	17.2
100	[m/sec]	1.8	2.2	2.3	2.3	0.9	1.6	1.4	1.6	0.7	1.2
	[m³/h]	53	65	68	68	27	47	31	47	21	36
125	[m/sec]	2.0	2.3	2.4	2.5	1.1	1.7	1.5	1.7	0.8	1.4
	[m³/h]	93	107	112	116	51	74	70	79	37	65
150	[m/sec]	2.2	2.4	2.5	2.6	1.3	1.8	1.5	1.8	0.9	1.6
	[m³/h]	148	161	168	175	87	114	101	121	60	107
200	[m/sec]	2.3	2.5	2.6	2.7	1.3	1.8	-	-	-	-
	[m³/h]	267	291	302	314	151	198	-	-	-	-
Aluminium brass	[m/sec]	2.6		-	-	-	-	-	-	-	-
	[m³/h]	302		-	-	-	-	-	-	-	-
250	[m/sec]	2.5	2.6	2.7	2.7	1.3	1.9	-	-	-	-
	[m³/h]	458	476	494	494	238	330	-	-	-	-
Aluminium brass	[m/sec]	2.7		-	-	-	-	-	-	-	-
	[m³/h]	494		-	-	-	-	-	-	-	-
300	[m/sec]	2.6	2.6	2.7	2.7	1.3	1.9	-	-	-	-
	[m³/h]	676	676	702	702	338	494	-	-	-	-

Nominal pipe diameter	Medium	Seawater		Freshwater		Lubricating oil		Marine diesel oil		Heavy fuel oil	
	Pipe material	steel galvanized		mild steel		mild steel		mild steel		mild steel	
	pumpside	suction	delivery	suction	delivery	suction	delivery	suction	delivery	suction	delivery
Aluminium brass	[m/sec]	2.8		-	-	-	-	-	-	-	-
	[m³/h]	728		-	-	-	-	-	-	-	-
350	[m/sec]	2.6	2.6	2.7	2.7	1.4	2	-	-	-	-
	[m³/h]	817	817	848	848	440	597	-	-	-	-
Aluminium brass	[m/sec]	2.8		-	-	-	-	-	-	-	-
	[m³/h]	800		-	-	-	-	-	-	-	-
400	[m/sec]	2.6	2.6	2.7	2.7	1.4	2	-	-	-	-
	[m³/h]	1,067	1,067	1,108	1,108	575	780	-	-	-	-
Aluminium brass	[m/sec]	2.8		-	-	-	-	-	-	-	-
	[m³/h]	1,149		-	-	-	-	-	-	-	-
450	[m/sec]	2.6	2.7	2.7	2.7	1.4	2	-	-	-	-
	[m³/h]	1,351	1,403	1,403	1,403	727	987	-	-	-	-
Aluminium brass	[m/sec]	2.9		-	-	-	-	-	-	-	-
	[m³/h]	1,507		-	-	-	-	-	-	-	-
500	[m/sec]	2.6	2.7	2.7	2.7	1.5	2.1	-	-	-	-
	[m³/h]	1,678	1,743	1,743	1,743	968	1,227	-	-	-	-
Aluminium brass	[m/sec]	2.9		-	-	-	-	-	-	-	-
	[m³/h]	1,872		-	-	-	-	-	-	-	-

Table 15.1: Recommended fluid velocities and flow rates for pipework

NOTICE

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

15.2 Piping symbols

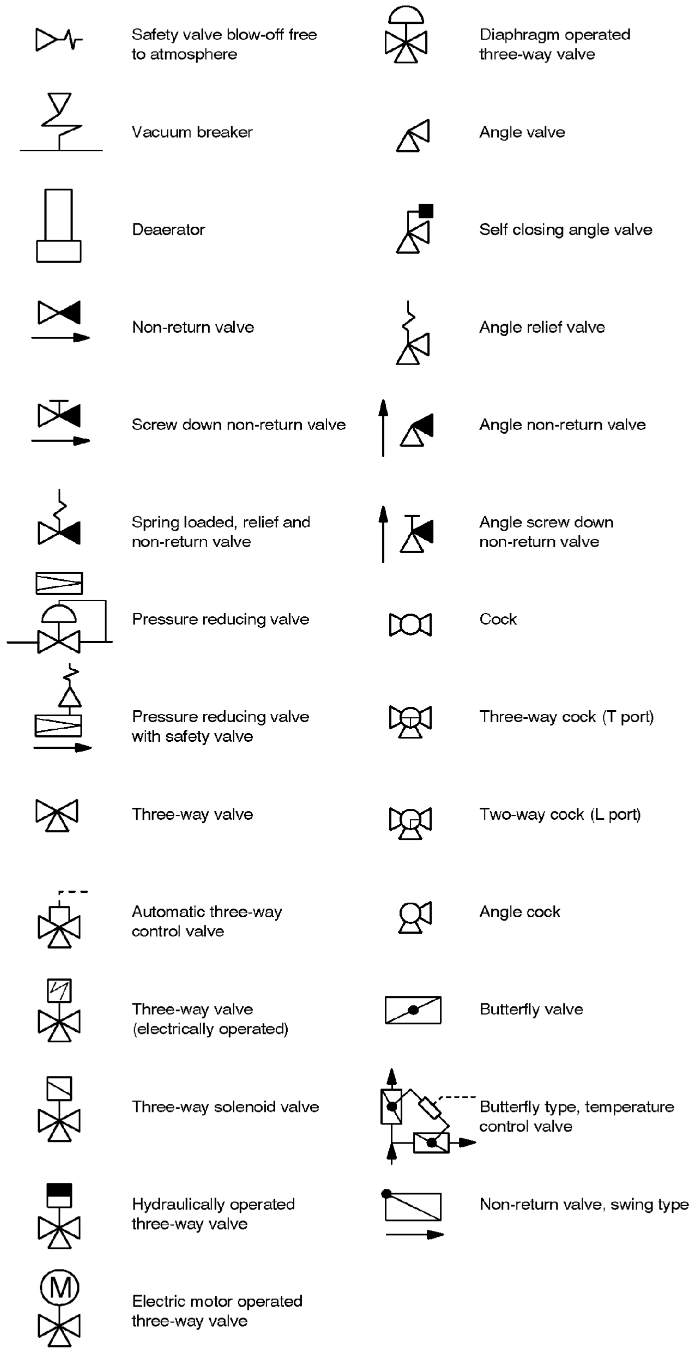

Figure 15.1: Piping symbols 1/3

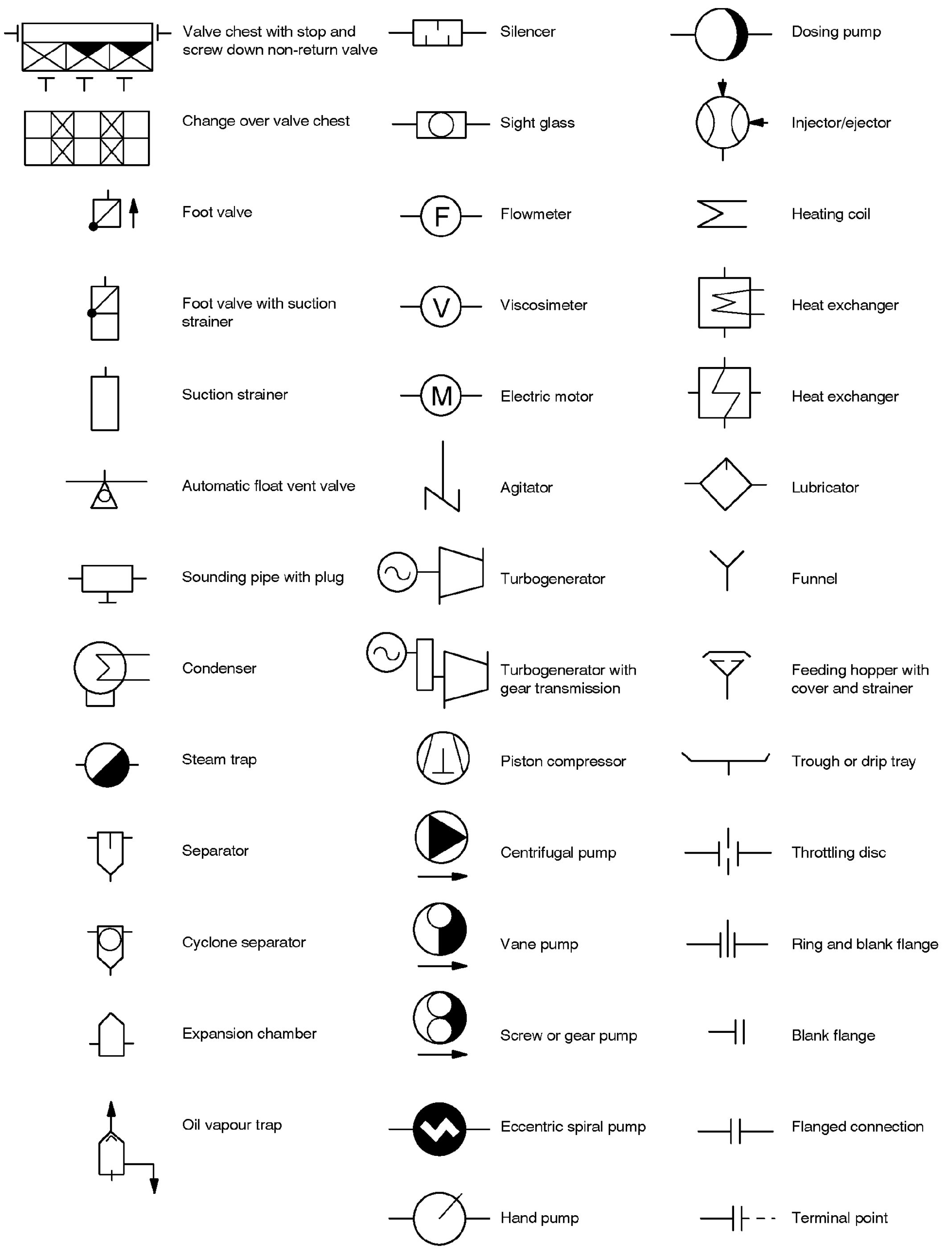

Figure 15.2: Piping symbols 2/3

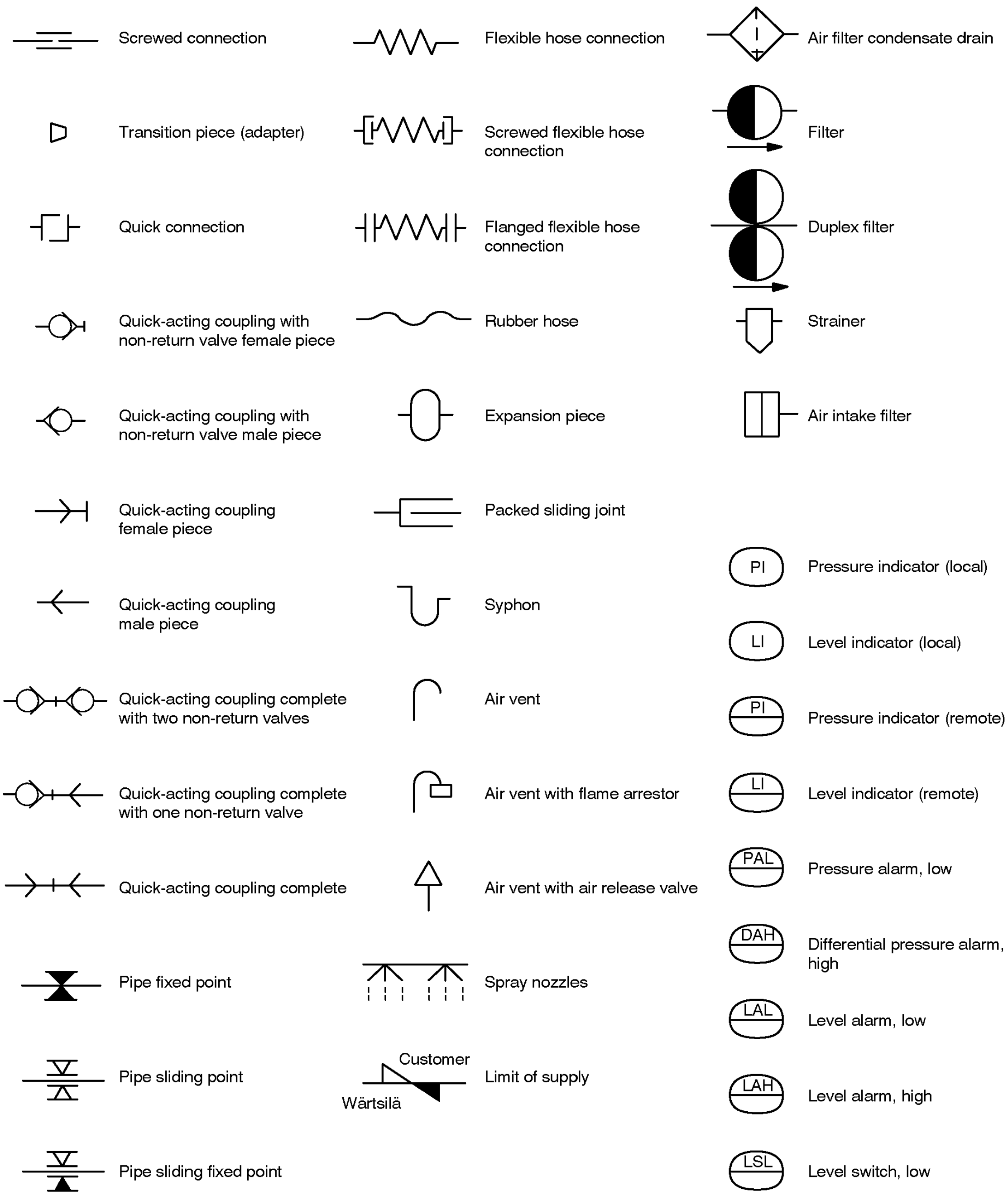

Figure 15.3: Piping symbols 3/3

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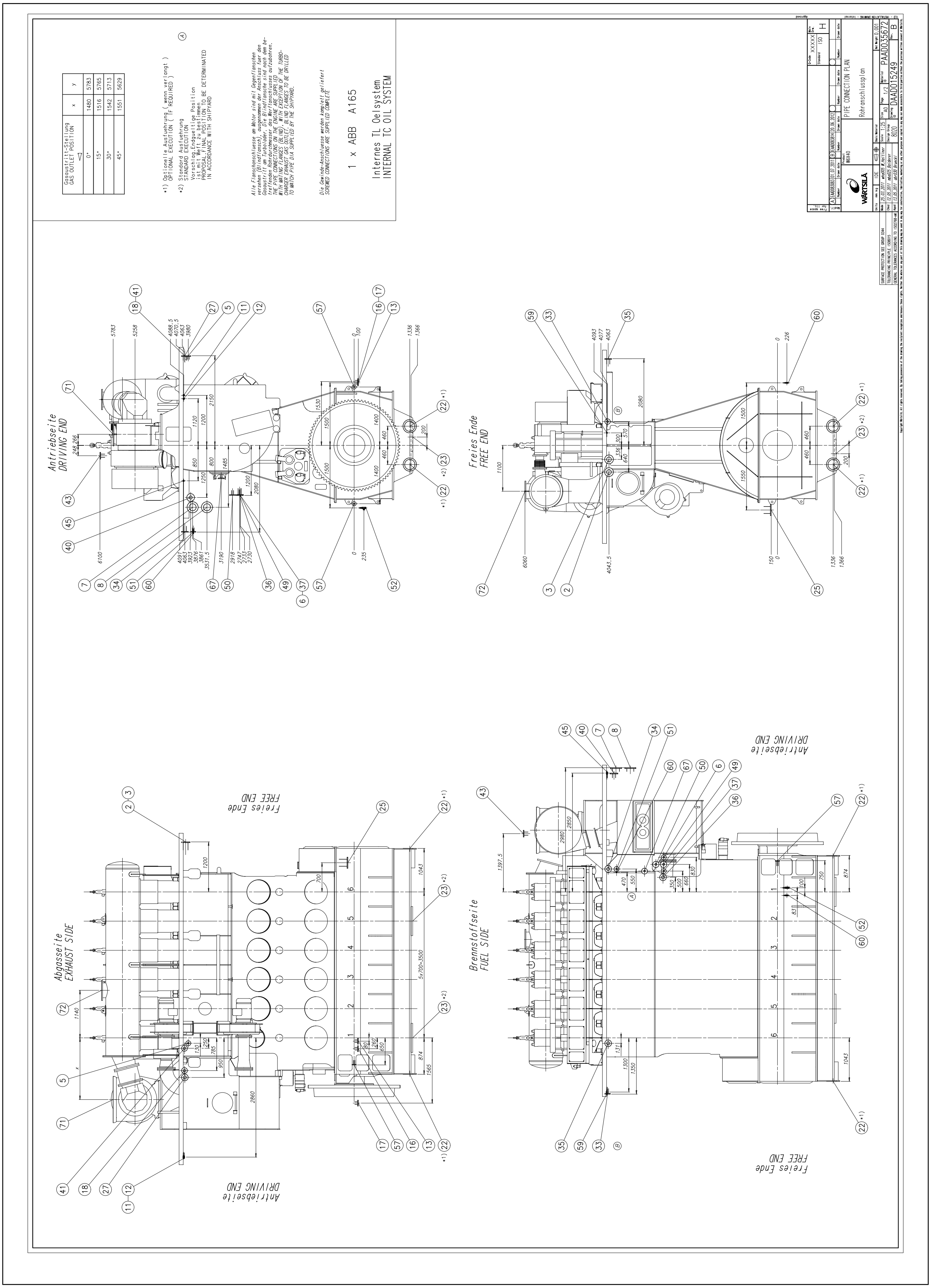
16. Pipe Connections

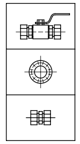
16.1 Drawings


Gasaustritt-Stellung GAS OUTLET POSITION
0° 1480 5783
15° 1516 5765
30° 1542 5713
45° 1551 5629
1 x ABB A165
Internes TL Oelsystem
INTERNAL TC OIL SYSTEM
Antriebseite DRIVING END
Freies Ende FREE END
Abgasseite EXHAUST SIDE
Brennstoffseite FUEL SIDE
PIPE CONNECTION PLAN
Rohranschlussplan
WÄRTSILÄ
PAAD035672
DAAD015249

No.		Bezeichnung / Description	DN / PN	Ko.Gr. KO.GR.	Freies Ende FREE END	Antriebseite DRIVING END	Abgasseite EXHAUST SIDE	Brennstoffseite FUEL SIDE
1		Zylinderkuehlwasser Eintritt / CYLINDER COOLING WATER INLET	DN / PN	8301	Nicht benoetigt NOT USED			
2		Zylinderkuehlwasser Eintritt / CYLINDER COOLING WATER INLET	DN 100 / PN 6	8305	X		X	
3		Zylinderkuehlwasser Austritt / CYLINDER COOLING WATER OUTLET	DN 100 / PN 6	8310	X		X	
4		Zylinderkuehlwasser Entlueftung Entlueftung / CYLINDER COOLING WATER VENTING VENTING	DN / PN	8310	Nicht benoetigt NOT USED			
5		Zylinderkuehlwasser Entleerung Austritt / CYLINDER COOLING WATER DRAIN OUTLET	DN 32 / PN 6	8313		X	X	
6		SLK Entleerung Austritt / SAC DRAIN OUTLET	DN 32 / PN 6	8314		X		X
7		SLK-NT-Kuehlwasser Eintritt / SAC-LT-COOLING WATER INLET	DN 150 / PN 6	8335		X		X
8		SLK-NT-Kuehlwasser Austritt / SAC-LT-COOLING WATER OUTLET	DN 150 / PN 6	8335		X		X
9		SLK-HT-Kuehlwasser Eintritt / SAC-HT-COOLING WATER INLET	DN / PN	8335	Nicht benoetigt NOT USED			
10		SLK-HT-Kuehlwasser Austritt / SAC-HT-COOLING WATER OUTLET	DN / PN	8335	Nicht benoetigt NOT USED			
11		Wasser fuer Reinigungsanlage TL und SLK Eintritt / WATER FOR CLEANING PLANT TC AND SAC INLET	DN 20 / PN 16	8338		X	X	
12		Luft fuer Reinigungsanlage TL und SLK Eintritt / AIR FOR CLEANING PLANT TC AND SAC INLET	DN 20 / PN 16	8338		X	X	
13		Oeliges Wasser vom Receiver Austritt / OILY WATER FROM RECEIVER OUTLET	DN 50 / PN 6	8352		X	X	
14		Turbolader Schmutzwasser Austritt / TURBOCHARGER DIRTY WATER OUTLET	DN / PN	8355	Nicht benoetigt NOT USED			
15		Ablauf vom Wasserabscheider Austritt / WATER DRAIN FROM WATERSEPERATOR OUTLET	DN / PN	8356	Nicht benoetigt NOT USED			
16		SLK Kondenswasser Austritt / SAC CONDENSATE WATER OUTLET	DN 50 / PN 6	8357		X	X	
17		SLK Waschwasser Austritt / SAC WASHING WATER OUTLET	DN 50 / PN 6	8357		X	X	
18		SLK Entlueftung Entlueftung / SAC VENTING VENTING	DN 50 / PN 6	8357		X	X	
19								
20								
21								
22	siehe Detail SEE DETAIL	Oelablauf Grundplatte Horizontal / OIL DRAIN BEDPLATE HORIZONTAL		1110	X	X		
23	siehe Detail SEE DETAIL	Oelablauf Grundplatte Vertikal / OIL DRAIN BEDPLATE VERTICAL		1110	X	X		
24		Zylinder Schmieroel Austritt / CYLINDER LUB. OIL OUTLET	DN 40 / PN 6	8472	Nicht benoetigt NOT USED (B)			
25		Hauptschmieroel Eintritt / MAIN LUBRICATING OIL INLET	DN 150 / PN 6	8406	X		X	

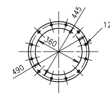
No.		Bezeichnung / Description	DN / PN	Ko.Gr. KO.GR.	Freies Ende FREE END	Antriebseite DRIVING END	Abgasseite EXHAUST SIDE	Brennstoffseite FUEL SIDE
26		Schmieroel Turbolader Eintritt / LUBRICATING OIL TURBOCHARGER INLET	DN / PN	8430	Nicht benoetigt NOT USED			
27		Schmieroel Turbolader Austritt / LUBRICATING OIL TURBOCHARGER OUTLET	DN 65 / PN 6	8431		X	X	
28		Spueloel Automatikfilter Austritt / FLUSHING OIL AUTOMATIC FILTER OUTLET	DN / PN	8445	Nicht benoetigt NOT USED			
29		Schmutzoel Ablauf Versorgungseinheit Austritt / DIRTY OIL DRAIN SUPPLY UNIT OUTLET	DN / PN	8452	Nicht benoetigt NOT USED			
30		Schmieroel Kreuzkopf Eintritt / LUBRICATING OIL CROSSHEAD INLET	DN / PN	8455	Nicht benoetigt NOT USED			
31		Leckagen vom Motor Austritt / DIRTY OIL LEAKAGE FROM ENGINE OUTLET	DN / PN	8463	Nicht benoetigt NOT USED			
32		Zylinder Schmieroel Eintritt / CYLINDER LUB. OIL INLET	DN / PN	8473	Nicht benoetigt NOT USED			
33		Zylinder Schmieroel Eintritt / CYLINDER LUB. OIL INLET	DN 40 / PN 6	8475	X			X
34		Leckoel Antriebseite Austritt / LEAKAGE OIL DRIVING END OUTLET	DN 65 / PN 6	8482		X		X
35		Leckoel Freies Ende Austritt / LEAKAGE OIL FREE END OUTLET	DN 65 / PN 6	8483	X			X
36		Schmutzoel Kolbenunterseite Austritt / DIRTY OIL PISTON UNDERSIDE OUTLET	DN 65 / PN 6	8487		X		X
37		Leckoel Stopfbuechse Austritt / LEAKAGE OIL GLAND BOX OUTLET	DN 32 / PN 6	8488		X		X
38		Oelablaufltg. Versorgungseinheit Austritt / OIL PIPE DRAIN SUPPLY UNIT OUTLET	DN / PN	8454	Nicht benoetigt NOT USED			
39		Leckageablauf Zylinderblock Austritt / LEAKAGE DRAIN CYLINDER BLOCK OUTLET	DN / PN	8462	Nicht benoetigt NOT USED			
40		Anlassluft Eintritt / STARTING AIR PIPE INLET	DN 65 / PN 40	8605		X		X
41		Entlueftung Kurbelgehaeuse Austritt / VENTING CRANKCASE OUTLET	DN 50 / PN 6	8608		X	X	
42		Entlueftung Waste Gate Austritt / VENTING WASTE GATE OUTLET	DN / PN	8609	Nicht benoetigt NOT USED			
43		Entlueftung Turbolader Austritt / VENTING TURBOCHARGER OUTLET	DN 65 / PN 6	8610		X		X
44		Entlueftung Zylinderkuehlwasser Austritt / VENTING CYLINDER COOLING WATER OUTLET	DN / PN	8611	Nicht benoetigt NOT USED			
45		Steuerluftversorgung Eintritt / CONTROL AIR SUPPLY INLET	DN 15 / PN 12	8630		X		X
46		Steuerluftversorgung Eintritt / CONTROL AIR SUPPLY INLET	DN / PN	4605	Nicht benoetigt NOT USED			
47								
48								
49		Brennstoff Eintritt / FUEL INLET	DN 40 / PN 40	8702		X		X
50		Brennstoffruecklauf Austritt / FUEL RETURN OUTLET	DN 40 / PN 40	8704		X		X

No.		Bezeichnung / Description	DN / PN	Ko.Gr. KO.GR.	Freies Ende FREE END	Antriebseite DRIVING END	Abgasseite EXHAUST SIDE	Brennstoffseite FUEL SIDE
51		Leckbrennstoff Rail Unit Austritt / FUEL LEAKAGE RAIL UNIT OUTLET	DN 32 / PN 6	8740		X		X
52		Leckbrennstoff Austritt / FUEL LEAKAGE OUTLET	DN 20 / PN 6	8744		X		X
53		Leckbrennstoff HD-Leitungen Austritt / FUEL LEAKAGE HP-PIPES OUTLET	DN / PN	8742	Nicht benoetigt NOT USED			
54		Leckbrennstoff Einspritzpumpe Austritt / FUEL LEAKAGE INJECTION PUMP OUTLET	DN / PN	8743	Nicht benoetigt NOT USED			
55								
56		Leckbrennstoff Einspritzeinheit Austritt / FUEL LEAKAGE ICU OUTLET	DN / PN	8745	Nicht benoetigt NOT USED			
57		Diverse Leckagen Austritt / VARIOUS LEAKAGE OUTLET	DN 25 / PN 6	8746		X	X	X
58								
59		Begleitheizung Brennstoff Eintritt / TRACE HEATING FUEL INLET	DN 12 / PN 16	8810	X			X
60		Begleitheizung Brennstoff Austritt / TRACE HEATING FUEL OUTLET	DN 12 / PN 16	8810		X		X
61		Begleitheizung Brennstoff Eintritt / TRACE HEATING FUEL INLET	DN / PN	8812	Nicht benoetigt NOT USED			
62		Begleitheizung Brennstoff Austritt / TRACE HEATING FUEL OUTLET	DN / PN	8812	Nicht benoetigt NOT USED			
63		Begleitheizung Brennstoffzirkulation Eintritt / TRACE HEATING FUEL CIRCULATION INLET	DN / PN	8820	Nicht benoetigt NOT USED			
64		Begleitheizung Brennstoffzirkulation Austritt / TRACE HEATING FUEL CIRCULATION OUTLET	DN / PN	8823	Nicht benoetigt NOT USED			
65								
66								
67		Feuerloesch Anlage Zylinderblock Eintritt / FIRE EXTINGUISHING PLANT CYLINDER BLOCK INLET	DN 32 / PN 16	8830		X		X
68		Feuerloesch Anlage Rail Unit Eintritt / FIRE EXTINGUISHING PLANT RAIL UNIT INLET	DN / PN	8831	Nicht benoetigt NOT USED			
69		Feuerloesch Anlage Rail Unit Eintritt / FIRE EXTINGUISHING PLANT RAIL UNIT INLET	DN / PN	8832	Nicht benoetigt NOT USED			
70								
71	siehe Detail SEE DETAIL	Abgas Turbolader Austritt / EXHAUST GAS TURBOCHARGER OUTLET		6506 6509		X	X	
72	siehe Detail SEE DETAIL	Abgas Bypass Austritt / EXHAUST GAS BY-PASS OUTLET		8103 8108		X	X	
73								
74								
75								



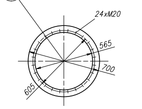
Abmasse der Flansche siehe 4-107.390.729

(72) Bypass zur Auspuffleitung
EXHAUST BY-PASS



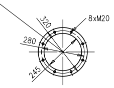
fuer vertikalen Oelablauf
FOR VERTICAL LUB. OIL DRAIN

(23) ×2)

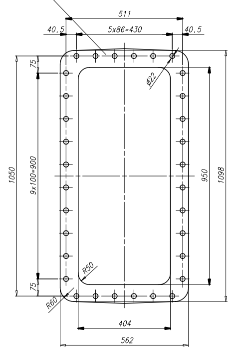


fuer horizontalen Oelablauf
Freies Ende und Antriebseite
FOR HORIZONTAL LUB. OIL DRAIN
FREE END AND DRIVING END

(22) ×1)



(71) Gas-Austritt vom Turbolader
GAS OUTLET FROM TURBOCHARGER



1 x ABB A165

Free space for lic.				Q-Code XXXXX / Standard ISO	Main Drw. H
Modif.	(A) EAAD083083 01.07.2011	(B) EAAD083814 20.06.2012			
WÄRTSILÄ	Product W6X40	PIPE CONNECTION PLAN / Rohranschlussplan			
Units mm kg	IDE	Basic Material		Net Weight 0.001	
Made 25.03.2011 wha005 W.Haltiner	Scale 1:25	Size A0	Page 2/2	Material ID PAAD035672	
Chkd 12.05.2011 mba025 Balderer	Design Group 8020	Drawing ID DAAD015249		Rev. B	
Appd 13.05.2011 abr030 Brueckl					

SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK

ILD - INSTALLATION DRAWING - Internal

Approved

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17. Engine Automation

Developments in Automation & Controls at Wärtsilä are focussed on the latest trends in ship automation that tend to still higher integration levels.

The standard electrical interface, designated DENIS-UNIC (**D**iesel **E**ngine Co**N**trol and opt**I**mizing **S**pecification), assures a perfect match with approved remote control systems, while the UNIC (**W**ärtsilä **E**ngine **C**ontrol **S**ystem) takes care of all RT-flex-specific control functions.

All those systems provide data bus connection to the ship automation to facilitate installation and make specific data available wherever required. Complete ship automation systems provided by one of the leading suppliers approved by Wärtsilä 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.

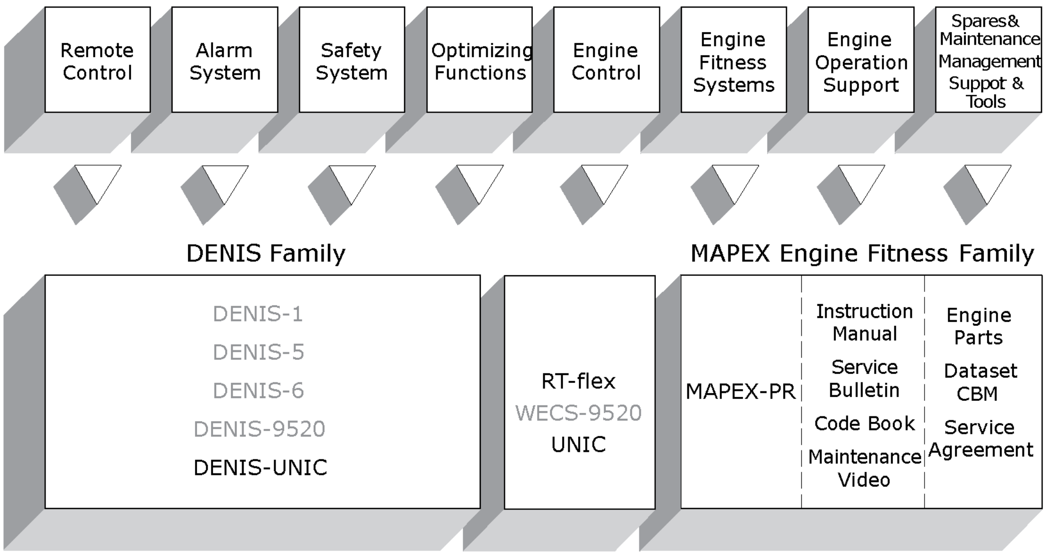

Figure 17.1: EMA concept comprising DENIS, UNIC

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 is DENIS-UNIC.

UNIC .... Under the designation of UNIC, Wärtsilä Switzerland Ltd. provides a fully embedded engine control system. The UNIC system is handling e.g. tasks related to fuel injection, exhaust valve control, cylinder lubrication, engine crank angle measurement and speed/load control. The system uses modern bus technologies for safe transmission of sensor- and other signals.

17.1 UNIC - engine control system interface

17.1.1 Concept

The concept of UNIC meets the requirements of increased flexibility and higher integration in modern ship automation and provides the following advantages for shipowners, 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 ship automation supplier. It allows authorised suppliers to adapt their systems to the RT-flex engines with reduced engineering effort. The clear signal exchange simplifies troubleshooting.

Approved propulsion control systems

Propulsion control systems including remote control, safety and telegraph systems are available from suppliers approved by Wärtsilä. 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 UNIC, the propulsion control and the vessel's alarm and monitoring system enables an easy integration of the different systems. The human-machine interface (HMI) of the vessel's automation can therefore also handle the additional MMI functions attributed to the UNIC.

Ship automation from one supplier - integrated solution

Automation suppliers approved by Wärtsilä 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 UNIC 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 HMI of the UNIC can provide additional features when using such an integrated solution.

Ship automation from different suppliers - split solution

In case the propulsion control and alarm / monitoring systems are from different suppliers, the UNIC also supports such a split solution by providing two separate redundant data bus lines, one each for the propulsion control and the alarm / monitoring system. In that case the MMI functions are also split within propulsion control and alarm / monitoring system.

UNIC describes the signal interface between the RT-flex engine and the ship automation..

UNIC specification does not include any hardware. It summarises all the data. UNIC specification is presented in two sets of documents:

UNIC engine specification

This file contains the specification of the signal interface on the engine and is made available 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 UNIC engine specification covers the engine-built components for control, alarm and indication.

UNIC 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. Therefore this file is licensed to remote control partners of Wärtsilä only. The companies offer systems which are built exactly according to the engine designer's specifications, tested and approved by Wärtsilä.

17.1.2 Propulsion control system

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

- Remote control system
- Safety system
- Telegraph system

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

17.1.3 Approved propulsion control systems

Wärtsilä has an agreement with each of the following marine automation suppliers concerning the development, production, sales and servicing of remote control and safety systems for their engines. All approved propulsion control systems listed below comprise the same functionality specified by Wärtsilä

Supplier / company		**Remote control system**
Kongsberg Maritime		**AutoChief C20**
Kongsberg Maritime AS P.O. Box 1009 N-3194 Horten Norway	km.sales@kongsberg.com Tel. +47 81 57 37 00 Fax +47 85 02 80 28	
NABTESCO Corporation		**M-800-III**
NABTESCO corp., Marine Control Systems Company 1617-1, Fukuyoshi-dai 1-chome Nishi-ku Kobe, 651-22413 Japan	Tel. +81 78 967 5361 Fax +81 78 967 5362	
SAM Electronics GmbH / Lyngsø Marine		**DMS2100i**
SAM Electronics GmbH Behringstrasse 120 D-22763 Hamburg Germany	Tel. +49 40 88 25 0000 Fax +49 40 88 25 4116	
Lyngsø Marine AS 2, Lyngsø Allé DK-2970 Hørsholm Denmark	Tel. +45 45 16 62 00 Fax +45 45 16 62 62	

Table 17.1: Suppliers of remote control systems

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 bus connections. The engine signals described in the UNIC specification are connected via the terminal boxes on the engine to the electronic modules placed in the engine control room.

These electronic modules are 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.

17.1.4 Interface to alarm and monitoring systems

General layout - operator interface (OPI)

Hardwired signals from alarm sensors mounted on the engine had to be connected to the vessel's alarm and monitoring system. Additional sensors with hardwired connections are fitted in order to monitor RT-flex-specific circuits of the engine. In addition to that, the RT-flex engine control system (UNIC) 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 engine. Connection from UNIC to engine automation can be made in two ways.

Integrated solution

Propulsion control system and alarm / monitoring system from same supplier:

- This allows connecting both the propulsion control system and the alarm / monitoring system through one redundant bus line only (CANopen) to the UNIC.
- By using the integrated solution the testing and commissioning can be done already at the engine builders testbed. The wiring during installation to the ship is kept to a minimum consisting of power cables and bus communication.

Split solution

Propulsion control system and alarm / monitoring system from different suppliers except Kongsberg:

- The propulsion control system is connected through one redundant bus line (CANopen) to the UNIC.
- For the separate alarm / monitoring system an additional redundant Modbus RTU serial connection is available.
- Wärtsilä provides modbus lists specifying the display values and alarm conditions as part of the UNIC engine specification.

Requirements for any alarm / monitoring system to be fulfilled 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 UNIC to the standard alarm list (100-200 alarms depending on engine type and number of cylinders).

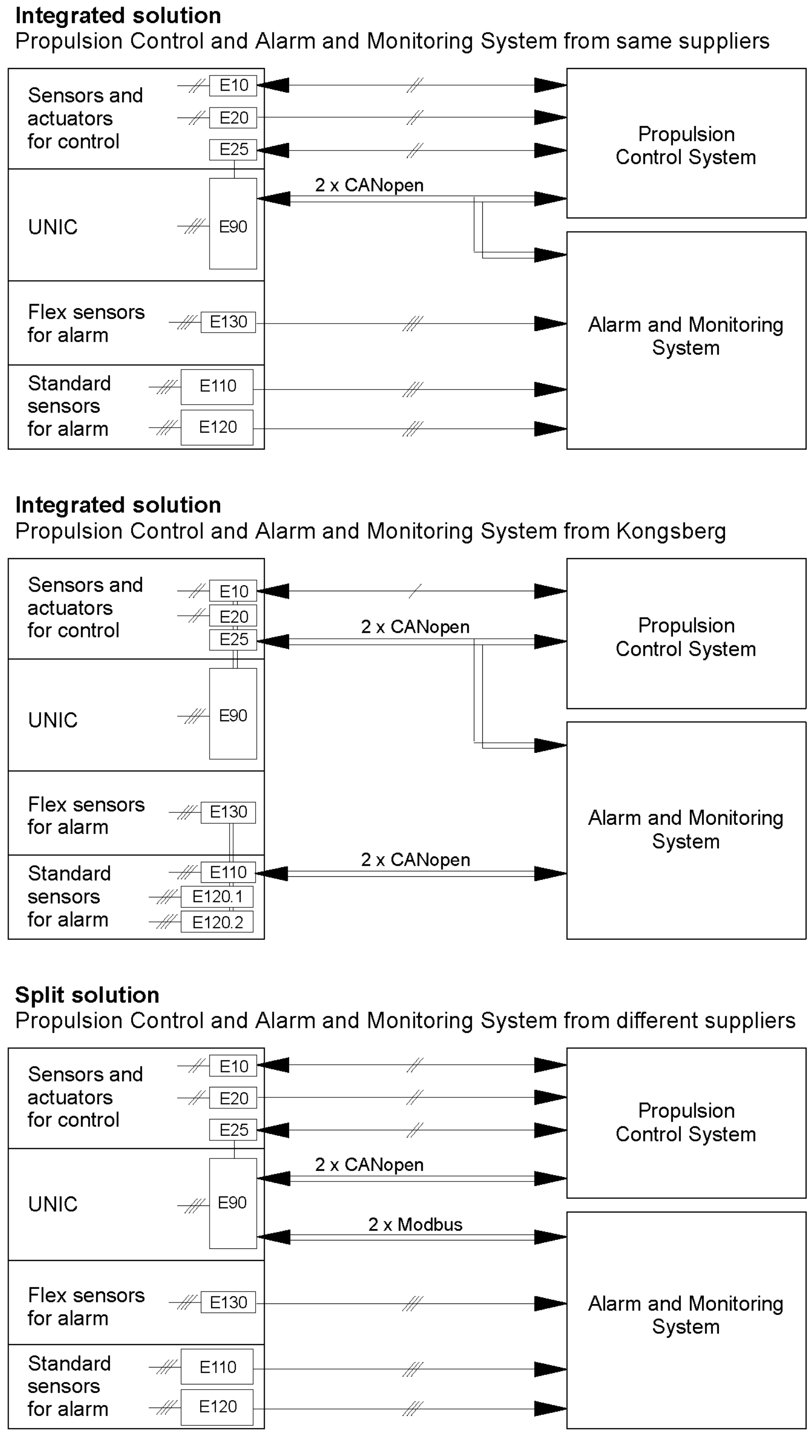

Figure 17.2: Integrated/split solution

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 in the tables below.

The time delays for the slow-down and shut-down functions given in tables below 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.

Included in the standard scope of supply are the minimum of safety sensors as required by Wärtsilä for attended machinery space (AMS). If the option of unattended machinery space (UMS) was chosen, the respective sensors have to be added according to the requirements issued by Wärtsilä.

There are also some additional sensors defined for the monitoring of flex system-specific engine circuits.

The extent of delivery of alarm and safety sensors has to cover the requirements of the respective classification society, Wärtsilä, the shipyard and the owner. The sensors delivered with the engine are basically connected to terminal boxes mounted on the engine. Signal processing is performed in a separate alarm and monitoring system usually provided by the shipyard.

Alarm sensors and safety functions (part 1)

Alarm and safety functions					Values		
Medium	**Phys. Value**	**Location**	**Signal No.**	**Function**	**Level**	**Setting**	**Delay [s]**
Cylinder cooling water							
	Pressure	Engine Inlet	PT1101A	ALM	L	2.0 bar	0
				SLD	L	1.8 bar	60
			PS1101S	SHD	L	1.5 bar	60
	Temperature	Engine Inlet	TE1111A	ALM	L	65 °C	0
		Outlet each cyl.	TE1121-28A	ALM	H	90 °C	0
				SLD	H	95 °C	60
Scavenge air cooling water							
fresh water single-stage	Pressure	Inlet cooler	PT1361A	ALM	L	2.0 bar	0
	Temperature	Inlet cooler	TE1371A	ALM	L	25 °C	0
		Outlet cooler	TE1381A	ALM	H	80 °C	0
Main bearing oil							
	Pressure	Supply	PT2001A	ALM	L	3.8 bar	0
				SLD	L	3.6 bar	60
			PS2002S	SHD	L	3.1 bar	10
	Pressure	Before injectors	PT2003A	ALM	L	3.8 bar	0
				SLD	L	3.6 bar	60
	Temperature	Supply	TE2011A	ALM	H	50 °C	0
				SLD	H	55 °C	60
	Temperature	Oultet Bearing 2-10	TE2102-10A	ALM	H	65 °C	0
				SLD	H	70 °C	60
Servo oil							
	Flow *1)	Pump inlet	FS2061-62A	ALM	L	no flow	0
Leakage monitoring	Level	Supply Unit	LS2055A	ALM	H	max.	0
Thrust bearing oil							
	Temperature	Outlet Thrust rad. bearing	TE2101A	ALM	H	65 °C	0
				SLD	H	70 °C	60
Thrust bearing pads							
	Temperature	Fore side	TE4521A	ALM	H	80 °C	0
				SLD	H	85 °C	60
			TE4521S	SHD	H	90 °C	60
		Aft side	TE4522S	SHD	H	90 °C	60
Oil mist concentration							
	Concentration	Crankcase	AS2401A	ALM	H	--	0
			AS2401S	SLD	H	--	60
	Failure	Detection unit	XS2411A	ALM	F	--	0

Alarm and safety functions					Values		
Medium	**Phys. Value**	**Location**	**Signal No.**	**Function**	**Level**	**Setting**	**Delay [s]**
Piston cooling oil							
	Temperature	Outlet each cyl.	TE2501-08A	ALM	H	80 °C	0
				SLD	H	85 °C	60
	Flow	Inlet each cyl.	FS2521-28S	SHD	L	no flow	15
Turbocharger oil							
ME bearing oil supply ABB A100-L	Pressure	Inlet each TC	PT2611A *2)	ALM	L	1.0 bar	5
				SLD	L	0.8 bar	60
			PS2611S	SHD	L	0.6 bar	5
	Temperature	Outlet TC	TE2601A	ALM	H	110 °C	0
				SLD	H	120 °C	60
ME bearing oil supply MHI MET	Pressure	Inlet each TC	PT2611A	ALM	L	0.7 bar	5
				SLD	L	0.6 bar	60
			PS2611S	SHD	L	0.4 bar	5
	Temperature	Outlet TC	TE2601A	ALM	H	85 °C	0
				SLD	H	90 °C	60
Geislinger damper oil							
	Pressure	Casing inlet	PT2711A	ALM	L	1.0 bar	0
Axial damper (detuner) oil							
	Pressure	Aft side	PT2721A	ALM	L	1.7 bar	60
		Fore side	PT2722A	ALM	L	1.7 bar	60
Cylinder lubricating oil							
	Temperature	Supply unit inlet	TE3101A	ALM	H	50 °C	0
				ALM	L	35 °C	0
Fuel oil							
	Viscosity	Before supply unit		ALM	H	20 cSt	0
				ALM	L	13 cSt	0
	Temperature	Before supply unit	TE3411A *3)	ALM	H	50-160 °C	0
				ALM	L	20-130 °C	0
		After fuel pump	TE3431-32A	ALM	D	-30 °C	30
	Pressure	Before supply unit	PT3421A	ALM	L	7 bar	0
Leakage	Level	Rail unit	LS3444A	ALM	H	max.	0
		Fuel pipe	LS3446A	ALM	H	max.	0
Heating	Failure	Fuel pipe	XS3463A	ALM	F	--	0

Alarm and safety functions					Values		
Medium	**Phys. Value**	**Location**	**Signal No.**	**Function**	**Level**	**Setting**	**Delay [s]**
Exhaust gas							
	Temperature	After each cylinder	TT3701-08A	ALM	H	515 °C	0
				ALM	D	± 50 °C	0
				SLD	H	530 °C	60
				SLD	D	± 70 °C	60
	Temperature	Before each turbocharger	TE3721A	ALM	H	515 °C	0
				SLD	H	530 °C	60
		After each turbocharger	TE3731A	ALM	H	480 °C	0
				SLD	H	500 °C	60
Scavenge air							
	Temperature	After each cooler	TE4031A *4)	ALM	L	25 °C	0
				ALM	H	60 °C	0
				SLD	H	70 °C	60
		Each piston underside	TE4081-88A	ALM	H	80 °C	0
				SLD	H	120 °C	60
Condensation water *5)	Level	Water separator	LS4071A	ALM	H	max.	0
				SLD	H	max.	60
		Before water separator	LS4075A	ALM	H	max.	0
				SLD	H	max.	60
Staring air							
	Pressure	Engine inlet	see UNIC list	Start interlock		--	--
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	L	4.5 bar	0
Leakage oil	Level	Exh. Valve air	LS4351A	ALM	H	max.	0
Control air							
Supply	Pressure	Engine inlet	PT4401A	ALM	L	6.0 bar	0
Stand-by supply			PT4411A	ALM	L	5.5 bar	0
			PT4421A	ALM	L	5.0 bar	0
UNIC control system							
	Power failure	Pwr. supply box	XS5056A	ALM	F	--	--
Engine							
Overspeed	Speed	Crankshaft	ST5111-12S	SHD	H	110%	0
*1) ALM has to be suppressed at low load.							
*2) The indicated alarm and slow-down values and the values indicated 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 commisioning / sea trial of the vessel.							
*3) ALM vale depending on fuel viscosity.							

Alarm and safety functions					Values		
Medium	**Phys. Value**	**Location**	**Signal No.**	**Function**	**Level**	**Setting**	**Delay [s]**
*4) For water separators made from plastic material the sensor must be placed right after the separator.							
*5) Alternatively, low temperature alarm **or** condensation water high level alarm.							

Table 17.2: Table of alarm sensors and safety functions (part 1)

Alarm sensors and safety functions (part 2)

Alarm and safety functions			min. WCH requirements			Request of classification societies for UMS											
Medium	Signal No.	Function	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																	
	PT1101A	ALM		•		•	•	•	•	•	•	•	•	•	•	•	•
		SLD	•			•	•	•	•	•	•	•	•	•	•	•	•
	PS1101S	SHD	•								•						
	TE1111A	ALM		•							•						•
	TE1121-28A	ALM		•		•	•	•	■	•	•	•	•	•	•	•	•
		SLD		•		•	•	•	•	•	•	•	•	•	•	•	•
Scavenge air cooling water																	
Fresh water single-stage	PT1361A	ALM		•													
	TE1371A	ALM		•													
	TE1381A	ALM		•													
Main bearing oil																	
	PT2001A	ALM		•		•	•	•	•	•	•	•	•	•	•	•	•
		SLD	•			•			•		•		•		•	•	
	PS2002S	SHD	•			•	•	•	•	•	•	•	•	•	•	•	•
	PT2003A	ALM															
		SLD															
	TE2011A	ALM		•		•	•	•	•	•	•	•	•	•	•	•	•
		SLD		•			•	•	•		•			•		•	•
	TE2102-10A	ALM				•	A	A	A	A	A	A	A	A	A	A	A
		SLD									A						
Servo oil																	
	FS2061-62A	ALM	•														
Leakage monitoring	LS2055A	ALM	•														
Thrust bearing oil																	
	TE2101A	ALM				•	A	A	A	A	A	A	A	A	A	A	A
		SLD									A						
Thrust bearing pads																	
	TE4521A	ALM		•		•	•	•	•	•	•	•	•	•	•	•	•
		SLD		•		•	•	•	•	•	•				•	•	
	TE4521S	SHD				•	•		•							•	
	TE4522S	SHD															
Oil mist concentration																	
	AS2401A	ALM	•			•	B	B	B	B	B	B	B	B	B	B	B
	AS2401S	SLD	•			•	B	B	B	B	B	B	B	B	B	B	B
	XS2411A	ALM	•								•		•				

Alarm and safety functions			min. WCH requirements			Request of classification societies for UMS											
Medium	**Signal No.**	**Function**	**for AMS**	**add. to AMS for UMS**	**add. flex signals**	**IACS**	**ABS**	**BV**	**CCS**	**DNV**	**GL**	**KR**	**LR**	**MRS**	**NK**	**PRS**	**RINA**
Piston cooling oil																	
	TE2501-08A	ALM		•		•	•	•	•	•	•	•	•	•	•	•	•
		SLD		•		•	•	•	•	•	•	•	•	•	•	•	•
	FS2521-28S	SHD	•						•		•						
Turbocharger oil																	
ME bearing oil supply ABB A100-L	PT2611A	ALM		•					■		•					•	
		SLD		•													
	PS2611S	SHD	•														
	TE2601A	ALM		•					▲		•					•	
		SLD	•														
ME bearing oil supply MHI MET MB	PT2611A	ALM		•					■		•					•	
		SLD		•													
	PS2611S	SHD	•														
	TE2601A	ALM		•					▲		•					•	
		SLD	•														
Geislinger damper oil																	
	PT2711A	ALM		•													
Axial damper (detuner) oil																	
	PT2721A	ALM		•													
	PT2722A	ALM		•													
Cylinder lubricating oil																	
	TE3101A	ALM															
		ALM															
Fuel oil																	
		ALM		•		D	D	D	D	D	D	D	D	D	D	D	D
		ALM		•		•	•	•	•	•	•	•	•	•	•	•	•
	TE3411A	ALM		•							C						
		ALM		•		C	C	C	C	C	C	C	C	C	C	C	C
	TE3431-32A	ALM			•												
	PT3421A	ALM		•		•	•	•	•	•	•	•	•	•	•	•	•
	LS3444A	ALM			•												
	LS3446A	ALM			•												
Failure	XS3463A	ALM															

Alarm and safety functions			min. WCH requirements			Request of classification societies for UMS											
Medium	**Signal No.**	**Function**	**for AMS**	**add. to AMS for UMS**	**add. flex signals**	**IACS**	**ABS**	**BV**	**CCS**	**DNV**	**GL**	**KR**	**LR**	**MRS**	**NK**	**PRS**	**RINA**
Exhaust gas																	
	TT3701-08A	ALM		•		•	•	•	•	•	•	E	•	•	•	•	•
		ALM		•		•	•	•	•	•	•	F	•	•	•	•	•
		SLD		•		•	•	•	•	•	•	•	•	•	•	•	G
		SLD		•							•					•	•
	TE3721A	ALM				•			•		•				•	•	•
		SLD															H
	TE3731A	ALM				•			•		•		•		•	•	
		SLD								•							
Scavenge air																	
	TE4031A	ALM		•			I				I	•		○	•	•	I
		ALM		•			•		I		•	•		○	•	•	•
		SLD							I								
	TE4081-88A	ALM		•		•	•	•	K	•	•	•	•	•	•	•	•
		SLD		•		•	•	•	K	•	•	•	•		•	•	•
Condensation water	LS4071A	ALM		•		•	K	•	•		K		•		•		K
		SLD		•													
	LS4075A	ALM		•		•	K	•	•		K				•		K
		SLD		•													
Starting air																	
Start interlock	see UNIC list	--		•		•	•	•	•	•	•	•	•	•	•	•	•
Air spring air																	
	PT4341A	ALM	•	•		•											
		ALM	•			•			•		•						
		SLD	•			•											
	PS4341S	SHD	•			•											
Leakage oil	LS4351A	ALM	•			•											
Control air																	
Supply	PT4401A	ALM		•		•	•	•	•	•	•	•	•	•	•	•	•
Stand-by supply	PT4411A	ALM		•					•								
	PT4421A	ALM		•					•		•						
UNIC control system																	
	XS5056A	ALM			•												
Engine																	
Overspeed	ST5111-12S	SHD	•			•	•	•	•	•	•	•	•	•	•	•	•

Table 17.3: Table of alarm sensors and safety functions (part 2)

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

Table 17.4: Classification societies

Request of classification societies

Request of classification societies for UMS:				**Special request for AMS:**	
●	Request	A or B	are requested alternatively	▲	Request for AMS only
○	Recommendation	C or D		■	Additional request to UMS for AMS
AMS	Attended machinery space	E or F			
UMS	Unattended machinery space	G or H			
		I or K			

Table 17.5: Request of classification societies

Functions and level

Function:		**Level:**	
ALM	Alarm	H	High
SLD	Slow down	L	Low
SHD	Shut down	D	Deviation
		F	Failure

Table 17.6: Functions and level

17.2 Drawings

SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK

DENIS INTERFACE SPECIFICATION DENIS-UNIC CONTENT

QTY	SEQ NO	Material ID	Material Name / Dimension/Occ.Dimension	Standard or Drawing	Basic Material Material Standard	Weight GR./NET
1	006	PAAD012765	INTERFACE SPECIFICATION / MODBUS TO AMS-SIGN.LIST	DAAD023074		0.001
1	005	PAAD020618	INTERFACE SPECIFICATION / MODBUS TO AMS-SPEC.	DAAD010110		0.01
1	004	PAAD017073	BLOCK DIAGRAM	107.428.695		0.001
1	003	PAAD012690	ELECTRIC POWER DIAGRAM / POWER SUPPLY	DAAD007443		0.001
1	002	107.382.086.500	CONTROL SPECIFICATION / PROJECT DATA	107.382.086		0.001
1	001	PAAD012736	INTERFACE SPECIFICATION / DENIS-UNIC SIGN. LIST	107.430.751		0.001

Approved

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Q-Code XXXXX | Main Drw. H | Standard ISO JIS

Modif.	Number	Drawn date	Number	Drawn date	Number	Drawn date	Number	Drawn date
A	EAAD083290	02.02.2012						

WÄRTSILÄ

Product: W5-8X35, W5-8X40

DENIS INTERFACE SPECIFICATION
DENIS-UNIC / CONTENT

Units mm kg	IDE	Basic Material	Net Weight 0.006
Made 30.07.2010 mbu002 Buner	Scale 1:1	Size A4	Page 1/1	Material ID PAAD012694
Chkd 16.02.2011 jst014 Stopper	Design Group 4001	Drawing ID DAAD007603	Rev. A
Appd 16.02.2011 jst014 Stopper			

DID - DIMENSIONAL DRAWING - Confidential

18. General Installation Aspects

The purpose of this chapter is to provide information to assist in planning and installation of the engine. It is for guidance only and does not supersede current instructions.

⚠ WARNING

The illustrations in this chapter do not necessarily represent the actual configuration or the stage of development, nor the type of your engine.

For all relevant and prevailing information consult section 'drawings' of this chapter.

18.1 Engine Dimensions and masses

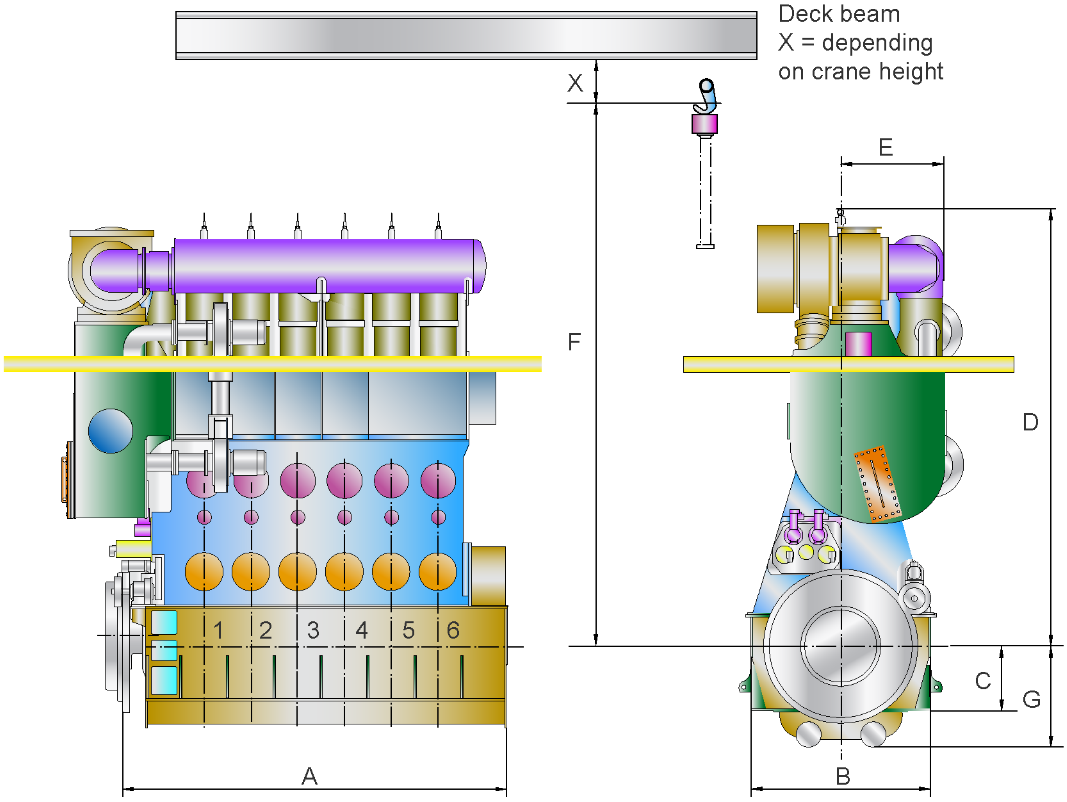


Figure 18.1: Engine dimensions

Number of cylinders		5	6	7	8
Dimensions in mm with a tolerance of approx. ±10 mm	**A**	5,107	5,807	6,507	7,207
	B	2,610			
	C	950			
	D	6,344			
	E	1,430 *1)			
	F	7,700			
	G	1,411			
Net engine mass (without oil/water) [tonnes]		109	125	140	153
Minimum crane capacity [kg]		1,500			

NOTICE

F: Min. height to crane hook for vertical piston removal.

- Mass estimated according to nominal dimensions of drawings, including turbocharger and SAC, pipings and platforms.

*1) Dimension E depends on type of turbocharger

18.1.1 Dimensions and masses of main components

Number of cylinders			5	6	7	8
Bedplate including bearing girders	length	[mm]	4,935	5,635	6,335	7,035
	mass	[kg]	18,000	20,000	22,000	24,000
Crankshaft	length	[mm]	4,750	5,450	6,150	6,850
	mass	[kg]	20,000	23,000	26,000	29,000
Flywheel (light)	diametre	[mm]	2,230			
Column, complete (monoblock)	length	[mm]	4,110	4,810	5,510	6,210
	mass	[kg]	12,540	14,520	16,720	18,810
Tie rod complete	length	[mm]	4,025			
	mass	[kg]	50			
Cylinder block	length	[mm]	3,729	4,429	5,129	5,829
	mass	[kg]	9,010	10,617	12,250	13,865
Cylinder liner	height	[mm]	1,990			
	mass	[kg]	880			
Connecting rod without bearing covers	length	[mm]	2,362			
	mass	[kg]	825			
Crosshead, complete with guide shoes	length	[mm]	730			
	mass	[kg]	590			
Piston, complete with rod	height	[mm]	2,420			
	mass	[kg]	455			
Scavenge air receiver	length	[mm]	3,850	4,550	5,250	5,950
	mass	[kg]	1,228	1,460	1,692	1,924
Exhaust valve, complete	height	[mm]	1,005			
	mass	[kg]	745			
Cylinder cover	length	[mm]	ø 696 x 330			
	mass	[kg]	458			

Table 18.1: Dimensions and masses of main components

18.1.2 Thermal expansion at the turbocharger expansion joint

Before making expansion pieces, enabling connections between the engine and external engine services, the thermal expansion of the engine has to be taken into account. The expansions are defined (from ambient temperature 20°C to service temperature 55°C) as follows (see also fig. *18.2*):

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

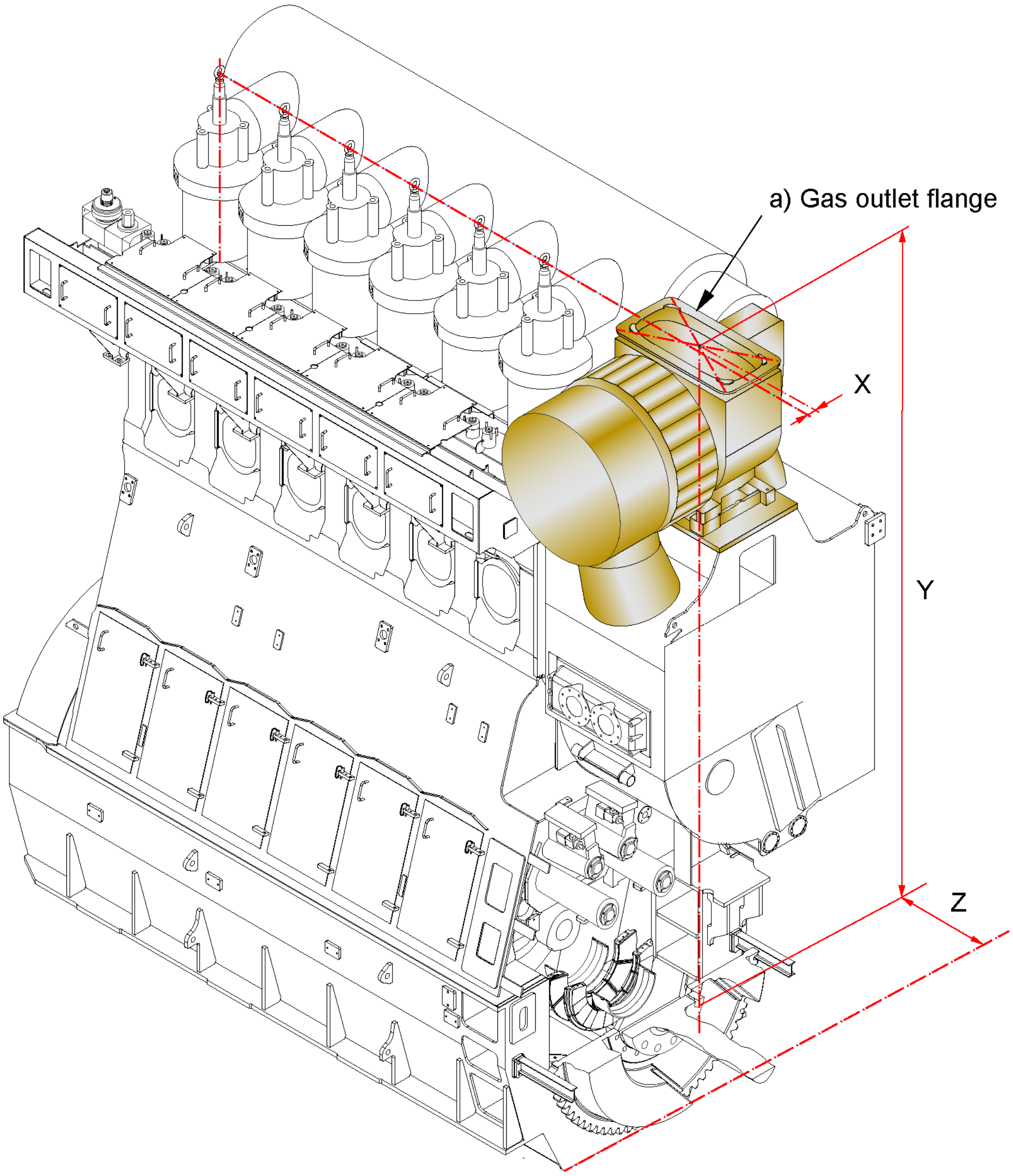


Figure 18.2: Thermal expansion, dim. X, Y, Z

18.1.3 Contents of fluid in the engine

No. of cyl.	**Lubricating oil**	**Cylinder cooling water**	**Freshwater in scavenge air cooler(s)** *1)	**Total of water and oil in engine** *2)
	[kg]	[kg]	[kg]	[kg]
5	414	135	110	659
6	447	153	110	710
7	531	171	145	847
8	572	256	145	973

Table 18.2: Fluid quantities in the engine

NOTICE

*1) The given water content is approximate.

*2) These quantities include engine piping except piping of scavenge air cooling.

18.1.4 Crane requirements

- An overhead travelling crane of min. 1,500 kg 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. recommends a two-speed hoist with pendent control, allowing to select high or low speed, i.e. high 6.0 m/minute, low 0.6-1.5 m/minute.

18.1.5 Piston and tie rod dismantling heights

Piston dismantling heights

For the possibility of reducing the standard piston dismantling height applying special tools and/or tilted piston position please ask Wärtsilä Switzerland Ltd. These dimensions are for guidance only and may vary depending on the crane dimension, handling tools and dismantling tolerances.

These dimensions are absolutely not binding. However, please contact Wärtsilä Switzerland Ltd. or any of its representatives if these values cannot be maintained or more detailed information is required.

See section 'Drawings' in this chapter.

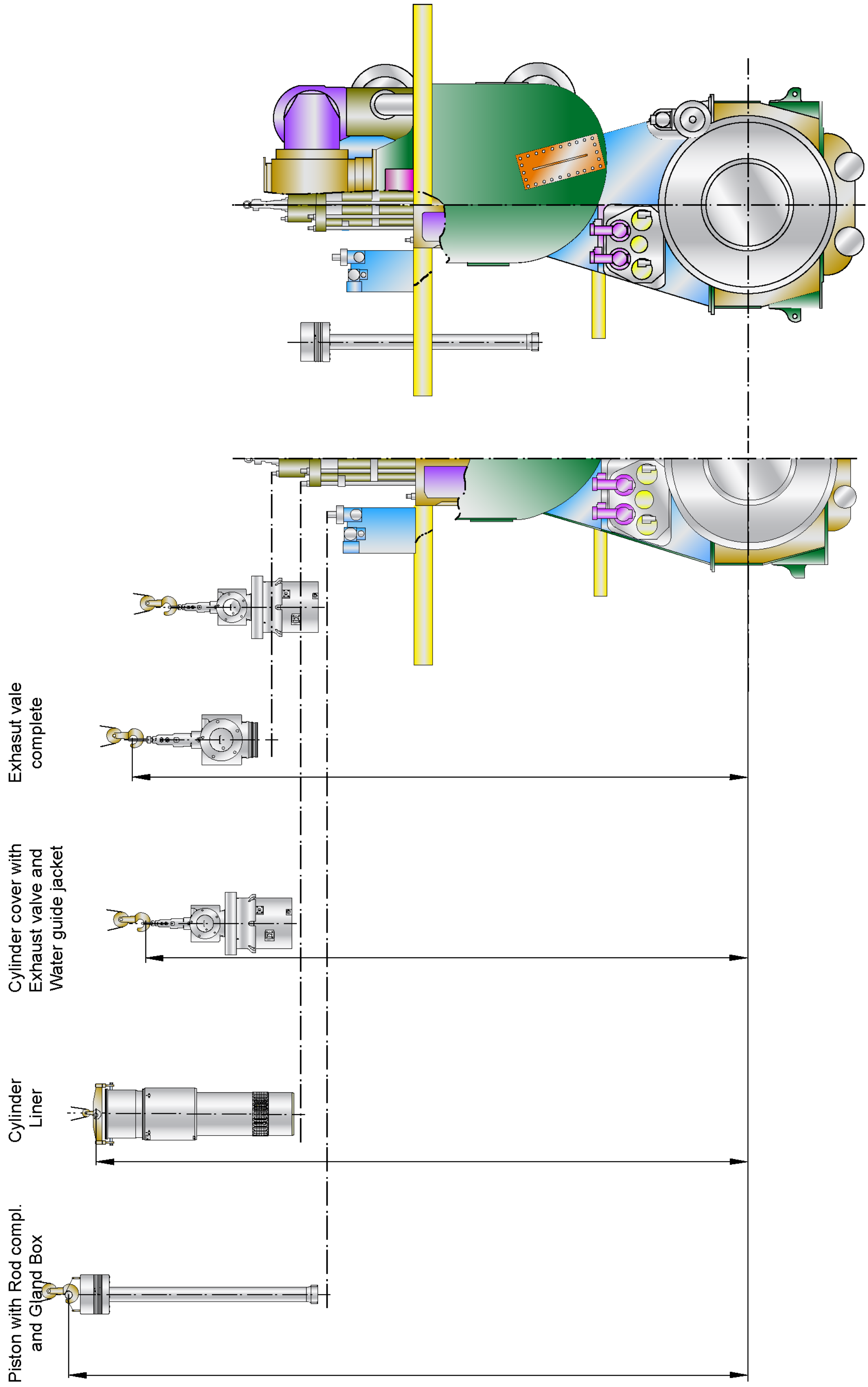


Figure 18.3: Space requirements and dismantling heights for vertical piston lifting

18.1.6 Dismantling of scavenge air cooler

To facilitate dismantling of the scavenge air coolers, an adequate lifting facility may be provided.

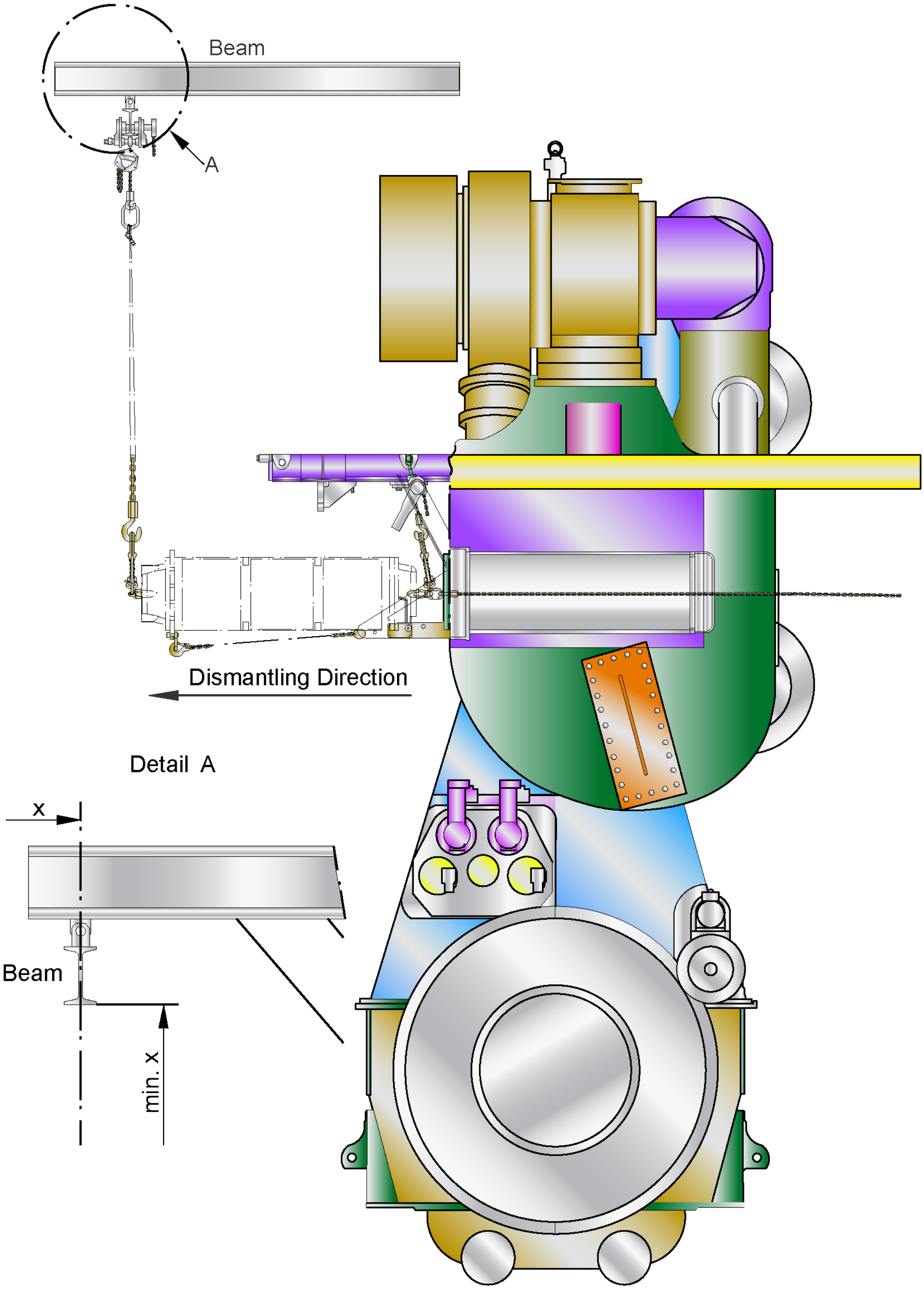
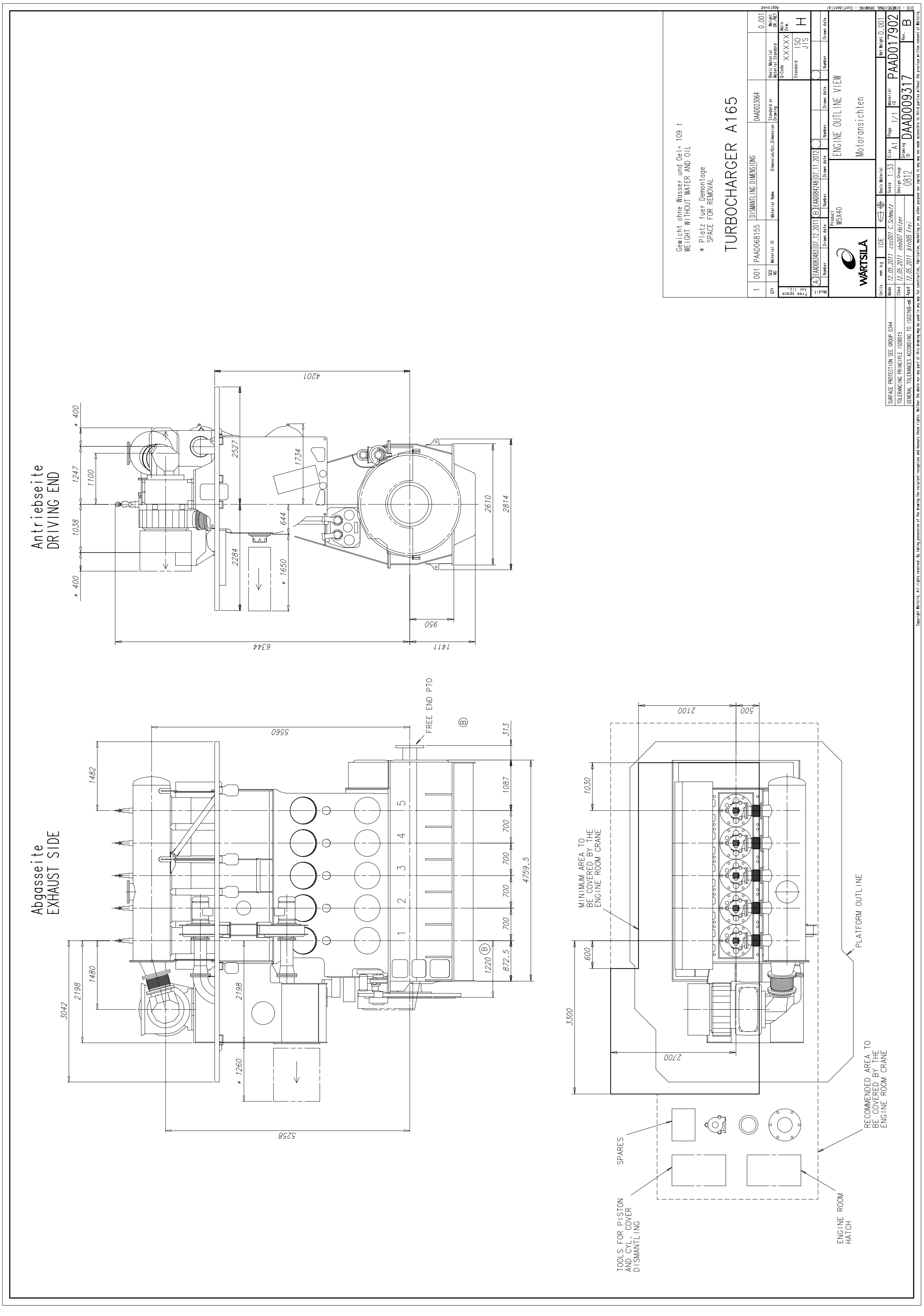
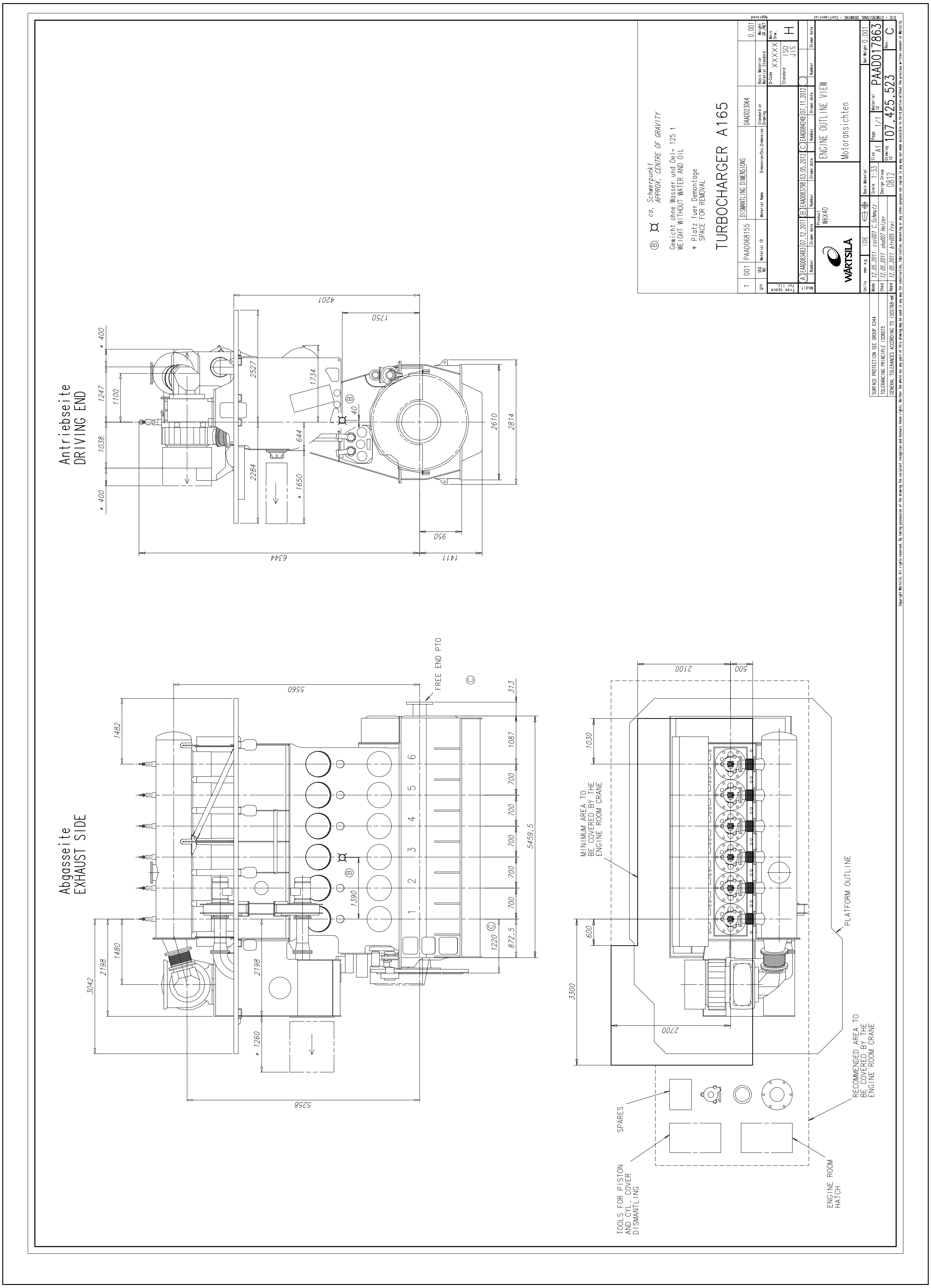


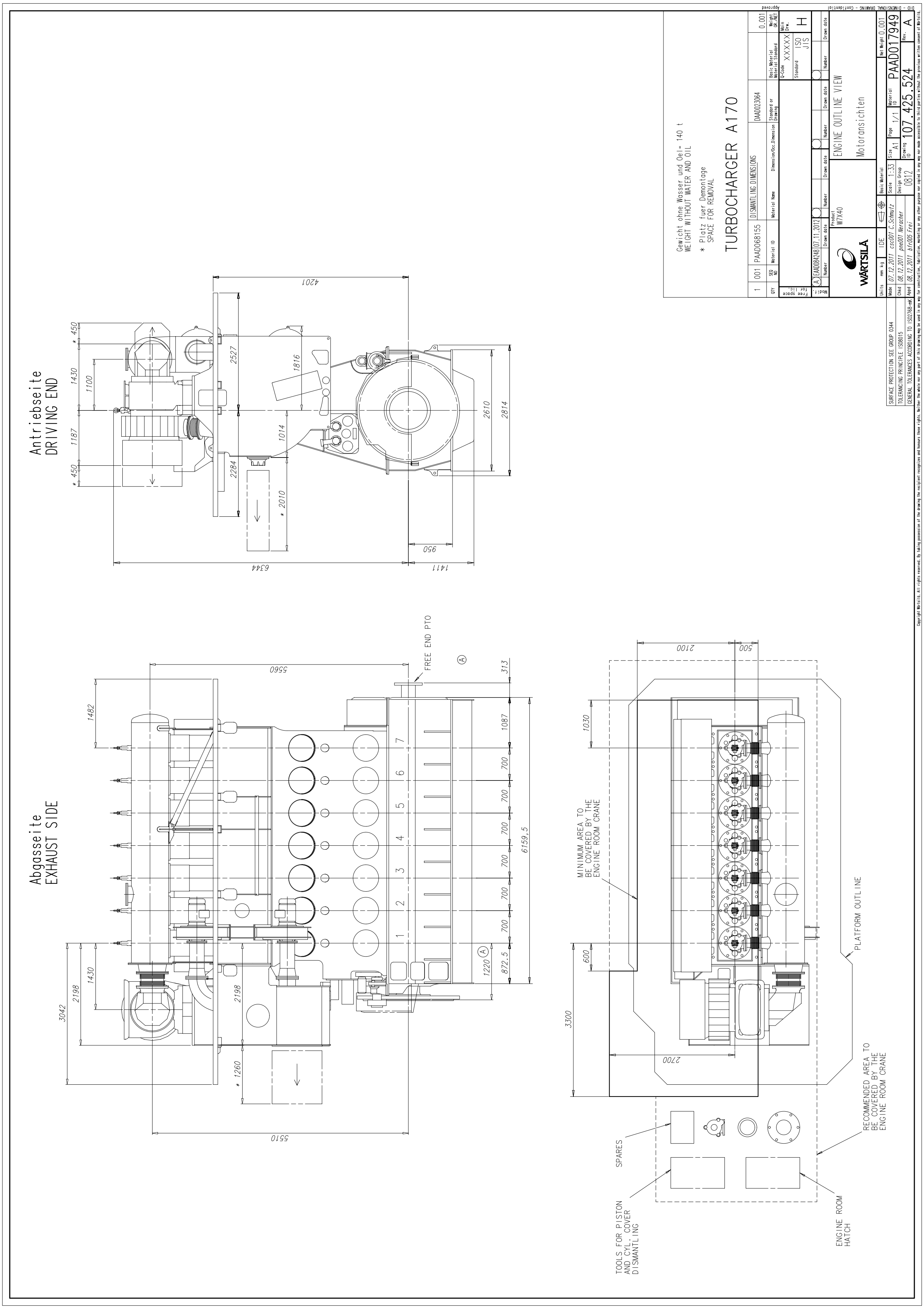
Figure 18.4: Dismantling of SAC

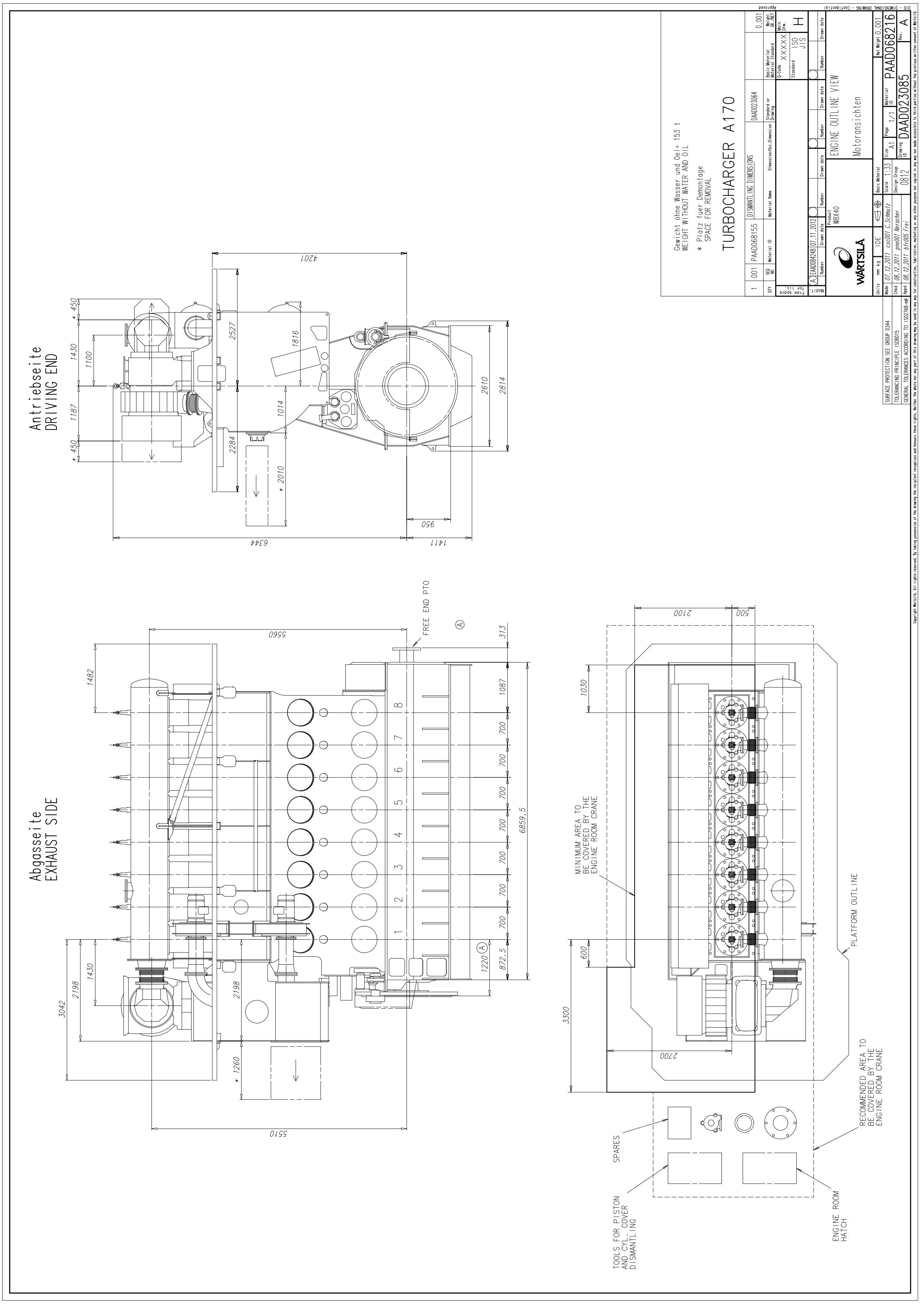
18.2 Outlines

18.2.1 Drawings


Gewicht ohne Wasser und Oel= 109 t
WEIGHT WITHOUT WATER AND OIL
* Platz fuer Demontage
SPACE FOR REMOVAL
TURBOCHARGER A165
ENGINE OUTLINE VIEW
Motoransichten
PAAD017902
DAAD009317
Antriebseite
DRIVING END
Abgasseite
EXHAUST SIDE
FREE END PTO
MINIMUM AREA TO
BE COVERED BY THE
ENGINE ROOM CRANE
PLATFORM OUTLINE
RECOMMENDED AREA TO
BE COVERED BY THE
ENGINE ROOM CRANE
SPARES
TOOLS FOR PISTON
AND CYL. COVER
DISMANTLING
ENGINE ROOM
HATCH


Antriebseite
DRIVING END
Abgasseite
EXHAUST SIDE
FREE END PTO
MINIMUM AREA TO
BE COVERED BY THE
ENGINE ROOM CRANE
PLATFORM OUTLINE
RECOMMENDED AREA TO
BE COVERED BY THE
ENGINE ROOM CRANE
SPARES
TOOLS FOR PISTON
AND CYL. COVER
DISMANTLING
ENGINE ROOM
HATCH
ca. Schwerpunkt
APPROX. CENTRE OF GRAVITY
Gewicht ohne Wasser und Oel= 125 t
WEIGHT WITHOUT WATER AND OIL
* Platz fuer Demontage
SPACE FOR REMOVAL
TURBOCHARGER A165
ENGINE OUTLINE VIEW
Motoransichten
W6X40
PAAD017863
107.425.523


Antriebseite
DRIVING END
Abgasseite
EXHAUST SIDE
FREE END PTO
MINIMUM AREA TO BE COVERED BY THE ENGINE ROOM CRANE
PLATFORM OUTLINE
RECOMMENDED AREA TO BE COVERED BY THE ENGINE ROOM CRANE
SPARES
TOOLS FOR PISTON AND CYL. COVER DISMANTLING
ENGINE ROOM HATCH
Gewicht ohne Wasser und Oel= 140 t
WEIGHT WITHOUT WATER AND OIL
* Platz fuer Demontage
SPACE FOR REMOVAL
TURBOCHARGER A170
ENGINE OUTLINE VIEW
Motoransichten
W7X40
PAAD017949
107.425.524



Antriebseite
DRIVING END
Abgasseite
EXHAUST SIDE
FREE END PTO
MINIMUM AREA TO BE COVERED BY THE ENGINE ROOM CRANE
PLATFORM OUTLINE
RECOMMENDED AREA TO BE COVERED BY THE ENGINE ROOM CRANE
SPARES
TOOLS FOR PISTON AND CYL. COVER DISMANTLING
ENGINE ROOM HATCH
Gewicht ohne Wasser und Oel= 15.3 t
WEIGHT WITHOUT WATER AND OIL
* Platz fuer Demontage
SPACE FOR REMOVAL
TURBOCHARGER A170
ENGINE OUTLINE VIEW
Motoransichten
W8X40
WÄRTSILÄ
DAAD023085
PAAD068216

18.3 Platform arrangements

18.4 Engine seating

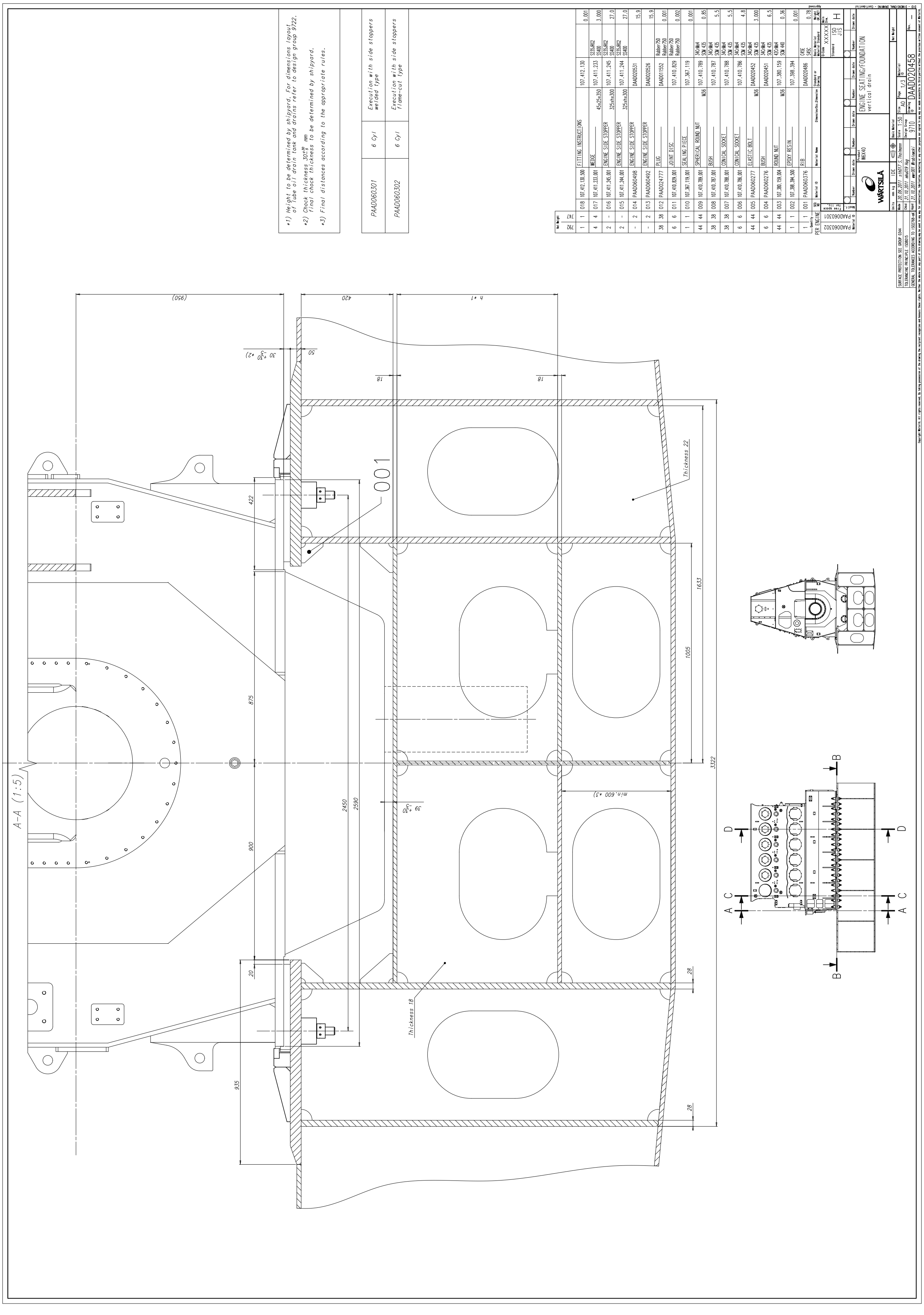
The engine seating is integral with the double-bottom structure and has to be of sufficient strength to support the weight of the engine, transmit the propeller thrust, withstand external couples and stresses related to propeller and engine resonance.

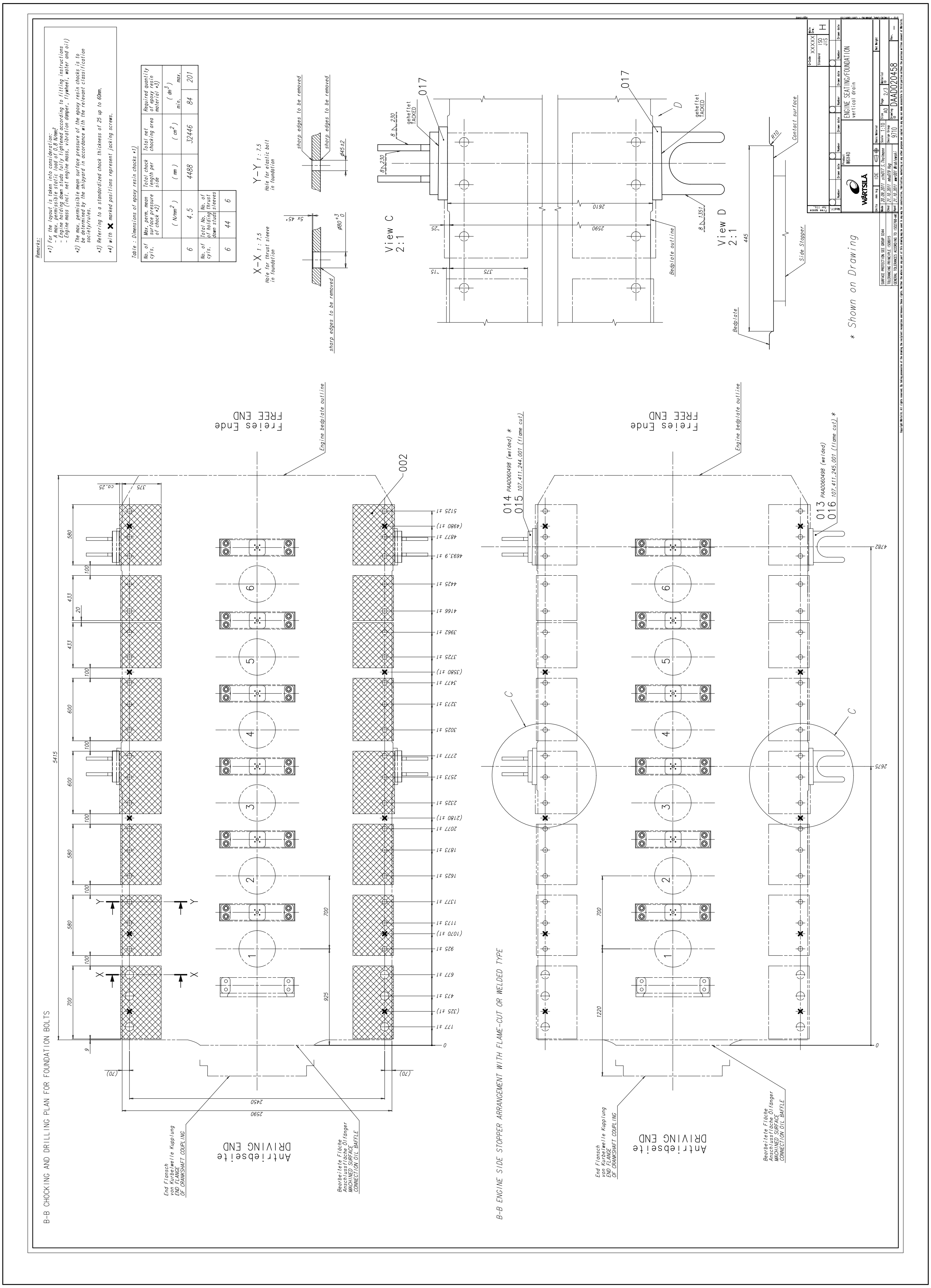
The longitudinal beams situated under the engine are to extend forward of the engine room bulkhead by at least half the length of the engine, and aft as far as possible.

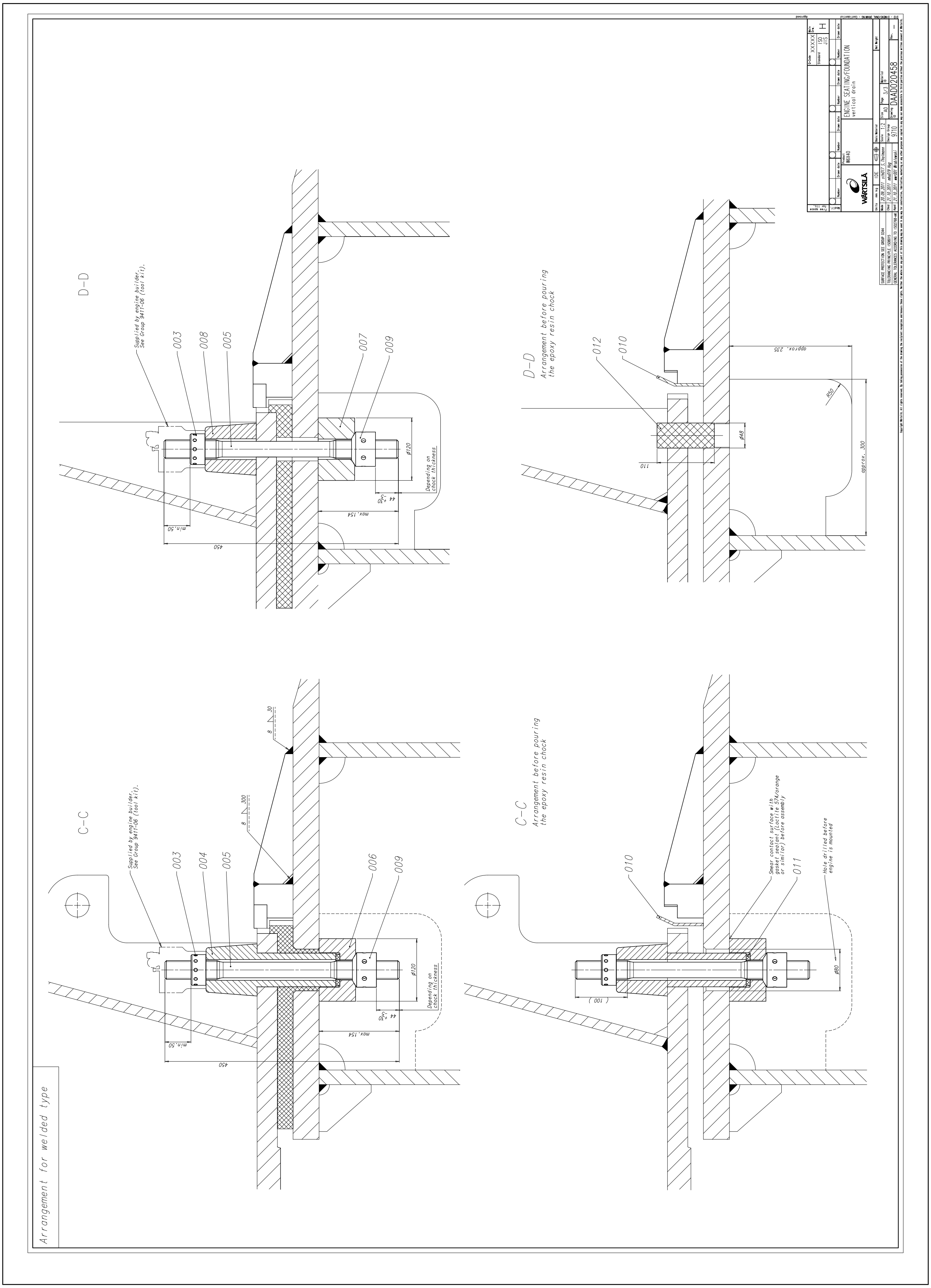
The maximum allowable rake is 3° to the horizontal.

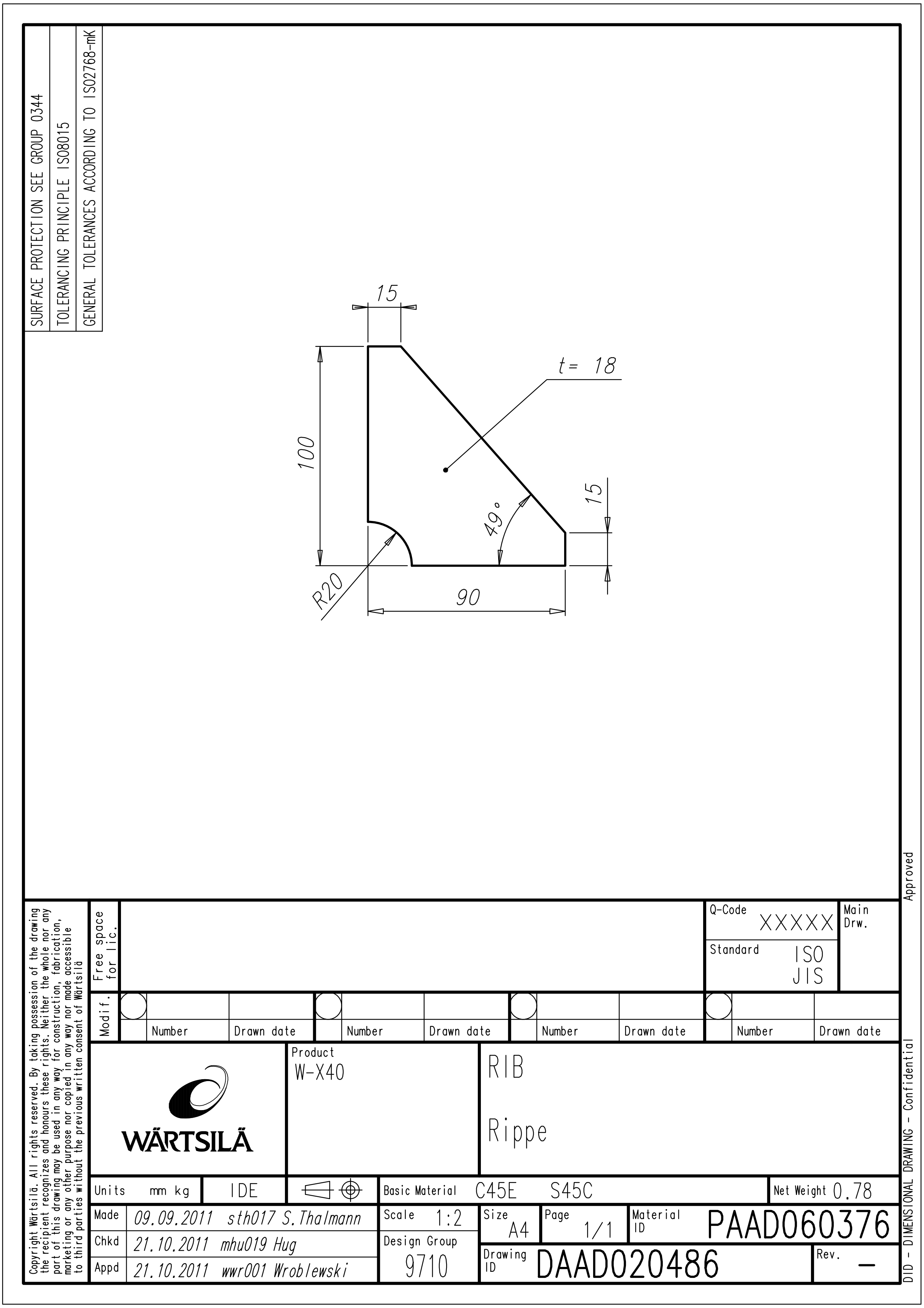
Before any engine seating work can be performed, make sure the engine is aligned with the intermediate propeller shaft.

18.4.1 Drawings


*1) Height to be determined by shipyard. For dimensions layout of lube oil drain tank and drains refer to design group 9722.
*2) Chock thickness 30+30-5 mm final chock thickness to be determined by shipyard.
*3) Final distances according to the appropriate rules.
PAAD060301 6 Cyl Execution with side stoppers welded type
PAAD060302 6 Cyl Execution with side stoppers flame-cut type
A-A (1:5)
Thickness 22
Thickness 18
001
ENGINE SEATING/FOUNDATION
vertical drain
DAAD020458
WÄRTSILÄ


B-B CHOCKING AND DRILLING PLAN FOR FOUNDATION BOLTS
B-B ENGINE SIDE STOPPER ARRANGEMENT WITH FLAME-CUT OR WELDED TYPE
FREE END
Freies Ende
DRIVING END
Antriebseite
View C
2:1
View D
2:1
* Shown on Drawing
ENGINE SEATING/FOUNDATION
vertical drain
DAAD020458


Arrangement for welded type
C–C
D–D
Supplied by engine builder, See Group 9411-06 (tool kit).
Depending on chock thickness
C–C Arrangement before pouring the epoxy resin chock
D–D Arrangement before pouring the epoxy resin chock
Hole drilled before engine is mounted
ENGINE SEATING/FOUNDATION
vertical drain
DAAD020458


SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
15
t= 18
100
15
49°
R20
90
Copyright Wärtsilä. All rights reserved. By taking possession of the drawing the recipient recognizes and honours these rights. Neither the whole nor any part of this drawing may be used in any way for construction, fabrication, marketing or any other purpose nor copied in any way nor made accessible to third parties without the previous written consent of Wärtsilä
Free space for lic.
Q-Code XXXXX
Main Drw.
Standard ISO JIS
Modif.
Number
Drawn date
Product W-X40
RIB
Rippe
Units mm kg
IDE
Basic Material C45E S45C
Net Weight 0.78
Made 09.09.2011 sth017 S.Thalmann
Chkd 21.10.2011 mhu019 Hug
Appd 21.10.2011 wwr001 Wroblewski
Scale 1:2
Design Group 9710
Size A4
Page 1/1
Material ID PAAD060376
Drawing ID DAAD020486
Rev. –
Approved
DID - DIMENSIONAL DRAWING - Confidential

SURFACE PROTECTION SEE GROUP 0344

GENERAL TOLERANCES ACCORDING TO ISO/2768-m

Properties	Standart	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 Load550 N / 70°C Load1100 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. $50x10^{-6}$ 1/K
Coefficient of friction	normal	min. 0.3

Required properties of epoxy resin material

Free space for lic.

First introduced at RTMOT

Modifications | Number | Drawn date | Number | Drawn date | Number | Drawn date

Q-Code X Q X X X Substitute for

Scale %

Drawn: M.PRSTEC 02.04.08

Epoxydharz

EPOXY RESIN

Wartsila Switzerland Ltd

CAD

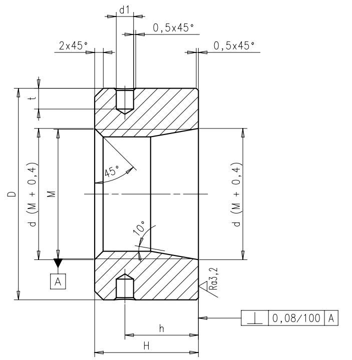
Design group 9710

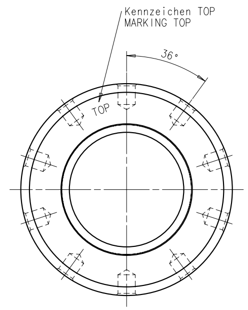
ISO JIS

4-107.398.394

Page:

WÄRTSILÄ





POS.	M	D	d	H	h	d1	t
001	M27	44	27,4	22	15	$4^{+0.2}_{0}$	4,8
002	M30	49	30,4	24	17	$4^{+0.2}_{0}$	4,8
003	M33	54	33,4	26	18	$4^{+0.2}_{0}$	4,8
004	M36	59	36,4	29	20	$6^{+0.2}_{0}$	7,2
005	M39	64	39,4	31	22	$6^{+0.2}_{0}$	7,2
006	M42	68	42,4	34	24	$6^{+0.2}_{0}$	7,2
007	M45	73	45,4	36	25	$6^{+0.2}_{0}$	7,2
008	M48	78	48,4	38	27	$6^{+0.2}_{0}$	7,2
009	M52	85	52,4	42	29	$6^{+0.2}_{0}$	7,2
010	M56	91	56,4	45	31	$6^{+0.2}_{0}$	7,2
011	M60	98	60,4	48	34	$9{,}5^{+0.2}_{0}$	11,4
012	M64	104	64,4	51	36	$9{,}5^{+0.2}_{0}$	11,4
013	M68	111	68,4	54	38	$9{,}5^{+0.2}_{0}$	11,4
014	M72	117	72,4	58	40	$9{,}5^{+0.2}_{0}$	11,4
015	M76	124	76,4	61	43	$9{,}5^{+0.2}_{0}$	11,4
016	M80	130	80,4	64	45	$9{,}5^{+0.2}_{0}$	11,4
017	M85	139	85,4	68	48	$14^{+0.2}_{0}$	16,8
018	M90	147	90,4	72	50	$14^{+0.2}_{0}$	16,8
019	M95	155	95,4	76	53	$14^{+0.2}_{0}$	16,8
020	M100	163	100,4	80	56	$14^{+0.2}_{0}$	16,8

Ra6,3 (Ra3,2)

MATERIAL:	42CrMo4 (ISO) SCM440 (JIS)
D >40 - ≤100	verguetet Rm = 900-1100 N/mm² HEAT TREATED
D >100 - ≤160	verguetet Rm = 800-950 N/mm² HEAT TREATED
D >160 - ≤250	verguetet Rm = 750-900 N/mm² HEAT TREATED

QTY	SEQ NO	Material ID	Material Name	Dimension/Occ.Dimension	Standard or Drawing	Basic Material Material Standard	Weight GR./NET
1	020	107.380.159.020	ROUND NUT	M100	107.380.159	42CrMo4 SCM 440	7.954
1	019	107.380.159.019	ROUND NUT	M95	107.380.159	42CrMo4 SCM 440	6.796
1	018	107.380.159.018	ROUND NUT	M90	107.380.159	42CrMo4 SCM 440	5.74
1	017	107.380.159.017	ROUND NUT	M85	107.380.159	42CrMo4 SCM 440	4.808
1	016	107.380.159.016	ROUND NUT	M80	107.380.159	42CrMo4 SCM 440	4.108
1	015	107.380.159.015	ROUND NUT	M76	107.380.159	42CrMo4 SCM 440	3.514
1	014	107.380.159.014	ROUND NUT	M72	107.380.159	42CrMo4 SCM 440	2.979
1	013	107.380.159.013	ROUND NUT	M68	107.380.159	42CrMo4 SCM 440	2.493
1	012	107.380.159.012	ROUND NUT	M64	107.380.159	42CrMo4 SCM 440	2.068
1	011	107.380.159.011	ROUND NUT	M60	107.380.159	42CrMo4 SCM 440	1.692
1	010	107.380.159.010	ROUND NUT	M56	107.380.159	42CrMo4 SCM 440	1.412
1	009	107.380.159.009	ROUND NUT	M52	107.380.159	42CrMo4 SCM 440	1.127
1	008	107.380.159.008	ROUND NUT	M48	107.380.159	42CrMo4 SCM 440	0.879
1	007	107.380.159.007	ROUND NUT	M45	107.380.159	42CrMo4 SCM 440	0.723
1	006	107.380.159.006	ROUND NUT	M42	107.380.159	42CrMo4 SCM 440	0.584
1	005	107.380.159.005	ROUND NUT	M39	107.380.159	42CrMo4 SCM 440	0.464
1	004	107.380.159.004	ROUND NUT	M36	107.380.159	42CrMo4 SCM 440	0.36
1	003	107.380.159.003	ROUND NUT	M33	107.380.159	42CrMo4 SCM 440	0.284
1	002	107.380.159.002	ROUND NUT	M30	107.380.159	42CrMo4 SCM 440	0.212
1	001	107.380.159.001	ROUND NUT	M27	107.380.159	42CrMo4 SCM 440	0.152

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Q-Code XQXXX Main Drw.

Standard ISO JIS

Modif. A EAAD700213 24.11.2011 B EAAD700366 05.11.2012

Number Drawn date Number Drawn date Number Drawn date Number Drawn date

WÄRTSILÄ

Product W-2S

ROUND NUT

Rundmutter

SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK

Units mm kg IDE

Made 18.12.2006 J.RIETMANN

Chkd

Appd 16.05.2007 esc002 Bohren

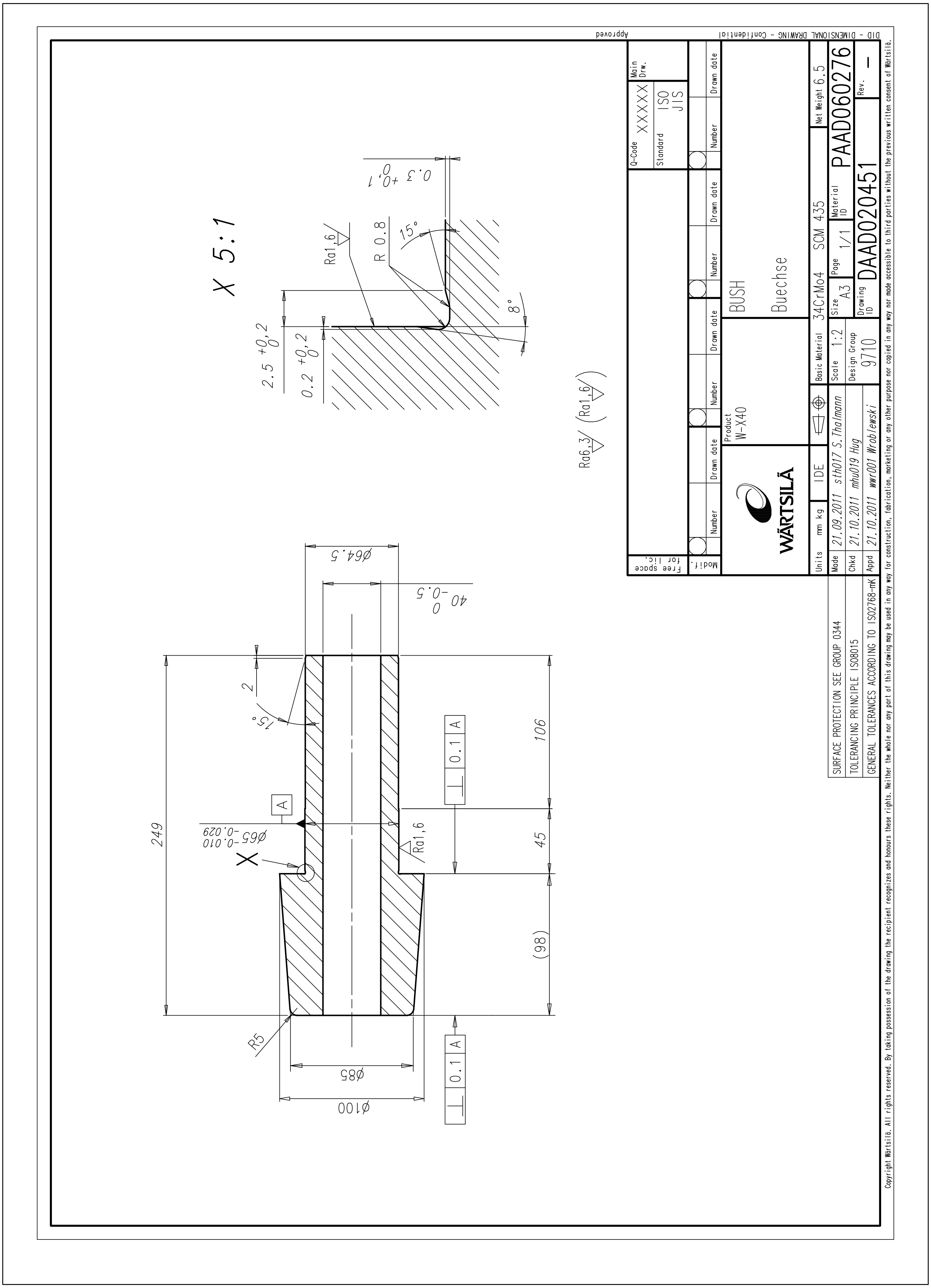
Basic Material

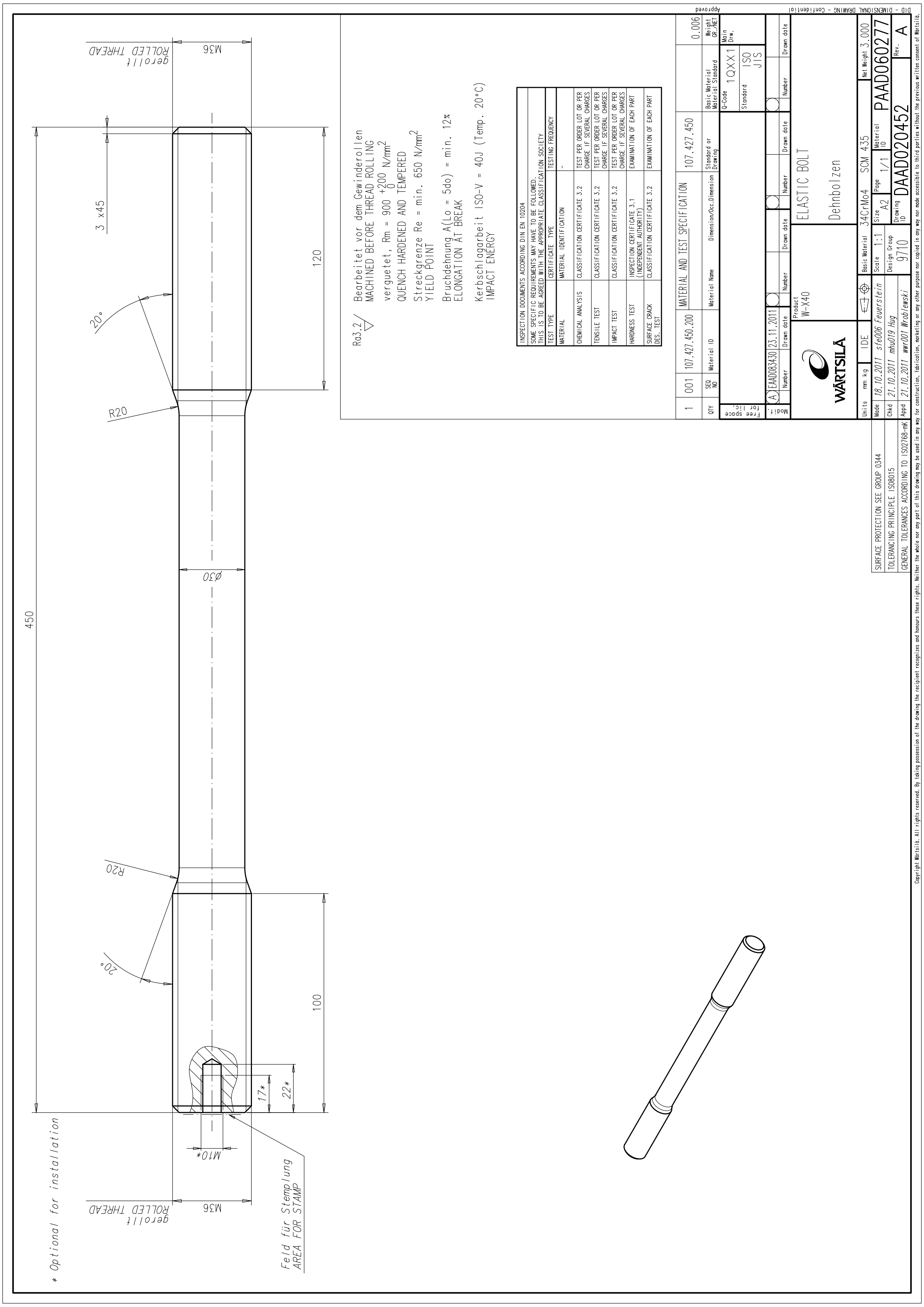
Scale 1:1 Size A1 Page 1/1 Material ID

Design Group 3306 Drawing ID 107.380.159 Rev. B

Net Weight

DID - DIMENSIONAL DRAWING - Confidential


X 5:1
BUSH
Buechse
Product W-X40
Basic Material 34CrMo4 SCM 435
Scale 1:2
Size A3
Page 1/1
Net Weight 6.5
Material ID PAAD060276
Drawing ID DAAD020451
Design Group 9710
Units mm kg
Made 21.09.2011 sth017 S.Thalmann
Chkd 21.10.2011 mhu019 Hug
Appd 21.10.2011 wwr001 Wroblewski
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
DID - DIMENSIONAL DRAWING - Confidential
Q-Code XXXXX
Standard ISO JIS
Ra6,3 (Ra1,6)
Ø100
Ø85
Ø64.5
249
106
45
(98)
R5
15°
8°
R 0.8
Copyright Wärtsilä. All rights reserved.


ROLLED THREAD
gerollt
M36
3 x45
120
20°
R20
Ø30
450
100
17*
22*
M10*
* Optional for installation
Feld für Stemplung
AREA FOR STAMP
Ra3.2
Bearbeitet vor dem Gewinderollen
MACHINED BEFORE THREAD ROLLING
verguetet, Rm = 900 +200 0 N/mm2
QUENCH HARDENED AND TEMPERED
Streckgrenze Re = min. 650 N/mm2
YIELD POINT
Bruchdehnung A(Lo = 5do) = min. 12%
ELONGATION AT BREAK
Kerbschlagarbeit ISO-V = 40J (Temp. 20°C)
IMPACT ENERGY
INSPECTION DOCUMENTS ACCORDING DIN EN 10204
SOME SPECIFIC REQUIREMENTS MAY HAVE TO BE FOLLOWED.
THIS IS TO BE AGREED WITH THE APPROPRIATE CLASSIFICATION SOCIETY
MATERIAL AND TEST SPECIFICATION
107.427.450.200
107.427.450
0.006
1QXX1
ISO
JIS
W-X40
ELASTIC BOLT
Dehnbolzen
34CrMo4
SCM 435
A2
1:1
1/1
9710
PAAD060277
DAAD020452
Net Weight 3.000
Rev. A
18.10.2011 sfe006 Feuerstein
21.10.2011 mhu019 Hug
21.10.2011 wwr001 Wroblewski
EAAD083430 23.11.2011
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
WÄRTSILÄ

Exec. code no 200 / Number of		Pos. code no		Article number / Drawing number	Designation / Material and remarks	Source of supply / Mass kg/piece	Modification letter	
	1	001		107.427.386.500	Material- and test specification			
			4-	107.427.386				
	1	002		107.385.952.500	Heat treatment specification			
			4-	107.385.952	Quench and temper of low-alloy steels			
	1	003		107.385.948.500	Testing specification			
			4-	107.385.948	Evaluation of mechanical properties			
	1	004		107.385.946.500	Testing specification			
			4-	107.385.946	Hardness testing			
	1	005		107.385.944.500	Testing specification			
			4-	107.385.944	Chemical analysis of materials			
	1	006		107.131.611.500	Quality and test specification			
			4-	107.131.611	Bolts and studs			
		007						
			4-					

Pos. 001	Material and testing specification – Elastic Bolt
Pos. 002 - 006	Included in pos. 001

Substitute for:							PC	Q-Code	X	X	X	X	X
Modif	A	EAAD700239	24.01.2012										
		Number	Drawn Date	Number	Drawn Date	Number	Drawn Date	Number	Drawn Date				

WÄRTSILÄ

Product	W-2S	Specifications/Instructions	Elastic Bolt		
Made	24.02.2010	T. Daniels	Main Drw.	Page 1 / 1	Material ID 107.427.450.200
Chkd	24.02.2010	W. Luft	Design Group	Drawing ID 107.427.450	Rev A
Appd	24.02.2010	B. Frei	0330		

T_PC-Drawing_portrait | Made by: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.12 (6/28/2012)

Material and Testing Specification: Elastic bolt

Table of contents

Substitute for:								PC	Q-Code	X X X X X	
Modif	A	EAAD079625	15.03.2010	B	EAAD083151	27.07.2011	C	EAAD083572	23.01.2012		
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date	Number	Drawn Date

WÄRTSILÄ	Product **W-2S**	**Material and Testing Specification** **Elastic Bolt**	
Made 17.02.2010 T.Daniels	Main Drw.	Page 1 / 12	Material ID **107.427.386.500**
Chkd 24.02.2010 W.Luft	Design Group	Drawing ID **107.427.386**	Rev **C**
Appd 24.02.2010 W.Luft	**1115**		

T_PC-Drawing_portrait | Made by: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.10 (3/22/2012)

1 General

1.1 Scope

This specification is valid for the elastic bolt for Wärtsilä R-engines.

The quality of the finished parts must meet the requirements of this specification.

1.2 Range of Application

This specification describes the quality aspects of the elastic bolt, such as material and quality standards and testing.

Deviations from the content of this specification must be previously agreed by Wärtsilä Switzerland Ltd (WCH) in written form by RAE (request of alternate execution).

This specification (together with the drawing) overrules the Parts Acceptance List and Material Specification List of group 400.

1.3 References

In addition to the requirements of this specification, the requirements of the following shall also apply:

EN 10083-3:2007	“Steels for quenching and tempering-alloy steels”
JIS G 4053:2003	“Low alloyed steels for machine structural use”
GB/T 3077-1999	“Alloy structure steels”

2 Material

42CrMo4 according to EN 10083-3:2007, SCM 440 according to JIS G 4053:2003 and 42CrMoA according to GB/T 3077-1999.

34CrMo4 according to EN 10083-3:2007, SCM 435 according to JIS G 4053:2003 and 35CrMo according to GB/T 3077-1999.

34CrNiMo6 according to EN 10083-3:2007, SNCM 439 according to JIS G 4053:2003 and 40CrNiMoA according to GB/T 3077-1999.

The material has to fulfill the requirements given on the drawing and in this specification.

Substitute for:										PC	Q-Code X X X X X
Modif	A	EAAD079625	15.03.2010	B	EAAD083151	27.07.2011	C	EAAD083572	23.01.2012		
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date	Number	Drawn Date

WÄRTSILÄ	Product: W-2S		Material and Testing Specification Elastic Bolt	
Made	17.02.2010	T.Daniels	Main Drw.	Page 2 / 12	Material ID 107.427.386.500
Chkd	24.02.2010	W.Luft	Design Group	Drawing ID 107.427.386	Rev C
Appd	24.02.2010	W.Luft	1115		

T_PC-Drawing_portrait | Made by: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.10 (3/22/2012)

2.1 Heat Treatment

2.1.1 Quench hardening and tempering

Quench hardening and tempering has to be performed in order to achieve the required mechanical properties (see material data sheets in the appendix).

The specification **107.427.450** position **002** applies here.

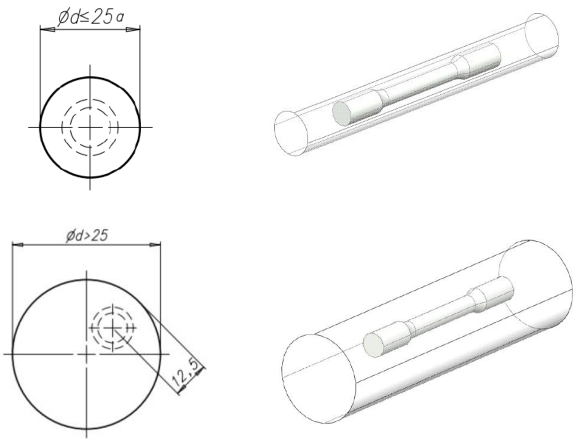
2.2 Mechanical Properties

The following mechanical properties must be determined and meet the requirement of corresponding standards, see relevant **Material Data Sheets in the appendix**. If different values are specified in the drawing, the mechanical properties must meet the requirement of drawing.

2.2.1 Tensile test

The tensile tests have to be performed on one tensile test specimen from the dummy with the same diameter after final heat treatment. The specimen for tensile test has to be machined from certain position which is based on the size of the original part, as shown in Figure 1.

The tensile test has to be performed according to specification **107.427.450** position **003**.



[a] For small products (d ≤ 25 mm), the test piece shall, if possible, consist of an un-machined part of the bar.

Figure 1. Location of the test pieces in dummy

Substitute for:									PC	Q-Code	X X X X X
Modif	A	EAAD079625	15.03.2010	B	EAAD083151	27.07.2011	C	EAAD083572	23.01.2012		
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date	Number	Drawn Date

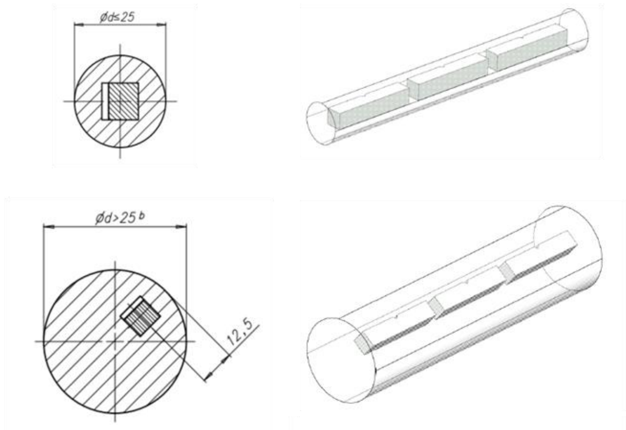
WÄRTSILÄ	Product W-2S	Material and Testing Specification Elastic Bolt	
Made 17.02.2010 T.Daniels	Main Drw.	Page 3 / 12	Material ID 107.427.386.500
Chkd 24.02.2010 W.Luft	Design Group 1115	Drawing ID 107.427.386	Rev C
Appd 24.02.2010 W.Luft			

T_PC-Drawing_portrait | Made by: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.10 (3/22/2012)

2.2.2 Impact test

The impact test has to be performed on three impact test samples from bars machined from the dummy with same diameter after final heat treatment. The specimen for impact energy test has to be machined from certain position which is based on the size of the original part, as shown in Figure 2.

The impact test has to be performed according to specification **107.427.450** position **003**.



[a] For small products (d ≤ 25 mm), the test piece shall, if possible, consist of an un-machined part of the bar.

[b] For round bars the longitudinal axis of the notch shall be about parallel to the direction of a diameter.

Figure 2. Location of the test pieces in dummy

2.2.3 Hardness testing

For all types of hardness testing the specification **107.427.450** position **004** is valid.

The hardness has to be measured on a polished area using the Brinell method.

2.3 Chemical Composition

The chemical analysis has to be preformed for each raw material batch (material from one melt). The chemical composition of the material has to meet the specification given on the material data sheets in the appendix, please refer to specification **107.427.450** position **005**.

Substitute for:										PC	Q-Code	X	X	X	X	X
Modif	A	EAAD079625	15.03.2010	B	EAAD083151	27.07.2011	C	EAAD083572	23.01.2012							
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date				

WÄRTSILÄ	Product **W-2S**		**Material and Testing Specification** Elastic Bolt	
Made	17.02.2010	T.Daniels	Main Drw.	Page 4 / 12 · Material ID **107.427.386.500**
Chkd	24.02.2010	W.Luft	Design Group	Drawing ID **107.427.386** · Rev **C**
Appd	24.02.2010	W.Luft	**1115**	

T_PC-Drawing_portrait | Made by: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.10 (3/22/2012)

3 Non-Destructive Testing (NDT)

VT has to be done on each finished part.

MT or PT has to be performed on each finished part.

Instructions and acceptance criteria are given below and in the specification **107.427.450** position **006**.

3.1 Visual Testing (VT)

All parts have to be free of cracks, crack-like indications, laps, seams, folds or other injurious indications. No burrs, dents, debris or dirt are allowed.

The specification **107.427.450** position **006** applies here.

3.2 Magnetic Particle Testing (MT) or Dye Penetrate Test (PT)

Following the Magnetic Particle Test, the part has to be demagnetized: max 3 Oertsted.

The specification **107.427.450** position **006** applies here.

4 Reporting

A test report has to be provided with the following information given in a 3.1 or 3.2 inspection certificate, which is defined on drawing, according ISO 10474 / EN10204:

1. Purchaser and order number
2. Number (stamp) of the part and corresponding batch number
3. Material used / specified on the drawing
4. Test results
   a. Chemical analysis report from each raw material batch (mill sheet)
   b. Tensile test result (R_m, R_e, A and Z) of each test batch
   c. Impact energy of each test batch
   d. Brinell hardness of each part
5. NDT inspection report
6. All reports from heat treatments have to be attached
7. Name and address of laboratory
8. Date, name and signature of responsible person

Substitute for:									PC	Q-Code	X	X	X	X	X
Modif	A	EAAD079625	15.03.2010	B	EAAD083151	27.07.2011	C	EAAD083572	23.01.2012						
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date			

WÄRTSILÄ	Product W-2S	Material and Testing Specification Elastic Bolt	
Made 17.02.2010 T.Daniels	Main Drw.	Page 5 / 12	Material ID 107.427.386.500
Chkd 24.02.2010 W.Luft	Design Group 1115	Drawing ID 107.427.386	Rev C
Appd 24.02.2010 W.Luft			

T_PC-Drawing_portrait | Made by: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.10 (3/22/2012)

5 APPENDIX: Material Data Sheets

- 42CrMo4 EN 10083-3:2007
- SCM 440 JIS G 4053:2003
- 42CrMoA GB/T 3077-1999
- 34CrMo4 EN 10083-3:2007
- SCM 435 JIS G 4053:2003
- 35CrMo GB/T 3077-1999
- 34CrNiMo6 EN 10083-3:2007
- SNCM 439 JIS G 4053:2003
- 40CrNiMoA GB/T 3077-1999

Substitute for:								PC	Q-Code	X X X X X	
Modif	A	EAAD079625	15.03.2010	B	EAAD083151	27.07.2011	C	EAAD083572	23.01.2012		
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date	Number	Drawn Date

WÄRTSILÄ	Product W-2S	Material and Testing Specification Elastic Bolt	
Made 17.02.2010 T.Daniels	Main Drw.	Page 6 / 12	Material ID 107.427.386.500
Chkd 24.02.2010 W.Luft	Design Group 1115	Drawing ID 107.427.386	Rev C
Appd 24.02.2010 W.Luft			

T_PC-Drawing_portrait | Made by: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.10 (3/22/2012)

Ferrous Materials Alloyed
42CrMo4

Info Compliance of further requirements from the classification societies based upon agreement.

Chemical Composition

The following data cover all materials included in "Similar Standards". Within the grey area the values are given as defined in the highlighted Standard in "Similar Standards".
Acc. min./max.: accepted limits for chemical composition according to similar standards, as long as mechanical properties are fulfilled

	C	Si	Mn	P	S	Cr	Mo	Ni	Cu
Acc. Min	0.35		0.35			0.80			
Min.	0.38		0.60			0.90	0.15		
Max.	0.45	0.40	0.90	0.025	0.035	1.20	0.30		
Acc. Max.	0.46		1.00	0.035				0.30	0.30

Comments: Fe: remainder
-

Mechanical Properties

The raw material can be purchased with or without heat treatment; Heat treatment which determines the final mechanical properties can also be performed in pre-machined state
Unless different values are given on the drawing or in the material specification, all mechanical properties are mandatory for final products.
Only in case tensile tests or impact tests are requested by Wärtsilä, the values in 1) are mandatory. In any other case the values in 2) apply and the values in 1) are only for information.

1)								
Material Condition			quench hardened and tempered (QT)					
d / t	[mm]		d≤16	16<d≤40	40<d≤100	100<d≤160	160<d≤250	
Rm	[MPa]		1100-1300	1000-1200	900-1100	800-950	750-900	
Re	[MPa]		≥ 900	≥ 750	≥ 650	≥ 550	≥ 500	
A	[%]	long.	≥ 10	≥ 11	≥ 12	≥ 13	≥ 14	
		tang.					≥ 12	
		trans.					≥ 10	
Z	[%]	long.	≥ 40	≥ 45	≥ 50	≥ 50	≥ 55	
		tang.						
		trans.						
ISO-V [a]	[J]	long.	≥ 35	≥ 35	≥ 35	≥ 35	≥ 35	
		tang.						
		trans.						
Hardness	[HBW]							

[a] Temperature for measurement of impact energy: +23 ± 5 °C (RT)

2)	Rm values converted into HBW according to ISO 18265:2004							
Rm	[MPa]		1100-1300	1000-1200	900-1100	800-950	750-900	
Hardness	[HBW]	calc.	346-411	315-379	283-346	251-299	236-283	

Comments: For the dimension 250 < d ≤ 500 according to SEW 550: Rp0.2 = 460 N/mm2
- For the dimension 500 < d ≤ 750 according to SEW 550: Rp0.2 = 390 N/mm2
-

Substitute for:								PC	Q-Code	X	X	X	X	X
Modif	A	EAAD079625	15.03.2010	B	EAAD083151	27.07.2011	C	EAAD083572	23.01.2012					
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		

WÄRTSILÄ	Product **W-2S**	**Material and Testing Specification** **Elastic Bolt**	
Made 17.02.2010 T.Daniels	Main Drw.	Page 7 / 12	Material ID **107.427.386.500**
Chkd 24.02.2010 W.Luft	Design Group **1115**	Drawing ID **107.427.386**	Rev **C**
Appd 24.02.2010 W.Luft			

T_PC-Drawing_portrait | Made by: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.10 (3/22/2012)

WÄRTSILÄ

Ferrous Materials Alloyed
42CrMo4

Forming and Heat Treatment

Only heat treatment processes have to be performed that are mentioned on the drawing and/or in the material and testing specification of the part.
The given temperatures are for guidance only. The temperature must be chosen part-related.

Process	Description
Forging	1050 - 850 °C
Normalising	840 - 880 °C
Soft Annealing	680 - 720 °C
Stress Relief Annealing	530 - 670 °C
Quench Hardening	820- 860 °C (in water or oil)
Tempering	540- 680 °C (min. 1h)

Similar Standards

The material properties on this datasheet are based on the grey highlighted standard.

Grade	Standard	Comments
42CrMo4 (1.7225)	EN 10083-3:2007	
SCM440	JIS G 4053:2008	
42CrMo	GB/T 3077-1999	

Obsolete Standards

Grade	Standard	Comments
42 CrMo 4	EN 10083-1:1996-10	invalid; replaced with: EN 10083-3:2007

Additional Information

Attribute	Description
Forming	hot deformable, cold compressible
Weldability	limited weldability
Machinability	well machinable at HB max. 241
Scaling Resistance	up to 540 °C
Magnetic Properties	magnetisable
Application Range	for parts with high ductility; studs, shafts, cranks, cogs

Substitute for: PC Q-Code X X X X X

Modif											
A	EAAD079625	15.03.2010	B	EAAD083151	27.07.2011	C	EAAD083572	23.01.2012			
	Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date

WÄRTSILÄ

Product **W-2S**

Material and Testing Specification
Elastic Bolt

Made	17.02.2010	T.Daniels	Main Drw.	Page 8 / 12
Chkd	24.02.2010	W.Luft	Design Group	Material ID **107.427.386.500**
Appd	24.02.2010	W.Luft	**1115**	Drawing ID **107.427.386** Rev **C**

T_PC-Drawing_portrait | Made by: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.10 (3/22/2012)

WÄRTSILÄ

Ferrous Materials Alloyed
34CrMo4

Info

Compliance of further requirements from the classification societies based upon agreement.

Chemical Composition

The following data cover all materials included in "Similar Standards". Within the grey area the values are given as defined in the highlighted Standard in "Similar Standards".
Acc. min./max.: accepted limits for chemical composition according to similar standards, as long as mechanical properties are fulfilled

	C	Si	Mn	P	S	Cr	Mo	Ni	Cu						
Acc. Min			0.40			0.80									
Min.	0.30		0.60			0.90	0.15								
Max.	0.37	0.40	0.90	0.020	0.035	1.20	0.30								
Acc. Max.	0.40		0.95	0.035				0.30	0.30						

Comments: Fe: remainder
-

Mechanical Properties

The raw material can be purchased with or without heat treatment; Heat treatment which determines the final mechanical properties can also be performed in pre-machined state
Unless different values are given on the drawing or in the material specification, all mechanical properties are mandatory for final products.
Only in case tensile tests or impact tests are requested by Wärtsilä, the values in 1) are mandatory. In any other case the values in 2) apply and the values in 1) are only for information.

1)										
Material Condition			quench hardened and tempered (QT)							
d / t	[mm]		d ≤ 16	16 ≤d≤40	40≤d≤100	100≤d≤160	160≤d≤250			
Rm	[MPa]		1000-1200	900-1100	800-950	750-900	700-850			
Re	[MPa]		≥ 800	≥650	≥550	≥500	≥450			
A	[%]	long.	≥ 11	≥ 12	≥ 14	≥ 15	≥ 15			
		tang.								
		trans.								
Z	[%]	long.	≥ 45	≥ 50	≥ 55	≥ 55	≥ 60			
		tang.								
		trans.								
ISO-V [a]	[J]	long.		≥ 40	≥ 45	≥ 45	≥ 45			
		tang.								
		trans.								
Hardness	[HBW]									

[a] Temperature for measurement of impact energy: +23 ± 5 °C (RT)

2)	Rm values converted into HBW according to ISO 18265:2004									
Rm	[MPa]		1000-1200	900-1100	800-950	750-900	700-850			
Hardness	[HBW]	calc.	315-379	283-346	251-299	236-283	220-268			

Comments:
-

Substitute for:								PC	Q-Code	X	X	X	X	X

Modif	A	EAAD079625	15.03.2010	B	EAAD083151	27.07.2011	C	EAAD083572	23.01.2012			
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date

WÄRTSILÄ	Product: **W-2S**	**Material and Testing Specification** **Elastic Bolt**

Made	17.02.2010	T.Daniels	Main Drw.	Page 9 / 12	Material ID **107.427.386.500**
Chkd	24.02.2010	W.Luft	Design Group **1115**	Drawing ID **107.427.386**	Rev **C**
Appd	24.02.2010	W.Luft			

T_PC-Drawing_portrait | Made by: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.10 (3/22/2012)

WÄRTSILÄ

Ferrous Materials Alloyed
34CrMo4

Forming and Heat Treatment

Only heat treatment processes have to be performed that are mentioned on the drawing and/or in the material and testing specification of the part.
The given temperatures are for guidance only. The temperature must be chosen part-related.

Process	Description
Normalising	850 - 890 °C
Forging	1050 - 850 °C
Soft Annealing	680 - 720 °C
Stress Relief Annealing	650 - 680 °C
Quench Hardening	830- 870 °C (in water or oil)
Tempering	540- 680 °C

Similar Standards

The material properties on this datasheet are based on the grey highlighted standard.

Grade	Standard	Comments
34CrMo4 (1.7220)	EN 10083-3:2006	
SCM 435	JIS G 4053:2008	
35CrMoA	GB/T 3077-1999	

Obsolete Standards

Grade	Standard	Comments
34 CrMo 4	EN 10083-1:1996-10	invalid; replaced with: EN 10083-3:2006

Additional Information

Attribute	Description
Forming	hot formable, cold compressible
Weldability	limited weldability
Machinability	well machinable
Scaling Resistance	up to 540 °C
Magnetic Properties	magnetisable
Application Range	for parts with high ductility; cranks, shafts, piston rods, valve control unit

Substitute for: | PC | Q-Code | X | X | X | X | X

Modif								
A	EAAD079625	15.03.2010	B	EAAD083151	27.07.2011	C	EAAD083572	23.01.2012
	Number	Drawn Date		Number	Drawn Date		Number	Drawn Date

WÄRTSILÄ

Product **W-2S**

Material and Testing Specification

Elastic Bolt

Made	17.02.2010	T.Daniels	Main Drw.	Page 10 / 12
Chkd	24.02.2010	W.Luft	Design Group	Material ID **107.427.386.500**
Appd	24.02.2010	W.Luft	**1115**	Drawing ID **107.427.386** Rev **C**

T_PC-Drawing_portrait | Made by: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.10 (3/22/2012)

WÄRTSILÄ

Ferrous Materials Alloyed
34CrNiMo6

Info Compliance of further requirements from the classification societies based upon agreement.

Chemical Composition

The following data cover all materials included in "Similar Standards". Within the grey area the values are given as defined in the highlighted Standard in "Similar Standards".
Acc. min./max.: accepted limits for chemical composition according to similar standards, as long as mechanical properties are fulfilled

	C	Si	Mn	P	S	Cr	Mo	Ni	Cu
Acc. Min			0.40			0.60		1.25	
Min.	0.30		0.50			1.30	0.15	1.30	
Max.	0.38	0.40	0.80	0.025	0.035	1.70	0.30	1.70	
Acc. Max.	0.44		0.90	0.035				2.00	0.30

Comments: Fe: remainder
-

Mechanical Properties

The raw material can be purchased with or without heat treatment; Heat treatment which determines the final mechanical properties can also be performed in pre-machined state
Unless different values are given on the drawing or in the material specification, all mechanical properties are mandatory for final products.
Only in case tensile tests or impact tests are requested by Wärtsilä, the values in 1) are mandatory. In any other case the values in 2) apply and the values in 1) are only for information.

1)							
Material Condition			quench hardened and tempered (QT)				
d / t	[mm]		d ≤ 16	16 ≤d≤40	40≤d≤100	100≤d≤160	160≤d≤250
Rm	[MPa]		1200-1400	1100-1300	1000-1200	900-1100	800-950
Re	[MPa]		≥ 1000	≥ 900	≥ 800	≥ 700	≥ 600
A	[%]	long.	≥ 9	≥ 10	≥ 11	≥ 12	≥ 13
		tang.					
		trans.					
Z	[%]	long.	≥ 40	≥ 45	≥ 50	≥ 55	≥ 55
		tang.					
		trans.					
ISO-V [a]	[J]	long.		≥ 45	≥ 45	≥ 45	≥ 45
		tang.					
		trans.					
Hardness	[HBW]						

[a] Temperature for measurement of impact energy: +23 ± 5 °C (RT)

2)	Rm values converted into HBW according to ISO 18265:2004						
Rm	[MPa]		1200-1400	1100-1300	1000-1200	900-1100	800-950
Hardness	[HBW]	calc.	379-444	346-411	315-379	283-346	251-299

Comments:
-

Substitute for:							PC	Q-Code X X X X X
Modif	A	EAAD079625	15.03.2010	B	EAAD083151	27.07.2011	C	EAAD083572 23.01.2012
		Number	Drawn Date		Number	Drawn Date		Number / Drawn Date / Number / Drawn Date

WÄRTSILÄ

Product **W-2S**

Material and Testing Specification
Elastic Bolt

Made	17.02.2010	T.Daniels	Main Drw.	Page 11 / 12
Chkd	24.02.2010	W.Luft	Design Group **1115**	Material ID **107.427.386.500**
Appd	24.02.2010	W.Luft		Drawing ID **107.427.386** Rev **C**

T_PC-Drawing_portrait | Made by: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.10 (3/22/2012)

WÄRTSILÄ

Ferrous Materials Alloyed
34CrNiMo6

Forming and Heat Treatment

Only heat treatment processes have to be performed that are mentioned on the drawing and/or in the material and testing specification of the part.
The given temperatures are for guidance only. The temperature must be chosen part-related.

Process	Description
Forging	1100 - 850 °C
Soft Annealing	650 - 680 °C
Normalising	850 - 880 °C
Quench Hardening	830 - 860 °C (water or oil)
Tempering	540 - 660 °C

Similar Standards

The material properties on this datasheet are based on the grey highlighted standard.

Grade	Standard	Comments
34CrNiMo6 (1.6582)	EN 10083-3:2006	
SNCM439	JIS G 4053:2008	
40CrNiMoA	GB/T 3077-1999	
SNCM 439	KS D 3709:1990	
36 CrNiMo 6	ISO 683-18:1996	

Obsolete Standards

Grade	Standard	Comments
34 CrNiMo 6	EN 10083-1:1996	invalid: replaced with: EN 10083-3:2006
34 CrNiMo 6	DIN 17200:1969	invalid: replaced with: EN 10083-3:2006

Additional Information

Attribute	Description
Weldability	limited weldability, welding should be done after QT-treatment, pre-heating to 300-400 °C
Forming	hot deformable, cold compressible
Machinability	well machinable
Scaling Resistance	up to 500 °C
Magnetic Properties	magnetisable
Application Range	parts with specially high load; gears, studs, bolts, shafts, cogs

Substitute for:							PC	Q-Code	X	X	X	X	X
Modif	A	EAAD079625	15.03.2010	B	EAAD083151	27.07.2011	C	EAAD083572	23.01.2012				
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date	

WÄRTSILÄ	Product W-2S		**Material and Testing Specification** **Elastic Bolt**
Made	17.02.2010	T.Daniels	Main Drw.
Chkd	24.02.2010	W.Luft	Design Group **1115**
Appd	24.02.2010	W.Luft	

Page 12 / 12 | Material ID **107.427.386.500**
Drawing ID **107.427.386** | Rev **C**

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Heat Treatment Specification: Quench and Temper of Low Alloy Steels

Table of contents

Substitute for:							PC	Q-Code	X X X X X
Modif	A	EAAD073008	28.05.2009	B	EAAD700229	19.12.2011	C	EAAD084038	10.08.2012
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date

WÄRTSILÄ	Product W-2S		**Heat Treatment Specification** Quench and Temper of Low Alloy Steels
Made	09.01.2009	M. Damani	Main Drw.
Chkd	09.01.2009	W.Luft	Design Group
Appd	09.01.2009	W.Luft	0330

Page 1 / 7	Material ID 107.385.952.500	
Drawing ID 107.385.952		Rev C

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1 Introduction

Parts made of low-alloy steels are quenched and tempered in order to achieve the required mechanical properties.

2 Range of Application

This specification is applicable for parts made of low-alloy steels which are subjected to a subsequent surface heat treatment (e.g. quench and temper, nitriding, nitrocarburizing, case hardening).

3 General quality requirements on quenched and tempered parts

3.1 Requirements according to the drawing

The requirements given on the drawing must be fulfilled. The tensile strength has to be tested only for first time production and frequent checking procedures. The hardness measurement has to be done on a polished surface with Brinell or Rockwell (mentioned in the drawing) hardness testing on one part per batch. The impact energy has to be tested if required.

Tensile test, impact energy test and hardness test have to be carried out according to WCH specification “Evaluation of Mechanical Properties” (**107.385.948**) and “Hardness Testing” (**107.385.946**). In this specification all applicable standards, also for hardness – tensile strength conversion are given.

4 Heat treatment process specifications

4.1 Charging of the parts

For each batch the parts have to be charged vertically in baskets or on grids with enough distance between each other to guarantee a good heat transfer during heating up and a good cooling behavior while quenching.

4.2 Cleaning of the parts

All the parts have to be thoroughly cleaned by alkaline washing. Grease, oil; emulsion and dust have to be removed completely. For this suitable cleaning agents have to be used. This is necessary as otherwise the oil and grease evaporating can disturb to the protective atmosphere of the gas.

Substitute for:										PC	Q-Code X X X X X
Modif	A	EAAD073008	28.05.2009	B	EAAD700229	19.12.2011	C	EAAD084038	10.08.2012		
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date	Number	Drawn Date

WÄRTSILÄ	Product W-2S		Heat Treatment Specification Quench and Temper of Low Alloy Steels	
Made	09.01.2009	M. Damani	Main Drw.	Page 2 / 7	Material ID 107.385.952.500
Chkd	09.01.2009	W.Luft	Design Group 0330	Drawing ID 107.385.952	Rev C
Appd	09.01.2009	W.Luft			

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4.3 Preheating

The preheating has to be done in a pre-heating furnace in air.

The preheating has to be carried out between 400 - 450 °C for min. 90 minutes. Depending on the cross section of the parts, the pre-heating time can take as long as 180 minutes. Afterwards the batch has to be transferred to the seal quench furnace immediately.

4.4 Hardening temperature, Holding time

The whole process in the seal quench furnace has to be carried out in protective atmosphere in order to prevent decarburization or carburization of the parts. The carbon potential in the atmosphere has to be chosen in correspondence with the chemical analysis of the material.

The hardening temperature has to be chosen according the used material (see material data sheets).
The holding time on hardening temperature depends on the cross section of the part.
The holding time is defined by:
1 h + 1 h per 25 mm wall thickness of the part
e.g.: round bar Ø 200 mm:

1 h + 4 h (wall thickness 100 mm) = 5 h total holding time

4.5 Quenching

At the end of the holding time, the batch has to be quenched directly in oil. The oil temperature should be between 60 and 80°C. Depending on the geometry of the parts, the person responsible for the heat treatment has to choose the agitation of the oil bath in order to prevent too much distortion. The parts have to remain in the oil bath until the core of the parts has reached the same temperature as the oil. If the parts are taken out of the oil too early, this can cause cracking during the subsequent washing process.

4.6 Washing

After quenching the parts have to be washed properly before tempering. The washing temperature in alkaline bath should be between 70 and 80°C.

4.7 Hardness testing

After washing the hardness has to be checked on the parts. This is important in order to choose the appropriate tempering temperature

Substitute for:									PC	Q-Code	X	X X X X
Modif	A	EAAD073008	28.05.2009	B	EAAD700229	19.12.2011	C	EAAD084038	10.08.2012			
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date

WÄRTSILÄ	Product W-2S		Heat Treatment Specification Quench and Temper of Low Alloy Steels	
Made	09.01.2009	M. Damani	Main Drw.	Page 3 / 7 — Material ID 107.385.952.500
Chkd	09.01.2009	W.Luft	Design Group 0330	Drawing ID 107.385.952 — Rev C
Appd	09.01.2009	W.Luft		

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4.8 Tempering

Tempering has to be carried out in neutral atmosphere, e.g. nitrogen or in air (in case of air atmosphere sand blasting is obligatory, see 4.10). The tempering temperature has to be chosen according to the hardness of the parts after hardening and the specified value for tensile strength or hardness of the material.

The holding time on tempering temperature should be at least the same as the holding time on hardening temperature.

4.9 Hardness testing

After finishing the tempering process, the hardness of the parts has to be checked again and the hardness has to correspond to the specified value on the drawing (in case only the tensile strength is given a conversion is admissible; see WCH specification “Evaluation of mechanical properties” (**107.385.948**). The surface has to be properly ground before hardness testing is carried out.

4.10 Sand blasting

All parts which have been tempered in air have to be sand blasted before delivery in order to achieve a suitable surface condition for the further production steps.

5 Quality assurance

5.1 Test specimens for metallurgical investigations

5.1.1 Tensile tests

The specimen for tensile test has to be machined from certain position which is based on the size of the original part, as shown in Figure 1. If there are sketches for location of the tensile test sample specified in particular first time production approval specification or material and testing specification, then position of the test sample has to be chosen according to particular specification. This test part has to be heat treated in the same hardening batch as the other parts. The position of the test part has to be in the middle of the batch.

Hardness measurements have to be carried out on the same part. The measured values are valid for comparison for batch production testing.

For batch production only hardness measurements have to be carried out in order to prove the required tensile strength. Conversion has to follow ISO 18265 : 2004.

Substitute for:											PC	Q-Code	X	X	X	X	X
Modif	A	EAAD073008	28.05.2009	B	EAAD700229	19.12.2011	C	EAAD084038	10.08.2012								
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date					

WÄRTSILÄ	Product: W-2S	Heat Treatment Specification Quench and Temper of Low Alloy Steels	
Made: 09.01.2009 M. Damani	Main Drw.	Page: 4 / 7	Material ID: 107.385.952.500
Chkd: 09.01.2009 W.Luft	Design Group: 0330	Drawing ID: 107.385.952	Rev: C
Appd: 09.01.2009 W.Luft			

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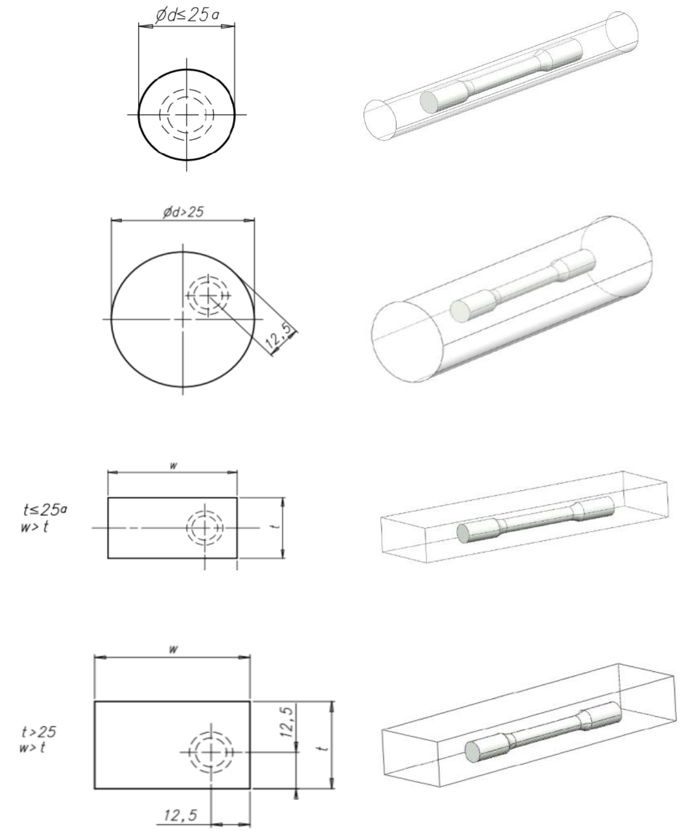


[a] For small products (d or w ≤ 25 mm), the test piece shall, if possible, consist of an un-machined part of the bar.

Figure 1. Location of the test pieces in rods and bars

5.1.2 Hardness tests

The surface hardness test has to be carried out on a polished area of the original part. Three measurements have to be made per part and documented. For the first time production one part has to be cut and the hardness has also to be tested in the centre of the part (same part as for tensile test).

Substitute for:										PC	Q-Code X X X X X
Modif	A	EAAD073008	28.05.2009	B	EAAD700229	19.12.2011	C	EAAD084038	10.08.2012		
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date	Number	Drawn Date

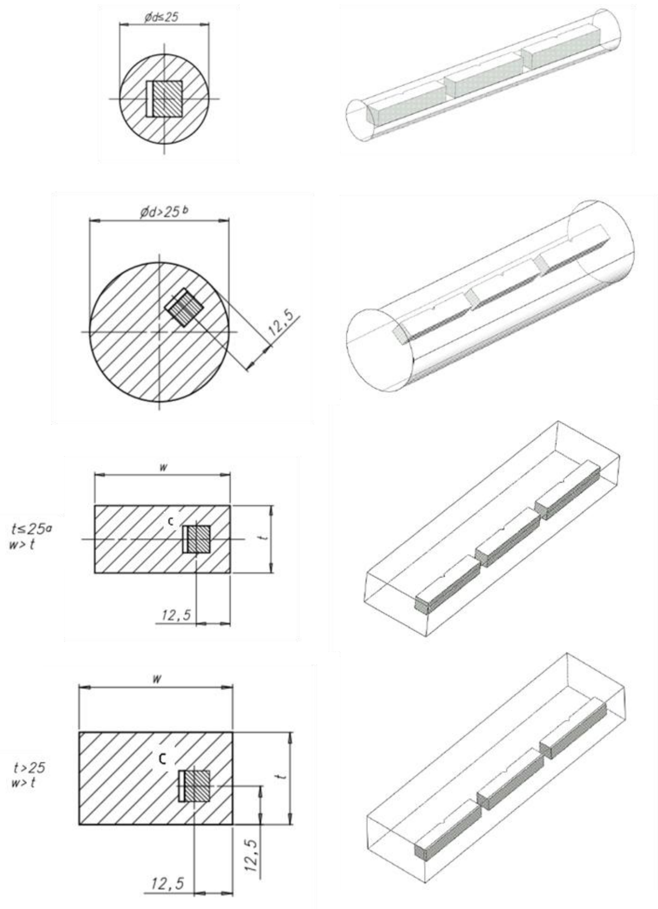
WÄRTSILÄ	Product **W-2S**	**Heat Treatment Specification** **Quench and Temper of Low Alloy Steels**	
Made 09.01.2009 M. Damani	Main Drw.	Page 5 / 7	Material ID **107.385.952.500**
Chkd 09.01.2009 W.Luft	Design Group **0330**	Drawing ID **107.385.952**	Rev **C**
Appd 09.01.2009 W.Luft			

T_PC-Drawing_portrait | Made by: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.10 (3/22/2012)

5.1.3 Impact energy

If required the impact energy has to be determined (ISO-V notch samples).

The specimen for impact energy test has to be machined from certain position which is based on the size of the original part, as shown in Figure 2. . If there are sketches for location of the impact test sample specified in particular first time production approval specification or material and testing specification, then position of the test sample has to be chosen according to particular specification.



[a] For small products (d or w ≤ 25 mm), the test piece shall, if possible, consist of an un-machined part of the bar.

[b] For round bars the longitudinal axis of the notch shall be about parallel to the direction of a diameter.

[c] For rectangular bars, the longitudinal axis of the notch shall be perpendicular to the wider rolling surface

Figure 2. Location of the test pieces in rods and bars

Substitute for:											PC	Q-Code	X	X	X	X	X
Modif	A	EAAD073008	28.05.2009	B	EAAD700229	19.12.2011	C	EAAD084038	10.08.2012								
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date					

WÄRTSILÄ	Product W-2S		Heat Treatment Specification Quench and Temper of Low Alloy Steels	
Made	09.01.2009	M. Damani	Main Drw.	Page 6 / 7	Material ID 107.385.952.500
Chkd	09.01.2009	W.Luft	Design Group 0330	Drawing ID 107.385.952	Rev C
Appd	09.01.2009	W.Luft			

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5.2 Documentation

With the dispatch of the finished pre-heat treated parts a certificate with the following content has to be handed over to the customer:

- Measured hardness
- Measured tensile strength (if required)
- Impact energy (if required)
- Applied process parameters,(temperatures, soaking time, oil temperature)
- Name of heat treatment company
- Date, name and signature of responsible person

Substitute for:										PC	Q-Code X X X X X
Modif	A	EAAD073008	28.05.2009	B	EAAD700229	19.12.2011	C	EAAD084038	10.08.2012		
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date	Number	Drawn Date

WÄRTSILÄ	Product W-2S		Heat Treatment Specification Quench and Temper of Low Alloy Steels	
Made	09.01.2009	M. Damani	Main Drw.	Page 7 / 7	Material ID 107.385.952.500
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Evaluation of Mechanical Properties (Tensile Test and Impact Test)

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Substitute for:											PC	Q-Code	X	X	X	X	X
Modif	A	EAAD700240	25.01.2012	B	7-84.038	10.08.2012	B	EAAD084038	10.08.2012								
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date					

WÄRTSILÄ	Product W-2S		**Testing Specification** Evaluation of Mechanical Properties		
Made	25.07.2007	W. Luft	Main Drw.	Page 1 / 8	Material ID **107.385.948.500**
Chkd	01.10.2007	M. Damani	Design Group		
Appd	01.10.2007	M. Damani	**0330**	Drawing ID **107.385.948**	Rev **B**

T_PC-Drawing_portrait | Made by: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.12 (6/28/2012)

1 Introduction

Tensile testing and notch bar impact testing are important test methods for material characterisation. In order to achieve comparable results some rules have to be followed. Both test methods are well defined in international standards. This specification gives a summary of all relevant standards and defines sample geometries for testing.

2 Relevant standards

ISO 10474: 1991	Steel and s. products – Inspection documents
EN 10204: 2004	Metallic Products - Types of inspection documents

2.1 Tensile Tests

EN 10002-1: 2001	Metallic materials - Tensile testing Part 1: Method of test at ambient temperature
ISO 377: 1997	Steel and steel products - Location and preparation of samples and test pieces for mechanical testing
ISO 6892-1: 1998	Metallic materials - Tensile testing - Part 1: Method of test at room temperature
JIS Z 2241: 1998	Method of tensile test for metallic materials
JIS Z 2201: 1998	Test pieces for tensile test for metallic materials
GB/T 228: 2002	Metallic materials – Tensile testing at ambient temperature
ISO 7500-1: 2004	Metallic Materials – verification of static unaxial testing machines – Part 1; Tension/compression testing machines – Verification and calibration of the force measuring system.
EN 10083-1: 2006	Steels for quenching and tempering – Part 1: General technical delivery conditions
EN 1561: 2011	Founding – Grey Cast Iron’s

2.2 Notch Bar Impact Tests

EN 10045-1: 1991	Charpy impact test on metallic materials - Part 1: Test method
ISO 148-1: 2009	Metallic materials- Charpy pendulum impact test - Part 1: Test Method
JIS Z 2242: 2005	Method for charpy pendulum impact test of metallic materials
JIS Z 2202: 1998	Test pieces for impact test for metallic materials
GB/T 229: 2007	Metallic materials – Charpy pendulum impact test method
EN 10083-1: 2006	Steels for quenching and tempering – Part 1: General technical delivery conditions

Substitute for:									PC	Q-Code	X	X	X	X	X
Modif	A	EAAD700240	25.01.2012	B	7-84.038	10.08.2012	B	EAAD084038	10.08.2012						
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date			

WÄRTSILÄ	Product W-2S		Testing Specification Evaluation of Mechanical Properties	
Made	25.07.2007	W. Luft	Main Drw.	Page 2 / 8 — Material ID 107.385.948.500
Chkd	01.10.2007	M. Damani	Design Group 0330	Drawing ID 107.385.948 — Rev B
Appd	01.10.2007	M. Damani		

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3 Sample Geometry and Size

3.1 Tensile Tests

Tensile tests shall be performed in proportional round bar samples according to EN°10002-1/ISO 6892. Alternative standards JIS Z 2201, JIS Z 2241 and GB/T 228 can also be used. Alternative geometries can be used, provided the part geometry and tolerances are according to one of the mentioned standards. Test equipment shall be fully compliant with ISO 7500-1/Class 1 or better.

The following values have to be determined by tensile tests:

- Tensile strength: R_m [MPa]
- Yield strength: R_e [MPa]
- Proof Strength: R_p [MPa]
- Elongation: A [%]
- Reduction of area: Z [%]

3.1.1 Sample size and requirements of Steel forgings, Non-Ferrous alloys and Cast Iron

It is recommended to use the standard sample ***Sample A*** for steel forgings and non-ferrous alloy samples. For cast iron it is recommended to use ***Sample B***, for grey cast irons it is recommended to use ***Sample C*** according to EN 1561.
In case of test samples machined from specific test location, use should preferably be made of short proportional test specimens with an initial gauge length of:

$$L_o = 5{,}65 \times \sqrt{S_o} = 5 \times d$$

L_o is the original gauge length
S_0 is the original cross section area of the test piece
d is the diameter of the test piece along the gauge length

Parts geometries and tolerances as summarised in Table 1 and Table 2.

Dimensions for Round Bar Samples							
	d	***L_o***	***L_c***	***L_t***	***l_t***	***r***	***D***
Sample A	10	50	55	120	20	15	M16
Tolerances	± 0.075	± 0.5	± 0.5 %	± 0.5 %	± 0.5 %	± 0.5 %	--
Sample B	14	70	84	140	20	20	M20
Tolerances	± 0.09	± 0.5	± 0.5 %	± 0.5 %	± 0.5 %	± 0.5 %	--

- ***d*** : Diameter of specimen [mm]
- ***L_0*** : Initial gauge length [mm]
- ***L_c*** : Test parallel length [mm]
- ***L_t*** : Total length of test piece [mm]
- ***l_t*** : Height of head [mm]
- ***r*** : Transition radius [mm]
- ***D*** : metric thread [mm]

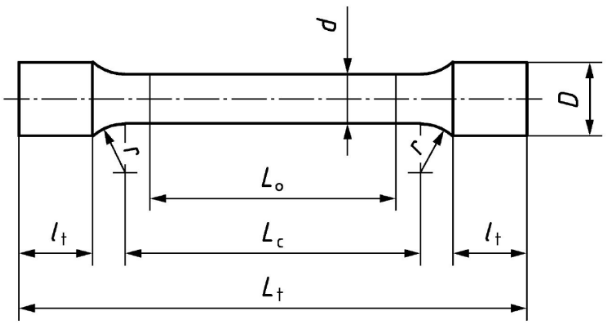

Table 1: Dimensions and tolerances of round bar samples for tensile tests.

Substitute for:								PC	Q-Code	X	X	X	X	X
Modif	A	EAAD700240	25.01.2012	B	7-84.038	10.08.2012	B	EAAD084038	10.08.2012					
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		

WÄRTSILÄ	Product W-2S		Testing Specification Evaluation of Mechanical Properties	
Made	25.07.2007	W. Luft	Main Drw.	Page 3 / 8 — Material ID 107.385.948.500
Chkd	01.10.2007	M. Damani	Design Group	Drawing ID 107.385.948 — Rev B
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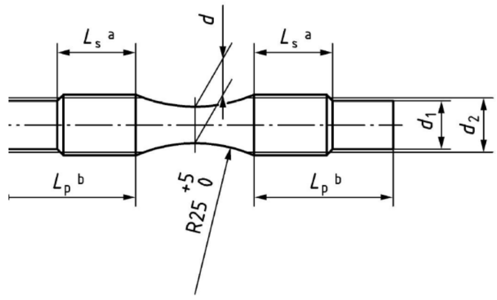
	Dimensions for Round Bar Samples					
	d	***L_s***	***L_p***	***L_t***	***d_1***	***d_2***
Sample C	20	36	[a]	102	23	M30
Tolerances	± 0.1	± 0.5 %	± 0.5 %	± 0.5 %	± 0.5 %	--

d : Diameter of specimen [mm]

- ***L_s*** : Thread length [mm]
- ***L_p*** : Plain ends length [mm]
- ***L_t*** : Threaded test piece total length [mm]
- ***d_1*** : Diameter for plain ends [mm]
- ***d_2*** : Thread type for threaded test piece [mm]



[a] $L_s > L_p$, to suit clamping device.

Table 2: Dimensions and tolerances of round bar samples for tensile tests of grey cast iron.

The main test requirements are summarized in Table 1 and should serve as guideline.

--- Testing Conditions for Determination of Tensile Strength ---	
Strain rate	- for R_e: max. 0.0025 s^{-1} - for R_m: max. 0.008 s^{-1}
Surface Roughness	max. N6 (R_a ≤ 0.8 µm)
Surface Quality	No radial grooves allowed
Temperature	Room temperature: RT = 23 ± 5 °C
Method of Gripping	Wedges, screwed grips, parallel jaw faces, shouldered holders

Table 1: Parameters for determination of tensile strength as guidance

3.1.2 Sample locations

In general the test sample has to be taken from the location according the relevant standard.
If there are sketches for location of the tensile test sample specified in individual first time production approval specification or material and testing specification, then position of the test sample has to be chosen according to individual specification.

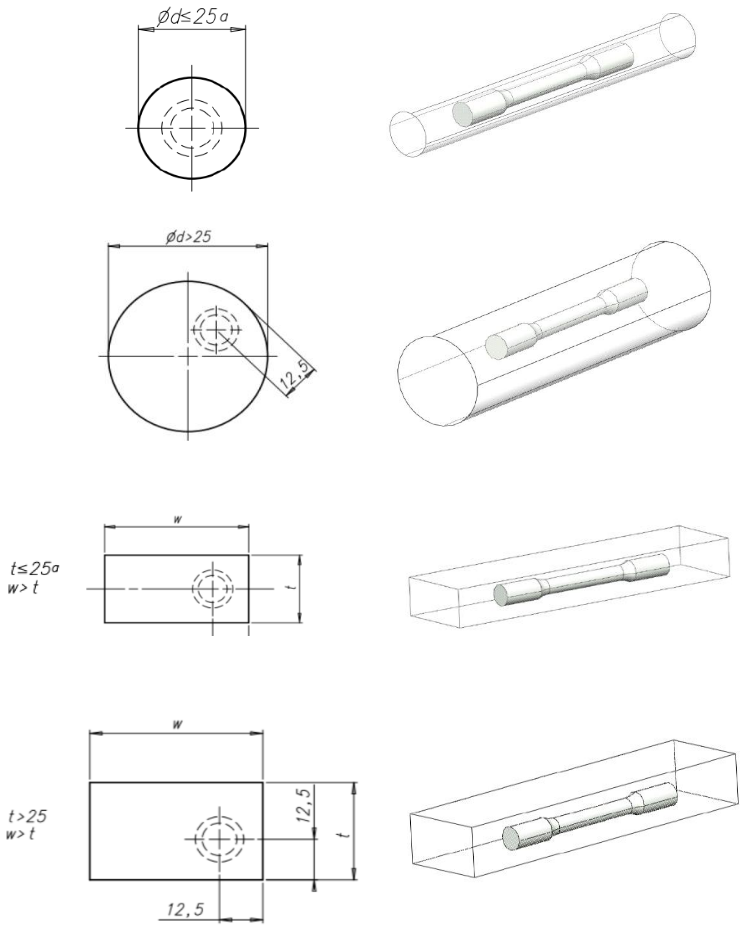
3.1.3 Sample locations of steel forgings

The samples for tensile test of steel forgings with round or rectangular shape have to be machined from certain position, which is based on the size of the original component according EN 10083-1, as shown in Figure 1.

Substitute for:						PC	Q-Code	X X X X X
Modif	A EAAD700240	25.01.2012	B 7-84.038	10.08.2012	B EAAD084038	10.08.2012		
	Number	Drawn Date	Number	Drawn Date	Number	Drawn Date	Number	Drawn Date

WÄRTSILÄ	Product **W-2S**	**Testing Specification** **Evaluation of Mechanical Properties**	
Made 25.07.2007 W. Luft	Main Drw.	Page 4 / 8	Material ID **107.385.948.500**
Chkd 01.10.2007 M. Damani	Design Group **0330**	Drawing ID **107.385.948**	Rev **B**
Appd 01.10.2007 M. Damani			

T_PC-Drawing_portrait | Made by: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.12 (6/28/2012)



[a] For small products (d or w ≤ 25 mm), the test piece shall, if possible, consist of an un-machined part of the bar.

Figure 1: Location of the test pieces in rods and bars

3.2 Notch Bar Impact Tests (ISO-V)

Impact tests shall be performed applying ISO-V notch test samples according to EN 10045 or ISO 148. The test pieces shall be taken from the location referred to below or the relevant material and testing specification, international standards or classification society's guidelines. Alternatively impact tests should be performed according to JIS Z 2242, JIS Z 2202 and GB/T 229. The test equipment shall be compliant with EN 10045-2 or the equivalent JIS and GB/T standard. Sample dimensions and tolerances are given in Figure 4. Additionally, testing conditions are summarised in Table 4.
The following value has to be determined by notched bar impact tests:

- Impact energy: ISO-V [J]

Substitute for:									PC	Q-Code	X X X X X
Modif	A	EAAD700240	25.01.2012	B	7-84.038	10.08.2012	B	EAAD084038	10.08.2012		
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date	Number	Drawn Date

WÄRTSILÄ	Product **W-2S**		**Testing Specification** **Evaluation of Mechanical Properties**		
Made	25.07.2007	W. Luft	Main Drw.	Page 5 / 8	Material ID **107.385.948.500**
Chkd	01.10.2007	M. Damani	Design Group	Drawing ID **107.385.948**	Rev **B**
Appd	01.10.2007	M. Damani	**0330**		

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Dimensions of V-notch Samples for Impact Testing		
Dimensions	V-notch Samples	
	Normal Size	Tolerance
Sample Length Sample Width	55 mm 10 mm	± 0.60 mm ± 0.06 mm
Width of Sample: - Normal Size	10 mm	± 0.11 mm
Notch Angle	45°	± 2°
Height at Notch Base	8 mm	± 0.06 mm
Notch Radius	0.25 mm	± 0.025 mm
Distance: Notch Centre – Sample Ends	27.5 mm	± 0.42 mm
Angle between plane of symmetry of notch and longitudinal axis	90°	± 2°
Angle between adjacent longitudinal faces	90°	± 2°

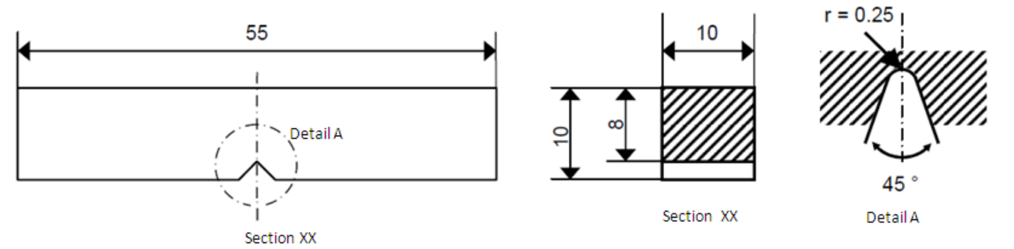

Table 3: Dimensions and tolerances of samples for impact tests.

Testing Conditions for Impact Tests	
Spacing between anvils	$(40^{+0.2}_{0})$ mm
Anvil radius	$(1^{+0.5}_{0})$ mm
Taper angle for each anvil	11° ± 1°
Taper angle of pendulum	30° ± 1°
Pendulum tip radius	$(2^{+0.5}_{0})$ mm
Max. pendulum face thickness	18 mm
Striking velocity of pendulum	5 to 5.5 m/s
Angle between anvil/support	90° ± 0.1°
Testing Temperature	23 ± 5 °C
Testing Impact Energy	300 ± 10 J

Table 4: Testing conditions for impact tests

3.2.1 Sample locations

In general the test sample has to be taken from the location according the relevant standard.
If there are sketches for location of the notch bar impact test sample specified in individual first time production approval specification or material and testing specification, then position of the test sample has to be chosen according to individual specification.

Substitute for:								PC	Q-Code	X X X X X		
Modif	A	EAAD700240	25.01.2012	B	7-84.038	10.08.2012	B	EAAD084038	10.08.2012			
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WÄRTSILÄ	Product **W-2S**	**Testing Specification** **Evaluation of Mechanical Properties**	
Made 25.07.2007 W. Luft	Main Drw.	Page 6 / 8	Material ID **107.385.948.500**
Chkd 01.10.2007 M. Damani	Design Group	Drawing ID **107.385.948**	Rev **B**
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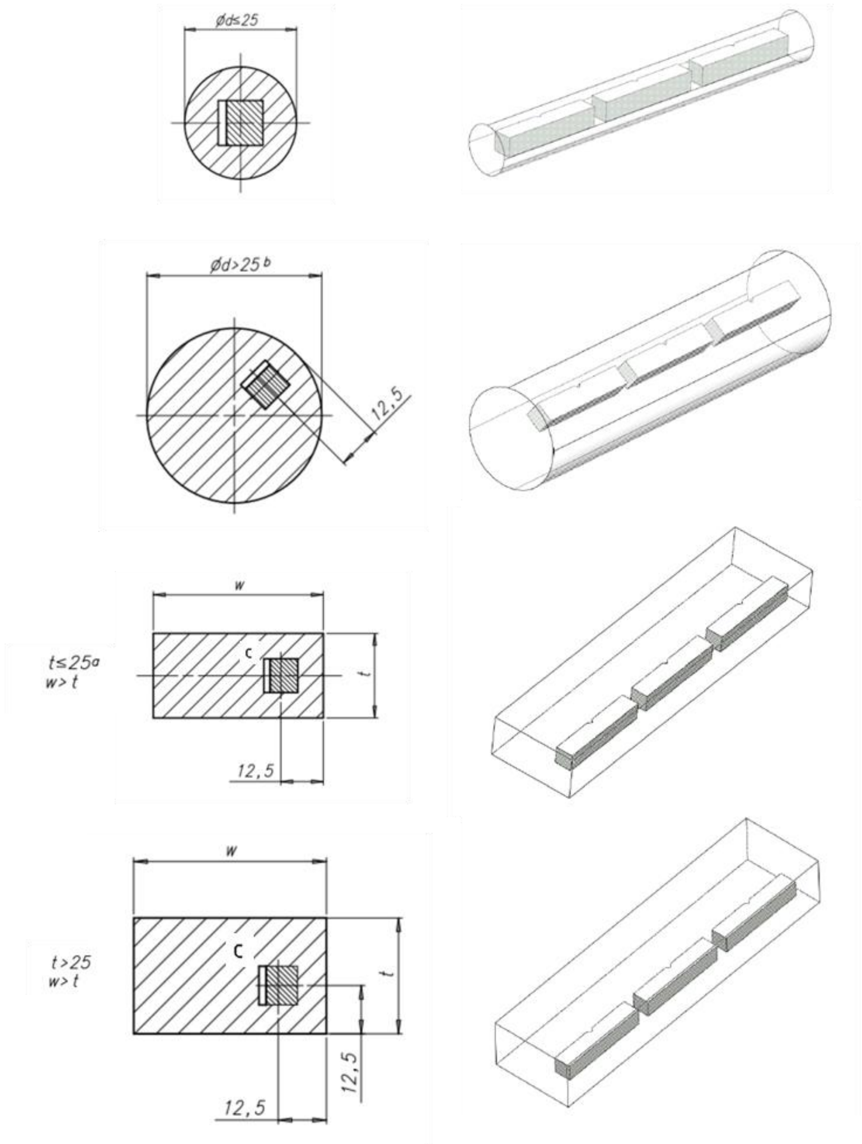
3.2.2 Sample locations of steel forgings

The three samples for notch bar impact test of steel forgings with round or rectangular shape have to be machined from certain position, which is based on the size of the original component according EN 10083-1, as shown in Figure 2.



[a] For small products (d or w ≤ 25 mm), the test piece shall, if possible, consist of an un-machined part of the bar.
[b] For round bars the longitudinal axis of the notch shall be about parallel to the direction of a diameter.
[c] For rectangular bars, the longitudinal axis of the notch shall be perpendicular to the wider rolling surface

Figure 2. Location of the test pieces in rods and bars

Substitute for:									PC	Q-Code X X X X X
Modif	A	EAAD700240	25.01.2012	B	7-84.038	10.08.2012	B	EAAD084038	10.08.2012	
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WÄRTSILÄ	Product W-2S	Testing Specification Evaluation of Mechanical Properties	
Made 25.07.2007 W. Luft	Main Drw.	Page 7 / 8	Material ID 107.385.948.500
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4 Documentation

A test report has to be provided with the following information given in a 3.1 or 3.2 inspection certificate, which is defined on drawing, according ISO 10474 / EN10204:

1. Purchaser and order number
2. Number (stamp) of the part and corresponding batch number
3. Material used / specified on the drawing
4. Test results
5. Tensile test result (R_m, R_e or $R_{p0.2}$, A and Z)
6. Notch Bar Impact test results (all values and average)
7. Name and address of laboratory
8. Date, name and signature of responsible person

Substitute for:									PC	Q-Code	X	X	X	X	X
Modif	A	EAAD700240	25.01.2012	B	7-84.038	10.08.2012	B	EAAD084038	10.08.2012						
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date			

WÄRTSILÄ	Product **W-2S**	**Testing Specification** **Evaluation of Mechanical Properties**

Made	25.07.2007	W. Luft	Main Drw.	Page 8 / 8	Material ID	**107.385.948.500**
Chkd	01.10.2007	M. Damani	Design Group	Drawing ID	**107.385.948**	Rev
Appd	01.10.2007	M. Damani	**0330**			**B**

T_PC-Drawing_portrait | Made by: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.12 (6/28/2012)

Hardness Testing

Content:

Q-Code	-	-	-	-	-

a	7-73.008	02.06.09						Replaced by:
								Substitute for:

WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTMOT	**Testing Specification** Hardness Testing	Group 0330
	drawn: M. Damani 15.07.07 verified: W. Luft 01.10.07	**4-107.385.946**	1 / 4

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1. Introduction

Hardness testing is an important test method for material characterisation. In order to achieve comparable results some rules have to be followed. Depending on the material condition and the requirements different hardness testing methods are applicable. All methods are well defined in international standards. This
specification gives a summary of all relevant standards and additional information on hardness testing.

2. Relevant standards

2.1 Vickers hardness testing

Applications:	Hardness profiles, surface hardness, micro hardness measurements, etc.
DIN EN ISO 6507	Metallic materials – Vickers hardness test
JIS Z 2244	Vickers hardness test – Test method

2.2 Brinell hardness testing

Applications:	Core/bulk hardness of metallic materials (macro hardness)
DIN EN ISO 6506	Metallic materials- Brinell hardness test
JIS Z 2243	Brinell hardness test – test method

Important Notice: The standard Brinell hardness testing method shall be as following unless specified differently on the drawing or in a material and testing specification:
HBW10/3000 with a loading time of 10-15 seconds for steel and 30 seconds for cast iron parts.

2.3 Rockwell hardness testing

Applications:	Core/bulk hardness of hardened metallic materials (also surface hardness)
DIN EN ISO 6508	Metallic materials – Rockwell hardness test
JIS Z 2245	Rockwell hardness test – Test method

2.4 Conversion of hardness values

Applications:	Conversion of core hardness of metallic materials to tensile strength
DIN EN ISO 18265 values	Metallic materials – Conversion of hardness

a						Q-Code	-	-	-	-	-

WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTMOT drawn: M. Damani 15.07.07 verified: W. Luft 01.10.07	**Testing Specification** Hardness Testing **4-107.385.946**	Group 0330 2 / 4

2.5 Determination of case depth of case hardened parts

DIN EN ISO 2639	Steel: Determination and verification of the depth of carburized and hardened cases
JIS G 0557	Methods of measuring case depth hardened by carburizing treatment for steel

2.6 Determination of nitriding depth and surface hardness of nitrided parts

DIN 50 190-3	Härtetiefe Wärmebehandelter Teile (only in German)
JIS G 0562	Method of measuring nitrided case depth for iron and steel
JIS G 0563	Method of measuring surface hardness for nitrided iron and steel

2.7 Determination of case depth of induction or flame hardened parts

DIN EN 10328	Iron and Steel: Determination of the conventional depth of hardening after surface heating
JIS G 0559	Methods of measuring case depth for steel hardened by flame or induction hardening process

3. Additional information

3.1 Remark on determination of hardness profiles

The procedure for hardness profile determination is described in more detail in the following specification:
“Case hardening specification” 107.385.939
“Gas Nitriding specification” 107.385.945

3.2 Used abbreviations for surface hardening parameters

3.2.1 For case hardening

Designation:
OLD : Eht
NEW :CHD; according DIN ISO 15787

Definition:
Case Hardening Depth = perpendicular distance between surface and the layer having a hardness of 550HV1 (= harness limit) measured on a polished micro section; according DIN EN ISO 2639

a						Q-Code	-	-	-	-	-

WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTMOT	**Testing Specification** Hardness Testing	Group 0330
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3.2.2 For flame and induction hardening

Designation:
OLD : Rht
NEW :SHD; according DIN ISO 15787

Definition:
Surface Hardening Depth = perpendicular distance between surface and the layer having a hardness of 80% of the minimal surface hardness (= hardness limit) measured with HV1on a polished micro section; according DIN EN 10328

3.2.3 For nitriding

Designation:
OLD : Nht
NEW :NHD; according DIN ISO 15787

Definition:
Nitriding Hardness Depth = distance between surface to hardness limit (core hardness + 50 HV1) measured on a polished micro section; according DIN 50 190-3

4. Choice of method and load

The method for hardness testing and the required load is usually given on the drawing.

5. Sample preparation and number of tests

Generally for hardness measurement the surface has to be ground (and polished) properly to obtain defined hardness indents. The hardness profiles have to be deter-mined on polished (to mirror finish) microsections.
Generally at least three measurements have to be made and an average value calculated.

6. Documentation

A test report has to be provided with the following information given:
- Number (stamp) of the part and corresponding batch number
- Material specified on the drawing
- Applied test method and used load
- Measured hardness values (all values and average)
- Hardness profile (if applicable)
- Measured core hardness value(s) and converted tensile strength (if applicable)
- Name and address of laboratory
- Date, name and signature of responsible person

a						Q-Code	-	-	-	-	-

WÄRTSILÄ	RTMOT	**Testing Specification** Hardness Testing	Group 0330
Wärtsilä Switzerland Ltd.	drawn: M. Damani 15.07.07 verified: W. Luft 01.10.07	**4-107.385.946**	4 / 4

Chemical Analysis of Materials

Table of contents

Substitute for:											PC	Q-Code	X	X	X	X	X
Modif	A	EAAD700130	10.06.2011	B	EAAD700240	25.01.2012											
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date					

WÄRTSILÄ		Product W-2S		**Testing Specification** Chemical Analysis of Materials	
Made	25.07.2007	M.Damani	Main Drw.	Page 1 / 5	Material ID **107.385.944.500**
Chkd	01.10.2007	W.Luft	Design Group	Drawing ID **107.385.944**	Rev **B**
Appd	01.10.2007	W.Luft	**0330**		

T_PC-Drawing_portrait | Made by: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.7 (13.01.2012)

1 Introduction

Chemical analysis is required in order to check the material composition in comparison with the material specification. For this laboratories with suitable facilities and competences are required. In this specification the appropriate methods for various analysis tasks and the requirements are given.

2 Materials to be analyzed

On the base of the necessities exposed by Wärtsilä, following groups of materials were defined:

1. Cast iron
2. Steel
3. Bronce

Very small samples, having sizes inferior to some cm, may require alternative analysis techniques, which are generally less precise than those used for the analysis of larger samples. Due to this difference, it is reasonable to define a further group of specimens:

4. Small size samples (microanalysis required)

3 General requirements

3.1 Assessment / Choice of a laboratory

General requirements for the assessment of the competence of testing laboratories may be obtained from the standard ISO /IEC 17025:2005. It specifies the minimal criteria to be assured when testing materials not only by standard methods but also using non standard methods and laboratory-developed methods.
The criteria are applicable to laboratories regardless of the number of personnel and of the extent and scope of the testing activities. Laboratory clients, regulatory authorities and accreditation bodies may also use it in confirming or recognizing the competence of laboratories. If testing and calibration laboratories fulfill the requirements of this International Standard they will operate on a quality system (for their testing and calibration activities) that also meets the requirements of ISO 9001, when they engage in the design/development of new methods and/or develop test programs combining standard and non-standard test and calibration methods. In the case of standard methods they will operate on a quality system that meets the requirements of ISO 9002.

From the general point of view, when evaluating the activities of a testing laboratory, the following criteria should be fulfilled:

- A specialized materials testing laboratory is preferable to any other kind of laboratories which also perform chemical analysis (environmental laboratory; etc.).

Substitute for:								PC	Q-Code	X X X X X		
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WÄRTSILÄ	Product W-2S	Testing Specification Chemical Analysis of Materials	
Made 25.07.2007 M.Damani	Main Drw.	Page 2 / 5	Material ID 107.385.944.500
Chkd 01.10.2007 W.Luft	Design Group 0330	Drawing ID 107.385.944	Rev B
Appd 01.10.2007 W.Luft			

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- Laboratories with at least 10 employees (who are directly concerned with the analytical work) are preferable.
- Personnel education: at least two persons should have a university degree. Well-founded experience in analytical chemistry should be guaranteed.
- The laboratory should have excellent references; testing activities for external customers, preferably larger companies, is essential.
- Inter-laboratory comparisons (“round robin” tests) should be periodically carried out and documented.
- The laboratory should be quality certified. We strongly suggest preferring laboratories which are accredited to one of the following international standards: ISO 17025, Nadcap, A2LA or similar.

From the analytical point of view, following aspects should be taken in account:

- The technical/analytical devices should be state of the art. In the mean, the equipment should not be older than approximately 10-15 years. Frequent maintenance should be carried out and documented.
- Traceability of all Certified Reference Materials (CRMs) used to calibrate the analysis devices to international standards, such as NIST (National Institute of Standards and Technology) or SI (International System of Units) is essential.
- Traceability of all measurements, storage of all relevant information concerning the measurement (setup of the analytical device, machine print outs, measurements of reference materials, ..) as well as the storage of the analyzed samples over at least a couple of years should be assured.
- Instructions should be present to assure that the sample preparation (collection, cutting, grinding, cleaning, ..) is kept constant over time for all specimens and that sample mix-up or sample loss are avoided.
- The measurements range of each procedure (lower limit (= detection limit) and upper limit) should be clearly defined and applied for each measurement (for example: data lower than the specific detection limit DL should be expressed as "< DL").
- Basic information on the uncertainty of measurements should be provided to customers on request.
- All reports should be signed by the author and approved by a qualified person.

3.2 Choice of Analysis Techniques and Procedures

For the analysis of the different materials, the most appropriate techniques are listed below for different types of materials. In all cases, it is generally reasonable to apply the measurement procedures suggested by the manufacturers of the different measurement devices.
Generally, for combustion and gas hot extraction analysis it is recommended to analyze at least two (better: three) pieces of material for each selected sample. The given element contents (in wt. %) should then be calculated as the average of the measured values.

Substitute for:										PC	Q-Code	X	X	X	X	X
Modif	A	EAAD700130	10.06.2011	B	EAAD700240	25.01.2012										
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WÄRTSILÄ	Product W-2S		Testing Specification Chemical Analysis of Materials		
Made	25.07.2007	M.Damani	Main Drw.	Page 3 / 5	Material ID 107.385.944.500
Chkd	01.10.2007	W.Luft	Design Group 0330	Drawing ID 107.385.944	Rev B
Appd	01.10.2007	W.Luft			

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As already noticed, sample preparation should be kept as constant as possible. Particular emphasis should be applied on the preparation of carburized/nitrided samples. In this case, the carburized/nitrided zone has to be eliminated by cutting and/or grinding the material up to a depth of some millimeters.

3.2.1 Methods recommended for steel and bronze

Major and trace elements:

- X-Ray Fluorescence Spectrometry (XRF) - wave length dispersive systems only
- Optical Emission Spectroscopy (OES)
- Inductively-Coupled Plasma Analysis (ICP)
- Glow discharge Optical Emission Spectrometry (GDOES)
- Atomic Absorption Spectroscopy (AAS)

Carbon and sulfur (steel):

- Combustion Analysis
- Optical Emission Spectroscopy (OES)
- Glow Discharge Optical Emission Spectrometry (GDOES)

Nitrogen/oxygen/hydrogen (steel):

- Gas hot extraction

3.2.2 Method recommended for cast iron

- X-Ray Fluorescence Spectrometry (XRF) - wave length dispersive systems only
- Inductively-Coupled Plasma Analysis (ICP)
- Carbon and sulphur: Combustion Analysis

3.2.3 Methods recommended for small size samples (microanalysis required)

For the chemical analysis of very small samples (< 1 cm) only a few analytical techniques are suitable. The following can be recommended:

- Electron Probe Microanalysis (EPMA / WDX)
- Scanning Electron Microscopy (SEM) with associated Energy Dispersive X-Ray Analysis (EDX)
- Inductively-Coupled Plasma Analysis (ICP)
- Atomic Absorption Spectroscopy (AA)

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WÄRTSILÄ	Product W-2S		Testing Specification Chemical Analysis of Materials
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For precise analysis or analysis of elements in the concentration range < 0.5 wt.% we strongly recommend to favor Electron Probe Microanalysis (EPMA / WDX) with regard to Energy Dispersive X-Ray Analysis (EDX).

4 Documentation

An analysis report has to be provided with the following information given:

- Number (stamp) of the part and corresponding batch number
- Material specified on the drawing
- Sample preparation
- Applied procedures / methods
- Measurement range of the method chosen
- Name and address of laboratory
- Name and signature of the person carrying out the analysis
- Date and signature of person approving the document

Substitute for:											PC	Q-Code	X	X	X	X	X
Modif	A	EAAD700130	10.06.2011	B	EAAD700240	25.01.2012											
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WÄRTSILÄ	Product **W-2S**	**Testing Specification** **Chemical Analysis of Materials**

Made	25.07.2007	M.Damani	Main Drw.	Page 5 / 5	Material ID **107.385.944.500**	
Chkd	01.10.2007	W.Luft	Design Group **0330**	Drawing ID **107.385.944**		Rev **B**
Appd	01.10.2007	W.Luft				

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1. Validity range

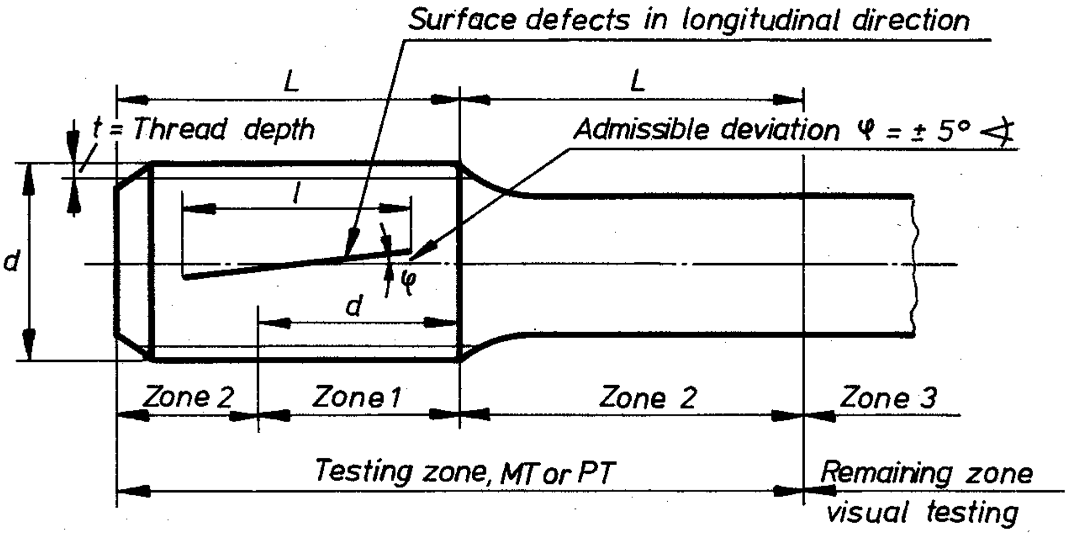
Important bolts and studs for Diesel engines according to instructions on drawing.

2. Quality standard

2.1 Admissible defects

On principle no surface cracks are accepted in the testing zones 1 and 2.

Exception:
Isolated indications are admissible for dye-penetrant (PT) or magnetic particle (MT) process on the surface according to data in figure below, if these are only linear inclusions and not crack-like defects.



2.1.1 Nominal values for admissible defect sizes (in longitudinal direction)

Defect length	L ≤ 25 mm	
Defect depth:	Zone 1:	Depth ≤ 0,8 x t, i.e., the region of thread base rounding off must be free of defects.
	Zone 2 and 3:	Depth ≤ 0,15 x d

2.2 Non admissible defects

All crack like defects, as well as inclusion-like surface defects which deviate more than 5°(angle) from the longitudinal axis, are under no circumstances admissible. All defects which are more extensive than indicated under para. 2.1.1.

A	EAAD700239	22.10.2012	Replaced by:	PC
			Substitute for:	

WÄRTSILÄ	W-2S	Quality and test Specification Bolts and studs		Group 0330
	Drawn: Doebeli 09.11.78 Verif: Doebeli 09.11.78	(E)	4-107.131.611	A	1/5

ISO-Basic Document Nr.X-107.XXX.XXX / 12.02.96 / Rev. 1.0
File name: 107.131.611-a.doc /

3. Testing

3.1 Scope of testing
In the machined state all surfaces are to be tested.

3.2 Testing method

Testing zone
see Fig.1: by means of magnetic particle (MT) or dye-penetrant (PT) process.

Remaining zone
through visual inspection

3.3 Clarification of defects
If necessary, for clarification of defects in the remaining zone an MT or PT test is to be carried out.

4. Records

The test results are to be recorded in the individual sheet (enclosures) per manufacturing series.

Enclosures:	sheet MT,	Enclosure 1
	sheet PT,	Enclosure 2
	sheet MT/PT,	Enclosure 3

A				
WÄRTSILÄ	W-2S		Error! Reference source not found. Bolts and studs	Group 0330
	Drawn: Doebeli 09.11.78 Verif.: Doebeli 09.11.78	(E)	4-107.131.611 A	2/5

ISO-Basic Document Nr.X-107.XXX.XXX / 12.02.96 / Rev. 1.0
File name: 107.131.611-a.doc

WÄRTSILÄ	**Protokoll der Magnetpulverprüfung** *MAGNETIC PARTICLE EXAMINATION RECORD*	Nr. / No. Seite PAGE / von OF / Seiten PAGES

Kunde CUSTOMER	WNSD – Auftragsnummer / WNSD ORDER NO.
Anlage PROJECT	Position POSITION — OP.-Nr. / OP. NO.
Bauteil PART	Bauprüfplan INSPECTION PLAN — Schritt Nr. SEQUENCE NO.
Kundenbestellnummer. CUSTOMER'S ORDER NO.	Zeichnungsnummer DRAWING NO.
	Fabrikationsnummer SERIAL NO.

PRUEFSPEZIFIKATION NR. / TESTING SPECIFICATION NO. — **REV. NO.**

PRUEFUNG / TESTING		**ZEITPUNKT CERTIFICATE TIME**
Grundmaterial BASE MATERIAL	Schweissnaht-Nr. WELD - No.	☐ Vor Waermebehandlung BEFORE HEAT TREATMENT
☐ Grundmaterial. % BASE MATERIAL	☐ Innenseite % INSIDE	☐ Nach Waermebehandlung AFTER HEAT TREATMENT
☐ Schweisskante % WELDING EDGE	☐ Aussenseite % OUTSIDE	☐ Nach Druckprobe AFTER PRESSURE TEST
☐ Fehlstellen augeschliffen FLAWS GROUND OUT	☐ Ausgeschliffene Fehlstellen FLAWS GROUND OUT	☐
☐ Fehlstellen repariert FLAWS REPAIRED	☐ Reparierte Fehlstellen FLAWS REPAIRED	☐
☐	☐	☐

Muster
SAMPLE 1

Fehlerkriterien
ACCEPTANCE STANDARDS (Nur wenn nicht in der Spezifikation enthalten) (ONLY IF NOT INCLUDED IN SPECIFICATION)

PRUEFVERFAHREN / TECHNICAL PROCEDURE

Magnetisierungsart / TYPE OF MAGNETIZATION	Stromart / CURRENT	Anzeigeart / INSPECTION MATERIALS
☐ Stromdurchflutung A — A CURRENT	☐ ~ AC ☐ = DC	☐ Trocken, Farbe: DRY, COLOR
☐ Kontaktelektroden — A / mm PROD CONTACTS	Gerät / EQUIPMENT	☐ Nass, Flüssigkeit: WET, CARRIER FLUID:
☐ Spulenmagnet — AW SOLENOID	Typ TYPE	☐ Fluoreszierend: FLUORESCENT MEDIUM
☐ Jochmagnet FLAWS REPAIRED	Obj.-Nr. SERIAL-No.	Entmagnetisiert / DEMAGNETIZATION
Testkörper / TEST PIECE:		☐ ja / YES ☐ nein / No.

PRÜFERGEBNIS / RESULT OF EXAMINATION

☐ Ohne Befund NO INDIFICATION — ☐ Mit Befund INDICATION — ☐ Fehlermeldung-Nr. NONCONFORMITY REPORT No. — Beilagen: ANNEXES:

Befund / FINDING

Entscheid / DECISSION: ☐ Erfüllt / ACCEPTABLE ☐ Nicht erfüllt / UNACCEPTABLE

Kontroll- oder Prüfstelle INSPECTION / EXAMINATION	Ueberpruefung REVIEW	Abnahme durch ACCEPTED BY
Ko.-St.: *Sect. No.:* …………... Name: *Name:* …………………….. Datum: *Date:* ……….	Ko.-St.: *Sect. No.:* …………... Name: *Name:* …………………….. Datum: *Date:* ……….	Ko.-St.: *Sect. No.:* …………... Name: *Name:* …………………….. Datum: *Date:* ……….

A					

WÄRTSILÄ	**W-2S**		Error! Reference source not found. Bolts and studs		**Group 0330**
	Drawn: Doebeli Verif.: Doebeli	09.11.78 09.11.78	**(E)**	**4-107.131.611**	**A**	**3/5**

ISO-Basic Document Nr.X-107.XXX.XXX / 12.02.96 / Rev. 1.0
File name: 107.131.611-a.doc

WÄRTSILÄ	*Protokoll der Farbeindringprüfung* *LIQUID PENETRANT EXAMINATION*	Nr. / No. Seite PAGE / von OF / Seiten PAGES

Kunde CUSTOMER	WNSD – Auftragsnummer / WNSD ORDER NO.
Anlage PROJECT	Position POSITION OP.-Nr. / OP. NO.
Bauteil PART	Bauprüfplan INSPECTION PLAN Schritt Nr. SEQUENCE NO.
Benennung DESIGNATION	Prüfnummer EXAM. NO. Lfd. Nr. CURR. NO.
Kundenbestellnummer. CUSTOMER'S ORDER NO.	Zeichnungsnummer DRAWING NO.
	Fabrikationsnummer SERIAL NO.

PRUEFSPEZIFIKATION NR. / TESTING SPECIFICATION NO.   **REV. NO.**

PRUEFUNG / TESTING		**ZEITPUNKT CERTIFICATE TIME**
Grundmaterial / BASE METAL	Schweissnaht-Nr. / WELD – No.	☐ Vor Waermebehandlung BEFORE HEAT TREATMENT
☐ Grundmaterial BASE MATERIAL. %	☐ Innenseite INSIDE %	☐ Nach Waermebehandlung AFTER HEAT TREATMENT
☐ Schweisskanten WELDING EDGE %	☐ Aussenseite OUTSIDE %	☐ Keine Waermebehandlung NO HEAT TREATMENT
☐ Ausgeschliffene Fehlstellen FLAWS GROUND OUT	☐ Ausgeschliffene Fehlstellen FLAWS GROUND OUT	☐ Nach Druckprobe AFTER PRESSURE TEST
☐ Reparierte Fehlstellen FLAWS REPAIRED	☐ Reparierte Fehlstellen FLAWS REPAIRED	☐
☐ Plattierung CLADDING	☐	☐

Fehlerkriterien
ACCEPTANCE STANDARDS
(Nur wenn nicht in der Spezifikation enthalten)
(ONLY IF NOT INCLUDED IN SPECIFICATION)

PRUEFVERFAHREN / TECHNICAL PROCEDURE

Pruefmittelbezeichnung DESIGNATION MEDIUM		Charge Nr. BATCH NO.	Art der Aufbringung MODE OF APPLICATION	Einwirkzeit (MINUTEN) TIME OF APPLICATION (MIN.)
Reiniger DEGREASING FLUID				
Penetrant PENETRANT				
Emulgator EMULSION				
Zwischenreiniger INTERPASS CLEANING				
Entwickler DEVELOPER				

Muster
SAMPLE 2

PRÜFERGEBNIS / RESULT OF EXAMINATION

☐ Ohne Befund NO INDIFICATION   ☐ Mit Befund INDICATION   ☐ Fehlermeldung-Nr. NONCONFORMITY REPORT No.   Beilagen: ANNEXES:

BEFUND / FINDING

Entscheid / DECISSION: ☐ Erfüllt / ACCEPTABLE   ☐ Nicht erfüllt / UNACCEPTABLE

Kontroll- oder Prüfstelle INSPECTION / EXAMINATION	Ueberpruefung REVIEW	Abnahme durch ACCEPTED BY
Ko.-St.: *Sect. No.:* …………... Name: *Name:* …………………… Datum: *Date:* ………..	Ko.-St.: *Sect. No.:* …………... Name: *Name:* …………………… Datum: *Date:* ………..	Ko.-St.: *Sect. No.:* …………... Name: *Name:* …………………… Datum: *Date:* ………..

A					
WÄRTSILÄ	**W-2S**		Error! Reference source not found. Bolts and studs		**Group 0330**
	Drawn: Doebeli 09.11.78 Verif.: Doebeli 09.11.78	**(E)**	**4-107.131.611**	**A**	**4/5**

ISO-Basic Document Nr.X-107.XXX.XXX / 12.02.96 / Rev. 1.0
File name: 107.131.611-a.doc

WÄRTSILÄ	**Protokoll der Oberflächenprüfung** *Skizzenblatt* *SKETCH*	Nr. / *No.* Seite PAGE / von OF / Seiten PAGES

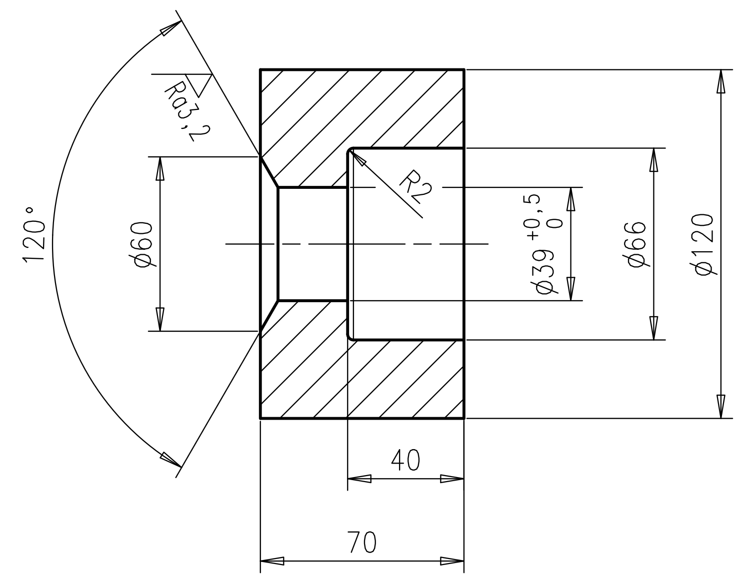
Muster
SAMPLE 3

Kontroll- oder Prüfstelle INSPECTION / EXAMINATION			Ueberpruefung REVIEW			Abnahme durch ACCEPTED BY		
Ko.-St.: *Sect. No.:* …………..	Name: *Name:* ……………………	Datum: *Date:* ……….	Ko.-St.: *Sect. No.:* …………..	Name: *Name:* ……………………	Datum: *Date:* ……….	Ko.-St.: *Sect. No.:* …………..	Name: *Name:* ……………………	Datum: *Date:* ……….

A								
WÄRTSILÄ	**W-2S**			Error! Reference source not found. Bolts and studs			**Group** **0330**
	Drawn: Doebeli Verif.: Doebeli	09.11.78 09.11.78	**(E)**	**4-107.131.611**	**A**		**5/5**

ISO-Basic Document Nr.X-107.XXX.XXX / 12.02.96 / Rev. 1.0
File name: 107.131.611-a.doc

SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK

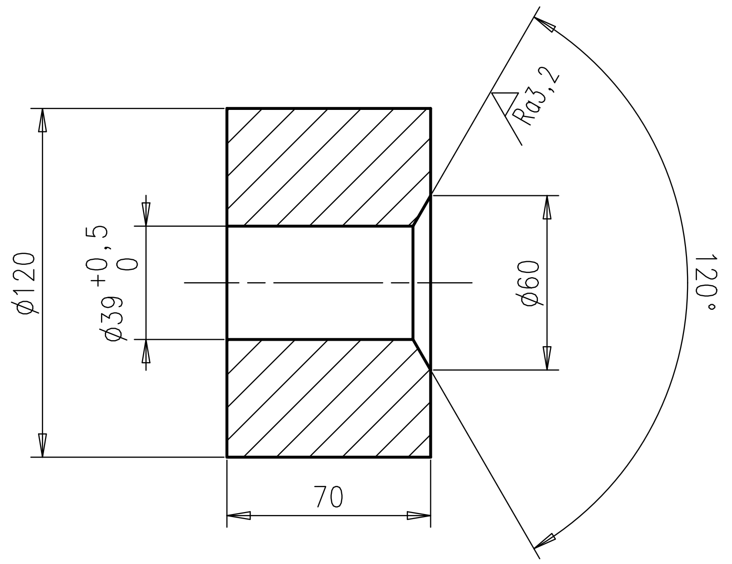


Ra6,3 (Ra3,2) Kanten gebrochen 0,2 x45°
SHARP EDGES REMOVED

Approved

Free space for lic.		Q-Code XXXXX	Main Drw.
		Standard ISO JIS	
Modif.	Number / Drawn date	Number / Drawn date	Number / Drawn date / Number / Drawn date
WÄRTSILÄ	Product W-X35	CONICAL SOCKET Konische Buechse	
Units mm kg	IDE	Basic Material 34CrMo4 SCM 435	Net Weight 4.8
Made 20.09.2010 jba029 Baumann	Scale 1:2	Size A4 / Page 1/1	Material ID 107.410.786.001
Chkd 23.12.2010 wwr001 Wroblewski	Design Group 9710	Drawing ID 107.410.786	Rev. –
Appd 23.12.2010 dst009 Stroedecke			

SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK

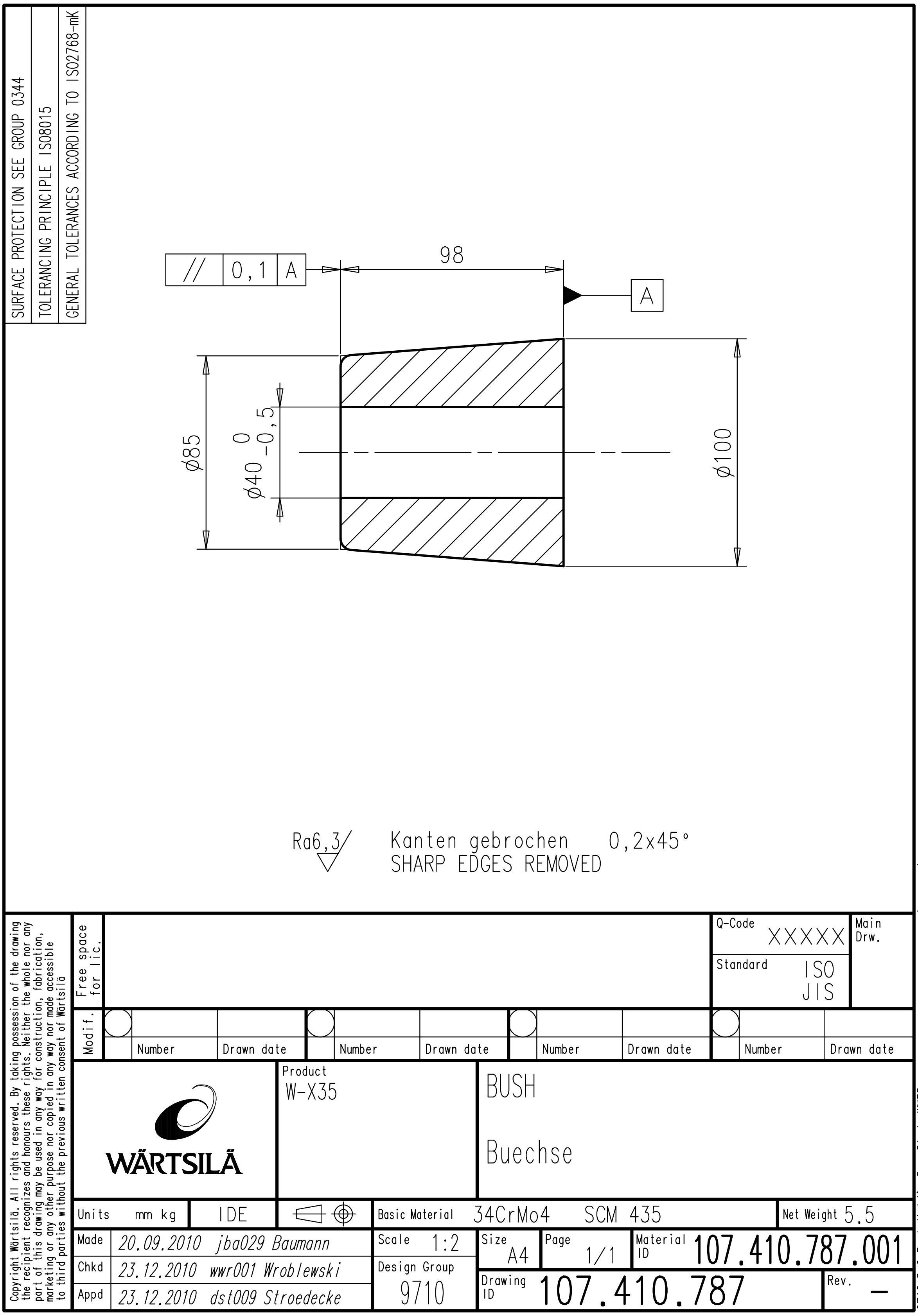


Ra6,3 Kanten gebrochen
SHARP EDGES REMOVED 0,2x45°

Free space for lic.		Q-Code XXXXX	Main Drw.
		Standard ISO JIS	
Modif.	Number / Drawn date	Number / Drawn date	Number / Drawn date / Number / Drawn date
WÄRTSILÄ	Product W-X35	CONICAL SOCKET Konische Buechse	
Units mm kg	IDE	Basic Material 34CrMo4 SCM 435	Net Weight 5.5
Made 20.09.2010 jba029 Baumann	Scale 1:2	Size A4, Page 1/1	Material ID 107.410.788.001
Chkd 23.12.2010 wwr001 Wroblewski	Design Group 9710	Drawing ID 107.410.788	Rev. –
Appd 23.12.2010 dst009 Stroedecke			

Approved

9710_D_0_ConicalSocketNormalHoles_WX35


SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
// 0,1 A
98
A
ø85
ø40 0 -0,5
ø100
Ra6,3
Kanten gebrochen 0,2x45°
SHARP EDGES REMOVED
Approved
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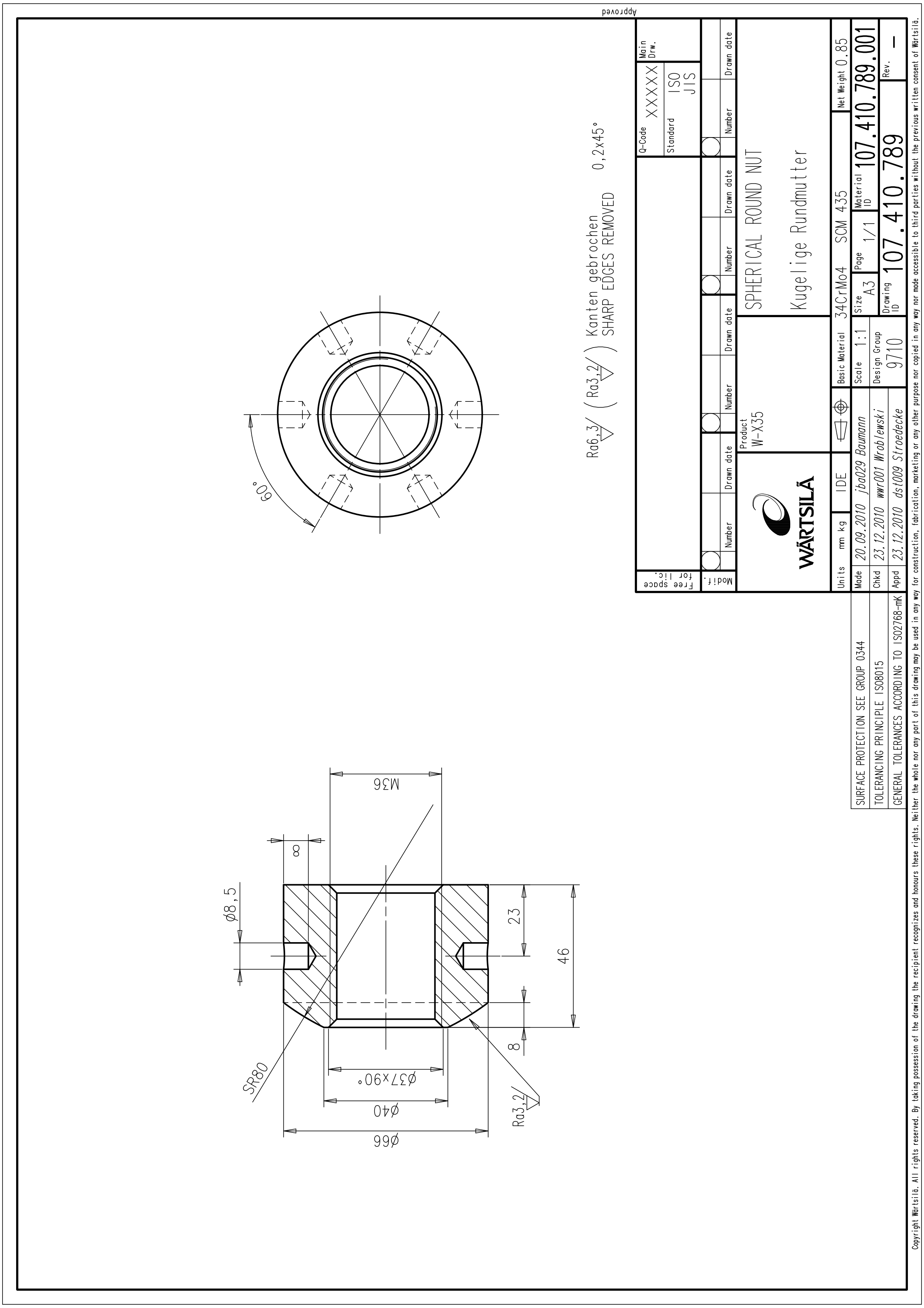
Q-Code XXXXX
Main Drw.
Standard ISO JIS
Modif.
Number
Drawn date
WÄRTSILÄ
Product W-X35
BUSH
Buechse
Units mm kg
IDE
Basic Material 34CrMo4 SCM 435
Net Weight 5.5
Made 20.09.2010 jba029 Baumann
Chkd 23.12.2010 wwr001 Wroblewski
Appd 23.12.2010 dst009 Stroedecke
Scale 1:2
Design Group 9710
Size A4
Page 1/1
Material ID 107.410.787.001
Drawing ID 107.410.787
Rev. –
9710_D_O_Bush_HoldingDownStuds_WX35


Approved
Ra6,3 (Ra3,2) Kanten gebrochen 0,2x45°
SHARP EDGES REMOVED
60°
M36
8
ø8,5
23
46
8
SR80
ø37x90°
ø40
ø66
Ra3,2
Free space for lic.
Modif.
Number
Drawn date
Q-Code XXXXX
Main Drw.
Standard ISO JIS
Product W-X35
SPHERICAL ROUND NUT
Kugelige Rundmutter
WÄRTSILÄ
Units mm kg
IDE
Basic Material 34CrMo4 SCM 435
Net Weight 0.85
Made 20.09.2010 jba029 Baumann
Chkd 23.12.2010 wwr001 Wroblewski
Appd 23.12.2010 ds1009 Stroedecke
Scale 1:1
Size A3
Page 1/1
Material ID 107.410.789.001
Design Group 9710
Drawing ID 107.410.789
Rev. –
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
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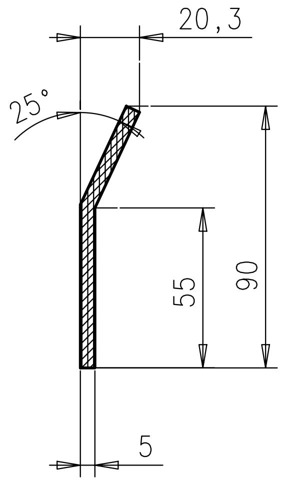
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK



Approved

Free space for lic.	
Q-Code	XXXXX
Standard	ISO JIS
Main Drw.	

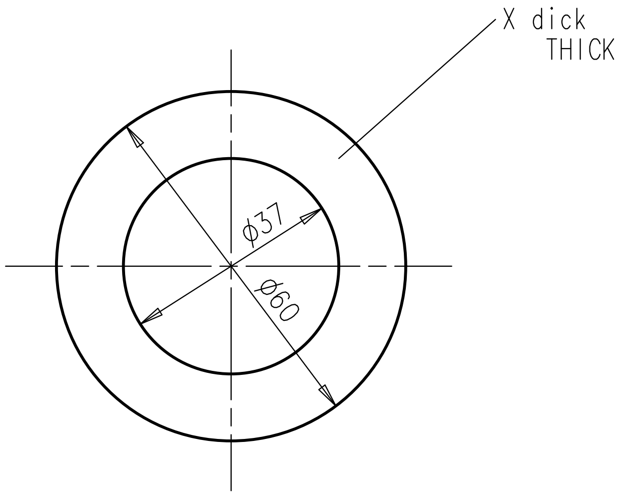
Modif.	Number	Drawn date		Number	Drawn date		Number	Drawn date		Number	Drawn date
A	EAAD082947	21.06.2011									

WÄRTSILÄ

Product	RTMOT
Title	SEALING PIECE FOR CHOCKING FAST Dichtleiste fuer chocking fast
Units	mm kg
	IDE
Basic Material	material acc.to shipyards experience
Net Weight	0.001
Made	13.02.2006 R. ZUCCHI
Chkd	
Appd	03.04.2006 sna001 Natali
Scale	1:1
Design Group	9710
Size	A4
Page	1/1
Material ID	107.367.119.001
Drawing ID	107.367.119
Rev.	A

PD - PRODUCTION DRAWING - Confidential

SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK



X = determined during assembly

Approved

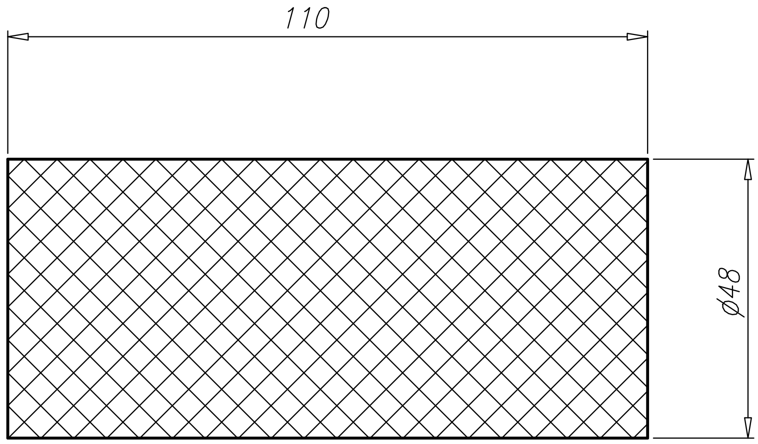
Free space for lic.		Q-Code: XXXXX	Main Drw.
		Standard: ISO JIS	

Modif.: Number / Drawn date (×4)

WÄRTSILÄ	Product: W-X35	JOINT DISC Dichtscheibe

Units: mm kg	IDE	Basic Material: Rubber750		Net Weight: 0.002
Made: 20.09.2010 jba029 Baumann	Scale: 1:1	Size: A4	Page: 1/1	Material ID: 107.410.829.001
Chkd: 23.12.2010 wwr001 Wroblewski	Design Group: 9710	Drawing ID: 107.410.829		Rev.: –
Appd: 23.12.2010 dst009 Stroedecke				

SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK



Q-Code	XXXXX	Main Drw.	
Standard	ISO JIS		

Modif.	Number	Drawn date	Number	Drawn date	Number	Drawn date	Number	Drawn date

WÄRTSILÄ

Product: W5-8X35

PLUG
FOR CHOCKING FAST
fuer chocking fast

Units mm kg	IDE	Basic Material Rubber750		Net Weight 0.001
Made 22.11.2010 S. Feuerstein	Scale 1:1	Size A4	Page 1/1	Material ID PAAD024777
Chkd 19.01.2011 wwr001 Wroblewski	Design Group 9710	Drawing ID DAAD011552		Rev. –
Appd 19.01.2011 dst009 Stroedecke				

Approved

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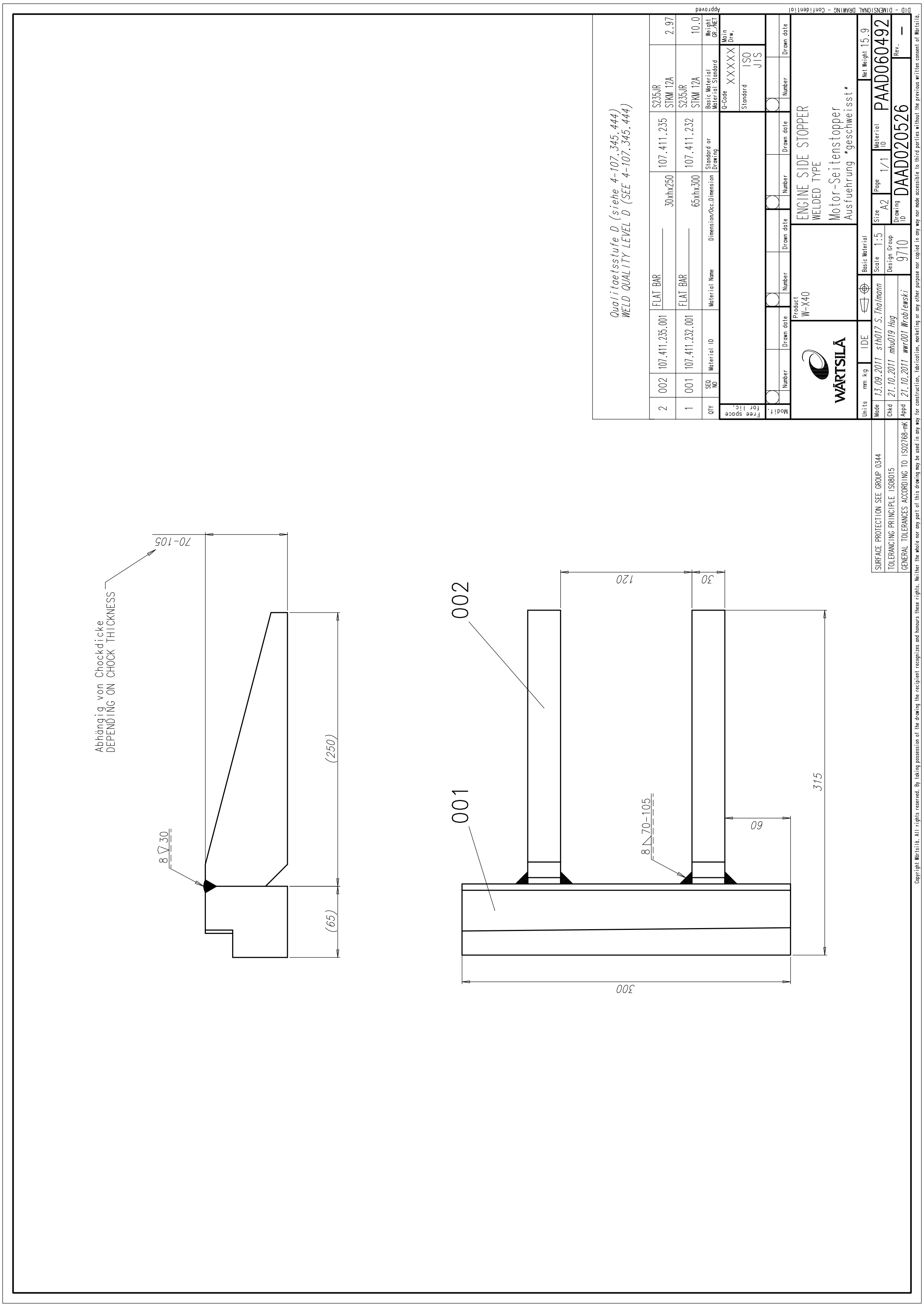
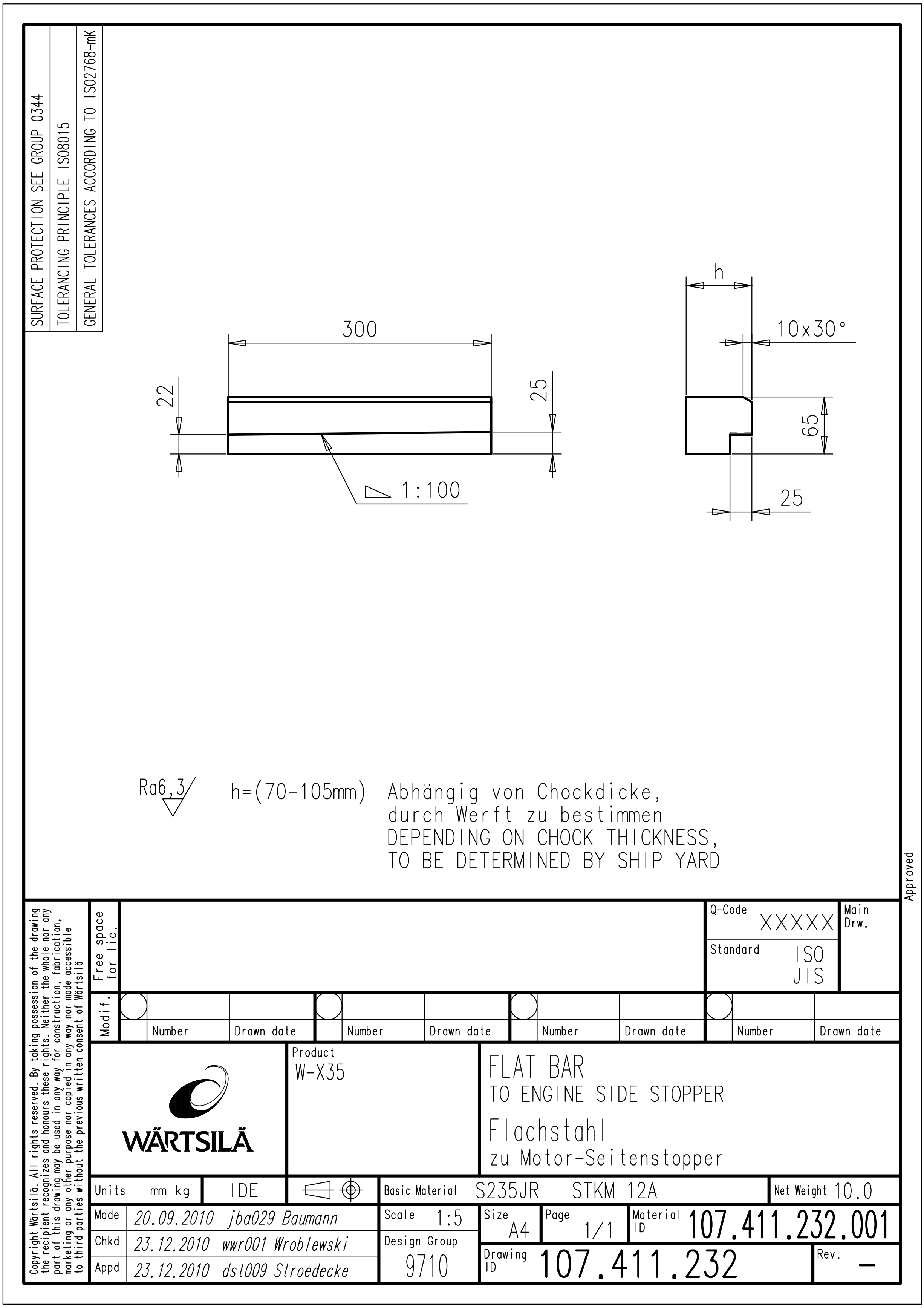

Qualitaetsstufe D (siehe 4-107.345.444)
WELD QUALITY LEVEL D (SEE 4-107.345.444)
2 002 107.411.235.001 FLAT BAR 30xhx250 107.411.235 S235JR STKM 12A 2.97
1 001 107.411.232.001 FLAT BAR 65xhx300 107.411.232 S235JR STKM 12A 10.0
QTY SEQ NO Material ID Material Name Dimension/Occ.Dimension Standard or Drawing Basic Material Material Standard Weight GR./NET
Q-Code XXXXX
Standard ISO JIS
Main Drw.
Free space for lic.
Modif.
Number Drawn date
Product W-X40
ENGINE SIDE STOPPER
WELDED TYPE
Motor-Seitenstopper
Ausfuehrung "geschweisst"
WÄRTSILÄ
Units mm kg
IDE
Made 13.09.2011 sth017 S.Thalmann
Chkd 21.10.2011 mhu019 Hug
Appd 21.10.2011 wwr001 Wroblewski
Basic Material
Scale 1:5
Design Group 9710
Size A2
Page 1/1
Material ID PAAD060492
Drawing ID DAAD020526
Net Weight 15.9
Rev. –
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
DID - DIMENSIONAL DRAWING - Confidential
Approved
Abhängig von Chockdicke
DEPENDING ON CHOCK THICKNESS
70-105
8 30
(250)
(65)
002
001
120
30
8 70-105
60
315
300


SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
300
22
25
1:100
h
10x30°
65
25
Ra6,3
h=(70-105mm) Abhängig von Chockdicke, durch Werft zu bestimmen
DEPENDING ON CHOCK THICKNESS, TO BE DETERMINED BY SHIP YARD
Approved
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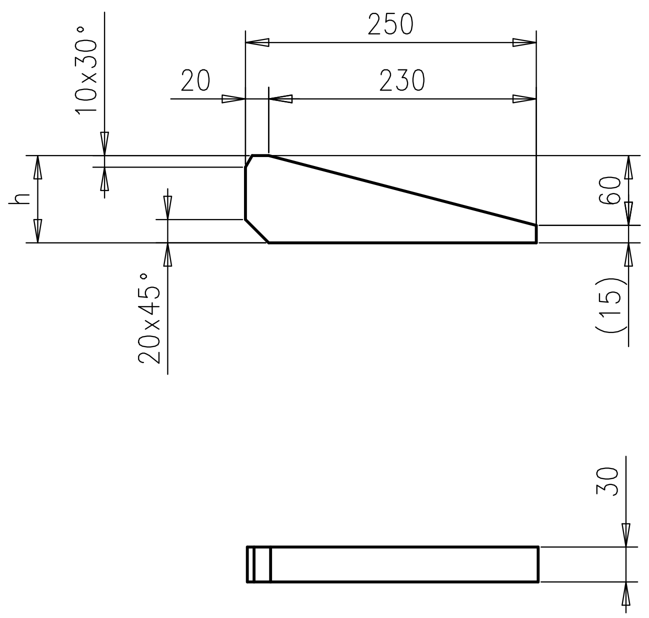
Free space for lic.
Q-Code XXXXX
Main Drw.
Standard ISO JIS
Modif.
Number
Drawn date
WÄRTSILÄ
Product W-X35
FLAT BAR
TO ENGINE SIDE STOPPER
Flachstahl
zu Motor-Seitenstopper
Units mm kg
IDE
Basic Material S235JR STKM 12A
Net Weight 10.0
Made 20.09.2010 jba029 Baumann
Chkd 23.12.2010 wwr001 Wroblewski
Appd 23.12.2010 dst009 Stroedecke
Scale 1:5
Design Group 9710
Size A4
Page 1/1
Material ID 107.411.232.001
Drawing ID 107.411.232
Rev. –

SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK

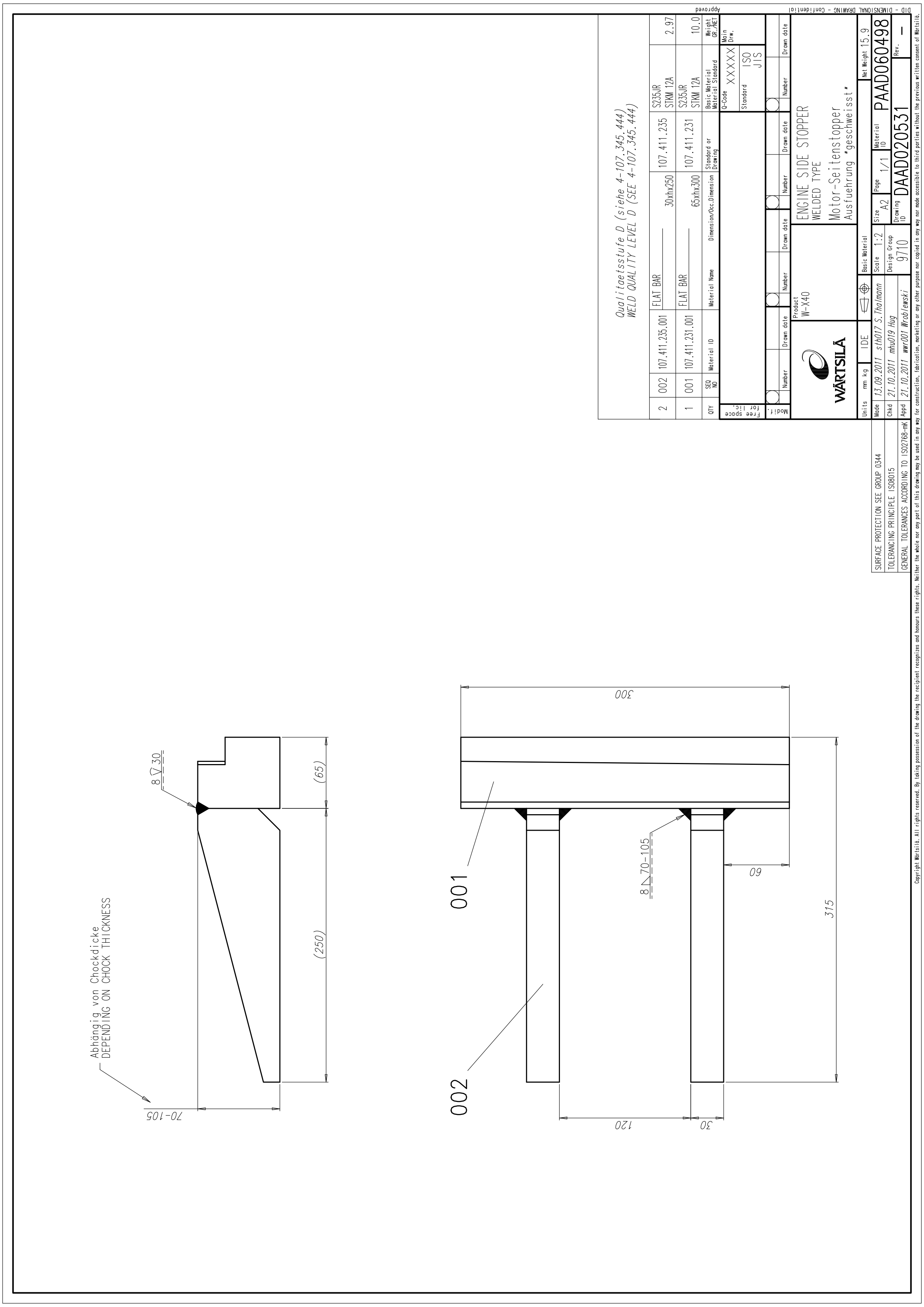


Ra50 Kanten gebrochen
SHARP EDGES REMOVED

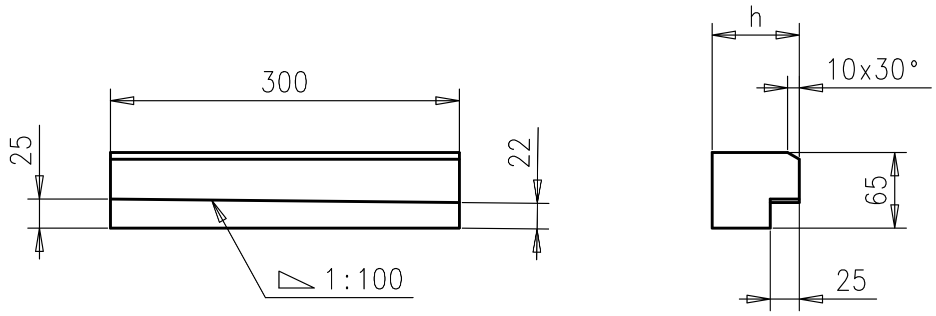
h=(70-105mm) Abhängig von Chockdicke, durch Werft zu bestimmen
DEPENDING ON CHOCK THICKNESS, TO BE DETERMINED BY SHIP YARD

Approved

Free space for lic.		Q-Code XXXXX Standard ISO JIS	Main Drw.
Modif.	Number / Drawn date	Number / Drawn date	Number / Drawn date / Number / Drawn date
WÄRTSILÄ	Product W-X35	FLAT BAR TO ENGINE SIDE STOPPER Flachstahl zu Motor-Seitenstopper	
Units mm kg	IDE	Basic Material S235JR STKM 12A	Net Weight 2.97
Made 20.09.2010 jba029 Baumann	Scale 1:5	Size A4 / Page 1/1	Material ID 107.411.235.001
Chkd 23.12.2010 wwr001 Wroblewski	Design Group 9710	Drawing ID 107.411.235	Rev. –
Appd 23.12.2010 dst009 Stroedecke			


Qualitaetsstufe D (siehe 4-107.345.444)
WELD QUALITY LEVEL D (SEE 4-107.345.444)
2 002 107.411.235.001 FLAT BAR 30xhx250 107.411.235 S235JR STKM 12A 2.97
1 001 107.411.231.001 FLAT BAR 65xhx300 107.411.231 S235JR STKM 12A 10.0
QTY SEQ NO Material ID Material Name Dimension/Occ.Dimension Standard or Drawing Basic Material Material Standard Weight GR./NET
Q-Code XXXXX
Standard ISO JIS
WÄRTSILÄ
Product W-X40
ENGINE SIDE STOPPER
WELDED TYPE
Motor-Seitenstopper
Ausfuehrung "geschweisst"
Net Weight 15.9
PAAD060498
DAAD020531
Size A2 Page 1/1
Scale 1:2
Design Group 9710
Units mm kg IDE
Made 13.09.2011 sth017 S.Thalmann
Chkd 21.10.2011 mhu019 Hug
Appd 21.10.2011 wwr001 Wroblewski
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
DID - DIMENSIONAL DRAWING - Confidential
Abhängig von Chockdicke
DEPENDING ON CHOCK THICKNESS
8 30
(65)
(250)
70-105
001
002
300
315
60
8 70-105
120
30

SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK



Ra6,3 h=(70–105mm) Abhängig von Chockdicke, durch Werft zu bestimmen
DEPENDING ON CHOCK THICKNESS, TO BE DETERMINED BY SHIP YARD

Approved

Free space for lic.		Q-Code: XXXXX	Main Drw.
		Standard: ISO JIS	

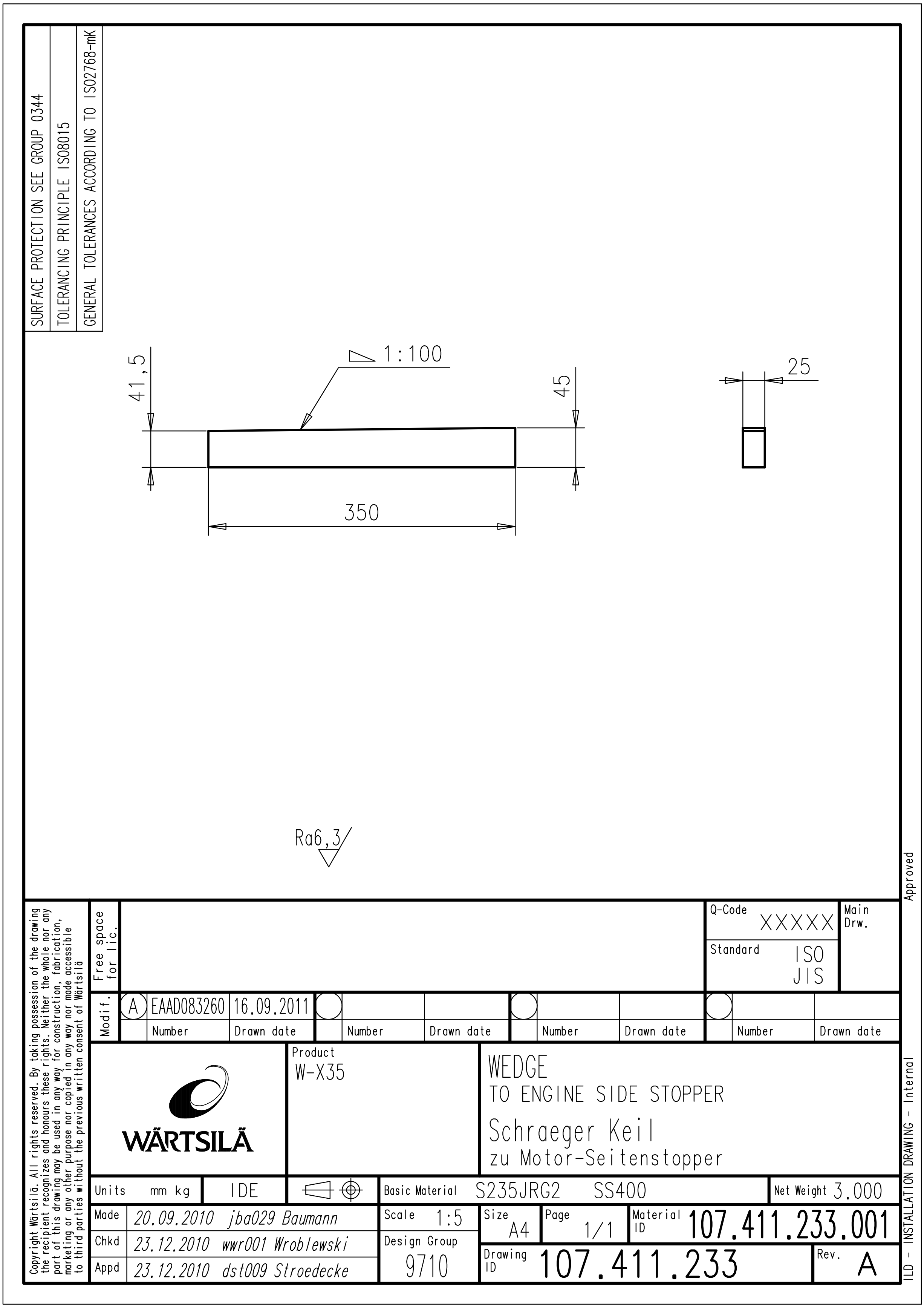
Modif.	Number	Drawn date	Number	Drawn date	Number	Drawn date	Number	Drawn date

WÄRTSILÄ

Product: W-X35

FLAT BAR
TO ENGINE SIDE STOPPER
Flachstahl
zu Motor-Seitenstopper

Units mm kg	IDE	Basic Material S235JR STKM 12A		Net Weight 10.0
Made 20.09.2010 jba029 Baumann	Scale 1:5	Size A4	Page 1/1	Material ID 107.411.231.001
Chkd 23.12.2010 wwr001 Wroblewski	Design Group 9710	Drawing ID 107.411.231		Rev. –
Appd 23.12.2010 dst009 Stroedecke				


SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
1:100
41,5
45
25
350
Ra6,3
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Free space for lic.
Q-Code XXXXX
Main Drw.
Standard ISO JIS
Approved
Modif.
A EAAD083260 16.09.2011
Number
Drawn date
WÄRTSILÄ
Product W-X35
WEDGE
TO ENGINE SIDE STOPPER
Schraeger Keil
zu Motor-Seitenstopper
Units mm kg
IDE
Basic Material S235JRG2 SS400
Net Weight 3.000
Made 20.09.2010 jba029 Baumann
Chkd 23.12.2010 wwr001 Wroblewski
Appd 23.12.2010 dst009 Stroedecke
Scale 1:5
Design Group 9710
Size A4
Page 1/1
Material ID 107.411.233.001
Drawing ID 107.411.233
Rev. A
ILD - INSTALLATION DRAWING - Internal

1 Introduction

Apart from the normal conventional engine holding down stud 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 thrust sleeves located adjacent to the engine thrust bearing.

Substitute for:									PC	Q-Code	X	X	X	X	X
Modif		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date			

WÄRTSILÄ	Product **W-X35**	**Fitting Instruction** **to engine seating with epoxy resin chocks**	
Made	19.01.2011 S. Feuerstein	Main Drw.	Page 1 / 6	Material ID **107.412.130.500**
Chkd	19.01.2011 M. Hug	Design Group	Drawing ID **107.412.130**	Rev -
Appd	19.01.2011 D. Strödecke	**9710**		

T_PC-Drawing_portrait | Author: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.2 (06.09.2010)

2 Thrust sleeve

2.1 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 plate is larger than the diameter of the sleeve to allow engine alignment without re-machining 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 holding down 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 plate. 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.

2.2 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, section B-B’. The holes for the normal holding down studs can be drilled or flame-cut either before or after setting the engine in position.

2.3 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 socket, 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 socket 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 conical socket allows for this variability. If chock thickness needs to be more than 60 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 in- or decreased accordingly. Please note: In any case, if the minimum thickness is less than 25 mm, the epoxy resin supplier must be consulted.

Substitute for:							PC	Q-Code	X X X X X		
Modif		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date	Number	Drawn Date

WÄRTSILÄ	Product W-X35	Fitting Instruction to engine seating with epoxy resin chocks	
Made 19.01.2011 S. Feuerstein	Main Drw.	Page 2 / 6	Material ID 107.412.130.500
Chkd 19.01.2011 M. Hug	Design Group 9710	Drawing ID 107.412.130	Rev -
Appd 19.01.2011 D. Strödecke			

T_PC-Drawing_portrait | Author: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.2 (06.09.2010)

3 Pouring of the epoxy resin chocks

3.1 Conditions before pouring

- Engine fully aligned
- All side stoppers welded in place, wedges not fitted
- For thrust sleeves (see figure 1): Thrust sleeves and their accompanying holding down studs inserted into the corresponding holes with the studs/nuts tightened by hand. The bush and the sponge rubber sealing fixed correctly under the tank top plate. Contact surface conical socket/top plate smeared with gasket sealant.
- For normal holding down studs (see figure 2): Sponge rubber plugs or similar inserted into bedplate where normal studs are applied.

3.2 Pouring

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. 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 materials 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 • 10^{-6} 1/K
Coefficient of friction – normal		min. 0.3

Table 1: Required properties of epoxy resin material

Substitute for:				PC	Q-Code	X	X	X	X	X
Modif	Number	Drawn Date	Number	Drawn Date	Number	Drawn Date	Number	Drawn Date		

WÄRTSILÄ	Product **W-X35**	**Fitting Instruction** **to engine seating with epoxy resin chocks**
Made 19.01.2011 S. Feuerstein	Main Drw.	Page 3 / 6 — Material ID **107.412.130.500**
Chkd 19.01.2011 M. Hug	Design Group **9710**	Drawing ID **107.412.130** — Rev -
Appd 19.01.2011 D. Strödecke		

T_PC-Drawing_portrait | Author: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.2 (06.09.2010)

4 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’s 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 or in parallel on both sides in the direction of the engine free end. After tightening all engine holding down studs, fit the side stopper wedges.

Substitute for:											PC / Q-Code / X X X X X
Modif	Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date

WÄRTSILÄ	Product: W-X35	**Fitting Instruction** to engine seating with epoxy resin chocks	
Made: 19.01.2011 S. Feuerstein	Main Drw.	Page: 4 / 6	Material ID: **107.412.130.500**
Chkd: 19.01.2011 M. Hug	Design Group: **9710**	Drawing ID: **107.412.130**	Rev: -
Appd: 19.01.2011 D. Strödecke			

T_PC-Drawing_portrait | Author: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.2 (06.09.2010)

5 Table and figures

5.1 Tightening pressures

Engine type	Pretension force per stud Fv [kN][*1]	Hydraulic tightening pressure p [bar]	Code-No. of hydr. pre-tensioning jack[*2]
W-X35	280	1500	94145

Table 2: Foundation bolts tightening data

Remarks: *1) Including an efficiency loss during tightening process
*2) The hydraulic pre-tensioning jack is part of the engine builder's tool kit

5.2 Figures

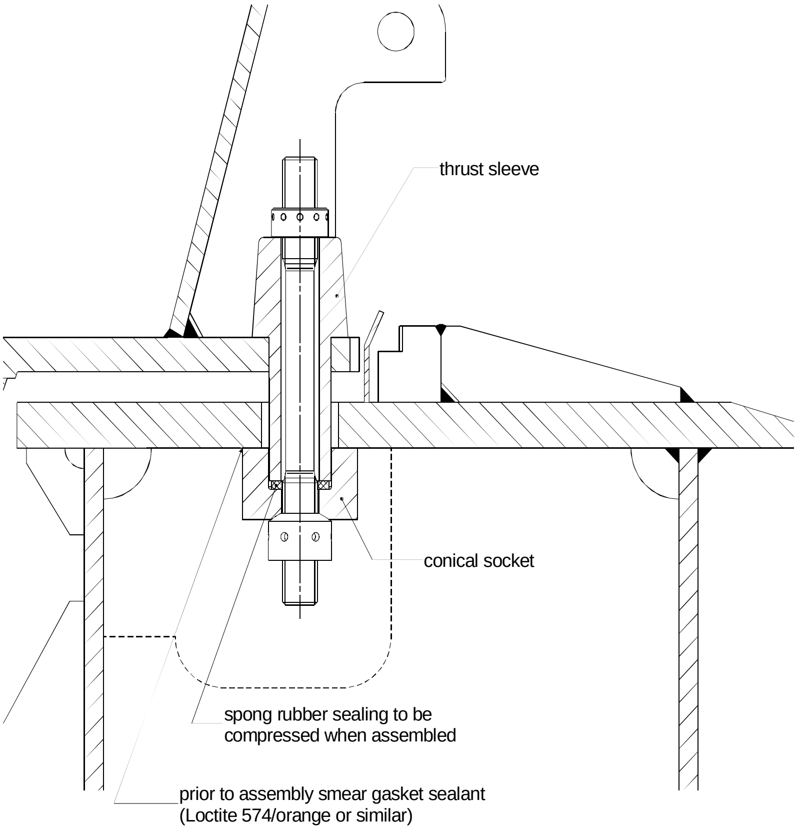


Figure 1: Arrangement of thrust sleeve with stud prior pouring the epoxy resin chocks

Substitute for:	PC	Q-Code	X	X	X	X	X

Modif	Number	Drawn Date	Number	Drawn Date	Number	Drawn Date	Number	Drawn Date

WÄRTSILÄ	Product W-X35	Fitting Instruction to engine seating with epoxy resin chocks

Made	19.01.2011	S. Feuerstein	Main Drw.	Page 5 / 6 — Material ID 107.412.130.500
Chkd	19.01.2011	M. Hug	Design Group	Drawing ID 107.412.130 — Rev -
Appd	19.01.2011	D. Strödecke	9710	

T_PC-Drawing_portrait | Author: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.2 (06.09.2010)

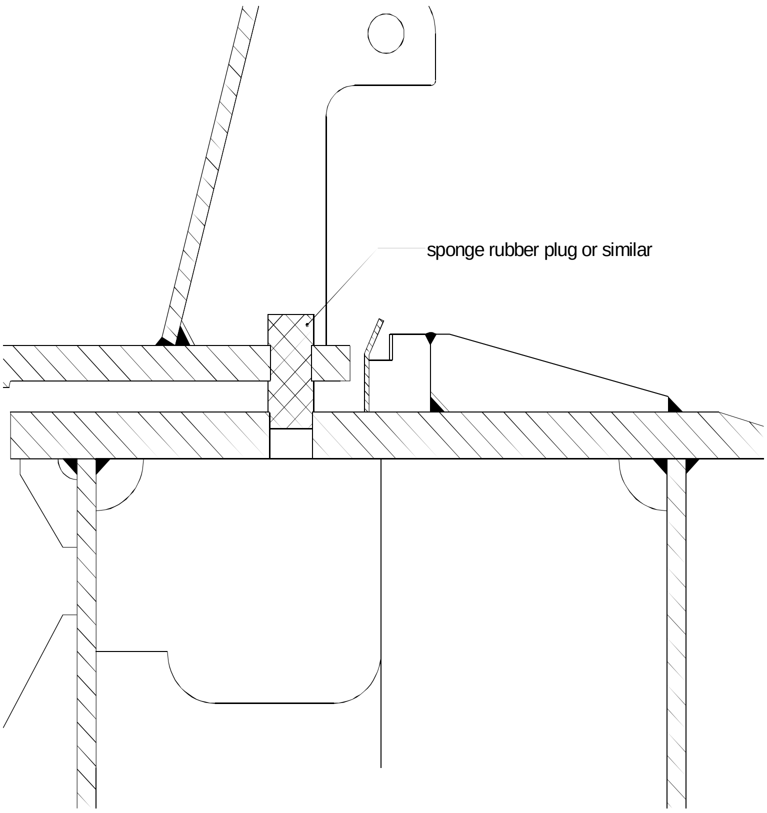
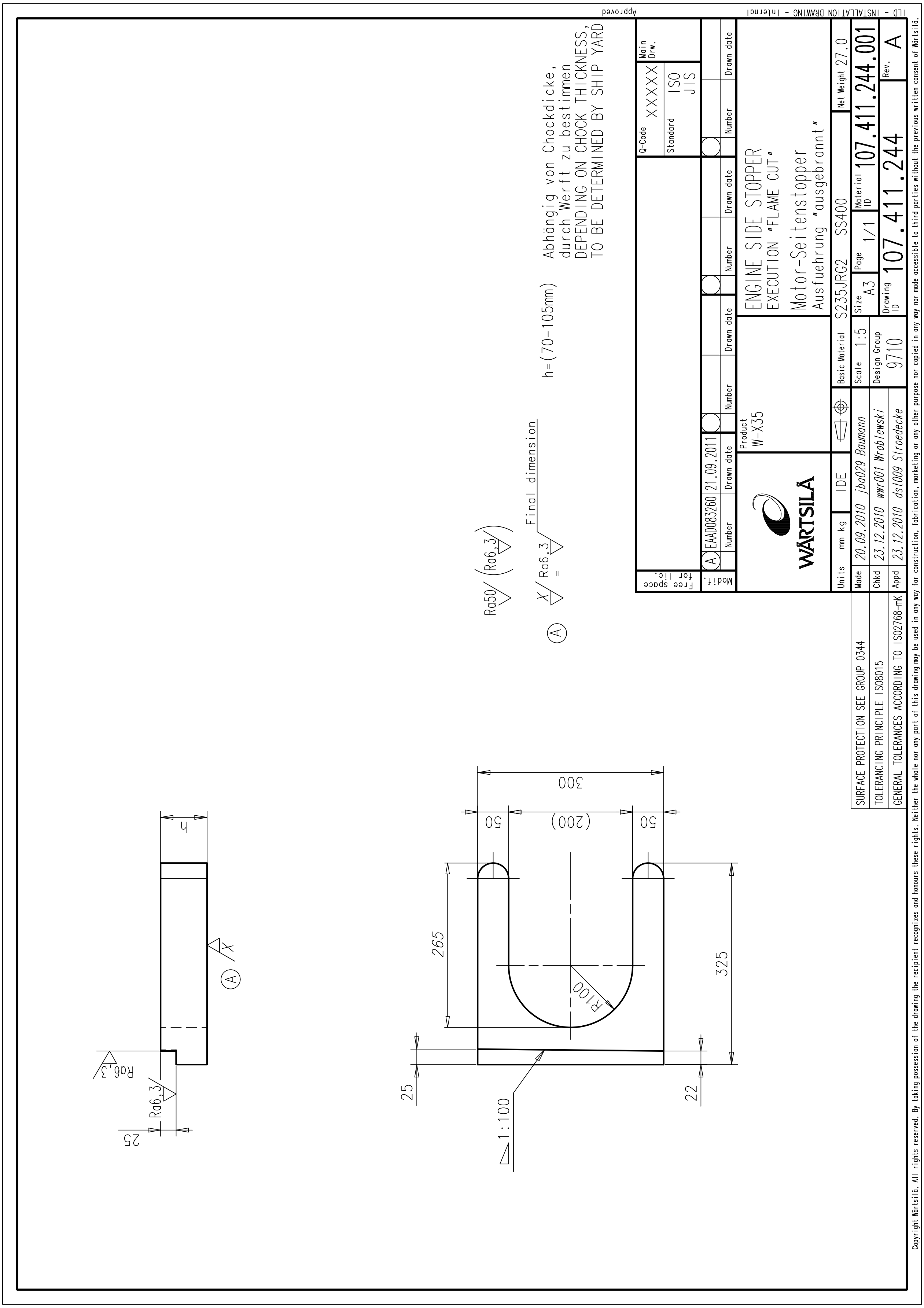
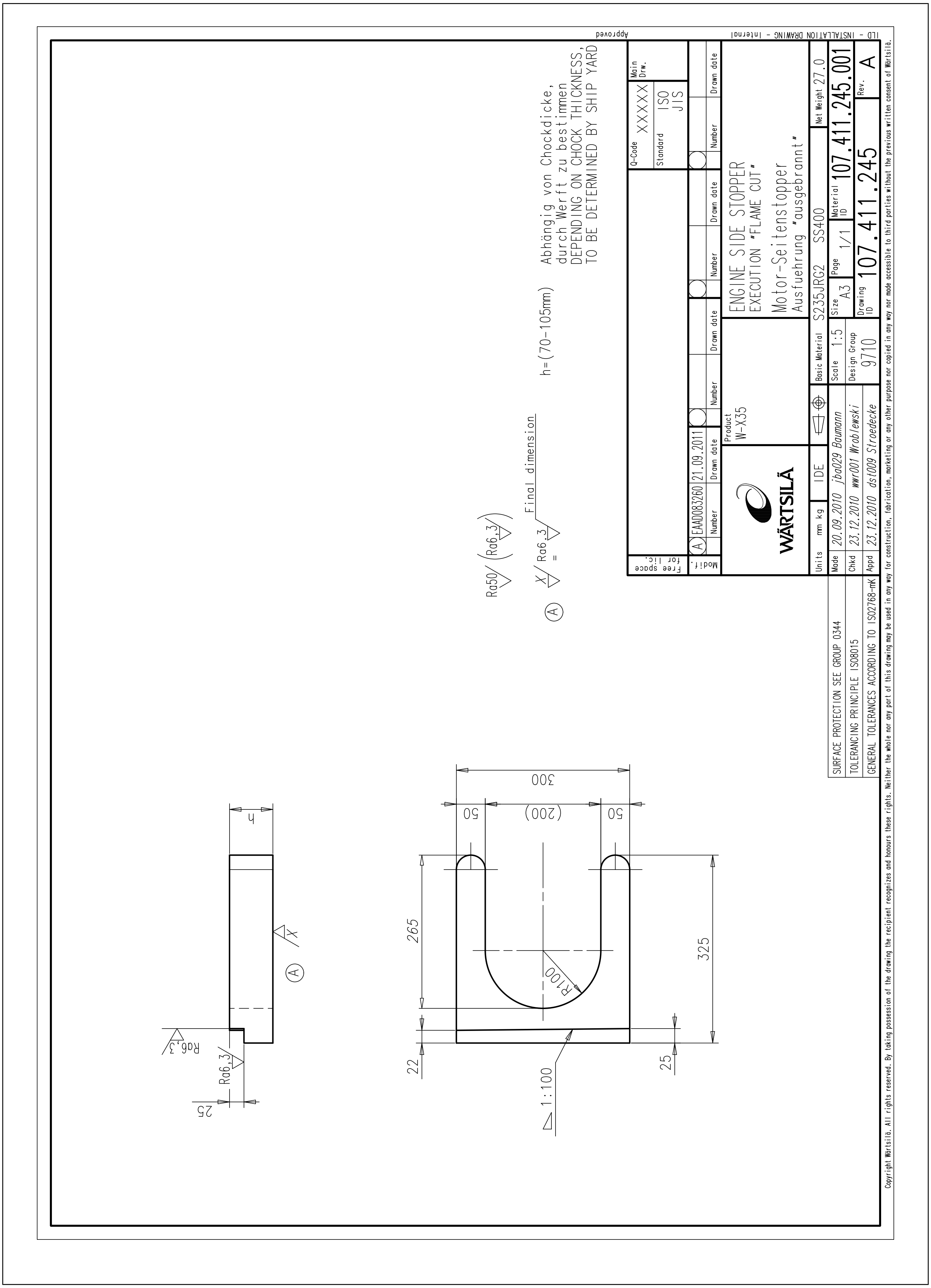


Figure 2: Arrangement prior pouring the epoxy resin chocks for normal stud (proposal)

Substitute for:						PC	Q-Code X X X X X
Modif Number	Drawn Date	Number	Drawn Date	Number	Drawn Date	Number	Drawn Date
WÄRTSILÄ	Product W-X35			Fitting Instruction to engine seating with epoxy resin chocks			
Made	19.01.2011	S. Feuerstein	Main Drw.	Page 6 / 6	Material ID 107.412.130.500		
Chkd	19.01.2011	M. Hug	Design Group 9710	Drawing ID 107.412.130		Rev -	
Appd	19.01.2011	D. Strödecke					

T_PC-Drawing_portrait | Author: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.2 (06.09.2010)


Abhängig von Chockdicke,
durch Werft zu bestimmen
DEPENDING ON CHOCK THICKNESS,
TO BE DETERMINED BY SHIP YARD
h=(70-105mm)
Final dimension
Ra50
Ra6,3
300
(200)
50
50
265
325
R100
25
22
1:100
ENGINE SIDE STOPPER
EXECUTION "FLAME CUT"
Motor-Seitenstopper
Ausfuehrung "ausgebrannt"
Product
W-X35
WÄRTSILÄ
S235JRG2 SS400
Scale 1:5
Size A3
Page 1/1
Design Group 9710
Drawing ID 107.411.244
Material ID 107.411.244.001
Net Weight 27.0
Rev. A
EAAD083260 21.09.2011
Made 20.09.2010 jba029 Baumann
Chkd 23.12.2010 wwr001 Wroblewski
Appd 23.12.2010 ds1009 Stroedecke
Units mm kg IDE
Q-Code XXXXX
Standard ISO JIS
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
ILD - INSTALLATION DRAWING - Internal


Abhängig von Chockdicke, durch Werft zu bestimmen
DEPENDING ON CHOCK THICKNESS, TO BE DETERMINED BY SHIP YARD
h=(70-105mm)
Final dimension
Ra50 (Ra6,3)
A X Ra6,3 =
300
50
(200)
50
h
265
325
R100
22
25
1:100
Ra6,3
25
A
X
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
Free space for lic.
Modif.
A EAA083260 21.09.2011
Number Drawn date
Q-Code XXXXX
Standard ISO JIS
Main Drw.
WÄRTSILÄ
Product W-X35
ENGINE SIDE STOPPER
EXECUTION "FLAME CUT"
Motor-Seitenstopper
Ausfuehrung "ausgebrannt"
Units mm kg IDE
Basic Material S235JRG2 SS400
Net Weight 27.0
Made 20.09.2010 jba029 Baumann
Chkd 23.12.2010 wwr001 Wroblewski
Appd 23.12.2010 ds1009 Stroedecke
Scale 1:5
Size A3
Page 1/1
Material ID 107.411.245.001
Design Group 9710
Drawing ID 107.411.245
Rev. A
ILD - INSTALLATION DRAWING - Internal
Approved
Copyright Wärtsilä. All rights reserved. By taking possession of the drawing the recipient recognizes and honours these rights. Neither the whole nor any part of this drawing may be used in any way for construction, fabrication, marketing or any other purpose nor copied in any way nor made accessible to third parties without the previous written consent of Wärtsilä.

18.5 Engine coupling

18.5.1 Fitting of coupling bolts

Drilling and reaming of the engine and shaft couplings is to be carried out using a computer controlled drilling machine or an accurately centred jig. 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 a pitch circle error leading to a misalignment of bolt holes, the situation has to be remedied by applying joint cylindrical reaming to an oversize hole and fitting an individually machined fitted bolt. Fitted bolts are to locate with a medium 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.

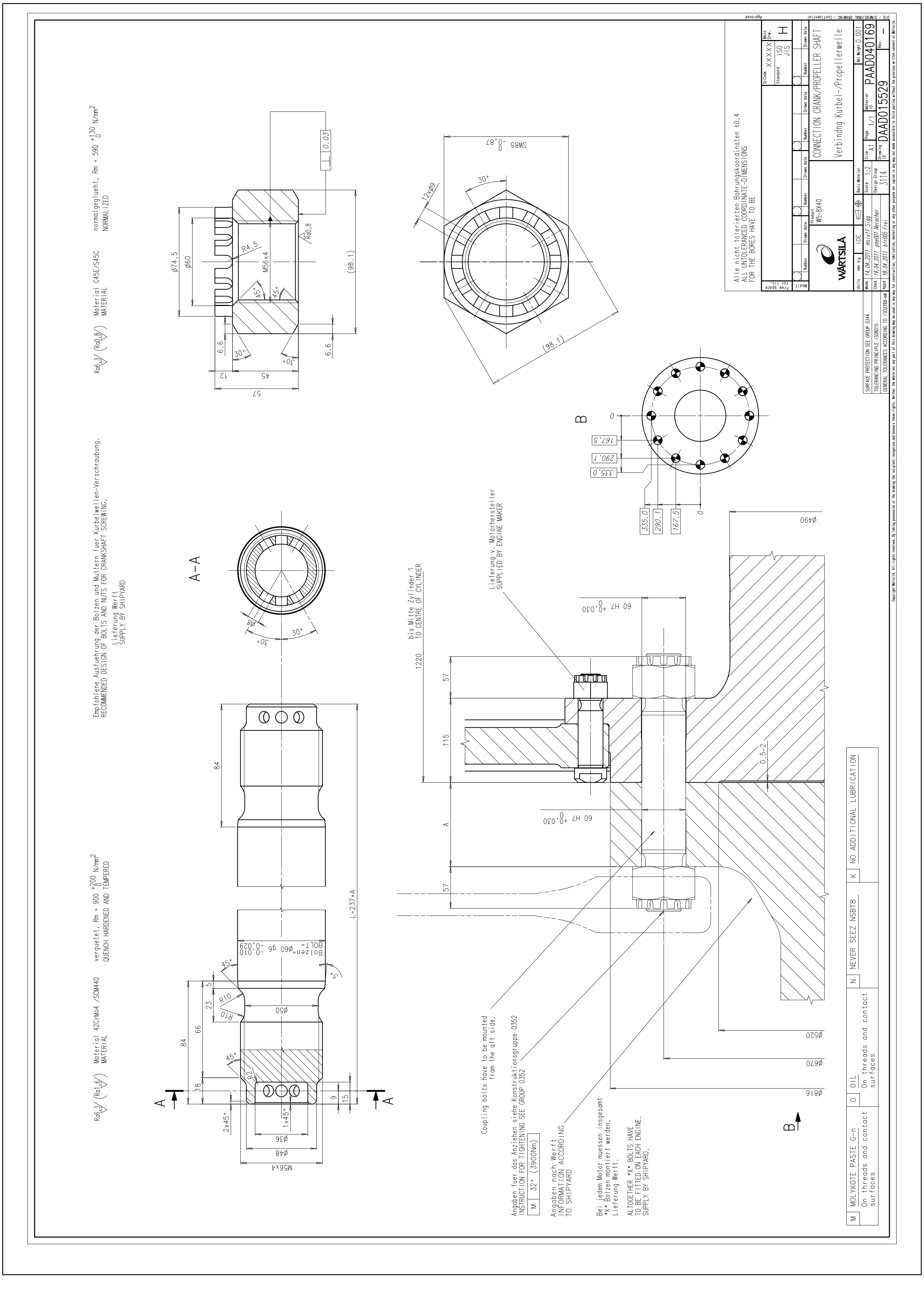
The connection crankshaft/propeller shaft with bore, bolt and nut is part of the engine designer's submission to the Classification Societies for Design Approval.

When tightening the coupling bolts it is essential 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 32°, 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 wires or split pins. Use feeler gauges during the tightening process to ensure that the coupling faces are properly mated with no clearance.

Drawings



CONNECTION CRANK/PROPELLER SHAFT
Verbindng Kurbel-/Propellerwelle
DAAD015529
PAAD040169
Alle nicht tolerierten Bohrungskoordinaten ±0,4
ALL UNTOLERANCED COORDINATE-DIMENSIONS
FOR THE BORES HAVE TO BE
Empfohlene Ausfuehrung der Bolzen und Muttern fuer Kurbelwellen-Verschraubung.
RECOMMENDED DESIGN OF BOLTS AND NUTS FOR CRANKSHAFT SCREWING.
Lieferung Werft
SUPPLY BY SHIPYARD
Material C45E/S45C
MATERIAL
normalgeglueht, Rm = 590 +130 0 N/mm2
NORMALIZED
Material 42CrMo4 /SCM440
MATERIAL
verguetet, Rm = 900 +200 0 N/mm2
QUENCH HARDENED AND TEMPERED
A-A
bis Mitte Zylinder 1
TO CENTRE OF CYLINDER
Lieferung v. Motorhersteller
SUPPLIED BY ENGINE MAKER
Coupling bolts have to be mounted
from the aft side.
Angaben fuer das Anziehen siehe Konstruktionsgruppe 0352
INSTRUCTION FOR TIGHTENING SEE GROUP 0352
M 32° (3900Nm)
Angaben nach Werft
INFORMATION ACCORDING
TO SHIPYARD
Bei jedem Motor muessen insgesamt
"X" Bolzen montiert werden.
Lieferung Werft.
ALTOGETHER "X" BOLTS HAVE
TO BE FITTED ON EACH ENGINE.
SUPPLY BY SHIPYARD.
M MOLYKOTE PASTE G-n
On threads and contact
surfaces
O OIL
On threads and contact
surfaces
N NEVER SEEZ NSBT8
K NO ADDITIONAL LUBRICATION

18.6 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 lead to component failures or in some cases result in fires and interference with control and monitoring instrumentation.

18.6.1 Preventive action

Using earthing brushes in contact with slip-rings and bonding the chassis by braided copper wire are common ways 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 with handheld 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 that instrument wiring meets the building and classification society specifications and that it 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.

18.6.2 Main shaft earthing system

Figure *18.5* shows 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 *18.6* 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.

Different 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.

Wärtsilä Switzerland Ltd. recommends installing a shaft earthing device on the intermediate shafting as illustrated in figure *18.5*.

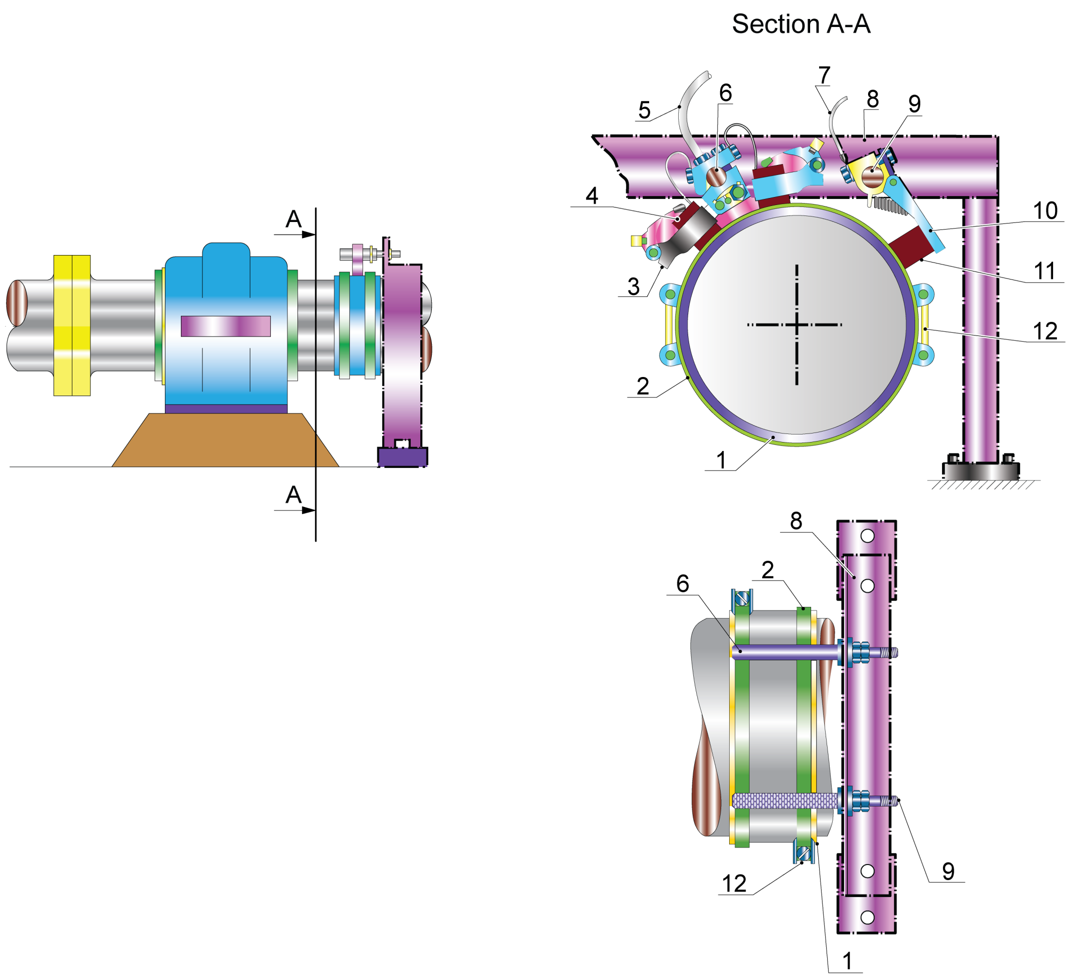


Figure 18.5: Shaft earthing arrangement

View on 'A' - Brush gear omitted			
1	Slip ring	7	Connection to the voltmeter
2	Tension bands	8	Mounting bracket
3	Twin holder	9	Insulated spindle
4	Brushes	10	Single holder
5	Connection to the ship's hull	11	Monitoring brush
6	Steel spindle	12	Clamps

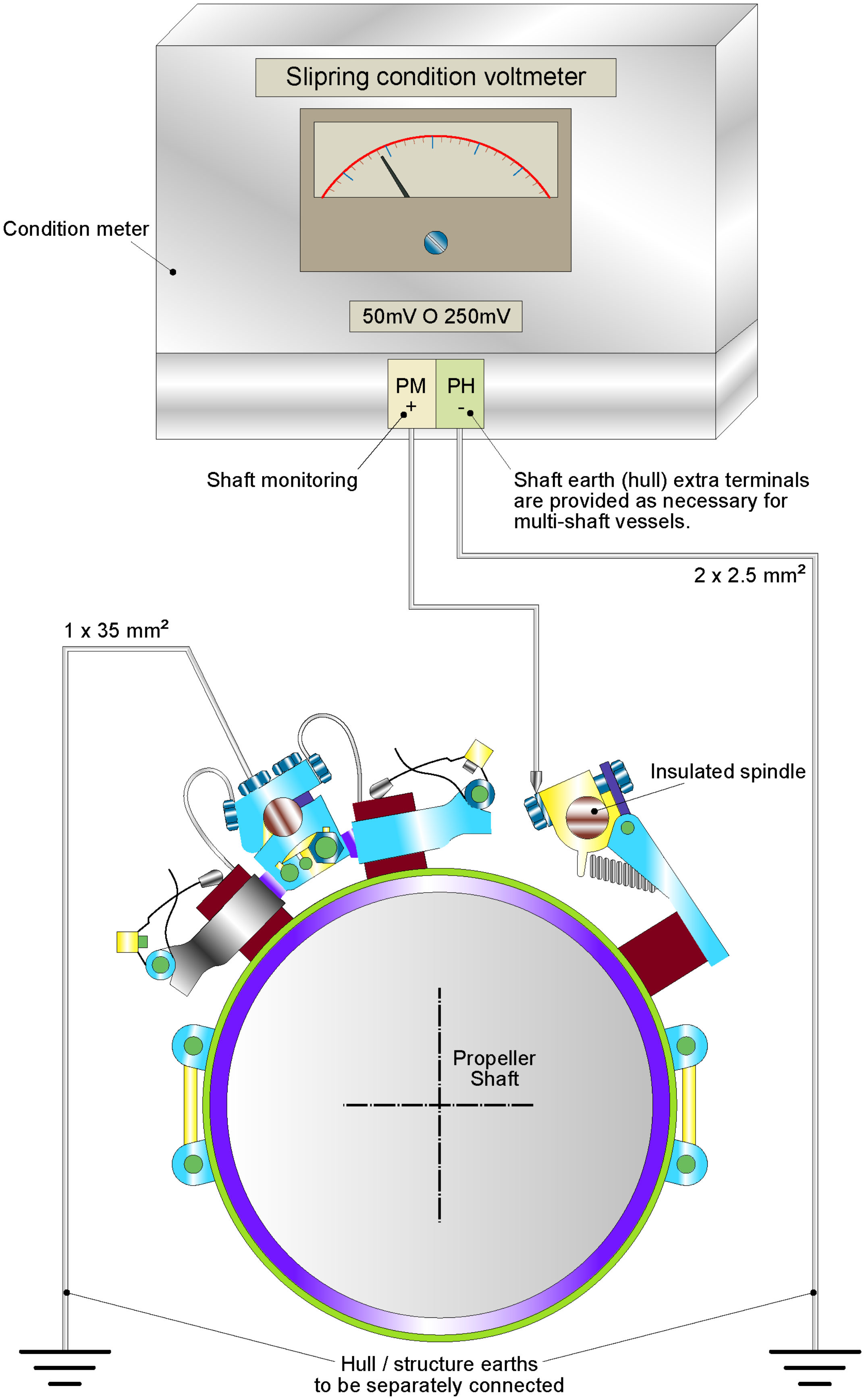


Figure 18.6: Shaft earthing with condition monitoring facility

18.7 Engine stays

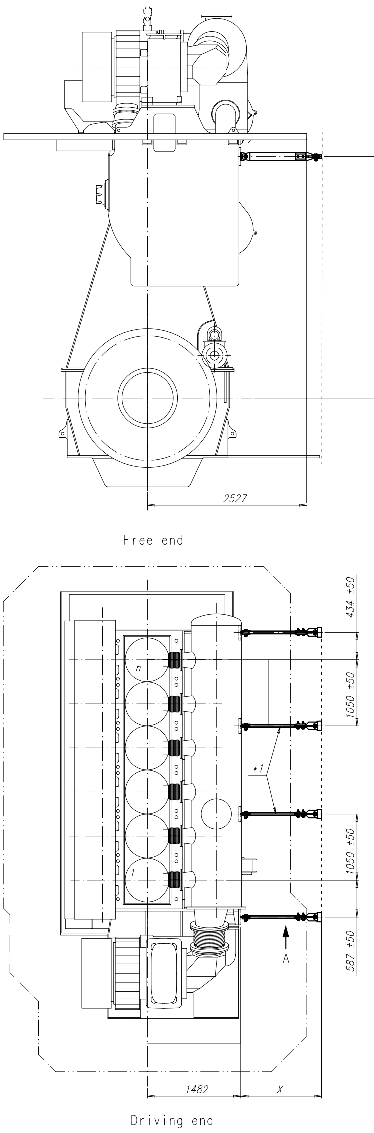
The engine seating is integral with the double-bottom structure and has to be of sufficient strength to support the weight of the engine, transmit the propeller thrust, withstand external couples and stresses related to propeller and engine resonance.

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 is 3° to the horizontal.

Before any engine seating work can be performed, make sure the engine is aligned with the intermediate propeller shaft.

18.7.1 Drawings



Requirements for ship side attachment point

Max. force acting on ship's hull	$F_{max.}$	(kN)	±60
Minimum stiffness	$k_{min.}$	(N/m)	0.5 x 10^9
Permissible deflection per 100 kN	$Def_{max.}$	(mm)	0.2

Material ID	X (mm)	T (mm)
PAAD073747	2000-2280	15
PAAD073748	2281-2560	20
PAAD073749	2561-2840	25
PAAD073750	2841-3120	30
PAAD073751	3121-3400	35

Lateral rocking

No. of Cyl.	5	6	7	8
Lateral stays	A	B	B	A

Remarks:

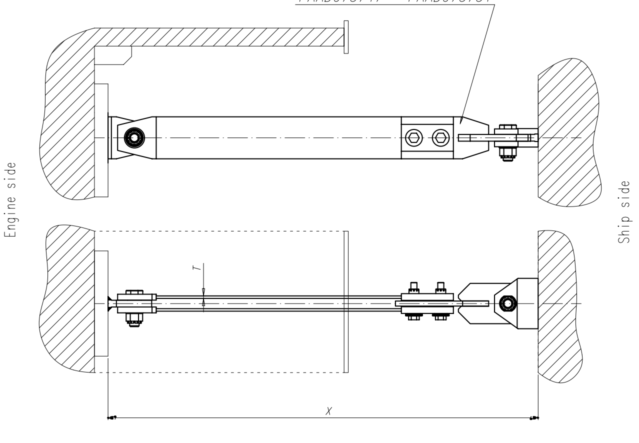
A: The countermeasure indicated is needed.
B: The countermeasure indicated maybe needed and provision for the corresponding countermeasure is recommended.

X defines the clear width between engine attachment points on engine and ship side (TO BE DETERMINED BY SHIPPYARD)

X min. = 2000 mm
X max. = 3400 mm

*1) Optional.
final amount of stays determined by shipyard.

A-A 1:10
PAAD073747 - PAAD073751



Net Weight 820	760	704	650	592	SEQ NO	Material ID	Material Name	Dimension/Occ.Dimension	Standard or Drawing	Basic Material Material Standard	Weight GR./NET
1	1	1	1	1	006	107.246.429.500	ASSEMBLY INSTRUCTIONS		107.246.429		0.001
2	-	-	-	-	005	PAAD073390	ENGINE STAYS/ FRICTION TYPE		DAAD024355		410
-	2	-	-	-	004	PAAD073392	ENGINE STAYS/ FRICTION TYPE		DAAD024355		380
-	-	2	-	-	003	PAAD073388	ENGINE STAYS/ FRICTION TYPE		DAAD024355		352
-	-	-	2	-	002	PAAD073385	ENGINE STAYS/ FRICTION TYPE		DAAD024355		325
-	-	-	-	2	001	PAAD073387	ENGINE STAYS/ FRICTION TYPE		DAAD024355		297
Quantity PER ENGINE											
PAAD073751	PAAD073750	PAAD073749	PAAD073748	PAAD073747							
Material ID											

Approved

Free space for lic.

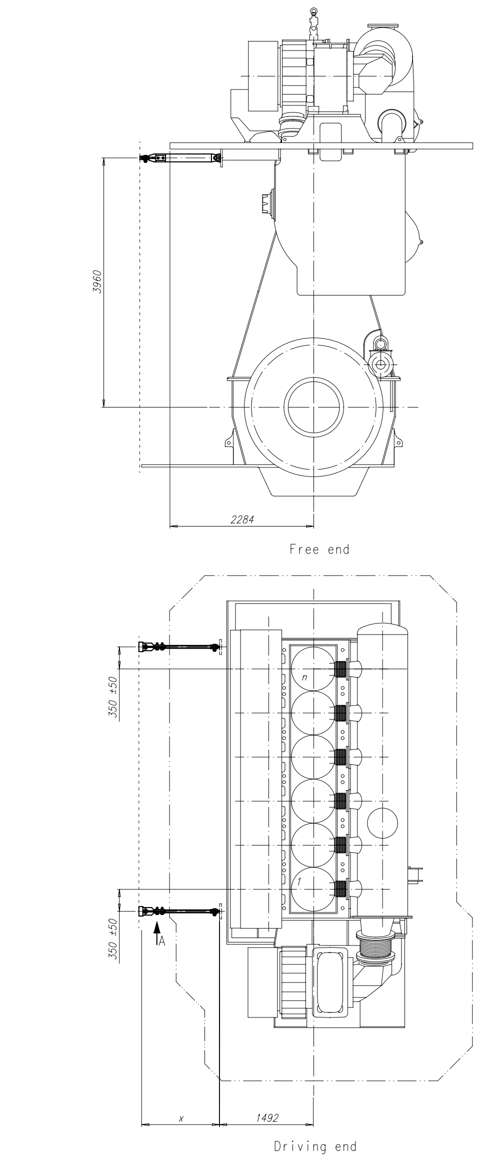
Q-Code XXXXX | Standard ISO JIS | Main Drw. H

Modif. | Number | Drawn date | Number | Drawn date | Number | Drawn date | Number | Drawn date

WÄRTSILÄ | Product W-X40

ENGINE STAYS
FRICTION TYPE, EXHAUST SIDE
Motorabstuetzung
mit Reibbelag, Abgasseite

SURFACE PROTECTION SEE GROUP 0344	Units mm kg	IDE		Basic Material	Net Weight
TOLERANCING PRINCIPLE ISO8015	Made	25.01.2012 sfe006 Feuerstein	Scale 1:100	Size A1	Page 1/1
GENERAL TOLERANCES ACCORDING TO ISO2768-mK	Chkd	30.01.2012 wwr001 Wroblewski	Design Group 9715	Material ID	
	Appd	30.01.2012 dst009 Stroedecke		Drawing ID DAAD024500	Rev. –



Requirements for ship side attachment point

Max. force acting on ship's hull	$F_{max.}$	(kN)	±60
Minimum stiffness	$k_{min.}$	(N/m)	0.5×10^9
Permissible deflection per 100 kN	$Def_{max.}$	(mm)	0.2

Material ID	X (mm)	T (mm)
PAAD073383	2000-2280	15
PAAD073386	2281-2560	20
PAAD073389	2561-2840	25
PAAD073393	2841-3120	30
PAAD073391	3121-3400	35

Lateral rocking

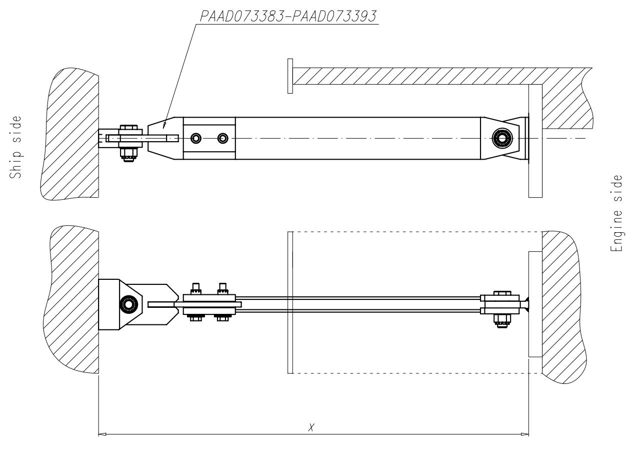
No. of Cyl.	5	6	7	8
Lateral stays	A	B	B	A

Remarks:

A: The countermeasure indicated is needed.
B: The countermeasure indicated maybe needed and provision for the corresponding countermeasure is recommended.

X defines the clear width between engine attachment points on engine and ship side (TO BE DETERMINED BY SHIPPYARD)
X min. = 2000 mm
X max. = 3400 mm

A-A 1:10



Quantity PER ENGINE: PAAD073391 (Net Weight 820)	PAAD073393 (760)	PAAD073389 (704)	PAAD073386 (650)	PAAD073383 (592)	SEQ NO	Material ID	Material Name	Dimension/Occ.Dimension	Standard or Drawing	Basic Material Material Standard	Weight GR./NET
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-	2	-	-	-	004	PAAD073392	ENGINE STAYS/ FRICTION TYPE		DAAD024355		380
-	-	2	-	-	003	PAAD073388	ENGINE STAYS/ FRICTION TYPE		DAAD024355		352
-	-	-	2	-	002	PAAD073385	ENGINE STAYS/ FRICTION TYPE		DAAD024355		325
-	-	-	-	2	001	PAAD073387	ENGINE STAYS/ FRICTION TYPE		DAAD024355		297

Approved

Free space for lic.
Q-Code XXXXX
Standard ISO JIS
Main Drw. H

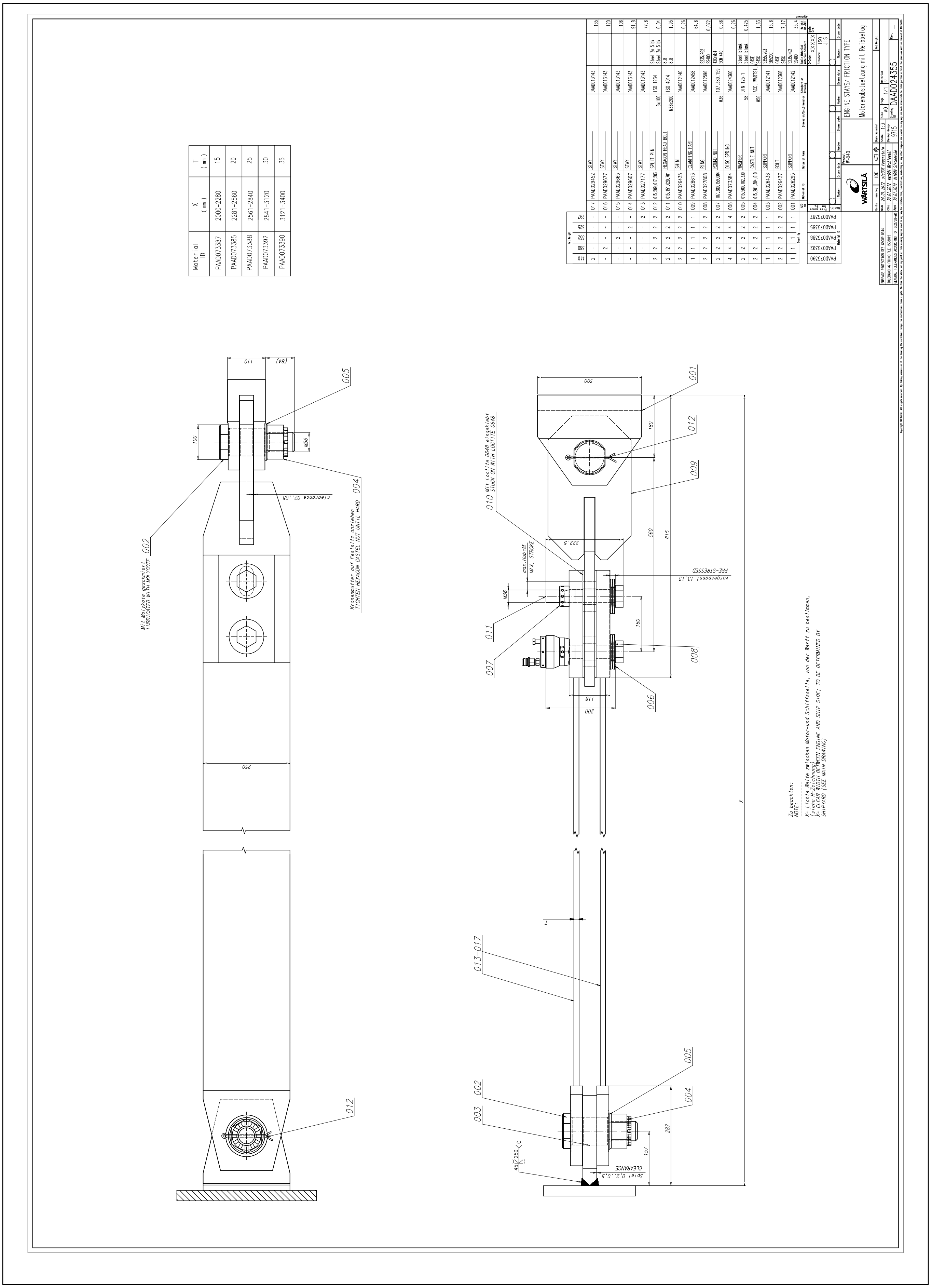
Modif. | Number | Drawn date | Number | Drawn date | Number | Drawn date | Number | Drawn date

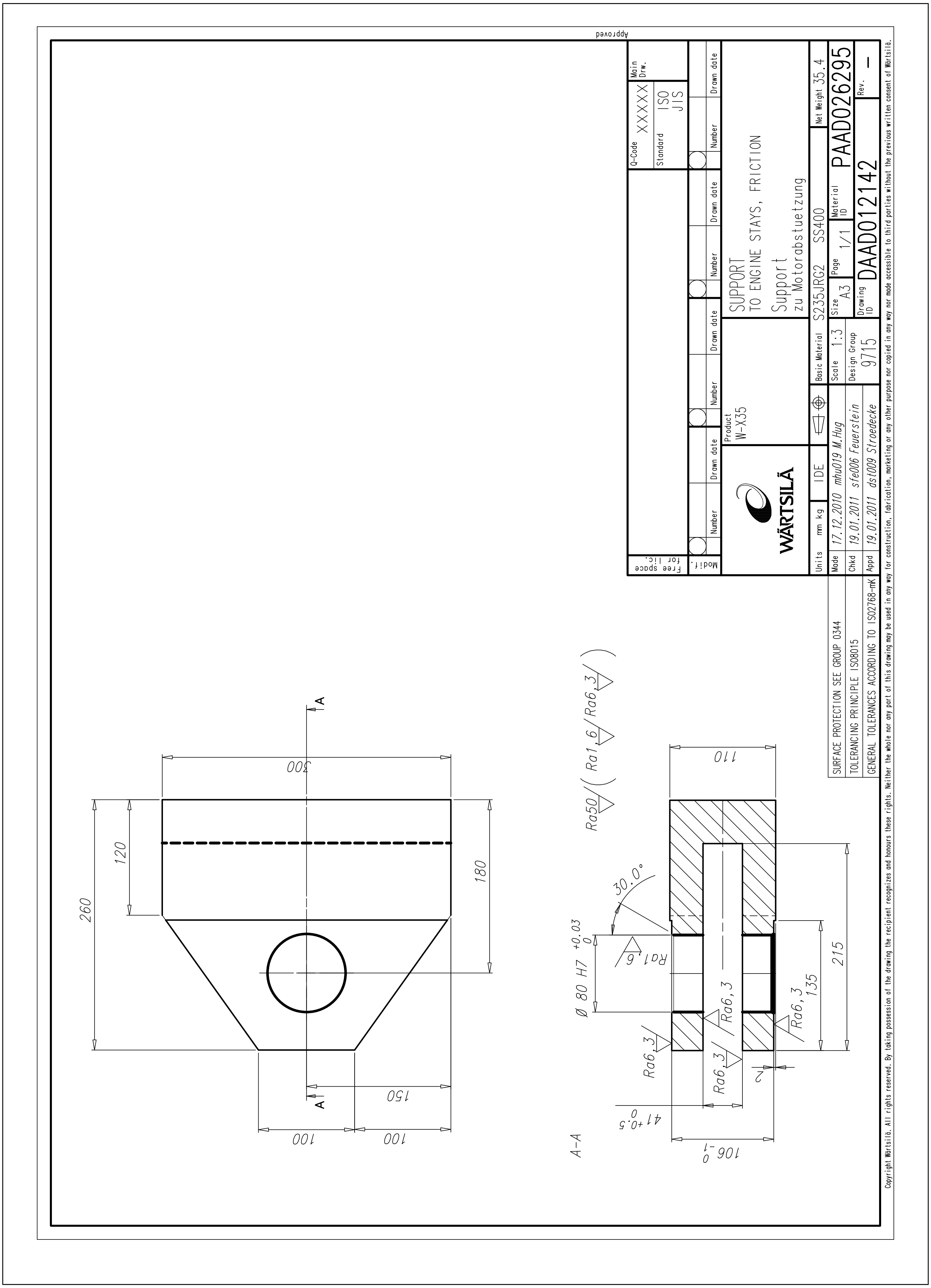
WÄRTSILÄ

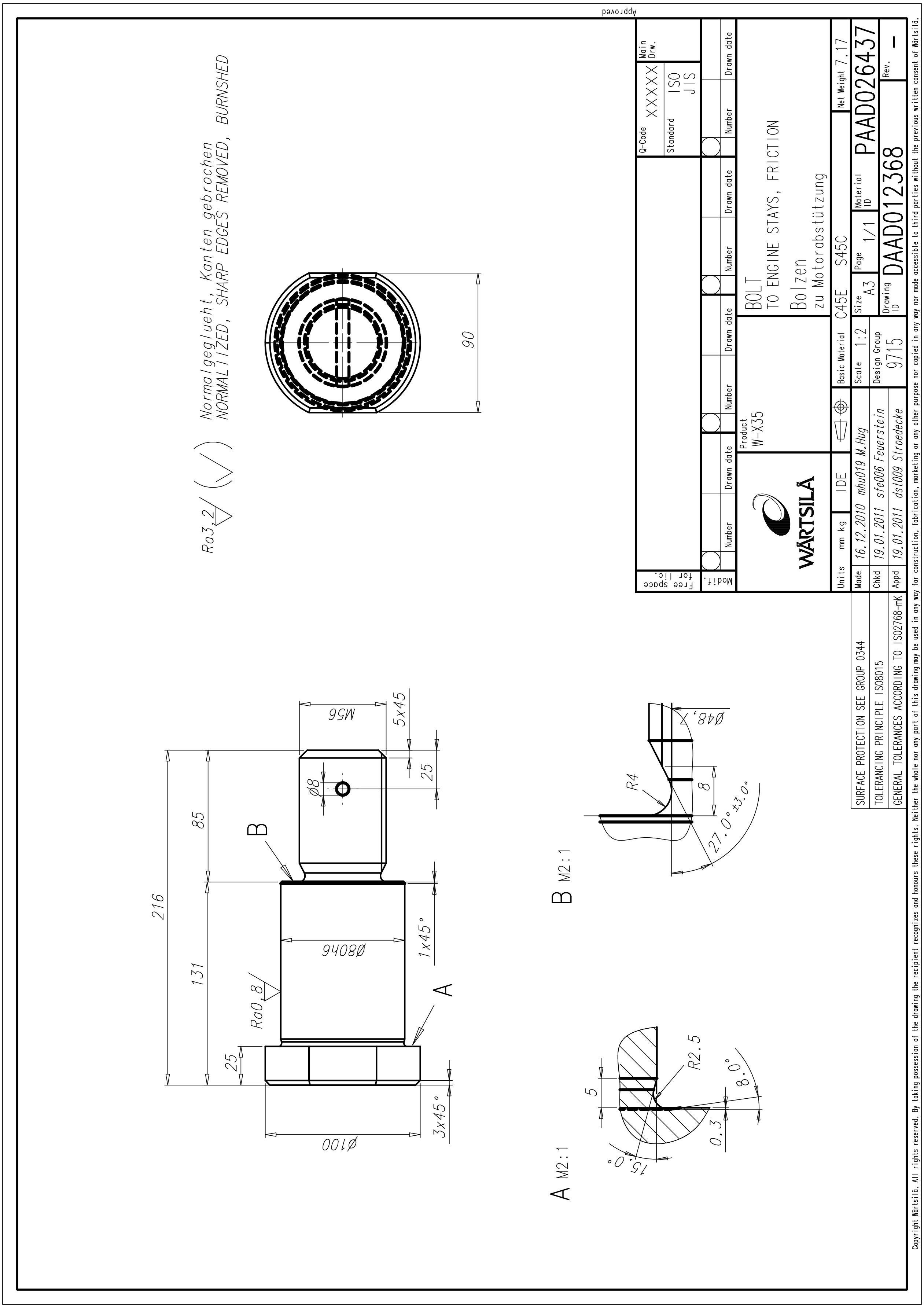
Product W-X40

ENGINE STAYS
FRICTION TYPE, FUEL PUMPE SIDE
Motorabstuetzung
mit Reibbelag, Pumpenseite

Units mm kg	IDE		Basic Material	Net Weight
SURFACE PROTECTION SEE GROUP 0344	Made 24.01.2012 sfe006 Feuerstein	Scale 1:100	Size A1	Page 1/1
TOLERANCING PRINCIPLE ISO8015	Chkd 30.01.2012 wwr001 Wroblewski	Design Group 9715	Material ID	
GENERAL TOLERANCES ACCORDING TO ISO2768-mK	Appd 30.01.2012 dst009 Stroedecke		Drawing ID DAAD024352	Rev. –


ENGINE STAYS/ FRICTION TYPE
Motorenabstuetzung mit Reibbelag
DAAD024355


SUPPORT
TO ENGINE STAYS, FRICTION
Support
zu Motorabstuetzung
Product
W-X35
Basic Material S235JRG2 SS400
Units mm kg
IDE
Scale 1:3
Size A3
Page 1/1
Net Weight 35.4
Material ID PAAD026295
Drawing ID DAAD012142
Design Group 9715
Rev. –
Made 17.12.2010 mhu019 M.Hug
Chkd 19.01.2011 sfe006 Feuerstein
Appd 19.01.2011 ds1009 Stroedecke
Q-Code XXXXX
Standard ISO JIS
Main Drw.
Number
Drawn date
Modif.
Free space for lic.
Approved
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
A-A
300
260
120
180
150
100
100
110
215
135
2
30.0°
Ø 80 H7 +0.03 0
41 +0.5 0
106 0 -1
Ra50 (Ra1,6 Ra6,3)
Ra1,6
Ra6,3



Ra3,2
Normalgeglueht, Kanten gebrochen
NORMALIZED, SHARP EDGES REMOVED, BURNSHED
90
M56
5x45
25
Ø8
85
216
131
B
Ø80f6
1x45°
Ra0,8
A
25
3x45°
Ø100
B M2:1
R4
Ø48,7
8
27,0°±3,0°
A M2:1
5
R2,5
8,0°
0,3
15,0°
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
Approved
Free space for lic.
Modif.
Number
Drawn date
Q-Code XXXXX
Main Drw.
Standard ISO JIS
WÄRTSILÄ
Product W-X35
BOLT
TO ENGINE STAYS, FRICTION
Bolzen
zu Motorabstützung
Units mm kg
IDE
Basic Material C45E S45C
Net Weight 7.17
Made 16.12.2010 mhu019 M.Hug
Scale 1:2
Size A3
Page 1/1
Material ID PAAD026437
Chkd 19.01.2011 sfe006 Feuerstein
Design Group 9715
Drawing ID DAAD012368
Rev. –
Appd 19.01.2011 dst009 Stroedecke
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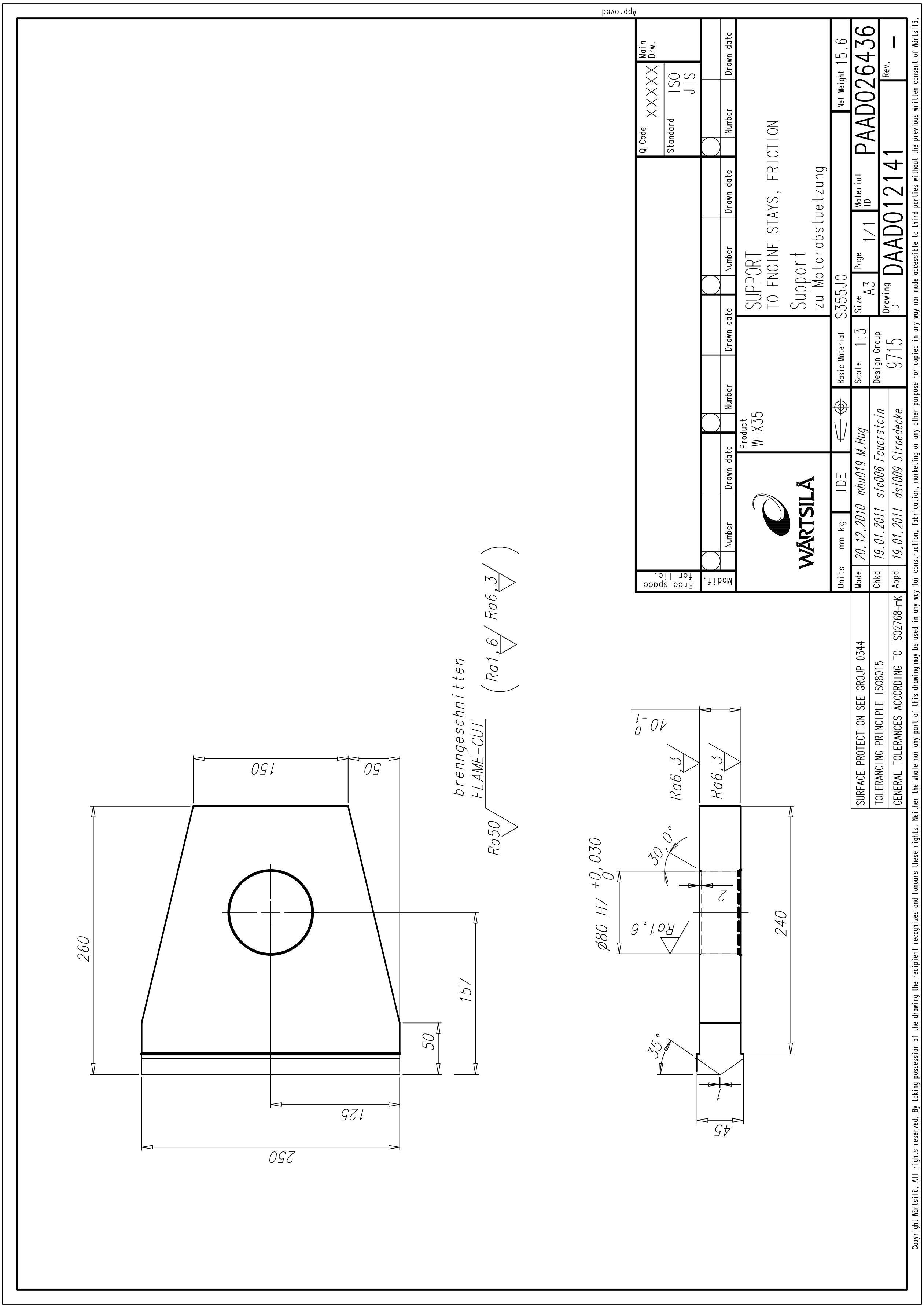
SUPPORT
TO ENGINE STAYS, FRICTION
Support
zu Motorabstuetzung
Product W-X35
Basic Material S355J0
Scale 1:3
Size A3
Page 1/1
Material ID PAAD026436
Drawing ID DAAD012141
Design Group 9715
Net Weight 15.6
Rev. –
Q-Code XXXXX
Standard ISO JIS
Units mm kg
IDE
Made 20.12.2010 mhu019 M.Hug
Chkd 19.01.2011 sfe006 Feuerstein
Appd 19.01.2011 ds1009 Stroedecke
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
brenngeschnitten
FLAME-CUT
Ra50
(Ra1,6 / Ra6,3)
Ø80 H7 +0,030 0
Ra1,6
Ra6,3
40 0 -1
30,0°
35°
260
150
50
157
125
250
240
45
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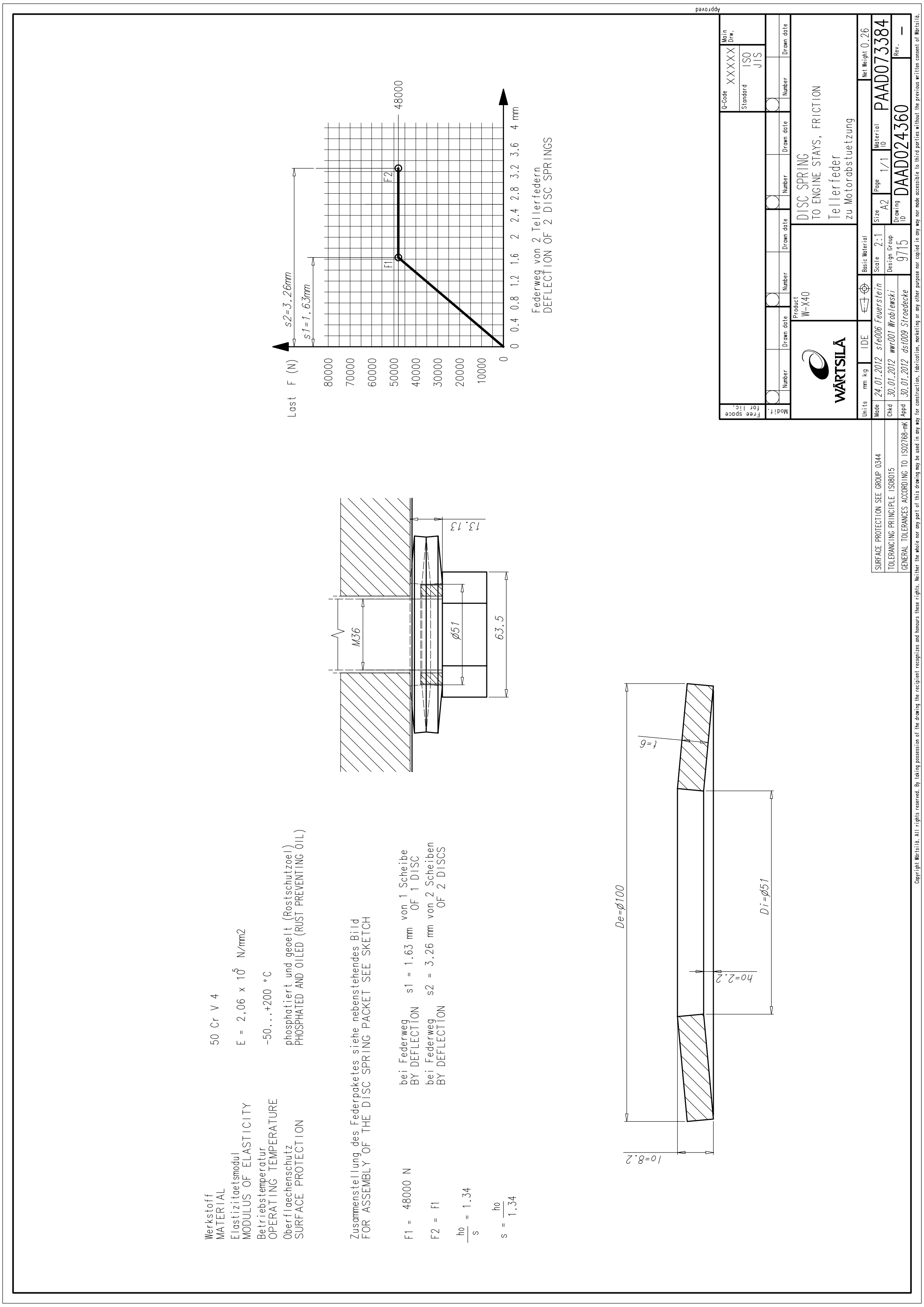
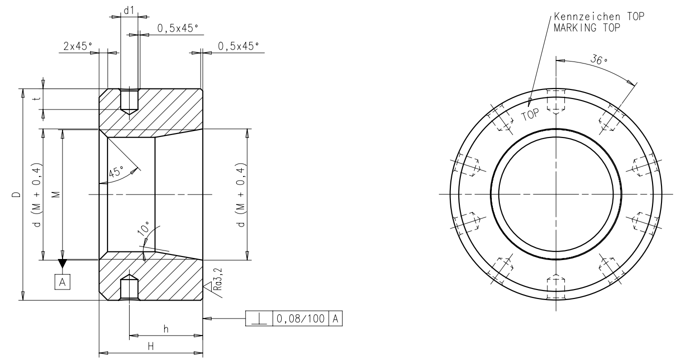

Werkstoff
MATERIAL
50 Cr V 4
Elastizitaetsmodul
MODULUS OF ELASTICITY
E = 2,06 x 10^5 N/mm2
Betriebstemperatur
OPERATING TEMPERATURE
-50...+200 °C
Oberflaechenschutz
SURFACE PROTECTION
phosphatiert und geoelt (Rostschutzoel)
PHOSPHATED AND OILED (RUST PREVENTING OIL)
Zusammenstellung des Federpaketes siehe nebenstehendes Bild
FOR ASSEMBLY OF THE DISC SPRING PACKET SEE SKETCH
F1 = 48000 N
bei Federweg
BY DEFLECTION
s1 = 1.63 mm
von 1 Scheibe
OF 1 DISC
F2 = F1
bei Federweg
BY DEFLECTION
s2 = 3.26 mm
von 2 Scheiben
OF 2 DISCS
ho/s = 1.34
s = ho/1.34
lo=8.2
De=Ø100
t=6
ho=2.2
Di=Ø51
M36
Ø51
63.5
13.13
Last F (N)
80000
70000
60000
50000
40000
30000
20000
10000
0
0 0.4 0.8 1.2 1.6 2 2.4 2.8 3.2 3.6 4 mm
48000
s2=3.26mm
s1=1.63mm
F1
F2
Federweg von 2 Tellerfedern
DEFLECTION OF 2 DISC SPRINGS
Approved
Main Drw.
Q-Code XXXXX
Standard ISO JIS
Modif.
Free space for lic.
Number
Drawn date
WÄRTSILÄ
Product
W-X40
DISC SPRING
TO ENGINE STAYS, FRICTION
Tellerfeder
zu Motorabstuetzung
Units mm kg
IDE
Basic Material
Net Weight 0.26
Made 24.01.2012 sfe006 Feuerstein
Chkd 30.01.2012 wwr001 Wroblewski
Appd 30.01.2012 dst009 Stroedecke
Scale 2:1
Size A2
Page 1/1
Material ID PAAD073384
Design Group 9715
Drawing ID DAAD024360
Rev. –
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK



POS.	M	D	d	H	h	d1	t
001	M27	44	27,4	22	15	$4^{+0.2}_{0}$	4,8
002	M30	49	30,4	24	17	$4^{+0.2}_{0}$	4,8
003	M33	54	33,4	26	18	$4^{+0.2}_{0}$	4,8
004	M36	59	36,4	29	20	$6^{+0.2}_{0}$	7,2
005	M39	64	39,4	31	22	$6^{+0.2}_{0}$	7,2
006	M42	68	42,4	34	24	$6^{+0.2}_{0}$	7,2
007	M45	73	45,4	36	25	$6^{+0.2}_{0}$	7,2
008	M48	78	48,4	38	27	$6^{+0.2}_{0}$	7,2
009	M52	85	52,4	42	29	$6^{+0.2}_{0}$	7,2
010	M56	91	56,4	45	31	$6^{+0.2}_{0}$	7,2
011	M60	98	60,4	48	34	$9,5^{+0.2}_{0}$	11,4
012	M64	104	64,4	51	36	$9,5^{+0.2}_{0}$	11,4
013	M68	111	68,4	54	38	$9,5^{+0.2}_{0}$	11,4
014	M72	117	72,4	58	40	$9,5^{+0.2}_{0}$	11,4
015	M76	124	76,4	61	43	$9,5^{+0.2}_{0}$	11,4
016	M80	130	80,4	64	45	$9,5^{+0.2}_{0}$	11,4
017	M85	139	85,4	68	48	$14^{+0.2}_{0}$	16,8
018	M90	147	90,4	72	50	$14^{+0.2}_{0}$	16,8
019	M95	155	95,4	76	53	$14^{+0.2}_{0}$	16,8
020	M100	163	100,4	80	56	$14^{+0.2}_{0}$	16,8

Ra6,3 (Ra3,2)

MATERIAL:	42CrMo4 (ISO) SCM440 (JIS)
D >40 - ≤100	verguetet Rm = 900-1100 N/mm² HEAT TREATED
D >100 - ≤160	verguetet Rm = 800-950 N/mm² HEAT TREATED
D >160 - ≤250	verguetet Rm = 750-900 N/mm² HEAT TREATED

QTY	SEQ NO	Material ID	Material Name	Dimension/Occ.Dimension	Standard or Drawing	Basic Material / Material Standard	Weight GR./NET
1	020	107.380.159.020	ROUND NUT	M100	107.380.159	42CrMo4 SCM 440	7,954
1	019	107.380.159.019	ROUND NUT	M95	107.380.159	42CrMo4 SCM 440	6,796
1	018	107.380.159.018	ROUND NUT	M90	107.380.159	42CrMo4 SCM 440	5,74
1	017	107.380.159.017	ROUND NUT	M85	107.380.159	42CrMo4 SCM 440	4,808
1	016	107.380.159.016	ROUND NUT	M80	107.380.159	42CrMo4 SCM 440	4,108
1	015	107.380.159.015	ROUND NUT	M76	107.380.159	42CrMo4 SCM 440	3,514
1	014	107.380.159.014	ROUND NUT	M72	107.380.159	42CrMo4 SCM 440	2,979
1	013	107.380.159.013	ROUND NUT	M68	107.380.159	42CrMo4 SCM 440	2,493
1	012	107.380.159.012	ROUND NUT	M64	107.380.159	42CrMo4 SCM 440	2,068
1	011	107.380.159.011	ROUND NUT	M60	107.380.159	42CrMo4 SCM 440	1,692
1	010	107.380.159.010	ROUND NUT	M56	107.380.159	42CrMo4 SCM 440	1,412
1	009	107.380.159.009	ROUND NUT	M52	107.380.159	42CrMo4 SCM 440	1,127
1	008	107.380.159.008	ROUND NUT	M48	107.380.159	42CrMo4 SCM 440	0,879
1	007	107.380.159.007	ROUND NUT	M45	107.380.159	42CrMo4 SCM 440	0,723
1	006	107.380.159.006	ROUND NUT	M42	107.380.159	42CrMo4 SCM 440	0,584
1	005	107.380.159.005	ROUND NUT	M39	107.380.159	42CrMo4 SCM 440	0,464
1	004	107.380.159.004	ROUND NUT	M36	107.380.159	42CrMo4 SCM 440	0,36
1	003	107.380.159.003	ROUND NUT	M33	107.380.159	42CrMo4 SCM 440	0,284
1	002	107.380.159.002	ROUND NUT	M30	107.380.159	42CrMo4 SCM 440	0,212
1	001	107.380.159.001	ROUND NUT	M27	107.380.159	42CrMo4 SCM 440	0,152

Q-Code XQXXX
Standard ISO JIS

Modif. A EAAD700213 24.11.2011 B EAAD700366 05.11.2012

Product W-2S

ROUND NUT

Rundmutter

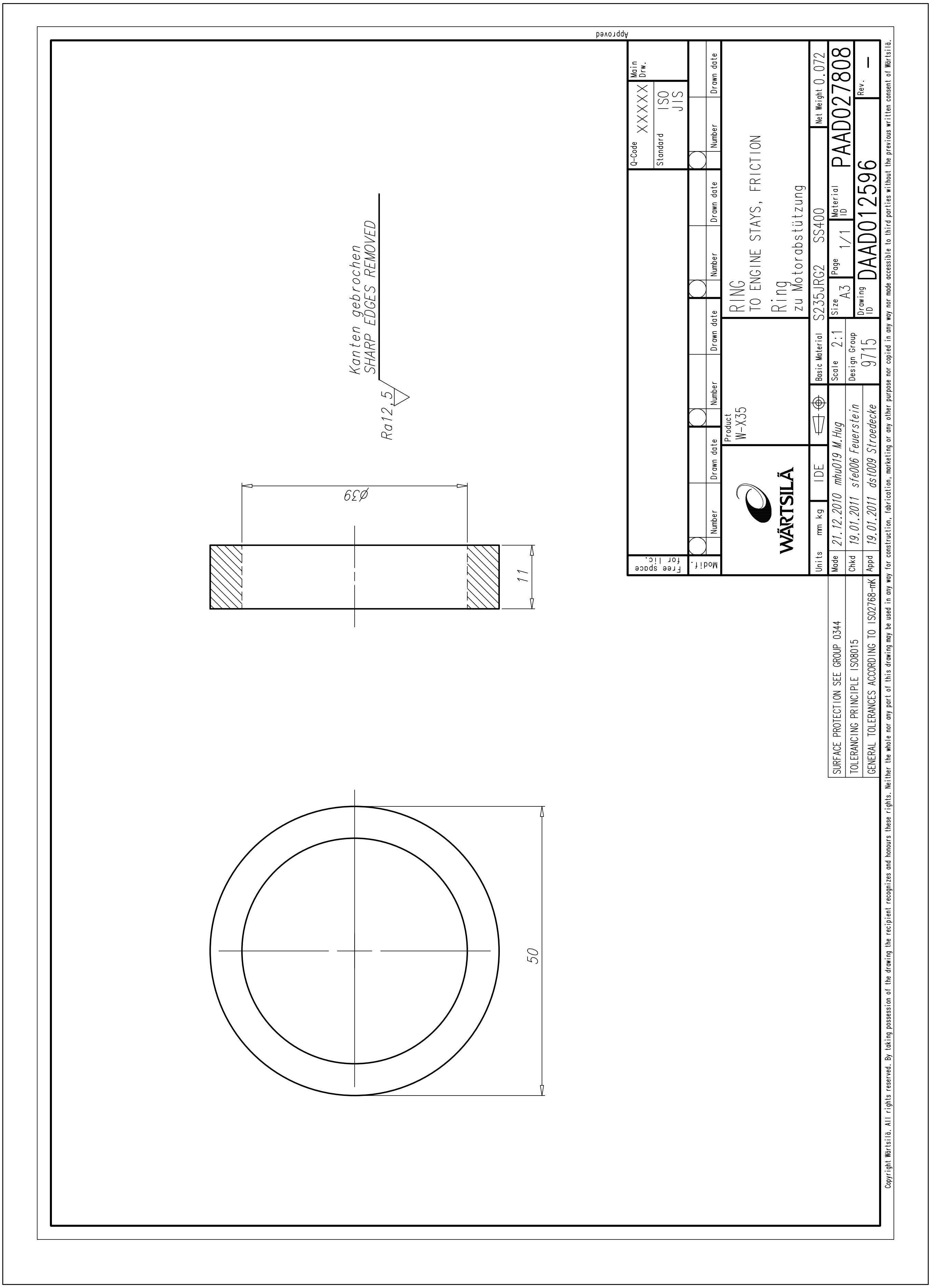
WÄRTSILÄ

Units mm kg IDE

Made 18.12.2006 J.RIETMANN — Scale 1:1 — Size A1 — Page 1/1

Appd 16.05.2007 esc002 Bohren — Design Group 3306 — Drawing ID 107.380.159 — Rev. B

SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK


Ø39
11
50
Ra12.5
Kanten gebrochen
SHARP EDGES REMOVED
Approved
Q-Code XXXXX
Main Drw.
Standard ISO JIS
Free space for lic.
Modif.
Number
Drawn date
Product W-X35
RING
TO ENGINE STAYS, FRICTION
Ring
zu Motorabstützung
Units mm kg
IDE
Basic Material S235JRG2 SS400
Net Weight 0.072
Made 21.12.2010 mhu019 M.Hug
Scale 2:1
Size A3
Page 1/1
Material ID PAAD027808
Chkd 19.01.2011 sfe006 Feuerstein
Design Group 9715
Drawing ID DAAD012596
Rev. –
Appd 19.01.2011 ds1009 Stroedecke
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
WÄRTSILÄ
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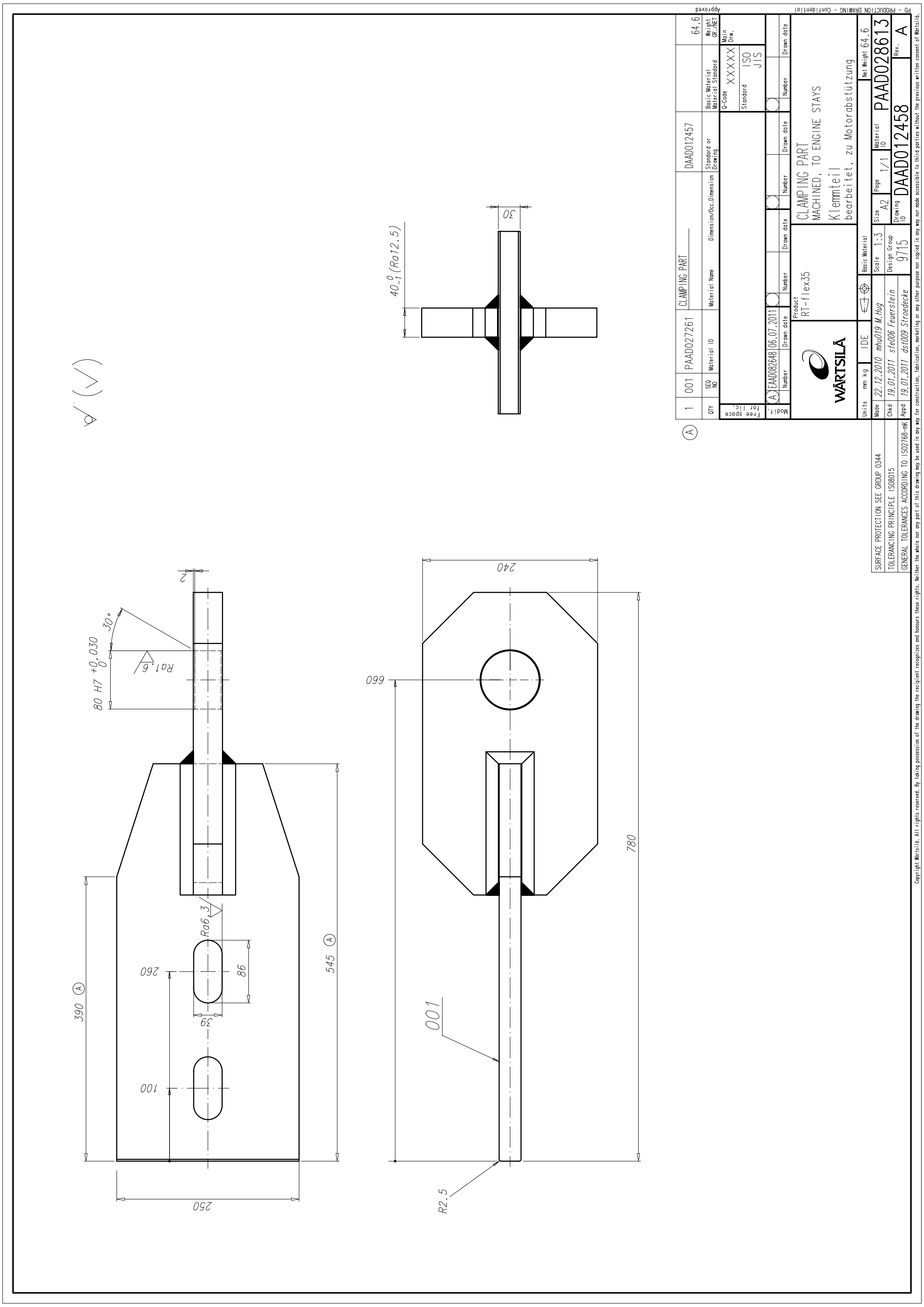
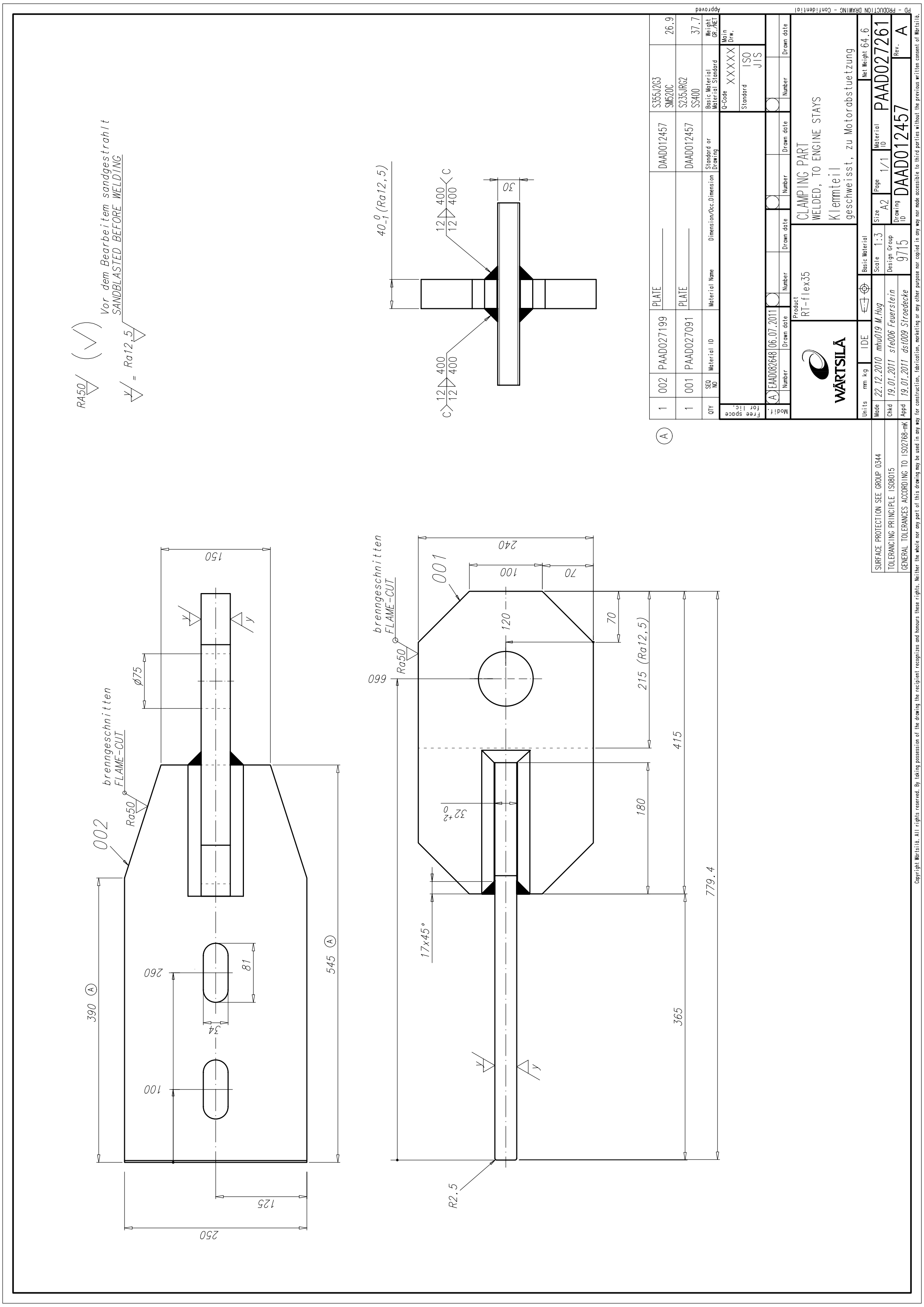
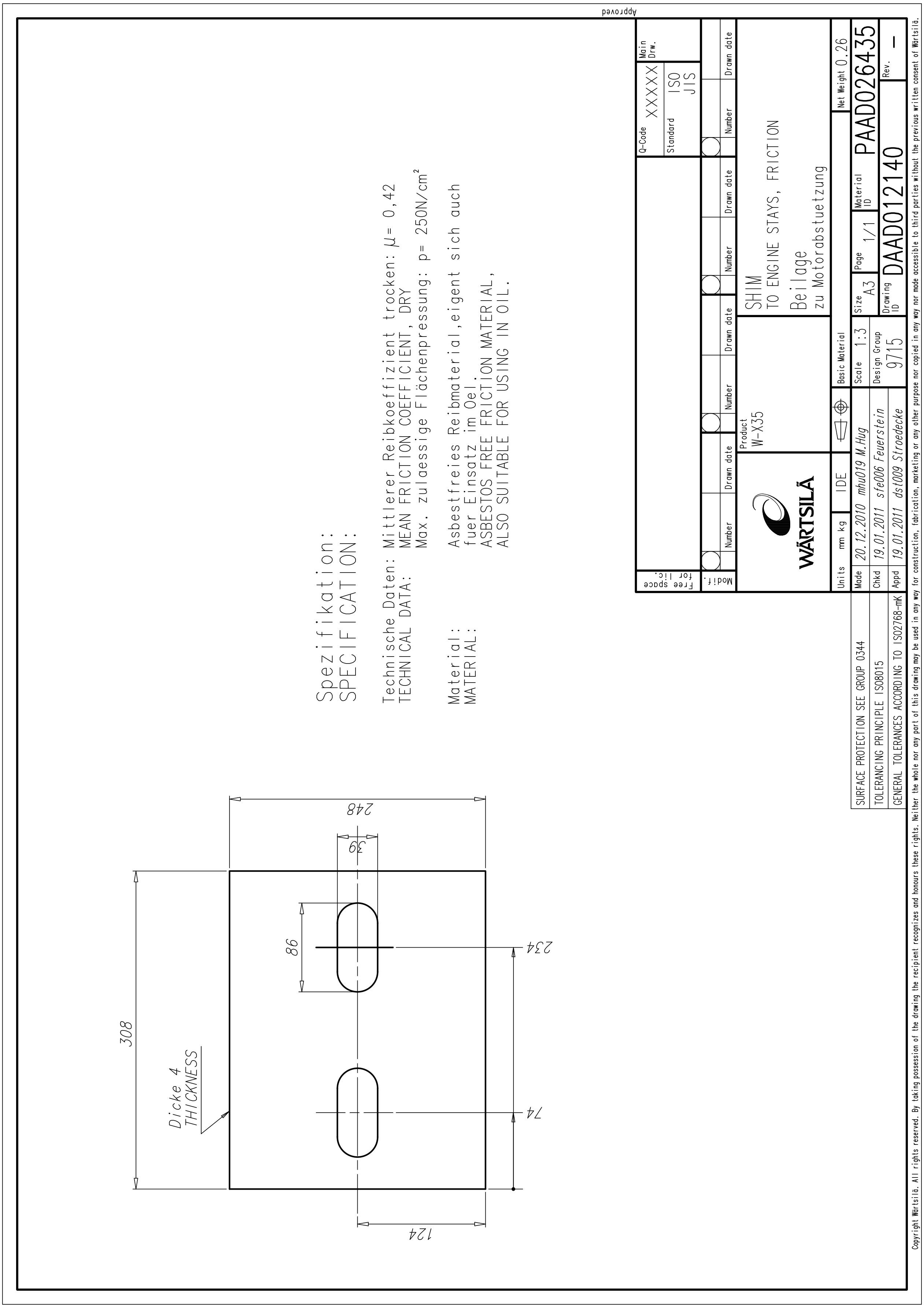

CLAMPING PART
MACHINED, TO ENGINE STAYS
Klemmteil
bearbeitet, zu Motorabstützung
RT-flex35
PAAD028613
DAAD012458
PAAD027261
DAAD012457
64.6
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
22.12.2010 mhu019 M.Hug
19.01.2011 sfe006 Feuerstein
19.01.2011 dsl009 Stroedecke
EAAD082648 06.07.2011
9715
1:3
A2
1/1
WÄRTSILÄ
PD - PRODUCTION DRAWING - Confidential
250
390
545
780
660
240
30
100
260
86
39
2
30°
80 H7
Ra1.6
Ra6.3
Ra12.5
R2.5
001


Vor dem Bearbeitem sandgestrahlt
SANDBLASTED BEFORE WELDING
brenngeschnitten
FLAME-CUT
PLATE
PAAD027199
PAAD027091
DAAD012457
S355J2G3
SM520C
S235JRG2
SS400
RT-flex35
CLAMPING PART
WELDED, TO ENGINE STAYS
Klemmteil
geschweisst, zu Motorabstuetzung
PAAD027261
DAAD012457
WÄRTSILÄ
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK


248
39
86
234
74
124
308
Dicke 4
THICKNESS
Spezifikation:
SPECIFICATION:
Technische Daten: Mittlerer Reibkoeffizient trocken: μ= 0,42
TECHNICAL DATA: MEAN FRICTION COEFFICIENT, DRY
Max. zulaessige Flächenpressung: p= 250N/cm²
Material: Asbestfreies Reibmaterial,eigent sich auch
fuer Einsatz im Oel.
MATERIAL: ASBESTOS FREE FRICTION MATERIAL,
ALSO SUITABLE FOR USING IN OIL.
Approved
Free space for lic.
Modif.
Number
Drawn date
Q-Code XXXXX
Main Drw.
Standard ISO JIS
WÄRTSILÄ
Product W-X35
SHIM
TO ENGINE STAYS, FRICTION
Beilage
zu Motorabstuetzung
Units mm kg
IDE
Basic Material
Net Weight 0.26
Made 20.12.2010 mhu019 M.Hug
Chkd 19.01.2011 sfe006 Feuerstein
Appd 19.01.2011 ds1009 Stroedecke
Scale 1:3
Size A3
Page 1/1
Material ID PAAD026435
Design Group 9715
Drawing ID DAAD012140
Rev. –
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
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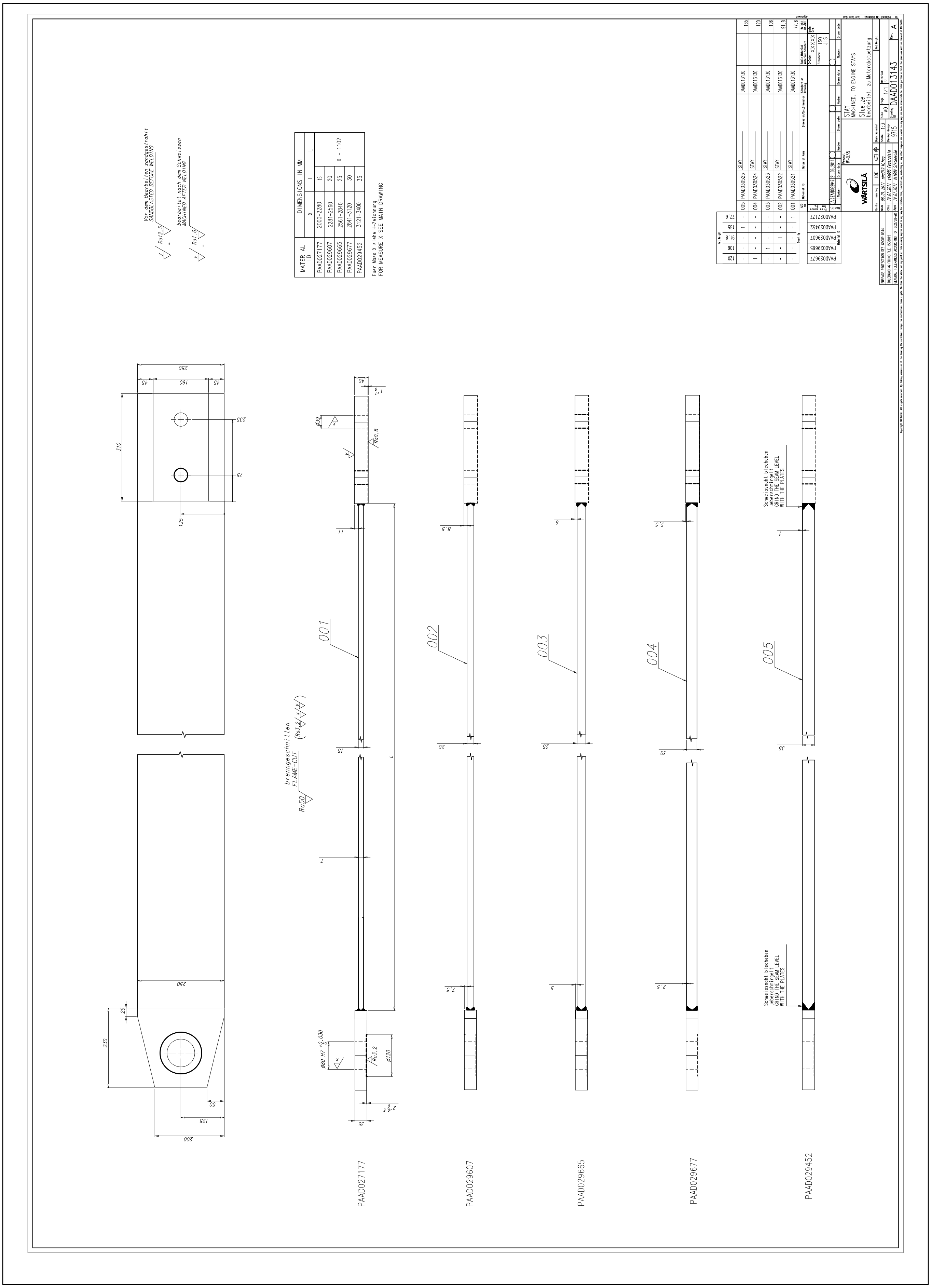
MATERIAL ID
DIMENSIONS IN MM
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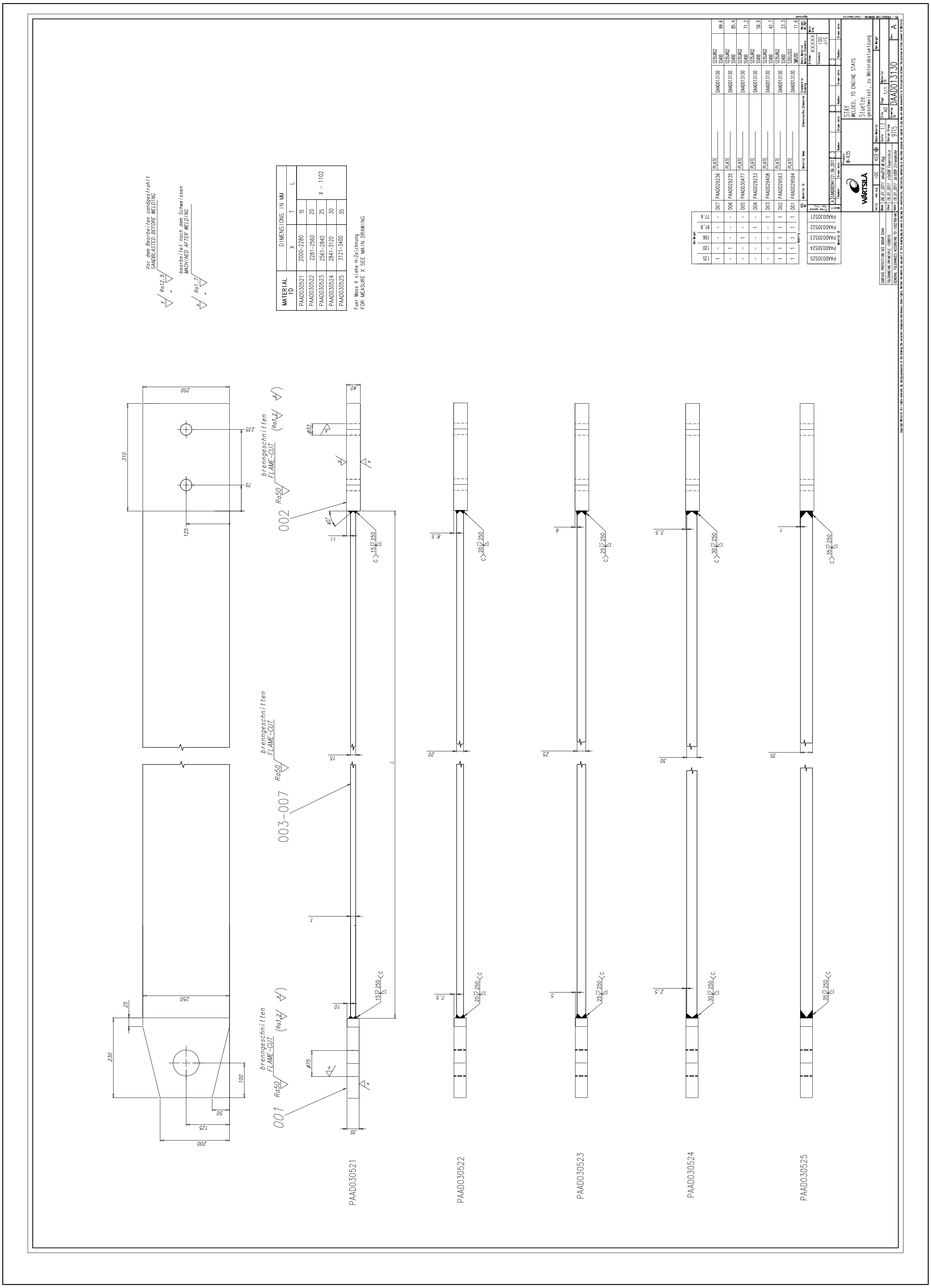
PAAD029607
PAAD029665
PAAD029677
PAAD029452
001
002
003
004
005
STAY
WÄRTSILÄ


MATERIAL ID
DIMENSIONS IN MM
X
T
L
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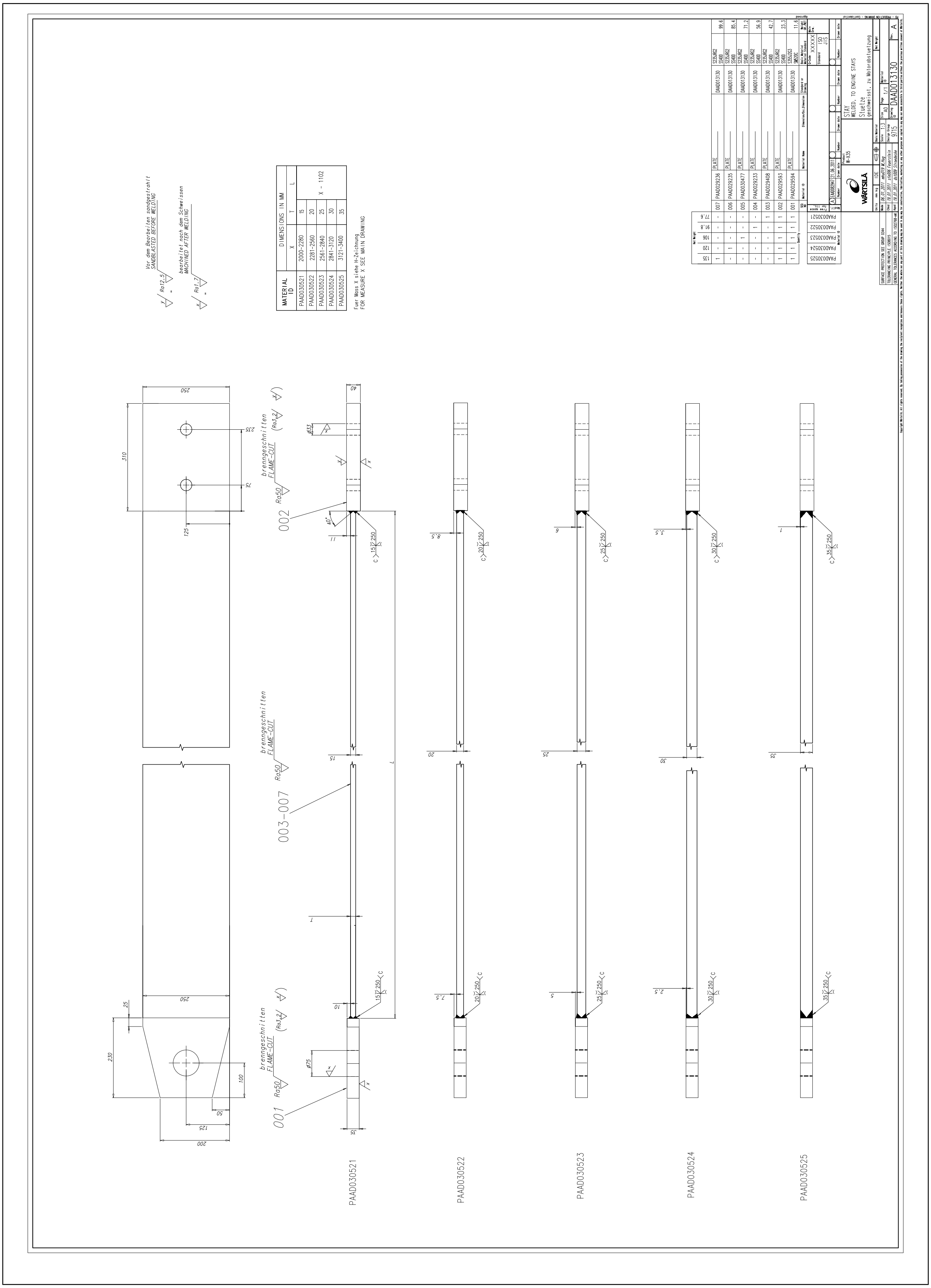
2000-2280
15
PAAD030522
2281-2560
20
PAAD030523
2561-2840
25
PAAD030524
2841-3120
30
PAAD030525
3121-3400
35
X - 1102
Fuer Mass X siehe H-Zeichnung
FOR MEASURE X SEE MAIN DRAWING
Vor dem Bearbeiten sandgestrahlt
SANDBLASTED BEFORE WELDING
bearbeitet nach dem Schweissen
MACHINED AFTER WELDING
brenngeschnitten
FLAME-CUT
001
002
003-007
PAAD030521
PAAD030522
PAAD030523
PAAD030524
PAAD030525
STAY
WELDED, TO ENGINE STAYS
DAAD013130



1 Introduction

Lateral and longitudinal stays are installed where countermeasures against dynamic effects are necessary (for indications refer to Marine Installation Manual, chapter Engine Dynamics). For stay arrangement and details refer also to the relevant installation drawings of the corresponding design group 9715.
It is vital that the stays are fitted correctly to ensure proper operation and to prolong the lifetime of the components.

2 Description and function

The stays are fitted between the engine and the ship hull. They transmit lateral, respectively longitudinal forces, from the engine via friction shims and sheet metal girders to the ship hull. The clamping force of the two clamping bolts is adjusted in such a way that during engine operation the engine's pulsating forces are transmitted to the ship hull. During loading and unloading, the stay is able to adapt the deformations of the ship's hull within its stroke.
To reduce material stress in the stay itself and also in the attachment points, hinge pins are provided in the supports to allow movements in both vertical and longitudinal directions.

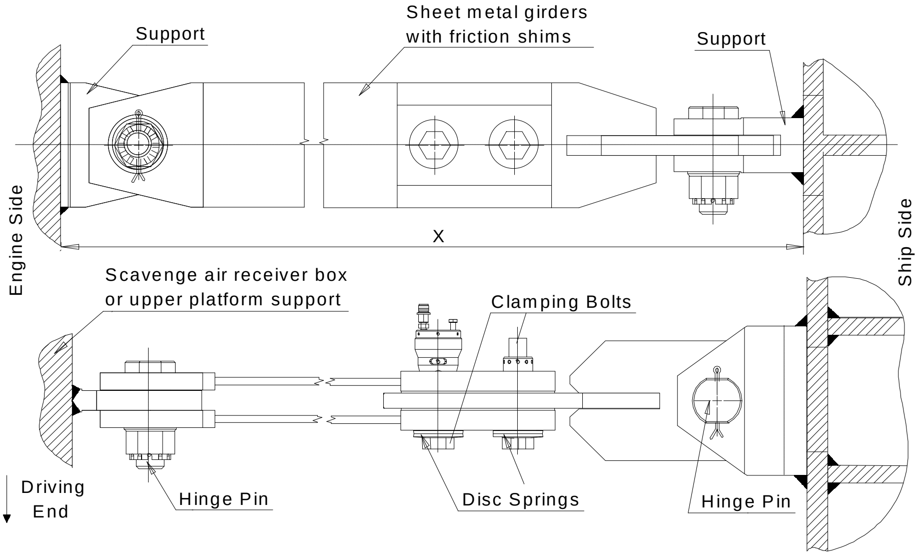


Figure 1: Principal stay arrangement

Substitute for:												PC	Q-Code X X X X X
Modif	B	EAAD067959	19.11.2008	C	EAAD082173	04.08.2010	D	EAAD082947	13.05.2011	E	EAAD083505	16.12.2011	
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date	

WÄRTSILÄ	Product RTMOT		**Assembly Instruction** for engine stays, friction type		
Made	27.01.1998 T.Landert	Main Drw.	Page 1 / 8	Material ID **107.246.429**	
Chkd	W.Wroblewski	Design Group	Drawing ID **107.246.429**		Rev
Appd	D.Strödecke	**9715**			**E**

T_PC-Drawing_portrait | Author: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.2 (06.09.2010)

For lateral application the stays are fixed on the engine's exhaust side or fuel side, according to the arrangement shown on the main drawing of design group 9715.
For longitudinal application the stays are fixed on engine's free end.
Examples of stay arrangements are provided in figure 2, figure 3 and figure 4.
Which stay arrangement is applicable depends on the engine type and is specified by the corresponding drawing of design group 9715.
As the design of the clamping bolts is similar to that applied for the engine holding down studs, the same hydraulic tool (design group 9411-06) can be used for pre-tensioning.

Lateral arrangement with attachment on scavenge air receiver box

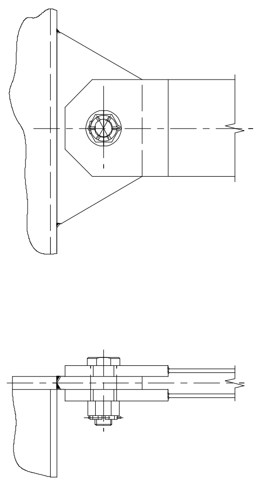


Figure 2

Lateral arrangement with attachment on platform support

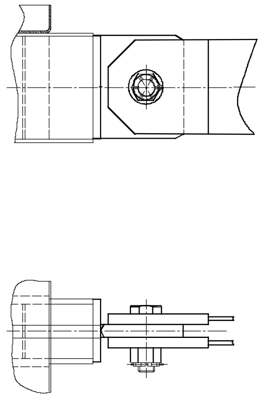


Figure 3

Longitudinal arrangement with attachment on platform support

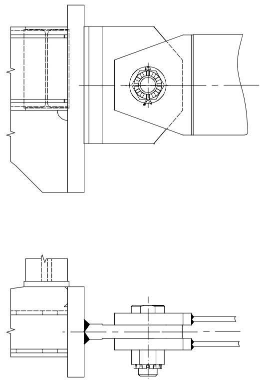


Figure 4

3 Fitting of the stays

3.1 Starting conditions

Before fitting the stays, the following conditions must be fulfilled:

- Ship afloat
- Engine aligned and chocked
- Engine coupled to intermediate shaft
- Engine holding down studs fully tightened
- Side stoppers fitted
- Engine preheated to starting condition
- Relevant installation drawings available

Substitute for:											
Modif	B	EAAD067959	19.11.2008	C	EAAD082173	04.08.2010	D	EAAD082947	13.05.2011	E	EAAD083505	16.12.2011
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date

PC | Q-Code | X | X | X | X | X

WÄRTSILÄ

Product: **RTMOT**

Assembly Instruction
for engine stays, friction type

Made	27.01.1998	T.Landert	Main Drw.	Page 2 / 8
Chkd		W.Wroblewski	Design Group	Material ID **107.246.429**
Appd		D.Strödecke	**9715**	Drawing ID **107.246.429** — Rev **E**

T_PC-Drawing_portrait | Author: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.2 (06.09.2010)

- The attachment points of the stays on engine and ship hull side are marked in the final position according to the relevant main drawing of design group 9715
- Hydraulic tensioning device is ready for use (engine builder's tool kit, code-No. 94145)

Note:

When fitting the stays it is very important that the engine is preheated to starting condition. This is necessary to reduce any possible misalignment of the stay due to engine thermal expansion between fitting and service condition. Excessive horizontal and vertical misalignment of the stay between the engine's and the ship's attachment points may restrict the stay's function. It may even lead to buckling or cracking of the stay. For admissible tolerances refer to table 2. During positioning and fitting use a crane to avoid overstress to the stay.

3.2 Installation steps

1. Prepare all parts and installation tools.
2. Make sure that all starting conditions according to section 3.1 are fulfilled.
3. Assemble the stay according to the relevant assembly drawing of design group 9715 and tighten the clamping bolts slightly by hand.
4. Shift the stay until the nominal position (defined by the distance M in table 1) is achieved. Then tighten the clamping bolts with 100 bar pressure.
5. Check at the marked attachment points on ship hull and engine side that there is no platform support, piping or something else which could collide with the stay. In particular pay attention to the space requirements of the hydraulic tensioning device in order to allow proper tightening of the clamping bolts.
6. Put the stay in the final position between ship hull and engine and align the stay's support without fixing on engine side. Check whether the stay is longer, shorter or equal in relation to the clear width between engine and ship hull.
   - In case the stay is **longer** than the clear width between ship hull and engine, measure its overall length X. Then measure the clear width between ship hull and engine and calculate the difference to the overall stay length X. If the difference exceeds the maximum allowed value limited by the tolerances in table 1, the support on the engine side has to be shortened and the edges must be prepared for welding.
   - In case the stay is **shorter** than the clear width between ship hull and engine, measure the gap between stay end and ship hull directly.

     If the gap exceeds the maximum allowed value limited by the tolerances in table 1, a steel plate has to be added as spacer under the support to compensate the undersize.

Substitute for:												PC	Q-Code	X	X	X	X	X
Modif	B	EAAD067959	19.11.2008	C	EAAD082173	04.08.2010	D	EAAD082947	13.05.2011	E	EAAD083505	16.12.2011						
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date						

WÄRTSILÄ	Product RTMOT	Assembly Instruction for engine stays, friction type	
Made 27.01.1998	T.Landert	Main Drw.	Page 3 / 8 — Material ID 107.246.429
Chkd	W.Wroblewski	Design Group	Drawing ID 107.246.429
Appd	D.Strödecke	9715	Rev E

T_PC-Drawing_portrait | Author: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.2 (06.09.2010)

- In case stay's length is **equal** to the clear width between ship hull and engine, no modifications are necessary.

Note:

During loading, the ship's hull tends to deform towards the ship's centre line, respectively to engine side. Therefore it is suggested to fit a stay of a length just correct or rather 'too short' than with overlength, in order to allow an extra stroke in longitudinal direction (see table 1).

7. Make sure that the surfaces of the receiver box/platform support and the ship side attachment points are clean.
8. Attach the stay on engine side in the final position and fix the support by spot welding.
9. Align the stay horizontally and vertically (observe the tolerances given in table 2) and fix the support on ship hull side by spot welding.
10. Before accomplishing the final welding, loosen the clamping bolts in order to avoid material stress due to thermal expansion.
11. Perform final welding at the supports on engine and ship hull side.
12. After all parts have cooled down, tighten the clamping bolts with the final pressure according to table 4.
13. Measure the height of each pre-tensioned disc spring pack and check with the relevant assembly drawing of design group 9715 whether the height is according to Wärtsilä´s specifications.

    If the height deviates from the given value the following need to be checked:

- Was the correct tensioning device used for tensioning the clamping bolts?
    - In case a too small tensioning devise was used, re-tighten the clamping bolts with the correct devise and given pressure.
    - In case a too big tensioning devise was used, calculate whether the maximum permissible yield strength of the clamping bolts, nuts, friction shims and disc springs was already exceeded and the elements need to be replaced due to damage by plastic deformation. Even if the calculation result indicates that the maximum permissible yield strength was not exceeded, make finally a visual check to ensure that no element was damaged due to the wrong tensioning.
- Were the clamping bolts, nuts, friction shims and disc springs correctly assembled according to the relevant assembly drawing?
    - In case one or more elements were wrong assembled, re-arrange those accordingly.

Substitute for:											PC	Q-Code	X	X	X	X	X
Modif	B	EAAD067959	19.11.2008	C	EAAD082173	04.08.2010	D	EAAD082947	13.05.2011	E	EAAD083505	16.12.2011					
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date					

WÄRTSILÄ	Product: RTMOT	Assembly Instruction for engine stays, friction type	
Made: 27.01.1998 T.Landert	Main Drw.	Page: 4 / 8	Material ID: 107.246.429
Chkd: W.Wroblewski	Design Group: 9715	Drawing ID: 107.246.429	Rev: E
Appd: D.Strödecke			

T_PC-Drawing_portrait | Author: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.2 (06.09.2010)

- Are the material and dimensions of all elements in compliance with Wärtsilä´s specifications?
  - In case the material or dimensions of one or more elements are not according to Wärtsilä´s specifications replace those accordingly.

Substitute for:												PC	Q-Code	X	X	X	X	X
Modif	B	EAAD067959	19.11.2008	C	EAAD082173	04.08.2010	D	EAAD082947	13.05.2011	E	EAAD083505	16.12.2011						
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date						

WÄRTSILÄ	Product RTMOT		Assembly Instruction for engine stays, friction type		
Made	27.01.1998 T.Landert	Main Drw.	Page 5 / 8	Material ID 107.246.429	
Chkd	W.Wroblewski	Design Group 9715	Drawing ID 107.246.429		Rev E
Appd	D.Strödecke				

T_PC-Drawing_portrait | Author: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.2 (06.09.2010)

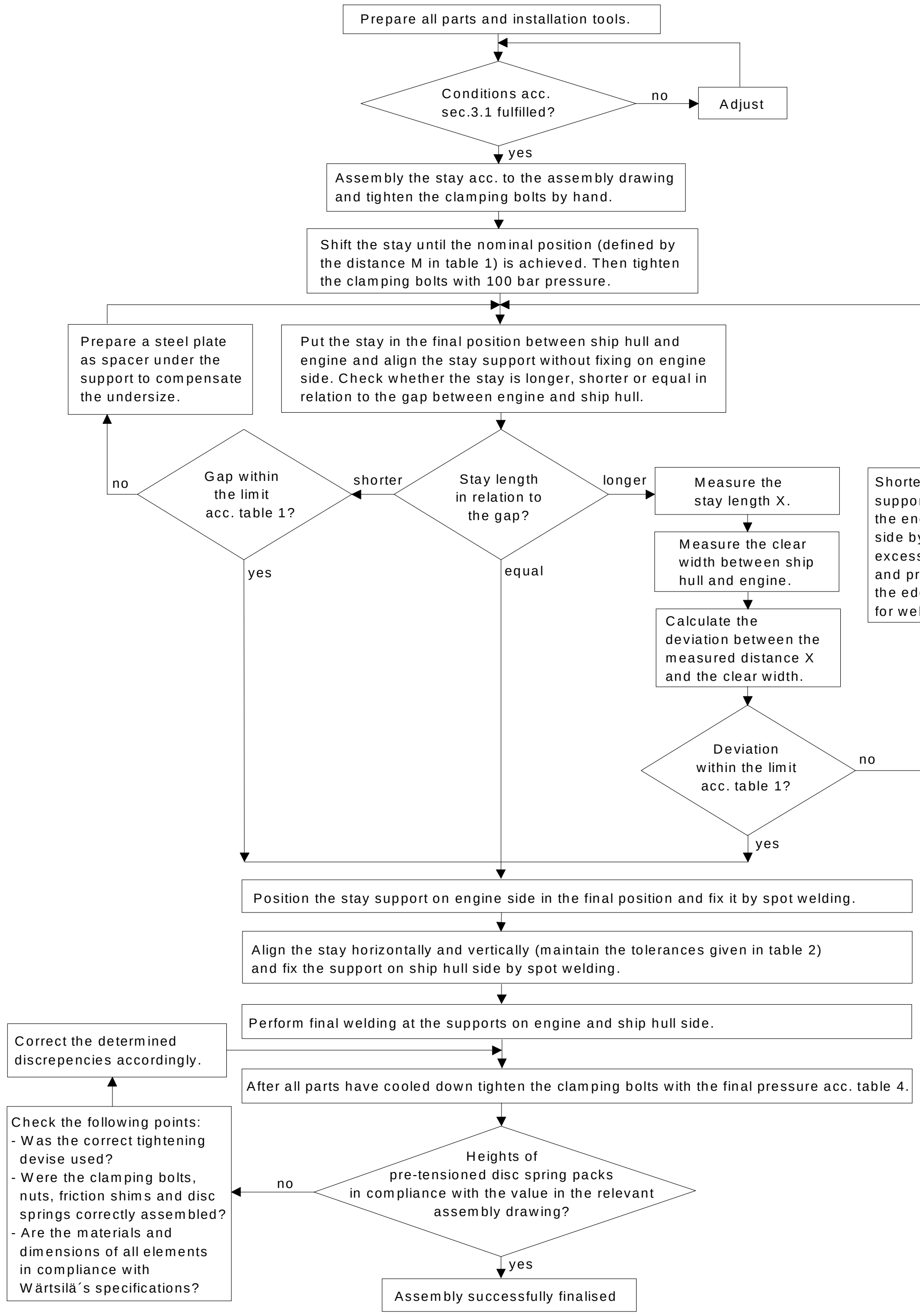


Figure 5: Stay installation process diagram

Substitute for:											PC / Q-Code X X X X X
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		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		Number / Drawn Date

WÄRTSILÄ	Product: **RTMOT**	**Assembly Instruction** for engine stays, friction type	
Made: 27.01.1998 T.Landert	Main Drw.	Page: 6 / 8	Material ID: **107.246.429**
Chkd: W.Wroblewski	Design Group: **9715**	Drawing ID: **107.246.429**	Rev: **E**
Appd: D.Strödecke			

T_PC-Drawing_portrait | Author: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.2 (06.09.2010)

14.

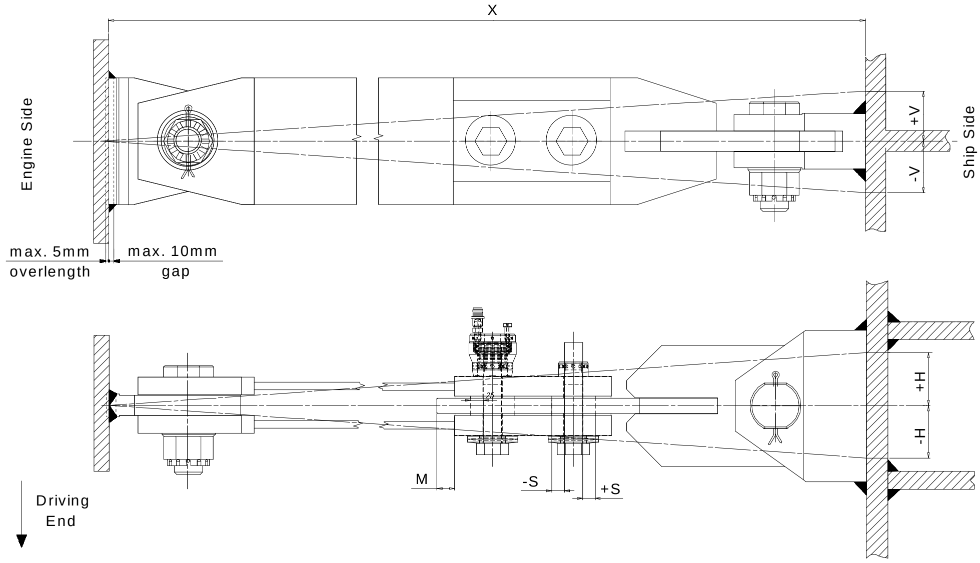


Figure 6

	Deviation of stay length **X** related to clear width	Reference **M**	Resulting stroke **-S**	**+S**
Nominal position	**0**	**25**	**24.5**	**24.5**
Stay too long (max. over length)	+5	30	29.5	19.5
Stay too short (max. gap)	-10	15	14.5	34.5

Table 1 : Admissible deviation of stay length when commissioning (in mm)

Clear width	Lateral application				Longitudinal application			
X	**+V**	**-V**	**+H**	**-H**	**+V**	**-V**	**+H**	**-H**
2000 to 2280	2	0	1.5	0	2	0	1.5	1.5
2281 to 2560	2	0	2	0	2	0	2	2
2561 to 3120	4	0	3	0	4	0	3	3
3121 to 3400	4	0	4	0	4	0	4	4

Table 2 : Admissible vertical and horizontal deviation (in mm)

Substitute for:											
Modif	B	EAAD067959	19.11.2008	C	EAAD082173	04.08.2010	D	EAAD082947	13.05.2011	E	EAAD083505 / 16.12.2011
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		Number / Drawn Date

PC | Q-Code | X | X | X | X | X

WÄRTSILÄ

Product: **RTMOT**

Assembly Instruction
for engine stays, friction type

Made	27.01.1998 T.Landert	Main Drw.	Page 7 / 8	Material ID **107.246.429**
Chkd	W.Wroblewski	Design Group	Drawing ID **107.246.429**	Rev **E**
Appd	D.Strödecke	**9715**		

T_PC-Drawing_portrait | Author: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.2 (06.09.2010)

4 Operational check and final adjustment

4.1 During sea trial

During service check whether relative movements between the ship side attachment device and the sheet metal girders occur. If this is the case, the following might be the cause:

- Insufficient or incorrect tightening of the clamping bolts
- Dirty or damaged friction shims
- Material or quality of friction shims is not according to WCH specification
- Incorrect assembly of the stays
- Incorrect fitting or alignment, i.e. welding

4.2 After sea trial

After sea trial, when the engine and machinery space are still in hot condition, check whether measure ‘M’ remained within the limits given in table 3 and check also whether the stays are still in line with the engine (horizontally and vertically). If not, it may help to loosen the clamping bolts. The sheet metal girders can then move within the clearance of the through holes of the ship side attachment device. Undesirable tension in the stay can release and possible misalignment may be compensated.
At a later stage, when the vessel has been loaded and unloaded, check whether a displacement between engine and ship hull has taken place to make sure the stays work properly. Check also whether measure ‘M’ remained within the limits given in table 4. If this is not the case, refer to the possible causes listed under 4.1
For maintenance repeat the above mentioned checks i.e. check the pretension of the bolts at intervals as scheduled for the maintenance of the engine holding down studs.

	Reference M (mm)	Loaded state
absolute minimum	2	ballast condition
absolute maximum	48	fully loaded

Table 3 : Admissible values for ‘M’ in service

Engine type	Hydr. pressure for lateral and longitudinal application (bar)
W-X35	230
W-X40	250
RT-flex48T-D	180
RT-flex50-B/-D	310
RT-flex58-D V2	150
RTA/RT-flex68-D	120
RTA/RT-flex82C/T	170
RTA/RT-flex84T-D	150
RTA/RT-flex96C-B	200

Table 4 : Pre-tensioning pressure

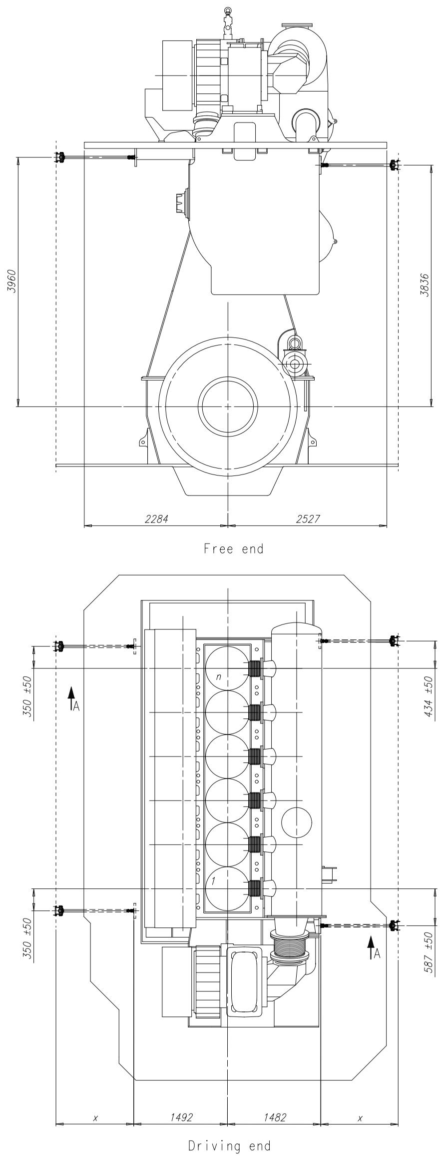
Substitute for:											
Modif	B	EAAD067959	19.11.2008	C	EAAD082173	04.08.2010	D	EAAD082947	13.05.2011	E	EAAD083505	16.12.2011
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date

PC | Q-Code | X | X | X | X | X

WÄRTSILÄ

Product: RTMOT	Assembly Instruction for engine stays, friction type	
Made: 27.01.1998 T.Landert	Main Drw.	Page 8 / 8	Material ID 107.246.429
Chkd: W.Wroblewski	Design Group 9715	Drawing ID 107.246.429	Rev E
Appd: D.Strödecke			

T_PC-Drawing_portrait | Author: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.2 (06.09.2010)



Requirements for ship side attachment point

Max. force acting on ship's hull	$F_{max.}$	(kN)	200
Minimum stiffness	$k_{min.}$	(N/m)	0.5 x 10^9
Permissible deflection per 100 kN	$Def_{max.}$	(mm)	0.2

Material ID	L (mm)	ø E (mm)	
PAAD061850	up to 1500	60	With integrated bladders accumulator
PAAD061851	1501 to 2200	75	
PAAD061852	2201 to 2800	90	
PAAD061853	up to 1500	60	With external bladders accumulator
PAAD061854	1501 to 2200	75	
PAAD061855	2201 to 2800	90	

Lateral rocking

No. of Cyls. n	5	6	7	8
Lateral stays	A	B	B	A

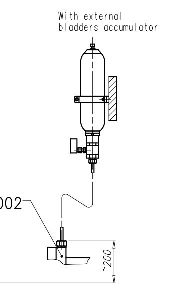
Remarks:

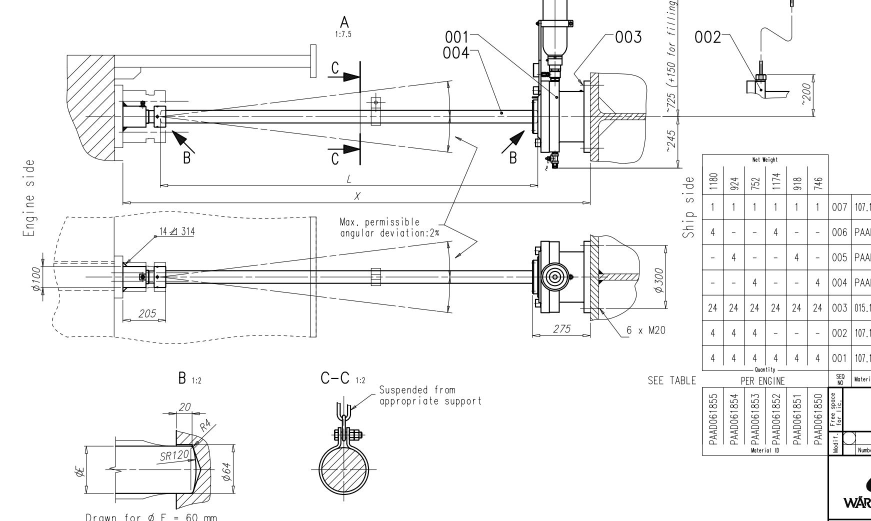
A: The countermeasure indicated is needed.
B: The countermeasure indicated mabey needed and provision for the corresponding countermeasure is recommended.

X defines the clear width between engine attachment points on engine and ship side

X TO BE DETERMINED BY SHIPYARD

When determining $X_{min.}$ and L observe: $X_{min.}$ = 1260mm, L = X - 430mm





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4	-	-	4	-	-	006	PAAD005758	ROUND BAR	2201 to 2800	DAAD006100	C45E S45C	140
-	4	-	-	4	-	005	PAAD005756	ROUND BAR	1501 to 2200	DAAD006100	C45E S45C	76.0
-	-	4	-	-	4	004	PAAD005752	ROUND BAR	up to 1500	DAAD006100	C45E S45C	33.0
24	24	24	24	24	24	003	015.151.044.641	HEXAGON HEAD SCREW	M20x170		8.8 8.8	0.422
4	4	4	-	-	-	002	107.165.800.201	HYDRAULIC CYLINDER		107.165.800		1.47
4	4	4	4	4	4	001	107.165.800.200	HYDRAULIC CYLINDER		107.165.800		151
PAAD061855	PAAD061854	PAAD061853	PAAD061852	PAAD061851	PAAD061850							

SEE TABLE — Quantity PER ENGINE — Material ID

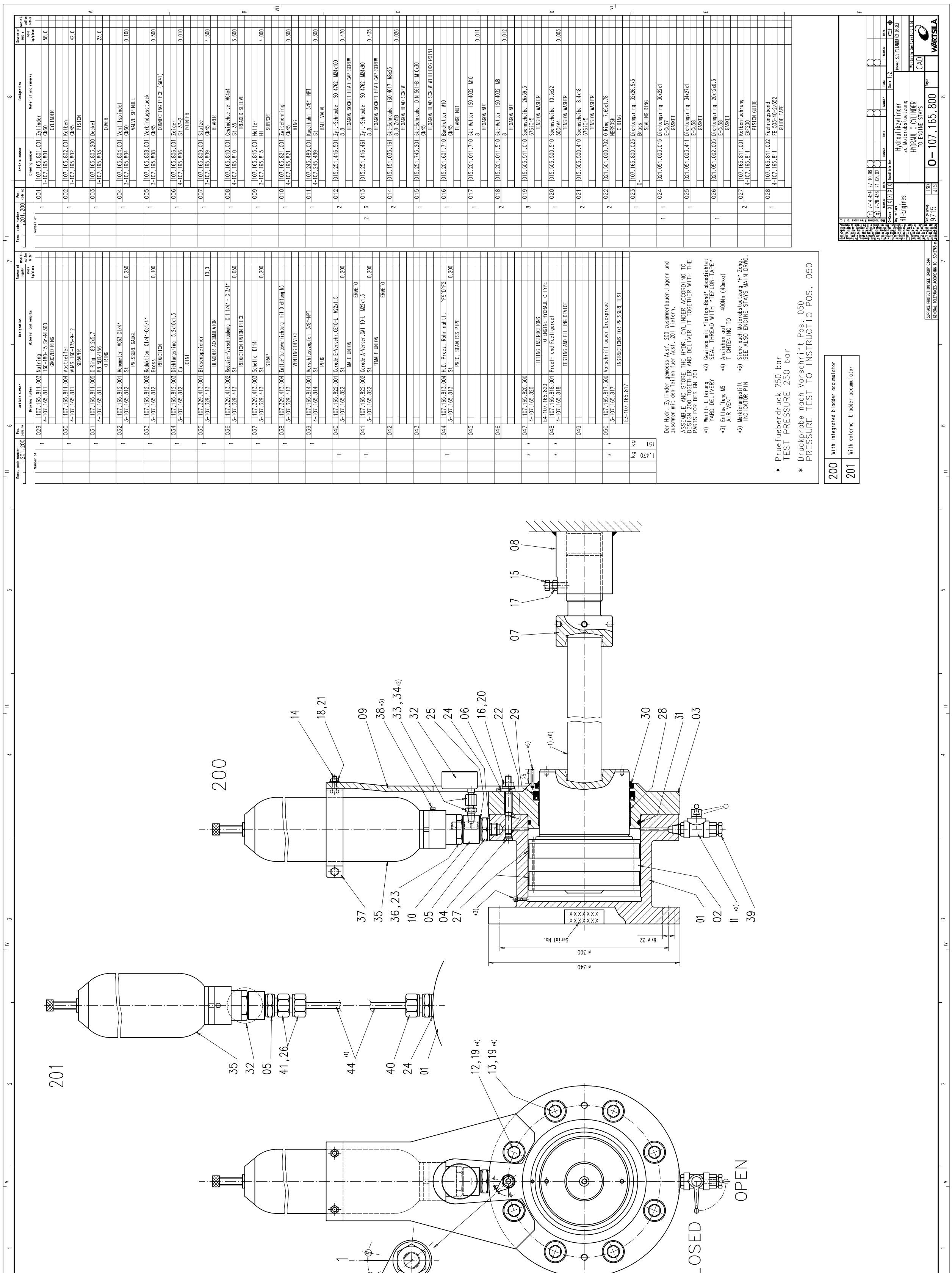
Free space for lic. | Q-Code XXXXX | Standard ISO JIS | Main Drw. H

Modif. | Number | Drawn date | Number | Drawn date | Number | Drawn date | Number | Drawn date

WÄRTSILÄ | Product W5-8X40 | ENGINE STAYS HYDRAULIC TYPE | Motorabstuetzung hydraulische Ausführung

Units mm kg	IDE		Basic Material	Net Weight
SURFACE PROTECTION SEE GROUP 0344	Made 01.11.2011 sfe006 Feuerstein	Scale 1:100	Size A1	Page 1/1
TOLERANCING PRINCIPLE ISO8015	Chkd 03.11.2011 wwr001 Wroblewski	Design Group 9715	Material ID	
GENERAL TOLERANCES ACCORDING TO ISO2768-mK	Appd 03.11.2011 dst009 Stroedecke		Drawing ID DAAD020880	Rev. –

Approved
DID - DIMENSIONAL DRAWING - Confidential



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OPEN
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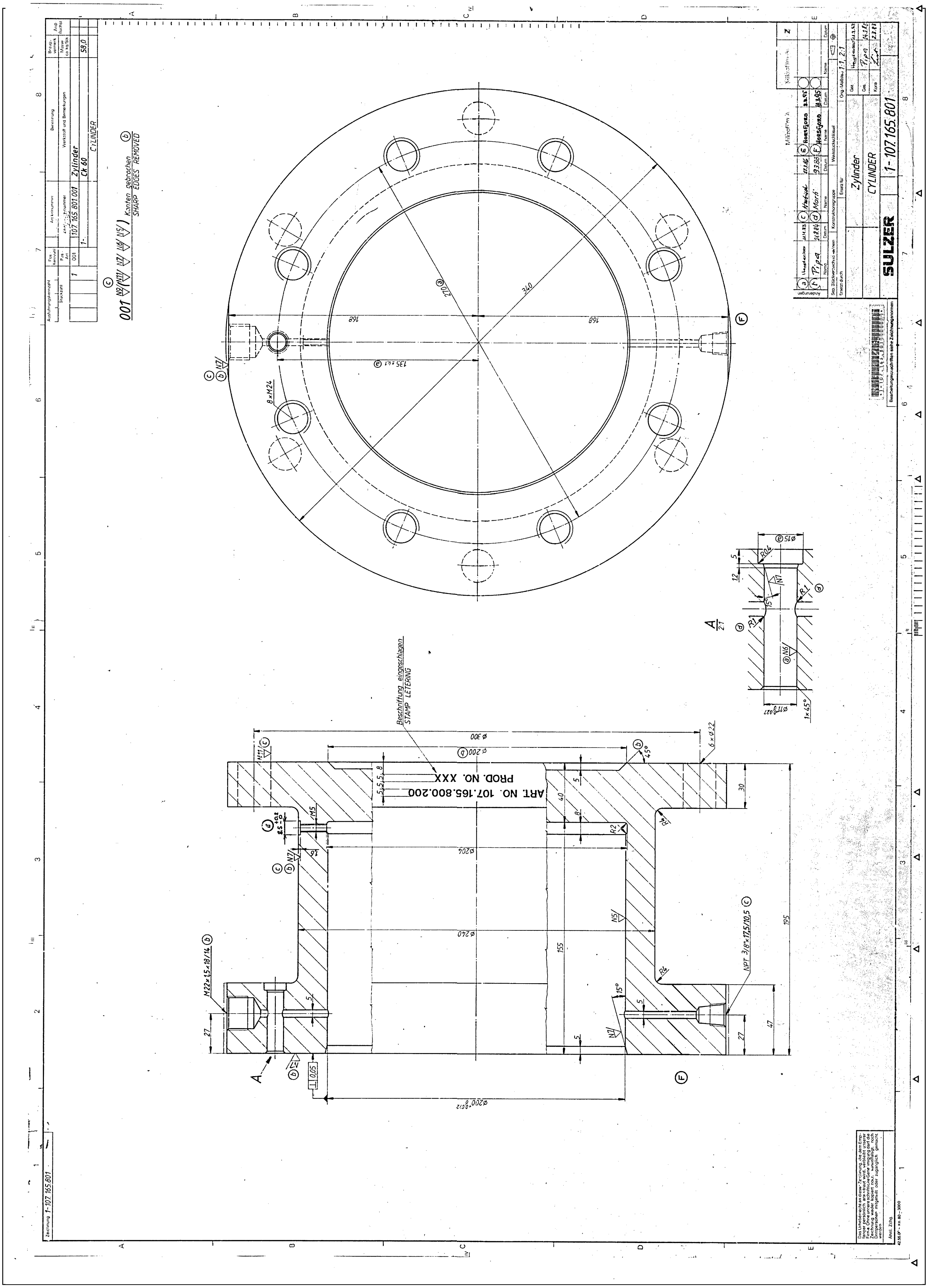
200 With integrated bladder accumulator
201 With external bladder accumulator
HYDRAULIC CYLINDER
TO ENGINE STAYS
O-107.165.800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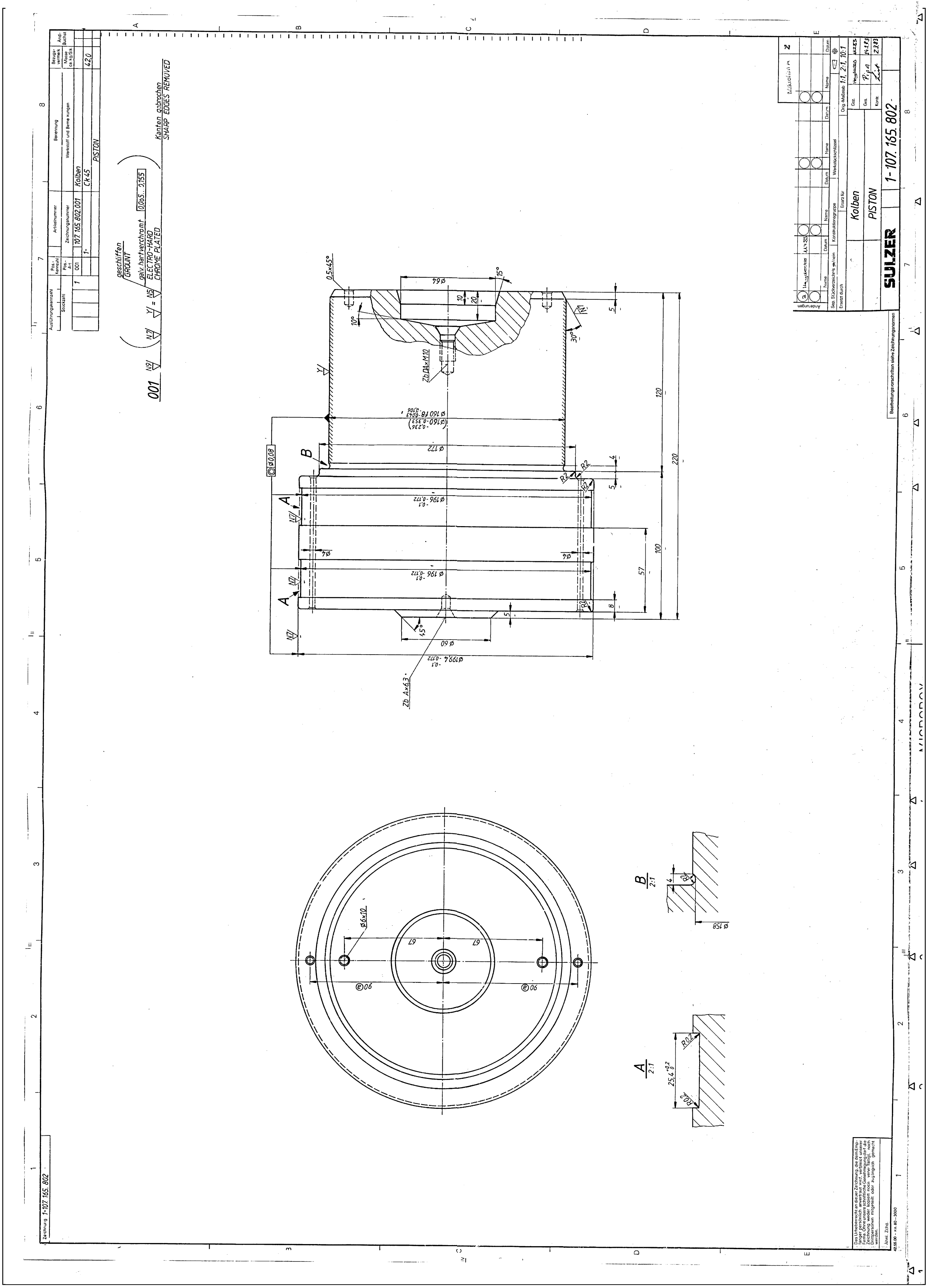
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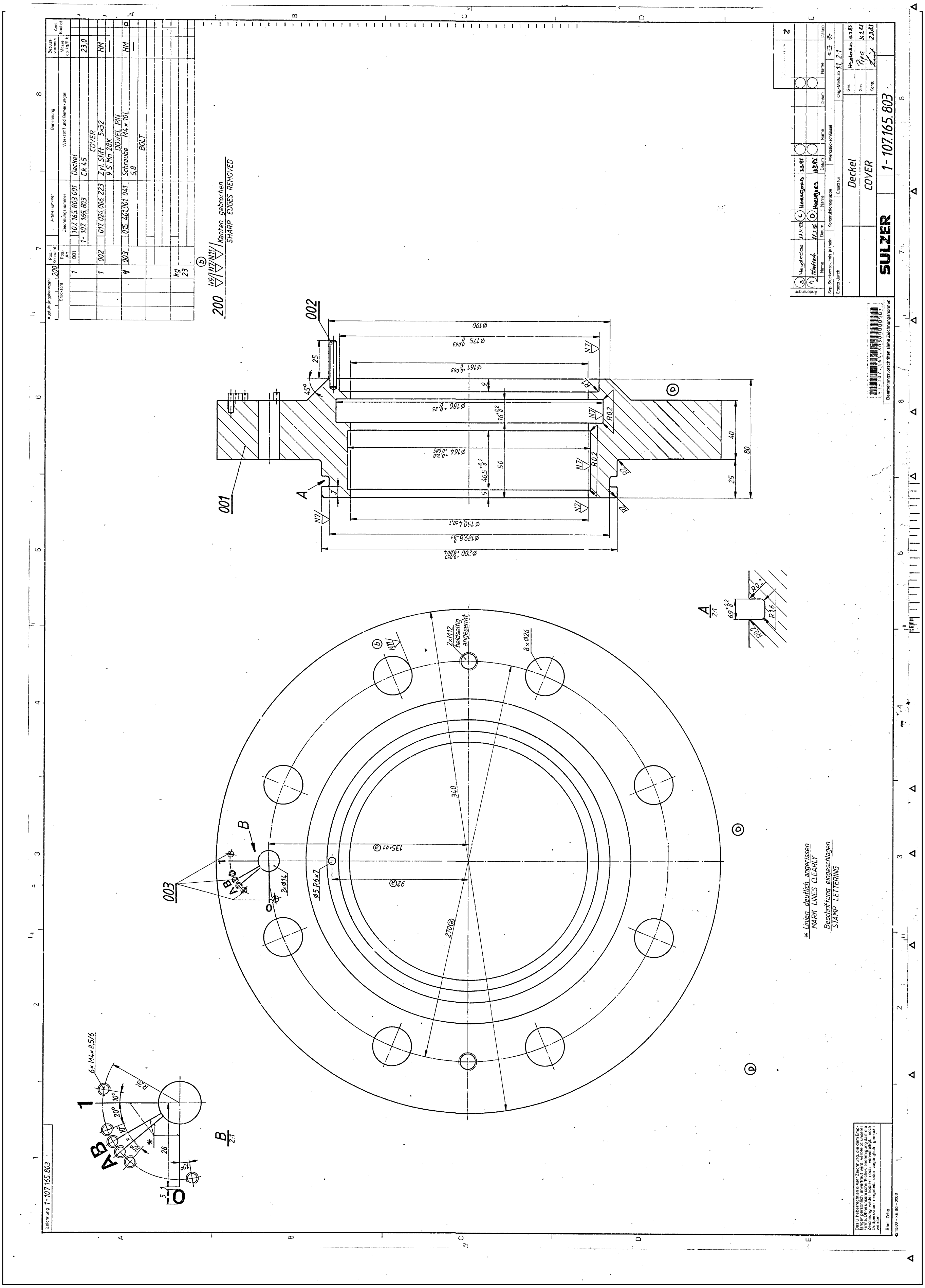
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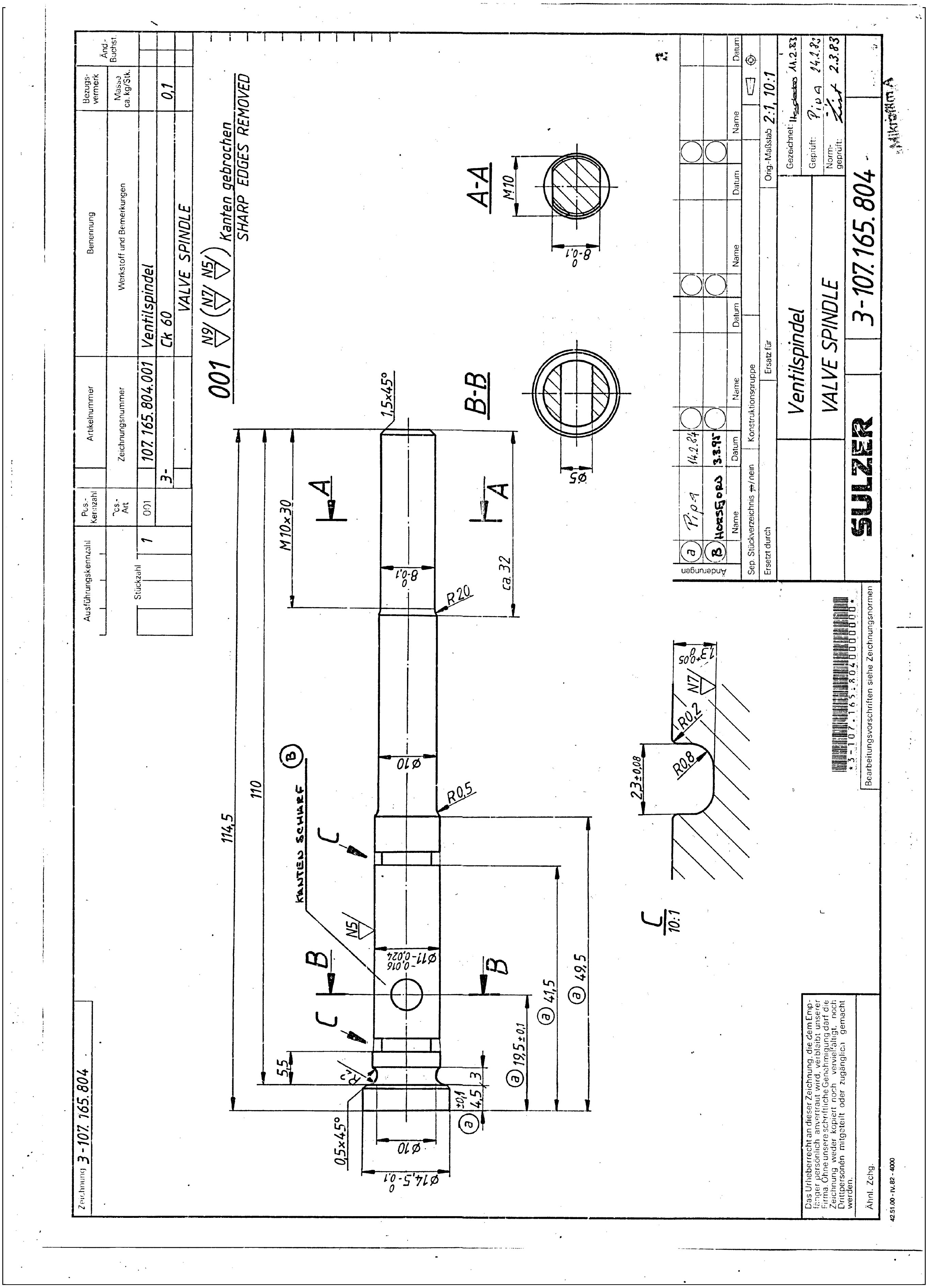
SULZER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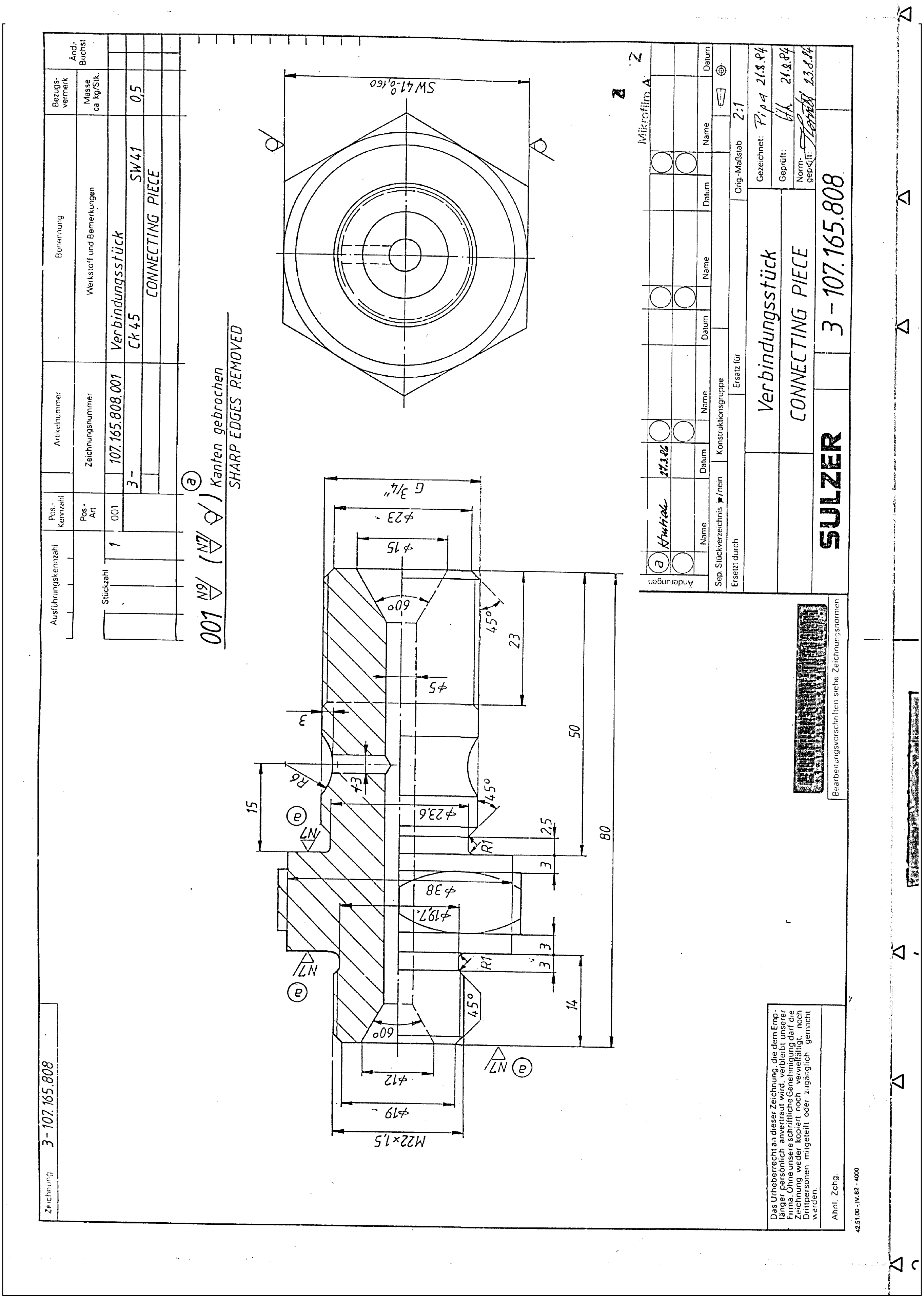
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Das Urheberrecht an dieser Zeichnung, die dem Empfänger persönlich anvertraut wird, verbleibt unserer Firma. Ohne unsere schriftliche Genehmigung darf die Zeichnung weder kopiert noch vervielfältigt, noch Drittpersonen mitgeteilt oder zugänglich gemacht werden.

Ausf.-Kennzahl / Stückzahl	Pos. Kennz. / Pos. Art	Artikelnummer / Zeichnungsnummer	Benennung / Werkstoff und Bemerkungen	Bezugsvermerk / Masse ca. kg/Stk.	Änd. Buchst.
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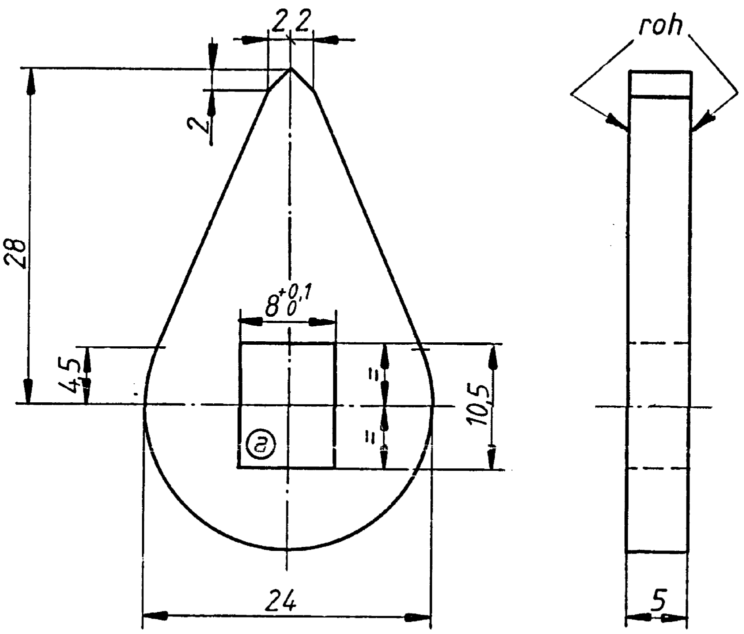

Bearbeitungsvorschriften siehe Zeichnungsnormen

Ähnl. Zchg.

Zeichnung 4-107.165.806

Änderungen											
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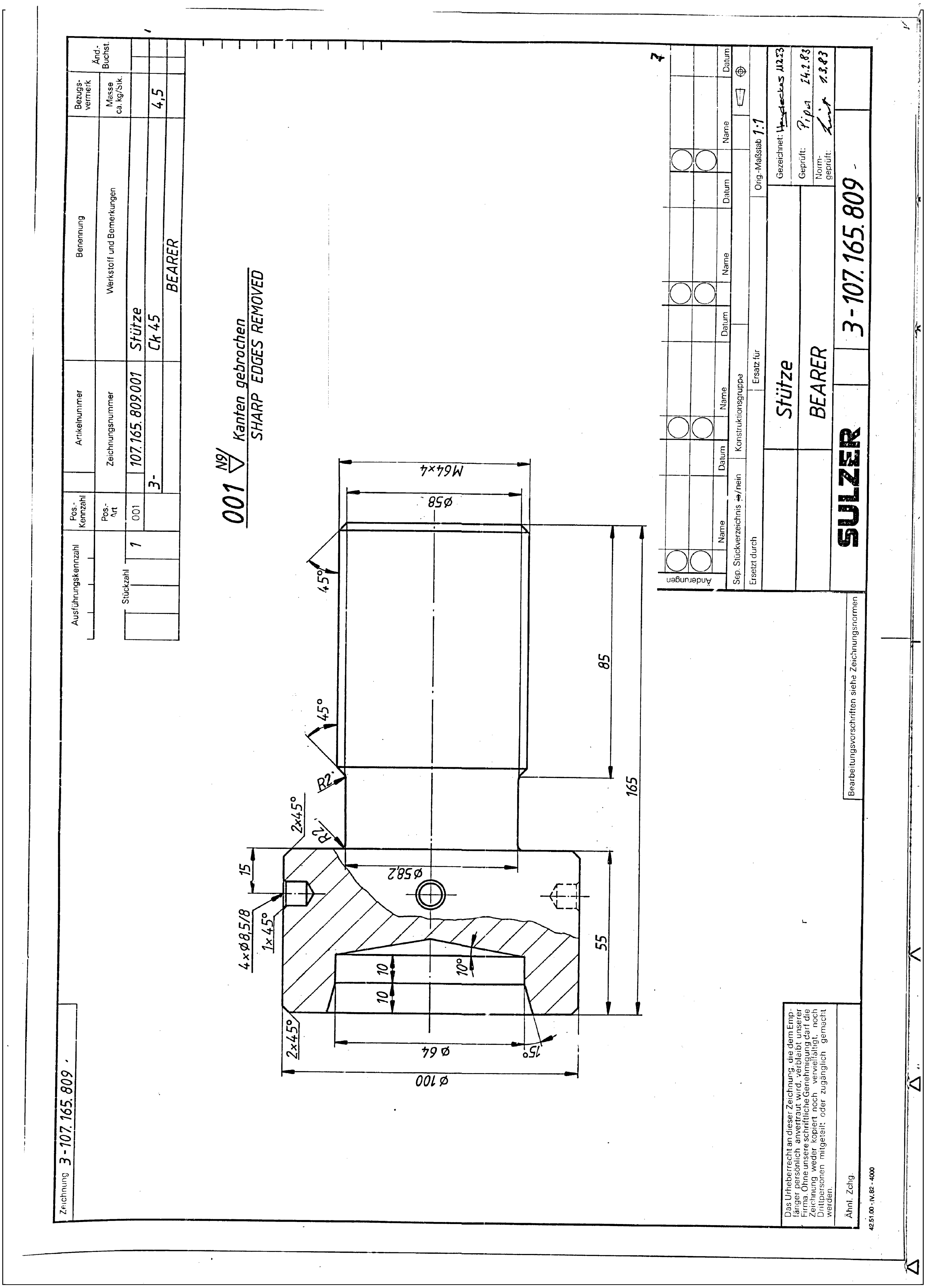
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BEARER
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Zeichnung 3-107.165.809
Bearbeitungsvorschriften siehe Zeichnungsnormen

SURFACE PROTECTION SEE GROUP 0344

GENERAL TOLERANCES ACCORDING TO ISO/2768-m

Exec. code no / Number of	Pos. code no		Article number / Drawing number	Designation / Material and remarks	Source of supply / mass kg/piece	Modification letter
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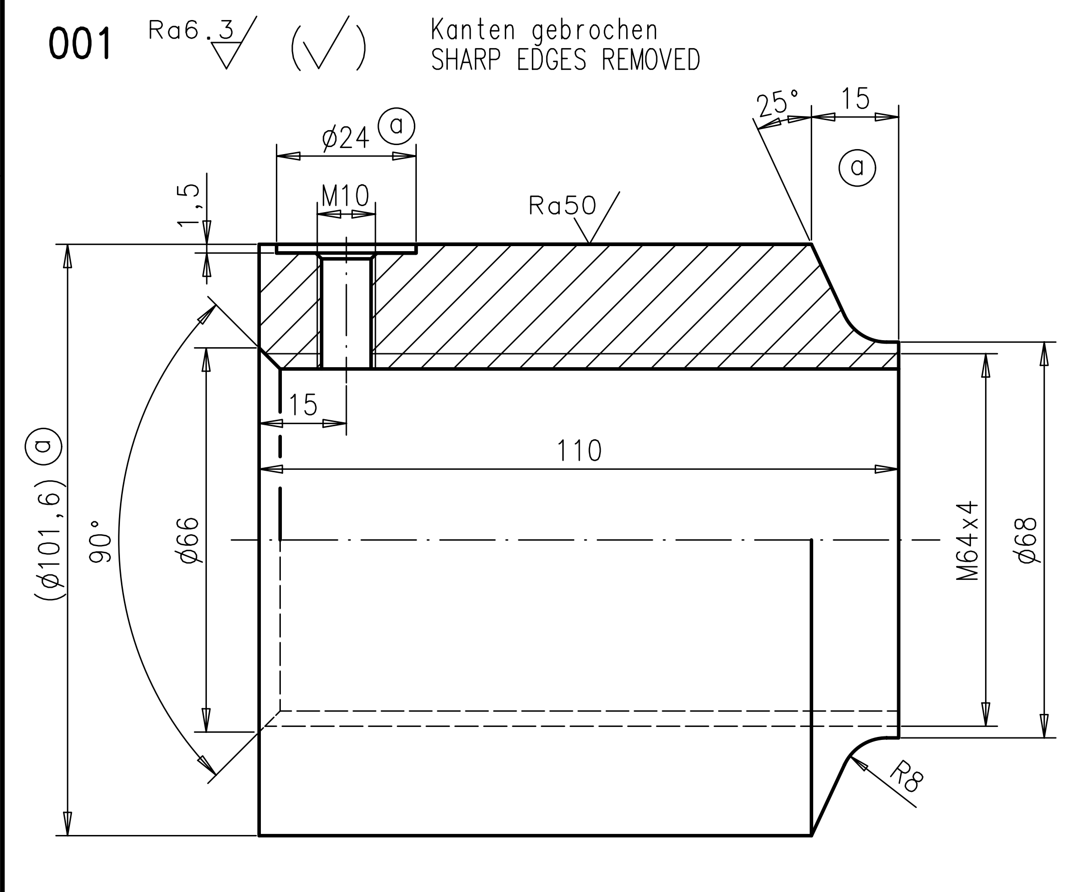
				SCREWED SLEEVE		



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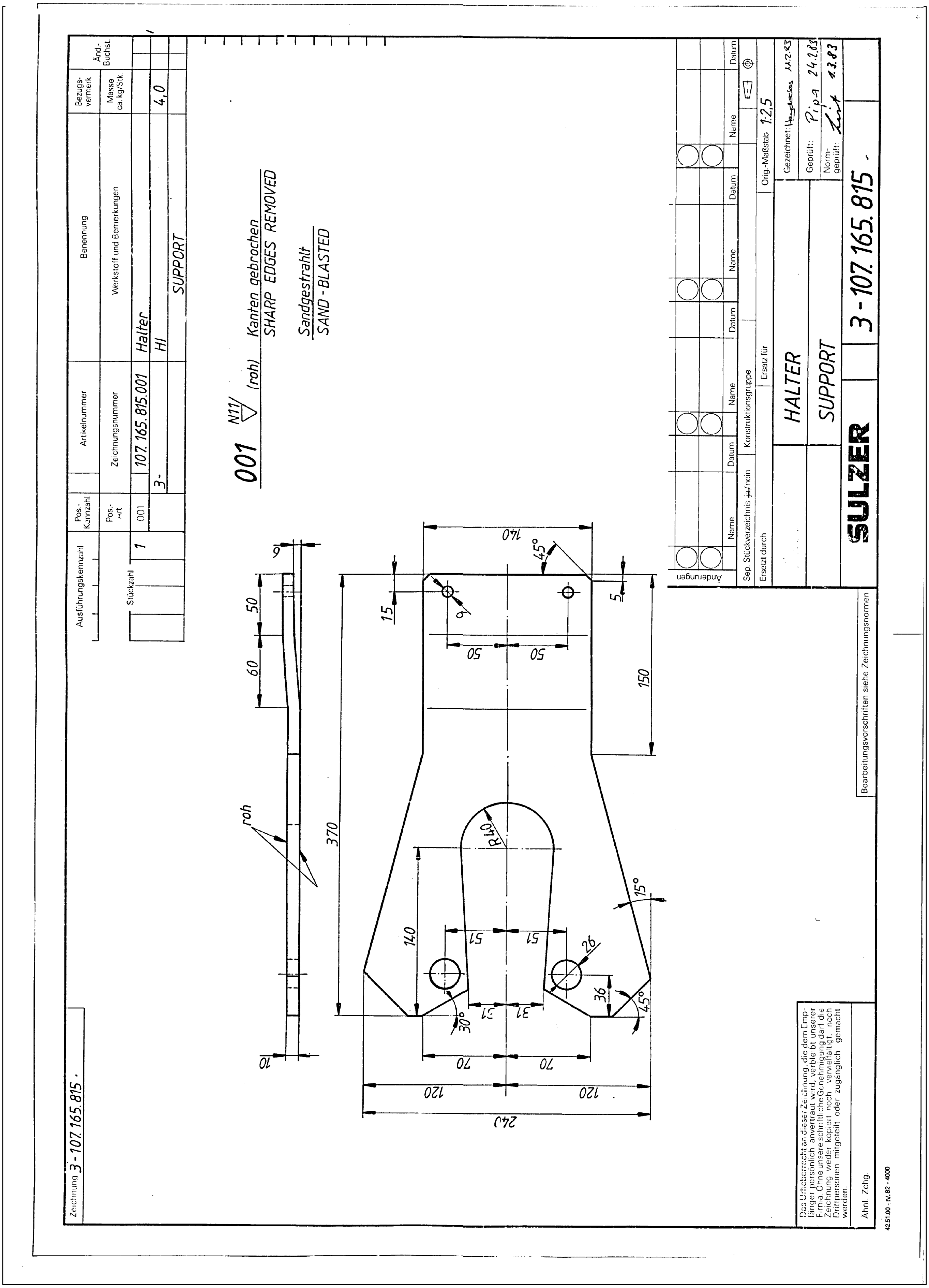
Modifications	Number	Date		Number	Date		Number	Date		Number	Date
a	7-14.494	02.08.01									

Q-Code X X X X X | Substitute for | Scale 1:1

Engine type: RTMOT	Version	Gewindehuelse Motorabstuetzung SCREWED SLEEVE ENGINE STAYS	Drawn: Heydecker 11.02.83 Wartsila Switzerland Ltd CAD WÄRTSILÄ
Design group: 9715	ISO / JIS	4- 107.165.810	Page: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SUPPORT
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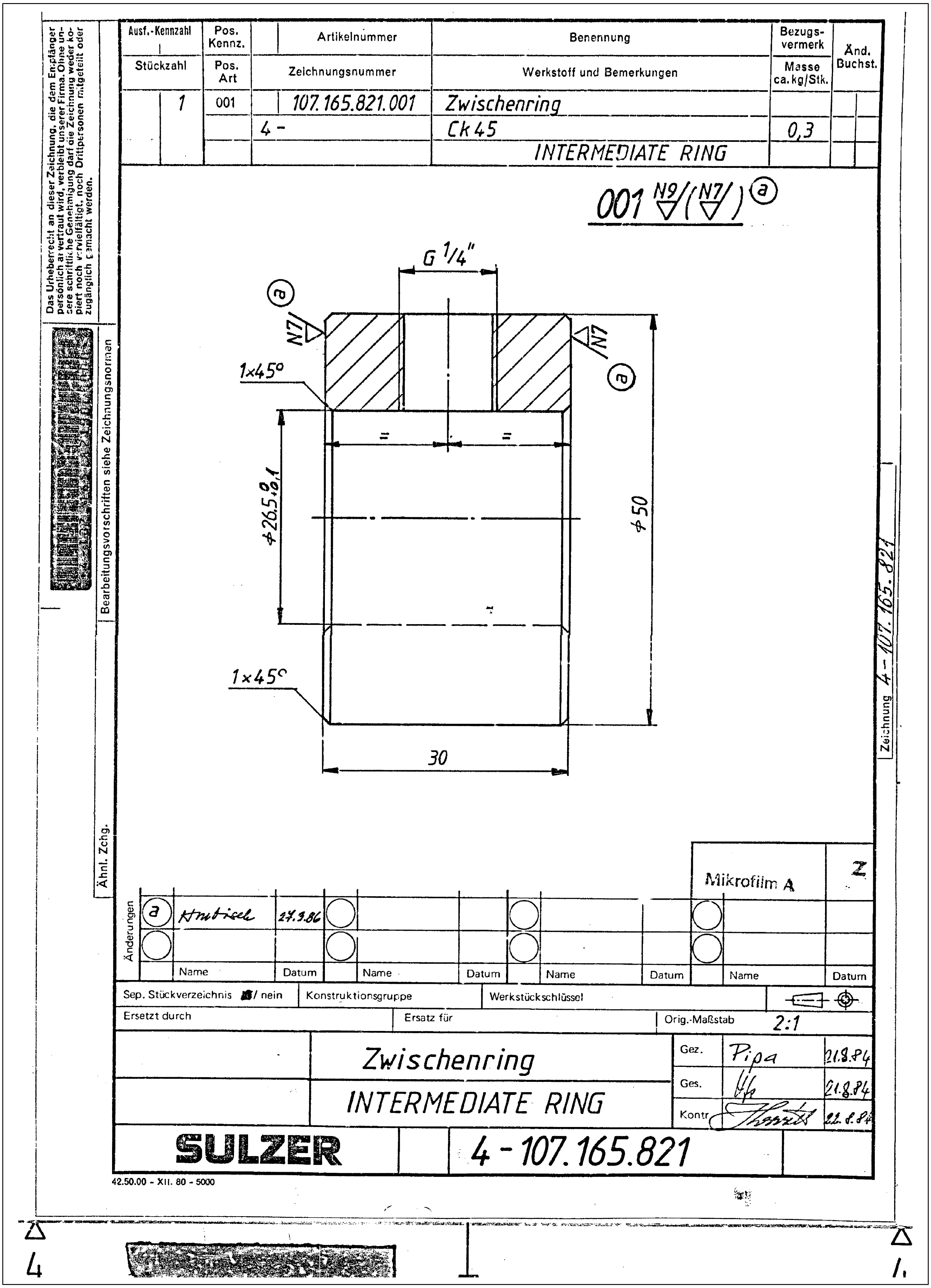
3-107.165.815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N7
1x45°
⌀26,5 +0,1
⌀50
30
Bearbeitungsvorschriften siehe Zeichnungsnormen
Ähnl. Zchg.
Zeichnung 4-107.165.821
Mikrofilm A
Z
Änderungen
a
27.3.86
Name
Datum
Sep. Stückverzeichnis / nein
Konstruktionsgruppe
Werkstückschlüssel
Ersetzt durch
Ersatz für
Orig.-Maßstab 2:1
Zwischenring
INTERMEDIATE RING
Gez. Pipa 21.8.84
Ges. 21.8.84
Kontr. 22.8.84
SULZER
4 - 107.165.821
42.50.00 - XII. 80 - 5000

SURFACE PROTECTION SEE GROUP 0344
GENERAL TOLERANCES ACCORDING TO ISO/2768-m

Exec. code no / Number of	Pos. code no		Article number / Drawing number	Designation / Material and remarks	Source of supply / ~ mass kg/piece	Modification letter
200						
1	001		107.245.489.001	Kugelhahn 3/8" NPT	AD	
		4-		St.	.3	
				BALL VALVE 3/8" NPT		

Best. Nr. Order No.

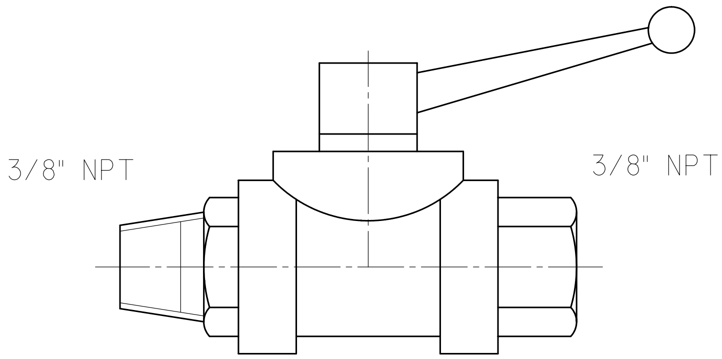
001 KUGELHAHN

Typ KHG - V 500.6/808-1 SO
PN 500 - DN 8 - NPT 3/8"

Einerseits:	Innengewinde
Anderseits:	Aussengewinde
Gehaeuse:	Stahl verz.
Kugel:	Stahl hv
Dichtschale:	Polyamid
O-Ringe:	Perbunan
Schaltgriff:	K60

Lieferant:

Huber
Muenchensteinstrasse 270
CH - 4002 Basel



Modifications | Free space for lic.

Number	Date	Number	Date	Number	Date	Number	Date

~~Q-Code~~ | Substitute for | Scale 1:1

Engine type: RTA
Version

Kugelhahn
Bestellzeichnung

BALL VALVE
ORDER DRAWING

Drawn: A. Horsfjord 16.03.95

Wärtsilä NSD Switzerland Ltd

CAD

WÄRTSILÄ NSD CORPORATION

Design group: 9712 | 70

4-107.245.489

Page:

Ausf.-Kennzahl 200 / Stückzahl	Pos. Kennz. / Pos. Art	Artikelnummer / Zeichnungsnummer	Benennung / Werkstoff und Bemerkungen	Bezugsvermerk / Masse ca. kg/Stk.	Änd. Buchst.
2	001	107.165.811.001	Kolbenführung	AD	
		4-	EKF 200	—	
			PISTON GUIDE		
1	002	107.165.811.002	Führungsband	AD	
		4-	FB 503-40-2/552	—	
			GUIDE TAPE		
1	003	107.165.811.003	Nutring	AD	
		4-	160-180-15Sn - NI300	—	
			GROOVED RING		
1	004	107.165.811.004	Abstreifer	AD	
		4-	AUAS 160-175-9-12	—	
			SCRAPER		
1	005	107.165.811.005	O-Ring Ø189,2×5,7	AD	
		4-	88 NBR/156	—	
			"O"-RING		

200

Bestell Nr.
ORDER NO.

001	Kolbenführung	Best. Nr.	EKF 200
002	Führungsband	-"-	FB 503-40-2/552
003	Nutring	-"-	160-180-15 Sn - NI300
004	Abstreifer	-"-	AUAS 160-175-9-12
005	O-Ring	-"-	O-Ring Ø189,2×5,7-88 NBR/156

Lieferant: Simrit AG Thurgauerstr. 39, CH 8050 Zürich
SUPPLIER:

2

Änderungen | Name | Datum | Name | Datum | Name | Datum | Name | Datum

Sep. Stückverzeichnis ja / nein | Konstruktionsgruppe | Werkstückschlüssel

Ersetzt durch | Ersatz für | Orig.-Maßstab

Dichtungs-Satz Bestellzeichnung
JOINT SET ORDER DRWG.

Gez.	Heydecker	11.2.83
Ges.	Pipa	24.2.83
Kontr.	List	2.3.83

SULZER | 4-107.165.811

Zeichnung 4-107.165.811

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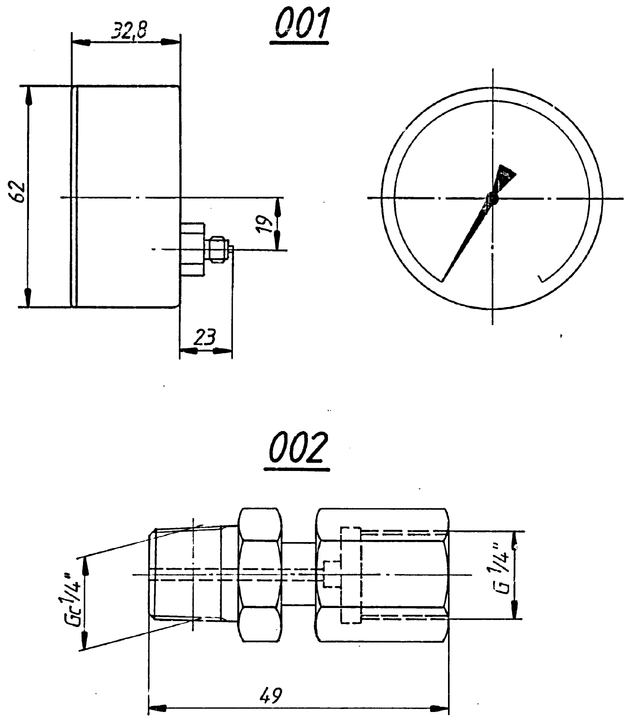
Bearbeitungsvorschriften siehe Zeichnungsnormen

Ähnl. Zchg.

42.50.00 - XII. 80 - 5000

Zeichnung 3-107.165.812

200



Ausführungskennzahl 200 / Stückzahl	Pos.-Kennzahl / Pos. Art	Artikelnummer / Zeichnungsnummer	Benennung / Werkstoff und Bemerkungen	Bezugsvermerk / Masse ca. kg/Stk.	Änd.-Buchst.
1	001	107.165.812.001	Manometer, NG 63, G 1/4"	AD	
		3-	St.	0,23	
			PRESSURE GAUGE		
1	002	107.165.812.002	Reduktion G 1/4" - Gc 1/4"	AD	
		3-	Ms.	0,1	
			REDUCTION		
1	003	107.165.812.003	Dichtungsring 5,2 x 10 x 1,5	AD	
		3-	Cu	—	
			JOINT		
kg 0,25					

001 Manometer mit Rohrfeder — PRESSURE GAUGE WITH BOURDON
mit Glyzerinfüllung — TUBE. GLYCERINE FILLED
Gehäusedurchmesser NG: 63mm — HOUSING DIA.
Skalaeinheiten: 0-250bar — SCALE GRADUATION
Anschluss: $G^1/4$" hinten — CONNECTION AT BACK
Best. Nr.: DRO 63/413.133/145
ORDER NO.:

002 Verschraubung — G1/4" - $Gc^1/4$" aus Messing (BRASS) CONN. PIECE
Best. Nr.: A 6443.3
ORDER NO.:

003 Lichtungsring — 5,2 x 10 x 1,5 aus Kupfer — COPPER JOINT
Best. Nr.: N 1890.2
ORDER NO.:

Lieferant: HAENNI & Cie
SUPPLIER: Bernstr.
CH 3303 Jegenstorf

Änderungen — Name / Datum — Name / Datum — Name / Datum — Name / Datum

Sep. Stückverzeichnis ja/nein — Konstruktionsgruppe
Ersetzt durch — Ersatz für — Orig.-Maßstab

Manometer Bestellzeichnung
PRESSURE GAUGE ORDER DR.

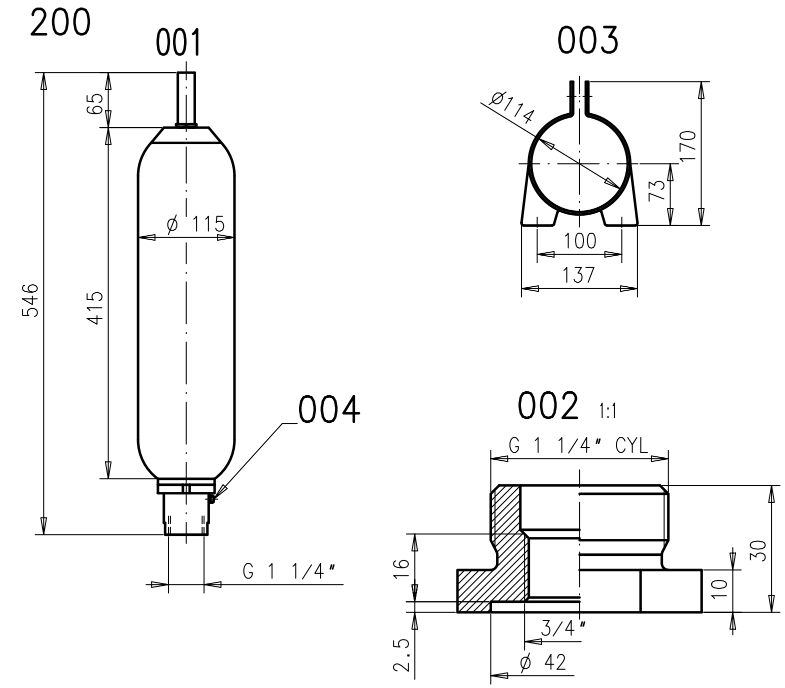
Gezeichnet: Heydecke 29.10.82
Geprüft: Pipa 24.2.83
Norm-geprüft: Zint 2.3.83

SULZER — 3-107.165.812

Ähnl. Zchg.

Bearbeitungsvorschriften siehe Zeichnungsnormen

42.51.00 - IV.82 - 4000



Exec. code number 200 / Number of	Pos. code no		Article number / Drawing number	Designation / Material and remarks	Source of supply / mass kg/piece	Modification letter
1	001		107.329.413.001	Blasenspeicher		
		3-			10.0	
				BLADDER ACCUMULATOR		
1	002		107.329.413.002	Reduzier-Verschraubung G 1 1/4" - G 3/4"		
		3-		St	0.050	
				REDUCTION UNION PIECE		
1	003		107.329.413.003	Schelle D114		
		3-		St	0.200	
				STRAP		
1	004		107.329.413.004	Entlueftungsvorrichtung mit Dichtung M5		
		3-				
				VENTING DEVICE		
kg 10.3						

001	Blasenspeicher	"OLAER" Best. Nr. 108547-01120	BLADDER ACCUMULATOR
	Nennvolumen:	2.4 l	NOMINAL VOLUME
	Anschluss:	G 1 1/4" CYL	CONNECTION
	Temperaturbereich	-15 °C bis +80 °C	WORKING TEMP.
	Typ	IHV 2.5-350/90	TYPE
002	Reduktion	G 1 1/4" - G 3/4"	REDUCTION
	mit Dichtung	zu Pos. 001	WITH JOINT
	Best. Nr.	107353-00238 / 101009-00038	ORDER NO.
003	Befestigungs-Schelle	ø 114	CLAMPLING STRAP
	Best. Nr.	200.570-04725	ORDER NO.
004	Entlueftungsschr.	M5	VENT SCREW
	mit Dichtung	Best. Nr. 200594-01200	WITH JOINT

Lieferant/SUPPLIER : OLAER (SUISSE) S.A Bonnstr. 3, CH-3186 Duedingen

SURFACE PROTECTION SEE GROUP 0344
GENERAL TOLERANCES ACCORDING TO ISO/2768-m

Free space for lic.

Modifications	Number	Date
a	7-28.674	06.12.02

Q-Code X Q X X X — Substitute for — Scale 1:5, 1:1

Engine type: RTMOT

Blasenspeicher
Bestellzeichnung
BLADDER ACCUMULATOR
ORDER DRAWING

Drawn: S.STYLIANOU 21.08.02
Wärtsila Switzerland Ltd
CAD

Design group: 9715 — ISO / JIS

3- 107.329.413

Page:

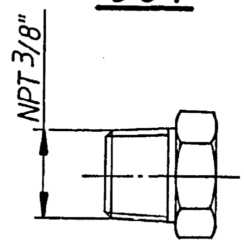
WÄRTSILÄ

Bearbeitungsvorschriften siehe Zeichnungsnormen

Ähnl. Zchg.

Ausf.-Kennzahl / Stückzahl	Pos. Kennz. / Pos. Art	Artikelnummer / Zeichnungsnummer	Benennung / Werkstoff und Bemerkungen	Bezugsvermerk / Masse ca. kg/Stk.	Änd. Buchst.
1	001	107.165.814.001	Verschlusszapfen 3/8"-NPT	AD	
		4-	St.	—	
			PLUG		

001



Best. Nr. - ORDER NO.

001 Verschlusszapfen 3/8"NPT Best. Nr. 134.0094

Lieferant: J.J. Derendinger GmbH
SUPPLIER: Technoramastr. 19
CH 8404 Winterthur

Zeichnung 4-107.165.814

Z

Änderungen	Name	Datum	Name	Datum	Name	Datum	Name	Datum

Sep. Stückverzeichnis ja / nein	Konstruktionsgruppe	Werkstückschlüssel
Ersetzt durch	Ersatz für	Orig.-Maßstab

Verschlusszapfen Bestell-zeichnung	Gez.	Heydecker	1.2.83
PLUG ORDER DRWG.	Ges.	Pipa	24.2.83
	Kontr.	[illegible]	1.3.83
SULZER	4-107.165.814		

42.50.00 - XII. 80 - 5000

1. General

Installation drawing see page 2
Sectional view drawing see page 3

Hydraulic transverse stays are used to shift the natural frequency when resonance can be expected in the normal operating range of the engine.

The applied arrangement enables:

- The adjustability of the pretension force.
- The adaptability to the slow movement of the ship's hull when loading or unloading the ship.

2. Description

The hydraulic lateral fixation device consists of:

- Hydraulic cylinder with differential piston, fitted with hydro accumulator and pressure gauge.
- Stays for lateral fixation of the engine to the ship's structure.
- Adjusting screw, fixed to the engine.

Accessories per ship for single main engine installation
(for multiple main engine installation the engine supplier is to be consulted)

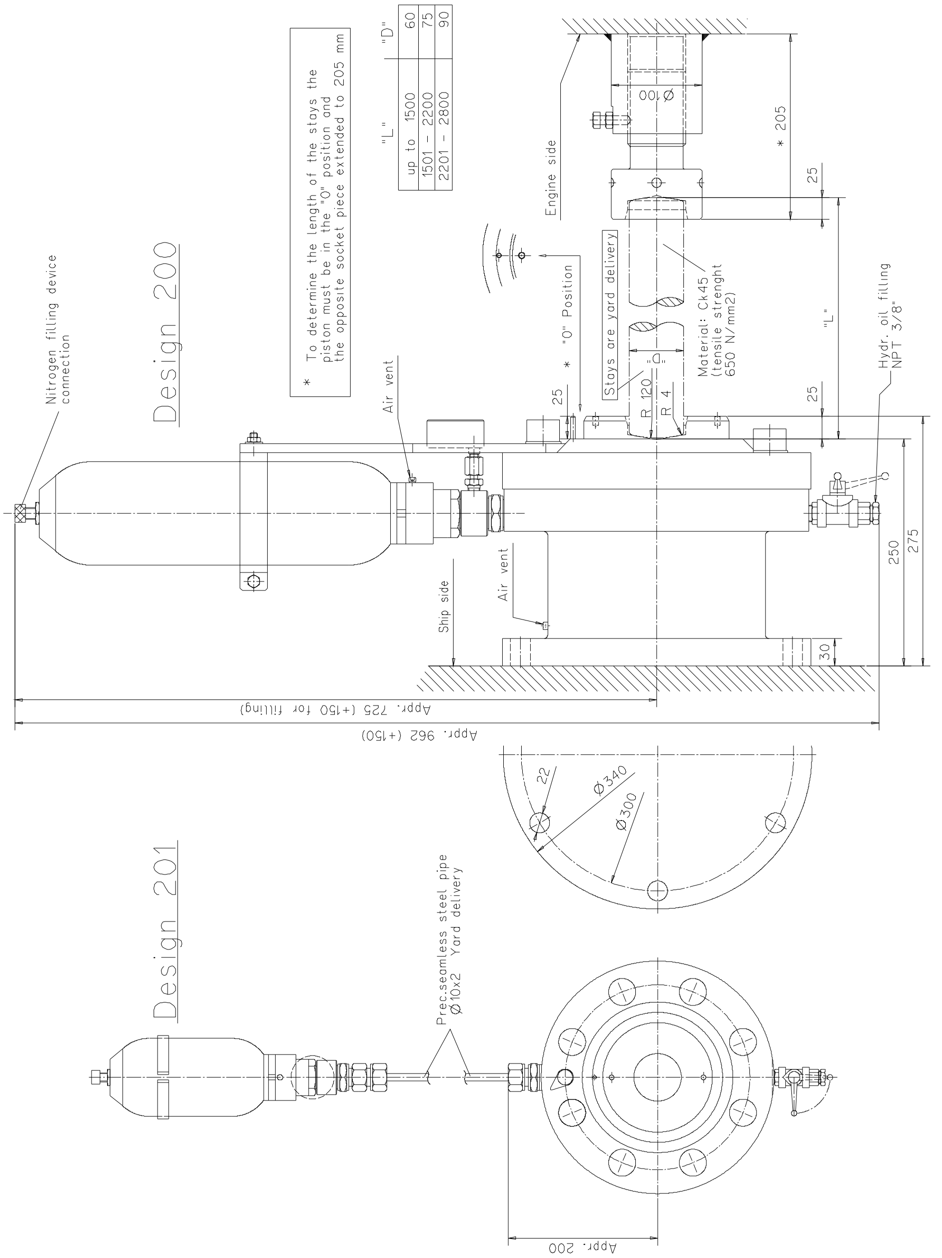
- Hydraulic cylinders either to design 200 or 201 with adjusting screw (stays are yard delivery)

  Design 200: Compact execution
  Design 201: Hydro accumulator detached for separate installation (Fittings included, but connection steel pipe ø 10 x 2 is yard delivery)

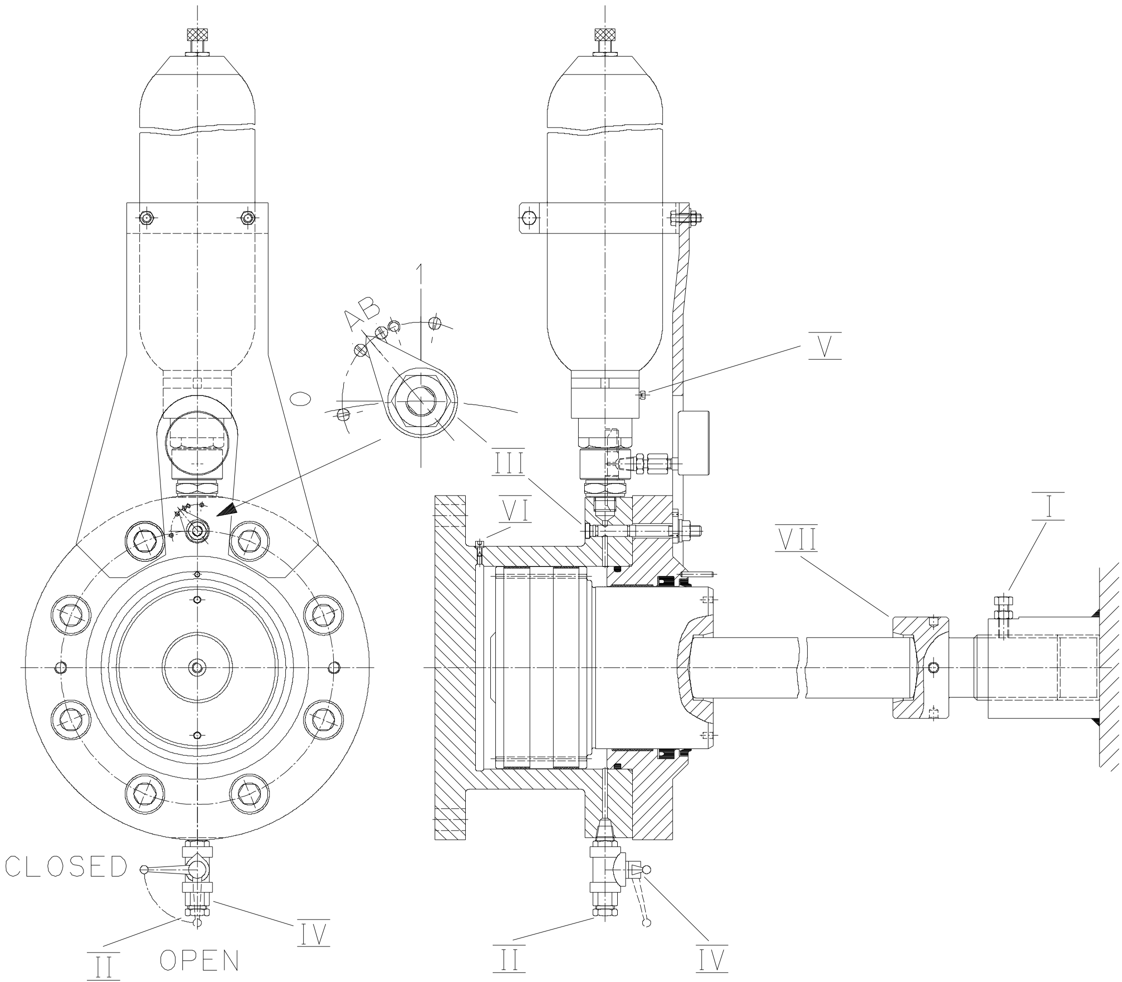
- Tester and pressurizer VGU - 250 - TS3 for nitrogen (for details see page 9)

- Hand pump for hydraulic oil (contained in the standard engine tool set)

	Replaced by:		Substitute for:	1
WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTA-Engines	HYDRAULIC LATERAL DEVICE FOR MAIN ENGINE		Design group 9715
	Created: 23.8.1984	E	4-107.165.820	Page 1/12

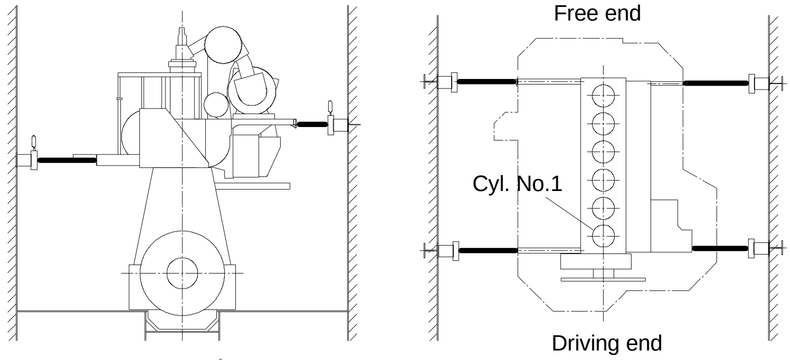


	Replaced by:		Substitute for:		2
WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTA-Engines	HYDRAULIC LATERAL DEVICE FOR MAIN ENGINE			Design group 9715
	Created: 23.8.1984	E	4-107.165.820		Page 2/12



I Set bolt
II Plug
III Throttling valve
IV Filling valve
V Vent screw
VI Vent screw
VII Adjusting screw

	Replaced by:		Substitute for:		3
WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTA-Engines	HYDRAULIC LATERAL DEVICE FOR MAIN ENGINE			Design group 9715
	Created: 23.8.1984	E	4-107.165.820		Page 3/12



For details see drawing "Engine stays, hydraulic type" of the relevant engine.

3. Function

Transverse vibrations of the engine cause rapid pressure fluctuations in the hydraulic cylinder. Thereby the unit behaves like a strong spring. By using the throttling valve III (page 3), the spring rate can be adjusted such that the rapid pressure fluctuations are practically filtered off and do not continue into the hydro accumulator. The hydraulic cylinder nevertheless adjusts itself to the slow deformations of the ship's hull.

4. Installation

The hydraulic cylinders are to be bolted to the reinforced attachment points on the ship structure. The adjustments screws are welded on the engine at position shown on the relevant arrangement drawing from the engine builder. Stay length "L" shown on page 2 is to be determined and the diameter "D" taken from the table or from the arrangement drawing.

5. Commissioning

Commissioning of the hydraulic cylinders should be carried out shortly before the sea trial as follows:

5.1. The stay is to be fitted between the hydraulic cylinder and the adjusting screw on engine side and secured against dropping. The adjusting screw is to be set as shown on page 2 (axially: piston face and indicator pin to be on same plane; radially: pin and holes in line). Set bolt pos. I to be secured.

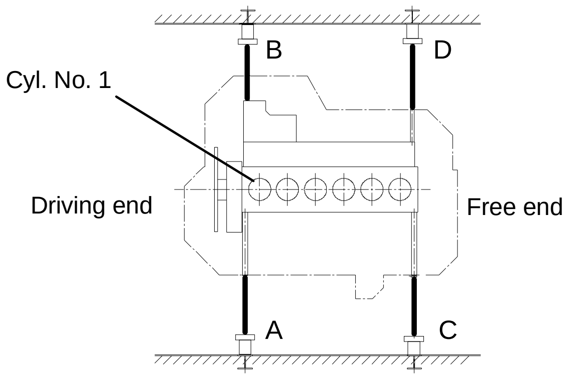
5.2. The hydro accumulator will be delivered pre-pressurised to 10 bar. The pressure is to be raised to the figure shown on page 7 with the help of the tester pressurizer (see page 9).

5.3. Plug pos. II is to be removed for filling of the hydraulic oil and the flexible hose connected to the hand pump. Throttling valve pos. III and filling valve pos. IV must be open (throttling valve switched to mark "1") as well as vent screws pos. V on the hydro accumulator and pos. IV on the hydraulic cylinder.

5.4. Hydraulic oil to be pumped slowly into the hydr. cylinder (oil to be warmed when engine room is cold). After perfect venting, first close vent screw pos. IV on the hydr. cylinder and then vent screw pos. V on the hydro accumulator. The 4 hydr. cylinders must then be pumped up to service pressure as follows:

	Replaced by:		Substitute for:			4
WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTA-Engines	HYDRAULIC LATERAL DEVICE FOR MAIN ENGINE				Design group 9715
	Created: 23.8.1984	E	4-107.165.820			Page 4/12

(Attention: Check that pump is always full and the filling hose completely filled before connecting up).



5.4.1. On cylinder A the oil pressure is to be raised to half the nominal pressure shown on page 7. (Pressure to be checked at the built on pressure gauge below the hydro accumulator). Filling valve pos. IV is to be closed and the hand pump disconnected.

5.4.2. On cylinder B the same preparatory work can be carried out, however, the pressure can be raised to 10 bar above the nominal pressure. Filling valve pos. IV is to be closed and the plug (II) fitted.

5.4.3. The hand pump is to be reconnected to cylinder A and the pressure increased to 10 bar above the nominal pressure. Filling valve pos. IV is to be closed and the plug (II) fitted.

5.4.4. The procedure for cylinders C and D is the same as for cylinders A and B.

5.4.5. After several hours, all hydraulic cylinders must be vented carefully at valves V and VI so as not to loose too much pressure. It must not sink below the nominal value.

5.5. The throttling valve pos. III is to be adjusted to mark "A" and secured on all cylinders.
Mark "B" is used for reduced stiffness.
At Mark "1" the function is practically ineffective.

Attention
The throttling valve pos. III must never be closed (Mark "0") in service because in this position the hydraulic piston cannot adjust itself to the movement of the ship's hull.

	Replaced by:		Substitute for:	5
WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTA-Engines	**HYDRAULIC LATERAL DEVICE FOR MAIN ENGINE**		Design group 9715
	Created: 23.8.1984	**E**	**4-107.165.820**	Page 5/12

6. Sea trial

The hydraulic cylinders must be checked frequently for oil pressure and general soundness.

6.1. At the end of the sea trial the following must be checked:

- "0" position of the piston according to page 2

- pressure to be the nominal value as shown on page 7. If the pressure is too high it can be corrected with careful opening of the vent screw pos. V. Where the pressure is too low, it has to raised with the hand pump.

7. Check when loading the ship fully for the first time

The position of the piston relative to the cylinder is to be checked when the ship is fully laden.

Should it occur that the piston is almost touching the bottom of the cylinder (this situation must not be allowed to occur, but it will happen when the piston is 15 mm on the inside of the "0" position) then the hydraulic lateral fixation device is to be shortened by about 7 mm with the adjusting screw pos. VII.

8. Regular checks

The oil pressures on the pressure gauges of the hydraulic cylinders are to be compared with each other at regular intervals. (The shown oil pressure may not be identical with the nominal pressure, because it varies according to the loading of the ship).

If one of the cylinders shows a considerably lower pressure, which could be caused by a leaking seal, the opposite hydraulic cylinder must be released of its pressure until the leaking seal has been replaced.

Afterwards both cylinders are to be put into service as mentioned under commissioning.

9. Spares

For spares see the following pages:

Pneumatic accumulator	page 8
Tester pressurizer	page 11
Hydraulic cylinder	page 12

Safety regulations regarding pressure vessels have to be adhered to

	Replaced by:		Substitute for:		6
WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTA-Engines	HYDRAULIC LATERAL DEVICE FOR MAIN ENGINE			Design group 9715
	Created: 23.8.1984	E	4-107.165.820		Page 6/12

Technical data

Hydraulic cylinder 200/160

Mass:	about 138 kg
Piston stroke:	± 15 mm
Oil Content:	about 2,5 l
Oil Type:	Hydraulic oil HL or HLP
Viscosity grade:	ISO VG 32/46 (20 - 30 mm²/s at 50° C)
Hydropneumatic accumulator type:	IHV 2,5 - 330/05 with bladder ref.: 105644-01120

Engine type	**RTA 68T-B, RTA72U/-B, RTA84T/-B/-D, RTA84C, RTA96C**	**RTA52U/-B, RTA62U/-B, RTA48T/-B, RTA58T/-B RTA60C**
Pre-pressurising pressure (gas)	40 bar	20 bar
Nominal oil pressure 1)	80 bar	50 bar
Nominal pre-tensioning force F_{vo}	160 kN	100 kN
Dynamic spring rate	about 320 kN/mm Throttl.valve pos."A"	about 270 kN/mm
Minimum oil pressure	about 60 bar when piston is protruding 15 mm in cylinder	about 37 bar
Maximum oil pressure	about 115 bar when piston is recessed 15 mm in cylinder.	about 80 bar

1) piston in position "0" (see sketch on page 2): Po_{max} = Po + 10 bar

Po = above given nominal pressure

	Replaced by:		Substitute for:		7
WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTA-Engines	HYDRAULIC LATERAL DEVICE FOR MAIN ENGINE			Design group 9715
	Created: 23.8.1984	E	4-107.165.820		Page 7/12

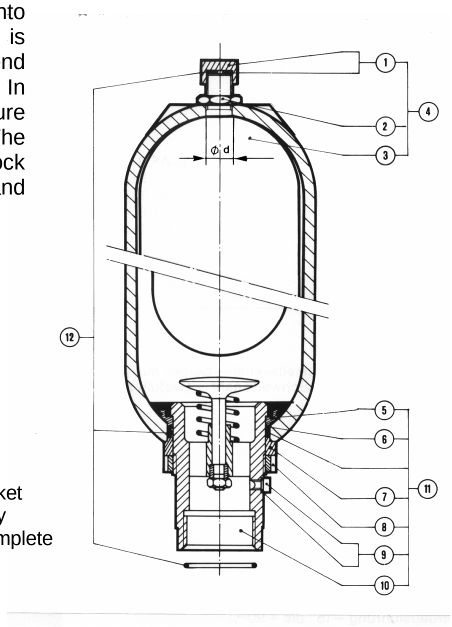
Hydropneumatic accumulator

(1) P_0V_0 state (2) P_1V_1 state (3) P_2V_2 state

P_0 = nitrogen pressurising pressure
P_1 = minimum working pressure
P_2 = maximum working pressure
V_0 = total nitrogen volume in the accumulator
V_1 = nitrogen volume at P_1
V_2 = nitrogen volume at P_2
$\triangle V$ = volume absorbed and/or returned beween P_1 and P_2

The bladder, enclosed in the accumulator body is pre-pressurised by means of an inert gas (nitrogen), capable of great compression, to a pressure determined by the needs of the work to be done. During this pressurising operation, the bladder expands, progressively approaches the lower part of the accumulator, and presses against its sides, so occupying the entire volume of the chamber (1).

When the circuit pressure generator causes the liquid to penetrate into the shell of the accumulator (2) the gas enclosed in the bladder is compressed and increases the pressure. The process comes to an end when the pressure of the liquid and of the gas reach equilibrium (3). In the reverse process, the return commences when the resisting pressure of the liquids is less than the pressure of the gas in the bladder. The lateral deformation of the latter in three lobes, forming a shamrock shape with three promontories excludes rubbing and inertia, and enables an efficiency of nearly 100% to be attained.



Spare Parts
1. Valve cap and gasket
2. Nut
3. Bladder
4. Bladder assembly
5. Anti-extrusion ring
6. Washer
7. Gland-ring
8. Ring nut
9. Venting screw and gasket
10. Fluid port sub-assembly
11. Fluid port assembly complete
12. Set of gaskets

	Replaced by:		Substitute for: 8	
WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTA-Engines	HYDRAULIC LATERAL DEVICE FOR MAIN ENGINE		Design group 9715
	Created: 23.8.1984	E	4-107.165.820	Page 8/12

TESTER AND PRESSURIZER VG U

DESCRIPTION

The VG U tester and pressurizer is used for charging of bladder, piston and membrane accumulators with nitrogen, and for testing or changing the pre-charge pressure. The instrument is suitable for all OLAER accumulators with $^{5}/_{8}$" flap valves, Schräder valves or screw plugs. It is screwed onto the gas inlet valve of the hydropneumatic accumulator, and connected to a standard nitrogen flask via a hose. If only the pre-charge pressure needs to be checked, the connection of the charging hose is not necessary.

Each unit comprises of:

- Tester and pressurizer with manometer, return valve on the charging hose, built-in release valve, valve spindle for opening the gas inlet valve on the accumulator.

- Charging hose, length 2.5m

- Connections for the accumulator
  $^{7}/_{8}$" - 14 UNF
  $^{5}/_{6}$" - 18 UNF
  0.305" - 32 NFT
  M28 x 1,5

- Plastic protective case

KEY TO MODEL DESIGNATION

VG U - 250 - TS 3

Model
Tester and Pressurizer

Manometer
6, 10, 25, 60, 100, 250, 400 bar

Charging hose
TS 3: for Ch, D, N, S,
A, FL, NL, DK, GUS
Connector
W24,32 x 1,814
245 bar
(for other countries, see part no. 40 on page 11)

	Replaced by:	Substitute for:		9
WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTA-Engines	HYDRAULIC LATERAL DEVICE FOR MAIN ENGINE		Design group 9715
	Created: 23.8.1984	E	4-107.165.820	Page 9/12

INSTALLATION AND USE

Setting up (see figure on page 11)
Before any pre-charge checks and/or nitrogen pressurizing, the hydraulic fluid of the hydro-pneumatic accumulator must be discharged.

Accumulator with hydraulic valve:
- Completely screw the lobed hand-wheel (no. 6) outwards
- Unscrew the protective cap(s) of the accumulator gas inlet valve.
- Screw pressurizer with intermediary no. 23 or 26 (+ connector no. 30 for Schräder valves) onto the hydraulic valve. Move the manometer into a convenient position for reading, and tighten the intermediary (no. 5) by hand.
- Check that the release valve is closed. (close the lobed hand-wheel no. 18 in an clockwise direction).

Checking the charge pressure:
- Turn the lobed hand-wheel (no. 6) in an anti-clockwise direction. This causes the gas inlet valve or allen screw to open. The pressure may now be read on the manometer.

Reducing the charge pressure:
- Rotate the lobed hand-wheel (no. 18) of the release valve slowly in an anti-clockwise direction. The nitrogen is released into the surrounding air.

Pressurizing/raising the charge pressure:
- Connect the charging hose: one end to the return valve (no. 7) and the other to a standard nitrogen flask.
- Open the stop valve on the nitrogen flask carefully. Allow the nitrogen to flow into the accumulator slowly, till the desired pre-charge pressure is reached.
- Close the stop valve on the nitrogen flask. After 5-10 minutes (temperature stabilisation), check the charge pressure again and correct where necessary.

Dismantling:
- Turn the lobed hand-wheel (no. 6) back.
- Screw the lobed hand-wheel (no. 18) outwards
- Unscrew instrument.
- Tighten screw valve with allen key SW6.
- Check the gas inlet valve seal with a foam-forming substance.
- Screw the protective cap(s) back on and tighten by hand.

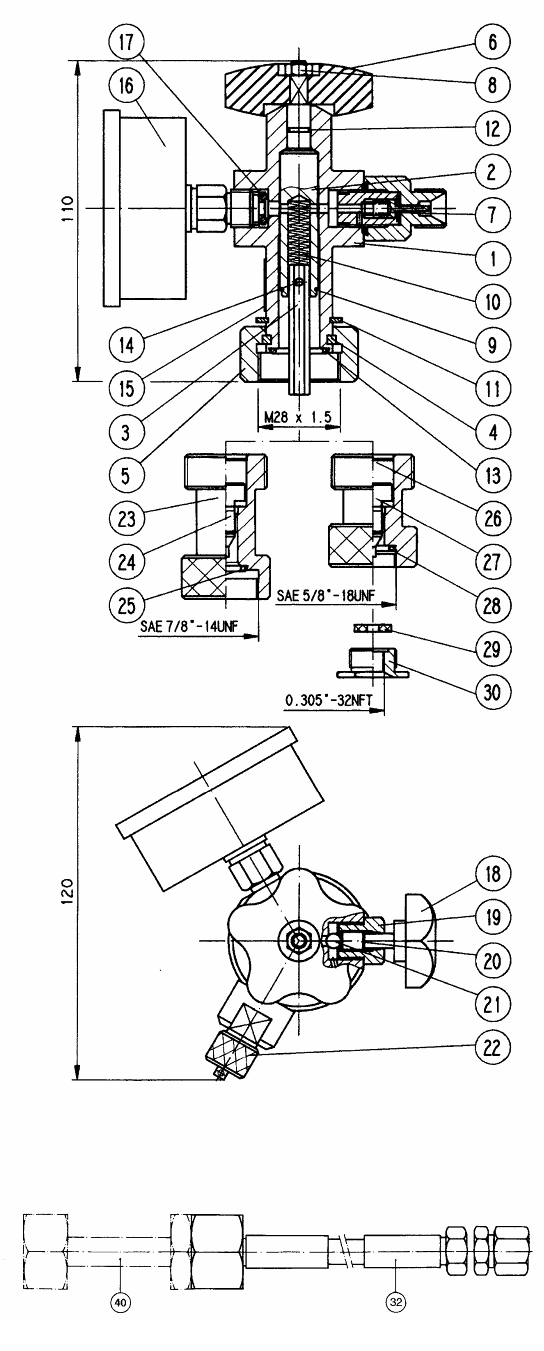
Caution:
- Never use oxygen to inflate the accumulator.
- Where the nitrogen flask pressure is higher than the permitted accumulator working pressure, a pressure limitation valve must be fitted.

	Replaced by:		Substitute for:	10
WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTA-Engines	HYDRAULIC LATERAL DEVICE FOR MAIN ENGINE		Design group 9715
	Created: 23.8.1984	E	4-107.165.820	Page 10/12

SPARE PARTS LIST
FOR VG U TESTER AND PRESSURIZER

Spares

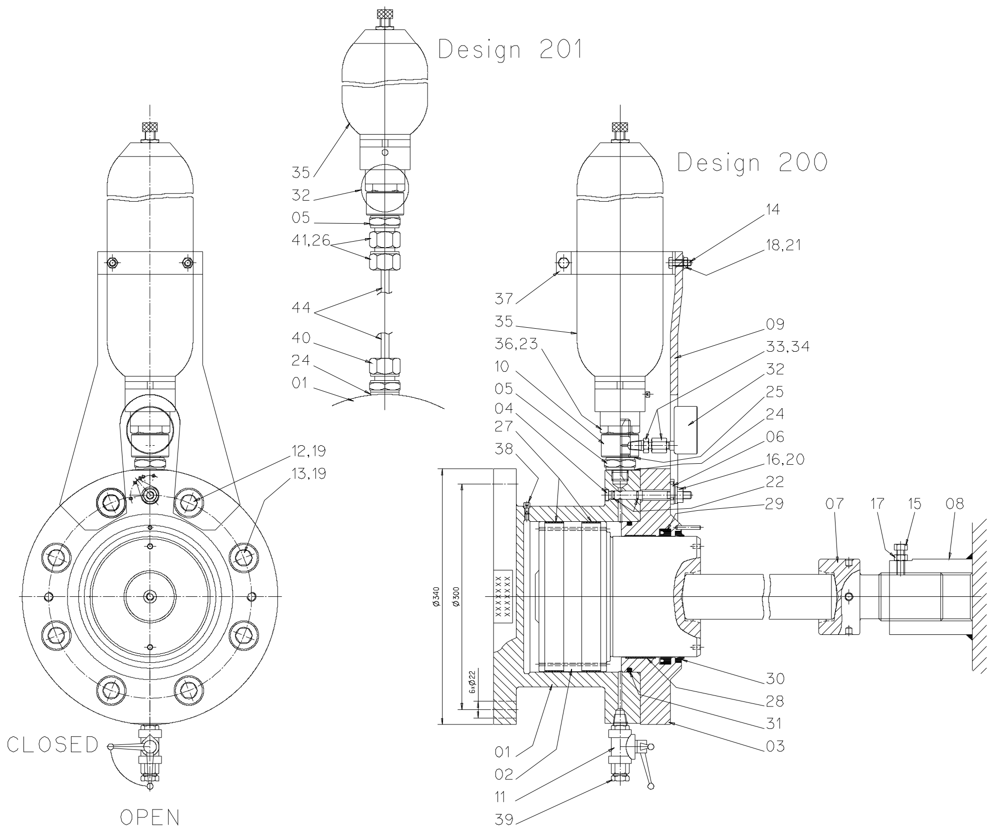
Part No:	Quantity	Description	Rec'd spares
1	1	Valve body	
2	1	Valve spindle	
3	1	Bolts	
4	1	Split ring	
5	1	Spigot nut	
6	1	Lobed hand-wheel	
7	1	Return valve	
8	1	Hexagon nut	
9	1	Snap ring	
10	1	Stand. press. spring	
11	1	Retaining ring	
12	1	O-Ring	x
13	1	O-Ring	x
14	1	Centre-grooved dowel pin	
15	1	Name plate	
16	1	Connect. for manom. G ¼"	
17	1	Copper seal	x
18	1	Lobed hand-wheel	
19	1	Gland	
20	1	Valve spindle	
21	1	Valve ball	
22	1	Knurled cap	
23	1	Adapter SAE $^{7}/_{8}$" - 14UNF	
24	1	Valve spindle	
25	1	O-Ring	x
26	1	Adapter SAE $^{5}/_{8}$" - 18UNF	
27	1	Valve spindle	
28	1	O-Ring	
29	1	Flat seal	x
30	1	Connect. 0.305" - 32NFT	x
31	1	Gasket assembly (complete set)	x
32	1	Charging hose	
40	1	Connections for foreign nitrogen flasks	x
40b	GB/AUS	R $^{5}/_{8}$" external	
40c	USA	24.51 x $^{1}/_{14}$" external	
40d	Italy	21.7 x $^{1}/_{14}$" external	
40e	Japan	22 x $^{1}/_{14}$" internal	
40f	Japan	W23 x $^{1}/_{14}$" external	
40g	Brazil	R ½" internal	
40h	F, B, E	21.7 x $^{1}/_{14}$" internal	
40i	China	M22 x 1.5 internal	
40k	China	$^{5}/_{8}$" internal	
40l	Malaysia	G $^{7}/_{8}$" external	
40m	Trinidad	$^{7}/_{8}$" - 14UNF external	
40n	Bulgaria	¾" internal	
40o	Philippines	W23 x $^{1}/_{14}$" left	



	Replaced by:		Substitute for: 11	
WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTA-Engines	**HYDRAULIC LATERAL DEVICE FOR MAIN ENGINE**		Design group 9715
	Created: 23.8.1984	**E**	**4-107.165.820**	Page 11/12

Spares (When ordering, please state complete serial No.!)

Pos.	No. off	Item	Pos.	No. off	Item	Pos.	No. off	Item
01	1	Cylinder	21	2	Spring washer	41	1	Female union
02	1	Piston	22	2	O-Ring	44	1	Prec. seamless pipe
03	1	Cover	23	1	Sealing ring			
04	1	Valve spindle	24	1	Sealing ring			
05	1	Connecting piece	25	1	Sealing ring			
06	1	Pointer	26	1	Sealing ring			
07	1	Bearer	27	2	Piston guide			
08	1	Threaded sleeve	28	1	Guide tape			
09	1	Support	29	1	Grooved ring			
10	1	Ring	30	1	Scraper			
11	1	Ball valve	31	1	O-Ring			
12	2	Bolt	32	1	Pressure gauge			
13	6	Bolt	33	1	Reduction			
14	2	Bolt	34	1	Joint			
15	1	Bolt	35	1	Bladder accumulator			
16	1	Shoulded nut	36	1	Reduction			
17	1	Nut	37	1	Clamping strap			
18	2	Nut	38	1	Vent screw with joint			
19	8	Spring washer	39	1	Plug			
20	1	Spring washer	40	1	Male union			



	Replaced by:		Substitute for:	12
WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTA-Engines	**HYDRAULIC LATERAL DEVICE FOR MAIN ENGINE**		Design group 9715
	Created: 23.8.1984	**E**	**4-107.165.820**	Page 12/12

ORDER SHEET

TESTER PRESSURIZER

VG U - 250 - TS3
Ref. 202 182-07733

Comprises of:
- Tester and pressurizer with manometer, return valve on the charging hose, built-in release valve, valve spindle for opening the gas inlet valve on the accumulator.
- Charging hose, length 2.5m
- Connections for the accumulator
  $^{7}/_{8}$" - 14 UNF
  $^{5}/_{6}$" - 18 UNF
  0.305" - 32 NFT
  M28 x 1,5
- Plastic protective case
- Additional nitrogen flasks connections for the following countries:

1) GB, AUS, NZ:	R$^{5}/_{8}$" external	Part No. 993507-02800
2) F, B, E:	21.7 x $^{1}/_{14}$" internal	Part No. 993513-02800
3) Italy:	21.7 x $^{1}/_{14}$" external	Part No. 993509-02800
4) USA:	24.51 x $^{1}/_{14}$" external	Part No. 993508-02800
5) Brazil:	R½" internal	Part No. 993512-02800
6) Japan:	22 x $^{1}/_{14}$" internal	Part No. 993510-02800
7) Japan:	W 23 x $^{1}/_{14}$" external	Part No. 993511-02800

KEY TO MODEL DESIGNATION

VG U - 250 - TS 3

Model
Tester and Pressurizer

Manometer
6, 10, 25, 60, 100, 250, 400 bar

Charging hose
TS 3: for Ch, D, N, S,
A, FL, NL, DK, GUS
Connector
W24,32 x 1,814
245 bar

SUPPLIER: **OLAER (SUISSE) SA**
Bonnstrasse 3
CH- 3186 Duedingen
e-mail: info@olaer.ch

a	Pipa	21.08.84									
b	7-14.418	10.11.99									

	Replaced by:		Substitute for:	
WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTA-Engines	**TEST AND FILLING UNIT** **TO ENGINE STAYS (HYDRAULIC TYPE)**		Design group 9715
	Created: 28.10.82	**E**	**4-107.165.818**	Page 1

Zeichnung E 3-107.165.817

The pressure test of the assembled hydraulic cylinder acc. to drawing No. 0-107.165.800 must be carried out in the following order:

1. Fill the bladder accumulator with nitrogen to a pressure of 40 bar using the testing and filling device drawing No. 4 107.165.818 as follows:

1.1 Unscrew the protective cap from the bladder accumulator gas filling valve and screw the filling device onto the valve by union nut "D". Bring the pressure gauge into such a position that it can be read easily and clamp it tight by hand with union nut "D".

1.2 Check to ensure that bleed valve "B" is closed (handle "B" must be fully screwed in). Connect up filling hose to connection "C" and the nitrogen cylinder.

1.3 Screw in valve spindle "A" thus opening the gas filling valve and allowing the pressure to be read on the pressure gange.

1.4 Carefully open the shut-off valve. Slowly release nitrogen into the bladder accumulator until a pressure of 40 bar is reached.

1.5 Close the shut-off valve on the nitrogen cylinder. After 5 minutes (temperature equalization) check the charge pressure and, if too high, correct it by slowly opening the bleed valve "B".

1.6 Screw out valve spindle "A", open bleed valve "B", remove filling hose from the connection "C" and unscrew the filling device. Check the tightness of the gas filling valve with soapy water. Put the protector cap onto the gas filling valve and tighten it by hand.

2. Unscrew closing plug, item 039, and connect up the connecting hose of the delivery pump.

3. Push the piston, item 002, as far as it will go. Marking on the piston must coincide with the marking pointer on the cover. Piston marking pointer must lie at the middle of the pointer.

4. (A) Set valve item 004 "A" to marking 1 and open the ball valve item 011, open both vent screws item 035 (bladder) and item 038 (cylinder).

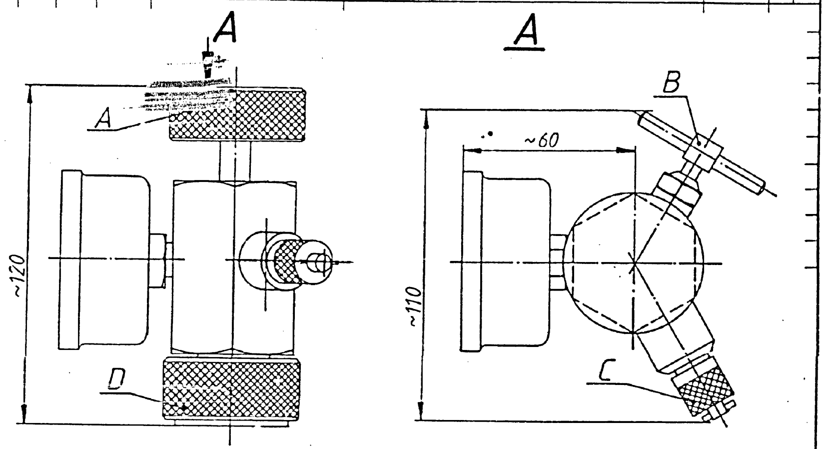
5. Pump hydraulic oil into the cylinder and close off the vent screws after complete venting. Continue pumping the hydraulic oil until a pressure of 250 bar can be held for approx. 10 mins. Check all joints for leakage.

6. (A) Release pressure back to 0 bar, drain the hydraulic oil, from the cylinder, close valve item 011, disconnect hose and screw on the closing plug item 039.

7. (A) Set valve item 004, "A" to marking "A" and lock valve with nut item 016.

8. Reduce the charge pressure in the bladder accumulator to 10 bar (see points 1.1, 1.3, 1.5 and 1.6).

Stückzahl	Pos. Kennzahl / Pos. Art	Artikelnummer / Zeichnungsnummer	Benennung / Werkstoff und Bemerkungen	Masse ca kg/Stk
*	001	107.165.817.500	Instr. for pressure test	—
		E3-	250 bar	—



A Valve spindel
B Bleed valve
C Filling conn.
D Union nut (Raccord)

E3-107.165.817000000

Änderungen: A A. Horsfjord 8.3.95

Name	Datum	Name	Datum	Name	Datum	Name	Datum

Sep. Stückverzeichnis ja/nein | Konstruktionsgruppe
Ersetzt durch | Ersatz für | Orig.-Maßstab —

Hydr. cylinder 200/160

Instruction for pressure test 250 bar

Gezeichnet Heydackas 11.2.83
Geprüft Pipa 24.2.83
Norm-geprüft 1.3.83

SULZER E 3-107.165.817

Das Urheberrecht an dieser Zeichnung, die dem Empfänger persönlich anvertraut wird, verbleibt unserer Firma. Ohne unsere schriftliche Genehmigung darf die Zeichnung weder kopiert noch vervielfältigt, noch Drittpersonen mitgeteilt oder zugänglich gemacht werden.

Abnl. Zchg.

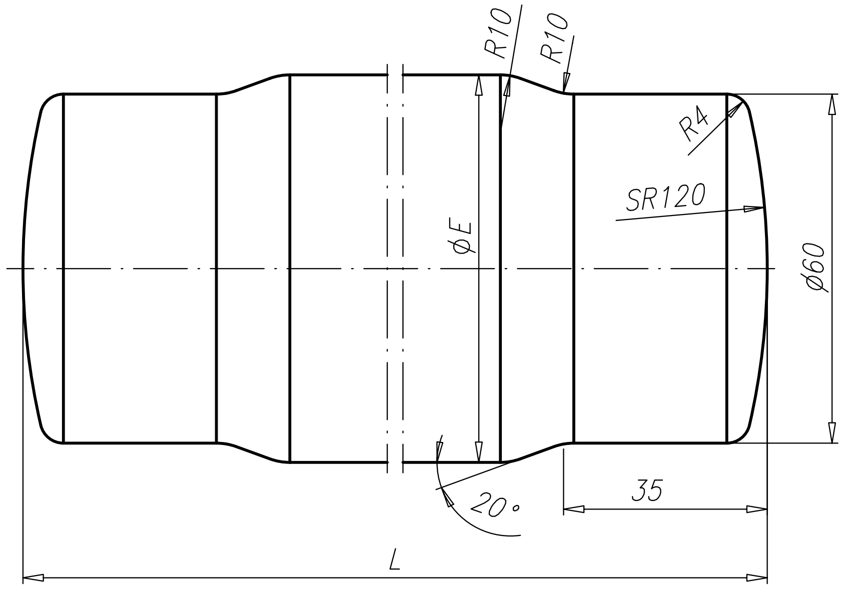
Bearbeitungsvorschriften siehe Zeichnungsnummer

42 51 00 IV.82 4000

Mikrofilm A

SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK

Material ID	L (mm)	ØE (mm)
PAAD005752	up to 1500	60
PAAD005756	1501 to 2200	75
PAAD005758	2201 to 2800	90



QTY	SEQ NO	Material ID	Material Name	Dimension/Occ.Dimension	Standard or Drawing	Basic Material Material Standard	Weight GR./NET
1	003	PAAD005758	ROUND BAR	2201 to 2800	DAAD006100	C45E S45C	140
1	002	PAAD005756	ROUND BAR	1501 to 2200	DAAD006100	C45E S45C	76
1	001	PAAD005752	ROUND BAR	up to 1500	DAAD006100	C45E S45C	33

Approved

Free space for lic.

Q-Code XXXXX
Main Drw.
Standard ISO JIS

Modif. | Number | Drawn date | Number | Drawn date | Number | Drawn date | Number | Drawn date

WÄRTSILÄ

Product: RT MOT

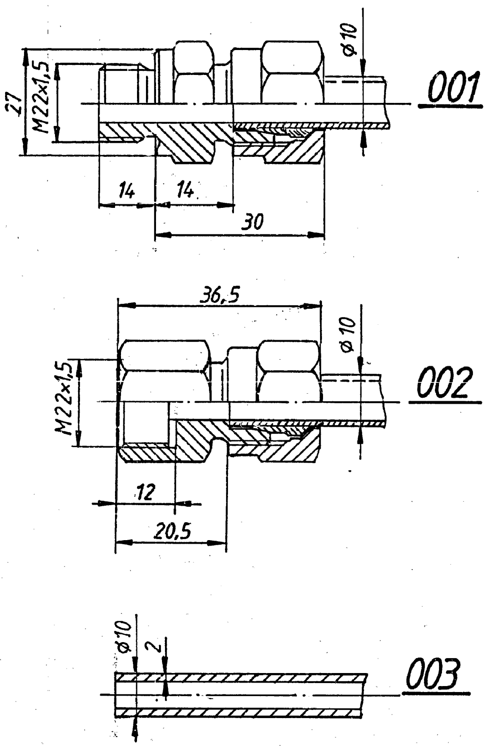
ROUND BAR

Rundstahl

Units	mm kg	IDE	
Basic Material	C45E S45C	Net Weight	1
Made	09.06.2010 wwr001 Wroblewski	Scale	1:1
Chkd	21.09.2010 jba029 Baumann	Design Group	9715
Appd	23.09.2010 dst009 Stroedecke	Size	A4
Page	1/1	Material ID	
Drawing ID	DAAD006100	Rev.	–

Zeichnung 3-107.165.822

Ausführungskennzahl / Stückzahl	Pos.-Kennzahl / Pos.-Art	Artikelnummer / Zeichnungsnummer	Benennung / Werkstoff und Bemerkungen	Bezugsvermerk / Masse ca. kg/Stk.	Änd.-Buchst.
1	001	107.165.822.001	Gerade E-Verschr. GE 10-LM 22×1,5	AD	
		3-	St. „ERMETO"	0,2	
			MALE UNION		
1	002	107.165.822.002	Gerade A-Verschr. GAI 10-LM 22×1,5	AD	
		3-	St. „ERMETO"	0,2	
			FEMALE UNION		
–	003	107.165.822.003	H.D. Präz. R. nähtl. 10×2	AD	
		3-	St. „ERMETO"		
			PREC. SEAMLESS PIPE		



001 Gerade Einschrauverschraubung GE 10-LM 22x1,5 MALE UNION
Best.Nr. GE 10-LM 22x1,5 / SA 331, Stahl
ORDER No.

002 Gerade Aufschraubverschraubung GAI 10 22x1,5 FEMALE UNION
Best.Nr. GAI 10-LM 22x1,5 / SA 7, Stahl
ORDER No.

003 H.D.Präz.Rohr,nahtl.phosphatiert,Stahl PREC.SEAMLESS PIPE
Best.Nr. Stahlrohr nach DIN 2391/C, Ø 10 x 2
ORDER No.

Lieferant: TECALTO AG
Rautistr.58
8048 Z ü r i c h

Änderungen | Name | Datum | Name | Datum | Name | Datum | Name | Datum

Sep. Stückverzeichnis ja/nein | Konstruktionsgruppe

Ersetzt durch | Ersatz für | Orig.-Maßstab

Verschraubungen Bestellzchng.
UNIONS ORDER DRWG.

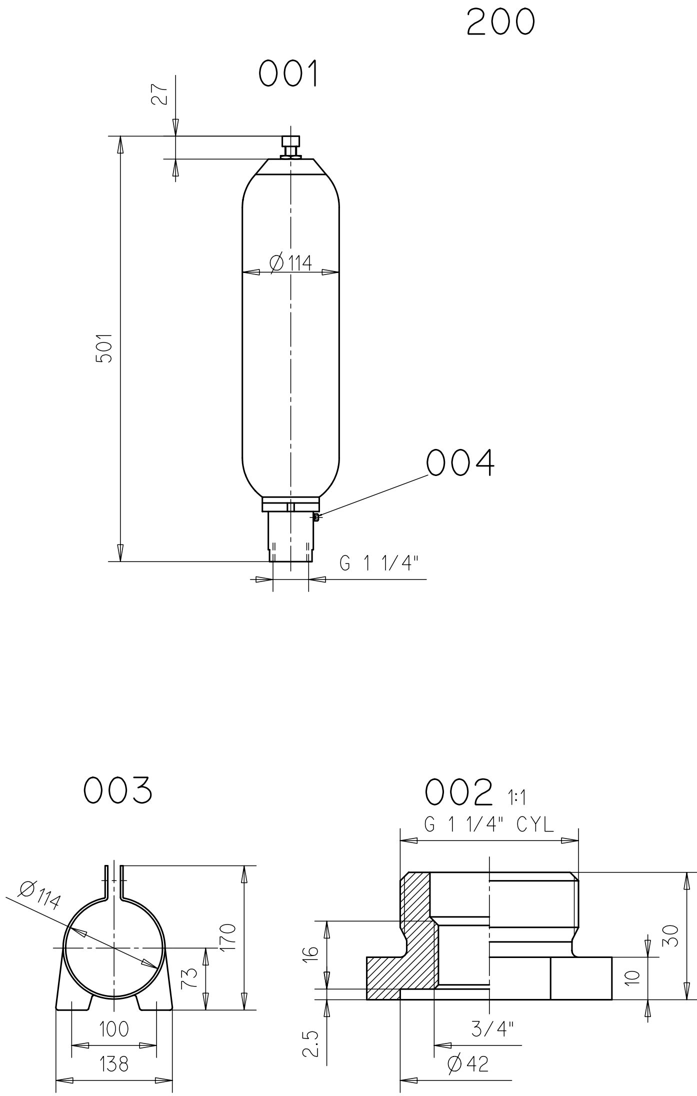
Gezeichnet: Pipa 21.2.84
Geprüft: 14.8.84
Norm-geprüft: 23.8.84

SULZER 3-107.165.822

Ahnl. Zchg.

Bearbeitungsvorschriften siehe Zeichnungsnormen

42 51.00 - IV.82 - 4000



Exec. code number 200 / Number of	Pos. code no	Article number / Drawing number	Designation / Material and remarks	Source of supply / ~ mass kg/piece	Modification letter
1	001	107.165.813.001	Blasenspeicher		
		3-	IHV 2.5-330-TUeV	10.0	
			BLADDER ACCUMULATOR		
1	002	107.165.813.002	Reduktion G 1 1/4" - G 3/4"		
		3-	St.	0.05	
			REDUCTION		
1	003	107.165.813.003	Schelle Ø114		
		3-	St.	0.2	
			STRAP		
1	004	107.165.813.004	Entlueftungsschr. mit Dichtung M5		
		3-	St.		
			VENT SCREW WITH JOINT		

001 Blasenspeicher	"OLAER" Best. Nr. 105644-01120	BLADDER ACCUMULATOR
Nennvolumen:	2.4 l	NOMINAL VOLUME
Anschluss:	G 1 1/4" CYL	CONNECTION
Temperaturbereich	-15°C bis +80°C	WORKING TEMP.
Typ	IHV 2.5-330-TUeV	TYPE
002 Reduktion	G 1 1/4" - G 3/4"	REDUCTION
mit Dichtung	zu Pos. 001	WITH JOINT
Best. Nr.	107353-00238 / 101009-00038	ORDER NO.
003 Befestigungs-Schelle	Ø114	CLAMPLING STRAP
Best. Nr.	200.570-04725	ORDER NO.
004 Entlueftungsschr.	M5	VENT SCREW
mit Dichtung	Best. Nr. 200594-01200	WITH JOINT

Lieferant/SUPPLIER : OLAER (SUISSE) S.A Bonnstr. 3, CH-3186 Duedingen

SURFACE PROTECTION SEE GROUP 0344
GENERAL TOLERANCES ACCORDING TO ISO/2768-m

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Modifications	Number	Date
a	Pipa	07.09.84
b	7-14.418	10.11.99

Q-Code X R X X X | Substitute for | Scale 1:5, 1:1

Engine type: RTMOT	Blasenspeicher Bestellzeichnung BLADDER ACCUMULATOR ORDER DRAWING	Drawn: Heydecker 11.02.83 Pipa 24.02.83 Wartsila NSD Switzerland Ltd CAD
Design group: 9715 (ISO / JIS)	3-107.165.813	Page:

WÄRTSILÄ NSD CORPORATION

18.8 Fire protection

Fires may develop in areas such as under-piston spaces and scavenge air receiver. The engine is fitted with a piping system which leads the fire extinguishing agent into the mentioned areas.

Where fire protection is required, the final arrangement of the fire extinguishing system is to be submitted for approval to the relevant classification society.

18.8.1 Extinguishing agents

Various extinguishing agents can be considered for fire fighting purposes. Their selection is made either by the shipbuilder or the shipowner in compliance with the rules of the classification society involved. Table gives the recommended quantity of 45 kg bottles of Carbon dioxide [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)

NOTICE

Steam is not suitable for fire extinguishing under-piston spaces, as this 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.

Recommended total number of fire extinguishing bottles					
No. cyl.	Extinguishing medium	Piston underside at bottom dead centre including common section of cylinder jacket		Bottle	
		Volume [m³/cyl.]	Mass [kg/cyl.]	Size [kg]	Qty
5	Carbon dioxide [CO_2]	1.6	6	45	1
6					1
7					1
8					2

Table 18.3: Recommended total number of fire extinguishing bottles

19. Engine Emissions

The International Maritime Organisation (IMO) is a specialized agency of the United Nations (UN), dealing with technical aspects of shipping. For more information see **http://www.imo.org**.

19.1 Exhaust gas emissions

19.1.1 Establishment of emission limits for ships

In 1973 an agreement on the 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, 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, resulting 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 until 2020.

19.1.2 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.

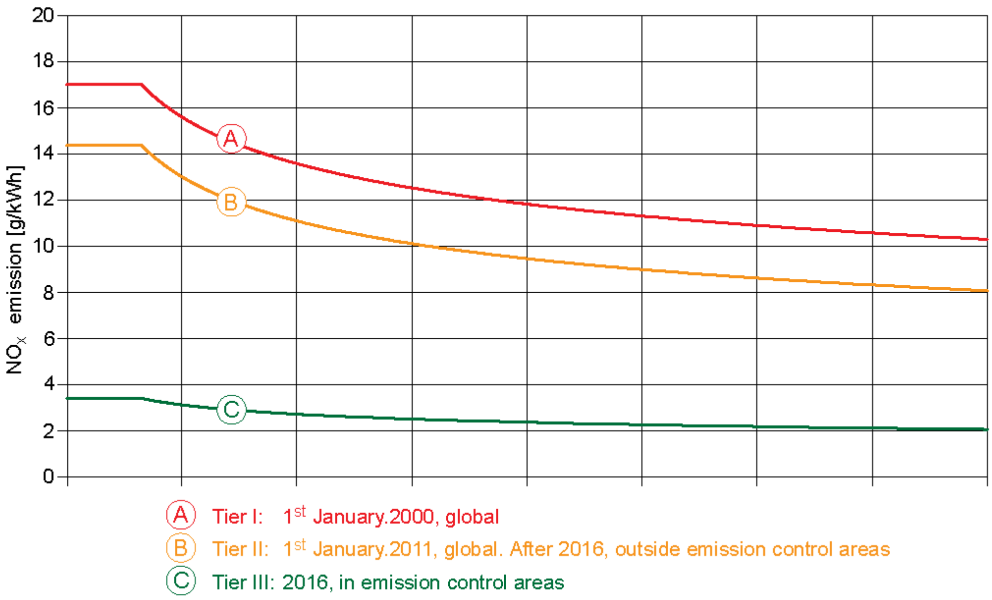


Figure 19.1: Speed dependent maximum average NO_x emissions by engines

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.

19.1.3 Measures for compliance with the IMO regulation

In the whole rating field, the IMO regulation is fulfilled by use of the Low NO_x Tuning concept as shown in figure *19.2*. No extended measures are necessary.

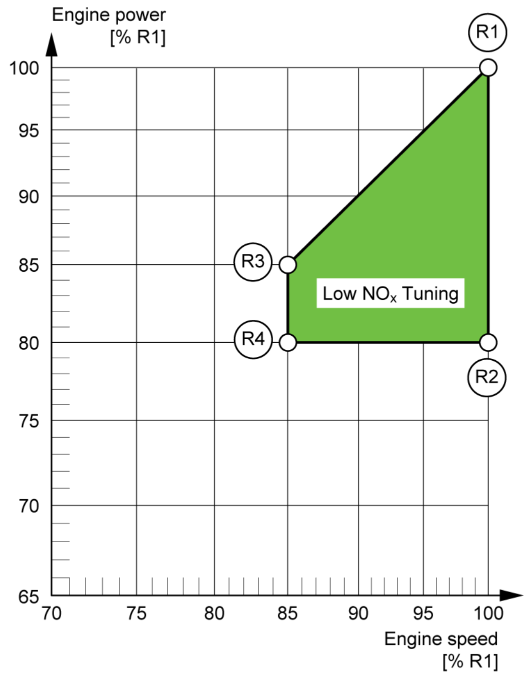


Figure 19.2: Compliance with IMO regulations

20. Engine Dispatch and Installation

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.

20.1 Treatment against corrosion

⚠ WARNING

Refer to document 4-107.426.585 (see attachment in section 'Drawings' of this chapter).

20.1.1 Drawings

GUIDELINE FOR ENGINE PROTECTION AFTER SHOP TEST

-	7-77.252	27.10.09							Replaced by:
									Substitude for:

WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTA / RT-flex	GUIDELINE FOR ENGINE PROTECTION AFTER SHOP TEST		Group 0345
	Drawn: K.Luethi 27.10.09 Verify: B.Schumacher 27.10.09	H	4-107.426.585	1 / 70

WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTA / RT-flex	GUIDELINE FOR ENGINE PROTECTION AFTER SHOP TEST		Group 0345
	Drawn: K.Luethi 27.10.09 Verify: B.Schumacher 27.10.09	H	4-107.426.585	2 / 70

WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTA / RT-flex	GUIDELINE FOR ENGINE PROTECTION AFTER SHOP TEST		Group 0345
	Drawn: K.Luethi 27.10.09 Verify: B.Schumacher 27.10.09	H	4-107.426.585	3 / 70

2.0 Introduction

This document is an overview guide line for the application of corrosion protection coating after shop test of RTA and RT-flex engines as also for temporally undetermined storage at shipyard / final destination.

For the corrosion protection of the engine and its parts, as well as for the treatment of the cooling water circuits during engine assembling and shop test, the specification 107.215.543i and its amendments are still valid.

The way of application might differ and depend on the expected or agreed engine storage period and the conditions at final destination.

There are normally 3 different timeframes to which the coating thickness as also the regular main inspection intervals are referring.

- normal period storage (up to 6 months)
- long period storage (6 – 12 months)
- undefined period of storage due to unpredictable postponement of ship project (over 12 months)

This guide line covers re-coating after the shop test, as during final assembly of the engine parts and even more during engine running, most of the protective coating will have been flushed away.
Therefore a proper re-coating after shop test is crucial.

It was chosen to divide this document in various chapters and sub-chapters in order to have separate steps, thus not losing the principal information by overloading the chapters.

3.0 Responsibility

The orderer specifies the duration of protection and the special requirements for transport and storage.
The engine manufacturer will be responsible that the specified corrosion protection is executed with care and that packaging is carried out in a professional manner.

Reliable preservation is assured if the drying time of the applied coating is observed and the processes and products described in the following are properly applied.

As transition area of taking over the responsibility for further proper storage and corrosion preservation of the engine, the chapters
9.0 - Final inspection before delivery (at engine maker)
&
11.0 - Inspection upon arrival (at shipyard)
and their sub-chapters have been written.

The manufacturers' specifications and safety sheets for these cleaning and coating products must be strictly observed. Other processes and products may be applied if they meet the specified requirements.

Wärtsilä Switzerland Ltd. will not accept any liability or responsibility for damage to the engine and its parts which is or has been sustained due to the none-observance of these preserving instructions, e.g. due to insufficient preservation, unsuitable storage or damaged preservation material.
Moreover, Wärtsilä Switzerland Ltd will not accept any liability for preservation measures that are carried out by the manufacturer or a third party.

It is in any case the responsibility of the orderer to check the engine and its parts for any corrosive damage promptly upon arrival.
Unless agreed differently in the purchase contract, any claim due to corrosion damage of the engine and its parts has to be made in writing to Wärtsilä Switzerland Ltd. within two weeks from the arrival of the engine and its parts to the final destination defined in the purchase contract.
Any claim made after the two weeks' notice period shall not be taken into account.
The orderer shall be responsible for the preservation of the engine and its parts for further transport and final storage.

4.0.0 Reason for proper corrosion protection

To give you an impression of corroded parts, respectively the possible or impossible access for repairing or replacing of them, the following short extract of pictures will illustrate the reasons for proper corrosion protection.
Without access by crane, available normally just in engine room condition, or proper storage warehouse, no proper repair or replacement work of heavy parts can be done!

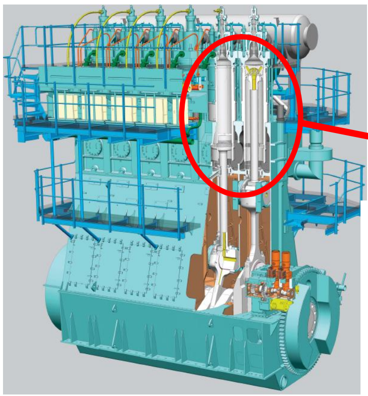
WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTA / RT-flex	GUIDELINE FOR ENGINE PROTECTION AFTER SHOP TEST		Group 0345
	Drawn: K.Luethi 27.10.09 Verify: B.Schumacher 27.10.09	H	4-107.426.585	5 / 70

4.0.1 Consequences for fully assembled engines on store side

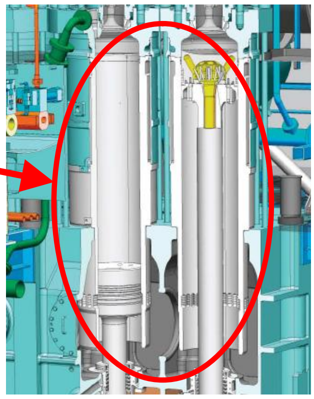
As e.g. the pistons and cylinder liners can be checked only through the scavenge air ports, a cleaning and possible recovery of the parts at time will not be possible. Further corrosion leads to such kind of material pitting that the parts must be exchanged at a later stage.

Heavily corroded: Cylinder liner and piston crown. At last the parts could be pulled or reached to be cleaned and judged for further procedure (replacement).

Repaired (cleaned of upper rust layer) cylinder liner (above) and piston crown (below) surface revealed that the pitting had been so heavy that the parts had to be replaced.



Situation of parts access without crane available



Situation of cyl.liner & piston crown in fully assembled condition.

Be aware: These are just samples !

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5.0.0 Range of application: Engine delivery condition

The intention of this chapter is to give an overview of different ways and engine stages the corrosion protection, the transport and the storage will be done, as this will affect either the way of corrosion protection application and even more the storage capabilities and additional re-coating work, which are required for long-term storage and unpredictable engine storage-time respectively.

Mainly for reasons of different crane capacities as also engine sizes either at engine maker or at shipyard, there are three different conditions of engine delivery:

- See 5.0.1 : Engine delivered in fully assembled condition.
- See 5.0.2 : Engine delivered in 3 major components (bedplate with crankshaft, column, cylinder jackets with cylinder liner installed).
- See 5.0.3. : Engine fully dismantled after shop test.

5.0.1 Engine delivered in fully assembled condition

Engine delivered in fully assembled conditions.

Engine stored in a tent-like warehouse.

Engine stored outside and covered with a waterproof tarpaulin.

- It is recommended to install dehumidifiers for transportation already.
It has to be assured that they are connected electrically at board side.

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5.0.2 Engine delivered in 3 pre-assembled major parts

In general it has to be mentioned that the storage of single parts, even major parts like bedplate with crankshaft, column with platforms as well as the cylinder jackets and all additional parts like pistons, connecting rods, etc. can be done with less expense of time and work if the protection and packing of the parts was properly done beforehand. Dehumidifiers have to be placed at each single major part.

Bedplates (2 parts) with crankshaft (in front) and column with fuel pumps (behind)

Cylinder jackets with scavenge air receivers

Connecting rods at cleaning stage at ship-yard. The sea-trial date is fixed.

Cylinder liners at cleaning stage at shipyard.

Main pistons and cylinder covers (still covered and exhaust cage closed by plate)

Turbocharger prepared (openings closed by wooden plates)

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5.0.3 Engine delivered in 3 pre-assembled major parts & crankshaft delivered separately

It might occur quite often that the crankshaft has to be dismantled after shop test.
This is mostly the case with bigger bore engines RTA/RT-flex 82; RTA/RT-flex 84; RTA/RT-flex96, but it might also be required for small bore engines. The principal reason is the crane load capacity either at engine maker or at the shipyard.

5.0.4 Engine delivered fully disassembled

Engine fully dismantled after shop test: All parts have been cleaned, protected and covered properly (bedplate, crankshaft, column, cylinder jacket as single components); all platforms and pipes are dismantled, all other parts like cylinder covers and exhaust valves, pistons, cylinder liners, connecting rods, crossheads and so on are packed and protected in wooden boxes.

Example of connecting rod with crosshead at transport packaging stage.
Stored outside just after arrival at shipyard.

6.0.0 Climatic conditions for: Cleaning – Coating – Storage

As the many different climatic conditions are one of the major impacts in relation to the applicable corrosion protection work, this issue has to be clarified more closely.

- High humidity conditions with humidity values as high as 80-85% over nearly the whole year on the one hand,
  and the corrosion protection liquid properties on the other hand,
  implicate the recommendation of preferably low humidity values, as otherwise the fast accretion of moisture on the blank surfaces will complicate any proper procedure.

  Therefore Wärtsilä Switzerland Ltd. recommends the a relative humidity value below 50% in general.

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6.0.1 For cleaning of machined surfaces – parts in general; before coating

The cleaning work has to be carried out in a well-ventilated room at a temperature between 15˚C (min) and 35˚C (max.). The relative humidity should be less than 50%.

6.0.2 For application of corrosion protection

The cleaning work has to be carried out in a well-ventilated room at a temperature between 15˚C (min) and 35˚C (max.). The relative humidity should be less than 50%.

6.0.3 For storage of engine or engine parts

The engine and its parts must be stored in well-ventilated rooms at a temperature between 15˚C (min) and 35˚C (max.). The relative humidity should be less than 50%.

7.0.0 Draining & cleaning of engine parts after shop test

The procedure described in this chapter has to be carried out hand in hand with chapter 8, taking into account that all painting work (coating of primer & top layer) has been done properly before engine assembly.

The application of corrosion protection has to be checked and renewed on all machined/blank surfaces, as the corrosion protection may be flushed due to the temperatures reached during engine running for shop test, or has melted away during the shop test itself or scraped away during assembly.

As general summary of this chapter 7, the following rule has to be considered stringently:

The clean and dry condition of the machined/blank surfaces is of outmost importance for a proper application of corrosion protection, as the adhesion of all applicants will be as good as cleaning and drying work was performed!

To accelerate the drying time, heaters with dry air fans for heating up the engine interior can be considered.
A heat venting system is probably even more useful in connection with drying of all water pipes and/or water cooling spaces.
Connection flanges at the transition between the venting system and the piping/ cooling spaces might be especially useful, as flange connections are easily adaptable to different engine sizes by the mere use of additional adaptors.

All parts which have been affected by carbon deposits during engine running have to be cleaned carefully, otherwise the carbon deposits will harm the parts, as there remains sulphuric acid which corrodes the material very much in connection with the long period of standstill.

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7.0.1 General preparations

- Heaters with dry air fans for heating up the engine internal can be considered due to the amounts of solvents as well as of the corrosion protectors used during a production year, and also to accelerate the drying time, in order to obtain a beneficial economical and environmental effect (one work carried out once) for the engine preservation work.

- A heat venting system is probably even more useful in connection with drying of all water pipes and/or water cooling spaces (see also 7.0.6).

- Connection flanges at the transition between the venting system and the piping/ cooling spaces might be especially useful, as flange connections are easily adaptable to different engine sizes by the mere use of additional adaptors.

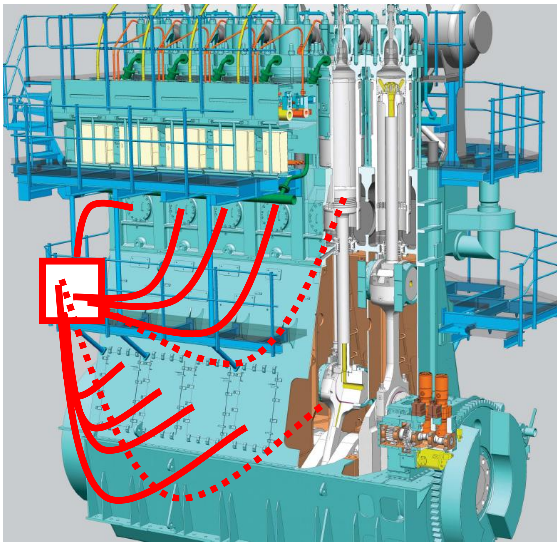
The engine maker and probably also the shipyard(*) should take the following into account:

(*)= For the shipyards this might be interesting by reason of unpredictable anchoring of ships after sea-trails due to re-arranged final ship-delivery or other force majeure reasons.

As the cleaning-, and much more, the drying work after a shop test can be of a dangerously annoying stimulus due to the fact that especially the oil will flow time and again over already cleaned surfaces, or, as in our case, over machined/blank surfaces, a fast heating and drying-up of the crankcase as well as of the piston underside by a heating fan system should be considered just after shop test.

A thickened oil film is much easier and faster cleaned with much less solvent. Likewise the thickened oil will not flow quickly again over the surfaces cleaned/prepared for corrosion protection.

Sample of hose connection of dehumidifier system.



Heating fan with multi-connectable hose system & adaptable flange connectors.

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7.0.2 Tools & materials to be used for cleaning

The following tools and products are to be used for cleaning work in general:

- Acid-free cotton cloth
- Paper towels
- Wooden or plastic spatula/scraper
- Airgun or airless spray unit (see chapter 15..2.3)
- White spirit (e.g. Shellsol : see chapter 16.0.1)
- Petroleum
- Kerosene

NOT to be used under any circumstances:

- Metallic scraper

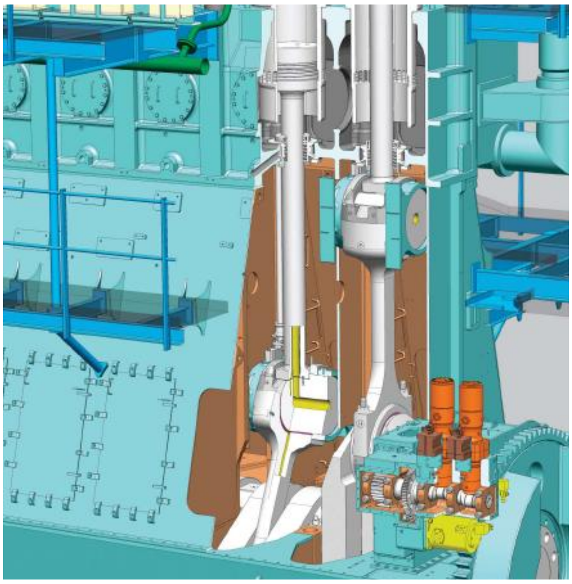
7.0.3.0 Crankcase – drying & cleaning

The crankcase can be cleaned and dried in usually three different engine stages:

- **7.0.3.1 Engine fully assembled**
- **7.0.3.2 Engine dismantled in 3 major parts** (bedplate with crankshaft)
- **7.0.3.3 Engine dismantled in 3 major parts** (bedplate without crankshaft)

7.0.3.1 Engine fully assembled

The engine will not be dismantled for transport and installation at shipyard.
All engine internal parts have to be dried and cleaned after shop test.



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The cylinder covers and the pistons have been removed for their cleaning and corrosion protection work!

All engine internal parts have to be dried and cleaned after shop test.

Either of system oil, like

- piston cooling oil
- crosshead lubrication
- main bearing lubrication
- servo oil rail
- servo oil pumps (Supply Unit)
- Turbocharger lubrication
- all pipe circuits belonging either to the ingoing or outgoing of fluid flow,

or of water residues/deposits of the cooling water system, like

- cylinder liner cooling space
- cylinder cover & exhaust valve cage
- scavenge air receiver/cooler spaces
- all pipe circuits belonging either to the ingoing or outgoing of fluid flow,

or of air of the starting air- or control air system, like

- starting air shut-off valve
- starting air distributor
- starting air valve at cylinder cover
- all pipe circuits belonging either to the ingoing or outgoing of fluid flow,

or of fuel, like

- Injection Control Unit (ICU) - RT-flex engines
- fuel rail
- fuel pumps
- all pipe circuits belonging either to the ingoing or outgoing of fluid flow.

All engine external machined surfaces and/or parts have to be cleaned and dried.

For all machined surfaces a cleaning solvent/white spirit should be used. See 16.1.2.

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7.0.3.2 **Engine dismantled in 3 major parts** (bedplate with crankshaft)

Column at cleaning stage. Cleaning solvent (white spirit) is used.

Cylinder jacket at cleaning stage. Cleaning solvent (white spirit) is used.

7.0.3.3 **Engine dismantled in 3 major parts** (bedplate without crankshaft)

Bedplate delivered as single part

Crankshaft delivered as single part. Already cleaned of corrosion protector by solvent and ready for bedplate assembling. Crank-throw journals protected with rubber and steel plates (8mm thick).

Crankshaft under cleaning / removing work of corrosion protection.

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7.0.4 Main bearings & thrust bearing pads dismantled

If the crankshaft is delivered as single part, also the main bearing shells and bearing covers as well as the thrust bearing pads are to be removed from the bedplate.
Carefully clean them with Shellsol / white spirit.

7.0.5.0 Crankshaft delivered as single part

This chapter describes the handling of the separately delivered crankshaft.

7.0.5.1 Crankshaft cleaning

- Thorough manual cleaning of the entire crankshaft surface with acid-free cotton cloth (no rags), paper towels and clean solvent, e.g. white spirit, Shellsol or a similar product.
- Flushing of all bores with clean solvent.
- **Important:** From this moment the crankshaft must not be touched with bare hands anymore!
- Allow the crankshaft to dry completely.
- Check whether clean and free of rust. Do not touch the cleaned surfaces with bare hands.
- If there are signs of rust, the quality assurance department will decide whether additional work is necessary. If the traces of rust are only slight, they can be removed with emery cloth No. 220 (or finer) and petroleum. Repeat cleaning!

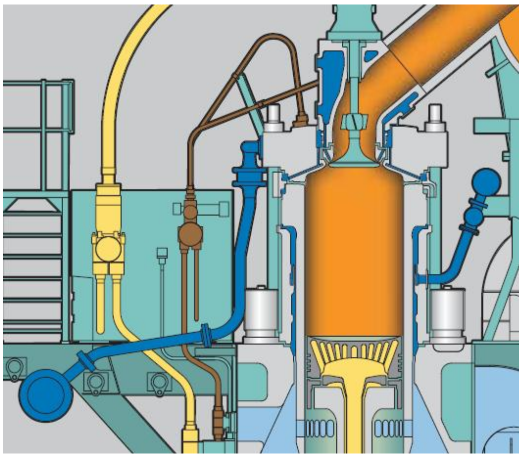
7.0.6 Cylinder liner & scavenge air cooler: cooling water system
(Cylinder liner – scavenge air cooler – piping for water circulation on engine)

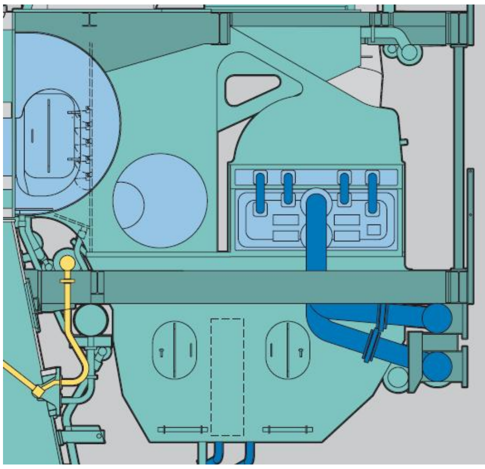
- Make sure that the cooling water circuits have been treated properly by adding a water inhibitor during engine running.
  (water inhibitors see chapter 16.0.2)

- The cooling water must be drained and dried. It is recommended to blow warm, pre-dried air through the pipes. The cooler has to be sufficiently vented.

or:

- Drain the water from cylinder liner & scavenge (charge) air cooler when the engine is still warm after shop test (around 60˚C).





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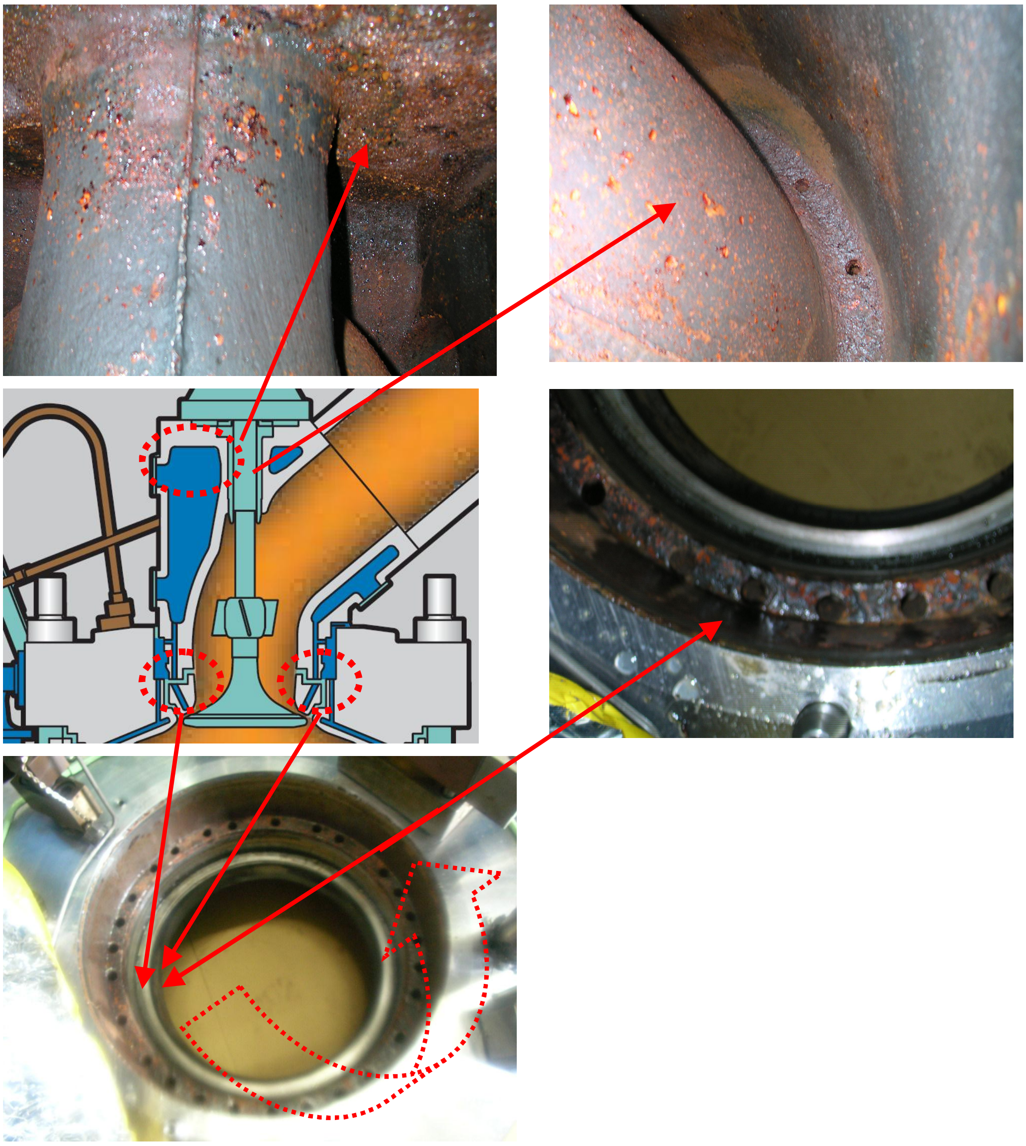
7.0.7 Consequences

The non-use of proper water inhibitors and soluble oil for proper corrosion protection will lead to severe corrosion, mostly in water cooling spaces which are not traced without additional inspection regulations/requirements. The pictures/sketches below are for reference only.



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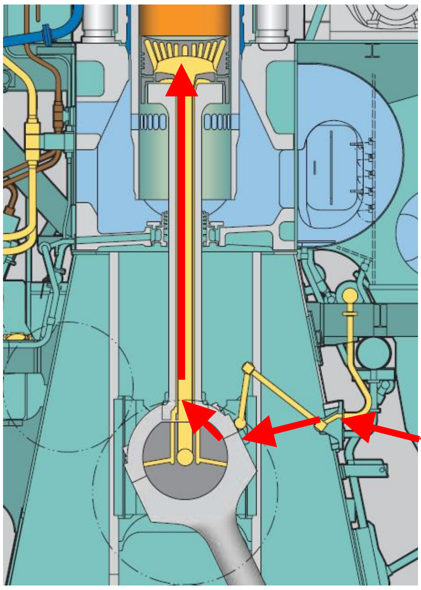
7.0.8 Cylinder liner & piston

If the engine is not dismantled, make sure that also the piston inner parts, like spraying plate with nozzles, as well as the piston inside itself are protected in a practicable way. This could be achieved by using either the piston cooling pipe system or the flange connections for lever.

- Piston dismantling after shop test:
After shop test, mainly the piston crowns, the piston rings and probably the piston ring grooves are to be cleaned of combustion residues.
- Gland box piston rod: To be opened and properly cleaned of carbon and dirt oil deposits.

- Cylinder liner dismantling after shop test:
It has to be determined whether the cylinder liners will be dismantled after shop test. The cylinder liners can be cleaned still assembled to the cylinder jacket, as also the pistons will have to be dismantled.



If the engine is not dismantled, make sure that also the piston inner parts, like spraying plate with nozzles, as well as the piston inside itself are protected in a practicable way.

This could be achieved by using either the piston cooling pipe system or the flange connections for lever.

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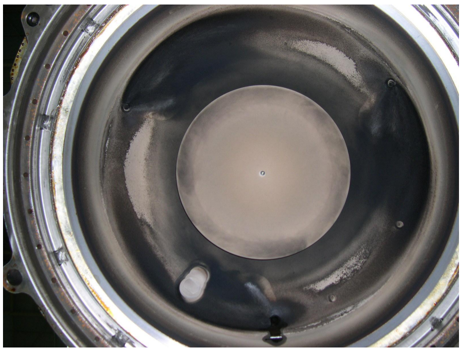
7.0.9 Cylinder cover

After shop test, the cylinder covers will have to be dismantled to clean the combustion residues in the combustion chamber as well as the exhaust cage. Drain the cooling water carefully (check exhaust cooling water space) and use warm/heated-up air if necessary.



Combustion chamber with carbon deposit after shop test.

Combustion chamber after cleaning.

7.1.0 Starting- & control air system

7.1.1 RTA Engine

- ❑ Drain the complete starting air system including air spring.
- ❑ Drain the complete control air system.
- ❑ Remove all starting air valves, open them, clean all parts, oil the parts slightly with rust protection oil and reassemble them.

  Option 1
  The starting air valves can be refitted in the engine after overhaul.

  Option 2 (recommended)
  The starting air valves can also be kept separate from the engine. In this case the starting air valves should be stored in a dry place, well preserved and packed in VCI (Vapour, Corrosion, Inhibitor) paper. Note that the openings in the cylinder covers need to be closed air-tight with steel flange covers (draft prevention).

- ❑ Dismantle the shut-off valve for starting air, clean all parts and oil them with rust protection oil. Afterwards the valve can be refitted in closed position.
- ❑ Remove the end cover of the main starting air pipe and place silica gel desiccant bags inside. Afterwards refit the cover (as a precaution a marking must be applied outside to indicate that a silica gel desiccant bag has been stored inside).

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- ❑ Overhaul the starting air distributor, extract the bushes and sleeves. All parts need to be cleaned and oiled before refitting. When extracting the valves, the air spaces of the housing can be cleaned and spray protected. The distributor control cam should be checked and spray coated as well.

7.1.2 RT-flex Engine

- ❑ Drain the complete starting air system including air spring.
- ❑ Remove all starting air valves, open them, clean all parts, oil the parts slightly with rust protection oil and reassemble them.

Option 1
The starting air valves can be refitted in the engine after overhaul.

Option 2 (recommended)
The starting air valves can also be kept separate from the engine. In this case the starting air valves should be stored in a dry place, well preserved and packed in VCI paper. Note that the openings in the cylinder covers need to be closed air-tight with steel flange covers (draft prevention).

- ❑ Dismantle the shut-off valve for starting air, clean all parts and oil them with rust protection oil. Afterwards the valve can be refitted in closed position.
- ❑ Remove the end cover of the main starting air pipe and place silica gel desiccant bags inside. Afterwards refit the cover (as a precaution a marking must be applied outside to indicate that a silica gel desiccant bag has been stored inside).

7.1.3 Fuel injection system

7.1.4 Fuel injection valve RTA & RT-flex engines

All fuel injection valves are to be overhauled according to the instructions given in the Maintenance Manual. It is recommended to flush the overhauled fuel injection valves on a test bench using a special calibration fluid (for corrosion protection reasons no MDO should be used). After flushing the injection valves the tension of the springs should be released. The openings at the cylinder cover are to be sealed air-tight.

7.1.5 RTA Engine – Fuel pump

To achieve the highest level of corrosion protection for the RTA fuel injection components, it is recommended to drain the MDO from the fuel system. The fuel inlet and outlet lines need to be closed. After dismantling the delivery valve, the fuel pump block can be filled with rust-preventing engine oil. Note that during filling up of the fuel pump block the spill and suction valves should be manually lifted in order to fill the complete fuel pump block. The oil level needs to be checked from time to time and if necessary oil has to be replenished.

- ❑ After the engine has been shut down on MDO, drain the complete fuel system.
- ❑ Overhaul the fuel cocks in the inlet and outlet lines. Afterwards reassemble them in closed position.
- ❑ Remove the delivery valve and fill the fuel pump block manually with rust-preventing engine oil.
- ❑ All open ports, adapters, pipes, etc. need to be preserved against corrosion and sealed in order to prevent ingress of foreign particles.
- ❑ Clean and then spray coat the fuel pump blocks and moving parts (springs, pushrods, etc.) with rust-preventing engine oil.
- ❑ Lubricate the fuel linkage including the spring link on the eccentric shaft.

7.1.6 RTA Engine – Camshaft housing

- ❑ Clean and then spray coat the camshaft, bearing cover rollers, roller guides, etc. with rust-preventing engine oil.

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- ❑ For transport and storage of the engine, the fuel pumps as well as the exhaust valve actuators have to be cut out under any circumstances. Not doing so will harm the rollers and cams.

7.1.7 RT-flex Engine

To achieve the highest level of corrosion protection for the RT-flex fuel injection components it is recommended to drain the MDO from the fuel system and to remove the ICUs from the engine. Afterwards the fuel rail and the intermediate accumulator including the fuel pumps need to be filled with system oil or special rust-preventing engine oil.

Fuel pump

In general the fuel pumps can be left in place during the transport / storage. However, some special measures are required to protect them against corrosion. To guarantee lubrication and preservation of the internal parts, the non return valve bodies including compression springs inside the fuel pump need to be removed.
Note that the non return valves bodies should not be interchanged; therefore they have to be marked for correct positioning during re-installation.

- ❑ After the engine has been shut down on MDO, drain the complete fuel system including low pressure circuit, intermediate fuel accumulator and fuel rail.
- ❑ Close the valves in the fuel inlet and return lines (low pressure circuit).
- ❑ Clean the fuel pump from outside and protect all blank parts.
- ❑ Lubricate the fuel regulating linkage including regulating rack.
- ❑ All open ports, adapters, pipes, etc. need to be preserved against corrosion and sealed in order to prevent ingress of foreign particles.

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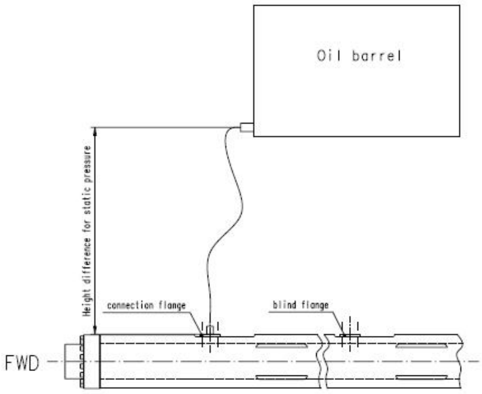
7.1.8 RT-flex Engine – ICU, IFA, Fuel Rail

All ICUs need to be removed from the engine; depending on the number of running hours it should be considered to send them to a Wärtsilä reconditioning workshop for overhaul. If the ICUs are not due they must be stored in an oil bath during the lay-up period. The openings on the fuel rail need to be sealed with blind flanges so that the fuel system can be completely filled with system oil or special rust-preventing engine oil.

1. After the engine has been shut down on MDO, make sure that the whole fuel system including low pressure circuit, intermediate fuel accumulator and fuel rail is completely drained.
2. Clean all ICUs as well as possible from outside.
3. Remove all rail valves and fuel quantity sensors from the ICUs. Preserve the fuel quantity sensors and rail valves and store them in a dry place.
4. Remove all ICUs from the engine and store them in an oil bath for corrosion protection. As soon as the ICU is in the oil bath, it is recommended to move the fuel quantity piston by manually carrying out a few strokes.
5. Blank off all openings on the fuel rail with blind flanges, except the one on the forward side. There a flange with a connection needs to be installed to supply oil into the fuel rail.
6. Blank off the control oil supply to the ICU to allow operating the control oil pumps.
7. Fill the fuel rail including rising pipes, intermediate accumulator and fuel pumps with system oil or special rust-preventing engine oil. As soon as the fuel system is completely air-free filled with oil, a small tank (oil barrel) can be connected to compensate slight leakages during the storage.

Additional lubrication oil tank connected to the fuel rail to keep it under constant static pressure.



Flange for oil supply to fuel rail and blind flange.

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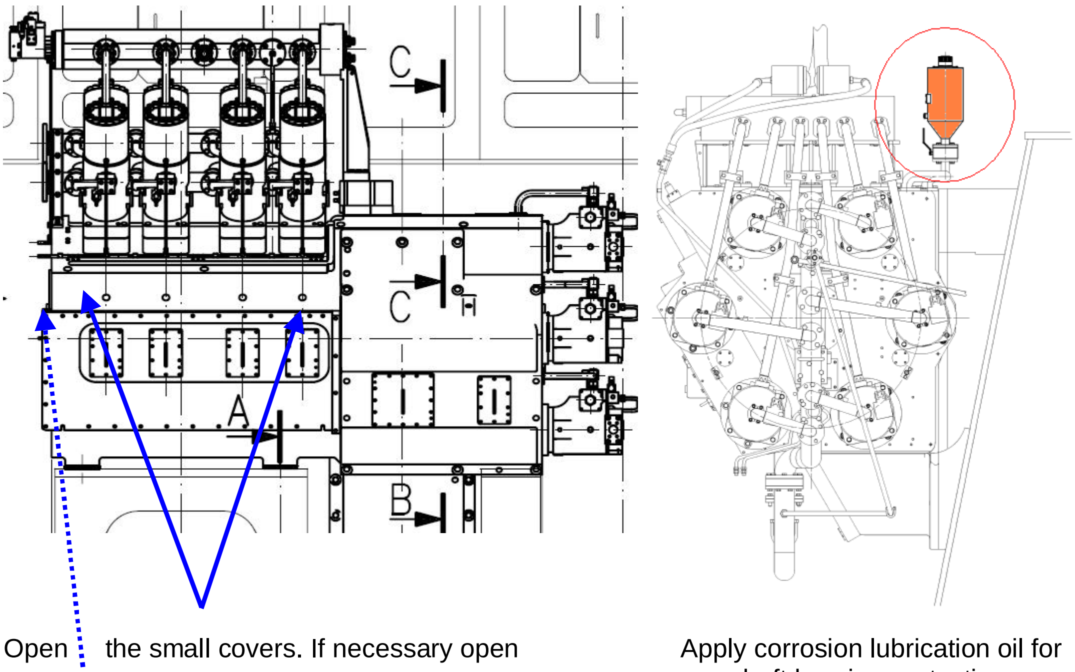
8. Check if the fuel pumps are filled with oil. Drain them if necessary.

7.1.9 Supply Unit

- Clean and then spray coat the camshaft, bearing covers rollers, roller guides, etc. with rust-preventing engine oil.



Open the small covers. If necessary open the bigger cover for corrosion protection application.

Apply corrosion lubrication oil for camshaft bearing protection as also as bearing lubrication for during engine turning.

8.0.0 Corrosion protection of machined surfaces / engine parts

The application of corrosion protection has to be checked and renewed on all machined/blank surfaces, as the corrosion protection may be flushed due to the temperatures reached during engine running for shop test, or has melted away during the shop test itself or scraped away during assembly.

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8.0.1 Overview of the general application range

For exposed parts (engine external), the following description of layer application might be used as “general guidance” regarding corrosion protection application.
(e.g. starting air distributor, manoeuvring linkage, camshafts for RTA engines,
RTA fuel pump block, etc.)

Apply a first layer of ”Tectyl 506” to all surfaces using an airless spray unit.
Allow to dry for at least 5 hours at 10°-20°C (3 hrs at 20°-25°C; 2 hrs at >25°C).

A second coating of ”Tectyl 506” must be applied to all surfaces, with the exception of the webs, using an airgun . Do not touch this coating. Allow to dry for at least 36 hours at 10°-20°C (24 hrs at >20°C).

A coating of ”Tectyl 132” must be applied to all crankshaft surfaces by means of an airless spray unit. Allow to dry for at least 36 hours at 10°-20°C (24 hrs at >20°C).

8.0.2 Application of the corrosion protectors / coating

The climatic properties have been described under 6.1.2.
To avoid the accretion of moisture on blank surfaces, the components must show room temperature during the work.
The coating must be applied straight after cleaning to the dried surfaces.
For the recommended coating materials with details of their application see pages 10 to 12.
The supplementary product specifications for the coating materials must be strictly observed.

8.0.3 Checking the quality of the coating

The inspection of the dry coating is made non destructively according to the magnetic-induction method, e.g. with the measuring device "Minitest".
The adhesion of the coating is to be checked with a cross-cut test according to DIN 53 151 (Code GT 1). The damaged coating resulting from this inspection is to be ground over and applied anew.
In case of non-fulfilment of the quality standard, the manufacturer's quality assurance department will decide whether further inspections are necessary and if the coating should be renewed.

8.0.4 Coating & corrosion protection of the components – General information

The different surface protection measures are listed in the table "Coatings and corrosion protection general". The components and surfaces are shown in groups, thus allowing to be treated by the manufacturers in a corresponding manner.

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8.0.5.0 Crankshaft corrosion protection at engine shop

8.0.5.1 Preservation for indoor and temporary storage

- The crankshaft must be free of rust, cleaned thoroughly as instructed in para. 7.0-5.1, and not have been touched since. If this is not fulfilled, repeat cleaning according to 7.0.5.1.
- Flush oil bores, threaded holes etc. with ”Dewatering Fluid WA” or "Anticorit DFW" and allow to dry completely (min. 5 hrs at 10° to 20°C; min. 3 hrs at 20° to 25°C; 2 hrs at >25°C).
- Close the bores, threaded holes, etc. with plastic protective plugs (do not use wooden pegs). These protective plugs are not to be removed until just before the crankshaft is fitted in the engine.
- Using an airgun, dewater and neutralize all surfaces with ”Dewatering Fluid WA” or "Anticorit DFW". Do not touch the surface. Allow the waxy protective film to dry for at least 5 hours at 10°-20°C (3 hrs at 20°-25°C; 2 hrs at >25°C) prior to further treatment. It is mandatory to keep to the drying time! The protective film must be touch proof (however, not to be touched with bare hands!). In case of **insufficient** drying, the adhesion of the subsequent coatings is not assured.

- Apply a first layer of ”Tectyl 506” to all surfaces with an airless spray unit. Allow to dry for at least 5 hours at 10°-20°C (3 hrs at 20°-25°C; 2 hrs at >25°C).

- A second coating of ”Tectyl 506” must be applied to all surfaces, with the exception of the webs, using an airgun. Do not touch this coating. Allow to dry for at least 36 hours at 10°-20°C (24 hrs at >20°C).

Duration of protection: indoor storage max. **12** months. Insulation protection must be guaranteed.
Before the storage time expires, the preservation must be removed and the crankshaft checked for signs of rust. Afterwards the preservation is to be applied again.

8.0.5.2 Preservation of crankshafts for land and sea transport

After corrosion treatment, the crankshaft is to be preserved further prior to shipment.
Any dust or layers of dirt are to be removed with dry compressed air or with clean cloths.

- Apply a first layer of ”Tectyl 506” to all surfaces with an airless spray unit. Allow to dry for at least 5 hours at 10°-20°C (3 hrs at 20°-25°C; 2 hrs at >25°C).

- A second coating of ”Tectyl 506” must be applied to all surfaces, with the exception of the webs, using an airgun. Do not touch this coating. Allow to dry for at least 36 hours at 10°-20°C (24 hrs at >20°C).
- A coating of ”Tectyl 132” must be applied to all crankshaft surfaces by means of an airless spray unit. Allow to dry for at least 36 hours at 10°-20°C (24 hrs at >20°C).

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Duration of protection: indoor storage max. **12** months, outdoor storage max. **6** months
Insulation protection must be guaranteed.

8.0.5.3 Additional mechanical protection of the crankshaft pins for open transport

The journals and pins must be wrapped with the following materials:

- one layer of VCI paper (Volatile Corrosion Inhibitor)
- two layers of polyethylene foil
- one layer of Ethafoam foil, 5 mm thick (must not absorb water)
- three layers of Lamiflex laminae
  All layers are to be fixed with chlorine-free adhesive tape.

To avoid damage to the mechanical protection and the preservation material during lifting, the journals are to be protected as follows:
steel shells with a thickness of at least 8 mm are to be fitted.

Instructions to the effect "Do not lift here" are to be posted on all other pins and journals.

- Supplier information :
  Lamiflex lamellae
  Lamiflex AB
  Gasverksvägen 4-6
  611 35 Nyköping - Sweden
  www.lamiflex.se

8.0.5.4 Additional mechanical protection of the axial surfaces of the thrust bearing flange

- one layer of VCI paper
- two layers of polyethylene foil
- one layer of Ethafoam foil, 5 mm thick
- plywood, 20 mm thick

8.0.5.5 Mechanical protection of crankshafts for transport in boxes

The crankshaft is to rest on the webs .To avoid damage to the preservation material during lifting, the corresponding journals are to be protected with thick and reinforced rubber.

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8.0.5.6 Packaging

The engine maker is responsible for proper packaging.
The crankshaft must rest on the webs, whatever the kind of transport.
The surfaces of wooden supports must be treated in advance with a **neutralising preservation product**.

8.0.5.7 Removal of the preservation material prior to fitting and for inspection purposes

The corrosion protective products can be removed manually with acid-free cotton cloth soaked with petroleum or aromatic-free white spirit. A proven method is to wrap the bearing journals concerned in acid-free cotton cloths, which are then dowsed with a solvent, such as white spirit or Shellsol (for lack of solvents use diesel oil). After a sufficient application time (min. 1 hour), the cloths may be removed. The preservation layers can now been scraped off by means of a wooden spatula. **Attention:** metallic scrapers or other means, such as steam- or hot water cleaners, must not be used!
The preservation must be checked before the expiration of the duration of protection and, if necessary, renewed.

8.0.6.0 Corrosion protection of cooling water circuits

(Cylinder liner – scavenge air cooler – piping for water circulation at engine)

As the cooling water will be drained off after shop test, further treatment against corrosive attack is absolutely essential, i.e. the admixture of a so-called ‘soluble oil’ to the cooling water in order to protect the engine cooling water system. The concentration must be maintained at levels between 0.5 and 0.8 per cent by volume. Prior to the complete shut-down of the system, 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.

Attention: The application of soluble oil might be just of helpful use, if the storage period is predicted as being very long (over 12 months). The reason is that the water circuits would have to be flushed at shipside after installation, before being finally connected to board circuit.
If the water circuits - especially the one for cylinder liners and cylinder cover cooling spaces with the cooling bores in the cylinder liner as well as the one in the cylinder cover - and exhaust valve cooling circuit are not flushed, the soluble oil foam, in connection with dust, will lead to clogging of the beforehand described cooling bores.

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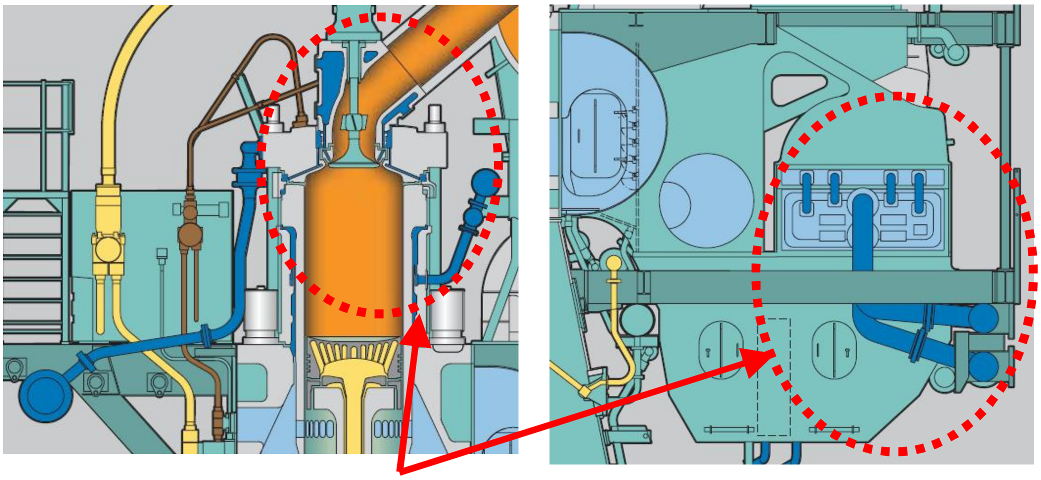

To carry out corrosion protection of water cooling pipes and spaces properly, … … the application of soluble oil has to be done right after shop test with still connected water circuit.

8.0.6.1 Electrical equipment

8.0.6.2 RTA Engine

- ❑ Make sure that the power supply for the heating of the electric motors is assured (if applicable).
- ❑ Place desiccant bags to all electrical connection boxes fitted on engine.

In case RPLS/PLS is installed:

- ❑ Place desiccant bags in control boxes E40 and E41.N for Pulse Lubrication; make sure that all cable glands are tight. Open holes should be sealed.

8.0.6.3 RT-flex Engine

- ❑ Place desiccant bags in control boxes E85, E90, E95.N, E87 (for Bosch servo oil pumps) and/or E40, E41.N for Pulse Lubrication; make sure that all cable glands are tight. Open holes should be sealed.
- ❑ Place desiccant bags in control safety system boxes E10, E20, E25, E28.
- ❑ Place desiccant bags in alarm system boxes E110, E15.1, E120.n, E130, etc.
- ❑ Place desiccant bags in Boll & Kirch automatic oil filter control box.
- ❑ Make sure that the power supply for the heating of the electric motors is assured (if applicable).

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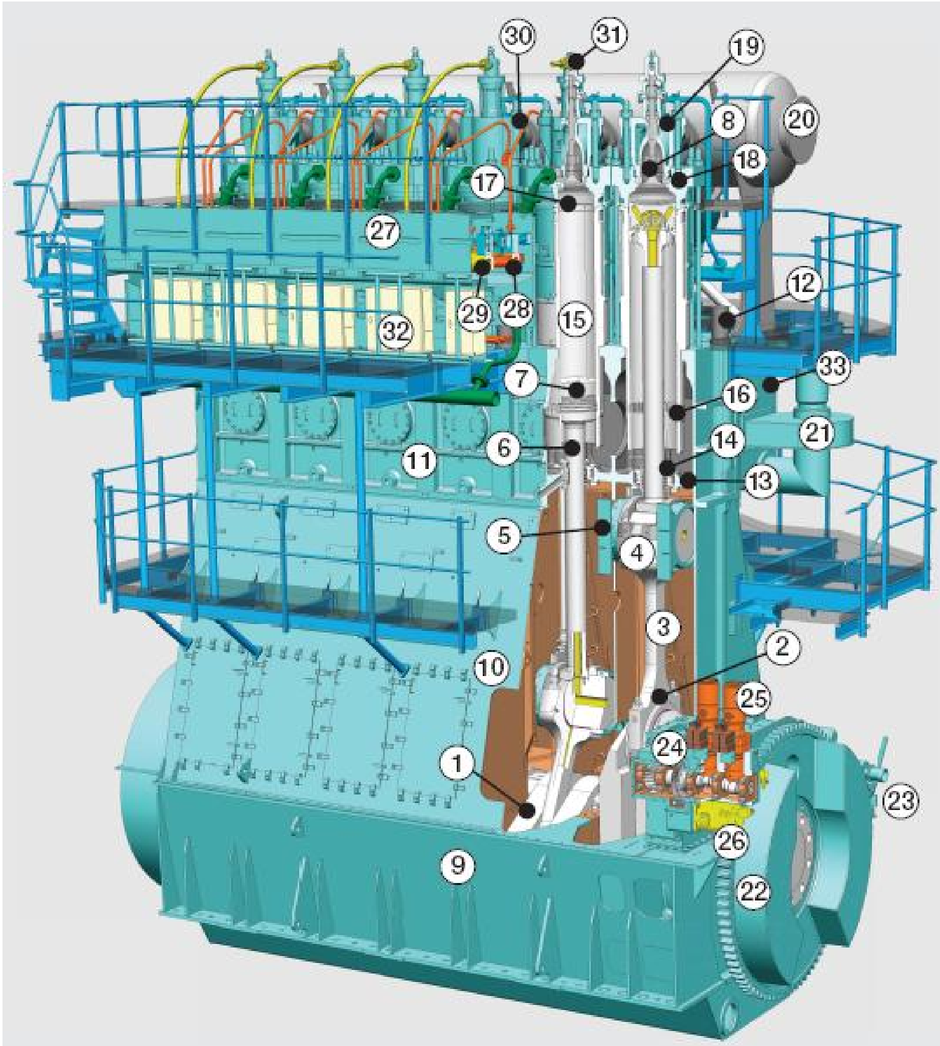
8.0.7.0 Overview of the components to be corrosion protected



The next page gives a preliminary overview of corrosion protection liquids which can be used. For a proper evaluation of the correct corrosion protection application and the liquids used, refer to the components given in the chapters overview on page 32-38. (Attention : valid only for fully assembled engines in storage condition with fully operational dehumidifier.)

- Tectyl 506 & 132: First layer with Tectyl 506. **Drying**. Second layer with Tectyl 132.
- Engine external: Generally all surfaces not painted with Tectyl 506 & Tectyl 132.
- Engine internal: Generally all machined (movable) parts with Tectyl 930.

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8.0.7.1 Quick overview of engine parts and the corresponding corrosion protection liquids - Refer (please compare) to chapter 16.0.0!

Pos.	Part	Engine location	Protector type
1.	Crankshaft	Internal	B or F
	Crank web	Internal	B or F
	Crankpin: web journal & main journal	Internal	B or F
	Gear wheels	Internal	B or F
	Thrust bearing pads	Internal	B or F
2.	Bottom end bearing	Internal	B or F
3.	Connecting rod	Internal	B or F
4.	Crosshead bearing	Internal	B or F
5.	Crosshead guide shoes	Internal	B or F
6.	Piston rod	Internal	B or F
7.	Piston	Internal	B or F
8.	Exhaust valve	Internal	B or F
9.	Bedplate	Internal	B or F
10.	Column (Guide rails)	Internal	B or F
11.	Cylinder block	External	C
12.	Tie rods	External	C
13.	Diaphragm	Internal	B or F
14.	Piston rod gland	Internal	B or F
15.	Cylinder liner	Internal	B or F
16.	Scavenge ports	Internal	B or F
17.	Anti-Polishing ring	Internal	B or F
18.	Cylinder cover	External	C
	Combustion space	Internal	B or F
19.	Exhaust valve cage	Internal	B or F
20.	Exhaust manifold	External	----
21.	Auxiliary scavenge air blower	External	Turn elect. motor
22.	Flywheel	External	C & D
23.	Turning gear		
	Electric motor	External	-----
	Wheel pin	External	C & D
24.	RT-flex Supply Unit		
	all flanged units	External	C
25.	High-pressure fuel pumps	External	C
26.	Servo oil pumps	External	C
27.	Rail Unit	External	C
28.	Fuel oil rail with injection units	External	C
29.	Servo oil rail with exhaust valve		
	exhaust valve control units	External	C
30.	High-pressure pipes to fuel injectors	External	C
31.	Exhaust valve drive	Internal	B or F
32.	Electronic cabinets	External	Silica Gel
33.	Scavenge air receiver		
	all relief valves	External	C

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8.0.8 Detailed overview of parts & spaces to be corrosion protected

- Group 1: bedplate and tie rod
- Group 2: cylinder liner and cylinder cover
- Group 3: crankshaft, connecting rod and piston
- Group 4: engine control system and control elements
- Group 5: supply unit, servo oil pump, fuel oil pump and exhaust valve actuator
- Group 6: scavenge air & turbocharger system
- Group 7: platforms (not mentioned in particular)
- Group 8: exhaust manifold; piping systems (see chapter 7.0.6)
- Group 9: engine monitoring

- Refer (please compare) to chapter 16.0.0!
- All corrosion protectors given under "C" are to be removed from engine internal spaces parts before starting the engine.

Group	Component	Comments	Preserving actions
1	Bedplate arrangement	All exposed machined surfaces to be coated	**C** ; 2 layers
1	Bedplate oil drain	Seal drains with a suitably sized steel flange and airtight gasket	**C** ; 1 layer
1	Bedplate free end	Where applicable seal the crankcase vent	**C** ; 2 layers
1	Bedplate driving end	Coat all machined surfaces, in particular the thrust area; remove the thrust bearing saddle drain to prevent any potential clogging and moisture accretion, refit before engine use	**C** ; 2 layers
1	Main bearing shell	All exposed surfaces to be coated	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
1	Main bearing cover	Coat all machined surfaces, pay attention to the stud threads where applicable	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
1	Thrust bearing arrangement	Coat all exposed machined surfaces	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
1	Thrust bearing pads	Coat all machined surfaces, prevent excessive dry turning	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
2	Engine frame assembly parts		**C** ; 2 layers
2	Column doors	Seal all crankcase relief valves, ensure that the valves are corrosion-free	**C** ; 1 layer
2	Casing free end	Coat all machined surfaces	**C** ; 2 layers
2	End casing driving end	Coat all machined surfaces	**C** ; 2 layers

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Group	Component	Comments	Preserving actions
2	Oil baffle two-parts driving end	Seal the end baffle, be mindful of any turning and potential damage to this	**C** ; 2 layers
2	Tie rod	Ensure that drain bores are clear, fill with oil at each inspection in order to flush	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
2	Cylinder jacket grouping	Clean after shop trial to remove any corrosive combustion by products	**C** ; 2 layers
2	Supporting ring	Ensure that water is drained completely, in particular in the area of the lower O-rings	**C** (external) or Water inhibitor (internal)
2	Cylinder liner	Ensure that water is drained completely and machined running surface coated If engine is fully assembled: - Layer application through bore of dismantled starting air valve and from piston underside or scavenge ports (piston at BDC – bottom dead centre)	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
2	Cylinder liner holder	Ensure that water is drained completely	**C** ; 2 layers
2	Water guide jacket	Ensure that water is drained completely	**C** ; 2 layers and Water inhibitor (internal)
2	Lubricating quill with accumulator for cylinder lubrication	Fill with cylinder oil and top up for inspection or removal, and store by one layer of "**C**", packed in VCI paper. Openings at water supporting ring to be closed / flanged air-tight.	**C** ; 1 layer VCI paper
2	Lubricating quill for Pulse	Fill with cylinder oil and top up for inspection or removal and store by one layer of "**C**", packed in VCI paper. Openings at water supporting ring to be closed / flanged air-tight.	**C** ; 1 layer VCI paper
2	Gland box piston rod	Ensure that all machined surfaces are coated, pay attention to garter springs	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
2	Compression space	Be sure to coat all machined surfaces. If engine is fully assembled: - Layer application through bore of dismantled starting air valve	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
2	Cylinder cover	Ensure that all water spaces are drained. All fuel injection and starting air valves dismantled for storage. All openings sealed by flange air-tight. Cyl. cover external surface: C ; 2 layers Cyl. cover internal: B / F	**C** ; 2 layers **B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
2	Fuel valve complete (Fuel injectors)	Fuel injectors removed from cyl. cover and cleaned on test bench with "**A**"; packed in VCI after protection application	**A ;** **B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
2	Starting air valve	Remove, clean, and apply protector, then store, packed in VCI paper; flange bore in cylinder cover air-tight	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)

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Group	Component	Comments	Preserving actions
2	Relief valve	Remove, clean, and apply protector, then store, packed in VCI paper; flange bore in cylinder cover air-tight	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
2	Indicator valve	Remove and store, close the bore in cyl. cover air-tight by flange. Apply “B” or “F” and store packed in VCI paper.	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
2	Exhaust valve complete	Remove the valve and ensure that cooling spaces are completely drained. Seal off all openings (exhaust chamber to funnel) air-tight. Apply protection to valve seat.	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
2	Valve spindle for exhaust valve	Nymonic valve spindles should not corrode; ensure no damage occurs during transportation. Apply protection.	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
3	Complete crankshaft assembly	Coat all exposed machined surfaces. Grease the flywheel teeth.	See chapter **8.0.5.1**
3	Vibration damper crankshaft	Viscous fluid dampers are sealed and no access is possible. Spring type dampers can be flushed with system oil; carry out when inspecting the engine at regular intervals.	**C** ; 2 layers
3	Axial detuner	Flush when inspecting periodically	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
3	Turning gear	Ensure that the gearbox is filled and all components are coated	**C** ; 2 layers Grease gear pinion
3	Connecting rod assembly	All machined and uncoated surfaces to be coated as well as the central oil bore	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
3	Bearing shell crankpin	Coat all exposed surfaces	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
3	Upper bearing half of connecting rod top end bearing	Coat all exposed surfaces	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
3	Bearing shell for top end bearing	Coat all exposed surfaces	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
3	Screwed connection piston rod - crosshead	Ensure that the threads are coated, see notes on screw threads	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
3	Crosshead and guide shoe	Coat all machined and other uncoated surfaces	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
3	Piston assembly parts	Internal parts to be coated; system oil is used but may not adhere as specific products would	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)

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Group	Component	Comments	Preserving actions
3	Piston cooling and crosshead lubrication	All pipes to be coated. Operate pump with 3-4bar pressure force and connect to flange at column-exhaust entering.	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Pneumatic manoeuvring units	Remove all control valves and store them separately; apply protector and then pack in VCI paper	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Camshaft drive	See specific instructions on the following list	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Drive supply unit	See specific instructions on the following list	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Gear wheel on crankshaft	Coat all teeth and other machined surfaces; coat all uncoated surfaces. Fill bearings when rotating. This item is sensitive to corrosion.	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Intermediate wheel for camshaft drive	Coat all teeth and other machined surfaces; coat all uncoated surfaces. Fill bearings when rotating. This item is sensitive to corrosion.	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Gear wheel on camshaft	Coat all teeth and other machined surfaces; coat all uncoated surfaces. Fill bearings when rotating. This item is sensitive to corrosion.	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Intermediate wheel supply unit	Coat all teeth and other machined surfaces; coat all uncoated surfaces. Fill bearings when rotating. This item is sensitive to corrosion.	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Camshaft/reversing servomotor	Coat all uncoated surfaces, internal components to be filled with system oil; this will not be as effective as a dedicated preserving oil	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Fuel cam	Coat all surfaces, this item is sensitive to corrosion.	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Actuator cam	Coat all surfaces, this item is sensitive to corrosion.	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Vibration damper camshaft	Only viscous fluid dampers are used, no internal access; coat all external surfaces	**C** ; 2 layers
4	Damper casing camshaft	Remove for damper access, coat all surfaces	---
4	Bearing housing(s)	Apply protector "**C**" to all external machined surfaces. All internal parts & surfaces: apply "**B**"/"**F**"	**C** ; 2 layers **B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Bearing housing ancillary parts	Apply protector "**C**" to all external machined surfaces All internal parts & surfaces: apply "**B**"/"**F**"	**C** ; 2 layers **B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)

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Group	Component	Comments	Preserving actions
4	Gearing for auxiliary drives	Coat all gears, sensitive to corrosion	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Starting air distributor	External surface: "**C**" ; 2 layers Internal surfaces: "**B**" **/** "**F**" Internal pilot valves to be coated, sensitive to corrosion	**C** ; 2 layers **B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Valve unit for starting air distributor	Remove pneumatic valves and blank all ports/holes air-tight. Apply "**B**" **/** "**F**". Store separately, packed in VCI.	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Shut-off valve starting air	Coat all internal parts, removal is required for access. Apply silica gel, but mark outside.	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Reversing valve	Internal parts coated with system oil, not effective in the long term. To be packed in VCI paper and then stored. Apply "**B**" **/** "**F**" beforehand. Blank openings air-tight.	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Rotation direction safeguard	Internal parts coated with system oil, not effective in the long term. To be packed in VCI paper and then stored. Apply "**B**" **/** "**F**" beforehand. Blank openings air-tight.	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Control air supply	Disconnect supply and seal pipes. Control air usually contains humidity, ensure that all pipes are dry after shop trial. All control valves to be removed. Apply "**B**" **/** "**F**", pack in VCI paper and store. Blank all openings.	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Valve unit reversing interlock	Remove pneumatic valves and blank all ports/holes. Apply "**B**" **/** "**F**", pack in VCI paper and store separately.	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Valve group B by gearing for auxiliary drive	Remove all valves and store them. Apply "**B**" **/** "**F**" and pack in VCI paper. Blank all ports/connecting points.	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Control box local manoeuvring. stand	Remove all valves and store them, packed in VCI paper. Blank all ports/connecting points. Apply "**B**" **/** "**F**".	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Pick-up engine speed/TDC	Sensitive to corrosion, seal or remove; if removed, pack in VCI paper and seal the cable ends	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Control elements unit	Remove all valves and store them; blank all ports/connecting points	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Fuel interlock override device	Remove and seal pipe/ports/connections. Store separately.	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Local manoeuvring stand	All surfaces to be coated	**C** ; 2 layers
4	Reversing interlock	Remove and seal pipe/ports/connections. Store separately.	

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Group	Component	Comments	Preserving actions
4	Rod for local manoeuvring stand and pneumatic logic unit	Coat and seal to exclude moisture. All surfaces must be adequately protected.	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Speed indication	Remove and store in VCI paper	----------
4	Speed indication drive	Ensure that all surfaces are coated	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
4	Rotation counter	Remove and store separately in VCI paper. Blank off bore air-tight.	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
5	Governor and booster arrangement	For mechanical and electrical governors remove and store as per makers' instructions	-------
5	Safety cut-out device	Critical component sensitive to corrosion, ensure that no moisture remains	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
5	Fuel pump block	Flush with calibrating fluid and seal; top up when inspecting	External surface **C** ; 2 layers
5	Eccentric shaft injection pump	Sensitive to corrosion, to be lubricated with system oil, but ineffective in the length of time	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
5	Plunger with bush	Seal lower area to prevent air entry. Ensure that fuel pump is cut out. No touching of roller and cam.	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
5	Valves injection pump	See above actions for fuel pump	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
5	Roller guide fuel pump	Assembly to be coated with system oil, not effective in the length of time	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
5	Gear wheel supply unit		**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
5	Pump servo oil	Remove and store separately; seal all ports/pipes and access points	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
5	Supply unit	All internal parts to be coated with system oil, not effective in the length of time. Coat all external surfaces.	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
5	Fuel pump	All internal parts to be coated with system oil. Coat all external surfaces.	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
5	Fuel pump plunger	Seal lower area to prevent air entry. Ensure that fuel pump is cut out. No touching of roller and cam.	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
5	Rail unit	Coat all surfaces. Cabling and sensors are sensitive to corrosion.	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
5	Fuel rail	Coat all surfaces. Cabling and sensors are sensitive to corrosion (as for rail unit).	**C** ; 2 layers

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Group	Component	Comments	Preserving actions
5	Injection control unit	See Instructions 107.378.493. To be dismantled and stored in wooden box.	---
5	Actuator (RTA only)	Internal parts to be coated with system oil; coat all external surfaces.	**C** ; 2 layers
5	Roller guide actuator pump	To be cut off. No contact of roller & cam. Assembly to be coated with system oil, not effective over longer periods.	**B** (ValvolineTectyl 930) or **F** (Shell Valvata 1000)
5	Servo oil rail	Coat all surfaces. Cabling and sensors are sensitive to corrosion.	**C** ; 2 layers
5	Exhaust Valve Drive / Partition Device / Assembly	Coat all parts and inspect regularly. Or: to be dismantled and stored in wooden box.	**C** ; 2 layers
5	Regulating linkage arrangement	Coat all parts and inspect regularly	**C** ; 2 layers
5	Regulating linkage air cylinder	Sensitive to internal corrosion	**C** ; 2 layers
5	Positioning unit VIT/FQS	Coat all surfaces. Cabling and sensors are sensitive to corrosion (as for rail unit).	**C** ; 2 layers
6	Scavenge air receiver	The internal and external surfaces should be coated; this is a large area which should be kept dry, use a dehumidifier	is painted
6	Underslung separator	Ensure that water is drained completely	--------
6	Turbocharger	Store as per manufacturers' instructions.	-----
6	Auxiliary blower	The motor and bearings are sensitive to corrosion. Electric motors should be covered and heated where possible. Check winding resistance when inspecting.	------
6	Auxiliary blower switch box	Keep sealed and internal spaces warm, use silica gel	-------
6	Scavenge air cooler	Ensure that the water side is completely drained. This component is less sensitive to corrosion, but care should be taken when transporting.	Inhibitor has been used.
6	Water separator scavenge air	Ensure that the water side is completely drained	-------
6	Scavenge air waste gate	The internal components should be free of corrosive combustion residue. Coat all parts.	**C** ; 2 layers
8	Exhaust gas manifold	Clean and seal	--------
8	Automatic oil filter	See manufacturer's Operation Manual. Drain the system and place silica gel bags to each candle tube.	---------

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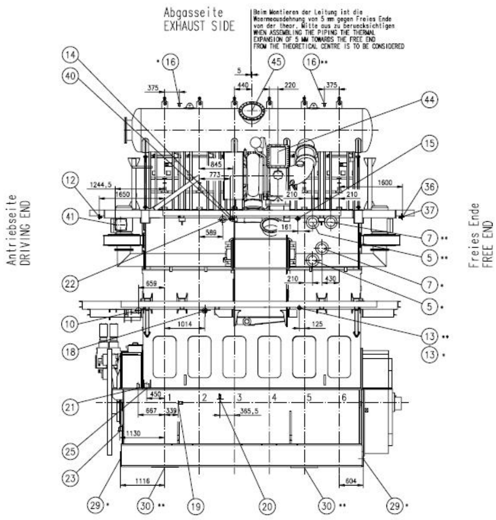
8.0.9 Corrosion protection of piping

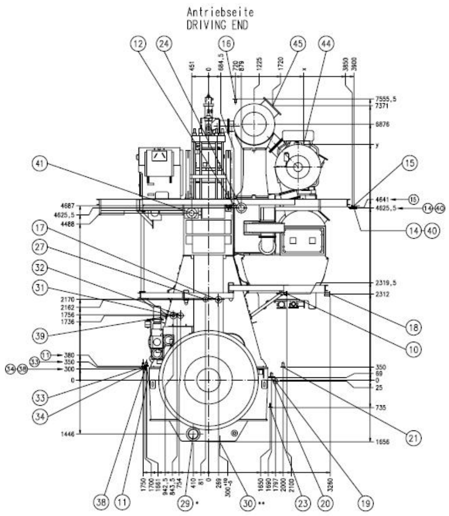
See chapter 7.0.6.

8.1.0 Overview of flange connections to be sealed air-tight

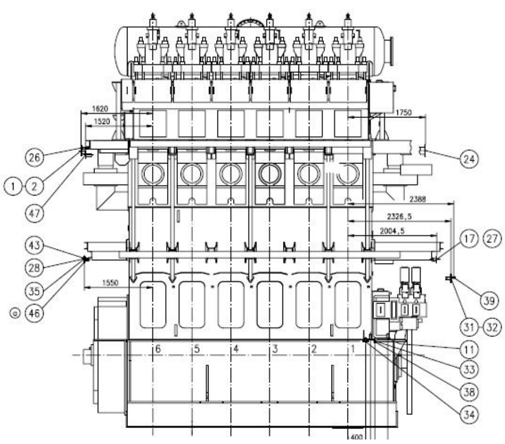
To provide an overview of the flange connection options, some sketches of the Pipe Connection Plan are given below for your reference. The drawings of each corresponding engine type are available at the Licensees.

The flange geometry can be used to produce proper steel flanges for air-tight sealing after the application of final corrosion preservation.
For checking the positions, see the parts list.
This Pipe Connection Plan differs with every engine type; therefore check carefully.





Brennstoffseite
FUEL SIDE



30	24x M20; 780; 670	Grundplatte Oelablauf (Vertikal) / BEDPLATE OIL DRAIN (VERTICAL)	DN / PN	1110	X
31	8x ø 19; 175; 140	Brennstoff Eintritt / FUEL OIL INLET	DN 65 / PN 16	8702	
32	8x ø 19; 155; 120	Brennstoff Austritt / FUEL OIL OUTLET	DN 50 / PN 16	8704	
33	4x ø 15; 120; 95	Leckbrennstoffleitung RAIL-UNIT / FUEL LEAKAGE PIPE RAIL-UNIT	DN 40 / PN 5	8740	
34	4x ø 15; 120; 95	Leckbrennstoffltg. Einspritzventil / FUEL LEAKAGE PIPE INJECTION VALVE	DN 40 / PN 5	8741	

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8.1.1 Dehumidifier installation

- ❑ Install a dehumidifier system to crankcase, piston underside and supply unit or camshaft housing (RTA).
- ❑ Install a real-humidity monitoring system to crankcase and piston underside to record real humidity and temperature during the lay-up period.

The dehumidifier needs to be connected with flexible hoses to the engine as described below. A real humidity of 40% - 50% inside the engine needs to be reached to keep the risk of corrosion low. The execution of the connection may vary depending on the dehumidifier system used and engine type. It is recommended to use a booster fan within the dehumidifier circuit to obtain a constant slight overpressure inside the engine.

1. Connect the dehumidifier to the piston underside, inlet on the AFT side and outlet on the FWD side of the engine (opposite direction is also possible).
2. Connect all camshaft housings together with the dehumidifier to one loop.
3. Connect the dehumidifier to the crankcase, inlet on the AFT side and outlet on the FWD side of the engine (opposite direction is also possible). The flexible hoses can either be connected to the crankcase door openings with a dummy plate, or two relief valves can be removed for the connection.
4. Record humidity values daily of each engine space given on the “Inspection List for Dehumidifier” – see chapter 17.0.2.

Sample picture of the installation of a Munters M120 dehumidifier

Dehumidifier outlet air taken from the crankcase

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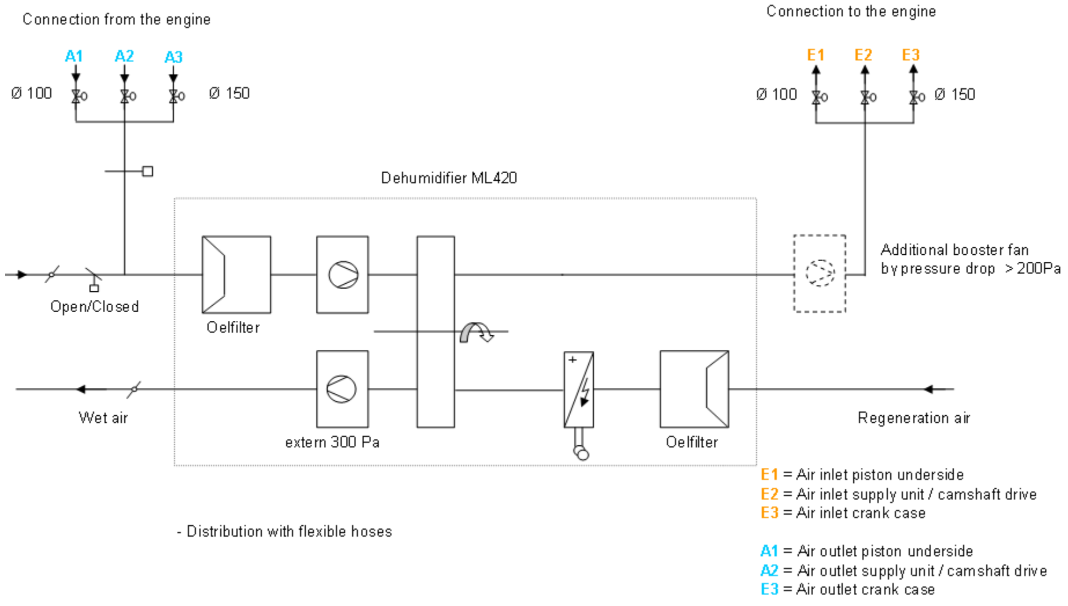
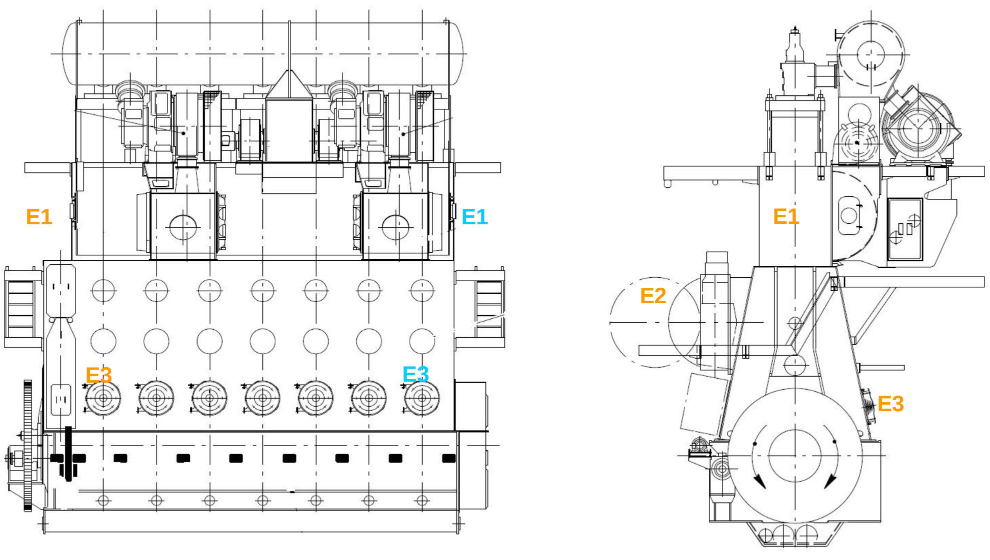
Example for the connection of an ML420 dehumidifier by Munters





Note that the dehumidifier's wet air outlet must be led outside the engine room.

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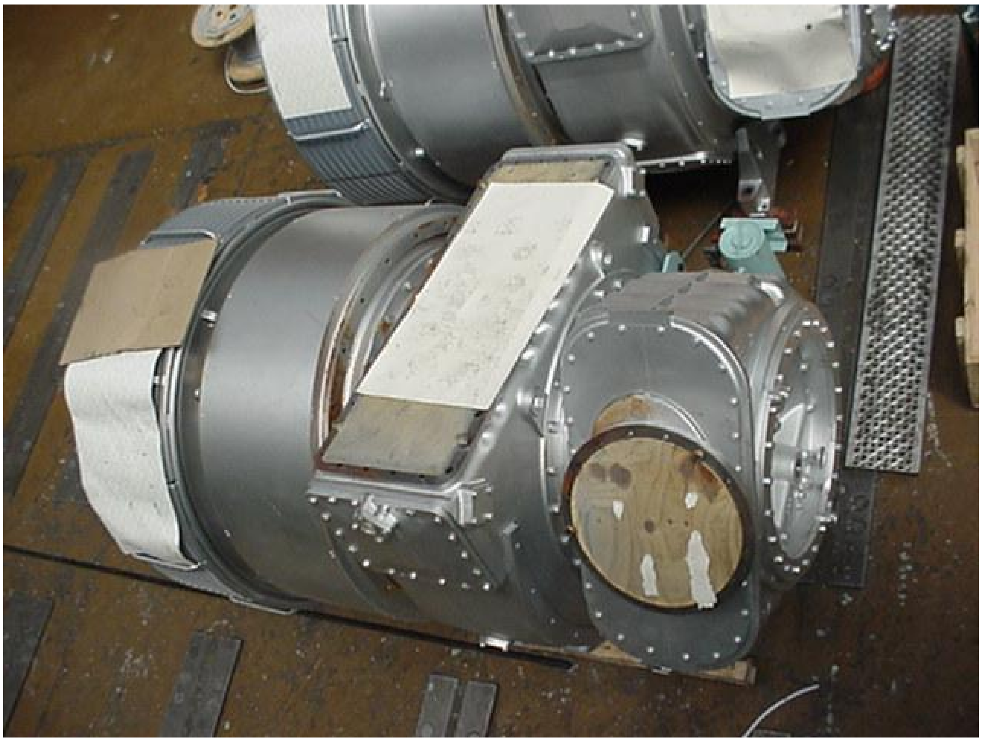
8.1.2 Turbocharger

Generally the turbocharger manufacturer operation manual has to be consulted to carry out any kind of work. It has to be assumed that all cast- or flange-contact surfaces have been corrosion protected properly with Tectyl 506 as first layer and Tectyl 132 as second layer.

- It is of outmost importance that the turbochargers be sealed against moisture penetration, and also the sealing of the exhaust silencer by proper application of so-called VCI (**V**olatile **C**orrosion **I**nhibitor) foil has to be assured.

- It is strongly recommended that reliable re-commissioning of the turbocharger be carried out by an authorised service branch the manufacturers. This is mostly by reason of detecting the proper condition (e.g. VTR 4: concentricity of rotor, condition of bearing space and bearing, as also the proper measuring of the clearances thereof), if necessary carrying out further action and finally, assuring readiness for operation.



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9.0.0 Final Delivery Inspection (at engine maker)
Sample of a cover sheet of the Final Delivery Inspection
The cover sheet is accompanied by the checking list given in chapter 17.0.4.

9.0.1 Sample sheet : Final Delivery Inspection (at engine maker)

To be provided by the engine manufacturer

Engine Type:

Corrosion-protective products applied

Conditions for storage

Indoors in dry conditions, protected against dirt and damage.

Duration of protection

After a period of X months, calculated from the date of shipment, the corrosion protection material is to be removed and the engine/engine parts inspected for signs of rust. After this, the preservation is to be renewed in accordance with the enclosed specification no. 107.426.585.

Inspection and removal of the preservation material

Final delivery inspection at engine maker

Inspection carried out on (Date YYYY-MM-DD :) ____-__-__:

- Engine / engine parts are checked according to the detailed parts list as attached. See inspection parts list in chapter 17.0.4.
  The complete preservation is to be inspected for damage.

Removal of the preservation material prior to fitting and for inspection purposes after the period of protection has expired

The corrosion-protective products can be removed manually with acid-free cotton cloth soaked with petroleum or aromatic-free white spirit. Mechanical means, steam or hot water cleaners are not to be used.
The following products are recommended: white spirit, Shellsol
If necessary, the preservation must be renewed.

Engine manufacturer's information

Date of preservation:
Date of shipment:
Name of manufacturer:
Stamp of quality department and name of inspector:
Documentation:
Hand over the Guideline for Engine Protection 107.426.585
together with the signed Final Delivery Inspection sheet (chapter 9.0)
to shipyard inspector

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10.0 Protection condition during transport to shipyard

As the engine and/or its parts have been checked at engine maker, see 9.0, and therefore the engine and/or its parts and the packaging are assumed to be in proper condition, the engine with connected dehumidifiers has to be checked on a daily basis for proper operation.
As transportation can take even several weeks and/or the discharge at arrival port may be postponed due to unexpected occurrences, the further inspection procedure has to be guaranteed.

11.0.0 Inspection upon arrival (at shipyard)

The inspection is to be carried out within **two weeks** after the engine/engine parts have arrived to the final destination. Any shortcomings because of an improper preservation are to be reported in writing to Wärtsilä Switzerland Ltd within this time limit. **After this time limit, no claims about corrosion damage of the engine and the engine parts respectively shall be taken into account.** See also para. 9.0 .

Sample of a cover sheet of the Final Delivery Inspection.

The cover sheet is accompanied by the checking list given in chapter 17.0.4.

To be provided by the shipyard

Engine Type:

11.0.1 Sample sheet: Inspection of engine upon arrival at the destination

Inspection carried out on (Date YYYY-MM-DD :)____-__-__:

- Engine / engine parts are checked according to the detailed parts list as attached.

See inspection parts list in chapter 17.0.4.
The complete preservation is to be inspected for damage.

Copy of the Final Delivery Inspection with the filled-out recording sheets is available.
Yes / No

Removal of the preservation material prior to fitting and for inspection purposes after the period of protection has expired

The corrosion-protective products can be removed manually with acid-free cotton cloth soaked with petroleum or aromatic-free white spirit. Mechanical means, steam or hot water cleaners are not to be used.
The following products are recommended: white spirit, Shellsol

If necessary, the preservation must be renewed.

Manufacturer's information
Date of preservation:
Date of shipment:
Name of manufacturer:
Stamp of quality department and name of inspector:

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12.0.0 Storage conditions at shipyard

The stored engine and/or engine parts will be checked.

12.0.1 Installation and/or maintaining of dehumidifier operation

The dehumidifier should have been installed already since final corrosion protector application has been carried out, if the climatic conditions (humidity) required this.
If not done so, install according to chapter 8.1.1. Check the dehumidifier and record the humidity values daily.

12.0.2 Installation of turning gear power supply

The main power source required for generally all turning gear types is AC 440V – 60Hz. Please check beforehand on type plate of turning gear or verify with engine maker.

If the engine has been delivered fully assembled or part-wise (bedplate with crankshaft installed), it is necessary to turn the crankshaft once a week by minimum of 3-4 turns.
If so, check if the

- main bearings,
- connecting rod bottom end bearing,
- crosshead bearing,
- guide rails; the 4 guide shoes respectively of each cylinder,
- cylinder liners,
- pistons (either through the starting air valve bores at the cylinder covers, or through the scavenge ports),
- gear wheel drive,
- RTA engines: camshaft bearings (assure that guide pistons for fuel delivery as well as exhaust actuator have been cut out),
- RT-flex engines: camshaft bearings

have been greased with Tectyl 930 or Valvata 1000.

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13.0.0 Regular Re-inspection & re-coating of machined surfaces / engine parts at yard condition

13.0.1 Once a week

(if possible at yard stage!)

- Operate the main engine system oil pump for 20 minutes while turning the engine. During this time the cylinder lubrication should be operated manually. The engine should be stopped each time in another position. Note that the dehumidifying system needs to be turned off prior to starting the lube oil pumps. Two hours after stopping the lube oil pumps the dehumidifier may be turned on again.

  Important! The number of pulses / turns required to keep the cylinder liner surface properly lubricated must be verified by visual inspections of the liner surface and piston ring package from the piston underside space.

  CLU-3 type lubricating system (if possible at yard stage!)
  Operate the manual/emergency cylinder lubrication for 10 – 15 minutes. During this time, keep the engine turning with the turning gear.

  Retrofit Pulse and Pulse Lubricating System (RPLS & PLS) (if possible at yard stage!)
  Start the main lube oil pump and rotate the engine with the turning gear. Start the oil supply pump and set the delivery pressure to 12-14 bar by means of the oil supply unit's pressure regulating valve. Actuate manual cylinder lubrication. At such low pressure (normally 50 bar), the cylinder oil will not be injected but will flow along the liner wall. Give each cylinder approx. 100 pulses. During this time, keep the engine turning with the turning gear.

  Pulse Feed Lubricating System (if possible at yard stage!)
  Start the main lube oil pump and rotate the engine with the turning gear. Start the control oil pump, or the Servo Oil Service pump on engines without control oil pumps, in order to provide hydraulic pressure for driving the dosage pumps. The lubricating system servo oil pressure has to be adjusted to 12 to 14 bar by means of the pressure regulating valves which are, depending on the execution, either located inside or just outside the rail unit. Start manual lubrication to individual cylinders. At such low pressure (normally 50 bar), the cylinder oil will not be injected but will flow along the liner wall. Give each cylinder approx. 100 pulses. During this time keep the engine turning with the turning gear.

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Pulse Jet Lubrication System (if possible at yard stage!)
Start the main lube oil pump and rotate the engine with the turning gear. Start the control oil pump, or the so-called service pump on engines without control oil pumps, in order to provide hydraulic pressure for driving the dosage pumps. The servo oil pressure needs not be reduced. Start manual lubrication to individual cylinders. Give each cylinder approx. 100 pulses.

- In case the cooling water system has not been drained, the cooling water pumps need to be operated for around 20 minutes to get some circulation in the cooling system.
- Check the level of the corrosion-protective oil which has been filled into the fuel system (if required refill).
- The fuel linkage needs to be moved by hand; re-lubricate it if required.
- Check the recorded relative humidity and temperature inside the engine on the data logger.
- Open the drain cock of the turbocharger gas outlet casing for one minute (water check).
- Re-spray rust-preventive coating on piston rods if required.

Please note: Always use pumps alternately, a long standstill could lead to detriments (if there is no power supply to some pumps, they should be turned by hand on a weekly basis):

- LO pumps
- X head pumps
- booster pumps
- water pumps

13.0.2 Every two weeks

- Open the crankcase (on one side) and piston underside doors and check for condensation and rust traces, particularly on:
  - thrust bearings
  - gear wheels
  - guide rails
  - camshaft (RTA - & RT-flex engines)
  - cams and rollers (RTA - & RT-flex engines)
  - pistons

- piston rods
- cylinder liners
- fuel rail- & servo oil rail units

If necessary re-spray coating on blank parts in the crankcase that are not covered with system oil when the engine is turned over.

- Open and close the main starting shut-off valve from time to time. Make sure that the supply from the starting air bottles is depressurised.
- Check the dehumidifying system and clean/replace the filter(s).
- Inspect the exhaust manifold for any moisture deposits or corrosion.
- Turn the rotor of the turbocharger(s) at an angle of 90° to avoid bending of the shaft.
- Turn the auxiliary scavenge air blower(s) by hand a few revolutions to avoid detriments.

13.0.3. Every month

- Lift a crosshead pin and check for signs of corrosion. Spray-coat again all mentioned parts with rust-preventing engine oil. For re-assembling use steam engine cylinder oil.
- Remove a main bearing cover and check the journal pin for signs of corrosion. Spray-coat again all mentioned parts with rust-preventing engine oil. For re-assembling use steam engine cylinder oil.
- Replace the silica gel desiccant bags inside the control boxes.
- Replace the silica gel desiccant bags inside the main starting air pipe.
- Replace the silica gel desiccant in the automatic filter candles.
- If the fuel injectors, the starting air valves, the indicator cocks, the injection control units

(ICU) have not been removed after shop test for single part storage, they must be removed and checked

- Check by analysis the following liquid media **(if possible at yard stage!)** :

  - cooling water
  - system oil
  - MDO in the fuel system of the engine

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13.0.4. Overview parts inspection time-frame

Main inspection parts	Period of Inspection						
	Daily	Every week	Every two week	Monthly	Every 3 month	Every 4 - 6 month	Remark
De-Humidifier	●						
Bedplate				●	(3)	(4)	
Column				●	(3)	(4)	
Guide Rails Column		●			(3)	(4)	
Crankshaft		●			(3)	(4)	
Main Bearings				(5)	(3)	(4)	
Connecting Rod		●			(3)	(4)	
Bottom End Bearing				(5)	(3)	(4)	
Cross-Head Bearing				(5)	(3)	(4)	
Piston Head		●			(3)	(4)	
Piston Rod		●			(3)	(4)	
Gland Box Springs		●			(3)	(4)	
Cams & Camshaft		●			(3)	(4)	
Fuel pump block (RTA)			●		(3)	(4)	
Cyl. Liner Inside		●			(3)	(4)	
Cyl. Liner Outside		●			(3)	(4)	
Fuel rail pipe		●			(3)	(4)	
Servo rail pipe		●			(3)	(4)	
Exhaust Valve drive		●			(3)	(4)	
Injection Control Unit		●			(3)	(4)	
Starting Air Distributor		●			(3)	(4)	
Rotation Direction Safeguard		●			(3)	(4)	
Engine turning			●				
Ancillary Parts (*) installed at engine				(1)	(2)		
Ancillary Parts (*) stored in VCI paper & closed woodenbox					(1)	(2)	
(*) = Fuel Injection valves; Starting Air valves ; Indicator cock valve ; Injection Control Unit (ICU)							
(1) = Max. humidity 75% & dry condition at storage place							
(2) = Max. humidity 50% & dry condition at storage place							
(3) = Max. humidity 75% - dry condition - single part							
(4) = Max. humidity 50% - dry condition - single part							
(5) = To be opened for inspection							

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14.0 Recovery of corroded parts

If there are signs of rust, the quality assurance department will decide whether additional work is necessary. If the traces of rust are only slight, they can be removed with emery cloth No. 220 (or finer) and petroleum. Repeat cleaning!
If the parts are too heavily corroded, contact your next Wärtsilä Ltd. Service Branch for further decision.

15.0.0 Tools needed for storage

15.0.1 Dehumidifier

It is up to the engine maker or shipyard to decide which tools are used, as long as the technical properties/specifications are complying with the samples attached.

15.0.2 Introduction

The requirements on a dehumidifier system always depend on the engine type/size (volume to be dried) and the storage location (temperature and real humidity). On the following pages three recommended dehumidifier products are shown which are able to cover the Wärtsilä 2-stroke engine portfolio, even in subtropical areas. The main task of a dehumidifier system is to maintain the real humidity inside the engine between 40% and 50%, in order to keep the level of corrosion as low as possible.

15.0.3 Engine volume overview

The list below can be used as a rough reference for the volume (crankcase, piston underside and camshaft housing) which needs to be dried in the engine.
~ Volume per cylinder in m³ (crankcase & scavenge air space & camshaft housings)

RTA 48T/T-B	16 m³
RTA 52U/U-B	17 m³
RTA 58	23 m³
RTA 58T/T-B	30 m³
RTA 62U/U-B	24 m³
RTA 68	36 m³
RTA 68T-B	40 m³
RTA 72U/U-B	39 m³
RTA 76	48 m³
RTA 84	63 m³

Example for the definition of the air volume to be dried in a 12RTA96C engine

12 x 60 m³ = 720 m³ total air volume inside the engine

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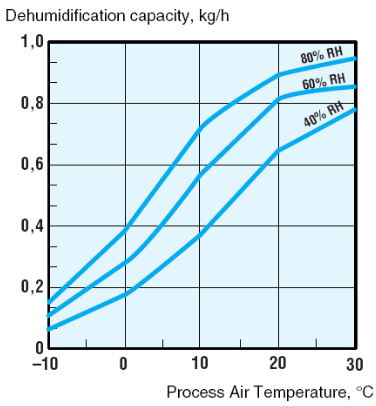
RTA 84M	75 m³
RTA 84C(U)	60 m³
RTA 84T-(B,D)	68 m³
RTA 96C/C-B	60 m³

Depending on the lay-up location, temperature, humidity and engine type, the capacity of the dehumidifier system needs to be defined case by case.

15.1.0 Tools for dehumidification & corrosion protector application

Below is a recommendation for three types of absorption dehumidifiers made by the Munters company. The marine industry has already had positive experience with these dehumidifiers.

15.1.1. Munters M120



Process air

Rated airflow (m³/h)	120
Available static pressure 50Hz (Pa)	200
Available static pressure 60Hz (Pa)	360

Miscellaneous

- Operating temperature (ºC) -40/+40
- Available for different voltage supplies from 115V to 240V

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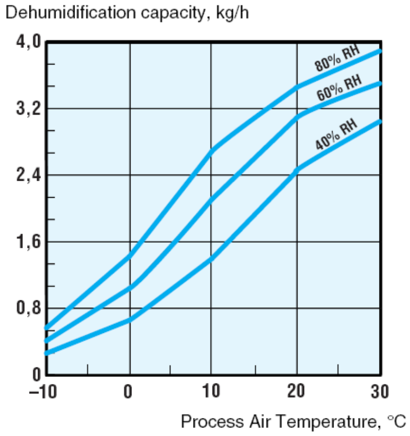
15.1.2 Munters ML420



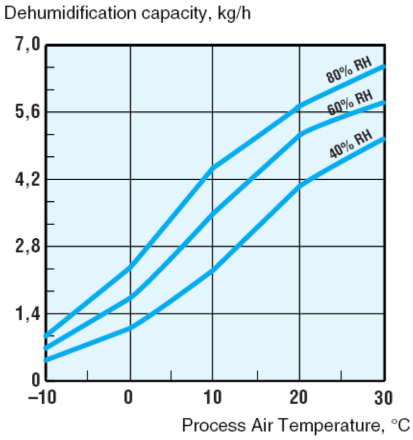
Process air

Rated airflow (m³/h)	420
Available static pressure (Pa)	200

Miscellaneous

- Operating temperature (ºC) -20/+40
- Available for different voltage supplies from 220V to 500V

15.1.3 Munters ML690



Process air

Rated airflow (m³/h)	690
Available static pressure (Pa)	300

Miscellaneous

- Operating temperature (ºC) -20/+40
- Available for different voltage supplies from 220V to 500V

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15.2.0 Accessories

- Booster fan
- Oil filter elements (to assure the efficiency of the dehumidifier)
- Controller
- Pipe distributor with flaps
- Flexible hose Ø 80 mm
- Flexible hose Ø 125 mm
- Flexible hose Ø 160 mm
- Flexible hose Ø 200 mm
- Connecting T-pieces
- Transport frame

15.2.1 Humidity and temperature control

During the lay-up a humidity and temperature data logger must be fitted to the crankcase, piston underside and camshaft housing/supply unit, in order to monitor the conditions inside the engine and check proper working of the dehumidifier system. Below is a recommendation for a tool which can be used for this purpose.

15.2.2 HygroLog NT3

- Relative humidity, temperature, dew point or other calculated parameter
- Multi-probe capability, wide selection of probes to satisfy every application
- Measurements from 0 to 100%RH and -50..200°C /-58..392°F (with external probe)
- Optional internal humidity-temperature probe, protected against unauthorized removal
- Monitoring of up to two external contacts (door, relay contact, etc.)
- Optional LC display and multi-function keypad
- Large recording capacity with removable flash memory card
- Operates with a 9 VDC standard or rechargeable battery
- Data download without interrupting the measurements

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15.2.3 Equipment for preservation oil spraying

To spray coat engine components and blank metal parts, a portable oil sprayer may be used. There are different types and executions of oil sprayers. Below two examples are shown for reference only.

Airless spray unit, made e.g. by Wagner (www.wagner-group.com)

Airgun, e.g. type 405T, made by Gloria (www.gloriagarten.de)

16.0.0 Overview of liquids & application properties

Below a sample list has been compiled of fluids to be used for various applications, which have been summarized. Note that the fluids have been divided in various categories; they are referred to in the subsequent component tables. Where applicable the application method is referred to. The list is not complete: where the products referred to are not available locally, a suitable replacement can be used; however, the basic properties should remain the same. In all cases where cabling and sensors are concerned the compatibility of the preserving agent with the relevant cabling should be confirmed.
Please contact Wärtsilä Switzerland Ltd. or any other Wärtsilä Branch next to you, if any doubt remains.

Product*	Description	Class	Application method
Shell calibration fluid S9365	Calibrating fluid for testing fuel injectors and pumps	A	Used in conjunction with a test pump/bench
Shell Ensis Engine Oil 30 Valvoline Tectyl 930 Mobilarma 524	Mineral oils with excellent rust prevention properties Used for coating engine parts including cylinder liners, piston	B	Spray coating or brush. Where spraying is used, a manual pump is

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Total Osyris DWY 3500/5500	rods, gears, etc. Only used for engine storage.		preferred. Any air pumps must use moisture-free air.
Tectyl 502 EH Tectyl 506 H Tectyl 132 Chevron Rustproof Compound L Shell Ensis DW2462 Mobilarma 798 Castrol Safecoat DW33	Solvent cutback, soft-wax based, corrosion-preventive compound. Can be used to protect external blank metal parts, for example fuel pump blocks, rails, cylinder covers, etc.	**C**	Brush.
Pyroshield LE 5182 Klüberfluid CF Ultra	High-pressure grease which can be used for lubricating flywheel teeth.	**D**	Brush.
Mobilcut 200 Shell Dromus B / BX Total Lactuca MS 5000	Soluble oil inhibitors which are used to protect emptied cooling water spaces.	**E**	Added to cooling water.
Castrol Cresta SHS Chevron Cylinder oil 1000 Shell Valvata Oil 1000 Mobil 600 W Super Cylinder Oil Total Cyl 1000	High-viscosity steam engine cylinder oils with excellent corrosion protection and resistance to wiping. Used for bearing shells	**F**	Brush.

16.0.1 Cleaning and degreasing agents

(inodorous aliphatic hydrocarbons, free of aromatics)

White spirit is the generic term for the following Shell products:
- Shellsol TD
- Shellsol T

Valvoline product: Solvent FP68

Properties	**Shellsol TD**	**Shellsol T**	**Solvent FP68**
Boiling range, at 760 mm Hg beginning at °C ending at °C	 172 195	 185 212	 194 251
Density at 20°C in kg/m^3	735	760	790
Colour SAYBOLT	+ 30	+ 30	+ 30
Aromatic content vol. %	≤ 0,2	≤ 0,2	≤ 0,5
Sulphur content weight %	≤ 0,005	≤ 0,005	≤ 0,005
Copper corrosion	1	1	1

Aniline point °C	84	84.5	75
Viscosity at 20°C in cst.	1.62	1.85	1.84
Relative evaporation time			
(ether = 1)	110	130	800
Flash point Abel °C	46	56	72
Drop ignition temperature°C	-	330	-
Danger class BVD	Fe-II/B	F-III/B	B-III
Transport danger class RID/ADR	IIIa2301/a	IIIa2301/a	Cl. 3 Pt. 32c
Poison class	5	5	free
Max. permissible concentration ppm	500	500	500
mg/m^3	3200	3400	2000

Toxicology: Only at very high vapour concentrations: will have narcotic effects and may cause dizziness.

Application: Solvents, thinning, cleaning and degreasing agents for lacquers and paints. Non-fluorescent dielectric material for non-destructive testing.

Manufacturers: Royal Dutch Shell plc Shellsol TD and T
Carel van Bylandtlaan 30
NL – 2596 HR DEN HAAG
www.shell.com

Valvoline Europe, Solvent FP68
Pesetastraat 5
NL – 2991 XT, Barendrecht
www.valvolineeurope.com

16.0.2 Corrosion inhibitors for Wärtsilä 2-stroke diesel engines

For closed cooling water circuits

Approved and recommended for use in Wärtsilä 2-stroke diesel engines

Product brand name	Supplier	Main reagent
Liquidewt	Ashland Drew Marine	Nitrite/borate
Maxigard	Ashland Drew Marine	Nitrite/borate/organic
CorrShield OR4411	GE Betz	Organic compounds
Q8 Corrosion Inhibitor Long-Life	Kuwait Petroleum	Organic compounds
D.C.W.T. Non Chromate	Marichem Marigases	Nitrite/borate
Marisol CW	Maritech	Nitrite/borate
Nalfleet EWT 9-108	Nalco / Nalfleet	Nitrite

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RD 25 Complex	Rohm and Haas	Molybdate/phosphate
Havoline XLI	Texaco	Organic compounds
WT Supra	Total	Organic compounds
Colorcooling	Uniservice	Nitrite
Anticorr	Uniservice	Phosphonate
NCLT	Uniservice	Nitrite
Cooltreat AL	Unitor Chemicals	Organic compounds
Dieselguard NB	Unitor Chemicals	Nitrite/borate
Rocor NB Liquid	Unitor Chemicals	Nitrite/borate

The condition of the cooling water before treatment should be as follows:
min. pH 6.5
max. 10 °dH (corresponds to 180 mg/l $CaCO_3$)
max. 80 mg/l chloride
max. 150 mg/l sulphate

The dosage of the corrosion inhibitor and the maintenance of its concentration in service should be carried out according to the supplier's instructions. The supplier company undertakes all responsibility for the performance of the water treatment in service to the exclusion of any liability of Wärtsilä Switzerland Ltd.

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16.0.3 Overview of some corrosion protection product specifications

16.0.4 Dewatering Fluid WA

Type of corrosion-protective product	**Dewatering with corrosion protection** **Waxy, dry protective film**
Name of product: **Dewatering Fluid WA**	Article No: Specification No: Substitute for Spec. No:
General and physical properties: Oil-based corrosion preventive	Protection against: Humidity, perspiration, shower-proof

Application Temperature:	15°C to 35°C	Application-method		Thinner %	Viscosity	Spraying pressure	Nozzle mm	k / Oh
Humidity:		Brush	Yes					
Colour:	like Vaseline	Roller	Yes					
Degree of gloss:	mat	Dipping	Yes					
Covering power:		Spraying: low press.	Yes					
Density:	810 kg/m^3 at 15°C	high press.	Yes					
Content of solids:	15.5 %	Airless	Yes					
Viscosity:		Electro-static	Yes					
Danger class:	A-II	Drying: Air	dust-free	set to touch	completely dry	Recoatable after: spraying		
Poison class:	free BAG T Nr. 611 500	20°		1 h		no	no	
Flash point:	40°C in closed pot	Oven	Time no		Temperature of component:			
Identification duty:	ADR/SDR Cl. 3 Pt. 31 c	Forced	Time no		Temperature of component:			

Shelf life:	12 months cool/dry	Technical data:	
Mixing ratio: 1)	2)	Cross-cut test DIN 53151	
With hardener:		Hardness acc. to:	
Pot life:		Steel ball jet: DIN 53154	
Coverage:	180 m^2/l	Mandrel bend test: DIN 53152	
with dry film thickness of	0.8 microns 3)	Ericcson cupping index IE: DIN 53156	
Temperature range:	- 20°C to + 60°C	Salt-spray test: DIN 50021	DIN 50'907 150 hrs
Dry film melting-point:		Kesternich test: DIN 50018	
1) Weight 2) Volume	3) On smooth surface	Condensed water climate: ASTM-D-148, DIN 51359	DIN 51'359 150 hrs

Surface preparation:	Grease-free surface. May be applied to moist surface.
Features:	Highly water displacing, liquid repellent films on metal surfaces, displaces liquids and moisture out of pocket holes
Duration of protection:	Indoor storage 9 - 12 months / shed storage 4 - 8 months
Removal, cleaning:	Normally not necessary. Considered as coat structure for further preservation. Removal with white spirit or petroleum.
Supplier:	Valvoline Oil Co. Ltd., Hardturmstr. 175, P.O. Box, CH-8005 Zurich, Switzerland Tel. +41 (0) 1/446 50 50

The data given are mean values based on practical experience. Application according to the supplier's specification and at user's risk with regard to climatic and specific conditions.

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16.0.5 Tectyl 506

Type of corrosion-protective product	**Waxy, dry, grip-dry protective film for long-term preservation and external protection**							
Name of product: **TECTYL 506**	Article No: Specification No: Substitute for Spec. No:							
General and physical properties: Oil-based corrosion preventive	Protection against: Atmospheric influences incl. rain, snow, etc., aggressive industrial atmosphere and gases such as SO_2							
Application Temperature: 10°C to 35°C	Application-method		Thinner %	Viscosity	Spraying pressure	Nozzle mm	k / Oh	
Humidity:	Brush	Yes						
Colour: brown	Roller	No						
Degree of gloss: wax-like, consistent	Dipping	No						
Covering power:	Spraying: low press.	Yes						
Density: 870 kg/m³ at 20°C	high press.	Yes						
Content of solids: 54 %	Airless	Yes						
Viscosity:	Electro-static	Yes						
Danger class: A-II	Drying: Air	dust-free	set to touch	completely dry	Recoatable after: spraying			
Poison class: free BAG T Nr. 16889	20°C	2hrs	3 hrs	4 hrs				
Flash point: 41°C in closed pot	Oven	Time		Temperature of component:				
Identification duty: ADR/SDR Cl. 3 Pt. 31 c	Forced	Time		Temperature of component:				
Shelf life: 12 months cool/dry	Technical data:							
Mixing ratio: 1) 2)	Cross-cut test DIN 53151							
With hardener:	Hardness acc. to:							
Pot life:	Steel ball jet: DIN 53154							
Coverage: 16 m²/l	Mandrel bend test: DIN 53152							
with dry film thickness of 35 microns 3)	Ericcson cupping index IE: DIN 53156							
Temperature range: - 40°C to + 120°C	Salt-spray test: DIN 50021	5 % 80 days						
Dry film melting-point:	Kesternich test: DIN 50018							
1) Weight 2) Volume 3) On smooth surface	Condensed water climate: ASTM-D-148, DIN 51359	> 100 days						
Surface preparation:	Dry, dust-free, oil- and grease-free surface; surface treated with Dewatering Fluid WA							
Features:	Non water displacing							
Duration of protection:	Indoor storage up to 4 years / outdoor storage up to 2 years							
Removal, cleaning:	With petroleum, aromatic-free white spirit, alkaline soaker; steam or hot-water cleaner with corrosion protection additive							
Supplier:	Valvoline Oil Co. Ltd., Hardturmstr. 175, P.O. Box, CH-8005 Zurich, Switzerland Tel. +41 (0) 1/446 50 50							
The data given are mean values based on practical experience. Application according to the supplier's specification and at user's risk with regard to climatic and specific conditions.								

WÄRTSILÄ Wärtsilä Switzerland Ltd.	**RTA / RT-flex**	**GUIDELINE FOR ENGINE PROTECTION** **AFTER SHOP TEST**		**Group 0345**
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16.0.6 Tectyl 5006W

Type of corrosion-protective product	**Waxy, dry, grip-dry protective film for long-term preservation and external protection**						
Name of product: **TECTYL 5006W**		Article No: Specification No: Substitute for Spec. No:					
General and physical properties: Oil-based corrosion preventive emulsifiable with water	Protection against: In dry state resistant to atmospheric influences such as rain, snow and aggressive industrial atmosphere and gases such as SO_2						
Application Temperature: 10°C to 35°C	Application-method		Thinner %	Viscosity	Spraying pressure	Nozzle mm	k / Oh
Humidity:	Brush	Yes					
Colour: milky white	Roller	Yes					
Degree of gloss: wax-like, consistent	Dipping	Yes					
Covering power:	Spraying: low press.	Yes					
Density: 1090 kg/m^3 at 20°C	high press.	Yes					
Content of solids: 40 %	Airless	Yes					
Viscosity: DIN 4 - 20°C - 30 sec.	Electro-static	Yes					
Danger class: none	Drying: Air	dust-free	set to touch	completely dry	Recoatable after: spraying		
Poison class: none	20°	1,5h	2 hrs	3 hrs	no	no	
Flash point: none (emulsion)	Oven	Time 1 ½ h	Temperature of component:		max. 60°C		
Identification duty: no	Forced	Time 1 ½ h	Temperature of component:		max. 60°C		
Shelf life: cool/dry + 5°C to + 35°C	Technical data:						
Mixing ratio: 1) 2)	Cross-cut test DIN 53151						
With hardener:	Hardness acc. to:						
Pot life:	Steel ball jet: DIN 53154						
Coverage: 10 m^2/l	Mandrel bend test: DIN 53152						
with dry film thickness of 40 microns 3)	Ericcson cupping index IE: DIN 53156						
Temperature range: - 30°C to + 120 °C	Salt-spray test: DIN 50021	5 % > 240 hrs					
Dry film melting-point:	Kesternich test: DIN 50018						
1) Weight 2) Volume 3) On smooth surface	Condensed water climate: ASTM-D-148, DIN 51359	> 240 hrs					
Surface preparation:	Dust-free, oil- and grease-free surface. May be applied to moist surface. Surface treated with Dewatering Fluid WA.						
Features:	Storage: protect against frost. Treated parts should only be taken outside when completely dry.						
Duration of protection:	Indoor storage up to 4 years / outdoor storage up to 2 years						
Removal, cleaning:	With petroleum, aromatic-free white spirit, alkaline soaker, steam or hot-water cleaner with corrosion protection additive						
Supplier:	Valvoline Oil Co. Ltd., Hardturmstr. 175, P.O. Box, CH-8005 Zurich, Switzerland Tel. +41 (0) 1/446 50 50						
The data given are mean values based on practical experience. Application according to the supplier's specification and at user's risk with regard to climatic and specific conditions.							

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16.0.7 Tectyl 5805W

Type of corrosion-protective product Dry protective coat for short-term preservation

Name of product: **TECTYL 5805 W**	Article No: Specification No: Substitute for Spec. No:
General and physical properties: Oil-based corrosion preventive emulsifiable with water	Protection against: Industrial atmosphere in case of indoor storage. Not resistant against atmospheric influences such as rain, etc.

Application Temperature:	10°C to 35°C	Application-method		Thinner %	Viscosity	Spraying pressure	Nozzle mm	k / Oh
Humidity:		Brush	No					
Colour:	yellowish	Roller	No					
Degree of gloss:	oily	Dipping	Yes					
Covering power:		Spraying: low press.	Yes					
Density:	900 kg/m^3 at 20°C	high press.	Yes					
Content of solids:	none	Airless	Yes					
Viscosity:	17 mm^2/s at 40°C	Electro-static	No					
Danger class:	none	Drying: Air	dust-free	set to touch	completely dry	Recoatable after: spraying		
Poison class:	none	20°C			2 hrs			
Flash point:	140°C	Oven	Time ½ h		Temperature of component:		max. 60°C	
Identification duty:	none	Forced	Time ½ h		Temperature of component:		max. 60°C	
Shelf life:	12 months cool/dry	Technical data:						
Mixing ratio: 1)	1:4 2) 1:10	Cross-cut test DIN 53151						
With hardener:		Hardness acc. to:						
Pot life:		Steel ball jet: DIN 53154						
Coverage:	150 - 400 m^2/l	Mandrel bend test: DIN 53152						
with dry film thickness of	1 - 2 microns 3)	Ericcson cupping index IE: DIN 53156						
Temperature range:	- 10°C to + 50°C	Salt-spray test: DIN 50021						
Dry film melting-point:		Kesternich test: DIN 50018						
1) Weight 2) Volume 3) On smooth surface		Condensed water climate: ASTM-D-148, DIN 51359	Mixture 1:3 > 10 days					

Surface preparation:	Dust-free, oil- and grease-free surface. May be applied to moist surfaces.
Features:	Storage: protect against frost. Mixable in every ratio with water, results in milky emulsion
Duration of protection:	Indoor storage up to 6 months, depending on mixture ratio
Removal, cleaning:	If required, with petroleum, aromatic-free white spirit, alkaline soaker, steam or hot-water cleaner with corrosion protection additive
Supplier:	Valvoline Oil Co. Ltd. Hardturmstr. 175, P.O. Box, CH-8005 Zurich, Switzerland Tel. +41 (0) 1/446 50 50

The data given are mean values based on practical experience. Application according to the supplier's specification and at user's risk with regard to climatic and specific conditions.

WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTA / RT-flex	**GUIDELINE FOR ENGINE PROTECTION** **AFTER SHOP TEST**			**Group 0345**
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16.0.8 Tectyl 910 / Tectyl 930

Type of corrosion-protective product	Rust-preventing oil for preservation and lubrication
Name of product: **TECTYL 910 / TECTYL 930**	Article No: Specification No: Substitute for Spec. No:
General and physical properties: Oil-based corrosion preventive. Stays oil, does not become gummy. MIL-L-21260 B+C, API SF/CD	Protection against: Atmospheric influences such as aggressive air, etc. Not resistant to mechanical loads and rain, etc.

Application		Application-method		Thinner %	Viscosity	Spraying pressure	Nozzle mm	k / Oh
Temperature:	0°C to 50°C							
Humidity:		Brush	Yes					
Colour:	yellow-brown	Roller	Yes					
Degree of gloss:	wet gloss	Dipping	Yes					
Covering power:		Spraying: low press.	Yes					
Density:	880 - 890 kg/m^3 at 15°C	high press.	Yes					
Content of solids:	none	Airless	Yes					
Viscosity:	910: VG46 930: VG100	Electro-static	Yes					
Danger class:	none	Drying: Air	dust-free	set to touch	completely dry	Recoatable after: spraying		
Poison class:	free BAG T No. 611 500							
Flash point:	218-230°C in closed pot	Oven	Time		Temperature of component:			
Identification duty:		Forced	Time		Temperature of component:			

Shelf life:	24 months cool/dry	Technical data:	
Mixing ratio: 1)	2)	Cross-cut test DIN 53151	
With hardener:		Hardness acc. to:	
Pot life:		Steel ball jet: DIN 53154	
Coverage:	910:140 930:110 m^2/l	Mandrel bend test: DIN 53152	
with dry film thickness of	5 - 7 microns 3)	Ericcson cupping index IE: DIN 53156	
Temperature range:	- 20°C to + 50°C	Salt-spray test: DIN 50021	passed 20 hrs
Dry film melting-point:		Kesternich test: DIN 50018	
1) Weight 2) Volume	3) On smooth surface	Condensed water climate: ASTM-D-148, DIN 51359	Jan-791 720 hrs without findings

Surface preparation:	Dry, dust- and grease-free surface
Features:	
Duration of protection:	Indoor storage 6 - 24 months, depending on climatic conditions
Removal, cleaning:	Normally not necessary. If required, with white spirit.
Supplier:	Valvoline Oil Co. Ltd. Hardturmstr. 175, P.O. Box, CH-8005 Zurich, Switzerland Tel. +41 (0) 1/446 50 50

The data given are mean values based on practical experience. Application according to the supplier's specification and at user's risk with regard to climatic and specific conditions.

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16.0.9 Tectyl 175GW ; Tectyl 185 GW ; Tectyl 132

Type of corrosion-protective product term	**Waxy and resinous, dry, grip-dry protective film for long-preservation and external protection**
Name of product: **TECTYL 175GW; 185 GW; 132**	Article No: Specification No: Substitute for Spec. No:
General and physical properties: Oil-based corrosion preventive	Protection against: Extreme atmospheric influences, aggressive industrial atmosphere and gases such as SO_2 and acid vapours. Absolutely resistant in water.

Application Temperature:	10°C to 35°C	Application-method		Thinner %	Viscosity	Spraying pressure	Nozzle mm	k / Oh
Humidity:		Brush	yes					
Colour:	yellow	Roller	no					
Degree of gloss:	waxy	Dipping	no					
Covering power:		Spraying: low press.	no					
Density:	950 kg/m³ at 20°C	high press.	no					
Content of solids:	65 ± 3 %	Airless	yes					
Viscosity:		Electro-static	yes					
Danger class:	A-II	Drying: Air	dust-free	set to touch	completely dry	Re-coatable after: spraying		
Poison class:	free BAGT No. 611 500	20°C	2 h	5 h	10 h			
Flash point:	43°C in closed pot	Oven	Time		Temperature of component:			
Identification duty:	ADR/SDR cl. 3 zif. 31c	Forced	Time		Temperature of component:			

Shelf life:	12 months cool/dry storage	Technical data:	
Mixing ratio: 1)	2)	Cross-cut test DIN 53151	
With hardener:		Hardness acc. to:	
Pot life:		Steel ball jet: DIN 53154	
Coverage:	5 m²/l	Mandrel bend test: DIN 53152	
with dry film thickness of	100 microns 3)	Ericcson cupping index IE: DIN 53156	
Temperature range:	- 23°C to + 175°C	Salt-spray test: DIN 50021	5 % at 75 microns, 1500 h
Dry film melting-point:		Kesternich test: DIN 50018	
1) Weight 2) Volume	3) On smooth surface	Condensed water climate: ASTM-D-148, DIN 51359	

Surface preparation:	Dry, dust-free, oil- and grease-free surface; surface treated with Dewatering Fluid WA and TECTYL 506 or 5006W
Features:	Non water displacing.
Duration of protection:	Indoor storage up to 5 years / outdoor storage up to 3 years. Immersion-resistant in water.
Removal, cleaning:	With petroleum, aromatic-free white spirit, alkaline soaker; steam or hot-water cleaner with corrosion protection additive
Supplier:	Valvoline Oil Co. Ltd., Hardturmstr. 175, P.O. Box, 8005 Zurich, Switzerland Tel. +41 (0) 1/446 50 50

The data given are mean values based on practical experience. Application according to the supplier's specification and at user's risk with regard to climatic and specific conditions.

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17.0.0 Overview of regular inspection lists during engine storage

Mainly four lists have to be used during engine storage:

- 17.0.1 Inspection List for general parts purpose
- 17.0.2 Inspection List for dehumidifier
- 17.0.3 Inspection List for time-dependant inspections or moving of parts
- 17.0.4 Inspection List for final delivery inspection
  (carried out at engine maker / see chapter 9.0)
  Same list to be used for "Inspection upon arrival"
  (carried out at shipyard / see chapter 11.0)

17.0.1 Inspection List for general parts purpose

The below-mentioned inspection record list for the inspection of engine and/or parts is for reference only, as every person responsible for storage may create his/her own list, as long as the 7 items given in the list below are mentioned in a way or other and clearly identified respectively.

If possible the temperature and humidity should be recorded in the same daytime period

Part inspected	Re-coated Yes/No	Temp. ˚C	Humidity %	Signature	Date	Remark (e.g. rust visible)

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17.0.2 Inspection List for daily dehumidifier inspection

Humidity record sheet

Date	Total hour	Temp (°C)	Humidity (%rh) Crankcase	Humidity (%rh) Piston underside	Humidity (%rh) Camshaft housing

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17.0.3 Inspection List for time-dependant inspections or moving of parts

Repeated treatment record sheet

Date		Treatment	Comments
Once a week		Engine turned with main lube oil pump running Lubrication of the cylinder liners Check oil level in the fuel system Operation of the cooling water pumps Move the fuel regulating linkage Temperature and humidity recording Inspection/re-coating of blank metal parts	
Once a month		Inspection of the crankcase Inspection of the piston underside Inspection of the exhaust manifold Open/close main starting shut-off valve Check dehumidifying system (filter, hoses, etc.) Turn the rotor of the turbocharger(s) by 90° Turn the auxiliary blower(s) by hand	
After three months		Inspection of a cross head bearing pin Inspection of a main bearing journal pin Replacement of the silica gel desiccant bags Analysis of the cooling water Analysis of the system oil	

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17.0.4. Inspection List for final delivery inspection / inspection upon arrival

- Final delivery inspection (carried out at engine maker / see chapter 9.0)
- Inspection upon arrival (carried out at shipyard / see chapter 11.0)

This parts list can/should be used for:
Final delivery inspection (at engine maker) &
Inspection upon arrival (at shipyard)

No.	Part - Designation	Inspected Yes/No	Re-coated Yes/No	Signature	Date	Remark (e.g. rust visible)
1	Crankshaft					
2	Main bearing shell					
3	Main bearing cover					
4	Jacking bolt main bearing (For RTA52U ; RTA62U-B ; RTA72U-B ; RTA84T-D only)					
5	Crank web					
6	Crankpin : web journal & main journal					
7	Gear wheels					
8	Thrust bearing					
9	Thrust bearing pads					
10	Bottom end bearing					
11	Connecting rod					
12	Crosshead bearing					
13	Crosshead guide shoes					
14	Piston rod					
15	Piston					
16	Exhaust valve					
17	Bedplate: machined surfaces					
18	Column: machined surfaces					
19	Column (guide rails)					
20	Cylinder block					
21	Tie rods					
22	At cyl. block top					
23	At bedplate bottom					
24	Diaphragm					
25	Piston rod gland					
26	Cylinder liner					
27	Scavenge ports					
28	Anti-Polishing ring					
29	SAC cooler					

WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTA / RT-flex	GUIDELINE FOR ENGINE PROTECTION AFTER SHOP TEST		Group 0345
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30	Cylinder cover					
31	Fuel injectors					
32	Combustion space					
33	Starting air valve					
34	Starting air shut-off valve					
35	Exhaust valve cage					
36	Exhaust manifold					
37	Scavenge air receiver					
38	Auxiliary scavenge air blower					
39	Flywheel					
40	Turning gear					
41	Electric motor					
42	RTA fuel pump block					
43	Starting air distributor					
44	Camshaft/reversing servomotor					
45	Linkage local manoeuvring stand					
46	RT-flex Supply Unit					
47	All flanged SU parts					
48	High-pressure fuel pumps					
49	Servo oil pumps					
50	Rail unit box					
51	Fuel oil rail					
52	Injection Control Unit (ICU)					
53	Servo oil rail					
54	Exhaust valve drive					
55	High-pressure pipes to fuel injectors					
56	Electronic cabinets					
57	All relief valves					
58	Turbocharger					

18.0 Engine tools

The engine tools should be stored in a clean, well ventilated and dry place; in addition they need to be protected against corrosion. It is advisable to check the condition and completeness of the engine tools to avoid any problems during commissioning and engine hand over.

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19.0 Spare parts

All spare parts must be firmly secured to prevent any movement. Metal-to-metal contact is to be avoided during storage of any components. All open ports, adapters, pipes, etc. are to be sealed in order to prevent ingress of foreign particles.

All spare parts have to be protected against corrosion. Large components should be treated with 'Valvoline' Tectyl 506 or a suitable equivalent. Smaller components, with the exception of electronic equipment, may be wrapped in a corrosion-protective VCI paper.

20.0 Health protection and safety at work

The official statutes and regulations for occupational hygiene and technical equipment measures are to be stringently observed, and the working conditions with cleaning agents and corrosion protective products have to be allowed for.

Samples of safety mask & safety goggle which are to be used:

Safety mask with exchangeable filter system.

Must be used during corrosion protection application or use of cleaning solvent inside closed spaces (inside the engine)

Safety goggle with closed side frame.

Must be used during corrosion protection application or use of cleaning solvent inside closed spaces (inside the engine)

21.0 Disposal

The generation of waste should be avoided or minimized wherever possible.
Avoid dispersal of spilled material, their contact with soil and further runoff, waterways, drains and sewers. Disposal of these products, solutions and any by-products should at all times comply with the requirements of environmental protection and waste disposal legislation and any regional or local authority requirements.

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20.2 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 as well as corrosion protected by rust preventing oils or paper (see section *20.1*). To ensure correct reassembly and eliminate the risk of parts from one cylinder unit being fitted to another by mistake, it is indispensable that bearings and running gear are clearly marked cylinder by cylinder. Use a paint brush to apply high-viscosity rust preventing oil to the piston and connecting rods, crosshead guides, gear wheels, camshaft and rollers. Air powered spray guns are 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 a similar product.

20.3 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 properties similar to 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 their own as solvents; they are to be mixed with 2 to 3 parts of a ‘cold cleaner’, such as ‘Magnusol’, ‘Agitol’ or ‘Emultan’.

20.4 Engine installation

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 the event 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. The engine alignment can be done with either jacking screws or wedges.

20.4.1 Installation and assembly of subassemblies

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 the preliminary alignment of the bedplate using one of the methods mentioned in section *20.4* 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. Place bearing caps in position, install turning gear and check that crankshaft deflections are as recorded on the “Engine Assembly Records”. To check the bedplate level in longitudinal and diagonal direction a taut-wire measuring device will be provided by the engine builder. Compare the readings with those recorded at works. Optical devices or lasers may also be used.

All final dimensions are to be witnessed by the representatives of the engine builder and the classification society and to be recorded on appropriate log sheets. Crankshaft deflections at this stage are to correspond with the values recorded at works. Secure the bedplate temporarily against unexpected movement.

Continue engine assembly by mounting the columns, cylinder blocks, running gear 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 and chocking is carried out with the vessel afloat.

20.4.2 Installing a complete engine

In the event that the engine is shipped in part deliveries and assembled at the shipyard before installation in the vessel, the shipyard is to undertake the assembly work in accordance with the demands of a representative of the engine builder and the classification society. The engine mounting is to be carried out systematically and measurement readings taken, recorded on appropriate log sheets and compared for correctness with the data of the “Engine Assembly Records” completed after test run in the works of the manufacturer.

NOTICE

Strict attention is to be paid to the removal of anti-corrosion coatings and the subsequent application of rust preventing oil where required.

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 in such a manner 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.

20.4.3 Installing an engine from assembled subassemblies

Subassemblies of the engine may be assembled ashore before 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 *20.4.1*.

20.4.4 Engine installation with ship on slipway

Installing complete or partially assembled engines in ships under construction on an inclined slipway is possible when careful attention is paid to the following:

1. Suspending large components to take account of the incline
2. Tie rods to be centred and exactly perpendicular to the bedplate before tightening
3. Fit temporary side, fore and aft arresters to prevent the engine from moving during launching
4. Attach additional temporary stays at the upper platform level to steady the engine during launching.

21. Engine and Shaft alignment

21.1 Procedure

21.1.1 Drawings

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WÄRTSILÄ

Product: **RT-Engines**

Engine Alignment

direct - coupled marine propulsion

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Appd	12.05.2011	K. Moor	**9709**			

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1 Introduction

1.1 Preface

This instruction aims to facilitate the complete alignment process, from the initial shafting arrangement design stage to the final normal ship's service operation condition. The objective is an easy and trouble-free alignment by guiding through this process. The final goal is a safe and trouble-free propulsion system operation over the complete ship's lifetime.
The instruction contains different kinds of information:

- General information and background information to provide better technical understanding of alignment procedures
- Guidelines and guidance values, guiding through the alignment process
- Alignment limits which have to be kept in order to ensure safe propulsion system operation.

1.2 Validity of this instruction

This instruction is valid for direct-coupled Wärtsilä two-stroke engines under the conditions mentioned in the following.

A proper bearing arrangement is the prerequisite for proper engine and shaft alignment. Section 3, p.13 provides further information. If the bearing arrangement does not fulfil the mentioned requirements, the guidance values of this instruction are **not applicable**. All data mentioned in this instruction are only valid for *standard installations* of the mentioned Wärtsilä two-stroke engines on board of seagoing vessels. The term *standard installations* means:

- the bearing arrangement fulfils the requirements defined in section 3, p.13
- no additional heavy masses like shaft generators are installed on the shaft line.

In case of non-standard installations it is strongly recommended to contact Wärtsilä[1]. However, even for standard installations it is not possible to cover all possible installation variants and their characteristics, as the ship design varies[2].
Therefore the given guidance values can only provide strong indication whether the alignment is acceptable or needs to be improved. In some special cases the guidance values might be exceeded, while the alignment is acceptable, and vice versa. In case of

[1] Case-specific guidance values will be defined according to the basic approach of this instruction.

[2] Ship design in general, frame arrangement and design, properties of applied steel, tank arrangements, applied components, etc.

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any doubts, Wärtsilä can provide case-specific support. Wärtsilä case-specific instructions supersede the general values provided in this document.
All engine type-specific data provided in this instruction are valid for all crankshaft executions, e.g. FCV1, FCV2, FCV3.
Finally, after ship delivery it is essential that under all normal operating conditions all bearings are statically loaded and the crankweb deflections do not exceed the admissible limits (= aim of alignment, as explained in following section 1.5, p. 6). The referred crankweb deflection limits are provided in table 7.1, p. 52, and the main bearing[3] load limits are provided in table 7.2, p. 53.

1.3 Responsibilities

It is the shipyard's responsibility to guarantee that the final ship service requirements will be kept under all operation conditions. The referred crankweb deflection limits are provided in table 7.1, p. 52, and the main bearing load limits are provided in table 7.2, p. 53. Guidelines on how these requirements can be fulfilled are given in this instruction. However, Wärtsilä does not take any responsibility for the correctness of these guidance values.
As long as Wärtsilä is not involved as direct contractual partner, Wärtsilä will just provide technical support and issue comments if requested, e.g. whether an alignment condition meets Wärtsilä's expectations or not. Therefore Wärtsilä only provides guidelines and proposals for the complete alignment process, but will not specify the exact way of working, as this remains within the shipyard's responsibility.

1.4 Wärtsilä alignment services

Wärtsilä provides various services concerning the engine and shafting alignment of direct-coupled two-stroke marine diesel engines. Certain services, e.g. the review of the shafting arrangement during design stage, are free of charge, whereas other services, e.g. complete shafting alignment calculations, will be charged to the purchaser, except when otherwise stipulated. A special service exclusively provided by Wärtsilä is the offer of a special alignment calculation program which includes all portfolio engines as full three-dimensional models for quick and easy alignment calculations. This program is provided on order and free of charge to Wärtsilä's licensees and shipyards installing a Wärtsilä engine[4]. Further information concerning Wärtsilä services can be found in the document 'Engine / Shafting Alignment - Scope of Services'.

3 The abbreviation *mb* is used for *main bearing*.

4 Wärtsilä agrees to the use of this program in parallel also for other alignment projects, e.g. four-stroke installations, different engine brands, etc. The program is suitable for such tasks. In connection with Wärtsilä products the full advantage of the program can be utilised as more detailed information can be provided.

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For additional information, ordering alignment layout calculation, any kind of alignment review or requesting the EnDyn alignment program[5], please contact Wärtsilä, e.g. by email to: application.engineering.ch@wartsila.com. Onsite support for alignment execution can be ordered from Wärtsilä field service: fieldservice.ch@wartsila.com or by contacting the local Wärtsilä office.

1.5 Aim of alignment

All bearings need to be statically loaded under all conditions! (The term 'all bearings' refers to all shaft line bearings as well as to all engine main bearings.) In addition, all crankweb deflections – engine stopped – need to be within the service limits under all ship service conditions.

In order to get this requirement fulfilled, the following three principles have to be considered, mentioned in sequence of decreasing priorities:

1. The influences on bearing load distribution need to be kept small[6].
2. The various influences on the shaft line and the engine during the ship's lifetime need to be considered in the alignment process, i.e. the expected changes due to the different influences[7] need to be pre-compensated.
3. Take care of the new crankweb deflection limits during engine installation[8].

The main influence on the shafting system is the ship's hull bending. It is obvious that the aft hull section of the engine bends downwards with increasing draught. The engine alignment in new ship buildings is performed at very light draughts and therefore the hull bending due to increasing draughts needs to be pre-compensated. The following figure shows a typical shaft bending line of an Aframax tanker. It is obvious that the aft end bends downward with increasing draught.

---

5 Please ask regularly, e.g. when starting a new project or about every 6 months, for updates in order to have up-to-date documentation at hand.

6 See section 3, p. 13.

7 Mainly ship hull bending; see figure 1.1, p. 7.

8 Lowest priority: in some special cases Wärtsilä might introduce case-specific limits.

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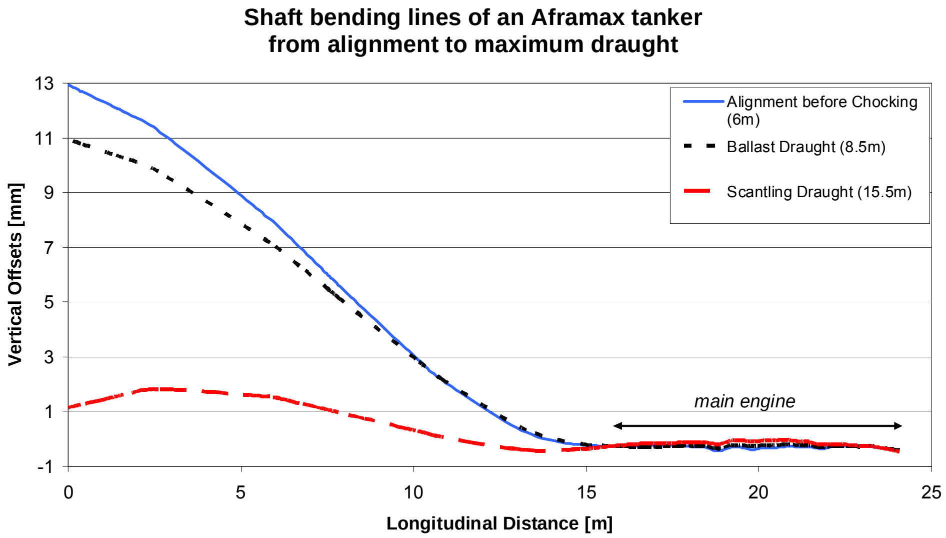

Figure 1.1: shaft line bending due to hull bending – engine position fixed as reference.

The effect on the aft main bearings can be clearly seen in the following magnification of the above figure.

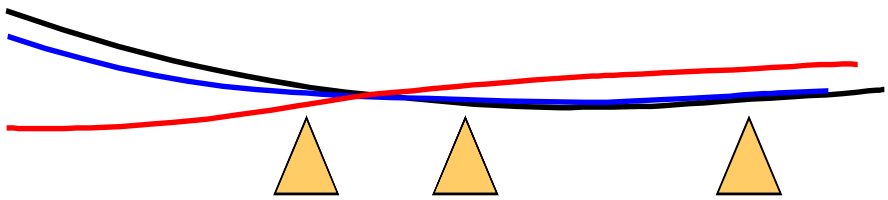

Figure 1.2: magnification of shaft line bending due to hull bending at main bearing #1 to #3 positions.

It is obvious that at very light draught condition main bearing #1 is very low loaded whereas main bearing #2 is very well loaded, while at scantling draught condition the load distribution is inverted.
The corresponding main bearing load distribution is shown in the following figure 1.3.

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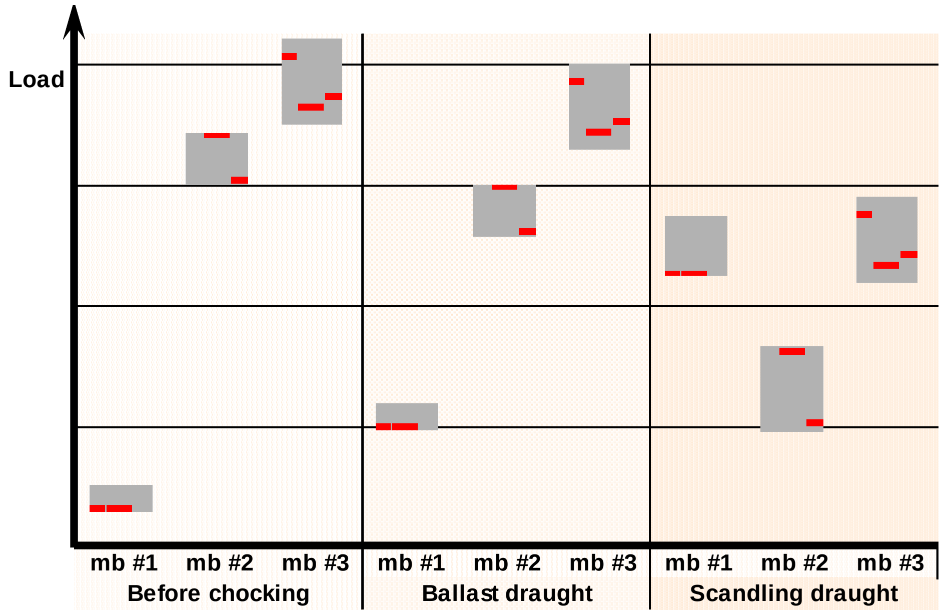

Figure 1.3: overview of static main bearing load distribution[9] at different draught conditions. Load on mb #1 increases with increasing draught while mb #2 load decreases with increasing draught[10].

The influence of hull bending on alignment is the greater, the smaller the distances between the bearings are. Therefore the distance between the bearings, especially between the aftmost engine main bearing and the foremost shaft line bearing, needs to be kept as long as possible. For further information please refer to section 3 (p. 13) regarding optimisation of the shaft bearing arrangement.

---

9 Further explanations of how to understand this illustration are provided in figure 4.2, p. 22, and in section 5.5.2, p. 40.

10 In general most critical: mb #2 load at scantling or design draught as the bearing must not be unloaded.

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Engine Alignment

direct - coupled marine propulsion

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Appd	12.05.2011	K. Moor		9709

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2 Alignment in brief

The required steps for alignment are described below. Figure 2.1, p. 11, shows the alignment process diagram.

Project stage:

1. Optimise the bearing arrangement (see section 3, p. 13).
2. Create the alignment layout calculation (see section 4, p. 15).

Dock condition:

3. Finalise the engine assembly: alignment <u>does not</u> start before the engine assembly is finalized[11].

Afloat condition - before chocking the engine:

4. Align the shafts (propeller shaft and intermediate shafts) to each other as well as the engine[12] to the forward intermediate shaft by using the gap & sag method (see section 5.1, p. 28).
5. Couple the shafts to each other and to the engine[13].
6. Alignment checks before pouring the chock fast: check the alignment by measuring the crankweb deflections for all cylinders (see section 5.4, p. 33) and the bearing loads for all shaft line bearings and engine main bearings #1, #2 and #3[14] (see section 5.5, p. 37).
   If the limits are exceeded or in case of doubt about the correct alignment[15], re-adjust the alignment. If required, check the bedplate bending shape.

---

[11] Engine assembly needs to be carried out according to the engine assembly instruction, i.e. especially a proper bedplate levelling is of utmost importance. If engine assembly is not carried out correctly, good engine alignment might become very difficult or even (almost) impossible!

[12] Before aligning the engine to the shafts, a reference crankweb deflection measurement might be taken according to shipyard's experience.

[13] Alternatively the gap & sag alignment can be done step by step, starting from the aft. This means first of all that the gap & sag between propeller shaft and aft intermediate shaft is adjusted, followed by coupling of these shafts. Then all intermediate shafts are aligned and coupled accordingly. Finally the engine is aligned by gap & sag in relation to the forward intermediate shaft and coupled. In this case the alignment calculation needs to provide for all those gap & sag alignment steps.

[14] In some cases a load measurement for further main bearings might be required. More information can be found in section 5.5, p. 35.

[15] If needed, please contact Wärtsilä for further support.

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Afloat condition - chocking and fixation:

7. Weld the side stoppers in position; do not yet fit the side stopper wedges.
8. Pour the resin cock under the engine.
9. Install the chock under the shaft bearings. Alternatively this step could be carried out after the engine is bolted down and a preliminary alignment check has been performed.
10. Bolt down the engine.
11. Install the side stopper wedges.

Afloat condition - before ship delivery:

12. Alignment checks before ship delivery: Wärtsilä recommends the same alignment checks as before chocking, at least for the first vessel of a ship series. The limits can be found in section 6, p. 45.

Afloat condition: after ship delivery / ship service:

13. Generally no alignment checks are required during normal ship service[16]. However, if anyway required[17] the limits given in section 7, p. 50, have to be applied.

[16] Ship service means: after ship delivery, draught between normal ballast and scantling draught, engine stopped for measurements as a matter of course.

[17] Alignment check in normal ship service might be required in case of bearing failures or other alignment related abnormalities, like an extraordinary change of the crankweb deflections.

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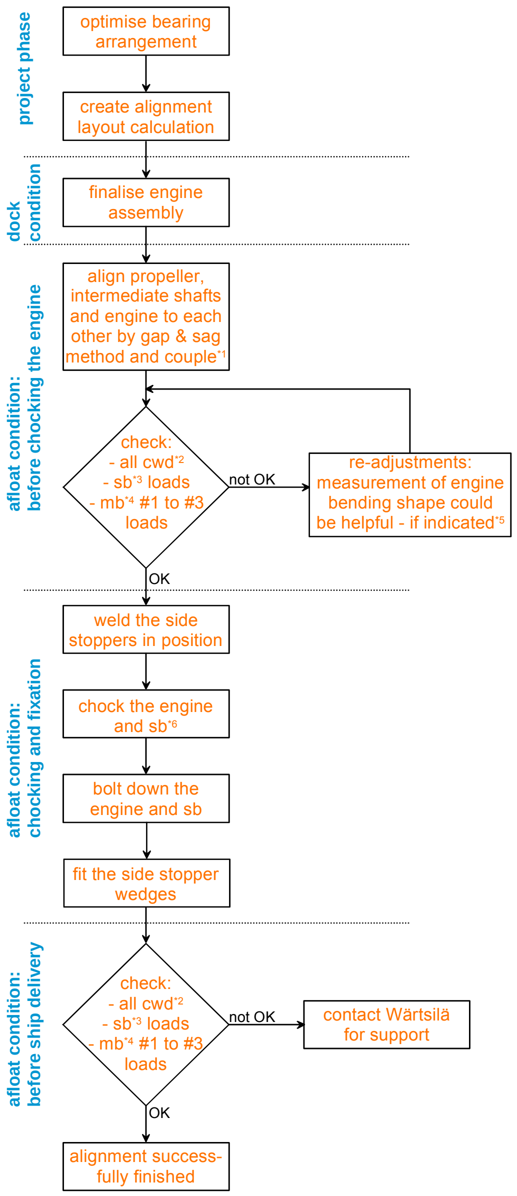

*1 according to alignment layout calculation and yard's experience
*2 cwd: crankweb deflection
*3 sb: shaft bearing
*4 mb: engine main bearing
*5 it is indicated if the reason for exceeding the limits is not clear
*6 if shaft bearings need to be chocked

Figure 2.1: alignment process diagram.

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Summary:
All bearings need to be loaded under all conditions! Therefore:

- Influences on alignment are to be kept as small as possible, i.e. optimised bearing distances are needed.
- Expected alignment changes due to the different influences during ship service need to be pre-compensated in the alignment process.

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3 Shaft bearing arrangement / Optimum bearing distances

The key to a successful propulsion system installation is an optimized bearing arrangement. It is essential to optimise the distances[18] between the shaft line bearings as recommended by the following in order to avoid poor shaft and main bearing performances.
In case of too long bearing distances the risk of whirling vibration with its negative effects will be increased.
On the other hand, in case of too short bearing distances, the risk of excessive bearing load changes will be increased. In such cases the bearing design loads may easily exceed both the upper and the lower limits, even more down to totally unloaded bearings; this means the system will be out of its (approved!) design. The following problems may be expected in case of unloaded bearings:

- In case of totally unloaded shaft line bearings, the distance between the still loaded bearings may become too long, i.e. whirling vibration may become a problem.
- In case of a totally unloaded engine main bearing (usually main bearing #2), engine main bearing damage may occur, namely on the unloaded bearing itself or on another engine main bearing due to vibration effects, as the engine is then operated out of design.
- In addition, an unloaded bearing means that its load has to be carried by other bearings, which might then become overloaded.

Optimum shaft bearing distances are the most important prerequisite for proper alignment. On the one hand, too long bearing distances may, as mentioned, lead to whirling vibration, while on the other hand too short bearing distances cause excessive static bearing load changes due to ship hull bending. Furthermore, in case of too short bearing distances, the bearings are relatively low loaded and consequently the risk for unloading is quite significant. According to experience, designs with too long bearing distances are very seldom, but with too short distances oftentimes.
The usual maximum limit for bearing distances can be calculated according to the following guidance formula[19] by putting the outer shaft diameter d_{shaft} in millimetres, resulting in the maximum bearing distance x_{max} in millimetres:

$$x_{max} = 450\sqrt{d_{shaft}} \qquad (3.1)$$

The following table gives an approximative overview on the recommended optimum bearing distances. However, for a detailed layout please apply formula 3.2.

[18] Also required by class rules.

[19] Formula of GL class. Confirmed by Wärtsilä experience.

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Shaft diameter	Recommended optimum intermediate bearing distances, including distance foremost intermediate bearing to main bearing #1
400 mm	6.5 m to 8 m
600 mm	8 m to 10 m
800 mm	9 m to 11.5 m

Table 3.1: guideline for recommended bearing distances.

As mentioned in section 1.2, p. 4, this instruction is only valid for standard installations in new ship buildings which consider the following rules of bearing distances:

- The distance x_{actual} between the aftmost engine main bearing #1 and the forward shaft line bearing is in a range of

$$67\%\, x_{max} \leq x_{actual} \leq 90\%\, x_{max} \tag{3.2}$$

- Or at least within the exceed range of

$$60\%\, x_{max} \leq x_{actual} \leq 100\%\, x_{max} \tag{3.3}$$

If it is necessary to apply the extended range, Wärtsilä should be contacted.
Installations with distances outside the limits given in above formula 3.3 are not at all recommended and not covered by this instruction.

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4 Alignment layout calculation

From the engine installation aspect, the binding alignment layout calculation is created for the real alignment condition as it can be found on board the vessel, i.e. for very light draught conditions with engine cold and stopped (as it is not yet installed). During the installation process this allows referring directly to the calculation and finally makes it possible to compare the alignment measurement results directly with the calculation. However, the later ship operation conditions need to be considered in the layout calculation as well. From the shaft line installation aspect, the so called 'running condition' is the most important calculation, as the influence of the propeller forces and moments on the shafting system can be checked. The aim is to achieve reliable static loads on all bearings in all ship service conditions.
In the calculation the following influences need to be considered:

- Ship hull bending
- Engine temperature
- Propeller service forces.

Detailed information about ship hull bending, which could be used as an input for the alignment layout calculation, is usually not available. In such cases the ship hull bending needs to be considered based on experience. An increase of ship draught generally leads to a more hogging shape of the engine and shaft line foundation. This causes a load shift from main bearing #2 – and to a very low extent also from main bearing #3 – to main bearing #1. This means, the more ship hull bending is expected, the less load on main bearing #1 and the more load on main bearing #2 has to be adjusted.

The following exemplary ship hull bending can be expected:

- VLCC and bulk carriers have most hull bending due to the huge difference between ballast and scantling draught. In the alignment layout calculation[20] and during the alignment process, loads just above zero should be adjusted for main bearing #1.
- Container vessels have less hull bending than VLCC and bulk carriers, but still significant.
- Gas tankers have quite limited hull bending.
- Car carriers have only very limited hull bending.

In those cases where the hull bending is known, the alignment calculation has also to be carried out for the alignment condition as mentioned before, but in addition it is possible to carry it out for any other service draught condition. At least the ballast

[20] Cold / stopped condition.

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draught and scantling or service draught conditions should be calculated, as these are usually the conditions with the biggest hull bending difference during normal ship operation[21]. The alignment calculation results in the considered draught conditions must fulfil completely - i.e. including some safety margin - the service condition requirements as described in section 7.1.1, p. 50. In such cases it is not necessary to fulfil the recommended bearing loads for the alignment layout condition as provided in table 4.2, p. 23. Anyway, usually the alignment layout condition requirements will be fulfilled automatically.

Engine and shaft alignment for new buildings is usually performed in an empty ship, thus at very light draught.
For this condition a high static load needs to be designed for the engine main bearings #2 and #3. In contrast, a low static load should be designed for the aftmost main bearing #1. Table 4.2, p. 23, provides guidance values.

In the alignment layout calculation the engine has to be considered as straight, even if it may be installed with some pre-sag. The reason is that:

- the practically adjusted bedplate pre-sag[22] is different compared to an idealised, calculated one
- the bedplate pre-sag measured at the bedplate sides is not identical to the main bearing offsets.

Experience has shown that the differences between the main bearing loads calculated for an idealised straight engine and the finally measured bearing loads are less, compared to bearing loads calculated for a pre-sagged engine.
The offset machining[23] of engine main bearings #1 and #2 needs not be considered: the offset machining intends to compensate the influence of tie rod tightening on the main bearing offsets, i.e. after tightening the tie rods the offset machining finally results in equal main bearing offsets.

Please consider the validity of this instruction as well as its guiding character, as mentioned in section 1, p. 4 at the beginning of this instruction.

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21 In general the scantling draught is the most different condition. However, for some container ships experience has shown that the service draught condition is the most different compared to the alignment condition.

22 Pre-sag is not required by Wärtsilä. Please refer to section 5.2.2, p. 30.

23 Depending on engine type.

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4.1 Whirling calculation

Whirling calculations are required from the engine's[24] perspective if:

- demanded by the classification society or other involved parties
- bearing distances exceed the normal maximum limit (see formula 3.1, p. 13)
- no forward stern tube bearing is installed
- shaft generator or shaft motor is installed
- in case of very low loaded shaft bearings (less than 15% of design load)

For all other cases no whirling calculation is needed from the engine's perspective.

4.2 Calculation basics and definitions

Independent of which alignment calculation program is used, the following basics need to be taken into account:

- Stiffness of all bearings, i.e. shaft bearings as well as engine main bearings[25]; as alignment is carried out in stopped condition, the static structure stiffness (without oil film) has to be taken.
- Bearing clearance, at least for the engine main bearings, as otherwise a low loaded main bearing might be calculated with negative load.
- The shaft line model used in the calculation program has to provide a realistic picture of the real installation.
- If the EnDyn alignment program is used, also the real bearing load measurement positions should be included, as this allows calculating the expected jack-load curves. A direct comparison between the jack-load curves calculated in the layout calculation and the really measured jack-load curves is possible. This is very helpful to evaluate the alignment.

24 Two-stroke engine's perspective. In contrast, the whirling calculation is always needed for four-stroke installations.

25 While non-observance of shaft bearing stiffness will just produce inaccurate calculation results, non-observance of main bearing stiffness may produce totally wrong results, i.e. even the load distribution trend might not be correct.

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The definitions used in the calculation need to be clear:

- Definition of gap & sag, e.g. sag referring to the centre line or to the top sides of flanges. This consideration is important if the coupling flange pair has different diameters.
- Definition of reference / datum line, e.g. defined by the forward and aft stern tube bearings, by the main engine position, etc.
- Definition of bearing offset, e.g. difference between datum line and centre of unloaded bearing[26].

4.3 Wärtsilä's alignment program EnDyn integrated engine models

It is strongly recommended to use the EnDyn calculation program for alignment layout calculations of Wärtsilä two-stroke diesel engines, as it provides accurate and detailed results. The program incorporates the full three-dimensional FE based models of all actual portfolio RT-flex and RTA engines. No further modelling by the user is required, only the correct crankshaft type needs to be selected.
Before starting a new project, it should be ensured that the latest release of the EnDyn program is available. The EnDyn calculation program can be ordered by licensees and shipyards free of charge (see also section 1.4, 'Wärtsilä alignment services' on page 5).

4.4 Two-dimensional crankshaft model

Two-dimensional[27] crankshaft models are provided for use, if other programs than EnDyn are used for preparing the alignment calculations. The relevant information is given in figure 4.1, p. 20, along with the data in table 4.1, p. 20. As common use, these models simulate the reduced stiffness of the crank by a cylinder of similar stiffness.
The two-dimensional crankshaft model is also known under the name 'equivalent crankshaft model'. However, a two-dimensional crankshaft model provides only a very limited picture of reality, as the content of information is quite limited. Consequently the results deviate from reality and therefore the naming 'equivalent crankshaft model' might be misleading.
The two-dimensional crankshaft models provide similar results[28] for static main bearing loads as obtained from the EnDyn integrated three-dimensional FE crankshaft models at crank angle (CA) 0 degree position (aftmost crankpin in top dead centre). But this applies only to the three aftmost engine main bearings.

---

[26] This definition is used by Wärtsilä.

[27] Two-dimensional under the aspect that just the element lengths and diameters are considered.

[28] It is essential to apply the model exactly as described in this instruction (e.g. considering the bearing stiffness), otherwise the calculation results are not valid!

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However, some deviations compared to the results calculated with the EnDyn program[29] will occur. For main bearings #1 and #2 deviations of about 5% can be expected and up to about 10% for main bearing #3 – in some special cases even more. The static loads calculated for main bearing #4 and main bearing #5 are not to be regarded, but these bearings need to be included in the calculation model in order to get correct results within the a.m. accuracy for main bearings #1 to #3.
As the two-dimensional crankshaft models only consider symmetrical shafts and external loads, the following information cannot be gained from the calculation:

- Pre-calculation of the expected bearing load measurement curves (jack-up test). For such calculation a realistic calculation model considering the geometry of the cranks is required, e.g. as it is contained in the EnDyn program.
- Direct comparison between the calculated and measured static loads for main bearings #2 to #n (foremost main bearing). The reason is that the static main bearing load is different for different crank angles, i.e. while turning the engine with the turning gear, the static bearing loads are continuously changing. This is caused by the geometry of the cranks where the vertical bending stiffness depends on the crank angle position due to the crank geometry; contrary to that the vertical stiffness of a simple shaft is independent of the turning angle due to the symmetrical rotary geometry. The loads calculated by applying the two-dimensional crankshaft model refer to the condition of 0°CA, i.e. cylinder #1 in top dead centre position, as this is the reference condition[30]. Please refer to section 5.5.2, p. 40.

The two-dimensional crankshaft model consists of the following elements:

- Main coupling flange and thrust shaft
- Cylinders of similar stiffness in the range of the cranks
- Forces to simulate the masses of cranks, running gears, thrust collar and gear wheel (if arranged on thrust collar)
- Elastic main bearings with clearance.

The aft end of the crankshaft, including the three aft cylinders, are modelled according to the syntax of the alignment calculation program.

29 The results gained from the three-dimensional calculation model are very realistic and can be considered as reference.

30 The sum of all static bearing loads in one crank angle position, e.g. 0°CA, refers directly to the masses carried by the bearings. However, the sum of all measured static (main) bearing loads does not directly refer to the related masses, as the measurements are taken at different crank angles.

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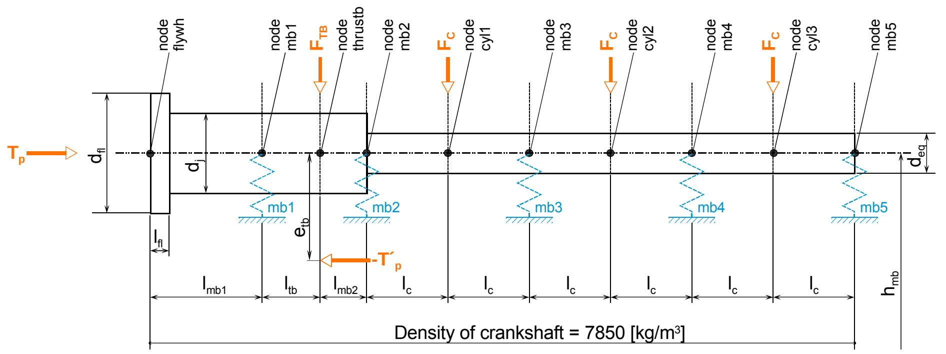

Figure 4.1: two-dimensional crankshaft model.

Designation	l_{fl}	d_{fl}	l_{mb1}	d_j	l_{tb}	l_{mb2}	d_{eq}	l_c	F_{TB}	F_C	h_{mb}	e_{tb}*1	Bearing stiffness*2	Bearing clearance
Engine Type	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[N]	[N]	[mm]	[mm]	[N/m]	[mm]
5-8 RT-flex35	100	695	328	430	277	155	220	306	7926	34192	830	-183	4.0E+09	0.3
5-8 RT-flex40	115	816	370	490	325	175	255	350	9359	46454	980	-210	4.0E+09	0.3
5-8 RTA48T-B/T-D 5-8 RT-flex48T-D	125	913	451	585	307.5	196.5	309	417	14'960	76390	1085	-188	3.0E+09	0.4
5-6 RTA/RT-flex50/-B/-D	120	970	436	600	365	211	328	440	16986	96200	1088	-282	4.5E+09	0.4
7-8 RTA/RT-flex50/-B-/D												-215		
5-8 RTA58T-B/-D 5-8 RT-flex58T-B/-E 5-8 RT-flex58T-D, V1, V2	150	1108	520	706	367.5	237.5	375	503	25418	138341	1300	-228	3.5E+09	0.5
5-8 RTA/RT-flex60C/C-B	160	1118	550	730	412	235	404	520	30411	146856	1300	-250	5.0E+09	0.5
5-8 RTA68-B/-D 5-8 RT-flex68-B/-D, V1	175	1298	622	828	448	270	441	590	24535	213740	1520	-276	4.0E+09	0.6
6-8 RTA/RT-flex82C	220	1458	810	980	587.5	350	575	752.5	62505	356710	1607	-342	6.0E+09	0.7
9-12 RTA/RT-flex82C									47700					
6-9RT-flex82T/T-B 6-8RTA82T/T-B	220	1458	810	1020	587.5	350	565	752.5	62505	411120	1600	-317	8.0E09	0.7
9RTA82T/T-B	220	1458	810	1020	587.5	350	565	752.5	47700	421610	1600	-317	8.0E09	0.7
5-7 RTA/RT-flex84T-D	220	1458	870	980	635	365	552	750	59282	350894	1800	-299	6.0E+09	0.7
8-9 RTA/RT-flex84T-D									37'818			-317		
6-7 RTA/RT-flex96C-B	210	1458	870	990	615	295	620	840	68503	434348	1'800	-314	5.0E+09	0.7
8-12 RTA96C-B 8-14 RT-flex96C-B									43743			-342		

*1 The minus sign means that the reaction point is below the shaft centre line.
*2 The static bearing stiffness has to be considered correctly.

Table 4.1: two-dimensional crankshaft model data for Wärtsilä RTA/RT-flex engines.

Notes:

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Modif	Number	Drawn Date		Number	Drawn Date	Number	Drawn Date	Number	Drawn Date
-	EAAD082941	12.05.2011	A	EAAD083309	04.10.2011				

WÄRTSILÄ

Product: **RT-Engines**

Engine Alignment
direct - coupled marine propulsion

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Chkd	11.05.2011	W. Schiffer	Design Group	
Appd	12.05.2011	K. Moor		9709

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It is mandatory to use the full two-dimensional crankshaft model as described in figure 4.1, p. 20, and above table 4.1.
This includes the aftmost main bearing #1 up to main bearing #5 as well as their elastic supports. The elasticity of the main bearing supports refers to stopped conditions – that means no oil film is considered, corresponding to the actual condition during the alignment process and the jack-up tests. Alignment calculations which do not consider the correct elasticity of engine main bearing supports are wrong and consequently cannot be judged with the Wärtsilä limits and recommendations.

4.5 Calculation for cold condition

This is the calculation for the condition at which the real alignment will be carried out.

4.5.1 Basic principle: main bearing load distribution

As introduced in section 4, p. 15, the ship hull bending influence on the bearing loads needs to be pre-compensated by adjusting the appropriate bearing loads during the alignment process. It is expected that static load will be transferred from main bearing #2 – and to a limited degree also from main bearing #3 – to main bearing #1. The expected extent of total load shift depends on the shaft arrangement and the vessel type, i.e.:

- the closer the distance between main bearing #1 and the foremost intermediate bearing, the more load shift is expected
- the bigger the difference between alignment and scantling draught, the more load shift is expected.

Consequently, in the alignment layout calculation low load has to be defined for main bearing #1; the less load, the more load change is expected.

Figure 4.2 below gives a simplified general overview on the recommended bearing load[31] distribution between main bearings #1 to #3.

31 Further information regarding the indicated load range box and the red lines therein is provided in section 5.5.2, p. 40.

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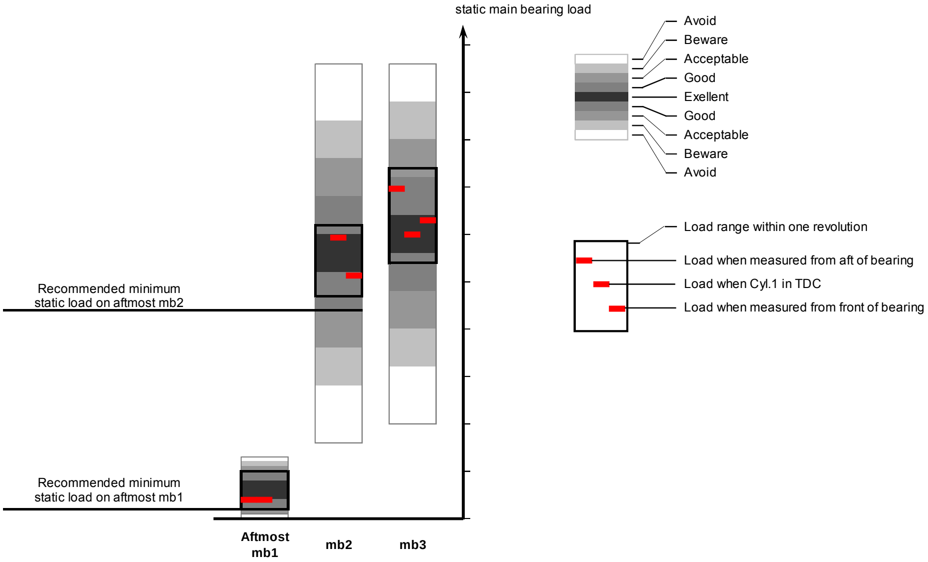

Figure 4.2: simplified presentation of recommended static main bearing loads for alignment layout calculation at cold, stopped condition.

As a mathematical description the following can be stated:

$$F_{stat}(mb\#1) << F_{stat}(mb\#2) \quad (4.1)$$

while

$$0.8 \times F_{stat}(mb\#2) \leq F_{stat}(mb\#3) \quad (4.2)$$

4.5.2 Recommended static main bearing loads, alignment layout calculation condition

The recommended main bearing loads for alignment layout calculations of new buildings are provided for guidance in order to achieve a good static main bearing load distribution. They refer to a ship afloat at light ballast draught and the engine in **cold / stopped condition** – as this is the physically existing condition during final alignment[32]. However, more important than the calculated absolute bearing loads is the before mentioned main bearing load distribution, see previous section 4.5.1, p. 21.

32 For engine alignment calculation only the cold, stopped condition needs to comply with the recommended bearing loads. The calculation for hot condition as well as for hot running condition is for reference only, i.e. to verify the layout and to get information about the sensitivity of the shafting system to changes. If the changes between the cold and hot condition are significant, the shaft arrangement should be checked and optimized as explained in section 3, p. 13.

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Recommended*[1] static main bearing loads [kN] for alignment layout calculation*[2], stopped cold condition				
	mb #1*[3]	mb #2	mb #3*[4]	mb #4 to n[33]
RT-flex35	4-15	30-45	30-45	>15
RT-flex40	5-20	45-70	45-70	>20
RT-flex48T-D RTA48T-D RTA48T-B	10-35	70-140	70-140	>35
RT-flex50-D RT-flex50-B RT-flex50	10-40	80-150	80-150	>35
RT-flex58T-E RT-flex58T-D, V1, V2 RTA58T-D RT-flex58T-B RTA58T-B	10-60	120-210	120-210	>35
RT-flex60C-B RT-flex60C	10-65	140-220	140-220	>35
RT-flex68-D, V1 RTA68-D RT-flex68-B RTA68-B	10-90	190-280	190-280	>50
RT-flex82C RTA82C	10-130	310-460	310-460	>90
RT-flex82T-B RT-flex82T RTA82T-B RTA82T	5-120	360-540	360-540	>90
RT-flex84T-D RTA84T-D	5-110	320-480	320-480	>90
RT-flex96C-B RTA96C-B	10-140	350-550	350-550	>90

*1 The given values are for guidance only. More important than the absolute main bearing loads is the relative load distribution between the bearings, as explained in section 4.5.1, p. 21 and illustrated in figure 4.2, p. 22.

*2 If calculated with the two-dimensional crankshaft model:
- Calculation accuracy has to be kept in mind
- No calculation results available for mb #4 to #n (please refer to section 4.4, p. 18)

*3 The lower and upper values refer to the installation type and should not be considered as recommended tolerance ranges! The following has to be considered:
Lower value: target if distance between engine and next shaft line bearing is short[34] and / or a heavy flywheel is installed.
Upper value: target if distance between engine and next shaft line bearing is long[34] and / or a light flywheel is installed.

*4 mb #3 load should be ≥80% of mb #2 load.

Table 4.2: recommended static main bearing loads [kN] for alignment layout calculations of new buildings at cold/stopped condition.

33 These minimum values have to be kept for each crank angle position.

34 As defined in formula 3.3, p. 14

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4.6 Calculation for hot condition

The alignment layout calculation for hot condition considers the following:

- the thermal rise of the engine main bearings

It is possible to consider in addition the thermal rise of the shaft bearings. However, as the distances between the shaft bearings are quite long, this influence can be usually neglected. Otherwise, the shaft bearing thermal rise has to be considered analogous as described in the following for the main bearings.

The recommended static loads provided in previous table 4.2 are valid for new buildings at very light ship draught in cold/stopped condition. The results of alignment layout calculations which refer to cold/stopped condition are used to align the shafts and the engine. Also the verification of alignment before chocking and fixation refers to cold / stopped condition at very light ship draught. Additional conditions contained in the alignment layout calculations are calculated for verifying the alignment result.

The hot condition calculation provides information about the sensitivity of the shafting system regarding the thermal rise “Δh_{mb}“ of the engine main bearings. If the changes between the cold and hot condition are significant, the shaft arrangement should be checked and optimized as explained in section 3, p. 13.

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The thermal rise of main bearing offsets is calculated with to the following formula (dimensions in [mm]):

$$\Delta h_{mb} = (h_{mb} + h_{found}) \times C \times \frac{11.5 \times (t_{eng} - t_{ref})}{10^6} \qquad (4.3)$$

If h_{found} is not available at the stage of alignment layout calculation preparation, the following formula should be used:

$$\Delta h_{mb} \approx h_{mb} \times D \times \frac{11.5 \times (t_{eng} - t_{ref})}{10^6} \qquad (4.4)$$

Δh_{mb}	[mm]	thermal rise of all engine main bearings from cold to hot condition
h_{mb}	[mm]	height between bedplate bottom and crankshaft centre line
h_{found}	[mm]	height from the middle of the LO sump tank below main engine to the top plate of the engine foundation
C	[–]	correction factor[35], usually between 0.3 and 0.5: to be applied according to shipyard's experience with current ship design. If no experience is available, 0.4 should be applied
D	[–]	correction factor for simplified calculation of thermal rise: 0.75
t_{eng}	[°C]	engine operating temperature (default: 55°C)
t_{ref}	[°C]	reference temperature during alignment for foundation, shaft bearing supports and engine

35 The correction factor is applied as finally only the thermal rise of the engine in relation to the shafting system needs to be considered.

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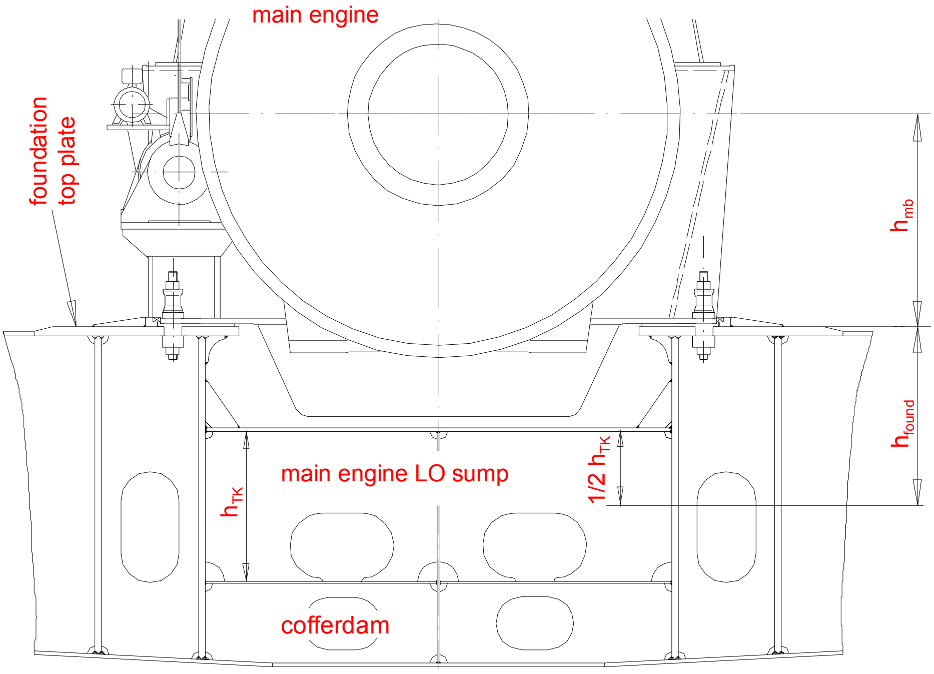

Figure 4.3: heights for calculating the thermal rise of the engine main bearings.

Example for Wärtsilä RT-flex50-D engines:

h_{mb}	1088 mm
h_{found}	1090 mm
C	0.4
t_{ref}	20°C

$$\Delta h_{mb} = (1088 + 1090) \times 0.4 \times \frac{11.5 \times (55 - 20)}{10^6} \quad (4.5)$$

$$\Delta h_{mb} = 0.35\text{mm} \quad (4.6)$$

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4.7 Calculation for running condition

The alignment layout calculation for the running condition considers the following service-related forces and moments:

- The thermal rise of the engine main bearings
- The maximum axial propeller thrust
- The maximum bending moment at the propeller due to the propeller thrust eccentricity
- The maximum bending moment at the thrust bearing due to the thrust bearing eccentricity.

This calculation is the most important calculation under the aspect of shaft bearing alignment, as the alignment is verified under consideration of the following influences:

- The bending moment produced by the propeller thrust eccentricity as well as the propeller service forces, which will mainly shift static bearing load from the aft stern tube bearing to the next forward bearing, i.e. to the forward stern tube bearing or the next intermediate bearing, if no forward stern tube bearing is installed. Also some minor changes on the more forward bearings can be seen. In addition the misalignment between propeller shaft and the aft, respectively the forward stern tube bearing, will change.
- The bending moment produced by the thrust bearing eccentricity, which will reduce the static load of the intermediate bearing next to the engine.

It has to be checked that under this condition the bearing loads are still within the allowable range.

However, the alignment layout calculation for running condition is not of much importance from the engine's point of view. This is due to the fact that the alignment calculation is a static calculation; gas and mass forces from the engine are not taken into account. Therefore the calculated main bearing loads are not realistic and this calculation provides only very limited information. Based on that, a calculation result with unloaded main bearing #1 is fully acceptable. In contrast, calculated negative bearing loads[36] are not acceptable.
However, the full propeller thrust condition will not act at alignment draught condition, but at full draught condition. Consequently the result can only provide a general indication regarding the safety margin of the installation.

[36] Considering the given bearing clearance.

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5 Alignment steps and alignment checks before chocking

Before starting the final alignment, the engine has to be finally assembled and the main ship components, especially the superstructure, need to be installed and finally welded. In addition all major welding operations in the vicinity of the engine have to be completed.
For all alignment measurements it is important to keep the external influences on the measurement as limited as possible. This means that:

- draught changes during the measurements have to be avoided as far as possible, i.e. no ballasting operation, no movement of heavy parts like hatch covers, etc.
- local heat sources have to be avoided, i.e. lubricating oil sump tank heater has to be shut off, no welding works in vicinity of the propulsion system, etc.

It is strongly recommended to carry out the final alignment in afloat condition[37]!
Please consider the validity of this instruction as well as its guiding characteristic as described in section 1, p. 4 at the beginning of this instruction.
An overview of the alignment steps is given in section 2, p. 9 and by the alignment process diagram in figure 2.1, p. 11.

5.1 Shaft and engine alignment by gap & sag method

Propeller and intermediate shafts are aligned to each other by applying the gap & sag method, i.e. the uncoupled shaft flanges are aligned to each other in such a way that the vertical gap & sag between the flanges comply with those of the alignment layout calculation.
In the horizontal plane the shaft line has to be aligned straight, i.e. the horizontal gap & sag values have to be zero.

Before starting the gap & sag alignment, a reference crankweb deflection measurement might be taken according to shipyard's experience.

[37] It is within the responsibility of the shipyard to carry out the final alignment including chocking of the engine according to their experience already gained at the dry dock. However, the risk of a possibly required re-chocking has to be born in mind.

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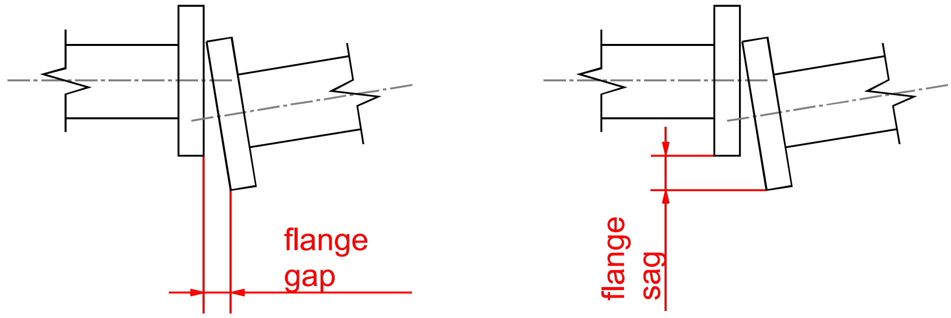

Figure 5.1: definition of flange gap & sag.

The following tolerances should be applied between the adjusted gap & sag values and the calculated vertical and the targeted zero horizontal values respectively:

- Gap tolerance: ±0.05 mm
- Sag tolerance: ±0.10 mm

In general two different procedures for gap & sag alignment are possible:

- Adjusting of each single flange connection according to the calculated values, starting from the aftmost flange connection followed by direct coupling after each adjustment. After coupling, the next forward shaft has to be aligned in relation to the already coupled shaft line; no changes of any bearing offset of the already coupled shaft are allowed.
- Adjusting of all flange connections before starting with any coupling. After the shafts are aligned to each other, all flanges will be coupled; no further adjustments are allowed at the coupling stage.

If temporary supports need to be removed for the step-by-step method, a higher error rate may be expected, as it is very difficult to consider the correct temporary support stiffness in the alignment layout calculation. Therefore it is recommended in such cases to prepare all flange connections according to calculation before starting the coupling process. Anyway the coupling should be started aft. For control after each coupling, the gap & sag values of the next flange connection can be checked and compared with the calculation of this coupling stage, if available. This may help to find some coupling errors before the whole coupling is finalized.

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5.2 Bedplate bending curves

The bedplate of an engine installed in the ship is not always ideally straight. This is caused mainly by:

- the influence of engine temperature
- the installation tolerances
- the ship hull bending.

In general an ideal straight bedplate can be considered as being the optimum for engine operation. However, more important than straightness is that the bedplate bending line is as smooth as possible, i.e. without kinks.
From the alignment point of view the interesting thing is not the bedplate bending itself, but its influence on the main bearing offsets. However, measuring the main bearing offsets directly is not possible, but it is possible to measure the bedplate bending shape on both sides of the bedplate by a piano wire or laser measurement.
However, direct information regarding the bearing offsets can be obtained by analysing the crankweb deflection measurement results together with the bearing load measurement results, as it is done by Wärtsilä, if a review of the alignment measurement results is ordered. Therefore the bedplate sag measurement has a negligible priority regarding the final alignment check criteria and consequently **Wärtsilä does not ask any longer for the bedplate measurement as a criterion for alignment approval** (please refer to figure 2.1, p. 11). The main function of the bedplate bending measurement is to find the possible reasons if horizontal or vertical crankweb deflections as well as bearing loads are not within the required range. This means, the measurement of the engine bedplate shape can be considered as a tool for getting the alignment properly done.

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5.2.1 Bedplate bending in relation to the engine temperature

The bedplate bending curve changes from alignment condition with a cold engine to operation condition with a hot engine. The general bending shape of cold and hot condition is shown by the following illustrations.

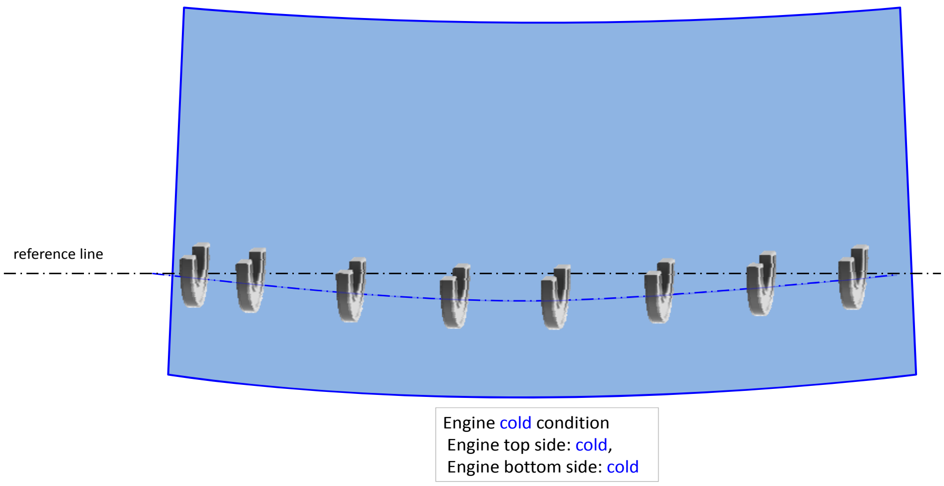

Figure 5.2: cold engine bending shape, engine pre-sagged.

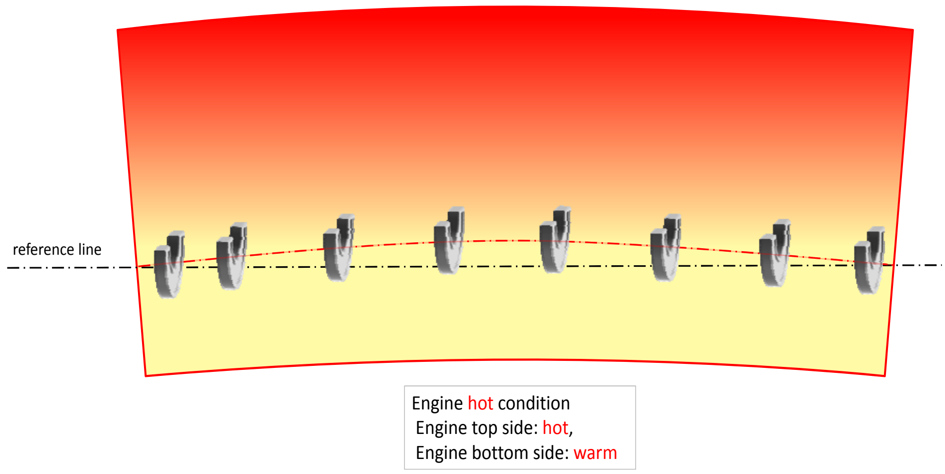

Figure 5.3: hot engine bending shape.

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5.2.2 Engine pre-sag

As the bedplate bending shape will change to hogging for hot condition, the engines may be installed with some pre-sag for pre-compensating the expected change. However, as long as all crankweb deflections are within the limits, no special care for engine pre-sag is required. More positive crankweb deflections[38] of cylinders #2 to #n-1, measured before chocking, give an indication that the engine is pre-sagged. Experience has shown that more important than pre-sagging is that the bedplate bending is as smooth as possible, i.e. the variation from one main bearing measurement position to the next is as low as possible in relation to the actual sag curve. Consequently **the pre-sag measurement is not any longer a check criterion for alignment confirmation**.

It is not at all recommended to support the engine only in its four corner positions in order to adjust a pre-sag. This is of disadvantage in the aspect of smooth engine bending. It is much more preferable to have less or no pre-sag instead of distorting the bedplate. The engine has to be supported by all supporting points (wedges or jacking screws), as indicated on the engine installation drawings.

5.2.3 Bedplate bending measurement: piano-wire or laser measurement

The engine **bedplate bending measurement is no longer a check criterion for alignment confirmation**. However, this measurement should be considered as a perfect **tool for aligning the engine**. The bedplate bending measurement is recommended in case the alignment criteria ‘bearing load distribution’ and / or ‘crankweb deflections’ exceed the limits and the reason for that needs to be investigated further (see also the alignment process diagram in figure 2.1, p. 11).
Exceeding vertical crankweb deflections as well as unexpected bearing load distributions might be reflected in a sharp upward respectively downward bending change. Correcting the engine bending shape can help solving the problem.
Exceeding horizontal crankweb deflections which are not caused by an improper horizontal alignment between engine and shaft might be reflected in different bending shapes on both of the engine’s longitudinal sides. Correcting the engine bending to similar shapes on both longitudinal sides can help solving the problem.

5.3 Static shaft bearing loads, before chocking condition

The static loads of all shaft bearings – except the aft stern tube bearing which is not accessible – need to be checked by jack-up test measurements. The loads must comply with the alignment layout calculation. Usually this is considered as being the case if the measured loads are within a tolerance range of ±20% of the loads determined by the alignment layout calculation.

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[38] Sign definition: _/+_ _\-/_

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It is essential to carry out these measurements directly before or after the engine alignment checks and under the same measurement conditions, i.e. same draught, same temperature conditions (engine, tanks in vicinity), etc. Taking such complete sets of measurements is needed as engine, shaft line and propeller make up one common propulsion system[39]; consequently this also needs to be considered as one system during the evaluation. Hence Wärtsilä asks for information about the shafting system as well as the shaft bearing load measurement results, if Wärtsilä is required to review the engine alignment. However, the shaft alignment is not within the responsibility of Wärtsilä Switzerland.

5.4 Crankweb deflection limits for new alignment, before chocking condition

The absolute crankweb deflection limits are increasing from the most strict testbed reference measurement condition[40] to the final ship service condition[41]. Compared to the absolute crankweb deflection limits for final service, the ‘before chocking’ condition limits are still quite strict. This is to provide sufficient reserves for later changes produced by the influences of engine operation and ship hull bending.
The absolute vertical and horizontal crankweb deflections indicate different aspects:

- The absolute vertical crankweb deflections are related to the main bearing offsets and by that to the static main bearing loads.
- The absolute horizontal crankweb deflections indicate the twisting of the engine housing, which has to be avoided. Therefore the limits for the absolute horizontal crankweb deflections are of utmost importance and as a consequence more stringent than those for the absolute vertical crankweb deflections.

The main purpose of the crankweb deflection limits is to ensure proper engine running behaviour.

39 These three parts are coupled rigidly, i.e. without any flexible coupling or gear.

40 This measurement is taken from the uncoupled cold engine on the testbed as a basic reference.

41 This is the maximum which must not be exceeded. Exception: Wärtsilä provided case-specific values, based on detailed case-specific investigations.

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5.4.1 Validity of new alignment crankweb deflection limits

These limits are valid for the <u>completely assembled engine</u> on board the <u>afloat vessel</u>[42] before chocking the engine. The <u>flywheel is installed</u> and the <u>tie rods are correctly tightened</u> according to latest engine assembly instruction. The engine is **<u>cold</u>** and **<u>coupled</u>** to the shaft line, i.e. all intermediate and propeller shafts are coupled and temporary supports are removed. No tank heating close or below the engine is active.
These limits are not valid for any other measurements on board the vessel[43].

5.4.2 Description of new alignment crankweb deflection limits

Compared to the limits for the inner cylinders, the positive[44] vertical crankweb deflection limit for cylinder #1 is increased to more positive. This is due to the typical shaft bending line at alignment condition, see figure 1.1, p. 7. The described shaft line shape is a result of pre-compensating the expected ship hull bending at increased draught conditions; usually the ship hull bending at increasing draught conditions causes decreasing (less positive) cylinder #1 crankweb deflections.
The vertical crankweb deflection limit for the foremost engine free-end cylinder allows more negative values in case of an installed external mass like a T/V damper or a front disc, as the more negative crankweb deflection is caused by the bending moment created by the external mass. This is fully acceptable and – even more – required in order to keep all main bearings statically properly loaded.
It has to be kept in mind that the crankweb deflection measurement results provide quite complex information. Therefore the limits provided in this document may not cover all possible installation cases and situations. Hence Wärtsilä may provide case-specific limits, if indicated[45].

For the vertical as well as for the horizontal crankweb deflections, the maximum deviations between two adjacent crankweb deflections have to be checked. The maximum values provided in the deflection limit tables have an indicator function[46], as huge deviations between two adjacent cylinders give the indication that there might be some deficiencies. In such cases further investigations are required; Wärtsilä should be contacted. Depending on the particular investigation results, the crankweb deflections might be accepted or countermeasures might be recommended. These additional limits

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42 New ship building

43 In case of an engine re-alignment on board vessels already in service, values between 'before chocking' and 'ship delivery' can be applied. Wärtsilä should be contacted for further assistance.

44 Sign definition: _/+_ _\-/_

45 Based on detailed case-specific investigation results.

46 These values are no final acceptance limits.

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made the increased new crankweb deflection limits possible, as they will indicate most harmful deflections.
For applying the new limits, the following should be kept in mind:

- The new absolute crankweb deflection limits have to be considered as final acceptance criteria.
- The newly introduced limits for the maximum deviation between the crankweb deflections of two adjacent cylinders are no final acceptance criteria, provided the results of the particularly required further investigations are positive.

5.4.3 Overview: limits for crankweb deflection before chocking

Rotation direction for measurement:

- Counter-clockwise rotation for engines with turning gear on fuel pump side
- Clockwise rotation for engines with turning gear on exhaust side
  (e.g. RT-flex 48T-D, RT‑flex50/-B/-D, RT-flex68-D/V.I, RT‑flex82C/T)

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Crankweb deflection limits [mm] before chocking						
Reading convention: 	vertical				horizontal	
	cyl.1	cyl.2 to cyl.(n-1) cyl.(n)*[1]	cyl.(n)*[2]	max. absolute deviation between two adjacent cranks*[3]	cyl.1 to cyl.(n)	max. absolute deviation between two adjacent cranks*[3]
RT-flex35	+0.16 -0.10	±0.10	+0.10 -0.17	0.10	±0.04	0.04
RT-flex40	+0.20 -0.13	±0.13	+0.13 -0.22	0.13	±0.06	0.06
RT-flex48T-D RTA48T-D RTA48T-B	+0.36 -0.22	±0.22	+0.22 -0.36	0.22	±0.09	0.09
RT-flex50-D RT-flex50-B RT-flex50	+0.36 -0.22	±0.22	+0.22 -0.37	0.22	±0.09	0.09
RT-flex58T-E RT-flex58T-D, V1, V2 RTA58T-D RT-flex58T-B RTA58T-B	+0.40 -0.24	±0.24	+0.24 -0.52	0.24	±0.10	0.10
RT-flex60C-B RT-flex60C	+0.33 -0.20	±0.20	+0.20 -0.40	0.20	±0.08	0.08
RT-flex68-D, V1 RTA68-D RT-flex68-B RTA68-B	+0.53 -0.32	±0.32	+0.32 -0.55	0.32	±0.13	0.13
RT-flex82C RTA82C	+0.37 -0.23	±0.23	+0.23 -0.40	0.23	±0.09	0.09
RT-flex82T-B RT-flex82T RTA82T-B RTA82T	+0.59 -0.36	±0.36	+0.36 -0.64	0.36	±0.14	0.14
RT-flex84T-D RTA84T-D	+0.53 -0.32	±0.32	+0.32 -0.58	0.32	±0.13	0.13
RT-flex96C-B RTA96C-B	+0.44 -0.27	±0.27	+0.27 -0.46	0.27	±0.11	0.11

*1 For engines without T/V damper or front disc.
*2 For engines with T/V damper or front disc[47].
*3 This value is not a limit for final acceptance, but it is used as an indicator that further investigations are required.

Table 5.1: crankweb deflection limits [1/100mm] for new alignment – before chocking, engine coupled to the intermediate shaft.

[47] In this case the maximum absolute deviation between the deflection values of the two foremost vertical crankwebs might be exceeded. If so, the bearing loads of the two foremost main bearings have to be checked. Provided the bearing loads are within the limit, no counter-actions are required.

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5.5 Recommended static main bearing loads, before chocking condition

Recommended*1 static main bearing loads [kN] before chocking				
	mb #1*2	mb #2	mb #3*3	mb #4 to n[48]
RT-flex35	4-20	25-50	20-55	>12
RT-flex40	5-25	40-75	35-80	>15
RT-flex48T-D **RTA48T-D** **RTA48T-B**	10-40	60-155	50-160	>30
RT-flex50-D **RT-flex50-B** **RT-flex50**	10-45	70-165	55-170	>30
RT-flex58T-E **RT-flex58T-D, V1, V2** **RTA58T-D** **RT-flex58T-B** **RTA58T-B**	10-65	100-230	85-240	>30
RT-flex60C-B **RT-flex60C**	10-70	120-240	100-250	>30
RT-flex68-D, V1 **RTA68-D** **RT-flex68-B** **RTA68-B**	10-100	170-310	140-320	>40
RT-flex82C **RTA82C**	10-140	280-510	230-530	>70
RT-flex82T-B **RT-flex82T** **RTA82T-B** **RTA82T**	5-130	330-600	270-630	>70
RT-flex84T-D **RTA84T-D**	5-120	290-530	230-560	>70
RT-flex96C-B **RTA96C-B**	10-150	320-610	260-640	>70

*1 The given values are for guidance only. More important than the absolute main bearing loads is the relative load distribution between the bearings, as explained in section 4.5.1, p.21 and illustrated in figure 4.2, p. 22. The measured bearing loads have to be similar to those determined in the alignment layout calculation.

*2 The lower and upper values refer to the installation type and should not be considered as recommended tolerance ranges! The following has to be considered:
Lower value: target if distance between engine and next shaft line bearing is short[49] and / or a heavy flywheel is installed.
Upper value: target if distance between engine and next shaft line bearing is long[49] and / or a light flywheel is installed.

*3 mb #3 load should be ≥60% of mb #2 load.

Table 5.2: recommended static loads [kN] for alignment in new buildings at cold/stopped condition.

48 Before chocking usually just mb #1 to #3 are measured, except if the maximum absolute vertical crankweb deflection deviation between two adjacent cranks has been exceeded or Wärtsilä recommends further case-specific measurements. These minimum values have to be kept for any crank angle position.

49 As defined in formula 3.3, p. 14.

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5.5.1 Jack correction factors

The jack correction factors provided by the alignment layout calculation should be used for the evaluation of static bearing loads.
EnDyn provides jack correction factors for the shaft bearings according to the user-defined jack positions and for the engine main bearings as defined by its integrated crankshaft models of Wärtsilä RT-flex and RTA engines.
However, if the alignment layout calculation was created with any other programs, then the average jack correction factors provided by table 5.3, p. 38, should be applied.

Bearing	Jack and gauge position	Jack correction factor
aftmost mb1	below flywheel	1.5
mb2 (fwd)	aft crank of aft cylinder #1	0.8 or 1.2[50]
mb3 (aft)	forward crank of aft cylinder #1	1

Table 5.3: average jack correction factors[51].

The jack correction factor depends not only on the arrangement of jack and gauge positions in relation to the bearings, but also on the bearing load distribution. While for most bearings the jack correction factor changes only within the negligible range of ±0.1 due to different load distributions, the jack correction factor of main bearing #2 may change significantly:

- If main bearing #1 is very low loaded, it will lift off prior to main bearing #2. In this case a steep inclination can be expected for the analyse line of main bearing #2 load and the correction factor is usually within the range of 0.8-0.9. This is usually only the case in very light draught conditions as found before or shortly after chocking the engine.

50 See the following explanation. In short: if mb #1 is very low loaded: 0.8; otherwise: 1.2.
51 Only to be applied if not provided by alignment calculation.

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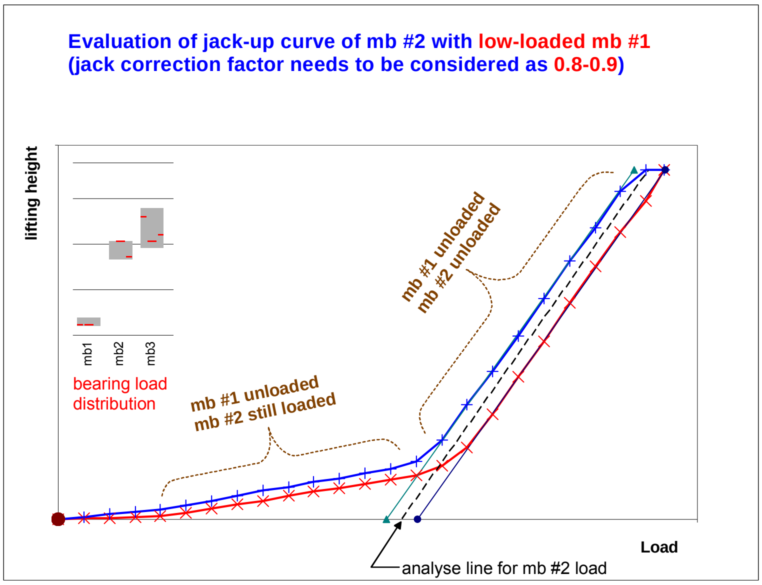

Figure 5.4: average jack correction factor of mb #2 for low-loaded mb #1.

- If main bearing #1 is more loaded, main bearing #2 will lift off prior to main bearing #1. In that case a flatter inclination can be expected for the analyse line of main bearing #2 load and the correction factor is usually within the range of 1.1-1.2.

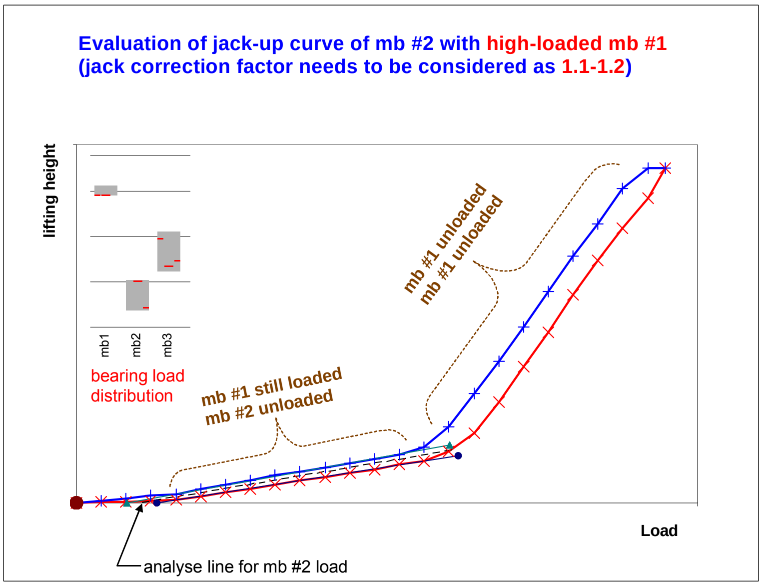

Figure 5.5: average jack correction factor of mb #2 for high-loaded mb #1.

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Wärtsilä provides support for that analysis free of charge by performing a so called ‘reverse calculation’.

5.5.2 Influence of crank angle on bearing load

The main bearing loads vary depending on the crank angle (CA). The reason for this can be found in the geometry of the cranks which causes non-rotary symmetrical stiffness of the cranks, i.e. the crankshaft stiffness between the bearings is different for different crank angles and consequently the bearing load distribution is different. Therefore a reference condition is defined which refers to 0° CA, i.e. cylinder #1 in top dead centre position.

The total extent of each bearing’s load range within one 360° rotation is indicated on the EnDyn calculation output graphics by a grey load range field. The cylinder #1 top dead centre position (TDC) which refers to 0° CA is marked by the longer red centre line. The shorter red lines on the left and right sides in the grey box mark the main bearing loads at jack-up test condition, i.e. on the left side for jack-up test from the main bearing’s aft side and on the right side for the jack-up test from the main bearing’s forward side. As main bearing #1 can only be measured from aft side, the line on the right side is omitted, and the left line accordingly for main bearing #2, as this bearing can only be measured from forward side.

The following figure 5.6 shows an example of the vertical bearing load graphic as provided by EnDyn, but reduced to just the aft main bearings #1 to #3.

Vertical bearing load [kN]

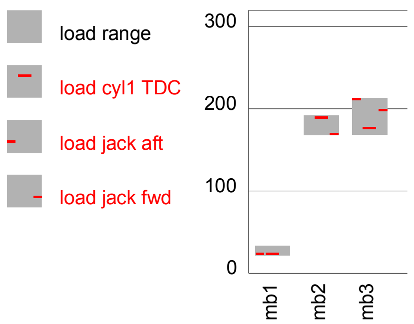

Figure 5.6: example of RT-flex58T-D main bearing #1 to #3 loads as plotted by the EnDyn alignment calculation program.

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The static load variation within one complete turn of main bearing #2 is shown in figure 5.7; that of main bearing #3 is shown in figure 5.8.

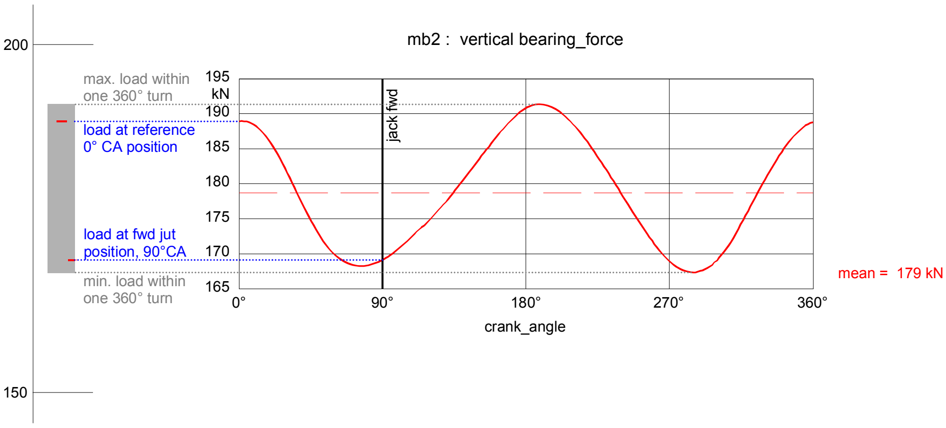

Figure 5.7: magnification of figure 5.6 main bearing #2 load and the corresponding bearing loads within one 360° rotation.

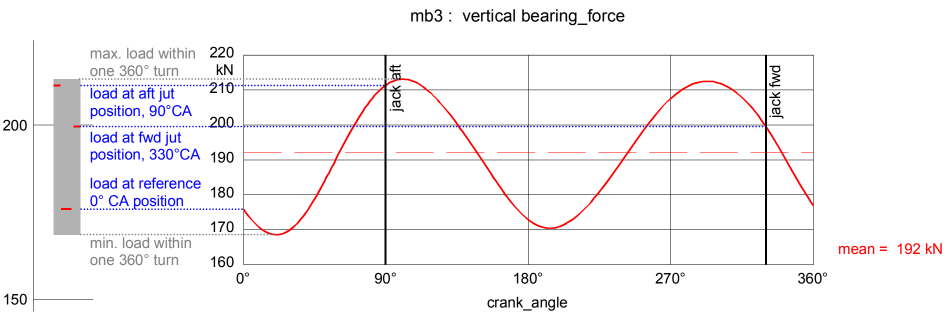

Figure 5.8: magnification of figure 5.6 main bearing #3 load and the corresponding bearing loads within one 360° rotation.

The loads calculated by applying the two-dimensional crankshaft model refer to the reference condition, while the measured bearing loads refer to the crank angle which is adjusted for carrying out the load measurements. Applying the EnDyn calculation program makes information about the bearing loads at measurement condition and any other crank angle condition available.

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Main bearing #1 load is measured at 0° CA (reference condition) position and therefore the measured load refers directly to the calculated load. However, the jack-up tests for main bearings #2 and #3 are usually carried out with the aftmost crankpin on exhaust side, as indicated in the bearing load graphics. For these jack-up test conditions the bearing loads generally deviate compared to 0°CA as follows:

Mb #2: lower[52] static bearing load[53], close to the minimum of the one-revolution load range.

Mb #3: higher[54] static bearing load[53], close to the maximum of the one-revolution load range.

The extent of the bearing load change depends on the engine type as well as the current situation (bending moments in the crankshaft). In general the range of expected load change within one 360° rotation is less for main bearing #2 than for main bearing #3. The following two figures provide the related relative maximum and minimum ranges.

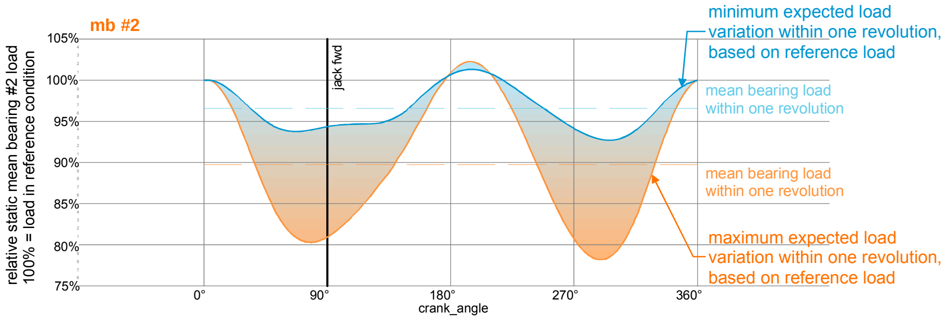

Figure 5.9: load plot of main bearing #2 load within one 360° turn – minimum and maximum percentaged changes.

[52] In most cases between 80% and 90% of reference load for high-loaded bearing #2 as requested for the layout condition. In case of low-loaded main bearing #2, the load might be reduced to 0%, i.e. unloaded.

[53] Static bearing load = jack load multiplied by the jack correction factor.

[54] Depending on engine type and current situation (bending moments in the crankshaft), usually a variation within the range of 15% to 70% can be expected, as long as main bearing #3 is loaded as recommended. EnDyn alignment layout calculation helps at least to know the influence of the engine type. Advanced analyses support is provided on request by Wärtsilä.

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Appd	12.05.2011	K. Moor			

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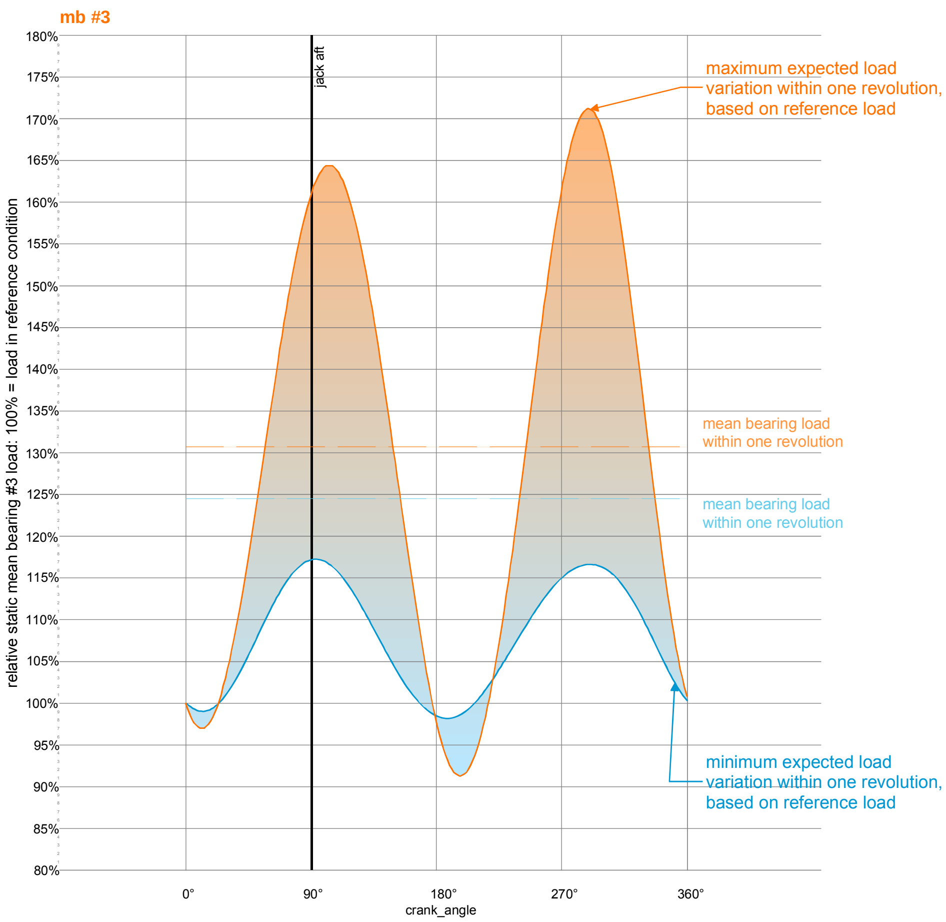

Figure 5.10: load plot of main bearing #3 load within one 360° turn – minimum and maximum percentaged changes.

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Appd	12.05.2011	K. Moor	**9709**	Drawing ID **107.404.952**	Rev **A**

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5.6 Chocking and fixation

Before pouring the resin chock under the engine, the engine side stoppers have to be placed in their final positions. The correct heights and the minimum contact surfaces as given in the relevant side stopper drawings have to be ensured.
The chocking of the engine has to be prepared as described in the Marine Installation Manual (MIM). It is important that the epoxy resin material (chock) meets the defined properties. Then chock the engine, following the pouring procedure of the epoxy resin manufacturer's instructions.
Also the shaft bearings need to be chocked, either by pouring epoxy resin chocks or by installing metal chocks. It is possible to do that as a final installation step, after a preliminary alignment check after engine fixation has been carried out. The advantage of performing that step as last step is that some minor errors occurred during the engine chocking and fixation process can be corrected. However, the extent of such a correction has to be considered as very limited and should not counter-act any accurate working procedure. Therefore it is also suitable to do this along with engine chocking.
After the time required for resin chock hardening has elapsed, the engine holding-down bolts have to be tightened. For tightening the holding-down studs, please follow the instruction on the relevant drawing.
Finally the side stopper wedges need to be fitted.

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6 Alignment checks for commissioning / ship delivery

The limits for crankweb deflections and static main bearing loads should be maintained at ship's commissioning, i.e. just before, during or after sea trial, when the ship is afloat and ready for operation.
The ship has a normal draught and trim within the limits for normal ship service.
The measurements can be taken almost straight after stopping the engine[55] or with the engine already cooled down, but in all cases the engine temperature (crankshaft temperature, e.g. measured by a handheld infrared thermometer) needs to be recorded for reference. More important than the engine temperature itself is an equal longitudinal temperature of the engine and the engine foundation / sump tank in the aft half of the engine – as this is the case during normal engine operation. Therefore it is essential to stop the sump tank preheater early before starting the measurements – otherwise unequal temperature distribution will cause unequal thermal rise and by that unequal main bearing offsets, which may cause inacceptable main bearing load distribution.

6.1 Static shaft bearing loads, commissioning / ship delivery condition

The same requirements as mentioned in section 5.3, p. 32, have to be fulfilled.

6.2 Crankweb deflections, commissioning / ship delivery condition

6.2.1 Validity of crankweb deflection limits for commissioning / ship delivery

These limits are valid for the completely assembled engine on board the afloat vessel at commissioning / delivery of the ship to the owner, i.e. usually directly before, during and after the sea trial. The engine is **hot or cold**. The draught is within the normal ship operation limits. The lubricating oil sump tank heating has to be inactive in order to avoid any local heat spot below the engine, which does not exist under normal engine operation condition.
These limits can be applied for additional measurements after chocking the engine. However, if the ship has not yet been in operation, the limit should not be maxed out, as influences of settling effects cannot be predicted exactly.
These limits are not valid for the condition before chocking.

6.2.2 Description of crankweb deflection limits for commissioning / ship delivery

The limits are defined close to the normal ship service limits. However, some reserve for the unexpected is kept.

55 Please consider the safety advices provided in the Maintenance Manual.

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The negative crankweb deflection limit of the foremost cylinder is increased in case of installed external masses like T/V damper or front disc, as the negative crankweb deflection is caused by the bending moment produced by an external mass. This is fully acceptable and - even more - required in order to keep all main bearings statically properly loaded, which has top priority.

6.2.3 Overview: crankweb deflection limits for commissioning / ship delivery

Rotation direction for measurement:

- Counter-clockwise rotation for engines with turning gear on fuel pump side
- Clockwise rotation for engines with turning gear on exhaust side
  (e.g. RT-flex48T-D, RT-flex50/-B/-D, RT-flex68-D/V.I, RT-flex82C/T)

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Crankweb deflection <u>limits</u> [mm] for commissioning / ship delivery						
Reading convention: 	vertical				horizontal	
	cyl.1	cyl.2 to cyl.(n-1) cyl.(n)*1	cyl.(n)*2	max. absolute deviation between two adjacent cranks*3	cyl.1 to cyl.(n)	max. absolute deviation between two adjacent cranks*3
RT-flex35	±0.23	±0.15	+0.15 -0.17	*0.10*	±0.06	*0.04*
RT-flex40	±0.29	±0.19	+0.19 -0.22	*0.13*	±0.07	*0.05*
RT-flex48T-D RTA48T-D RTA48T-B	±0.52	±0.33	+0.33 -0.36	*0.22*	±0.13	*0.09*
RT-flex50-D RT-flex50-B RT-flex50	±0.52	±0.33	+0.33 -0.37	*0.22*	±0.13	*0.09*
RT-flex58T-E RT-flex58T-D, V1, V2 RTA58T-D RT-flex58T-B RTA58T-B	±0.58	±0.36	+0.36 -0.52	*0.24*	±0.14	*0.10*
RT-flex60C-B RT-flex60C	±0.48	±0.30	+0.30 -0.40	*0.20*	±0.12	*0.08*
RT-flex68-D, V1 RTA68-D RT-flex68-B RTA68-B	±0.77	±0.48	+0.48 -0.55	*0.32*	±0.19	*0.13*
RT-flex82C RTA82C	±0.54	±0.34	+0.34 -0.40	*0.23*	±0.14	*0.09*
RT-flex82T-B RT-flex82T RTA82T-B RTA82T	±0.86	±0.54	+0.54 -0.64	*0.36*	±0.22	*0.14*
RT-flex84T-D RTA84T-D	±0.77	±0.48	+0.48 -0.58	*0.32*	±0.19	*0.13*
RT-flex96C-B RTA96C-B	±0.64	±0.40	+0.40 -0.46	*0.27*	±0.16	*0.11*

*1 For engines without T/V damper or front disc.

*2 For engines with T/V damper or front disc[56].

*3 This value is not a limit for final acceptance, but it is used as an indicator that further investigations are required.

Table 6.1: crankweb deflection limits [mm] for commissioning / ship delivery.

56 In this case the maximum absolute deviation between the deflection values of the two foremost crankwebs might be exceeded. If so, the bearing loads of the two foremost main bearings have to be checked. Provided the bearing loads are within the limit, no counter-actions are required.

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6.3 Recommended static main bearing loads, commissioning / ship delivery condition

For jack correction factors and the crank angle influence on the bearing load, please refer to section 5.5.1, p. 38 and section 5.5.2, p. 40 respectively.

Table 6.2 gives the recommended main bearing loads at commissioning / ship delivery condition for measurements under ballast draught condition, table 6.3 for measurements under scantling / design draught condition.

Recommended*1 static main bearing loads [kN] for commissioning / ship delivery, ballast draught condition				
	mb #1	mb #2	mb #3*2	mb #4 to n[57]
RT-flex35	4-25	20-55	15-60	>10
RT-flex40	5-30	30-80	25-85	>15
RT-flex48T-D RTA48T-D RTA48T-B	10-50	50-170	35-180	>20
RT-flex50-D RT-flex50-B RT-flex50	10-55	60-180	40-190	>20
RT-flex58T-E RT-flex58T-D, V1, V2 RTA58T-D RT-flex58T-B RTA58T-B	10-85	90-250	60-260	>20
RT-flex60C-B RT-flex60C	10-90	110-265	70-280	>20
RT-flex68-D, V1 RTA68-D RT-flex68-B RTA68-B	10-130	150-340	90-360	>30
RT-flex82C RTA82C	10-180	230-550	150-580	>50
RT-flex82T-B RT-flex82T RTA82T-B RTA82T	5-170	270-650	180-680	>50
RT-flex84T-D RTA84T-D	5-160	240-580	160-610	>50
RT-flex96C-B RTA96C-B	10-200	260-660	180-690	>50

*1 The given values are for guidance only.
*2 mb #3 load should be ≥50% of mb #2 load.

Table 6.2: recommended main bearing loads [kN] for commissioning / ship delivery, valid at ballast draught condition.

57 Usually just mb #1 to #3 are measured, except if Wärtsilä recommends further case-specific measurements.
These minimum values have to be kept for any crank angle position.

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Recommended static main bearing loads [kN] for commissioning / ship delivery, scantling or design draught condition				
	mb #1	mb #2	mb #3	mb #4 to n[58]
RT-flex35	>5	>10	>10	>10
RT-flex40	>5	>15	>15	>15
RT-flex48T-D RTA48T-D RTA48T-B	>10	>20	>20	>20
RT-flex50-D RT-flex50-B RT-flex50	>10	>20	>20	>20
RT-flex58T-E RT-flex58T-D, V1, V2 RTA58T-D RT-flex58T-B RTA58T-B	>10	>20	>20	>20
RT-flex60C-B RT-flex60C	>10	>20	>20	>20
RT-flex68-D, V1 RTA68-D RT-flex68-B RTA68-B	>20	>30	>30	>30
RT-flex82C RTA82C	>20	>50	>30	>30
RT-flex82T-B RT-flex82T RTA82T-B RTA82T	>20	>50	>30	>30
RT-flex84T-D RTA84T-D	>20	>50	>30	>30
RT-flex96C-B RTA96C-B	>20	>50	>30	>30

Table 6.3: recommended main bearing loads [kN] for commissioning / ship delivery, valid at scantling or design draught condition.

In general the design draught condition is the hull bending condition which in container vessels diverges the most from the alignment draught condition, whereas in bulk carriers and tankers it is the scantling draught condition.

[58] Usually just mb #1 to #3 are measured, except if Wärtsilä recommends further case-specific measurements.

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7 Alignment checks during normal ship's service

Usually no detailed alignment checks during normal ship's service are needed! Regular crankweb deflection measurements following the intervals defined by the class rules are sufficient. Only in case of abnormalities, like sudden change of crankweb deflection measurement results, bearing temperature alarms or bearing damages, detailed alignment measurements might become necessary. In any such cases it is recommended to contact Wärtsilä for further support.

7.1 Crankweb deflection limits for normal ship's service

7.1.1 Validity of crankweb deflection limits for normal ship's service

The limits for *normal ship's service* are valid for any condition of ship's service, i.e. after ship delivery, vessel afloat. The engine is hot or cold.

7.1.2 Description of crankweb deflection limits for normal ship's service

The main purpose of the vertical crankweb deflection limits is to ensure that all main bearings are statically properly loaded.
The main purpose of the horizontal crankweb deflection limits is to ensure that the engine housing is not twisted.
The crankweb deflections are affected by:

- the difference in temperature between the lubricating oil sump tank and the seawater
- the engine temperature
- the draught.

Therefore the measured crankweb deflections need to be considered along with the a.m. conditions. On any measurement protocol at least the engine temperature (in crankcase / at crankshaft) and the draught need to be mentioned.

As the draught change has its main influence on the aft cylinder #1, the permissible range of crankweb deflection for cylinder #1 is wider compared to the other cylinders.

Another aspect of the maximum allowed crankweb deflections is the limitation of the crankshaft stress. However, this aspect can be neglected as the limits are defined even more strictly for the above mentioned reasons.

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7.1.3 Overview: crankweb deflection limits for normal ship's service

Rotation direction for measurement:

- Counter-clockwise rotation for engines with turning gear on fuel pump side
- Clockwise rotation for engines with turning gear on exhaust side
  (e.g. RT-flex48T-D, RT-flex50/-B/-D, RT-flex68-D/V.I, RT-flex82C/T)

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Crankweb deflection <u>limits</u> [mm] for ship's service						
Reading convention:	vertical				horizontal	
	cyl.1	cyl.2 to cyl.(n-1) cyl.(n)*1	cyl.(n)*2	max. absolute deviation between two adjacent cranks*3	cyl.1 to cyl.(n)	max. absolute deviation between two adjacent cranks*3
RT-flex35	±0.26	±0.16	+0.16 -0.17	*0.10*	±0.06	*0.04*
RT-flex40	±0.33	±0.20	+0.20 -0.22	*0.13*	±0.08	*0.06*
RT-flex48T-D RTA48T-D RTA48T-B	±0.58	±0.36	+0.36 -0.36	*0.22*	±0.14	*0.09*
RT-flex50-D RT-flex50-B RT-flex50	±0.58	±0.36	+0.36 -0.37	*0.22*	±0.14	*0.09*
RT-flex58T-E RT-flex58T-D, V1, V2 RTA58T-D RT-flex58T-B RTA58T-B	±0.64	±0.40	+0.40 -0.52	*0.24*	±0.16	*0.10*
RT-flex60C-B RT-flex60C	±0.53	±0.33	+0.33 -0.40	*0.20*	±0.13	*0.08*
RT-flex68-D, V1 RTA68-D RT-flex68-B RTA68-B	±0.85	±0.53	+0.53 -0.55	*0.32*	±0.21	*0.13*
RT-flex82C RTA82C	±0.60	±0.37	+0.37 -0.40	*0.23*	±0.15	*0.09*
RT-flex82T-B RT-flex82T RTA82T-B RTA82T	±0.95	±0.59	+0.59 -0.64	*0.36*	±0.24	*0.14*
RT-flex84T-D RTA84T-D	±0.85	±0.53	+0.53 -0.58	*0.32*	±0.21	*0.13*
RT-flex96C-B RTA96C-B	±0.71	±0.44	+0.44 -0.46	*0.27*	±0.18	*0.11*

*1 For engines without T/V damper or front disc.
*2 For engines with T/V damper or front disc[59].
*3 This value is not a limit for final acceptance, but it is used as an indicator that further investigations are required.

Table 7.1: crankweb deflection limits [1/100mm] for ships service.

59 In this case the maximum absolute deviation between the deflection values of the two foremost crankwebs might be exceeded. If so, the bearing loads of the two foremost main bearings have to be checked. Provided the bearing loads are within the limit, no counter-actions are required.

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7.2 Minimum main bearing load in ship's service condition under any draught condition

As already stated in the introduction, section 1.5, p. 6, all main bearings need to be statically loaded under all normal ship's service operation conditions after ship delivery, i.e. at all draught conditions between ballast draught and scantling draught, engine hot or cold.

The minimum bearing loads which have to be reached are given in the following table. Reaching the **minimum bearing loads** is the **finally binding bearing load requirement for alignment**.

For jack correction factors and the crank angle influence on the bearing load, please refer to section 5.5.1, p. 38 and section 5.5.2, p. 40 respectively.

Static main bearing load *limits* for ship service condition, engine stopped, cold or hot, any draught, any crank angle position [kN]		
	mb #1	**mb #2 to n**
RT-flex35	>5	>10
RT-flex40	>5	>15
RT-flex48T-D **RTA48T-D** **RTA48T-B**	>10	>20
RT-flex50-D **RT-flex50-B** **RT-flex50**	>10	>20
RT-flex58T-E **RT-flex58T-D, V1, V2** **RTA58T-D** **RT-flex58T-B** **RTA58T-B**	>10	>20
RT-flex60C-B **RT-flex60C**	>10	>20
RT-flex68-D, V1 **RTA68-D** **RT-flex68-B** **RTA68-B**	>20	>30
RT-flex82C **RTA82C**	>20	>30
RT-flex82T-B **RT-flex82T** **RTA82T-B** **RTA82T**	>20	>30
RT-flex84T-D **RTA84T-D**	>20	>30
RT-flex96C-B **RTA96C-B**	>20	>30

Table 7.2: minimum main bearing load limits [kN] for ship service condition.

Substitute for: 107.329.209										PC	Q-Code X X X X X
Modif	-	EAAD082941	12.05.2011	A	EAAD083309	04.10.2011					
		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date	Number	Drawn Date

WÄRTSILÄ	Product: RT-Engines	Engine Alignment direct - coupled marine propulsion	
Made 10.05.2011 D. Strödecke	Main Drw. H	Page 53 / 54	Material ID PAAD043682
Chkd 11.05.2011 W. Schiffer	Design Group 9709	Drawing ID 107.404.952	Rev A
Appd 12.05.2011 K. Moor			

T_PC-Drawing_portrait | Author: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.2 (06.09.2010)

In general the scantling draught (=maximum draught) condition is the most critical condition for fulfilling the minimum main bearing load requirements as stated in the above table 7.2, because at this condition the ship hull bending usually diverges the most from the alignment condition. Therefore, in case an in-service alignment check is required, it may be reasonable to do so under scantling draught condition.

Substitute for: **107.329.209** | PC | Q-Code | X | X | X | X | X

Modif											
-	EAAD082941	12.05.2011	A	EAAD083309	04.10.2011						
	Number	Drawn Date		Number	Drawn Date		Number	Drawn Date		Number	Drawn Date

WÄRTSILÄ

Product: **RT-Engines**

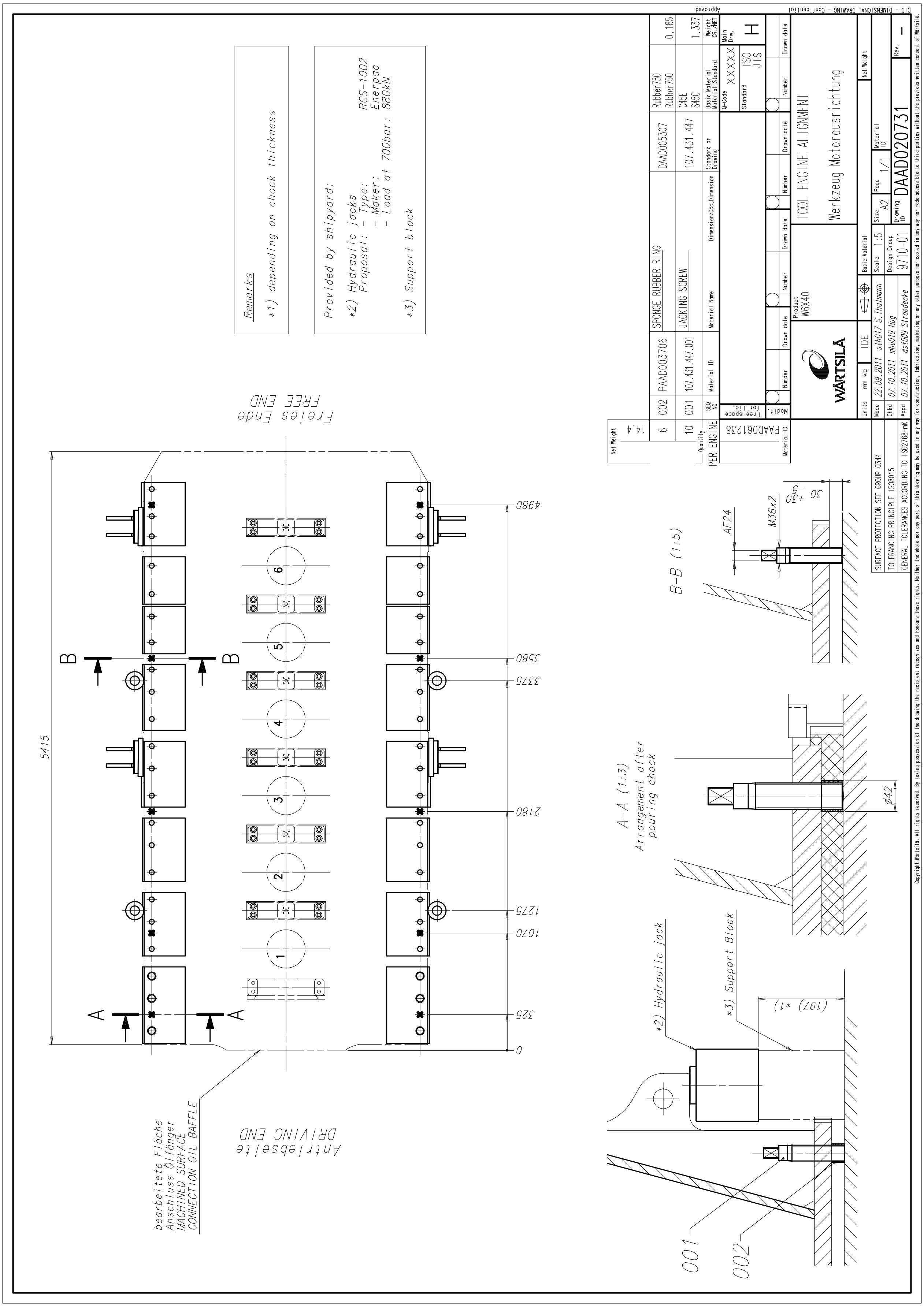
Engine Alignment
direct - coupled marine propulsion

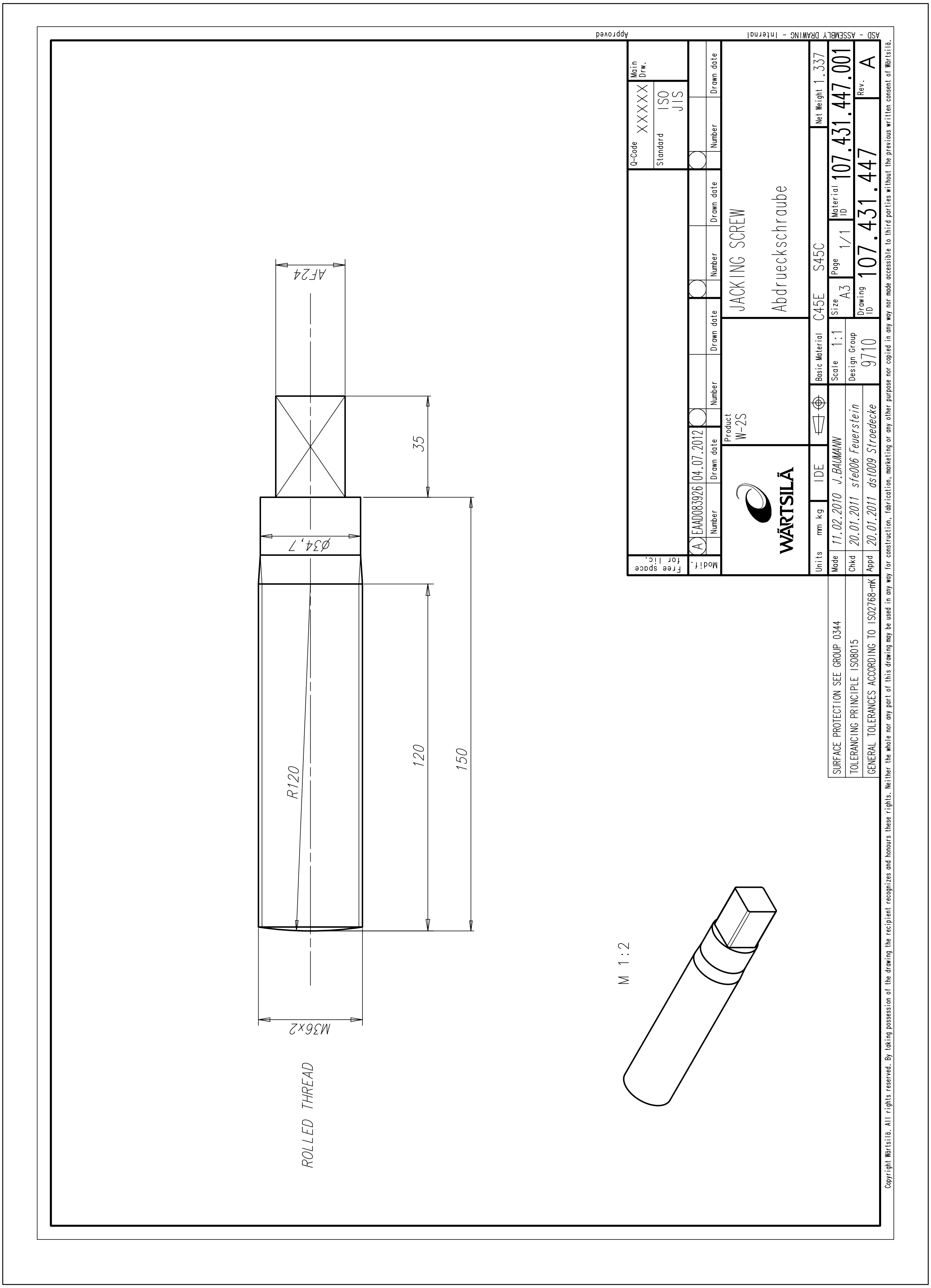
Made	10.05.2011	D. Strödecke	Main Drw. **H**	Page 54 / 54	Material ID **PAAD043682**
Chkd	11.05.2011	W. Schiffer	Design Group		
Appd	12.05.2011	K. Moor	**9709**	Drawing ID **107.404.952**	Rev **A**

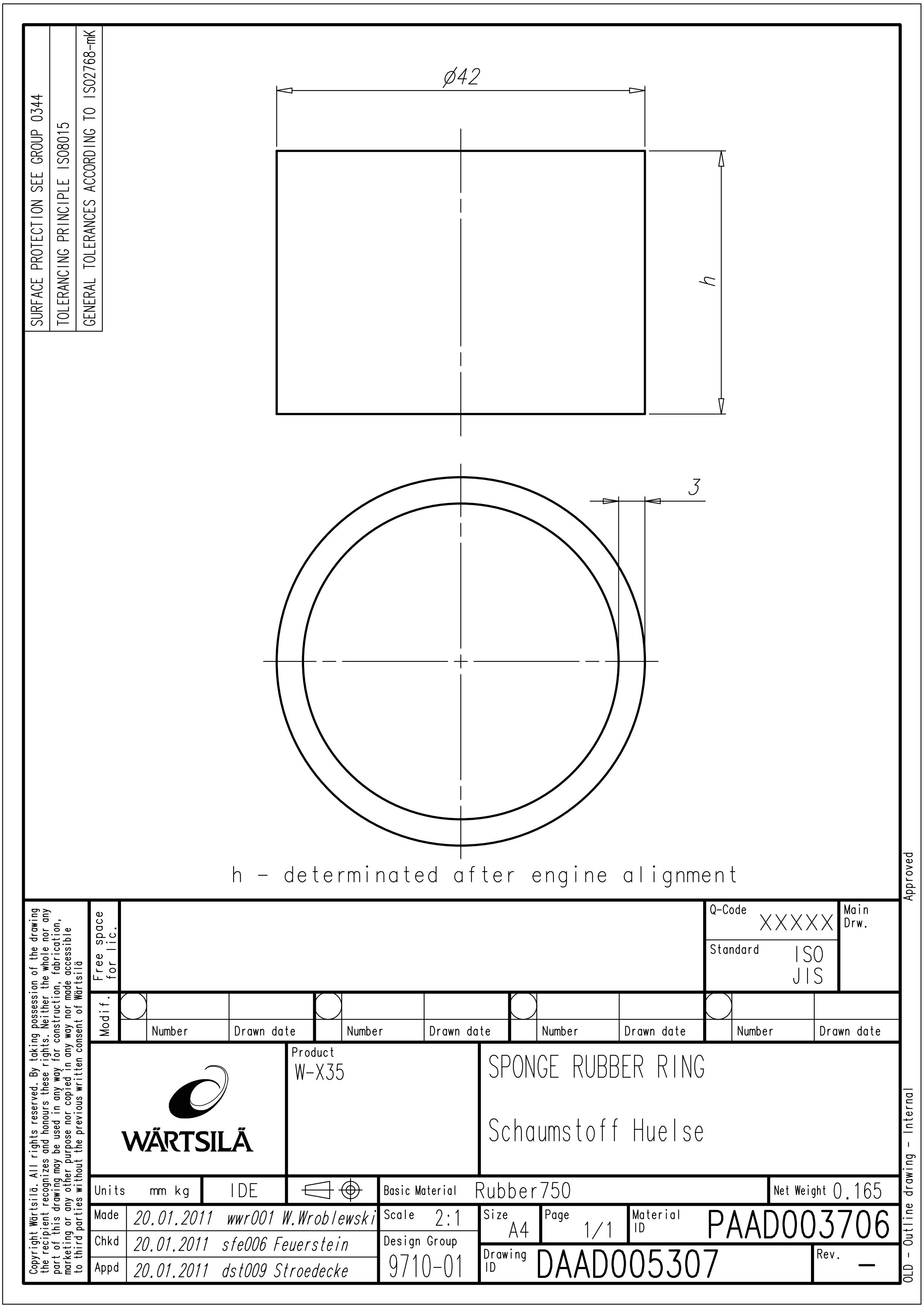
T_PC-Drawing_portrait | Author: Y. Keel, S. Knecht | Released by: K. Moor | First released: 29.07.2010 | Release: 1.2 (06.09.2010)

21.2 Tools

21.2.1 Drawings


Remarks
*1) depending on chock thickness
Provided by shipyard:
*2) Hydraulic jacks
Proposal: - Type: RCS-1002
- Maker: Enerpac
- Load at 700bar: 880kN
*3) Support block
FREE END
Freies Ende
DRIVING END
Antriebseite
bearbeitete Fläche
Anschluss Ölfänger
MACHINED SURFACE
CONNECTION OIL BAFFLE
5415
0
325
1070
1275
2180
3375
3580
4980
A-A (1:3)
Arrangement after pouring chock
B-B (1:5)
AF24
M36x2
Ø42
(197) *1)
*2) Hydraulic jack
*3) Support Block
001
002
SPONGE RUBBER RING
JACKING SCREW
PAAD003706
107.431.447.001
DAAD005307
107.431.447
Rubber750
C45E
S45C
0.165
1.337
14.4
PER ENGINE
PAAD061238
W6X40
TOOL ENGINE ALIGNMENT
Werkzeug Motorausrichtung
DAAD020731
9710-01
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
22.09.2011
07.10.2011
WÄRTSILÄ


AF24
35
Ø34,7
120
150
R120
M36x2
ROLLED THREAD
M 1:2
JACKING SCREW
Abdrueckschraube
Product W-2S
Basic Material C45E S45C
Scale 1:1
Size A3
Page 1/1
Design Group 9710
Drawing ID 107.431.447
Material ID 107.431.447.001
Rev. A
Net Weight 1.337
Units mm kg
Made 11.02.2010 J.BAUMANN
Chkd 20.01.2011 Feuerstein
Appd 20.01.2011 ds1009 Stroedecke
A EAAD083926 04.07.2012
Q-Code XXXXX
Standard ISO JIS
SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
ASD - ASSEMBLY DRAWING - Internal
Approved


SURFACE PROTECTION SEE GROUP 0344
TOLERANCING PRINCIPLE ISO8015
GENERAL TOLERANCES ACCORDING TO ISO2768-mK
Ø42
h
3
h - determinated after engine alignment
Q-Code XXXXX
Main Drw.
Standard ISO JIS
Free space for lic.
Modif.
Number Drawn date
Product W-X35
SPONGE RUBBER RING
Schaumstoff Huelse
WÄRTSILÄ
Units mm kg
IDE
Basic Material Rubber750
Net Weight 0.165
Made 20.01.2011 wwr001 W.Wroblewski
Chkd 20.01.2011 sfe006 Feuerstein
Appd 20.01.2011 dst009 Stroedecke
Scale 2:1
Design Group 9710-01
Size A4
Page 1/1
Material ID PAAD003706
Drawing ID DAAD005307
Rev. –
Approved
OLD - Outline drawing - Internal
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22. Appendix

22.1 Abbreviations

ABB	ASEA Brown Boveri	MAPEX	Monitoring and maintenance performance enhancement with expert knowledge
ALM	Alarm	MCR	Maximum continuous rating (R1)
AMS	Attended machinery space	MDO	Marine diesel oil
BFO	Bunker fuel oil	mep	Mean effective pressure
BN	Base Number	METxxMB	Turbocharger (Mitsubishi manufacture)
BSEF	Brake specific exhaust gas flow	MHI	Mitsubishi Heavy Industries
BSFC	Brake specific fuel consumption	MIM	Marine installation manual
CCAI	Calculated Carbon Aromaticity Index	MMI	Man-machine interface
CCR	Conradson carbon	N, n	Rotational speed
CCW	Cylinder cooling water	NAS	National Aerospace Standard
CMCR	Contract maximum continuous rating (Rx)	NCR	Nominal continuous rating
CPP	Controllable pitch propeller	NOR	Nominal operation rating
CSR	Continuous service rating (also designated NOR and NCR)	OM	Operational margin
cSt	centi-Stoke (kinematic viscosity)	OPI	Operator interface
DAH	Differential pressure alarm, high	P	Power
DENIS-UNIC	Diesel engine control and optimizing specification	PAL	Pressure alarm, low
EM	Engine margin	PI	Pressure indicator
EMA	Engine Management & Automation	PLS	Pulse Lubricating System (cylinder liner)
FCM	Flex control module	ppm	Parts per million
FPP	Fixed pitch propeller	PRU	Power related unbalance
FQS	Fuel quality setting	PTO	Power take-off
FW	Freshwater	RCS	Remote control system
GEA	Scavenge air cooler (GEA manufacture)	RW1	Redwood seconds No. 1 (kinematic viscosity)
HFO	Heavy fuel oil	S/G	Shaft generator
HT	High temperature	SAC	Scavenge air cooler
IMO	International Maritime Organisation	SAE	Society of Automotive Engineers
IND	Indication	SHD	Shut down
IPDLC	Integrated power-dependent liner cooling	SIB	Shipyard interface box
ISO	International Standard Organisation	SLD	Slow down
kW	Kilowatt	SM	Sea margin

kWe	Kilowatt electrical	SSU	Saybolt second universal
kWh	Kilowatt hour	SW	Seawater
LAH	Level alarm, high	TBO	Time between overhauls
LAL	Level alarm, low	TC	Turbocharger
LCV	Lower calorific value	tEaT	Temperature of exhaust gas after turbine
LI	Level indicator	TI	Temperature indicator
LLT	Low-Load Tuning	A1xx-Lxx	Turbocharger (ABB manufacture)
LR	Light running margin	UMS	Unattended machinery space
LSL	Level switch, low	VI	Viscosity index
LT	Low temperature	WCH	Wärtsilä Switzerland
M	Torque	UNIC	UNIfied Control
M1H	External moment 1st order horizontal	winGTD	General Technical Data program
M1V	External moment 1st order vertical	ΔM	Torque variation
M2V	External moment 2nd order vertical		

Table 22.1: Abbreviations

22.2 SI dimensions for internal combustion engines

Symbol	Definition	SI-Units	Other units
l,L	Length	m, mm, mm	
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	
v	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	

Symbol	Definition	SI-Units	Other units
$L_{(LIN)TOT}$	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)	

Table 22.2: SI dimensions for internal combustion engines

22.3 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
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
Volume	1 in^3			=	16.4 cm^3
	1 ft^3			=	0.0283 m^3
	1 yd^3			=	0.7645 m^3
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

Table 22.3: Approximate conversion factors

Wärtsilä Switzerland Ltd.
PO Box 414
CH-8401 Winterthur
Switzerland

Tel: +41 52 262 07 14
Fax: +41 52 262 07 18
http://www.wartsila.com

WÄRTSILÄ