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Envirosafe - WCS01

(G127 internal manufacturing code)

Water Lubricated Propeller Bearings

Design & Procedures Manual

DPM-01

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Enquiries should be directed to the above address.

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1 INTRODUCTION

Wärtsilä UK Ltd, (Wärtsilä), is a manufacturer of mechanical seals and composite bearings used as marine propulsion systems for the Naval and Commercial marine industry.

Wärtsilä has developed a new bearing formulation specifically for the water lubricated marine market. The new material address the limitations of manufacturing sizes of the historic products and offer compatibility with a much wider range of propeller shafts and liners. The product has been designated “WCS01”.

Subdivision “F” – indicates that the bearing and inner housing are Fully Split
Subdivision “N” – indicates that neither the bearing nor the housing is Split
Subdivision “P” – indicates that the bearing is Split but the housing is not
Subdivision “M” – indicates that the bearing is Shock compatible

WCS01 bearing composition is based upon Wärtsilä filament winding technologies and a modified epoxy resin system to produce a material with superior bearing performance, capable of operating with high Nickel content shafting, as well as the softer stainless steel and bronze shafting.

Wärtsilä materials are generally approved by the major Classification Societies for use in bracket/sterntube and rudder bearings.

The product is being offered under the Wärtsilä corporate branding name of “ENVIROSAFE”.

2. GENERAL

2.1 Rules relating to Wärtsilä's propeller shaft bearings vary between Naval specifications and Classification Societies etc; the applicable institutions should be consulted at the bearing design stage to ensure compliance with their requirements.

2.2 Wärtsilä presently offer WCS01 material for water lubricated bearing applications. WCS01 composite material comprises of a filament wound synthetic fibre with epoxy resin and additional friction modifiers.

2.3 Wärtsilä offer bearing materials in several different forms and supply conditions as shown below:

- **(R/T)** Rough turned billets - the bearings require full machining by the customer.

- **(S/F)** Semi-finished bearings - the bearing material requires some machining by customer for example on O/D, I/D and Length on tubes, arc and ID on shells and staves.

- **(F/M)** Finished bearings - the bearings are fully machined and ready for installation. This would require the shipyard to accurately machine the shaft, housing and arc lengths to the required tolerance or provide the actual measured housing and shaft dimensions to Wärtsilä UK. Finished bearings are not recommended for long term storage unless supplied as a bearing package.

For optimum accuracy Wärtsilä recommend that shipbuilders take delivery of bearings in the billet or semi-finished condition.

Once the stern bore, shaft and retaining keys have been measured, Wärtsilä can assist the shipbuilder in the design of finish machined bearings to suit the measurements.

2.4 Both materials are offered in either tube or half shell form to suit shaft sizes from 70 to 1100mm in diameter.

2.5 The fully machined bearing is installed directly into the vessel's sterntube or bracket bore using interference fits for tubes or retaining keys for shells. Alternatively bearings can be supplied as a package – fitted inside a housing for installation, using interference fit or resin casting techniques. The resin casting method may offer cost savings, as the vessel's sterntube or bracket may not require accurate boring.

2.6 To ease handling, Wärtsilä bearings are normally supplied in several sections. The sections are tightly butted together on installation into the housing and no allowance is made for axial expansion.

2.7 To simplify machining and future bearing replacement, any slope or offset requirements should be incorporated into the bore of the sterntube or bracket. Alternatively, the composite material can be fitted in a housing that is then machined accordingly. Resin casting can be used to support the housing in the correct alignment.

2.8 For repair work where time constraints apply, housing alignment corrections, or compensation for housing irregularities, (ovality, taper etc) can be machined into the bearing inside diameter by in-situ machining.

2.9 Wärtsilä stern tube bearing materials swell in water or atmospheric moisture. This factor is taken into consideration during design; however, it is recommended to fit the bearings within 1 week of final machining.

Bearings supplied in a package can be stored in the finished machined condition provided the storage requirements detailed in section 2.10 are observed. It should be noted that some dimensional movement may occur to the original ID supply size after long term storage. Bearing ID sizes should always be checked before and after installation. If ID sizes are found below the minimum design value stated on the Wartsila drawing please complete the ID dimensional report in the Appendix and forward a copy to Wartsila UK for review and final approval.

2.10 Wärtsilä bearings should be stored on the vertical axis, indoors, out of direct sunlight and ideally between 10°C and 30°C and 20% to 80% humidity. They should at all times be sheltered from the elements, frost and excessive temperatures. Individual bearing sections not supplied in a package should be stored in either a billet or semi-finished condition and final machined just prior to the fitment date.

2.11 When the vessel is out of operation it is important to turn the shaft (a few revolutions) at intervals not exceeding one week (preferably, every second day). This is to prevent damage to the bearing material caused by a build-up of marine growth and cathodic chalk on the shaft which are highly abrasive and the build up may result in rapid initial wear of the bearing liners. If it becomes necessary to turn the shafts in dry dock, the bearing segments are to be protected from damage by directing a flow of water onto the bearing and shaft journals.

2.12 For vessels operating in brown water, Inland waterways (IWW) it is advised that you contact the Wartsila technical design team. Bearing lengths and groove quantity are typically increased to those of deep water vessels along with an optimised groove profile to aid debris removal.

3. MATERIAL PROPERTIES

Typical physical properties of the material are tabulated below.

	Test Method	Units	WCS01
Compressive Strength (Radial) (Axial)	RTM 504	MPa	80 80
Compressive Modulus Radial	ISO 604	MPa	2300
Coefficient of Friction – Wet – Dry	RTM519	(μ)	0.2 0.1
Max. Operating Temperature		°C	130
Swell in Water – (water at ambient temperature)	RTM 307	%	0.2
Thermal Expansion Radial Axial Hoop	ASTM E 831	$x10^{-5}$ /°C $x10^{-5}$ /°C $x10^{-5}$ /°C	6.0 6.0 3.0
Thermal Conductivity		W/m.k	0.5
Hardness	ISO 2039/2	Rockwell	70
Density	ISO 1183	g/cm^3	1.34

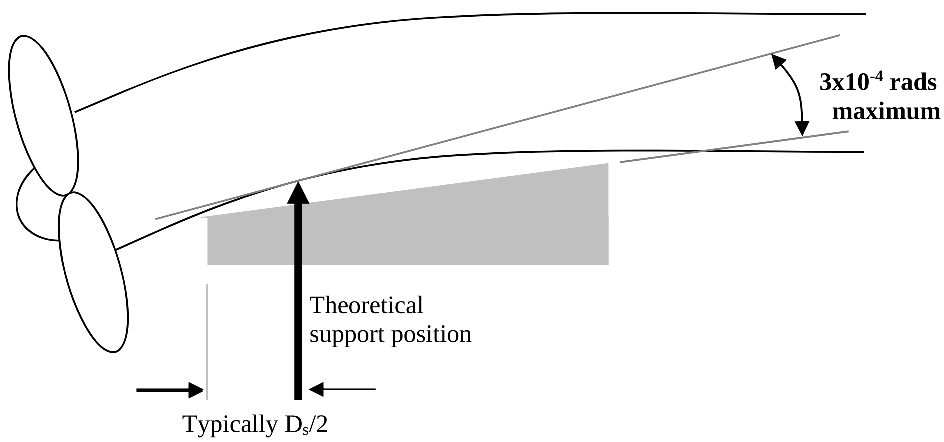
These figures are intended to act as a guide only as variations may occur due to the limits of the materials manufacturing specification. These values were obtained from new bearings at ambient temperatures unless otherwise stated using Wärtsilä Laboratory methods, differences may therefore be experienced when testing by other methods or on used bearings.

4. OPERATIONAL REQUIREMENTS

4.1 Alignment

A bearing should always be aligned to its shaft journal. The material properties of the bearing should be taken into consideration when designing the shaft line.

This however, is impracticable for the bearing adjacent to and supporting the weight of the propeller. In this case the bearing should be aligned such that the angle between the static journal running surface and the bearing is not greater than 3×10^{-4} radians with the theoretical support position typically half the shaft diameter forward from the aft extremity of the bearing. This is a maximum value for the installed condition and the design value should be such that machining and installation tolerances do not cause this limiting value to be exceeded.



To ease machining and future bearing replacement, any slope or offset requirements should be incorporated in the bore of the sterntube or bracket, alternatively, the composite material can be fitted into a metal sleeve that is then machined accordingly. Wärtsilä UK does not recommend that any slope or offsets are incorporated directly into the bearing material.

4.2 Lubrication and Cooling

The bearings are to be seawater lubricated by free flooding the bracket bearings and providing a pumped supply to the forward end of the stern tube bearing. The water should be continuously supplied to the forward stern tube bearings at a rate of 0.15 litres/minute per mm of shaft. An example being 500mm diameter shaft requiring 75 Litres/min water flow. To ensure the required water flow rate is achieved the pump capacity should exceed the external hydrostatic water pressure at the bearing level.

It is good practice to fit a redundant pump to prevent water flow loss to the system in the event of the primary pump failure.

Bearing wear life is closely related to the exposure to abrasive particles over the operational life of the vessel. For vessels that regularly transit areas of contaminated waters Wartsila recommend minimising the exposure by using either filtration or separators to process the cooling water. The following table can be used for guidance:

Bearing Installed Location	**Water Quality**	**Filtration Used**	**Expected Bearing Wear Life**
Stern tube	Clean	Strainer / Screen	High
	Dirty	Strainer / Screen	Reduced
	Dirty	200 µm	Normal
	Dirty	Wartsila WQS with Cyclone Separator	High
	Dirty	50 µm	High
Open Bracket	Clean	Not Applicable	High
	Dirty	Not Applicable	Reduced

Use of a cyclone separator will greatly reduce the exposure of the bearings to abrasive particles. The performance of Wartsila cyclone separators is as follows:

Material	**Typical Relative Density**	**Separation efficiency for ≥ 75 micron particle [%]**
Earth Silt Soil	1.7	90
Sand / Silica / Shale	2.6	95
Metallic Particles	>7	98

A flow meter should also be added to the pumped cooling system to indicate loss of water flow. The temperature of the water supplied to the stern tube bearing for cooling should not exceed 40°C. Engine cooling water should not be used for the bearing water supply, it should be sourced directly from the sea or river.

It is good practise to fit temperature sensors to monitor the bearings during operation. Consult Wärtsilä for advice on sensor installation.

4.3 Bearing Pressures

Nominal bearing pressures are calculated, in line with Classification Society methods, from,

$$Pressure = \frac{Bearing\ Load}{Bearing\ Length \quad x \quad Shaft\ Diameter}$$

The bearing pressure and length to diameter ratio is generally limited by Classification Societies and information on permitted values may be obtained from Wärtsilä UK or the relevant Society. Bearing pressures are typically designed to ≤4 kg/cm² (Bar), if the design exceeds this value then Wartsila should be consulted. Bearing lengths typically exclude Wärtsilä standard lead in chamfers profiled in the ends of each bearing.

4.4 Shaft Journal

Approved shaft journal materials are shown in the table below. The journal should be machined to the design sizes within an ISO h7 tolerance on its diameter and a maximum surface roughness of 0.8μm Ra. Finer surface finishes to some journal materials may be requested for optimum bearing performance. For dirty river water applications consult Wartsila design team for recommended shaft journal material.

Shafting Material	Alloy	Tensile MPa	Hardness Brinell	Minimum Surface finish microns Ra
LG4 (C93400, ASTM B-505)	CuSn7Zn2Pb3	250 - 320	70 - 85	0.8
Tin Bronze (C90500, ASTM B-271, B-584)	CuSn10Zn2	150 - 310	75	0.8
Copper Nickel (C96400, ASTM B-369, B-505)	Cu70, Ni30	415	140	0.8
Stainless Steel (S316, ASTM A240)	Fe65, Cr17, Ni12, Mo3, Mn3	515	215	0.8
Duplex 2205 (ASTM A276, A479, A789, A890)	Fe78, Cr22, Ni12, Mo3, Mn2	620	290	0.4
Inconel 625 (ASTM B444, B446)	Ni60, Cr22, Mo9, Fe5, Nb4	830 - 1000	170 - 250	0.3

For IWW applications shaft journals may have coatings such as Nickel Chrome Boron (NCB), which is acceptable for use provided the surface finish is ≤0.3μm Ra. For any other shaft coating systems please contact Wartsila UK for advice regarding their suitability.

4.5 Bearing Housing Bore

Wärtsilä composite bearings require full radial support from the bearing housing around their circumference and throughout their length. Any cavities should be either filled or lined. The housing should be bored to within an ISO, H7 tolerance, and have a surface finish of, 1.6µm Ra maximum. A full inspection report should be undertaken and a copy sent to Wärtsilä UK.

For tube bearings retained by interference fit, the entrance to the housing and any internal steps should be chamfered to prevent 'shaving' of the bearing material during press fitting.

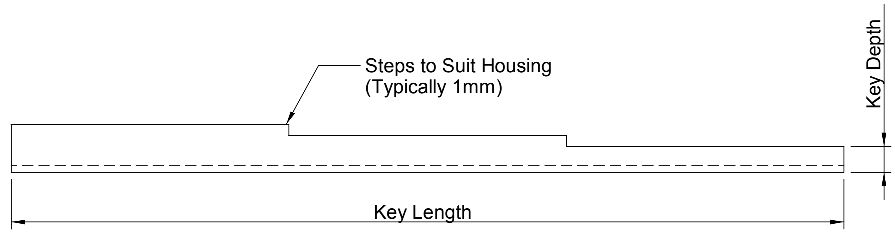
For repair situations, remove high spots and rust with an abrasive wheel. Fill large cavities with suitable fillers to provide full support to the bearing. The housing bore dimensions may vary from those on new build installations. Please consult Wartsila for bearing design sizes if the housing ovality exceeds 0.3mm and/or there is a taper across the housing length that is greater than 0.2mm.

4.6 Bearing Retention

4.6.1 Tube Bearings

Typically, bearings with shaft <300mm do not require an anti-rotation key. However, location of the bearing within its housing by interference fit alone may not be accepted by the relevant classification society. In such cases, the bearing can be drilled and pinned. If the bearing is drilled ensure the drill holes are on the side of the bearing away from the shaft operating area. Check to ensure the pins do not distort the bearing inside diameter when fitted.

For larger bearings the preferred method is to fit a bronze anti-rotational key. An additional benefit with an anti-rotation key is simplified bearing location for multi-section bearings. It will ensure lubrication washways are correctly aligned. The key is positioned ideally at top dead centre and must extend the full length of the multi section bearing. Other annular positions may be acceptable in the top half of the bearing; however, Wärtsilä UK should be consulted in these cases. If the sterntube or bracket bore is stepped, the key's depth should be correspondingly increased such that the radius from the longitudinal centreline of the bore to the key surface remains constant.



Securing using setscrews is typical but the key should be aligned to the bores longitudinal axis, to within ±0.5mm. Failure to align the key can result in bearing installation issues. The securing of the key should be sufficient to resist the torque that could occur during initial engine start-up.

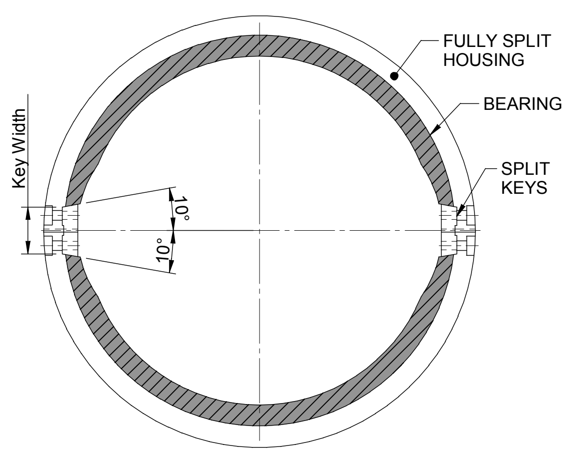
Recommended key dimensions are given in the table below:

Shaft Diameter, Ds	**Key**	
	Width	**Depth**
mm	mm	mm
301-400	26	8
401-500	31	9
501-600	31	11
601-700	41	13
701-800	41	14
801-900	49	16
901-1000	49	18
1001-1100	59	20

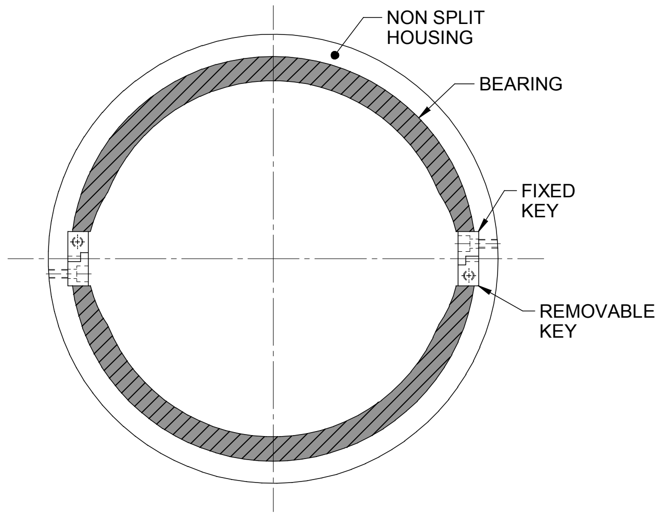
Above Key dimensions are to a tolerance of +/-0.25mm

4.6.2 Half Shell, Segment Bearings

There are two typical designs, fully split (F) or partially split (P). Both types of installations prevent bearing rotation using bronze keys. Typical arrangement sketches for the two designs of half shell bearing installations are shown below:



Fully – split housing with half shells



Partially – non split housing with half shells

The half shell bearings are typically supplied at an arc of 168°, to allow for machining allowances on the arc length. The typical keeper bar width can be calculated using the formula shown below:

[(H x π) / 360] x 14 (round up to the nearest whole number)

The keeper bars are normally secured by A4 stainless steel cap head bolts (sized to suit the bar). Bolts must be secured with a thread-locking agent.

The keeper bar thickness should be designed so it assembles level with the lubrication washway radius.

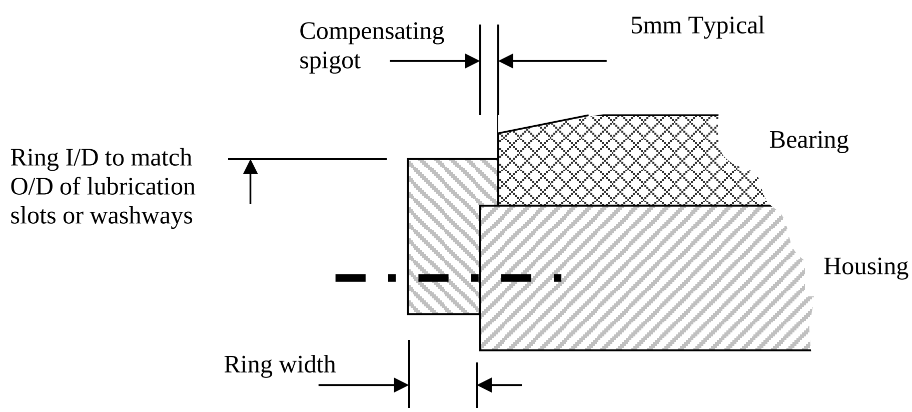
For new build installations the bearing surface can be lightly tapped to determine reduced bearing contact with housing. Refurbishment of partially split assemblies with the shaft in-situ can be checked only at the free end, with a feeler gauge.

4.6.3 Keeper and Stopper Rings

Axial support to the bearing ends is advised in the form of retaining rings on bearings with shaft size >300mm. Below 300mm the bearings can be axially secured with grub screws machined into the O/D of the bearing through the sterntube or bracket frame (typically required when bearings are bonded into position) or by interference fit alone.

Normal practice is to bolt the rings in position or alternatively the stopper ring can be designed as an integral part of the cast housing while the external keeper ring must be bolted in position to allow fitment of the bearings.

The ring I/D typically matches the O/D of the lubrication washways or slots (see section 5.9). On smaller shaft diameters the ring I/D should be sized to ensure at least 7mm wear allowance. The rings, and their securing arrangements, must be capable of withstanding an axial force equal in magnitude to the shaft load vertically imposed on the bearing under emergency conditions and consequent to compression of the bearing material.



Wärtsilä recommend that bronze or Wartsila composite rings have a minimum thickness as shown in the table below and, when bolted, secured by equi-spaced bolts such as DIN 912 socket cap screws in A4 stainless steel

Shaft Diameter	Ring Width (Minimum)	Number Of Bolts (Minimum)	Size of Bolts (Minimum)
70-200 (optional)	10	8	M8
201-300 (optional)	20	10	M10
301-400	25	12	M12
401-500	25	12	M12
501-600	25	16	M12
601-700	30	16	M16
>701	30	16	M16

4.7 Condition based monitoring (CBM)

Bearing condition can be monitored using temperature sensors and/or wear down checks. Although not commonly fitted, PT100 temperature sensors can be mounted just below the bearing operating surface. The sensors can be connected into the engine control room (ECR) and alarms set to warn ships crew of any issues. High temperatures are unlikely in water lubricated bearings. In the event of a loss of water flow or foreign material is drawn through the bearing, the sensor should indicate a rise in temperature allowing the crew to reduce shaft speeds and investigate.

Normal operating temperatures would typically be <5°C higher than the inlet water temperature. The alarm would typically be set at no more than 10 Celsius above the maximum inlet water temperature. In addition to the high temperature alarm it is recommended to fit a temperature gradient alarm as this may warn of a potential problem before the high temperature alarm activates. Typical temperature gradient should not exceed 5°C/min.

Bearing wear down is typically measured using a poker gauge system. Poker gauges and their mounts can be designed and supplied by Wartsila. Wear down should always be recorded at each docking to check bearing performance and to predict when bearing replacements are required. Bearing wear is typically acceptable up to 6mm, anything greater than this would require consultation with the vessel shaft line designer to ensure other systems are not affected.

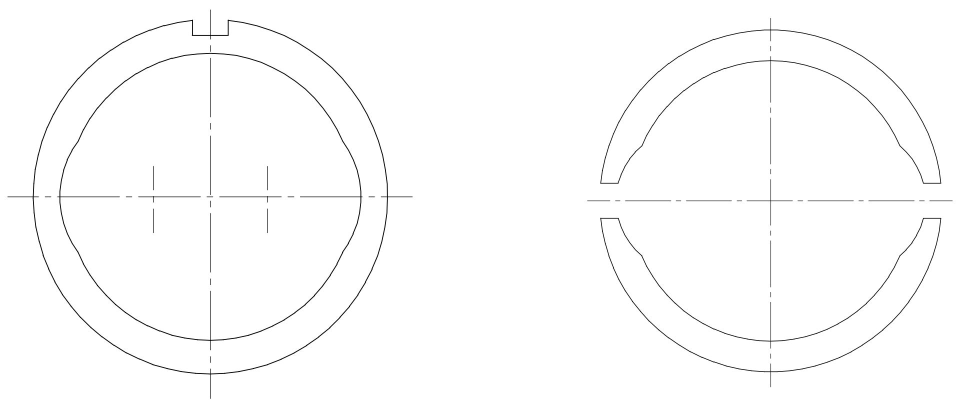
Wartsila also offer a sensor system for in service wear measurements. The installation of this shaft proximity CBM system is done on a case by case basis to ensure the sensor can be mounted and cable routed correctly. Classification Societies may offer extended tail shaft survey intervals when CBM systems are installed.

5 GENERAL DESIGN

Wärtsilä UK should be consulted if there is any doubt about any aspect of the standard design parameters. For optimum accuracy, the final bearing design should be undertaken using the actual shaft and housing dimensions measured after final machining.

5.1 General Design Types

Wärtsilä water lubricated bearings are supplied in two different forms, tube and half shells. A diagrammatical representation is shown below:



1) Tube Bearings 2) Half Shell Bearings

5.2 Nomenclature

TERM	DESCRIPTION
WT	Wall Thickness of Bearing
M	Anti-rotation Key Groove Width
Z	Anti-rotation Key Groove Depth
K	Wall Thickness Under Anti-Rotation Key Groove
R	Water Washway Radius
S	Water Washway Offset Position
Ds	Shaft Diameter
H	Housing Bore Diameter
L	Bearing Length
ID	Bearing Inside Diameter
OD	Bearing Outside Diameter
X	Bearing Inside Diameter Chamfer Width
Y	Interference Between Bearing & Housing
Rc	Bearing Running Clearance
V	Shaft surface velocity – in m/min
P	Bearing pressure – in kg/cm^2 (bar)
T	Velocity/Pressure (V/P)

5.3 Shaft Diameter, Ds,

Wärtsilä bearings are designed based on the bearing journal diameter, **Ds,** measured in millimetres.

5.4 Bearing length, L,

Bearing lengths are optimised to ensure that maximum bearing pressures set by Classification Societies are not exceeded. Bearing lengths typically exclude the Wärtsilä standard lead in chamfers profiled in the ends of each bearing.

Wärtsilä standard lengths are :

Bracket & Sterntube aft bearings,	Standard	**L = 2 x Ds**
	Maximum	**L = 2.5 x Ds**
	Minimum	**L = 1.5 x Ds**
Sterntube forward bearing,	Typically	**L = Ds**

If bearing lengths are required outside the above recommendations please consult the technical design team at Wartsila.

For inland waterway applications, increased bearing contact lengths are often adopted (3:1 L/D typical), please consult Wartsila technical design team for optimum shaft to bearing contact lengths.

5.5 Hydrodynamic Bearing Conditions

Nominal bearing pressures are calculated, in line with Classification Society methods, from,

$$Pressure\ (P) = \frac{Bearing\ Load}{Bearing\ Length \quad x \quad Shaft\ Diameter}$$

The maximum permitted values may be obtained from Wärtsilä UK or the relevant Classification Society.

Shaft velocity (V) required in m/min

For maximum life of a bearing it should be designed to operate hydrodynamically. Wärtsilä calculate the hydrodynamic condition using shaft surface velocity / bearing pressure values obtained from extensive testing. The values of V/P (T) contain a suitable safety margin and are based on a pressure of 4 kg/cm^2. If higher design pressures are used or if the calculated value of ‘T’ is lower that shown below Wärtsilä should be consulted.

Bearing Length to Diameter Ratio	Minimum Design V/P Value (T) WCS01
2.5:1	4
2:1	5
1.5:1	6
1:1	7

The following formula should be used to determine the minimum shaft speed rating.

V/P = T (See Table)

V= Velocity (m/minute)
P= Pressure (kg/cm^2)

$$\frac{\pi \cdot Ds \cdot N}{P} \geq T$$

Ds= Shaft Diameter (m)

N= Hydrodynamic Running Speed (RPM)

$$N = \frac{T \cdot P}{\pi \cdot Ds}$$

If the value of 'T' is below that shown in the table the shaft may not be operating hydrodynamically at the selected shaft speed. In such conditions there may be accelerated bearing wear. Consider increasing minimum shaft speed or reduce the bearing load by increasing bearing length.

5.6 Housing Nominal Bore Size, H_{nom}

The housing bore should be designed to an H7 tolerance. If for any reason the housing bore measures outside this tolerance, a full dimensional report should be referred to Wärtsilä UK for approval and acceptance.

As the bearing running clearance is proportional to the bearing wall thickness, housing bore diameter selection is an important issue with Wärtsilä materials. Graph 2 should be viewed for optimum and maximum wall thickness in order to achieve the correct housing design sizes. Any sizes above or below the range shown should be referred back to Wärtsilä UK for approval.

H_{nom} = (1.09 x Ds) + 20 (round up to next whole mm)

5.7 Bearing Minimum Running Clearance, Rc_{min},

Wärtsilä materials require a small swell allowance to compensate for water absorption. The minimum design running clearance formula includes allowance for this (see section 6.1.6 under detailed design for formula).

After fitting a bearing into its housing the inside diameter must be inspected to ensure that the minimum design running clearance is maintained at all points around the inside diameter and throughout the length of the bearing.

5.8 Slope or Offset

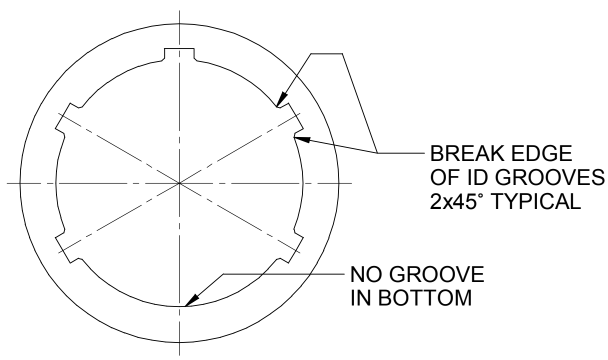
For new build applications Wärtsilä recommends that required bearing offsets and slopes are incorporated in the sterntube or bracket housing. In repair situations where time does not permit the re-machining of metalwork small adjustments can be accommodated in the bearing ID by way of in-situ machining.

5.9 Lubrication Washway / Grooving

There are several different styles of lubrication washway or grooves to suit both bearing size and design.

5.9.1 Shaft Diameters Below 200mm (non IWW applications)

Bearings with shaft diameters below 200mm it is recommended to machine axial grooves according to the table below.



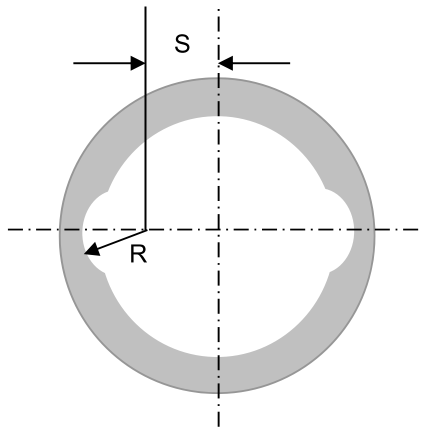
Shaft Size	Groove Quantity	Typical Groove Depth	Typical Groove Width
70-100	5	4.0	10
101-120	5	4.5	12
121-150	6	5.0	12
151-180	6	5.5	14
181-200	6	6.0	16

Axial grooves should be equi-spaced around the bearing inside diameter and symmetrical about the vertical centre line. As maximum bearing load is in the bottom dead centre position grooves should not be placed in this area as shown in the sketch below.

Example: 100mm shaft has 5 grooves, you equi-space for 6 grooves leaving the 6th groove in the bottom un-machined as per the diagram above.

5.9.2 Shaft Diameters Above 200mm

The standard washway design adopted above 200mm shaft diameters can both be used for either tubes or half shells.

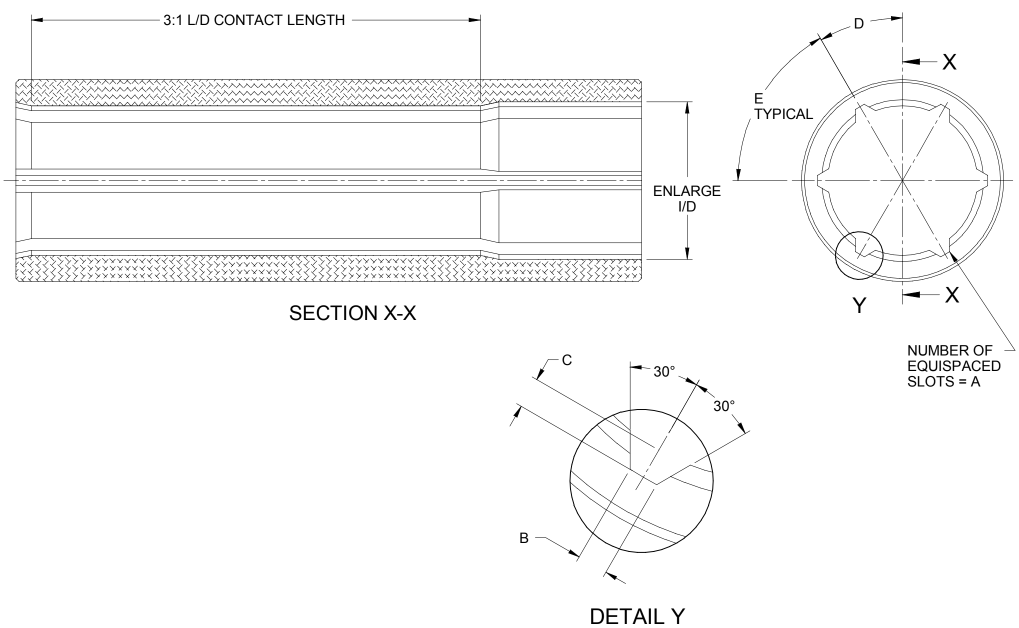


Radius, R = 0.33 x Ds (round up to next whole number)

Offset,	For Ds from 200 to 500mm	S = 0.193 x Ds
	For Ds from 500 to 800	S = 0.191 x Ds
	For Ds over 800	S = 0.189 x Ds
		(round to one decimal place)

5.9.3 Inland Waterway (IWW) Applications

For vessels operating in dirty river water conditions it is recommended to use the Wartsila WCS01 material. The bearing should have lubrication slots to assist in debris removal. Where possible the lubrication slot should adopt a chamfered profile as per the diagram below. Additional slots are machined into the bearing to assist in debris removal. To compensate for the increased number of slots the shaft to bearing contact lengths are often increased to 3:1 L/D ratio but not normally greater than 4:1. For replacements of longer length bearings the end of the bearing can be enlarged to reduce the shaft to bearing contact length.



The following table gives a guide for groove size, quantities and positions.

Shaft Size	Slot Quantity (A)	Typical Slot Depth (C)	Typical Slot Width (B)	Start Position (D)	Slot Spacing (E)
70-100	5	5.0*	6	0º	72º
101-130	5	6.0*	8	0º	72º
121-150	6	7.0*	10	30º	60º
151-180	6	8.0*	12	30º	60º
181-230	7	9.0*	12	0º	51.4º
231-300	8	10.0*	12	22.5º	45º

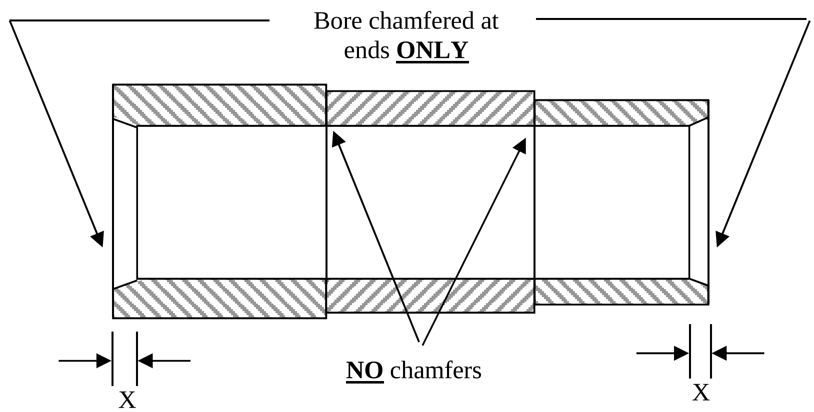
* Depth of slot is dependent on bearing wall thickness. Basic guide is to machine the depth of slot to approximately 1/3rd of the wall thickness of the bearing. Slot depth can be increased on bearings which have a thicker wall thickness. Use the following formula as a guide.

Minimum wall thickness under any groove = (0.03 x Ds) + 4

5.10 Bearing Interior

Where adjoining bores of adjacent sections meet, the inside diameter should NOT be chamfered. See diagram below.

The bearing bore should be chamfered ONLY at the bearing extremities to an angle of 12° from the bearing running surface and for the length given in table below.



Shaft Sizes	I/D Chamfer Width X
60-200	10
201-300	15
301-600	25
>601	35

6 DETAILED DESIGN

6.1 Tube Bearings

6.1.1 Number of Bearing Sections

To ease handling, the bearing length will be supplied in sections (typically <800mm). The numbers of sections are shown below,

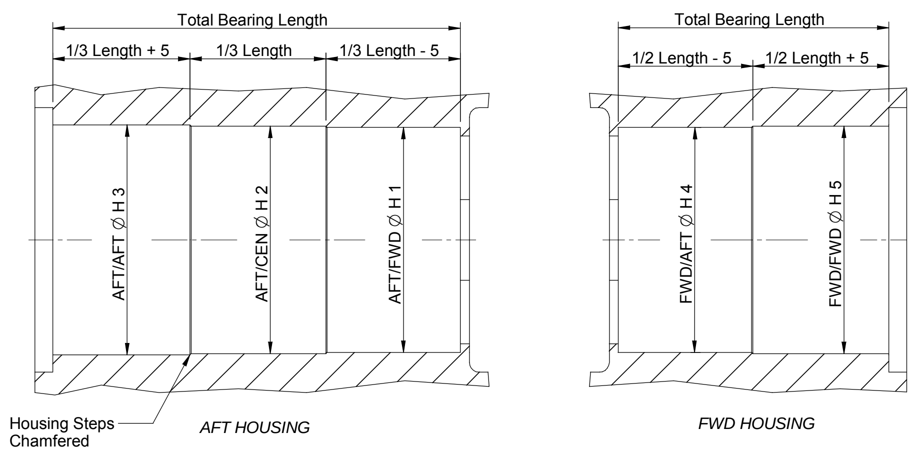
Shaft Diameter (Ds)	Number of Bearing Sections			
	L:Ds up to 1:1	L:Ds from 1:1 to 1.5:1	L:Ds from 1.5 to 2:1	L:Ds from 2:1 to 2.5:1
70 – 200 mm	1	1	1	1*
201 – 300 mm	1	1	1*-2	2
301 – 400 mm	1	1*- 2	1*-2	2
401 – 500 mm	1*	1*-2	2	2
501 – 600 mm	1*	1*-2	2	2
601 – 700 mm	1*-2	1*-2	2	2-3
701 – 800 mm	2	2	2	2-3
801 – 900 mm	2	2	2-3	2-3
901 – 1000 mm	2	2	2-3	3
1001 – 1100 mm	2	2	2-3	3

* Bearing O/D may be stepped to facilitate fitting

For IWW applications where freeze fitting and bonding are common, bearings up to 300mm shaft are typically supplied in 1 piece up to 4:1 L/D ratio.

6.1.2 Bearing Housing Bore, H,

Small diameter bearings can be supplied and fitted as one length. However, press fit bearings which exceed 400mm in length, the housing bore (H) and corresponding bearing outside diameter (OD) are typically stepped to aid assembly. To achieve this, it is recommended that the housing diameters should be increased in increments of 2mm. The housing step lengths should be adjusted by 5mm to ensure that the bearing section lengths do not contact (foul) the housing steps.



Aft Bearing Housing

Aft/Fwd Section **H1 = (1.09 x Ds) + 20** (round up to next whole mm)

Aft/Ctr Section **H2 = H1 + 2mm**

Aft/Aft Section **H3 = H1 + 4 mm**

Note: On two-piece bearings, the Aft Aft section becomes H2.

Forward Bearing Housing

Fwd/Aft Section **H4 = (1.09 x Ds) + 20** (round up as H1)

Fwd/Fwd Section **H5 = H4 + 2 mm**

6.1.3 Housing / Bearing Interference, Y,

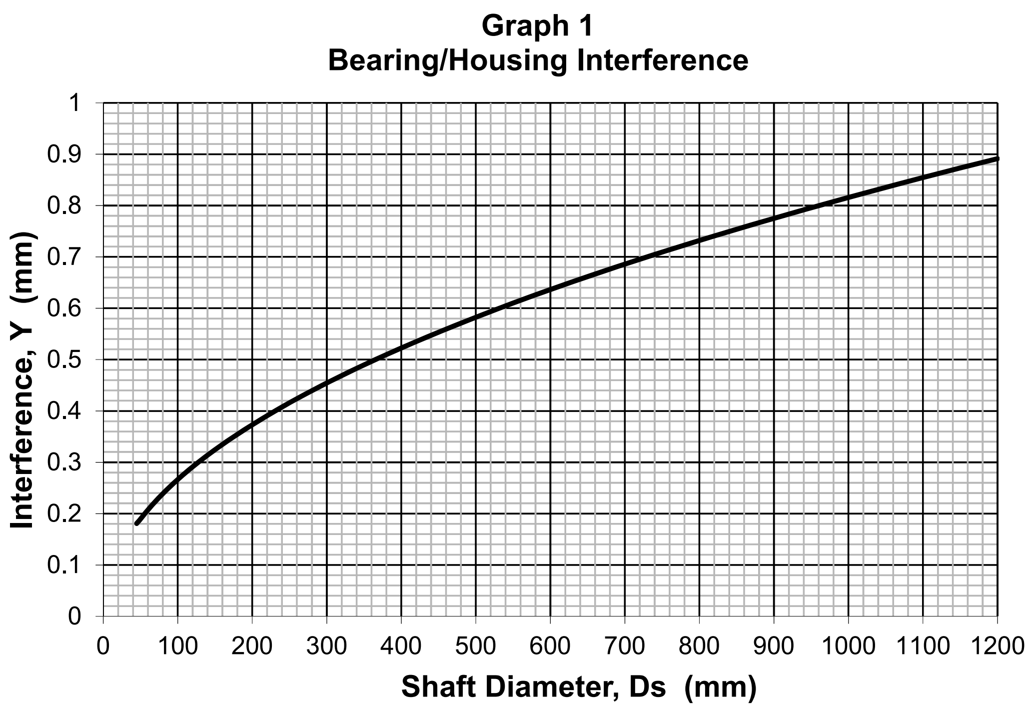
Bush type bearings are designed to have an interference fit in its housing. The minimum interference, **Ymin,** is given in **Graph 1**.

$Ymin = 0.0284 \times (Ds^{0.4861})$

The maximum interference can be calculated after the OD calculation by,

$\mathbf{Y_{max} = OD_{max} - H_{min}}$

As the elastic modulus for steel and bronze is many times that of the bearing material, all strains consequent to the interference fit between the housing and bearing are considered to occur in the bearing material. Hence, when fitted, the bore of the bearing will contract in direct proportion to the actual amount of interference applied.



6.1.4 Bearing Outside Diameter, OD,

In the free state, the bearing OD should be machined to the following diameter to give the correct interference fit.

$$OD_{min} = H_{max} + Y_{min} \quad \text{(round up to next mm/100)}$$
$$OD_{max} = OD_{min} + 0.15$$

For repair situations where housing tolerances exceed 0.2mm the H_{max} value may in some instances be substituted for an average value. A typical example would be housings with consistent ovality throughout the bore length.

Bearings to be directly bonded into the housing can be machined to **H_{min} – 0.24mm** (Tol +0 / -0.15) for optimum adhesive layer thickness. Maximum adhesive layer thickness is not to exceed manufacturers recommendations.

The fully machined free state bearing OD for half shell bearings is given by,

$$OD_{min} = H_{max} \quad \text{Tolerance of } -0 / +0.15$$

6.1.5 Bearing Inside Diameter, ID, Machining size

The free state bearing ID for each corresponding housing diameter for bush type bearings, **with an interference fit**, is given by,

$$ID_{min} = Ds_{max} + RC_{min} + Y_{max} \quad \text{(round up to next mm/100)}$$
$$ID_{max} = ID_{min} + 0.15$$

The fitted bearing inside diameter for each corresponding housing diameter can therefore be calculated by,

$$ID_{fitted\ max} = ID_{max} - Y_{min}$$
$$ID_{fitted\ min} = ID_{min} - Y_{max}$$

Bearings which are bonded directly into housings **without interference fit** should machine to the following formula.

$$ID_{min} = Ds_{max} + RC_{min} \quad \text{(round up to next mm/100)}$$
$$ID_{max} = ID_{min} + 0.15$$

6.1.6 Running Clearance, Rc

The minimum design running clearance formula is given by,

$$Rc_{min} = 0.001 \times Ds_{max} + 0.15 + [(H - Ds) \times 0.01]$$

(round up to next mm/100)

The maximum fitted running clearance on bush type bearing installations with interference fits can be calculated from the build-up of machining tolerances,

$\mathbf{Rc_{max} = ID_{max} - Y_{min} - Ds_{min}}$ (round up to next mm/100)

Bearings which are bonded directly into housings should exclude the interference (Y_{min}) value from the formula.

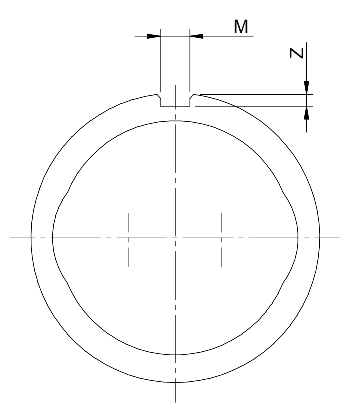
6.1.7 Anti-rotation Keyway Groove

Anti-rotation keys are recommended for bearings with shaft size >300mm. If an anti-rotation key is fitted, a keyway with 1mm minimum clearance on width and typically 2mm on depth should be provided. Standard key and keyway dimensions are given in the table below. It should be noted that the key depth specified below applies to housing section H1 and the depth of slot will need to be increased in accordance with the remaining housing steps.

Shaft Diameter, Ds	**Key**		**Keyway**	
	Width	**Depth**	**Width (M)**	**Depth (Z)**
mm	mm	mm	mm	mm
301-400	26	8	27	10
401-500	31	9	32	11
501-600	31	11	32	13
601-700	41	13	42	15
701-800	41	14	42	16
801-900	49	16	50	18
901-1000	49	18	50	20
1001-1100	59	20	60	22

Above Key and keyway dimensions are to a tolerance of +/-0.25mm

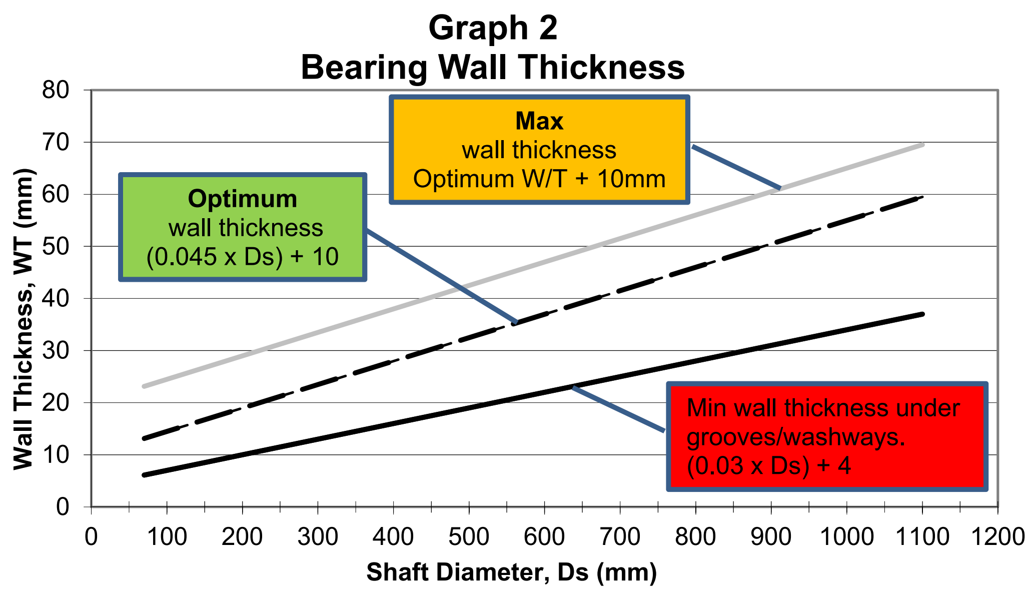
Keyway depth should not compromise minimum wall thickness (see graph 2)
Keyway width may be adjusted to suit stock bar / box channel section available – providing it does not exceed the widths shown above.



6.1.8 Additional external Grooves

Additional external grooving may be introduced due to sensors, sealing pipes and other channel requirements it should be noted that, where possible, they are not to be machined in the bottom half of the bearing in the high load area.

The wall thickness under any groove or washway radius of the bearing must equal or exceed the minimum value shown in GRAPH 2.



Note: If maximum wall thickness is greater than shown above please contact Wartsila UK for a design review.

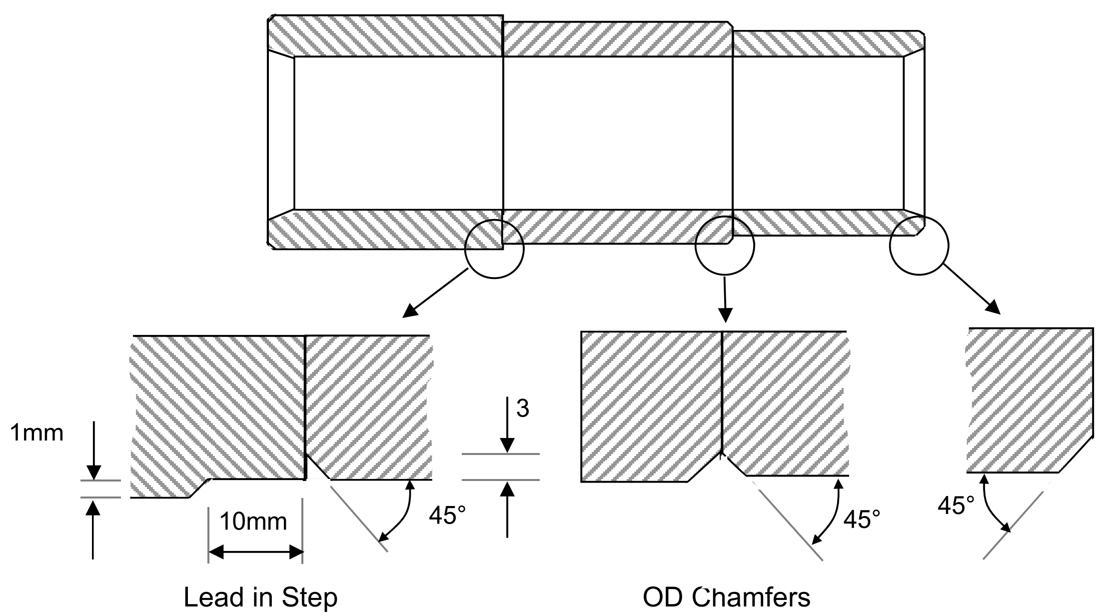
Groove width should be kept to a minimum and the bottom of the groove should have radii machined to prevent stress raising of the material. If the groove width exceeds the width of the anti-rotation key groove, then Wärtsilä UK should be consulted for advice.

The maximum number of additional external grooves is 2 plus an anti-rotational keyway. If fitment requires more groves – then Wärtsilä UK should be consulted for advice.

6.1.9 Bearing Exterior

Ends of bush sections should be chamfered on the OD at 3x45° for bearings with OD up to 400mm and 5x45° for anything larger.

An un-stepped bearing, or the last fitted section of a multi-section bearing, should have a lead-in step to facilitate alignment of the bush within its housing for press fitting. The step has a diameter reduction of 2mm ± 0.5mm and is 10mm long. The diameter increase from this lead-in step to the bearing OD is chamfered at 45°. The leading step can be omitted if the bearing is to be freeze fitted or "glued" into the housing.



6.2 Half Shell Bearings

6.2.1 Number of Bearing Sections

To ease handling of large shell type bearings, the total bearing length will be supplied in sections. The numbers of sections are shown in the table below.

Shaft Diameter (Ds)	Number of Bearing Sections			
	L:Ds up to 1:1	L:Ds from 1:1 to 1.5:1	L:Ds from 1.5 to 2:1	L:Ds from 2:1 to 2.5:1
200 – 300 mm	1	1	1	1-2
301 – 400 mm	1	1	1	1-2
401 – 500 mm	1	1	1-2	2
501 – 600 mm	1	1	1-2	2
601 – 700 mm	1	1-2	2	2-3
701 – 800 mm	1-2	1-2	2	2-3
801 – 900 mm	2	2	2-3	3
901 – 1000 mm	2	2	2-3	3
1001 – 1100 mm	2	2	2-3	3-4

Typical shell length is up to 800mm, for larger sizes consult Wartsila.
For aft stern tube and bracket bearings exceeding 700mm shaft diameter, the bearing retention system should be discussed with Wartsila to optimise design.

6.2.2 Bearing Housing Bore, H,

In the case of half shell bearings housing steps are not required as the bearings are not installed with an interference fit. The nominal housing bore can be calculated as shown below,

H = (1.09 x Ds) + 20 (round up to next whole mm)

6.2.3 Bearing Outside Diameter, OD,

The outside diameter for half shell bearings is given by,

OD = H Tolerance of –0 / +0.15

6.2.4 Running Clearance, Rc

As section 6.1.6

6.2.5 Bearing Inside Diameter, ID,

The inside diameter of half shell bearings require machining after installation into the housing to,

$Ds_{max} + Rc_{min}$ (Tolerance -0 / +0.15)

7 MACHINING and INSPECTION TECHNIQUES

7.1 All Wärtsilä water lubricated propeller shaft bearing materials are readily machined using conventional metalworking techniques. They can be machined either horizontally on a conventional lathe or on a vertical borer. The latter method is preferred as it simplifies the work holding of the bush and minimises the bearing distortion when clamping to the work table. Semi-finished bearings and rough-turned billets supplied for final machining will normally include a clamping allowance, typically 55mm, on their length. During all operations the material must be suitably supported to maintain shape and avoid breakage.

When machining longer bearing sections on a lathe, centres and steadies can be used to minimise sag. Boring bars should be checked to ensure they are machining straight without introducing taper across the length of the bearing. Heavier bearing sections clamped in four jaw chucks should have ID fixtures or small mandrels fitted to prevent the chuck from distorting the bearing.

7.2 To minimise bearing distortion it is recommended to machine washway radius on the ID prior to final OD and ID machining. After washway machining is completed allow the bearing to spring to its natural position. Clamping the bearings in its sprung state without bringing back to a round condition will allow the final OD and ID machining to be completed without introducing stress into the bearing. For small bearings with lubrication grooves this process is not necessary.

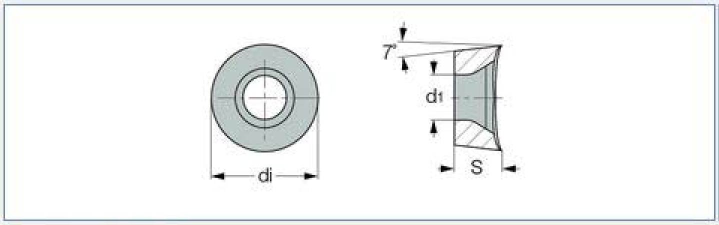
7.3 When bush sections are being finish machined it is important that both the OD and ID are machined without removing the bearing from the machine table. Failure to observe this requirement may result in bearing ovality or misalignment.

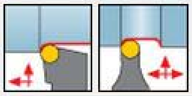
7.4 For best results tungsten carbide tipped tools are recommended with relatively high speeds and feeds. Selection of speeds and feeds is largely dependent on the operation and operator experience, however the following parameters are suggested for tungsten carbide tipped tools.

Turning and Boring

Cutting speed	90m/min
Feed rate	0.22mm/rev
Depth of rough cut	2.4mm
Depth of final cut	0.25mm
Minimum cut depth	0.25mm

ISO interchangeable Tool Profile RCGT-1003MO-AS
Tool hardness IC20, ISCAR 5540020 or equivalent.





di	S	d1
10.00	3.18	4.00

Milling (single cutter)
Cutting speed: 400m/min
Feed rate: 660mm/min

7.5 Bearing wall thickness to be checked whilst on the machine to validate concentricity of OD and ID. Typical wall thickness tolerance should be within 0.1mm. If wall thickness checks after the initial roughing cuts show inconsistent wall thickness readings check work holding method and tooling to improve tolerance before final cutting. Failure to machine a concentric bearing may result in alignment issues after installation.

7.6 When a bearing is parted to length it is recommended that the open face be skimmed flat then the bearing parted off with an additional 5mm in length. The bearing can then be turned over or around and the extra 5mm faced off. This will ensure the end faces are square and no damage or chipped edges left from the parting operation. After removal from the machine, bearing wall thickness to be checked on clamp end to validate concentricity of OD and ID.

7.7 In-situ machining of the bearing inside diameter may be required for alignment corrections or if the housing ovality or tapering is excessive. Typical in-situ machining tolerance is 0.1mm on roundness with a maximum straightness tolerance of 0.1mm. The alignment and straightness of the boring bar must be checked during this process.

8.0 BEARING INSTALLATION

Unless the installer is fully conversant and experienced with all aspects of the installation process, it is recommended that a technically competent service representative from Wärtsilä should attend.

Throughout the bearing installation and checking processes, the bearing material must be protected against damage.

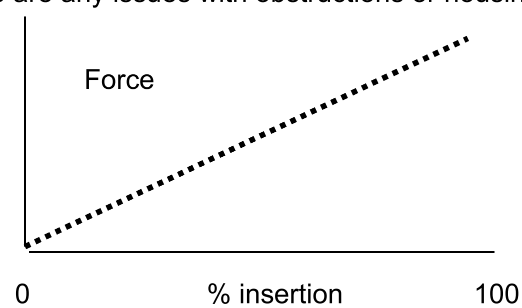
All information should be recorded throughout the installation on a Wärtsilä UK 'Bearing Fitting Report' (See Appendix 1) and a copy should be sent to Wärtsilä UK upon completion.

8.1 Fitting – Bush Type Bearings

Wärtsilä bush type bearings are suitable for force fitting into their housings, normally with the use of a hydraulic jack.

The force required for bush insertion is dependent on the interference within the housing, machining tolerances and the friction between the bush and housing surfaces. The friction is determined by the bush and housing surface finishes, and can vary considerably. Fitting forces different from those shown can therefore be experienced and should not cause concern providing correct bush / housing interference has been achieved.

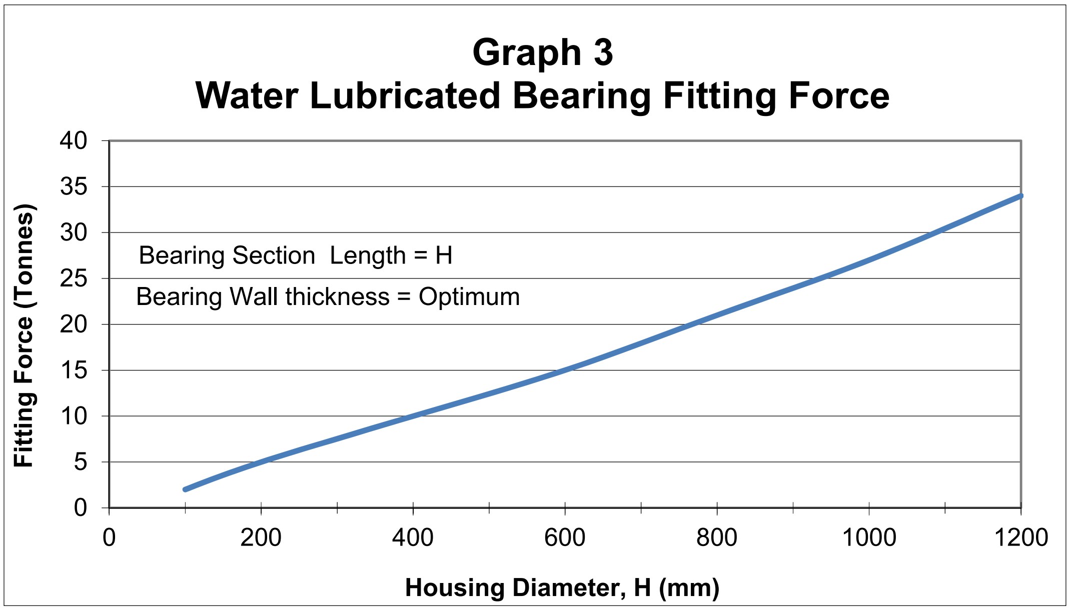
Experience indicates that there is a linear relationship between the fitting force and bearing length. The fitting force should be recorded at regular intervals, together with the length of bearing inserted, throughout the fitting operation to indicate if there are any issues with obstructions or housing bore changes.



Provision must be made to ensure the press-in force is equally distributed around the bearing bush using a pressing plate. This should be in the form of a suitable round, flat steel plate (typically 40mm thick for bearing diameters greater than 400mm), with the O/D of the plate approximately 10mm less than the O/D of the bearing to be fitted. Using a partial section of plate is not recommended as it can cause damage to the end of the bearing.

It may be necessary to cut clearance grooves for the anti-rotation key and any other pipe work that may be present. It is recommended to monitor the fitting progress from within the stern tube cavity or by a viewing hole in the plate for smaller diameters.

Checks should be undertaken to ensure that all sharp corners have been removed from the bearing housing and that there is sufficient clearance around the key, temperature sensor tubing (if fitted). Anti-rotation key should be checked and confirmed as straight to ensure it does not distort the bearing during fitting.



Graph 3, shows the anticipated fitting forces for bearing sections with standard design dimensions and interference. Bearing section lengths are shown equal to housing diameter, for alternative lengths adjust fitting forces proportionally. These values, plus suitable safety factor allowances, should be considered when selecting fitting equipment.

Application of a lubricant to either the bush or housing to assist fitting is not required.

Prior to applying the fitting force check to ensure any pipe grooves in the metalwork align to the grooves in the bearing. Ensure the depth and width of the anti-rotation key (if fitted) is less than the groove depth in the bearing to ensure it will not interfere during the pressing.

The bearing must be aligned to its housing and anti-rotation key before commencement of and throughout the insertion operation. Great care is required to ensure that the bushes enter squarely, especially with the aft most bush. Measurement of the protruding bearing length in four places will indicate if the bearing is being fitted “squarely”. Uneven values may require re-positioning of the hydraulic drive to achieve correct fitment. Practical experience indicates that the measured values on start-up should be less than 5mm variation.

The bearings are to be inserted as smoothly and continuously as possible. Ideally, each bearing section should be fitted in one continuous movement. This is seldom achieved however, and the section often moves with a 'stick/slip' motion.

Once insertion of a bearing section has started, interruptions should be limited as if the bush is allowed to remain stationary for too long, it will become difficult to resume insertion due to the stresses within the material.

Each section must be pressed into the housing until it fully contacts the internal stopper ring or its adjacent bearing section. The pressure applied to the bearing should be monitored closely as there will be a sharp rise in pressure when the bearing makes full contact with the stopper ring or adjoining section. The pressure should be stopped immediately at this point to prevent damage to the bearings. Once fitted, there should be **no gaps** between adjoining bearing sections or the internal stopper ring.

If temperature sensors, (Condition based monitoring), for the aft bearing are being fitted from the forward end of the aft bearing, the sensor conduit should be installed before it is pressed into the housing. Sensor conduit should be conformal to the bearing sensor hole and conduit marked to ensure complete insertion into the bearing. The bearing should be supported with lifting strops to prevent damage to the sensor conduit. Ensure the conduit is guided through any additional slots in bearing / retaining ring.

The temperature sensor is normally fitted after bearing installation. The sensor should be marked to ensure full insertion into the sensor conduit (forward mounted) or sensor hole in the bearing (aft mounted).

Sensor validation must be undertaken to verify correct sensor fitment. This can be achieved by placing a hot (less than 100Celsius), container to contact the bearing at the sensor location and recording the temperature rise.

If a keeper ring is fitted there should be no gaps between it and the bearing material. With axially bolted keeper rings, a spigot can be machined and adjusted on the ring to eliminate any such clearance.

After completion of bearing insertion, the material should be allowed to normalise for at least 3 hours, or preferably overnight, before final dimensional measurements are taken.

8.2 Freeze Fitting

Health & Safety precautions relating to liquid nitrogen need to be considered when freeze fitting composite bearings.

Lowering the bearing’s temperature can cause material shrinkage in excess of the amount of interference between the bearing and it’s housing, and so facilitate easy bearing insertion.

Cooling with ‘dry-ice’ (Solid Carbon Dioxide) will not achieve the necessary shrinkage to fully insert the bearing in its housing. However it can be used to assist press fitting.

Cooling with liquid nitrogen will normally provide sufficient time for complete bearing insertion before the material expands. The bearing should be placed in an insulated steel container just large enough to allow the bearing to be fully immersed. When pouring the liquid nitrogen it will begin to boil off on contact with the container, however, it will fill up once the container has cooled. Once the container is full it should be covered and left until the boiling ceases.

Due to the large temperature differential the liquid will continue to boil off, therefore it may require topping up to keep the bearing immersed. When the boiling has subsided it should be left to stand for a minimum of 30 minutes, for small bearings, up to 1 hour, for larger bearings, before the bearing can be taken from the container and fitted into the bearing housing.

To utilise the minimum amount of time between removal from the liquid nitrogen and the fitting of the bearing, the container should be placed as near to the bearing housing as is safely possible. However, it should be noted that liquid nitrogen is an oxygen depleting substance and should therefore not be used in confined places. Liquid nitrogen operators should ensure that they are fully conversant with the necessary precautions for its handling and use, as prescribed by the supplier and the correct protective clothing and eye protection used at all times.

When subjected to a change in temperature the exact change in diameter of the bearing is dependent upon the wall thickness to diameter ratio due to the material being anisotropic. Practical experiments have proved that a coefficient of thermal expansion of 3×10^{-5} provides an accurate guide to calculate the change in diameter for typical bearing tubes.

Shrinkage = Bearing Outer Diameter x 3×10^{-5} x Temperature Change

Where typical Liquid Nitrogen cooling temperatures are down to -178˚C

Bearings need to be marked with a groove positional identifier with a corresponding mark on the housing to ensure correct bearing orientation during freeze fitting if an anti-rotation key is not fitted. Refer to the general arrangement for the correct orientation of the bearing.

If multi-sectioned bearings are to be freeze fitted – ensure that the chamfer on the bearing inside diameter is correctly positioned (at either end of the bearing – see section 6.1.9)

8.3 Adhesive Bonding

If the sterntube or bracket housing has excessive ovality or tapers in the bore it may preclude press fit or freeze fit installation as the bearing will distort after fitting. An alternative fitting solution in cases where the housing is irregular is to use adhesive between the bearing and housing. Adhesive bonding is only suitable for single piece bearings, multi-sectioned bearings should not be bonded.

Wartsila recommend using Araldite 2014 which can be applied to the bearing and the housing. The optimum adhesive thickness is 0.12mm although it has non sagging, gap filling properties up to a maximum of 5mm. Other products such as Belzona 1321 can also be used.

The housing should be blasted and all loose contamination brushed from the surface. It should be degreased with an effective cleaner which does not leave any residue. The bearing outer diameter should be wiped with a clean cloth to ensure it is dust free prior to adhesive application. Squeeze the product from the dispenser and smear evenly over the full surface of the housing and bearing using a plastic spatula. Insert bearing and apply a small twisting action once fully inserted to ensure good adhesive coverage. Allow the adhesive time to dry according to manufacturers recommendations.

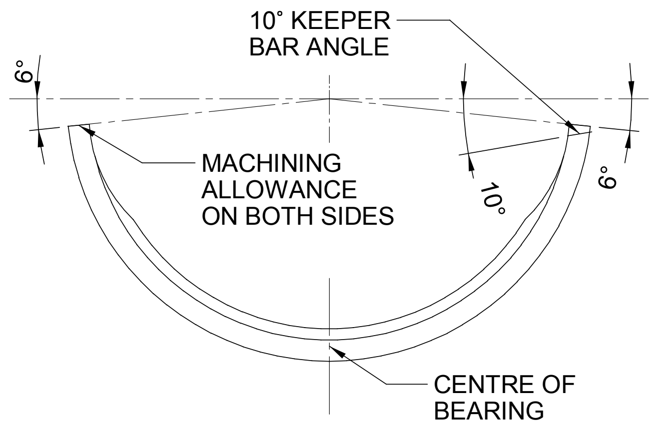
For additional anti-rotation security holes can be drilled through the housing and into the bearing (typically in the horizontal position) and metal pins or studding inserted. Care must be taken to avoid distortion to the bearing inside diameter.

For bearing installation using other larger gap filling products such as resin chocking the bearing must be fixed and aligned correctly prior to resin pouring. It is important to measure the bearing before and after resin pouring to ensure it remains in a round condition.

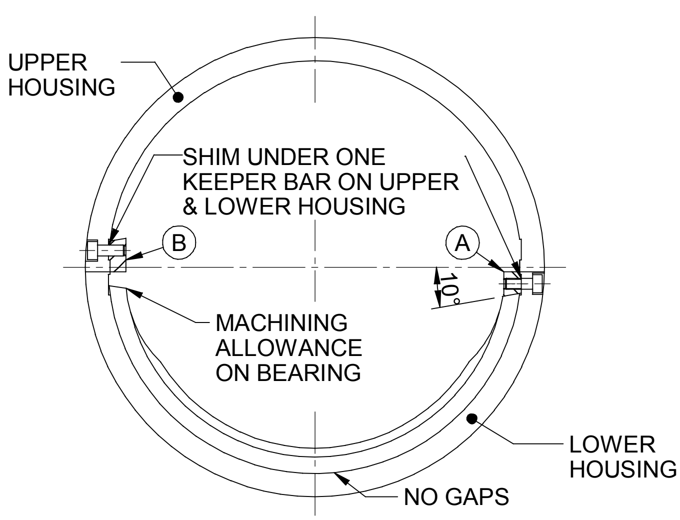
8.4 Fitting - Half Shell Bearings into fully split housings -Type F

Bearing shells are normally supplied finished on OD with a machining allowance on both arc length and ID.

Begin by identifying the centre position of the bearing ID between lubrication washways. Mark and machining a 10° angle on one side of the bearing to match the keeper bar angle (see sketch below). Note: ensure that the bearing arc lengths are at equal distances from the vertical centre line in order to keep the lubrication wash way radii equally spaced along the length of the assembly.
Bolt one of the keeper bars into position with a shim underneath the flat face



on the I/D of the housing as shown below. The thickness of the shim will vary depending on the size of bearing to give additional interference fit (see table below).

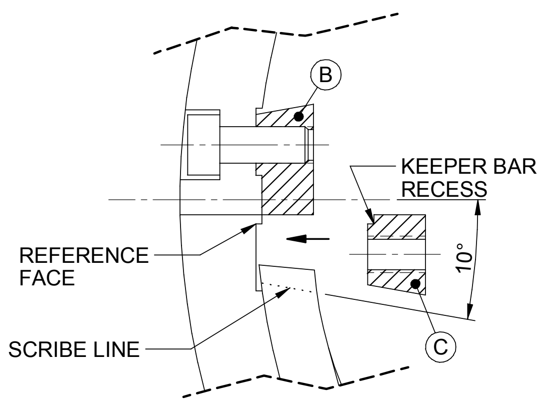


Shaft Size (mm)	Shim Thickness (mm)
200	3.0
300	3.5
400	4.0
500	4.5
600	5.0
700	5.5
800	6.0
900	6.5
1000	7.0

Fit the machined edge of the Wärtsilä bearing so that it is tight against the keeper bar.

There should be no gaps evident between the bearing and the housing (check using feeler gauges at either end, also use a small hammer to lightly tap for hollow sounds along the full length of the bearing I/D).

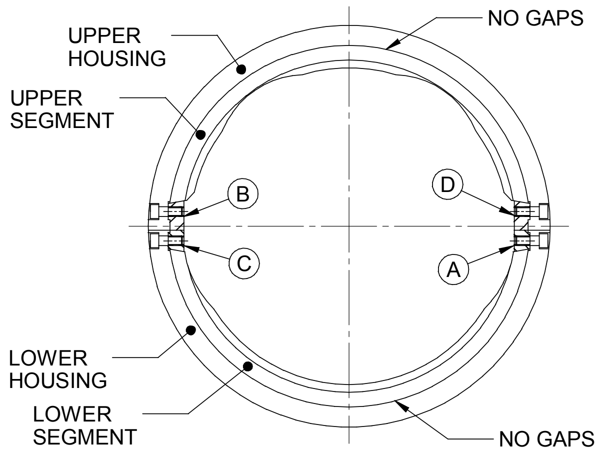
It may be necessary to use clamps in order to remove all gaps between the housing and bearing. Note: Make sure that the surface of the Wärtsilä bearing material is protected if clamps are to be used.



Using the other keeper bar to mark the end face of the bearing at the required 10° angle and machine the remaining material from the arc length.

Remove the shim from underneath the keeper bar and refit the bar. The Wärtsilä bearing material can now be refitted into position. Clamps may be necessary at this stage to assist in the fitting of the Wärtsilä material.

When all keeper bars are in place, check for any gaps between the housing and the bearing. **A 0.1mm feeler gauge should not fit under any section between the housing and the bearing**. Using a small hammer tap the I/D of the bearing along the full length to check for any hollow sounds between the housing and the bearing. Any gaps or hollows should be recorded and you should consult the findings with the Wärtsilä UK.

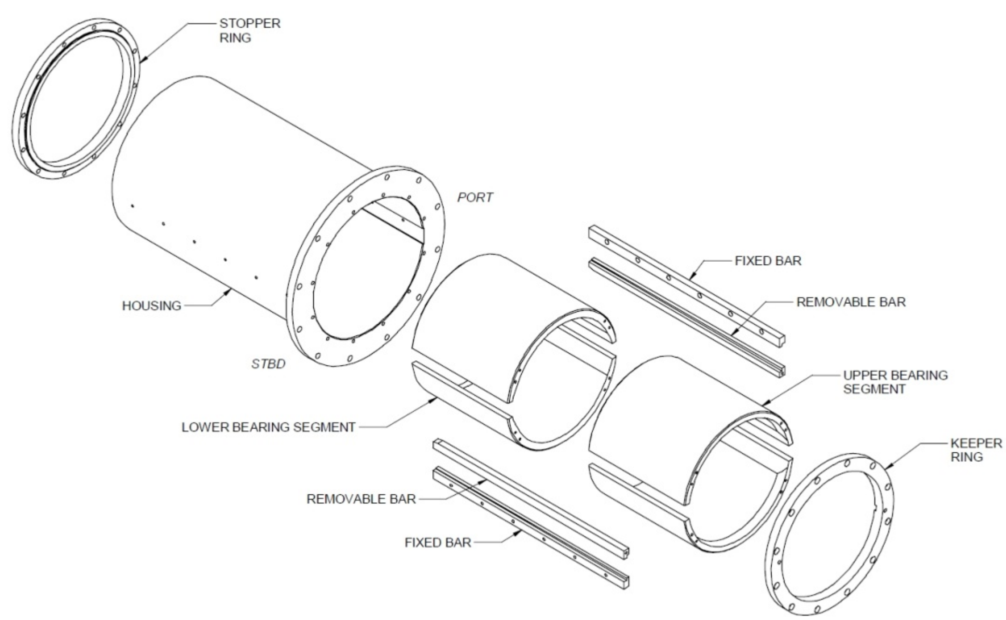


Remove the keeper bar bolts one at a time and apply a suitable thread locking agent and retighten. This is to prevent the possibility of the bolts coming loose during operation.

The Inside diameter can now be bored to the required size (see section 6.2.5).

8.5 Fitting - Half Shell Bearings into Partially Split Assemblies -Type P

The installation and removal process for partially split assemblies (Split Key Design) is covered under a separate Wartsila manual **TM-CB-01** available on request from Wartsila UK.



Typical Partially Split Bearing Assembly

8.6 Bearing Final Checks

The bearing bore dimensions should be measured and recorded in accordance with the Wärtsilä ‘Bearing Fitting Report’ (see Appendix 1). Measurements are required throughout the bearing length in both vertical and horizontal directions. For bearings with washways on the horizontal plane, the horizontal dimensions should be replaced by diagonal measurements taken from positions above each washway.

For press fitted bearings, correct bush / housing interference should be confirmed by verification that the bearing inner diameter has reduced, as a result of fitting, by the amount of interference applied.

Throughout the bearing the running clearance must equal or exceed the design minimum value. Local deviations such as small steps in the washway radii or lubrication slots, may be corrected by surface blending using a hand tools.

The bearing running surface should be verified as straight to within 0.1mm. This test is normally conducted by placing an engineering ‘straight edge’ along the lower bearing surface and checking for clearances between it and the bearing surface with ‘feeler gauges’.

Where stopper and keeper rings are fitted, there should not be any continuous gaps between the rings and the bearing, nor between the bearing sections.

The bearing should be lightly tapped with a small ball-peen hammer around the bore and along the length while listening for ‘hollow’ sounds. Hollow sounds in the bottom / shaft operating area will require further investigation.

If the shaft is not to be fitted immediately, the bearing should be protected from damage.

Finally – Return a copy of the completed inspection records to Wartsila UK.

9 COMMISSIONING PROCEDURE

The practical problems associated with restricting the operation of a vessel's main propulsion system are recognised, however a new bearing with a fixed pitch propeller should be 'run-in' and the programme detailed below is suggested.

Helm angles should be restricted to a minimum throughout the commissioning process. If high speed turns are required as part of the boat commissioning they should be performed after the bearing commissioning process is completed.

For vessels which are fitted with temperature sensors, the normal operating range would be between ambient sea temperature and 10°C above sea temperature. There may be some slight fluctuations in temperature at the early stages of the bedding in process. It is recommended that the high temperature alarm be set at 50°C. In addition it is also recommended to fit a temperature gradient alarm so that it activates in the event of a rise in bearing temperature of >3°C/minute.

I. Ensure the sterntube bearing water coolant pump is fully operational and all filters, (if fitted), are clean.

II. Ideally, the propeller should be fully immersed. If vessel draught restrictions preclude this, the propeller should be immersed to the maximum amount possible and the consequent effects of offset propeller thrust must be considered when operating the vessel's engine/s.

III. Using the turning gear, or similar, rotate the shaft in the ahead direction for a minimum of 10 shaft revolutions. If the shaft direction is reversible, repeat in the astern direction.

IV. Operate at 'Dead Slow Ahead' shaft speed for 15 minutes.

V. Turn the shaft using the turning gear for 15 minutes.

VI. Operate at 'Dead Slow Ahead' shaft speed for 15 minutes.

VII. Turn the shaft using the turning gear for 15 minutes.

VIII. Operate at 'Slow Ahead' shaft speed for 15 minutes.

IX. Turn the shaft using the turning gear for 15 minutes.

X. Operate at 'Slow Ahead' shaft speed for 30 minutes.

XI. Operate at 'Half Ahead' shaft speed for a minimum of 30 minutes.

XII. Operate at 'Full Ahead' shaft speed for a minimum of 60 minutes.

XIII. Operate at ‘Full Away’ shaft speed for a minimum of 60 minutes.

The bearing should now be fully commissioned. Should any discrepancies arise during the procedure, Wärtsilä UK should be consulted for advice.

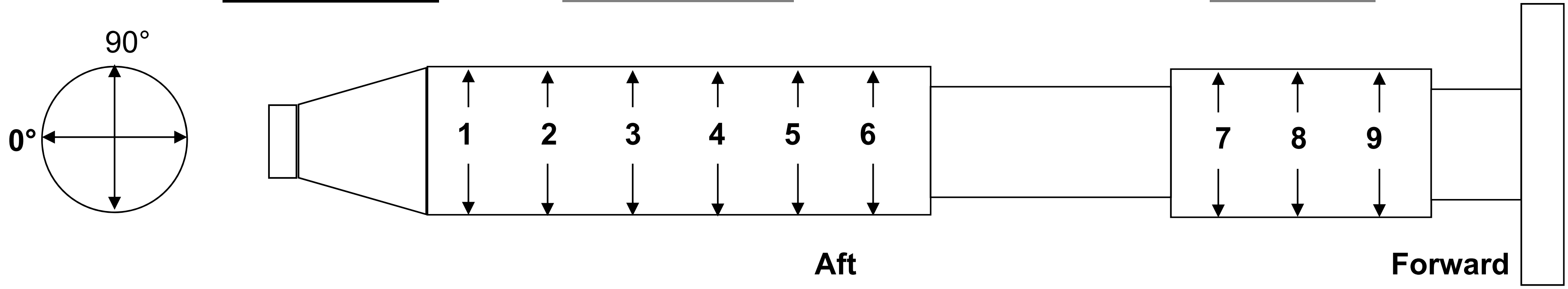
Bearing commissioning for vessels fitted with controllable pitch propellers should start at zero pitch for 1 hour then increase pitch angle in 5 degree increments and hold for 1 hour at each position.

APPENDIX 1

- Shaft Journal Dimensional Report
- Housing Dimensional Report
- Bearing Machining Dimensional Report
- Press Fitting Forces Report
- Fitted Bearing Inside Diameter Dimensional Report
- Straight Edge and Gap Check Report

SHAFT JOURNALS:

Surface Finish ______________Ra __________Ra



	1	2	3	4	5	6
0°						
90°						

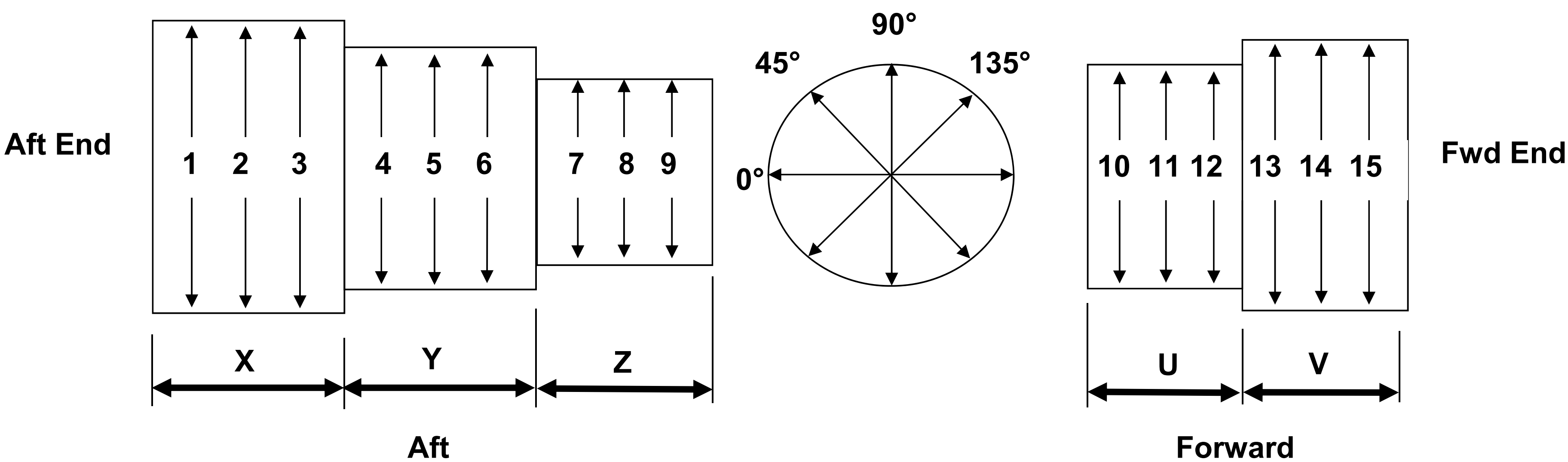
7	8	9

Observations:

Recorded temperature: Ambient (^oC)
Shaft (^oC)

HOUSING SIZES:

Surface Finish __________Ra __________Ra



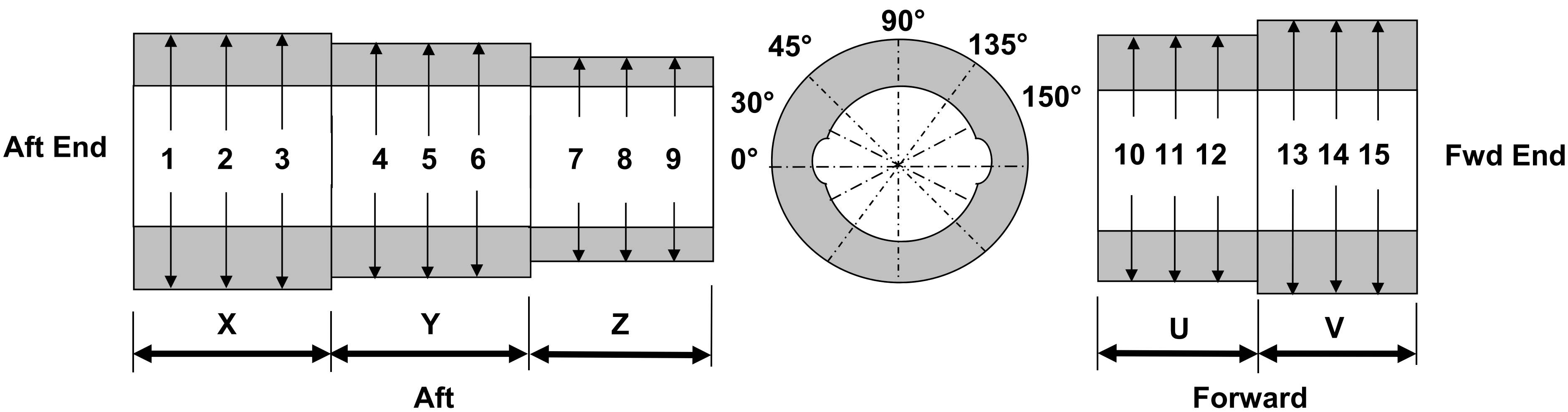
	1	2	3	4	5	6	7	8	9
0°									
45°									
90°									
135°									
	X =			Y =			Z =		

10	11	12	13	14	15
U =			V =		

NOTE: if housing bore is not stepped use all boxes above and state single bore housing.

Recorded temperature: Ambient (ºC)
Housing (ºC)

NEW BEARING - MACHINED SIZES:



	1	2	3	4	5	6	7	8	9
0°									
45°	O/D								
90°									
135°									
30°									
90°	I/D								
150°									
	X =			Y =			Z =		

10	11	12	13	14	15
U =			V =		

	Aft	
Interference	**Design**	**Actual**
Min		
Max		

Fwd	
Design	

Recorded temperature: Ambient (ºC)
Bearing (ºC)

NEW BEARING - FITTING:

Fitting Forces (T) – For press fitted bearings only

Insertion Amount	Aft Bearing Section		
	Aft	Ctr	Fwd
25%			
50%			
75%			
100%			
Design Value			

Fwd Bearing Section	
Aft	Fwd

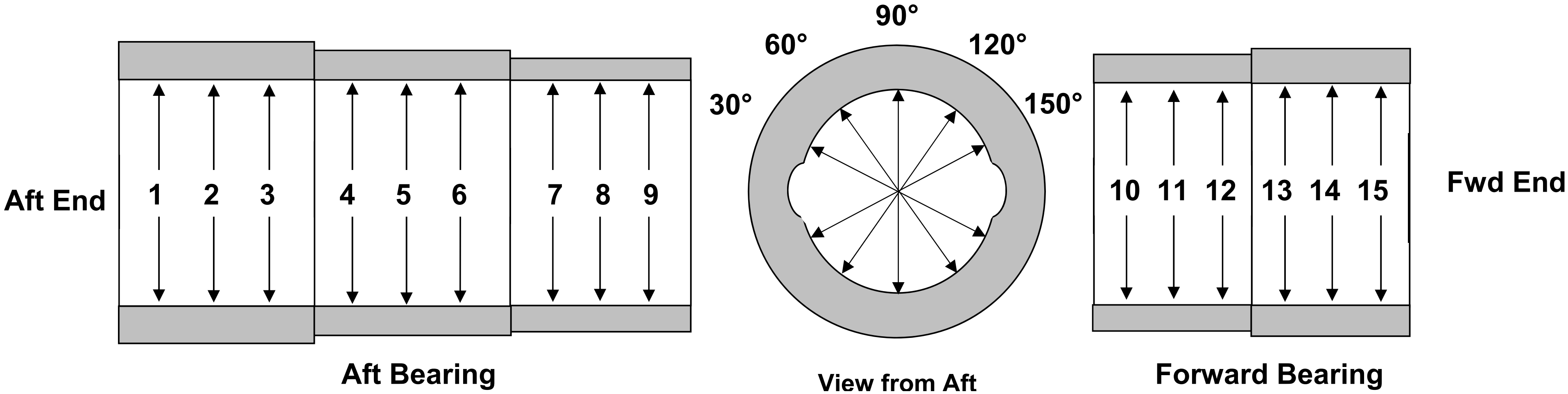
Stick-Slip Observed ? **Amount of section 'jump'**

The force required to fit a Wartsila Composite bearing is dependent on many variables, including the amount of interference fit and the friction between the bush and housing. Forces at variance to those of the calculated design value are often observed, and if consequent to the smoothness of the surfaces, are not necessarily causes for alarm. A more critical parameter is the amount of bearing bore closure from its free to fitted states.

Observations:

Recorded temperature: Ambient (^{o}C)
Bearing (^{o}C)

NEW BEARING - FITTED BORE SIZES:



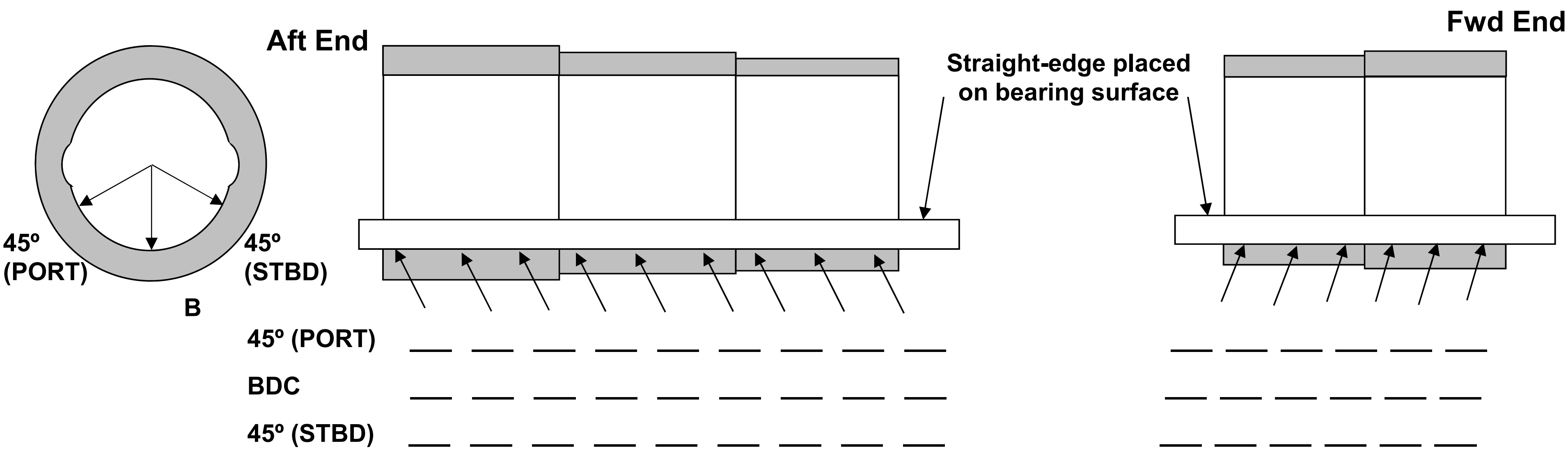
	1	2	3	4	5	6	7	8	9
30°									
60°									
90°									
120°									
150°									

10	11	12	13	14	15

Bearing ID Fitted Sizes	**Design (Aft)**	**Actual (Aft)**	**Design (Fwd)**	**Actual (Fwd)**
Min				
Max				
Operating Clearance (Fitted I/D - Shaft Dia)				
Min				
Max				

Recorded temperature: Ambient (°C)
Bearing (°C)

NEW BEARING - STRAIGHTNESS & GAP INSPECTION:



Gap Check	AFT BEARING				FWD BEARING		
	Keeper Ring	Aft/ctr section	Ctr/fwd section	Stopper Ring	Stopper Ring	Aft/fwd section	Keeper Ring
Top							
Bottom							
Port							
Stbd							

Confirm any hollow sounds and their position/s when bearing walls are lightly tapped with small hammer? ____________

If **YES**, consult Wartsila.